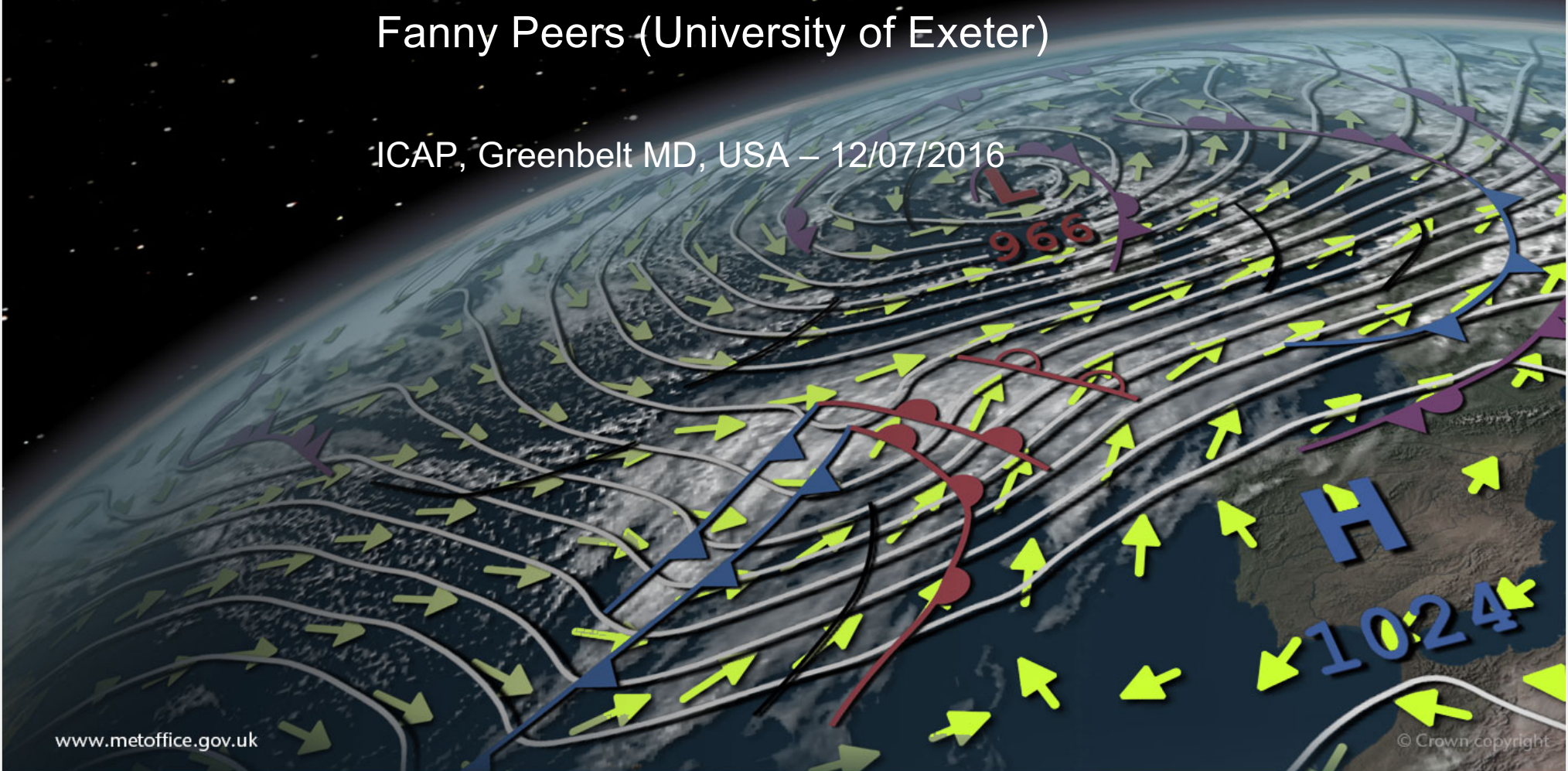# Met Office update

Malcolm Brooks, Yaswant Pradhan, Ben Johnson

Fanny Peers (University of Exeter)

ICAP, Greenbelt MD, USA – 12/07/2016

www.metoffice.gov.uk

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Contents

The Met Office Unified Model

Dynamics:

- Regular lat/lon grid.

- Non-hydrostatic dynamics with a deep atmosphere.

- Semi-implicit time integration with 3D semi-Lagrangian advection.

- Atmospheric tracer advection

Physics:

- Spectral band radiation

- Diagnostic or prognostic cloud

- Mixed-phase ppn

- Mass flux convection

- Boundary layer

- Gravity wave schemes
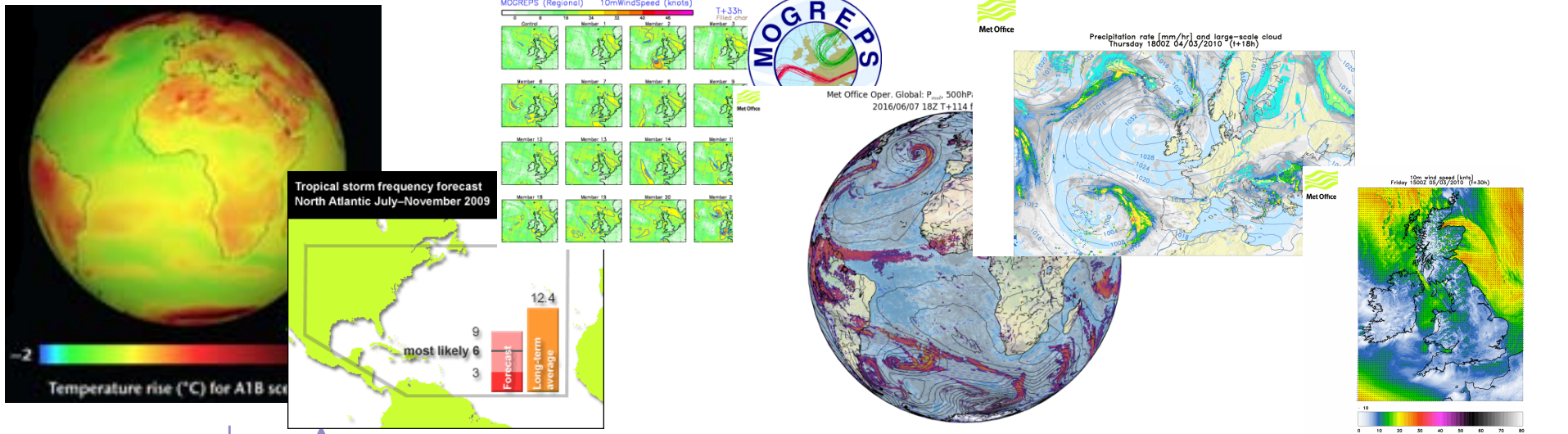
Coupling possible to non-atmospheric components:

- Land surface model

- Ocean model

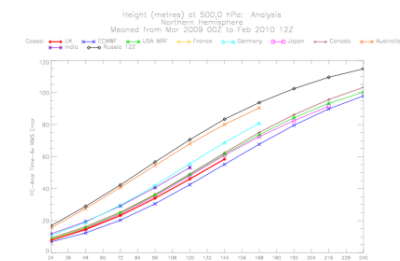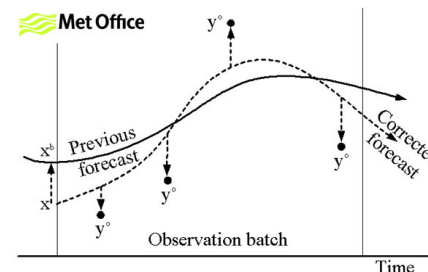- Sea ice model

- Chemistry/aerosol model …

Flexibility of the Unified Model
(David Walters)
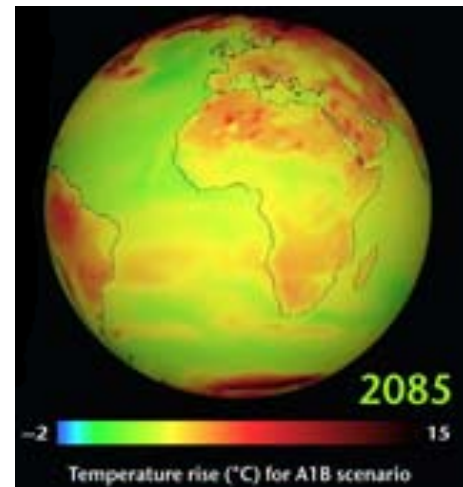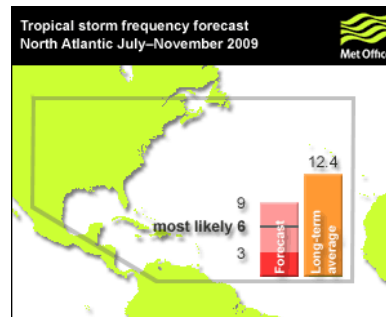
"Operational" applications of the Unified Model
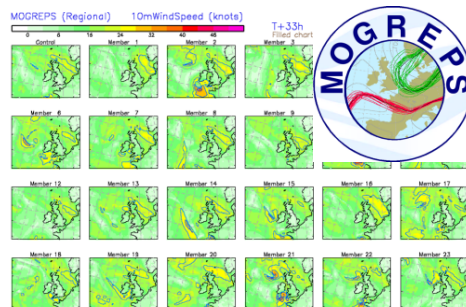

UM framework includes:

OPS, VAR, VER …

Unifying the Unified Model
Synergies between NWP models and GCMs
Senior et al. (2010)

Timescale →

← Resolution
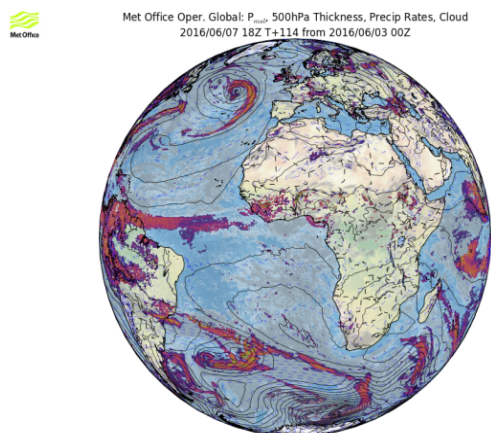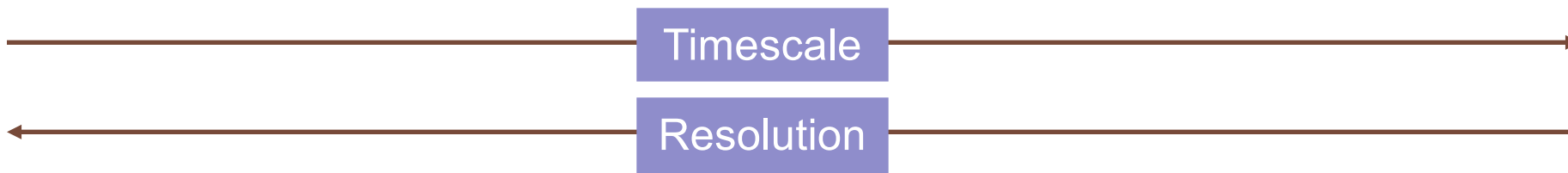
- Many model characteristics present across all timescales

