New Generation Atmospheric Model AM4.0 Simulation Characteristics with Prescribed SSTs

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Key changes in AM4

- **Dynamic core:** hydrostatic FV^3, high-order divergence damping & model-top sponge layer
- **Aerosols and chemistry**:
  - Full chemistry: 100km/49L 1Pa top + 17 aerosols + 82 gas tracers, interactive O3
  - Light chemistry: 100km/33L 1hPa top + 17 aerosols + 4 gas tracers, prescribed O3
- **Radiation:** substantial recent updates
  - 10um CO2 + WV continuum + refitting to LBL spectroscopy + reduced SW time-step
- **Mountain gravity wave drag**: new formulation based on Garner (2005)
- **Moist convection:** new double plume scheme developed based on UWShCu
- **Aerosol-cloud interactions:** significant modifications from AM3
  - Activation scheme (macro and micro) + convective rain and snow wet deposition
- **Surface fluxes:** new ocean roughness formulation based on COARE3.5
- **Large-scale clouds, cloud microphysics, PBL, and non-orographic gravity wave drag are the same as in AM3 except with** some parameter retuning

AM4.0 simulations with prescribed SSTs and sea-ice

- **Short AMIP runs (1980-2014):** 5 members
- **Long AMIP runs (1870-2014):** 3 members

  runs with individual forcing agents on and off → forcing
- **Climatological runs:** climatological SSTs and sea-ice

  prescribed PD or PI forcing agents → forcing

  2K SST warming → feedbacks and Cess sensitivity
- **Boundary condition and atmospheric forcing agents:**

  CMIP6 specification of SSTs, sea-ice, solar irradiances, volcanos, GHG and aerosol emissions
- **LM4.0 land model:** static present-day vegetation and land use

AM4.0 documentation papers (submitted to JAMES)

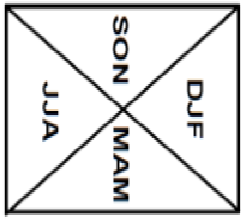
Zhao, Golaz, Held, and 42 co-authors: The GFDL global atmosphere and land model AM4.0/LM4.0. Part I: simulation characteristics with prescribed SSTs

Part II: model description, sensitivity studies and tuning strategies

PCMDI portrait plot: Comparison with previous GFDL models

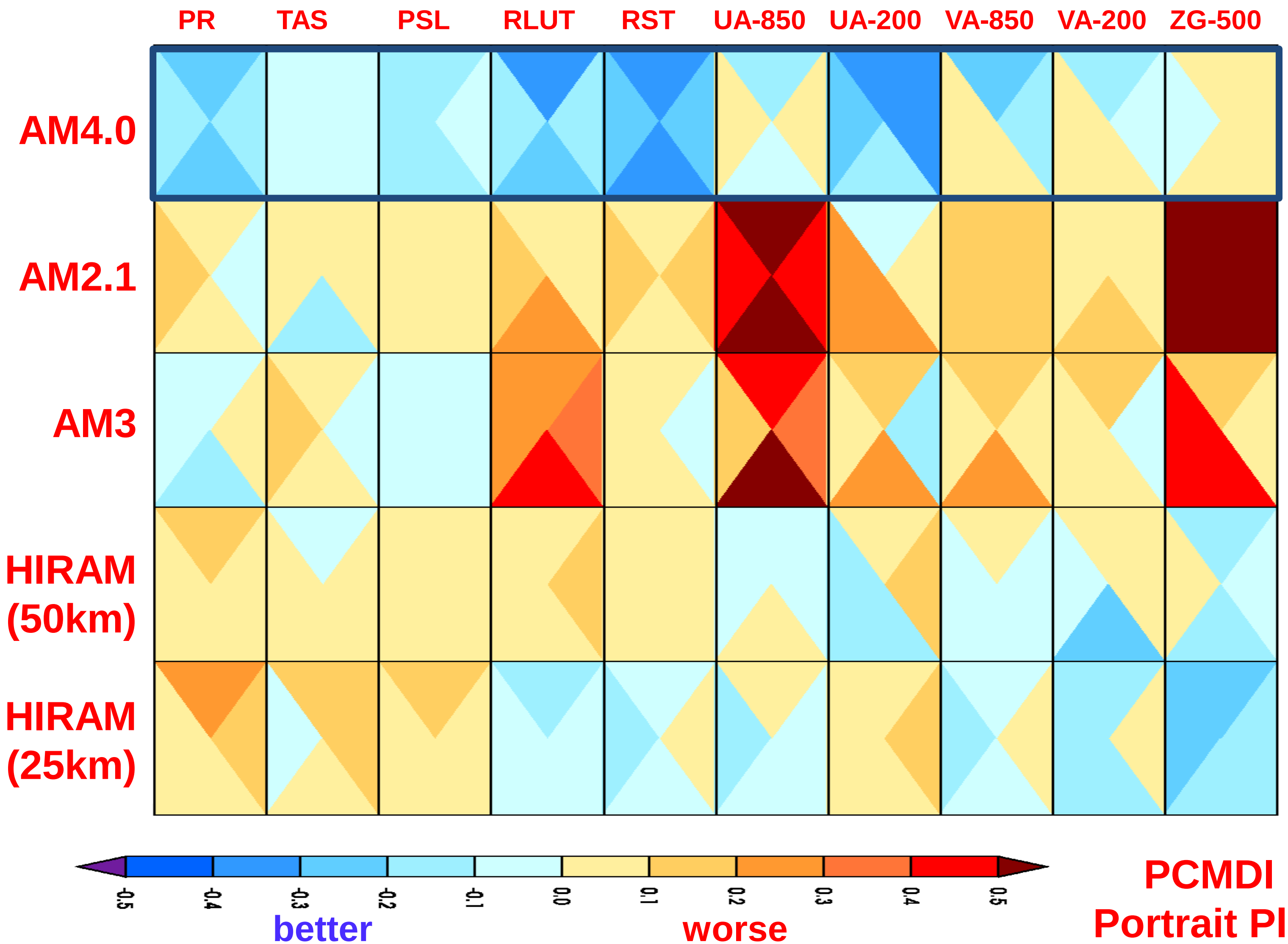
PR: Precipitation; **TAS**: Surface air temperature; **PSL**: Sea-level pressure; **RLUT**: Outgoing LW radiation; **RST**: TOA net SW radiation; **UA-850 & UA200**: 850 and 200hPa zonal wind; **VA-850 & VA-200**: 850 and 200hPa meridional wind; **ZG-500**: 500hPa geopotential height.

PCMDI metrics



Values are RMS error normalized by the ensemble median (Glecker et al. 2008, 2016)

Comparison with GFDL models (AMIP)



