Progress toward aerosol assimilation within GEMS

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with contributions from:

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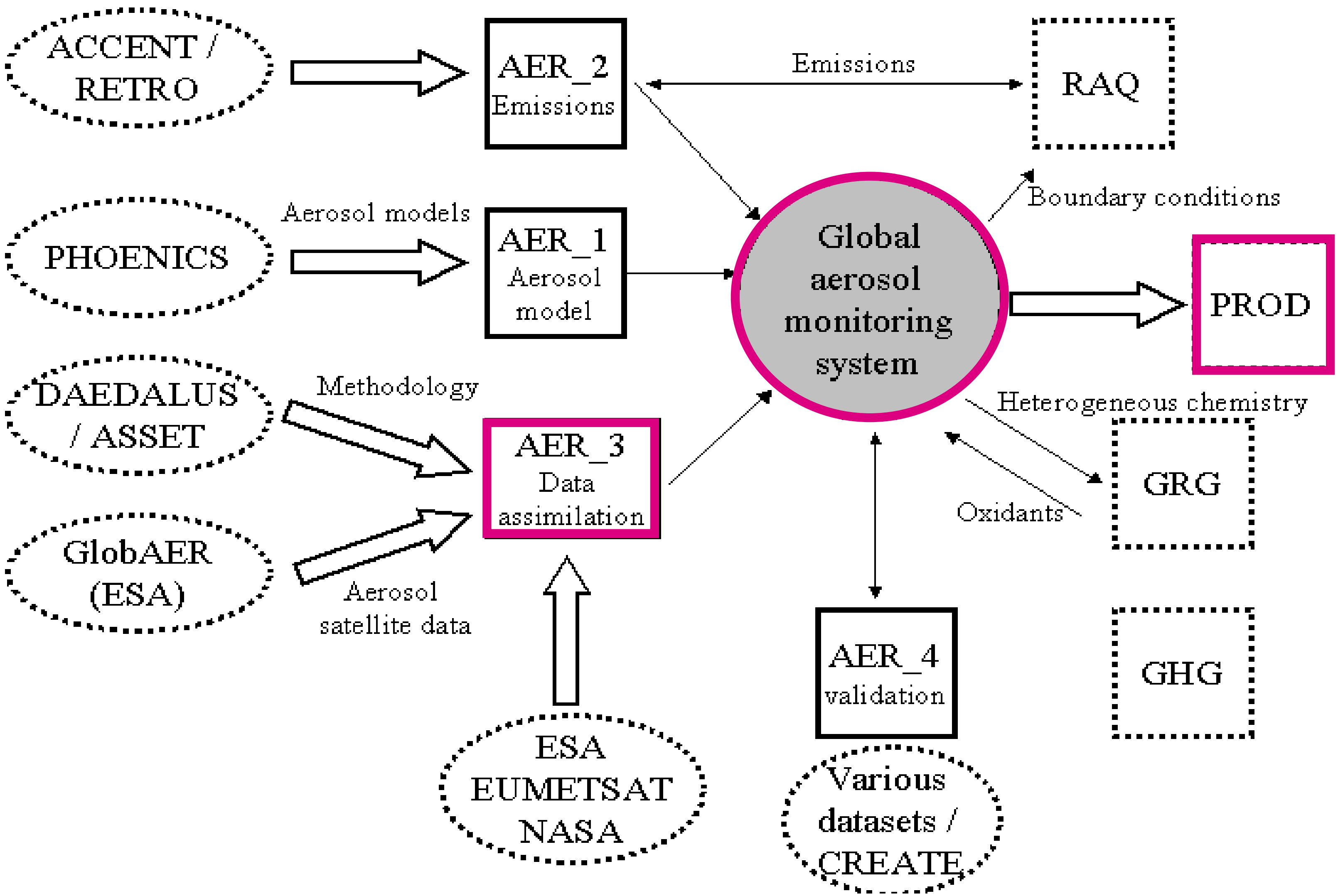
ECMWF

Achieved milestones (Mar 2005-Jan 2006)

- Definition of a new observation pathway in IFS for aerosol optical depth
- Definition of a preliminary background error covariance matrix for aerosol mixing ratios using the NMC method
- Technical changes to IFS to allow for an aerosol optical depth analysis
- Implemented an aerosol optical depth observation operator (including tangent linear and adjoint, tested off-line)
- First analysis increments at T159L60 with MODIS observations

GEMS AEROSOL Global Monitoring System



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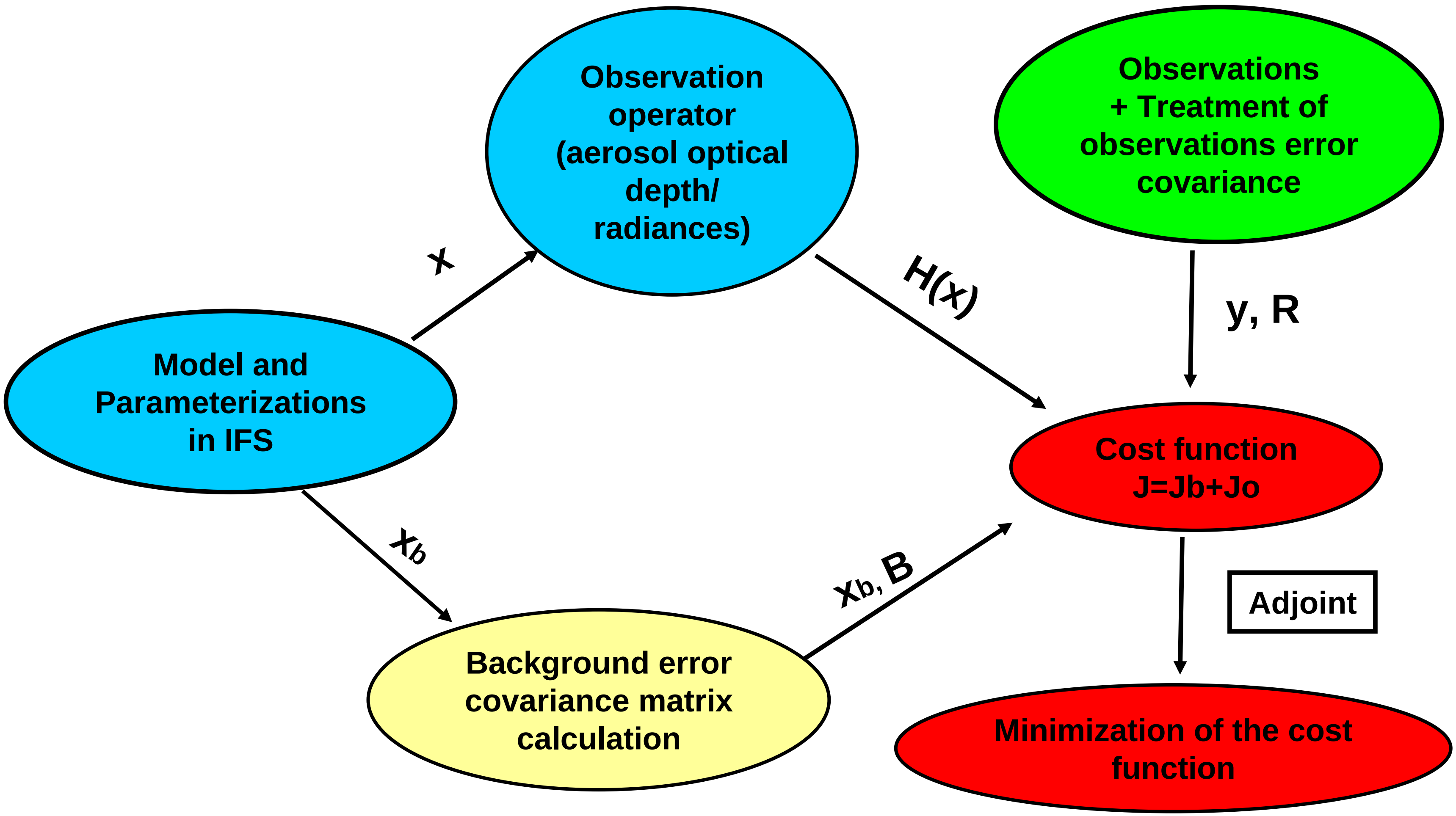
4D-Var aerosol assimilation: main ingredients

$$J(\mathbf{x}) = (\mathbf{x} - \mathbf{x_b})^T \mathbf{B}^{-1} (\mathbf{x} - \mathbf{x_b}) + \sum_{\mathbf{t}} (\mathbf{y_t} - H(\mathbf{x_t}))^T \mathbf{R}^{-1} (\mathbf{y_t} - H(\mathbf{x_t}))$$



