Chemical data assimilation in CAM-chem

CESM Chemistry Climate Working Group Meeting

10-11 Feb 2014

Model and DA system setup

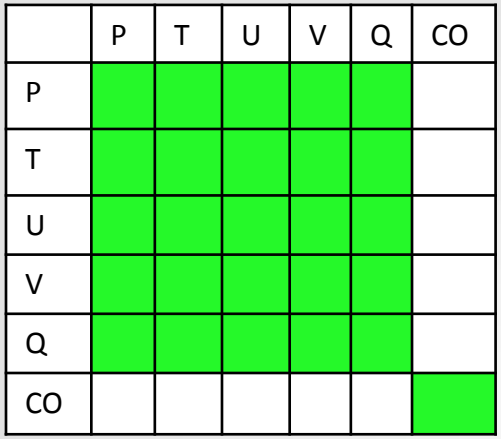
CESM1_1_1: F_2000_MOZMAM_CN compset:

- With tropospheric MOZART chemistry: Prescribed OCN/ICE, CAM5 physics, Carbon Nitrogen in CLM
  dust_emis_fact = 0.21 (?)

- Resolution is 0.9x1.25gx1v6: A ~1degree atmosphere/land grid with a nominal 1 degree ocean/ice grid using the gx1v6 ocean mask

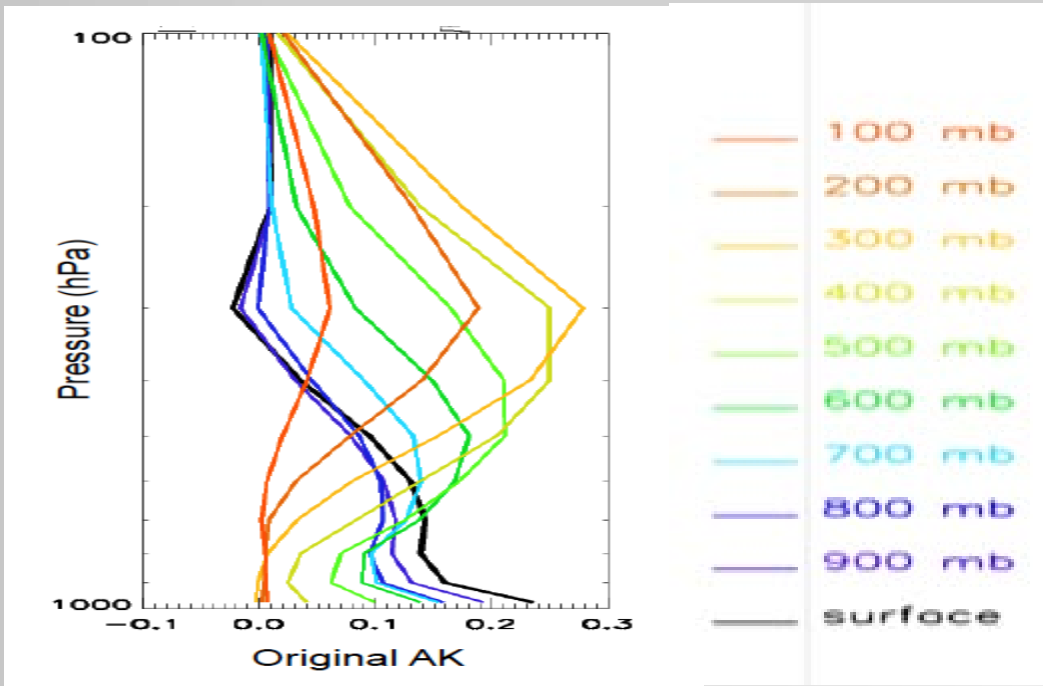
DART DA system (EAKF):

- Ensemble Adjustment Kalman Filter 30 members
- Meteorological data assimilated P, T, U, V, Q (Raeder et al. 2012)
- Adding chemistry in the state vector: For now only CO assimilated with MOPITT data.



MOPITT CO data

- Version 5
- Partial columns/ Profiles : 10 levels (hPa:1000,900,800,700,600,500,400,300,200,100)
- Averaging kernel matrix defines the sensitivity on the vertical of each level.
- Taking into account the AK matrix is mandatory in the data assimilation process



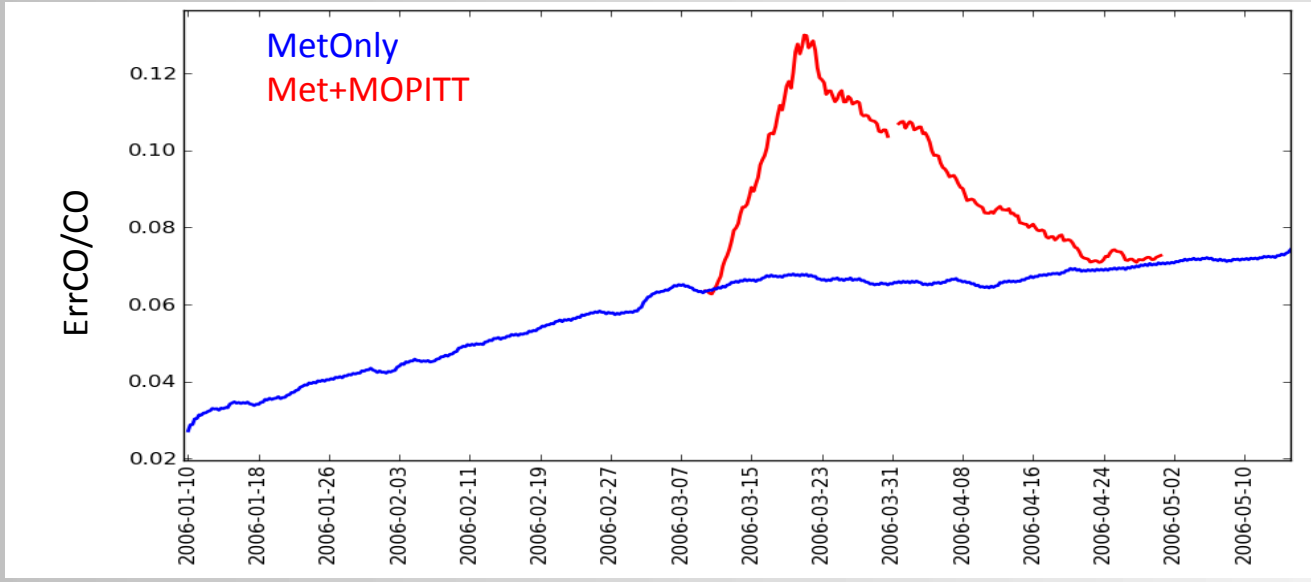
Experiment setup

CAM chem spin-up (1 year): From 2005-01 to 2006-01

MetObs DA and perturbed emission spin-up (2 months):
From 2006-01-10 to 2006-03-10
CO model error (ensemble spread) is generated via **MetObs assimilation** and **perturbed emissions**. Needs 2 months to reach a "significant" value.

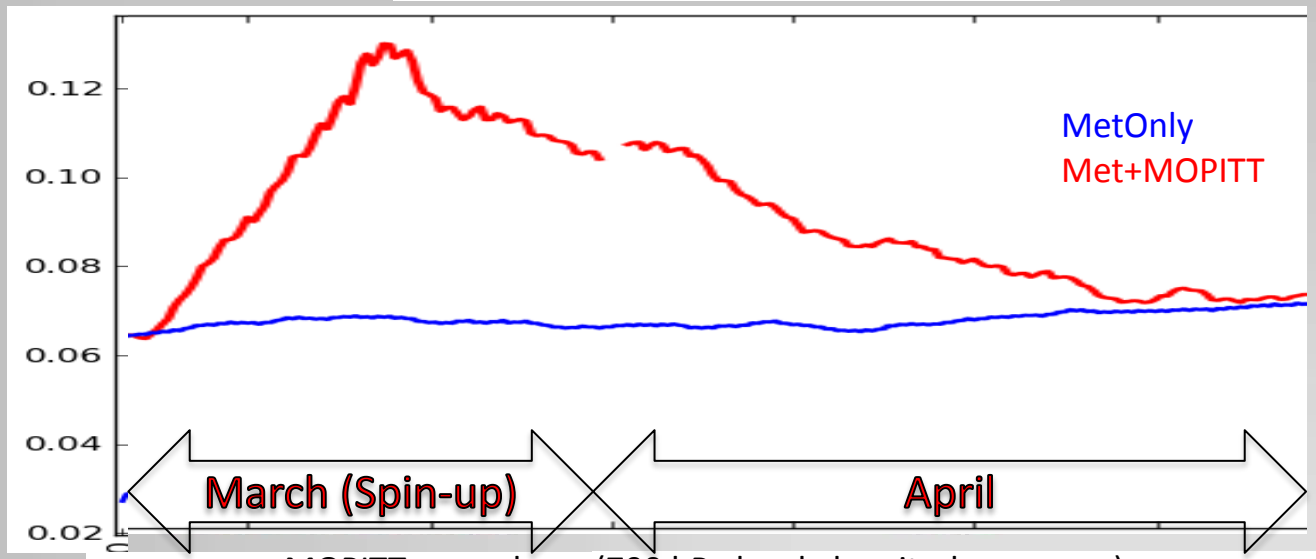
MOPITT DA spin-up (2 weeks): From 2006-03-10 to 2006-04-01

