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An update on the CMC Ensemble medium-range forecast system

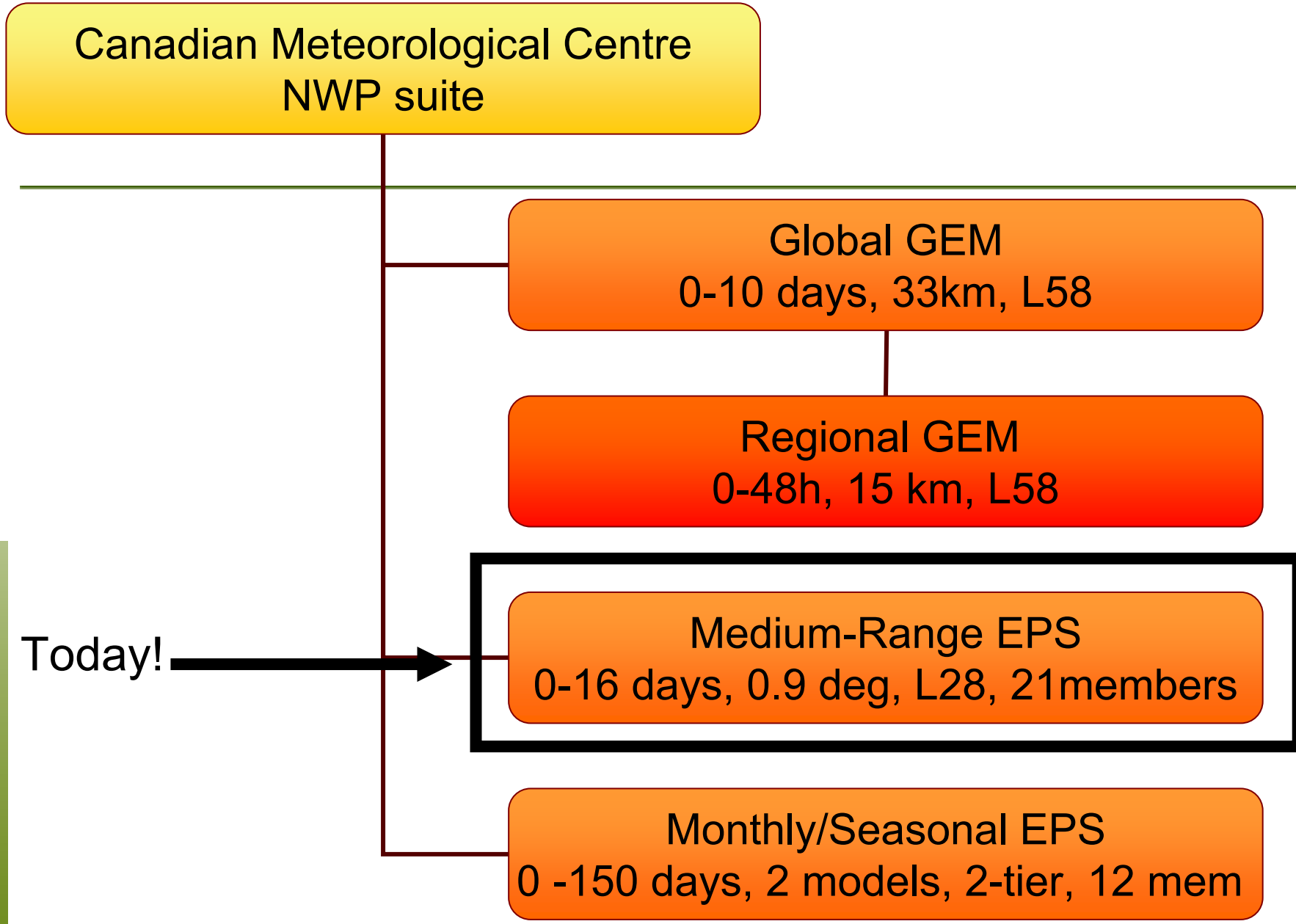
Normand Gagnon[1], Gérard Pellerin[1], Martin Charron[2], Peter Houtekamer[3], Herschel Mitchell[3], Guillem Candille[3], Lubos Spacek[2], Xing-Xiu Deng[1], Bin He[3] and Richard Verret[1]

[1]Canadian Meteorological Centre

[2]Recherche en prévision numérique

[3]ARMA

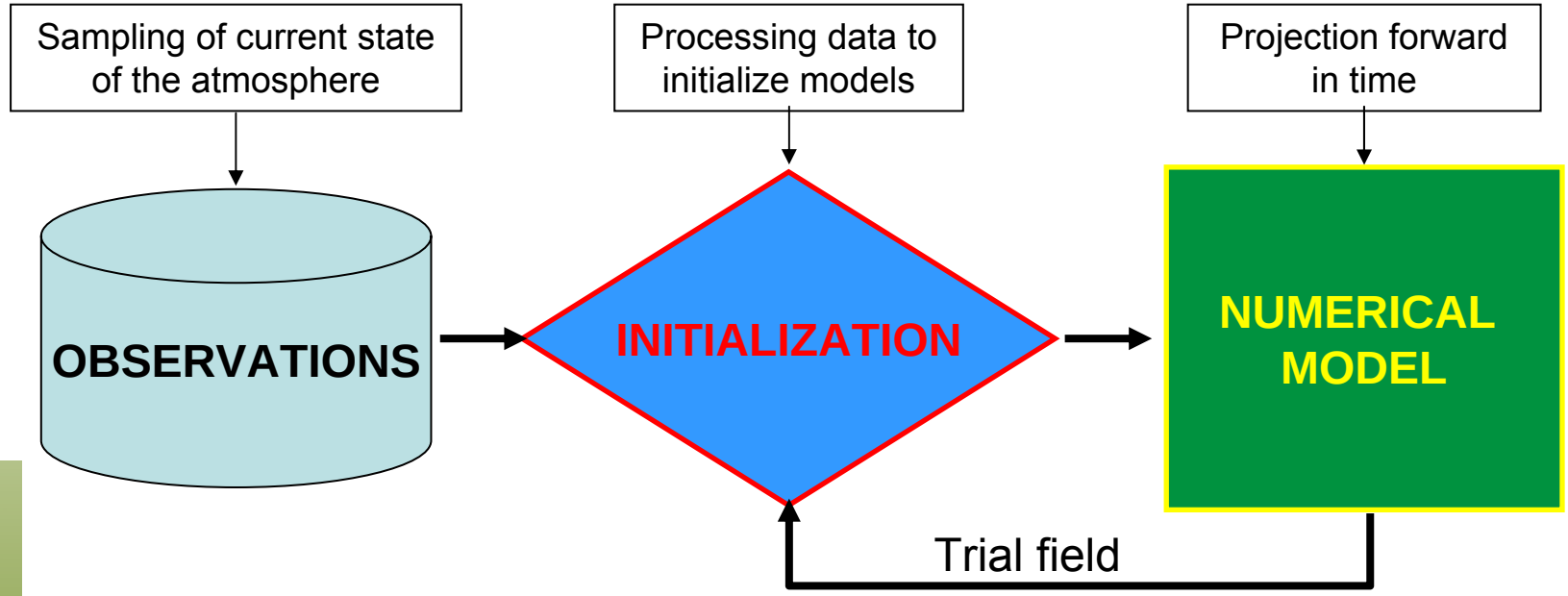
Meteorological Service of Canada


Canadian Meteorological Centre
NWP suite
Global GEM
0-10 days, 33km, L58
Regional GEM
0-48h, 15 km, L58
Today!
Medium-Range EPS
0-16 days, 0.9 deg, L28, 21members
Monthly/Seasonal EPS
0 -150 days, 2 models, 2-tier, 12 mem

Outline

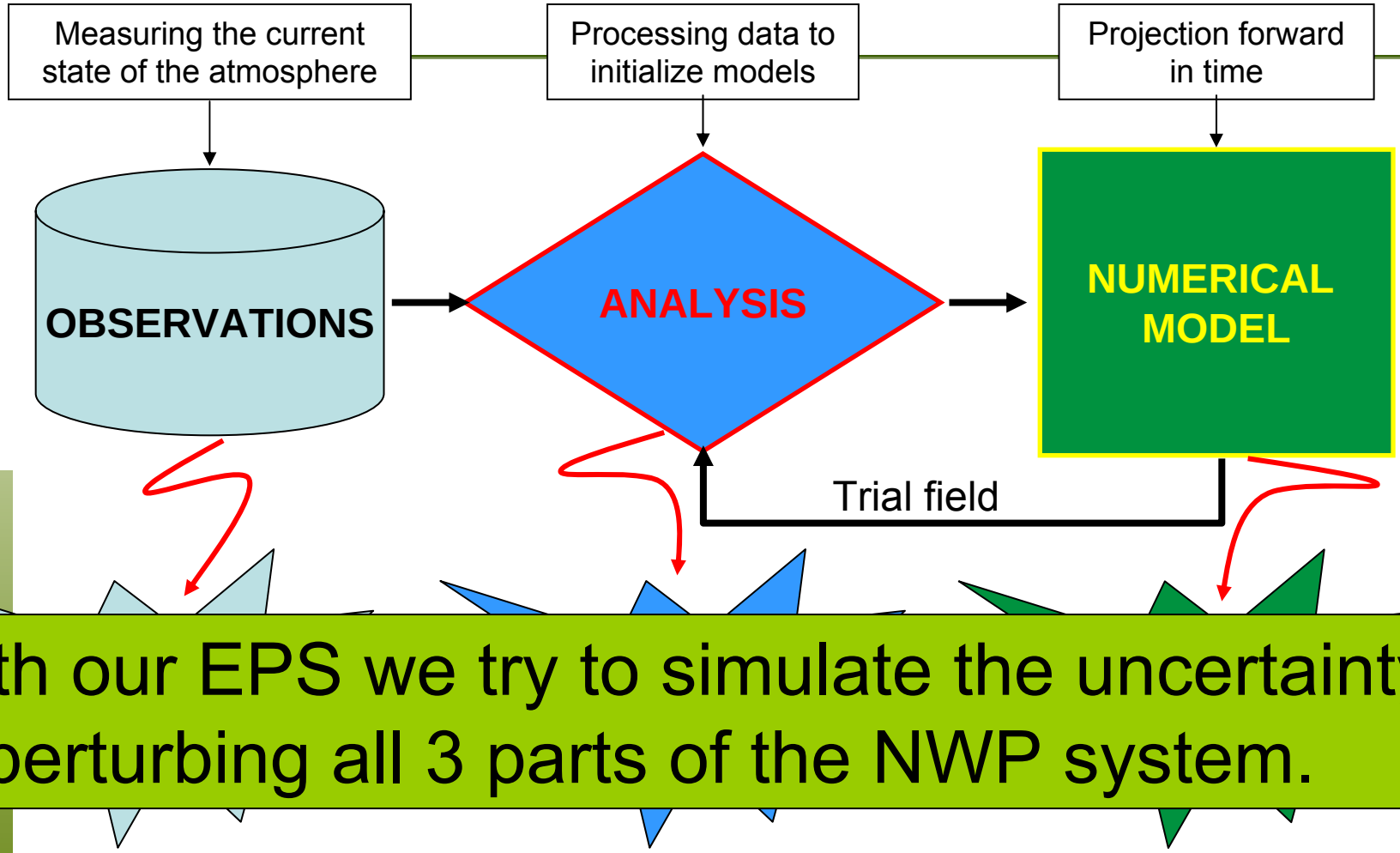
- Introduction
- Description of the modifications
  - Assimilation component
  - Forecast component
- Comparison with the previous system
- NAEFS initiative
- Training tour
- Summary and future work

Sources of error – uncertainties



Where are the possible sources of error / uncertainty in the NWP forecast process?

Sources of forecast error



With our EPS we try to simulate the uncertainty in perturbing all 3 parts of the NWP system.

