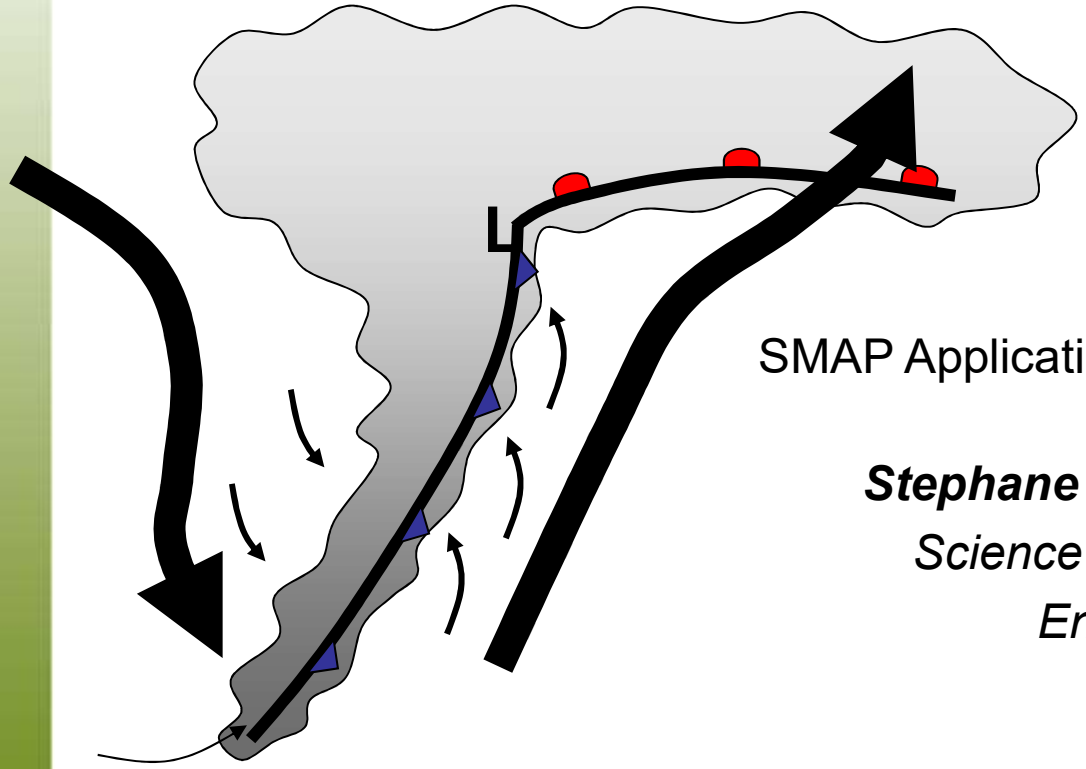
Assimilation and Impact Evaluation of SMAP Observations in Environment Canada's Numerical Prediction Systems



