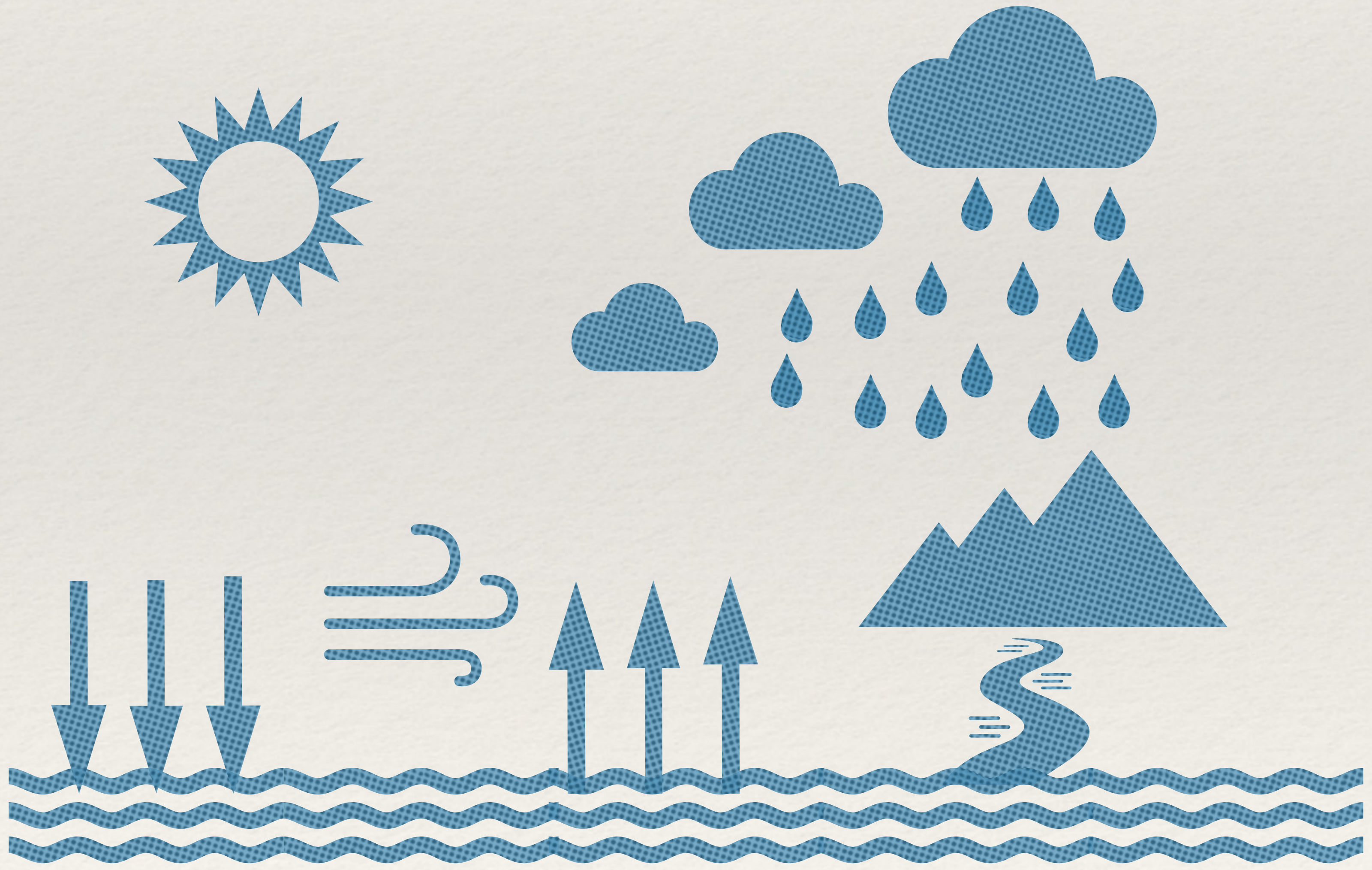
Fifth Workshop on Water Resources in Developing Countries: Hydroclimate Modeling and Analysis Tools

ICTP

27 May - 07 June 2019

The Regional Earth System Model RegCM-ES

Di Sante Fabio,
Coppola Erika,
Farneti Riccardo,
Giorgi Filippo



OGS

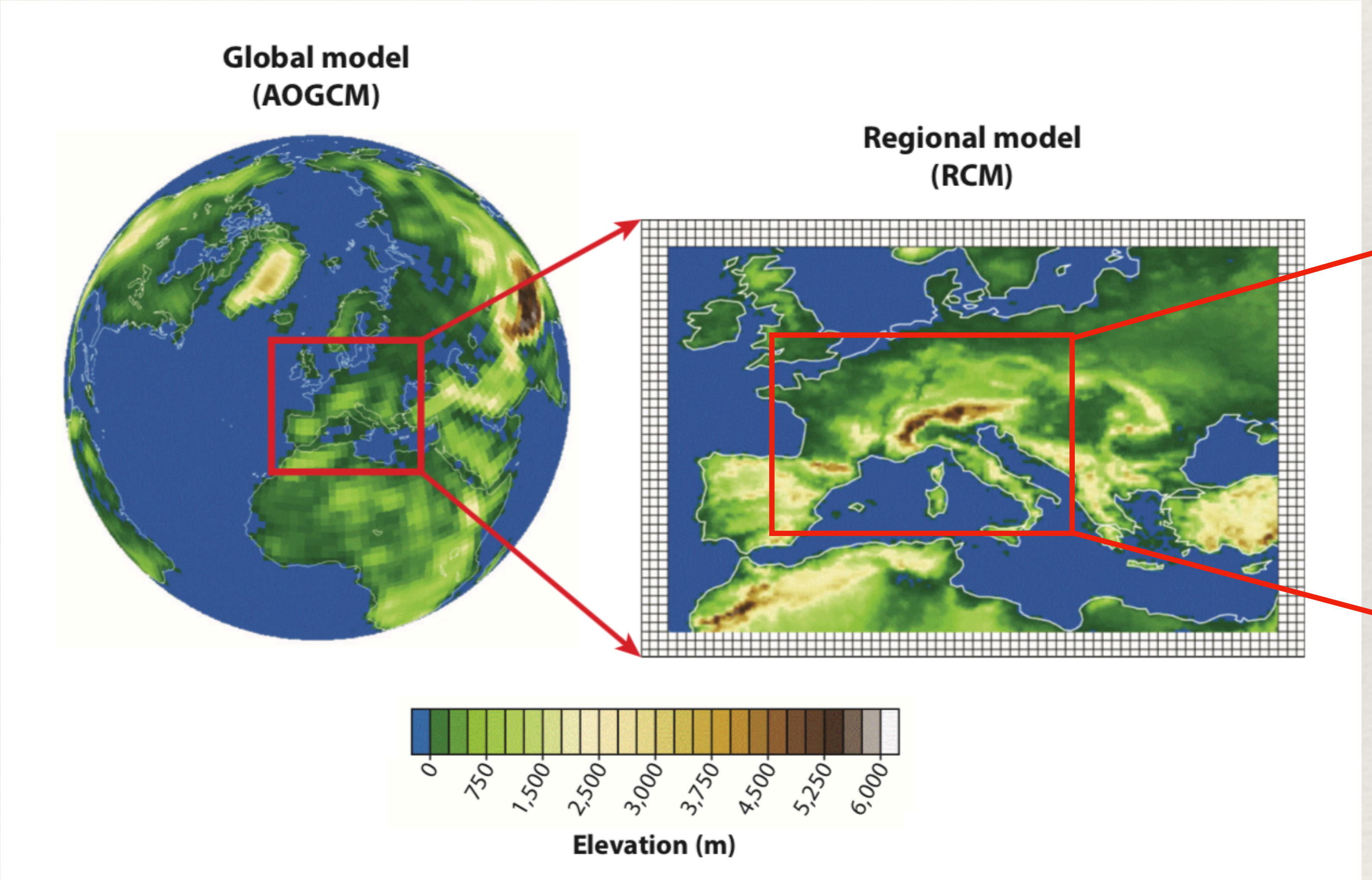
ICTP

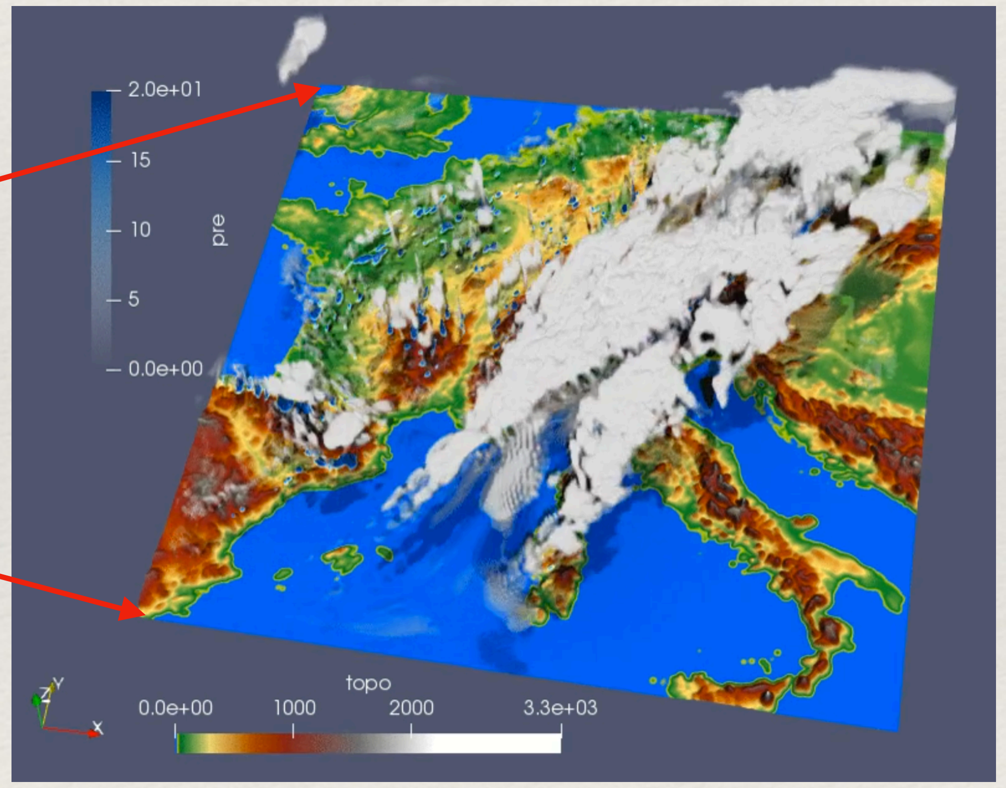
* Fabio Di Sante is supported by OGS and CINECA under HPC-TRES project

RCMs

Convection permitting

Dynamical downscaling of GCM usually using a nested RCM (<50km) and a nested convection permitting RCM (<5km)



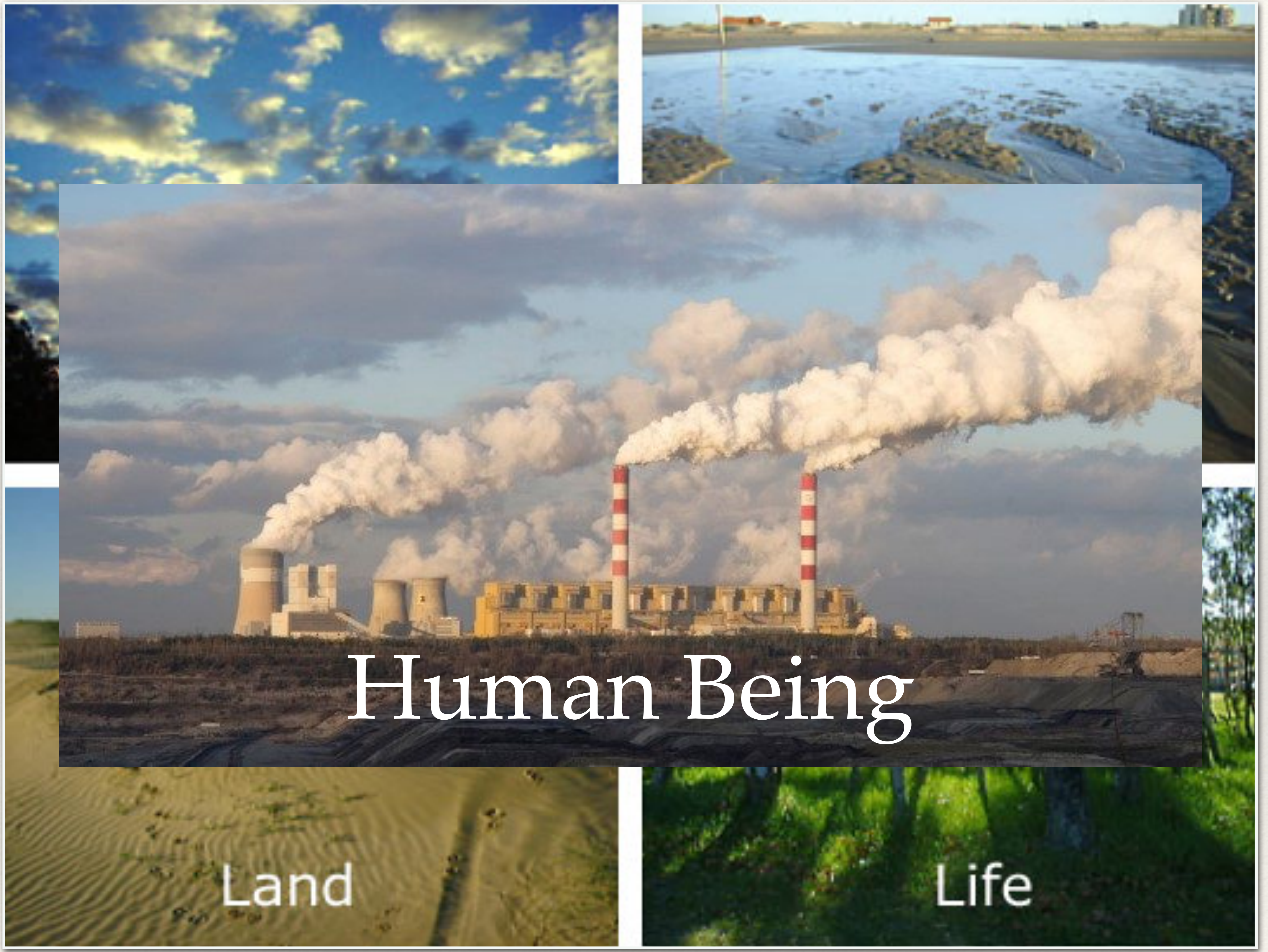


Modify from Figure 1 of Giorgi, F., and W. J. Gutowski. 2015. "Regional Dynamical Downscaling and the CORDEX Initiative." *Annual Review of Environment and Resources* 40: 467–490.

RESM

https://www.eduweb.com/portfolio/earthsystems/parent_printable.html

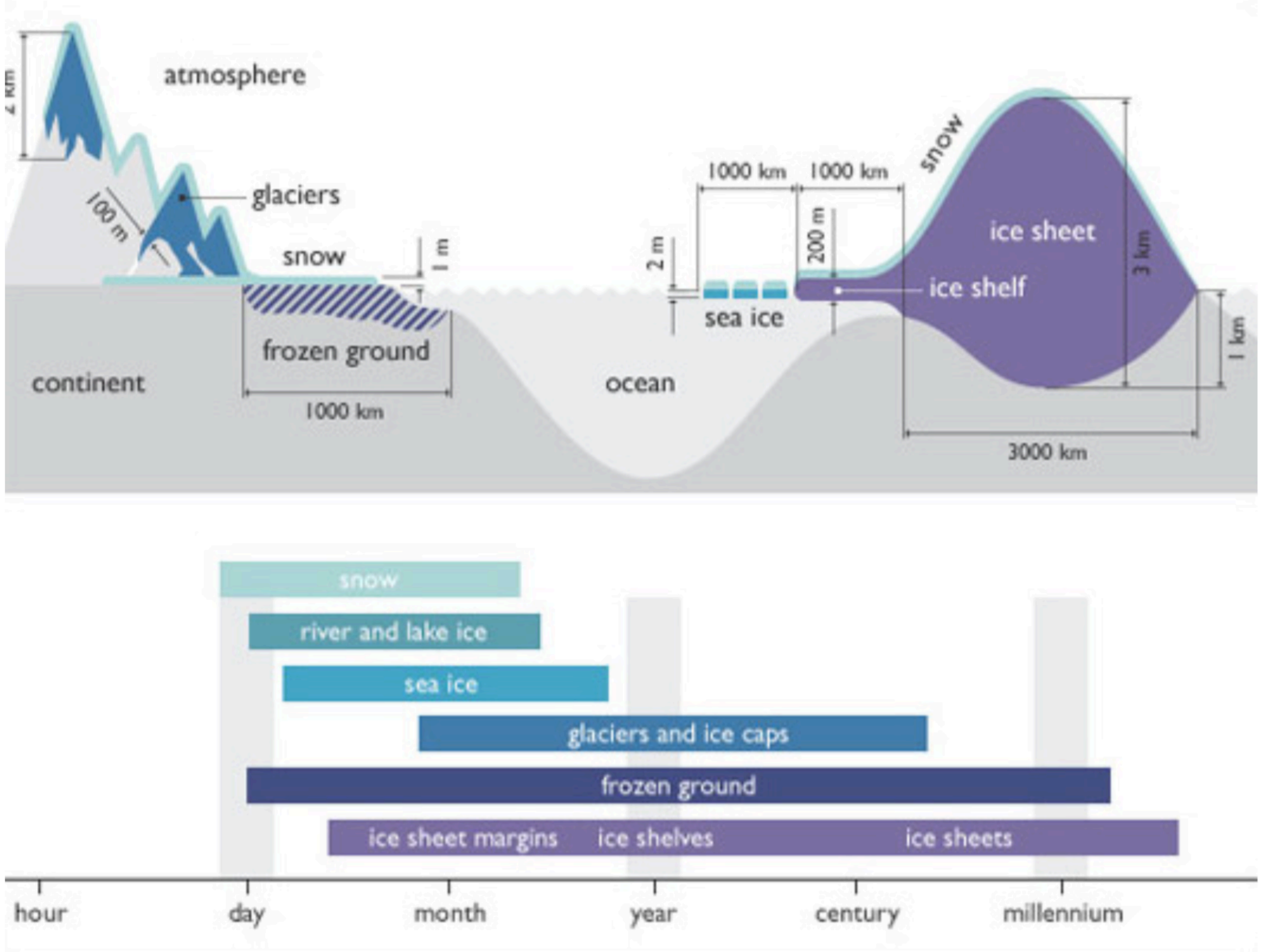
Earth System:
Interactions of different components through positive and negative feedbacks



USRA, Earth System Science Education strategy, 2008

Different spatial and temporal scales

Earth System: Response time



IPCC Report

Different spatial and temporal scales

What does it means couple model?

