Does increasing horizontal resolution improve seasonal prediction of Indian summer monsoon? A climate forecast system model perspective

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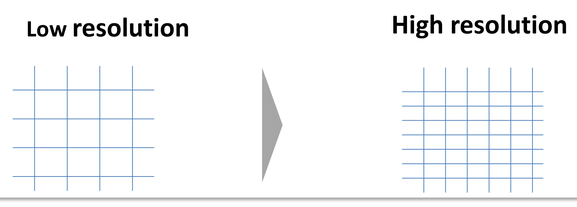
A possible way to improve model biases and prediction skill

Increasing horizontal resolution (one of the most popular approaches)



In favor of the approach

- Prodhomme et al. (2016)
- Ramu et al. (2016)
- Jia et al. (2015)
- Delworth et al., (2012)
- Gent et al. (2010)
- Kobayashi and Sugi (2004)

Against the approach

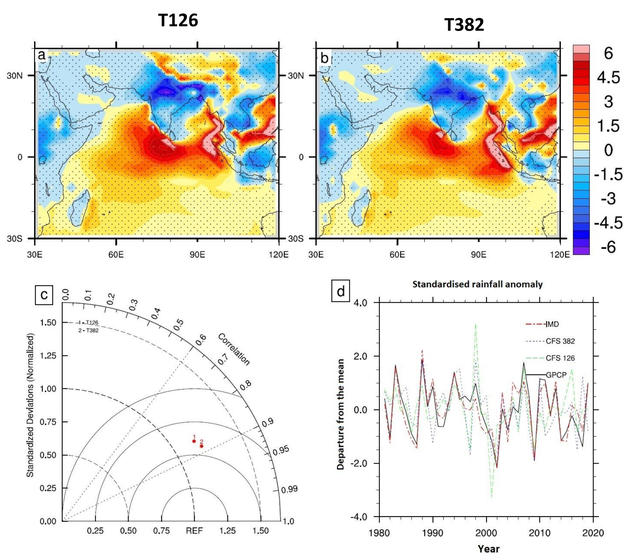
- Scaife et al., (2019)
- Scaife et al. (2019)
- Zhu et al., (2015)

Whether increasing the horizontal resolution of the model has any impact on the seasonal prediction skill, remains elusive in literature

A brief description of the model

Model Description	CFSv2 T126	CFSv2T382
Truncation	126	382
Convective Parameterization	Simplified Arakawa Schubert (Pan and Wu, 1995)	Simplified Arakawa Schubert (Pan and Wu, 1995)
Microphysics	Zhao and Carr (1997)	Zhao and Carr (1997)
Radiation	Rapid radiative transfer (RRTM) (Clough et al., 2000)	Rapid radiative transfer (RRTM) (Clough et al., 2000)
land surface model	NOAH (Ek et al., 2003)	NOAH (Ek et al., 2003)
Vertical Levels	64	64

Do seasonal means improve with resolution?



Seasonal means and anomalies in CFSv2 T126 and T382

Anomaly correlations

r_1 (T126 with observation)	r_2 (T382 with observation)
0.42 (IMD)	0.44 (IMD)
0.34 (GPCP)	0.43(GPCP)

Hypothesis testing

H_0: $r_1 = r_2$
H_1= $r_2 > r_1$
Convert r to z-score (Fisher's *r* to *z* transformation)

P-value > 0.2

What about qualitative (categorical) prediction?

- q_1 and q_2 ➔ Respective probabilities of an accurate forecast in a randomly chosen year that the low and high-resolution versions of the CFSv2 model will produce
- $X_1, X_2 \ldots, X_n$ ➔ random variables (RV) associated with the forecast of CFSv2 (T126)
- $Y_1, Y_2 \ldots, Y_n$ ➔ random variables (RV) associated with the forecast of CFSv2 (T382)
- X_i's and Y_i's ➔ ~ Ber (q_1) and Ber (q_2) respectively

$$X_i = max\left\{0, \frac{|\text{anom}(i)_{\text{CFS126}}\ \text{anom}\ (i)_{obs}|}{\text{anom}(i)_{\text{CFS126}}\ \text{anom}\ (i)_{obs}}\right\}$$

$$Y_i = max\left\{0, \frac{|\text{anom}(i)_{\text{CFS382}}\ \text{anom}\ (i)_{obs}|}{\text{anom}(i)_{\text{CFS382}}\ \text{anom}\ (i)_{obs}}\right\}$$

H_0: $q_1 = q_2$
H_1: $q_1 \neq q_2$

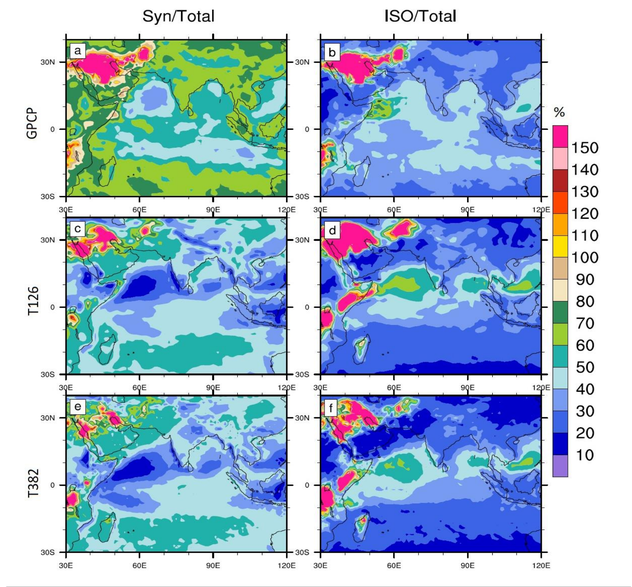
Contingency Table	**T126** gives **accurate** prediction	**T126** gives **inaccurate** prediction
T382 gives **accurate** prediction	17 (A)	7 (C)
T382 gives **inaccurate** prediction	5 (B)	10 (D)

