Final Report

Climate Variability of the Tropical Western Atlantic Storms: Is it hinged to Intra-Americas Seas climate processes?

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I Results and accomplishments

There were in total 45 peer reviewed publications (34 published and 11 in review) from this project. The brief details of these publications are as follows:

1. Dynamic downscaling of the 20th Century Reanalysis over the Southeastern United States
V. Misra, S. DiNapoli, and S. Bastola, Regional Env. Change, doi:10.1007s/10113-012-0372-8.
A 108-year (1901-2008) downscaling of the 20th Century Reanalysis (20CR) using the Regional Spectral Model (RSM) has been conducted for the Southeastern United States (SEUS) at a horizontal grid resolution of 10km. This 108-year product, named as the **F**lorida Climate Institute-Florida State University **L**and-**A**tmosphere **Re**analysis for the **S**outheastern United States at 10-km resolution version **1.0** [FLAReS1.0]), has primarily been developed for anticipated application studies in hydrology, crop management, ecology and other inter-disciplinary fields in the SEUS. The analysis of this downscaled product reveals that it ameliorates the issue of artificial discontinuity in the precipitation time series of the 20CR from the variations inherent to RSM. This centennial scale product allows us to begin examining decadal scale variations of the regional features of the SEUS. The fidelity of the low frequency variations of the winter rainfall associated with the Atlantic Multi-decadal Oscillation (AMO) and the Pacific Decadal Oscillation (PDO) is reasonably well captured in FLAReS1.0. In fact, the modulation of the El Niño-Southern Oscillation (ENSO) teleconnection with the SEUS rainfall by AMO in the downscaled product is also validated with observations. The ENSO associated variations of accumulated rainfall from landfalling hurricanes in the SEUS is also well simulated in the downscaled climate simulation. It is to be noted that the success of this dynamical downscaling is also because the global reanalysis of 20CR showed comparable fidelity in these low frequency variations of the SEUS climate. This method of dynamic downscaling global reanalysis with inclusion of spectral nudging at large wavelengths (in this case ≥ 500km) towards the driving global reanalysis (20CR) is sometimes referred as a form of regional reanalysis.

2. Evaluation of Twentieth-Century Atlantic Warm Pool Simulations in Historical CMIP5 Runs
M. Kozar and V. Misra, Clim. Dyn. DOI:10.107/S00382-012-1604-9
State-of-the-art coupled global climate models are evaluated for their simulation of the Atlantic Warm Pool (AWP). Historical runs from 17 coupled climate models included in the Fifth Phase of the Coupled Model Intercomparison Project (CMIP5) serve as the basis for this model evaluation study. The model simulations are directly compared to observations and reanalysis data to evaluate the climatological features and variability of the AWP within each individual model. Results reveal that a select number of models—namely the GISS-E2-R, CSIRO-Mk3.6, and MPI-ESM-LR—are successful at resolving an appropriately sized AWP with some reasonable climatological features. However, these three models exhibit an erroneously broad seasonal peak of the AWP, and its variability is significantly underestimated. Furthermore, all of the CMIP5 models exhibit a significant cold bias across the tropical Atlantic basin, which hinders their ability to accurately resolve the AWP.

3. Evaluating the fidelity of downscaled climate data on simulated wheat and maize production in the southeastern US

Cammarano, D., L. Stefanova, B. V. Oriiz, M. Ramirez-Rodrigues, S. Asseng, V. Misra and G. Wilkerson, Regional Environmental Change, 13, S101-110, doi:10.1007/s10113-013-0410-1
Crop models are one of the most commonly used tools to assess the impact of climate variability and change on crop production. However, before the impact of projected climate changes on crop production can be addressed, a necessary first step is the assessment of the inherent uncertainty and limitations of the forcing data used in these crop models. In this paper, we evaluate the simulated crop production using separate crop models for maize (summer crop) and wheat (winter crop) over six different locations in the Southeastern United States forced with multiple sources of actual and simulated weather data. The paper compares the crop production simulated by a crop model for maize and wheat during a historical period, using daily weather data from three sources: station observations, dynamically downscaled global reanalysis, and dynamically downscaled historical climate model simulations from two global circulation models (GCMs). The same regional climate model is used to downscale the global reanalysis and both global circulation models' historical simulation. The average simulated yield derived from bias-corrected downscaled reanalysis or bias-corrected downscaled GCMs were, in most cases, not statistically different from observations. Statistical differences of the average yields, generated from observed or downscaled GCM weather, were found in some locations under rainfed and irrigated scenarios, and more frequently in winter (wheat) than in summer (maize). The inter-annual variance of simulated crop yield using GCM downscaled data was frequently overestimated, especially in summer. An analysis of the bias-corrected climate data showed that despite the agreement between the modeled and the observed means of temperatures, solar radiation, and precipitation, their intra-seasonal variances were often significantly different from observations. Therefore, due to this high intra-seasonal variability, a cautious approach is required when using climate model data for historical yield analysis and future climate change impact assessments

4. A high resolution ocean-atmosphere coupled downscaling of the present climate over
H. Li, M. Kanamitsu, S. –Y. Hong, K. Yoshimura, D. R. Cayan, V. Misra and L. Sun, Clim. Dyn. DOI:10.107/S00382-012-1604-9
This study examines a future climate change scenario over California in a 10-km coupled regional downscaling system of the Regional Spectral Model for the atmosphere and the Regional Ocean Modeling System for the ocean forced by the global Community Climate System Model version 3.0 (CCSM3). In summer, the coupled and uncoupled downscaled experiments capture the warming trend of surface air temperature, consistent with the driving CCSM3 forcing. However, the surface warming change along the California coast is weaker in the coupled downscaled experiment than it is in the uncoupled downscaling. Atmospheric cooling due to upwelling along the coast commonly appears in both the present and future climates, but the effect of upwelling is not fully compensated for by the projected large-scale warming in the coupled downscaling experiment. The projected change of extreme warm events is quite different between the coupled and uncoupled downscaling experiments, with the former projecting a more moderate change. The projected future change in precipitation is not significantly different between coupled and uncoupled downscaling. Both the coupled and uncoupled downscaling integrations predict increased onshore sea breeze change in summer daytime and reduced offshore land breeze change in summer nighttime along the coast from the Bay area to Point Conception. Compared to the simulation of present climate, the coupled and uncoupled downscaling experiments predict 17.5 % and 27.5 % fewer Catalina eddy hours in future climate respectively.

5. Ocean-Atmosphere Interaction

V. Misra, In Y. Q. Wang (Ed.), *Encyclopedia of Natural Hazards*. Taylor and Francis. doi:10.1081/E-ENRW-120048428.

In this paper we define ocean-atmosphere interaction in terms of exchange of fluxes at the interface of ocean-atmosphere boundary and through compensatory dynamical circulations that maintain the observed climate of the planet. We describe the strong feedback between the atmosphere and ocean that is characterized in the fluxes, their global distribution of the fluxes, and diagnosis of the feedbacks.

6. Sensitivity of Hydrological Simulations of Southeastern United States Watersheds to Temporal Aggregation of Rainfall

S. Bastola and V. Misra, J. Hydromet., doi:10.1175/JHM-D-12-096.1

This study investigates the sensitivity of the performance of hydrological models to certain temporal variations of precipitation over the southeastern United States (SEUS). Because of observational uncertainty in the estimates of rainfall variability at subdaily scales, the analysis is conducted with two independent rainfall datasets that resolve the diurnal variations. In addition, three hydrological models are used to account for model uncertainty. Results show that the temporal aggregation of subdaily rainfall can translate into a markedly higher volume error in flow simulated by the hydrological models. For the selected watersheds in the SEUS, the volume error is found high (~ 35%) for a 30-day aggregation in some of the selected watersheds. Hydrological models tend to underestimate flow in these watersheds with a decrease in temporal variability in precipitation. Furthermore, diminishing diurnal amplitude by removing subdaily rainfall corresponding to times of climatological daily maximum and minimum has a detrimental effect on the hydrological simulation. This theoretical experiment resulted in the underestimation of flow, with volume error as high as 77% in some watersheds. Observations indicate that over the SEUS variations of diurnal variability of rainfall explain a significant fraction of the seasonal variance throughout the year, with especially strong fractional variance explained in the boreal summer season. In other words the results from this study suggest that should diurnal variations of precipitation get modulated either from anthropogenic or natural causes in the SEUS, there will be a significant impact on the streamflow in the watersheds. These conclusions are quite robust since both observational and model uncertainties have been considered in the analysis.

