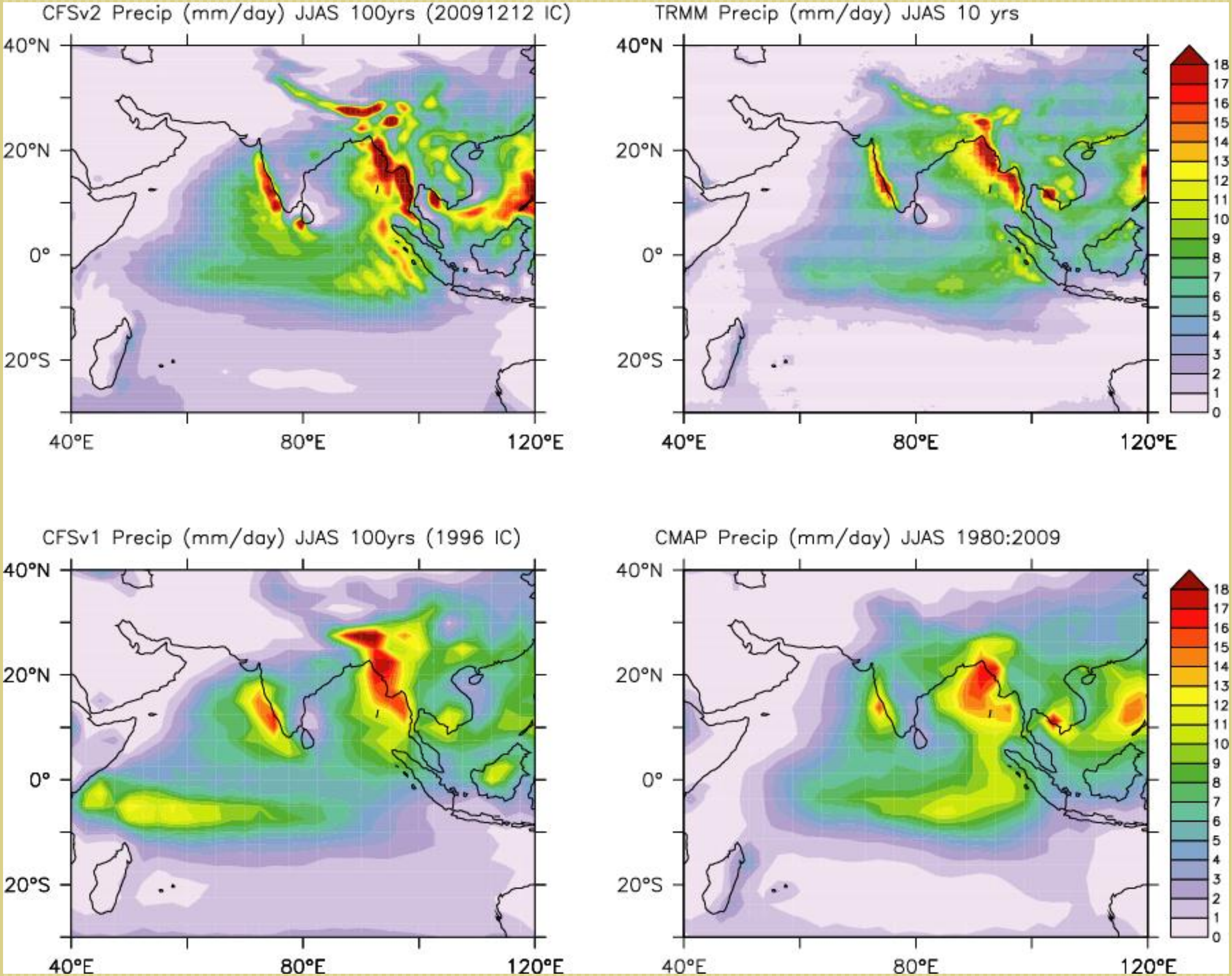
CFSv2 activities at CCCR/IITM

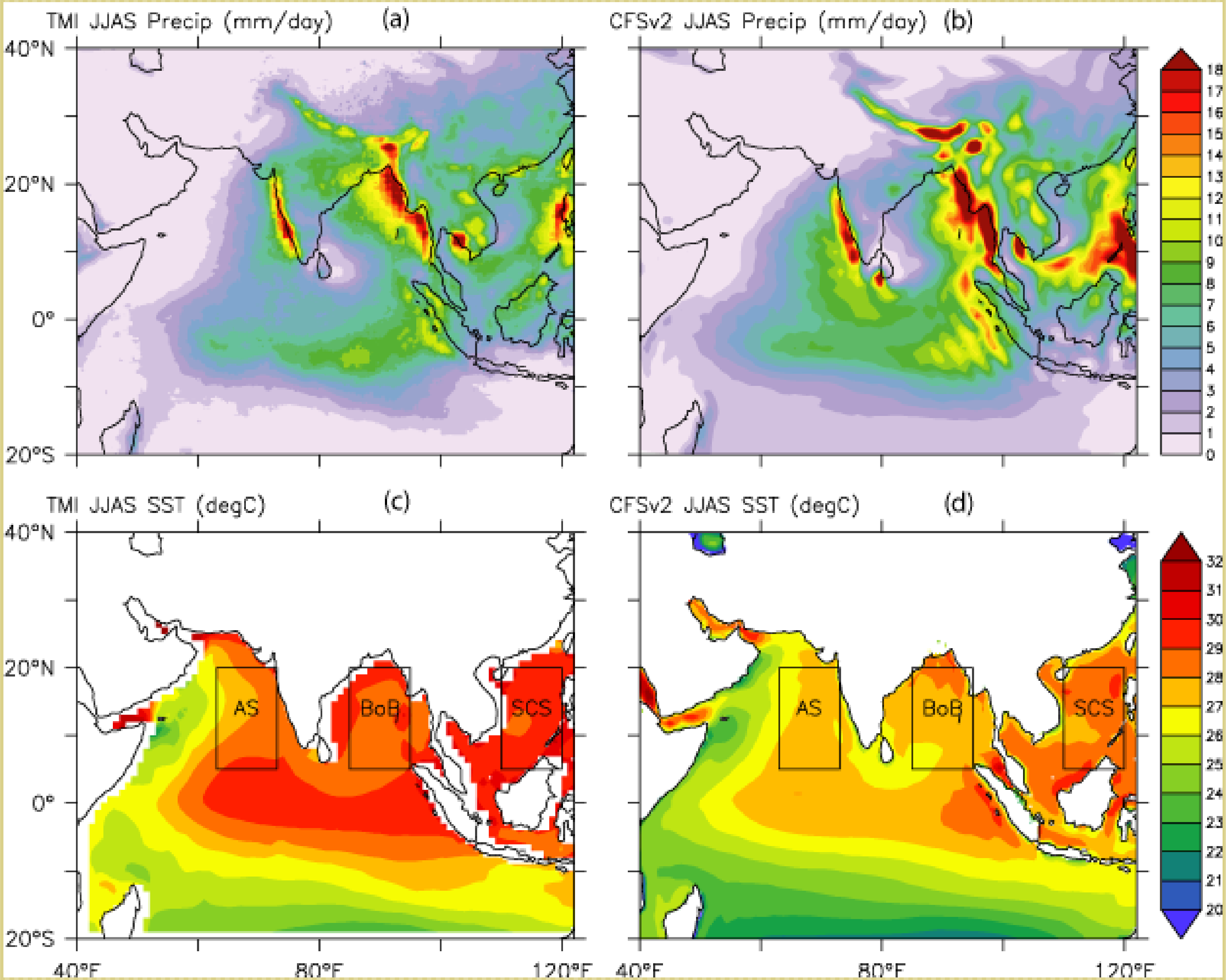
Roxy Mathew
Indian Institute of Tropical Meteorology

1. **Fixed (1xCO_2) runs – 100 years**
2. **Increasing (1% to 2xCO_2) runs – 100 years**
3. Monsoon ISV - Experiments
4. ESM development – Ocean BGC & Aerosol

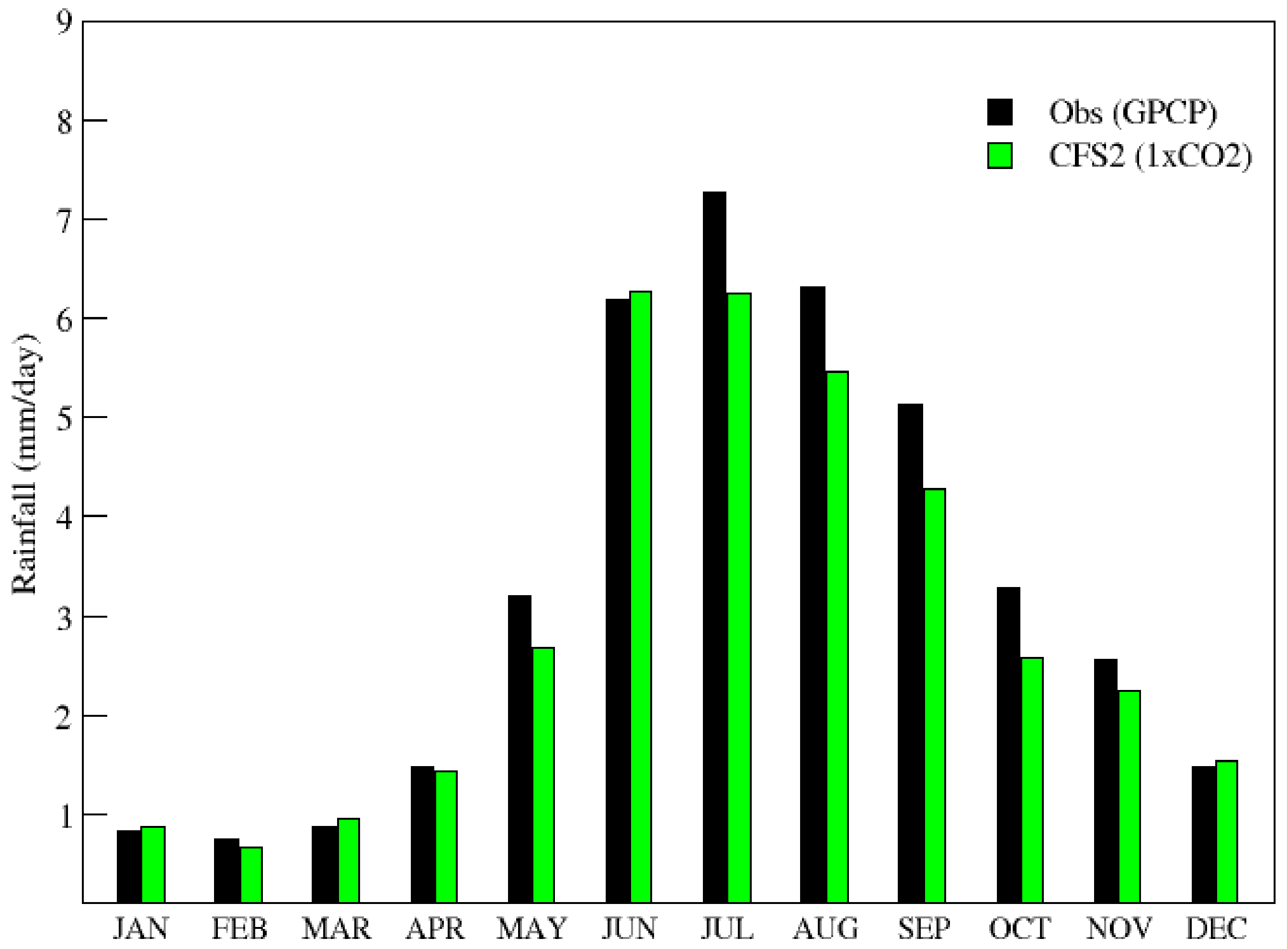
Climatology of Precipitation (June-Sept)



