The New Global Ensemble Prediction System at CMC: Description and Results

Recherche en prévision numérique
Meteorological Research Division
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Background

- This new EPS should become operational at CMC in June or July 2007
- The resources that MRD and CMC-Development have put into this specific project is close to 10 PYs
- The duration of this project from its initiation to its operational implementation: 24 months

Outline

1. Introduction: The former global EPS
2. Description of the new elements in the EPS
    a) New physics / New dynamics / Horizontal resolution
    b) Stochastic physical tendency perturbation
    c) Stochastic kinetic energy backscatter scheme
    d) Initial conditions / Data assimilation
3. Comparison between the former and new EPS
4. Impact on scores of each new element
5. Conclusions and future directions

1. The former global EPS

- 16 members: 8 using the Spectral Éléments Finis (SEF) model, and 8 using the Global Environmental Multiscale (GEM) model
- Horizontal resolution: T149 (SEF), 1.2° (GEM)
- Model lid: 10 hPa
- Forecasts up to 16 days
- Assimilation component: 4x24 members at 1.2° (GEM only) with data supposed valid at synoptic times
- The multi-parameterization approach...

1. The former global EPS (continued)

TABLE 1a. Parameterizations/parameters for the former EPS. Members 1 to 8 employ SEF. Members 9 to 16 employ GEM.

Mem.	Deep conv.	Shallow conv. 1	Shallow conv. 2	Condens.	Surface scheme	Vert. levels	Adv. time levels	$E\mu_e/2$ $(10^{-5}\mathrm{m}^{-1})$
01	Kuo	Conres	Nil	Mod. Sundq.	ISBA	27	2	1.2
02	R. A.-S.	Turwet	Kuo trans.	Sundq.	F.-rest.	27	2	1.2
03	Kuo	Conres	Nil	Mod. Sundq.	F.-rest.	27	2	0.4
04	R. A.-S.	Turwet	Kuo trans.	Sundq.	ISBA	27	2	0.4
05	R. A.-S.	Conres	Nil	Sundq.	F.-rest.	27	3	1.2
06	Kuo	Conres	Nil	Mod. Sundq.	ISBA	27	3	1.2
07	R. A.-S.	Turwet	Kuo trans.	Sundq.	ISBA	27	3	0.4
08	Kuo	Conres	Nil	Mod. Sundq.	F.-rest.	27	3	0.4
09	Kuo sym.	Turwet	Kuo trans.	Sundq.	F.-rest.	28	2	0.8
10	R. A.-S.	Conres	Nil	Sundq.	ISBA	28	2	0.8
11	R. A.-S.	Conres	Nil	Sundq.	F.-rest.	28	2	0.8
12	Kuo sym.	Turwet	Kuo trans.	Sundq.	ISBA	28	2	0.8
13	Kuo	Turwet	Kuo trans.	Sundq.	F.-rest.	28	2	0.8
14	Kuo	Conres	Nil	Sundq.	ISBA	28	2	0.8
15	Kuo sym.	Conres	Nil	Sundq.	ISBA	28	2	0.8
16	Kuo	Conres	Nil	Mod. Sundq.	F.-rest.	28	2	0.8

2. Description of the new elements in the EPS

a) New physics / New dynamics / Horizontal resolution

- 20 GEM members (SEF not used in the new global EPS)
- Horizontal resolution: 0.9°
- Model lid: 10 hPa
- Forecasts up to 16 days
- Inclusion of two stochastic components in the physics
- Multi-parameterization approach...

2. Description of the new elements in the EPS

TABLE 1b. Parameterizations/parameters for the current EPS. All members employ GEM.

Mem.	Deep conv.	Shallow conv. 1	Shallow conv. 2	Condens.	Surface scheme	Turb. bound. layer	β	$E\mu_e/2$ (10^{-5}m^{-1})
01	K.-F.	Conres	Kuo trans.	Sundq.	ISBA	Bougeault	1.00	0.4
02	Kuo	Conres	Nil	Mod. Sundq.	F.-rest.	Bougeault	0.85	1.2
03	K.-F.	Conres	Kuo trans.	Sundq.	F.-rest.	Blackadar	0.85	0.4
04	Kuo	Conres	Nil	Mod. Sundq.	ISBA	Blackadar	1.00	1.2
05	Kuo sym.	Turwet	Kuo trans.	Sundq.	F.-rest.	Blackadar	1.00	0.4
06	R. A.-S.	Conres	Nil	Sundq,	ISBA	Blackadar	0.85	1.2
07	Kuo sym.	Turwet	Kuo trans.	Sundq.	ISBA	Bougeault	0.85	0.4
08	R. A.-S.	Conres	Nil	Sundq.	F.-rest.	Bougeault	1.00	1.2
09	R. A.-S.	Conres	Nil	Sundq.	ISBA	Bougeault	0.85	0.4
10	Kuo sym.	Turwet	Kuo trans.	Sundq.	F.-rest.	Bougeault	1.00	1.2
11	R. A.-S.	Conres	Nil	Sundq.	F.-rest.	Blackadar	1.00	0.4
12	Kuo sym.	Turwet	Kuo trans.	Sundq.	ISBA	Blackadar	0.85	1.2
13	Kuo	Conres	Nil	Mod. Sundq.	F.-rest.	Blackadar	0.85	0.4
14	K.-F.	Conres	Kuo trans.	Sundq.	ISBA	Blackadar	1.00	1.2
15	Kuo	Conres	Nil	Mod. Sundq.	ISBA	Bougeault	1.00	0.4
16	K.-F.	Conres	Kuo trans.	Sundq.	F.-rest.	Bougeault	0.85	1.2
17	K.-F.	Conres	Kuo trans.	Sundq.	F.-rest.	Blackadar	1.00	0.4
18	R. A.-S.	Conres	Nil	Sundq.	ISBA	Bougeault	0.85	1.2
19	Kuo sym.	Turwet	Kuo trans.	Sundq.	F.-rest.	Bougeault	0.85	0.4
20	Kuo	Conres	Nil	Mod. Sundq.	ISBA	Blackadar	1.00	1.2

2. Description of the new elements in the EPS

b) Stochastic physical tendency perturbations

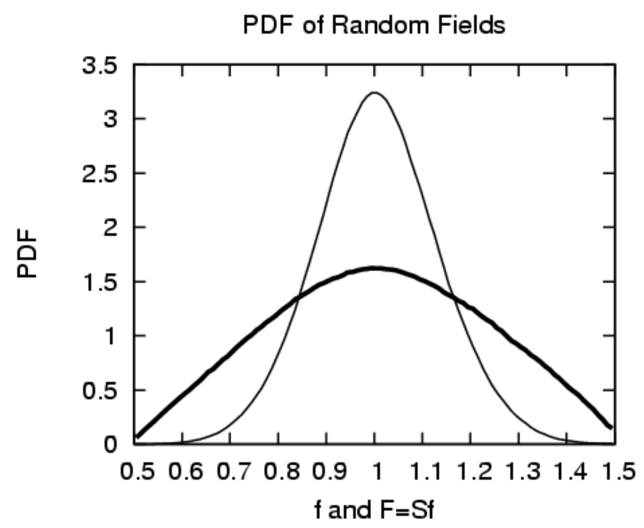
- All physical tendencies on horizontal winds, temperature, and humidity of each member are multiplied by a random function:
  - Defined in the range [0.5 , 1.5]
  - With a decorrelation time scale of 3 hours
  - And a decorrelation length scale of ~1700 km

2. Description of the new elements in the EPS

$$\psi(\lambda,\phi,t)=1+\sum_{l=1}^{10}\sum_{m=-l}^{l} a_{lm}(t)Y_l^m(\lambda,\phi)$$

$$a_{lm}(t+\Delta t)=e^{-\Delta t/\tau}a_{lm}(t)+R_{lm}(t)$$

The R's are uncorrelated random processes



2. Description of the new elements in the EPS

c) Stochastic kinetic energy backscatter algorithm

- Numerical models are over-dissipative near the truncation limit
- This likely inhibits upscale energy transfer that can affect the large scale flow
- It is thought that this phenomenon can be a cause of under-dispersion in EPSs
- Parameterization: Inject energy near the truncation limit to compensate for the over-dissipation

2. Description of the new elements in the EPS

$$F_\psi = \frac{\alpha \Delta x}{\Delta t} \psi(\lambda, \phi, t) \sqrt{\Delta t \hat{D}}$$

$$\frac{Du}{Dt} + \ldots = \ldots - \frac{1}{a} \frac{\partial F_\psi}{\partial \phi}$$

$$\frac{Dv}{Dt} + \ldots = \ldots + \frac{1}{a \cos\phi} \frac{\partial F_\psi}{\partial \lambda}$$

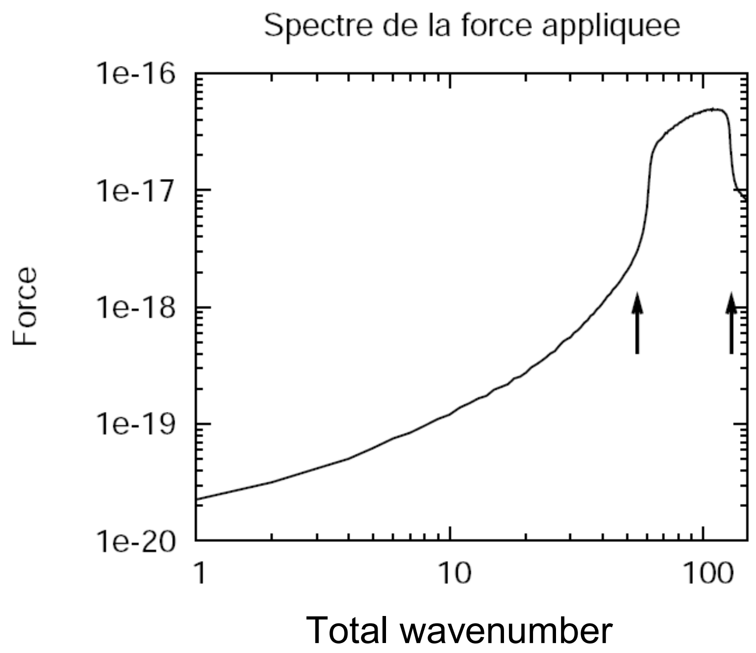
$$\frac{DT}{Dt} + \ldots = \ldots + \frac{\alpha_T \psi \hat{D}}{c_p}$$

F_ψ is a stochastic (because of ψ) potential modulated by the gravity wave drag and horizontal diffusion ($\hat{D}$)

2. Description of the new elements in the EPS

$$\psi(\lambda,\phi,t)=\sum_{l=40}^{128}\sum_{m=-l}^{l} a_{lm}(t)\,Y_l^m(\lambda,\phi)$$