- Offline coupling -> The models run sequentially and the interactions among them are in one direction only
- Online coupling -> The interactions between the model are in both directions

E.g.
Nesting between a global and a regional model

RegCM

E.g.
Fully coupled Regional Earth System model

RegCM-ES

Earth System Model: Driver approach

Multiple model components

Only one executable

Interpolation among different grid if needed

Control the simulation time of the various components

Receive information from components and send back to the others

Sequential and concurrent support

CPL Design

Components can have different scale of complexity

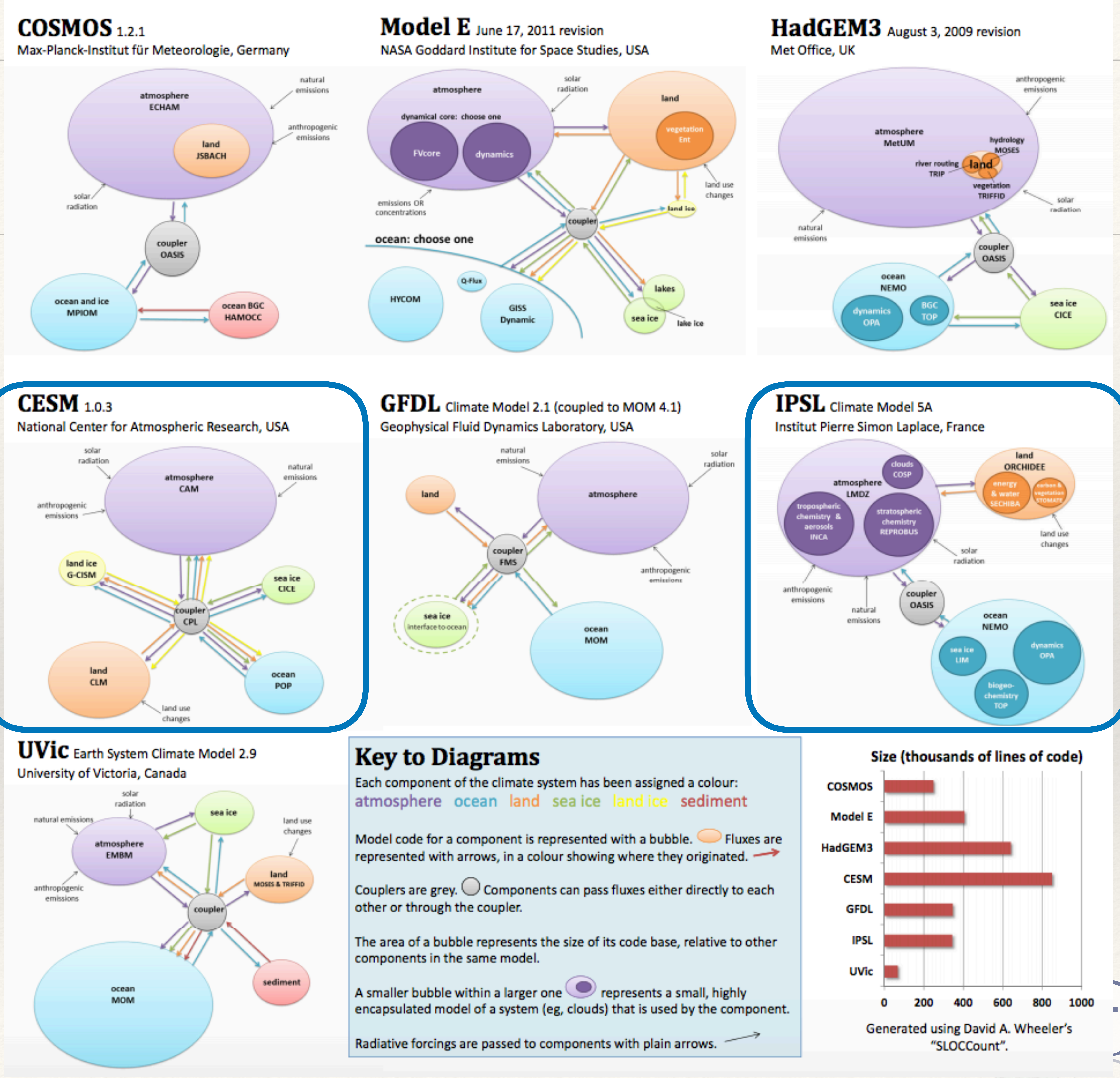
↓

Ocean or Atmospheric centric

The coupler may or not have a centric role

↓

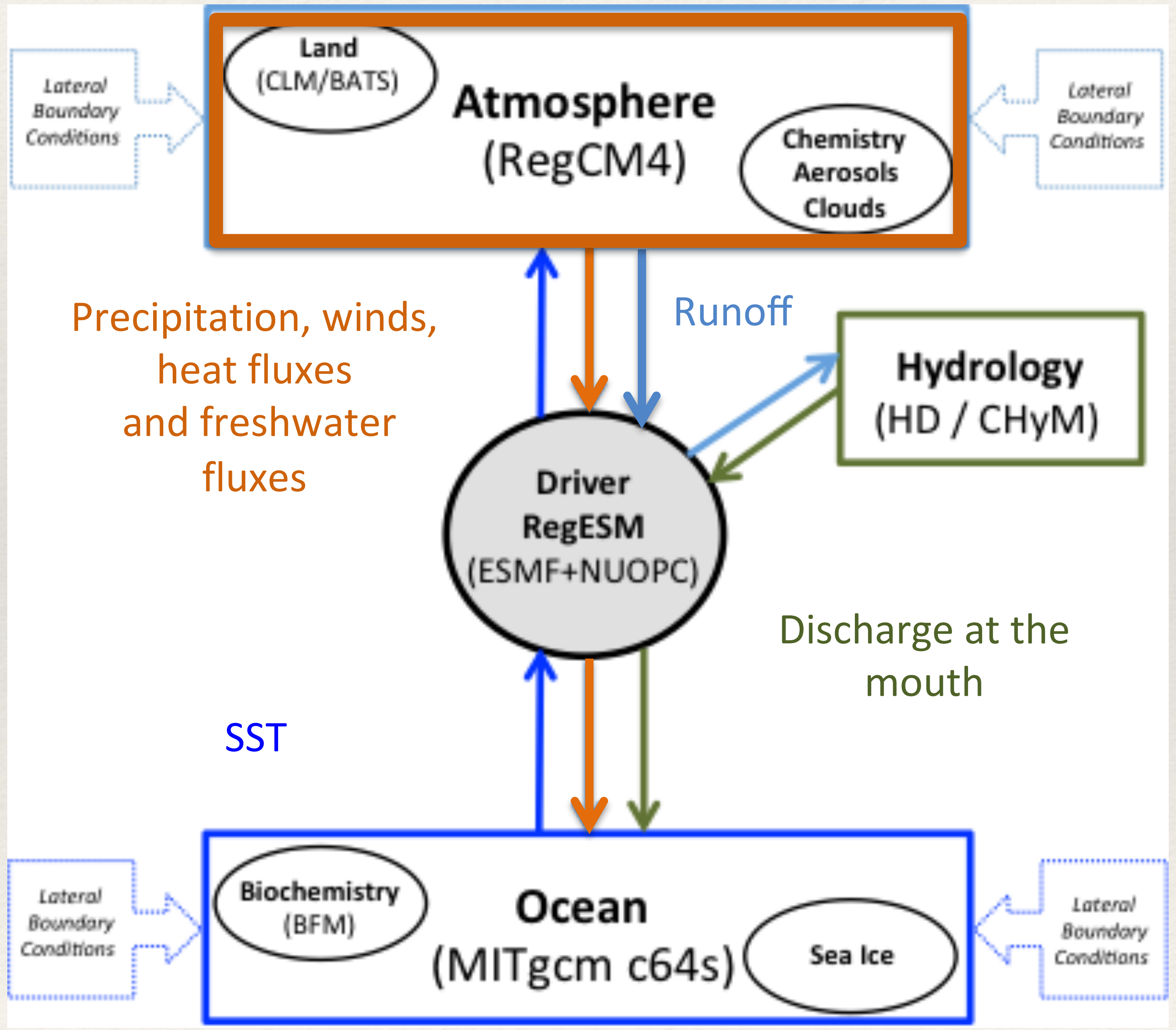
CESM vs IPSL



https://climatesight.files.wordpress.com/2011/08/poster.pdf

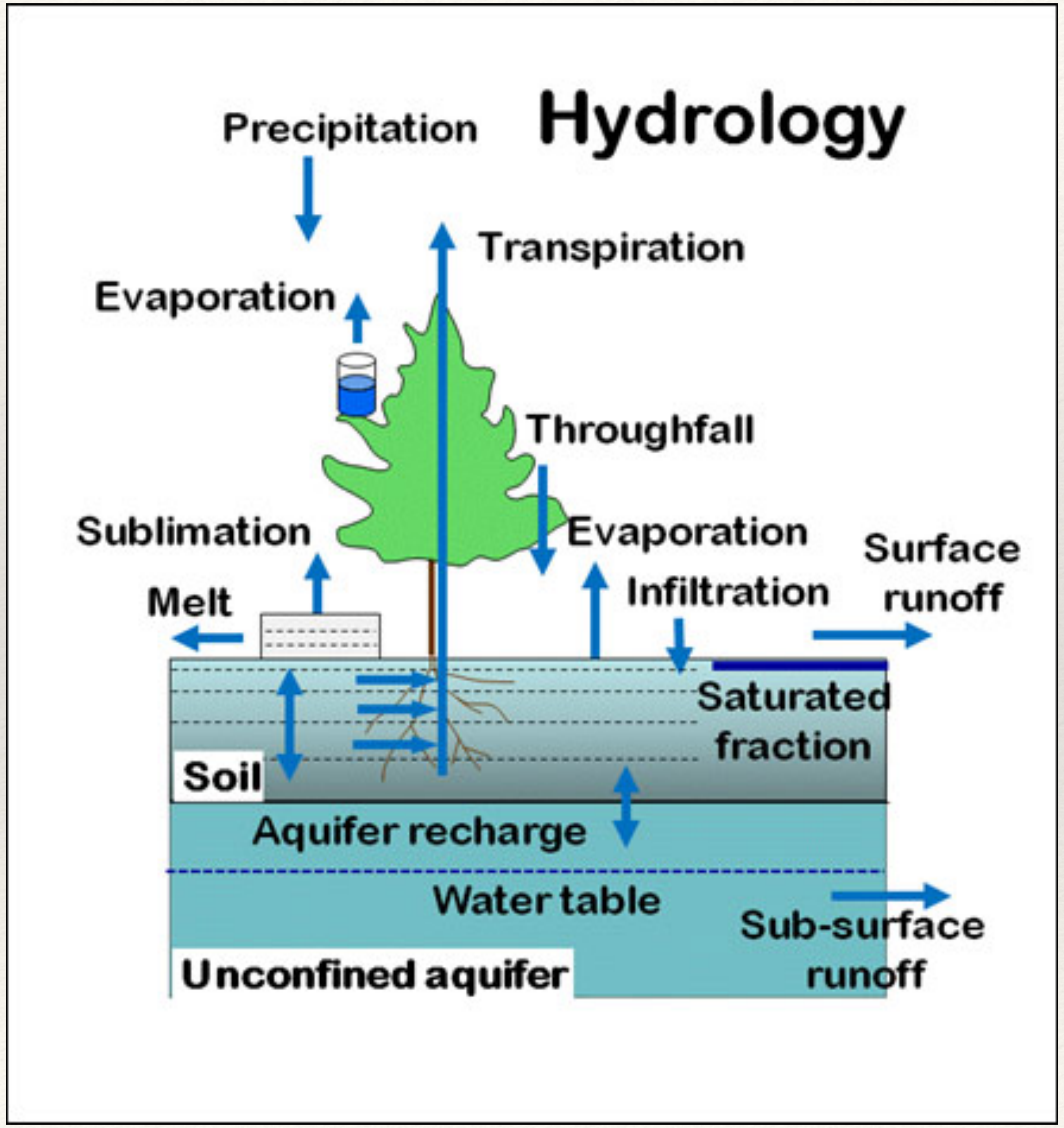
Description of RegCM-ES

- State-of-the-art Regional earth system model (Atmosphere, Ocean, Land and River components)
- Open source community model (source code distributed by the developers of the components and drivers)



Sitz, L. E., Di Sante, F., Farneti, R., Fuentes-Franco, R., Coppola, E., Mariotti, L., Reale, M., Sannino, G., Barreiro, M., Nogherotto, R., Giuliani, G., Graffino, G., Solidoro, C., Cossarini, C., and Giorgi, F. (2017). Description and evaluation of the eart system regional climate model (regcm-es). J. Adv. Model. Earth Syst.

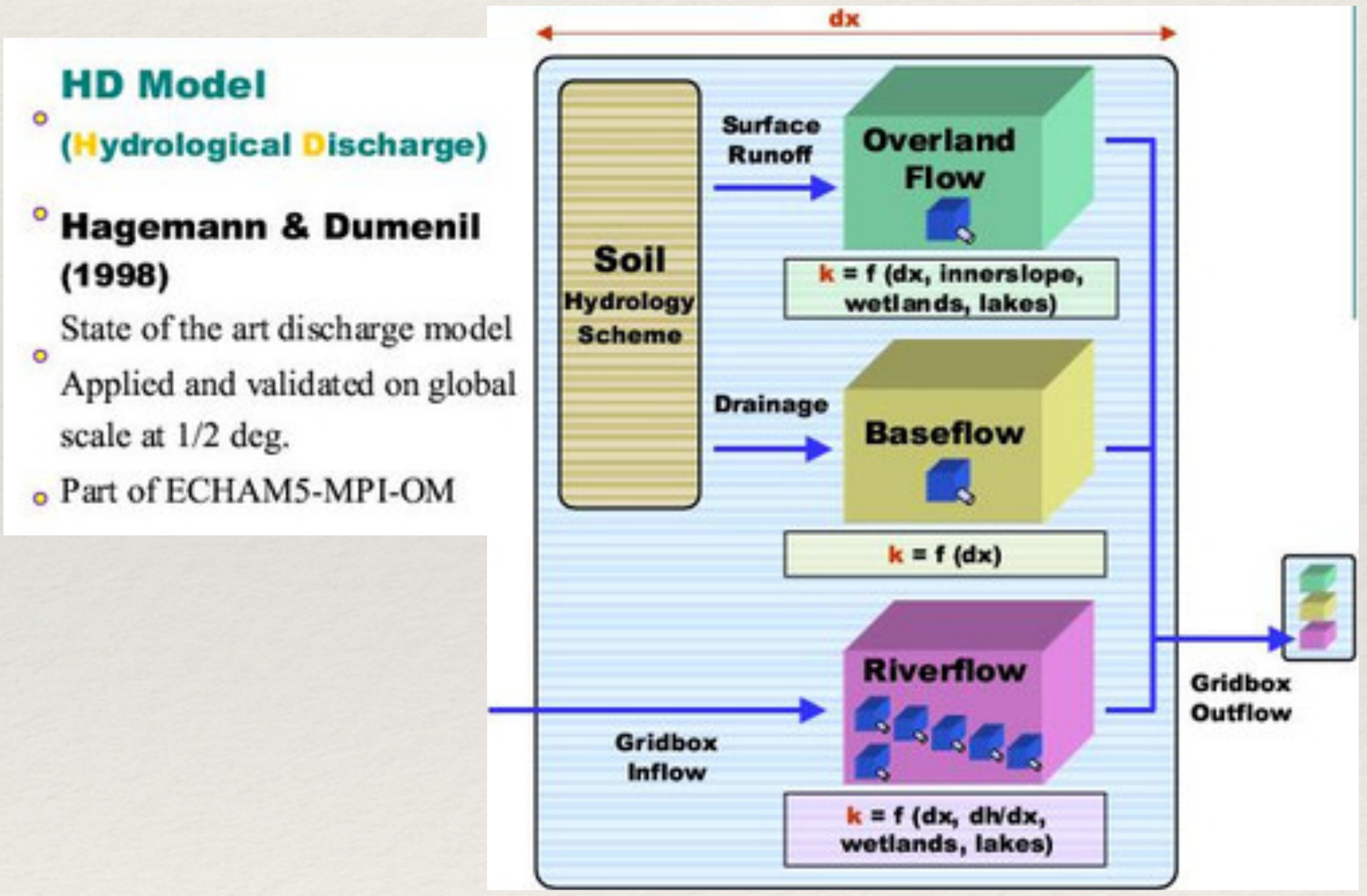
RegCM-ES: The land and hydrological models