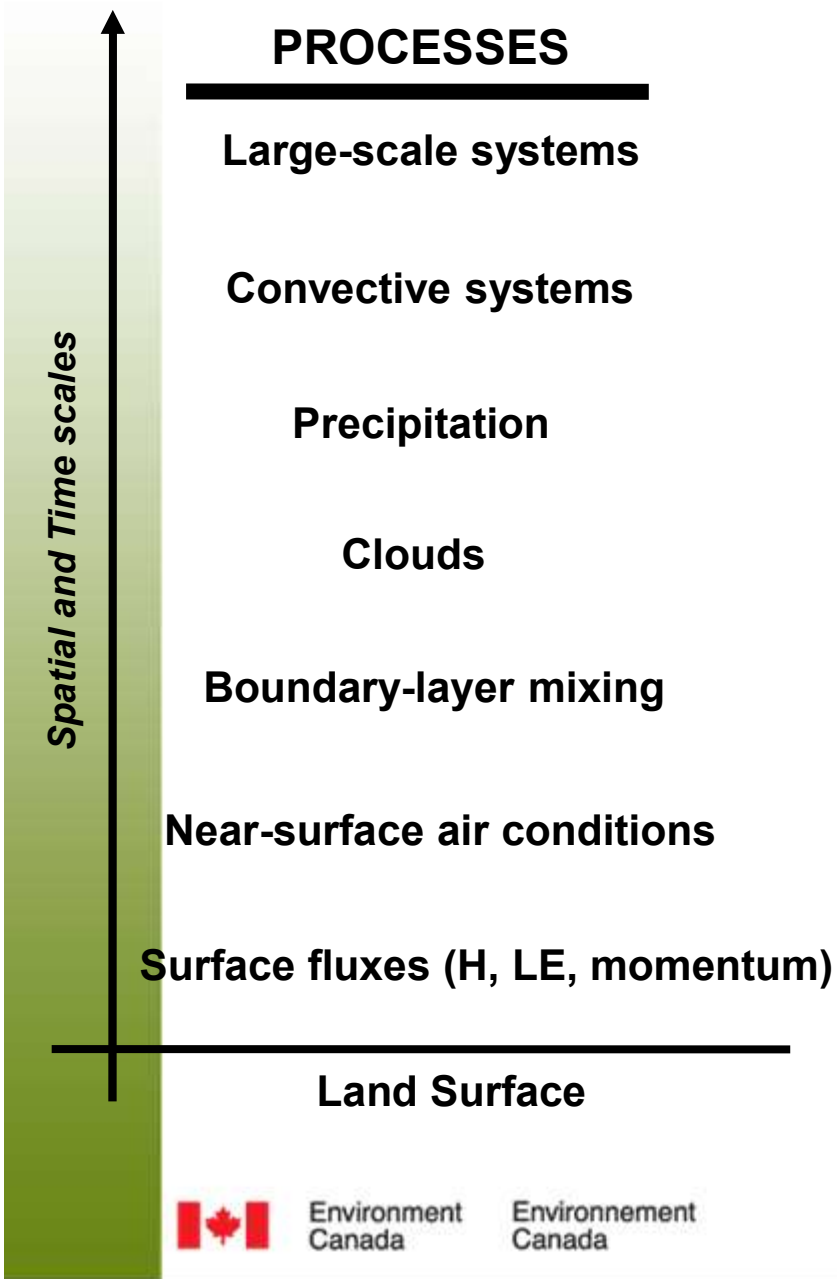
SMAP Applications Workshop, Washington DC,
12-13 October 2011

Stephane Belair and Marco Carrera

Science and Technology Branch,

Environment Canada

MOTIVATION: WHY EC NEEDS SMAP OBSERVATIONS



Impact on numerical weather prediction (all scales, all ranges)

Impact on hydrological prediction

Impact on other types of environmental prediction (drought, air quality, urban)

