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John Hanesiak

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Dans l’index situé à la fin de quelques documents, le nom des auteurs est suivi des numéros d’identification et de présentation de tous les résumés correspondants.

Monday, May 28, 2001
10:20 – 11:40
Ballroom A
Session 1
Significant Weather Case Studies and Modelling

1. Water Quality Implications of a Heavy Rain Event in Southwestern Saskatchewan

Fraser G. Hunter[1], David B. Donald[1], Brian N. Johnson[1], Ed Sverko2, Bernard D. Hill[3], Jim Syrgiannis[1], Wayne D. Hyde[1], John M. Hanesiak[4], Marcus O. B. Kellerhals[5], and Ronald F. Hopkinson[1]

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On July 3, 2000, up to 375 mm of rain fell in eight (8) hours from an intense and slow moving thunderstorm complex in southwestern Saskatchewan. An area in excess of 1300 km^2 received at least 100 mm of rainfall making this a record storm on the Canadian prairies for this duration and area. The storm was centred over the Notukeu Creek drainage basin. On July 4, the Notukeu Creek hydrometric gauging station reported a record instantaneous discharge of 267 m^3/s. The storm generated 286.6 million m^3 rain, of which an estimated 100.3 million m^3 or 35% was discharged to Notukeu Creek. Herbicides (2,4-D, MCPA, dichlorprop, bromoxynil, and triallate) commonly applied to crops in May and June along the air-parcel back trajectory path, from Texas north into Saskatchewan, were detected in rainwater. These herbicides, in addition to trifluralin, lindane, and some pesticides not used in Saskatchewan (2,3,6-TBA, alpha-HCH, endosulfan, heptachlor-epoxide, and dieldrin), were detected in flooded wetlands situated near the centre of the storm. Concentrations of individual pesticides in the surface waters were less than Canadian guidelines established to protect drinking water sources, and were usually less than guidelines established to protect aquatic life. The cumulative effects of relatively high concentrations of multiple pesticides in wetland waters are unknown.

This paper will focus on the overall synoptic conditions leading up to the storm event, the magnitude of the storm itself, remotely sensed storm data, hydrologic measurement, and the potpourri of agricultural chemicals detected in the run-off water.

2. Meteorological analysis of the July 3, 2000 Vanguard heavy rainfall case

J. M. Hanesiak
Prairie Storm Prediction Centre, MSC, Winnipeg, Manitoba

A severe convective outbreak on July 3, 2000 within and around Vanguard, Saskatchewan produced one of the largest heavy rainfall events ever recorded in the Canadian prairies. Several local farms reported extreme hail damage and over 350 mm of rain over an 8 hour period that resulted in flash flooding. Although the Prairie Storm Prediction Centre (PSPC) issued several severe thunderstorm warnings, the amount of rainfall that fell over a confined area was not anticipated. The Global Environmental Multi-scale model (GEM) predicted a much smaller Quantitative Precipitation Forecast (QPF) maximum and located it further north compared to observations. A post-storm analysis indicates that this heavy rainfall case (and meso-scale convective system (MCS)) contained many known attributes of MCS development but also had unique attributes and processes occurring in the planetary boundary layer (PBL) that may have enhanced the event. A discussion of the meteorological aspects of the Vanguard case are discussed, including the possible PBL influences and the results of hi-resolution modelling efforts in attempting to capture these extreme meso-scale events.

3. The Winnipeg Hailstorm of 16 July 1996: Synoptic and Radar Observations

Amin Erfani
Prairie Storm Predication Centre, Winnipeg, Manitoba.
Gerhard W. Reuter
Department of Earth and Atmospheric Sciences, University of Alberta,

The 16 July 1996 hailstorm over Winnipeg, Manitoba was analysed using radar observations, sounding data, and synoptic charts. Data were part of the operational observations of Environment Canada. Warm humid air was advected by a low level jet, resulting in the classical "loaded gun" sounding with a large potential for instability (CAPE was 4220 Jkg^{-1}). The hailstorm started as a multicell complex, triggered by the southerly low level jet converging with outflow from pre-existing showers. The development was fed by the low level jet and the release of the convective instability. Within 30 minutes the multicell storm structure developed into a supercell with a persistent hook echo, overhang and Bounded Weak Echo Region. Radar reflectivity echoes that exceed 52 dBZ at 7 km altitude matched closely with surface observations of the hailstones having diameter of 40 mm or more. The storm closely resembled the conceptual models of severe hailstorms.

Synoptic and Mesoscale Study of a Severe Convective Outbreak with the Nonhydrostatic Global Environmental Multiscale (GEM) Model

Amin Erfani [1], André Méthot [4], Ron Goodson[2], Stéphane Bélair [3], Kao-San Yeh [5], Jean Côté [3],Richard Moffet [4]

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A nonhydrostatic 4-km version of the Global Environmental Multiscale (GEM) model, with detailed microphysics included, was used to forecast the initiation, development and structure of a tornado-producing supercell storm that occurred near Pine Lake (Alberta, Canada) on 15 July 2000. Examination of observations and comparison with conceptual models indicated that this storm was a good example of supercell storms that regularly produce summertime severe weather over Alberta.

It was found that the high-resolution model was able to reproduce the early initiation of convective activity along the Alberta foothills, as well as the rapid northeastward propagation towards the Pine Lake area and the subsequent intensification into a supercell storm. The general structures of the forecasted convective system corresponded well with conceptual representations of such events. Overall, this high-resolution forecast of the Pine Lake supercell storm was a significant improvement over the current operational version of the GEM model (24 km), which was not able to intensify the foothills' convection into a supercell storm. Finally, it was found that the nonhydrostatic version of the model produced better trajectory and propagation speed of the convective system, as compared with the hydrostatic one.

Monday, May 28, 2001
10:20 – 11:40
Ballroom B
Session 2
Synoptic and Mesoscale Processes of Extreme Weather

1. Coupled atmospheric-hydrological simulations and model validation for some heavy rainfall and flooding events in southern Ontario

Zuohao Cao[1*], Paul Pilon[1], Robert Benoit[2], Stephane Chamberland[2], Paul Ford[1], Brian Murphy[1], Paul Campbell[1], Harold Ritchie[3], Pierre Pellerin[2], and Herman Goertz[1]

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Heavy precipitation in southern Ontario during the warm season can, at times, result in significant social hardships and economic impacts through flooding. The ability to estimate and predict streamflow in such cases is highly related with the ability to accurately track and predict rainfall events. This presentation will focus on the latter aspect, which is our ability to accurately forecast precipitation. Some important characteristics for establishing the resultant streamflow include the location (areal extent), spatial distribution of the intensity, and the timing of the event.

The objectives of this study are comprised of three components. The first is directed at ascertaining the accuracy of Quantitative Precipitation Forecasts (QPFs) based on meso-scale model simulations. Accuracy is established through comparison of model derived fields with various observations (e.g., Doppler Radar, raingauge data). The second objective is geared to ascertaining our ability to estimate surface streamflows by coupling high-resolution nested numerical weather prediction models (such as MC2 and GEM HIMAP) with hydrological process models (e.g., Watflood). This ability is assessed by the comparison of model estimated streamflow with observed streamflow. A water budget approach is also adopted to examine the overall accuracy of major aspects within the atmospheric-hydrological modelling system. Initial results for the first and second objectives are presented for a number of extreme rainfall events that occurred in May 2000 over southern Ontario. Preliminary results indicate that there are some advantages of using high-resolution mesoscale models in estimating precipitation fields. Certain advantages will be presented.

The third and final objective is to identify key physical processes that were characteristic of some of the heavy rainfall events that have occurred during the summer of 2000 over southern Ontario. Diagnoses were performed and some of which will be presented, as these help to increase our understanding of the physical elements that are responsible for formation and maintenance of intensive precipitation.

2. Analyses of Montreal's record-breaking heavy rainfall event of 8-9 November 1996, and its associated analogues

Dorothy Durnford

MSc candidate in Meteorology at McGill University,
(supervised by Professor John R. Gyakum.)

Montreal received 134 mm of precipitation in 27 hours over November 8-9, 1996. The 93.5 mm which fell on November 8, representing 70% of the total amount, constitutes the largest single-day precipitation value on record for Dorval.

We are analysing this event and its analogues from a synoptic viewpoint. We investigate the quasi-geostrophic forcings for vertical motion and the resulting omega fields. We construct an Eulerian moisture budget, and calculate the coupling index. This index is a crude measure of the tropospheric lapse rate. For the base case we consider the 24 hours centred at 00 UTC November 9, 1996. We find that the quasi-geostrophic forcing in the Montreal area is weak, producing minimal ascent at both 850 hPa and 500 hPa. The moisture in the area has its origin in both the Gulf of Mexico and the Atlantic ocean. Advection of water vapour and convergence in the presence of water vapour are found to be equally important mechanisms in the accumulation of precipitable water for the region.

A Multi-Scale Study Of Ice Storms In The Saint Lawrence River Valley

John R. Gyakum
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Paul J. Roebber
Atmospheric Science Group, Department of Mathematical Sciences
University of Wisconsin-Milwaukee

Freezing rainstorms have the potential to inflict crippling economic loss. An excellent extreme example was that of the Ice Storm of 5-9 January 1998, which affected parts of the eastern provinces and the northeastern United States (US) with precipitation amounts greater than 100 mm. The economic loss exceeded 4 billion dollars.

The purpose of this research is to improve the forecasting of ice storms. We perform this research with a novel combination of observational analyses and mesoscale modeling. First, we define the planetary-scale environment that is conducive to ice storms in the Saint Lawrence River Valley. The next component of this research is to define the synoptic-scale perturbations that are crucial to the production of a major freezing rain event in the region. Finally, we study the mesoscale details that are necessary to produce freezing rain in the Saint Lawrence Valley.

We use historical global gridded reanalyses from the National Centers for Environmental Prediction (NCEP) to produce the planetary-scale signatures associated with relatively heavy ice storms. We find anomalously-strong surface ridging that covers much of eastern Canada and the US New England states,

combined with negative pressure anomalies extending from the Gulf of Mexico into the central and eastern US. We show that these planetary-scale flows provide a necessary condition for the transport of water vapour from the subtropical regions of the Atlantic and Gulf of Mexico. Additionally, a cold anticyclone, centred north and east of the Saint Lawrence Valley, transports cold lower-tropospheric air into the ice storm region. The offshore subtropical anticyclone transports warm, moist air above the shallow cold dome to produce the temperature inversion.

We study the synoptic-scale features of ice storms with the use of a high-resolution mesoscale model. Piecewise potential vorticity (PV) inversion is used to provide a balanced initial state in which various synoptic-scale perturbations are removed from the initial state. A quantitative evaluation is made of the forecast impacts of synoptic-scale components in the upstream surface cyclone, the cold anticyclone, and the subtropical anticyclone. Additionally, we study the role of relatively shallow orographic features in modulating the intensity of ice storms.

ELBOW 2001: The Effects of Lake Breezes On Weather Project

David Sills[1], Peter Taylor[2], Patrick King[1], Wayne Hocking[3], Ian Nichols[4], Art Schaafsma[4]

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Environment Canada's Meteorological Service of Canada, York University, University of Western Ontario and University of Guelph–Ridgetown College are conducting a field experiment this spring and summer called ELBOW 2001: The Effects of Lake Breezes On Weather. The object of the study is to better understand the relationship between lake breezes and severe weather in southwestern Ontario. MSC and York conducted a successful pilot ELBOW study in 1997 and the results indicated that lake breezes have a considerable influence on the timing, location and intensity of severe weather in this area, including heavy rain, tornadoes and hail.

The current experiment will be more comprehensive and build on the experience gained in 1997. It will run mainly from May 1 to August 31. There will be an intensive observation period window from May 28 to July 20 over which several intensive, multi-day investigations will be conducted. We will have research aircraft support and have a portable Doppler radar in addition to our operational Doppler radars at Exeter and King City. We will also be installing a mesonet, using two wind profilers, launching special upper-air rawinsondes, and coordinating mobile observations. The main study region will be the area of southwestern

Ontario between Lakes Huron and Erie, and in particular the area north of London within Doppler range of the Exeter Doppler radar.

The anticipated benefits of the study include concepts, tools and algorithms to help severe weather forecasters assess the threat associated with lake breezes and tailor watches and warnings based on this information. This will hopefully result in more accurate watches / warnings and longer lead times. We will also be evaluating the skill of various numerical models in forecasting both lake breezes and lake breeze-associated severe weather.

Monday, May 28, 2001
10:20 – 11:40
Solarium

Session 3
Middle Atmosphere

Anomalous Atmospheric Circulations Forced By Volcanic Aerosols

Alyssa Young
MSc Student, Department of Mathematics, University of British Columbia

A Principal Component Analysis (PCA) and Combined PCA (CPCA) is applied to 30 mbar and 300 mbar Northern Hemisphere geopotential height fields, with temperature as the combined field. In the stratosphere, CPCA is found to extract a strong volcanic signal. This method and the resulting volcanic modes are compared to the traditional PCA which extracts only a weak volcanic signal. The stratospheric volcanic modes, found with CPCA, are different patterns from the normal linear PCA modes, suggesting that the system's response to the volcanic forcing is not obvious and is different from what might be expected. No clear volcanic signal can be extracted from a troposphere analysis, due in part to the weaker volcanic influence, the more chaotic nature of the lower atmosphere, and other forcings such as El Nino. However, a vertical CPCA, combining 30 mbar and 300 mbar heights, extracts the volcanic modes at both levels. The resulting tropospheric volcanic mode is shown to have similarities to a composite map of 300 mbar heights representing the difference between years with a strong polar night jet and years with a weak one.

Trends in Stratospheric Temperature Extremes over North America and Europe between 1979 and 1999

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This study uses data from a re-analysis database to determine if any significant trends can be detected in the yearly temperature maximum and minimum values at 8 stratospheric levels over two geographical areas (North America (associated with winter total ozone ridge) and Europe (associated with stratospheric polar vortex) for the period 1979-1999. Because stratospheric temperatures oscillate between a cold winter minimum (Tmin) and a warm summer maximum (Tmax), Tmax and Tmin were extracted for each year in the period and grouped accordingly. A least squares linear regression technique was used to fit a line through the points for Tmax and then for Tmin. The slope of the fitted trend lines can provide us with information about how the values for Tmax and Tmin may be changing over time and offer insight into the yearly cycles of the stratosphere. In summary the majority of levels displayed cooling trends for both yearly Tmax and

Tmin temperatures. The largest trend in cooling occurred at 10mb over northern Europe with trend of negative 3.2 C over 20 years. Results from this study may allow estimates of stratospheric temperatures in the near future for input into various climate models.

SUMMARY OF RESULTS

SOUTHERN NORTH AMERICA DATA (calibration points)

Most levels displayed a negative trend for Tmax

Suggests that during last 20 years, yearly Tmax temperatures slowly decreasing

Largest negative Tmax trend was at 10mb level representing a change of negative 1.7 C over 20 years

All levels except 300mb displayed a negative trend in the Tmin values over the 20 year period

The largest negative Tmin trend was at 10mb representing a change of -2.6 C over the 20 year period

NORTHERN NORTH AMERICA DATA (area associated with winter total ozone ridge)

All levels except 300mb display negative trends in points for Tmax

The largest negative Tmax trends range from -1.31C @ 50mb to -2.25C @ 200mb over 20 years

Suggests that warm summer stratospheric temperatures have been gradually decreasing.

3 highest levels displayed cooling trend in Tmin while remaining lower levels displayed warming trend

Largest negative trend in Tmin was at 10mb with a value of negative 2.0 C over the 20 year period

Largest positive trend in Tmin was at 100mb with a value of positive 1.3C over the 20 year period

SOUTHERN EUROPE DATA (calibration points)

All levels except 300mb displayed negative trend for Tmax

Largest negative Tmax trend was at 70mb with a value of negative 1.9 C over 20 years

All levels except 300mb and 200mb displayed a negative trend in Tmin over 20 years

The largest negative Tmin trend was at 30mb with a value of negative 2.3 C over 20 years

NORTHERN EUROPE DATA (associated with winter stratospheric polar vortex)

All levels except 10mb and 300mb displayed a negative trend in the points for Tmax

Largest negative trend for Tmax was at 70mb with a value of negative 1 C over 20 years.

All levels except 70,100,150mb displayed negative trends in Tmin

The largest negative trend in Tmin occured at 10mb with a value of negative 3.2 over 20 years

The largest positive trend in Tmin occured at 150mb with a value of positive 1.1 over 20 years

Monday, May 28, 2001
13:00 –15:00
Ballroom A

Session 1
Warning Programs, Preparedness, and Training
Monday, May 28, 2001
13:00 –15:00
Ballroom A

A Generalized GUI To Display Weather Watches (Aviation, Public, Marine Forecasts,…) In Real Time

Ronald Frenette, Denis Jacob, Michel Nadeau, Jean Souviron, Viateur Turcotte

We will present a Unix/Motif GUI that can display different kinds of weather watches. We will go through the basic features (alarms, pop-up, colour display, fonts, language and personalization). Three watches will be presented as examples. First, an aviation watch comparing TAFOR against METARS. Then a marine watch comparing MAFOR against observations within the marine area and near the coast. And finally a comparison of the public forecast and warnings (wind chill, frost, strong winds, freezing rain, …) with a spatial analysis of observations.

An Application For Collecting, Managing And Displaying A Severe Weather Database (Events And Forecasts)

Ronald Frenette, Jean Souviron, Viateur Turcotte, Denis Jacob, Michel Nadeau, Pierre Vaillancourtt

Quebec region has been collecting severe weather data (events and warnings) since 1989. Gathering and validating these data can be difficult and time consuming. A new program was installed to improve data collecting. Warnings are now automatically collected, analysed and put into a unix database. Data are extracted from warnings (issued time, regions) and public bulletins (phenomena, amounts). Events originating from different sources impossible to automate (phone, newspapers,...) still have to be entered manually. A Unix/Motif GUI allows to consult, modify or add information to the database. Users are also able to display observations and warnings that fall within performance criteria (lead time, intensity, amounts, etc.). Performances (hits, false alarms, etc.) are calculated dynamically according to a particular set of criteria (regional, national, etc.) selected by the user. Reports (statistics index, contingency table, histograms, etc) can be produced for different selected time period.

Pelmorex Inc. All Channel Alert System

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Pelmorex Communications Inc. is a privately owned Canadian company founded in 1989 and which now employs over 275 people. Pelmorex owns and operates two national specialty channels, The Weather Network and MétéoMédia, which are broadcast in both official languages and are distributed to eight and a half million Canadian households representing 95 percent of Canadian cable and direct-to-home satellite subscribers. The Pelmorex family of companies are leaders in providing customized weather-related content and services to business and consumer markets in Canada, including the popular websites http://www.theweathernetwork.com, http://www.meteomedia.com.

Pelmorex has developed a technology, the All Channel Alert (ACA) system, that can alert cable television viewers to weather-related or other emergencies in their area. The technology can intercept ALL channels distributed by a cable company in the area affected by the emergency and overlay a warning message on the television screen to alert viewers to an impending emergency, no matter which particular channel they might be watching.

Initially, the ACA system will broadcast weather-related emergency alerts, as established by Environment Canada's overall weather warning program. Eventually other authorized federal government agencies or applicable provincial or municipal authorities, will be able to access the ACA system to broadcast emergency messages. Pelmorex acts as a conduit only – authorized government agencies will determine the content for the messages and to whom they are directed.

Meteorology Training on the Internet Using Multimedia

Douglas Wesley, Wendy Schreiber-Abshire, Timothy Spangler, Kevin Fuell and Greg Byrd
University Corporation for Atmospheric Research / Cooperative Program for Operational Meteorology, Education and Training (COMET®), Boulder, CO USA

For more than ten years, the COMET Program has delivered both residence courses and multimedia distance learning materials to operational forecasters. The computer based training modules have been delivered via a variety of media including laser discs, CD-ROMs, and most recently, the World Wide Web. In the past two years we have added the ability to deliver audio, and now even video, in our Web-based training materials. Web-based presentations by experts with an extensive audio or video component are referred to as "Webcasts". These are live or on-demand multimedia presentation delivered over the Internet. The initial response to training delivered to operational forecasters via Webcast technology has been very positive. Many learners prefer the guidance that an instructor's or expert's presence brings, as opposed to material that only contains text and stationary graphics.

Webcasts use Internet "streaming" technologies to deliver long media files while a viewer watches, rather than sending all the files before the viewer begins to see them. Newly available high-bandwidth service options and sophisticated compression schemes have made video, photographs, and computer-generated slides reasonable Webcast components. Because they are delivered via the Internet, Webcasts can also include interactivity created using HTML, Javascript, and/or Java as well. The benefit of this technology is that an expert's presentation can be captured and made available to an audience of any size. With the appropriate production system in place, Webcasts can even be used to disseminate live presentations.

Recently, COMET has embarked upon a "Mesoscale Primer" project primarily aimed at Navy forecasters. This is a series of Web-based modules and expert presentations that address basic mesoscale meteorology topics such as cold air damming, definition of the mesoscale, flow interaction with topography, and gap winds. Furthermore, a series of Web-based modules on Numerical Weather Prediction topics, ranging from data assimilation to the forecast process and case studies, has recently been completed.

The COMET Program hopes to create a virtual library of Webcasts where learners can access key topics, discussed by leading subject matter experts whenever it is convenient or appropriate. It is our intent to bring a variety of the latest science topics pertaining to our sponsors' needs directly to operational weather forecasters via this method. The Webcast and Web module collection may be viewed by visiting the MetEd training site:

http://meted.ucar.edu/

Just a few of the modules with extensive audio or video components that are already available include: Predicting Supercell Motion Using Hodograph Techniques, Cold Air Damming and Coastal Fronts, Rain Gauges: Are They Really Ground Truth?, The Use and Misuse of Conditional Symmetric Instability, and Radiation Fog.

MSC/COMET Winter Weather Course: A Partnership for Learning

Kent A. Johnson, Jim D. Abraham, Gregory P. Byrd, John R. Gyakum, and **Doug A. Wesley**

The inaugural MSC/COMET Winter Weather Course was held in Boulder, Colorado, from February 11 to 23. This course was developed as a partnership between the Meteorological Service of Canada (MSC) and the Cooperative Program for Operational Meteorology, Education and Training (COMET). Sixteen MSC meteorologists and two colleagues from the National Weather Service participated in this prototype course, funded primarily through the Environment Canada Learning Fund. The primary focus of the course was to foster an increased understanding of and improved forecast techniques for severe winter weather.

