Radiative Forcings of Wildfire Aerosols Estimated with CAM5

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Outline

- ✧ Introduction
- ✧ Methods, data and experiments
- ✧ Fire aerosol radiative forcings

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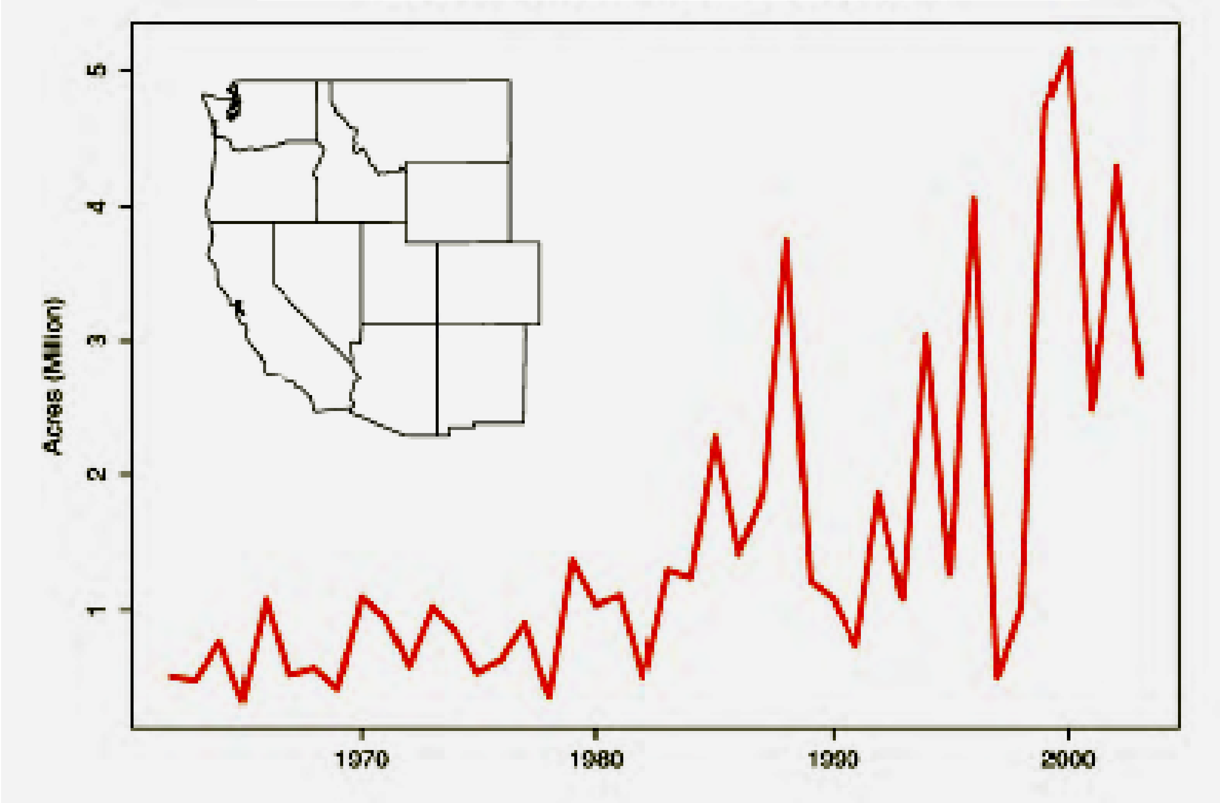
Fires Are Increasing World-Wide

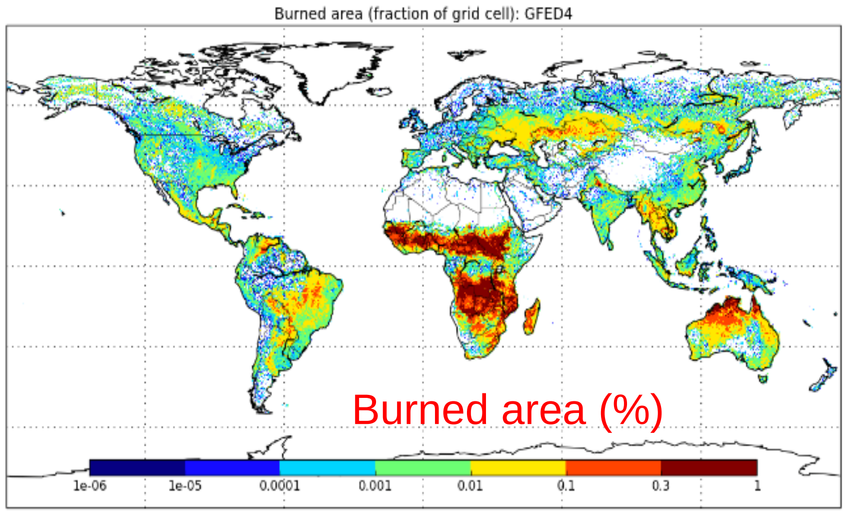
Wildfires in Western US have increased 4-fold in 30 years.

Western US area burned



Source: Westerling et al. 2006

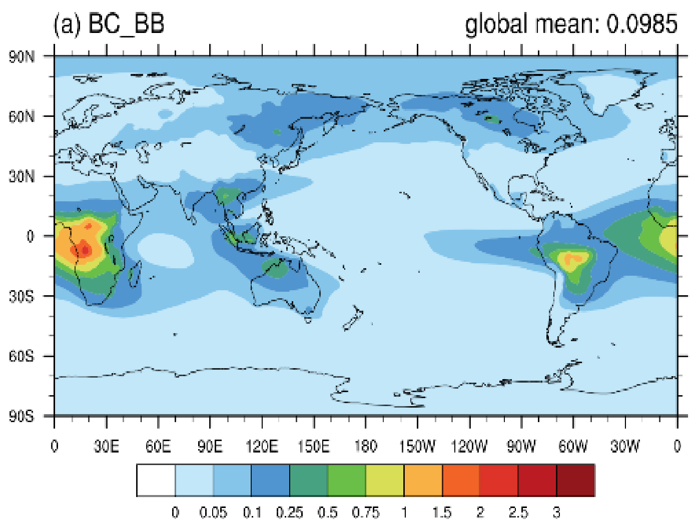
Fire Aerosol Distribution

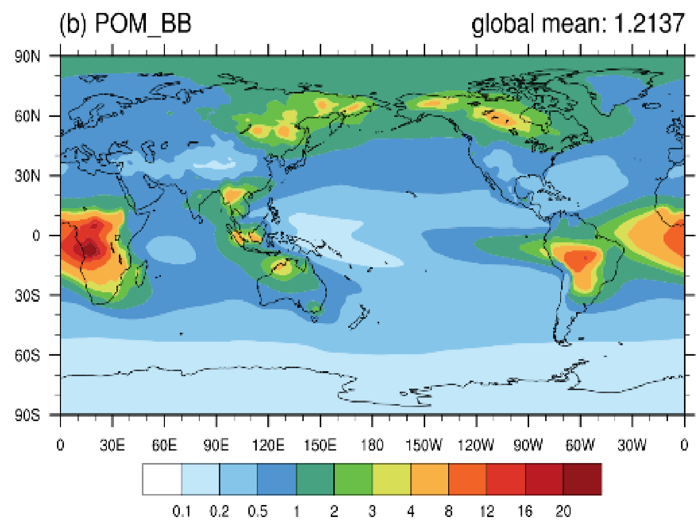


Burned area (%)

Fire BC

Fire POM





Unit : mg m^{-2}

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- ✧ Fire aerosol radiative forcing

