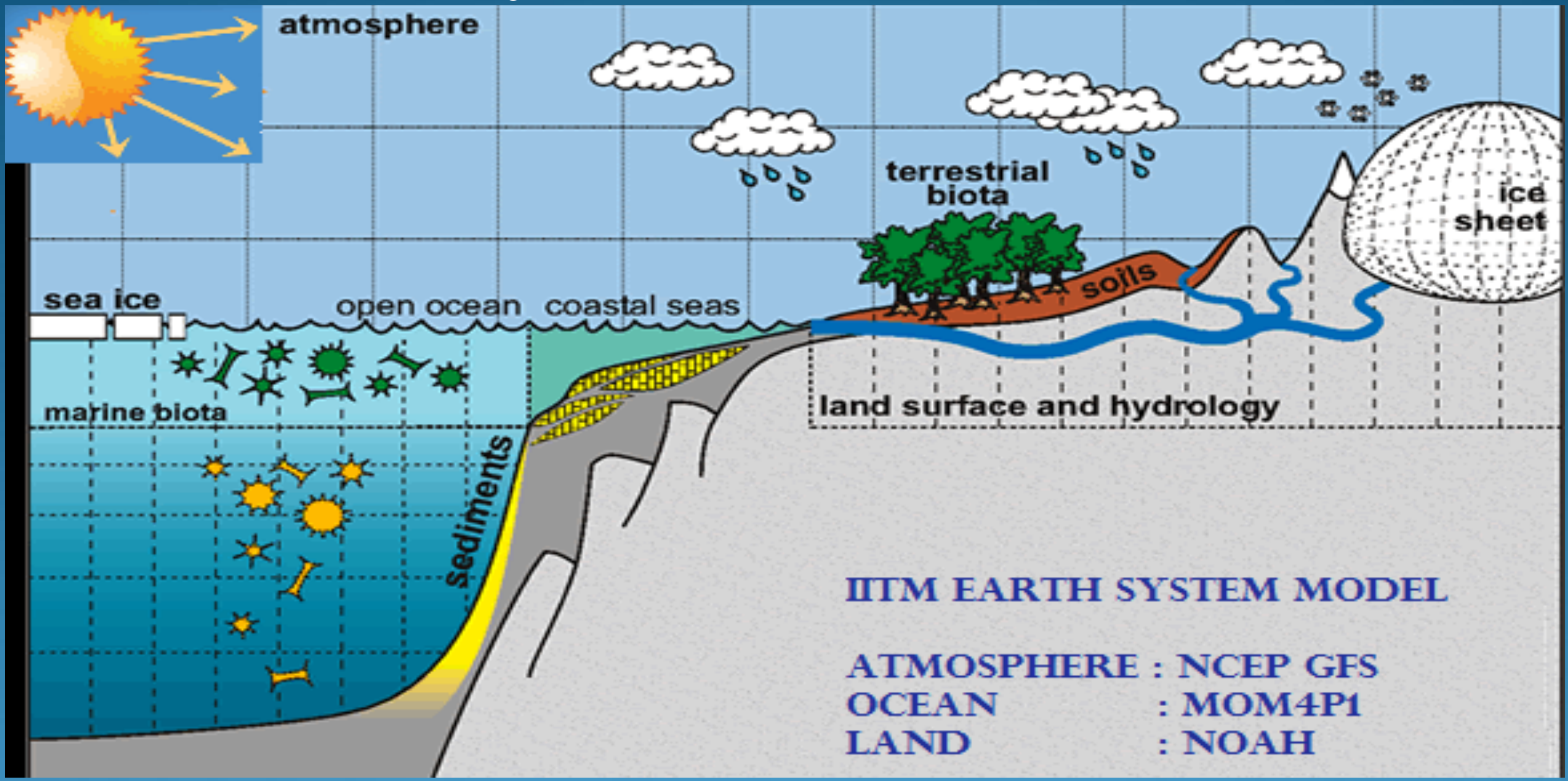
Monsoon Simulation in IITM ESM : Present Day and Future Scenario



Swapna Panickal

Centre for Climate Change Research
Indian Institute of Tropical Meteorology (IITM)

ICTP TTA: Monsoon in a changing climate, Italy, 31st-4th August 2017

Background

- Reliable predictions of Asian monsoon rainfall to climate change are extremely important; lives of nearly half of the world's population depend on monsoon for food and energy security

- Understanding how the monsoon will change in the future is a fundamental challenge for climate science

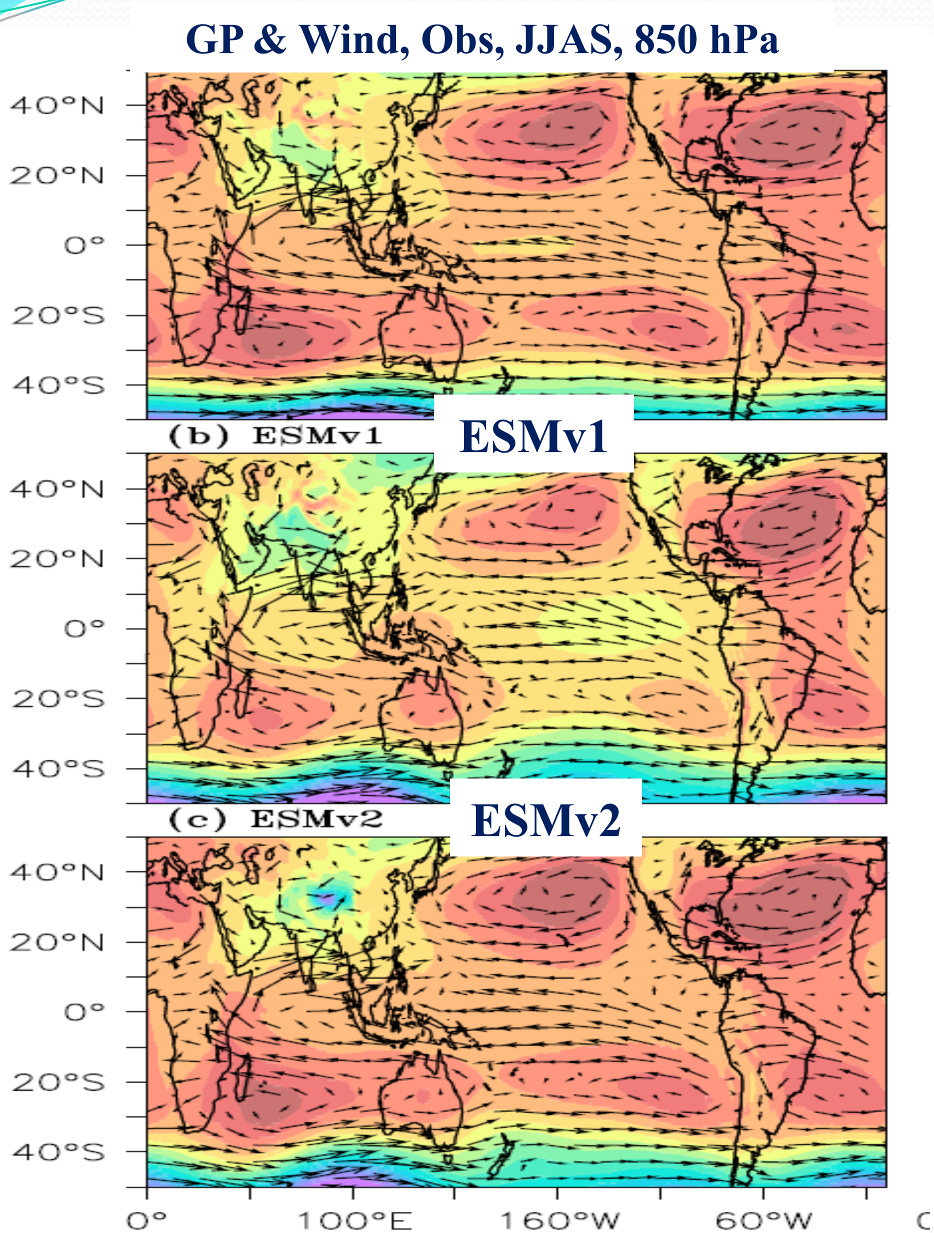
- The Coupled Modeling Inter-comparison Project coordinated by the World Climate Research Programme (WCRP) form the basis of the climate projections in the Intergovernmental Panel on Climate Change (IPCC) Assessment Reports

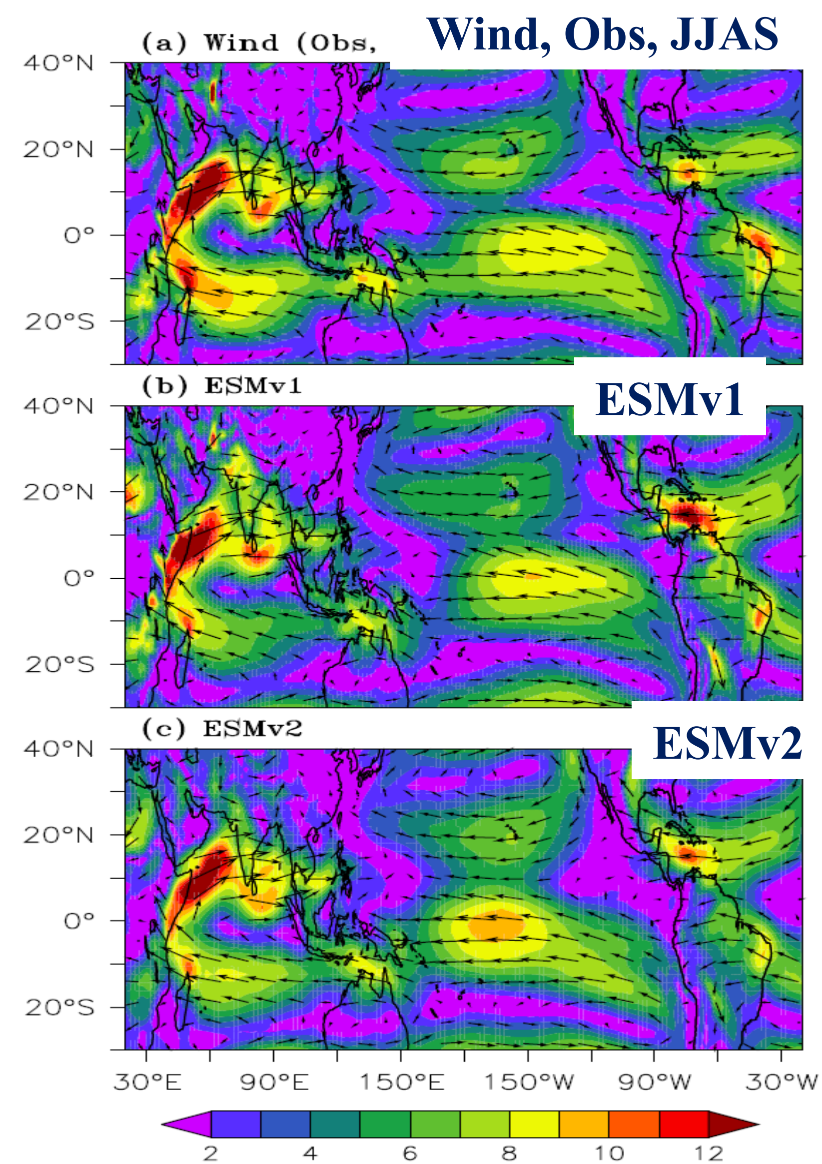
- To address the future monsoon projections to climate change using the CMIP6 simulations of IITM-ESM, first from India.

Outline

- Present day Mean Climate from IITM-ESM Simulation
- Mean Features during Boreal Summer Monsoon Season
- Land-Atmosphere-Ocean Feedbacks and South Asian Monsoon
- ENSO and IOD Teleconnections on South Asian Monsoon Variability
- Impact of doubling CO2 on Indian Summer Monsoon

