The assimilation of SSM/I radiance observations with interchannel error correlations

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June 20, 2008

Outline

- Introduction and motivation
- Estimation of SSM/I interchannel error covariances
- Changes in EnKF software
- Experiments and preliminary results
- Summary

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Introduction

- The Ensemble Kalman filter (EnKF) system

   Data assimilation component of the Canadian EPS

   Uses GEM global forecast model, 0.9°, 28 levels

   Data types assimilated:

   (data count for a typical 6h period):

Radiosonde upper air	34113	Surface	11862
Radiosonde surface	1460	Aircraft	54343
AMSU-A	69420	AMSU-B	31061
Satellite wind	37270	Total	239529

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Introduction – cont'd

- New data types for the recently completed parallel run

  QuickScat data　　　　　(16630)

  Wind profiler observations　　(5762)

  Special Sensor Microwave Imager (SSM/I) data

  　(14371)　 (not included)

- SSM/I channel characteristics

Channel No.	1	2	3	4	5	6	7
Frequency (GHz)	19.35	19.35	22.235	37.0	37.0	85.5	85.5
Polarization	V	H	V	V	H	V	H

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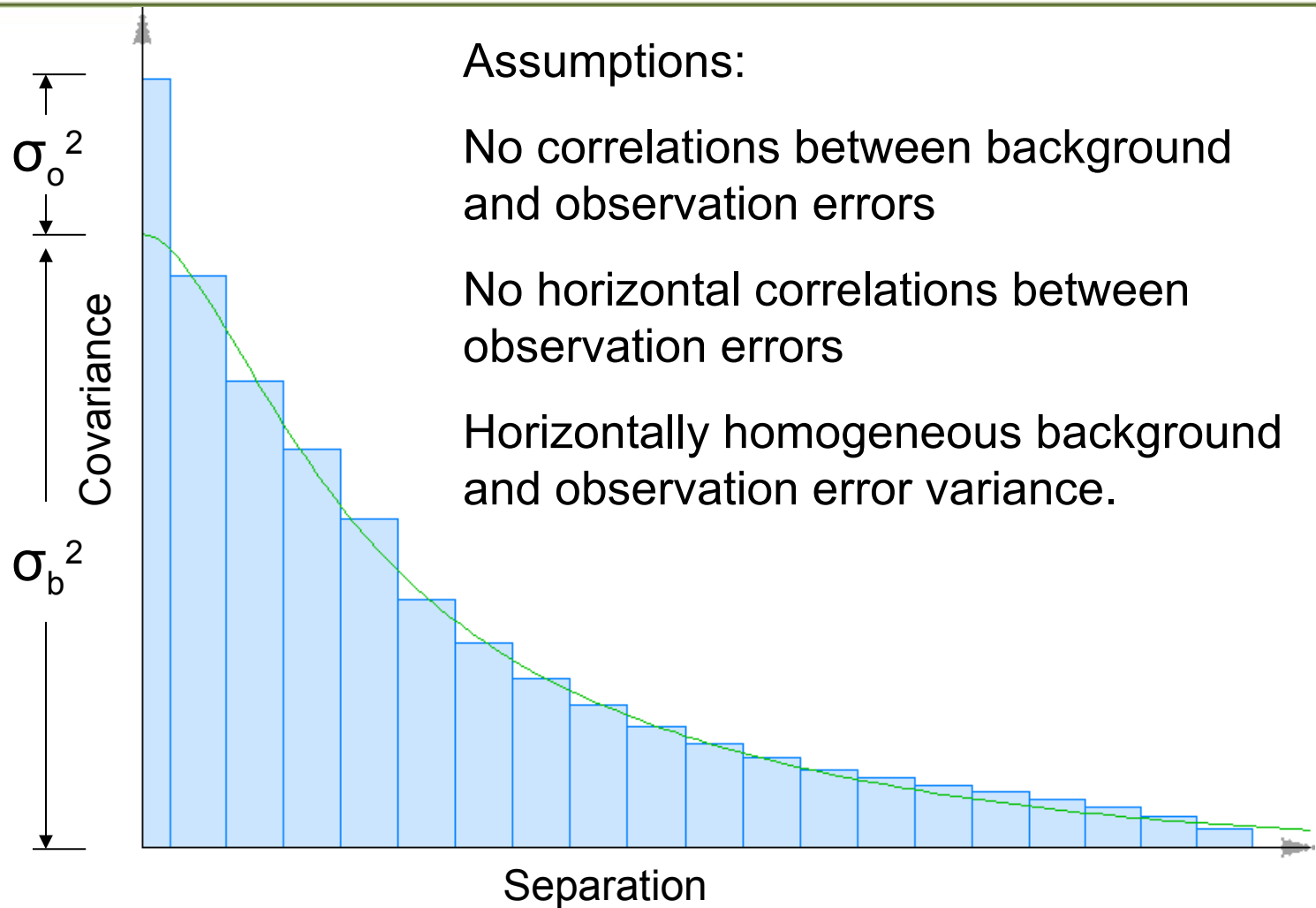
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Motivation

- Making the commonly used assumption that the interchannel error correlations are negligible for the SSM/I data, we obtained disappointing results in the EnKF system. Hoping for improvement, we determined and used interchannel error correlations.

