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Canada

Assimilation of L-band Soil Moisture Brightness Temperatures (TB) into the Soil, Vegetation and Snow (SVS) Scheme within the Canadian Land Data Assimilation System (CaLDAS)

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Environment and Climate Change Canada (ECCC)

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Soil Moisture & Numerical Weather Prediction (NWP)

Soil moisture affects:

- Land surface evaporation and evapotranspiration
- Sensible and latent heat fluxes (partition of net radiation)
- Evolution and structure of the boundary layer
- Formation of clouds, precipitation (convection) and weather systems

Common approach in NWP:

- Infer soil moisture from short-range forecast errors in screen-level (2m) temperature and humidity (so-called "pseudo-analysis" of soil moisture)

Issues:

- 2m observations have highly variable spatial and temporal density
- "Tunes" soil moisture of the model to provide accurate fluxes, less focus on improving soil moisture itself

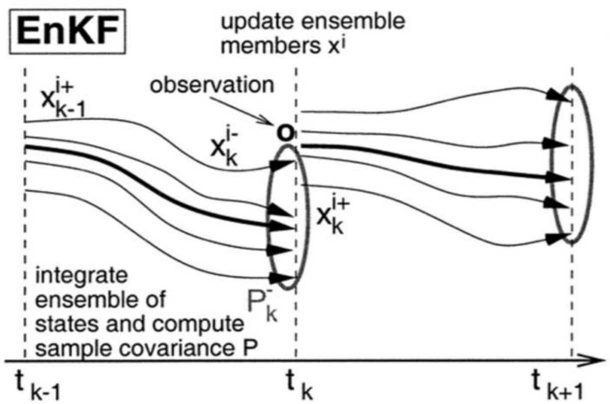
Goal at ECCC :

Improve both (1) the initialization and (2) modeling of soil moisture to improve:

1. Standard NWP variables (Air temp. , humidity, precipitation)
2. Soil moisture (and related variables: runoff, drought and flood conditions etc.) (** Increasing focus on environmental prediction)

Canadian Land Data Assimilation System (CaLDAS)

- **Ensemble Kalman Filter (EnKF) (24 members)**
- **Observations** assimilated:
  - Screen-level Temp and Humidity, Snow depth , ****NEW: SMAP L-band TBs**



- **Analyzed variables:**
  - Land surface temperature , snow depth, Soil Moisture (superficial, and root zone)
- **Background/First guess**:

Off-line land surface prediction system with 2 choices of land surface scheme:

ISBA : Interaction between **S**urface, **B**iosphere, **A**tmosphere

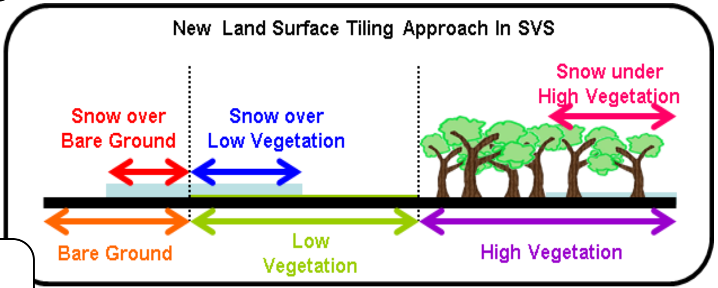
- One energy budget for land surface
- **Force-restore equation for soil moisture + 2 soil layers**

or

SVS : **S**oil **V**egetation and **S**now (**New at ECCC)

- Separate energy budget for bare ground, veg. and snow
- **Vertical soil water diffusion + 7 soil layers**
- Updated parametrizations for snow, runoff, stomatal resistance etc.

NOTE:
ISBA & SVS also in full 3D GEM model
(GEM: Global Environmental Multiscale)

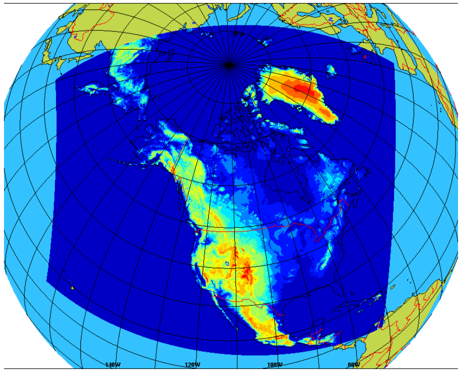


Carrera et al., 2015: The Canadian Land Data Assimilation System (CaLDAS): Description and Synthetic Evaluation Study
Alavi et al., 2016: Warm Season Evaluation of Soil Moisture Prediction in the Soil, Vegetation, and Snow (SVS) Scheme
Husain et al , 2016: The Multibudget Soil, Vegetation, and Snow (SVS) Scheme for Land Surface Parameterization: Offline Warm Season Evaluation

CaLDAS and SMAP :

Goal :

Evaluate the impact of assimilating SMAP (Soil Moisture Active Passive) brightness temperatures (TBs) in CaLDAS upon the estimation of the soil moisture state and the subsequent NWP forecasts.



Experimental Set-up :

