RECENT GCIP ADVANCEMENTS IN COUPLED LAND-SURFACE MODELING AND DATA ASSIMILATION IN THE NCEP MESOSCALE ETA MODEL

Ken Mitchell, Fei Chen#, John Schaake*, Dan Tarpley**,

Hua-Lu Pan, Ying Lin, Mike Baldwin, Eric Rogers, Geoff Manikin,

Alan Betts##, Zavisa Janjic, Qingyun Duan*, Victor Koren*

Environmental Modeling Center

National Centers for Environmental Prediction

* National Weather Service Office of Hydrology

** NESDIS Office of Research and Applications

National Center for Atmospheric Research (RAP)

Atmospheric Research Inc

Over the past several years, under the sponsorship of the NOAA GEWEX Continental Scale International Project (GCIP), the Environmental Modeling Center (EMC) of the National Centers for Environmental Prediction (NCEP) has joined with hydrologists in the NWS Office of Hydrology (OH), satellite land-surface remote sensing experts in NESDIS, and numerous non-NOAA GCIP and GEWEX investigators to develop and implement a series of advancements to the land-surface and hydrology physics of the NCEP mesoscale Eta Model (and its associated Eta-based 4-D Data Assimilation System or EDAS). These advancements (e.g. Chen et al., 1996; Chen et al., 1997) include a new land-surface model (LSM) with four soil layers with thicknesses of 10, 30, 60, 100 cm, an explicit vegetation canopy, snowpack physics, sub-grid runoff treatments, satellite-derived daily snow cover updates, and a satellite-derived seasonal cycle of green vegetation fraction.

We will first describe the model configuration and review off-line uncoupled development and testing approaches, including numerous retrospective experiments that span the GEWEX programs of ISLSCP/FIFE, ISLSCP/GSWP, and PILPS 2a, 2b, 2c, and 2d. Presented results will include our latest off-line tests at the Valdai, Russia site in PILPS 2d, focusing on our proposed upgrades adding frozen soil and patchy snow cover physics.

Next we will present experiences from the operational coupled model, implementation milestones, and validation examples of surface fluxes, skin temperature (from satellite), shelter temperature and dewpoint, PBL profiles, and precipitation skill scores. Substantial validation and assessment efforts have been carried out by collaborating with extramural GCIP-sponsored investigators (e.g. Betts et al., 1997). Early first-year problems with a low-level warm/dry bias in the summer of 1996 have been largely solved. For a site in central Illinois, Figure 1 shows negligible bias in the 50-day mean, during 10 Jun - 10 Aug 1997, of hourly daytime PBL depth as forecast by the Eta model, compared to observations from a surface wind profiler (Angevine, 1998, NOAA/AL, personal communication). Figure 2 shows negligible bias in the 30-day running mean of daily average 2-m air temperature in northeast Oklahoma over 180 days during 01 Jan - 30 Jun 1997 (Hinkelman, 1998, personal communication). Our present attention in 1998 is focused on 1) a low-level cool/moist bias in the early spring over moist soils with little vegetation and 2) an overly large ground-heat flux over moist soils.

Hallmarks of our land-surface modeling system include the significant use of four satellite-derived land-surface databases, from which we will present examples. We recently implemented a satellite-based daily update of snow cover and sea ice on a 23-km N. Hemisphere grid. Additionally, we specify our seasonal vegetation cycle using a 5-year climatology of global, 0.144 degree, monthly green vegetation fraction, derived from a carefully cloud-screened 1985-1990 climatology of AVHRR-based NDVI. In the validation area, we apply GOES-derived, hourly, 0.50 degree retrievals of skin temperature and downward surface solar insolation. Under development is a new global, 0.144 degree, 5-year climatology of monthly surface albedo, to serve as a self-consistent companion to the cited vegetation phenology.

The Eta model land-surface upgrades have been incorporated into NCEP's Global Medium Range Model (MRF), during the mid-June 1998 MRF upgrade to T170 resolution. This most recent MRF configuration is being embraced as NCEP's next generation seasonal and annual climate prediction model (run at lower resolution). Hence GCIP-sponsored land-surface advancements at NCEP are impacting numerical weather and climate prediction over a wide range of space/time scales.

