Effects of Snow on Seasonal Predictability of the Indian Summer Monsoon Rainfall

by

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The Indian Summer Monsoon

- Indian summer monsoon is a land-atmosphere-ocean coupled system with seasonal mean~852 mm, SD~85 mm. Economy and livelihood depend on quantum of rainfall. A big source of heating.

- Following the Great Indian Drought of 1877, H.F. Blanford issued the first seasonal forecast of Indian monsoon rainfall in 1884.

- In the early part of the 20th century, Sir Gilbert Walker initiated extensive studies of global teleconnections which led him to the discovery of Southern Oscillation.

- Walker introduced the concept of correlation for long-range forecasting of Asian monsoon, which is relevant even today.

ISMR => All India averaged seasonal (JJAS) monsoon rainfall

Sources of Seasonal ISMR Predictability

Slowly varying boundary conditions (SST, soil moisture, snow, sea ice etc.) and their interactions with atmosphere forms the basis of seasonal/decadal prediction (*Charney and Shukla, 1977; Shukla 1998*).

"..... so, ironically, the seasonal mean in the tropic are more predictable than the extratropics, in contrast to the situation for weather predictability" (*Shukla & Kinter 2006*)

Previous studies indicates that about 50% of IAV of ISMR is predictable ? i.e. Limit of predictability ~0.7 ?

Eurasian snow is one of the important predictor of the Indian summer monsoon rainfall (*Hahn and Shukla 1976; Kripalani and Kulkarni 1999; Fasullo 2004 and many others*)

Relation of ISMR with Eurasian Snow

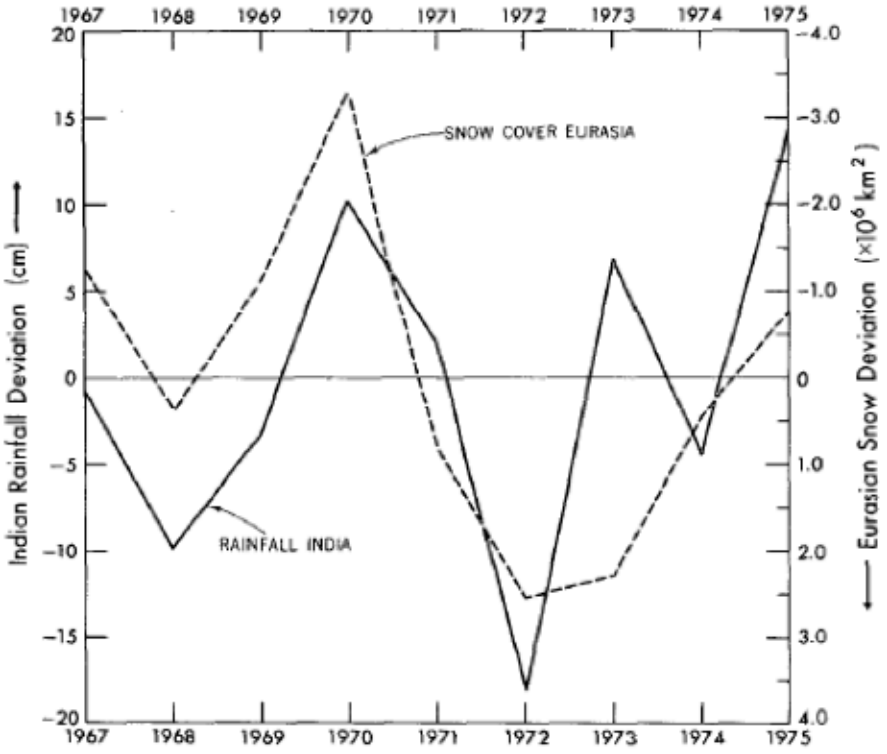
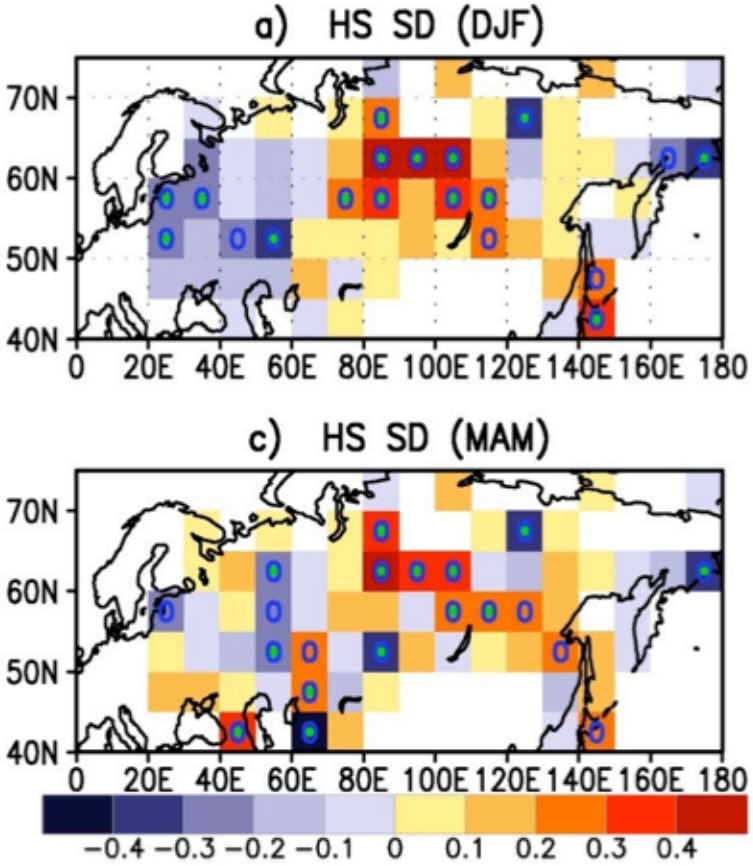


FIG. 1. Graphs of year-to-year variation of winter snow cover departure over Eurasia south of 52°N, and the corresponding variation of summertime area mean rainfall departure for India.

Han and Shukla 1976; J. Atmos. Sci.



