WORLD METEOROLOGICAL ORGANIZATION

COMMISSION FOR BASIC SYSTEMS
OPAG on DPFS

EXPERT MEETING ON
VERY SHORT-RANGE FORECASTING (EM-VSRF)

Geneva, Switzerland, 21-23 March 2011

CBS-DPFS/EM-VSRF/Doc. 6(1)

(10.III.2011)

____

Agenda Item: 6

ENGLISH ONLY

DRAFT GUIDELINES ON THE USE OF OPERATIONAL NWP CAPABILITIES FOR SEVERE WEATHER FORECASTING

(Submitted by Jean-Marie Carrière, Météo-France, Rapporteur of the OPAG on DPFS on the application of NWP to Severe Weather Forecasting)

Summary and purpose of document

This document has been prepared by the Rapporteur of the OPAG on DPFS on the application of NWP to severe weather forecasting. It aims at proposing a general scheme for the use of numerical weather prediction tools, including seasonal forecasting, probabilistic forecasting and nowcasting systems, as regards severe weather forecasting. The first version of this document was presented and discussed during the 2007 EM-VSRF meeting. The present version is an update of the 2007 version.

Action Proposed

The meeting is invited to consider this document as regards nowcasting, very short-range and short-range forecasting and provide views on the interest of technical guidance on implementation of VSRF systems, focusing on developing countries.

INTRODUCTION

The NWP system, including data assimilation and atmospheric modeling, simulates and forecasts the atmosphere. It has reached a point where it is now widely used in operational short-range and medium-range weather forecasting all over the world. A history of the developments of NWP can be found e.g. in Kalnay (2004). NWP has extended in the last years towards ensemble forecasting techniques, both for medium-range and monthly forecasting at relatively large scales and more recently for short-range very high resolution forecasting. Severe weather features can be identified at the full spectrum of these scales : one finds for example droughts or ENSO events at the seasonal scale, or severe convective or flash floods events at the local scale. Different types of numerical prediction systems have been developed in the various GDPFS centres around the world corresponding to long-range forecasting, short-range forecasting, etc. Indeed, a deterministic meso-scale model for instance will not be able to forecast the trend in temperatures for the months in advance. For this, it would have to be coupled with an ocean model and used in a probabilistic mode at a coarser resolution. Likewise, a global climate model cannot be used to forecast convective developments locally in the hours to come. However, both rely on NWP models. Thus, in all cases, NWP techniques, including data assimilation, are the basis for forecasting atmospheric characteristics and phenomena at all scales.

Additionally, severe weather features may worsen or be the cause of phenomena not *directly* linked with atmospheric characteristics. For instance, air or water pollution may be increased under conditions of high temperature or heavy precipitation. In some cases, NWP meteorological models can be used along with other sources of information to derive an assessment or a diagnostic of weather-related risks. However, these methods are not dealt with in this document.

The objective of this document is to give a general guidance on the use of NWP capabilities *at all time ranges, going from nowcasting to seasonal forecasting, with a focus on severe weather*, and to clarify what type of models is to be used to forecast what type of severe weather, and how they can be chained together.

This guidance document is based on the work of the DPFS OPAG of CBS. Some of the guidance material provided (e.g. regarding the use of EPS) can be found in the documents listed in the Bibliography.

1. THE DIFFERENT TYPES OF MODELING SYSTEMS

The different types of modeling systems are presented following the definitions of meteorological forecasting ranges given in Appendix I-4 of the WMO Manual on the Global Data-processing and Forecasting System. Generally speaking, the weight given to observations in these systems will decrease as the time range of forecasting increases.

Although model verification is not treated in this document, it is worth mentioning that it would benefit from verifying models according to criteria oriented towards severe weather as far as possible. However, a difficulty may arise from the relative scarcity of severe weather cases, making the production of statistics more difficult.

When disaster management and civil protection agencies are alerted to severe weather episodes, decisions and protective measures often have to be taken whenever possible a few days before the expected event, depending on the level of uncertainty that is associated with the forecast. However, during severe weather episodes, forecasting the evolution at different time ranges remains necessary to adapt the response of the authorities.

