

DEVELOPMENT OF A DYNAMIC DOWNSCALING STRATEGY FOR GANGA BASIN AND INVESTIGATION OF THE HYDROLOGICAL PATTERN

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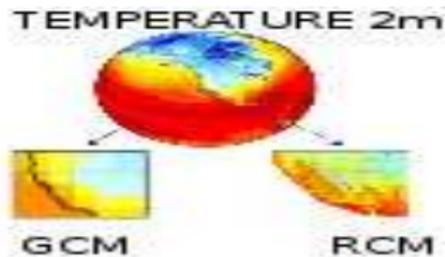
Indian Institute of Technology Kanpur

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FAILING OF GCMs

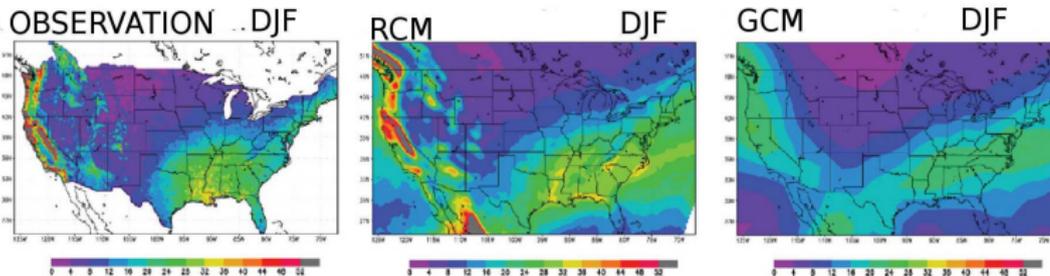


(a) Local subgrid scale(depts.washington.edu)



(b) Surface variables(meteora.ucsd.edu)

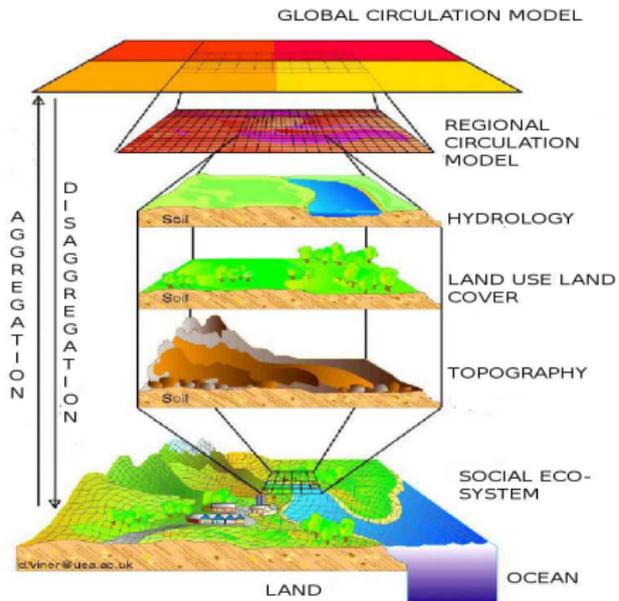
DAILY ACCUMULATED RAINFALL



(c) Hydrologic variables eg. Precipitation(www.meted.ucar.edu)

What is Dynamic Downscaling?

DYNAMIC DOWNSCALING



Courtesy:ccsn.ca

WRF-A TOOL TO DOWNSCALE

WRF : Weather Research and Forecasting Model

- Developed by NCAR (Skamarock et al.,2005)
- Designed to serve both operational and atmospheric research needs
- Features terrain following eta-coordinate
- Improved and advanced physics and dynamics options

DIFFERENT DATA SET USED FOR THE STUDY

- Indian Space Research Organization AWS (<http://www.mosdac.gov.in>). Data temporal frequency is 1 hr. and the span of the record are 00 UTC 1st January,2010 to 00 UTC 1st January,2011. Total no. of stations inside the domain of interest are 174.
- TRMM 3B42v6 daily rainfall data (<http://mirador.gsfc.nasa.gov/>). Data frequency is 1 day. The temporal span of the data are 1st January, 2010 to 31st December, 2010. Spatial resolution is $0.25^{\circ} \times 0.25^{\circ}$.