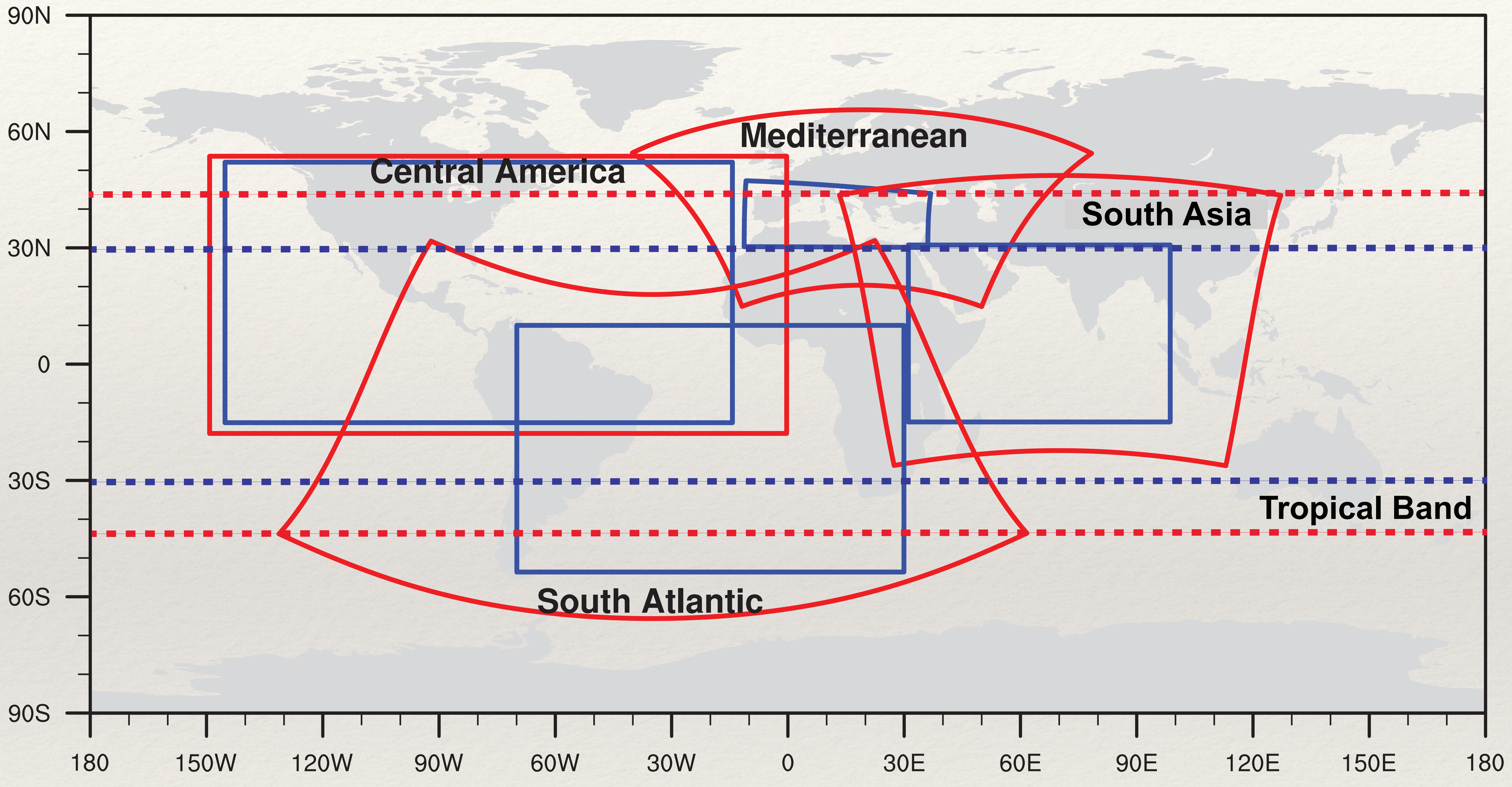
CLM4.5

HD

CHyM



Simulated domains

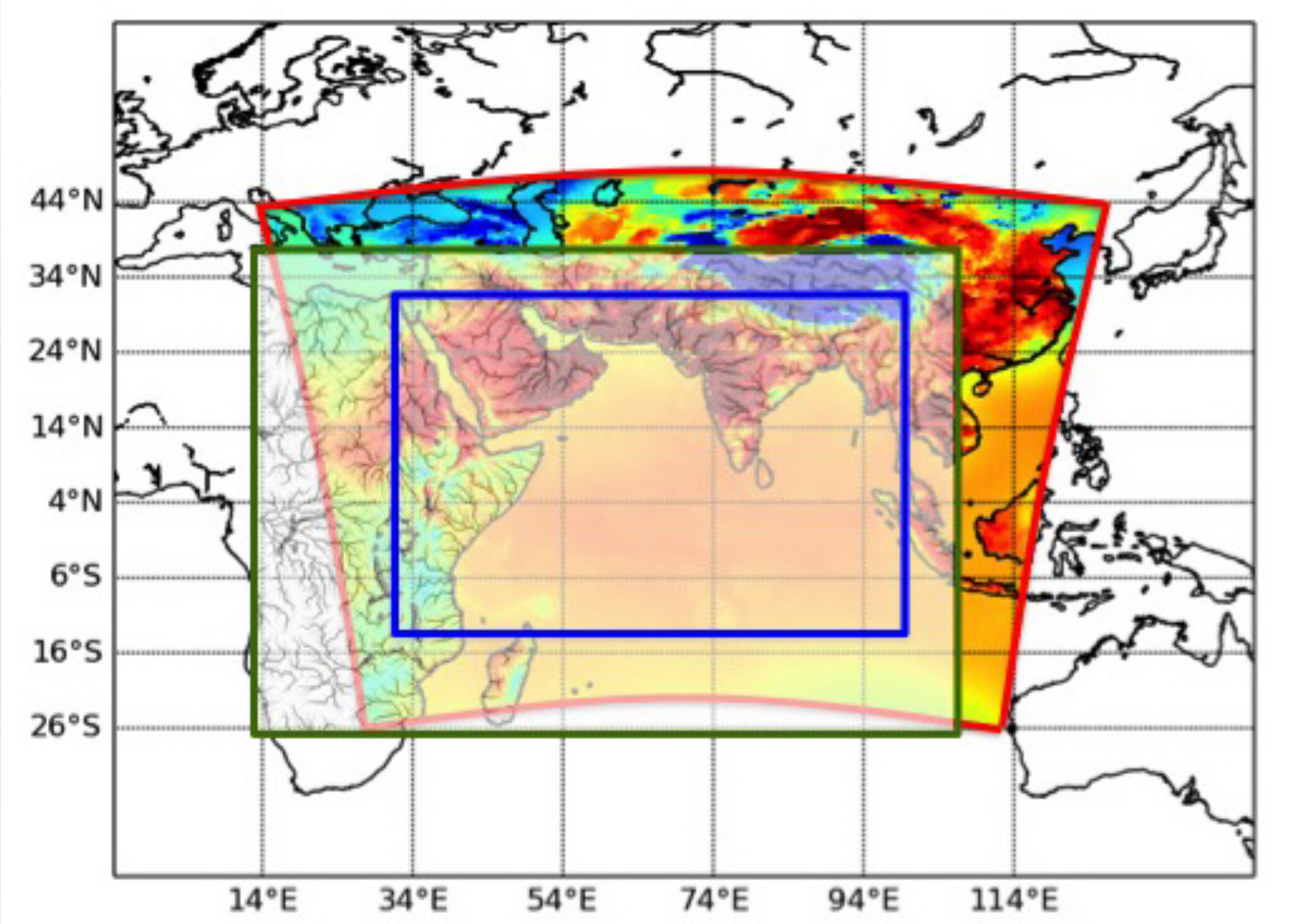


First tests and simulations

Description			Atmosphere				Ocean			River
Domain	# Exp.	# Sim. Years	Spatial Resolution	Vertical Levels	Convective Scheme	ICBC	Spatial Resolution	Vertical Levels	ICBC	Model
Central America	1	1988-1997	50 Km	23	Tiedtke(lnd) Emanuel(ocn)	Era-Int	1/8°	40	MOM	HD
Mediterranean	1	1979-2015	20 Km	23	Tiedtke	Era-Int	1/12°	75	Medar/ Medatlas	HD
South Asia	1) 2) 3)	1979-2008 1979-2015 1979-2015	50 Km	18	Emanuel(lnd/ocn) Tiedtke(lnd/ocn) Tiedtke(lnd/ocn)	Era-Int	1/6°	45	MOM ORAP ORAP	HD HD CHyM
South Atlantic	1	1988-1997	50 Km	23	Tiedtke	Era-Int	1/8°	40	MOM	HD
Tropical Band	1	1979-2008	100 Km	23	Tiedtke	Era-Int	1/4°	40	SODA	HD

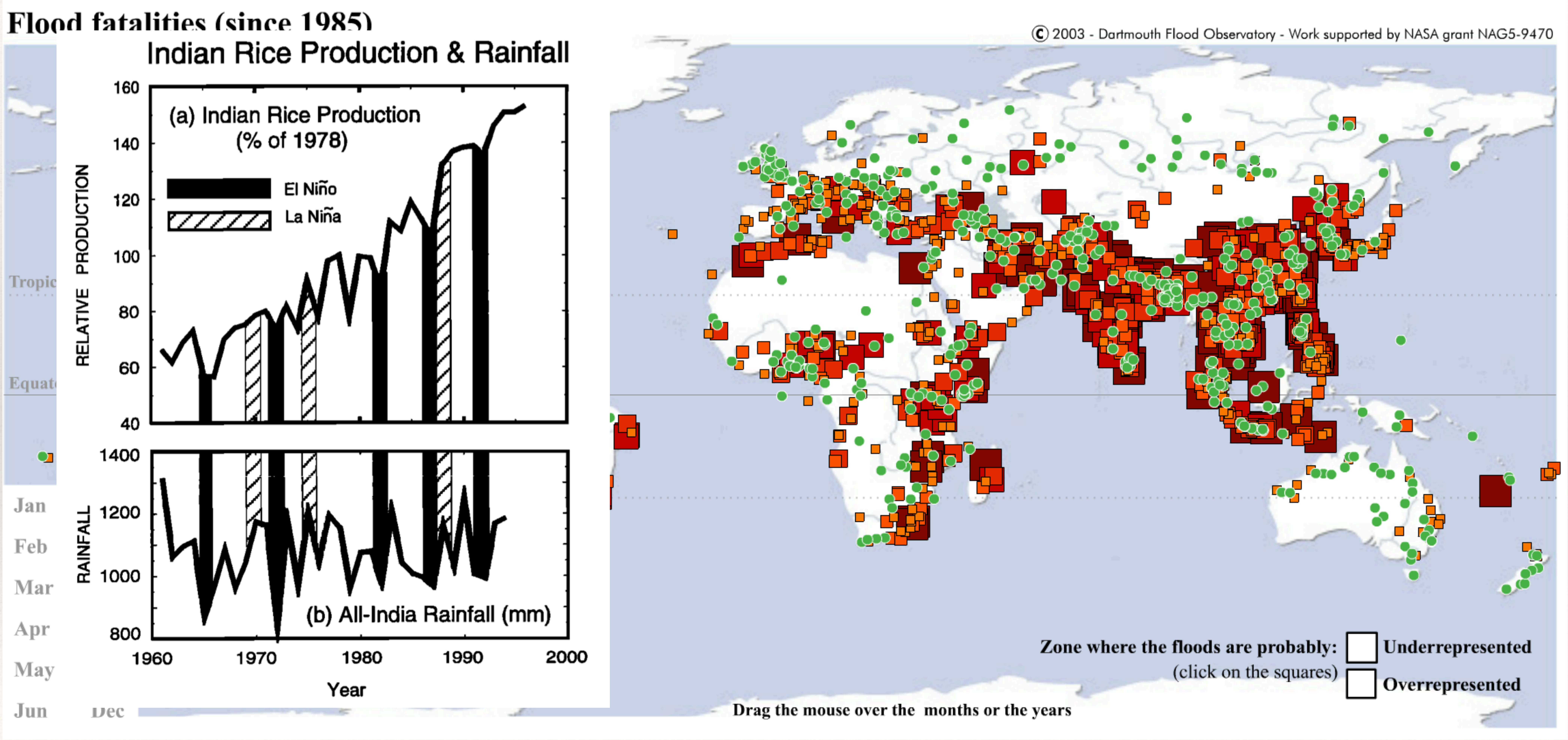
Why and when we need to use regional coupled models?

The South Asia experiment



OCN domain   HYD domain   ATM domain

Motivations: Socio-Economic implications



Webster et Al 1999

http://www.dartmouth.edu/~floods/archiveatlas/floodfatalities.htm

South Asia experimental design

29 years simulated (1979-2007)

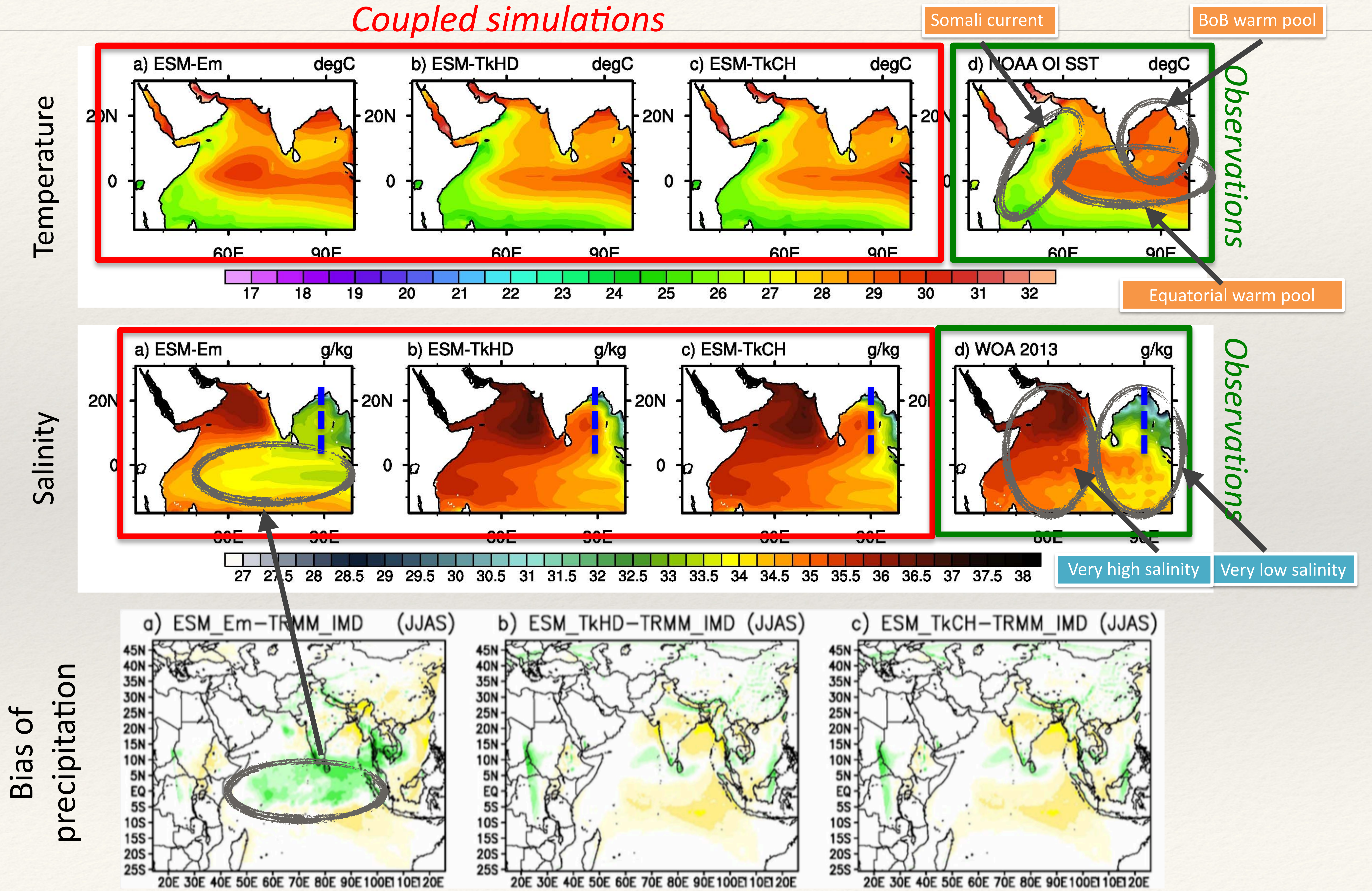
ATM:
Horizontal spatial Res. 50km
ICBC ERA Interim reanalysis 0.75°

OCN:
Horizontal spatial resolution 0.16°
ICBC MOM global integration 0.25° and ORAP reanalysis 0.25°

HYD:
Horizontal spatial resolution 0.5° HD and 0.12° CHyM

Simulation Acronym	Convective schemes	Ocean model ICBC	Hydrological model
RCM-Em	Emanuel		
RCM-Tk	Tiedtke		
ESM-Em	Emanuel	MOM (GOCM)	HD
ESM-TkHD	Tiedtke	ORAP5 (Reanalysis)	HD
ESM-TkCH	Tiedtke	ORAP5 (Reanalysis)	CHyM

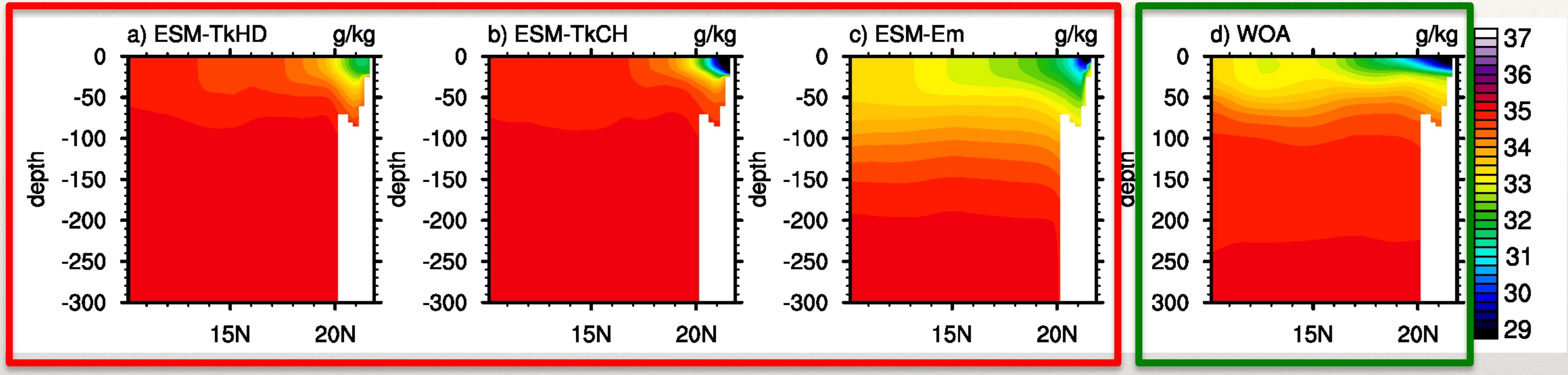
Results: Ocean validation



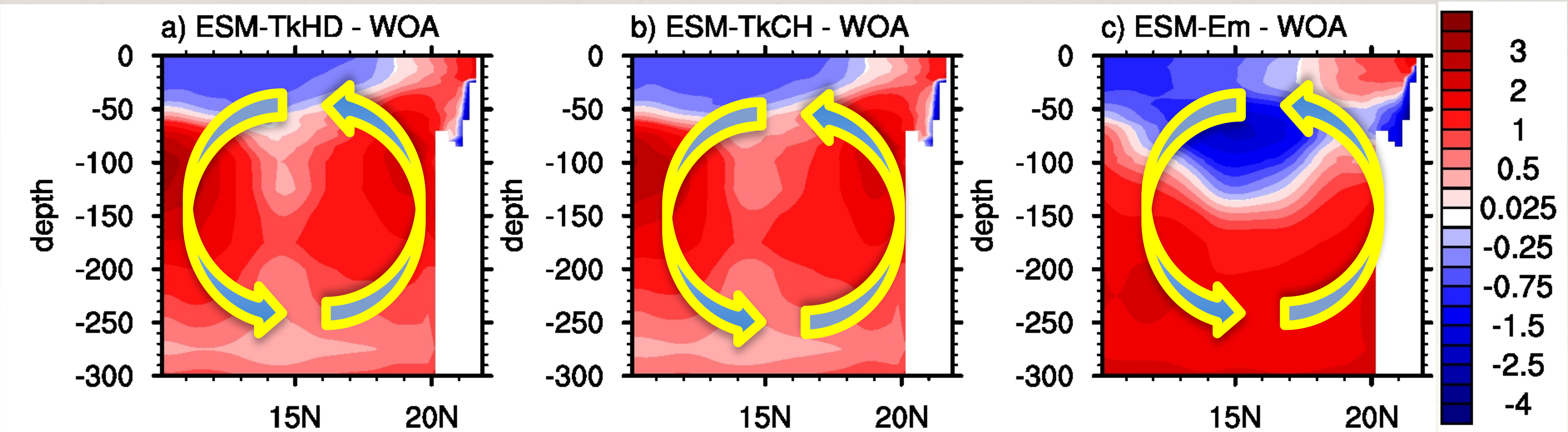
Results: Ocean validation

Coupled simulations | *Observations*

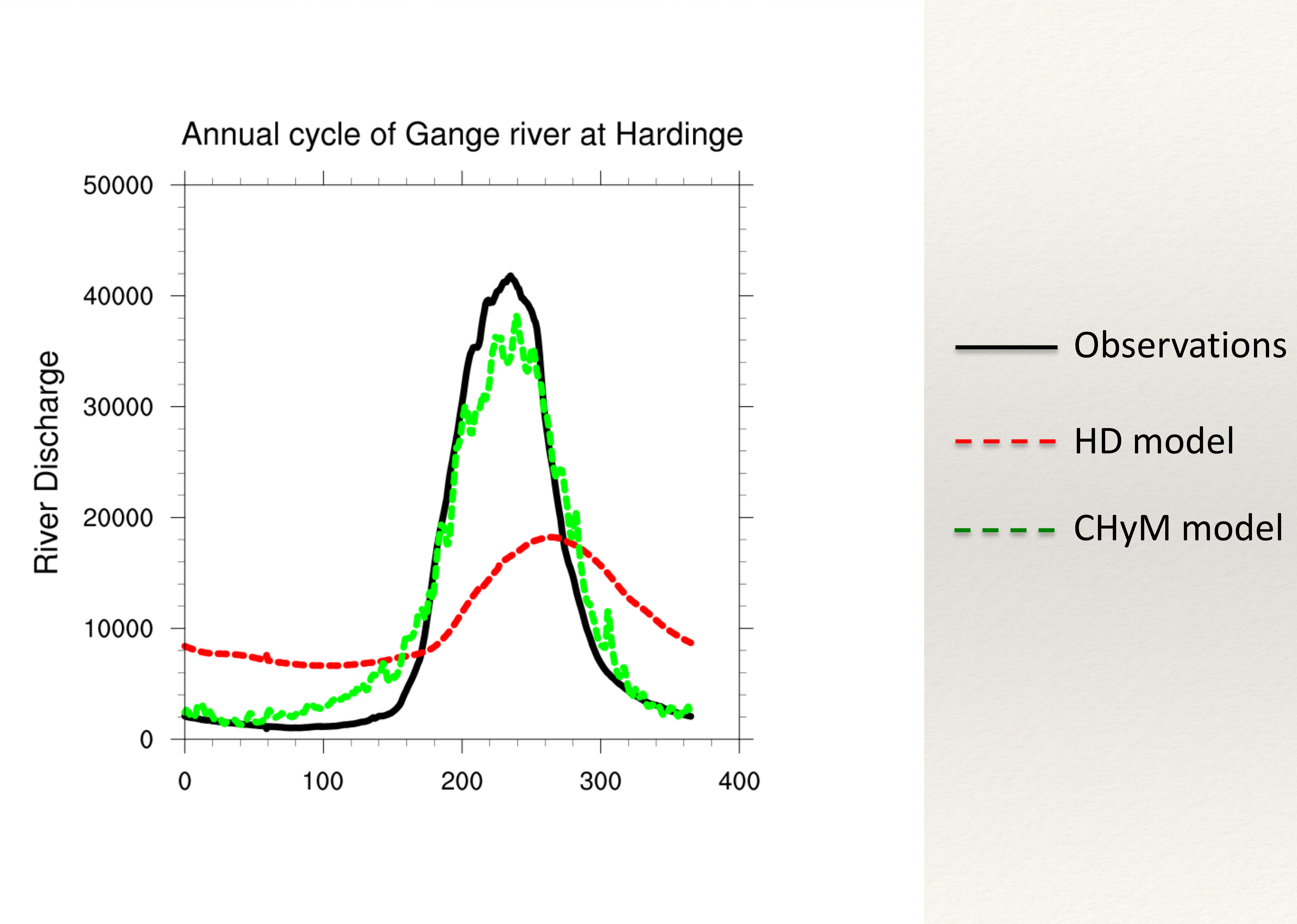
Salinity transect at 90°E (in the middle of BoB)

