The Effects of Anthropogenic Aerosols and Agriculture on South Asian Summer Monsoon

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Influence of climate on SASM

nature climate change

REVIEW ARTICLE

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Climate change and the South Asian summer monsoon

Andrew G. Turner[1]* and H. Annamalai[2]*

Indian Monsoon Variability in a Global Warming Scenario

Natural Hazards **29:** 189–206, 2003.

Authors | Authors and affiliations

R. H. Kripalani, Ashwini Kulkarni, S. S. Sabade, M. L Khandekar

GEOPHYSICAL RESEARCH LETTERS, VOL. 29, NO. 7, 1118, 10.1029/2001GL013808, 2002

Simulated changes of the Indian summer monsoon under enhanced greenhouse gas conditions in a global time-slice experiment

Wilhelm May

Danish Meteorological Institute, Copenhagen, Denmark

- Affects TOA /surface radiation and energy fluxes
- Modulates tropospheric temperature and temperature gradients

Influence of anthropogenic aerosols on SASM

Anthropogenic Aerosols and the Weakening of the South Asian Summer Monsoon

Massimo A. Bollasina[1], Yi Ming[2,*], V. Ramaswamy[2]
+ See all authors and affiliations

Science 28 Oct 2011:
Vol. 334, Issue 6055, pp. 502-505
DOI: 10.1126/science.1204994

Clim Dyn (2011) 36:1633–1647
DOI 10.1007/s00382-010-0982-0

Simulation of the anthropogenic aerosols over South Asia and their effects on Indian summer monsoon

Zhenming Ji · Shichang Kang · Dongfeng Zhang · Chunzi Zhu · Jia Wu · Ying Xu

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 117, D13209, doi:10.1029/2012JD017508, 2012

Climate response of the South Asian monsoon system to anthropogenic aerosols

Dilip Ganguly,[1] Philip J. Rasch,[1] Hailong Wang,[1] and Jin-Ho Yoon[1]

- Amplify or attenuate climate forcings
- Affect cloud properties

Influence of land use and land cover change on SASM

Clim Dyn (2014) 42:21–36
DOI 10.1007/s00382-013-1786-9

The response of the South Asian Summer Monsoon circulation to intensified irrigation in global climate model simulations

Sonali P. Shukla · Michael J. Puma · Benjamin I. Cook

GEOPHYSICAL RESEARCH LETTERS, VOL. 36, L20711, doi:10.1029/2009GL040625, 2009

Impact of irrigation on the South Asian summer monsoon

Fahad Saeed,[1] Stefan Hagemann,[1] and Daniela Jacob[1]

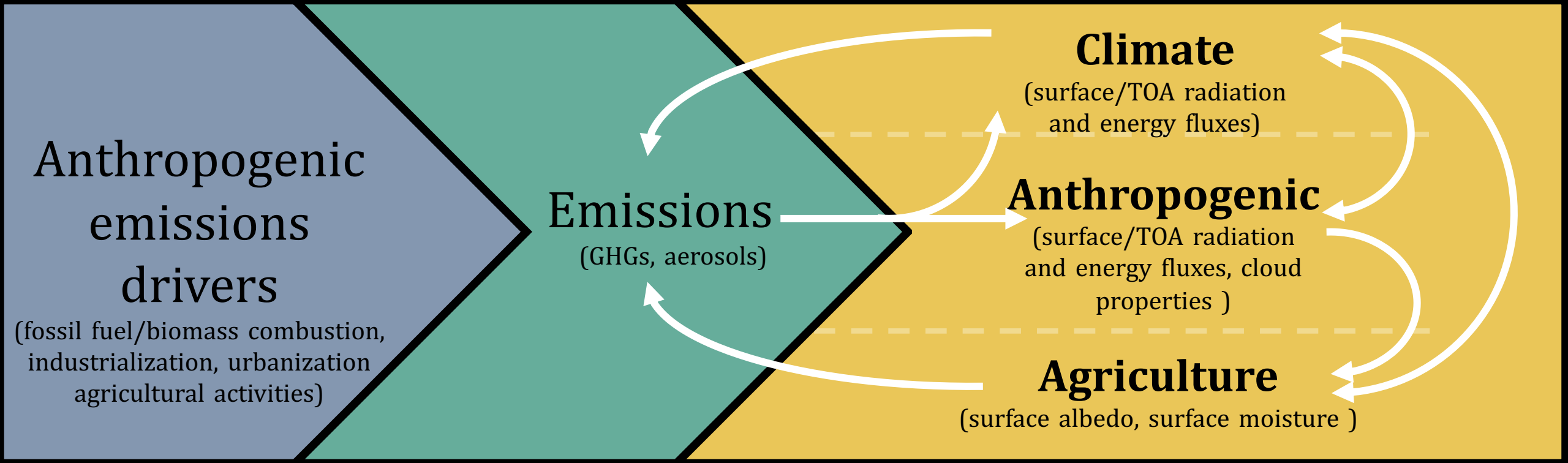
WATER RESOURCES RESEARCH, VOL. 46, W03533, doi:10.1029/2008WR007082, 2010

Observational evidence that agricultural intensification and land use change may be reducing the Indian summer monsoon rainfall

Dev Niyogi,[1] Chandra Kishtawal,[2] Shivam Tripathi,[3] and Rao S. Govindaraju[3]

- Heavily influence surface moisture and surface albedo
- Amplify greenhouse and anthropogenic aerosols forcings

South Asian Summer Monsoon [SASM]: a complex coupled system



Modified from Karambelas et al. (in prep)

Global Climate Model: NASA GISS-E2.1

- GISS climate model GISS-E2.1: CMIP6 (Schmidt et al., 2014)
- Horizontal resolution : 2° X 2.5° and 40 vertical layers (model top at 0.1hPa)
- Tropospheric and stratospheric chemistry (Shindell et al., 2013)
- Mass based aerosol scheme : OMA (Koch et al. 2006)
  MATRIX (Bauer et al., 2008)
- Dynamic vegetation module [Ent]
- Emission inventories, GHG, Land-use change and other inputs based on CMIP6
- Irrigation (Puma and Cook, 2010 and Cook 2011)

Global Climate Model: NASA GISS-E2.1

- Model run from 1960-2015 with prescribed ocean and transient ocean
- Model output frequency: monthly and running weekly average
- Four sensitivity tests

★ **Control**

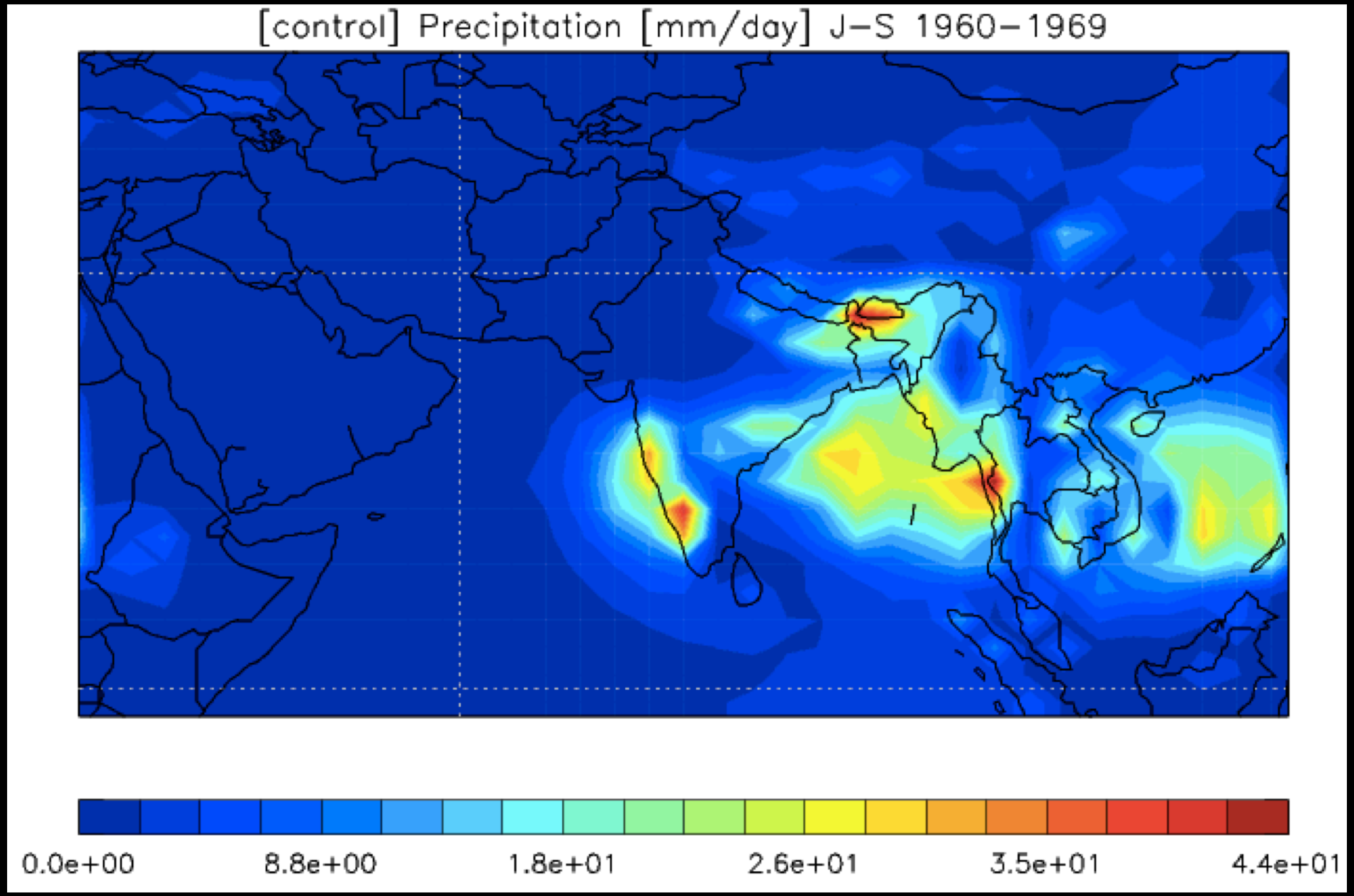
★ Control – All anthropogenic aerosols

- Control – Global aerosols
- Control – Regional aerosols
- All aerosols including Anthropogenic and biomass

