Impact of the FSU/COAPS Soil Moisture Initialization to Subseasonal Forecast Skill

Marie Boisserie1, Steve Cook2

1Department of Oceanography and Center for Ocean-Atmospheric Prediction Studies, Florida State University, Tallahassee, Florida, USA

Introduction

Although soil moisture amount seems to be insignificant when compared to the total amount of water on the global scale, this variable is today widely recognized to be crucial for climate studies. Soil moisture is a key variable because: 1) it has a long memory (annual and seasonal persistence), and it controls the partition between latent and sensible heat fluxes, which in turn regulates the interactions between the land surface and the atmosphere. Many numerical studies指出 extreme" soil moisture values have shown that an accurate soil moisture initialization could lead to improved seasonal forecasts of near-surface climatological variables (Rahim and Mahr 1992; Reed et al. 1992; Saha et al. 1994; steel and Freitas 2006; Koster et al. 2000; Hong and Kiladis 2000 among others). However, the question whether a realistic soil moisture initialization increases the subseasonal forecast skill of near surface variables is still an open question. This is a challenging issue since there is no global observational dataset of soil moisture to initialize climate models.

Soil Moisture Initializations

The second phase of Global Land-Atmosphere Coupling Experiment (GLACE-2) is an ongoing model intercomparison project aimed at assessing the above issue. Florida State University/Center for Ocean-Atmospheric Prediction Studies (FSU/COAPS) recently joined this research group. To generate a realistic soil moisture initialization, all the participants but the FSU/COAPS model share their land model output (LSM) offline with GSWP2 observation-based forcing data. The land surface state variables derived from the offline assimilation are then used to initialize their coupled land-atmosphere model. With such a direct assimilation into the offline LSM, the state of near-surface variables may undergo an adjustment (or spurious process) once run online. This spurious process can decrease the short-term to subseasonal forecast skill of near surface variables. A land data assimilation system conducted in two coupled model runs is expected to solve this spurious problem.

Using a coupled land data assimilation system, the research products provided by operational centers have attempted to produce realistic soil moisture state to improve the forecast of near-surface variables. For instance, the National Center for Environmental Prediction (NCEP)/Department of Energy (DOE) (Reed et al. 2002) adjusts the top 10 cm soil moisture using the difference between model and LFA observed precipitation data (Krisman et al. 2000). However, this land data assimilation simulation may reduce the soil moisture predictability when the soil moisture analysis is not in conjunction with atmospheric physics (Koster et al. 2000). Indeed, a soil moisture analysis affected by a small observed rain event, the atmospheric state of the model may not seamlessly simulate a clear sky if the strong radiative and surface fluxes. Those strong surface fluxes can in turn have a negative impact on the given soil moisture simulation.

In this study, we produce a realistic soil moisture analysis that remains physically consistent with the atmosphere's processes of the model, by assimilating precipitation into the atmospheric component of the model. This technique is known as the Precipitation Assimilation Boundary (PAB, Steel and Cook, 2003). It assimilates an observation-based precipitation dataset for adjusting the vertical root zone of the atmospheric wetness, using the difference between the model-estimated and the observed precipitation. This assimilation is performed throughout an integration of the two-way coupled land-atmosphere FSU/COAPS model. Hence, the analysis procedure of the atmospheric boundary vertical root zone net energy is not only to balance the model precipitation close to observation but also helps to redistribute the heat load and moisture in the atmosphere, which in turn affect the adiabatic heating and therefore the climatological and surface energy fluxes that are directly affected by the climatological and surface energy fluxes through the atmospheric component of the model.

Objectives

1. Generate real-time soil moisture initial conditions using a consistent coupled land data assimilation system.
2. Understand the impact of realistic soil moisture initialization on short-term to subseasonal forecasting skill of near-surface variables (precipitation, air-temperature).

Differences Between FSU/COAPS and GLACE-2

We recently joined the GLACE-2 team and are the only participant using a different soil moisture initialization approach based on a coupled land surface data assimilation system.

GLACE-2 approach:
- Offline initialization
- Forecasting data: the 1st Global Soil Wetness Project (GSWP2)-observation-based data
- Requires an adjustment before being used in the forecast

FSU/COAPS approach:
- COAPS/FSU approach:
  - Coupled initialization
  - Formatted initialization data, the 1st Global Land-Meteorological Forcing Dataset for land surface modeling (Shields et al. 2004)
- No adjustment is required

Model and Datasets

CLIMATE MODEL

Florida State University (FSU) model coupled to the National Center for Atmospheric Research (NCAR) Community Land Model (CLM) (Minn et al. 2000) with a T63 (1.875°) horizontal resolution.

PREDICTION OBSERVATION

For assimilation: 5hr, 1st precipitation observation-based data provided by Shields (2006)

For forecast verification: daily, 0.25° precipitation data over the continental United States defined by interpolating National Centers for Environmental Information National Quality-controlled Gauge Observation System and 800 stations, collected from multiple sources (Minn et al. 2000)

Air Temperature Observation

2hr 1st precipitation observation-based dataset provided by Shields et al. (2006)

Conclusion

We find that our realistic soil moisture initialization has a positive impact on the 24m air temperature forecasts of the FSU/COAPS model and leads to a increase in the short-term and the subseasonal forecast embedding skills of most of the U.S.A. However, the identification of positive soil moisture initialization skill is not apparent in the increased sensitivity of the subseasonal forecasting skill. This is expected since accurate basin mean precipitation forecasts are very challenging to make (Nash et al. 2002). It is evident that precipitation affects soil moisture conditions, which in turn affect the generation of precipitation. The question whether a realistic soil moisture initialization affects precipitation is less evident. To answer this question, the PAB shows a significant relationship between the forecasted precipitation change and the soil moisture change at the time lag of -1 month (soil moisture preceding precipitation). The results are not as encouraging as for the air temperature forecasts. In regions 3 and 4, the forecasted precipitation values do not show much response to soil moisture change, which in turn affect precipitation. This is not the case in region 3 and 5, as the forecasted precipitation values show a positive response. Therefore, the increase in the 3-month precipitation forecast skill seen in regions 3, 4, and 5 could be attributed to the realistic soil moisture initialization.

Acknowledgments

This project was supported by the Applied Research Center, funded by NOAA Office of Global Programs awarded to Dr. James J. O Brien. The authors would like to thank the Applied Research Center, funded by NOAA Office of Global Programs awarded to Dr. James J. O Brien for their support.

For more details, please refer to the original publication.