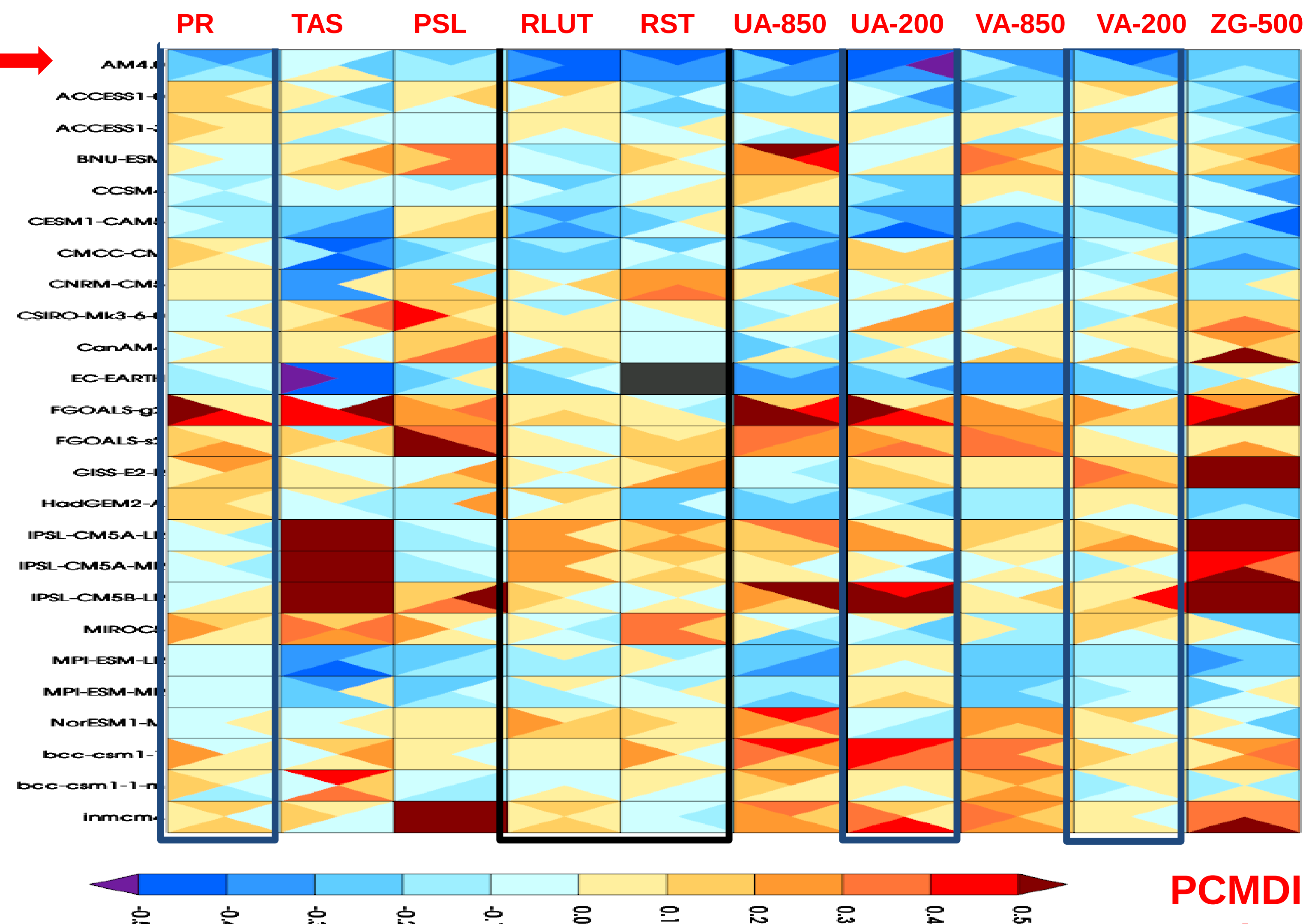
PCMDI metrics package version 1.1.2

PCMDI Portrait Plot

PCMDI portrait plot: Comparison with CMIP5 models (AMIP)

PR: Precipitation; **TAS**: Surface air temperature; **PSL**: Sea-level pressure; **RLUT**: Outgoing LW radiation; **RST**: TOA net SW radiation; **UA-850 & UA200**: 850 and 200hPa zonal wind; **VA-850 & VA-200**: 850 and 200hPa meridional wind; **ZG-500**: 500hPa geopotential height.

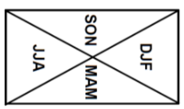
AM4.0



better

worse

PCMDI metrics



Values are RMS error normalized by the ensemble median (Gleckler et al. 2008, 2016)

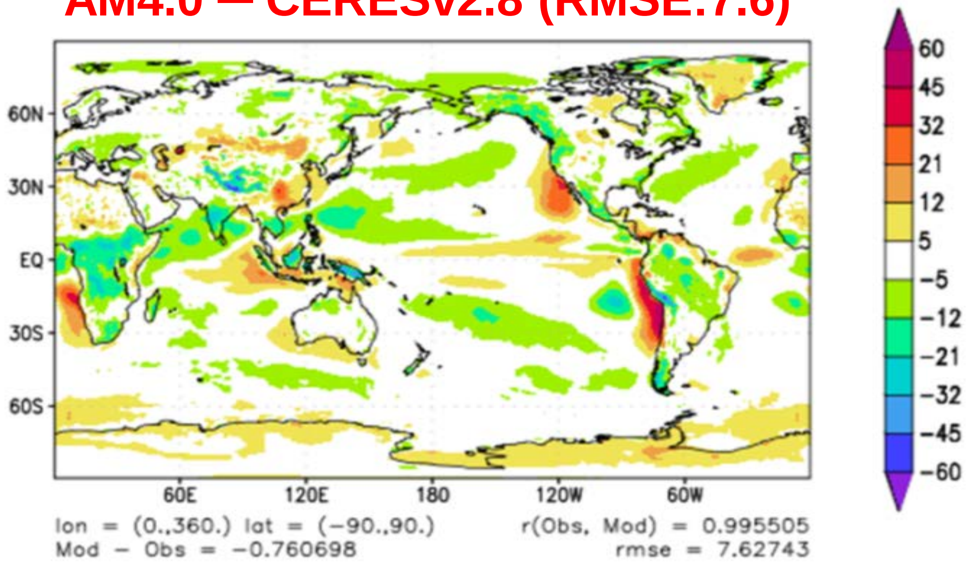
Comparison with CMIP5 models (AMIP)

PCMDI metrics package version 1.1.2

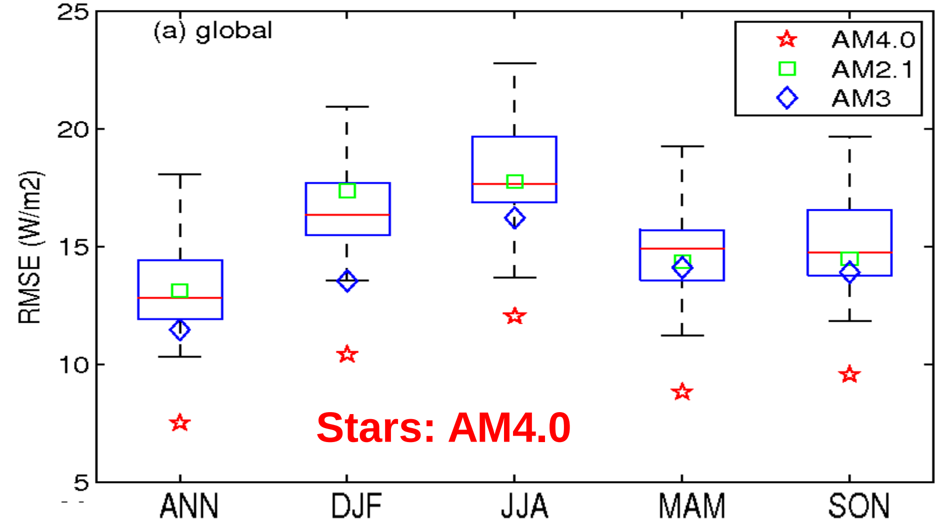
PCMDI Portrait Plot

AM4.0 bias in annual mean TOA SW radiation comparison with AM2.1 AM3 and CMIP5 models (W/m2)

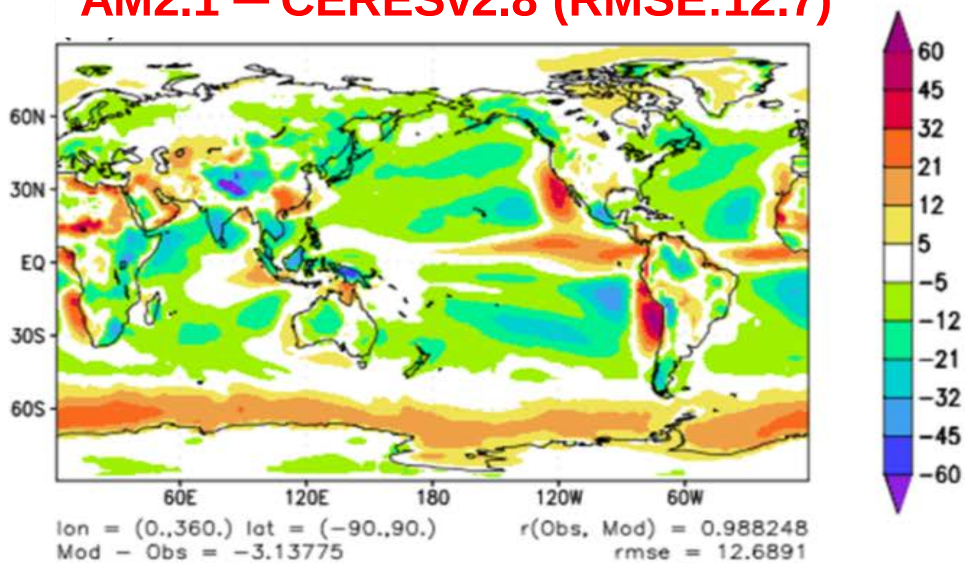
AM4.0 – CERESv2.8 (RMSE:7.6)



