Joint Center for Satellite Data Assimilation (JCSDA) Land Working Group

Christa Peters-Lidard (NASA/GSFC/HSB)
John Eylander (AFWA)
Mike Ek (NCEP/EMC)

JCSDA 8th Workshop on Satellite Data Assimilation, UMBC, 4-5 May 2010

JCSDA Land Working Group Topics:

- Snow assimilation
- Blended global snow product
- Land surface temperature assimilation
- Land surface thermal infrared emissivity
- Improved Noah land model physics/data assimilated
  - Snow
  - Surface-layer
- MW emissivity and soil/vegetation characteristics
- Land data sets
- Real-time greenness in NASA/LIS
- NASA/LIS and CRTM

Assimilation of multi-sensor snow observations into a land surface model

S.V. Kumar (SAIC/614.3), R.H. Reichle (GMAO/610.1), M.J. Shaw (SAIC/614.3), C.D. Peters-Lidard (614.3), D.H. Hall (614.1), J.Foster (614.3), G.A.Riggs (SSAI/614.1), J.B. Eylander (AFWA)

•A recent joint effort between the U.S. Air Force and NASA has developed a blended, multi-sensor snow dataset (ANSA) by utilizing the MODIS and AMSR-E retrieved snow datasets. This dataset includes estimates of snow cover area (SCA), snow water equivalent (SWE) and SWE-derived snow depth fields.

•These multi-sensor snow observations are employed in the NASA Land Information System (LIS) data assimilation framework to generate spatially and temporally continuous estimates of snow states.

•The evaluation of assimilation runs against in-situ observations of snow depth (from NCDC's COOP and Global Summary of the Day (GSOD)) datasets and NRCS' SNOTEL observations of SWE demonstrate improvements as a result of data assimilation

ANSA snow map 15 January 2007

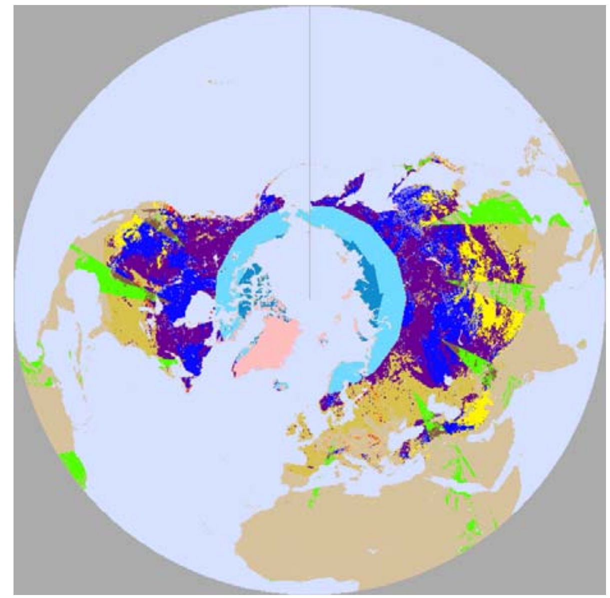


Figure 1

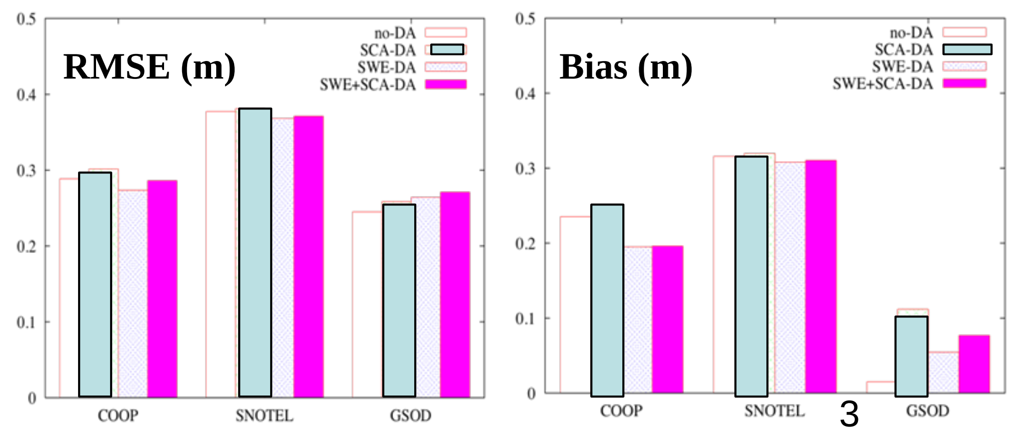
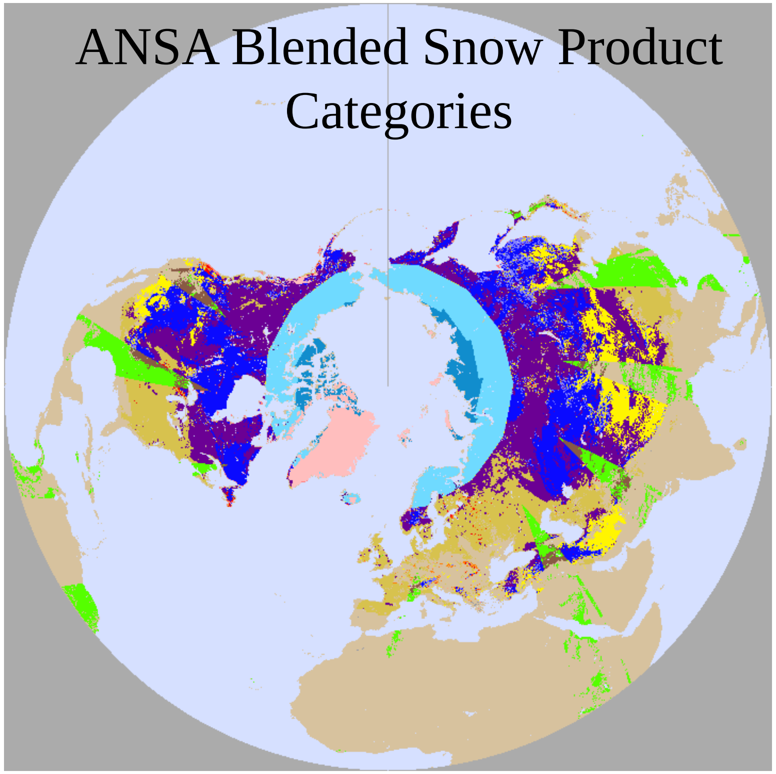


