Overview of Energy Exascale Earth System Model (E3SM)

a new model from US Department of Energy
from Ruby Leung, E3SM Chief Scientist

- E3SM (formerly ACME) started with CESM v1 as E3SM v0
- E3SM v1 model components:
  - **Atmosphere (EAM)**: A fork of CAM5.3; increased vertical levels from 30 to 72; CLUBB + MG2; MAM4 aerosols; other minor improvements
  - **Ocean (MPAS-Ocean)**: A free surface ocean model with unstructured grid for variable resolution modeling
  - **Sea ice (MPAS-Sea Ice)**: An unstructured grid model with CICE physics
  - **Land ice (MPAS-Land Ice)**: An unstructured grid model with ice-ocean interactions beneath Antarctic ice sheet
  - **Land (ELM)**: A fork of CLM4.5; new soil hydrology; CNP cycle and other new biogeochemistry representations
  - **River (MOSART)**: A scale adaptive river transport model

E3SM v1 model configurations

- Three model configurations:
  - Low resolution: ~100 km (ne30) atmosphere/land; 60-30 km ocean/ice
  - High resolution: ~25 km (ne120) atmosphere/land; 18-6 km ocean/ice
  - Low resolution BGC: low resolution model + land and ocean BGC
- Model release:
  - E3SM v1 will initially be released with (1) a low resolution model configuration and DECK simulations and (2) a high resolution model configuration with a 1950s simulation – tentatively April 2018
  - E3SM v1 low resolution BGC will be released after completion of low resolution BGC experiments (TBD)

Planned simulations

- CMIP6 DECK experiments using low resolution configuration for ~ 3 ensemble members – tentatively completed by March 2018
- Water cycle experiments:
  - Full transient forcing simulations at low and high resolution for 1950-2050 (similar to HighResMIP)
  - Single transient forcing simulations at low and high resolution for 1950-2050
- BGC experiments (estimate carbon-climate and carbon-CO2 feedbacks):
  - (1) Preindustrial control simulation – 1850 for 250 years
  - (2) Transient forcing 1850-2100 with 1850 GHG concentrations
  - Same as (2), except including BGC influence of transient atmospheric CO2 concentration
  - Same as (2), except including full radiative effects of GHG

Community Earth System Model (CESM) for CMIP6

NCAR
NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

NSF

U.S. DEPARTMENT OF ENERGY
Office of Science

Target CESM2 and CMIP6 versions (2018-2019):

DECK and most MIP simulations:

1. AOGCM physical climate (atmos 1°, ocean 1° , low-top) with biogeochemistry (CO_2 emission and/or concentration driven)
2. + atmospheric chemistry (atmos 1°, ocean 1° , high-top; WACCM)

DECK + ScenarioMIP tier 1 simulations:

1. AOGCM physical climate (atmos 1/4°, ocean 1° , low-top)

(currently with CESM1 at this resolution: time slice, PI control 100 years, 20th century; planning on RCP8.5 and RCP2.6 in 2017)

Low-top: 32 levels up to 40 km
High-top: 72 levels up to 150 km

2019-2020: simulations with AOGCM atmos 1/4° , ocean 1/10° : 50 year PI control; 20C and RCP8.5

(currently with CESM1 at this resolution have 50 year perpetual 2000 and RCP8.5 to 2050)

CESM2 participation in CMIP6

MIP acronym	MIP name	Name of primary sponsor(s)
AerChemMIP	Aerosols and Chemistry Model Intercomparison Project	Lamarque/Emmons/Liu (Wyoming)
C4MIP	Coupled Climate Carbon Cycle Model Intercomparison Project	Lindsay
CFMIP	Cloud Feedback Model Intercomparison Project	Medeiros/Kay (CU)/Klein (LLNL)
DAMIP	Detection and Attribution Model Intercomparison Project	Tebaldi/Arblaster
DCPP	Decadal Climate Prediction Project	Danabasoglu/Meehl
GeoMIP	Geoengineering Model Intercomparison Project	Tilmes/Mills
GMMIP	Global Monsoons Model Intercomparison Project	Fasullo/Kinter (COLA)
HighResMIP	High Resolution Model Intercomparison Project	Neale/Bacmeister
ISMIP6	Ice Sheet Model Intercomparison Project for CMIP6	Lipscomb (LANL)/Otto-Bliesner
LS3MIP	Land Surface, Snow and Soil Moisture	D. Lawrence
LUMIP	Land-Use Model Intercomparison Project	D. Lawrence/P. Lawrence
OMIP/OCMIP	Ocean Model Intercomparison Project	Danabasoglu/Lindsay
PMIP	Palaeoclimate Modelling Intercomparison Project	Otto-Bliesner
RFMIP	Radiative Forcing Model Intercomparison Project	Gettelman/Neale
ScenarioMIP	Scenario Model Intercomparison Project	Meehl/O'Neill/P. Lawrence
VolMIP	Volcanic Forcings Model Intercomparison Project	Mills/Otto-Bliesner
Data only		
CORDEX	Coordinated Regional Climate Downscaling Experiment	Mearns/Gutowski
DynVar	Dynamics and Variability of the Stratosphere-Troposphere System	Marsh
SIMIP	Sea-Ice Model Intercomparison Project	Bailey/Holland/Jahn (CU)/Hunke (LANL)
VIAAB	VIA Advisory Board for CMIP6	Mearns/O'Neill
! Tentative subject to resources		
FAFMIP	Flux-Anomaly-Forced Model Intercomparison Project	Aixue Hu
NonlinMIP	Nonlinear climate responses to CO2	

OMIP: ocean - sea-ice simulation at 1/10 degree resolution forced with the JRA-55 atmospheric data sets (in addition to 1 deg ocean)

Improved performance for CESM2 on current and upcoming supercomputers has been a focus over the last year

Throughput estimates for CESM2:

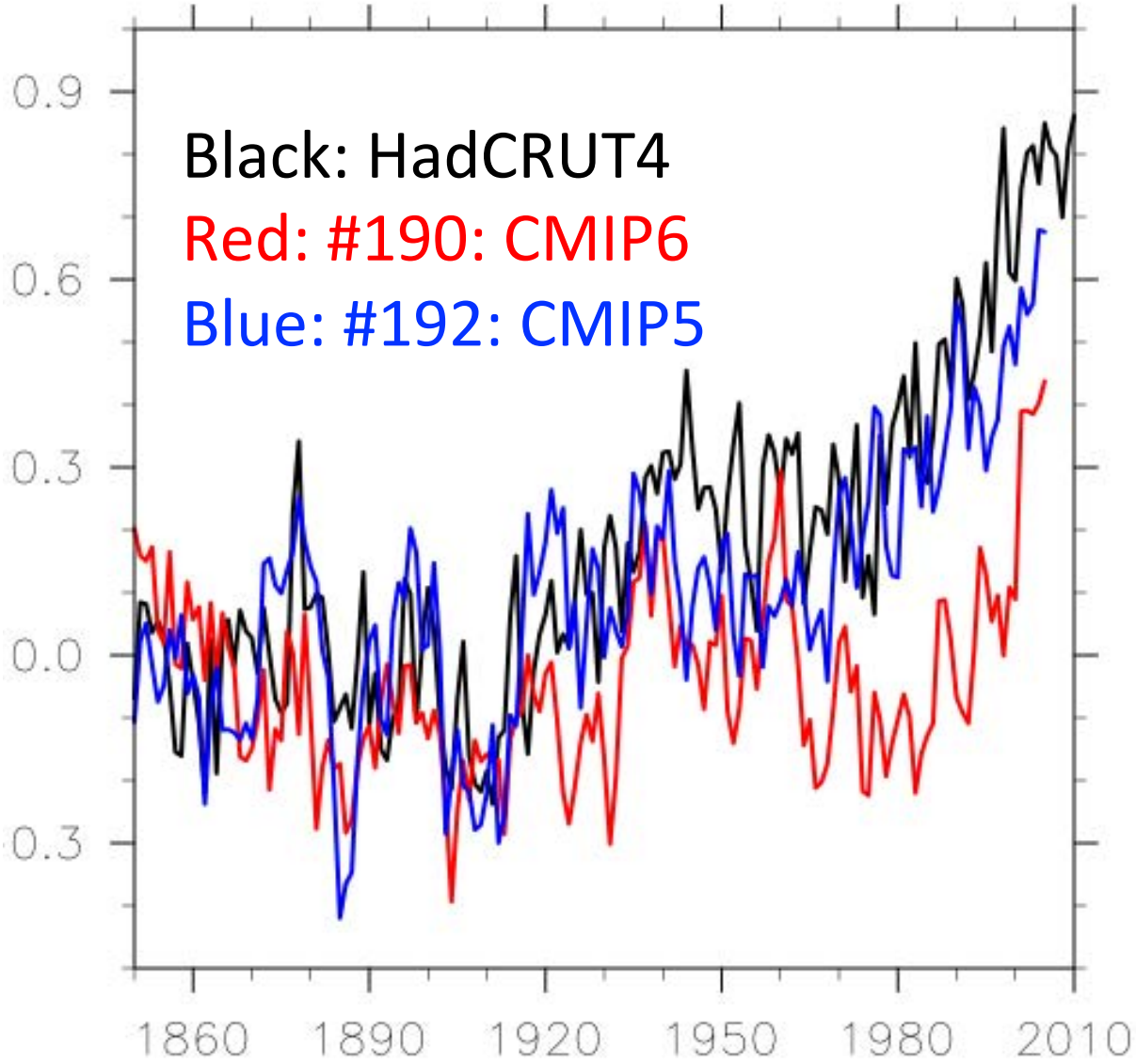
1. 1 deg atmos 1 deg ocean standard CESM2: ~20 model years per calendar day on NCAR Yellowstone (climate sensitivity ~4.5°)

2. 1/4 deg atmos 1 deg ocean CESM2: ~2.4 model years per calendar day (on Blue Waters and Mira)

3. high top 1 deg WACCM, 72 layers ~6 model years per day on NCAR Yellowstone.

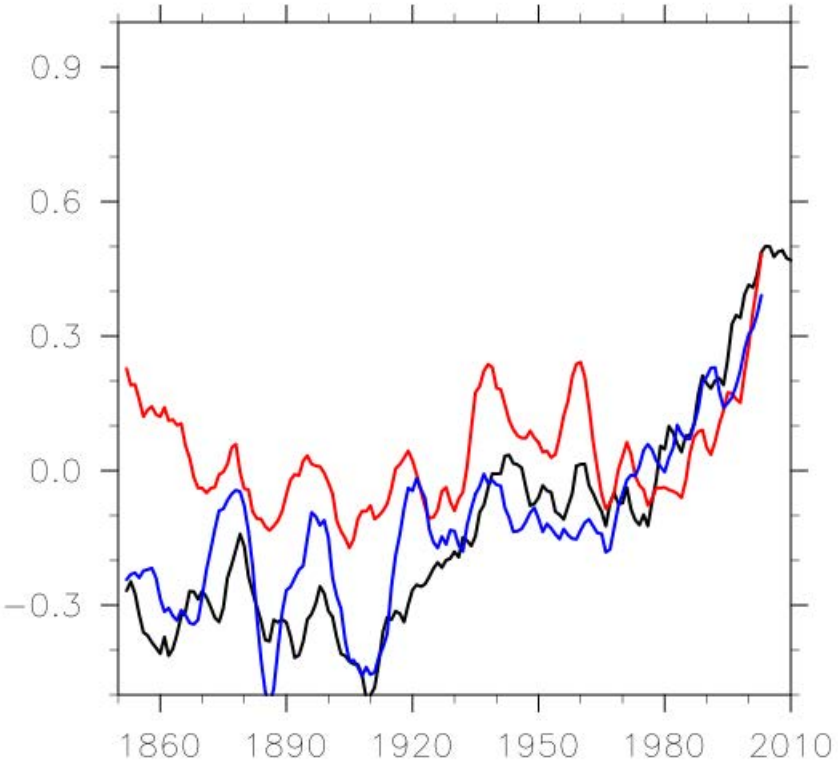
4. 1/4 deg atmos 1/10 deg ocean CESM2: ~1 model year per day (on Blue Waters)

Current status of CESM2: issue when switching CMIP5 -> 6 emissions

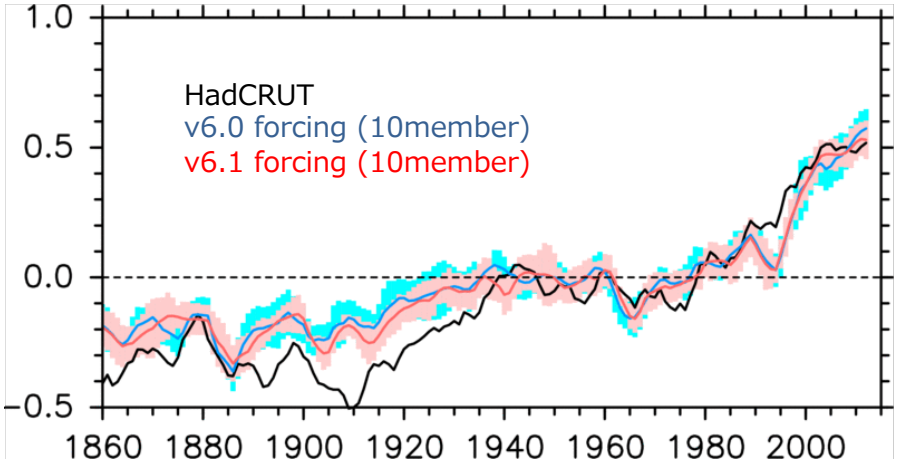


CESM2 Global surface temperature (anomaly w.r.t.1850-1880)