Model error 700hPa lat-lon average

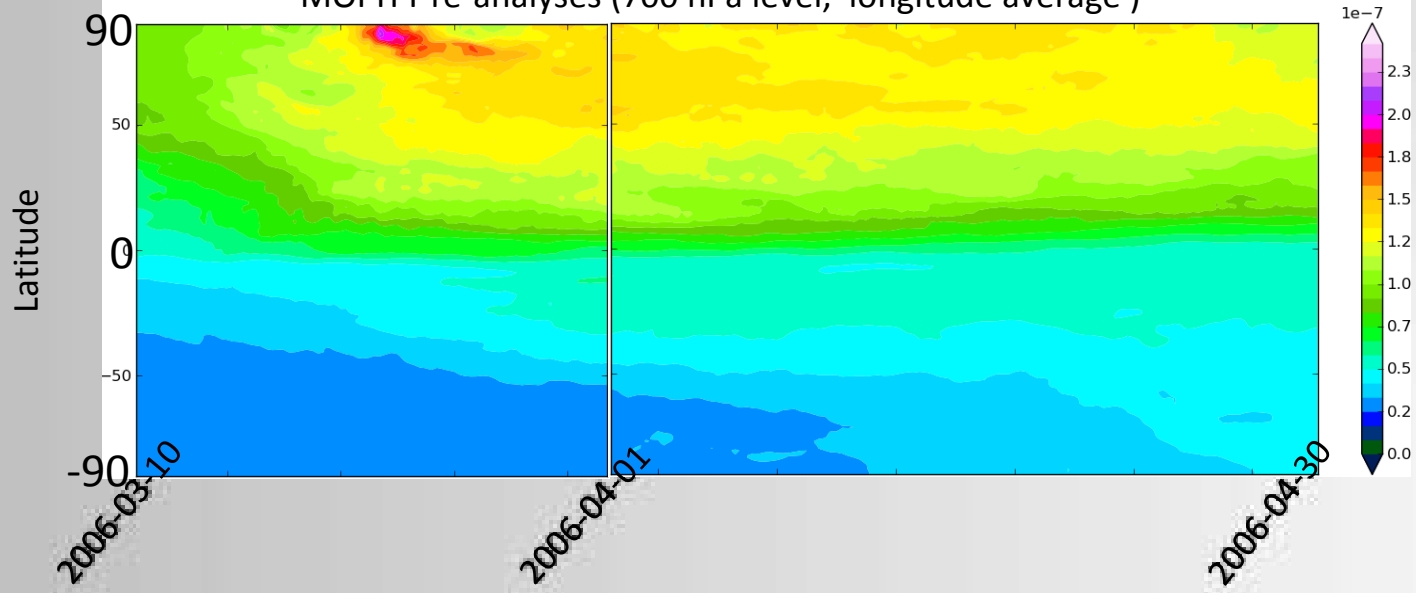


Experiment setup

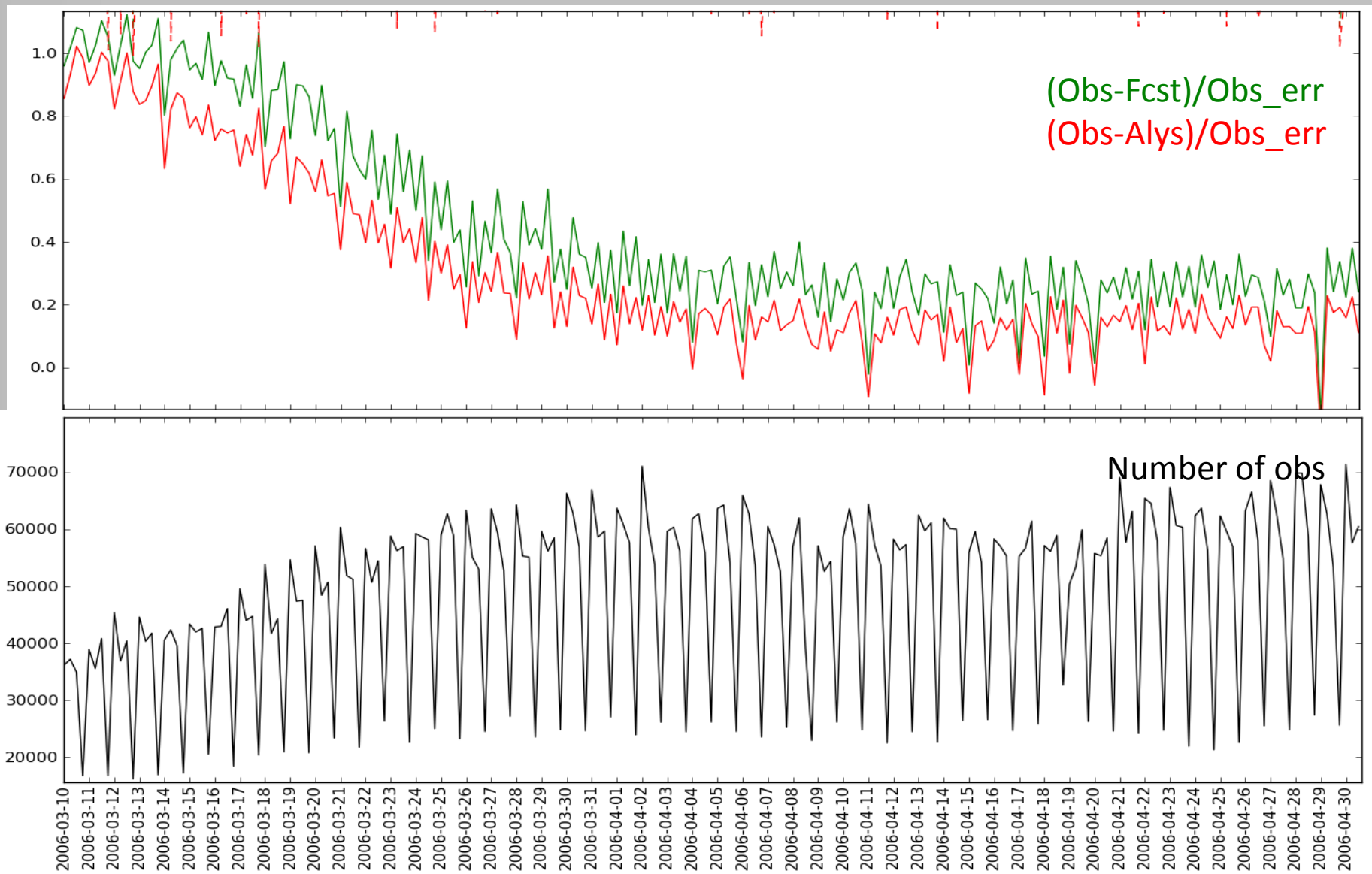
Model error 700hPa level lat-lon average



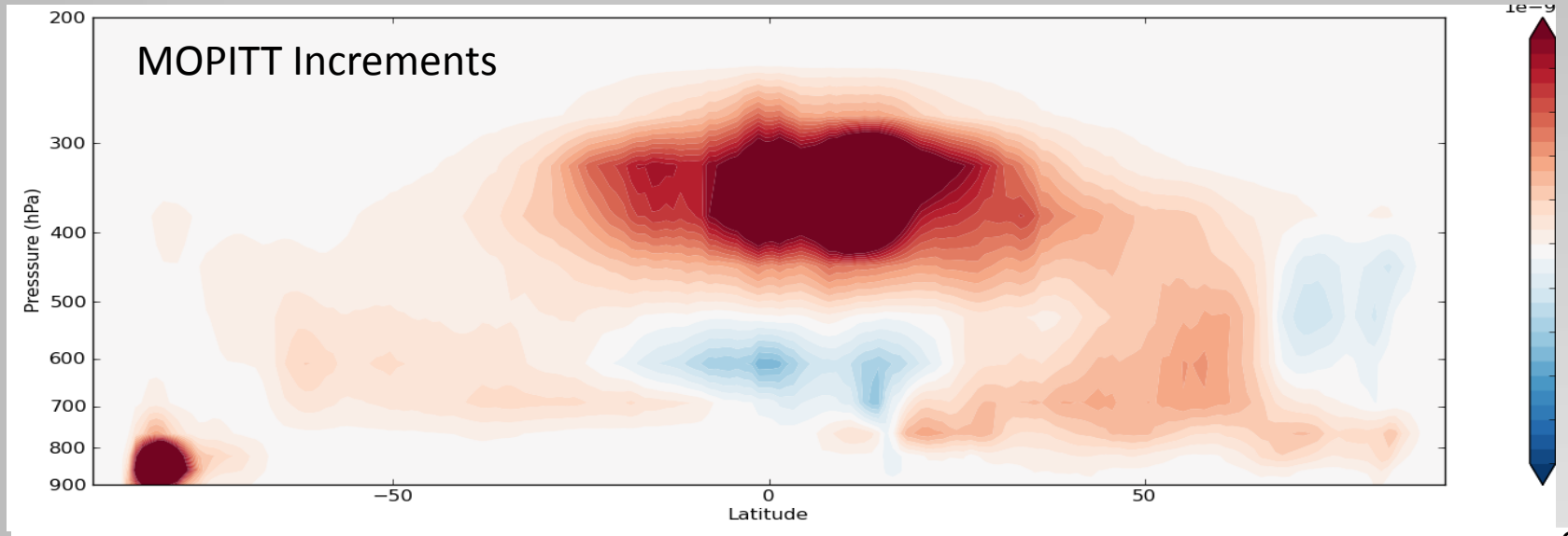
MOPITT re-analyses (700 hPa level, longitude average)