Estimation of the background error covariance

Different approaches to define the background error covariance:

- Impose a general analytical model for background error correlations:
  + easy to implement and test
  - arbitrary choice of model (usually exponential decay of off-diagonal elements)

- Use NMC method (difference between 48 and 24 hour forecast):
  + easy to implement (also for diagnostics of pathologies in B-matrix)
  - does not include analysis error, but only forecast error
  - not fully representative (especially if observations related to the new control variable, i.e aerosol mixing ratio, are not yet included in the system)

- Use the ensemble method (statistics are derived from an ensemble of forecasts runs from perturbed analysis) :
  + more robust statistics (several model realizations)
  + forecast length same as for background fields
  - sub-optimality deriving from using own analysis (biases)

Background error covariance for aerosol mixing ratio (first estimate)

- Use NMC method (differences between 48 and 24h forecasts, Derber and Parrish, 1992) to seek any obvious pathologies in the background error correlations

- Three aerosol species:
  - desert dust
  - seal salt
  - continental particulate

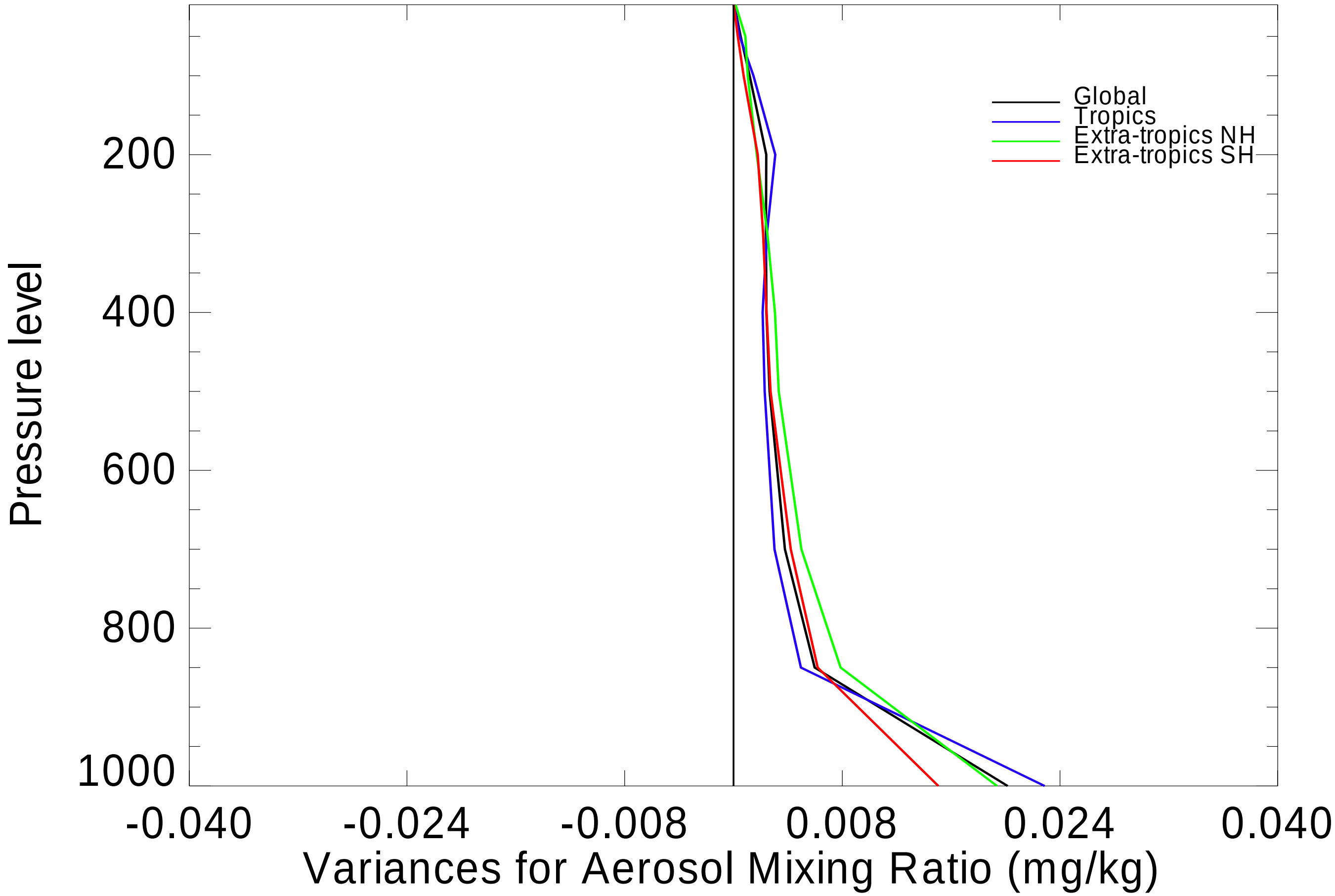
- Forecasts initialized from new aerosol climatology (Tegen et al. 1997)

- Thirty days of 5-day forecasts for January and July 2001 (extended to 4 months to be used in the 4D-Var; little seasonal differences)

- Parameters computed: vertical and horizontal covariances and error correlations (global fields, zonal fields and integral averages over whole globe, Tropics, Northern Hemisphere and Southern Hemisphere) for total aerosol mixing ratio.

Global averages of aerosol mixing ratio variance

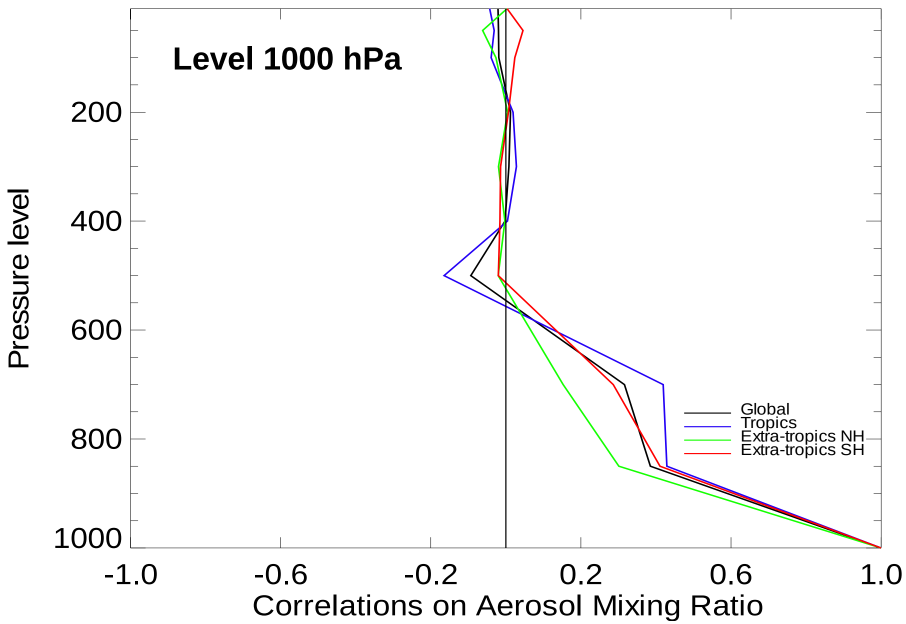
- some regional differences
- “good” behavior (no apparent pathologies)
- small values (only forecast errors)



