Program of the Fog Remote Sensing and Modeling (FRAM) Workshop

Subjects:	Fog, visibility, low clouds, and ceiling
Emphasis:	Observations, field projects, remote sensing methods, statistical methods, climatology, nowcasting and forecasting issues, modeling applications, operational applications (current and user needs), model verification and forecast verification
Goals:	1) Promote scientific advancement, and 2) Develop interactions among groups and create more collaborations
Location:	Great Hall, University Club, Dalhousie University, Halifax, Nova Scotia, Canada
Dates:	21-22 May 2008
Webpage:	Program updates, maps, travel and hotel information, www.chebucto.ca/Science/AIMET/fog

This is a *workshop*; therefore, participants are encouraged to shine a light on challenging issues as well as on promising results, to open up discussions on common problems, and to exchange ideas and information on effective strategies and techniques.

The FRAM Workshop Organizing Committee can be reached at framworkshop@gmail.com.

Preparation

In keeping with the spirit of a workshop, to give plenty of time for discussion of issues, talks are limited to 20 minutes each. Presenters are advised to plan to speak for about 15 minutes, with extra emphasis on current challenges, and to leave about 5 minutes for discussion immediately afterwards. After blocks of talks, there will be additional time for discussion.

You can bring your presentation to the workshop on a memory stick or CD. At the workshop, we would like to collect and copy all presentations, to share afterwards. We will ask permission first, as sometimes people want to edit a public version. Depending on participants' preferences, we will either share the collection on CD's for everyone or on a website. Participants have the option to add supplementary articles to the collection if they like, such as an extended abstract or a paper.

We would appreciate your suggestions for discussion questions, general or detailed, and/or issues we should focus on. Please advise us and we will see that these questions and issues are raised during appropriate rounds of discussion. To date, the following specific subjects have been proposed: freezing fog, ice fog, marine environments, arctic environments, conditional climatology for fog and ice fog, remote sensing techniques, ice microphysics for parameterization / modeling applications, 3D modeling issues, nowcasting of fog and visibility, airport applications for visibility and ceiling. The following more general subjects are also open to discussion: observations, field projects, remote sensing methods, modeling issues and applications, statistical methods, climatology, nowcasting and forecasting issues, operational applications, model verification and forecast verification.

Organizing Committee

Chairperson: Dr. Ismail Gultepe

Organizers: Bjarne Hansen, Garry Pearson, Dr. Harold Ritchie

Any questions and suggestions you have can be addressed to the FRAM Workshop Organizing Committee and /or to:

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May 21, Wednesday

8:30	*Informal gathering with coffee and tea provided*		
9:00	*Workshop begins*		
	Stewart Cober	Opening address	
Search and Rescue			
9:05	Peter Stow	The impact of fog and fog forecasting on Search and Rescue operations	6
Field Experiments and Observations			
9:35	Ismail Gultepe	The Fog Remote Sensing and Modeling (FRAM) Field Project: observations and visibility applications in warm and cold environments	7
9:55	Thierry Bergot and <u>Robert Tardif</u>	Fog field experiment in France, from ParisFog to ToulouseFog: goal and description of the observations	8
10:15	Michèle Colomb	Use of ground-fog observations to determine visibility parameterization and droplet distribution model	9
10:35	*Discussion **		
10:40	*Break — coffee, tea, drinks and snacks provided*		
Modeling and Forecasting			
10:55	Jason Milbrandt	Upcoming status of explicit fog forecasting with the GEM-LAM-2.5	10
11:15	Junfeng Miao	Sea fog modelling over the Nova Scotia coast using the GEM-LAM15: Sensitivity to vertical resolutions	11
11:35	Robert Tardif	Understanding precipitation fog: fundamental research using field observations and numerical modeling	12
11:55	*Discussion **		
12:00	*Lunch — refer to map*		
Modeling and Forecasting (continued)			
13:30	Jérôme Rangognio	Influence of aerosol on the life cycle of fog	13
13:50	Alexander Kann	Parameterizing low stratus in Aladin-Austria: Its added value and limitations	14
14:10	Duo Yang	Performance of high resolution GEM-LAM in marine fog prediction	15
14:30	Binbin Zhou	Talk 1: Ensemble forecast of ceiling, visibility and fog with NCEP Short-Range Ensemble Forecast System (SREF)	16
		Talk 2: Asymptotic analysis of equilibrium of radiation fog	17
14:50	*Discussion **		
15:10	*Break — coffee, tea, drinks and snacks provided*		

May 21, Wednesday

Nowcasting

15:30	Claude Landry	Nowcasting the visibility in Scribe	18
15:50	George Isaac and Faisal Boudala	The Canadian Airport Nowcasting Project (CAN-Now): Vision for future and preliminary results	19
16:10	Harald Seidl	Towards very high resolution forecasting of fog/low visibility in Central Europe	20
16:30	Samuel Rémy	Numerical prediction of fog for airport: local assimilation, nowcasting and predictability	21
16:50	*Discussion **		
17:20	*Coordination of evening activities*		
17:30	*Break for day-1*		

May 22, Thursday

8:30	*Informal gathering with coffee and tea provided*		
9:00	*Workshop reopens with a summary of important issues raised on day-1*		

Satellite-based Detection and Forecasting

9:10	James Gurka	Expected benefits from GOES-R for fog detection and forecasting	22

Statistical Forecast Applications

9:30	Gaetano Zazzaro	An index for local fog forecast by applying data mining techniques	23
9:50	Bjarne Hansen	Fog forecasting applications of conditional climatology	24