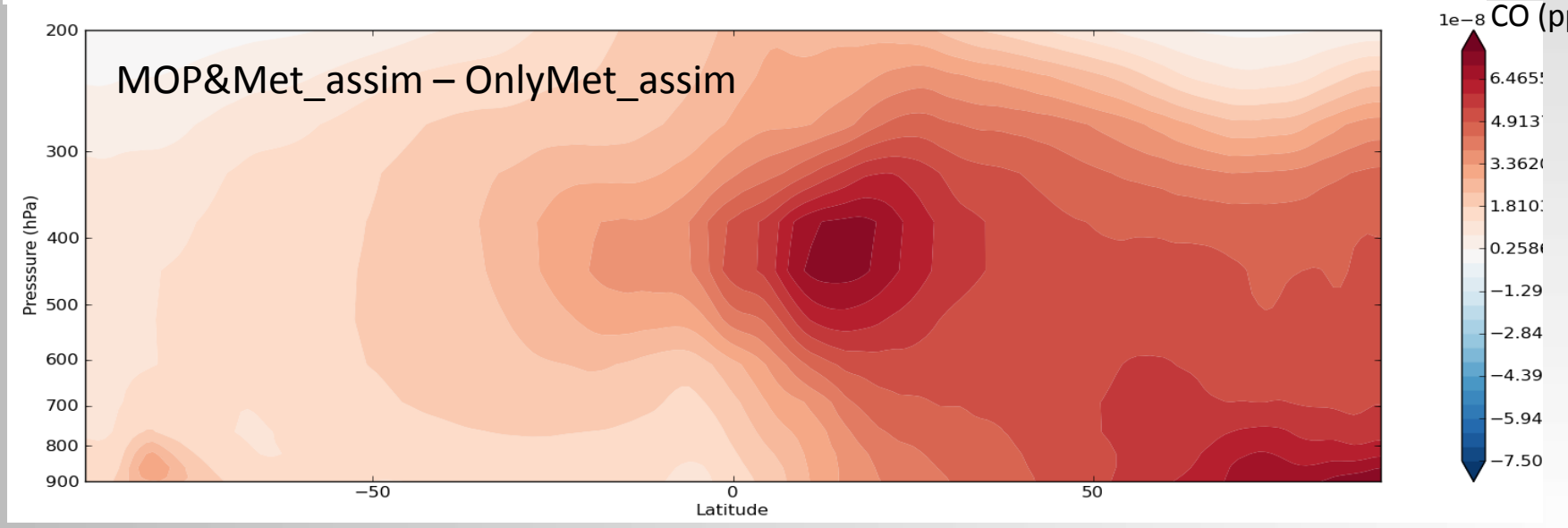


Self consistency tests



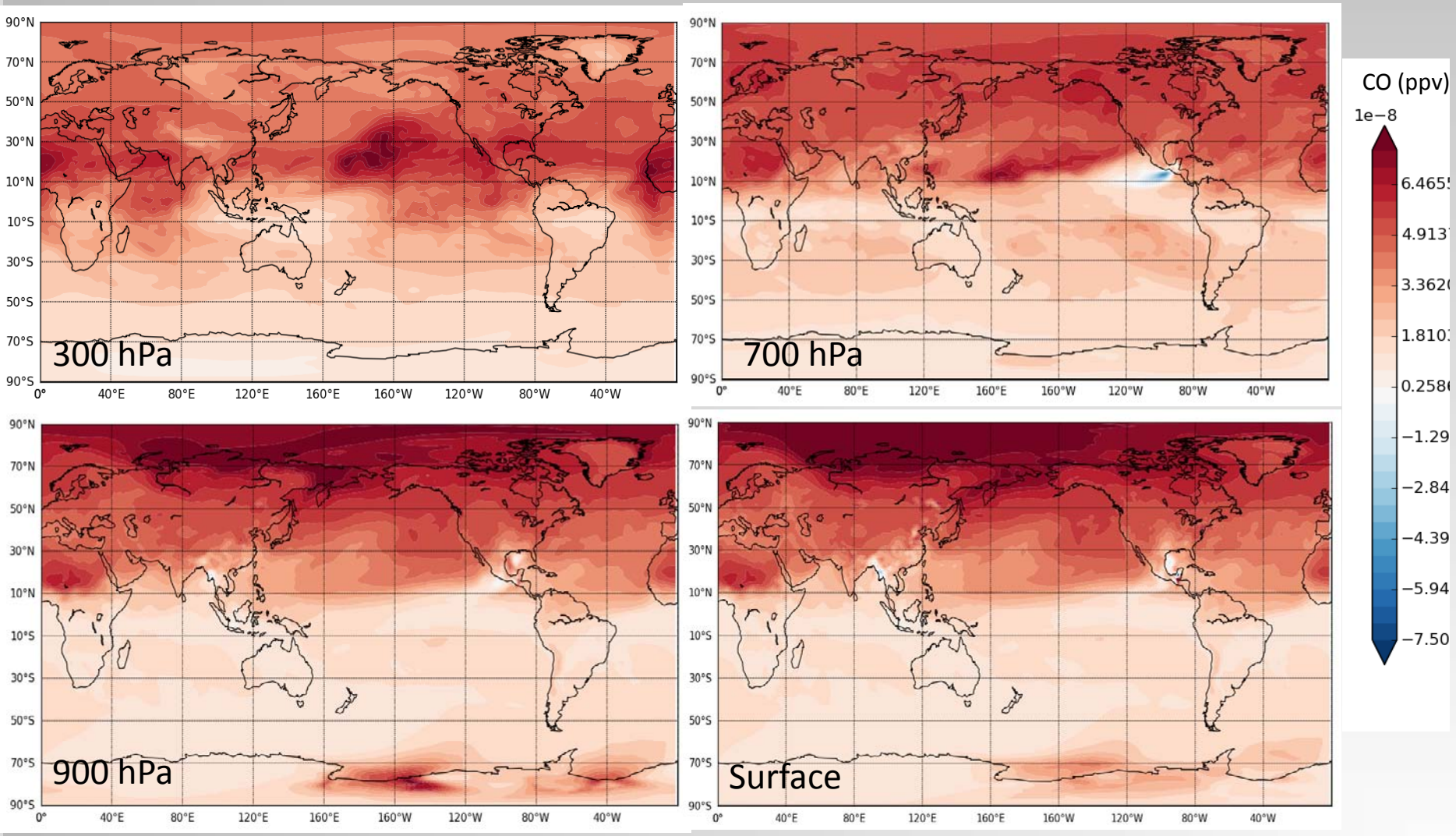
Longitude Time averages
2006-04-01 to 2006-04-30





Time averages
2006-04-01 to 2006-04-30

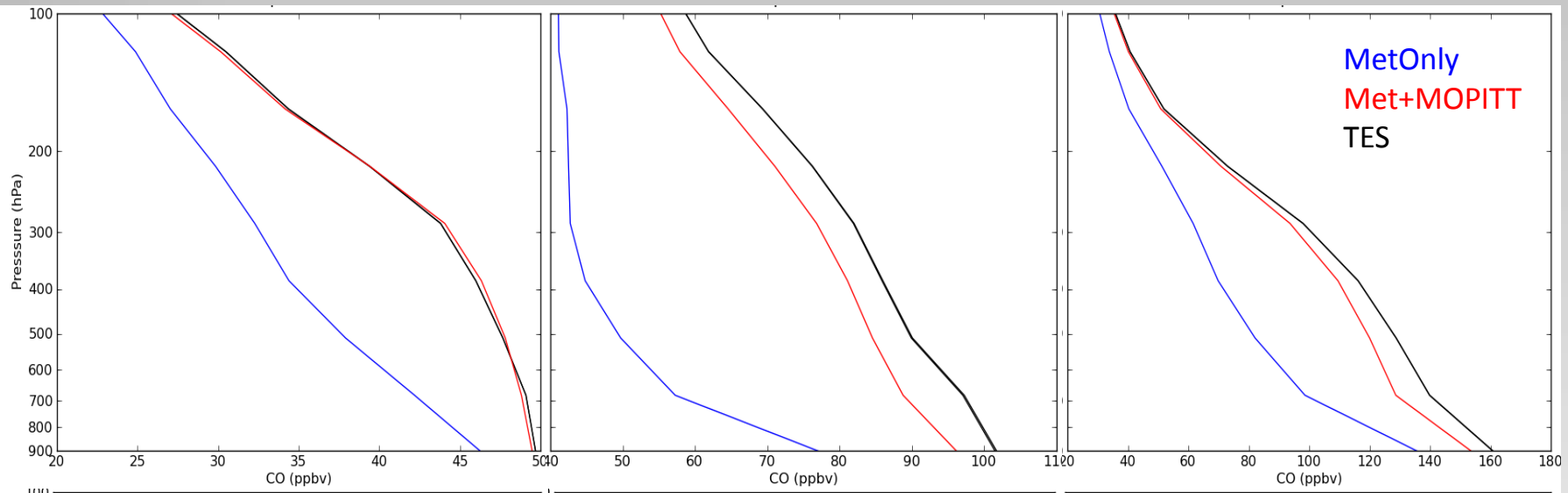
MOPITT&Met_assim – MetOnly_assim



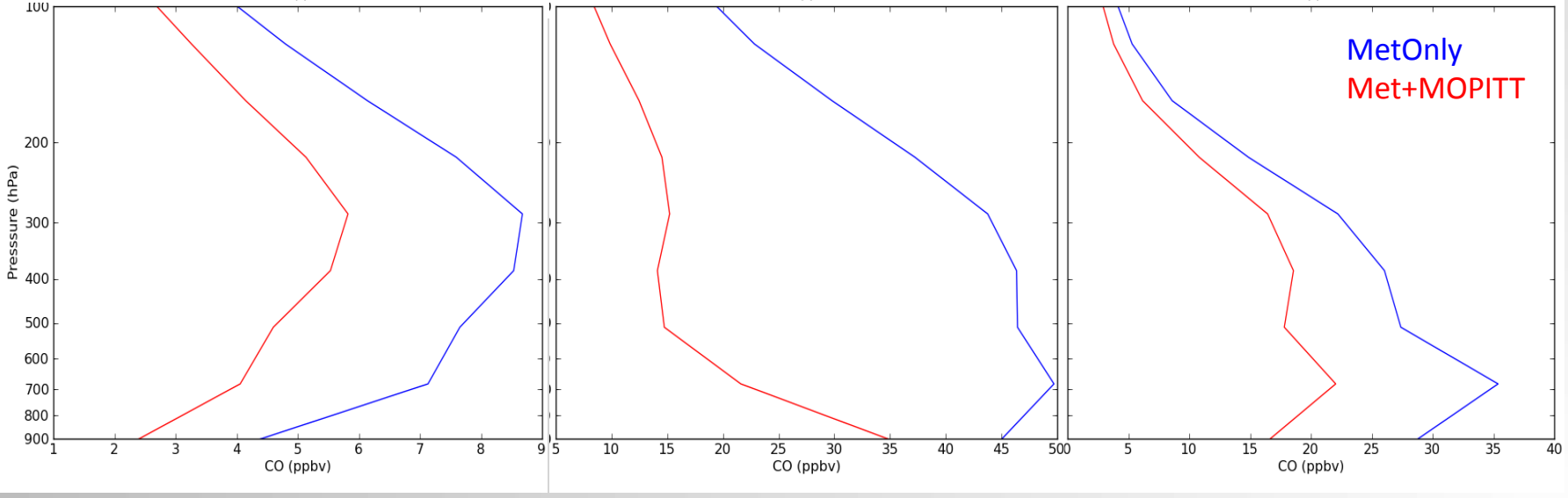
Evaluation with TES CO
April 2006
(profiles are smoothed by TES AVK)

90°S : 30°S | 30°S : 30°N | 30°N : 90°N

Average profiles



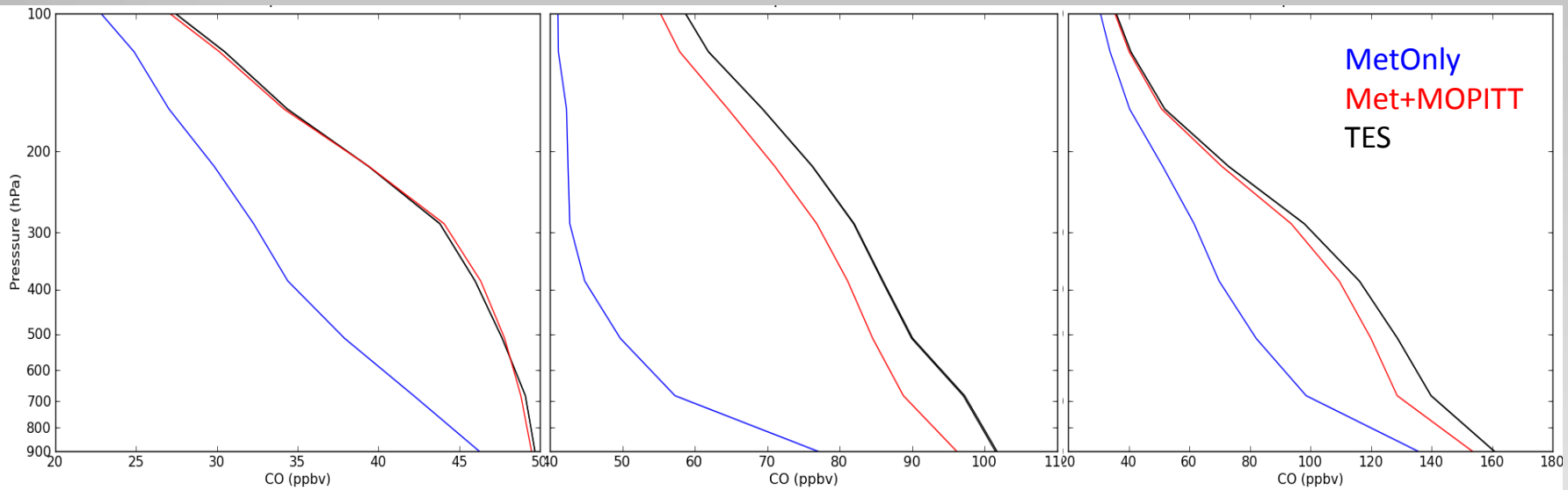
RMSE (un-biased)