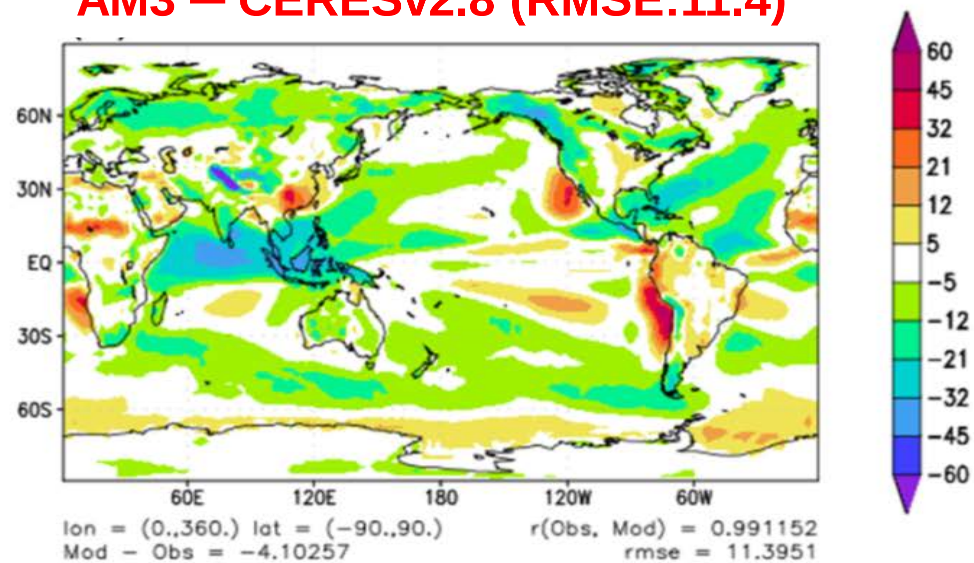
Comparison with CMIP5 models



AM2.1 – CERESv2.8 (RMSE:12.7)

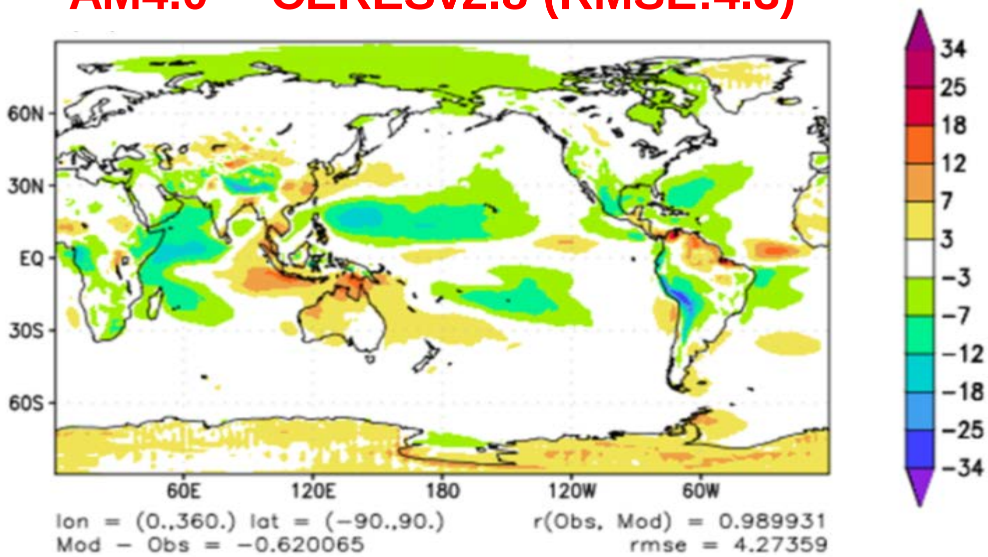


AM3 – CERESv2.8 (RMSE:11.4)

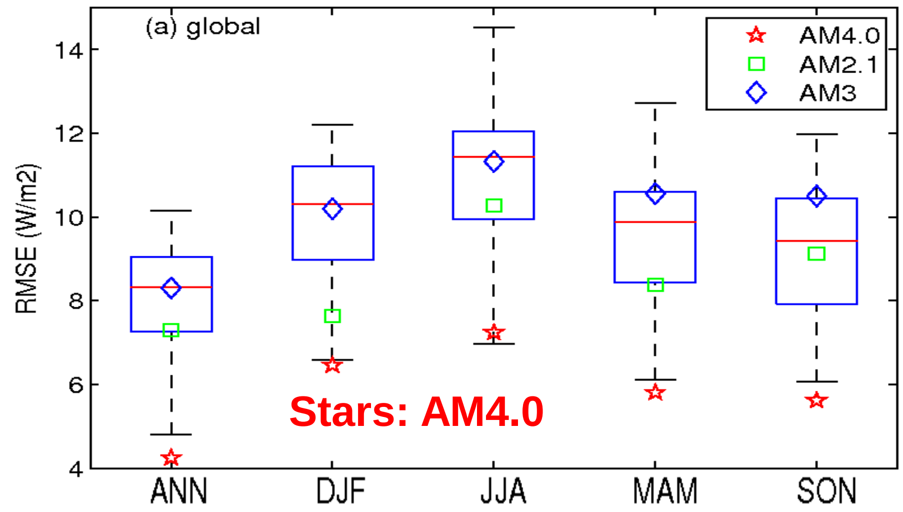


AM4.0 bias in annual mean OLR comparison with AM2.1 AM3 and CMIP5 models (W/m2)

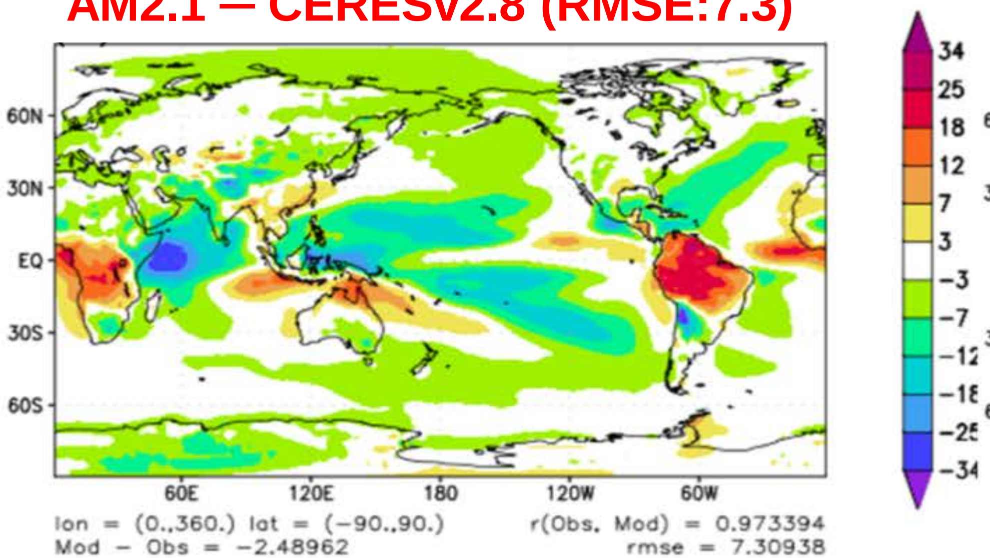
AM4.0 – CERESv2.8 (RMSE:4.3)



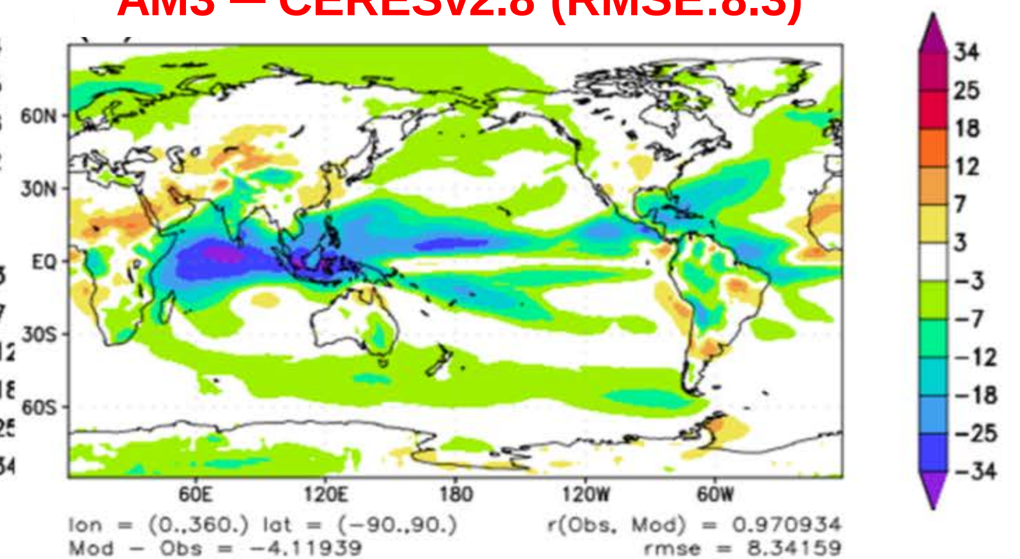
Comparison with CMIP5 models



AM2.1 – CERESv2.8 (RMSE:7.3)