1.1. Nowcasting

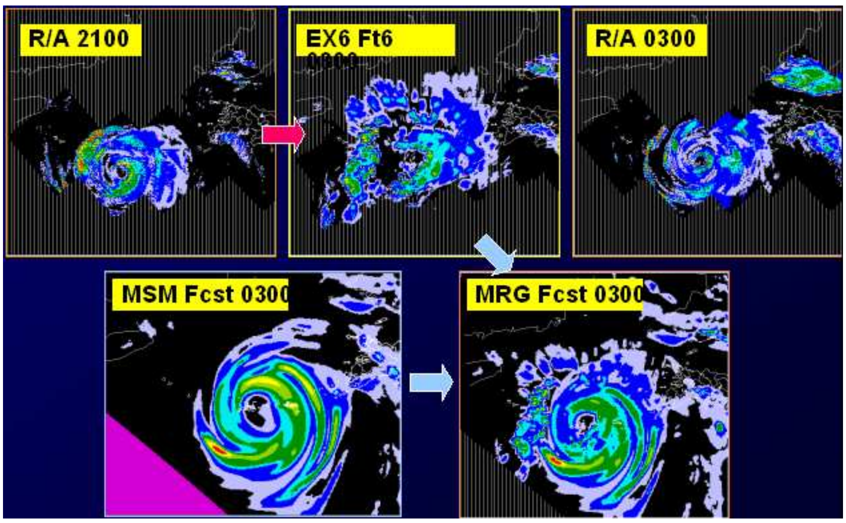
Nowcasting is a description of current weather as well as forecast weather parameters up to 2 hours in advance. The “Nowcasting” terminology loosely refers to the 0 to 6-hour period beyond the present within which forecasting techniques are used to improve forecasts over persistence of current conditions.

Nowcasting relies on observational data and systems, high-resolution NWP and such techniques as image-processing, visualization, data fusion, data analysis or extrapolation.
Nowcasting improves the forecasting of such high-impact severe weather elements as:

- Convective hazards (heavy rain, hail, lightning, wind gusts)
- Flash floods and heavy precipitations
- Winter weather events (snowstorm, blizzard)
- Fog
- Extreme fire danger
- Freezing rain
- Dust storms

To support nowcasting, blending methods are used to merge observations and high-resolution NWP. The type of blending method depends on the phenomenon, lead-time and actual events. As far as high resolution NWP is concerned in nowcasting applications, particular attention must be paid to the use of frequent and recent observations in the assimilation of NWP. In this regard, it may be interesting to run nowcasting-oriented NWP models very frequently (e.g. every hour) to take into account the latest observations.

Nowcasting systems can be implemented on a wide variety of systems and means, ranging from local treatment on a PC to dedicated centres. High resolution NWP requires the use of sufficient computing capacity.



Merging of extrapolated radar rain observations (echo intensity) and meso-scale numerical weather prediction to provide 1 to 6 hour precipitation forecasts
After Sugiura, Japan Meteorological Agency, World Weather Research Programme’s Symposium on Nowcasting and Very Short Range Forecasting (WSN05)

1.2. Very short-range weather forecasting

Very short-range weather forecasting is a description of weather parameters up to 12 hours ahead. While the 0 to 2-hour range belongs to the Nowcasting category, forecasting severe weather parameters beyond a few hours should be made with the guidance of one or more NWP models.

In this forecasting range, the NWP models must be used at a high resolution, of the order of a few kilometers, if not less. The boundary conditions then come from a larger scale NWP model, often a regional one covering a limited area itself. To realistically simulate convective developments at this scale, NWP models must be run in a non-hydrostatic mode, the vertical velocity becoming in this case a model variable like the horizontal velocity. The hydrostatic approximation, indeed, does not allow the explicit resolution of convective scale vertical drafts. The horizontal and vertical resolution depends on the available computer power. Following the use of non-hydrostatic variables, very high resolution NWP models often include a detailed representation of water transformations, with such variables as water vapour content, liquid water content (either rain or cloud), solid water (graupels, snow, ice,…) thus providing a detailed description of the cloud cover.

