Community Earth System Model CESM

Chemistry-Climate Working Group
Current Status – June 2017

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Chemistry-Climate Working Group Session – June 22, 2017

CESM2-Chemistry for CMIP6

CESM2 (CAM6 with MAM4 modal aerosol scheme)

- WACCM: TSMLT (troposphere-stratosphere-mesosphere-lower thermosphere) chemistry
- Expanded tropospheric chemistry ("T1" - speciated aromatics, updated isoprene and terpenes oxidation, new organic nitrates)
- New SOA-VBS framework
- Prognostic volcanoes
- Atmospheric nitrogen deposited to land model
- CMIP6 emissions *** corrected June 2017 ***
- Multiple emissions files per species can be read at runtime

CESM2 special issue in AGU – JGR, JAMES, etc.

CMIP6: AerChemMIP

Other features of CESM2

- Compsets for WACCM and CAM-chem
- CAM-chem uses TS mechanism
- New nitrate aerosol scheme
- Online fire model in CLM, coupled to atmospheric chemistry
- Many features not scientifically released yet

CESM1.2.2

CAM4-chem and CAM5-chem, scientific release

CESM1.1.1

CAM4-chem, CCMI version includes some non-released updates now in CESM1.2 and CESM2

Chemistry Updates

Improved treatment of SOA precursors:

- Replace lumped aromatic "TOLUENE" with specific BENZENE, TOLUENE, XYLENES
- Updates to isoprene oxidation scheme
- Updated oxidation of terpenes: replaced "C10H16" with MTERP ($C_{10}H_{16}$), BCARY ($C_{15}H_{24}$)
  or
  speciated monoterpenes (APIN, BPIN, MYRC, LIMON) and MBO
- Improved treatment of organic nitrates (replace ONIT with more specific nitrates from alkanes, isoprene, etc.)

Development Plans

Refine and test:

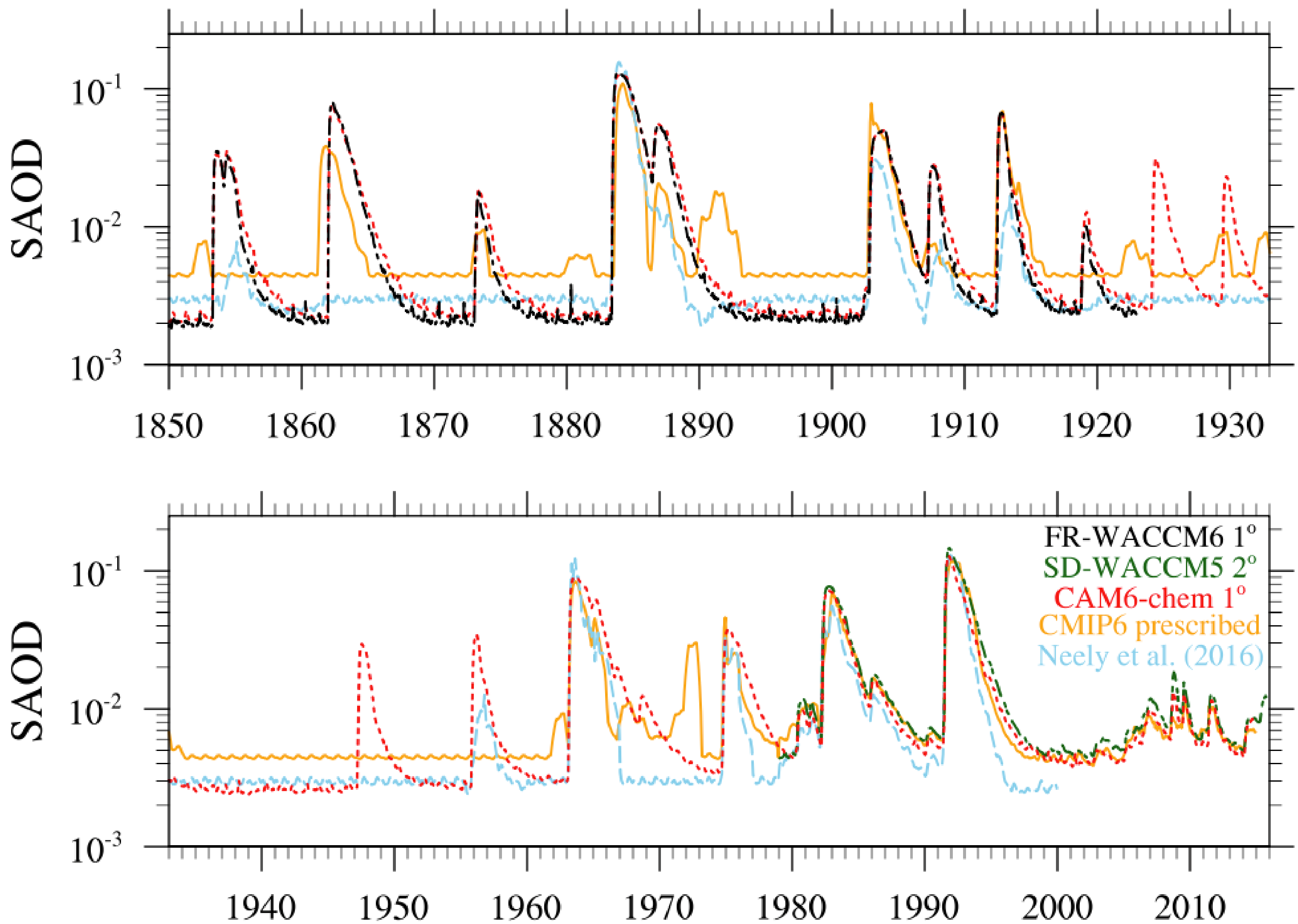
- Nitrate aerosol in MAM
- Brown Carbon
- Aerosol dry deposition
- Specified Dynamics simulations, MERRA2, 56→32L
- Interactive fire emissions (from CLM-fire)
- Update chemistry post-processing for diagnostics
- SOA-VBS in CESM2 (including differences for low and high NOx)
- Port VSL halogen chemistry to CESM2

