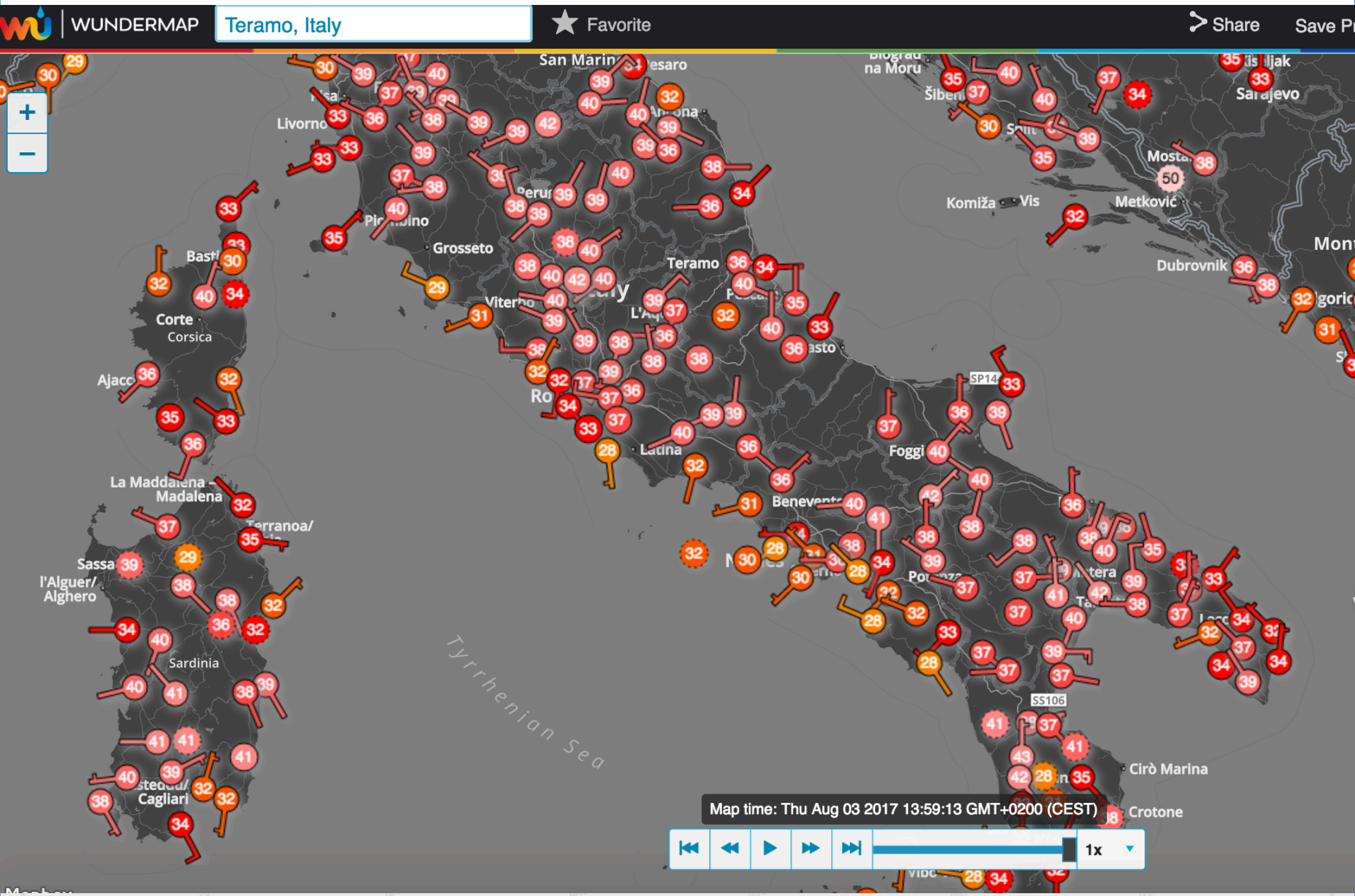
Assessing the role of local air-sea interaction over the South Asia region in simulating the Indian Summer Monsoon (ISM) using the new earth system model RegCM-ES

Targeted Training Activity (TTA) 2017: Monsoons in a Changing Climate (smr 3170)

03/08/2017

Fabio Di Sante, Erika Coppola, Riccardo Farneti, Fred Kucharski and Filippo Giorgi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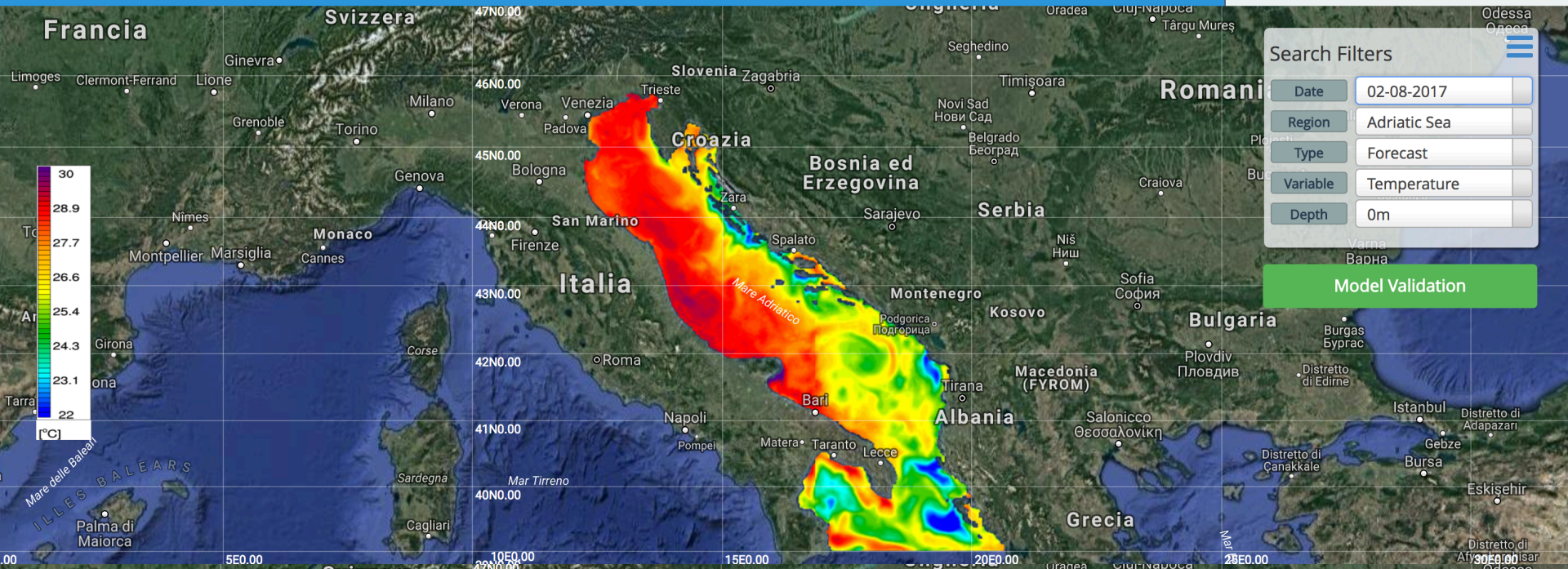
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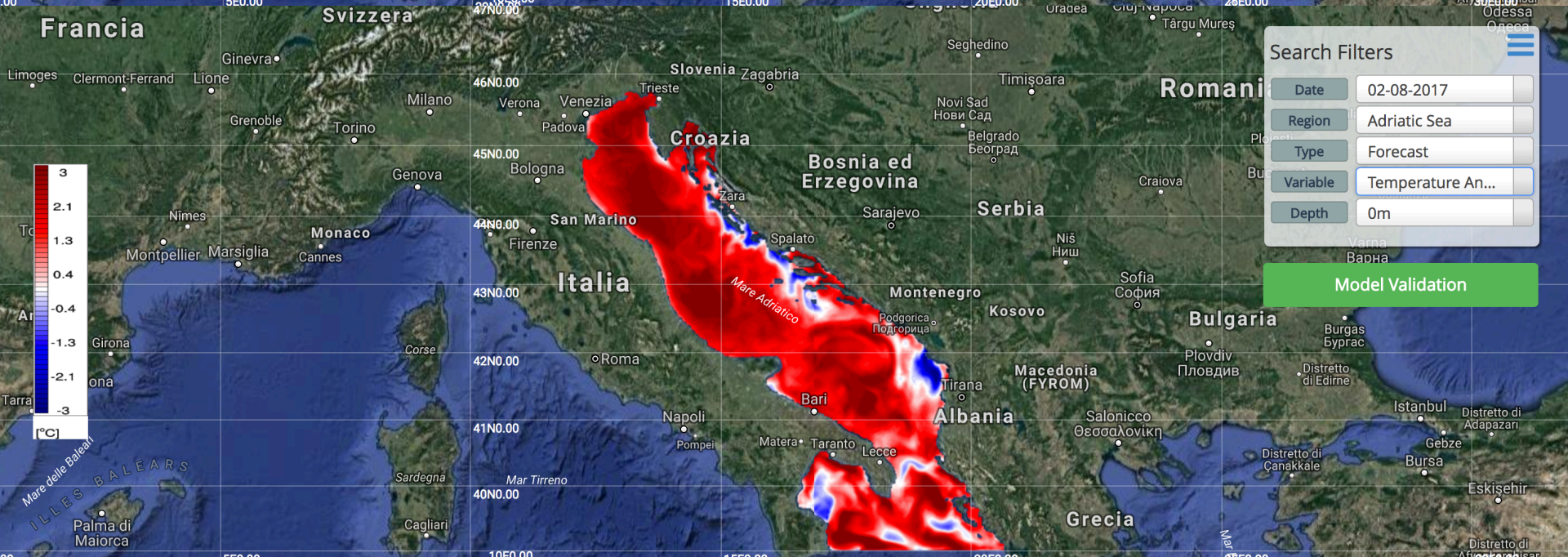
Mare delle Baleari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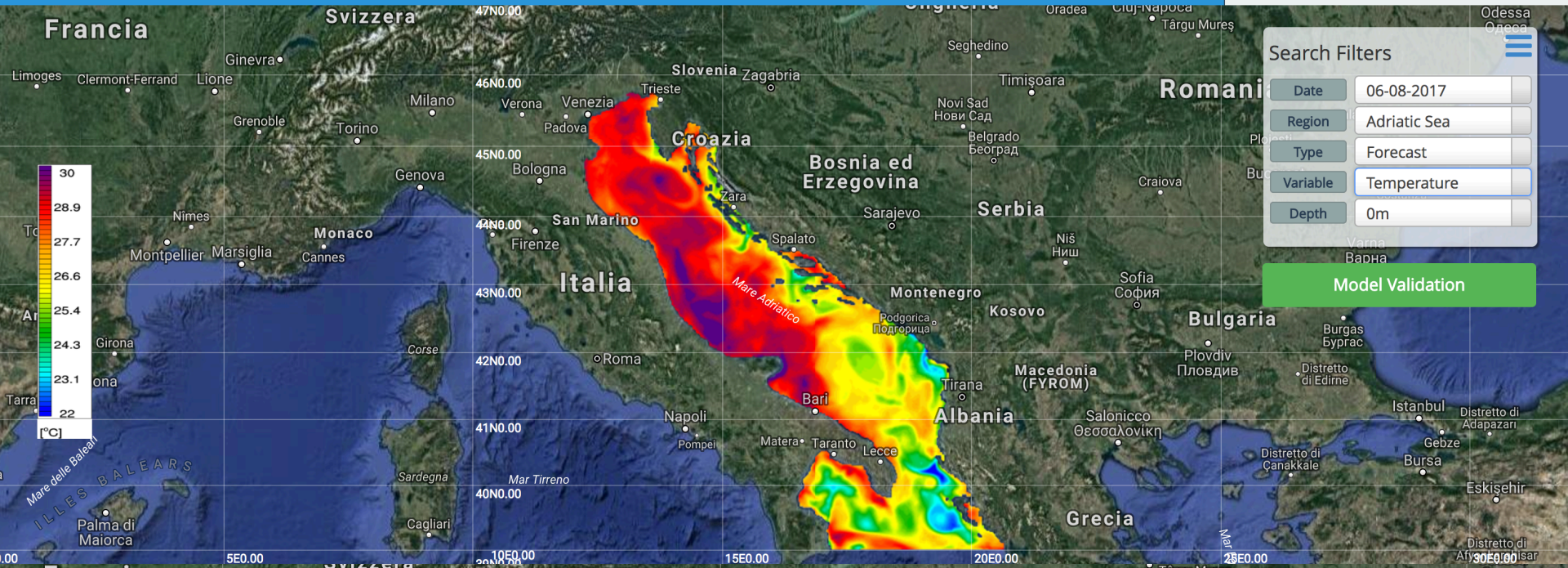
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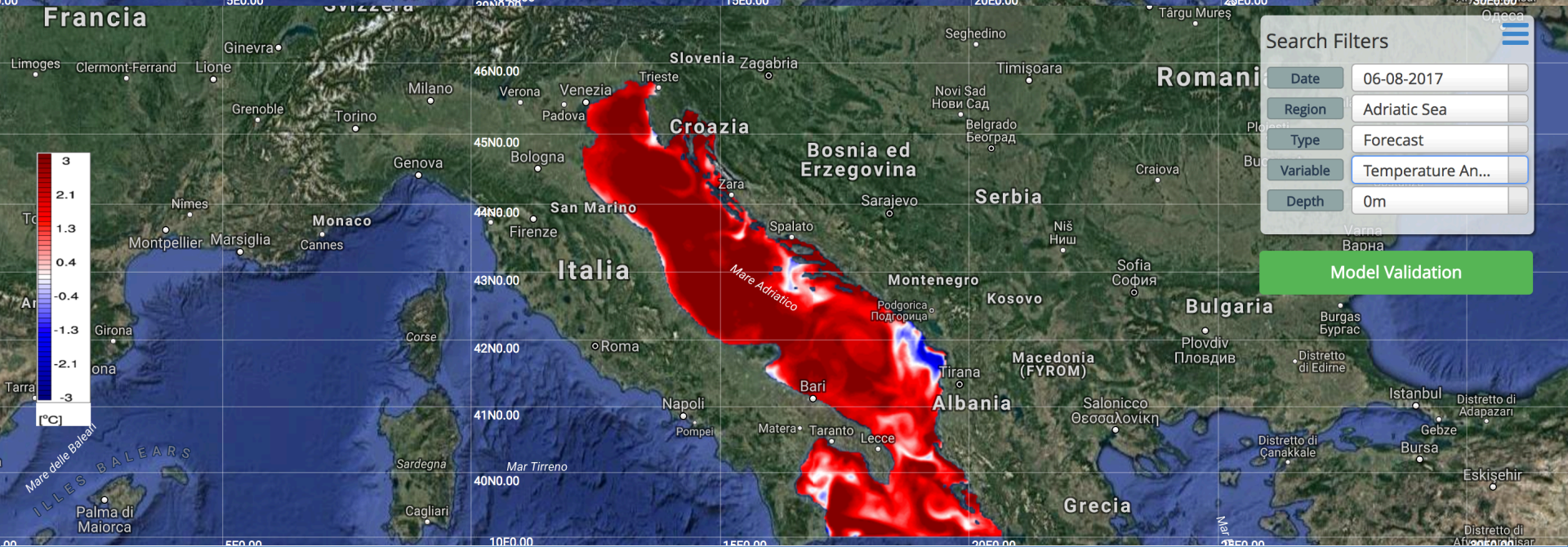
Sardegna
Corse
Mare delle Baleari
ILLES BALEARS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Serbia
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Kosovo
Albania
Macedonia (FYROM)
Bulgaria
Grecia
Mar Tirreno
Sardegna
Corse
Mare delle Baleari
ILLES BALEARS