Prognostic aerosols
Same model (CESM2) run with CMIP5 SO2 emissions and CMIP6 SO2 emissions

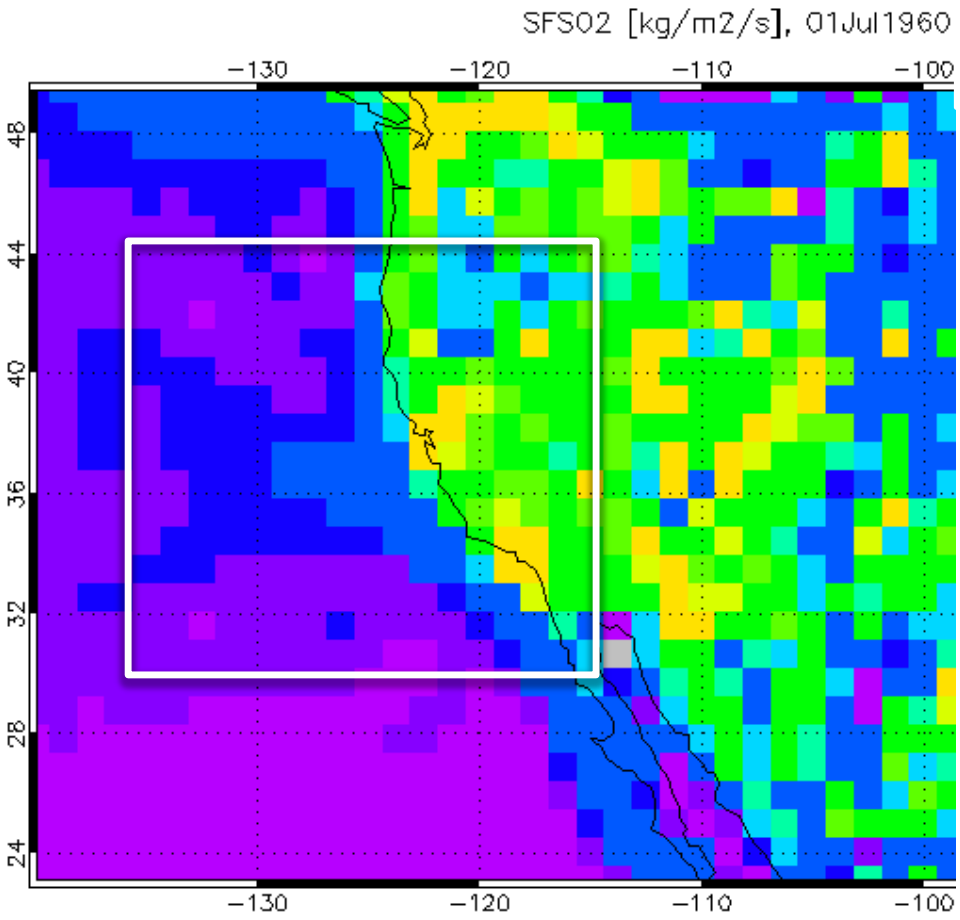


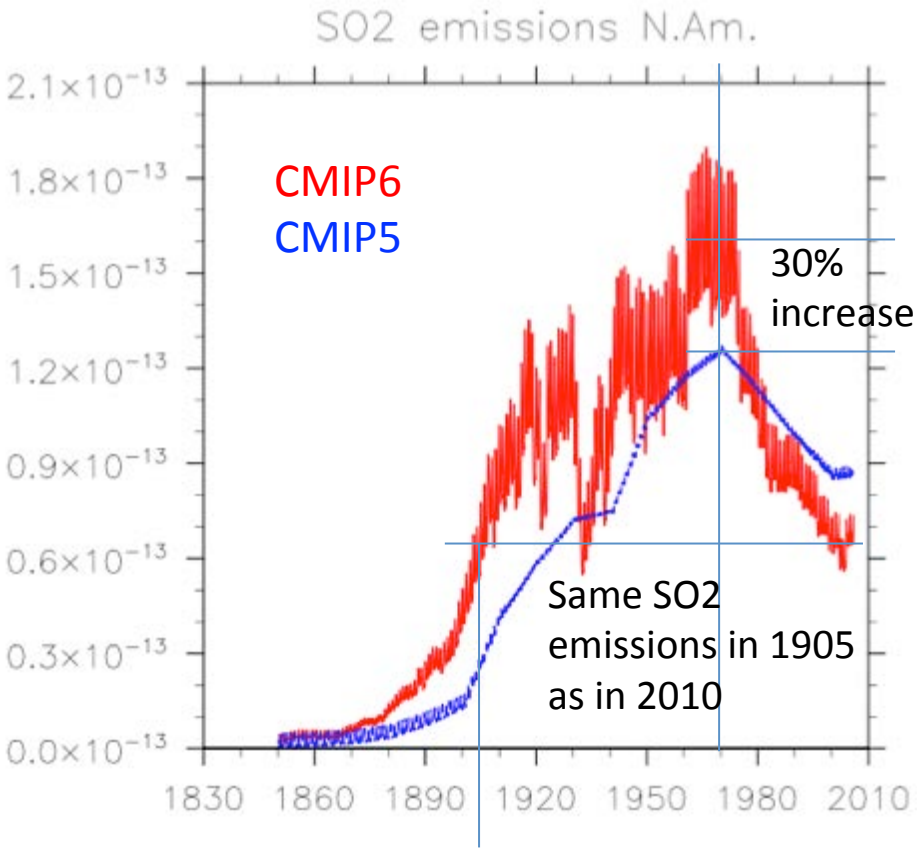
CESM2
Red: CMIP6
Blue: CMIP5
5 year running mean
1961-1980 base period