The NCEP Eta model executes at 32-km with 45 layers over a very large domain including all of North and Central America and extensive neighboring ocean areas. In the data assimilation arena, this large domain is one major factor that has prompted us to test and operationally implement (03 June 1998) a fully continuous Eta-based cycling of all model prognostic state variables, including the land states of soil moisture/temperature. (Prior to this, we initialized soil moisture/temperature from the GDAS, our Global Data Assimilation System). For the time being, we are cycling the land-surface states without any nudging of the soil moisture. This omission of nudging may have to be revisited after one full year of continuous cycling, depending on the extent of land-surface drift that is encountered. Figure 3 shows the volumetric soil moisture on 12 Jun 1998 from the cycled EDAS in the 10-cm top layer (upper frame) and 30-cm second layer (bottom frame).

To address the possibility of drift in the continuously cycled, coupled, land-surface state (primarily arising from precipitation and surface solar insolation errors in the coupled systems), we are testing the EDAS assimilation of a) a newly developed hourly, national, 4-km, radar/gage rainfall analysis and b) the hourly, 0.50 degree, national, GOES-based retrieval of skin temperature cited earlier. The skin temperature assimilation tests are using a variational technique that utilizes the adjoint of the LSM.

Finally, in a more aggressive attempt to avoid land-surface state drift, we have just embarked on the development of an uncoupled, national, Land-Data Assimilation System (LDAS), in which the Eta LSM will be uncoupled from the Eta mesoscale model and executed in a real-time stand-alone mode forced by the cited, model-independent, hourly analyses of observed precipitation and solar insolation. This LDAS will provide an alternative setting for the assimilation of satellite-derived skin temperature and satellite-derived soil moisture.

To promote widening Eta model applications to the hydrology, agriculture, and air pollution communities, NCEP has greatly expanded the suite of Eta model output products for the land surface, to include all land state variables (soil moisture, soil temperature, snowdepth), all land-surface energy and water fluxes (surface and baseflow runoff, snowmelt, potential evaporation, actual evaporation), and detailed PBL profiles. A near-future effort will be to route the gridded runoff output into streamflow and river discharge rates.

Remaining future challenges include 1) refining key hydrologic parameters over the continental domain (in areas of soil water capacity, hydraulic conductivity, and runoff), 2) modeling the sub-grid variability of vegetation type, 3) specifying seasonal anomalies in the phenology cycle, and 4) data assimilation of satellite-derived land-surface information.

REFERENCES:

Betts, A., F. Chen, K. Mitchell, Z. Janjic, 1997: Assessment of the land surface and boundary layer models in two operational versions of the NCEP Eta Model using FIFE data. MWR, 125, 2896-2916.

Chen, F., K. Mitchell, J. Schaake, Y. Xue, H.-L. Pan, V. Koren, Q. Duan, M. Ek, A. Betts, 1996: Modeling of land surface evaporation by four schemes and comparison with FIFE observations. JGR, 101, No. D3, 7251-7268.

Chen, F., Z. Janjic, and K. Mitchell, 1997: Impact of atmospheric surface layer parameterizations in the new land-surface scheme of the NCEP mesoscale Eta model. Boundary-layer Meteor, 85, 391-421.