It is not necessary for very short-range weather forecasting to take into account dynamic oceanic forcings as for medium-range or monthly forecasting because they do not vary significantly within a few hours. However, when very short-range NWP model outputs are used in storm surge models to forecast coastal phenomena, wave and tide forecast must be accounted for. As far as flash and rapid floods are concerned, very high-resolution NWP models often have their own ground models to take into account the effects of ground saturation under heavy precipitation.

It may be interesting to run very short-range weather forecasting NWP models frequently (e.g. every 6 hours) to take into account the latest observations.

When extending the forecast range from nowcasting to very short-range forecasting (up to 12 hours ahead), the uncertainty increases and the forecast state of the atmosphere may differ significantly from the initial state the forecast was issued from. Forecasters or end-users often find an interest in knowing the uncertainty that is associated with the forecast, or the probability of occurrence of the forecast scenario, especially in the case of severe weather forecasts where important decisions have to be made. To do this, ensemble prediction techniques are useful and can applied to very short range forecasting depending on the computer power available. “Ensemble prediction systems” means using either outputs of several NWP models or the same NWP model executed with varying initial conditions (analyses). In the latter case, the variations in the initial state must be coherent with the level of confidence on the observations and the resolution of the analysis. The perturbations in the initial state can be chosen so they will amplify the differences in the forecast along preferred directions representing the sensitivity of the model to observations. In the case of very short range weather forecasting, an ensemble of forecast can be produced either by varying the initial state of the NWP model itself – this will be the case if the model has its own limited area assimilation system- or by using larger scale coupling ensemble data.

The severe weather features relevant for very short-range forecasting are:

- Heavy precipitations episodes
- Individual convective events (squall lines, organized convection)
- Generalized freezing precipitations
- Snow storms and streamers

- Windstorms
- Fire danger
- Severe heat or cold weather
- Dust storms

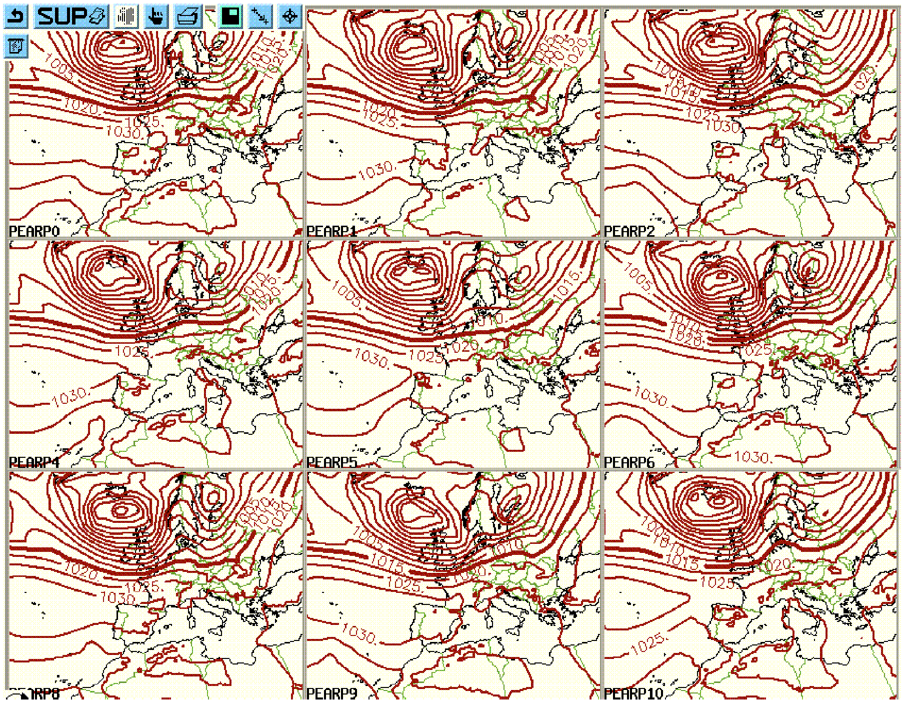
1.3. Short-range weather forecasting

Short-range weather forecasting is a description of weather parameters beyond 12 hours and up to 72 hours. At such time ranges, forecasting severe weather events necessitates the use of one or more NWP models. The boundary conditions come from a larger scale NWP model, either a regional one covering a limited area itself or a global one. When non-hydrostatic models are used, then the spatial resolution allows for more realistic representation of convective developments. However, hydrostatic models can be used for short-range weather forecasting too, convective activity being then parameterized to take into account sub-grid scale effects that cannot be neglected as they have a feed-back effect on the variables at the hydrostatic scale. The representation of water phase exchanges can be of a non-hydrostatic type or slightly simplified with for instance explicit simulation of the exchanges between the solid, liquid or vapour phases and a parameterization of the inner partition between each phase (e.g. cloud vs rain liquid water).

