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Canada

Impact of SMAP data in ECCC's numerical predictions

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SMAP-Canada Workshop – 2017

University of Guelph, Ontario, Canada

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Soil Moisture and Numerical Weather Prediction (NWP)

- Accurate initialization of the soil moisture state has been shown to be important for skillful weather and climate prediction.
  - Depth and stability of atmospheric boundary layer
  - Controls on evaporation in the pre-squall environment associated with intense convection
  - Influences air quality and the dispersion of pollutants
- At several meteorological centres, soil moisture is inferred from short-range NWP forecast errors in screen-level temperature and humidity, so-called "pseudo-analysis" of soil moisture.
- Increasing applications in hydrology, flood forecasting and agricultural and drought monitoring have placed more emphasis on accurate estimates of soil moisture.
- Gap in soil moisture observations is being alleviated by Soil Moisture Ocean Salinity (SMOS) and Soil Moisture Active Passive (SMAP), two separate satellite missions dedicated to the measurement of L-band microwave emission.

Objectives

- Quantitatively assess the impacts of assimilating SMAP brightness temperatures (Tbs) upon the estimation of the soil moisture state and the subsequent NWP forecasts with Environment Canada's Regional Deterministic Prediction System (RDPS).

- NWP verification will focus upon :

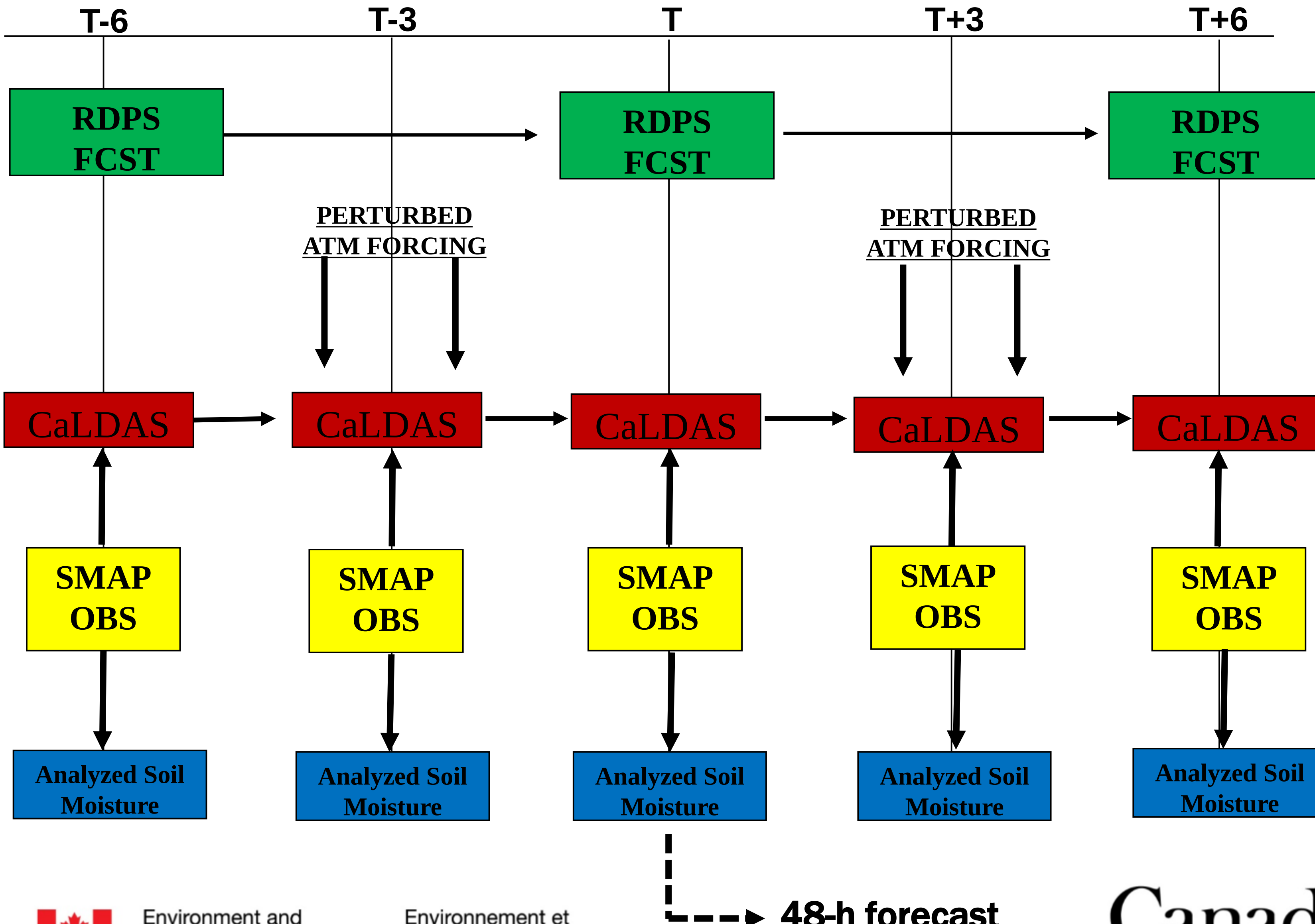
  – (i) upper-level variables with measurements from the radiosonde network over North America;

  – (ii) the SYNOP and METAR surface networks will be used to quantify skill improvements in surface temperature, dew-point temperature and precipitation.

Canadian Land Data Assimilation System (CaLDAS)

- Based upon an externalized (off-line) land-surface modeling capability, currently the Canadian implementation of ISBA.
- Uses the Ensemble Kalman Filter (EnKF) methodology.
- CaLDAS is currently run operationally to provide initial soil and snow characteristics to the High-Resolution Deterministic Prediction System.
- CaLDAS has been configured to assimilate passive L-band Tbs using the Community Microwave Emission Modeling (CMEM) Platform (Carrera et al. 2015).

CaLDAS-SMAP Experimental Setup



Experiment Parameters

Strategy : The current operational assimilation, CaLDAS-Screen soil moisture will be compared with various configurations of the Canadian Land Data Assimilation System (CaLDAS) setup to assimilate the SMAP TBs.

- Time Period : July – August 2015.
- NWP System : Regional Deterministic Prediction System (RDPS) with a grid spacing of 10 km covering North America.
- SMAP TBs : SMAP Level 1B Radiometer Half-Orbit Time-Ordered Brightness Temperatures (Version 3).
- Soil Moisture Analyses: Quantitative verification of soil moisture analyses produced using AGDMN, SCAN and USCRN networks.
- NWP Forecasts: Impacts upon near-surface parameters from a series of 48-h forecasts with the GEM model issued with soil moistures from the various soil moisture analyses.

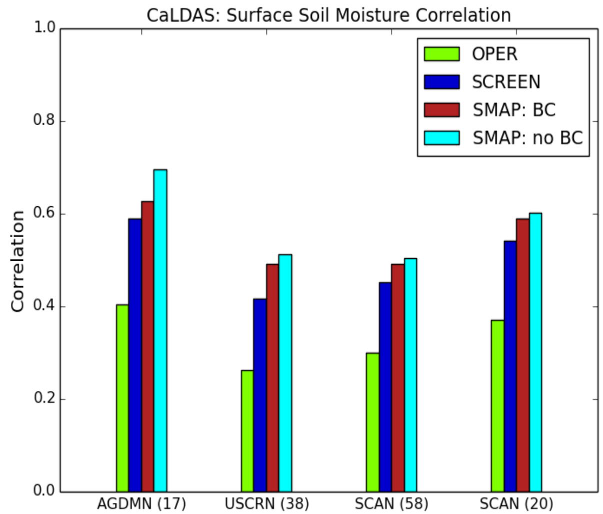
Description of Assimilation Experiments July – August 2015

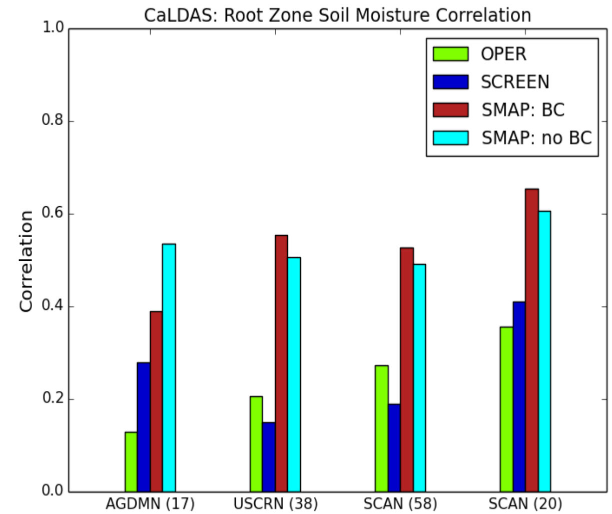
Experiment	Assimilation Methodology	Observations Assimilated	Analyzed Variables	Temporal Frequency	STATUS	LABEL
OI-Operational	Sequential Assimilation	T_{2m}, RH_{2m}	T_s, T_2 w_g, w_2	1 / day	OPERATIONAL RDPS (10 km)	OPER
CaLDAS-Screen	EnKF (24)	T_{2m}, TD_{2m}	w_2, T_2	3 hours	HRDPS (2.5 km)	SCREEN
CaLDAS-SMAP-BC	EnKF (24)	TBH (SMAP) + T_{2m}, TD_{2m}	w_g,w_2, T_2	3 hours	Development	SMAP - BC
CaLDAS-SMAP-no BC	EnKF (24)	TBH (SMAP) + T_{2m}, TD_{2m}	w_g,w_2, T_2	3 hours	Development	SMAP - no BC
CaLDAS-SMAP-no BC - SVS	EnKF (24)	TBH (SMAP) + T_{2m}, TD_{2m}	$w_{1\text{-}4}$, $TG_{1\text{-}2}$, $TVG_{1\text{-}2}$	3 hours	Development	SMAP - no BC - SVS

