



Indian Monsoon Rainfall: ENSO, IOD and EQUINOO in NCMRWF Global Coupled System

Ashis K.Mitra, Ankur Gupta, Imran M. M. and E.N.Rajagopal

**National Center for Medium Range Weather Forecasting
(NCMRWF)**

Ministry of Earth Sciences, Government of India

www.ncmrwf.gov.in

e-mail: ashis.mitra@nic.in

NCMRWF is a Centre of Excellence in Numerical Modelling and Data Assimilation

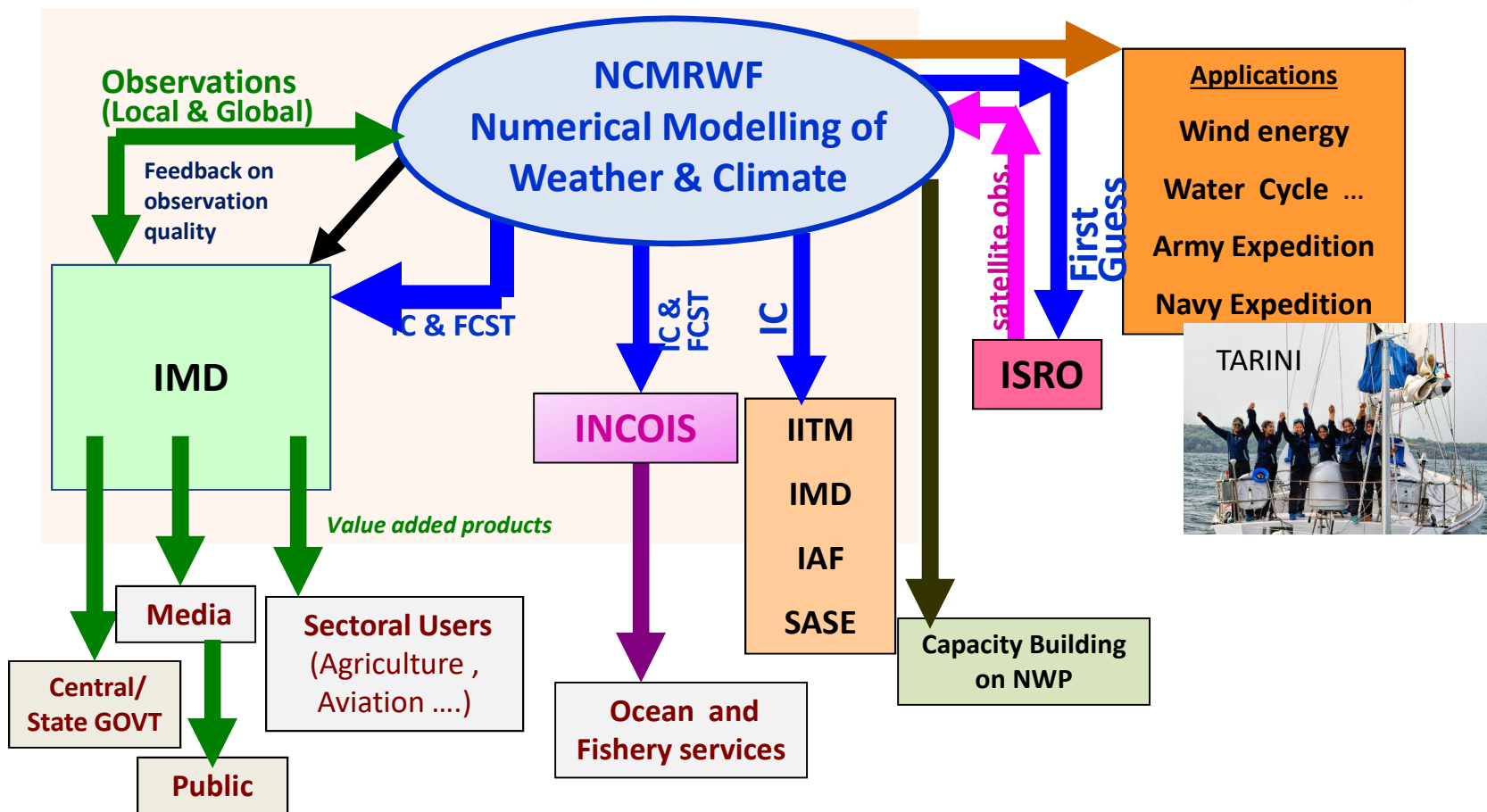
Major Mandates

- **Development and improvement of Weather/Climate prediction models for IMD to underpin their forecasting capability**
- **Development & Maintenance of Data Assimilation (DA) systems for Global/Regional Models**
- **Development & Maintenance of a State-of-art Seamless Prediction System**
- **Full Establishment of BCWC under BIMSTEC cooperation**



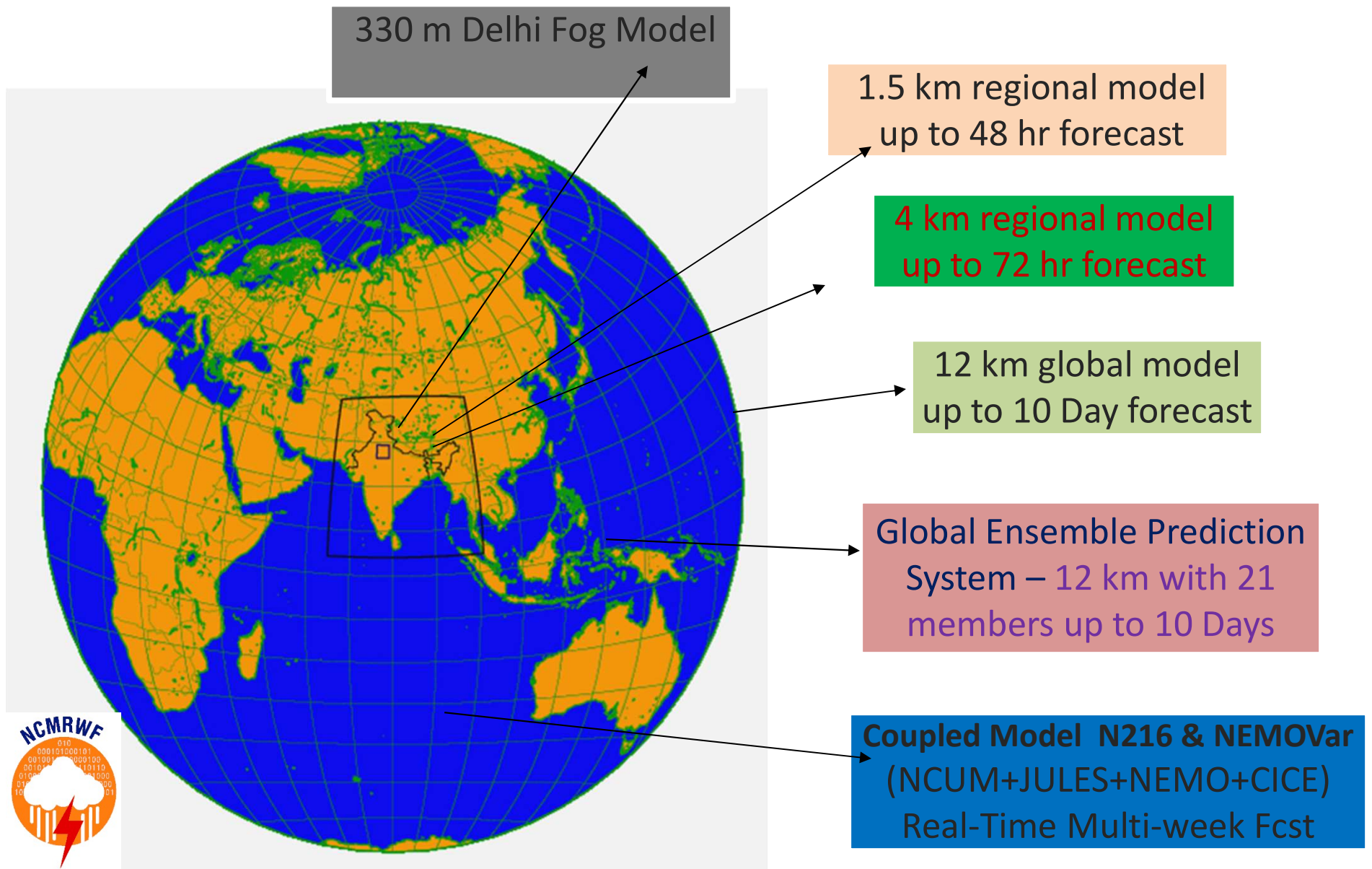
Linkage of NCMRWF with Various Organizations

NCMRWF is doubling as BIMSTEC center for Weather & Climate (BCWC)



NCMRWF Seamless Modelling System with DA systems at NCMRWF

Same Model Core for Global/Regional/Mesoscale/City/ Coupled





12-km NCMRWF-EPS in TIGGE Portal



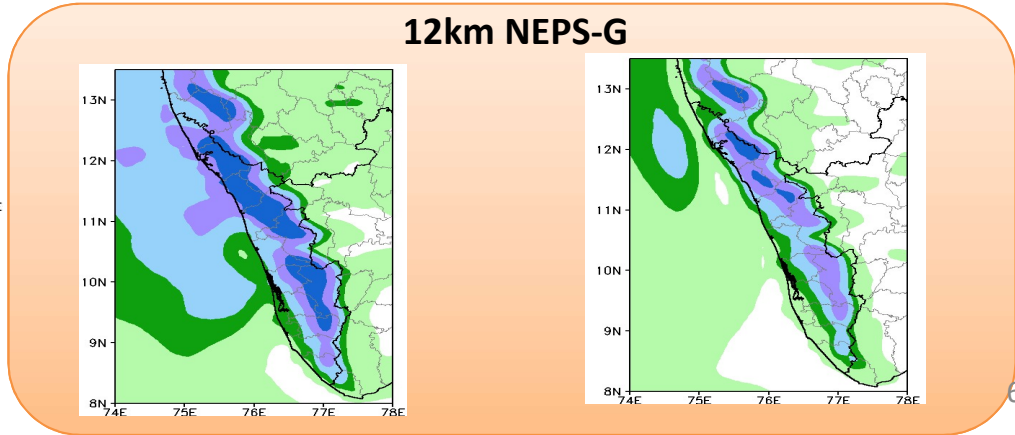
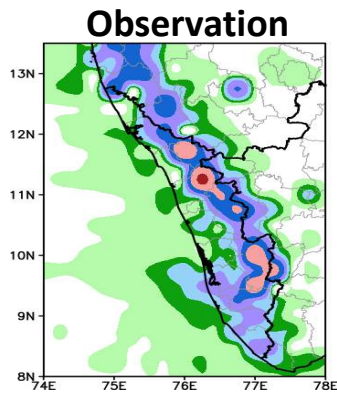
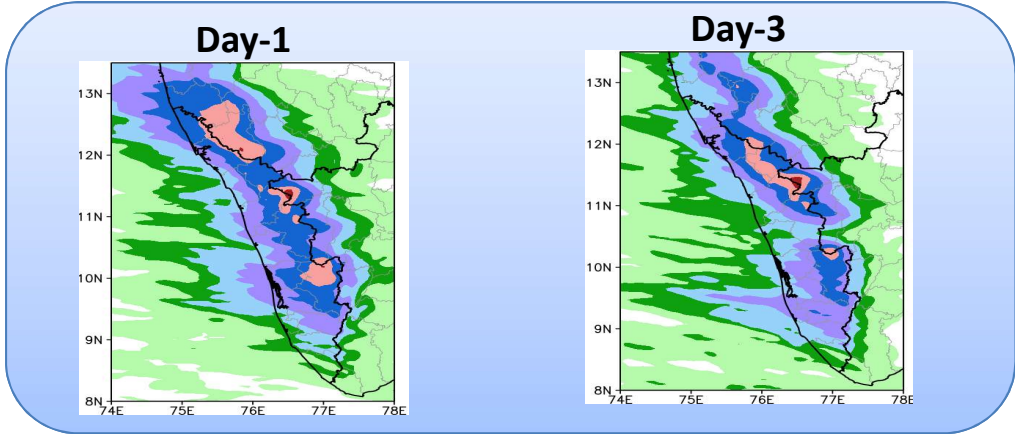
The screenshot shows a web browser window displaying the TIGGE News page on the ECMWF Confluence Wiki. The browser's address bar shows the URL `confluence.ecmwf.int`. The page header includes the ECMWF logo and a search bar. The left sidebar contains navigation links for TIGGE, SPACE SHORTCUTS (S2S, TIGGE, TIGGE-LAM, UERRA, YOPP), and PAGE TREE (News, Description, Support, Resources, Site map). The main content area is titled "News" and lists recent updates:

- 24-07-2018 NCMRWF forecast system change**
Update of NCMRWF forecast system. A new version of NCMRWF model was introduced. The first archived updated model runs are from the 1st of July. The main changes are:
 - reduced number of the ensemble size from 45 to 12
 - two model runs 00 and 12 UTC at very high resolution (0.12x0.18 degree)Click [here](#) for more details.
- 18-06-2018 Usage statistics**
A new page with [TIGGE data usage statistics](#) was added.
- 20-12-2017 New model (NCMRWF, India) added to TIGGE archive**
New model outputs (NCMRWF, India) were added to TIGGE archive. The first starting date available thanks to the back-archiving is the 1st of August 2017. Click [here](#) for more details.
- 11-07-2017 ECMWF forecast system change**
Update of ECMWF forecast system. A new version of ECMWF model (IFS cycle 43r3) was introduced. Click [here](#) for more details.



