Effective Aerosol Forcing in E3SMv1 and E3SMv2 Candidates

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U.S. DEPARTMENT OF ENERGY

Effective Aerosol Forcing

The top-of-atmosphere radiative flux perturbation caused by anthropogenic emissions of aerosols and aerosol precursors

-2.0 to -0.4

Bellouin et al. (2020)

Table 1
Best Estimates and Uncertainty Ranges of Radiative Forcing of Aerosol-Radiation and Aerosol-Cloud Interactions, and Total Aerosol Radiative Forcing, in W m^{-2}, as Given by Successive Assessment Reports of the IPCC

Assessment report	Forcing period	Aerosol-radiation interactions	Aerosol-cloud interactions	Total
2 (Schimel et al., 1996)	1750–1993	−0.50 (−1.00 to −0.25)	N/A (−1.5 to 0.0)	N/A
3 (Penner et al., 2001)	1750–1998	N/A	N/A (−2 to 0.0)	N/A
4 (Forster et al., 2007)	1750–2005	−0.50 (−0.90 to −0.10)	−0.70 (−1.80 to −0.30)	−1.3 (−2.2 to −0.5)
5 Boucher et al. (2013)	1750–2011	−0.45 (−0.95 to +0.05)	−0.45 (−1.2 to 0.0)	−0.9 (−1.9 to −0.1)

Note. Uncertainty ranges are given at the 90% confidence level. The First Assessment Report did not have the scientific understanding needed to quantify aerosol radiative forcing, although they noted that it was potentially substantial. All values are for radiative forcing, except for the Fifth Assessment Report, which are for effective radiative forcing. Adapted from Table 8.6 of (Myhre, Shindell, et al., 2013).

Simulations

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EAMv1

FC4AV1C-04P2 compset (year 2000 forcing)

CLIM_E3SMv1_04P2_noDECK (default, without DECK tunings for 3 parameters)
CLIM_E3SMv1_04P2

F2010SC5 (year 2010 forcing)

