Atmosphere Monitoring

Aerosol activities at ECMWF

Zak Kipling and Mel Ades

With thanks to: Anna Agusti-Panareda, Jerome Barre, Angela Benedetti, Nicolas Boussarez, Alessio Bozzo, Richard Engelen, Johannes Flemming, Vincent Huijnen, Antje Inness, Mark Parrington, Luke Jones, Julie Letertre-Danczak, Mark Parrington, Vincent-Henri Peuch, Samuel Remy, Roberto Ribas.

ICAP workshop, 6–8 June 2018, Exeter

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Part I: Modelling aspects

(Zak Kipling)

Evolution of the CAMS global system

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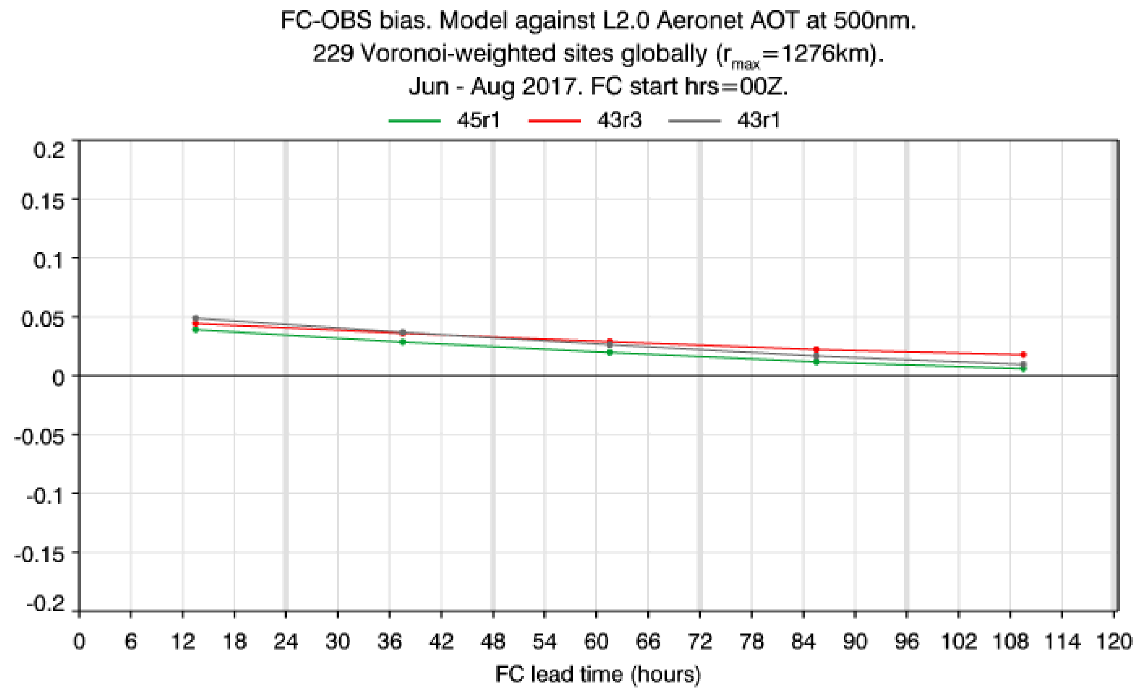
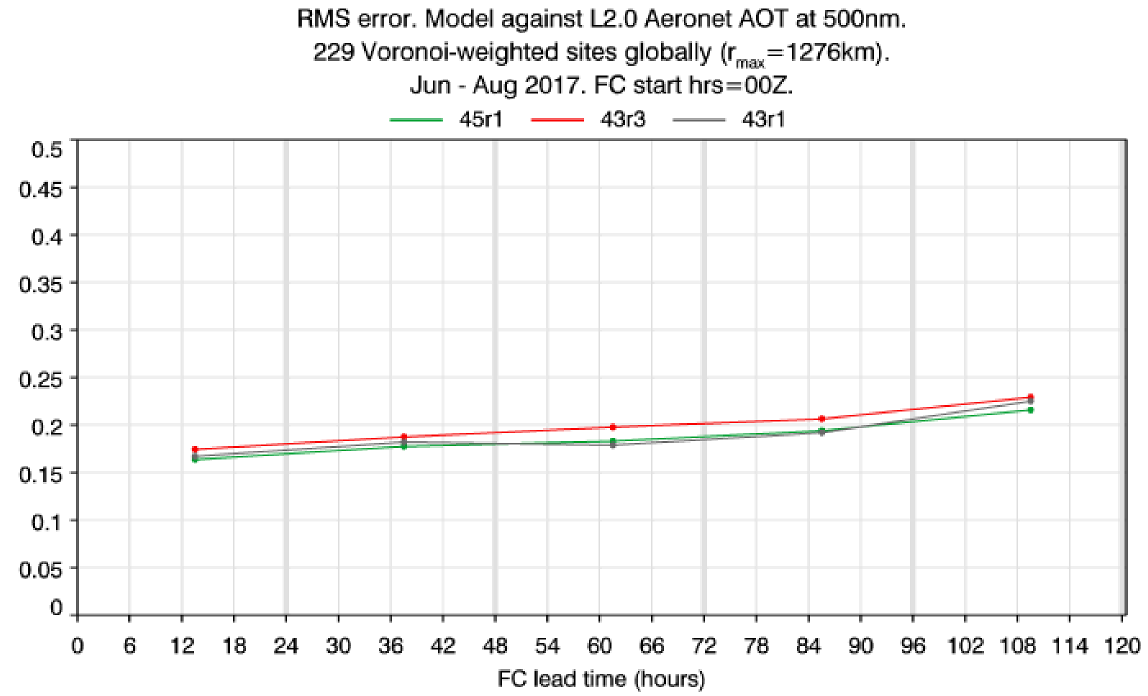
Evolution of the CAMS global system

500nm AOD vs Aeronet (L2 V3)

Bias



RMSE



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AERONET verification tool: *Luke Jones*

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… but it depends what you compare to

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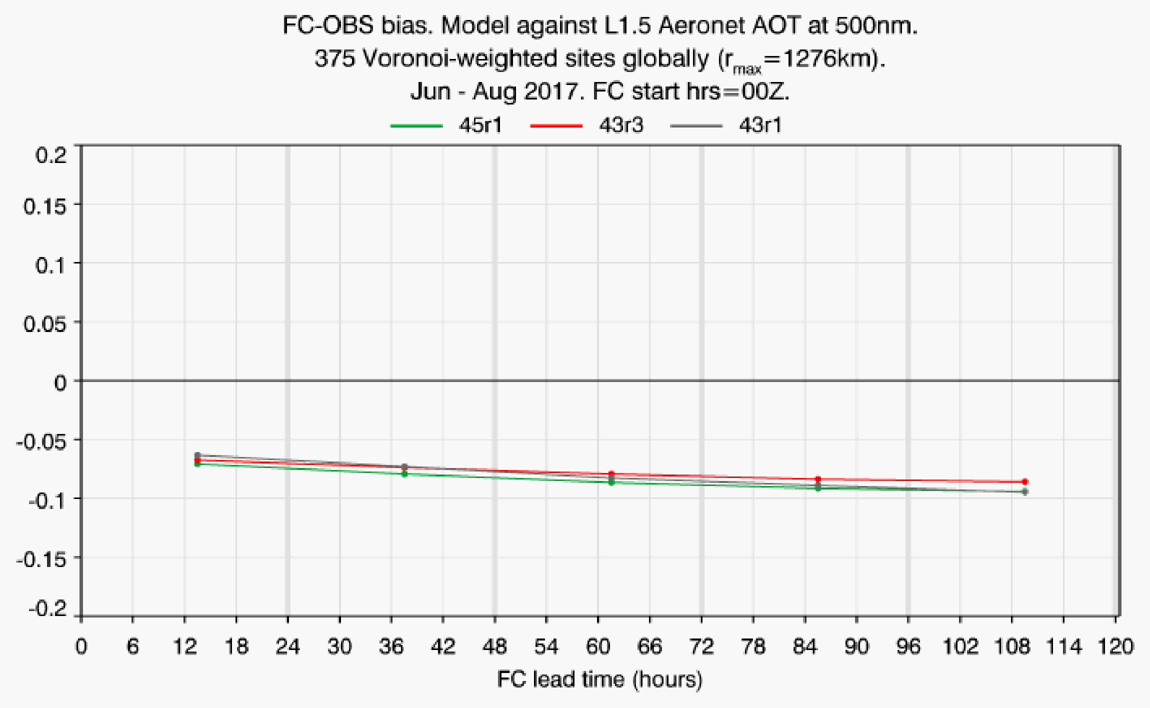
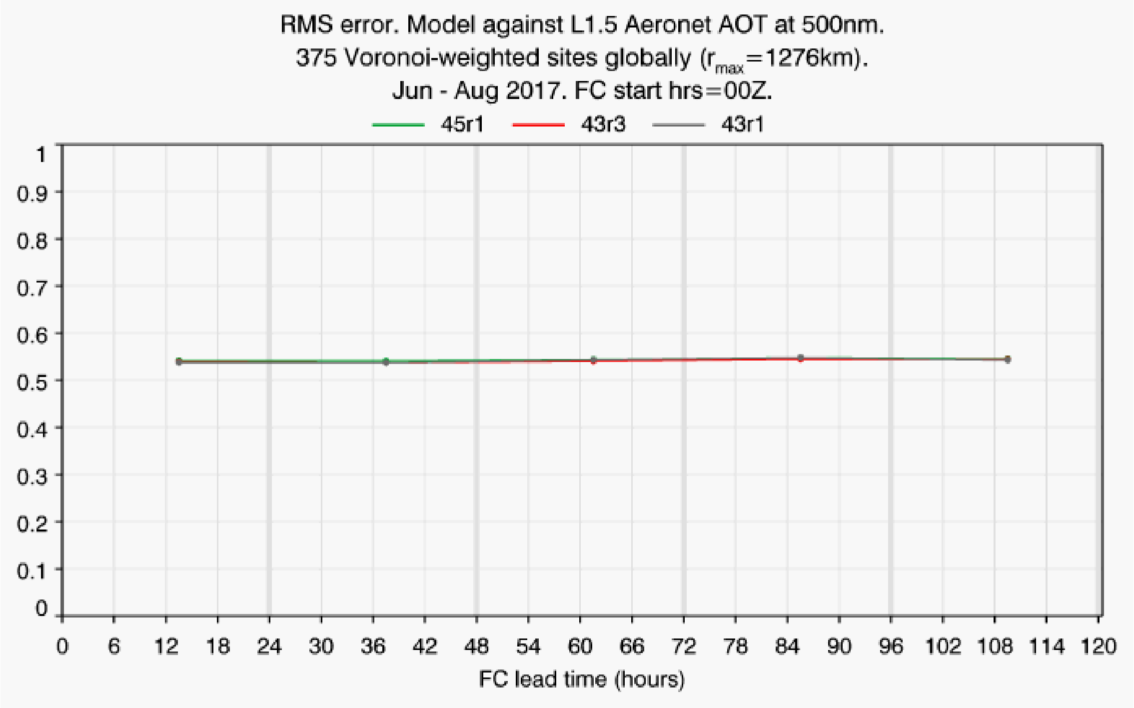
500nm AOD vs Aeronet (L1.5 V2)