Climatology of Precipitation and SST (June-Sept)



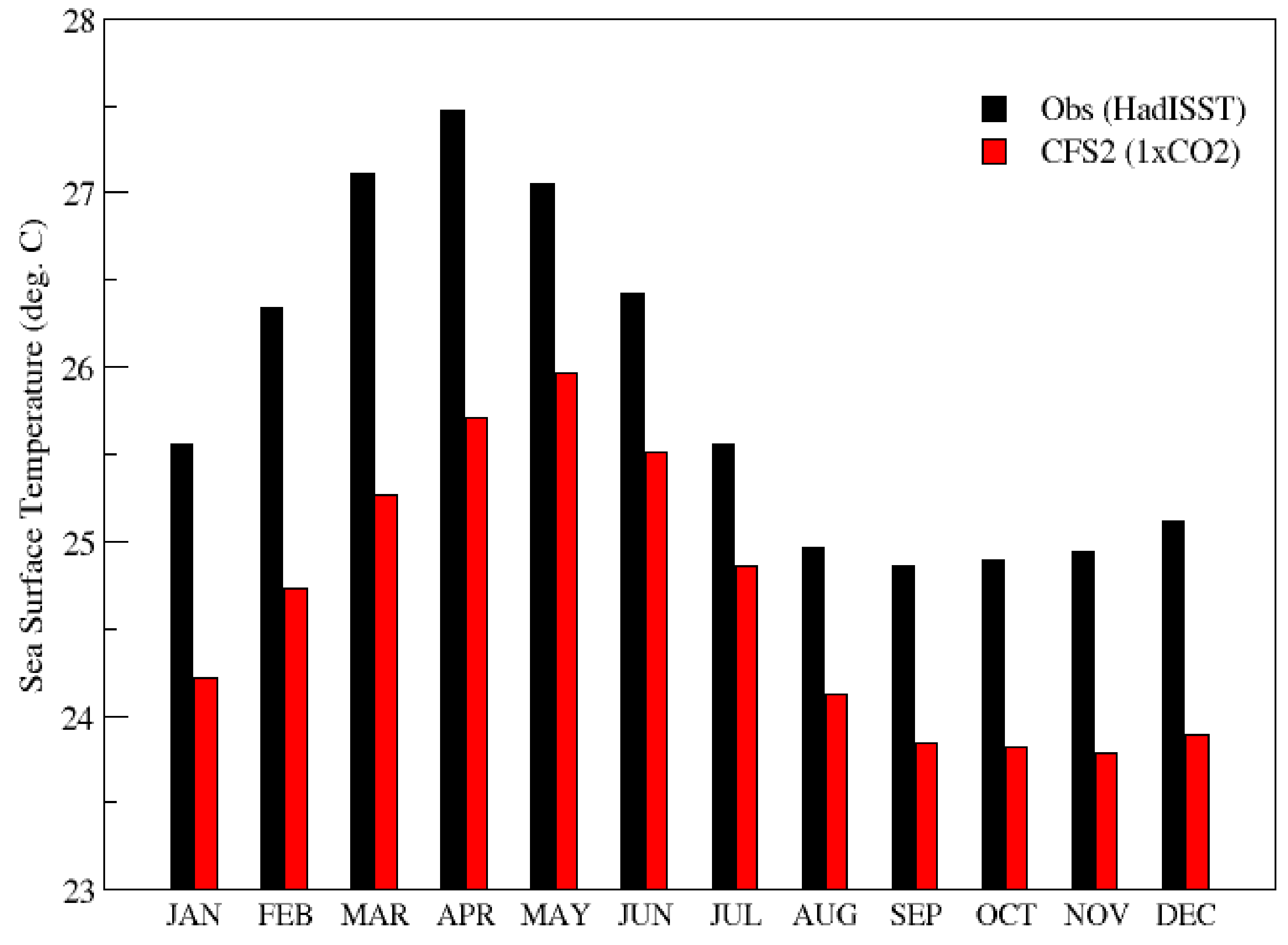
Mean Annual Cycle of All-India Rainfall [65-95E; 5-35N]



GPCP (1981-2010)

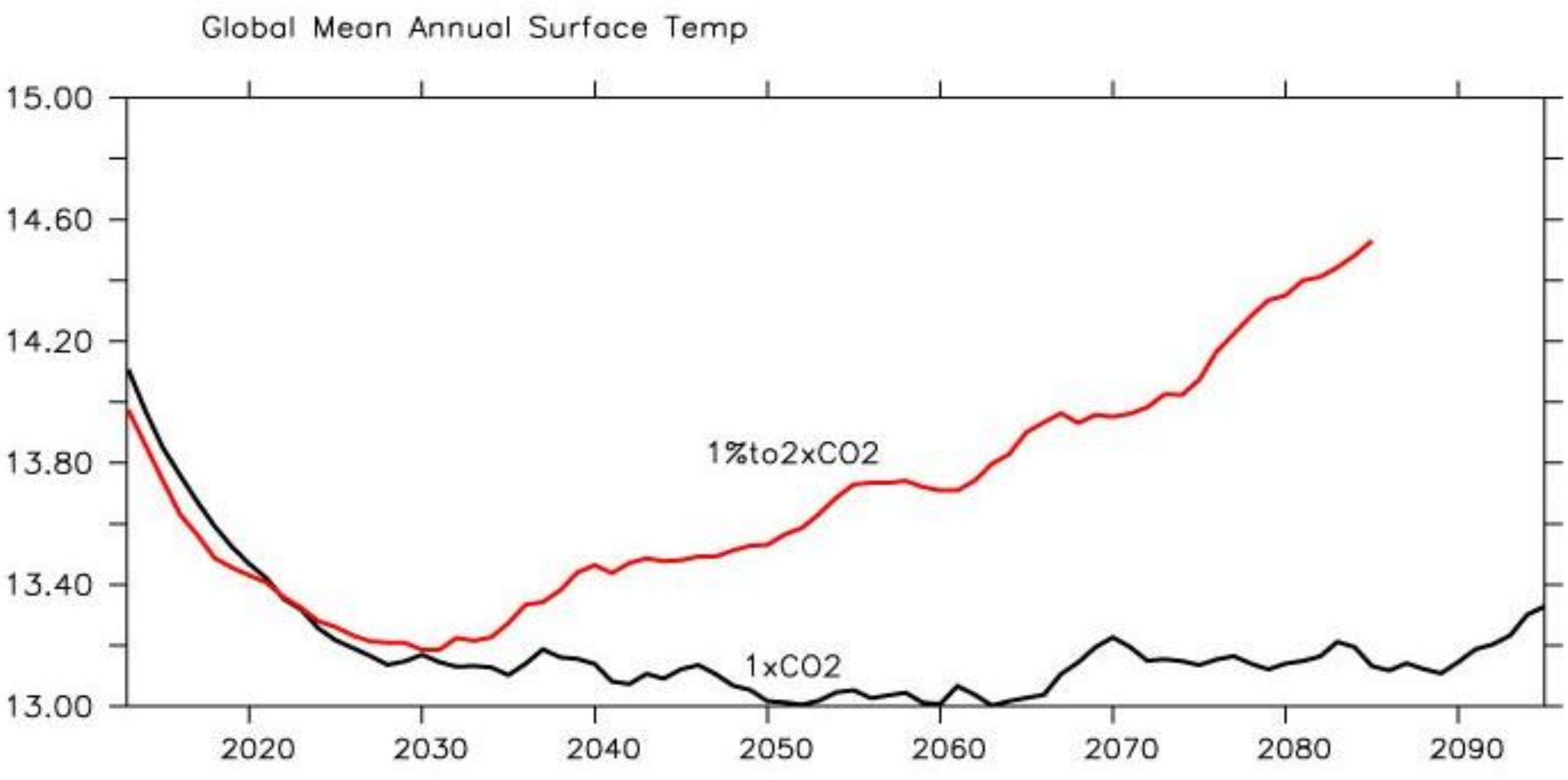
CFS2 (100 yrs)

Mean Annual Cycle of Nino3 SST

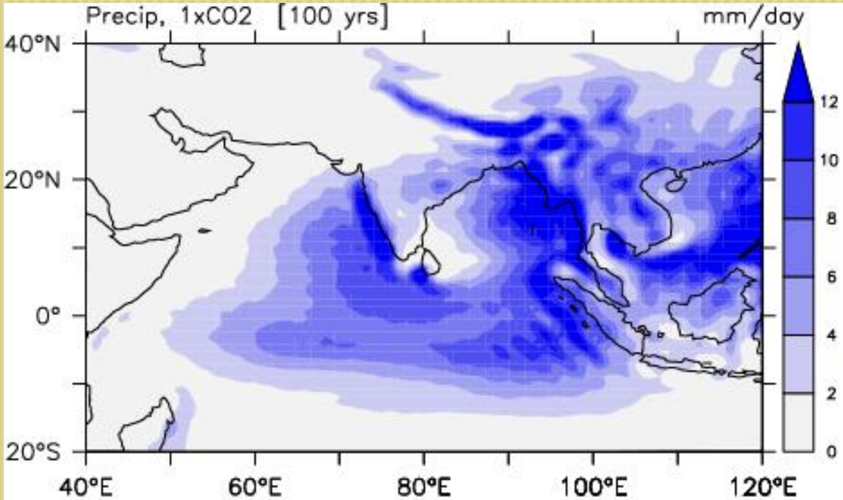


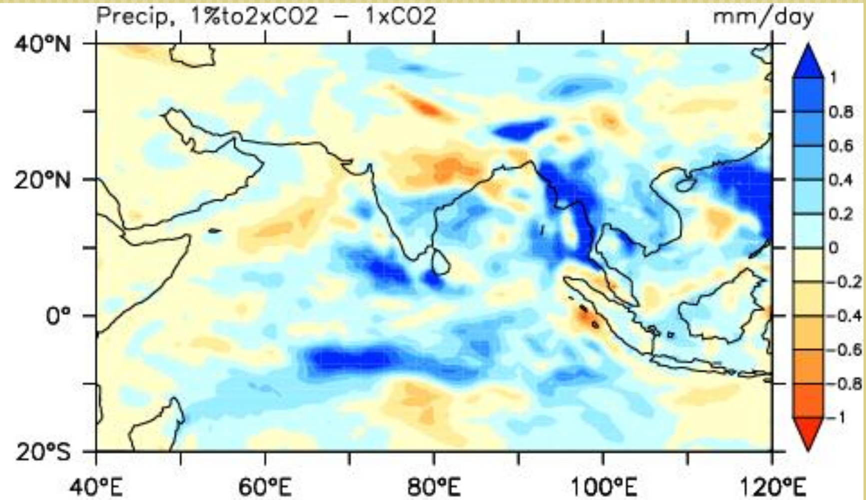
HadISST
(1981-2010)
CFS2 (100 yrs)

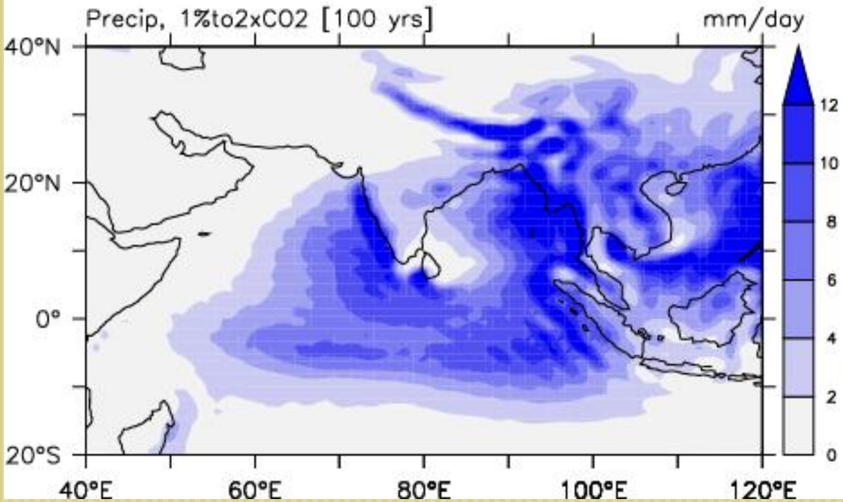
Global Mean Annual Surface Temp (°C)