Assimilation time period : June-August 2015

Evaluation time period :July-August 2015

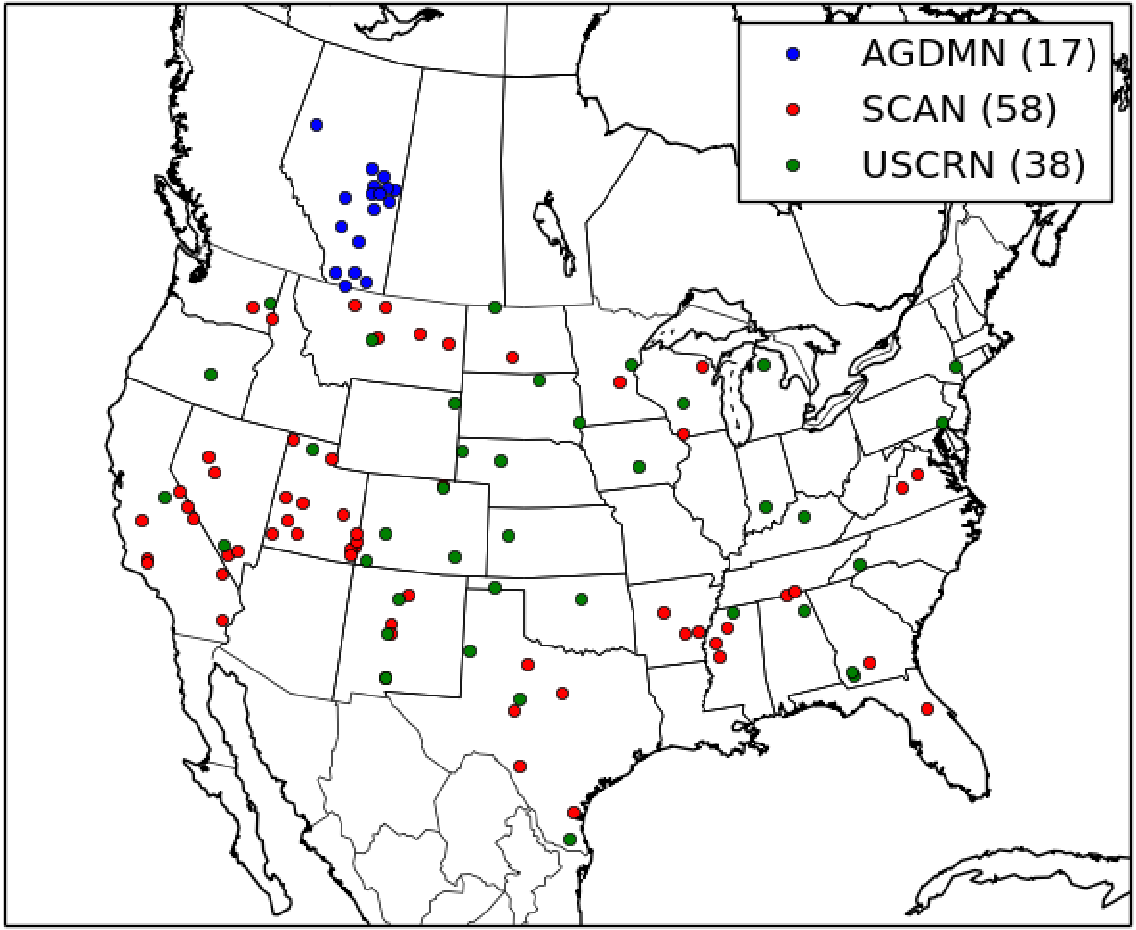
Domain: North America at ~10km grid spacing

Forward Model : Community Microwave Emission Modelling Platform (CMEM)

SMAP : SMAP Level 1B Radiometer Half-Orbit Time-Ordered Brightness Temperatures (Version 3)

EXPERIMENT	Observations Assimilated	Temporal Frequency	Control Variables	Land - Surface Model
SCREEN	TT, TD @2m	3hr	mean surface temp. surface and root zone soil moisture	ISBA
SMAP-ISBA	TT, TD @2m SMAP (TBs)	3hr	mean surface temp. surface and root zone soil moisture	ISBA
SMAP-SVS	TT, TD @2m SMAP (TBs)	3hr	surface temperatures and soil layers 1-4 (depth=5,10,20,40cm)	SVS

Soil Moisture Verification
Sparse Networks



AGDMN :Agriculture Ground Drought Monitoring Network
SCAN : USDA Soil Climate Analysis Network
USCRN : US Climate Reference Network

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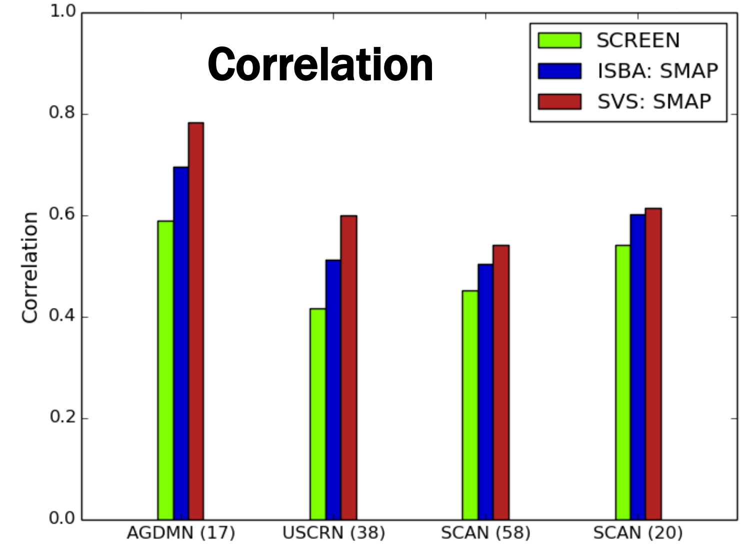
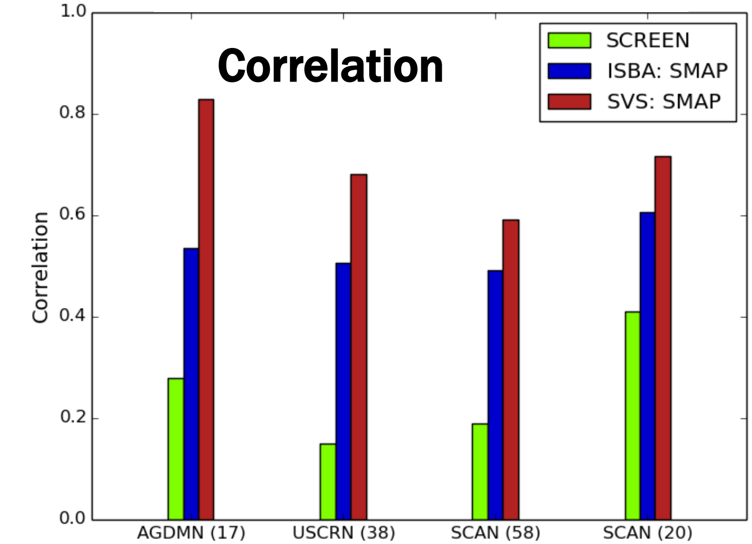
Soil Moisture Verification : Sparse Networks

