NASA-Unified WRF Updates

Toshi Matsui, Eric Kemp, Joe Santanello,
and

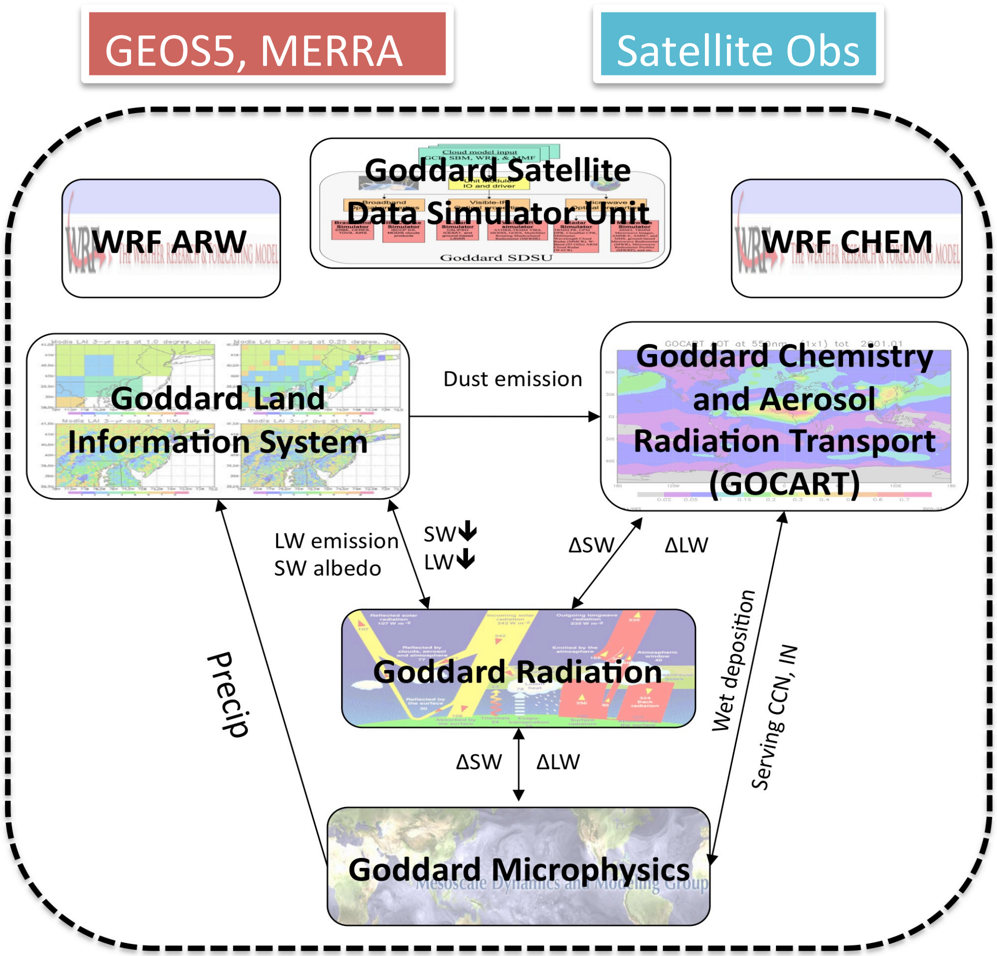
NU-WRF Team:
PI: C. Peters-Lidard
Co-PIs: T. Matsui,
Co-Is: J. Santanello, Jr., W.-K. Tao, M. Chin, B. Zavodsky, J. Case, J. Geiger,
Y. Liu, J.-J. Shi, Z. Tao, B. Zaitchik, S. Zhang, M. Zupanski
Software Team : E. Kemp, J. P. Jacob, B. Van Aarsten

Support: NASA MAP Program (D. Considine@NASA HQ)

NU-WRF V7 "Arthur"

v7lis7-3.5.1

- NU-WRF is defined as **observation-driven regional earth system modeling and assimilation system at satellite-resolvable scale** (dx=1~4km).
- NU-WRF components have been updated.
  - GSFC Land Information System (land models and LDA)
  - Goddard Bulk Microphysics (3ICE + 4ICE Beta)
  - Goddard SW/LW radiation (2011+2014 Beta)
  - WRF-Chem GOCART model (aerosols: Dynamic dust, 1km dust emission)
  - G-SDSU (satellite simulator: V3.3.3)
- NU-WRF can be driven by MERRA/GEOS-5 and MERRAero/GOCART aerosol simulation.



Peters-Lidard, C.D., E. M. Kemp, T. Matsui, J. A. Santanello, Jr., S. V., Kumar, J. Jacob, T. Clune, W.-K. Tao, M. Chin, A. Hou, J. L. Case,, D. Kim, K.-M. Kim, W. Lau, Y. Liu, J.-J. Shi, D. Starr, Q. Tan,, Z. Tao, B. Zaitchik, B. Zavodsky, S. Zhang, M. Zupanski (2015), Integrated Modeling of Aerosol, Cloud, Precipitation and Land Processes at Satellite-Resolved Scales with the NASA Unified-Weather Research and Forecasting Model, *Environmental Modelling & Software*, **67**, 149–159. doi: http://dx.doi.org/10.1016/j.envsoft.2015.01.007

NU-WRF V8 "Bjerknes"

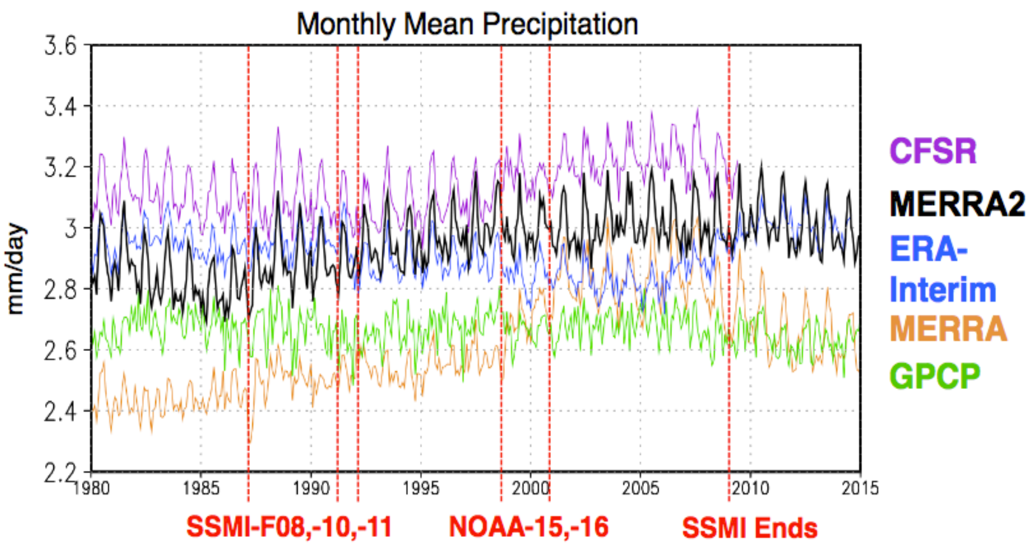
v8dev3-wrf371-lis71rp7

1. Features WRF ARW: Version 3.7.1
2. **MERRA2 IC/BC (Meteorology + Aerosol fields).**
3. **Updated high-resolution ICs.**
4. **NU-WRF Ensemble Data Assimilation System (EDAS) package.**
5. **LIS Updates: Subsystems and Coupling (LDA).**
6. **Updated Goddard Microphysics (4ICE) and Radiation (2014) package.**
7. **Updated GOCART aerosols and database.**
8. **Updated satellite simulators: G-SDSU V3.5.1.**