NDG_E3SMv1_F2010SC5

CLIM: free running simulation
NDG: nudged simulation towards baseline CLIM

Simulations

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EAMv2 candidates

alpha22 code, but with v1 tunings and different grids/compsets

NDG_ alpha22_F2010SC5_v1_np4
NDG_ alpha22_F2010SC5_v1
NDG_ alpha22_F20TRC5_v1

alpha22 tunings, new pg2 grid

CLIM_ alpha22_F2010SC5
NDG_ alpha22_F2010SC5

v1p tunings, new pg2 grid

NDG_ alpha22_F2010SC5_v1p

Simulations

EAMv2 candidates

alpha22 tunings, but with different IN schemes

NDG_ alpha22_F2010SC5_Mey
NDG_ alpha22_F2010SC5_Nie
NDG_ alpha22_F2010SC5_Dem

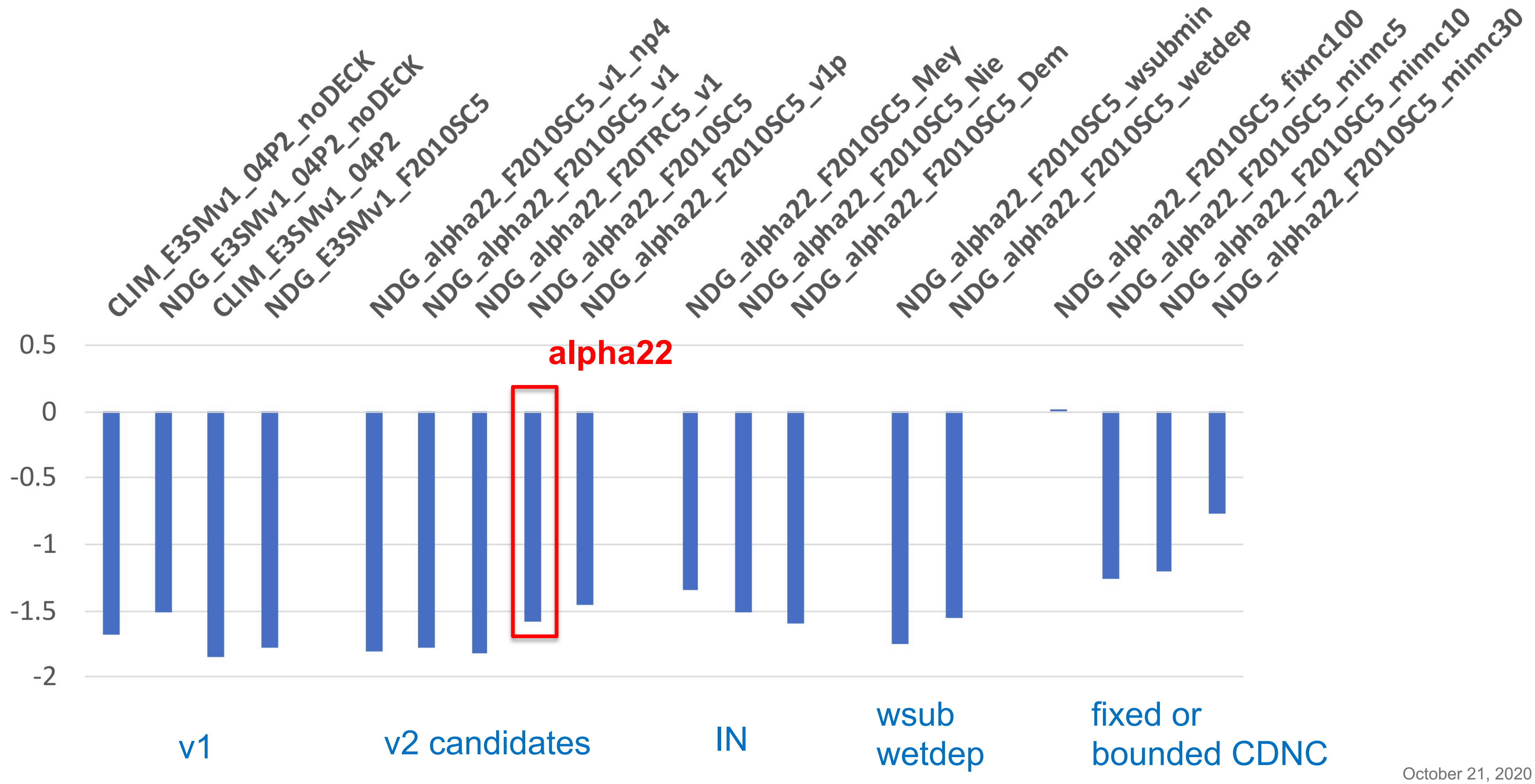
alpha22 tunings with tunings for wsub and aerosol wet removal

NDG_ alpha22_F2010SC5_wsubmin
NDG_ alpha22_F2010SC5_wetdep

alpha22 tunings

NDG_ alpha22_F2010SC5_fixncXX,   XX = 50, 100
NDG_ alpha22_F2010SC5_minncXX, XX = 2, 5, 10, 20, 30

