Project Title: **High Performance Simulation using NASA Model and Observation Products for the Study of Land Atmosphere Coupling and its Impact on Water and Energy Cycles**

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Science issue: Assess impact of land-atmosphere coupling and heterogeneities (e.g., topography, soils, vegetation, and land cover) on the local, regional, and global hydrological cycle.

Approach: Examine impact of various spatial/temporal scales of land surface physics on boundary layer evolution, and quantify the interactive soil-vegetation-precipitation processes and feedbacks and their influence on preferential convective initiation and precipitation processes.

Other data: CEOP, DOE/ARM/SGP/CART, IHOP, and LBA

Models: Multi-scale Modeling Framework (MMF) - Goddard Cumulus Ensemble (GCE) model, Land Information System (LIS), and finite volume Global Circulation Model (fvGCM). Coupled LIS/WRF/GCE system - land modeling and data assimilation system (NOAH, CLM2, and TESSEL), atmospheric modeling and data assimilation system, and atmospheric model, respectively.

Study particulars: LIS-WRF: 1-7 day simulations, ARM-SGP, 1km horizontal resolution, diurnal focus. MMF: simulations from May 2005 to Sep 2007, NA water and energy extremes from global connections, diurnal cycle to interannual variability.

Project status:

Year 1 & 2 complete - Coupled LIS-WRF simulations using CLM, Noah LSMs completed for IHOP '02 and GABLS Cases 99 case studies & derived metrics of land-atmosphere coupling that describe the impact of entrainment and advection on surface flux evolution. Carried out a series of ensemble fvGCM and MMF one-month simulations to study the land surface coupling strength.

Year 3 (now) - Complete & publish (J. Hydromet.) analyses of LIS-WRF case study simulations that demonstrate the LoCo diagnostic approach developed in Years 1-2. Import ECMWF's TESSEL LSM into LIS-WRF. Complete LIS-MMF coupling and publish results with and without 2-D LSM representations.

Year 4 & 5 - Implement generic LSM-PBL coupler and engage modeling community for LoCo. Repeat case studies including DA experiments: soil moisture, surface temperature, snow. Implement full 3-D LSM representation for MMF based on LoCo work.

Mixing Diagram approach depicts L-A fluxes and feedbacks through the evolution of T, q

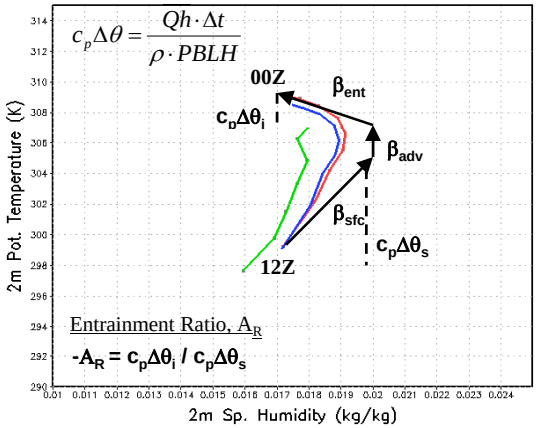


Figure 1: Diurnal evolution (12-00Z) of 2m-potential temperature vs. 2m-specific humidity simulated by LIS-WRF during dry soil moisture conditions in the Southern Great Plains using the Noah LSM with the different PBL schemes. Components of L-A coupling that can be quantified from these diagrams are the magnitude and slope (β) of the surface and entrainment fluxes, advection, and the entrainment ratio.

Noah LSM

PBL Schemes

- •= YSU
- •= MYJ
- •= MRF

NEWS linkages: (pull, push, collaborate, external)

-**Adler:** MMF results are being evaluated against TRMM-based products.

-**Betts:** Our results offer a quantitative, regional, diurnal, and flexible approach to describing L-A equilibrium in LIS-WRF w/various LSM+ PBL combinations.

-**Koster:** We focus on the lower boundary and L-A 'link' of his soil moisture-precip 'chain' that can be applied to GCM scale as well (we plan this for MMF diagnostics).

-**Reichle:** Our coupling diagnostics provide a methodology for later DA experiments and highlight the impact of different offline vs. coupled models, DA techniques, and observations on the L-A equilibrium. Importantly, Rolf's EnKF has been implemented in LIS and will be used in the later LIS-WRF coupling experiments to examine the role of DA in L-A coupling.

-**Rodell:** The LIS infrastructure is common to both projects, and the L-A coupling work will help inform the proper representation of the surface layer and/or PBL in uncoupled GLDAS.

C. Peters-Lidard, Updated: October 31, 2007

Modeling System Overview

Weather Research and Forecasting (WRF) Model

- 1-km horizontal resolution
- Advanced Research version 2.1.2 (WRF-ARW)
- NARR forcing
- 43 vertical levels (~42m sfc)
- 3 PBL + 3 LSM schemes

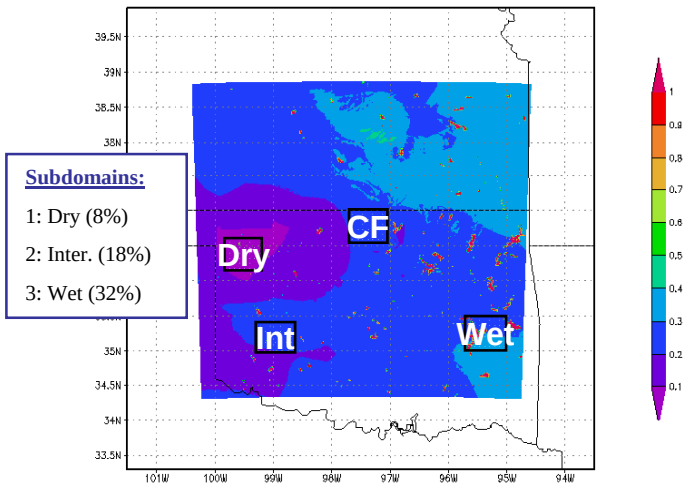
WRF THE WEATHER RESEARCH & FORECASTING MODEL

Land Information System (LIS)

- Suite of LSMs,coupled to WRF
- Flexible resolution, forcing and parameters
- Provides spinup capability for improved initialization
- NASA's 'Software of the Year'

LIS

WRF Initial SWC



Initial soil moisture for the WRF 1km-domain and locations of the dry, intermediate, and wet analysis regions and ARM-SGP Central Facility.