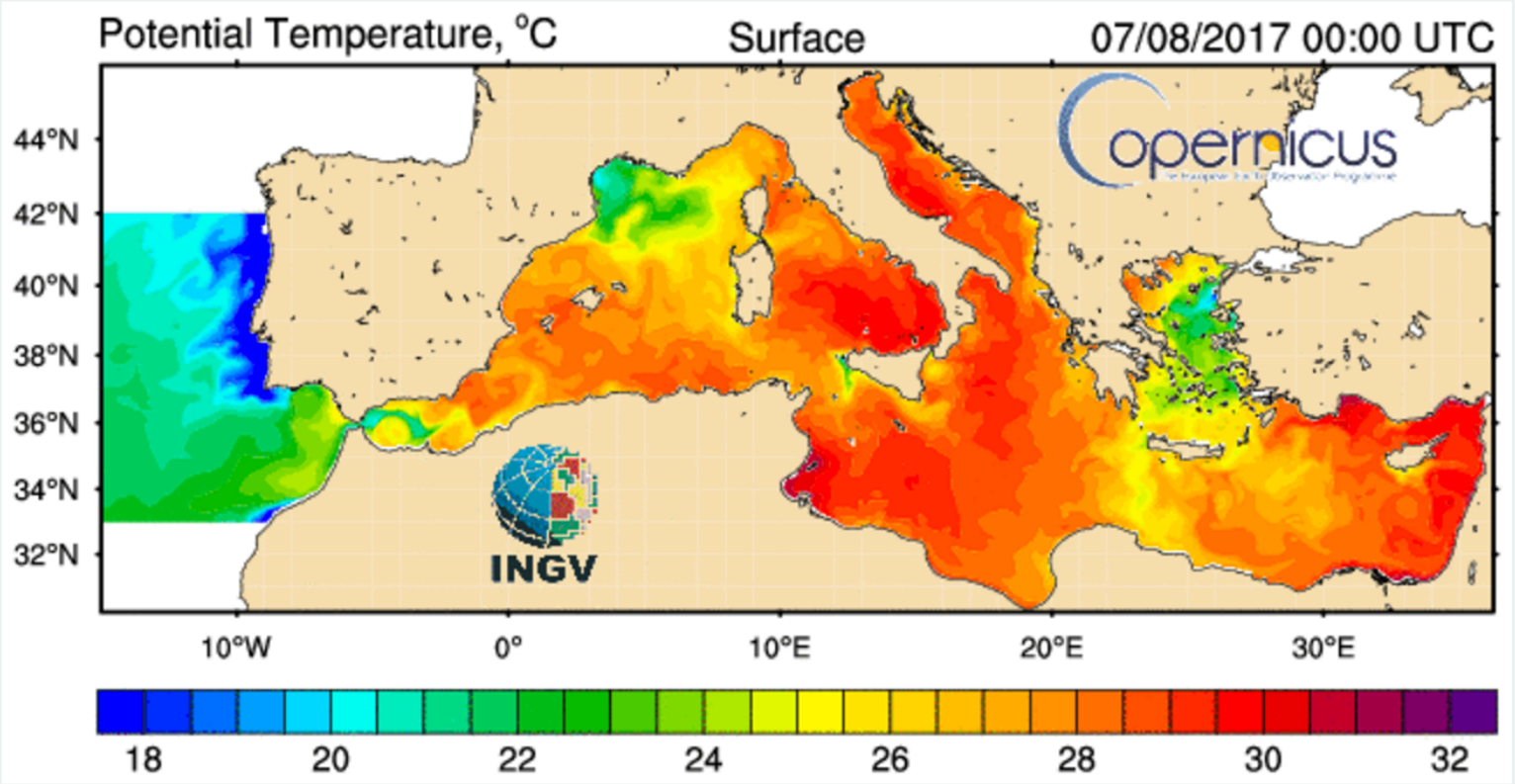
MFS-Copernicus Forecast

Data | Volume Transports

Date: 2017-08-07 00:00

Variable: Potential Temperature

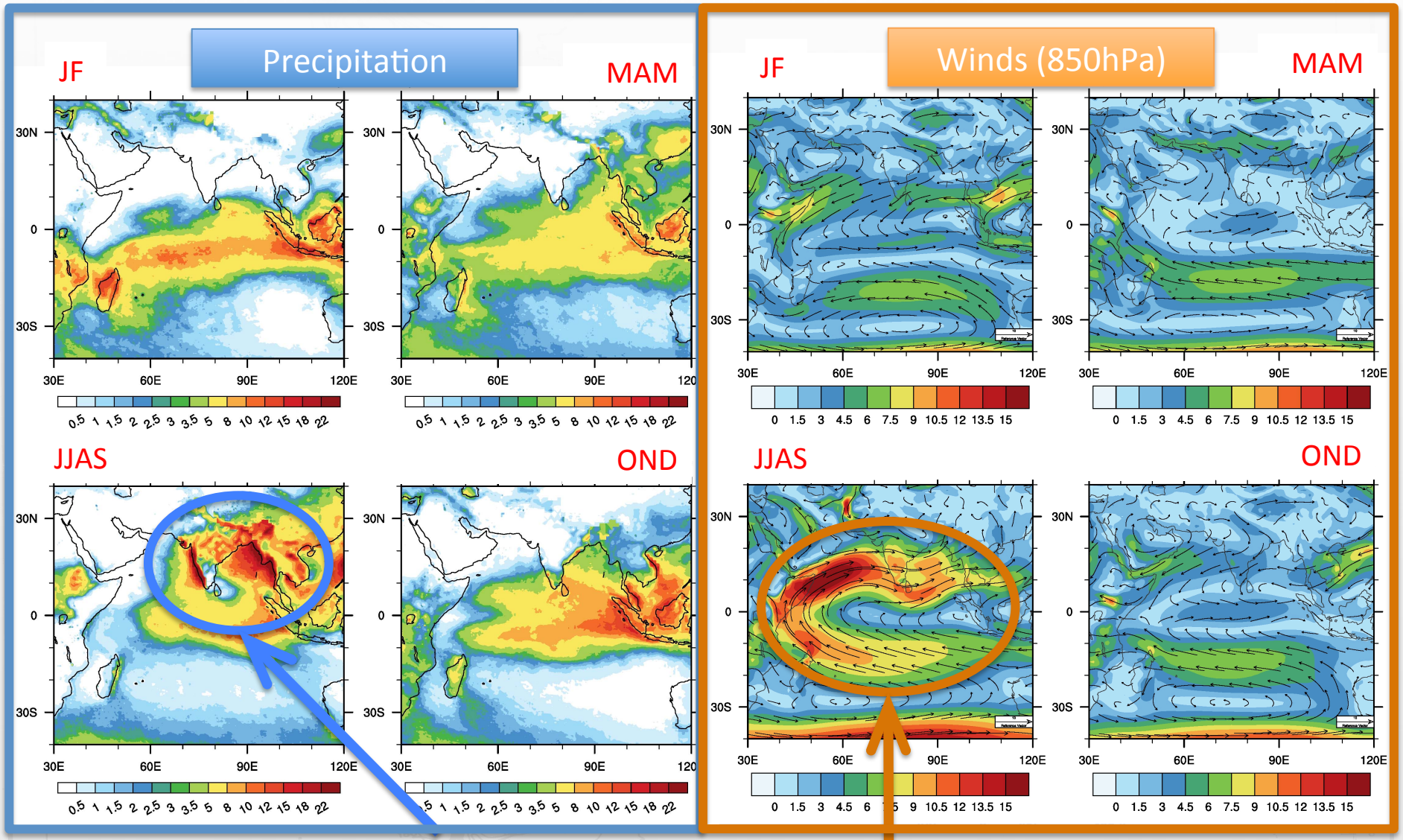
Region: Mediterranean



The Indian Summer Monsoon (ISM)

- Climatology
- Intraseasonal oscillations (ISV)
- Interannual variability (IAV)

Climatology of the ISM



Large Increase in precipitation and runoff

Low Level Jet

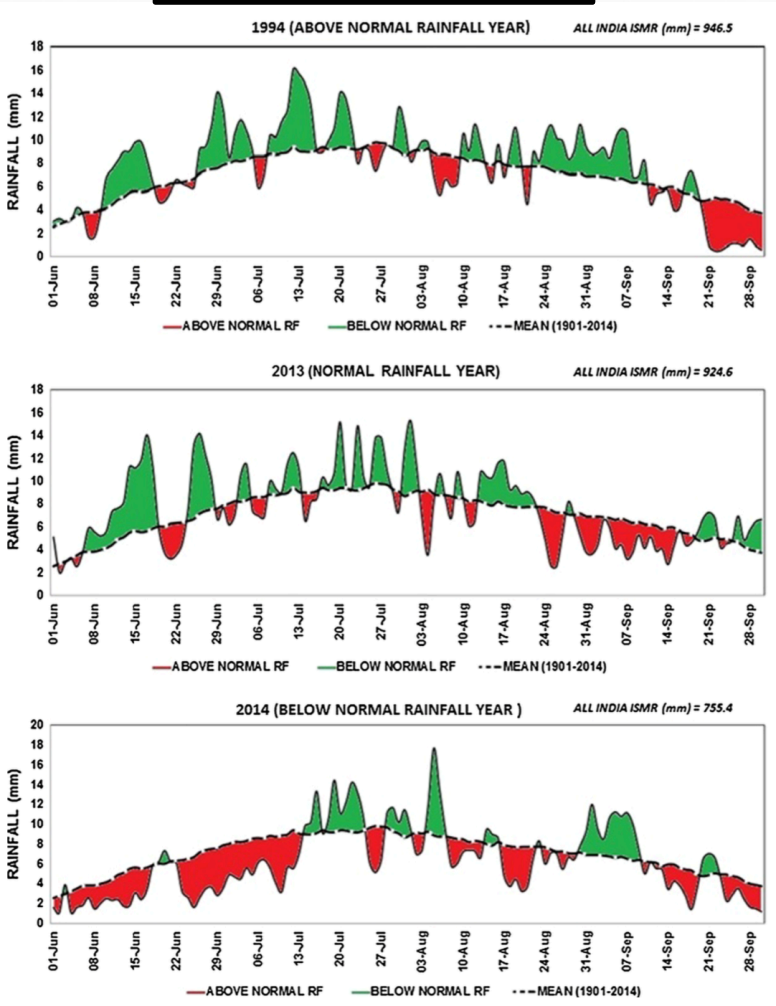
Intraseasonal oscillations of the ISM

Rainfall

1994

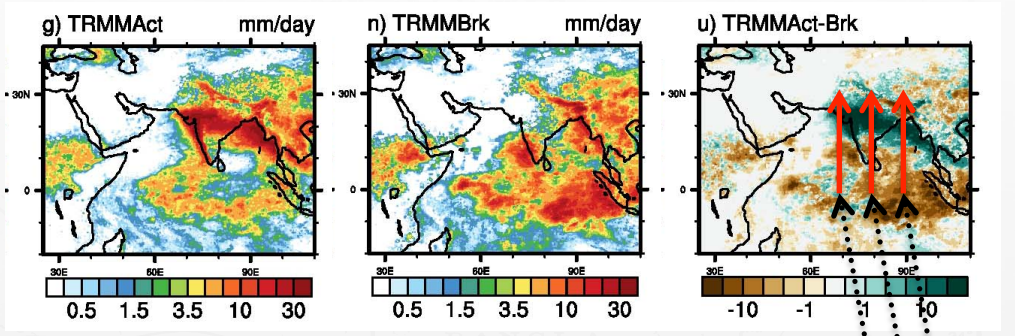
2013

2014

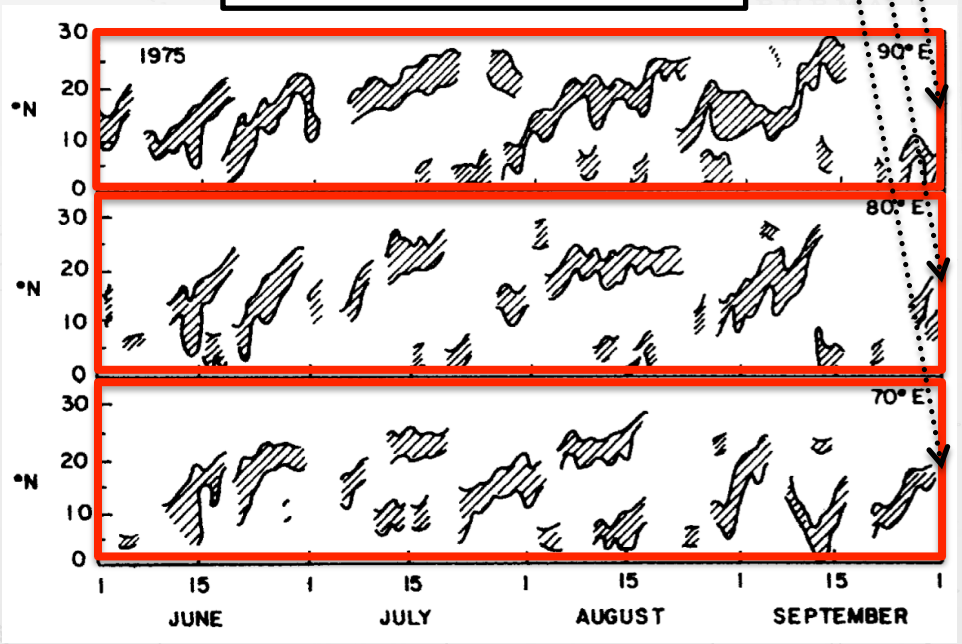


Pai et al. [2016]