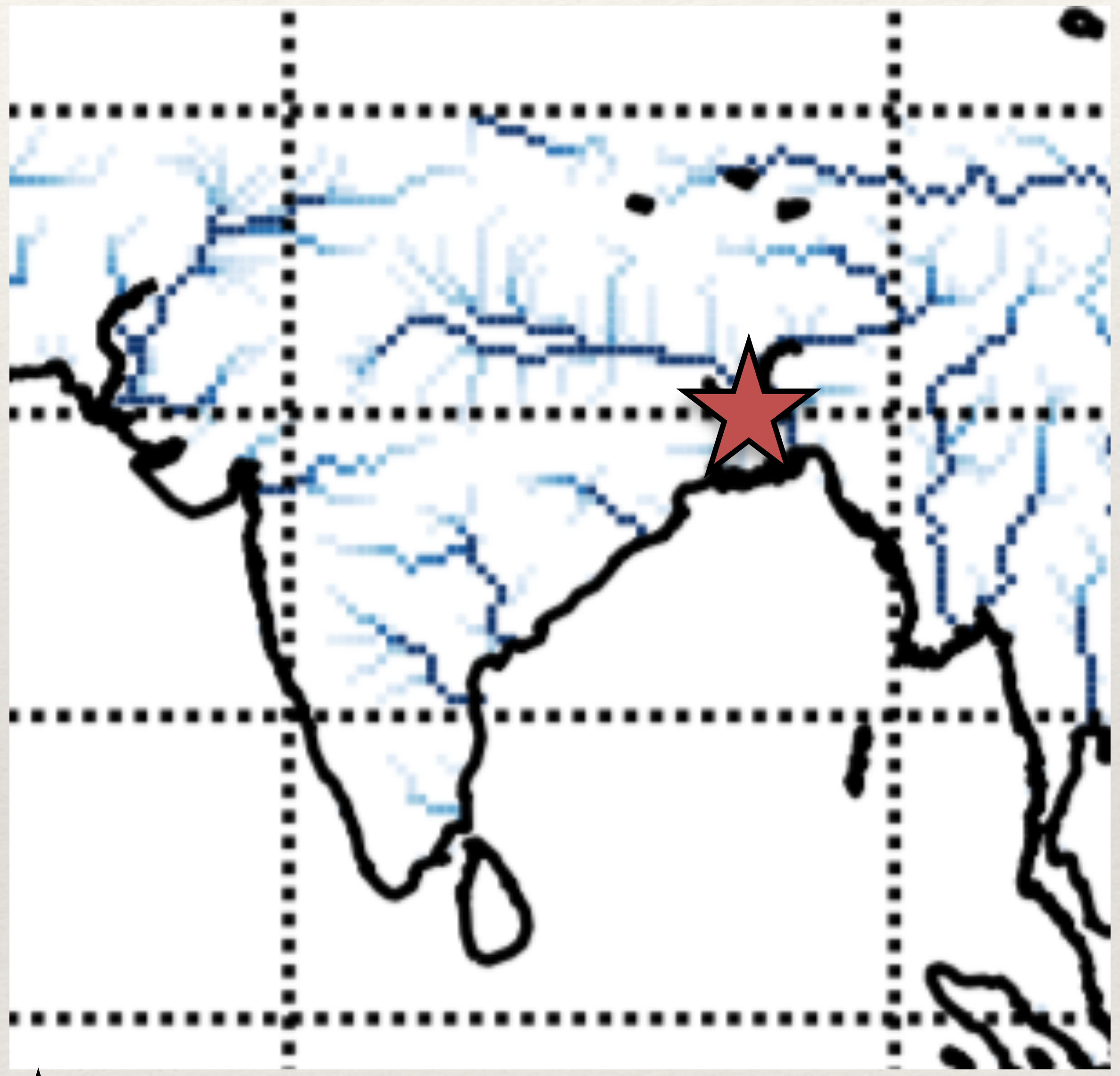


Bias of Temperature transect at 90°E (in the middle of BoB)



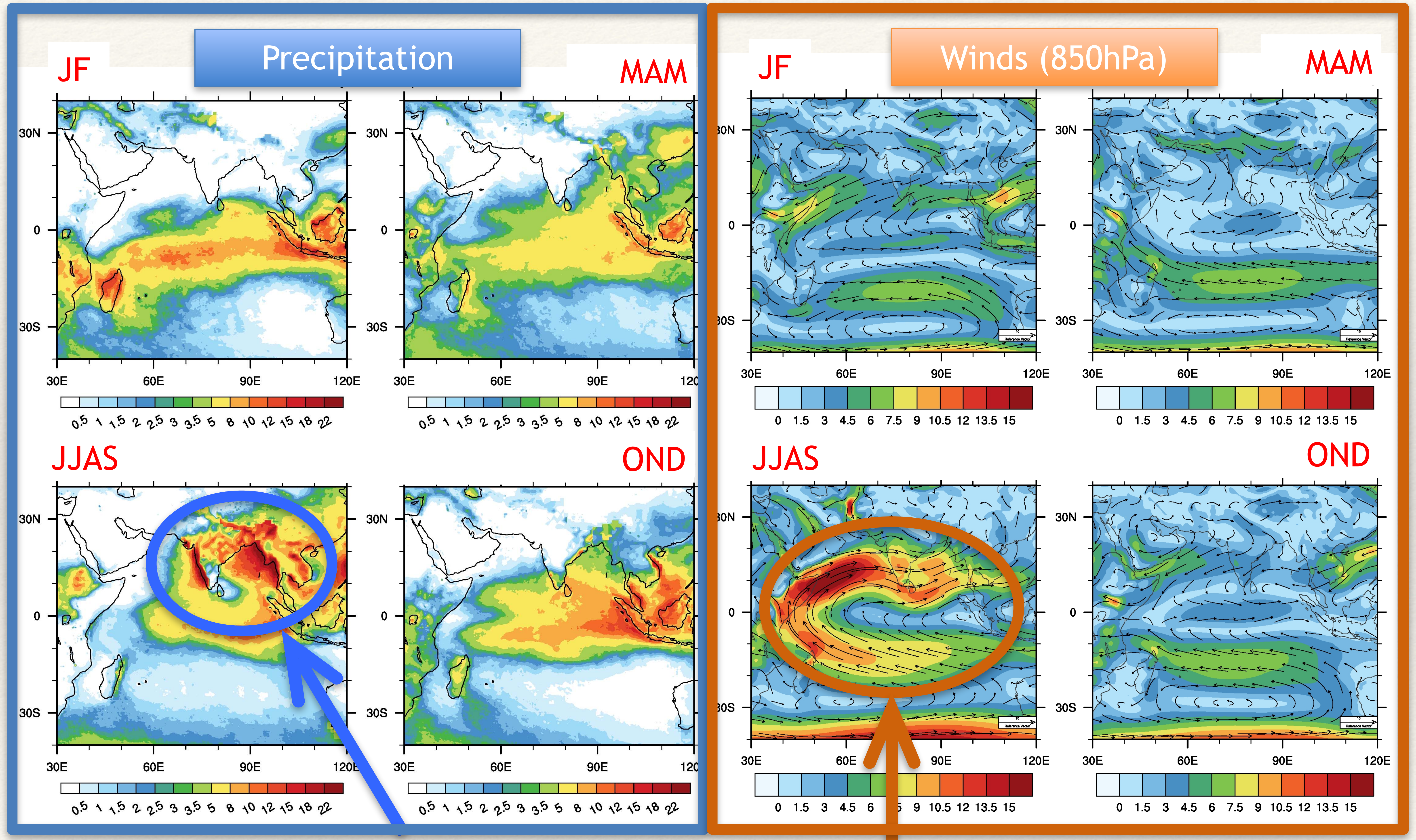
Results: freshwater validation





Hardinge station

Climatology of the ISM

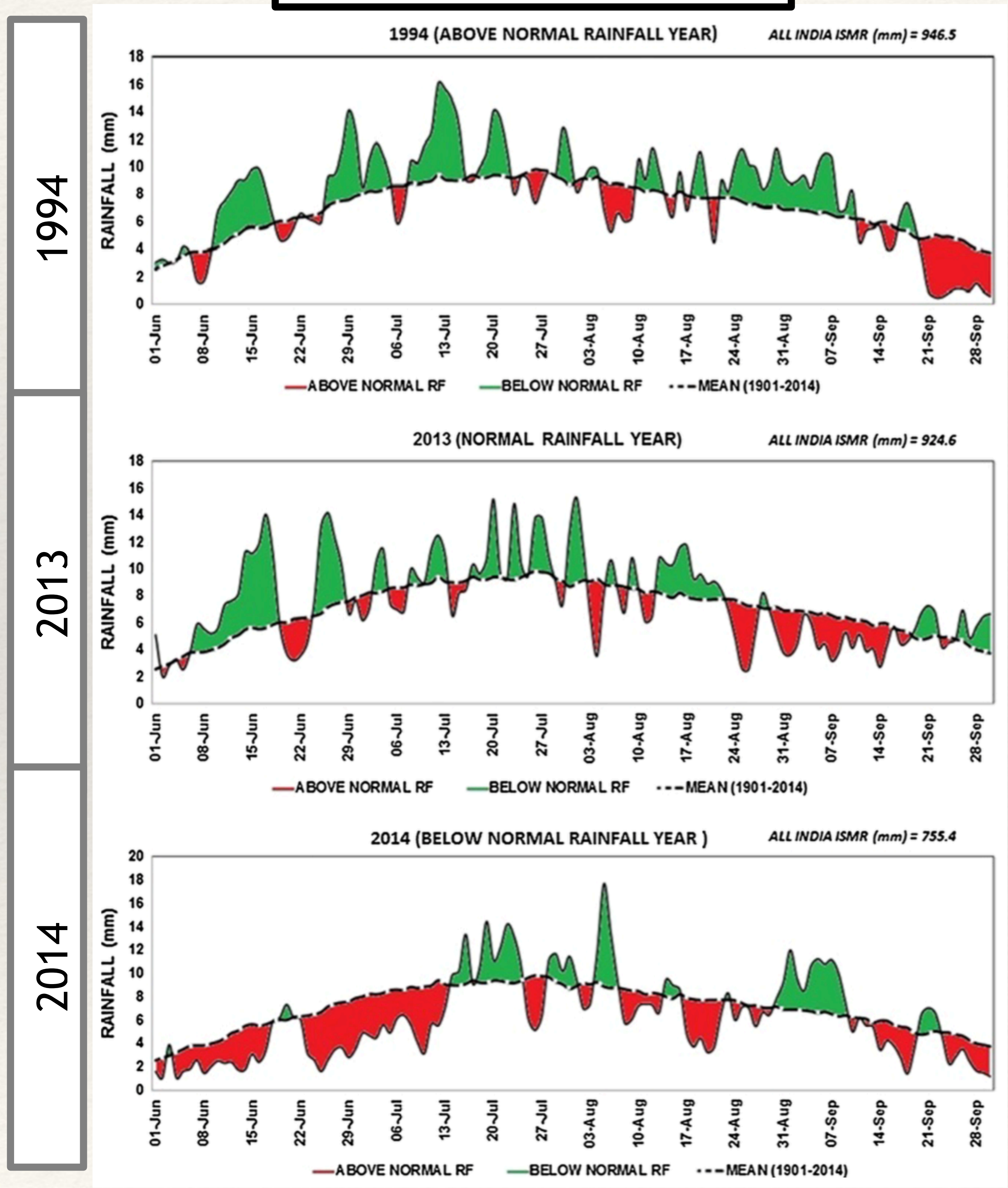


Large Increase in precipitation and runoff

Low Level Jet

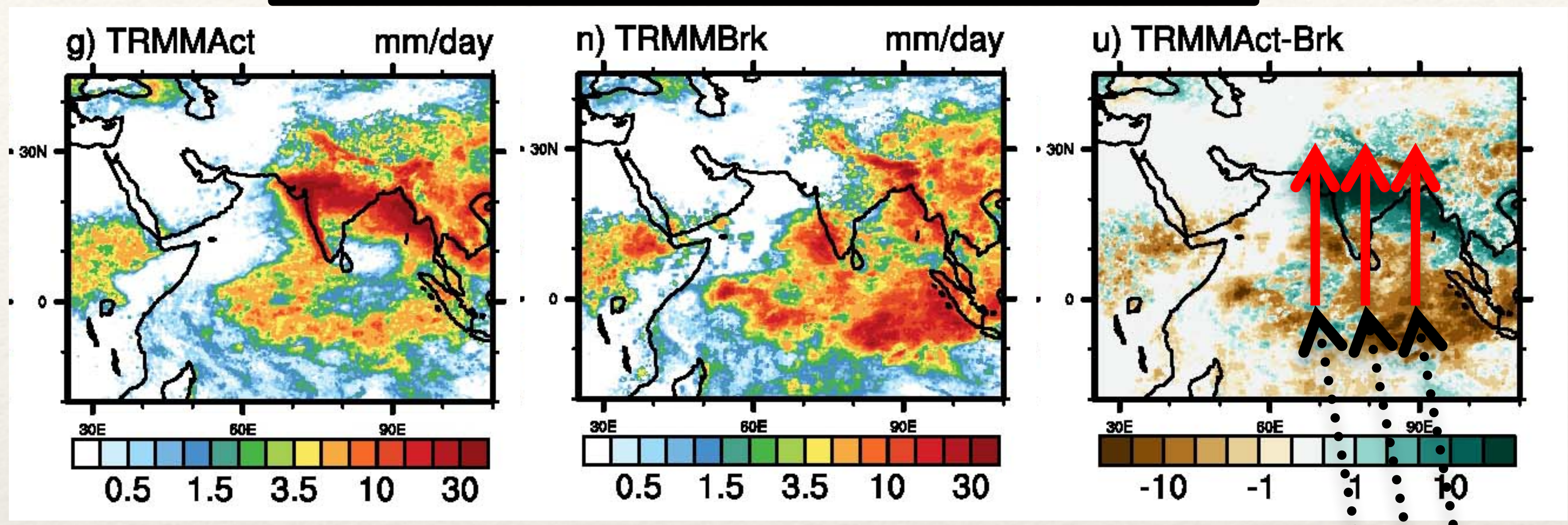
Intraseasonal oscillations of the ISM

Rainfall

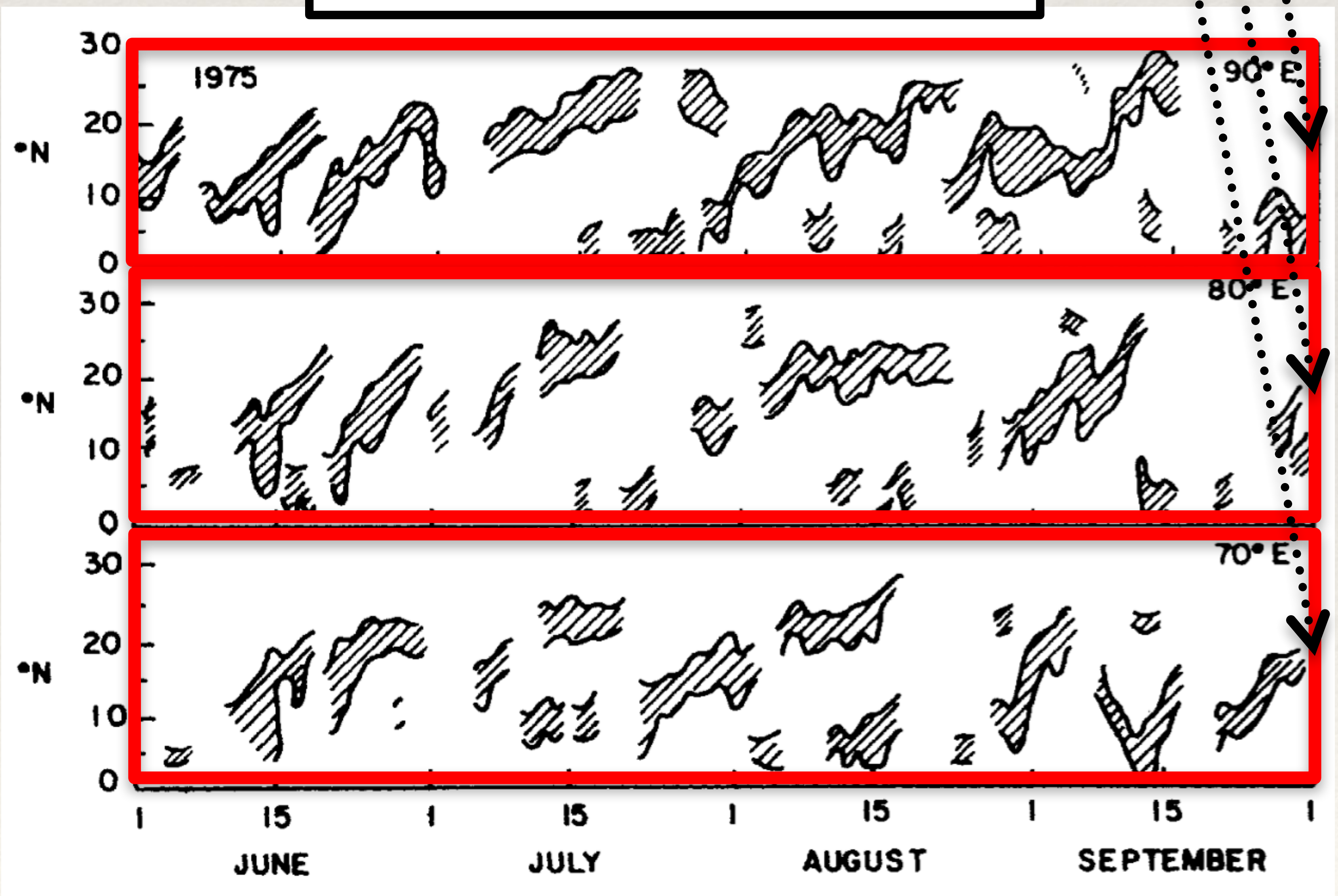


Pai et al. [2016]