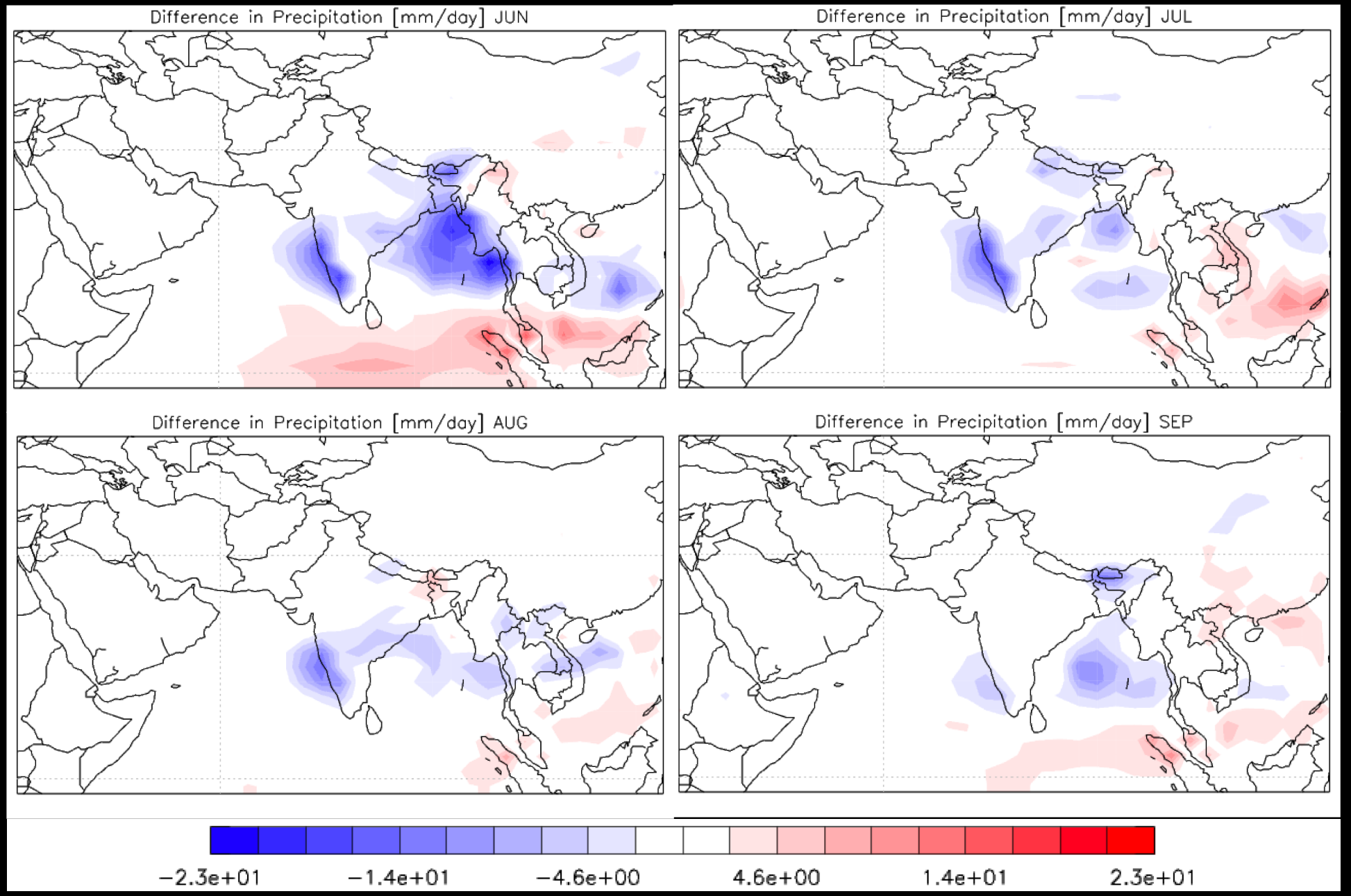
★ Control – Anthropogenic aerosols and biomass burning

- Irrigation
- Control – Irrigation and LULCC
- Land-cover and land-use change (LULCC)

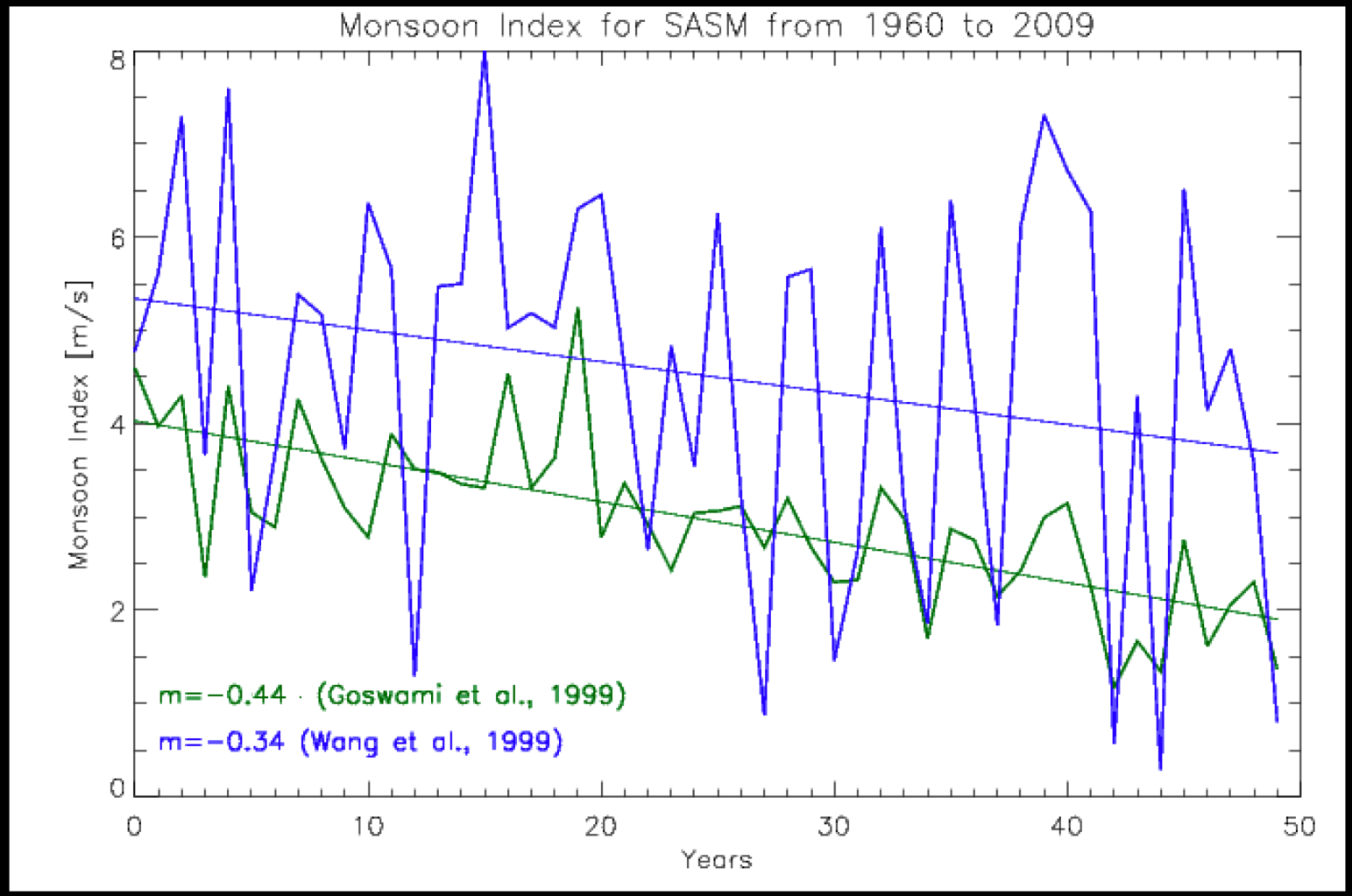
Model represents SASM in most but not all locations