- Long runs to compare NWP models with climatologies

- Short runs with assimilation to study error growth in climate models

Met Office and UM community well placed to take advantage of these synergies → Develop single scientific configuration for use at all timescales

The science configuration of Met Office Global model

Global Atmosphere (GA), Global Land (GL), Global Ocean (GO), Global Sea Ice (GSI)

GloSea seamless EPS

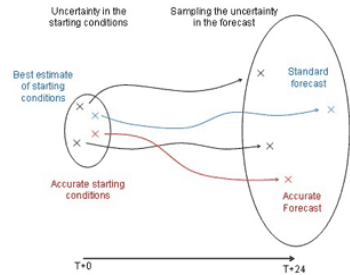Decadal Prediction
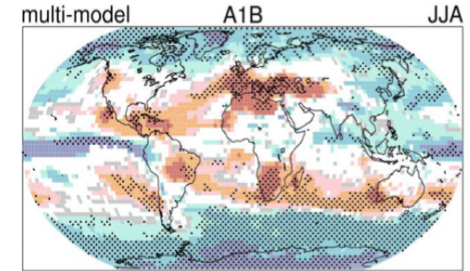
Climate Change studies

GC
Global Coupled modelling configuration

Oasis

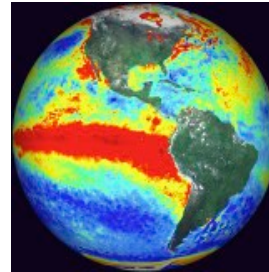| Global Atmosphere **6.0**	Global Land **6.0**	Global Ocean **5.0**	Global Sea Ice **6.0**
um Unified Model	JULES Joint UK Land Environment Simulator	NEMO	Los Alamos National Laboratory CICE The Los Alamos Sea Ice Model
N96 (~135km) → ~12km		ORCA025 (0.25°)	ORCA025 → ORCA1 (1°)

The science configuration of Met Office Global model

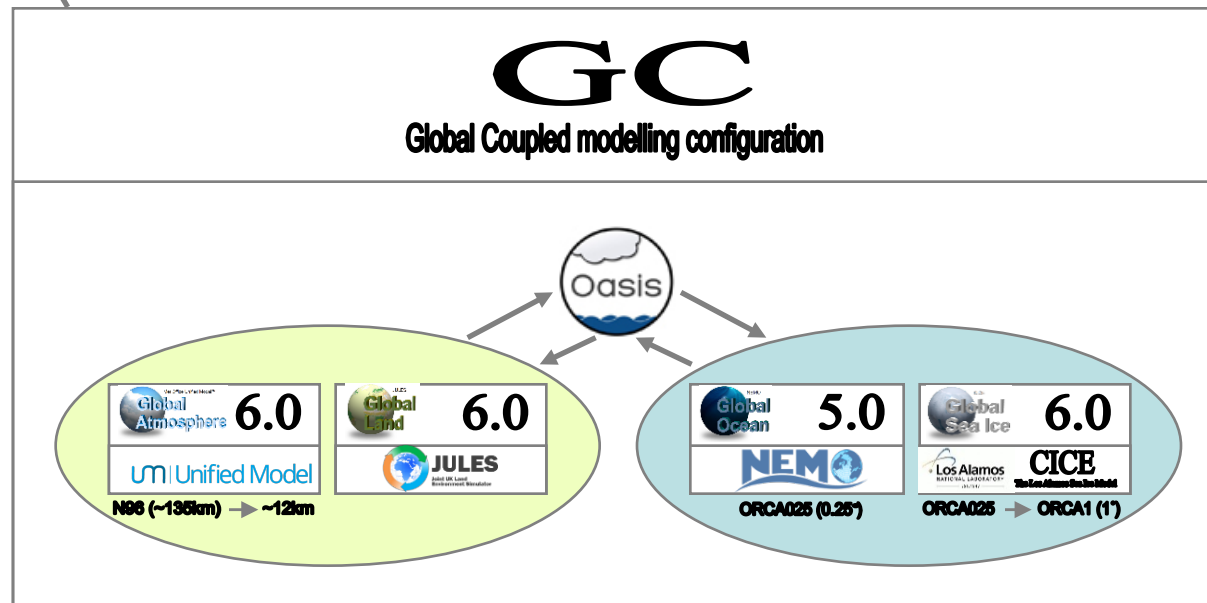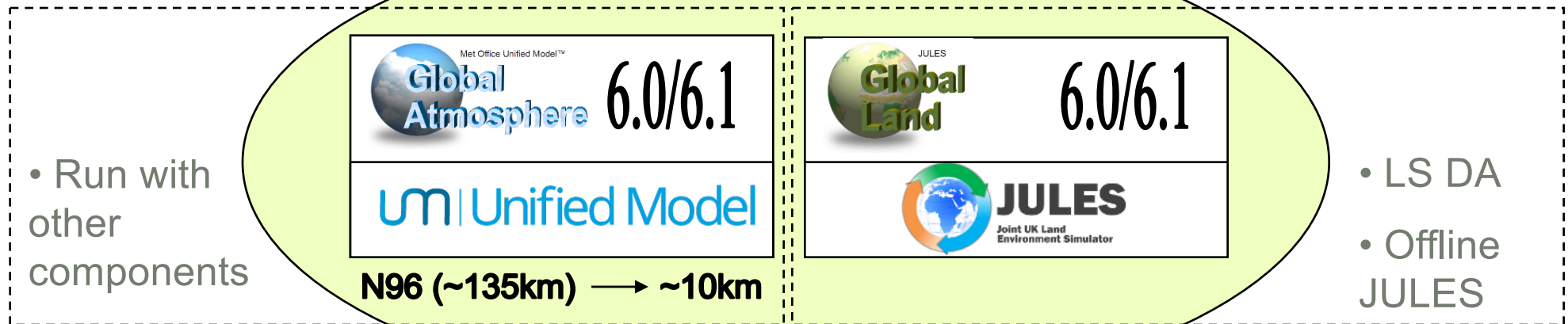Global Atmosphere (GA), Global Land (GL), Global Ocean (GO), Global Sea Ice (GSI)

Global/regional deterministic NWP

MOGREPS-G short-range EPS

AMIP-like climate simulations

• Run with other components

Met Office Unified Model™

Global Atmosphere 6.0/6.1

υм | Unified Model

N96 (~135km) ⟶ ~10km

JULES

Global Land 6.0/6.1

JULES
Joint UK Land Environment Simulator

• LS DA

• Offline JULES

GA/L/O/SI components developed in a annual cycle:
- Allows evaluation, focussed development and packaging
- Changes need to fit into this cycle (no shortcut to operations)

Global Atmosphere 7

Changes from GA6/GC2
https://code.metoffice.gov.uk/trac/GA/wiki/GADocumentation/GA7.0

2 "Critical" priority
- #60: UKCA-Glomap-mode aerosol scheme
- #64: 6A convection scheme

28 other tickets:

- Cloud, radiation, *μ*phys
- Other physics changes:
  w-based CAPE, GWD heating, Stoch. Phys.
- Dynamics improvements
- Model tunings
- Bug-fixes, ancillary changes

- GL:#4 Multilayer Snow
- 4 other tickets:
- Revised ocean/land albedo
- Sea ice roughness,

- Dust changes: minor retune in response other changes.
- Alongside resolution upgrade for NWP: to ~13 or ~10km.
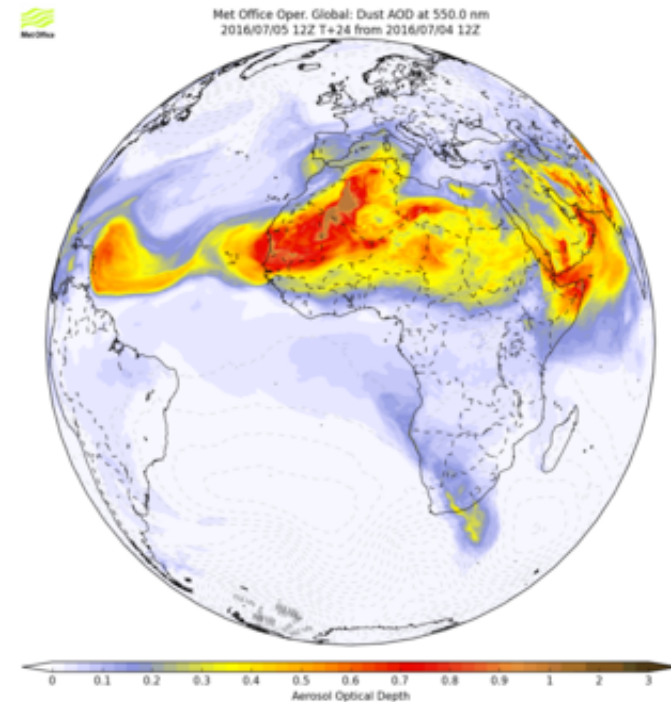
Aerosol in the Met Office NWP models

Dust:

Operational global model:
- Deterministic at   0.23°x 0.15° (~17 km)
- Ensemble at   0.45°x 0.4° (~30 km)
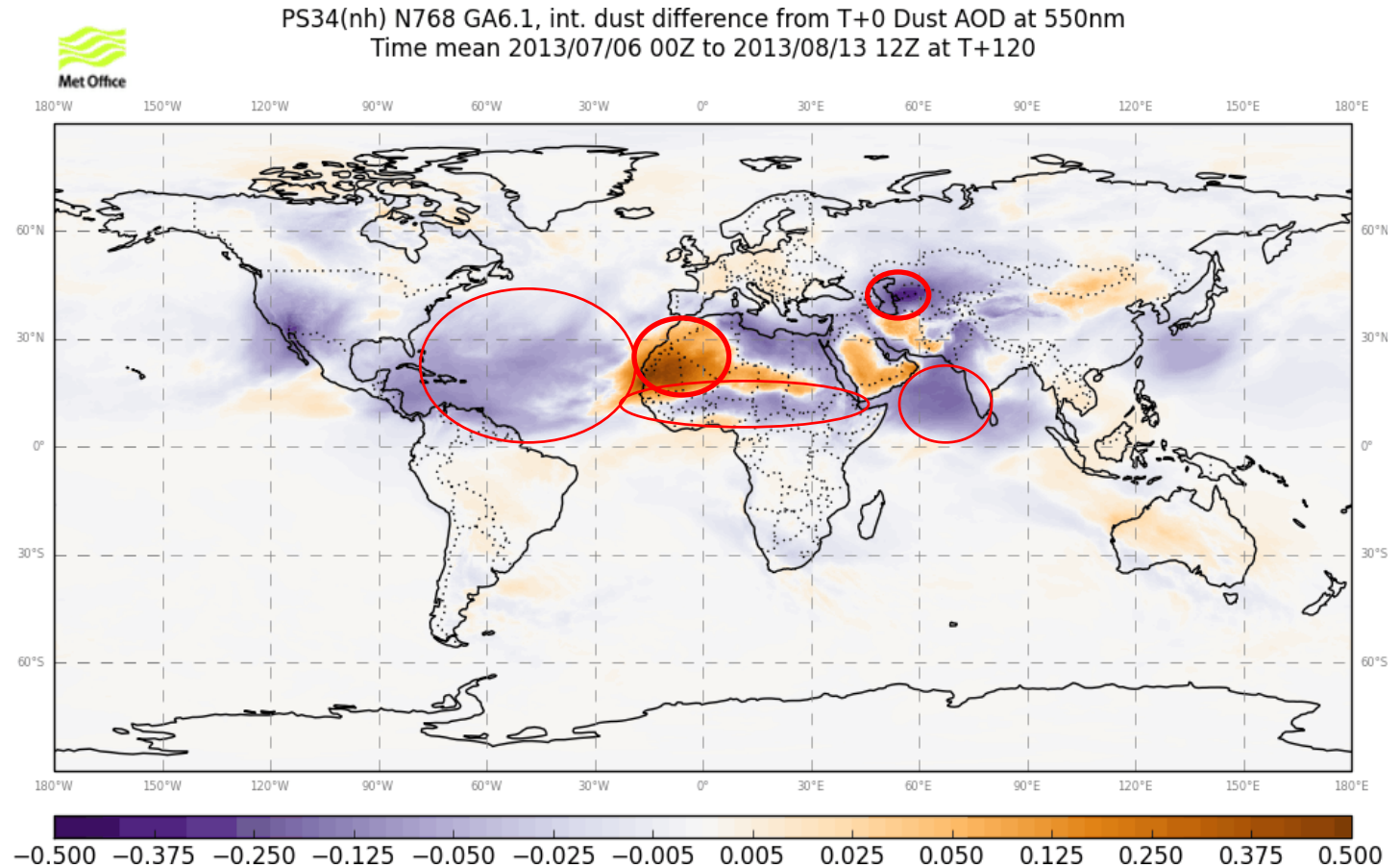
Assimilates dust AOD from MODIS

