#601

Impact of SMAP Soil Moisture Data Assimilation on Soil Moisture and on Warm Season Convection Forecasts

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SPoRT Short-term Prediction Research and Transition Center

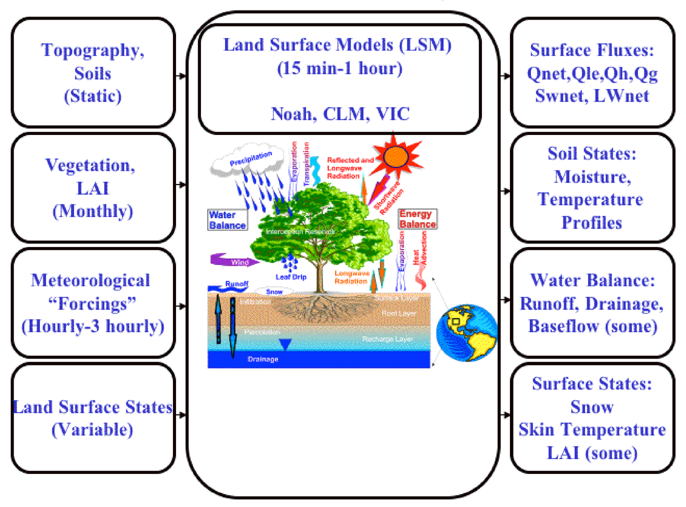
1. LIS and SMAP Data Assimilation Overview

SMAP – The NASA Soil Moisture Active Passive Mission

- The SMAP radiometer is an L-band (1.4 GHz) sensor in polar orbit, launched in April 2015.
- L-band radiometer can be used to estimate soil moisture to a higher accuracy, greater depth, and in denser vegetation than higher-frequency instruments
- SMAP has a 36-km resolution and a 4% volumetric accuracy. Enhanced SMAP retrieval is interpolated to 9-km.
- Coverage up to 2x/day
- The ESA Soil Moisture and Ocean Salinity (SMOS) satellite provided similar measurements using a synthetic aperture radiometer.

The Land Information System (LIS)

- NASA SPoRT has managed a near-real-time version of LIS for several years, which is the basis for the data assimilation
- Noah 3.3 Land Surface Model
- NLDAS-2 forcing data (1/8 deg, 3-hourly)
- 3-km res CONUS domain
- Soil type from 1 km STATSGO
- Land use from 1 km IGBP-MODIS
- Daily 4-km VIIRS GVF estimates
- Established 30+ year climatology
- Can be used for NWP initialization

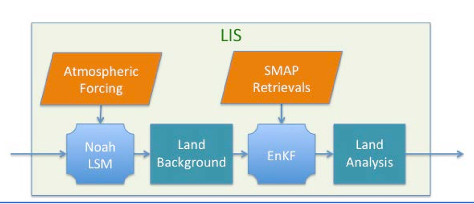


Data Assimilation

SMAP soil moisture retrievals were assimilated into the NASA LIS, combining the **background** of the previous model output, and the SMAP **observations** into a new **analysis**.

Goals

- Improve depiction of soil moisture in LIS
- Improve NWP through surface initialization

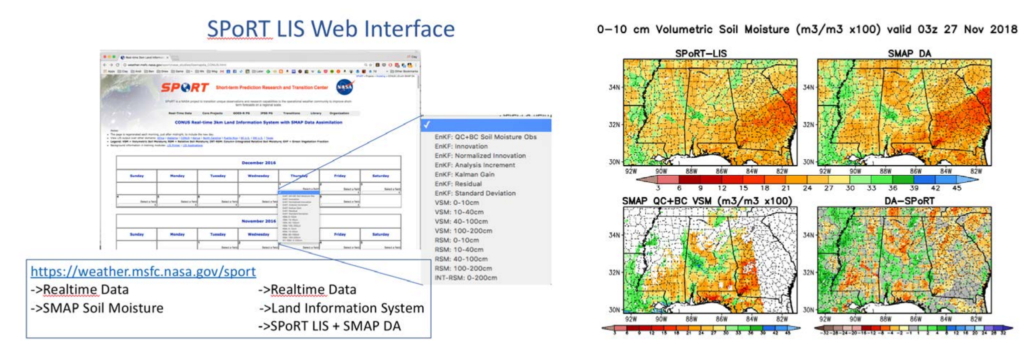


Data Assimilation (cont.)