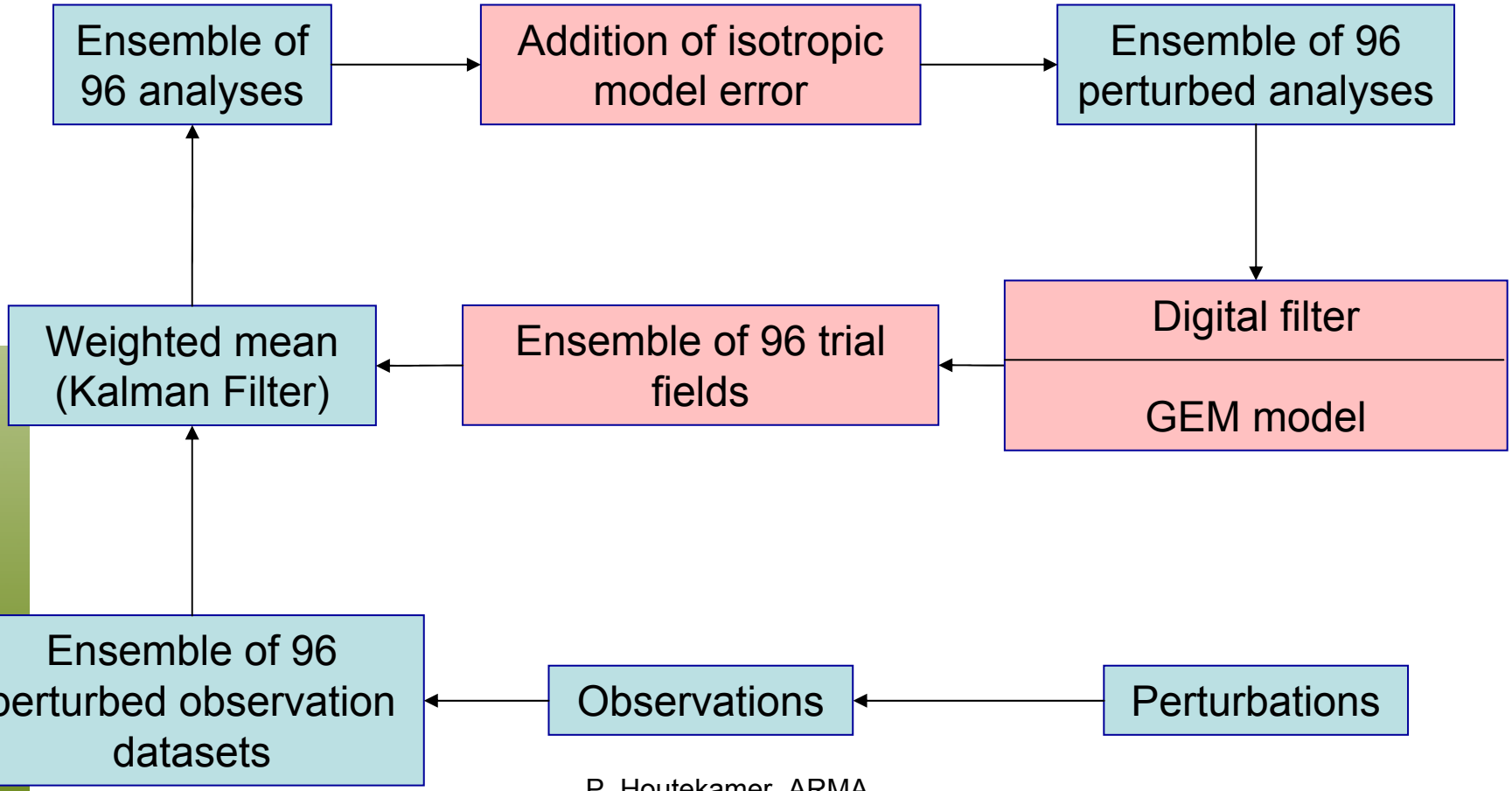
Canadian EPS: new system
(implemented July 10 2007)

- Members:
  - 20+1 members:
  - GEM 0.9° L28 (~100 km resolution).
  - 16-day integration.
  - Twice a day (00 and 12 UTC).
- Simulation of initial condition uncertainties:
  - multi-model ensemble Kalman filter data assimilation with perturbed observations.
- Simulation of model uncertainties:
  - A multi-model approach, each member having its own physics parameterization.
  - Stochastic perturbations added to tendencies in the parameterized physical processes (as in Buizza et al. 1999).
  - Shutts (2005) energy back-scattering parameterization is used.

Modifications to the data assimilation component:

- Horizontal resolution is increased from 1.2 to 0.9 degree (grid of 400x200 points instead of 300x150 points).
- The 24 different configurations of the GEM model are introduced instead of one to produce the trial fields. This direct simulation of model error permits the reduction of the parameterized, homogeneous and isotropic model error components.
- Trial fields at 3, 4.5, 6, 7.5 and 9-h allow time interpolation toward observations – become a 4-D data assimilation cycle.

Data assimilation component – **OLD**



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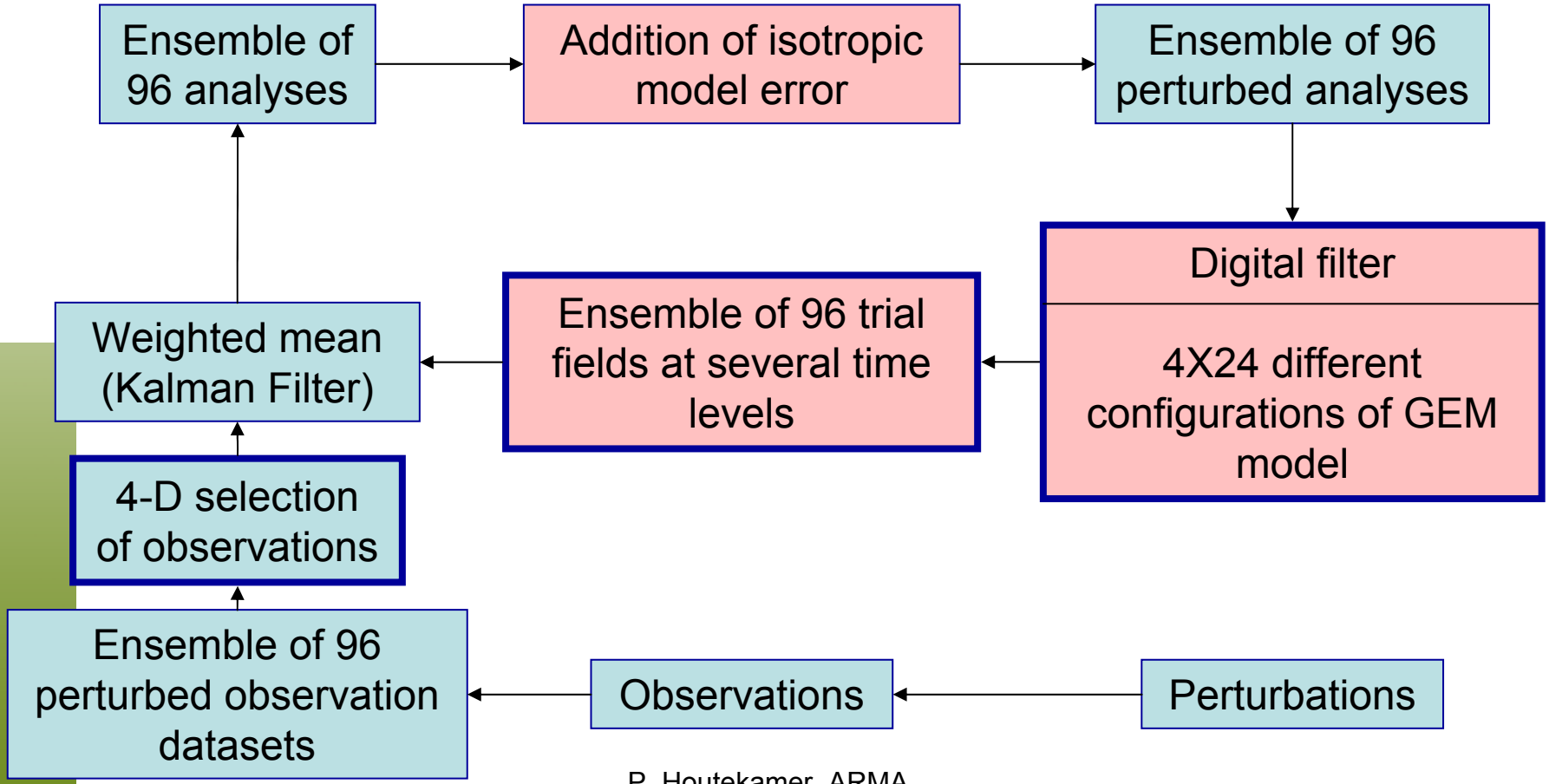
Data assimilation component – **NEW!**



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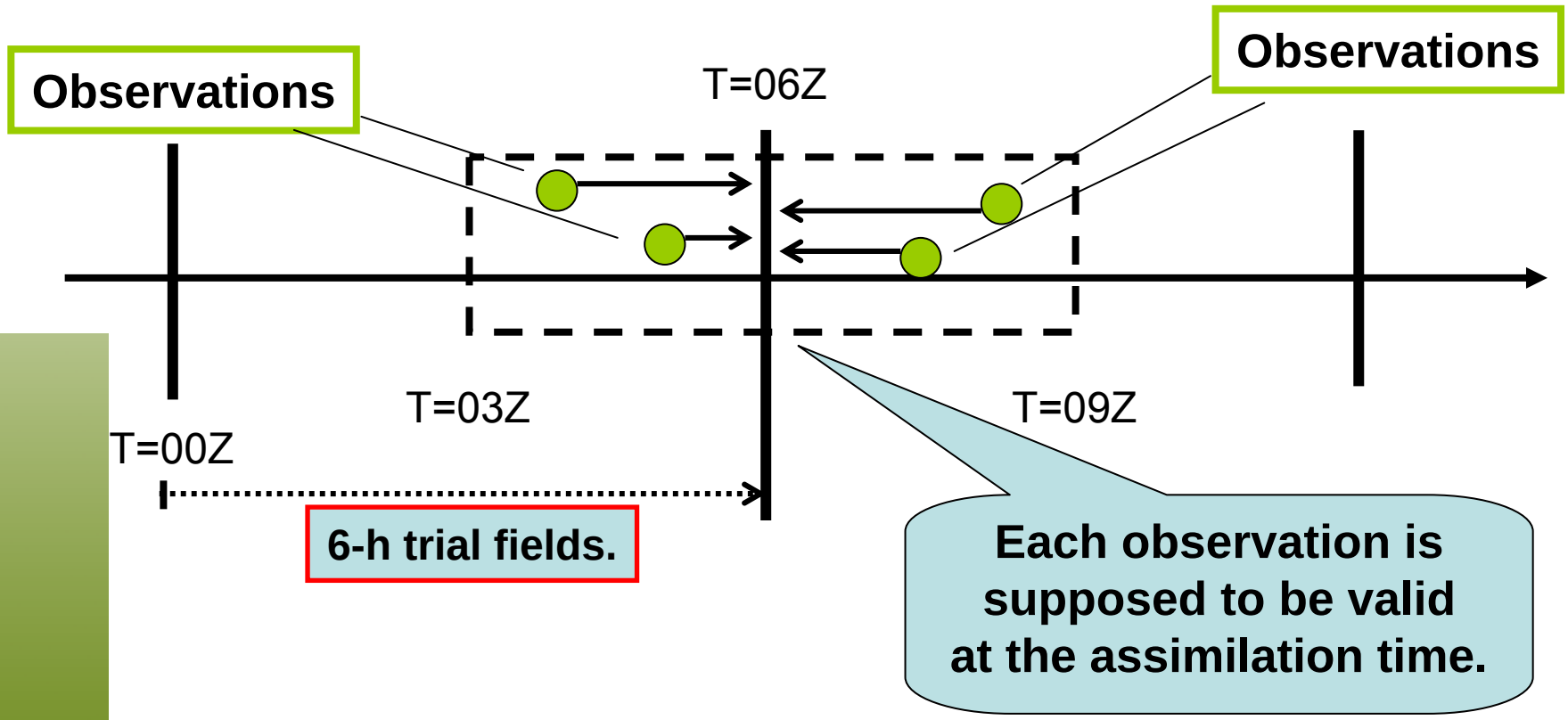
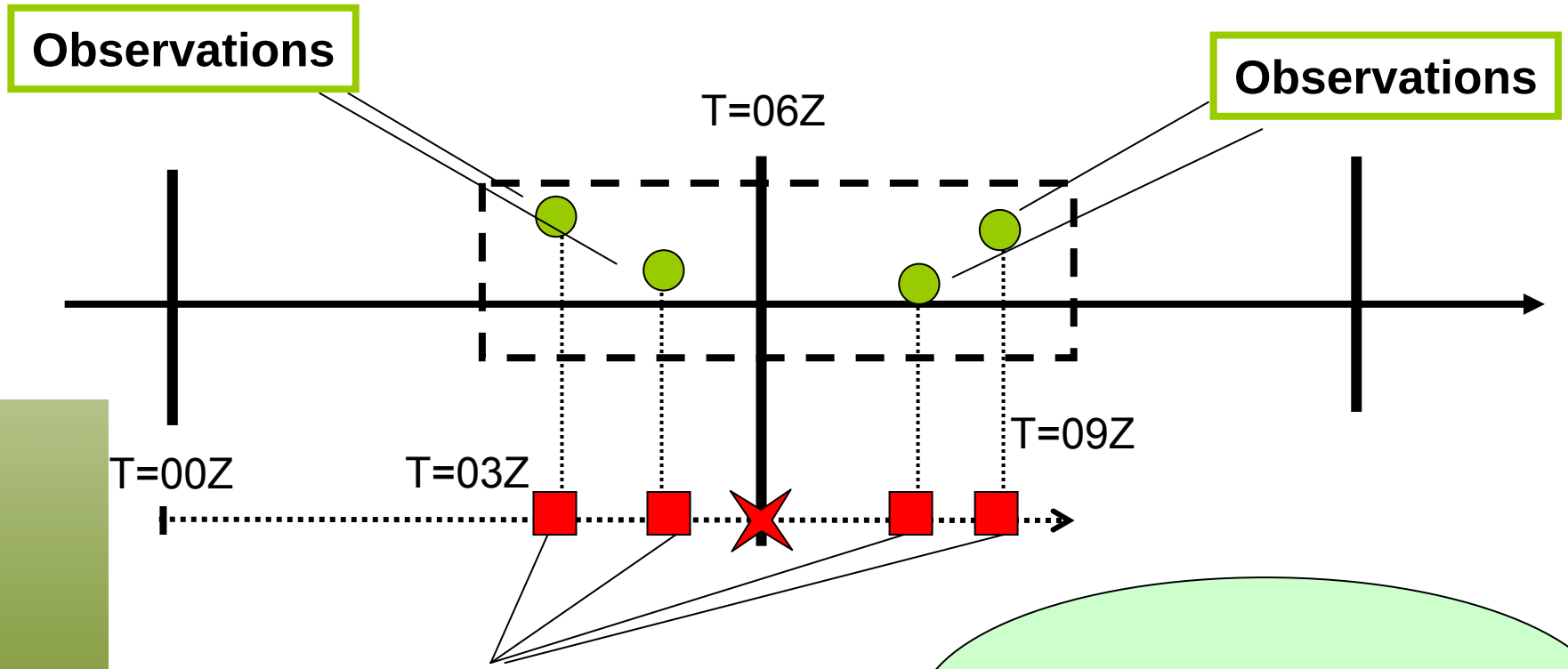
Assimilation window – OLD version



N. Gagnon, CMC

Assimilation window – NEW! version



3- to 9-h trial fields.
Interpolated at the observation time.

