Progress in the GEMS-aerosol sub-project

Met Office, ECMWF, CNRS-LOA, MPI-M, CEA-IPSL-LSCE, NUIG, SA-UPMC, FMI, DWD, RMIB, DLR (no cost)

Olivier Boucher

Presentation to the GEMS annual assembly

Reading, 7 February 2006

Irak – May 2005

© Crown copyright 2004

Malaysia – August 2005

11 August 2005

"Malaysia has declared a state of emergency as the air pollution index soars to extremely hazardous levels on the west coast, which is worst-hit by smoke from fires in Sumatra."

© Crown copyright 2004

Status of staff hired in GEMS-aerosol

ECMWF	Noone hired yet	
MetOffice	Noone hired, internal resources are used	
CNRS_LOA	Bertrand Crouzille	Since 01 Jan 06
MPI-M	Stefan Kinne	Since 01 Mar 05
CEA-IPSL-LSCE	David Fillmore	Since 01 July 05
NUIG	Conor Milroy	Since 01 April 05
SA_UPMC	Noone hired, internal resources are used	
FMI	Noone hired, internal resources are used	
DWD	Harald Flentje	Since 01 August 05
RMIB	Alexander Mangold	Since 06 June 05

+ pre-existing internal resources

© Crown copyright 2004

Reasons for being interested in aerosols

MONITORING

• climate effect (clear-sky, cloudy-sky)

- anthropogenic aerosols are responsible for a radiative forcing
- anthropogenic aerosols may modify the hydrological cycle
- natural aerosols may response to climate change

• deposition and acid rain issues
 ==> ecosystems

• satellite atmospheric corrections
 ==> retrieval of the properties of ocean, land, and atmosphere

• role of aerosol deposition on ocean biology

• depletion of the stratospheric ozone layer

• improvement in meteorological reanalysis

FORECASTING

• Visibility ==> tourism, aviation

• Boundary conditions for air quality models ==> human health

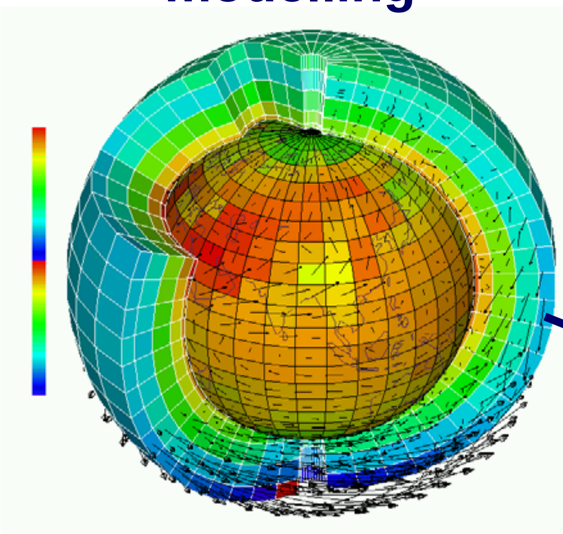
• Improvements in weather forecasts and analysis

• Dust deposition on railways (catenary)

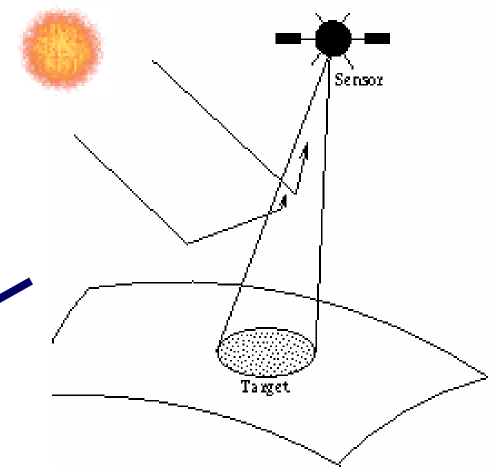
Aerosol monitoring in GEMS

Met Office

modelling



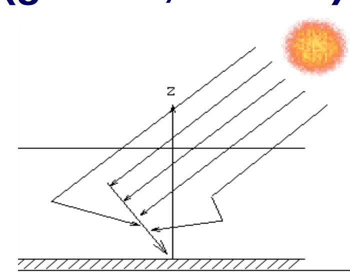
Spaceborne remote sensing



data assimilation

Operational Weather Centre

in-situ (ground, aircraft)



Ground-based remote-sensing

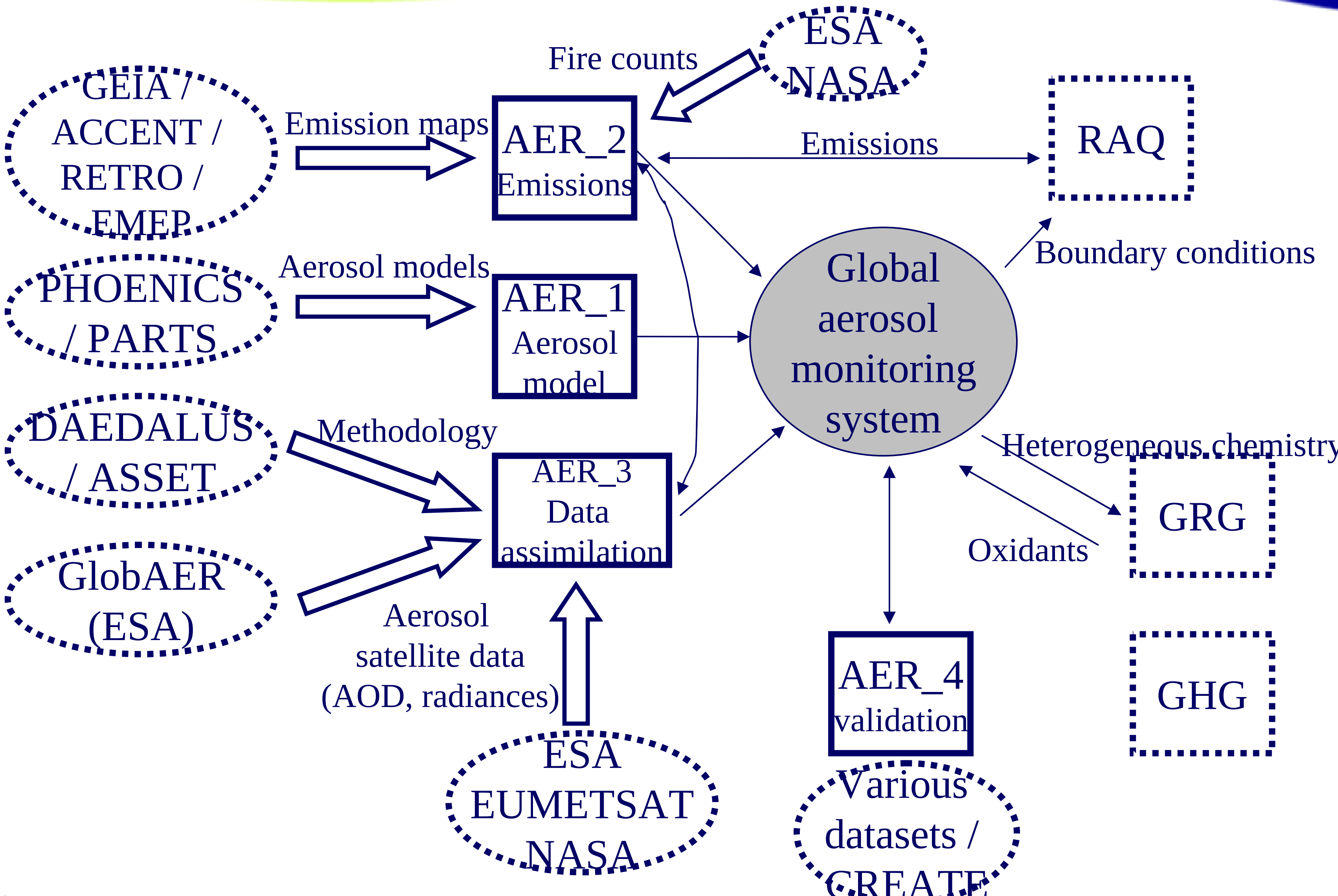
validation

Analyses

Users community: meteorology/climate/ pollution/ecosystems/ atmospheric corrections