$$a_{lm}(t+\Delta t)=e^{-\Delta t/\tau}a_{lm}(t)+R_{lm}(t)$$



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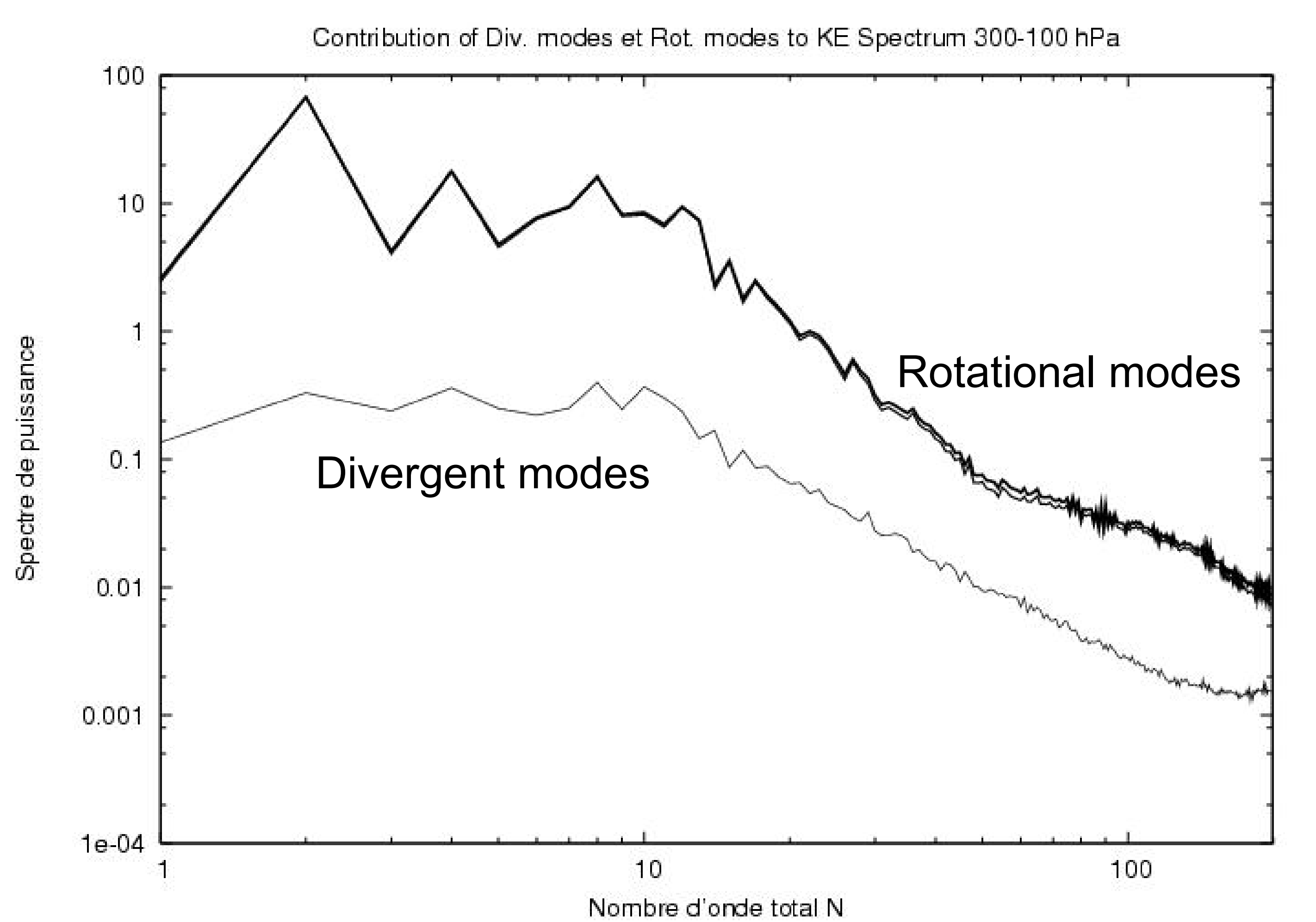

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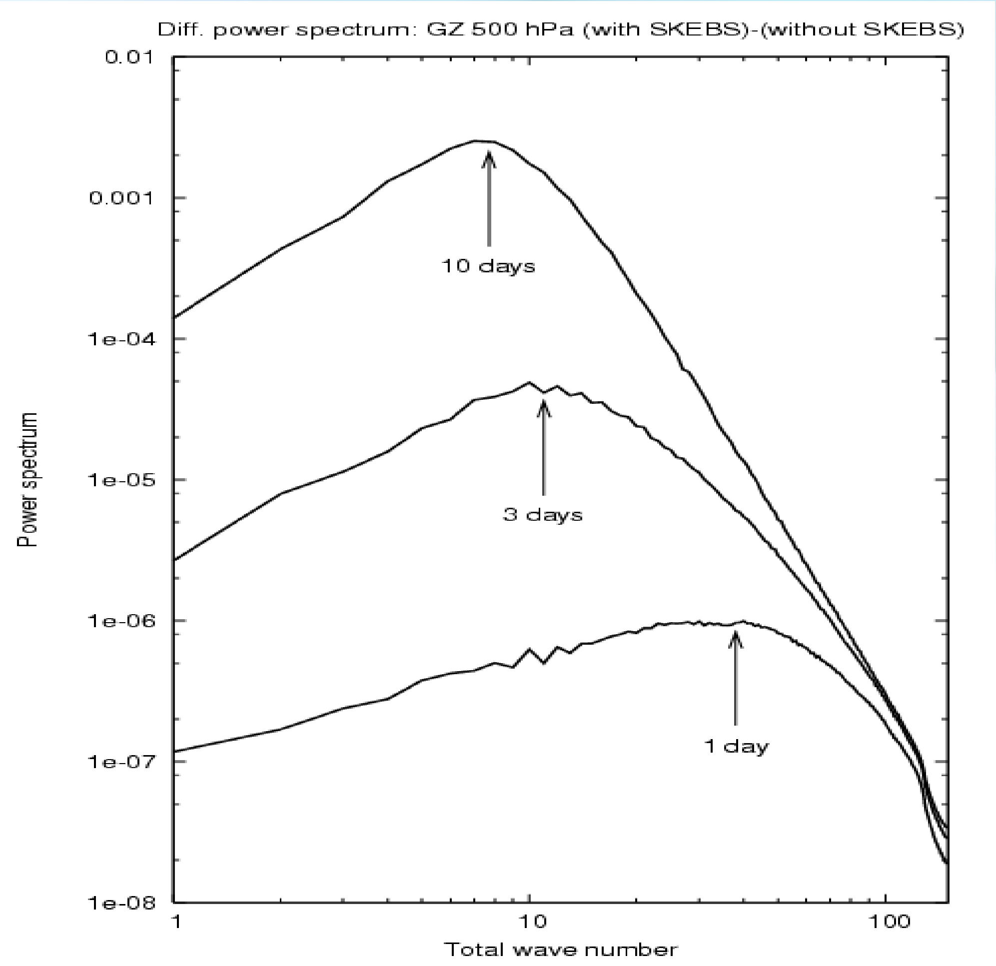


2. Description of the new elements in the EPS

d) Initial conditions / Data assimilation

- Total number of members (multi-parameterization approach): 4x24=96
- Complementary ensemble size to estimate statistics for the analysis increments of 24 members: (4-1)x24=72
- First guess linearly interpolated from 3h, 4h30, 6h, 7h30, and 9h forecasts to match all observation validity times
- Horizontal resolution of members: 0.9°
- See Peter Houtekamer's internal seminar for details

3. Comparison between the former and new EPS

- Upper-air verification in January 2006 for U at 250 hPa, GZ at 500 hPa, and T at 850 hPa against ~374 radio-sondes (i.e. ~6000 observations monthly) distributed globally
- Probabilistic scores: bias, dispersion, Continuous Ranked Probability Score (CRPS), reliability, resolution

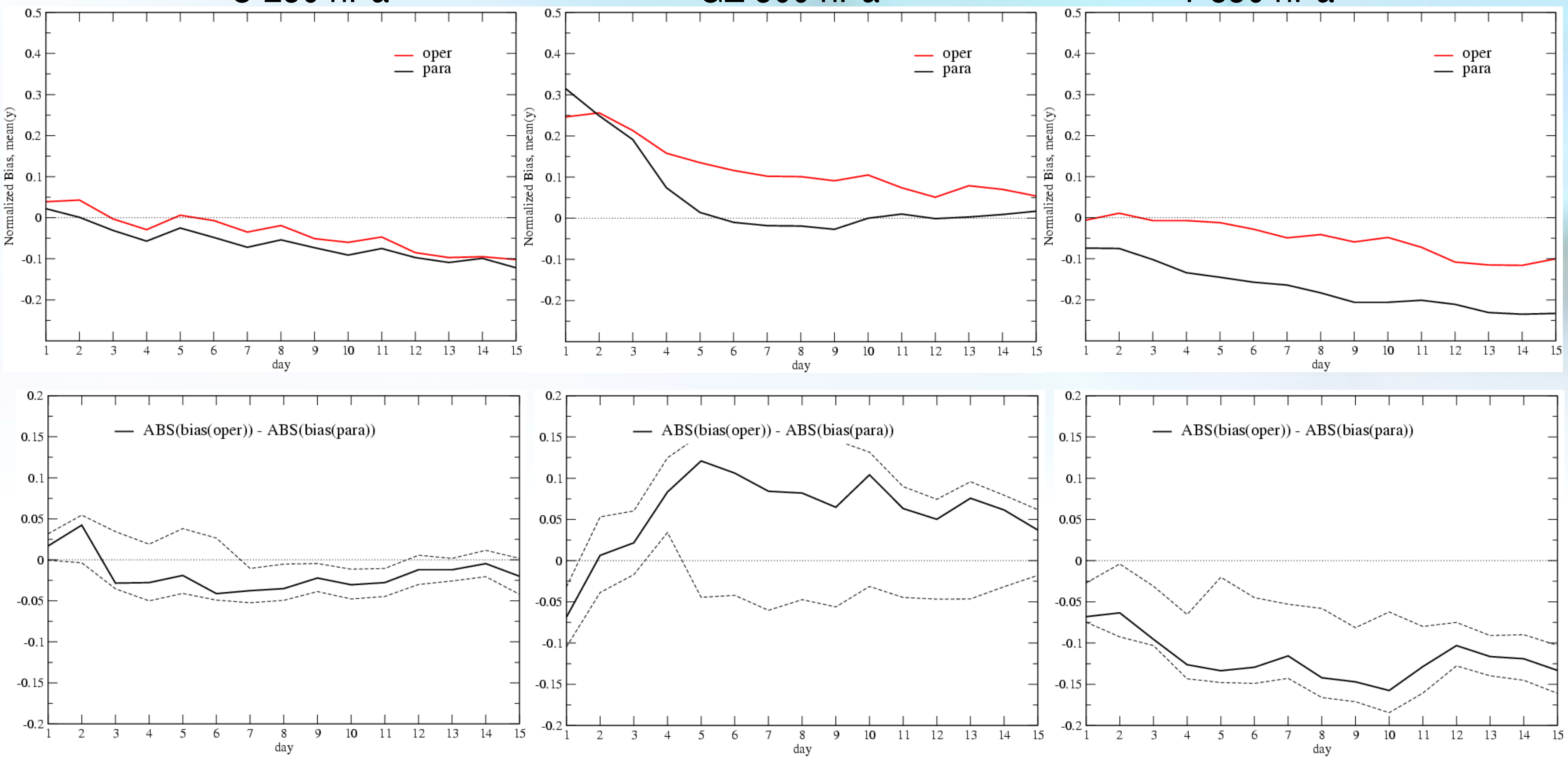
$$y = \frac{o - m}{\sqrt{\sigma_f^2 + \sigma_o^2}}$$

3. Comparison between the former and new EPS

U 250 hPa | GZ 500 hPa | T 850 hPa

Bias

Bias difference



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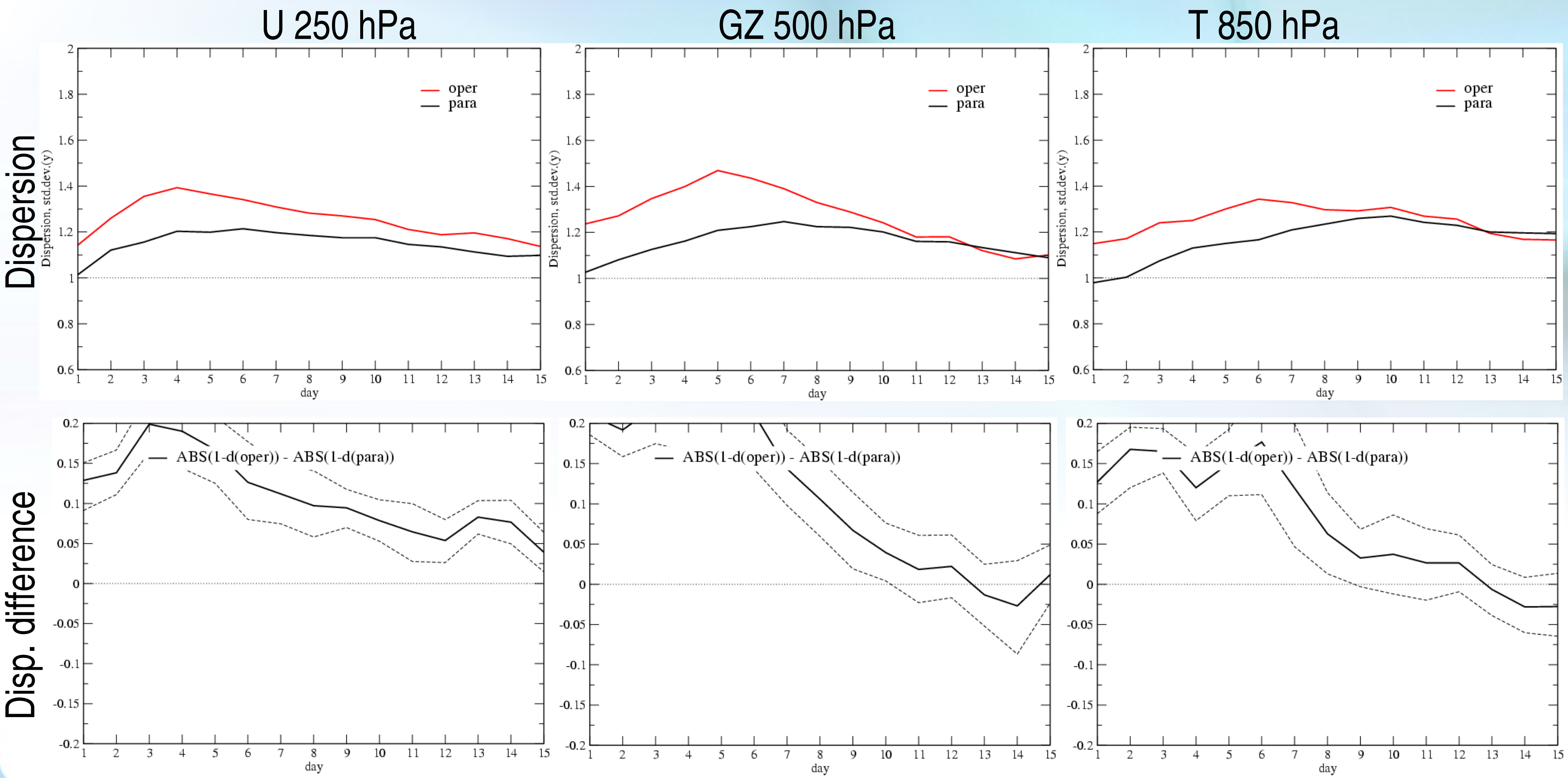