Application and Verification Issues (two 5-minute talks)

10:10	Garry Pearson	Plans for a "fog shootout" and forecaster evaluation of different techniques	
10:15	Bjarne Hansen	Concept of a NinJo smart tool for aviation forecasters	
10:20	*Discussion **		
10:30	*Break — coffee, tea, drinks and snacks provided*		

Applications, Operations, and Verification

10:50	Garry Toth and William Burrows	Automated fog forecasts from an operational NWP model	25
11:10	Michael Rohn and Björn-R. Beckmann	iPort-VIS: Site-specific fog forecasting at Munich Airport — A proposal to implement an operational system	26
11:30	Nico Maat	Verification of statistical forecasts of low visibility at Amsterdam Airport	27
11:50	*Discussion **		
12:00	*Lunch — refer to map*		

May 22, Thursday Afternoon

13:30 *Full-group discussion, brainstorming, and identification of future projects **

Discuss issues raised so far and the following.

- field projects
- modeling issues and applications
    - 3D modeling issues
    - freezing fog, ice fog
    - model verification and forecast verification
- arctic environments
    - ice microphysics for parameterization / modeling applications
- marine environments
- observations
    - in situ and satellite, real-time and climatological
    - remote sensing (methods, techniques, processing)
- statistical methods
- climatology
    - conditional climatology for fog and ice fog
    - nowcasting and forecasting issues
    - nowcasting of fog and visibility
- operational applications
    - airport applications for visibility and ceiling
    - technology transfer, lessons learned

Proposed questions and/or discussion points:

- Strategy in development efforts in the NWP community... which aspects the development efforts should focus on? How?
- How best to put resources in common? Databases from field experiments for example.
- Streamline development efforts... how to best take advantage of what others have accomplished... how can I best share my development... to not re-invent what others have done, etc. Continuous coordination, beyond workshops and conferences.

~14:30 *Break-out groups*

We break out into smaller groups to go into details of specific subjects of most personal interest, and to plan how to collaborate on shared problems.

15:00 *Break — coffee, tea, drinks and snacks provided*

15:30 *Full-group discussion and resolutions*

We reconvene to sum up everything, and to share any new insights, opportunities, and plans. This last session takes place in the Earl of Dalhousie Room.

17:00 *Workshop formally ends*

* Rounds of discussion will be loosely guided and may refer to the presentations which took place before the round. Additionally, any issues and questions participants would like to discuss will be collected in advance.

The impact of fog and fog forecasting on Search and Rescue operations

Peter Stow, Regional Supervisor Maritime Search and Rescue,
Canadian Coast Guard, Joint Rescue Coordination Halifax

The Joint Rescue Coordination Centre (JRCC) in Halifax has an area of responsibility of approximately 4.7 million square kilometers covering a large northwestern section of the North Atlantic. In 2007 the centre coordinated the federal response to 2700 search and rescue cases, most of which occurred in the marine environment.

Accurate weather reports and weather forecasting are critical factors in the development of all search and rescue plans. JRCC Halifax tasks aircraft and vessels to proceed hundreds and even thousands of miles to respond to search and rescue incidents. Accurate weather for remote locations help the search and rescue coordinator determine the appropriate resource to send and the expected capability when on scene.

Fog is a prevalent phenomenon in the coastal area of Eastern Canada and has a huge effect on how the Canadian Coast Guard conducts business. Fog hampers the safe navigation of vessels and often creates an increase in the number of search and rescue cases. Fog can obscure visual distress signals and result in a call for assistance going unnoticed. Fog can obscure the surface of the water and prevent any visual aerial searching for survivors.

Search and Rescue (SAR) coordinators use fog forecasting to determine which resources to send, the track spacing of search patterns and where to send specific resources. Accurate and timely forecasting of fog is critical in the development of a search and rescue plan.

The Fog Remote Sensing and Modeling (FRAM) Field Project: observations and visibility applications in warm and cold environments

Ismail Gultepe, Cloud Physics and Severe Weather Research Section, Science and Technology Branch, Environment Canada, Toronto, Ontario, M3H 5T4, Canada

This work will summarize the three phases of the Fog Remote Sensing and Modeling (FRAM) project on fog microphysics and visibility. The FRAM focuses on: 1) better description of fog environments, 2) development of microphysical parameterizations for model applications, 3) development of remote sensing methods for fog nowcasting/forecasting, 4) understanding of issues related to instrument capabilities and improvement of the analysis, and 5) integration of model data with observations to predict and detect fog areas and particle characteristics. The FRAM project has been conducted over three regions including: 1) Center for Atmospheric Research Experiments (CARE), Egbert, Ontario (FRAM-C), 2) Lunenburg, Nova Scotia (FRAM-L1;L2), and 3) Barrow, Alaska (FRAM-B). FRAM-C was undertaken in a continental fog environment while FRAM-L was in a marine environment. FRAM-B was designed to collect the observations related to ice fog and develop a better instrument suite for future applications. The FRAM-C and FRAM-L components took place from November 2005 to April 2006, and during June of 2006 and 2007, respectively. The FRAM-B took place during April of 2008.