SMAP Assimilation Details

- Assimilating SMAP P_L2_SMP_E "Enhanced" retrievals (9-km grid)
- 12-member Ensemble Kalman Filter assimilation
- Assimilation cycle every 3h.
- Tested various perturbations and bias corrections

Output available in near real time at
https://weather.msfc.nasa.gov/sport/case_studies/lissmapda_CONUS.html

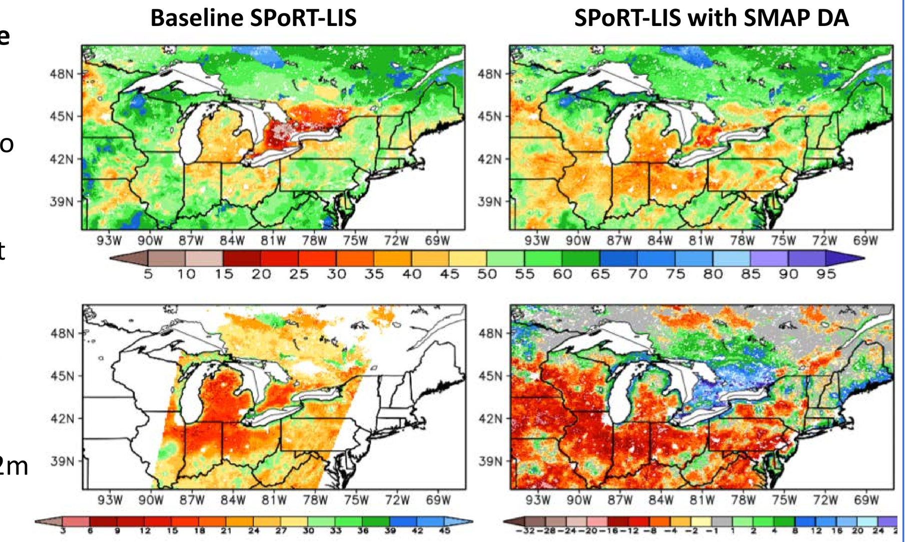


SPoRT LIS is used by partner WFOs to assess **flood potential**, **drought severity**, and **wildfire threat**. An experimental Alaska run is being developed currently.

US-Canada Border Case

SPoRT-LIS too dry in southern Ontario due to a problem in NLDAS-2 blended forcing data. SMAP retrievals did not have this anomaly. Analysis (upper right) shows conditions more consistent with SMAP retrievals.
This case shows the 0-2m SM after over 1 year of SMAP assimilation, allowing changes to propagate to lower levels.

0-2 m Column Integrated Relative Soil Moisture (%)
12Z 4 Jun 2016

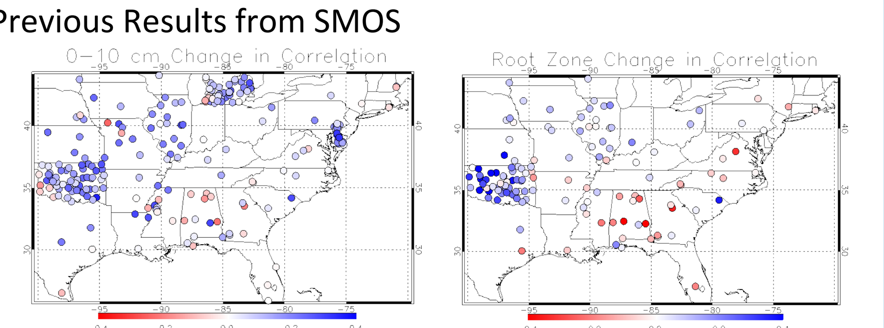


SMAP Retrieved Soil Moisture
0-5 cm, volumetric (m³/m³ x100)