TOPOGRAPHY AND AWS LOCATION

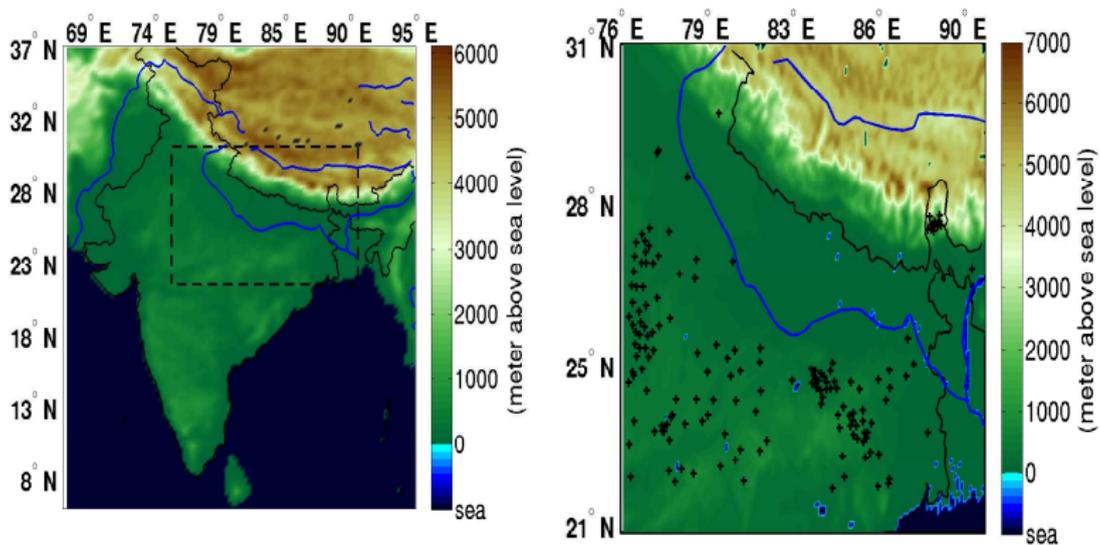


FIGURE: Topography of simulation domain, Indo-Gangetic basin(IGB) and Location of the AWS stations

OBJECTIVE OF THE STUDY

- Develop strategy to dynamic downscale the GCM results(synoptic scale) to Indo-Gangetic basin(regional scale).
- Investigate the sensitivity of different input dataset and physics parameterizations.
- Analyze the distribution of hydrologic variables, especially for the regions where no data are available.

CONTROL EXPERIMENT

Dynamics Options	Specification
Domain Center	22°N, 81°E
Resolution	27 km
Time Step	Adaptive
Grid Dimension	110 X 130
Vertical Levels	45
Static Fields	USGS
IC and BC	FNL Reanalysis
SST	FNL Reanalysis
Time Integration	Normal

Physics Options	Specification
Mirophysics	Lin
Surface Layer	Monin-Obukhov (Janjic)
Cumulus	Kain-Fritsch
Shortwave Radiation	Dudhia
Longwave Radiation	RRTM
Boundary Layer	MYJ
Land Surface Model	Unified Noah

SENSITIVITY EXPERIMENT

Dynamics Options	Specification	Sensitivity
Domain Center	22°N, 81°E	
Resolution	27 km	
Time Step	Adaptive	
Grid Dimension	110 X 130	
Vertical Levels	45	
Land Cover	USGS	USGS, MODIS
IC and BC	FNL Reanalysis	FNL, CFSR (*)
SST	FNL Reanalysis	FNL, RTG
Time Integration	Normal	Normal, Analysis Nudge(*)

Physics Options	Specification	Sensitivity
Mirophysics	Lin	Lin, Morrison, Milbrandt
Surface Layer	Monin-Obukhov (Janjic)	
Cumulus	Kain-Fritsch	KF, Grell, Tiedke
Shortwave Radiation	Dudhia	
Longwave Radiation	RRTM	
Boundary Layer	MYJ	
Land Surface Model	Unified Noah	Noah, RUC