Composite of break/active



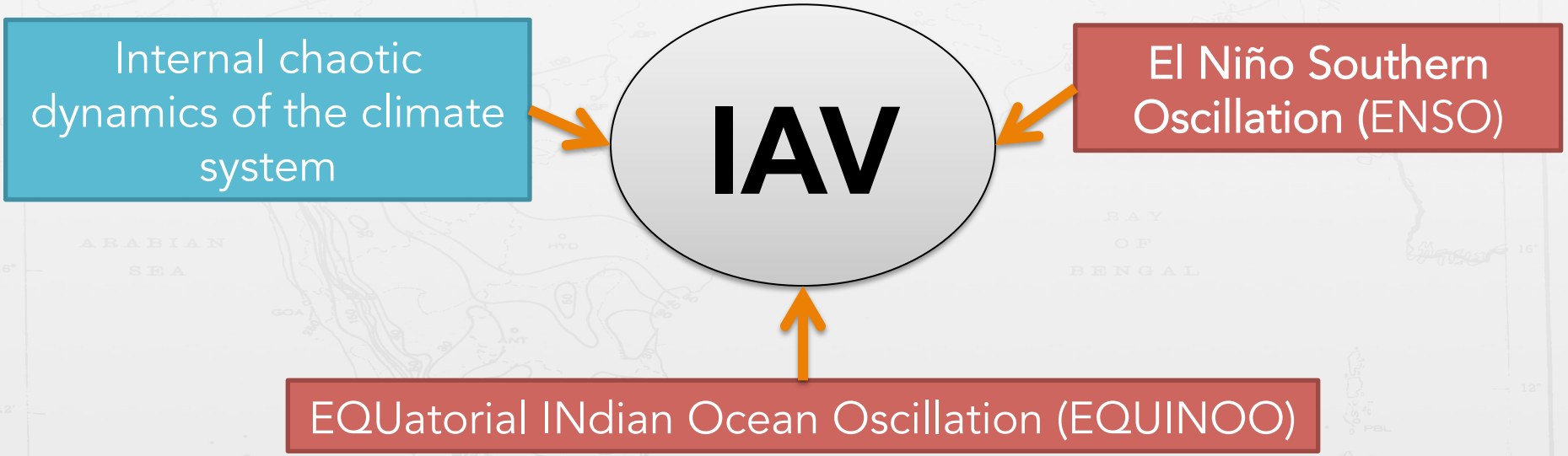
Maximum cloud zone



Goswami [1994]

Interannual variability of the ISM

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



Scientific objectives

- Develop an instrument that is able to realistically reproduce the mean state of the ISM and variability on its two main scales: the intraseasonal and the interannual (RegCM-ES);

- Improve the hydrological cycle simulation in the coupled system implementing a new ad-hoc developed hydrological model important for a more realistic freshwater discharge into the ocean over the BoB;

- Use the developed instrument to study the main forcings that influence the variability of the ISM;

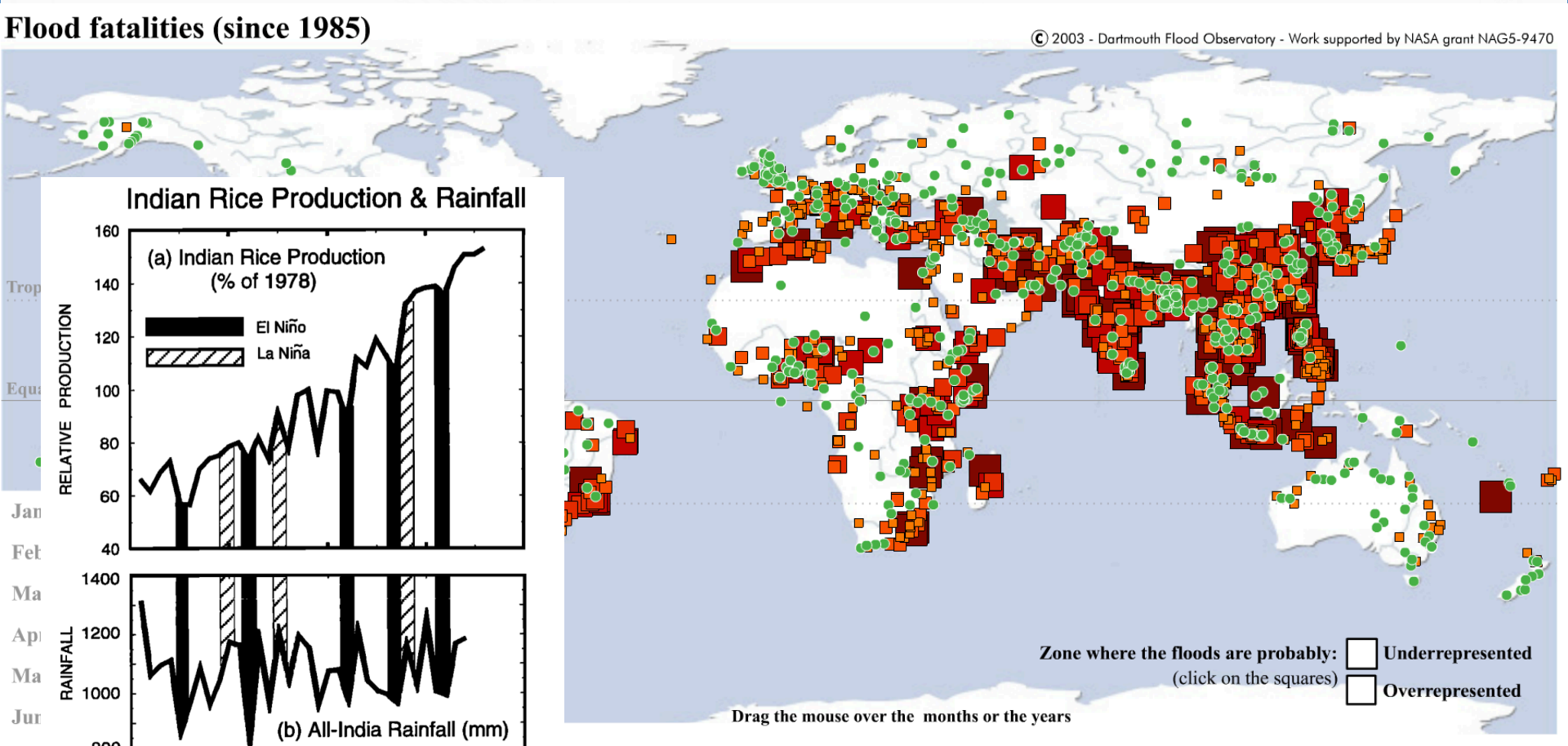
Motivations

- To correctly simulate the interannual and the intraseasonal oscillation (ISO) of the Indian monsoon it is necessary to use a coupled atmosphere-ocean model as supported by different studies (Fu et. al 2002 ; Fu et al. 2007; Ratnam et al. 2008; Seo et al. 2009; Samala et al. 2013)

- Precipitation and river discharge well exceed the evaporation in the Bay of Bengal making this area the region with more fresh water in the Indian Ocean

- Socio-economic implications

Motivations: Socio-Economic implications



Webster et Al 1999

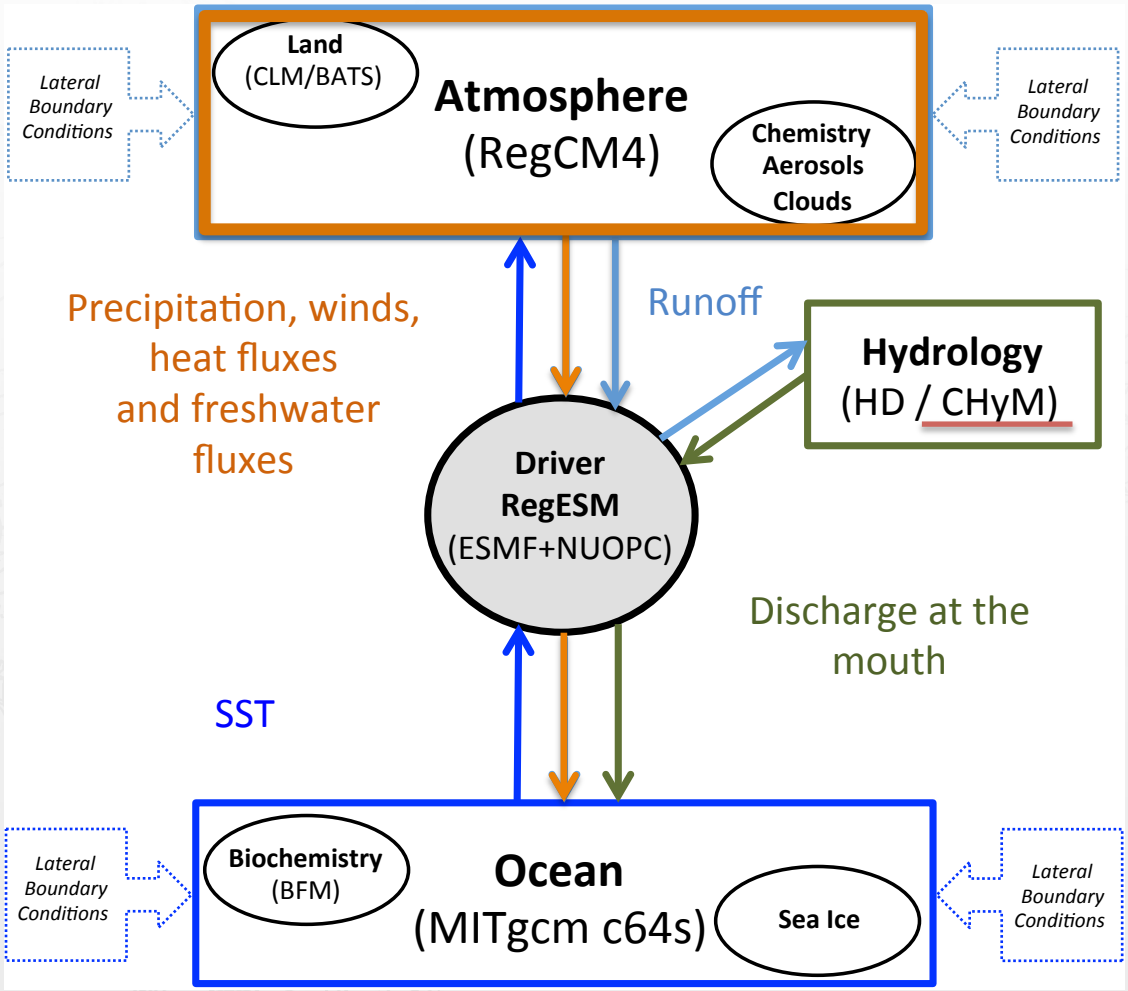
http://www.dartmouth.edu/~floods/archiveatlas/floodfatalities.htm

General 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)

General description of RegCM-ES



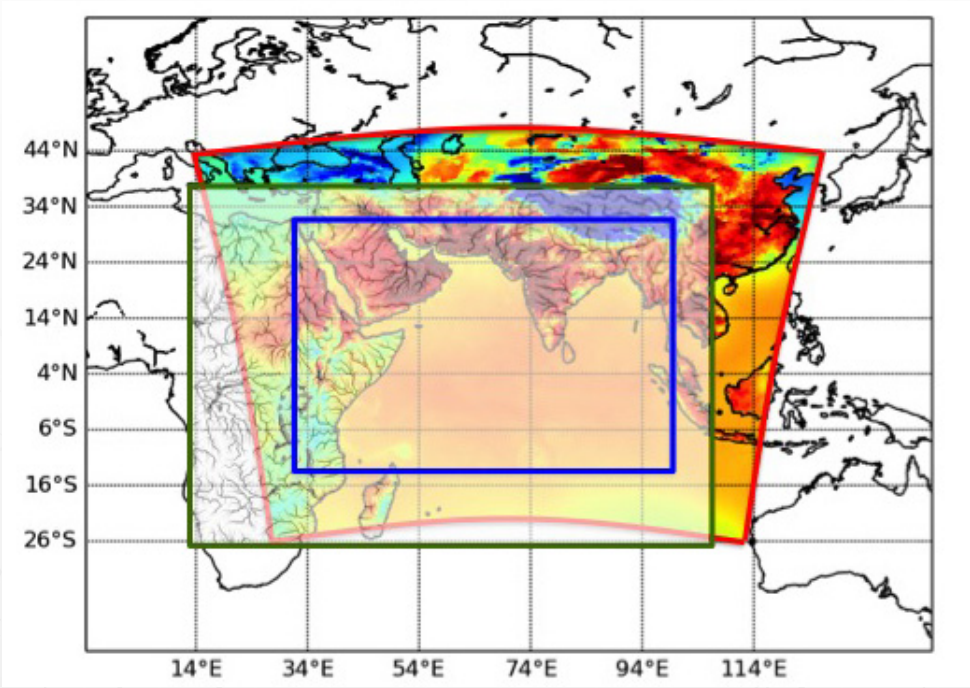
Sitz, L. E., **Di Sante, F.**, Farneti, R., Fuentes-Franco, R., Coppola, E., Mariotti, L., Reale, M., Sannino, G., Barreiro, M., Nogherotto, R., Giuliani, G., Graffino, G., Solidoro, C., Cossarini, C., and Giorgi, F. (2017). Description and evaluation of the eart system regional climate model (regcm-es).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

South Asia experimental design

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°

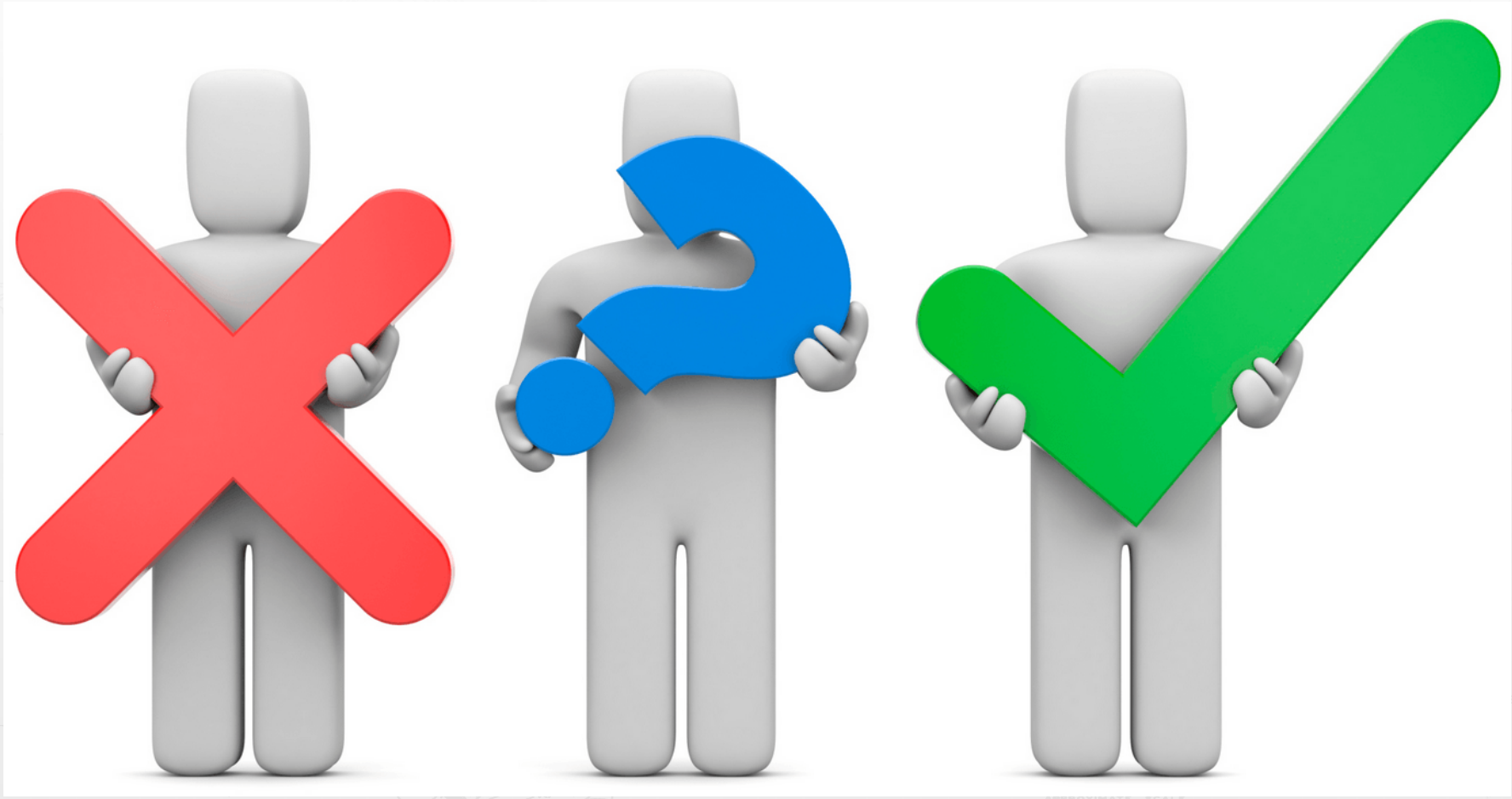
HYD:
Horizontal spatial resolution 0.5° HD and 0.12° CHyM