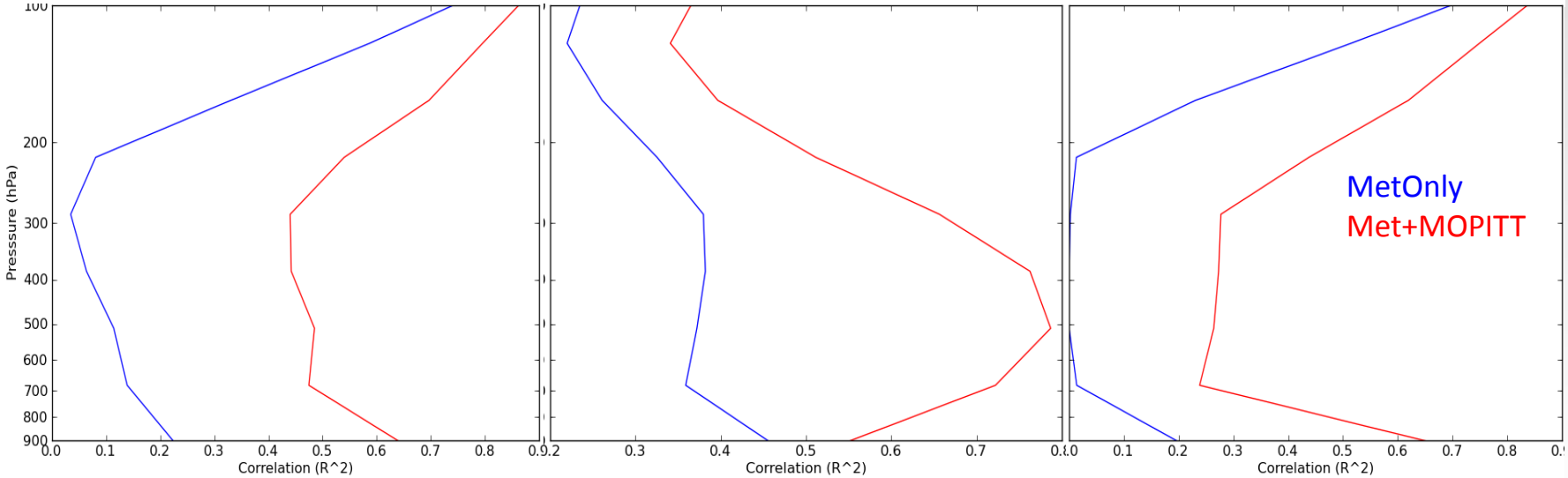
Evaluation with TES CO
April 2006
(profiles are smoothed by TES AVK)

90°S : 30°S | 30°S : 30°N | 30°N : 90°N

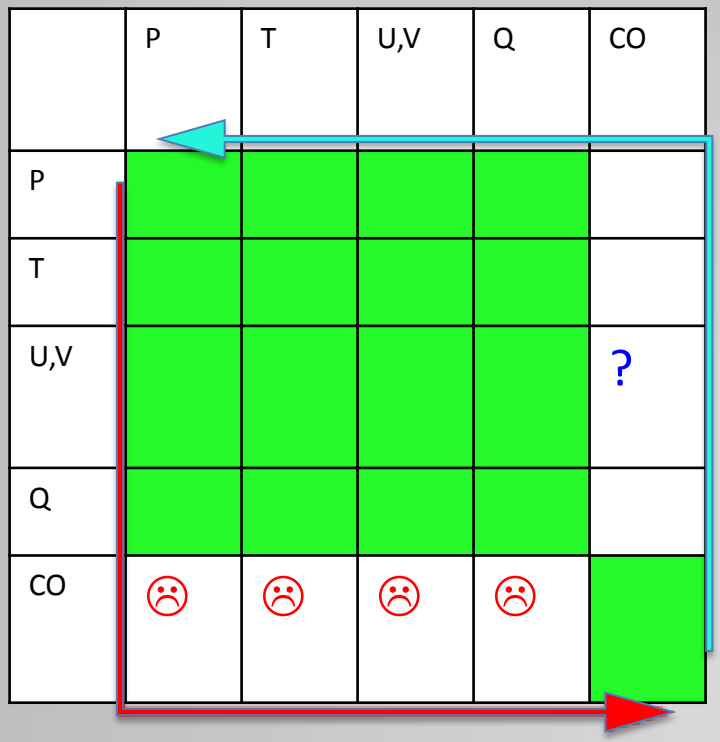
Average profiles



Correlation R^2



Covariance matrix & state vector



- Assimilation of MetObs mess-up the chemistry variables (negatives values and models crashes). Cut-off the covariances between Met variables and chemical variables: stable Met-Chem Data assimilation.
- What is the added value of chemical DA on meteorology. One way coupling ?

Covariance matrix & state vector

	P	T	U,V	Q	CO	03	??
P							
T							
U,V							
Q							
CO						?	?
O3					?		?
??					?	?	

- Is a “state augmentation” for chemistry stable? Test on ozone or a more related chemistry species/variable?

Covariance matrix & state vector (Emissions)

	P	T	U,V	Q	CO	??	Emissions
P							
T							
U,V							
Q							
CO						?	?
??					?		?
Emissions					?	?	

- Put the emission in the state vector ? (Ben Gaubert post-doc work)

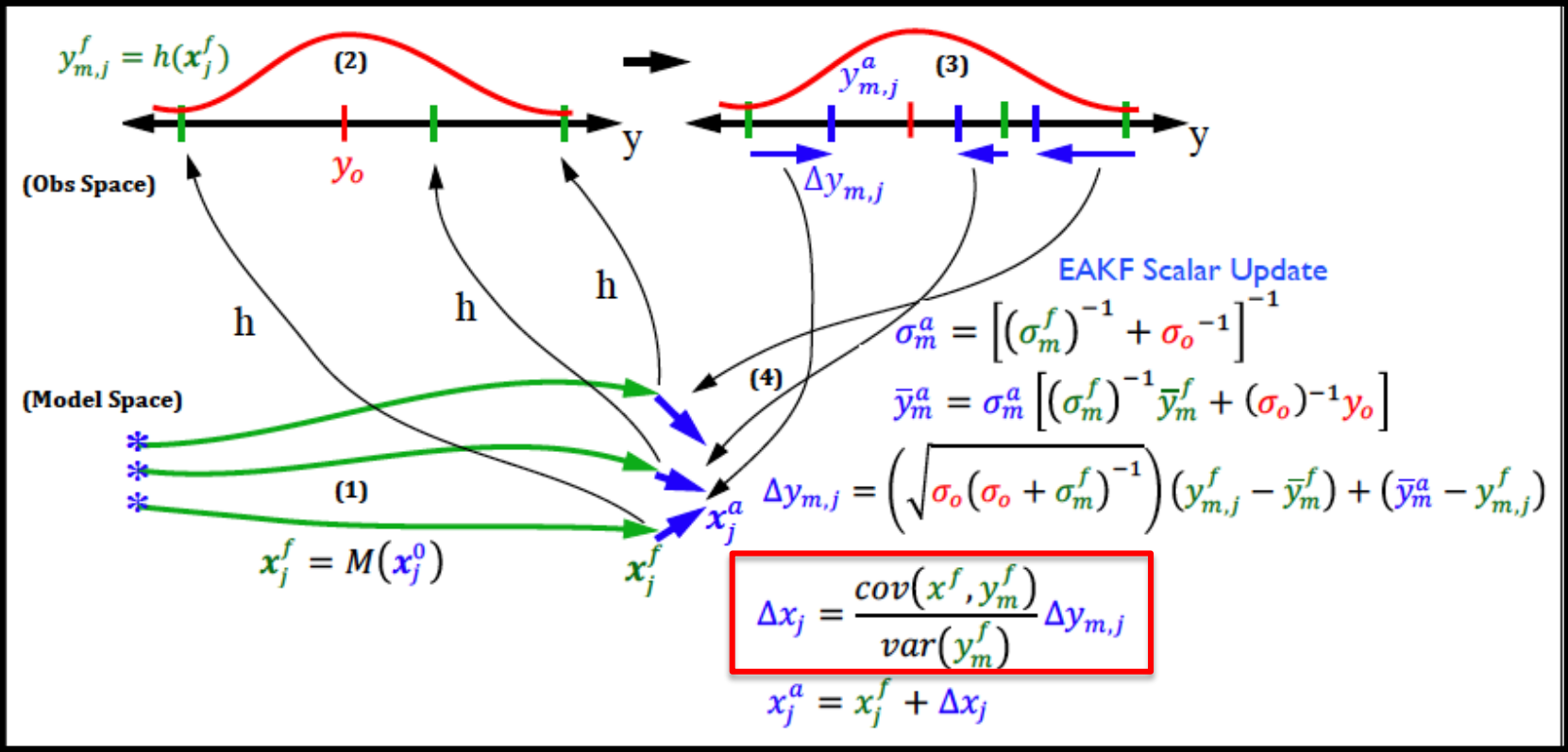
Conclusion

- CESM DA system needs time to spin up (~3 months)
- MOPITT CO Data assimilation corrects the CO negative bias in CAM-Chem: first validation shows promising results
- Need to understand the impact of improved CO on the other linked chemical species and meteorology:
    - Model itself effect
    - Data assimilation effect
- Effects of (CO) data assimilation on emissions