Soil Moisture Verification
Sparse Networks

Sparse Network Soil Moisture Verification
July – August 2015

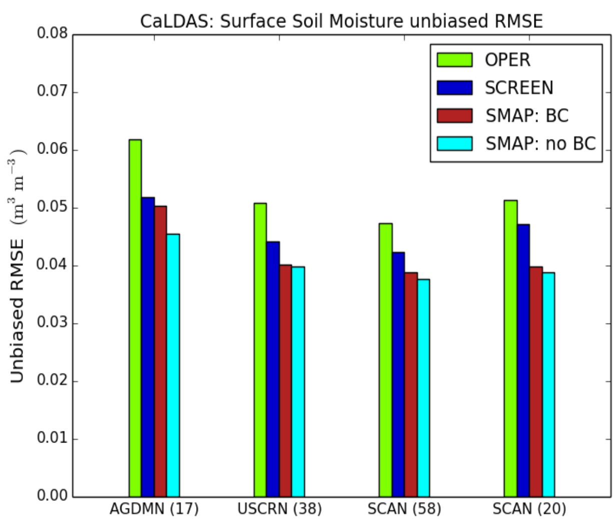
Correlation

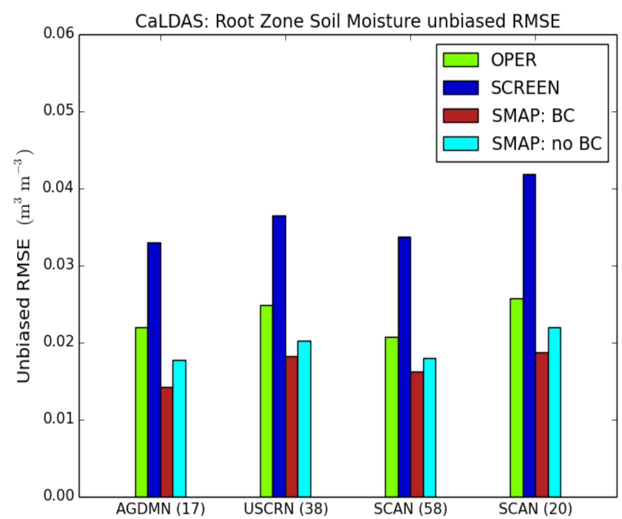




Superficial Soil Moisture w_g

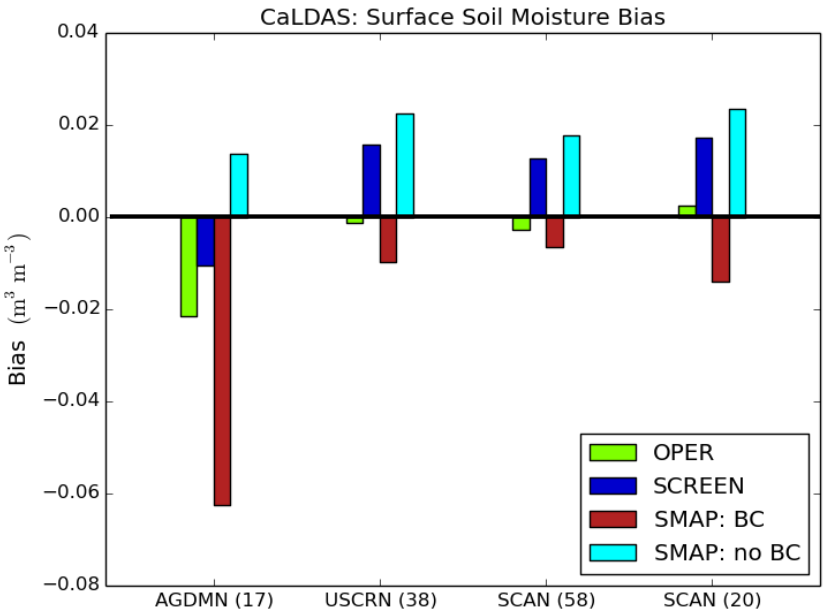
STDE





Root Zone Soil Moisture w_2

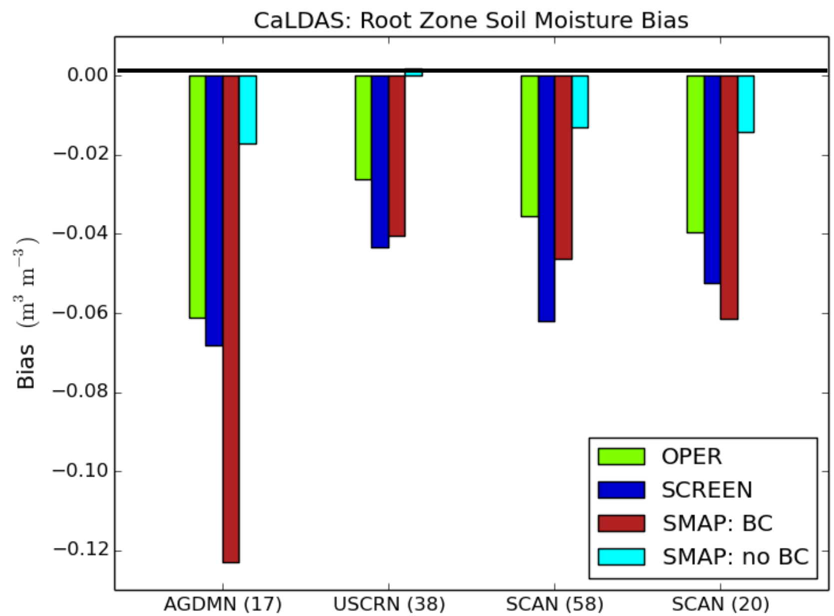
Sparse Network Soil Moisture Verification : Bias
July – August 2015



Wet

Dry

Superficial Soil Moisture w_g



Wet

Dry

Root Zone Soil Moisture w_2

Numerical Weather Prediction Scores

• Series of 48-h integrations with the GEM (Global Environmental Multiscale) NWP model initialized at 0000 UTC for July-August 2015.

• Upper-air radiosonde verification scores.

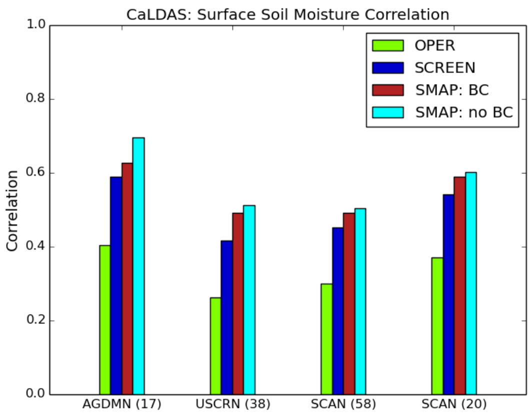
• Surface verification scores : TT_{2m} and TD_{2m} along with precipitation.

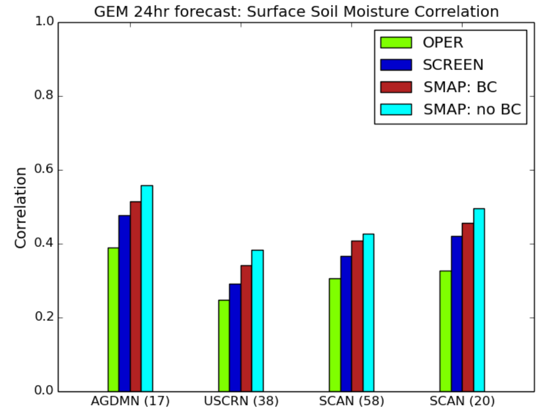
Soil Moisture Forecast Verification : Sparse Network
Correlation : July – August 2015

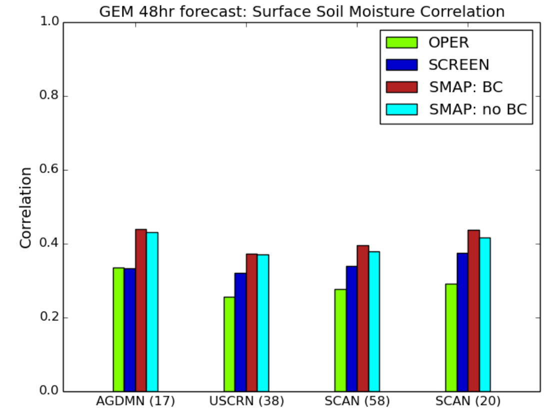
24h

48h

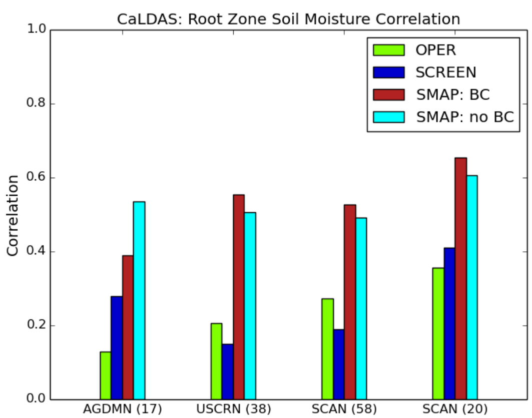
W_g

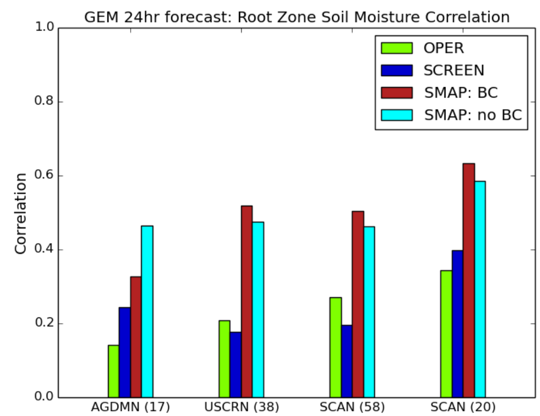


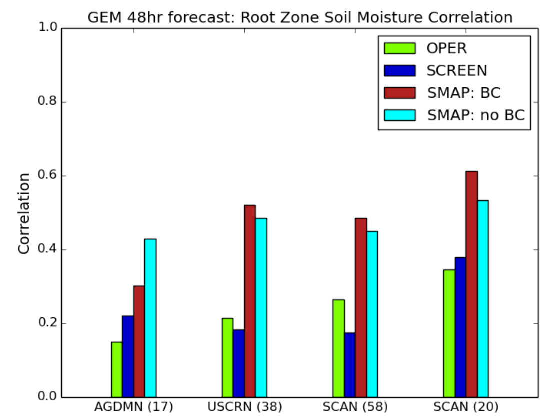




W_2







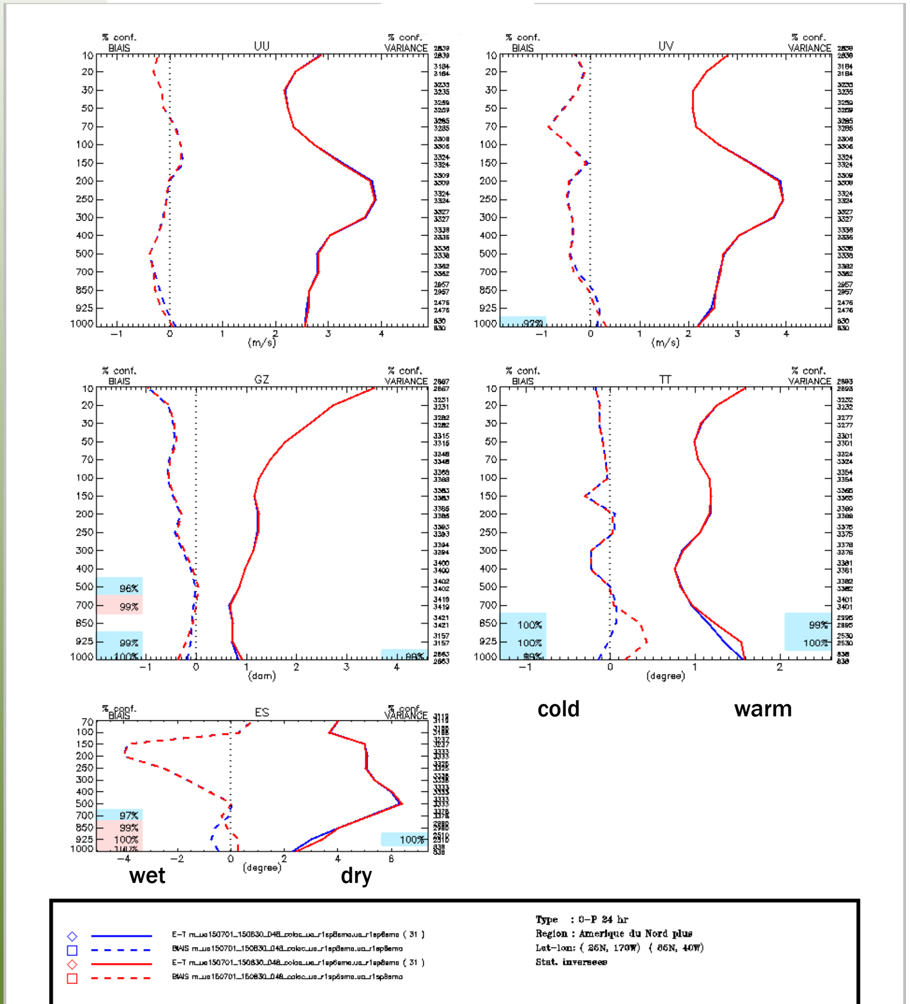
CaLDAS-Screen (T_{2m}, TD_{2m}, 3hrs; w_2, T_2) vs