Composite of break/active

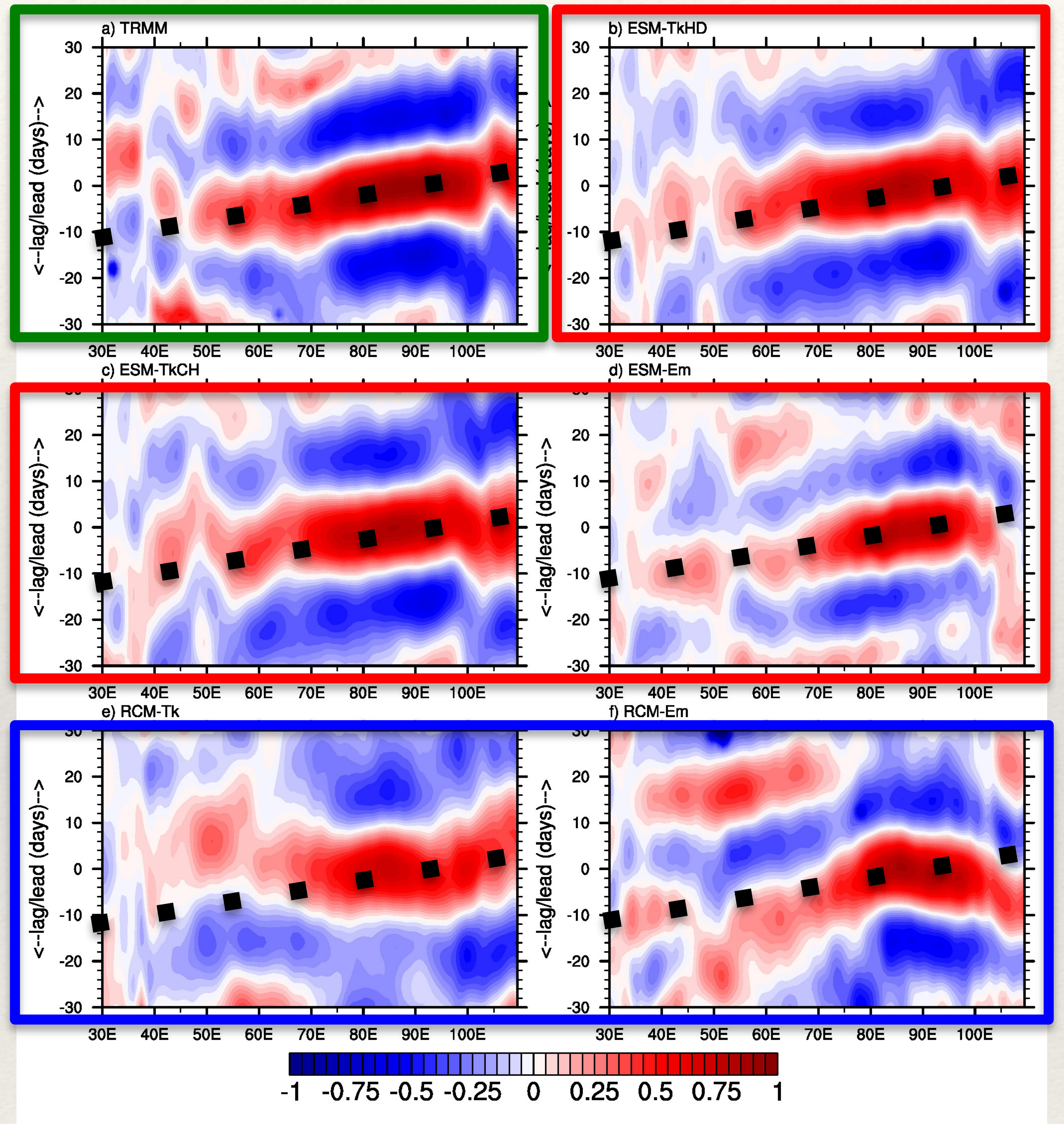


Maximum cloud zone

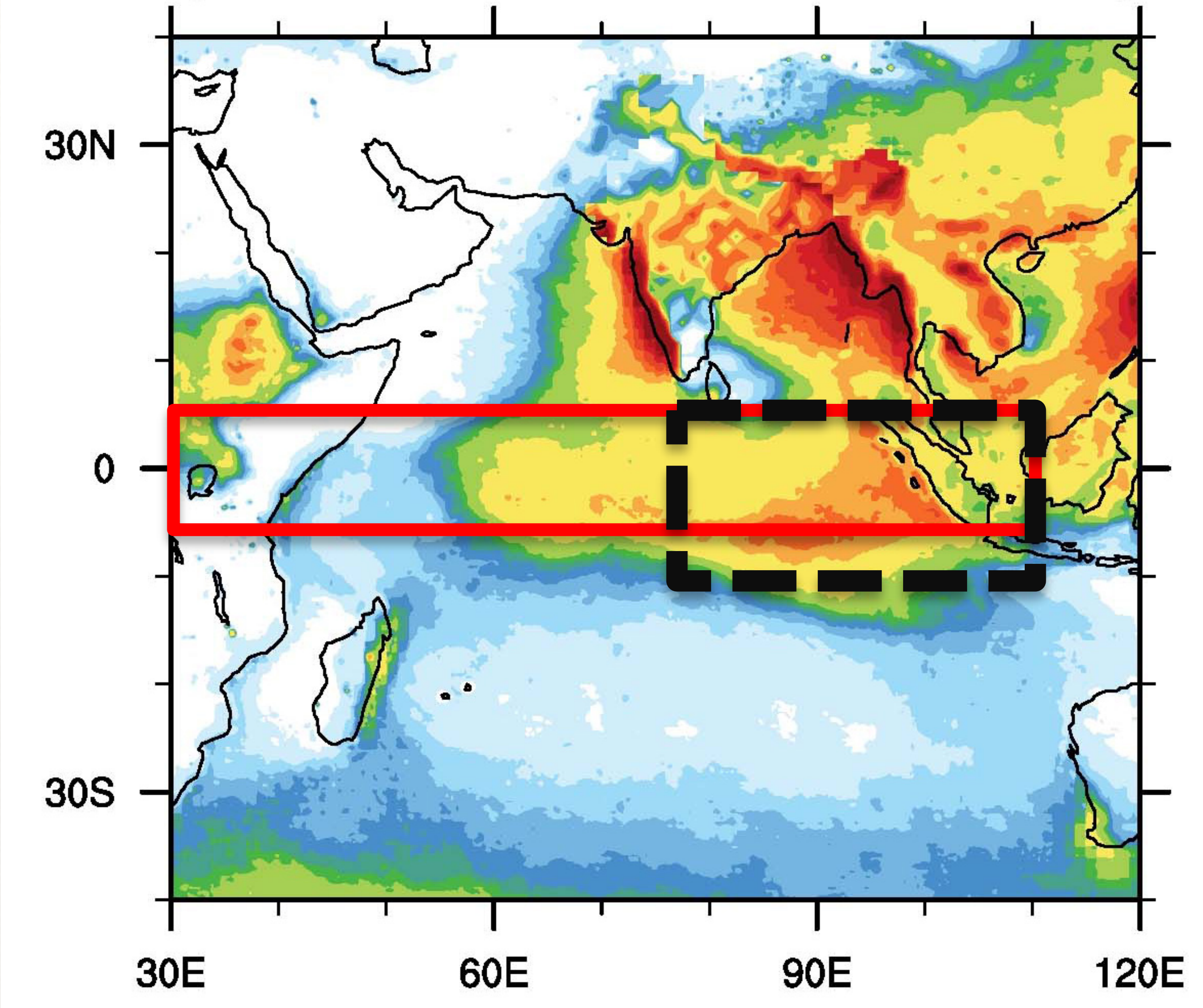


Goswami [1994]

Results: intraseasonal oscillations

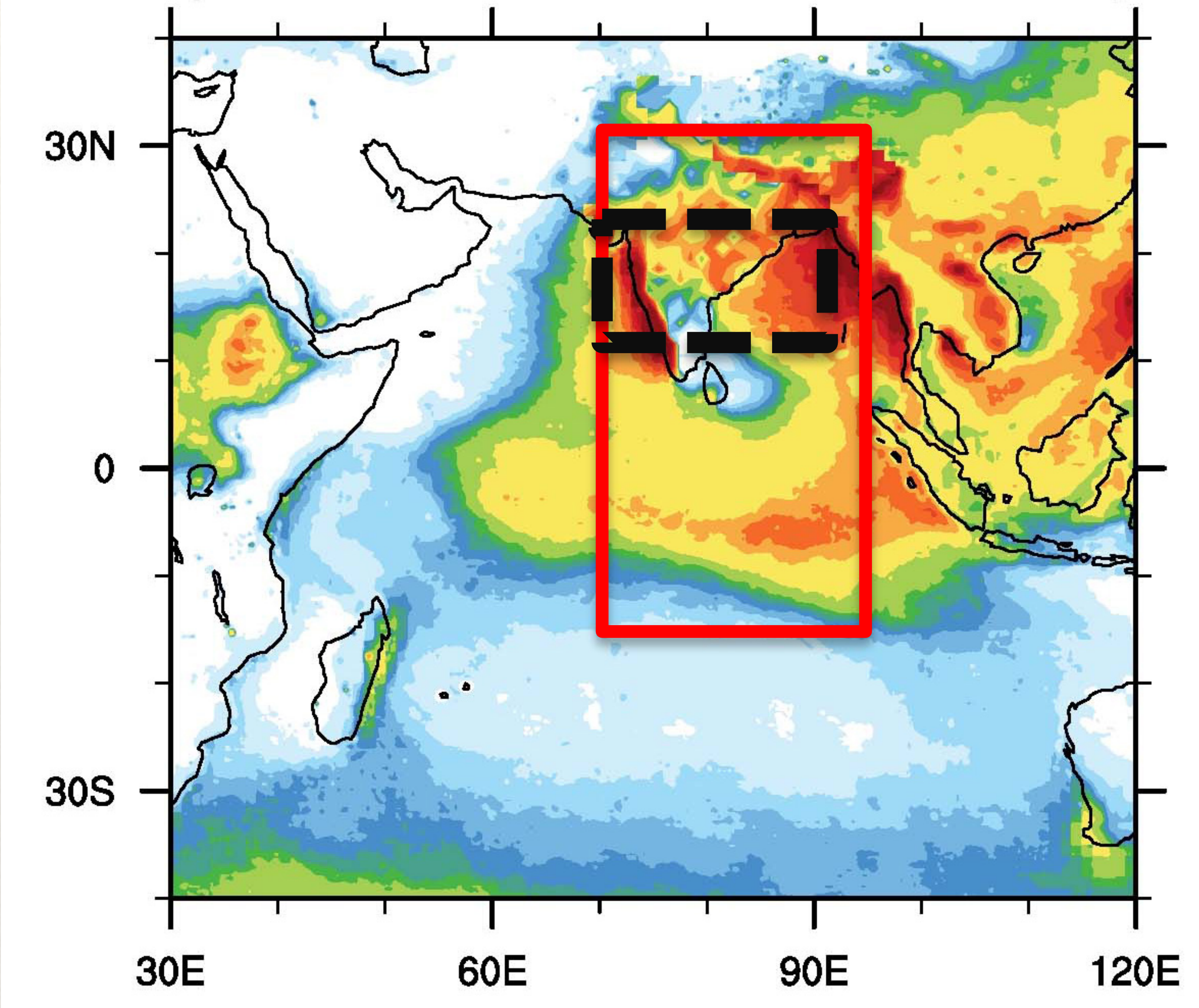


Eastward propagation of rainfall

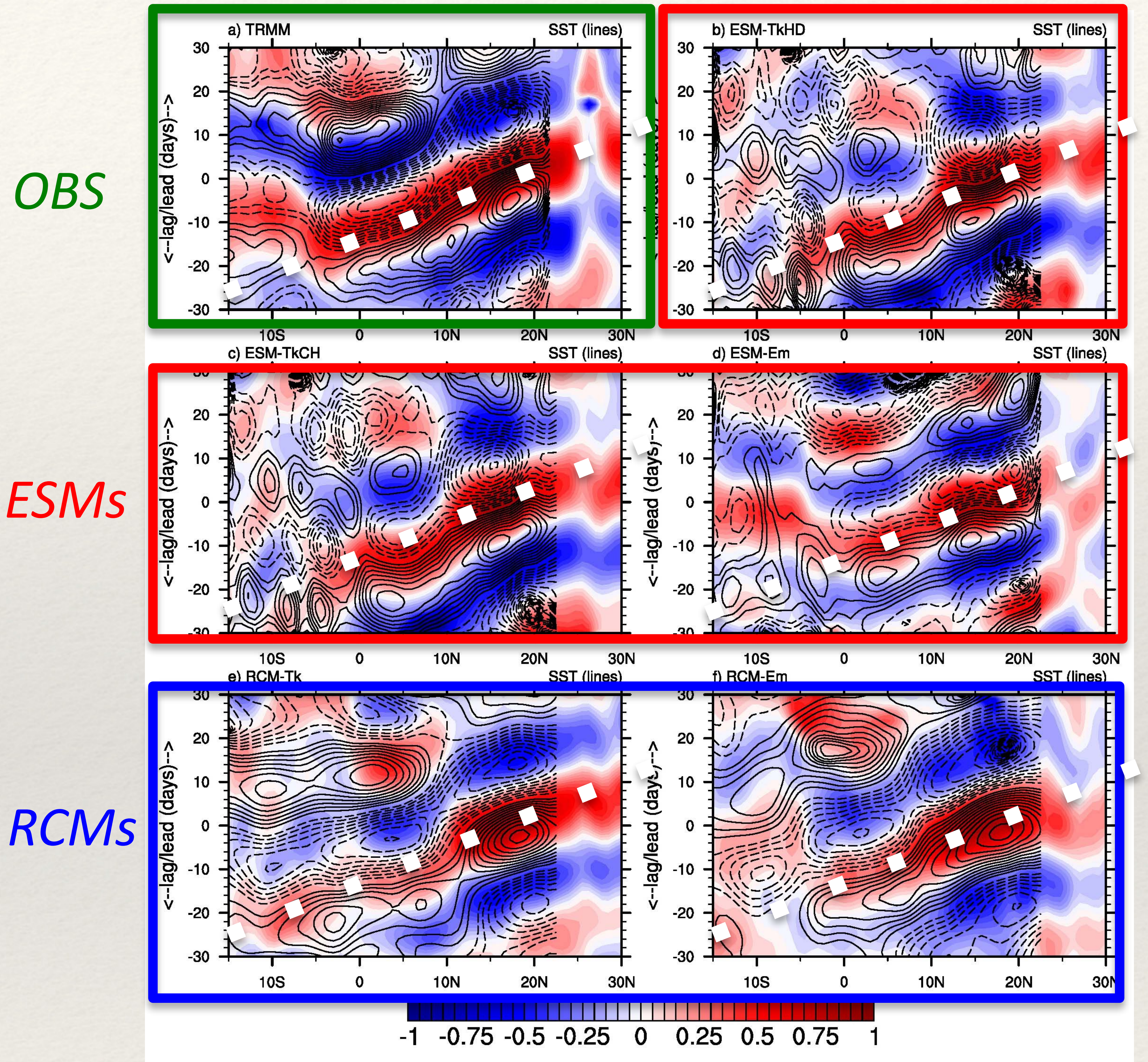


Lat average vs box average

Results: intraseasonal oscillations



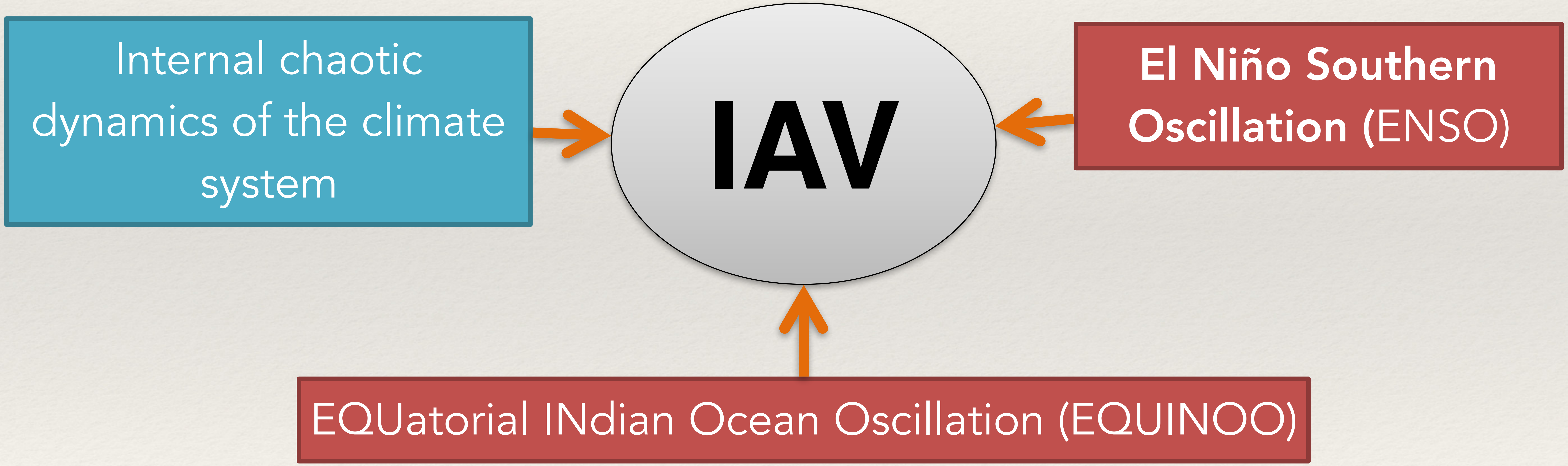
Lon average vs box average



Northward propagation of rainfall

Interannual variability of the Indian Summer Monsoon

The Indian summer monsoon is characterized by large year-to-year variations in the total amount of rainfall over the Indian continent.



Results: ENSO forcing on ISM (direct effect during JJAS)