© Crown copyright 2004

Aerosol monitoring in GEMS



© Crown copyright 2004

Aerosol monitoring in GEMS

Products	**Usage**
4D distribution of aerosol concentrations at 50-100 km resolution (troposphere and stratosphere)	climate research; monitoring of the atmospheric chemical composition; monitoring of the stratosphere (air traffic); monitoring of volcanic eruptions for local populations; initial and boundary conditions for regional air quality models
4D distribution of aerosol optical properties at 50-100 km resolution (troposphere and stratosphere)	atmospheric corrections for remote sensing of land surfaces and ocean; prediction of surface UV radiation
Surface distribution of particulate matter PM	regional air quality
Improved visibility range	air traffic, tourism
Improved photosynthetically active radiation (PAR) at the surface	study of the carbon cycle; monitoring of the Kyoto protocol
Aerosol deposition flux (dry and wet)	study of the ocean biology; impact on ecosystems (acid rain monitoring)
Improved photolysis rates	regional air quality; global monitoring of the atmospheric chemical composition
Improved surface, atmospheric, and top-of-atmosphere radiative budget	climate research

© Crown copyright 2004

Key milestones in first year

Meeting on stratospheric aerosols (ECMWF, Met Office, SA-UPMC) (Exeter, September 2005)

Meeting on satellite data and observational error covariance matrix (ECMWF, Met Office, CNRS-LOA, CEA-IPSL-LSCE) (Exeter, September 2005)

Working documents on skill scores, injection heights, emissions.

Preliminary aerosol simulation (sea-salt, dust) performed at ECMWF and incorporated into the AEROCOM web-based evaluation tools.

© Crown copyright 2004

Good progress in DA and model evaluation

On-going work on the observational operator and DA plumbing.

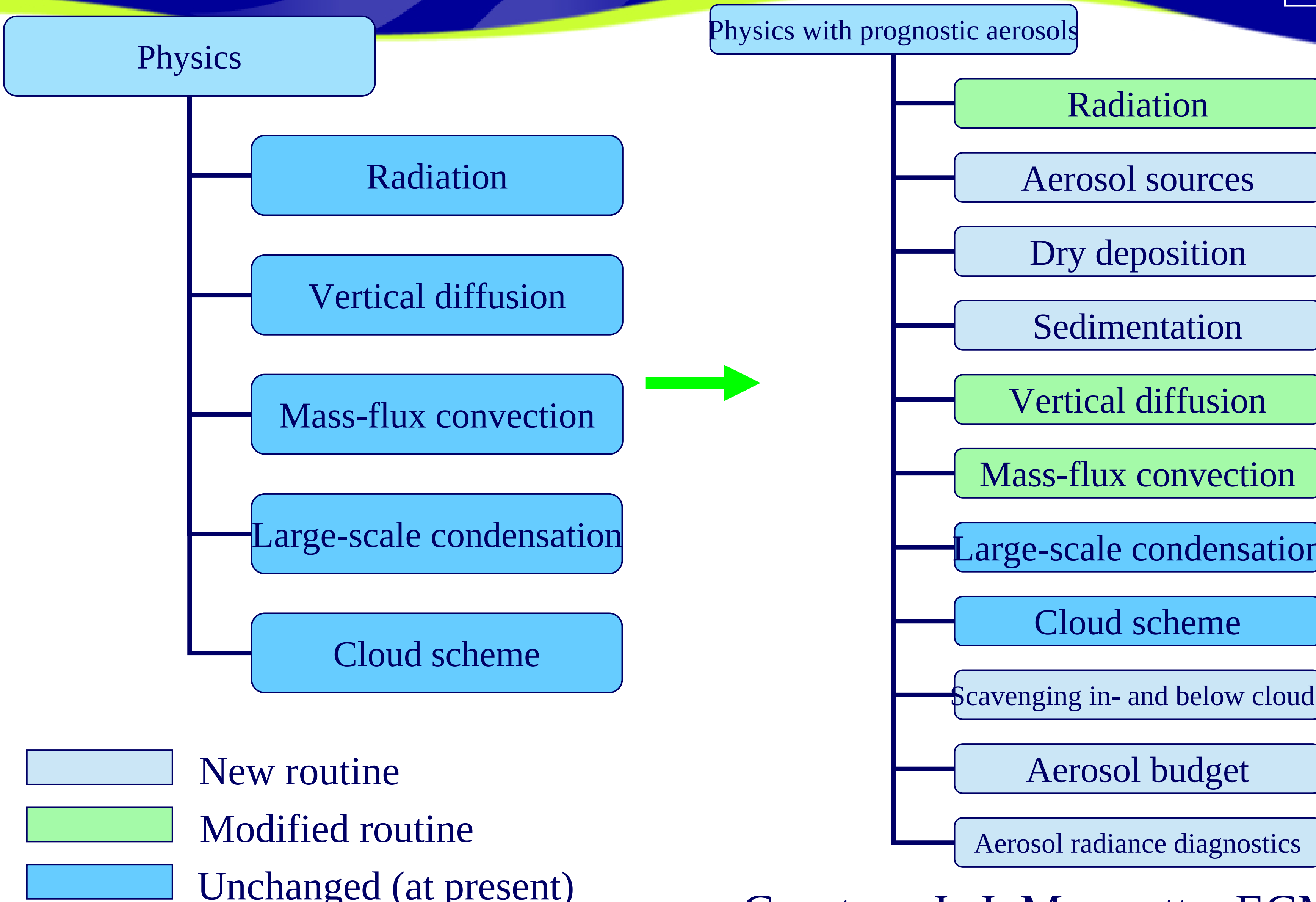
Significant on-going activities in data preparation for DA and evaluation.