Figure 2

A NEW BLENDED GLOBAL SNOW PRODUCT USING VISIBLE, MICROWAVE AND SCATTEROMETER SATELLITE DATA

JAMES FOSTER, DOROTHY HALL, GEORGE RIGGS, ED KIM, MARCO TEDESCO, SON NGHIEM, RICHARD KELLY, BHASKAR CHOUDHURY



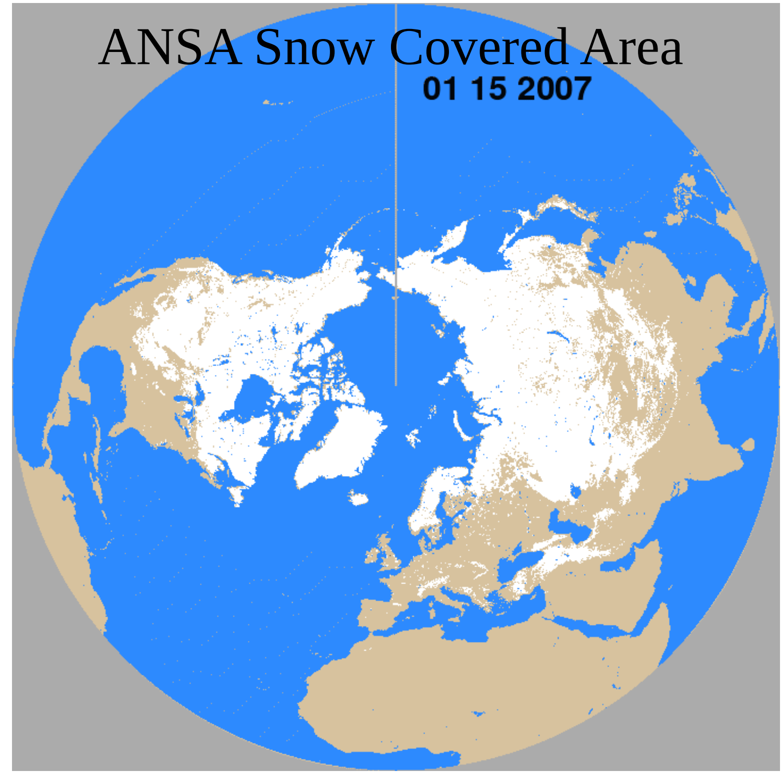


Figure 1 (left) shows a Northern Hemisphere ANSA (**A**ir Force **N**ASA **S**now **A**lgorithm) map of the blended visible and passive microwave images for January 15, 2007. Twenty one separate categories are shown, fifteen of which show snow from either or both the MODIS and AMSR-E products. The deeper blue or lapis color represents snow cover from both the visible and microwave products. The purple color shows cloud cover as observed on MODIS – AMSR-E detects snow beneath these clouds. Red portrays areas where MODIS detects snow but AMSR-E misses -- especially evident near the border of the continental snowline where snow depths are typically shallow. On this rendition, the yellow color represents snow that AMSR-E has observed but MODIS does not. This is often a false-positive signal. The AMSR-E algorithm is detecting snow I areas where the ground surface is cold but not always snow covered. Sky blue and medium blue colors, in the high Arctic, are areas dark on MODIS (polar night) – AMSR-E is able to observe the surface at nighttime as well as during the day. Lime green represents the AMSR-E orbital gap.

A NEW BLENDED GLOBAL SNOW PRODUCT USING VISIBLE, MICROWAVE AND SCATTEROMETER SATELLITE DATA

JAMES FOSTER, DOROTHY HALL, GEORGE RIGGS, ED KIM, MARCO TEDESCO, SON NGHIEM, RICHARD KELLY, BHASKAR CHOUDHURY

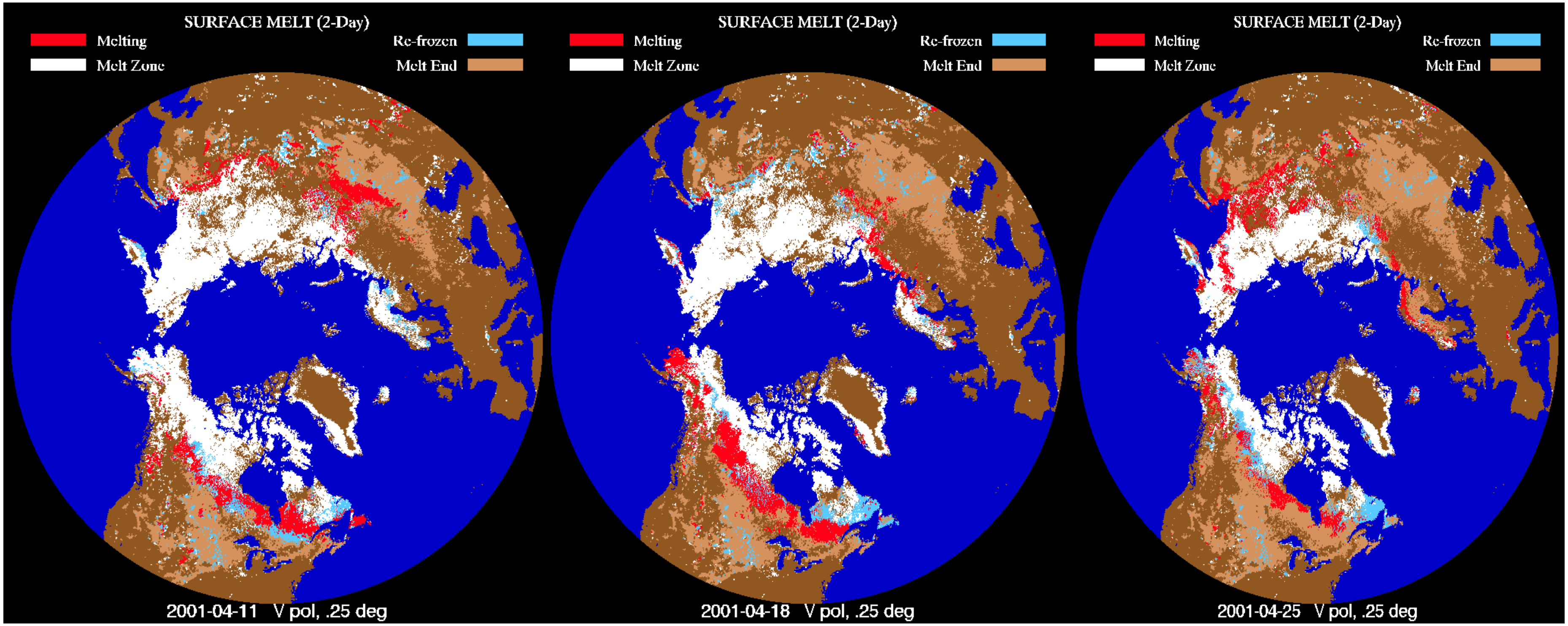


Figure 3: Snowmelt maps derived from global QuikSCAT backscatter data for the period 3/21/2001 to 4/25/2001. White is dry snow, red is currently melting snow, light blue is re-frozen snow after previously melting conditions, light brown is completed snowmelt (snow-free of bare ground).

Land Surface Temperature (LST) Assimilation

R. Reichle (GMAO/610.), **S. Kumar** (SAIC/614.3), **S. Mahanama** (GEST/610.1),**R. Koster** (GMAO/610.1), **Q. Liu** (SAIC/610.1)

LST retrievals from the International Satellite Cloud Climatology Project (ISCCP) are assimilated into the Noah and Catchment (CLSM) land surface models using an ensemble-based land data assimilation system.

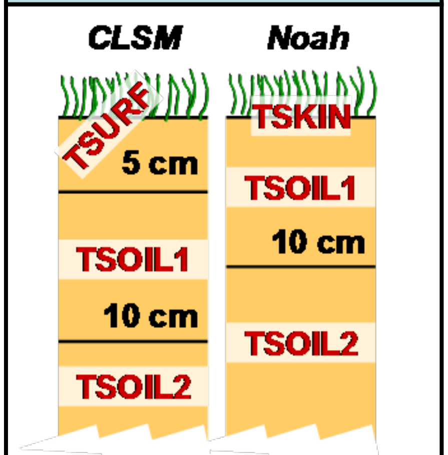
Performance is measured against 27 months of in-situ data from the Coordinated Energy and Water Cycle Observations Project at 48 locations around the world.

LST estimates from model runs without data assimilation are comparable to each other and superior to ISCCP retrievals.

Assimilation of ISCCP observations provides modest, yet statistically significant RMSE improvements (up to 0.7 K).