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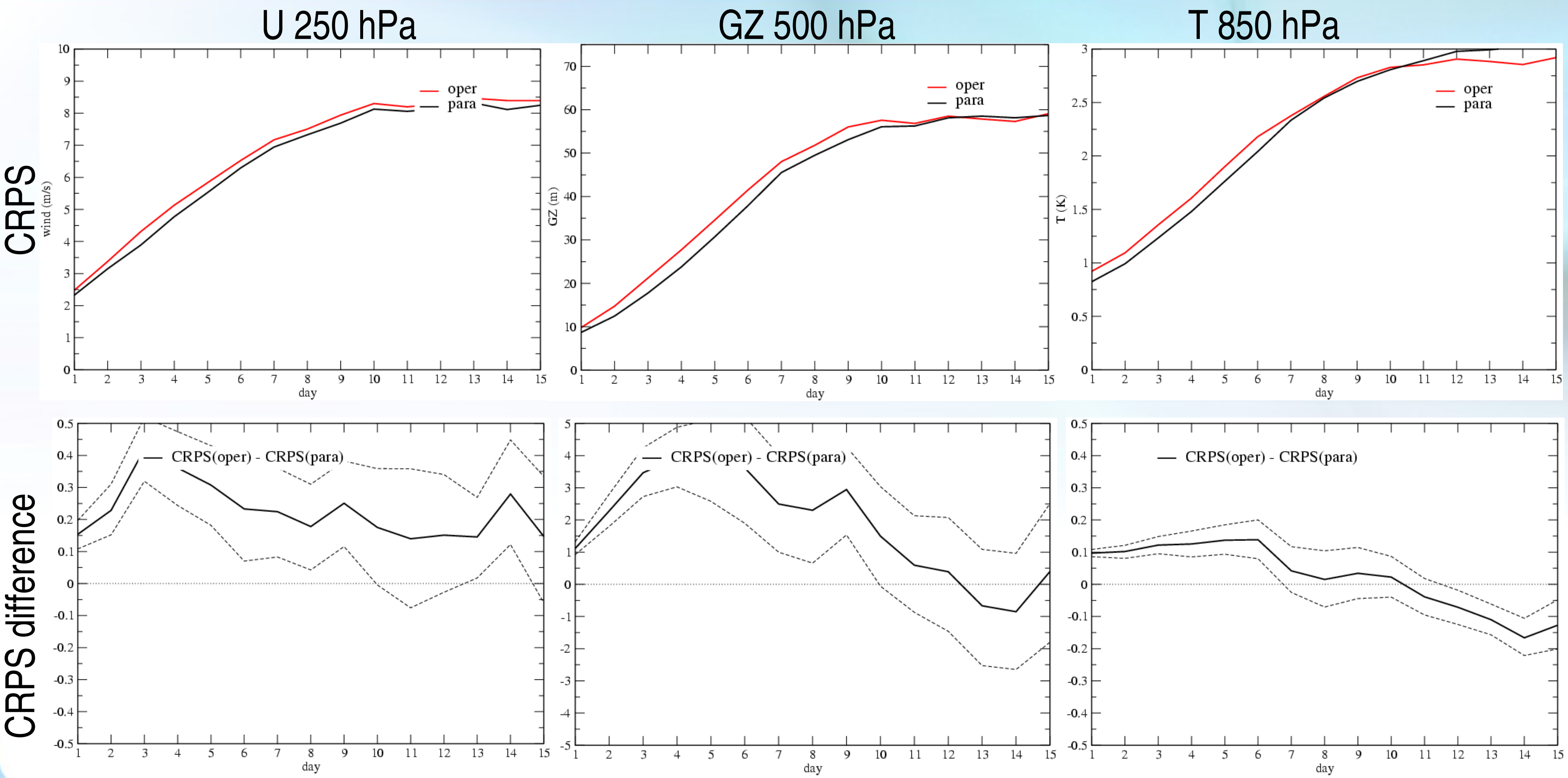

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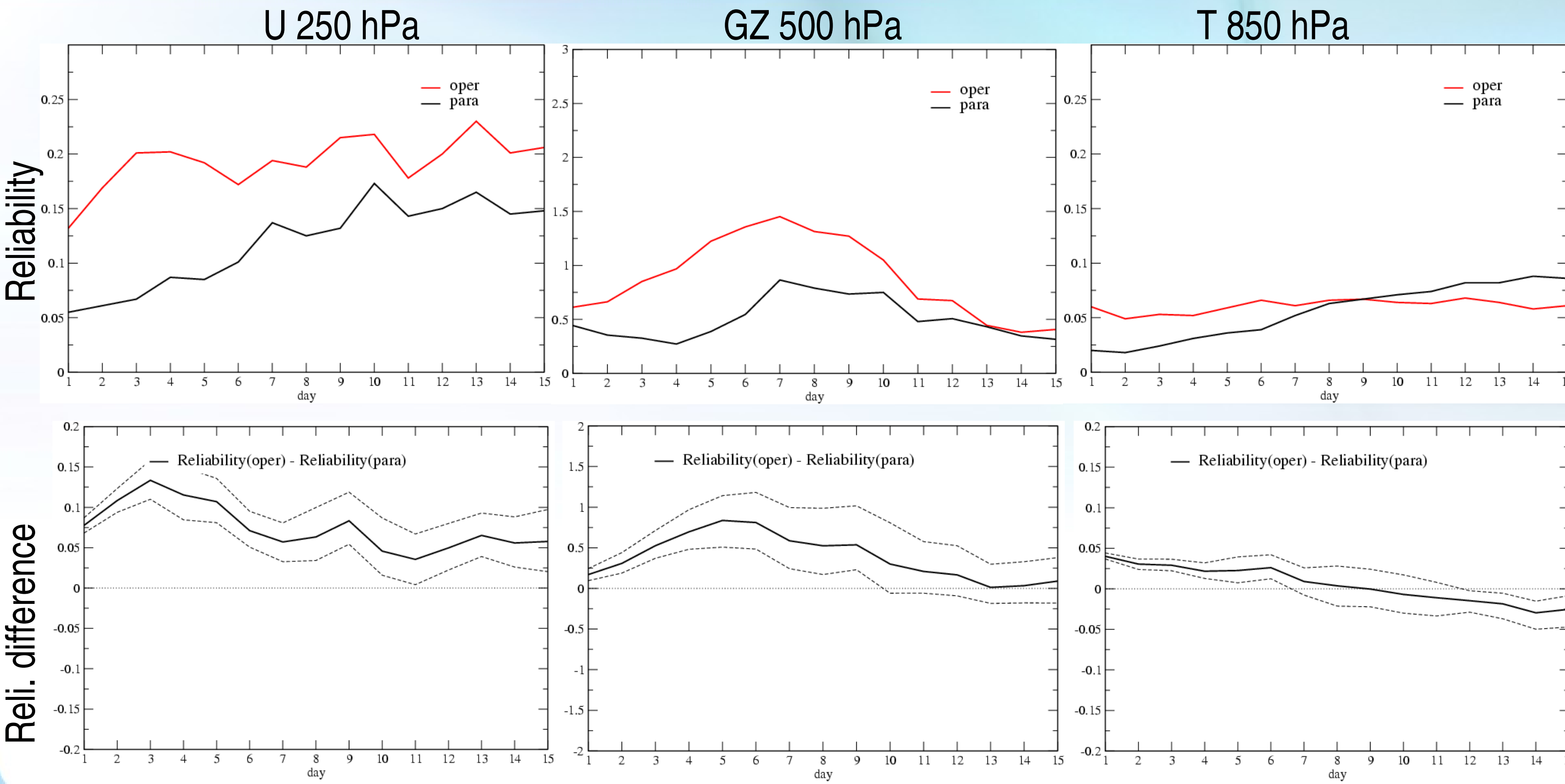

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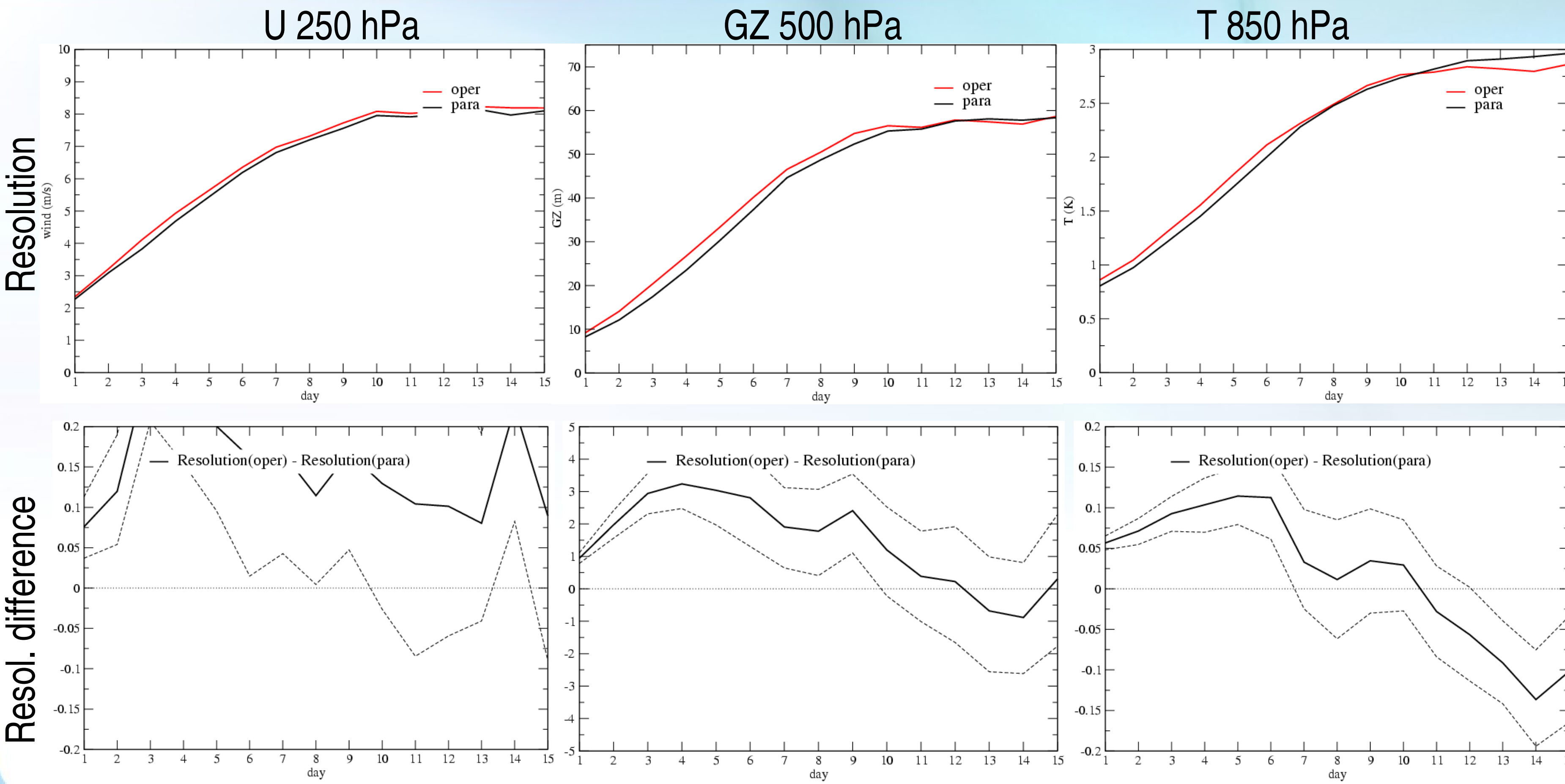