- MODIS data uploaded
- data sampling strategy
- removal of bias
- observational error covariance matrix

- AOD from GAW stations
- UV AOD from Brewer spectrophotometer
- Physical and chemical aerosol data
- SEVIRI AOD
- AEROCOM tools

© Crown copyright 2004

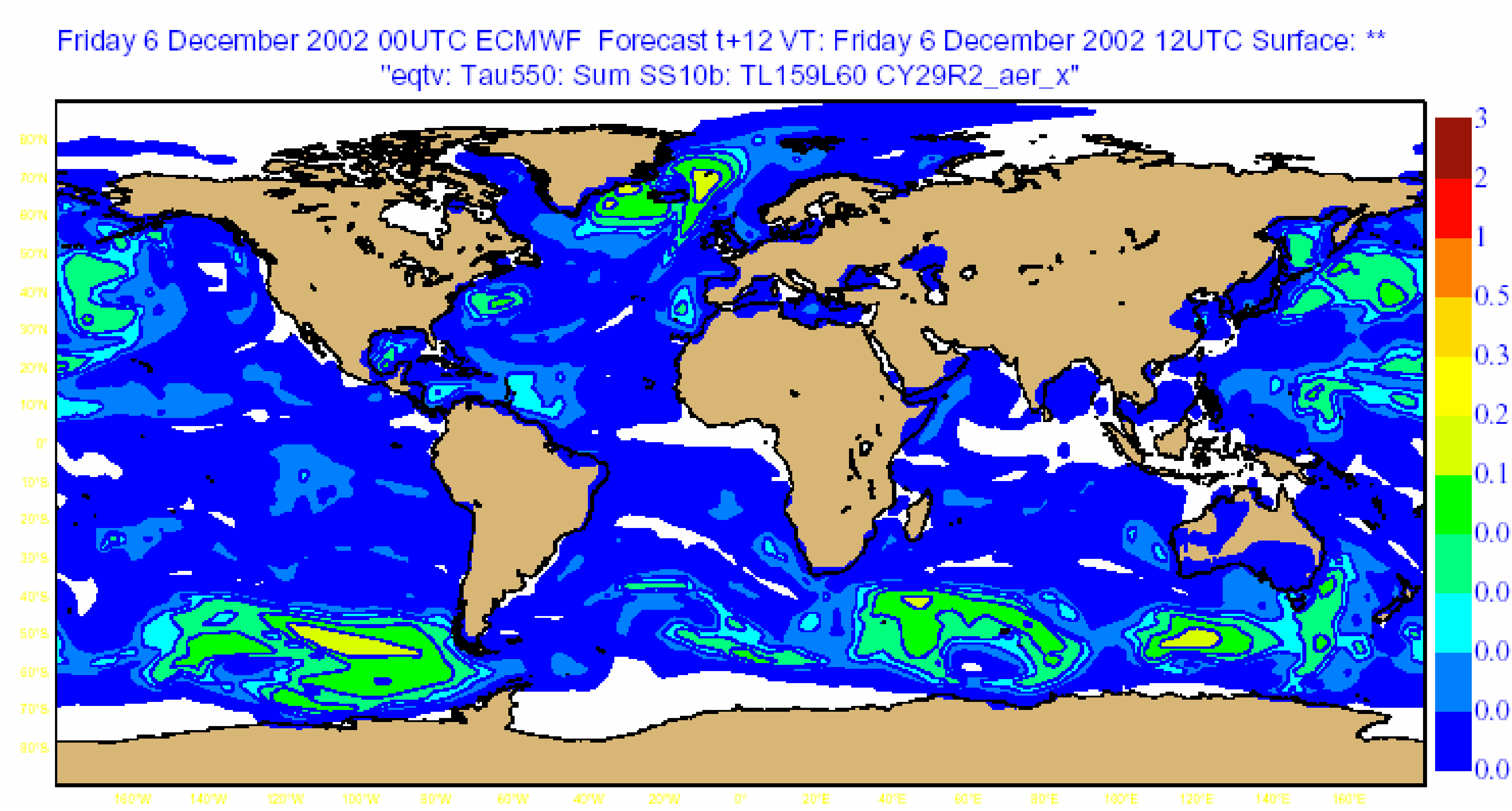
Development of a prognostic aerosol package in the ECMWF model