- This pilot project will guide future development work for other data types, like AIRS (87 channels to be assimilated), with significant interchannel error correlations (Garand, L., S. Heilliette and M. Buehner, 2007)

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Estimation of SSM/I interchannel error covariances

- Method
- Assumptions
- Data
- Estimation results

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Separation of observation and background errors (Rutherford 1972; Hollingsworth and Lönnberg 1986)

Assumptions:

No correlations between background and observation errors

No horizontal correlations between observation errors

Horizontally homogeneous background and observation error variance.

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DATA

- **For estimation of interchannel error covariances**

  Unthinned quality-controlled O - P from SSM/I aboard DMSP13 and DMSP14 (5 – 14 Jan. 2007) (data count for 6-h period: 548814).

  P: 6-hr forecasted radiance from EnKF cycle without assimilating any SSM/I data

- **For data assimilation experiments presented later**

  Thinned quality-controlled O from SSM/I aboard DMSP13, DMSP14 and DMSP15 (27June – 10 July 2006) (data count for 6-h period: 14371).

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Example of estimated covariance

(L = 58.5031 V0 = 4.0720 alpha = 0.8200)
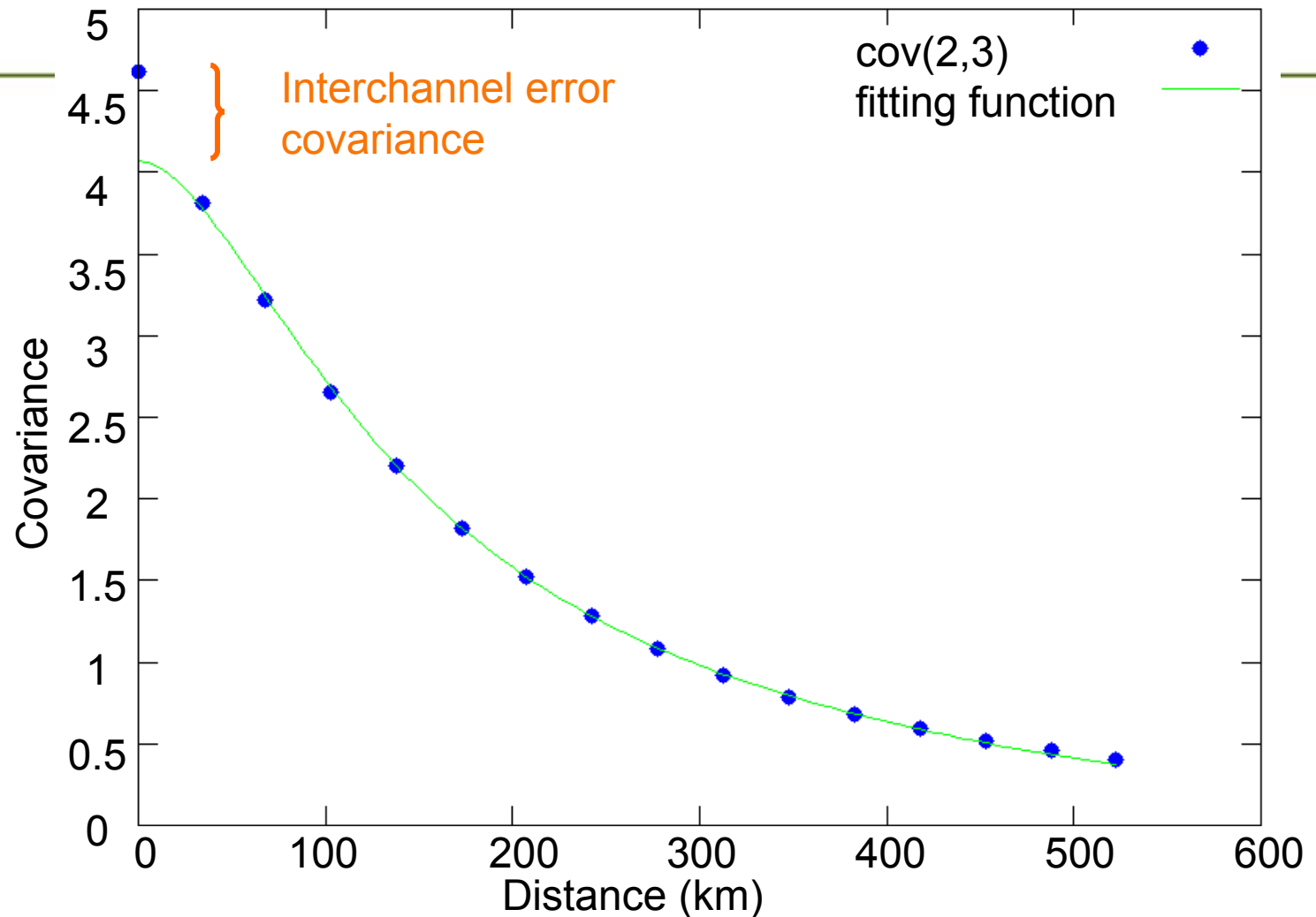
Sum of second-order auto-regressive functions, Mitchell et al (1990)