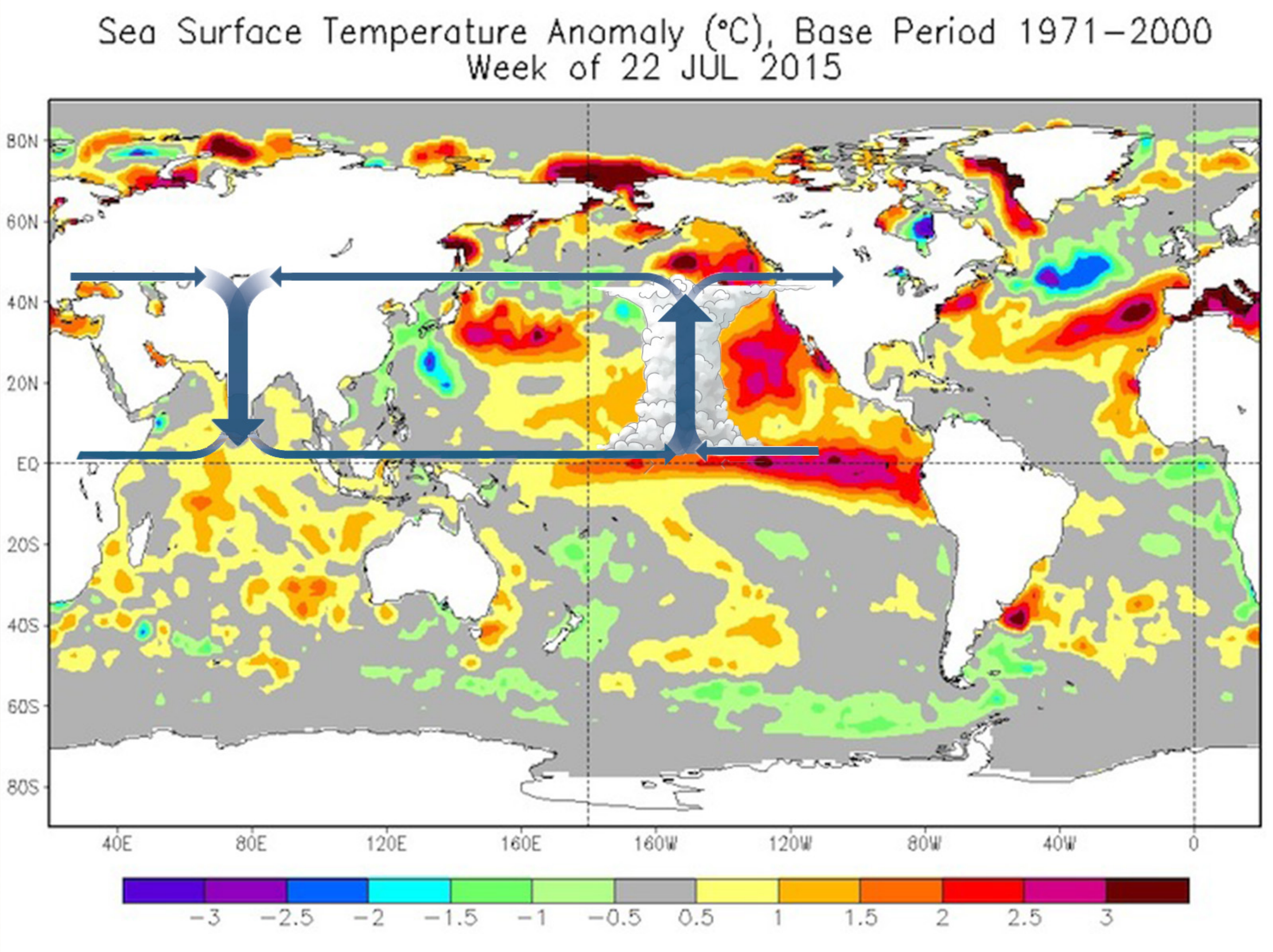
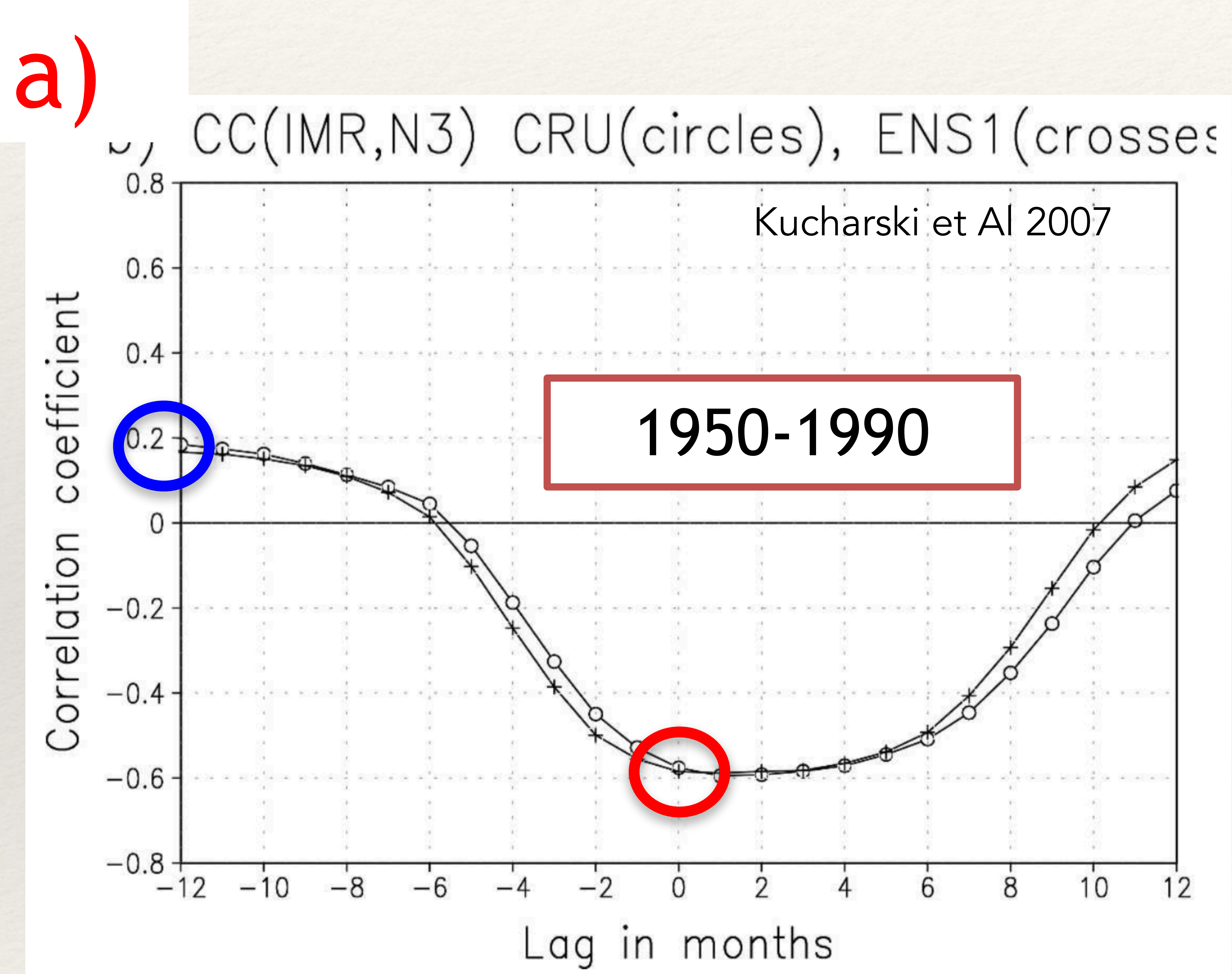
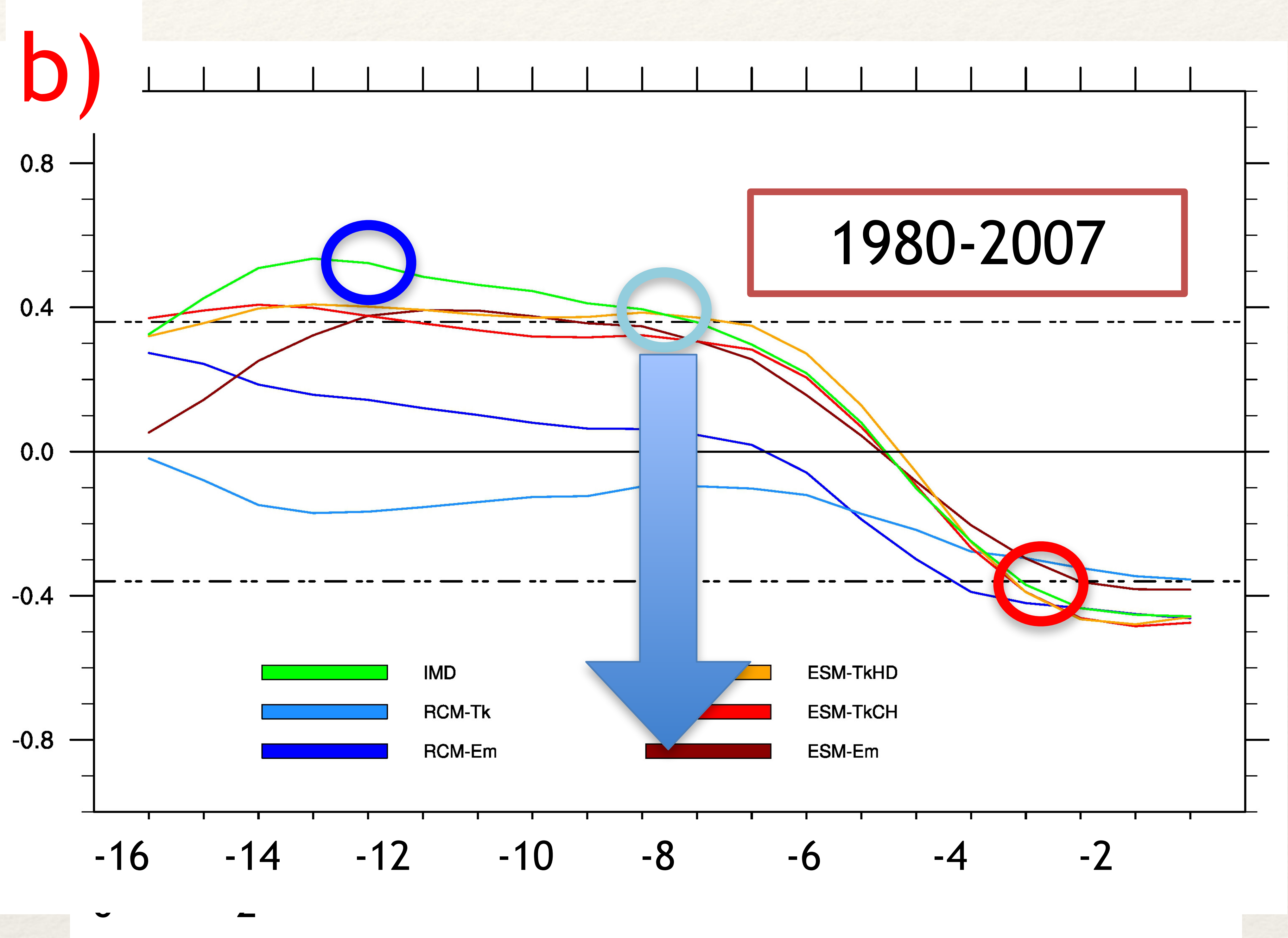


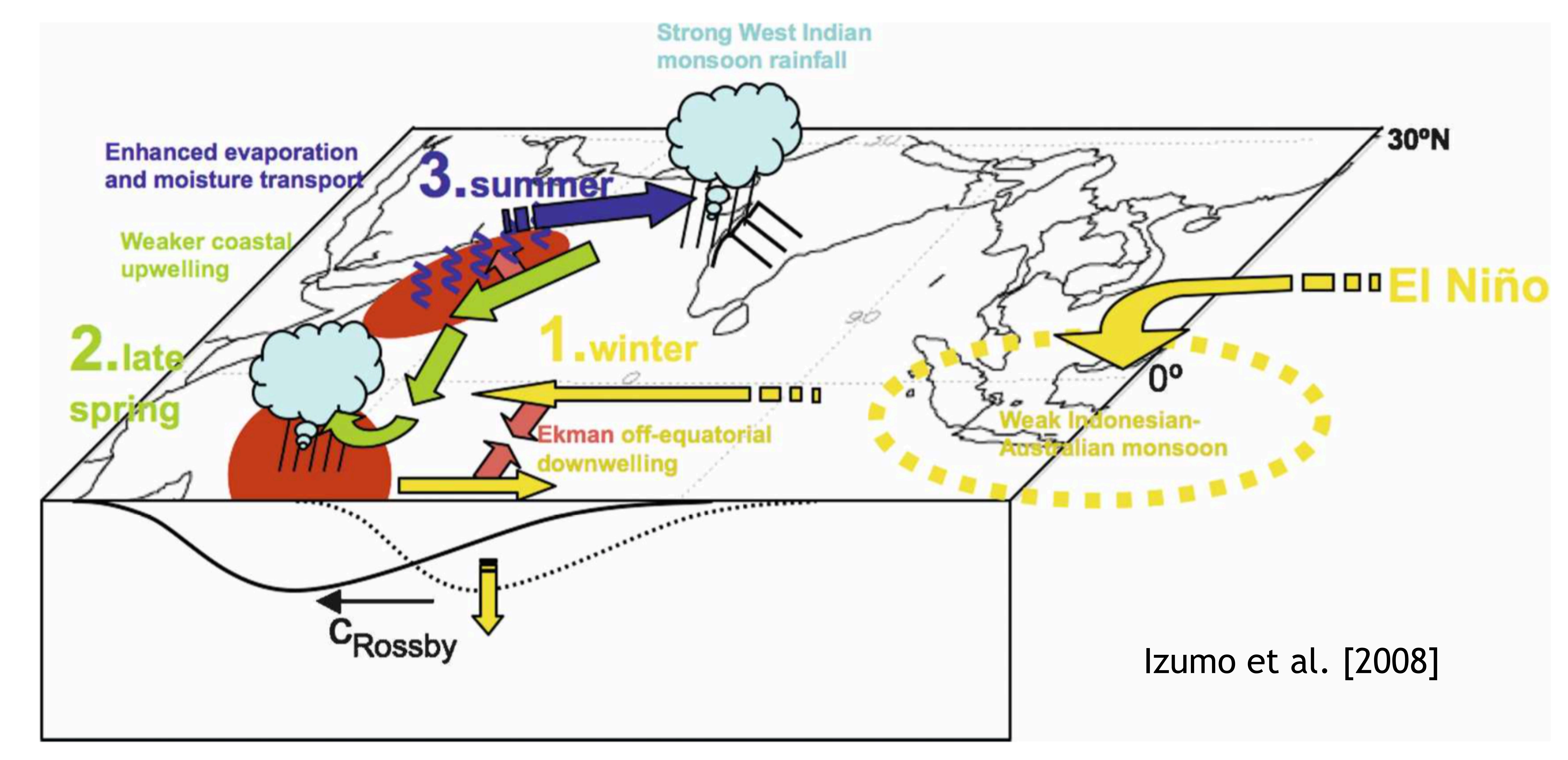
Image credit: NOAA National Centers for Environmental Information

Results: ENSO forcing on ISM (delayed effect)



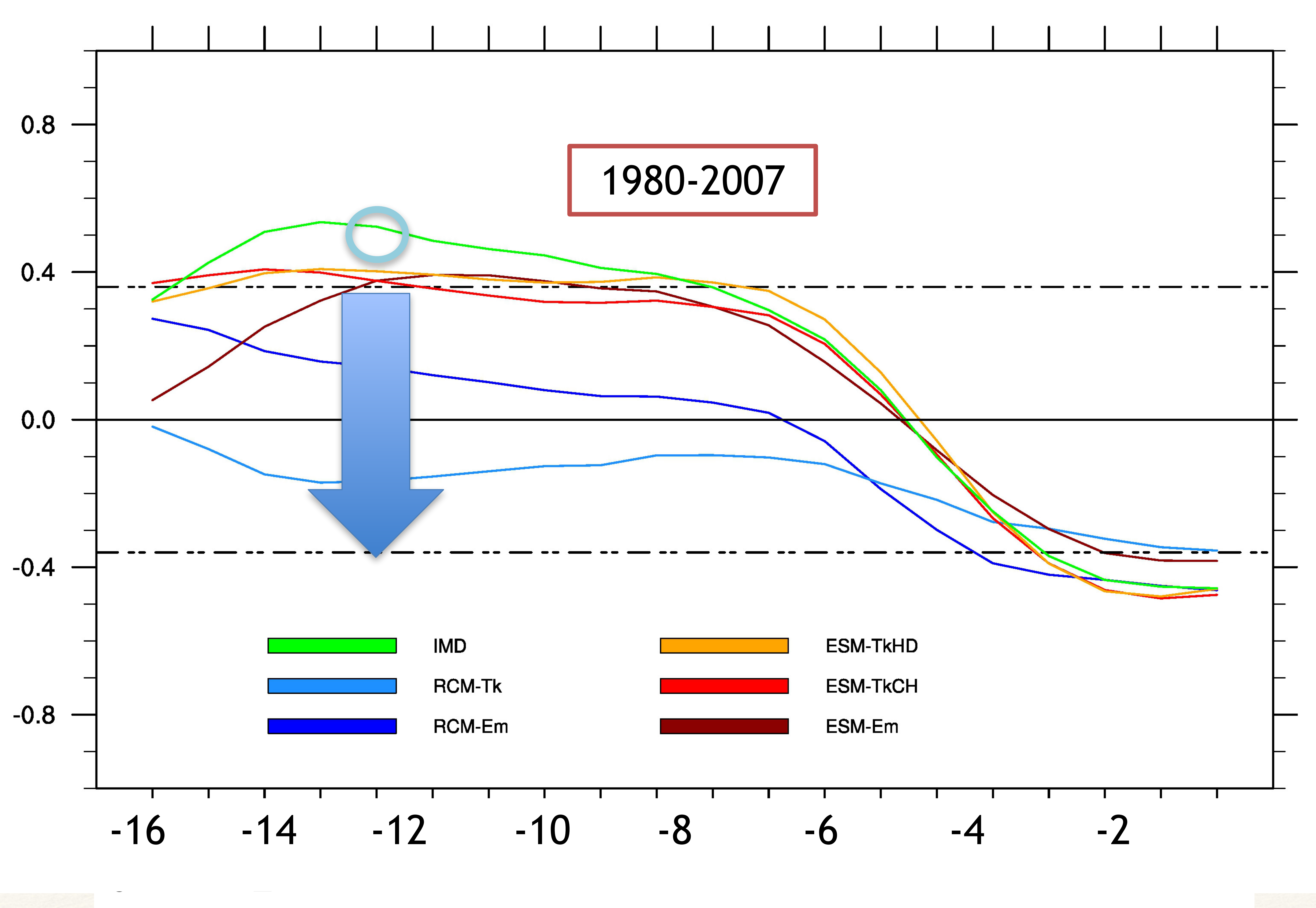


Results: ENSO forcing on ISM (delayed effect from NDJF)



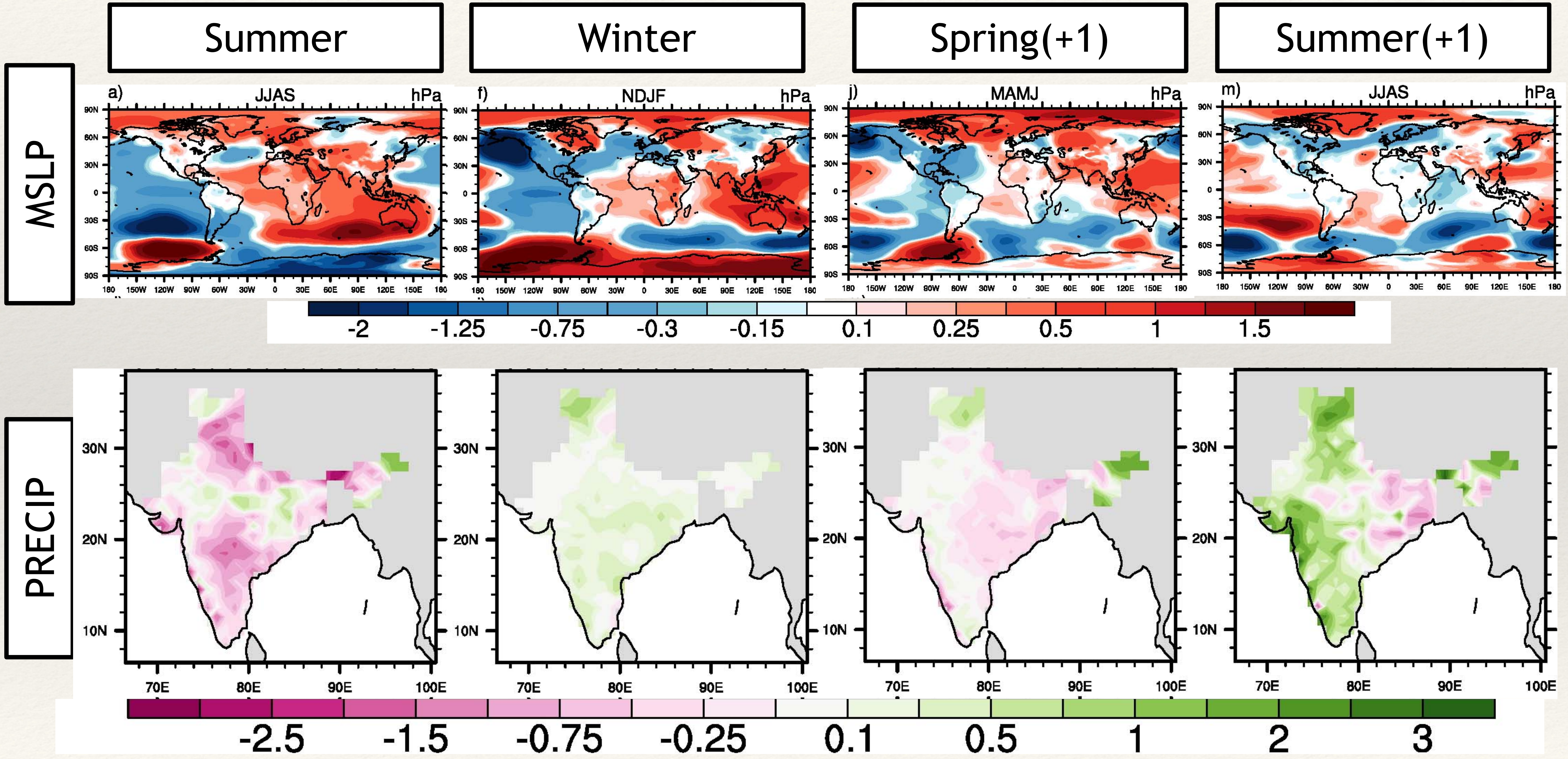
Izumo et al. [2008]

Results: ENSO forcing on ISM (delayed effect from JJAS)