As for very short-range weather forecasting, it is not strictly necessary for short-range weather forecasting to take into account dynamic oceanic forcings as for medium-range or monthly forecasting because they only have a weak effect on atmospheric variables a few days ahead. However, using forecast sea surface or ground surface temperatures may improve the results through the ground energy fluxes parameterization of short-range NWP models.

As with very short range forecasting, ensemble forecasting techniques can be used in short-range forecasting to know the uncertainty of the forecast.

The severe weather features relevant for short-range forecasting are:
- Heavy precipitations episodes
- Areas of convective events (probability of occurrence)
- Snow storms or streamers
- Windstorms
- Heat wave or cold wave (start, continuation or end)
- Fire danger



Operational Ensemble short-range numerical prediction of sea-level pressure
Météo-France, January 2007

1.4. Medium-range weather forecasting

Medium-range weather forecasting is a description of weather parameters beyond 72 hours and up to 240 hours. At such time ranges, it is not possible to forecast severe weather events without the help of one or more NWP models. Medium-range weather forecasting NWP models can be either global or working on a limited area. In the latter case, the geographic domain must be large enough to stay in accordance with the forecast range. The hydrostatic approximation can be made at this scale because the spatial resolution remains usually larger than a few kilometres.
Therefore, sub-grid scale effects must be carefully parameterized, including the effect and interaction of convection, turbulence, radiative fluxes, orographic drag, etc, in the resolved large scale flow. As regards the representation of water phase exchanges and formation of clouds, at this scale the cloud fraction is often parameterized too as water cannot condensate entirely in an elementary grid volume. Thus, clouds represent only a fraction of an elementary grid volume (sub-grid scale condensation) and it is this fraction which is parameterized.

For such time ranges, it becomes useful to take into account dynamic oceanic and ground surface forcings as they drive a part of the evolution of the atmosphere. This can be made by using prescribed forcings coming from an oceanic model for instance.

When extending the forecast range above 72 hours, the uncertainty increases significantly. Starting from slightly varying initial states, different forecast scenarios can be identified, each having a given probability of realization which can be assessed by means of ensemble prediction methods. Moreover, if on the very short term a deterministic solution remains useful for critical “go/no-go” decisions related to severe weather episodes, the decisions to take on the medium-range often need to know the probability of the different possible scenarios. This is why ensemble prediction systems are very useful to medium-range weather forecasting.

The severe weather features relevant for medium-range weather forecasting are:
- Heavy precipitations episodes (early warning and probability of occurrence)
- Areas of convective events (early warning and probability of occurrence)
- Snow storms (early warning and probability of occurrence)
- Windstorms (early warning and probability of occurrence)
- Heat wave or cold wave (start, continuation or end)

1.5. Extended-range weather forecasting

Extended-range forecasting is defined in the Manual on the GDPFS as a description of weather parameters beyond 10 days and up to 30 days usually averaged and expressed as a departure from climate values for that period. It is often made as an extension of ensemble prediction systems for medium-range weather forecasting, with a lower spatial resolution as the time range is extended to one month. Deterministic forecasting is not possible for extended-range weather forecasting because the uncertainty is such that only probable departures from climate values can be given along with a rough indication on the probability of realization. The occurrence of extreme events cannot be accurately forecast by such systems. Extended-range weather forecasting will take advantage of using the different EPS systems available in the world.

The time range 10 to 30 days is probably still short enough that the atmosphere retains some memory of its initial state and it may be long enough that the ocean variability has an impact on the atmospheric circulation. Therefore, extended-range weather forecasting can be built as a combination of the medium-range ensemble prediction systems and seasonal forecasting systems and contain features of both systems, like coupled ocean-atmosphere integrations.