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SSM/I observation error correlation matrix

	19.35V 1	19.35H 2	22.235V 3	37.0V 4	37.0H 5	85.5V 6	85.5H 7
1	1.0000	0.6148	0.6159	0.6474	0.5442	0.3669	0.3714
2	0.6148	1.0000	0.5815	0.6213	0.7623	0.3475	0.4961
3	0.6159	0.5815	1.0000	0.6359	0.4934	0.4754	0.4820
4	0.6474	0.6213	0.6359	1.0000	0.7236	0.5208	0.5882
5	0.5442	0.7623	0.4934	0.7236	1.0000	0.4244	0.6723
6	0.3669	0.3475	0.4754	0.5208	0.4244	1.0000	0.6858
7	0.3714	0.4961	0.4820	0.5882	0.6723	0.6858	1.0000

Interchannel error correlations are high

Changes in EnKF software

$$x_i^a = x_i^f + \mathbf{K} \left(y_i^o - H\, x_i^f \right), \quad i = 1, \ldots, 96$$

$$\mathbf{K} = \mathbf{P}^f H^T \left(H\, \mathbf{P}^f H^T + \mathbf{R} \right)^{-1}$$

$$y_i^o = y^o + N(\, 0, \mathbf{R}\,), \quad i = 1, \ldots, 96$$

$$x_i^f = M\left[\, x_i^a (t\text{-}6\ hr) + N(0, \mathbf{Q})\, \right], \quad i = 1, \ldots, 96$$

$\mathbf{R}$: observation error covariance
$\mathbf{P}^f$: background error covariance (estimated from
a 96-member ensemble of background fields)
M: GEM global forecast model

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Data assimilation experiments

EXP Name	Changes in EnKF software	SSM/I data	SSM/I error statistics
CNTL	no	no	no
NCEP	no	yes	NCEP
NEW	yes	yes	new
X1.5	yes	yes	new times1.5

Forecast experiments: 7-day medium-range forecasts were initiated from each ensemble mean for each of the above data assimilation experiments