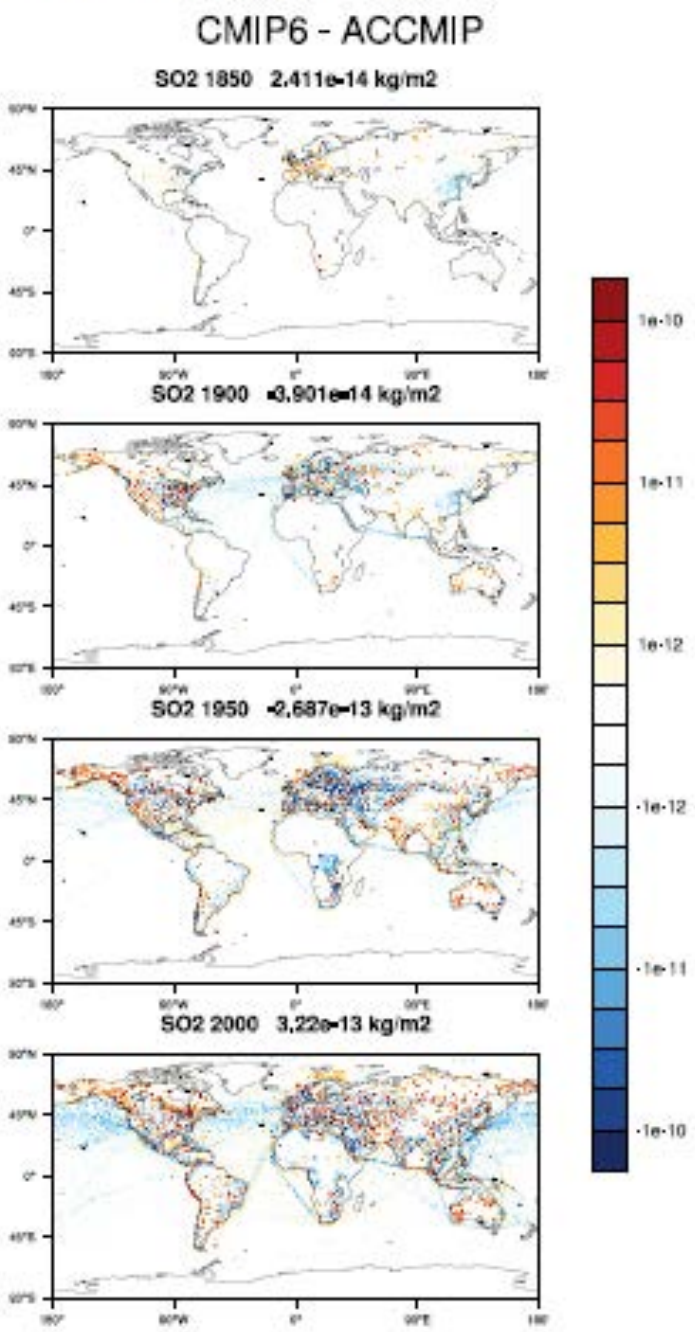
MIROC6

Differences in emissions



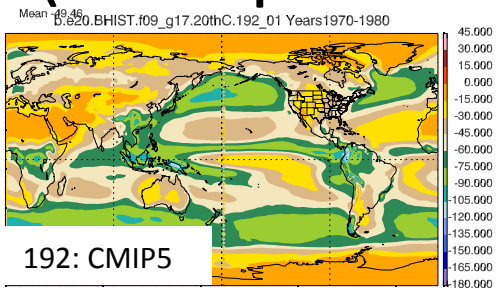


DIFFERENCE CMIP6-CMIP5

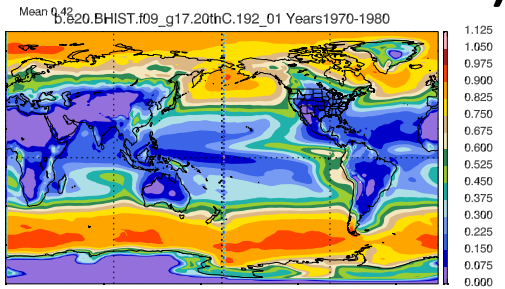


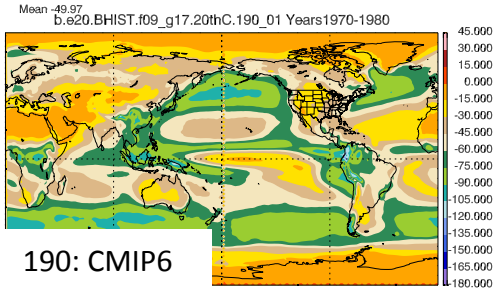
Michou, M.,
Geosci. Model Dev. Discuss.,
https://doi.org/10.5194/gmd-2017-43-SC2, 2017

Differences in forcing CMIP5 -> CMIP6 (example for decade 1970-1980)