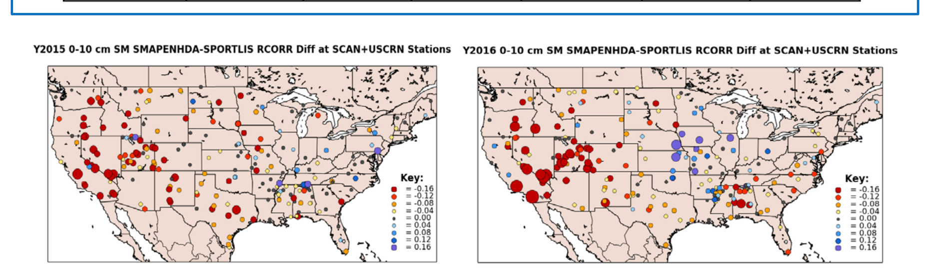
LIS Difference
(SMAP DA Minus Baseline SPoRT)
Column Integrated RSM (%)

2. Soil Moisture Validation

Previous Results from SMOS

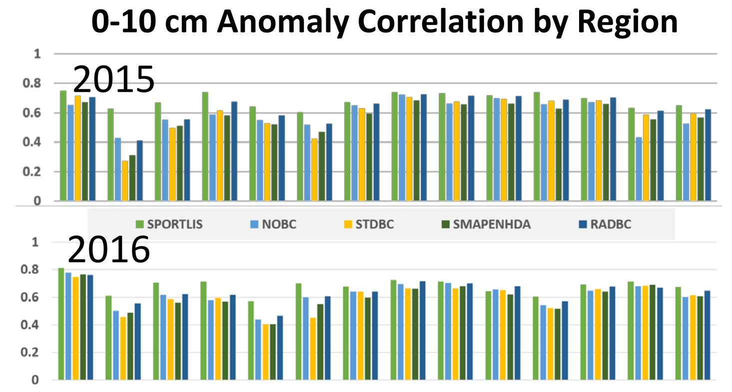


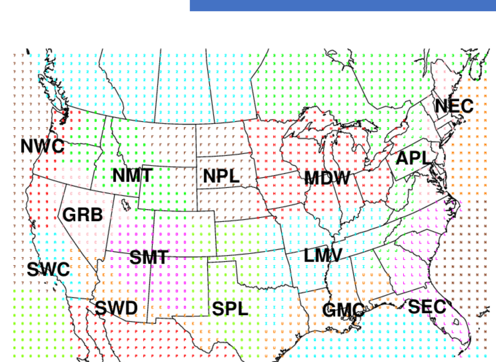
	Near Surface (0-10 cm)			Root Zone (10-100 cm)		
	Bias	Err SD	Corr.	Bias	Err SD	Corr.
Control	3.6%	23.5%	**0.47**	4.0%	10.6%	**0.61**
SMOS DA	-0.5%	21.8%	**0.57**	10.6%	11.8%	**0.67**



- We were unable to duplicate the significant positive impact from SMOS data assimilation over the whole domain.
  (Differences: year of experiment, domain, resolution of LIS)
- SMAP results are generally better in central and northeastern part of domain, worst in southwest.
  Possible contributing factors: soil or land cover category, amount of vegetation, wetness, terrain, spatial variability
- Bias correction tests led to the choice of the "RADBC" method which used a 300-km radius to build a CDF from points with matching soil types, which outscored other bias corrections in terms of correlation
- Scores by NCEP Verification region show better results in east in terms of correlations (anomaly correlation shown below) and ubRMSE (improves MDW, LMV, GMC, SEC).

0-10 cm Anomaly Correlation by Region





NCEP Verification Regions for CONUS

0-10 cm Soil Moisture Verification by Land Cover Category*
May-Oct, 2015-2016

Land Cover	Count	Ctrl Corr	DA Corr	Δ Corr positive is good	Δ Abs(Bias) negative is good
Cropland	46	0.691	0.717	0.026	0.024
Grassland	73	0.769	0.745	-0.023	-0.024
Cropland+natural	26	0.739	0.713	-0.026	0.028
Deciduous broadleaf	13	0.717	0.654	-0.063	0.027
Open shrubland	35	0.745	0.681	-0.065	-0.043
Mixed forest	14	0.720	0.578	-0.142	0.019