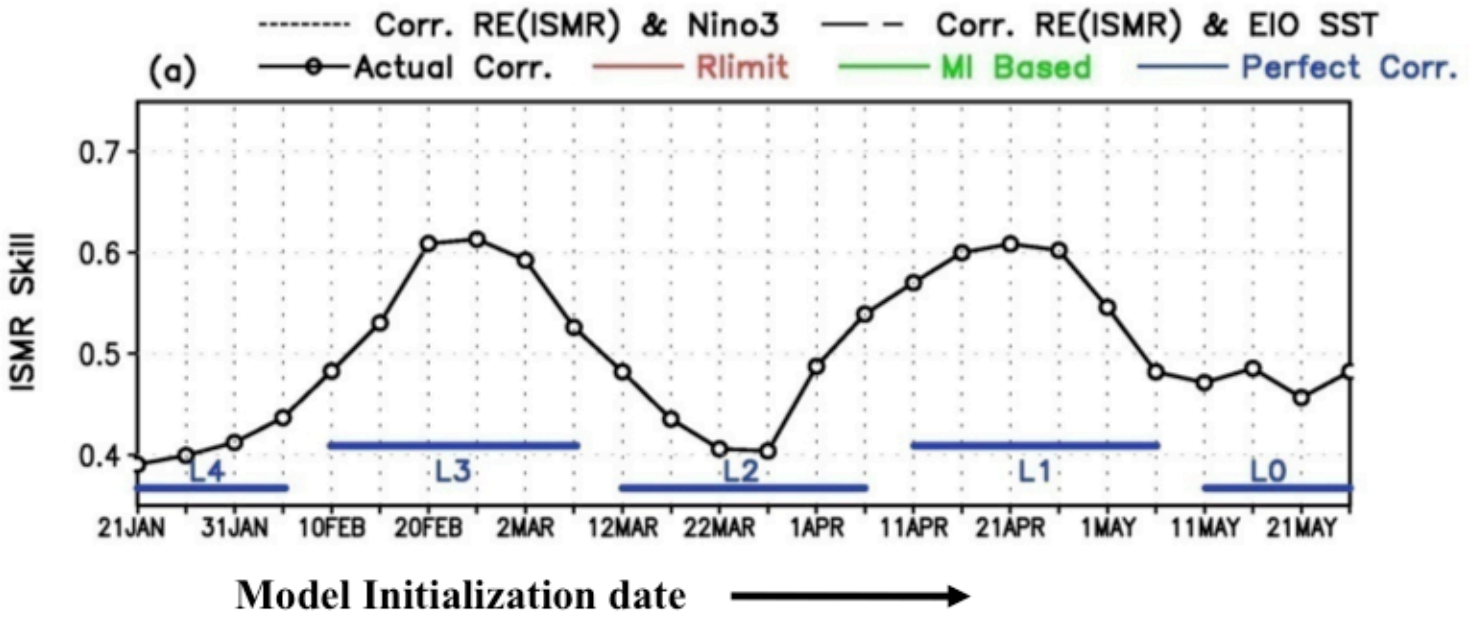
Correlation between observed JJAS all India rainfall and snow depth of previous a) winter (DJF) and c) spring (MAM) using data of 1951-1995. Green (blue) contours and circles show significance at 95 % (90 %) level.

Saha et al., 2013; Clim. Dyn.

ISMR Prediction with NCEP CFSv2

NCEP CFSv2 is used for seasonal ISMR forecast at IITM and IMD

Several development activities are going on at IITM to improve forecast skill of the CFSv2



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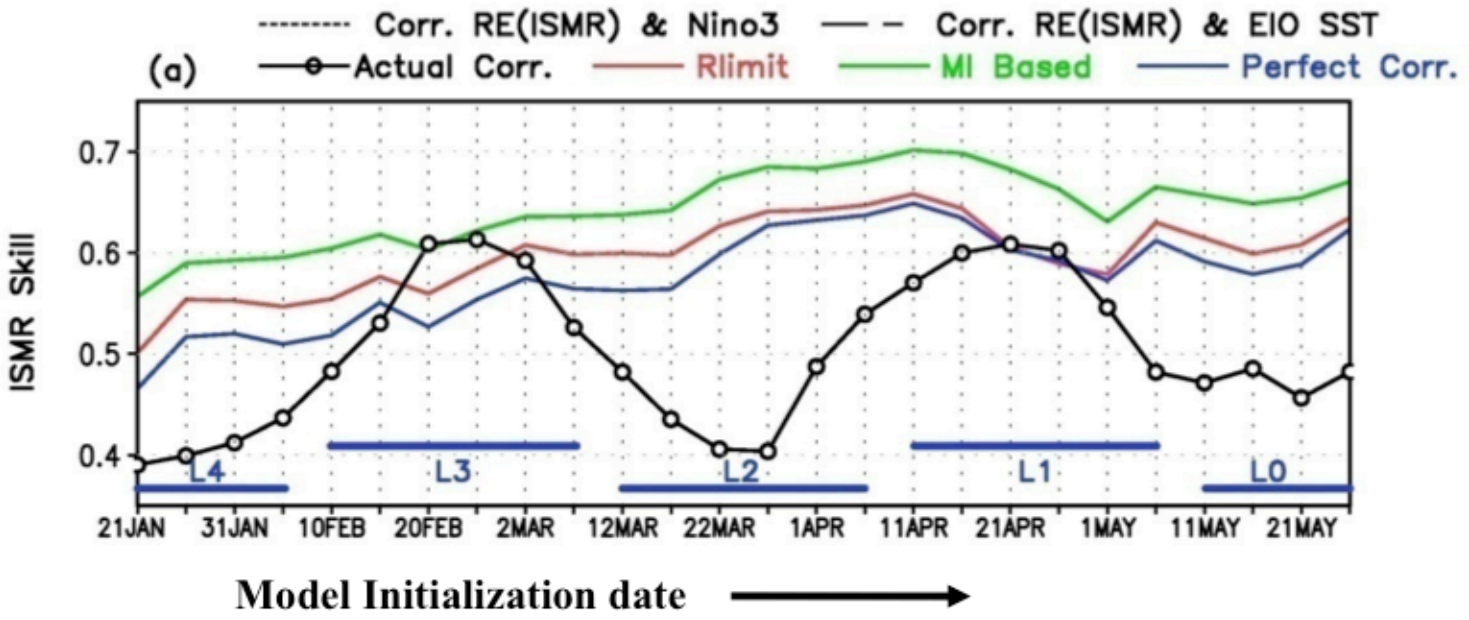
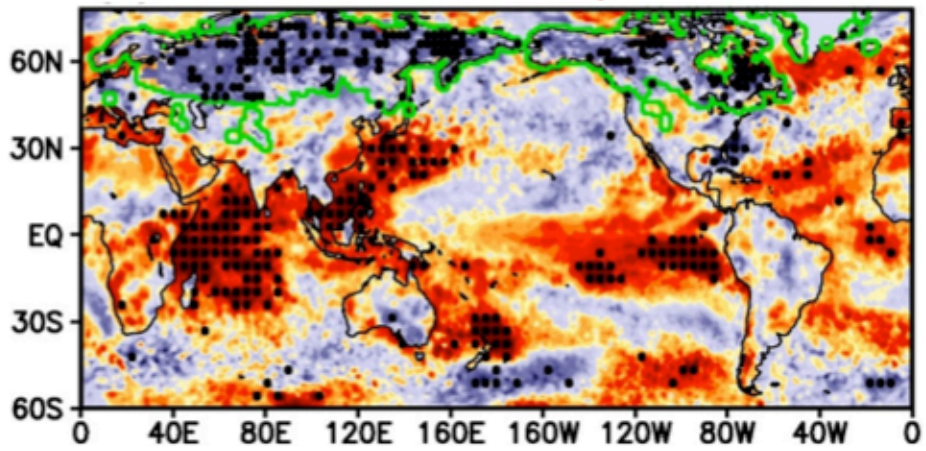


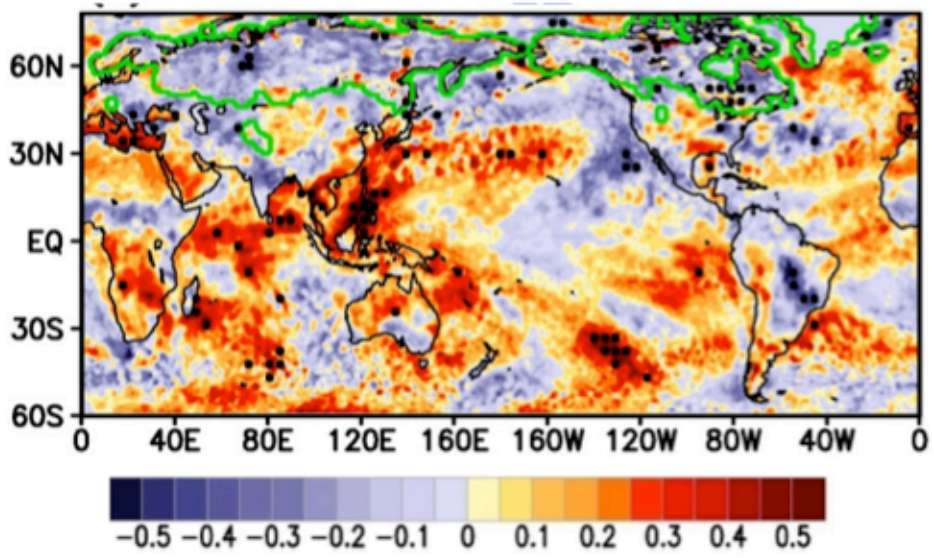
Saha et al., 2016; J. Adv. Mod. Ear. Sci.