Global averages of aerosol mixing ratio vertical correlations

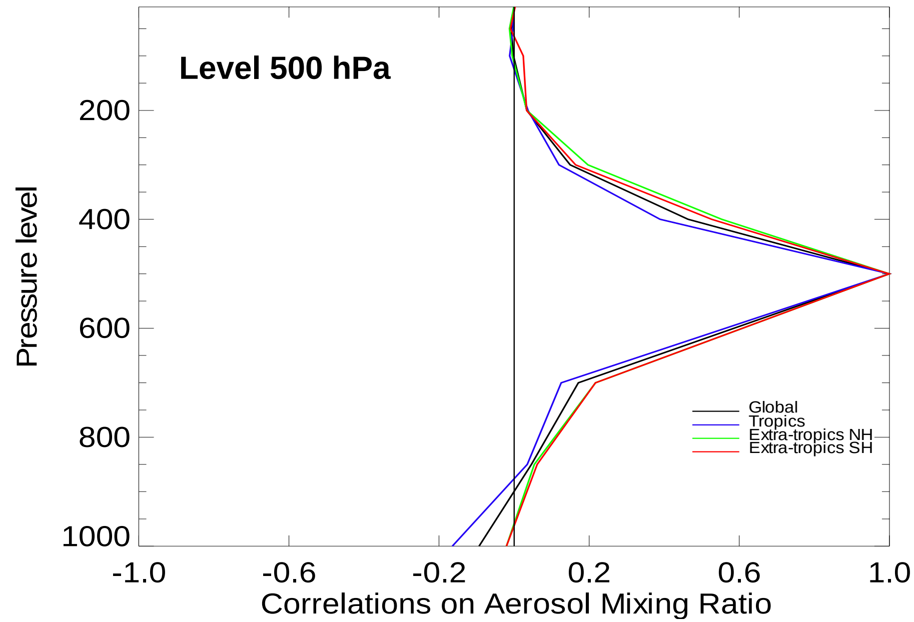
- No evident pathologies
- Some regional differences

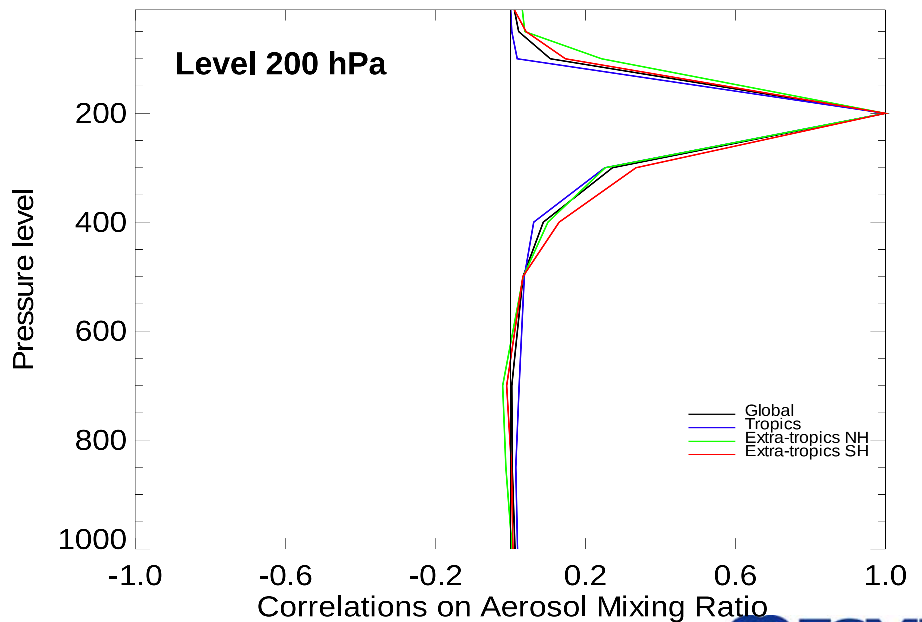
  (especially at 1000 hPa)