SMAP – BC (T_{2m}, TD_{2m}, TBH(SMAP), 3hrs; w_g, w_2, T_2)

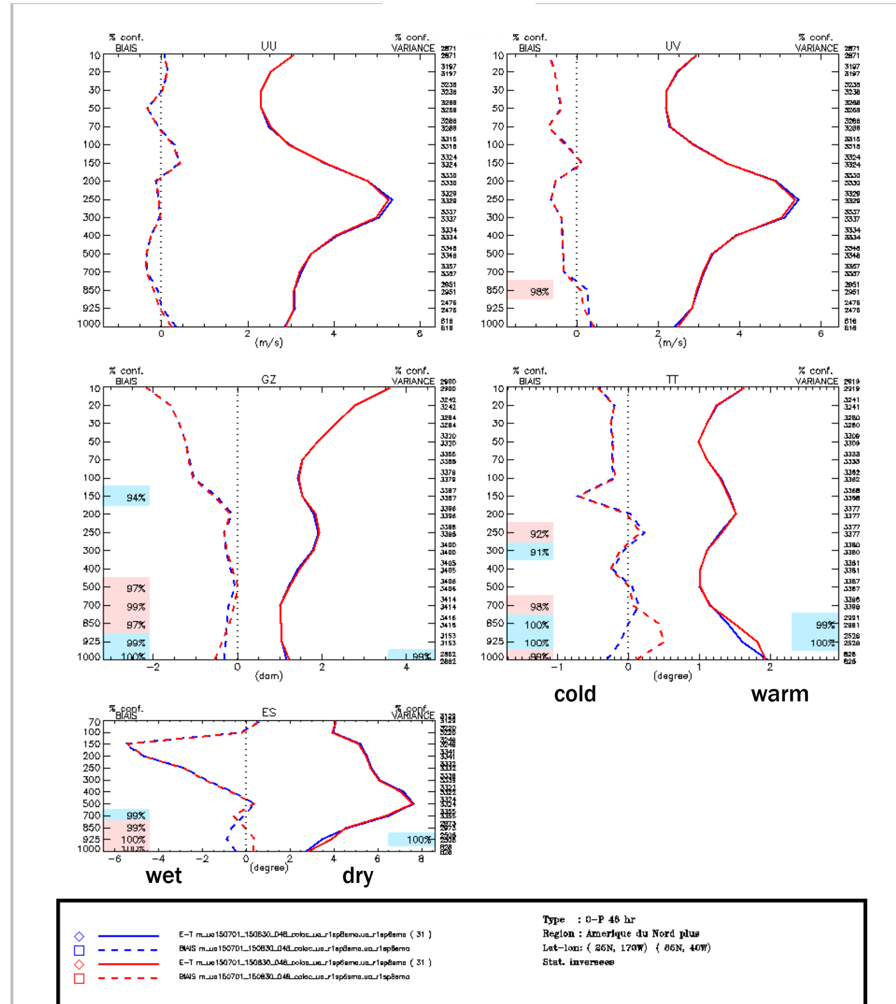
CaLDAS-Screen vs CaLDAS-SMAP – BC

Greater North America :Forecast - Observation

24h



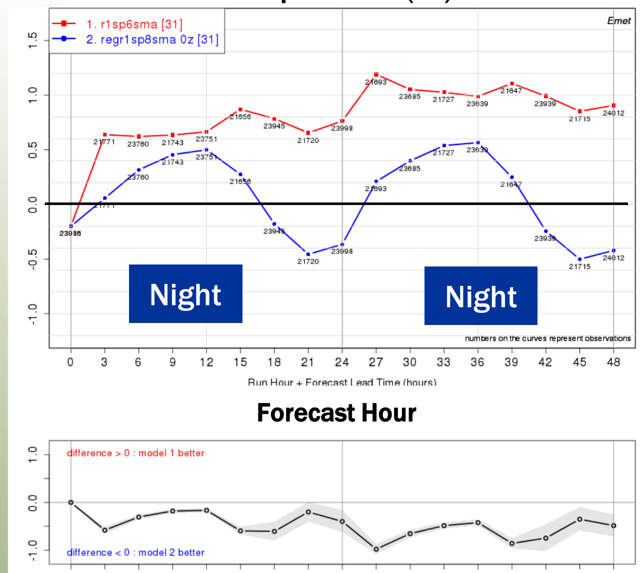
48h



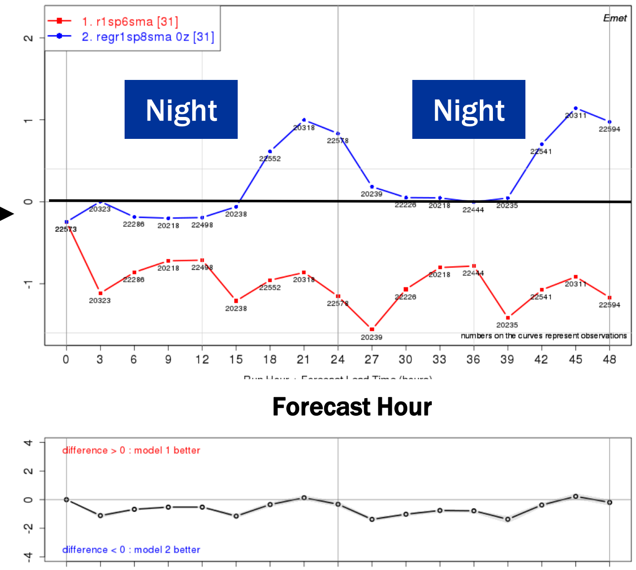
CaLDAS-SCREEN vs CaLDAS-SMAP-BC

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

Temperature (ºC)



Dew-Point Temperature (ºC)



CaLDAS-SCREEN

CaLDAS-SMAP-BC

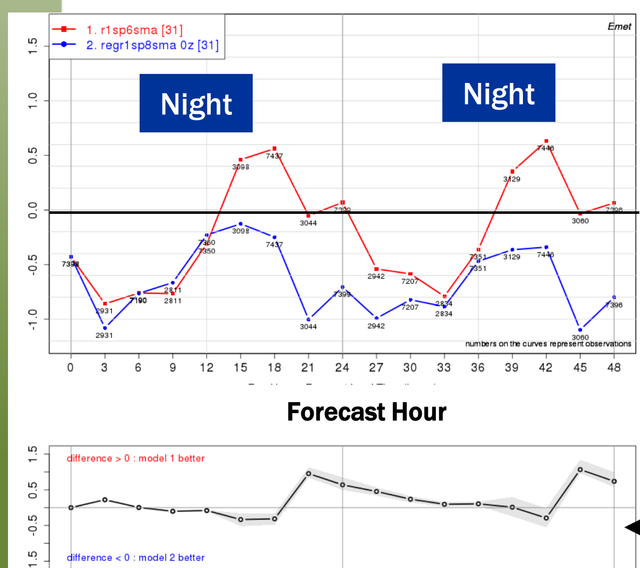
warmer

colder

Canada

wetter

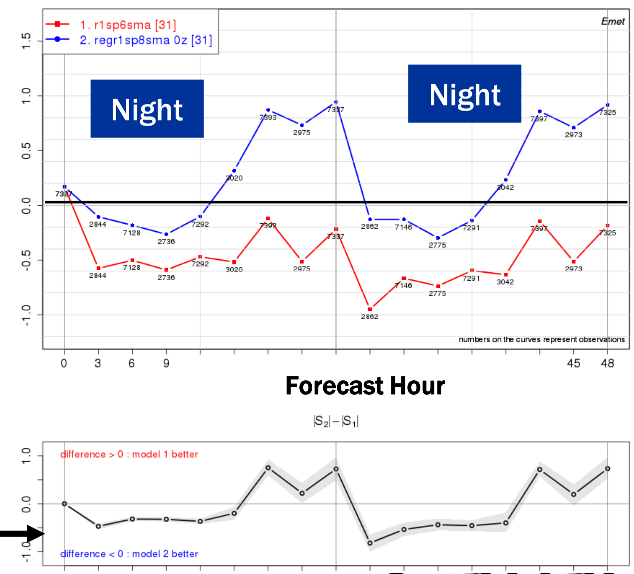
drier



warmer

colder

USA



wetter

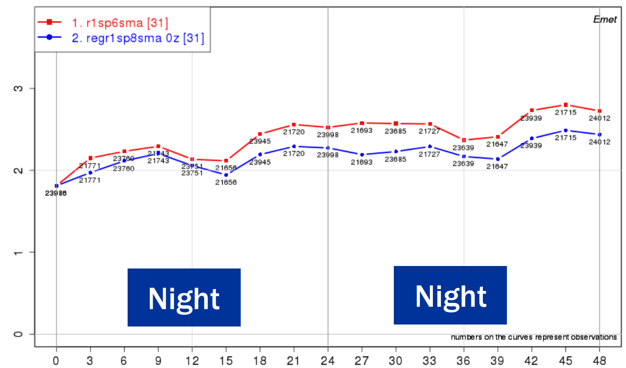
drier

90% confidence interval based upon block bootstrapping

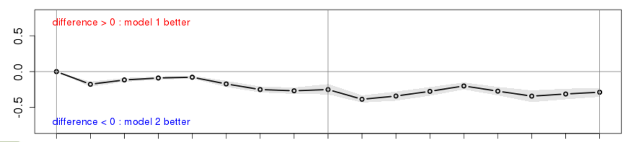
CaLDAS-SCREEN vs CaLDAS-SMAP-BC
Temperature STDE : July - August 2015, 00Z Runs

CaLDAS-SCREEN
CaLDAS-SMAP-BC

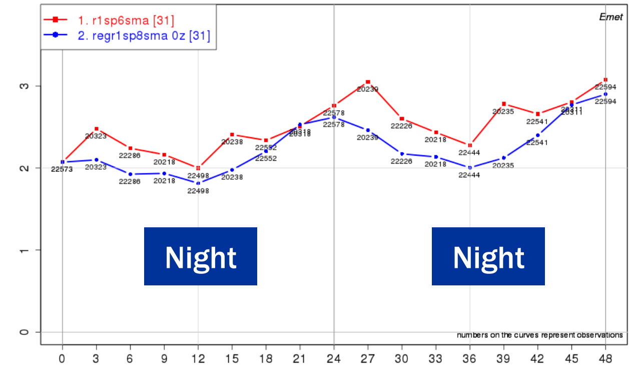
Temperature (°C)