Large-scale Atmospheric Circulation

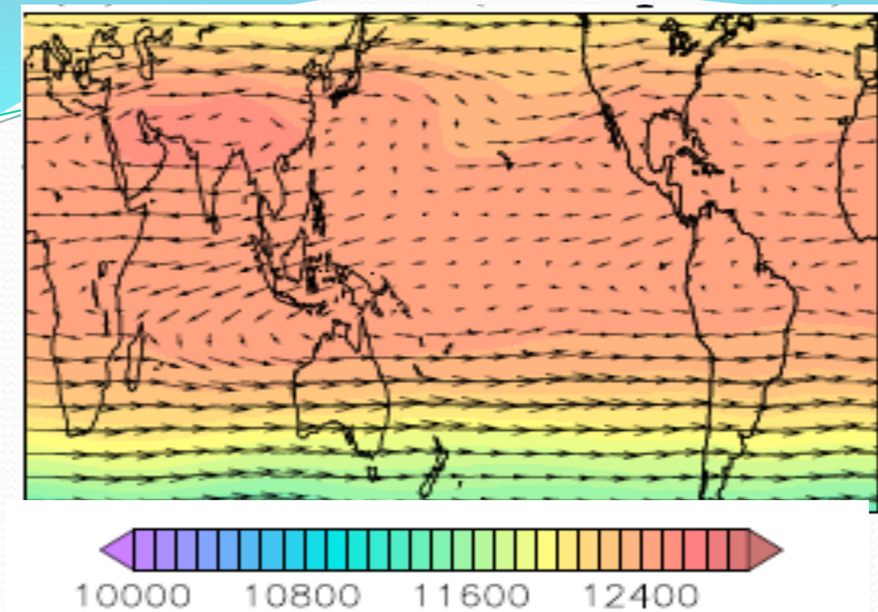




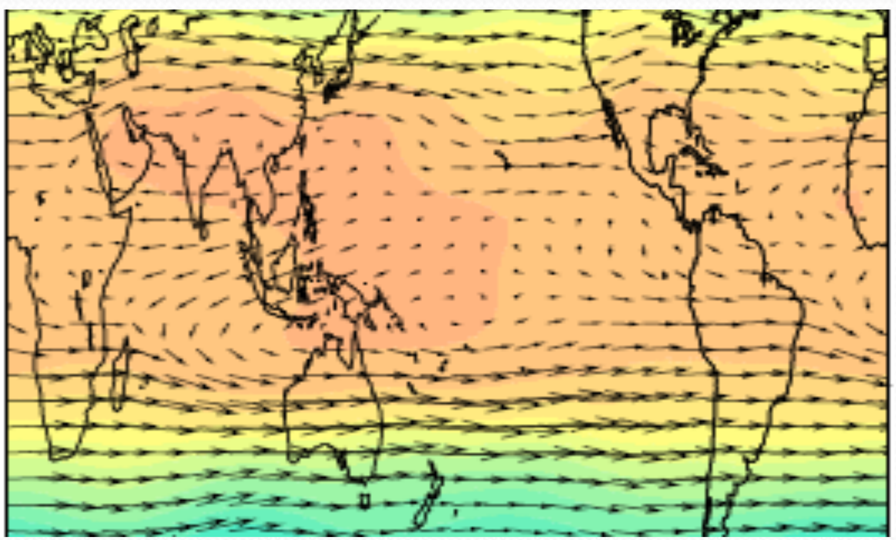
Swapna et al. 2017

Winds & Geopotential Height: 200 hPa, JJAS

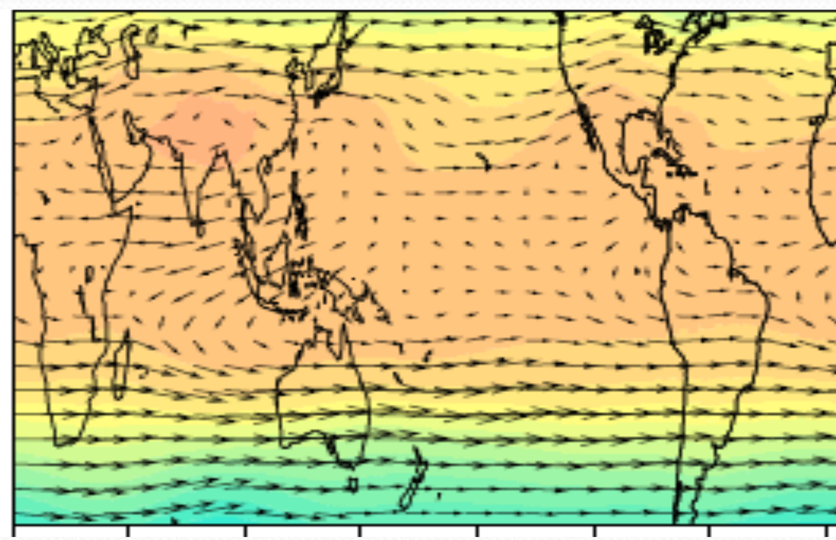
ERA-Interim



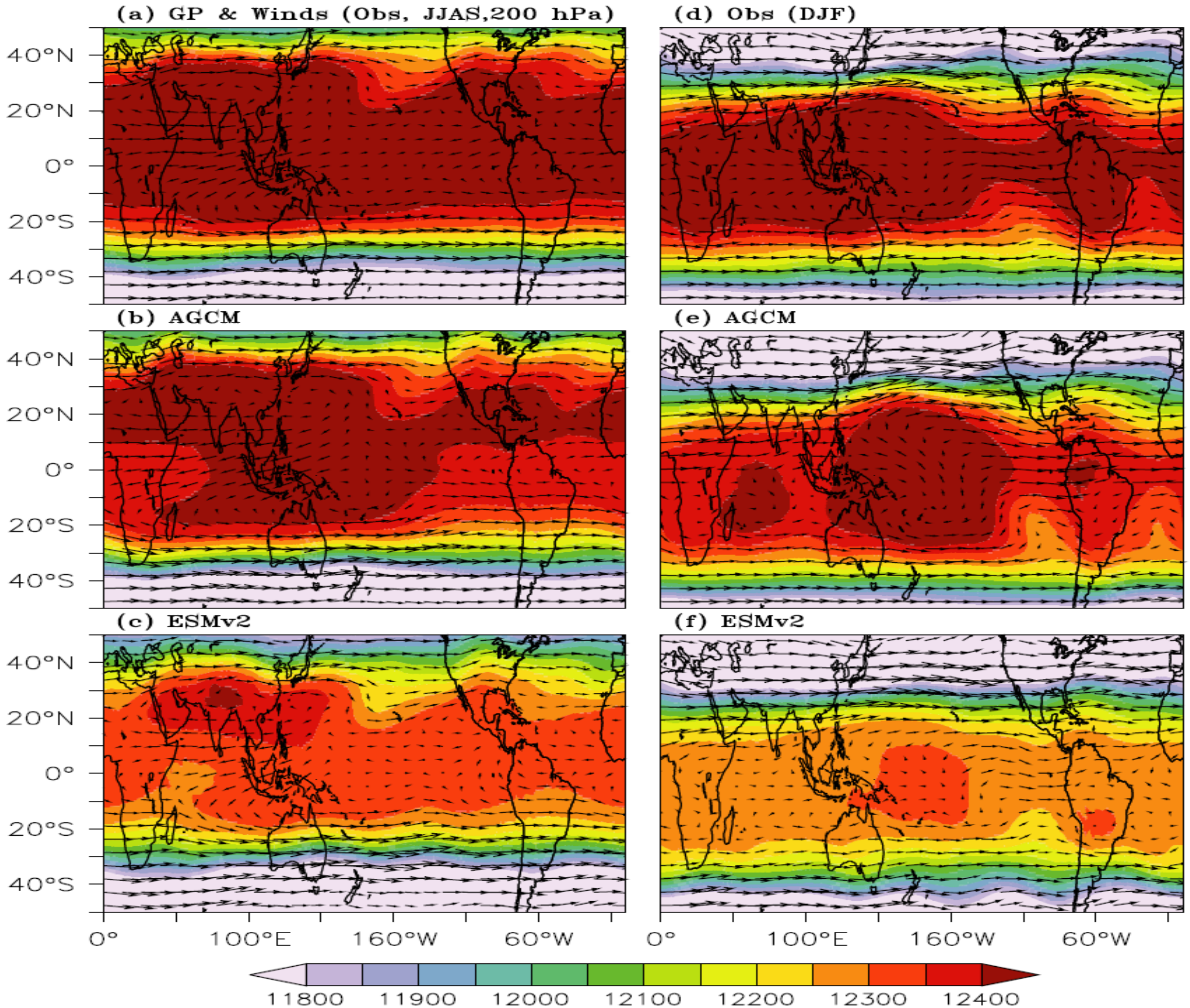
ESM-v1



ESM-v2



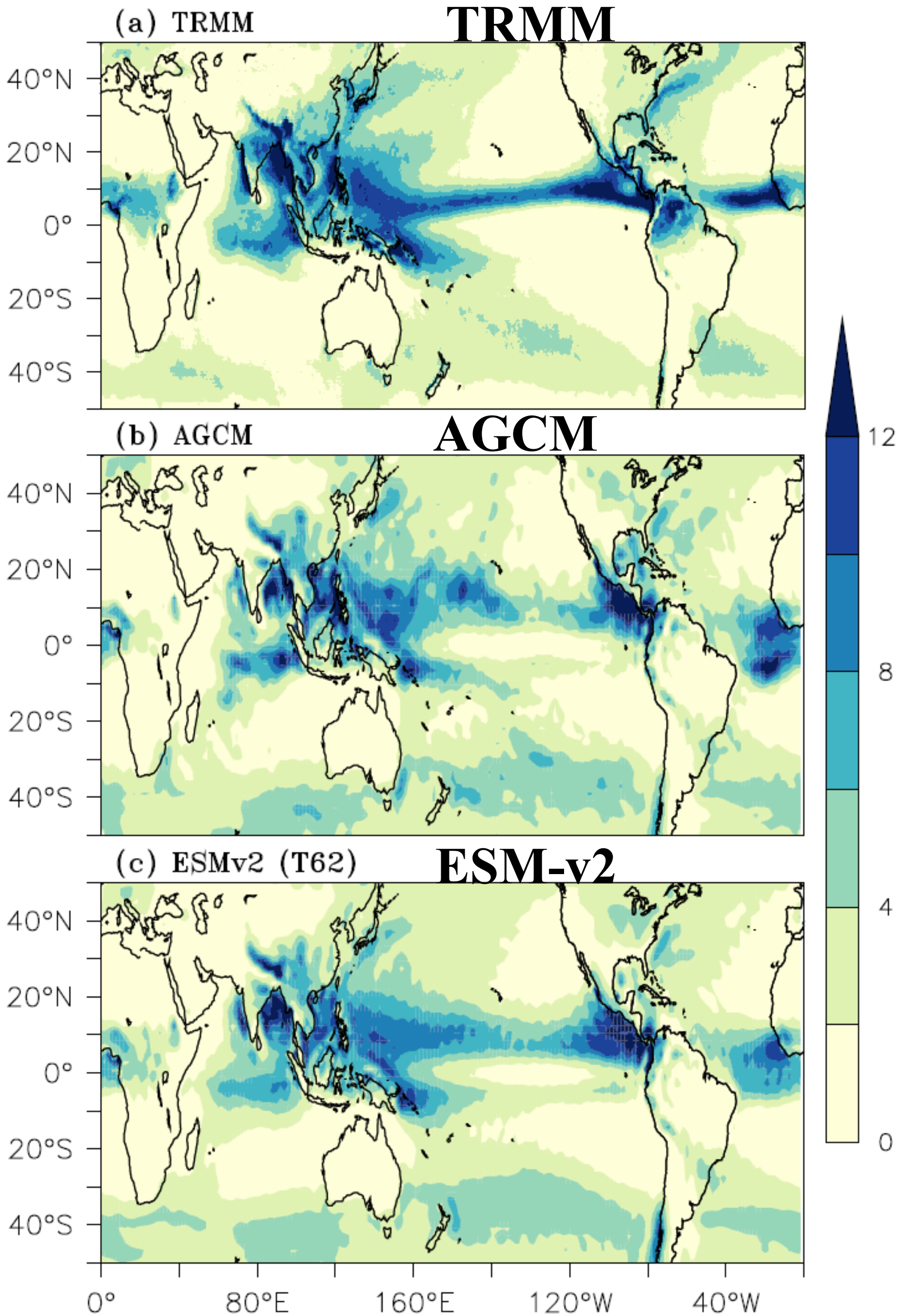
Winds & Geopotential Height: 200 hPa

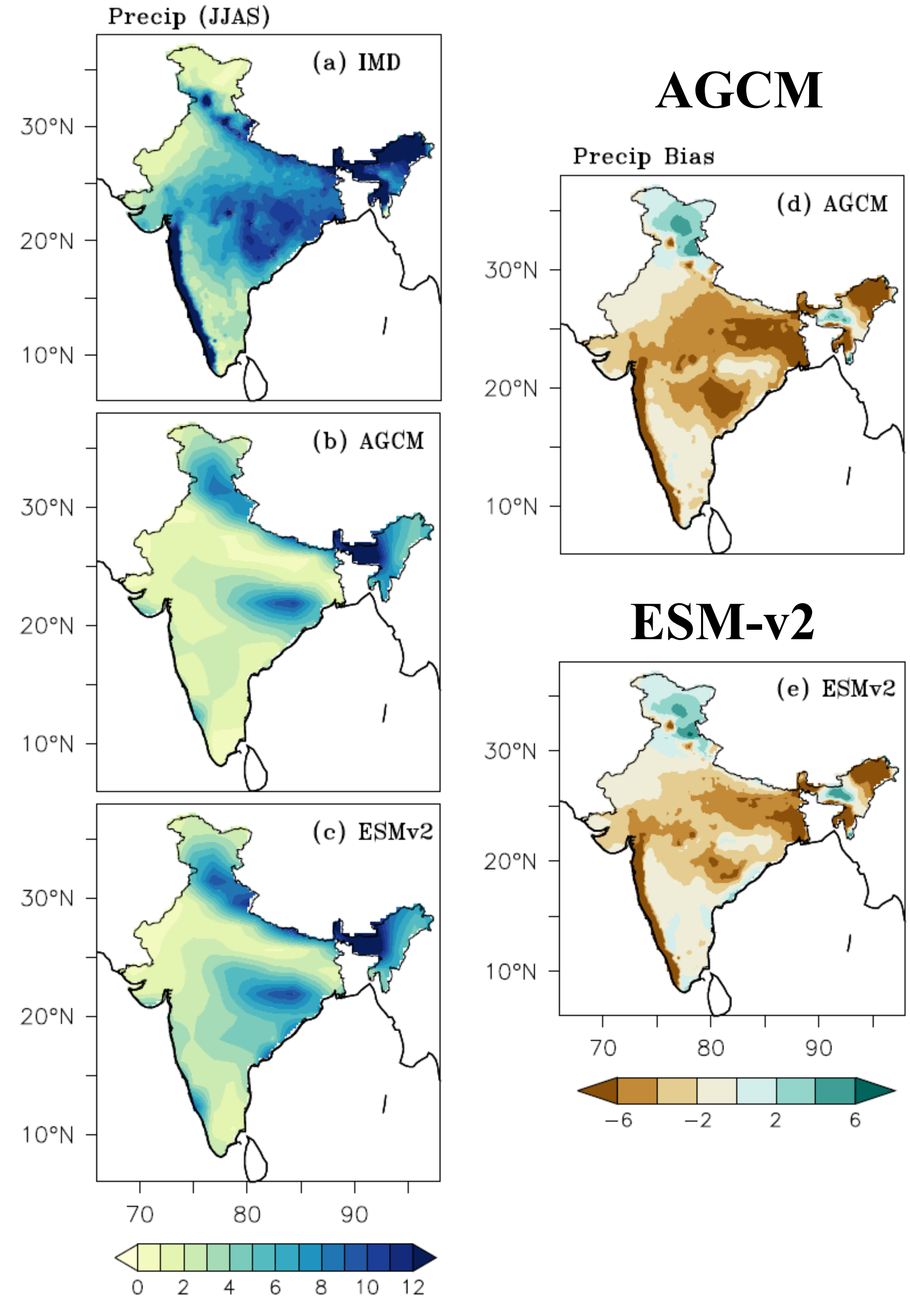


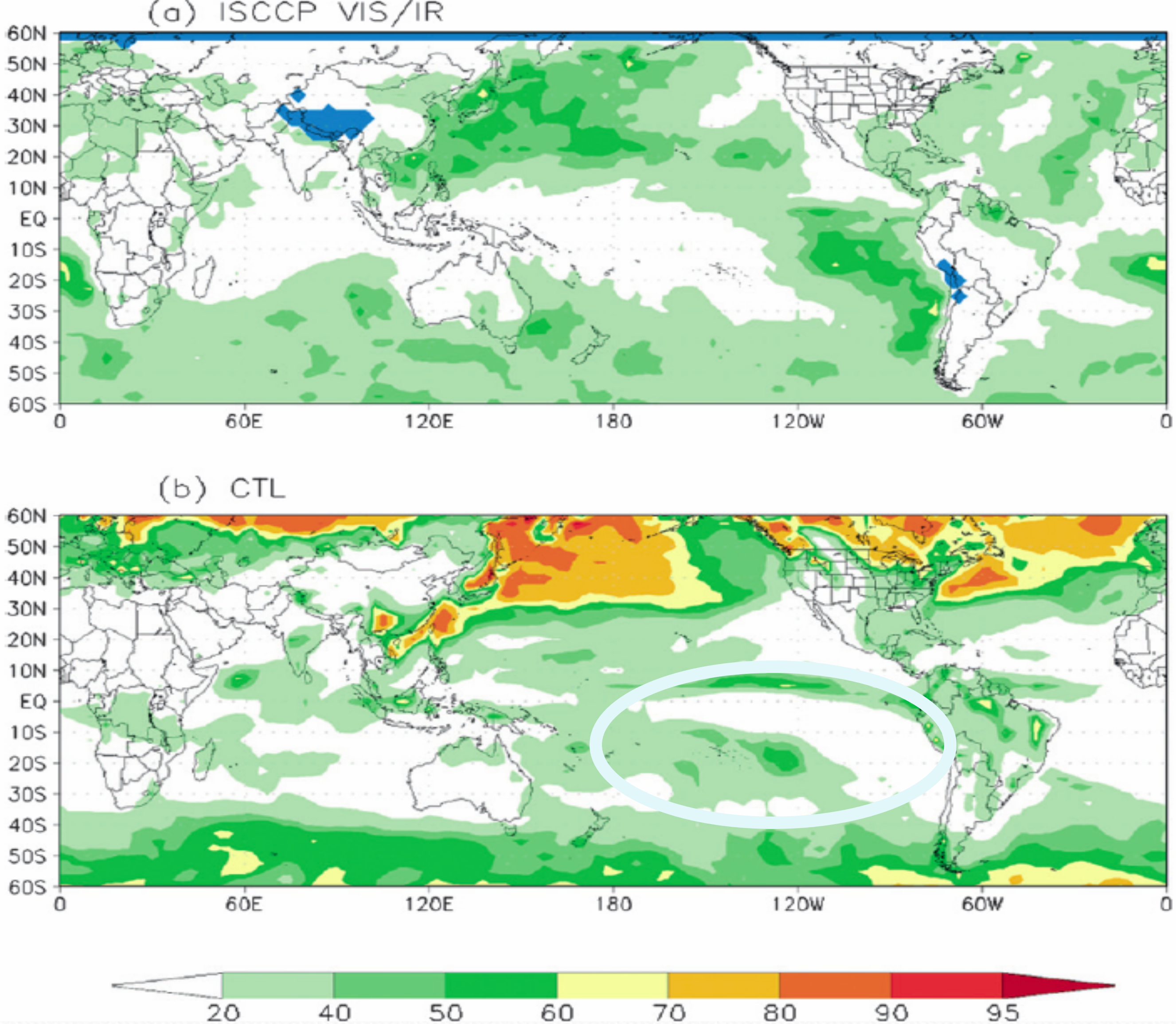
ERA-Interim

AGCM

ESM-v2


(a) TRMM
TRMM
(b) AGCM
AGCM
(c) ESMv2 (T62)
ESM-v2
40°N
20°N
0°
20°S
40°S
0°
80°E
160°E
120°W
40°W
0
4
8
12


Precip (JJAS)
(a) IMD
(b) AGCM
(c) ESMv2
30°N
20°N
10°N
70
80
90
0
2
4
6
8
10
12
AGCM
Precip Bias
(d) AGCM
ESM-v2
(e) ESMv2
−6
−2
2
6



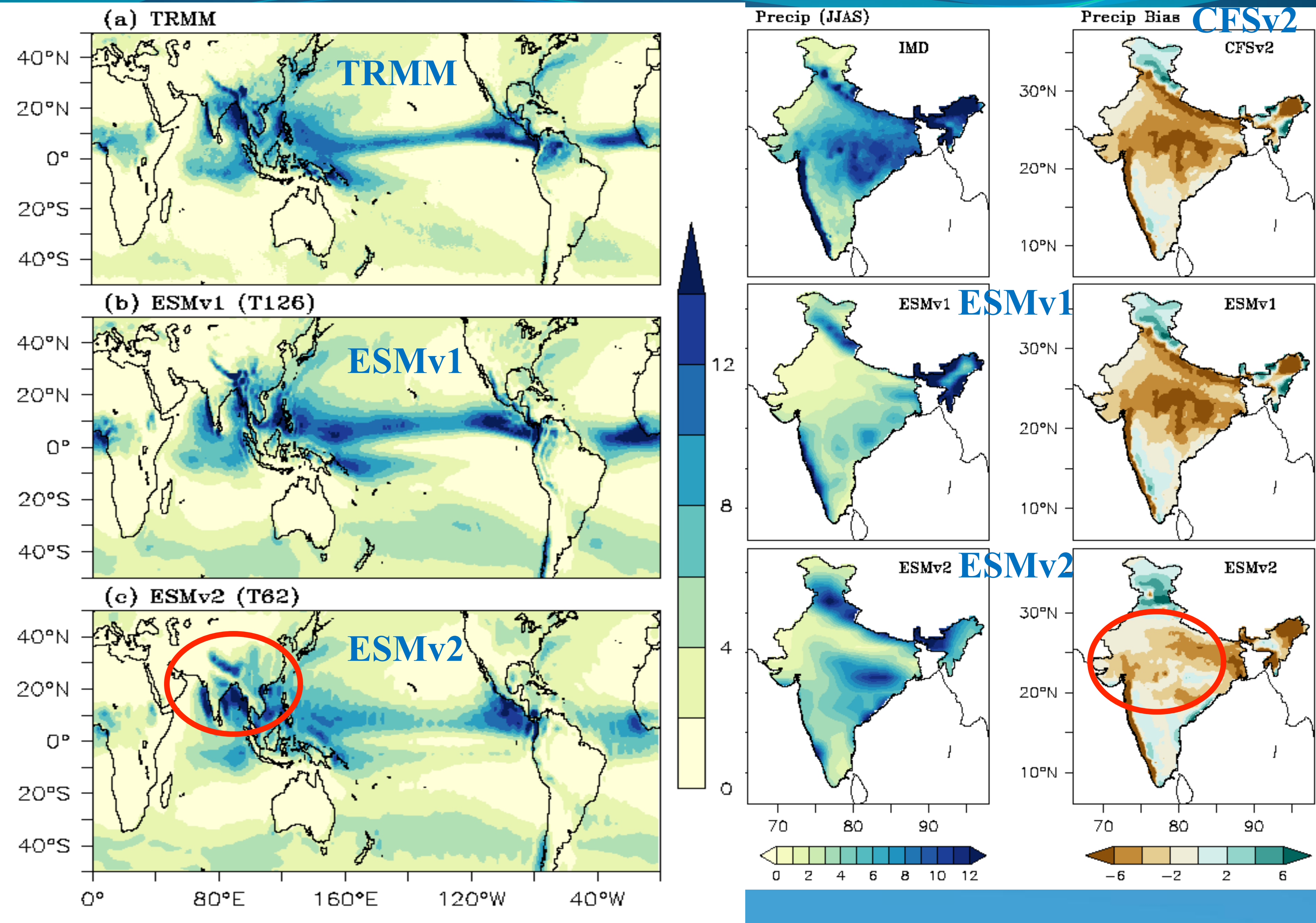
Monthly mean low cloud cover (%) for January 2003 from ISCCP (Rossow and Schiffer, 1991) VIS/IR satellite observations (blue color indicates 'no data' available).