New developments:

- FAST-J/CLOUD-J and/or online TUV
- Add polar halogen chemistry (Alfonso Saiz-Lopez)
- Further improve terpenes, aromatics chemistry (Becky Schwantes, NCAR)
- Test next generation dy. cores: Spectral Element/CSLAM and CESM-MPAS
- Update MEGAN biogenic emissions (in CLM) (Alex Guenther, UCI)
- Improved dust (Xiaohong Liu et al.)
- Interactive methane and other BGC compounds: DMS, …

Transient CESM2 CAMchem 1850-2015 (FHIST)

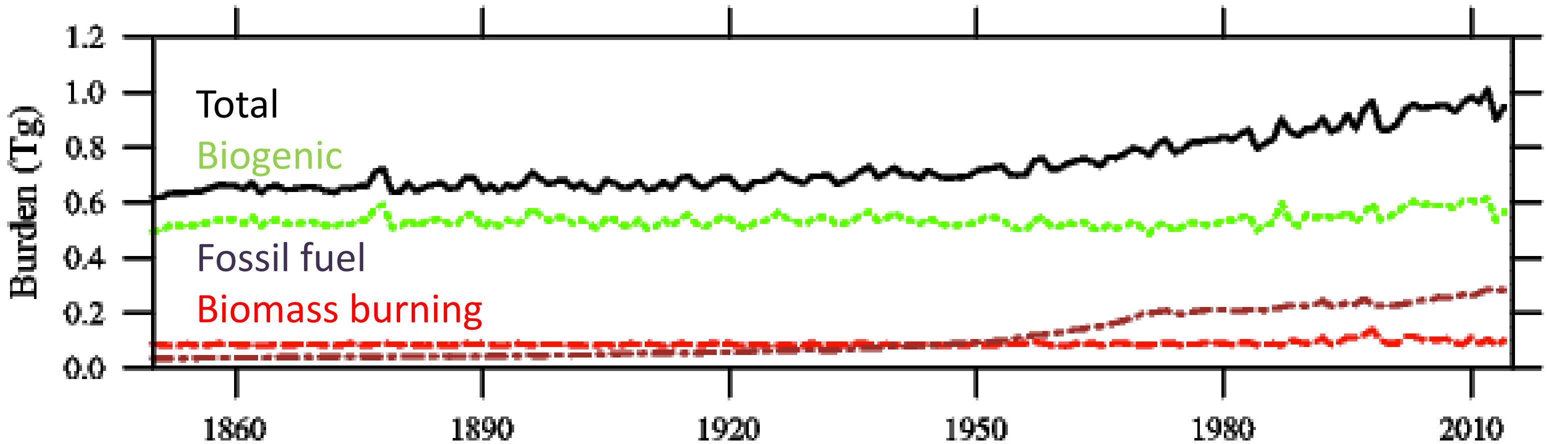
Stratospheric Aerosol Optical Depths



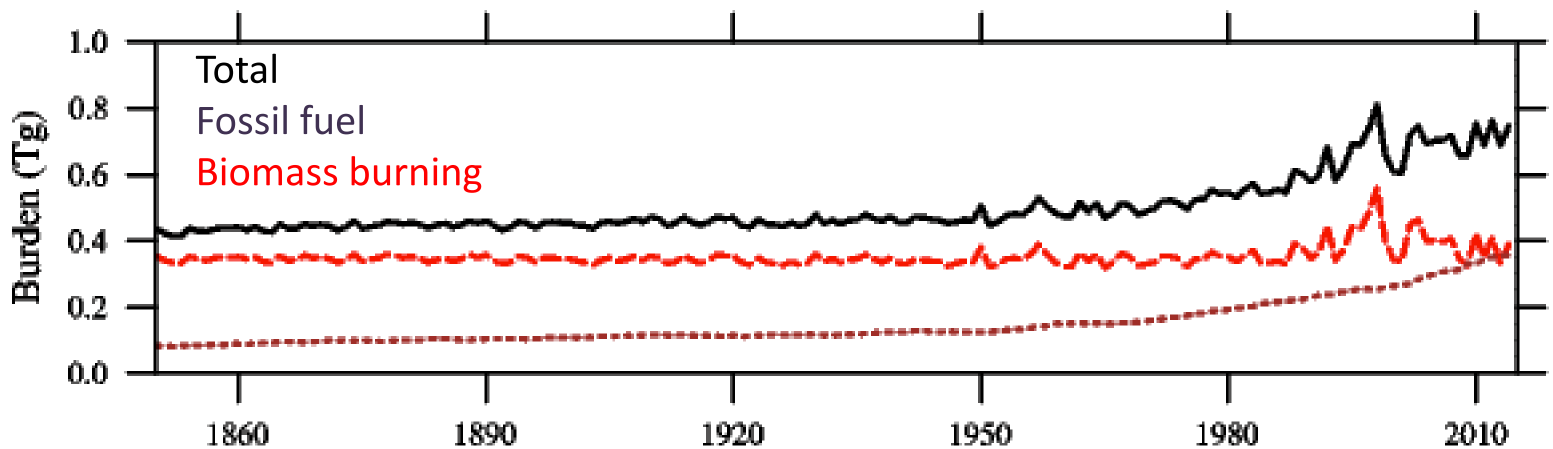
Transient CESM2 CAMchem 1850-2015 (FHIST)