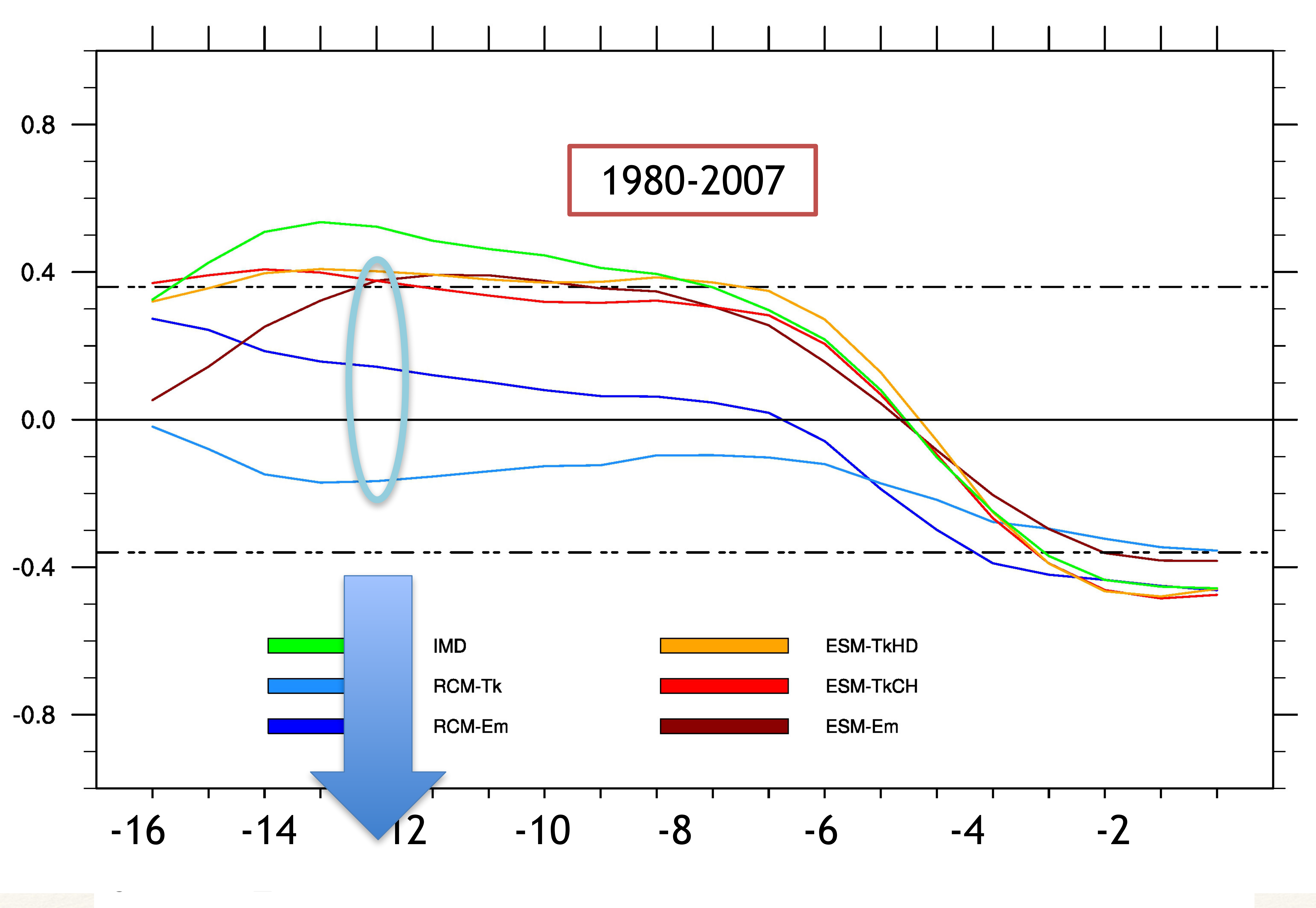


Results: ENSO forcing on ISM (delayed effect from JJAS)

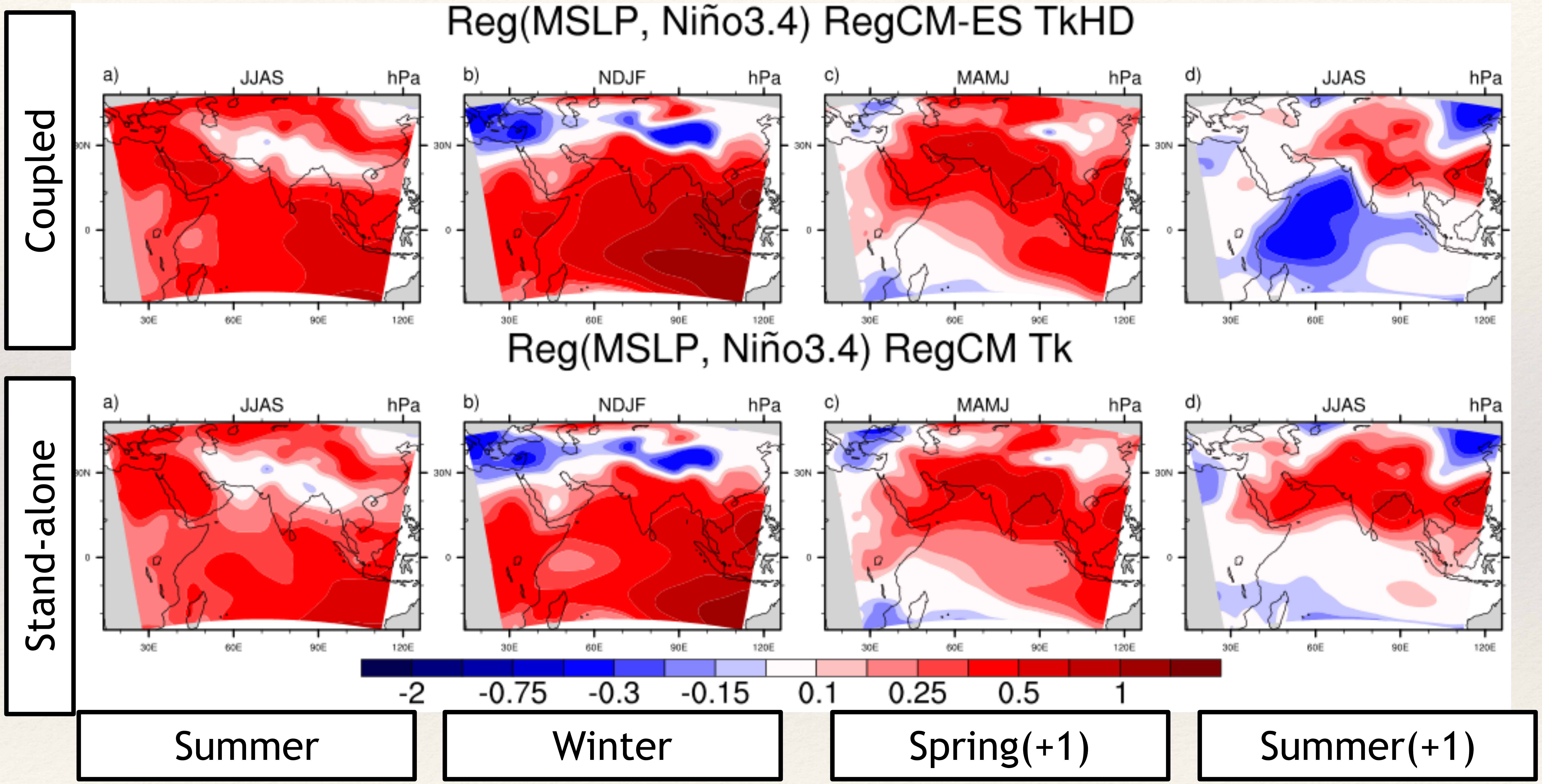
Regressed maps (OBS) of Niño3.4 (JJAS)



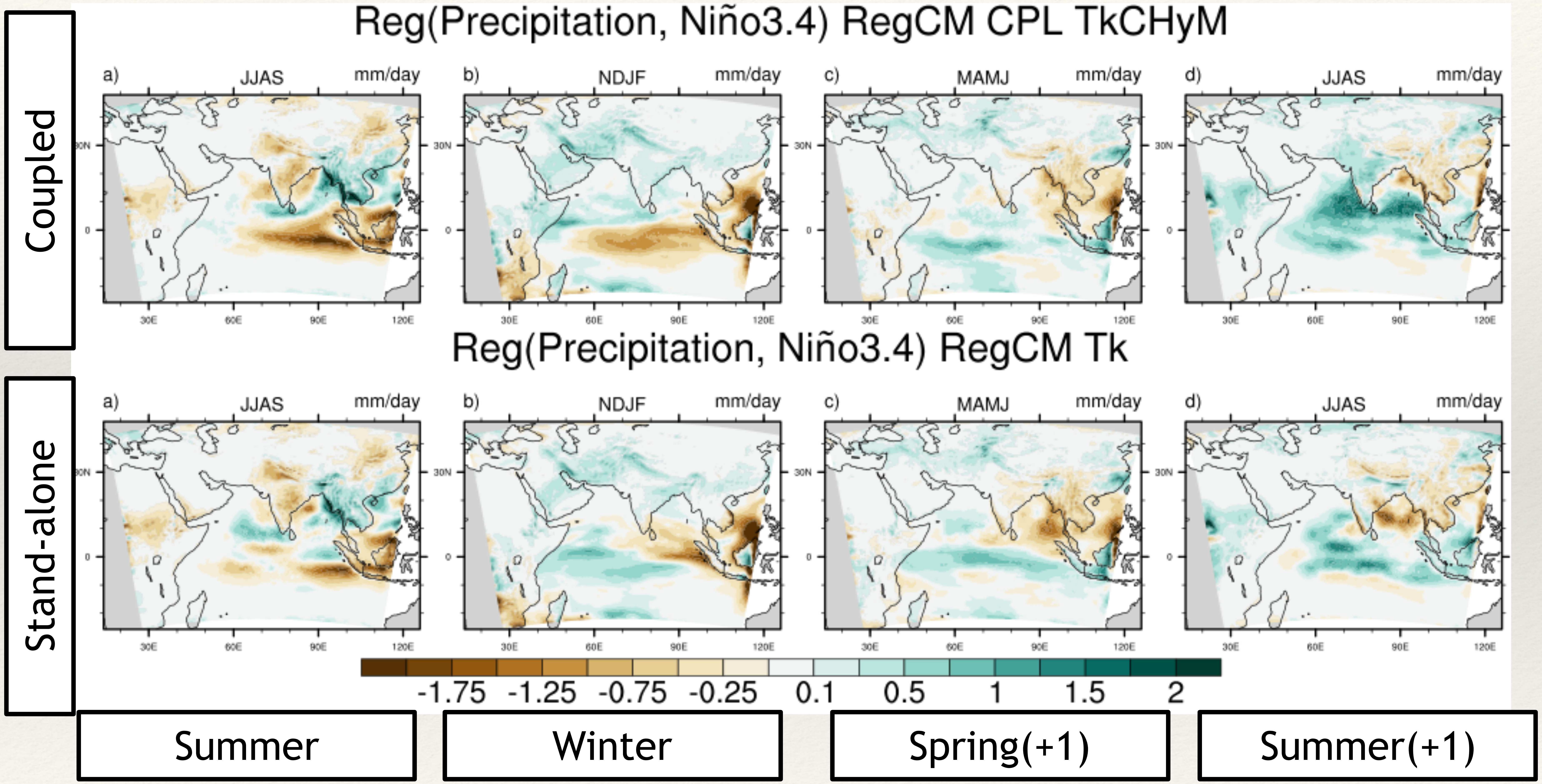
Results: ENSO forcing on ISM (delayed effect from JJAS)



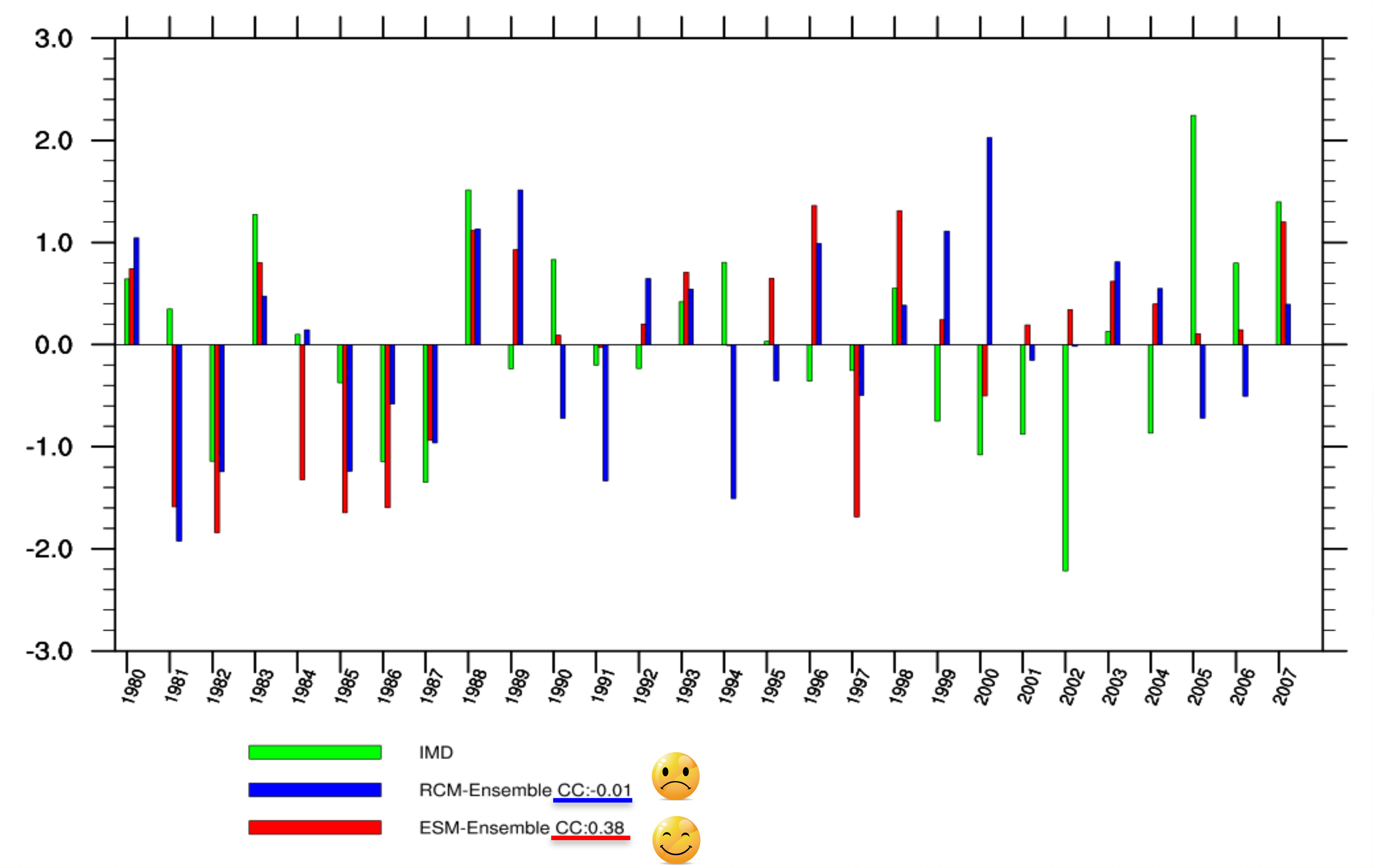
Results: ENSO forcing on ISM (delayed effect from JJAS)



Results: ENSO forcing on ISM (delayed effect from JJAS)

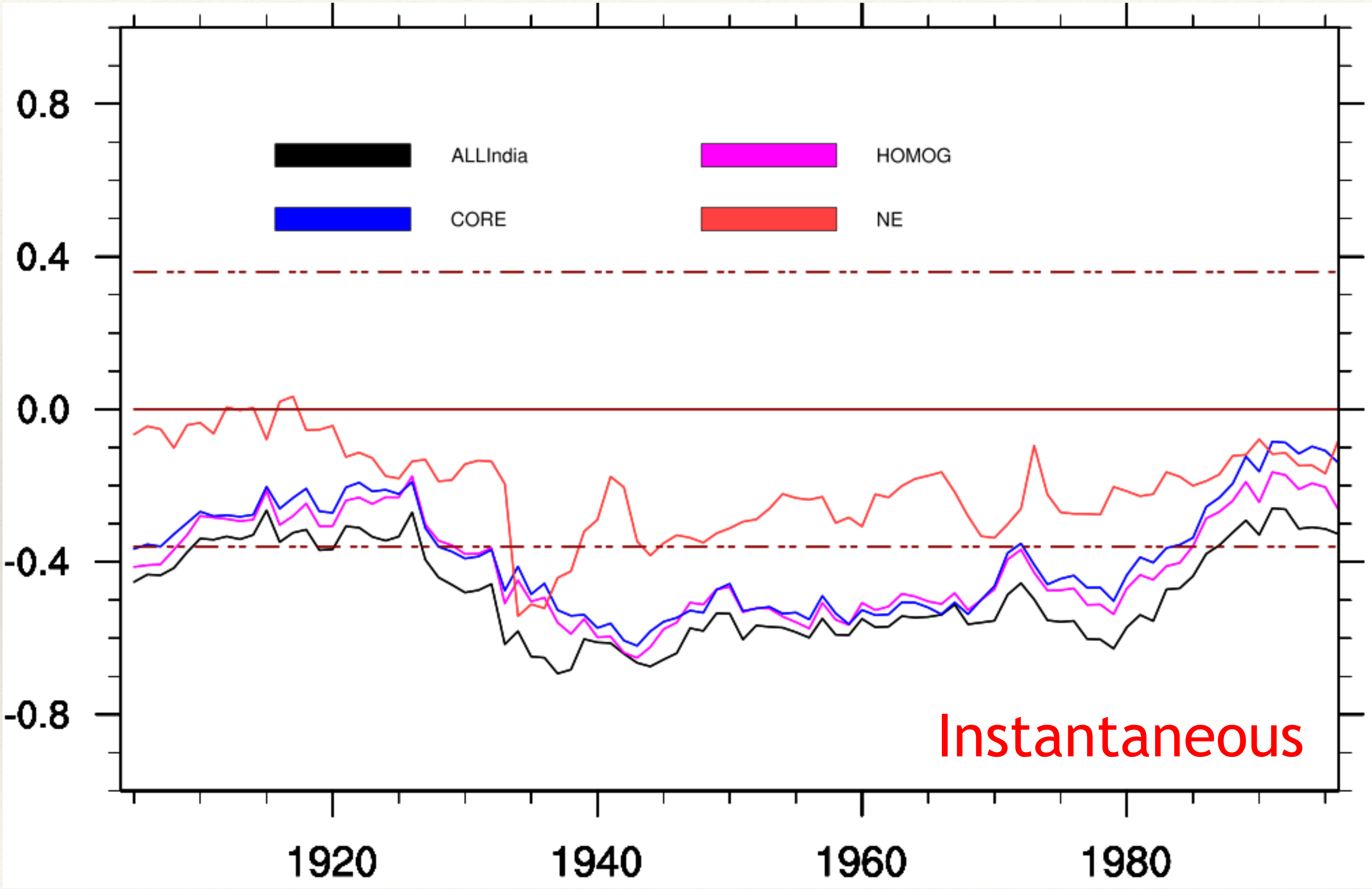


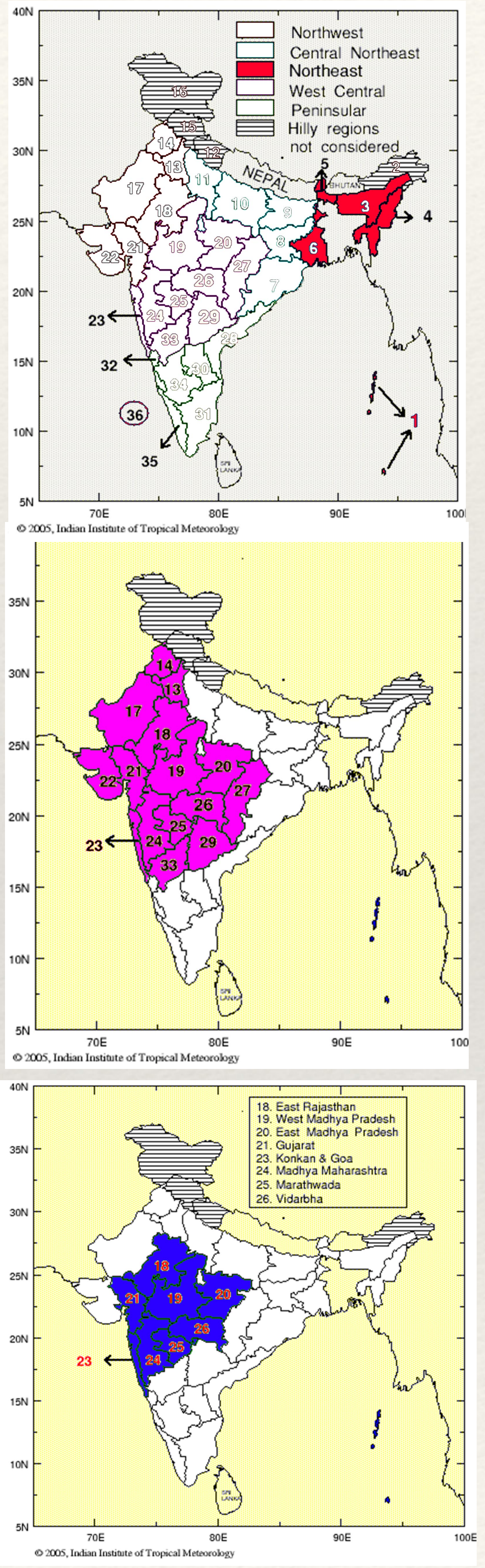
Results: interannual variability



Our analysis confirm what found in the previous studies, namely the necessity of using a coupled system to simulate the Indian Summer Monsoon variability