During the project phases, numerous measurements at the surface were obtained, including droplet and ice spectra and concentration, aerosol concentration, visibility, 3D turbulent wind components, radiative fluxes, precipitation, liquid water content profiles, ceiling, and satellite measurements. These observations are being used to better forecast/nowcast fog events in association with results obtained from numerical forecast models using the Canadian Global Environmental Multiscale (GEM) model based on both regional and limited area configurations. Accurate forecasting of Vis by numerical weather prediction models is dependent on the accuracy of the prognostic parameters that are related to fog and precipitation microphysics, and relative humidity (*RH*). The explicit forecasting of Vis in forecasting models, such as the Rapid Update Cycle (RUC) model, have been performed based on parameterizations developed since 1980. As a potential improvement to earlier parameterizations based on a small set of model variables (mainly mean condensed water content), forecast models with sufficiently detailed cloud microphysics schemes could be used to estimate *Vis* based on a larger set of model variables that includes droplet number concentration (N_d), liquid water content (*LWC*), ice water content (*IWC*), precipitation rate (*PR*), and *RH*.

Results suggested that improved scientific and observational understanding of fog microphysics and its forecasting in warm and cold environmental conditions can lead to better forecasting/nowcasting skills benefiting both aviation and public forecasting applications. It is also concluded that a better understanding of ice fog microphysics and its forecasting using numerical models are needed if the visibility forecasting is required in cold remote areas. In addition, this work will summarize the instrumental capabilities to measure fog microphysical parameters and visibility.

Fog field experiment in France, from ParisFog to ToulouseFog: goal and description of the observations

Thierry Bergot and Robert Tardif,

Centre National de Recherches Meteorologiques, Meteo-France, Toulouse, France

Fogs are weather conditions with significant socio-economic impacts. The life cycle of fogs involves complex interactions between dynamical, turbulent, microphysical and radiative processes that are still not fully understood.

Two 6-month filed experiments named ParisFog and ToulouseFog, were carried out in France during winter 2006-2007 and 2007-2008 respectively. The goal of these field experiments was to monitor simultaneously all key processes that drive the life cycle of fog, from formation to dissipation.

This presentation will summarize the active and passive instruments deployed during Paris-Fog and Toulouse-Fog. A classification of the fog and near-fog events, following the work of Tardif and Rasmussen (2007), [1] shows that the documented cases are mainly radiative fog and stratus lowering fog. The dataset collected during these field experiments will be of great interest for the future research in fog prediction.

[1] Tardif, R. and R. M. Rasmussen, 2007: Event-Based Climatology and Typology of Fog in the New York City Region, Journal of Applied Meteorology and Climatology, 46, 1141–1168. [abstract]

Use of ground-fog observations to determine visibility parameterization and droplet distribution model

M. Colomb, F. Bernardin and P. Morange, Laboratoire Régional des Ponts et Chaussées, Ministère de l'Écologie, de l'Energie, du Développement durable et de l'Aménagement du territoire [Ministry of Ecology, Energy, Sustainable Development and Regional Planning], Clermont-Ferrand, France.

More efficient predictions of fog occurrence and visibility are required in order to improve both safety and traffic management in critical adverse weather situations. Observation and simulation of fog characteristics contribute to a better understanding of the phenomena and help to adapt technical solutions counteracting visibility reduction.

A ground observation campaign was carried out at Clermont-Ferrand, France, in order to collect microphysical fog data. Microphysical observations were performed thanks to a “Palas” optical granulometer. On the basis of these data including radiation fog, a preliminary microphysical parameterization scheme is proposed. This preliminary analysis is compared to the method developed by Gultepe et al (2006) based on the large set of data collected by aircraft during the Radiation and Aerosol Cloud Experiment (RACE). The results show some differences among the various parameterizations. The influence of the nature of fog (continental or maritime) on the various parameterizations is discussed, as well as the hypothesis on Visibility calculation. A new observation campaign took place during the ParisFog experiment that provided us with a new data set that is analysed in the same way. Smaller particles are observed, which drastically modifies the proposed parameterizations based on the droplet distribution over 2µm. The influence of the particle range is discussed.

Based on the same data set a complementary analysis is carried out in order to provide a droplet distribution model. The simulation of reduced visibility during fog using a light scattering model depends on the size and concentration of droplets. Therefore it is necessary to include some functions in the software for the droplet distribution model rather than data files of single measurements. The first approach consists in testing the four Gamma laws proposed by Shettle and Fenn (1979). Coefficient adjustments allow characteristics to be changed from advection to radiation fog. These functions did not fit the new set of data collected with the Palas sensor. New algorithms based on Gamma and Lognormal laws are proposed and discussed in comparison to the previous models.

Upcoming status of explicit fog forecasting with the GEM-LAM-2.5

Jason Milbrandt, Numerical Weather Prediction Research Section,
Environment Canada, Dorval, Quebec, Canada

The appropriate method of inferring the presence of fog from a numerical weather prediction model depends in part on the model's horizontal grid spacing which is important in determining the appropriate type of parameterization scheme(s) that treats moist processes. The Canadian Meteorological Centre (CMC) currently runs several high-resolution (2.5 km) windows with the limited-area (LAM) version of the Canadian GEM forecast model. With this grid-spacing, clouds are essentially resolved and cloud processes are modelled with a grid-scale condensation scheme, whereby the quantities of various hydrometeor species are prognosed. Fog is thus explicitly predicted, represented as grid-scale liquid or frozen cloud.

CMC will soon be implementing a new cloud scheme into the operational GEM-LAM-2.5 model. The new scheme has prognostic variables for the mass content and number concentration of cloud water (as well as other hydrometeor categories). With the independent prediction of liquid water content and droplet number concentration, the scheme not only explicitly predicts the occurrence of fog but also allows for the parameterization of visibility as a function of both mass and number.