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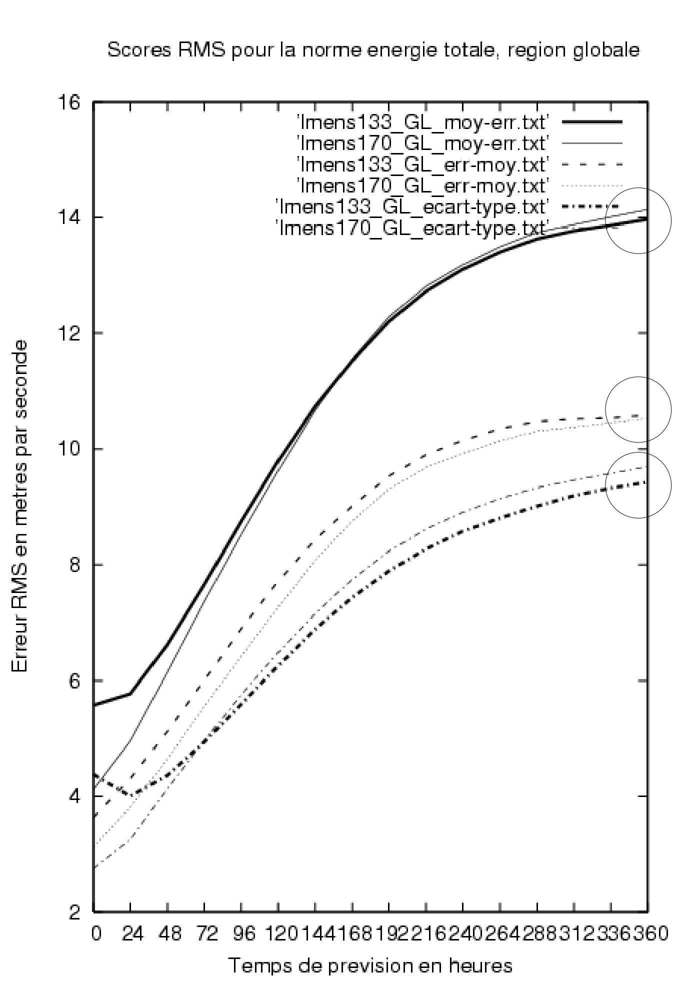


Global RMS Scores

Mean of errors

Error of the mean

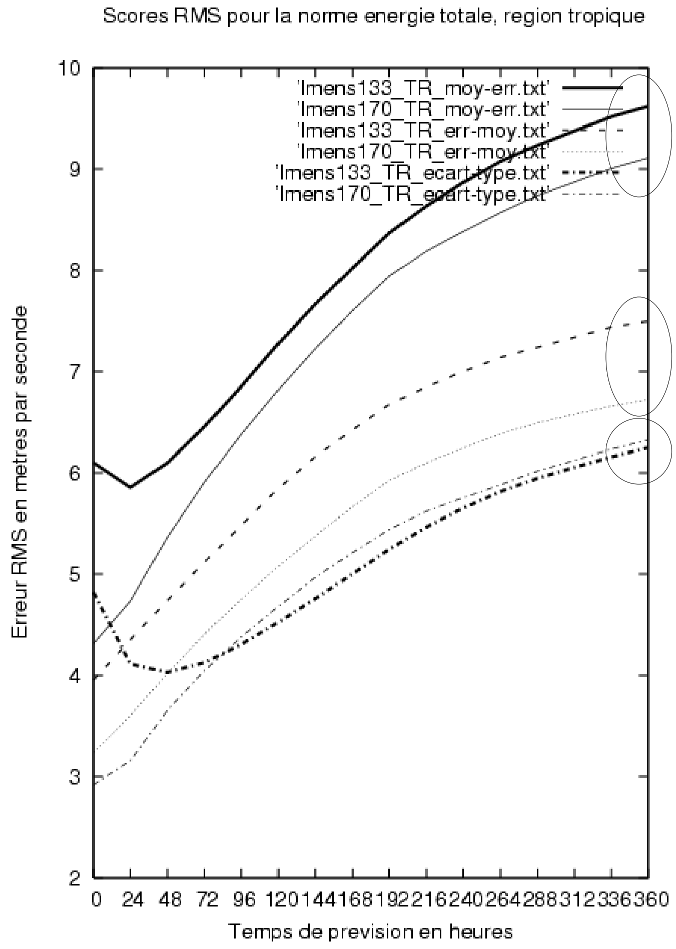
Ensemble spread

Thin lines: New EPS

Thick lines: Old EPS

3. Comparison between the former and new EPS

Tropical RMS Scores



Mean of errors

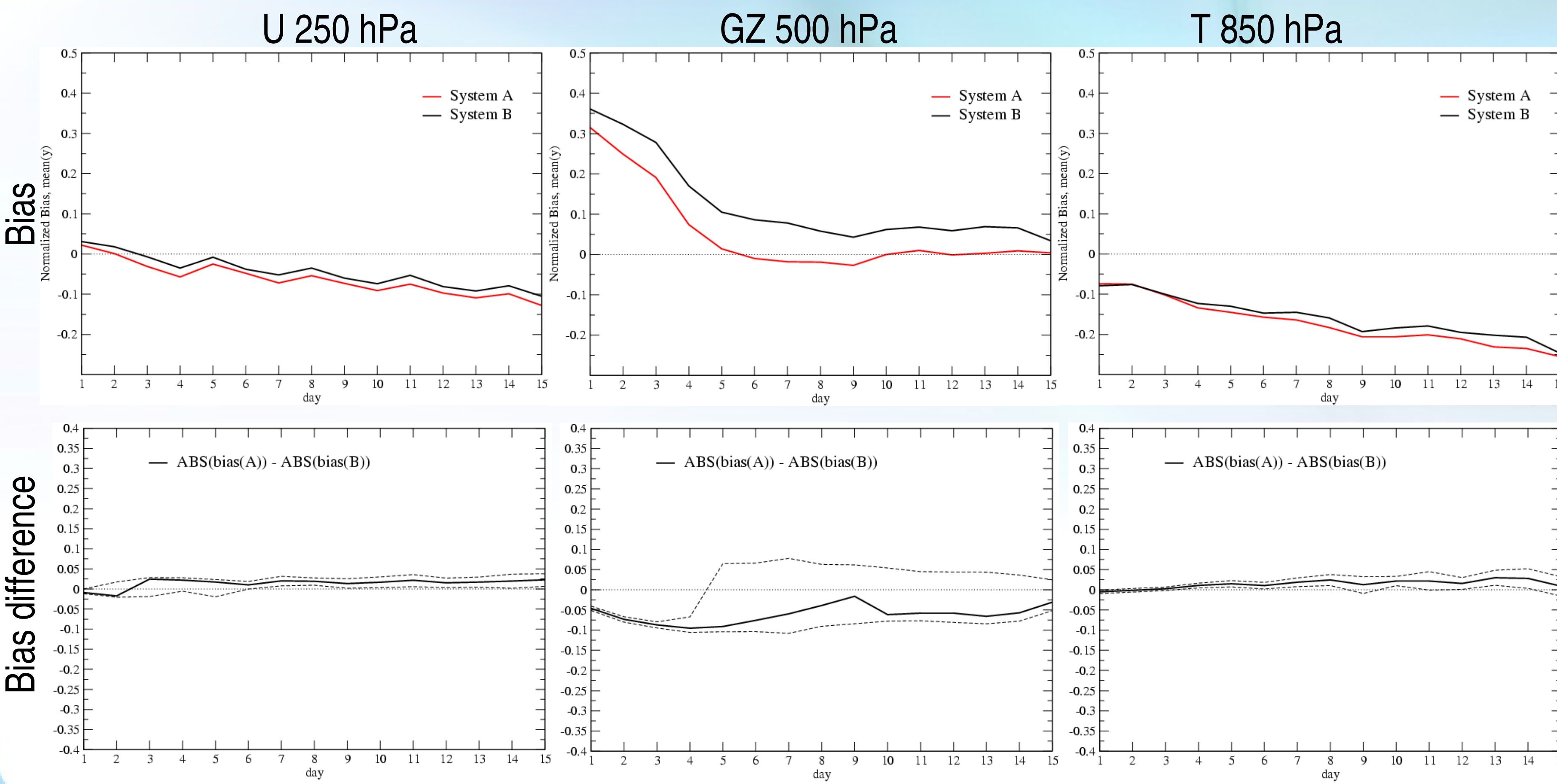
Error of the mean

Ensemble spread

Thin lines: New EPS

Thick lines: Old EPS

4a. Impact of physical tendency perturbations



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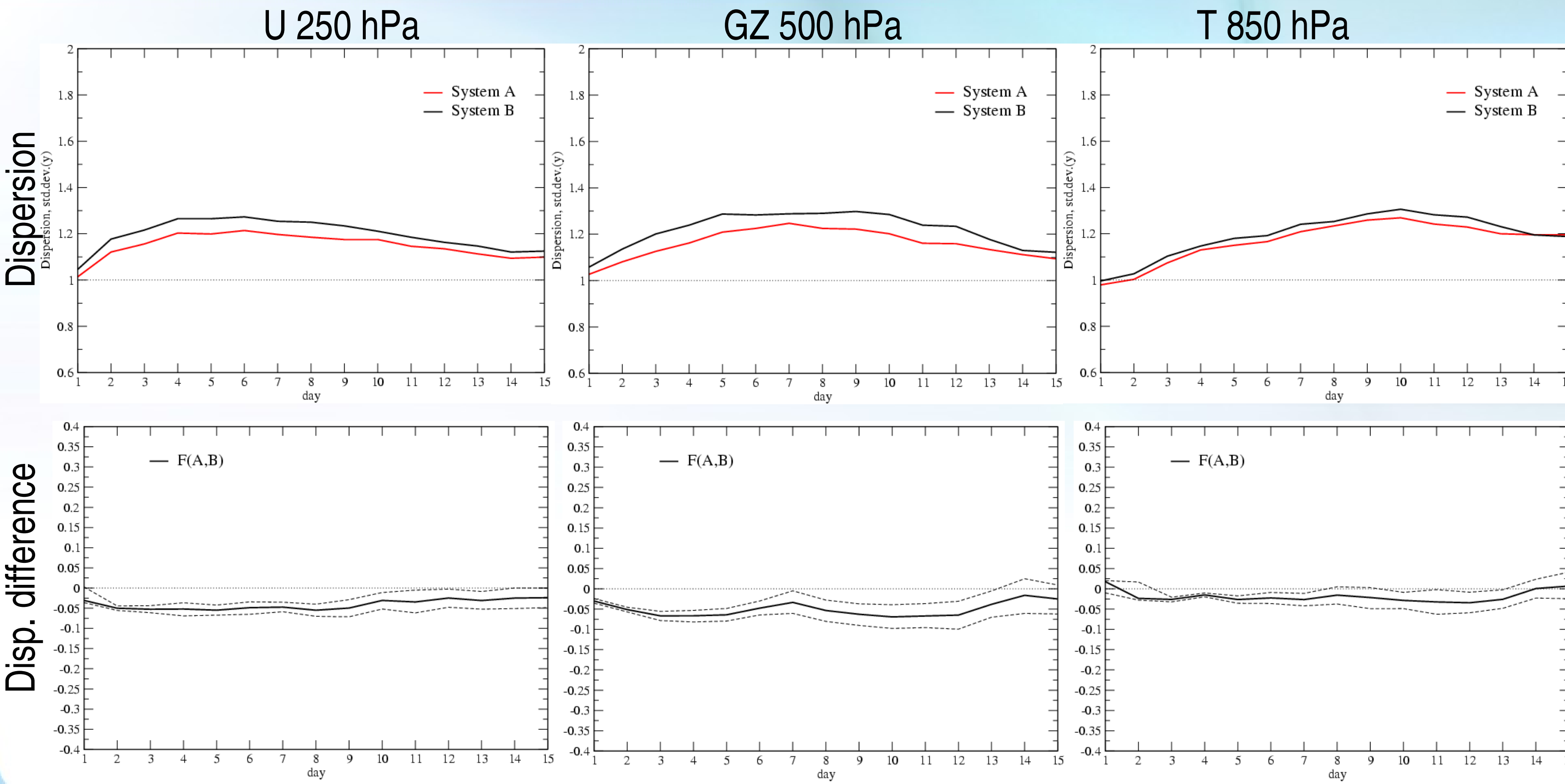