Bias



RMSE



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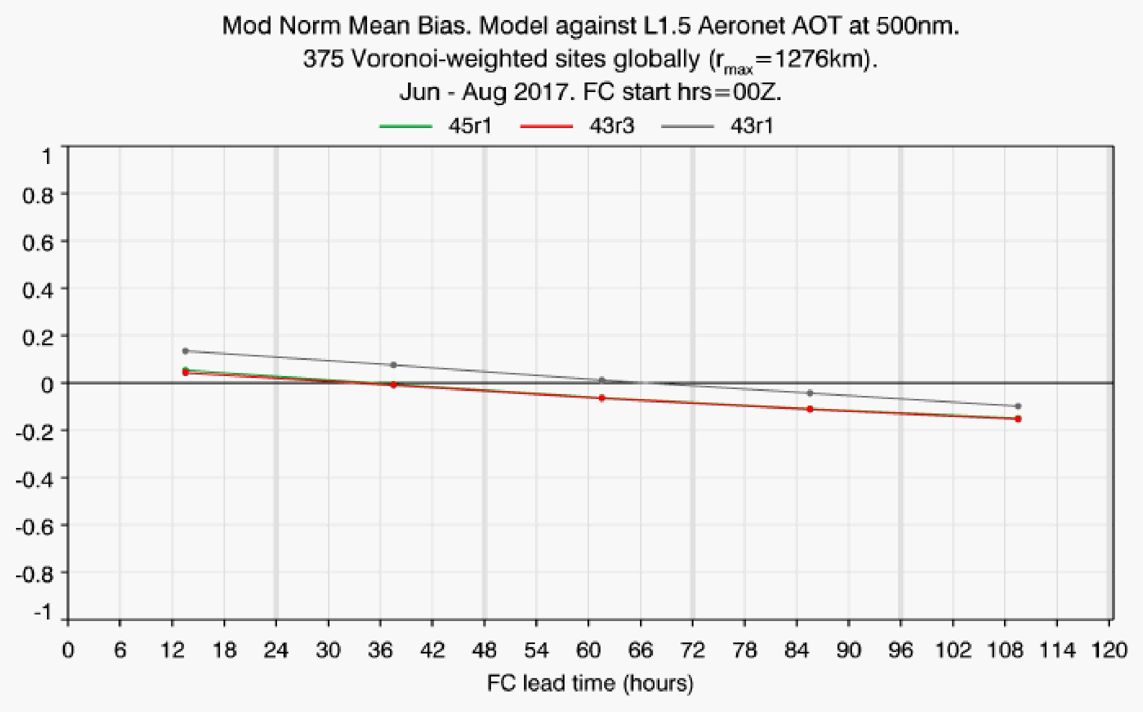
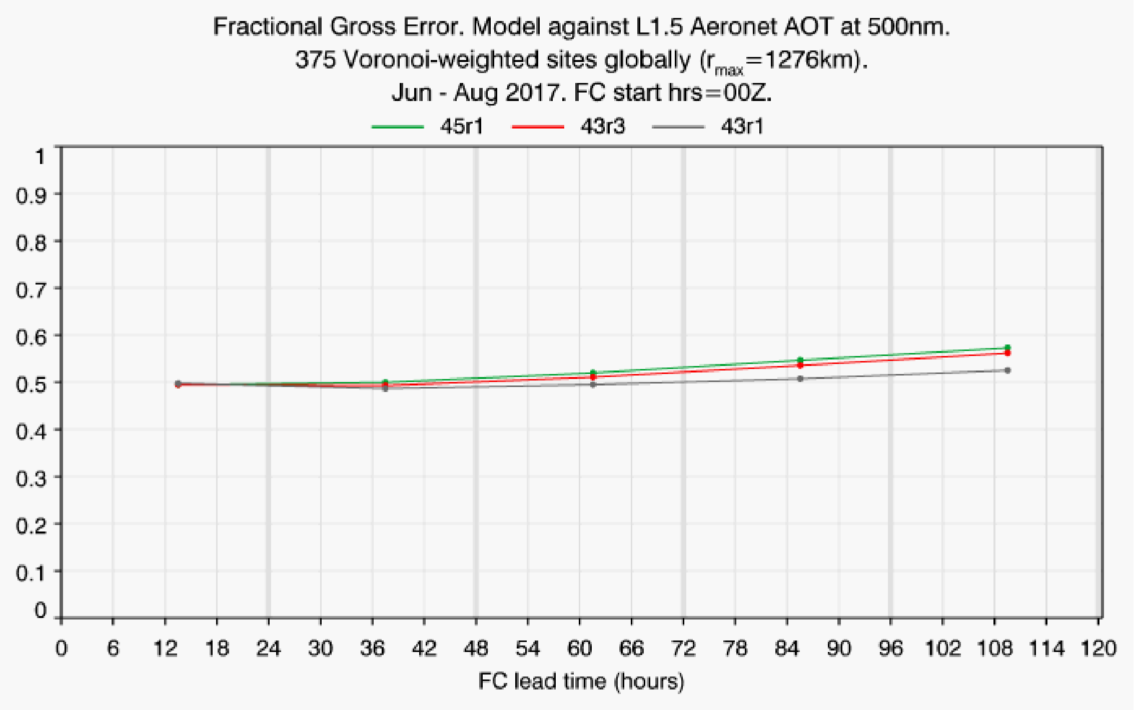
… and how you compare it!

500nm AOD vs Aeronet (L2 V3)

Modified Normalised Mean Bias (MNMB)



Fractional Gross Error (FGE)



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Operational CAMS global system (IFS cycle 43r3, from 26 September 2017)

- *Updated aerosol optical properties (esp. for organic matter)*
- *Tuning of sulphur cycle oxidation and deposition*
- *Correction of sea salt sedimentation rate*
- *Proper GRIB output of extinction and attenuated backscatter profiles*

Experimental CAMS global system (IFS cycle 45r1, from 26 June 2018)

- **New online sea-salt scheme (Grythe et al., 2014)**
- **Online-calculated dry deposition velocities (Zhang et al., 2001)**
- *Sub-grid-scale volcano heights for outgassing SO_2 emissions*
- *Proper GRIB output of AOD at many extra wavelengths, plus AAOD and fine-mode AOD.*
- *Proper GRIB output of many aerosol mass budget terms.*
- *Optional coupling with chemical sulphur cycle*
- *Optional ammonium nitrate aerosol*

Recap: new sea-salt scheme: Grythe et al. (2014)

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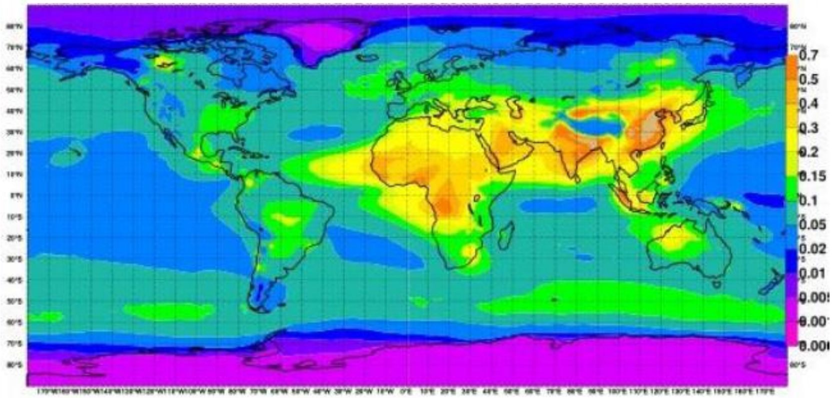
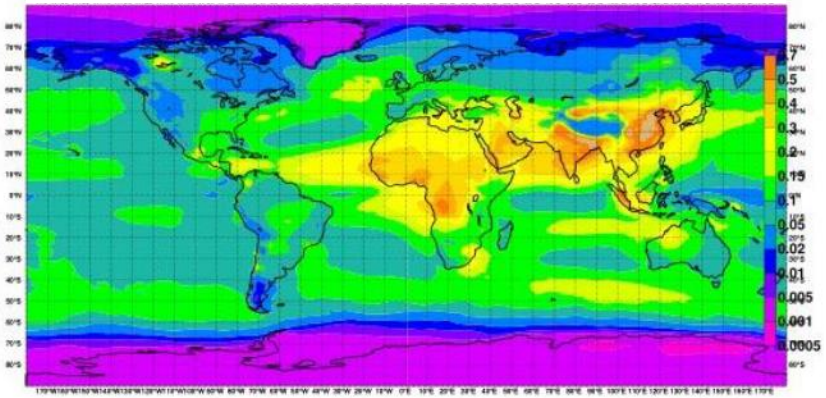
- Replaces older Monahan et al. (1986) scheme
- Wind scaling varies on particle size
- Emissions increase with SST

Emis. / Tg	M86	G14
Bin 1	0.022	0.033
Bin 2	1.928	1.462
Bin 3	2.344	36.37
Total	2.73	13.61