Correlation of Initial Snow, SST, SM with RE

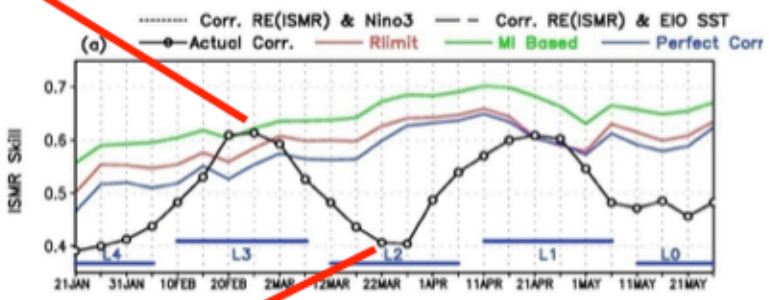
February IC



March IC



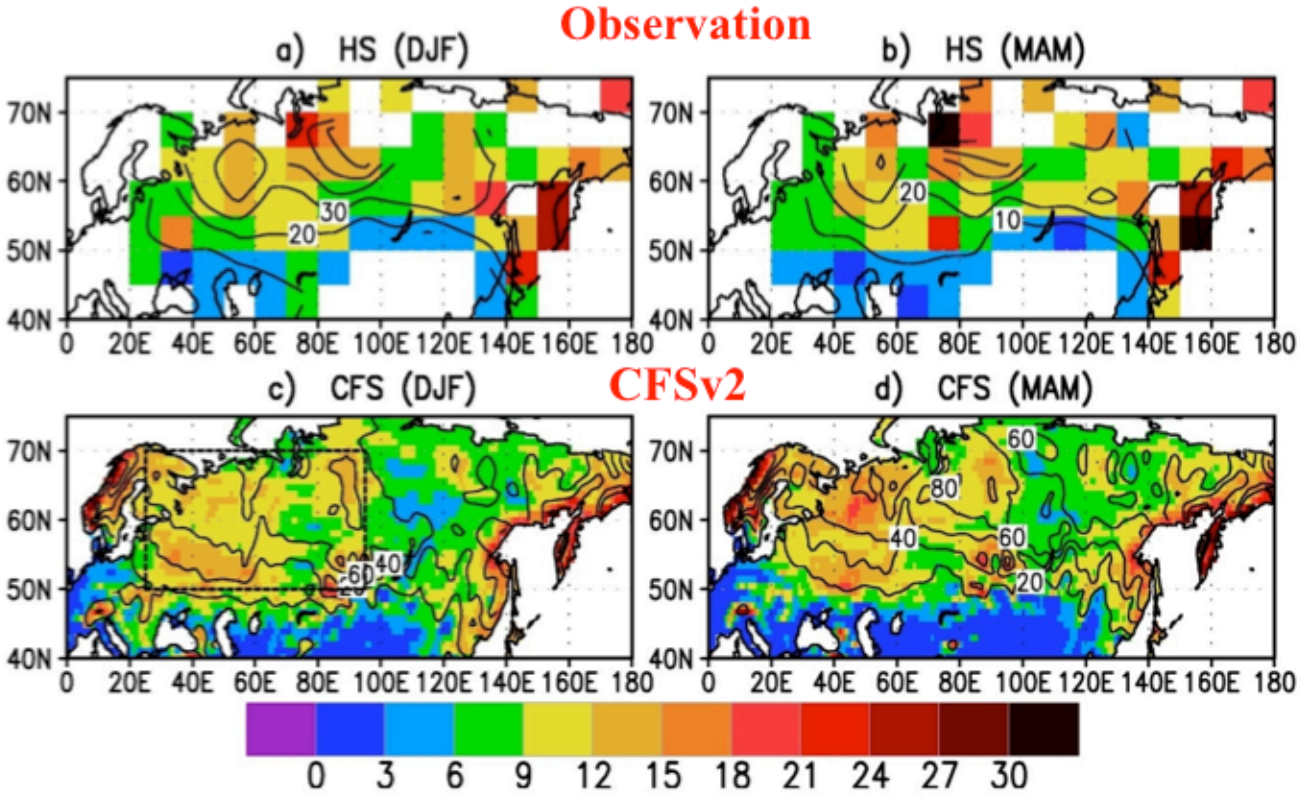
Relative Entropy (RE) is a prognostic measure of predictability



A combined effect of the initial states of the Eurasian snow along with SSTs during February makes the model (CFSv2) most skilful for the ISMR prediction.

Saha et al., 2016; J. Adv. Mod. Ear. Sci.

Bias in Snow Depth



- Positive bias in simulation of snow depth by CFSv2 is of the order of mean in observation.

- Improvements in simulation of Eurasian snow may improve dry bias over India

Saha et al., 2013; Clim. Dyn.

AGU PUBLICATIONS

Journal of Advances in Modeling Earth Systems

RESEARCH ARTICLE
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Effects of multilayer snow scheme on the simulation of snow: Offline Noah and coupled with NCEP CFSv2

Subodh Kumar Saha[1], K. Sujith[1,2], Samir Pokhrel[1], Hemantkumar S. Chaudhari[1], and Anupam Hazra[1]

Key Points:
- Multilayer (maximum six layers) snow scheme is implemented in the land surface model Noah

Key Points:

- A multilayer (maximum six) snow scheme is introduced in LSM Noah. The modified Noah is also coupled with CFSv2
- ".....models that more closely replicate the observed climatological mean tend to have better skill." (*Delsole and Shukla 2010*)

