Data assimilation & parameter estimation for global aerosol

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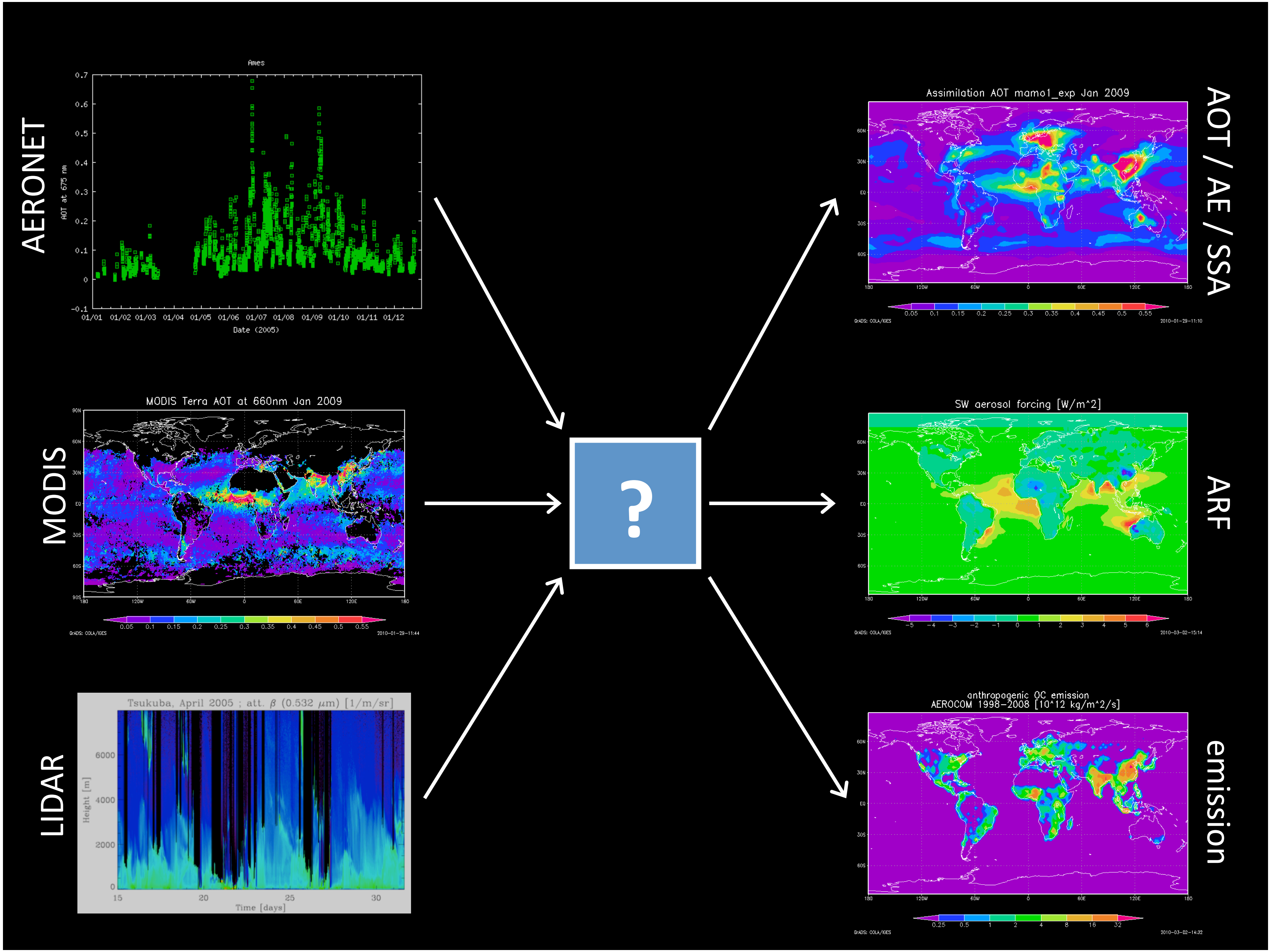
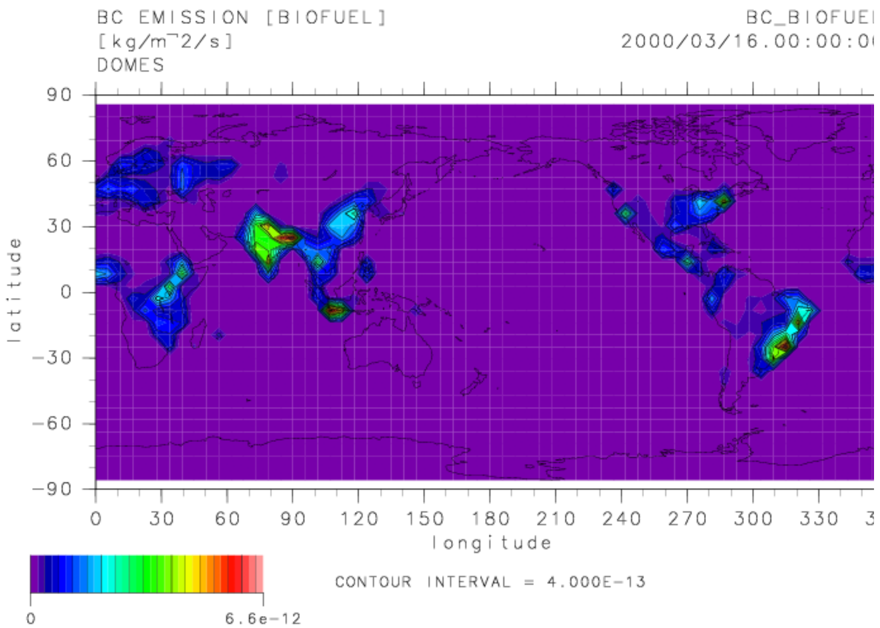


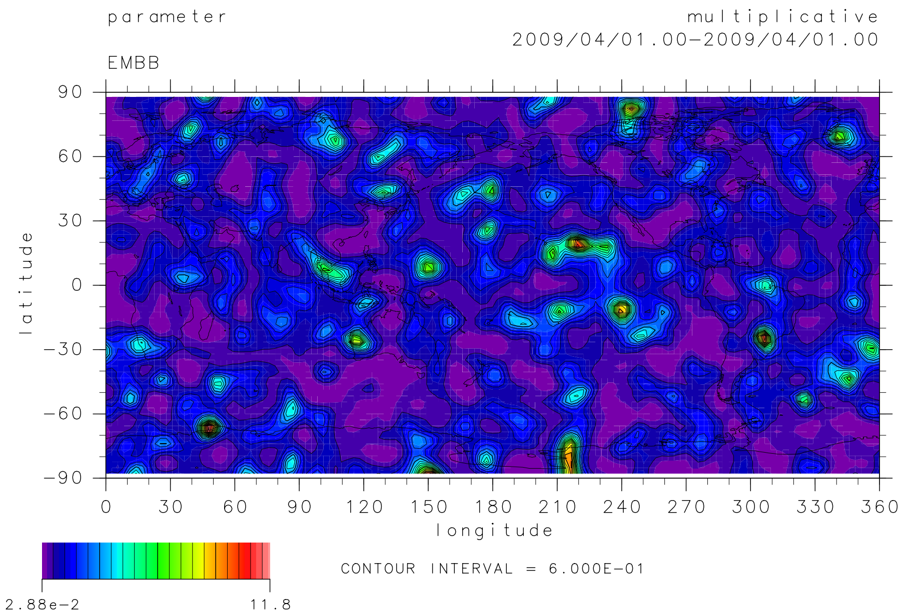
AERONET
Ames
AOT at 675 nm
Date (2005)
MODIS
MODIS Terra AOT at 660nm Jan 2009
LIDAR
Tsukuba, April 2005 ; att. β (0.532 μm) [1/m/sr]
Height [m]
Time [days]
?
Assimilation AOT mamo1_exp Jan 2009
AOT / AE / SSA
SW aerosol forcing [W/m^2]
ARF
anthropogenic OC emission
AEROCOM 1998-2008 [10^12 kg/m^2/s]
emission