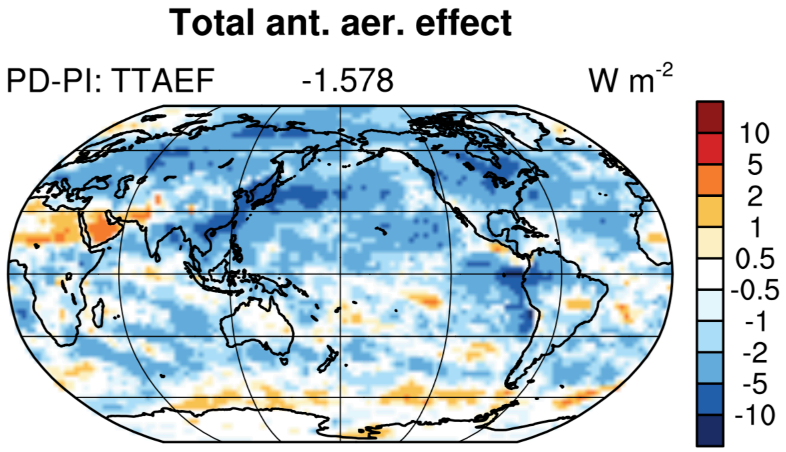
Overall results



E3SMv2 alpha22

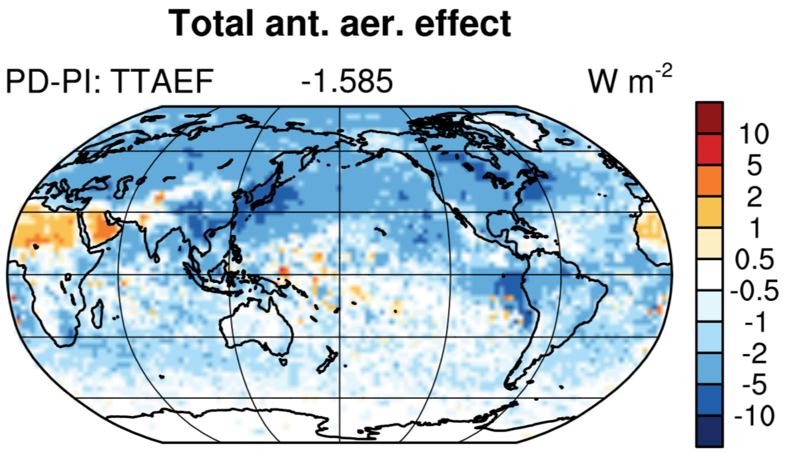
- pg2 grid and SL transport
- CLUBB and Bergeron process rate tunings from Po-Lun's V1P tuning settings
- Detrainment temperature change (by Xue Zheng following Kay et al.)
- Dust emission tuning for the new source scheme (Yan Feng)

Climatological runs (PD –PI)



10 years

Nudged towards CLIM (PD – PI)



1 year

E3SMv2 alpha22 vs V1_like (V1+pg2+SL)

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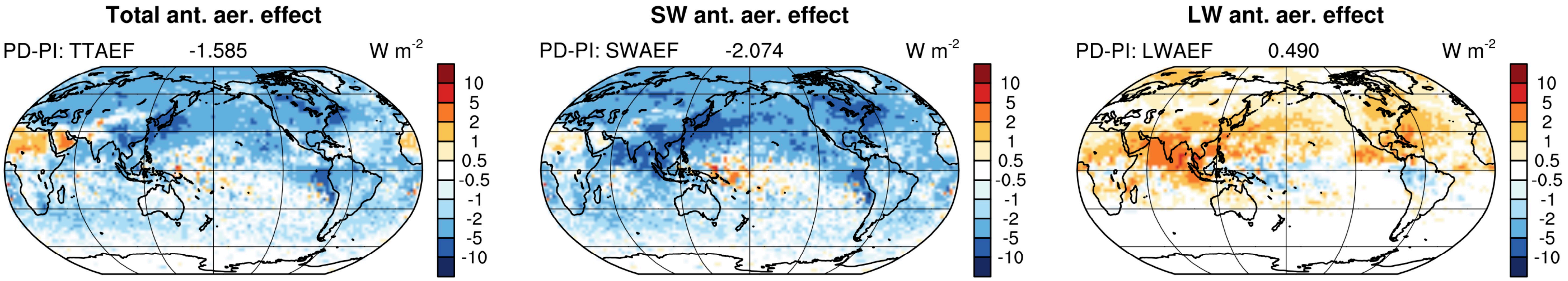
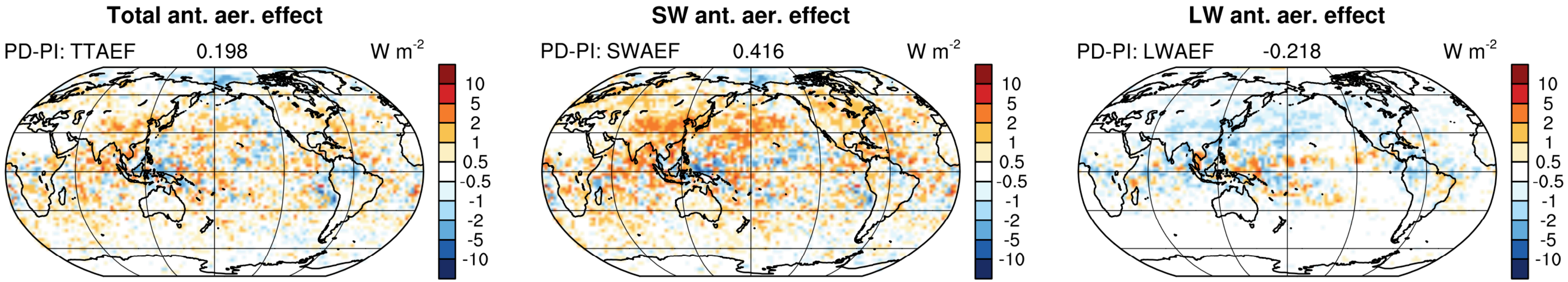
alpha22 (PD –PI)



alpha22 (PD –PI) – V1_like (PD –PI)

