Status of the EPS systems at Environment Canada

The global EPS has a data-assimilation, a forecast, a verification and a product development component.
A regional EPS is being developed.

- Peter Houtekamer and Herschel Mitchell: Data-assimilation research,
- Xingxiu Deng: Data-assimilation, development,
- Bin He: Data-assimilation,link with operations, part-time,
- Martin Charron: Stochastic parameterizations and regional ensemble,
- Xiaoli Li and Ronald Frenette: regional ensemble,
- Normand Gagnon: model development, link with operations,
- Lubos Spacek: model development, librarian, part-time,
- Guillem Candille: ensemble verification (post-doc),
- Marc Klasa and Pierre Bourgouin: product development, part-time,
- Lewis Poulin: our link at operations, part-time.

Part-time here means also supporting other projects.

Overview

1) Description of the global EPS:
   a) Ensemble Kalman Filter (EnKF) data-assimilation
   b) Medium-range forecasts

2) North American Ensemble Forecast System (NAEFS),

3) Current problems and development projects,

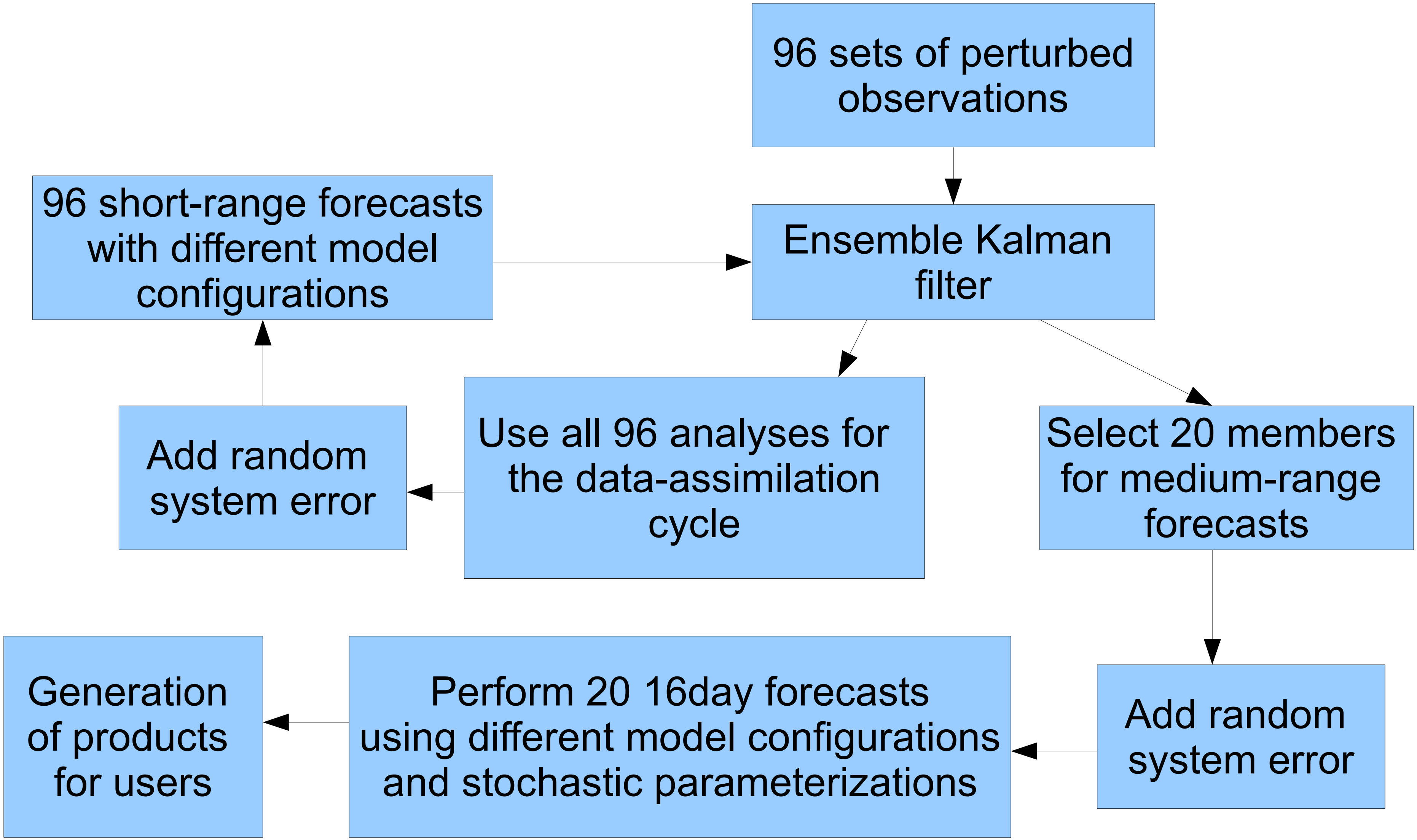
4) Regional EPS,

5) Intended comparison between EnKF and 4D-Var,

6) Conclusion

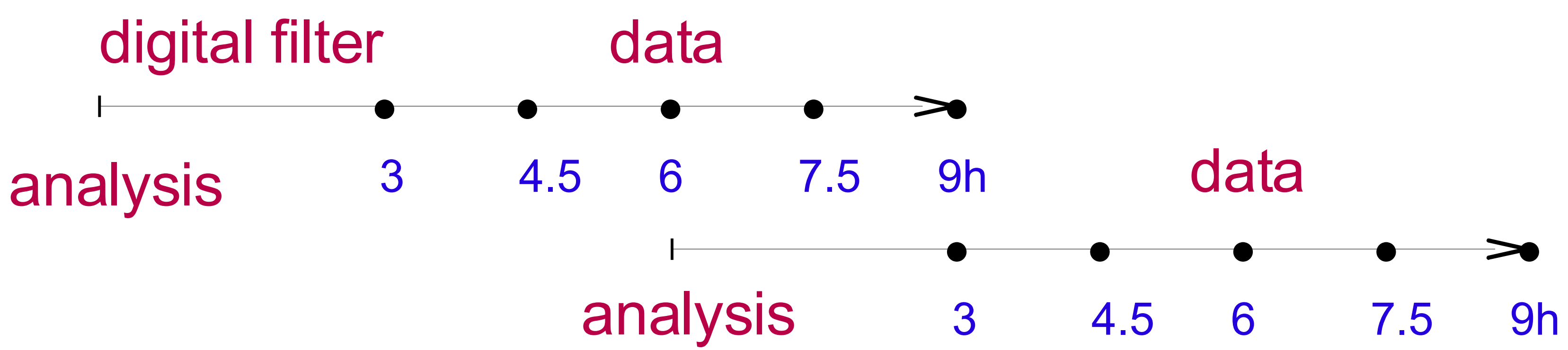
The Global Ensemble Prediction System

Monte Carlo methods are used to estimate the uncertainty.