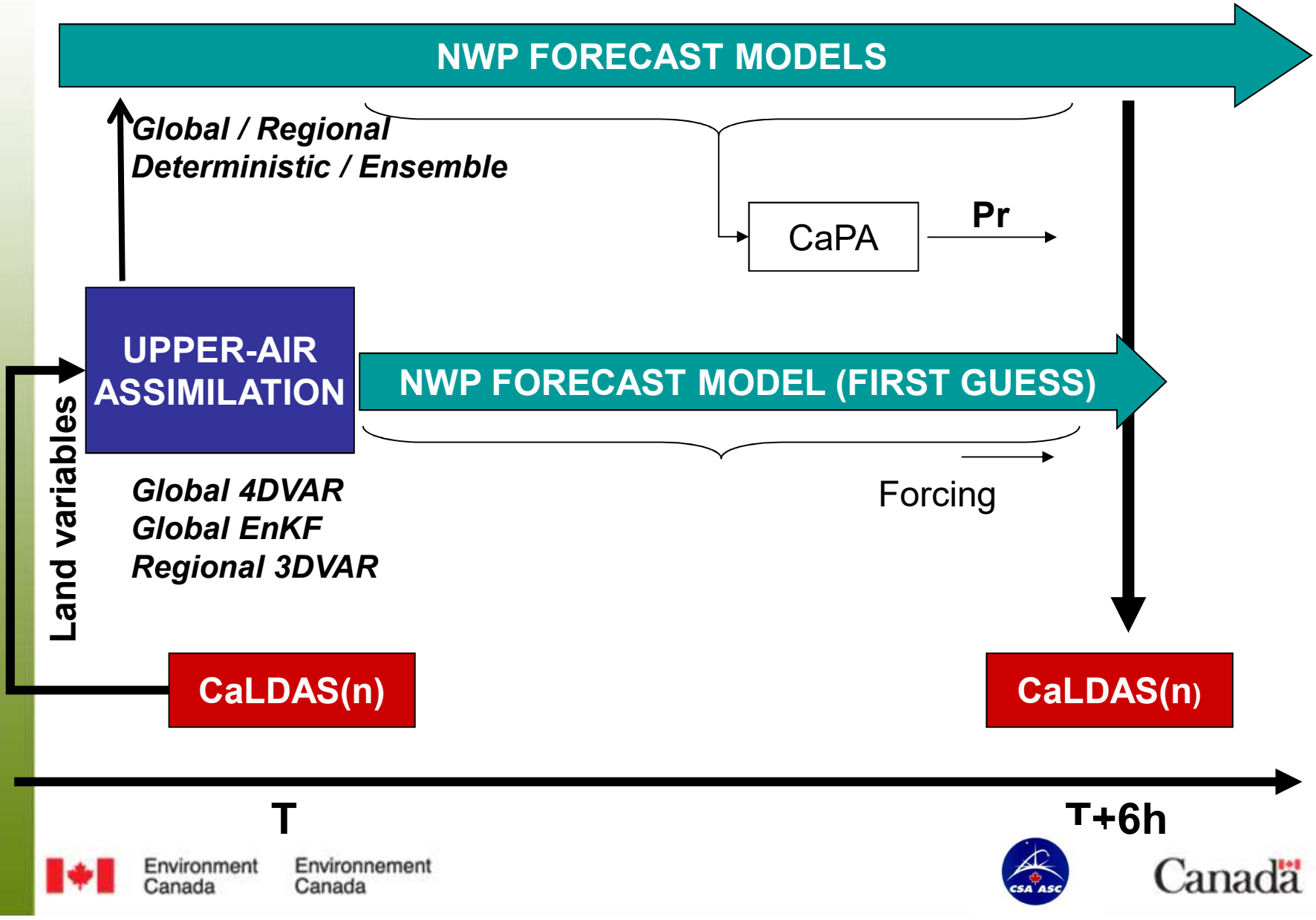
New products in collaboration with partners (e.g., Agriculture Canada, Health Canada)