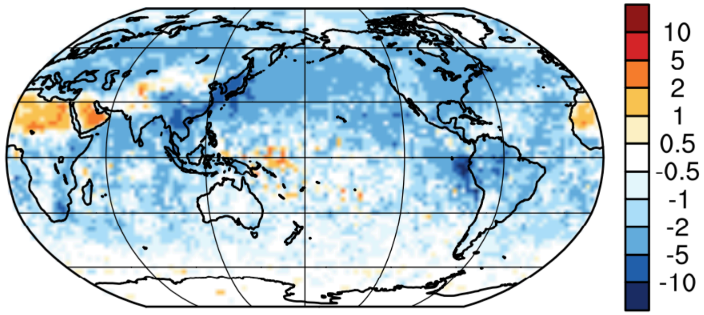


E3SMv2 alpha22 + other V1P tunings (for ZM and MP)

V1P (PD –PI)

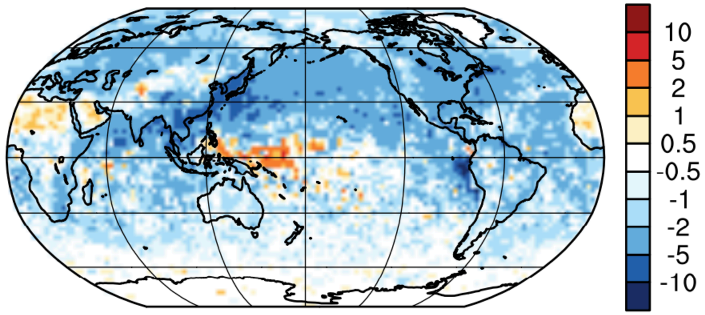
Total ant. aer. effect

PD-PI: TTAEF -1.447 W m^{-2}



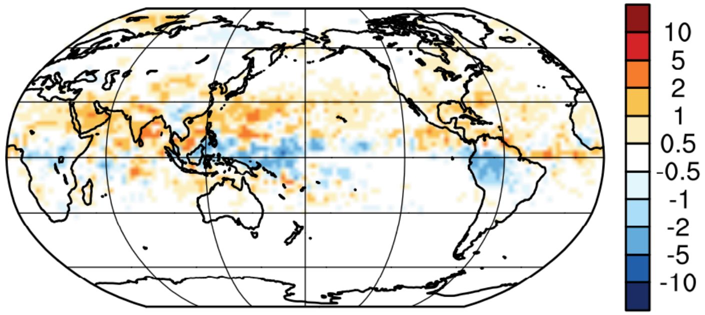
SW ant. aer. effect

PD-PI: SWAEF -1.604 W m^{-2}



LW ant. aer. effect

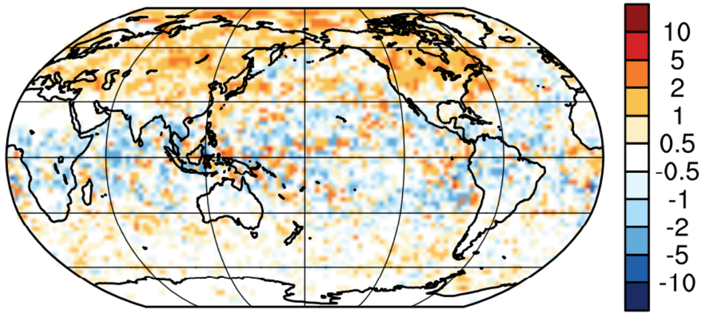
PD-PI: LWAEF 0.156 W m^{-2}



V1P (PD –PI) – alpha22 (PD –PI)