An overview of the upcoming cloud scheme will be presented along with results from a simulation of marine fog using the operational model configuration. Comparisons will be made to measurements of fog water content, droplet concentration, and visibility taken from the FRAM-L2 field experiment conducted in June 2007 in Lunenburg Bay, Nova Scotia.

Sea fog modelling over the Nova Scotia coast using the GEM-LAM15: Sensitivity to vertical resolutions

Junfeng Miao, Department of Oceanography, Dalhousie University, Halifax, NS, Canada

In this study, the Limited-Area Model (LAM) version of Environment Canada's Global Environmental Multiscale (GEM) model with a horizontal resolution of approximately 15 km (GEM-LAM15) is applied to simulate sea fog events along the Nova Scotia coast during the period of 27-29 June 2006. The focus is on investigating the sensitivity of simulated sea fog to vertical resolutions. The control experiment's configuration is similar to the 15-km version of the Canadian regional forecast system with 58 vertical levels. The sensitivity is the same as the control experiment but with 115 vertical levels. The spatial and temporal variations of cloud variables are analyzed in detail for the two experiments, and visibility is diagnosed (calculated) using the parameterizations based on cloud liquid water content. Also, the radiation variables and the surface fluxes such as sensible heat, latent heat and momentum are compared for the different experiments. The observational data (temperature, dew point temperature, specific humidity, wind, surface pressure and/or visibility) from 20 routine meteorological (climate) stations over Nova Scotia, including two RAOB sites and one field site for Fog Remote Sensing and Modeling (FRAM) measurement at Lunenburg (FRAM-L), are chosen and used in this study to evaluate the model performance.

In short, the study examines two lines of questions: (1) Can GEM-LAM15 simulate sea fog? (2) How sensitive are the overall performance of the model and its applications to sea fog simulations to the setup of vertical levels (resolutions)? The overall objectives of the study are to evaluate the model performance in predicting sea fog and to suggest some improvements to be pursued in future work.

Understanding precipitation fog: fundamental research using field observations and numerical modeling

Robert Tardif, Météo-France, Centre National de Recherches Météorologiques, Groupe de Météorologie de Moyenne Echelle, Meteo-France, Toulouse, France

The phenomenon of fog is complex in many ways, including the variety of scenarios in which it occurs (radiational cooling in the nocturnal boundary layer, under advective processes out at sea, stratus lowering etc.). A lack of understanding and comprehensive representations in numerical models of key processes and interactions involved in each of these scenarios contribute to our ongoing difficulty in accurately predicting the life cycle of fog.

Efforts have been undertaken to shed new light on a common fog type for which the underlying physical mechanisms remain largely unknown, e.g. fog forming during precipitation (precipitation fog). A multi-faceted approach has been used, incorporating a climatological data analysis, dedicated observations from an instrumented site and detailed numerical modeling. Results indicate that precipitation fog is common over the northeastern United States, and is generally associated with light rain falling in low-level temperature inversions. A microphysical numerical model, representing the evolution of the temperature of raindrops evaporating while falling in continuously changing ambient conditions, was built to elucidate the possible role of non-equilibrium raindrops on fog formation. Simulations show that drops falling in temperature inversions remain warmer than the ambient air (out of equilibrium), and can therefore evaporate even in a saturated environment thus producing supersaturation and fog. Observations gathered during a precipitation fog event are combined with simulations to show that evaporation of non-equilibrium raindrops was a key mechanism responsible for the observed fog.

From a practical point of view, this fundamental research has shown that the equilibrium assumption used in rainfall evaporation parameterizations prevents the proper representation of this fog type by NWP models. A greater understanding of the phenomenon allowed the identification of the environmental conditions leading to fog, thus paving the way to a targeted evaluation and improvement of NWP models and the development of nowcasting systems that could lead to more comprehensive and accurate fog forecasts.

Influence of aerosol on the life cycle of fog

Rangognio, J., Bergot T., and Tulet P.,
GAME/CNRM (Météo-France, CNRS), Toulouse, France

Fogs are typically meteorological phenomenon of small scale. The life cycle of a fog layer is driven by complex interactions between turbulent, microphysical and radiative processes. This work focuses mainly on the influence of microphysical processes. The characteristics of aerosols (concentration, size and chemical composition) have a large impact on the life cycle of a fog layer. The liquid water content inside the fog layer, the droplet size distribution – and consequently the visibility – strongly depends on the characteristics of the aerosol.

To improve our understanding and our capability to describe and model physical processes governing the life cycle of fog, a collaborative fog field experiment has been performed over the 2006 - 2007 winter season (the PArisFOG experiment, October 2006 - April 2007) near Paris, France, see http://parisfog.sirta.fr. The objectives are :

- characterize the conditions that leads to fog formation: turbulent mixing in stable layers, energy balance at ground, role of microphysical processes in nucleation and radiative processes;
- monitor the conditions controlling fog development: thickness of fog layer, thermodynamic conditions, fog microphysics;
- identify conditions for fog dissipation: in addition to the above mentioned processes, absorption by aerosols and dynamic structures (e.g. convection rolls).

A numerical investigation of the influence of aerosol on the fog properties has been performed. The French research atmospheric numerical model Meso-NH (see http://mesonh.aero.obs-mip/mesonh.fr, Lafore et al. 1998) has been coupled with the lognormal aerosol model ORILAM (Organic Inorganic Log-normal Atmospheric Model, Tulet et al., 2005) and the cloud scheme C2R2 (Cohard et Pinty, 2000). 1D simulations clearly show the influence of the aerosol size distribution and the influence of aerosol chemistry on the life cycle of fog.