STATISTICAL MEASURES

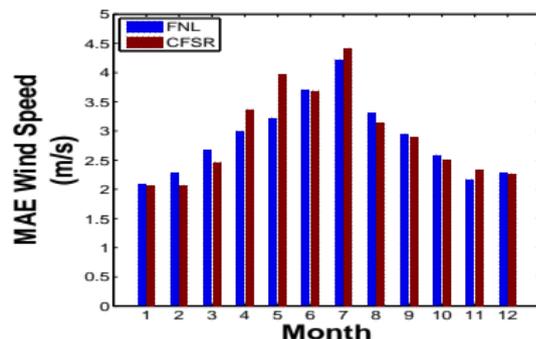
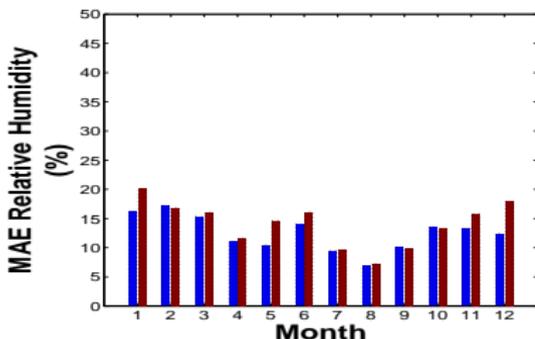
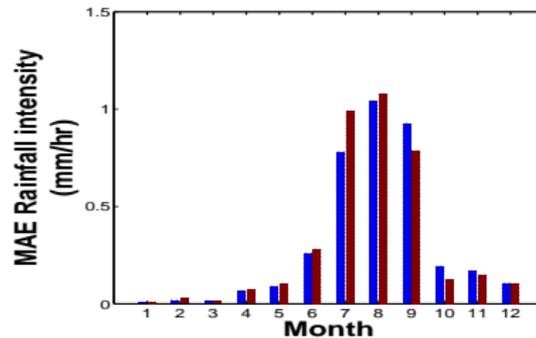
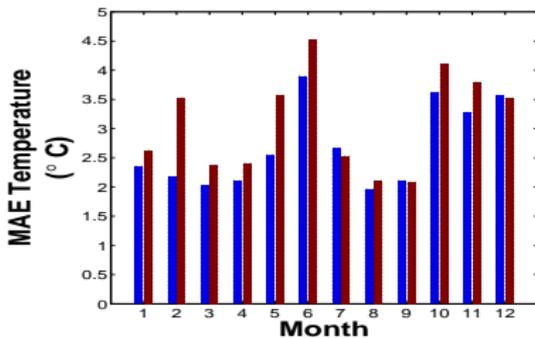
Mean Absolute Error:

$$MAE = \frac{1}{N_{time} N_{stations}} \sum_{t=1}^{N_{time}} \sum_{i=1}^{N_{stations}} |f_i^t - o_i^t|$$

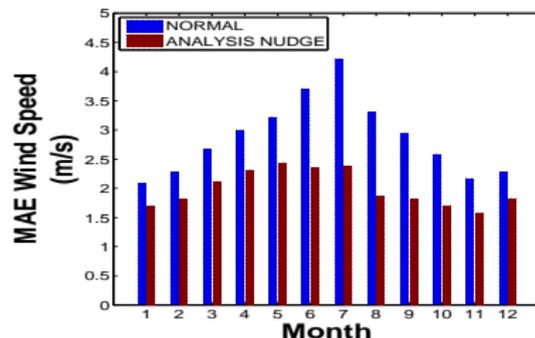
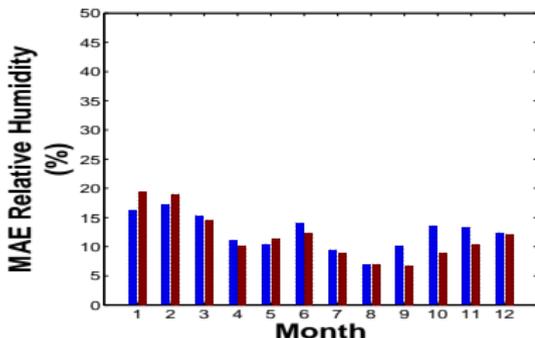
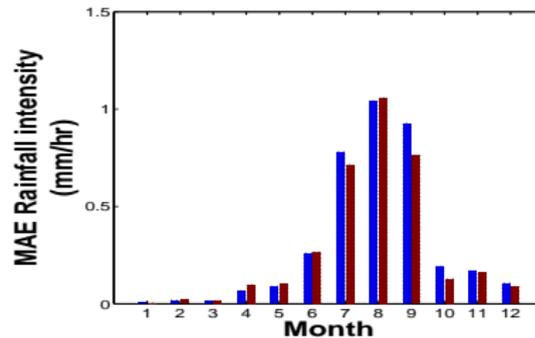
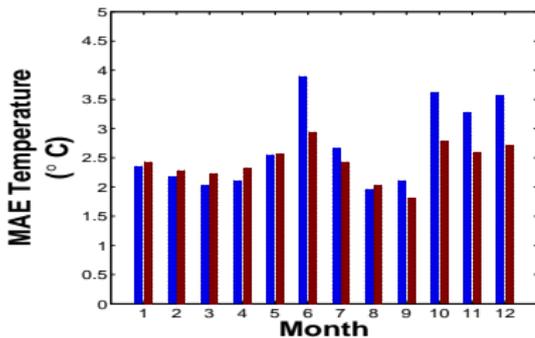
Pearson Correlation Coefficient:

$$\rho_{fo} = \frac{\sum_{i=1}^{N_{obs}} (f_i - \bar{f})(o_i - \bar{o})}{\sqrt{\sum_{i=1}^{N_{obs}} (f_i - \bar{f})^2} \sqrt{\sum_{i=1}^{N_{obs}} (o_i - \bar{o})^2}}$$