- Horizontal correlations also look

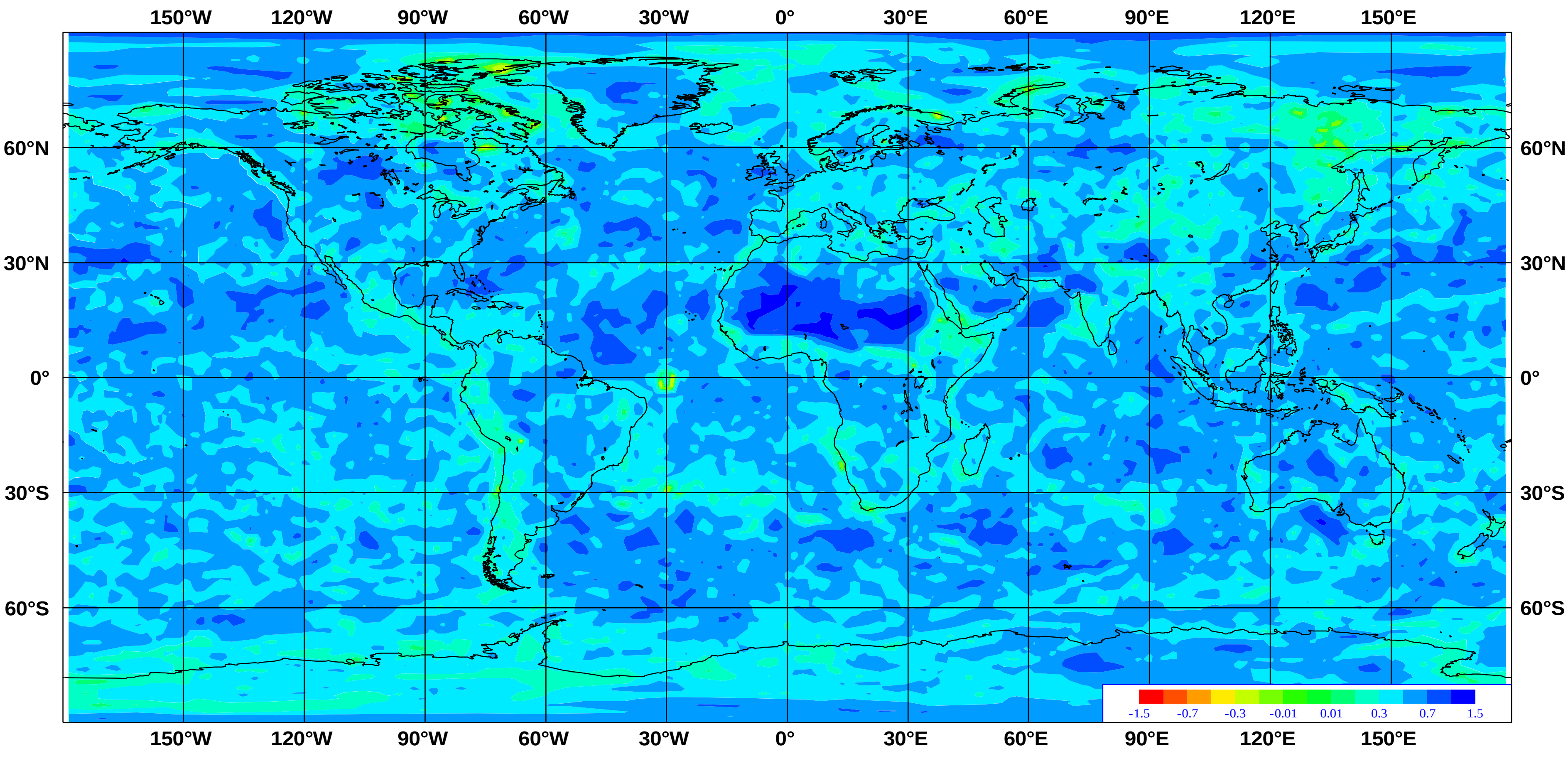
  reasonable





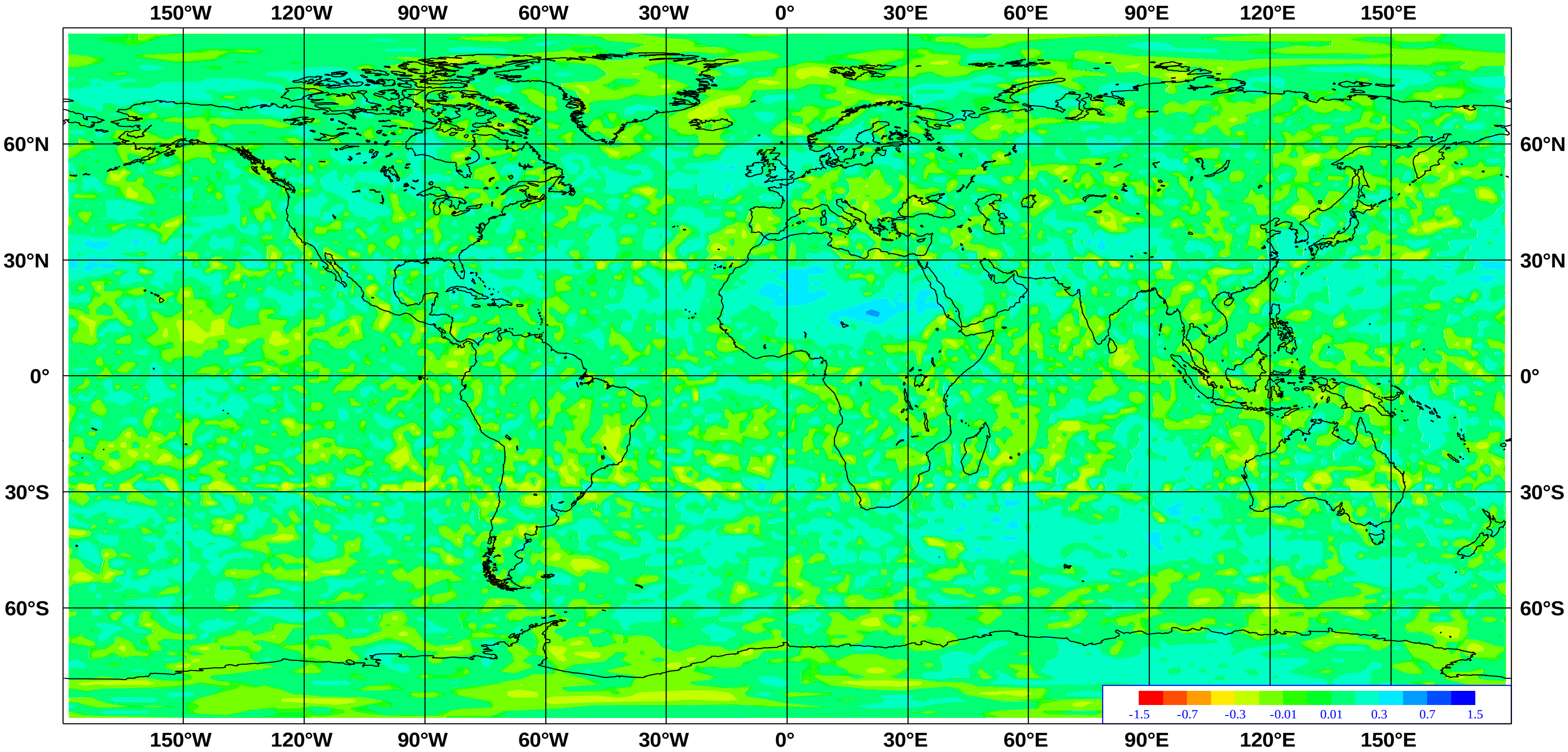
Maps of horizontal correlations for aerosol mixing ratios (200 Km, 1000 hPa)

- Large error correlations over the Sahara desert
- Mainly positive values (color scale: Red=-1, Blue=1, Green=0)



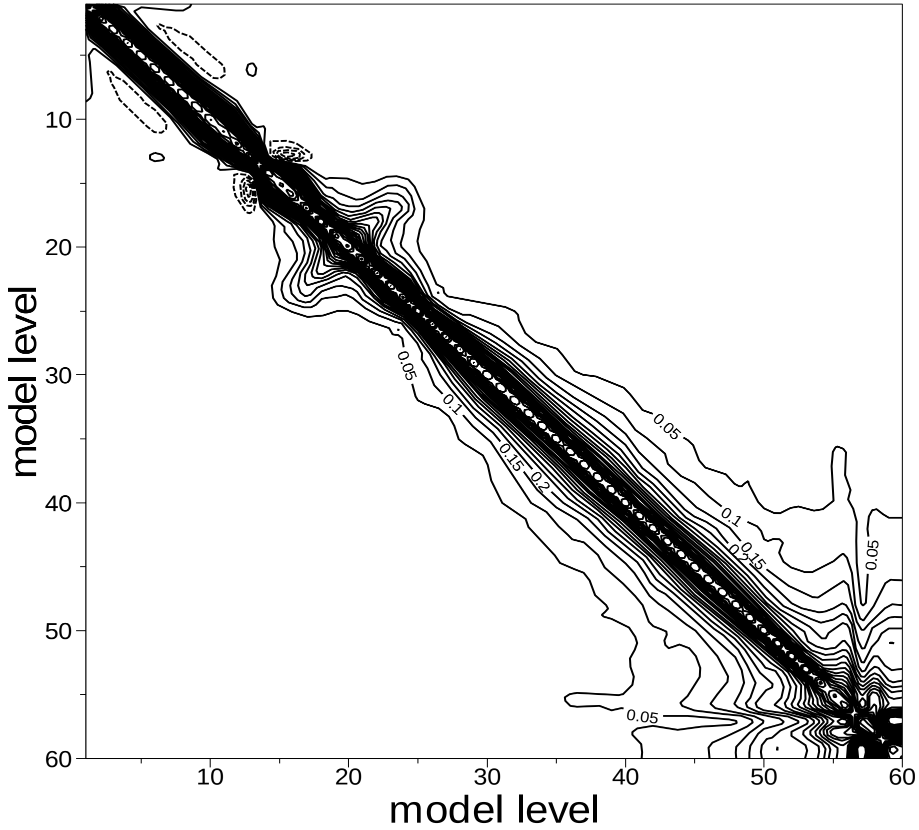
Maps of horizontal correlations for aerosol mixing ratios (1000 Km, 1000 hPa)

- Correlations decay with distance
- Some persistence in non-zero correlations over the Sahara