Parameterizing low stratus in Aladin-Austria: Its added value and limitations

Alexander Kann, Central Institute of Meteorology and Geodynamics, Vienna, Austria

Forecasting low stratus is one of the most challenging fields in NWP. Typically, these models are demonstrated to lack forecast skill in the prediction of cloudiness related to (elevated) inversions. The reasons are manifold: Often, even the analysis of the vertical structure of temperature and humidity diverge from real lower atmospheric conditions to a great extent. Consequently, the analysis error is propagated or even increased during integration and finally leads to significantly biased forecasts. Furthermore, the temperature inversion is losing its strength due to problems in horizontal and vertical diffusion or generally within the boundary layer parameterization.

The low stratus scheme (SK-scheme), developed and upgraded at ZAMG during the last years, tries to compensate these model deficiencies and parameterizes sub-inversion cloudiness within the framework of the numerical weather prediction model Aladin – Austria. Low cloudiness is diagnosed if the following criterions are fulfilled: The temperature inversion has to reach a given strength, a quasi-saturated layer, which must exceed a specific humidity threshold, has to fulfill a given thickness criteria and this quasi-saturated layer must not penetrate arbitrarily into the inversion layer (in order to avoid synoptically decoupled phenomena). With respect to these properties, this parameterization can be regarded as a low-stratus-enhancement-scheme.

It will be shown that the usage of the sub-inversion cloudiness scheme results in a better forecast of low cloudiness and, due to positive feedback on radiative flux divergence during integration, of near surface temperature. The influence of the modifiable settings on the results and the operational implementation will be discussed. An outlook to future activities (e.g. incorporation of liquid water information into the scheme) will complete the talk.

Performance of high resolution GEM-LAM in marine fog prediction

Duo Yang, [a] *Hal Ritchie,* [a,b] *Serge Desjardins,* [c]
Garry Pearson, [c] *Al MacAfee,* [c] *and Ismail Gultepe* [b]
[a] *Dalhousie University*
[b] *Meteorological Research Division, Environment Canada*
[c] *National Lab for Marine and Coastal Meteorology, Meteorological Service of Canada*

As a component of the Lunenburg Bay Multidisciplinary Modeling System, a high resolution GEM-LAM configuration (a limited area version of the Global Environmental Multiscale Model with a resolution of 2.5 km) was implemented for a demonstration project that started in June 2007 and included real-time fog prediction in cooperation with the FRAM (Fog Remote Sensing and Modelling) field experiment. This GEM-LAM 2.5 model is now running daily and being evaluated by the Atlantic Storm Prediction Centre. In this study our objective is to examine this model's marine fog prediction capabilities, and particularly the sensitivity to new physical parameterizations for high resolution modeling. Several case studies have been performed and carefully examined. The condensation scheme that directly generates the cloud liquid water content (or fog) and boundary layer processes (such as MoisTKE) that lead to the vertical redistribution of the cloud liquid water content are important factors that influence marine fog prediction. We also found that there is a significant contribution from their interactions with the radiation scheme that interacts fully with clouds. As well, there is a non-negligible impact from input fields including the pilot fields (initial and boundary conditions) and geophysical fields. Some aspects of the evaluation and/or diagnosis will be presented.

Ensemble forecast of ceiling, visibility and fog with NCEP Short-Range Ensemble Forecast System (SREF)

Binbin Zhou, Jun Du, Jeff McQueen, Zoltan Toth and Geoff DiMego,
Environmental Modeling Center, NCEP/NWS/NOAA

The NCEP SREF System is an ensemble forecast system composed of 21 ensemble members generated from multiple models (Eta, WRF, RSM), multiple physical schemes and breeding of initial conditions. SREF System has been implemented operationally since 2001. The forecast domains cover the Continental US (CONUS) and Alaska regions. In 2002, it was extended to aviation weather including ceiling, visibility, flight restrictions and fog ensemble forecast. One of the goals for the NCEP SREF System is providing probabilistic central guidance on both regular and aviation weather to local forecasters.

In this talk, the SREF's aviation forecast will be briefly introduced, including its framework, configuration, and the generation of the four ceiling/visibility related ensemble products. The SREF aviation weather forecast is still experimental but routinely displayed on NCEP website for reference by the local forecasters at NWS Weather Forecast Offices (WFOs) in various regions, Aviation Weather Center (WAC), commercial airports and airlines.

The grid-to-grid objective verifications of these four aviation weather products over whole domains are extremely difficult because observational data in gridded format are still not available. Current verification strategy is asking the local forecasters at various regions to evaluate what they are interested by and to send their feedbacks, comments and suggestions to NCEP. Some pilots from commercial airlines voluntarily participate in evaluation. In such a forecast center through local forecaster interactive communication, we hope to gradually improve and upgrade the four aviation weather ensemble products.

In the next implementation bundle of the SREF System, some of the aviation products will be delivered to the NOAA/NWS Advanced Weather Interactive Processing System (AWIPS) for processing, analysis and objective evaluation by the local forecasters.

Asymptotic analysis of equilibrium of radiation fog

Binbin Zhou and Brad Ferrier, Environmental Modeling Center, NCEP/NWS/NOAA

It is well accepted that radiation fog is a threshold event. In other words, it happens only after turbulence drops below a certain level and as RH reaches 100%. However, the turbulence threshold is still not known to us. Is it a fixed value or certain explicit relationship we can address? The goal of this work attempts to answer this question.