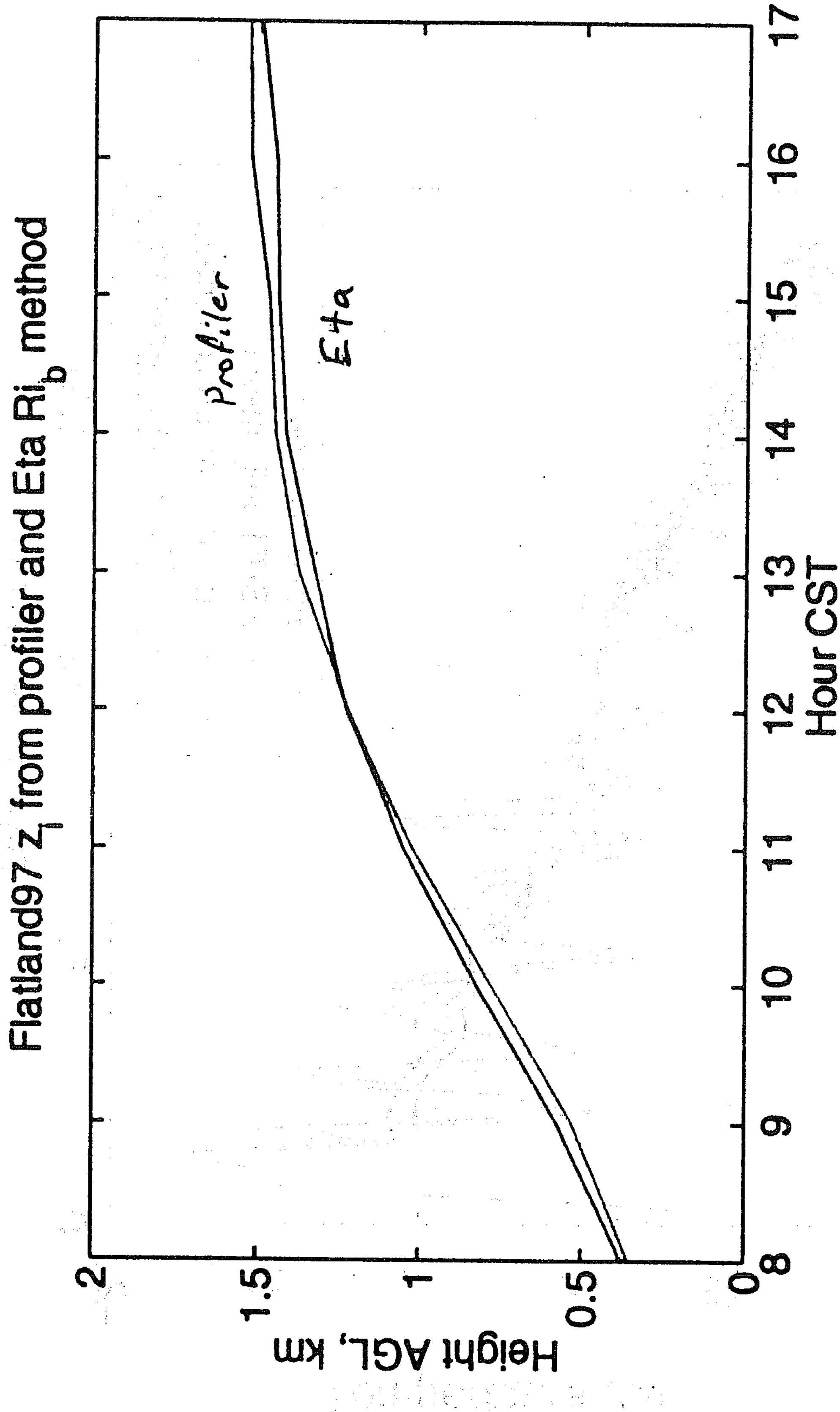

Flatland97 z_i from profiler and Eta Ri_b method
Height AGL, km
0
0.5
1
1.5
2
Hour CST
8
9
10
11
12
13
14
15
16
17
Profiler
Eta