*from MODIS Land Cover Type (MCD12Q1) using IGBP classifications

0-10 cm Soil Moisture Verification by Soil Type Category*
May-Oct, 2015-2016
5 largest categories

Soil Category	Count	Ctrl Corr	DA Corr	Δ Corr positive is good	Δ Abs(Bias) negative is good
Clay Loam group	26	0.728	0.769	0.041	-0.020
Silt Loam group	62	0.735	0.708	-0.027	0.007
Sand	13	0.733	0.692	-0.041	0.017
Loam	59	0.770	0.721	-0.049	-0.019
Sandy Loam group	58	0.721	0.661	-0.060	0.003

*from STATSGO soil type categories, some categories aggregated as in Blankenship et al. (2016)

0-10 cm Soil Moisture Verification by Tree Cover*
May-Oct, 2015-2016

Tree Cover	Count	Ctrl Corr	DA Corr	Δ Correlation	Δ Abs(Bias)
Sparse (0.00-0.33)	173	0.748	0.727	-0.021	-0.014
Medium (0.33-0.67)	28	0.728	0.651	-0.077	0.028
Dense (0.67-1.00)	27	0.717	0.626	-0.092	0.035

*from Hansen Global Forest Change, v1.3, 2012 data

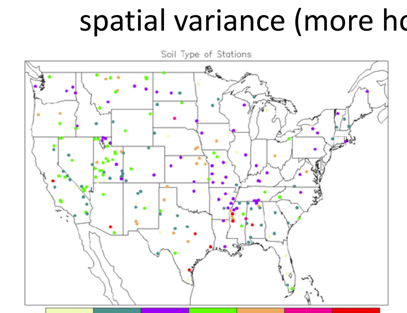
0-10 cm Soil Moisture Verification by Spatial Variance*
May-Oct, 2015-2016

9-km standard deviation of soil moisture	Count	Ctrl Corr	DA Corr	Δ Corr positive is good	Δ Abs(Bias) negative is good
Low (<.01)	6	0.649	0.678	0.029	-0.004
Medium (.01-.03)	106	0.708	0.728	0.020	0.000
High (>.03)	116	0.742	0.676	-0.066	0.006

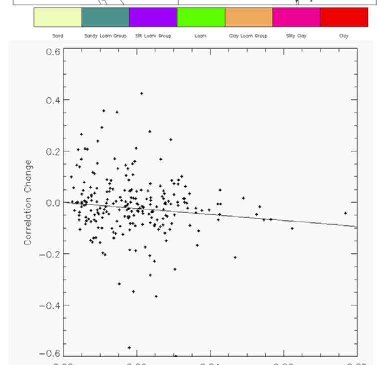
*calculated by average (modeled) spatial standard deviation of soil moisture within the SMAP product's 9-km EASE grid

Investigation of results by categories, focusing on correlation, the metric where we have seen the strongest impacts, revealed:

- Cropland was the only land cover type with a positive impact to correlation (+.026)
- The Clay loam group was the only soil type categoru with a positive impact (+.041)
- All three tree cover categories had negative impact, and this was larger for denser tree coverage.
- There was no trend in the effect of Volumetric Water Content, an error term in the soil moisture retrieval (not shown)
- Correlation improvement was better for low spatial variance (more homogeneous) areas.

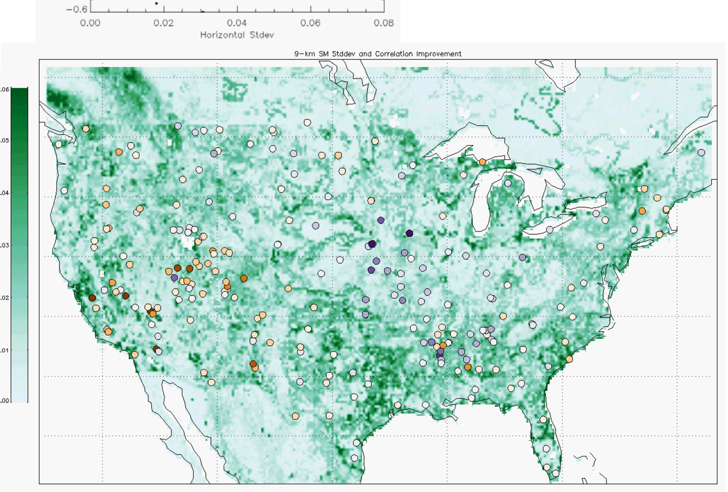


◄ Distribution of soil type categories at validation stations.