4 km LAMs covering hot dusty places of interest

Based on Woodward 2001, with 2 bins (global) and 6 regional models, with prescribed emission size distribution

Met Office Oper. Global: Dust AOD at 550.0 nm
2016/07/05 12Z T+24 from 2016/07/04 12Z

Aerosol Optical Depth
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1 2 3

Update: Dust model biases

Oceanic MYDAOD assimilation gives a better view of model biases.

PS34(nh) N768 GA6.1, int. dust difference from T+0 Dust AOD at 550nm
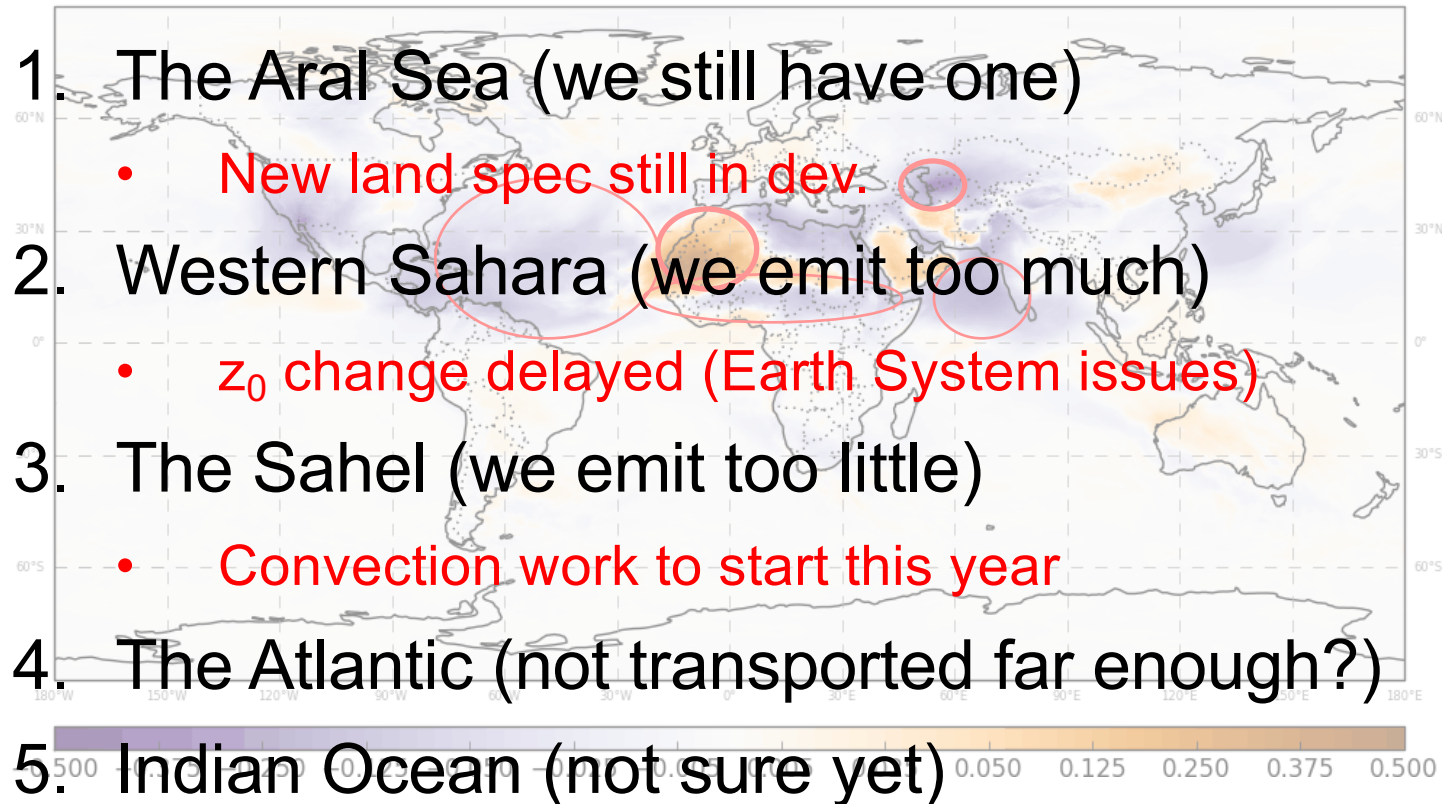Time mean 2013/07/06 00Z to 2013/08/13 12Z at T+120

Current model biases

Oceanic MYDAOD assimilation gives a better view of model biases.

PS34(nh) N768 GA6.1, int. dust difference from T+0 Dust AOD at 550nm
Time mean 2013/07/06 00Z to 2013/08/13 12Z at T+120

Biases:

1. The Aral Sea (we still have one)
   - New land spec still in dev.

2. Western Sahara (we emit too much)
   - z_0 change delayed (Earth System issues)

3. The Sahel (we emit too little)
   - Convection work to start this year

4. The Atlantic (not transported far enough?)

5. Indian Ocean (not sure yet)

Global dust assimilation updates

Yaswant Pradhan

- Migration Aqua/MODIS C5.1 → C6

- Include Terra/MODIS C6

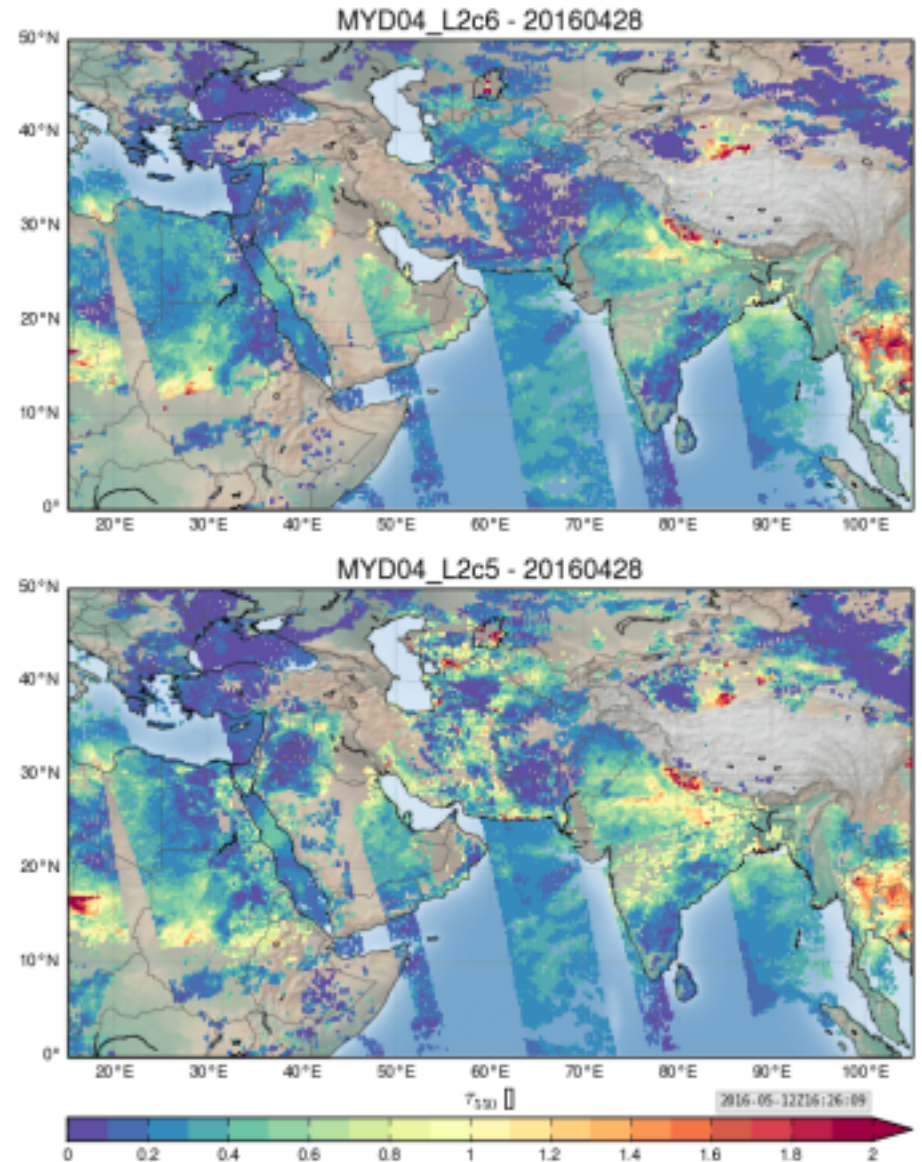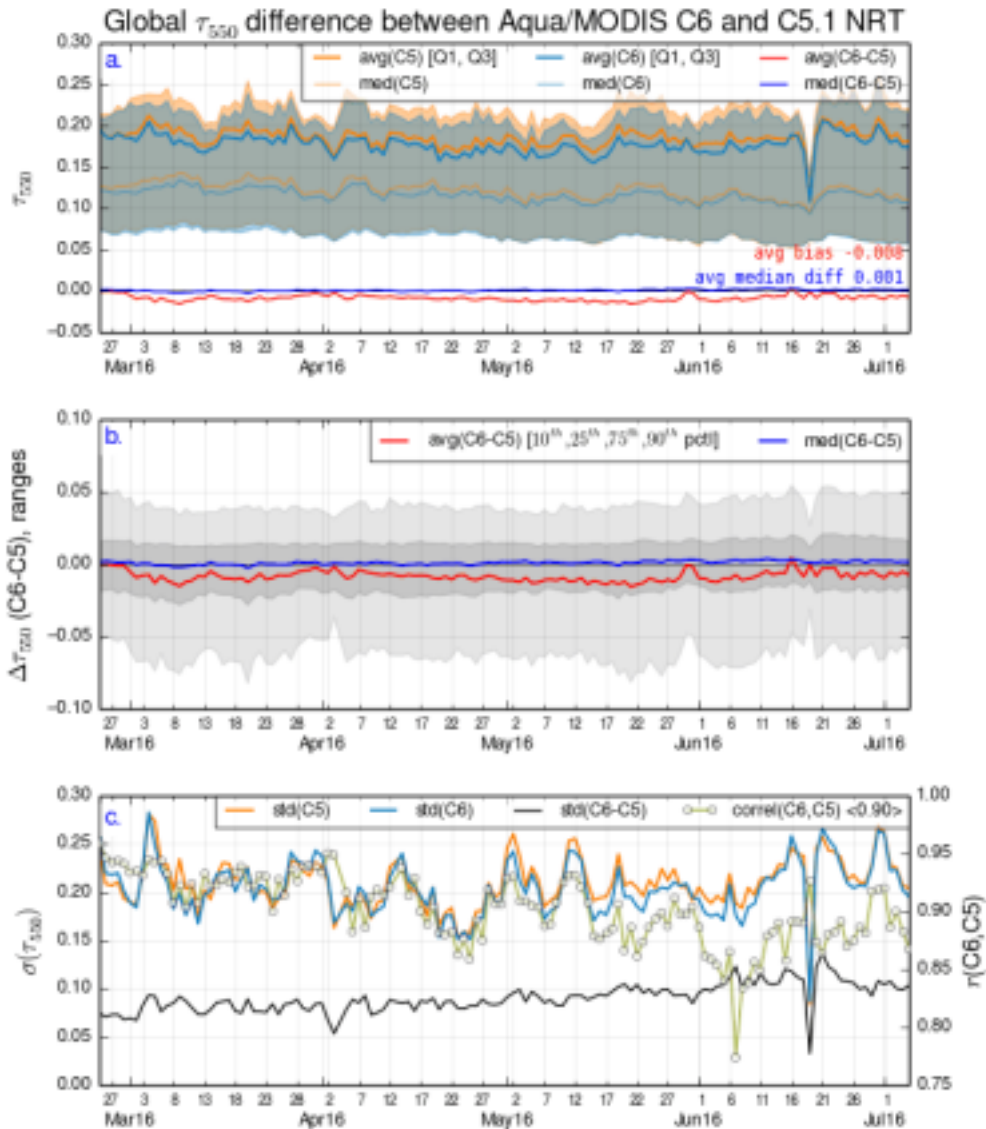- Include of PMAP dust? (monitoring v. Terra)