Tropospheric Burden (< 200hPa)

Secondary Organic Aerosols



Primary Organic Aerosols



Comparison of POSIDON observations with CAM-chem

Obs: Sue Schauffler, Elliot Atlas, Maria Navarro (U.Miami/NCAR)
Model: Doug Kinnison, L. Emmons, S. Tilmes, J.-F. Lamarque, A. Saiz-Lopez

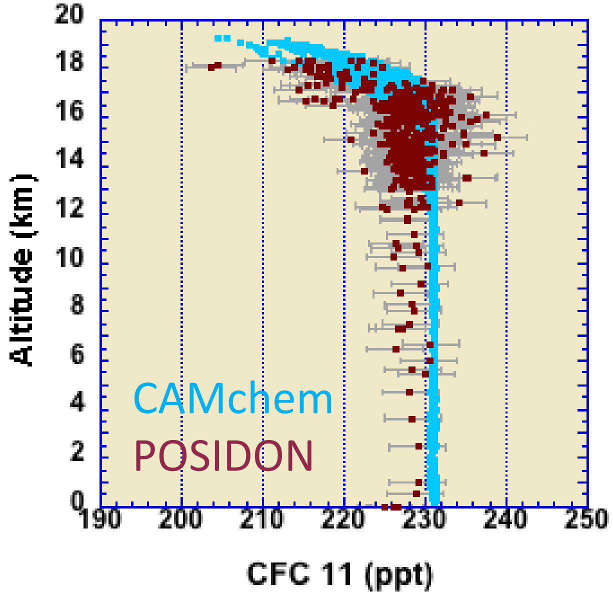
POSIDON: Pacific Oxidants, Sulfur, Ice, Dehydration, and cONvection

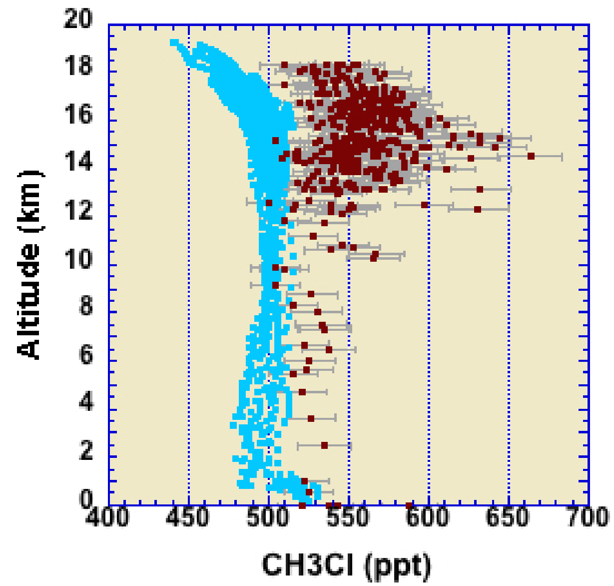
- Western Pacific, Oct 2016, NASA WB-57
- Whole Air Samples provide numerous HFCs, VOCs

CESM1.1.1. CAM-chem (CCMI) + Short-lived Halogens

- Includes Short-lived halogens chemistry from Ordonez et al., 2012, Saiz-Lopez et al., 2014 and Fernandez et al., 2014.
- Resolution: 1.0 degree horizontal
- Levels: 56 from surface to ~1 hPa
- Dynamics: Specified dynamics from GEOS5
- Long-lived organic halogens and methane: from Meinshausen, et al., 2016 with updates from S. Montzka for 2015 and 2016. Used for CMIP6 and includes a latitudinal gradient based on observations.

POSIDON provides great opportunity to evaluate new VSL chemistry!

