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Canada

Model Error Representation in the Canadian Ensemble Prediction Systems

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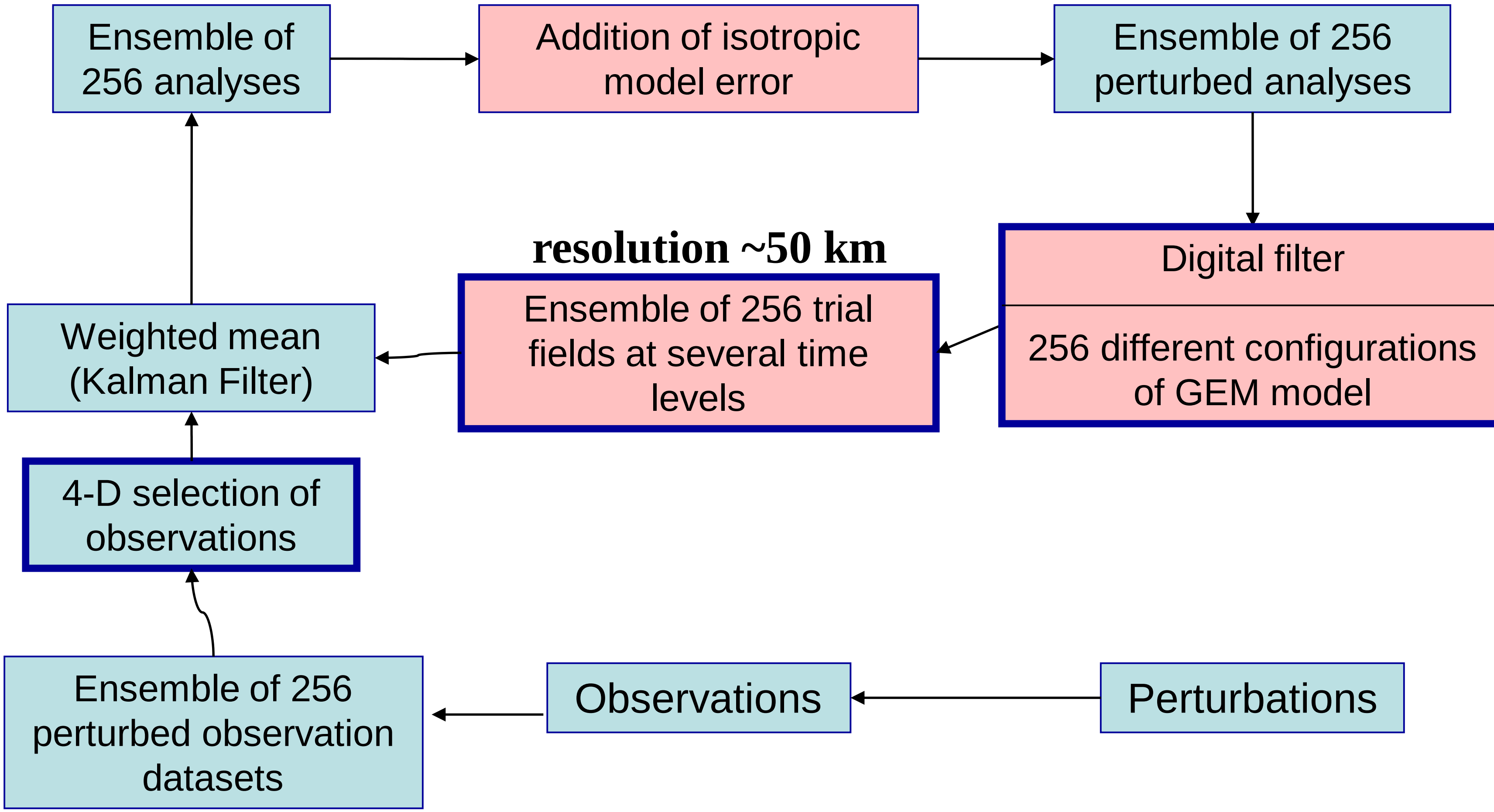
Outline

- Current error sampling practices at Meteorological Service of Canada
  - Data Assimilation with Ensemble Kalman Filter (EnKF)
  - Ensemble Prediction based on
    - Multi-parameterization approach
    - Stochastic physical tendency perturbations (PTP)
    - Stochastic kinetic energy backscatter scheme (SKEB)
- Ongoing work on a stochastic deep convection scheme
  - Modification of the Bechtold scheme (Bechtold *et al.*, 2001) to include stochastic component
  - Approach based on the Plant-Craig scheme (Plant and Craig, 2008).

Data assimilation (EnKF)



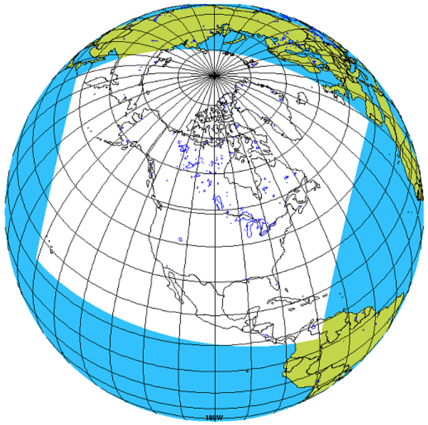
(Houtekamer *et al*., 2014)

Global Ensemble Prediction System (GEPS)

- System configuration:
  - **21** members (one control and 20 perturbed).
  - GEM dynamical core
  - A 0.45º **(~50 km** at the equator) global uniform grid, **40** vertical levels
  - **16-day** integrations (32 days once a week).
- Model error representation:
  - **Initial conditions**: selection of 20 out of the 256 EnKF perturbed analyses to initialize GEPS members.
  - **PTP** (Buizza *et al.* 1999; Charron *et al.* 2010) disabled if deep convection is active
  - **SKEB** scheme (Shutts, 2005)
  - **Multi-physics** approach.

Regional Ensemble Prediction System (REPS)

- System configuration:
  - **21** members
  - GEM dynamical core
  - A ~**15 km** limited-area grid over N. America, **48** vertical levels
  - Lateral boundary conditions updated hourly from GEPS
  - **72-hr** integrations.
- Model error representation:
  - Initial conditions: Interpolated global analyses
  - Lateral boundary conditions: 21 GEPS members
  - **PTP**
  - **no** SKEB, **no** multi-physics.