O-A stats (total AOD)
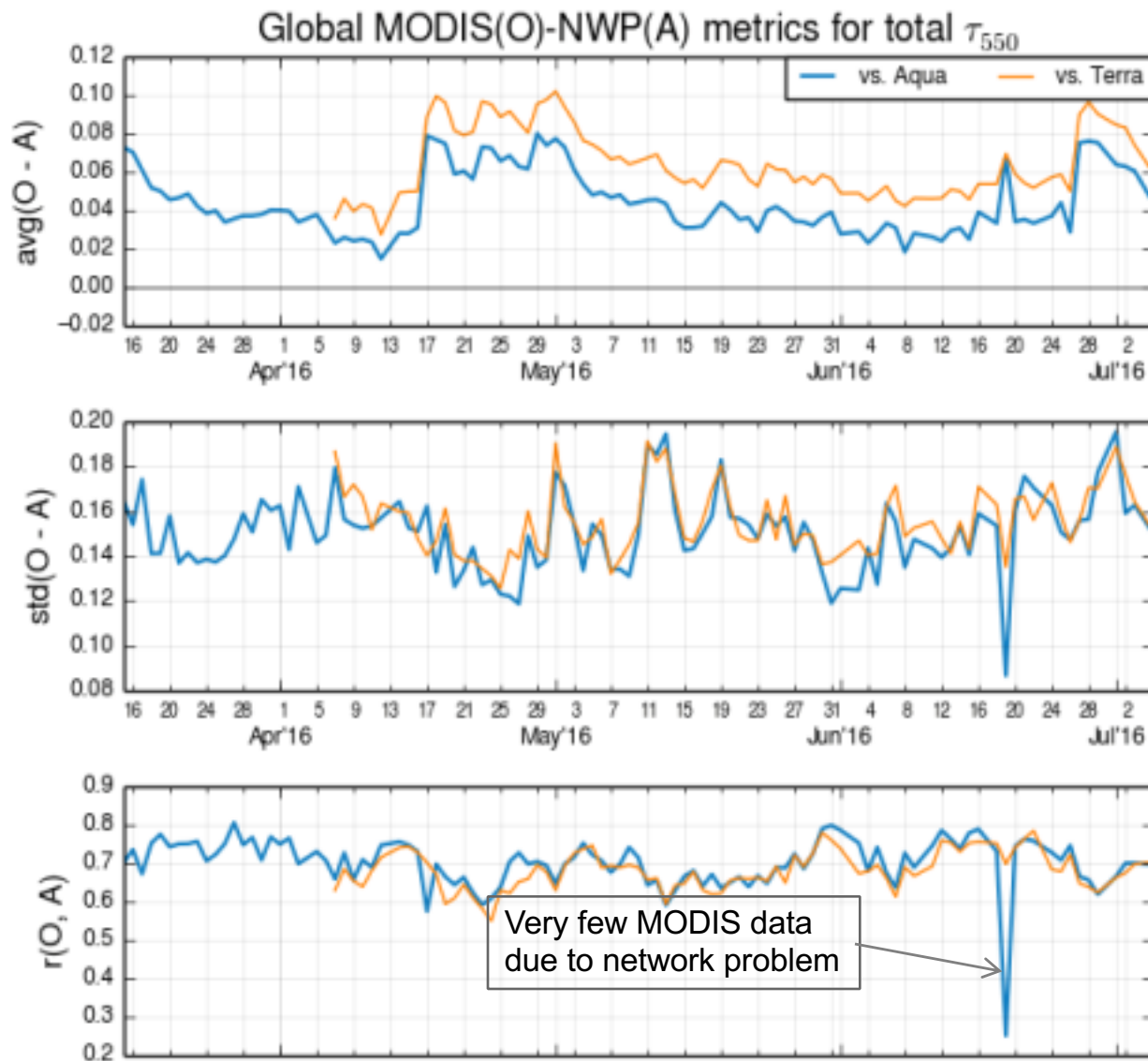
Combined DeepBlue+DT (Q=3)

Other Met Office aerosol models: AQUM (Nick Savage)

Air Quality Modelling in the UM

NO (ug/m³) 09/06/2010 10Z

- Limited area configuration of the UM + UKCA

- First Operational 2010. Currently:

  - 12km horizontal resolution

  - Physical model based on GA6

  - 63 model levels (surface-39km)

- NWP LBCs from UM global run

- Composition LBCs from Copernicus/MACC global model (forecasts or reanalysis)
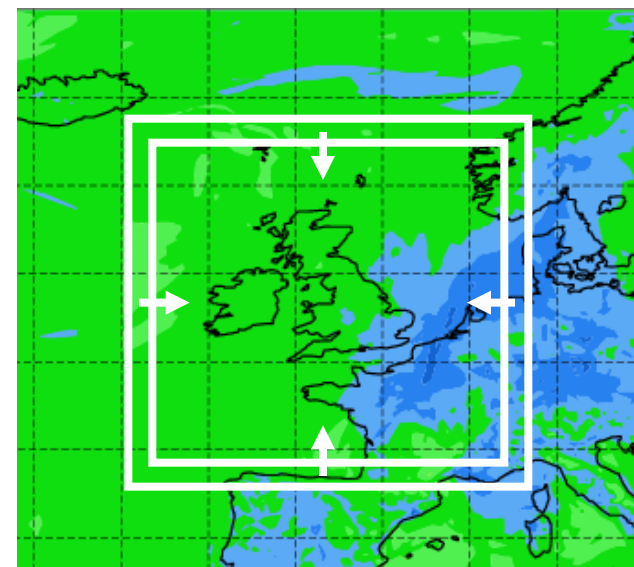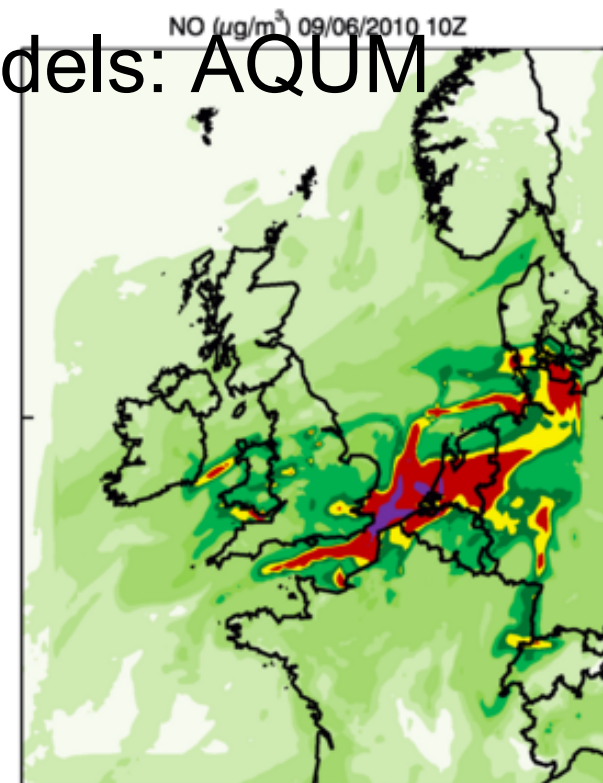
AQUM
Chemistry and aerosols

- Chemistry: UKCA with RAQ mechanism

  - 40 transported species (16 emitted) + 18 non-advected

  - 116 gas-phase reactions + 23 photolysis reactions

- Aerosol: Classic

  - Sulphate, Black Carbon, Organic Carbon, Sea Salt, Dust (6 bins), Nitrate

- Emissions, combination of:

 - UK National Inventory @ 1km

  - Outside UK: MACC @ 5 km

Savage et al. [GMD, 2013]

Other Met Office aerosol models: GLOMAP-mode
(Slides, Colin Johnson, Jane Mulcahy)

- Will replace the CLASSIC aerosol scheme in the next Earth-System and AO climate models

- Dynamically evolving aerosol size distributions with particle number as a prognostic variable