SENSITIVITIES OF INPUT DATA SOURCES, USED IN MAKING IC AND BC



SENSITIVITIES OF NUDGING



TIME SERIES OF VARIABLES

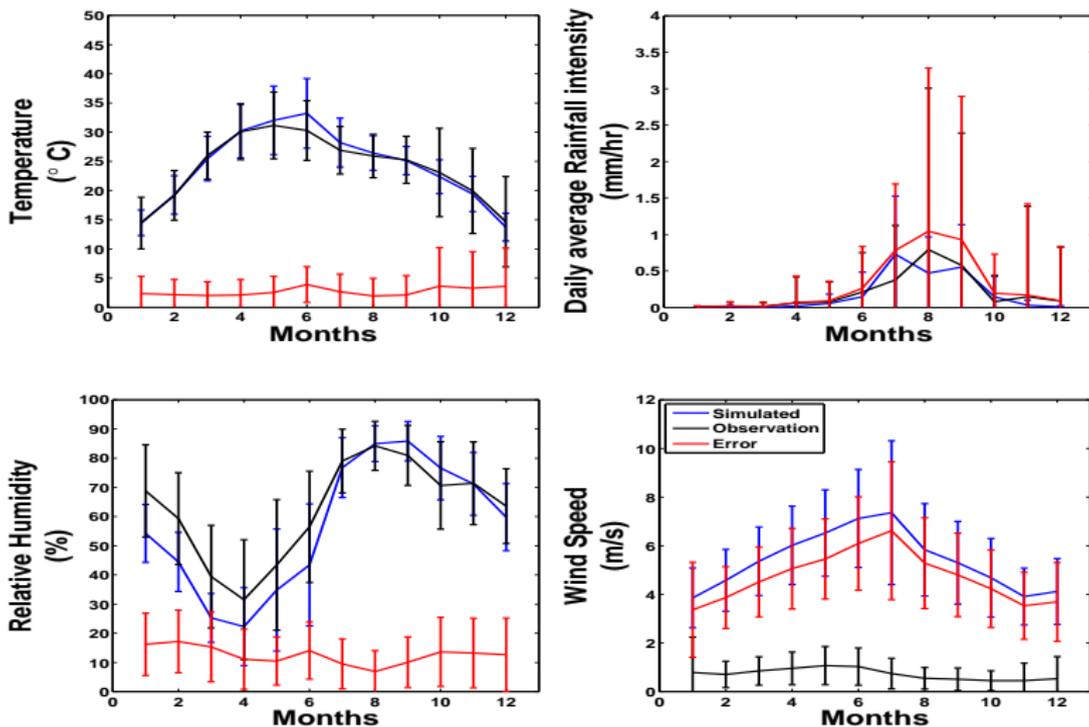
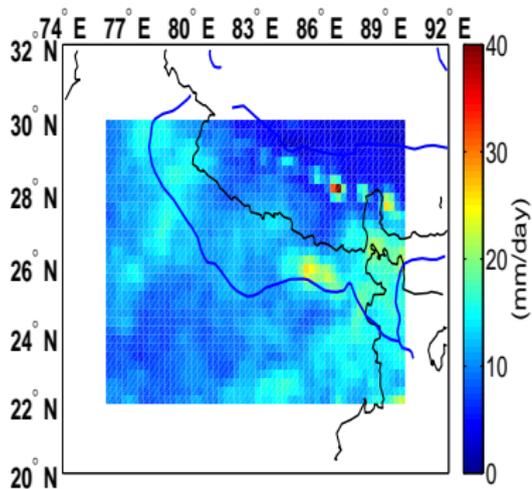
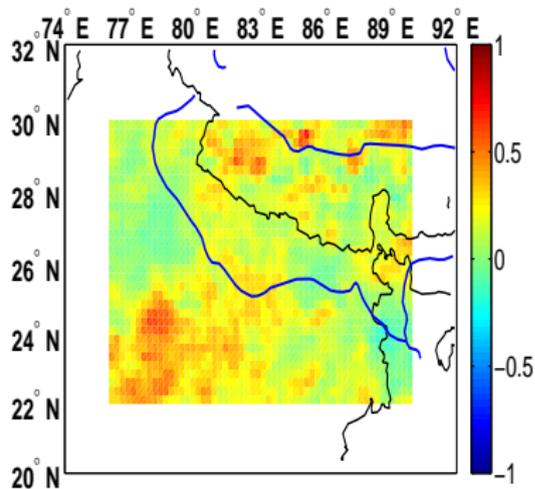


FIGURE: Time Series of average observed, simulated and error of Temperature, Rainfall, Relative Humidity and Wind Speed