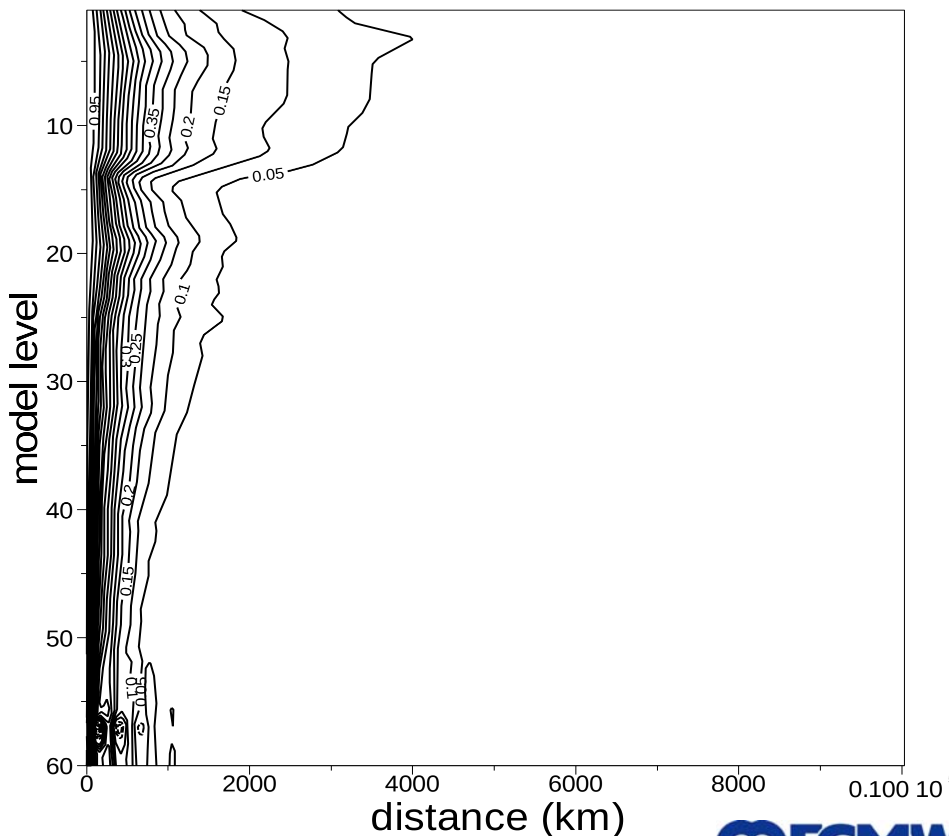


4D-Var aerosol background matrix: correlations

Vertical correlations



Horizontal correlations



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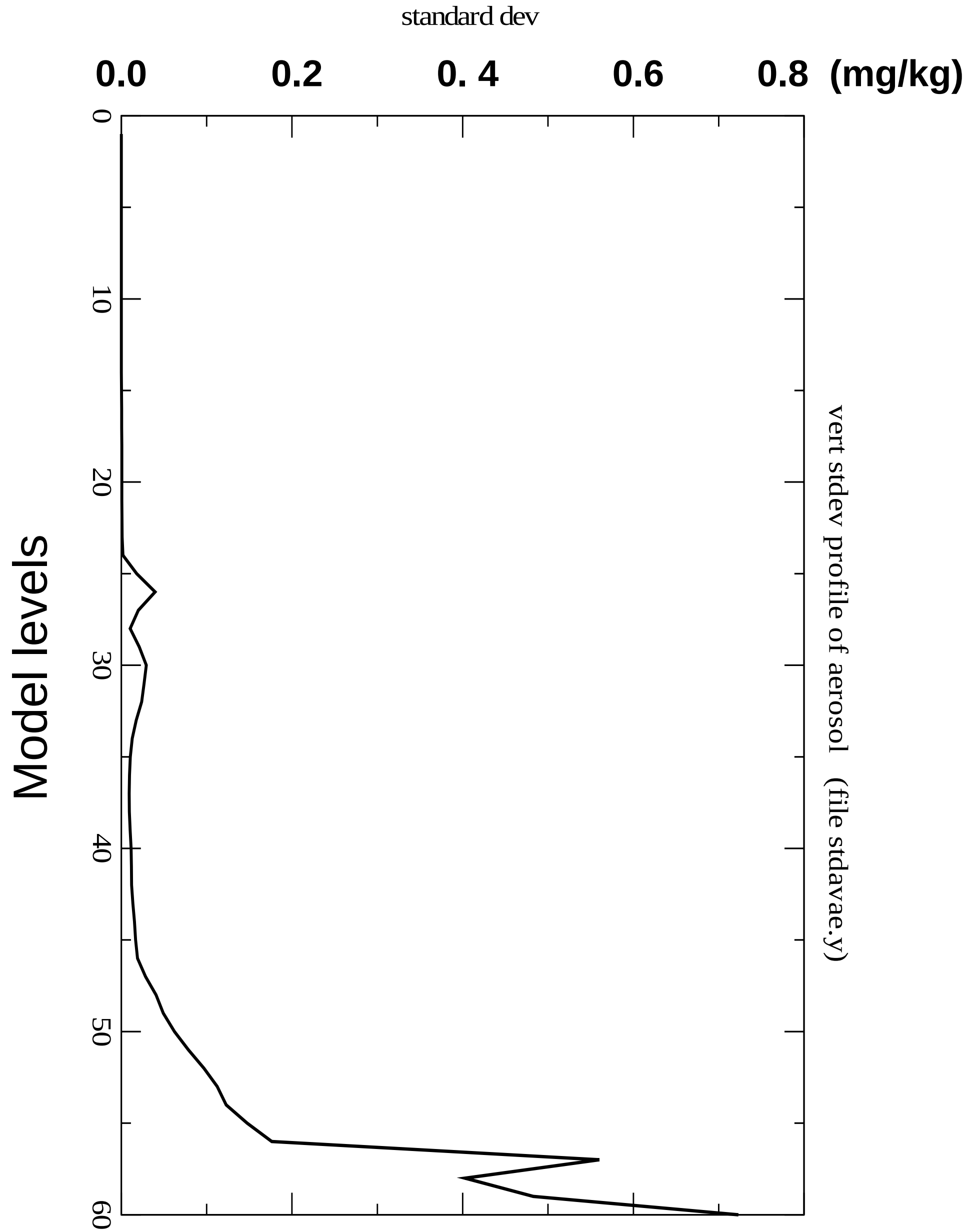
4D-Var aerosol background matrix: standard deviation



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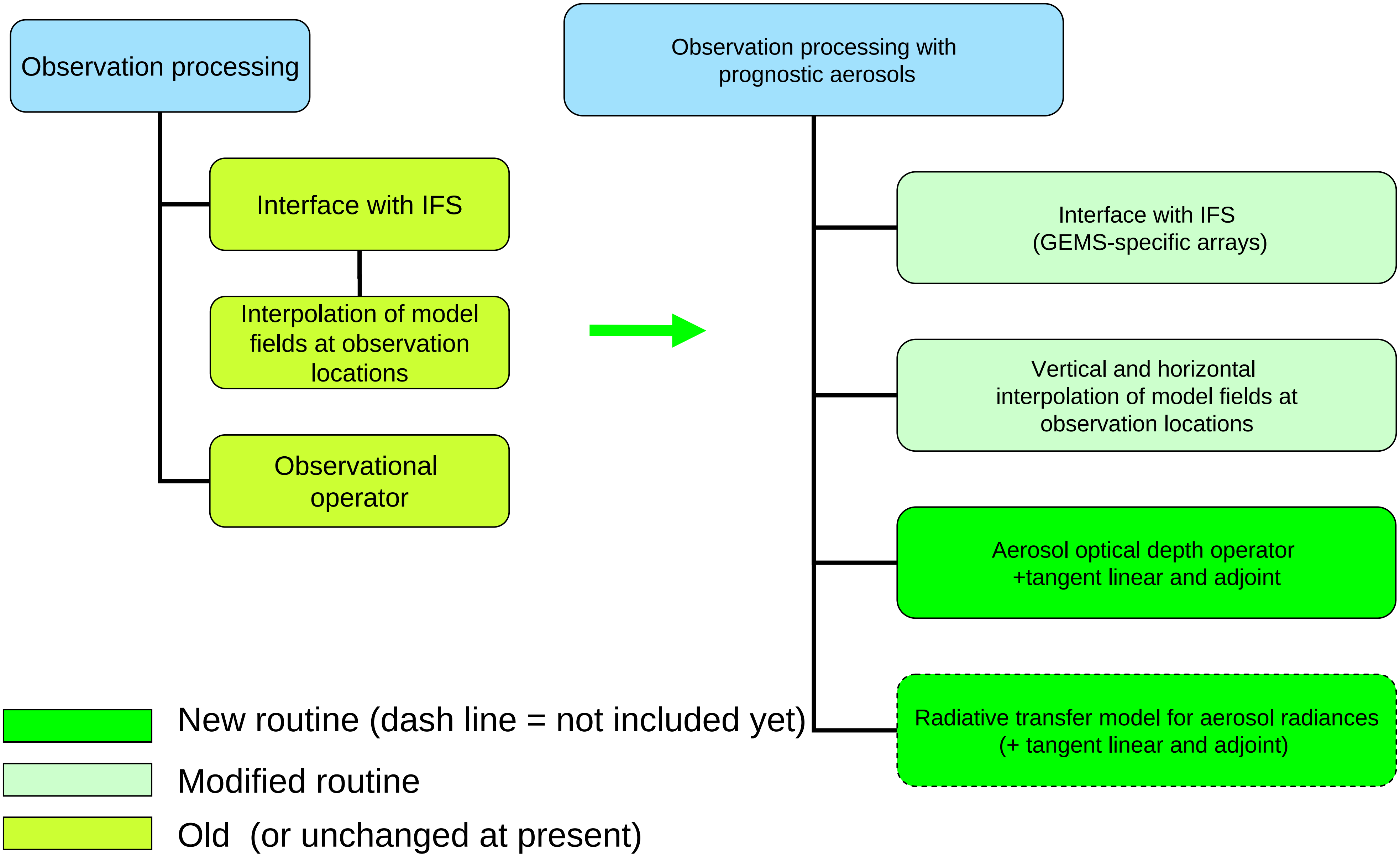
Development of an aerosol assimilation package in the ECMWF model: observation processing