Thanks

Backup slides

SVD data assimilation increments

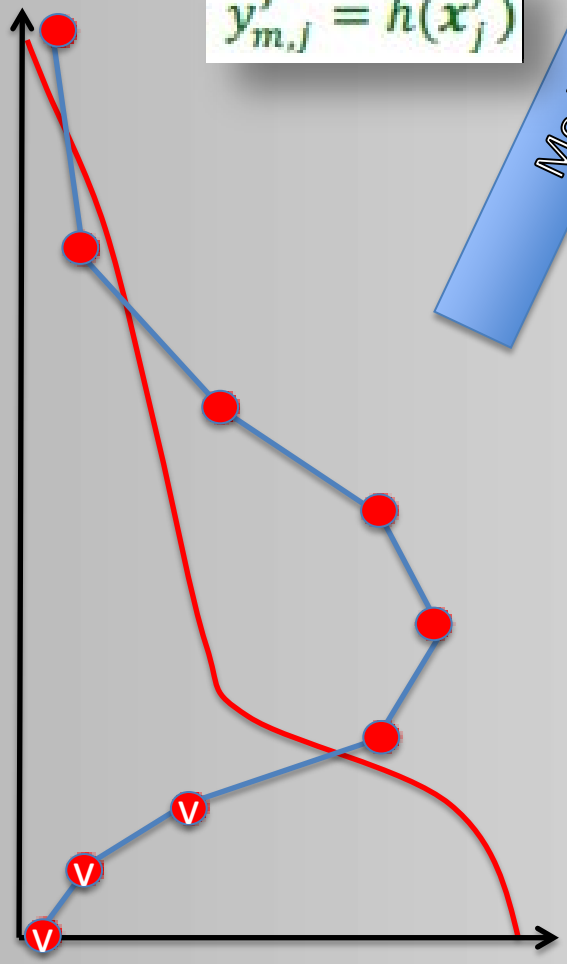


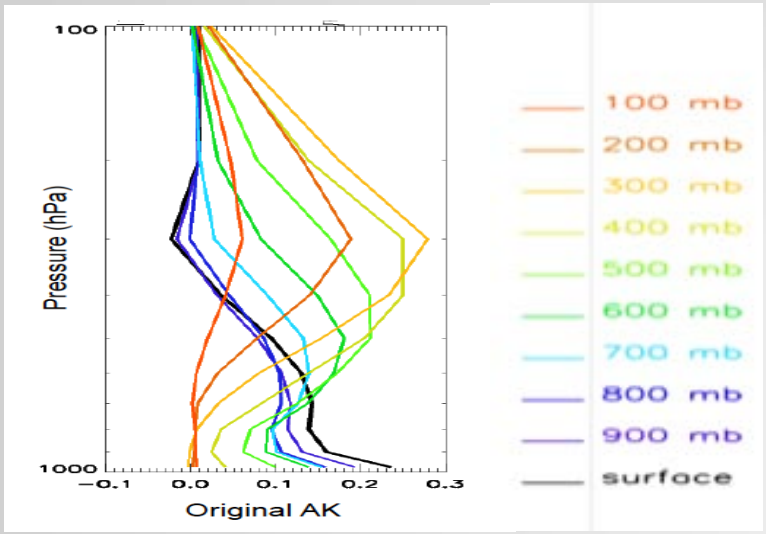
$y^f_m = Ax_f - (I-A)x_a$

$$y^f_{m,j} = h(x^f_j)$$

Model to Obs

x to y





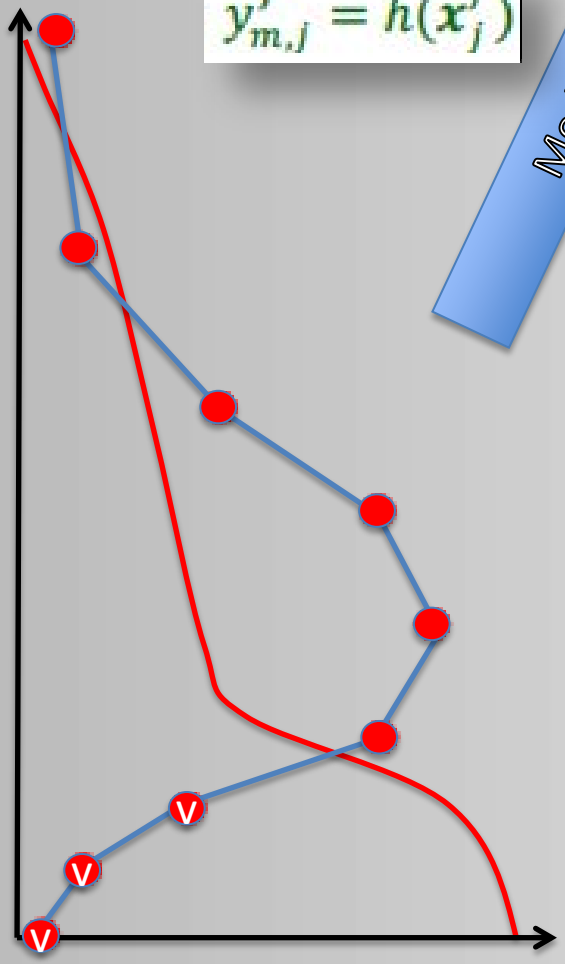
$$\Delta y_{m,j} = \left(\sqrt{\sigma_o(\sigma_o + \sigma_m^f)^{-1}}\right)(y_{m,j}^f - \bar{y}_m^f) + (\bar{y}_m^a - y_{m,j}^f)$$

$y^f_m = Ax_f - (I-A)x_a$

$$y_{m,j}^f = h(x_j^f)$$

Model to Obs

x to y



$$\Delta y_{m,j} = \left(\sqrt{\sigma_o\left(\sigma_o + \sigma_m^f\right)^{-1}}\right)\left(y_{m,j}^f - \bar{y}_m^f\right) + \left(\bar{y}_m^a - y_{m,j}^f\right)$$

$$y^f{}_m = Ax_f - (I-A)x_a$$

$$y_{m,j}^f = h(x_j^f)$$

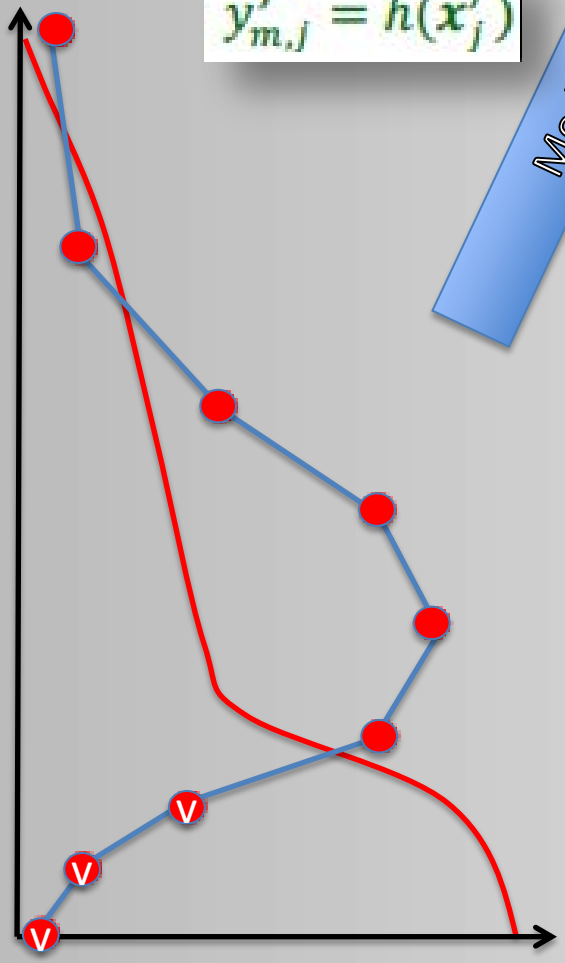
Model to Obs

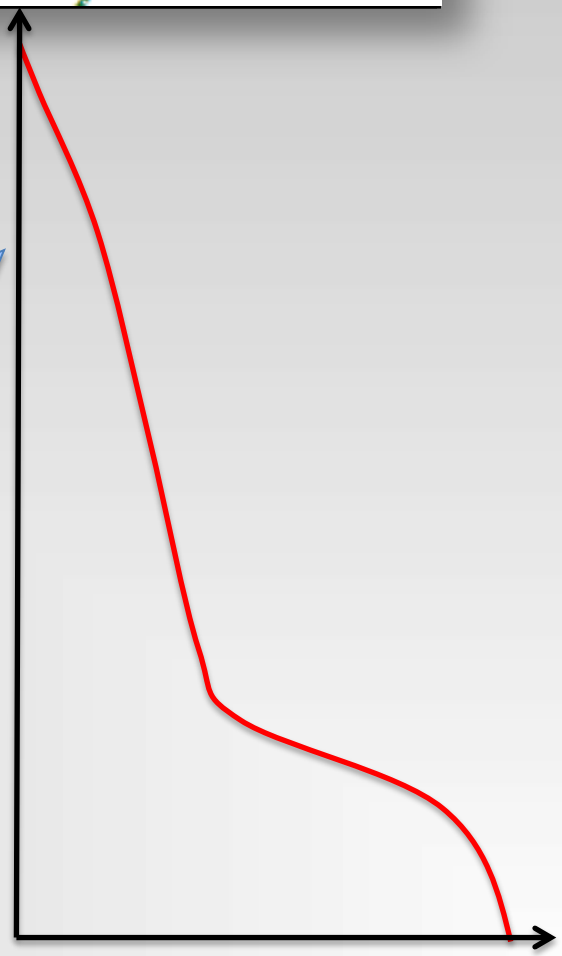
x to y

Obs to Model

y to x

$$\Delta x_j = \frac{cov\left(x^f, y_m^f\right)}{var\left(y_m^f\right)} \Delta y_{m,j}$$





$$\Delta y_{m,j} = \left(\sqrt{\sigma_o(\sigma_o + \sigma_m^f)^{-1}}\right)(y_{m,j}^f - \bar{y}_m^f) + (\bar{y}_m^a - y_{m,j}^f)$$