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

29 years simulated (1979-2007)

Results



Results

- Ocean Validation
- Freshwater validation
- Precipitation Climatology
- Intraseasonal oscillations (ISV)
- Interannual variability (IAV)

Results: Ocean validation

BoB warm pool

Somali current

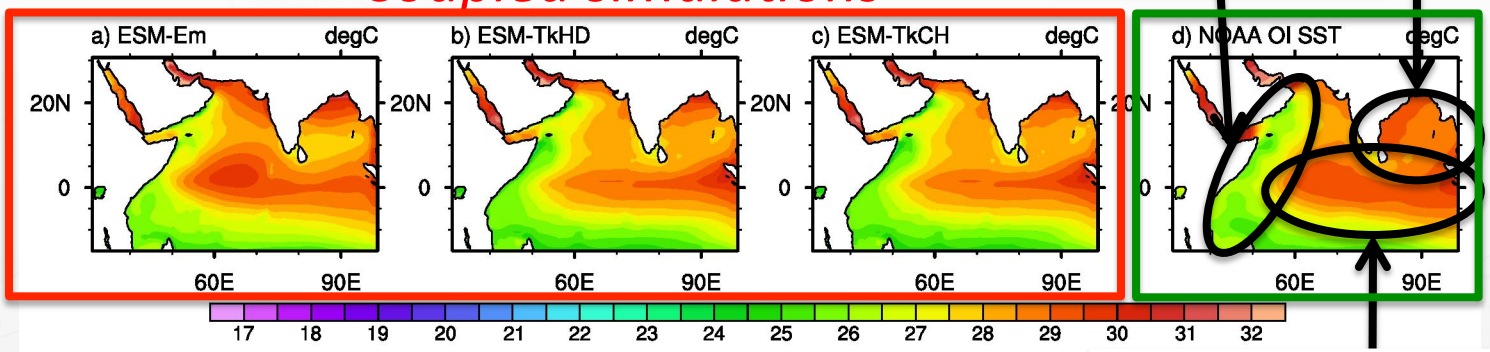
Equatorial warm pool

Very low salinity

Very high salinity

Temperature

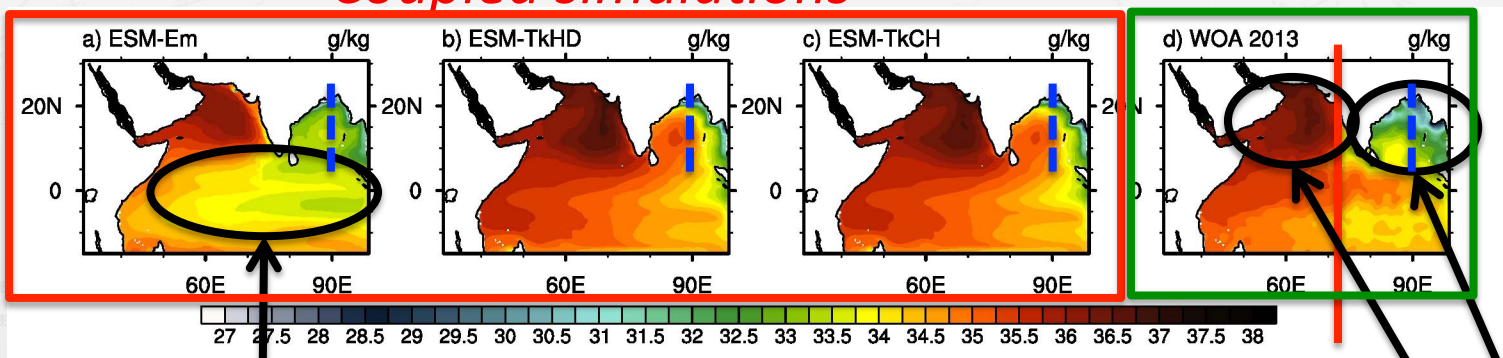
Coupled simulations



Observations

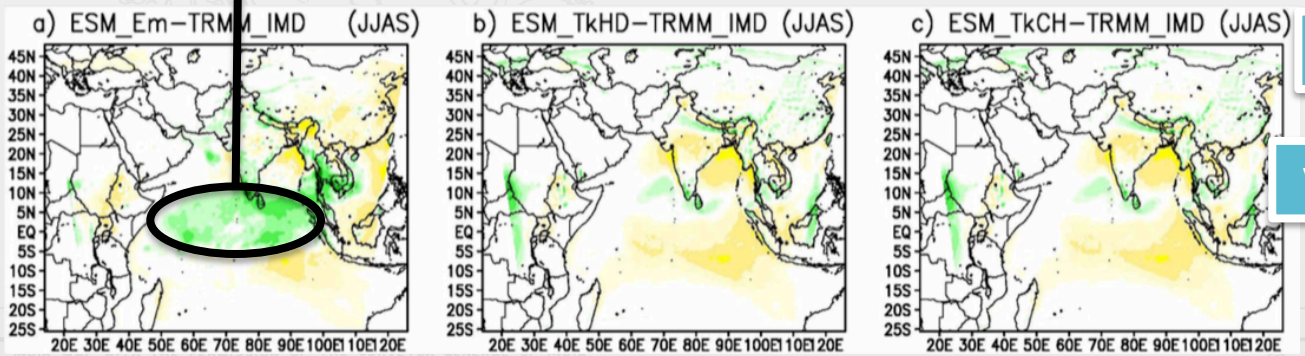
Salinity

Coupled simulations



Observations

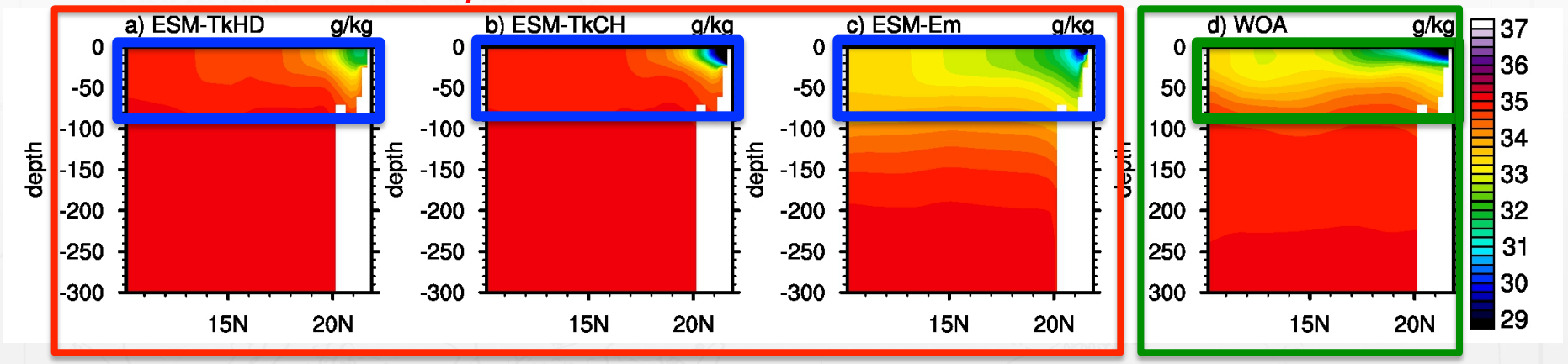
Bias of precipitation



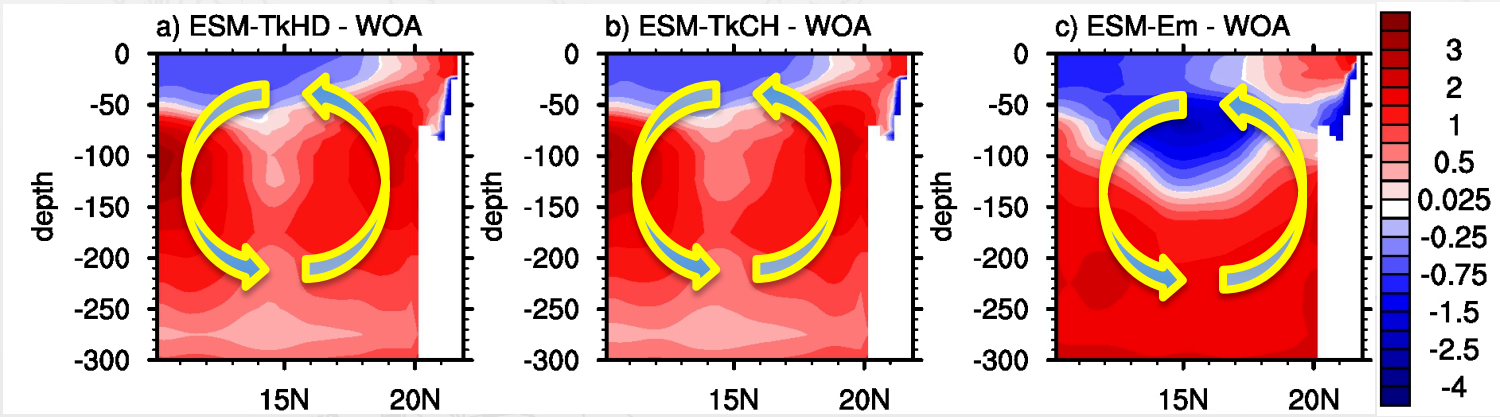
Results: Ocean validation

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

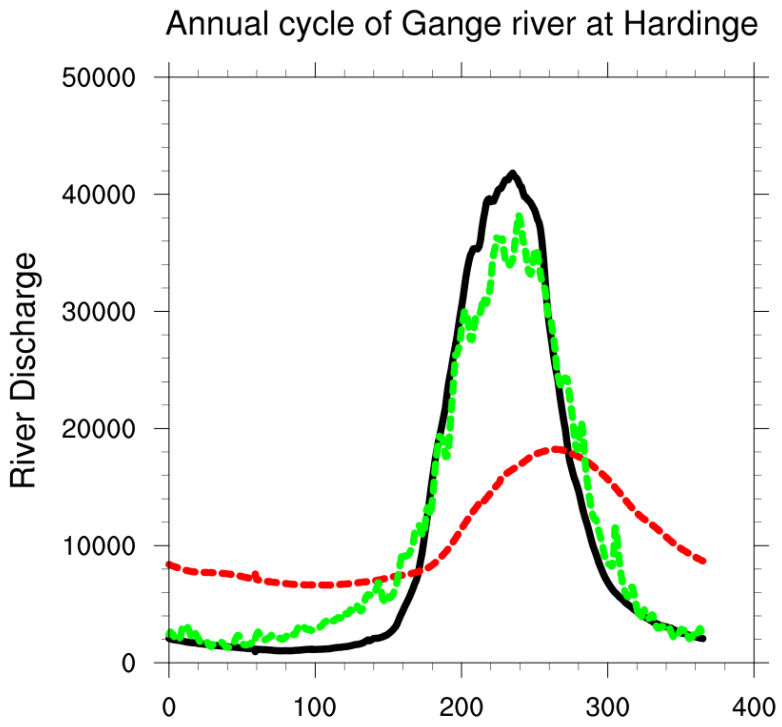
Coupled simulations *Observations*

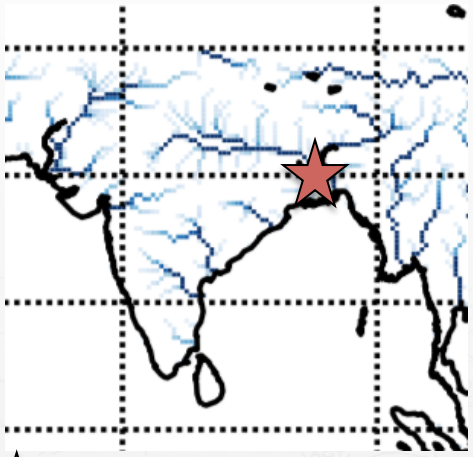


Bias of Temperature transect at 90°E (in the middle of BoB)