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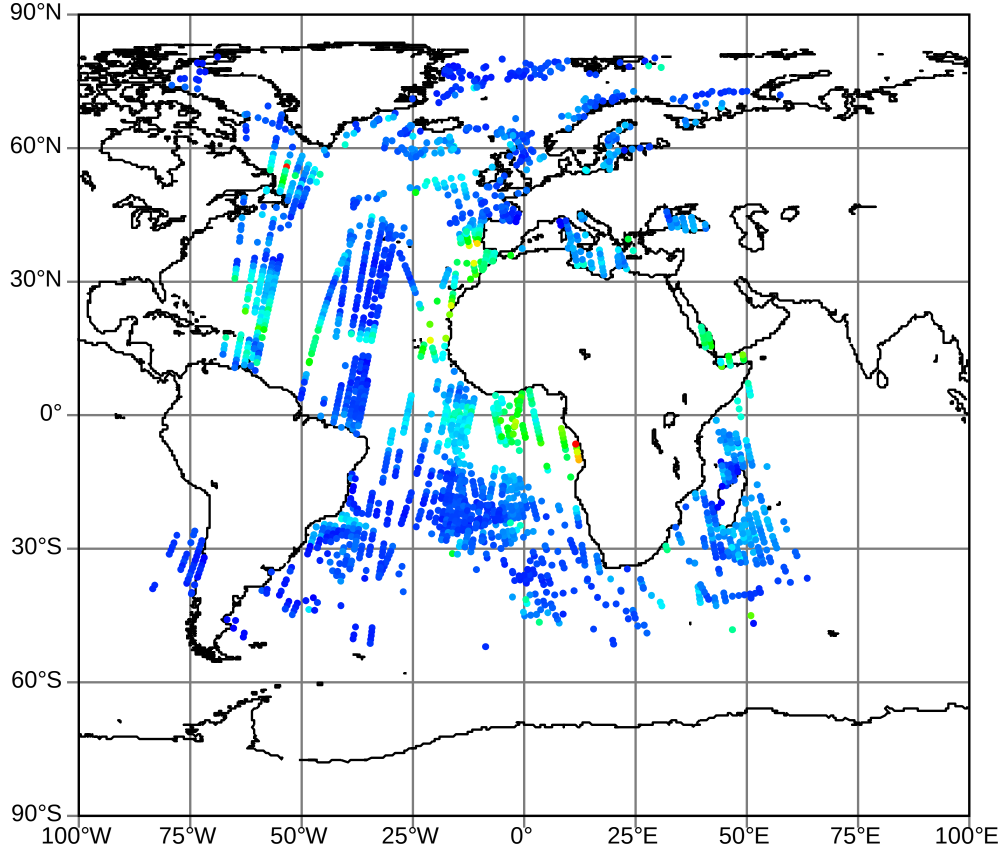
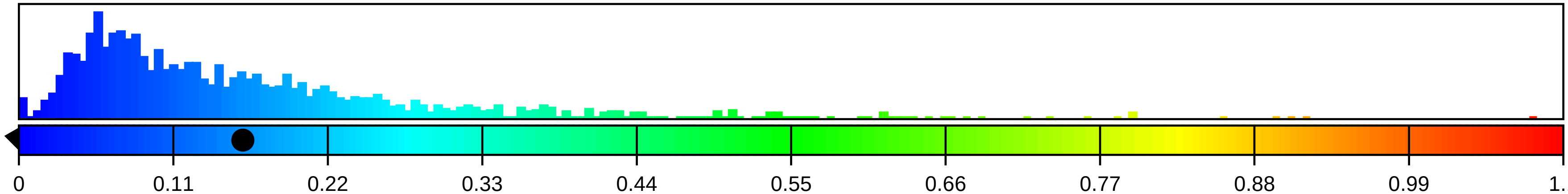
Preliminary results (2003080112 – one analysis cycle)

MODIS Aqua+Terra AOD at 0.55 microns (ocean only)

- Without thinning: ~200,000 observations per cycle.

- With thinning (one obs every 100 km): ~2,000 observations per cycle. More compatible with analysis resolution (T159 ~ 125km).