7. The El Niño Southern Oscillation in the Historical Centennial Integrations of the new generation of Climate Models.

J. –P. Michael, V. Misra, and E. Chassignet, egional Environmental Change, 1-x. doi:10.1007/s10113-013-0452-4

In this study we compare the simulation of El Niño and the Southern Oscillation (ENSO) in the historical integrations of 17 Coupled Model Intercomparison Project 5 (CMIP5) models with corresponding observations. The mean-state and ENSO variations are analyzed in both the atmosphere and ocean and it is found that most of the CMIP5 models exhibit cold (warm) biases in the equatorial (subtropical eastern) Pacific Ocean sea surface temperature that are reminiscent of the split inter-tropical convergence zone phenomenon found in previous studies. There is, however, a major improvement in the representation of the power spectrum of the Niño3.4 sea surface temperature variations which shows that, as in the observations, a majority of the models display a spectral peak in the 2-7 year range, have a near linear relationship with the displacement of the equatorial thermocline and exhibit a robust atmospheric response to ENSO variations.

Several issues remain such as erroneous amplitudes in the Niño3.4 sea surface temperature spectrum's peak and a width of the spectral peak that is either too broad or too narrow. It is also seen that most CMIP5 models unlike the observations extend the ENSO variations in the equatorial Pacific too far westward beyond the dateline and there is very little asymmetry in event duration between the warm and cold phases. ENSO variability forces a dominant mode of rainfall variability in the southeastern United States, especially in the boreal winter season. The CMIP5 exhibited a wide range of response in this metric with several displaying weak to non-existent, some showing relatively strong, and one indicating excessively zonally symmetric teleconnection over the southeastern United States.

8. The Track Integrated Kinetic Energy of Atlantic Tropical Cyclones

V. Misra, S. DiNapoli, and M. Powell, Mon. Wea. Rev., doi:10.1175/MWR-D-12-00349.

In this paper we introduce the concept of Track Integrated Kinetic Energy (TIKE) as a measure of seasonal Atlantic tropical cyclone activity and applied to seasonal variability in the Atlantic. It is similar in concept to the more commonly used Accumulated Cyclone Energy (ACE) with an important difference that in TIKE we accumulate the Integrated Kinetic Energy (IKE) for the lifespan of the Atlantic tropical cyclone. The IKE is however computed by volume integrating the 10m level sustained winds of tropical strength or higher quadrant-by quadrant, while ACE uses the maximum sustained winds only without accounting for the structure of the storm. In effect TIKE accounts for the intensity, duration, and size of the tropical cyclones. In this research we have examined the seasonality and the interannual variations of the seasonal Atlantic TIKE over a period of 22 years from 1990-2011. We find that the Atlantic TIKE climatologically peaks in the month of September (Fig. 1) and the frequency of storms with the largest TIKE are highest in the eastern tropical Atlantic. The interannual variations of the Atlantic TIKE reveal that it is likely influenced by SST variations in the equatorial Pacific and in the Atlantic Oceans. The SST variations in the central equatorial Pacific are negatively correlated with the contemporaneous seasonal (June-November) TIKE. The size of the Atlantic Warm Pool (AWP) is positively correlated with seasonal TIKE.

9. Evaluation of Dynamically Downscaled Reanalysis Precipitation Data for Hydrological Application

Bastola, S. and V. Misra, Hydrological Processes. Doi:10.1002/hyp.9734.

Skillful and reliable precipitation data is essential for seasonal hydrologic forecasting, and generation of hydrological data. Though output from dynamic downscaling methods is used for hydrological application, the existence of systematic errors in dynamically downscaled data adversely affects the skill of hydrologic forecasting. This study evaluates the precipitation data derived by dynamically downscaling the global atmospheric reanalysis data by propagating them through three hydrological models. Hydrological models are calibrated for 28 watersheds located across the southeastern United States (U.S.) that is minimally affected by human intervention. Calibrated hydrological models are forced with five different types of datasets: global atmospheric reanalysis (NCEP R2 and ERA40) at their native resolution; dynamically downscaled global atmospheric reanalysis at 10km grid resolution; stochastically generated data from weather generator; bias-corrected dynamically downscaled and bias-corrected global reanalysis. The reanalysis products are considered as surrogates for large-scale observations. Our study indicates that over the 28 watersheds in the southeastern U.S., the simulated hydrological response to the bias-corrected dynamically downscaled data is superior to the other four meteorological datasets.

In comparison to synthetically generated meteorological forcing (from weather generator), the dynamically downscaled data from global atmospheric reanalysis result in more realistic hydrological simulations. Therefore, we conclude that dynamical downscaling of global reanalysis, which offers data for sufficient number of years (in this case 22 years), although resource intensive is relatively more useful than other sources of meteorological data with comparable time period in simulating realistic hydrological response at watershed scales.

10. Understanding Differing Regional and Global Climate Model Projections of the 21st Century Wet Season Over the Southeastern United States

Selman, C., V. Misra, L. Stefanova, S. DiNapoli, and T. J. SmithIII, Regional Env. Change, doi:10.1007/s10113-013-0477-8

This paper reconciles the difference in the projections of the wet season over the Southeastern United States (SEUS) from a global climate model (the Community Climate System Model Version 3 [CCSM3]) and from a regional climate model (the Regional Spectral Model [RSM]) nested in the CCSM3. The CCSM3 projects a dipole in the summer precipitation anomaly: peninsular Florida dries in the future climate, and the remainder of the SEUS region becomes wetter. The RSM forced with CCSM3 projects a universal drying of the SEUS in the late 21st century relative to the corresponding 20th century summer. The CCSM3 pattern is attributed to the "upped-ante" mechanism, whereby the atmospheric boundary layer moisture required for convection increases in a warm, statically stable global tropical environment. This criteria becomes harder to meet along convective margins, which include peninsular Florida, resulting in its drying. CCSM3 also projects a southwestward expansion of the North Atlantic subtropical high that leads to further stabilizing of the atmosphere above Florida, inhibiting convection. The RSM, because of its high (10-km grid) resolution, simulates diurnal variations of summer rainfall over SEUS reasonably well. The RSM improves upon CCSM3 through the RSM's depiction of the diurnal variance of precipitation, which according to observations accounts for up to 40% of total seasonal precipitation variance. In the future climate, the RSM projects a significant reduction of the diurnal variability of convection. The reduction is attributed to large-scale stabilization of the atmosphere in the CCSM3 projections.

11. The variability of the Southeast Asian Summer Monsoon

V. Misra and S. DiNapoli, International journal of climatology, 1-x. doi:10.1002/joc.3735

In this paper we focus on the analysis of the climate variability of the Southeastern Asian Summer Monsoon (SEAM) region encompassing Myanmar, Thailand, Cambodia, Vietnam, Laos and parts of southern China. This region is climatologically found to have one of the longest wet seasons in the Asian monsoon region (of nearly 160 days) and also exhibits one of the strongest interannual variations in the length of the monsoon (wet) season. The interannual variations of the length of the SEAM are characterized by corresponding variations in the onset and demise pentad dates of the wet season, with the former dominating slightly over the latter except over Myanmar. Our study reveals that the pentad of late onset of SEAM is characterized by anomalous increase in remote moisture source from Bay of Bengal and Arabian Sea while a substantial decrease of moisture source from the near Andaman Sea and Gulfs of Martaban and Thailand. Furthermore anomalously strong June-August Somali Jet is found to be associated with earlier than normal onset of the SEAM. Similarly, the pentad of late demise of the SEAM features excess moisture source from the South China Sea associated with a slow eastward withdrawal of the north Pacific subtropical high.We suggest on the basis of the findings of this study that careful monitoring of the onset the SEAM season will provide important information on the evolution of an ongoing SEAM. Likewise observing low level winds over the northern equatorial Indian Ocean, Bay of Bengal, Gulfs of Martaban and Thailand and South China Sea could be very useful in understanding the seasonal variability of the SEAM. Finally, monitoring of the demise would be equally helpful in characterizing the variation of the concluded SEAM as the length of the wet season seems to be a very robust climate feature of the region.