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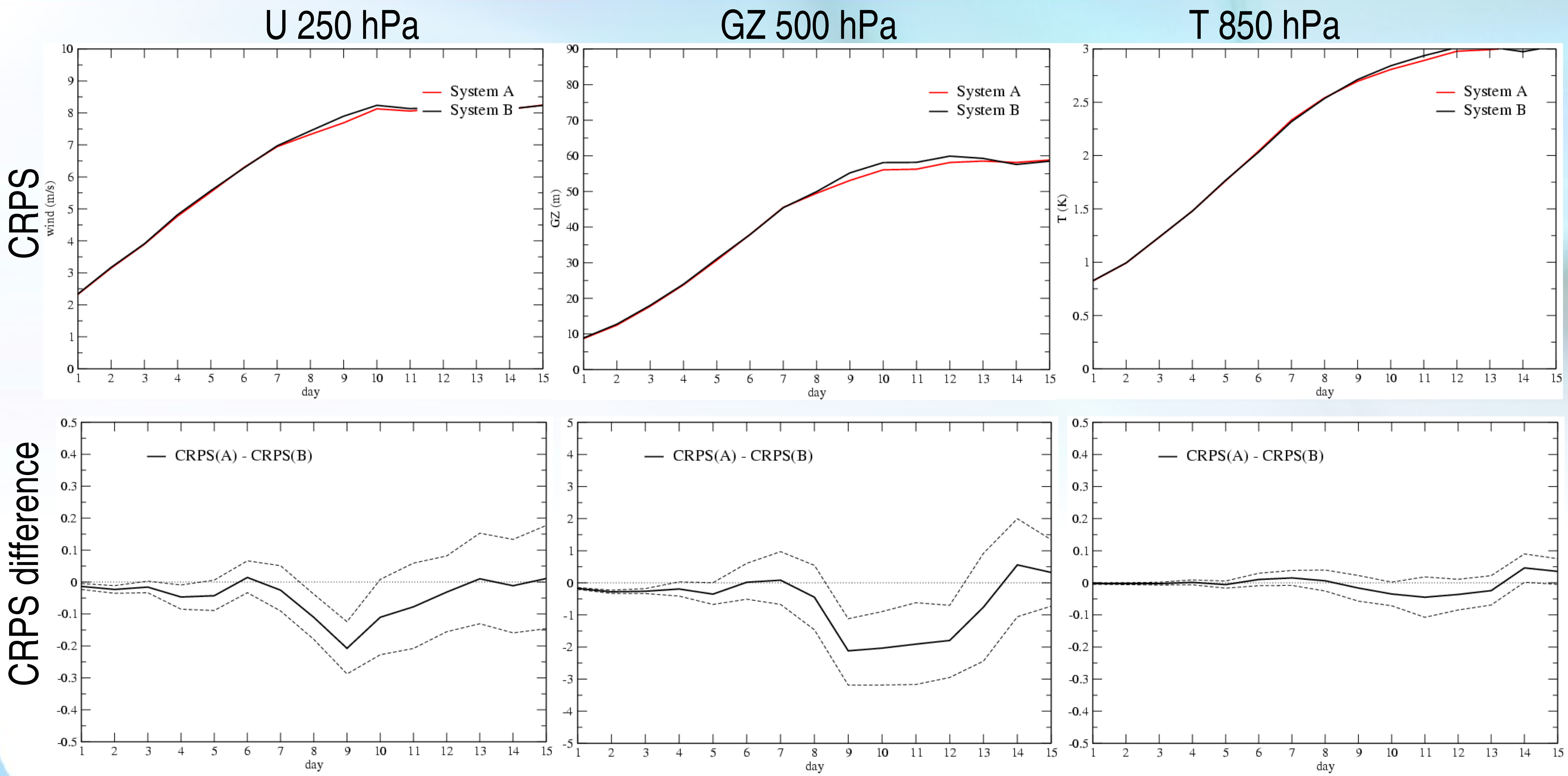

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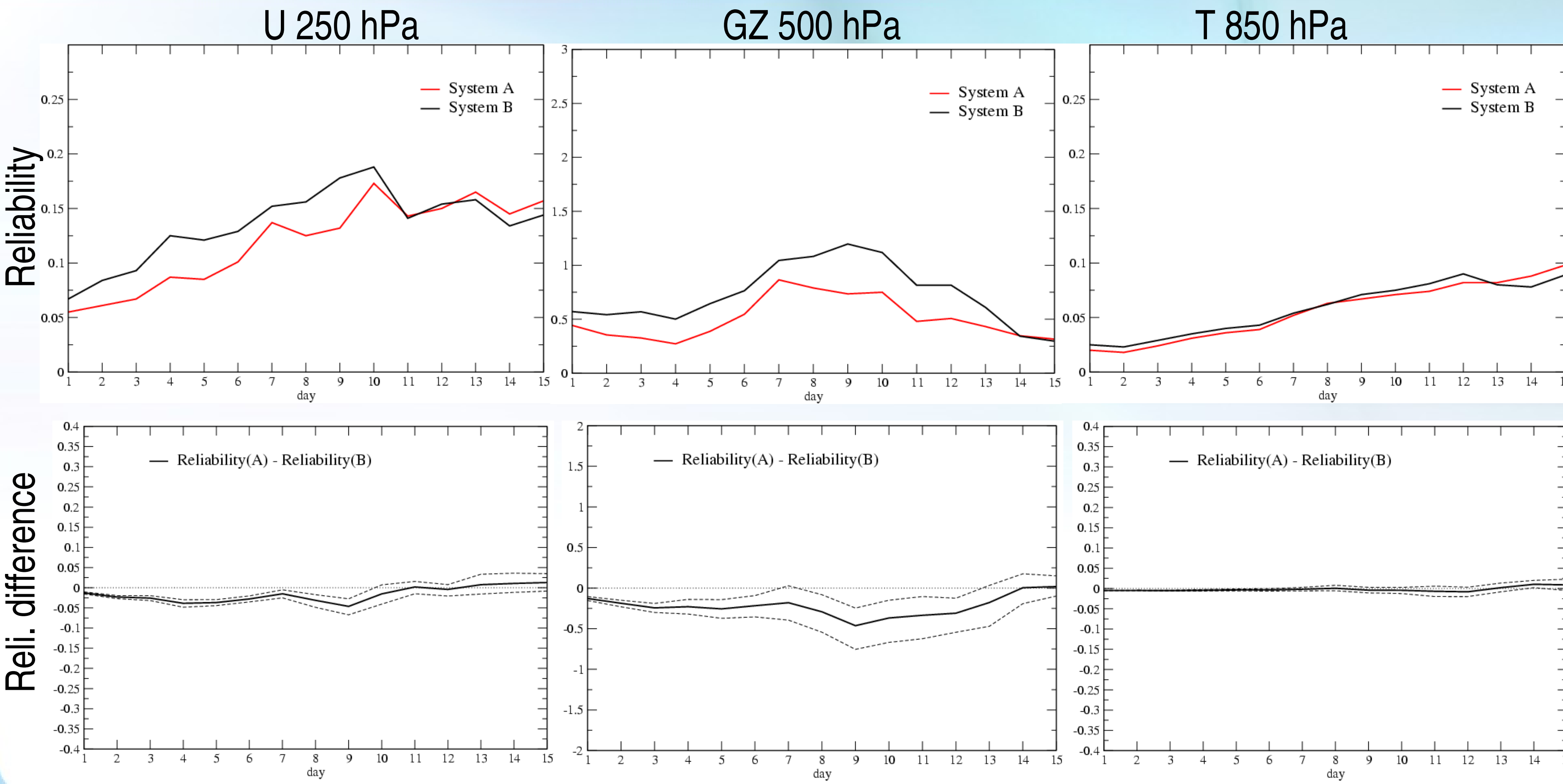