COMPARISON AGAINST TRMM MONSOON RAINFALL

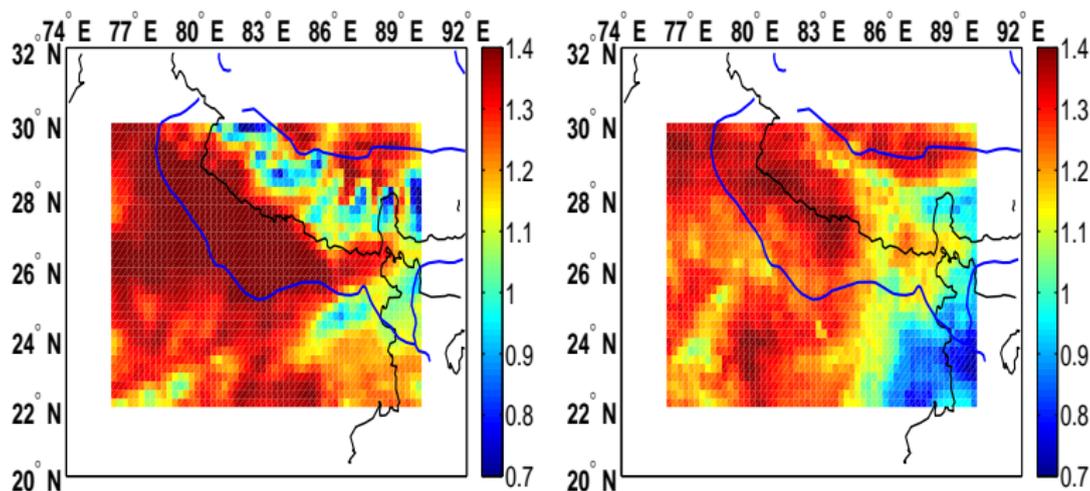


(a) Mean Absolute Error



(b) Correlation

SEASONALITY OF THE SIMULATED AND TRMM RAINFALL



(c) Simulated

(d) TRMM

$$\text{SeasonalityIndex} : SI = \frac{1}{f_{\text{annual}}} \sum_{t=1}^{N_{\text{seasons}}} \left| f_{\text{season}} - \frac{f_{\text{annual}}}{N_{\text{seasons}}} \right|$$

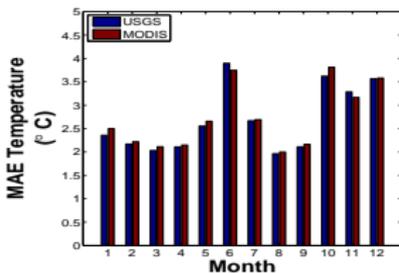
SUMMARY

- Surface meteorological variables and precipitation are reasonably simulated
- Sensitivity experiments of input data, physics parameterizations and time integration is performed
- Simulated rainfall distribution shows significant correlation with the TRMM at the middle Indo-Gangetic basin, along the foothills of Himalaya, and over some portion of Tibetan Plateau
- The simulation captured strong seasonality over Indo-Gangetic basin.
- **Study demonstrate the suitability of WRF to study the hydrological cycle over Indo-Gangetic basin.**

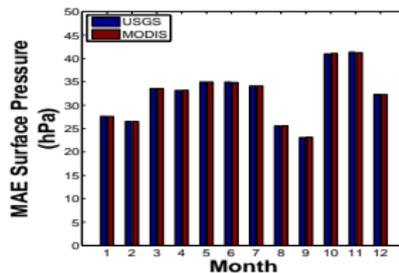
ACKNOWLEDGEMENT

The data for this study are from the Meteorological and Oceanographic Satellite Data Archival Centre (MOSDAC), which is maintained by the Indian Space Research Organization (ISRO) and Space Application Center(SAC) . TRMM data used in this study were acquired from NASA's Goddard Earth Sciences (GES) Data and Information Services Center (DISC). This project is funded by Central Water Commission(CWC). We want to thank Dr. Shivam Tripathi for his insightful suggestions and discussions.