12. Reconstructing the 20th century high-resolution climate of the southeastern United States
Dinapoli, S. and V. Misra, J. Geophys. Res., **117**, D19113, doi:10.1029/2012JD01833
We dynamically downscale the 20th Century Reanalysis (20CR) to a 10-km grid resolution from 1901 to 2008 over the southeastern United States and the Gulf of Mexico using the Regional Spectral Model. The downscaled data set, which we call the Florida Climate Institute-Florida State University Land-Atmosphere Reanalysis for the Southeastern United States at 10-km resolution (FLAReS1.0), will facilitate the study of the effects of low-frequency climate variability and major historical climate events on local hydrology and agriculture. To determine the suitability of the FLAReS1.0 downscaled data set for any subsequent applied climate studies, we compare the annual, seasonal, and diurnal variability of temperature and precipitation in the model to various observation data sets. In addition, we examine the model's depiction of several meteorological phenomena that affect the climate of the region, including extreme cold waves, summer sea breezes and associated convective activity, tropical cyclone landfalls, and midlatitude frontal systems. Our results show that temperature and precipitation variability are well-represented by FLAReS1.0 on most time scales, although systematic biases do exist in the data. FLAReS1.0 accurately portrays some of the major weather phenomena in the region, but the severity of extreme weather events is generally underestimated. The high resolution of FLAReS1.0 makes it more suitable for local climate studies than the coarser 20CR.

13. Global seasonal climate predictability in a two tiered forecast system: Part I: Boreal summer and fall seasons
V. Misra, H. Li, Z. Wu and S. DiNapoli, Climate Dynamics, doi:10.1007/s00382-013-1812-x
This paper shows demonstrable improvement in the global seasonal climate predictability of boreal summer (at zero lead) and fall (at one season lead) seasonal mean precipitation and surface temperature from a two-tiered seasonal hindcast forced with forecasted SST relative to two other contemporary operational coupled ocean-atmosphere climate models. The results from an extensive set of seasonal hindcasts are analyzed to come to this conclusion. This improvement is attributed to:

i) The multi-model bias corrected SST used to force the atmospheric model
ii) The global atmospheric model which is run at a relatively high resolution of 50km grid resolution compared to the two other coupled ocean-atmosphere models
iii) The physics of the atmospheric model, especially that related to the convective parameterization scheme.

The results of the seasonal hindcast are analyzed for both deterministic and probabilistic skill. The probabilistic skill analysis shows that significant forecast skill can be harvested from these seasonal hindcasts relative to the deterministic skill analysis. The paper concludes that the coupled ocean-atmosphere seasonal hindcasts have reached a reasonable fidelity to exploit their SST anomaly forecasts to force such relatively higher resolution two tier prediction experiments to glean further boreal summer and fall seasonal prediction skill.

14. Global seasonal climate predictability in a two tiered forecast system: Part II: Boreal winter and spring seasons

H. Li and V. Misra, Climate Dynamics, doi:10.1007/s00382-013-1813-x

We examine the Florida Climate Institute-Florida State University Seasonal Hindcast (FISH50) skill at a relatively high (50km grid) resolution two tiered Atmospheric General Circulation Model (AGCM) for boreal winter and spring seasons at zero and one season lead respectively. The AGCM in FISH50 is forced with bias corrected forecast SST averaged from two dynamical coupled ocean-atmosphere models. The comparison of the hindcast skills of precipitation and surface temperature from FISH50 with the coupled ocean-atmosphere models reveals that the probabilistic skill is nearly comparable in the two types of forecast systems (with some improvements in FISH50 outside of the global tropics). Furthermore the drop in skill in going from zero lead (boreal winter) to one season lead (boreal spring) is also similar in FISH50 and the coupled ocean-atmosphere models. Both the forecast systems also show that surface temperature hindcasts have more skill than the precipitation hindcasts and that land based precipitation hindcasts have slightly lower skill than the corresponding hindcasts over the ocean.

15. The seasonal predictability of the Asian summer monsoon in a two tiered forecast system

V. Misra and H. Li, Climate Dynamics, Doi: 10.1007/s00382-013-1812-y

An extensive set of boreal summer seasonal hindcasts from a two tier system (or uncoupled Atmospheric General Circulation Model [AGCM] forced with SST from another source) is compared with corresponding seasonal hindcasts from two other coupled ocean-atmosphere models for their seasonal prediction skill (of precipitation and surface temperature) of the Asian summer monsoon. The unique aspect of the two-tier system is that it is at relatively high resolution and the SST forcing is uniquely bias corrected from the multi-model averaged forecasted SST from the two coupled ocean-atmosphere models. Our analysis reveals:

a) Resolving air-sea interaction does not necessarily translate to improved seasonal predictability of the Asian monsoon. This however does not preclude the fact that systematic and other errors of coupled ocean-atmosphere models are so grave that it could obfuscate the benefits of air-sea interaction. It is seen that the uncoupled AGCM forced with the bias corrected multi-model averaged forecasted SST has seasonal prediction skill that is comparable (over the Southeast Asian monsoon) or even higher (over the South Asian monsoon) than the coupled ocean-atmosphere models.

b) There is no useful deterministic skill over the Asian summer monsoon region from any of the three models examined. But there is useful probabilistic skill for tercile anomalies of precipitation and surface temperature that could be harvested from both the coupled and the uncoupled climate models. They are useful because these hindcast skills are better than climatology. Furthermore, the tercile anomalies of precipitation and surface temperature of the Asian summer monsoon (which are the forecast metrics used in this probabilistic skill analysis) isolate anomalies, which are over one standard deviation in both observations and in the model hindcasts that make these metrics of practical interest.

c) Seasonal predictability of the South Asian summer monsoon (rainfall and temperature) does seem to stem from the remote ENSO forcing especially over the Indian monsoon region and the relatively weaker seasonal predictability in the Southeast Asian summer monsoon could be related to the comparatively weaker teleconnection with ENSO.

16. Seasonal hydrological forecasts over the Southeastern United States Watersheds for boreal summer and fall seasons

Bastola, S. and V. Misra, Earth Interactions, doi:10.1175/2013EI000519.1

In this study we evaluate the skill of a suite of seasonal hydrological prediction experiments over 28 watersheds spread in the South-Eastern United States (SEUS) that include Florida, Georgia, Alabama, South Carolina and North Carolina. These watersheds were selected from Model Parameter Estimation Experiment (MOPEX) for their minimal intervention by water management. The seasonal climate retrospective forecasts (called Florida Climate Institute-Florida State University Seasonal Hindcast at 50km [FISH50]) was initialized in June and integrated through November of each year from 1982-2001. Each seasonal climate forecast had 6 ensemble members. In an earlier study it is shown that FISH50 represents the state-of-the-art seasonal climate prediction skill for the summer and fall seasons, especially in the subtropical and higher latitudes. The retrospective prediction of streamflow is based on multiple calibrated rainfall-runoff models. Each of the hydrological models were carefully initialized by forcing them with observed rainfall for several years before the start of the seasonal forecast for a given year. The hydrological models were forced with rainfall from FISH50, (quantile based) bias corrected FISH50 rainfall (FISH50_BC), and resampled historical rainfall observations based on matching observed analogues of forecasted quartile seasonal rainfall anomalies (FISH50_Resamp).