The Course took advantage of the state of the art COMET infrastructure (and the supporting human resources) and utilized the expertise of over twenty guest instructors from the operational and academic communities across Canada and the United States. A full description of the Course appears on the COMET website at "http://www.comet.ucar.edu/class/aes_canada/index.htm" __http://www.comet.ucar.edu/class/aes_canada/index.htm_. A comprehensive evaluation will be completed in the autumn of 2001 and will consider the knowledge transfer component from course participants to

regional forecast offices. A summary of the development of the Course, an overview of its content, the logistical and scientific challenges, the advantages of the MSC/COMET partnership and recommendations for future meteorological training will be provided to interested parties both within and outside the MSC.

Students on the course were unanimous in their appreciation of the opportunity while, at the same time, were aware that their most important work will occur in following months.

Public Awareness And Need For Severe Weather Warnings - Results Of Some Recent Public Opinion Research

Heather A. Aucoin,
Policy and Corporate Affairs Directorate, Meteorological Service of Canada

Environment Canada's Meteorological Service of Canada (MSC) provides Canadians with weather forecasts and warnings 24 hours a day, seven days a week. Weather services are among the most frequently used federal government services. Hazardous weather resulting in serious social and economic disruptions is experienced in all regions of Canada.

The MSC has conducted surveys in the past on public satisfaction with the content and timeliness of weather warnings. However, in order to track its success in reducing negative impacts of weather hazards on Canadians' health, safety and economic prosperity, the MSC needs to know what actions Canadians take when weather warnings are issued; i.e do they change their behaviour based on this information.

To address this information gap, some surveys were conducted recently by Ipsos Reid, under the direction of the MSC's Policy and Corporate Affairs Directorate. A national survey was conducted of over 2000 Canadians, on their awareness of weather warnings, the actions they take when hearing about impending summer or winter storms, and their perceived vulnerability to severe weather. To validate the results of the survey, post-warning surveys were conducted in St. John's, Newfoundland, and the Saguenay Lac St. Jean region in Quebec, following winter freezing rain and heavy snow warnings, to test what actions respondents actually took following a warning message.

Survey results will be presented, along with an analysis of past survey findings on weather warnings, and the implications for the effective delivery and communication of warning information to the public.

Session 2
Boundary Layers
Monday, May 28, 2001
13:00 –15:00
Ballroom B

Evaporation Estimates from a Lined Reservoir

G.S. Strong[1] and **C. Hrynkiw**[2]

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2 Meteorological Service of Canada, Saskatoon, SK

Water balance estimates of evaporation from two lined dugouts in Swift Current, Saskatchewan are used to evaluate and fine-tune semi-empirical operational methods for estimating open-water evaporation over small water bodies. The two dugouts were each 30 m by 55 m by 4 m deep. During 1994, both were instrumented to provide detailed half-hourly basic-state meteorological data, as well as precipitation, water levels, and water temperatures. Daily evaporation pan data were also recorded.

An unidentified leak in one of the dugouts, followed by a defective water level recorder part way through the summer, and dismantling of the site due to city construction in 1995, hampered the analysis effort and delayed reporting of these results. Back-up optical measures of water level recorded periodically during 1994 have provided a means to readjust the recorder data. The validity of adjusted data is discussed, and evaporation estimates determined from the water balance methods are compared with estimates from evaporation pan data and Meyer's mass transfer method.

Internal Boundary-Layer Growth Under Non-Neutral Conditions

S. A. Savelyev and **P A Taylor**
EATS, York University, Toronto, Ontario, M3J 1P3

The Internal Boundary-Layer (IBL) formula derivation by Panofsky-Dutton employed the “diffusion analogy” idea proposed by Miyake (and Monin). The hypothesis assumes proportionality of the IBL growth rate to flow and equilibrium mean velocity above new surface conditions. Under neutral conditions this is simply related to the difference in surface roughness. Non-neutral stratification will involve changes in heat flux. The comparison between equilibrium states allows use of Monin-Obukhov similarity theory. Numerical simulation has been done to check the validity of the hypothesis on the proportionality coefficient

On Momentum Transfer Over Water Waves

Wensong Weng and **Peter A. Taylor**
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Peter P. Sullivan
National Center for Atmospheric Research, Boulder, Colorado 8037, USA

In the idealised framework of a constant stress layer above a 2D wavy surface, averaging over a horizontal plane will yield the result that the sum of mean flow Reynolds stress <-UW> and turbulent shear stress <-u'w'> will be a constant, =u*2. The naïve assumption has been that both terms will contribute positively to the total stress. DNS calculations by Sullivan et al have however shown that <-UW> can be negative close

to the wave surface and, in consequence, that <u'w'> is greater than u*2, when the average is over a horizontal surface.

Calculations with models based on ensemble averaged equations confirm this. However averages along mean-flow streamlines show that the form drag across these surfaces is positive and the horizontal force associated with turbulent shear stress across the streamlines is less than u*2, matching with the naive assumption.

Results illustrating this will be shown for both fixed wavy surfaces and for flow over water waves, and the impact on field measurements of turbulence in airflow over water waves will be discussed.

Applying Rotating-Stratified Turbulence Theory To Numerical Models Of Mesoscale Meteorology

Peter Bartello
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In the past two decades spatial truncation scales in numerical atmosphere/ocean models have decreased by an order of magnitude. Over the range from large-scale quasigeostrophic flow to boundary-layer turbulence, the nature of the dynamics as characterised by the relative importance of stratification and rotation, changes a great deal. Such issues as the breakdown of balance and the interaction between vortical motions and the gravity-inertial wave field are not completely understood. This study examines a series of recent theoretical and numerical explorations of rotating stratified turbulence (Bartello 1995; Bartello, Metais & Lesieur 1996; Bartello & Thomas 1996) to suggest future directions for numerical methods in GFD.

The various sets of nonlinear interactions between modes possessing potential vorticity (vortices) and those that do not (mostly waves) have been examined in unbalanced rotating stratified turbulence. The wave/vortex interactions which are permitted by the conservation properties may be rendered weak if they are far from resonance, i.e. if their frequencies are sufficiently mismatched. For many applications in GFD, wave timescales are considered too short to be treated explicitly. Two common methods to avoid the resulting CFL instability are the semi-implicit method and the split explicit method. When these schemes are implemented the numerical wave frequencies are severely reduced, but differently in the two schemes. Using the same resonance/conservation analysis, but now applying it to the numerical frequencies, yields some surprising results concerning the climatological cascades of fast and slow energy and of potential enstrophy in models employing these schemes. Whereas a reduced wave/vortex frequency separation can be maintained with semi-implicit methods, this is not always possible with split-explicit schemes. These points will be illustrated with numerical simulations.

Monday, May 28, 2001
13:00 –15:00
Solarium

A Parametrisation Of Subgrid-Scale Convection Due To Sea-Ice Growth In A Global Ocean-Atmosphere Model

Oleg.A.Sayenko, Andrew J.Weaver
School of Earth and Ocean Sciences, University of Victoria

Gregory M.Flato
Canadian Centre for Climate Modelling and Analysis

A parametrisation of brine-induced subgrid-scale convection is presented for a global ocean-atmosphere model with a multi-category sea ice component. The parametrisation employs explicit subsurface mixing of brine-enriched surface waters, resulting from sea ice growth. Using the multi-category approach to sea ice modelling, an attempt is made to parameterise the under-ice convection by mixing both ocean temperature and salinity for unstable water columns under the associated ice categories within a model grid cell with growing ice. In a series of sensitivity model runs the response of simulated ocean, ice, and atmosphere is discussed, emphasizing a chain of physical processes and feedbacks. It is shown that better representation of the brine rejection improves a simulation of intermediate and deep ocean waters. This is achieved by reducing an excessive grid-scale Southern Ocean convection, which is a common problem in OGCM and climate models. Ocean-air heat exchange is mainly affected around Antarctica, being modulated by sea ice cover response. Over the Arctic Ocean it is shown that the parametrisation of the brine-induced convection improves the simulation of the warm Atlantic Layer and sharpens the halocline.

Analysis Of Passive-Tracer Transport As Modelled By An Ocean General Circulation Model

Francois Primeau and **Peter Sutherland**
Canadian Centre for Climate Modelling and Analysis
Meteorological Service of Canada
University of Victoria

The pathways and time-scales for fluid elements to be transported from the ocean surface to the interior and from the interior back to the surface are explored using a global ocean general circulation model. The diagnostic tool used to summarize the transport properties of the modeled ocean circulation is the probability density function (pdf) of transit time computed as a function of position in the ocean interior. Several characteristics of the transit time pdfs are discussed as a function of the model resolution. These include the decay rate of the tails of the pdfs and the first moments of the surface-to-interior and interior-to-surface transit-time pdfs – the so called "mean age" and "mean escape time". The goal of the research is to gain better understanding of the large-scale transport properties of the ocean circulation that are important for understanding the oceanic carbon cycle.

Chaos or Critters?

Tetjana Ross
Dept. of Physics, University of Victoria

Many oceanographers, both physical and biological, use sound to probe the ocean. Where there are low levels of turbulence, researchers have been quite successful in translating volume backscatter measured by echosounders into zooplankton distributions. Turbulent microstructure also scatters sound, however, and there is some circumstantial evidence that suggest backscatter from turbulence may drown out the biological return in some turbulent regions, thereby hampering the ability to make acoustical estimates of zooplankton distributions.

Models for sound scattering from turbulence and zooplankton show that, at frequencies popular in oceanographic use (10 kHz to 1 MHz), either turbulence or zooplankton can be dominant depending on the strength of the turbulence and the density of zooplankton.

In August 2000, simultaneous measurements were made of turbulent microstructure(with thermistors and shear probes), fine-scale zooplankton distribution with a video camera)and backscatter at 2 frequencies (12 kHz and 100 kHz) in Sansum Narrows,B.C., with the aim of quantifying the relative importance of turbulence and zooplankton to the acoustic pictures seen. Some results from this study will be discussed.

Dynamics of Inner Spiral Bands in a Simulated Hurricane

Yongsheng Chen and **M. K. Yau**
Department of Atmospheric & Oceanic Sciences
McGill University
Montreal, Canada

An initially axisymmetric hurricane was explicitly simulated using the high-resolution PSU-NCAR non-hydrostatic mesoscale model (MM5). Spiral potential vorticity (PV) bands which formed in the model were analyzed. It was shown that PV bands and cloud bands are strongly coupled. The PV anomalies in and at the top of the boundary layer interact with friction to produce upward motion which gives rise to the inner cloud bands. The propagation properties of the PV bands were studied and found to be consistent with predictions of vortex Rossby wave theory.

PV budget study suggested that non-conservative processes, especially diabatic heating, generates high values of PV in the eyewall and the spiral rainbands to maintain a “bowl-shape” PV field which is fundamentally unstable for PV waves. Inward transport of high PV by the vortex Rossby waves and the process of non-linear mixing tend to increase PV in the inner core which in turn intensifies the hurricane. Meanwhile, the redistribution of the momentum by wave-mean-flow interaction leads to the deepening of the central pressure.

Methods To Reduce Biases Between Wind Speeds From Ships And Buoys

Bridget Thomas and Val Swail
Environment Canada
Halifax, N. S. and Downsview, Ont.

Surface marine wind observations are important for input into numerical weather and wave models, for diagnosis and forecasting of tropical and extra-tropical cyclones, for climatological research, and for the air-sea flux calculations used to drive atmosphere-ocean models. *In situ* observations are important also for calibration and validation of other sources of marine wind data such as satellite wind measurements. However, ship and weather buoy wind observations are inhomogeneous due to differences in measuring method and platform. This study considers methods for adjusting wind speeds to reduce these biases, using data from an 8-year period on Canada's east coast, and a 16-year period on the west coast, up to the end of 1995. The ship reports are from the Comprehensive Ocean-Atmosphere Data Set (COADS), Release 1a. The buoy observations are from Environment Canada's moored NOMAD buoys, as archived by the Canadian Marine Environmental Data Service.

We pair buoy reports with ship reports that are close in space and time, and analyze these pairs. Ship measurements are corrected for anemometer height using an accepted boundary layer model; and buoy observations are corrected for a change in the method of averaging buoy wind, which took place during the period of the study. As part of our analysis, we develop new ways to homogenize databases using these wind speed pairs; and we compare these to existing methodologies. The influence of factors such as wave height and flow distortion on vessels of different types will be discussed. The main goal of the project is the development of methods to adjust entire climate databases. However, we also give examples of the adjustment of data from some specific extreme marine cyclones.

Session 1
Significant Weather Case Studies and Modelling
Monday, May 28, 2001
15:30 –17:10
Ballroom A

Lightning Activity During the 1999 Superior Blowdown

J. F. Hopper[1], K. Everett[2], B. P. Murphy[2]
Meteorological Service of Canada - Ontario Region

[1]Thunder Bay Regional Weather Centre, 105-33 South Court Street, Thunder Bay ON P7B 2W6

A severe derecho caused extensive damage along the Minnesota-Ontario border on 4 July 1999, with peak winds approaching 150 km hr^{-1} (estimated). Several hundred thousand hectares of trees on both sides of the border were blown down, resulting in extreme hazards to residents of the area as well as to many visitors in the popular Boundary Waters Canoe Area and Quetico Park. The system was also associated with heavy rains and local flash floods. Forest blowdowns occur every year, but the effects of the widespread destruction fromthis event continue to be a concern, and are expected to remain so for years. The downed

trees represent a massive fuel supply for a potential forest fire outbreak on a scale unprecedented in recent decades.

The rapid movement of the system, its small size, and occurrence in an observation-sparse area made timely recognition and prediction of the event problematic. Post-analysis of the event is also difficult because of the lack of mesoscale observations and the absence of reports from trained observers. To overcome this problem, data from the Canadian Lightning Detection Network (CLDN) have been used to trace the path of the system and correlate reported areas of destruction. As well, the event was characterized by an overwhelming predominance of positive cloud-to-ground lightning flashes (+CG), a pattern distinctly different from lightning patterns associated with other mesoscale phenomena during the very unstable conditions present in the area during the first week of July. The lightning patterns may have considerable usefulness as a signature of unusual events such as derechos, and indeed may be the only reliable means of detecting and tracking sub-synoptic events, especially in data-sparse areas.

Overview and Impacts of the 1999 Superior Blowdown: A Long-lived Derecho

J. F. Hopper[1], B. P. Murphy[2], K. Everett[1]
Meteorological Service of Canada - Ontario Region

[1]Thunder Bay Regional Weather Centre, 105-33 South Court Street, Thunder Bay ON P7B 2W6

The extent and severity of the damage caused by a derecho which struck on 4 July 1999 has caused considerable ongoing concern because of the large numbers of trees downed. Many of the blowdown areas remain impassable nearly 2 years after the event. The greatest continuing concern is with the potential for forest fires, since the downed trees represent a nearly perfect fuel source. It is likely that similar severe weather events which caused undocumented extensive blowdowns were contributing factors to massive forest fires of earlier centuries.

Destructive meteorological events in northern forested areas cannot be dismissed as negligible simply because they occur outside populated areas. This particular event, known locally as the Superior Blowdown or the Superior Green-Sky Event, caused extensive physical damage to forests and road/trail infrastructure. While damage to residential and commercial areas was limited, forest damage from destructive meteorological events has considerable impact on the local economy especially in the forest sector. After this derecho, forest harvest areas were changed where access had become impossible. Regional harvest policies have also been changed to attempt to mitigate the extremely hazardous forest fire potential. Moreover, this event stuck the highly popular Boundary Waters Canoe Area and Quetico Park on a holiday weekend. Several thousand recreational visitors to these areas were exposed to high risks from a meteorological event, in an area and under conditions where they had no possibility of receiving appropriate warnings. The event emphasizes that current weather forecasting and dissemination procedures have no adequate provision for this segment of the population.

Meteorological conditions associated with the development of this derecho are summarized, the damage characterized, and a potential derecho signature reviewed. An intriguing feature of this event was its long life. Considerable damage was also caused in Quebec the next day. Using lightning data, we have

been able to link the areas of damage in NW Ontario and Quebec, and show them to be part of the same meteorological phenomena, rather than separate regional events. An interesting aspect is speculation on the cause of its apparent variation in intensity, as there were few reports of major damage in NE Ontario.

Major Hazardous Meteorological Events on the Great Lakes: A Historical Review and Changing Forecast Priorities

J. F. Hopper[1], D. J. Simpson[1]
Meteorological Service of Canada - Ontario Region

The Great Lakes have a long maritime heritage, and disasters caused by meteorological events are a big part of that heritage. Weather conditions and waves can change quickly, and have led to tragic events. Unfortunately, the hazards associated with sailing on the Great Lakes, whether in large commercial vessels or small private boats, are often ignored or dismissed by those not familiar with the unique environment. There have been a number of large-scale disasters on the Great Lakes, which are summarized here using archived accounts and pictures. Early vessels were no match for severe weather events on the Great Lakes, but even modern vessels can be placed in jeopardy by extreme weather events such as the Edmund Fitzgerald storm. Accounts are also included of a few of the many losses of individual ships that were caused by unpredicted storms, or attitudes that under-estimated the environmental dangers. Tragic, often poignant, the accounts are an excellent introduction to the hazards posed by weather and wave conditions on the Great Lakes.

Current technologies and practices in the commercial shipping industry, as well as modern weather forecasting techniques and dissemination methods, have greatly lessened the risk to commercial mariners from storms. New priorities for environmental prediction on the Great Lakes are emerging as a result of environmental and user changes. An example is shown of how the concept of value added to a weather forecast can play a role in developing new products for weather prediction and dissemination for the Great Lakes.

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The Derecho Of July 5, 1999 In Quebec : A Rare Event

Serge Mainville SMC, Ville St-Laurent, and René Héroux, Pierre Vaillancourt

During the night of July 5, 1999, severe thunderstorms affected most of southern Quebec. This derecho, moving at 100 km/hr, caused considerable destruction on its path. By definition, a derecho is a rapidly moving extratropical convective system that produces downbursts resulting in significant and widespread damage. This outflow-dominated storm possesses some of the features of a mesoscale convective system (MCS) as well as some of the features of a squall line.

Recent studies were undertaken on the shear patterns related to derechos with the intention of improving the forecast of such a convective phenomenon. The most distinctive features are found at low levels, such as the 0-2 km shear value and the low level storm-relative inflow. The latter yields that radar has a critical role identifying in detail the structure of the event.

This case study documents the evolution of the derecho and reviews the dynamic and thermodynamic factors leading to its formation and its rapid propagation. With the support of recent publications, it gives a greater insight into the associated shear pattern that is conducive to such a destructive event. Finally, it enhances the particular combination of parameters that makes the formation of derechos possible.

Monday, May 28, 2001
15:30 –17:10
Ballroom B
Session 2
Climate Impacts and Analysis

The Influence Of The Atmosphere Circulation On Canadian Temperature Trends

Xuebin Zhang, J. Sheng, and W. D. Hogg
Climate Research Branch, Meteorological Service of Canada

The association between trends in Canadian temperature and changes in the atmospheric circulation over the Northern Hemisphere is investigated. A principal component analysis was performed on sea level pressure field of the Northern Hemisphere, and the first 6 principal components were retained as predictors. Multiple linear regressions were then established between gridded temperature anomalies and the above predictors to reconstruct temperature anomalies based on a cross-validation framework. Trends were then computed for the original and reconstructed (from regression) temperatures.

The results suggest that 50-80% of observed trends in annual, winter, and spring mean temperatures and a considerable portion of summer and autumn temperatures trends can be associated with variations of the atmospheric circulation. The results also indicate that circulation patterns linked to the Arctic Oscillation and the Pacific Decadal Oscillation influence temperature trends over northeastern and southwestern Canada, respectively. The analytical procedure was also applied to screen temperature and mean sea level pressure fields obtained from an ensemble of three forced climate change simulations by a coupled Canadian GCM. It was found that a large portion of the temperature trends over the high latitude lands in the

ensemble mean for winter may be associated with circulation changes. But winter temperature trends were not associated with circulation changes in one member of the ensemble simulation. Moreover, temperature trends in other seasons are linearly independent of circulation change.

These seem to suggest that circulation changes in forced climate change simulations may reflect more the internal variability of the model climate system. Since this CGCM realistically simulates natural climate variability, it is thus suggested that the portion of observed temperature trends that can be associated with circulation change may still be within the range of natural climate variability.

Extreme Daily Temperature And Precipitation Trends In Canada During The 20th Century

Xuebin Zhang(1), Barrie Bonsal(2), W.D. Hogg(3), Eva Mekis(1), and Lucie Vincent(1)

(1) Climate Research Branch, MSC
(2) Aquatic Ecosystem Impacts research Branch, NWRI
(3) Reach Consulting

Trends and variability in extreme daily temperature and precipitation in Canada during the 20th century are summarized, based on the findings of two recent studies (Bonsal et al. 2001; Zhang et al. 2001). From 1900-98, the majority of southern Canada shows significantly increasing trends to the lower and higher percentiles of the daily minimum and maximum temperature distribution. The findings translate into fewer days with extreme low temperature during winter, spring, and summer; and more days with extreme high temperature during winter and spring. No consistent trends are found for the higher percentiles of summer daily maximum temperature indicating little change to the number of extreme hot summer days. The 1950-98 results are somewhat different from the entire century, especially, during winter and spring. This includes significant increase to the low and high percentiles over the west, and decrease over the east. From 1900-98, decadal variability is the dominant feature in both the frequency and intensity of extreme precipitation events over the country. There appear to be no identifiable trends in extreme precipitation. The observed increase in precipitation totals in the 20th century was mainly due to increase in the number of small to moderate events. From 1951-98, significant upward trend is found only in the frequency and intensity of extreme snowfall events in northern Canada.