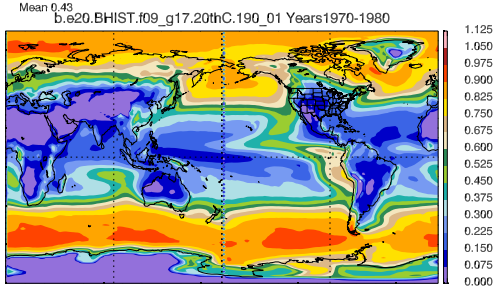


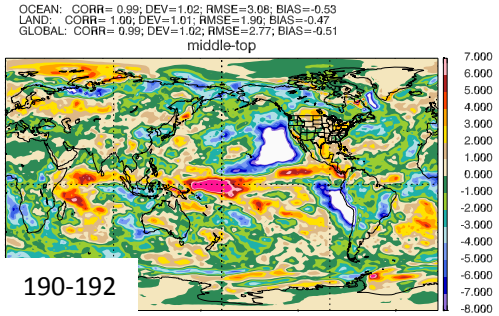
192: CMIP5



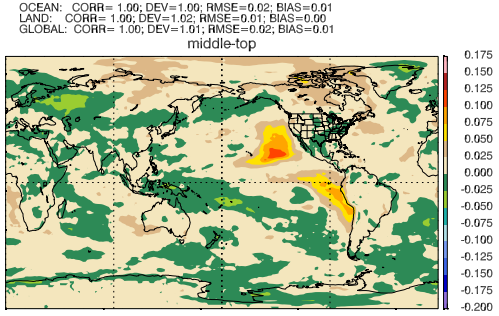


190: CMIP6





190-192

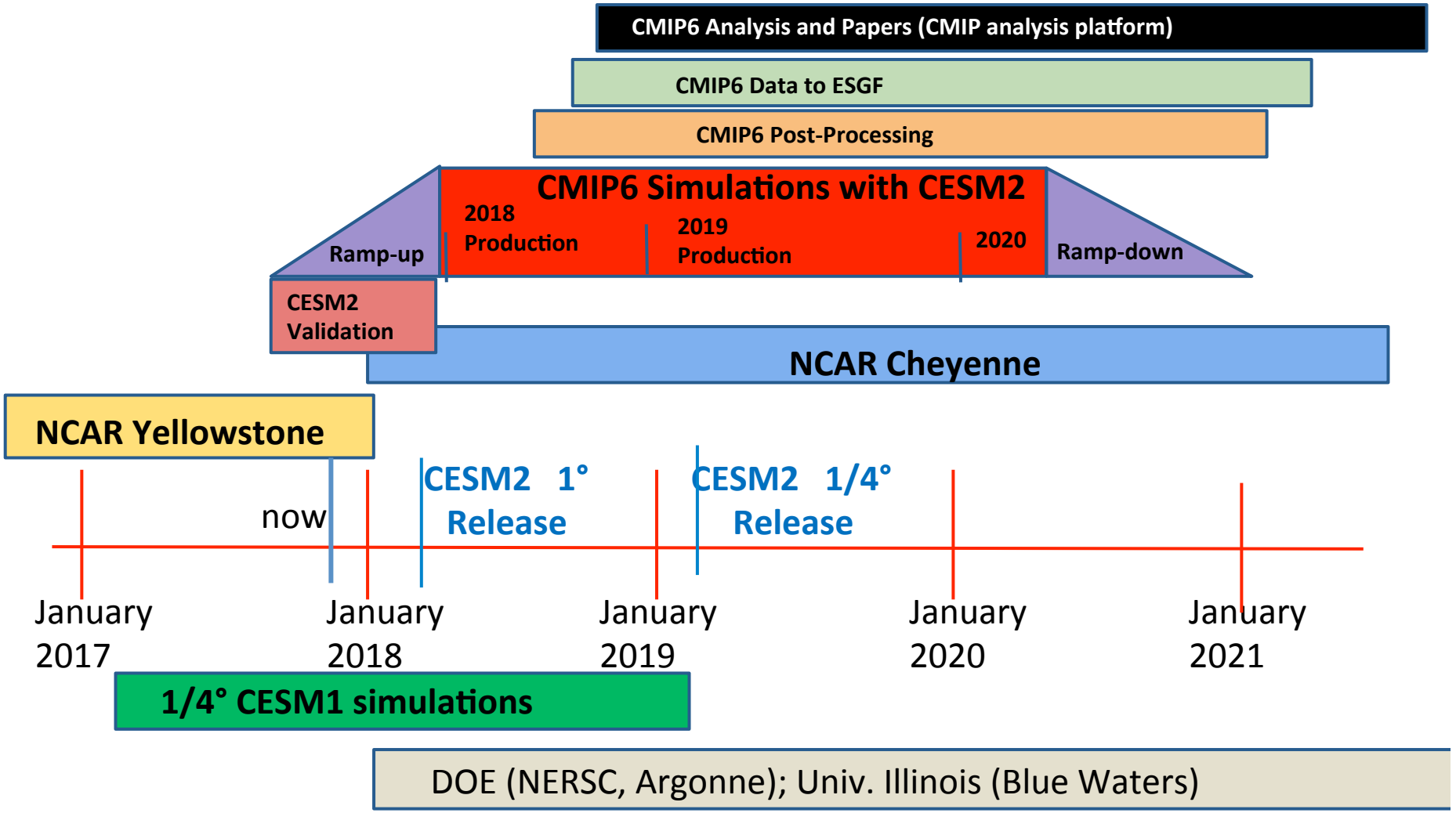


Annual SWCF (W/m^2)

Annual Low Clouds (%)