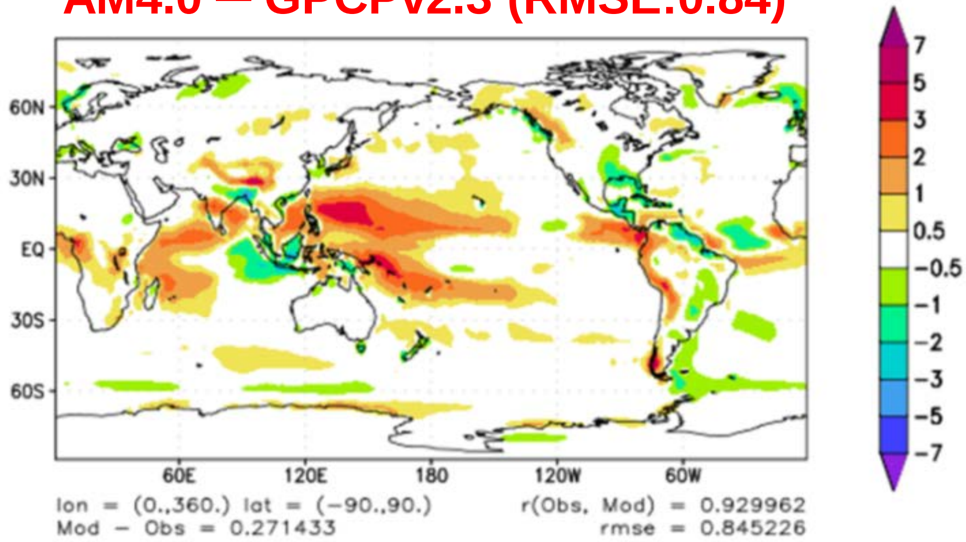


AM3 – CERESv2.8 (RMSE:8.3)

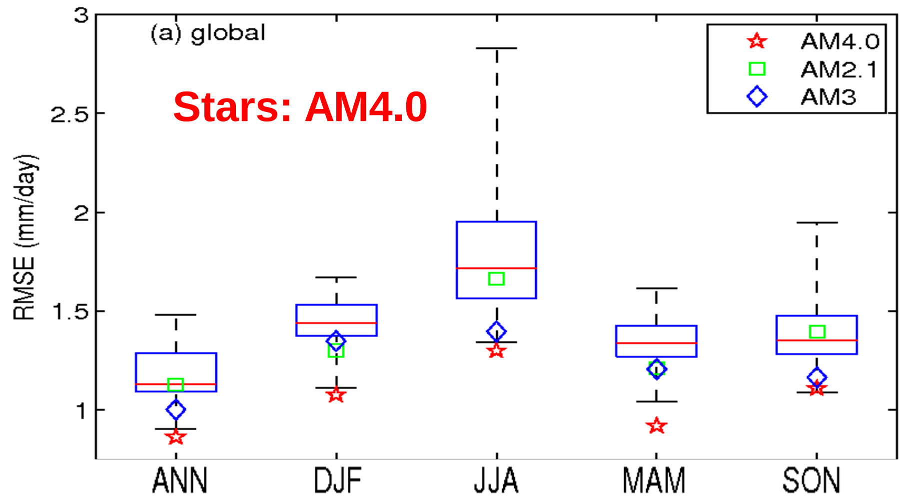


AM4.0 bias in annual mean precipitation comparison with AM2.1 AM3 and CMIP5 models (mm/day)

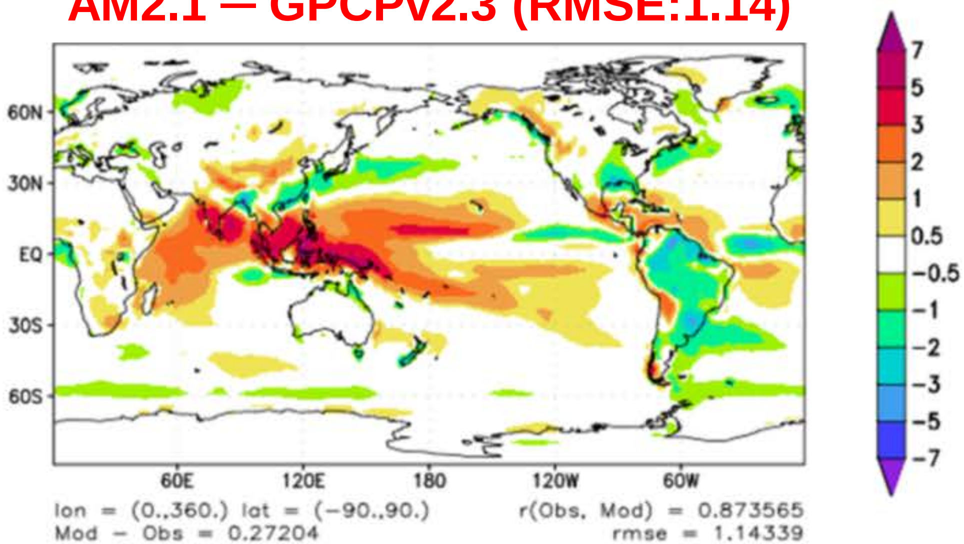
AM4.0 – GPCPv2.3 (RMSE:0.84)



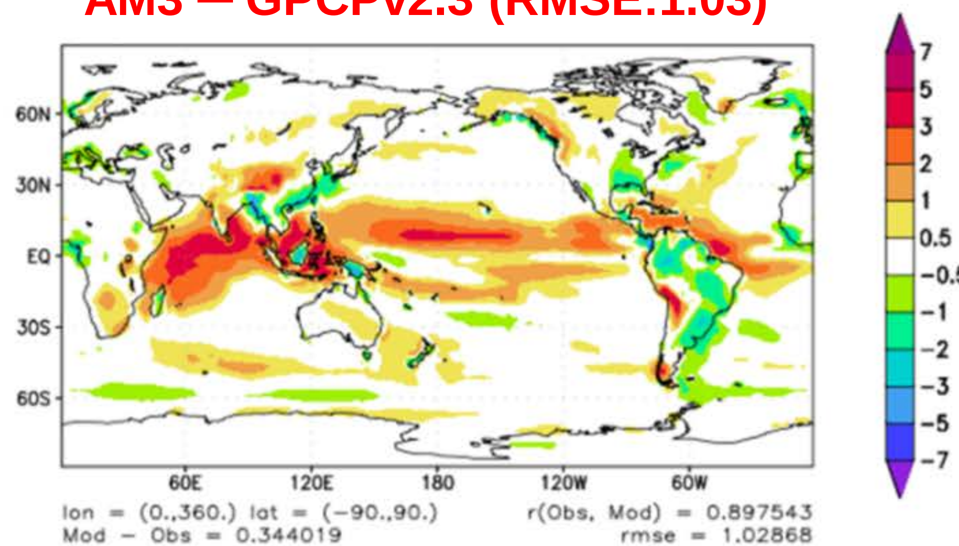
Comparison with CMIP5 models



AM2.1 – GPCPv2.3 (RMSE:1.14)



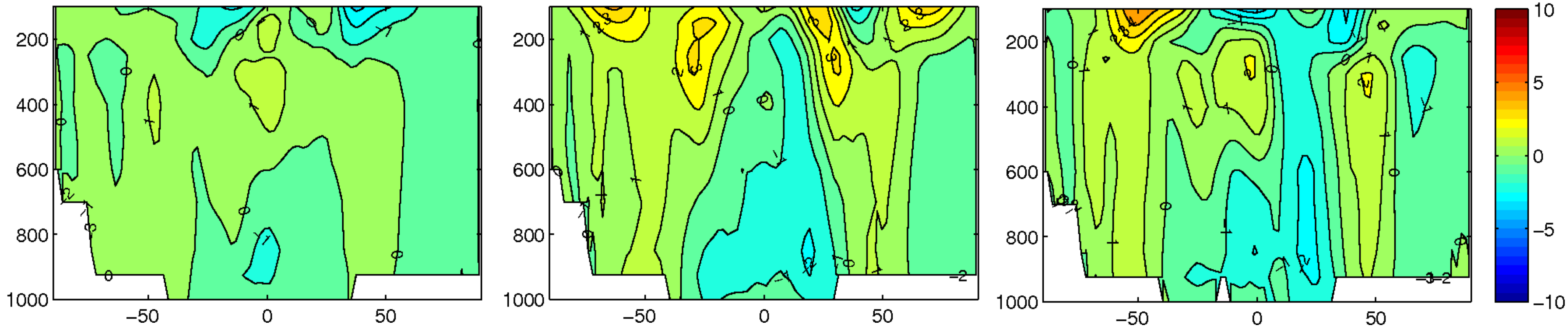
AM3 – GPCPv2.3 (RMSE:1.03)