Creating the ensemble

E_0

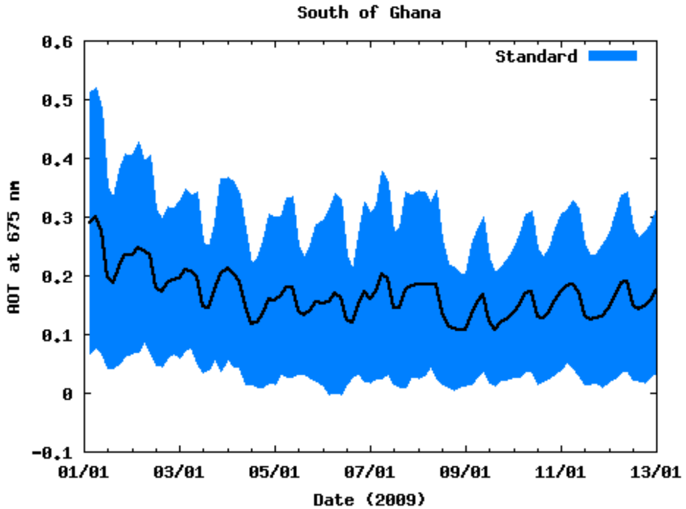


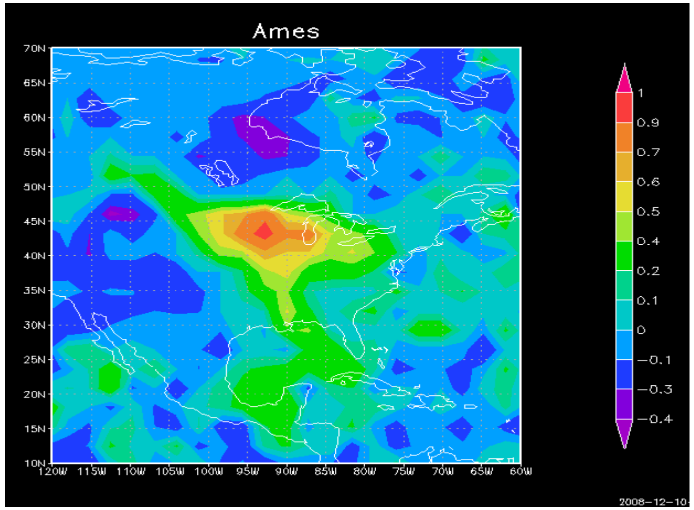
f_{rnd}

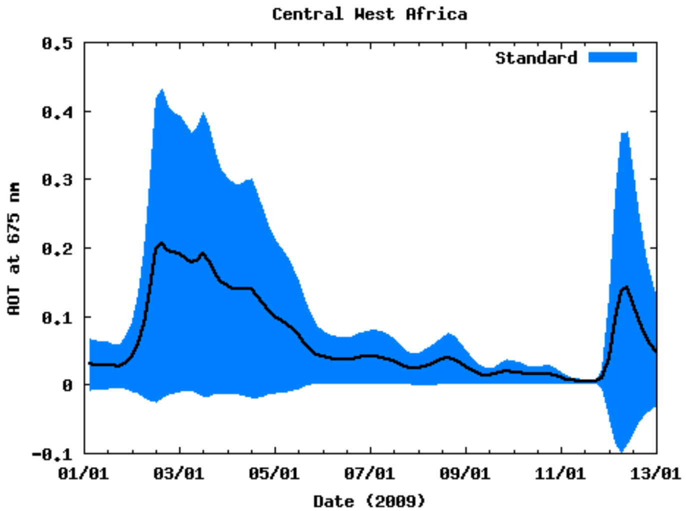


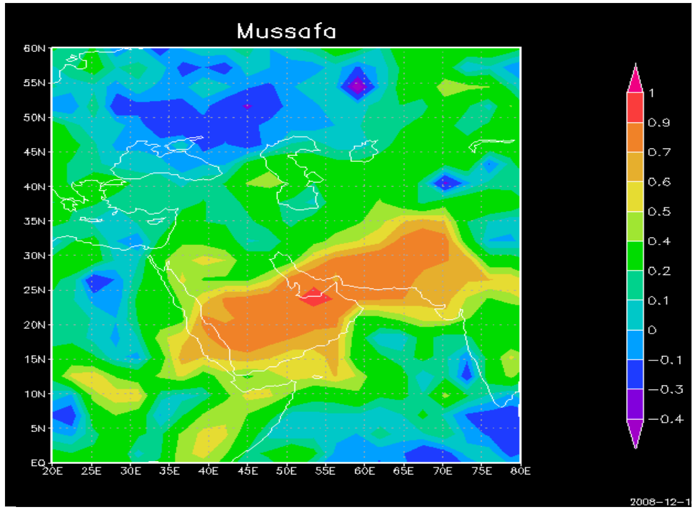
$$E(\phi,\theta) = E_0(\phi,\theta)\ f_{rnd}(\phi,\theta)$$

The model prediction covariant









The Kalman equation

Mixing ratios

Emissions

Regular DA

Parameter estimation

Observation operator

Mixing ratio

Observation errors

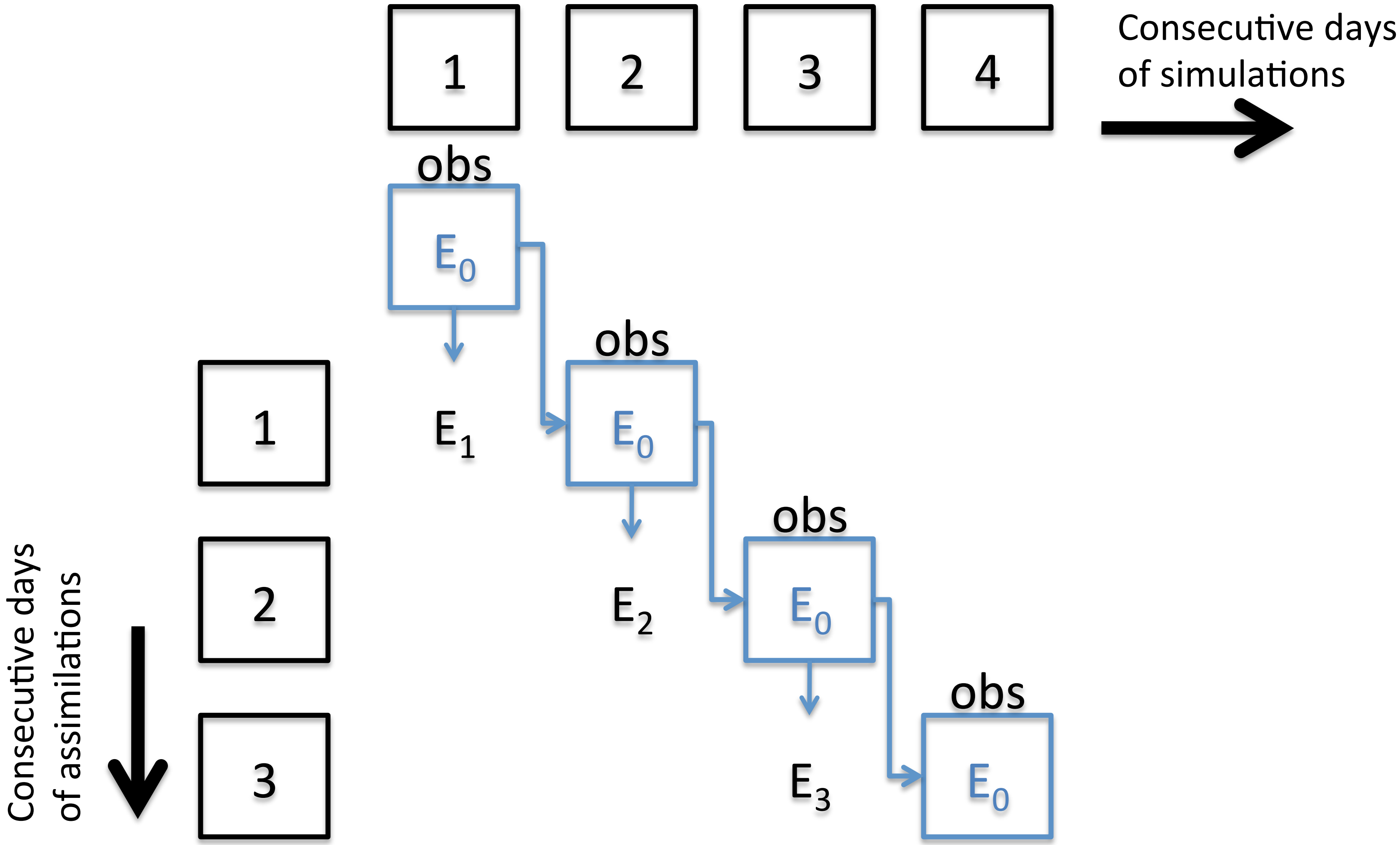
$$\mathbf{x}_a = \mathbf{x}_f + \mathbf{P}_a \mathbf{H}^T \mathbf{R}^{-1} \left(\mathbf{y} - \mathbf{H}\mathbf{x}_f \right)$$