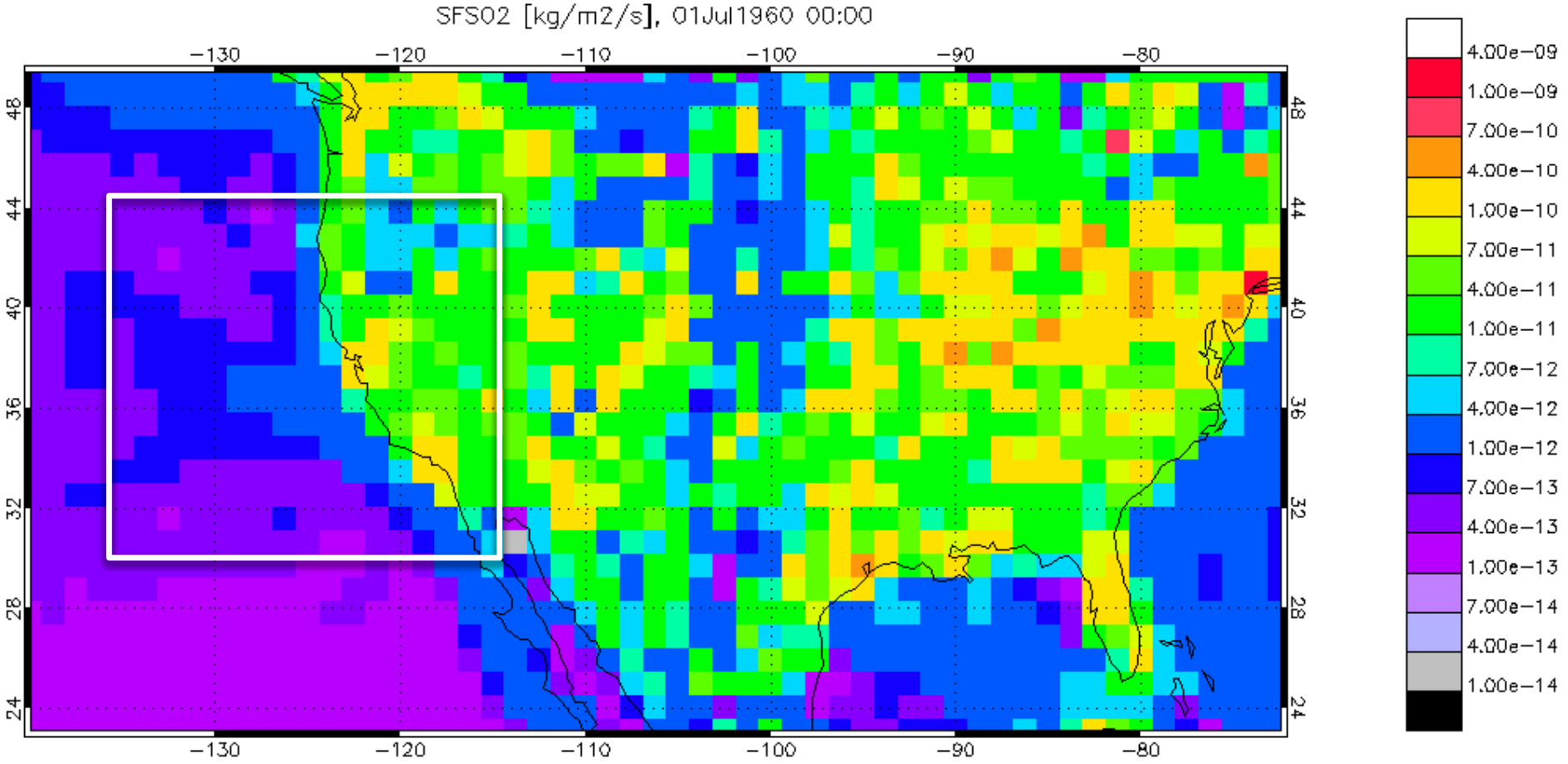
Slide from J. Bacmeister

NCAR CMIP6 Planning



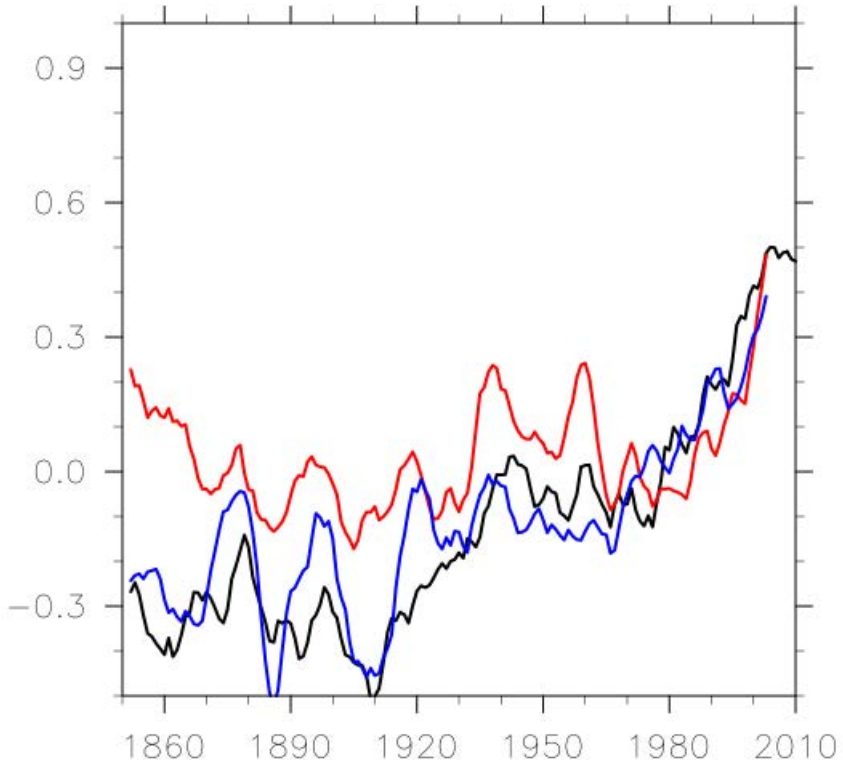
END

Differences in emissions



CMIP6 DECK + Tier 1 Requirements

- CESM2 1^{o} coupled/uncoupled versions
  - CESM2-BGC: ≈18,000
  - CESM2 WACCM-BGC: ≈ 5,500
  - Total cost: ≈ 240M core-hours
- CESM2 1/4^{o} coupled/uncoupled version
  - CESM2 1/4°: ≈ 400 years
  - Total cost: ≈ 50M core-hours



CESM2
Red: CMIP6
Blue: CMIP5
5 year running mean
1961-1980 base period

Model improvements (1): examples from MIROC6 (Update from MIROC5)

AGCM (T85L81)

- Shallow convection
- High-Top TOA (3hPa → 0.004 hPa)
- SOA, Oceanic organic Aerosol
- Scattering by non-spherical cloud ice
- Non-orographic GWD
- modified CMT, water leak fixed, etc.

OGCM

- Higher resolutions (1.4°L50 → 1°L63)
- Tripole coordinate
- Improved TKE estimate under sea-ice

Land Surface Model

- Subgrid snow cover distribution
- Wet land due to snow melting

Current status of CMIP6 experiments (Done, On-going, Preparing)