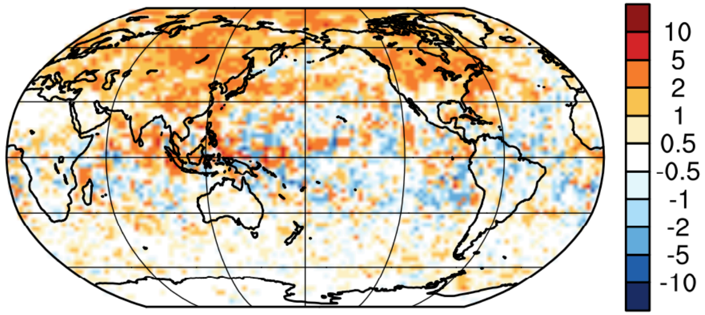
Total ant. aer. effect

PD-PI: TTAEF 0.137 W m^{-2}



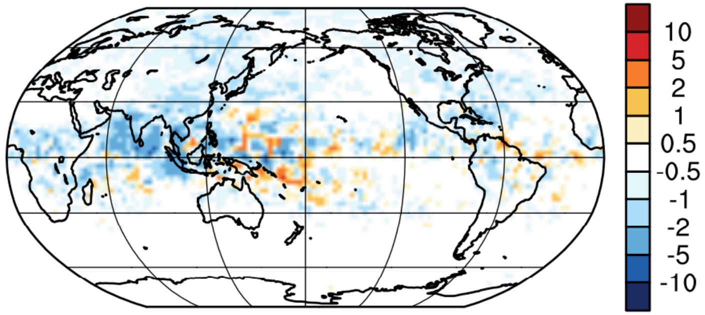
SW ant. aer. effect

PD-PI: SWAEF 0.471 W m^{-2}



LW ant. aer. effect

PD-PI: LWAEF -0.333 W m^{-2}



Impact of $CDNC_{min}$ (based on alpha22)

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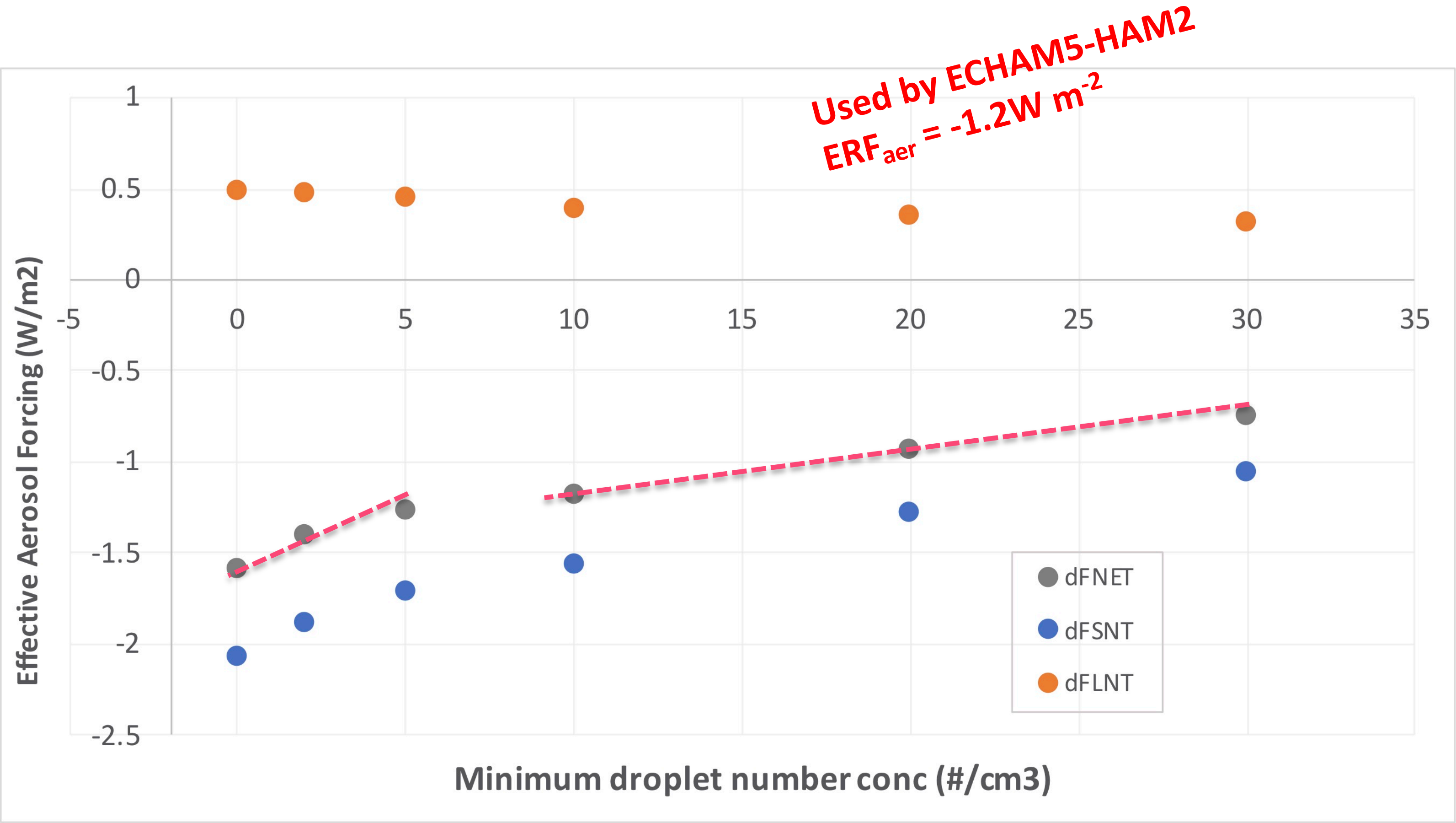
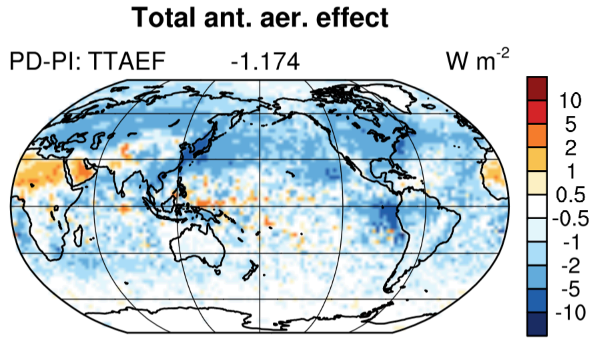
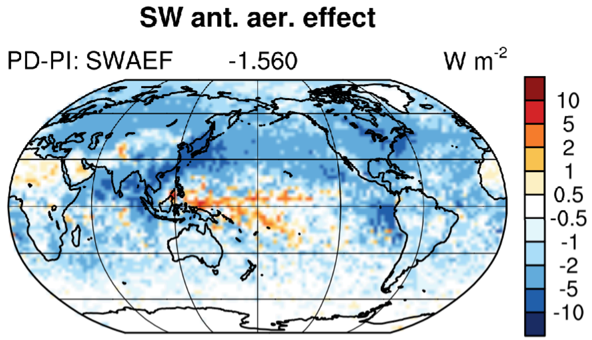
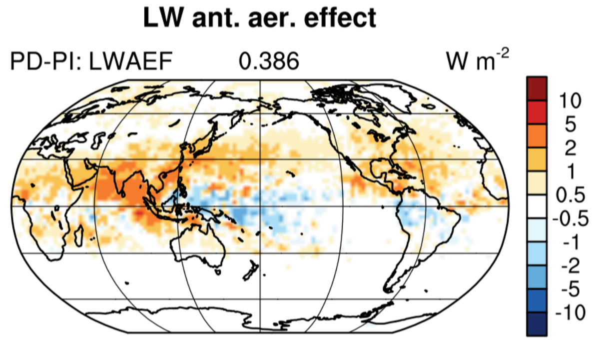