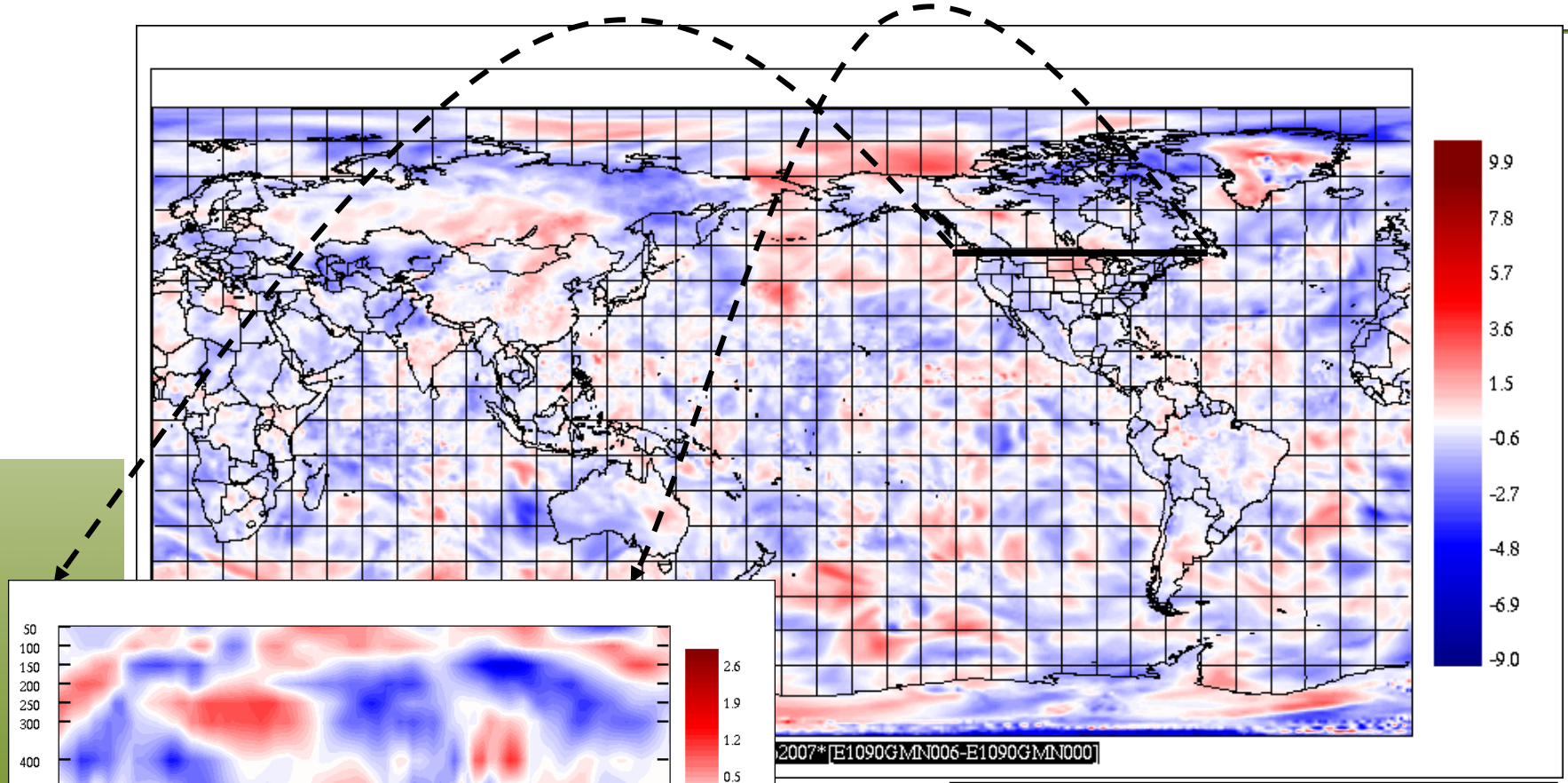
Each observation is assimilated at its time of validity.

N. Gagnon, CMC

Multi-model EPS for the assimilation

#	Deep convection	Surface scheme	Mixing length	Vertical mixing parameter
1	Kain & Fritsch	ISBA	Bougeault	1.0
2	Oldkuo	ISBA	Blackadar	0.85
3	Relaxed Arakawa Schubert	force-restore	Bougeault	0.85
4	Kuo Symétrique	force-restore	Blackadar	1.0
5	Oldkuo	force-restore	Bougeault	1.0
6	Kain & Fritsch	force-restore	Blackadar	0.85
7	Kuo Symétrique	ISBA	Bougeault	0.85
8	Relaxed Arakawa Schubert	ISBA	Blackadar	1.0
9	Kain & Fritsch	ISBA	Blackadar	0.85
10	Oldkuo	ISBA	Bougeault	1.0
11	Relaxed Arakawa Schubert	force-restore	Blackadar	1.0
12	Kuo Symétrique	force-restore	Bougeault	0.85
13	Oldkuo	force-restore	Blackadar	0.85
14	Kain & Fritsch	force-restore	Bougeault	1.0
15	Kuo Symétrique	ISBA	Blackadar	1.0
16	Relaxed Arakawa Schubert	ISBA	Bougeault	0.85
17	Kuo Symmetric	force-restore	Bougeault	1.0
18	Kain & Fritsch	ISBA	Blackadar	0.85
19	Oldkuo	ISBA	Bougeault	0.85
20	Relaxed Arakawa Schubert	force-restore	Blackadar	1.0
21	Relaxed Arakawa Schubert	ISBA	Blackadar	0.85
22	Oldkuo	force-restore	Bougeault	1.0
23	Kain & Fritsch	force-restore	Blackadar	1.0
24	Kuo Symétrique	ISBA	Bougeault	0.85

Example of initial perturbation on 700 hPa temperature field:



Initial perturbations – member 6 (GEM)
Temperatures at 700 hPa
00 UTC 01-10-2007

Gagnon, CMC

Perturbation = Analysis(Member 6) - Mean of 96 analyses

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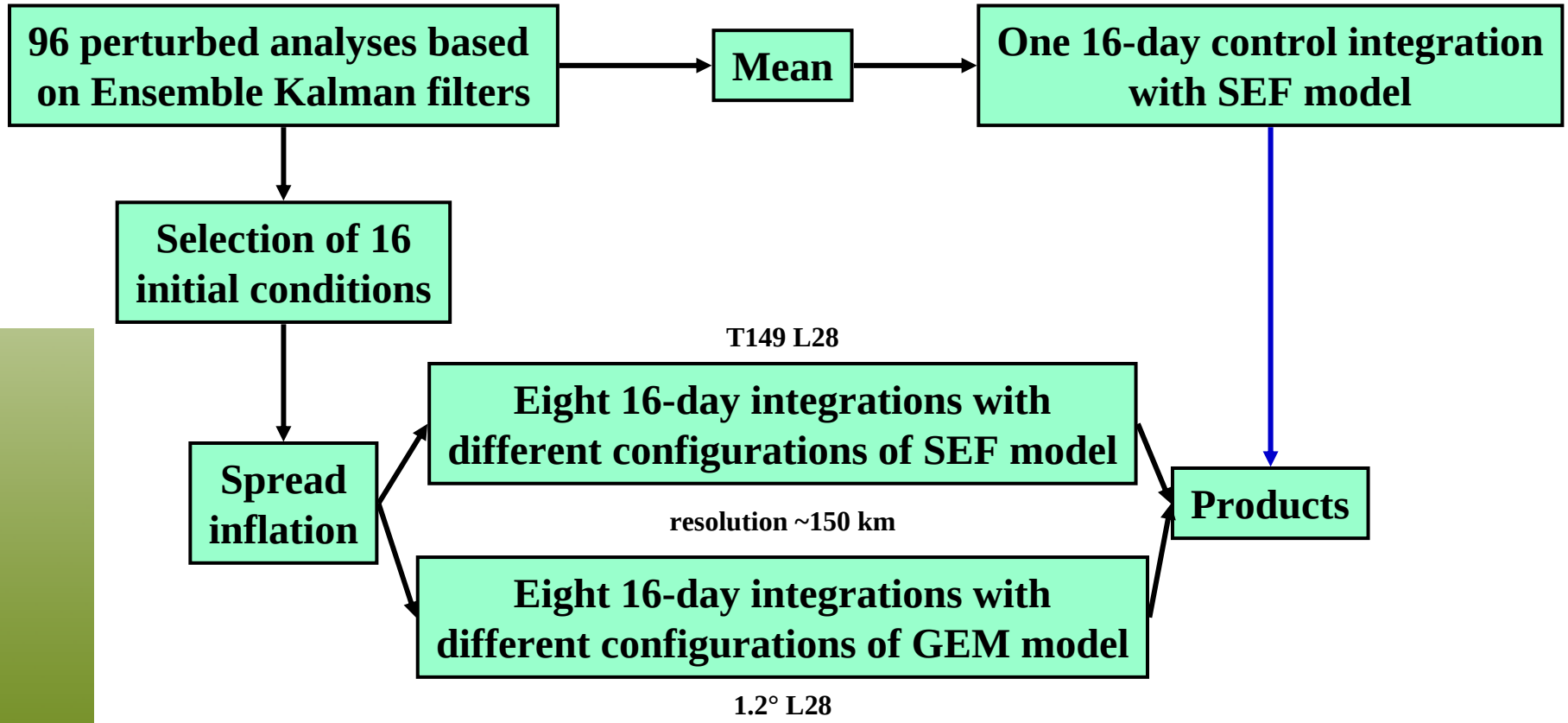
Modifications to the forecast component:

- Now only one dynamical core : GEM (SEF is dropped).
- Horizontal resolution is increased from 1.2 to 0.9 degree .
- 4 additional members (ensemble size is now 20).

Modifications to the forecast component (suite):

- Addition of stochastic perturbation of the physical tendencies as in Buizza et al.(1999) (random number between 0.5 and 1.5).
- An stochastic kinetic energy back-scattering parameterization is used as in Shutts (2005).
- The physical parameterization package was extended to include the Kain&Fritsch deep convection scheme and the Bougeault-Lacarrère mixing length formulation.