Courtesy J.-J. Morcrette, ECMWF

© Crown copyright 2004

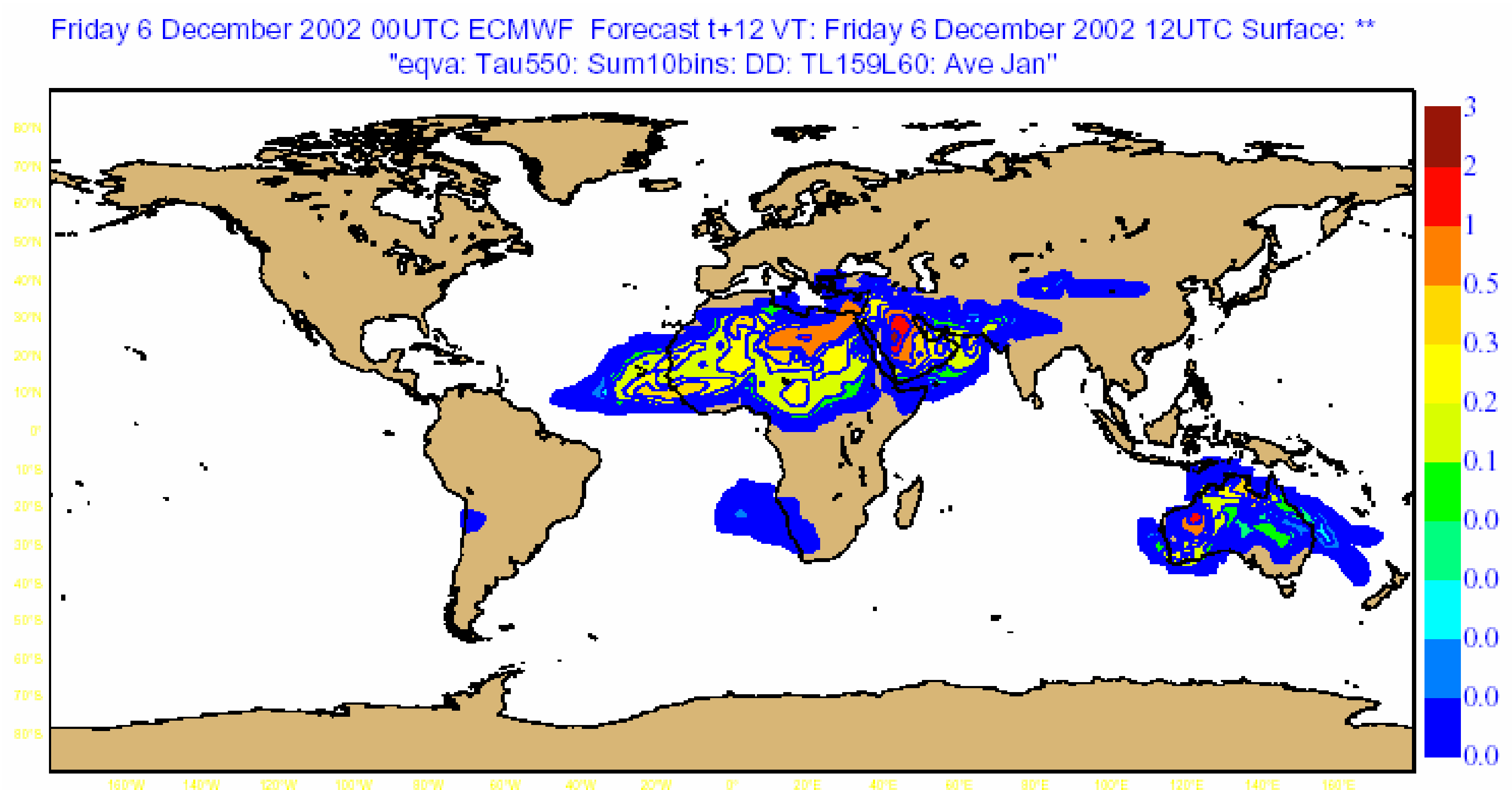
10-day sea-salt AOD @ 550 nm



Hadley Centre © Crown copyright 2004 Courtesy J.-J. Morcrette, ECMWF

10-day pseudo-dust AOD @ 550 nm

Met Office



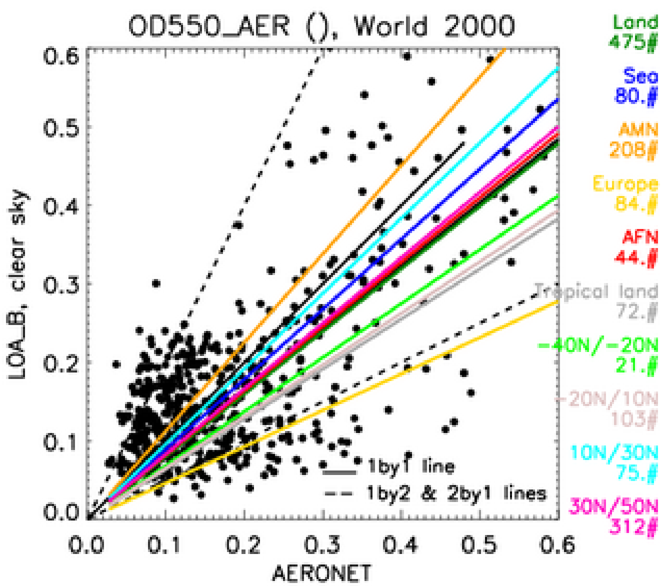
Hadley Centre

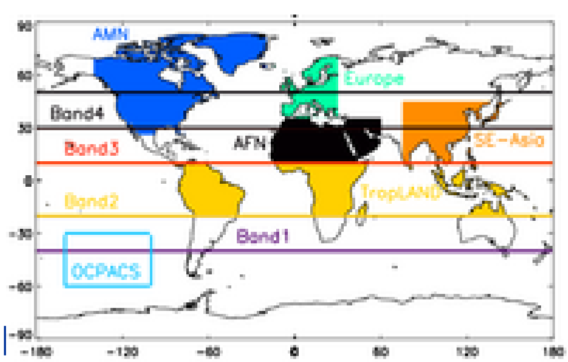
© Crown copyright 2004

Courtesy J.-J. Morcrette, ECMWF

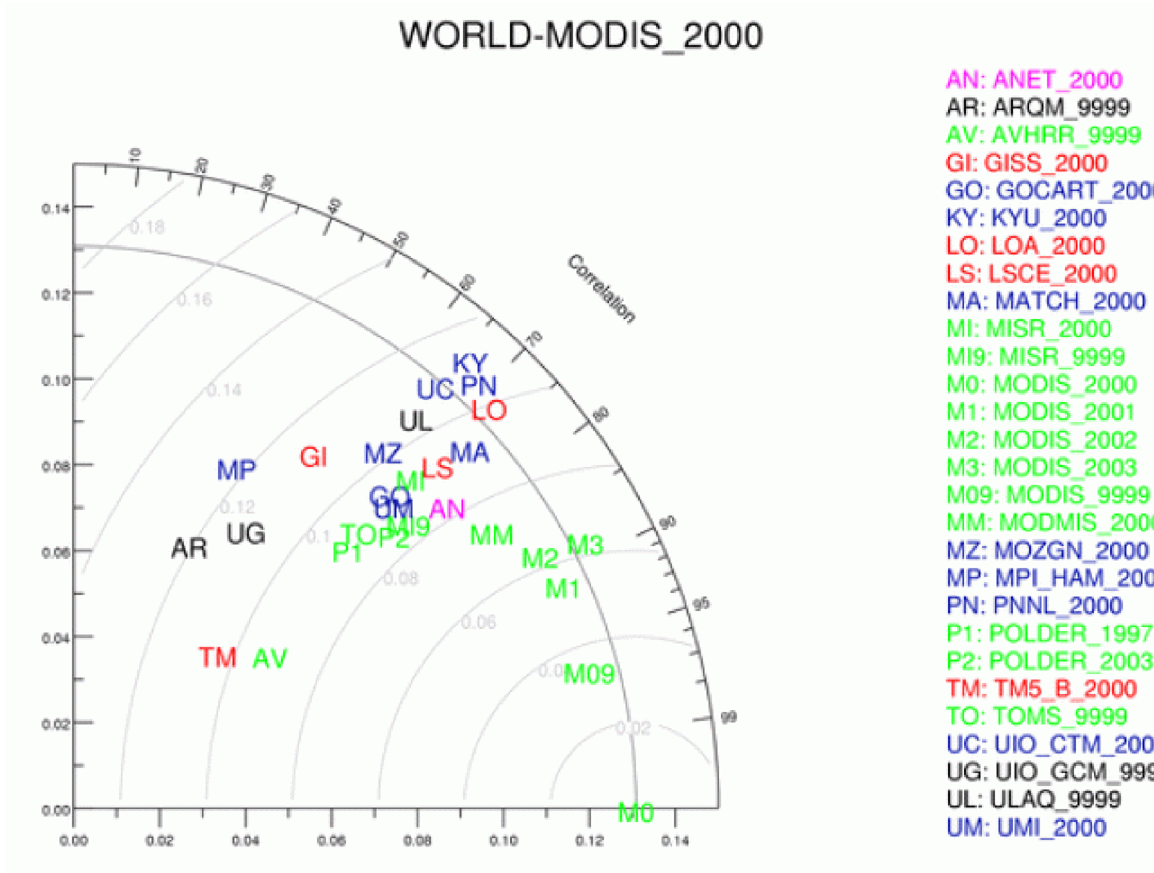
AEROCOM web-based tools

- Correlation plots



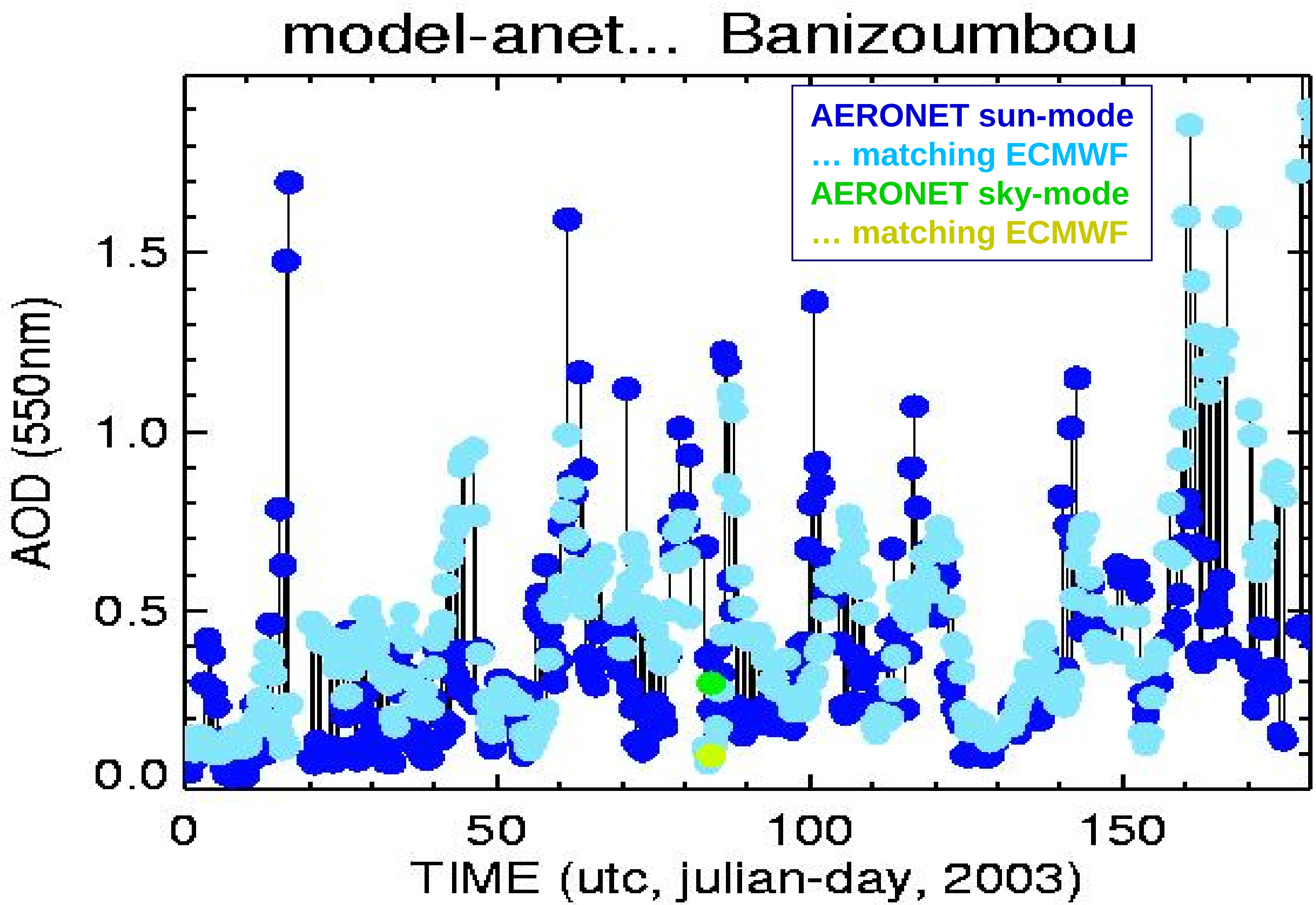


- Taylor diagram



© CEA-IPSL-LSCE, MPI-M

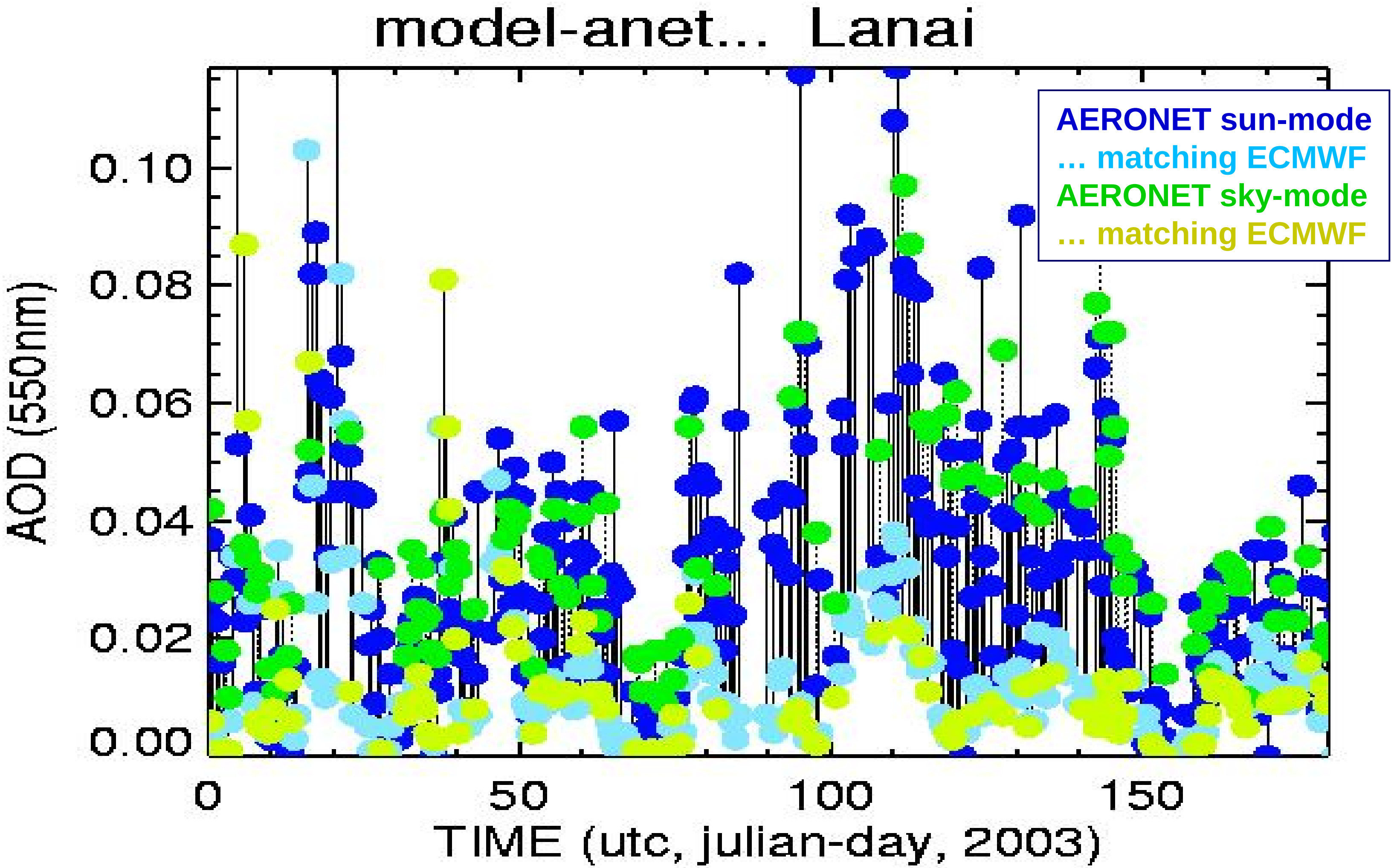
DUST – Western Africa



Courtesy S. Kinne, MPI-M

© Crown copyright 2004