Model and Experiments

- CAM5.3 + MAM4: 0.9 degree x 1.25 degree
- CLM4.0 with SNICAR (SNow, ICe, and Aerosol Radiative Model)
- Fire emissions: GFED 3.1 **daily** emissions (2003 to 2011)
- Fire injection heights based on the AeroCom (0-6 km)
- Simulation time: 2003 to 2011 with observed SST

AMIP-Type Experiments with CAM5.3

	Fire BC	Fire POM	Fire SO2
Fire	On	On	On
NoFire	Off	Off	Off
NoFireBC	Off	On	On
NoFirePOM	On	Off	On

- Each experiment for 2003-2011, with 10 ensembles
- 0.9x1.25 horizontal resolution, 30 vertical levels
- Anthropogenic aerosol emissions: IPCC AR5 emissions (Lamarque et al., 2010)

AMIP-Type Experiments with CESM-CAM5

BBFFBF

Tag BC/POM in three categories :

Fossil Fuel (FF)
Biomass Burning (BB)
Bio-Fuel (BF)

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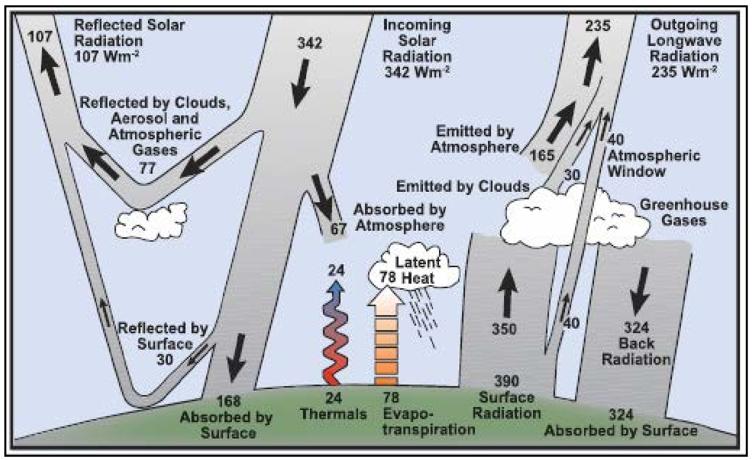
Method to Calculate Aerosol Radiative Forcing (Ghan 2013)

Shortwave Longwave



ΔF = Fire – NoFire (All fire aerosol radiative forcing)

ΔF = Fire – NoFireBC (Fire BC radiative forcing)

ΔF = Fire – NoFirePOM (Fire POM radiative forcing)

$\Delta F = \Delta(F - F_{noaer})$ + (direct)

$\Delta(F_{noaer} - F_{noaer,clearsky})$ + (cloud)

$\Delta F_{noaer,clearsky}$ (albedo)

F: net shortwave flux at TOA

$F_{clearsky}$ = F without cloud

F_{noaer} = F without aerosol

$F_{noaer,clearsky}$ = F without aerosol & cloud

- *Direct forcing* should be estimated in all-sky condition
- *Indirect forcing* should be estimated without influence of aerosol direct effect

Method to Calculate Aerosol Radiative Forcing

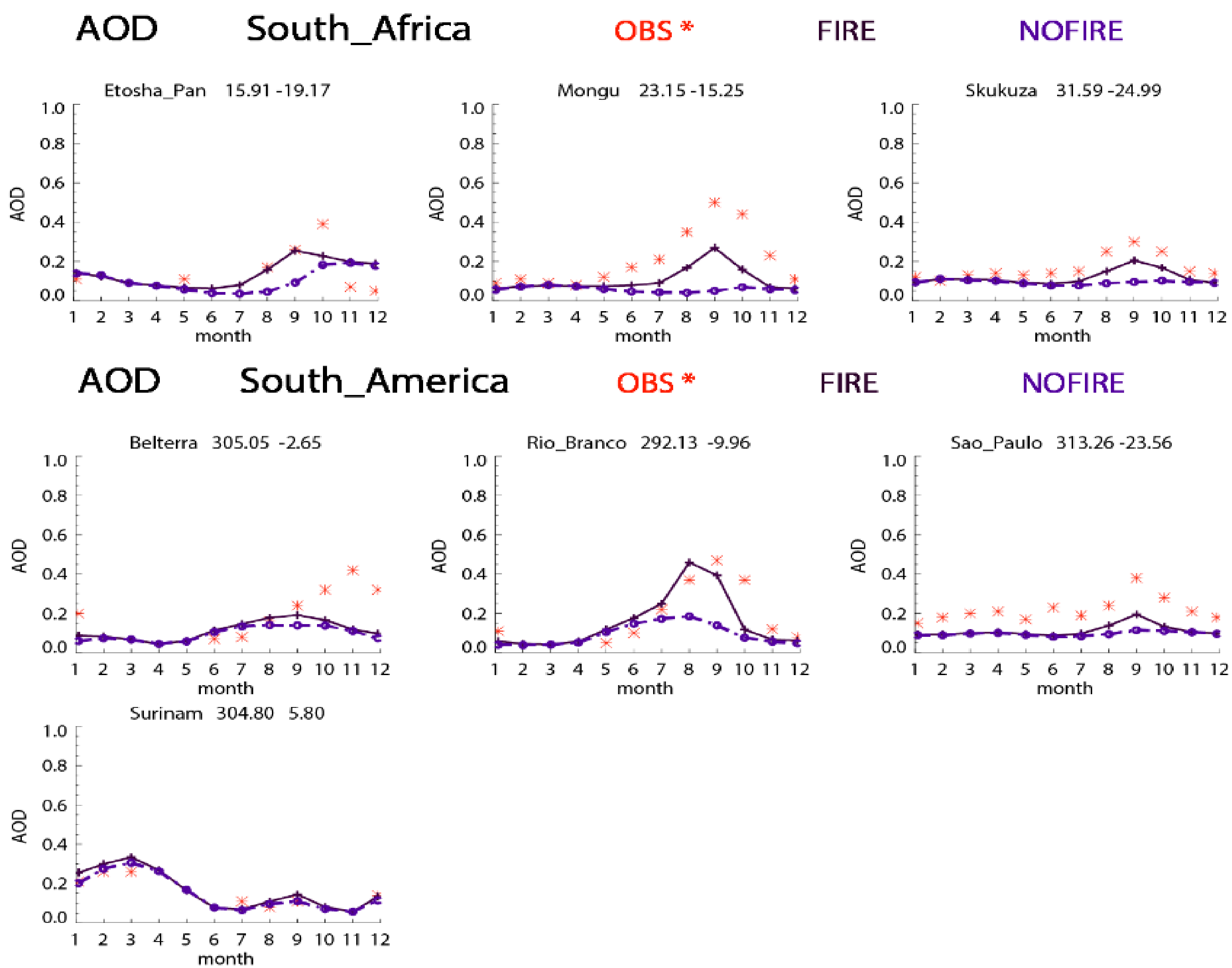
BBFFBF:

F – F_NoFire (Fire aerosol direct forcing)

F – F_NoFireBC (Fire BC direct forcing)