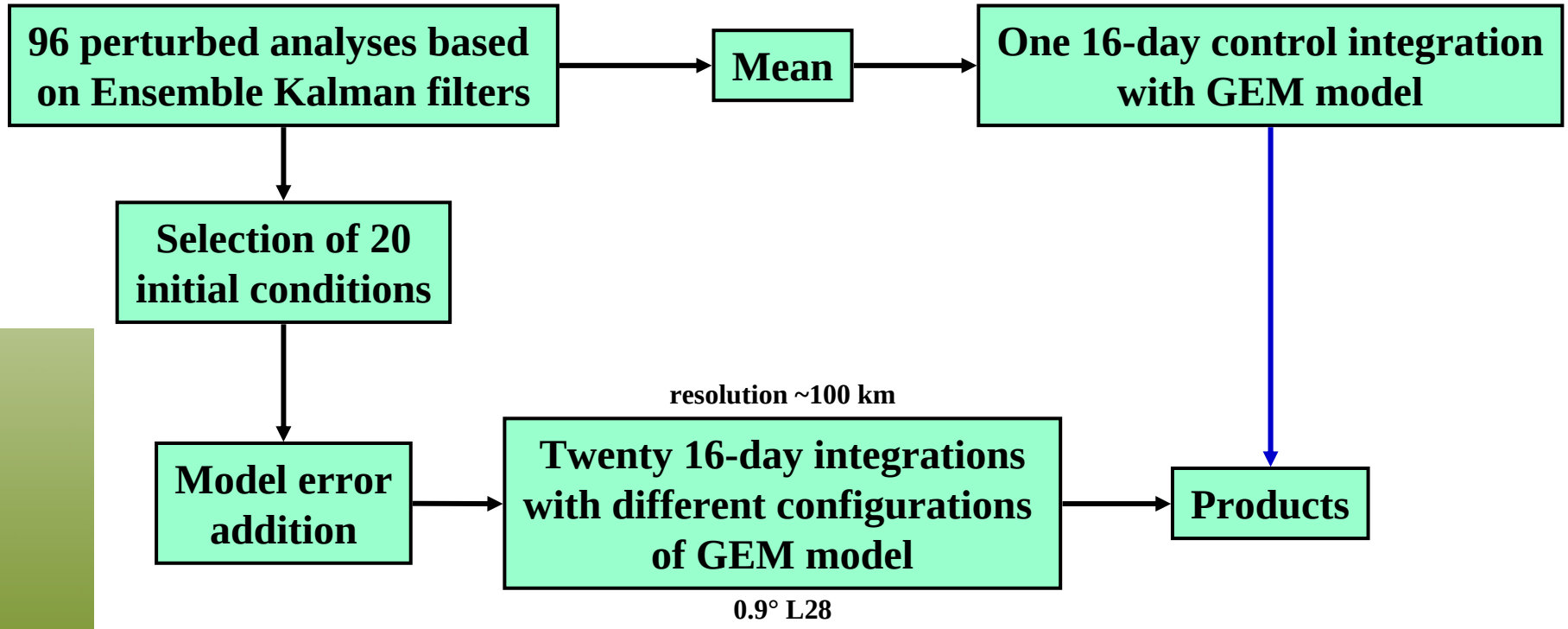
Coupling between data assimilation and forecasts - OLD



Integration done twice a day (00 and 12 UTC)

P. Houtekamer, ARMA

Coupling between data assimilation and forecasts – **NEW!**



Integration done twice a day (00 and 12 UTC)

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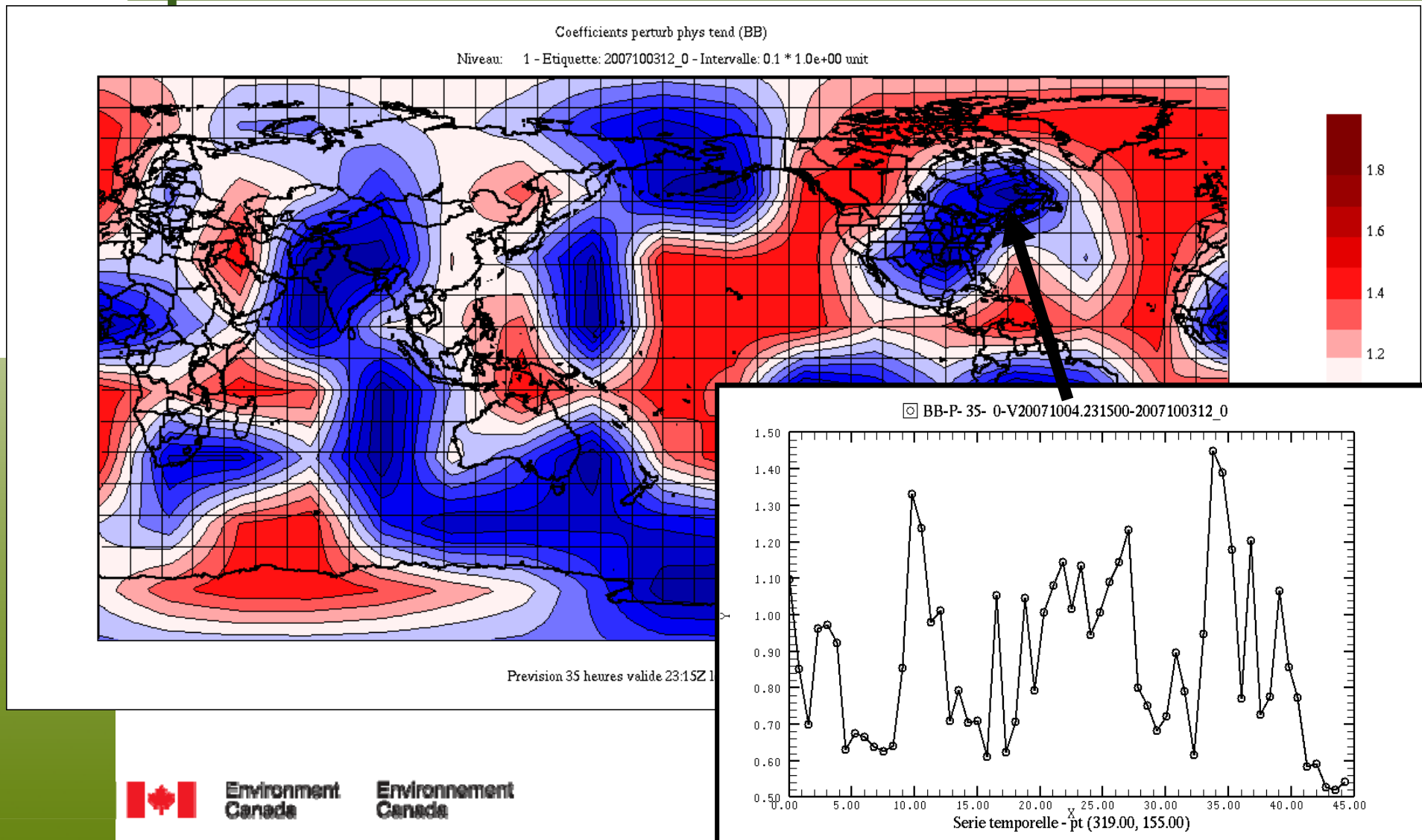
Canadian EPS Forecast component

#	Deep convection	Land surface scheme	Mixing length	Vertical mixing parameter	GWD	Back-scattering	Stochastic Physics
0	Kain & Fritsch	ISBA	*Bougeault*	1.0	std	No	No
1	Kain & Fritsch	ISBA	*Bougeault*	1.0	Weak	Yes	Yes
2	Oldkuo	ISBA	Blackadar	0.85	Strong	Yes	Yes
3	Relaxed Arakawa Schubert	Force-restore	*Bougeault*	0.85	Weak	Yes	Yes
4	Kuo Symmetric	Force-restore	Blackadar	1.0	Strong	Yes	Yes
5	Oldkuo	Force-restore	*Bougeault*	1.0	Weak	Yes	Yes
6	Kain & Fritsch	Force-restore	Blackadar	0.85	Strong	Yes	Yes
7	Kuo Symmetric	ISBA	*Bougeault*	0.85	Weak	Yes	Yes
8	Relaxed Arakawa Schubert	ISBA	Blackadar	1.0	Strong	Yes	Yes
9	Kain & Fritsch	ISBA	Blackadar	0.85	Weak	Yes	Yes
10	Oldkuo	ISBA	*Bougeault*	1.0	Strong	Yes	Yes
11	Relaxed Arakawa Schubert	Force-restore	Blackadar	1.0	Weak	Yes	Yes
12	Kuo Symmetric	Force-restore	*Bougeault*	0.85	Strong	Yes	Yes
13	Oldkuo	Force-restore	Blackadar	0.85	Weak	Yes	Yes
14	Kain & Fritsch	Force-restore	*Bougeault*	1.0	Strong	Yes	Yes
15	Kuo Symmetric	ISBA	Blackadar	1.0	Weak	Yes	Yes
16	Relaxed Arakawa Schubert	ISBA	*Bougeault*	0.85	Strong	Yes	Yes
17	Kuo Symmetric	Force-restore	*Bougeault*	1.0	Weak	Yes	Yes
18	Kain & Fritsch	ISBA	Blackadar	0.85	Strong	Yes	Yes
19	Oldkuo	ISBA	*Bougeault*	0.85	Weak	Yes	Yes
20	Relaxed Arakawa Schubert	Force-restore	Blackadar	1.0	Strong	Yes	Yes

Perturbation of physical tendencies coefficients (a la Buizza et al. 1999): spherical harmonics at T8



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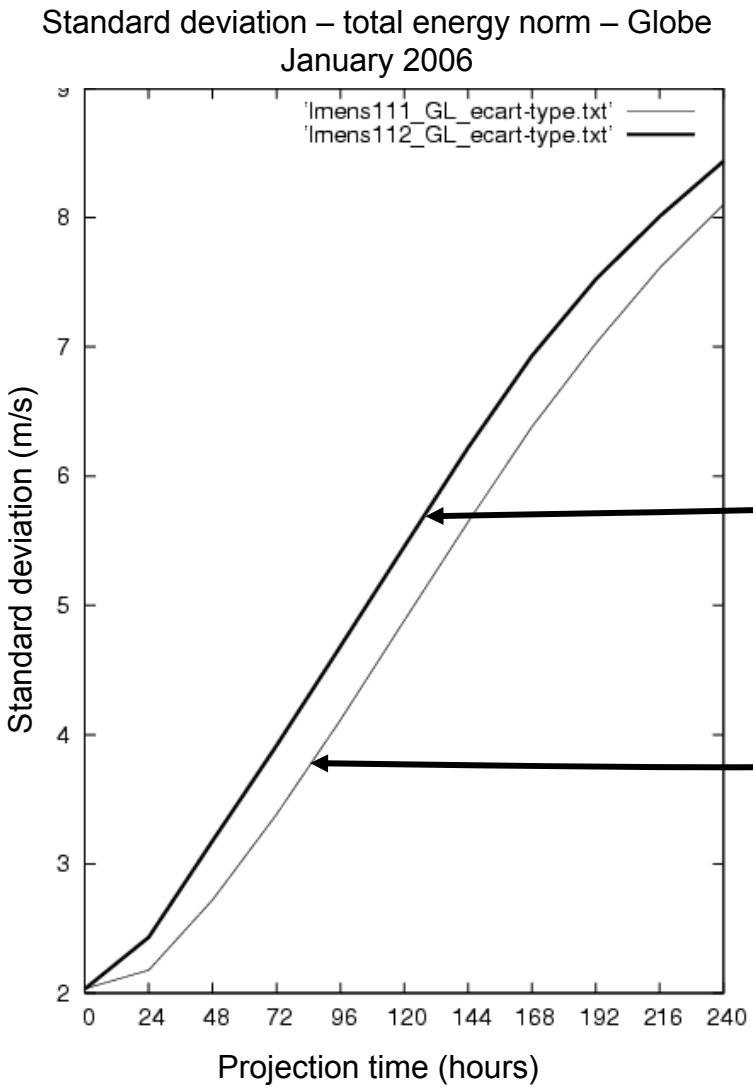
Effect of stochastic perturbation of physical tendencies

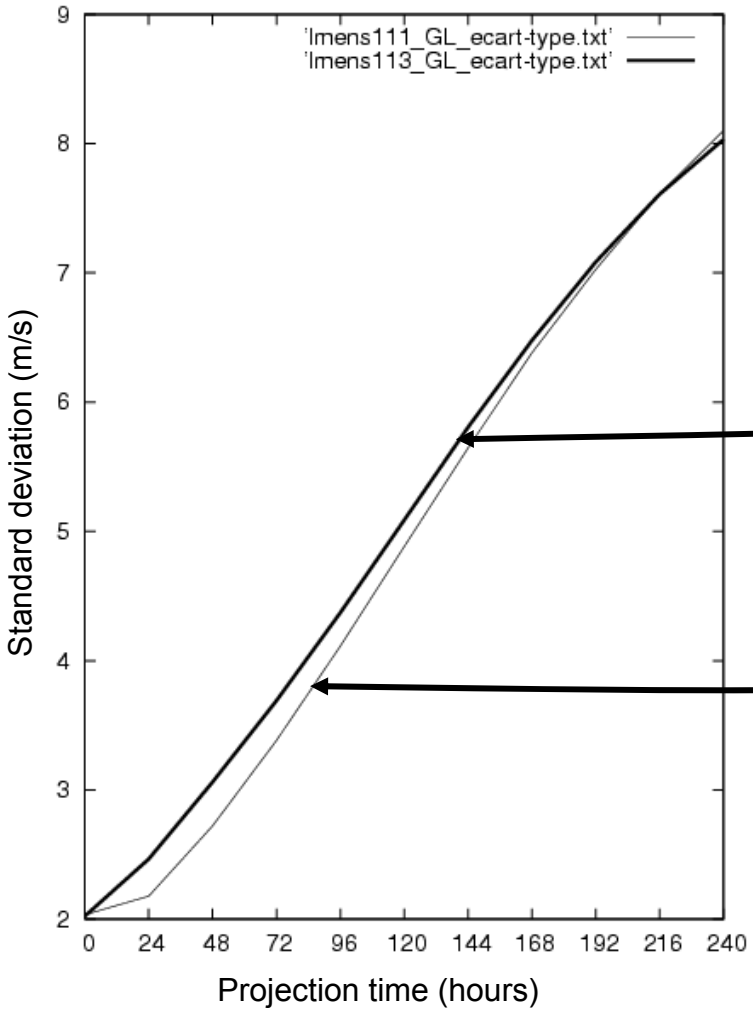


Spread – with stochastic physics

Spread – without stochastic physics

Effect of kinetic energy back-scattering a la Shutts (2005)