GEPS physics configurations

No.	Convection	Gravity wave drag	Mixing length	Vertical Diffusion	Orographic blocking	Deacu Z0T	Salty QSAT	SKEB	PTP
0	Kain&Fritsch	Standard	Bougeault	1.0	1.0	Yes	Yes	No	No
1	Kain&Fritsch	Strong	Blackadar	1.0	1.5	Yes	No	Yes	Yes
2	Kuo	Strong	Blackadar	1.0	0.5	No	No	Yes	Yes
3	Kain&Fritsch	Weak	Bougeault	0.85	0.5	Yes	Yes	Yes	Yes
4	Kuo	Weak	Bougeault	0.85	0.5	No	No	Yes	Yes
5	Kain&Fritsch	Weak	Blackadar	1.0	1.5	No	No	Yes	Yes
6	Kuo	Weak	Blackadar	1.0	0.5	Yes	Yes	Yes	Yes
7	Kain&Fritsch	Weak	Bougeault	1.0	1.5	No	Yes	Yes	Yes
8	Kuo	Weak	Bougeault	1.0	0.5	No	Yes	Yes	Yes
9	Kain&Fritsch	Strong	Bougeault	1.0	1.5	Yes	Yes	Yes	Yes
10	Kuo	Strong	Bougeault	1.0	0.5	No	Yes	Yes	Yes
11	Kain&Fritsch	Strong	Bougeault	0.85	1.5	No	No	Yes	Yes
12	Kuo	Strong	Bougeault	0.85	0.5	No	No	Yes	Yes
13	Kain&Fritsch	Weak	Blackadar	0.85	1.5	Yes	No	Yes	Yes
14	Kuo	Weak	Blackadar	0.85	0.5	Yes	Yes	Yes	Yes
15	Kain&Fritsch	Strong	Blackadar	0.85	1.5	Yes	Yes	Yes	Yes
16	Kuo	Strong	Blackadar	0.85	0.5	No	Yes	Yes	Yes
17	Kain&Fritsch	Strong	Blackadar	1.0	0.5	No	No	Yes	Yes
18	Kuo	Strong	Blackadar	1.0	1.5	No	Yes	Yes	Yes
19	Kain&Fritsch	Weak	Bougeault	0.85	1.5	No	No	Yes	Yes
20	Kuo	Weak	Bougeault	0.85	0.5	No	Yes	Yes	Yes

EnKF physics configurations

No.	Convection	Gravity wave drag	Mixing length	Vertical Diffusion	Orographic blocking	Deacu Z0T	Salty QSAT	SKEB	PTP
0	Kain&Fritsch	Standard	Bougeault	1.0	1.0	Yes	Yes	No	No
1	Kain&Fritsch	Strong	Blackadar	1.0	1.5	Yes	No	Yes	Yes
2	Kuo	Strong	Blackadar	1.0	0.5	No	No	Yes	Yes
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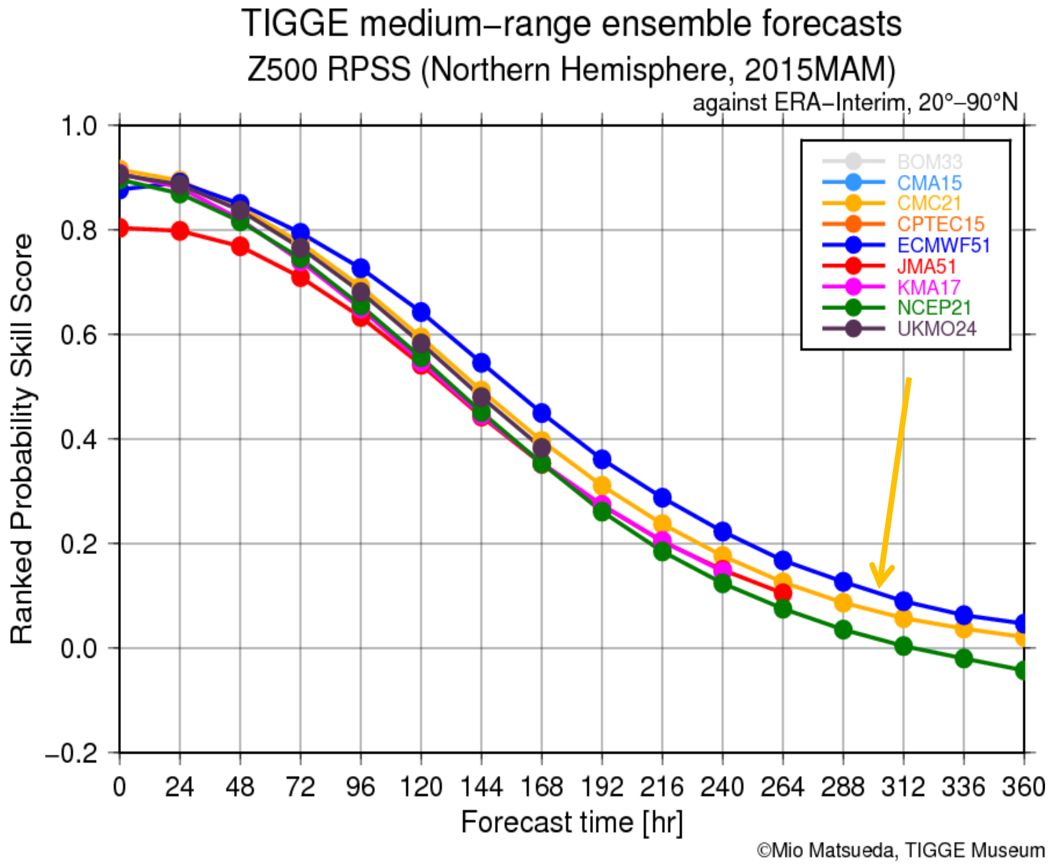
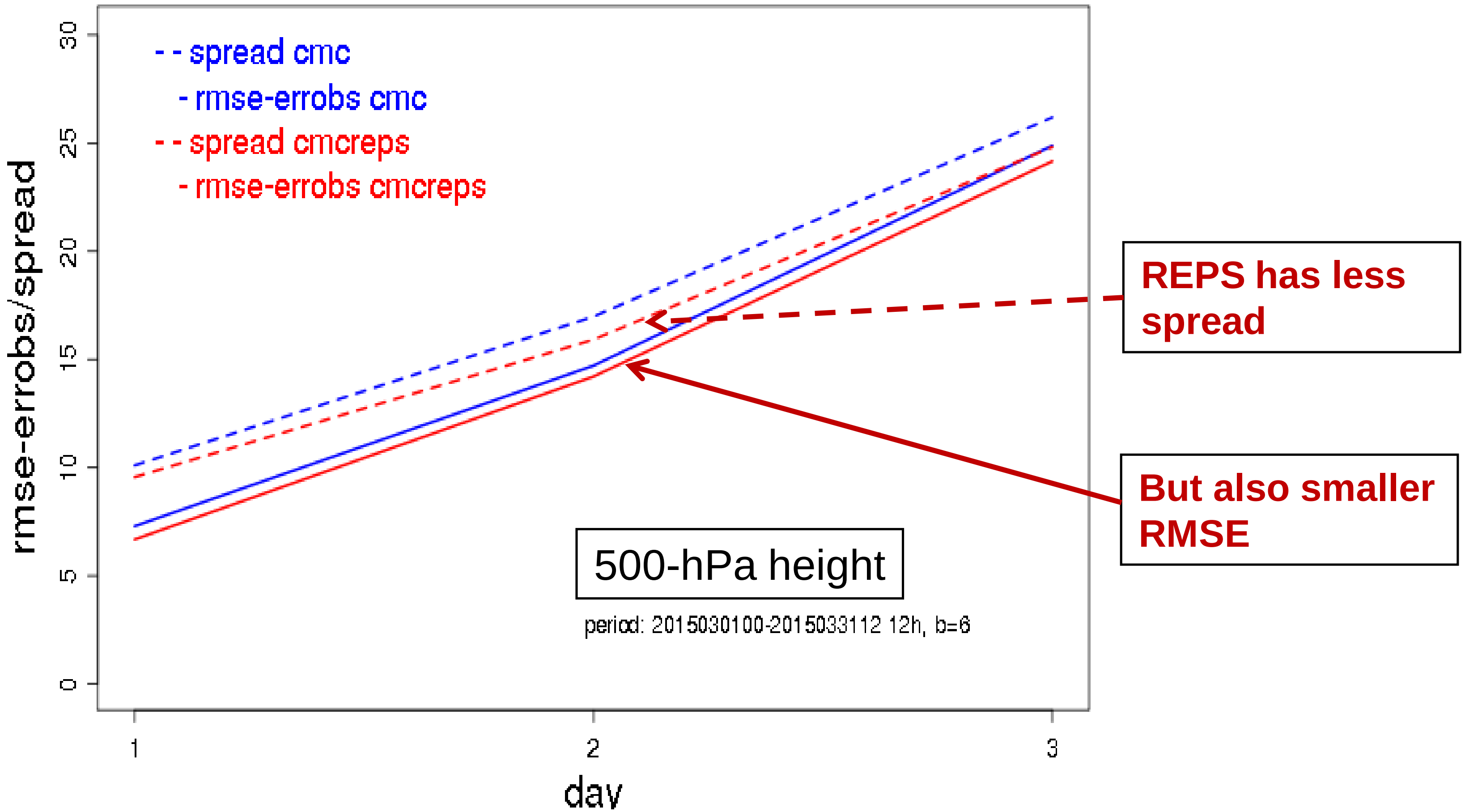
20	Kuo	Weak	Bougeault	0.85	0.5	No	Yes	Yes	Yes