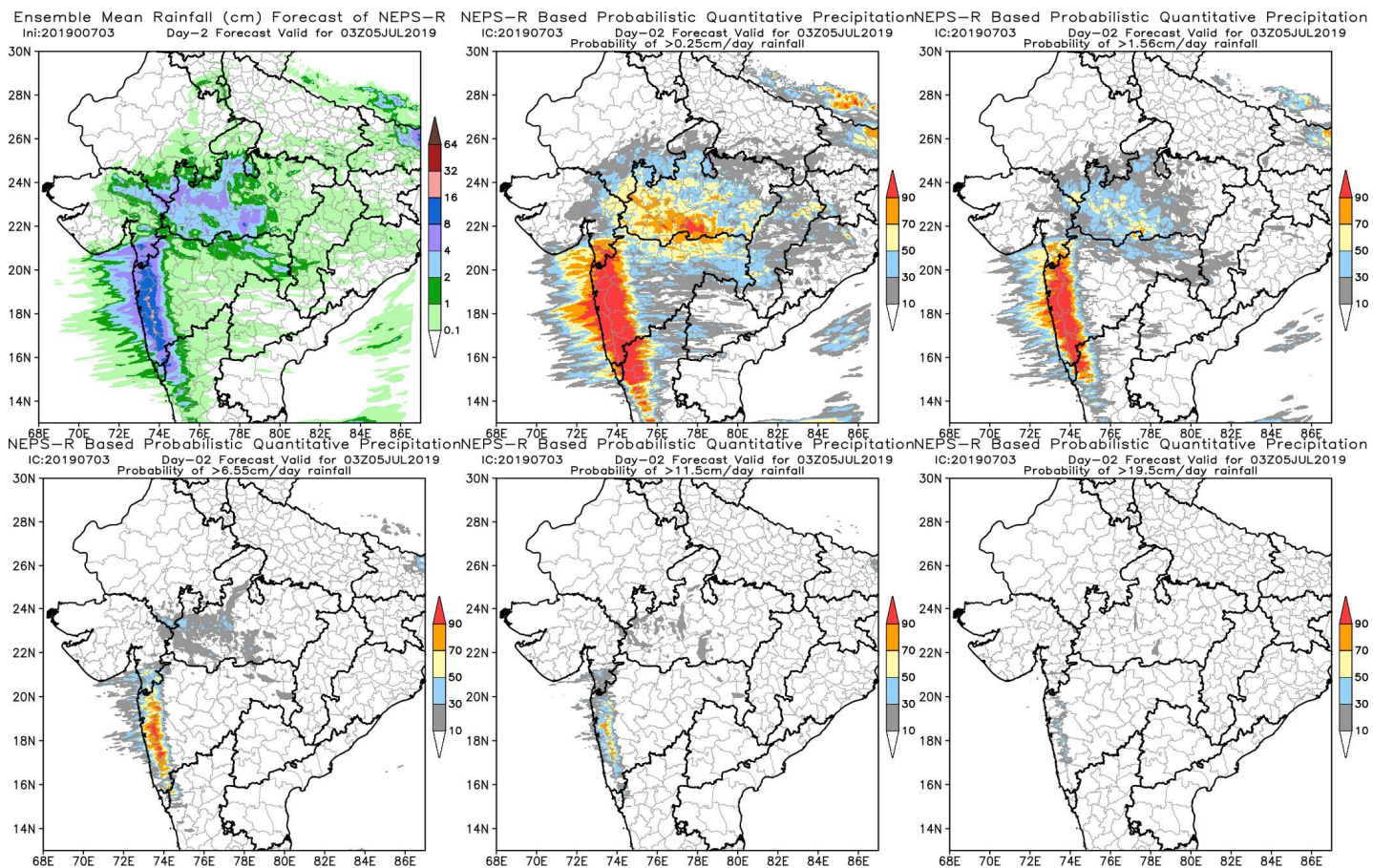
Ensemble mean Rainfall (cm/day) Forecast valid on 9th Aug 2018

4km NEPS-R





NCMRWF Real-Time Regional Ensemble Prediction System (11 Member)



Global Coupled Modelling and Initialisation: NCMRWF Status



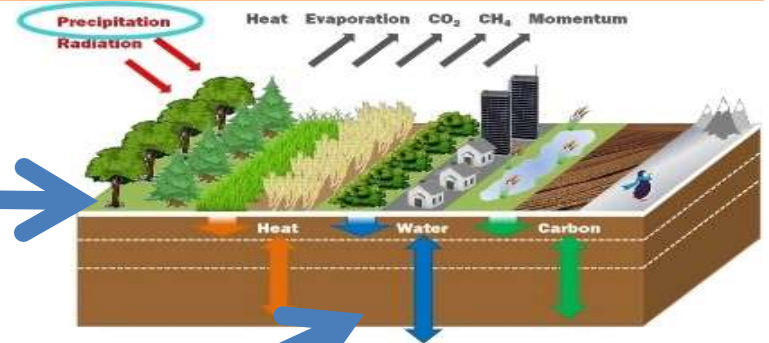
- 1. Global Ocean Data Assimilation running real-time**
(NEMOVar 25 km L75 daily on CRAY HPC; with stand-alone global NEMO forecast up to 10 days)
- 2. Coupled daily 15 days (MRF) runs on IBM HPC**
(For developing Coupled NWP ultimately)
Currently coarse atmosphere N216 GC2; 10 km atmosphere being tested
- 3. Extended range (multi-week) real-time currently N216 atmosphere**
Up to 4-weeks now being run once a week , 6 ensemble, GC2 configuration
- 4. Seasonal tested and implemented**
(experimental Monsoon2019 forecast runs from Apr/May start dates done)
- 5. Regional 4 km high resolution coupled model for severe weather and process studies (being implemented)**



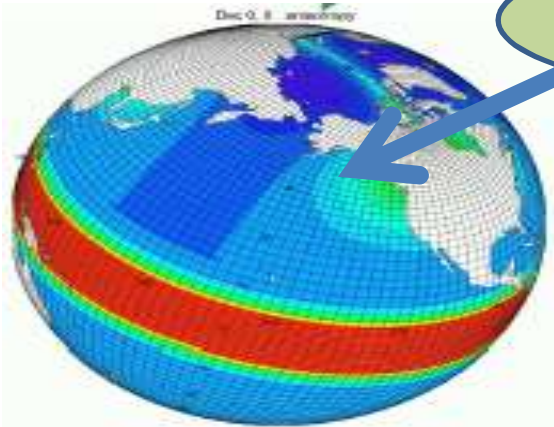
Atmos NCUM



LS Model, JULES



Coupler, OASIS



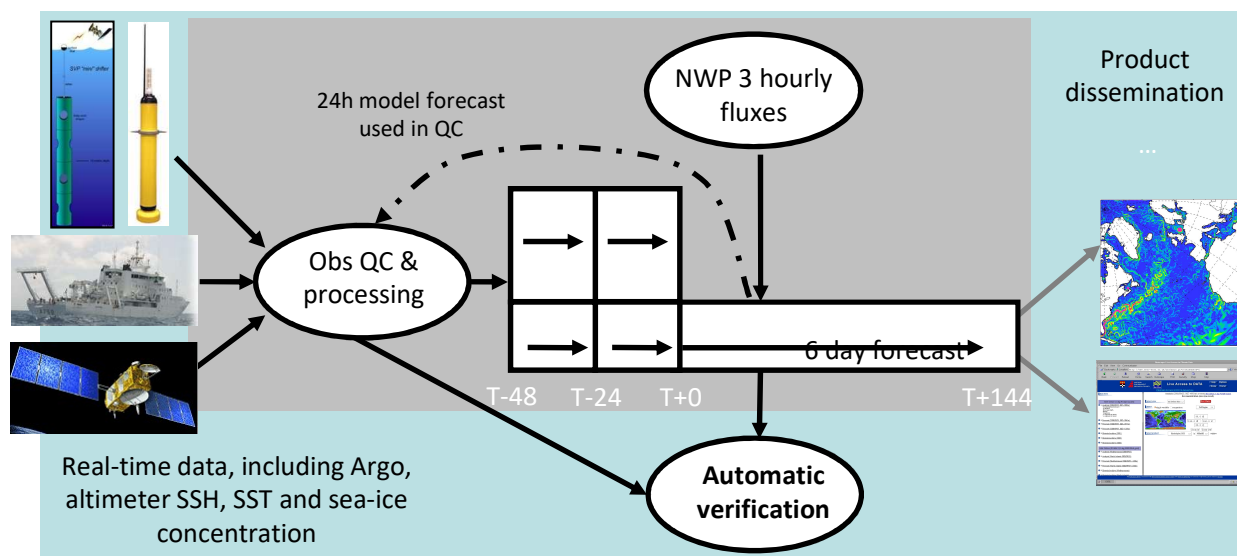
Ocean. NEMO 3.4



Sea Ice CICE 4.3



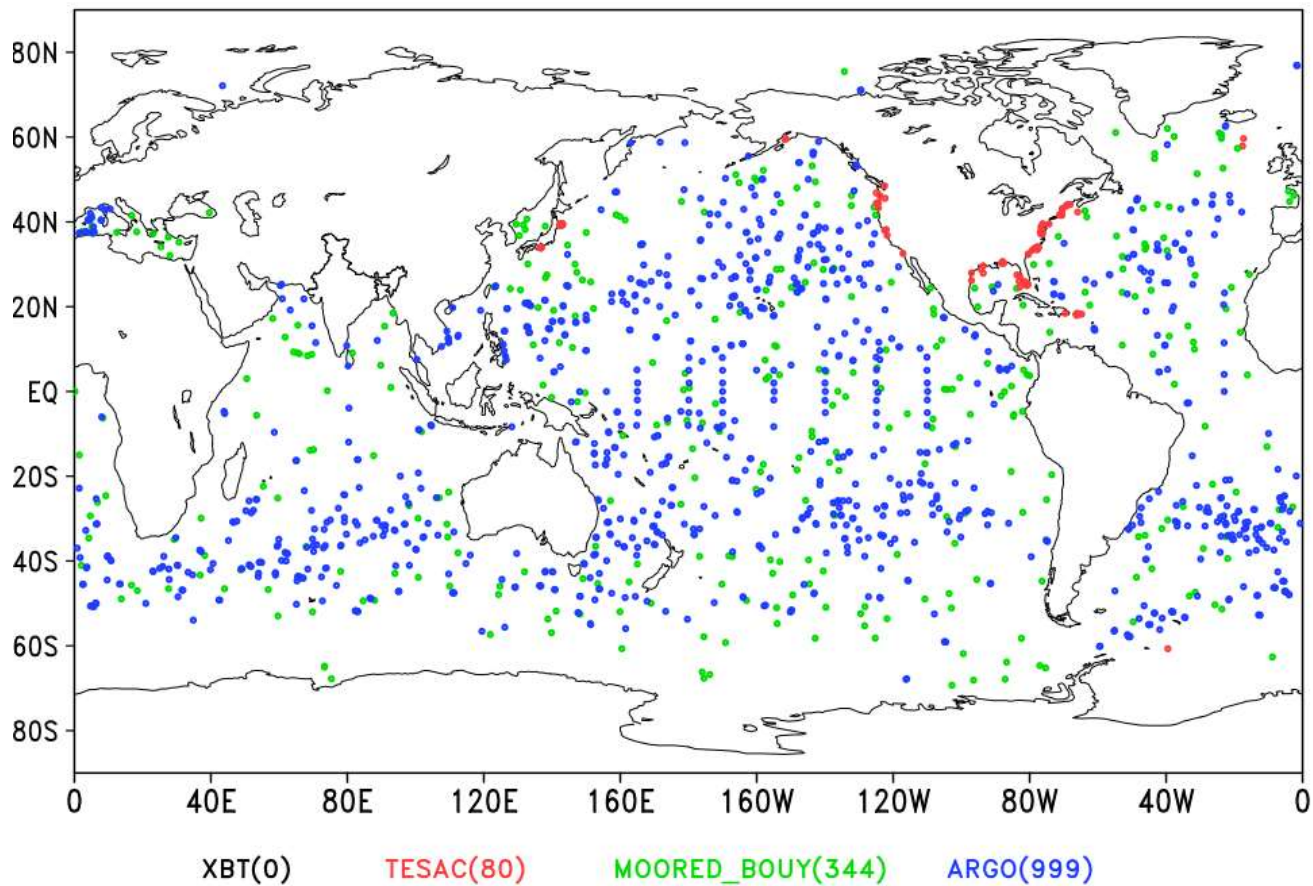
Role of Ocean: Coupled NWP, ERP/Seasonal, Inter-Annual Prediction
Ocean & Sea-Ice Data Assimilation System