Impact of $CDNC_{min}$ = 10 cm^{-3}

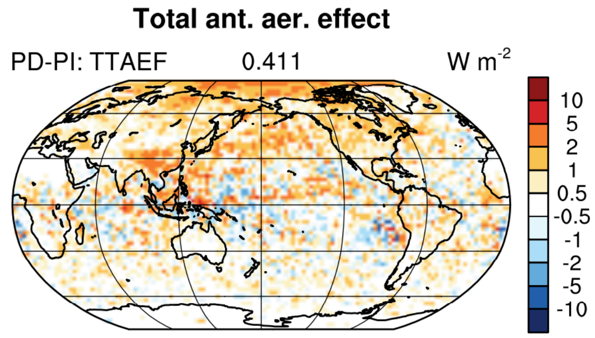
CDNC10 (PD –PI)

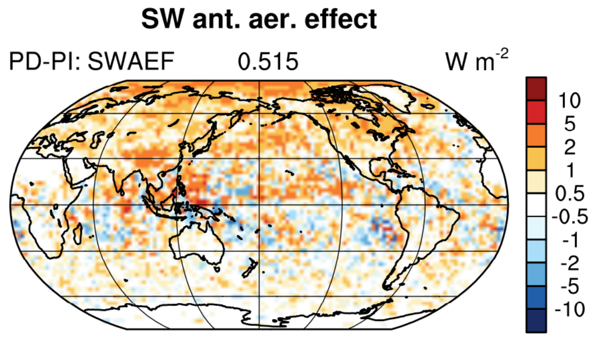


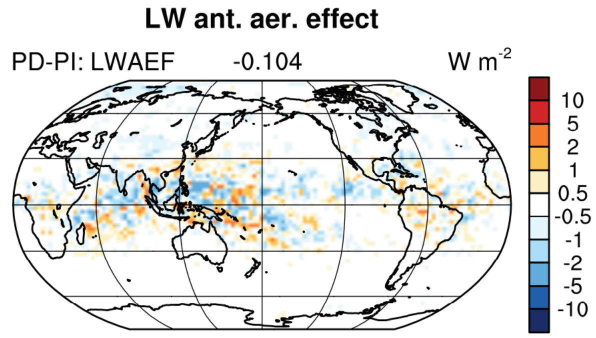




CDNC10 (PD –PI) – alpha22 (PD –PI)







Where and how frequent does CDNC< 10 cm^{-3} happen?