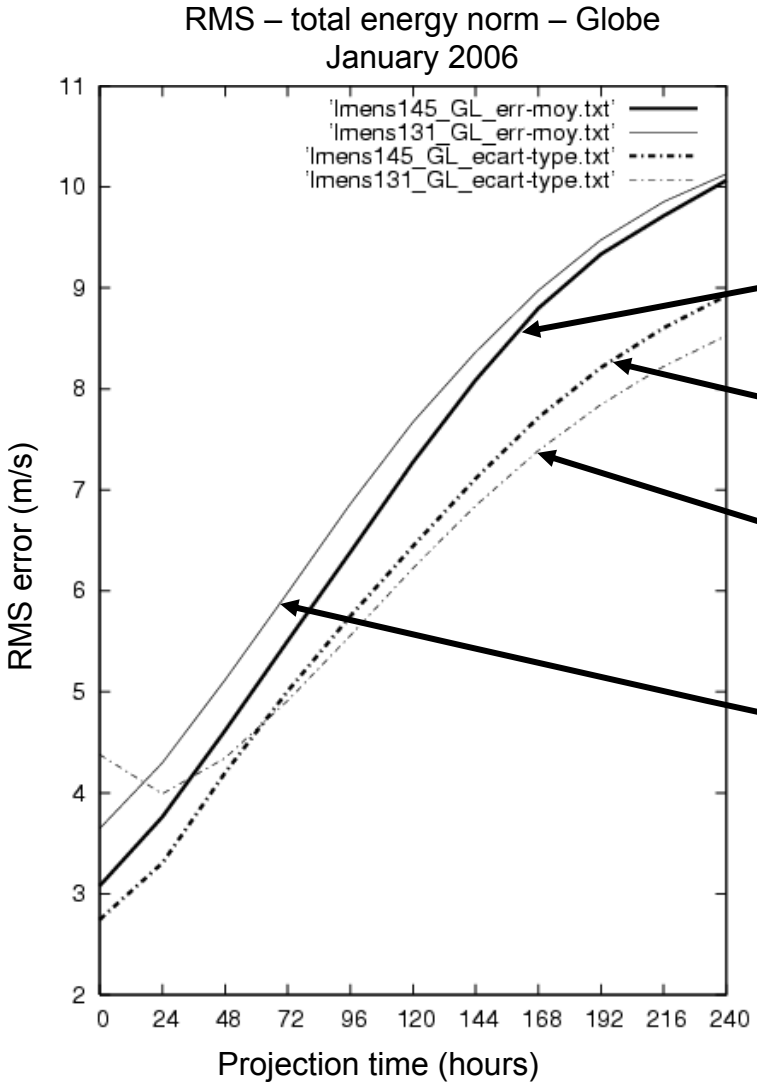
Standard deviation – total energy norm – Globe
January 2006



Spread – with back-scattering

Spread – without back-scattering

Reduced error and increased spread!



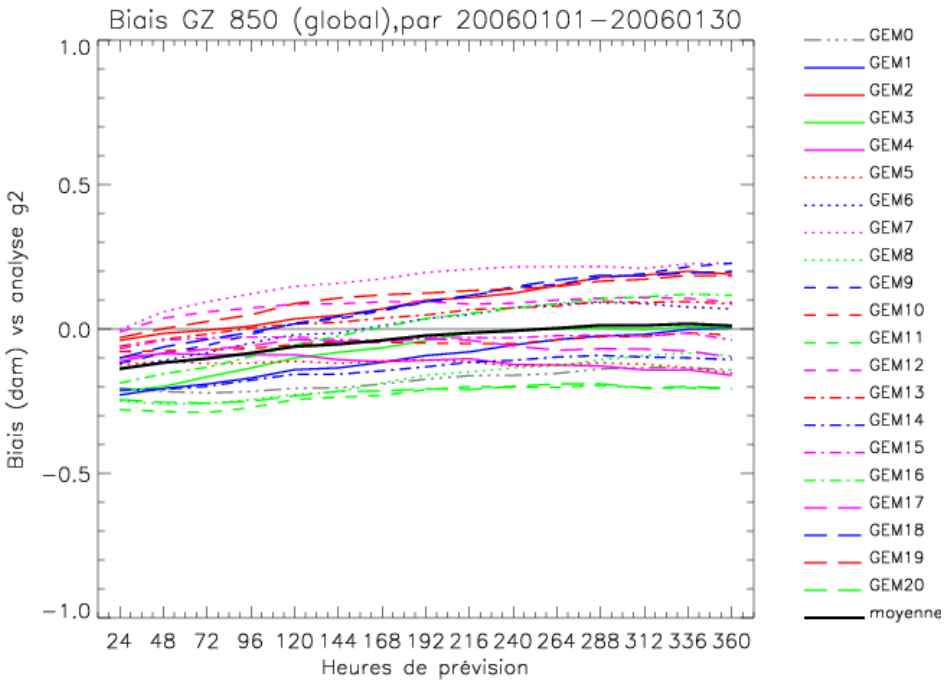
RMS error ensemble mean – New

Spread – New

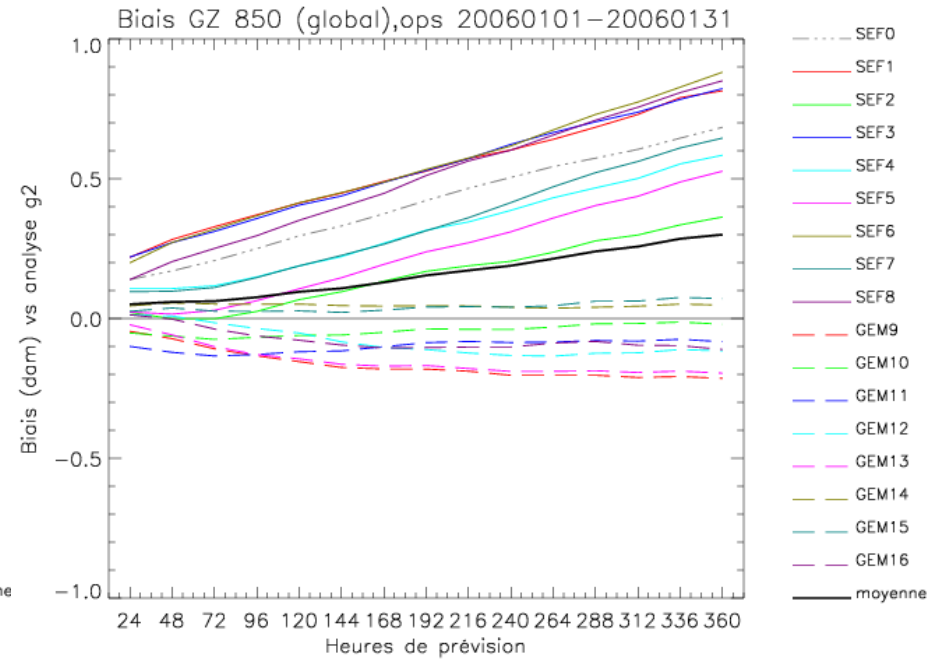
Spread – Old

RMS error ensemble mean – Old

Bias of individual models

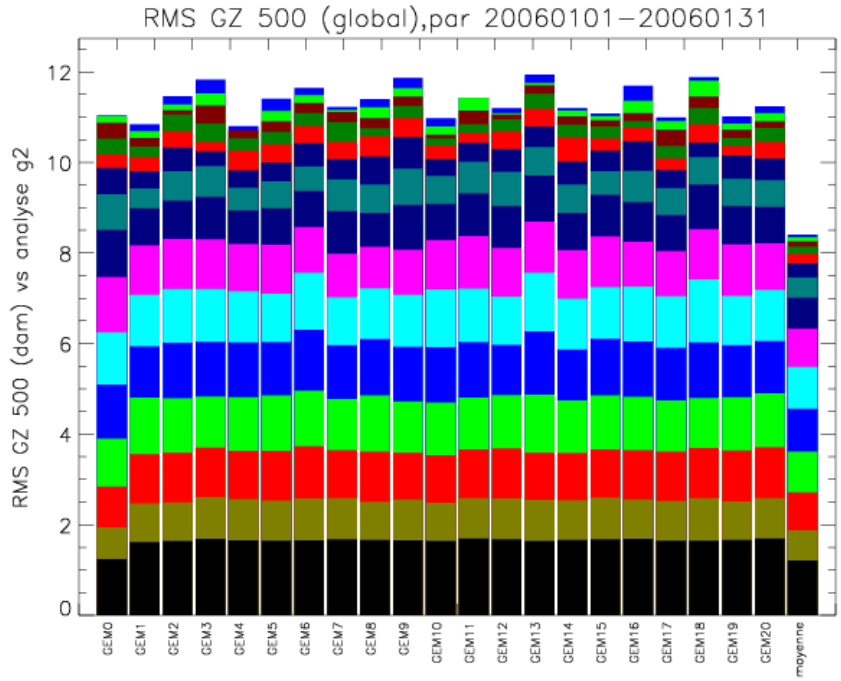


NEW!

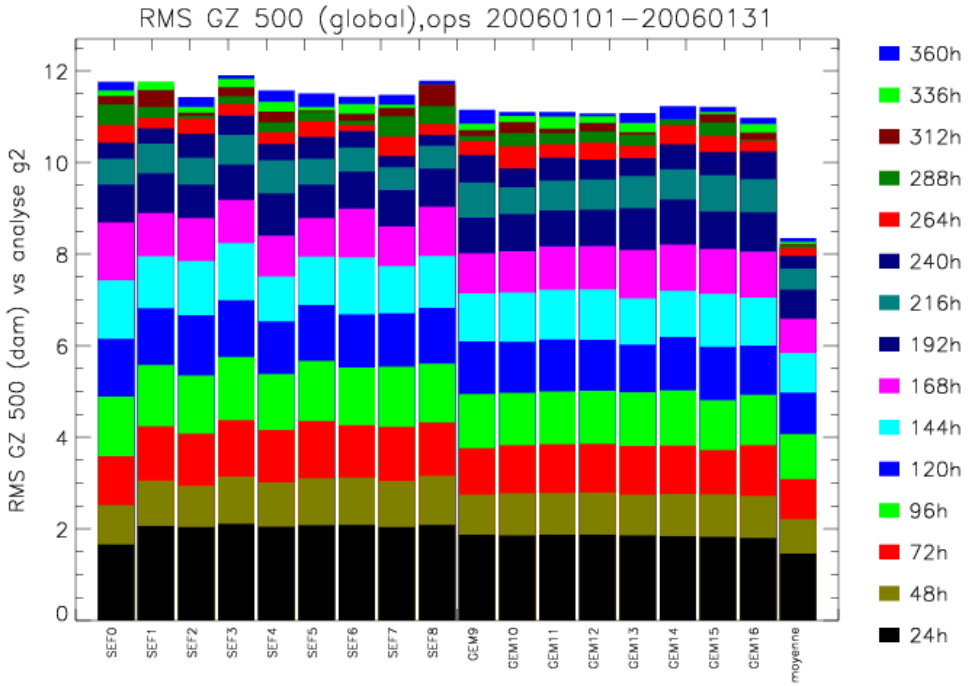


PREVIOUS!

RMS of individual models



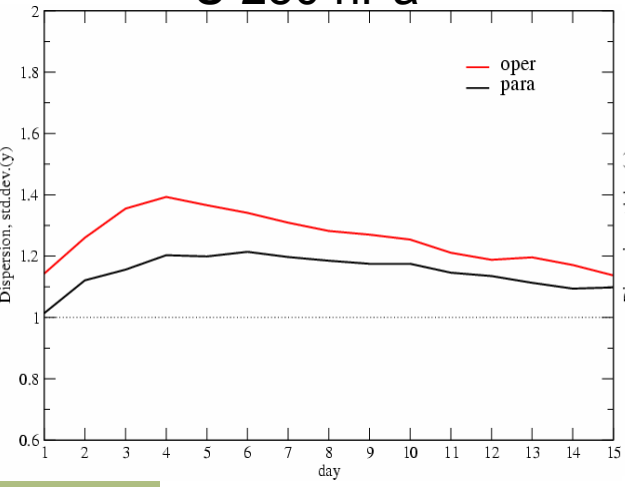
NEW!



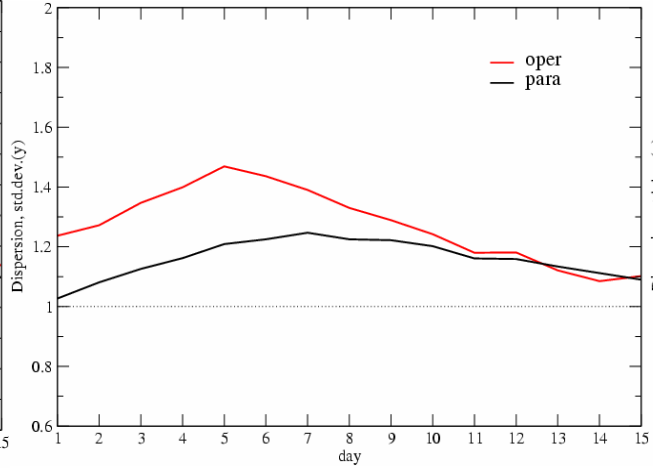
PREVIOUS!