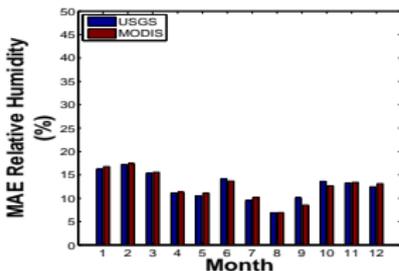
SENSITIVITIES OF LAND COVER SOURCES



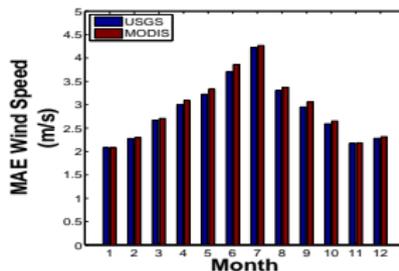
(e) Temperature



(f) Pressure



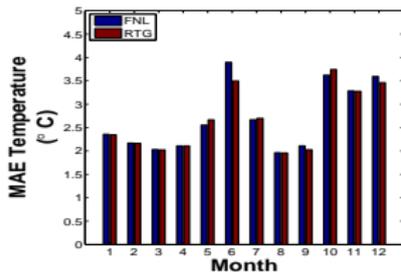
(g) Relative Humidity



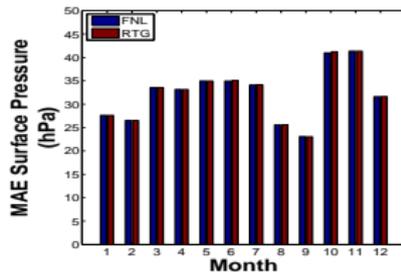
(h) Wind Speed

FIGURE: Mean Absolute Error of Temperature, Pressure, Relative Humidity and Wind Speed

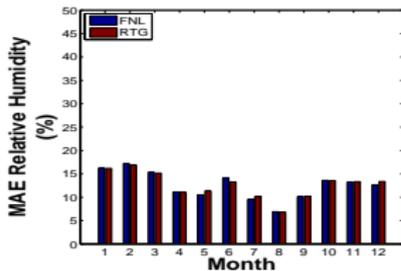
SENSITIVITIES OF SST



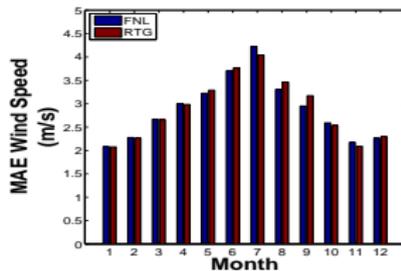
(a) Temperature



(b) Pressure



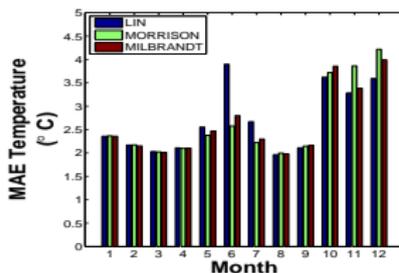
(c) Relative Humidity



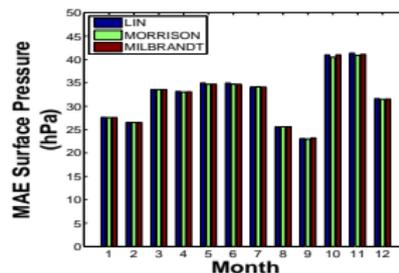
(d) Wind Speed

FIGURE: Mean Absolute Error of Temperature, Pressure, Relative Humidity and Wind Speed

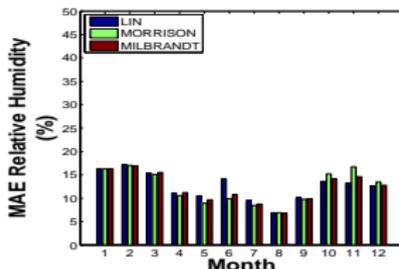
SENSITIVITIES OF MICROPHYSICS



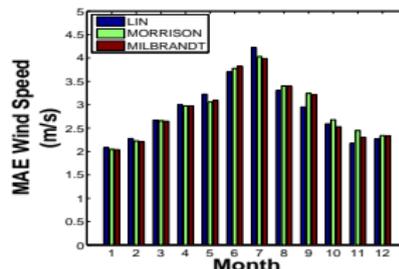
(a) Temperature



(b) Pressure



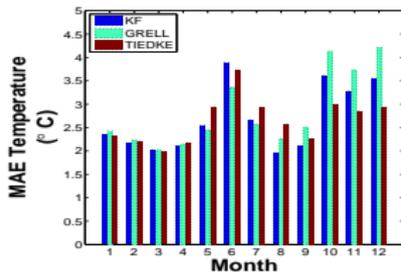
(c) Relative Humidity



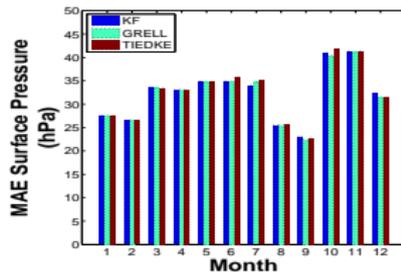
(d) Wind Speed

FIGURE: Mean Absolute Error of Temperature, Pressure, Relative Humidity and Wind Speed