$y^f_m = Ax_f - (I-A)x_a$

$$y_{m,j}^f = h(x_j^f)$$

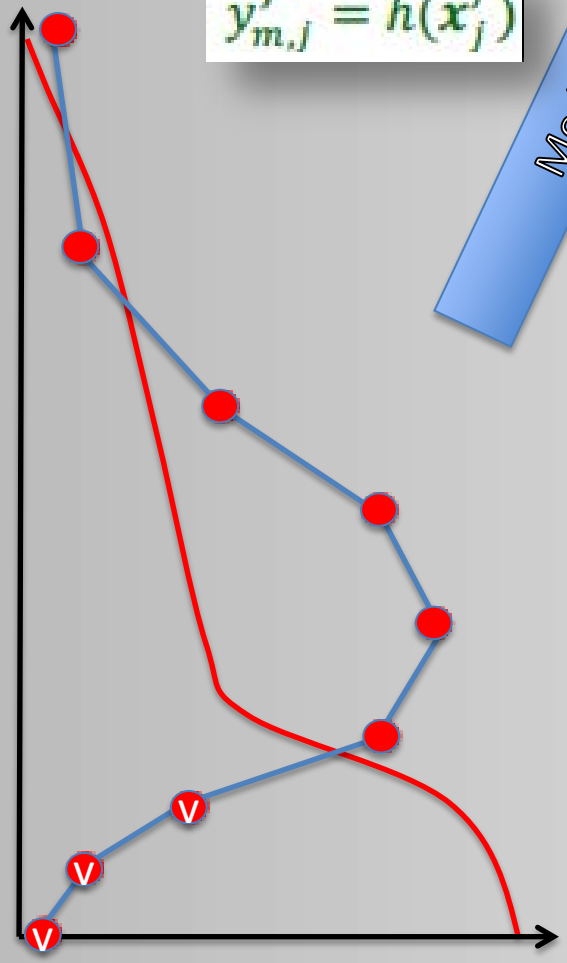
Model to Obs

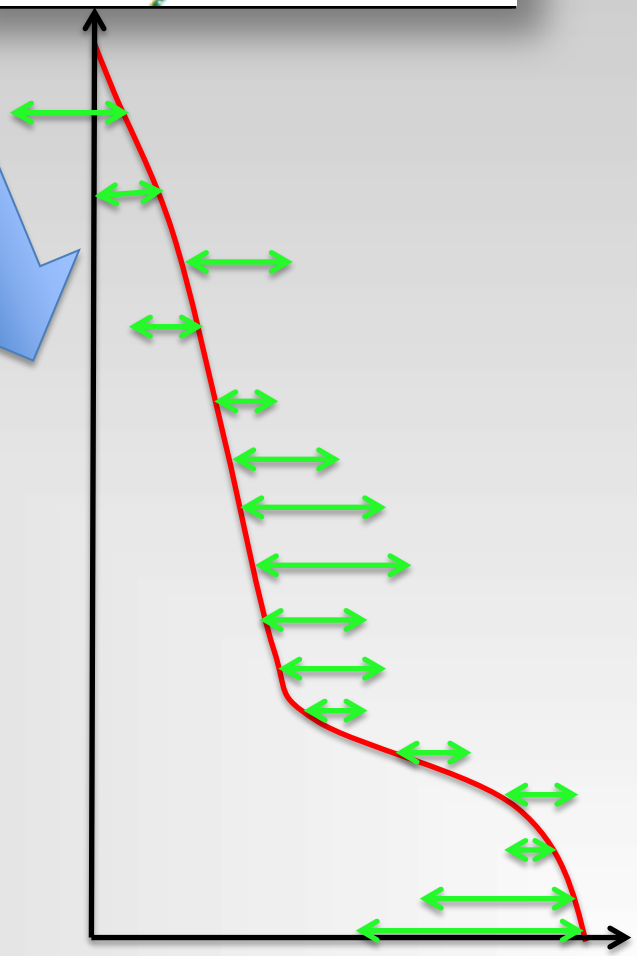
x to y

Obs to Model

y to x

$$\Delta x_j = \frac{cov(x^f, y_m^f)}{var(y_m^f)} \Delta y_{m,j}$$





$$\Delta y_{m,j} = \left(\sqrt{\sigma_o(\sigma_o + \sigma_m^f)^{-1}}\right)(y_{m,j}^f - \bar{y}_m^f) + (\bar{y}_m^a - y_{m,j}^f)$$

$y^f_m = Ax_f - (I-A)x_a$

$$y_{m,j}^f = h(x_j^f)$$

Model to Obs

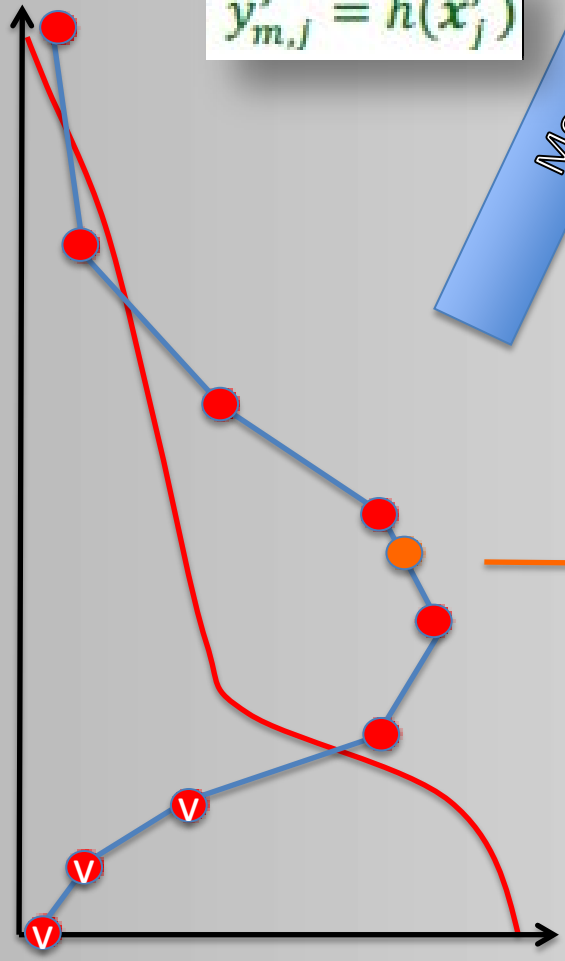
x to y

Obs to Model

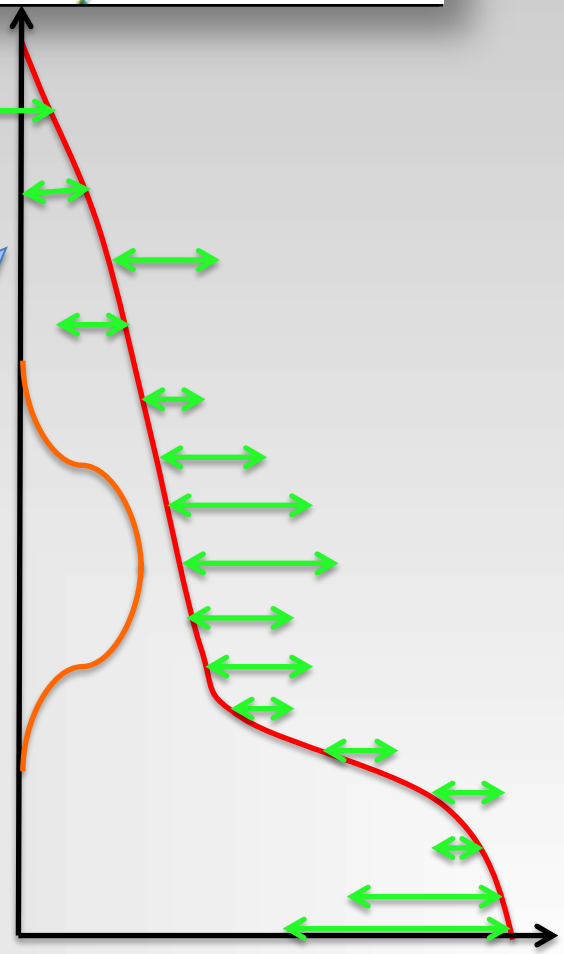
y to x

$$\Delta x_j = \frac{cov(x^f, y_m^f)}{var(y_m^f)} \Delta y_{m,j}$$

xGC



With vertical localization



$$\Delta y_{m,j} = \left(\sqrt{\sigma_o\left(\sigma_o + \sigma_m^f\right)^{-1}}\right)\left(y_{m,j}^f - \bar{y}_m^f\right) + \left(\bar{y}_m^a - y_{m,j}^f\right)$$

$y^f_m = Ax_f - (I-A)x_a$

$$y_{m,j}^f = h(x_j^f)$$

Model to Obs

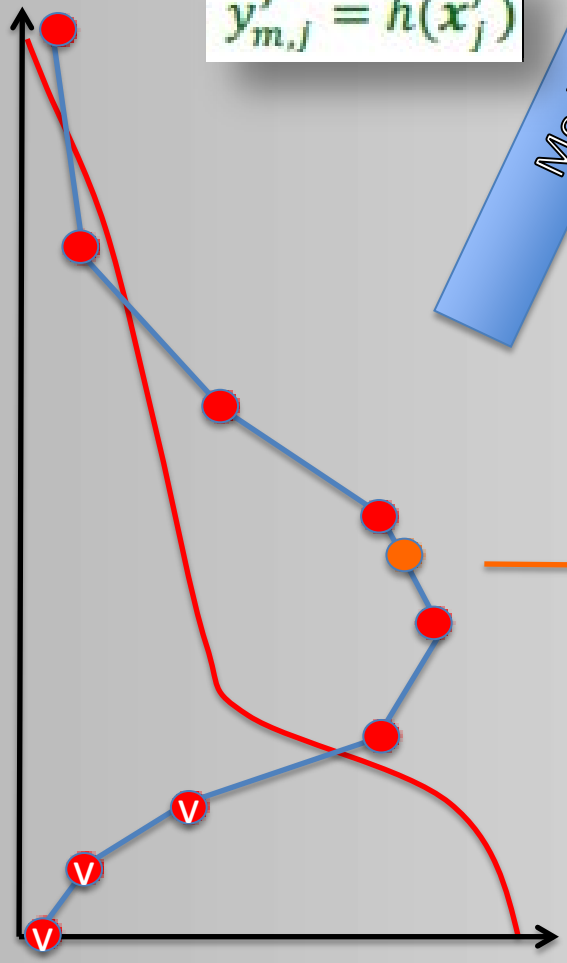
x to y

Obs to Model

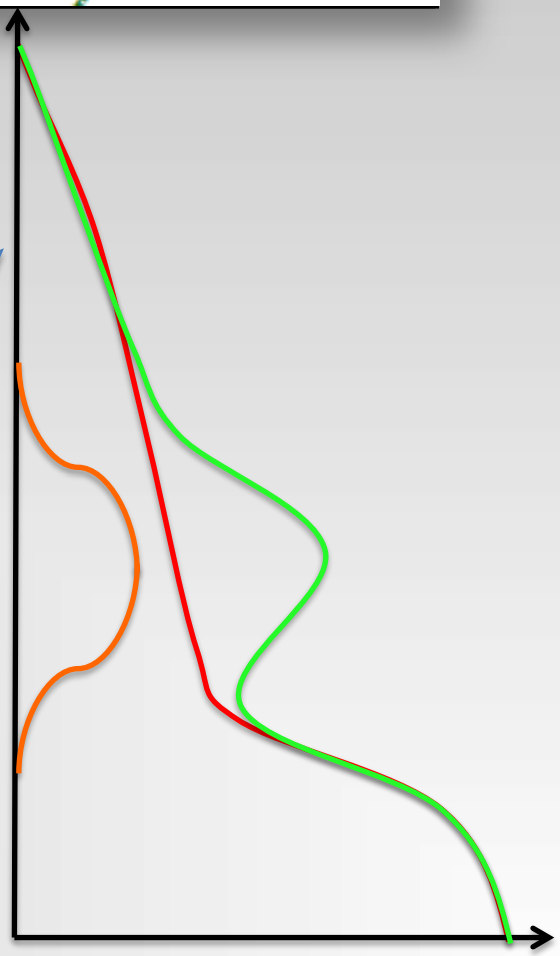
y to x

$$\Delta x_j = \frac{cov\left(x^f, y_m^f\right)}{var\left(y_m^f\right)} \Delta y_{m,j}$$

xGC



With vertical localization



$$\Delta y_{m,j} = \left(\sqrt{\sigma_o(\sigma_o + \sigma_m^f)^{-1}}\right)(y_{m,j}^f - \bar{y}_m^f) + (\bar{y}_m^a - y_{m,j}^f)$$