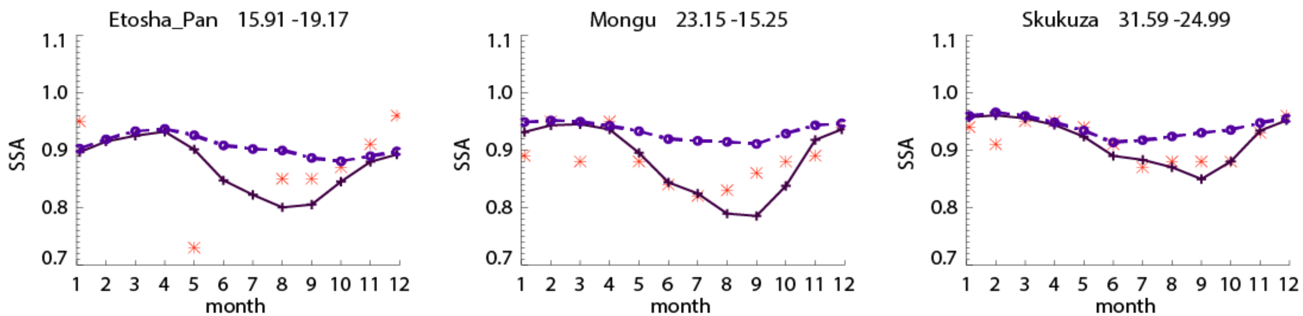
F – F_NoFirePOM (Fire POM direct forcing)