6-h assimilation window

With the EnKF we can assimilate all data in a 6-h window as is currently done in 4D variational algorithms.



To permit time interpolation, the state vector consists of the five dotted points. Only the analysis at the central time is used to start the subsequent integration.

Addition of parametrized system error

We add random perturbation fields, with isotropic structures, to the ensemble of analyses. The random fields have error structures like in the background error covariance matrix of traditional 3-dimensional systems (like 3D-Var). Basically, the properties of the random fields are obtained by tuning. The isotropic structures tend to blur the interesting flow-dependent structures that are developed by the EnKF. We, therefore, tend to look at the isotropic component as a bad model-error component.

Inspired by our variational system, the random errors are first generated on stream function and unbalanced temperature and subsequently transformed to wind, temperature and surface pressure components.

It is non-trivial to obtain new system error statistics and transformation operators when we change the vertical coordinate of the model by for instance raising the model top, adding vertical levels or introducing vertical staggering.

Model error simulation in the EnKF (4 x 24)

#	Deep convection	Surface Scheme	Mixing Length	Bowen ratio
1	Kain & Fritsch	ISBA	Bougeault	1.0
2	Old Kuo	ISBA	Blackadar	0.85
3	Relaxed Arakawa Schubert	force-restore	Bougeault	0.85
4	Symmetric Kuo	force-restore	Blackadar	1.0
5	Old Kuo	force-restore	Bougeault	1.0
6	Kain & Fritsch	force-restore	Blackadar	0.85
7	Symmetric Kuo	ISBA	Bougeault	0.85
8	Relaxed Arakawa Schubert	ISBA	Blackadar	1.0
9	Kain & Fritsch	ISBA	Blackadar	0.85
10	Old Kuo	ISBA	Bougeault	1.0
11	Relaxed Arakawa Schubert	force-restore	Blackadar	1.0
12	Symmetric Kuo	force-restore	Bougeault	0.85
13	Old Kuo	force-restore	Blackadar	0.85
14	Kain & Fritsch	force-restore	Bougeault	1.0
15	Symmetric Kuo	ISBA	Blackadar	1.0
16	Relaxed Arakawa Schubert	ISBA	Bougeault	0.85
17	Symmetric Kuo	force-restore	Bougeault	1.0
18	Kain & Fritsch	ISBA	Blackadar	0.85
19	Old Kuo	ISBA	Bougeault	0.85
20	Relaxed Arakawa Schubert	force-restore	Blackadar	1.0
21	Relaxed Arakawa Schubert	ISBA	Blackadar	0.85
22	Old Kuo	force-restore	Bougeault	1.0
23	Kain & Fritsch	force-restore	Blackadar	1.0
24	Symmetric Kuo	ISBA	Bougeault	0.85

Accounting for model error in the medium-range forecasts

To account for model error we:

1) add random errors, with homogeneous and isotropic structures to the ensemble of 20 initial states,
2) use different physical parameterizations for different members of the ensemble (like in the EnKF),
3) use a stochastic algorithm for the backscatter of kinetic energy (Shutts, QJ, 2005),
4) use a stochastic algorithm to perturb model tendencies (Buizza, QJ, 1999).

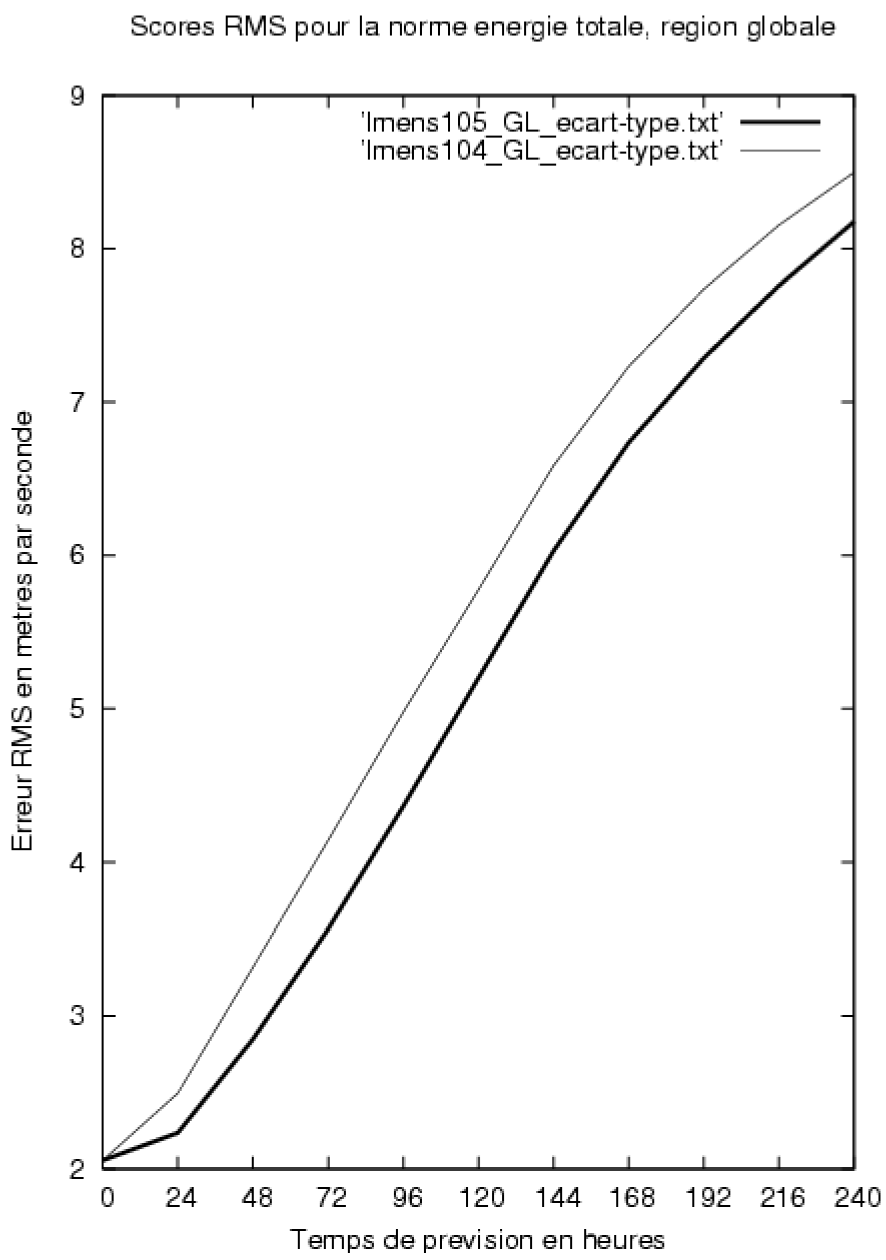
The stochastic algorithms (3) and (4) use Markov chains. Consequently, only (2) will create systematically different biases for different members.