Control simulation using the old shallow convection Scheme of NCEP GFS

Han and Pan, 2011

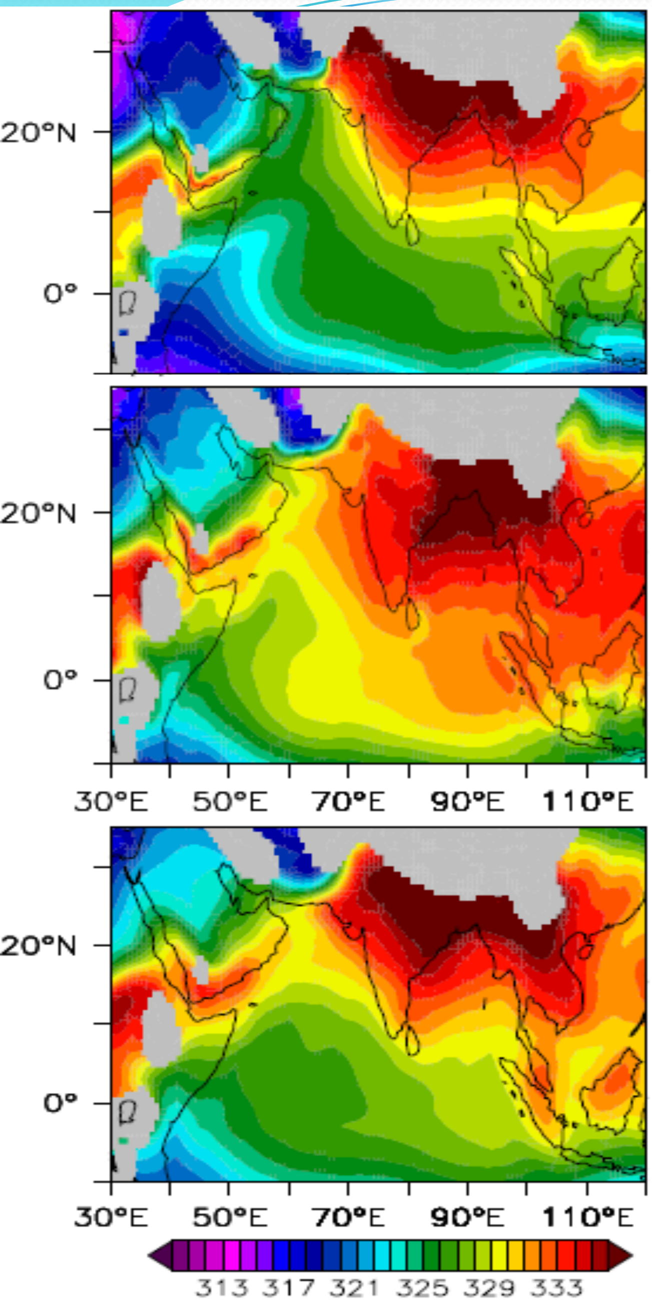
Long-standing problems in NCEP GFS: Systematic underestimation of stratocumulus clouds in the eastern Pacific and Atlantic Oceans; and the frequent occurrence of unrealistic excessive heavy precipitation, the so-called grid-point storms

Boreal summer monsoon (JJAS) precipitation (mm day^{-1})



Moist Static Energy

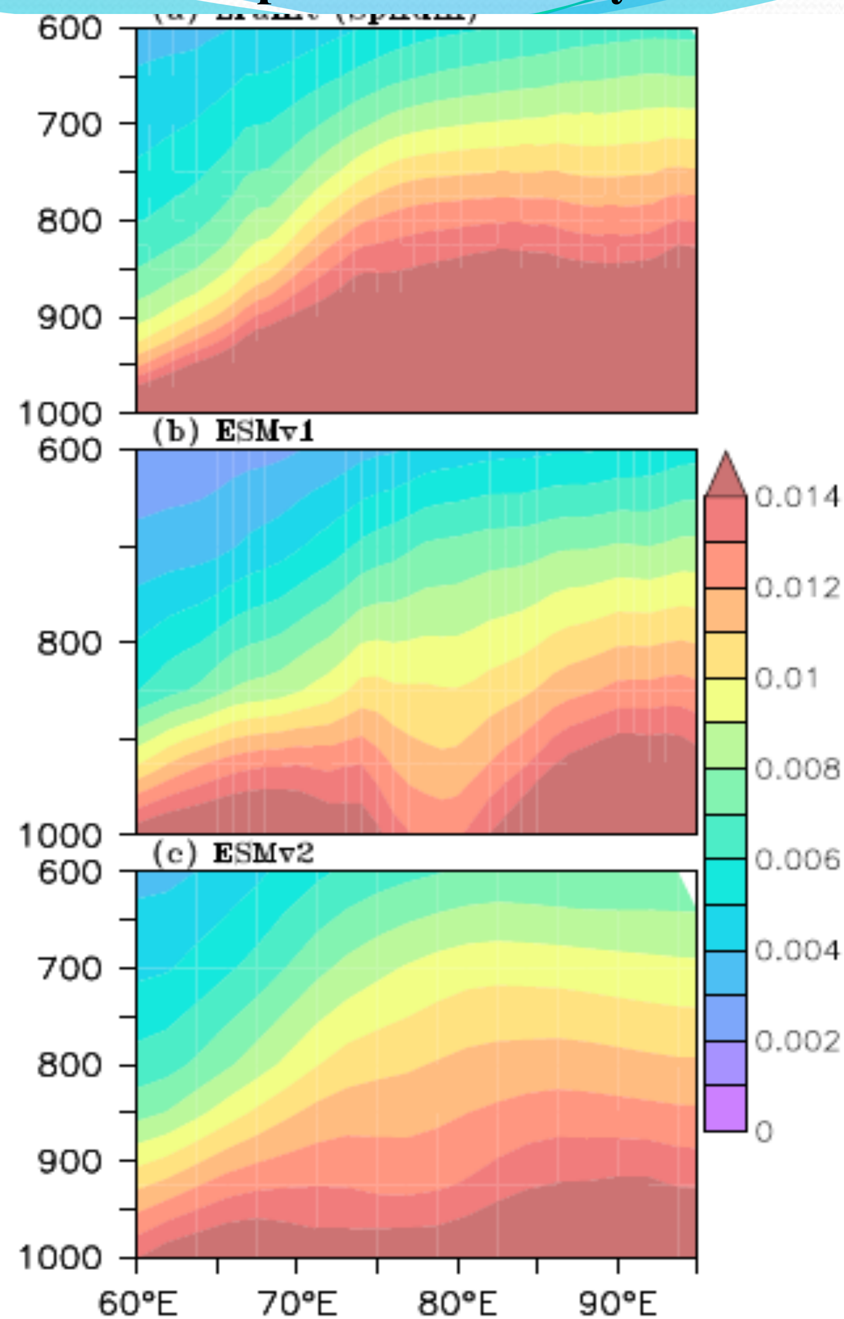
Specific Humidity



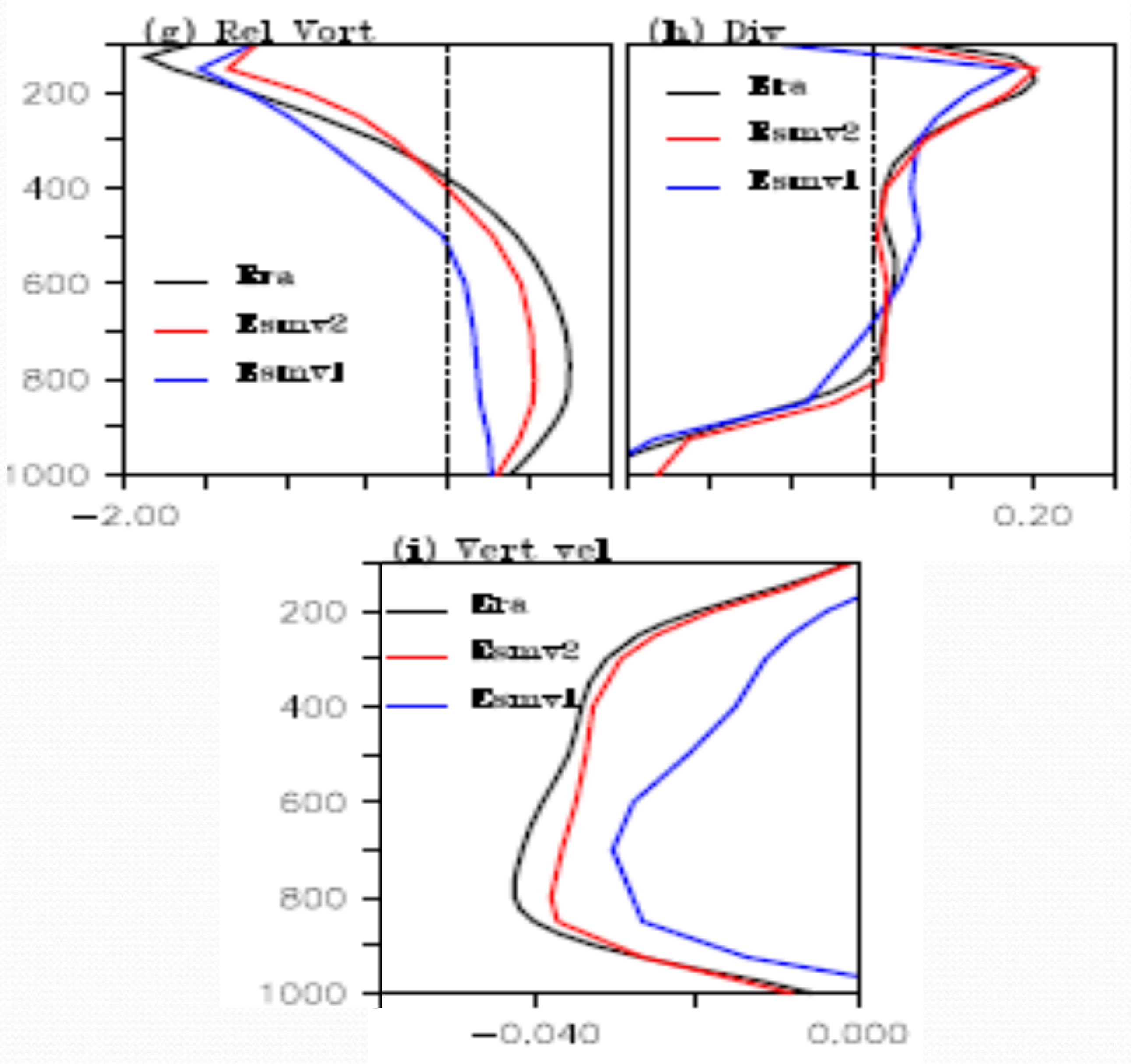
ERA Interim

ESMv1

ESMv2

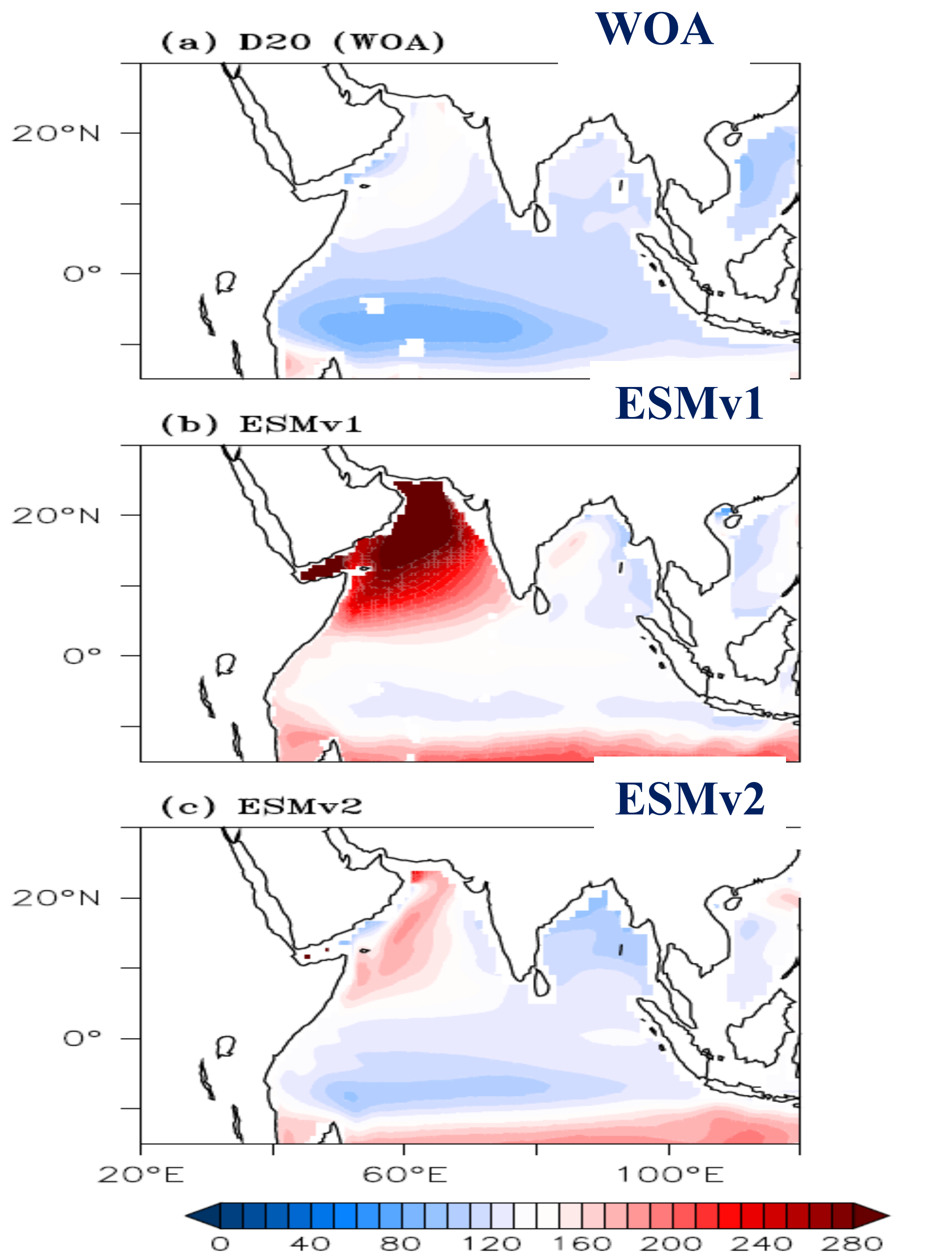


Moist processes over South Asian monsoon region



Indian Ocean-Monsoon Coupled Feedbacks

Indian Ocean-Monsoon Coupled Interaction



Improved cross-equatorial flow

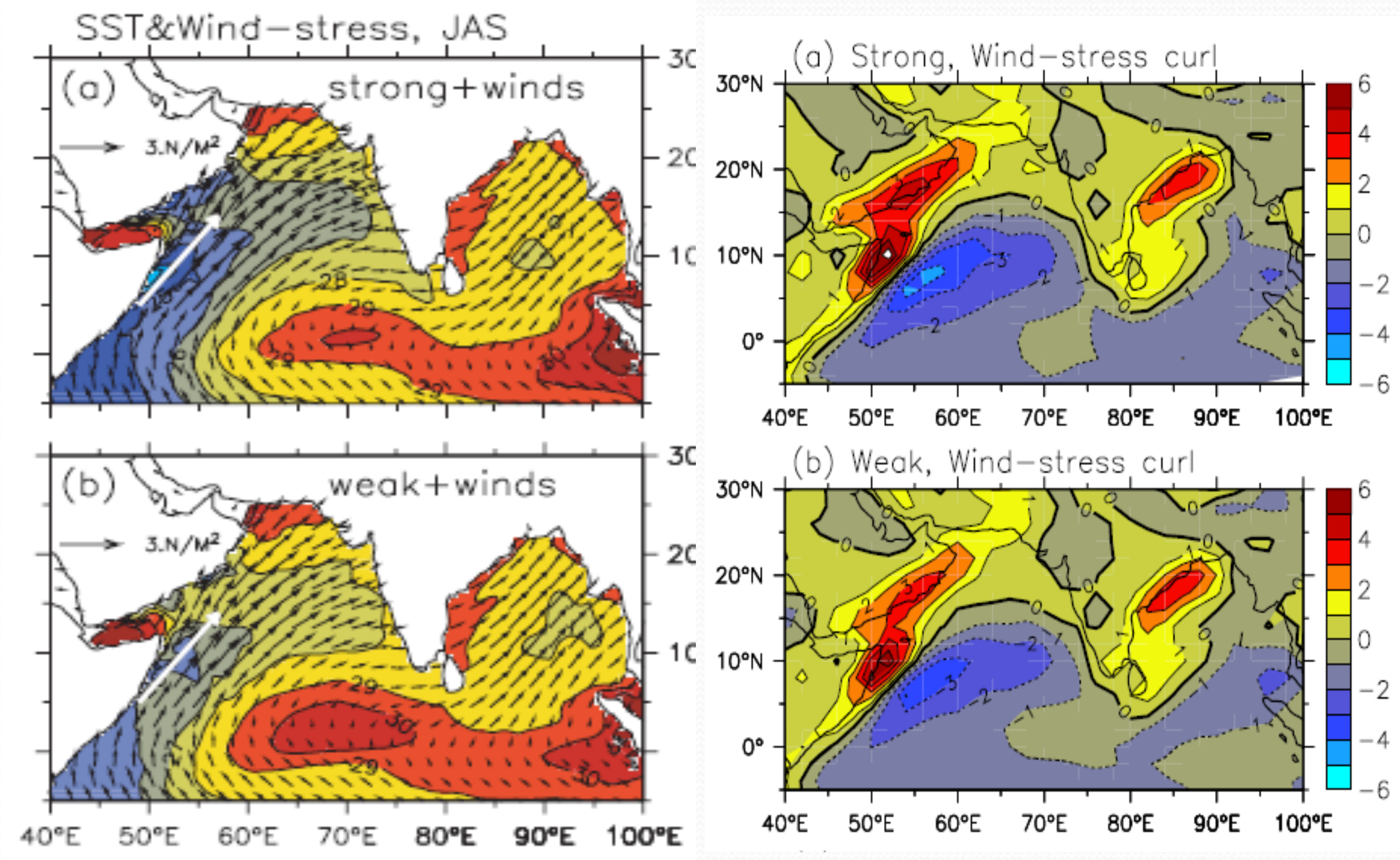
⬇

Improved Ekman Upwelling, shoaling of the SWIO thermocline and thermocline dome

⬇

The shallow SW IO thermocline dome warm the SST through westward propagating Rossby waves, generate zonal SST Gradient and influence the IOD and IOBM

Indian Ocean-Monsoon Coupled Interaction

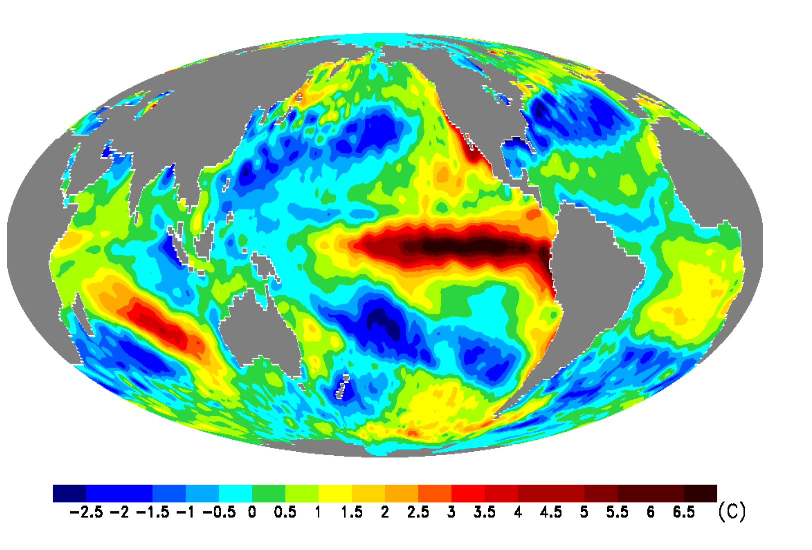


Arabian Sea response to monsoon variability (Murtugudde et al., 2007)

1997-98: Strongest El Niño ever recorded!

Sea Surface Temperature

Dec 1997 minus Dec 1998



In January 1998 (top right) the 1997-1998 El Nino event was at its height. Because of the weakness of the trade winds at this time, the upwelling of nutrient-rich water was suppressed in the equatorial Pacific. The absence of a green band along the equator in this image is indicative of relatively low chlorophyll concentrations there.