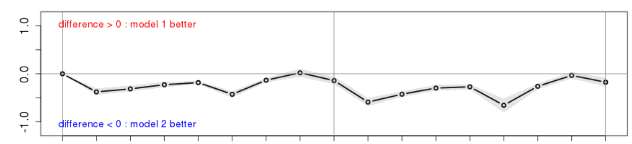
Forecast Hour



Dew-Point Temperature (°C)

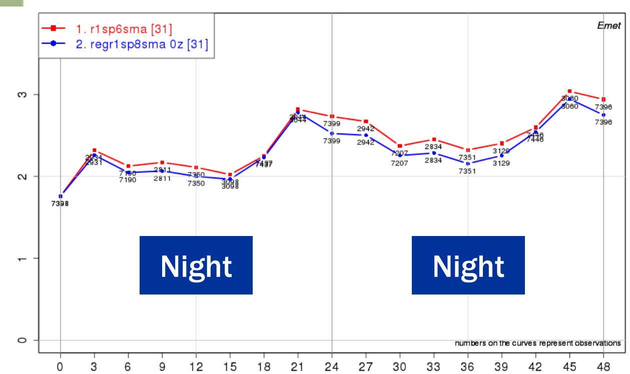


Forecast Hour

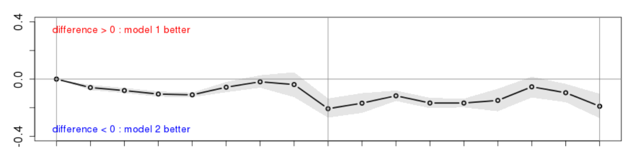


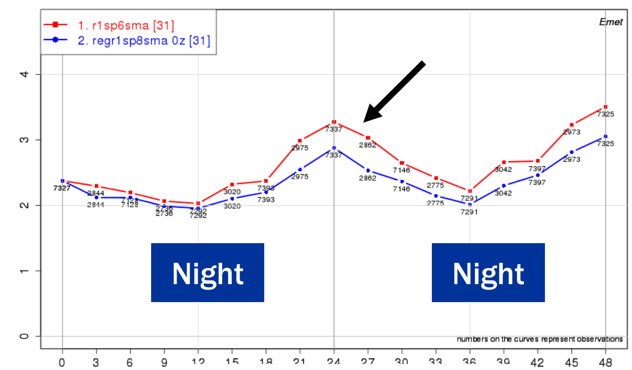
Canada

USA

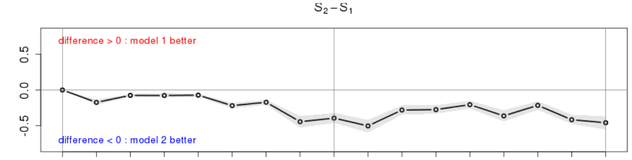


Forecast Hour





Forecast Hour



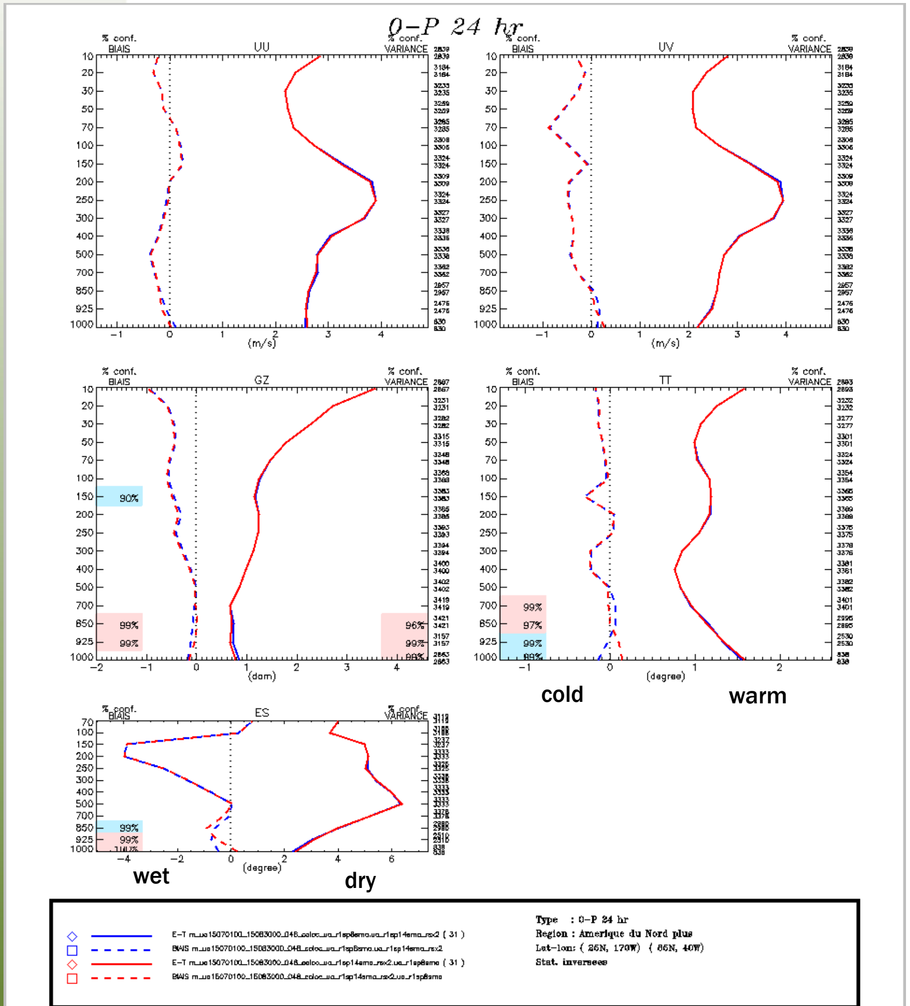
CaLDAS-Screen (T_{2m}, TD_{2m}, 3hrs; w_2, T_2) vs

SMAP – no BC (T_{2m}, TD_{2m}, TBH(SMAP), 3hrs; w_g, w_2, T_2)

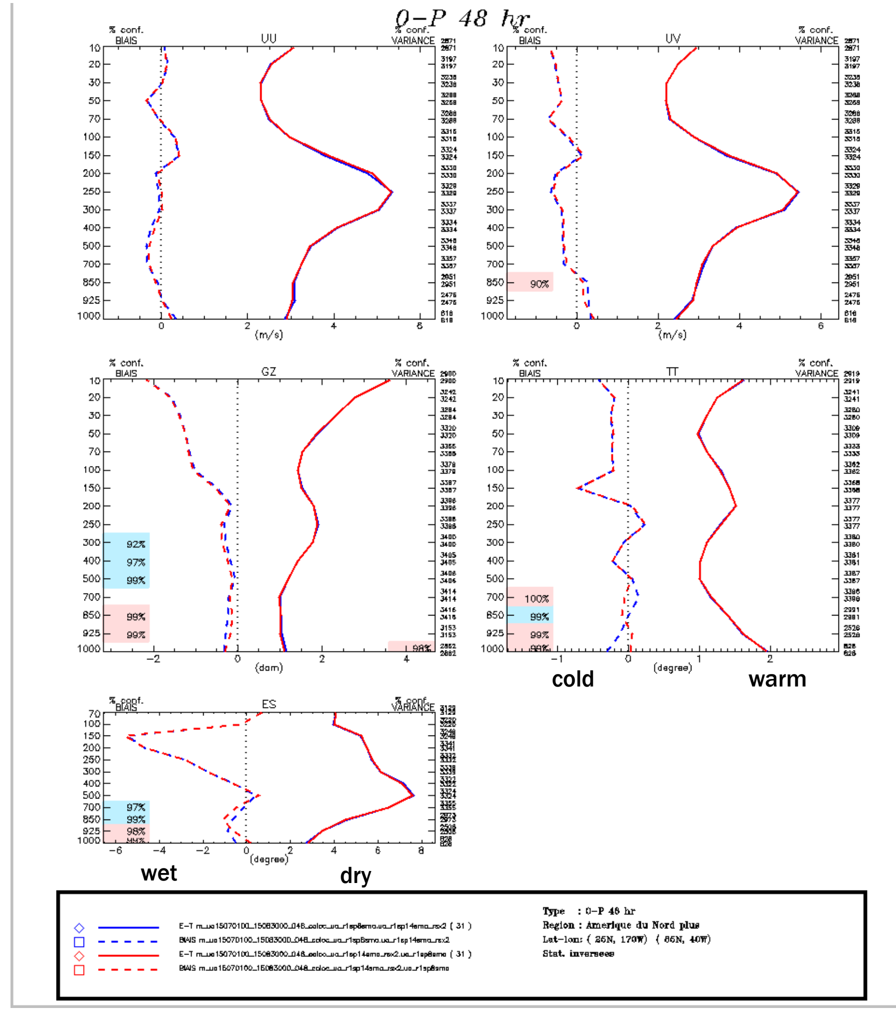
CaLDAS-Screen vs CaLDAS-SMAP – no BC

Greater North America :Forecast - Observation

24h



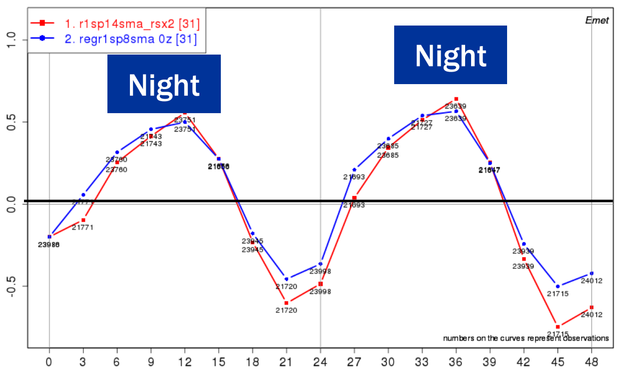
48h



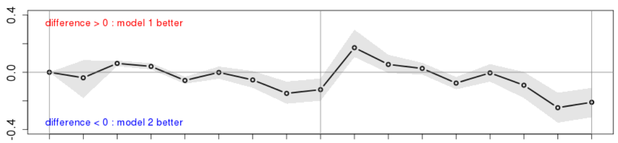
CaLDAS SCREEN vs CaLDAS-SMAP-no BC

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

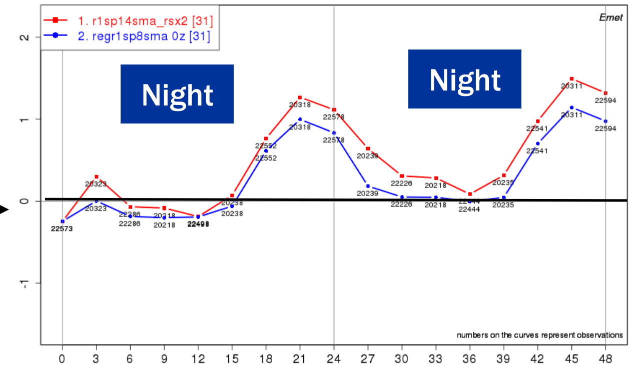
Temperature (°C)