Sea Salt - Pacific Ocean



 © Crown copyright 2004

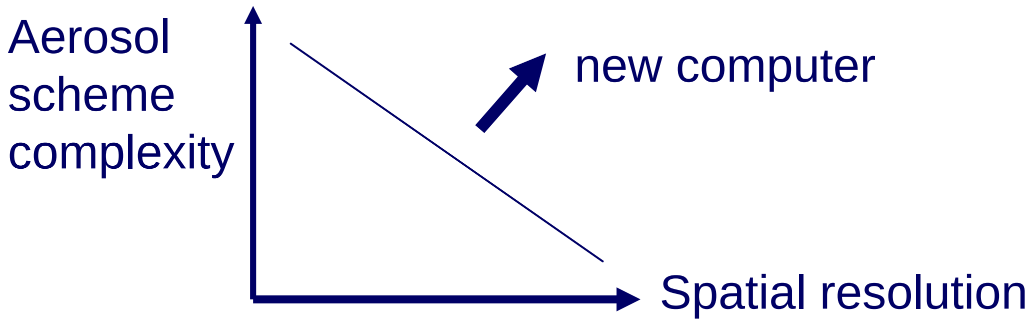
Courtesy S. Kinne, MPI-M

Ongoing aerosol modelling

Important criteria for model implementation:

- aerosol parametrisations need to be consistent with the ECMWF physics
- aerosol parametrisations need to be computationally affordable
- choice of aerosol parametrisations guided by skill scores
- to become interactive aerosols should not deteriorate the weather scores

Balance between aerosol model complexity and spatial resolution



Modal scheme (N, m) for the stratosphere

Emissions

Reduced scheme (4 variables) for the troposphere?
Modal scheme (M7 or UKCA) later on?