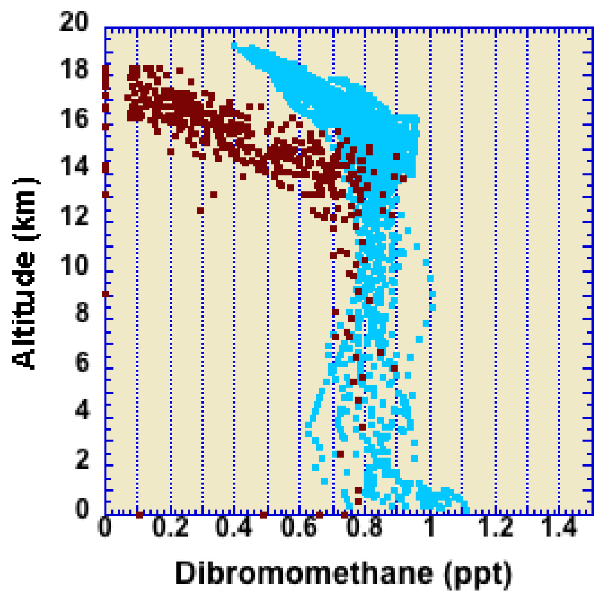


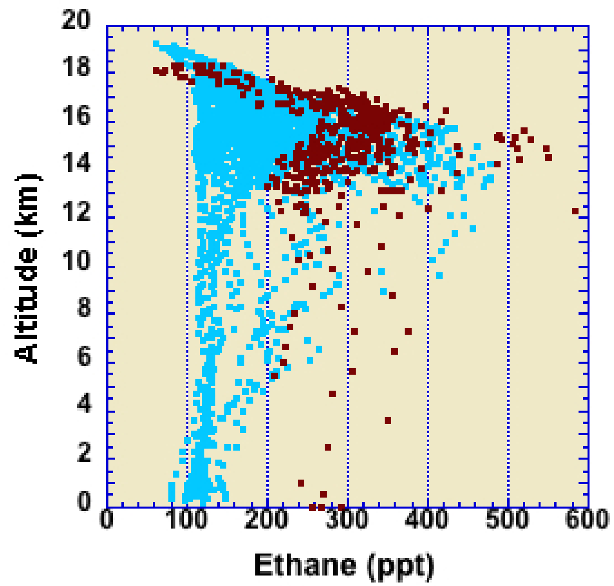


from lower boundary cond.

Most long-lived CFCs agree well

CH_3Cl drops quickly above BL – too little convection? Too much OH? Other???





from emissions

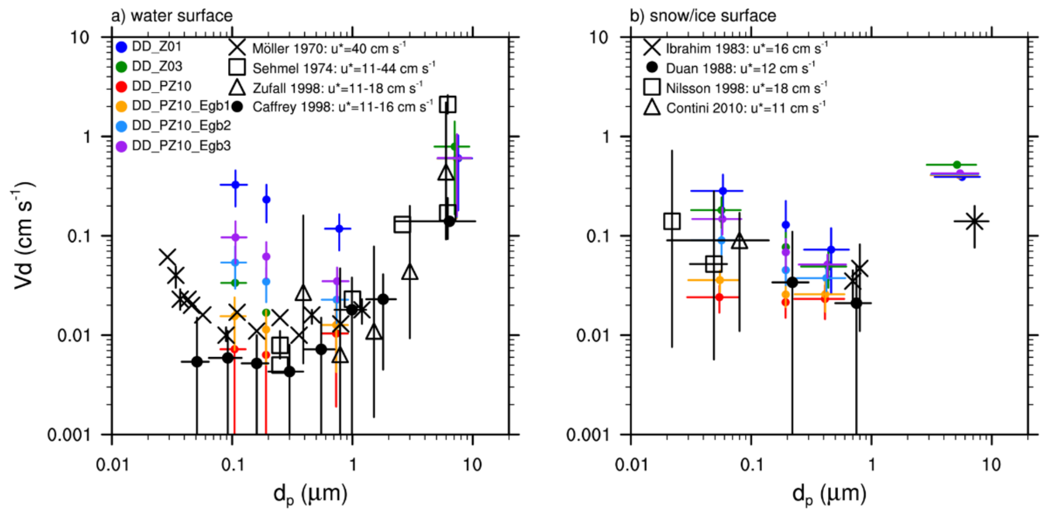
CH_2Br_2 model too high above 13km (inconsistent with CONTRAST comparison)

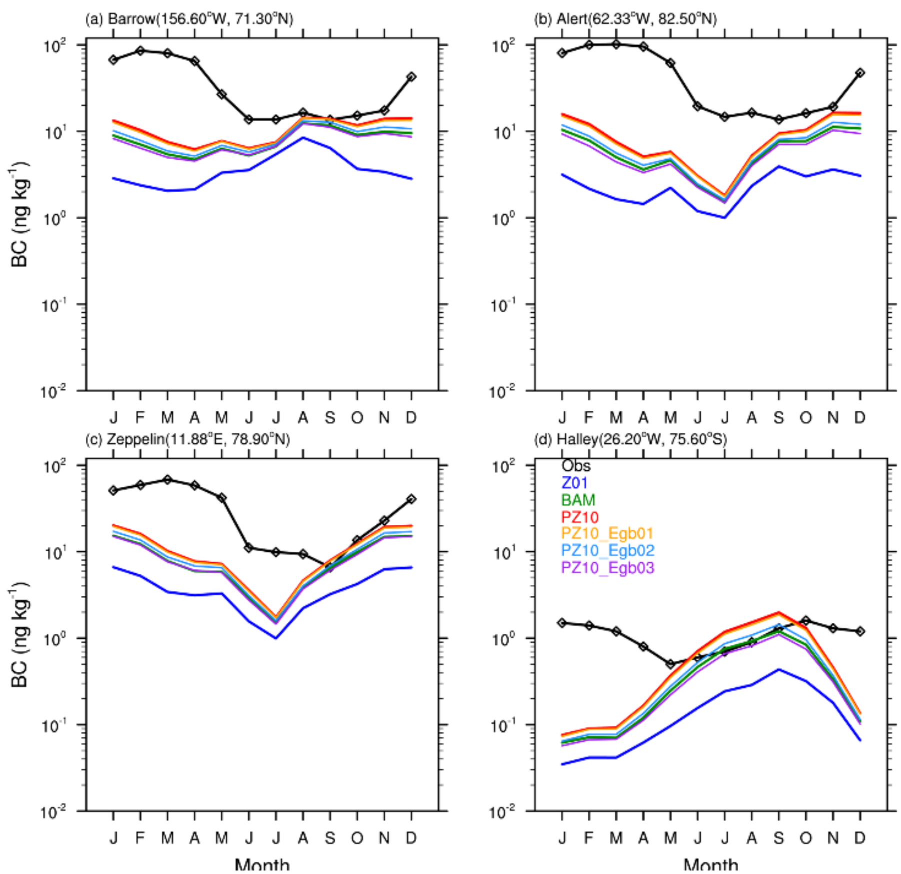
Ethane low (but somewhat better than prev. comp.)

