Royal Netherlands Meteorological Institute
Ministry of Infrastructure and Water Management

CRESCENDO

Preparing EC-Earth for CMIP6 and AerChemMIP

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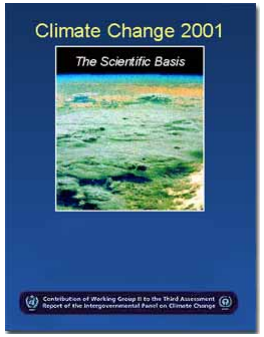
EC-EARTH

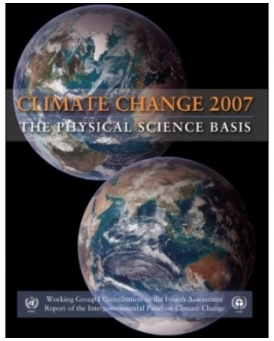
TM5 meeting, WUR, 21 Nov. 2017

WCRP CMIP6
World Climate Research Programme

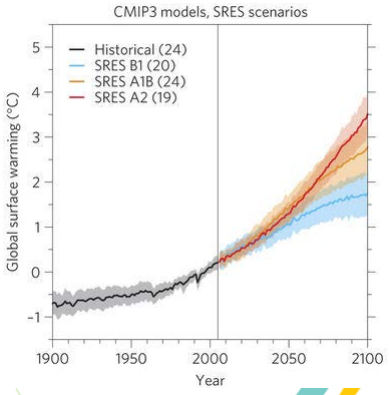
This talk

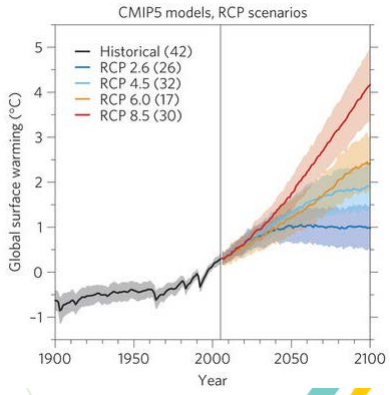
- Introduction CMIP6 and AerChemMIP
- EC-Earth configurations
- Status EC-Earth3 GCM
- TM5 and EC-Earth3-AerChem





ar6





WCRP CMIP3
World Climate Research Programme

WCRP CMIP5
World Climate Research Programme

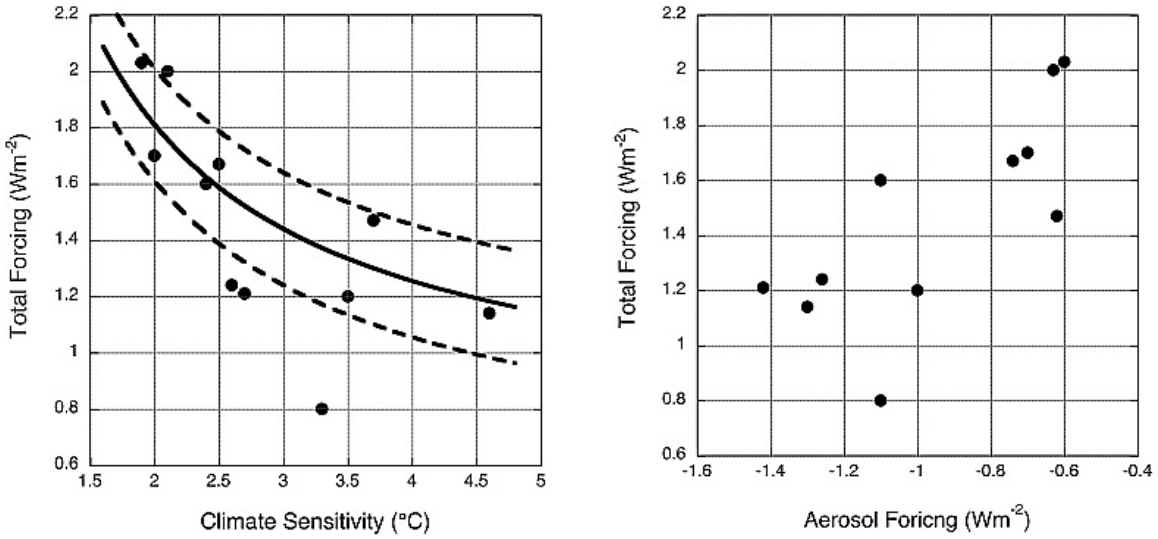
WCRP CMIP6
World Climate Research Programme