GEPS performance

- GEPS generally places well as compared to other centres:

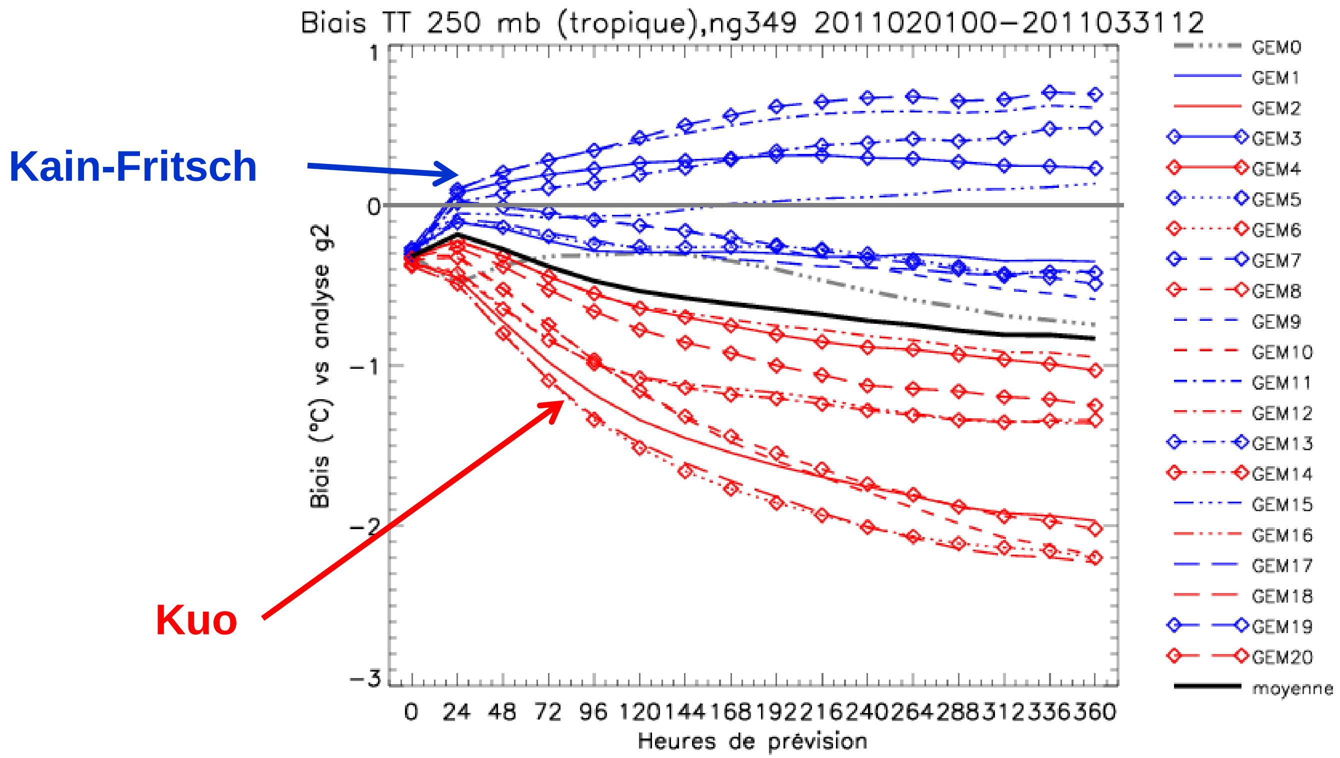


REPS vs. GEPS performance



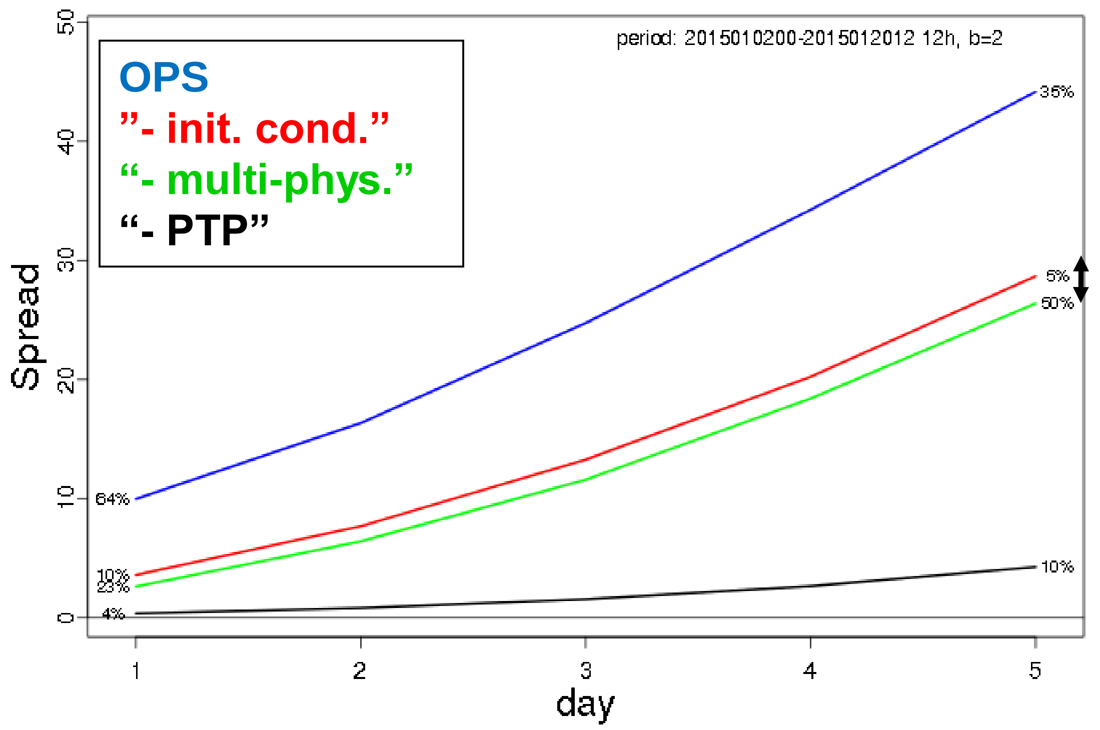
GEPS performance

- Bimodality in T-250mb in the tropics due to the use of two deep-convection schemes:



GEPS performance

- Contribution of the system subcomponents to ensemble spread for NH 500mb height:



The impact of multi-physics is relatively small

(poster of **N. Gagnon)**

Stochastic Deep Convection Scheme

- Current scheme is based on the **Plant-Craig (PC)** stochastic deep convection parameterization (Plant and Craig, 2008).
- The cloud model is however adopted from the **Bechtold scheme**:
  - A bulk mass flux convection parameterization
  - Modular structure
  - Consistent deep and shallow convection representation.
- Two principal modifications to the Bechtold scheme:
  - Closure modification: calculate tendency based on the weighted-average plume properties (*still deterministic*)
  - Plume random generation : draw plumes from the size distribution (*stochastic component to the scheme*).

Plant-Craig scheme

- **Exponential distribution** of cloud-base mass flux of subgrid-scale plumes:

$$p(m) = \frac{1}{\langle m \rangle} \exp\left(-\frac{m}{\langle m \rangle} \right)$$

  where < > denotes the expected value and <m> is a tunable parameter.

- **Constant vertical velocity** at the cloud base:

$$m = \langle m \rangle r^2 / \langle r^2 \rangle$$

- PDF of the cloud radius at the LCL follows (Plant and Craig, 2008):

$$p(r) = \frac{2r}{\langle r^2 \rangle} \exp\left(-\frac{r^2}{\langle r^2 \rangle} \right)$$

Plant-Craig scheme

- **Plume sampling function** – on average **<N>** plumes is generated during the specified cloud life time **T**:

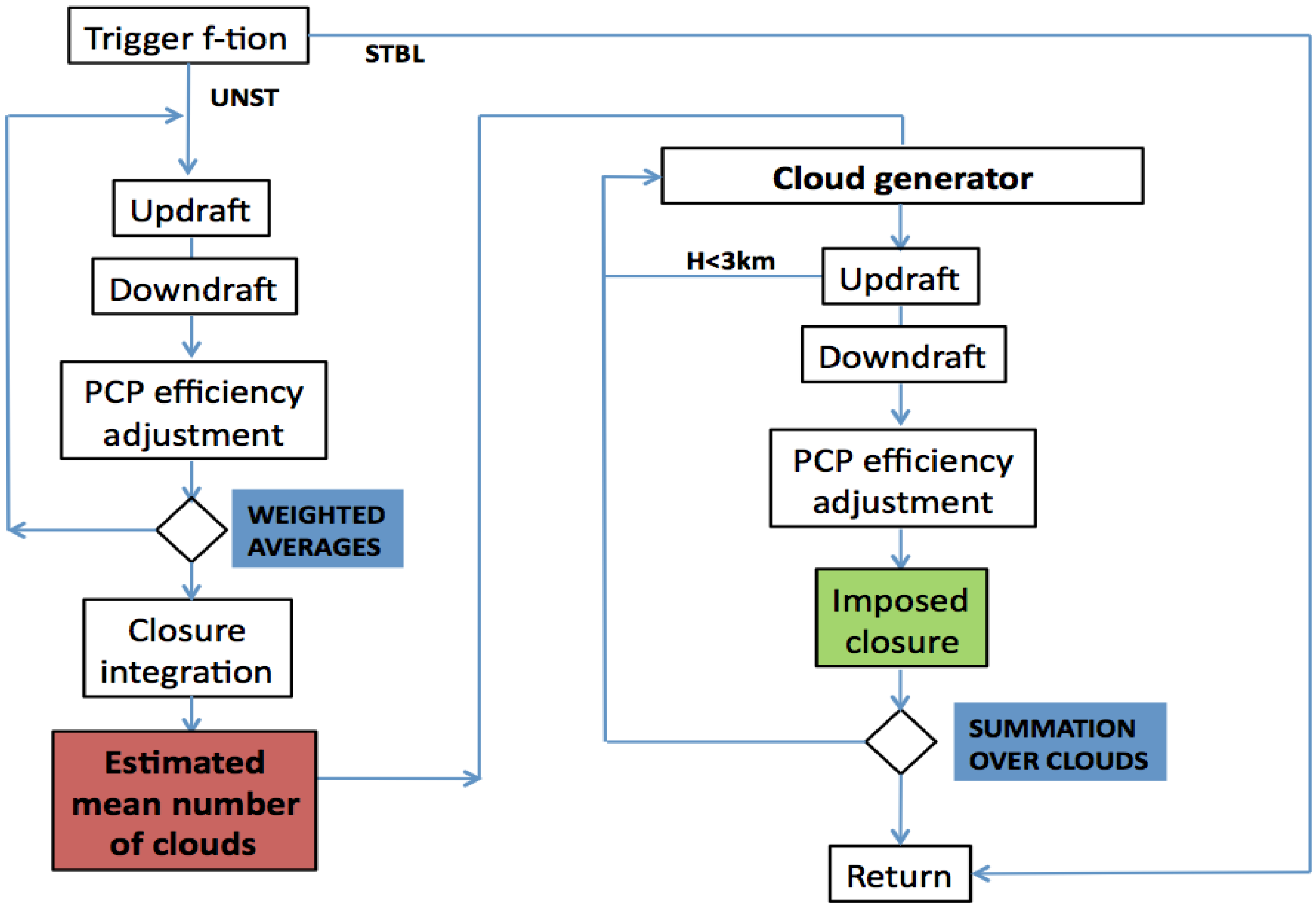
$$p(r)dr = \langle N \rangle \frac{\Delta t}{T} \frac{2r}{\langle r^2 \rangle} \exp\left(-\frac{r^2}{\langle r^2 \rangle} \right) dr$$

- **Mean number of plumes <N>** is calculated from the net grid-area updraft mass flux **<M>** and the expected individual updraft mass flux **<m>** at the LCL, as

$$\langle N \rangle = \langle M \rangle / \langle m \rangle$$

- **Net grid-area mass flux <M>** is obtained **from closure** assumptions in the deep-convection scheme.