Environment Canada Environnement Canada

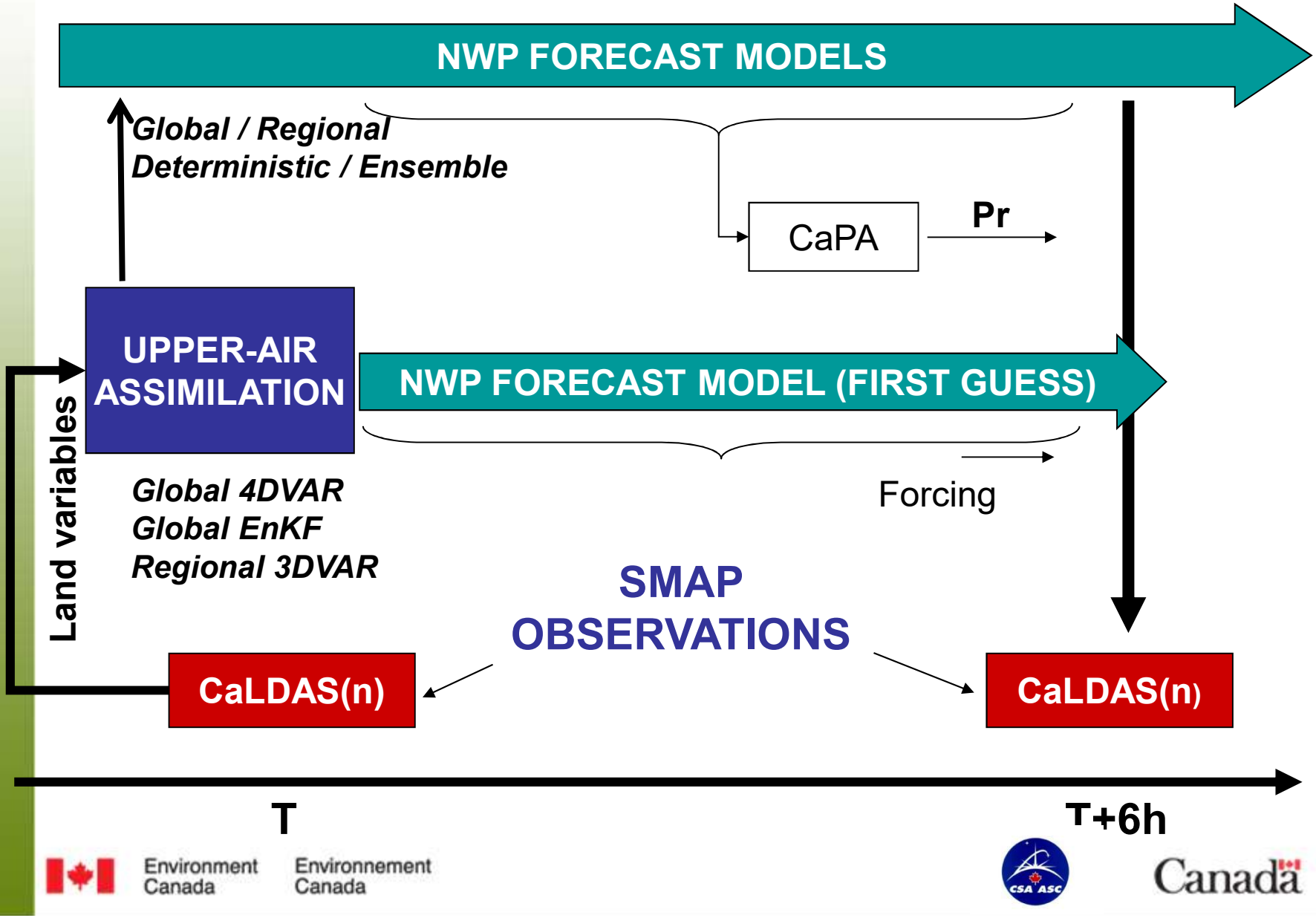
CSA ASC

Canada

ROLE of SMAP OBSERVATIONS in EC's NUMERICAL PREDICTION SYSTEMS



ROLE of SMAP OBSERVATIONS in EC's NUMERICAL PREDICTION SYSTEMS



The CANADIAN LAND DATA ASSIMILATION SYSTEM (CaLDAS)