EC EARTH2

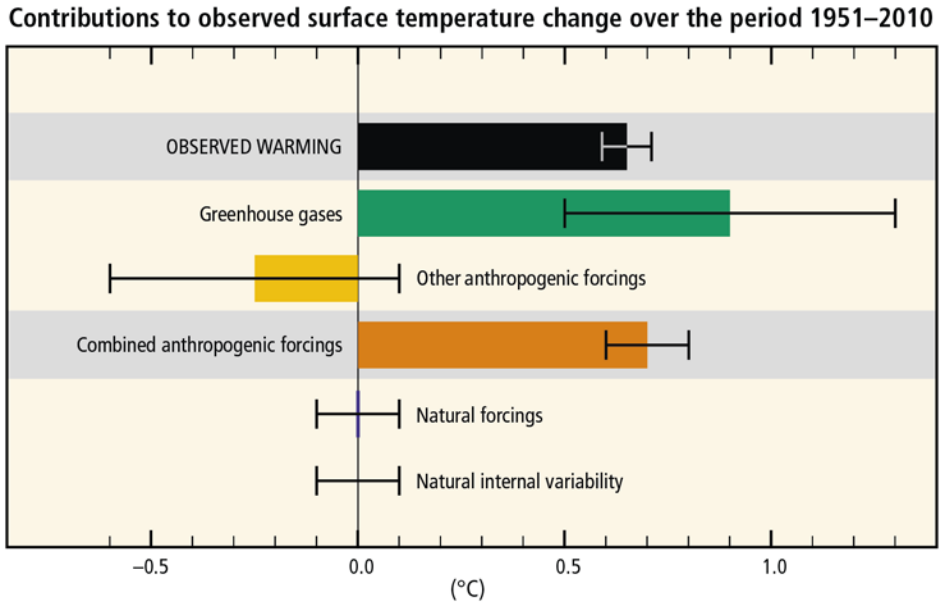
EC EARTH3

Aerosol Forcing and Climate Sensitivity

Twentieth century climate model simulations

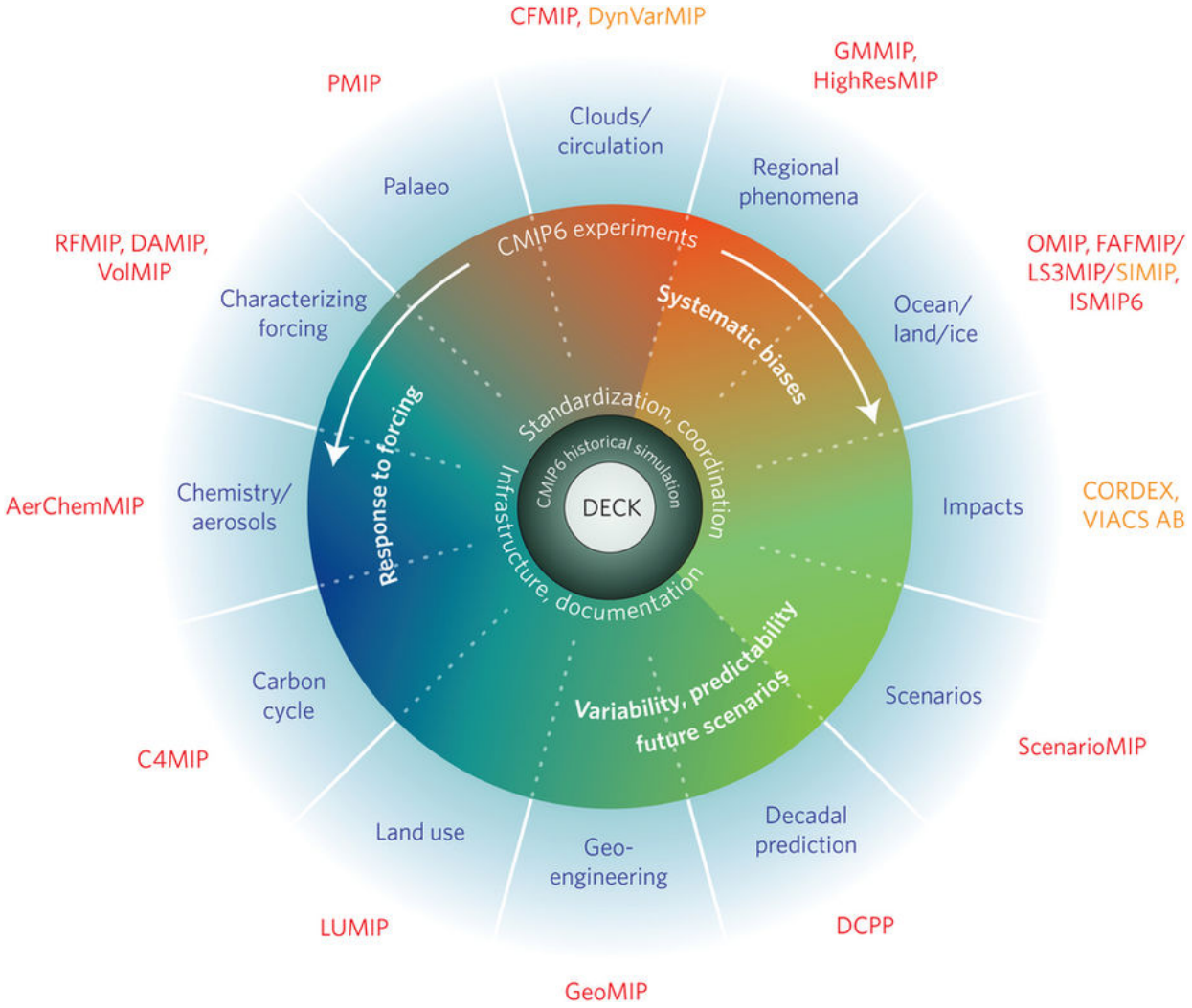


Kiehl (GRL, 2007)



AR5

CMIP6 Design



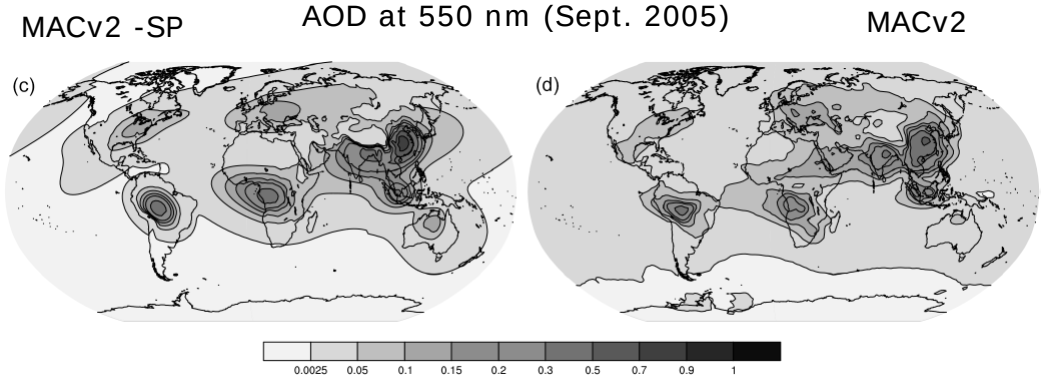
- DECK ("Diagnostic, Evaluation and Characterization of Klima"):
  - AMIP (1979-2014)
  - Pre-industrial control
  - 1% per year CO2 increase
  - Abrupt 4xCO2
- Historical (1850-2014)
- More specific simulations in MIPs
- Common experiment protocols, forcing datasets and output requirements

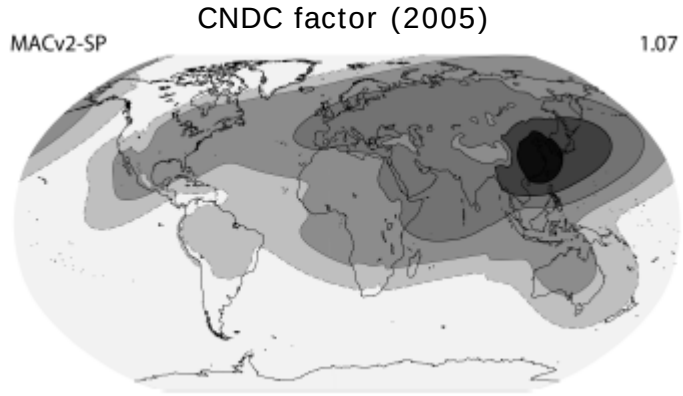
Tropospheric aerosols in CMIP6

- Simple plume model (MACv2-SP)
  - Simplified representation of anthropogenic (fine-mode) aerosols based on MPI Aerosol Climatology v2
  - Nine plumes (industrial + biomass burning), describing profiles of optical properties
  - Extinction scaled by regional emissions of SO2 & NH3 above 1850 levels (SSA fixed!)
  - Twomey effect described by CDNC factor depending on AOD:

$$\frac{N(x,y,t)}{N_{1850}(x,y,t_f)} = \frac{\ln\left(b_N(\tau_a+\tau_{bg})+1\right)}{\ln\left(b_N\tau_{bg}+1\right)}$$