Evaluation of Simulated AOD

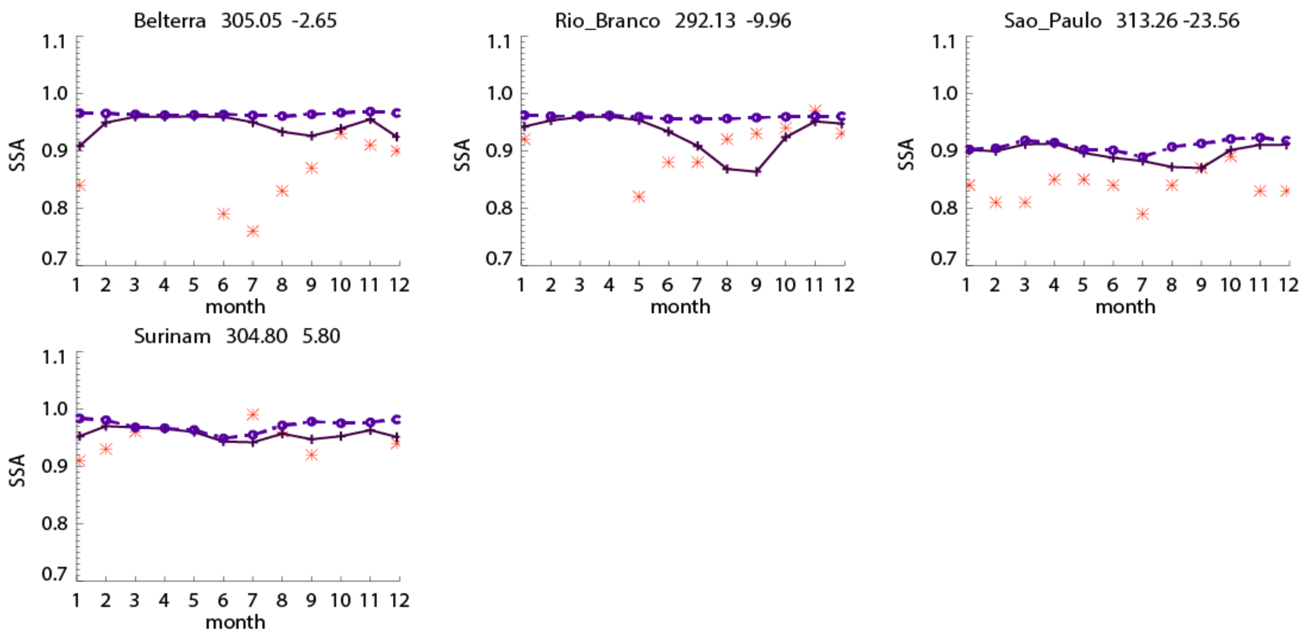


Evaluation of Simulated SSA

SSA South_Africa OBS * FIRE NOFIRE

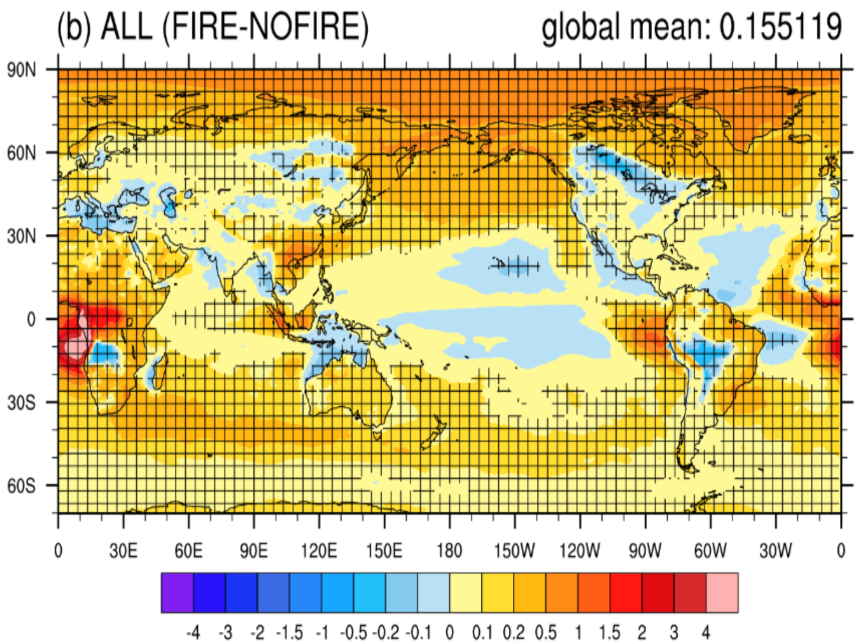


SSA South_America OBS * FIRE NOFIRE

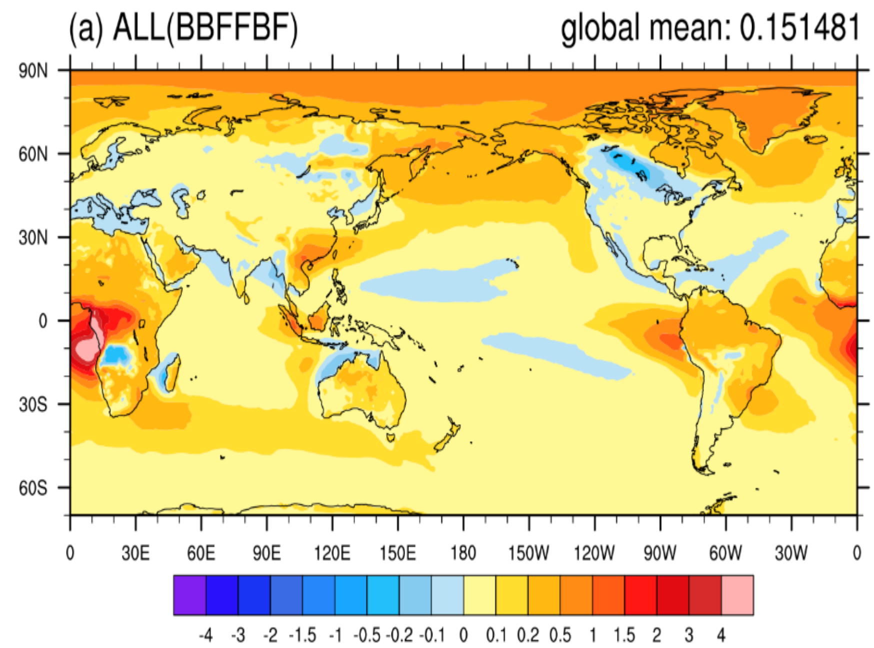


Direct forcing of all fire aerosols

Method: Fire - NoFire



Method: BBFFBF

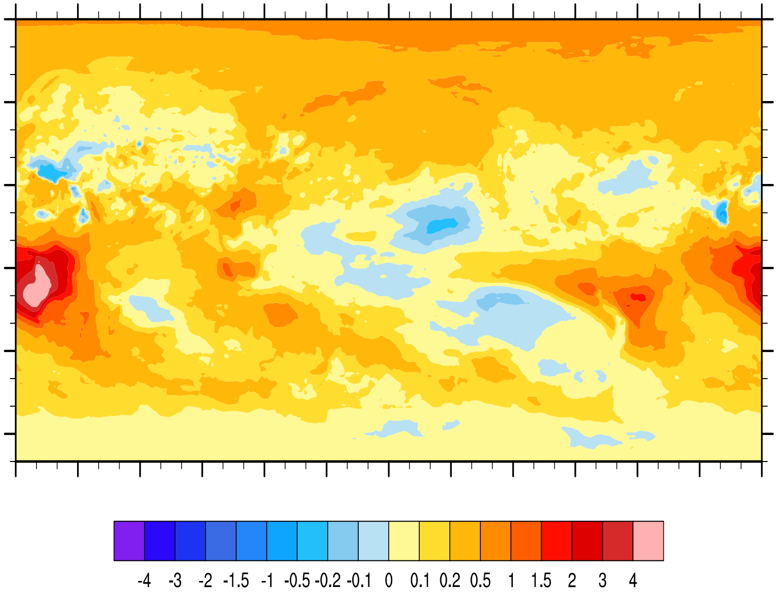


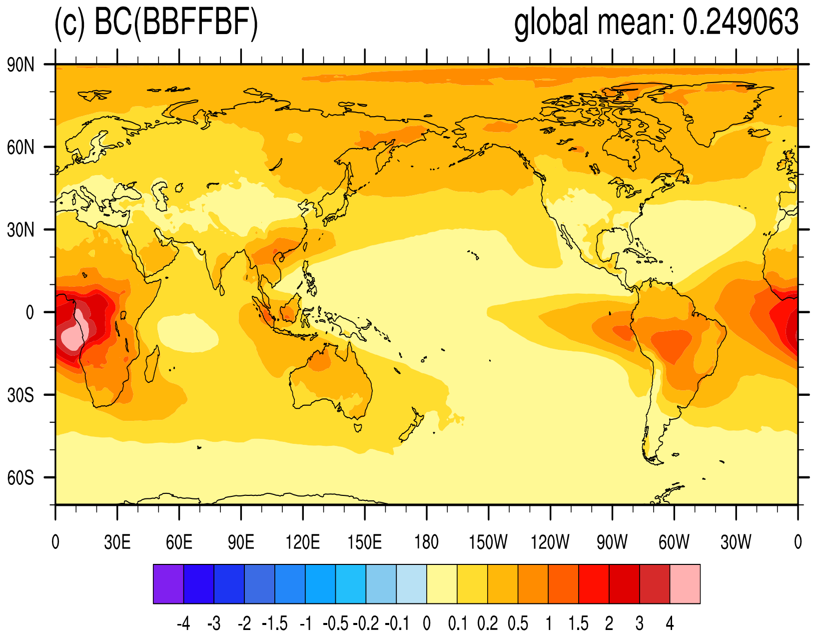
Fire aerosol direct forcing : 0.15 W/m^2