Results: freshwater validation





Hardinge station

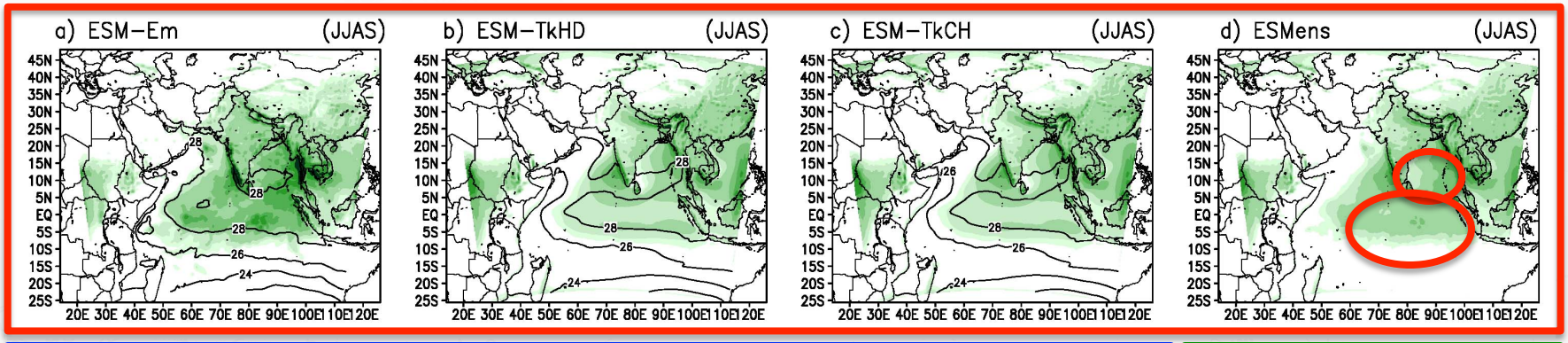
Observations

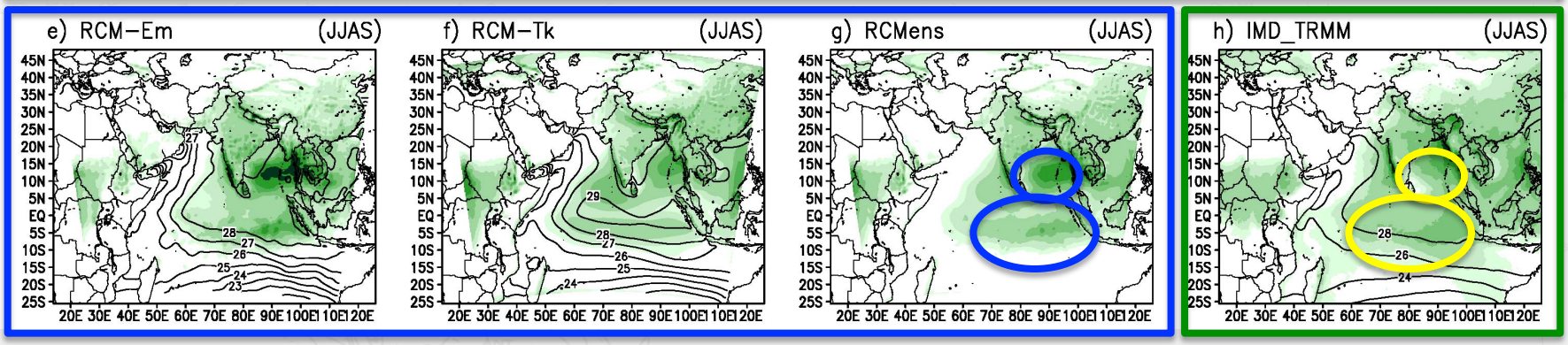
CHyM model

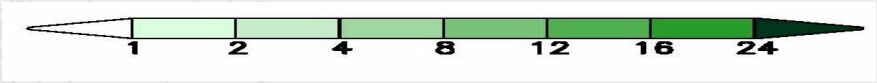
HD model

Results: precipitation climatology

ESMs experiments





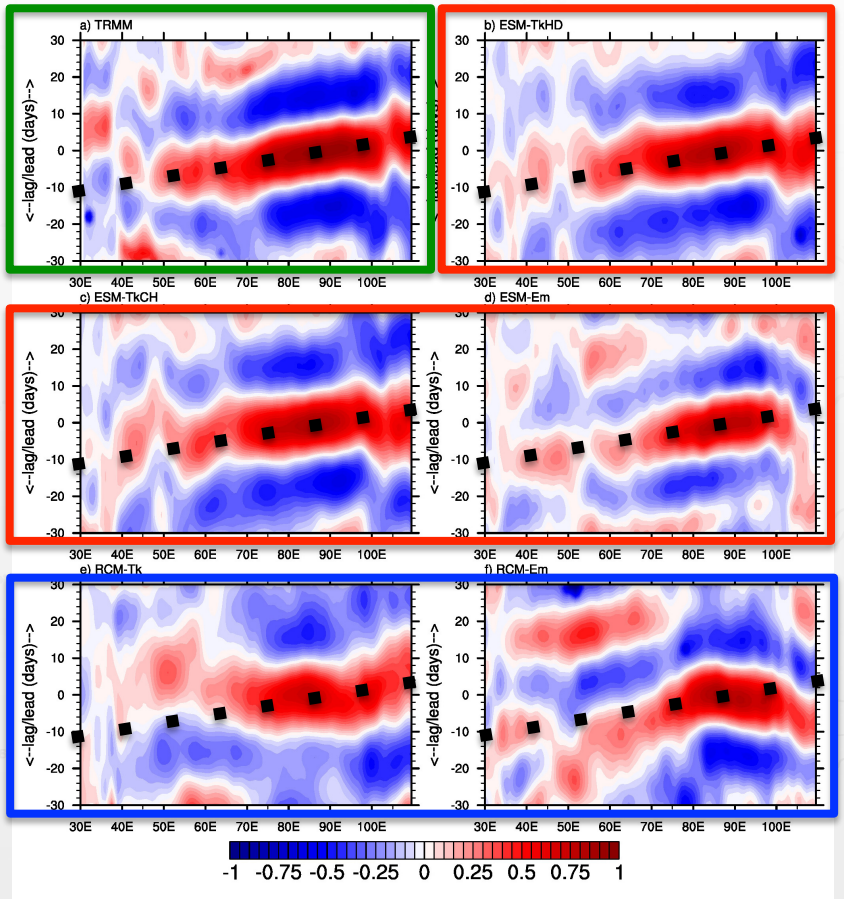


RCMs experiments

Observations

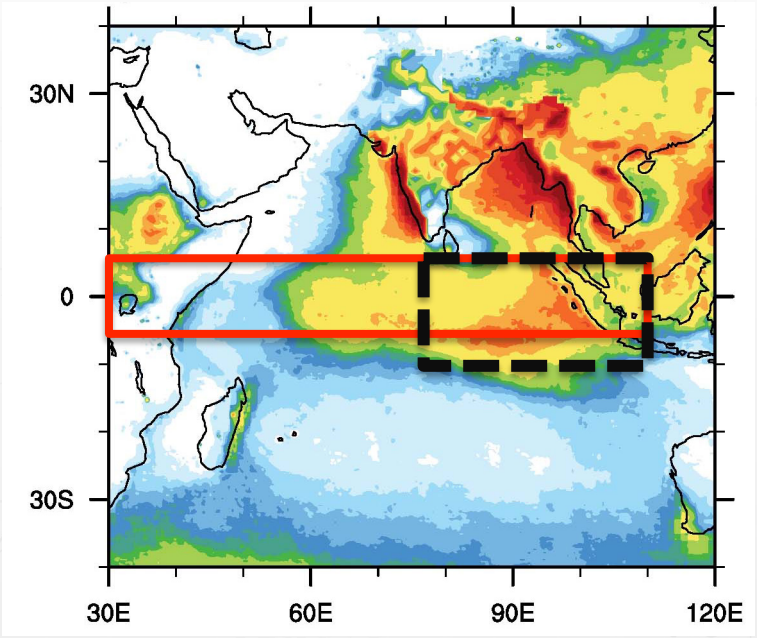
Results: intraseasonal oscillations

OBS



ESMs

RCMs

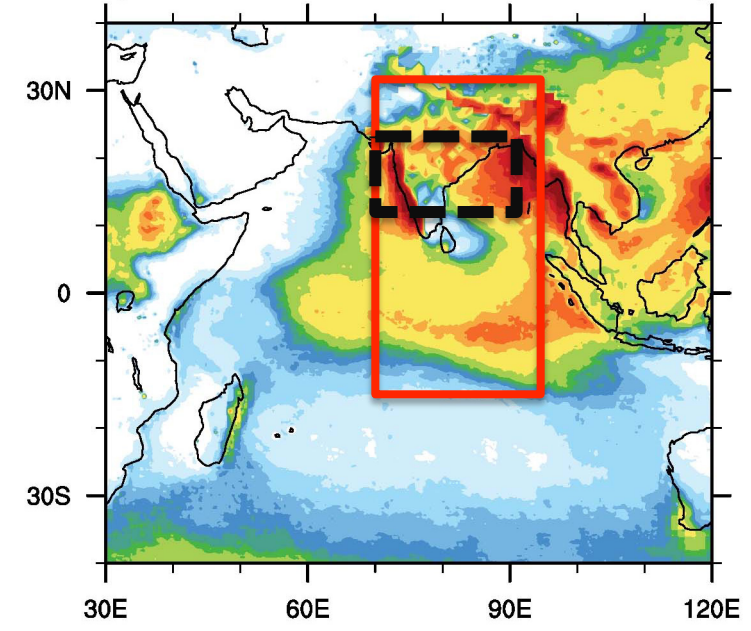


Lat average vs box average

Eastward propagation of rainfall

Sabeerali et al. [2013]