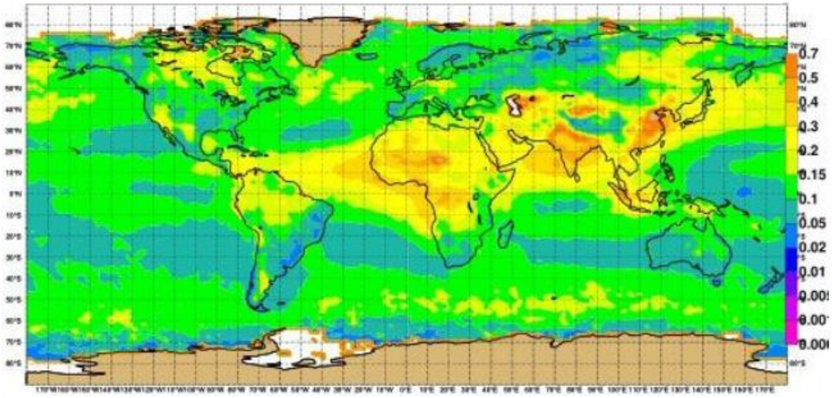
Old scheme (M86)



New scheme (G14)



MODIS C6



PM*x* over Europe, and evaluation against AERONET also improved. But… (see later from Mel)

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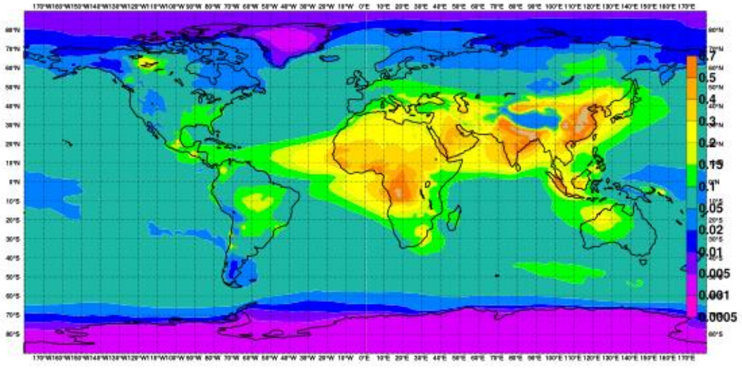
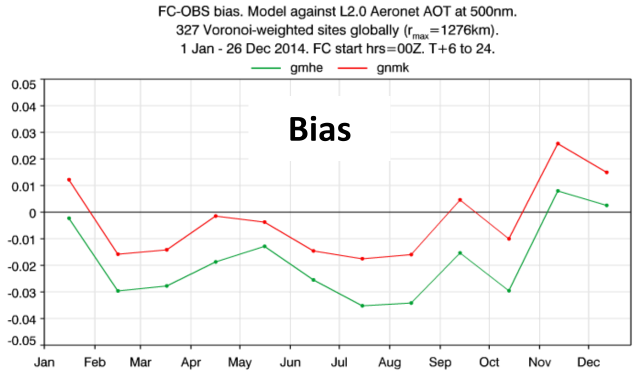
Recap: online dry deposition velocities (Zhang et al., 2001)

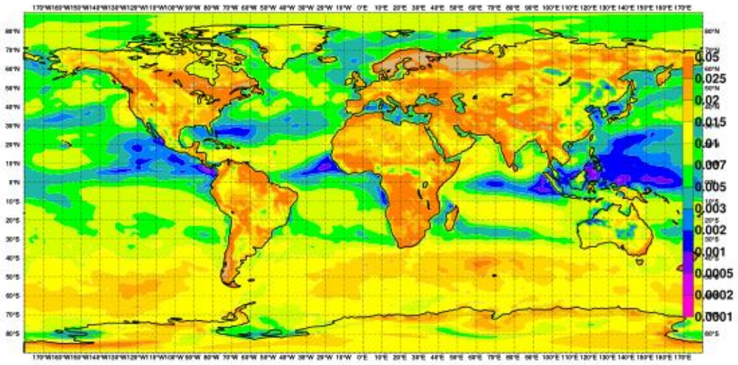
- Based on particle size, friction velocity, roughness length

— Online velocities —

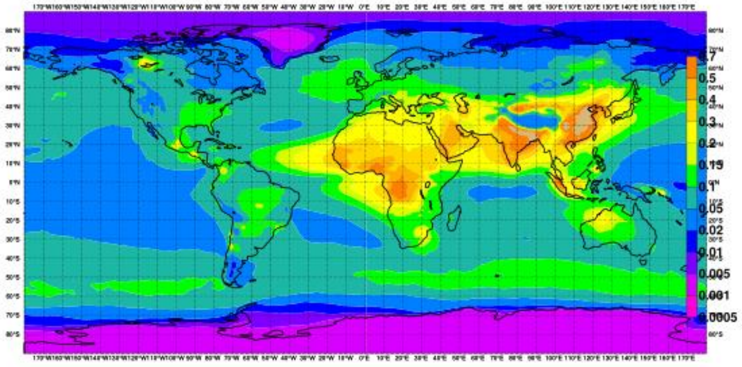


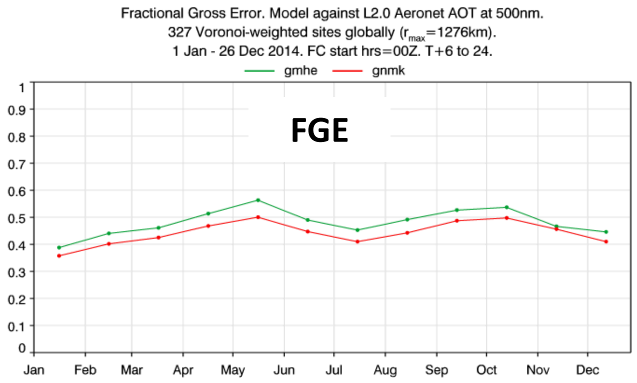


Dry deposition velocity for sea-salt bin 2 (m/s)



— Prescribed velocities —





- Also positive impact on European PM10

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Recent developments (IFS cycle 46r1, for some time in 2019)

- **New online dust emission scheme (Nabat et al., 2012) and source function**
- **Updates to optical properties (especially OM, BC)**
- **Resuspension of aerosol deposited on rough urban surfaces**
- **Option for SOA as distinct species from primary OM**
- **Option to use GLOMAP instead of LOA/LMDz aerosol scheme**
- *Option to use explicit oxidant climatology for sulphate production*
- *Improved diurnal cycle for biomass-burning emissions*
- *Elimination of "lake sea-salt"*

Recap: new dust scheme: Nabat et al. (2015)

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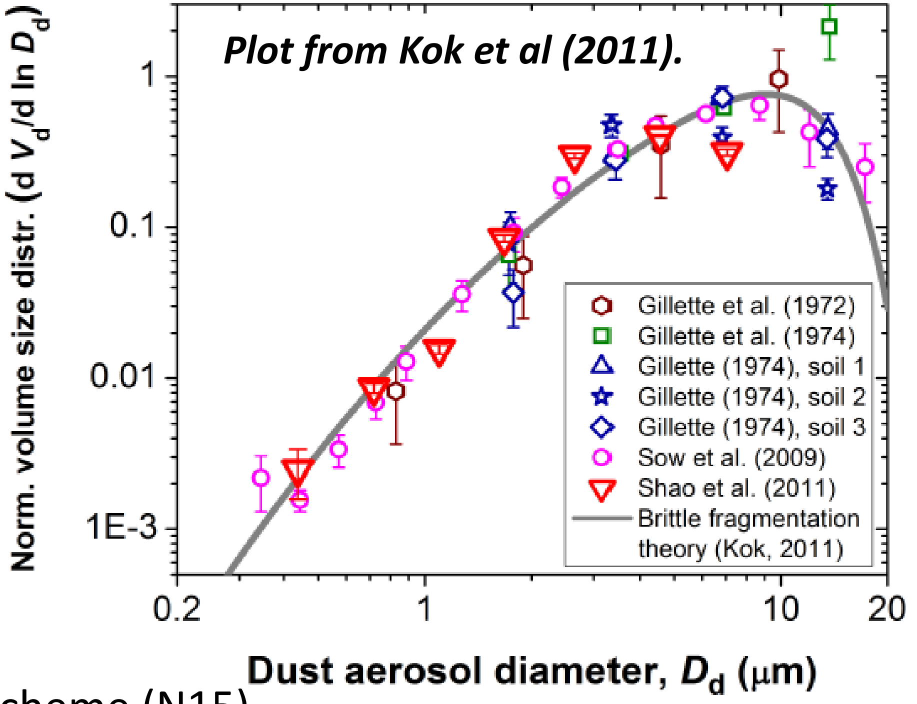
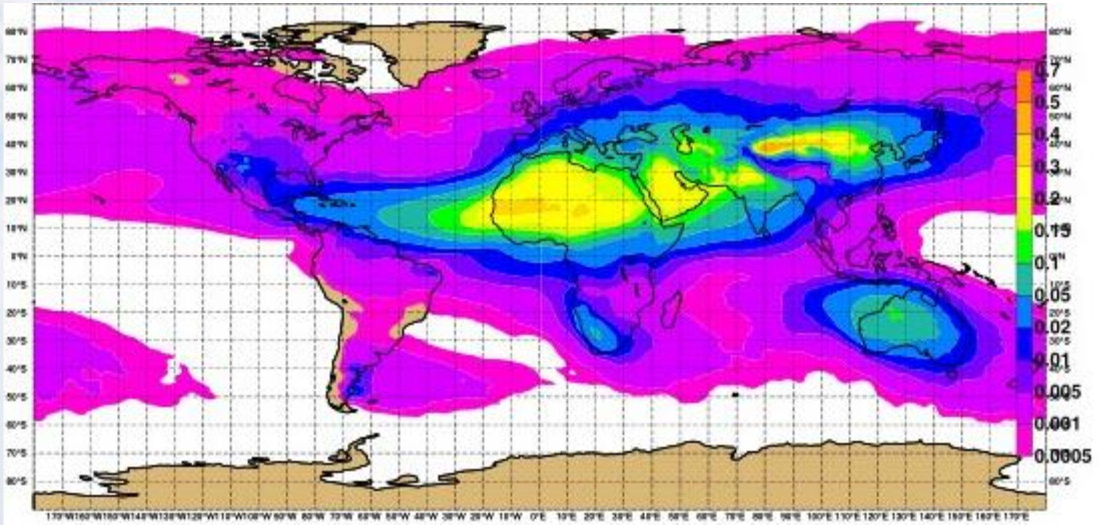
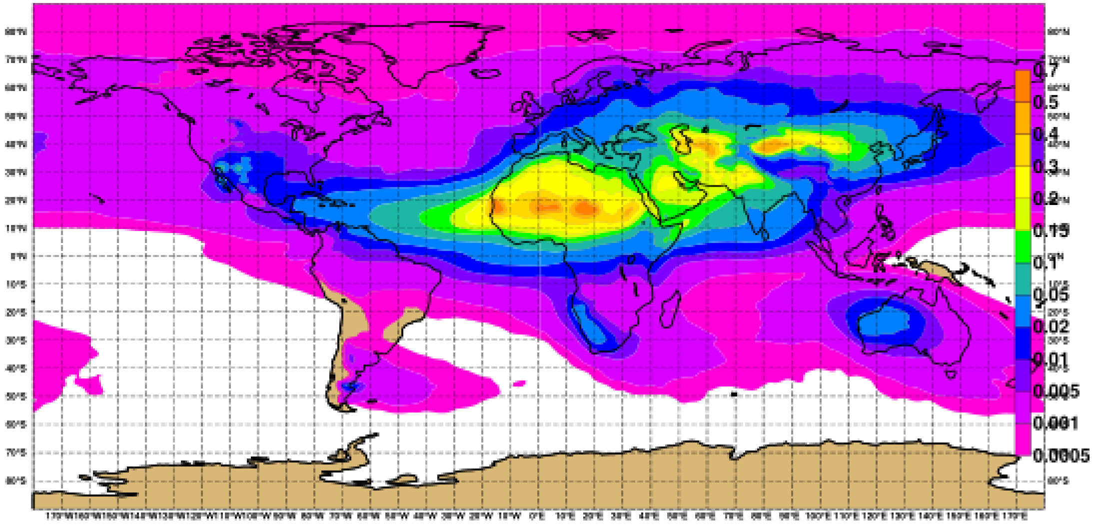
- Replaces older Ginoux et al. (2001).
- Marticorena and Bergametti (1995) saltation
- Kok et al. (2011) size distribution at emission
- Sand and clay fraction from SURFEX (Météo-Fr)
  (recently updated)
- 4-fold increase in super-coarse particles
- Greater total emissions