Seasonal and Annual Precipitation Climate Indicators over Canada

Eva Mekis and Xuebin Zhang
Climate Research Branch, MSC

Trends and variations in precipitation extremes has been identified as an important indicator of global climate change. In the presentation spatial and temporal characteristics of selected climate change indicators related to precipitation, namely the number of days with precipitation, number of days with

snowfall, maximum daily precipitation, maximum number of consecutive dry days and multi-day precipitation extreme indices are investigated for the periods 1900-1999 and 1950-1999. Seasonal and annual trend analyses are performed for 495 stations across Canada and the results mapped and examined. Precipitation measurements are particularly susceptible to inhomogeneities that may affect extremes. The computation is performed on the recently created Canadian Historical Rehabilitated Precipitation dataset (Mekis and Hogg, 1999) which contains adjusted daily rain gauge and snow ruler values for carefully selected 495 best-quality stations. The adjustment includes the corrections for known inhomogeneities introduced by station relocation, instrument changes or different measurement practices, trace and SWE adjustments and based on extended metadata information. Preliminary results indicate considerable spatial variability over the country with some regional patterns evident. The significant decrease in the maximum number of dry days is in agreement with the increasing trend in the number of days with precipitation

Sensitivity of Greenhouse Warming Induced Changes in Cyclone Frequencies and Strengths to Model Formulation

Steven J. Lambert
Canadian Centre for Climate Modelling and Analysis
Meteorological Service of Canada, University of Victoria, Victoria, B. C.

Analysis of enhanced Greenhouse warming simulations has suggested that the frequency of mid-latitude winter cyclone will decrease in a warmer world. Although the total number of cyclone events decreases, the number of intense cyclones increases. Climate change simulations have been made with two versions of the CCCma Coupled Model. The two models use the same atmospheric component but coupled with slightly different ocean components resulting from improvements to the ocean model. Both simulations are analyzed for changes in the cyclone behaviour with enhanced warming in order to verify the robustness of signal in the cyclone event climatology seen in previous climate change simulations

The Atmospheric Response To SST Anomalies In The North Atlantic

Hai Lin and Jacques Derome
Department of Atmospheric& Oceanic Sciences and
Centre for Climate and Global Change Research,
McGill University, Montreal, Canada

The seasonal forecasts performed over a 26 year period as part of the Historical Forecasting Project (HFP) are used to analyze the atmospheric response to sea surface temperature (SST) anomalies in the North Atlantic, its seasonality and model dependence. Signals related to the El Nino events are first removed from both the SST and the atmospheric data. The North Atlantic SST used during a seasonal forecast and the ensemble mean forecast are correlated over the 26 years to identify the model response to the SST forcing. The two models used in the HFP yield highly consistent SST forced responses in the spring. For other seasons the response is sensitive to the model used.

Monday, May 28, 2001
15:30 -17:10

Solarium
Session 3
Coastal Oceanography

Transfer, Evaluation and Implementation of Canada's First Operational Storm Surge Prediction System

Hal Ritchie(1), Natacha Bernier(2), Josko Bobanovic(2), Serge Desjardins(3), Janya Humble(4), Al MacAfee(3), George Parkes(3) and Keith Thompson(2)

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(4) Department of Physics, Dalhousie University, Halifax NS, B3H 4J2

For about twenty years the Meteorological Service of Canada (MSC), through the Maritimes Weather Centre (MWC) in its Atlantic (MSC-A) region, has had the responsibility of advising the public when the combination of a high tide and an intense storm produces a risk of higher than normal water levels that may flood some coastal areas. The tides are easily predicted due to their periodic nature, but in the past no numerical model guidance has been available to forecast the additional "storm surge" component of sea level that is caused by the weather systems.

A team of oceanographers at Dalhousie University (Dal) has recently developed a storm surge forecast system for the east coast of Canada. The system is based on a two-dimensional barotropic model that is forced by atmospheric surface pressure and winds. As a collaboration within the Atlantic Environmental Prediction Research Initiative (AEPRI) this system has been transferred from Dal to MWC where it has been implemented as Canada's first operational storm surge prediction system. The operational system is forced by three-hourly atmospheric surface pressure and wind provided by the MSC operational regional weather forecast model and produces storm surge predictions up to 48 hours in advance. The transfer included a preliminary evaluation (as a "hindcast" study) for the period September 1996 to February 1997 and another evaluation for the period October 18 to December 6 1999 when the system first started running at MWC. The system soon demonstrated its potential by producing very accurate forecasts for the January 21, 2000 severe storm surge event that caused considerable coastal flooding and damage in Prince Edward Island and eastern New Brunswick. Storm surge prediction specialists in MWC have since produced a storm surge alert system that automatically warns the forecasters when predicted coastal total water levels (surge plus tide) exceed predetermined site specific thresholds that have been chosen to reflect varying degrees of expected flood damage.

The system was "put to the test" by an event predicted for the afternoon of February 6, 2001 when stage 1 thresholds were forecast to be exceeded in some locations in PEI and eastern NB. MWC forecasters were able to successfully identify which areas would be flooded and alert the Emergency Measures Office (EMO) in PEI, who notified the affected areas and monitored the situation as it unfolded. As a result of this inter-agency cooperation, some property damage was avoided.

Was The January 2000 Case A Probable Maximum Storm For The Atlantic Region ? Diagnosis Of The Storm And Its Steroided Clones Using Dionysos

Serge Desjardins, Hal Ritchie, Pierre Pellerin*
*Environment Canada, Dartmouth, Nova Scotia, Canada**

In January 2000 the Atlantic region was hit by three successive major winter storms. As each of them succeeded the other, they gained in intensity to culminate with the super-storm of January 21st 2000 which strongly impacted the Maritimes by its very strong winds coinciding with high tides, causing record storm surge values.

This presentation analyses the observed super-storm using traditional methods and introducing as well another way of diagnosing it using a diagnostic package called Dionysos. Impacts of the different forcings on the surface development and on the upper vertical motion are closely examined to better understand the extreme and rapid intensification of this storm. Furthermore, using the results of these diagnoses, an attempt is made to generate the most probable maximum storm (PMS) using the PMS model developed by Pierre Pellerin. Diagnoses of these theoretical cases are also performed to verify the changes in the various forcings.

This work is done in collaboration with Dalhousie University to which are supplied the surface fields from the theoretical "boosted" storms to study the storm surge that would be generated by such storms. Results of this latter study are also presented at this conference (see Bernier et al.).

Sensitivity of Storm Surges to the Maximized January 21 2000 Storms

Natacha Bernier(1), Hal Ritchie(2), Pierre Pellerin(2), Serge Desjardins(3), Josko Bobanovic(1) and Keith Thompson(1)

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(3) Meteorological Service of Canada - Atlantic, Dartmouth NS, B2Y 2N6

The January 21st 2000 storm was explosive and resulted in very strong winds and extremely low surface pressures. It hit the Maritimes at high tide and flooded vast areas, with record high surges at Charlottetown in particular. In this study we use a validated storm surge model (Bobanovic 1997) to examine the sensitivity of the storm surge predictions to changes in the storm track and intensity that are produced by applying a probable maximum storm (PMS) methodology to this case.

The surge model is 2-D barotropic and is driven by surface winds and air pressure provided by the operational Meteorological Service of Canada (MSC) regional weather forecast model. At the time of this event the surge model was running in validation mode at the Maritimes Weather Centre (MWC) in the Atlantic (MSC-A) region and was very successful in predicting the surge that was actually observed. The PMS methodology consists of modifying the initial conditions for the atmospheric simulation in such a way as to maximize the baroclinic development, hence generating the largest possible storm and/or modifying the storm track (see the companion presentation by Desjardins et al.). This is achieved by optimizing the lag

between the temperature and geopotential waves while retaining dynamical stability. These modified initial conditions are then used to rerun the atmospheric model which produces more intense surface wind and pressure fields. Here these atmospheric forcings are fed to the storm surge model and the resulting surges are compared with the original and observed ones, to examine their sensitivity to modified storm track and intensity.

This study is being conducted as part of a research project entitled "Sea Level Rise and Climate Change: Impacts and Adaptation Needs, Prince Edward Island - A Case Study", sponsored by the Canadian Climate Change Action Fund. Latest results will be presented at the Congress.

Surface Current Variability Over The Scotian Slope

Guoqi Han, C.L. Tang and Peter C. Smith
Fisheries and Oceans Canada
Bedford Institute of Oceanography

TOPEX/Poseidon (T/P) altimetry and numerical modeling have been analyzed to examine sea surface currents over the Scotian Slope. A modified orthogonal response analysis is used to derive the annual cycle while simultaneously removing the residual tides and other dynamical processes at the appropriate T/P alias periods. The along-track sea surface slopes, which represent surface geostrophic current components normal to the track, are estimated on selected T/P ascending and descending ground tracks. The altimetric results are compared with steric height anomalies and solutions from a regional diagnostic model forced by baroclinicity, wind stress, and boundary flows. Wintertime intensification of the shelf-break flows is indicated in the altimetric surface currents, consistent with the model solutions. Altimetric results clearly demonstrate seasonal variability of northeastward slope current stronger in fall and winter and weaker in spring and summer, which is less well resolved in the model. Assimilation of altimetric data into regional circulation models could help improve their prognostic ability to hindcast and nowcast seasonal variability of shelf-edge and slope water circulation. This study also indicates that better shelf tidal models that are compatible with global models are required to detide altimetric data for extraction of semi-annual and shorter-period processes.

Unusual Long Period Wave Events in Southeastern Newfoundland

Doug Mercer and Bruce Whiffen
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On two occasions in the fall of 1999 and 2000, unusual rises and falls of water level were observed in harbours in Southeastern Newfoundland. These rises and falls had periods of tens of minutes, and were large enough to cause local flooding and damage in several harbours. When this occurred conditions had generally calm seas and light winds, making this event unusual and frightening to many local people. The event occurred for a few hours at most, and then ended.
These events are important because under more severe local conditions they could easily have contributed to more widespread damage, and because they were unexpected, unexplained, and unpredictable using

current operational techniques and theory.

Work is currently underway to identify the mechanism causing these long period waves, and then to predict how they will affect coastal areas of Newfoundland. Currently investigation is ongoing with oceanographers on barotropic waves generated by intense rapidly moving low pressure systems on the Grand Banks as were present during both events. The long-term goal is to develop an operational technique to predict the occurrence and severity of these events.

Tuesday, May 29, 2001
08:30 – 09:50
Ballroom A
Plenary Session

A Vision for Meteorology in Canada

Marc Denis Everell, Assistant Deputy Minister,
Meteorological Service of Canada, Environment Canada.

Meteorology from a public, private and academic perspective is slowing growing in Canada. It needs to grow much faster and there are many opportunities to help it grow. But a clear vision is needed to guide its development. There is a sense of obligation for the Meteorological Service of Canada (MSC), as the largest meteorological service in Canada, to show some leadership in that regard and this CMOS congress provides a good venue to begin discussing such a vision and plotting a way forward.

The presentation begins with a broad vision for the year 2011 then steps back to look at where meteorology in Canada sits today. What are the challenges and opportunities facing he development of meteorology in Canada? Strategies are proposed to overcome those challenges, take advantage of the opportunities, and begin moving towards the proposed vision. MSC's positions on these issues and commitments towards implementing the strategies will also be presented.

Meteorology, including weather, climate, air quality, water and ice, affects the daily lives and businesses of people around the world. Studies from various countries clearly show the link between meteorological and related environmental services on a company's bottom line and some companies even understand that taking the environment into account pays off through gains in productivity and competitiveness . Value added meteorological services are growing in other countries and innovative services such as weather derivatives have been developed. As well, Canadians are now making strong links between their health and the environment. These

trends, among others, provide good opportunities for strong growth of the Canada's meteorological sector.

Right now the meteorological sector in Canada could be represented by a small pie. The Canadian private and academic sectors, with support from the public sector, need to grow that pie, not just in Canada, but into global markets. The talk focusses on the challenges, strategies and commitments needed to encourage the growth of meteorology from the perspective of the public, private and academic sectors and within the context of a ten year vision.

Tuesday, May 29, 2001
10:20 – 11:40
Ballroom A
Session 1
Warning Programs, Preparedness and Training

Examining Warning Criteria For Canada's Northwest Territories And Nunavut

Sharyn Straathof
MSC, Edmonton, AB

The purpose of weather warnings issued by Environment Canada is to inform the public of weather conditions which may cause injury or damage so that people can take action to protect themselves or their belongings. Currently, meteorologists at Canada's Prairie Aviation and Arctic Weather Centre use the same criteria for issuing warnings across Canada's Northwest Territories and Nunavut. However, the extreme variation in climate across these regions may suggest that warning criteria should vary geographically. Regions which frequently experience extreme weather may have adapted infrastructure and behavior to these conditions and may therefore be less susceptible to property damage and personal injury. Conversely, regions which do not tend to encounter extreme weather are likely poorly adapted to these conditions and may therefore be more susceptible to damage and injury.

The climatology of extreme weather for selected sites in the Northwest Territories and Nunavut will be reviewed. Feedback from residents in the North regarding the effects of extreme weather on their communities will also be discussed.

Wind Chill Warning Program Renewal

Joseph E. Shaykewich
MSC, SCPD, PMSB

Statistics Canada reports indicate that up to 90 Canadians die every year due to hypothermia. Public surveys show that Canadians, particularly in the North, consider windchill information important in order to make decisions on how to protect themselves from the dangers of high windchill (hypothermia, frostbite), to plan the duration of outdoor activities for themselves and their children, to dress themselves and their children and even when making travel plans.

Environment Canada has been providing Canadians with wind chill reporting and forecasting services since the 1950s. This program has been based on the research undertaken by a couple U.S. military investigators in Antarctic. Essentially these investigators researched the rate at which water cooled in a plastic cylinder.

MSC is working to make wind chill a more exact science and to find a way to more effectively communicate its impact to those exposed. The current methods of operationally computing wind chill are based on "old" science and did not involve any human experiments or experiences. There is a consensus among scientists that wind chill information in current practice are somewhat exaggerated, i.e. "too cold"! The MSC has investigated research undertaken elsewhere in the world and is participating with close collaborators internationally to ensure that wind chill calculations are scientifically sound and relevant to human populations. In addition, as MSC revitalizes the wind chill program in the MSC, it must ensure that wind chill information meets the needs of the public and the various sectors (such as public educators, the construction industry, EMO's).

The recent MSC Internet workshop on wind chill was a significant factor in initiating an international collaborative effort to review and revise wind chill calculations, and more generally to develop a "universal" method of calculating thermal indices. In this regard, a special Commission, established by the International Society of Biometeorology, is examining the issue. The U.S. Office of the Federal Coordinator of Meteorology (OFCM) established a Joint Action Group on Thermal Indices and has invited active Canadian participation with a view to the establishment of a common North American standard. Agreement has been achieved for a standard to be implemented in the fall of 2001. The new standard encompasses significant scientific improvements over current practices:

- A facial model rather than equations from plastic cylinders.
- The wind speed will be brought down to 1.5 metres, assuming a flat, unobstructed terrain (roughly 2/3 of 10-m value)
- Walking speed of 3 miles per hour (about 5 km/h).
- A correction term for radiation; value dependant on time of day, latitude and cloud conditions.
- Skin temperature (currently fixed at 33°) will vary according to environmental conditions
- The index will be expressed on a pseudo-temperature scale only since all indices brought forward in the scientific community were on that scale.

The thresholds for inclusion in forecast and warnings will likely be regional, to take into account adaptation (e.g. threshold in the Arctic will be much higher than in southerly places like Virginia). Clinical trials are

being undertaken at the Defence and Civil Institute of Environmental Medicine [DCIEM-DND], Toronto) to refine these thresholds. These improvements need to be reflected in the operational forecast programs in Canada. As well, a substantial public education program is being developed.

Use of the Advanced Hydrologic Prediction Services at a NWS Forecast Office: Operational Utility and Emergency Management Response

Lee Anderson, Greg Gust, Brad Bramer, Michael Lukes, and **Lynn Kennedy**
National Weather Service Eastern North Dakota, (Grand Forks, ND, USA

The Advanced Hydrologic Prediction Services (AHPS) are tools which provide an advanced hydrological modeling system and the delivery of a suite of both textual and graphical products for utilization during a variety of hydrological events. AHPS was developed following the devastating Mississippi River Valley Floods of 1993 and 1995. Operational implementation of AHPS occurred at the National Weather Service's (NWS) Forecast Office in Eastern North Dakota (Grand Forks) in January 2001, in part, because of the catastrophic 1997 flood in the Red River Basin. One of the benefits of AHPS is the generation of graphical products showing probabilistic river stages (and flows) and crest timing up to several months in advance. Additionally, five-day hydrographs during a flood cycle are produced for short-term river crest forecasting. Products from AHPS can provide significant flood-preparation lead time to emergency managers, engineers, and other flood planners. AHPS information may also be utilized in low flow situations during periods of drought.

The NWS Office in Eastern North Dakota completed numerous demonstrations, and outreach efforts through the implementation of AHPS in early 2001. Communication and coordination about AHPS occurred with municipal, state, and federal governmental officials, including emergency managers, Manitoba Water Resources, and Environment Canada in Winnipeg. Overall, the application of AHPS has produced favorable responses from emergency managers and other users of hydrologic products in the Red River Valley. The continued use of AHPS is likely during the next several years as a response to needs of flood planners and hydrologic operations.

Teaching Extreme Weather To A Diverse Group of Undergraduates

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For each of the past two years, the University of Alberta has offered a course on extreme weather (specifically EAS 202 Violent Weather) to a class of between 300 and 450 undergraduate students in various program years and from a wide variety of departments and faculties. The author will share his philosophy of teaching and experiences with the course, addressing particularly the broad issue of science vs.

"edutainment", and also the practical issues that arise in teaching such a large body of students from such diverse backgrounds.

Tuesday, May 29, 2001
10:20 – 11:40
Ballroom B
Session 2
Private Sector Forum

Private Sector Forum

Industrial Strategy: Q&A Session

Moderated by Peter Taylor

Tuesday, May 29, 2001
10:20 – 11:40
Solarium
Session 3
Climate Modelling: Prediction and Analysis

A Potential Seasonal Predictability Study with a Simple GCM

Hai Lin, Jacques Derome
Department of Atmospheric& Oceanic Sciences and
Centre for Climate and Global Change Research,
McGill University, Montreal, Canada

Gilbert Brunet
Recherche en prevision numerique,
Meteorological Service of Canada

A simple General Circulation Model (GCM), with time-independent forcing, is used to study the potential predictability of mean-winter atmospheric conditions. An empirical forcing is derived for each of 51 winters using the National Centers for Environmental Prediction (NCEP) / National Center for Atmospheric Research (NCAR) reanalyses. An ensemble of 20 90-day integrations is performed for each winter (December through February). The initial conditions for the ensemble members are randomly selected from the observed winter conditions in the 50 years other than the winter being forecast. While the initial conditions are random, the observed winter-mean forcing for the winter of interest is used, so that the results indicate potential predictability rather than actual prediction skill.

The interannual variability in the ensemble average of the forecasts in the second and third months is determined by the specified empirical forcing. This is compared with the interannual variability of the average of January and February (JF) conditions in the NCEP reanalyses. The results show that the temporal correlation over the 51 winters between the observed and model JF flows is highly significant, indicating that potential predictability exists. The actual prediction skill is examined in a separate study.

The empirical forcing embodies all the external sources of interannual variability that are expressed explicitly in more complex GCMs, as well as those that are difficult to represent in full GCMs. The characteristics of the forcing field are explored through an EOF analysis. The first EOF of the temperature forcing is found to correspond closely to the classical El Nino forcing.

Historical Seasonal Forecasts using a Simple GCM

Hai Lin, Jacques Derome
Department of Atmospheric& Oceanic Sciences and
Centre for Climate and Global Change Research,
McGill University, Montreal, Canada

Gilbert Brunet
Recherche en prevision numerique, Meteorological Service of Canada

A simple GCM using a time-independent forcing is used to perform a series of seasonal predictions. The predictions are done for 51 winter seasons (DJF) from 1948 to 1998. Ensembles of 20 forecasts are produced, with initial conditions of December 1st plus small perturbations. The model uses a forcing field that is calculated empirically from the National Centers for Environmental Prediction (NCEP) / National Center for Atmospheric Research (NCAR) reanalyses. The forcing used for a given winter is the sum of the winter climatological forcing plus an anomaly. The anomalous forcing is taken to be that of the month prior to the start of the forecast (November), which is also calculated from NCEP data. The forecast system does not use any data from the winter months (DJF) being predicted.

The ensemble mean predictions for the 51 winters are verified against the NCEP reanalyses. The simple GCM is found to have statistically significant skill in forecasting the DJF mean 500 mb height field, a skill that compares favourably with that of more complex models.

Climate Predictions With Multi-Model Ensembles

V. V. Kharin and **F. W. Zwiers**
Canadian Centre for Climate Modelling and Analysis,
Meteorological Service of Canada, Victoria, B.C., Canada

We consider several methods of combining individual forecasts from a group of climate models to produce an ensemble forecast. These methods are applied to an ensemble of 10 forecasts derived from Atmospheric Model Intercomparison Project (AMIP) integrations performed by 10 different modeling groups. The variables considered are monthly mean 500 hPa geopotential height and 850 hPa temperature. Forecasts are verified against re-analyses from the European Centre for Medium Range Weather Forecasts. Forecast skill is measured by means of forecast error variance. In the tropics the simple ensemble mean produces the most skillful forecasts. In the extra-tropics, a scaled version of the ensemble mean performs best. The (superensemble) forecast that is obtained by optimally weighting the individual ensemble members does not perform as well as either the simple ensemble mean or the scaled ensemble mean.

Relative Economical Value of CMC Seasonal Forecasts

Normand Gagnon and **Richard Verret**
Canadian Meteorological Centre
Meteorological Service of Canada

Since 1995, the Canadian Meteorological Centre (CMC) produces seasonal forecasts using dynamical and empirical models. These forecasts are deterministic in nature. The seasonal temperature and precipitation anomalies at any one location are forecast as being above normal, near normal or below normal. This approach does not take explicitly into account the confidence associated to the individual forecasts, which makes it difficult to users to make efficient use of this type of deterministic forecasts. In making use of the ensemble technique, a simple method to associate a probability of occurrence to each possible category is proposed. This method is called probabilistic. The probability of occurrence is simply calculated counting the number of model integrations that forecast occurrences in each one of the three categories.

Another important factor that prevents a large use of long-range forecasts is that their economical value has not been demonstrated. It has been shown that the CMC seasonal forecast system has some skill, although modest, for the prediction of surface air temperature anomaly in Canada. However, the relation between skill and economical value is complex and reliance on skill alone may give a misleading impression of forecast value. In this paper, a simple cost-loss decision model will be used to study the relative economical value of CMC seasonal forecasts.

Using twenty-six years of historical data, the relative economical value of CMC deterministic and probabilistic long range forecast systems for forecasting three equi-probable categories for surface air temperature and precipitation is evaluated. Results show that there is clearly some value in the surface air temperature anomaly forecasts in each season for the two extreme categories. The deterministic system adds value to the probabilistic one in Winter only, although it benefits from an error correction process (called Best Linear Unbiased Estimator or BLUE). For the precipitation forecasts, it is found that the current system has little or no relative economical value in any season.