By July 1998 (bottom right) the trade winds had strengthened and equatorial upwelling had resumed giving rise to widespread phytoplankton blooms in the equatorial belt

(Ref: Wallace and Hobbs, 2006)

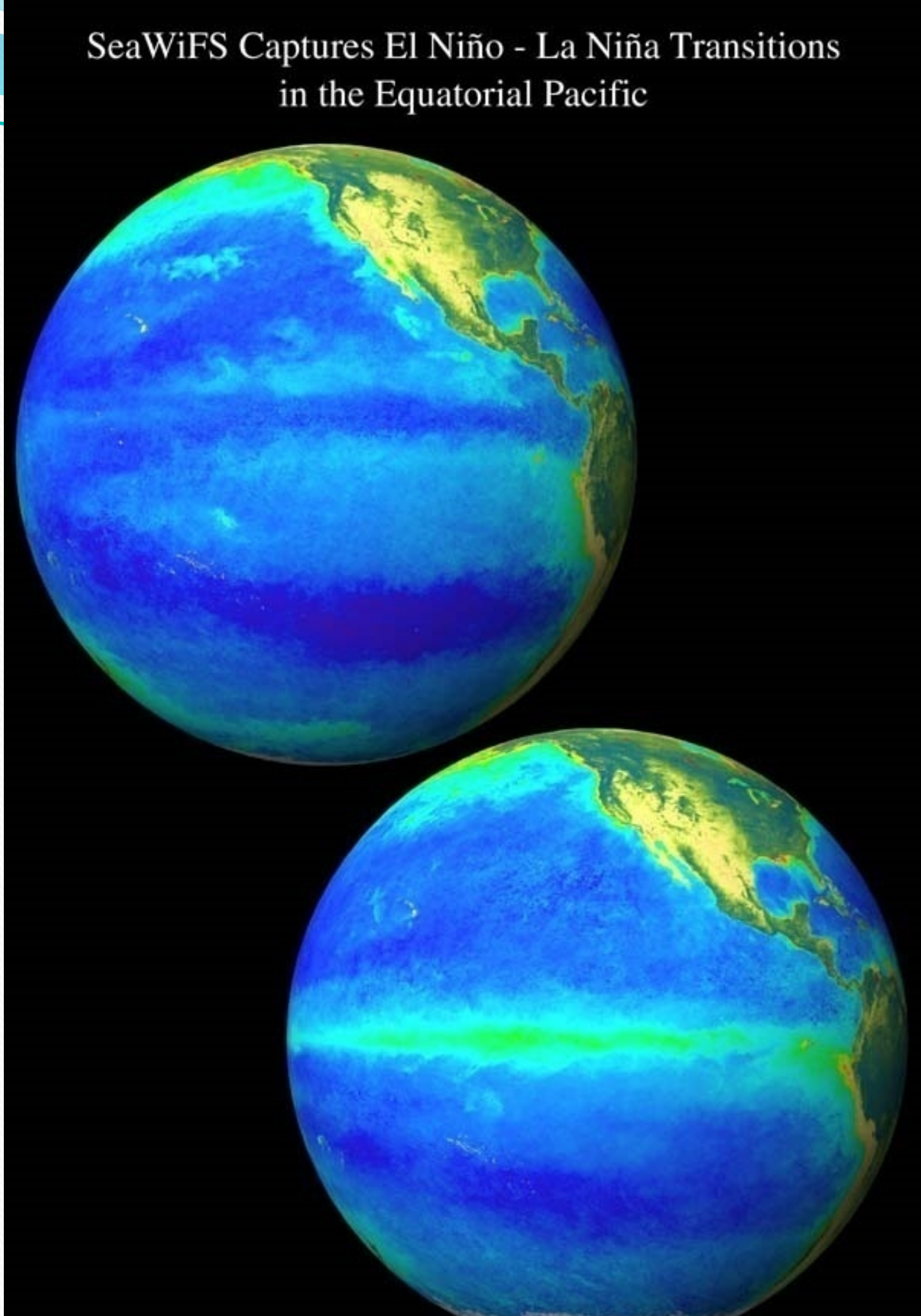
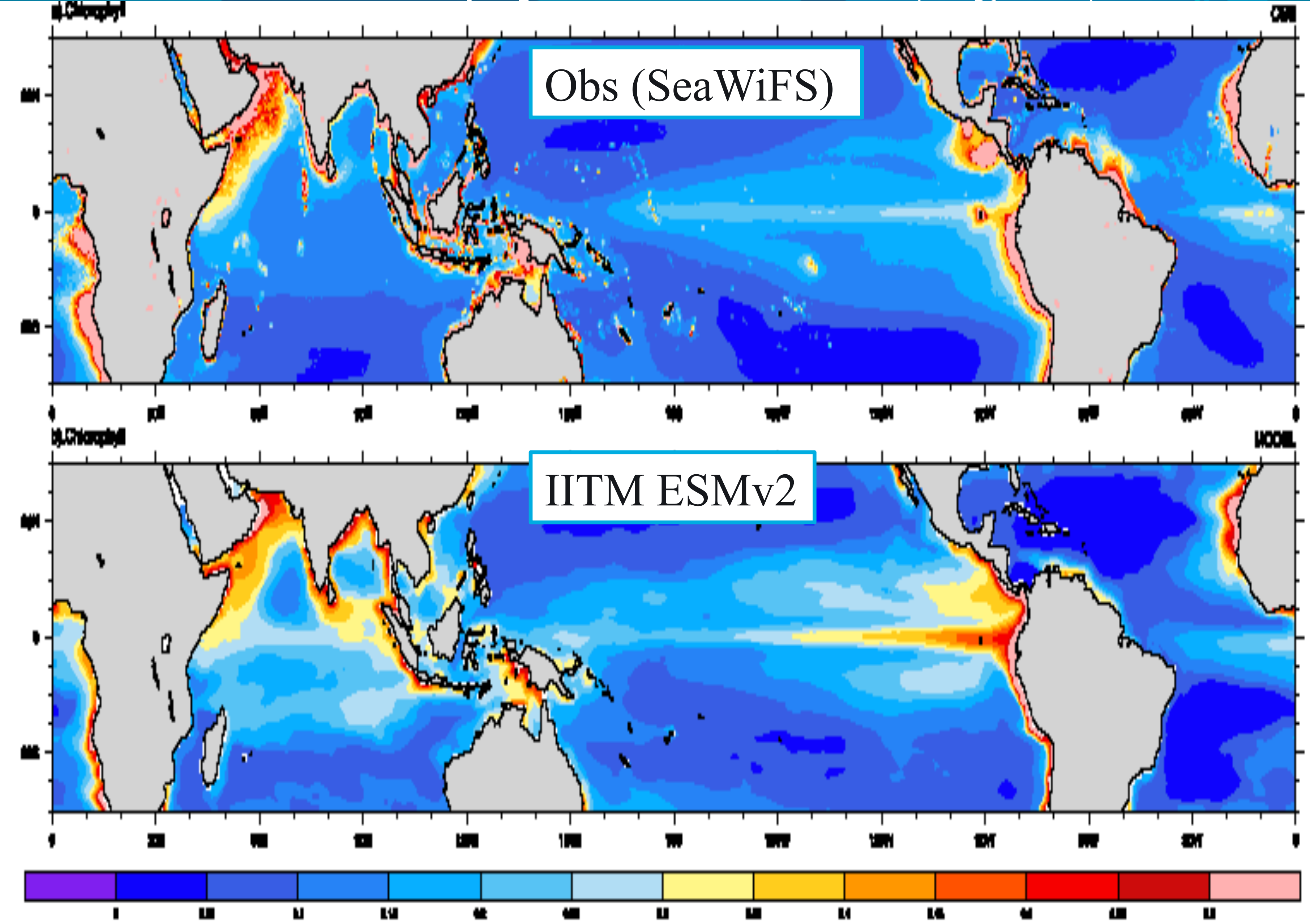


Image from SeaWIFS Project, NASA /

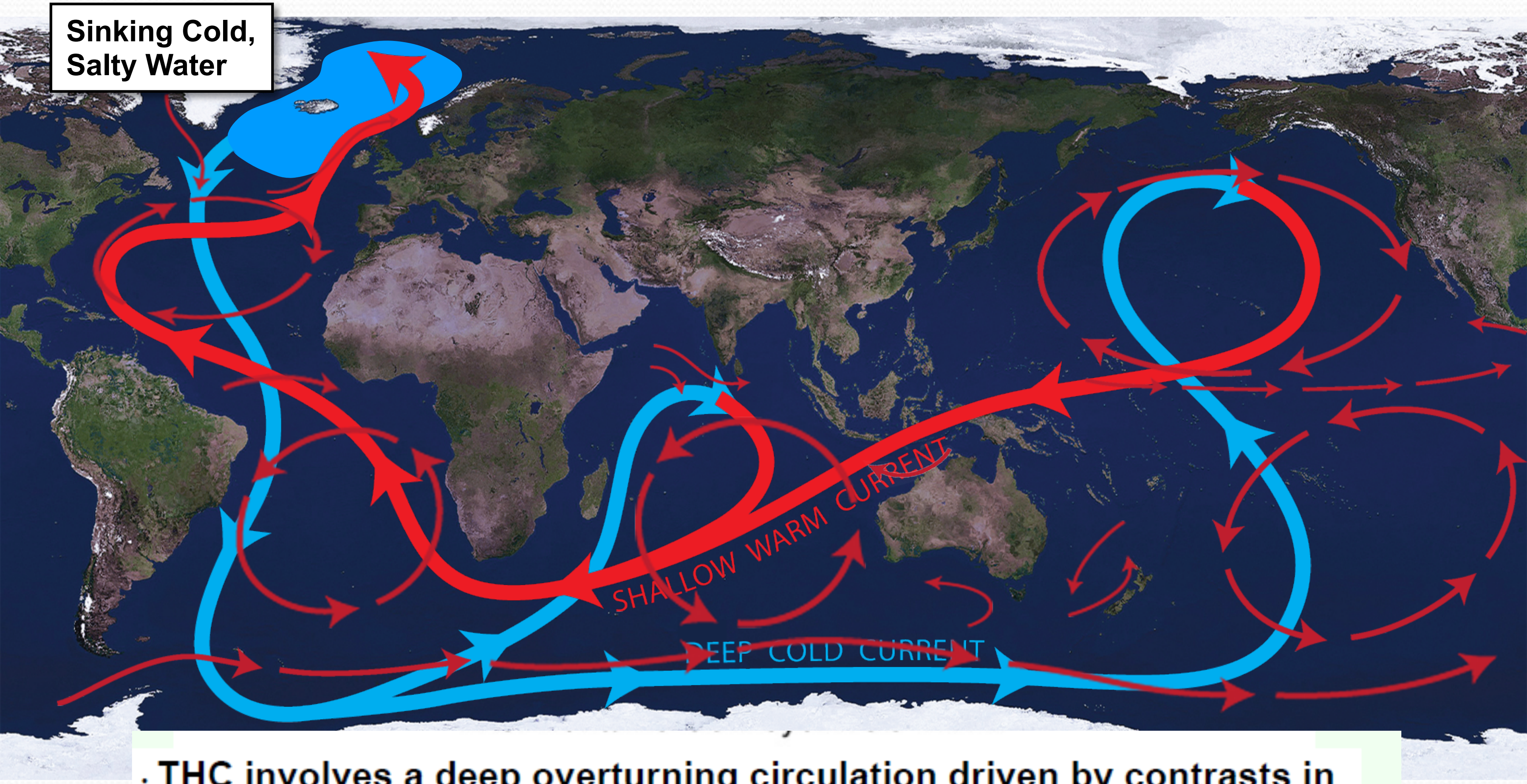
Chlorophyll Concentration (Mg m^{-3})



Courtesy: Sandeep, CCCR

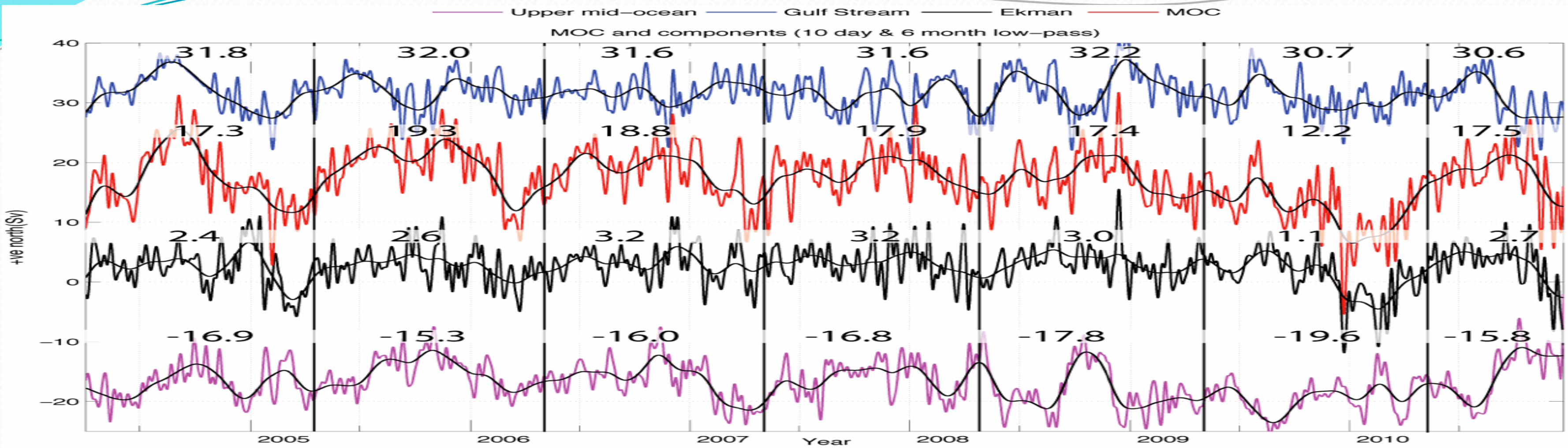
Large-scale Ocean Circulation : Global Overturning Circulation and Energy Transport

Thermohaline Circulation (THC) Global Conveyor Belt



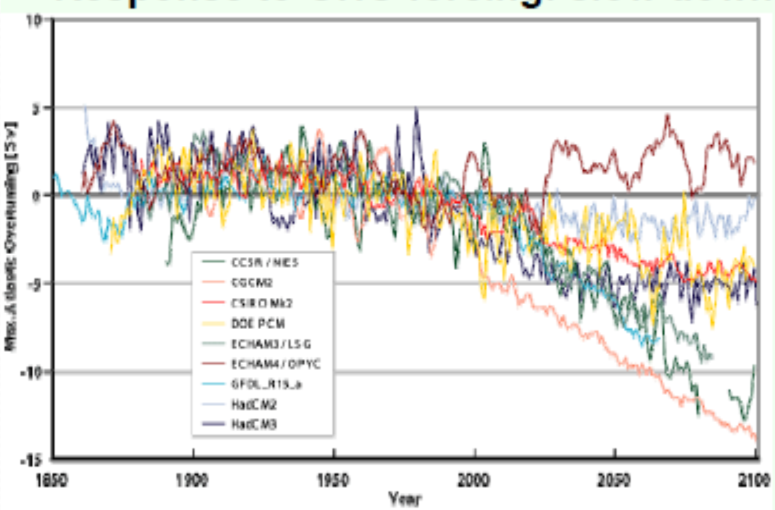
- THC involves a deep overturning circulation driven by contrasts in density, and hence pressure, between different regions
- THC is responsible for a large fraction of the ~O(1PW) northward heat transport of the Atlantic Ocean

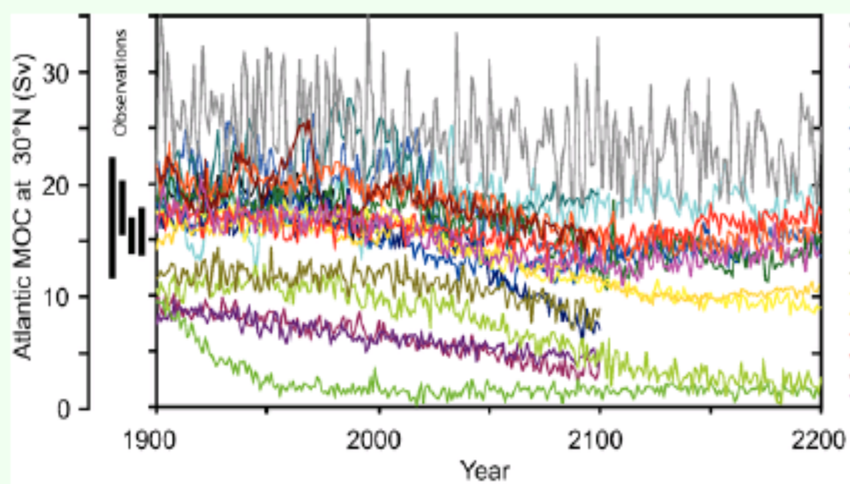
AMOC Variability in the Subtropical Atlantic (RAPID 26.5N)

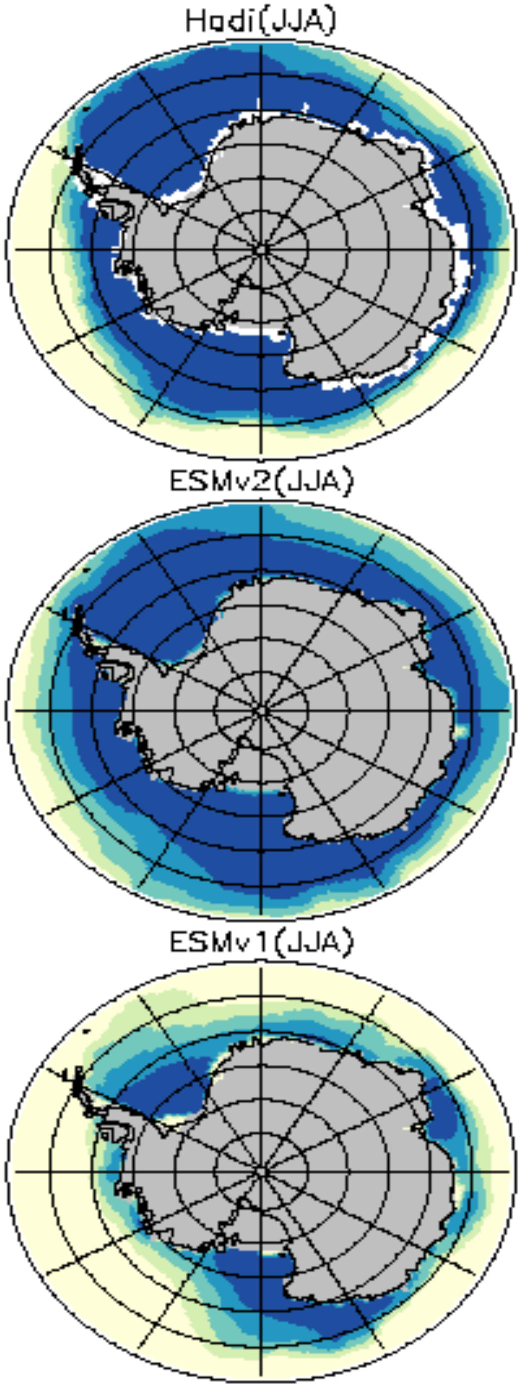


- Natural (e.g. volcanic) and anthropogenic (e.g. GHG, aerosols) forcings can modify buoyancy fluxes, and influence AMOC

Response to GHG forcing: slow down due to warming and freshening **Source: IPCC**