- Model specific, mostly interactive (AerChemMIP)



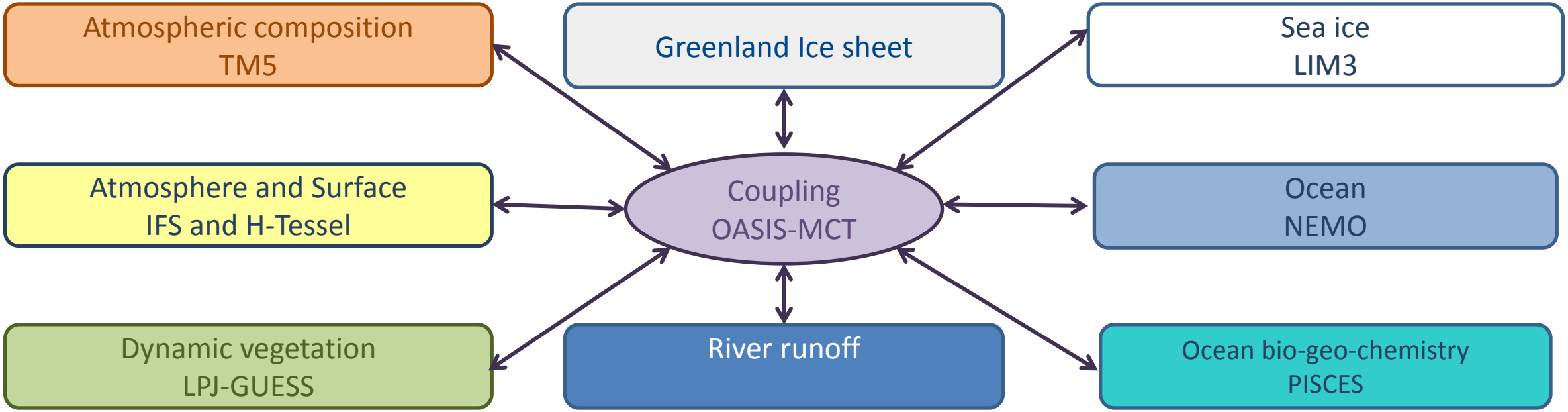


Stevens et al., 2017

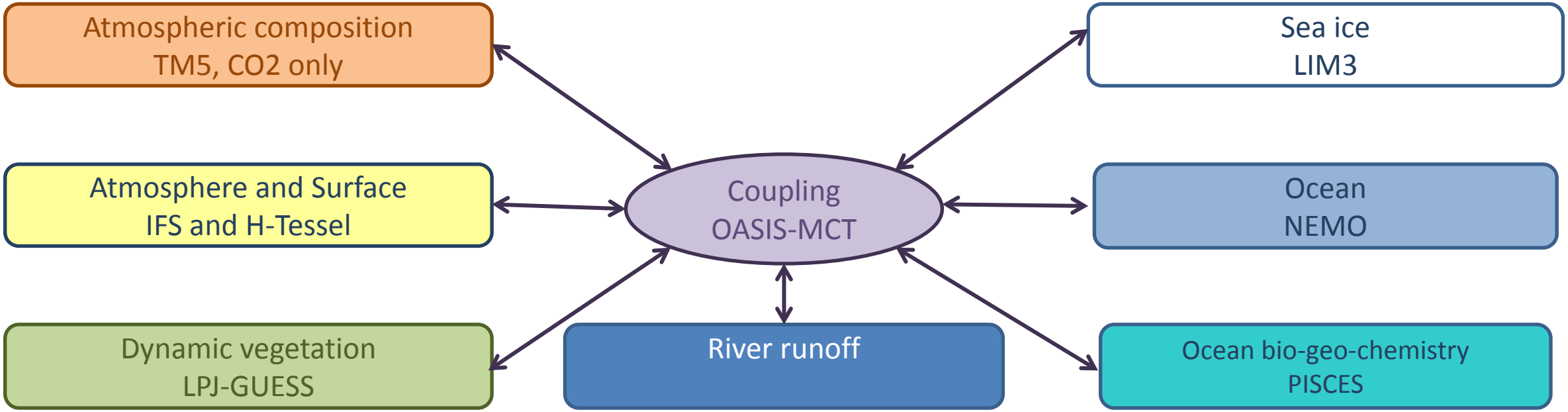
Aerosols and Chemistry MIP

- Focus on role of aerosols and chemically reactive gases:
  - Near-Term Climate Forcers (NTCFs): trop. aerosols + ozone, methane, and their precursors
  - Nitrous oxide and ozone depleting halocarbons
- Climate models with interactive trop. aerosols and/or atm. chemistry (strat. aerosols prescribed in most models)
- Builds upon AeroCom, ACCMIP, CCMI
- Key science questions:
  - How have anthropogenic emissions contributed to global radiative forcing and affected regional climate over the historical period?
  - How might future policies (on climate, air quality and land use) affect the abundances of NTCFs and their climate impacts?
  - How do uncertainties in historical NTCF emissions affect radiative forcing estimates?
  - How important are climate feedbacks to natural NTCF emissions, atmospheric composition, and radiative effects?

EC-Earth3 Components

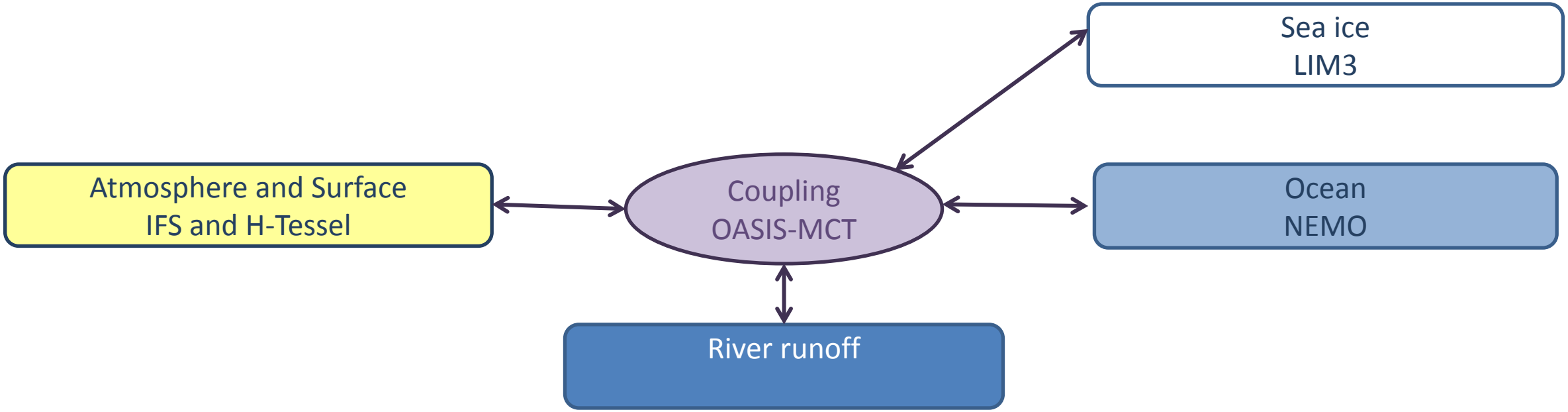


Carbon Cycle version



For Coupled Climate Carbon Cycle MIP (C4MIP)