Stochastic physics

Following ECMWF (Roberto, Buizza), we use random perturbations to the physical tendencies.

Tendencies are multiplied with a random number that is between 0.5 and 1.5, that changes in time, in space, and is different for each member.

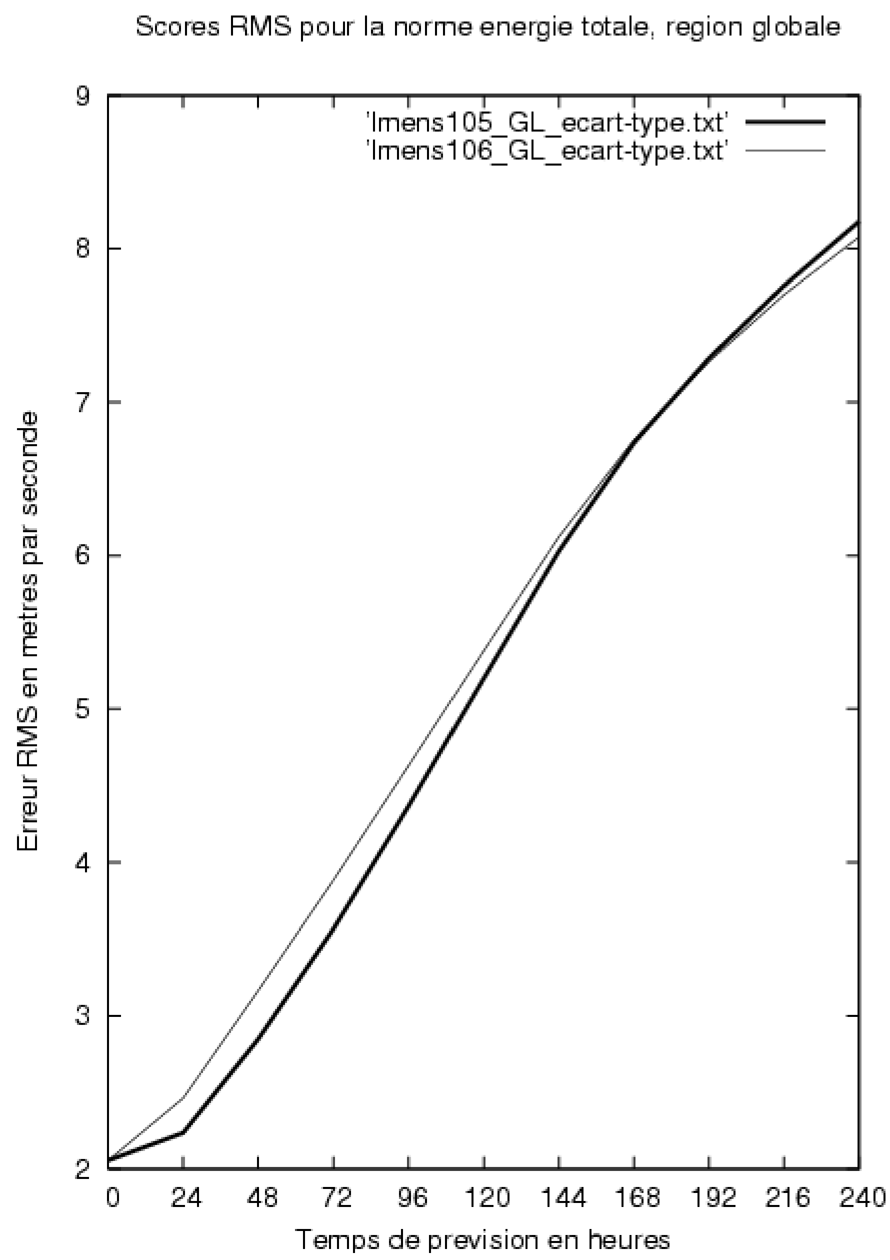
The ensemble spread increases significantly due to the stochastic physics.