Old scheme (G01)



New scheme (N15)



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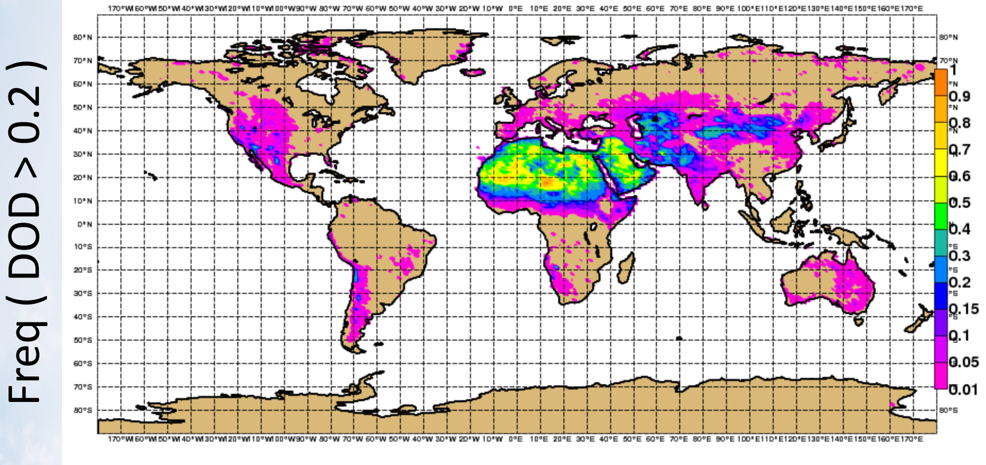
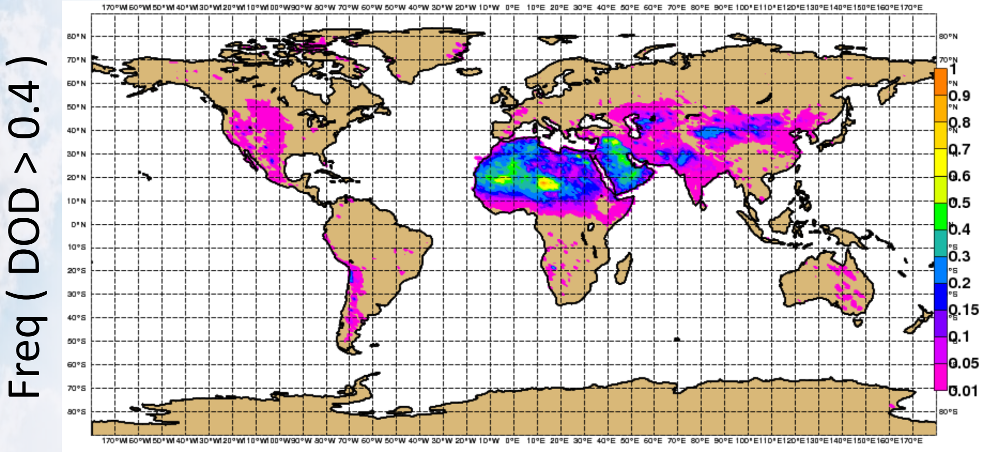
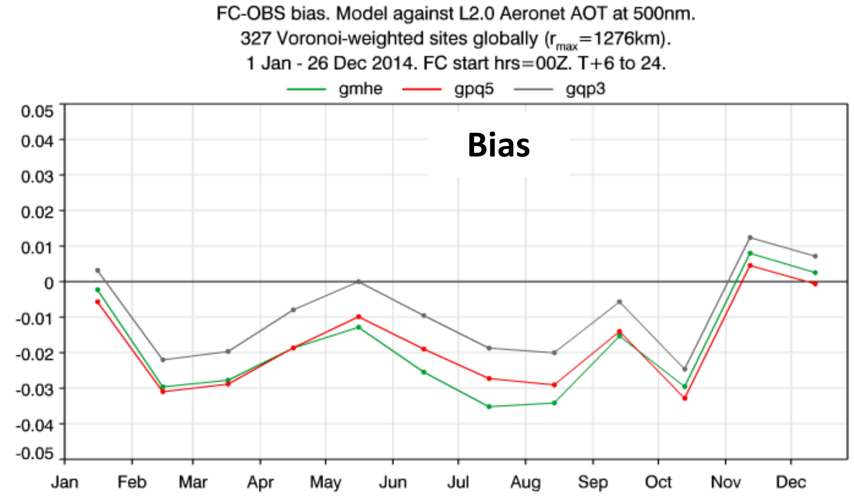
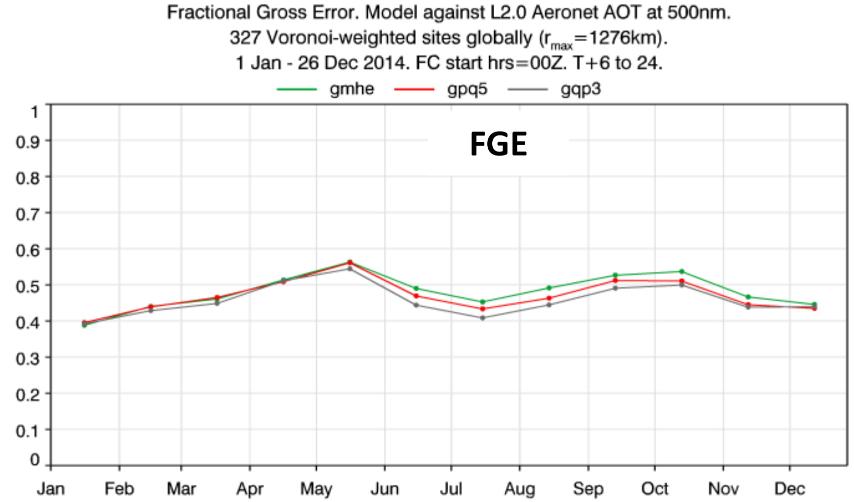
Dust Source Function and larger size bins

— Ref (43r1, G01) — N15+DSF — N15+DSF+largebins









DSF based on AquaMODIS DOD 2003–14 (P. Ginoux) to replace empirical local dust emission criteria

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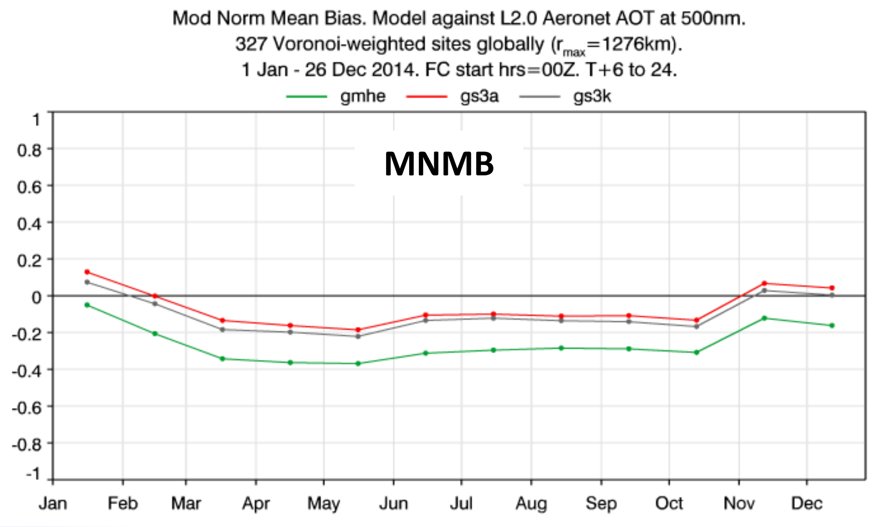
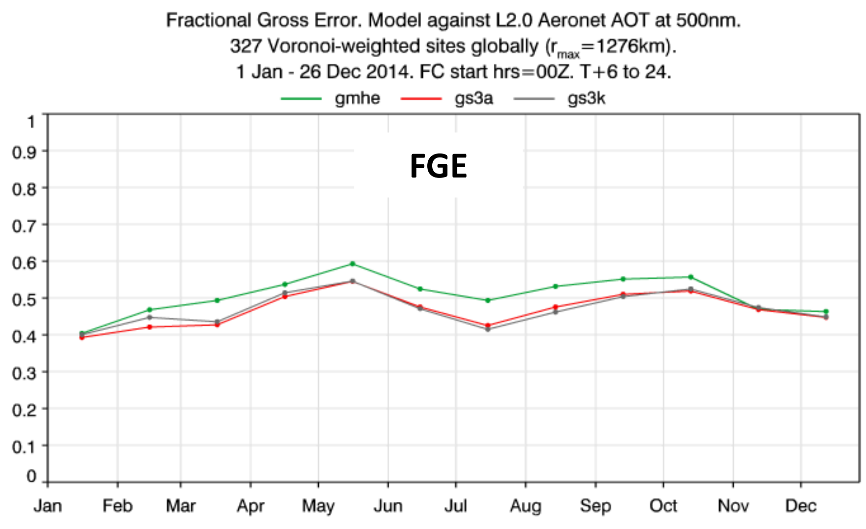
Separate SOA species