AM4.0 bias in zonal mean zonal wind and zonal mean temperature (comparison with AM2.1 and AM3)

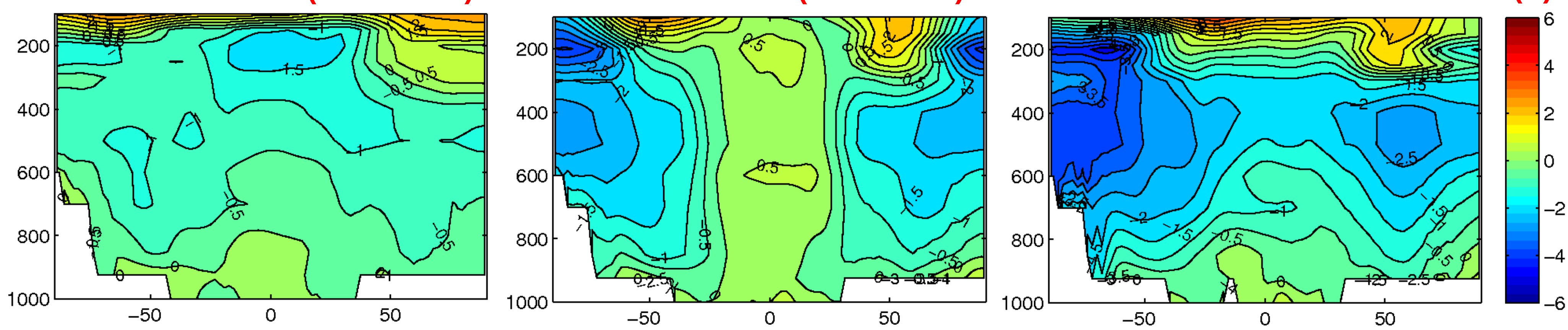
Annual mean zonal mean zonal wind

AM4.0 — INTERIM (RMSE:0.76) AM3 — INTERIM (RMSE:1.52) AM2.1 — INTERIM (RMSE:1.52) (m/s)



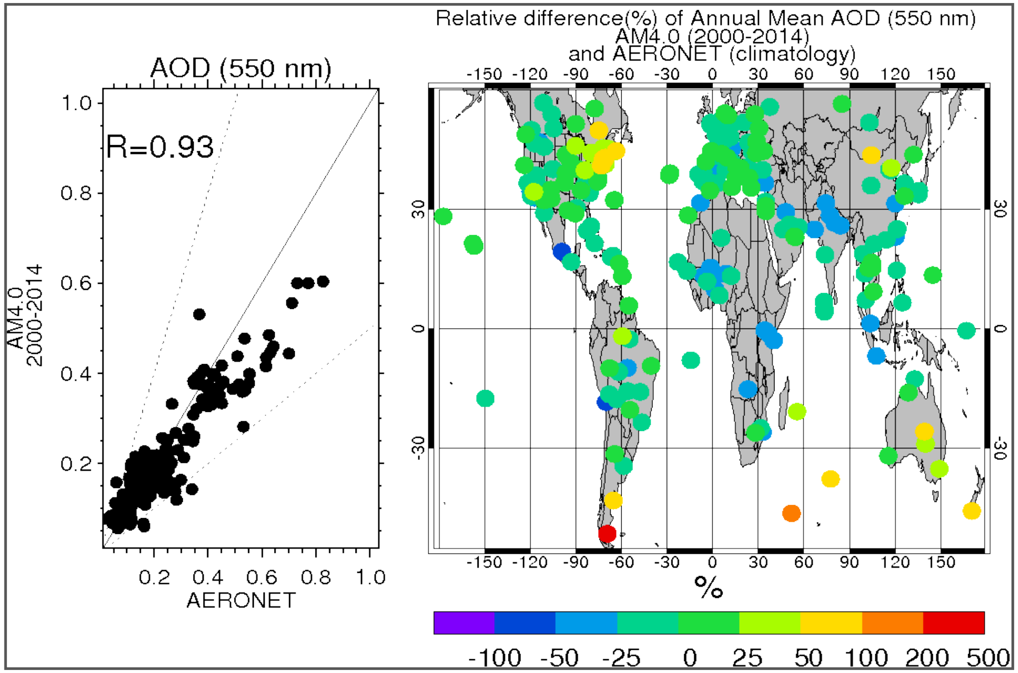
Annual mean zonal mean temperature

AM4.0 — INTERIM (RMSE:0.96) AM3 — INTERIM (RMSE:1.05) AM2.1 — INTERIM (RMSE:1.87) (K)



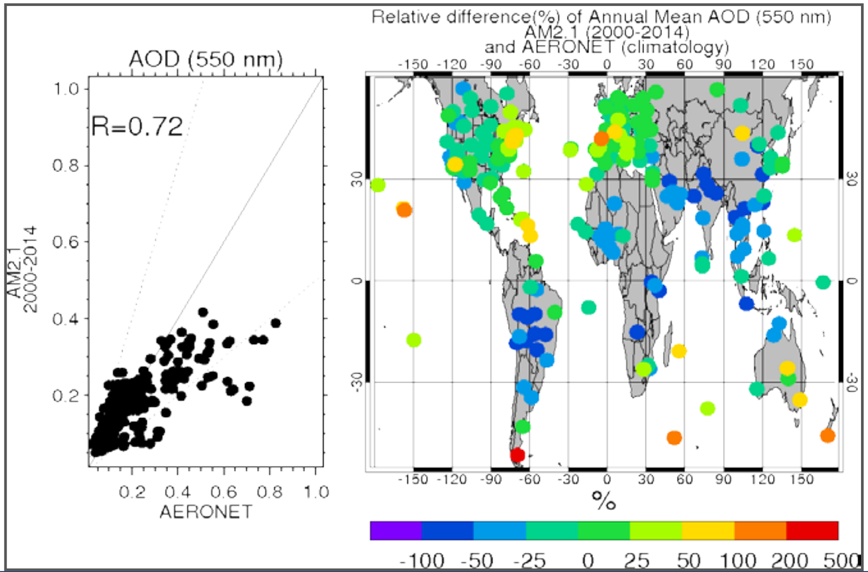
AM4.0 bias in simulated aerosol optical depth comparison with AM2.1 and AM3 (OBS: AERONET)