Impact of SMAP TBs & Land Surface Schemes

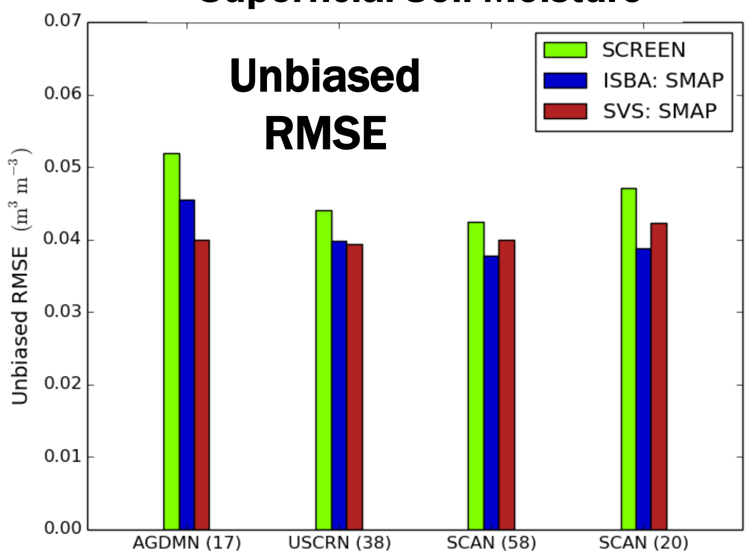
Superficial Soil Moisture



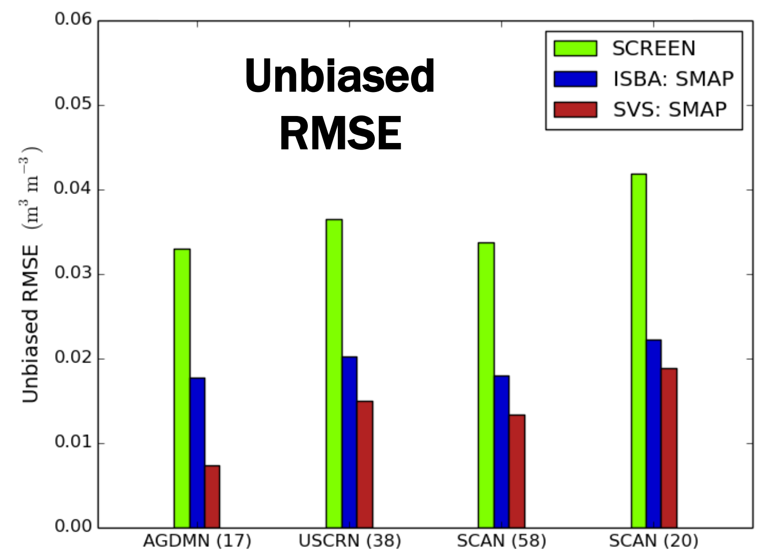
Root Zone Soil Moisture



Superficial Soil Moisture



Root Zone Soil Moisture



NWP Forecast Verification

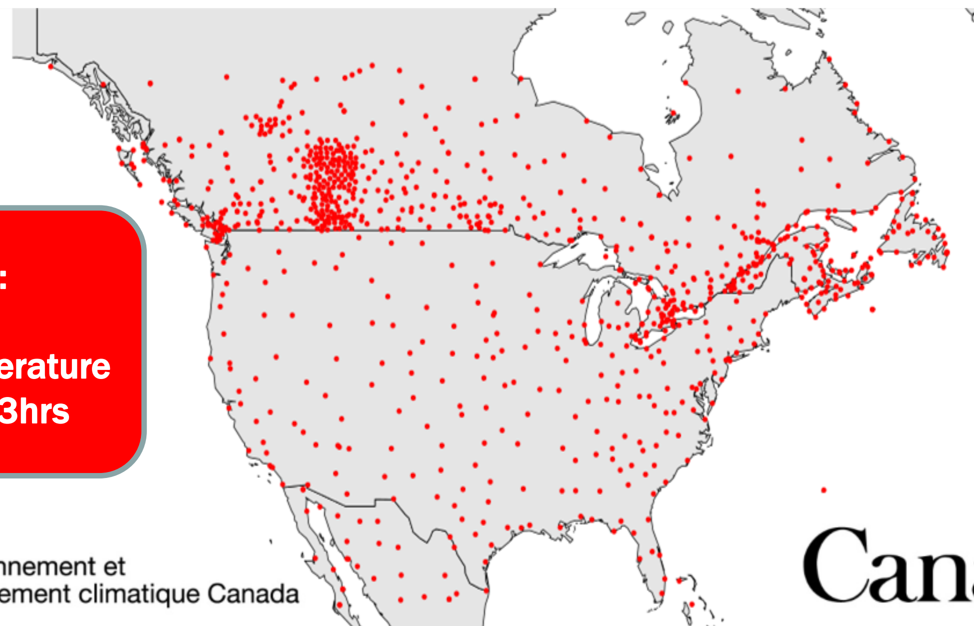
Screen-Level (2m) Temperature (TT) and Dew point Temperature (TD) and Soil Moisture Verification against Sparse Networks

July-August 2015

48 hr forecasts every 48hrs , initialized using CaLDAS analysis at 00Z (31 cases)