Environnement Canada Environment Canada

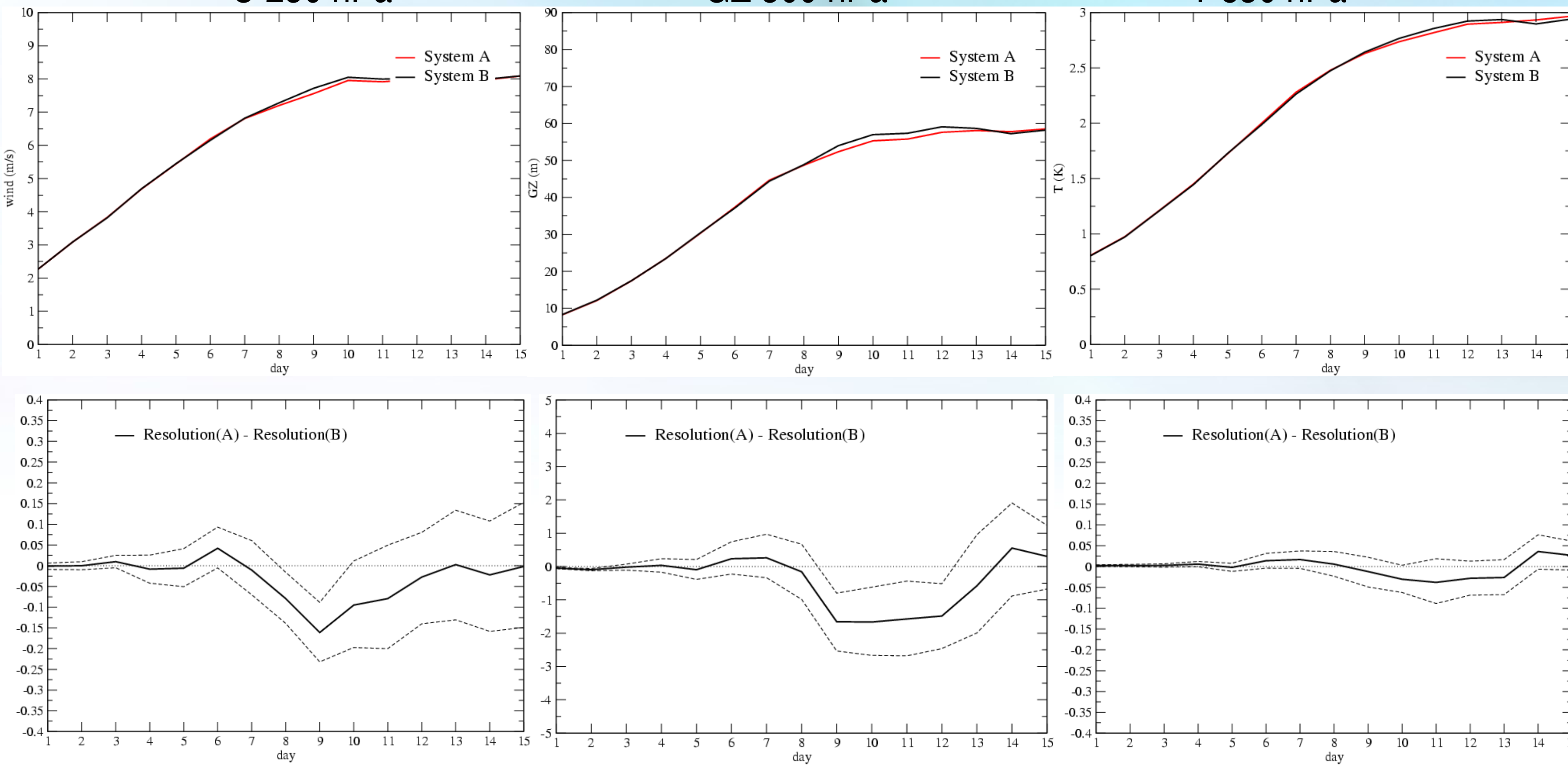
Canada

4a. Impact of physical tendency perturbations

U 250 hPa | GZ 500 hPa | T 850 hPa

Resolution

Resol. difference

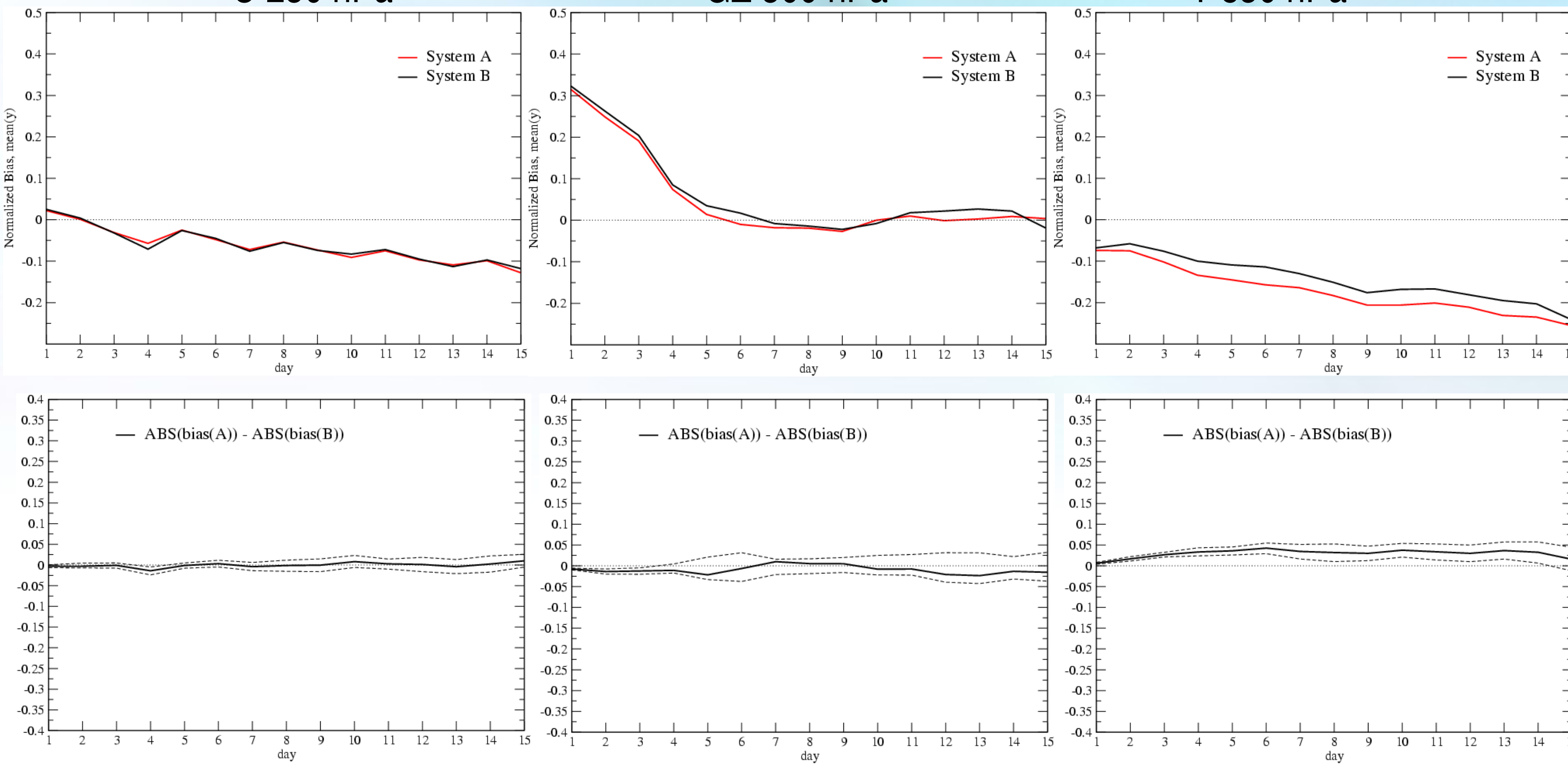


4b. Impact of stochastic KE backscatter scheme

U 250 hPa | GZ 500 hPa | T 850 hPa

Bias

Bias difference

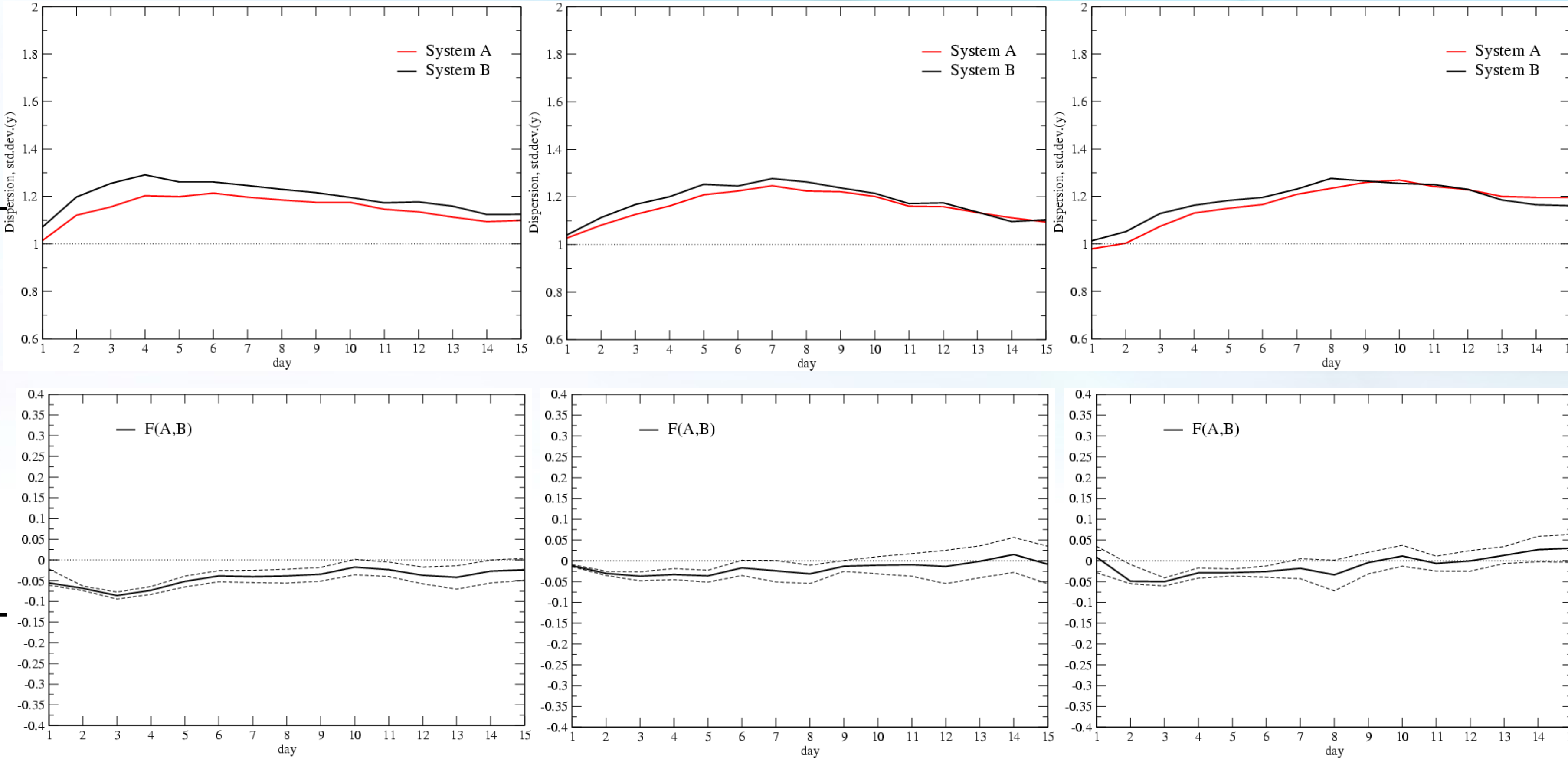


4b. Impact of stochastic KE backscatter scheme

U 250 hPa | GZ 500 hPa | T 850 hPa

Dispersion

Disp. difference



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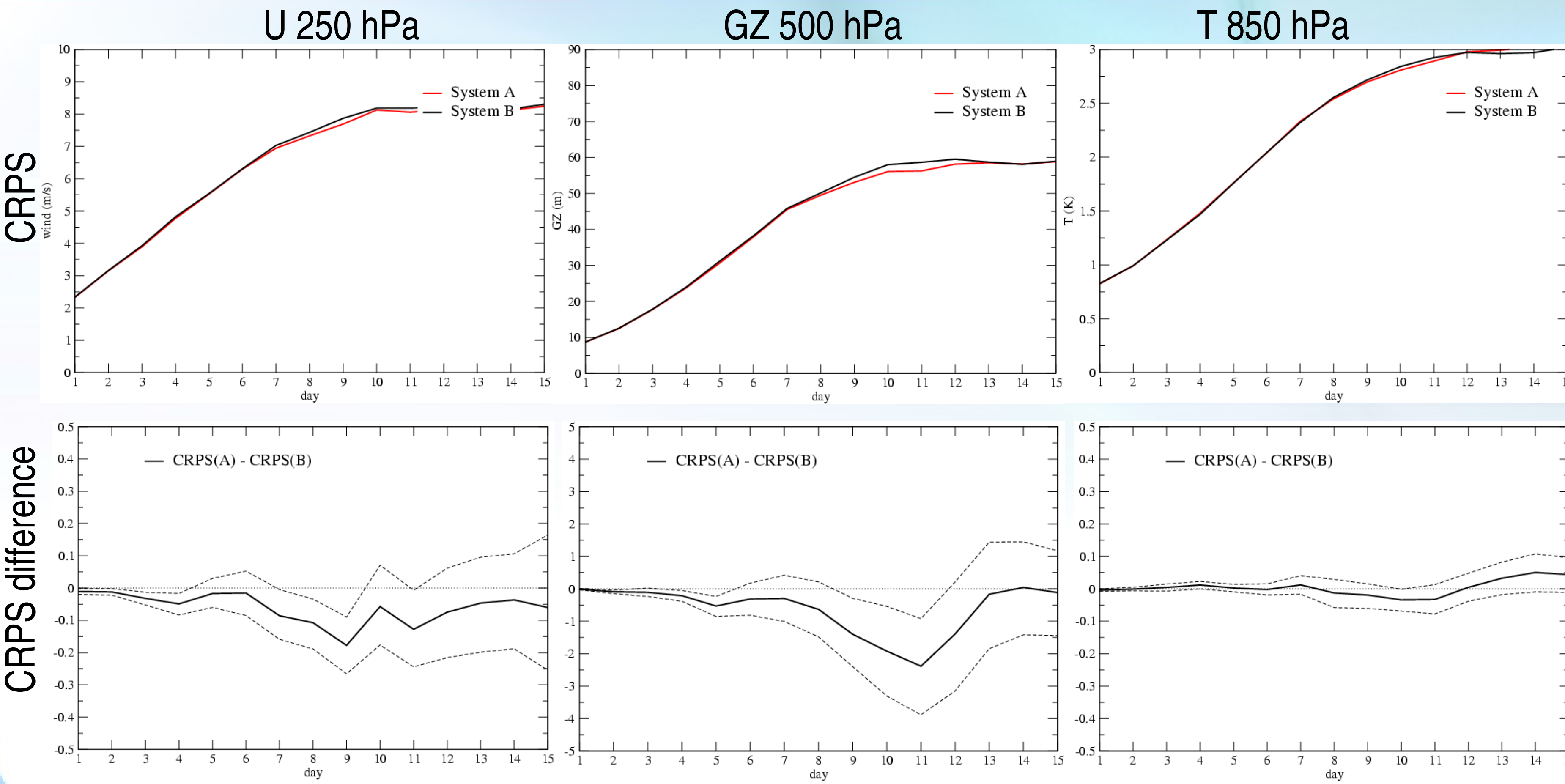

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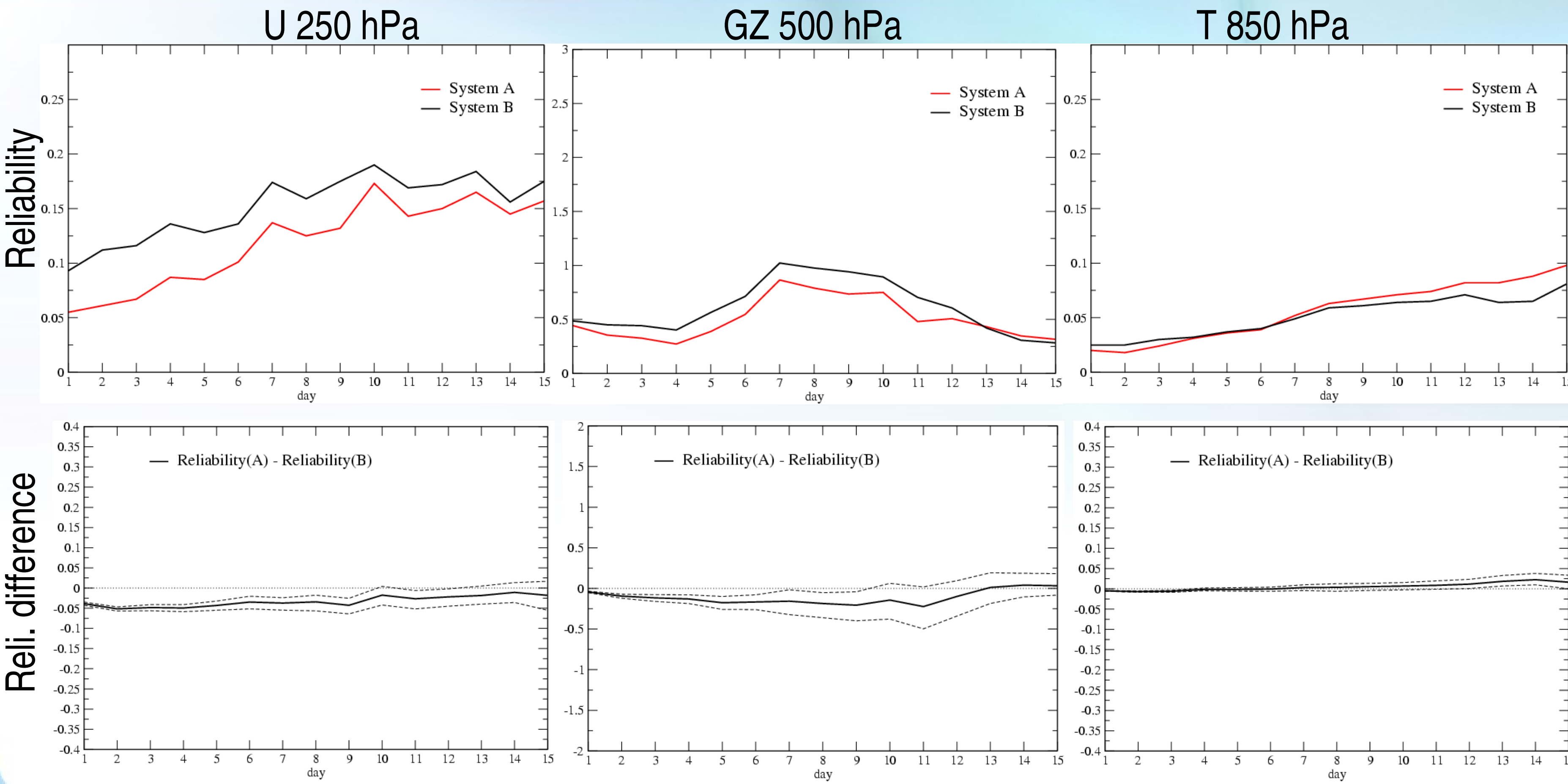