AM4.0-vs-OBS correlation=0.93

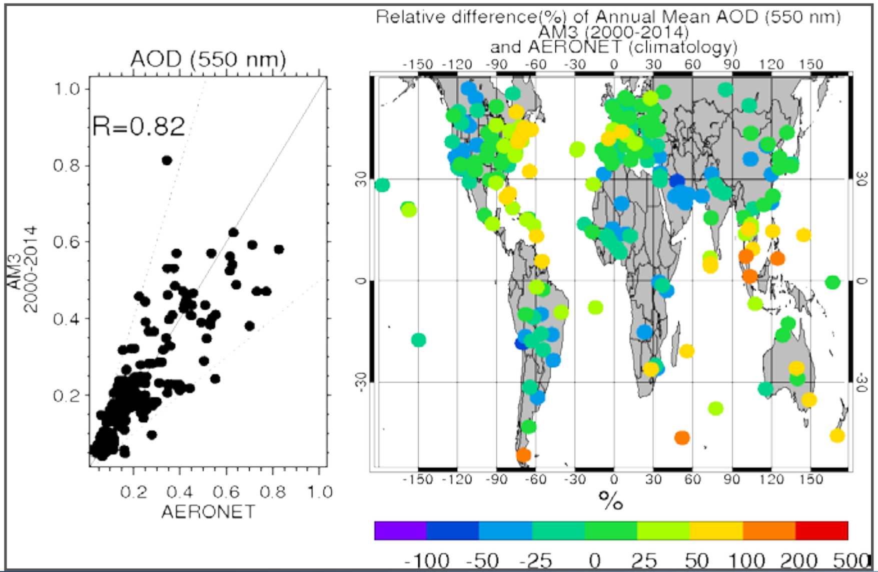


Color: percent error compared to AERONET

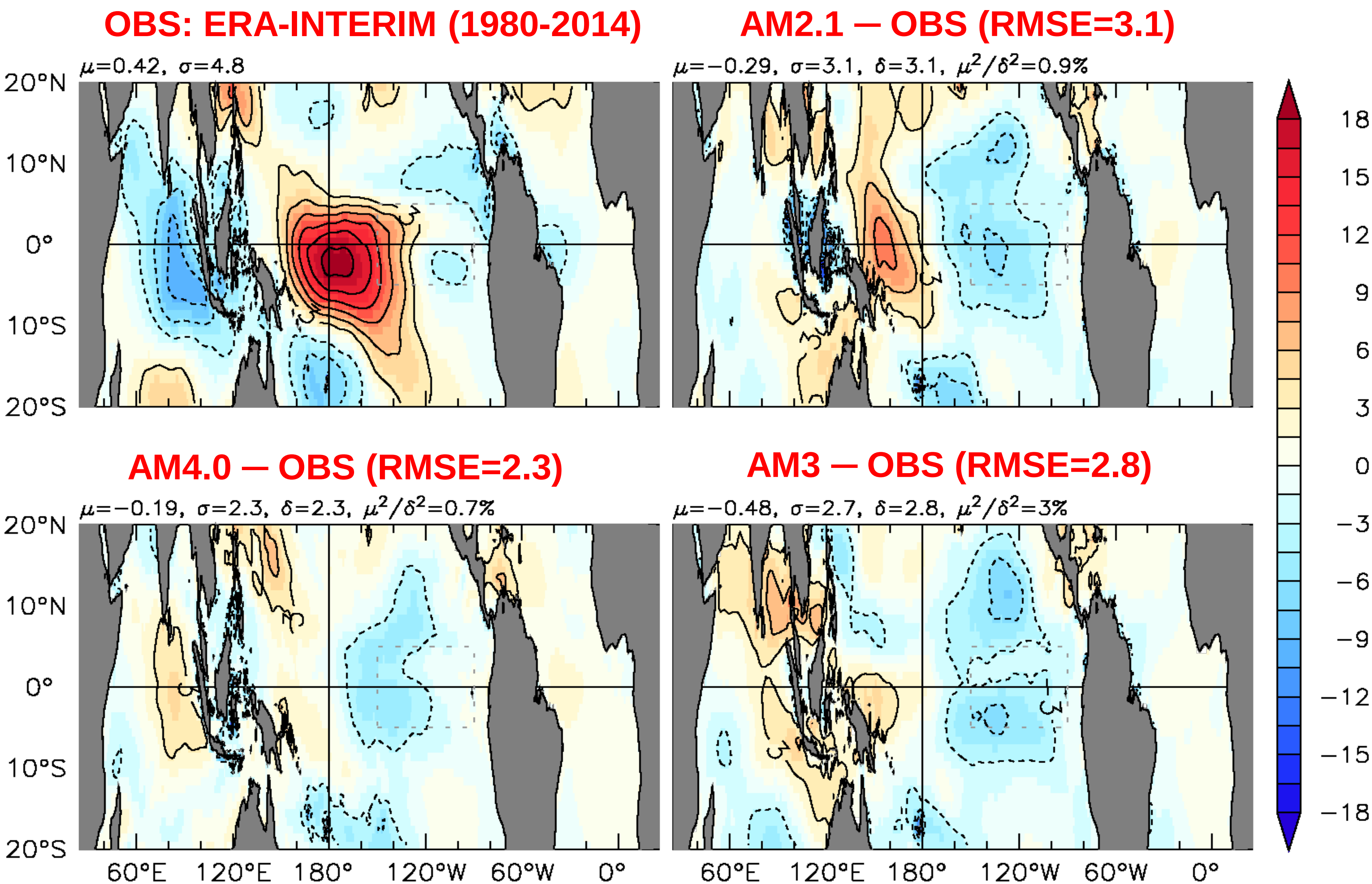
AM2.1-vs-OBS correlation=0.72



AM3-vs-OBS correlation=0.82

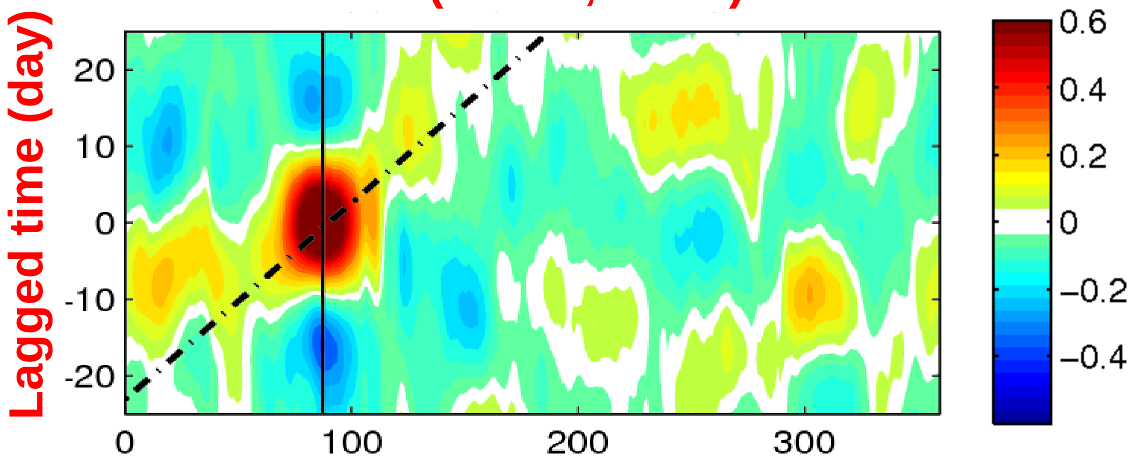


AM4.0 bias in surface wind stress response to NINO3 SST anomalies - comparison with AM2.1 and AM3 (mPa/K)



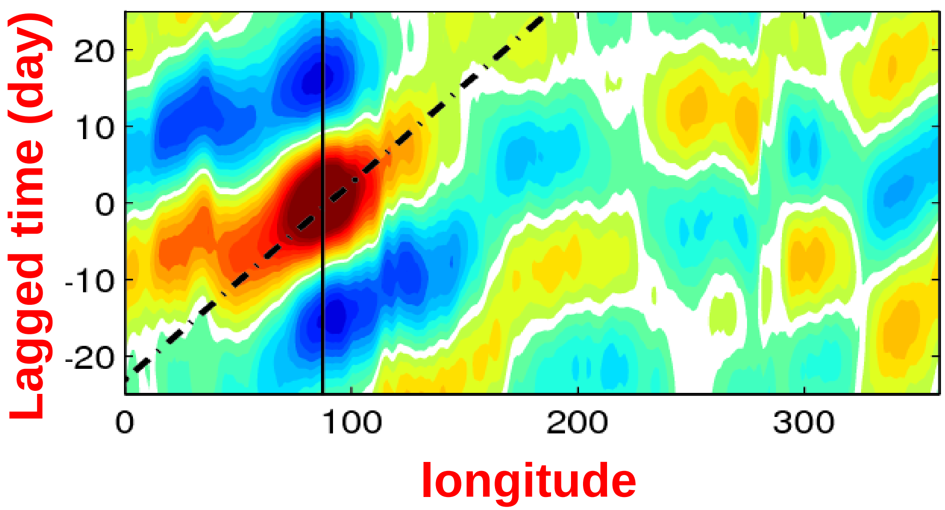
AM4/CM4 simulated eastward propagation of MJO (Lag-Longitude-Diagram; winter season)

OLR (AM4.0, AMIP)

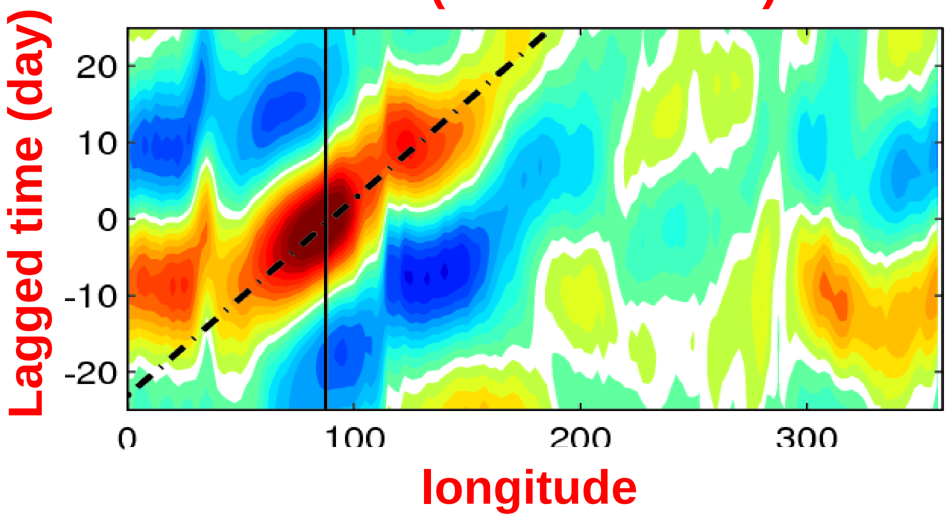


Lag correlation between central Indian ocean OLR and associated near equatorial OLR at all longitudes