DECK

CMIP6 historical simulations using v6.0/v6.1 forcing datasets

FAFMIP

DAMIP

OMIP

CFMIP

DCPP

HighresMIP

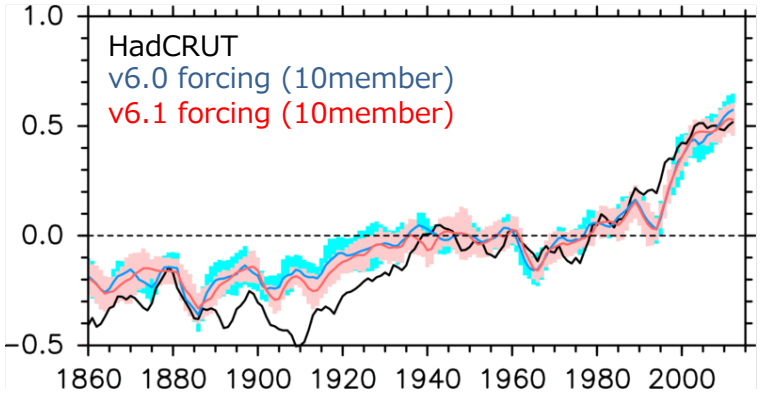
GMMIP

LS3MIP

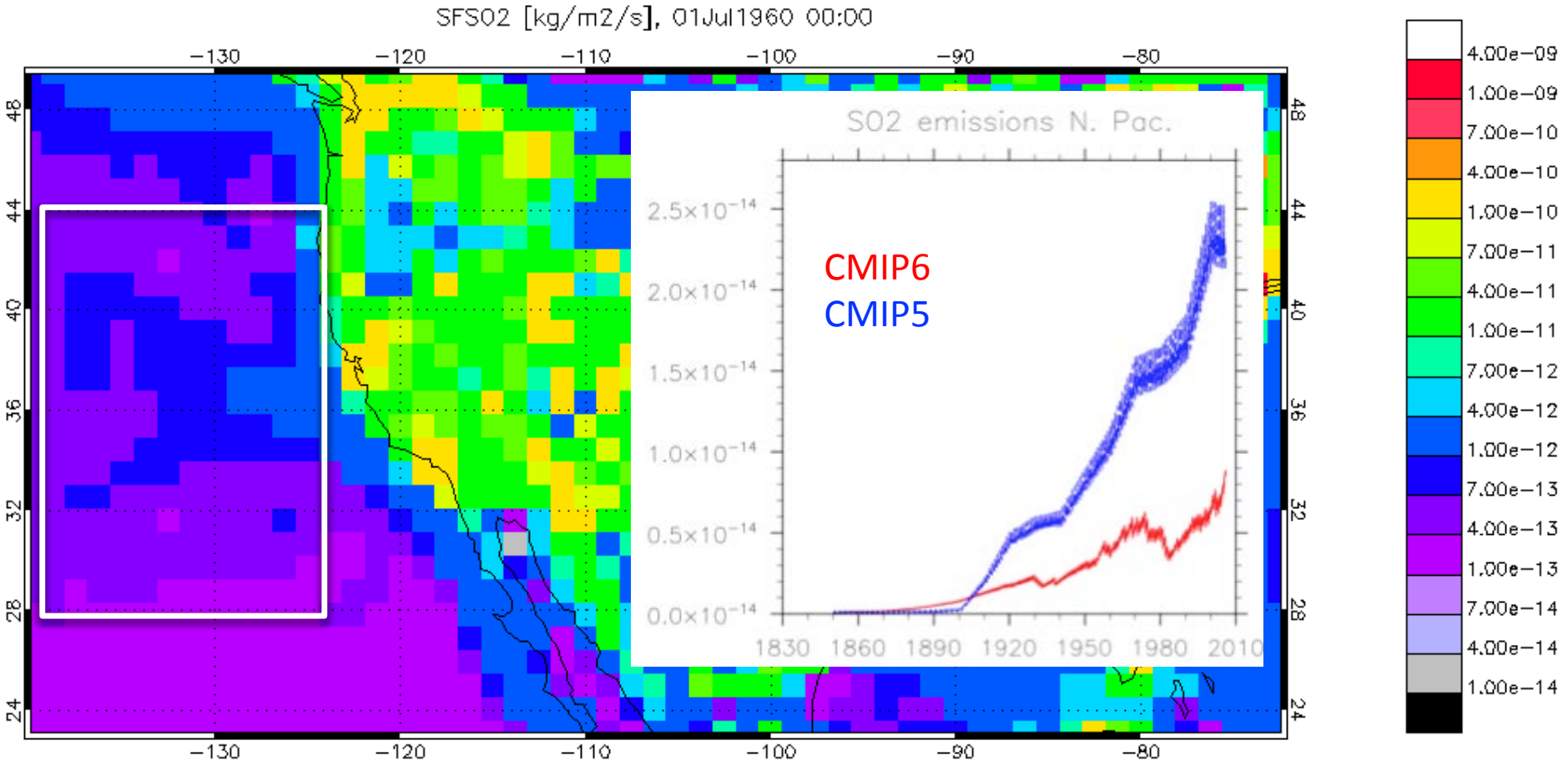
RFMIP

ScenarioMIP

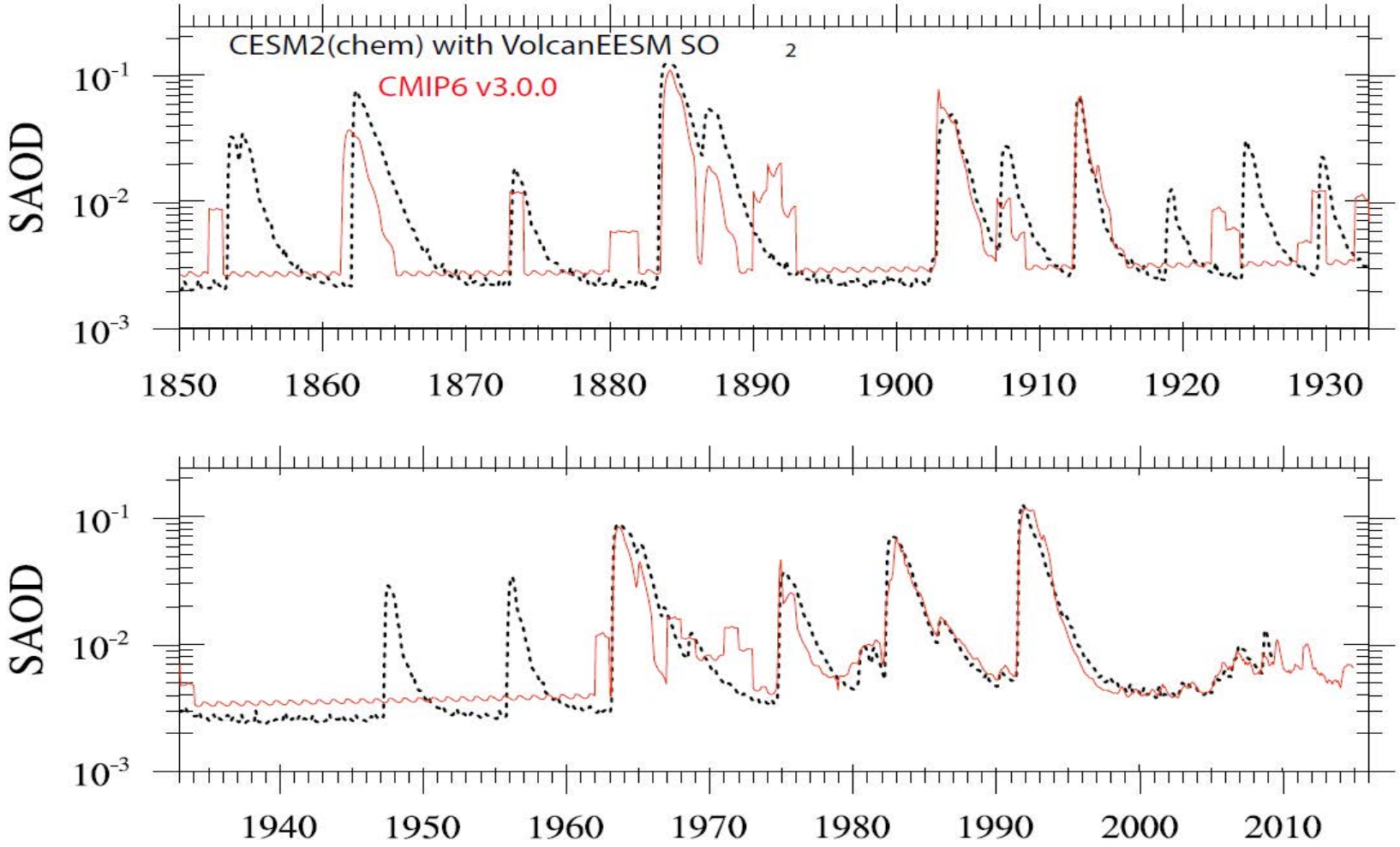
Global-mean SAT (5yr running-mean; Ref: 1961/90)