Emissions

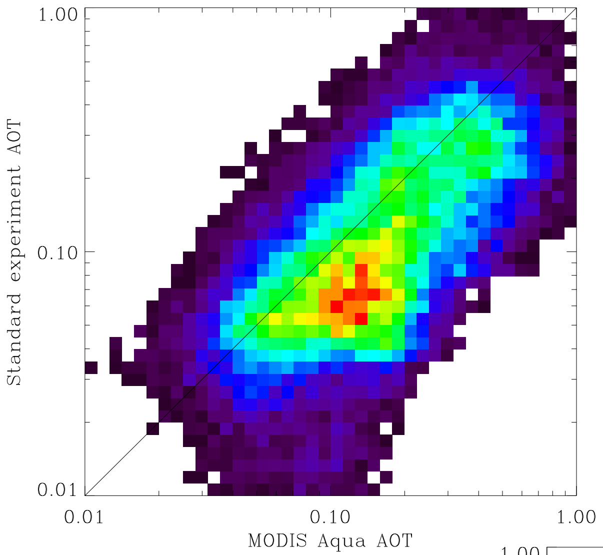
Transport & Observation errors

Transport operator
&
Observation operator

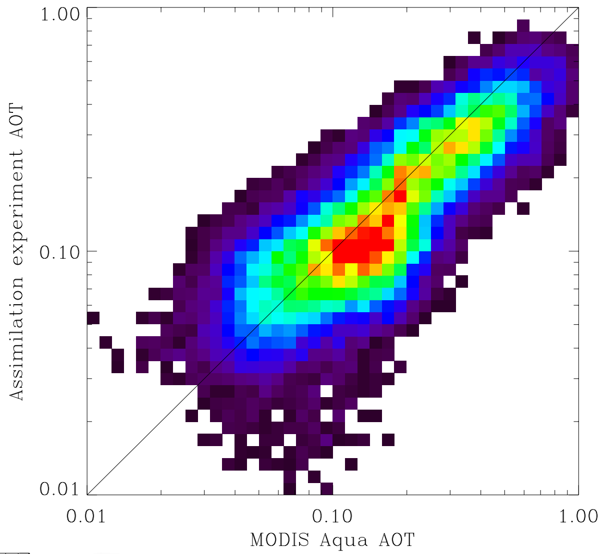
Regular Data Assimilation

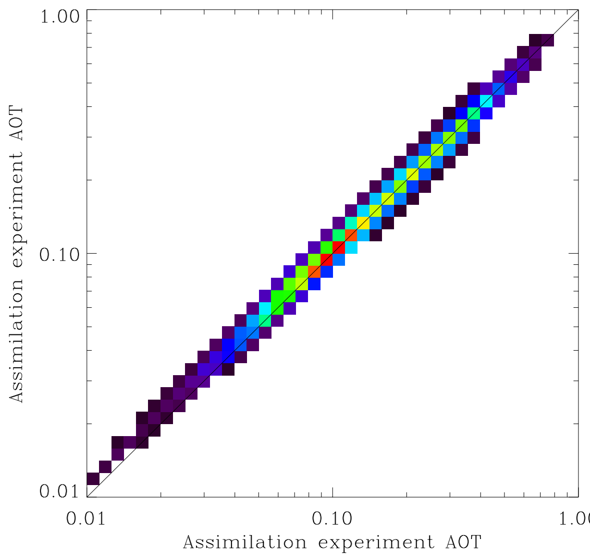


Regular DA: robust estimates of AOT etc.