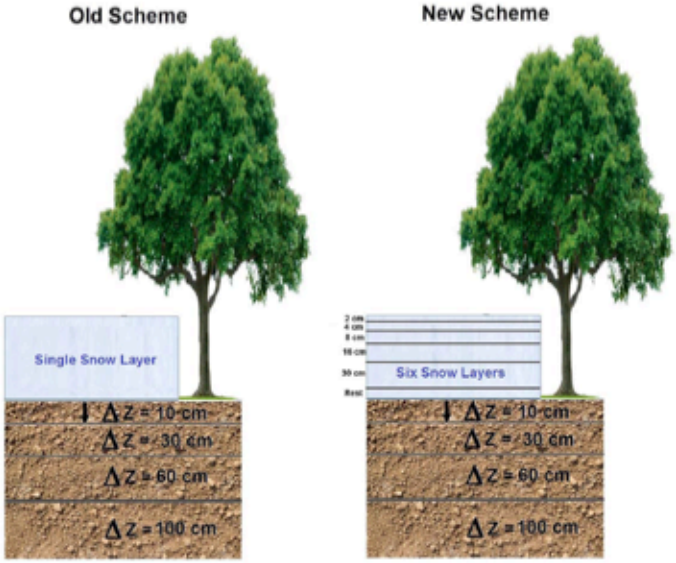
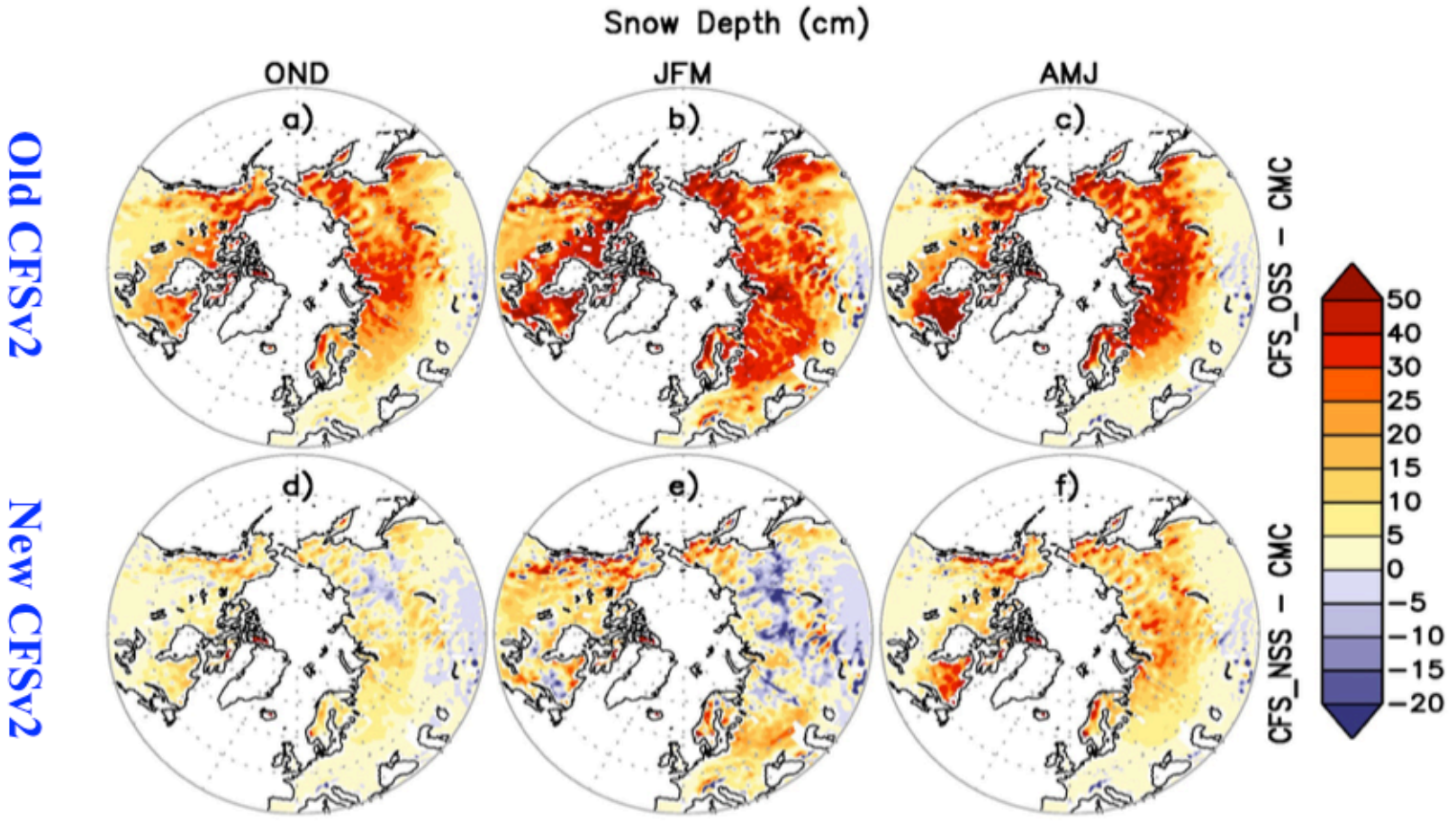


Figure 1. Schematic diagram of the snow and soil layers in the original and modified Noah.

Snow Depth

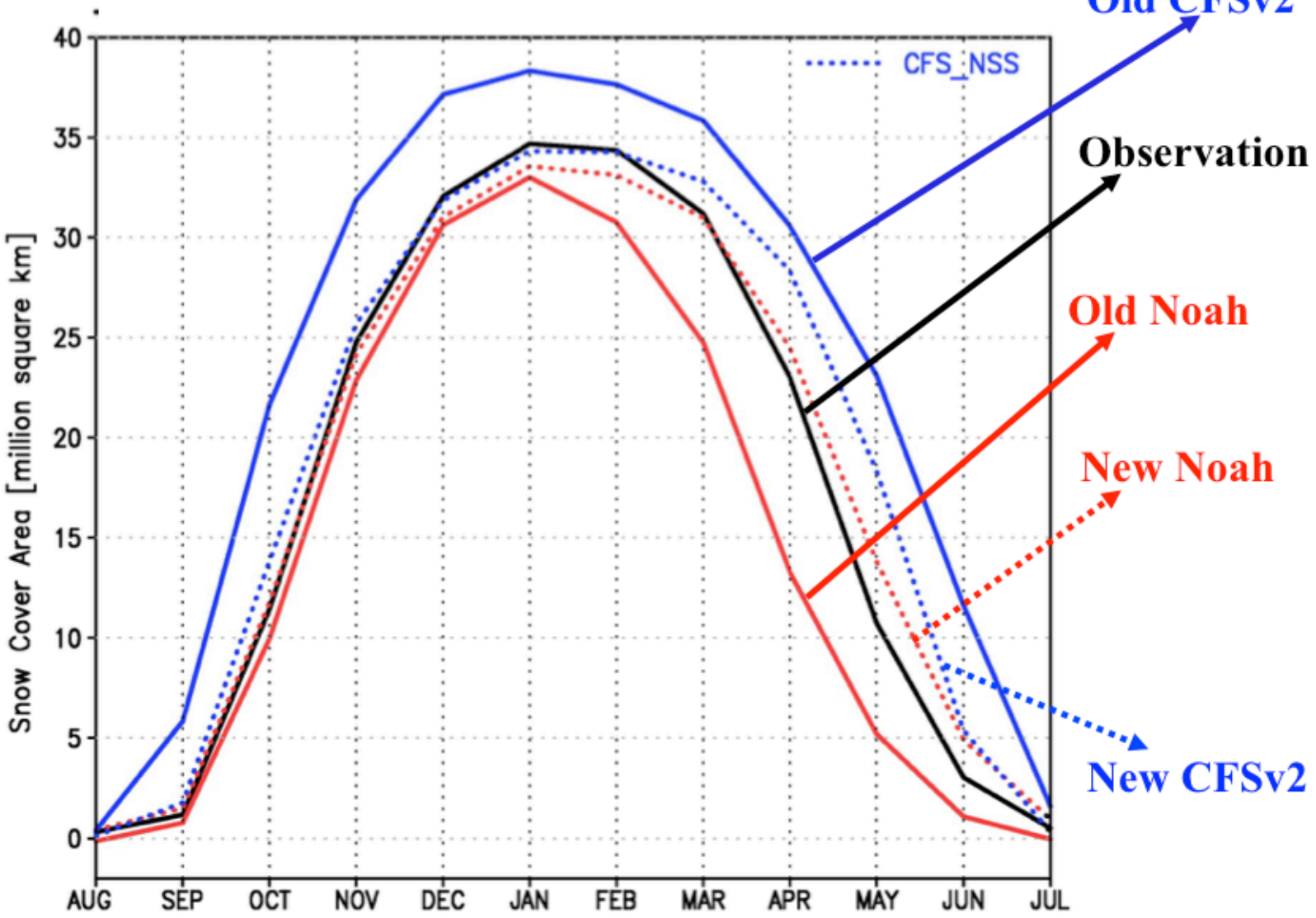


CFSv2 with New Snow Scheme (CFS_NSS)