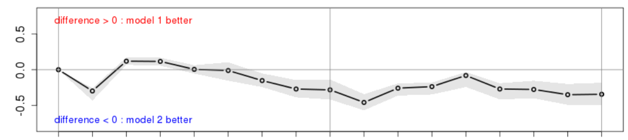
Forecast Hour



Dew-Point Temperature (°C)



Forecast Hour



CaLDAS SCREEN

CaLDAS-SMAP-no BC

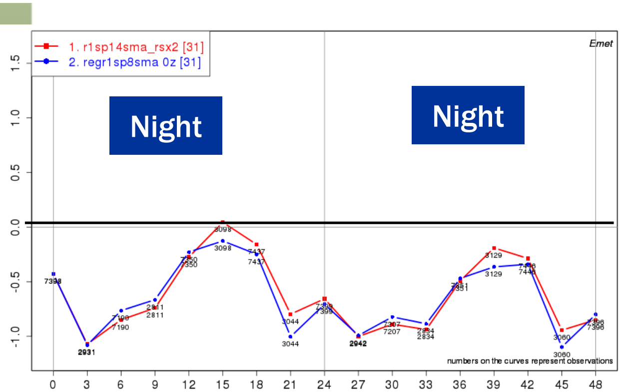
warmer

colder

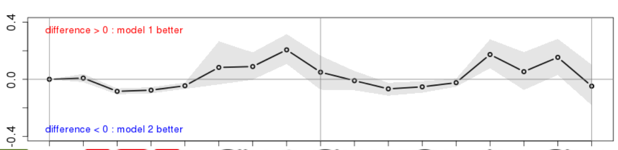
Canada

wetter

drier



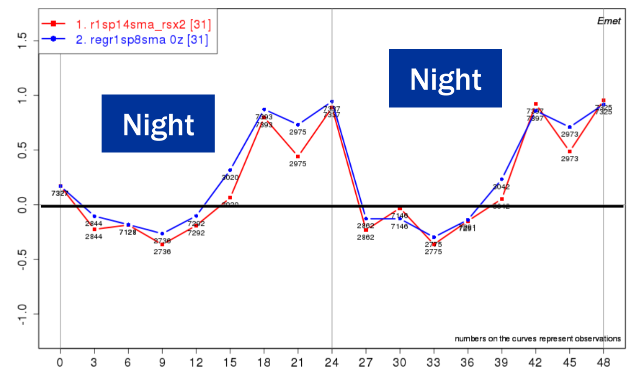
Forecast Hour



warmer

USA

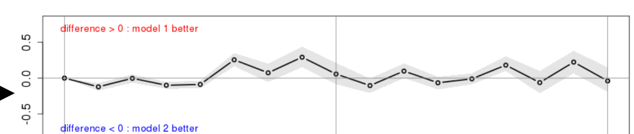
colder



Forecast Hour

wetter

drier



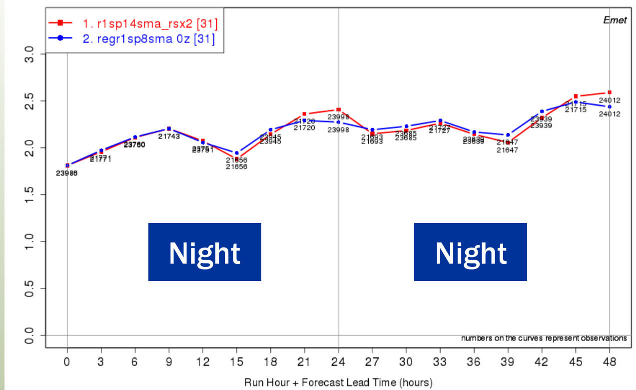
90% confidence interval based upon block bootstrapping

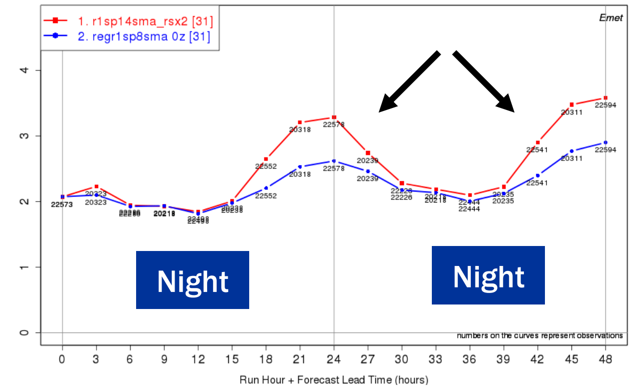
CaLDAS SCREEN vs CaLDAS-SMAP-no BC

Temperature STDE : July - August 2015, 00Z Runs

Temperature (ºC)

Dew-Point Temperature (ºC)



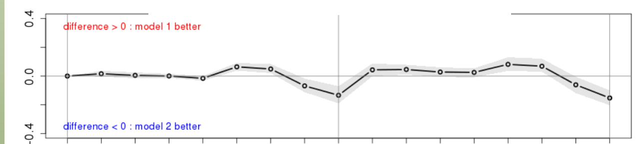


CaLDAS SCREEN

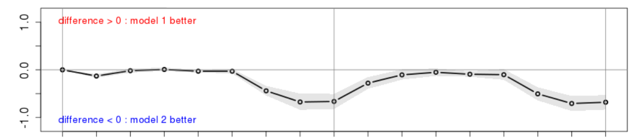
CaLDAS-SMAP-no BC

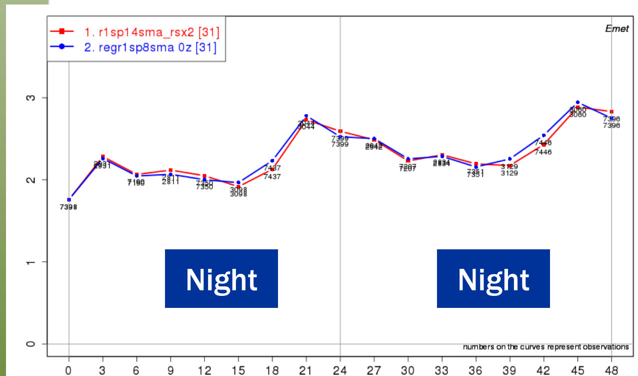
Canada

Forecast Hour

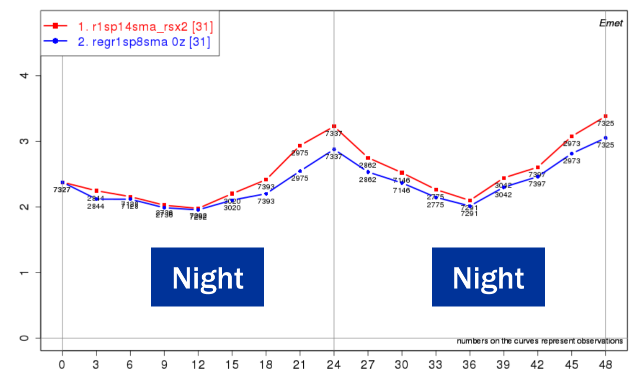


Forecast Hour



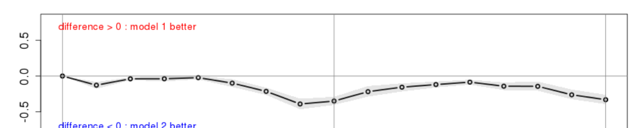


USA



Forecast Hour

Forecast Hour



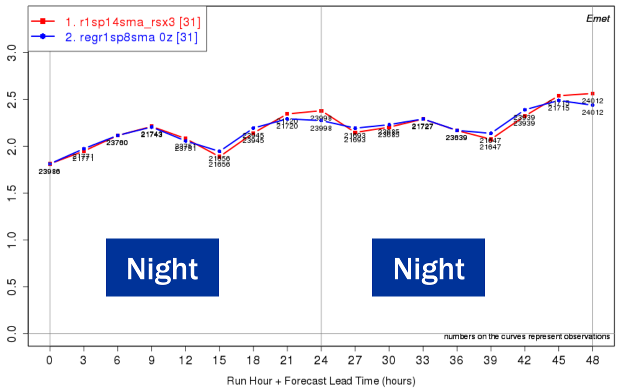
CaLDAS-Screen (T_{2m}, TD_{2m}, 3hrs; w_2, T_2) vs

SMAP – no BC (r_sx3) (T_{2m}, TD_{2m}, TBH(SMAP), 3hrs; w_g, w_2, T_2)

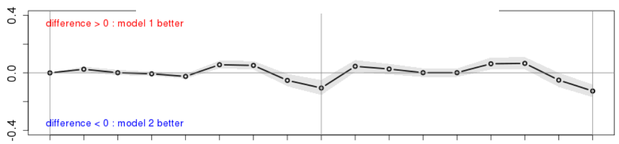
CaLDAS SCREEN vs CaLDAS-SMAP –no BC (r_sx3)

Temperature STDE : July - August 2015, 00Z Runs

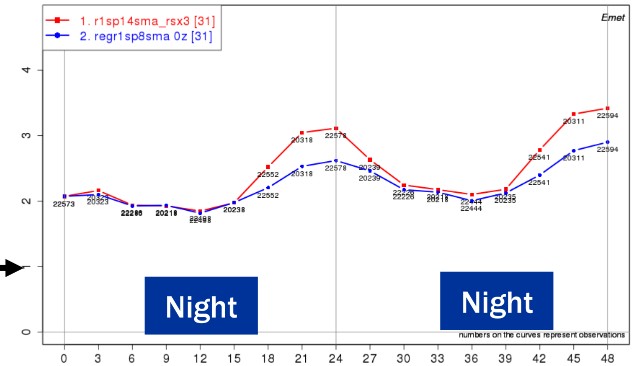
Temperature (ºC)



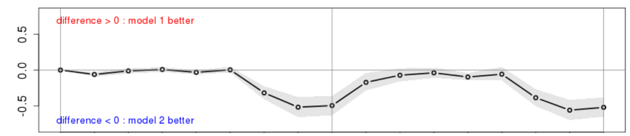
Forecast Hour



Dew-Point Temperature (ºC)



Forecast Hour

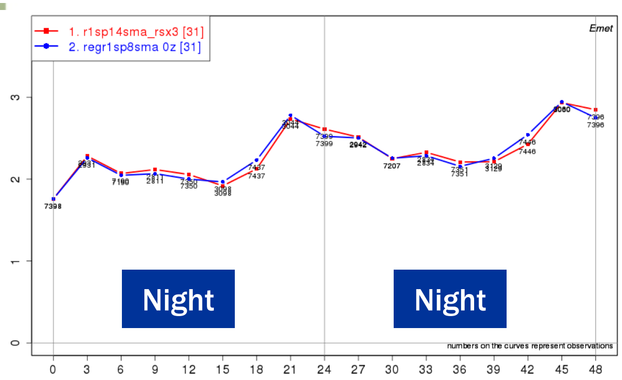


CaLDAS SCREEN

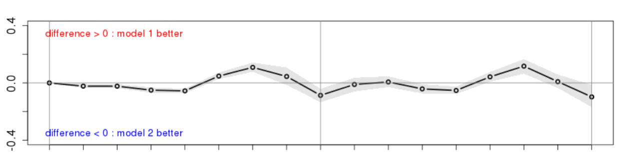
CaLDAS-SMAP-no BC (r_sx3)