The severe weather features relevant for extended-range weather forecasting are:
- Higher- or lower-than normal precipitation episodes.
- Higher- or lower-than normal temperatures : can be associated with e.g. ENSO events, cold waves, heat waves, droughts.

1.6. Long-range forecasting

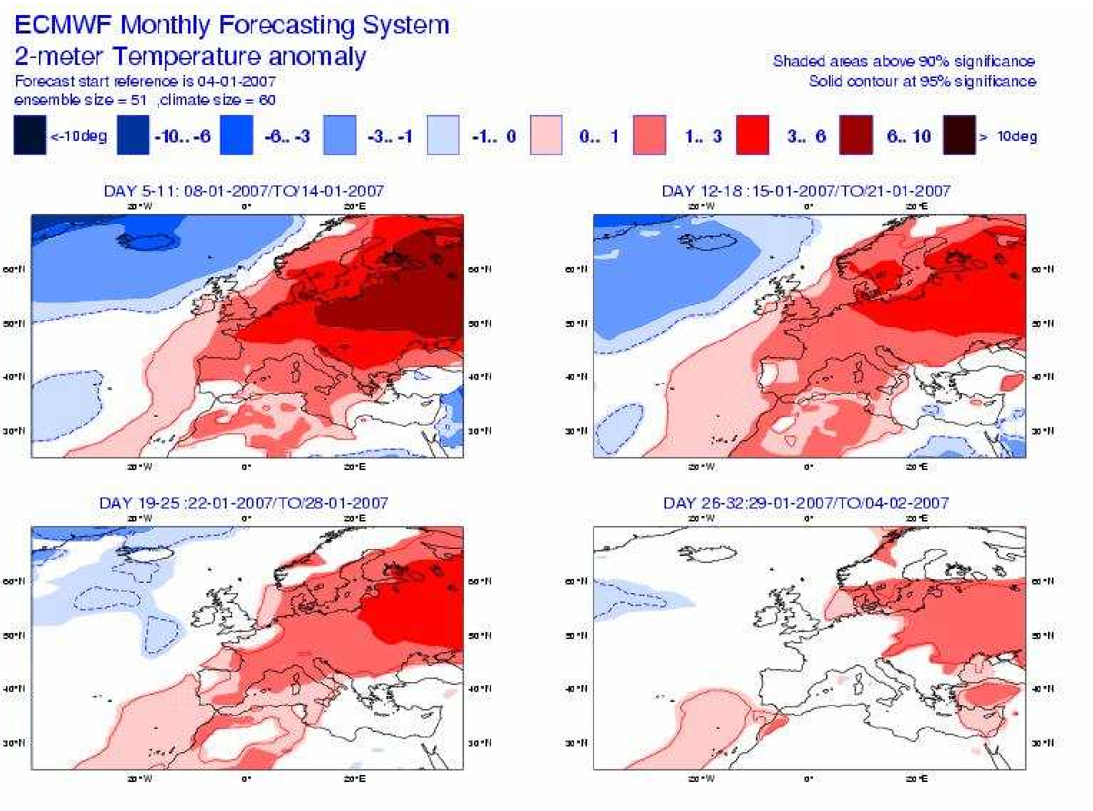
Because of the long predictability of the oceanic circulation - of the order of several months - and the fact that the variability in tropical sea surface temperatures has a significant global impact on the atmospheric circulation, the oceanic circulation is a major source of predictability in long-range forecasting. Therefore, long-range forecasting needs to use coupled ocean-atmosphere integrations: it remains an initial value problem, but, compared with medium-range forecasting, with much of the information contained in the initial state of the ocean.

1.6.1. Monthly outlook

Monthly outlook is a description of averaged weather parameters expressed as a departure from climate values for that month.

Monthly outlooks can be obtained by running ensemble prediction systems at a larger scale than for medium-range forecasting – for computer resources reasons -, nevertheless allowing for usable trends up to a month in advance. The analysis of multi-model ensembles is useful in long-range forecasting.