Tuesday, May 29, 2001
13:40 – 14:40
Ballroom A
Plenary Session

Severe thunderstorm climatology: Of what can we speak?

Harold Brooks
Head, Mesoscale Applications Group
National Severe Storms Laboratory

Accurate knowledge of severe thunderstorm occurrences are important in forecasting, risk assessment, and detection of possible climate change. Unfortunately, development of high-quality climatologies is extremely difficult since severe thunderstorms are rare events at any location. Some efforts to produce such climatologies will be described, with a focus on the limits of what we can and cannot describe well. Consistent and inconsistent features will be discussed, so that even with a short

record at a particular location, it is possible knowledge of climatological information from other locations may be useful for certain parameters.

Session 1
Synoptic and Mesoscale Processes of Extreme Weather
Tuesday, May 29, 2001
15:10 – 17:10
Ballroom A

Elevated Thunderstorms across the Northern Plains

Daniel Riddle, David Kellenbenz, and **Jonathan Brazzell**
National Weather Service Grand Forks, North Dakota

The forecast problem of determining when or where convection will occur is often a difficult task. This job is made even more difficult when convection is elevated and develops in locations where an examination of typical surface parameters would not suggest convection. In 1999, the National Weather Service Forecast Office (NWSFO) in Grand Forks, North Dakota began a research project to examine the frequency and forcing mechanisms that cause elevated thunderstorms (severe and non-severe) across portions of the Northern Plains. Seven cases were identified across eastern North Dakota and northwestern Minnesota in 1999. The study was continued in the year 2000 where an additional nine cases were identified. These were broken down into cool season (October-April) and warm season (May-September) events. All but one of the cases during the two year period occurred in the warm season. For the purpose of this study, the definition of elevated thunderstorms was taken from research presented by Bradley R. Colman in 1990 and Bradford Grant in 1995. In Colman's research, elevated thunderstorms typically occur northeast of an associated surface low pressure system and north of a surface front (warm or stationary).

It must be stressed that few conclusive results can be gleaned from the limited number of cases studied. But one finding was that it is important the forecaster examine model forecast soundings to recognize where the most unstable layer is located. Once this is known, the forecaster can then more closely examine data from that layer to see if parameters are condusive for elevated thunderstorms to form. Another finding is that elevated convection often occurs in the left quadrant of an 850 hPa jet. The stronger the jet and more moist the atmosphere, the more likely the thunderstorms will be severe. In addition, the most severe thunderstorms form closer to the surface warm front while non-severe elevated thunderstorms often occur 150 miles (240 km) or more from the surface warm front. Elevated severe thunderstorms most commonly produce hail around 1.00 inch (2.5 cm). Peak time for elevated convection is 0400 UTC to 1000 UTC.

This study will be continued over the next few years with the goal of developing guidelines to assist forecasters in determining when and where elevated thunderstorms are likely to occur.

Genesis and Morphology of the Alberta Dryline

Neil M. Taylor
Prairie Aviation and Arctic Weather Center
Meteorological Service of Canada, Environment Canada

Isodrosotherm and surface wind analyses are used in combination with remote sensing data to demonstrate the role of the dryline in convective initiation on severe weather days in Alberta. Synoptic and mesoscale conditions indicative of dryline development are identified and the mechanisms responsible for dryline formation are discussed and compared with those proposed for the U.S. high plains. This work is motivated by the lack of documentation of the dryline in Alberta and the need for Canadian prairie forecasters to understand its development, behaviour, and significance for convective initiation.

From 1 May to 30 September 2000, twenty-two days were identified as having three or more reports of hail (

20 mm or at least one report of hail (30 mm and / or a tornado. On eleven of these days convection was initiated in close proximity to a dryline. The Alberta dryline develops in response to convergence of moist upslope flow with dry, subsiding air in the lee of the Canadian Rockies. The dryline often bulges eastward in southern Alberta where stronger dry air advection can result depending on the direction and speed of the flow over the mountains. In rare cases, storms initiated on the western portion of the dryline may become tornadic as they interact with the bulging portion of the dryline. Through recognition of antecedent synoptic and mesoscale conditions, the forecaster can anticipate dryline development well in advance and thus identify a preferre d axis for thunderstorm development.

Potentially Extreme Consequences of Slantwise Convection

Kent Johnson and **Gabor Fricska**
Mountain Weather Centre, Kelowna, BC

On 2000-12-31, a band of precipitation developed over southern British Columbia and produced several centimeters of snow through the Okanagan Valley. This relatively small snowstorm produced potentially dangerous consequences. Snow commenced nearly simultaneously at the two major airports in the Okanagan Valley rendering both unsuitable for instrument approaches or landings.

Traditional precursors for snow in the Okanagan Valley were non-existent in this case. In almost all cases, snow can be seen at upstream stations or moves from one end of the north-south valley to the other. Thus, there is generally some forecast lead time for most of the populated area, even in surprise precipitation events. In this case, a north to south band of snow formed over both Kelowna and Penticton within a few minutes of each other.

The synoptic flow pattem was a gentle southwesterly flow aloft, that tending to produce dry subsident conditions over the Okanagan Valley. Given that virtually no snow occurred at an upstream station to the west, forecasters did not anticipate significant snow. The band that formed eventually dropped approximately 5 centimetres of snow in the Okanagan Valley with significantly lower amounts over the higher terrain to the east and west. The band dissipated several hours after its onset.

Slantwise convection is a challenging forecast problem as precipitation tends to be banded with width scales as small as 10 km. In addition, no reliable weather radar information is available for most of BC. Due to the scale of the precipitation bands, current operational NWP is incapable of accurately predicting their positions. However, although slantwise convection is a mesoscale phenomenon, it results from synoptic scale forcing where NWP tends to be more reliable. In addition, forcing for slantwise convection is often at mid levels of the atmosphere where terrain impacts, such as those in BC, are lessened. An analysis of the case of December 31 is presented along with suggestions for how slantwise convection might be effectively forecast.

Assessing Rain, Snow Delineators over the Canadian Rocky Mountains

Derrick Kania

Environment Canada Prairie Storm Prediction Centre Winnipeg, Manitoba

On July 03 1999 and July 14 1999 between 25 and 60 cm of snow was reported along Highway 93 connecting Jasper and Banff. In both incidences the heavy snowfall resulted in highway closure. Traditional rain/snow boundaries such as low level thickness, 500-1000 mb thickness, 850 temperature and 700 temperature were not effective. Furthermore limited upper air and surface reports made snow fall estimates difficult. In hindsight the surface wet bulb zero line was a useful predictor of the rain/snow boundary.

Modelling Maximum Hail Size in Alberta Thunderstorms

Julian C. Brimelow and Gerhard W. Reuter
Department of Earth and Atmospheric Sciences, University of Alberta

A one-dimensional, steady-state cloud model was combined with a time-dependent hail growth model to predict the maximum hailstone diameter on the ground. Model runs were based on proximity soundings and the observed surface temperatures and corresponding dew-points recorded within the Alberta Hail Project area for 160 days between 1983 and 1985. The forecast hail sizes were evaluated against reports of maximum hail size gathered from a high-density observation network within the project area. A nomogram developed to forecast maximum hail size in Alberta was also evaluated against the Alberta Hail Project hail data. The probability of detection (POD), the false alarm ratio (FAR) and Heidke's skill score (HSS) were calculated to objectively assess the skill of the two techniques. The model displayed significant skill when forecasting the occurrence of hail (POD=0.85; FAR=0.26; HSS=0.64). On days with hail larger than 2.0 cm in diameter, the model performed even better (POD=0.90; FAR=0.40; HSS=0.67). Analysis of the skill scores suggests that employing a coupled cloud and hail model noticeably improves the overall skill and accuracy of hail forecasts as compared to those determined using a nomogram.

Boundary Layer Processes in Alberta's Pre-Storm Environment

G.S. Strong[1] and **C. D. Smith**[2]

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Atmospheric boundary layer (ABL) processes in the pre-storm environment of severe Alberta thunderstorms are reviewed using new analyses of an old dataset from LIMEX-85. The rapidity of ABL changes during late-morning are explored, emphasizing the need for such information over the foothills where most such storms initiate. The use of proxy data is considered, and an attempt is made to reconstruct ABL profiles for some recent severe thunderstorms.

Tuesday, May 29, 2001
15:10 – 17:10
Ballroom B
Session 2
Climate Impacts and Analysis

Climate Change: Impact of Prairie Land Use on Convective Rainfall

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Meteorological Service of Canada
Prairie & Northern Region, Environment Canada

In addition to the widely publicized "greenhouse effect", the Prairie climate has been incrementally changed, and could be further altered, by the cultivation of agricultural crops (land-use effect). During the growing season, the water-use (evapotranspiration) pattern of the dominant vegetation, currently annual field crops, controls the partitioning of net radiation between latent and sensible heat.

From a consideration of the horizontal moisture influx per unit area, and the areal average evapotranspiration and rainfall, the average summer recycling ratio (i.e., rainfall from regional evapotranspiration to total rain) for the southern Saskatchewan-Manitoba region was found to be 25-33%. Evapotranspiration from Prairie crops was secondary to advection, yet significant, as a source of water vapour for summer rains.

A relationship between the Bowen ratio (sensible heat/latent heat), noon global radiation and the change in the Lifted Index was used to ascertain the impact that the change in the dominant vegetation from native perennial grasses to annual field crops may have had on the potential for deep convection. Given similar dynamic and advection patterns, this vegetation transformation has likely reduced the frequency of thunderstorms during the early and the late portions of the growing season, and it may have made them more frequent and possibly more intense during the middle of the season.

These results imply that: (1) regional evapotranspiration, as a source of water vapour and convective available potential energy, may be a factor in the persistence of summer droughts and wet periods, and (2) further anthropogenic change (land-use, CO_2 radiative or physiological effects) that modifies the evapotranspiration regime, may affect the strength of the water cycle and, thus, the aridity of the region.

The Impact of Climate Change Scenarios on Wetlands and Waterfowl Populations on the Canadian Prairies

R.F. Hopkinson
Environment Canada, MSC, Prairie & Northern Region

The number of wetlands (sloughs) on the prairies and the total waterfowl population are highly correlated with the Palmer Drought Index (PDI) for April or May. Climate change scenarios from a number of general circulation models were applied to the temperature and precipitation data sets and the PDI was recalculated

for each model scenario for time periods centered on the 2020s, 2050s and 2080s. The result for the Canadian model (CGCM1) was a general reduction in the PDI by about two units by the 2050s. Using the regression relationships between the pond counts and the PDI and between the waterfowl populations and the PDI, the impacts of the scenarios were quantified. The predicted impact was a 45% reduction in the average number of waterfowl in southern Saskatchewan. Similarly the predicted number of ponds was reduced by 54% on average from historic (1961 to 1999) values. The Palmer Drought Index is very sensitive to temperature because the evaporation term is a Thornthwaite representation which is driven solely by temperature. Thus it is probable that the impact is overestimated to some extent but the coupled atmospheric-hydrological simulations and model validation for some heavy rainfall and flooding events in southern Ontario

Prediction of Agricultural Drought on the Canadian Prairies

Steven M. Quiring and **Timothy N. Papakryiakou,**
Department of Geography,
Centre for Earth Observation Science,
University of Manitoba

The Canadian prairies are dominated by a semi-arid climate where there is considerable variability in growing season precipitation and evapotranspiration routinely exceeds precipitation. Since drought is a common occurrence, and since agriculture is central to the Prairie economy, it is necessary that the spatial and temporal dynamics of drought be fully understood. Of particular concern is our inability to forecast drought events. In this study we examine the linkages between global teleconnections and agricultural drought on the Canadian prairies to assess the utility of such indices for drought prediction. The relationship between agricultural drought and global teleconnections is examined throughout the Prairie Provinces at the crop district level, between 1950 and 1999. The indices we considered include the Arctic Oscillation, the Pacific/North American Index, and the El Niño Southern Oscillation. We find that although there are some significant links between teleconnections and drought, there is a great deal of spatial and temporal variability in the performance of the models.

Long-Lead Forecasting of Saskatchewan Precipitation and Wheat Yields Utilizing Teleconnection Indices

Ray Garnett
University of Saskatchewan

At a value of $162/tonne for the period 1993 to 1997 the value of spring wheat production in Saskatchewan can vary from $1.4 to $ 2.3 billion dollars depending on yield without considering a ripple effect. A key determinant of spring wheat yield is June and especially July temperature and precipitation. Interannual climatic variability can contribute to larger deviations in production and poses a threat to the agro-ecosystem and rural sustainability especially during times of low prices. The effect of the 1988 drought on agriculture is an indicator of society's vulnerability to such events which caused a direct production loss of 1.8 billion (in 1981 dollars). Early warning of climatic extremes affecting grain production is thus of considerable importance to grain producers, marketers, and planners. Specifically there is a need for a

statistical teleconnection based model for the long-lead forecasting of climate, yield and quality.

There are many forcing functions governing the amount of precipitation that occurs on the Canadian prairies during the summer months. These include the El Niño/Southern Oscillation phenomenon, the Pacific North American teleconnection flow pattern, the position and strength of the Pacific High and the size, shape and long wave positions associated with the circumpolar vortex, North Pacific sea surface temperatures, North Atlantic Oscillation and feedback mechanisms between the surface and atmosphere. Less direct influences are factors such as the QBO, Eurasian snowcover and performance of the Indian monsoon. This study assesses the influence of the Southern Oscillation, Niño-4, Niño-3, and Pacific North American flow pattern on Saskatchewan precipitation, temperature, yield and quality.

Composite, correlation and regression analysis techniques are being used to investigate various teleconnections. Many of these techniques suggest an indication of temperature and precipitation several months in advance of the critical growing period of June-July. Ultimately regression equations including a suite of physically sound variables will be required for developing estimates of Western Canadian spring wheat yield with a lead time of 3 to 6 months.

Red River At Winnipeg Hydrometeorological Parameter Generated Floods For Design Purposes

A.A. Warkentin
Manitoba Water Resources

The 1997 Red River flood strained existing flood control works to near the limit and served as a reminder that the City of Winnipeg is not protected against larger floods such as that of 1826 or greater. Enhancement of the flood control system is being considered, but this cannot be properly done without knowledge of the magnitudes and return periods of major floods yet unseen. Flood records for the Red River at Winnipeg begin in 1875 with some anecdotal information for earlier events. Due to the relatively short record, standard frequency analysis may not give reliable estimates for major floods well beyond those recorded. This report describes the generation of 2000 spring flood peaks at Winnipeg based on an analysis of causal flood parameters, using a formula to determine peak flow. A correction factor is applied to the largest 34 flood peaks, based on a thorough analysis and flood routing of one of the major generated floods.

This study shows that natural flows on the Red River at James Avenue in Winnipeg could reach 210,000 cfs once every 200 years, 260,000 cfs once every 500 years and 295,000 cfs once every 1000 years on average. It is suggested that coincident major floods on the Red River and the Assiniboine River are very unlikely and that present control works on the Assiniboine River are adequate with respect to the City of Winnipeg. The most likely solution would be to increase the capacity of the Red River Floodway. If peak river levels in Winnipeg are to be no higher than 1997 crests, the Red River Floodway capacity required to control the 200, 500 and 1000 year floods would need to be 95,000 cfs, 135,000 cfs and 180,000 cfs respectively. The 1997 natural peak flow at James Avenue was 163,000 cfs and the peak Floodway flow was 66,000 cfs. At present, the Red River Floodway cannot convey more than 90,000 cfs without modifications.

This paper describes the methodology used in generating 2000 natural spring floods for the Red River at Winnipeg, including the meteorological scenarios involved. The analysis of the results enabled a

meaningful analysis of the feasibility and economics of enhanced flood control works for the City Of Winnipeg.

Development of Gridded Monthly Precipitation and Temperature Normals for Canada

F. Seglenieks [1] , E.D. Soulis [1] , S. Solomon [1] , B. Davison [1] , and N. Kouwen [1]
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Regional monthly precipitation and temp erature long term averages are fundamental data required for many climatological studies. These are typically derived from climate station means, interpolated by various geostatistical methods. The technique used in this study was developed in Canada for h ydrometric network planning purposes and has been used subsequently in a number of studies, most recently in the Loire district of France and in the Mackenzie basin in Canada as part of the Mackenzie GEWEX study (MAGS).

The Monitoring and Data Interpretation Division of the Climate Research Branch has reviewed a significant portion of the Meterological Service archive, applying state-of-the-art corrections to a large number of the station records. Revised data for 500 precipitation stations are now available and normals have been generated for all stations with more than 20 years of data in the 1961-1990 period. Temperature records have been corrected at over 1000 stations.

The technique used is an interpolation method based on station physiographic properties. The approach, known historically as the "square-grid" technique, uses station coordinates, station elevation, and a number of derived physiographic characteristics (such as barrier height and distance to the ocean) as independent variables in a regression analysis of the station normals.

The objective of this study was to develop regional maps of the monthly long term averages for both temperature and precipitation based on these revised data.

The project was defined in two phases. The first phase involved preparing the station data for analysis, setting up the physiographic database used for interpolation, and preparing regression equations for a preliminary set of regions.

Phase 2 consisted of refining the physiographic database, testing for and identifying statistically homogeneous regions, development of regression equations for each region, identification and correction of anomalous stations, application of interpolation techniques to the station residuals, and error analysis to assess the accuracy of the study.

This study summarizes the results of both phases of the project showing the final maps of monthly long term average temperature and precipitation.

Tuesday, May 29, 2001
15:10 – 17:10
Solarium

Session 3
Climate Modelling: Prediction and Analysis

Sensitivity Of The Canadian RCM To The Surface And Atmospheric Initial Conditions

Daniel Caya, Sébastien Biner and **René Laprise**

In a Regional Climate Model simulation it is usually assumed that for a given set of lateral boundary conditions (LBC) and a given model configuration, a unique simulation is produced. In other words, for a given grid location and size, the simulation of a RCM is expected to be strongly controlled by the LBC and should be independent of the initial conditions (IC). In this study we look further at this assumption.

The experimental set-up is built as follow. A one-month long Canadian RCM (CRCM) December simulation is performed followed by three 12-month CRCM simulations starting the following January 1st. All simulations are performed on the same grid and use identical time-dependent lateral boundary conditions supplied by a GCMii current climate simulation. The only difference between the three CRCM simulations is in the prescription of the IC for the atmospheric and surface fields. For the first simulation the IC for both atmospheric and surface fields were taken from the December simulation. In the second simulation atmospheric IC were taken from the GCMii simulation and surface IC from a climatological database. For the third simulation, atmospheric IC were again taken from the GCMii simulation but surface IC were taken from the December CRCM simulation. By comparing the results of the different experiments it is possible to look at the sensitivity to surface and/or atmospheric IC fields.

The results show that during the first few months every CRCM simulations follow each other closely until the beginning of summertime when there is an increase of the discrepancies between all the simulations. This increase is observed for all simulations. However, simulations sharing the same surface IC take longer before developing differences. After summertime the level of similarity between the simulations reaches values comparable to the first few months. Preliminary analysis suggests that the level of control exerted by the LBC and the more stochastic activity of parameterised sub-grid scale processes are responsible for this behaviour.

Observed and simulated cold ocean - warm land (COWL) patterns

Jian Sheng
Canadian Centre for Climate Modelling and Analysis
Victoria

The cold ocean-warm land (COWL) pattern identified by Wallace et al. (1995) is a spatial pattern associated with a large portion of the month to month variability in the observed temperature data. They speculated that the COWL pattern results from the internal dynamics of the atmosphere and the contrast in thermal inertia between the continents and oceans. They argued that the COWL related contribution to the hemispheric warming trend was not necessarily linked to radiatively induced global warming.

The COWL pattern in the Canadian Centre for Climate Modelling and Analysis (CCCma) coupled general circulation model (CGCM) is investigated. The COWL pattern can be detected both from the control run and the green house gas plus aerosol (GHG+A) simulation. The differences of the COWL patterns between the two model integrations are presented and possible physical explanations are discussed in this study.

Testing the Downscaling Ability of Regional Climate Models with the "Big-Brother Experiment"

Daniel Caya
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Département des sciences de la terre et de l'atmosphère
Université du Québec à Montréal

The fundamental hypothesis underlying the use of nested, limited-area models for climate applications (Regional Climate Models, RCM) is that they have skill in generating meaningful fine-scale features that are missing from the driving atmospheric information at the lateral boundaries of the computational domain. We try to experimentally check the validity of this assumption by following a perfect-model approach, and this methodology is used for testing the downscaling ability of nested RCMs. The proposed methodology is nick-named the Big-Brother Experiment (BBE); it is based on a perfect-prognosis approach, and hence does not suffer from model errors nor from limitations in observed climatologies. The BBE consists in first establishing a reference climate by performing a large-domain high-resolution RCM simulation: this simulation is called the Big Brother. This reference simulation is then degraded by filtering short scales that are unresolved in today's global objective analysis (OA) and/or general circulation models when integrated for climate projections. This filtered reference is then used to drive the same nested RCM (called the Little Brother), integrated at the same high-resolution as the Big Brother, but over a smaller domain embedded in the Big-Brother domain. The climate statistics of the Little Brother are then compared with those of the Big Brother over the common intersection of Little-Brother domain. Differences can thus be attributed unambiguously to errors associated with the nesting and downscaling technique, and not to model errors or observation limitations.

The BBE protocol was developed and first applied by PhD Student Bertrand Denis at UQAM. Limited results of the BBE applied to a one-month winter simulation over Eastern North-America at 45-km grid spacing show than the one-way nesting strategy has skill in downscaling large-scale information to the regional scales. The time mean and variability of fine-scale features in a number of fields, such as sea level pressure, precipitation and 975-hPa temperature, are successfully reproduced, particularly over regions where small-scale surface forcing is strong. Over other regions, such as over ocean surfaces and away from the surface, the small-scale reproducibility is more difficult to achieve.

Experiments have also been performed with a one-way nested RCM to study the sensitivity of the simulated climate to the lateral boundary condition (LBC) resolutions. The goal was to determine the maximum acceptable resolution jump between the driver and the nested model. Preliminary results show that a resolution jump of a factor of 10 is the maximum that can be used without affecting unacceptably the climate. Similar experiments are underway to assess the dependency of the simulated climate to the updating frequency of the LBC.