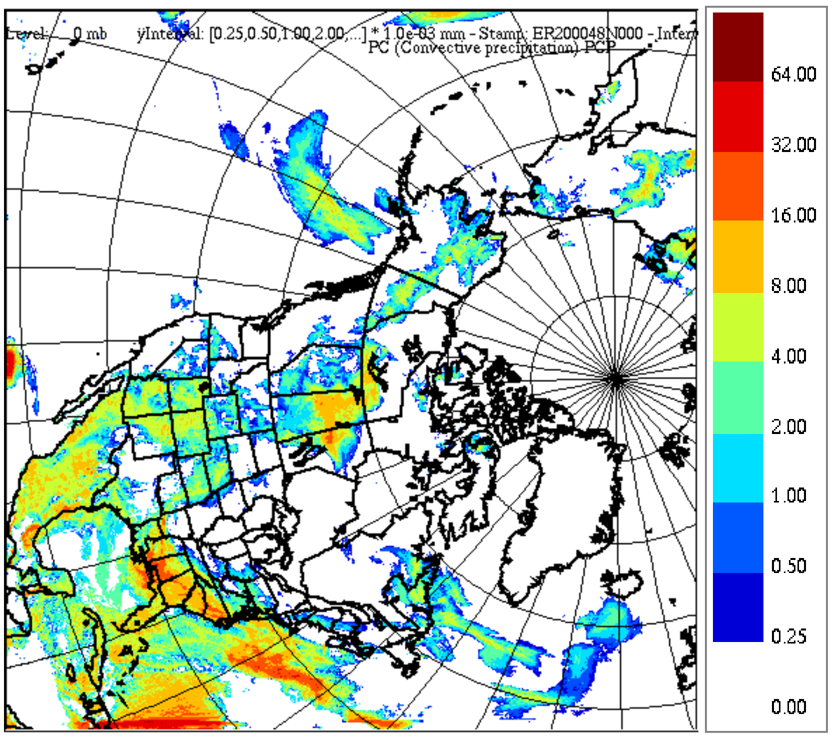
Modification of Bechtold Deep Convection Scheme



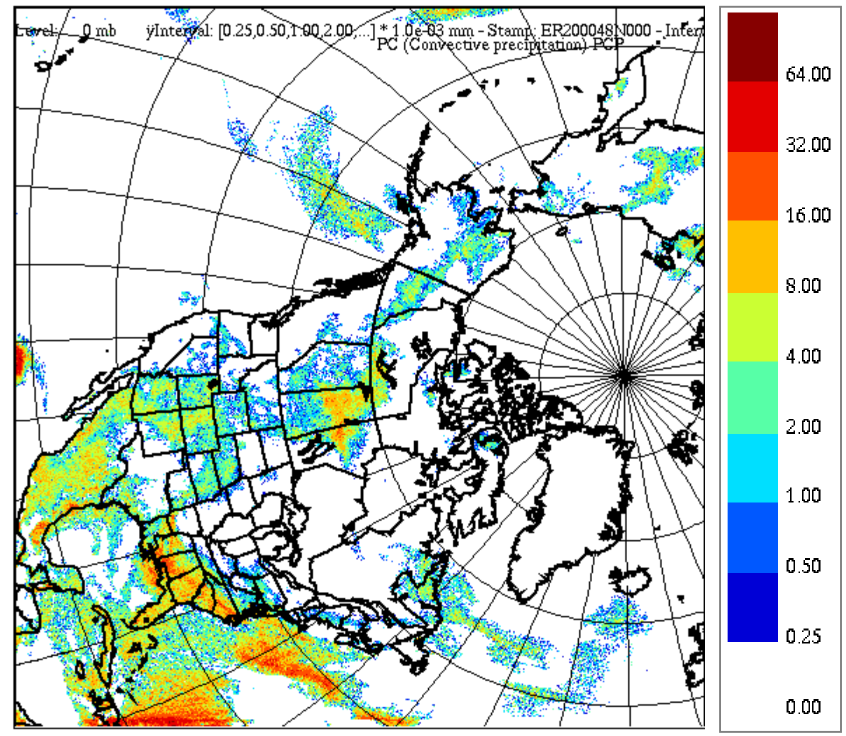
Application in REPS

- REPS 2014-07-10-00 CONTROL MEMBER: 00-24h **convective precipitation** accumulation [mm/day]

BECHTOLD SCHEME (DETERMINSTIC)



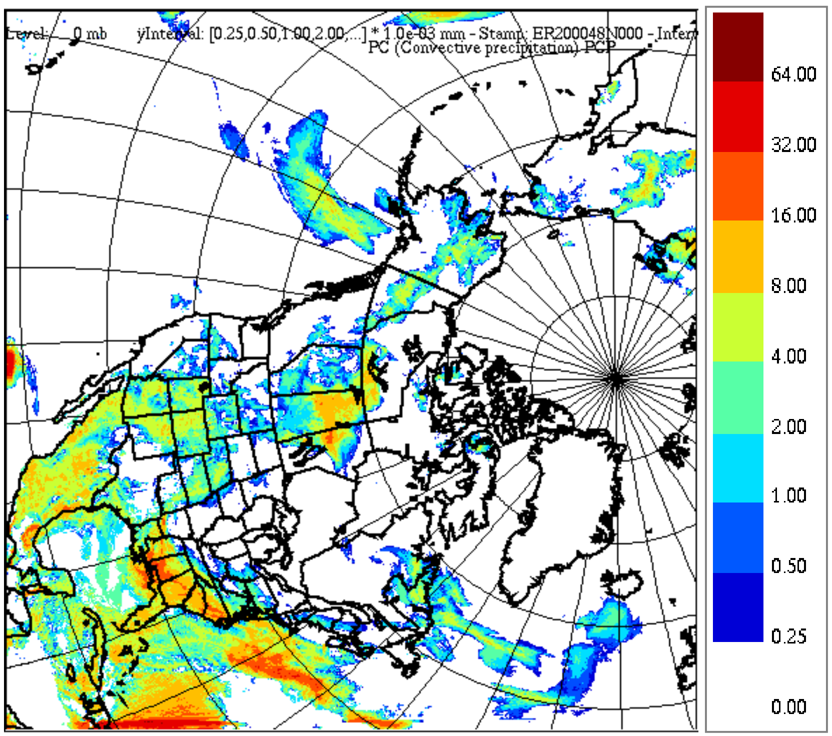
BPC SCHEME (STOCHASTIC)



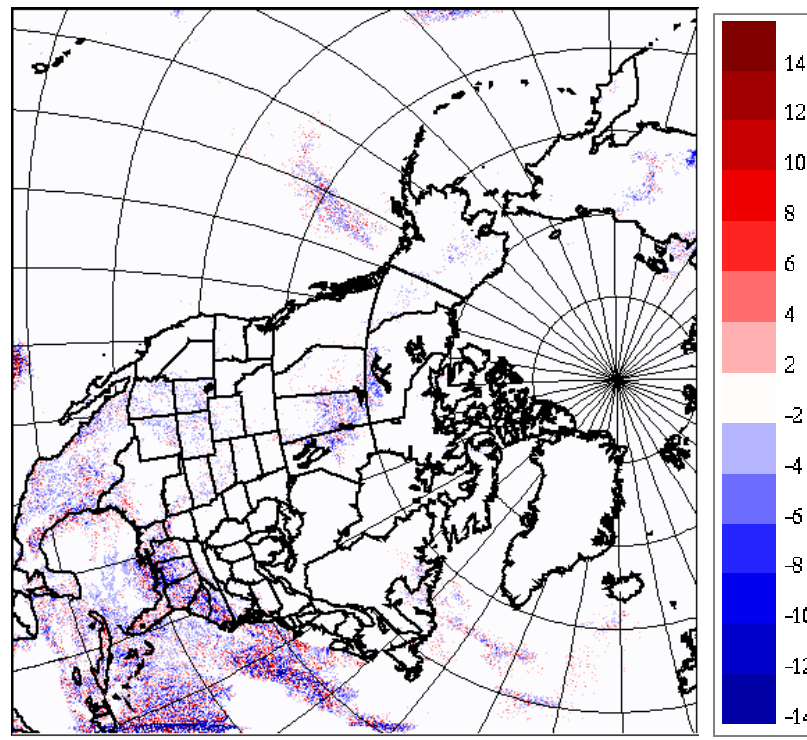
Application in REPS

- REPS 2014-07-10-00 CONTROL MEMBER: 00-24h **convective precipitation** accumulation [mm/day]