Overall decrease in precipitation amount – strongest in June



Evidence of SASM Weakening



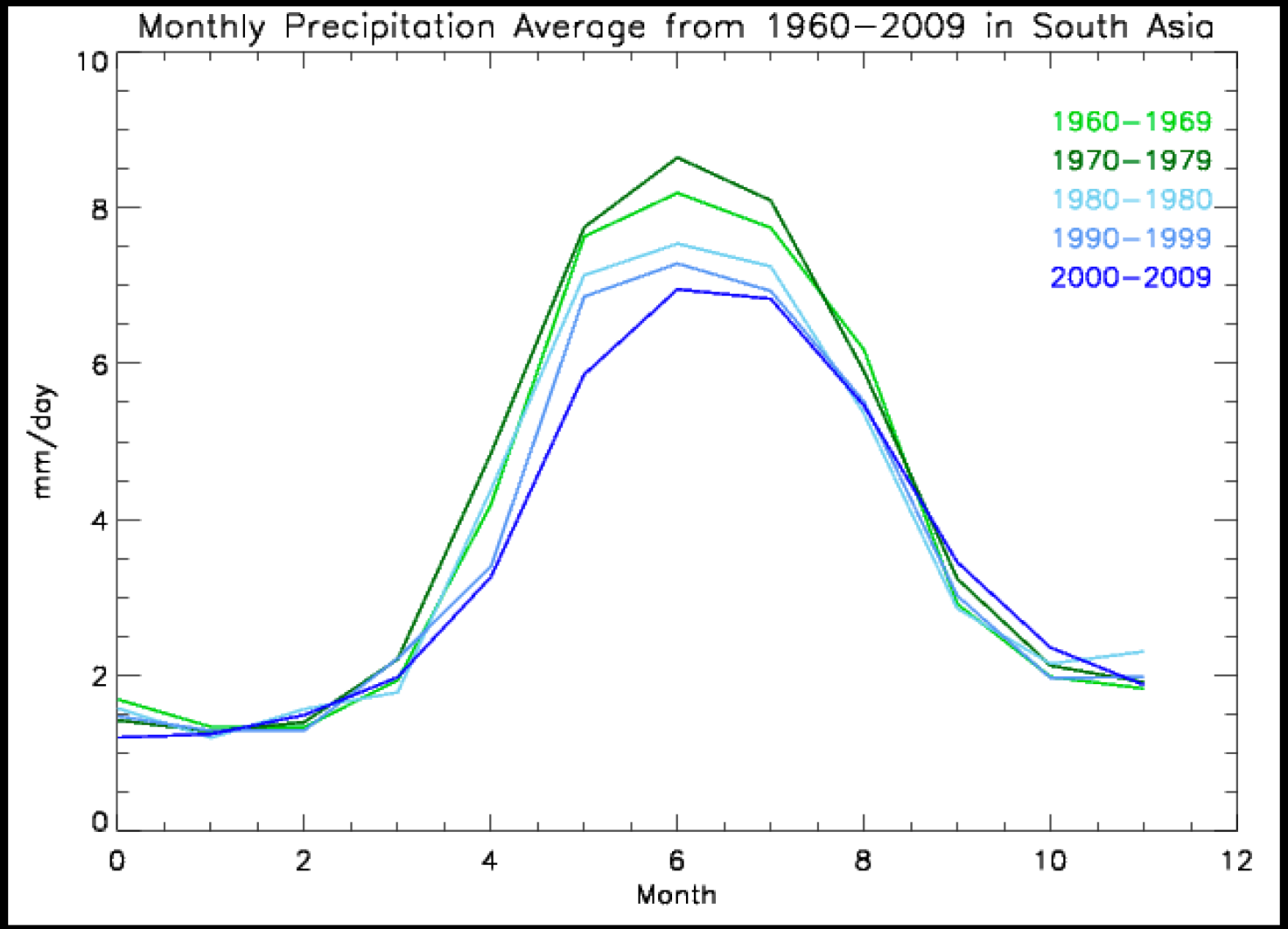
Dynamical Indian Monsoon Index (Wang et al 1999)

U850 (5-15N, 40-80E) – U850 (20-30N, 70-90E)

South Asian Monsoon Index (Goswami et al 1999)

V850 (10-30N, 70-110E) – V200 (10-30N, 70-110E)

Model simulation shows a decline in precipitation amount

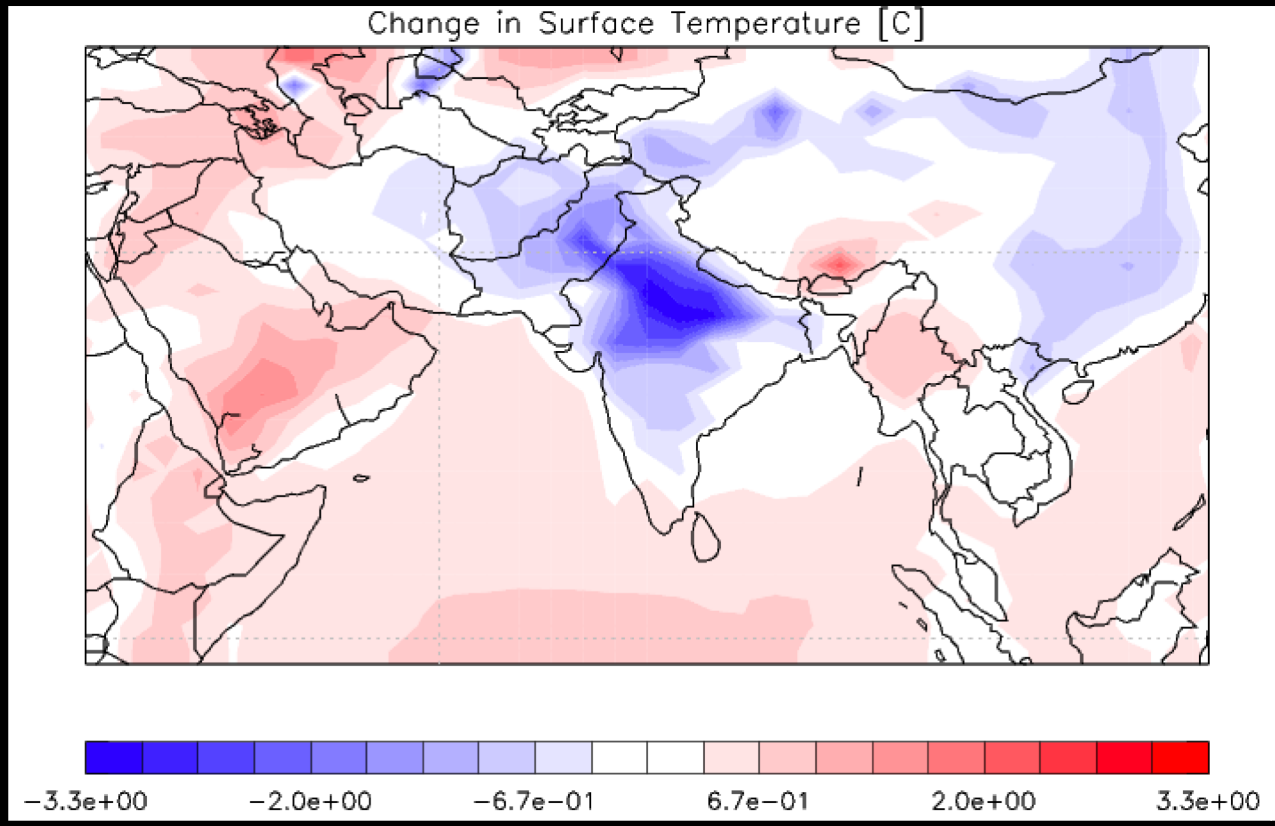


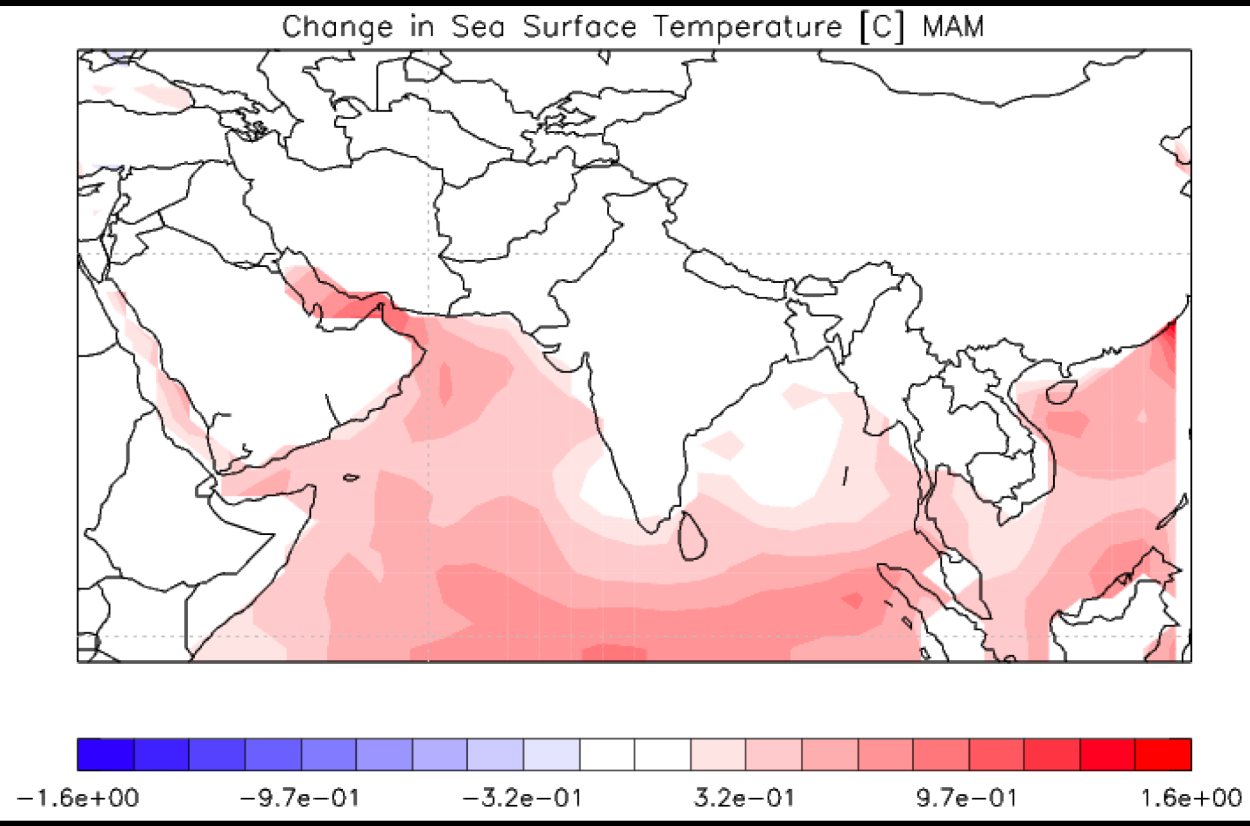
Strong declining trend (~10%) during peak months (Jin and Wang, 2017)

Drying of South Asian landmass by rapid Indian Ocean warming and a weakening land-sea thermal gradient (Chung and Ramanathan, 2006; Roxy et al., 2015)