Overall, CAM-chem compares well with WAS measurements from POSIDON, for long and short-lived components. Still looking into seasonal and latitudinal differences.

Aerosol Dry Deposition

- Current aerosol dry deposition scheme in CAM5 by **Zhang et al. (2001)** tends to overestimate the particle deposition in the fine mode significantly.





- We introduce **a new aerosol dry deposition scheme** by **Petroff and Zhang (2010)** into CAM5.

- The new scheme predicts **smaller dry deposition velocity for fine particles** in accumulation, Aitken, and primary carbon mode.

- Seasonality of BC concentration at Polar regions is improved.

Brown Carbon (BrC) in CAM5.4

BrC parameterization

From Saleh et al. (2014):

$1.7\ (\pm 0.2) + k_{OA} i =$
$1.7\ (\pm 0.2) + k_{OA,550}(550/\lambda)^{w}\ i$

$k_{OA,550} =$
$0.016 * \log_{10}(\text{BC-to-OA}) + 0.04$

$w = 0.21 / (\text{BC-to-OA} + 0.07)$

modal_aer_opt.F90

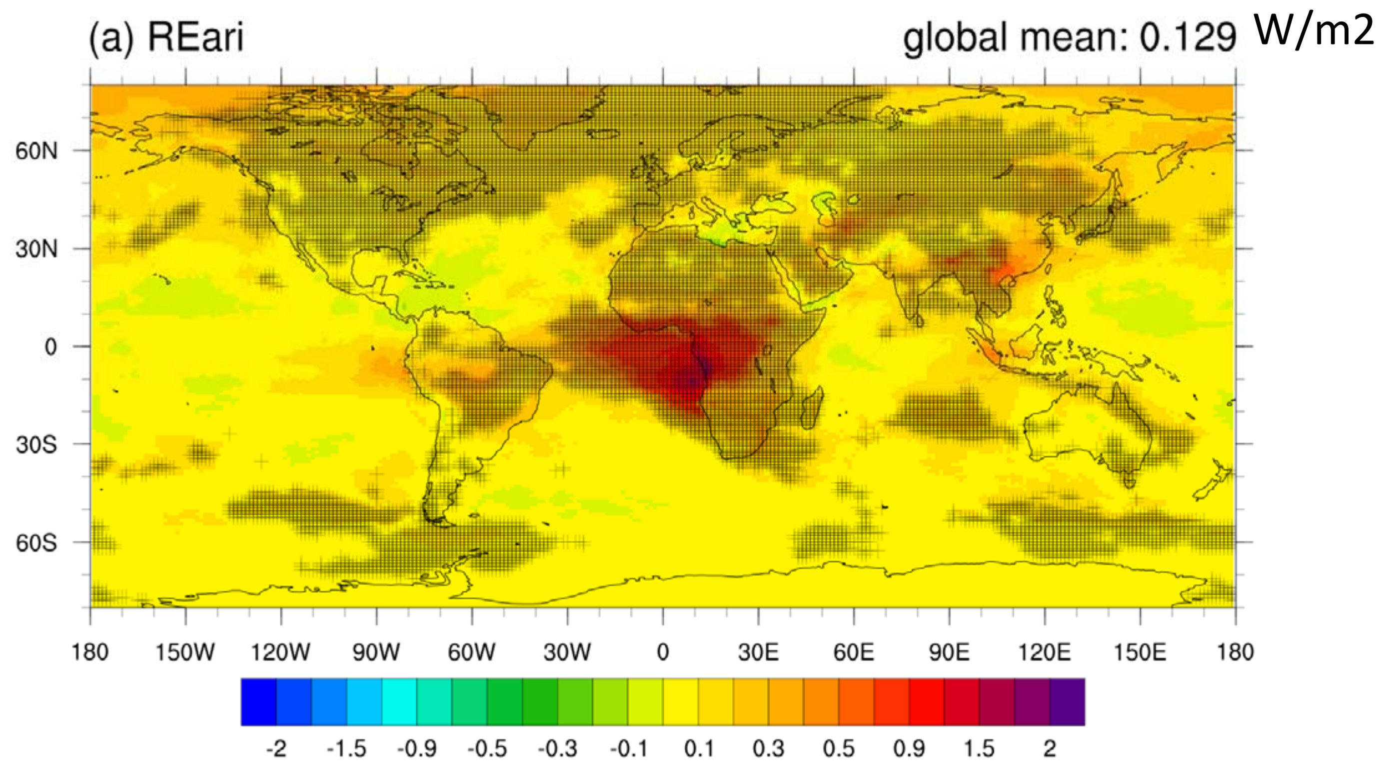
Call the different species optical properties at each mode, level, wavelength, lat/lon

Calculate bulk refractive index for each mode

Modify refractive index for *biomass burning* and *biofuel POM* based on BC-to-OA ratio calculated at each timestep, grid cell.

Saleh et al. (2014). "Brownness of Organics in Aerosols from Biomass Burning Linked to Their Black Carbon Content." , *Nature Geoscience* **7**, 647–650.