From Bosilovich et al. 2015

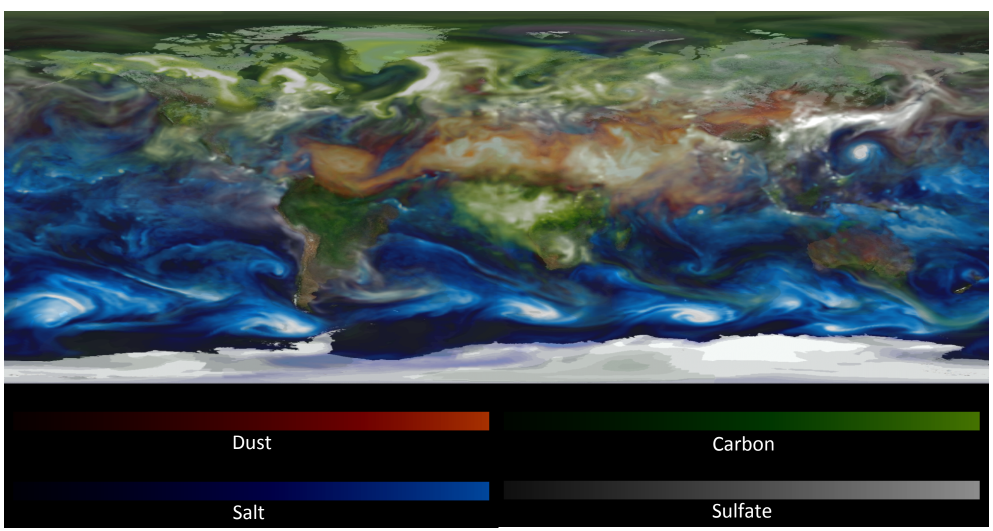
MERRA2 IC/BC

MODERN-ERA RETROSPECTIVE ANALYSIS FOR RESEARCH AND APPLICATIONS



MERRA-2 Meteorological Analysis

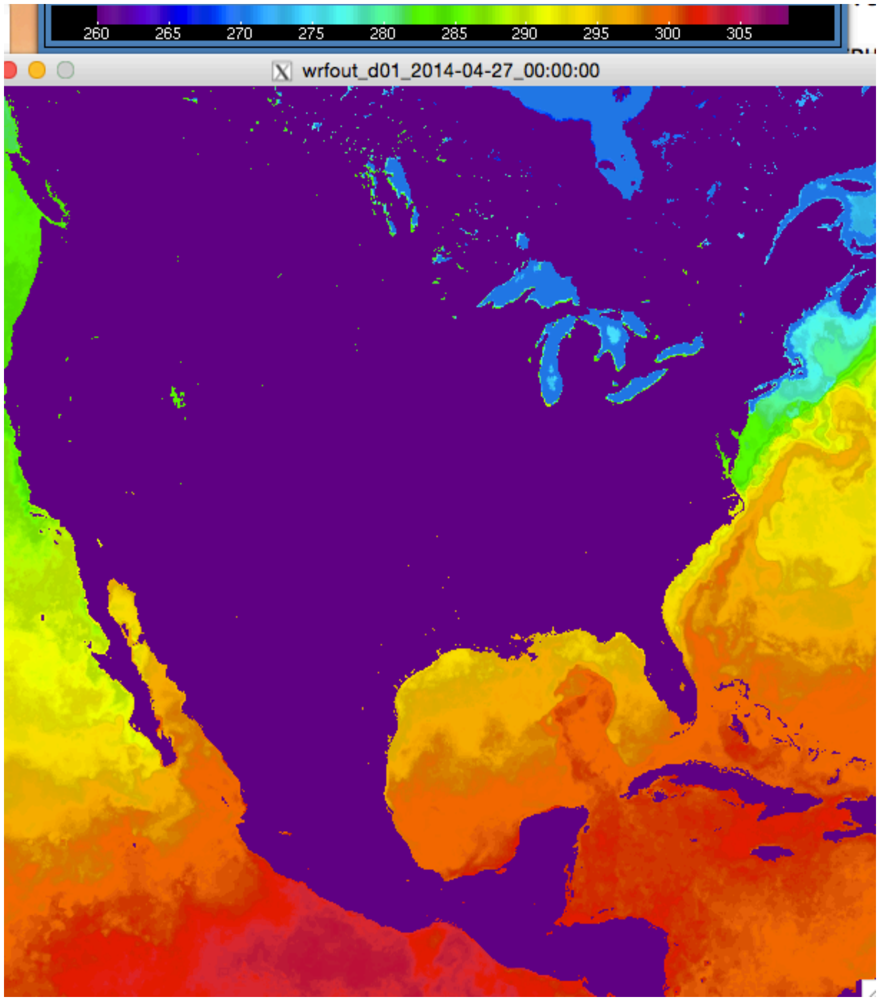
- AGCM: ***Cubed-sphere dynamics (Δ=50km)****, updated moist physics, improved glacier model and cryosphere albedos*
- GSI: *Modern observations: GPSRO, NOAA-19, MetOp-A/B, S-NPP, SEVIRI, Aura OMI and MLS, capable for JPSS, MetOp-C, TC-Relocation algorithm, Over-land precipitation correction for LSM, etc.*



MERRA-2 Aerosols Analysis

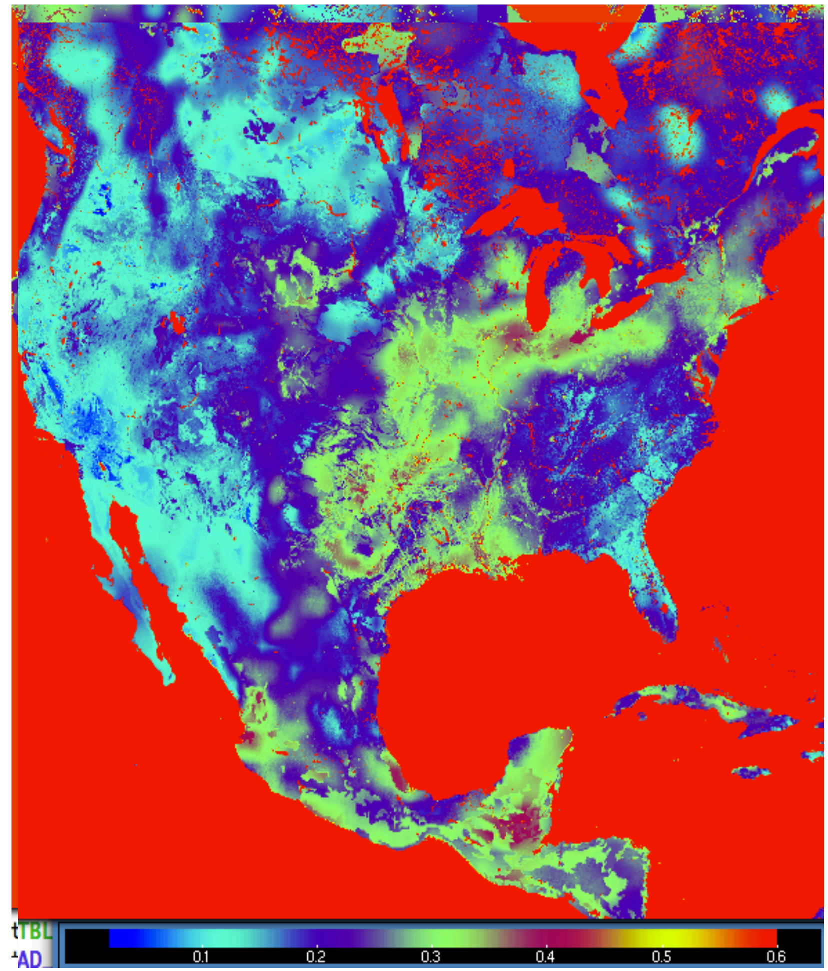
- GOCART is radiatively coupled with the dynamics
- Global 2-D AOD analysis with 3-D increments via local displacement ensembles
- Assimilated Data: AVHRR 1979–2002; MODIS 2000–present; MISR; AERONET

Updated Surface ICs



IR-microwave assimilated 9km SST (RSS)