Atmosphere-Ocean GCM version (EC-Earth3)



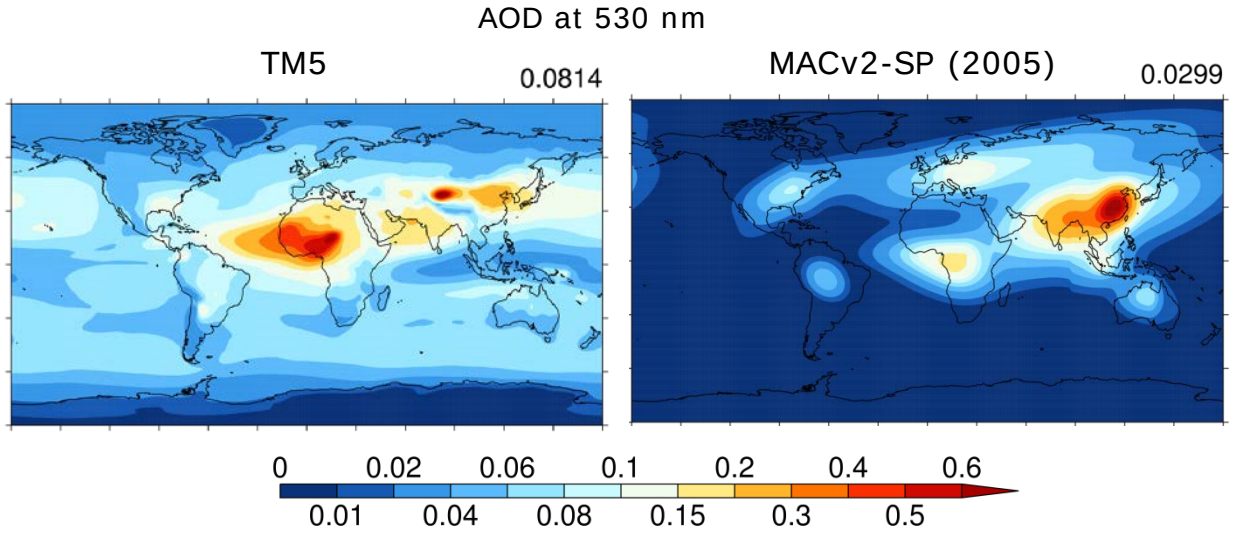
- Workhorse for RFMIP, DAMIP?, ScenarioMIP, DCPP, …
- EC-Earth3-HR version running in EU PRIMAVERA & HighResMIP

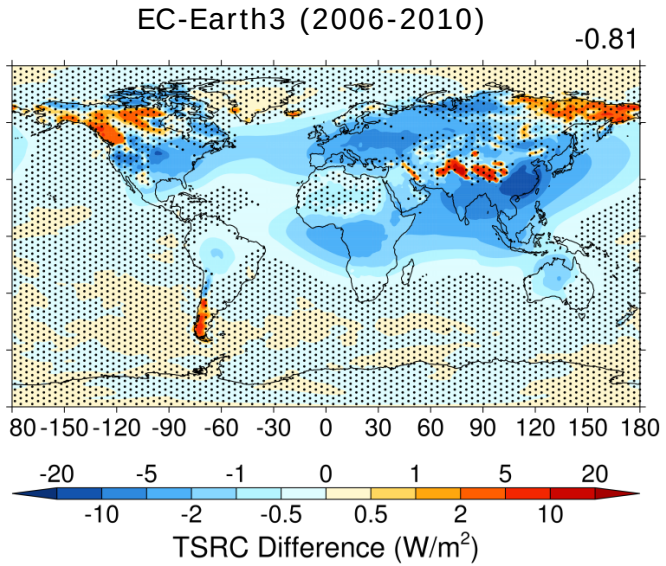
What has changed since CMIP5?

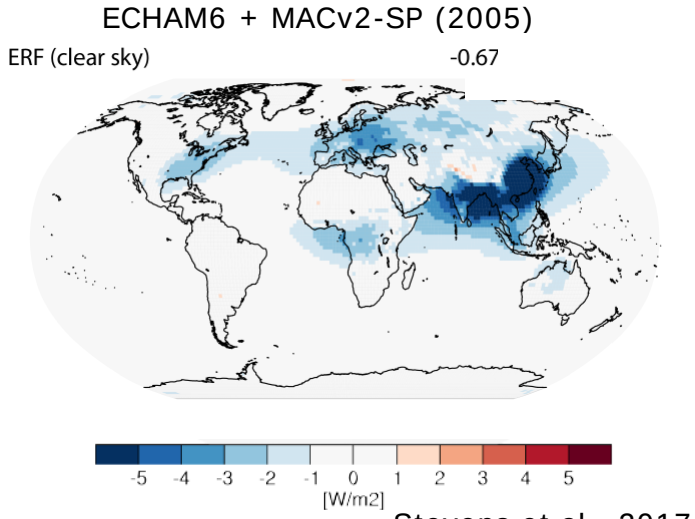
- IFS Cy31r1 → 36r4 (compare ERA-Interim 31r2)
  - T159L62 (~125km, top at 5 hPa) → T255L91 (~80 km, 0.01 hPa); EC-Earth3-HR T511L91 (~40 km)
  - McICA radiation scheme
  - New microphysics scheme with prognostic ice
  - Updated humidity conservation
  - …
  - CMIP6 forcings incl. MACv2-SP
- NEMO2 → NEMO3.6
  - 1° (ORCA1); 42 → 75 vertical levels; EC-Earth3-HR 1/4° (ORCA025)
  - Major changes in the TKE schemes, runoff, surface wave breaking, tidal mixing
  - Time discretization made energetically consistent
  - …
- LIM2 → LIM3
  - Multiple sea ice categories
  - New thermodynamics including bulk ice salinity
  - …

Simplified aerosols

- Pre-industrial climatology
  - Based on offline TM5 simulations with 1850 CMIP6 emissions, driven by ERA-Interim (1981-1985)
  - SW based on TM5 optical properties
  - LW based on TM5 mass concentrations combined w/ IFS absorption coefficients
  - Pre-industrial CDNC calculated as in standard IFS (Martin et al., 1994; constant CCN over land & sea)
- Anthropogenic forcing using MACv2-SP