NEMO Ocean Model & DA System

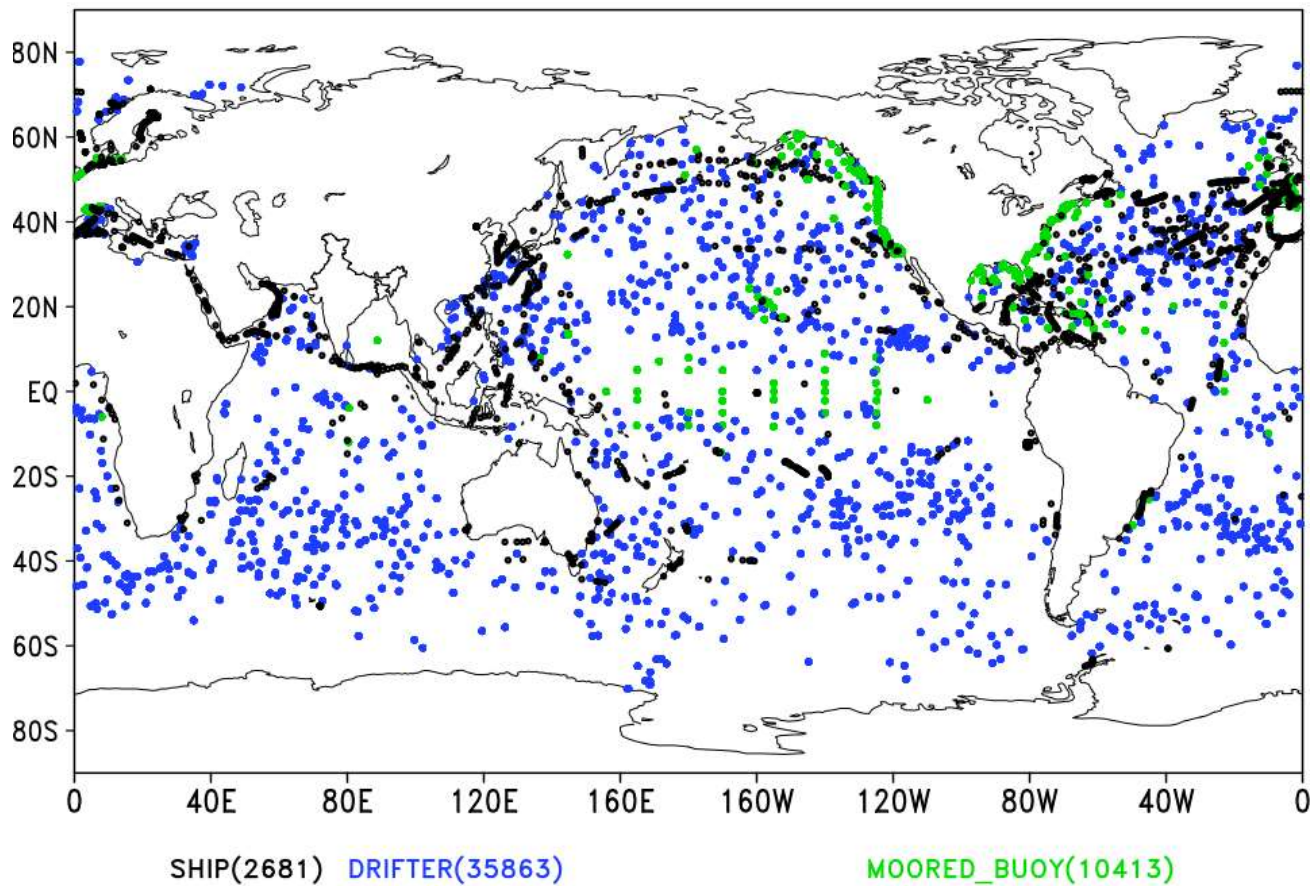


Profile Observations 00Z05apr2017





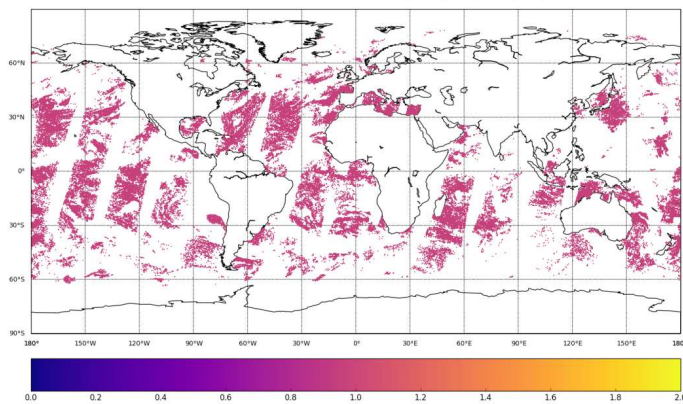
Surface Observations 00Z05apr2017





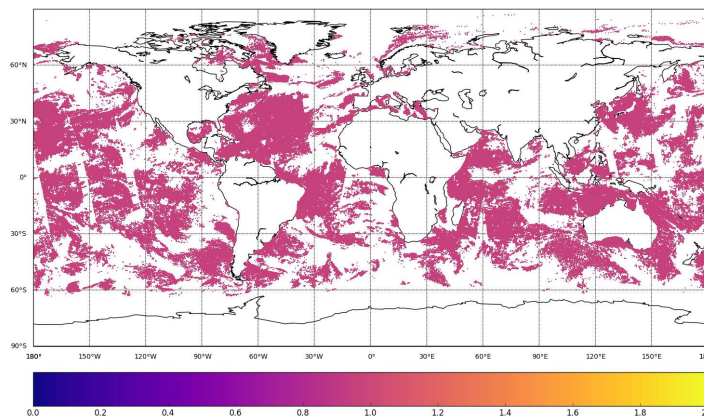
NOAA AVHRR

SST-time num (qc good only) (assim only) (global) 2013/08/15-00:01 to 2013/08/15-23:53 extrema (1.000, 1.000)
N 91304 rms 23237.475 mean 23237.475 in area (-180.00,-90.00,180.00,90.00)



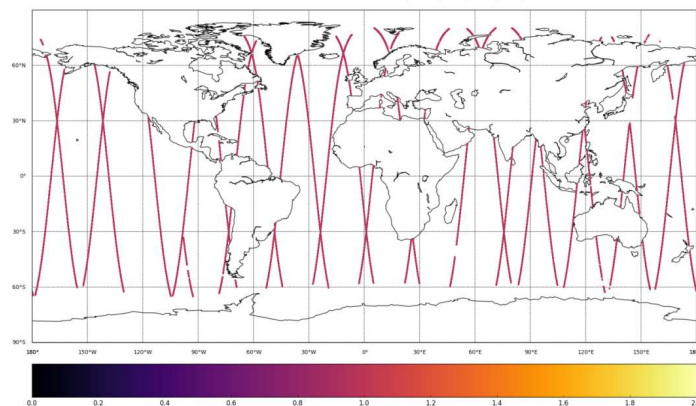
Metop AVHRR

SST-time num (qc good only) (assim only) (global) 2013/08/15-00:01 to 2013/08/15-17:43 extrema (1.000, 1.000)
N 275833 rms 23237.356 mean 23237.356 in area (-180.00,-90.00,180.00,90.00)



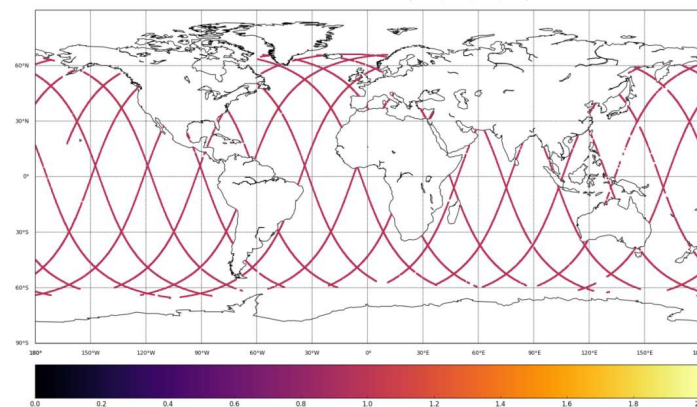
Cryosat-2

SLA-time num (qc good only) (assim only) (global) 2013/08/15-00:16 to 2013/08/15-23:57 extrema (1.000, 1.000)
N 30628 rms 23237.481 mean 23237.481 in area (-180.00,-90.00,180.00,90.00)



Jason-2

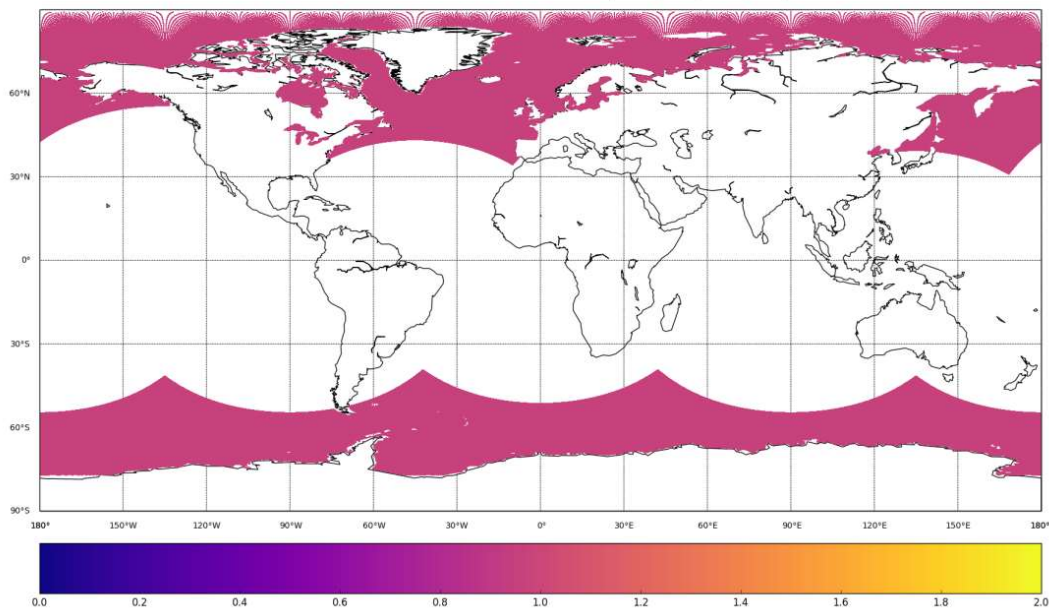
SLA-time num (qc good only) (assim only) (global) 2013/08/15-00:02 to 2013/08/15-23:57 extrema (1.000, 1.000)
N 16849 rms 23237.459 mean 23237.459 in area (-180.00,-90.00,180.00,90.00)





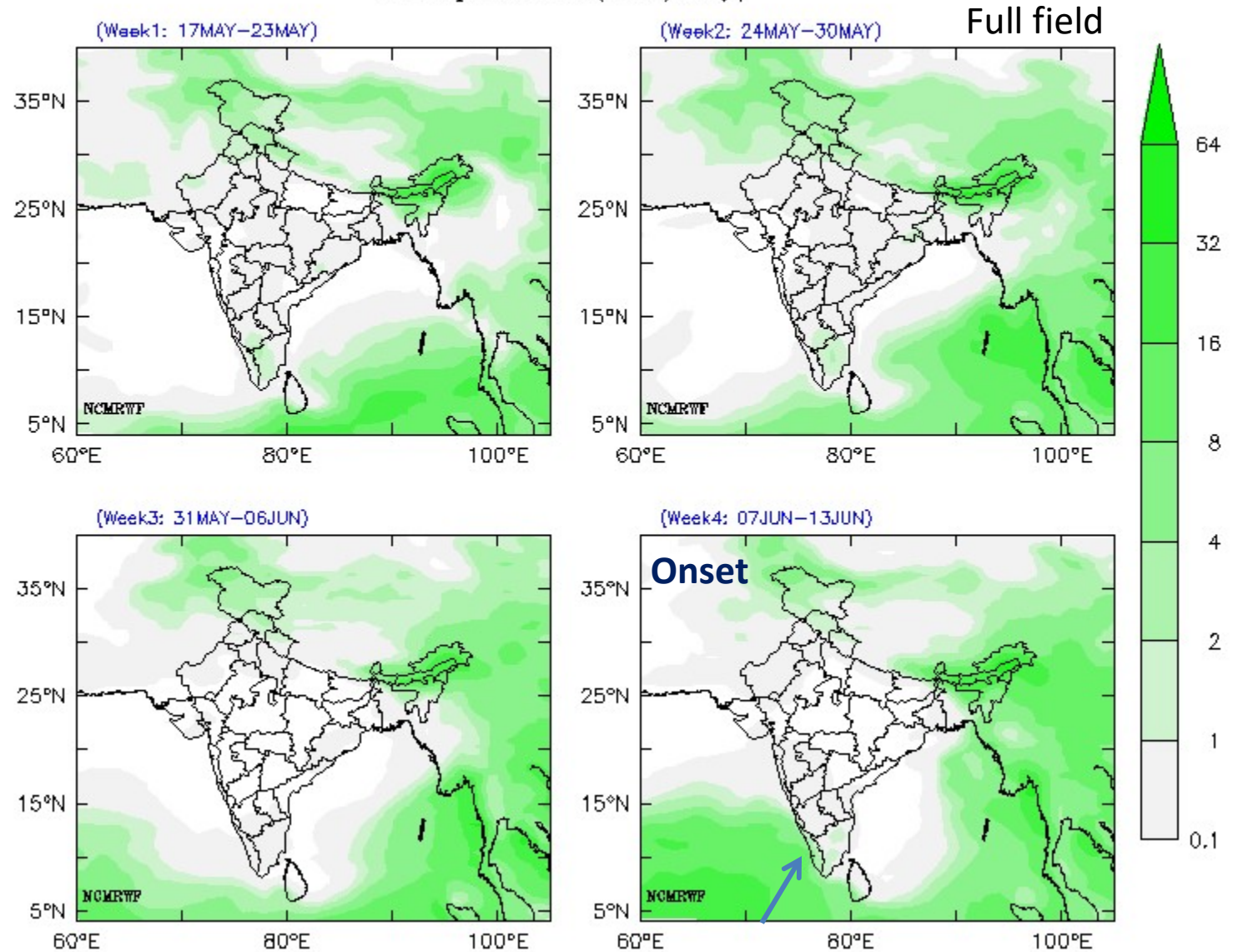
Sea Ice Concentration

ICECONC:time num (qc good only) (assim only) (global) 2013/08/15-12:00 to 2013/08/15-12:00 extrema (1.000, 1.000)
N 909408 rms 23237.500 mean 23237.500 in area (-180.00,-90.00,180.00,90.00)



Delayed Onset Monsoon 2019 from Real-Time NCMRWF Multi-Week (Extended Range) Forecast System : GC2 N216

NCMRWF CNCUM Experimental Extended Range Forecasts–20190516
Precipitation (mm/day)



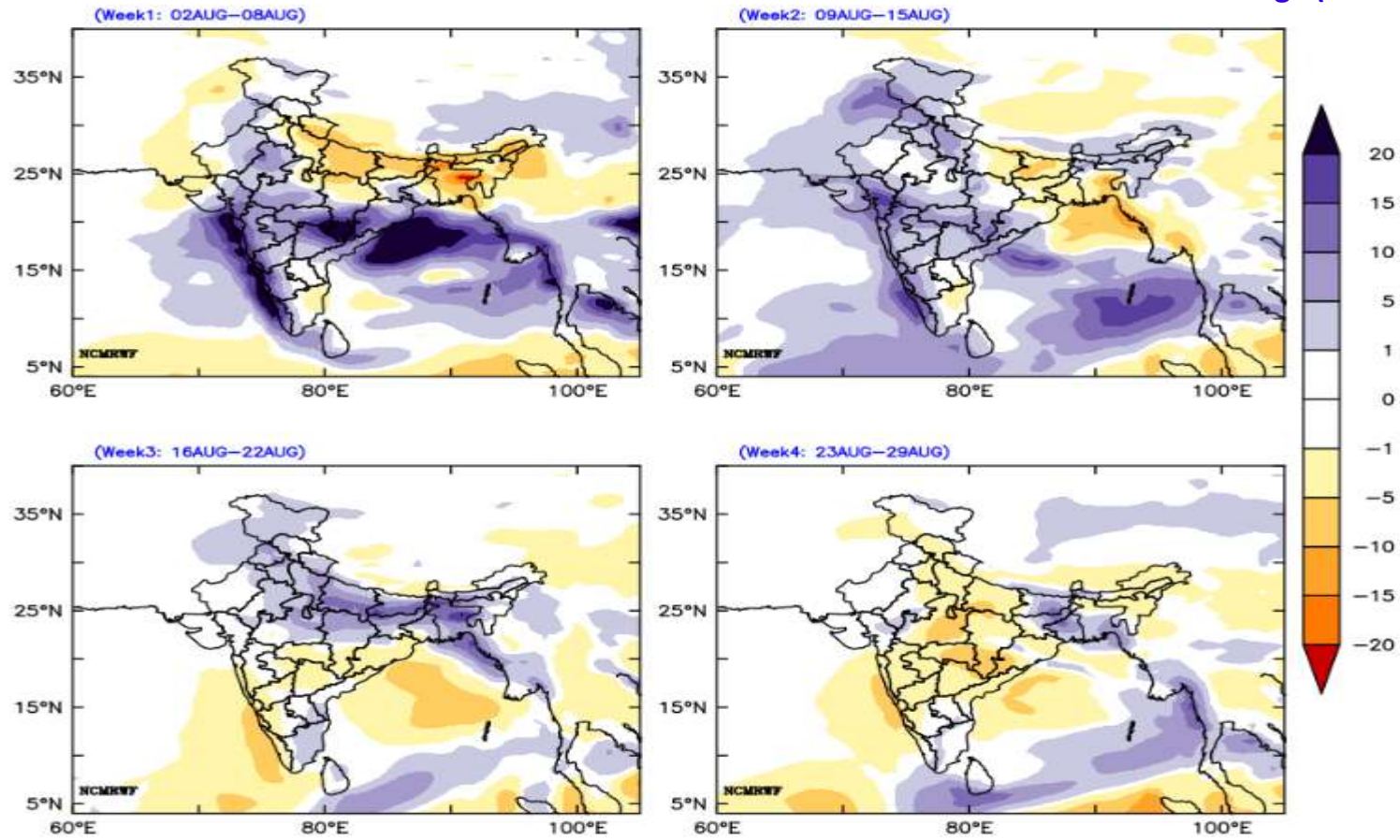
Anom Fcst from
23 years Hindcast
for 4 start dates
per month, for
all 12 months