- Separating SOA from primary OM allows better tracing and optical properties.
- Experimental dynamic SOA production via enhancements to the gas-phase chemistry scheme may bring further improvements.
- More realistic optical properties for SOA allow good AOD with reduced SOA mass production, better for PM.

— Ref (43r1, combined OM)
— Separate OM (prescribed sources only)
— Separate OM (online chemical production)

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Resuspension of deposited aerosols (Kim et al., 2010, 2016)

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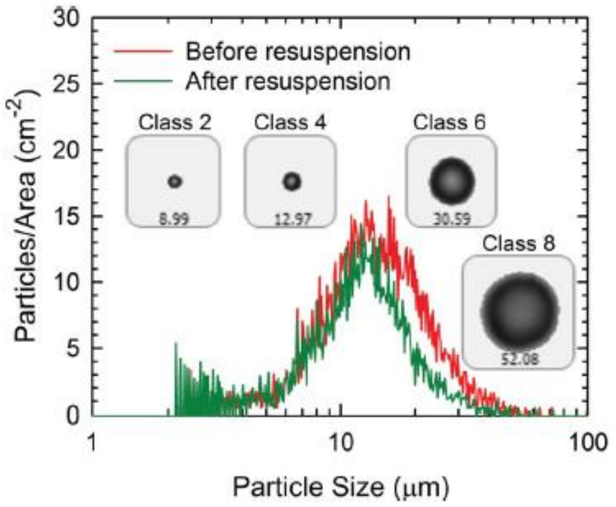
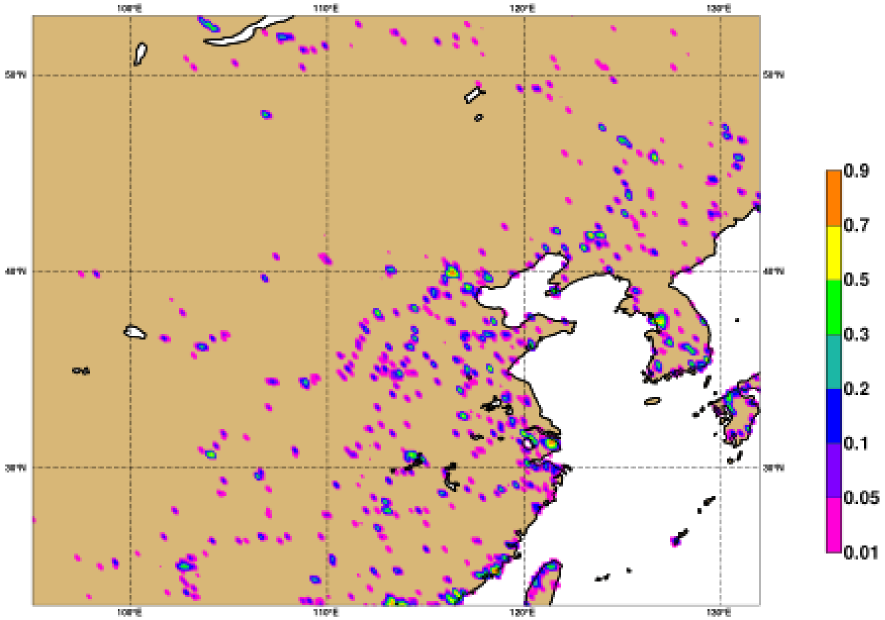
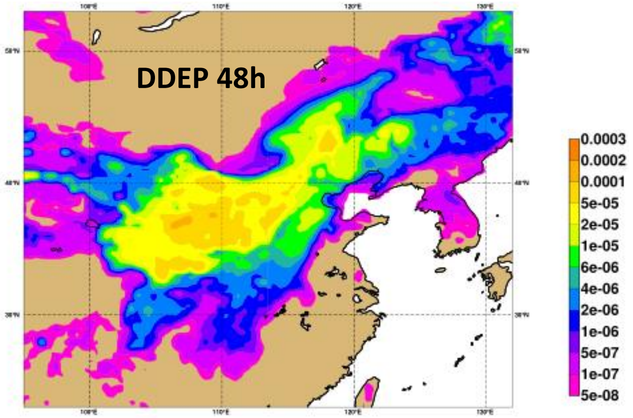


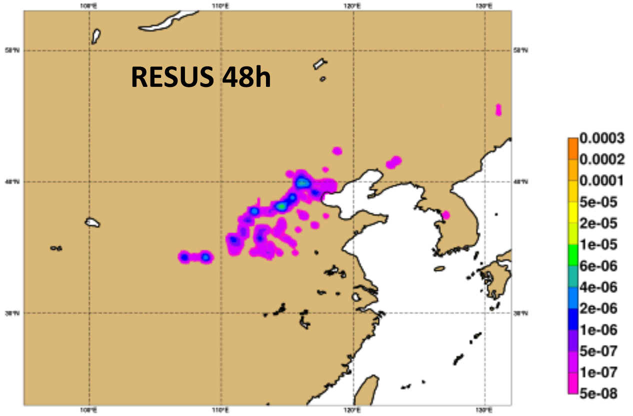
Figure 3. The particle size distribution of the PE spheres on a glass surface before and after a resuspension experiment. The images correspond to typical Classes 2, 4, 6, and 8 PE particles.

(Kim et al., 2016)



Urban fraction over China (USGS data)





- Resuspension significant for coarse particles over concrete surfaces with short roughness length.
- In urban areas, resuspended fraction parameterised empirically based on particle size, friction velocity and relative humidity.
- Generally small except during extreme events, more impact expected at very high resolutions

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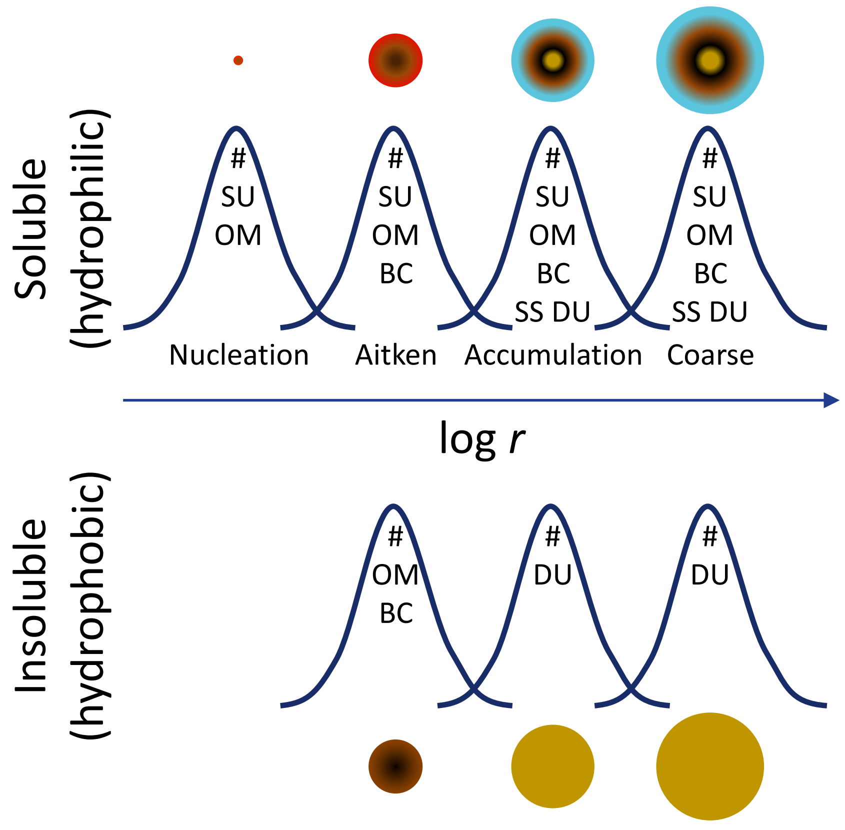
IFS–GLOMAP

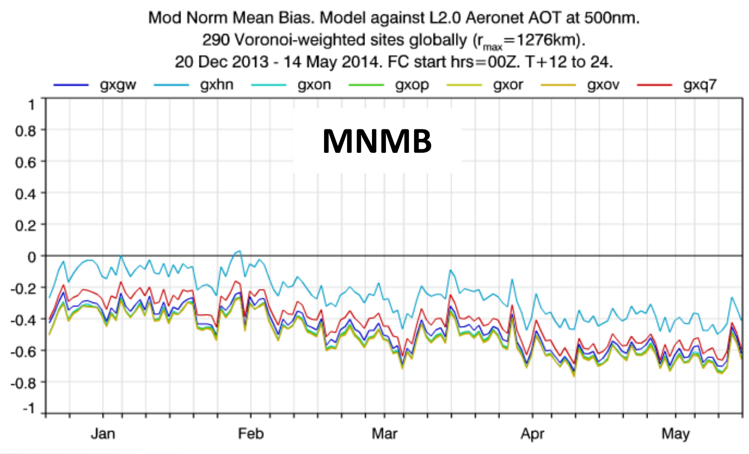
- GLOMAP-mode (Mann et al., 2010) introduced as alternative aerosol scheme in 46r1, based on work begun by Matt Woodhouse under MACC.