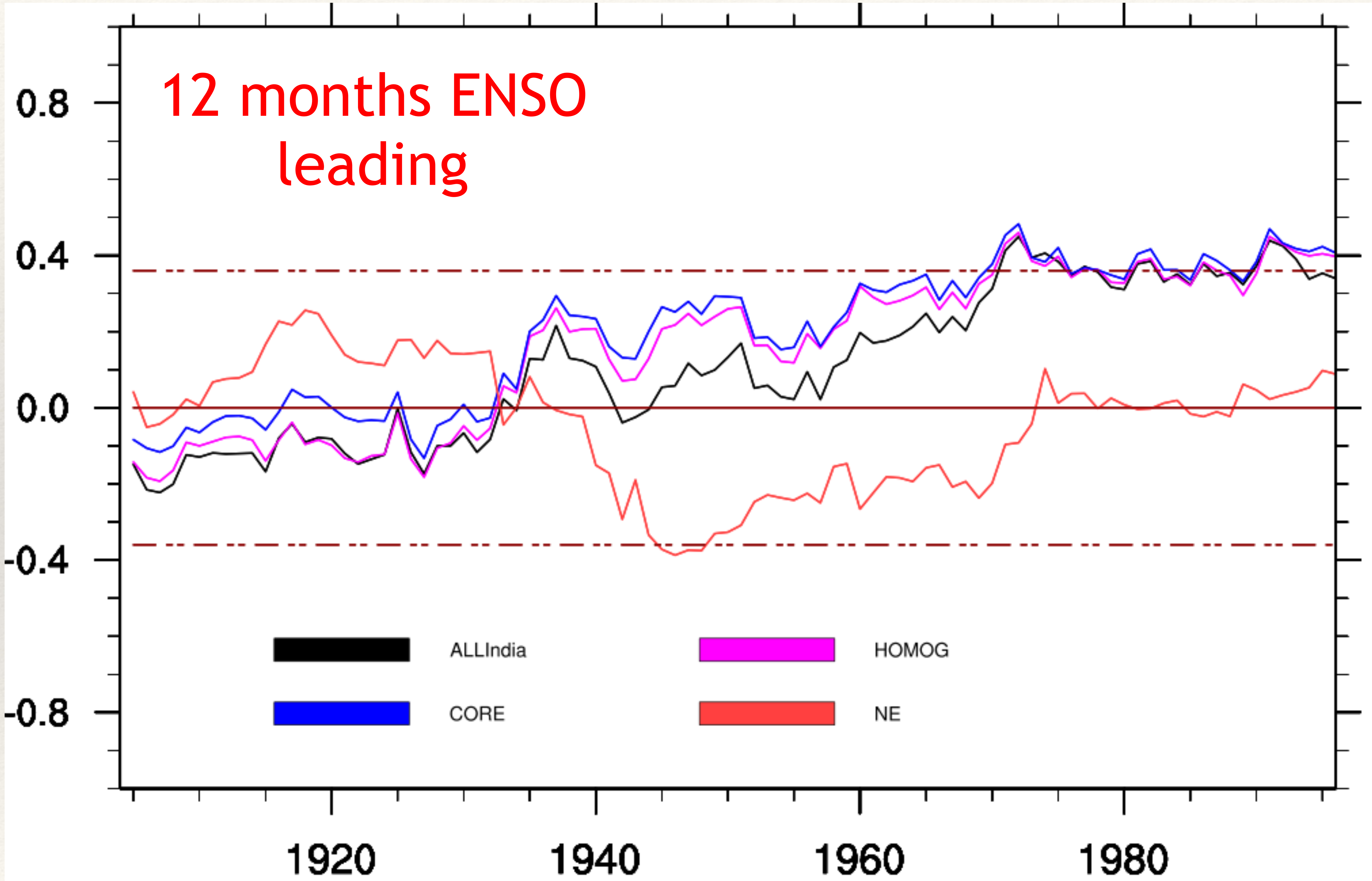
Historical ENSO monsoon correlation

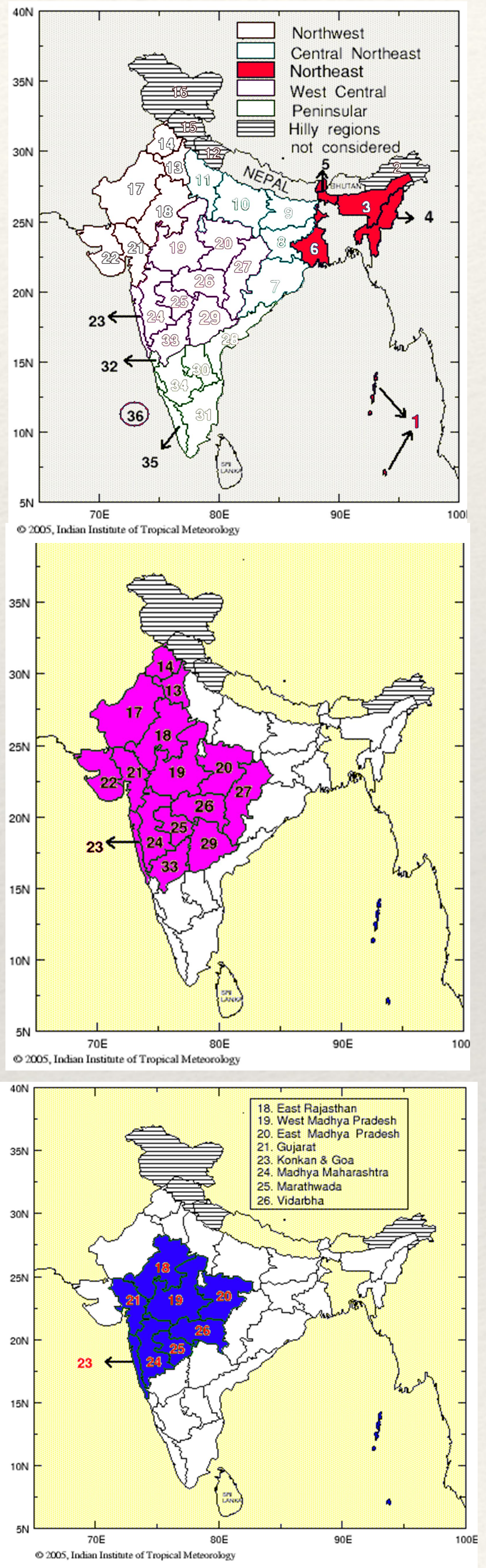




Based on IITM Homogeneous

Historical ENSO monsoon correlation

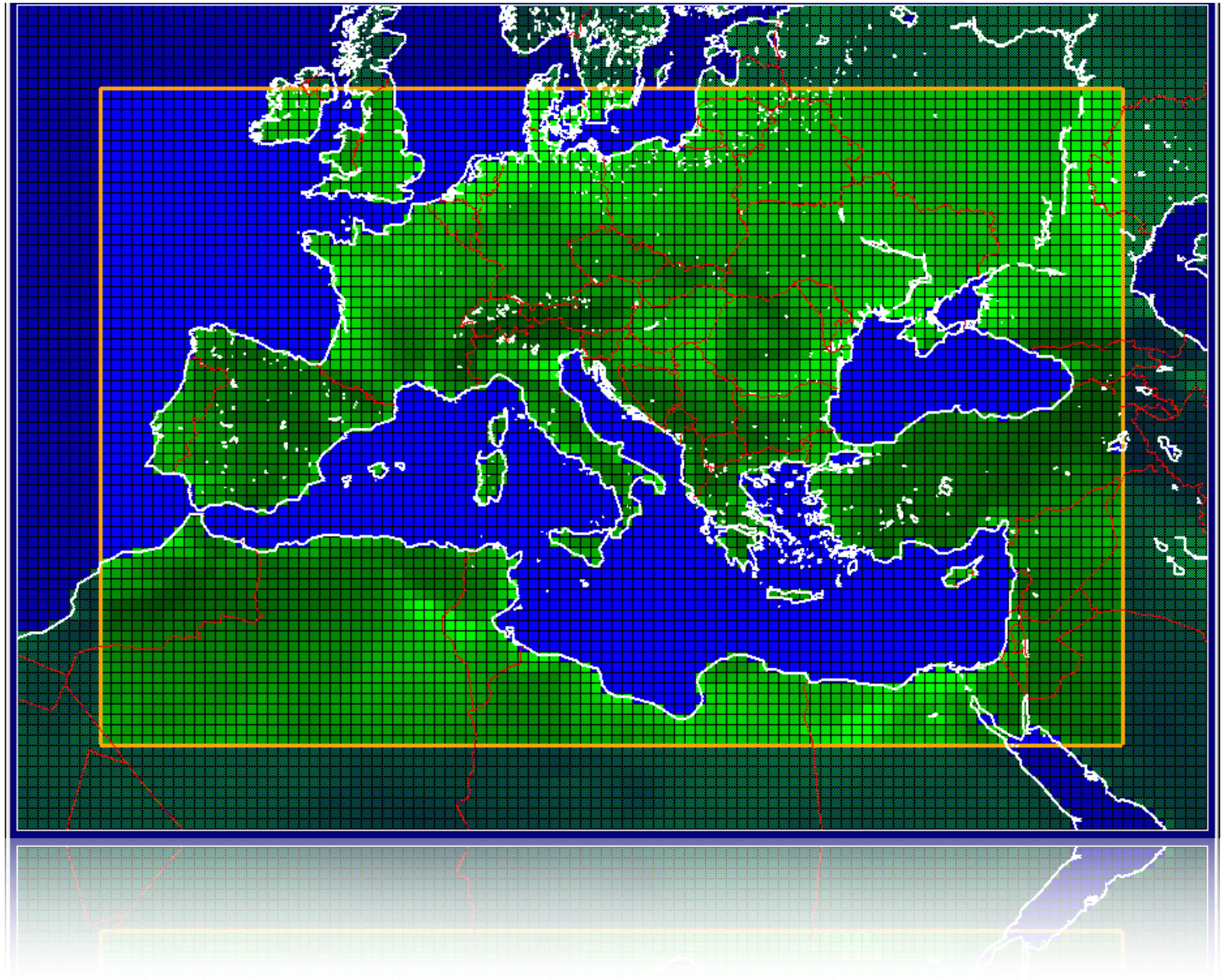


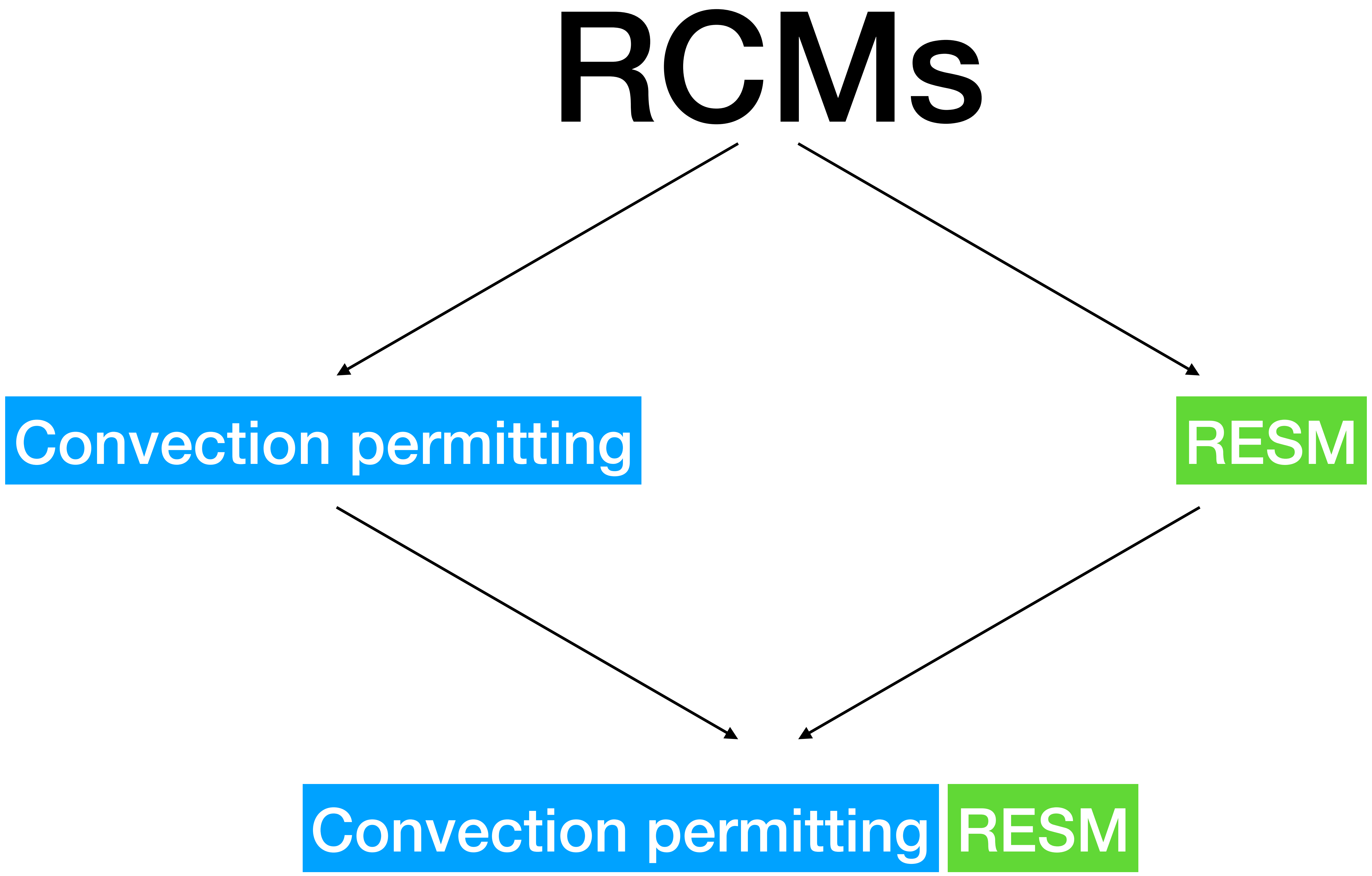


Based on IITM Homogeneous monsoon rainfall dataset (http://www.tropmet.res.in/)

MedCORDEX experiment

- ICTP is participating to the 2° phase of the experiment
- Fully-coupled RCSM with atm-land-river-ocean (RegCM-ES)
- More than 10 institutions involved
- Resolution 0.11° or higher in all the components is recommended
- Evaluation (Hindcast) simulations 1979-2018 using Era-Interim
- Historical and Scenario runs using CMIP5 models (waiting for CMIP6) 1971-2100 (1950-2100 recommended)





Study of Mistral and Bora events

Perspectives

- The powerful instrument implemented for this project, over the South Asia region, will allow to study more in deep the coupled phenomena linked with the two main scales of variability of the Indian Summer Monsoon.

- The implementation of RegCM-ES over regions where we have similar coupled mechanisms (as for example eastern tropical Africa and south-east Asia) will be of great interest, moreover, if we consider the possible impact of the climate warming on that mechanisms, the coupled model is absolutely necessary to perform climate projections over that regions.

- The new Hydrological model CHyM opens the doors to the possibility of simulates a more realistic representation of soil moisture (really important for the triggering of the convection) through the interactions with the land model.

Summary and conclusions

- Our analysis confirm what found in the previous studies, namely the necessity of using a coupled system to simulate the Indian Summer Monsoon variability

- The implementation of the CHyM model leads to large improvements on simulating river discharges over the study area and show an added value in the representation of the salinity over the BoB that is partially hidden by the not accurate representation of the ocean dynamic over the Bay of Bengal (low resolution, kpp vertical mixing scheme

- RegCM-ES allows to study the complex coupled phenomena that are related to the large scale forcing (ENSO) on the ISMR. The understanding of these phenomena may leads to an increase of predictability of the monsoon with a very high impact on socio-economic aspects of the region

- The nature of the increased predictability of the monsoon intensity during the last decades is not fully understood and further studies are needed

Bibliography

- Di Sante, F., Coppola, E., Farneti, R., & Giorgi, F. (2019). Indian Summer Monsoon as simulated by the regional earth system model RegCM-ES: the role of local air–sea interaction. Climate Dynamics, 1-20.
- Di Sante, F. and et al. (2019). One-year lead-time predictability of indian summer monsoon due to delayed enso impact. Nature Geoscience (In preparation).
- Giorgi, F. and Anyah, R. (2012). The road towards regcm4. Climate Research, 52:3–6.
- Izumo, T., Montégut, C. B., Luo, J.-J., Behera, S. K., Masson, S., and Yamagata, T. (2008). The role of the western arabian sea upwelling in indian monsoon rainfall variability. Journal of Climate, 21(21):5603–5623.
- Kucharski, F., Bracco, A., Yoo, J., and Molteni, F. (2007). Low-frequency variability of the indian monsoon–enso relationship and the tropical atlantic: the weakening of the 1980s and 1990s. Journal of Climate, 20(16):4255–4266.
- Xie, S.-P., Hu, K., Hafner, J., Tokinaga, H., Du, Y., Huang, G., and Sampe, T. (2009). Indian ocean capacitor effect on indo–western pacific climate during the summer following el niño. Journal of Climate, 22(3):730–747.
- M.Reale, F. Giorgi, C. Solidoro, V. Di Biagio, F. Di Sante, L. Mariotti, R. Farneti, G. Sannino, The Regional Earth System Model RegCM-ES: Evaluation of the Mediterranean climate and marine biogeochemistry. In submission in revised form to Journal of Advances in Modeling Earth Systems.
- Sitz, L. E., F. Sante, R. Farneti, R. Fuentes-Franco, E. Coppola, L. Mariotti, M. Reale, et al. 2017. "Description and Evaluation of the Earth System Regional Climate Model (RegCM– ES)." Journal of Advances in Modeling Earth Systems. doi:10.1002/2017MS000933.
- Surenkok, G. and Turuncoglu, U. U.: Investigating the Role of Atmosphere–Wave Interaction in the Mediterranean Sea using coupled climate model (RegESM), Geophys. Res. Abstr., 17, EGU2015-3644, EGU General Assembly 2015, Vienna, Austria, 2015.
- Turuncoglu, U. U., G. Giuliani, N. Elguindi, and F. Giorgi. 2013. "Modeling the Caspian Sea and Its Catchment Area Using a Coupled Regional Atmosphere–Ocean Model (RegCM– ROMS): Model Design and Preliminary Results." Geoscientific Model Development 6: 283–299.
- Turuncoglu, U. U. and Sannino, G.: Validation of newly designed regional earth system model (RegESM) for Mediterranean Basin, Clim. Dynam., 48, 2919–2947, 2017.