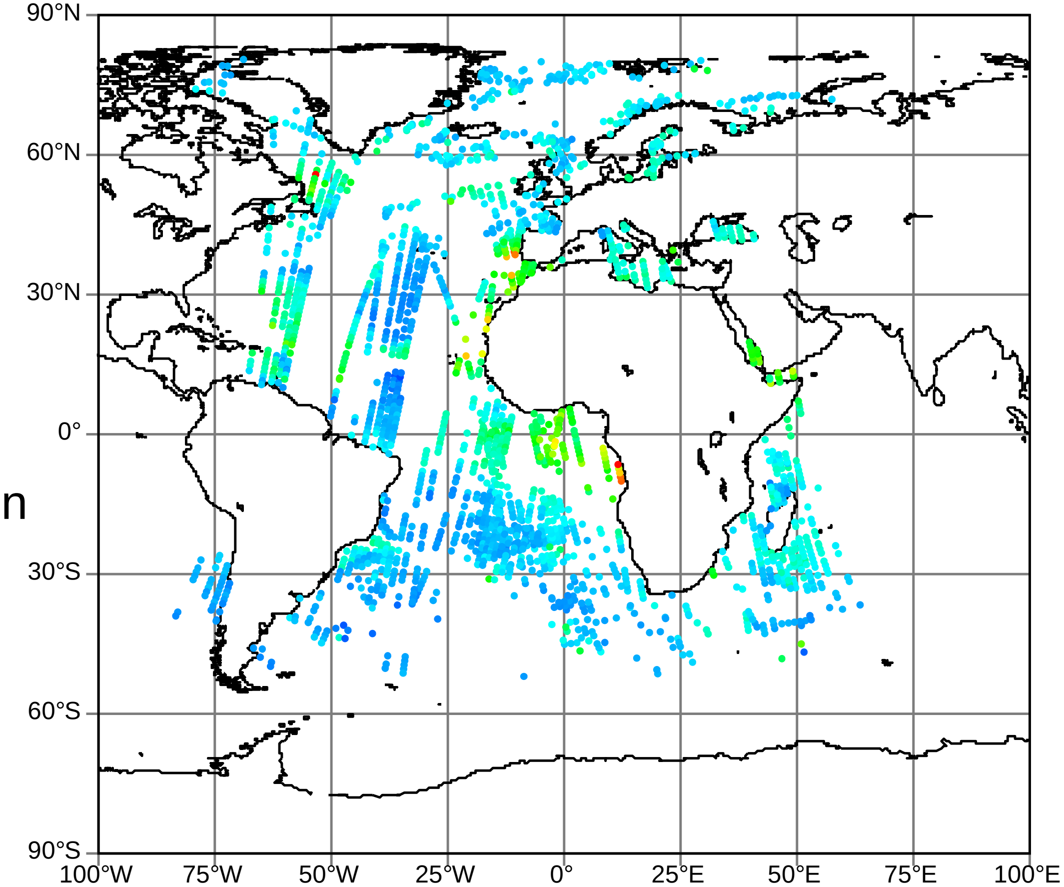




ECMWF

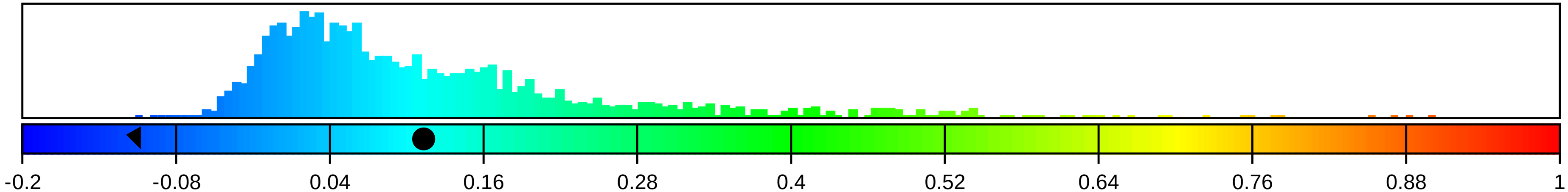
Preliminary results (2003080112 – one analysis cycle)

First guess departures (obs-model) for AOD at 0.55 microns



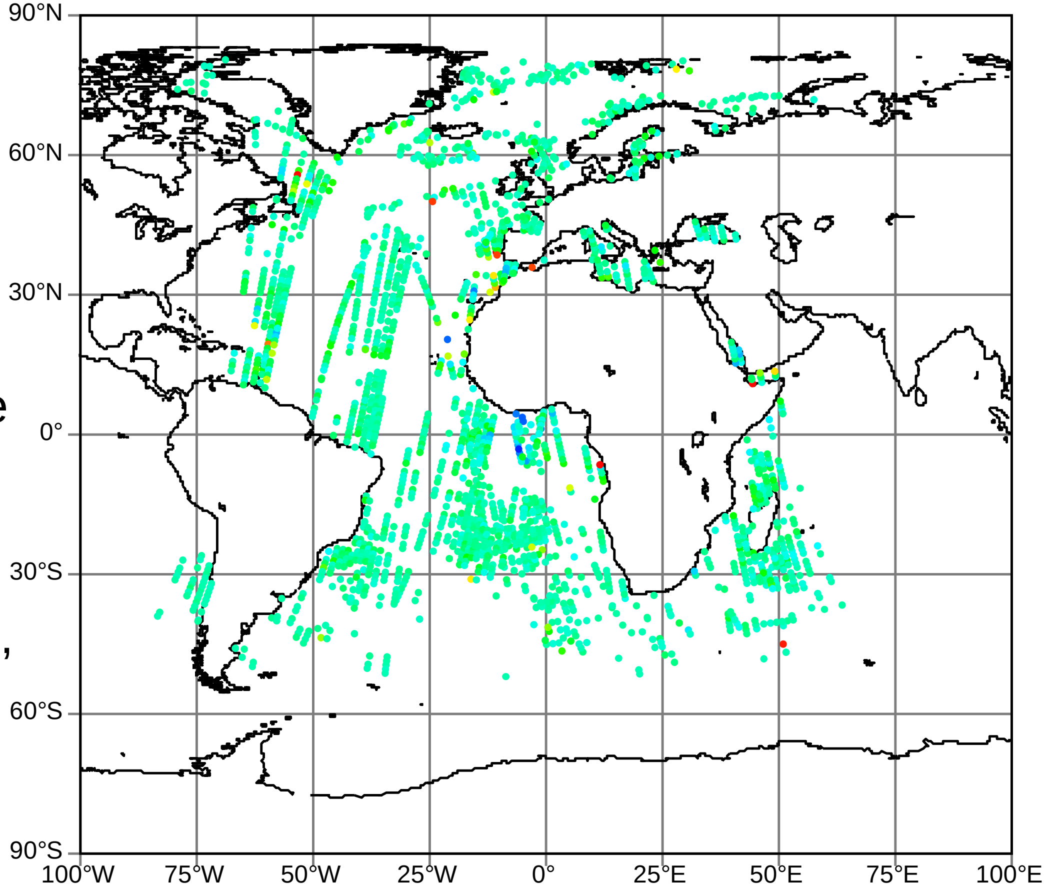
- Only one bin for sea-salt included: large bias is not realistic!!

- However, a bias correction for both model and observations will be likely needed.

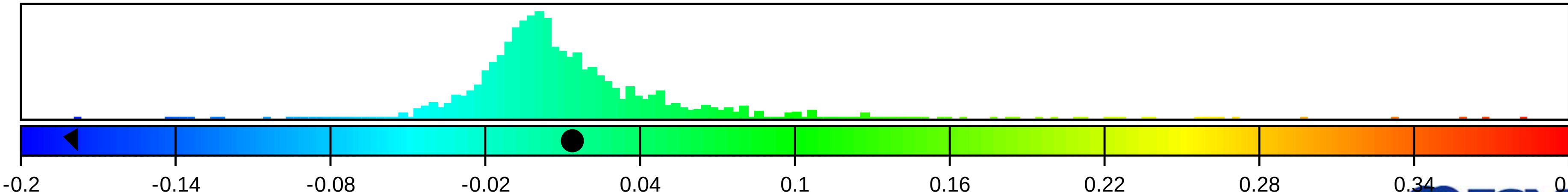


Preliminary results (2003080112 – one analysis cycle)