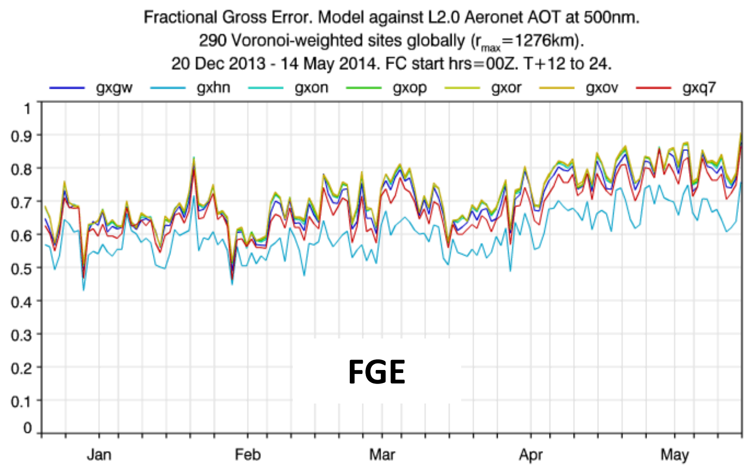
- Two-moment modal scheme combining M7-like size modes with microphysical parameterisations from GLOMAP-bin (Spracklen et al., 2005).

- Currently implemented in forecast mode; links to data assimilation still under way.



IFS–GLOMAP: nucleation issues





- IFS–GLOMAP does not yet match the performance of our operational system, but the gap is closing.
- AOD scores much better when the nucleation scheme is bypassed. (But need to check impact on PM, CCN.)
- Undesirable since physically-based nucleation and growth are a major attraction of GLOMAP.
- More investigation needed.

Future modelling priorities (2019 and beyond)

- Coupling with gas-phase chemistry (sulphates, nitrates, organics)
- Evaluation and improvement of vertical distribution
- More in-situ observations for evaluation

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Other modelling work: volcanos, climatology and impacts on NWP

Ad-hoc forecasts of volcanic ash, sulphate and SO2 for Mt Agung (Nov 2017)

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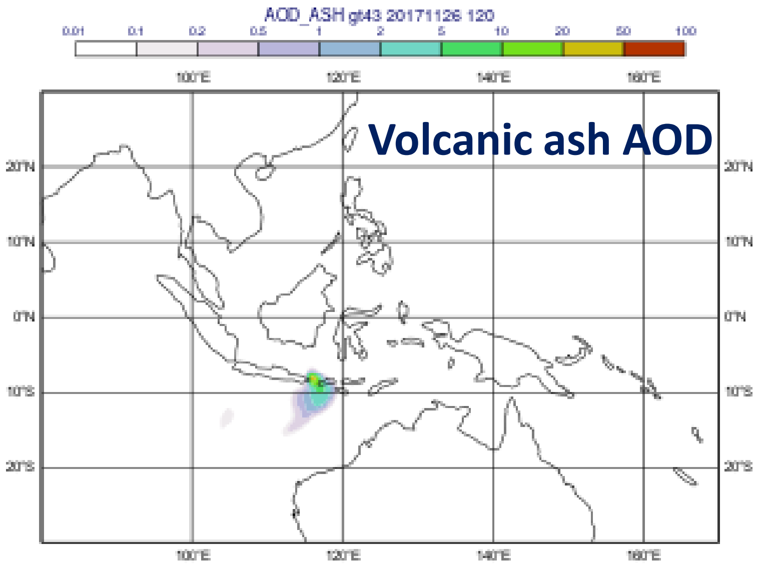

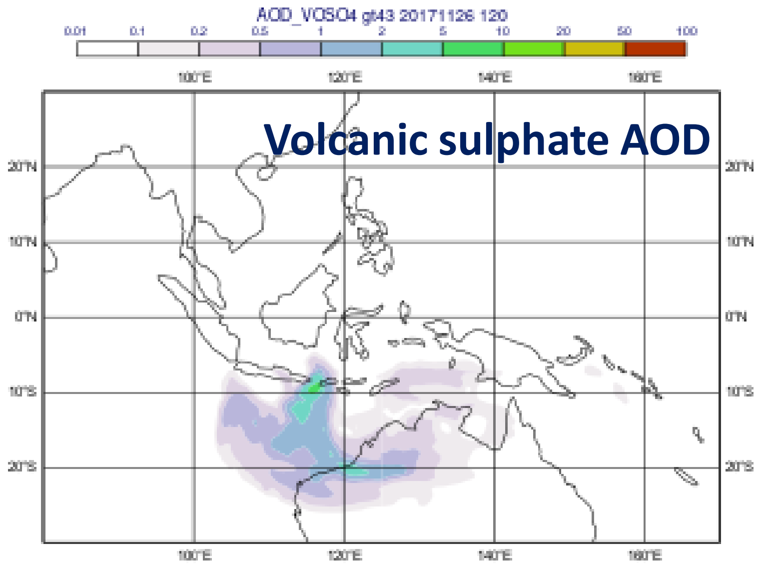

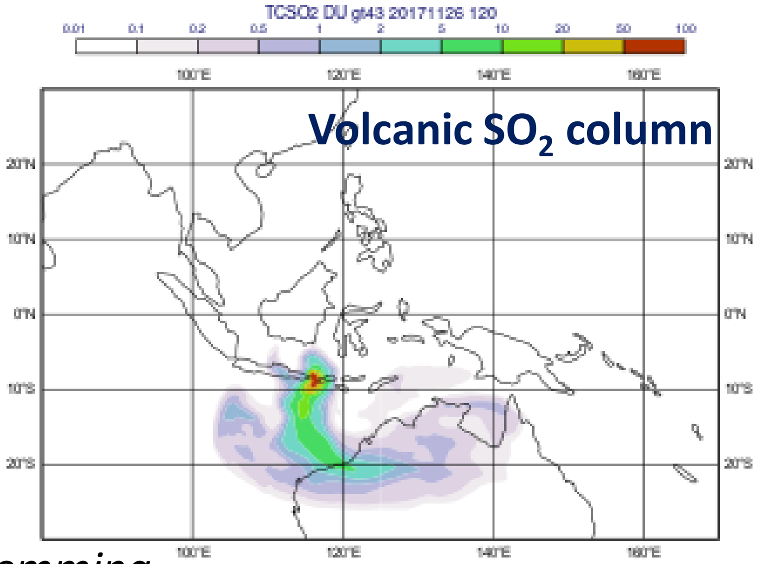

- Additional bins for volcanic ash, sulphate, SO_2
- Prescribed emission profile from knowledge of eruption
- Not part of operational system, but run on demand when a significant eruption occurs
- Can link to AOD assimilation (see later from Mel)

Johannes Flemming

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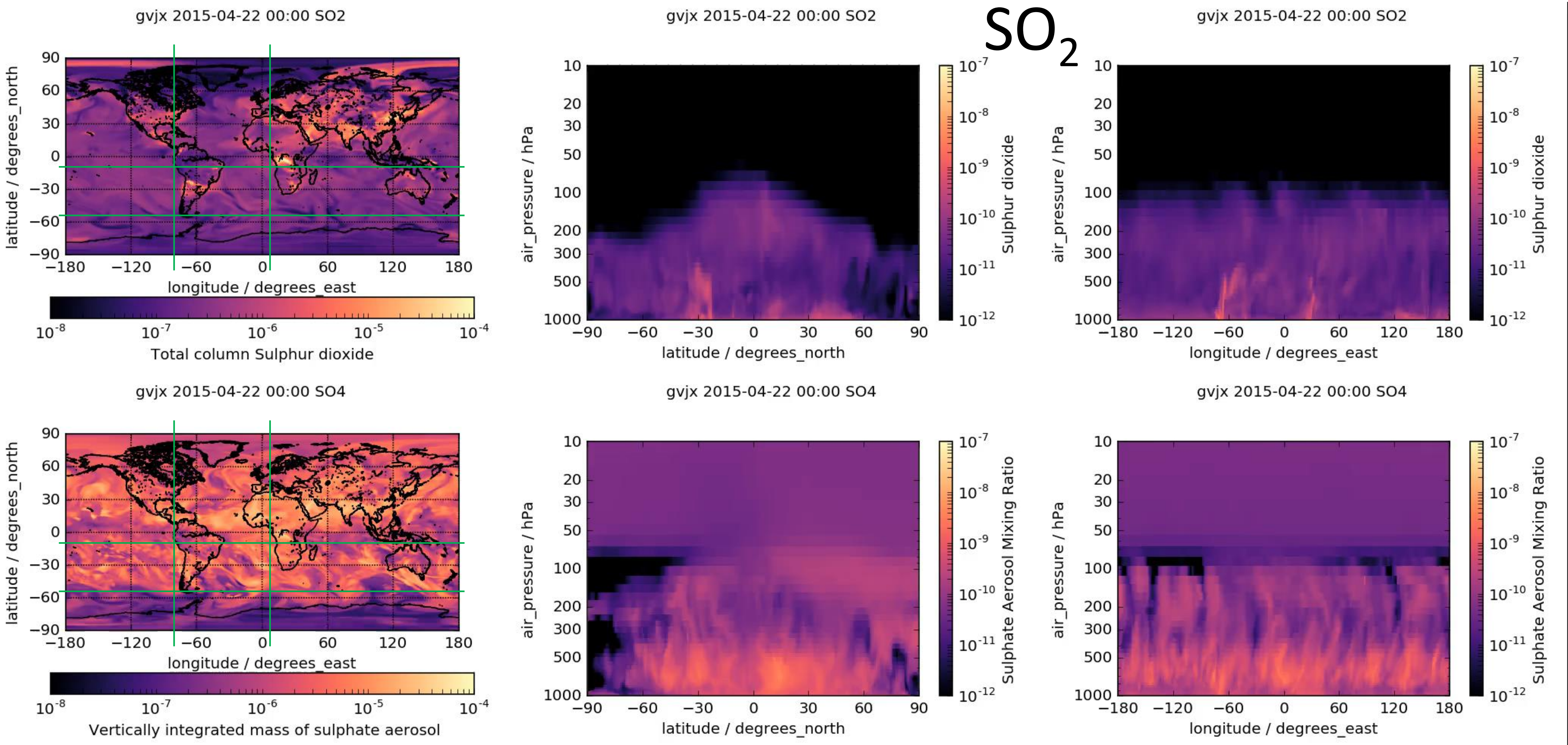
Sulphate from assimilation of volcanic SO_2 from Calbuco, peak ~100hPa (16.5km)

