Atmosphere-land surface coupling processes and hydrometeorological prediction - A study using the Eta/SSiB model

Progress Report

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Period: 10 May 2002 - 13 March 2003

During this time of period, our main focus is to test the Eta/SSiB model for regional climate study. We also conduct researches using the NCEP GCM/SSiB and using the snow model. In this time of period, my assistant Ratko Vasic and I have collaborated with Drs. Janjic, Mesinger, Michell, and Zhang for the Eta study.

1). Regional climate prediction study

We have conducted a series experiments to explore the predictability and sensitivity of the regional Eta model to boundary forcing. Several factors have been selected to explore their impact on the regional predictability. These factors include domain size, horizontal resolution, different lateral boundary conditions, convective parameterizations, and surface/PBL transfer schemes. The temporal and spatial variations of simulated precipitation, winds at 200mb and 850mb, temperature at 200mb, 500mb, and 850mb, humidity at 500mb and 850mb were compared with observations or reanalysis data. These model integrations were from May 1 through July 31 for year 1988, 1991, 1993, and 1998. Most of the experiments were conducted for 1998.

In domain size experiments, we selected the original Eta weather forecast big domain, a small domain, which only covers the US continent, and several domains between these two extremes. It was found that in general the Eta/SSiB model produced reasonable simulations for the temporal and spatial variations of wind, temperature, and humidity fields, but the simulations with big domain showed more substantial bias in several fields.

Water cycle is our focus. The runs with small domain and a domain that covers North American continent and parts of the Atlantic and Pacific Oceans produced reasonable monthly mean and domain-averaged daily mean precipitation for the four years' simulations (except July 1993). The big domain and a domain that extends to the south (the Gulf of Mexico) produced significant dry bias after one-month simulations. In all these runs, the American monsoon was weak. Except the simulation with big domain, the precipitation over the Atlantic Ocean was also weak in experiments with other domain size.

To further explore the factors that influence the regional predictability, we also tested the impact of the lateral boundary conditions. In all the following tests, we only used the median domain (North American continent with part of the Pacific and Atlantic Oceans. The south boundary is at the tip of the Florida Peninsular). The lateral boundary conditions included NCEP reanalysis II, ECMWF reanalysis, NOAA GCIP reanalysis, GCM outputs. In general NCEP reanalysis II produced the best results. However, lateral boundary condition with GCM outputs produced strong precipitation over the Atlantic Ocean and monsoon. With the ECMWF reanalysis, the monsoon simulation was also improved.

In addition, we also tested the vertical temperature advection scheme, the viscous sub-layer parameterizations, and the depth of the surface layer and the lowest atmospheric layer to examine the mechanisms that control the surface eddy transfer. But also these tests only showed moderate impact on the simulations.

Furthermore, sensitivity studies were also conducted to test the impact of surface boundary conditions. In the SST tests, we increased the SST by 1 and 2 degree C. Warm SST enhanced the precipitation over the Ocean. However, the impact on the continent was limited. We suspected that this was because the ocean areas in the domain were relatively small. We also introduced the diurnal variation to SST. The impact was very small.

2). Cold Season study

We also conducted studies to complete our off-line tests and produced a paper for the GCIP special issue. We also complete the coding and testing the snow code for coupling to the atmospheric model. The revised paper is attached to this report.

In this paper, a series of numerical experiments have been discussed to understand the physics at the soil-vegetation-snow-atmosphere interface and to find the major parameterizations/parameters, which are crucial to simulate cold season processes. This study shows that snow layering and compaction are among the most important factors affecting properly simulations of snow depth, snow water equivalent, surface temperature, and surface runoff. The fixed snow density could produce as high as 100 percent error in estimating the snow depth and cause significant biases in SWE simulation during the melting period. Furthermore, with a bulk snow/soil layer, the simulated surface temperature would persistently be close to the freezing point and its variability is substantially hampered, and the variability and the amplitude of the runoff during the snow-melting season could also be severely underestimated. The experiments also show that the proper snow albedo is crucial during the ablation period and affects the magnitude and timing in both SWE and runoff simulations. Furthermore, this study indicates that the parameterizations in the surface aerodynamic resistance in the stable regime play an important role in determining the sensible and latent heat fluxes during the winter season in the Arctic region, and then affect the snow depth simulations and prediction of snow melting as well as runoff timing. Although the snow may fully cover the ground in cold regions during the winter, numerical experiments in this study show the vegetation still exerts a substantial influence in the snow depth and runoff simulations. Numerical experimentation shows that less downward sensible heat on the bare ground (after replacing the trees) produces thick snow cover and extremely high peak runoff, which leads to a typical deforestation scenario in cold regions.

3) NCEP GCM Simulation

Study has also found the evidence that exchanges of water and energy between the vegetation and the atmosphere also play an important role in the precipitation and atmospheric circulation in equatorial American. The results are obtained by conducting five-month simulations of 1987 using a general circulation model (GCM) coupled with two different land-surface parameterizations: one with and one without explicit vegetation representation, referred to as the GCM/vegetation and the GCM/soil, respectively. The GCM/vegetation produced the large-scale turning of the low-level airflow in equatorial region, which was consistent with observation and did not appear in the simulation without explicit vegetation.

Publications

Luo. L., A. Robock and Co-authors (including Xue), 2002: Effects of frozen soil on soil temperature, spring infiltration, and runoff: results from the PILPS 2(d) experiment at Valdai,Russia. Accepted by *J. Hydrometeorology.*

Marland G., R. A. Pielke, sr., M. Apps and Co-authors (Including Y. Xue), 2002: The climatic impacts of land surface change and carbon management, and the implications for climate-change mitigation policy. Accepted by J. of *Climate Policy*.

Niyogi, D. D. S., Y. Xue, and S. Raman, 2002: Direct and indirect feedbacks of simultaneous soil moisture and atmospheric CO2 changes on terrestrial ecosystem response. Submitted to *J. Geophys. Res.*

Xue, Y., S. Sun, D. Kahan, Y. Jiao, 2002: The impact of parameterizations in snow physics and interface processes on the simulation of snow cover and runoff at several cold region sites. Submitted *to J. Geophy. Res*. For GCIP special issue.

Zhang, D.-L., W.-Z. Zheng, and Y. Xue, 2002: A numerical study of early summer regional climate and weather over LSA-East: Part I: Model description and verification. *Mon. Wea. Rev.* In press.