The method is first try to solve the radiation fog's LWC equation with so-called singular perturbation technique (a type of asymptotic methodology) in its steady state. Then from the asymptotic solution, interesting parameters, including the turbulence threshold, are revealed.

The vertical distribution of the LWC in steady fog is obtained. The asymptotic formulation has one-order accuracy with respect to turbulence and exhibits the balance between cooling, droplet gravitational settling and turbulence transfer. Cooling generates liquid water, which is redistributed by the droplet gravitational settling, while turbulence depletes the liquid water droplets.

The effect of turbulence depletion is dominant near the surface, decreases with height and can be parameterized by a fog boundary layer (FBL) near the surface. Within the FBL, the turbulence influence is large and above the FBL the cooling effect prevails. The FBL looks very like a mixing layer near the surface inside a fog: thinner in weak turbulence and develops upward from the ground as turbulence intensifies.

A critical turbulent exchange coefficient for steady fog can be revealed from the asymptotic formulation. Its value is proportional to $C^{0.5} H^{1.5}$, where C is cooling rate and H is fog depth. Its value defines the strongest turbulence intensity a steady fog can endure. When turbulence does not exceed its critical value or the FBL is less than the fog depth, steady fog can persist. When turbulence exceeds the critical value or the FBL grows and reaches the fog top, the balance inside the steady fog will be broken, leading to its rapid dissipation. Since the balance of all processes inside a fog is necessary for persistence of a fog bank, the critical turbulence value can be seen as an additional threshold for radiation fog besides the RH threshold.

This work was based on a theoretical analysis and awaits further verifications with observational data or model simulations. Its application is still an open issue.

Nowcasting the visibility in Scribe

C. Landry , R. Parent, J.-F. Deschênes, A. Giguère, G. Hardy, P. Bourgouin,
Canadian Meteorological Centre, Environment Canada, Dorval, Québec, Canada

The Scribe Nowcasting Sub-System (NSS) has been developed at the Canadian Meteorological Centre (CMC) and implemented in 2005. It ingests observed and nowcasting model weather data on a continuous basis. At every hour, a consistent set of forecasted weather elements is produced and can be used to update interactively the weather elements in Scribe for the short term. Three dynamic databases are updated hourly to support the NSS. All these data are then analysed by a network of rules which is inspired by a fuzzy logic approach. Among these forecasted weather elements the visibility and obstructions to visibility are included for a public forecast usage. In addition to the current surface observation and trend, a statistical model called PubTool using the latest surface observation is used. PubTool produces a probability of occurrence of 3 categories of visibility: good, fair, and poor. Based on surface weather elements trend analysis, persistency and PubTool, the rules will nowcast the type of obstruction and the visibility value in 5 categories.

The time resolution of the observed and nowcasting data is 1 hour, compared to three hours in the regular Scribe system matrices. Updated weather elements for more than 450 stations are currently available about 30 minutes after the hour ready to be merged with the Scribe weather elements or the current working forecast.

The Canadian Airport Nowcasting Project (CAN-Now): Vision for future and preliminary results

George A. Isaac and Faisal S. Boudala, Cloud Physics and Severe Weather Research Section, Environment Canada, Downsview, Ontario, Canada

The Canadian Airport Nowcasting Project (CAN-Now) is in the process of developing an advanced prototype weather forecasting and nowcasting system that can be used at major airports. This system is currently being tested at the Pearson International Airport (CYYZ). The system obtains data from numerical models, surface based observation sensors measuring meteorologically relevant parameters such as precipitation rate, ceiling, visibility, winds; and also includes remote sensing data obtained from satellite, radar and radiometer. The goal of this project is to provide detailed nowcasts out to approximately 6 hours to assist the decision makers at airports such as pilots, dispatchers, de-icing crews, ground personnel and air traffic controllers to make plans with increased margins of safety and improved efficiency. Algorithms are being developed for nowcasting visibility, blowing snow, turbulence, etc. In this talk some preliminary results will be presented and some of the challenges associated with these tasks will be discussed.

Towards very high resolution forecasting of fog/low visibility in Central Europe

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ZAMG is operating a nowcasting-suite at 1km x 1km named INCA (Integrated Nowcasting through Comprehensive Analysis), an operational limited area model ALADIN/AUT at approximately 10 km and a test-version of AROME at 2.5 km horizontal resolution. Visibility as the equivalent visual range at daytime has been introduced only recently into the operational Aladin suite. It is diagnosed from cloud liquid water and relative humidity at model levels close to the surface. Ground and lifted fog can be distinguished through simple relationships. The author will present short range forecast simulations for selected (dense) fog episodes and discuss related problems. Fog forecasts are very sensitive to initial conditions, in particular to soil moisture and temperatures. AROME involves much more sophisticated microphysics than ALADIN, at the same time it is more difficult to adjust. Tuning or calibrating visibility computations and improvements of model initialisation and (micro)physics must be a mutual process.

There is no unified validation package available yet: Synoptic Observations, Satellite Imagery products from MSG (METEOSAT Second Generation) and the INCA analysis mode are used to validate fog/low visibility forecasts.

Numerical prediction of fog for airport: local assimilation, nowcasting and predictability

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Short-term forecasting of fog is a difficult issue which can have a large societal impact and economical impact. For example at major international airports, restrictive procedures are taken under foggy conditions to regulate air traffic. A new methodology based on local observations, an adaptive assimilation scheme and the Cobel-Isba numerical model has been tested during 3 years at Paris-CdG international airport (France). This test over a long time period, allows an in-depth evaluation of the forecast quality of fog on local scale. This study demonstrates that the major features of the life cycle of fog (onset, vertical development and dissipation) are well forecasted up to +6h. The model is now in operational use at the Paris-CDG airport and is being installed on the Paris-Orly and Lyon-Saint Exupéry airports.