OLR (AM4.0, Coupled)

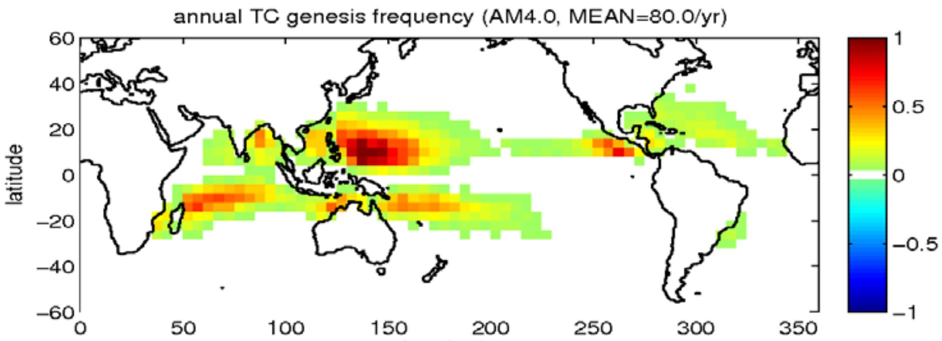


OLR (NOAA AVHRR)

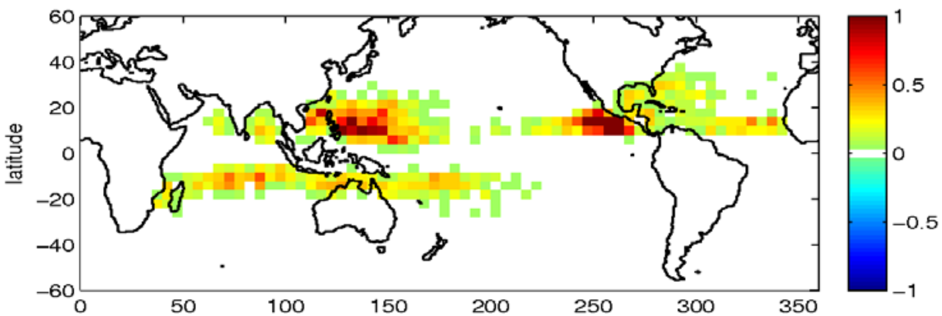


AM4.0 simulated geographical distribution of tropical cyclone frequency and its seasonal cycle