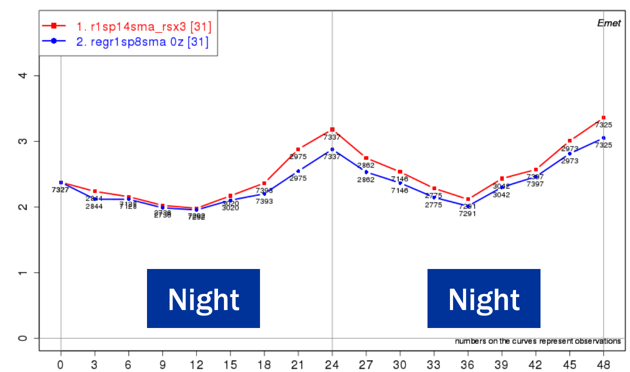
Canada

USA

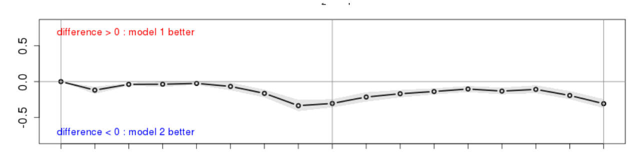


Forecast Hour





Forecast Hour

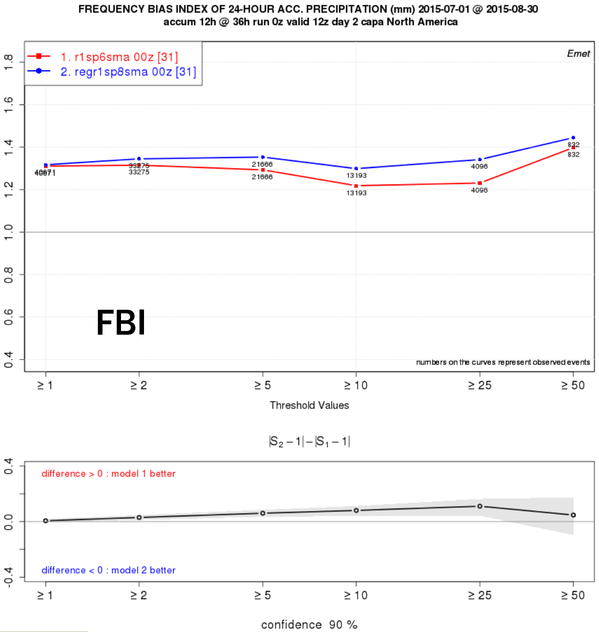


Precipitation Scores
24h Accumulation over North America

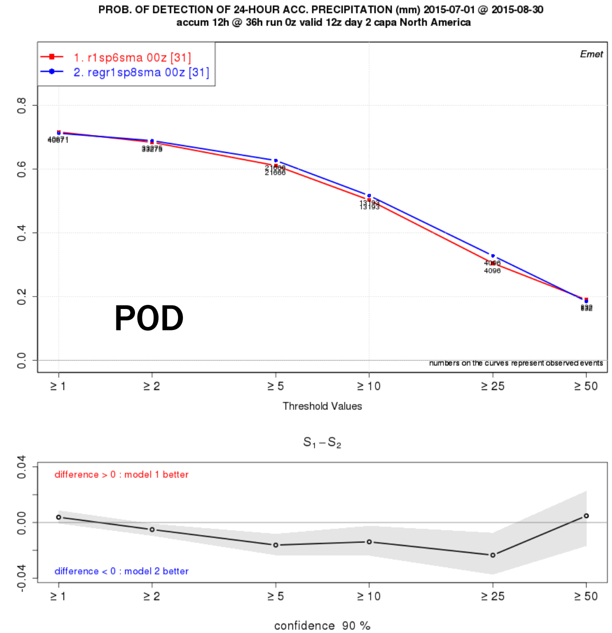
FBI = Frequency Bias Index
POD = Probability of Detection
FAR = False Alarm Ratio
ETS = Equitable Threat Score

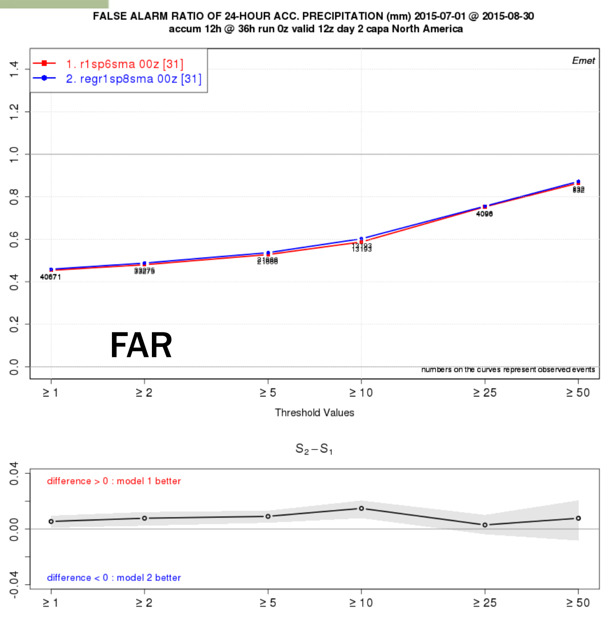
Precipitation-24 h : North America July - August 2015

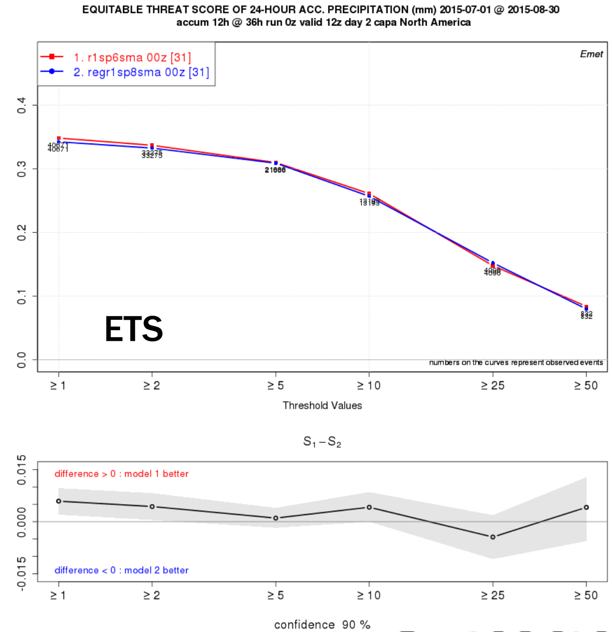
CaLDAS-SMAP-BC



CaLDAS SCREEN

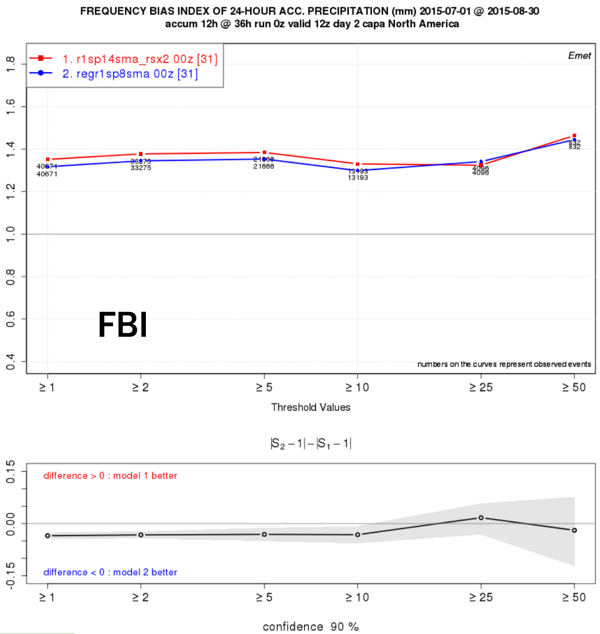




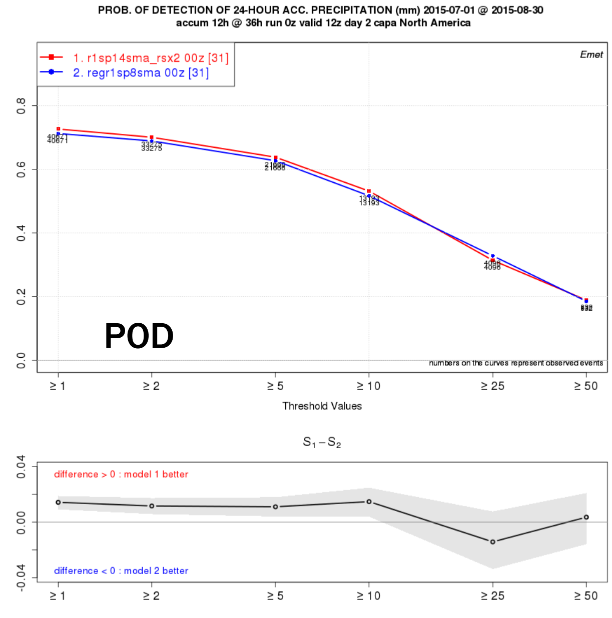


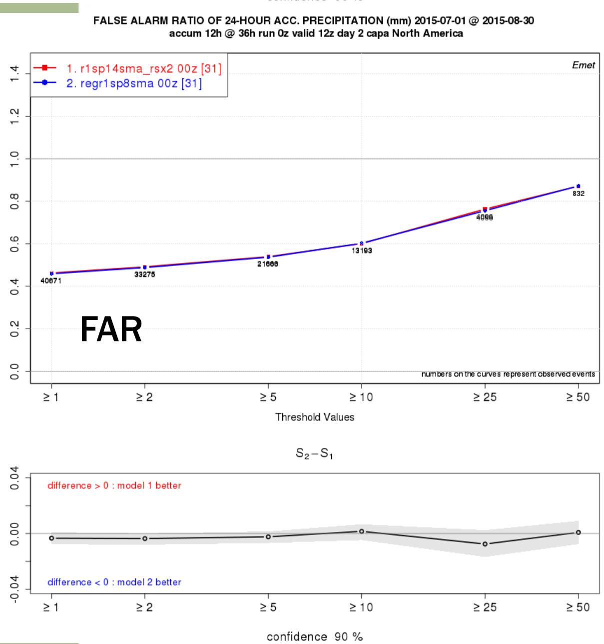
Precipitation-24 h : North America July - August 2015