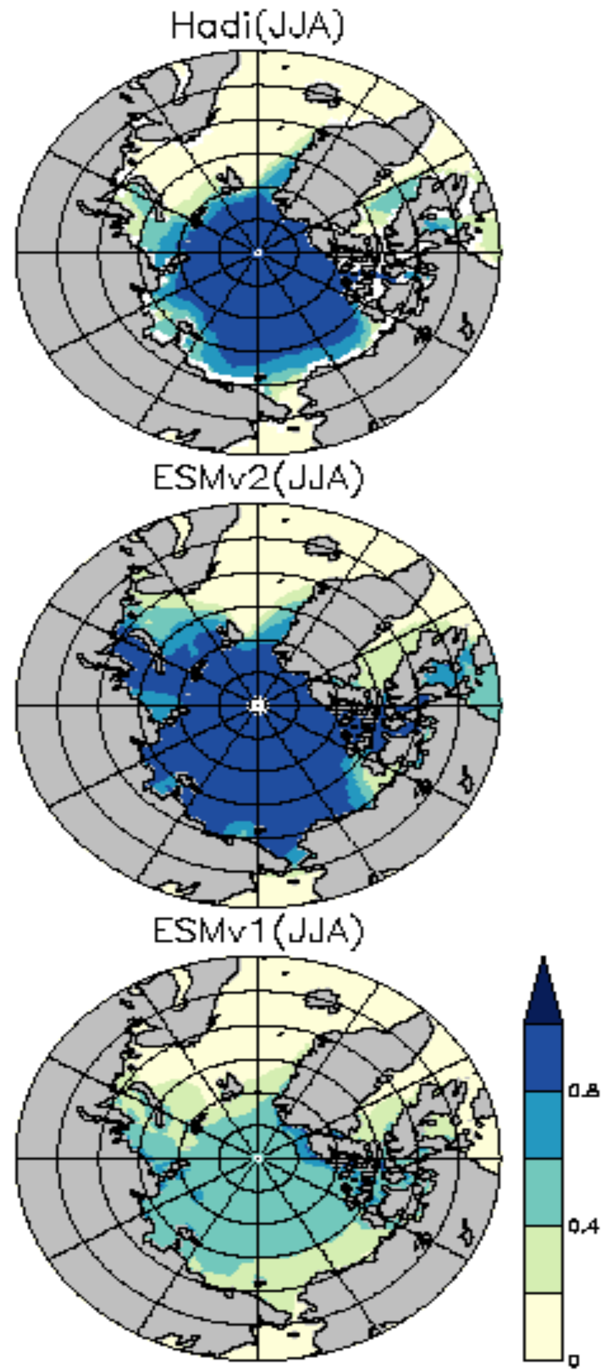
Sea-Ice concentration

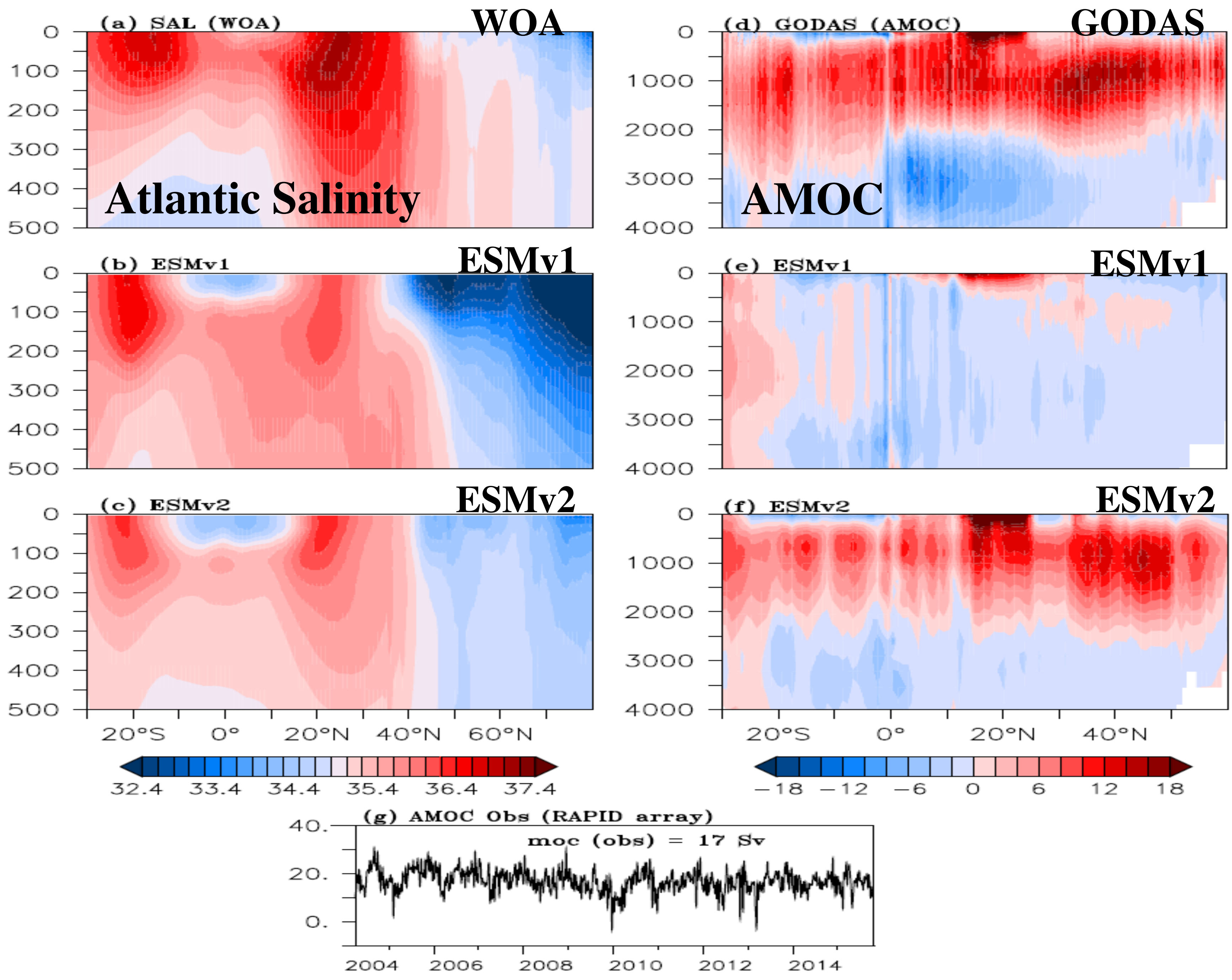
Obs

ESMv2

Improved simulation of NH sea-ice during JJA

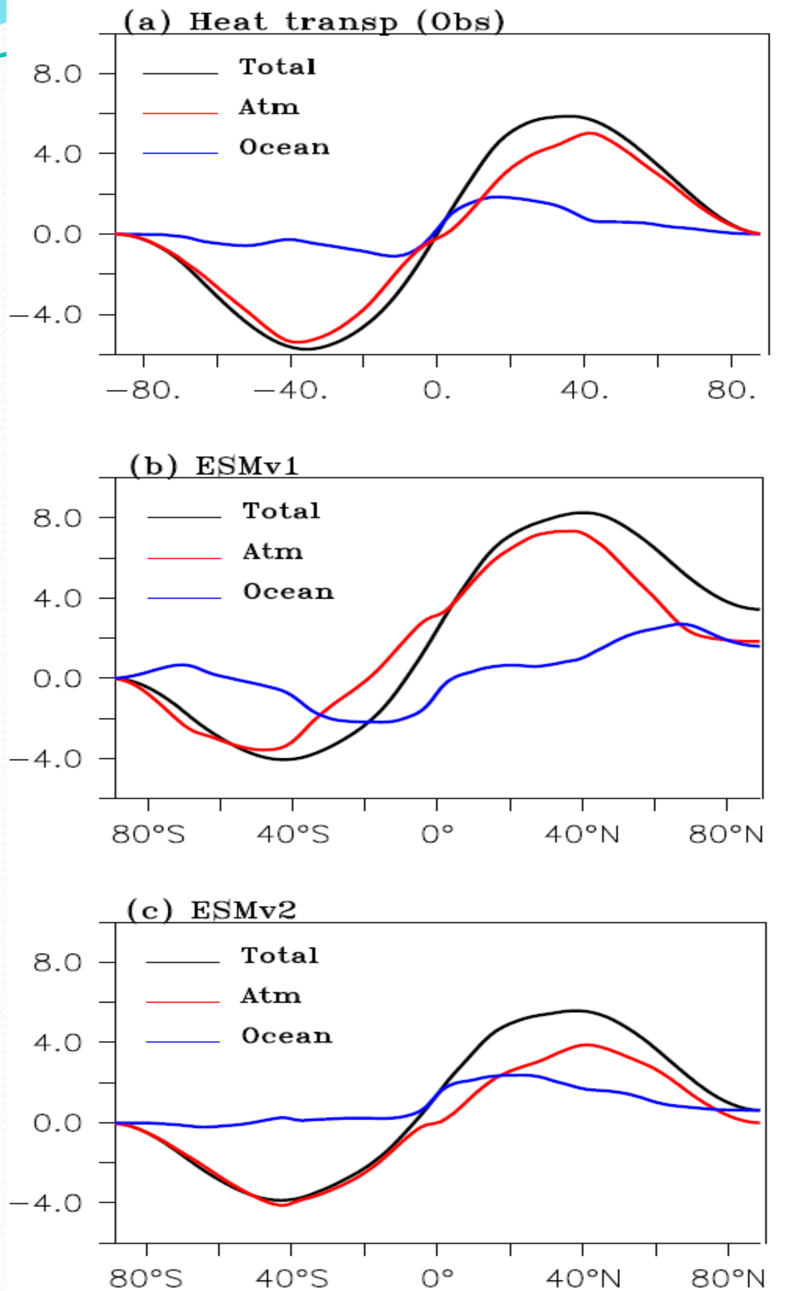
ESMv1





(a) SAL (WOA)
WOA
Atlantic Salinity
(d) GODAS (AMOC)
GODAS
AMOC
(b) ESMv1
ESMv1
(e) ESMv1
ESMv1
(c) ESMv2
ESMv2
(f) ESMv2
ESMv2
20°S 0° 20°N 40°N 60°N
20°S 0° 20°N 40°N
32.4 33.4 34.4 35.4 36.4 37.4
−18 −12 −6 0 6 12 18
(g) AMOC Obs (RAPID array)
moc (obs) = 17 Sv
2004 2006 2008 2010 2012 2014

Annual Mean Meridional Heat Transport



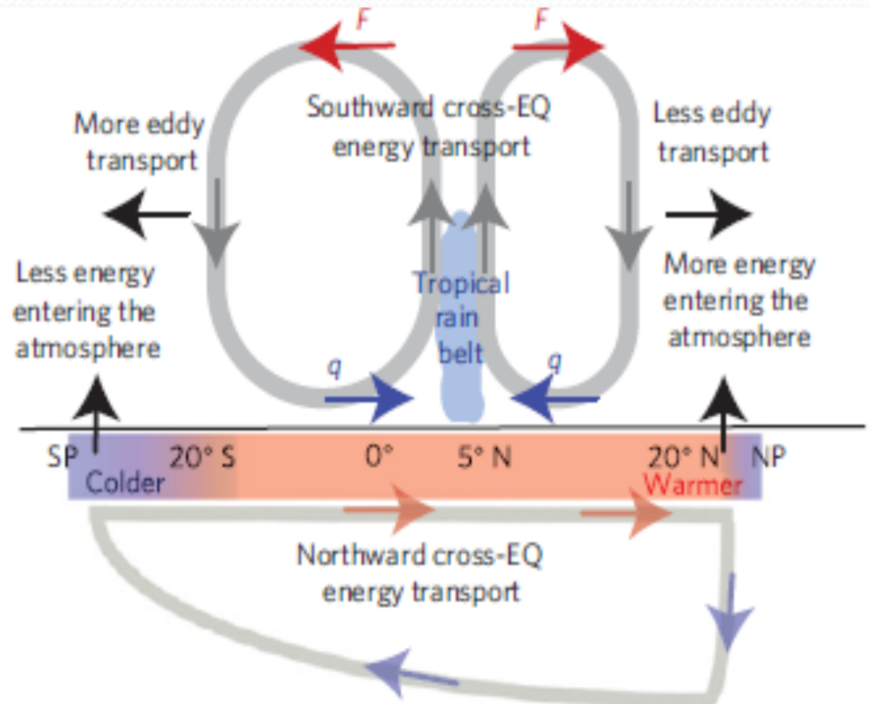
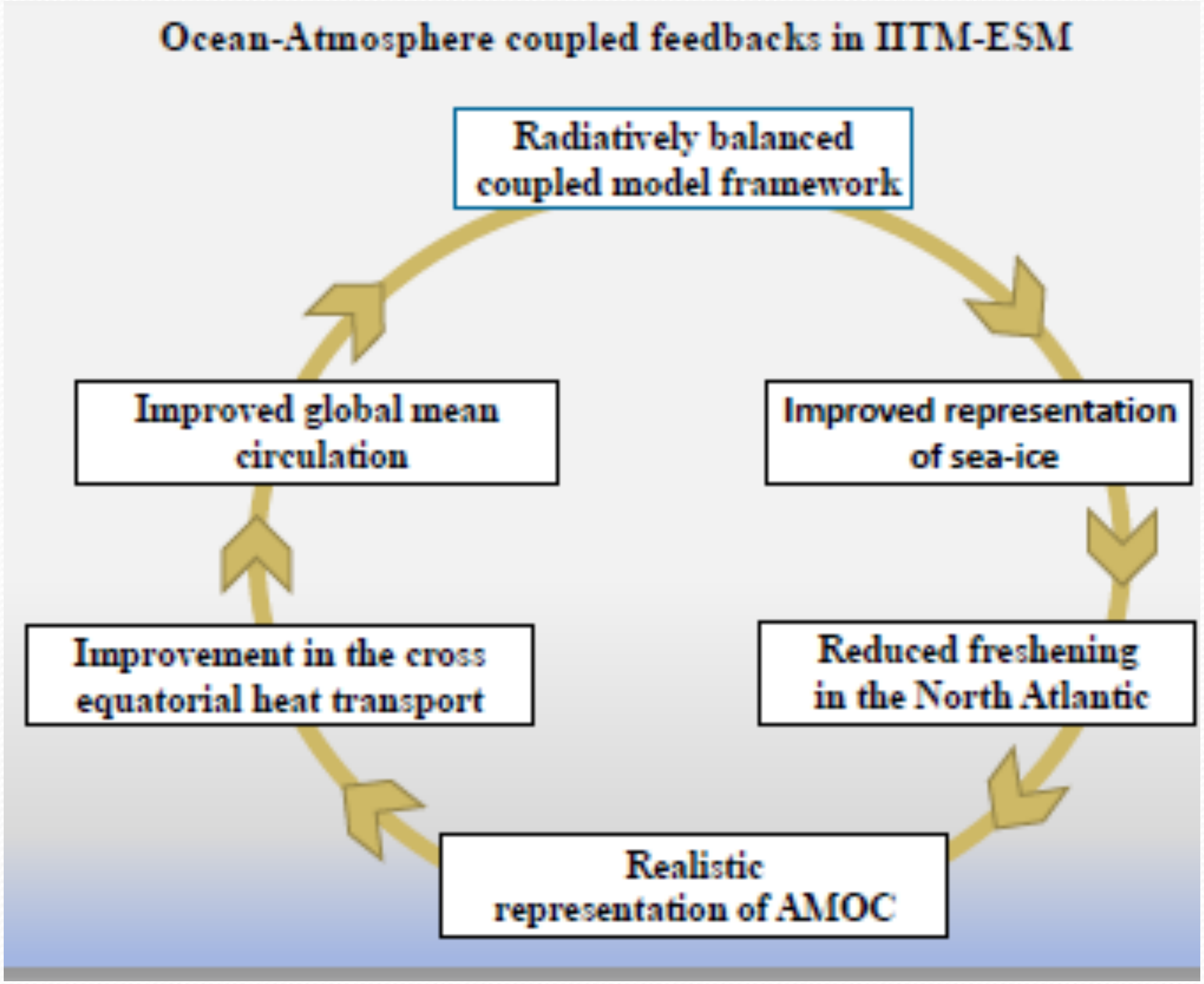


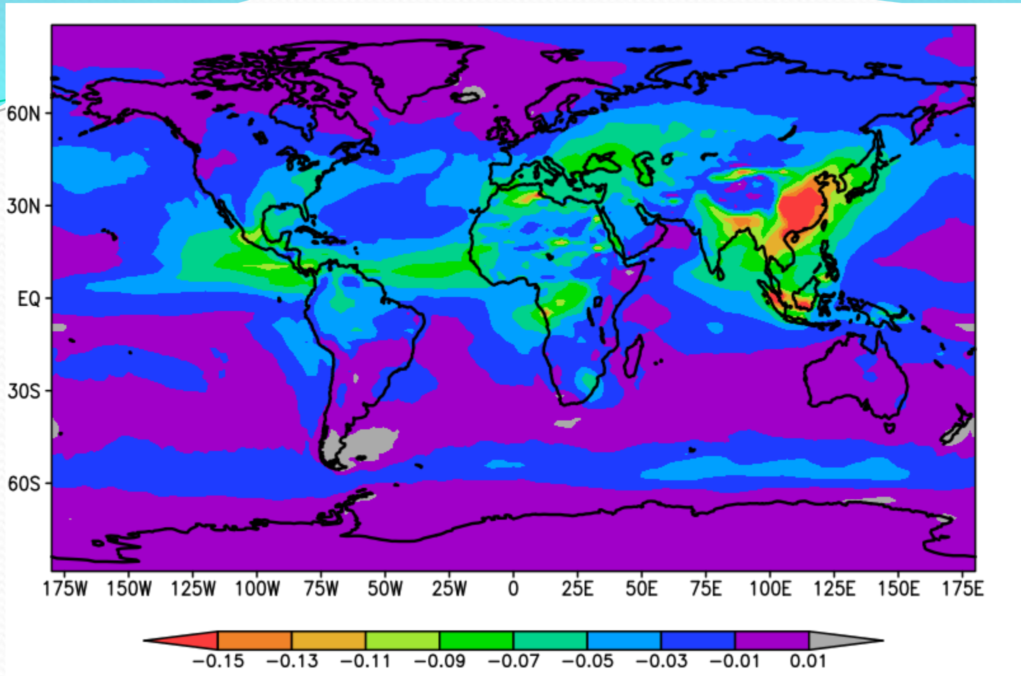
Figure 3 | Schematic of the role of the oceanic MOC in forcing the Northern Hemisphere maximum of tropical precipitation. Heat is released from the ocean to the atmosphere in the Northern Hemisphere owing to cross-equatorial OHT. The atmosphere responds through eddy energy transports in the extratropics, and a cross-equatorial Hadley circulation, which fluxes energy from the Northern Hemisphere to the Southern Hemisphere. The moisture transport by the Hadley circulation is in the opposite direction as the energy transport, so tropical precipitation moves northwards. SP, South Pole; NP, North Pole; cross-EQ, cross-equatorial; *q*, moisture transport; *F*, energy transport.