Direct forcing of fire BC

Method: Fire - NoFireBC

Method: BBFFBF

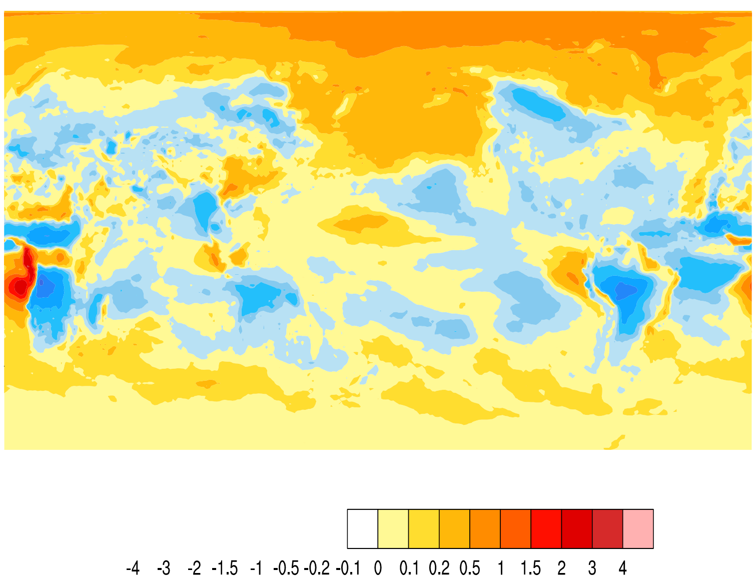




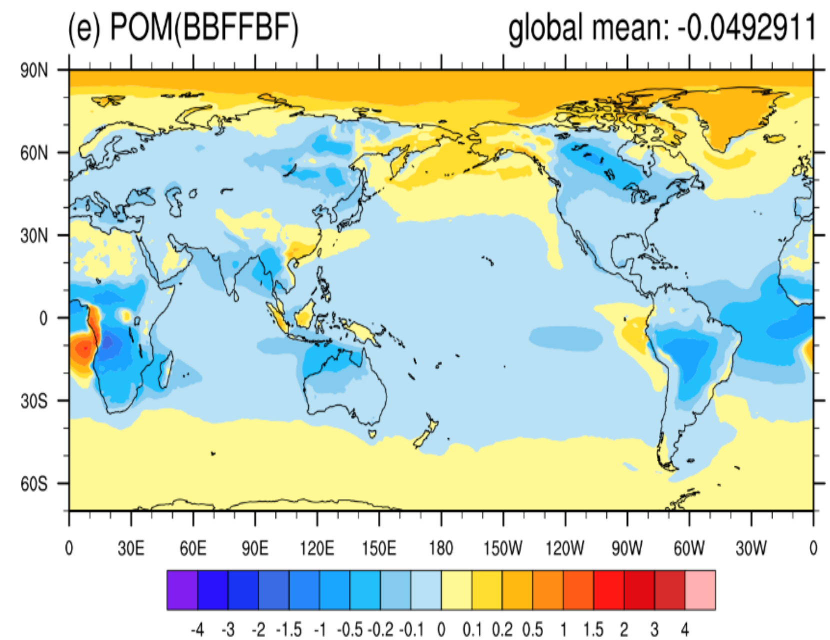
Fire BC direct forcing : 0.25 W/m^2

Direct forcing of fire POM

Method: Fire - NoFirePOM

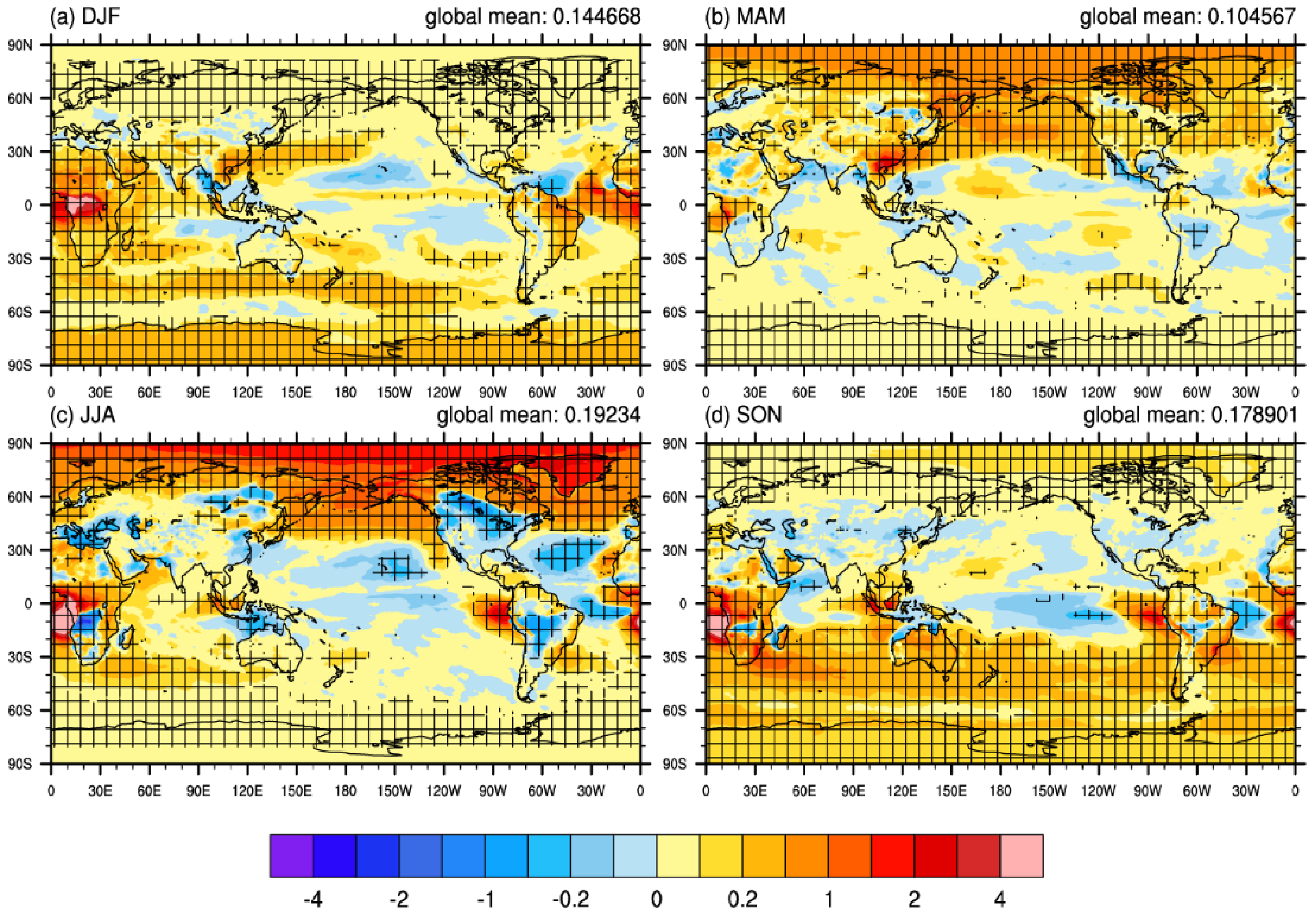


Method: BBFFBF

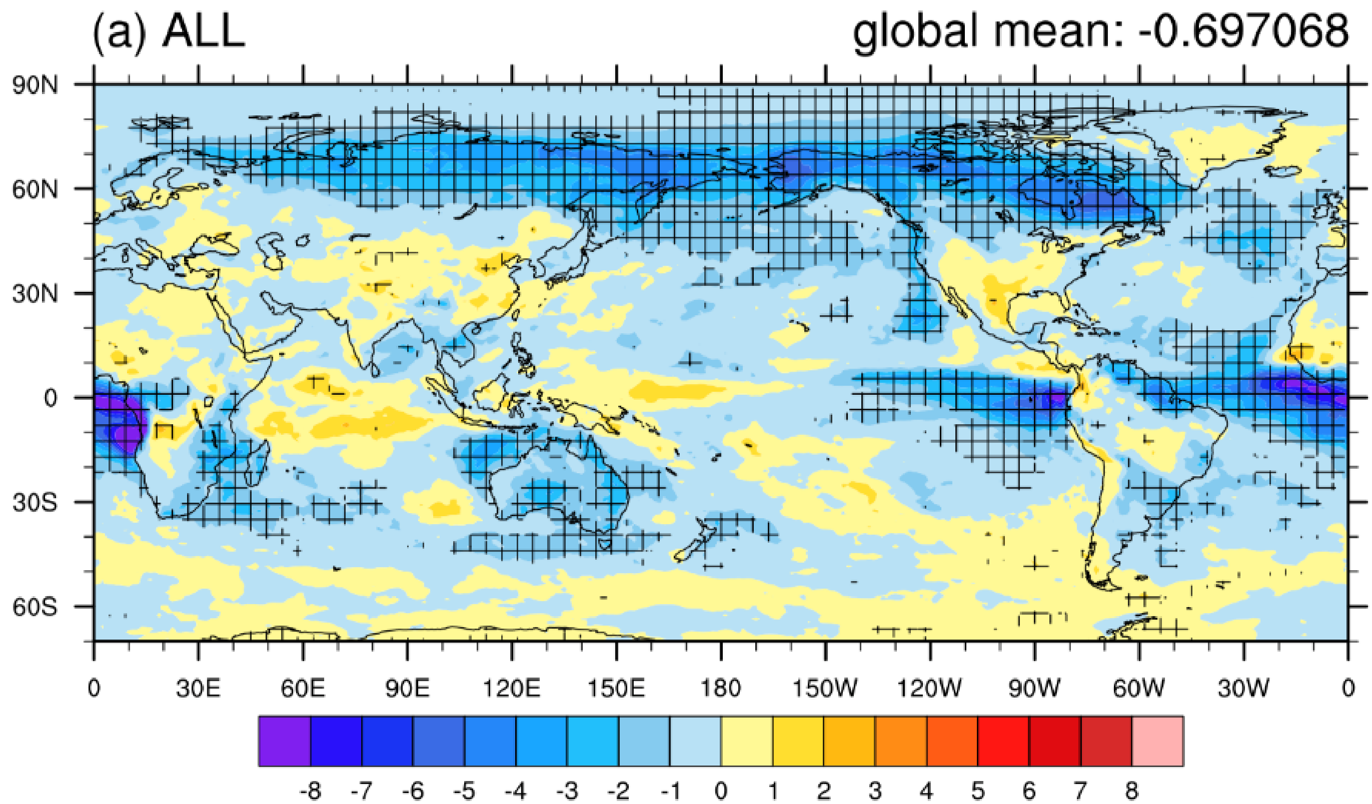


Fire POM direct forcing : 0.04 to -0.05 W/m^2

Seasonal variation of direct forcing of all fire aerosols



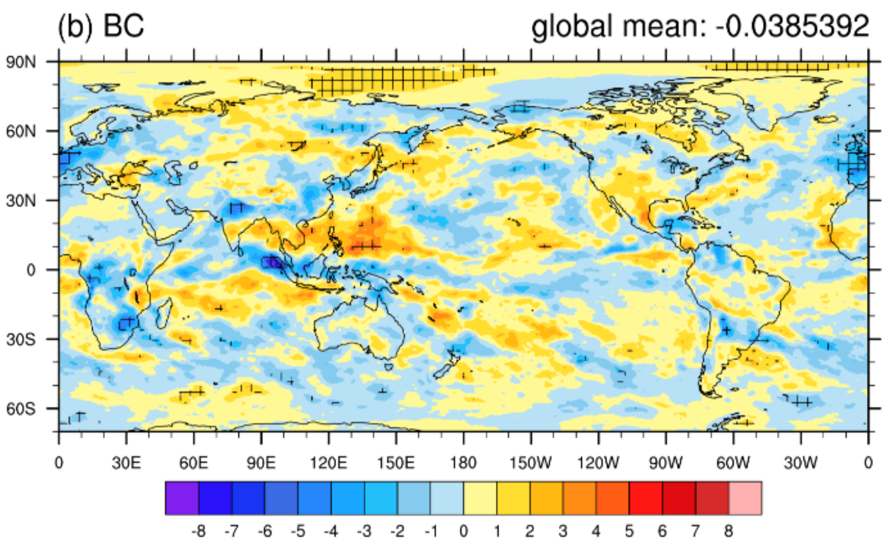
Cloud forcing change from all fire aerosols