Precip 1%to2xCO2 – 1xCO2

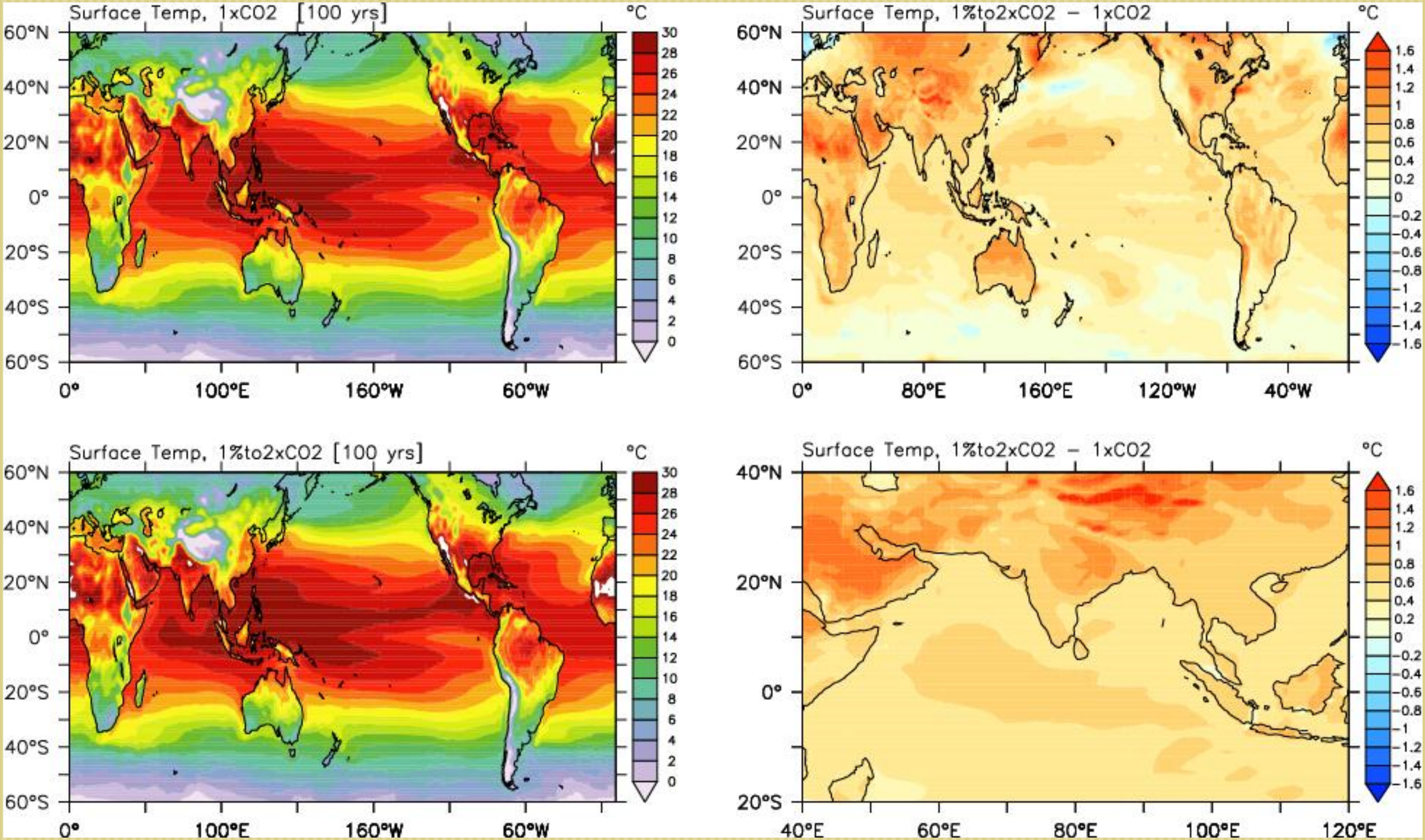






role of topography?

SST 1%to2xCO2 - 1xCO2



CFSv2 activities at CCCR/IITM

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2. Increasing (1% to 2xCO_2) runs – 100 years
3. **Monsoon ISV - Experiments**
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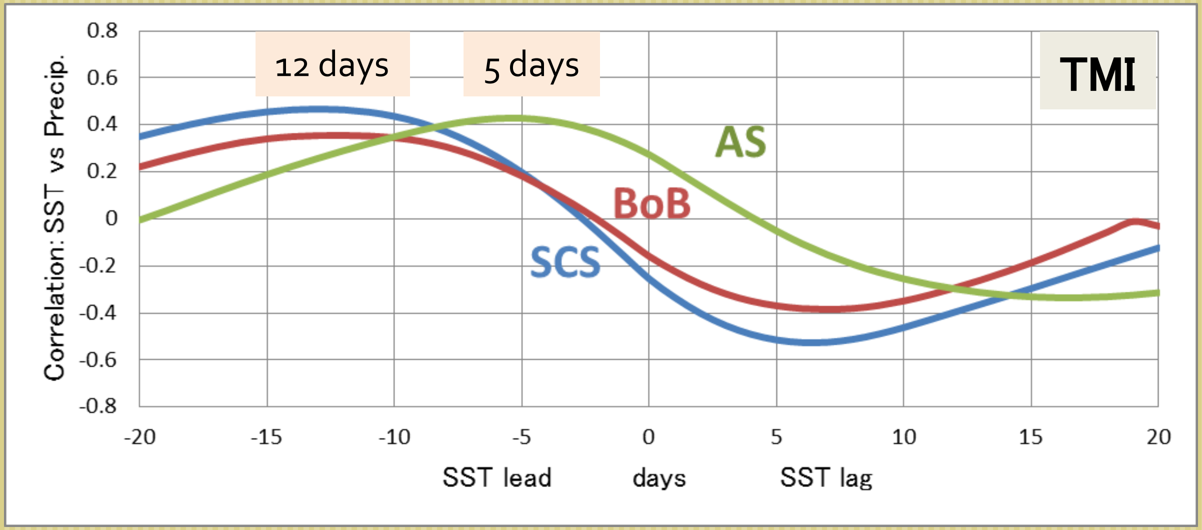
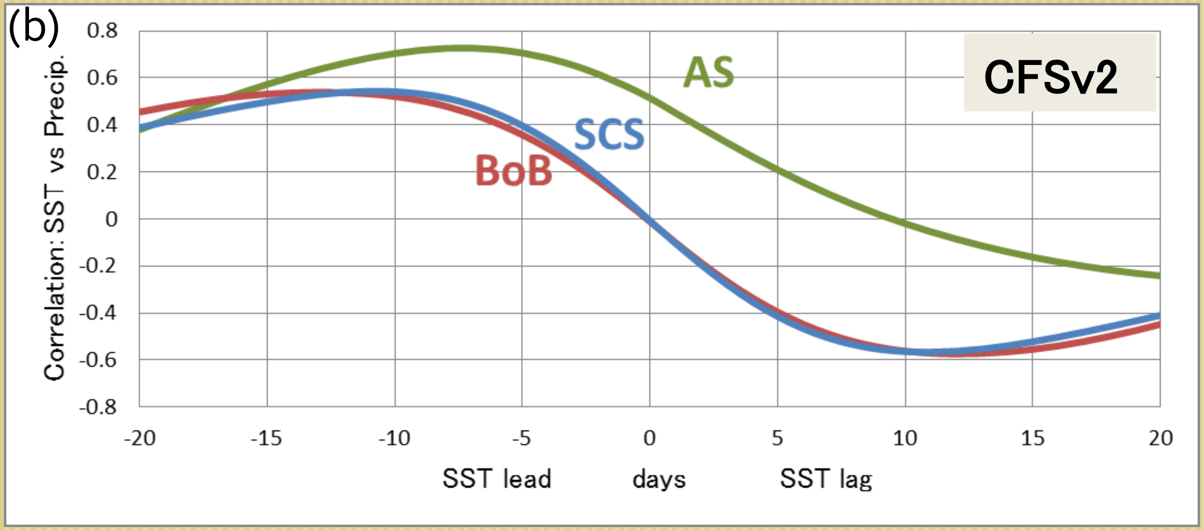
Spatial variability of SST – Precipitation relationship

The SST–precipitation relationship have different lead–lags over the Arabian Sea and the Bay of Bengal/South China Sea





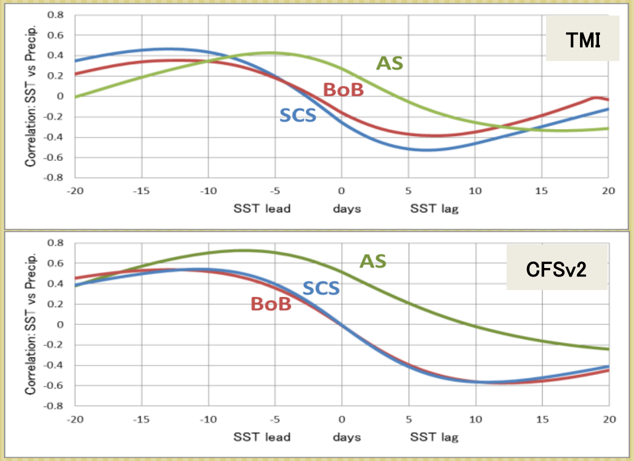
In CFSv2, correlation between SST & precip. is overestimated:

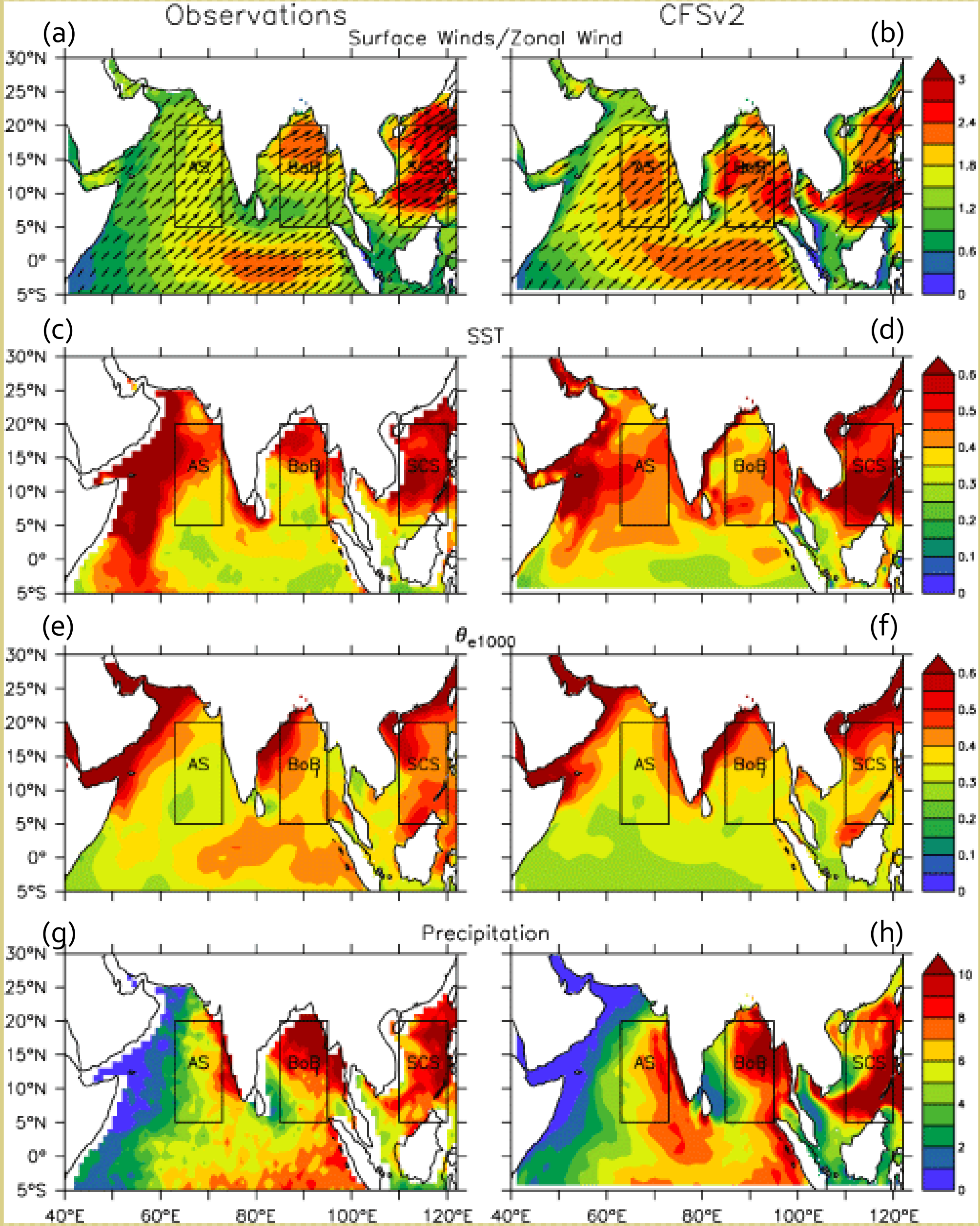
TMI r_{max}= 0.4

CFSv2 r_{max}= 0.7

ISV of anomalies in Observations and CFSv2

ISV overestimated over the n. Indian Ocean, esp. Arabian Sea





Overestimation of ISV in the CFSv2; model bias

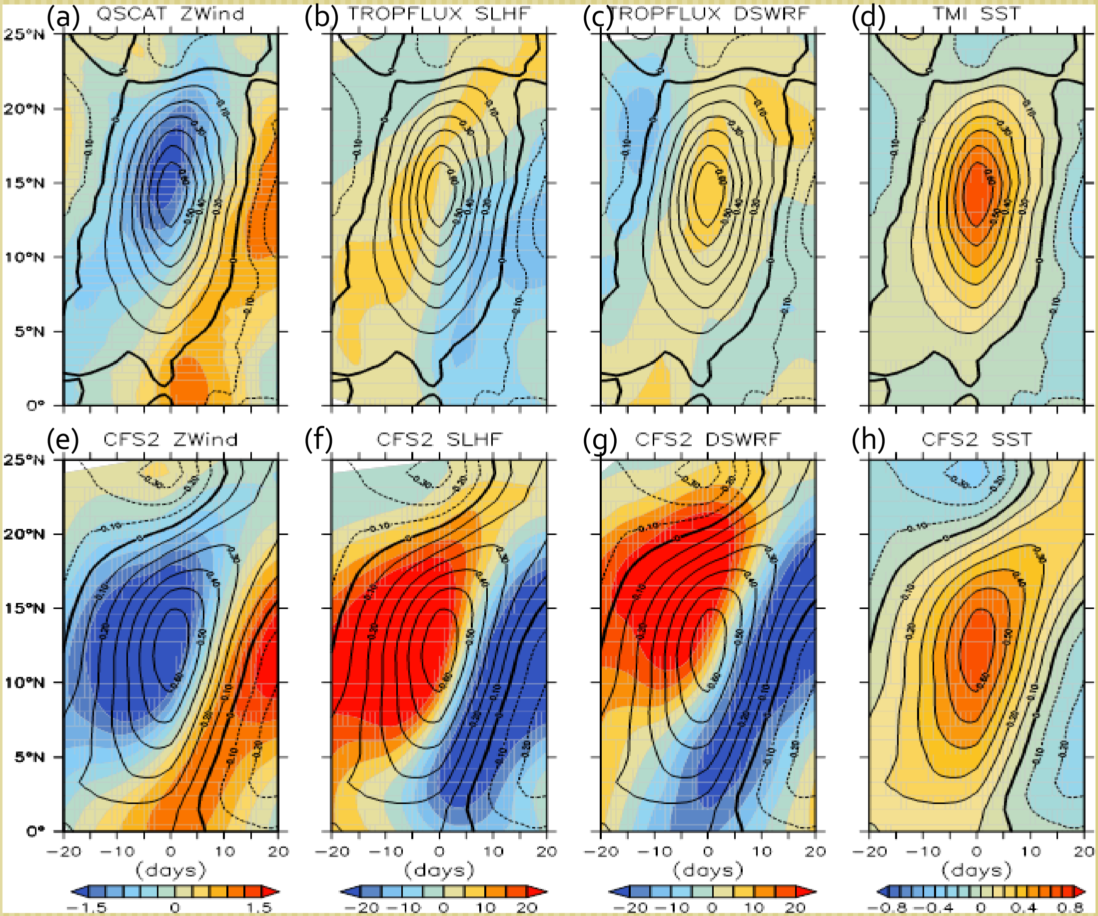
Is it due to coupling mismatch?

Flux Contribution => SST Tendency

The increased SST anomalies in the model are comparable to the simulated net surface flux anomalies, For 30 W m^{-2} (30m mld), dT = 0.025C day^{-1}.

Wind Contribution => LHF

Using the bulk aerodynamic equations, an overestimation of 1 m s^{-1} of wind speed is comparable to an increase of 14 W m^{-2} of latent heat flux anomalies, in the model.



Flux Contribution => SST Tendency

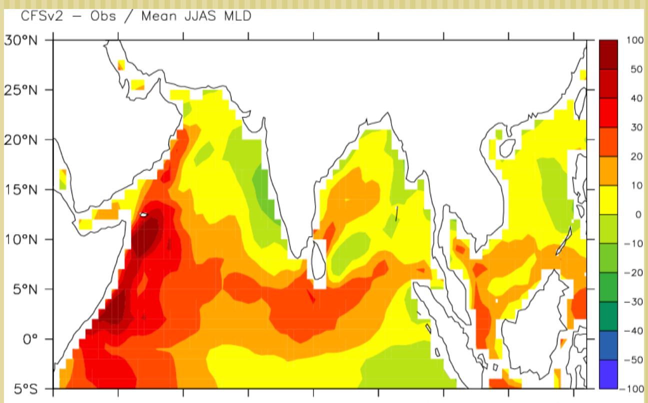
Wind Contribution => LHF

ISV of anomalies in Observations and CFSv2

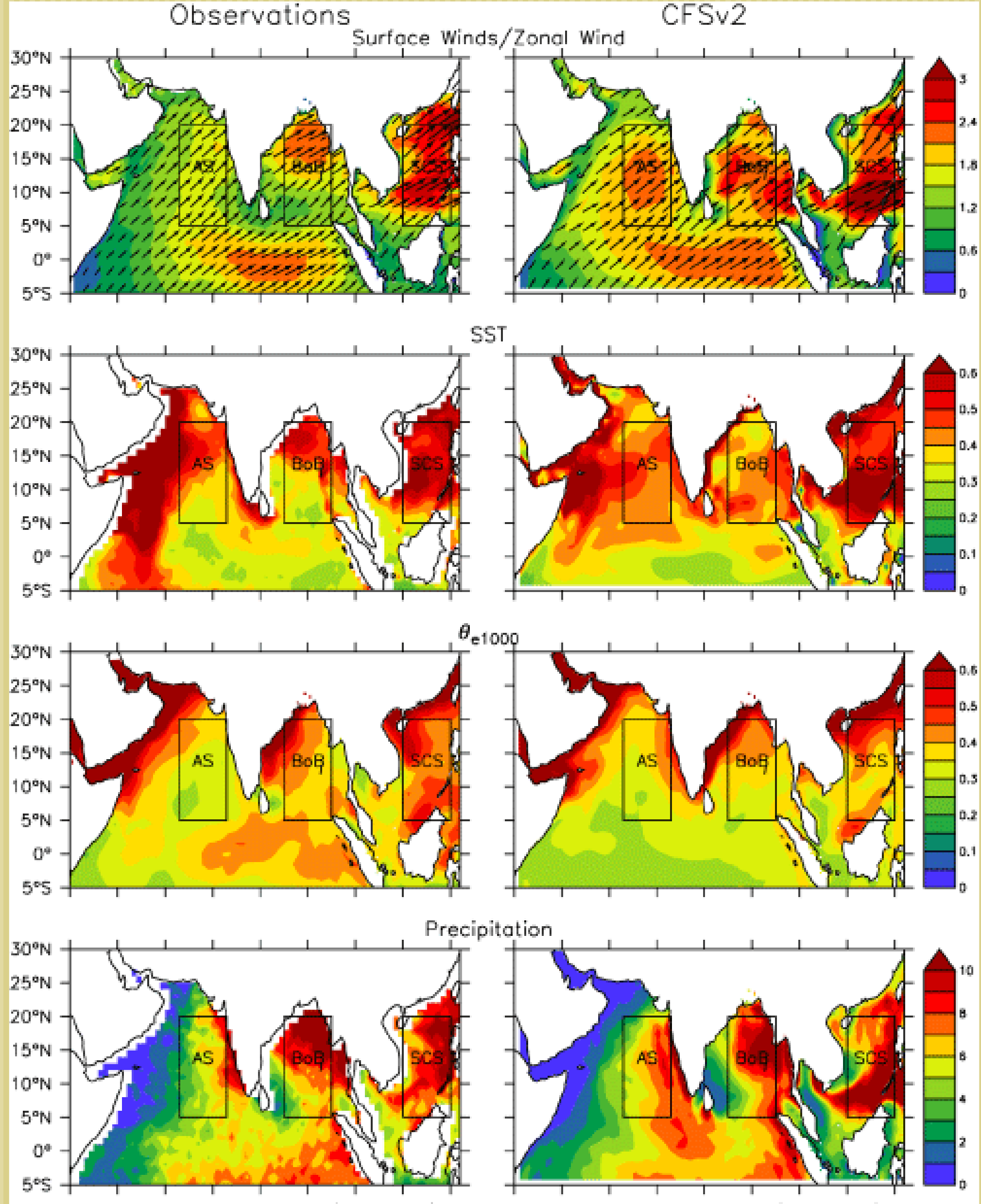
ISV overestimated over the n. Indian Ocean, esp. Arabian Sea