  - a multi-component aerosol system with internally mixed modes

  - binary nucleation of new sulfate aerosol

  - prognostic sea salt mass per particle
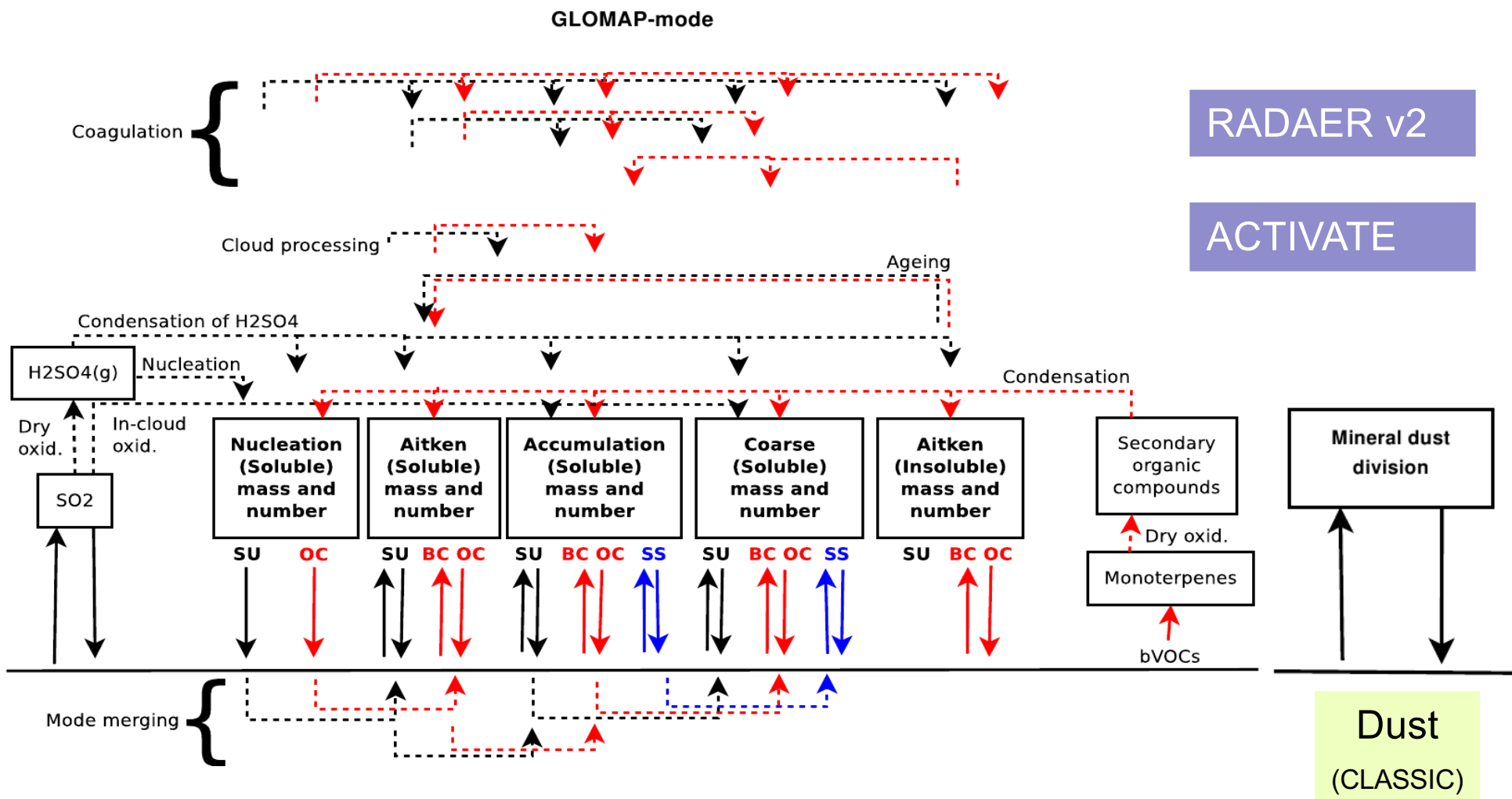
UKCA-Glomap-mode aerosol
Climate model aerosol *Jane Mulcahy (et al!)*

CLASSIC

Sulphur cycle

Other discrete species

Dust
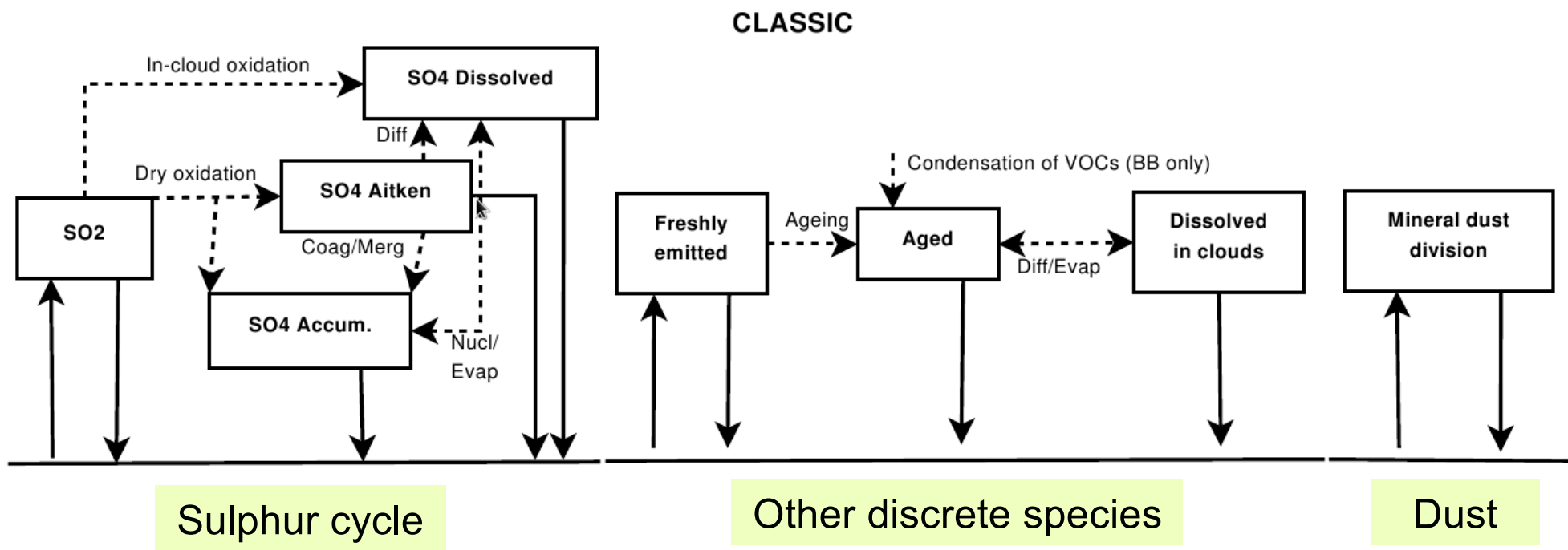
Bellouin et al. (2013)

UKCA-Glomap-mode aerosol
Climate model aerosol *Jane Mulcahy (et al!)*

GLOMAP-mode

RADAER v2

ACTIVATE

Bellouin et al. (2013)

Mode name	Size range	Composition	Soluble?
nucl-sol	r < 5 nm	SU	Yes
Aitken-sol	5 < r < 50 nm	SU, BC, OC	Yes
accum-sol	50 nm < r < 500 nm	SU, BC, OC, SS, DU	Yes
coarse-sol	r > 500 nm	SU, BC, OC, SS, DU	Yes
Aitken-ins	5 < r < 50 nm	BC, OC	No
accum-ins	50 nm < r < 500 nm	DU	No
coarse-ins	r > 500 nm	DU	No

Initially UKCA-mode to follow M7 model (Vignati et al., 2004; Stier et al., 2005).
SU=sulfate, BC=black carbon, OC=organic carbon, SS=sea salt, DU= dust.

- Ammonium nitrate and dust schemes are being added.

- Secondary Organic Aerosol in planning stage.

NERC Centres for Atmospheric Science

NATURAL ENVIRONMENT RESEARCH COUNCIL
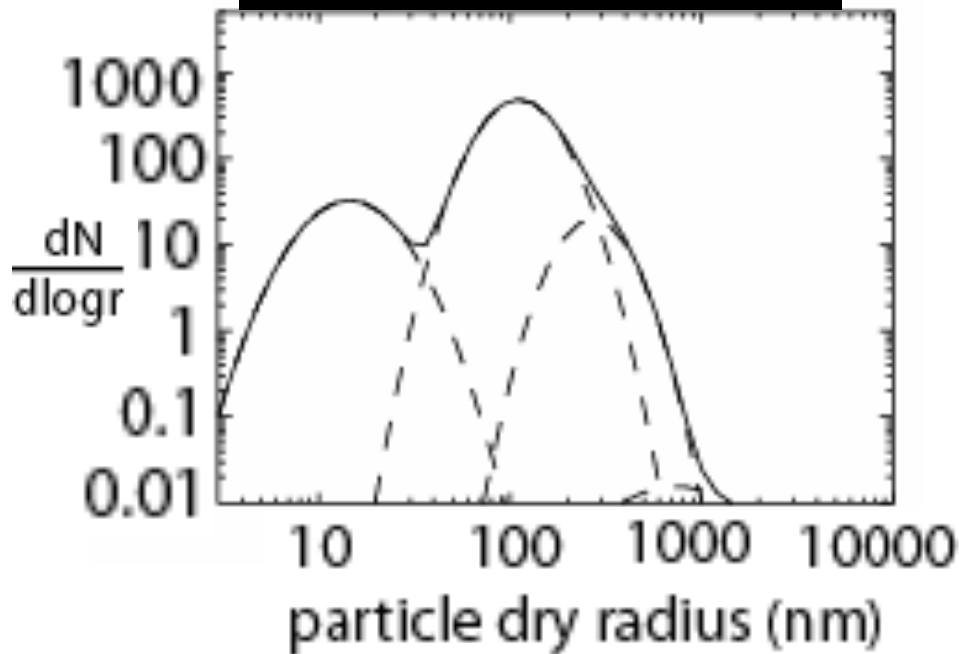
Eastern USA — **Southern Ocean**
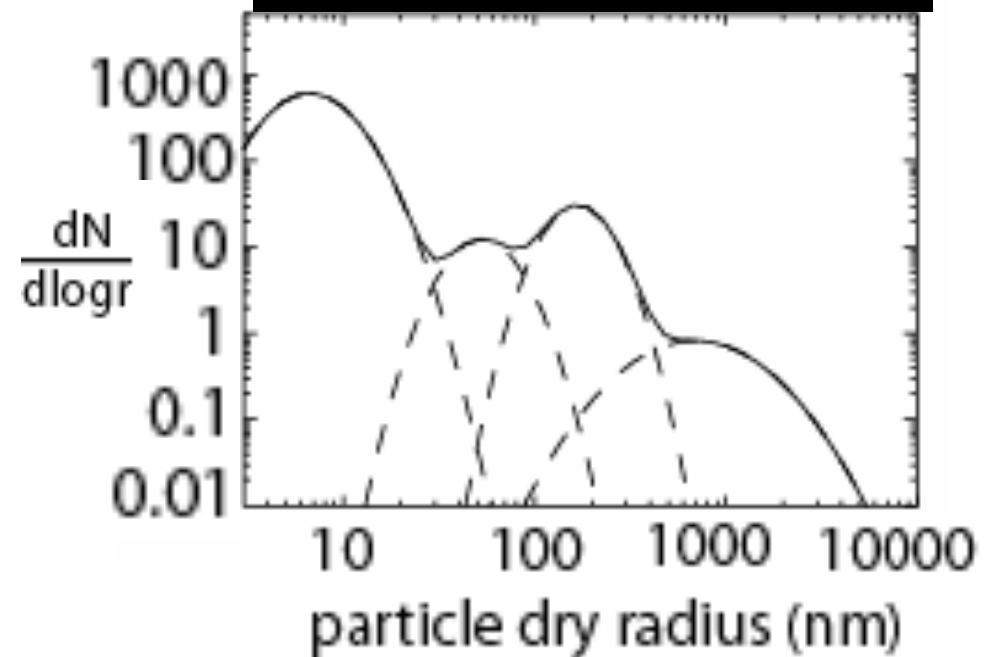
Size distributions from sulfate-and-sea-salt only global UKCA run within TOMCAT (T42L31).