Fig. 1

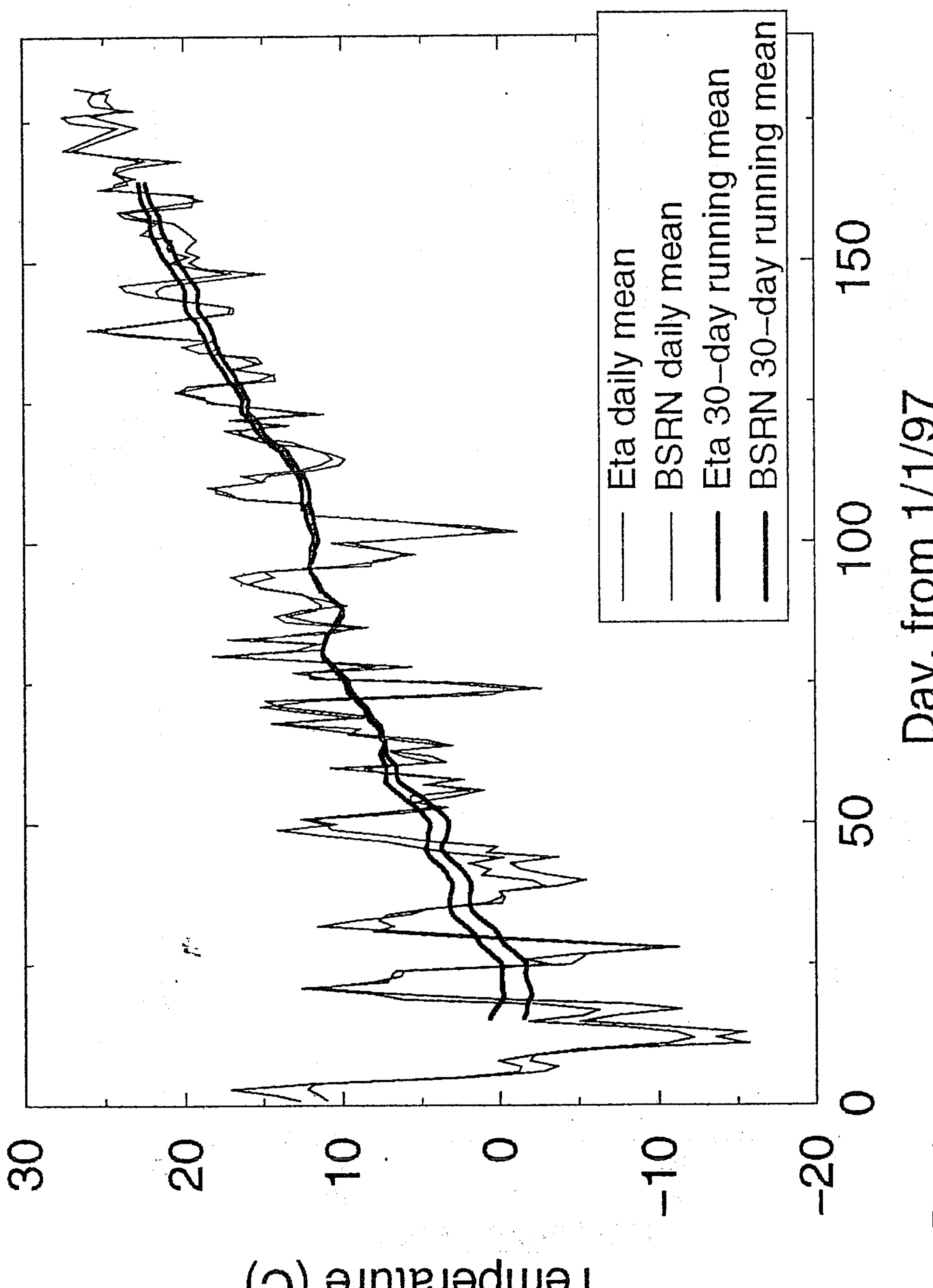
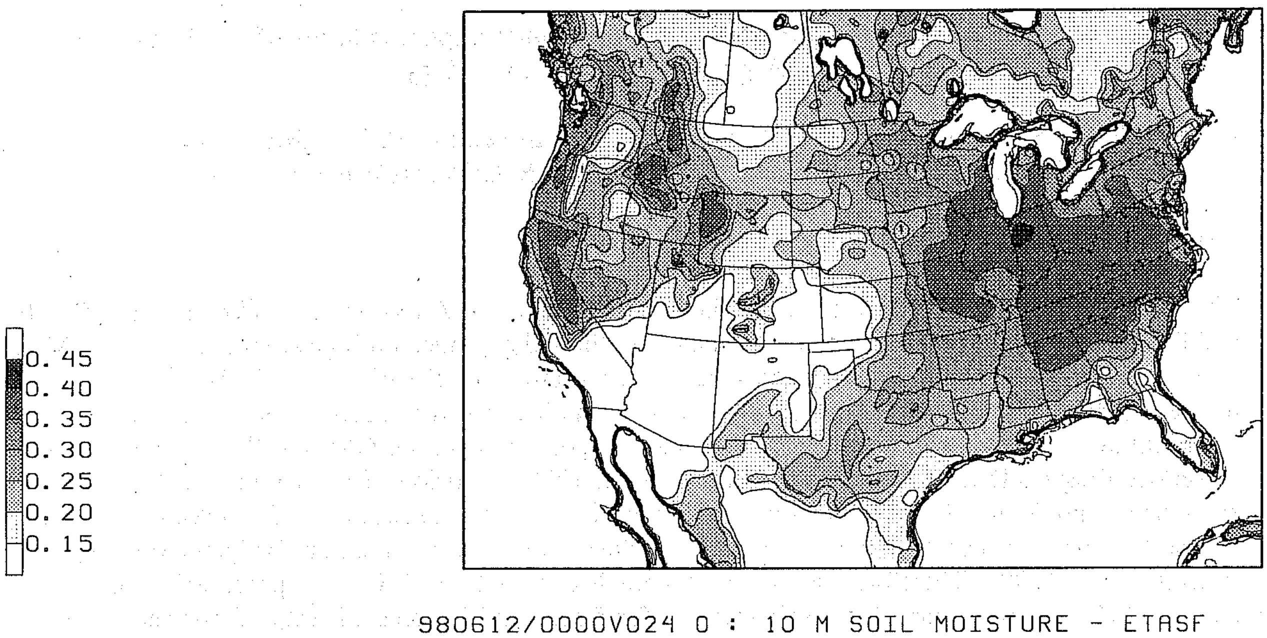