17. Thirty two year ocean-atmosphere coupled downscaling of global reanalysis over the Intra-Americas Seas

H. Li and V. Misra, Climate Dynamics, doi:10.1007/s00382-014-2069-9

This study examines the oceanic and atmospheric variability over the Intra-American Seas (IAS) from a 32-year integration of a 15-km coupled regional climate model consisting of the Regional Spectral Model (RSM) for the atmosphere and the Regional Ocean Modeling System (ROMS) for the ocean. It is forced at the lateral boundaries by NCEP-DOE (R-2) atmospheric global reanalysis and Simplified Ocean Data Assimilation (SODA) global oceanic reanalysis. This coupled downscaling integration is a free run without any heat flux correction and is referred as the **R**egional **O**cean-**A**tmosphere coupled downscaling of global **R**eanalysis over the Intra-American **S**eas (ROARS). The paper examines the fidelity of ROARS with respect to independent observations that are both satellite based and in-situ. In order to provide a perspective on the fidelity of the ROARS simulation, we also compare it with the Climate Forecast System Reanalysis (CFSR), a modern global ocean-atmosphere reanalysis product. Our analysis reveals that ROARS exhibits reasonable climatology and interannual variability over the IAS region, with climatological SST errors less than 1°C except along the coastlines. The anomaly correlation of the monthly SST and precipitation anomalies in ROARS are well over 0.5 over the Gulf of Mexico, Caribbean Sea, Western Atlantic and Eastern Pacific Oceans. A highlight of the ROARS simulation is its resolution of the loop current and the episodic eddy events off of it. This is rather poorly simulated in the CFSR. This is also reflected in the simulated, albeit, higher variance of the sea surface height in ROARS and the lack of any variability in the sea surface height of the CFSR over the IAS. However the anomaly correlations of the monthly heat content anomalies of ROARS are comparatively lower, especially over the Gulf of Mexico and the Caribbean Sea. This is a result of ROARS exhibiting a bias of underestimation (overestimation) of high (low) clouds. ROARS like CFSR is also able to capture the Caribbean Low Level Jet and its seasonal variability reasonably well.

18. The precursors in the Intra-Americas Seas to seasonal climate variations over North America

V. Misra, H. Li, and M. Kozar, J. Geophys. Res. (Oceans), 119 (5), 2938-2948, doi:10.1002/2014JC009911.

In this paper, we show from observations that the Intra-American Seas precursor as characterized by the onset of the Atlantic Warm Pool (AWP; defined by the area enclosed by 28.5°C isotherm in the tropical Atlantic Ocean) has discernible impact on the boreal summer and fall seasonal climate variations over North America, a season and a region well known for relatively poor seasonal predictability. The onset of the AWP season is objectively defined as the day when the daily anomaly of the AWP area, west of 50°W and north of the equator exceeds its climatological annual mean value. We show that early (late) onset of AWP is associated with following August-September-October (ASO) deficit (excess) seasonal rainfall anomalies over southern Mississippi valley extending to the Midwest US east of Iowa. On the other hand, Central America and the Caribbean region exhibit enhanced (decreased) ASO seasonal mean rainfall during an early (late) onset of AWP. We also find that early (late) onset of the AWP is associated with early (late) onset and early (late) demise of the rainy season over Mesoamerica. This relationship also leads to association of early (late) onset of AWP with increased (shortened) length of the rainy season over Mesoamerica. These teleconnections are dictated by the modulation of the low-level flow and moisture flux convergence associated with the varying development of the AWP. Similarly we find that early (late) onset years of the AWP are associated with a more active (inactive) seasonal Atlantic tropical cyclone activity. These teleconnections are sustained from the fact that the AWP onset date variations are found to be a precursor to the seasonal AWP size variations.

19. The seasonal predictability of the Atlantic Warm Pool and its teleconnections

V. Misra and H. Li, Geophys. Res. Lett., doi: 10.1002/2013GL058740

Our study reveals that there is promising seasonal predictability of the Atlantic Warm Pool (AWP; defined as the area enclosed by the 28.5°C isotherm in tropical western Atlantic) and its associated teleconnections of late summer-early fall seasonal rainfall anomalies over the continental US displayed by a subset of the North American Multi-Model Ensemble (NMME). We find that the of four NMME models at least two models (CFSv2 and GFDL) exhibit consistently useful deterministic and probabilistic skill in predicting the July-October (JASO) seasonal anomalies of the area of the AWP at lead times of up to four months. These two models shown are shown to beat the observed persistence skill by a significant margin at all lead times with the exception of lead time zero. The two NMME models also skillfully predict the teleconnections of the JASO AWP anomalies with the corresponding seasonal JASO rainfall anomalies in the eastern Mississippi valley. These prediction skills are significant improvement in warm season rainfall predictability over the continental US.

20. Statistical prediction of Integrated Kinetic Energy in North Atlantic Tropical Cyclones

M. Kozar and V. Misra, Mon. Wea. Rev. DOI: MWR-D-14-001117.1.

Integrated Kinetic Energy (IKE) is a useful quantity that measures the size and strength of a tropical cyclone wind field. As a result, it is inherently related to the destructive potential of these powerful storms. In most current operational settings, there are limited resources designed to assess the IKE of a tropical cyclone, as storm track and maximum intensity are typically prioritized. Therefore, to complement existing forecasting tools, a statistical scheme is created to project fluctuations of IKE in North Atlantic tropical cyclones for several forecast intervals out to seventytwo hours. The resulting scheme, named Statistical Prediction of Integrated Kinetic Energy (SPIKE), utilizes multivariate normal regression models trained on environmental and storm-related predictors from all North Atlantic tropical cyclones occurring from 1990 through 2011. During this training interval, SPIKE outperforms persistence and is capable of explaining more than 80% of observed variance in total IKE values at a forecast interval of 12 hours, trailing down to just below 60% explained variance at an interval of 72 hours. The skill of the SPIKE model is evaluated further using bootstrapping exercises in order to gauge the predictive abilities of the statistical scheme. In addition, the performance of the SPIKE model is also evaluated for the 2012 Atlantic Hurricane Season, which notably falls outside of the training interval. Ultimately, the validation exercises return shared variance scores similar to those found in the training exercises, serving as a proof of concept that the SPIKE model can be used to project IKE values when given accurate predictor data.

21. Validating ENSO teleconnections on Southeastern United States winter hydrology

B. Nag, V. Misra, and S. Bastola, Earth Interactions, DOI:EI-D-14-0007.1

In this study we contrast four centennial long datasets comprising of two sets of observations (Climate Research Unit [CRU] and Parameter-elevation Regressions on Independent Slopes Model [PRISM]) and two atmospheric reanalysis (20th Century Reanalysis [20CR] and Florida Climate Institute-Florida State University Land-Atmosphere Regional Reanalysis version 1.0 [FLAReS1.0]) to diagnose the El Niño and the Southern Oscillation (ENSO) forced variations on the streamflow in 28 watersheds spread across the Southeastern United States (SEUS). We force three different lumped (calibrated) hydrological models with precipitation from these four sources of centennial long datasets separately to obtain the median prediction from 1800 (= 3 models x 600 simulations per model per watershed per season) multi-model estimates of seasonal mean streamflow across the 28 watersheds in the SEUS for each winter season from 1906 to 2005. We then compare and contrast the mean streamflow and its variability estimates from all three of the centennial climate forcings. The multi-model strategy of simulating the seasonal mean streamflow is to reduce the hydrological model uncertainty. We focus on the boreal winter season when ENSO influence on the SEUS climate variations is well known.

We find that the atmospheric reanalysis over the SEUS are able to reasonably capture the ENSO teleconnections as depicted in the CRU and PRISM precipitation datasets. Even the observed decadal modulation of this teleconnection by Atlantic Multi-decadal Oscillation (AMO) is broadly captured. The streamflow in the 28 watersheds also show similar consistency across the four datasets in that the positive correlations of the boreal winter Niño3.4 SST anomalies with corresponding anomalies of streamflow, the associated shift in the pdf of the streamflow with the change in phase of ENSO and the decadal modulation of the ENSO teleconnection by AMO is sustained in the streamflow simulations forced by all four climate datasets (CRU, PRISM, 20CR, and FLAReS1.0). However the ENSO signal in the streamflow is consistently much stronger in the southern watersheds (over Florida) of the SEUS across all four climate datasets. But during the negative phase of the AMO there is a clear shift of the ENSO teleconnections with streamflow, with winter streamflows in northern watersheds (over the Carolinas) exhibiting much stronger correlations with ENSO Niño3.4 index relative to the southern watersheds of the SEUS. This study clearly indicates that the proposed methodology using FLAReS1.0 serves as viable alternative to reconstruct 20th century SEUS seasonal winter hydrology that captures the interannual variations of ENSO and associated decadal variations forced by AMO. However it is found that the

FLAReS1.0 forced streamflow is far from adequate in simulating the streamflow dynamics of the watershed over the SEUS at daily time scale.