- Aersol distributions comparable to CLASSIC

- Downside: expensive to run

  - not ready for NWP use yet

Other aerosol work, flight campaign support

A lot of aerosol research campaigns this year:

•INCOMPASS, SWAMMI, MONSOON: over India pre/during the monsoon.

•DACCIWA: aerosol and cloud focus over N. West Africa.
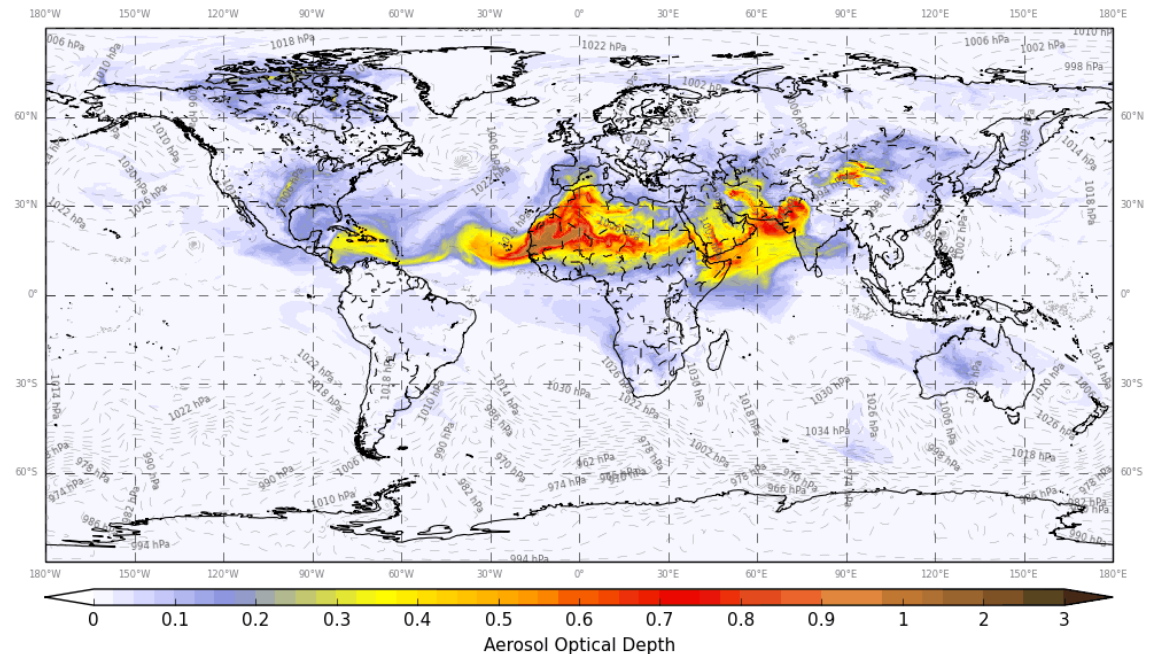
•CLARIFY: aerosol cloud interaction over Tropical South Atlantic.

Met Office Res. Global: Dust AOD at 550.0 nm
2016/07/07 18Z T+72 from 2016/07/04 18Z

Aerosol Optical Depth

A need for increased aerosol modelling support: not just dust

http://www.metresearch.com/flyingforecasts
http://gws-access.ceda.ac.uk/public/incompass/restricted/MetUM_Monitoring/xj_inc_dtime.html

Other aerosol work, flight campaign support (Ben Johnson)

Carbonaceous aerosol, CLASSIC:
- fossil fuel
- bio-fuel
- biomass burning

Anthropogenic emissions:
- 2014 monthly mean
- MACC/CityZen

Biomass burning:
- 1 day lagged from GFAS
- Total carbon scaled x1.7

MACC/CityZEN Anthopogenic carbonaceous aerosol emissions, January

MACC/CityZEN Anthopogenic carbonaceous aerosol emissions, April

MACC/CityZEN Anthopogenic carbonaceous aerosol emissions, July

MACC/CityZEN Anthopogenic carbonaceous aerosol emissions, October

μg m^{-2} s^{-1}

Aerosol Optical Depth
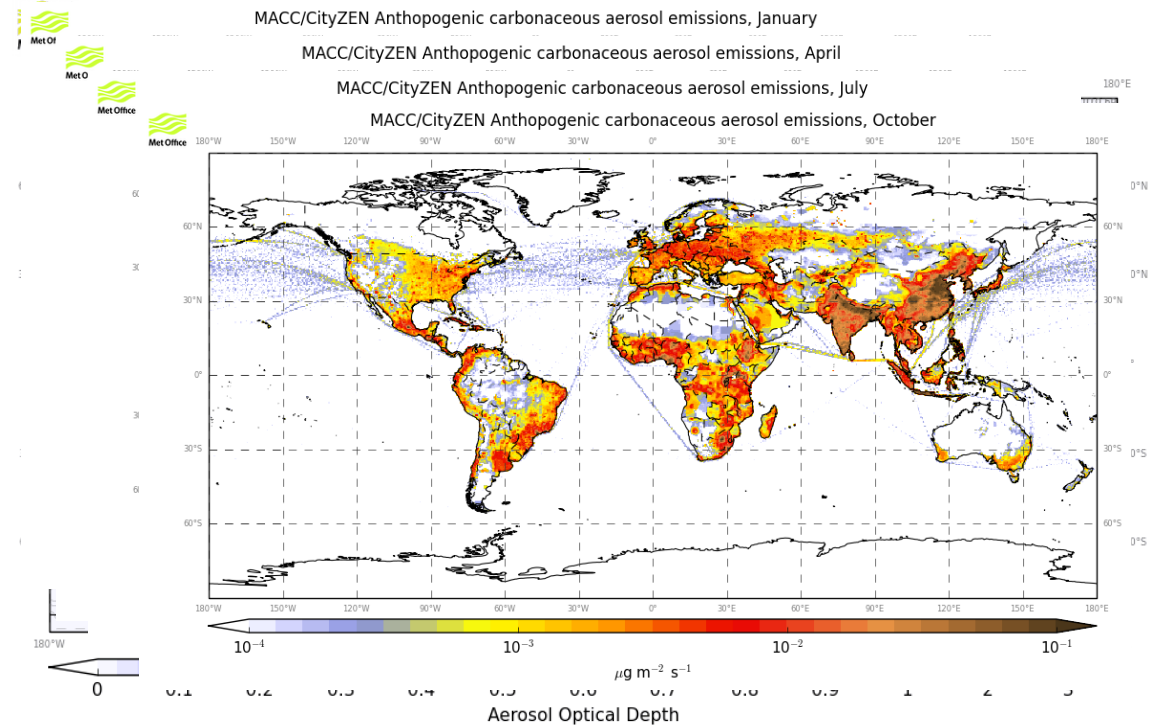
Once airborne, only dust assimilated in these runs!

Other aerosol work, flight campaign support

Land DMS emss.
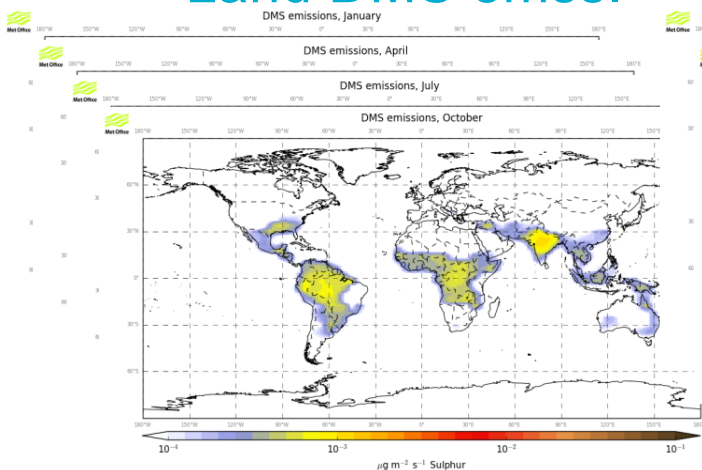
Ocean DMS
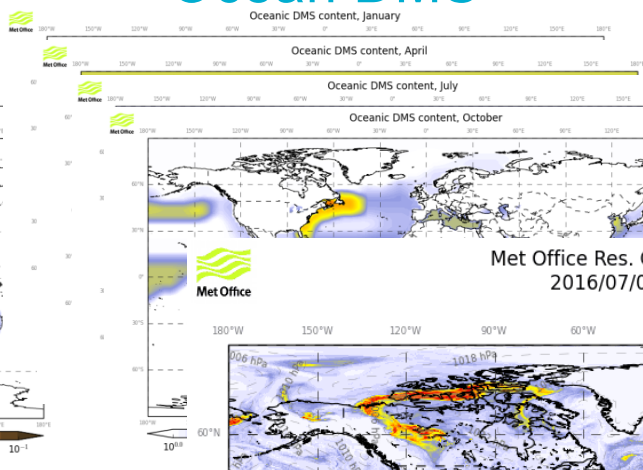
Antrhop. SO2 emiss.
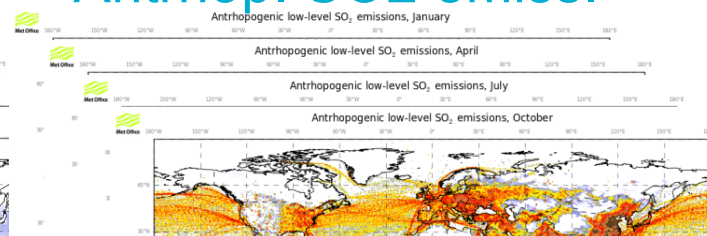
Met Office Res. Global: Total Prognostic AOD at 550.0 nm
2016/07/07 18Z T+72 from 2016/07/04 18Z