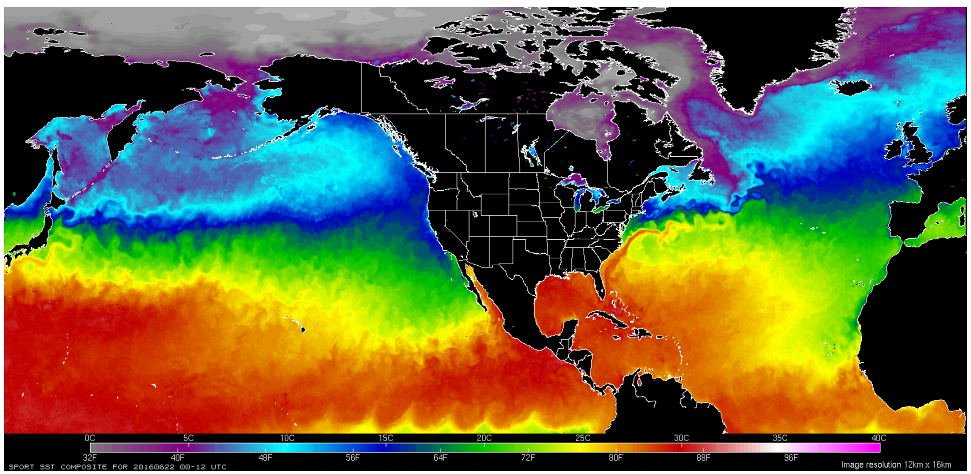
LIS spin up with MERRA2 forcing



Top Soil Moisture

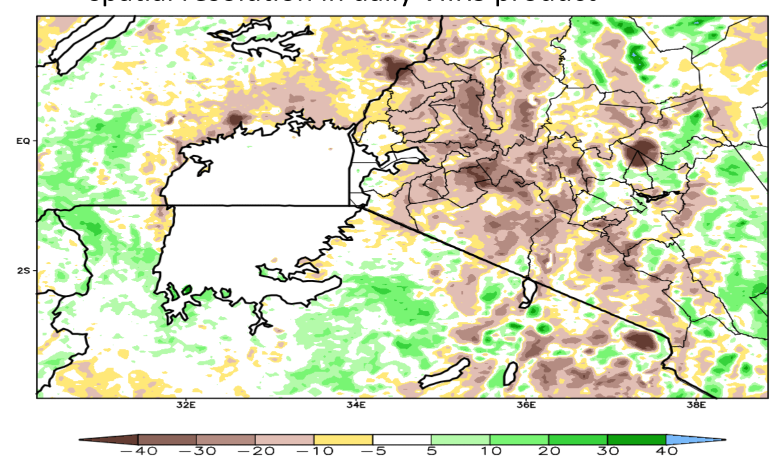
SPoRT IC Datasets

- NASA Marshall Space Flight Center's Short-term Prediction Research and Transition (SPoRT) team integrates high resolution SST product from MODIS and GVF product from VIIRS to improve convective initiation.



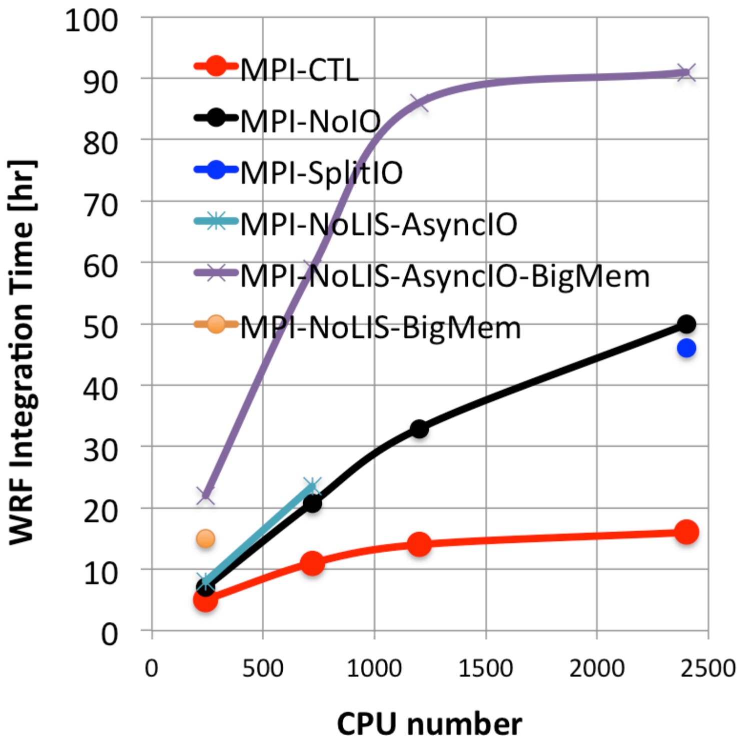
- SPoRT MODIS Sea Surface Temperature Composite
  - 2-km resolution; N. Hemi.
  - Generated twice daily
  - Provides details that allow model to account for over-ocean fluxes and seabreeze forecasting
  - Picture at left shows SST on June 22, 2016

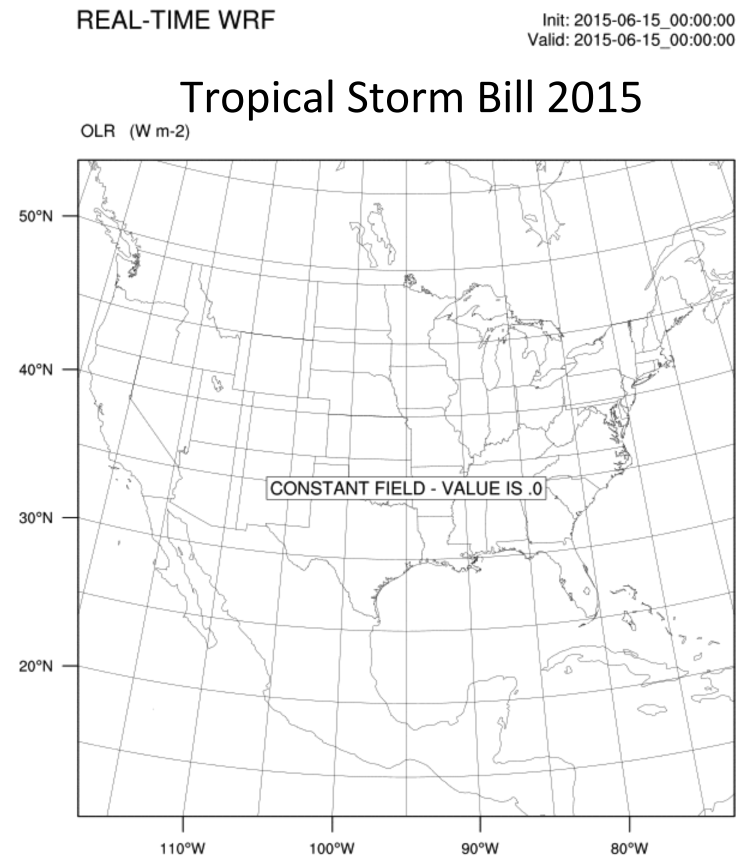
- NESDIS VIIRS Green Vegetation Fraction
  - 4-km resolution; global
  - Generated once daily
  - Replaces coarse climatology to produce weather-of-the-day details that affect energy fluxes for weakly-forced convection
  - Picture at right shows VIIRS GVF minus climatology for a day near Lake Victoria in East Africa; note better spatial resolution in daily VIIRS product



From B. Zavodsky, J. Case, A. Molthan

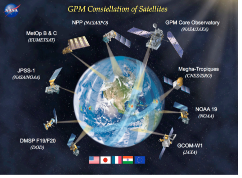
NU-WRF Benchmark in NASA's Supercomputer.