MODIS Terra is assimilated

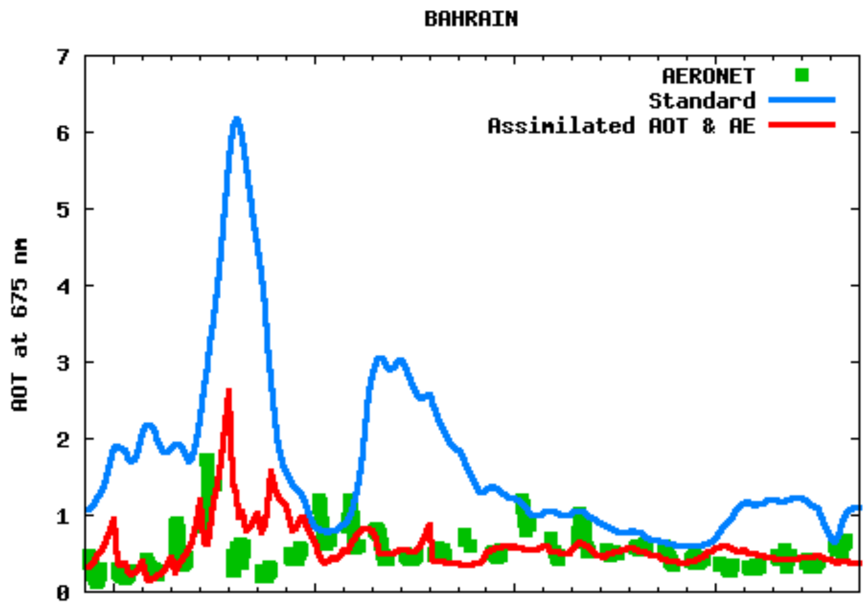


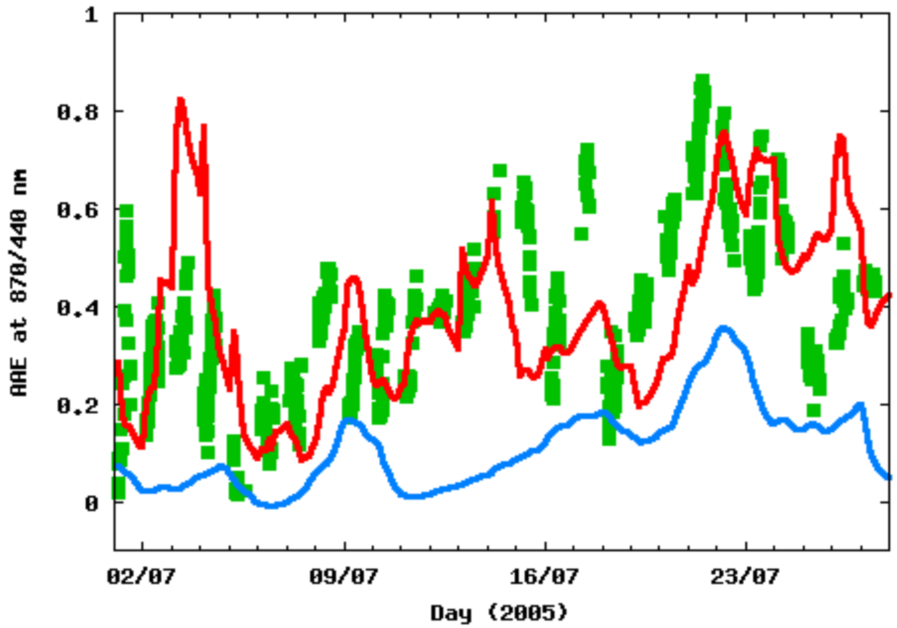


Impact of filter tuning is small

Regular DA: AERONET AOT & AE

- Assimilate AERONET AOT & AE
- Evaluate against independent AERONET sites

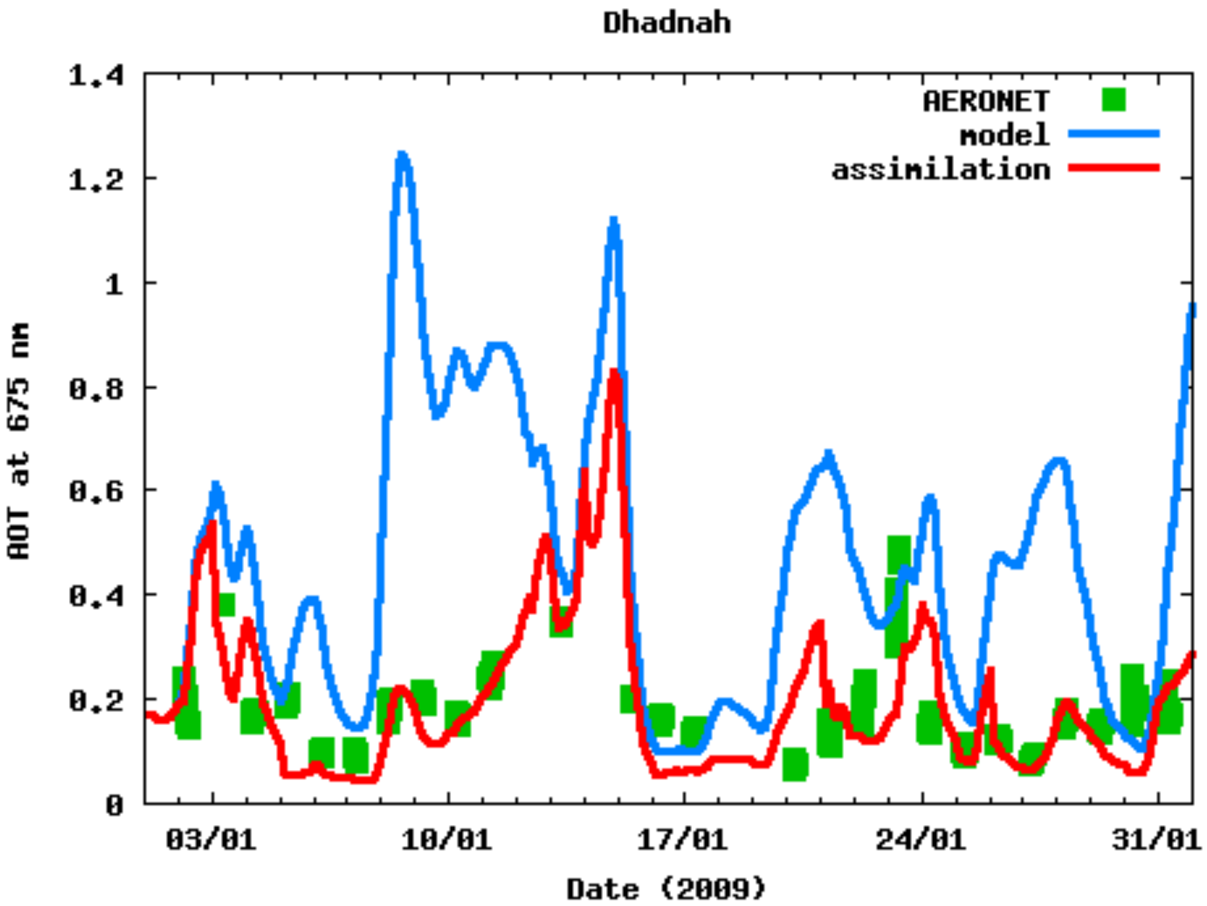




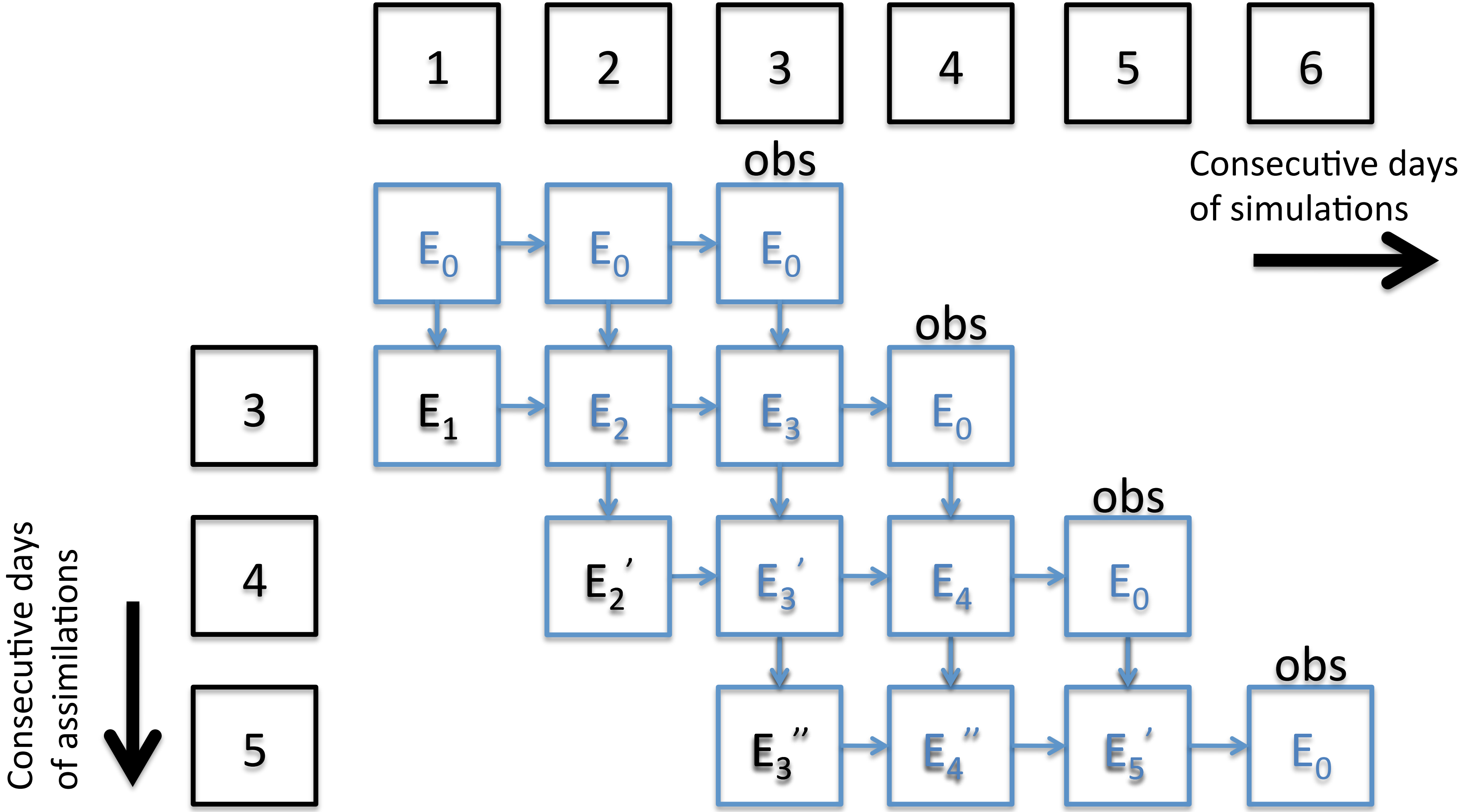
Mixing ratios are adjusted by filter to give correct AE