NCMRWF CNCUM Experimental Extended Range Forecasts—20190801

Precipitation Anomaly (mm/day)

Extended Range (Multi-Week) Prediction





Forecasts for Polar Regions

Arctic & Antarctic

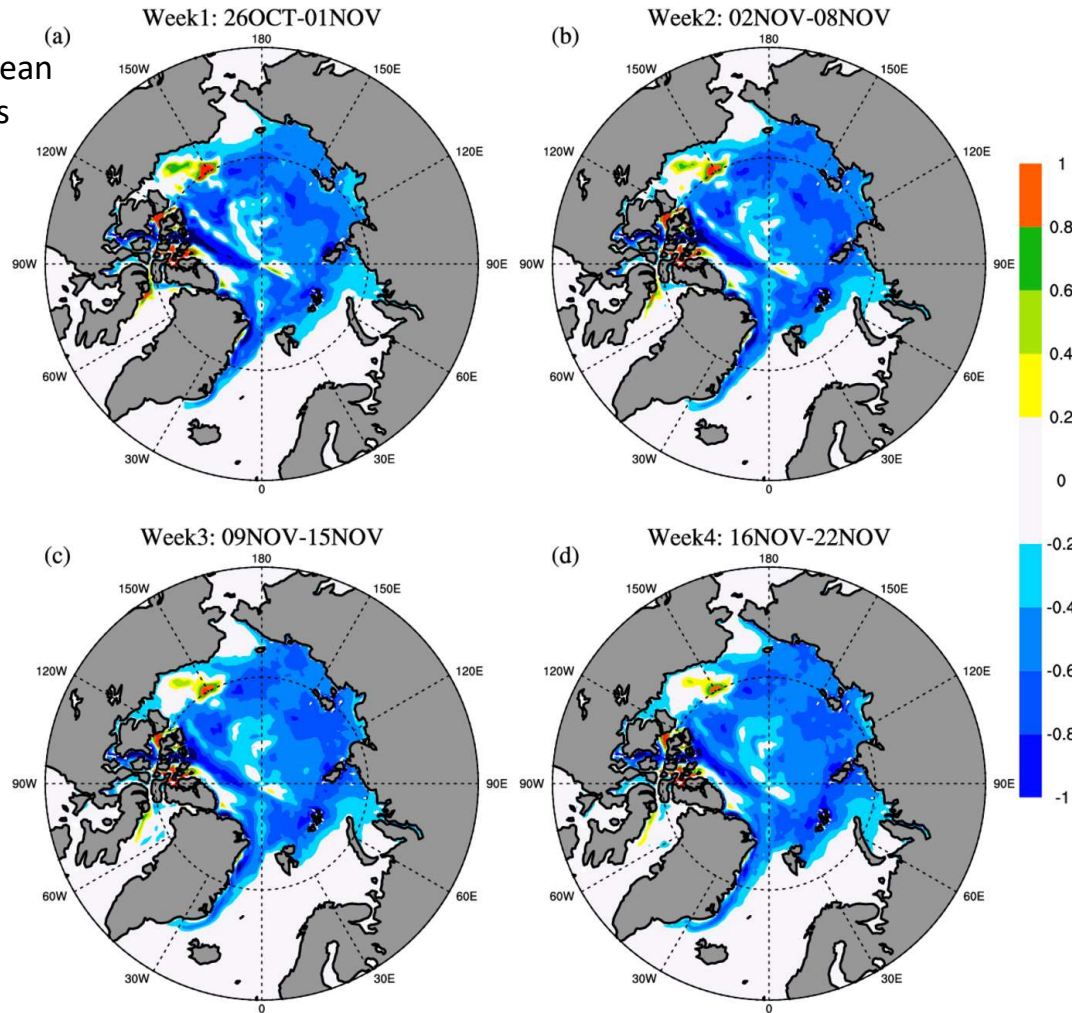
- 1) Daily up to 15 days
- 2) Once a week up to 4 weeks



NCMRWF CNCUM Extended Range Forecasts-2018

Mean Sea-Ice Thickness (m), Arctic

Arctic
Sea Ice/Ocean
Parameters

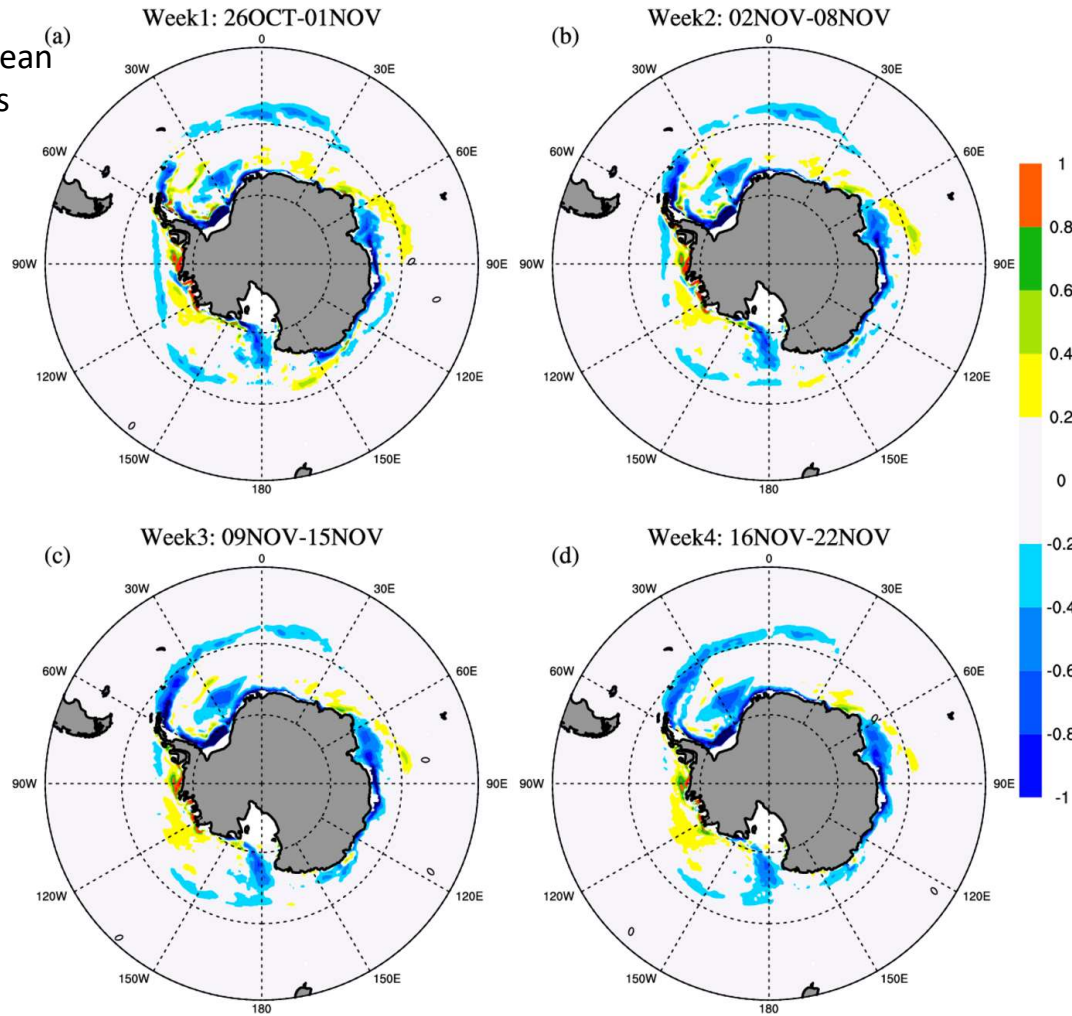




NCMRWF CNCUM Extended Range Forecasts-2018

Mean Sea-Ice Thickness (m), Antarctic

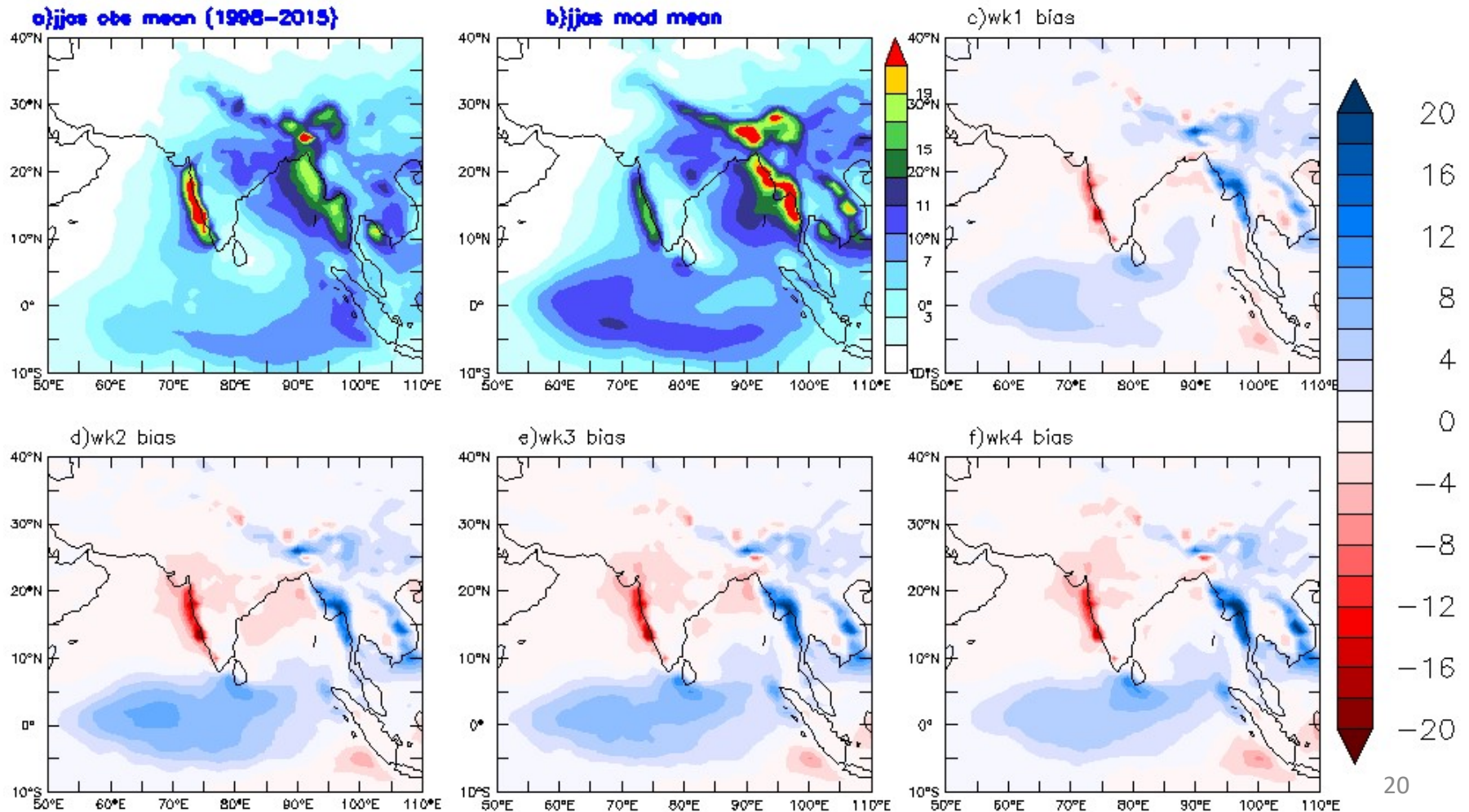
Antarctic
Sea Ice/Ocean
Parameters





Mean Monsoon Rainfall Bias

18 year (1998 to 2015) mean JJAS rainfall (mm/day) from (a) observations and (b) model Bias in forecast for (c) week1 (d) week2 (e) week3 and (f) week 4





Hindcast : 1998-2016

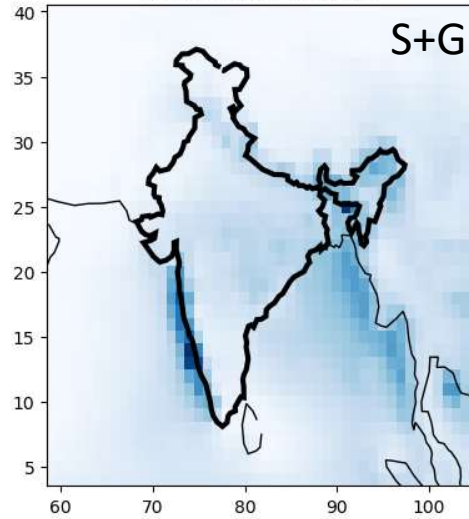
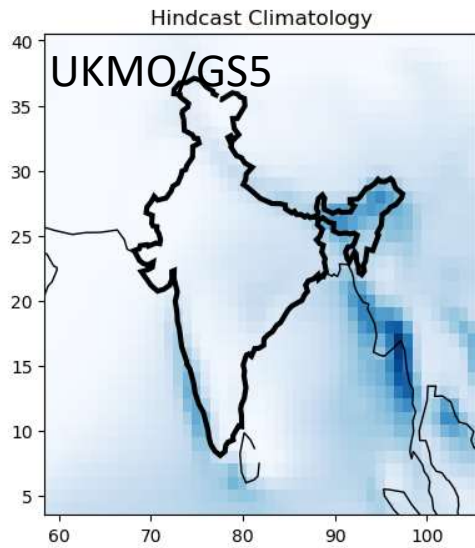
Monsoon (JJAS) Rain in mm

