Role of Cloud Relaxation Parameter in Inter-annual and Interdecadal Variability of the Indian Monsoon in an Atmospheric General Circulation Model

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Inter-annual and Interdecadal variability of Indian summer monsoon rainfall (ISMR) is studied in with the National Centers for Environmental Prediction (NCEP) seasonal forecast model (SFM) in Atmospheric Model Intercomparision Project (AMIP) style simulations. One of the major processes that control the strength of monsoons in an AGCM simulation is the parameterization of deep clouds. A factor that governs the effect of deep convection in the model is the cloud relaxation time scale. Our previous studies have shown that with larger as well as cloud type dependent relaxation time scales, the simulation of mean monsoon rainfall improves. In the present study we try to understand the role of deep convection on the simulation of interannual and interdecadal variability of the monsoons by varying the cloud relaxation time scales in cumulus parameterization. Interconnections between Nino 3.4 SST anomaly, IOD index and ISMR is also studied

Model Used -

The Seasonal Forecast Model (SFM) from NCEP used for the present study was run at T62L28 resolution. The model has 28 unequal vertical sigma levels and a horizontal resolution of 1.875 degrees. For uniform resolution throughout the globe, the model uses reduced grid. Chou (1992) short-wave radiation parameterization is used in the experiment while the long-wave parameterization is from Chou and Suarez (1994). Planetary boundary layer as parameterized by Hong and Pan (1996) is used. Cloud fraction is based on Slingo (1987). Mountain induced gravity wave drag parameterization is by Alpert et al (1988). Land process parameterization by Pan and Mahrt (1987) is used in the model. Smoothed mean orography is used in the study and ozone is prescribed using climatology. The Relaxed Arakawa Schubert cumulus parameterization scheme is based on Moorthi and Suarez (1992). Semi-implicit time integration is used for model dynamics. Kanamitsu et al (2002) provides detailed description of the model.

Experimental Details -

Experiment was started by giving an Atmospheric Model Inter-comparison Project (AMIP) style run starting on 1st January, 1982. The model was integrated for 28 years till 31st December, 2009. Monthly mean sea surface temperature's (SST's) are from Reynolds and Smith (1994) interpolated linearly to the model time step. Initial conditions are taken from NCEP reanalysis. Diagnostic variables are output as daily averages (once every day). The focus of the present study is to study the sensitivity of annual and inter annual variability of the simulated precipitation over India during the Indian summer monsoon (ISM) season to the choice of relaxation parameter. A thirty minute model time step was used for the integrations and the output was saved once a day. The present study include sensitivity studies between two simulations, one with α=0.10 and the other with α=0.30. We call the case in which α=0.30 as the control case or the default value of α. α=0.10 refers to cloud adjustment time of 300 minutes while in the control case cloud adjustment time is 100 minutes.

