# SUMMARY OF RESEARCH INTERESTS

*Hydrological Modeling of the Water Cycle*

1) Large spatial-scale and long-time hydrological modeling for water and energy budgets
2) Use of hydrological models to study extreme (floods and droughts) events
3) Spatial correlation and temporal persistence of hydrological fluxes
4) A one-dimensional modeling of the soil water column

*Water cycle characterization using modeling, remote sensing and data assimilation*

1) Remote sensing of soil moisture using aircraft active and passive sensors in a field experiment
2) Scaling and sensitivity of microwave brightness temperatures using Scanning Multichannel Microwave Radiometer
3) Assimilation of satellite derived land surface temperatures in a land surface hydrological model
4) Validation and estimation of land surface water and energy budgets using the TOVS Pathfinder data set for 1985-1992

*Role of land surface in climate*

1) Study of the North American Monsoon using satellite observations, mesoscale models and data analysis

*Hydrometeorological studies using models and data:*

1) Links between land cover, snow and monsoons in the United States South-west
2) Role of vegetation in modulation of land-atmosphere interactions
3) Use of satellite soil moisture data for improved prediction of the North American Precipitation Variability

*Response of land surface ecology to changes in weather and climate*

1) Modeling influence of plant cover on water and energy cycles at the land atmosphere interfaces

*Changing biodiversity in response to climate change for the rocky intertidals*

1) Climate change and intertidal bio-geography; Coupling a cascade of scales using observational data and models
2) Ecological Impacts of climate change on marine organisms

*Hydrological change detection in the context of climate change*

1) Use of time series to quantify land surface – atmospheric feedbacks in the context of climate change
2) Merging observational data sets, modeling and satellite remote sensing for detection of hydrological change

# ***Research Statement***

## Optimal Integration of eco-hydrological models, point observations and satellite remote sensing

Prediction of land surface and subsurface states by hydrological models is as accurate as (a) our model which consists of physical prognostic equations which may not represent reality, (b) parameters that “lump” our lack of understanding of the system into a few physical but mostly non-physical numbers and (c) inputs to land hydrology that may be incorrect in spatial variability and/or temporal description. Therefore it is proper to merge observations and model outputs using a weighting scheme that assigns weights in proportion to the reliability of the estimates (observations versus model outputs). Observations are classified as point-based (ground measurements: river discharge; measurements of soil moisture and temperature at a point) and spatial averages (remote sensing: temperature, soil moisture, precipitation). A proper merging of these two estimates (at any specific time step) will help in re-configuring the model for the next time step, thereby helping to alleviate some of the errors in the parameter inputs and/or model physics. With greater amounts of ground and satellite data being available to us today and in the foreseeable future, we should be able to optimize our hydrological predictability. Work on calibration of satellite retrieval algorithms and studies using satellite data at continental scales have yielded encouraging results.

*Examples: A simple surface temperature based assimilation model, Validation of satellite observations of hydrological variables; Use of Scanning Multichannel Microwave Radiometer for continental scale soil moisture; Validation studies of Passive Active L and S band Radiometer Radar and TRMM Microwave Imager*

## Feedbacks: Land-Atmosphere Relationships using Satellite Remote Sensing

The land surface is influenced by the atmosphere to a significant degree. Soil moisture and surface temperature are a result of precipitation and radiation from the atmosphere to the land. However, this coupling is in two ways. The land surface influences the atmospheric processes specifically through evapotranspiration of the vegetation. Increased soil water and radiation causes an increase in evapotranspiration that could lead to condensation and eventually precipitation (at the same location or elsewhere). The presence of vegetation is important in governing the evapotranspiration (latent heat) component of water (energy) budget. We have at our disposal numerous weather-scale meso-scale meteorological models for studying these phenomena. However, some of these models have inadequate representation of land surface effects that could benefit from the hydrological modeling advances described earlier.