$$\frac{\partial T_s}{\partial t} = \frac{F_{tot}}{\rho c_p * \mathbf{MLD}}$$

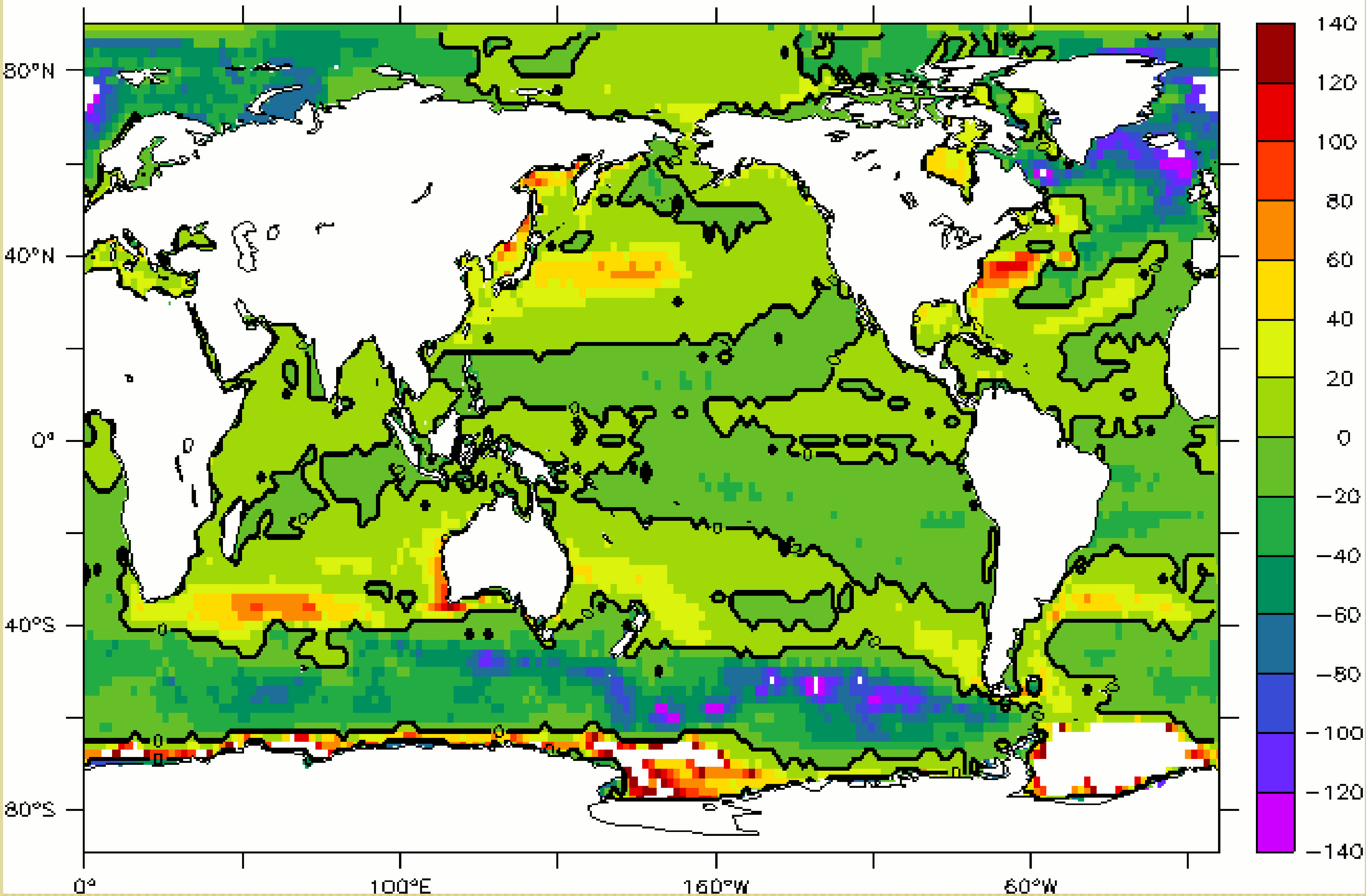
JJAS MLD Diff. [CFSv2 - Boyer]



For the same magnitude of fluxes, change in SST is different:
Shallow MLD –> ISV amplified
Deep MLD –> ISV weakened
r = **0.5**, significant at 95% levels



Difference of annual mean MLD between Model and Obs (m)



CFSv2 activities at CCCR/IITM

1. Fixed (1xCO_2) runs – 100 years
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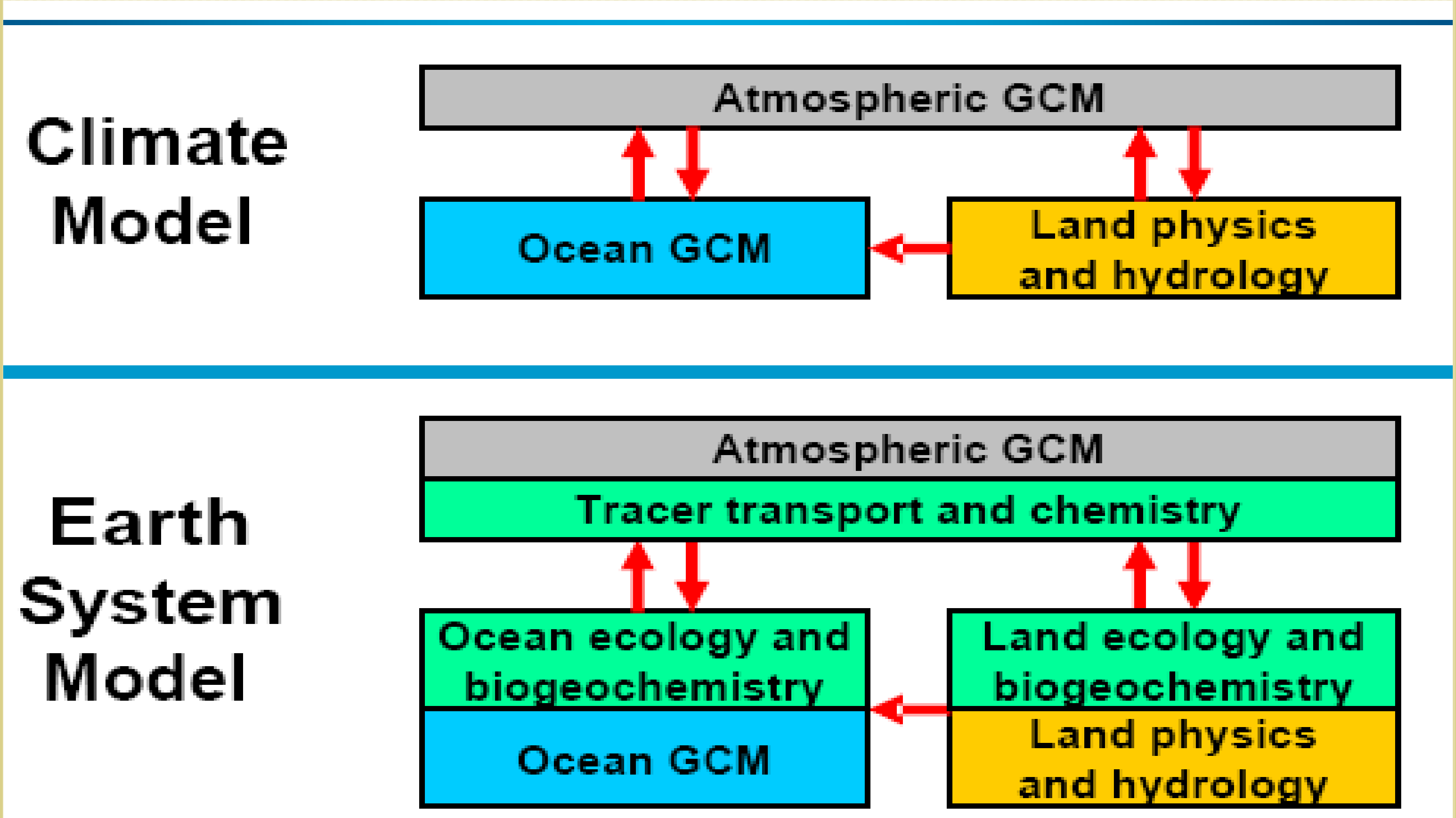
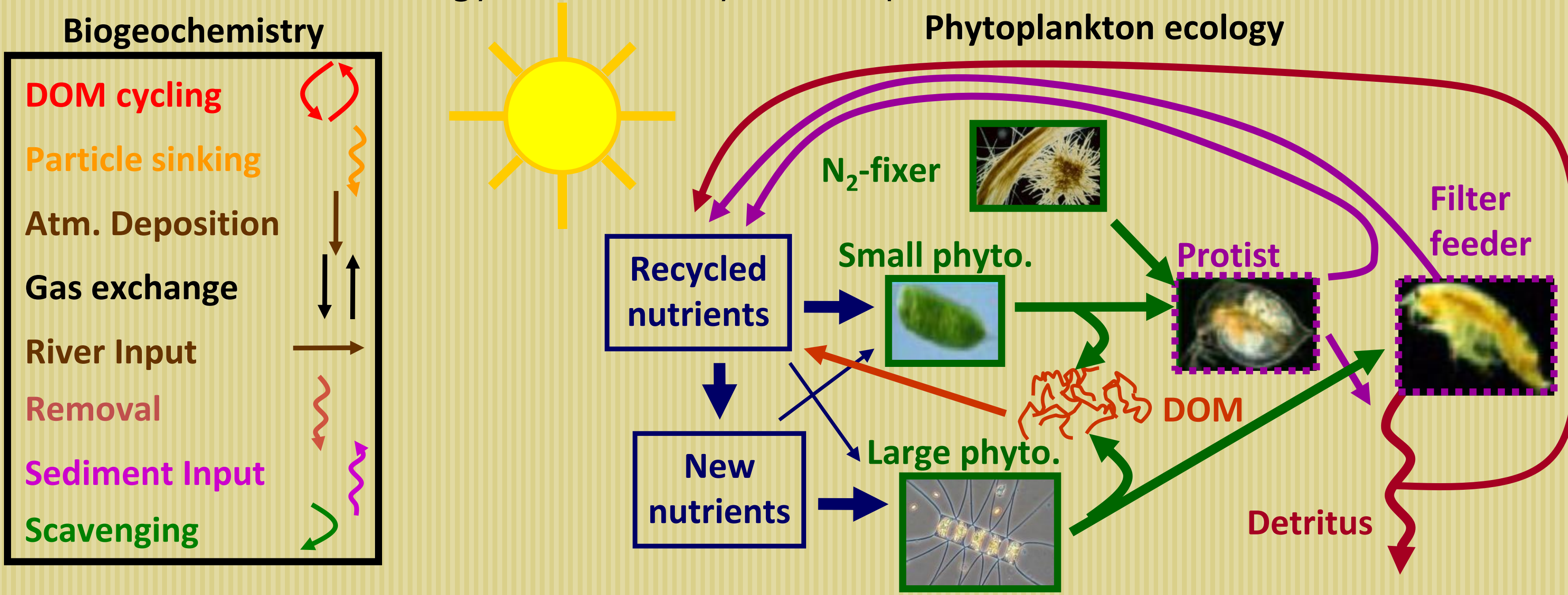
3. Monsoon ISV – Experiments
4. **ESM development – Ocean BGC & Aerosol**

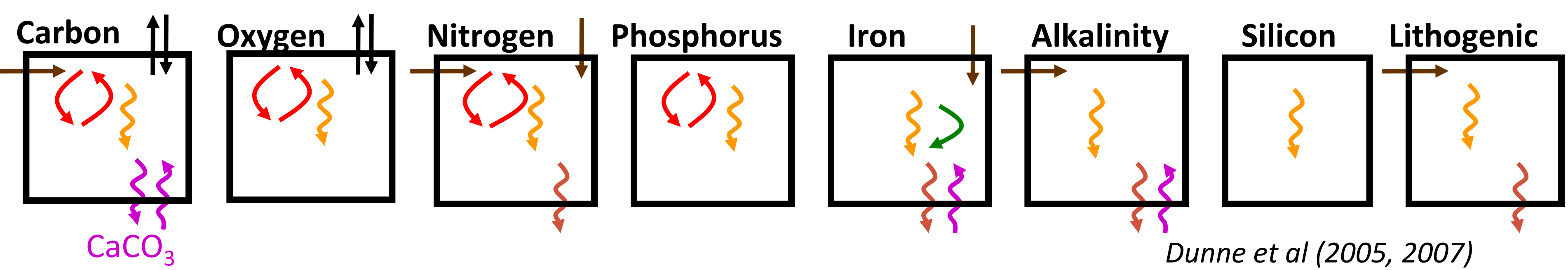

Climate Model
Atmospheric GCM
Ocean GCM
Land physics and hydrology
Earth System Model
Atmospheric GCM
Tracer transport and chemistry
Ocean ecology and biogeochemistry
Ocean GCM
Land ecology and biogeochemistry
Land physics and hydrology