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Comparison of error amplitudes
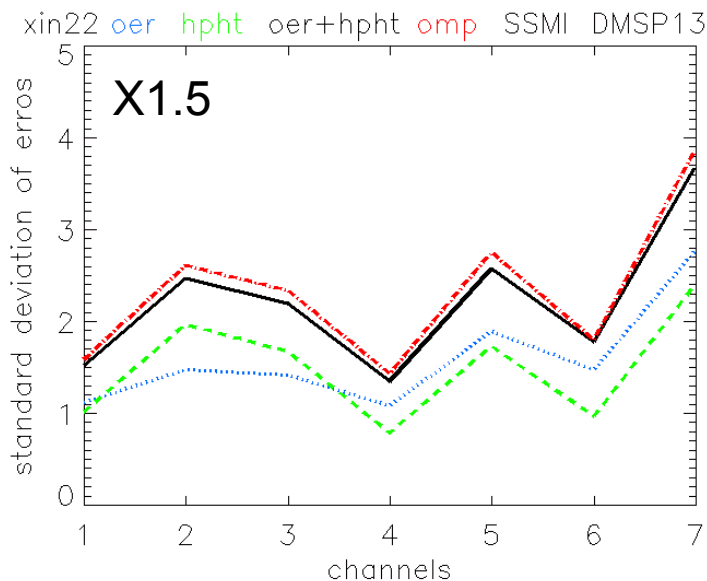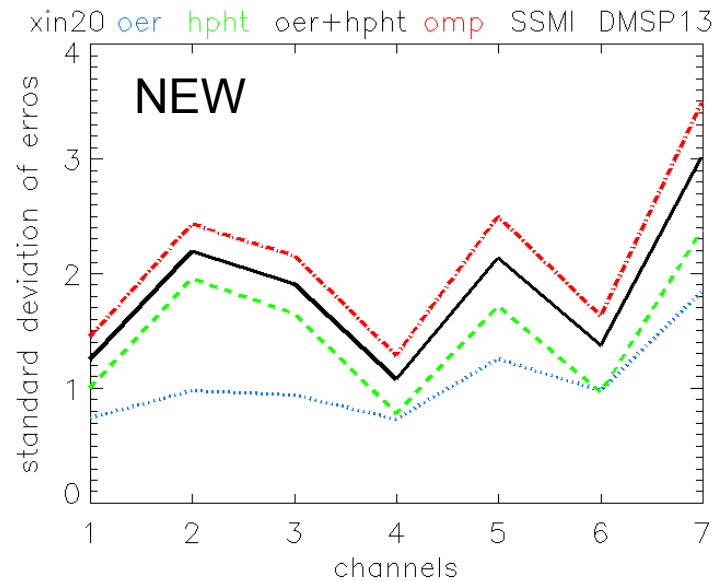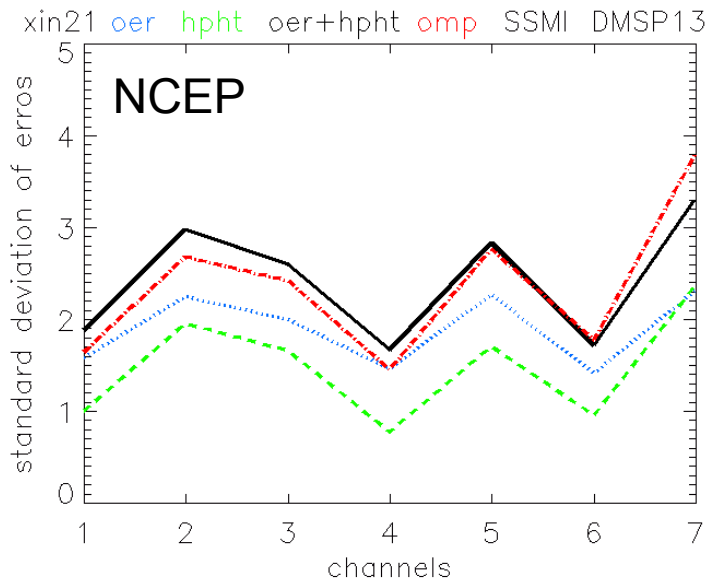
oer: rms obervation error

hpht: rms ensemble spread

omp: innovation std dev
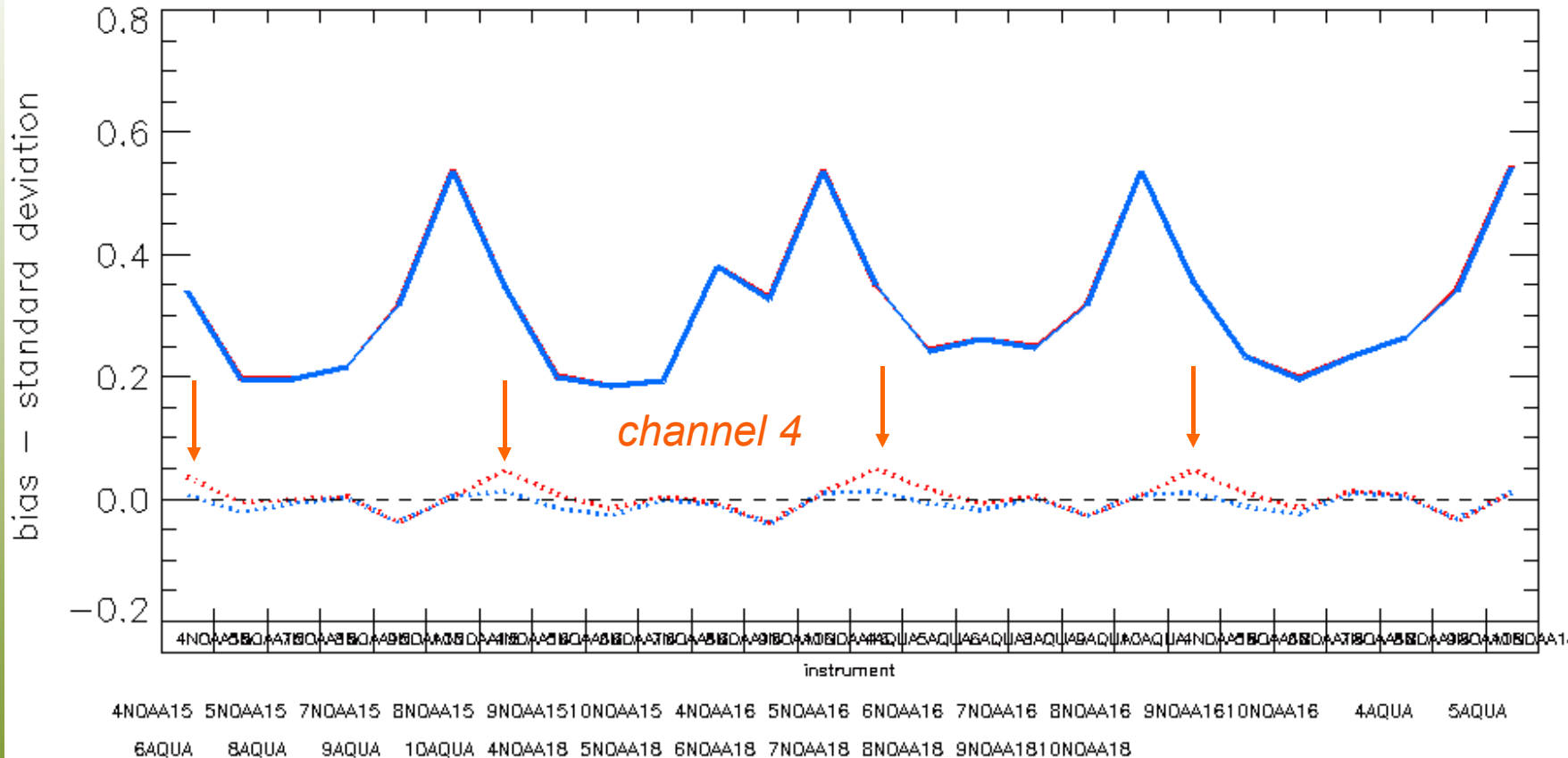
oer+hpht: predicted innovation