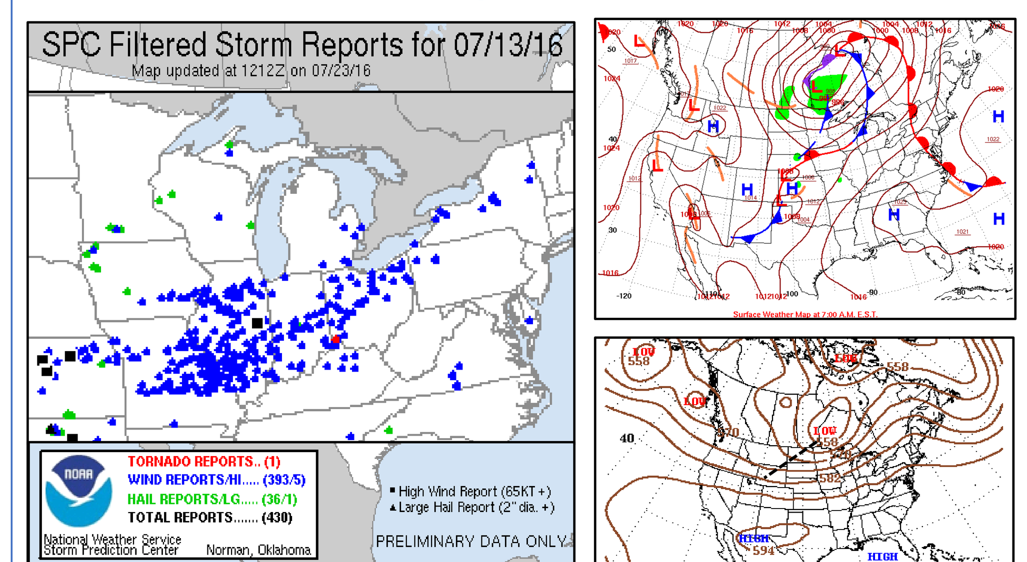


◄ Correlation change vs. time-averaged horizontal standard deviation of soil moisture within each 9-km EASE grid cell.

Right: Time-averaged horizontal standard deviation of model soil moisture within 9-km EASE grid cell (green color scale). Circles show change in correlation (DA minus control) for 0-10 cm soil moisture (blue is improvement)



3. Great Lakes Squall Line Case



This storm system on July 13-14, 2016 led to numerous significant high wind reports, some significant hail, and one tornado.

Discussion: EXP1 has the combined effect of too-moist coastlines from SMAP V1 [known issue corrected in V2] as well as a stronger signal in the bias-corrected soil moisture retrievals, in Northern Ontario. As a result, the impact of EXP1 on NWP was stronger than that of EXP2. The control run's prediction of the squall line lagged behind the observed position by about 2 h. Experiment 1 showed an improvement in the timing and position of this storm (e.g., 24-h forecast) and also in the development of leading convection in southern Ontario (26-28h). However, Experiment 2, with a new bias correction, showed less dramatic changes. It is possible that larger changes were needed due to the known problem here, and that the newer bias correction was unable to produce a significant enough soil moisture pattern change. The change in model output illustrates the sensitivity of forecasts to the surface conditions and the bias correction methodology.