22. Simulating diurnal variations over the southeastern United States

C. Selman and V. Misra, J. Geophysical Res. (atmsopheres), 120, 180-198, doi:10.1002/2014jd021812

The diurnal variations from a high-resolution regional climate model (Regional Spectral Model; RSM) are analyzed from 6 independent decade long integrations using lateral boundary forcing data separately from the National Centers for Environmental Prediction Reanalysis 2 (NCEPR2), and European Center for Medium-Range Weather Forecasts (ECMWF) 40-year Reanalysis (ERA40) and the 20th Century Reanalysis (20CR). With each of these lateral boundary forcing data, the RSM is integrated separately using two convection schemes: the Relaxed Arakawa-Schubert (RAS) and Kain-Fritsch (KF) schemes. The results show that RSM integrations forced with 20CR have the least fidelity in depicting the seasonal cycle and diurnal variability of precipitation and surface temperature over the Southeastern United States (SEUS). The remaining four model simulations show comparable skills. The differences in the diurnal amplitude of rainfall during the summer months of the 20CR forced integration from the corresponding NCEPR2 forced integration, for example, is found to be largely from the transient component of the moisture flux convergence. The root mean square error (RMSE) of the seasonal cycle of precipitation and surface temperature of the other four simulations (not forced by 20CR) were comparable to each other and highest in the summer months. But the RMSE of the diurnal amplitude of precipitation and the timing of its diurnal zenith were largest during winter months and least during summer and fall months in the four model simulations (not forced by 20CR). The diurnal amplitude of surface temperature in comparison showed far less fidelity in all models. The phase of the diurnal maximum of surface temperature however showed significantly better validation with corresponding observations in all of the 6 model simulations.

23. Reconciling droughts and landfalling tropical cyclones in the Southeastern United States

V. Misra and S. Bastola, Clim. Dyn., doi:10.1007/s00382-015-2645-7.

A popular perception is that landfalling tropical cyclones help to mitigate droughts in the Southeastern United States (SeUS). However intriguing paradigms on the role of large scale SST variations on continental US including SeUS droughts and seasonal Atlantic tropical cyclone activity confronts us. These paradigms suggest that in the presence of warm (cold) eastern tropical Pacific and cold (warm) Atlantic Ocean Sea Surface Temperature Anomaly (SSTA) lead to the increased likelihood of wetter (drier) conditions over the continental US including the SeUS. Juxtaposing this understanding with the fact that landfalling tropical cyclones contribute significantly to the annual mean total rainfall in the SeUS and in El Niño (La Niña) years with cold (warm) tropical Atlantic SSTA lead to reduced (increased) Atlantic tropical cyclone activity raises a conflict on the role of the large-scale SST variations in SeUS hydroclimate.

This study attempts to investigate the apparent dichotomous role of the large scale SST variations on the SeUS hydrology by examining the role of rainfall from landfalling tropical cyclones in the SeUS to local seasonal droughts. Our study finds that the contribution of the rainfall from landfalling tropical cyclone on the mitigation of monthly drought in the 28 SeUS watersheds is relatively insignificant. So much so that the hydrological model uncertainty in estimating the drought index over the 28 SeUS watersheds is larger than the sensitivity exhibited by the drought index to the inclusion of rain from landfalling tropical cyclone. The conclusions of this study are justified by the fact that the timing of the landfalling tropical cyclone in relation to overall soil moisture conditions of the watershed does not coincide with a drought like situation in the 1948-2006 time period analyzed in this study. This largely stems from the fact that the large-scale flow pattern resulting in abundant (lack of) advection of moisture for anomalously wet (dry) summer and fall seasons in the SeUS emanating from the source region of the Caribbean Sea and the northwestern tropical Atlantic Ocean coincides with the steering flow of the Atlantic tropical cyclones bound to make landfall in the SeUS (recurving away from the SeUS).

24. Seasonal hydrological and nutrient loading forecasts for watersheds for the Southeastern United States

S. Bastola and V. Misra, Env. Modeling and Software, 73, 90-102

In this study we show useful seasonal deterministic and probabilistic skill of streamflow and nutrient loading over several watersheds in the Southeastern United States (SEUS) for the winter and spring (December-May) seasons over a 20-year period (1982-2001). The merit of this seasonal forecast scheme lies in the adoption of forcing the three conceptual rainfall-runoff hydrological models used in this study with resampled historical rainfall observations derived by matching observed analogues of forecasted quartile rainfall anomalies from a seasonal climate forecast model. This prediction skill is despite the climate model overestimating rainfall of over 23% over the SEUS watersheds in December-May timeperiod.

A nutrient streamflow rating curve is developed using the LOADEST (a log-linear) tool for this purpose. As the log linear model explains much of the variability in nutrient loading during calibration, skill in prediction of seasonal nutrient loading is nearly identical to the skill in predicting the seasonal streamflow.

25. Does decadal climate variation influence wheat and maize production in the southeast USA

Tian, D., S. Asseng, C. J. Martinez, V. Misra, D. Cammarano, B. V. Ortiz, Ag. and Forest Meteorology, 204, 1-9.

Linking decadal variability with short-term variability could be potentially exploited for improving seasonal climate forecasting for assisting crop management decisions. The objective of this study was to explore whether there are decadal variations in wheat (winter crop) and maize (summer crop) production and whether these decadal variations correlate with any known variations of climate. Over one hundred years of wheat and maize yields were simulated using process-based crop models with dynamically downscaled daily reanalysis data over four locations in the southeast USA. Using wavelet and cross-wavelet analysis, we found that winter crop yields were dominated by 10- and 22-year decadal oscillations; the decadal variations of winter crop yields were driven by decadal variations of winter temperature and spring precipitation; no decadal variations were detected for summer crop yields and summer precipitation and temperature. Cross-wavelet analysis showed that the decadal variations of winter crop yields were correlated with indices of the annual Atlantic Multi-decadal Oscillation (AMO), the annual Pacific Decadal Oscillation (PDO), and the winter North Atlantic Oscillation (NAO). Therefore, this knowledge of decadal climate variability could potentially be leveraged to predict winter seasonal yields of crops

26. Hindcasts of Integrated Kinetic Energy: A neural network prediction scheme

M. Kozar and V. Misra, Mon. Wea. Rev.; doi: http://dx.doi.org/10.1175/MWR-D-16-0030.1

A new statistical-prediction scheme is presented for predicting Integrated Kinetic Energy (IKE) in North Atlantic tropical cyclones from a series of environmental input parameters. Predicting IKE is desirable because the metric quantifies the energy across a storm's entire wind field, allowing it to respond to changes in storm structure and size. As such, IKE is especially useful for quantifying the risk in large low-intensity high-impact storms such as Sandy in 2012. The prediction scheme, named the Statistical Prediction of Integrated Energy Version 2 (SPIKE2), builds upon a previous statistical IKE scheme, by using a series of artificial neural networks instead of more basic linear regression models. By using a more complex statistical scheme, SPIKE2 is able to distinguish non-linear signals in the environment that could cause fluctuations in IKE. In an effort to evaluate SPIKE2's performance in a future operational setting, the model is calibrated using input parameters from GEFS control analyses, and is run in a hindcast mode from 1990 to 2015 using National Centers for Environmental Prediction's Global Ensemble Forecast System version 9.0.1 (GEFS) reforecasts. The hindcast results indicate that SPIKE2 performs significantly better than both persistence and climatological benchmarks.