Land Surface Models

Noah (v2.7.1)
- 4 soil layers (10 cm upper)
- Derived from the OSU LSM
- Soil moisture and temp; veg, snow

Community Land Model (v2)
- 10 soil layers (2 cm upper)
- Extensive canopy and veg,
- Soil moisture, temp; veg, snow

TESSEL
- ECMWF operational lsm
- HTESSEL – latest version
- Tiled soil, canopy, snow sfc's

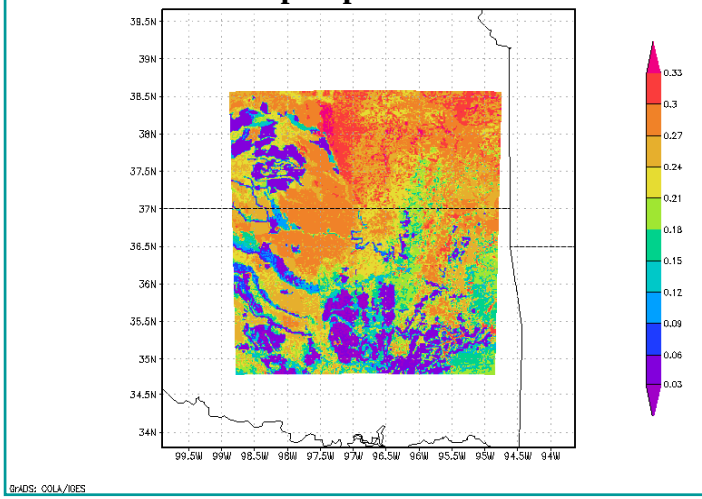
PBL Schemes

YSU (Yonsei University)
- Counter-gradient fluxes; Non-local K theory
- Explicit entrainment at PBL top
- PBL Height from critical Ri number

MYJ (Mellor-Yamada-Janjic)
- Nonsingular M-Y level 2.5 closure
- Length scale limited by TKE, buoyancy, shear
- PBL Height diagnosed based on TKE production

MRF
- Based on YSU scheme
- Implicit (local) vertical diffusion

LIS Spinup – Noah LSM



NEWS Team #2: "Two Golden Years" SGP 2006-2007 Extremes

Linkages to Question #2

1. Related Questions (from project outline)

- How does diurnal cycle of NEWS model data (LIS-WRF) change in wet vs. dry years?
- What are the L-A interactions and temperature, precipitation, and land hydrology feedbacks associated with anomalies that lead to drought?
- Is there any skill in any model at predicting drought?

2. Hypotheses

- The evolution of hydroclimate extremes and L-A coupling processes over NA during 2006/7 can be quantified by an integrative analysis of available observational and model data.
- The causal factors and inherent predictability of these observed hydroclimatic anomalies can be understood in terms of antecedent land surface conditions, remote forcing from ocean/land fluxes, and internal atmospheric dynamics.
- The integration of well-crafted numerical modeling experiments and observationally-based diagnostics is essential to realize and improve skill in predicting such events.

NEWS Team #2: "Two Golden Years" SGP 2006-2007 Extremes

Contribution from Peters-Lidard Group

- **LIS-WRF regional simulations for dry/moist regimes or other short-term periods of interest (1-7 days)**

  - Overall we are looking at performing one case study in 2006 and 2007 (dry vs. moist) to evaluate the coupling behavior in each.

  - Under the LIS-WRF framework, will be produce 9 simulations for each case (18 total) that consist of 3 LSMs in LIS (Noah/CLM/TESSEL) with 3 PBL schemes in WRF (YSU, MYJ, MRF). This will enable us to evaluate the sensitivity and accuracy of different L-A coupling during these periods.

  - Steps to Integration: Specific cases still need to be selected. These should be based on a combination of what the data (provided and analyzed through Data Gathering and Analysis Tasks) and models (MERRA, MMF) show us to be the most interesting and anomalous, and therefore would be a group effort to pinpoint the dates and regions. e.g. dry/wet composites?

- **Apply L-A coupling diagnostics to LIS-WRF output and corresponding observations from the area of interest**

  - These common model diagnostics can also be applied and compared to data from other modeling and observational efforts during this project (e.g. Data Gathering and Analysis results & dry/wet composite data, MERRA, MMF).

NEWS Team #2: "Two Golden Years" SGP 2006-2007 Extremes

Contribution from Peters-Lidard Group (cnt'd)

- **Perform long-term (3-4 year) land surface spinups for each case study using LIS and evaluate the role of high-resolution land surface states on regional LIS-WRF simulations**

  – This task will address the hypothesis regarding the role of antecedent land surface conditions.

  – The spun up land surface conditions will then be used to initialize LIS-WRF, and will determine the sensitivity of LIS-WRF and L-A coupling within to the initial state and high-resolution forcing (namely precipitation) and land surface (vegetation and soil) parameters.