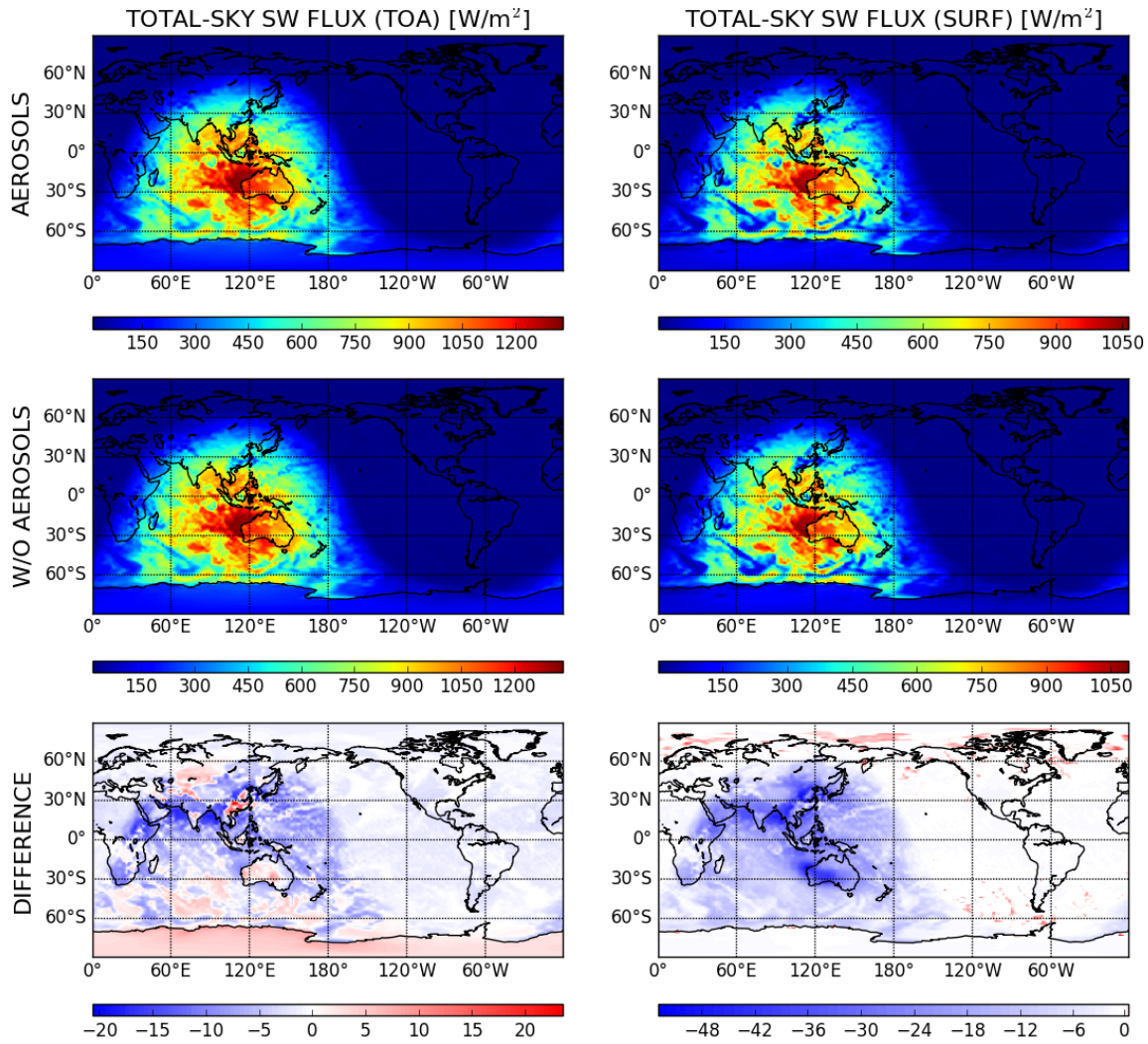


Stevens et al., 2017

Double call to radiation

Option included for EC-Earth to diagnose direct radiative effect of aerosols

Instantaneous fluxes (06 UTC)

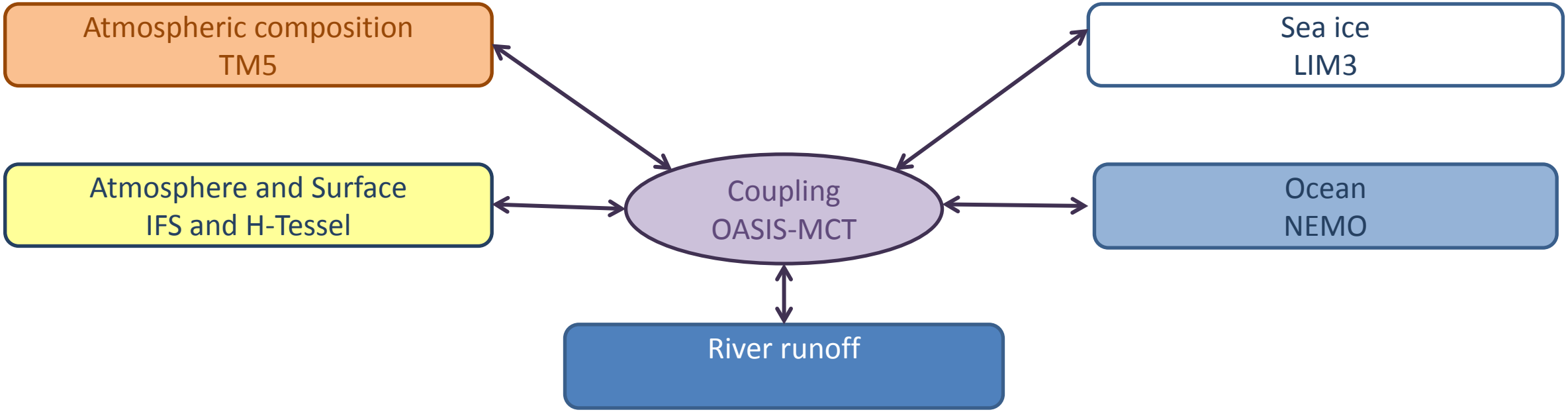


Pirkka Ollinaho (FMI)

Status EC-Earth3

- Preliminary version tuned in atmosphere-only mode for present-day conditions (global surface heat flux ca. -0.5 W/m2, i.e. heat uptake by ocean)
- Finalization of CMIP6 forcings:
  - Land use change
  - Stratospheric aerosols (simplified implementation running)
- Tuning of coupled model