27. The sensitivity of the regional coupled ocean-atmosphere simulations over the Intra-Americas Seas to the prescribed bathymetry

V. Misra, A. Mishra, and H. Li, Dyn. Atm. And Ocean, doi:http://dx.doi.org/10.1016/j.dynatmoce.2016.08.007.

This study examines the sensitivity of the coupled ocean-atmosphere climate of the Intra-Americas Seas (IAS; comprising of the Gulf of Mexico and the Caribbean Sea) and parts of western tropical and sub-tropical Atlantic Ocean to the prescribed bathymetry in three independent multi-decadal, high-resolution (15 km grid interval), regional coupled ocean-atmosphere model (RCM) integrations centered over the IAS. All of these RCM integrations with different prescribed bathymetries are forced by identical global atmospheric and oceanic reanalysis at the lateral boundaries. It is observed that the model integration with a smoother and coarser bathymetry in the region (RCM-C) results in more widespread SST bias across the IAS. The RCM with an intermediate bathymetry (RCM-I) and finest bathymetry (RCM-F) rectify the bias in ocean transport through the Yucatan Channel relative to RCM-C but display mixed results with respect to SST bias. The bias in the ocean transport in RCM-C is comparable to those displayed by some of the CMIP5 models. The RCM-C integration uses a bathymetry with a shallower Yucatan Channel, which tends to produce unrealistically weak flow through the Yucatan Channel and a weak Loop Current. The stronger heat transport through the Yucatan Channel in RCM-F results in warming the northwestern tropical Atlantic Ocean, which is also associated with significant weakening of the easterly surface atmospheric winds. The western Gulf of Mexico and southern Caribbean Sea has a severe cold SST bias over the IAS in RCM-F relative to either RCM-I and RCM-C owing to the weaker surface wind-induced shelf currents. RCM-I on the other hand significantly warms the western Gulf of Mexico relative to RCM-C and RCM-F. RCM-I displays the least SST bias over the IAS and the ocean transport through the Yucatan Channel is most comparable to the ocean reanalysis relative to either RCM-C and RCM-F. The findings of this study clearly suggest that amelioration of the SST bias in the IAS has to be addressed in a coupled ocean-atmosphere framework and is not solely on account of the bias in the ocean circulation. We further motivate this work by indicating that the bias displayed by the various RCM simulations of this study is analogous to bias in the IAS ocean circulation of some of the Coupled Model Intercomparison Project version 5 (CMIP5).

28. The oceanic influence on the rainy season of peninsular Florida
V. Misra and A. Mishra, J. Geophys. Res.; doi:10.1002/2016JD025002

In this study we show that the unique geography of the peninsular Florida with close proximity to strong mesoscale surface ocean currents among other factors warrant the use of relatively high resolution climate models to simulate its hydroclimate. In the absence of such high resolution climate models we highlight the uncertainty in the simulation of the warm western boundary current (the Gulf Stream) in two relatively coarse spatial resolution CMIP5 models. As a consequence it affects the coastal SST and the land-ocean contrast, affecting the rainy summer seasonal precipitation accumulation over peninsular Florida simulated by the two global models. We also show this through two sensitivity studies conducted with a regional coupled ocean atmosphere model with different bathymetries that dislocate and modulate the strength of the Gulf Stream and which locally affects the SST in the two simulations. These studies show that a stronger Gulf Stream produces warmer coastal SST's along the Atlantic coast of Florida that enhances the precipitation over peninsular Florida relative to the other regional climate model simulation. However the regional model simulations indicate that variability of wet season rainfall variability in peninsular Florida becomes less dependent on the land-ocean contrast with a stronger Gulf Stream current and warmer western Atlantic coastal SSTs.

29. The warm pool variability of the tropical northeast Pacific
V. Misra, D. Groenen, A. Bharadwaj, and A. Mishra, Int. J. Climatology, doi:10.1002/joc.4658

The East Pacific Warm Pool (EPWP) defined by the area enclosed within the 28.5°C isotherm, is examined for its seasonal cycle and interannual variability. The study characterizes the EPWP by its area and objectively defined onset, demise, and length of its seasonality. The onset of the EPWP season is defined by the day when the daily anomaly of the area of EPWP exceeds its climatological annual mean. Similarly, the demise of the EPWP season is defined when the daily anomaly of the area of the EPWP falls below its climatological annual mean, after the onset date is detected. We show that the seasonal evolution of the EPWP has a strong asymmetry, with the climatological peak of the EPWP area occurring approximately 41 days from the onset while the demise of the season occurs after nearly 106 days from the climatological peak.
The EPWP is part of a larger western hemisphere warm pool (WHWP) that extends into the Intra-Americas Seas and parts of the tropical northwest Atlantic Ocean. This study finds that the EPWP is weakly related to the Atlantic counterpart of the WHWP. This is partly due to the fact that the EPWP season precedes the seasonal peak of the warm pool in the Atlantic by several months and the size of the former is much smaller than the latter; therefore the EPWP does not have a strong remote forcing on the Atlantic warm pool. The interannual variability of the area of EPWP is closely related to the El Niño and the Southern Oscillation (ENSO) variations in the equatorial Pacific with large (small) EPWP years associated with warm (cold) ENSO years.

30. The impact of extreme case of irrigation on the southeastern United States
Selman, C. and V. Misra, Climate Dynamics, 40. doi:doi;10.1007/s00382-016-3144-1
The impacts of irrigation on southeast United States diurnal climate are investigated using simulations from a regional climate model. An extreme case is assumed, wherein irrigation is set to 100 % of field capacity over the growing season of May through October. Irrigation is applied

to the root zone layers of 10–40 and 40–100 cm soil layers only. It is found that in this regime there is a pronounced decrease in monthly averaged temperatures in irrigated regions across all months. In non-irrigated areas a slight warming is simulated. Diurnal maximum temperatures in irrigated areas warm, while diurnal minimum temperatures cool. The daytime warming is attributed to an increase in shortwave flux at the surface owing to diminished low cloud cover. Nighttime and daily mean cooling result as a consequence repartitioning of energy into latent heat flux over sensible heat flux, and of a higher net downward ground heat flux. Excess heat is transported into the deep soil layer, preventing a rapidly intensifying positive feedback loop. Both diurnal and monthly average precipitations are reduced over irrigated areas at a magnitude and spatial pattern similar to one another. Due to the excess moisture availability, evaporation is seen to increase, but this is nearly balanced by a corresponding reduction in sensible heat flux. Concomitant with additional moisture availability is an increase in both transient and stationary moisture flux convergences. However, despite the increase, there is a large-scale stabilization of the atmosphere stemming from a cooled surface.

31. Characterizing the onset and demise of the Indian Summer Monsoon
Noska, R. and V. Misra, Geophys. Res. Lett., doi:10.1022/2016GL068409.
An objective index of the onset and demise of the Indian summer monsoon (ISM) is introduced. This index has the advantage of simplicity by using only one variable, which is the spatially averaged all-India rainfall, a reliably observed quantity for more than a century. The proposed onset index is shown to be insensitive to all historic false onsets. By definition, now the seasonal mean rainfall anomalies become a function of variations in onset and demise dates, rendering their monitoring to be very meaningful. This new index provides a comprehensive representation of the seasonal evolution of the ISM by capturing the corresponding changes in large-scale dynamic and thermodynamic variables. We also show that the interannual variability of the onset date of the ISM is associated with El Niño–Southern Oscillation (ENSO) with early (late) onsets preceded by cold (warm) ENSO.

32. The sensitivity of southeastern United States climate to varying irrigation vigor
Selman, C. and V. Misra, J. Geophys. Res., doi:.1002/2016JD025002
Four regional climate model runs centered on the Southeast United States (SEUS) assuming a crop growing season of May through October are irrigated at 25% (IRR25), 50% (IRR50), 75% (IRR75), and 100% (IRR100) of the root zone porosity to assess the sensitivity of the SEUS climate to irrigation. A fifth run, assuming no irrigation (CTL), is used as the basis for comparison. Across all IRR runs, it is found that there is a general reduction in seasonal mean precipitation over the irrigated cells relative to CTL. This manifests as an increase in dry (0–1 mm/d) days and reduction in> 1 mm/d rainfall events. A comparative moisture budget reveals that area-averaged precipitation over the irrigated cells displays a reduction in precipitation and runoff in IRR100 with a weaker reduction in IRR25. This is despite an increase in vertically integrated moisture convergence and local evaporation. We find that irrigation increases the lower atmospheric stability, which in turn reduces the convective rainfall over the irrigated areas. Seasonally averaged temperatures reduce over irrigated areas, with the intensity of the reduction increasing with irrigation vigor. This is largely attributed to a repartitioning of sensible heat flux into latent heat flux. There is also, however, a small increase of heat flow to deeper soil layers. Precipitation ahead of transient cold fronts is also reduced by irrigation as they pass over irrigated cells, owing to the increased stability in the lower troposphere. The intensity of this precipitation reduction becomes

more intense as irrigation vigor increases. Lastly, heat waves in the SEUS are reduced in intensity over irrigated cells.