Ocean Heat Transport in CCCma Climate Change Simulations

Badal K. Pal [1]
George J. Boer [2]
Gregory M. Flato [2]

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[2] *Canadian Centre for Climate Modelling and Analysis, University of Victoria, BC*

We examine the oceanic heat budget and meridional heat transport in the CCCma coupled general circulation model (CGCM2) control and transient climate change simulations. Heat transports can be computed in two ways: 1) from the temperature and velocity fields (the direct method) and 2) from the surface heat flux and changes in ocean storage (the indirect method). To interprete the results, the mean global heat transports are decomposed into component parts associated with the meriodional overturning circulation, the gyre circulation, transient eddy transports, and the remaining transports due to unresolved parameterized processes.

The meridional transport dominates in the tropics and the gyre circulation in the sub-tropics. In general, the diffusive component is small except in the southern ocean where it counters the equatorward advective transport. The heat transports are computed for the major ocean basins and are compared with observations and other ocean models along selected sections across the globe. The changes in heat transports associated with a simulation of climate change (1900-2100) are also discussed.

Wednesday, May 30, 2001
08:30 - 09:50
Ballroom A

Plenary Session

Global climate change: Lessons from the past ‹ directions for the Future

Andrew Weaver
School of Earth and Ocean Sciences
University of Victoria

Central to the findings of the IPCC third assessment report, released in Shanghai in January 2001, was the statement:

“There is now new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities.”

This represents a significant strengthening of the analogous statement issued by the IPCC in 1996:

“The balance of evidence suggests a discernible human influence on global climate.”

What scientific evidence motivated these IPCC statements and what are their ramifications? In this presentation, the science leading up to them will be discussed. A historical perspective of the Earth's climate over the last 400,000 years, and the science of global warming over the last 200 years will also be offered. Finally, a discussion of some outstanding uncertainties and a vision towards the future of climate modelling will be presented.

Wednesday, May 30, 2001
10:20 – 11:40
Ballroom A
Session 1
Climate Impacts and Analysis

Solar Energy and Water Forecasts for a Greenhouse Planet

Lewis Poulin
Prairie Storm Prediction Center, Winnipeg Manitoba

Two innovative products will be presented to demonstrate how a new type of energy and water forecasts could assist the public reduce its production of greenhouse gases by helping make efficient use of renewable energy and precipitable water that is available on a daily basis.

ENERGY FORECASTS: One way to reduce our production of greenhouse gases is to use more renewable energy, if possible, for some of our energy requirements. Since the energy output from solar panels, wind turbines and solar water heaters is directly affected by local weather conditions, it will be shown how valuable solar energy information could be packaged into a new type of forecast called a "Solar Energy Forecast. It will be shown how our weather models can be used to create solar energy forecast products to inform the public, ahead of time, as to how many kWhrs will likely be available in local weather systems. KWhr information provided ahead of time could help the public and our utilities appreciate ahead of time how much energy is on the way and give enough lead time to allow them to plan to take advantage of that particular type of energy. Sample kWhr forecasts maps and derived products will be presented and discussed along with the benefits and role such products could play to connect renewable energy kWhrs onto the "grid" and make it a valuable commodity in today's changing energy sector.

WATER FORECASTS: A second area where energy and resources can be conserved is in water conservation. It will be shown how model data and observed precipitation data could be re-packaged in order to provide forecasts of volumes of water that are likely to fall on local watersheds from the various weather systems. Such information could be used to help in the creation and manufacturing of the technology to properly collect, treat and use rain water directly in our homes in a manner that many modern advanced houses have demonstrated. Using rain water at the source, helps conserve our water supply and helps reduce the energy required to treat and then distribute treated water. The benefits and role such Water forecasts could play to promote water conservation and sustainable lifestyles will be discussed.

African Easterly Waves Simulated By The Canadian Regional Climate Model

Leticia Hernandez Diaz
M.Sc. Student, Department of Earth and Atmospheric Sciences, UQAM.
Supervisor: Prof. René Laprise

African Easterly Waves (AEWs) are synoptic-scale disturbances forming in the easterlies over northern Africa. They propagate across the tropical North Atlantic Ocean reaching the Caribbean and even the

eastern Pacific. These disturbances have been recognized as contributing to the genesis of tropical cyclones not only in the Atlantic and in the Caribbean, but also in eastern Pacific. In the Atlantic basin, more than 65% of tropical cyclones are initiated as AEWs and 85% of the most intense hurricanes are triggered by AEWs. Much has been written about AEWs based on observational and modelling studies. In the present work, we show the results of a simulation of AEWs using a 50 km grid size version of the Canadian Regional Climate Model (CRCM) for the period of May-September 1995. The energetics of the AEWs were studied by calculating the components of the Lorenz energy cycle for the month of August 1995. The model reproduces the typical zonal wind structure in the West African region where the African Easterly Jet (AEJ) plays an important role. The AEWs are generated from instabilities of the AEJ through barotropic and baroclinic conversions of energy, the latter being more intense. The available potential energy generated by diabatic processes is also significant in the maintenance of these perturbations.

Interpolation of 1961-1997 Daily Temperature and Precipitation Data onto Alberta Polygons of Ecodistrict and Soil Landscapes of Canada

Darren Griffith
University of Alberta
griffith@ualberta.ca

Soil quality models developed for ecodistrict polygons (EDP) and the polygons of the soil landscapes of Canada (SLC), used in monitoring the concentration of soil organic matter, require daily climate data as an important input. The objectives of this paper are (i) to provide a method which interpolates the daily station data onto the 894 SLC and 150 EDP polygons in the province of Alberta Canada so that the interpolated data fit not only climate mean but also climate variability, especially for the precipitation field, and hence can be used as realistic climate input to soil quality models, and (ii) to understand the variability of the Alberta daily climate, such as precipitation frequency. The procedure interpolates the station data onto a dense network of grid points and then averages the grid-point values inside polygons. The procedure and results for maximum temperature, minimum temperature and precipitation are reported in detail. The interpolation uses the observed daily data for the period January 1, 1961 - December 31, 1997 (13,514 days) within the latitude-longitude box (45N-64N, 116W-124W). Because the precipitation field can have a short spatial correlation length scale and large variability, a hybrid of the methods of inverse-distance-weight and nearest-station-assignment is developed for interpolating the precipitation data. This method not only reliably calculates the number of precipitation days per month, but also the precipitation amount for a day. The temperature field has a long spatial correlation scale and its data are interpolated by the inverse-distance-weight method. Cross-validation shows that our interpolated results on polygons are accurate and appropriate for soil quality models. Our computing algorithm uses all the daily observed climate data, despite that some stations have a very short record-time or only summer records.

Interaction Between Arctic Oscillation And Asian Winter Monsoon

Dingwen Zhou
Chengdu University of Information Technology, Chengdu,China.

A 50-year NCEP dataset was used to study the interannual variations of the Asian winter Monsoon and its

relation with the Northern Hemispheric zonally symmetric oscillation. Significant differences were found in the winter seasonal circulation and transient activity over the East Asia between years of extreme positive and negative AO indices. The interannual variation of the zonal flow contributes to changes in frequency of cold surge, seasonal mean temperature, as well as precipitation in this region. On the other hand, synoptic-scale transient activities in the East Asia feedback to the zonal mean flow in such away that the interannual variation of the vorticity flux convergence positively contributes to the changes in the zonal flow. To better understand the relation described above, a global atmospheric model (T21L5) was modified to do linear integrations with basic flows of both extreme positive and negative zonal indices. An ensemble of 5-day runs were performed and the output at day 5 was used to do statistical analysis. It was found that the difference of eddy activity between the two extrema is very similar to what is observed. The eddy vorticity convergence also tends to reinforce the zonal flow.

Wednesday, May 30, 2001
10:20 – 11:40
Ballroom B
Session 2
Operational Modelling and Applications

Operational Forecasts Of Maximum Hail Size In Alberta

Julian C. Brimelow
Department of Earth and Atmospheric Sciences, University of Alberta, Edmonton, AB

Terry W. Krauss
Weather Modification Inc., Fargo, North Dakota

The feasibility of producing operational short-range forecasts of maximum hail size for the Alberta Hail Suppression Project was investigated. A steady-state, one-dimensional cloud model and a time-dependent hail growth model (collectively known as HAILCAST) were employed to forecast the maximum hail size on the ground between 1 June and 31 August 2000. The 00Z Eta-32 model forecast soundings for Edmonton, Red Deer and Calgary were used as input for the HAILCAST model.

A quasi-Monte Carlo ensemble approach was implemented when running HAILCAST to minimize the impact of small fluctuations (+/- 1°C) in the forecast surface temperature and dew-point on the modeled hail growth. An objective decision tree was employed to run HAILCAST only when conditions were favourable for deep convection. The model-derived maximum hail size for each day was verified against the maximum reported hail size within the project area obtained from crop insurance reports, Environment Canada and the media. Hail size forecasts determined using the following methods were also evaluated: HAILCAST control runs using the Eta-32 soundings; HAILCAST ensemble runs using the 12Z Stony Plain soundings and subjective forecasts of the maximum surface temperature and corresponding dew-point; and subjective forecasts prepared by Weather Modification Incorporated meteorologists.

The probability of detection (POD), the false alarm ratio (FAR) and Heidke's skill score (HSS) were calculated to objectively assess the skill of the various techniques. Ensemble forecasts based on the Eta-32 model soundings showed significant skill (POD=0.74; FAR=0.18; HSS=0.62) when forecasting the occurrence and size of hail, and displayed greater skill than the control and subjective hail forecasts. Moreover, ensemble forecasts based on the Eta-32 soundings markedly outperformed those determined using the 12Z Stony Plain soundings. The Stony Plain soundings are released approximately 12 hrs before the time of peak convection and located about 200 km from the project area, and consequently are not considered representative of the pre-storm environment on the majority of days.

Current status and future improvements in the Canadian Meteorological Center's analysis and forecasting system

Statut actuel et améliorations futures au système d'analyse et de prévision du Centre

Météorologique Canadien

Yves Pelletier, Richard Hogue
Operations Branch, Canadian Meteorological Center

The Operations Branch of the Canadian Meteorological Center (CMC) is responsible for running the operational models and analysis systems that have been developed by the R&D Divisions of CMC and RPN (Recherche en Prévision Numérique). The current status of the operational system will be reviewed with an emphasis on the recent improvements that have been implemented. Main improvements planned within the next year will be briefly presented. These include introduction of a new land-surface scheme (ISBA) in the regional GEM model, a new higher resolution (~16km) regional GEM model and an improved 3D-Var analysis. The availability of CMC operational products (charts, images, bulletins, GRIB, BUFR, etc) will be reviewed. As well, our involvement in the development and operational maintenance of Canadian and US radar data will be presented.

Spread-Skill Relationship In The Canadian Ensemble Prediction System

Franck Pithois[1], Richard Verret[2], Louis Lefaivre[2],
Peter Houtekamer[3], Lawrence Wilson[3], Gérard Pellerin[2] and Marc Klasa[2]

1 Météo-France
2 Canadian Meteorological Centre
3 Meteorological Research Branch

The usefulness of an Ensemble Prediction System resides mostly in the variety of possible solutions that the system can offer to a given meteorological forecast problem. The differences between all weather scenarios presented by each member of the Ensemble prediction System, or the variance within the ensemble forecasts, lead toward the study of the spread-skill relationship. If such a relationship exists, it would then be possible to associate higher skill and better confidence in the forecasts when the ensemble variance is low, and vice versa, forecasts with lower skill and a lower confidence should be expected when the ensemble variance is large. The outcomes of such a spread-skill relationship, amongst others, include the possibility of forecasting the forecast skill on one hand and to use the spread of the ensemble as an indication of the confidence on the deterministic forecast on the other hand.

The Perfect Prog statistical adaptation system operational at the Canadian Meteorological Center has been run on each of the sixteen members of CMC Ensemble Prediction System. The ensemble variance of the statistical 12-h probability of precipitation forecasts is being evaluated as a proxy for a confidence index. The 12-h probability of precipitation forecasts generated from each member of the ensemble have been verified at all projection times to ten days, at 264 Canadian stations over the period extending from June 2000 to December 2000 inclusive. The skill of the ensemble average forecasts converges toward that of climatology by 180 hour projection time. This is an indication that skill with respect to climatology can be expected up to 7 days. Contingency tables of Brier scores of the 12-h probability of precipitation forecasts of the control model versus the ensemble variance have been constructed to study the spread-skill relationship. The results indicate that it is possible to use the ensemble variance as a proxy for a confidence index. Based on the chi-squared test, the spread-skill relationship is statistically significant to 240 hour

projection time.

Wednesday, May 30, 2001
10:20 – 11:40
Solarium
Session 3
Ocean/Marine Processes and Storms

Atlantic Canadian Tropical Cyclone Forecast Responsibility

John Parker
Severe Weather Program Manager
Maritimes Weather Centre
Meteorological Service of Canada - Atlantic Region

Contributor:
Peter Bowyer
Hurricane Program Manager
Canadian Hurricane Centre, Maritimes Weather Centre
Meteorological Service of Canada - Atlantic Region

Though Tornadoes and microbursts may be less frequent in Atlantic Canada compared to Ontario and the Prairies they are not rare events. The East Coast also gets its share of winter storms, accompanied by rain, freezing rain, snow, and strong winds, wreaking havoc on power lines and transformers, ground and air transportation, shipping, fishing and other sectors. In addition to these traditional severe weather events, Atlantic Canadians also need to be aware of and prepare for Tropical Cyclones and their associated extreme weather.

On average, more than four tropical storms or hurricanes pose a threat to Canada or its territorial waters each year. In 1985, an intense hurricane—Gloria—was forecast to move along the eastern seaboard of North America. The Director of the U.S. National Hurricane Centre declared Gloria to be the "Storm of the Century!" Canadians, relying on American forecasts and media for information on this storm, were very concerned that it would be a repeat of 1954's Hurricane Hazel . . . Canada's most remembered hurricane. While Gloria did give heavy rain and strong winds to the western part of the Maritime provinces, it was not the storm many had feared. As a result of the confusion arising from the situation with Gloria, Environment Canada decided to establish its own Hurricane Centre.

Throughout the Atlantic Hurricane Season, The National Hurricane Centres in Miami and Dartmouth routinely consult each other to coordinate the tracks and positions of all storms that pose a threat to Canada. Research continues and new efforts have begun in the area of Extratropical Transition (ET). There is still work to be done to improve forecast track skill and to increase awareness in the emergency community and the public as a whole.

This presentation will give an overview of the Canadian Hurricane Centre, its role and responsibilities within the Meteorological Service of Canada (MSC), international cooperation, scientific research, and the Atlantic Canada 2000 season.

Canadian Hurricane Centre website: http://www.atl.ec.gc.ca/weather/hurricane/index_e.html

Extratropical Transition of Tropical Cyclones: Autumn Severe Weather Threats

Peter J. Bowyer
Canadian Hurricane Centre, Meteorological Service of Canada, Dartmouth, NS
George Parkes
Maritimes Weather Centre, Meteorological Service of Canada, Dartmouth, NS
William Richards
Atlantic Climate Centre, Meteorological Service of Canada, Fredericton, NB

In 1998, as Hurricane Danielle transited Maritime waters, a Canadian NOMAD buoy reported extraordinarily high seas, with significant wave heights that grew by nine metres in two hours. In 1999, Tropical Storm Harvey died off the east coast of Florida, but left a weak remnant low drifting northeastward. This low dramatically re-intensified over waters south of Atlantic Canada, bringing hurricane force winds to Newfoundland and intense rain to the Maritimes (more than twice the 100-year rainfall). In 2000, an unnamed subtropical low tracked northward into Atlantic Canada. Following re-intensification, a prolonged period of storm force winds in the Gulf of St Lawrence set up the highest storm surge ever recorded at the Lower Escuminac tide gauge on the east coast of New Brunswick and ocean waves that devastated the immediate coastal infrastructure. Significant and different forecast problems accompanied each storm.

Ever since Hurricane Hazel devastated Toronto, Ontario, in the Fall of 1954, Canadian meteorologists have sought to better understand the nature of tropical cyclones that undergo the transition to extratropical in mid latitudes. These transitioning storms—known as ETs—have delivered severe weather to eastern North America in every decade on record: almost always in the Fall.

As we ended the 1900s, the upswing in Atlantic tropical cyclone activity had reached an all-time high, setting five-year cumulative records for: named tropical cyclones; hurricanes; and tropical cyclones entering Canada's area of responsibility. This upturn in tropical cyclone frequency also means an increased threat of severe ETs. Because of the potential they bring for phenomenal seas, intense rainfalls, high winds, and devastating storm surges, ETs have become the focus of the Canadian Hurricane Centre. This paper will present an overview of the ET problem, highlighting the three storms named above.

Ocean Waves with Tropical Cyclones: Just How Big Can They Get?

Peter J. Bowyer and **Allan W. MacAfee**
Canadian Hurricane Centre, Dartmouth, NS

The extent of cyclone development—baroclinic or tropical—hinges on the phasing of different atmospheric and oceanographic conditions. Similarly, phasing-patterns play a critical role in the growth of ocean waves. The development of conceptual and analytical wave models over the last half century has greatly facilitated the understanding of wave evolution and growth. However, a detailed understanding of the phasing patterns that give rise to extreme wave events has been slow to come.

Operational meteorologists are trained in the art and science of analyzing, diagnosing, and predicting atmospheric phasing patterns that give rise to storm development. This skill—coupled with their training in wind prediction—uniquely positions them to be the wave-forecasters throughout the international community. Clearly, computer models are the future of wave forecasting. But where technology lags in its ability to incorporate the "human experience" into real-time models, forecasters will continue to play a vital role in the issuance of wave forecasts—especially for extreme events.

Our "path of enlightenment" was forged in the early 1990s when three extreme wave events in a span of four years mocked the climate records, catching east-coast meteorologists with their "waves down." Over the last couple of years, the Canadian Hurricane Centre's investigation into the problem of "what makes big waves" has resulted in the formulation of a conceptual storm-waves resonance model. This model shows that the waters of Atlantic Canada are highly vulnerable for these unique storms. The CHC's work has also led to the development of an operational, single-purpose tropical cyclone wave model which predicts the maximum possible significant wave height generated by a given tropical cyclone.

The First Canadian Experience with Research Flight Operations into an Extratropical Transition: Hurricane Michael

Jim Abraham , Chris Fogarty and J. Walter Strapp
Meteorological Service of Canada, Downsview, Ontario, Canada
Mengistu Wolde, Dave Marcotte, Jim Jordan, John Aitken
Flight Research Laboratory, Institute for Aerospace Research, Ottawa, Canada

The Convair 580 research aircraft operated by the Flight Research Laboratory (FRL) of the National Research Council has been equipped in collaboration with the Meteorological Service of Canada (MSC) with state-of-the-art instruments to make remote and in-situ measurements of atmospheric conditions including cloud properties, temperature and humidity and atmospheric motion. The aircraft has been used in diverse research projects such as studies of aircraft icing, atmospheric chemistry and in mesoscale storm projects. This paper presents data collected during the first Canadian field experiment to study hurricane transitions in Atlantic Canada.

In an average year, 2-3 tropical cyclones affect Atlantic Canada. These tropical cyclones approaching the mid-latitudes normally undergo Extratropical Transition (ET), while moving over colder water or making landfall. In tropical and subtropical latitudes, hurricane reconnaissance flights are performed routinely to determine the intensity for operational prediction, and to study the structure for research purposes. However, in situ data of hurricanes at Canadian latitudes and those that are undergoing ET are scarce. Although, some of the changes associated with ET are known from space and ground based remote sensing systems, ship reports, routine weather observations and numerical weather prediction models, more detailed data are needed to improve the understanding and prediction of ET events.

As part of the Canadian Weather Research Program, the Meteorological Service of Canada and the FRL are

considering a field campaign to study ET events in conjunction with the Hurricane Landfall component of the USWRP. In this paper, data is presented from a test flight that took place on October 19, 2000 into Hurricane Michael.
This paper will present dropsonde, cloud microphysical, and airborne radar data associated with this flight. It will be shown that remarkable structural changes associated with ET merit further studies.

Wednesday, May 30, 2001
13:00 – 15:00
Ballroom A
Session 1
Special Session: Learning to Adapt to Weather Extremes

Our Rising Vulnerability to Natural Disasters

David Etkin,
Adaptation and Impacts Research Group
Environment Canada at the University of Toronto

Recent decades have seen rapidly escalating costs as a result of natural disasters. These trends are not only Canadian, but are global and worrisome, and particularly interesting in that they coincided with a UN initiative during the decade of the 1990s intended to curb the rising costs of natural disasters (the International Decade for Natural Disaster Reduction - IDNDR). Natural disasters impose a large cost on society, not only in terms of economic impacts but also in terms of human misery, and there are some indications that global change, both environmental and social, may continue to exacerbate this issue.

Historically, natural disasters were viewed as events over which we had no control, with societies as victims. Attempts at mitigation were primarily technological and based on the assumption that nature could be controlled. The disaster paradigm has shifted significantly in recent years towards a perspective that, to a large extent, disasters occur because society allows itself to be vulnerable. There now exist many case studies that demonstrate that various disasters might not have occurred, or certainly would have been much less severe, had not development occurred in hazardous zones (such as on flood plains), had environmental degradation not reduced natural functions, or had the risk of rare but high consequent events been properly incorporated into risk analyses prior to development.

A model illustrating how society copes with natural disasters is presented, that includes not only exposure to physical hazards, but also vulnerability and response. The response part of the model is very dependent up human perception of risk, and it has become clear that many of the design decisions made by society actually increase risk in a long-term cumulative sense. The probability exists, therefore, for more large disasters in the future, perhaps worse than we have experienced thus far.

What Can Global Climate Models Tell Us About Future Extreme Events?

Elaine Barrow
Canadian Climate Impacts Scenarios (CCIS) Project
Canadian Institute for Climate Studies, Regina, Saskatchewan

Most climate change scenarios are derived from global climate model (GCM) experiments and are most commonly used to provide an indication of how mean climate may change in the future. However, for impacts and adaptation studies, information about future climate variability and the frequency and intensity of extreme events is also required. Although GCMs operate at a coarser spatial resolution than is desirable for most impacts studies, it is still possible to derive useful information about climate variability and extreme events. In addition to the climate change experiments, most climate modelling centres also undertake multi-century control simulations, i.e., simulations in which there are no imposed changes in radiative forcing. These control simulations provide information about model-simulated natural climate variability on multi-decadal time scales. Consequently, by comparing the control and climate change simulations, it is possible to determine whether or not the future changes are still within the range of model-simulated natural climate variability. If the future changes are outside of this range, this indicates that future extreme events may be more severe than those previously experienced. Model-simulated extreme events (e.g., cold winters or hot summers) can also be examined and changes in the return periods of particular events determined. Using output from several modelling centres also allows a number of realisations of future climate to be considered and, therefore, the determination of the likely range of future climate conditions. This presentation will focus on those events, which have socio-economic significance, for example, changes in space heating/cooling requirements.