SO_2



Sulphate

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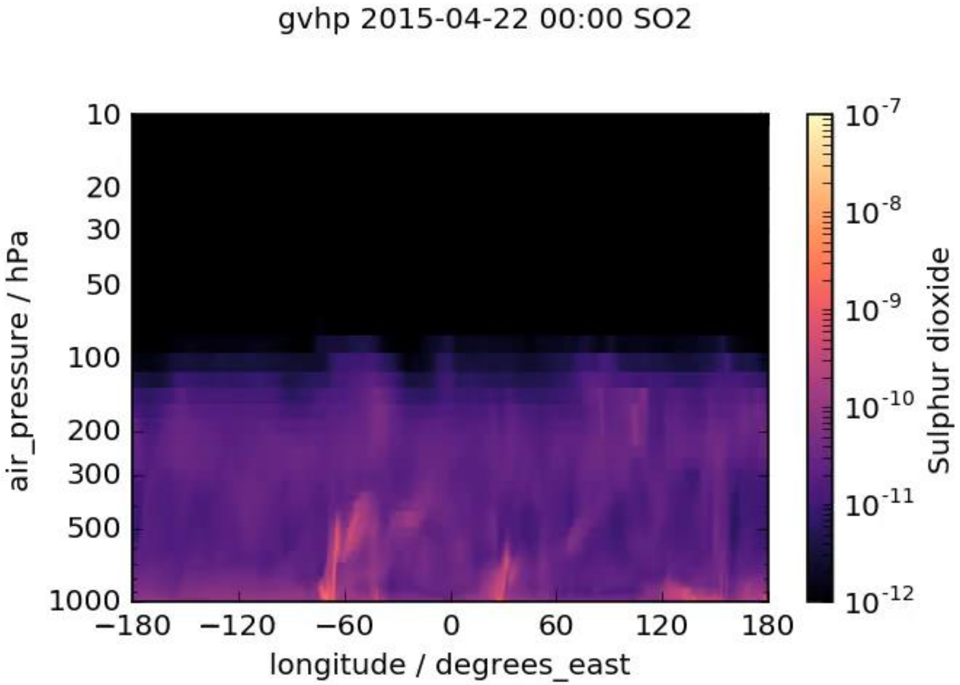
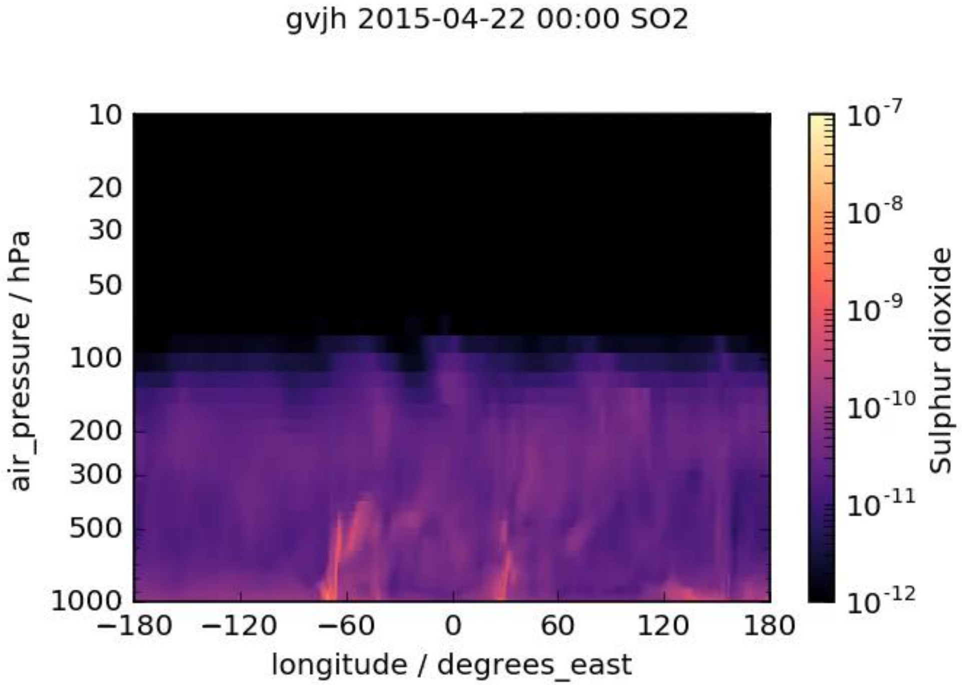
SO_2

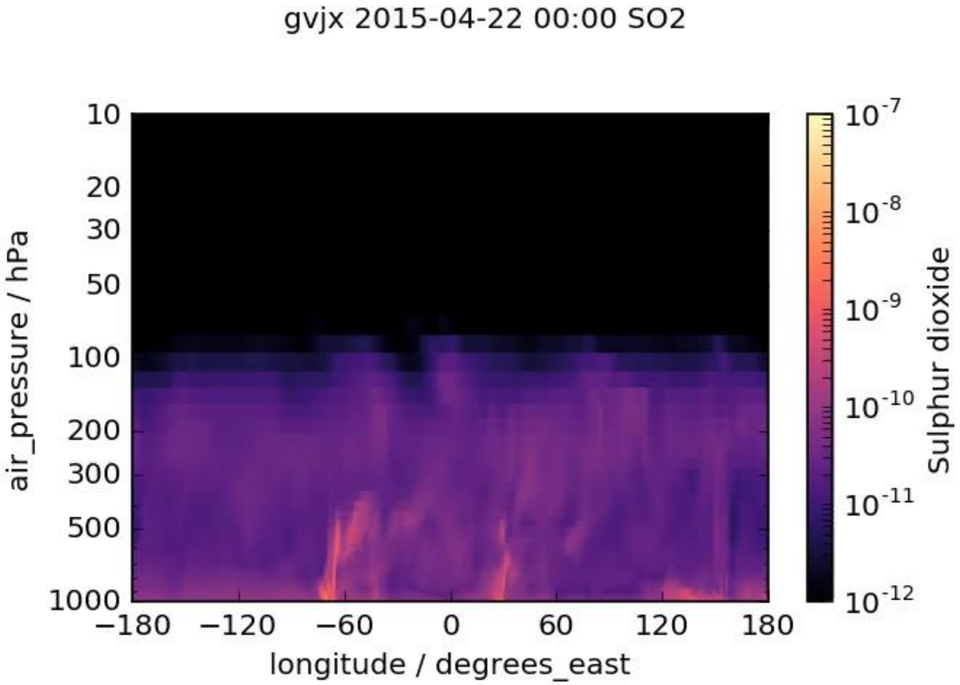
no SO_2 assimilated

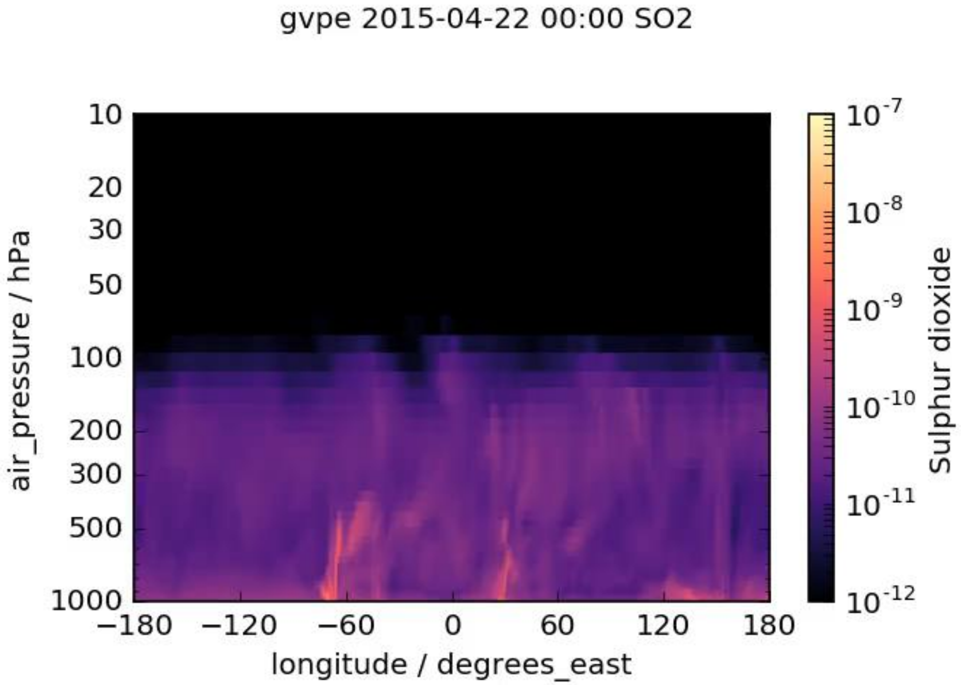




peak ~250hPa (10km)

peak ~100hPa (16.5km)





peak ~50hPa (20km)

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Evaluation of CAMS climatology: changes in TOA fluxes

4-years average TOA fluxes against CERES-EBAF (W/m²)