$y^f_m = Ax_f - (I-A)x_a$

$$y_{m,j}^f = h(x_j^f)$$

Model to Obs

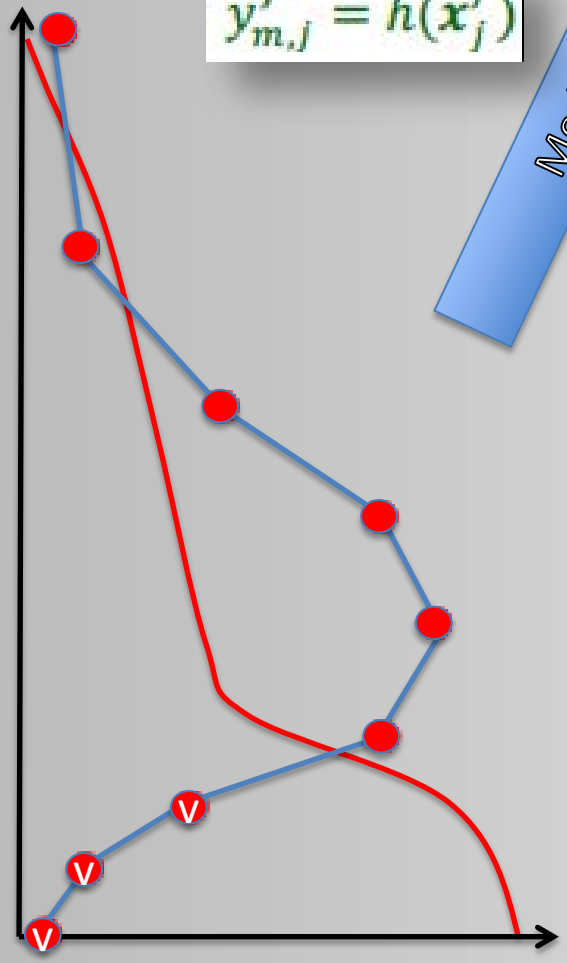
x to y

Obs to Model

y to x

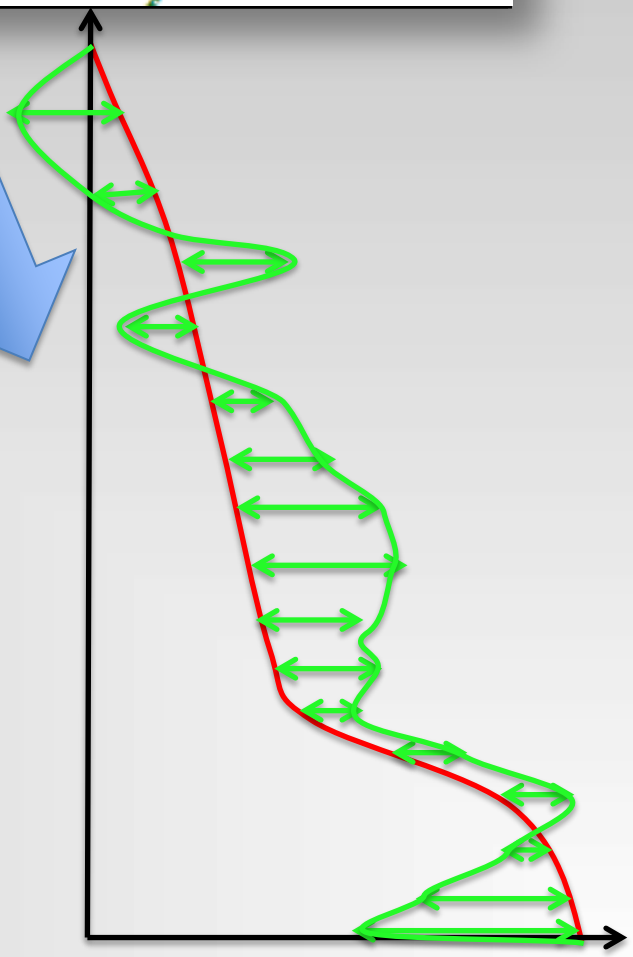
$$\Delta x_j = \frac{cov(x^f, y_m^f)}{var(y_m^f)} \Delta y_{m,j}$$

xGC



Without vertical localization

?



$$\Delta y_{m,j} = \left(\sqrt{\sigma_o\left(\sigma_o + \sigma_m^f\right)^{-1}}\right)\left(y_{m,j}^f - \bar{y}_m^f\right) + \left(\bar{y}_m^a - y_{m,j}^f\right)$$

$y^f_m = Ax_f - (I-A)x_a$

$$y_{m,j}^f = h(x_j^f)$$

Model to Obs

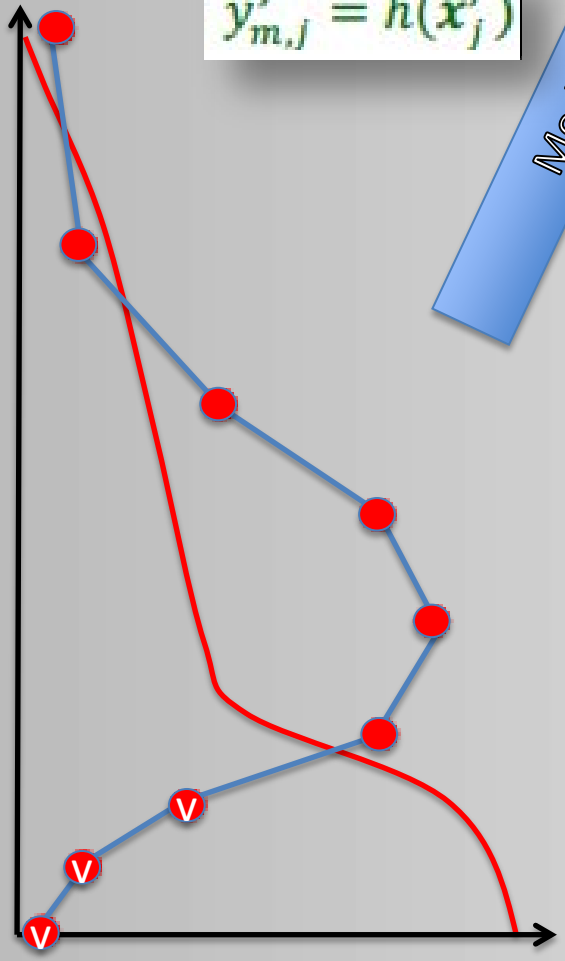
x to y

Obs to Model

y to x

$$\Delta x_j = \frac{cov\left(x^f, y_m^f\right)}{var\left(y_m^f\right)} \Delta y_{m,j}$$

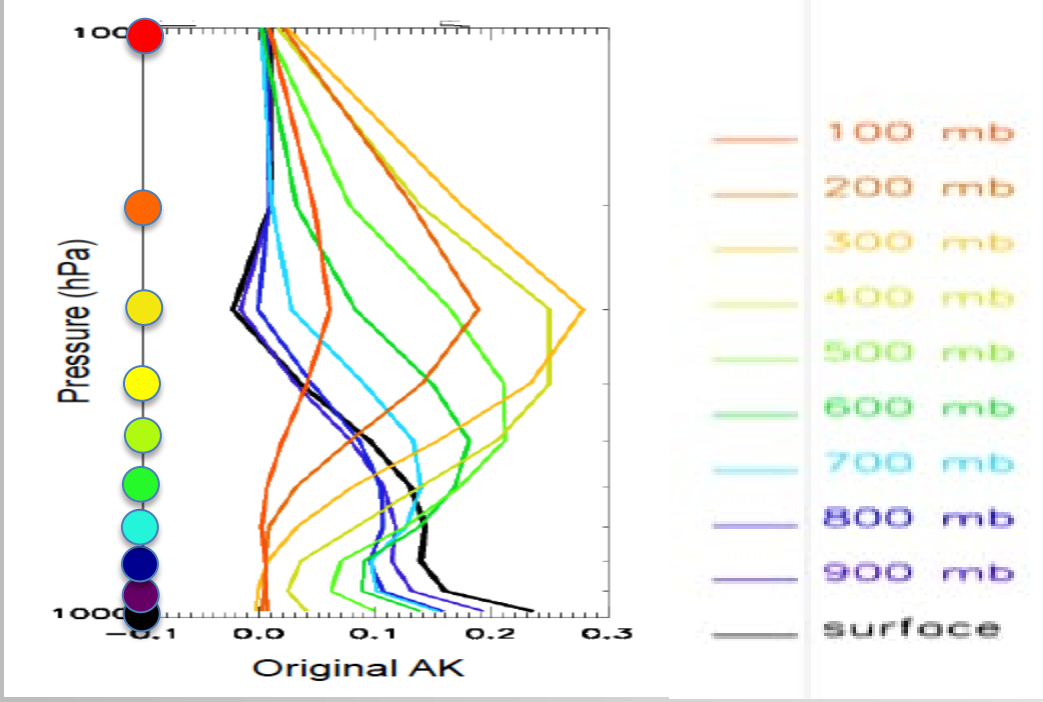
xGC

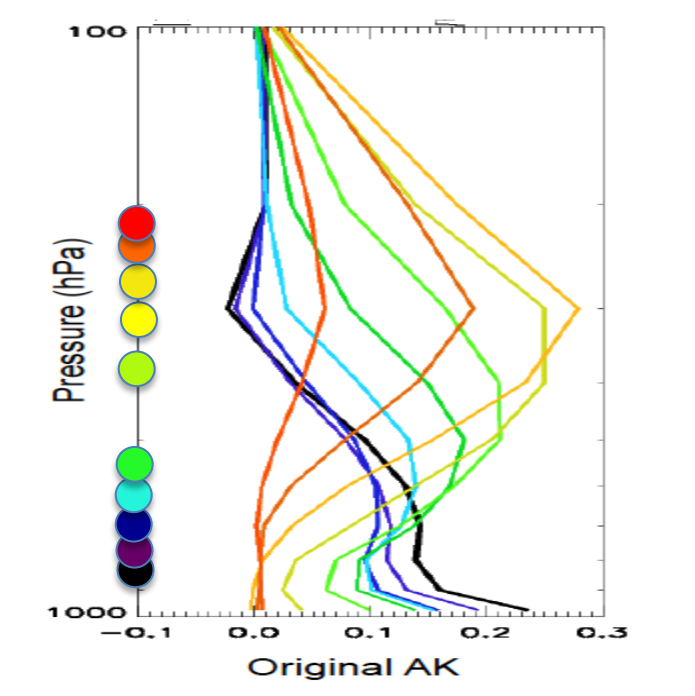


Without vertical localization

?