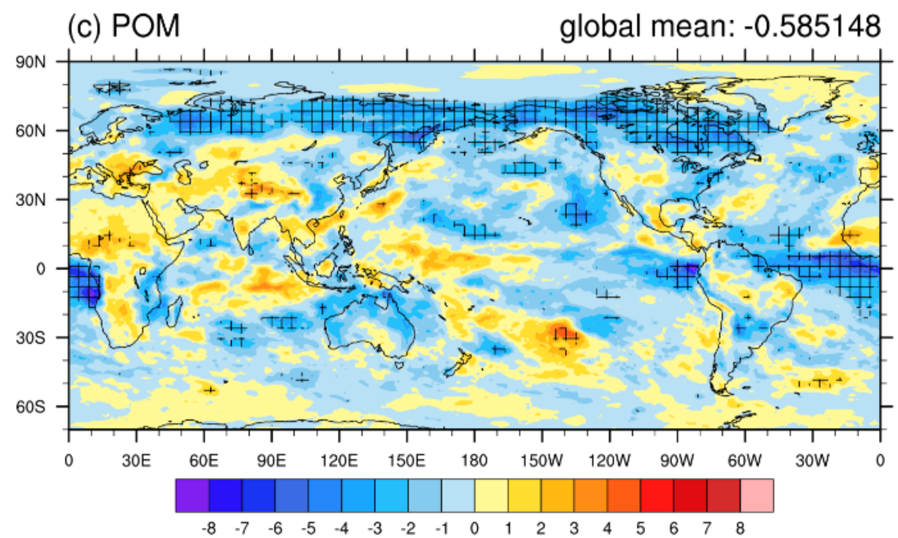
Fire aerosol indirect forcing : -0.70 W/m^2