The impact on flux estimates is small (not shown).

Fig 1: Assimilate LST retrievals into off-line land models



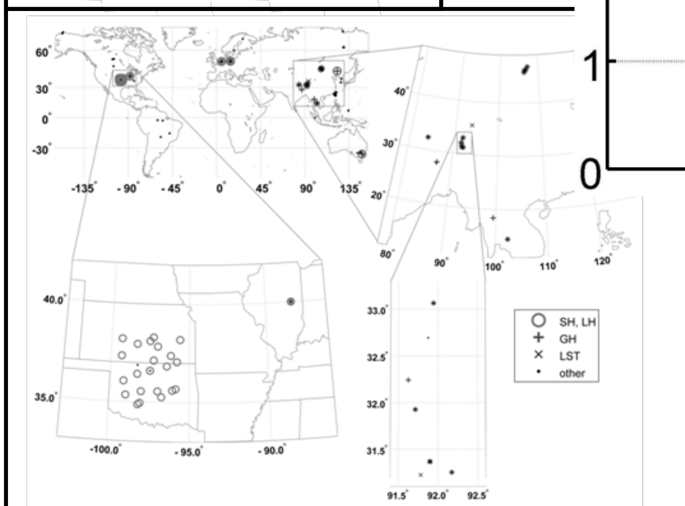
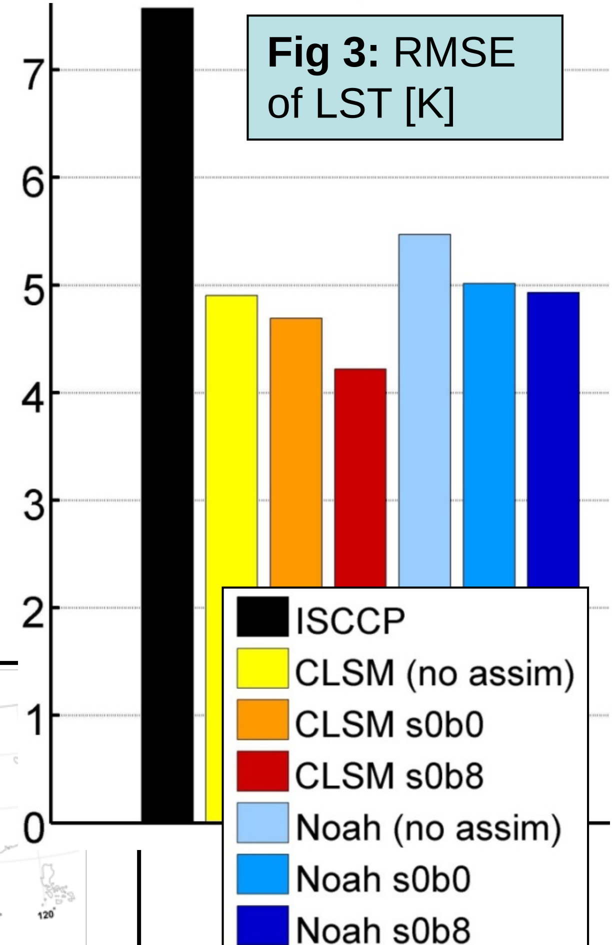


Fig 2: Validate against in situ obs

Fig 3: RMSE of LST [K]



Assimilation:
s0: *without* a priori scaling
b0, b8: Without and with dynamic bias correction

Land Surface Thermal Infrared Emissivity Database Development and Modeling for Operational Weather Prediction and Climate Models

PIs and Co-PIs: Shunlin Liang & John Townshend

NWP Center Collaborators: Fuzhong Weng

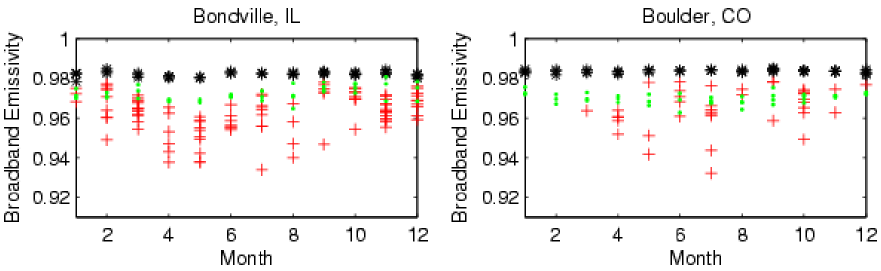
Accomplishments

1) Comprehensively assessing MODIS and ASTER skin temperature and emissivity products (Wang, et al., 2008; Wang and Liang, 2009). It is found MODIS emissivity product is not suitable for modeling applications at this stage;

2) Developing new methods to predicting broadband emissivity using MODIS albedo products and ASTER emissivity product;

3) Emissivity modeling of snow/ice surfaces (Cheng, et al., in revision), soil surfaces and partially vegetated surfaces;

4) Developing advanced algorithms for estimating surface emissivity from hyperspectral data in the mid-IR and thermal-IR spectrum (Cheng, et al., 2010; and in revision).



Broadband emissivity calculated from MODIS Collection 4 (green dot) and Collection 5 (black star) monthly emissivity products and ASTER daily emissivity products (red plus sign)

➢J. Cheng, S. Liang, J. Wang, and X. Li, "A stepwise refining algorithm of temperature and emissivity separation for hyperspectral thermal infrared data," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 48, pp.1588-1597, 2010.

➢J. Cheng, S. Liang, Q. Liu, and X. Li," Temperature and emissivity separation from ground-based MIR hyperspectral data ", *IEEE Transactions on Geoscience and Remote Sensing*, in revision.

➢J. Cheng, S. Liang, F. Weng, J. Wang, and X. Li, "Comparison of Radiative Transfer Models for Simulating Snow Surfaces Thermal Infrared Emissivity," *IEEE Journal in Special Topics in Applied Earth Observations and Remote Sensing*, in revision.

➢Wang, K., & Liang, S. (2009). Evaluation of ASTER and MODIS land surface temperature and emissivity products using long-term surface longwave radiation observations at SURFRAD sites. *Remote Sensing of Environment*, 113:1156-1165.

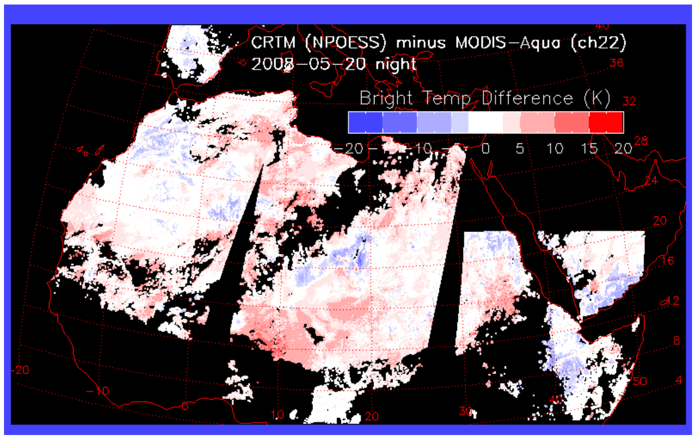
➢Wang, W., S. Liang, and T. Meyer, (2008), Validating MODIS land surface temperature products, *Remote Sensing of Environment*,112:623-635

New land surface emissivity for infrared assimilation:
CRTM land bias improvement & positive forecast impact

- Univ. Wisconsin (Seemann & Borbas) spectral infrared emissivity is derived from MODIS-channel emissivity retrievals (monthly composite, 416 wavenumbers)
- Comparison of CRTM simulation to observation shows reduced Tb bias for desert regions when using this emissivity dataset.