IN

Ancillary land surface data

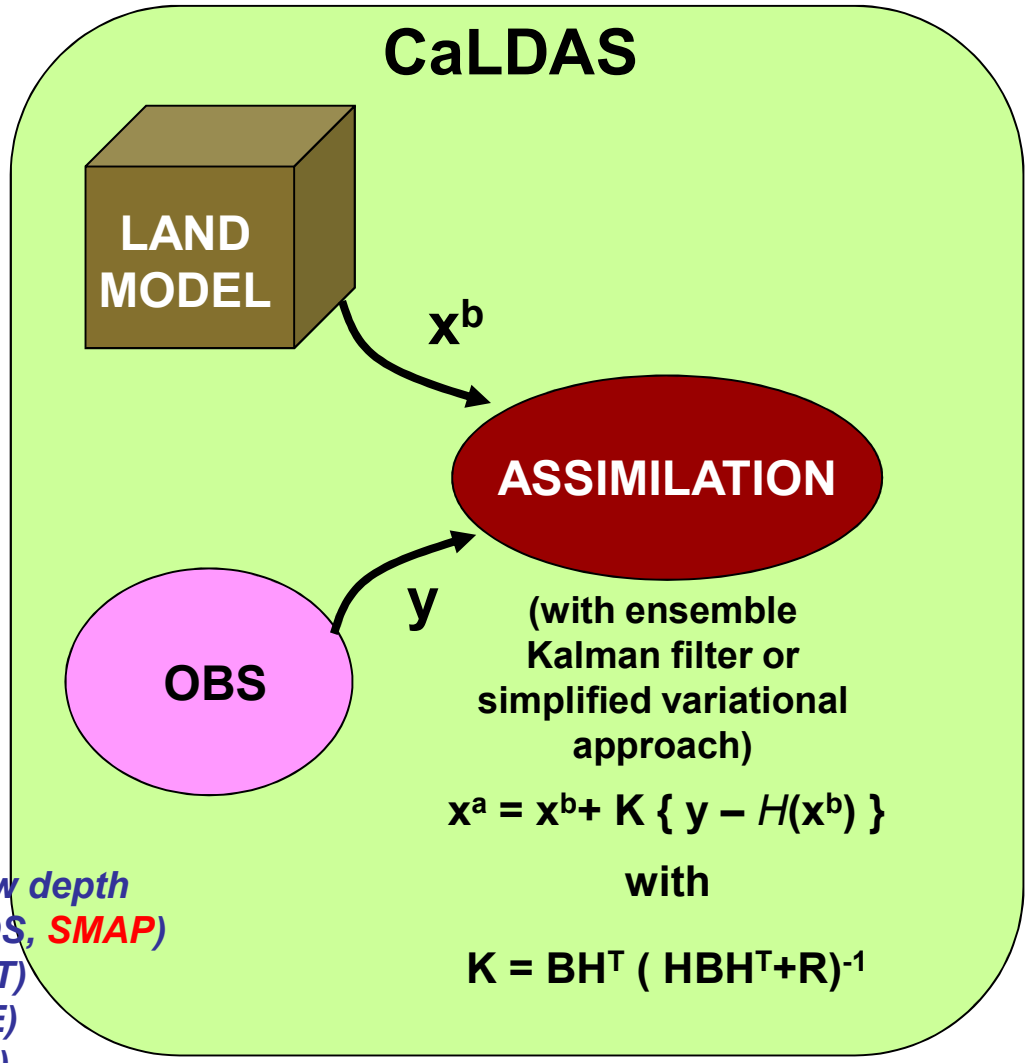
Orography, vegetation, soils, water fraction, ...

Atmospheric forcing

T, q, U, V, Pr, SW, LW

Observations

Screen-level (T, Td)
Surface stations snow depth
L-band passive (SMOS, SMAP)
C-band active (ASCAT)
MW passive (AMSR-E)
Multispectral (MODIS)
Combined products (GlobSnow)



OUT

Land surface initial conditions for NWP and hydro systems

Land surface conditions for atmospheric assimilation systems

Current state of land surface conditions for other applications (agriculture, drought, ...