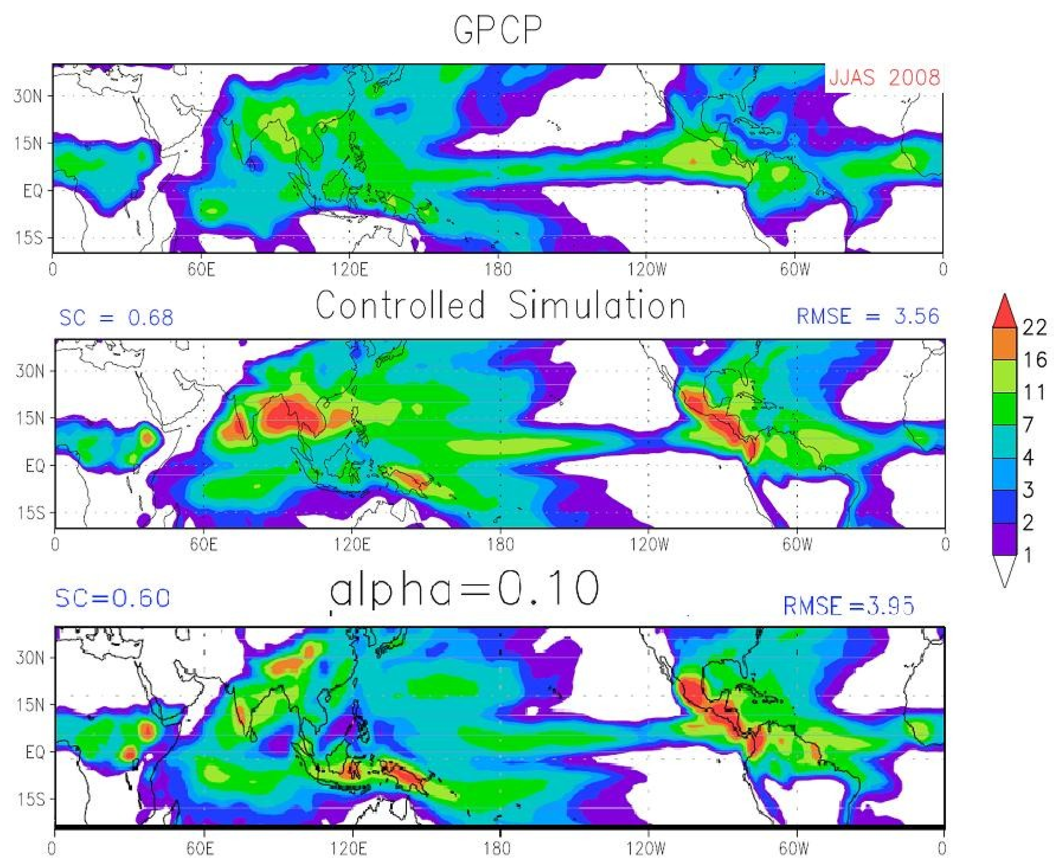

Figure 1. The model simulated precipitation is overestimated over most parts of the tropics in the control experiment. Alpha=0.10 simulates precipitation more realistically.

Renno and Ingersoll's (1996) definition of Cloud adjustment time scale

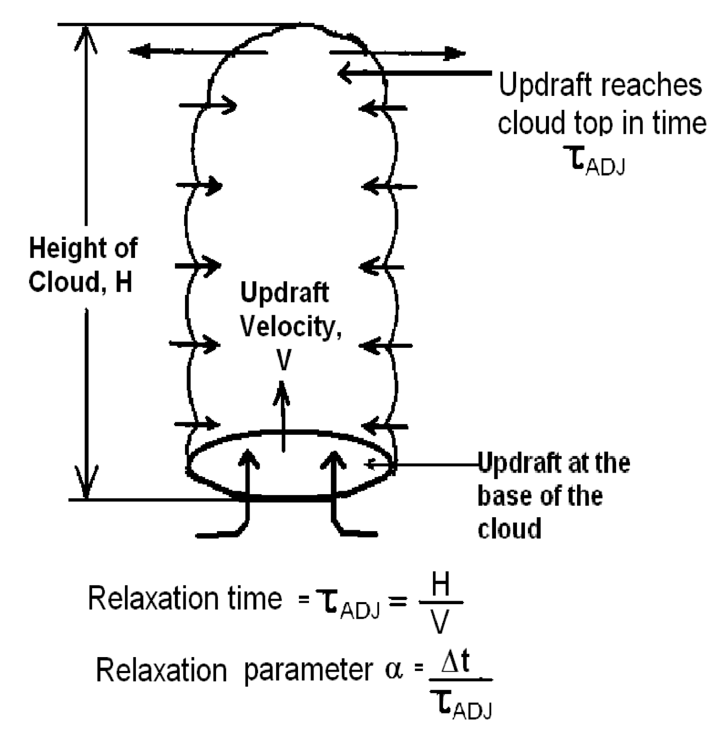

Figure 2. Cloud adjustment time can be imagined as the time taken by the parcel in the cloud to travel frokm bottom to top of it. Relaxation parameter in control simulation was 0.30