BECHTOLD SCHEME (DETERMINSTIC)

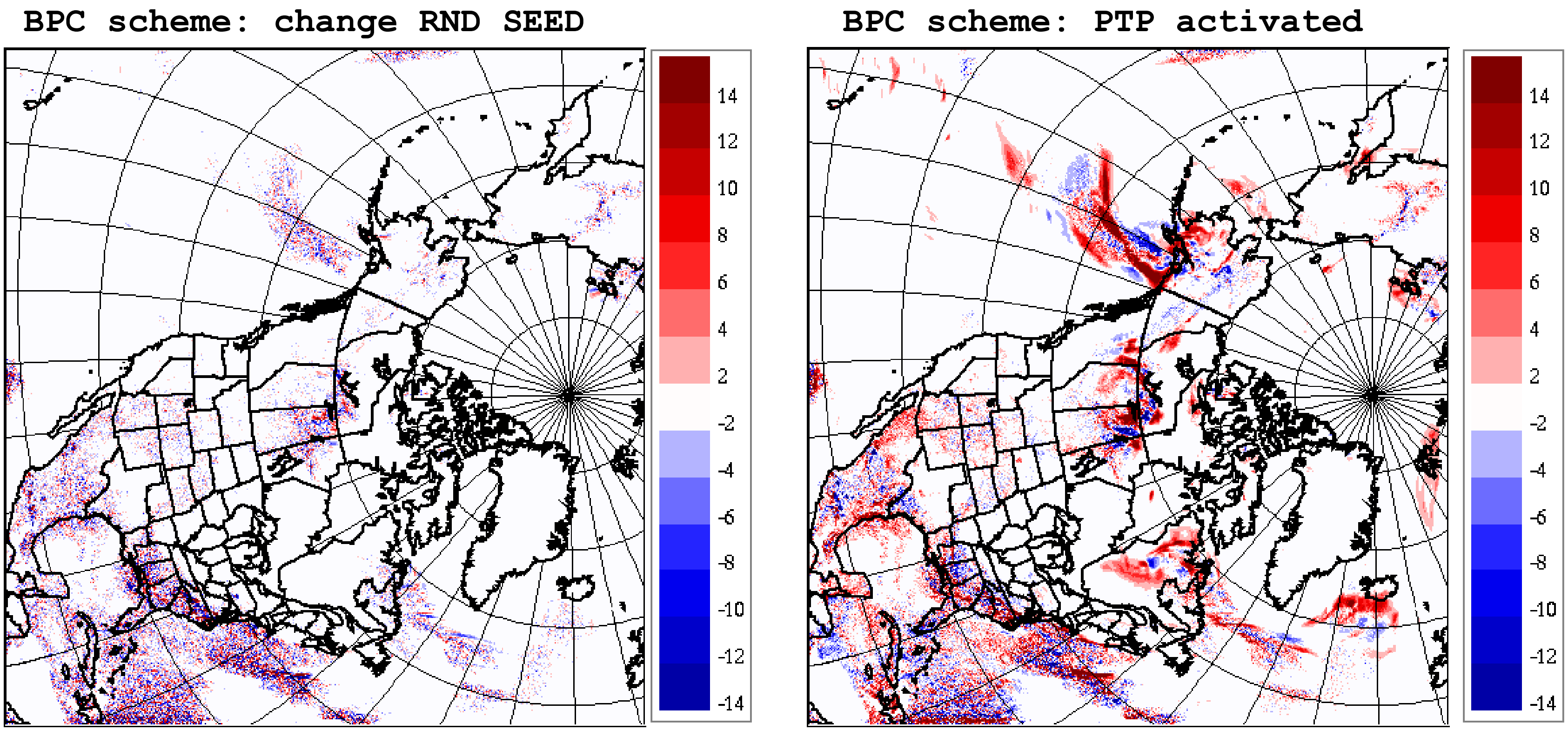


Difference BPC-BECHTOLD



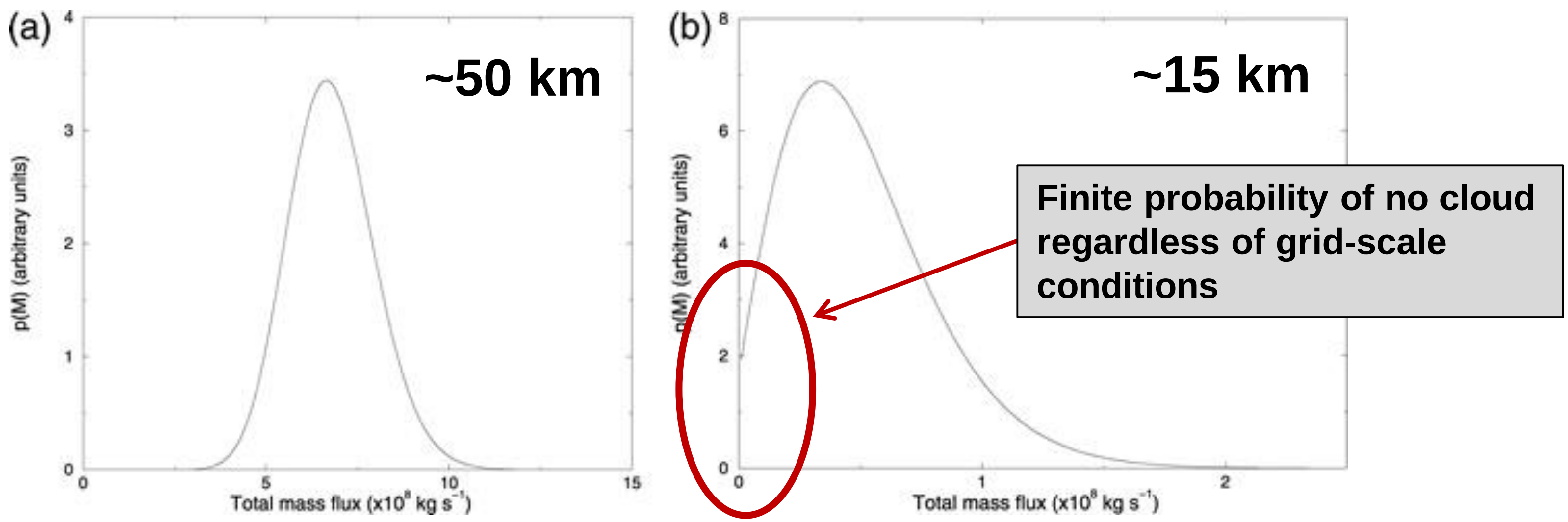
Application in REPS

- REPS 2014-07-10-00 CONTROL MEMBER: 00-24h **TOTAL precipitation** accumulation [mm/day]