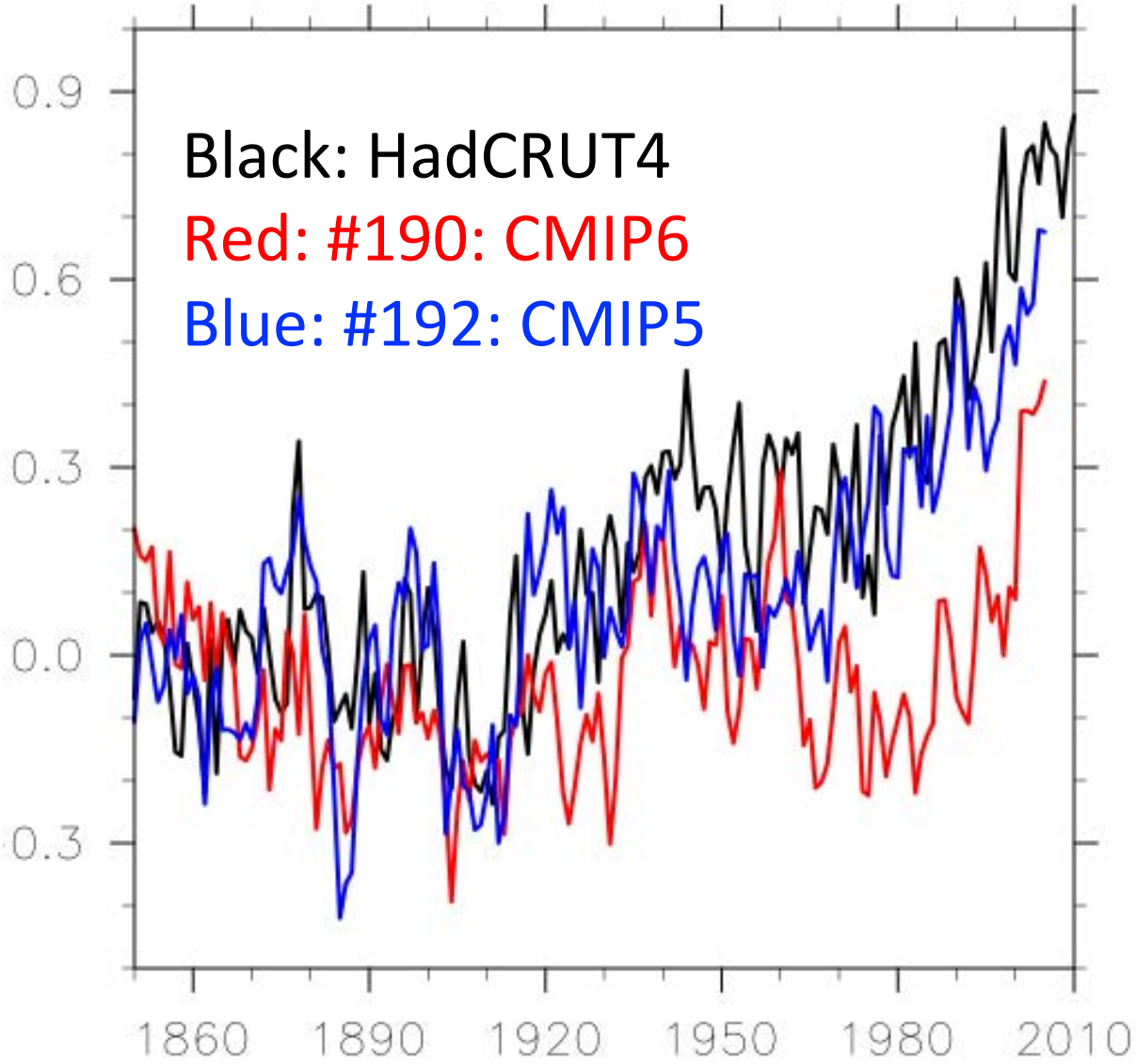
Differences in emissions



Transient volcanic forcing in CESM2 driven by emissions: comparison to CMIP6



Current status of CESM2: issue when switching CMIP5 -> 6 emissions

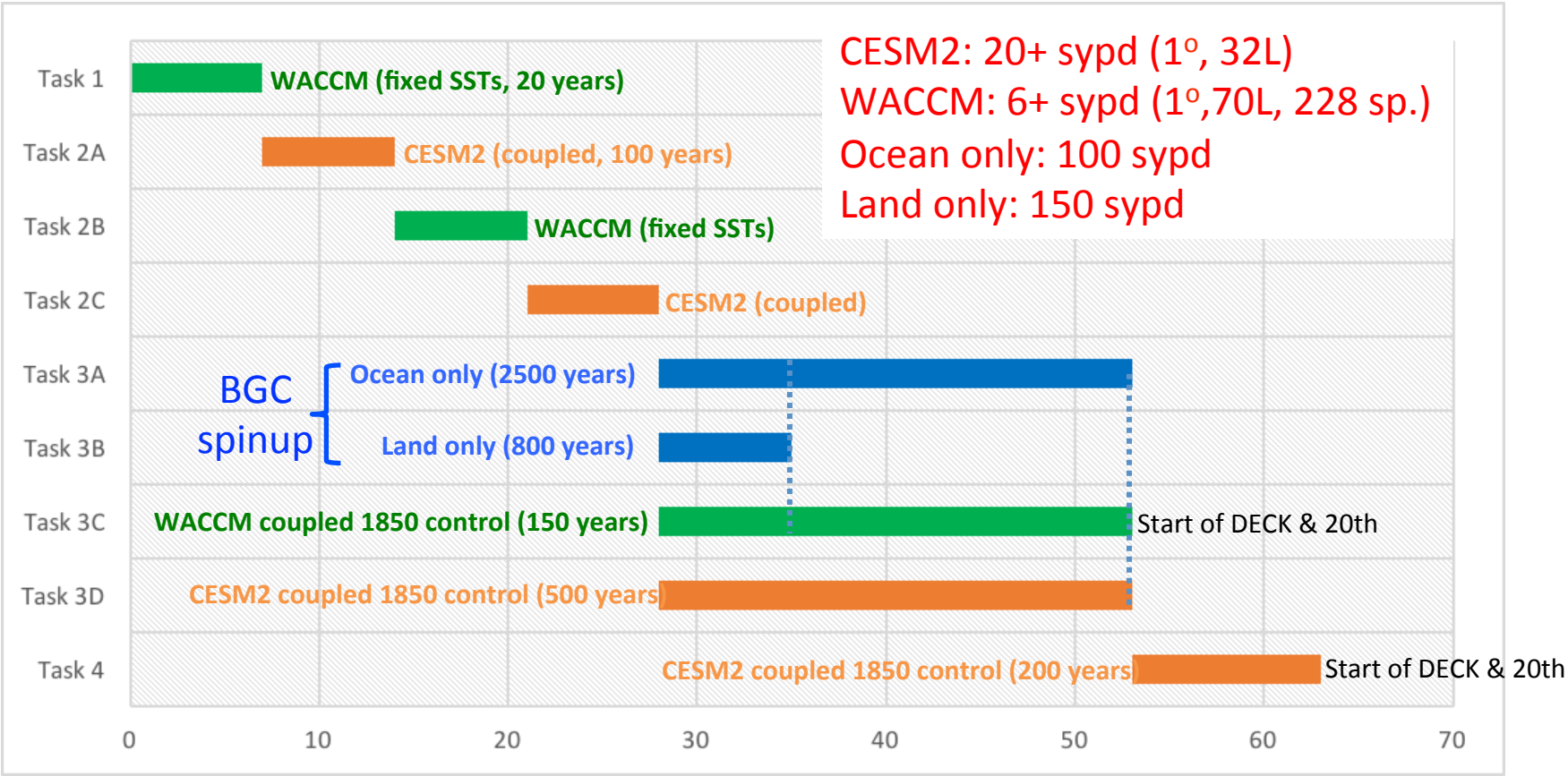


Global surface temperature (anomaly w.r.t. 1850-1880)

Same model version used in both. Only differ in anthropogenic/bb emissions and continuous volcanoes

Currently working on understanding reason for differences and remedies: focus on cloud-aerosol interactions and background aerosols

CMIP6: revised timeline and workflow



Approximately 2 months before simulations other than PI control can get started