TOA biases with TG97

Too little reflection

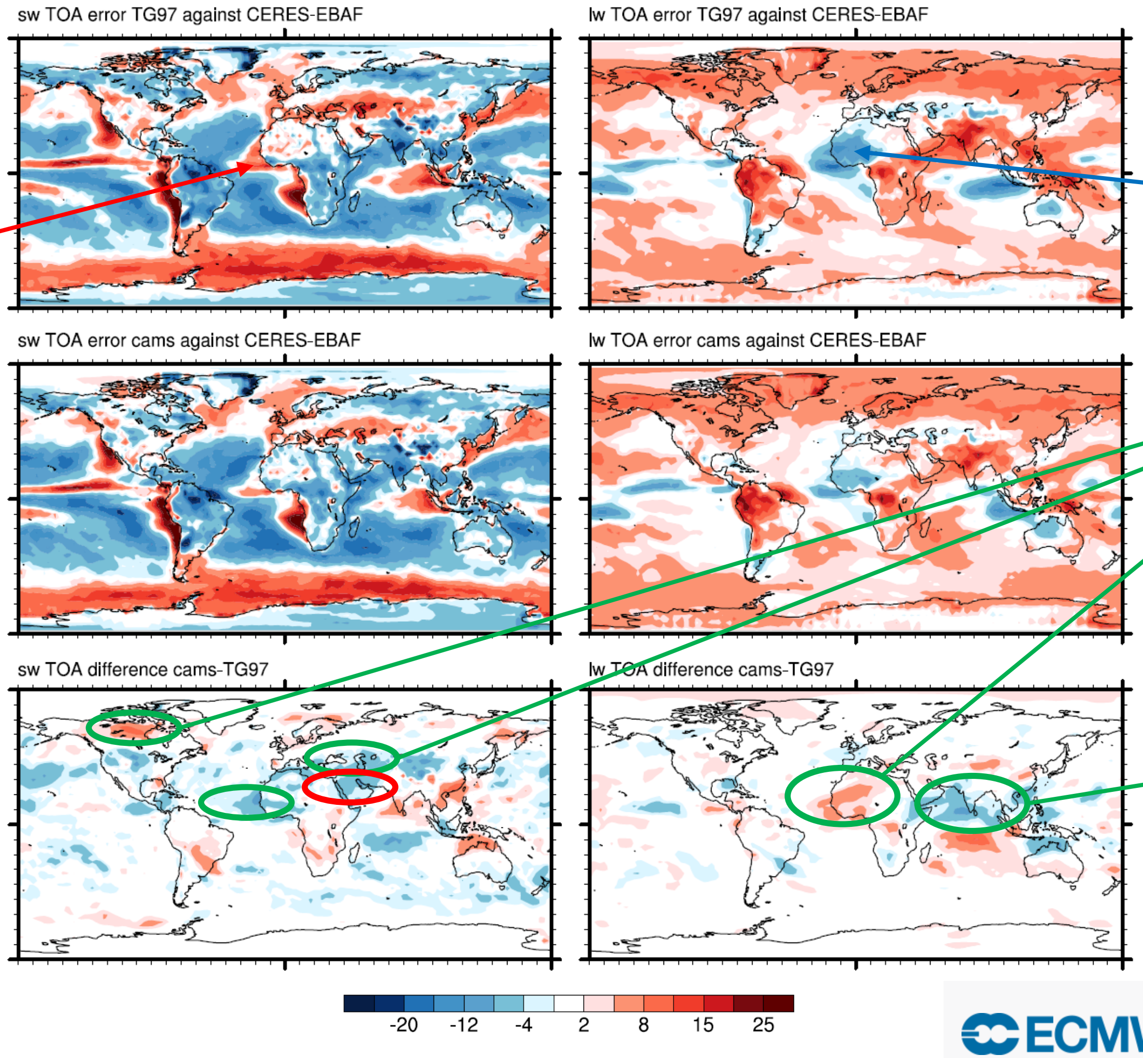
Too large OLR

TOA biases with CAMSiRA 2003-2011

Direct aerosol forcing

Difference in TOA biases

Feedback of changes in local circulation to cloud cover



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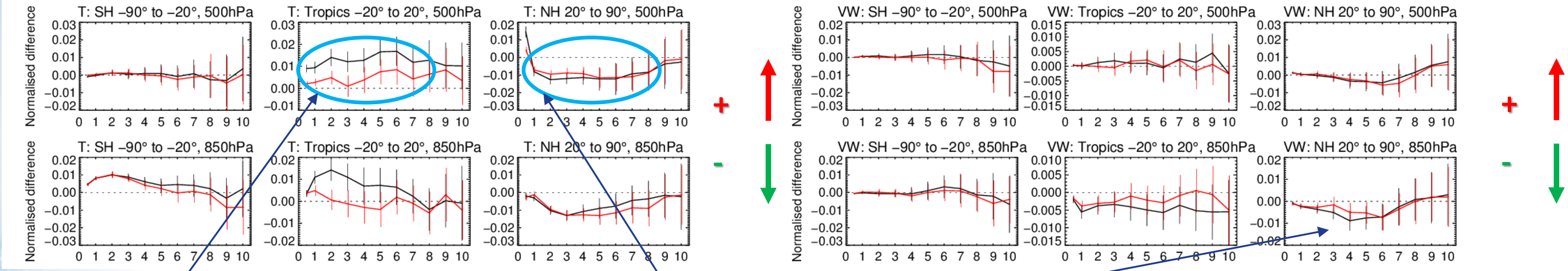
Evaluation of CAMS climatology: forecast skill scores

1–Jun–2017 to 20–Aug–2017 from 72 to 81 samples. Verified against 0001.

Confidence range 95% with AR(1) inflation and Sidak correction for 8 independent tests



Degradation in the tropics: too much biomass burning over Central Africa and less dust above 700 hPa in 3D climatology. Worsen (~1%) pre-existing model bias

Improvement (<= 1%) in the NH Summer (temperature and wind): reduced absorption of SW radiation by dust

Impact on large-scale forecast skill scores generally neutral or slightly positive. Dust regions show the largest differences between a full 3D climatology and a simple analytical exponential distribution with global-mean scale height, but impact generally small.

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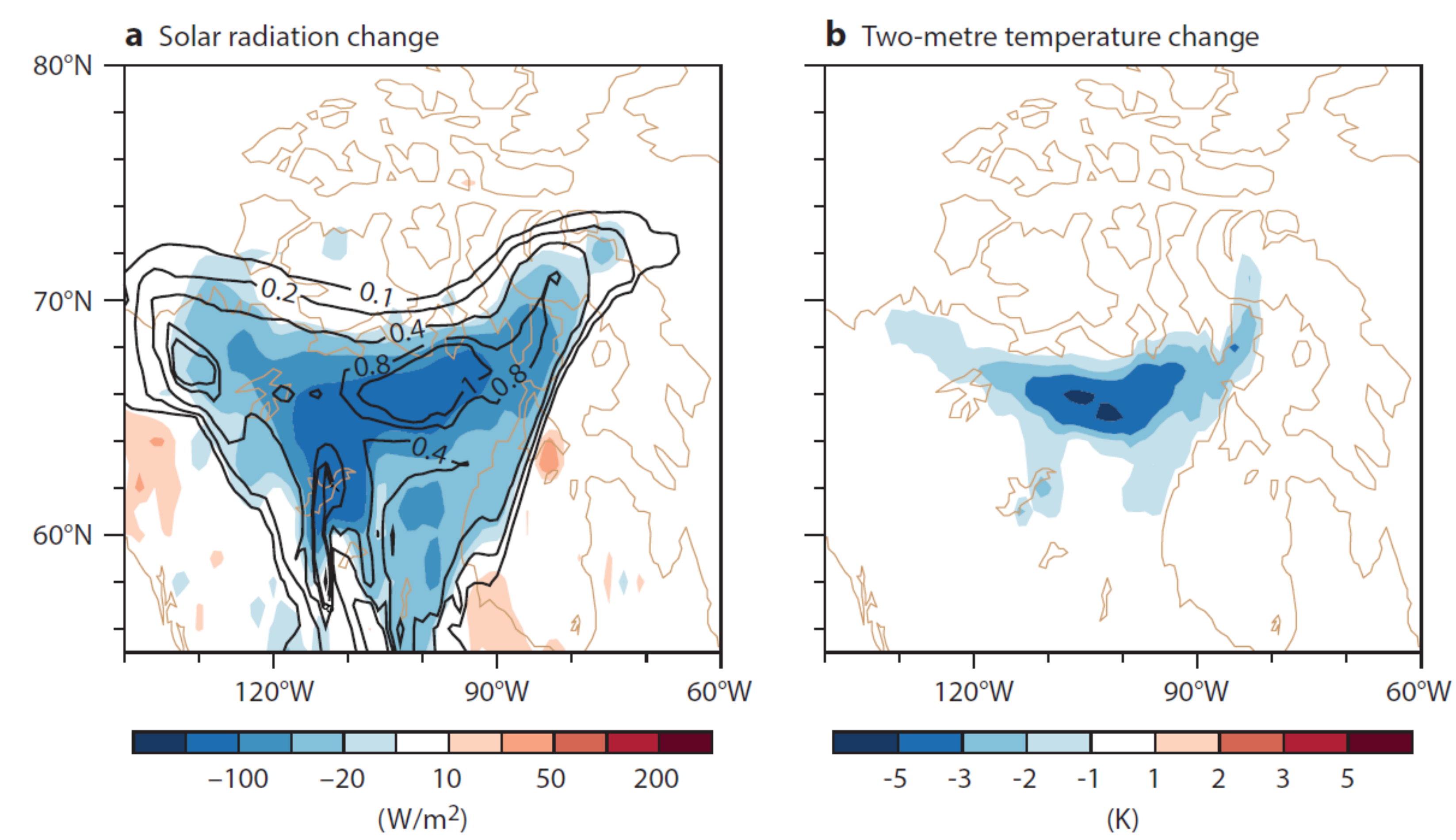
Impact of prognostic aerosol in radiation: summer 2017 forest fires in Canada



Impact of prognostic aerosols from the IFS bulk aerosol scheme on forecasts initialized at 00 UTC of (a) surface downwelling solar radiation averaged over the first full day of the forecast over Canada, and (b) 2-metre temperature averaged over 0600–1800 local time (forecast lead times of 12–24 hours), for 14 August 2017 when extensive forest fires occurred in Northern Canada. The contours in the left-hand panel show the 24-hour average optical depth of biomass burning aerosols.

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Part II: Data Assimilation

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