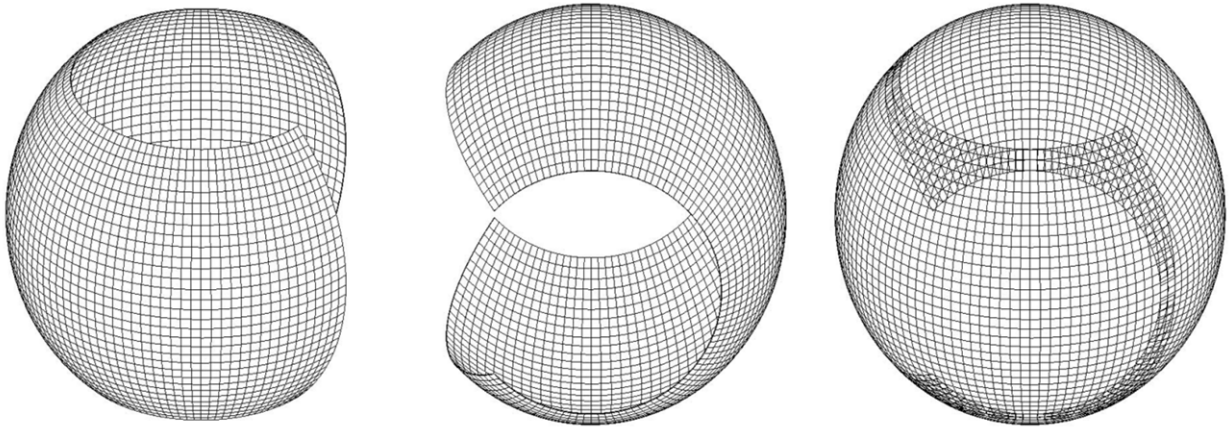
CURRENT RESEARCH at EC for SOIL MOISTURE DATA ASSIMILATION

Assimilation of screen-level data in all NWP systems (ensemble and deterministic, local to global, short-range to seasonal)

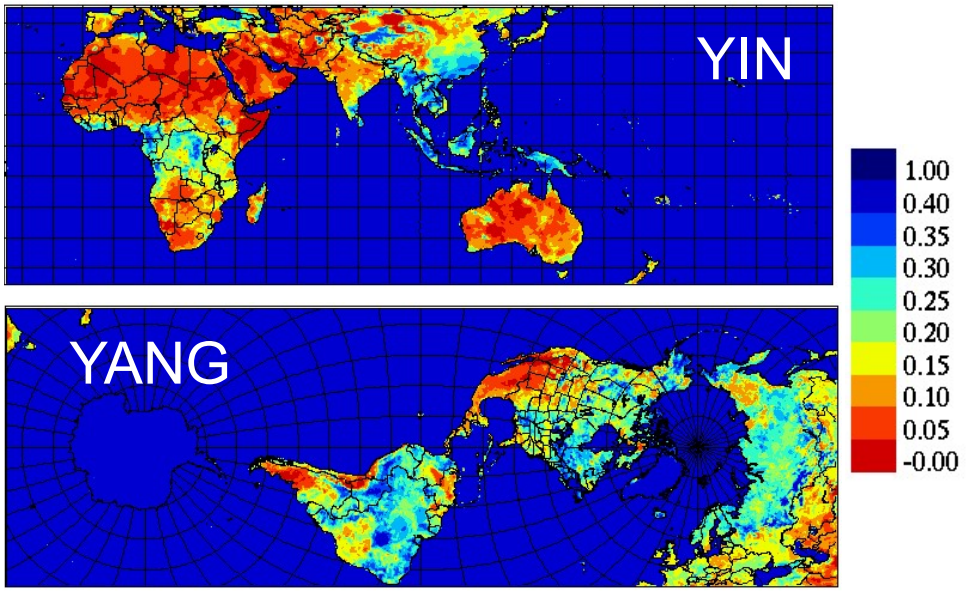
Synthetic experiments for the assimilation of L-band passive data

Assimilation of real SMOS data for the CanEx-SM10 experiment

LAND SURFACE ANALYSES for the GLOBAL DETERMINISTIC and ENSEMBLE PREDICTION SYSTEMS



YIN-YANG



Global, 33km (for GDPS)