BrC Direct Radiative Effect



- Radiative effect due to aerosol-radiation interaction (REari) calculated using Ghan (2013) method
- Strongest positive radiative effects correspond to biomass and biofuel emission regions

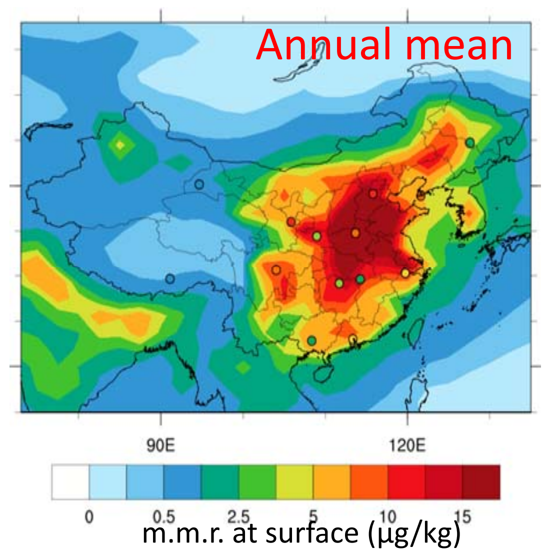
Nitrate in CAM5

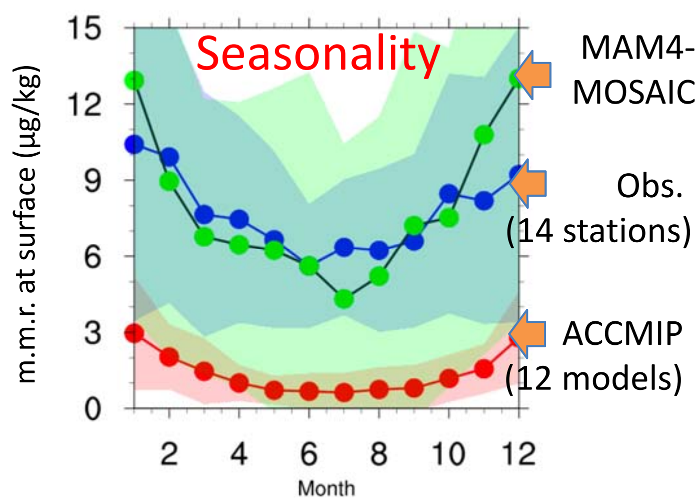
- In order to better treat NO3 aerosols, Model for Simulating Aerosol Interactions and Chemistry (MOSAIC) module [Zaveri et al., 2008] is coupled with MAM7 and MAM4 in CAM5.
- In the version of MAM coupled with MOSAIC, gas-aerosol exchange is treated by MOSAIC. The other processes are handled by MAM.

	BC	POM	SOA	SO4	NH4	NO3	Cl	Na	Dst	Ca	CO3	total
Acc.	X	X	X	X	X	X	X	X	X	X	X	11
Aitken			X	X	X	X	X	X				6
Coarse				X	X	X	X	X	X	X	X	8
P-Carb.	X	X										2