© Crown copyright 2004

FULL SCHEME

REDUCED SCHEME

24 tracers: DMS, SO_2, H_2S, DMSO,MSA,H_2O_2, SO_4, Black Carbon, Organic Matter, Fly Ash, 2 bins for Dust and 10 bins for Sea Salt

Black Carbon and Organic Matter exist in model as hydrophilic and hygrophobic

Tracer 1: Aerosol Precursors (DMS, SO_2, H_2S)

Tracer 2: Accumulation mode aerosol (SO_4, Black Carbon, Organic Matter, Dust & Sea Salt)

Tracer 3: Coarse mode aerosol (Sea Salt)

Tracer 4: Coarse mode aerosol (Dust)

$$DMS \xrightarrow{\text{oxidation}} SO_2 + DMSO + \ldots$$

$$SO_2 \xrightarrow{\text{oxidation}} SO4 + \ldots$$

$$H_2S \xrightarrow{\text{oxidation}} SO_2 + \ldots$$

Fixed oxidants but H_2O_2 chemistry

Aqueous-phase oxidation of SO_2

Sulphur chemistry is replaced by

an equivalent chemical lifetime

$$DMS+H_2S+SO_2 \xrightarrow[\text{lifetime}]{} SO_4$$

© Crown copyright 2004

Developed/tested in LMDZ by N. Huneeus

FULL SCHEME | REDUCED SCHEME

Met Office

• Dry Deposition

Full scheme

	Tracer 1*	Tracer 2**	Tracer 3	Tracer 4
Vdep_oce	0.0 & 0.7	0.05 & 0.1	0.1, 1.2 & 1.5	1.2
Vdep_sic	0.0 & 0.2	0.25 & 0.1	0.1, 1.2 & 1.5	1.2
Vdep_ter	0.0 & 0.3	0.25 & 0.1	0.1, 1.2 & 1.5	1.2
Vdep_lic	0.0 & 0.2	0.25 & 0.1	0.1, 1.2 & 1.5	1.2

*The value of SO_2 is taken for Tracer 1 in the simplified model, except for vdep_oce where it is a weighted average of deposition velocities of SO_2 and DMS
** The first value in the column represents de deposition velocity for SO_4 and all the other tracers grouped in tracer 2 have a value vdep of 1.2

Reduced scheme

	Tracer 1*	Tracer 2	Tracer 3	Tracer 4
Vdep_oce	0.28*	0.05	1.2	1.2
Vdep_sic	0.2	0.25	1.2	1.2
Vdep_ter	0.3	0.25	1.2	1.2
Vdep_lic	0.2	0.25	1.2	1.2

*Weighted average between deposition velocities of SO_2 and DMS

• Wet Deposition

• Sedimentation

Sedimentation velocity is a function of size. | Equivalent size is used to adjust burden

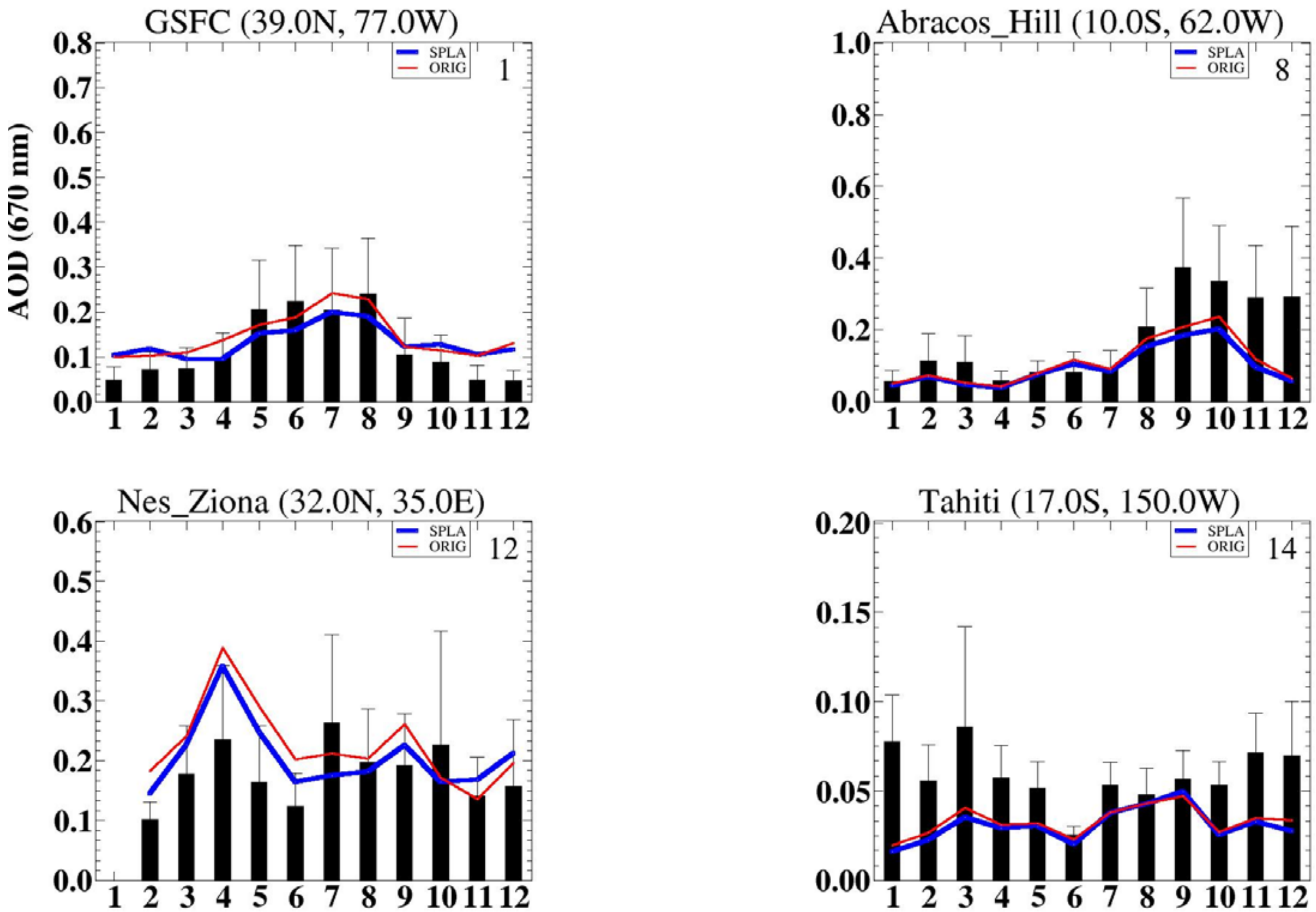
• Aerosol optical properties

Size distribution. Mie theory. | Equivalent size distribution is used.