Frierson et al. 2013


Ocean-Atmosphere coupled feedbacks in IITM-ESM
Radiatively balanced coupled model framework
Improved representation of sea-ice
Reduced freshening in the North Atlantic
Realistic representation of AMOC
Improvement in the cross equatorial heat transport
Improved global mean circulation

Impact of aerosols and land-use land-cover changes on South Asian Monsoon

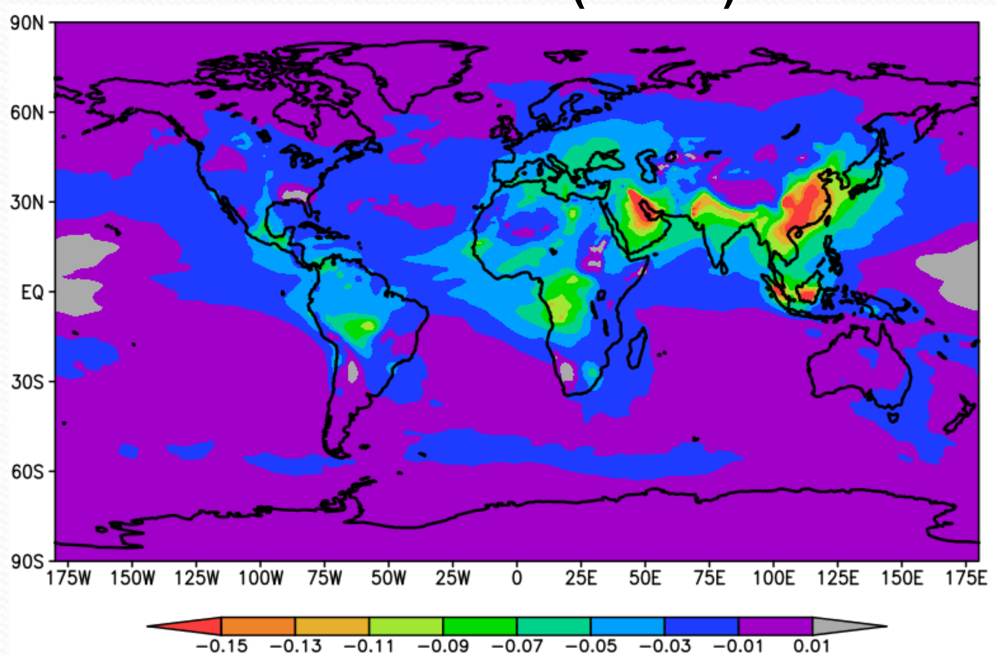
Calculated for IITM ESM



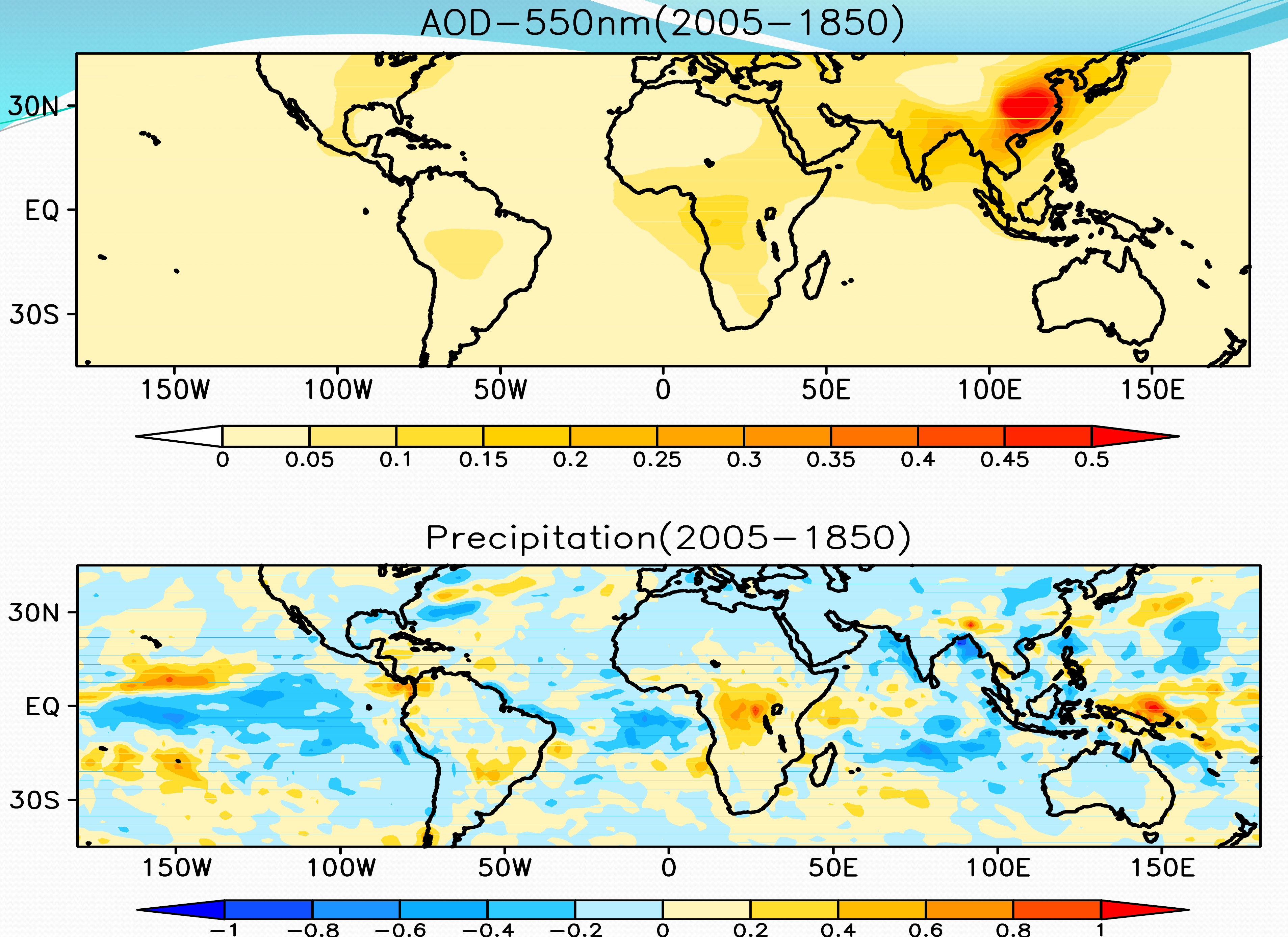
AOD difference map

Preindustrial (1870)- Present (2005)

CESM (CAM5)

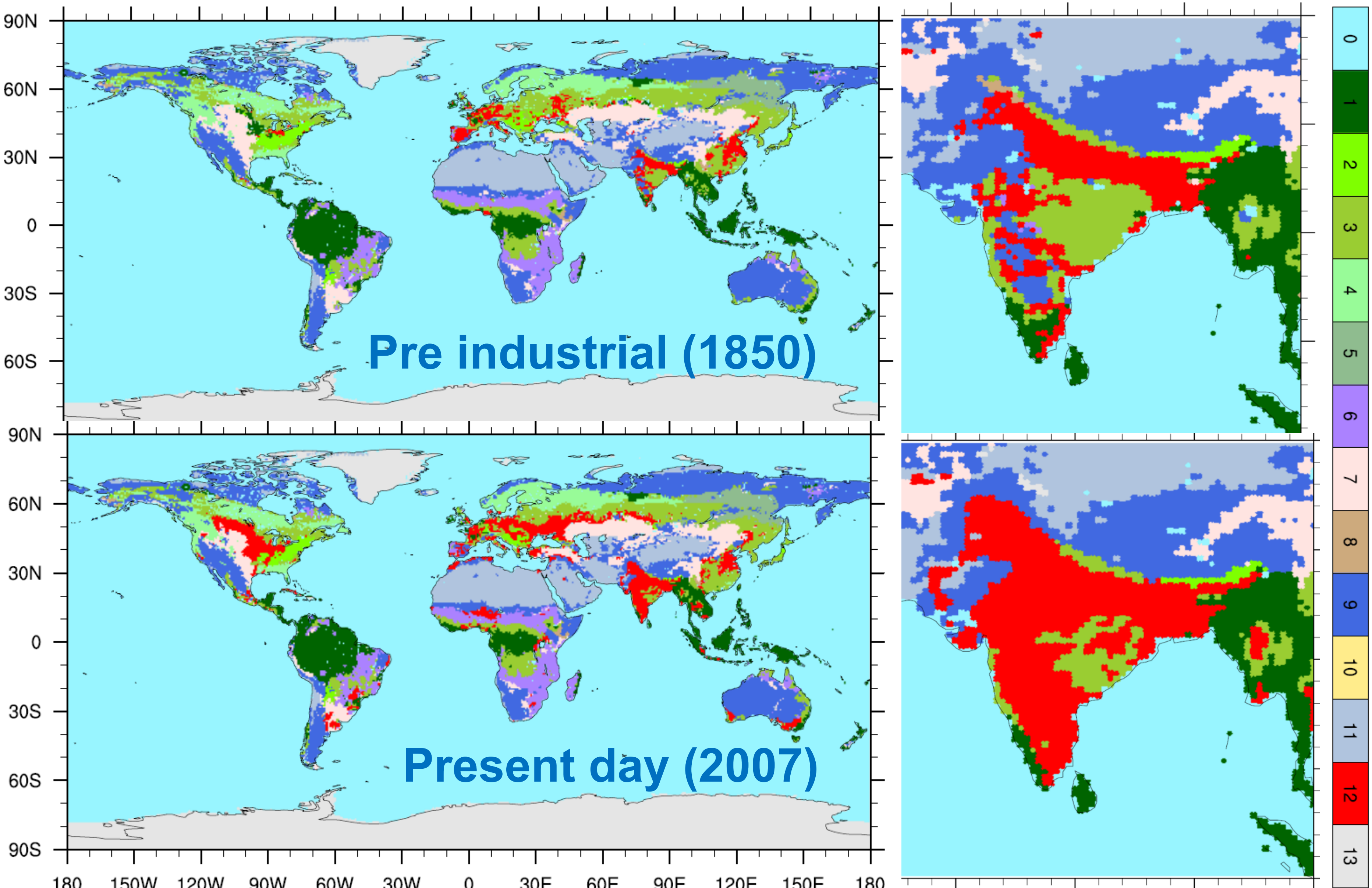


Courtesy: Ayantika, CCCR

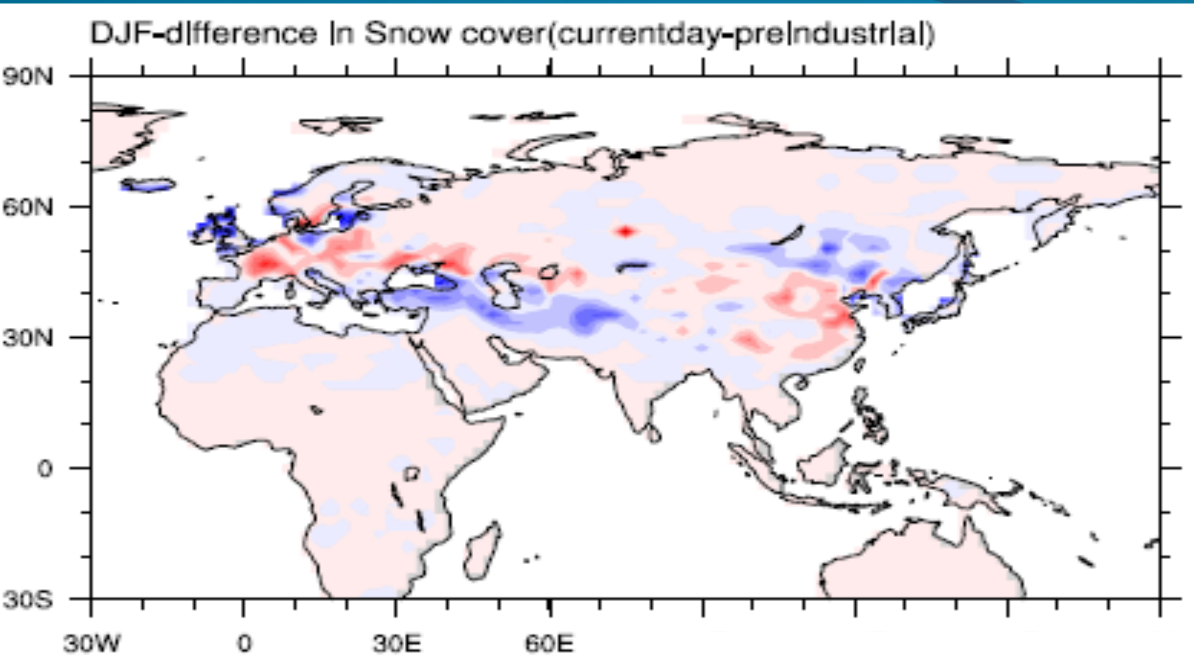


Ayantika et al.

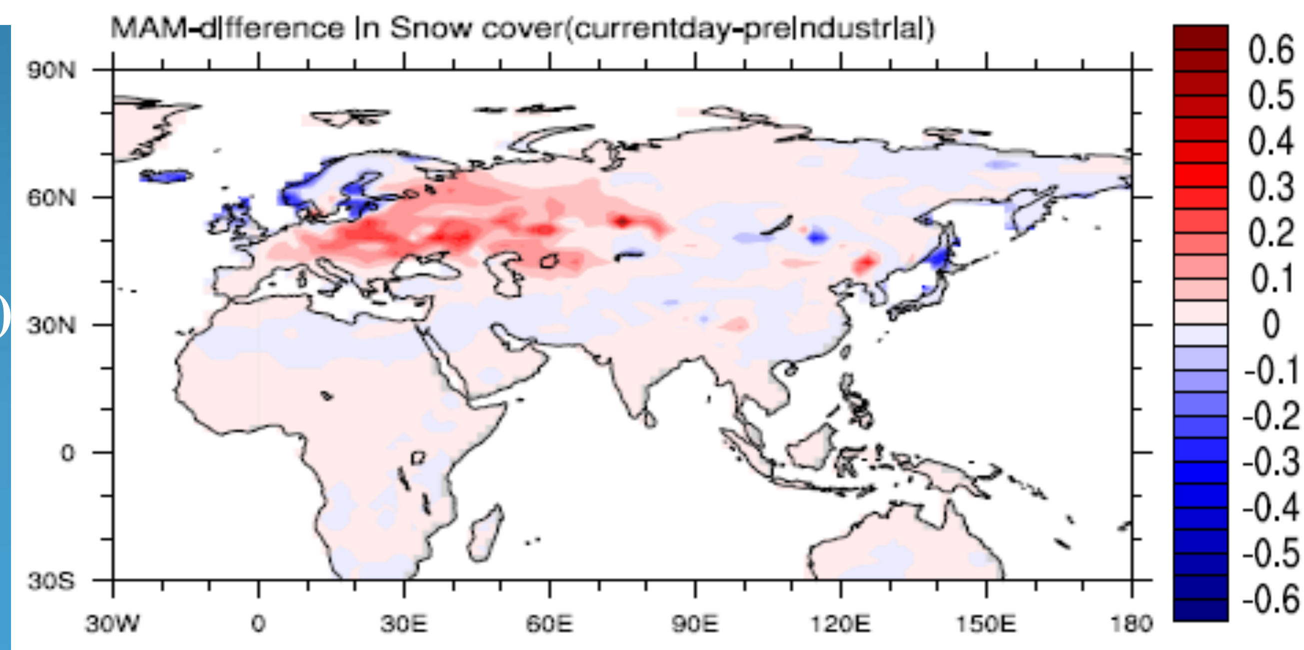
Land use/land cover changes (Hurtt et al., 2015)



0 waterbodies	3 mixedforests	6 savannas	9 openshrubs	12 crops
1 Evergreen Broad	4 Evergreen Needle	7 grasslands	10 Tundra	13 snowice
2 DeciduousBroad	5 Deciduous Needle	8 shrubs	11 Barren	



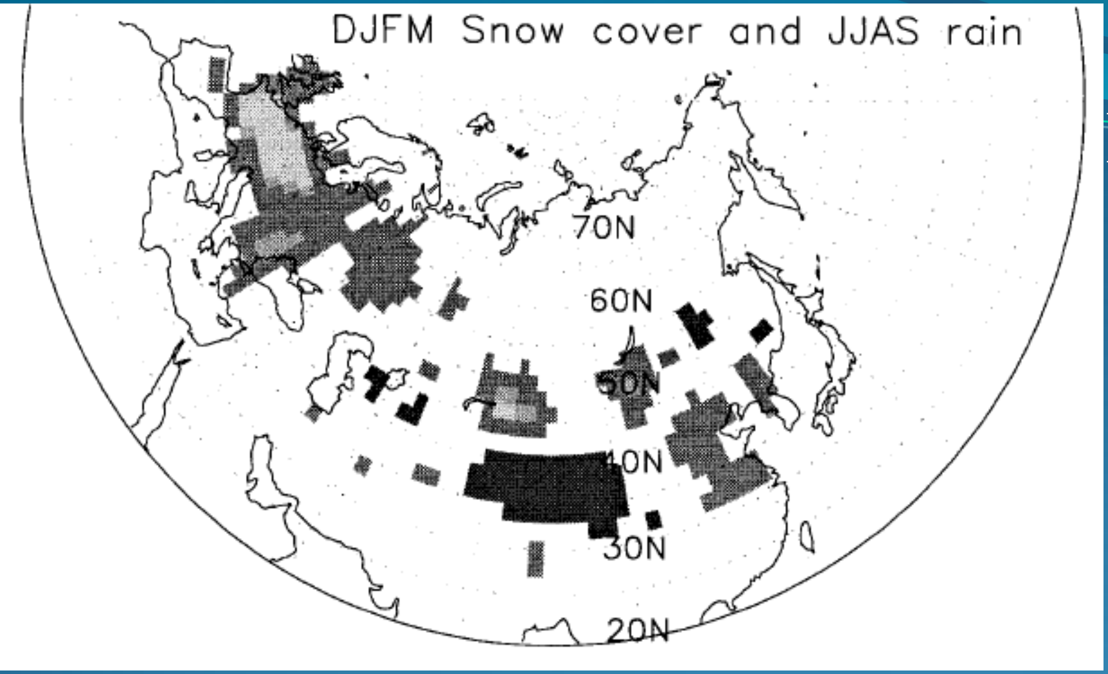
Difference in Snow Cover (Present – Pre-industrial) Dec-Feb