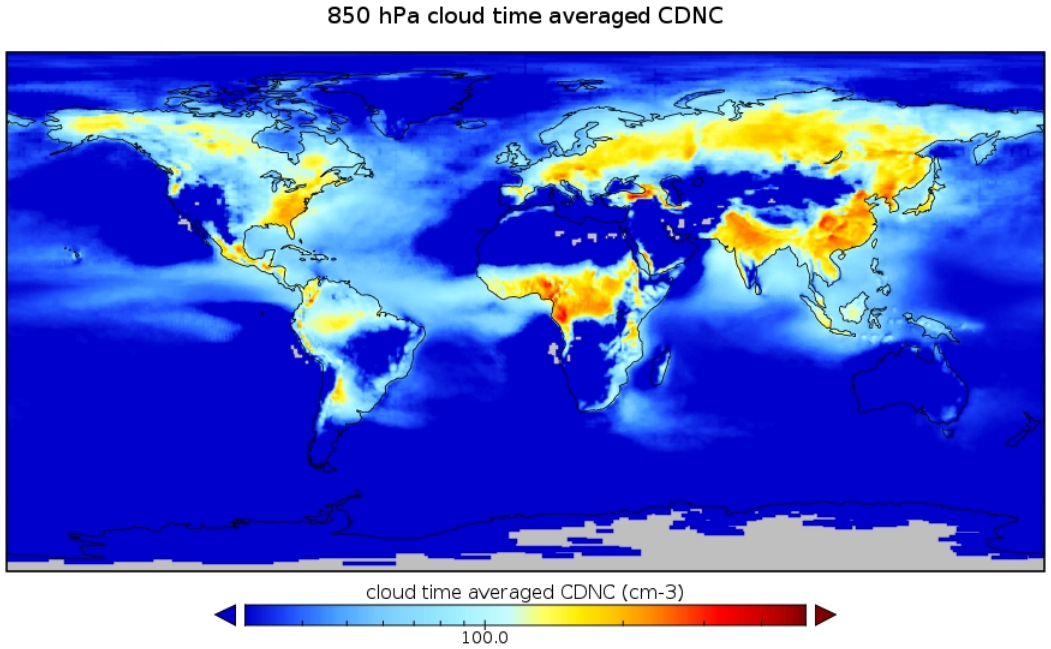
EC-Earth3-AerChem



For AerChemMIP w/ TM5 at 3x2 degrees and 34 levels

What's different on the IFS side?

- TM5 ozone and methane
- Aerosol radiative effects based on TM5 optical properties (SW) and mass concentrations (LW)
- Cloud activation based on TM5 aerosol mass/number concentrations (Abdul-Razzak and Ghan, 2000):
  - Based on standard Köhler theory to relate the aerosol size distribution and composition to the number activated as a function of maximum supersaturation
  - Designed for the case of multiple externally mixed lognormal modes, each composed of a uniform internal mixture of soluble and insoluble material (as for M7)



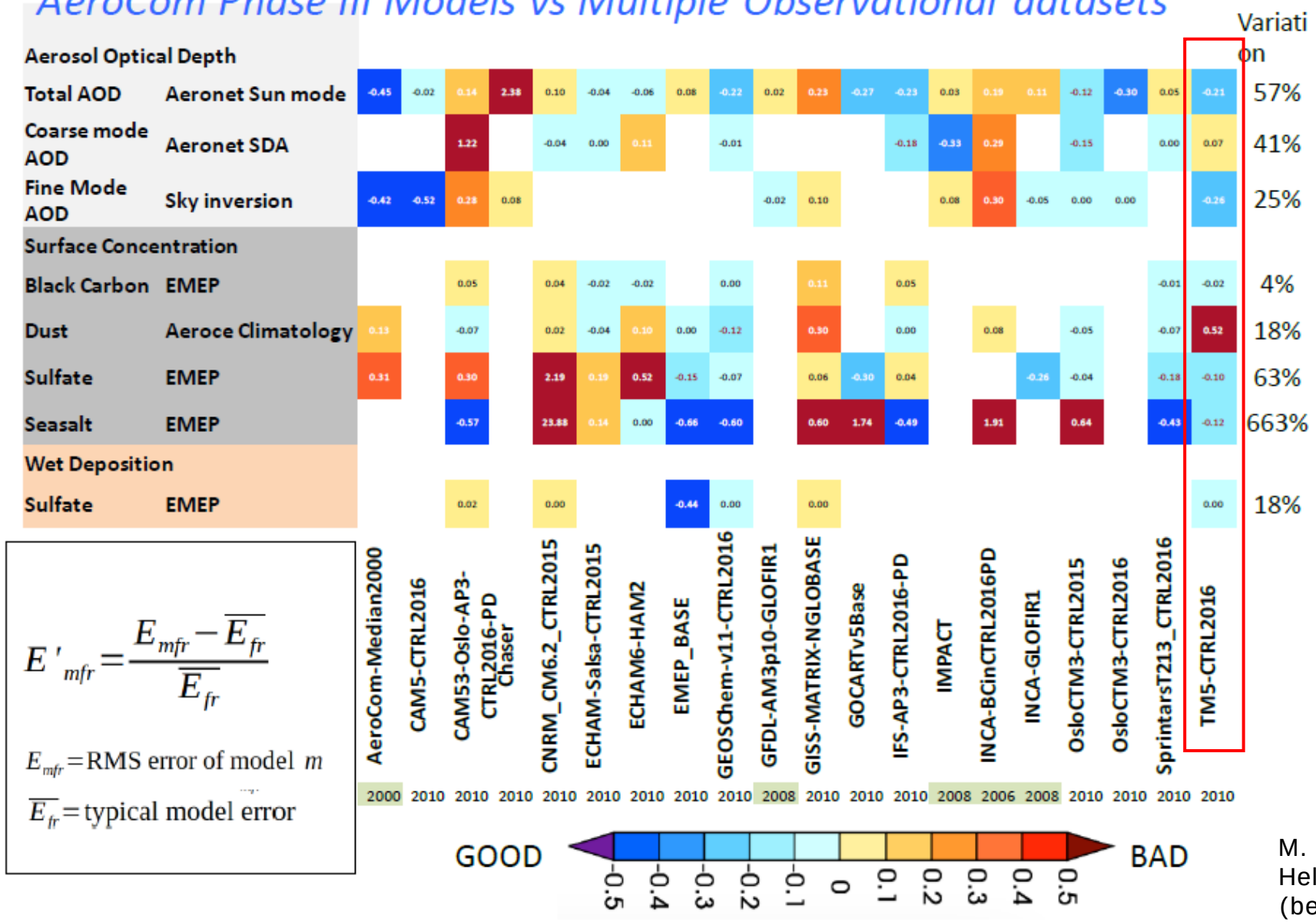
Declan O'Donnell (FMI)

What's new in TM5?