Tb difference (K) CRTM sim minus MODIS obs   (3.96 μm)

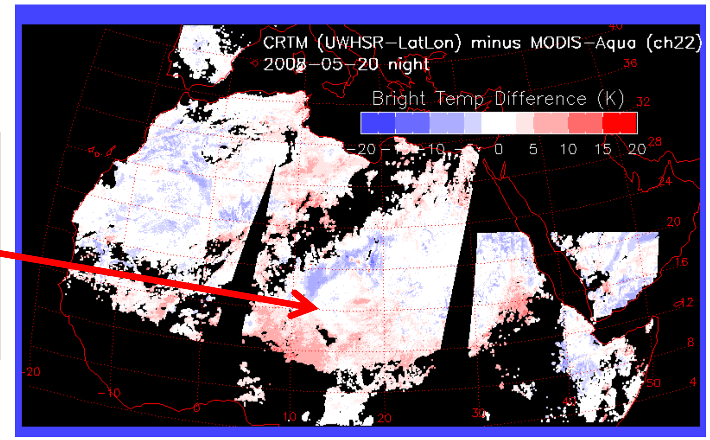
CRTM run with current emis



Sahara Desert

Less bias with U.Wisc emis

CRTM run with U.Wisc. emis

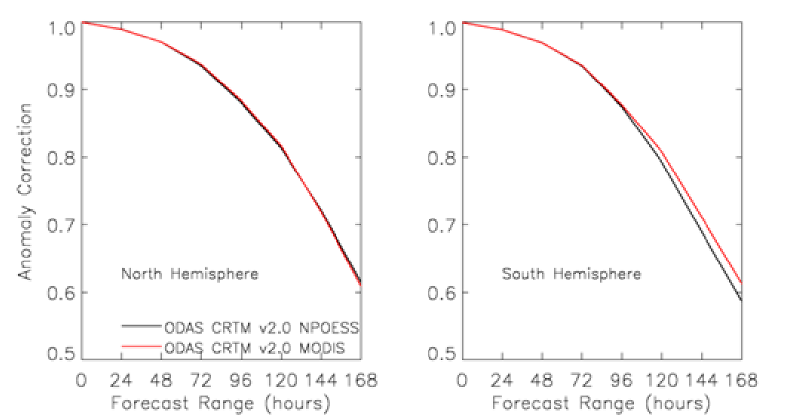


Forecast impact with GSI shows improved forecast in Southern Hemisphere

CRTM current IR emis = black line

U.Wisc. new IR emis = red line

1000 hPa geopotential height anomaly correlation from 01/09/2008-01/31/2008



R. Vogel, Y. Chen, Q. Liu, Y. Han, F. Weng
JCSDA & NESDIS/STAR

Improving the Noah Land Model for Better Noah/CRTM Coupling and Accelerated Use of Satellite Data

- PI: Xubin Zeng (Univ of Arizona)
- Goals:
  - Improve Noah land model;
  - Better Noah/CRTM coupling;
  - Increased use of satellite data
- Data: MW, IR, VIS/NIR, in-situ
- Methods: Model-data integration
- Collaborators: NCEP/EMC Land Team, and others
- Recent Major Result: New formulations to significantly improve Noah snow simulations

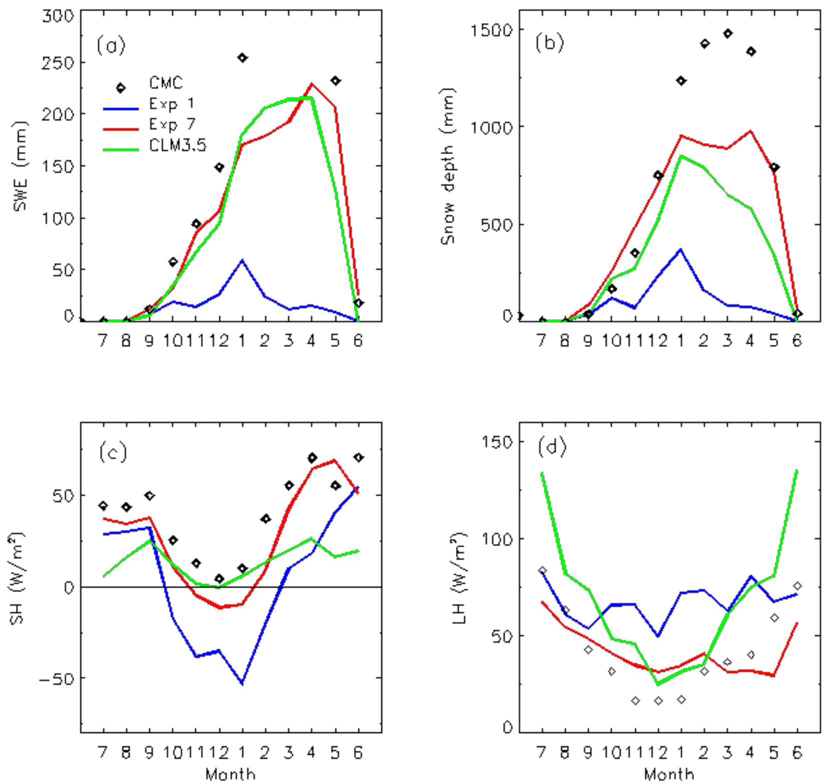
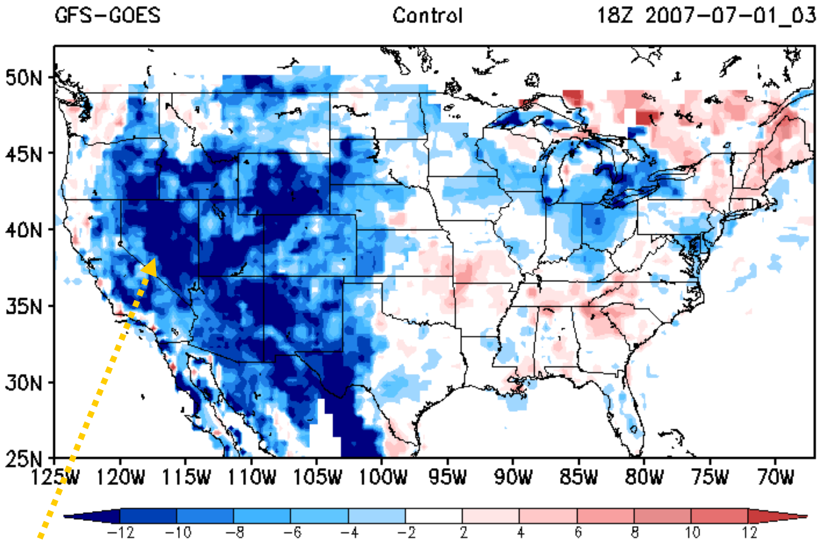