Weakening of SASM rainfall due to changes in land use land cover (Paul et al., 2006)

Model results show warming of Western and Southern IO and cooling of landmass



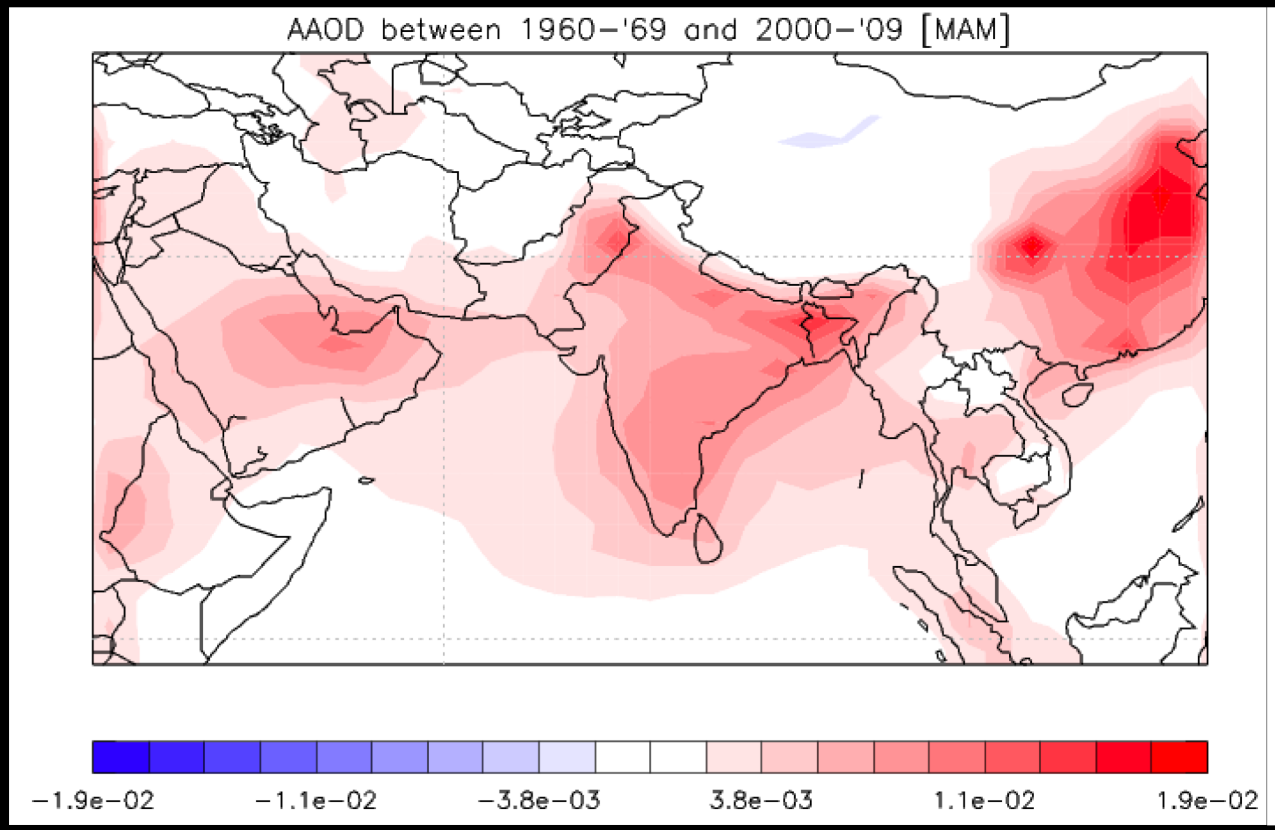


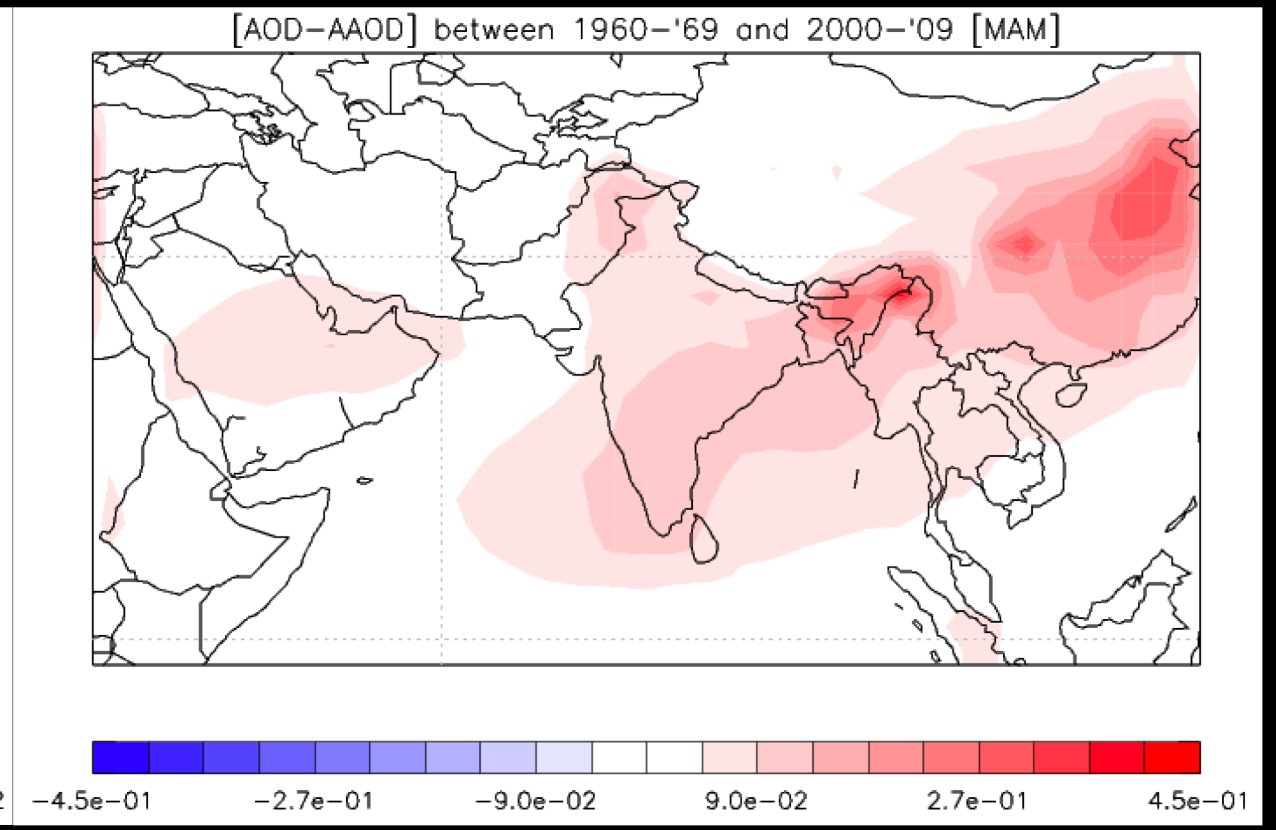
Warm IO leads to warm upper troposphere due to enhanced heating aloft from convection (Roxy et al., 2015)

Warmer upper troposphere creates weaker meridional tropospheric thermal gradient

Weaker thermal gradient influences the strength and location of meridional monsoon.

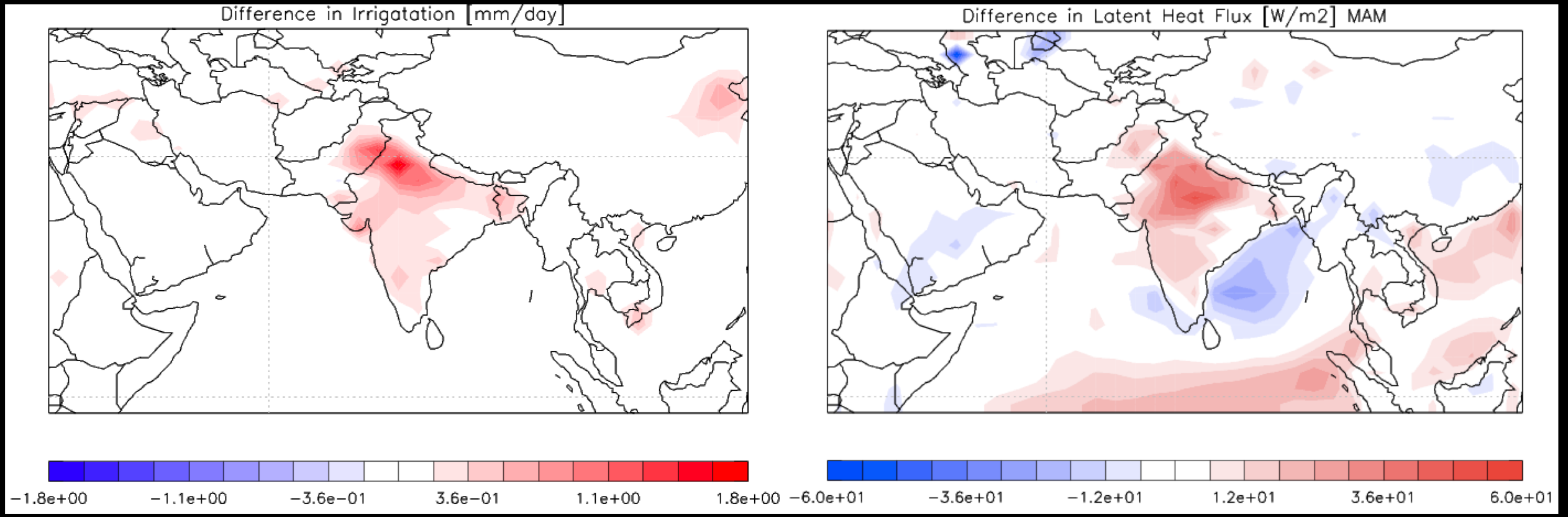
Both absorbing and scattering aerosols have increased