24h Observed/Forecast Valid 0Z 14 Jul 2016

26h Observed/Forecast Valid 2Z 14 Jul 2016

28h Observed/Forecast Valid 4Z 14 Jul 2016

Verification ► (NEXRAD radar)

Control ►

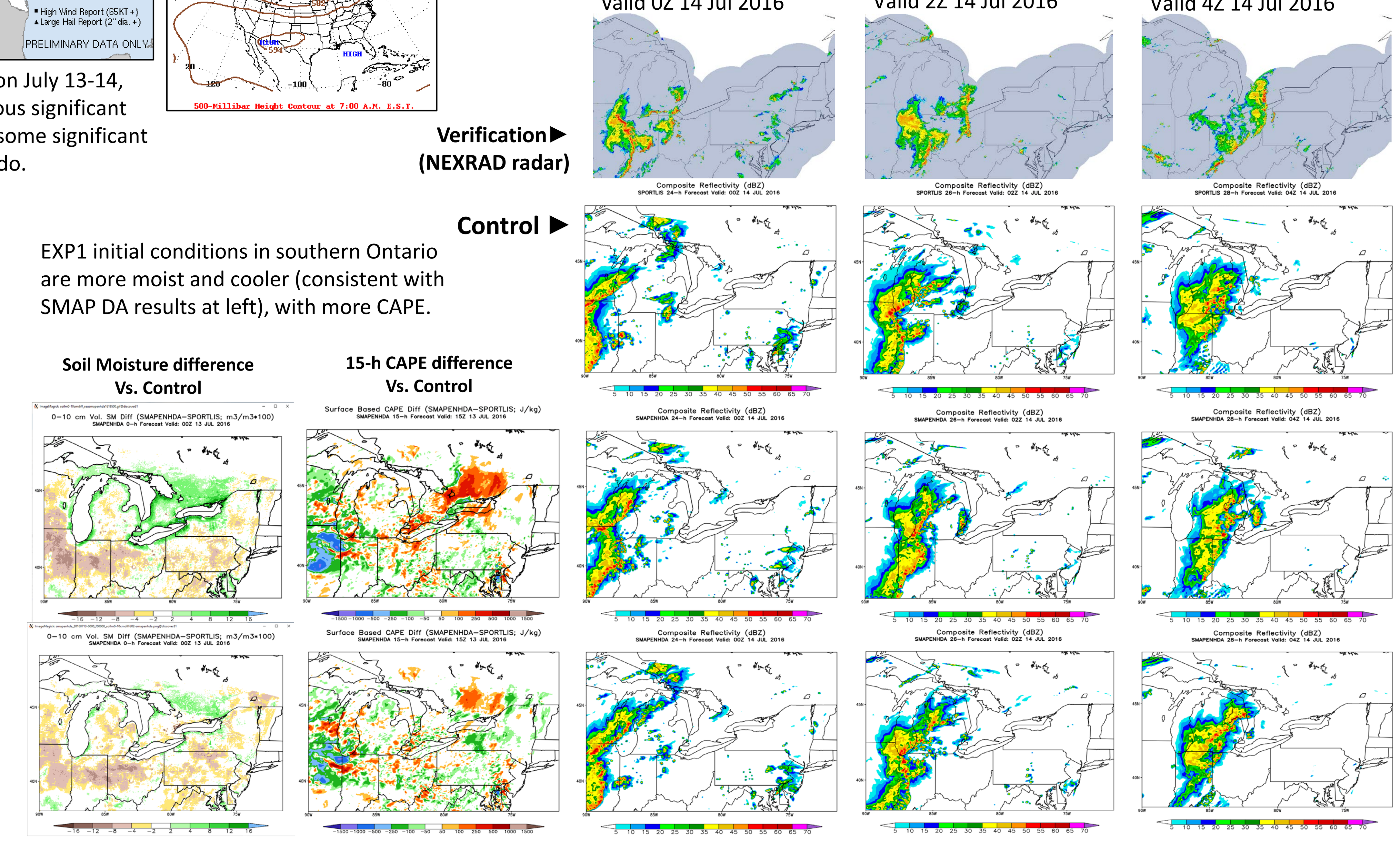
EXP1 initial conditions in southern Ontario are more moist and cooler (consistent with SMAP DA results at left), with more CAPE.