33. Understanding the variations of the length and the seasonal rainfall anomalies of the Indian Summer Monsoon

V. Misra, A. Bhardwaj, and R. Noska, Journal of Climate, 30, 1753-1763

The canonical relationship between the length and the total seasonal rainfall anomalies of the Indian Summer Monson (ISM) is the association of the longer (shorter) season with wetter (drier) seasonal rainfall anomalies. We show that such canonical behavior is clearly associated with relatively strong ENSO SST anomalies in the eastern equatorial Pacific Ocean that appear in boreal summer and fall seasons. The non-canonical relationship is borne by longer (shorter) season associated with drier (wetter) ISM seasonal rainfall anomalies. A majority of these non-canonical seasons, with anomalously short season length but anomalously high seasonal mean rain tend to occur under relatively weak La Niña forcing during boreal summer season. Although onset of such seasons occur through canonical ENSO forcing of large-scale meridional temperature gradient, its demise is dictated by the depletion of the moist static energy from the underlying cooling of the upper ocean in the northern Indian Ocean. This is from stronger meridional Ekman ocean heat transport forced by the stronger low-level atmospheric southwesterlies than the corresponding canonical wet ISM season.

34. Downscaling future climate change projections over Puerto Rico using a Non-hydrostatic atmospheric model

A. Bhardwaj, V. Misra, A. Mishra, A. Wootten, R. Boyles, J. H. Bowden, and A. J. Terando

We present the results from 20-year high resolution regional climate model simulations of precipitation change for the sub-tropical island of Puerto Rico. The nested Japanese Meteorological Agency Non-Hydrostatic Model (NHM) operating at a 2km grid resolution is nested inside the Regional Spectral Model (RSM) at 10km grid resolution, which in turn is forced at the lateral boundaries by the Community Climate System Model (CCSM4). At this resolution, the climate change experiment allows for deep convection permitting model integrations, which is an important consideration for sub-tropical regions in general, and on islands with steep precipitation gradients in particular that strongly influence local ecological processes and the provision of ecosystem services. Projected precipitation change for this region of the Caribbean is simulated for the mid-21st century (2041-2060) under the RCP8.5 climate-forcing scenario relative to the late 20th century (1986-2005). The results show that by the mid-21st century, there is an overall rainfall reduction over the island for all seasons compared to the recent climate with an added consequence of diminished MSD in the northwestern parts of the island. Importantly, extreme rainfall events on sub-daily and daily time scales also become slightly less frequent in the projected mid-21st century climate over most regions of the island.

35. Integrated Kinetic Energy in North Atlantic Tropical Cyclones: Climatology, Analysis, and Seasonal Applications

M. Kozar and V. Misra, in review

Integrated Kinetic Energy (IKE) is a recently developed metric that measures the destructive potential of Tropical Cyclones (TCs) by integrating of the square of the surface winds across these powerful storms. In this chapter, previous literature is reviewed to provide insights on the factors that make IKE a desirable metric. Namely, IKE complements existing scales and metrics by considering a TC's entire wind field, in lieu of just focusing on the maximum intensity of a storm. Using a dataset of six-hourly IKE estimates for two-decades of North Atlantic TC activity, the climatology of IKE in individual storms is explored, with emphasis on seasonal and spatial variability. The driving mechanisms for IKE variability during the lifetime of a TC are also reviewed to determine which environmental and storm-scale features promote IKE growth. These discussions provide a basis for understanding the variations of IKE in a future climate. The historical record of IKE can also be aggregated to a seasonal metric, called Track Integrated Kinetic Energy (TIKE), which is shown to offer a comprehensive outlook of seasonal TC activity and can be used to explore interannual TC variability over the last two to three decades.

36. Characterizing the rainy season of Florida

V. Misra, A. Bhardwaj, and A. Mishra, in review

Peninsular Florida has a very distinct wet season that can be objectively defined with onset and demise dates based on daily rainfall. The dramatic onset of rains and its retreat is monsoon like and hence the proposition to call it the Florida Monsoons (FM). Further, the regional scale atmospheric and upper ocean circulations and upper ocean heat content have a seasonal cycle that is consistent with the onset and the demise of the FM. In that, the gradual warming of the Intra-Americas Seas (includes Gulf of Mexico, Caribbean Sea and parts of northwestern subtropical Atlantic Ocean) with the seasonal evolution of the Loop Current and increased atmospheric heat flux in to the ocean eventually enhance the moisture flux into terrestrial Peninsular Florida around the time of the onset of the FM. Similarly, the FM retreats with the cooling of the IAS that coincides with the weakening of the Loop Current and reduction of the upper ocean heat content. This robust seasonal evolution of the atmosphere and the ocean centered around the wet season of Peninsular Florida is monsoon like. It is also shown that anomalous onset and demise dates of the rainy season have implications on the seasonal rainfall anomalies of the FM, much like the Indian summer monsoon.

37. The potential role of land cover on secular changes of the hydroclimate of Peninsular Florida

V. Misra, A. Mishra, A. Bhardwaj, K. Viswanathan, and D. Schmutz, in reivew

The seasonal cycle of Peninsular Florida rainfall is a robust feature that has monsoon like seasonality. We objectively define the onset, demise, and length of the wet seasons over the time period of 1948-2006 in Peninsular Florida based on daily rainfall from the Climate Prediction Center of the National Centers for Environmental Prediction. This definition defines onset (demise) of the wet season of Peninsular Florida as the first day the daily accumulated precipitation anomaly reaches a minimum (maximum) for the year at a given grid point. A discernible linear trend of later onset, earlier demise, and a resulting shorter length of the wet season in urban areas relative to the rural areas is observed. The wet season accumulation of rainfall however does not reveal a proportional change in the linear trend that implies a perceptible contrast of comparatively higher (lower) linear trend of the daily rain rate of the wet season over urban (rural) areas of Peninsular Florida.

38. A comparative study of the integrated kinetic energy of the tropical cyclones in the Northeast Pacific and the North Atlantic basins

J. Carsten and V. Misra, in review

The Integrated Kinetic Energy (IKE) of the Tropical Cyclones (TCs) in the North East tropical Pacific (NEP) and North Atlantic (AL) basins is computed from the best track data for the period 2004-2013. Our analysis reveals that TC's of the NEP basin have invariably much lower IKE than those in the Atlantic. The differences in IKE between TCs of AL and NEP are larger in the later part of the hurricane season, when a significant number of TCs in AL have a tendency to propagate to higher latitudes. Our analysis reveals that TCs with larger IKE in both basins have more of a deep tropical origin. In the NEP basin, the smaller sized TCs acquire their maximum IKE further east (more along the Mexican coast) than the larger sized TCs that attain their maximum IKE further west (in the open waters) and generally south of 20°N. In the Atlantic, the smaller sized TCs acquire their maximum IKE over a larger span of TC locations from the eastern Atlantic (e.g. Cape Verde type TCs) to those over the Caribbean Sea and the Gulf of Mexico, where TCs are likely to spend less time over the waters for it to further intensify. However, a fair number of small sized TCs also acquire their maximum IKE in the subtropical latitudes of the AL basin. The larger sized AL TCs show a clear preference of the northern latitudes to acquire their maximum IKE, which they invariably attain from their growth through extra-tropical transition. It is found that the rainfall volume of NEP TCs are far less than the AL TCs, which is largely because of the corresponding differences in the size of the TCs between the two basins.