Marine ecosystem and biogeochemistry modeling using TOPAZ

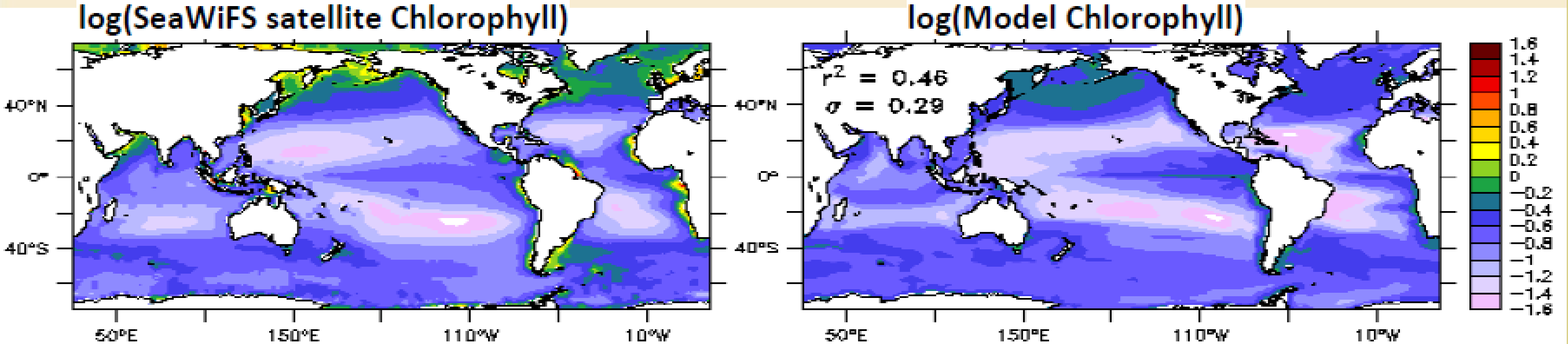
TOPAZ: Tracers of Ocean Phytoplankton with Allometric Zooplankon

- Marine phytoplankton absorb sunlight within the 350 - 700 nm spectral range and thereby modulate heat flux in the upper ocean
- Ecosystem response in the tropical Indian Ocean is linked with the seasonal cycle of monsoon winds and Indian Ocean circulation
- Variations in ocean biology influenced by climate phenomena - El Nino, IOD

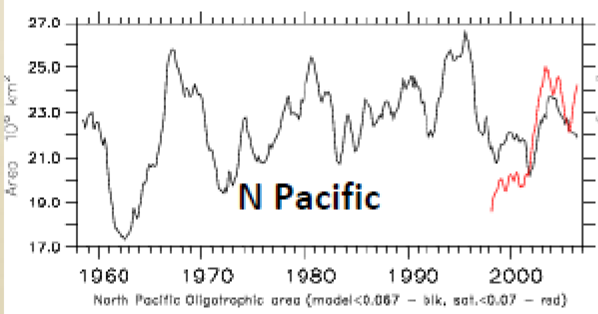


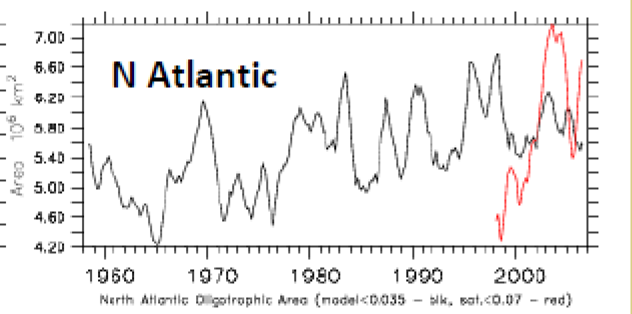


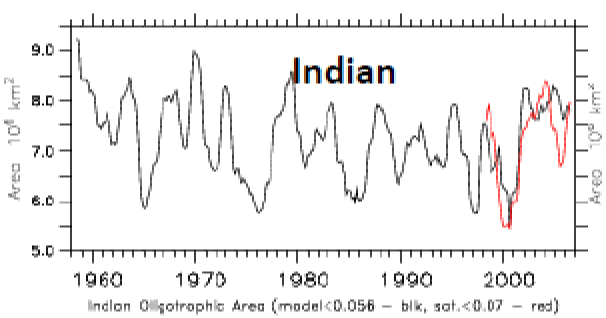
Dunne et al (2005, 2007)

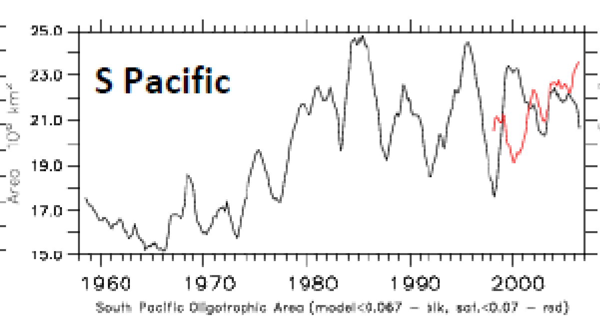


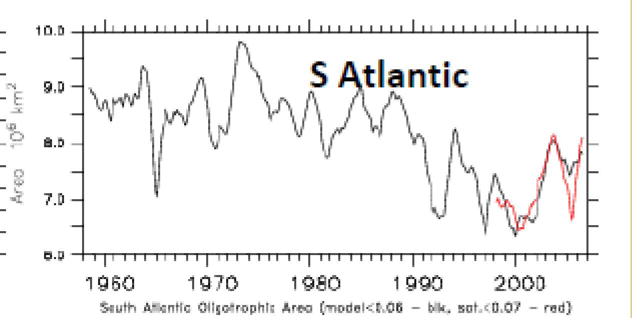
Simulated expansion of oligotrophic gyres (ocean deserts) is similar to SeaWIFS (Polovina et al, 2008) and within a large, multidecadal envelope.

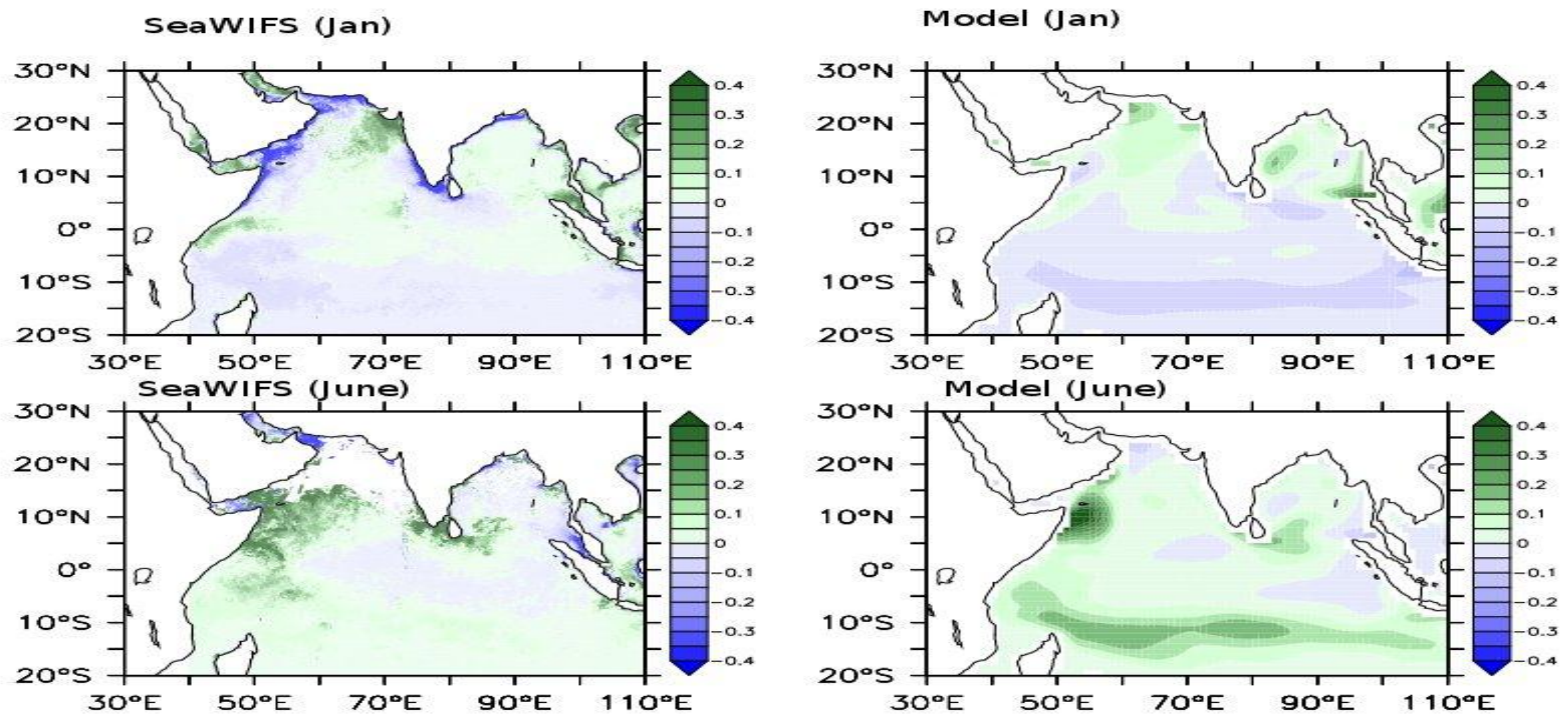












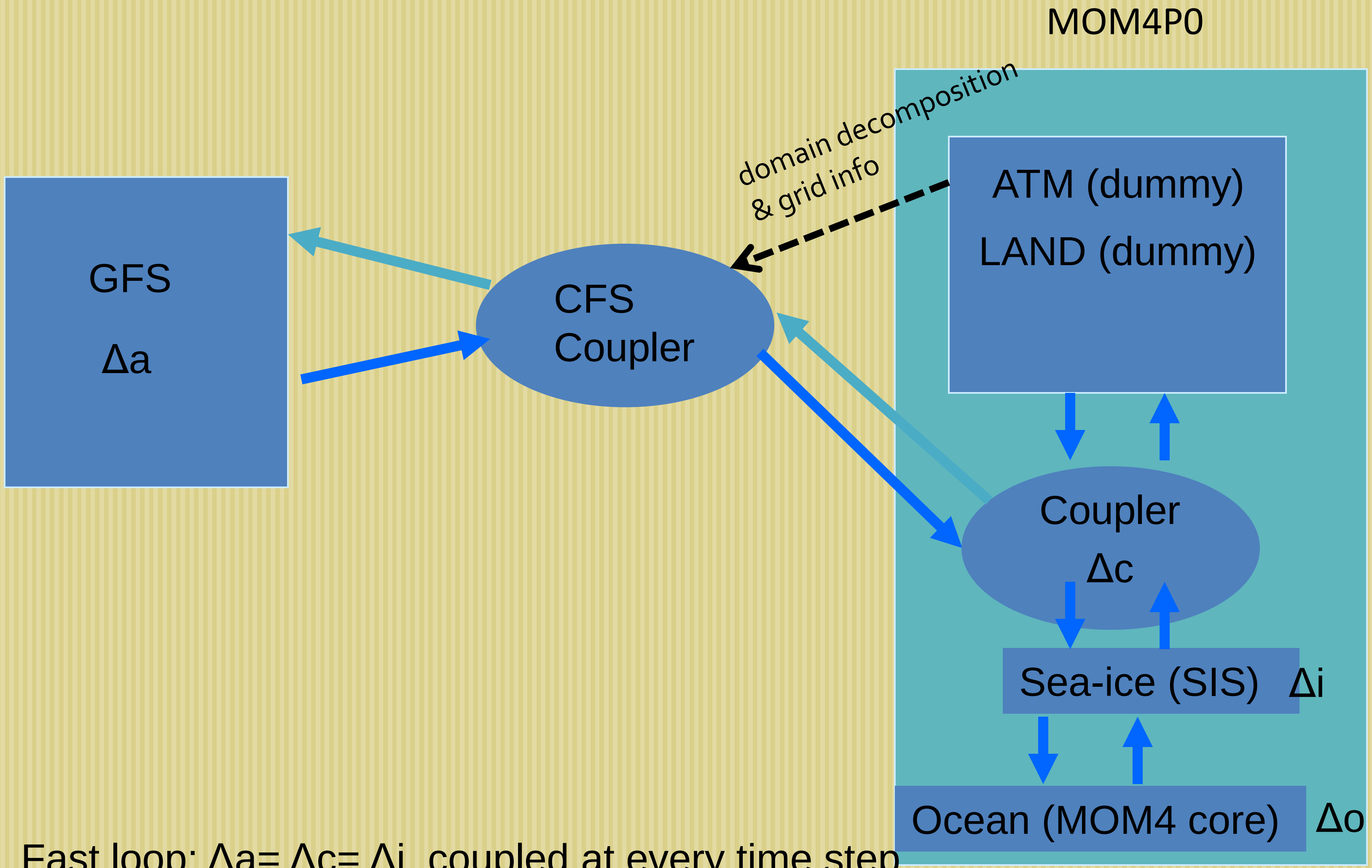
SeaWIFS (Jan)
Model (Jan)
SeaWIFS (June)
Model (June)
30°N
20°N
10°N
0°
10°S
20°S
30°E
50°E
70°E
90°E
110°E
0.4
0.3
0.2
0.1
0
−0.1
−0.2
−0.3
−0.4