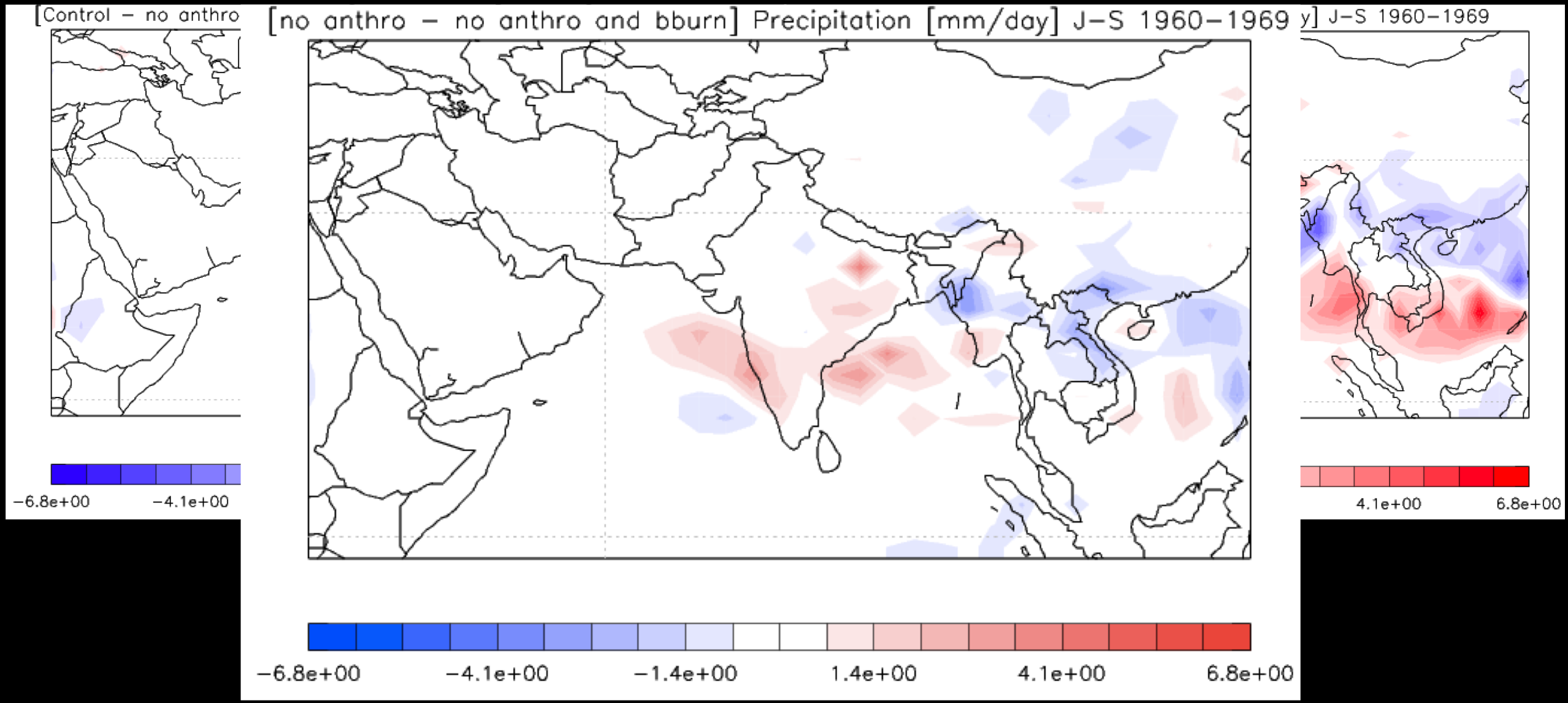
Anthropogenic aerosols have substantially masked the precipitation increase over the monsoon area (Bollasina et al., 2014)

Rapid expansion of agriculture supported by intensive irrigation.



Increase in pre-monsoon LHF over heavily irrigated IGP alters surface energy balance and transport of atmospheric water vapor (Shukla et al., 2014)

Positive impact of biomass burning on precipitation



Conclusion

- Precipitation is simulated well
- Decrease in wind shear and amount of precipitation during monsoon
- Increased aerosols, both absorbing and scattering over the region and weakening of land-sea surface temperature gradient
- Increase in LHF coincides with irrigation expansion
- Biomass burning estimated to have positive effect on precipitation