Decision makers are interested by a forecast of the probability density function in itself in order to minimize the potential economic impact of fog. A local ensemble prediction system (L-EPS) based on Cobel-Isba local forecast system has been build to help decision makers. Results indicate that L-EPS exhibits high potential economical value.

Research is under way to optimize the assimilation scheme in order to run the model with fewer observations. The aim is to make the model available for smaller airports which can not afford a large local observations system. An Ensemble Kalman Filter (EnKF) has been developed and tested with simulated observations.

Expected benefits from GOES-R for fog detection and forecasting

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The Advanced Baseline Imager (ABI) on the GOES-R series, with a planned first launch in December, 2014, has been designed to meet user requirements covering a wide range of phenomena. As with the current GOES Imager, the ABI will be used for a wide range of weather, oceanographic, climate, and environmental applications. The ABI will improve upon the current GOES Imager with more spectral bands, faster imaging, higher spatial resolution, better navigation, and more accurate calibration. The ABI expands from five spectral bands on the current GOES imagers to a total of 16 spectral bands in the visible, near-infrared and infrared spectral regions. There will be an increase of the coverage rate leading to full disk scans at least every 15 minutes. ABI spatial resolution will be 2 km for the infrared (IR) bands and 0.5 km for the 0.64 um visible band. The ABI will improve every product from the current GOES Imager and will introduce a host of new products.

The first step to improve fog forecasting is improved detection. The improved spatial resolution in the visible, near IR and IR channels will allow for detection of fog that cannot be seen on the present generation of GOES satellites. The improved temporal resolution will allow for quicker detection and improved monitoring of fog growth and decay. The increased number of channels will provide better information on cloud physics including cloud top phase and cloud top particle size distribution. Onboard visible calibration, along with improved image navigation and registrations, will allow for quantitative use of visible images leading to improved short-term forecasting of fog dissipation, and improved fog climatology. Additional channels will also provide better information on aerosols and thin cirrus to allow a more accurate assessment of the actual fog brightness and thus the thickness, and expected time of dissipation. Improved information on aerosols and low level water vapor should help in the short term forecasting of fog formation both over land and water. Improved satellite derived winds and sea surface temperatures will provide additional tools for forecasting sea fog. This presentation will describe the expected new capabilities of GOES-R with respect to fog observation and forecasting and illustrate these with the use of proxy GOES-R images from MODIS (MODerate-resolution Imaging Spectroradiometer) and NOAA polar orbiting satellites.

An index for local fog forecast by applying data mining techniques

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The present work illustrates the creation of some fog forecasting local indexes, based on the post-processing of meteorological variables from the ECMWF model, using data mining techniques for the data analysis. The ability to forecast fog events is of fundamental importance in order to avoid disasters due to visibility reduction in the context of transportation, in particular air transportation, where the relevancy of fog forecasting ability is independent on the specific fog frequency because of the huge damages that can derive. The fog indexes were created starting from a suitable combination of meteorological observation data, in the SYNOP format, collected in Trapani Birgi station from 1990 to 2002 and meteorological variables from the ECMWF model corresponding to the same time interval. A dataset containing a total amount of 17396 records which included 142 fog events was obtained. The rare event condition of the fog phenomenon in Trapani required some specific approaches, in applying the data mining techniques, in order to overcome the class imbalance problem: in the training data, the number of records corresponding to no-fog events was reduced (undersampling), and the obtained results were evaluated by means of adequate performance metrics able to highlight the forecasting ability of an index with respect to the fog events and the no-fog events separately (confusion matrix, ROC curve, Area Under Curve).

Using the open-source software WEKA, classification algorithms were applied to the prepared dataset. The obtained models were tested over 4349 records; six models overcame the AUC threshold of 0.7 and, for five of them, the ROC curves showed a good result: 80% (Detection Rate) of fog events correctly predicted.

Fog forecasting applications of conditional climatology

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Archives of hourly airport observations are a rich source of site-specific climatological data to be used for forecast systems. Such systems can use a variety of statistical and visualization techniques. One such system called WIND-3 (Weather Is Not Discrete - version 3) uses a combination of the analog method and the fuzzy logic approach to analyze and summarize hourly observations in order to produce probabilistic predictions of cloud base height (ceiling) and horizontal visibility at 198 airports in Canada (Hansen 2007). Another system called SDCC (Seasonal Diurnal Conditional Climatology) uses a combination of conditional climatology and the gnuplot package to reveal and visualize fog occurrence patterns in hourly airport observations (Hansen et al. 2007).

In this work, two systems in development that use hourly airport observations will be analyzed to make probabilistic forecasts of fog. The first system, CPC (Conditional Persistence Climatology), is used to predict probability of fog given the following initial conditions: visibility, presence or absence of fog, time of day, time of year, wind direction, and precipitation occurrence and type. CPC builds upon SDCC by describing the conditional climatology of the four distinct possible sequences: persistence of fog, dissipation of fog, formation of fog, and persistence of no fog. This distinction is significant for operational applications, where the initial condition (fog or no fog) is known, one can thus apply the appropriate conditional climatology. Verification of probabilistic forecasts will be given using Relative Operating Characteristic (ROC) diagrams, including comparison with the benchmark technique persistence.