Red crosses: new aerosol tracers in MAM4-MOSAIC

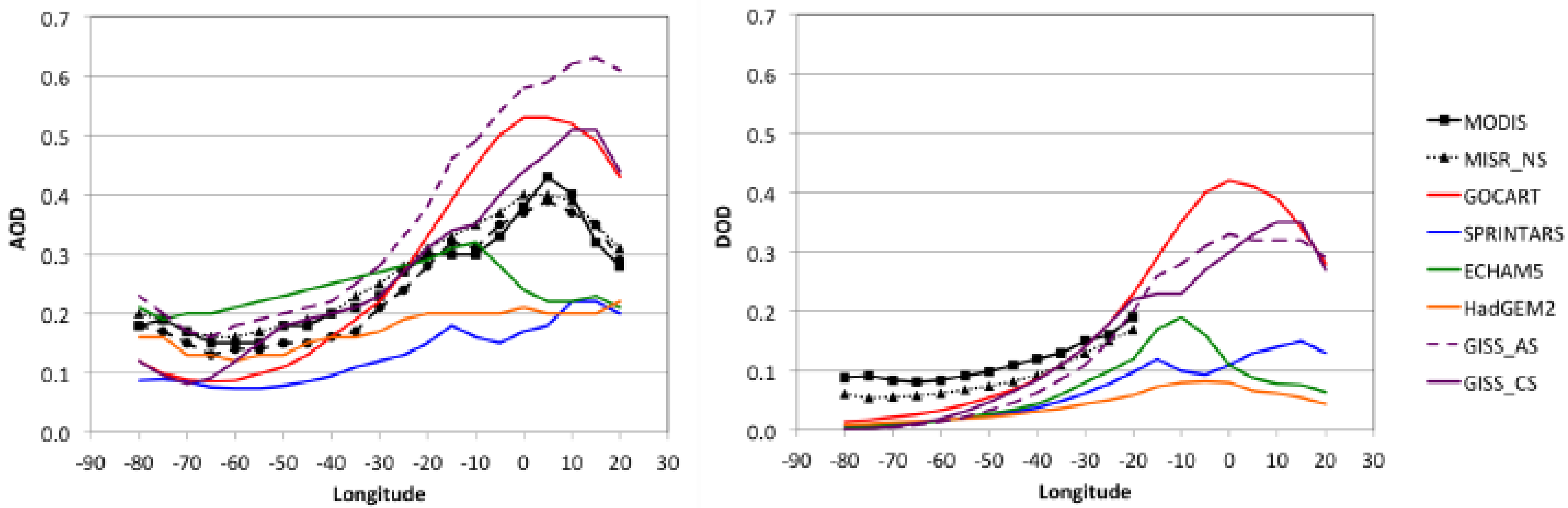
Modeled NO3 vs. observation over China





Dust Transport

Trans-Atlantic transport of North African dust aerosol

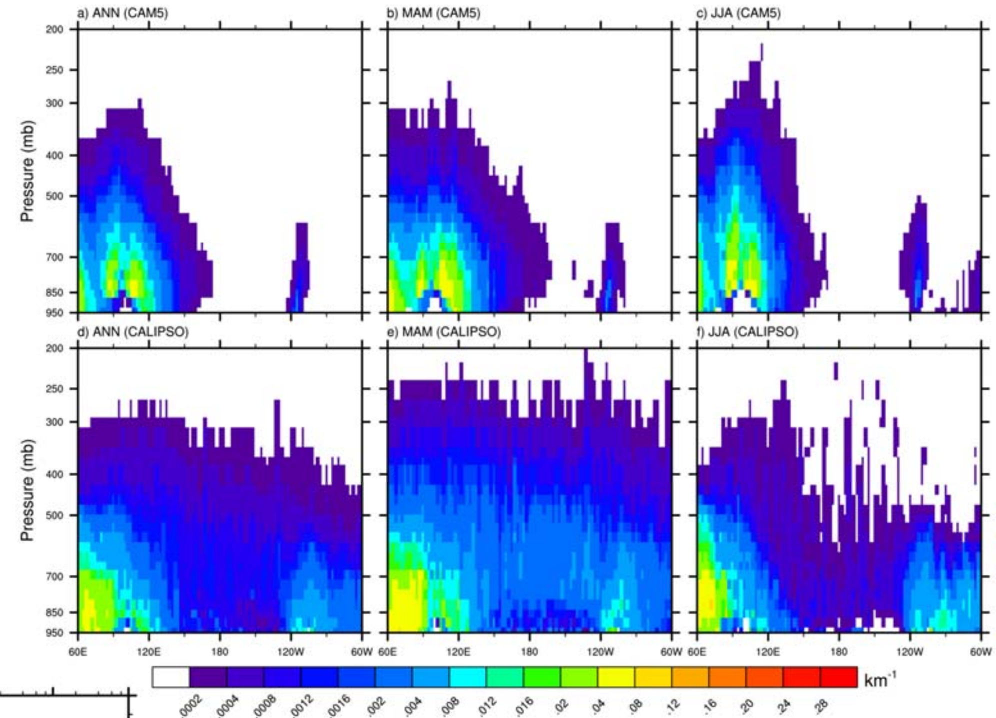


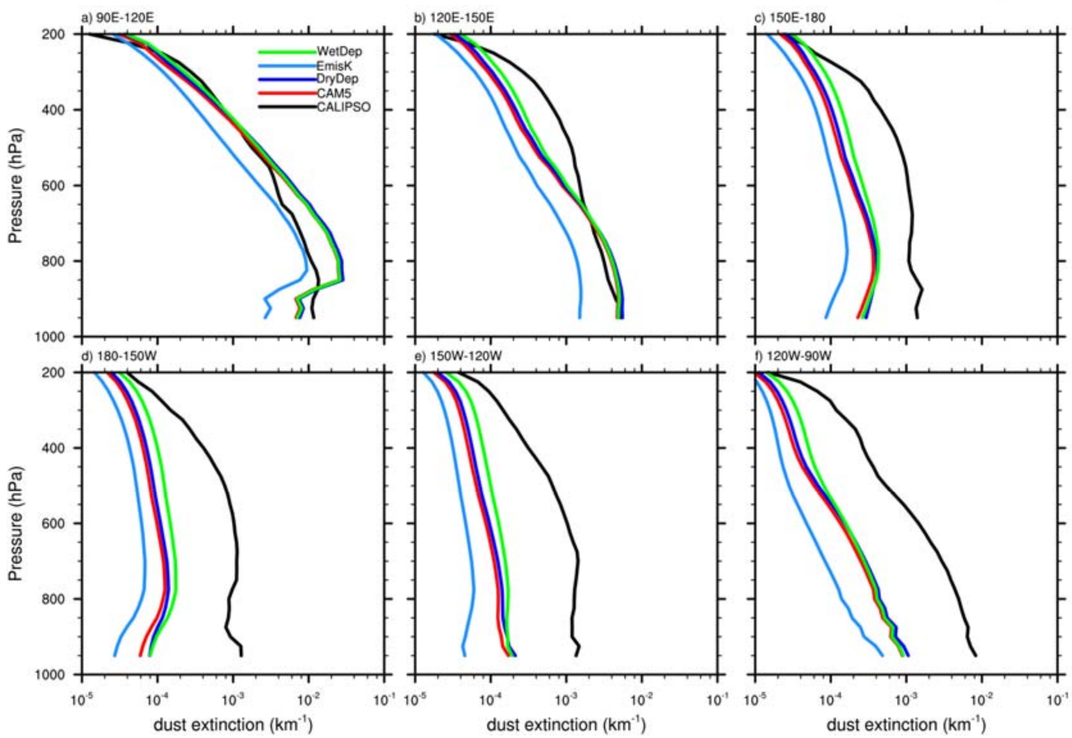
Kim et al. 2014

Dust Transport

- **CAM5 simulated dust extinction profiles are compared with a new dataset of global dust distributions** developed based on Calipso/CloudSat measurements (Luo et al. 2015a,b).

- **CAM5 significantly underestimates the dust transport across the Pacific**, failing to capture elevated high values of dust extinction.