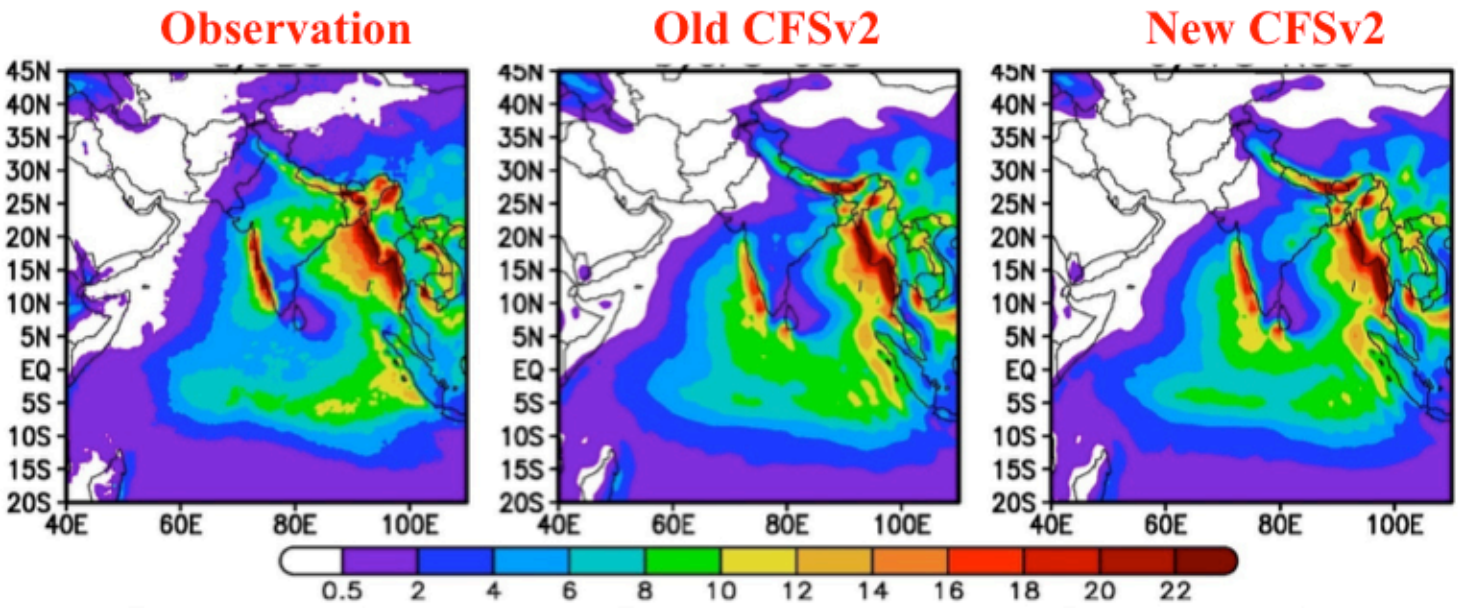
CFSv2 with Old Snow Scheme (CFS_OSS)

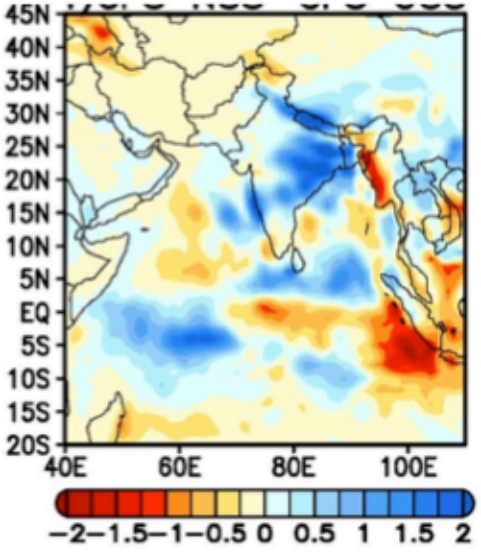
Saha et al., 2017; J. Adv. Mod. Ear. Sci.