Spread of the new system vs the previous one (January 2006)

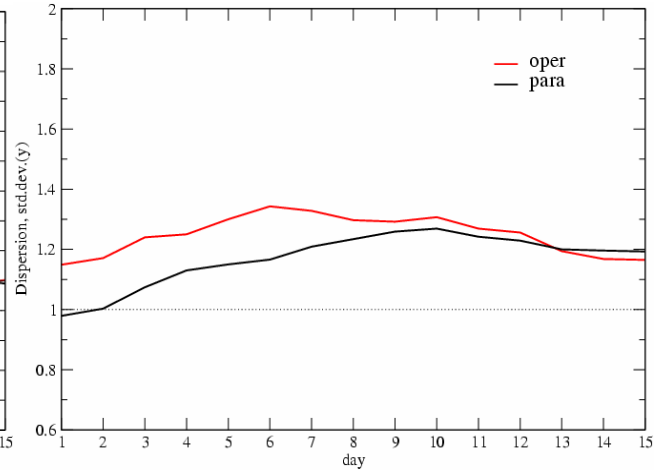
U 250 hPa

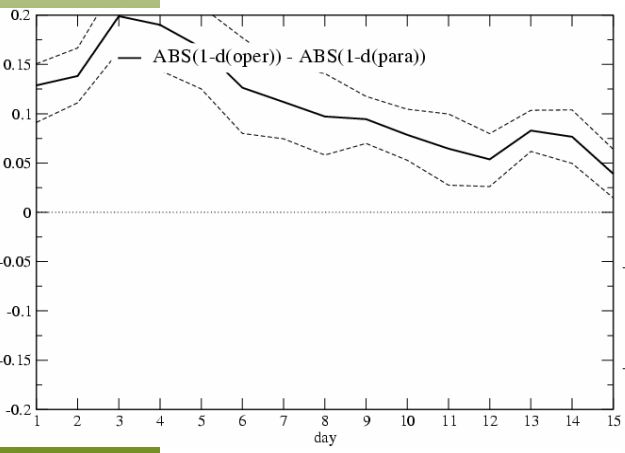


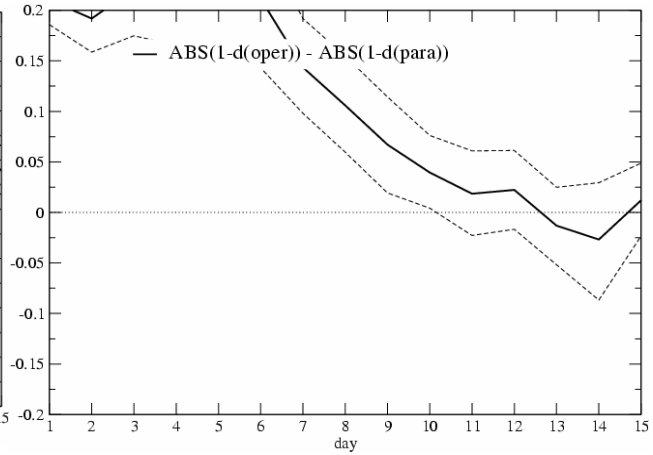
GZ 500 hPa

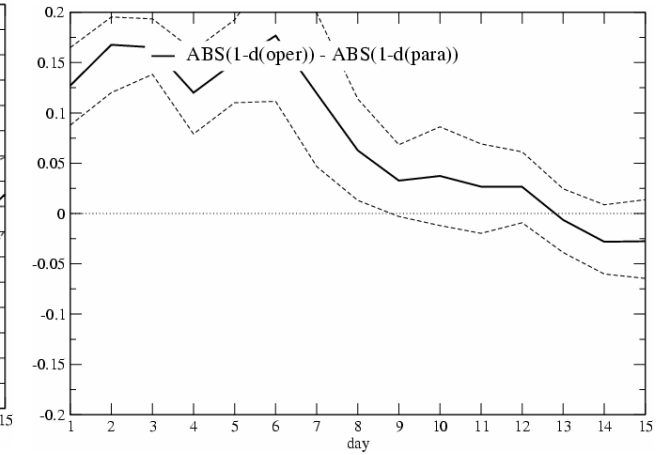


T 850 hPa









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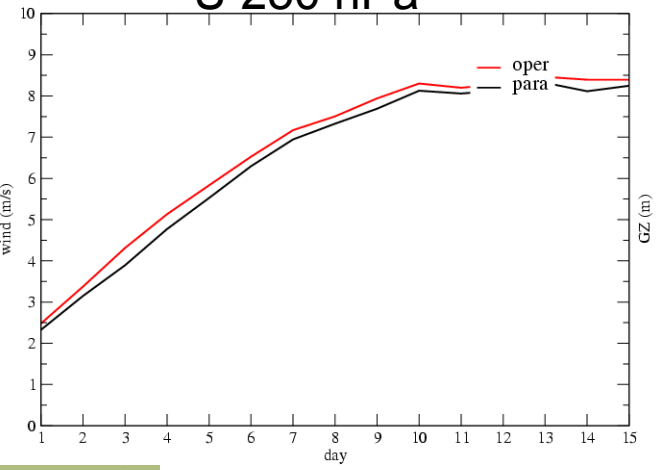
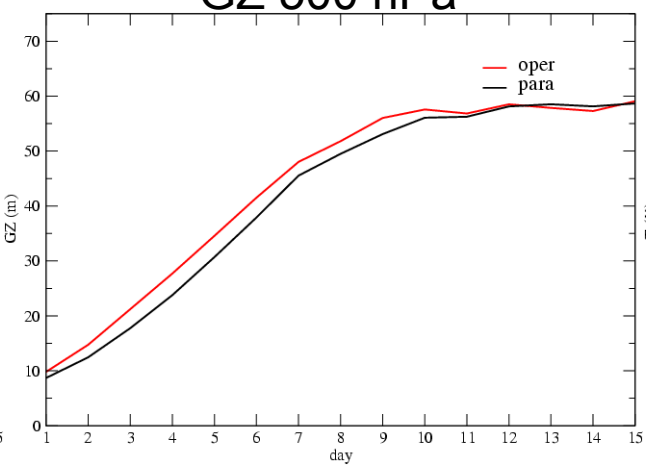
CRPS of the new system vs the previous one (January 2006)

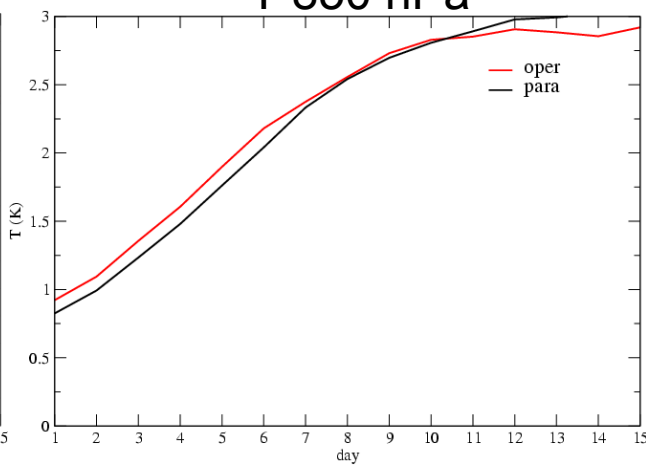
U 250 hPa

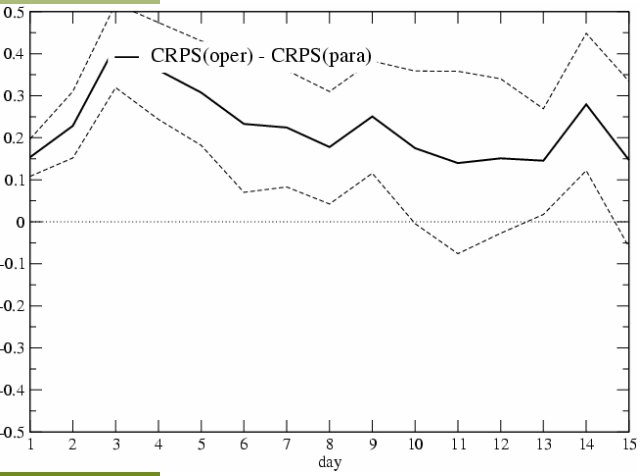


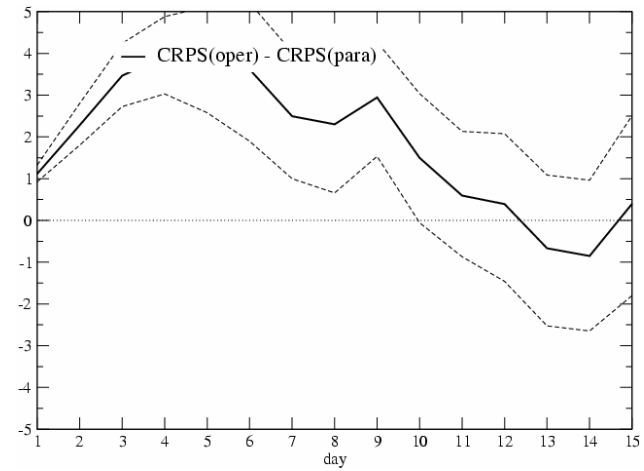
GZ 500 hPa

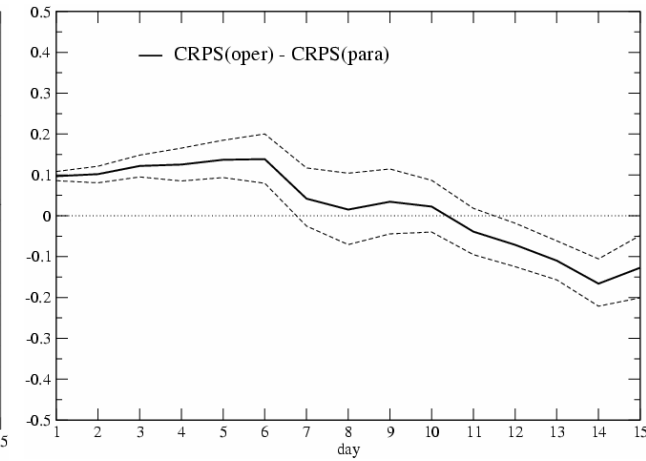


T 850 hPa









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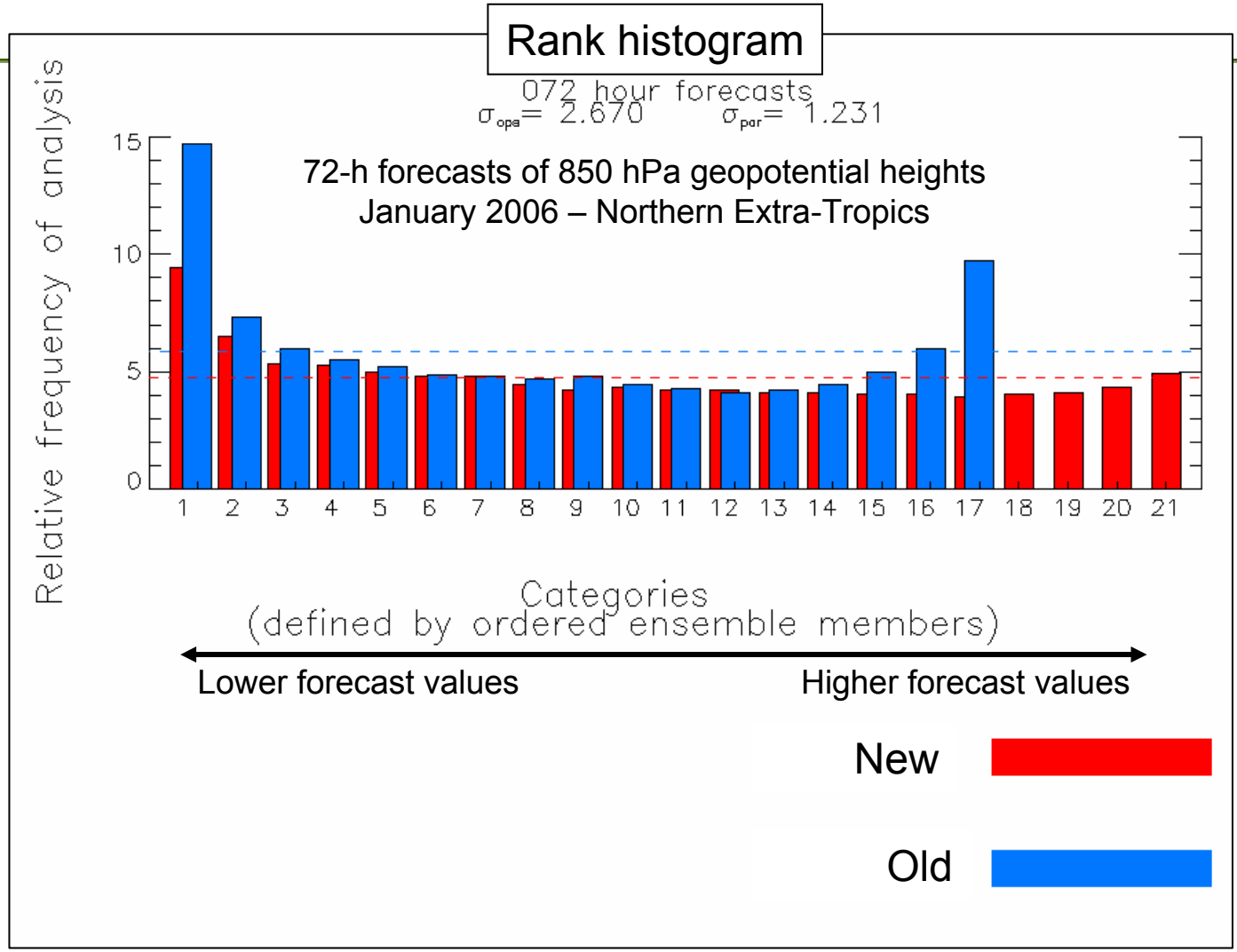