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Verification against SSM/I data

Positive impact on both bias and std dev

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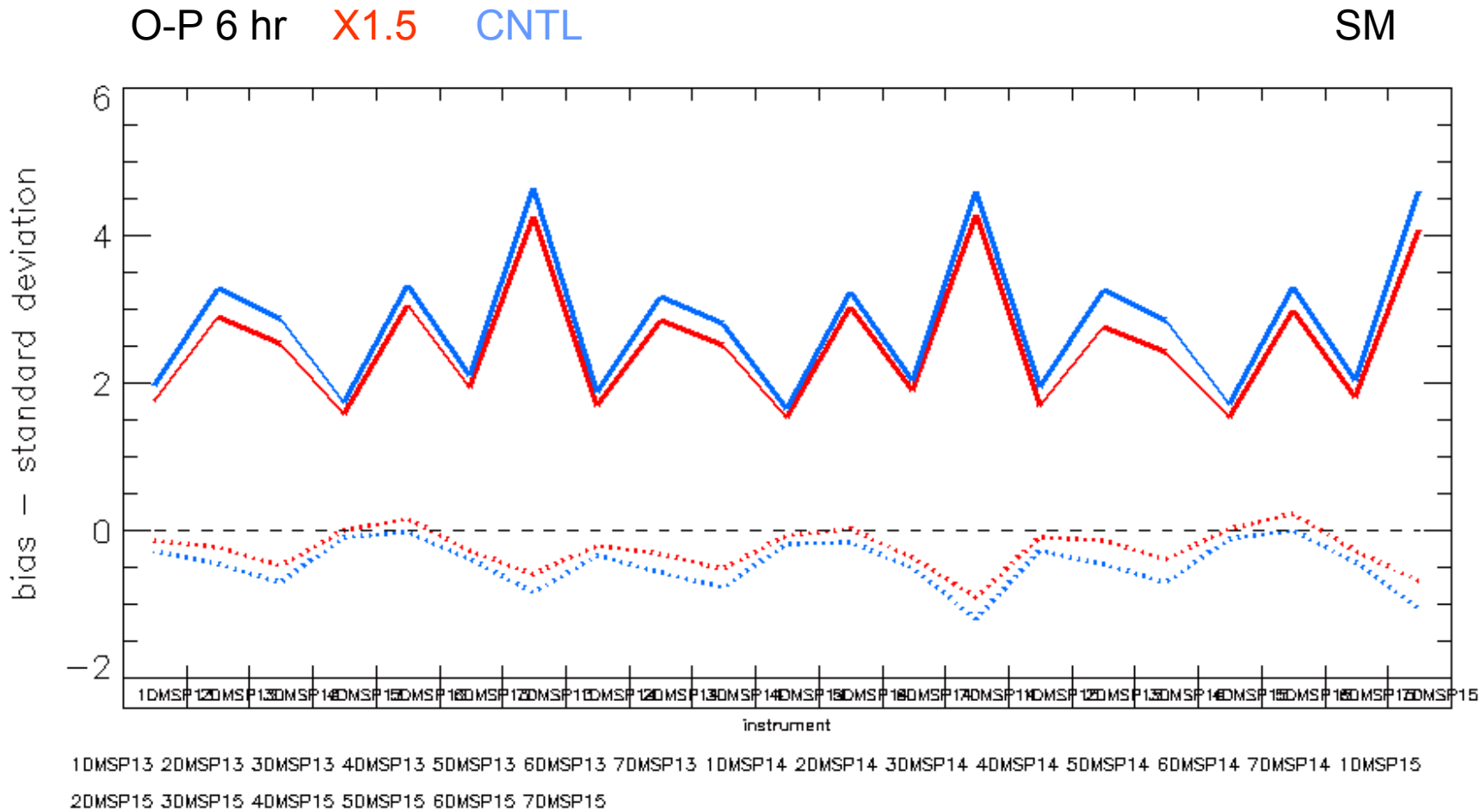
Verification against AMSU-A