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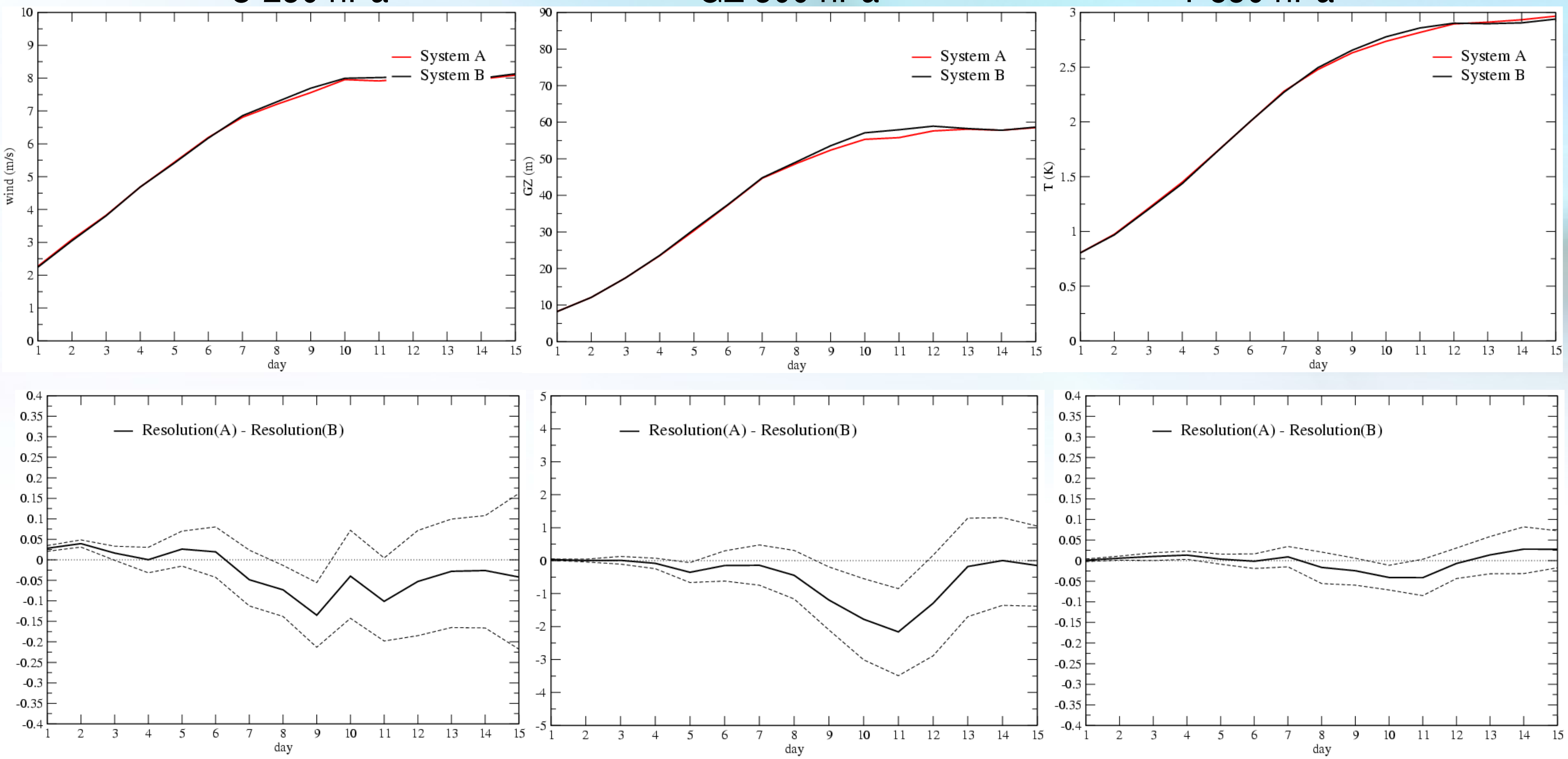
U 250 hPa | GZ 500 hPa | T 850 hPa

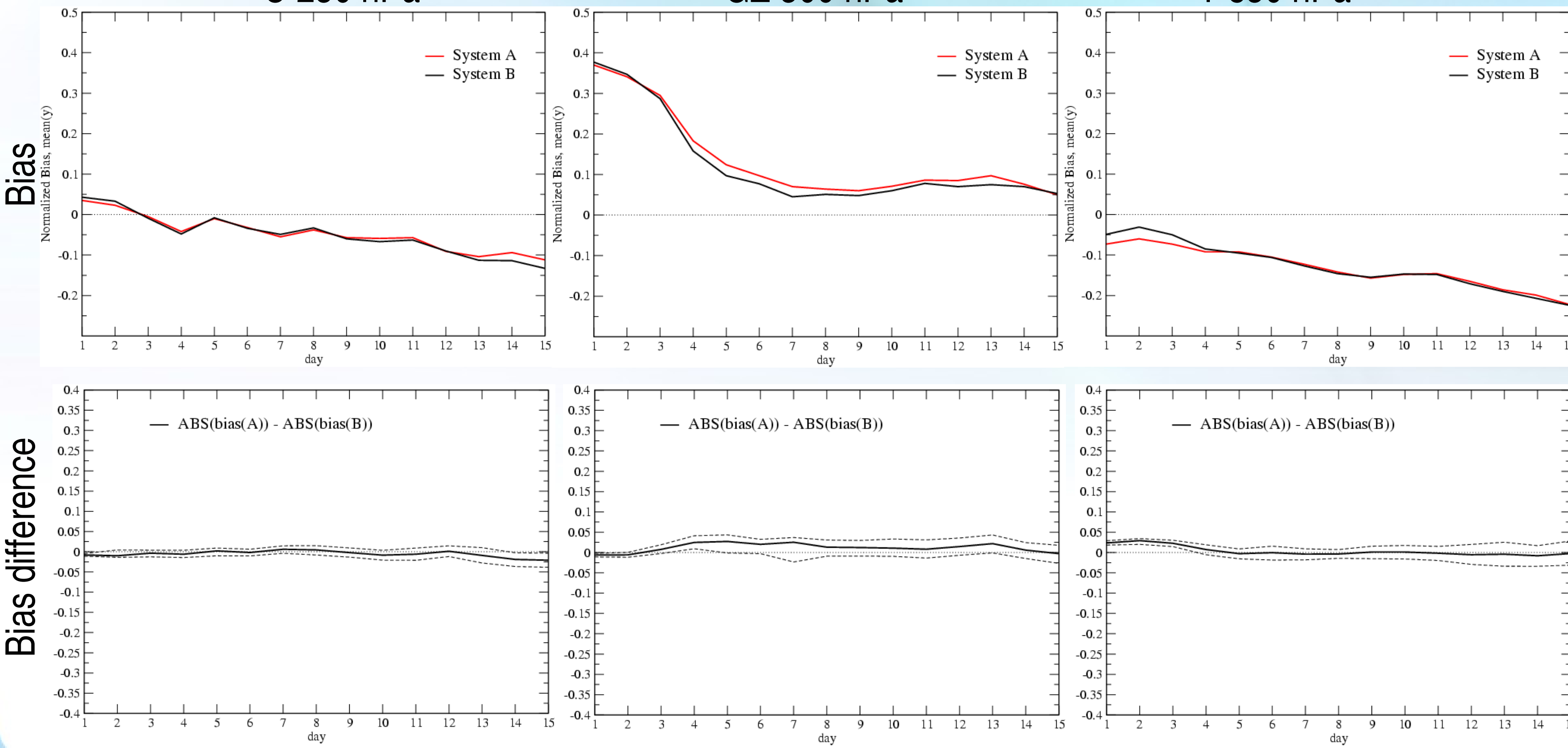
Resolution

Resol. difference



4c. Impact of horizontal resolution

U 250 hPa | GZ 500 hPa | T 850 hPa



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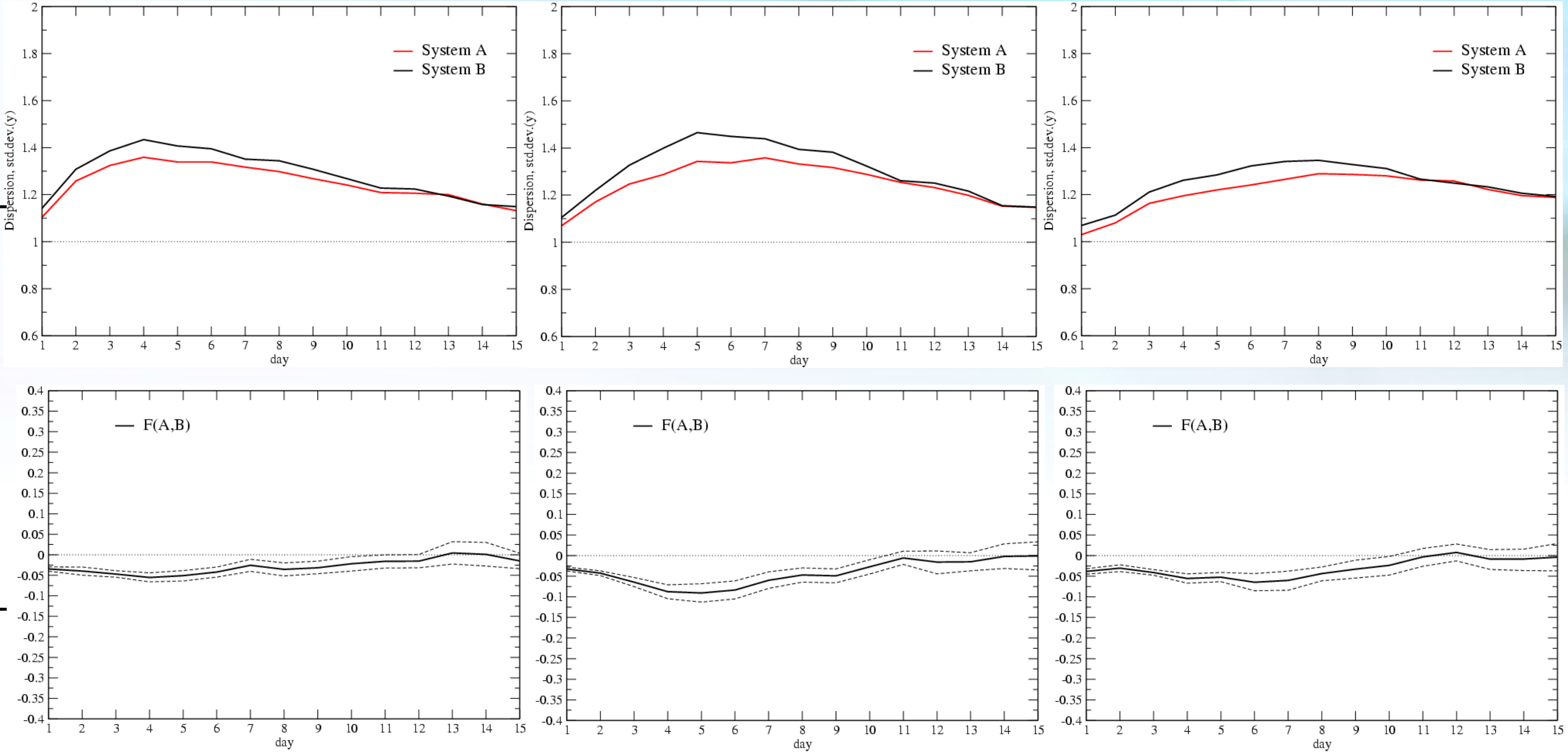
U 250 hPa | GZ 500 hPa | T 850 hPa