Eta daily mean
BSRN daily mean
Eta 30–day running mean
BSRN 30–day running mean
Temperature (C)
Day, from 1/1/97
30
20
10
0
−10
−20
0
50
100
150

Fig. 2


0. 45
0. 40
0. 35
0. 30
0. 25
0. 20
0. 15
980612/0000V024 0 : 10 M SOIL MOISTURE - ETASF

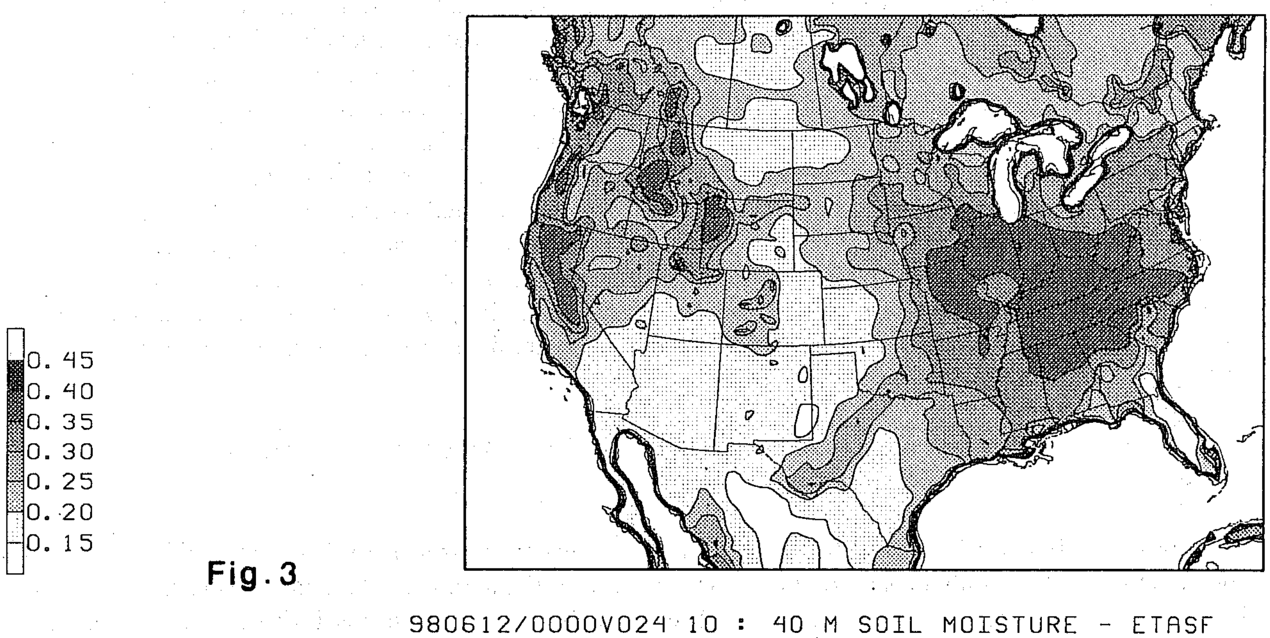

0. 45
0. 40
0. 35
0. 30
0. 25
0. 20
0. 15
980612/0000V024 10 : 40 M SOIL MOISTURE - ETASF

Fig. 3