JJAS Forecast from April IC

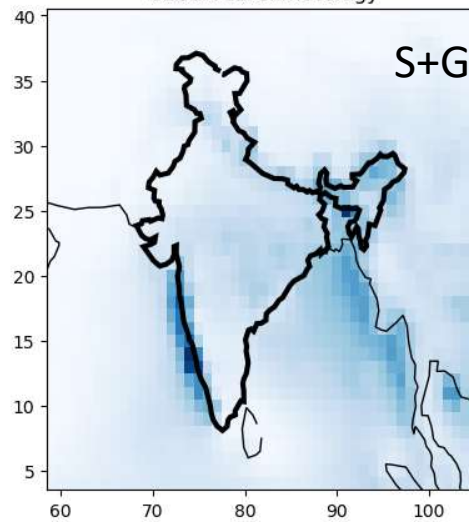
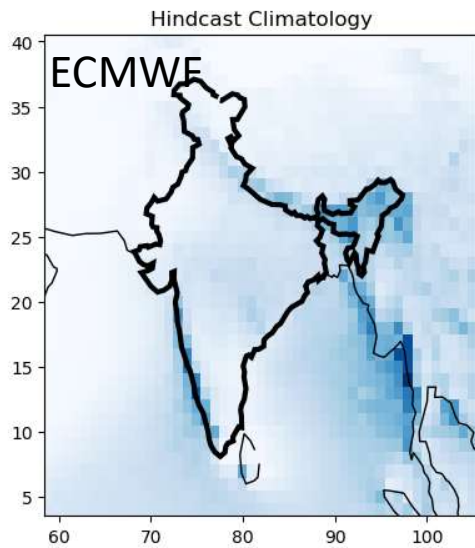
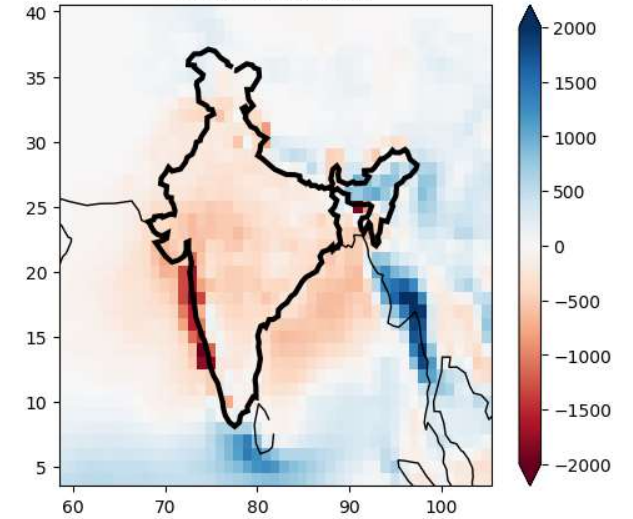
Observed Climatology

JJAS Forecast from April IC

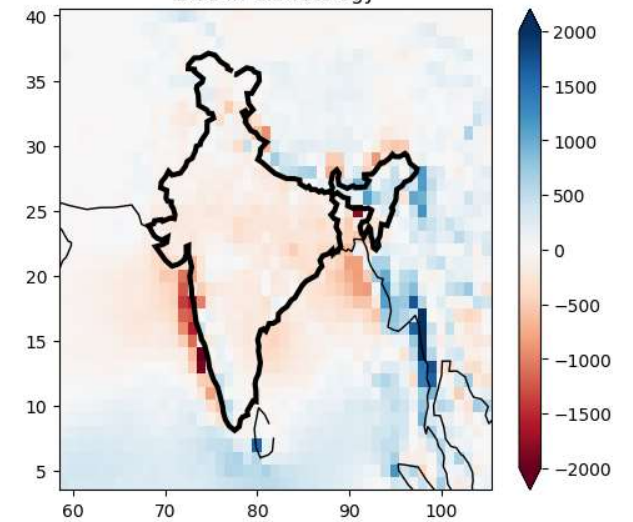
Observed Climatology



Bias in Climatology

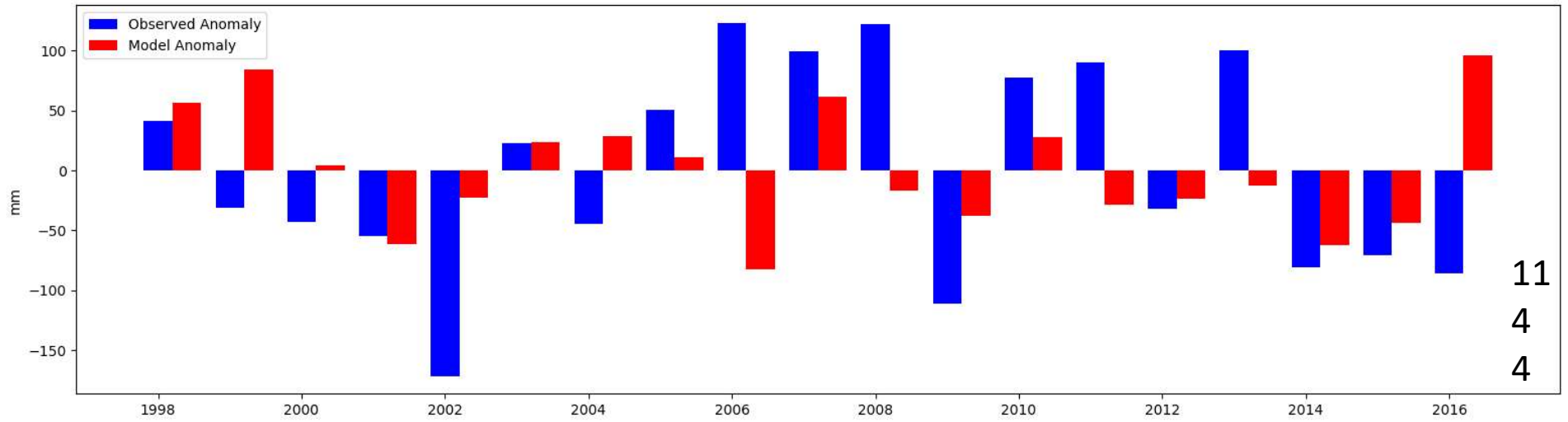


Bias in Climatology

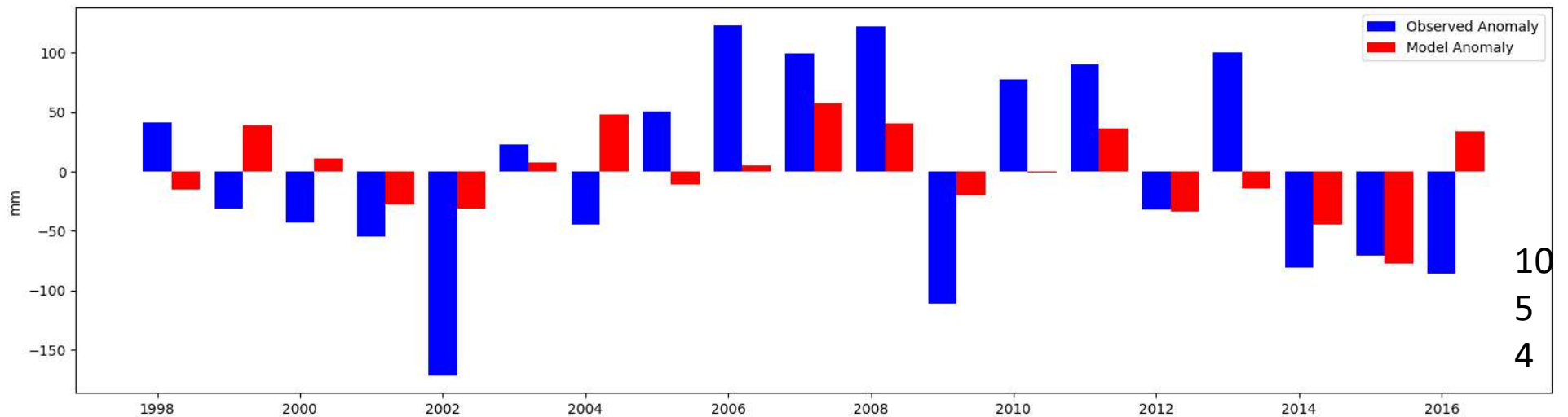


JJAS 1998-2016

UKMO

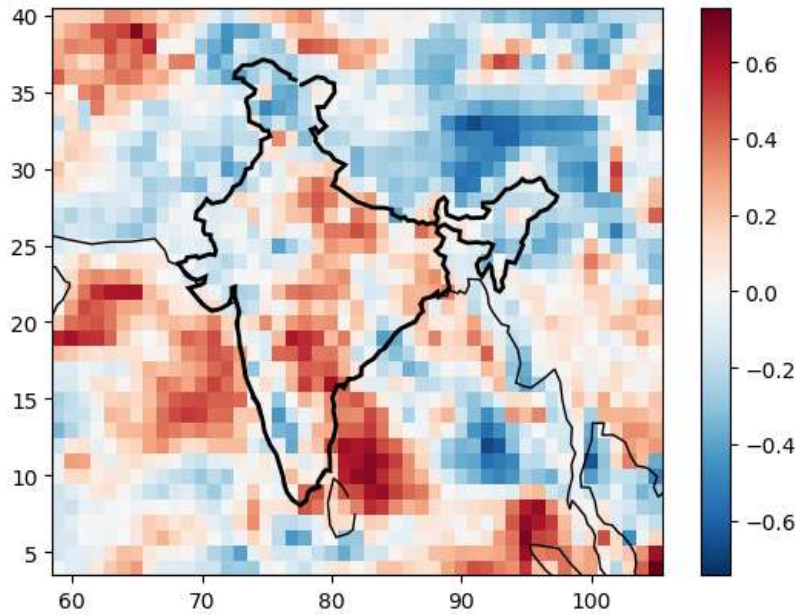


ECMWF

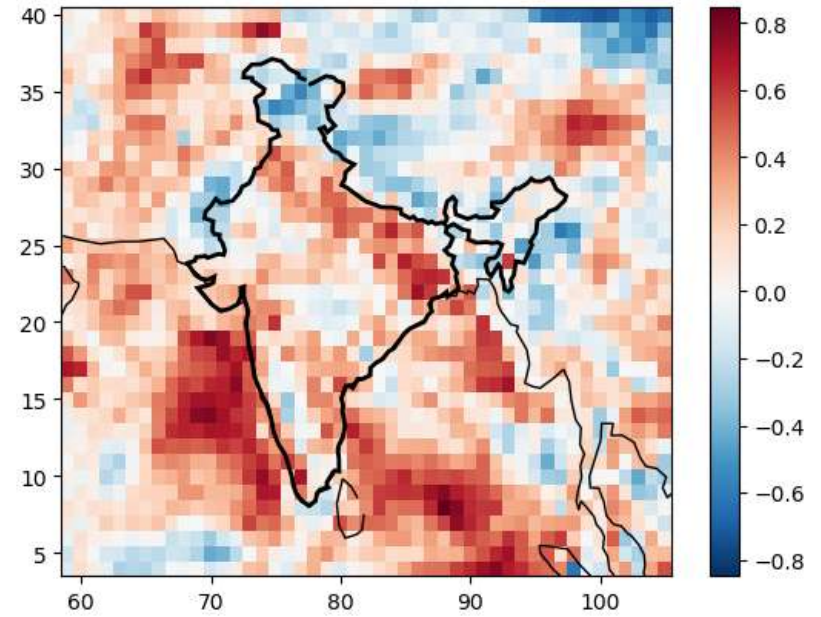


JJAS 1998-2016 Anomaly Correlations

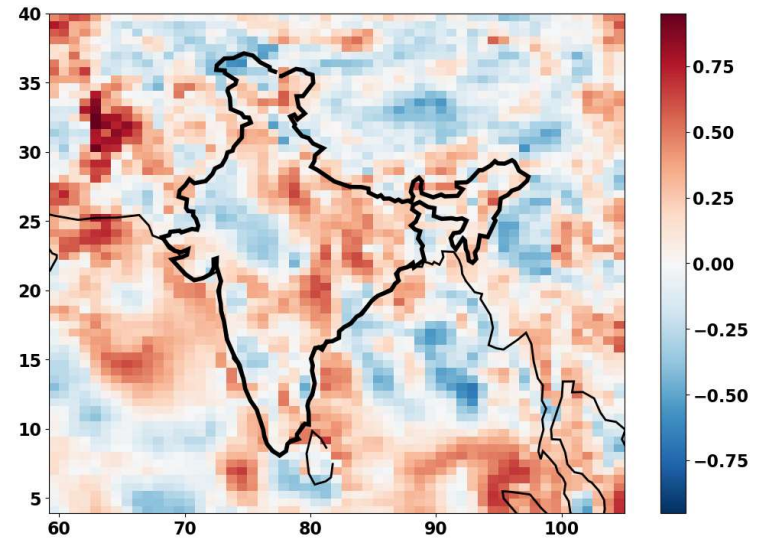
UKMO GS5



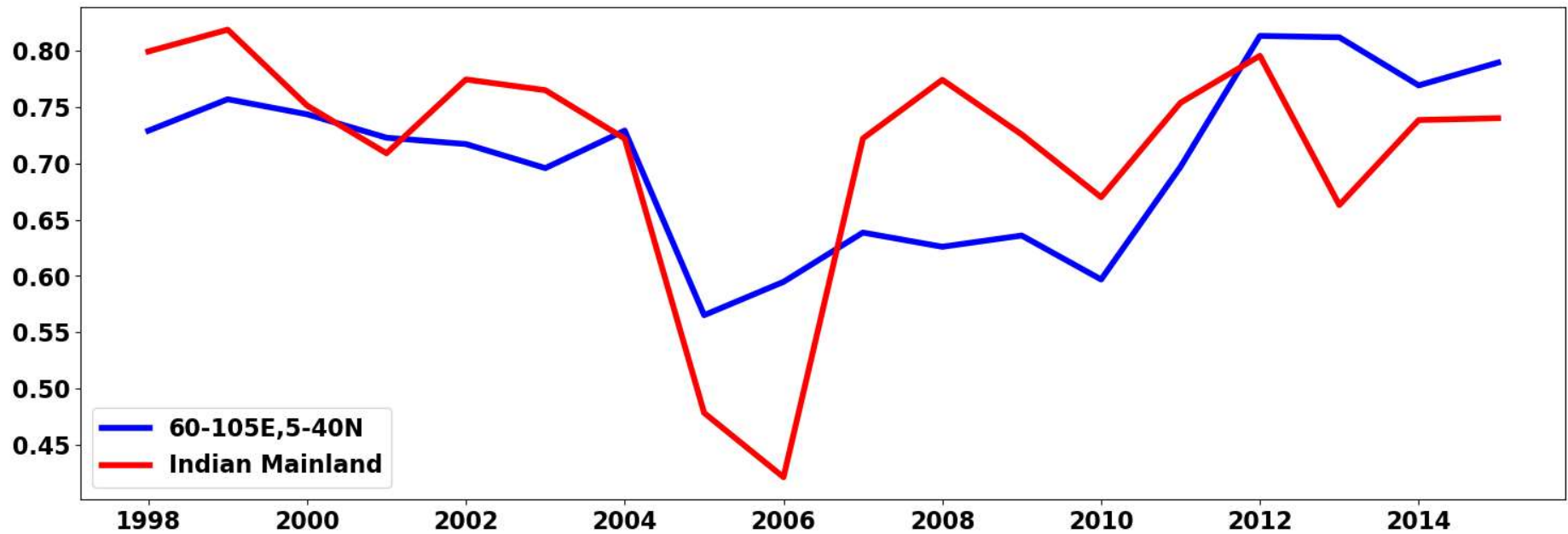
ECMWF



NCMRWF GC2 N216 →
1998-2016 Hindcast



Pattern Correlation of Observation Vs JJAS Forecast (17 May IC)