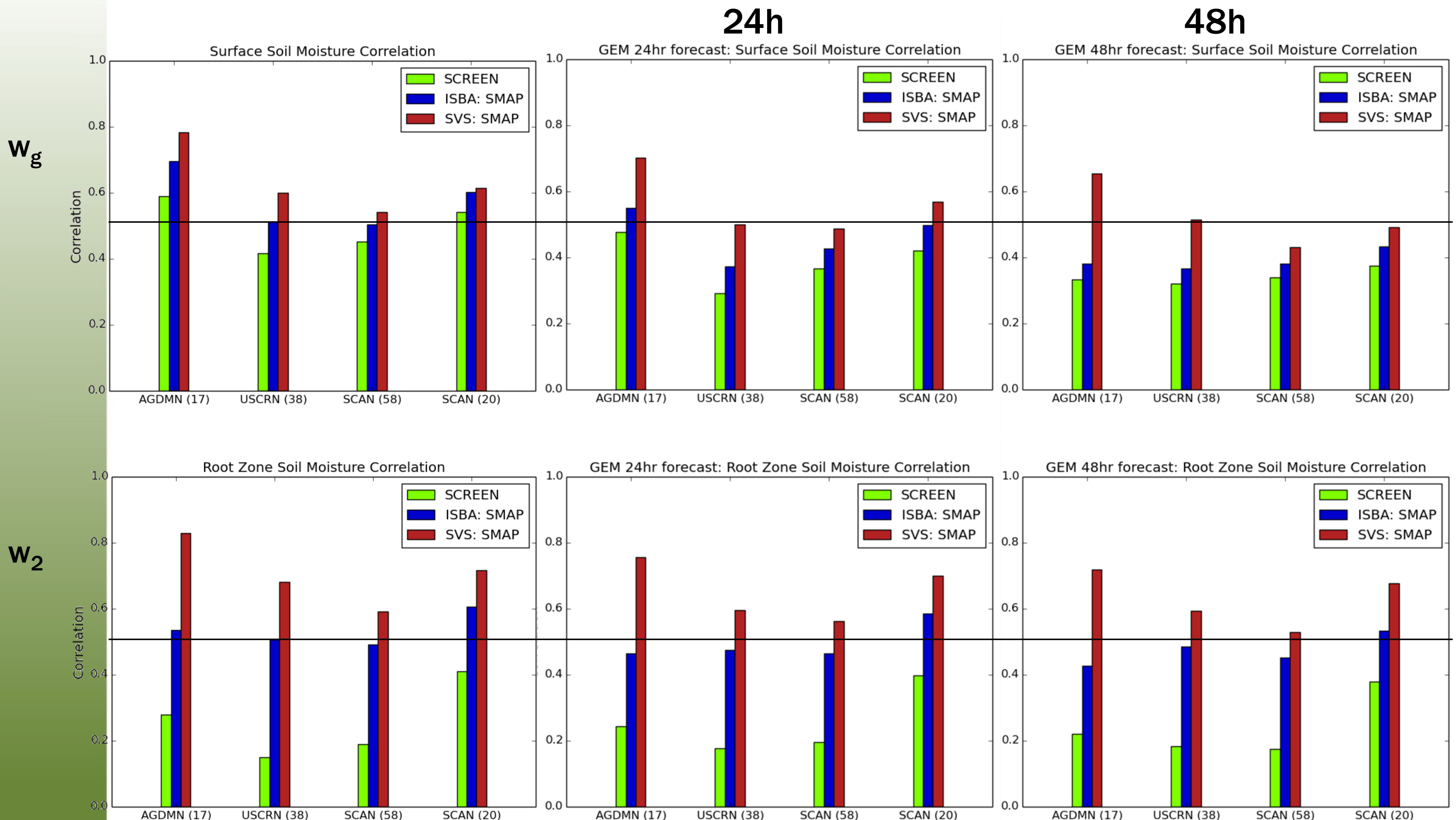
EXPERIMENT	Obs. Assimilated	Land Sfc Model*	Control Variables
SCREEN	TT, TD @2m	ISBA	mean surface temp. surface and root zone soil moisture
SMAP-SVS	TT, TD @2m SMAP (TBs)	SVS	surface temperatures and soil layers 1-4 (depth=5,10,20,40cm)

*Note: Land surface scheme (ISBA or SVS) in forecast same as in CaLDAS experiment



Verification against:
SYNOP stations
0.1˚C precision for Temperature
Temporal resolution of 3hrs

Soil Moisture Forecast Verification : Sparse Network
Correlation : July – August 2015



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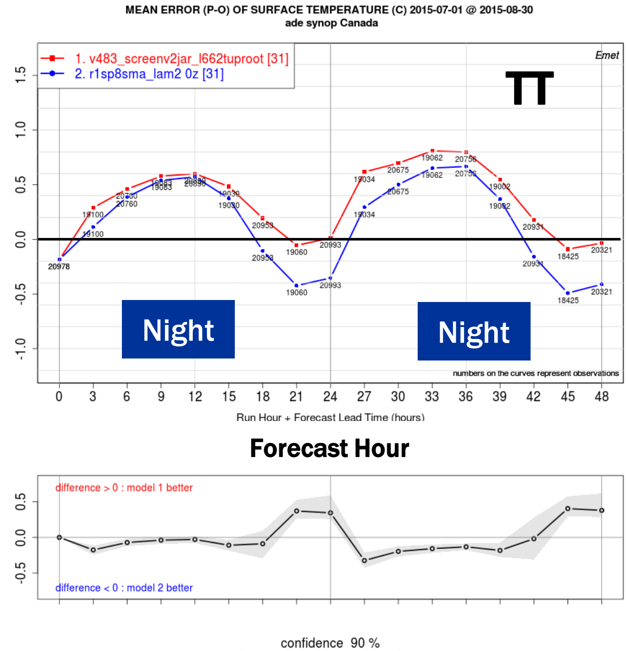
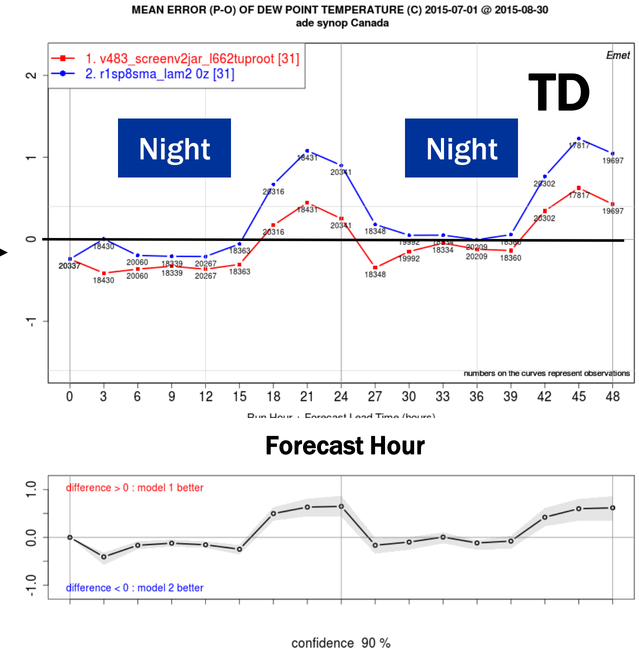
SCREEN+ISBA vs SMAP+SVS