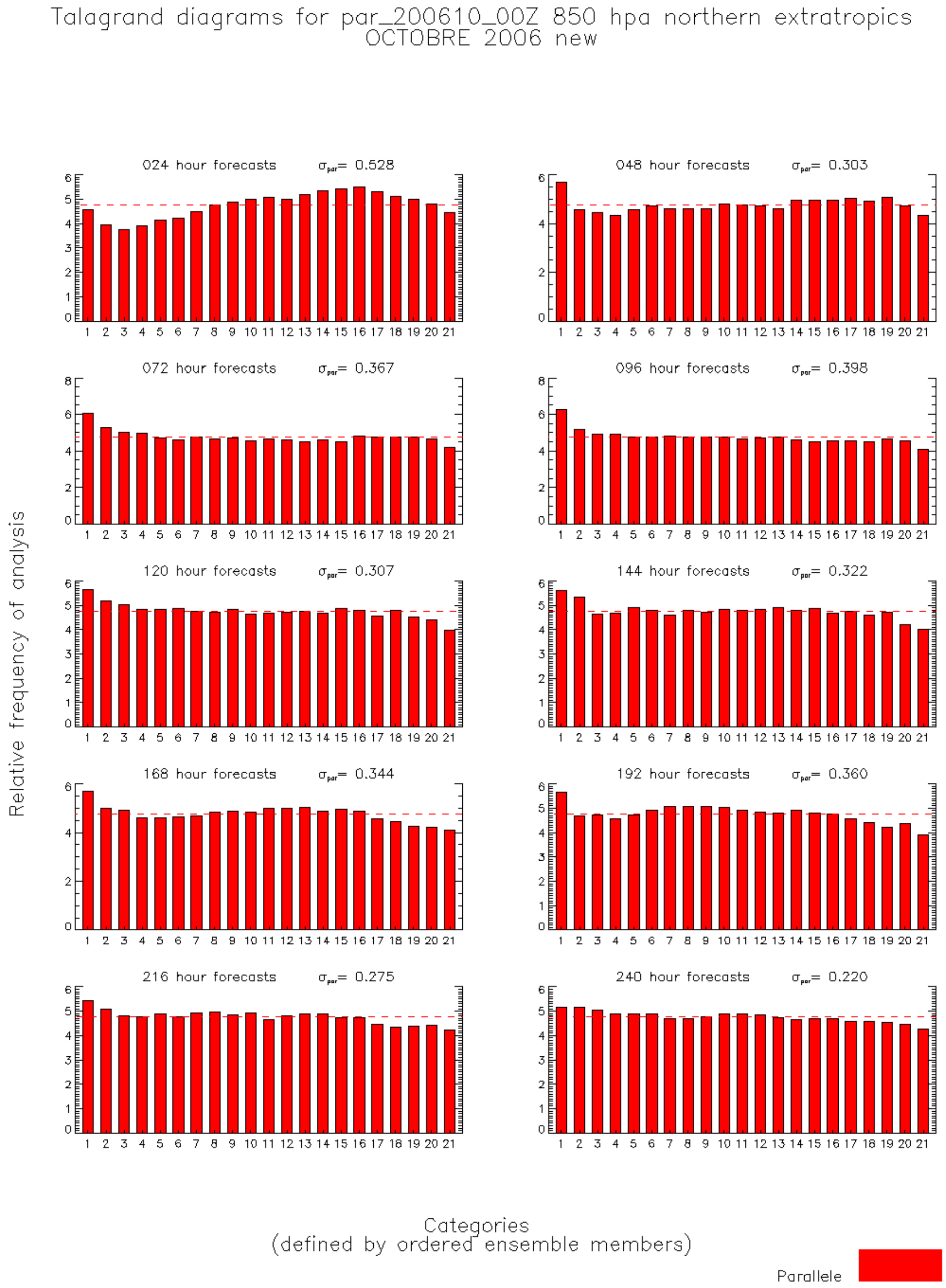


Stochastic Kinetic Energy Backscatter

Following UK Met (Glenn Shutts), we add random perturbations at the smaller scales of the model.

We observe a related increase in the ensemble spread for the early medium-range.





Reliability

For some variables, we have an ensemble-mean bias (first moment) that evolves with forecast time.

Upper Air verifications (for temperature, height and wind between 250 and 925 hPa) show a nearly perfect dispersion (second moment).

This is illustrated with the Talagrand diagram for 850 hPa heights for the northern extratropics, the global EPS:

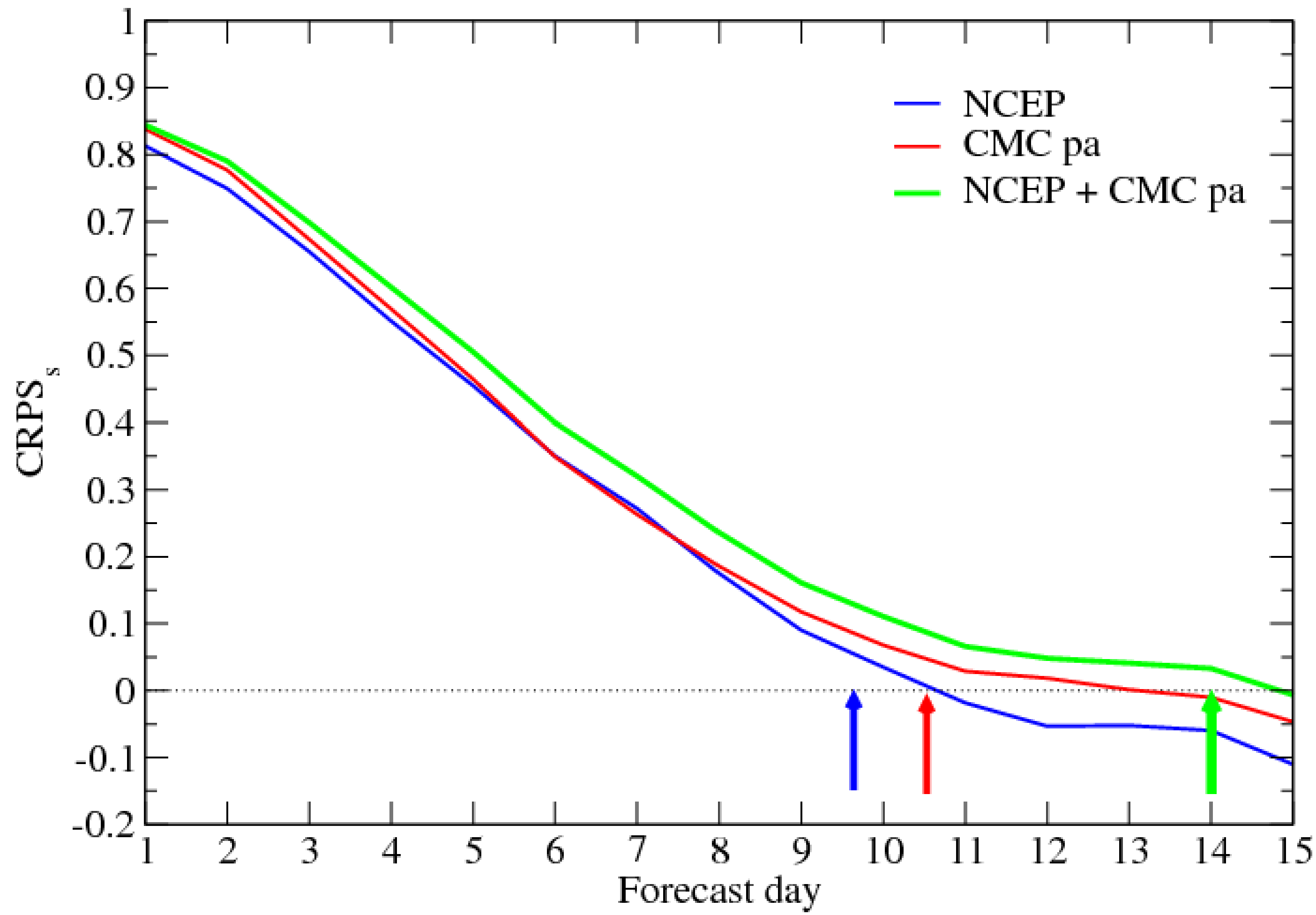
NORTH AMERICAN ENSEMBLE FORECAST SYSTEM

SYSTÈME DE PRÉVISION D'ENSEMBLE NORD-AMÉRICAIN

SISTEMA CONJUNTO DE PRONÓSTICOS DE AMÉRICA DEL NORTE

Impact of the combination with the NCEP ensemble

(global verification of 500 hPa geopotential height against radiosondes)



Current problems and projects

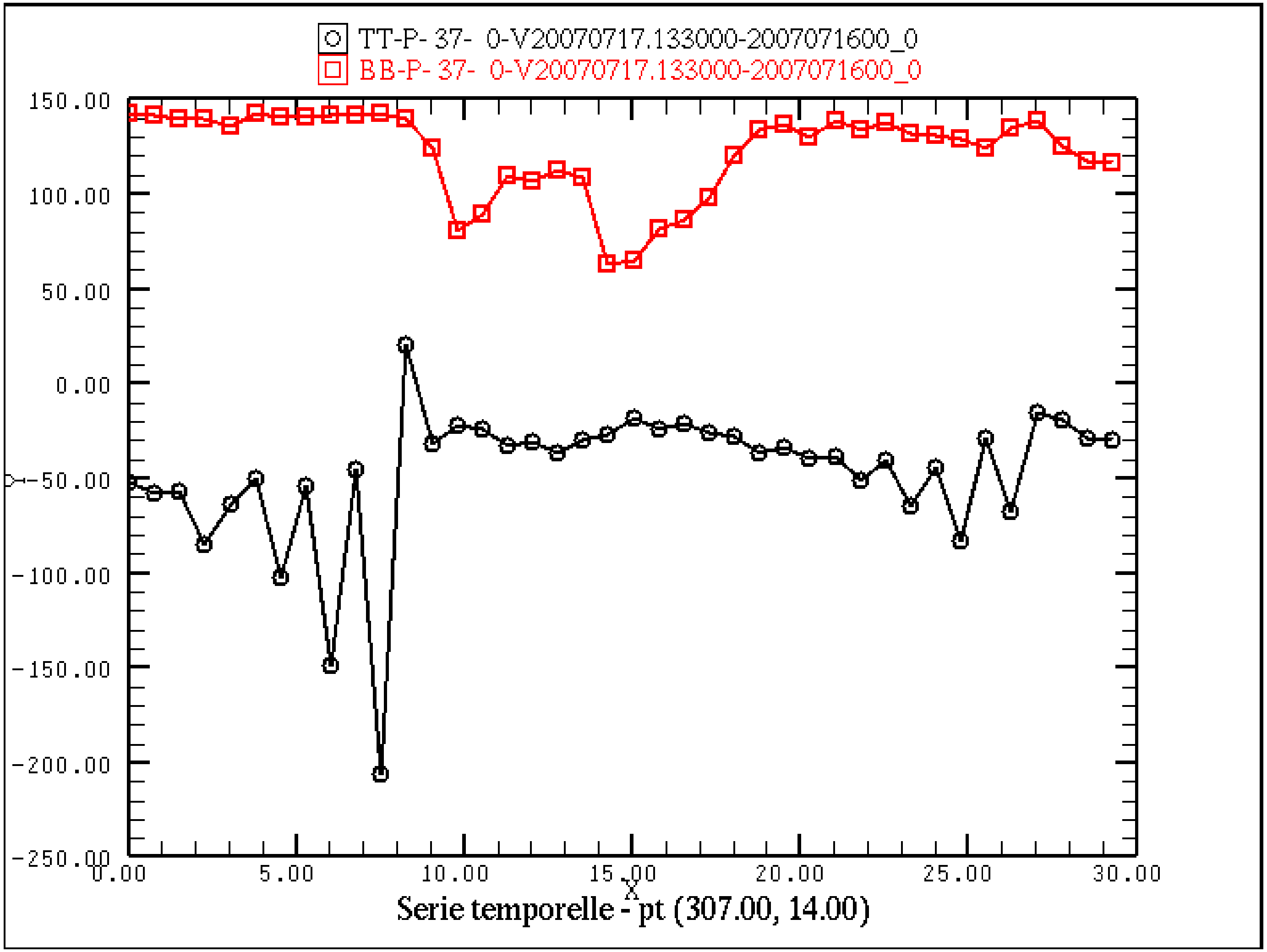
Or:

The importance of having a high-quality assimilation and forecast system.

Or:

How some pathological ensemble behavior is fixed ``automatically'' by the ever-improving quality of our forecasting system.