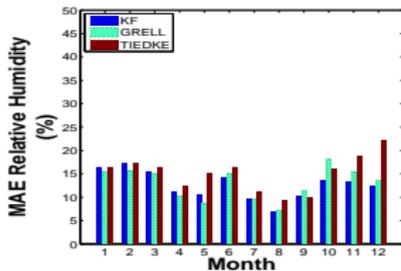
SENSITIVITIES OF CUMULUS PHYSICS



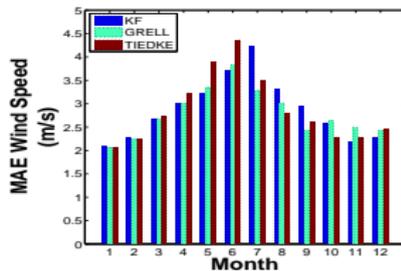
(a) Temperature



(b) Pressure



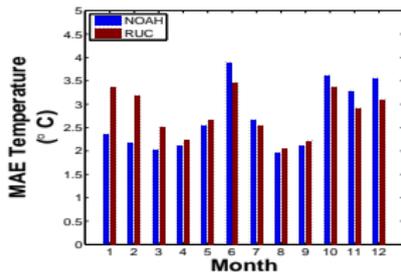
(c) Relative Humidity



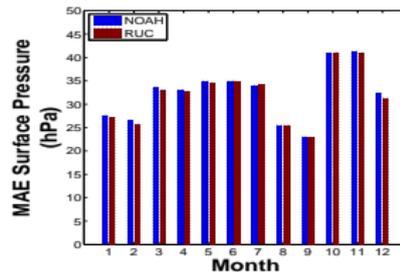
(d) Wind Speed

FIGURE: Mean Absolute Error of Temperature, Pressure, Relative Humidity and Wind Speed

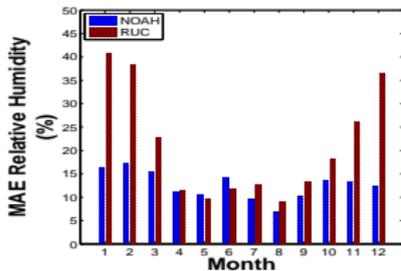
SENSITIVITIES OF LAND SURFACE MODEL



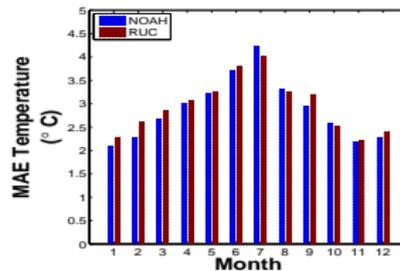
(a) Temperature



(b) Pressure



(c) Relative Humidity



(d) Wind Speed

FIGURE: Mean Absolute Error of Temperature, Pressure, Relative Humidity and Wind Speed