Temperature Biases (F - O) : July - August 2015, 00Z Runs





warmer

← Canada →

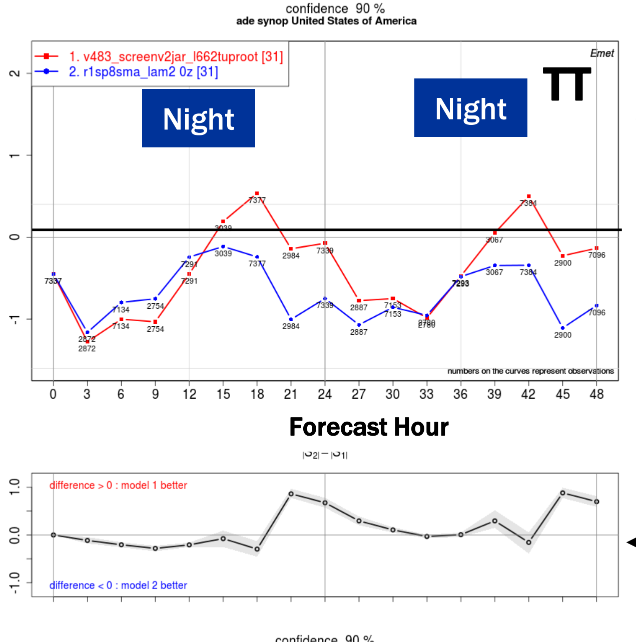
colder

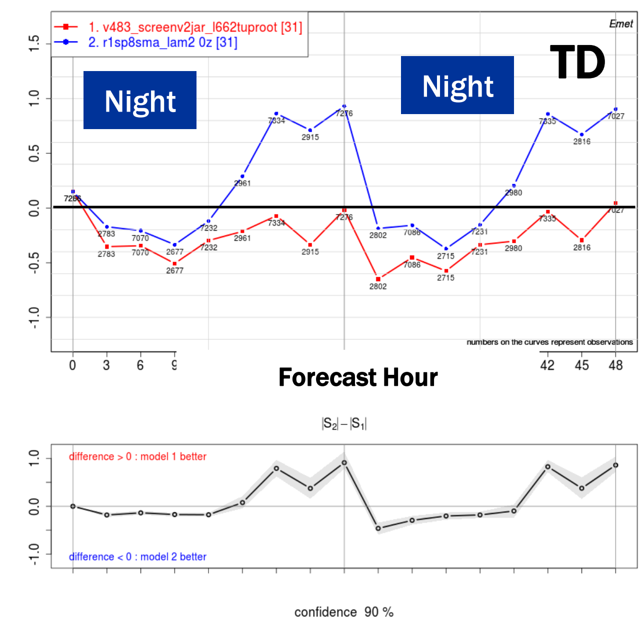
wetter

drier

CaLDAS-SCREEN

CaLDAS-SVS-SMAP





warmer

← USA →

colder

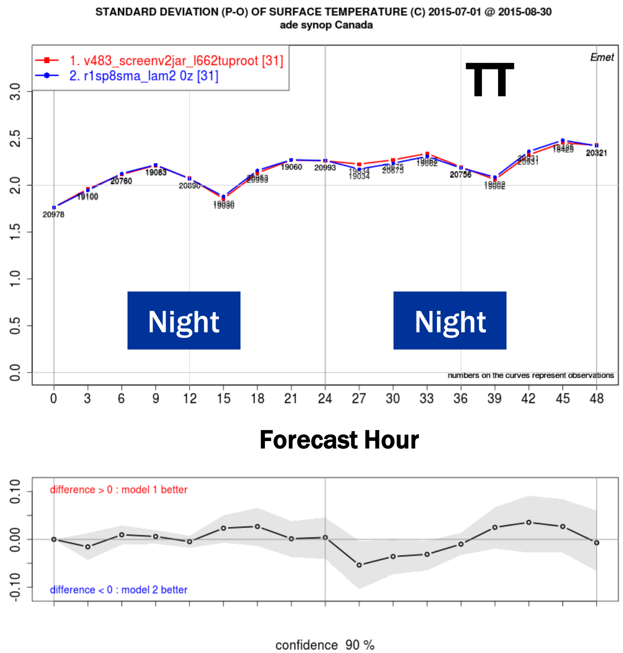
wetter

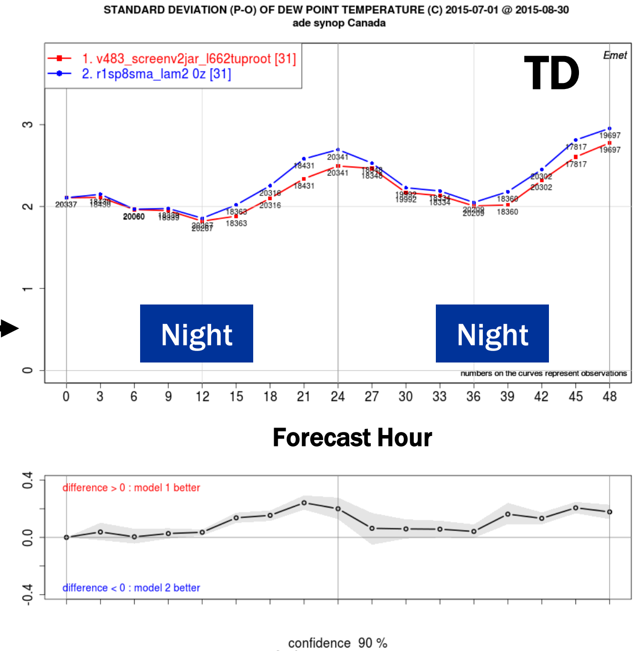
drier

← 90% confidence interval based upon block bootstrapping →