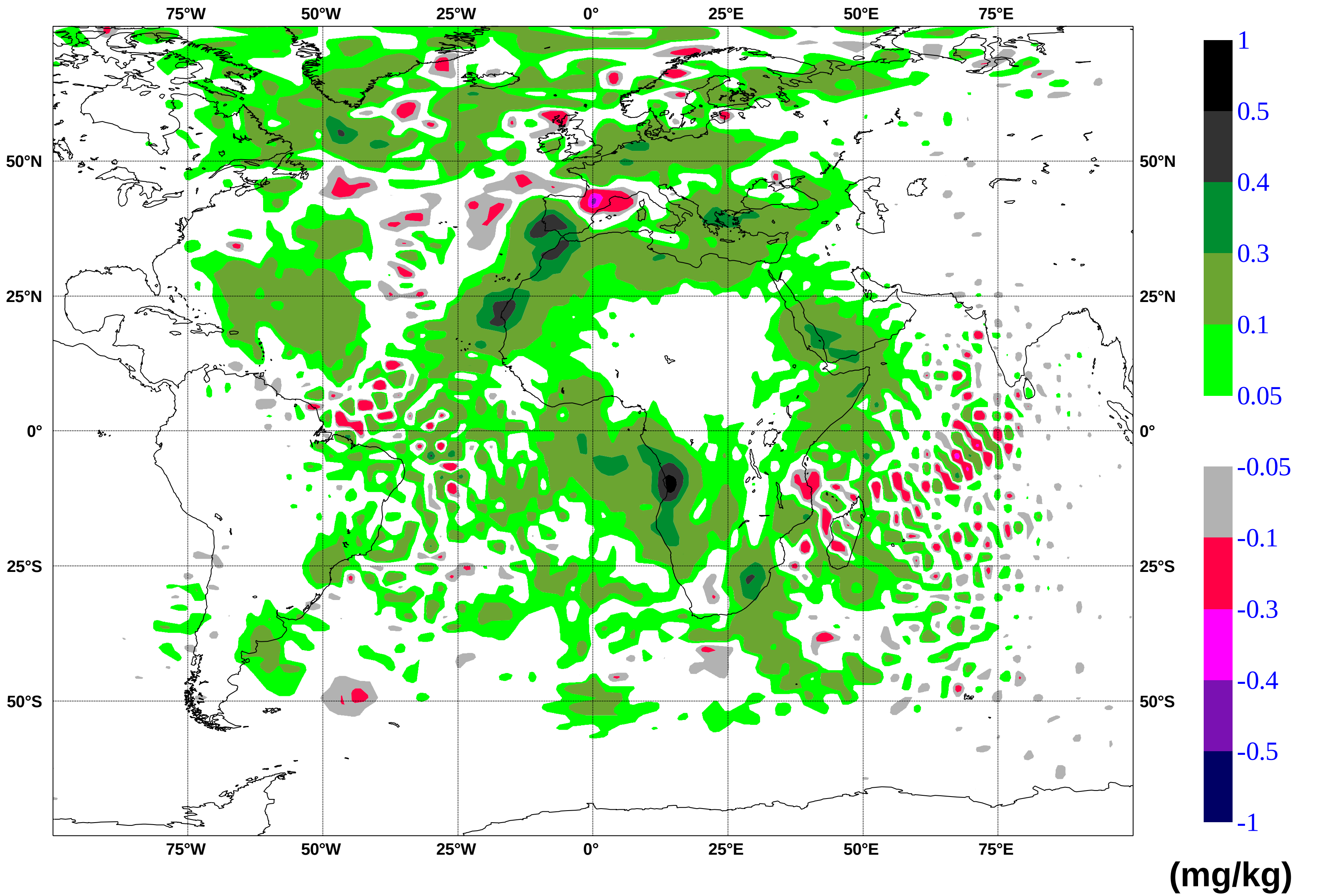
Analysis departures (obs-model) for AOD at 0.55 microns



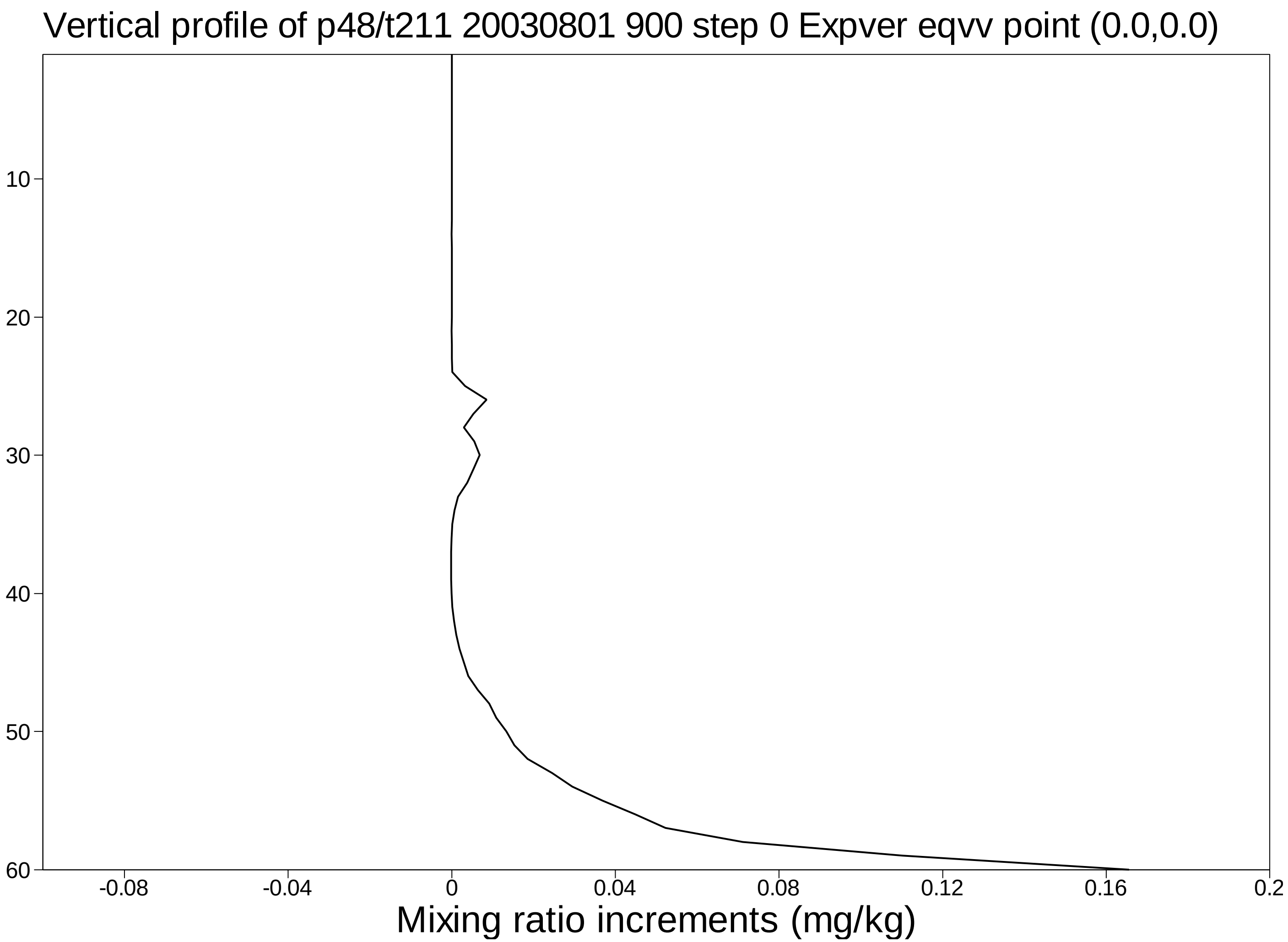
- Analysis departures are much smaller than first guess departures
- Bias is largely removed, but this should not be expected from the analysis



Preliminary results: aerosol mixing ratio increments at the surface



Preliminary results: profile of aerosol mixing ratio increments



- The shape of the profile is largely dictated by the background error covariance matrix!

OBSERVATIONS FOR ASSIMILATION/EVALUATION

Agency	Mission	Instrument	Parameters
ESA	ENVISAT	MERIS	AerOpDepth @0.865
			Angstrom coefficient
			Radiances 7 WL
ESA	ERS-2	ATSR	Radiances used in
	ENVISAT	AATSR	GLOBAER project
EUMETSAT	MSG	SEVIRI	Radiances
	MSG	GERB	Radiation budget
NASA	TERRA	MODIS	AerOpDepth
	AQUA		Radiances
NASA	AQUA	MISR	AerOptDepth
NASA	AURA	HIRDLS	AerOptThickn 4 WL
NASA		SAGE-2	AerOptThickn 8 WL
		SAGE-3	AerOptThickn 8 WL
NOAA		AVHRR	AerOpDepth
CNRS	PARASOL	POLDER	AerOpDepth
NASA/CNRS	CALIPSO	CALIOP	AerExtinction
		AERONET	AerOpDepth

Items for discussion

- Define the forward model configuration to be used in the reanalysis
- Finalize choice of control variables
- Implement a (simple) bias correction
- Implement an improved representation of observation and background errors
- 1D-VAR timeline (focus on getting the radiance observation operator in place)

Future perspectives

- Early days of aerosol modelling and assimilation at ECMWF
- Still many scientific and technical challenges
- Use of 1D-Var to test background matrix and observational operator for radiances (priority so far has been given to 4D-Var)
- Largely a team effort with GHG and GRG projects as well as ECMWF staff members (esp. Data Assimilation Section).
- Start of the first aerosol reanalysis is still scheduled for September 2006