O-P 6 hr   X1.5   CNTL   TOVS AMSU-A

channel 4

4NOAA15 5NOAA15 7NOAA15 8NOAA15 9NOAA15 10NOAA15 4NOAA16 5NOAA16 6NOAA16 7NOAA16 8NOAA16 9NOAA16 10NOAA16 4AQUA 5AQUA

6AQUA 8AQUA 9AQUA 10AQUA 4NOAA18 5NOAA18 6NOAA18 7NOAA18 8NOAA18 9NOAA18 10NOAA18

Negative impact on the bias for AMSU-A channel 4
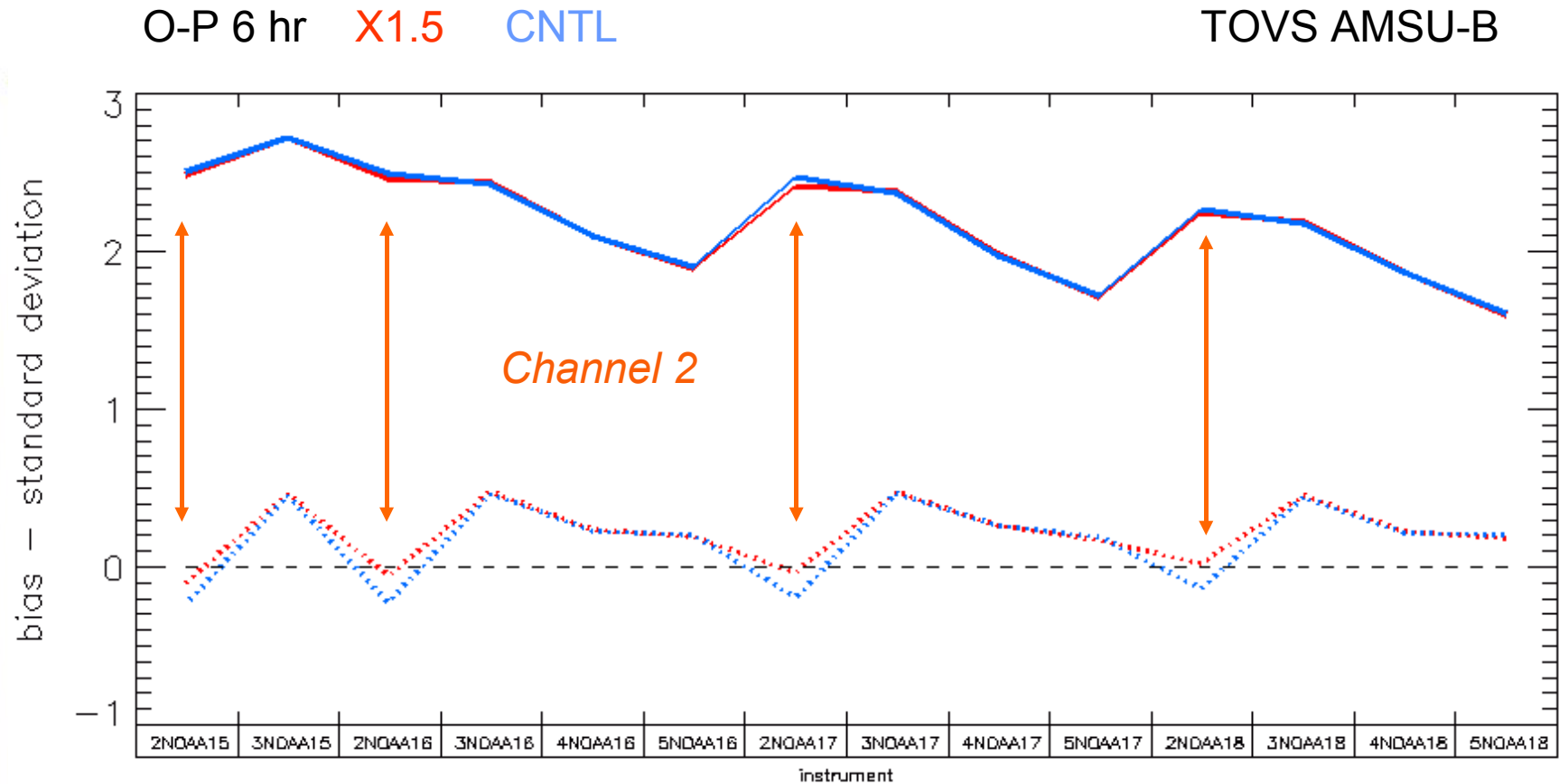
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Verification against AMSU-B