Regular DA: CALIOP backscatter

- Assimilate CALIOP night-time attenuated backscatter
- Evaluate against AERONET



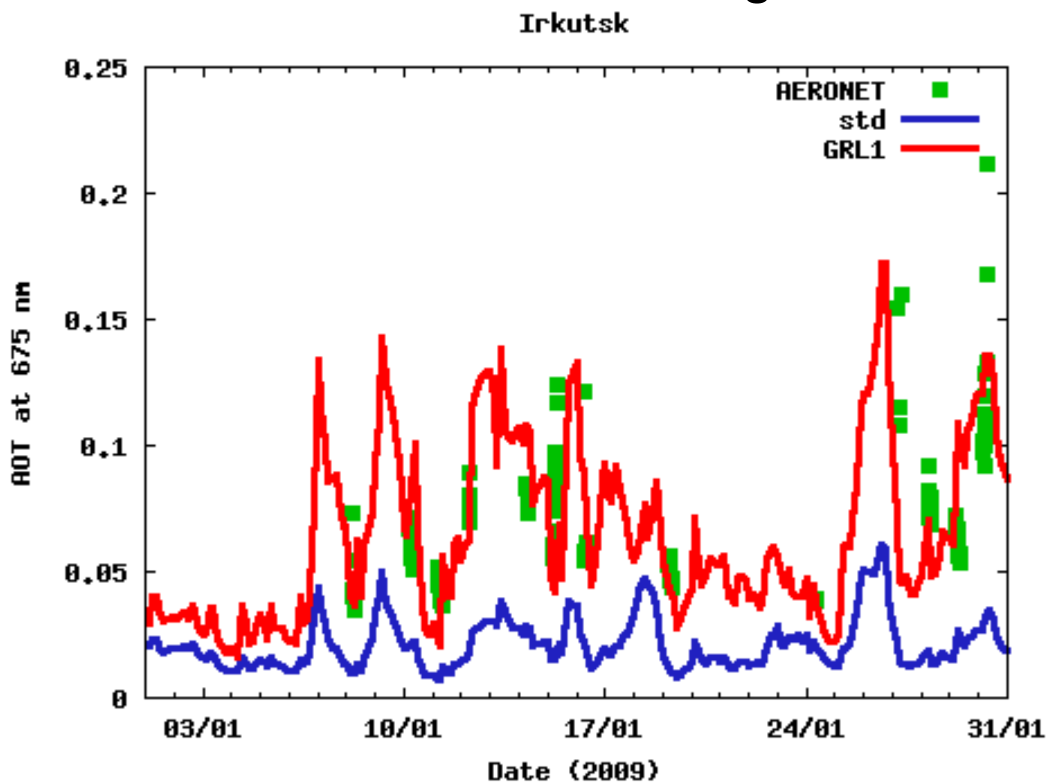
Parameter estimation



Parameter estimation

First, we estimate new emissions based on ensemble simulations (perturbed standard emissions) and observations
(over land: AERONET AOT & AE, over ocean: MODIS Terra AOT)

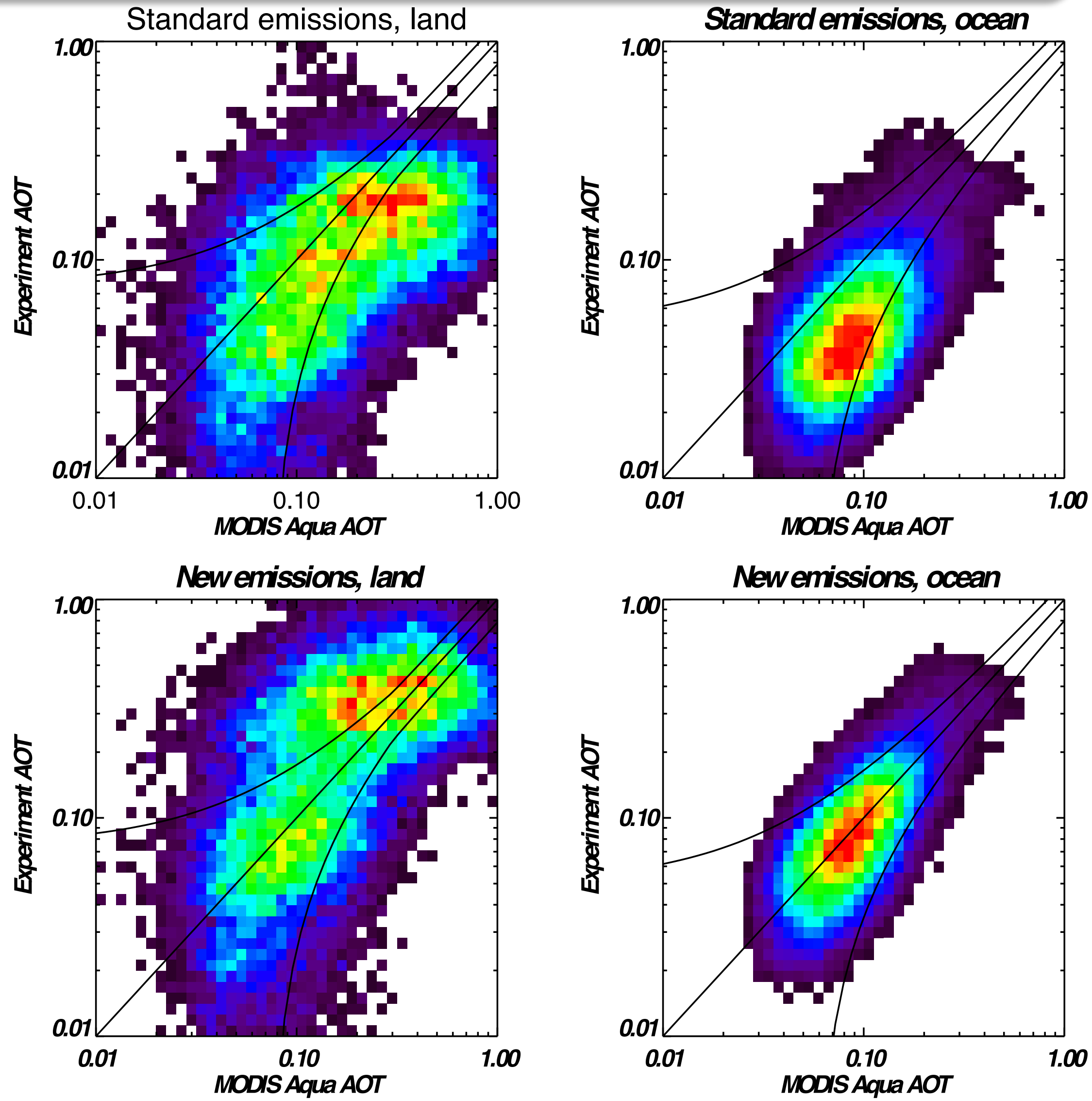
Next, we simulate AOT & AE using those new emissions.