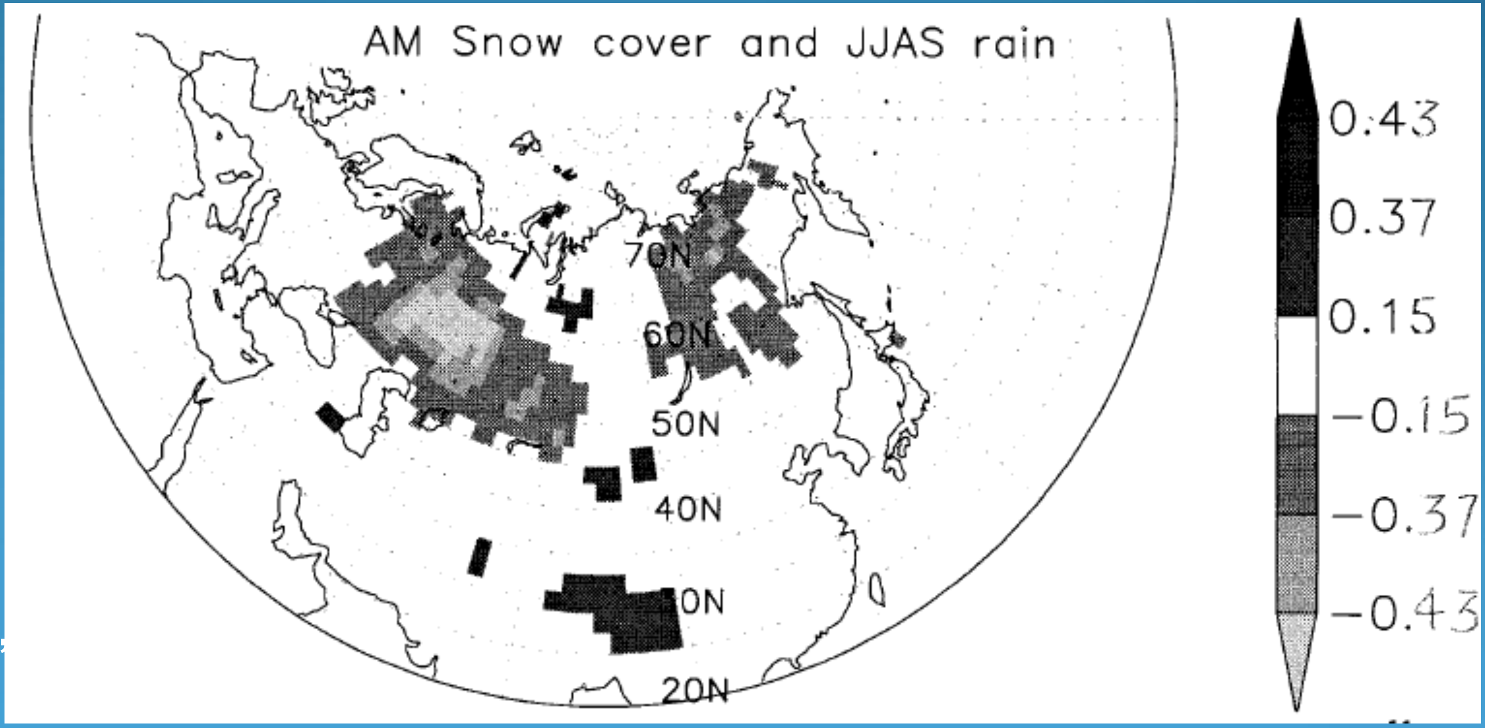


(Present – Pre-industrial) Mar-May

Sandeep et al. 2017

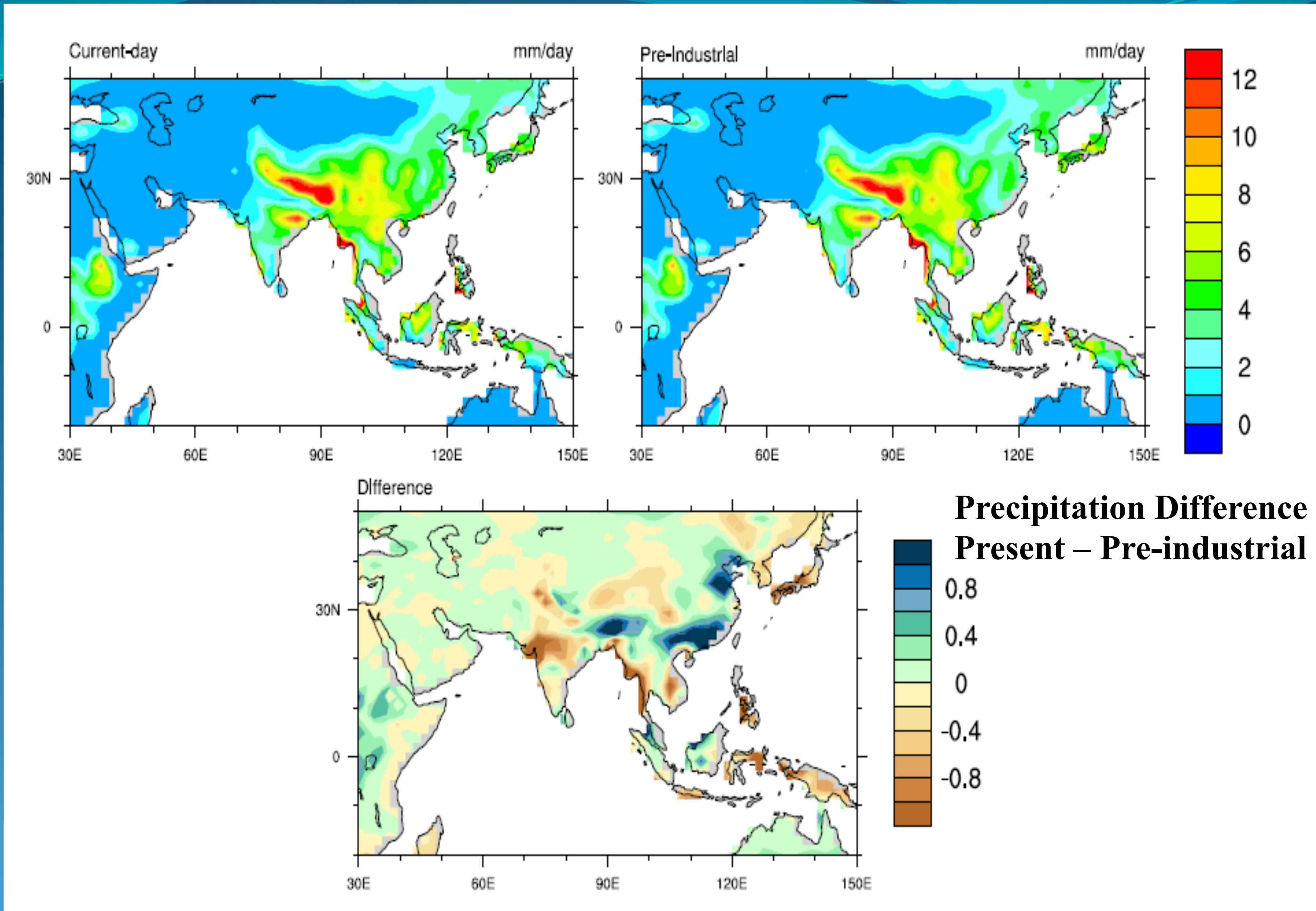
Eurasian snow cover and South Asian Monsoon





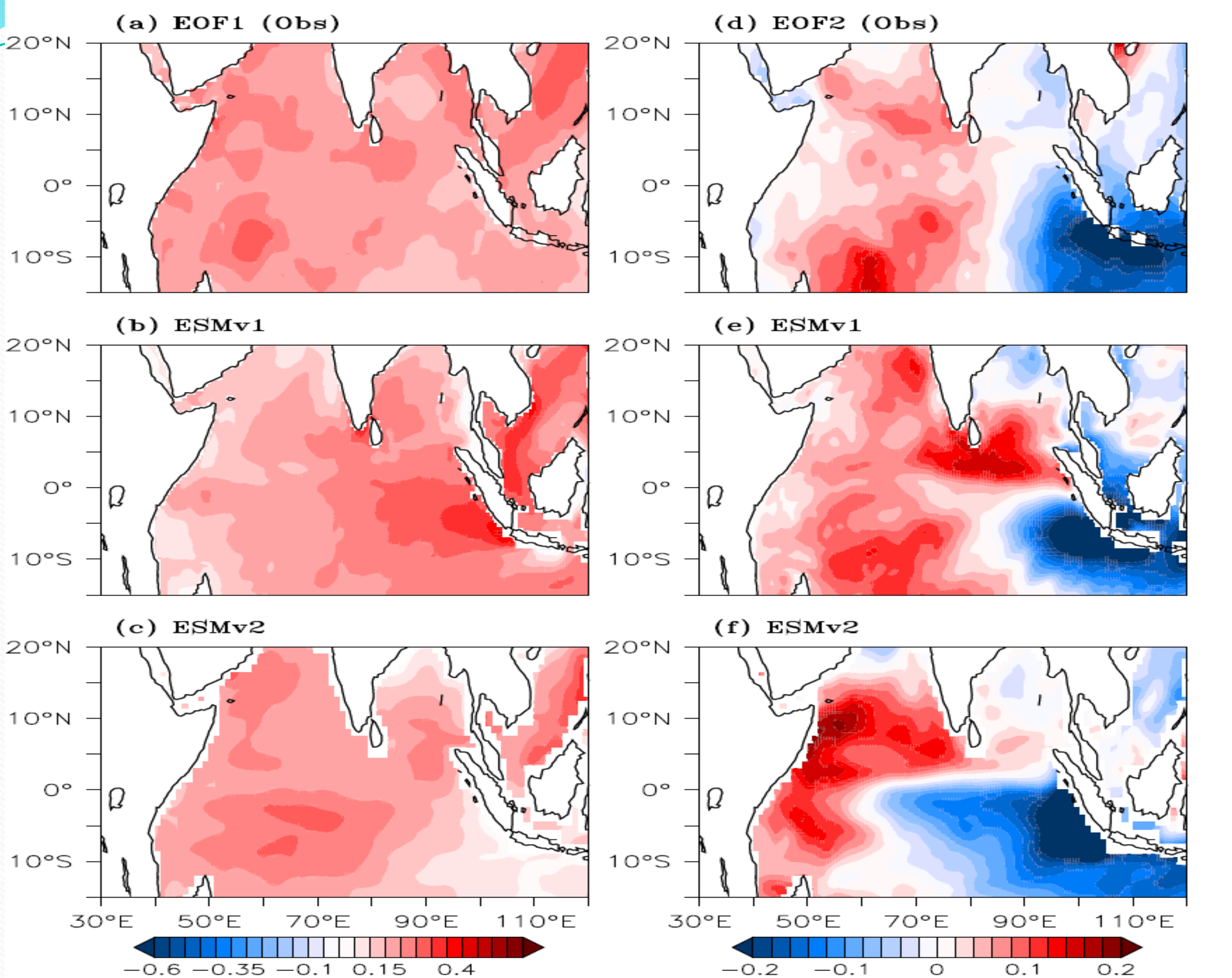
Bomzai & Shukla, 1998

Precipitation (Present) **Precipitation (Pre-industrial)**

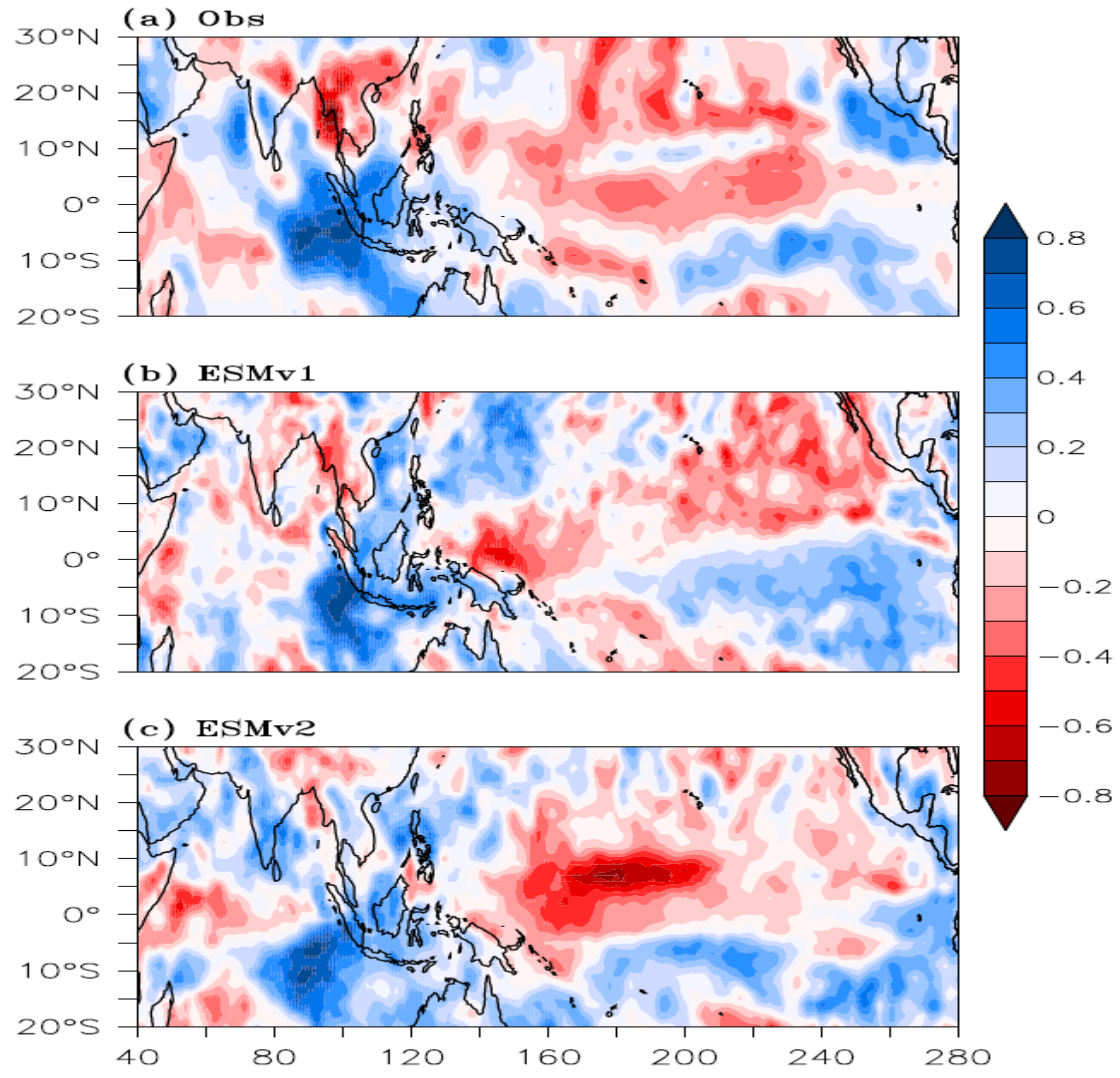


El Nino, IOD and its teleconnections to Indian Summer Monsoon Precipitation

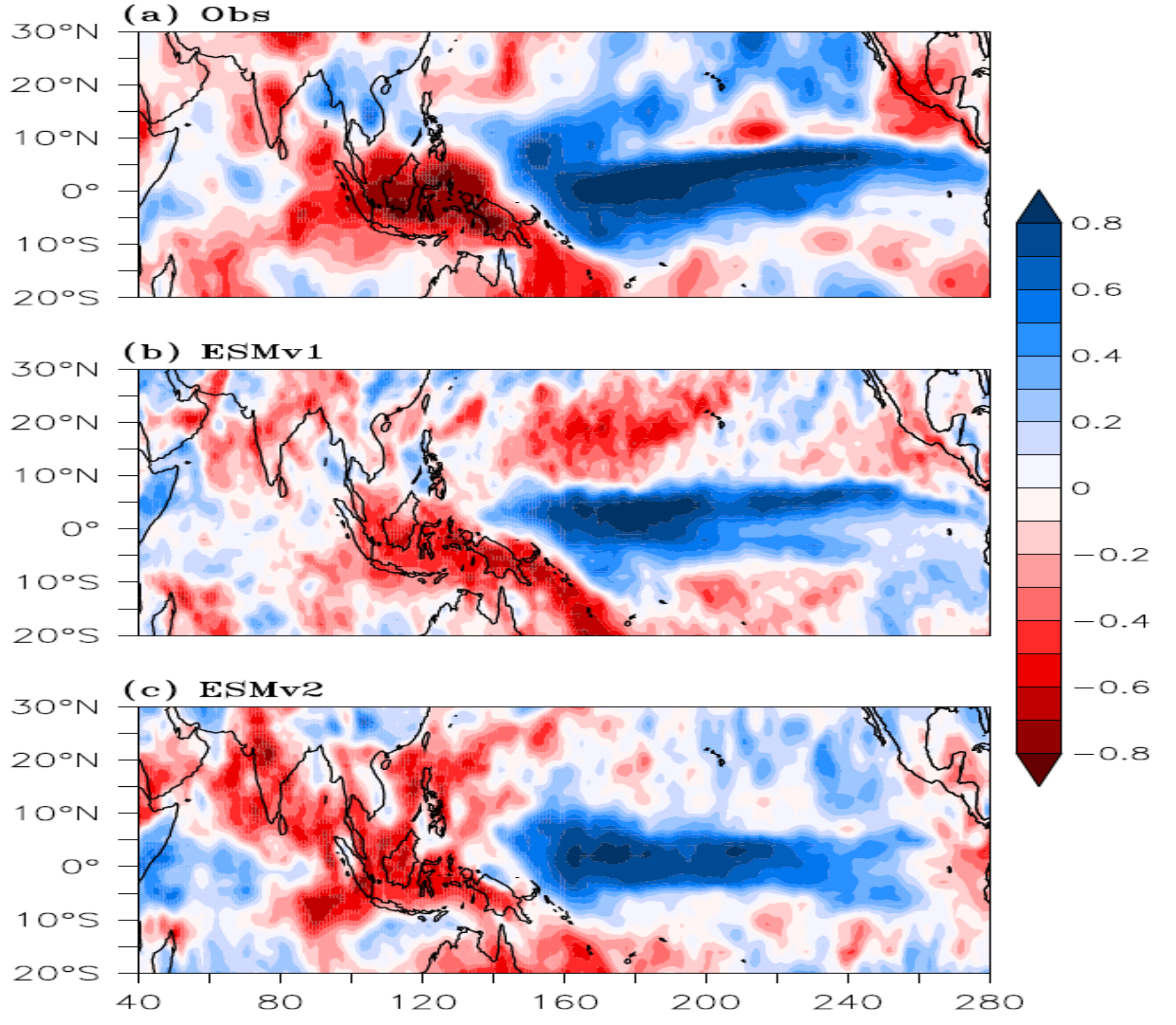
Tropical Indian Ocean Variability (IOBM & IOD)



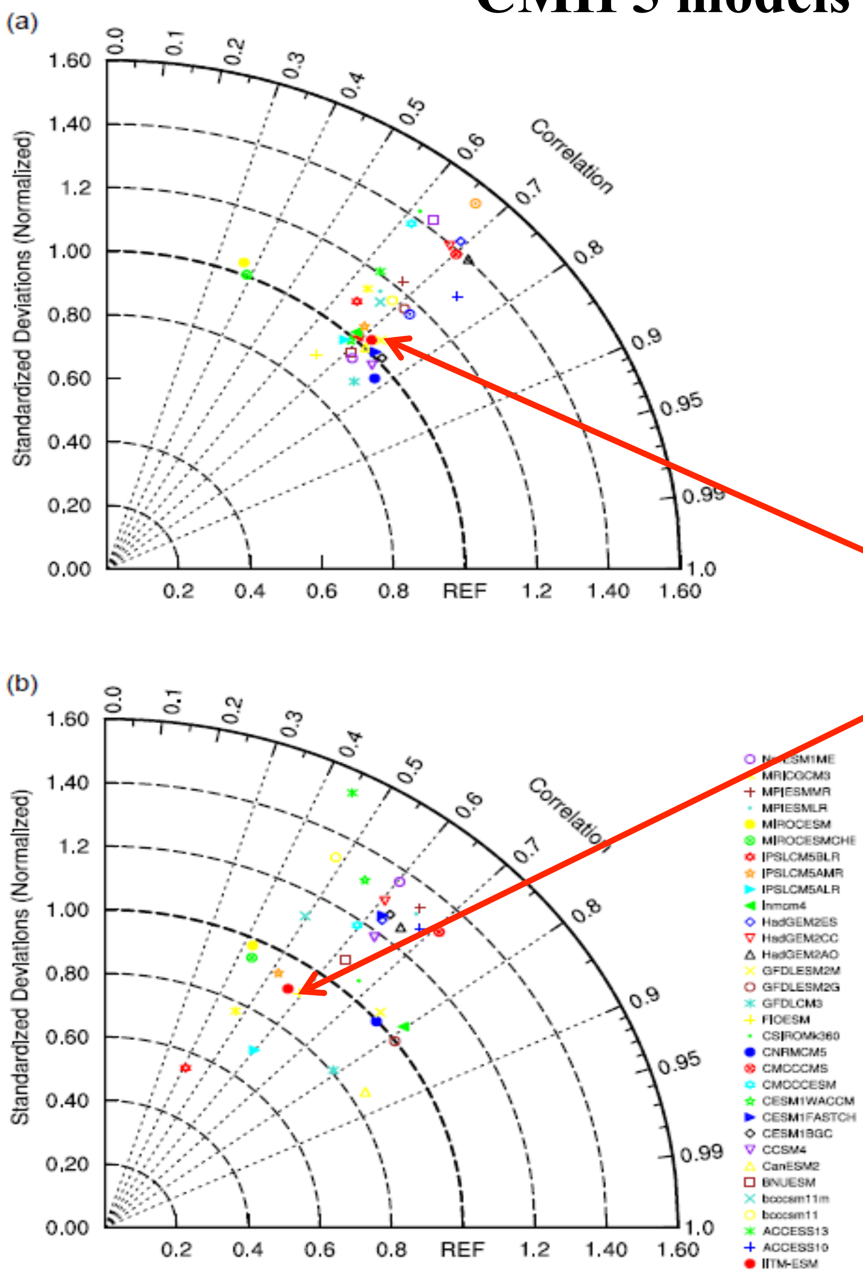
IOD and its teleconnection to South Asian Summer Monsoon Rainfall