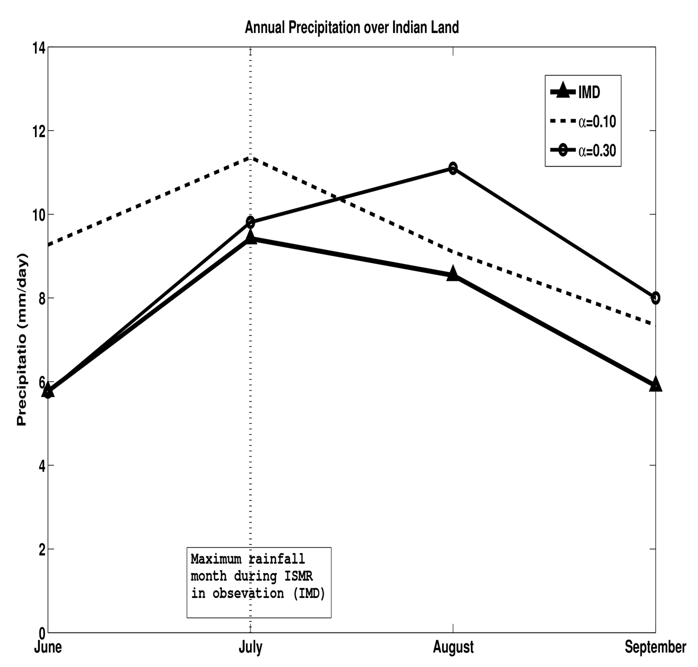

Figure 3. Monthly mean Rainfall over Indian land (8-28 N, 70-90 E) from June to September. Alpha=0.10 gives correct phase of peak precipitation as compared to control simulation (alpha=0.30)

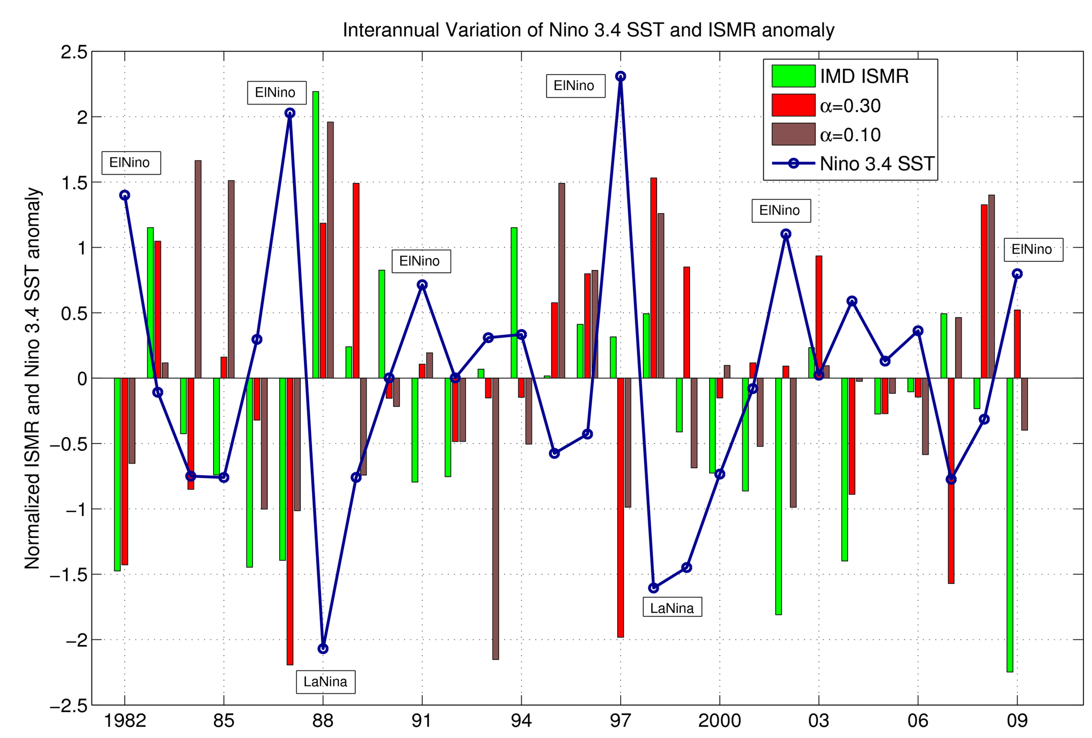

Figure 4. Inter-annual variability of JJAS mean ISMR in observation (IMD data) and two model simulations with cloud relaxation parameter as 0.30 and 0.10. Also shown is inter annual variability of Nino 3.4 SST anomaly. A strong positive Nino 3.4 (bounded by 120W-170W and 5S-5N) SST anomaly is associated with drought over India.