Need for a shorter time step and (perhaps) a filtered topography field.

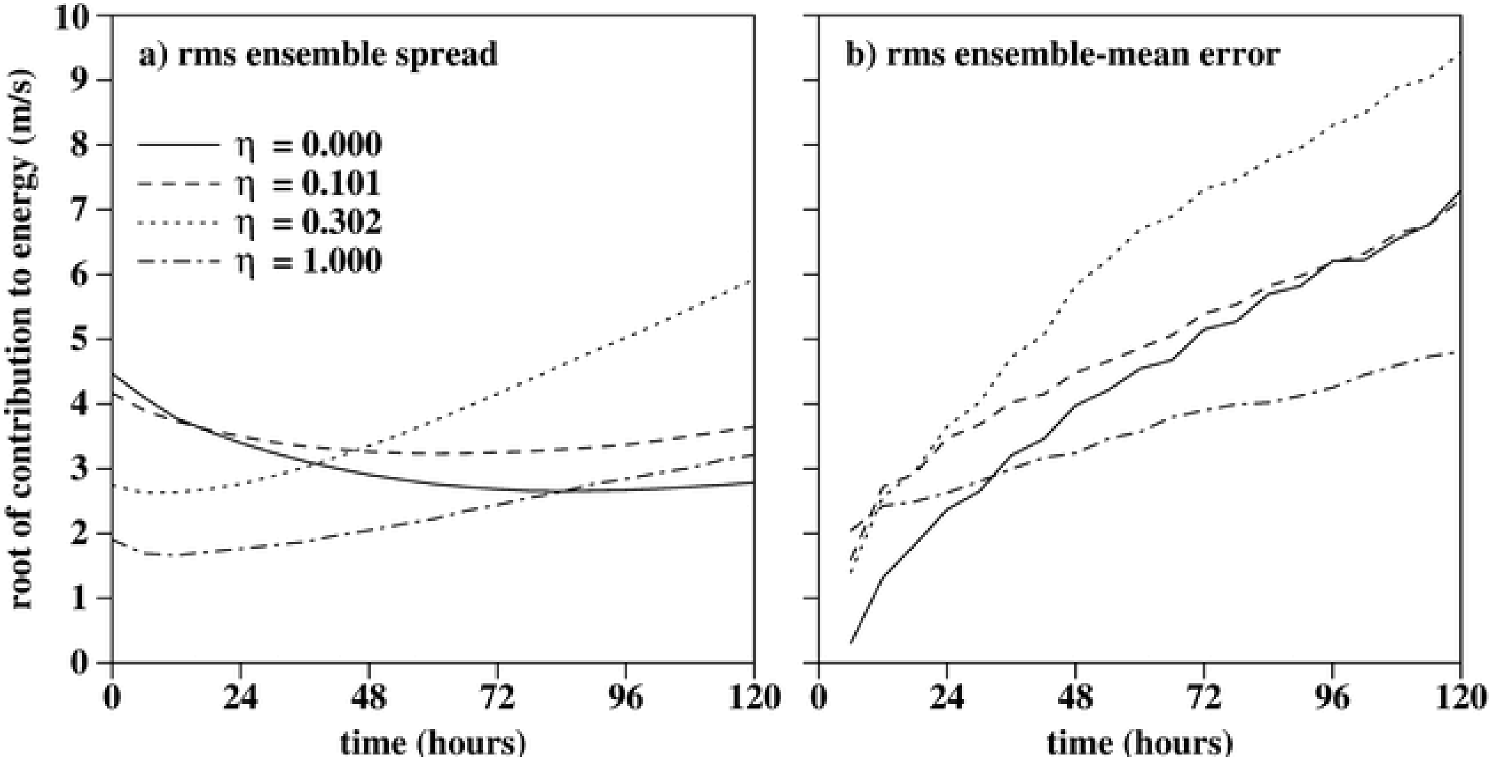


Since the recent (July 10 2007), upgrade to the EPS, we have problems with 2 -Δt oscillations near the surface.

These are most severe when the stochastic forcing is near its maximum.

Lack of error-growth between 10 and 100 hPa

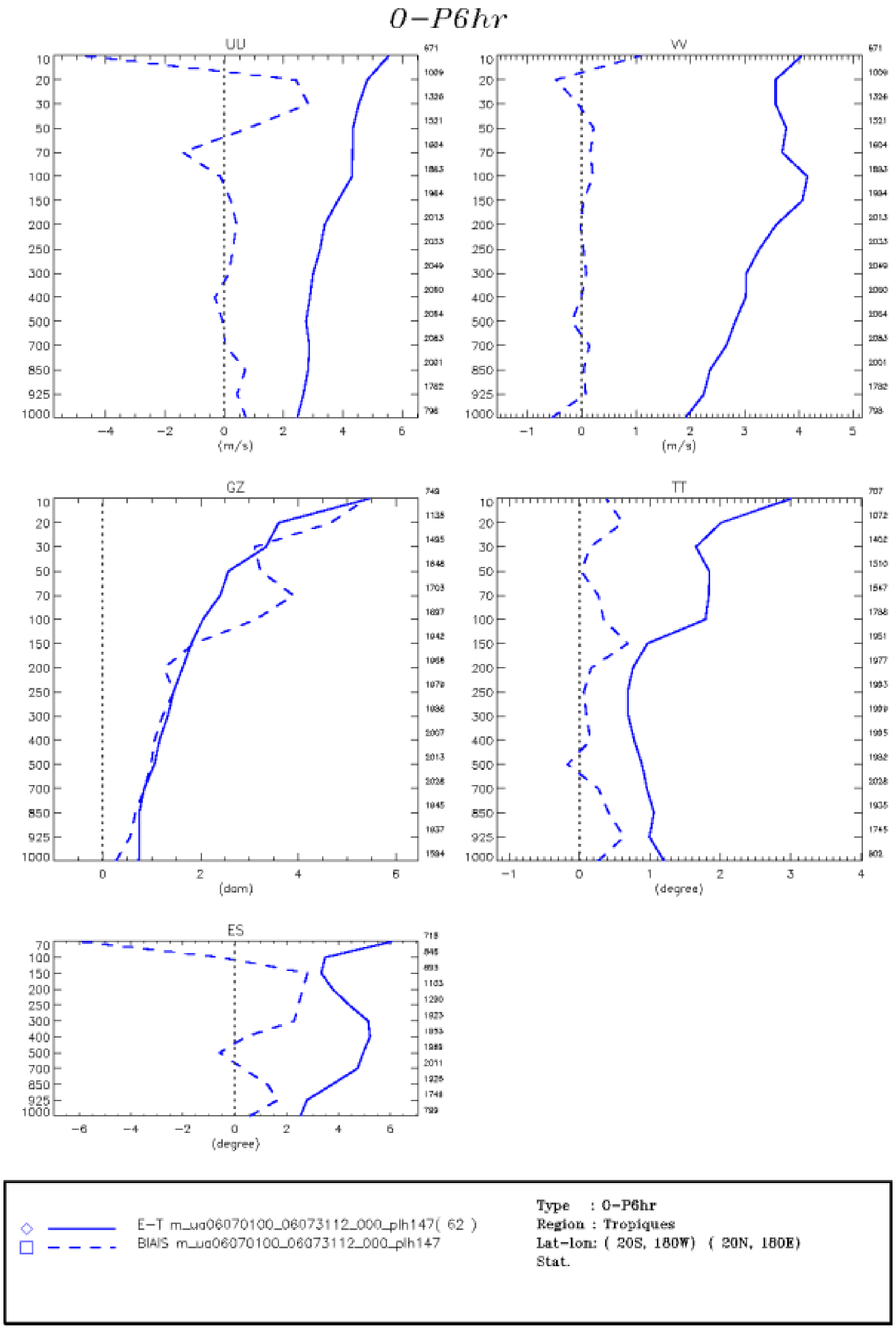
Near the top of the model (currently at 10 hPa), the model is rather diffusive. Consequently the EPS shows a lack of ensemble spread. We want to raise the top of the model to 2 hPa.