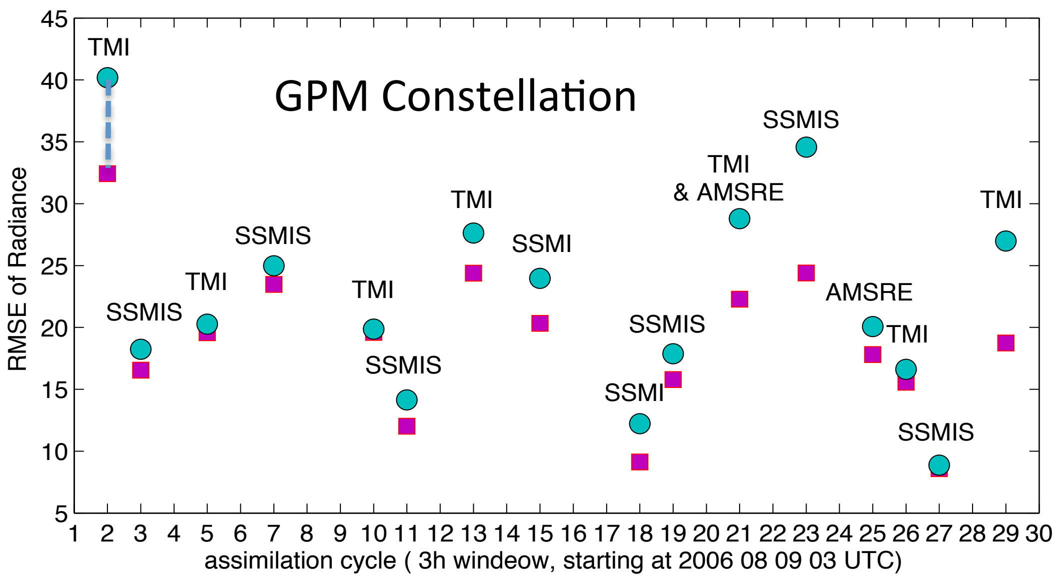
Quilting IO option with master-thread big-memory configuration boost the benchmark ~ **6x faster**

2500x2500x50 grid with Δ=2km
102 Intel Haswell node (=2448CPUs)



Ensemble Data Assimilation System (EDAS) package

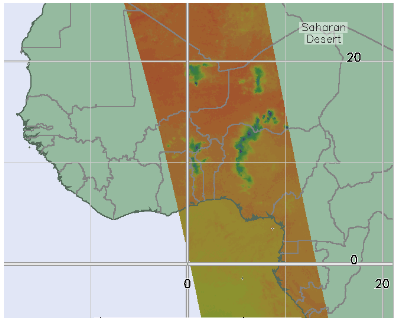
- Utilizes TRMM/GPM-era microwave Tb to constrain the model simulation of convection-dominant precipitation processes.
- Ensemble forecasts effectively update the background error covariance including dynamical and microphysical variables.



By S. Zhang

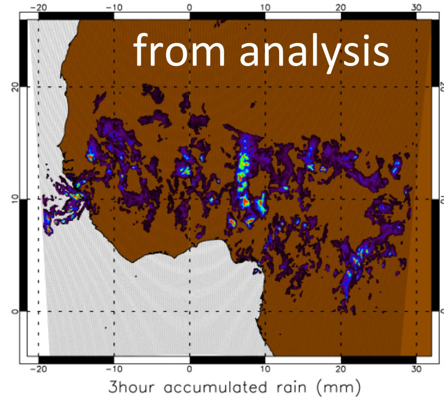
Observation Radiance

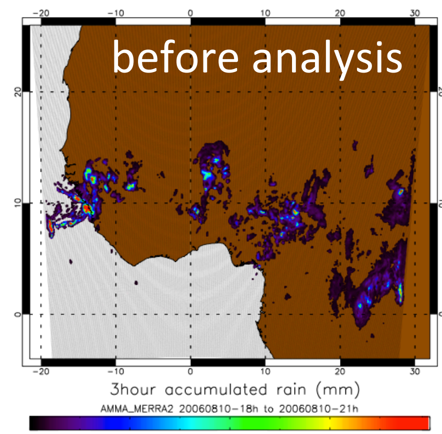
SSMI (F15) 89 GHz



Forecast from DA

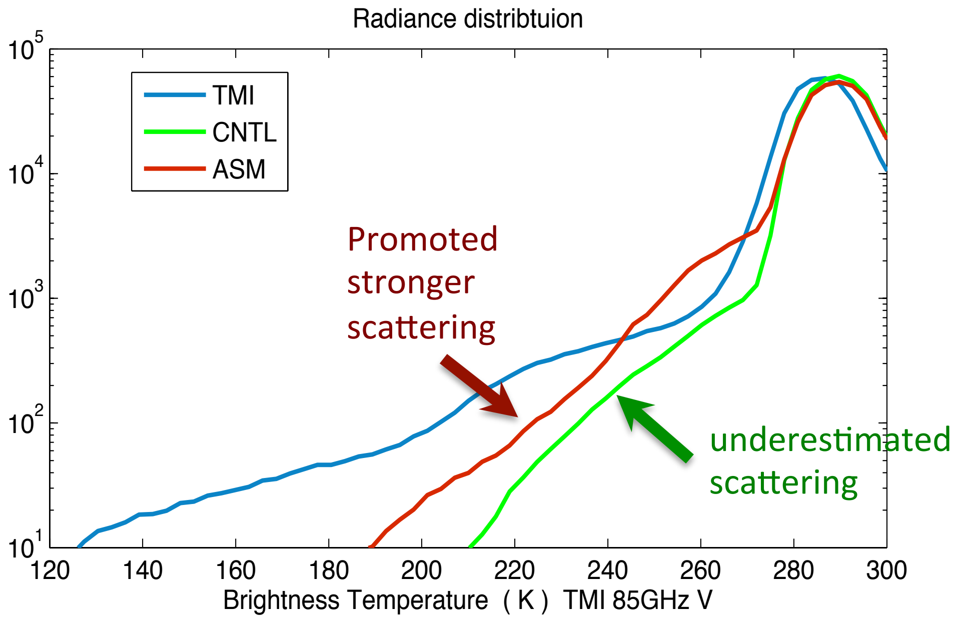
Surface precipitation





Ensemble Data Assimilation System (EDAS) package

Radiance: TMI 85GHz V



Sampled TMI at pixel (~5KM) resolution, CNTL and ASM at 9KM resolution

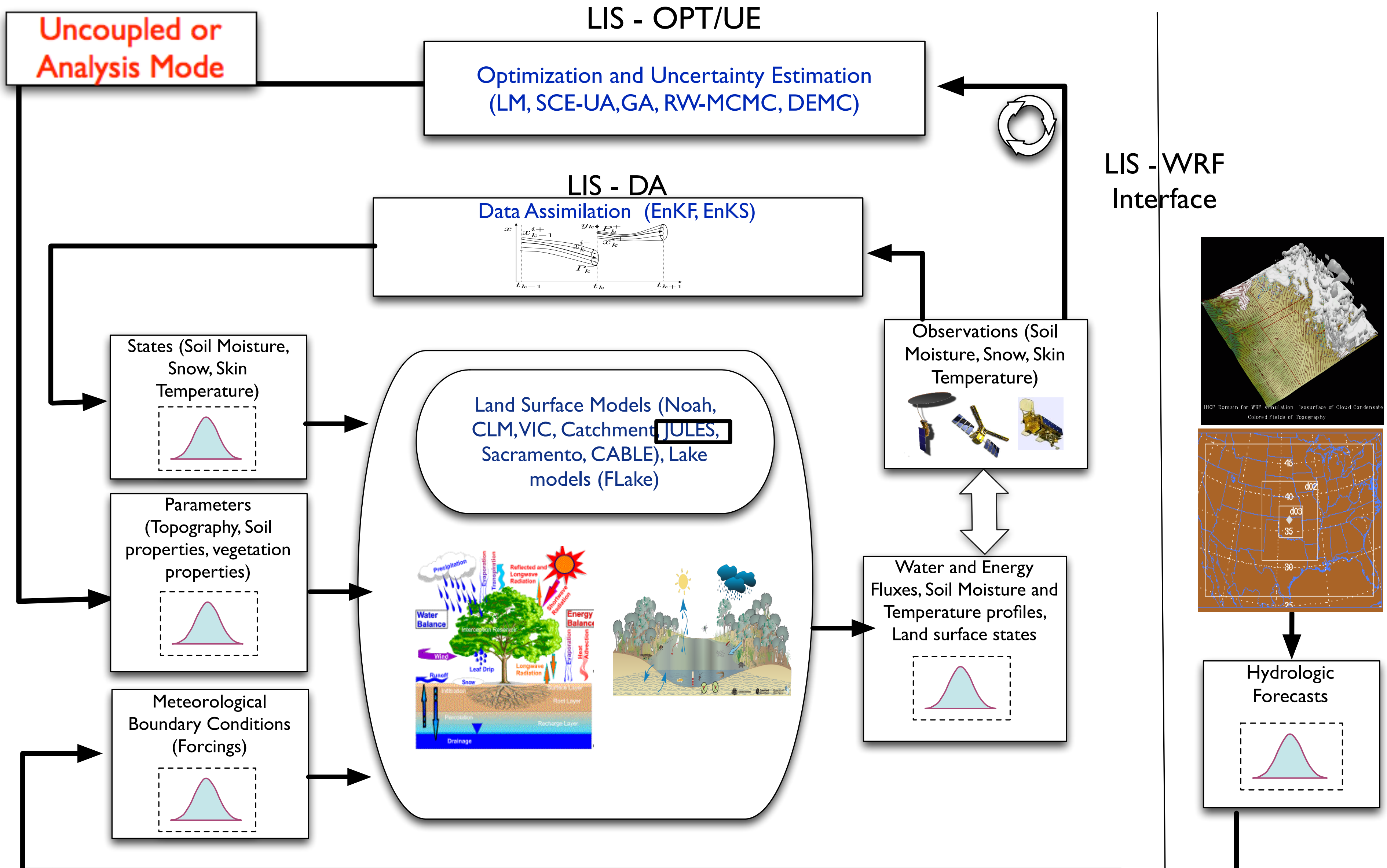
Improvement (warm) or degradation (cool) of Fractions Skill Score (FSS) against satellite-derived precipitation (3B42)