ENSO and its teleconnection to South Asian Summer Monsoon Rainfall



South Asian summer monsoon variability in IITM ESMv2 and CMIP5 models

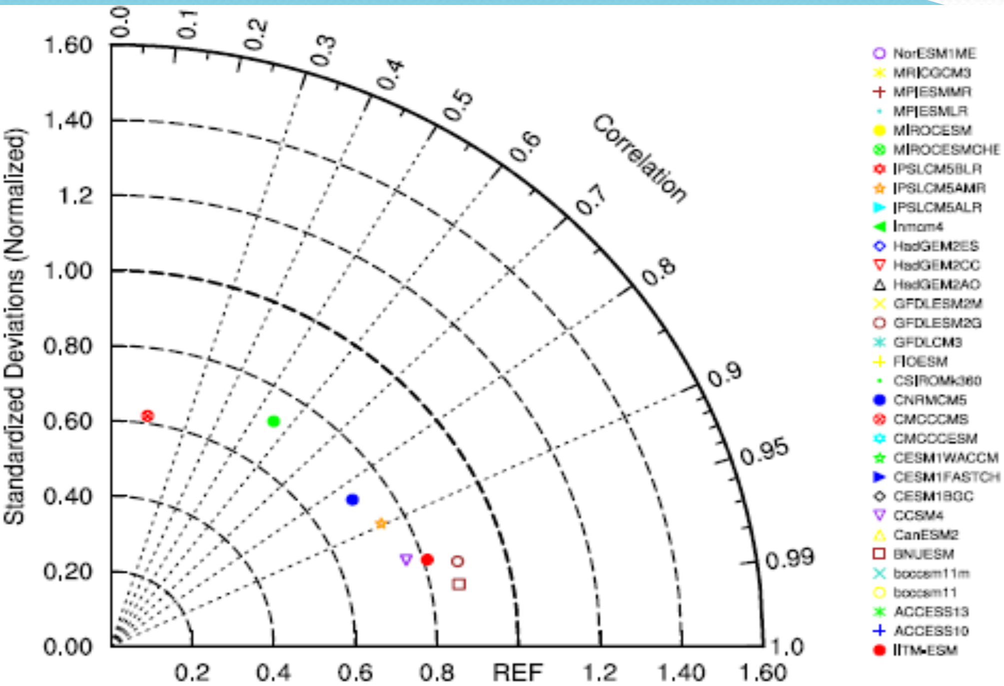


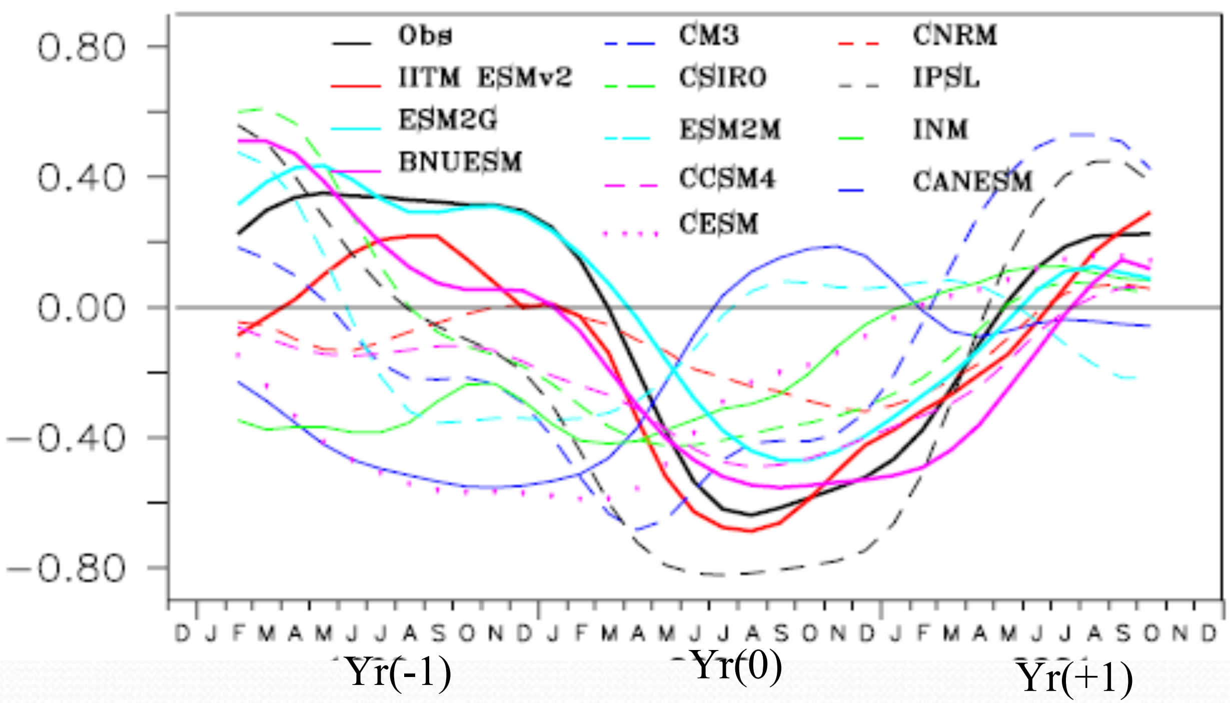
South and Southeast Asian Region (65E-140E; 10S-40N)

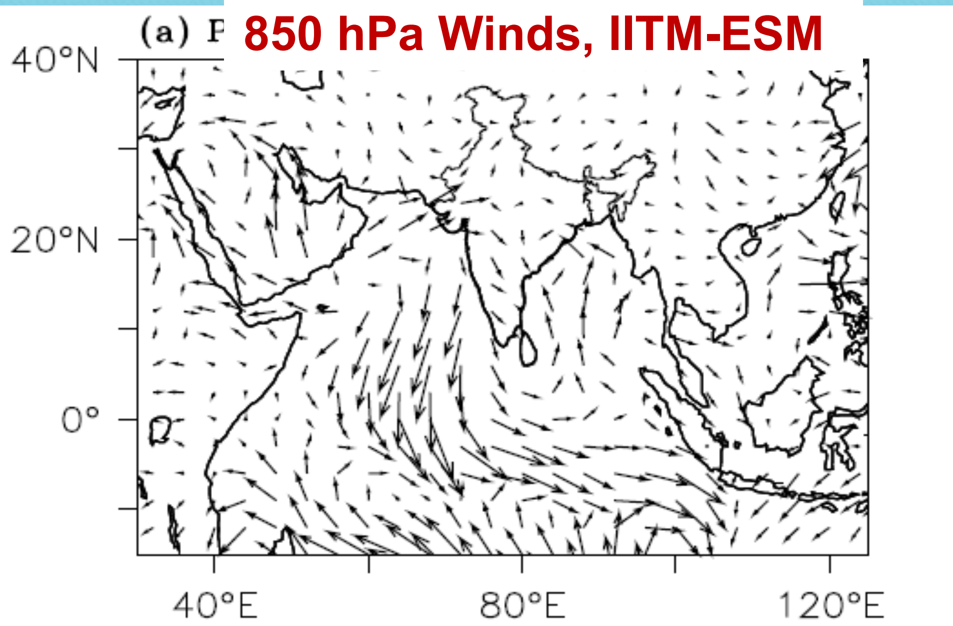
IITM ESMv2

Indian land region

ENSO-Monsoon Teleconnection

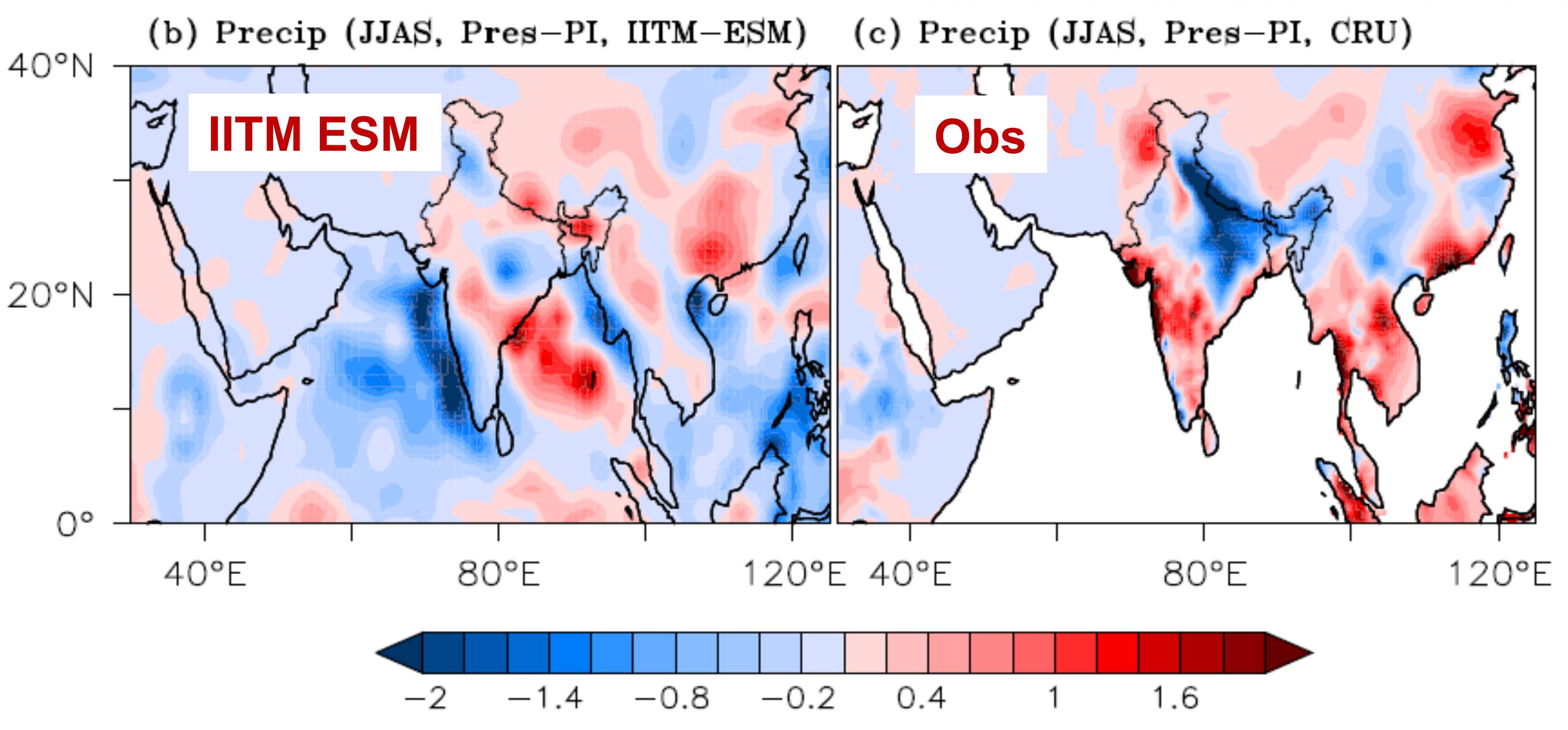




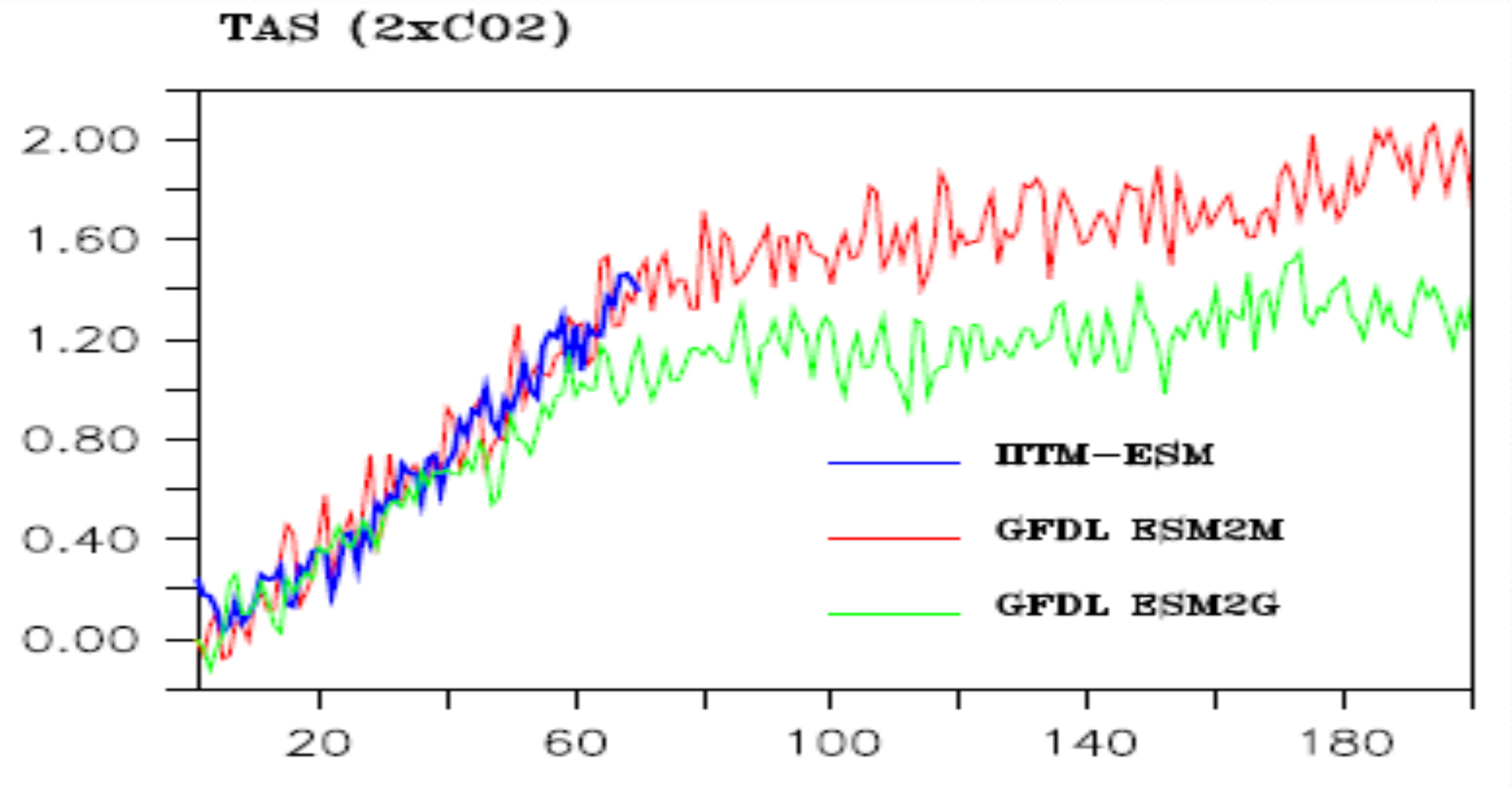


Present-Pre-industrial Simulation

- Weakening Summer Monsoon Circulation
- Desiccation of Summer Monsoon Precipitation

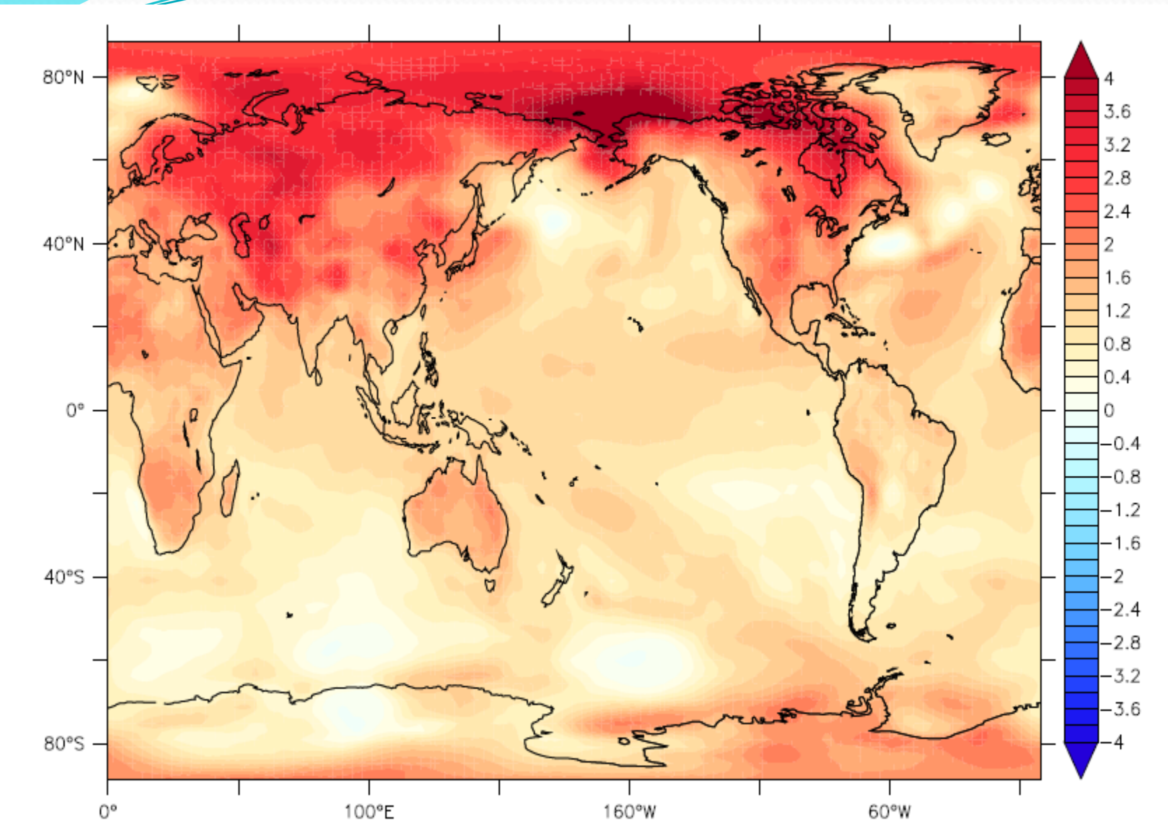


$2xCO_2$ response of IITM-ESM

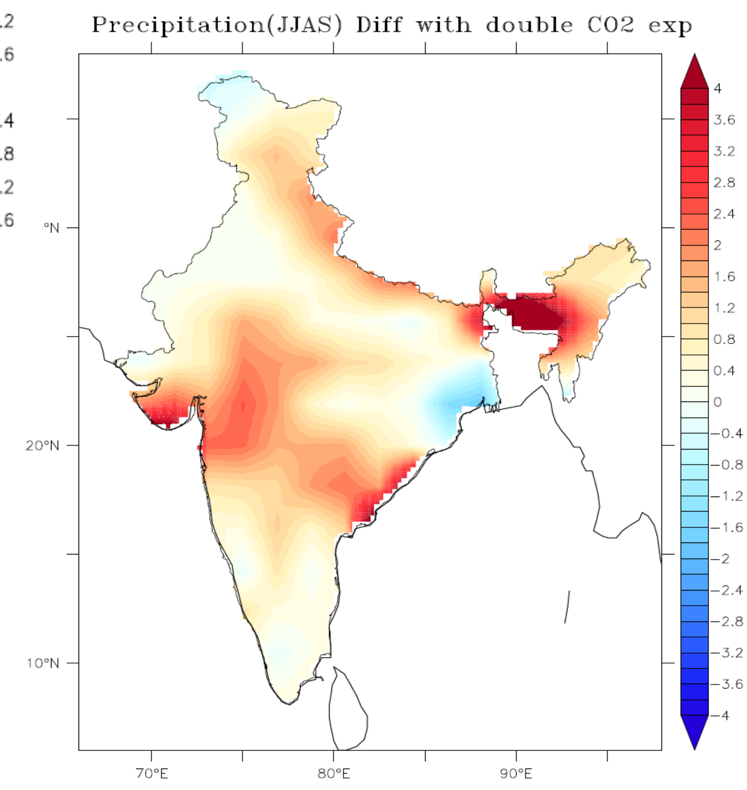


SST / SAT Anomaly: 2 x C02 experiment - PI Control

2xCO_2 response in IITM-ESM



Surface Temperature Anomaly



Precipitation Anomaly

Summary

The IITM-ESM has shown improvements in mean state & variability

- **Improved representation of mean monsoon features**
- **Land-atmosphere-ocean feedbacks**
- **ESNO & IOD, major drivers of Monsoon is well represented and teleconnections are robust**

These lead to improved mean and variability of summer monsoon precipitation over Asian region.

- **Need for improving the upper layer circulation features**

Thank You