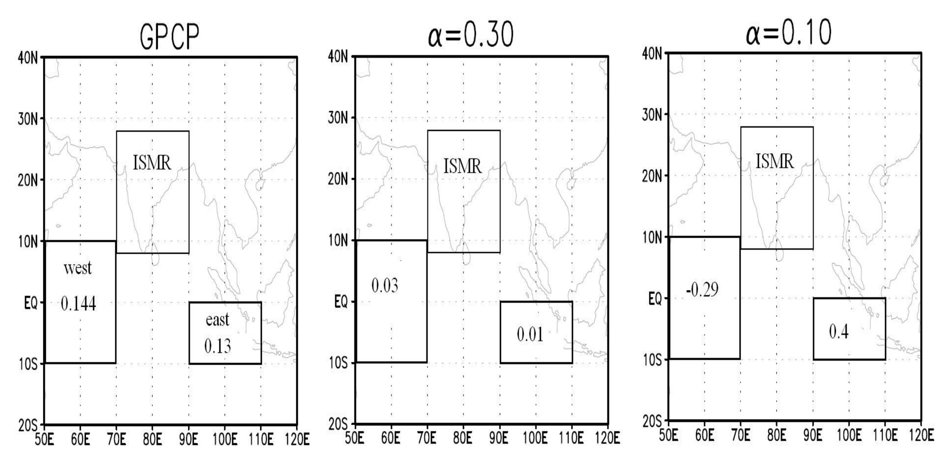

Figure 5. Interconnections between precipitation over Equatorial Indian ocean (EIO) and ISMR. The number shown is the correlation between precipitation over these regions and ISMR over Indian land. It can be seen that in observations, the correlation is not very high. However, alpha=0.10 simulation produces strong coupling between EIO rainfall and ISMR