Thank you for your attention

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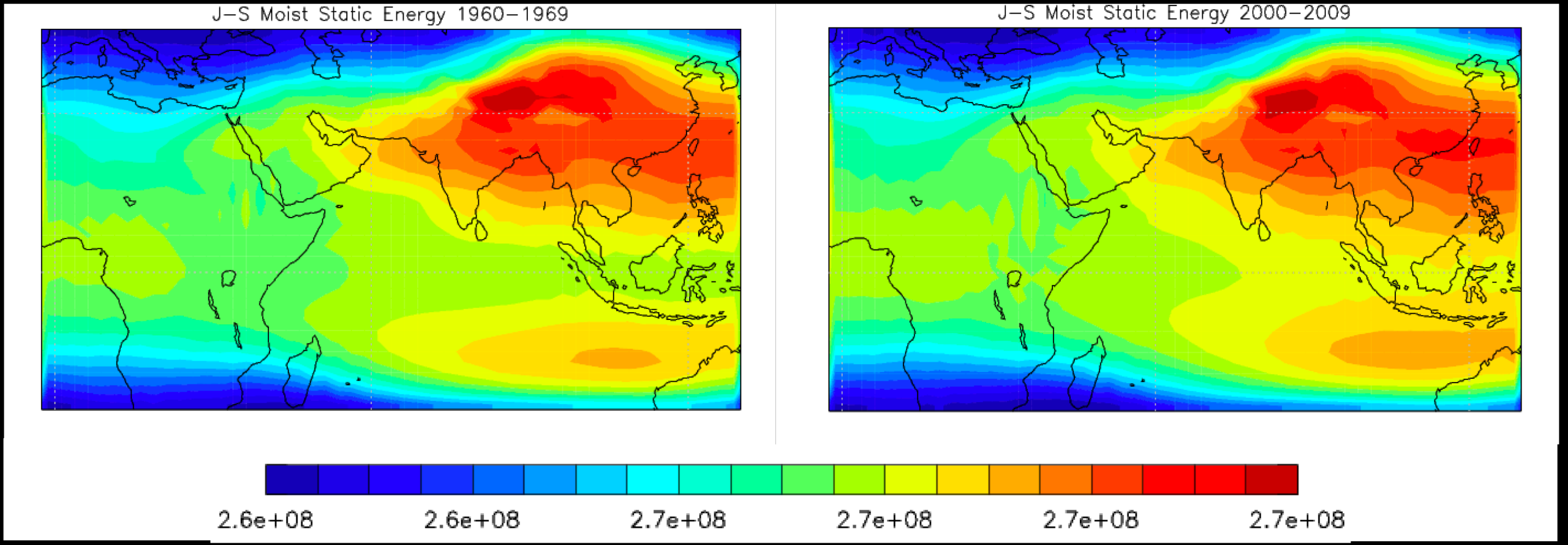
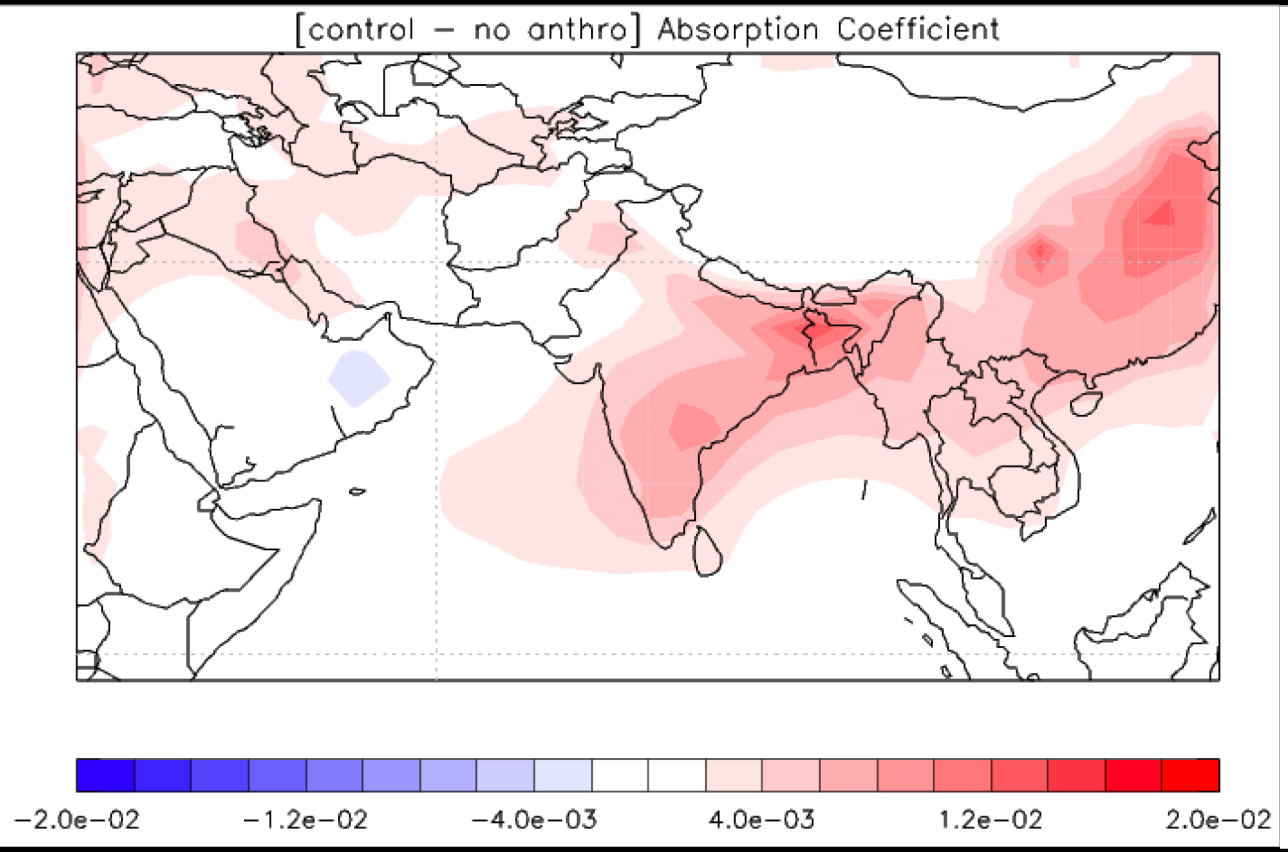
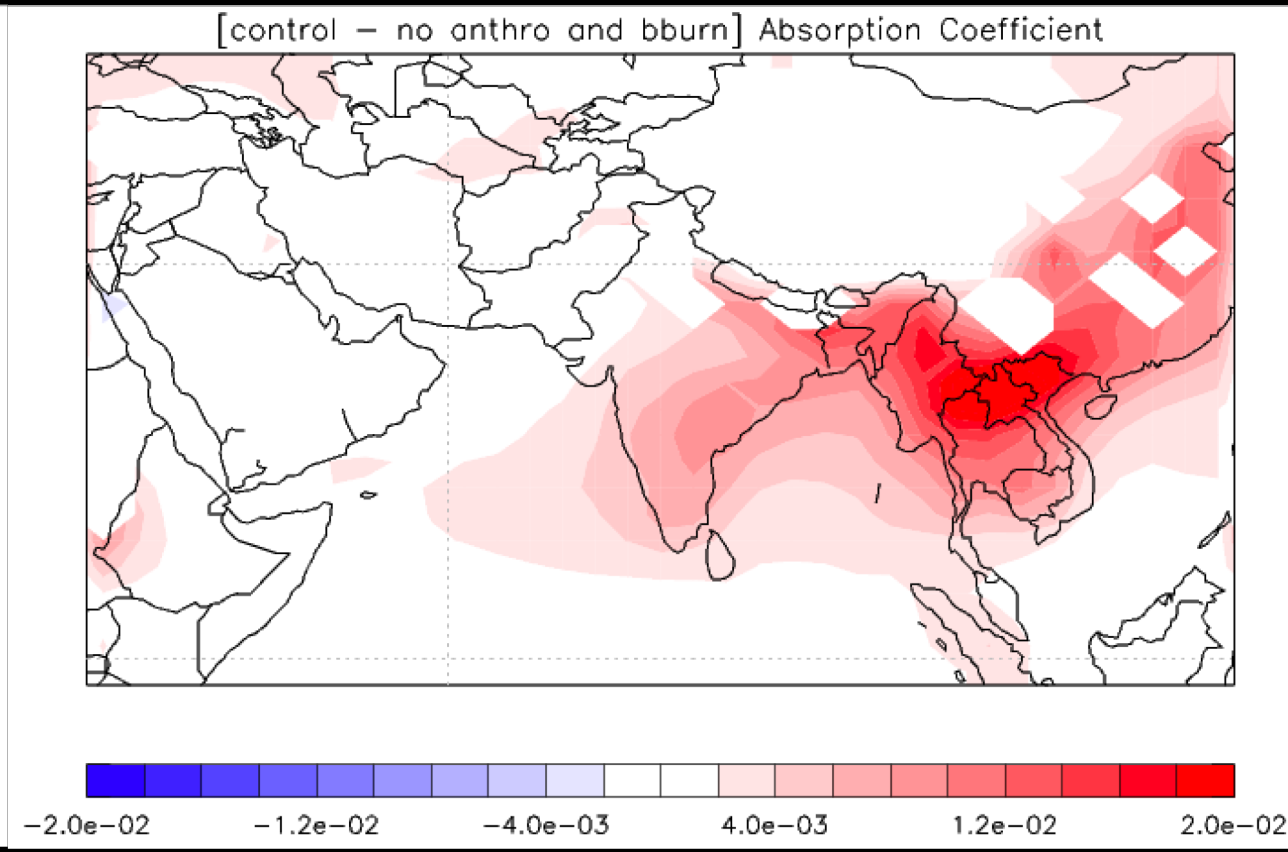
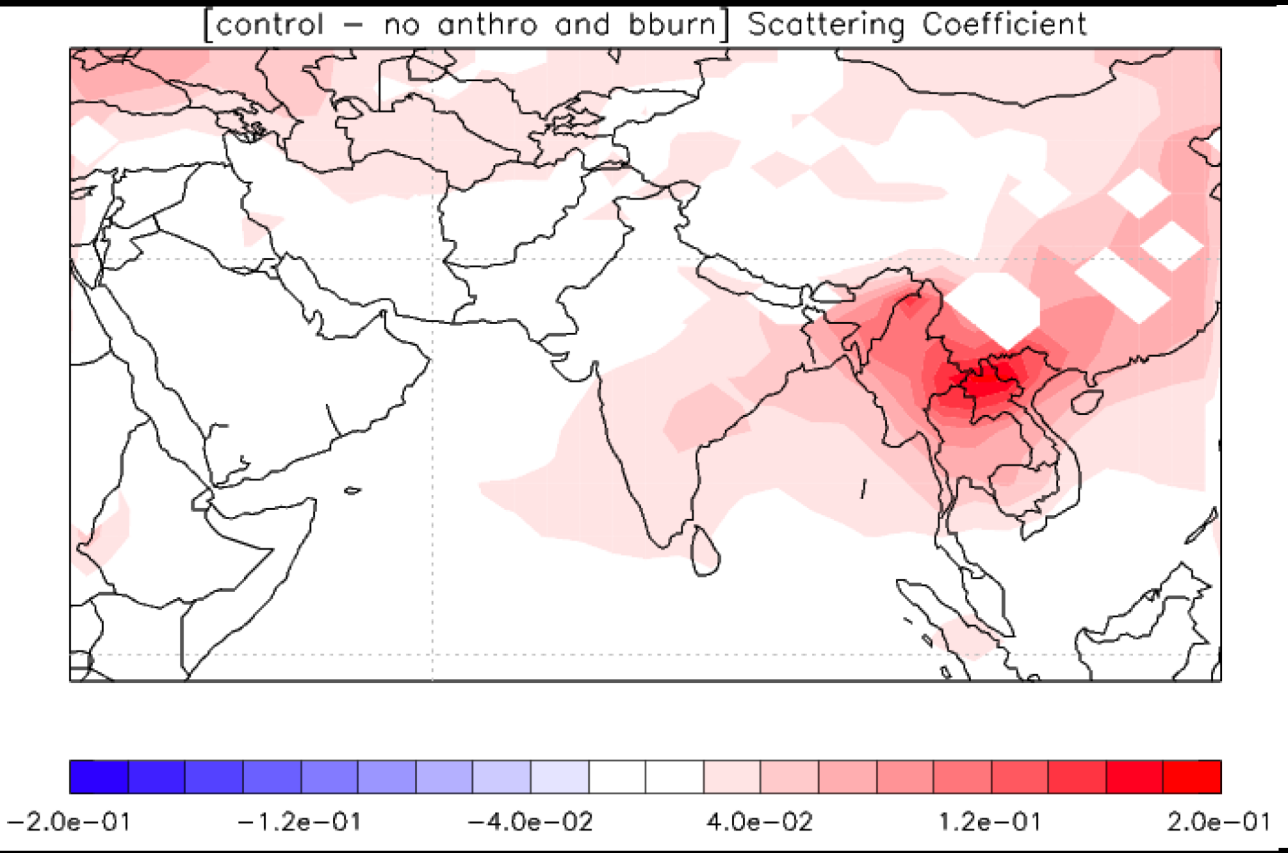
Change in moist static energy