Results: intraseasonal oscillations

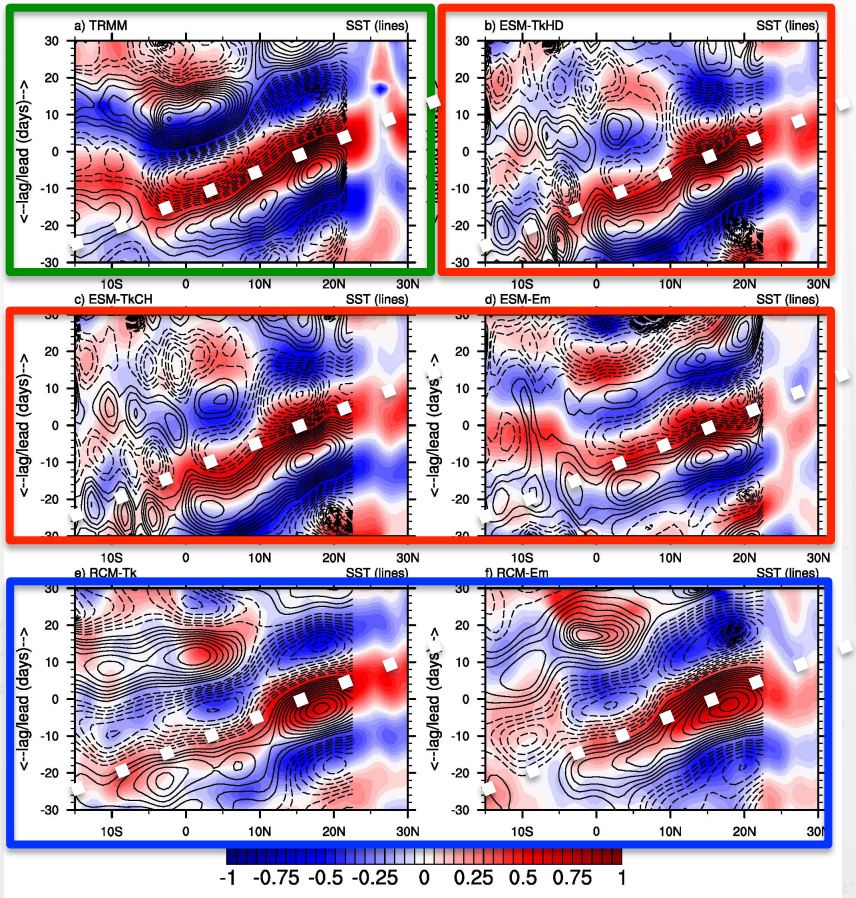


Lon average vs box average

OBS

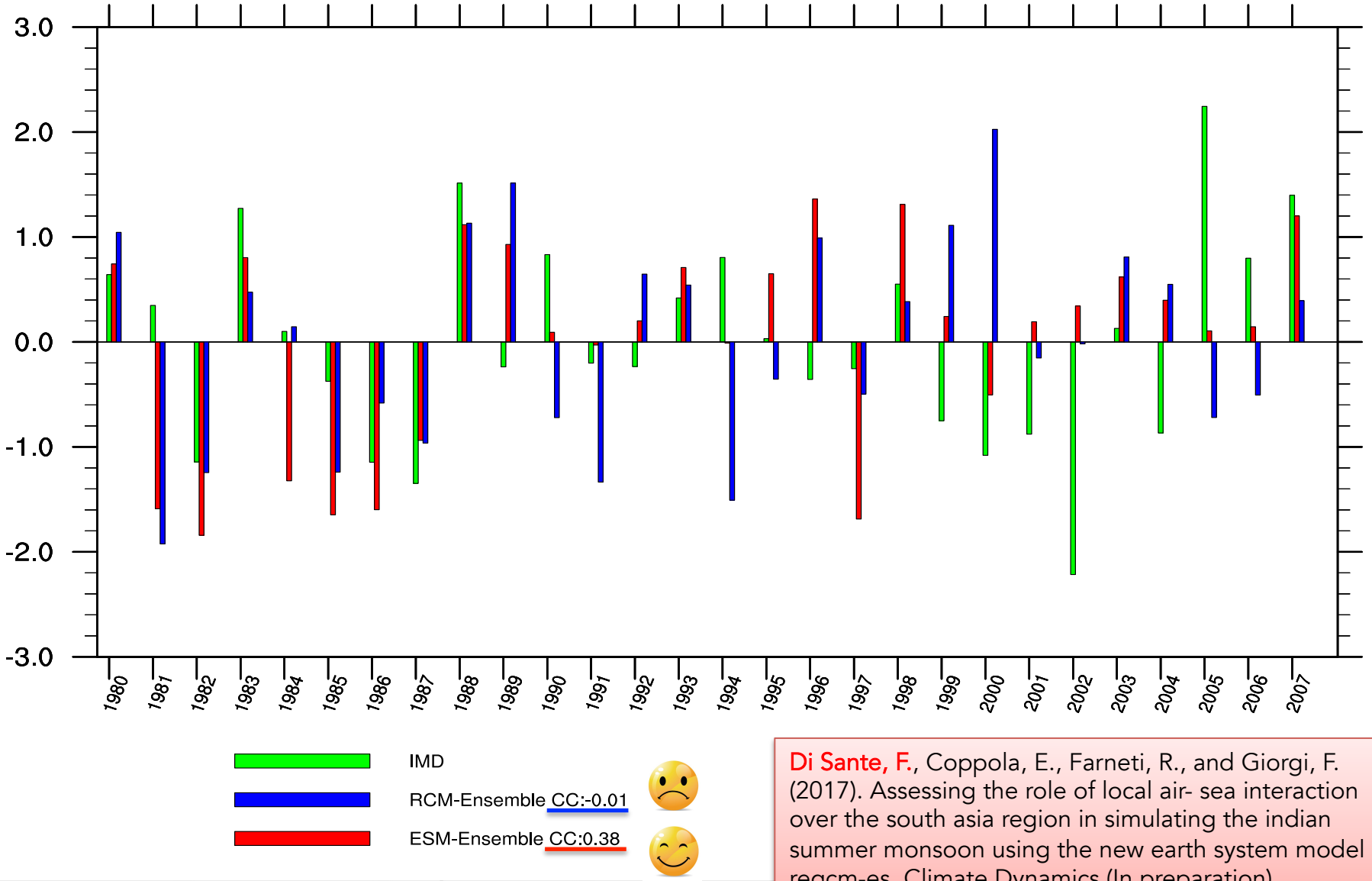
ESMs

RCMs



Northward propagation of rainfall

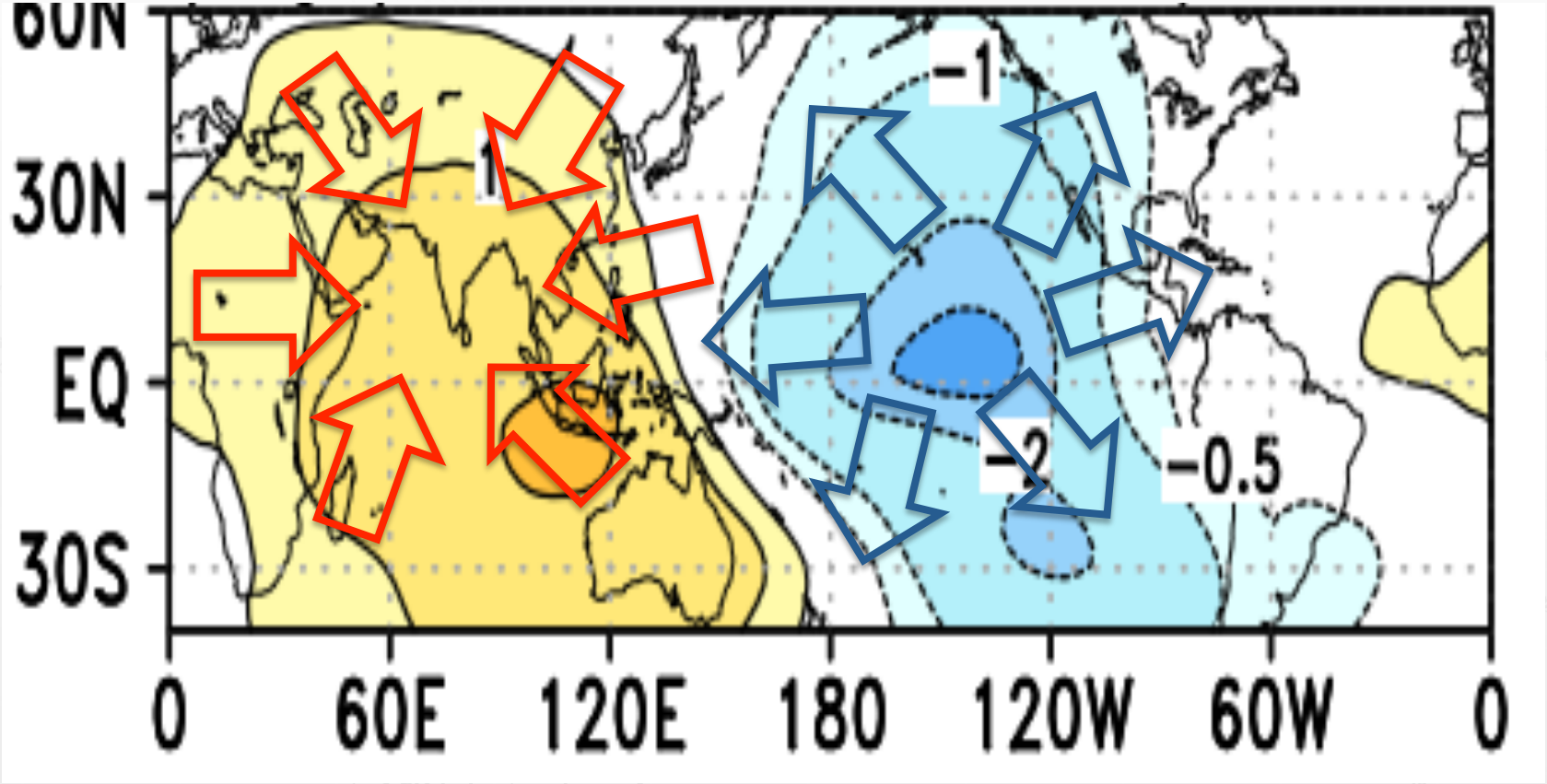
Results: interannual variability



Di Sante, F., Coppola, E., Farneti, R., and Giorgi, F. (2017). Assessing the role of local air- sea interaction over the south asia region in simulating the indian summer monsoon using the new earth system model regcm-es. Climate Dynamics (In preparation).

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

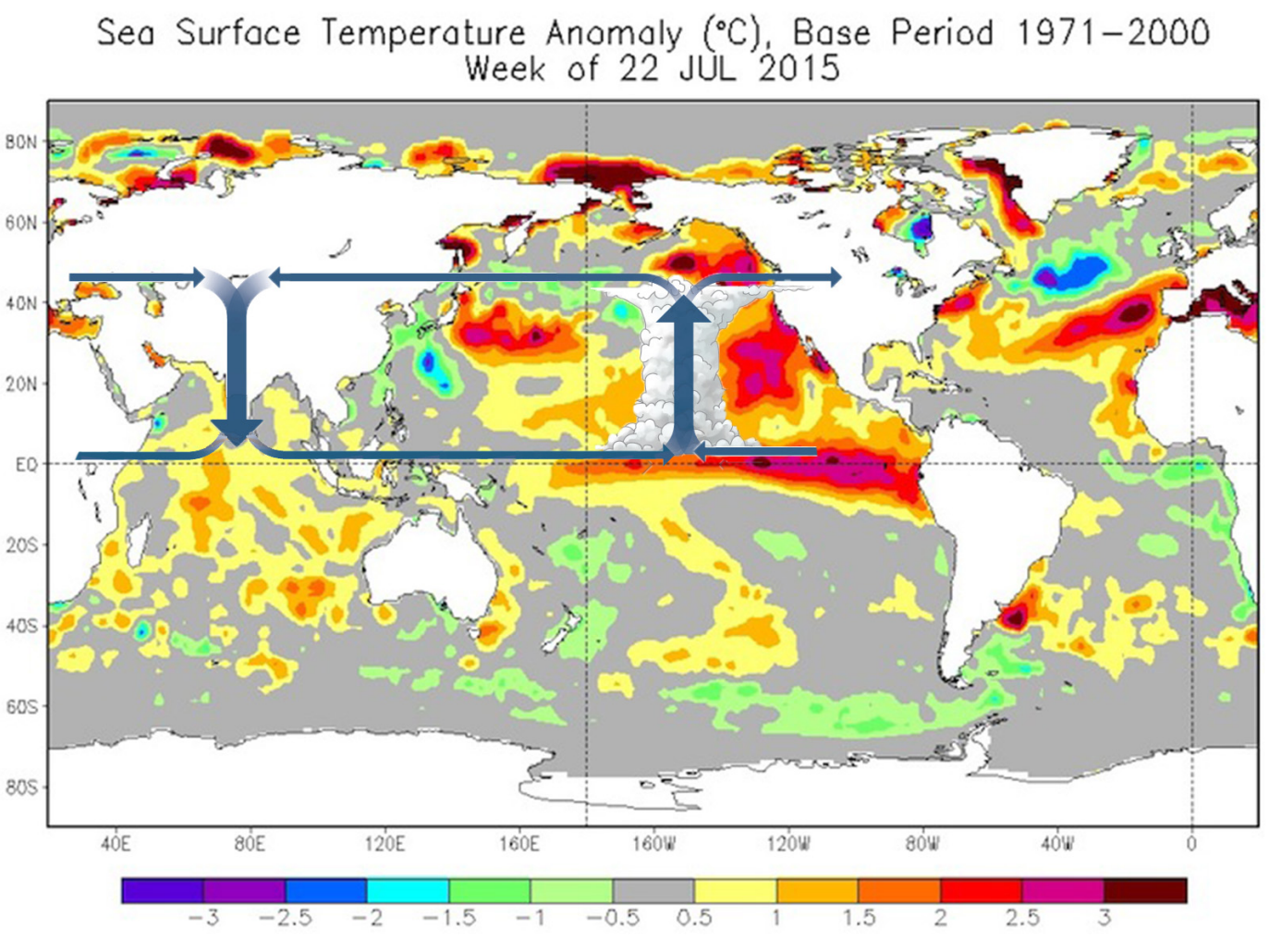
Regression maps (OBS) of Niño3.4 (JJAS) onto 200 hPa velocity potential



Thanks to Fred Kucharski for the Figure

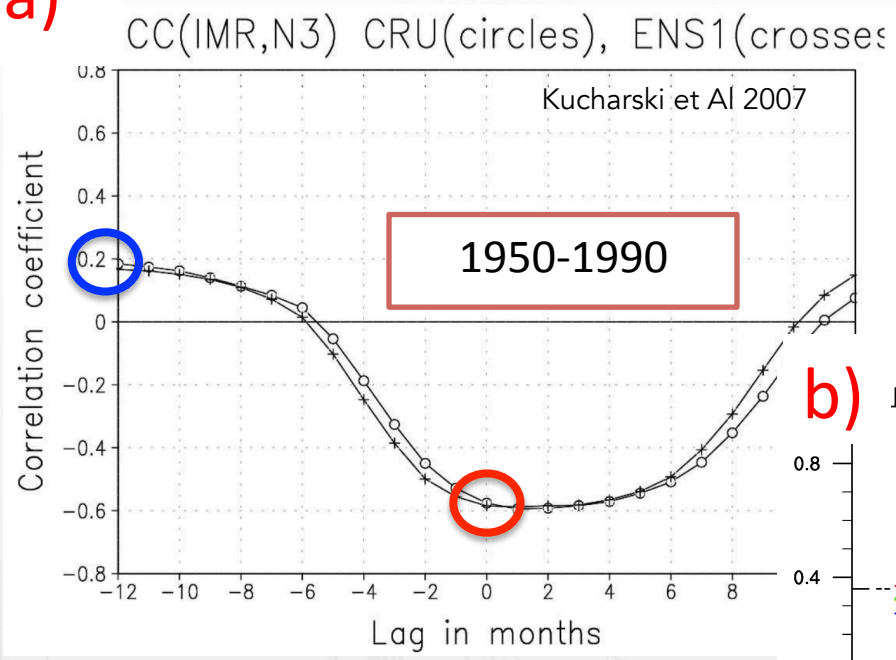
Results: ENSO forcing on ISM (direct effect during JJAS)

Atmospheric teleconnection between ENSO and ISMR

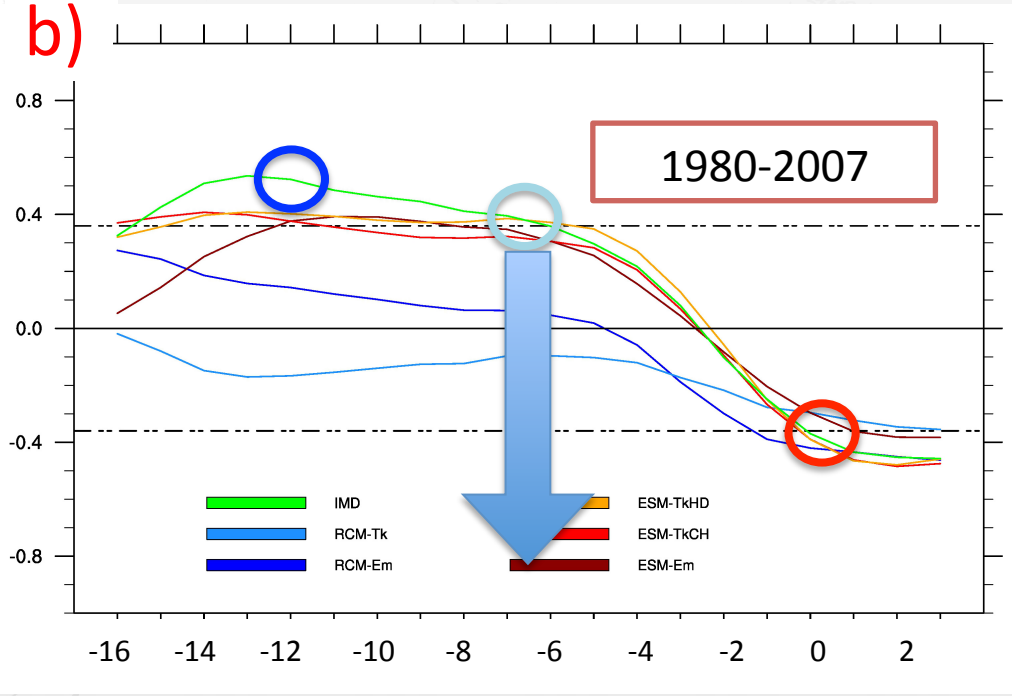


Results: ENSO forcing on ISM (delayed effect)

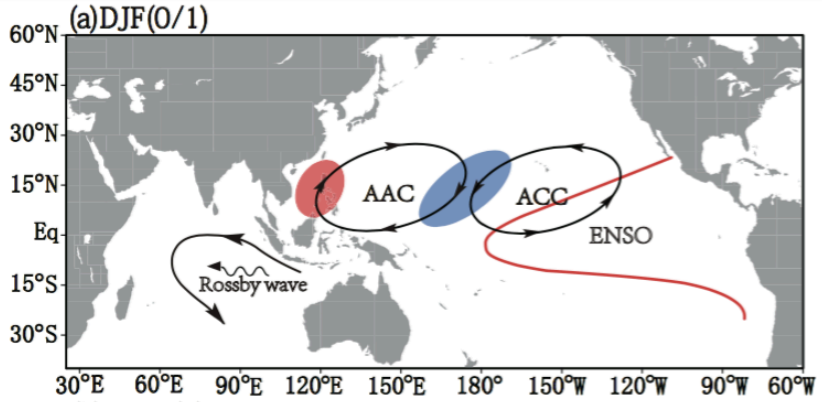
a)

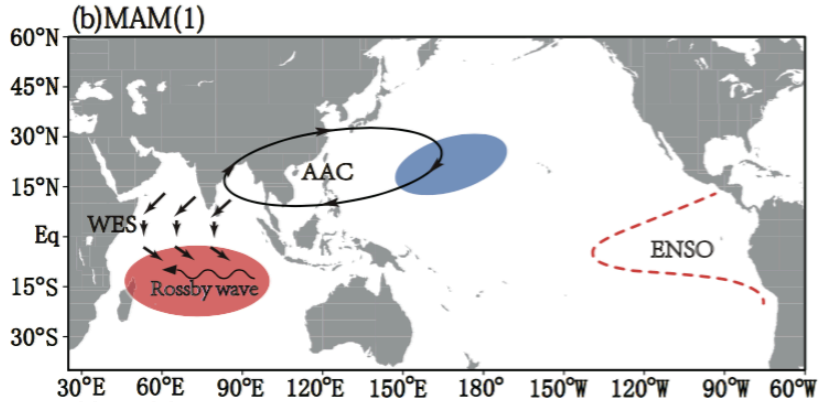


b)



Results: ENSO forcing on ISM (delayed effect)





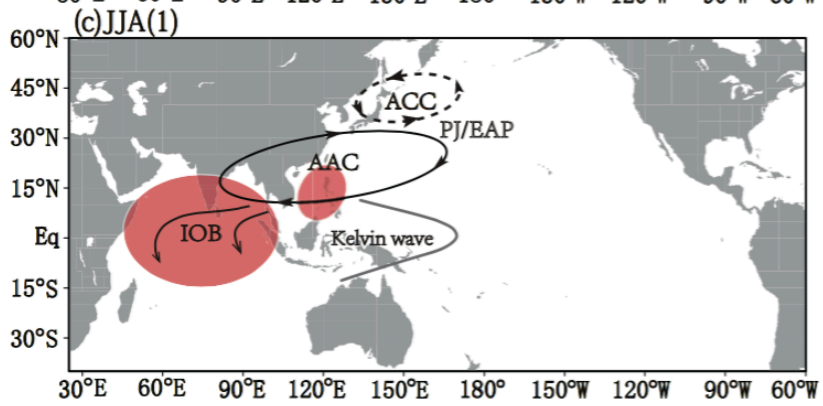


Fig. 3. Schematic representation of the major SST anomalies and atmospheric teleconnection over the Indo-Pacific oceans associated with El Niño events: (a) El Niño impacts on the South IO through westward Rossby waves during December–February; (b) Rossby waves inducing Southwest IO warming, which in turn induces an anti-symmetrical wind pattern over the tropical IO during March–May; (c) the second IO warming exciting a tropospheric Kelvin wave propagating into the western Pacific, forcing the AAC and PJ/EAP pattern to affect East Asia during the following summer.