SCREEN+ISBA vs SMAP+SVS

Temperature STDE : July - August 2015, 00Z Runs





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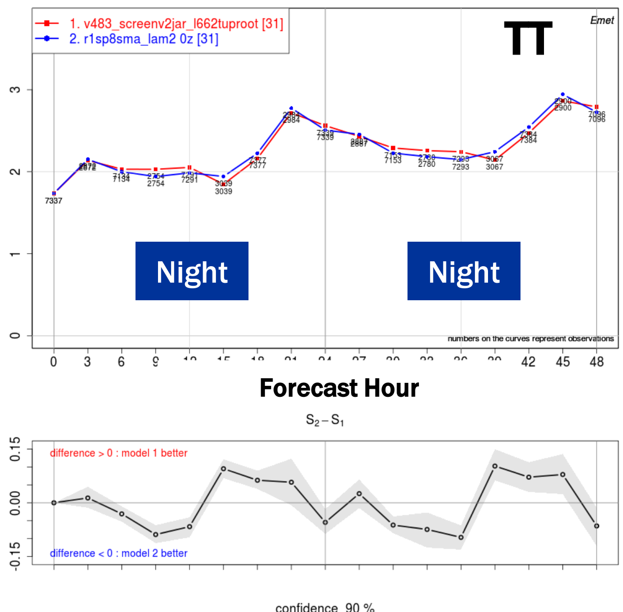
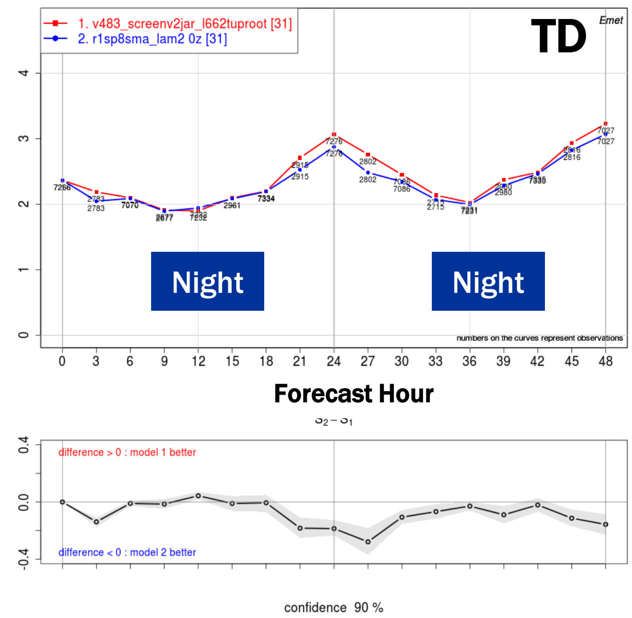
CaLDAS SCREEN

CaLDAS-SVS-SMAP

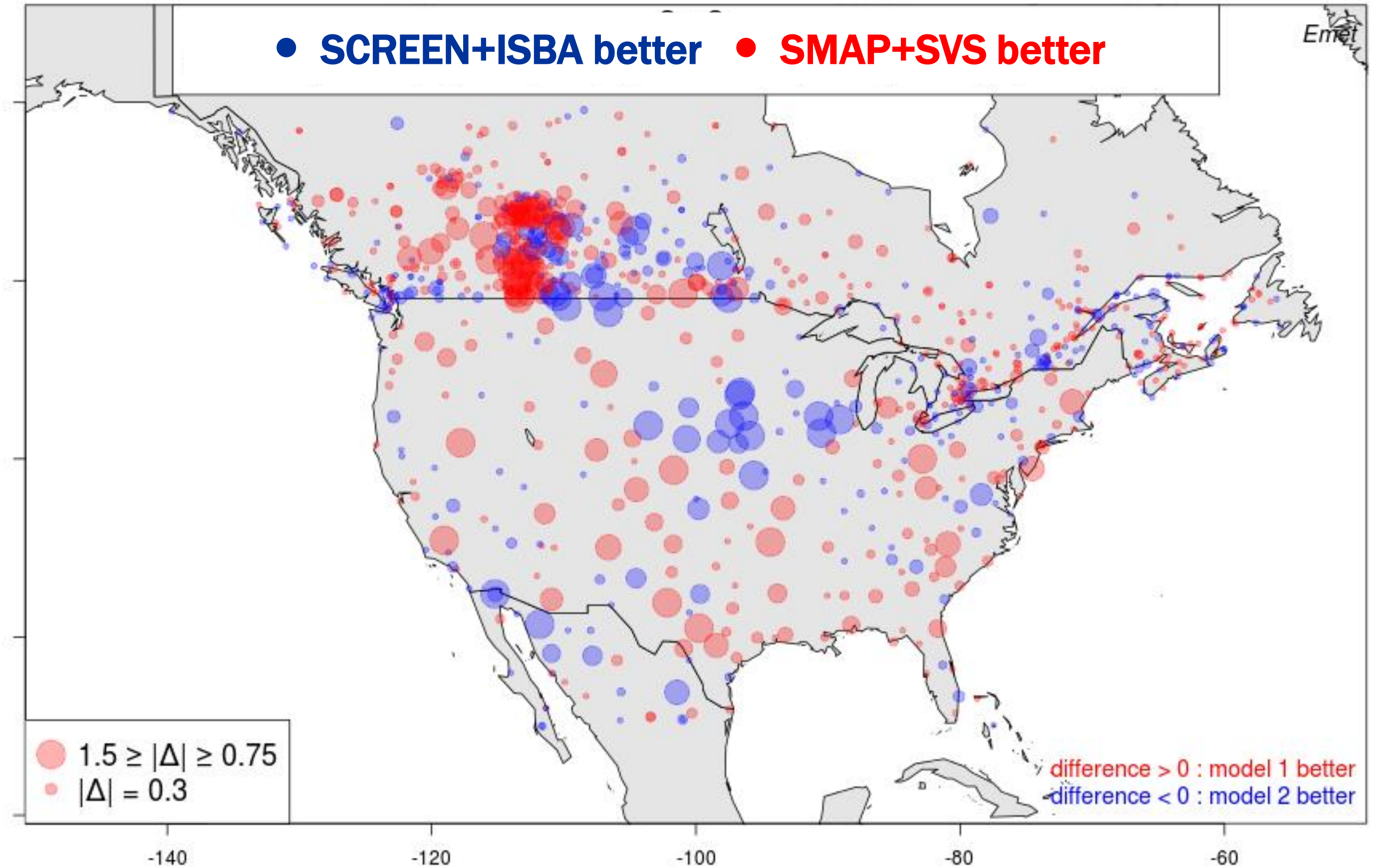
USA





SCREEN+ISBA vs SMAP+SVS

Temperature (TT) STDE : July - August 2015, at 00Z day 2 (24Z) ~mid/late afternoon