Bias in the trial fields.

In particular in the tropics and above 200 hPa, the trial fields show a relatively large bias component. Since the EnKF assumes (incorrectly) that the bias can be neglected, this is a severe problem.

Raising the model top to 2 hPa will likely help below 10 hPa. We also want to start assimilation GPS data, which contain bias free temperature information up to about 2 hPa.



Research issues

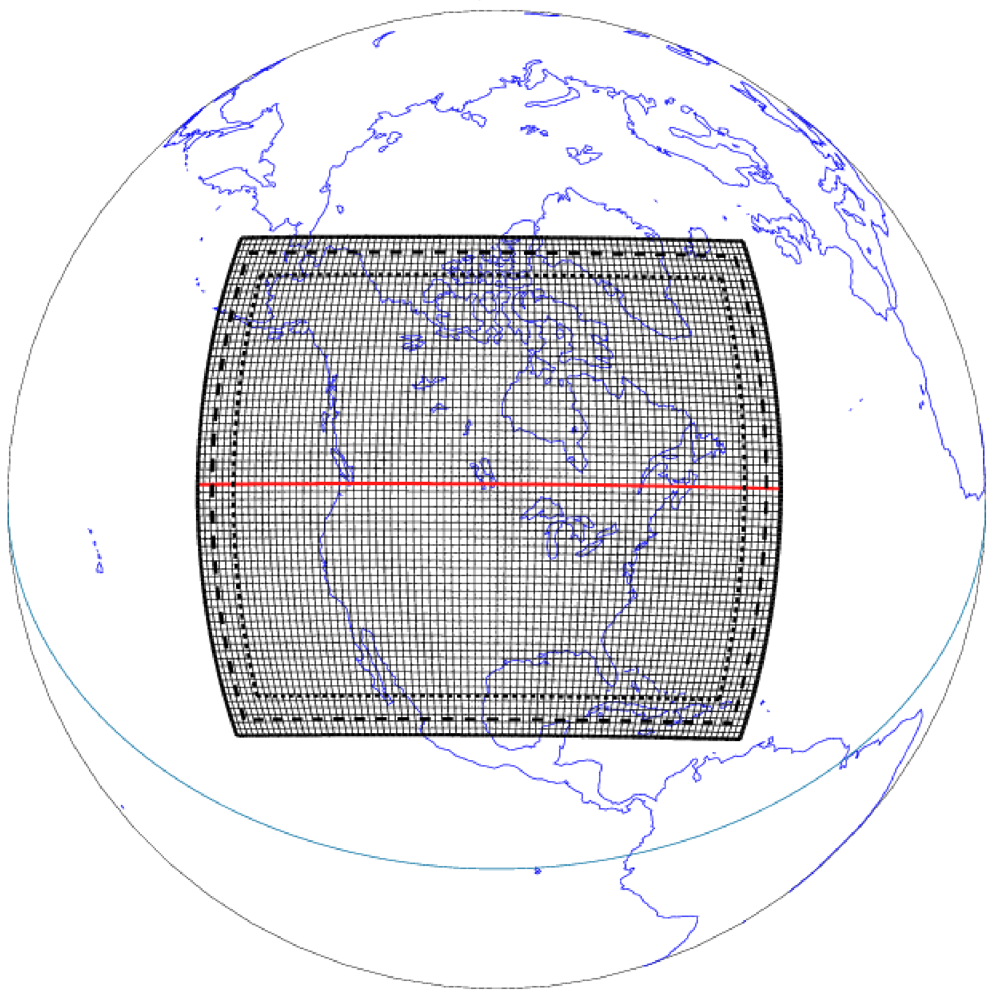
The following issues are thought to be important and non-trivial:

1) Can we use the global EPS to pilot a regional EPS?