Aerosol Optical Depth
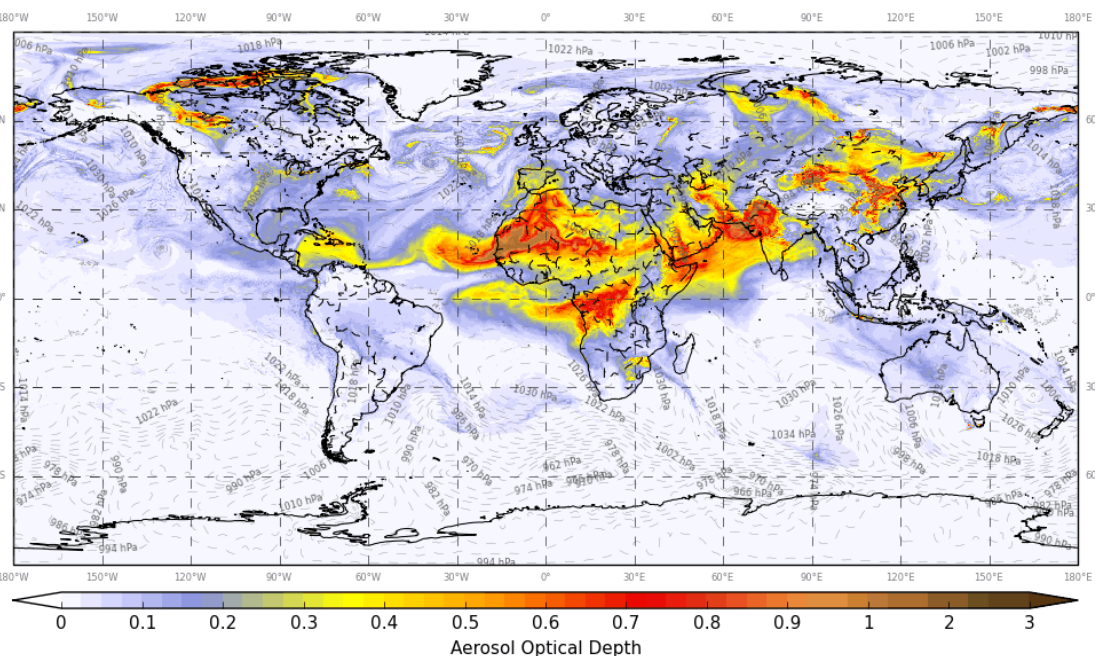
Sulphate aerosol forecasts with CLASSIC:
• Anthropogenic SO2 (MACC/CityZen)
• Volcanic SO2
• Land based DMS
• Ocean DMS conc (fluxes wind based)

Dust, carbonaceous, sulphate
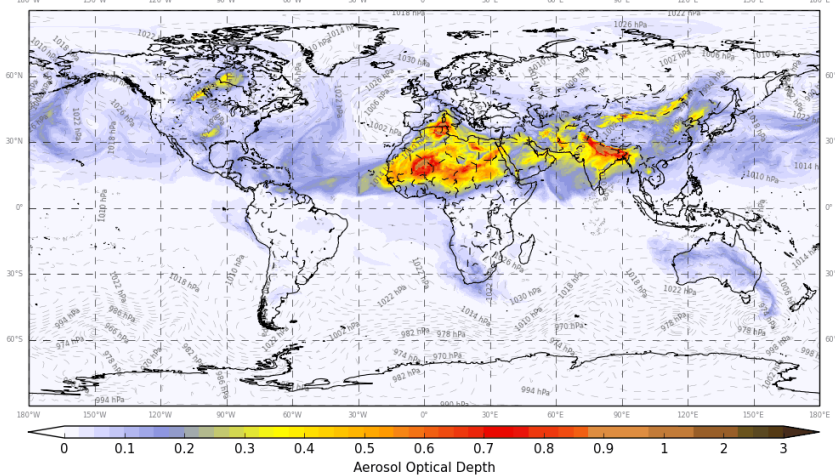Just missing nitrate and sea salt?

Cost increase ~30% to ~40%

Other aerosol work, flight campaign support

Monday 09 May 2016 00UTC CAMS Forecast t+036 VT: Tuesday 10 May 2016 12UTC
Biomass Burning Aerosols Optical Depth at 550 nm
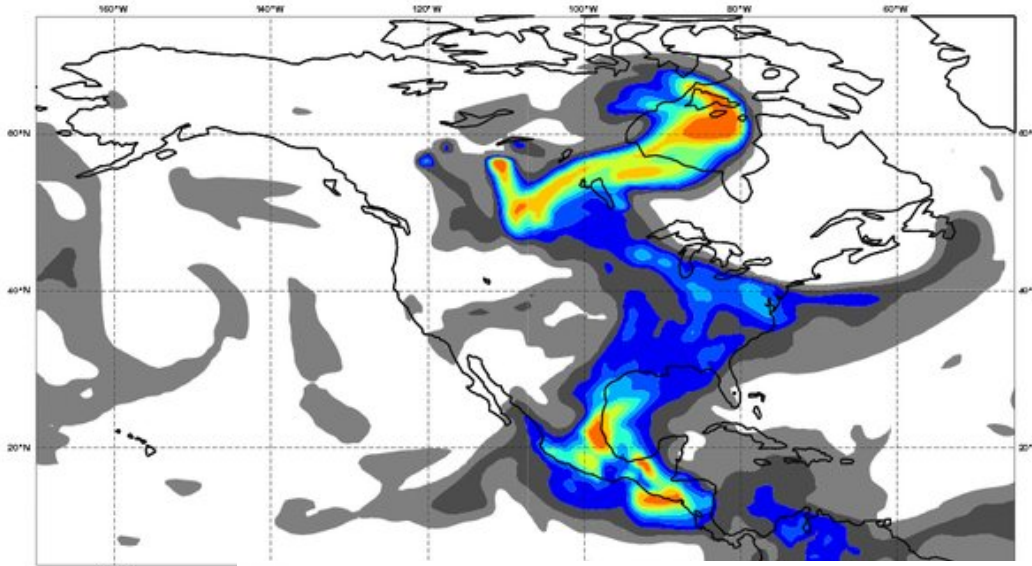
Met Office Res. Global: Carbonaceous AOD at 550.0 nm
2016/05/10 06Z T+0 from 2016/05/10 06Z

Met Office Res. Global: Dust AOD at 550.0 nm
2016/05/10 06Z T+0 from 2016/05/10 06Z
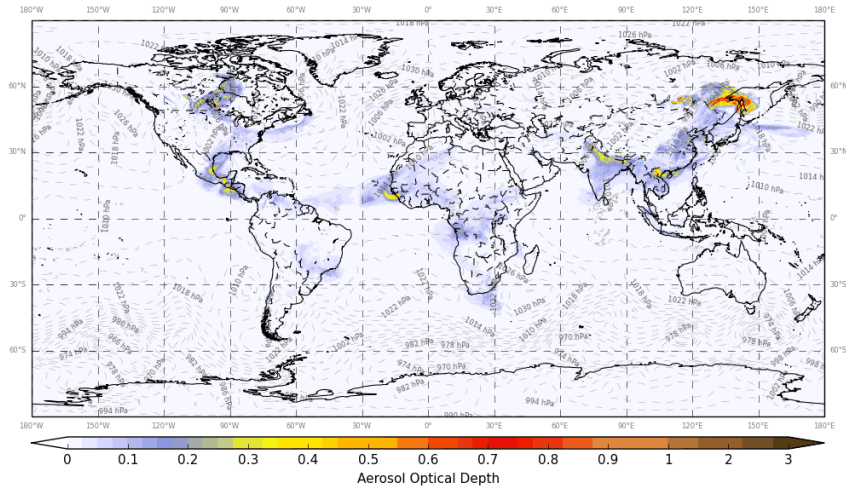
Met Office Res. Global: Sulphate AOD at 550.0 nm
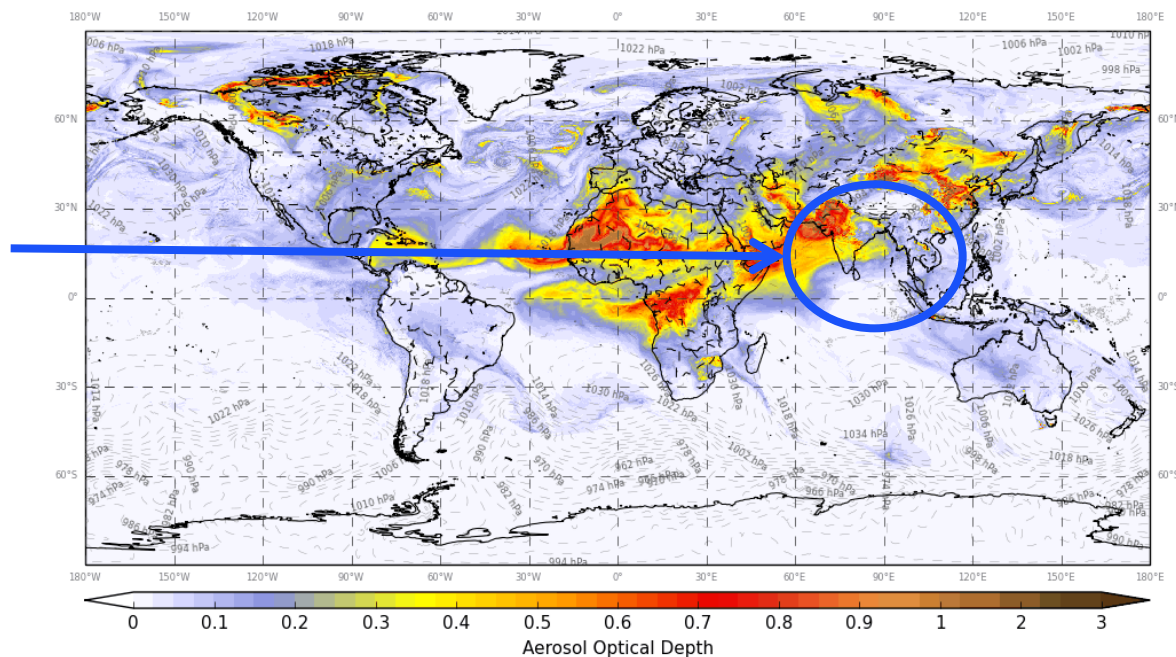2016/05/10 06Z T+0 from 2016/05/10 06Z
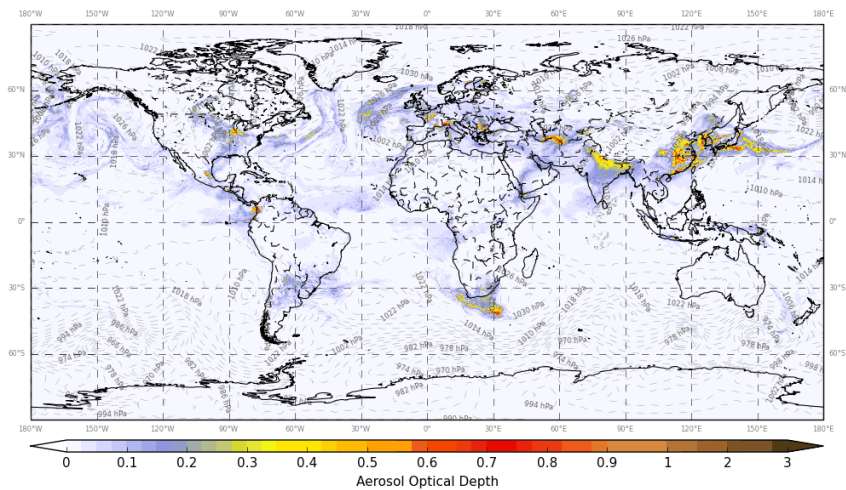
Other aerosol work, flight campaign support

Over India, combined AOD is often too high. We think:

• Dust assimilation of MODIS is adding non-dust as dust

• Then double counting by adding the non-dust aerosol again.