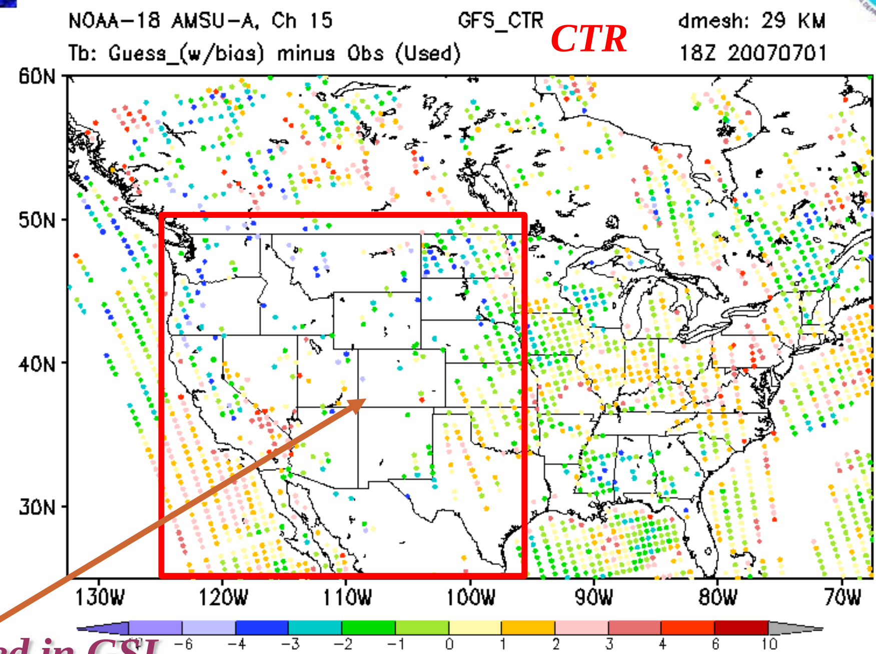
Fig.1 Comparison between the Noah control run (Exp 1), Noah new run with all revisions (Exp 7), and NCAR CLM3.5 in monthly averaged (a) SWE; (b) snow depth; (c) sensible heat flux; and (d) latent heat flux from July 2006 to June 2007 over the Niwot Ridge site (40.03°N, 105.55°W) .

GFS LST [K] Verification with GOES

Tb Simulation in GSI: AMSU_A Ch 15

GFS-GOES: CTR



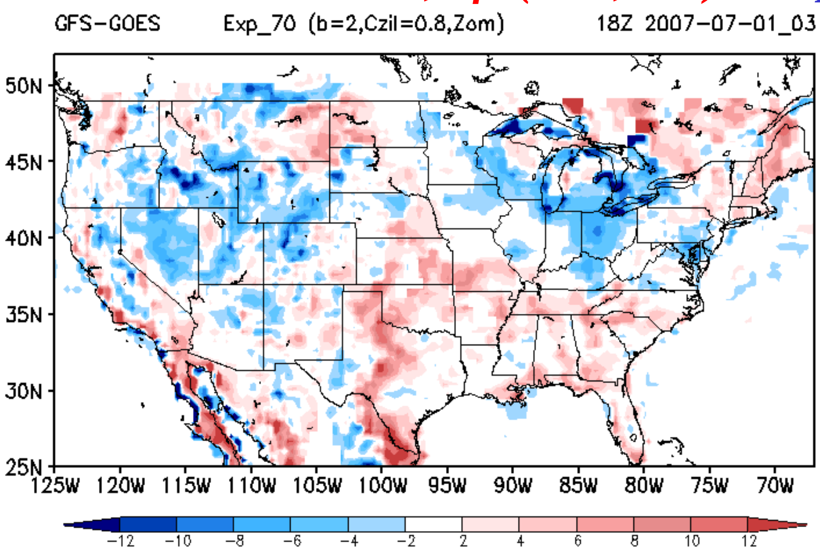


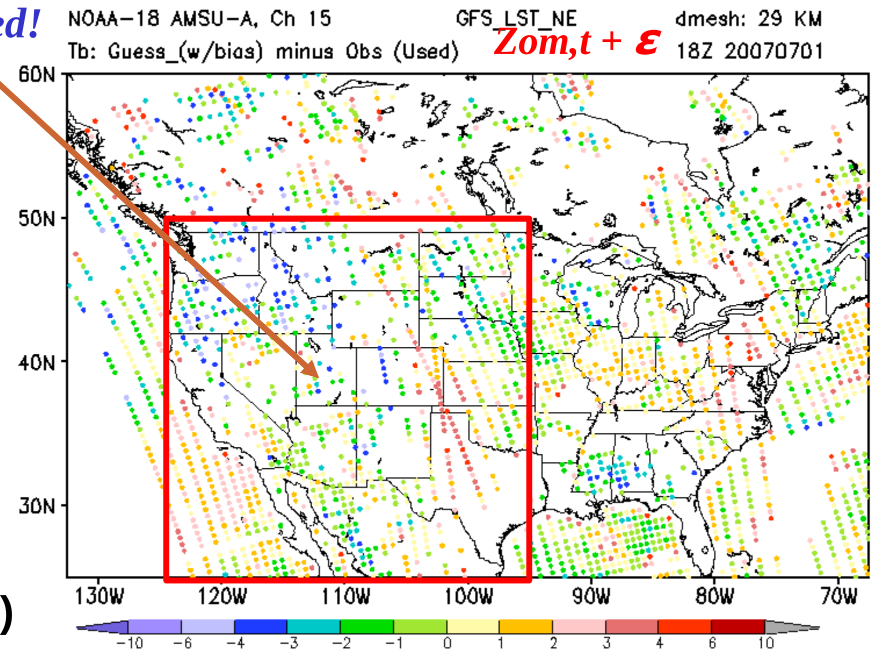
Large cold bias

Less data used in GSI

GFS-GOES: New Zom,t: fct(GVF, Czil)

Improved!