Snow Cover Area



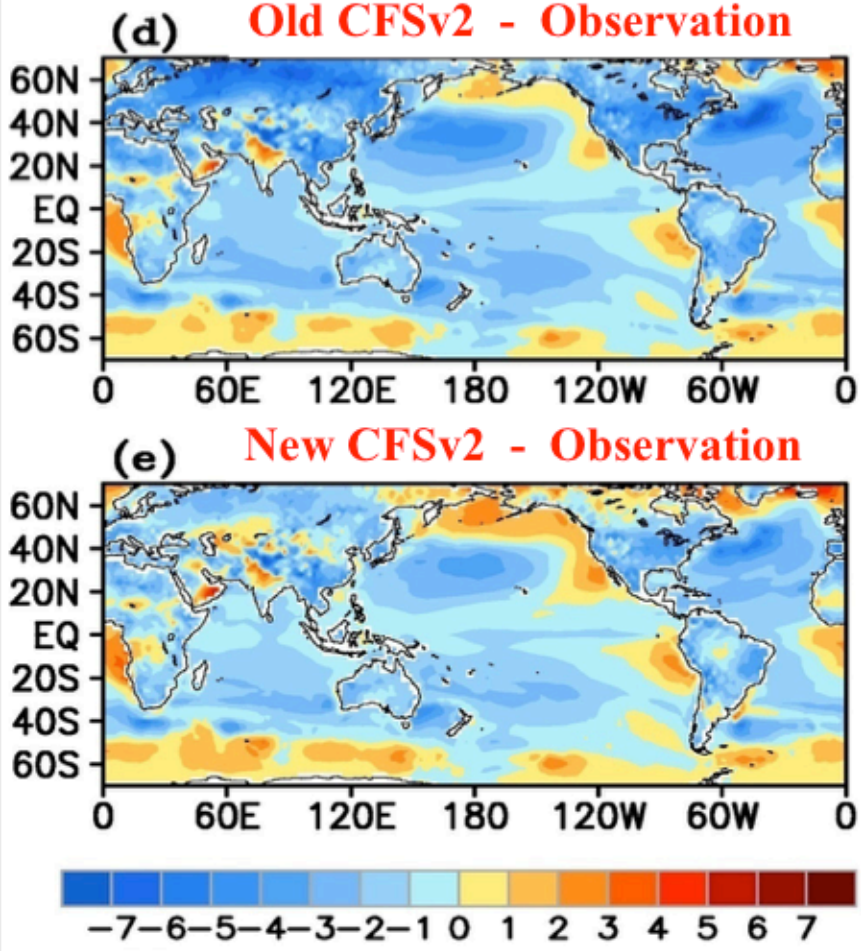
JJAS Mean Rainfall

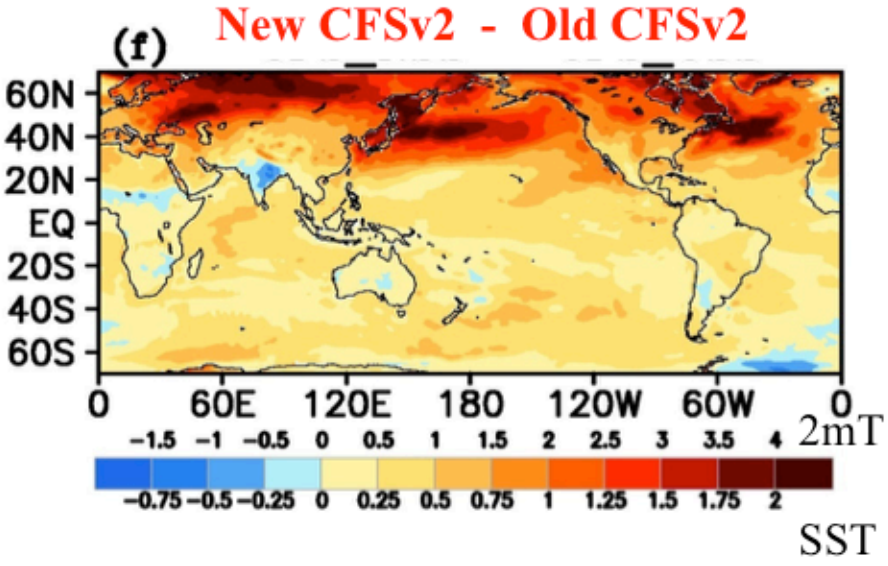




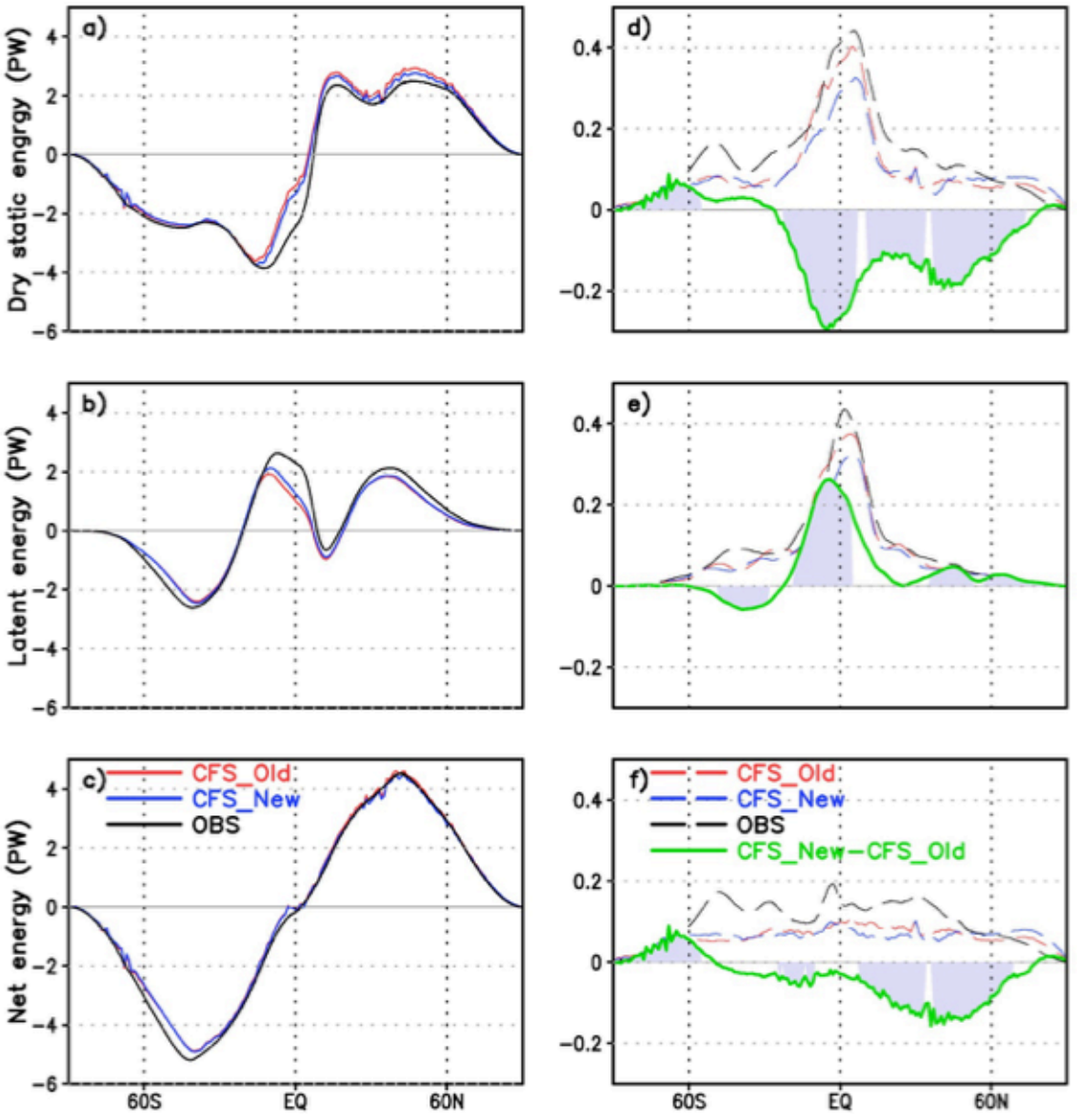
New CFSv2 - Old CFSv2

Bias in SST and 2mT





Atmospheric Energy Transport



As the north-south temperature gradient decreases in the New CFSv2, northward transport of energy decreases.

Increases SST of the tropics.