Adaptive vertical localization

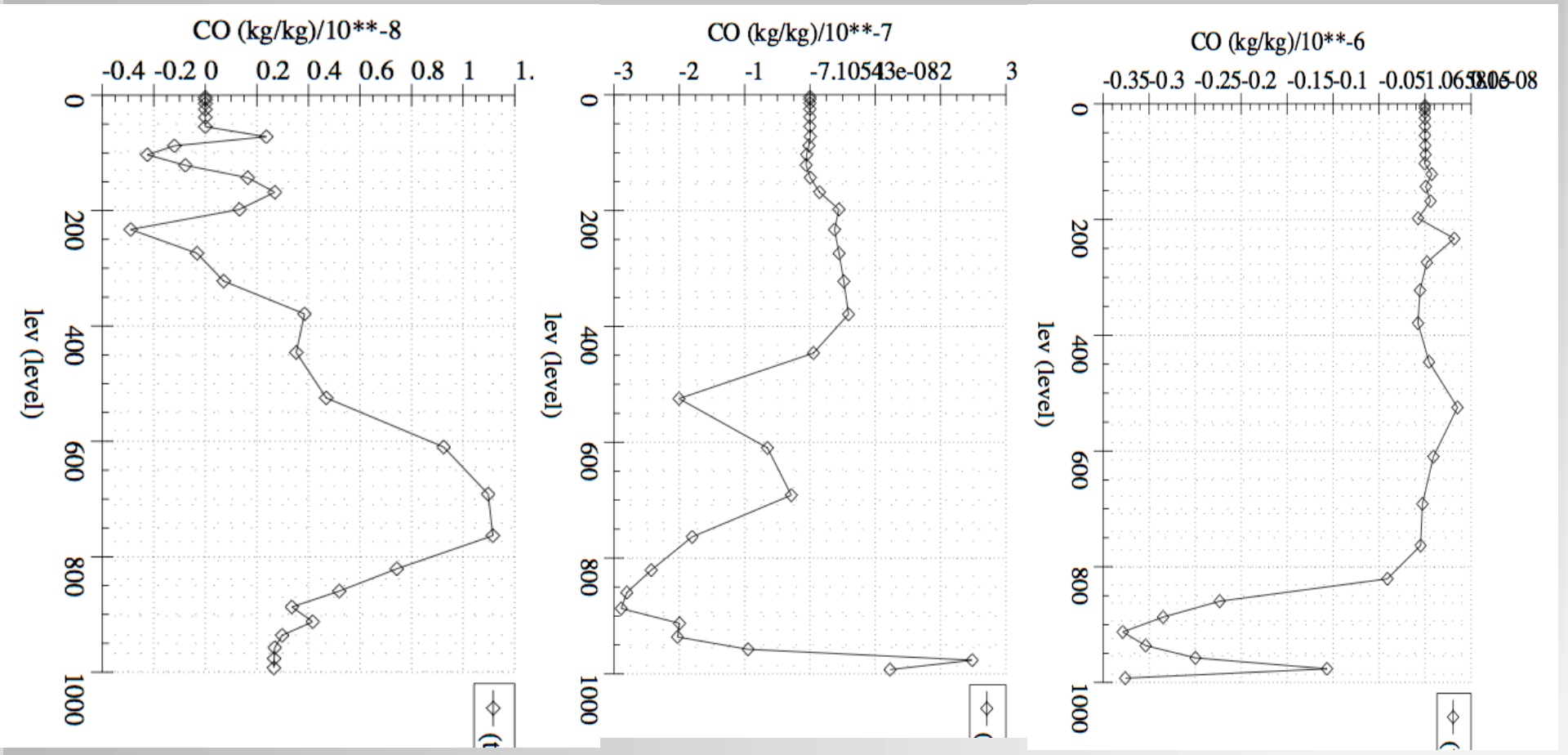




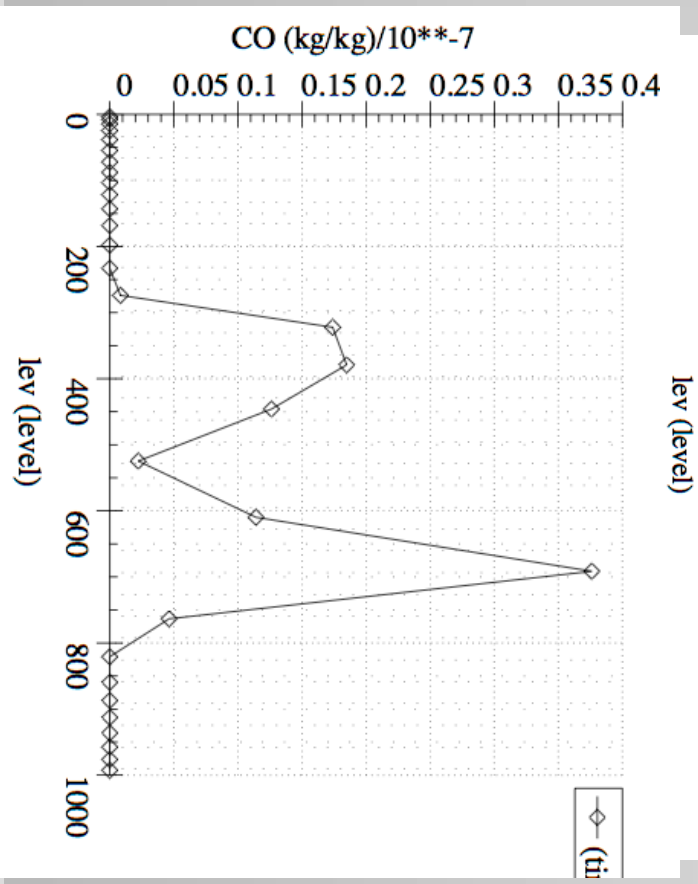
$$P_j = \sum_{i=1}^{N} w_i P_i \qquad w_i = f_i \Big/ \sum_{i=1}^{N} f_i$$

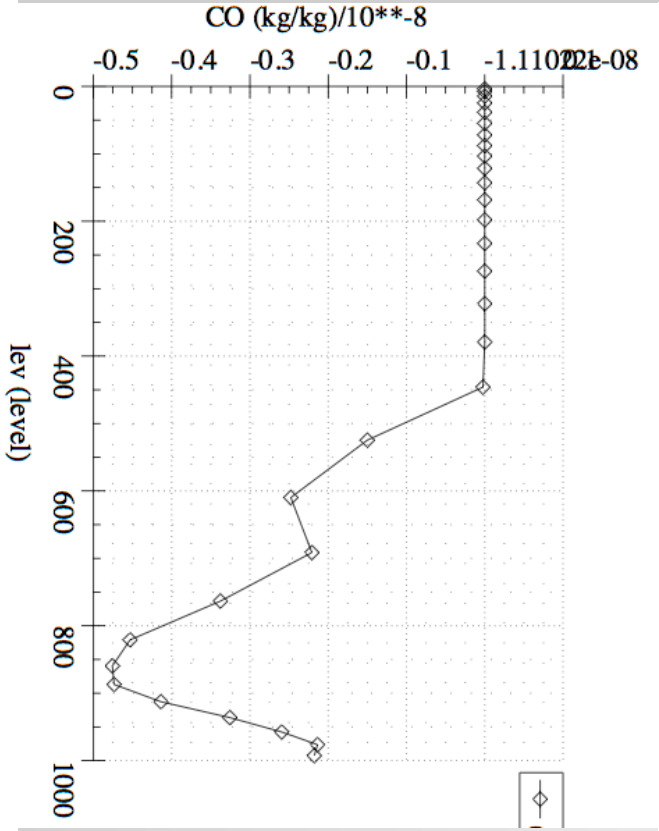
$$f_i = \frac{A_{ij} - \min(A_j)}{\max(A_j) - \min(A_j)}$$

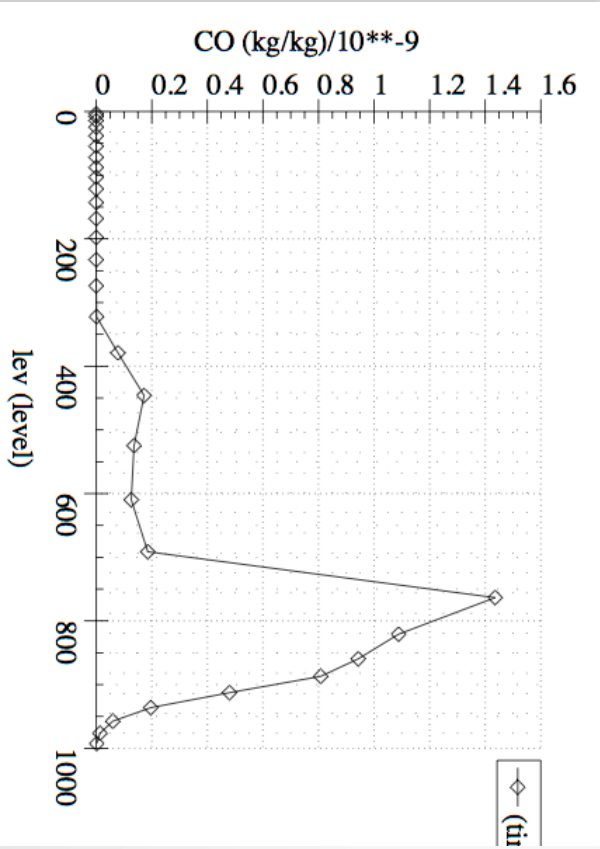
SVD data assimilation increments



10 levels increments with adaptive localization







Adaptative vertical localization

SVD ?