The severe weather features relevant for monthly outlooks are higher- or lower-than normal temperature or precipitation episodes (start, continuation or end).



2-m Temperature anomaly monthly prediction
European Centre for Medium Ranger Weather Forecasts, 2007

1.6.2. Three-month or 90-day outlook and seasonal outlook

Three-month and seasonal outlooks are a description of averaged weather parameters expressed as a departure from climate values for that three-month period or for that season of for the next seasons up to two years.

Three-month and seasonal outlooks rely on coupled ocean-atmosphere EPS systems. Taking into account the state of the vegetation and ice covers may be necessary to adequately represent seasonal trends. Seasonal outlooks can also rely on statistical methods, considering for instance the global seasonal temperature anomaly as the predictand (parameter to explain) and finding the good predictors for this parameter.

The severe weather features relevant for monthly outlooks are higher- or lower-than normal temperature or precipitation episodes (start, continuation or end).

1.6.3. Climate forecasting

According to the WMO Manual on GDPS, climate forecasting covers forecasting ranges beyond two years:

- Climate variability prediction is a description of the expected climate parameters associated with the variation of interannual, decadal and multi-decadal climate anomalies.

- Climate prediction is a description of expected future climate including the effects of both natural and human influences.

Climate forecasting can be achieved by using coupled models. However, as the time range is higher than 90 days and can reach several years if not centuries, slow varying phenomena must be taken into account to adequately represent climatic trends, with for instance model representations of polar ice fields or vegetation change. Thus, climate models can be built as coupled models with many different "bricks" interacting each other : atmosphere, ocean, ice fields, aerosols, vegetation, atmospheric chemistry,… Then, relying on economic studies, different scenarios of emission of greenhouse gases are used as an input in climate models so that the climate trends can be tentatively drawn following these scenarios.

As different methods of climate forecasting are used around the world, with different levels of sophistication and as there remain some uncertainties in climate forecasting due to the scenarios and the accuracy of the models used, it is necessary to compare the results and coordinate the production of synthesis reports. The WMO's World Climate Research Program is intended to identify knowledge gaps, prioritize needs and lead world-class research into climate variability and climate change to meet end-user requirements and policy needs. Recognizing the problem of potential global climate change, WMO and the United Nations Environment Programme (UNEP) established the Intergovernmental Panel on Climate Change (IPCC) in 1988. The role of the IPCC is to assess on a comprehensive, objective, open and transparent basis the scientific, technical and socio-economic information relevant to understanding the scientific basis of risk of human-induced climate change, its potential impacts and options for adaptation and mitigation.

The severe weather feature relevant for climate forecasting is climate change and associated trends : increase in the frequency of droughts or heat waves, changes in vegetation, ocean streams, ice cover,…

2. PARTICULAR CASES OF SEVERE WEATHER

Major hazards contributing to economic losses are windstorm and flood and contributing to loss of life are drought and windstorms. The effect of these phenomena are amplified where concentration of population is found. This section aims at considering certain aspects of NWP with regards to these categories of phenomena.

2.1. Heavy rains and floods

Heavy precipitation episodes can be forecast up to several days in advance. In some cases, early warning of higher-than-normal precipitation episodes may even be issued several weeks in advance by using extended-range weather forecasting systems. However, in the latter case, it is potential floods in large basins which can be anticipated, not extreme flash flood events.
Meteorological and hydrological experts often combine their numerical prediction capacities by coupling meteorological and hydrological or hydraulic models. Numerical models of the flow of water in rivers then uses precipitation forecasts as input. The soil moisture is an important parameter to take into account for the assessment of the run-off risk. This parameter may be accessed through the soil-

atmosphere interface models used to provide ground conditions in meteorological models. Following the coupling between meteorological and hydrological or hydraulic models:

- Small-scale non-hydrostatic meteorological models can be coupled with hydrological models to anticipate rapid flood events.
- Meteorological ensemble prediction systems can be used to derive probabilistic forecasts of river discharge.