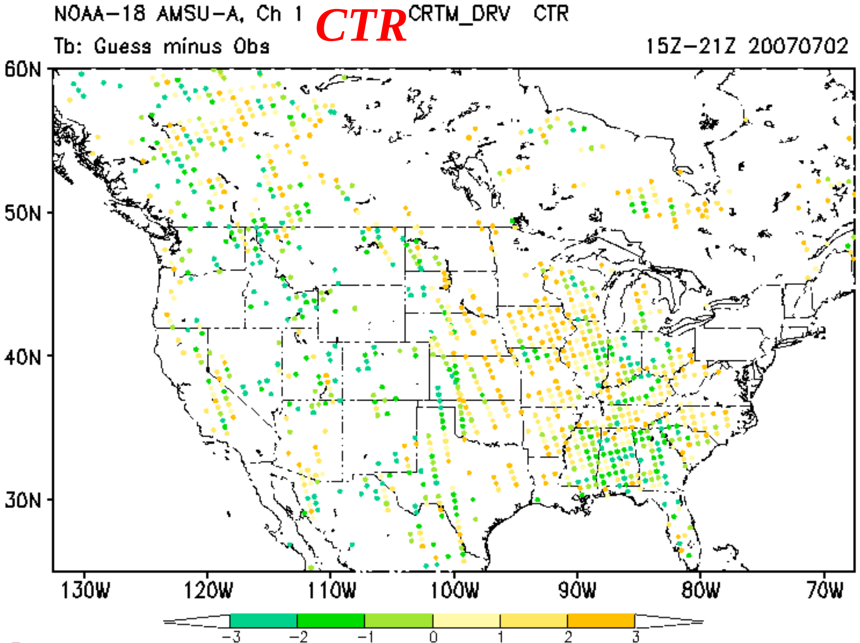




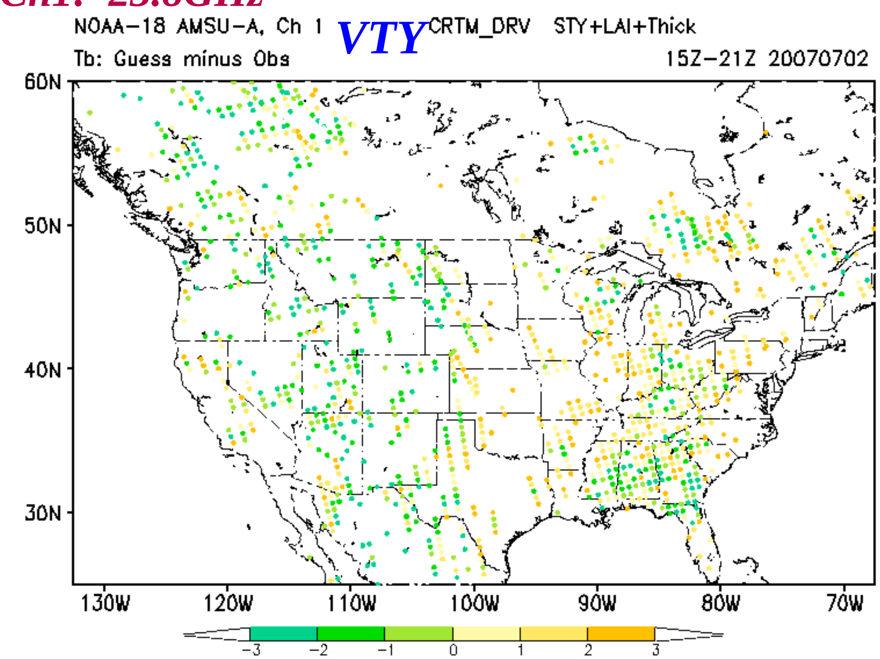
Improved Ts + updated MWεmodel (desert)

MW Land Emissivity Model

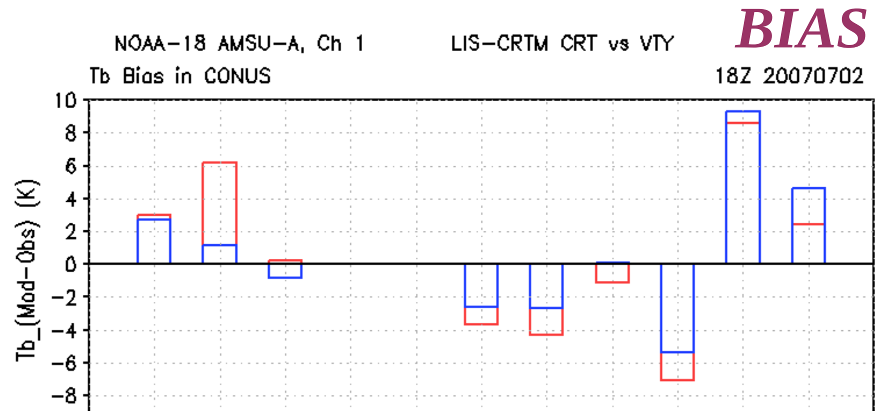
Poster 3.3, Wed. 12:30-2:00pm

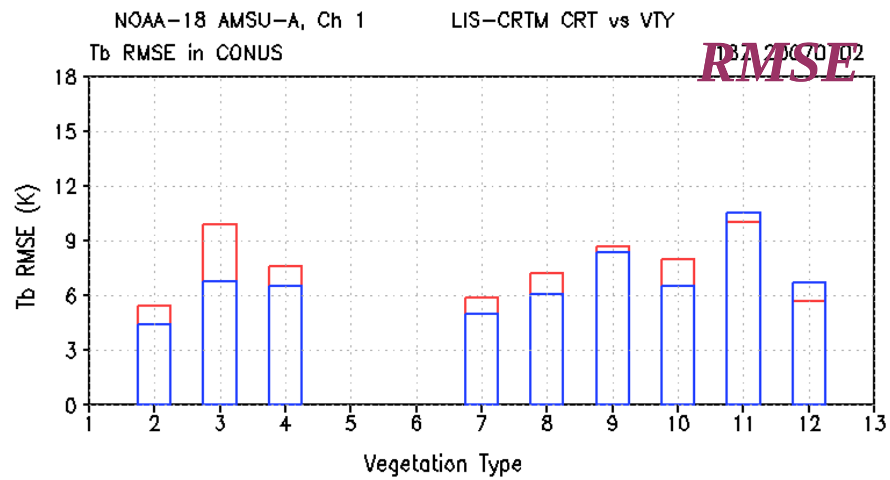


Ch1: 23.8GHz



Detailed soil and vegetation characteristics implemented in the CRTM for the MW land emissivity calculation, vs CTR (uniform character).





Forest

Red: CTR **Blue: VTY**

Less bias, more data assimilated !

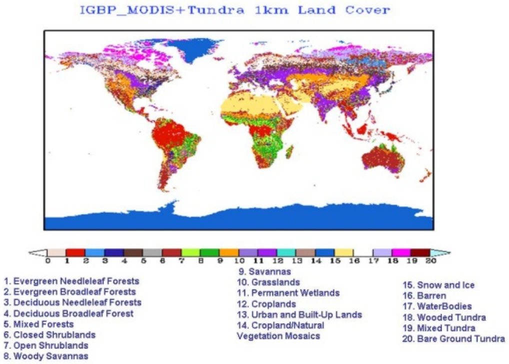
New Satellite-Derived Land Products at NCEP

Oral presentation, Wed. 11:00-11:15

1. Landuse - landcover class (LULC) (Improves warm/dry bias in NAM)

Fixed field of MODIS-based global 1-km land use class

(aka "vegetation class") -- from Boston U. (Mark Friedl PI) via JCSDA



2. Green vegetation fraction (GVF) (Improves warm/dry bias in NAM)

Weekly real-time and companion 25 yr. climo of AVHRR-based global 0.144

fraction from Le Jiang and Wei Guo of NESDIS, (Generally greener)

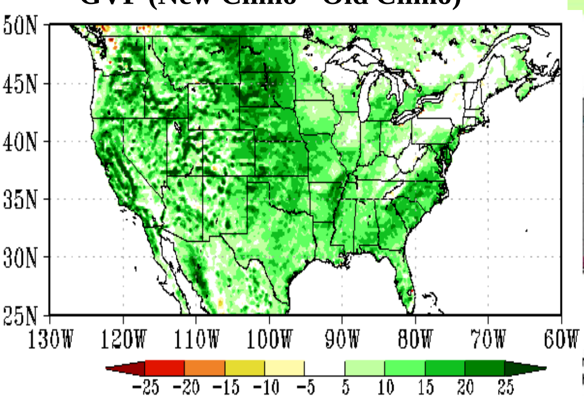
3. Albedo (Will be tested this fall)

Monthly climo of MODIS-based global 0.05-deg land surface albedo (to be treated as snow free albedo) -- from Boston U. (Mark Friedl PI) via JCSDA

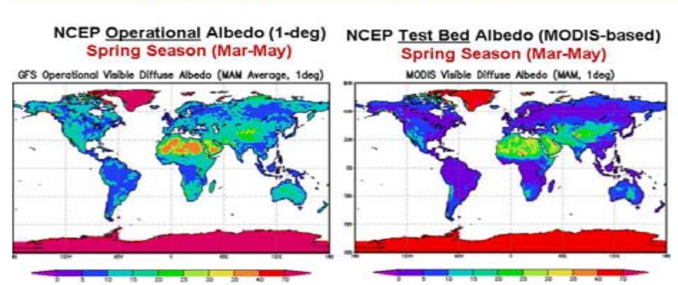
4. Max snow albedo (Will be tested this fall)

Fixed field of MODIS-based global 0.05-deg land surface albedo for deep snow conditions (what we call "max snow albedo") from U. Arizona (Xubin Zeng) via JCSDA

GVF (New Climo - Old Climo)



Snow-free Visible Albedo

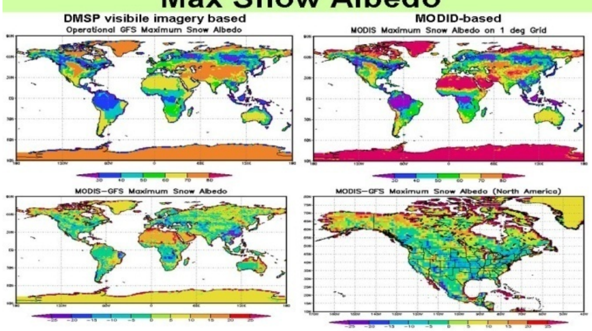


n the case of the visible diffuse band, he MODIS-based albedo is darker.