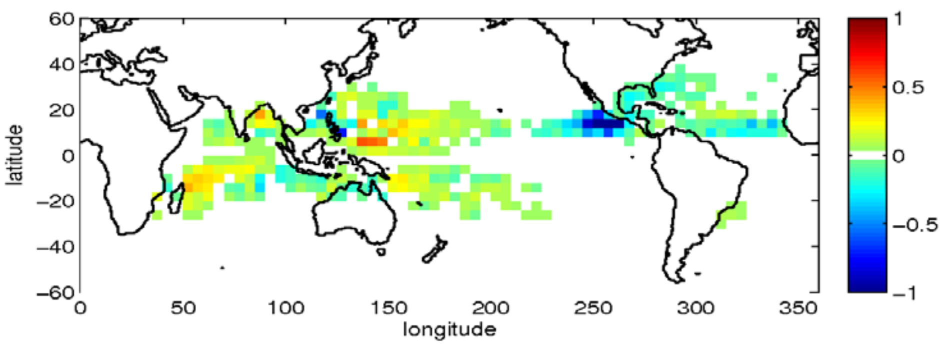
AM4.0 annual TC genesis frequency



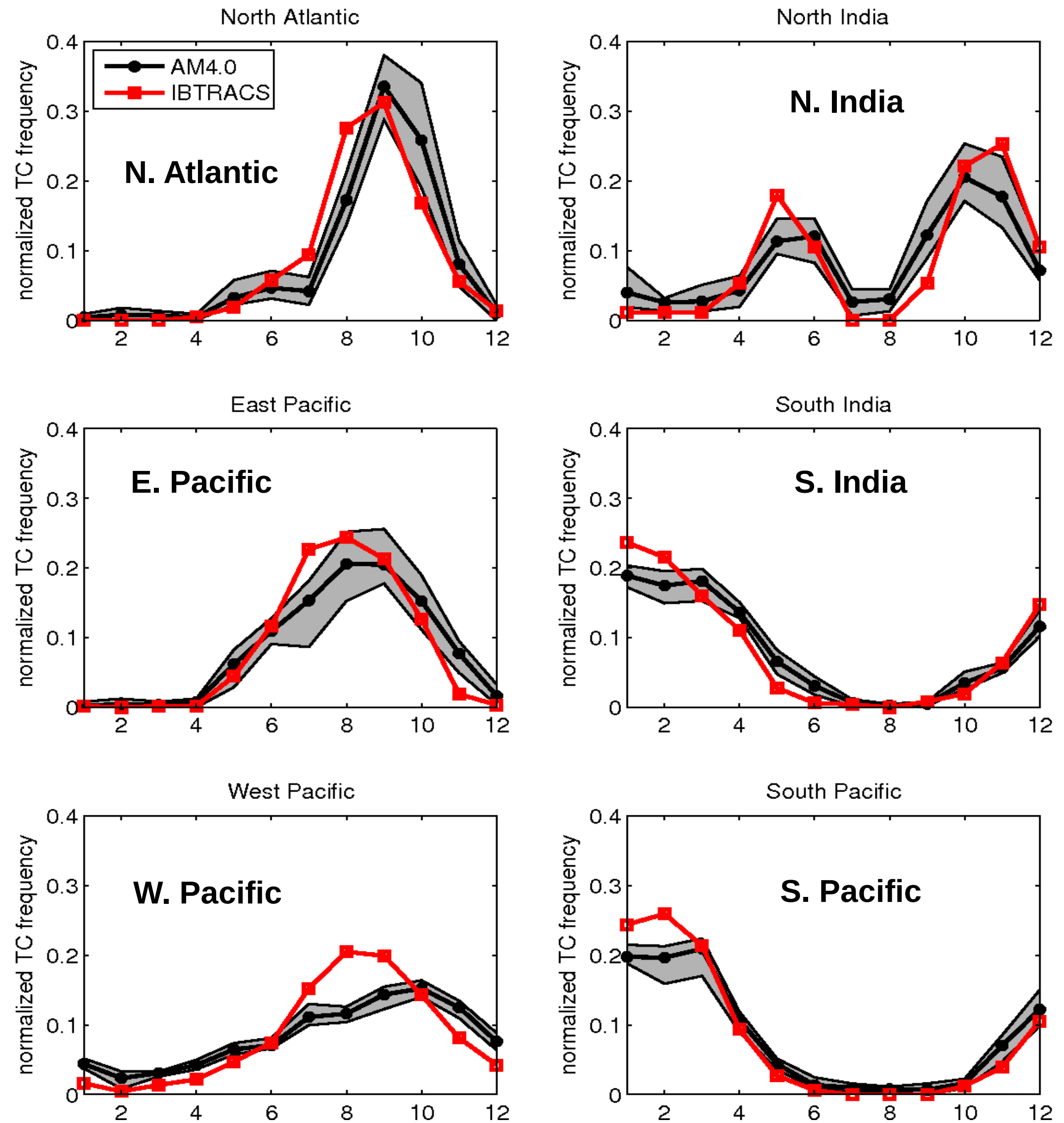
OBS: IBTRAC



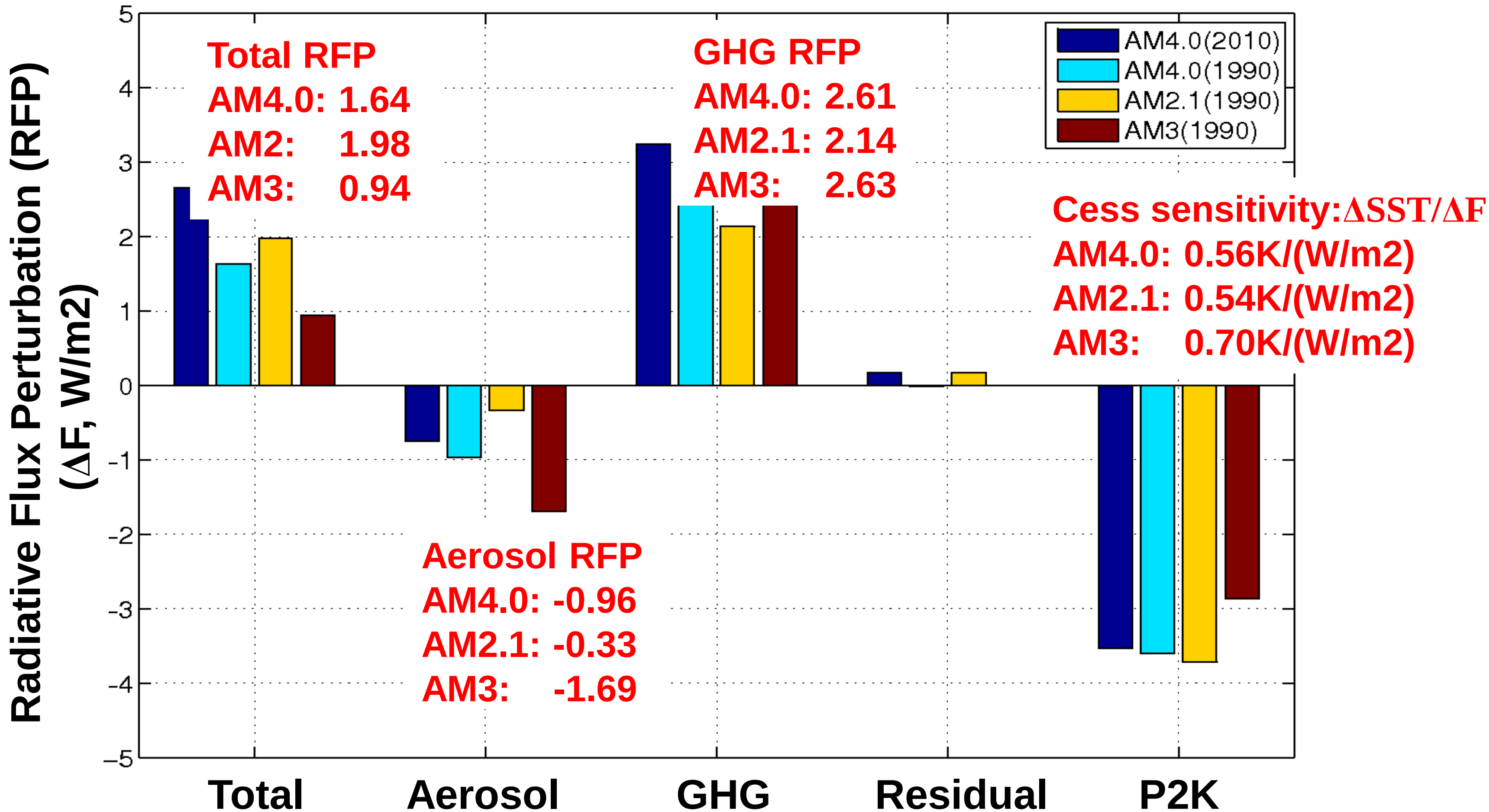
AM4.0 minus IBTRAC



AM4.0 seasonal cycle of TC genesis frequency



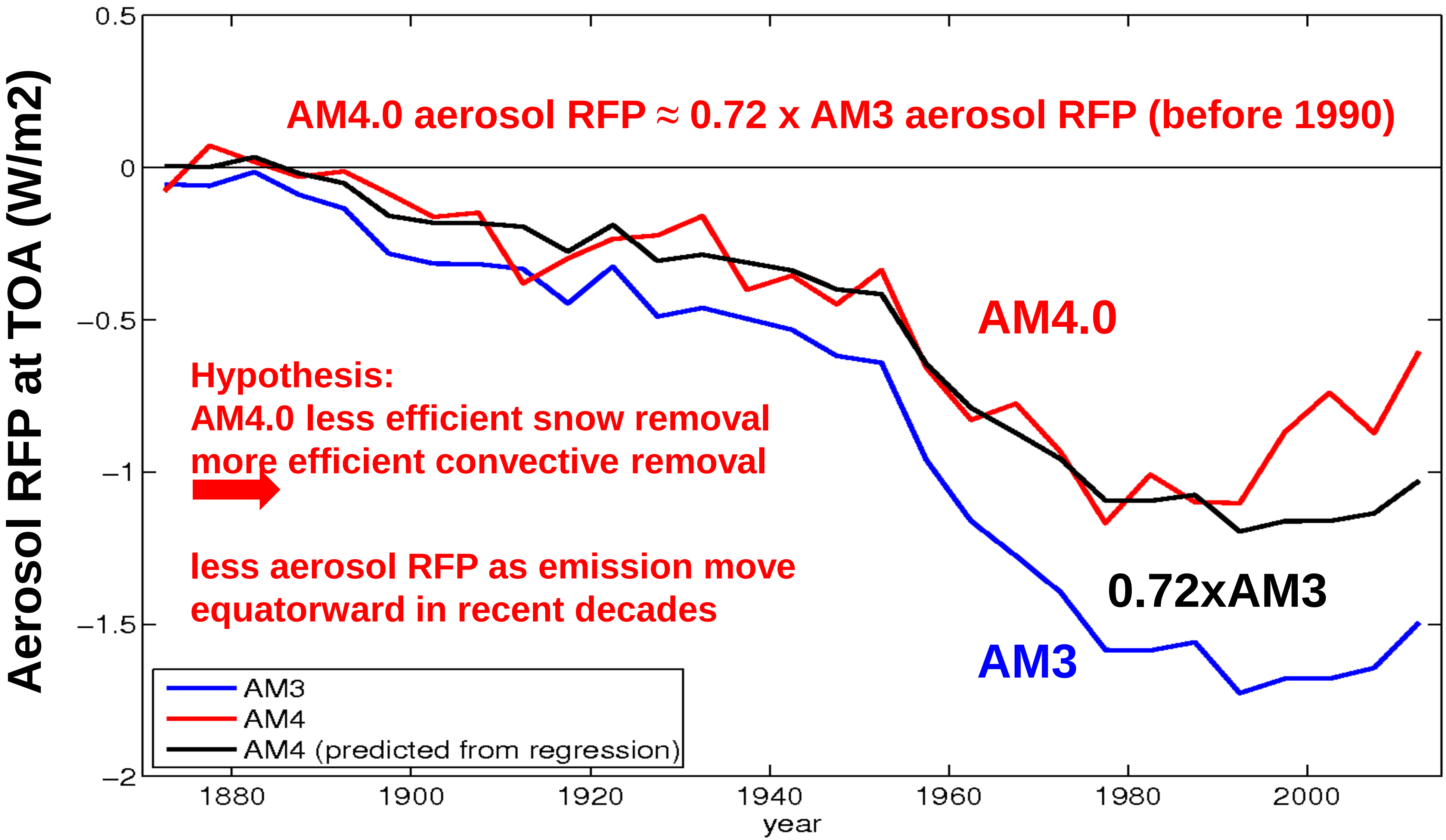
AM4.0 simulated change in TOA net radiative flux F in response to changes in GHG, aerosol emissions and global mean SST



Total RFP	**= F{GHG(PD),Aero(PD),…,SST(PD)}**	**– F{GHG(PI), Aero(PI), …,SST(PD)}**
Aerosol RFP	**= F{GHG(PI), Aero(PD),…,SST(PD)}**	**– F{GHG(PI), Aero(PI), …,SST(PD)}**
GHG RFP	**= F{GHG(PD),Aero(PI),…, SST(PD)}**	**– F{GHG(PI), Aero(PI), …,SST(PD)}**
Residual	**= Total RFP – Aerosol RFP – GHG RFP**	
P2K	**= F{GHG(PD),Aero(PD),…,SST(PD)+2K}**	**– F {GHG(PD),Aero(PD),…,SST(PD)}**

Comparison of AM4.0 aerosol RFP with AM3 in long AMIP simulations: AM4 ≈ 0.72xAM3 before 1990

Aerosol RFP(t) = F{GHG(PI),Aero(t),…,SST(t)} – F{GHG(PI),Aero(PI),…,SST(t)}



Summary

- **AM4.0 has an improved horizontal resolution, a new convection and mountain drag parameterization with radiative transfer, aerosol-cloud interactions significantly updated. AM4 predicts aerosols from emissions with two options in complexity of chemistry.**

- **AM4.0 forced by observed SSTs produces superior quality than most CMIP5 models in simulations of TOA radiative fluxes, clouds, and precipitation. It also improves simulations of aerosols, MJO, TC statistics, and response to ENSO SSTA compared to AM3/AM2.**

- **Compared to AM3, AM4.0 has a lower Cess sensitivity and a lower aerosol RFP, which should help coupled simulation of historical temperature trend.**