Floods in India, 2006

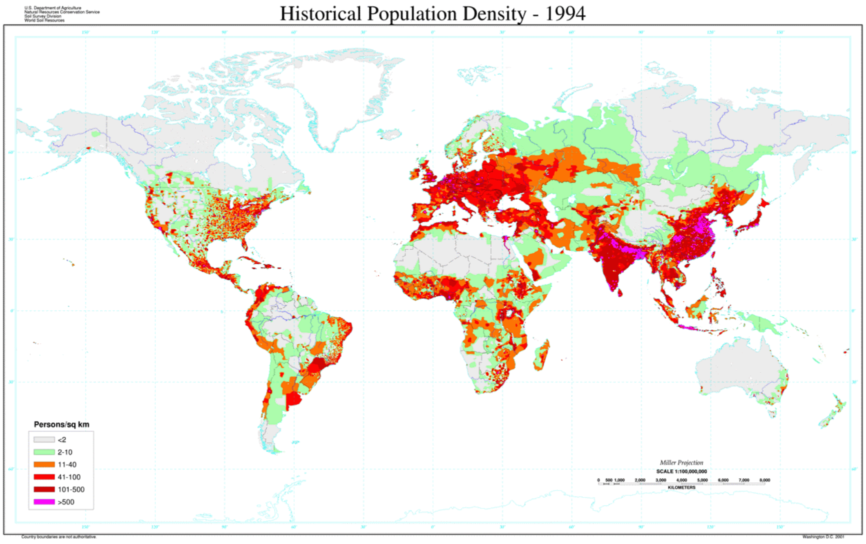
2.2. High destructive winds

High destructive winds may associated with windstorms, thunderstorms, tropical cyclones, typhoons or hurricanes. The wind which comes as an output from NWP models must be considered as mean wind at the scale of the model. Wind gusts can be assessed for instance by means of model output statistics or the use or turbulence parameters (e.g. turbulent kinetic energy). A way to cope with the uncertainty associated with wind gust forecasts is to derive risk information as the probability of wind gusts or mean wind reaching given thresholds. For instance, it is often considered that a wind higher than about 100 $km.h^{-1}$ is a significant threshold for subsequent damages caused by wind, the damages increasing rapidly with wind values. If one takes into account the uncertainty on wind forecasts in the definition of the thresholds, this information on risks is meaningful for users because it is already interpreted.

The effects of the December 1999 storms in France

2.3. High impact weather in high population density areas (sea shores, urban areas)

The effect of adverse weather is more important where population density is high, which is often the case along sea shores or rivers, in urban areas, fertile plains etc.

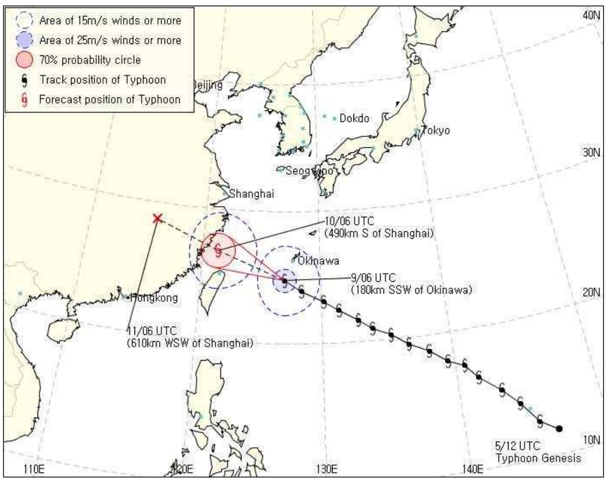


Population density map of the world in 1994
http://fr.academic.ru/pictures/frwiki/87/World_population_density_1994.png

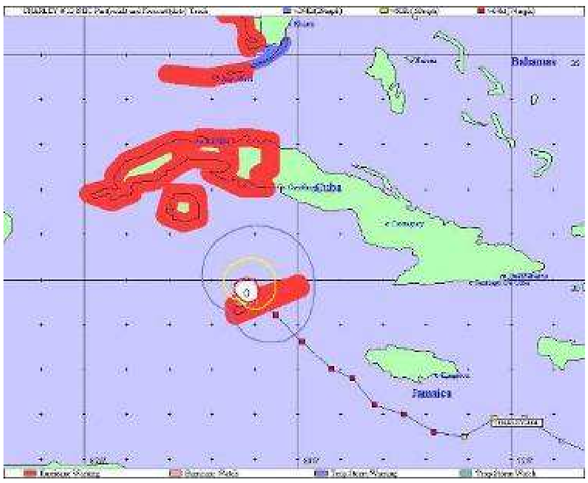
While the density of population is not a parameter of NWP models in itself, it is indirectly taken into account through ground boundary conditions which depend on the nature and characteristics of the ground (type of vegetation, percentage of impervious ground, etc). However, high resolution NWP modeling is useful to improve weather forecasts in high population density areas.