Sample Area			
297 km	1.0%	1.2%	2.0%
153 km	2.2%	1.3%	2.6%
81 km	2.3%	0.9%	0.5%
45 km	1.1%	0.8%	1.9%
27 km	2.4%	1.3%	2.4%
9 km	2.5%	1.3%	1.8%
	10 mm	30 mm	90 mm

Intensity threshold

Zhang, S.Q., T. Matsui, D. Wu, M. Zupanski and C. Peters-Lidard, 2016: Impact of assimilated precipitation-sensitive radiances on NU-WRF simulation of West African monsoon, *Mon. Wea. Rev.*, (submitted)

LIS Updates: Subsystems and Coupling



Kumar, S.V., C.D. Peters-Lidard, J.L. Eastman, W.-K. Tao (2007), An integrated High Resolution Hydrometeorological Modeling Testbed using LIS and WRF, *Environmental Modeling and Software*, 23(2), 169-181.

Impact of Soil Moisture Assimilation on LSM Spinup and Coupled L-A Prediction

J. Santanello, S. Kumar, C. Peters-Lidard, and P. Lawston (*J. Hydrometeorology*, **February 2016**)

- **AMSR-E assimilation has a significant impact on LSM soil moisture during spinup periods leading up to NU-WRF forecasts.**
- Magnitude and sign of impacts are dependent upon:
  - **Season and regime (dry vs. wet)**
  - **CDF-matching**
  - **Atmospheric forcing**
- Significant impacts of DA are felt on L-A prediction:
  - **Evaporative Fraction** (+/- 0.15)
  - **PBL Height** (+/- 500m)
  - **2-meter Temperature** (+/- 3K) **and Humidity**
- **Ambient weather** impacts are positive in 2006 (particularly with GDAS forcing), but 2007 shows overall degradation in T2m and Q2m.

NLDAS-2 Forcing | GDAS Forcing

	OL	RM	RL	SM	SL	GOL	GRM
Anomaly Correlation (-)	0.68	0.67	0.68	0.67	0.69	0.45	0.69
Anomaly RMSE (m^3m^{-3})	0.037	0.037	0.36	0.37	0.036	0.048	0.036

2006	OL	RM	RL	SM	SL	GOL	GRM
Qle RMSE	67.8	70.5	69.6	70.7	69.0	84.5	69.7
Qle Bias	-6.7	1.2	-15.6	-0.4	-16.1	-15.4	1.3
Qh RMSE	68.1	67.6	73.9	67.9	73.0	90.3	67.2
Qh Bias	12.7	5.2	20.0	6.7	20.5	27.2	5.2

2007	OL	RM	RL	SM	SL	GOL	GRM
Qle RMSE	83.9	79.3	79.7	80.0	78.3	85.3	81.2
Qle Bias	32.8	14.0	11.0	19.2	9.6	23.9	17.9
Qh RMSE	62.8	63.7	69.9	64.5	69.8	66.8	66.3
Qh Bias	-10.1	1.7	8.6	1.5	14.9	4.0	2.6

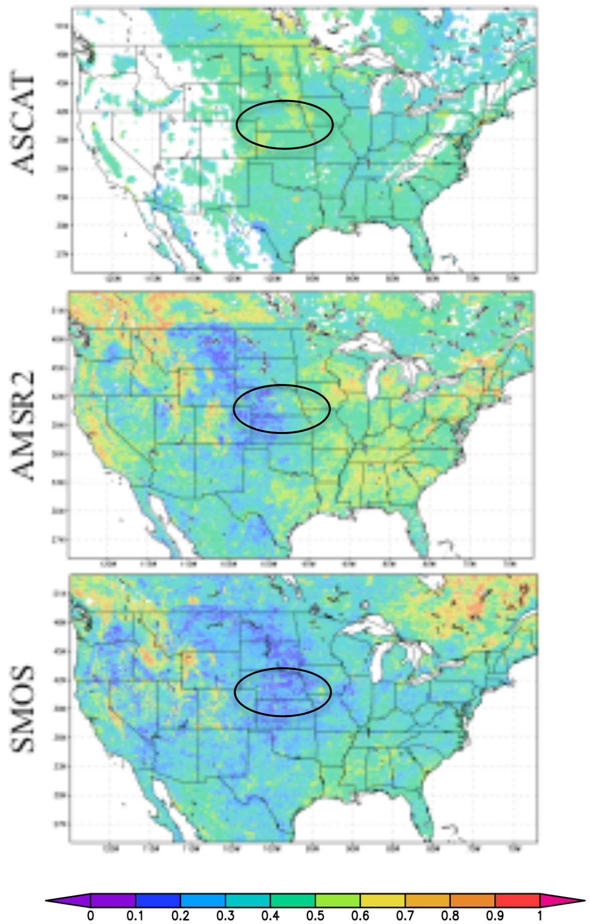
Details: J. Santanello in Poster Session (Wed Afternoon).

Challenges in remote sensing and simulation of irrigation

Sujay Kumar, Christa Peters-Lidard, Joseph Santanello, Grey Nearing, Mike Jasinski, Hydrological Sciences;
Rolf Reichle, Clara Draper, Randal Koster, GMAO, NASA GSFC