Solid line: SeaWIFS climatology
Dashed line: MOM4p1

Changes in MOM4p0 w.r.to MOM4p1

MOM4p0	MOM4p1	Problem addressed
Geopotential coordinate	Z* vertical coordinate	Eliminate vanishing top cell
Sweby tracer advection	Piecewise parabolic	Reduce spurious mixing and maintain stronger gradients
Bryan-Lewis vertical tracer diffusivity	Simmons et al.(2004) tidal mixing	Employ energetic based scheme with more physical basis
Neutral physics matching to mixed layer ala Treguier et al. (1997)	Ferrari et al. (2008) matching of streamfunction to boundary layer	Smooth the interaction between GM and surface boundary layer
Laplacian horizontal viscosity as per NCAR	Biharmonic plus laplacian	Reduce by ~10 the number of free parameters; enhance boundary currents; include TIWs to reduce cold tongue bias; ITF improve
No submesoscale closure	Fox-Kemper et al. (2008) scheme	Include restratification effects from upper ocean submesoscale eddies to reduce overly deep mixed layers
Morel and Antoine (1994) shortwave penetration	Manizza et al. (2005) shortwave penetration	Allow use of fully prognostic chlorophyll

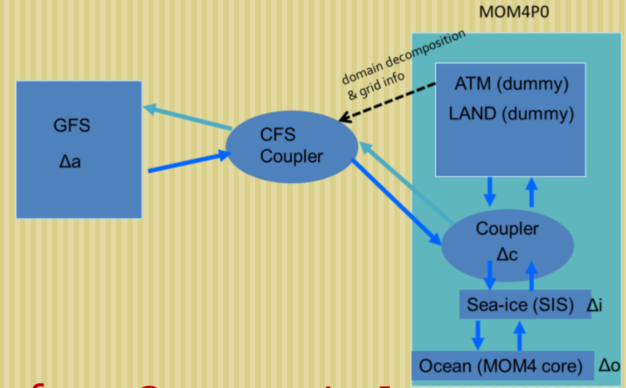
CFSv2 structure



Fast loop: Δa= Δc= Δi, coupled at every time step

Slow loop: Δo

MOM4 coupler in CFSv2

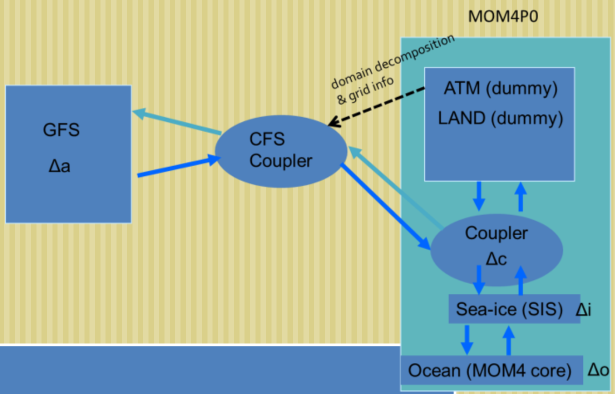


DO slow time steps (ocean)

- **call flux_ocean_to_ice** [transfers fluxes from Ocean to Ice]
- **call ICE_SLOW_UP** [from Ice bottom to Ice top]
- **DO fast time steps (atmos)**
  - **call flux_calculation** [flux correction]
  - **call ATMOS_DOWN** [*Not applicable*]
  - **call flux_down_from_atmos** [put fluxes to Ocean exchange grid]
  - **call LAND_FAST** [*Not applicable*]
  - **call ICE_FAST** [Atmosphere to Ice]
  - **call flux_up_to_atmos** [from Ice boundary to Atm. boundary]
  - **call ATMOS_UP** [*Not applicable*]
- **END DO**
- **call ICE_SLOW_DN** [gets GFS flux, ice top to bottom]
- **call flux_ice_to_ocean** [*Not applicable*]
- **call OCEAN** [MOM4 core]

END DO

CFSv2 coupler



	Data Flow within the CFS coupler
1	Sets the communication flow by assigning ranks and ids to the components
2	Allocate arrays for all the variables to be passed
3	Gets the domain decomposition from MOM4 ATM
4	Set the domain for these variables
5	Receive the grid from MOM4 ATM
6	Receive the variables, change the grids and exchange

	Stages of ESM Development: Coupling of **Ocean Ecosystem & Biogeochemistry with CFSv2**	**Status** *as on Jan 2012
1	Compilation/installation and test runs of CFSv2 and MOM4p1	DONE 07/2010 – 04/2011
2	Understanding and reconciling the coupled systems in CFSv2 and MOM4p1 and preparation of technical documentation.	**DONE** 05/2011 – 11/2011
3	a. Preparing CFSv2 for the ESM b. Preparing MOM4p1 for the ESM ***grid, initial conditions, spin-ups etc.*	**DONE** 05/2011 – 12/2011 * success!
4	Implementing the required modifications and coupling ** *replacing mom4po with mom4p1*	**Initial modifications DONE** 08/2011 – present
5	Test runs with the ESM	–

Stages of ESM Development:

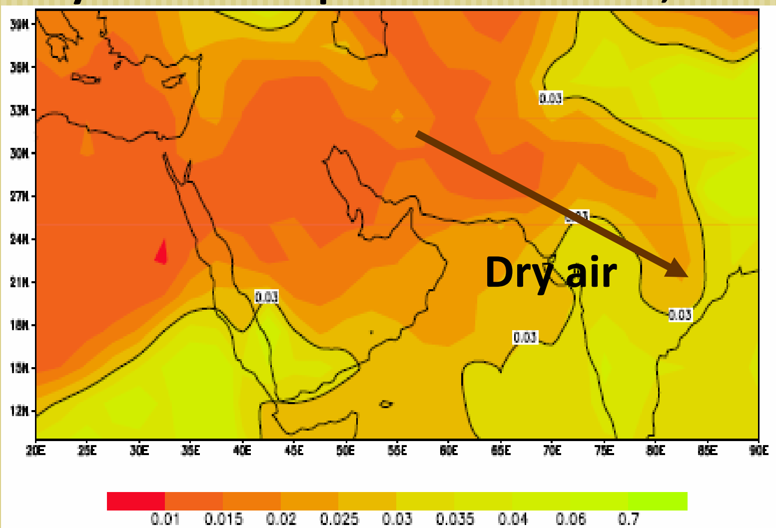
Modifications in MOM4p0 for coupling it with GFS (to be incorporated into MOM4p1)

	Modules	Modifications
1	mom4 ocean - core	**core**: ocean_model.f90, ocean_grids.f90, ocean_velocity.f90, ocean_density.f90, ocean_freesurf.f90, ocean_sbc.f90, ocean_tracer.f90, ocean_neutral_physics.f90, **diagnostics**: ocean_tracer_util.f90, **mixing**: ocean_bih_friction.f90, ocean_lap_friction.f90, ocean_vert_mix.f90
2	mom4 atmos	atmos_model.f90, monin_obukhov.f90, …
3	land module	land_model.f90
4	ice module	ice_model.f90, ice_type.f90, fms_io.f90
5	mom4 coupler	coupler_main.f90, surface_flux.f90, flux_exchange.f90
6	MPI	mpp_com.f90, mpp_domains_define.f90, mpp_util.f90, mpp_comm_mpi.inc, mpp_transmit.inc, mpp_transmit_mpi.h, mpp_util_mpi.inc, …

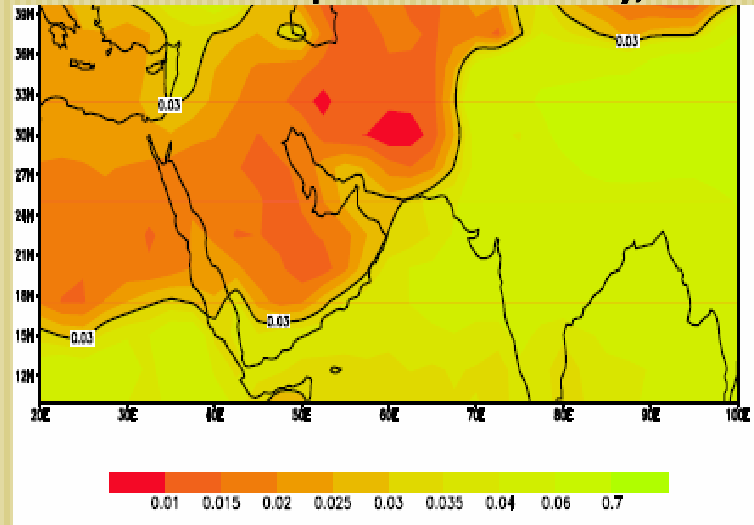
Aerosols and Monsoon: Desert air and aerosol incursions during dry Indian monsoon spells - Krishnamurti et al. 2010

Vertically integrated lower tropospheric (950 – 700 hPa) specific humidity (kg / kg)

Dry monsoon spell: 10 – 19 June, 2009

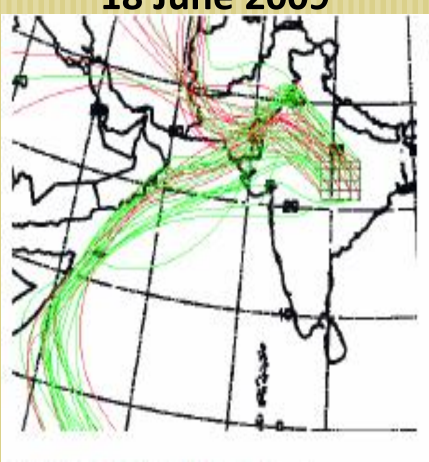


Wet monsoon spell: 14 – 20 July, 2009

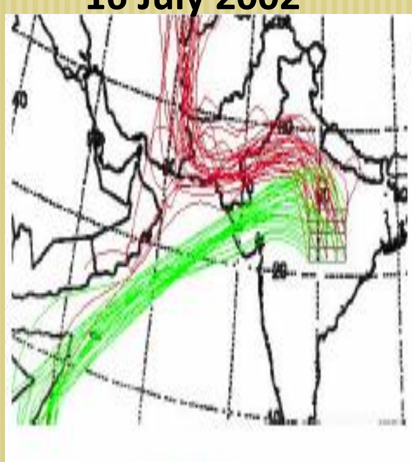


10 day back trajectories from Central India. Left panel is dry spell for trajectories terminating at the 850 (green) and 700 (red), the right panel is the same for the wet spells of the monsoon.