O-P 6 hr X1.5 CNTL   TOVS AMSU-B

Channel 2

Postive impact on both bias and std dev for channel 2

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Verification against RAOBS (20 6-day forecasts)
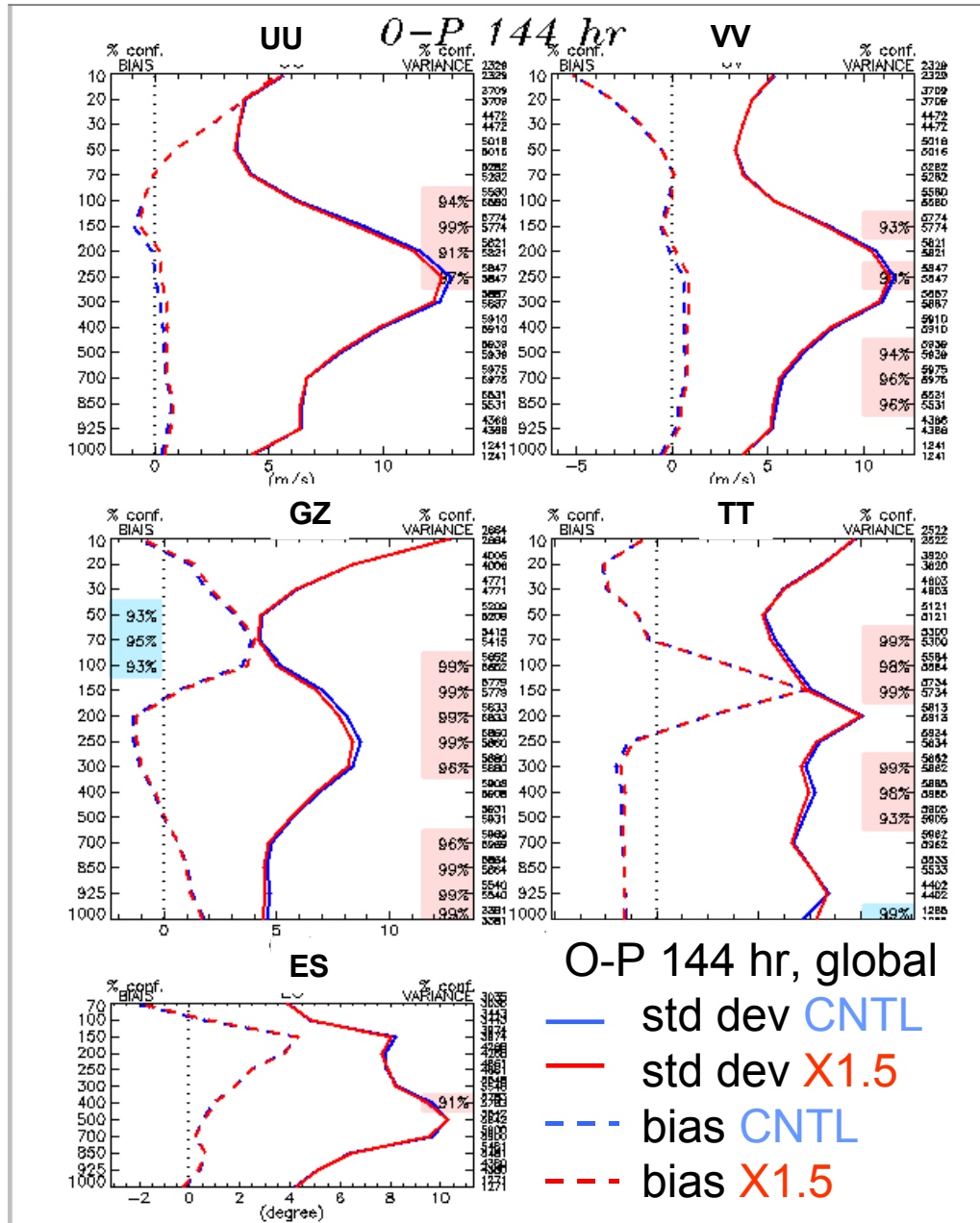
Verification against operational analysis
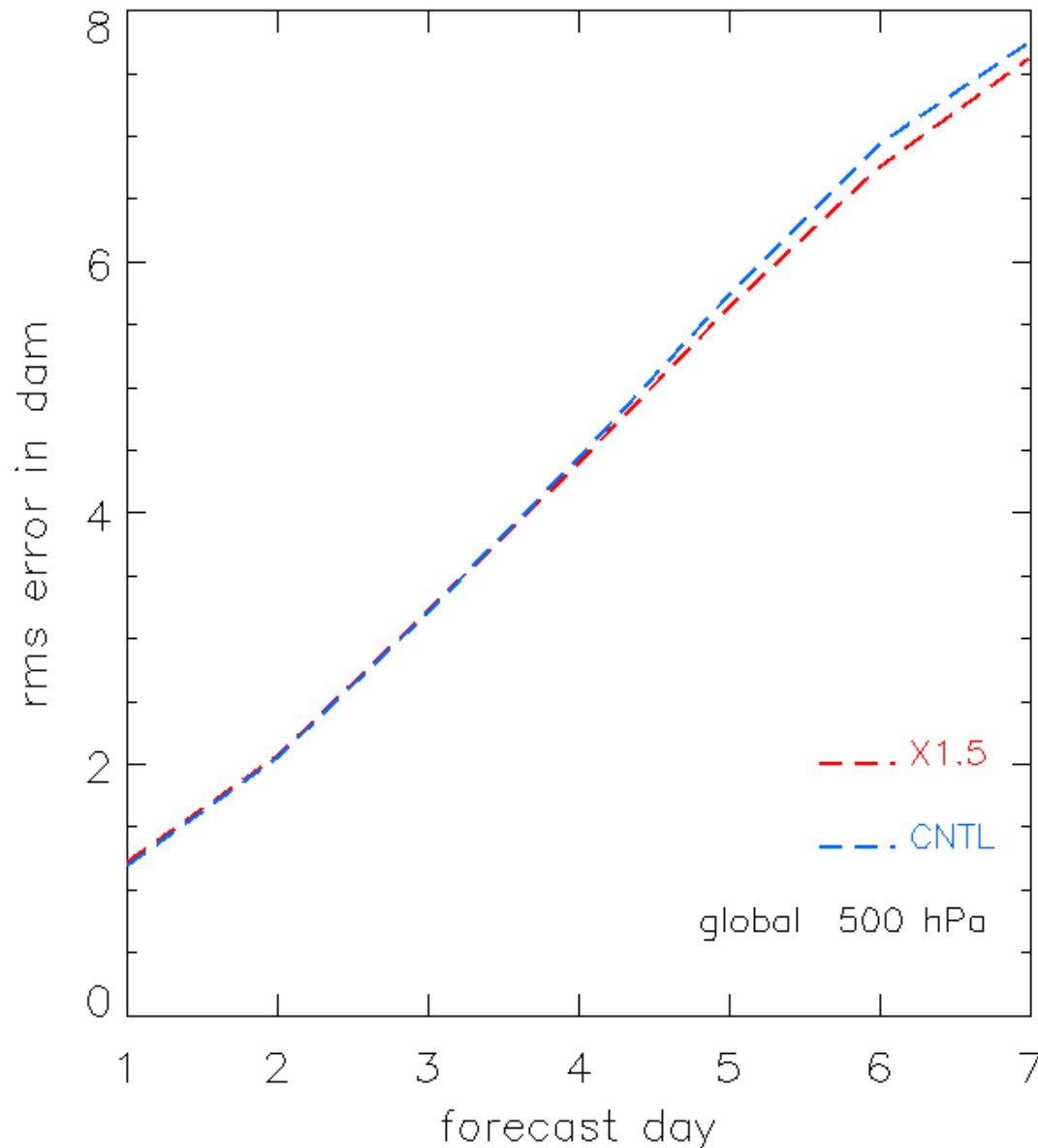
Summary

- (O-P) covariances were separated into observation and background error components. Large interchannel error correlations were found for SSM/I observations.

- These correlations were introduced into the existing EnKF algorithm.

- A positive impact is found in medium-range forecasts.

- This impact study favors the assimilation of SSM/I data with the new error statistics inflated by 1.5.

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Acknowledgements

- Louis Garand
- Sylvain Heilliette
- Normand Gagnon

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Thank you!

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