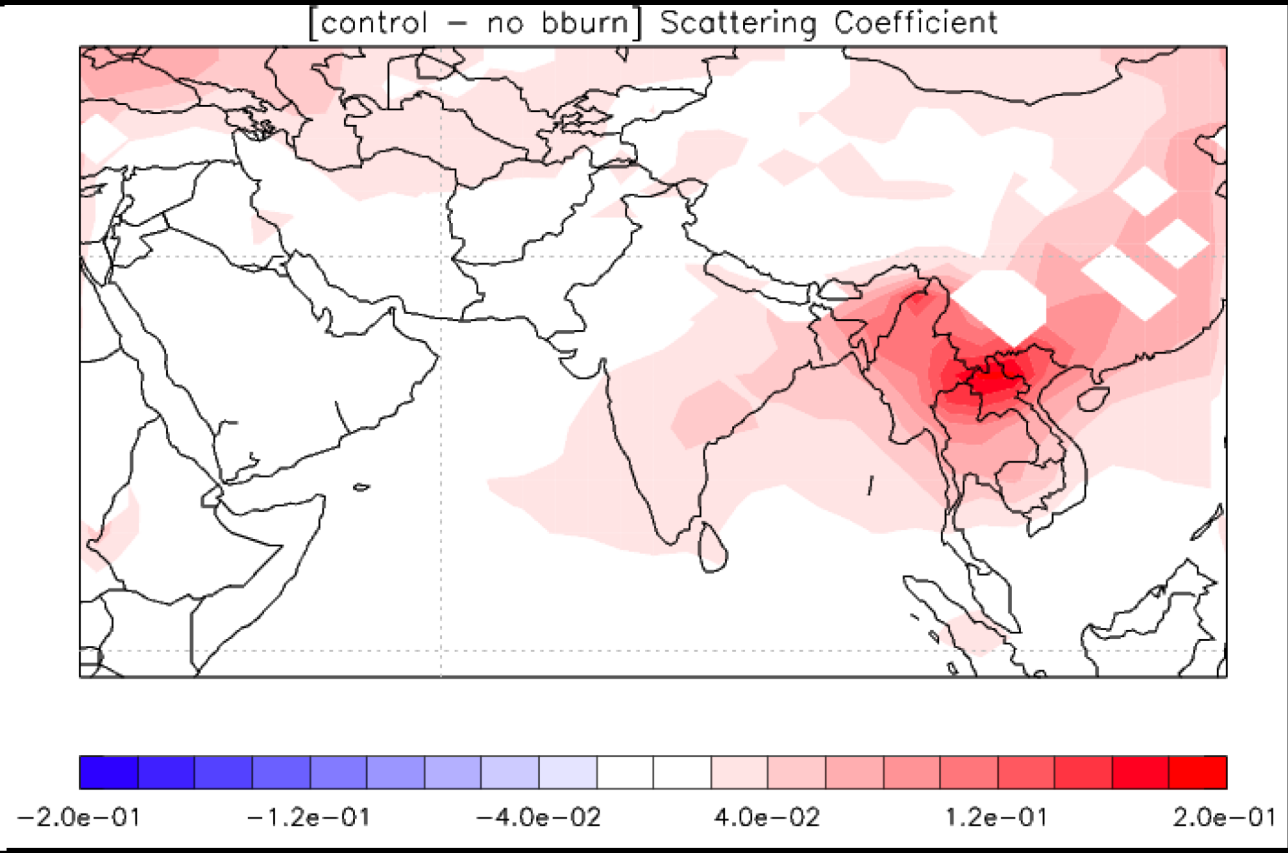


MSE is a function of temperature and moisture. [MSE = C_p . T + g . z + L_v . q]

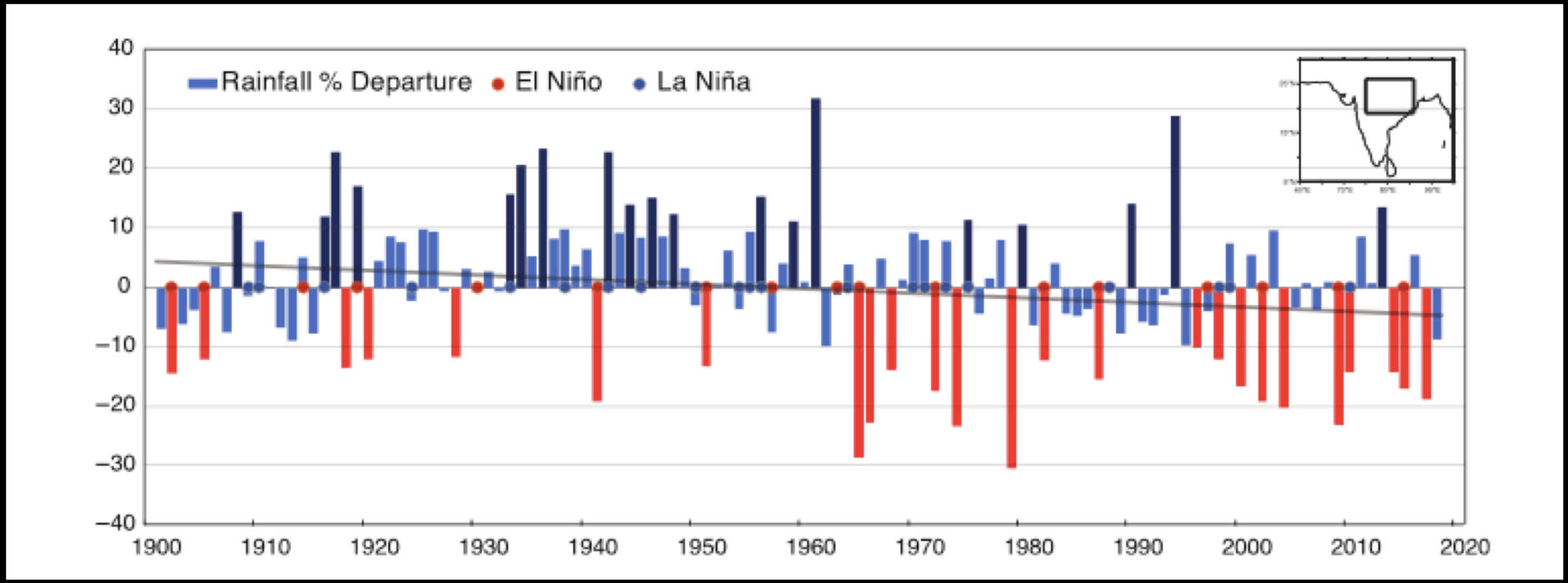

[control − no anthro] Absorption Coefficient
−2.0e−02
−1.2e−02
−4.0e−03
4.0e−03
1.2e−02
2.0e−02


[control − no anthro and bburn] Absorption Coefficient
−2.0e−02
−1.2e−02
−4.0e−03
4.0e−03
1.2e−02
2.0e−02


[control − no anthro and bburn] Scattering Coefficient
−2.0e−01
−1.2e−01
−4.0e−02
4.0e−02
1.2e−01
2.0e−01

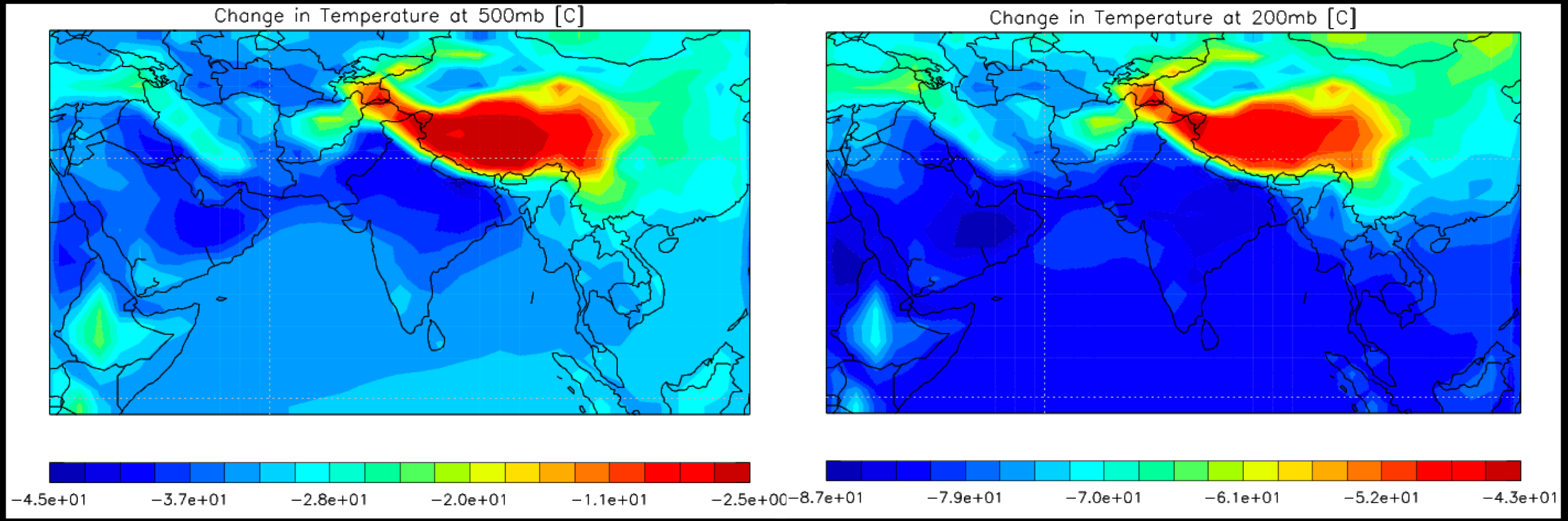

[control − no bburn] Scattering Coefficient
−2.0e−01
−1.2e−01
−4.0e−02
4.0e−02
1.2e−01
2.0e−01