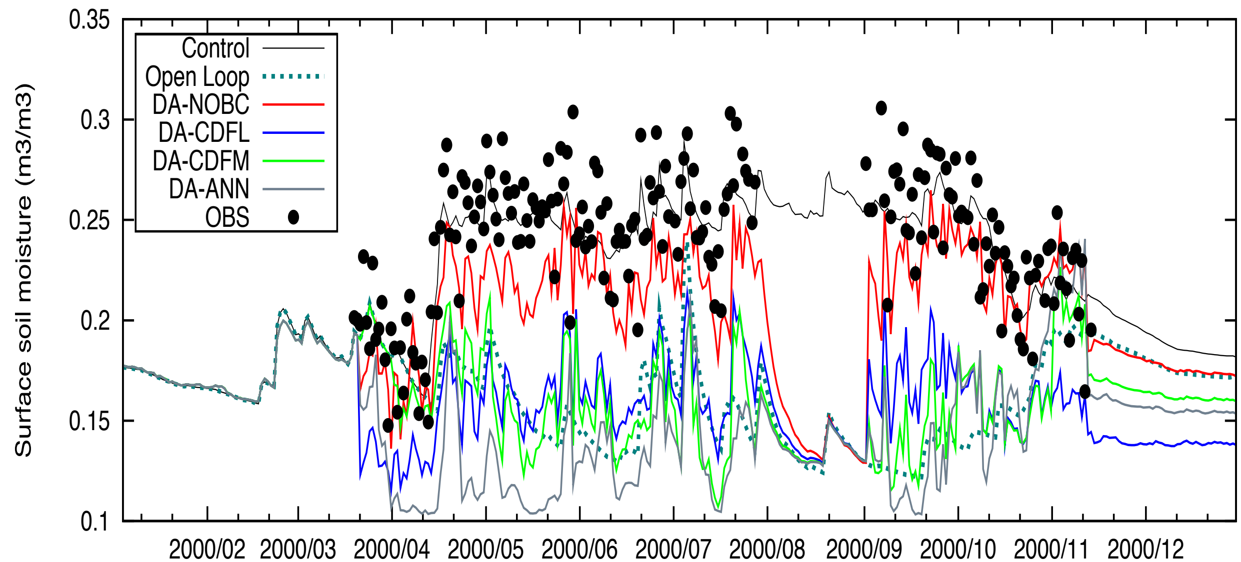
(*HESS*, **November 2015**)

Figure 1



The skill of the passive microwave soil moisture retrievals in detecting features of large-scale seasonal irrigation was mixed, with ASCAT retrievals more effective than SMOS and AMSR2 products.

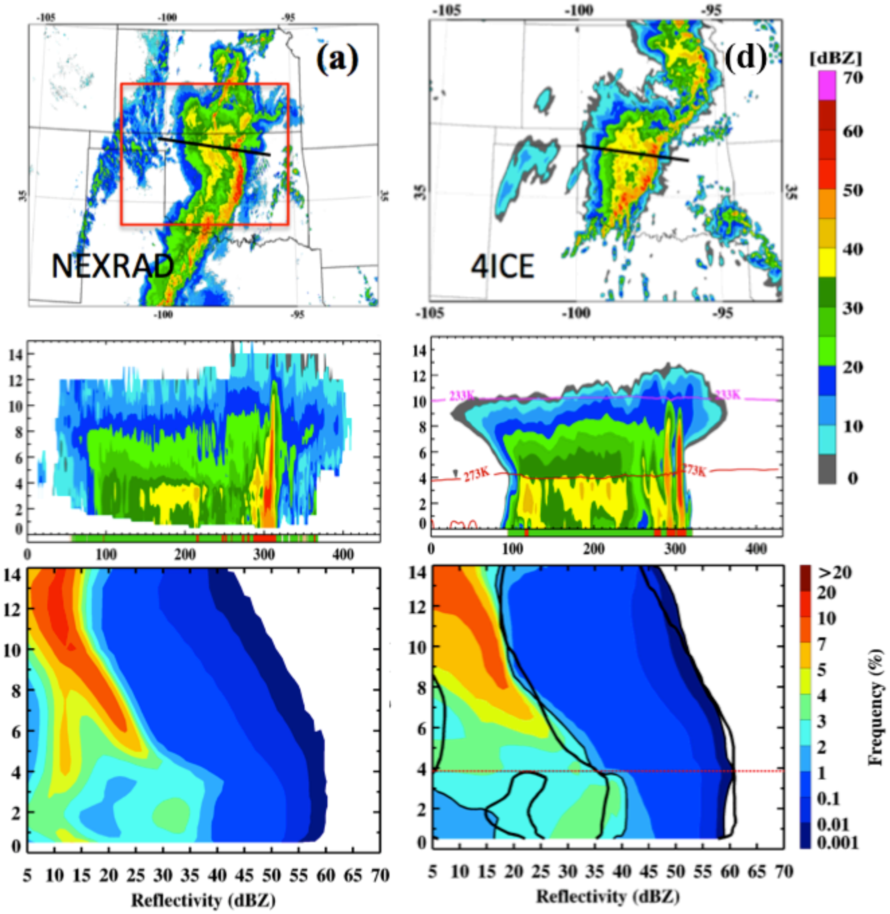
Figure 2



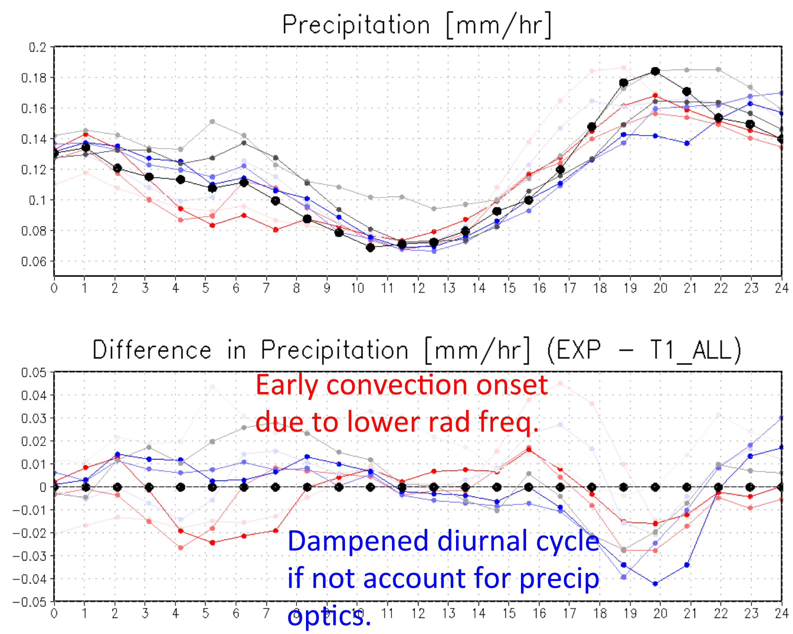
- DA runs with bias correction do not incorporate the wet signal of irrigation.
- The size of the innovations remain small in these runs as the anomalous wet signal is treated as a bias artifact and removed in the DA system
- The standard bias correction strategies make no distinction of the source of the biases. The signals from unmodeled processes are therefore, excluded

Updated Goddard Microphysics (4ICE) and Radiation (2014) package

Observation ***Goddard Microphysics (4ICE)***



Goddard 2014 SW/LW Radiation has a) Non-spherical precipitation optics and b) Grid aggregation options.



Details: W.K. Tao in Session 8 (Thu Morning).

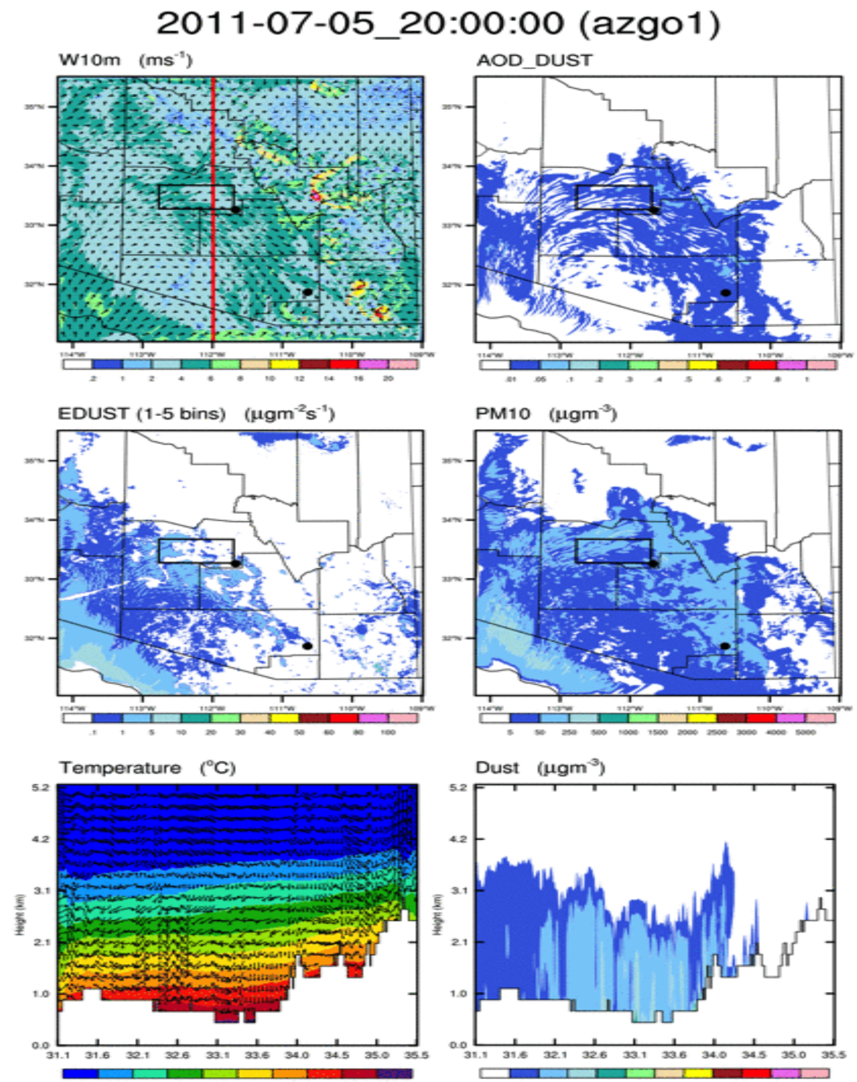
Details: T. Matsui in Poster Session (Wed Afternoon).