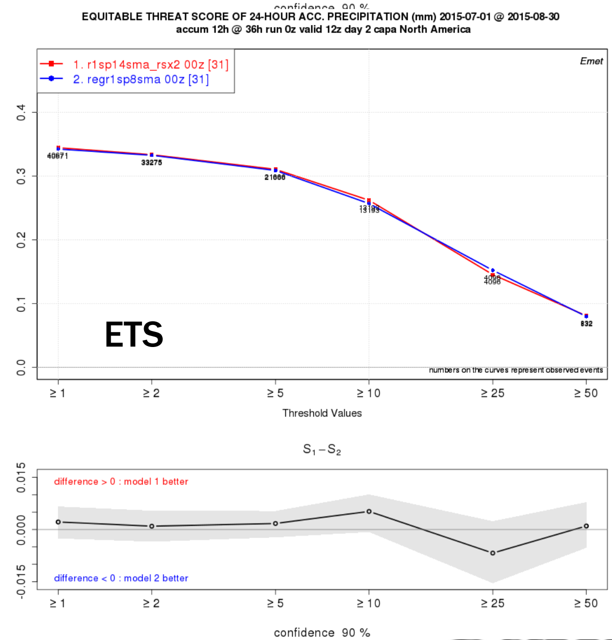
CaLDAS-SMAP-no-BC



CaLDAS SCREEN



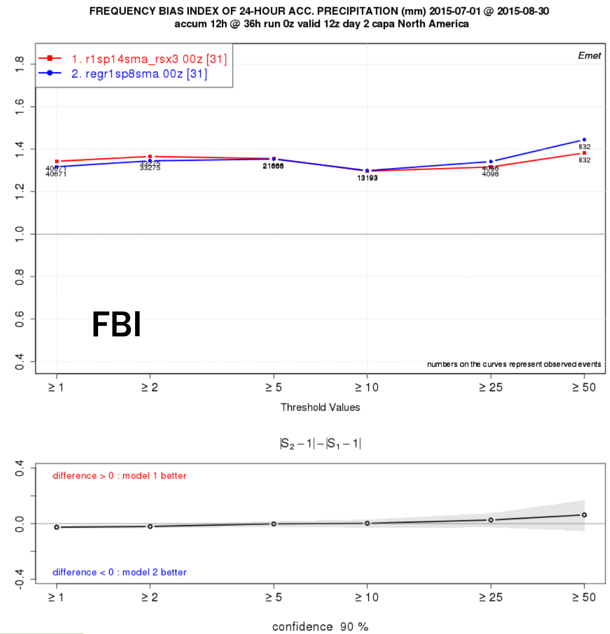


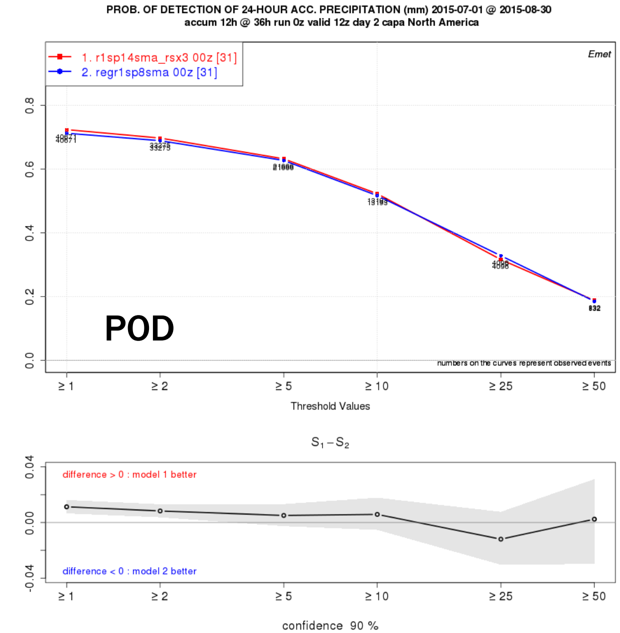


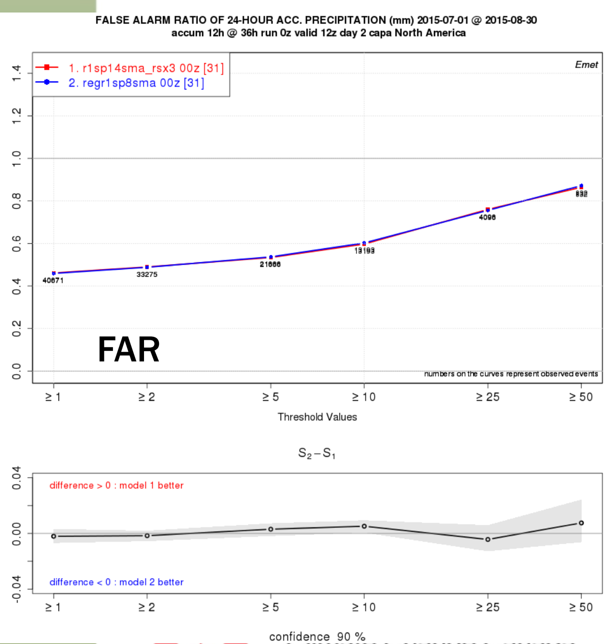
Precipitation-24 h : North America July - August 2015

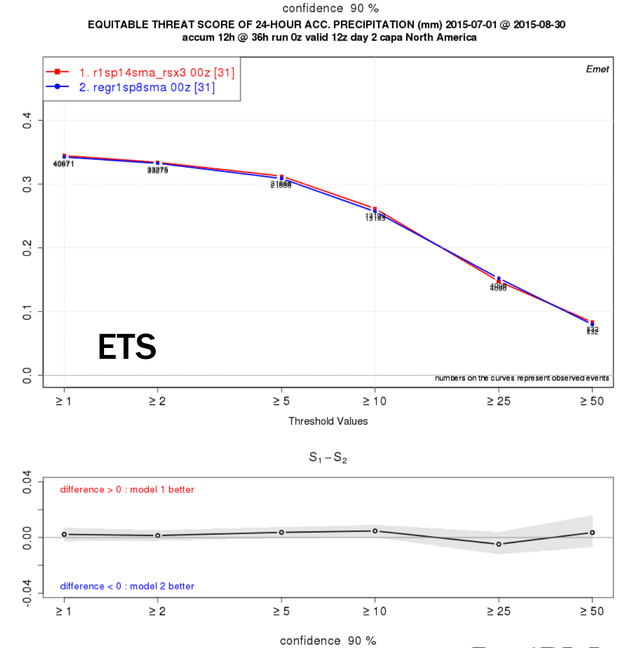
CaLDAS-SMAP-no-BC (r_sx3)

CaLDAS SCREEN









SVS (Soil, Vegetation, Snow) Land Surface Model

Alavi et al. (2016), Husain et al. (2016)

- **Multi budget energy calculations for bare soil, vegetation and snow.**
- **Improved soil hydrology with the inclusion of multiple soil layers .**

CaLDAS - Screen (T_{2m}, TD_{2m}, 3hrs; w_2, T_2) vs

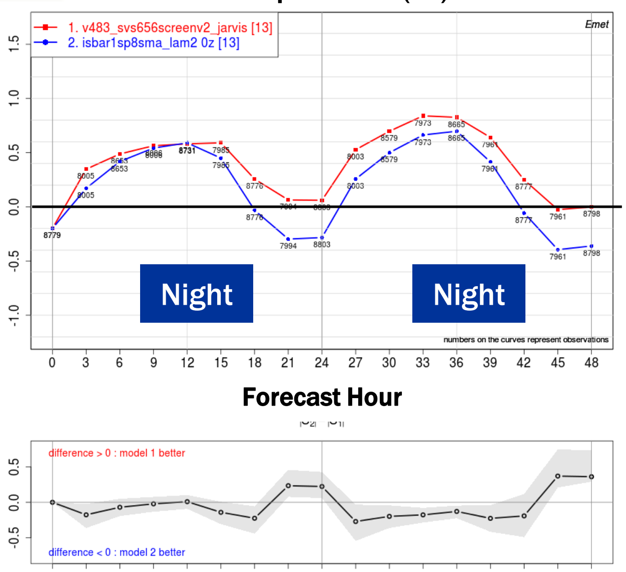
SMAP – no BC –SVS (T_{2m}, TD_{2m}, TBH(SMAP), 3hrs; $w_{1\text{-}4}$, $Tbg_{1\text{-}2}$, $Tvg_{1\text{-}2}$)

Limited to 13 48-h forecasts in July 2015

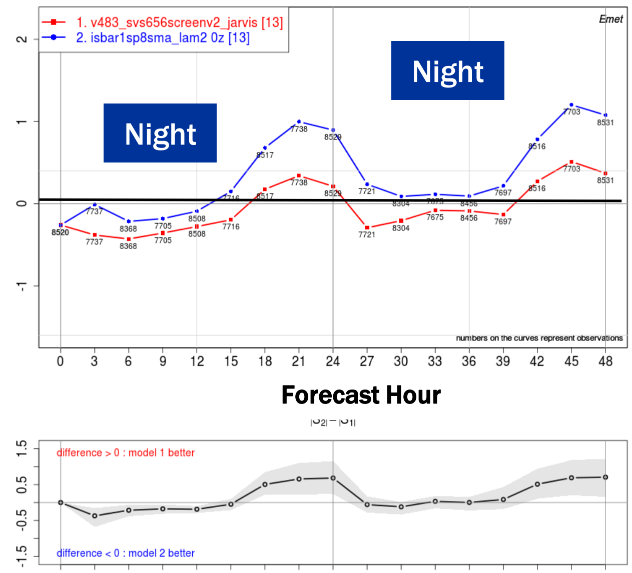
CaLDAS SCREEN vs CaLDAS-SMAP - no BC - SVS

Temperature Biases (F - O) : July 2015, (13) 00Z Runs

Temperature (°C)



Dew-Point Temperature (°C)