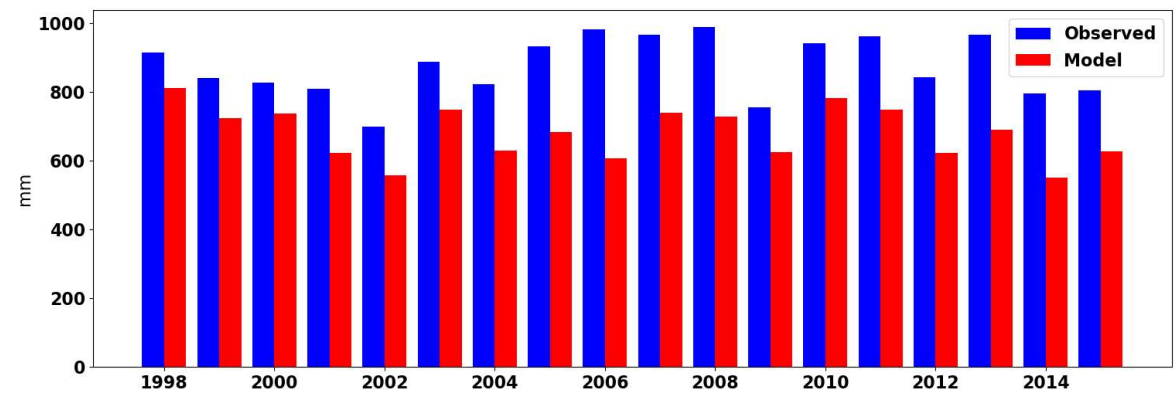
NCMRWF GC2 N216 Hindcast runs



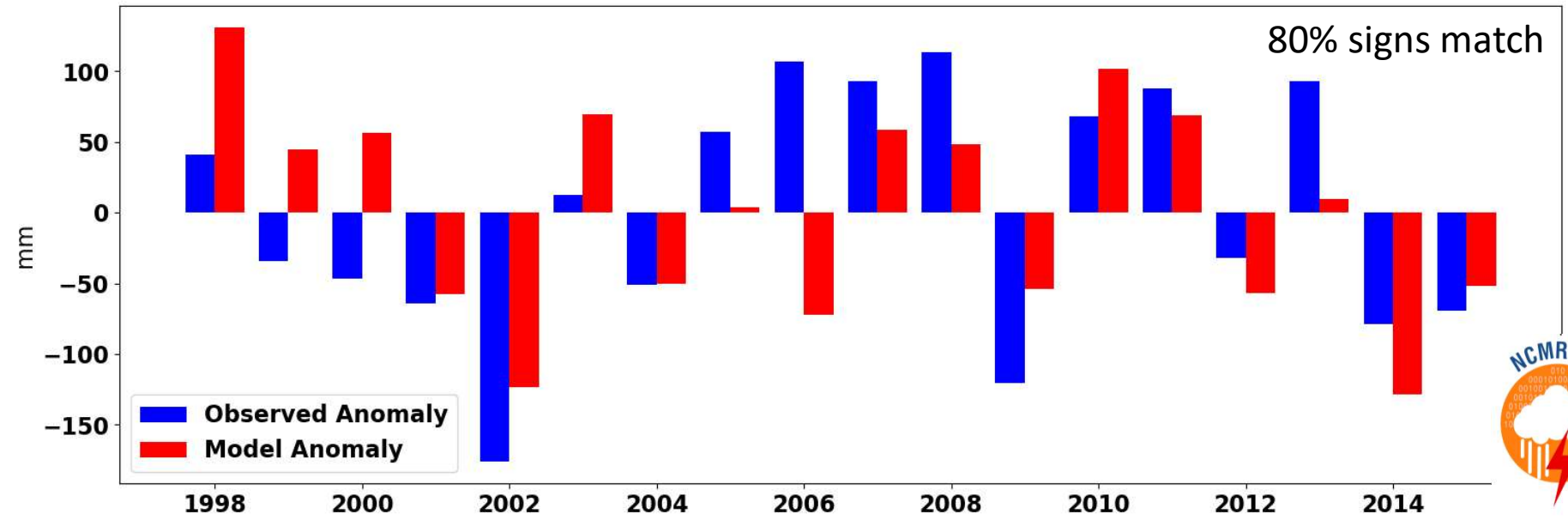
Inter-annual variability of JJAS rainfall over Indian Landmass

JJAS rainfall

NCMRWF GC2 N216 Hindcast runs



JJAS rainfall anomaly





Monsoon and ENSO

- 1. It is well known that the El Niño and Southern Oscillation (ENSO) play important role in the inter-annual variation of ISMR and particularly the extremes. Models capture Monsoon ENSO relations reasonably well**
- 2. Internal variability of Monsoon gets modulated by the Pacific SSTs
(In model simulations, Enhanced ensemble spread over the monsoon region during El Niño, compared to La Niña) ← Source of uncertainty in the model**
- 3. Locations/Intensity of Walker and Hadley circulations need to be realistic**
- 4. Ocean/Atmosphere Initial Conditions play important in ENSO prediction**
- 5. High Resolution Ocean ?
(Tele-connections between the Monsoon Rain and ENSO remained same in CFS by going to higher resolution Atmosphere T126 to T328, IITM study)**



Monsoon: ENSO, IOD, EQUINNO

1. Equatorial Indian Ocean Oscillation (EQUINOO) play an important role in the interannual variation of ISMR particularly during extremes. (Gadgil et al., 2004)

2. EQUINOO is east-west oscillation seen in zonal wind and convection anomaly over eq. Indian Ocean

2. Models have shown problems in simulating the observed simultaneous relationships between the monsoon rainfall and the Equatorial Indian Ocean Oscillation (EQUINOO)

Overestimation of rainfall over the Equatorial Indian Ocean and errors in simulating the seasonal cycle of rainfall over both the Eastern and Western Equatorial Indian Oceans.

3. Facets of ENSO and EQUINOO and the links with the monsoon that need to be improved for improving monsoon predictions by models. A combined index of ENSO and EQUINNO has been suggested for large anomalous monsoon rain years.

Seasonal Indian Summer Monsoon Rainfall Skill from CHFP Data

GloSea5 GC2 from SPECS; Obs rain GPCP; Common Period 1992-2007

Eight Models were studied, Some models have good skills (significant)

**Errors in Seasonal Prediction ~ Errors in ENSO teleconnections
(rather than the mean rainfall biases)**

Climate Dynamics

<https://doi.org/10.1007/s00382-018-4449-z>

Skill of Indian summer monsoon rainfall prediction in multiple seasonal prediction systems

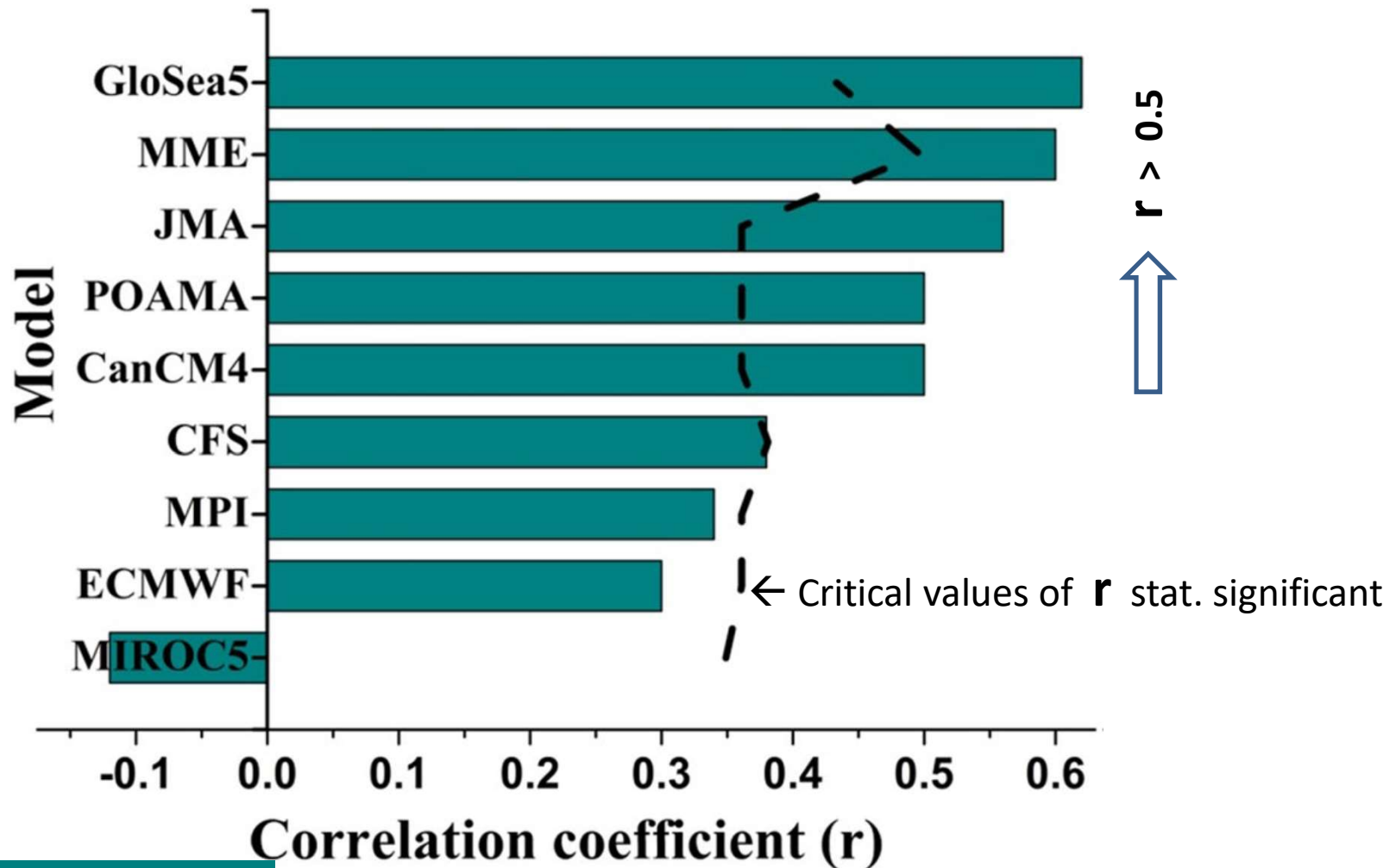
Shipra Jain^{1,2} · Adam A. Scaife^{3,4} · Ashis K. Mitra¹

Received: 13 January 2018 / Accepted: 15 September 2018

© Springer-Verlag GmbH Germany, part of Springer Nature 2018

Indian Monsoon Region: 5-40° N ; 65-100° E , Covers Indian land, BoB and AS close to WG

For this enhanced domain the variance of all models and observation are within some limit
[Variance of Obs 0.15 and Models 0.19 mm² day⁻²] **MME** is from top five models



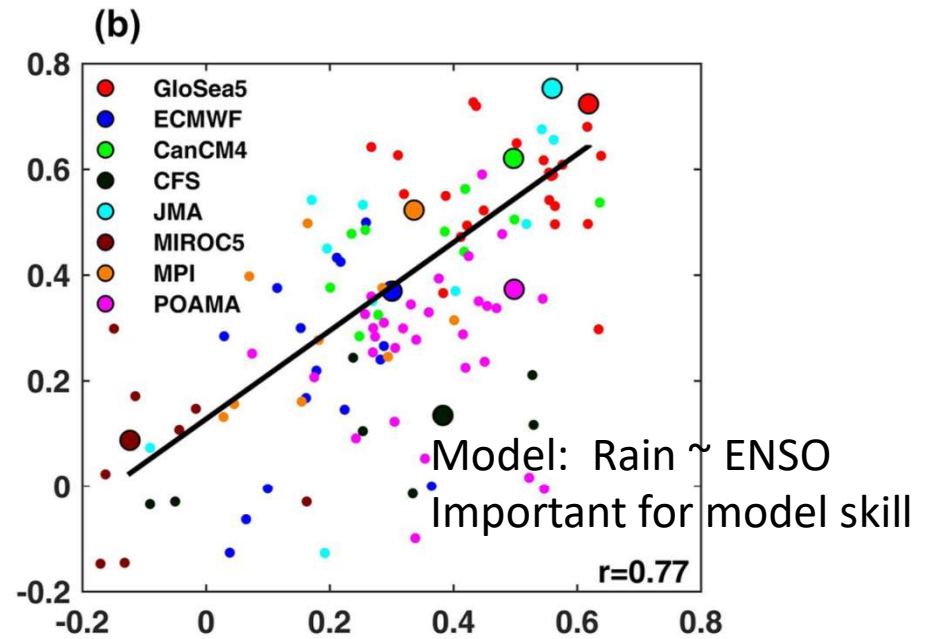
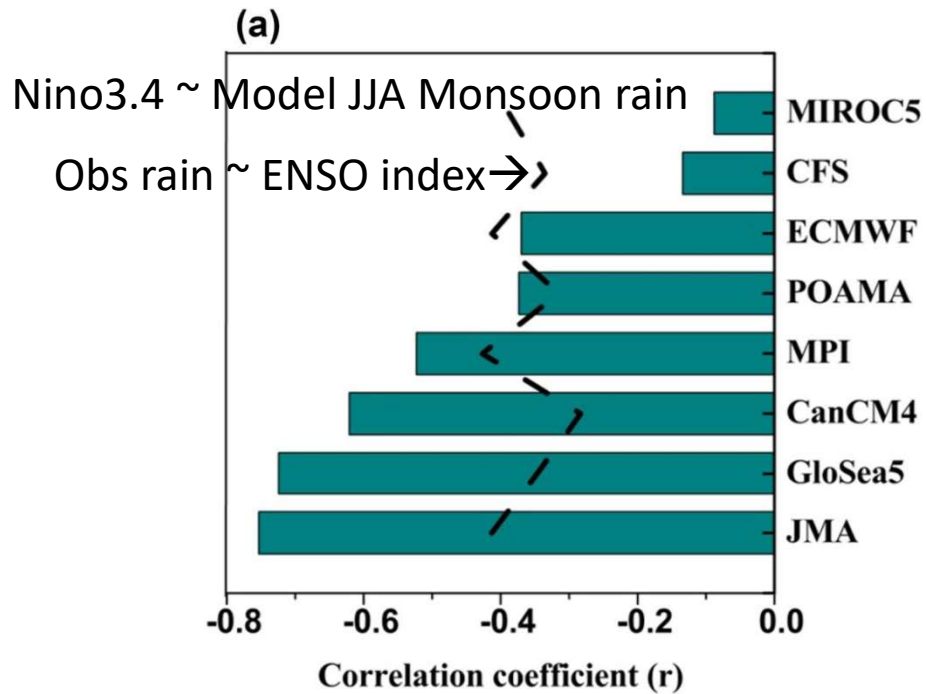
r : Ens Mean and Obs