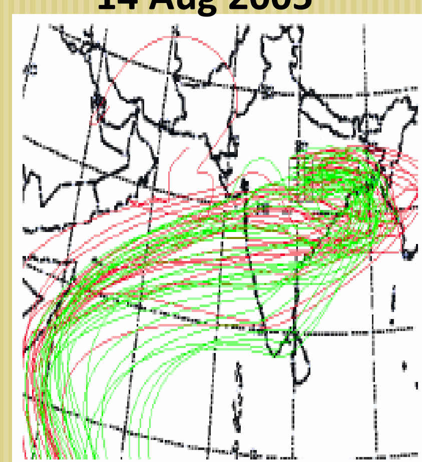
18 June 2009



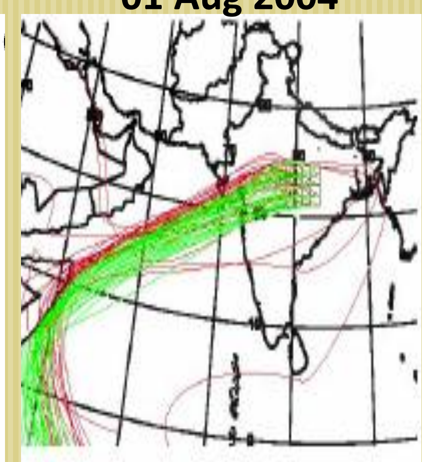
16 July 2002



14 Aug 2005



01 Aug 2004



Modeling the effects of Aerosols on the South Asian Monsoon

<u>HAM (Hamburg Aerosol Module)</u>

Predicts evolution of an ensemble of 7 interacting internally and externally-mixed aerosol modes.

Compounds considered are Sulfate, Black Carbon, Organic Carbon, Sea Salt, Mineral Dust

Main Components

•Microphysical core (coagulation of aerosols, condensation of gas-phase SO2 on aerosol surface)

•Aerosol radiative properties & sink processes

•Aerosol wet deposition

•Emissions of mineral-dust (based on 10 m winds)

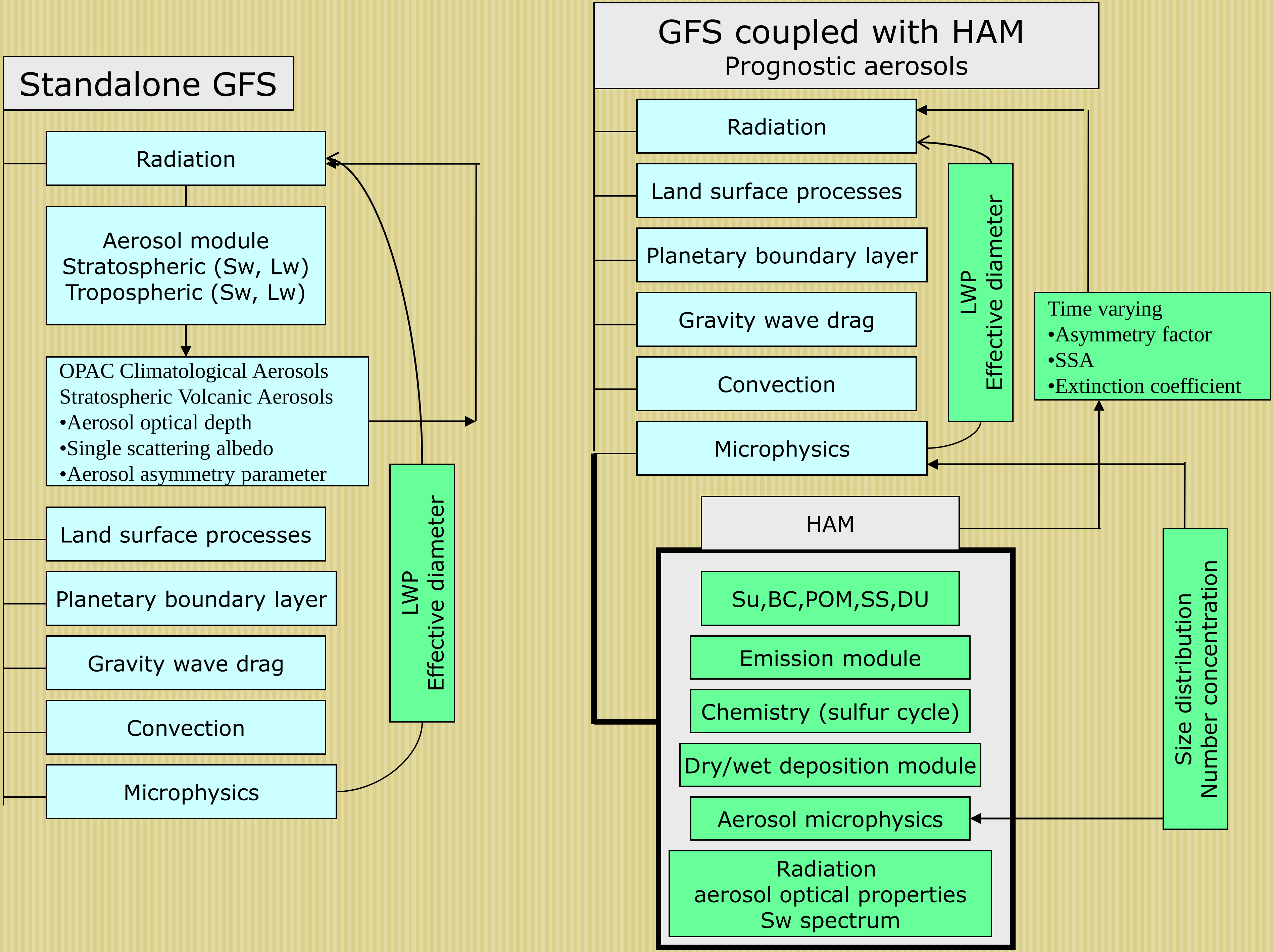
•Sea salt emissions (based on 10 m winds)

•Sulfur cycle (Inputs monthly oxidant fields)

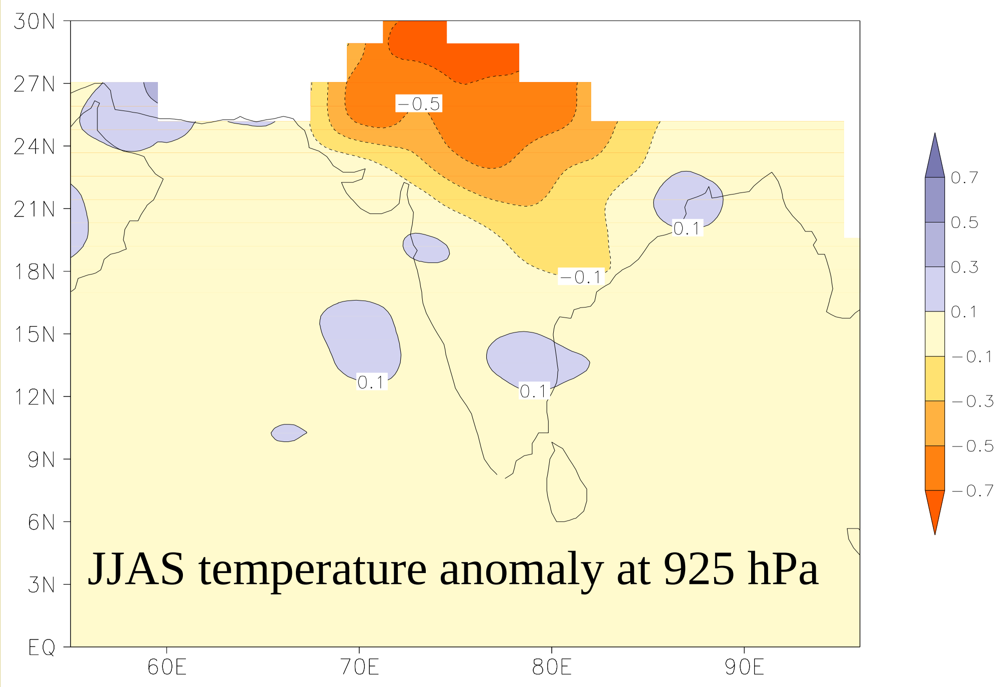
•Emissions of DMS (Inputs DMS sea-water concentrations; calculations using 10m winds, SST)

•Terrestrial biogenic DMS emissions are prescribed

•AeroCom inventory for all other compounds

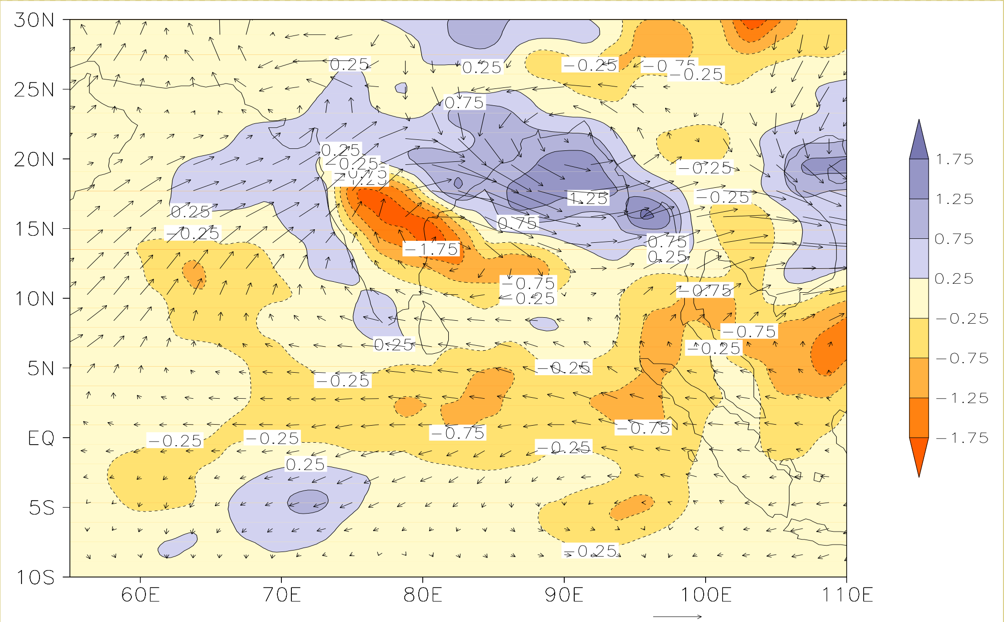

Standalone GFS
Radiation
Aerosol module
Stratospheric (Sw, Lw)
Tropospheric (Sw, Lw)
OPAC Climatological Aerosols
Stratospheric Volcanic Aerosols
•Aerosol optical depth
•Single scattering albedo
•Aerosol asymmetry parameter
Land surface processes
Planetary boundary layer
Gravity wave drag
Convection
Microphysics
LWP
Effective diameter
GFS coupled with HAM
Prognostic aerosols
Radiation
Land surface processes
Planetary boundary layer
Gravity wave drag
Convection
Microphysics
LWP
Effective diameter
Time varying
•Asymmetry factor
•SSA
•Extinction coefficient
HAM
Su,BC,POM,SS,DU
Emission module
Chemistry (sulfur cycle)
Dry/wet deposition module
Aerosol microphysics
Radiation
aerosol optical properties
Sw spectrum
Size distribution
Number concentration

Aerosol minus Control



JJAS temperature anomaly at 925 hPa

Very slight increase in precipitation over monsoon trough region



Rainfall & low level winds (JJAS)