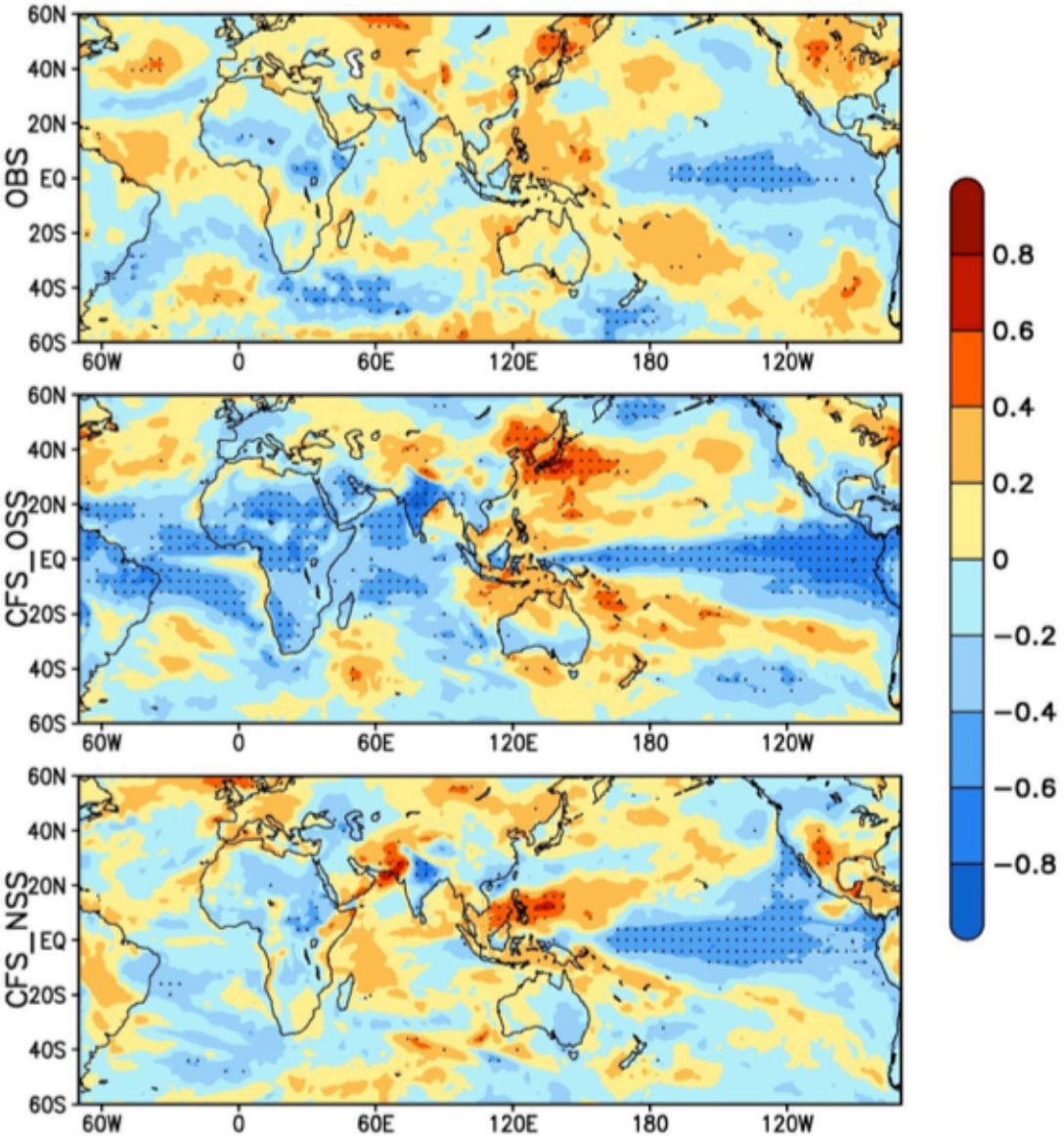
Consequently improves the air-sea interactions