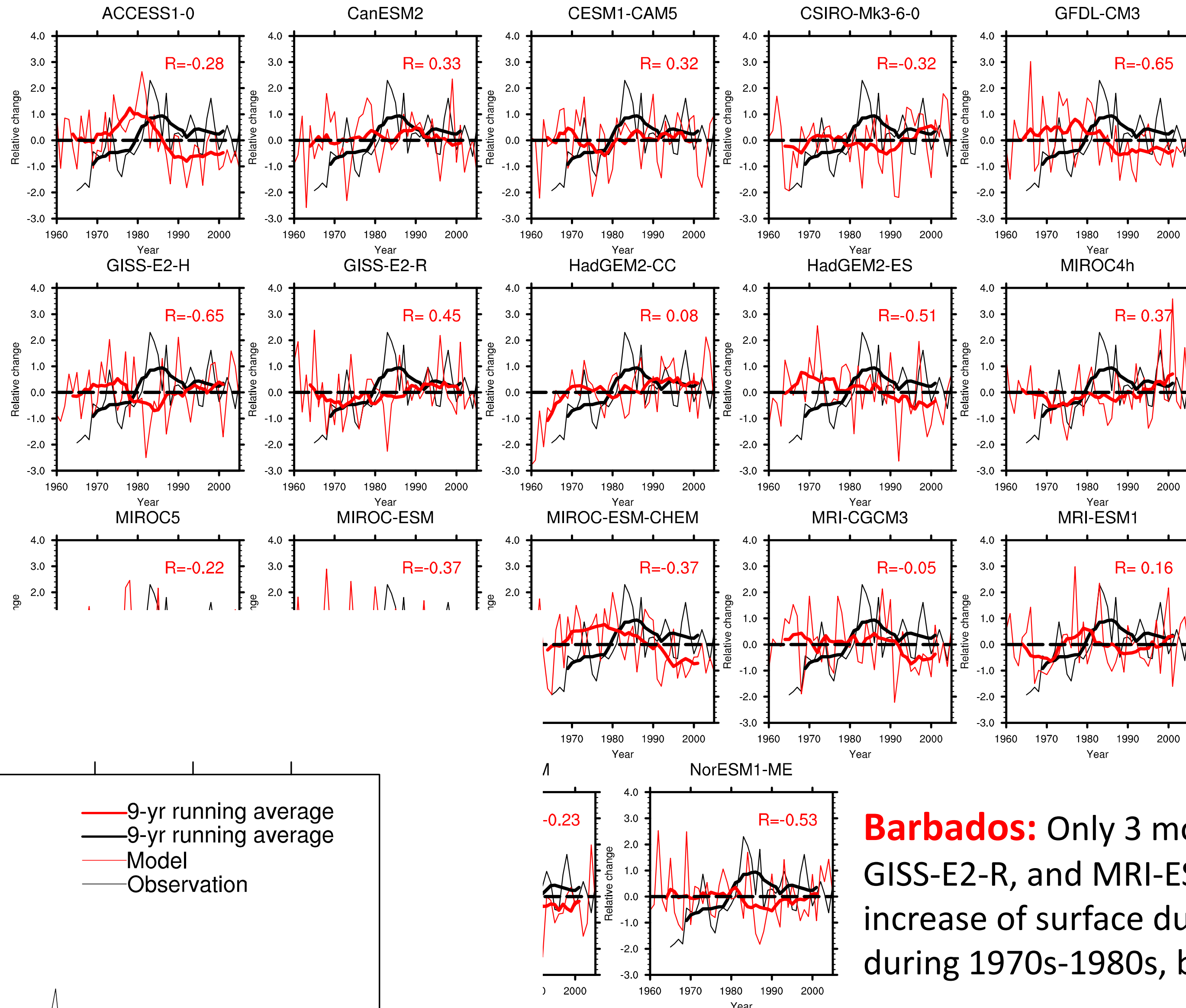


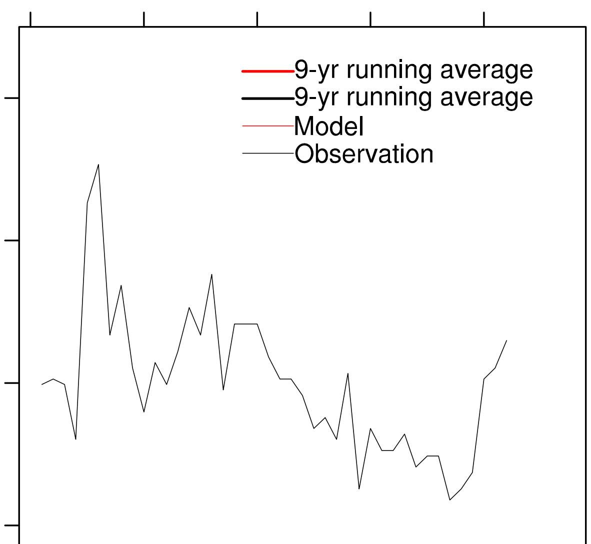


- Sensitivity experiments have been conducted to investigate processes (emission, dry deposition, wet deposition) that affect dust transport.

- A unified scheme for convective transport/wet scavenging of aerosols (Wang et al. 2013) will be tested.

Long-term variations of dust in CMIP5 models





Barbados: Only 3 models (CanESM2, GISS-E2-R, and MRI-ESM1) capture the increase of surface dust concentration during 1970s-1980s, but too weak.

al variations of dust aerosol in CMIP5 models (By