© Crown copyright 2004

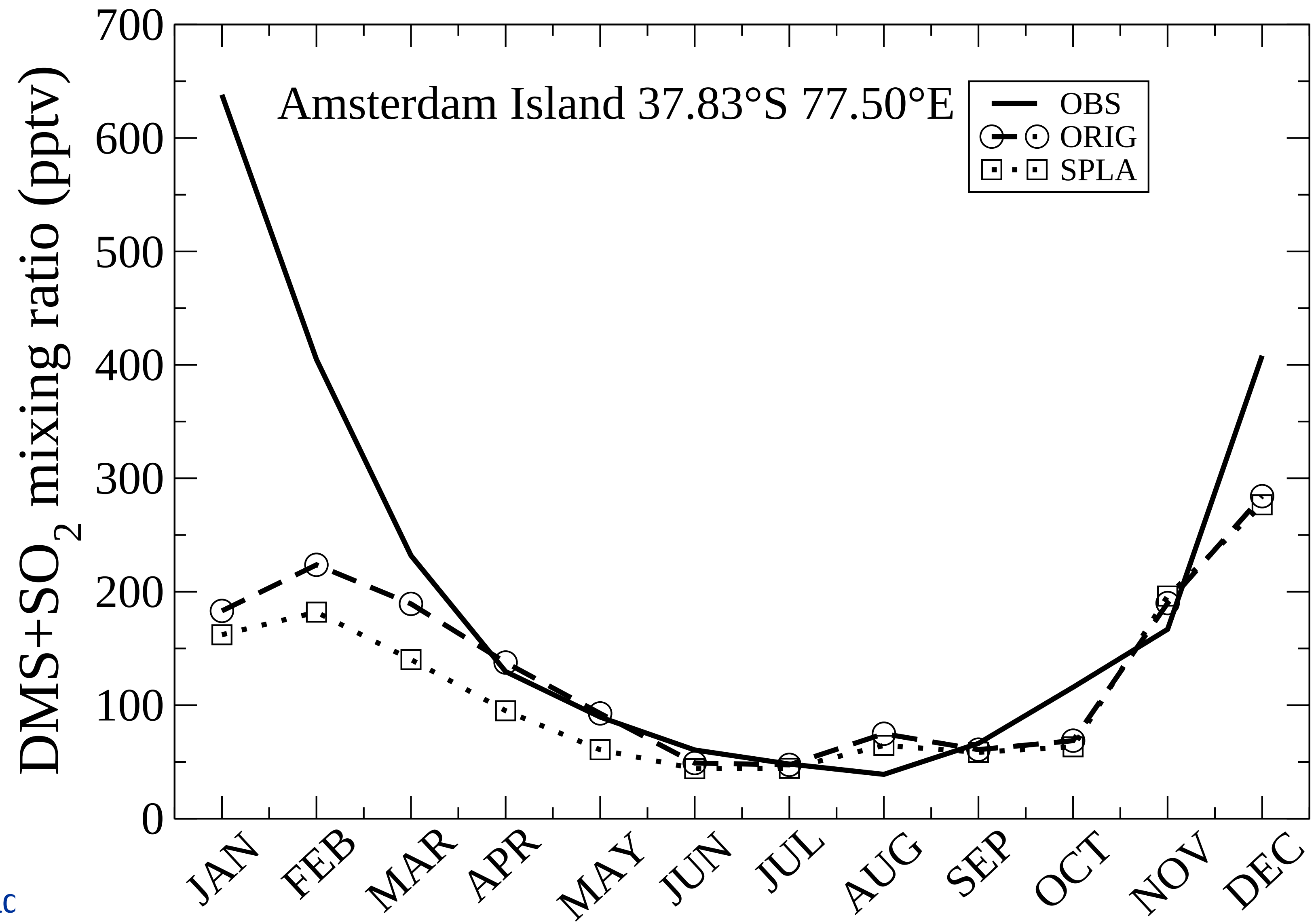
Developed/tested in LMDZ by N. Huneeus

Model evaluation: AERONET



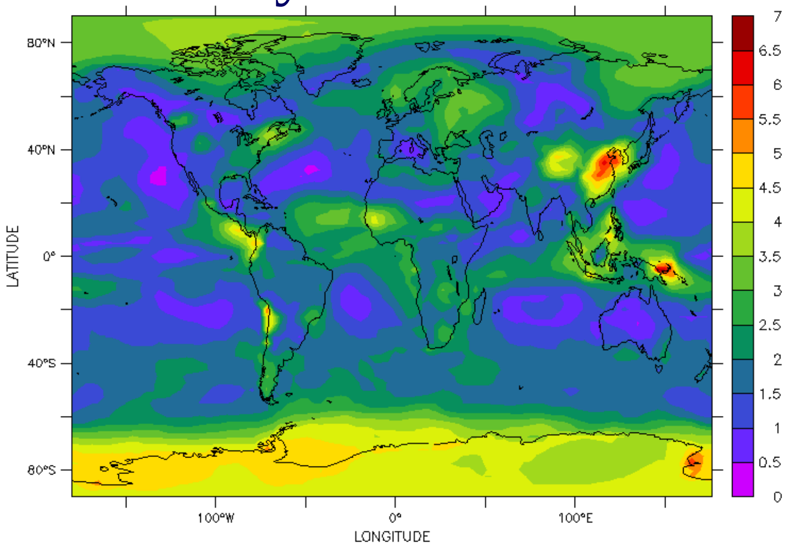
 © Crown copyright 2004

Model evaluation: Amsterdam Island

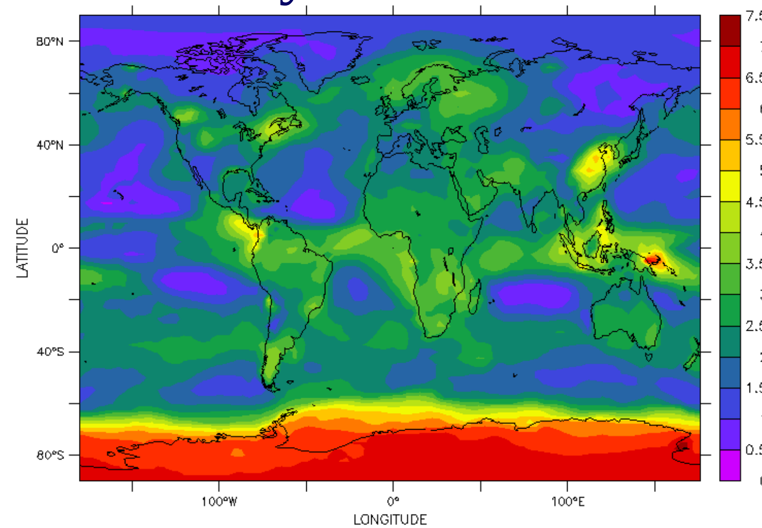


RMSE reduced versus full scheme

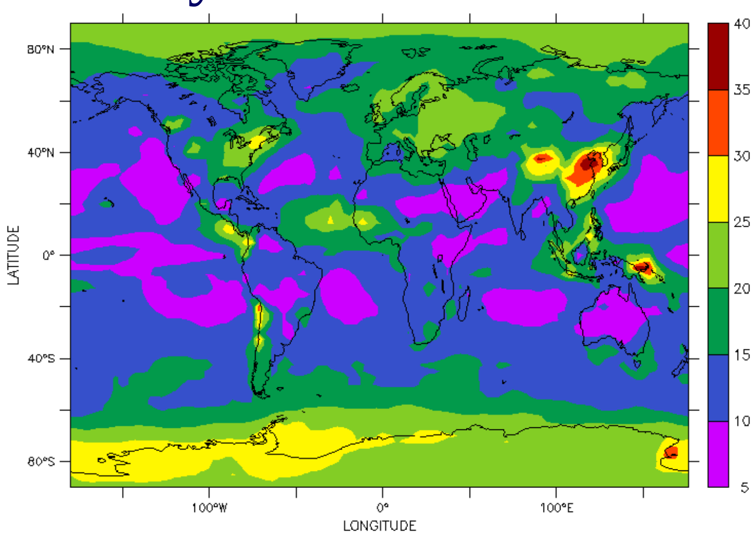
Monthly AOD at 550 nm



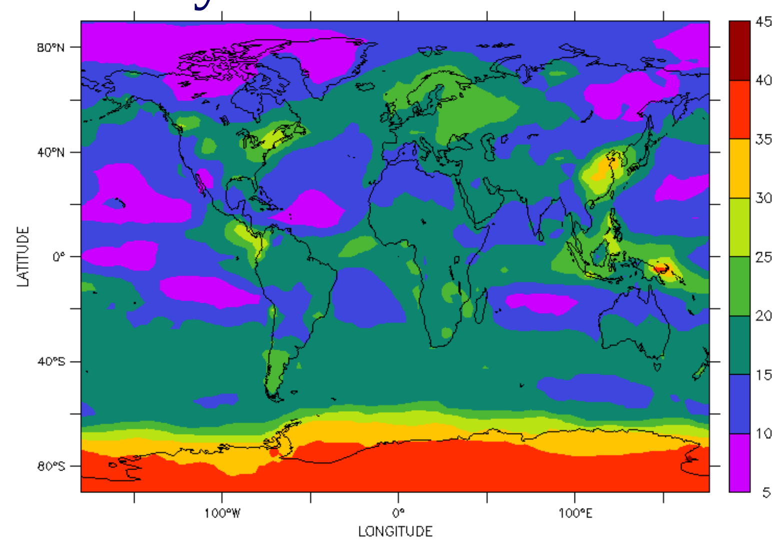
Monthly AOD at 865 nm



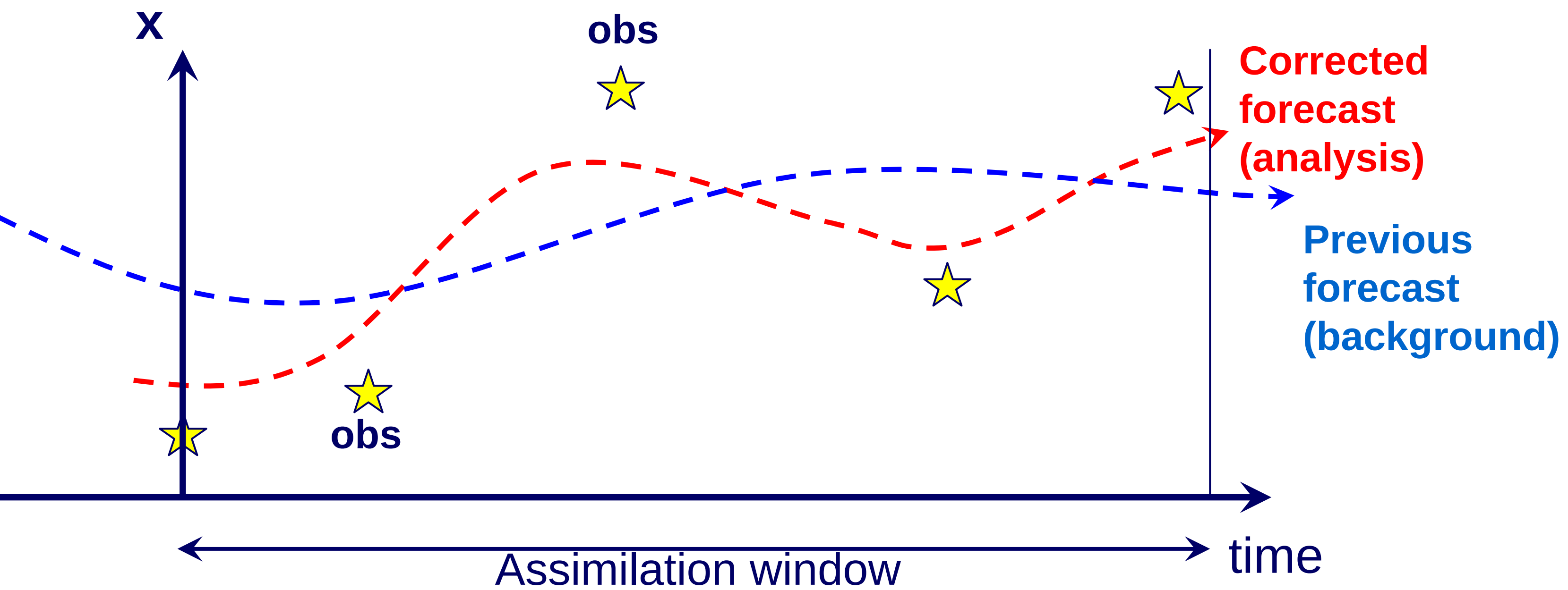
Daily AOD at 550 nm



Daily AOD at 865 nm



Variational assimilation



$$J=(x-x_b)^T \boldsymbol{B}^{-1}(x-x_b)+(y-\mathbf{H}[x])^T \boldsymbol{R}^{-1}(y-\mathbf{H}[x])$$

+ minimisation algorithm

B,R: Covariance error matrices

y: observation

x_b: background

H: obs operator

 © Crown copyright 2004

Variational assimilation

- Assimilated data

  1/ MODIS accumulation- and coarse-mode AOD

  AOD data delivered by ESA GlobAER project?

  2/ Satellite aerosol radiances

  6S model is being simplified and adjoint will be developed

- Observational error covariance matrix

  Data unbiased and error covariance matrix defined

  from +/- 30 min comparison to AERONET data

  Defining sampling strategy based on quality flags and local s.d.

  Operator uncertainty lumped with the observational error

- Background error covariance matrix:

  NMC method: difference between 48h and 24h forecasts for the same time

© Crown copyright 2004

Skill scores

- Correlation coefficients (observed vs simulated aerosol properties)
  - current models perform well on monthly means
  - challenge will be to get good correlation on daily means

- Linear fits: slope, offset

- Root-mean square errors
  - largely used in RAQ

- Taylor diagrams
  - summarizes model performance in terms of correlation coefficient, standard deviation, and RMS.

- Figures of merit
  - useful to test the transport for particular events
  - has been used for ETEX

© Crown copyright 2004

Objectives of the aerosol breakout session

1/ Review progress from all partners

2/ Make a number of key decisions

- model set up for the next year or so
- emission datasets
- satellite datasets for data assimilation
- interfaces with other sub-projects
- evaluation strategy

3/ Agree on and polish workplan for months 13 to 30

4/ Decide if interim aerosol meetings are needed

© Crown copyright 2004