Correlation between ISMR and SST/2mT

Observation

Old CFSv2

New CFSv2

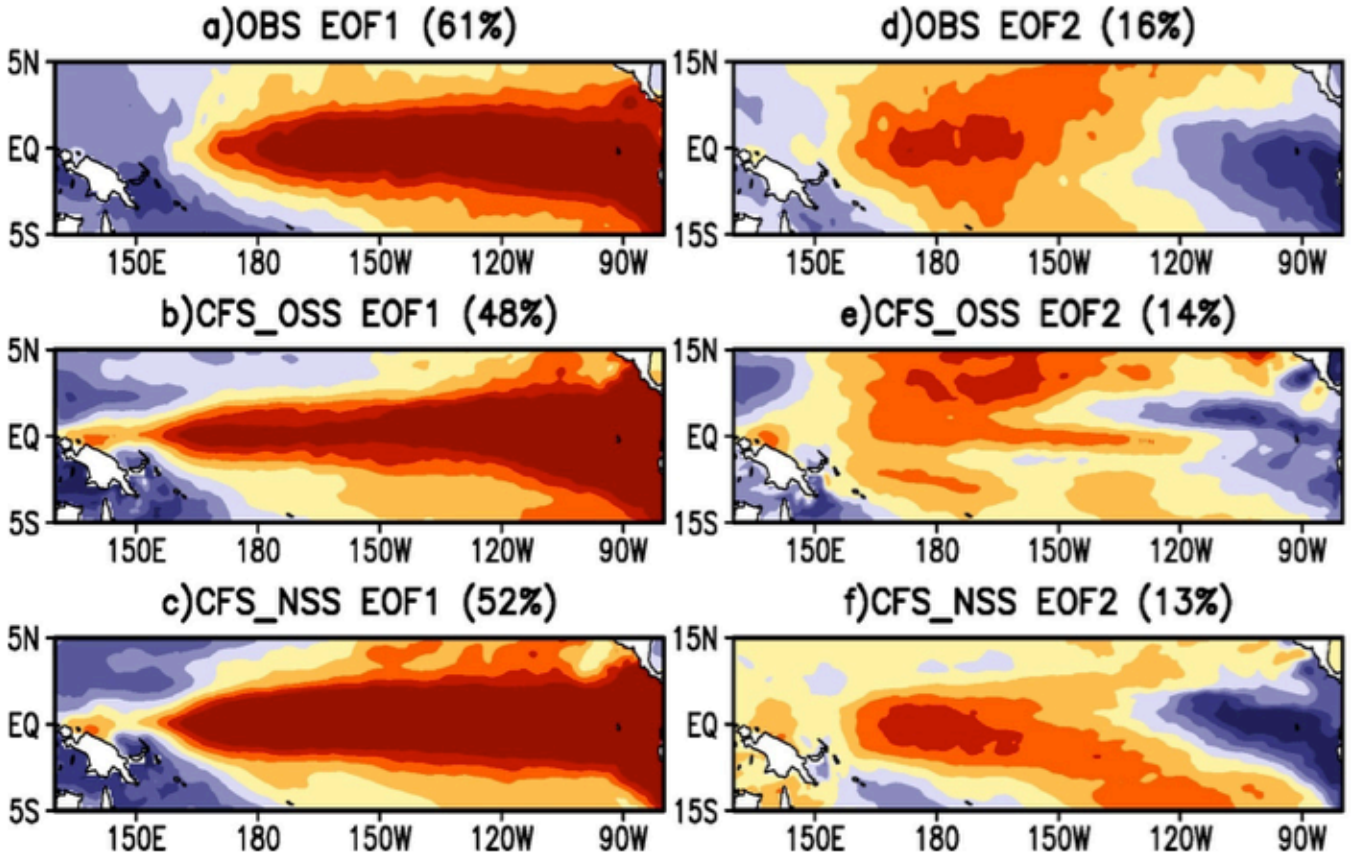


EOFs of Tropical Pacific SST

Observation

Old CFSv2

New CFSv2

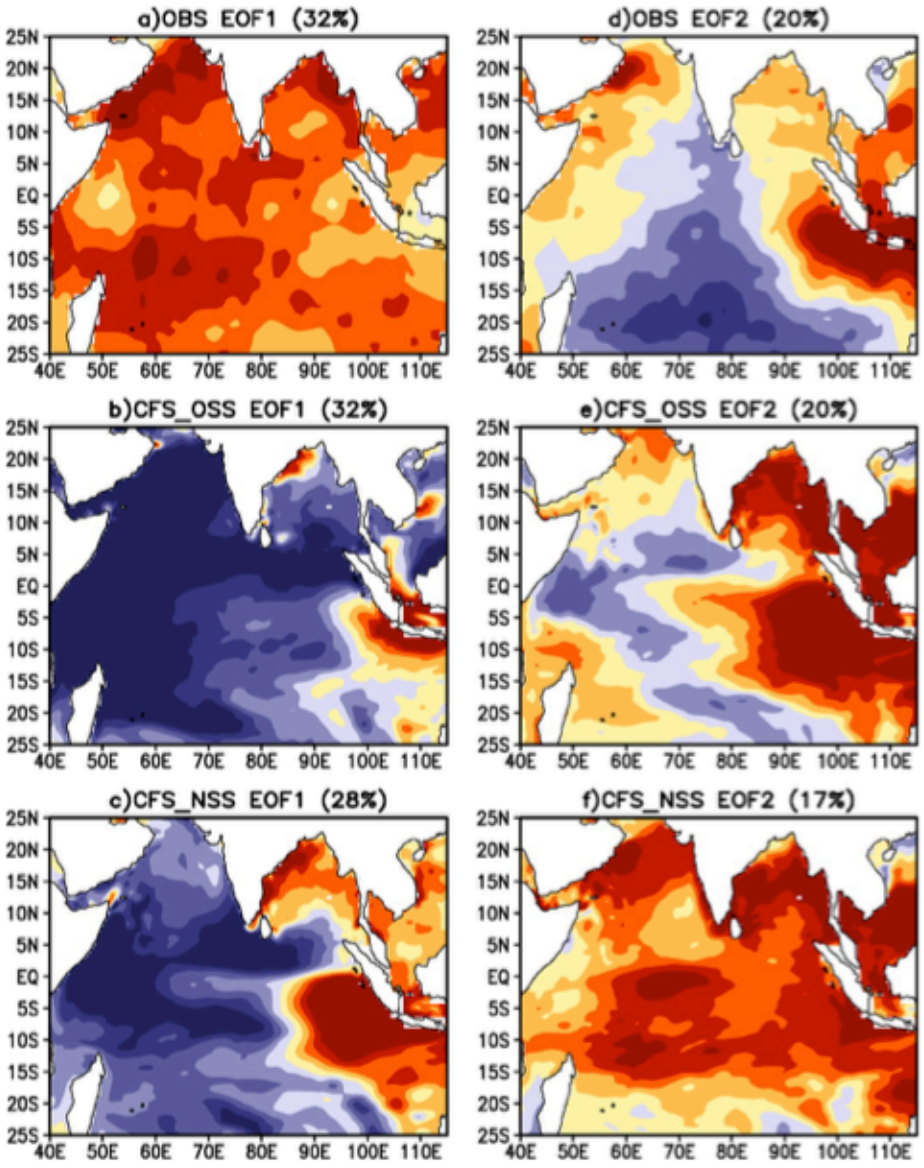


EOFs of Indian Ocean SST

Observation

Old CFSv2

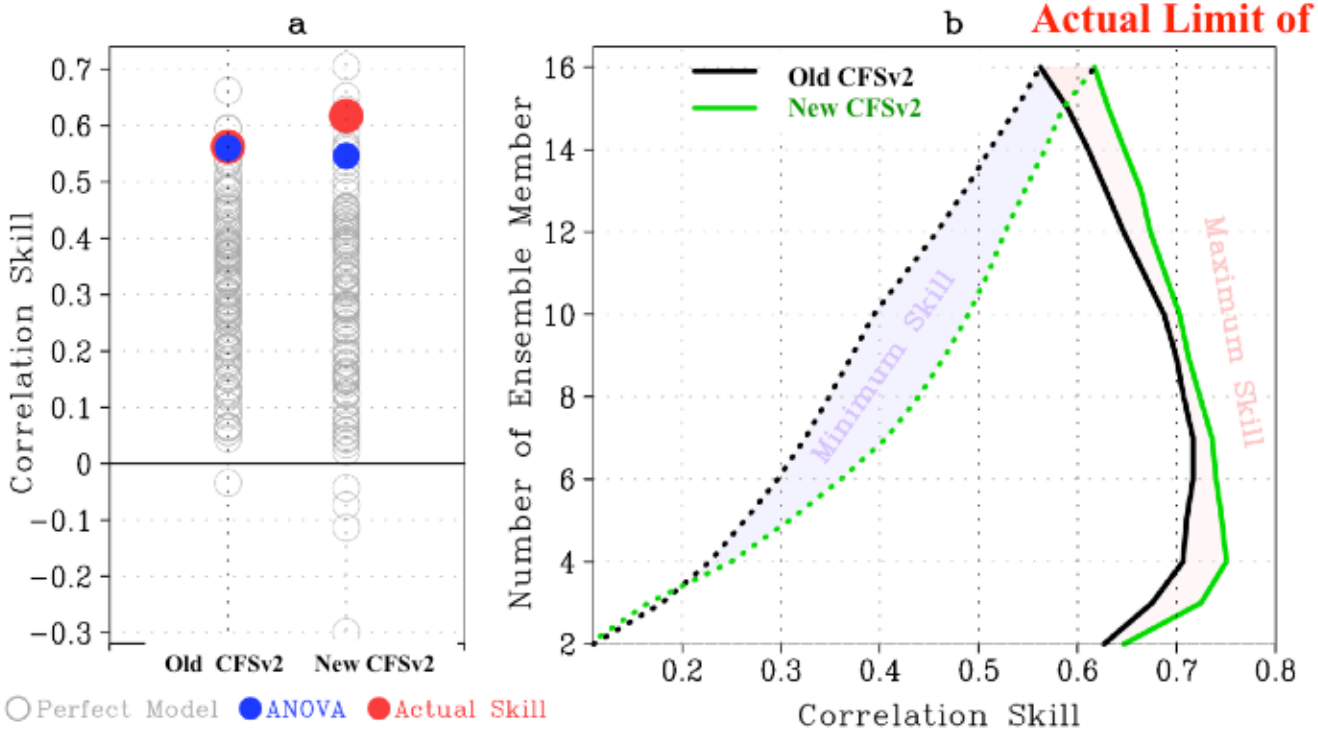
New CFSv2



ISMR Teleconnections

	Nino3.4	Nino3	IOD	EQWIN
OBS	-0.41	-0.42	0.24	0.37
Old CFSv2	-0.58	-0.70	-0.29	-0.08
New CFSv2	-0.56	-0.50	0.23	0.26

ISMR Hindcast Skill



ISMR prediction skill is improved from an older generation model (*Kumar et al., 2005*) to a newer generation models (*Rajeevan et al., 2012; Ramu et al., 2016*), but it is still low (r~0.5) and below the potential predictability limit (PPL ~0.70). PPL is also not very high.

"It remains an open question whether the problem is with the hypothesis or the model" (*Shukla 2007*).

Summary

- A combined effect of the initial states of the Eurasian snow along with SSTs during February makes the model (CFSv2) most skilful for the ISMR prediction.

- Eurasian snow affects the meridional energy flux and that changes the tropical air-sea interactions, consequently affecting the ISMR. ..... A framework to understand effects of snow on the summer monsoon.

- As the actual prediction skill is reached very close to PPL, what is the Future of ISMR Prediction ? Is there any Hope ? Is it possible to cross/exceed the potential limit of predictability ?

Thank You!

Outline

- The Indian Summer Monsoon
- Sources of Seasonal ISMR Predictability
- Link between ISMR and Eurasian Snow
- Development of Snow Physics, Teleconnections, Predictability
- Conclusions

Measures of Predictability

ANOVA based SNR, Rlimit

Information Theory based RE, MI

Classical Perfect Model Correlation

Mahalanobis distance measures the distance of a point from a data distribution (*Mahalanobis 1936*).

Relative Entropy (RE) is quantitative measure of the distance between climatological mean and forecast distribution.

RE is a prognostic measure of predictability, which retains the initial state information.

EOFs of Northwest Pacific SST

Observation

Old CFSv2

New CFSv2