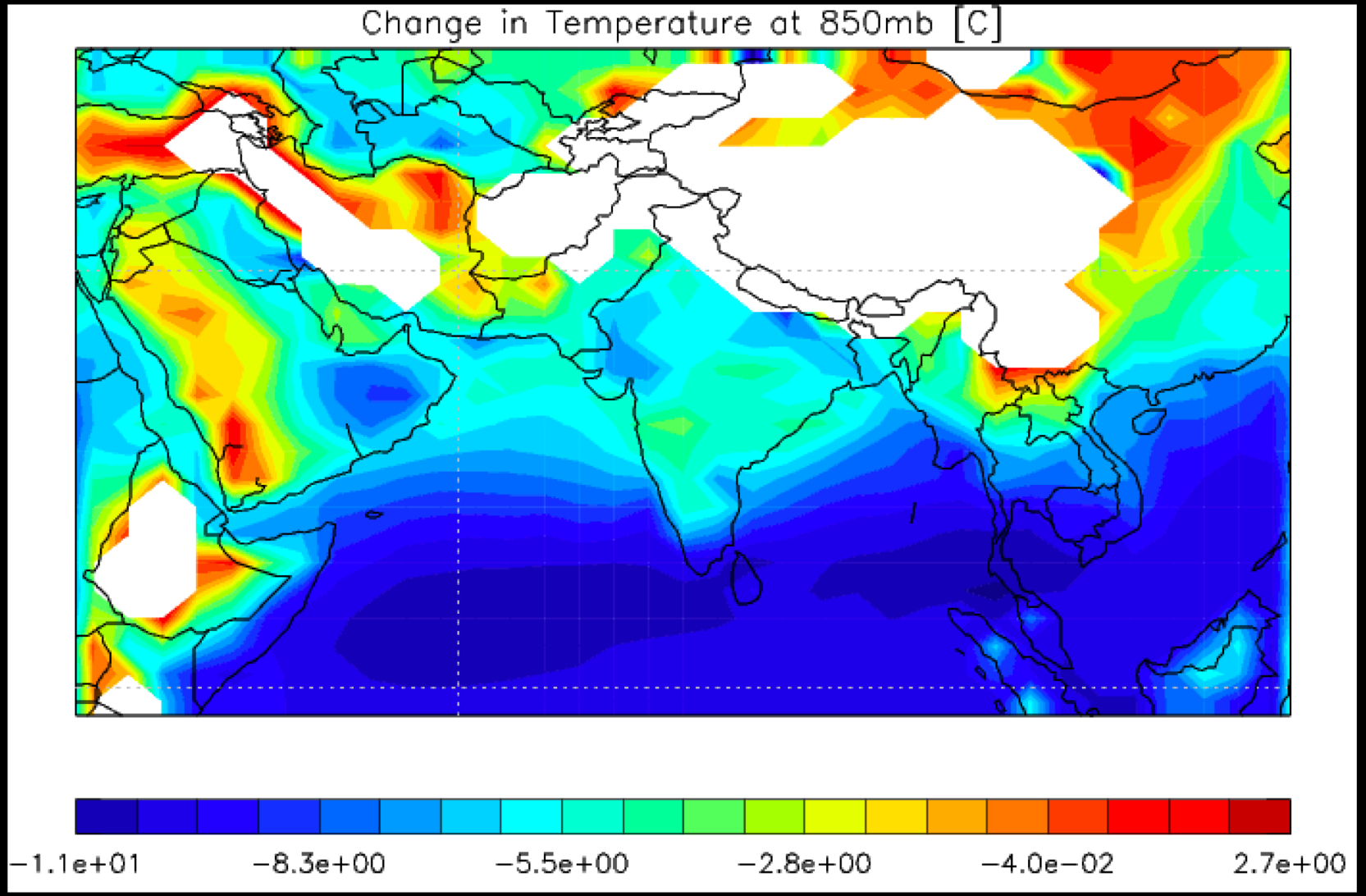
CONTROL: The difference in precipitation between 2000-2009 and 1960-1969



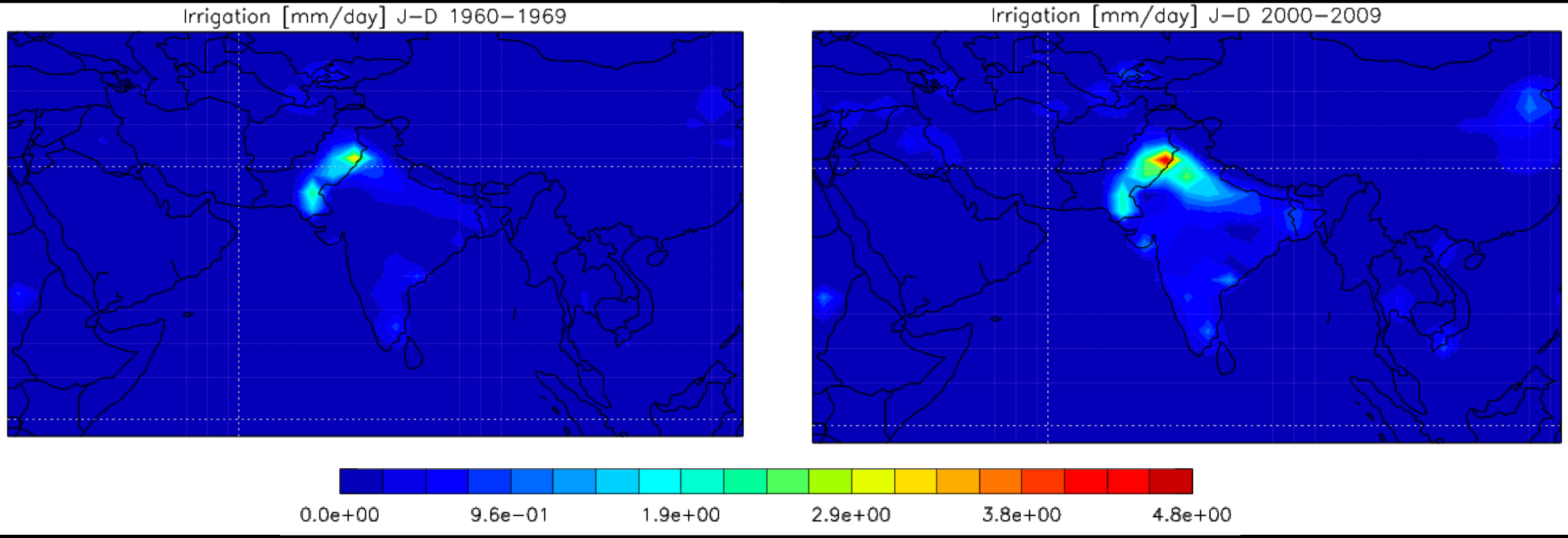
(Singh et al., 2018)

Significant weakening of the precipitation amount over central India (Mishra et al., 2012)

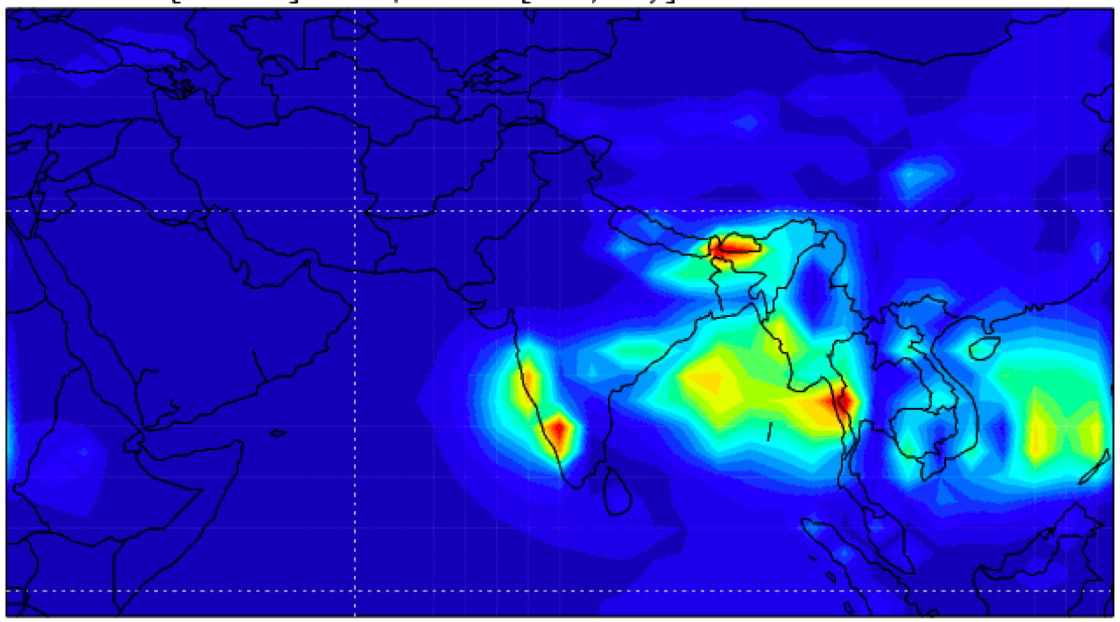

Change in Temperature at 500mb [C]
−4.5e+01
−3.7e+01
−2.8e+01
−2.0e+01
−1.1e+01
−2.5e+00
Change in Temperature at 200mb [C]
−8.7e+01
−7.9e+01
−7.0e+01
−6.1e+01
−5.2e+01
−4.3e+01


Change in Temperature at 850mb [C]
−1.1e+01
−8.3e+00
−5.5e+00
−2.8e+00
−4.0e−02
2.7e+00

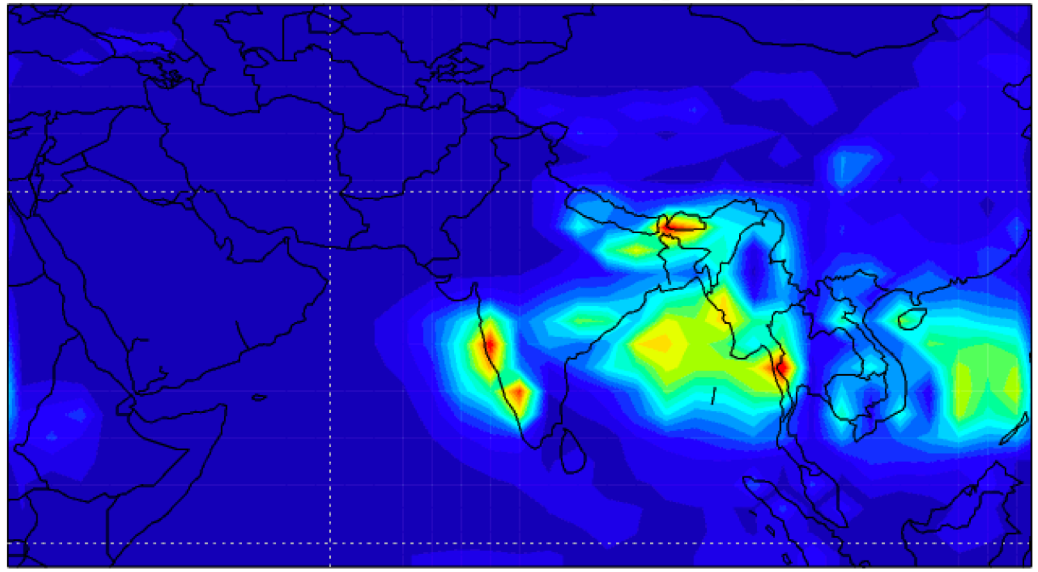
Intensive and expansive irrigation



[control] Precipitation [mm/day] J-S 1960-1969



[no anthro and biomass burning] Precipitation [mm/day] J-S 1960-1969



[no anthro] Precipitation [mm/day] J-S 1960-1969