Dispersion

Disp. difference



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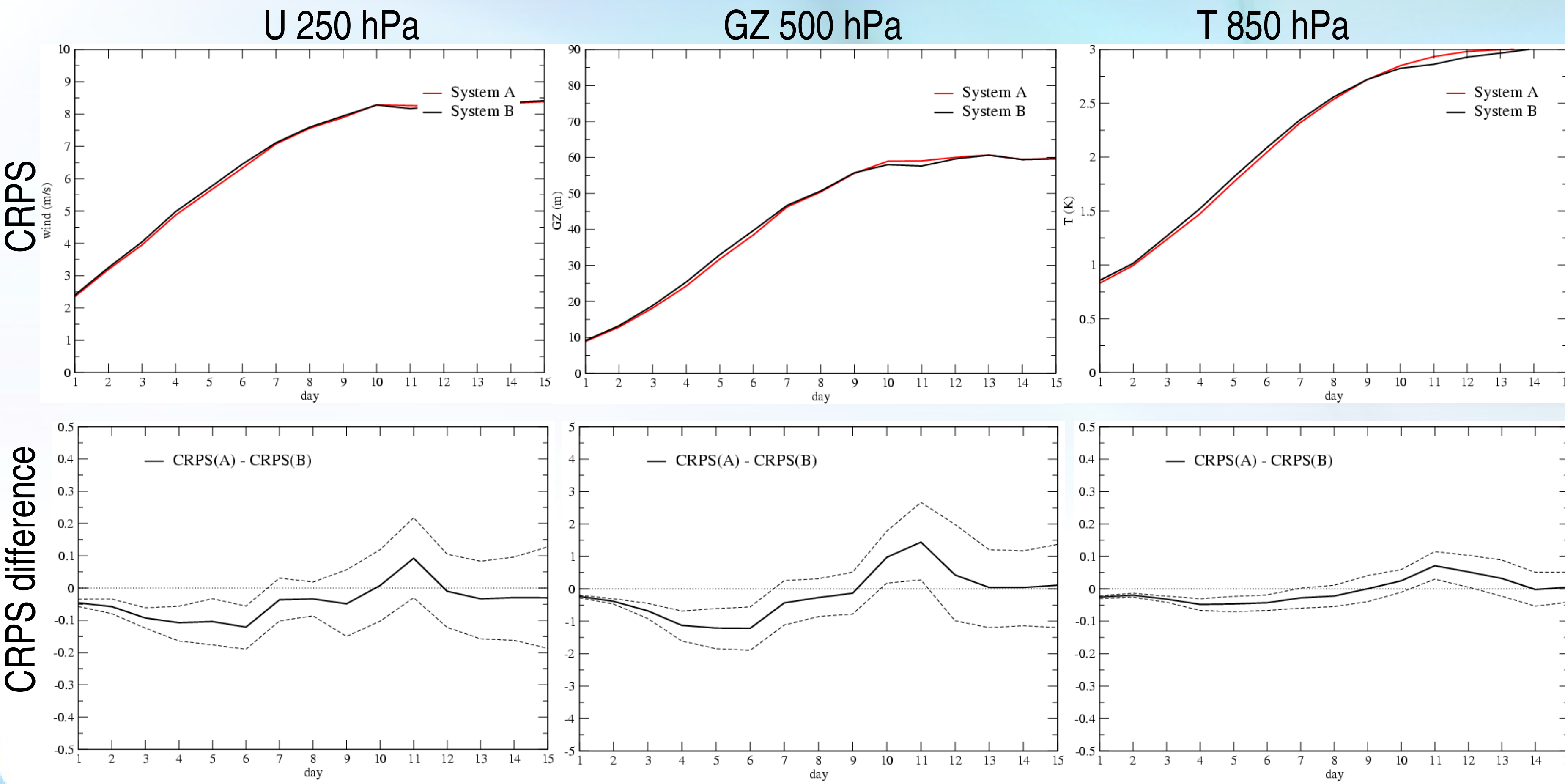

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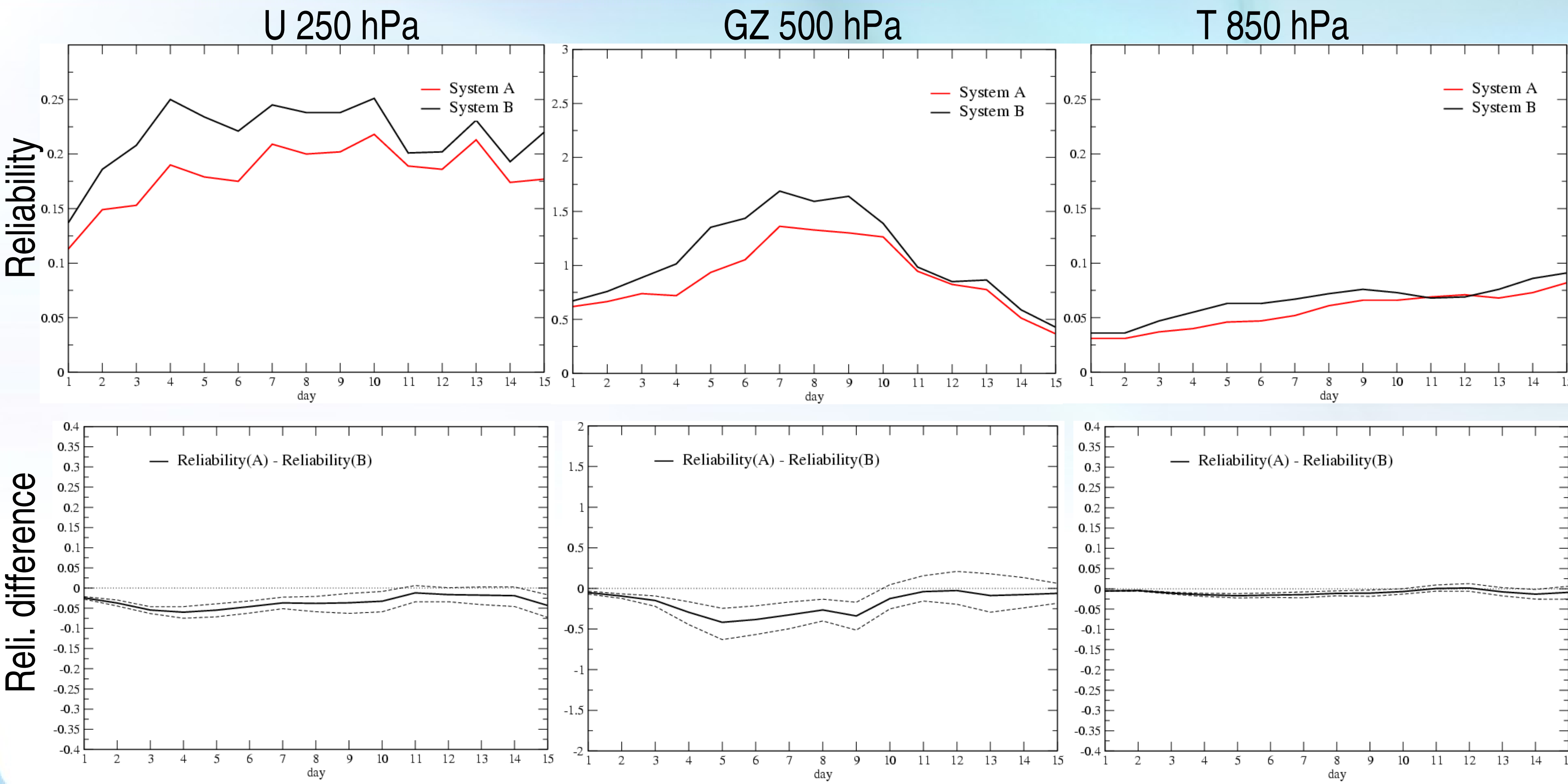

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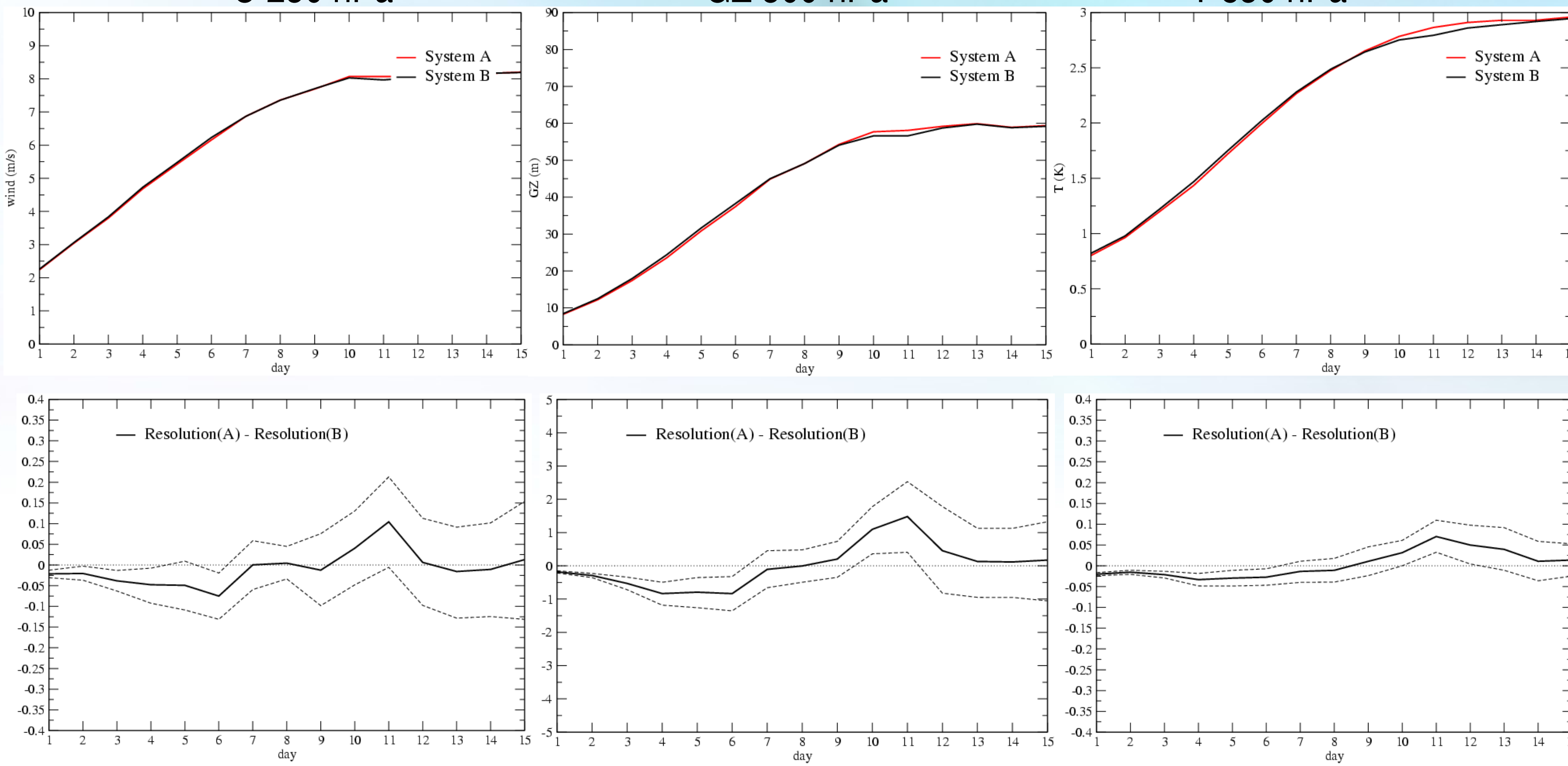
U 250 hPa | GZ 500 hPa | T 850 hPa

Resolution

Resol. difference



5. Conclusions and future directions

- At equal forecast quality, the forecast range has been increased by 12 to 18 hours with respect to the former EPS
- Quality of QPF is significantly improved (not shown here)
- Work is needed to improve low level temperature biases
- Raise model lid for better data assimilation and potentially improved week two forecasts
- Use vertical staggering for improved vertical correlations
- More unified stochastic parameterizations, e.g. stochastic Kain-Fritsch deep convection scheme
- Coupling with different SSTs, e.g. the Mercator project

Merci!