- Included CMIP6 forcing data sets for historical period (1850-2014):
  - CEDS anthropogenic and GFED biomass burning emissions #635
  - Stratospheric ozone #977
  - Surface and stratospheric methane #978
  - CO2 concentration #1089
- SOA + particle nucleation (Tommi's talk)
- Revised emission radii of carbonaceous aerosol emissions #635
- Natural emissions:
  - Revised sea spray source strength (Salisbury et al., 2013; 2014)
  - Updated ocean DMS source (Lana et al., 2011; Wanninkhof et al., 2014) #4961
  - Included marine organics (post-CMIP6; Jukka-Pekka Keskinen, UHEL)
- CMIP6 output and CMORization (Tommi, in progress)

Portrait Diagram Display of Relative Error Metrics

AeroCom Phase III Models vs Multiple Observational datasets



$$E'_{mfr} = \frac{E_{mfr} - \overline{E_{fr}}}{\overline{E_{fr}}}$$

E_{mfr} = RMS error of model m

$\overline{E_{fr}}$ = typical model error

M. Schulz, AeroCom, Helsinki, Oct. 2017 (before DMS update)

What's next?

- Tuning EC-Earth3
- Time slice simulations to estimate aerosol forcings (1850-2014)
- Tuning EC-Earth3-AerChem (also on TM5 side)
- Start pre-industrial spinup (ASAP in 2018)
- Complete CMIP6 output
- CMIP6 DECK + AerChemMIP production runs

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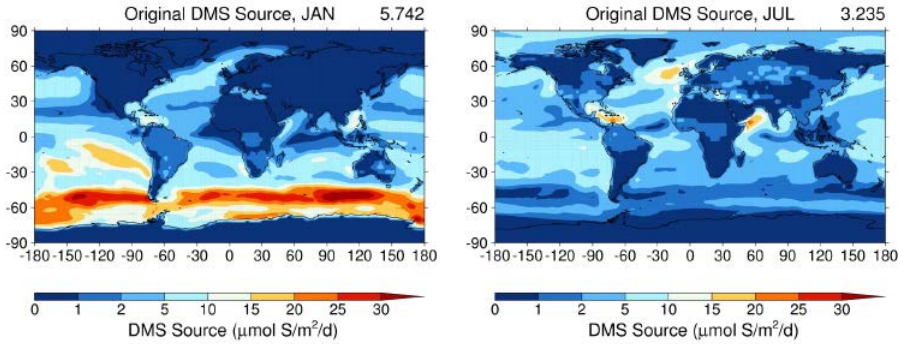
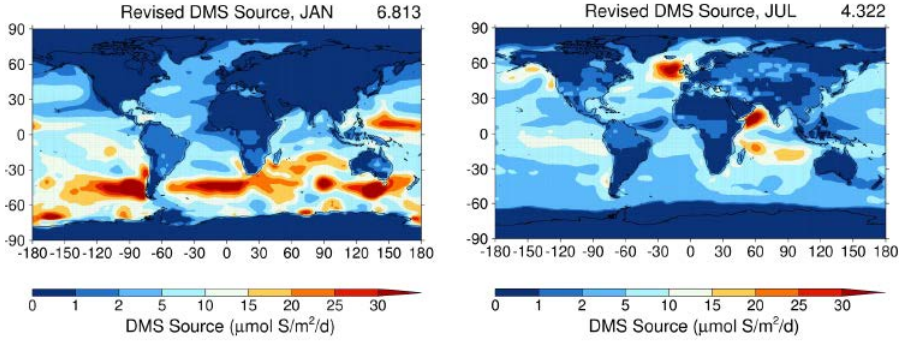
Thanks to all members of the EC-Earth consortium
who contributed to this talk!

Extra slides

Updated ocean DMS source

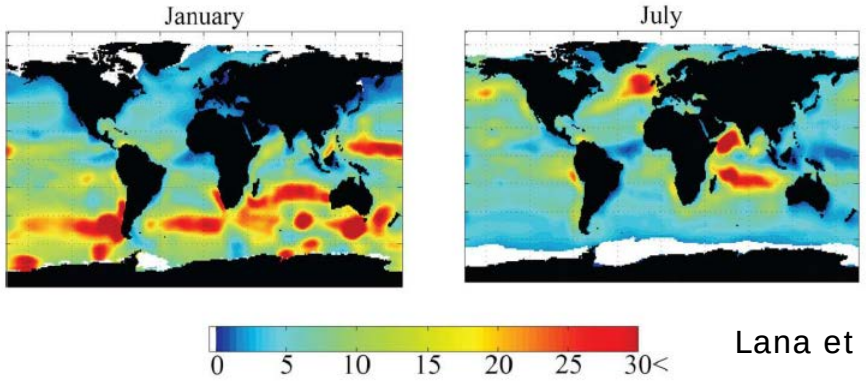


19.2 Tg S/yr



25.5 using $T_{2\text{-}m}$

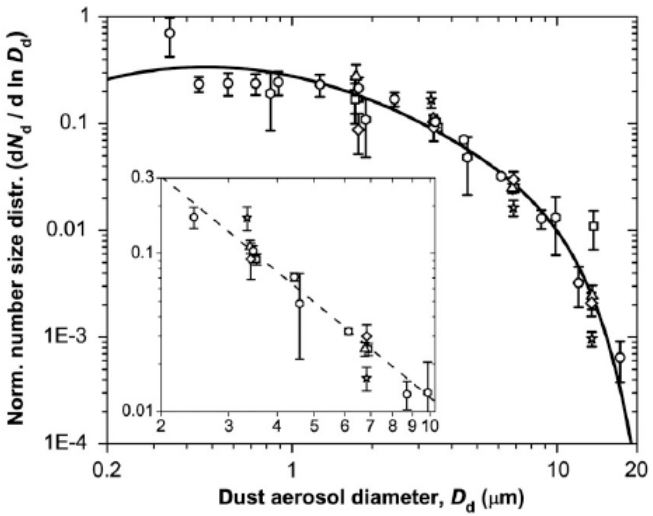
(26.1 using SST)

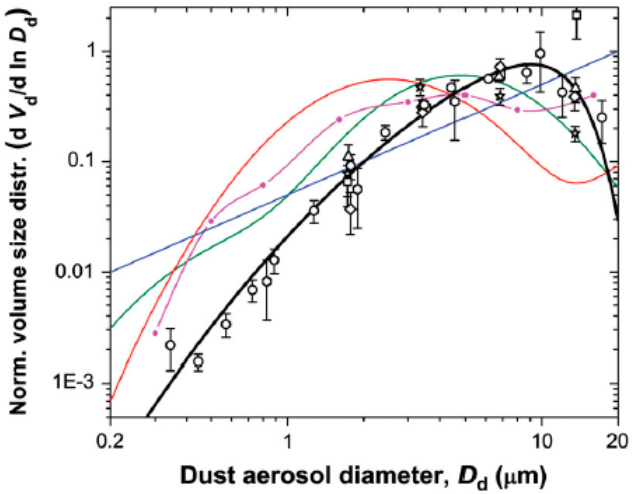


28.1

Lana et al. (2011)