2.4. Tropical cyclones

Tropical cyclones, or typhoons, or hurricanes, result in extreme winds or precipitation, floods, storm surge or destructive waves. Unfortunately, tropical cyclones originate over the oceans, where in most cases meteorological observations are very scarce. While cyclone tracking is possible where satellite imagery is available, accurate prediction of tropical cyclone movement remains a challenge. Some tropical cyclone prediction centres try “bogussing” tropical cyclones in NWP models by forcing cyclone characteristics -not directly available from satellite data- in the model. However, the uncertainty of tropical cyclone forecasts is such that the forecasts are often presented with probability envelopes.



Forecast of the Saomai typhoon
Korea Meteorological Administration
9 August 2006



Cyclone early warning in Cuba

Storm surge models coupled with NWP models are used in a number of tropical cyclone forecast centres.

Summary

Weather forecasting system	**Forecast range**	**Type of associated severe weather**
Nowcasting	Up to 2 hours The “Nowcasting” terminology loosely refers to the 0 to 6-hour period beyond the present within which forecasting techniques are used to improve forecasts over persistence of current conditions	Convective hazards (heavy rain, hail, lightning, wind gusts) Flash floods and heavy precipitations Winter weather events (snowstorm, blizzard) Fog Extreme fire danger Freezing rain Dust storms
Very short range forecasting	Up to 12 hours ahead	Heavy precipitations episodes Individual convective events (squall lines, organized convection) Generalized freezing precipitations Snow storms and streamers Windstorms Fire danger Severe heat or cold weather Dust storm
Short-range forecasting	Beyond 12 hours and up to 72 hours	Heavy precipitations episodes Areas of convective events (probability of occurrence) Snow storms and streamers Windstorms Heat wave or cold wave (start, continuation or end) Fire danger
Medium-range forecasting	Beyond 72 hours and up to 240 hours	Heavy precipitations episodes (early warning and probability of occurrence) Areas of convective events (early warning and probability of occurrence) Snow storms (early warning and probability of occurrence) Windstorms (early warning and probability of occurrence) Heat wave or cold wave (start, continuation or end)
Extended-range weather forecasting	Beyond 10 days and up to 30 days	Departure from climate values Higher- or lower-than normal precipitation episodes Higher- or lower-than normal temperatures : can be associated with e.g. ENSO events, cold waves, heat waves, droughts
Long-range forecasting (monthly, three-month and seasonal outlooks)	Beyond 30 days and up to the end of the next season	Departure from climate values Higher- or lower-than normal temperature and precipitation episodes (start, continuation or end)
Climate forecasting	Climate variability prediction is a description of the expected climate parameters	Climate change and associated trends : increase in the frequency of droughts or heat waves, changes in vegetation, ocean

	associated with the variation of inter-annual, decadal and multi-decadal climate anomalies. Climate prediction is a description of expected future climate including the effects of both natural and human influence	streams, ice cover,…

Bibliography

WMO

WMO CBS-related technical publications and miscellaneous documentation [1]

WMO Web site (http://www.wmo.int)

Manual on the global data-processing system, WMO Technical Regulations, Annex IV (WMO – No. 485)

A summary of Recommended Practices for Weather Forecasting, WMO, November 2005

Guidelines on Using Information from EPS in Combination with Single Higher Resolution NWP Forecasts, WMO, Feburary 2006

Others

Kalnay, E. (2004), Atmospheric modeling, data assimilation and predictability

ECMWF Web site (http://www.ecmwf.int)

[1] Available at http://www.wmo.ch/web/www/documents.html#GDPS