Test Statistic $T = \frac{(B-C)^2}{B+C}$

The test statistic T follows a chi-square ($\chi 2$) distribution with one degree of freedom

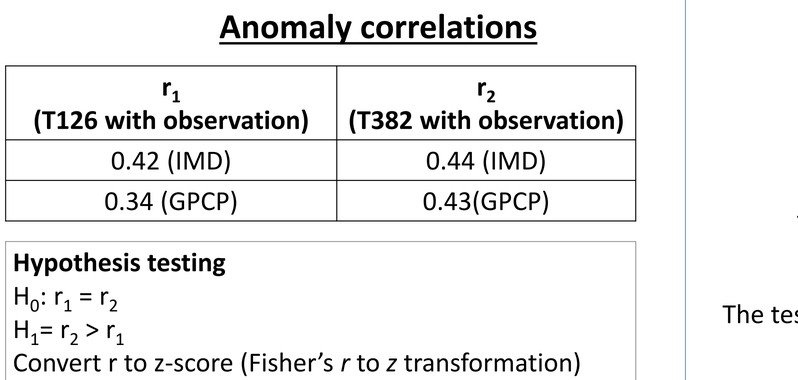
P-value > 0.5

Does increased resolution improve synoptic variance?

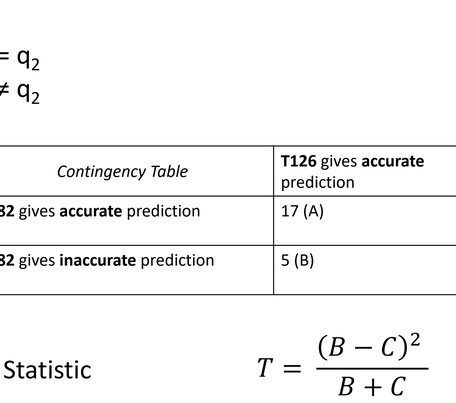


$$TVD = \frac{\int_{-\infty}^{\infty} |f1(x) - f2(x)|dx}{2}$$

Markov model of rain



Transition Probabilities



Mean recurrence time

Steady state probabilities calculation

$p_{ij} = P(X_{t+1} = j \mid X_t = i)$
$\{i, j\} \in \{0,1\}$

$$[S_0 \quad S_1]\begin{bmatrix} p_{00} & p_{01} \\ p_{10} & p_{11} \end{bmatrix} = [S_0 \quad S_1]$$

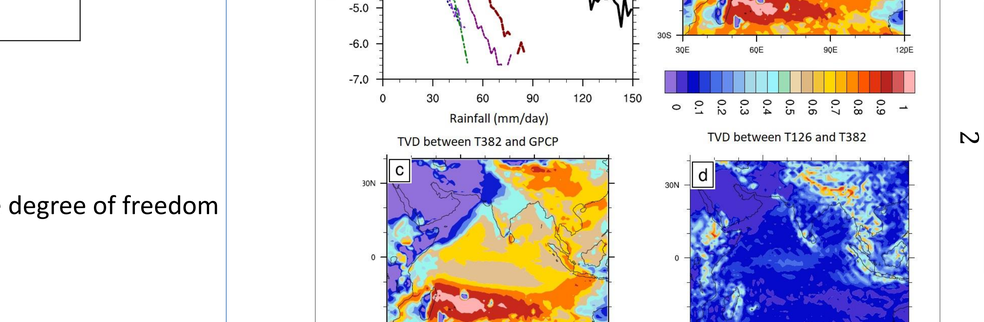
$$T_i = \frac{1}{S_i}$$

Convective quasi-equilibrium

$$\frac{\partial CAPE}{\partial t} = \left(\frac{\partial CAPE}{\partial t}\right)_{\text{largescale}} + \left(\frac{\partial CAPE}{\partial t}\right)_{\text{convection}}$$

$$\left(\frac{\partial CAPE}{\partial t}\right)_{\text{largescale}} \approx -\left(\frac{\partial CAPE}{\partial t}\right)_{\text{convection}}$$

$$dCAPE = CAPE(\text{ at time t} + 1) - CAPE(\text{ at time t})\left[\frac{J}{kgday}\right]$$



Reference: Kumar, S., Phani, R., Mukhopadhyay, P., & Balaji, C. (2022). Does increasing horizontal resolution improve seasonal prediction of Indian summer monsoon?: A climate forecast system model perspective. Geophysical Research Letters, 49(7), e2021GL097466.