Dust source size distribution

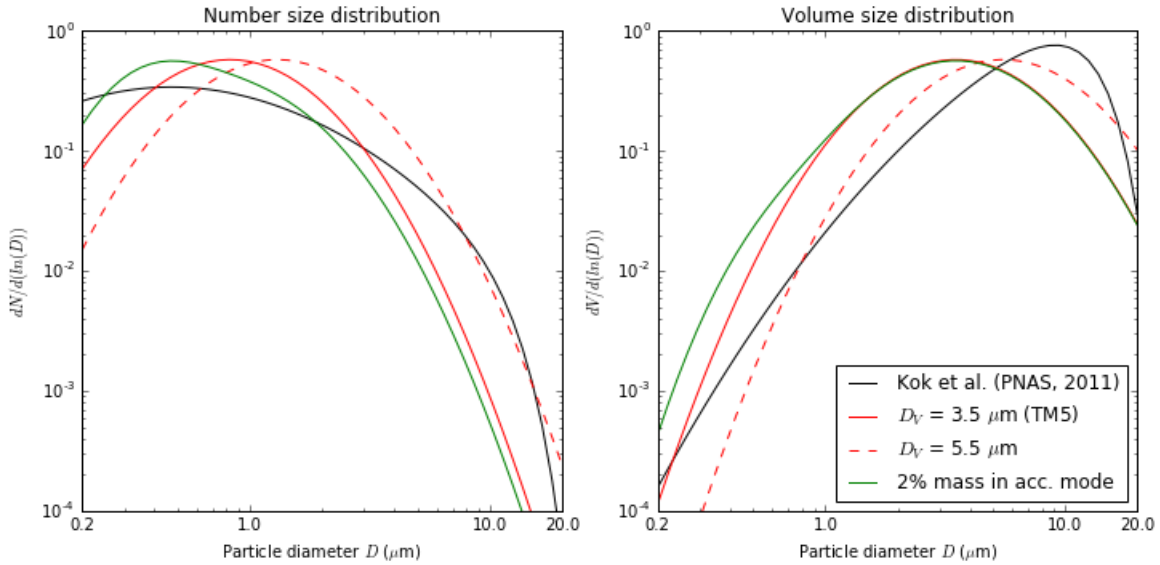




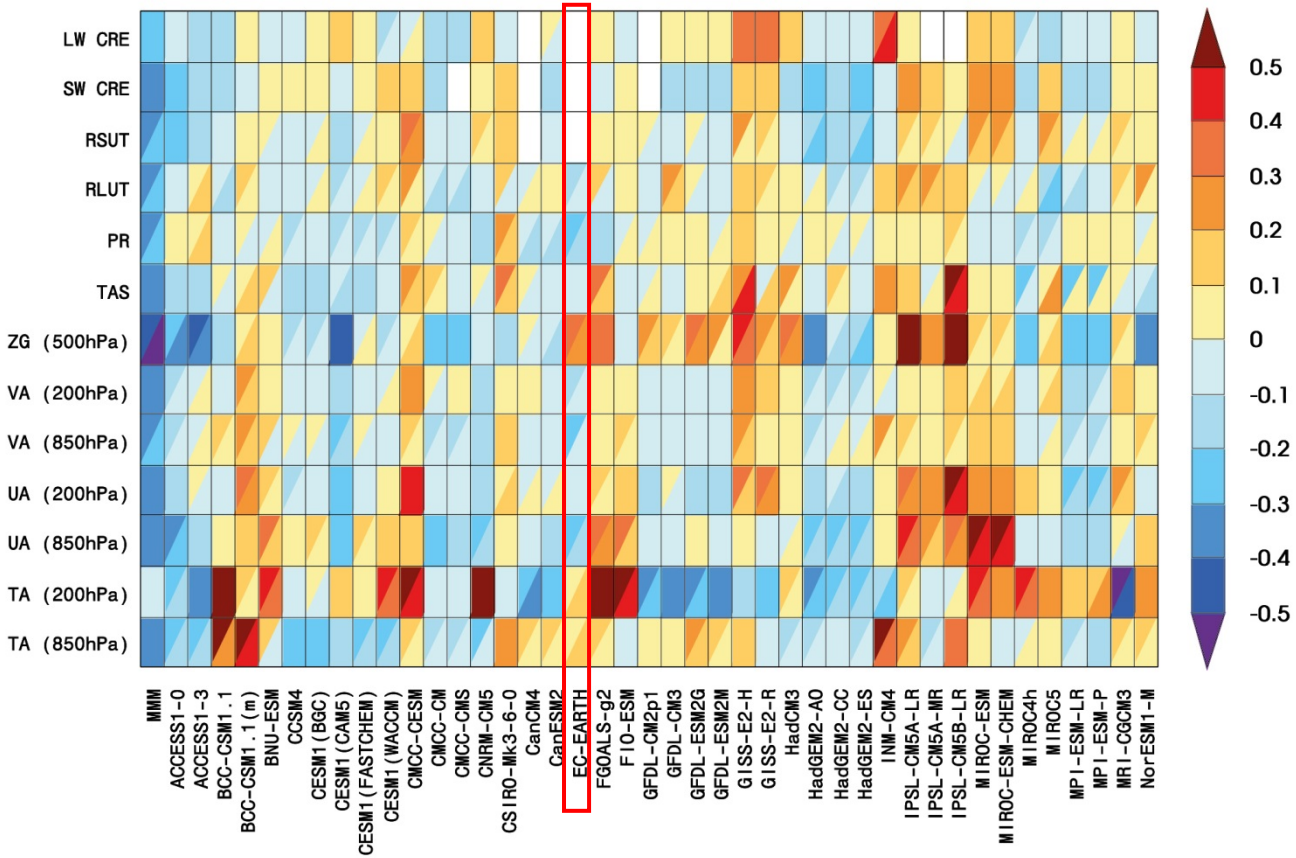
$$\frac{dN_d}{d\ln D_d} = \frac{1}{c_N D_d^2}\left[1+\mathrm{erf}\left(\frac{\ln(D_d/\bar{D}_s)}{\sqrt{2}\ln\sigma_s}\right)\right]\exp\left[-\left(\frac{D_d}{\lambda}\right)^3\right]$$

$$\frac{dV_d}{d\ln D_d} = \frac{D_d}{c_V}\left[1+\mathrm{erf}\left(\frac{\ln(D_d/\bar{D}_s)}{\sqrt{2}\ln\sigma_s}\right)\right]\exp\left[-\left(\frac{D_d}{\lambda}\right)^3\right]$$

Kok et al. (2011)



Evaluation of CMIP5 Models



Relative error measures, based on 1980-2005 climatologies from the historical simulations (Flato et al., AR5)

AOD in AeroCom Phase III Models vs. AERONET (monthly)