X. Deng, CMC

North American Ensemble Forecast System: NAEFS

- Partnership:
  - NOAA, MSC, NMS of Mexico: official agreement signed in November 2004.
  - Other partners (FNMOC, AFWA, UKMO, JMA, etc.) may join at a later time.
- Advantages:
  - Larger ensemble allowing better PDF definitions (super-ensemble).
  - Improved probabilistic forecast performance.
  - Seamless suite of forecast products across international boundaries and across different time ranges (1-14 days).
  - Minimal additional costs – levering computational resources.
  - Synergy with NCEP on R&D work.
  - Collaborative product development.
  - Contingency with another national NWP Centre.
- Challenges:
  - Combination of multi-model ensembles into a super-ensemble.
  - Real time exchange (operational considerations).

NAEFS

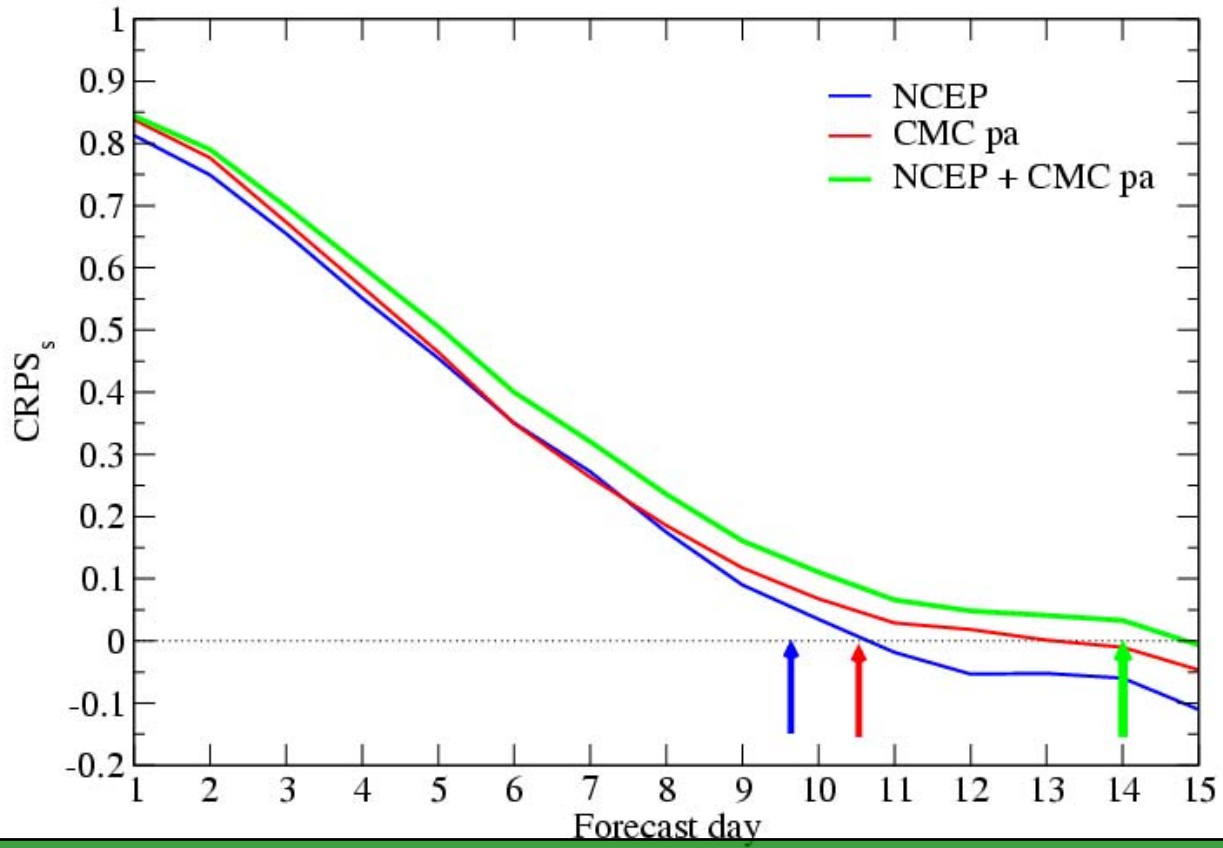
- **Raw data exchange (00 and 12 UTC runs).**
  - **00 and 12 UTC production runs.**
  - **~ 50 selected variables.**
  - **6-hourly output frequency over 16 days.**
  - **GRIB1 format moving to GRIB2.**

- Basic products:
  - Using same algorithms/codes.
  - Bias correction algorithm.
  - Forecast products in terms of climatological anomalies.
  - Week 2 (days 8 to 14) forecasts based on the combined MSC/NCEP ensembles.
  - Weighted combination of members.

- Center specific end products.
- Evaluation and feedback for improvements:
  - Verification using same approaches

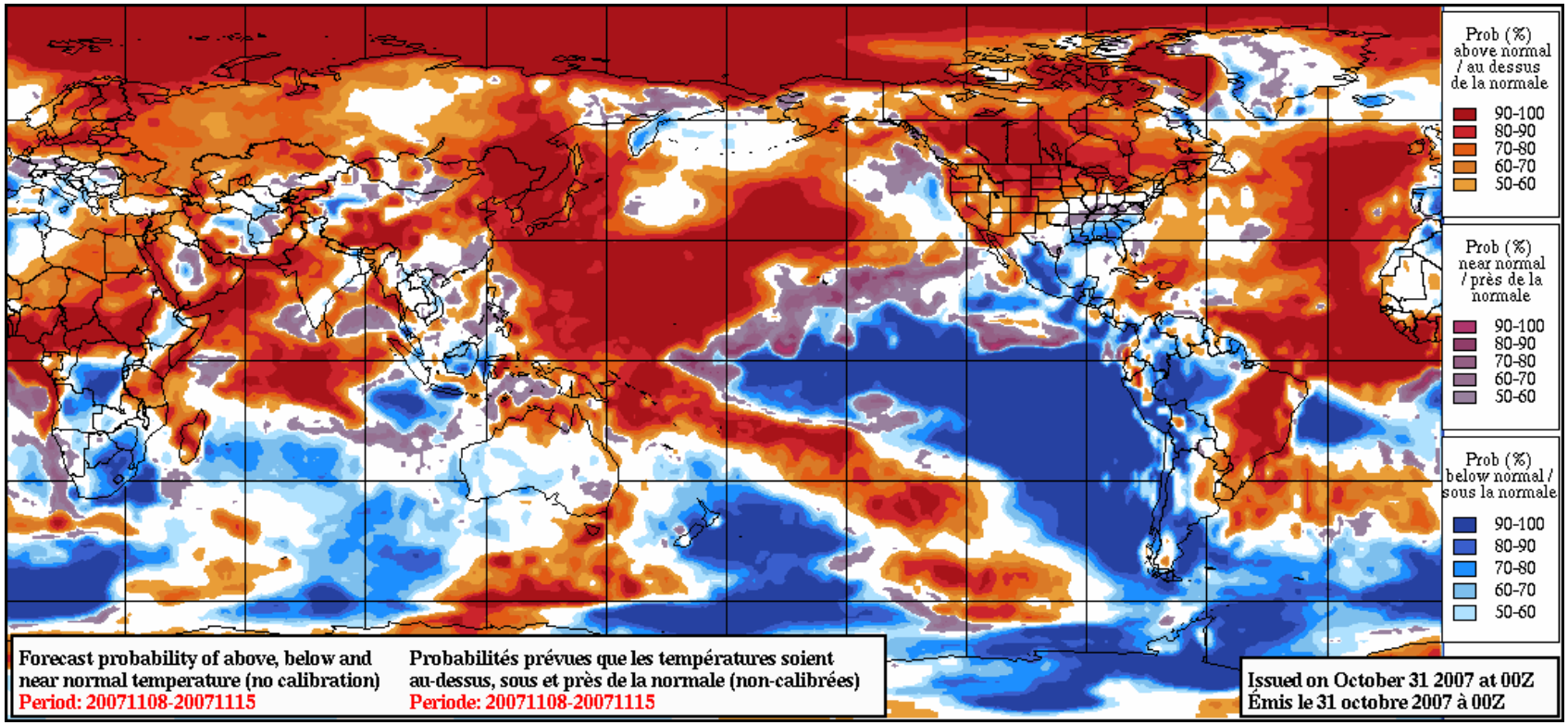
NAEFS reward: predictability gain of 0.5-1 day

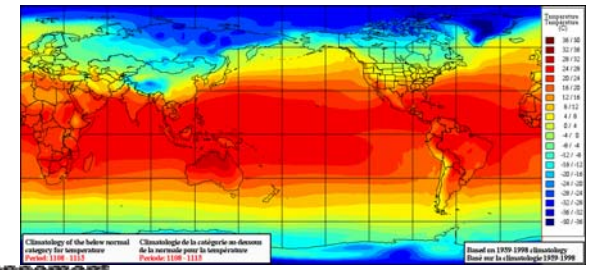
Geopotential heights at 500 hPa (global scale, 60 days Oct-Nov 2006)

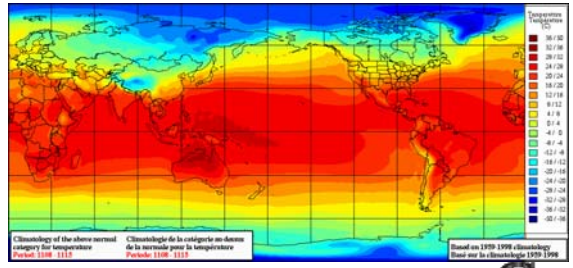


Generally, NCEP has better resolution while MSC has better reliability!

Common product: Week 2 temperature anomaly forecast







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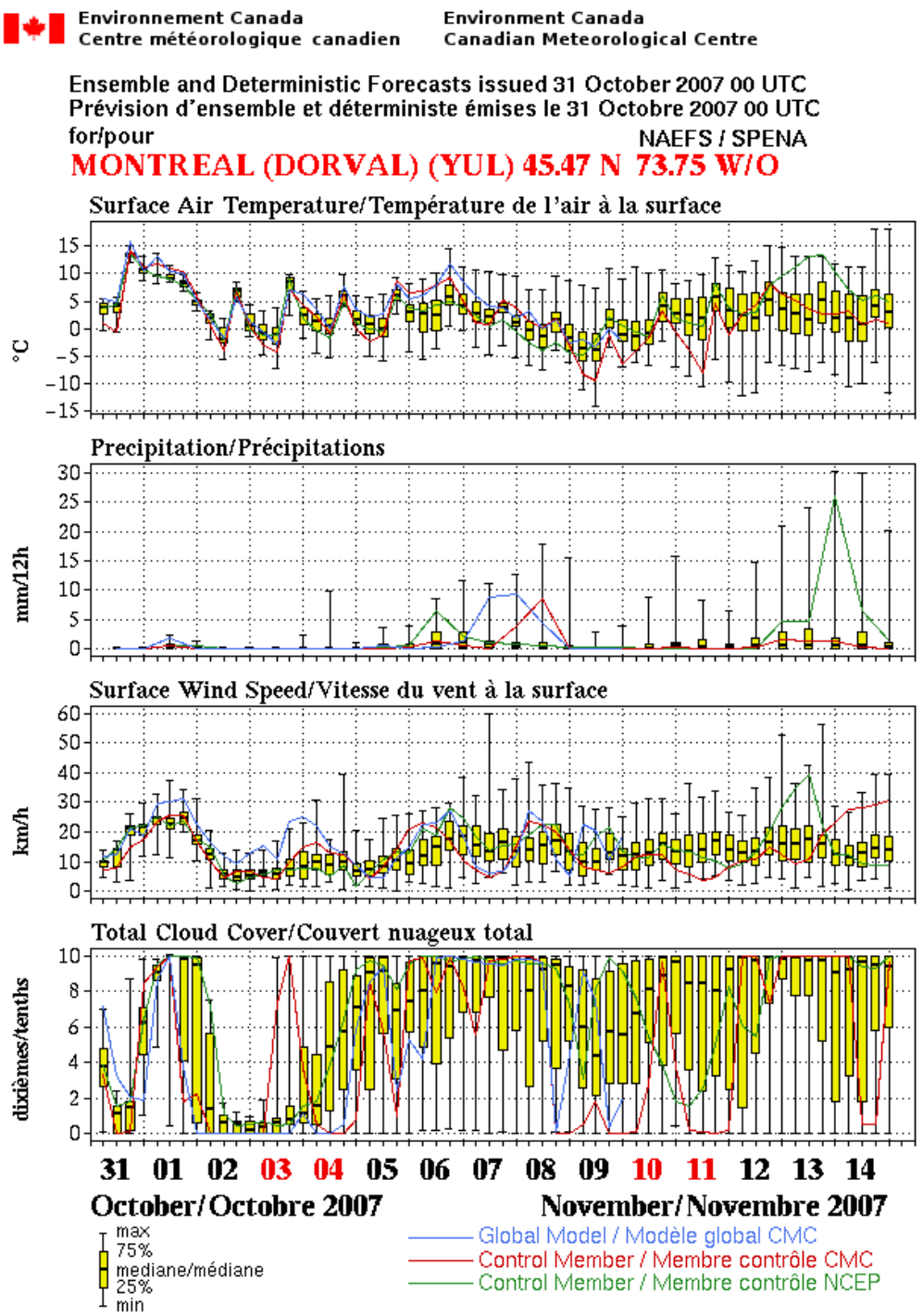
EPSgrams with 40 members