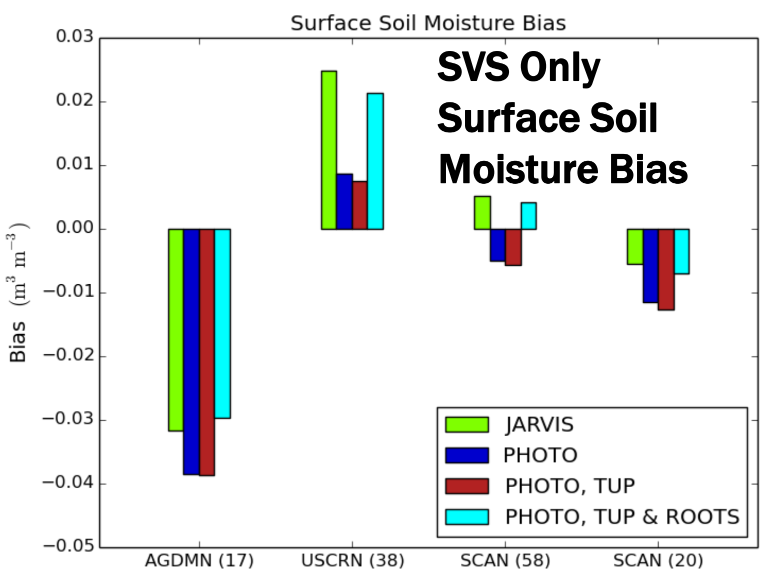
Localized problem areas… Central USA for example…

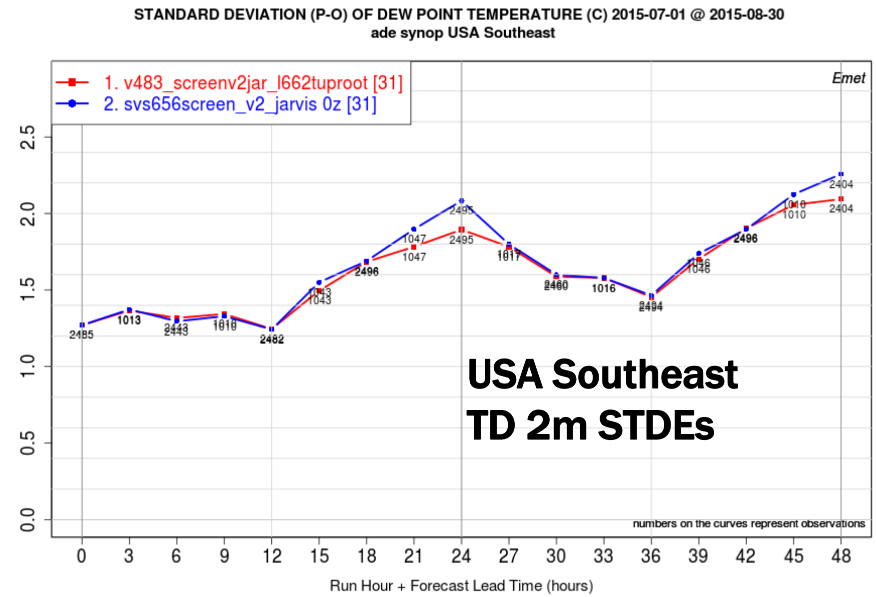
SVS and Vegetation

- Assuming that soil moisture is well specified, the vegetation becomes key in correctly simulating latent heat fluxes
- **Current hypothesis :** soil moisture is well initialized and simulated in SVS, but errors in evapotranspiration lead to errors in fluxes, which lead to low-level air temp. and humidity errors
- **Ongoing tests to**:
  - Improve parametrization of stomatal resistance (one of the main factors controlling vegetation latent heat fluxes)
  - Fine-tune vegetation characteristics (e.g., root depth) in problem areas using soil moisture and screen-level errors for guidance given lack of data

Note: Land surface model changes affect both CaLDAS assimilation cycle and forecasts

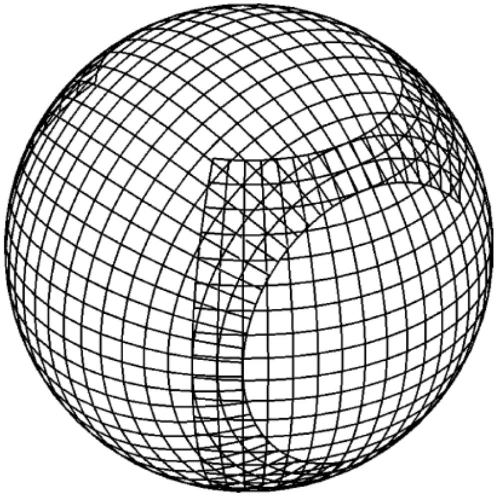
SVS stomatal resistance tests





SUMMARY

- Assimilating SMAP TBs leads to significant improvements in temporal correlations for both w_g and w_2 when compared to the use of screen-level parameters alone. Unbiased RMSEs are also improved.
- Using a more complex land surface model (SVS vs. ISBA) further improves the correlations and unbiased RMSEs.
- Better soil moisture (and land surface temperature) at start time generally leads to improved short-range (0-48hr) NWP forecasts (TT,TD) … but a few problem areas persist… ongoing work to address the areas where we see a deterioration in screen-level (2m) scores
- Ongoing tests focused on simulation of stomatal resistance and specification of vegetation characteristics (e.g., roots) in SVS. Modification to SVS impacts both the CaLDAS analysis cycle and the NWP forecasts.
- Irrigation (un-modeled processes)
- **Next Step:** Global Domain