Extreme Weather Related Research Initiatives at Emergency Preparedness Canada

Grace Koshida,
Research and Development Directorate
Emergency Preparedness Canada, Ottawa, Ontario

Emergency Preparedness Canada (EPC) is the federal government organisation within the Department of National Defence which is responsible for the development and maintenance of civil emergency preparedness across Canada. The rising socioeconomic costs of disasters in Canada necessitate a strengthened research programme as a fundamental mechanism to assess our risk and better prepare for all eventualities.

The Research and Development Directorate (DRD) of EPC initiates joint and shared national and international multi-disciplinary projects with scientists in other government departments, non-governmental research organizations, universities and the private sector.

The DRD supported 29 short-term research projects during Fiscal Year 2000-2001 to address knowledge gaps in the fields of emergency preparedness, hazard assessment, disaster prediction, and mitigation of disasters. Extreme weather-related projects included: assessment of flood mitigation measures in Canada, risk assessment and response to weather-related road transportation hazards, assessment of urban climate and weather extremes in Canada, assessment and prediction of prairie severe thunderstorm weather phenomena, and the Emergency Weather Net-BC.

Victoria – The Snow Storm of 1996 4

Giselle M. Duhamel
Applications and Services, Environment Canada - Pacific & Yukon Region

Vancouver, B.C.

The Snow Storm of '96 in Victoria, B.C., appropriately coined the "Snow Storm of the Century", was one of the unique extreme events in the period of record to affect southwestern British Columbia. The Snow Storm itself ranked the 3rd highest 24 hour amount of snowfall of 85.0 cm of any major Canadian City. The last time downtown Victoria experienced such adverse weather was the blizzard of 1916 in which 53.3 cm fell in 24 hours. Due to the infrequency of these extreme events and the magnitude of the Snow Storm of '96, Victoria was ill equipped to contend with this event and the city was paralyzed. The amount of snow followed by strong winds, freezing rain, ice pellets / hail and heavy rain created havoc for this city. For instance, the heavy snowpack caused the collapse of numerous roofs to homes, businesses, auditoriums / arenas, etc., transportation efforts were greatly hampered which affected the delivery of medical services to the elderly, and boats in the harbour were crumpled and/or sank under the weight of the snow. In an economic perspective, the Snow Storm resulted in $200 million in damages not counting loss in wages.

This presentation will focus on (a) the meteorological circumstances leading to this unique extreme event, (b) the various vulnerabilities inherent to Victoria such as the demographic composition, infrastructure, etc., (c) the economic, social and environmental impacts and (d) lastly, the challenges realized from this significant event.

A Consideration of the Socio-Economic Impacts of Flooding in the Red River Valley

Mark Reed and **Andrew McLaren**
InterGroup Consultants Ltd., Winnipeg, Manitoba

In the spring of 1997 the Red River Valley of Manitoba experienced extreme flooding that tested, and in some cases exceeded, the limits of existing flood control structures. A pre-feasibility study of expanded flood control options was undertaken and two project alternatives were recommended. As part of the selection process for the two options, quantitative modelling of flood damage was undertaken along with a qualitative analysis of the relationship between flood damage, event response and the stress and anxiety experienced by flood-affected individuals.

For the quantitative analysis, a geo-referenced structural damage model was previously developed to estimate structural, infra-structural and agricultural losses. This analysis builds upon the existing model and takes an indicator approach to assessing the quantitative socio-economic impacts of flooding not captured by traditional damage models. Five broad categories of indicators have been selected: population, agriculture, transportation, social infrastructure and commercial and industrial.

In addition to having physical consequences, flood damage and the threat of it are also sources of stress and anxiety for property owners and flood-plain residents. Stress and anxiety are flood impacts that are not as readily measured as damages to persons and property. Conceptual analysis of the relationship between the 1997 Red River flood, event response and stress and anxiety revealed that event response can be characterised as an intervening variable between the flood event and associated stress and anxiety. This perspective goes beyond the purview of traditional cost-benefit analyses to provide additional information about the social considerations relevant for making the project decision.

Temperature Extremes in Canadian Urban Centres: When and Where Are We at Risk?

Lianne Bellisario,
Adaptation and Impacts Research Group
Environment Canada at the University of Toronto

The health, safety and economic sustainability of Canadians are intricately linked to the weather and climate conditions in which we conduct our daily lives. This is never more obvious than when disasters, triggered by extreme weather events, wreak havoc on vulnerable communities. Some new research has been completed examining national trends in extremes, but to be more relevant to those studying the impacts of climate on the health and welfare of Canadians, greater emphasis needs to be placed on studying extremes in urban settlements. Recent human casualties in natural disasters serve to further highlight the need for a better understanding of the exposure of the Canadian population to extreme events, particularly since it is acknowledged that population growth and demographic shifts are major factors behind the increasing losses associated with weather-climate extremes.

Unfortunately, climate data from urban centres has often been neglected or avoided. This bias has created a gap in our knowledge of the climatology of extremes where the vast majorities of Canadians live and work. To address this, a preliminary analysis of temperature data from 16 Canadian cities was undertaken to create a picture of the climatology of urban temperature extremes. Probability distributions were examined for each city, and site-specific extreme temperatures were identified on a seasonal basis using percentile analysis of daily maximum and minimum. The results of this study could assist the hazard assessment community in determining the relative exposure of Canadians across the country to certain extreme temperature events, and should serve to highlight areas which merit further examination, at present and under climate change scenarios.

Wednesday, May 30, 2001
13:00 – 14:20
Ballroom B
Session 2
Operational Modelling and Applications

Spread-Skill Relationship In The Canadian Ensemble Prediction System

Franck Pithois[1], Richard Verret[2], Louis Lefaivre[2],
Peter Houtekamer[3], Lawrence Wilson[3], Gérard Pellerin[2] and Marc Klasa[2]

1 Météo-France
2 Canadian Meteorological Centre
3 Meteorological Research Branch

The usefulness of an Ensemble Prediction System resides mostly in the variety of possible solutions that the system can offer to a given meteorological forecast problem. The differences between all weather scenarios presented by each member of the Ensemble prediction System, or the variance within the ensemble forecasts, lead toward the study of the spread-skill relationship. If such a relationship exists, it

would then be possible to associate higher skill and better confidence in the forecasts when the ensemble variance is low, and vice versa, forecasts with lower skill and a lower confidence should be expected when the ensemble variance is large. The outcomes of such a spread-skill relationship, amongst others, include the possibility of forecasting the forecast skill on one hand and to use the spread of the ensemble as an indication of the confidence on the deterministic forecast on the other hand.

The Perfect Prog statistical adaptation system operational at the Canadian Meteorological Center has been run on each of the sixteen members of CMC Ensemble Prediction System. The ensemble variance of the statistical 12-h probability of precipitation forecasts is being evaluated as a proxy for a confidence index. The 12-h probability of precipitation forecasts generated from each member of the ensemble have been verified at all projection times to ten days, at 264 Canadian stations over the period extending from June 2000 to December 2000 inclusive. The skill of the ensemble average forecasts converges toward that of climatology by 180 hour projection time. This is an indication that skill with respect to climatology can be expected up to 7 days. Contingency tables of Brier scores of the 12-h probability of precipitation forecasts of the control model versus the ensemble variance have been constructed to study the spread-skill relationship. The results indicate that it is possible to use the ensemble variance as a proxy for a confidence index. Based on the chi-squared test, the spread-skill relationship is statistically significant to 240 hour projection time.

A brief description of the CMC Ensemble Prediction System will be presented. The spread-skill relationship applied to the Perfect Prog statistical 12-h probability of precipitation will be demonstrated and results of the cross-validation of the confidence index in forecast mode will be presented.

The New Canadian Regional 3D-Var Analysis Scheme On Model Vertical Coordinates

C. Chouinard, N. Wagneur, J. Morneau, C. Charette, R. Sarrazin, and **Jacques Hallé**

In June 2000, the CMC implemented its new Global (-coordinate 3D-Var analysis scheme that produces analyses directly on the model levels requiring no interpolation to initiate the forecast. The background and observational error statistics were completely revised including a better balance constraint. It replaced the then operational 16-pressure level 3D-var system that was implemented in June 1997. In September 2000, the new system was again updated for the use of TOVS satellite radiance data and the extended use of aircraft data (ACARS, AMDAR). This was the first major update concerning the use of new datasets. The impact of these changes were very significant as demonstrated by the extensive evaluation of both systems during the August-September parallel suite at the CMC.

CMC's regional 3D-var spin-up analysis system continued to operate on 16 pressure levels even though its driving global data assimilation system was in (. That was possible in the regional system since only the analysis increments are interpolated from the 16 pressure to the 28 model (-levels to produce the final analysis on model levels.

In order to take advantage of the new backgro und error statistics and the use of the new TOVS and ACARS datasets, the regional system was subsequently updated last January 2001. During the parallel suite that preceded the implementation, the pressure and (-level systems were compared on large ensemb le of cases,

and it became very evident that the new system showed very significant improvements not only in winds and geopotentials but also in QPF. Moreover, the boundary layer structures introduced by the analysis are better preserved in the new regional system leading to temperature forecast improvements in the low levels.

Multiple Discriminant Analysis within the Updateable MOS

Marcel Vallée and **Laurence J. Wilson**
Recherche en Prévision Numérique
Franco Petrucci and **Richard Verret**
Centre Météorologique Canadien

The Canadian updateable model output statistics (UMOS) became fully have been fully working over an operational environment since during spring 2000. The essence of UMOS is that most of the preparations for the statistical processing is carried out in real time, allowing frequent and rapid redevelopment of the equations. A weighting scheme is incorporated in the system to ensure a smooth transition during significant model changes. Latest data from the newer model are given higher stronger weights, while enough data from the old model is retained to ensure generation of stable statistical relationships. A second weighting scheme is also included to ensure smooth transition between seasons.

The current operational version of UMOS uses at this moment, multiple linear regression with forward stepwise predictor selection applied to predictands. We are currently extending the system to prediction of multi-category predictands such as cloud amount, ceiling and visibility, for which we have decided to use multiple discriminant analysis (MDA).

Our application of MDA is divided into three steps. First, predictors are selected using a forward selection technique. The test statistic is the improvement in the Mahalanobis distance calculated for each possible pair of predictand categories over all available predictors at each step. Second, linear combinations of the predictors are found (discriminant functions) which maximize the ratio of the variance between the predictand categories to the within-category variance, pooled over all the categories. Finally, the dependent data is transformed to discriminant function space, and used to estimate probabilities of category membership given a new set of predictor values. This last step uses Bayes' rule and an assumed multivariate normal distribution with parameters estimated from the dependent data. Preliminary test results for 4-category cloud amount forecasts show that MDA under the UMOS framework improves the forecast compared to the currently operational perfect prog cloud amount forecasts.
This presentation will give an overview of the various aspects of the multi-category tools under the UMOS environment. Some preliminary verification statistics will also be shown.

Diagnostic Studies Of 1999-2000 European Wind Storms As Simulated By The Canadian Global Forecast Model

J.-F. Caron, P. Zwack and **C. Pagé**
Department of Earth and Atmospheric Sciences, Université du Québec à Montréal

During the year 1999-2000, Western Europe was particularly affected by several major storms. The two storms of December 1999 in France, as well as the storm at the end of October in United Kingdom stand out

especially because of the intensity of the winds. Using realistic numerical simulations of these exceptional extratropical cyclones by the Canadian global model as a laboratory, several of these storms were studied to try to determine the factors responsible for producing such devastating winds. The storm of December 26, 1999, which was studied first, was produced by the interaction of a large Icelandic low and a mesoscale perturbation which traversed the Atlantic and developed explosively while approaching Europe. The UQAM-CMC operational diagnostic package, DIONYSOS, was then used to calculate the contributions of various physical processes in the development of the storms. DIONYSOS was then modified using a new methodology to be able to separate the contributions from upper and lower atmospheric processes. In addition, the model output was filtered to separate out the contributions of the Icelandic low and the perturbation to the extreme winds. Results for the December 26, 1999 storm: The mesoscale perturbation accounted for only 40% of the extreme winds over France while the large scale Icelandic low accounted for 60%. Latent heating in the lower troposphere and vorticity advection in the upper troposphere associated with a jet streak, were the major forcings directly implicated in the explosive surface development. While lower tropospheric vorticity advection, temperature advection and latent heating were essentially responsible for the motion of the system. The results from this storm will be compared to those of other severe wind storms.

Wednesday, May 30, 2001
14:20 – 15:00
Ballroom B
Session 2
High-Resolution Modelling

Support To COMM, The Mesoscale Modelling Community In Canada: Academy And Regional Offices

Robert Benoit, Stephane Chamberland, and **Weu Yu**
Recherche en Prevision Numerique, MSC, Dorval

Last year, the Meteorological Research Branch (MRB) of Environment Canada saw again the value of the community mesoscale modeling effort and created a group dedicated to its support, called COMM. The main goals of this group are to promote, support and unify mesoscale research done in universities and other laboratories, particularly the MSC Regional Offices, with the MRB-CMC modeling developments. The current context of the Canadian Weather Research Programme (CWRP), and its emphasis on the progress of our capacity to model heavy precipitation, as well as the broader CFCAS context, contribute to the importance of a well informed and well supported COMM.

At the moment, the support is focused on the MC2 model, but will gradually evolve towards the new LAM version of the GEM model as it becomes fully tested.

An outline of the models, the type of services offered by the group, and examples of planned developments will be presented.

The Study Of Theoretical Flow Problems With The MC2 Community Model

R. Benoit, C. Girard, P. Pellerin, M. Desgagné and **W. Yu**
Meteorological Service of Canada, Environment Canada
Dorval, Canada

The original developer of the now-called MC2 non-hydrostatic model, the late Prof. André Robert and his university students, frequently used the fluid flow problem of the convective bubble to design and build this well-known model, now used by a community of atmospheric research modellers; indeed Robert published the solutions back in 1993 (J. Atmos. Sci.). In fidelity to the spirit of Robert, several other "theoretical flow" problems were later introduced in the MC2 library and prove to be extremely useful to the overall improvement of this modelling system, both for the basic fluid dynamical and the physical subgrid-scale parameterizations viewpoints. The main workhorses now in place in the model library are the bubble, the mountain wave and the channel flow problems. The mountain wave problem allows in particular to reproduce some of the flows examined by Pinty et al (Mon.Wea.Rev., 1995). Nowadays, after more than 10 years of evolution of the MC2 code, the initial bubble results can still be reproduced and so constitute an important benchmark of the historical evolution of the model. Connected with these theoretical flow problems, several basic options are made accessible to the modeler, such as 2- or 3-dimensionality, solid wall, x- and y-periodic lateral boundary conditions, slab symmetric conditions, barotropic and baroclinic

modes. The introduction of flow obstacles along the floor of the domain can be made in a smooth, non-impulsive manner.

By using this tool for his theoretical atmospheric flow studies, the academic scientist at the university can benefit from the full power and reliability of a proven world-class efficient NWP model and apply it to fully-controlled analytical problems without having to worry about the complex real weather case studies and their huge initial and boundary files. The scientist can also be as free as air and pursue his research on even a small standalone LINUX laptop and yet contribute to the improvement of the Canadian Weather forecast system by the community.

Downscaling aerosols fields with NARCM

L. Spacek, J.-P. Blanchet
Earth Sciences Department,
University od Quebec at Montreal, Montreal Quebec

NARCM (Northern Aerosol Regional Climate Model) is a limited-area non-hydrostatic dynamical model with physical and chemical parameterizations and a size-distributed aerosol. It improves our understanding of aerosol in relation to radiation, clouds and other climate processes. At the beginning, the intention was to use it for a climate simulation on a hemisperic scale. Based on CRCM (Canada Regional Climate Model) dynamics, it performs well over a large range of spatial scales from hemispheric to micro scales and has been successively applied to studies on sub-continental scales and even urban scales. Traditional interpolation techniques are used when finer fields for initial and boundary conditions are created. However smooth those fiels may be, small perturbations, are always introduced into the original fields when interpolating. Due to the nature of physical and chemical processes where threshold values play an important role, such small perturbations can modify the resulting figure that differs from that obtained on a different scale.

Evaluation Of Northern Aerosol Regional Climate Model Using Observations From The North Atlantic Regional Experiment

Andrew Teakles and **Henry Leighton**
Department of Atmospheric and Oceanic Sciences, McGill University, Montreal, QC

The effects of aerosols on climate are potentially important but not well understood. The Northern Aerosol Regional Climate Model (NARCM) has been developed with the intent of improving the representation of aerosols in climate models. NARCM include an explicit, prognostic and interactive aerosol segregated according to size into 12 bins. The model includes clear-sky and in-cloud oxidation of sulphur dioxide, removal of aerosol by wet and dry deposition and interactions between aerosol particles.

The North Atlantic Regional Experiment (NARE) was an intensive field project near Yarmouth, Nova Scotia from Aug 06 to Sept 08, 1993. As part of this experiment aircraft measurements of chemical, physical and meteorological properties were collected from 48 flights over a period of about one month. These data provide a useful test bed to evaluate the aerosol physics and chemistry included in NARCM. Comparisons of modeled values of sulphur dioxide, sulphate and aerosol profiles will be made with the aircraft measurements.

Application Of NARCM Model To High Resolution Aerosol Simulations: Case Of Study Mexico City Basin During The IMADA-AVER Measurements Campaign

R. Munoz-Alpizar, J.P. Blanchet and **A. Quintanar**

The atmospheric pollution in Mexico City is one of the most severe cases of air pollution in the world. There is great concern among residents about the effects of elevated levels of ozone and suspended fine particles on human health and visibility degradation. The goal of this study is to explain the nature and causes of fine particulate concentrations and visibility impairment into and around Mexico City.
Three pollution events during the IMADA-AVER field campaign in the winter of 1997 are studied using direct measurements and the Northern Aerosol Regional Climate Model (NARCM). During this period, inhomogeneous ozone concentrations that varied from one day to the next were observed within the Mexico City basin.

The NARCM model results are used to identify the meteorological mechanisms associated with pollutant transport and diffusion. The observations and mesoscale analyses provided evidence that the circulations are highly complex, and the relatively weak upper-level synoptic systems have an impact on the local and regional thermally-driven flows in the area. The timing and location of the simulated maximum particles concentrations correspond quite well to the observed maximum ozone mixing ratios.
Visibility is a directional quantity, that is depends on direction in a horizontal plane. The visibility in Mexico City is greatly reduced because of the high concentration of absorbing aerosols due to strong urban activities. The only available visibility data coming from the Mexico City's Airport, have been used to examine the effects of air pollution on visibility. This experiment showed that the directional visibility is highly related to the topography. Visibility is also very sensitive to the size distribution of particles with a peek attenuation around 0.2(m. Therefore, visibility is also sensitive to the coagulation process in the aerosol.

The model produced good agreement between the calculated profiles of humidity, temperature, winds and the measurements. Thud indicating that NARCM model reproduces many of the meteorological phenomena associated with pollutant transport, diffusion and spatial distribution of particles across the basin during the 3-day period.

Wednesday, May 30, 2001
13:00 – 15:00
Solarium
Session 3
Atmospheric Radiation, Aerosols, Clouds and Water Vapour

MAGS Water Budget Error Estimates

G.S. Strong[1], **B. Proctor**[2], **R. Soulis**[3], **F. Seglenieks**[3], and **C. Smith**[2]

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2 Meteorological Service of Canada, Saskatoon, SK
3 University of Waterloo, Waterloo, ON

Closure of the atmospheric moisture budget and rationalizing it against the surface water balance is one of the important results of the Mackenzie GEWEX Study (MAGS). It is now possible to close the annual atmospheric and surface water budget, while monthly estimates are within acceptable error limits. This presentation discusses estimates of various sources of error for the five water-years 1994-99, and considers the accuracy of annual and monthly water budgets, and the data period required for errors to converge to zero.

Expanding And Enhancing The Automated Quality Control System For Solar Radiation Data Processed By MSC

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Environment Canada (Meteorological Service of Canada)
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The Canadian solar radiation network presently consists of 43 stations distributed throughout the country. The radiation fields commonly measured at most stations include RF1 (global irradiance), RF2 (diffuse irradiance), RF3 (reflected irradiance), RF4 (net irradiance), and in some cases RF9 (incoming infrared irradiance). The network was established in the mid 1960's. From 1980 onwards, the size of the network has been shrinking and resources for inspection, maintenance and quality control have been cut back. Until the mid-1990's, Canadian solar radiation data was subjected to vigorous human interactive quality control procedures. The interactive quality control program used for this operation has been identified as a critical component in the processing of solar radiation data, but requires that all data be visually inspected and that the operator be a highly trained technician.

At present, the quality control of solar radiation data is inadequately resourced and a backlog exists. To increase the efficiency in which solar radiation data are processed, there must be a coordinated effort to i) modernise data acquisition and transmission throughout the network, and ii) develop and enhance automated procedures to reduce the reliance on human data handling and interactive quality control. Network moderisation has already begun and it is expected that data will be transmitted automatically over the wide area network in near real-time mode. In anticipation of the receipt of digital data in near real-time, the MSC is developing automated quality control procedures to facilitate the archiving of solar radiation data in a more timely fashion. Algorithms under developed will assist in identifying potentially erroneous data, and direct a quality control technician to the suspect period for visual inspection and detailed analysis. This will greatly accelerate the processing and quality control of backlogged data. For stations that are transmitting data in near real-time (e.g. once a day), daily thumbnail graphs could be generated on several pages for quick inspection by a trained technician. From the visual analysis, subsequent interactive quality control can be efficiently targeted. The daily graphs can also be posted on the MSC Intranet and made available to regional offices so they can monitor the performance of their stations and instruments. The development of the data processing and quality control systems proposed will make solar radiation data more readily accessible to clients and ultimately improve the quality of the measurements since errors due to maintenance issues will be detected and corrected on the order of days, rather than weeks or months.