The second system, AFP (Advection Fog Probability), adapts and applies a basic technique used by forecasters to predict advection fog at coastal sites: *when onshore winds flow from certain sectors, then it predicts fog formation (or persistence).* In operational meteorology, this technique is applied subjectively. The AFP system applies the technique more objectively at selected sites. Training data consist of approximately 100 recent past cases. Each past case consists of a back-trajectory for the air parcel over a selected site at To+24 hours, and the corresponding observations. Each new case consists of a back-trajectory for a specific site. For each new case, probabilistic predictions of fog at To+24 hours are based on the outcomes of the past cases with the most similar forecast back trajectories.

Preliminary results suggest that both CPC and AFP produce significantly more accurate forecasts of fog and visibility compared to simple persistence and conditional climatology, and can thus help forecasters to improve fog forecasts.

Automated fog forecasts from an operational NWP model

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Among the objectives of the FRAM (Fog Remote Sensing and Modeling) Project is to provide new forecast tools to Canadian operational weather forecasters. Modern operational NWP models such as the Canadian GEM-15 (Global Environmental Multiscale model, 15 km horizontal resolution) are among the primary tools used by forecasters, because:

1. They have a large amount of meteorological "intelligence" built in;
2. They are executed regularly and their output is available on a reliable schedule;
3. Their forecasts are valid over a large geographic area;
4. A wide variety of post-processed forecast products are available.

Fog and stratus are key weather elements, particularly for aviation forecasters, but are highly variable in time and space and are notoriously difficult to predict. Can useful information concerning fog and stratus be extracted from an operational NWP model? The authors, working at the HAL (Hydrometeorology and Arctic Lab, Edmonton) have subjectively developed a variety of rules that constitute a system designed to forecast areas where dense fog (visibility ½ mile or less) or low stratus (ceiling 600 feet or less) are probable. The rules, applied to GEM-15, are grouped into the following main categories:

1. UPS fog [1] for radiation and radiation/advection fog;
2. Marine advection fog;
3. Land advection fog;
4. Inversion fog;
5. Visibility calculated directly as a function of model RH.

The resulting fog and stratus forecasts are now available to Canadian forecasters at http://hal-bobk.edm.ab.ec.gc.ca/HAL_Winter/FOG_Fields/FOG_Fields.html (site internal to Environment Canada).

This presentation will describe briefly the forecast rules, and then consider one case using the operationally-available forecast charts. Some evaluation of the forecast for this case will be presented, with emphasis on the difficulties of verifying fog and stratus forecasts over data sparse areas such as most of Canada.

If time permits, the presentation will conclude with some general observations on the overall performance of this forecast system based on the authors' ongoing subjective evaluation carried out during its development.

[1] Baker, R., J. Cramer, and J. Peters, 2002: Radiation fog: UPS Airlines conceptual models and forecast methods, 10th Conference on Aviation, Range, and Aerospace Meteorology. [PDF]

iPort-VIS: Site-specific fog forecasting at Munich Airport — A proposal to implement an operational system

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The German ministry for economy and technology is instigating improved effectiveness and competitiveness of the German aviation industry by funding an aviation research program between 2009 until 2012. This includes activities on improved forecasting techniques for weather phenomena affecting airport management and traffic: Precipitation and strong convection, wind shear and direction, and poor visibility.

Following other activities of site specific fog forecasting, the DWD attempts in cooperation with University at Bonn to implement a site specific fog forecasting system at Munich international airport. The planed system aims at coupling an one-dimensional version of the fog forecasting model PAFOG with the high-resolution model COSMO-DE of DWD. Following the experiences during recent years, local observations will be integrated in order to best determine the initial conditions.

An overview of project will be presented together with the current planned setup of local instrumentation and forecasting system. The presentation of this project at the FRAM workshop will provide an unique opportunity to discuss the early plans with the community of international experts on fog forecasting.

Verification of statistical forecasts of low visibility at Amsterdam Airport

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Accurate, reliable and unambiguous information concerning the actual and expected (low) visibility conditions at Amsterdam Airport, Schiphol, is very important for the available operational flow capacity. Inaccurate and unreliable visibility forecasts have therefore a negative impact on safety and operational expenses. KNMI has performed an update of the visibility forecast system in close collaboration with the main users of the forecasts (Air Traffic Control, the airport authorities and KLM airlines). The automatic forecasting system consists of a Numerical Weather Prediction Model (Hirlam) with a statistical post processing module on top of it. Output of both components is supplied to a human forecaster who issues a special Schiphol bulletin, which is tailored to the operational use at the airport. The following improvements are achieved in both the statistical post processing module and the Schiphol Probability Forecast bulletin:

1. Use of closer (20km) real time observational data as upstream advection predictors improves the short term (0-3h) statistical forecasts.
2. Joint Probabilities for specific combinations of visibility and cloud base height thresholds are developed
3. Probabilities for the operationally used Runway Visual Range (RVR) are calculated whereas formerly only the Meteorological Optical Range (MOR) values were forecasted. Since RVR depends on the local Background Luminance, a (deterministic) statistical forecast for the latter had to be developed.
4. Verification of the new system shows strongly increased reliability (on dependent data) and enhanced resolution for several visibility thresholds and lead times.

Finally a simple guideline model is developed that shows how to optimize a threshold percentage, in case a categorical choice / decision has to be made from the full probabilistic visibility forecast. It is shown that the performance of the forecast system combined with a user-specific sensitivity to false alarms and misses results in a cost-optimal decision threshold percentage.