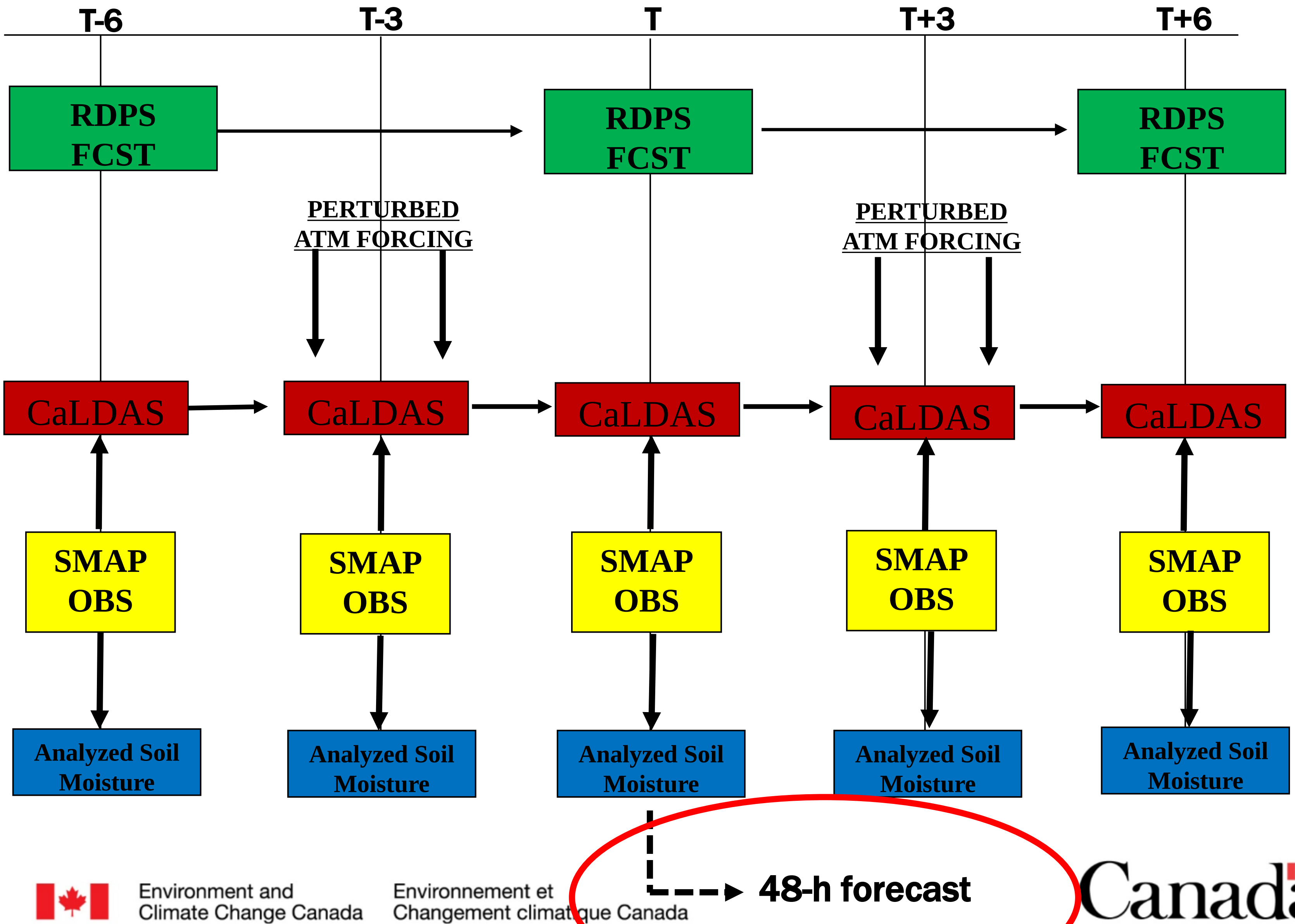


**NWP tests were performed over North America where the screen-level data coverage can be considered good. Anticipate larger impacts over more data sparse regions.

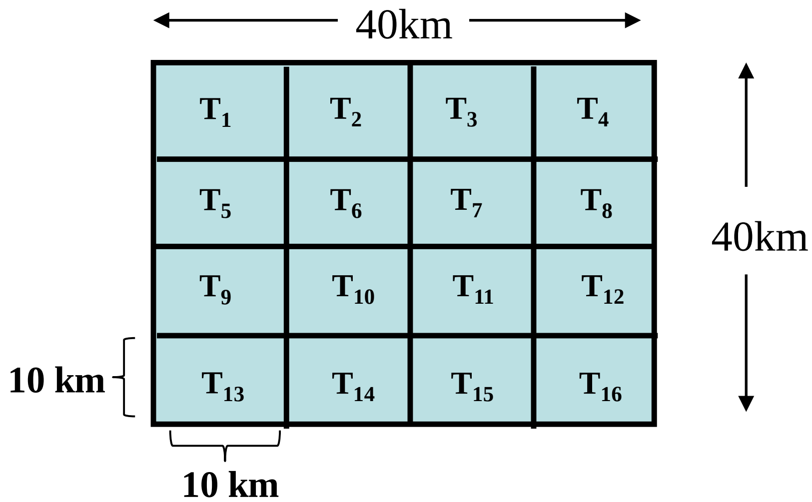
Thank you for your attention

(Nothing like SMAP and Vegetation…)

CaLDAS-SMAP Experimental Setup



TB "Downscaling" Strategy; Within EnKF algorithm



DeLannoy et al. (2010)

- Observation: TB at 40 km.
- Each sub tile (T_i) seems the same innovation: $TB(SMOS) - \frac{1}{16}\sum_{i=1}^{16} TB_i$

- This innovation needs to be distributed to each sub tile.
- Correlations between the fine-scale (10 km) model states and the coarse-scale (40 km) observation predictions downscales the coarse-scale innovations.

$$BH^T \cong Cov[(w_g, w_2); TB]; HBH^T \cong Cov[TB, TB]$$

fine-scale coarse -scale coarse -scale