Cloud forcing change from fire BC and POM

BC

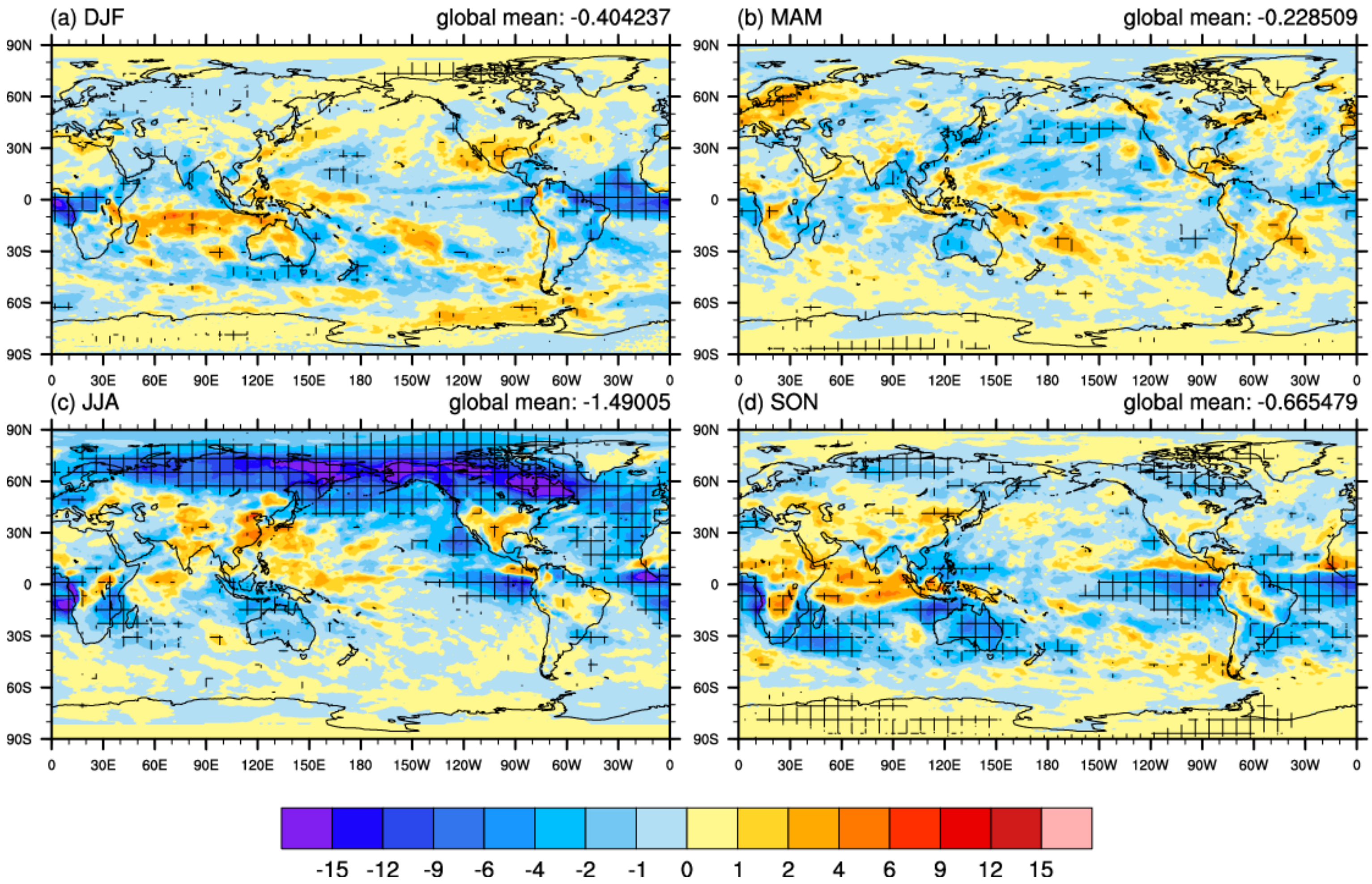


POM

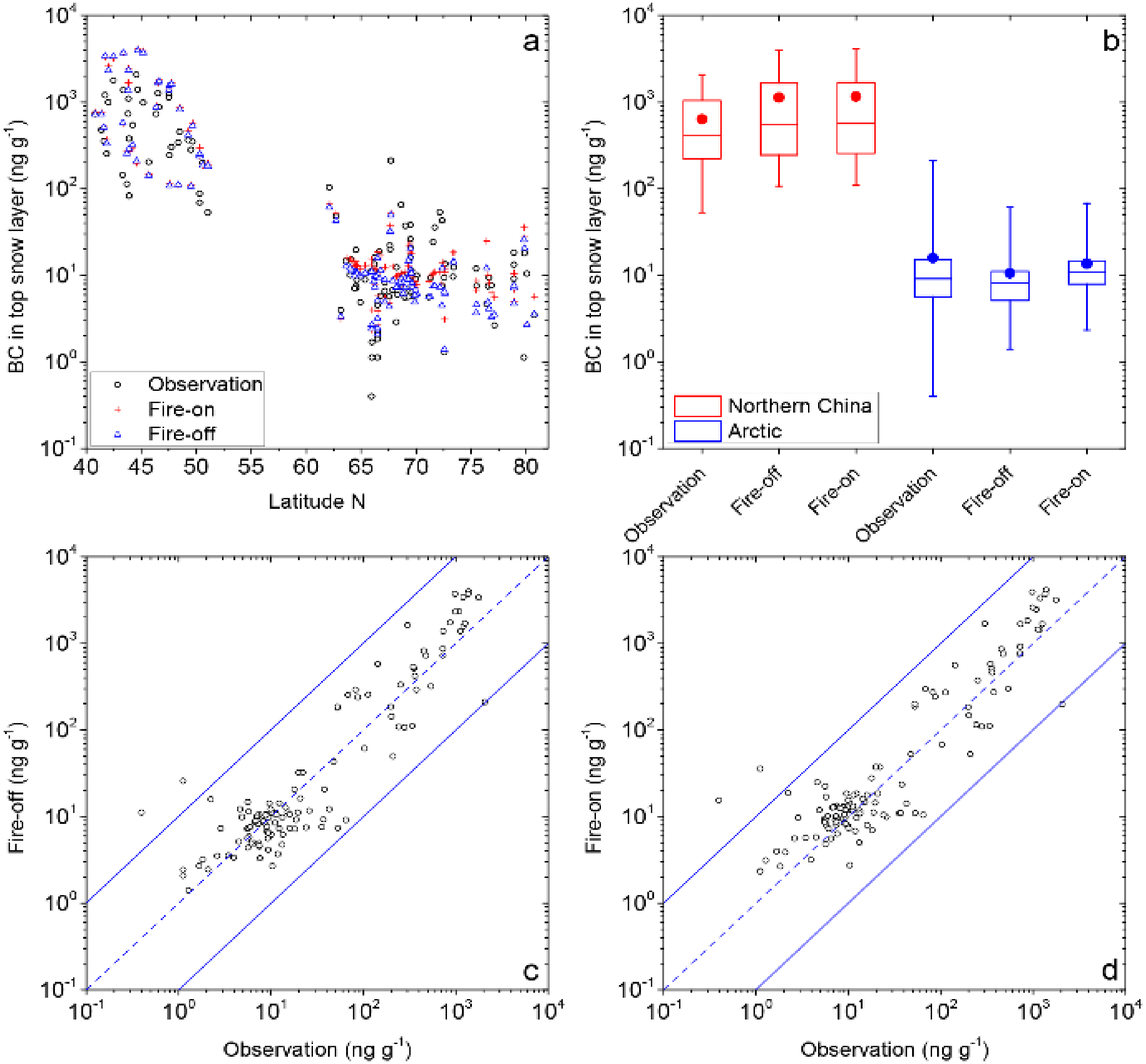


Fire BC and POM indirect forcing : -0.04, -0.59 W/m^2

Seasonal variation of cloud forcing from all fire aerosols



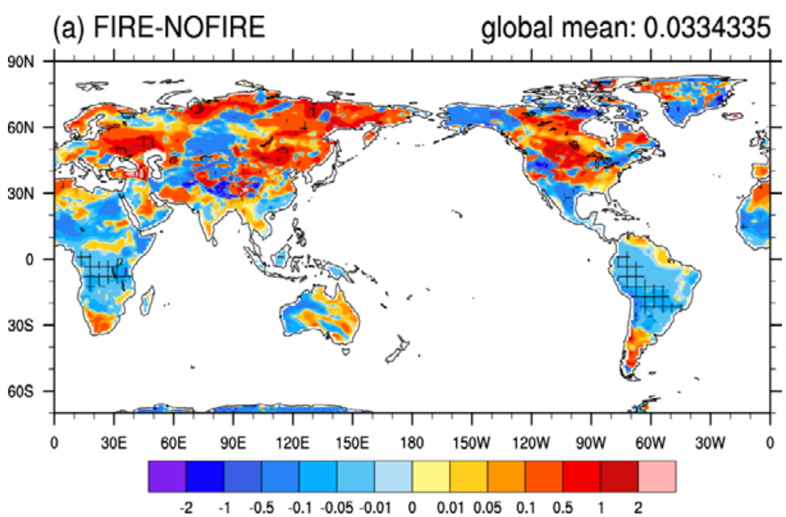
Albedo forcing of all fire aerosols



Evaluation of simulated BC concentration (in ng g^{-1}) in the top snow layer against observations in the Arctic (Doherty et al 2010) and Northern China (Wang et al 2013b).