Net grid-area updraft mass flux distribution

- **Resulting grid-scale cloud-base updraft mass flux PDF for average number of clouds: (a) <N>=68 and (b) <N>=5**



Craig and Cohen (2006)

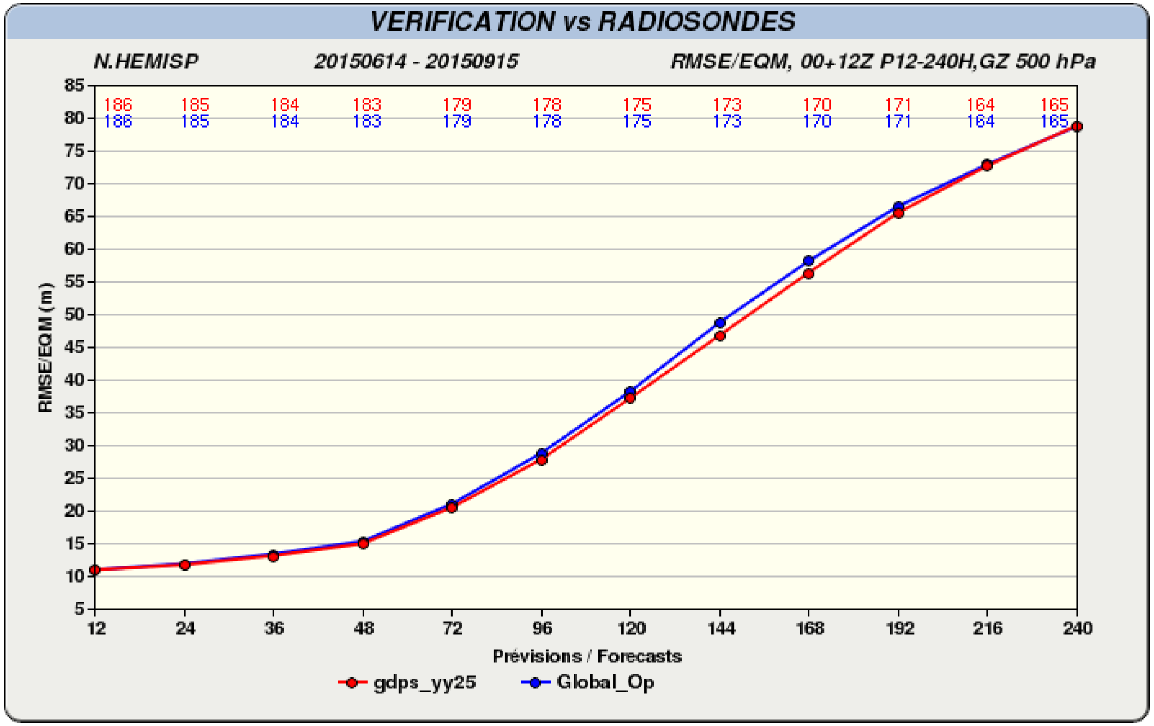
- Can model try to substitute the deep convection scheme with a “grid-scale storm”?

Summary

- GEPS and REPS in general place well, compared to other centres.
- Multi-physics approach
  - has relatively small impact on the spread in GEPS
  - bimodality - not correlated with uncertainty in the forecast.
- So far, rather moderate expectations from the stochastic deep convection approach
  - expected to add fine-scale variability to precipitation and near-surface fields and increase the spread
  - far from substituting PTP.
- Future work
  - stochastic shallow convection in the Bechtold scheme
  - other schemes (e.g., boundary layer, gravity wave drag).

Impact of Inconsistencies in Discretizations

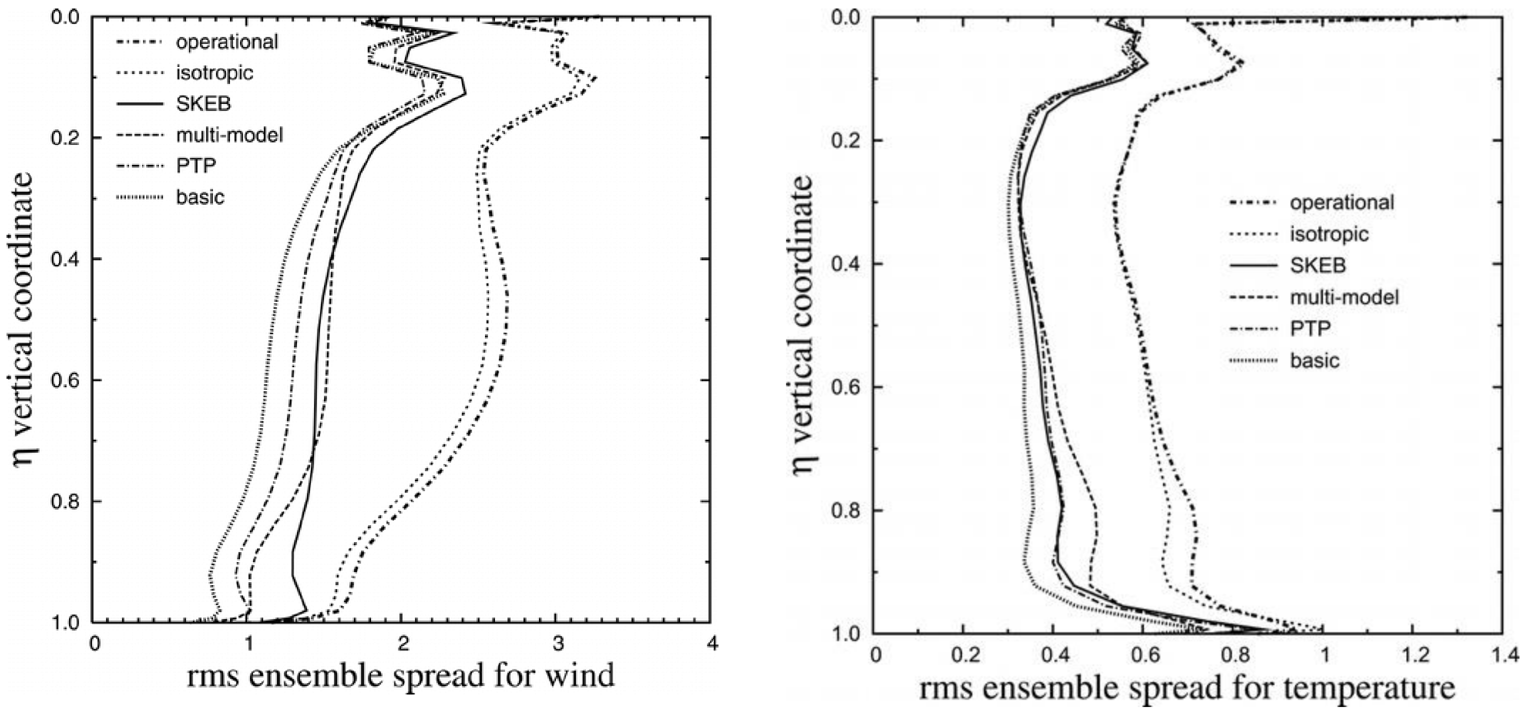
- Inconsistencies between the Semi-Lagrangian advection and trajectory calculations:
  - Mid-point -> Trapezoidal rule in trajectory calculations
  - Linear -> cubic interpolation in the calculations for departing positions.