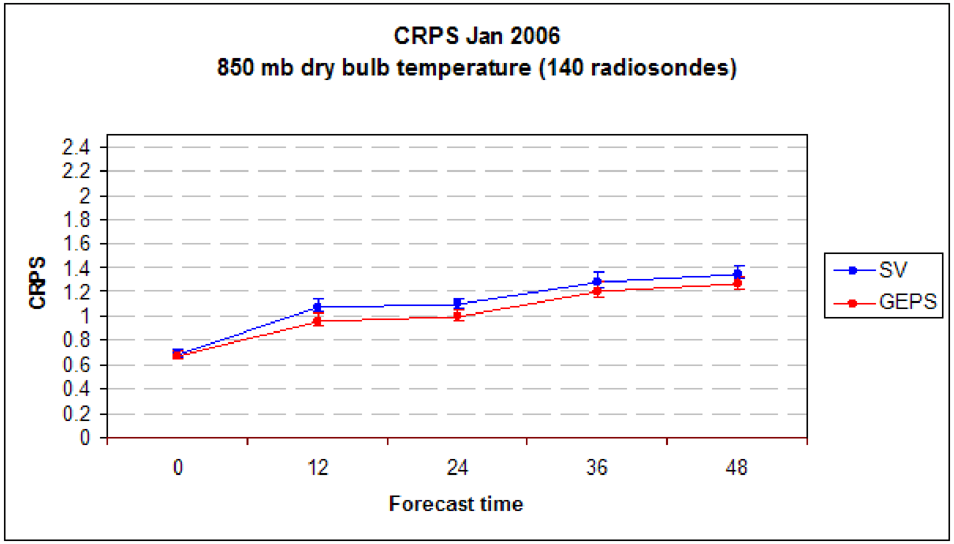
2) How does an incremental 4D-Var compare with an incremental EnKF?

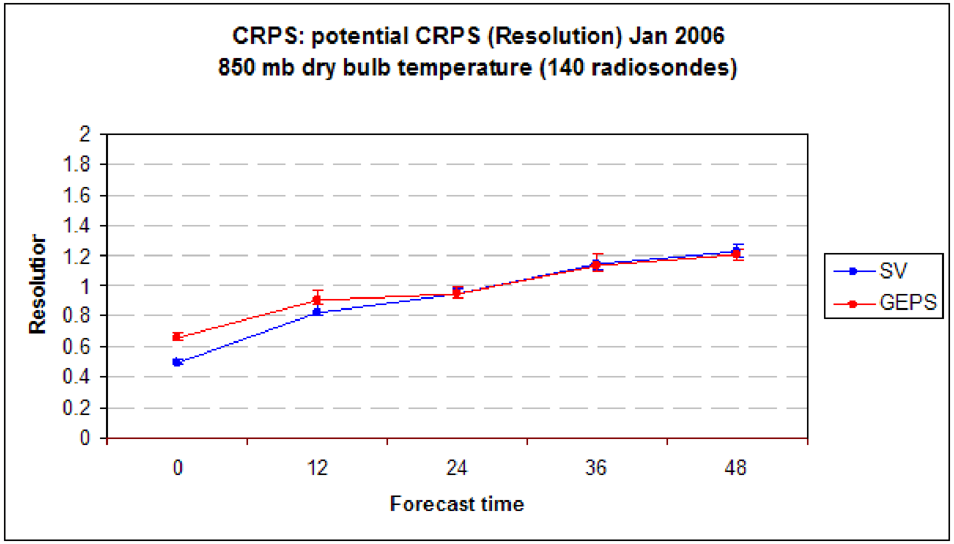
LAM EPS experiments (Martin Charron, Xiaoli Li, Ronald Frenette)

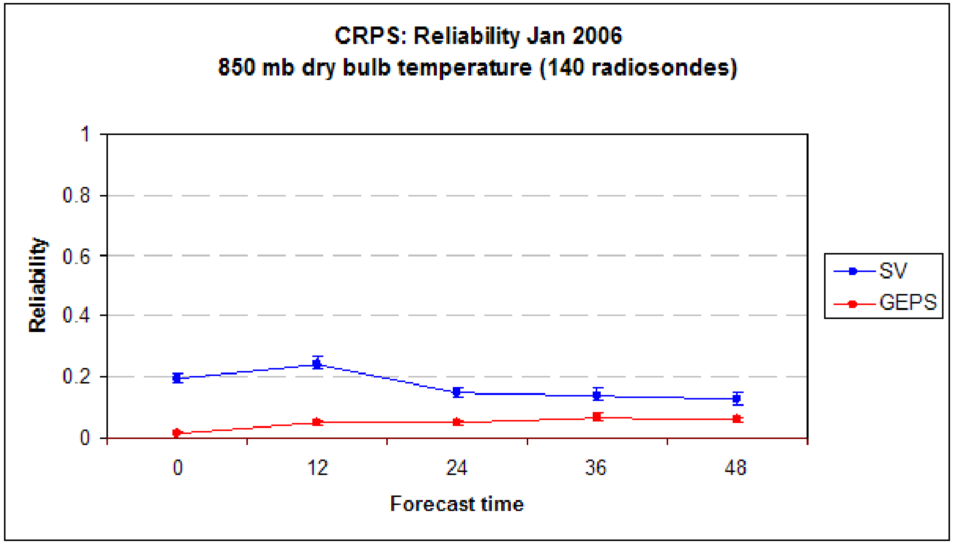
The domain of the two EPS system (4D-Var + SV, EnKF pilot)



Comparison of upper air scores against sondes (temperature at 850hPa)







Comparison of 4D-Var and EnKF

The EnKF and 4D-Var are both 4-dimensional data-assimilation systems. The EnKF provides an ensemble of low-resolution initial conditions to the Ensemble Prediction System, whereas 4D-Var provides a unique initial state to the meso-global model.

It is not evident how to compare the quality of a low-resolution ensemble mean and a high-resolution single state.

To facilitate the comparison of the two methods and to understand what causes the differences, an incremental (dual-resolution) EnKF will be developed. Here, the low-resolution ensemble statistics will be used to provide a single high-resolution analysis. The quality of that analysis can more easily be compared with the quality of the meso-global analysis, which is output from the incremental 4D-Var.

Conclusions

1) The EnKF can be used to provide initial conditions for a reliable global EPS,

2) To maintain reliability in the medium-range, model error has been simulated and parametrized in a variety of ways,

3) It is possible to pilot a reliable regional EPS from the global EPS.