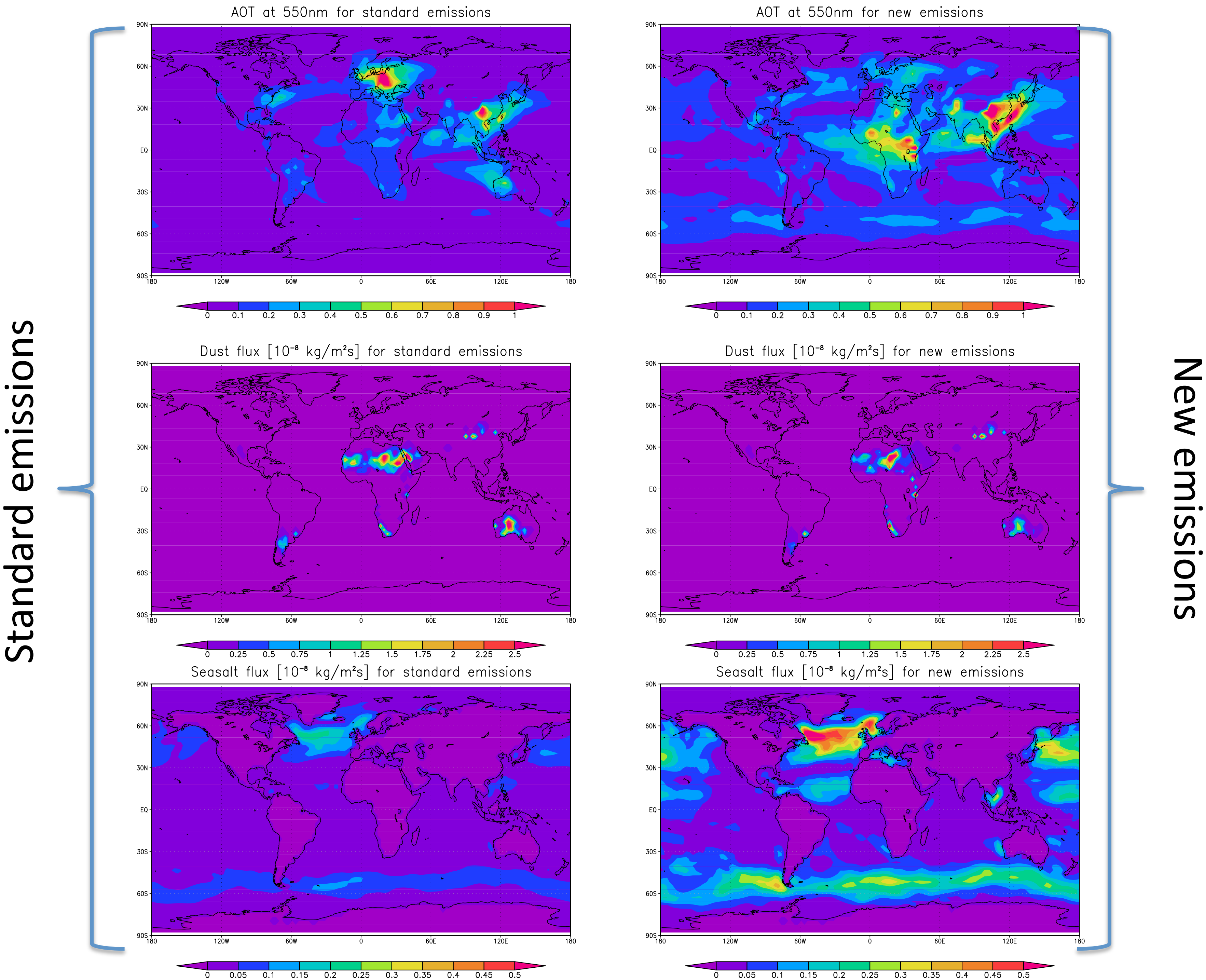


Sanity check:
AOT forecasts with either the standard or new emissions

Parameter estimation: evaluation vs Aqua

		bias	slope	corr.
land	std	-0.045	0.31	0.51
	new	0.008	0.8	0.57
ocean	std	-0.04	0.34	0.50
	new	0.005	0.79	0.64



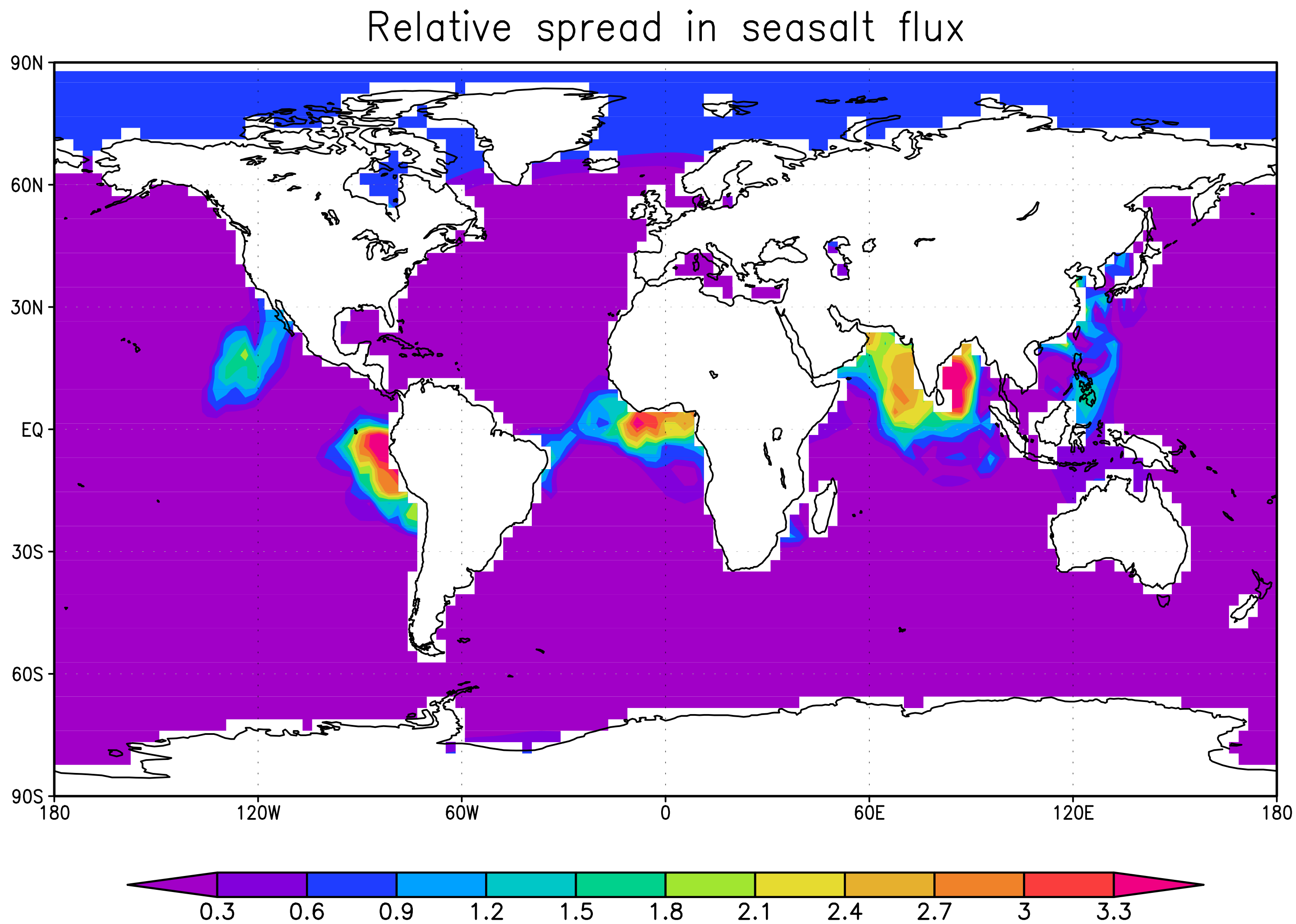

Standard emissions
New emissions
AOT at 550nm for standard emissions
AOT at 550nm for new emissions
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
Dust flux [10⁻⁸ kg/m²s] for standard emissions
Dust flux [10⁻⁸ kg/m²s] for new emissions
0 0.25 0.5 0.75 1 1.25 1.5 1.75 2 2.25 2.5
Seasalt flux [10⁻⁸ kg/m²s] for standard emissions
Seasalt flux [10⁻⁸ kg/m²s] for new emissions
0 0.05 0.1 0.15 0.2 0.25 0.3 0.35 0.4 0.45 0.5
90N 60N 30N EQ 30S 60S 90S
180 120W 60W 0 60E 120E 180

Parameter estimation: global emissions

Species	AEROCOM		MIROC-SPRINTARS		
	Mean [Tg/yr]	Diversity [%]	Std [Tg/yr]	New [Tg/yr]	Error [%]
SO_2			145	219	78
carbons	109	26	83	136	78
dust	1840	49	4470	3244	62
seasalt	16600	199	3145	9073	18

Estimated emission error
(assumes structural errors are negligible)