Soil Moisture difference Vs. Control

15-h CAPE difference Vs. Control

EXP1 ►
V1 SMAP retrieval
Nonlocalized soil-type bias correction ("SMAPENHDA" in Section 2)

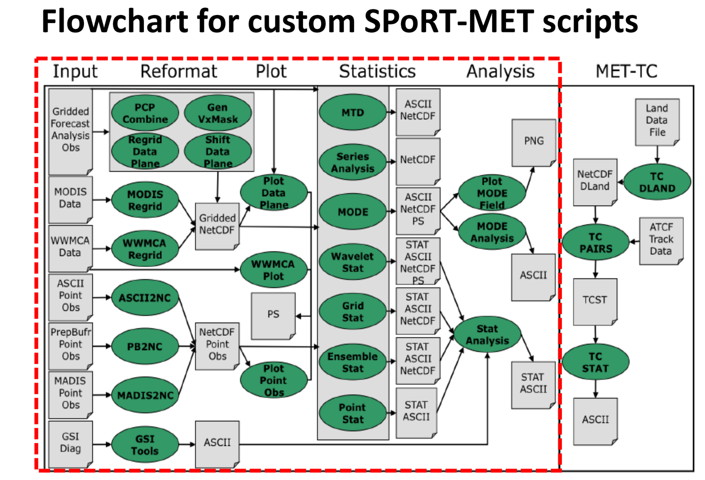
EXP2 ►
V2 SMAP retrieval
Radius-limited bias correction ("RADBC")