DISTRIBUTION OF VARIABLES

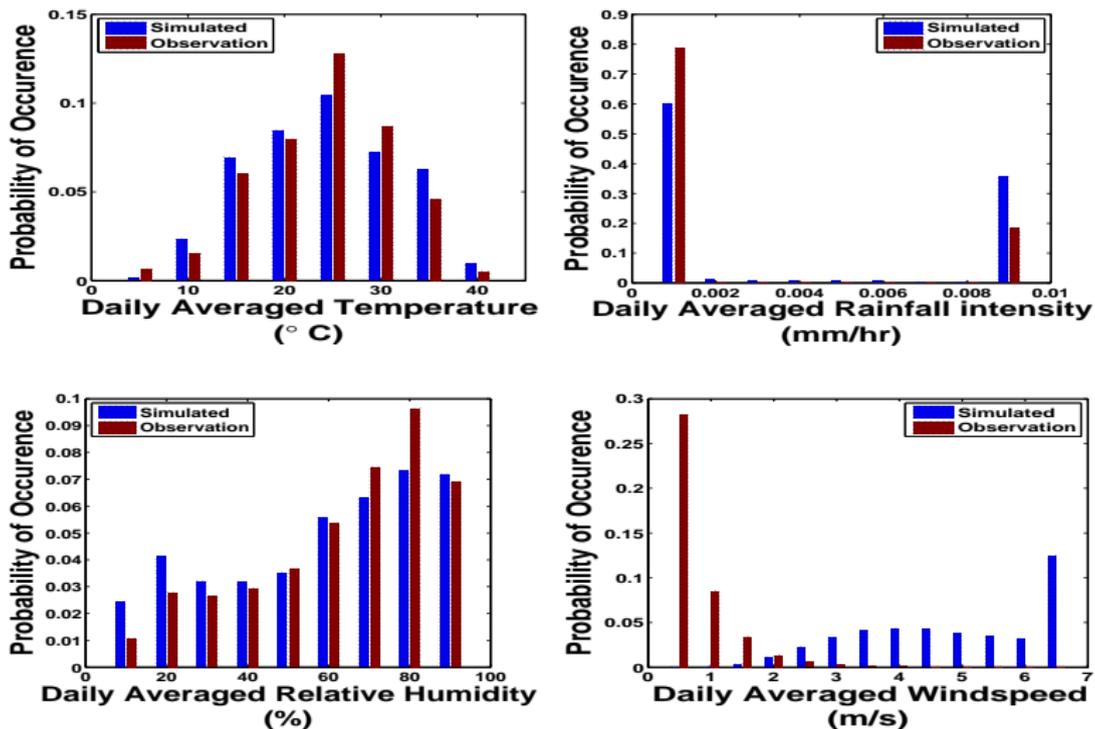


FIGURE: Distribution of average observed, simulated Temperature, Rainfall, Relative Humidity and Wind Speed

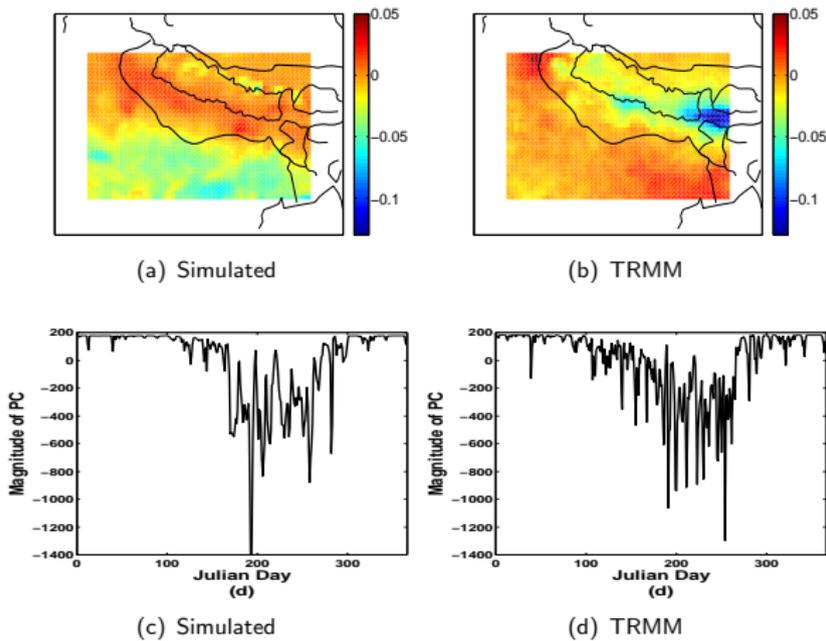
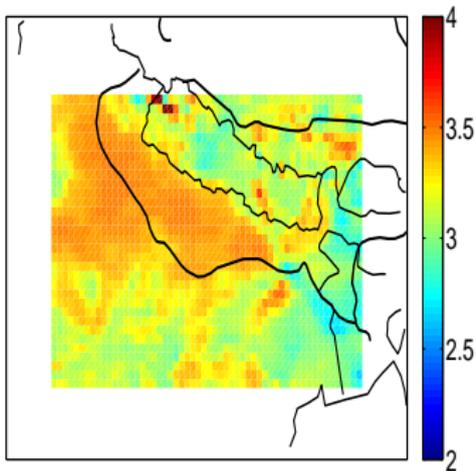
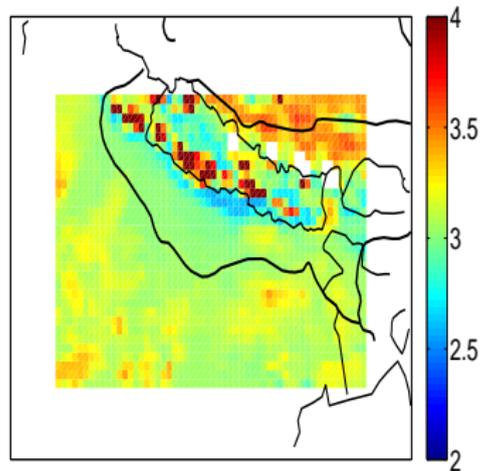
LEADING EOF SPATIAL AND TEMPORAL STRUCTURE COMPARISON
AGAINST TRMM RAINFALL

FIGURE: EOF analysis of Seasonal Rainfall

SEASONALITY OF HYDROLOGICAL VARIABLES



(a) Surface Runoff



(b) Underground Runoff