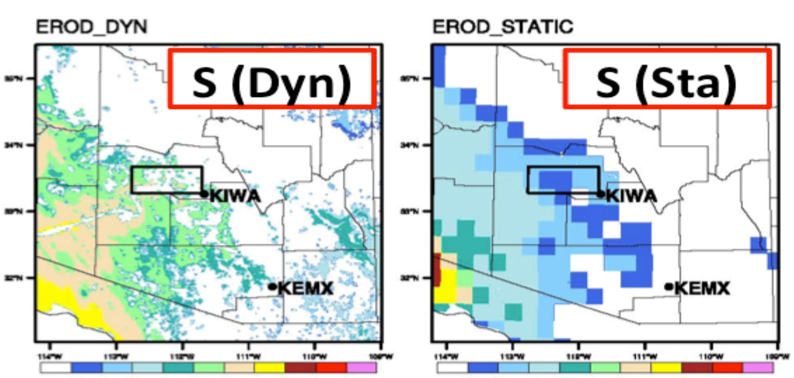
From D. Kim and M. Chin

Updated GOCART aerosols and database

NU-WRF Simulation Setup
Time: 00z July 5 - 00z July 7, 2011
Horizontal : 500x500 (1 km)
Vertical : 30 layers (~50mb)
Initial Condition: GFS
Aerosol scheme: GOCART
CPU: 200 cores + 10HR wall-time

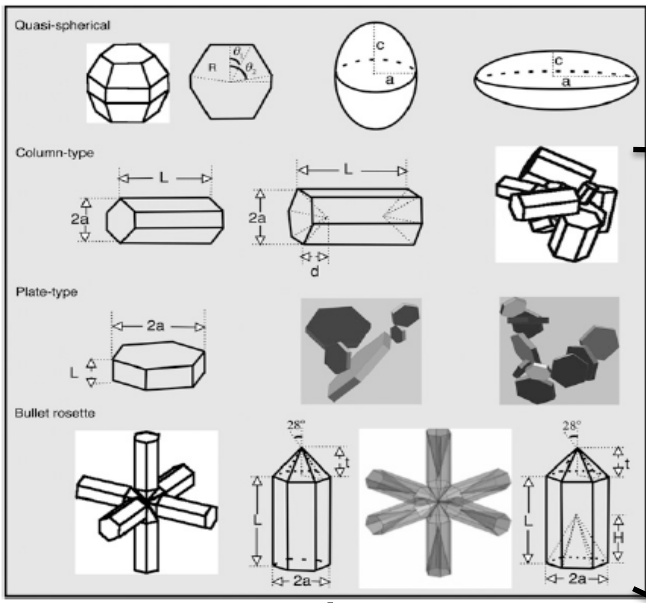
NU-WRF could generate realistic dust-storm driven by down burst from mountain. New 1km dust-source map also improved the simulation.





Updated satellite simulators: G-SDSU V3.5.1.

Ping Yang Visible-IR non-spherical SS.
(Yang et al. 2013, JAS)



<u>SARTA Simulator</u>
AIRS radiance

<u>Visible-IR Simulator</u>
Vis-IR radiance

<u>Broadband Simulator</u>
BB Radiation flux

<u>Goddard 2014 Rad</u>
BB Radiation flux

<u>Lidar Simulator</u>
Lidar backscatter and depolarization

IR spectrum emissivity map
(Seeman et al. 2008, JAMC)