return

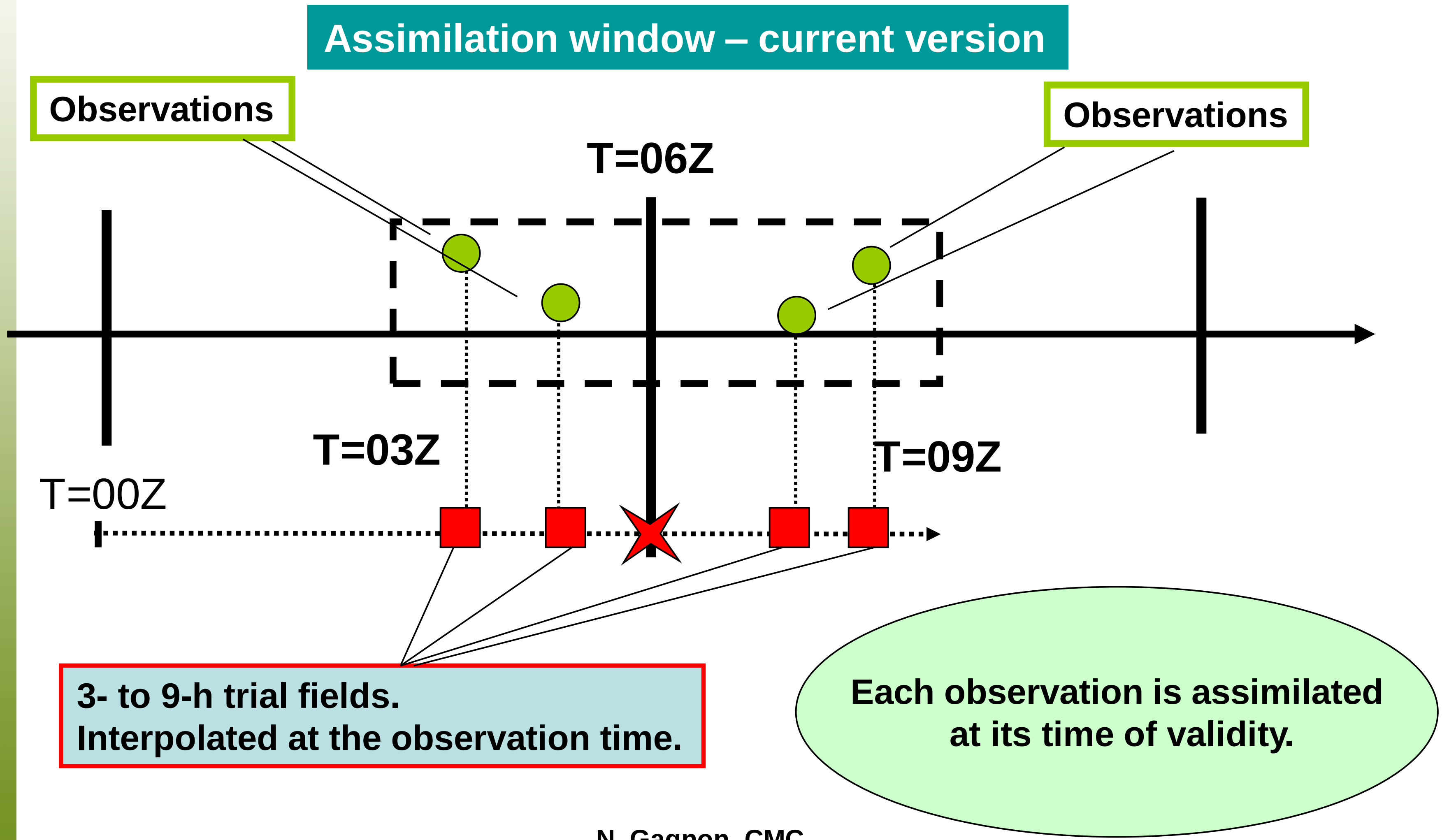
Stochastic perturbations in the EnKF

- Approaches to model error simulation, such as PTP and SKEB, are costly but have a small contribution to ensemble spread in the EnKF context:



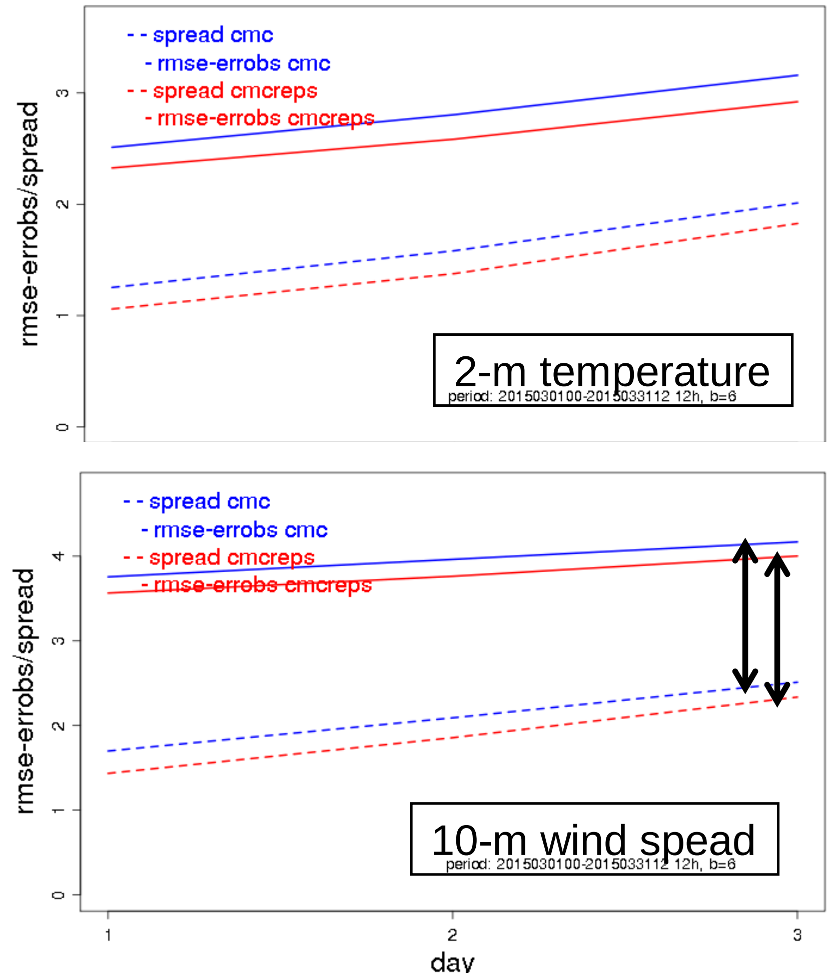
Houtekamer et al. (2009)

EnKF - 4D assimilation cycle



N. Gagnon, CMC

REPS vs. GEPS



At the surface REPS does not improve the RMSE/SPREAD ratio.

Space for improvement:

- no perturbations of land-surface fields
- uniform observation error statistics