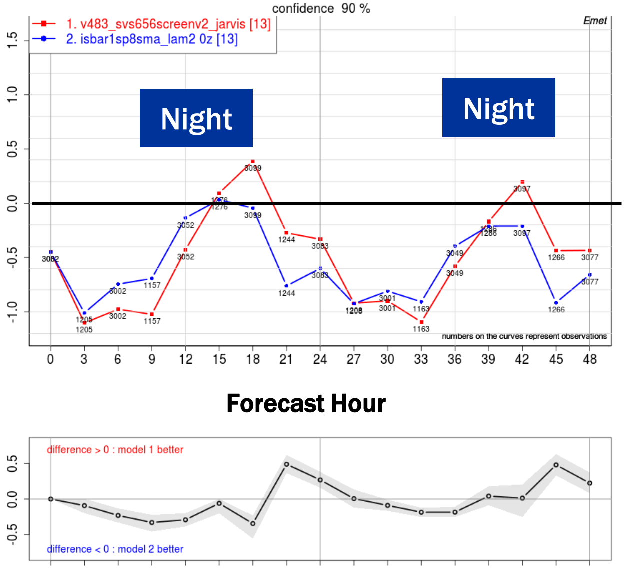
CaLDAS SCREEN

CaLDAS-SMAP-no BC - SVS

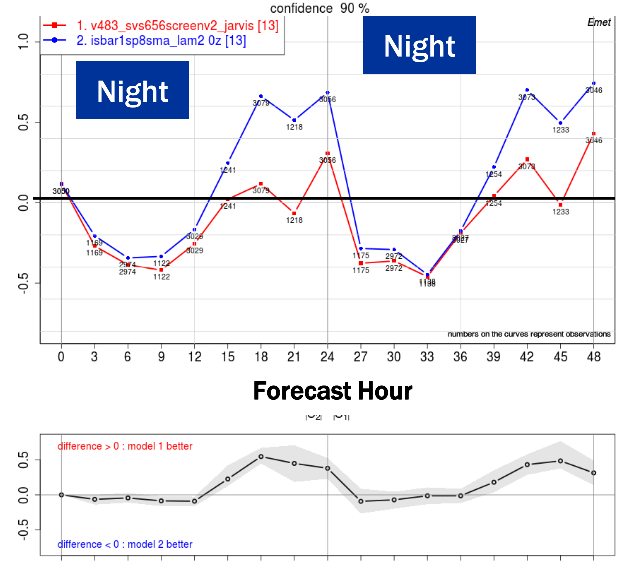
warmer — Canada — wetter

colder — drier

confidence 90 %



confidence 90 %



warmer — USA — wetter

colder — drier

90% confidence interval based upon block bootstrapping

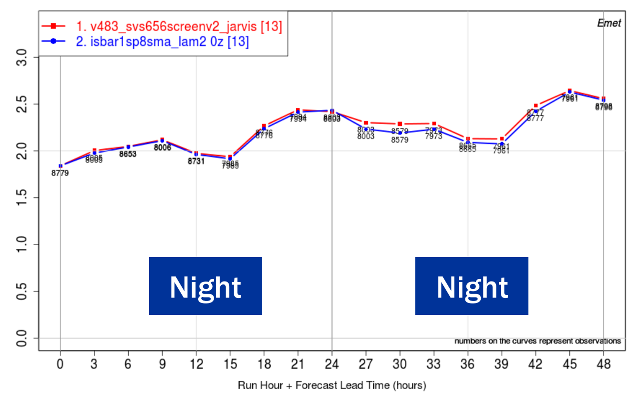
confidence 90 %

confidence 90 %

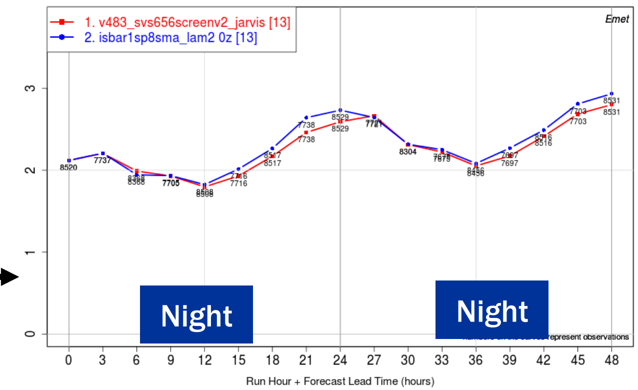
CaLDAS SCREEN vs CaLDAS-SMAP –no BC -SVS

Temperature STDE : July 2015, (13) 00Z Runs

Temperature (°C)



Dew-Point Temperature (°C)

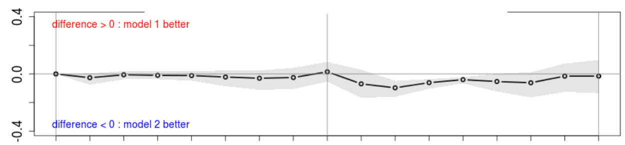


CaLDAS SCREEN

CaLDAS-SMAP-no BC - SVS

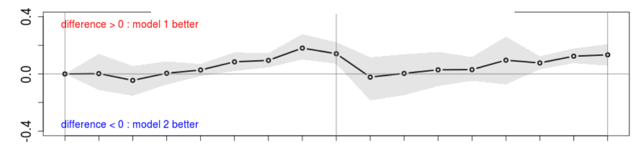
← Canada →

Forecast Hour

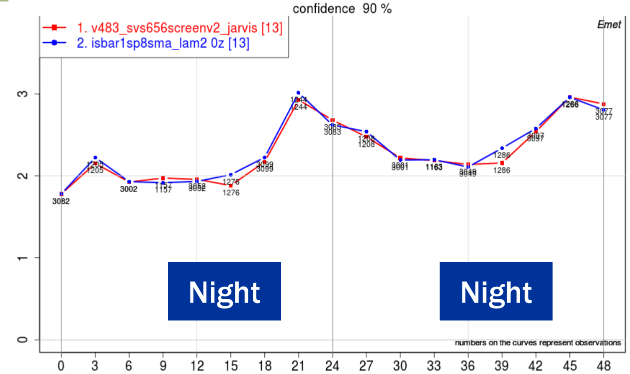


confidence 90 %

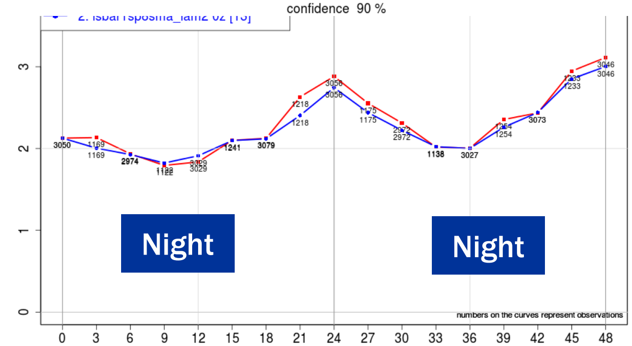
Forecast Hour



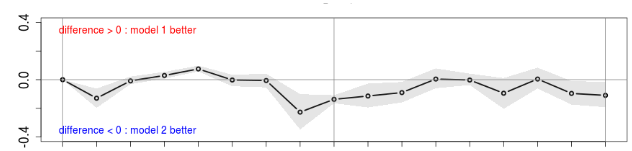
confidence 90 %



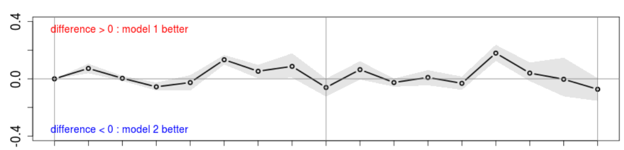
← USA →



Forecast Hour



Forecast Hour



confidence 90 %

confidence 90 %

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ement climatique Canada

Summary

- **<u>Soil Moisture</u>** : Assimilation of SMAP Tb data leads to significant improvements in temporal correlations for both w_g and w_2 when compared to the use of screen-level parameters alone. STDEs are also improved. Assimilating screen level variables more frequently, acts to deteriorate the w_2 verifications scores.

- Assimilation of screen-level variables appears to be necessary to give a comparable level of skill as to the current operational CaLDAS-Screen.

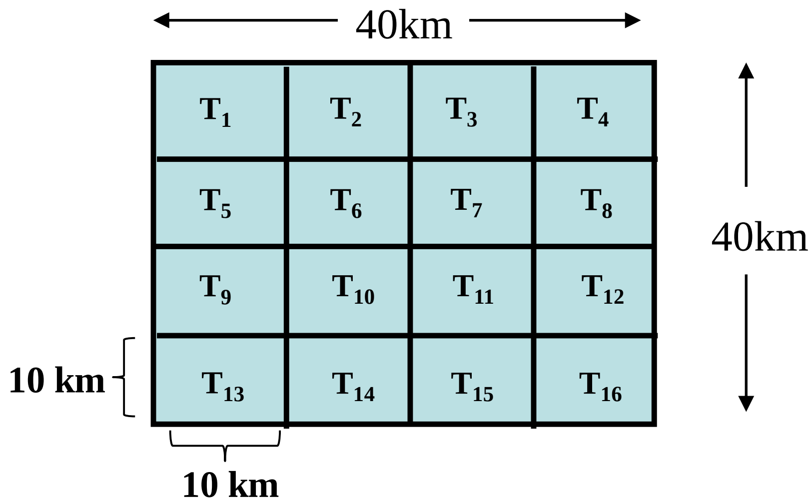
- **<u>Approaching a configuration where</u>** :

- Significantly Improved soil moisture with positive impacts on atmospheric forecasts as compared to the current operational assimilation system.

- <u>Recall</u> : 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

TB "Downscaling" Strategy; Within EnKF algorithm



DeLannoy et al. (2010)

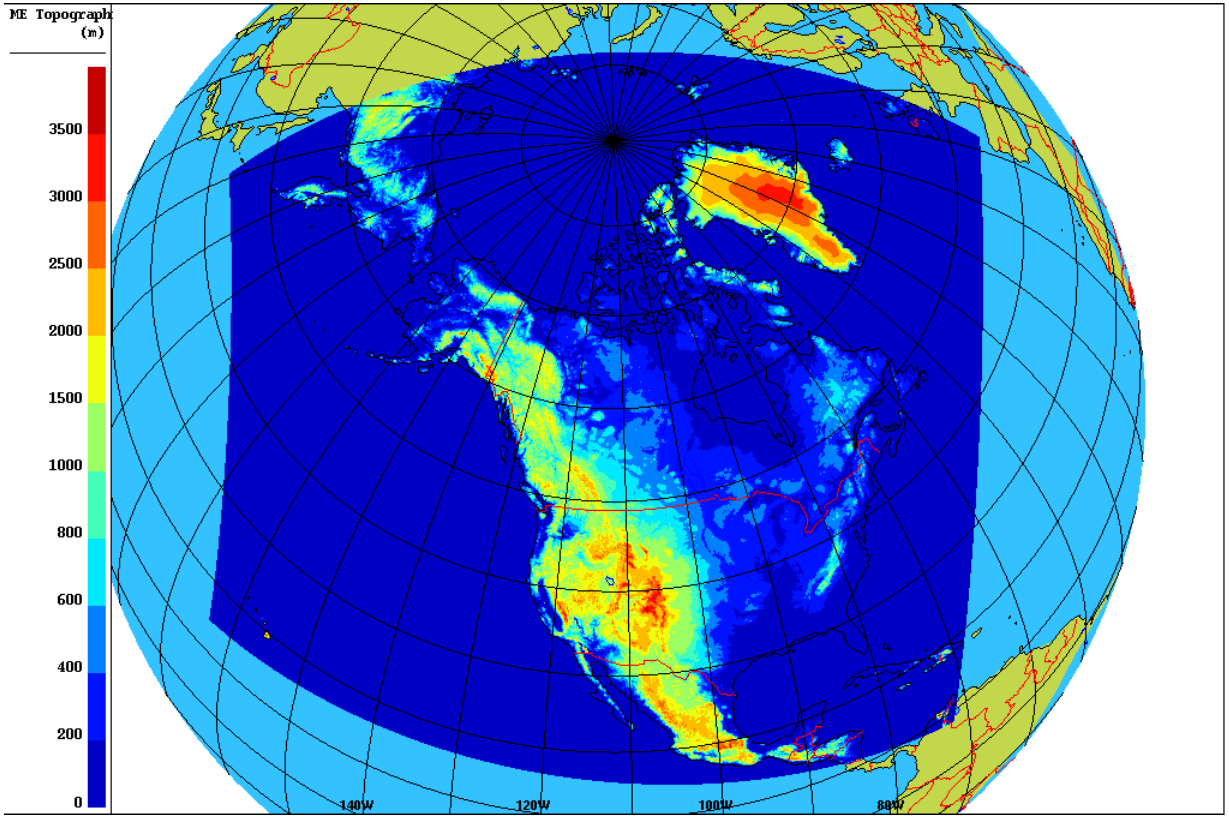
- Observation: TB at 40 km.
- Each sub tile (T_i) seems the same innovation: $TB(SMOS) - \frac{1}{16}\sum_{i=1}^{16} TB_i$

•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.

$$BH^T \cong Cov\left[\left(\underset{\text{fine-scale}}{w_g}, w_2\right); \underset{\text{coarse -scale}}{TB}\right]; HBH^T \cong Cov\left[\underset{\text{coarse -scale}}{TB, TB}\right]$$

RDPS Domain



- Principal short-range guidance (days 1-2) used by Meteorological Service of Canada forecasters.
- Grid spacing of 10 km covering North America and adjacent oceans.
- Launched 4x daily out to 48 h.