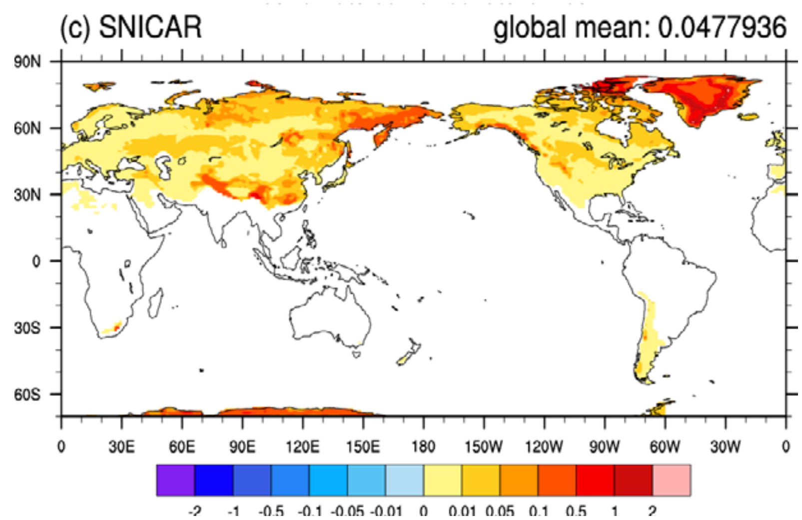
Albedo forcing of all fire aerosols

Method: Fire - NoFire



Fire aerosol surface albedo forcing : 0.033 W/m^2

Method: SNICAR



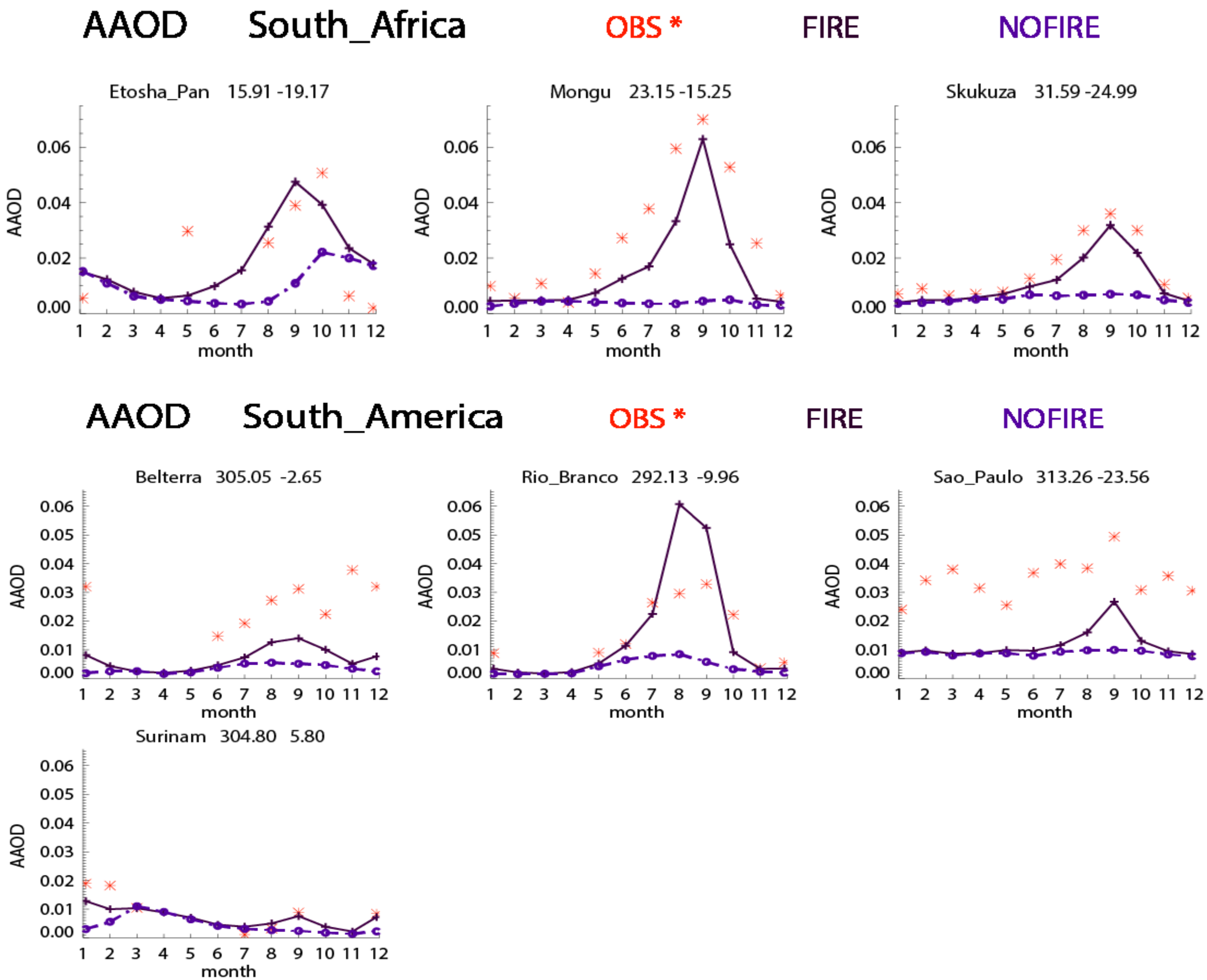
Fire aerosol snow albedo forcing : 0.048 W/m^2

Summary

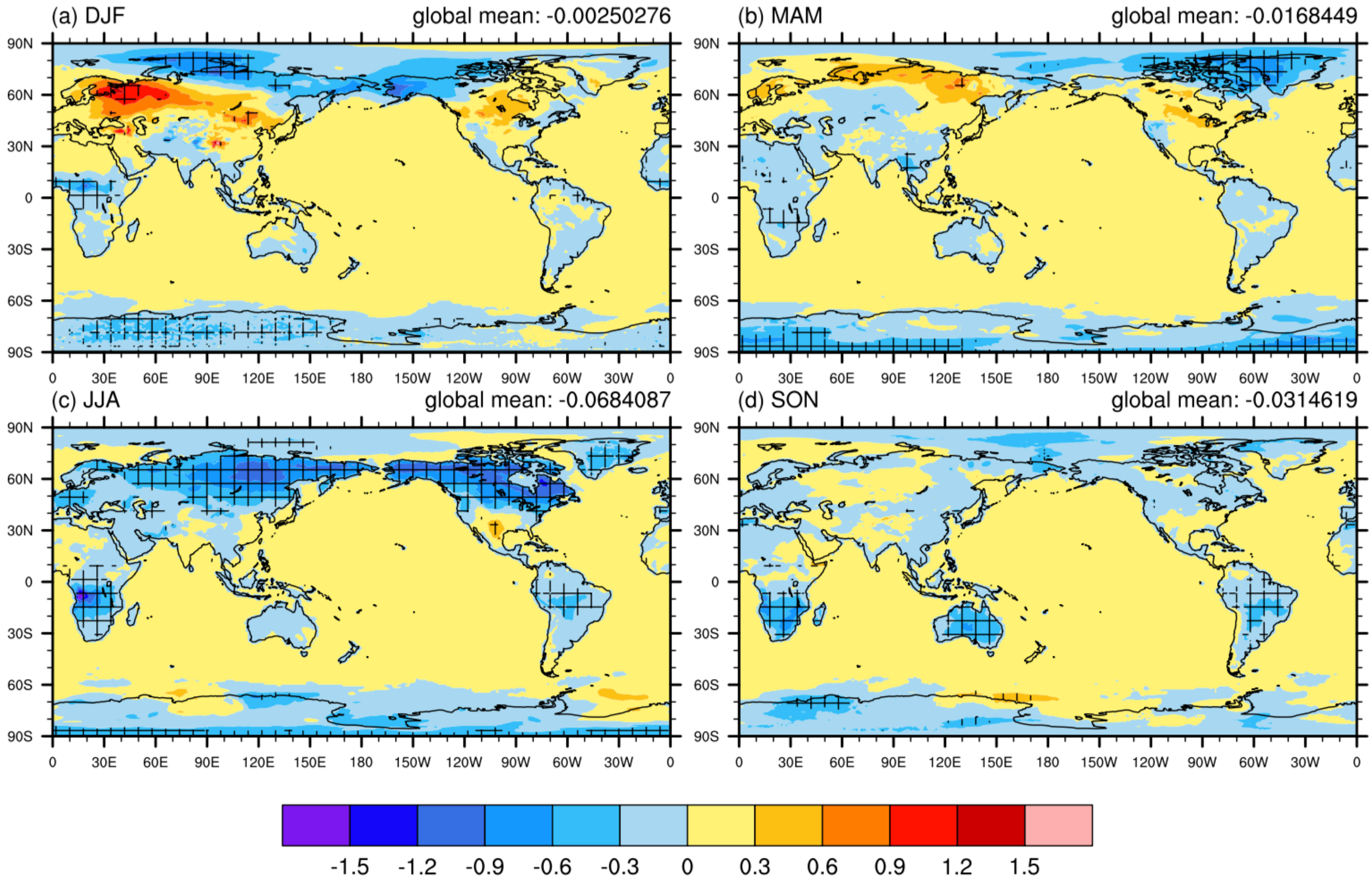
- The annual mean direct radiative forcing of all fire aerosols (+0.15 W m^{-2}) is mainly due to fire BC (0.25 W m^{-2}), while fire POM induce a weak forcing (-0.05 to 0.04 W m^{-2}).
- The global annual mean cloud forcing change (radiative forcing from aerosol-cloud interactions) of all fire aerosol is -0.70 W m^{-2} and mainly from indirect forcing of fire POM (-0.58 W m^{-2}). The cloud forcing is maximum in the NH high latitudes during boreal summer.
- The global annual mean surface albedo forcing (+0.03 W m^{-2}) is mainly due to fire BC snow forcing (0.04 W m^{-2}) and the maximum albedo forcing is in spring (0.12 W m^{-2}).
- Next step: studying the climate effect of fire aerosols

THANKS!

Evaluation of Simulated AAOD



Fire aerosol effects on surface temperature



Fire aerosol effects on surface precipitation