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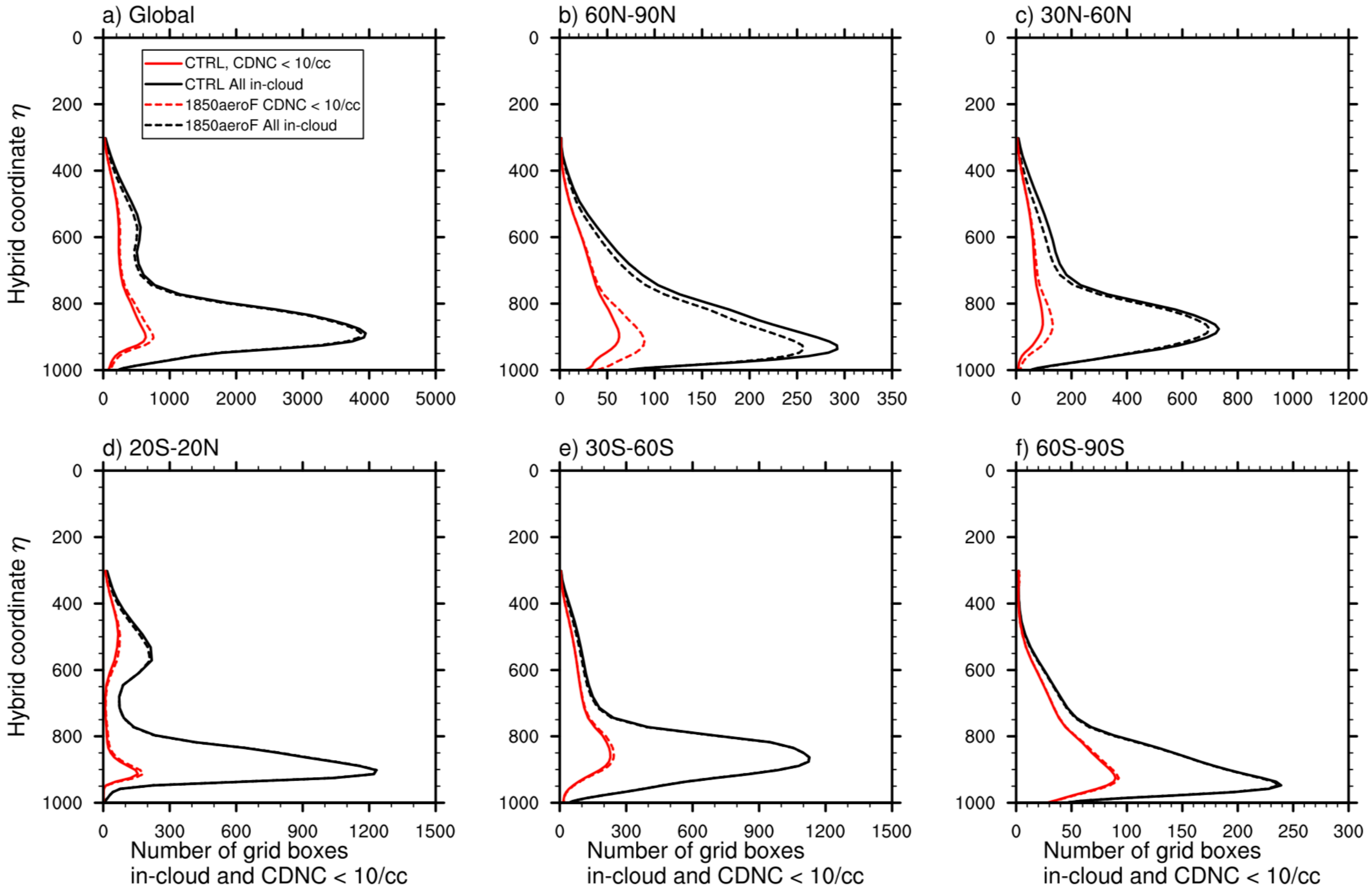

One-year average of high-frequency data

Seasonality of the impact ($CDNC_{min}$ = 10 cm^{-3})