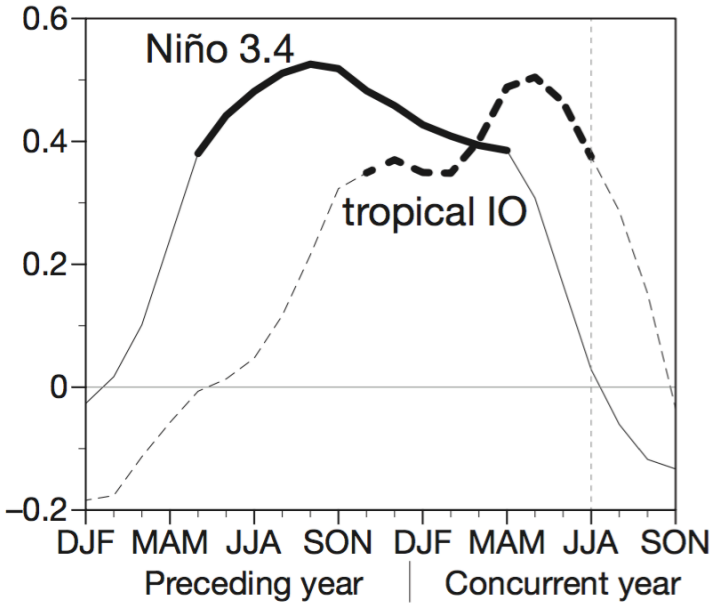
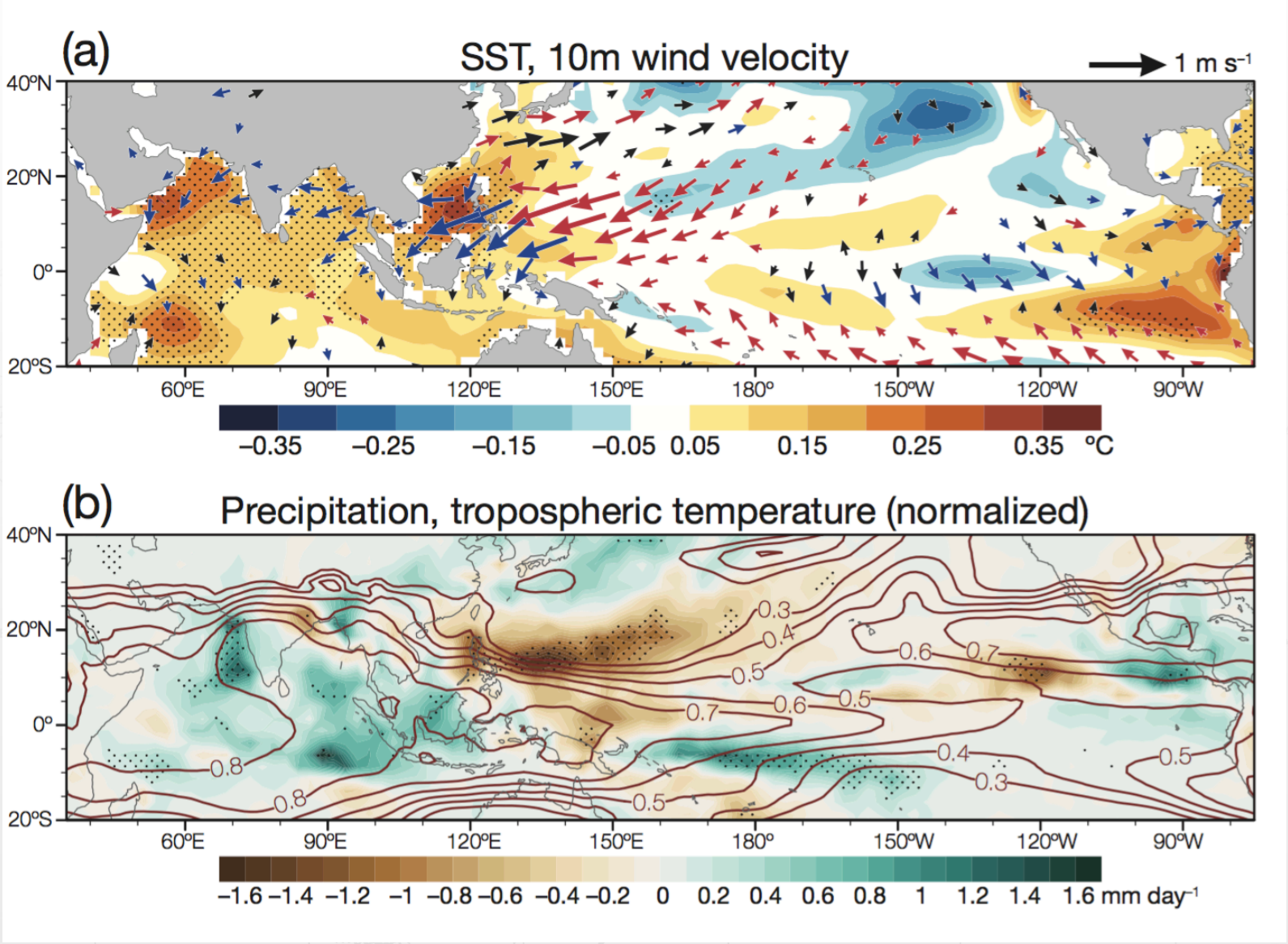


Fig. 6. Lag correlations of the summer PJ index (leading principal component for Fig. 5) with Niño3.4 (solid) and tropical IO (20°S–20°N, 40°–100°E; dashed) SST (detrended; three-month running averaged). Thick curves represent the >95% confidence level, based on the *t*-test.

Xie et al (2016)

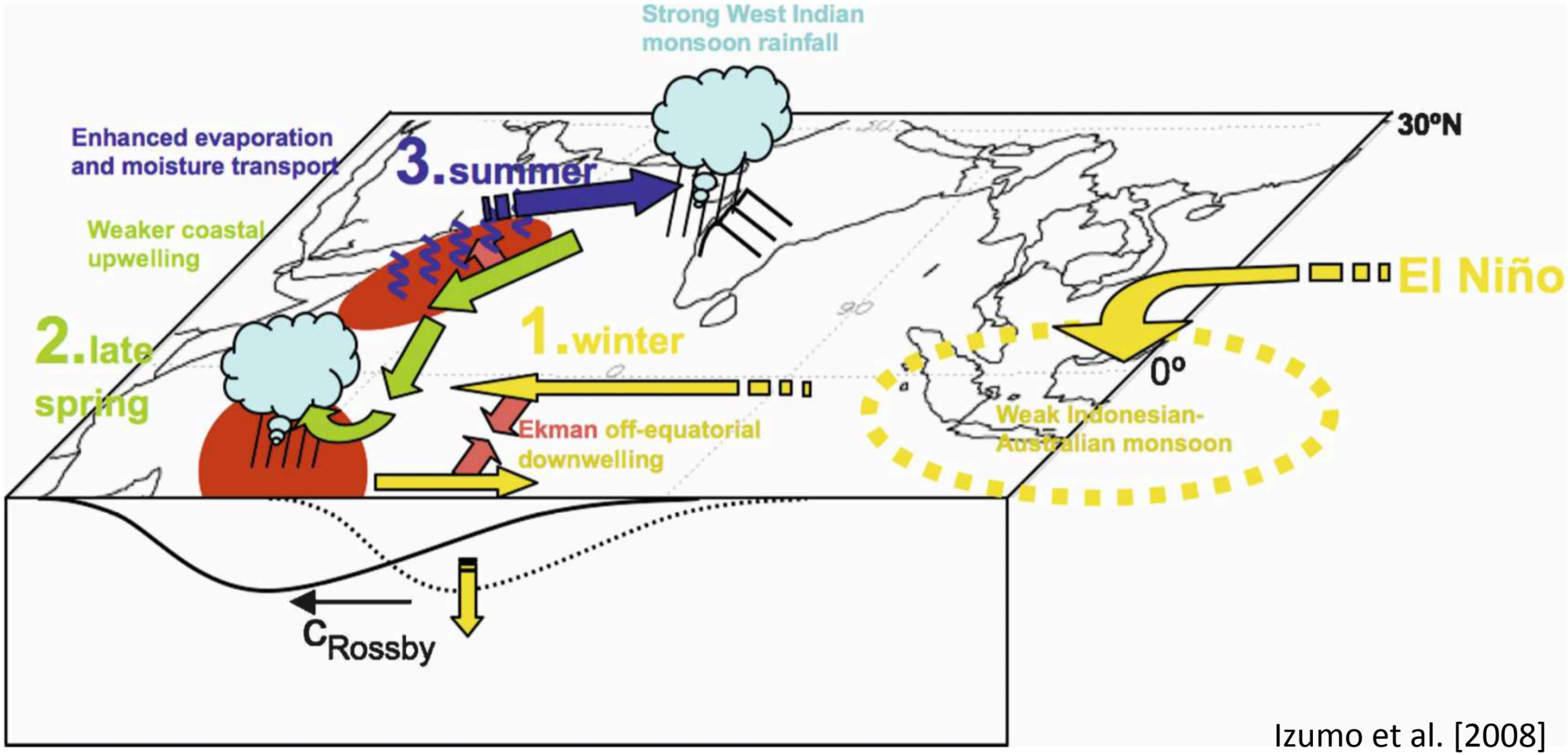
Results: ENSO forcing on ISM (delayed effect)



Xie et al (2016)

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

Starting from previous winter.....



Izumo et al. [2008]

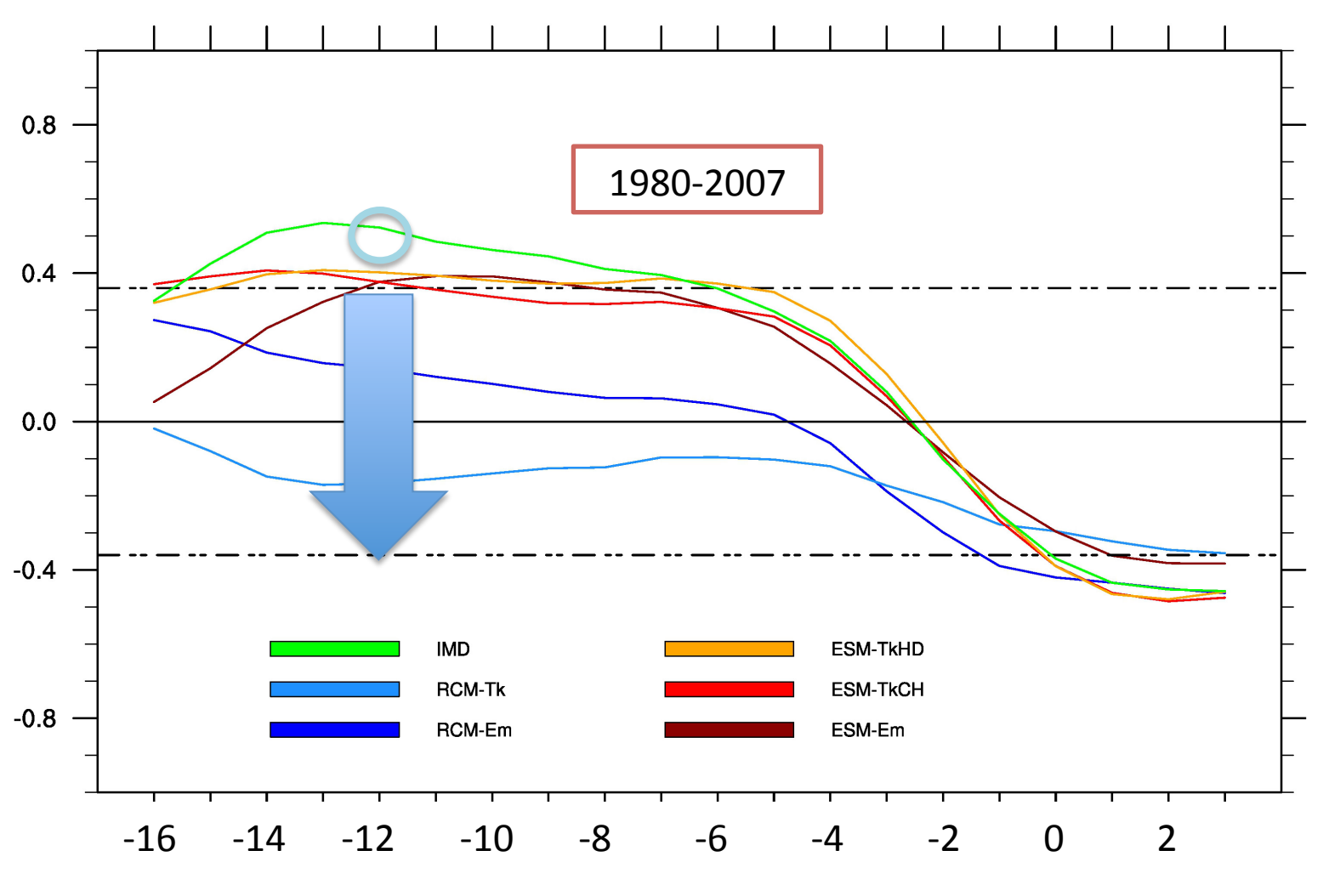
Results: ENSO forcing on ISM (delayed effect)

From late 70's: increase of later-decay El Niño events but not of later-decay La Niña events

Could be this the reason of the high correlation values found for the last thirty years

Li et al. (2012) ; Ren et al. (2016)