Met Office Res. Global: Total Prognostic AOD at 550.0 nm
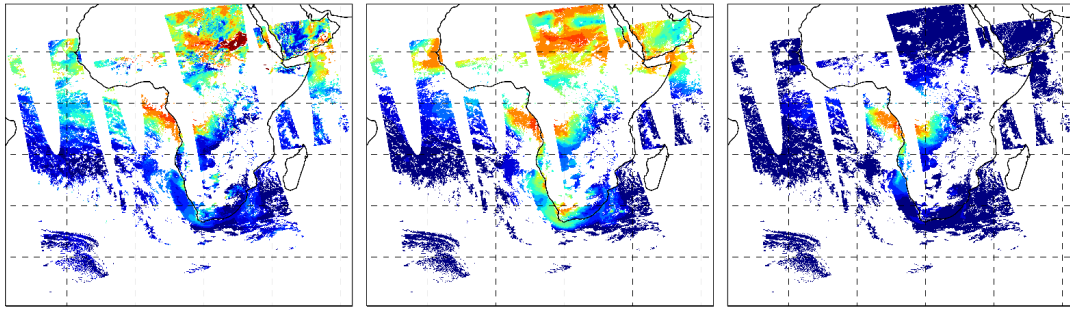2016/07/07 18Z T+72 from 2016/07/04 18Z

Aerosol Optical Depth

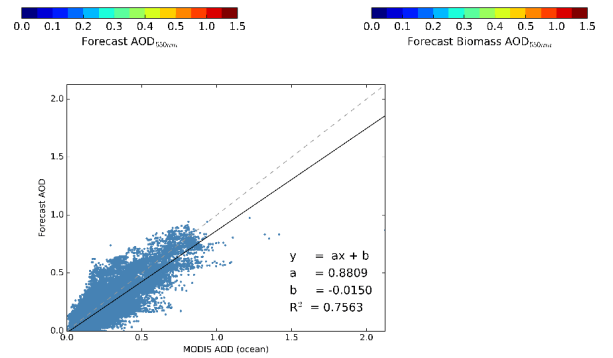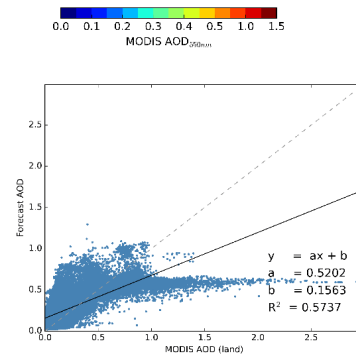# Evaluation of reseach aerosol model (Fanny Peers, Exeter Uni.)

vs AERONET
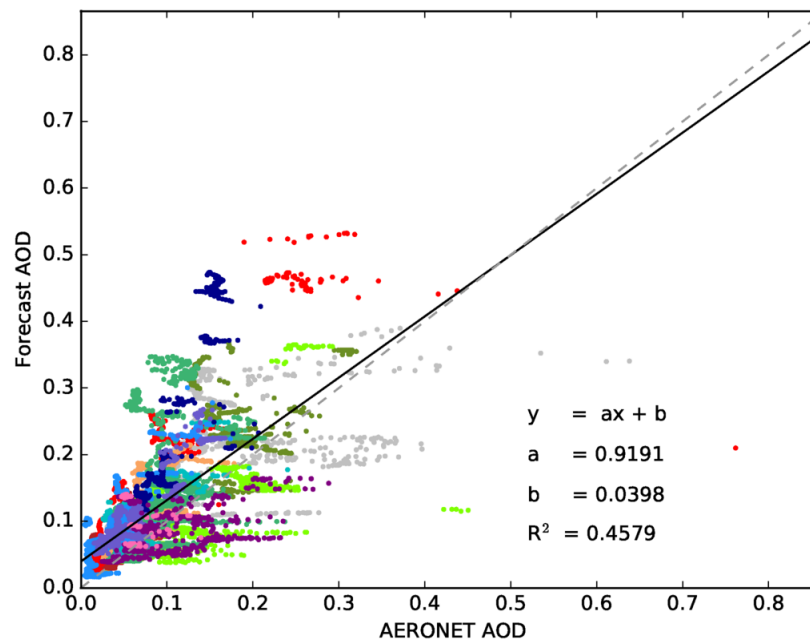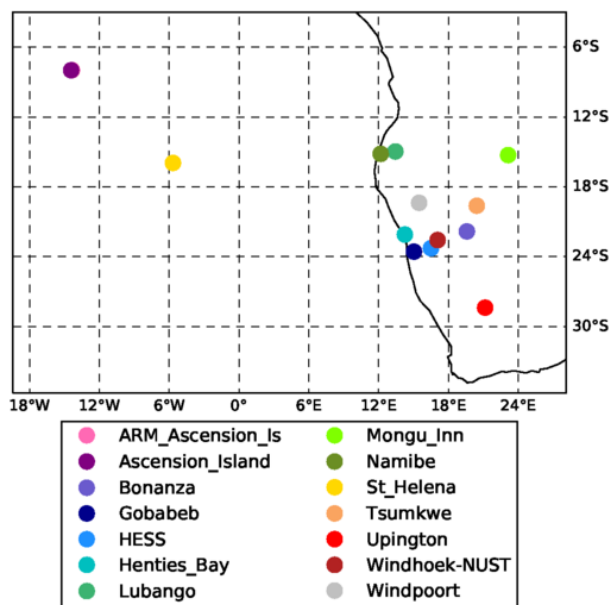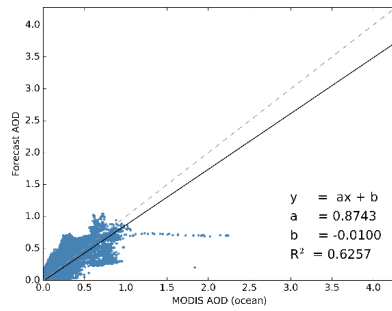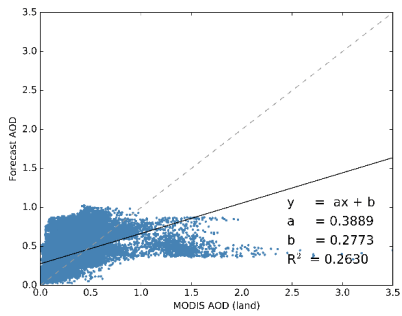
Case studies, comparing forecast vs MODIS

2016-06-07
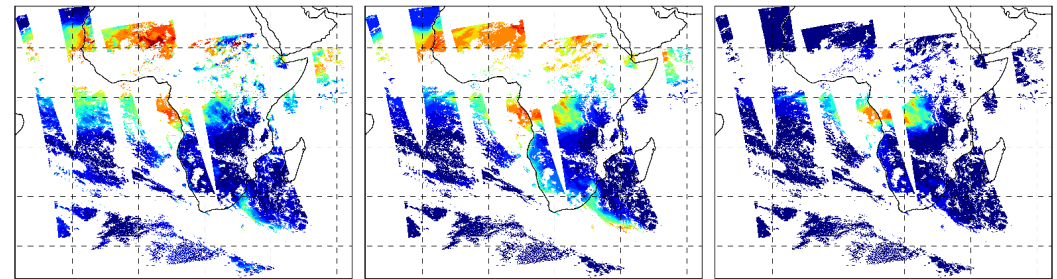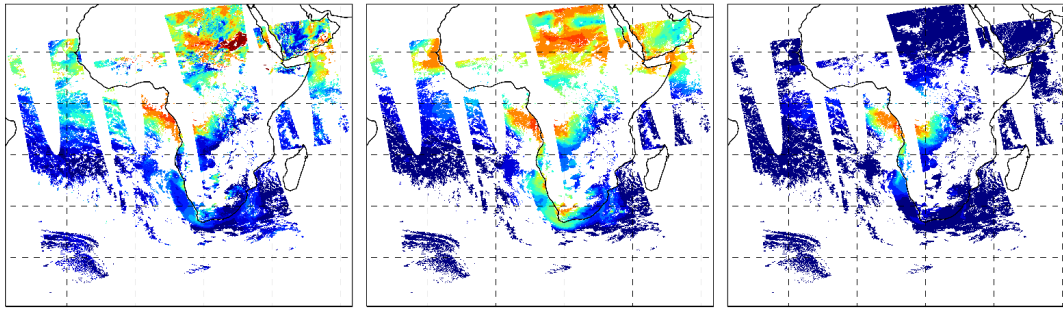
MODIS AOD$_{550nm}$ — Forecast AOD$_{550nm}$ — Forecast Biomass AOD$_{550nm}$

Case studies, comparing forecast vs MODIS
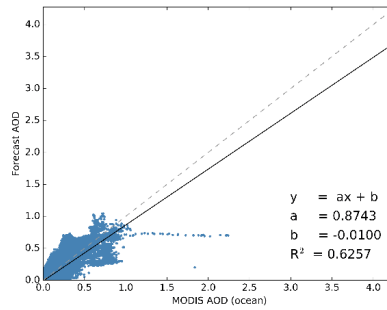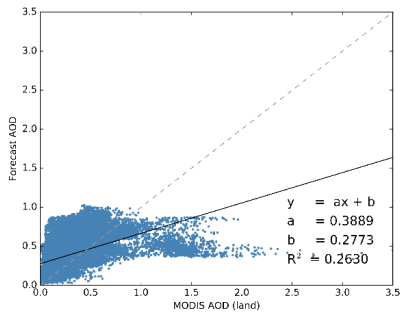
y = ax + b
a = 0.3889
b = 0.2773
R^2 = 0.2630

y = ax + b
a = 0.8743
b = -0.0100
R^2 = 0.6257

2016-06-08

MODIS AOD$_{550nm}$ — Forecast AOD$_{550nm}$ — Forecast Biomass AOD$_{550nm}$

y = ax + b
a = 0.7277
b = 0.1653
R^2 = 0.5040

y = ax + b
a = 1.0188
b = -0.0296
R^2 = 0.5398

Forecast performance:
• no systematic verification yet
• what has been done looks quite good.
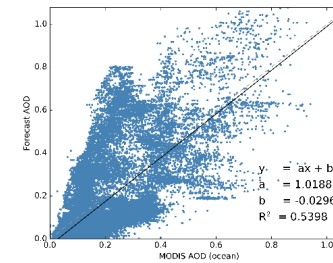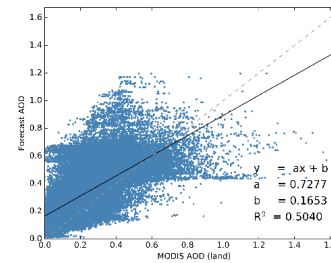
Summary

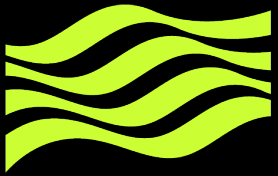1. Met Office global NWP model developed in tandem with atmosphere climate model component.

   - Resolution and major physics upgrade coming soon.

   - No dust changes included.

2. Dust changes for global NWP:

   - land surface, bare soil z0, and convection interaction in development.

   - Moving to MODIS Collection 6, monitoring PMAP.

3. UK regional aerosol/chemistry model now mature

4. Climate model migrated to GLOMAP MODE aerosol/chemistry

   - Not ready for NWP use yet.

Summary

5. In order to support flight campaigns, used old aerosol scheme (CLASSIC) to add 'carbonaceous' and sulphate aerosol to a research NWP run.

- Intended for Africa and India.

- Biomass burning aerosol used from GFAS fire emissions

- With a background biofuel+industrial emissions from climatology

- Cost is ~30 to 40% at 17km resolution.

- Limited verifcation so far, but looks good.

- Aircraft just completed first campaign in India. DACCIWA underway!

- Hopefully a demonstrated capability.

- Implementation pathway is not clear.

Questions and answers