Above MODIS-based albedo spatially averaged from its native 0.05-deg resolution and temporally averaged to quarterly from its original monthly frequency, to allow comparison with NCEP operational product.

Mark Friedl et al., Boston Univ.

Max Snow Albedo

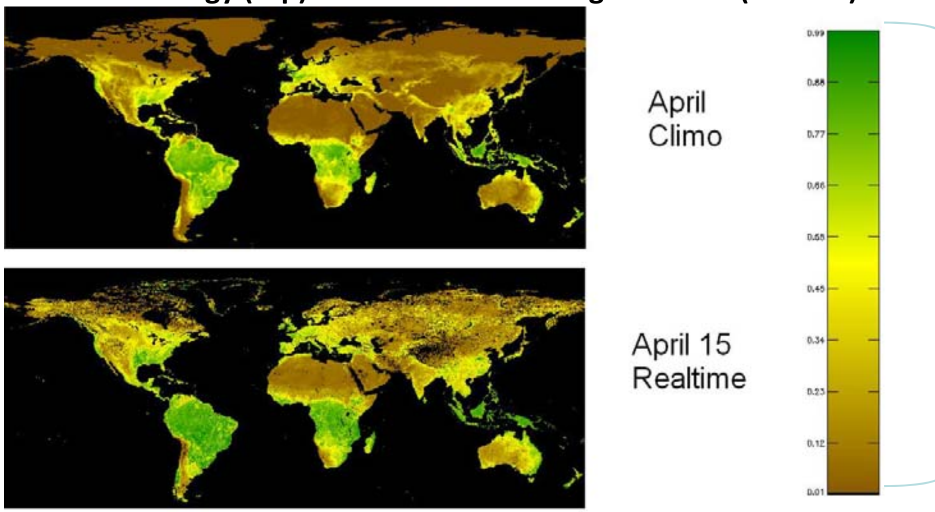


Xubin Zeng et al., Univ. Arizona

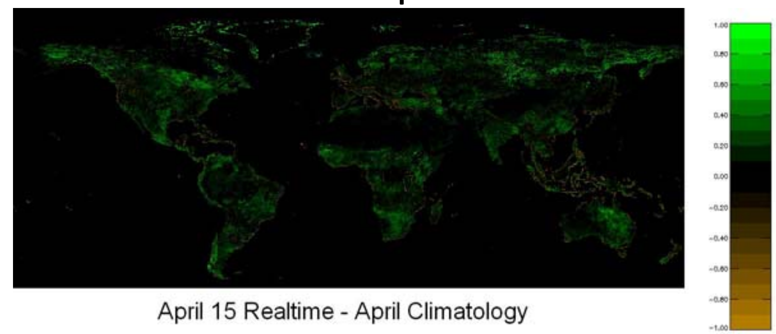
Evaluation of real-time MODIS Green Vegetation Fraction (GVF) use in LIS at AFWA

Ryan Ruhge (AFWA/NGAS) in collaboration with Michael Barlage (NCAR/RAL)

Climatology (top) vs. MODIS real-time global GVF (bottom)



Global differences map between climatology and MODIS real-time product

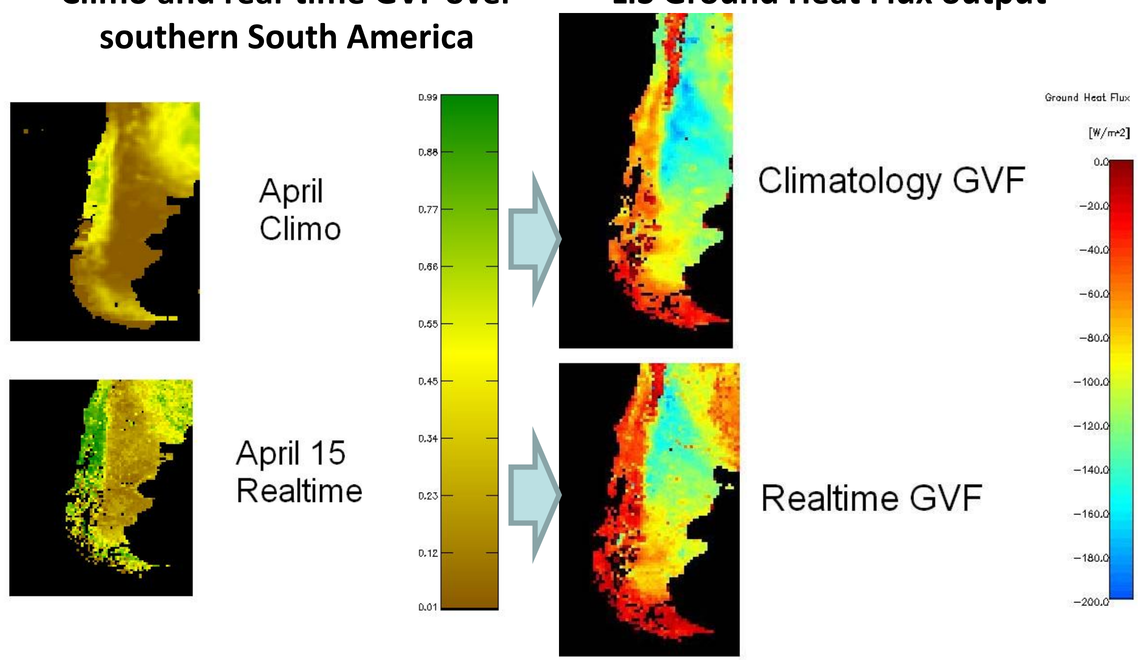


April 15 Realtime - April Climatology

- After Gutman & Ignatov, 1998 (Int. Journ Remote Sensing)
- 14-day accumulated GVF record
- Climatology used in regions of persistent cloud cover
- Real-time MODIS product is a direct replacement for climatology data in LIS
- LIS output (using Noah Land Surface Model) ground heat flux differences (see image)

Climo and real-time GVF over southern South America

LIS Ground Heat Flux output



Land-CRTM Working Group

W. Zheng (NCEP/EMC), M. Ek (NCEP/EMC), K.W. Harrison (ESSIC/614.3), Y. Tian (ESSIC/614.3), S.V. Kumar (SAIC/614.3), C.D. Peters-Lidard (614.3), J.B. Eylander (AFWA), F. Weng (NESDIS/STAR), B. Yang (NESDIS/STAR) and S. Ringerud (CSU)

Background: NASA's LIS-CRTM coupled system passes land surface model (LSM) output through CRTM's current surface interface (see right top). Several CRTM emissivity model parameters (see right bottom) can be linked more directly to land surface models (LSMs) and associated land datasets.