39. Integrated kinetic energy of Atlantic tropical cyclones in a global ocean surface wind analysis

S. Buchanan, V. Misra, and A. Bhardwaj, in review

The Integrated Kinetic Energy (IKE) of a Tropical Cyclone (TC), a volume integration of the surface winds around the center of the TC is computed from a comprehensive surface wind (NASA's Cross-Calibrated Multi-platform [CCMP]) analysis available over the global oceans to verify against IKE from wind radii estimates of extended best track data maintained by NOAA for the North Atlantic TCs. It is shown that CCMP surface wind analysis severely underestimates IKE largely from not resolving hurricane force winds for majority of the Atlantic TCs, under sampling short lived and small sized TCs. The CCMP analysis does reasonably well in verifying IKE for large sized TCs that have comparatively longer life spans but they continue to have erroneous wind structure of overestimating the areal coverage of gale-force winds (34-kt). The phase of the seasonal cycle of North Atlantic TC IKE however verifies in the CCMP analysis. In addition, a proxy IKE (PIKE) based on the kinetic energy of the winds at the Radius Of the last Closed Isobar (ROCI) shows promise for small sized TCs unresolved in the CCMP dataset. Therefore, PIKE for small TCs in combination with traditional diagnosis of IKE for rest of the TCs in the dataset would enhance the application of CCMP global ocean wind analysis for TC IKE related studies.

40. Characterizing the variations of the motion of the North Atlantic Tropical Cyclones

C. N. Laurencin and V. Misra, in review

In this study, we examine the seasonal and interannual variability of the North Atlantic (NATL) tropical cyclone (TC) motion from the historical Hurricane Database (HURDAT2) over the period 1988-2014. We characterize these motions based on their position, lifecycle, and seasonal cycle. The main findings of this study include: 1) Of the 11,469 NATL TC fixes examined between 1988-2014, 81% of them had a translation speed of < 20mph; 2) TCs in the deep tropics of the NATL are invariably slow-moving in comparison to TCs in higher latitudes. Although fast moving TCs (> 40 mph) are exclusively found north of 30N, the slow moving TCs have a wide range of latitude.

This is largely a consequence of the background steering flow being weaker (stronger) in the tropical (higher) latitudes with a minimum around the subtropical latitudes of NATL; 3) There is an overall decrease in the frequency of all categories of translation speed of TCs in warm relative to cold El Niño Southern Oscillation (ENSO) years. However, in terms of the percentage change, TCs with a translation speed in the range of 10-20 mph display the most change (42%) in warm relative to cold ENSO years; and 4) There is an overall decrease in frequency across all categories of TC translation speed in small relative to large Atlantic Warm Pool years, but in terms of percentage change in the frequency of TCs, there is significant and comparable change in the frequency over a wider range of translation speeds than the ENSO composites. This last finding suggests that Atlantic Warm Pool variations have a more profound impact on the translation speed of Atlantic TCs than ENSO.

41. Terrestrial and ocean climate of the 20th century

V. Misra, C. Selman, A. J. Waite, S. Bastola and A. Mishra, in review

The Florida peninsula, with its close proximity to the equator surrounded by robust surface and deep water ocean currents, has a unique climate. Generally, its climate is mild with variations on numerous time scales, punctuated by periodic extreme weather events. In this chapter, we review the mechanisms by which some well-known natural variations impact the regional climate and modulate the occurrence of extreme weather over Florida and its neighboring oceans. In addition, we explore the role of land cover and land use change on the regional climate over Florida and its surrounding oceans. It is made apparent from the review that remote variations of climate have an equally important impact on the regional climate of Florida as the local changes to land cover and land use.

42. Florida climate variability and prediction

B. P. Kirtman, V. Misra, R. J. Burgman, J. M. Infanti, in review

This chapter focuses and the sources and mechanisms for climate variability in Florida across time-scales (i.e., seasonal-to-decadal). How these sources and mechanisms are used to make predictions are also discussed. The chapter summarizes current capabilities in terms of prediction quality – here the emphasis in on precipitation and land surface temperature on seasonal time scales. The longer decadal time scales are discussed in the next chapter in conjunction with climate change associated with anthropogenic forcing. Finally, the chapter discusses challenges and opportunities for the future.

43. Future Climate Change Scenarios for Florida

B. P. Kirtman, V. Misra, and A. Swamy, in review

This chapter describes both the nature and anthropogenic mechanisms for climate change, and how scenarios and projections of future climate change are made. Specific emphasis is placed understanding the changes over the near-term (i.e., adaption time scale) where emission scenario has little impact vs. changes beyond the mid-century where the projections are conditional on emission scenario. The various tools and models used to assess climate change are also summarized and projections from global and regional models are presented. Finally, the new science of decadal prediction is also presented as it has potential to improve climate information in the near-term.

44. Ice versus liquid water saturation in simulations of the Indian summer monsoon

R. Glazer and V. Misra, in review

At the same temperature, below 0ºC, the saturation vapor pressure (SVP) over ice is slightly less than the SVP over liquid water. Numerical models use the Clausius-Clapeyron relation to calculate the SVP and relative humidity but there is not a consistent method for the treatment of saturation above the freezing level where ice and mixed phase clouds may be present. In the context of current challenges presented by cloud microphysics in climate models, we argue that a better understanding of the impact that this treatment has on saturation-related processes like cloud formation and precipitation, is needed. This study explores the importance of the SVP calculation through model simulations of the Indian Summer Monsoon (ISM) using the Regional Spectral Model (RSM) at 15 km grid spacing. A combination of seasonal and multiyear simulations is conducted with two saturation parameterizations. In one, the SVP over liquid water is prescribed through the entire atmospheric column (woIce), and in another the SVP over ice is used above the freezing level (wIce). When SVP over ice is prescribed, a thermodynamic drying of the middle and upper troposphere above the freezing level occurs due to increased condensation. In the wIce runs, the model responds to the slight decrease in the saturation condition by increasing, relative to the SVP over liquid water only run, grid-scale condensation of water. Increased grid-scale mean seasonal precipitation is noted across the ISM region in the simulation with SVP over ice prescribed. Modification of the middle and upper troposphere moisture results in a decrease in mean seasonal mid-level cloud amount and an increase in high cloud amount when SVP over ice is prescribed. Multiyear simulations strongly corroborate the qualitative results found in the seasonal simulations regarding the impact of ice versus liquid water SVP on the ISM's mean precipitation and moisture field. The forcing applied to the model when SVP over ice is prescribed increases with increasing integrated moisture above the freezing level, suggesting its importance for convectively active, moisture rich regions of the tropics.

45. The simulation of the intraseasonal variations of the Indian summer monsoon in regional coupled ocean-atmosphere model

V. Misra, A. Mishra, and A. Bhardwaj, in review

This paper describes the simulation of active and break spells of the Indian Summer Monsoon (ISM) from a relatively high resolution Regional coupled ocean-atmosphere Climate Model (RCM) run at 10km grid spacing. The active (break) spells are characterized like the observations with stronger (weaker) rainfall over central India and anomalous low-level flow that enhances (weakens) the climatological flow pattern in the atmosphere. The spatio-temporal structure and the propagation characteristics of the intraseasonal variations of ISM rainfall in the RCM simulation exhibit reasonable fidelity. The model simulation also displays associated variations in the upper ocean, with active (break) spells of the ISM coinciding with colder (warmer) SST both in the Arabian Sea and the Bay of Bengal. These SST anomalies are sustained by corresponding net heat flux anomalies on the ocean surface. The active (break) spells are further associated with shoaling (deepening) of the mixed layer depth, depth of the 20ºC and 26ºC isotherms, which is critical for the SST response to heat flux. All of these simulated features of the intraseasonal variations of the ISM have been observed in earlier observational studies, that further confirm the fidelity of the simulation and the importance of coupled air-sea interactions and upper ocean stratification.

II Highlights of Accomplishments

Several of the publications were highlighted in news media and magazines. For example,

a) Nature World News (http://www.natureworldnews.com/articles/9049/20140916/forecasting-hurricane-strength-destruction-using-new-model.htm)
b) Science Daily (https://theconversation.com/there-are-better-ways-to-quantify-how-big-and-bad-a-hurricane-is-40137),
c) EoS ((https://eos.org/research-spotlights/defining-the-onset-and-end-of-the-indian-summer-monsoon),
d) BAMS (http://blog.ametsoc.org/paper-of-note/a-new-metric-for-hurricane-destruction-potential/)