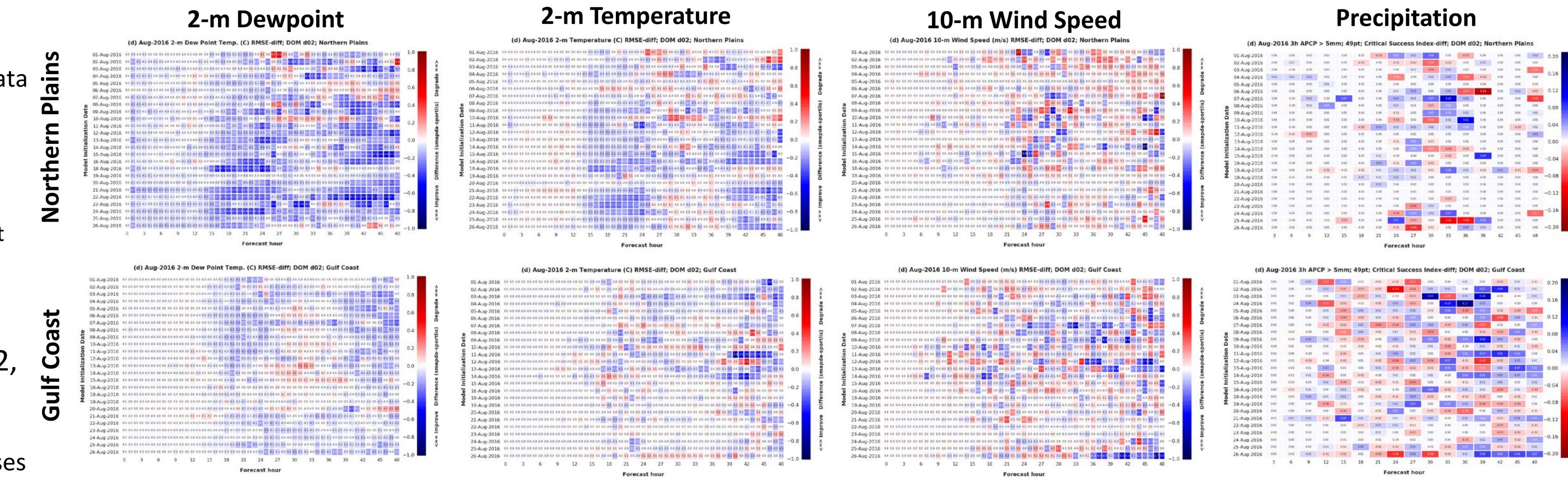
4. Comprehensive NWP Validation

- Point Forecast Verification (T, Td, winds)
  - Data source: NCEP Meteorological Assimilation Data Ingest System (MADIS) surface, upper-air, and cooperative mesonet observations
  - Run through NCAR/NCEP Model Evaluation Tools (MET) using SPoRT-MET python scripting package
    - ✓ Interpolate NU-WRF 9-km/3-km model grid forecast data to point locations
    - ✓ Generate statistics on model grids and mask by 14 NCEP/EMC verification regions
- Gridded Precipitation Verification (1, 3, 6, 12, 24h accumulation intervals)
  - Data source: Multi-Radar Multi-Sensor (MRMS) radar+gauge-corrected hourly precipitation analyses
  - Run through MET using customized SPoRT-MET scripting package
    - ✓ Upscale MRMS precip to 9-km and 3-km model grids
    - ✓ Generate statistics by grid point, and in neighborhood windows of ± 9km and ± 27km
    - ✓ Neighborhood verification determines how accurately the model can predict accumulated precipitation thresholds within a certain distance of a point
- Model Evaluation Tools (MET) is a software package developed by NCAR that will:
  - ✓ Reformat observations
  - ✓ Match model grid to observations
  - ✓ Compute statistical metrics & significance tests

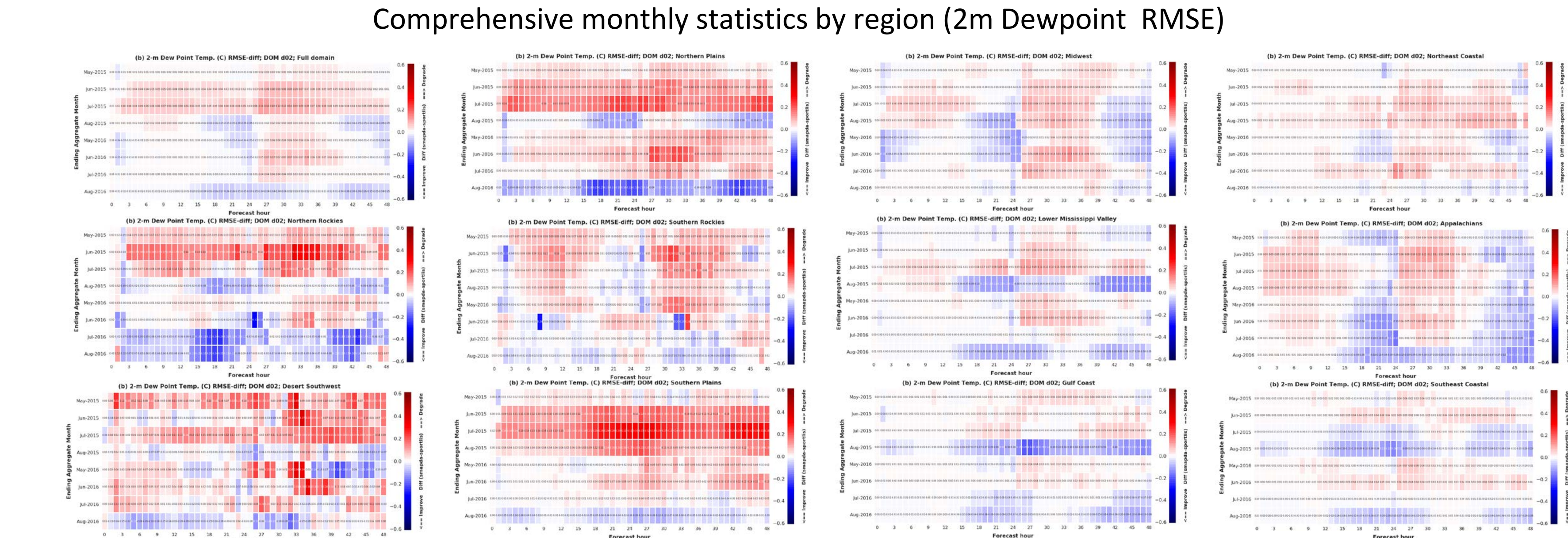
Flowchart for custom SPoRT-MET scripts



Heatmap Charts for NWP Forecasts



Comprehensive monthly statistics by region (2m Dewpoint RMSE)



- Generally better in eastern US, consistent with soil moisture results
- Overall trend improves over 2 years, possibly because time needed for surface soil moisture changes to translate into root zone (which affects atmosphere by evapotranspiration)
- Best results in August (and July)
- Diurnal cycle is evident with better results in daytime (12-24h from 0Z initialized forecasts)

Aggregate time series of dewpoint verification stats (Northern Plains, Aug 2016)