Skill partly from number of ens members

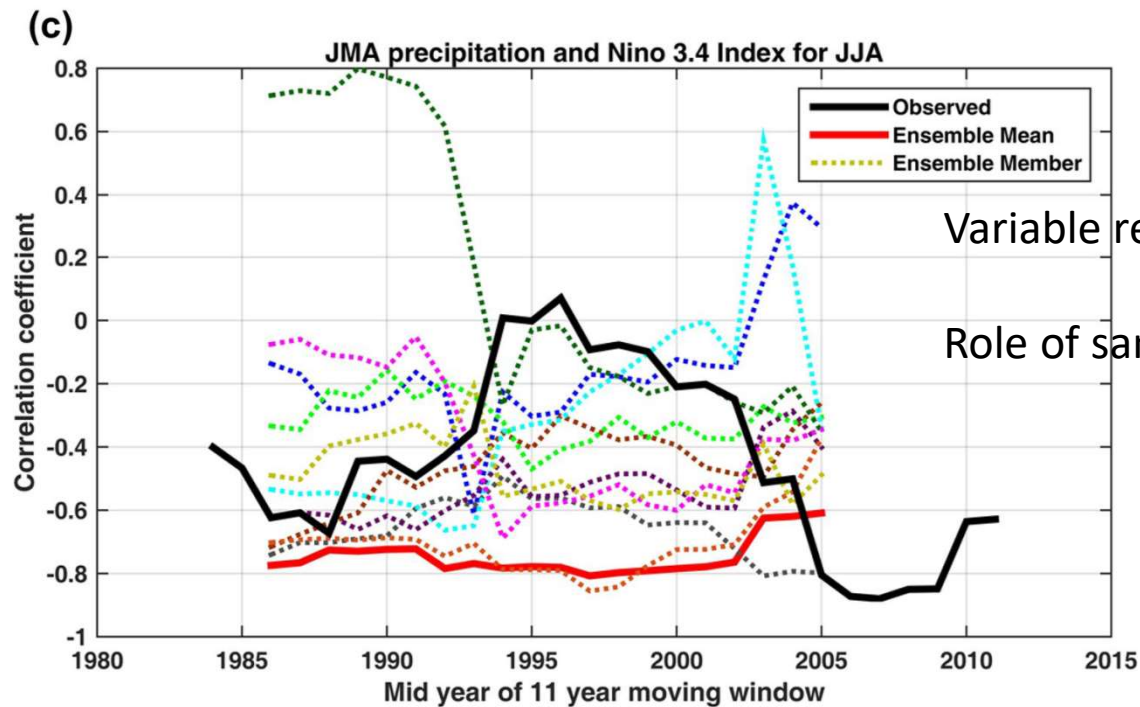
Now useful Skill for Indian Monsoon Region

How to improve Sub-Region S2S Skill ??

Particularly Indian land region



Internal Variability Imp
for individual years
wrt ENSO ~ Monsoon



Variable relation: Obs Rain ~ ENSO

Role of sampling variability ?

Various Indices used

ISMR: land points precipitation over India

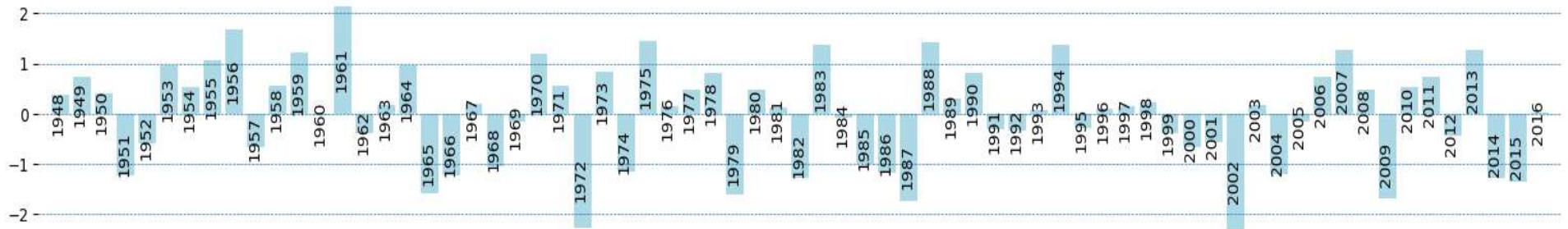
Niño 3.4: Negative of SSTs over (5N-5S, 170W-120W)

Equinoo: Negative of zonal wind (60-90E 2.5S-2.5N)

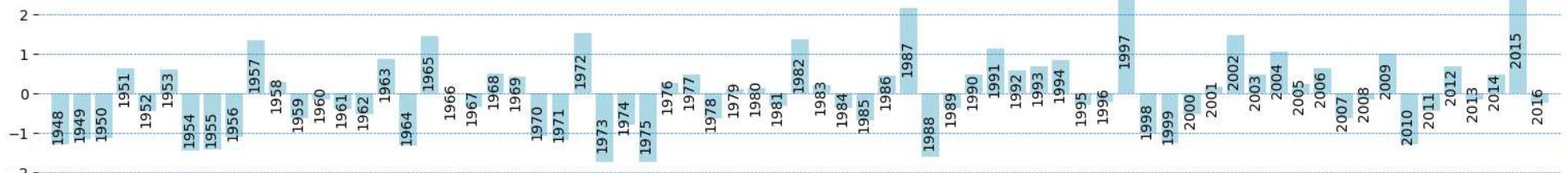
**DMI/IOD: Difference between WEIO (50E-70E and 10S-10N)
and SEIO (90E-110E and 10S-0N)**

JJAS Normalized Indices (1948-2016)

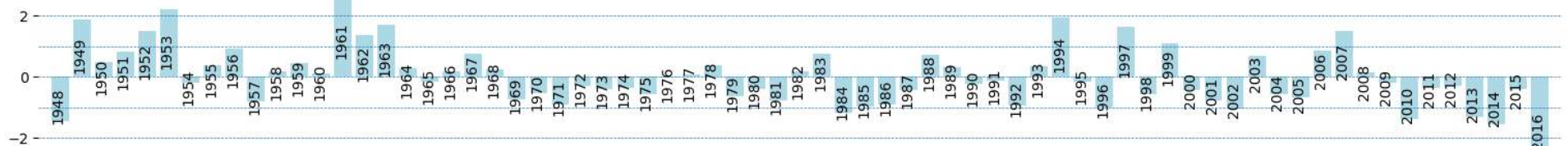
ismr



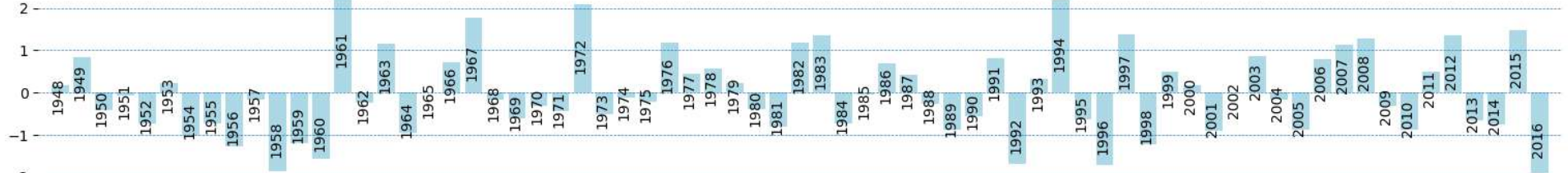
nino3p4



equino

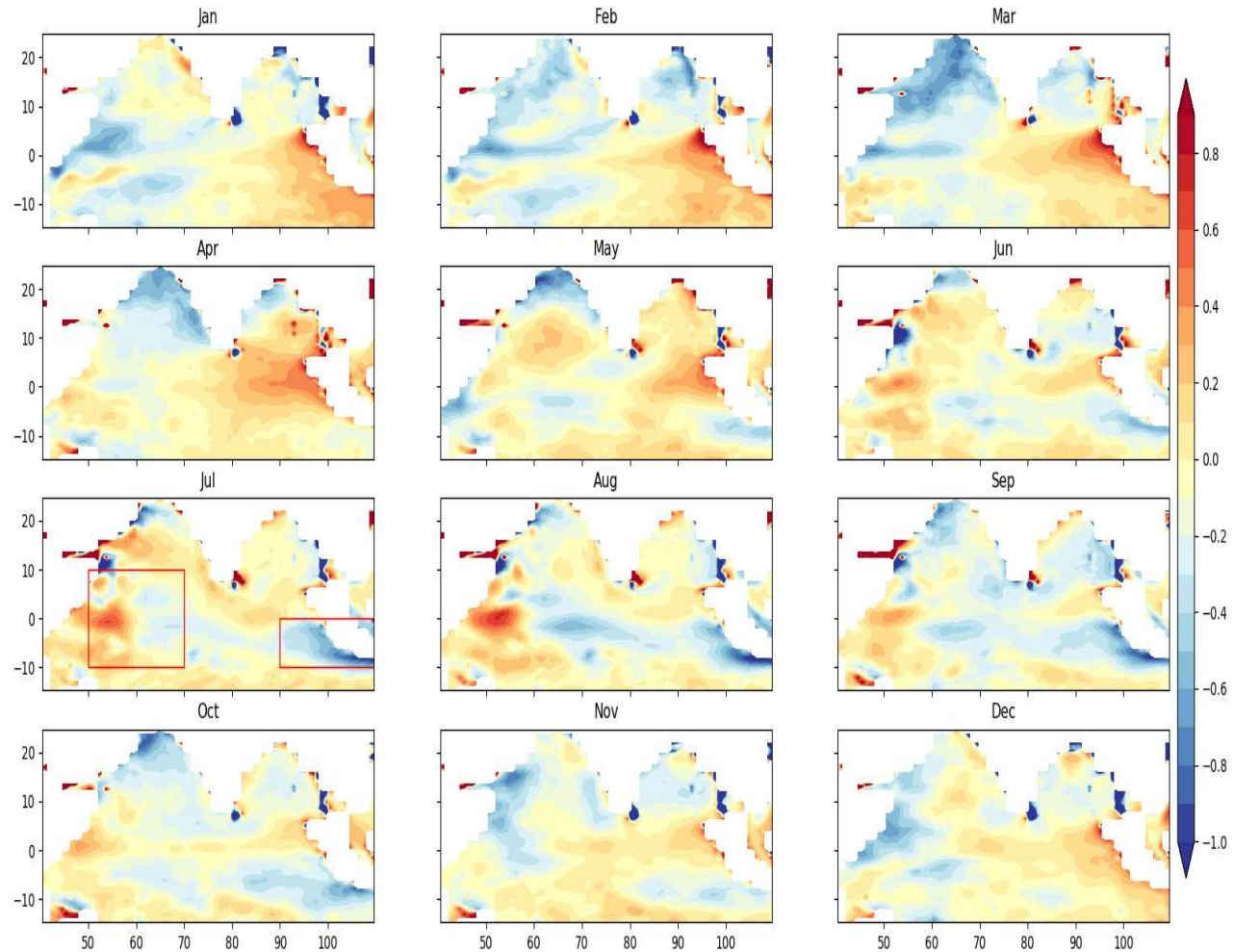


dmi



+ve Dipole biases in NCMRWF CM (JAS)

1993-2015 Hindcast

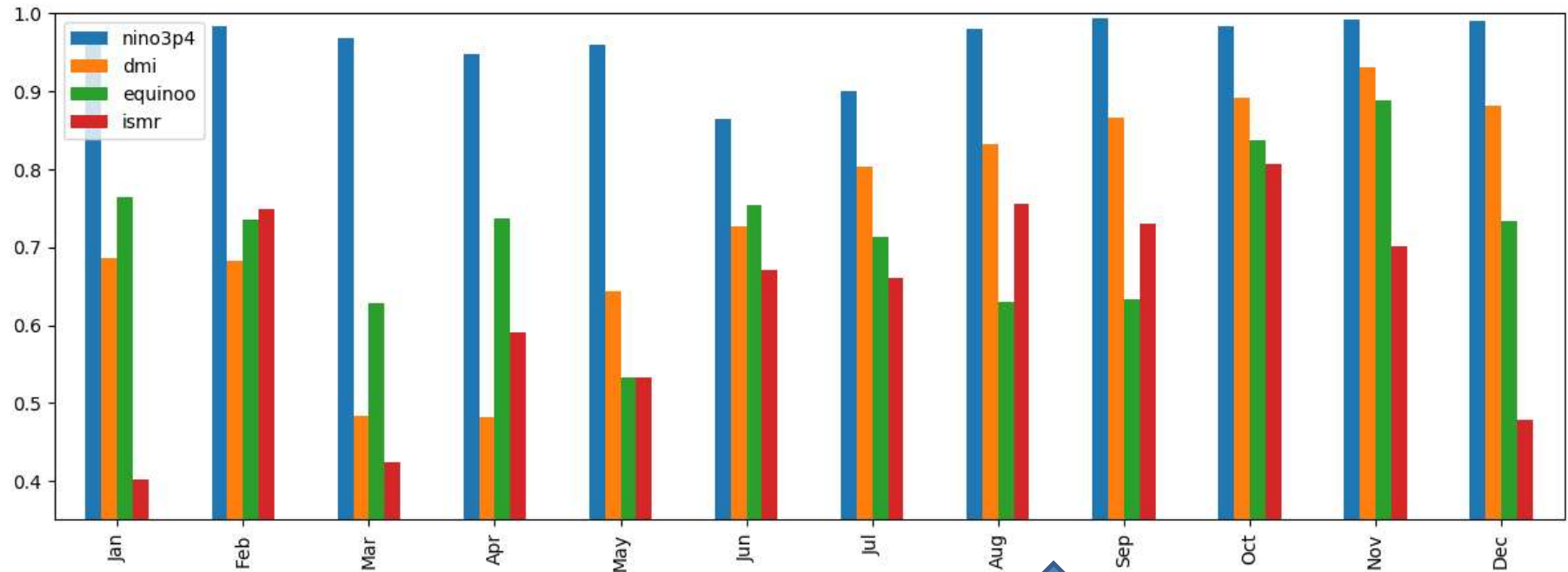


1-month lead

0-month lead corr of key indices

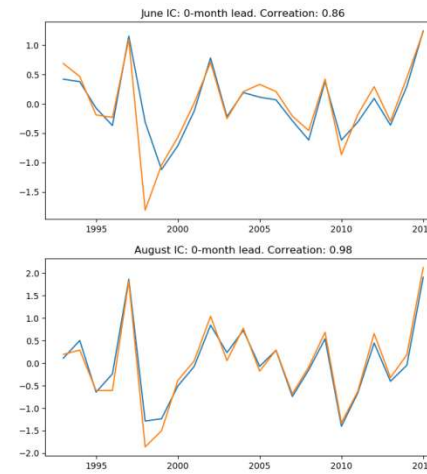
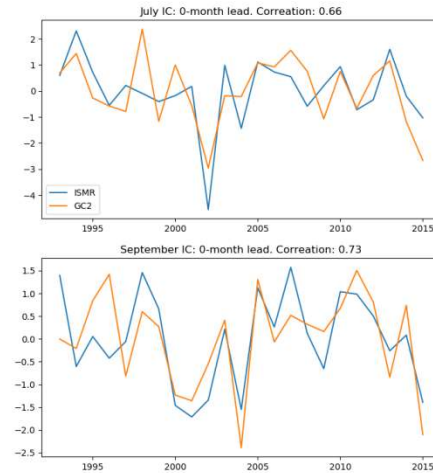
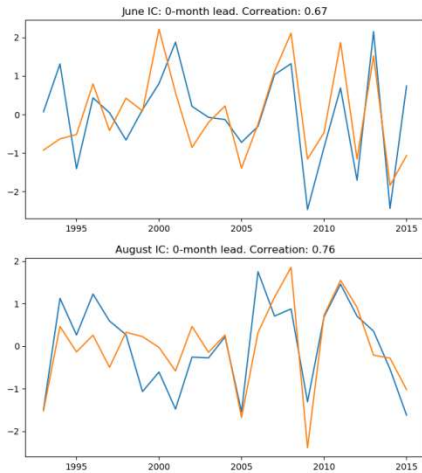
0-month lead corr are higher in August /September (except for equinoo)