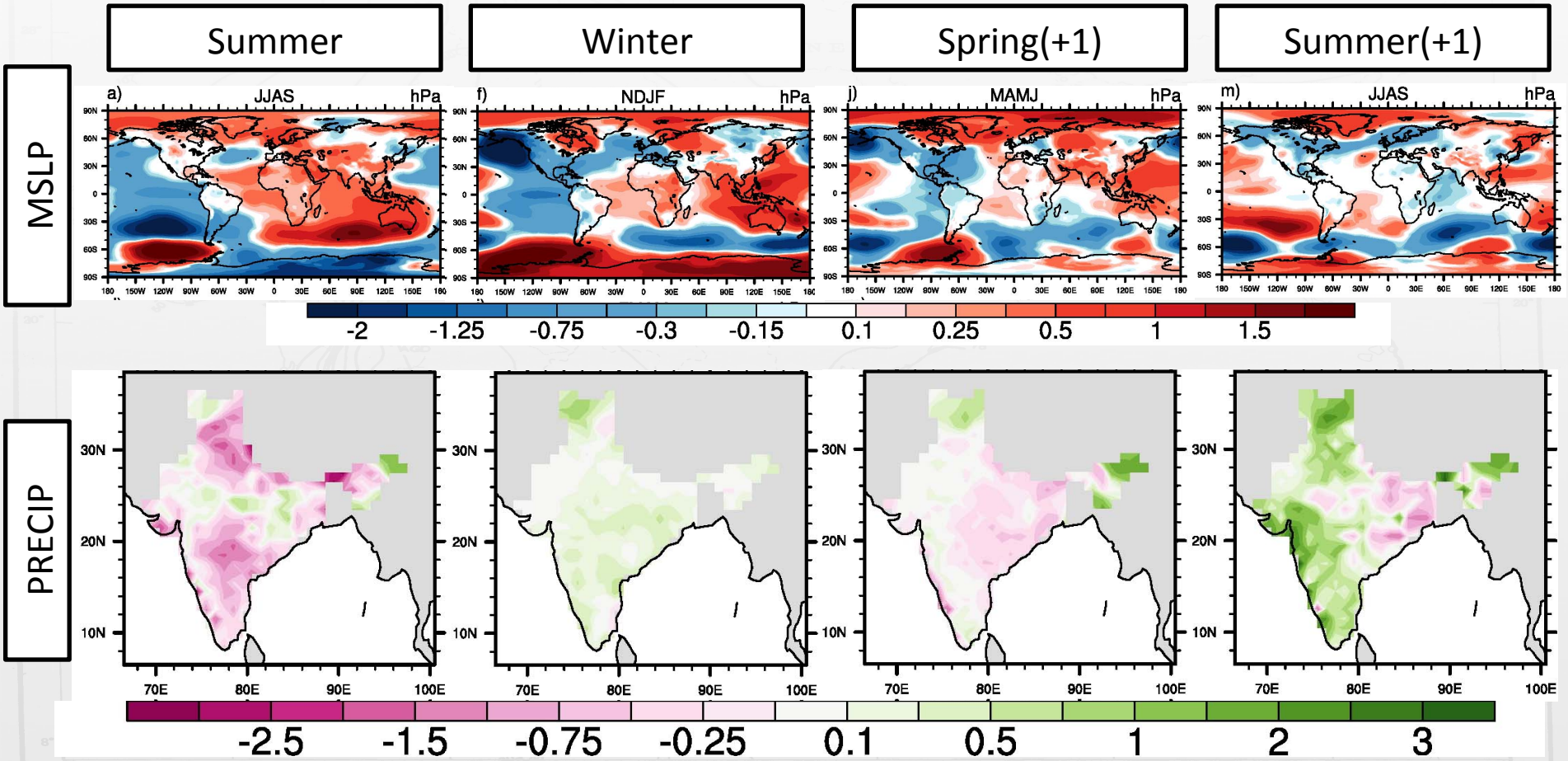
Results: ENSO forcing on ISM (delayed effect from JJAS)



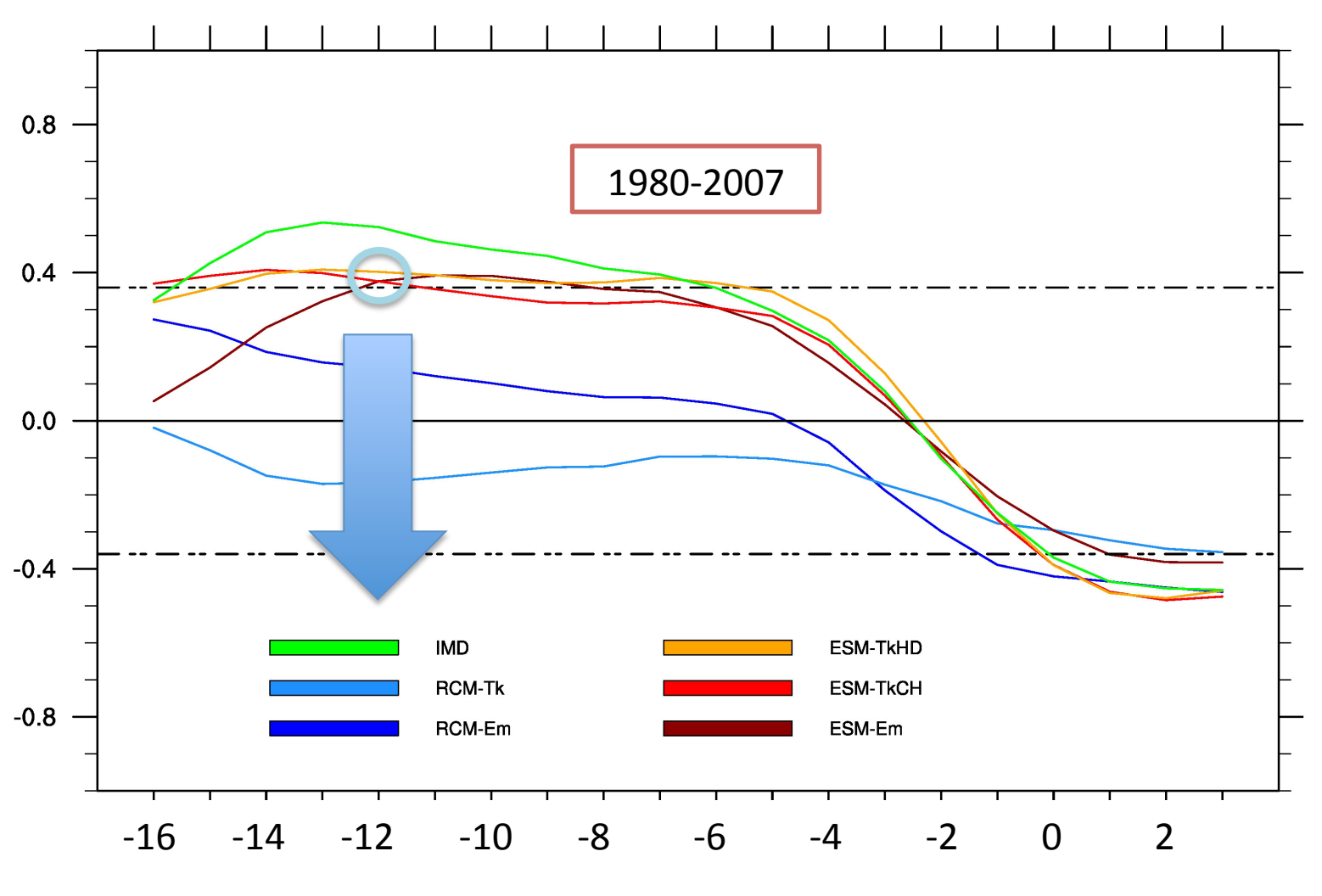
Results: ENSO forcing on ISM (delayed effect from JJAS)

Starting from previous summer.....

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

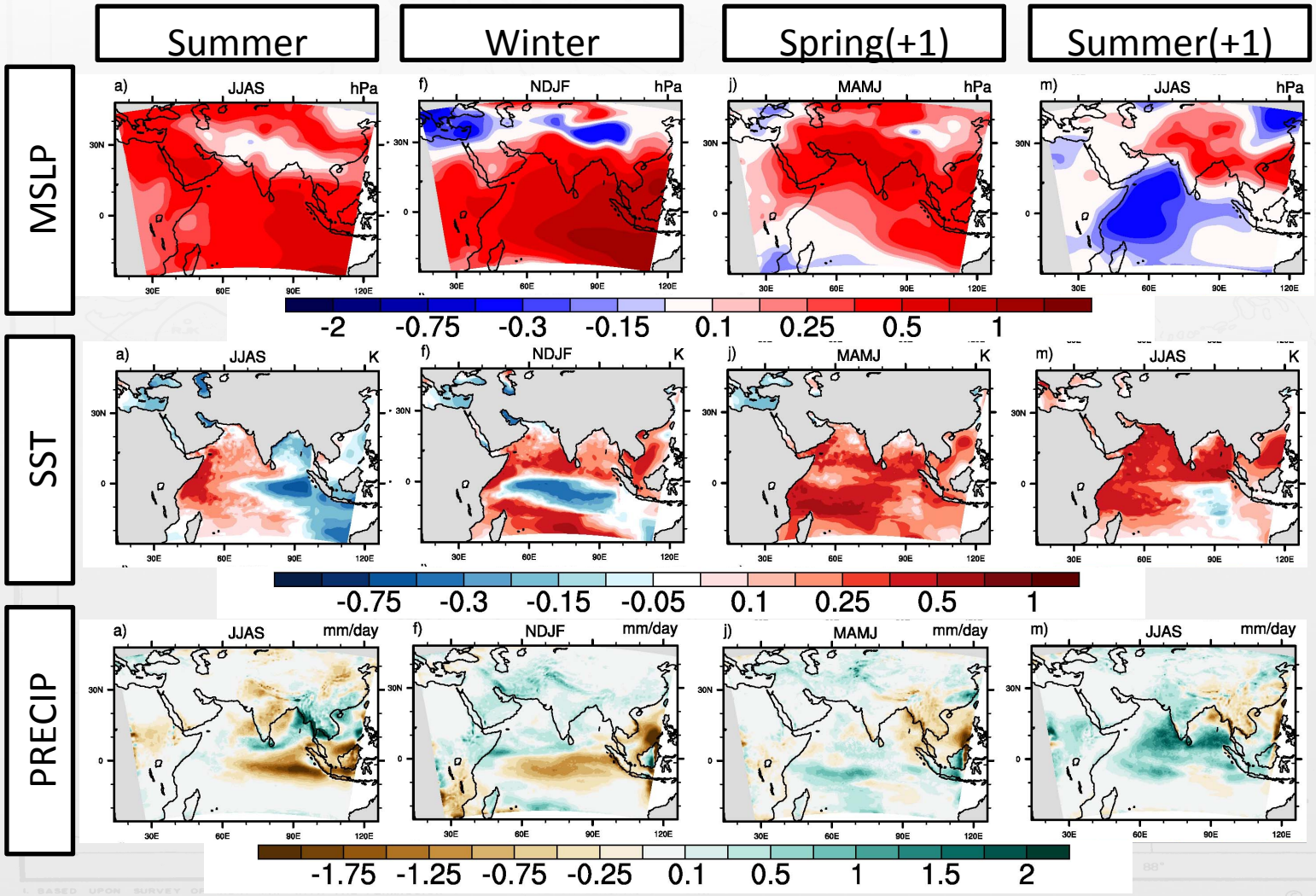


Results: ENSO forcing on ISM (delayed effect from JJAS)



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

Starting from previous summer.....



Regressed maps (ESM-TkHD) of Niño3.4 (JJAS)

Di Sante, F. and et al. (2017). One-year lead-time predictability of indian summer monsoon due to delayed enso impact. Nature Geoscience (In preparation).

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

Prespectives

- 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.

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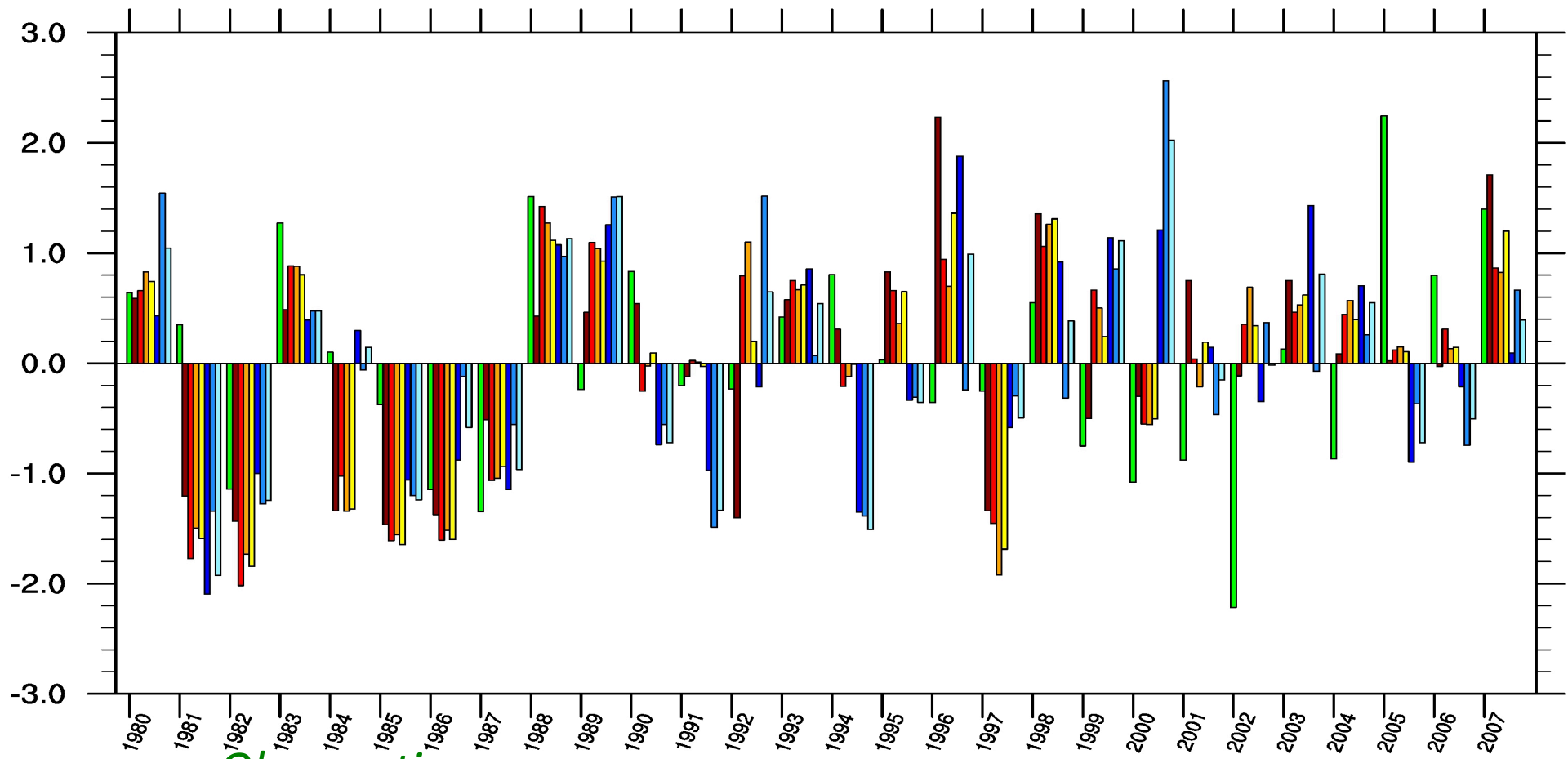
Results: interannual variability



Observations

IMD

RCM-Ensemble CC:-0.01

RCM-Tk CC:-0.04

RCM-Em CC:0.01

Standalone

ESM-Ensemble CC:0.38

ESM-TkHD CC:0.34

ESM-TkCH CC:0.37

ESM-Em CC:0.36

Coupled