*Examples: Influence of the land surface on the North American Monsoon; Impact of vegetation water content on plant-atmosphere interactions using MODIS and AMSR data sets*

## Hydrological Process Complexity and Representation

Land hydrological processes are incredibly complex and a proper representation of these is a challenging problem. Ranging from infiltration, evaporation and runoff at the surface to transpiration extraction by the roots, vertical/exchange flux between layers of the soil, to interflow, base flow and capillary rise from the water table in the sub surface, a proper parameterization of moisture fluxes if required for correct water (and energy) balance. Energy fluxes such as net radiation, latent, sensible and ground heat fluxes determine the land surface and sub-surface temperatures as well as provide a connection to the water balance through the latent heat variable. These moisture fluxes play a key role in the transport of nutrients, solutes and contaminants. There are three levels envisaged in this “accurate” quantification. The central issue in water (and energy) fluxes is the proper characterization of soil type, land cover, slope and topography. At the next level are the adequate constitutive relationships between soil moisture and hydraulic conductivity and/or soil water potential. The last level is the routing, i.e. transport of the moisture from the source downstream (i.e. along the gradient) using proper advection-dispersion relationships. These above-mentioned problems manifest in different ways for various spatial (individual hill-slope versus the whole Mississippi River Basin) and temporal (hours and days versus years and decades) ranges and resolutions. Each of these situations is dealt with individually and hydrological modeling is carried out to suit the situation and provide predictions for the problem under consideration.

*Examples: One dimensional watershed modeling, large-scale modeling of the Red River Basin and the Mississippi River basin using satellite data for input and validation*

### Impact of global changes in the hydrological cycle on animals and plants

This research is related to the changes in the hydrological cycle and to investigate the amount of moisture in the top layer of the soil and to understand the fluxes of this moisture through evapotranspiration, infiltration and runoff. These changes in the hydrological cycle over large time periods are an important part of global change. Therefore one has to be cognizant of the fact that these changes would ultimately affect the animals and plants. The changes in hydrological cycle occur on a seasonal time scale as well. My past research studies the hydrological cycle using a combination of field experiments where we collect observations of the soil moisture using instruments; satellite remote sensing and computer based hydrological modeling.

The purpose of my research plan is to study the global environmental change and this will impact how society perceives global climate change. How does society which disturbs the environment and the hydrological cycle reconcile and live within the same disturbed environment? How much does the changes in hydrological cycle impact animals and plants and can these adapt at a molecular level? Past studies have studied the impact of temperature changes on population of animal and plant species as well as the time of peak population. This research has shown that the global and regional air temperatures increases are correlated to earlier peak of species as well decrease in species population.

The challenge of the proposed research is to build a bridge between widely varying scales. The molecular scale is $10^{-6}$ m (micrometer) and the global climate change scale is $10^{6}$ m (1000km). The translation of the global climate change to the molecular scale is $10^{12}$ fold. It is a challenge to relate "trickle-down" of the global change signal to the molecular level and determine the genetic reason why plant and animal populations are on the decline and why they peak earlier. It is obvious that there is a connection at this sub-scale that is driving the process. Earlier studies have relied on statistical correlations which have picked up this signal but at the same time have been complicated by various issues such as local land-use changes; creation of heat islands due to urbanization and introduction of new plant and animal populations in non-native areas that has disturbed the ecological harmony.

With the use of climate data from direct observations and use of climate model simulations for precipitation, evapotranspiration and air temperatures and species data from published sources we will test various hypothesis. These are

[1] Is there an inherent connection between global change specifically in the hydrological cycle variables of precipitation and evapotranspiration impact animal and plant populations and their peak time during the year? Is this connection different that that between air temperature and populations

[2] Are these connections between global climate and population only statistical or are there connections at the basic molecular genetic levels?

Most of these questions can only be answered in the present day context by the use of satellite remote sensing.

*Examples: Climate change and intertidal biogeography: coupling remote sensing data to thermal physiology across a cascade of scales; Ecological impacts of global change on inter-tidal organisms*