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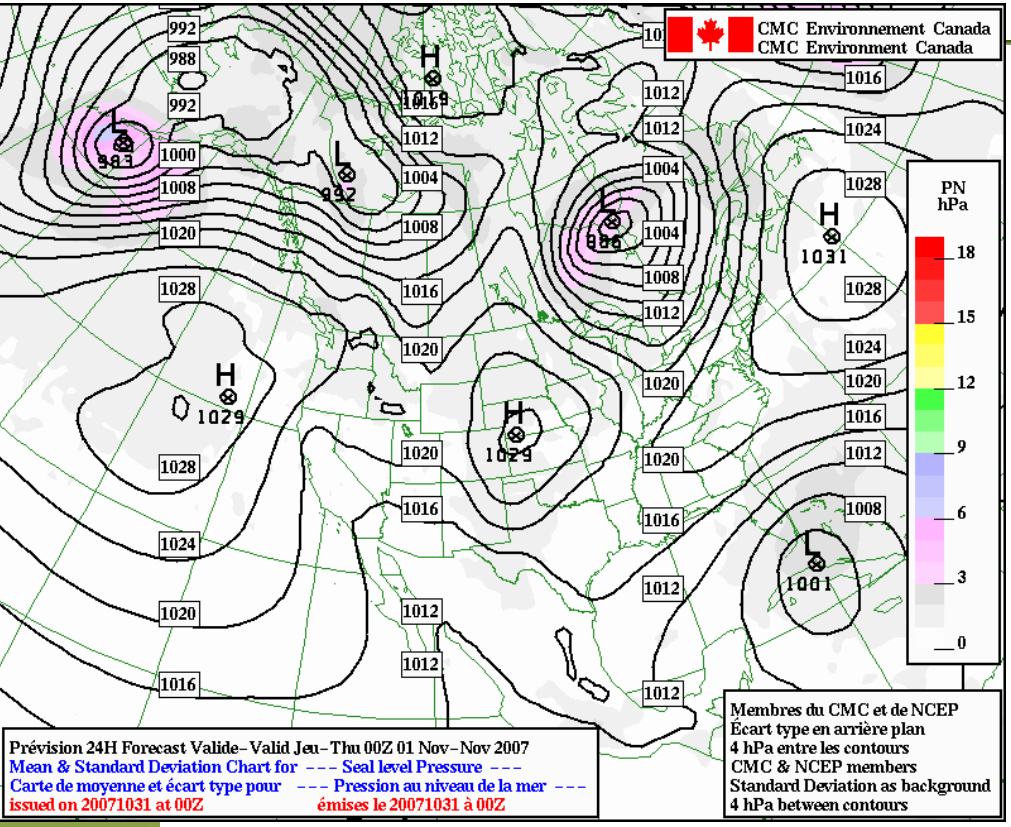
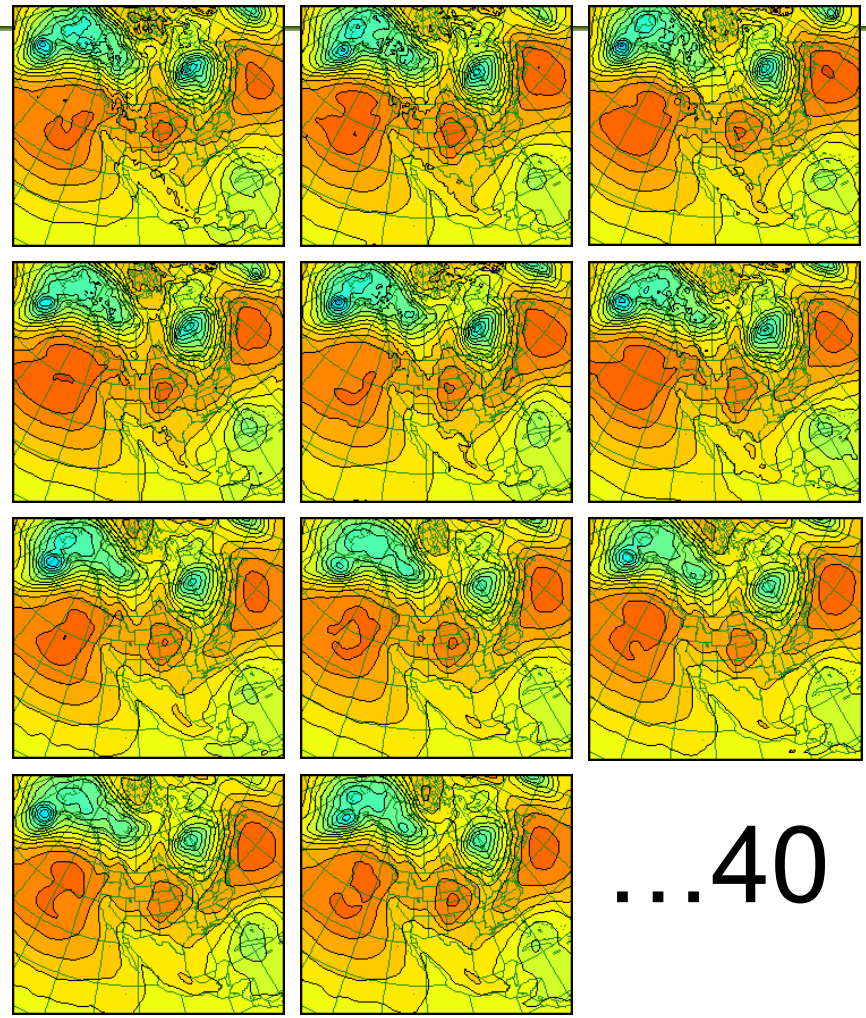
Mean and standard deviation of the NAEFS ensemble





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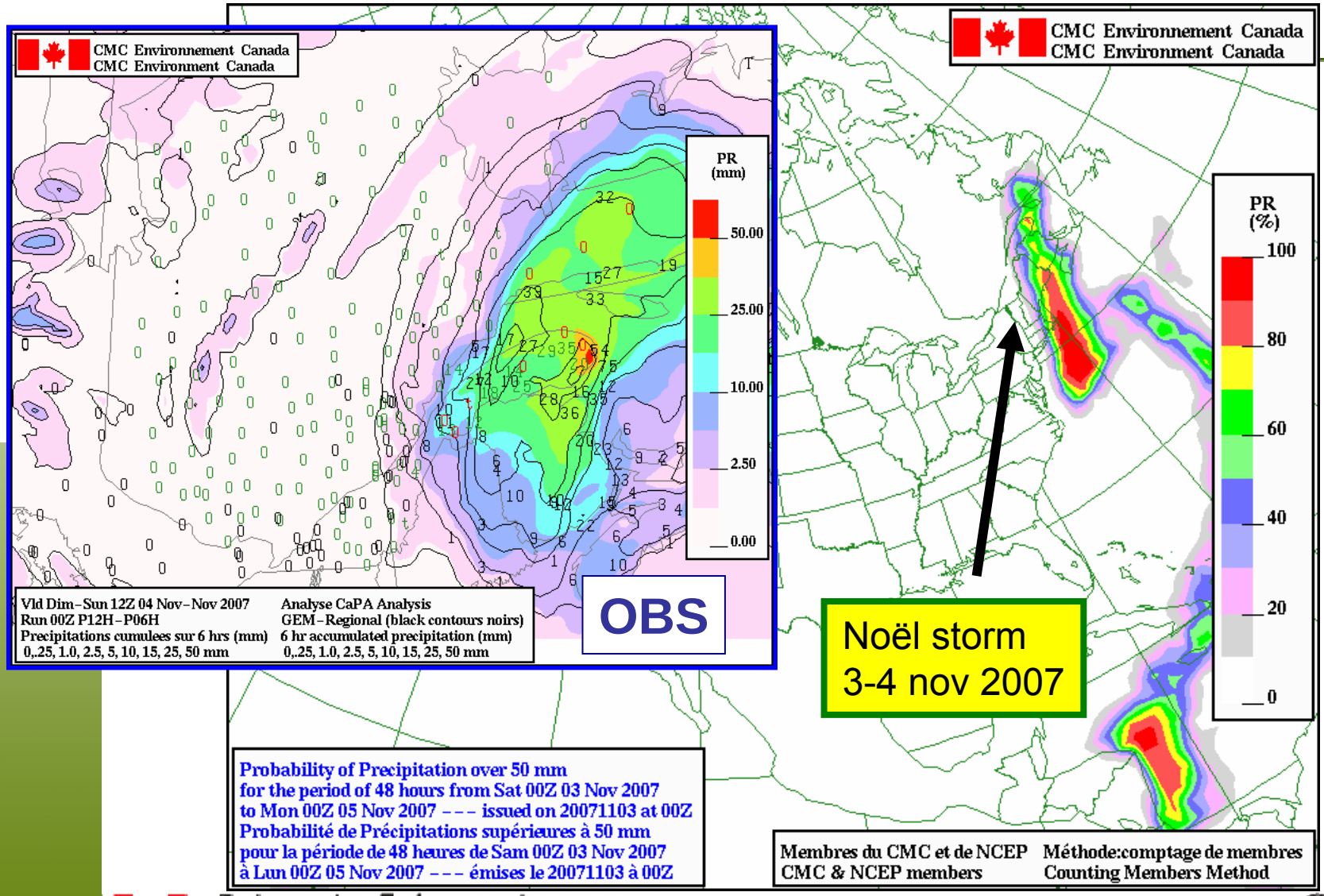
Probability of exceedance with 40 members



Products

- Images:
  - http://www.weatheroffice.gc.ca/ensemble/index_e.html
    http://www.meteo.gc.ca/ensemble/index_f.html
  - NAEFS:
    - http://www.weatheroffice.gc.ca/ensemble/index_naefs_e.html
      http://www.meteo.gc.ca/ensemble/index_naefs_f.html
- Digital data (GRIB1):
  - http://www.weatheroffice.gc.ca/grib/index_e.html

    http://www.meteo.gc.ca/grib/index_f.html

EPS Training Tour

- A 2-day workshop developed essentially by Richard Verret on a special assignment for a few months. A colossal work of more than 800 slides!
  - Module 1: The illusion of determinism
  - Module 2: Probabilistic forecasts
  - Module 3: EPS basic concepts
  - Module 4: EPS Construction
  - Module 5: EPS products
  - Module 6: Application of EPS
  - Module 7: Future

  + Case studies from regional weather forecasters

EPS Training Tour

- Given twice in each Canadian forecast centers in the Spring of 2007 by two teams of 2 members with operational and development background.
- French and English.
- Local case studies developed by regional forecasters.
- Reach a majority of operational forecasters.
- Additional sites will be visited this fall.
- Some of the content will be included in the initial training for new forecasters.
- Available at:
  - http://collaboration.cmc.ec.gc.ca/cmc/ensemble/Formation-Training/Lisez-moi.html
  - http://collaboration.cmc.ec.gc.ca/cmc/ensemble/Formation-Training/Read-me.html

Summary

- The Canadian EPS is now simply
  - bigger (+ 4 members),
  - finer (0.9 deg),
  - better (RMS, CRPS),
  - wider (more spread)
  - more balanced (spread/error),
  - more « trendy » (4D assimilation),
  - simpler (only one dynamical core),
  - more equi-probable (uniform quality of members),
  - more « tropical » (much better skill there)
  - more collaborative (NAEFS,TIGGE),
  - and better known (training tour).

Thanks!