Comparisons Of Solar Radiation Budgets From Satellite Measurements With Model Outputs From A Regional Climate Model And A Nwp Model For The Mackenzie Gewex Study

Jian Feng and **Henry Leighton**
Department of Atmospheric and Oceanic Sciences, McGill University, Montreal, QC

The Mackenzie GEWEX Study (MAGS) is one of the five hydrometeorology projects of the Global Energy and Water Cycles Experiment. One of the focuses of MAGS is to understand and model the high latitude water and energy cycles that play roles in the climate system. The solar radiation absorbed at the surface is an important component of the energy budget and it also influences the water cycles through its impact on evaporation and melting of snow. The radiation fields at the surface that are used to drive the hydrology models come from atmospheric models. A variety of atmospheric models are being applied to MAGS and it is important to evaluate these models carefully and to identify their weaknesses. Here we evaluate the solar radiation fields at the top of the atmosphere and absorbed at the surface generated by two models: the Canadian Regional Climate Model (CRCM); and the Global Environmental Multiscale (GEM) model, the latter being the Canadian forecast model.

The solar radiation fields at the top of the atmosphere are obtained from narrowband measurements of AVHRR and broadband measurements of ScaRaB. The narrowband fields are converted to broadband fields on the basis of previous work with collocated simultaneous narrowband and broadband measurements from the ScaRaB instrument that flew on the Russian Meteor 3/7 satellite. Net solar fluxes at the surface are deduced from the top-of-the-atmosphere fluxes using the methods of Li et al. (1993) and Masuda et al. (1995). Surface fluxes retrieved from satellite measurements for 1998-99 were compared with measured net solar fluxes and showed very good agreement. Comparisons of the top-of-the-atmosphere and surface fluxes from the satellite retrievals with results from the CRCM will be presented for the summer of 1994 and comparisons with output from the GEM model will be presented for the summer of 1999.

Wednesday, May 30, 2001
15:30 – 17:10
Ballroom A
Session 1
Special Session: Learning to Adapt to Weather Extremes

The 1990's... A Decade of Extreme Climatic Events in Quebec

Jennifer Milton
Climate Surveillance and Adaptation, Environment Canada - Quebec Region
Saint-Laurent, Quebec

In July 1996, more than 250 mm of rain fell over the mountainous area surrounding the Saguenay River as a major storm stagnated over eastern Quebec. Although almost all regions of southern Quebec were affected by this storm, the bulk of the weather and of its impacts occurred in the Saguenay area. Mudslides and flooding caused extensive property damage, destroyed road infrastructures and created havoc in the tourism industry.

January 1998 produced the worst ice storm to occur over eastern Canada in the last 50 years. Five days of more or less continuous precipitation, cumulating in amounts of 80 to more than 100 mm of fallen freezing rain, plunged many regions into darkness and literally paralyzed socio-economic, institutional, transportation and electrical services for many days. The ice storm also produced dramatic effects on forests and on livestock.

Most important of all, these two extreme climatic events shattered the daily welfare of the population of the affected areas and entailed loss of life but have also greatly increased our awareness of the vulnerability of our infrastructures. This presentation will review these and other recent extreme climatic events that have occurred in Quebec and of their socio-economic impacts.

Assessing and Predicting Socio-Economic Impacts of Extreme Events in the Face of Climate Change Using January 21, 2000 Storm in Prince Edward Island (PEI)

Mike Milloy
Corporate Affairs Branch, Environment Canada – Atlantic Region
Dartmouth, Nova Scotia

An integrated study funded by the Climate Change Action Fund (CCAF) began in September 1999 to examine the impacts of climate change on coastal communities, using Prince Edward Island (PEI) as a case study. The areas of study included coastal erosion on the North Shore of PEI, and urban flooding in Charlottetown. Five months into the project, PEI was hit with a benchmark storm. This storm had an effect approximating the maximum possible flood level in Charlottetown.

Team members went to the island immediately after the event, took photographs, and recorded water levels. During the following months, the team has worked with the PEI Emergency Measures Organization and PEI Department of Transportation to collect further data regarding storm impacts. The storm level was

calculated and overlaid on high resolution mapping of the city properties using the City's GIS. An economic analysis was performed, comparing actual Disaster Financial Assistance Arrangements compensation amounts with the total possible impacts, considering 'at risk' structures, sectors, and municipal infrastructure

Hogtown Turned Snowtown: A Review of the January 1999 Toronto Snow Emergency

Brian Mills [1], Jeffrey Suggett [2] and **Lisa Wenger [1]**
1 Adaptation and Impacts Research Group, Environment Canada at the University of Waterloo
2 Synectics Transportation Consulting, St. Catharines, Ontario

A series of winter storms, associated heavy snowfalls and very cold temperatures affected southern Ontario during the month of January 1999. Record amounts of snowfall and snowpack were reported in downtown Toronto. The weather conditions experienced in the Toronto region threatened life, damaged property, and impeded the normal level of mobility enjoyed and expected by citizens, commuters, institutions and businesses. Impacts were concentrated among particular populations and activities whose vulnerabilities were time-dependant and sensitive to weather conditions in very different ways. In terms of the number of people affected, impaired mobility was the most significant impact. In particular, repeated snowfalls exceeded the capacity of systems in place to maintain reliable road, rail and subway transportation services. Estimated economic losses, based on information for several key government agencies and businesses, exceeded $85 million. Organizations that coped well during the event cited previous experience dealing with emergency situations and effective communication among staff and clients. They were also able to implement contingencies that reduced their reliance on transportation. Transportation authorities have generally responded to the event by redesigning their systems to withstand a higher threshold of winter hazard. Much less effort has been made to reduce societal expectations (i.e., reliable mobility) of the system during brief periods of inclement weather.

Human Casualties in the Wake of Extreme Weather Events in Canada

Abdel Maarouf1, Emily Chan2, Louisa Chan2 and Cheong Lee2
1Adaptation and Impacts Research Group, Environment Canada at York University
2Undergraduate students, University of Toronto

A study is underway to compile and analyze a Canadian database on human casualties (deaths, injuries, illness, and evacuation) caused by extreme weather events. It aims to:

- Provide a comprehensive listing of all weather related disasters affecting Canadians;
- Determine possible trends of human casualties due to severe weather;
- Compare the occurrence, frequency and impact of the different types of extreme weather events on national and regional scales;
- Examine the effectiveness of improved weather forecasting and emergency preparedness in mitigating casualties; and
- Investigate where adaptive responses and improvements in emergency plans are required.

Preliminary analysis of the 20th century data set indicates that most weather related injuries occur in Canada in winter (mainly due to blizzards and icy conditions), except in the Prairies where most injuries occur in summer (mainly due tornadoes). Extreme weather related deaths occur mostly during springtime in Canada (mainly due to marine accidents), however seasonal variations are also observed across the regions. Death rates are decreasing with time over the study period, while injuries and evacuation are both on the rise.

Wednesday, May 30, 2001
15:30 – 17:10
Ballroom B
Session 2
High-Resolution Modelling

High Resolution Simulation Of Precipitation Over Complex Terrain: Full Forecast And Down Scaling

Benoit, W. Yu, G. Bergeron, and **J. Goldstein**
Meteorological Service of Canada

The MC2 was run operationally during the MAP SOP to provide field operation guidance. The comparison of the MC2 results with the field measurements show that MC2 has predicted reasonably well the precipitation and surface wind at a resolution of 3 km. However, the relatively high demand for computational resources prevents the institutions and university labs from doing operational forecast at very high resolution. The objective of the present study is to explore the feasibility of the down scaling of precipitation and surface wind over complex terrain, without actually running the model for the full forecast range but rather using several short range forecasts.

The methodology is as follows. MC2 is run at two horizontal resolutions: a coarse resolution simulation for the full forecast range which requires little computational resources, and a higher resolution simulation for a series of short range (about 30 minutes) forecast. The short range simulation provides the dynamic adaptation of the atmospheric flow to the high resolution topography. However, the precipitation from the short range simulation is not reliable due to the model spin-up. A statistical relation between the mean precipitation rate and the vertically integrated water vapor flux is established based on the coarse resolution simulation. This relation is then applied to the higher resolution simulation to retrieve the mean precipitation rate at higher resolution. Preliminary results will be presented.

A Large Database For Mesoscale Studies: The MC2 Forecast Archive And The Field Observations During The Mesoscale Alpine Programme (MAP)

R. Benoit, S. Chamberland and **Wei Yu**
Meteorological Service of Canada, Environment Canada
Dorval, Canada

The MC2 nonhydrostatic mesoscale model was run operationally on a daily basis during the MAP SOP to provide field operation guidance. Two forecast suites were operated with that model. The main one was driven by the Swiss Model (SM) and included two cascaded grids, with the coarser one at 14 km, similar to that of the SM, and the finer one at 3 km, lasting 27 hours, with explicit convection and covering all the Alps. The other suite was driven by the ECMWF Model and featured a 60-hour forecast period ending at T+72h, on the same 14 km grid as above. The value of the MC2 forecasts for the MAP-SOP has been evaluated

positively both by operational forecasters and SOP field scientists.

All the digital gridded forecasts from the MC2 have been assembled into a large internal archive at Environment Canada for the entire SOP and on the entire 3D modelling domains with an hourly output frequency. This service is offered to all scientists interested in obtaining dynamically consistent numerical distributions of atmospheric parameters over the Alps to complement the observational components of the SOP. This archive service offers customized retrievals as well as a host of software utilities and formats for the analysis.

Features of this unique MAP-SOP advanced modelling archive are presented with some examples and the retrieval procedure.

Opportunity is taken here to publicize the large Internet-accessible MAP Data Centre, where all of the special and routine atmospheric, ground and hydrological measurements for the MAP Special Observing Period (Fall 1999) are archived. This advanced international observational database features 8 research aircraft, 7 research radars, several research lidars, profilers, microbarographs, many extra radiosounding stations etc. A navigated version of the Meteosat Rapidscan imagery was prepared by our group, featuring very high sampling rate (5 min).

The Explicit Prediction Of Alberta Hailstorms Using A Double-Moment Bulk Microphysics Scheme

Jason A. Milbrandt and **M.K. Yau**
McGill University, Montreal, Quebec

Alberta receives more hail than any other province in Canada. There are hailstorms in Alberta two out of every three summer days and on average, five to seven severe storms that produce large, damaging hail occur per year. The annual cost of hail damage in Alberta amounts to hundreds of thousands of dollars. In current operational weather prediction models, the strong updrafts required for the growth of large hail in convective storms are still subgrid-scale processes and cannot be explicitly resolved. However, with the continuous increase in computer power, it is foreseeable that operational models will soon be able to resolve convection directly using only fully explicit microphysics schemes.

The purpose of this research is to develop a four-ice category double-moment microphysics scheme and to demonstrate its utility in the context of a simple one-dimensional kinematic cloud model. Specifically, we will show that the prediction of two moments of the hydrometeor size distributions, namely the mass mixing ratio (proportional to the third moment) and the total number concentration (the zeroth moment), possesses distinct advantages over a single moment scheme. The new scheme will be implemented into the Canadian Mesoscale Compressible Community model (MC2) for high-resolution simulations of Alberta hailstorms. Ultimately, this research will find application in operational models in predicting the occurrence of large, damaging hail.

Numerical Modelling of Freezing Rain Accretion on H.V. Insulators of Electrical Power Transmission Lines

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NSERC/Hydro-Québec/UQAC Industrial Chair on Atmospheric Icing of Power Network Equipment (CIGELE), Chicoutimi, Quebec, Canada

This paper addresses one of the most challenging problems in atmospheric icing research, namely realistic theoretical predictions of atmospheric ice formation on objects of complex shape. Understanding ice build-up on large structures during freezing precipitation is of great importance in an industrial context, for instance in designing power lines, and insulators which may experience flashover. The focus of this research is on the numerical simulation of ice accretion on high-voltage insulators under freezing rain conditions. This has not been accomplished heretofore because of the complexity of the insulator string with its numerous sheds, and because of the complexity of the resulting ice accretion with numerous icicles. In order to tackle this problem, we have developed a two-dimensional morphogenetic model, a hybrid of ballistic trajectory and random walk models. This model is able to simulate the variety of ice accretion shapes and icicle distributions that occur as a function of temperature, wind speed, precipitation rate and drop size. This is the first time that such a model has been applied on such a large scale, and in particular to insulator strings. The paper will discuss the principles behind morphogenetic modelling, its advantages, limitations and some preliminary results, as applied to H.V. insulators.

A Numerical Study Of The Effects Of Small Water Bodies Over The Mackenzie River Basin

Badrinath Nagarajan, M.K. Yau and **P. Schuepp**
Department of Atmospheric & Oceanic Sciences, McGill University, Montreal, QC

It is known that evaporation over the Mackenzie River Basin (MRB) exceeds advective transport of moisture during summer season suggesting the MRB as a significant source of moisture. The surface energy balance, in the Canadian sub-arctic regions are influenced by synoptic scale systems and the underlying surface characteristics. High-resolution satellite land use imagery and aircraft data over the MRB suggests the presence of numerous small sized lakes (few hundred meters in diameter). The effect of small lakes in the northern wetlands during typical warm season synoptic conditions is investigated by performing high-resolution numerical simulations using the Canadian Mesoscale Compressible Community (MC2) model.

Two cases classified as synoptic type 5 and 9 respectively occurred on 2 and 8 June 1999 when flight data were collected. Type 5 and 9 synoptic conditions occur respectively 12.5% and 20.6% of the time during the warm season over the western sub-arctic region. Type 5 is characterized by an elongated low in the vicinity of Trail Valley Creek (TVC) and type 9 is characterized by a high pressure system located northeast of TVC.

Five-hour numerical simulations starting from 1900 UTC, 2 and 8 June 1999 are performed. The fine mesh has a horizontal resolution of 50 (2 June 1999) and 100 m (8 June 1999). The model domain covers an area of 10 km^2 and is centered at 68.1N, 134.5W.

Wednesday, May 30, 2001
15:30 – 16:30
Solarium
Session 3
Atmospheric Radiation, Aerosols, Cloud and Water Vapour

Application of a Monte Carlo radiation scheme to the retrieval of cloud optical depth using the Barker-Marshak Method

Alain Beaulne
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Université du Québec à Montréal

Solar radiation is the only source of energy for the earth's atmosphere and surface. Therefore, the ability to simulate realistic radiative transfer is valuable in atmospheric studies. On the other hand, clouds modulate greatly the radiative transfer of energy and must be well represented in climate models. A reliable radiative transfer model based on Monte Carlo methods is presented. It is used to produce virtual measurements of spectral radiance and irradiance in realistic cloud scenes. The model accounts for vertical variability of the extinction coefficient in clouds, optical phase function during radiation-droplet interaction, variable ground albedo, instrumental errors and aerosols. These virtual observations are then used to test the new Barker-Marshak method for inferring doud optical depth of broken cloud fields using ground measurements of spectral radiance and irradiance. The parameters used in the Monte Carlo scheme help as to determine the sensibility of this method to atmospheric conditions and measured parameters. Initial results using simplified environment parameters (LANDSAT cloud scenes, Henyey-Greenstein phase function, homogeneous albedo, perfect instruments and no aerosols) show that the Barker-Marshak method can retrieve the average optical depth of clouds with an error lower than 8%.

The Absorption Of Nir Solar Radiation By Drizzle In Clouds

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Spectral measurements with FTIR spectroscopy of the transmission of solar infrared radiation through clear

and cloudy skies has indicated that certain clouds absorb unexpectedly large amounts of near-infrared (NIR)radiation. The amounts are unexpected in the sense that radiation codes, including sophisticated algorithms such as MODTRAN4, do not model this strong absorption effect. The absorption fingerprint of the mystery absorber in the cloud transmission spectra matches the spectrum of liquid water.

We also have observed the spectrum of liquid water absorption in the transmission spectrum of fog, which has a composition similar to clouds, suggesting that it is associated with drizzle in clouds. The same spectral signature of liquid water in the cloud NIR absorption has been observed from an aircraft during the AIRS project in January 2000. The spectral signature of ice was also observed on the same clouds.The liquid water absorption is not explained by Mie theory for cloud droplets in the size range from 10 to 20 microns. The absorption cannot be simulated using MODTRAN4 or other radiation codes. We postulate that the liquid water in the form of drizzle in clouds is absorbing the NIR solar radiation. The effect seems to be associated with precipitating clouds and includes Virga in many clouds which does not reach the ground. A possible explanation is that there is a bimodal droplet distribution with water droplets > 200 microns radius causing the absorption; drizzle consists of droplets around 500 microns. This effect was observed in the in-situ particle size distribution measurements during AIRS.The absorption of NIR flux can be up to 150 W/m2 for a particular cloud deck. On a globally averaged basis this corresponds to 13 W/m2, in comparison to the 3 W/m2 flux imbalance due to the increase in all of the greenhouse gases. Overall, clouds have been estimated to produce a net cooling effect of about 20 W/m2. Our measurements indicate that cloud absorption can be over 100 W/m2 for individual clouds, implying some clouds have a net warming instead of a cooling effect. The energy absorption of NIR short wave by clouds on a global basis may be a missing factor in GCMs, important to modelling the climate problem. This NIR absorption effect is not reproduced by the current radiation schemes in climate models. In current climate models, clouds do not absorb significantly more solar radiation than a clear atmosphere.

Anthropogenic Aerosol Effect On Arctic Precipitation ---A Case Study with the GESIMA Model

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The mesoscale model GESIMA is a three dimensional nonhydrostatic model developed to study stratiform clouds. It uses bulk parameterizations for the cloud microphysics and solves prognostic equations for the mass mixing ratio and number concentrations of cloud droplets, ice crystals, snow flakes and rain drops. Long range transport of anthropogenic aerosols and aerosol precursors is responsible for Arctic haze. Here we investigate whether anthropogenic aerosols that reduce the cloud droplet size can alter the collection efficiency of accretion of snow with supercooled droplets such that the snowfall rate at the ground is reduced significantly. We modify the collection efficiency so that it is dependent on the sizes of the snowflake and the cloud droplet. We select different days during the FIRE.ACE campaign that took place in the Canadian and U.S. Arctic in April/May 1998 to validate GESIMA with observations. Thereafter, we

examine a case where a precipitating ice cloud is above a supercooled liquid water stratus cloud to study the impact of the modified collection efficiency.

Thursday, May 31, 2001
08:30 – 09:50
Ballroom A
Plenary Session

The Severe Thunderstorm Record; A Hybrid of Meteorology and Sociology

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In the United States, severe thunderstorms with tornadoes, hail of 19 mm (3/4") diameter or larger, and convective wind gusts of 50 kt (26 ms^{-1}) or greater caused 421 deaths, 7,490 injuries, and $8.5 Billion in property damage from 1996 through 1999. There were 32 individual storms that caused over $50 Million of property damage. Surprisingly, these were not all strong, high-end events. Included in the $50 Million storms, were four straight line wind storms, eight hail storms (two with reported hail of 51 mm in diameter or less), and four of the tornadoes were only rated F-2 on the Fujita Damage Intensity Scale.

Before these data can be used to draw conclusions about society's vulnerability to convective storms, it is necessary to put them into context. The quality of the climatological record of severe thunderstorms is dubious at best. Not only are changes in observing technologies, verification techniques, and reporting procedures seen in the data, but also apparent are changes in society, such as instant access to telephones and the growing pervasiveness of the mass media.

The historical tornado record can be used to get an indication of the characteristics of tornado tracks. Using data from 1950 through 1999, the mean US tornado path is 5.8 km long, but the median tornado track is only 0.8 km long. Similarly, the mean width of a tornado damage track is 75 m, but the median width is 27 m. The mean tornado damage area is computed to be 1.16 km^2, and the median area is 0.02 km^2. The correlation between length and width is 0.3. There is a tendency for stronger tornadoes to be longer and wider, but the correlations between both length and F-scale, and width and F-scale are both only 0.4.

Several applications of the severe thunderstorm database are shown including a method of hazard estimation. A conservative (i.e. inflated) estimate of the maximum tornado hazard in the US is computed to be 4×10^{-4} per year. The relationship between the occurrence of El Nino/La Nina and tornado frequency is explored. It is shown that on regional scales no statistically significant relationship exists. Finally, the use of the severe thunderstorm record for meteorological studies is briefly discussed.

Thursday, May 31, 2001
10:20 – 11:40
Ballroom A
Session 1
Extreme Weather
Climatology

Tornado-day Climatology of the Canadian Prairie Provinces 1980-1999

James Cummine and **Michael Noonan**
Meteorological Service of Canada, Prairie and Northern Region

There have been several studies of Canadian tornadoes in the last four decades and these studies suggest that the number of tornadoes reported each year is increasing. However, the actual occurrence of tornadoes may not be increasing over time. It is generally believed that even today, there are two to three times more tornadoes occurring than are reported. There are several reasons for this suspected underreporting of tornadoes, including: low population density; night-time occurrence; minimal damage; and other tornado data collection issues, such as poor reporting due to lack of or untrained observers. Furthermore, few detailed inspections of tornado damage have been undertaken, which leaves considerable uncertainty about the details of each tornado such as time of occurrence, path, duration and intensity.

Although not frequent, tornadoes are common across the Canadian Prairies in the summer. Tornadoes are a significant public safety and economic concern for society. Analysis of their recent temporal and spatial occurrence update the level of risk for use by many sectors (e.g. emergency preparedness, insurance, utilities and general public). Anticipated possible increases in tornado frequency due to climate change highlight the importance of understanding tornado climatology and the associated risks.

In this study, days with reported tornadoes were used to quantify the tornadic risk on the Canadian Prairies. The study focused on tornado days from 1980 to 1999. The days were grouped by ecological zones and a risk analysis, similar to that done by Raddatz and Hanesiak (1991), was carried out. The study looked at the variability of tornado days from season to season over the twenty year period. Overall, the study identified areas of risk from tornado but found that in this small sample, external factors dominated the risk analysis more than meteorological or climatological factors.