Parameter estimation: remaining errors

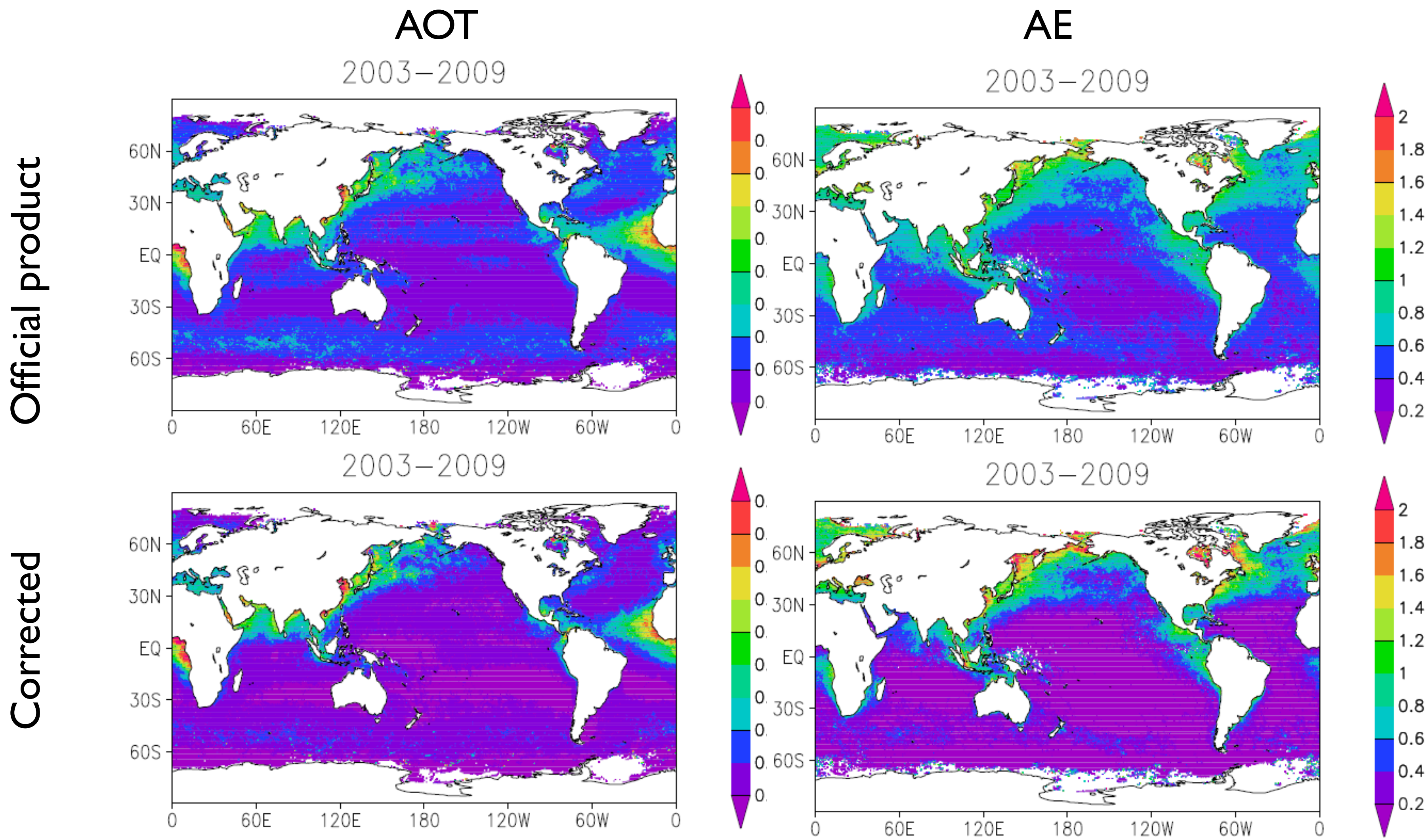


Summary

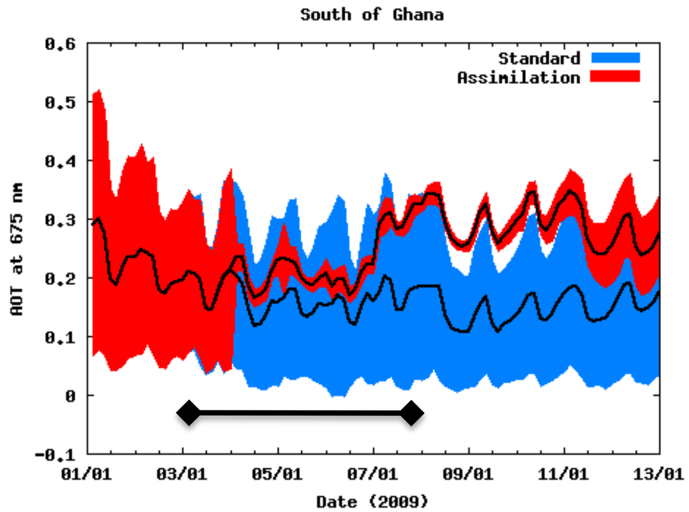
- A single framework for regular data assimilation (DA) and parameter estimation
- Ensemble Kalman filter

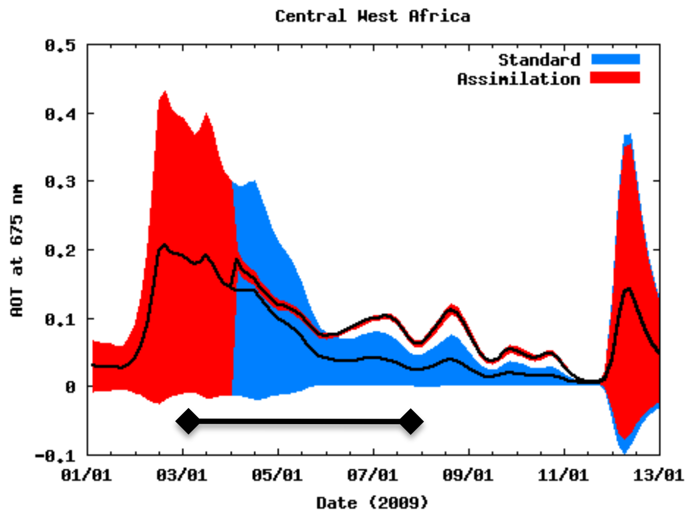
- Regular DA:
  - Japanese GOSAT & GCOM-C satellite missions
  - Tokyo metropole AQ forecasts
- Parameter (emission) estimation