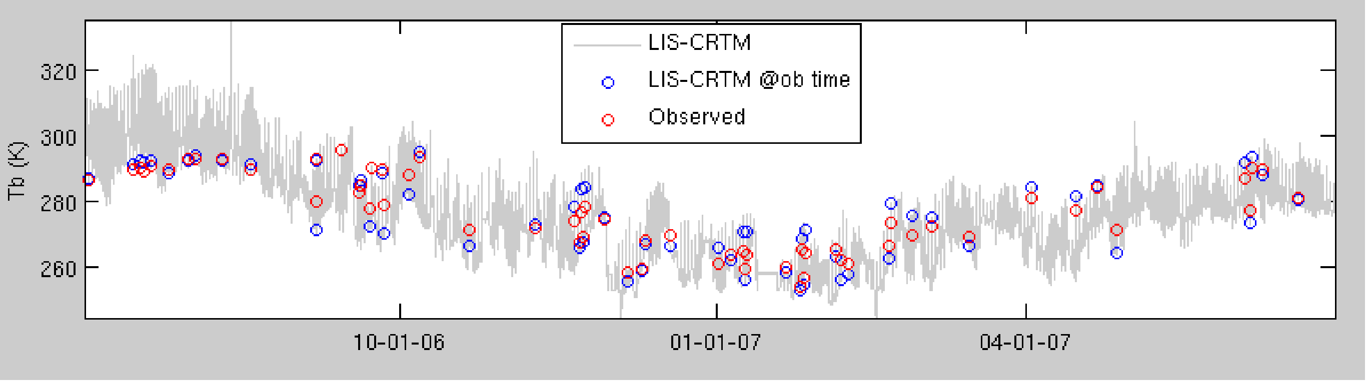
Goal: Propose changes to LSMs and CRTM to improve the performance of LIS-CRTM. Evaluate radiance simulation improvements over the Precipitation Measurement Mission (PMM) Land Surface Working Group (LSWG) study sites and over large domains.

Current parameters exposed through CRTM's surface data structure:

Land_Type	Land surface type
Land_Temperature	Land surface temperature
Soil_Moisture_Content	Volumetric water content of the soil
Canopy_Water_Content	Gravimetric water content of the canopy
Vegetation_Fraction	Vegetation fraction of the surface
Soil_Temperature	Soil temperature
Snow_Type	Snow surface type
Snow_Temperature	Snow surface temperature
Snow_Depth	Snow depth
Snow_Density	Snow density
Snow_Grain_Size	Snow grain size

Example CRTM embedded parameters that can be linked to LSM outputs/datasets:

Leaf Area Index (LAI)
Sand/Clay fractions

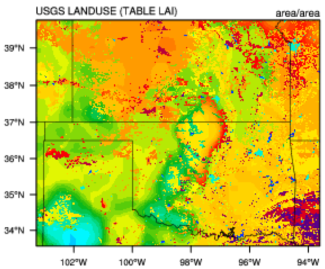


LIS(NOAH)-CRTM -simulated and observed AMSR-E Ch. 1 clear-sky, domain-averaged brightness temperatures over the LSWG Southern Great Plains site. The aim is to reduce errors with an improved coupling of LSMs/land datasets and CRTM

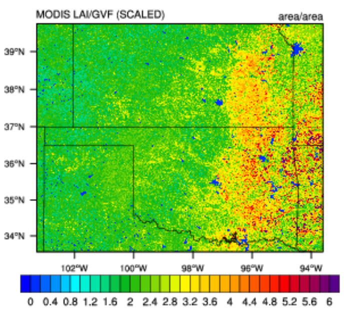
ASSESSING IMPACTS OF INTEGRATING MODIS VEGETATION DATA IN THE WEATHER RESEARCH FORECASTING (WRF)/NOAH COUPLED MODEL

Fei Chen (NCAR), Dev Niyogi (Purdue), Anil Kumar (NASA), Michael Barlage (NCAR)

Southern Great Plains LAI



Default WRF table-based LAI



MODIS LAI is much lower esp. in western portion of domain

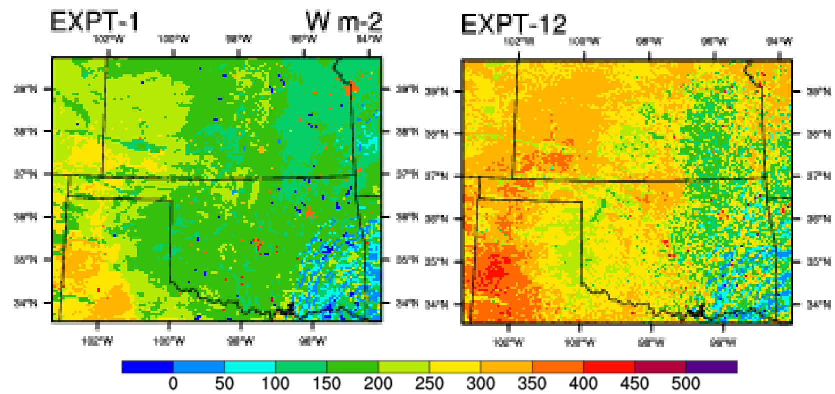
WRF/Noah Simulations (9km/3km domains)

12 WRF simulations are completed during a summertime convection case during IHOP2002 campaign using combinations of:

- MODIS vs. table LAI vs. constant LAI
- MODIS vs USGS land cover
- MODIS fPAR vs climatology green veg. fraction
- GEM photosynthesis model vs. Jarvis resistance scheme

Results

Significant differences and improvements are seen in surface fluxes (SHF at right) and temperatures when using MODIS data and new GEM model



This grant has been cited in the following publications with the theme of adopting remotely sensed data with WRF for improved high impact weather simulation

1. Routray A., et al., 2010: Impact of Doppler Weather Radar Data on Simulation of Indian Monsoon Depressions, Quart. J. Roy. Meteorol. Soc.
2. Routray, A., et al., 2009, First application of the 3DVAR - WRF data assimilation system for mesoscale simulation of heavy rainfall events over the Indian monsoon region, Meteorol. Atmos. Phys.
3. Chang H., et al, 2009, Possible relation between land sfc feedback and the post-landfall structure of monsoon depression, GRL.
4. Vinodkumar, A. et al., 2009: Assessment of data assimilation approaches for the simulation of a monsoon depression, BLM.
5. Niyogi, D., et al., 2009, Development and Evaluation of a Coupled Photosynthesis-Based Gas Exchange Evapotranspiration Model (GEM) for Mesoscale Weather Forecasting Applications. JAMC
6. Kumar, A. et al., 2009, Impact of Land Surface Representation and Surface Data Assimilation on the Simulation of an Off-Shore Trough over the Arabian Sea, Glob Plan Change.
7. Alapaty K., et al., 2008, Development of the Flux-Adjusting Surface Data Assimilation System for Mesoscale Models, JAMC

JCSDA LWG Accomplishments and Recommendations:

- LIS operational at AFWA since February 2009
  - Complete Final Operational Configuration in 2010
  - Implement ANSA (MODIS+AMSR-E) snow assimilation
  - Implement realtime GVF
  - Implement AMSR-E soil moisture assimilation
  - Implement new precip and radiation/cloud analysis
- LIS used at NCEP for CFS GLDAS
  - Additional investment required to benefit from AFWA LDA investments
- Implement new land surface thermal infrared emissivity in CRTM
- Generalize & improve land surface microwave emissivity in CRTM