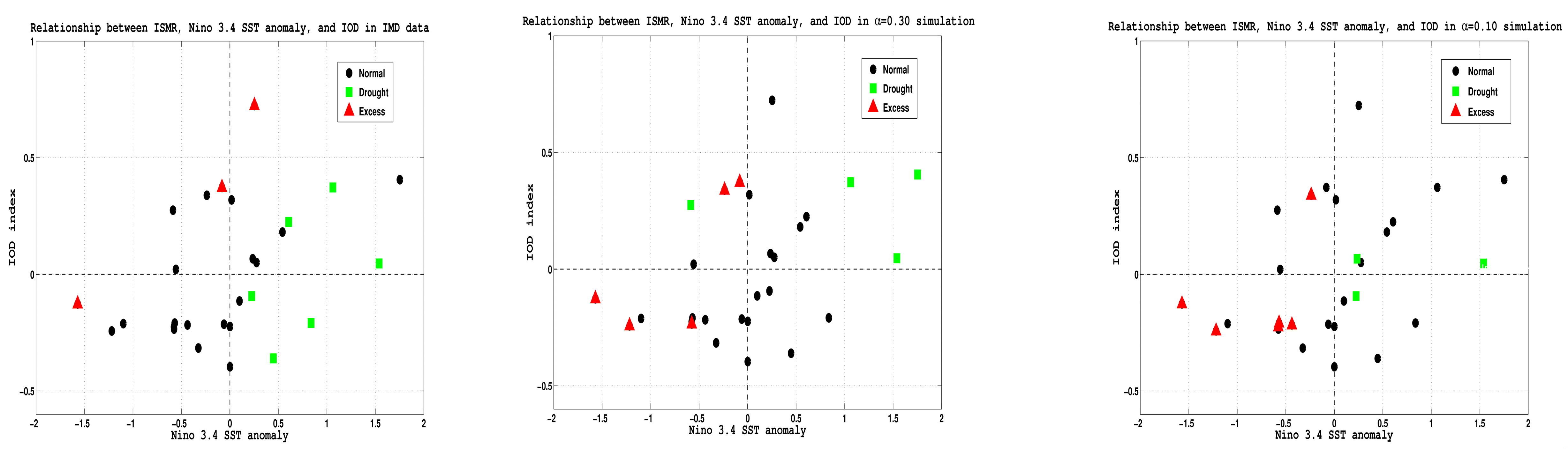

Figure 6. IOD index is defined as difference between SST anomaly over east EIO (10S-10N, 50 – 70E, the right box in Fig 5) and that over west EIO (10 – 0S, 90 – 110 E, the left box in Fig 5). In observations, a clear straight line can be drawn separating drought years from excess years. This is true with alpha=0.10 simulation as well. We do not see a clear separation between excess years and drought years in control simulation

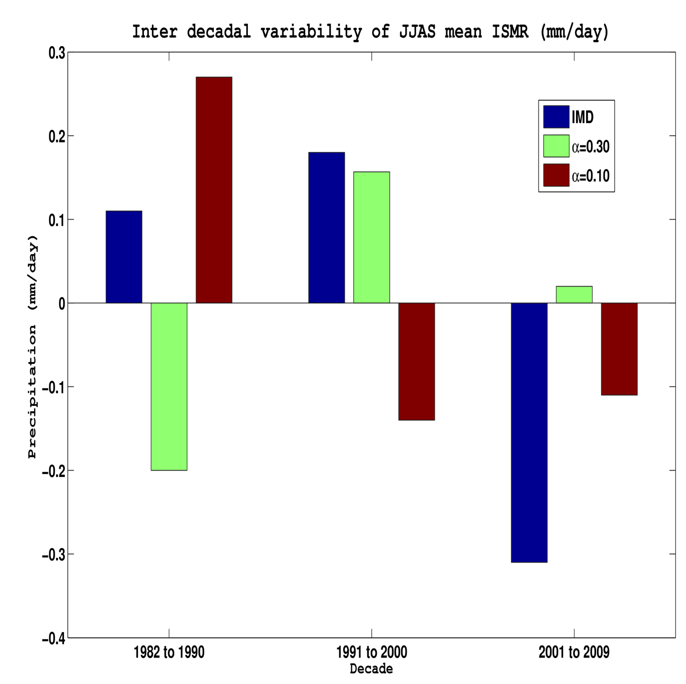

Figure 7. Inter-decadal variability of JJAS mean ISMR (mm/day) over Indian land (70-90 E, 8-28 N) in IMD data and two model simulations. The two simulations show opposite sign of anomaly for all the three decades. Sign of anomaly for 2 decades (1982 to 1990 and 2000 to 2009) is simulated correctly with alpha=0.10. Control simulation (alpha=0.30) gives the sign of anomaly correctly only for one decade (1991 to 2000) .

	alpha=0.3	alpha=0.1
Hit	16	18
Miss	12	10

Figure 8. Skill Scores of two simulations for 28 years.
Hit => When simulated precipitation gets the sign of precipitation anomaly correct.
Miss => When simulated precipitation gets the sign of precipitation anomaly wrong.

Conclusions

1. *A slower cloud relaxation parameter produces better monthly mean rainfall during June-September over Indian land.*
2. *In the 28 year simulation,many years having droughts associated with negative Nino 3.4 SST anomaly (El-Nino) (such as 2002 and 2009) are simulated well by the model when alpha=0.10. The year of 1994 and 1997 are simulated with wrong sign of anomaly in both the cases (alpha=0.10 and alpha=0.30).*
3. *The correlation between precipitation anomalies over EIO and ISMR is stronger in simulation when a slower relaxation parameter is used.*
4. *The observed IOD, Nino 3.4 SST anomaly, and ISMR relationship is strong and this is simulated well by the model when alpha=0.10. The correlation is not as strong in control experiment.*
5. *In terms of inter-decadal simulations also, alpha=0.10 simulates the sign of anomaly correct for the decade of 1980's and 2000's. The control simulation, however, simulates the sign of anomaly correct only for the decade of 1990's.*
6. *The skill scores for 28 years of simulations is also better for alpha=0.10 simulation.*

References - .

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