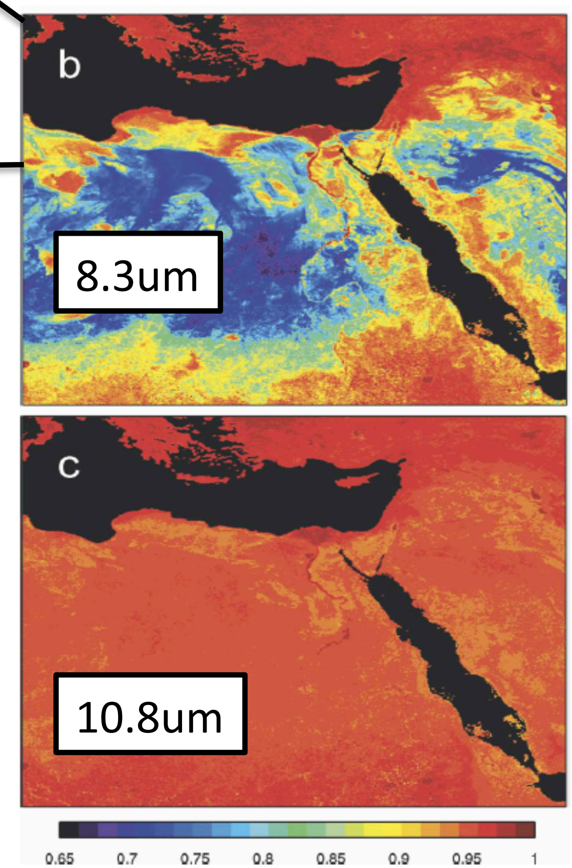


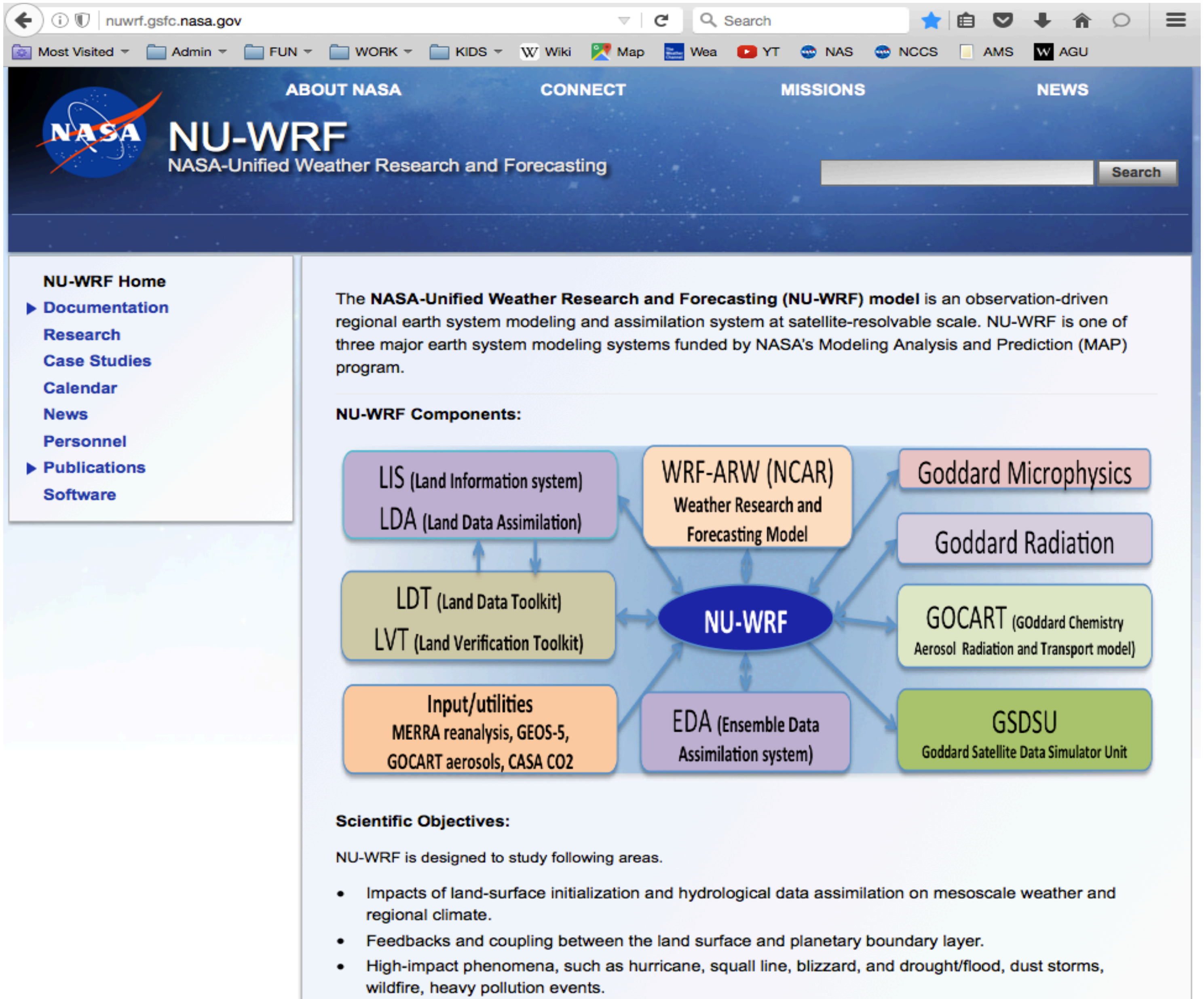
FIG. 10. Surface emissivity derived from the BF approach for August 2003 in the eastern Sahara Desert region. Emissivity is shown for three wavelengths: (a) 4.3, (b) 8.3, and (c) 10.8 μm. The Nile River can be seen curving south from its delta, as identified by the high emissivity characteristic of water.

TBD → MAP16

Future Directions

- **Atmosphere**: Multi-physics ensemble system, Sub-km-mesh (toward EPS) simulations, convection-permitting regional climate studies driven by **GISS Model-E** CMIP runs.
- **Land**: More complete hydrological cycles (river routing + lake discharge/recharge) through HyMAP, **LIS-WRF-Hydro coupling,** FLAKE.
- **Data Assimilation**: Intercomparison of AMSR-E, ASCAT, and SMOS assimilation in LIS-Noah. Combined GPM-SMAP assimilation for regional water cycle reanalysis.
- **New and Future Satellite Missions**:
  - **CATS ISS**, **GOES-R** aerosol-cloud-land measurements.
  - future **ICESat-2** and **SWOT** water level measurements.
  - many planned cubesat missions.

NU-WRF Website



nuwrf.gsfc.nasa.gov

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NU-WRF

NASA-Unified Weather Research and Forecasting

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- Software

The **NASA-Unified Weather Research and Forecasting (NU-WRF) model** is an observation-driven regional earth system modeling and assimilation system at satellite-resolvable scale. NU-WRF is one of three major earth system modeling systems funded by NASA's Modeling Analysis and Prediction (MAP) program.

NU-WRF Components:

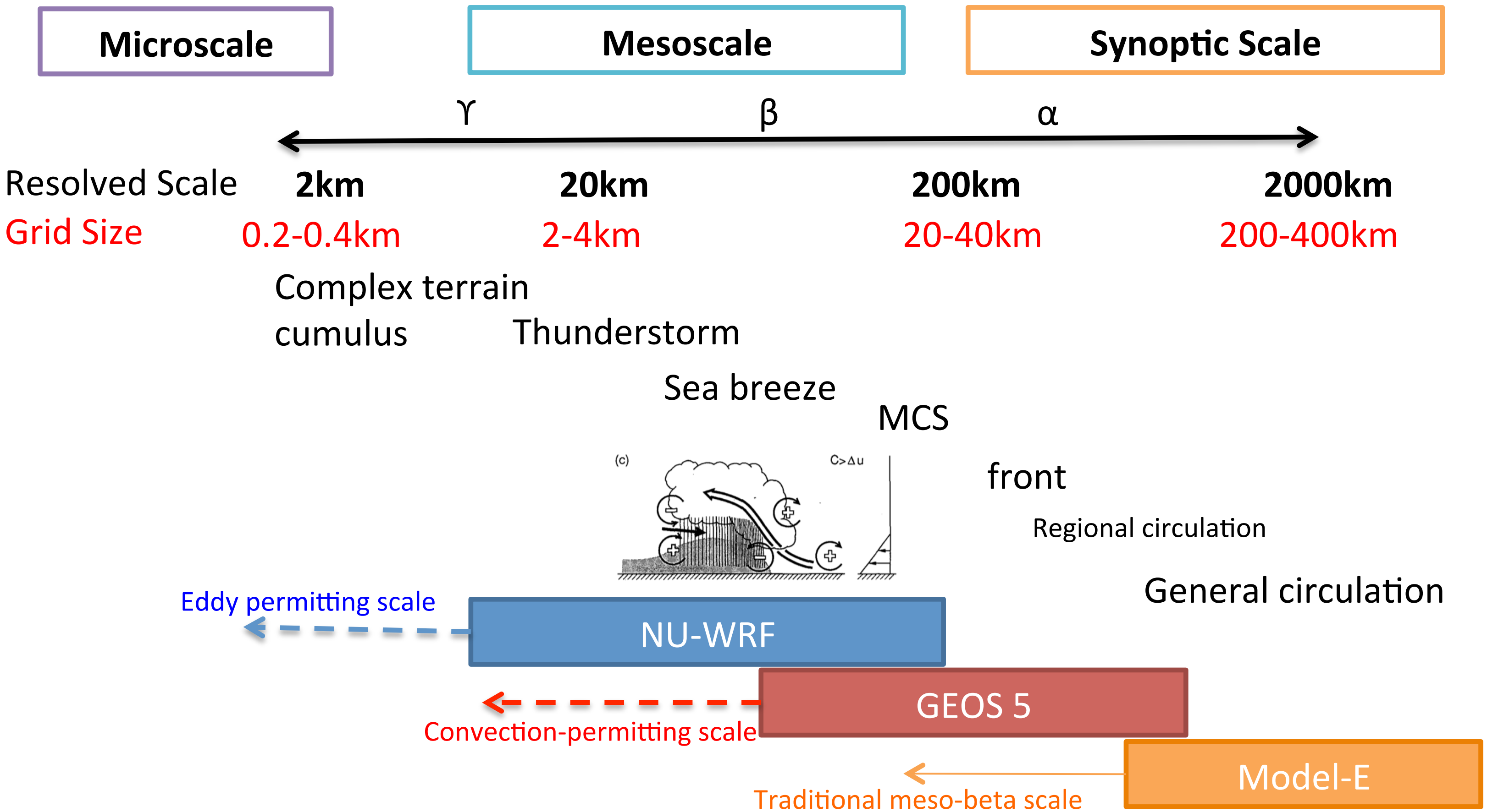
Scientific Objectives:

NU-WRF is designed to study following areas.

- Impacts of land-surface initialization and hydrological data assimilation on mesoscale weather and regional climate.
- Feedbacks and coupling between the land surface and planetary boundary layer.
- High-impact phenomena, such as hurricane, squall line, blizzard, and drought/flood, dust storms, wildfire, heavy pollution events.

Backups

NASA MAP Core Models



Orlanski, I. (1975). "A rational subdivision of scales for atmospheric processes". *Bulletin of the American Meteorological Society* **56** (5): 527–530.