Severe Weather Climatology for Three Canadian Regions - Preliminary Results

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Using records from the King City radar near Toronto, the Carvel radar near Edmonton and from the McGill radar near Montreal, we have begun to compile a preliminary severe weather climatology for these three

regions. We are concentrating on summer convective events over the entire period of availability of archived records. Because of its continuous 3-D space coverage, the radar is ideally suited to observe severe thunderstorms within its domain of observation (~120 km). Maps of VIL (Vertically Integrated Liquid water content) and of GUST (estimate of downburst winds at the surface using VIL and echo top) are used to assess the frequency of occurrence of critical threshold of these parameters over the years. The reflectivity on 7 km CAPPI maps and areas of reflectivity 'overhang' are also used as additional severe weather indicators. The number of mesocyclone detections, their strength, duration and track lengths are also being tabulated. Other objectives of the project are:

1) To develop a methodology for a future in-line and automatic compilation of severe weather for the Canadian radar network,

2) To relate severe weather events to larger scale climatology of weather patterns and

3) To provide a climatological data base for the validation of Regional Climate Models.

Climatology And Forecasting Hazardous Weather In Canada's Northwest Territories And Nunavut

Brian Paruk
Meteorological Service of Canada, Edmonton, AB

Meteorologists at Canada's Prairie Aviation and Arctic Weather Centre are charged with issuing public weather warnings and forecasts for Canada's Northwest Territories and Nunavut. The climatology of hazardous weather for selected sites in these territories, the synoptic systems that generate the hazardous weather, and the thresholds that dictate a warning should be issued are reviewed, as is how (well) the forecasters are meeting the challenge. The focus will be on forecasting blizzards and strong wind events.

Lightning Characteristics over the Prairie and Northern Region: 1998-2000

T-V Nguyen[1] , B. Kochtubajda[1], W.R. Burrows[2], P. King[2] and **C.M. Williams[1]**
1 Prairie and Northern Region, Meteorological Service of Canada, Edmonton, AB
2 Meteorological Research Branch, Meteorological Service of Canada, Downsview

Thunderstorm studies, historically, have been limited by the scarcity of surface weather observing sites. In recent years, the installation of lightning detection systems has provided meteorologists the opportunity not only to learn about the lightning activity but also about the thunderstorms causing the lightning.

The Canadian Lightning Detection Network (CLDN) has continuously monitored lightning occurrence across Canada since the installation was completed in February 1998. The sensor network was designed to provide a cloud-to-ground (CG) flash detection efficiency of 85-90% or more, with a median spatial accuracy of about 500 m. Since February 1999, the network has been able to discern between cloud-to-ground and cloud-to-cloud (CC) flashes. CLDN detected approximately 4 million CG+CC lightning flashes over the Prairies and Northwest Territories between February 1998 and December 2000.

The objective of this study is to advance our understanding of lightning and thunderstorms over the Prairie Provinces and Northwest Territories. Several characteristics including total flash, flash density, polarity and current strength were examined. Spatial, temporal, diurnal, and inter-annual analyses were undertaken to explore differences across the Region. Regional differences in lightning characteristics are closely associated with geographic features, solar heating and large scale flows.

Thursday, May 31, 2001
10:20 – 11:40
Ballroom B
Session 2
Atmospheric Monitoring and Applications

Estimating Tropospheric Delays with GPS

P. Héroux, F. Lahaye, P. Collins, Y. Mireault, P. Tétreault and **J. Kouba**
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To maintain and enhance the Canadian Spatial Reference System (CSRS), the Geodetic Survey Division (GSD) of Natural Resources Canada (NRCan) has developed, over the past decade, the Canadian Active Control System (CACS), a national network of continuously operating autonomous GPS tracking stations. CACS, as a regional data centre of the International GPS Service (IGS), has contributed daily GPS tracking data from a number > of Canadian stations since 1994. As an IGS Analysis Centre (AC), GSD has also submitted daily precise orbit, clock, station and Earth Rotation Parameter solutions to IGS.

Until recently, the tropospheric zenith path delay (ZPD) estimates at the tracking stations were considered nuisance parameters of the GPS orbit improvement model. Realising the value of the ZPDs and the interest existing in the meteorological and climate change communities, the IGS formed a tropospheric working group in 1997 to combine and validate ZPD estimates produced by all global ACs. GSD has been contributing to the IGS tropospheric working group since it was formed. As the needs of the weather forecasting community were better understood, the requirement for near real-time precise GPS orbit predictions was identified. GSD joined the IGS community in the production of GPS ultra-rapid orbit predictions in March 2000. GPS orbit predictions with 25-30 cm accuracy are required to support meteorological applications and enable ZPD recovery with cm precision for users processing GPS dual-frequency carrier phase observations.

At GSD, the ultra-rapid orbit predictions are being included in a wide-area carrier phase solution to compute real-time GPS Corrections (GPS*C), improving the quality of the GPS satellite clocks and ZPD estimates at the stations of our real-time CACS network. The GPS*C developments, leading to the availability of precise satellite clocks in Canada, will facilitate real-time precise point positioning (PPP). PPP is a processing approach that uses un-differenced GPS dual-frequency carrier-phase observations in a simplified, single receiver, operational model. Depending on user dynamics, it offers centimetre to decimetre positioning precision and tropospheric zenith and slant delay recovery with centimetre precision. Combining PPP derived tropospheric delays with surface meteorological data provides a simple model for integrated ground-based GPS-MET operations.

Sensitivity Of GPS Derived Precipitable Water Vapour Calculations To Surface And Atmospheric Variables

Craig D. Smith[1] (speaker), Frank Seglenieks[2], and **Brian Proctor[1]**
1 Climate Research Branch, Saskatoon, SK;
2 Dept. of Civil Engineering, University of Waterloo, Waterloo, ON

Dual frequency GPS receivers are becoming more commonly used to determine the amount of precipitable water vapour (PWV) in the atmospheric column. This is accomplished by observing the delay in the GPS signal related to atmospheric pressure, temperature, and moisture. The total delay is estimated using accurate satellite orbital information. From this, the hydrostatic delay, related to surface pressure, can be removed leaving only the wet delay. The wet delay, in combination with a known or derived temperature variable, can then be used to determine atmospheric moisture. This paper examines the sensitivity of the PWV calculation to measured surface pressure and surface temperature as applied to GPS stations located in Canada. Alternate methods of performing this calculation are examined. These involve using GEM average profile temperatures weighted by the model's moisture profile. Comparisons are made to available integrated PWV obtained using radiosonde observations. Implications towards determining diurnal trends in atmospheric moisture are examined.

Modernization of the Meteorological Service of Canada (MSC) Climate and Water Archives

Michael Minuk and **Tsoi-Ching Yip**
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MSC is planning to modernize the Climate and Water Archives. The goal is to create a paperless archive so that observational data will be captured and quality controlled in near real-time and quality data are made available to users in near-real-time fashion.

Metadata, Metadata Standards and Access to MSC data holdings

Tsoi-Ching Yip & Debra Allsopp
National Archives and Data Management Branch
Atmospheric Monitoring and Water Survey Directorate
Meteorological Service of Canada
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This paper describes briefly what are metadata, why we need metadata, what are metadata standards and how these standards would affect the way the Meteorological Service of Canada conducts its business, especially in areas related to data access.

Evidence Of Water Drop Shedding From Hailstones Using Aircraft And Dual-Polarization Radar Measurements From A Supercell Storm In Oklahoma

Matthew Loney (1,2,3#)
Dusan Zrnic (1,3)
Jerry Straka (1,2,4)
Alexander Ryzhkov (1,2,3)

1 School of Meteorology, University of Oklahoma
2 Cooperative Institute for Mesoscale Meteorological Studies
3 National Severe Storms Laboratory (NSSL)
4 Center for Analysis and Prediction of Storms, Norman, Oklahoma
 # Present affiliation: MSC, Prairie Storm Prediction Centre, Winnipeg

The shedding of liquid drops of median size 0.5 to 2 mm by hailstones undergoing wet growth or melting has been hypothesized as an important process in the formation of hailstone embryos by several previous investigators. This study links a recently observed dual-polarization radar signature by Hubbert et al. (1998), known as a column in specific differential phase (or Kdp), with the cloud microphysical process known as hailstone shedding. In 1995, an armoured and instrumented T-28 aircraft made several penetrations into a severe wind and hail producing supercell storm in northeast Oklahoma. At the same time, dual-polarization measurements were obtained with the NSSL's Cimarron S-band research radar. Fortuitously, the aircraft sampled a strong and persistent Kdp column, which was located on the western fringe of the main updraft. Oklahoma hailstorms, with their warm cloud bases and high liquid water content (LWC), tend to support shedding due to the interaction of hailstones with the relatively high temperatures and LWC found near the updrafts. Under such conditions, the transfer of latent heat from the surface of the ice particle to the airstream is insufficient to completely freeze all of the accreted cloud water. Stones in this state are said to be in wet growth. In this study, calculations on aircraft microphysical data using a shedding algorithm and the radar data indicate that the updraft core and fringes were a favorable area for wet growth to occur. The results are reinforced, compared with other similar studies, by the very particular size range of observed drops.

Determination Of Cloud Structure Using Multi-Sensor Remote Sensing Data

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Bradley Corner,
York University/CRESTech,
Michael Morassutti,
Climet Systems

Clouds and precipitation play a critical role not only by affecting our daily activities but also through impact on our environment. The information about the spatial variability of the cloud cover, as well as the distribution of hydrometeors, are crucial parameters in understanding the cloud and precipitation evolution. Additional requirements for generation of more accurate forecasts, especially on shorter time scales, are the presentation of such information in a concise manner. Weather radars (C-band) have unique capabilities of providing observations of the precipitating weather systems on space scales of 100's m and time scales of 10's min within about 250 km of the radar site. These observations that scan the entire volume of the atmosphere every 10 min can be used to generate vertical and horizontal variability of precipitation and

describe its evolution. Our objective for this project was to determine how additional information about cloud structure can be derived by combining ground-based weather radar observations with data from passive space borne sensors. Two types of satellite sensors were used in this study: Advanced Very High Resolution Radiometer and Special Sensor Microwave Imager.

Several weather events over Ontario were analysed using the King City Radar, AVHRR and/or GOES, as well as Special Sensor Microwave Imager. Severe precipitation events were be the initial focus of this work in testing the potential of using Multi-sensor data.

Doppler Radar Signatures Of In-Flight Icing Conditions

Frederic Fabry, Isztar Zawadzki, Candace Bell, Chantal Cote

In-flight icing occurs when aircraft fly in regions where supercooled cloud, freezing rain, and especially freezing drizzle are present. Work on the detection of such conditions by remote sensing is being sponsored in many countries and resulted in dedicated field experiments like the Alliance Icing Research Study which occurred in the Montreal area last winter (1999-2000). Detection of supercooled cloud and drizzle is particularly difficult, especially in the presence of ice crystals of much stronger reflectivity.

Although direct detection is difficult, the occurrence of icing conditions can often be determined by Doppler radars as supercooled water leave clues of its presence via its interaction with the snow crystals. When snowflakes fall through a supercooled cloud, they first grow quickly, resulting in a large dZ/dh, and then get rimed, resulting in denser crystals that fall faster. When rimed crystals melt, the resulting bright band will be considerably weaker. Some of these conditions can be detected by conventional scanning radars, while others require observations by a vertically pointing radar. Comparisons of prediction of icing conditions with radiometers and aircraft data show that these techniques have considerable potential. Finally, supercooled drizzle in the presence of snow can be detected by vertically pointing radars as it forms a distinct Doppler mode considerably slower than that of the rimed snow

Modernization of the Canadian Upper Air Observing Program

G. Fournier
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Upper-air data are a critical input for numerical forecasting, climate and air quality models, and are useful for weather forecasting and for validating satellite retrievals. There are a number of sources of upper-air data: radiosondes, satellites, ground-based weather radars, and wind profilers are currently operational upper-air observing systems. While aerosondes, automated aircraft reporting systems (AMDAR - Aircraft Meteorological Data Relay), dropwindsondes, GPS Meteorology systems, ground-based doppler lidars, etc., are new observing systems that are being developed and becoming operational.

Currently, the core source of upper-air data is the global radiosonde network (http://www.wmo.ch/), which includes the Canadian radiosonde network operated by Environment Canada that currently consists of 32 regular radiosonde stations with balloon launches twice daily. While the Canadian radiosonde network

exceeds the World Meteorological Organization's (WMO) accuracy standards for aerological observations, it does not meet the recommendations for spatial and temporal coverage by upper-air land stations, and expanding the core network of radiosondes would not be cost-effective.

With the advances in weather modeling and computer capabilities, high resolution upper air observations are required and the best technologies to provide such observations in the short-term and at low risk are considered to be through the use of commercial aircraft and GPS satellites. Consequently an AMDAR program and a GPS Meteorology program are being developed in Canada and form the cornerstones of the modernization of the Canadian Upper Air Observing Program. The GPS Meteorology Program is being developed in partnership with the Geodetic Survey Division of NRCan. Status of the development of these programs and plans for the future will be presented.

DIONYSOS 3.0: An Online Diagnostic Package for Weather Systems

Peter Zwack, Jean-François Caron, and **Christian Pagé**
Département des Sciences de la Terre et de l'atmosphère, UQAM

DIONYSOS is a flexible software package that can be used for studying the structure and evolution of weather systems. Its current capabilities include diagnostics of forcings responsible for vertical motion as well as vorticity and temperature, and geopotential tendencies. It provides useful derived 3-D fields such as potential vorticity, temperature and absolute vorticity advection, latent and sensible heating, as well as, frictional and orographic forcing. DIONYSOS is easily adapted to grided analyses or output from any numerical model and it currently runs operationally at CMC and at the Université du Québec à Montréal using output from 3 different numerical models from 2 different countries (see http://people.sca.uqam.ca/~peter/peter_res.html).

Since most extreme weather events combine mesoscale forcings and convection, DIONYSOS is a useful tool for understanding the forcings responsible for mesoscale vertical motion and convective instability. Recent capabilities that have been added to DIONYSOS include an adaptation to regions with zero absolute vorticity, which is especially useful for transitioning tropical cyclones, as well as the ability to quantitatively calculate the remote effects of a particular forcing. This latter effect is sometimes called action at a distance for which DIONYSOS calculates the impact of an individual forcing at a location (horizontal and vertical) in the atmosphere on vertical motion and tendencies elsewhere. DIONYSOS was then modified using this new methodology to be able to separate the contributions from upper and lower atmospheric processes. Example diagnostics will be presented to highlight the current online features along with the capabilities planned for the future.

Thursday, May 31, 2001
14:00 – 15:00
Ballroom A
Session 1
Significant Weather Case Studies and Modelling

Meteorological Conditions Associated With the 14 July 2000 Pine Lake, Alberta

Tornado

Pat McCarthy
Severe Weather Program Manager
Prairie Storm Prediction Centre
Meteorological Service - Environment Canada

During the early evening hours of 14 July 2000, a large rain-wrapped tornado struck the Green Acres campsite near the town of Pine Lake, Alberta. Much of the campground was devastated, leaving dozens injured and, tragically, 12 dead (the deadliest tornado in North America for 2000). The parent thunderstorm, a high-precipitation supercell, developed in a complex meteorological environment, resulting from a number of critical synoptic and mesoscale events.

This examination will be divided here into two sections: 1) the pre-storm environment - what happened to the atmosphere in the hours prior to the storm developing, and 2) the storm evolution - what did the storm do after it formed and why did it become so destructive.

This presentation will examine many aspects of the disaster, including the damage, the meteorological evolution of July 14 that is evident from a number of data sources, and the role of regional evapotranspiration.

A Case Study of the CAGES Hailstorm at Fort Simpson, Northwest Territories

Nicole C. Plette
Masters student at McGill University studying under Professor M. K. Yau

This research focuses on the numerical simulation of a rare, high-latitude hailstorm observed during the CAGES field experiment. On May 11 1999, a short-wave trough moved northward from British Columbia and continued its passage over the Northwest Territories. A hailstorm developed in an environment with little CAPE (Convective Available Potential Energy). To understand the processes responsible for the formation of the storm, the Canadian Mesoscale Compressible Community model (MC2) is used to simulate this case. The results indicated that the dynamics associated with the short-wave trough, coupled with diurnal heating effects, produced the weakly forced hailstorm that passed directly over Fort Simpson. The sensitivity of the simulation to variations of the surface, boundary layer, and cumulus parameterization schemes are also investigated. The results have implication in understanding the water and energy budgets of the Mackenzie River Basin.

A Numerical Study Of A Severe Arctic Ground Blizzard

Stephen Dery and **M. K. Yau**
McGill University, Montreal, QC

A severe ground blizzard occurred from 16 to 18 November 1996 in the northern sectors of the Mackenzie

River Basin (MRB) of Canada and adjacent Beaufort Sea. This hazardous event, accompanied by a low-level jet with wind speeds approaching 20 m/s and extensive blowing snow near the surface (but clear sky aloft), is forced by a strong sea-level pressure gradient that forms between a rapidly intensifying anticyclone over the Nunavut and Northwest Territories (NWT) of Canada and an intense depression over the frozen Arctic Ocean.

The event is first simulated at a horizontal grid size of 18 km using the uncoupled Canadian Mesoscale Compressible Community (MC2) model. This experiment is shown to capture the rapid anticyclogenesis event within 2 hPa of its central sea-level pressure and the blizzard conditions near the Canadian Arctic coastline and the Beaufort Sea. Meteorological conditions observed at Trail Valley Creek (TVC), a small Arctic tundra watershed where ground blizzard conditions were experienced during the event, are also accurately reproduced by the uncoupled simulation with the notable exception of the blowing snow process. Thus, the mesoscale model is then coupled to the PIEKTUK blowing snow model and a second simulation is conducted. This additional experiment reveals the presence of extensive blowing snow associated with a strong low-level jet over TVC and the adjacent frozen Beaufort Sea. Our findings show that blowing snow affects the surface mass balance through sublimation and transport which combine to erode about 1.4 mm snow water equivalent (swe) per day at TVC. The concurrent moistening and cooling of near-surface air due to blowing snow sublimation emerge during the blizzard, but to a lesser extent than in an idealized modelling framework as a consequence of entrainment and advective processes. Therefore, blowing snow sublimation rates are evaluated to be 1.8 times larger than in the stand-alone application of the PIEKTUK model to the same data

Thursday, May 31, 2001
14:00 – 15:00
Ballroom B
Session 2
Extreme Weather Climatology

Lightning Occurrence Patterns Over Canada and Adjacent United States From Lightning Detection Network Observations

W.R. Burrows [1], P. King [1], P. J. Lewis [2], B. Kochtubajda [3], B. Snyder [4], V. Turcotte [5]

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2 Atlantic Region, Meteorological Service Of Canada, Dartmouth, Nova Scotia
3 Prairie and Northern Region, Meteorological Service Of Canada, Edmonton, Alberta
4 Pacific and Yukon Region, Meteorological Service Of Canada, Vancouver, British Columbia
5 Quebec Region, Meteorological Service Of Canada, Montreal, Quebec

Continuous real-time coverage of lightning occurrence across southern Canada has been available since installation of the Canadian portion of the integrated North American Lightning Detection Network was completed in February 1998. Previously, information on lightning occurrence was available only in the vicinity of manned meteorological observing sites or in limited areas covered by provincial agencies. Until now there are vast stretches of the country where knowledge about lightning occurrence patterns is lacking.

Occurrence of lightning may have been underestimated in traditional climatologies based solely on surface observations. The Canadian Lightning Detection Network (CLDN) of 82 sensors detects lightning over most of Canada north to about 65°N in the far west and 55°N in the far east, and offshore to about 300 km. Over most of this area detection efficiency is 85-90 % and location accuracy is about 500 m. Distinction between cloud-to-ground and cloud-to-cloud lightning was made since February 1999.

Approximately 21 million lightning flashes observed by the CLDN were sorted by equal-area 20 km-sided squares covering Canada and adjacent United States. The data were analyzed for several characteristics: number of occurrence days, flash density, duration of continuous lightning, stroke multiplicity, ratio of positive to negative polarity, mean current strength. Diurnal, monthly, and annual patterns were established. In addition to national patterns, three local regions with especially interesting lightning occurrence patterns were analyzed in detail: Alberta, southern Ontario, and offshore Nova Scotia. Regional differences in characteristics of lightning occurrence are associated with land-water distribution, annual and daily solar heating cycles, and forced low level lift by elevated terrain features and synoptic scale meteorological dynamics. Many aspects of the patterns were consistent over the three years studied, thus while a true lightning climatology is likely a few years away, we believe significant features of the Canadian lightning climatology are identified.

Winter Lightning in The Maritime Provinces of Canada

Peter J. Lewis
Meteorological Service of Canada
Atlantic Region

The Canadian Lightning Detection Network (CLDN) became operational in the summer of 1998. Existing climatologies based on surface observations are limited to point observations of variable density and hence underestimate the occurrence of thunderstorms for a given region. The installation of the CLDN provides the opportunity to produce far richer and more detailed climatologies. It also provides an essential research tool for lightning science allowing correlation of lightning data with other meteorological parameters and hence the ability to improve the forecasting of severe weather.

The winter lightning hazard is enhanced because it is not expected. Historically it has been under reported and under forecast. This study compares the occurrence of winter lightning over the Maritime Provinces of Canada as detected by the CLDN during the winters of 1998/99 and 99/2000 with existing climatologies and surface observations. As expected, the number of "thunderstorm days" detected by the CLDN exceeded those reported by the surface observational network.

In agreement with other studies, winter lightning over the Maritimes was found to have a much higher positive to negative charge ratio than storms in other seasons. The higher currents and charge transfers associated with positive cloud to ground discharges further enhances the winter lightning hazard.

The Season Convective Index

Phil Chadwick

The Season Convective Index (SCI) is a simple quantity that can be calculated from readily available data to estimate the predictability of the events that occurred in a particular period of time. For a convective season, the SCI is based on the ratio of the number of severe events detected to the number of severe days on which they occurred. If the SCI number is large, then a large number of events occurred on just a few days. This would result when the convective season was mainly comprised of large-scale supercellular or squall line events. Large-scale events tend to be more predictable since these storms are more likely to exceed severe limits which eliminates the important question of "if" severe limits will be reached. Their organized character also makes the question of "where" and "when" easier to answer within the required precision of the severe weather program. The accurate solutions to the questions of "if", "where" and "when", all lead to more accurate forecasts and higher verification scores.

If SCI number is small, then a small number of events occurred on many days. This would result when the convective season was mainly comprised of small-scale pulse events. These small scale events are very difficult to predict. The important question of "if", "when" and "where", are all challenging to answer as small scale storms can quickly pulse to severe limits along meso-scale boundaries. Verification scores for pulse events, tend to be significantly lower.

The verification scores over the period of the Ontario Severe Weather Program have been compared to the Season Convective Index for the same period. A high degree of correlation has been found. Year to year variations in verification scores is a strong function of the type of events that characterized the season.