MODIS over ocean

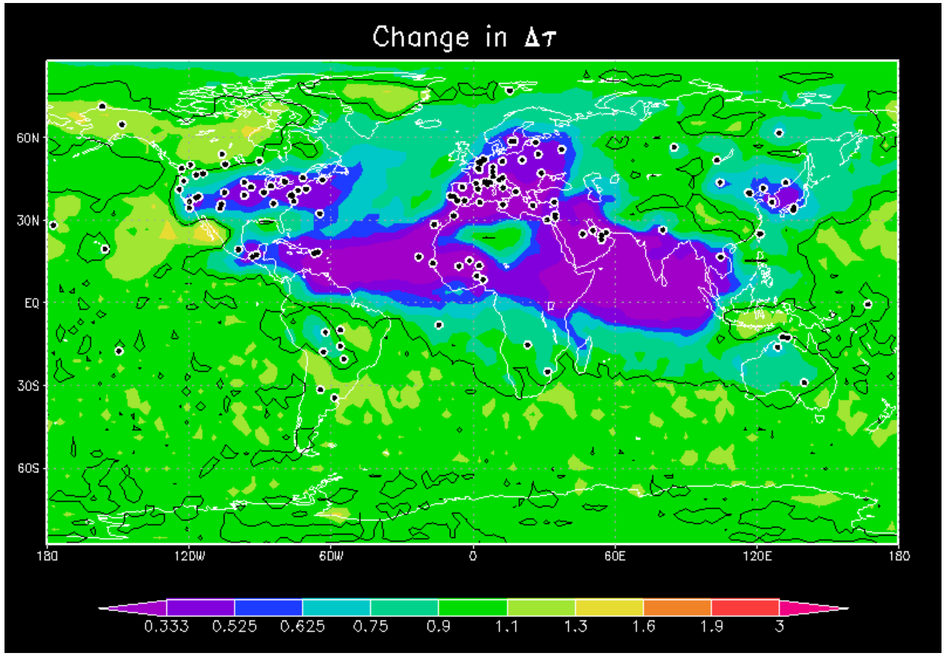


The model prediction error

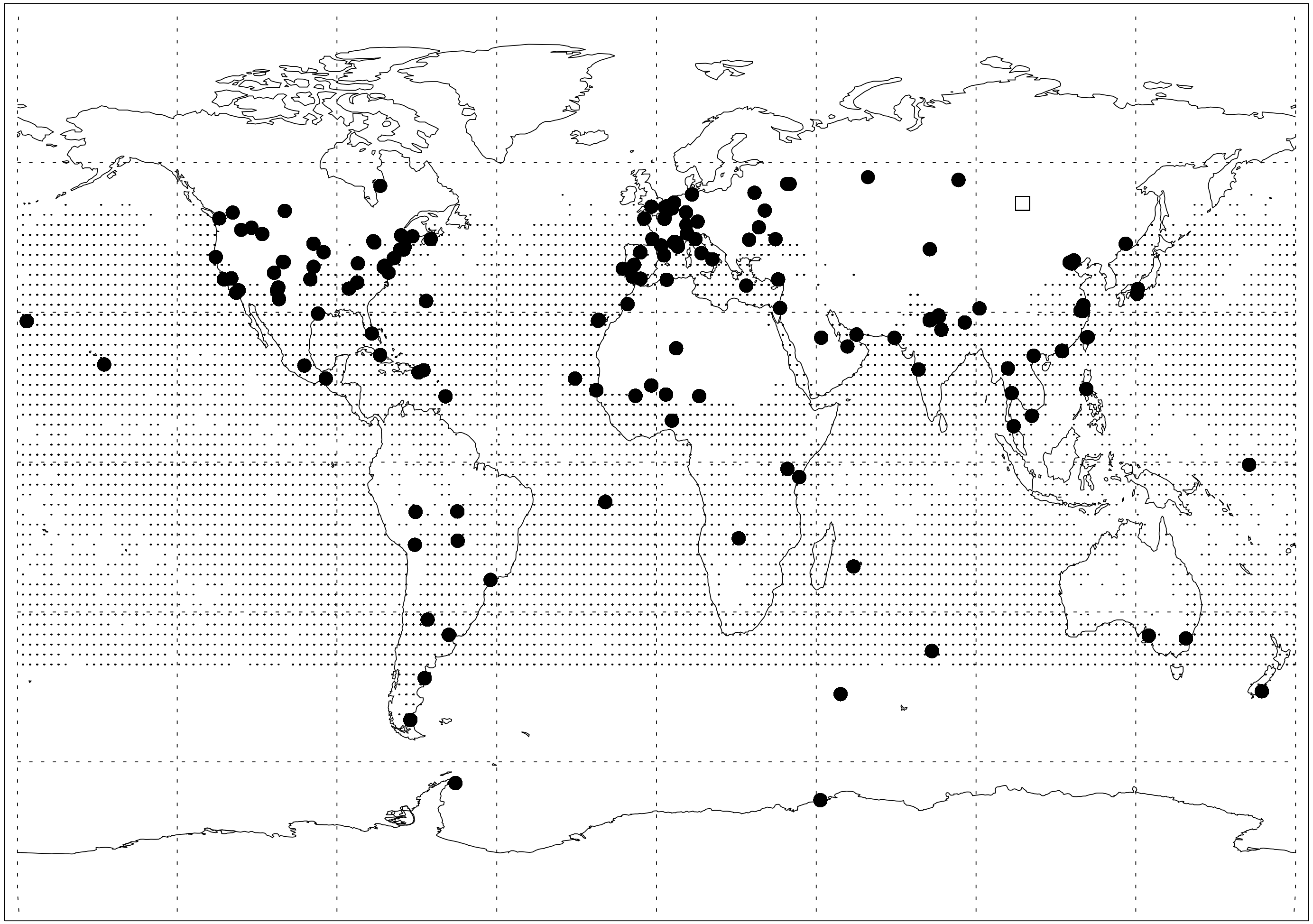




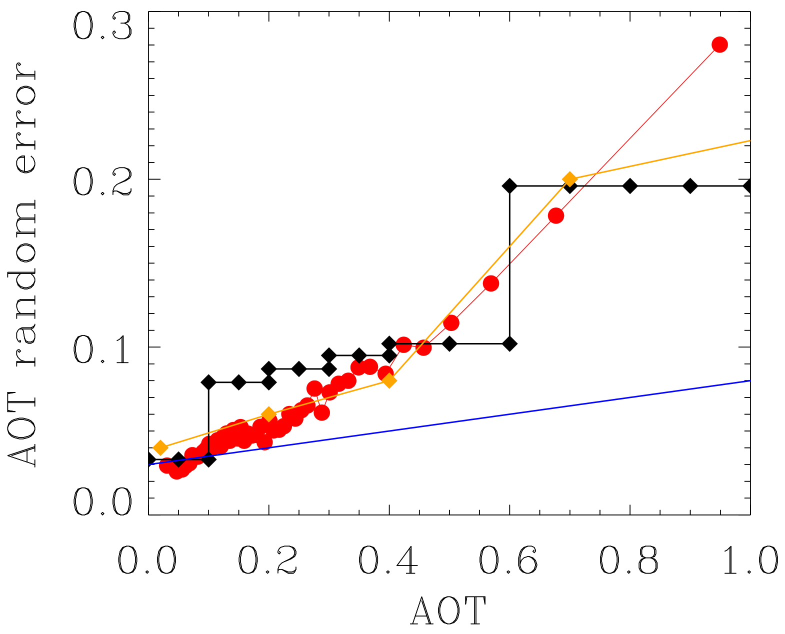
The estimated error in AOT (ensemble spread) evolves naturally, i.e. according to the physics of the model and the information content of the observations.

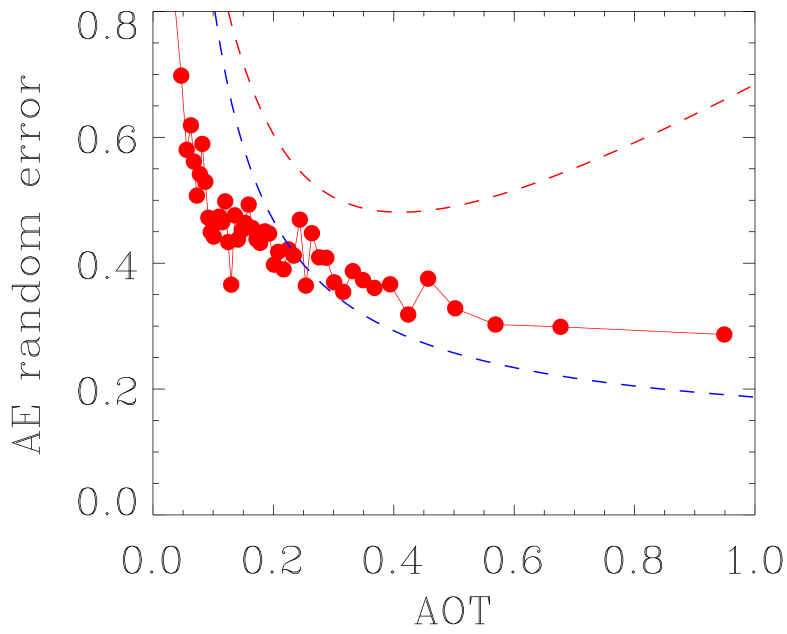


Observational sampling



MODIS random error





Schutgens et al. 2013

Remer et al. 2005: 0.03 + 0.05 AOT

Zhang & Reid 2006

Shi et al. 2011

Schutgens et al 2013

Using Remer et al. AOT error