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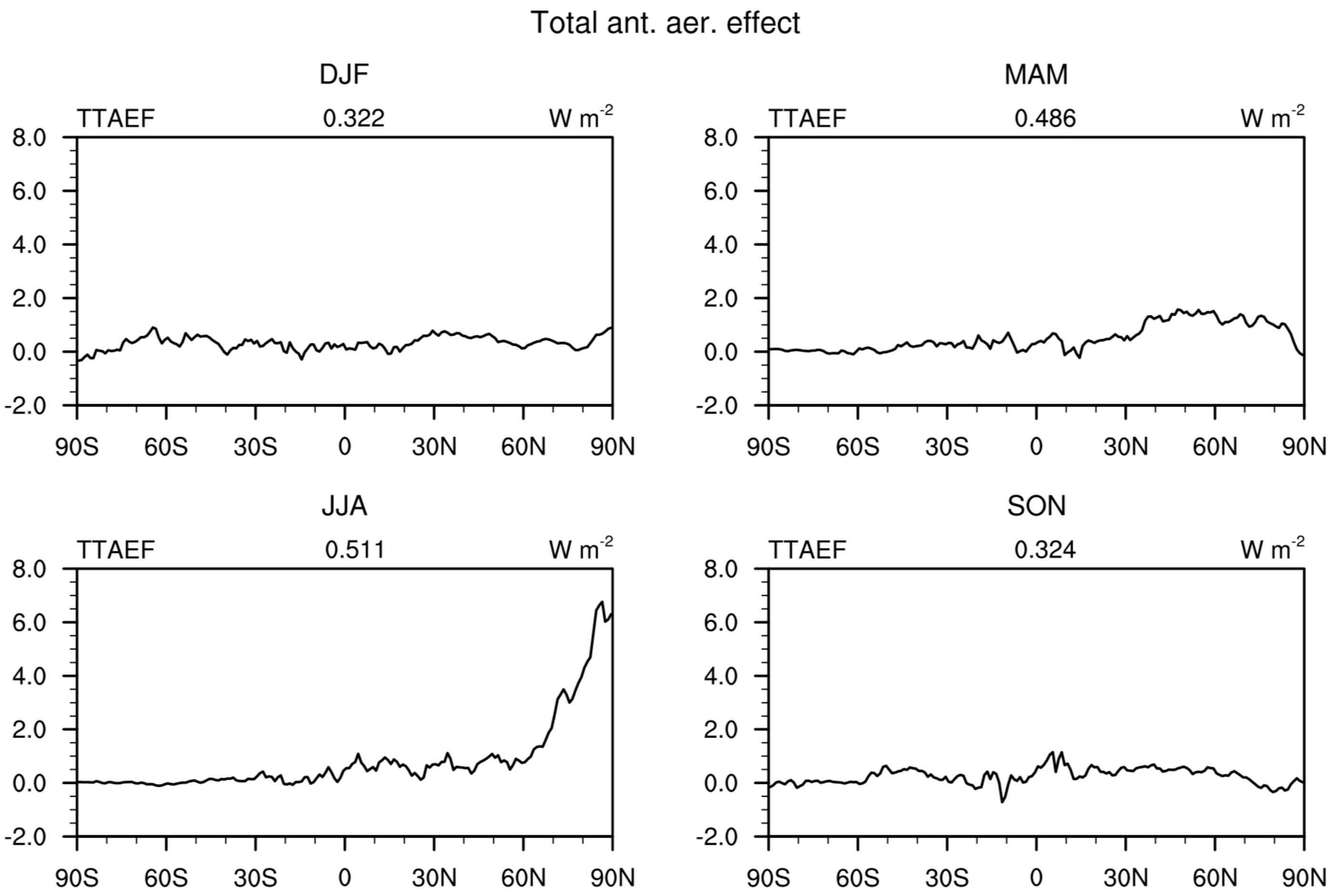

Summary

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- Effective aerosol forcing in E3SMv1 is large compared to IPCC AR5 estimate.
- 1 year nudged simulation (towards CLIM) can well reproduce the global mean estimate from climatological simulations (10 years)
- alpha22 and v1p tunings can significantly reduce component (SW/LW) ERF_{aer}, but the net change is relatively small (0.2-0.34 Wm^{-2}) .
- Using aerosol-sensitive ice nucleation schemes results enhanced ERF_{aer} magnitude (by 0.25Wm^{-2}) compared to the scheme that is not aerosol-sensitive.
- Imposing $CDNC_{min}$ can help further reduce the net ERF_{aer}.
- High-frequency data analysis shows near the Arctic
  - about **20%** in-cloud grid boxes have CDNC < 10 cm^{-3} under present-day conditions
  - about **35%** in-cloud grid boxes have CDNC < 10 cm^{-3} under pre-industrial conditions