Hindcast NCMRWF CM 1993-2015

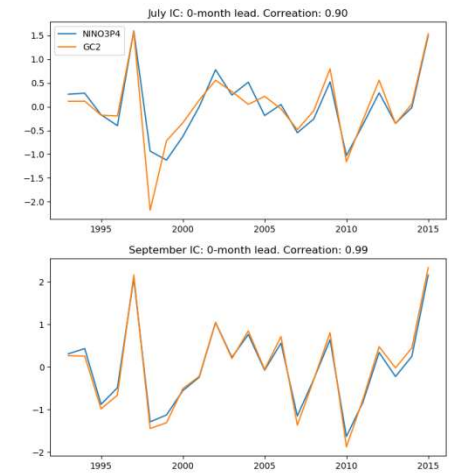


0-month lead normalized indices for Monthly Fcst GC2, Obs

ISMR

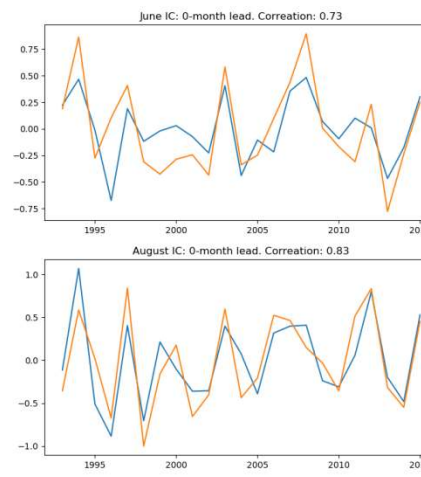
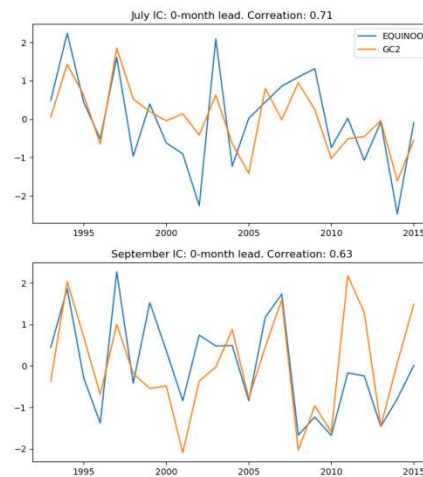
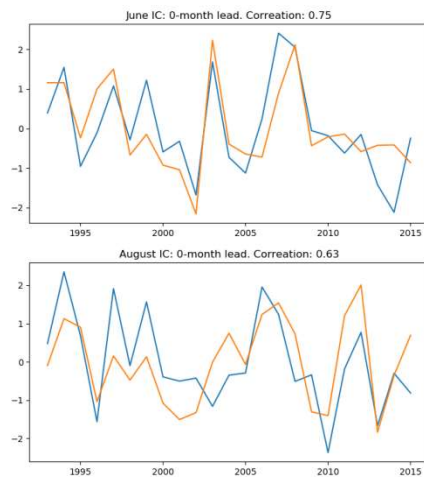


Nino3p4

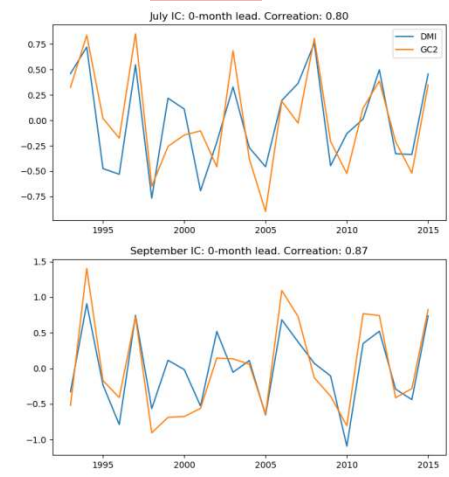


Even though there is systematic bias in DMI/EQUINOO, the correlation at 0-month lead is high (ie representation of inter-annual variability is good).

EQUINOO

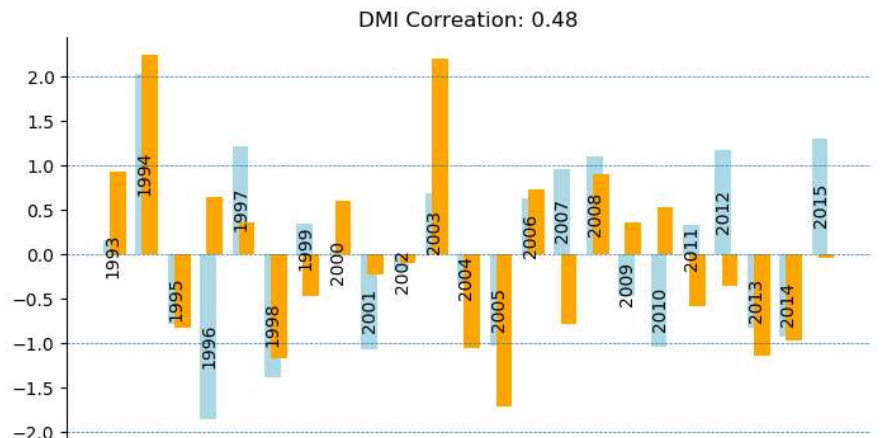
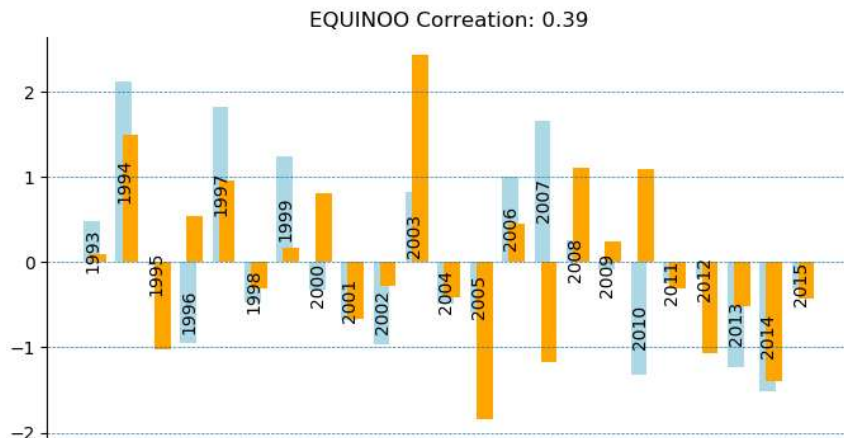
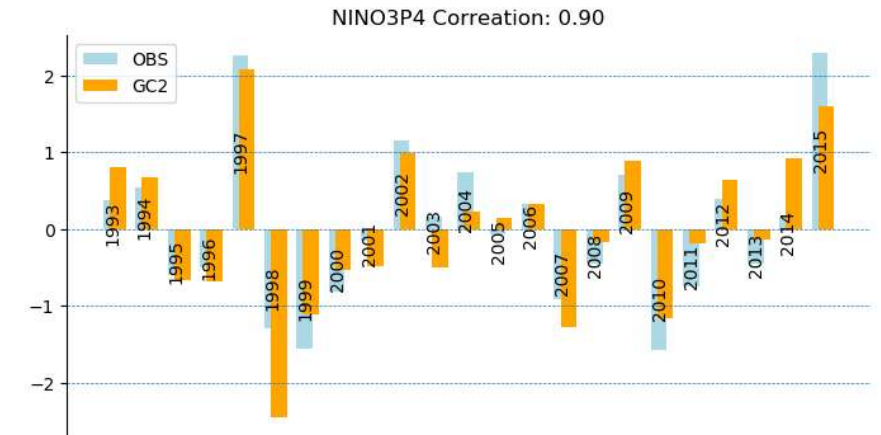
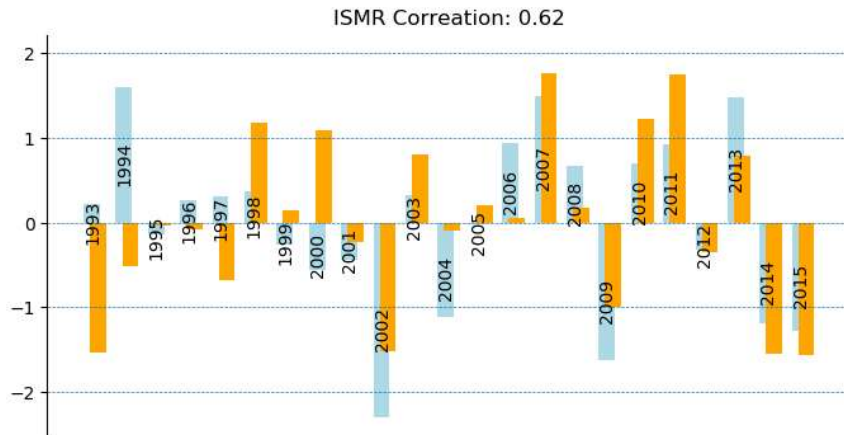


DMI



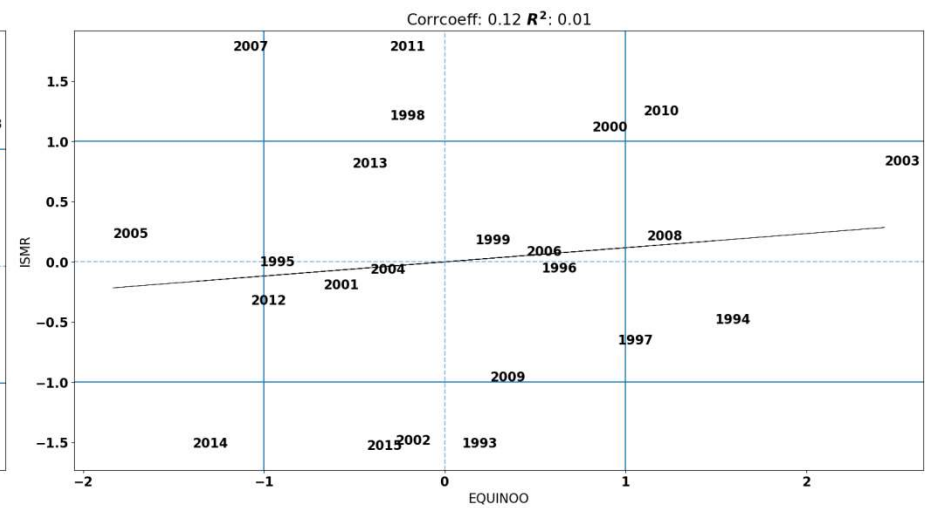
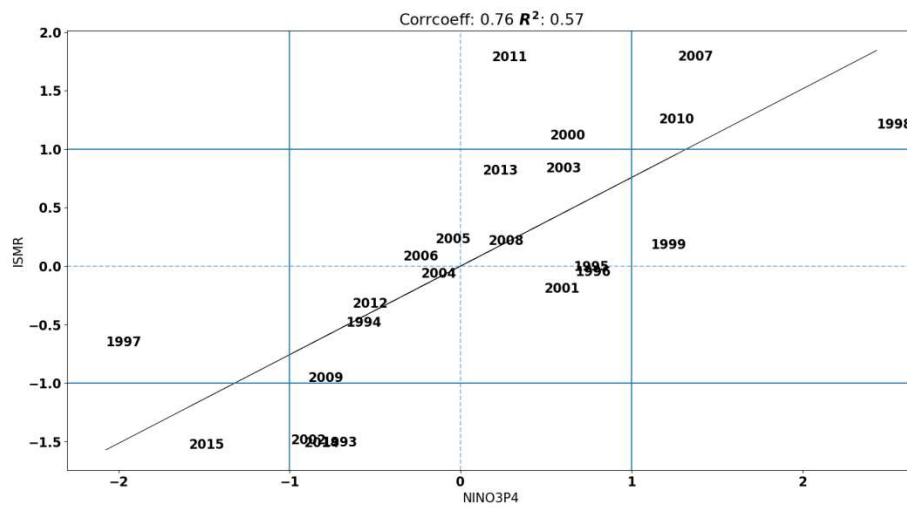
JJAS hindcast 1993-2015

Normalized Indices GC2 and OBS



- Under prediction in ISMR;but high corr. and correct sign of normalized index in most years.
- Systematic error in EQUINOO and DMI are seen , but with reasonable correlation

GC2 Teleconnections and Correlation JJAS



Summary

Current Models have useful skill for Indian Monsoon Region (Includes adjacent Seas)

Indian rain and ENSO relation is skillful in general

NCMRWF CM GC2 N216 has good skill for Indian Monsoon

On Individual years sampling and Sub-Seasonal variability, Internal variability could be important

Within Indian Ocean/Indian domain factors like IOD, EQUINOO might be important

Model skill wrt to IOD/EQUINOO has to be studied further for model development

Combined affect of ENSO, IOD and EQUINOO as an index to be examined

Ocean Model Resolution, Role of LS (over Indian land) feedback could be important

How to get skillful Indian Monsoon sub-regional variability in S2S in Indian Land, Bay of Bengal , NE Arabian Sea



Thank You