Obs: T_2m, Td_2m, SD

Ctrl variables: wg, w2, Ts, T2, SWE

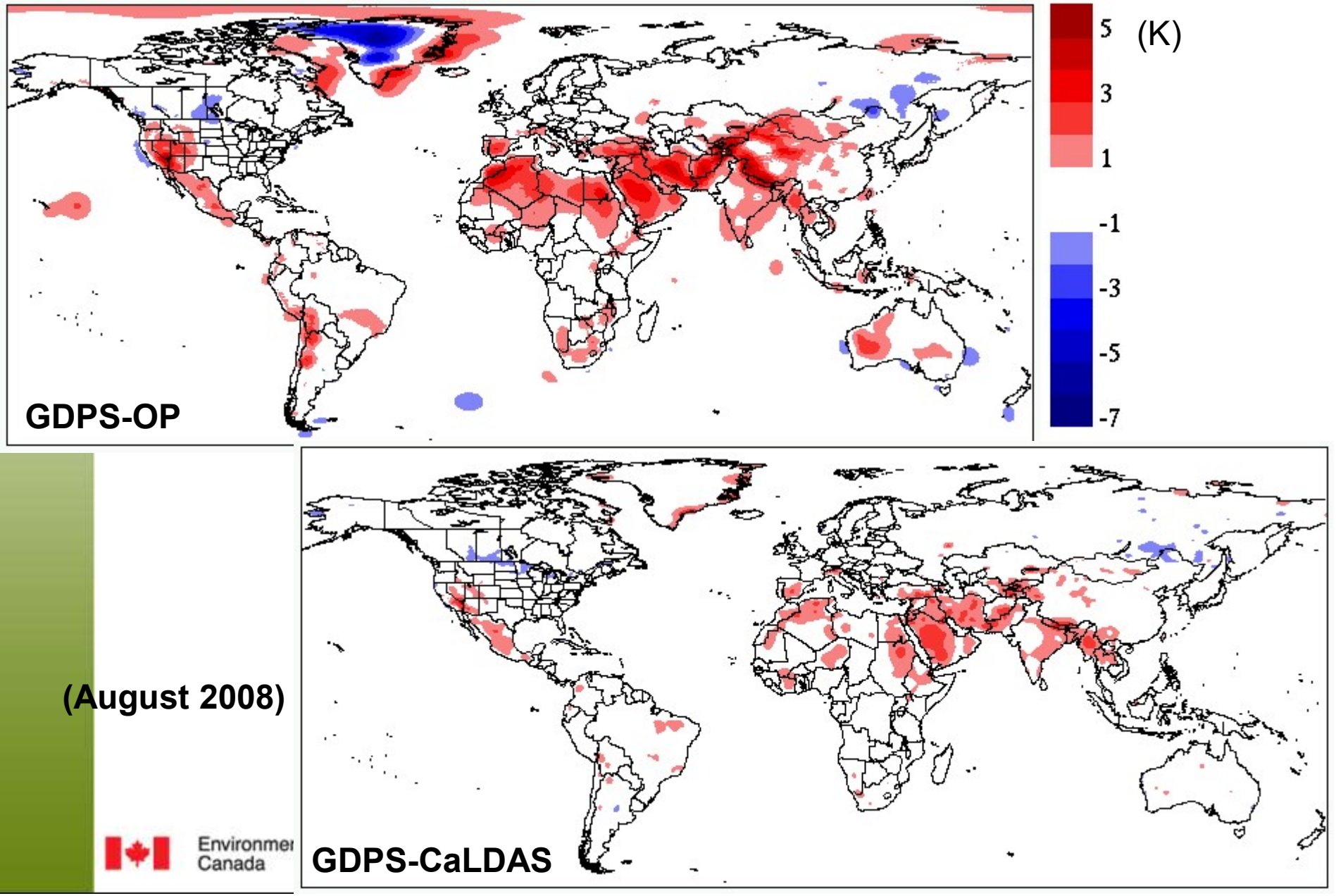
48 members (or more)

Assimilation step: 3h or 6h (using obs from -2h to +2h)

First cycle from April 2008 to March 2009 ongoing

Impact on GDPS / GEPS is being evaluated

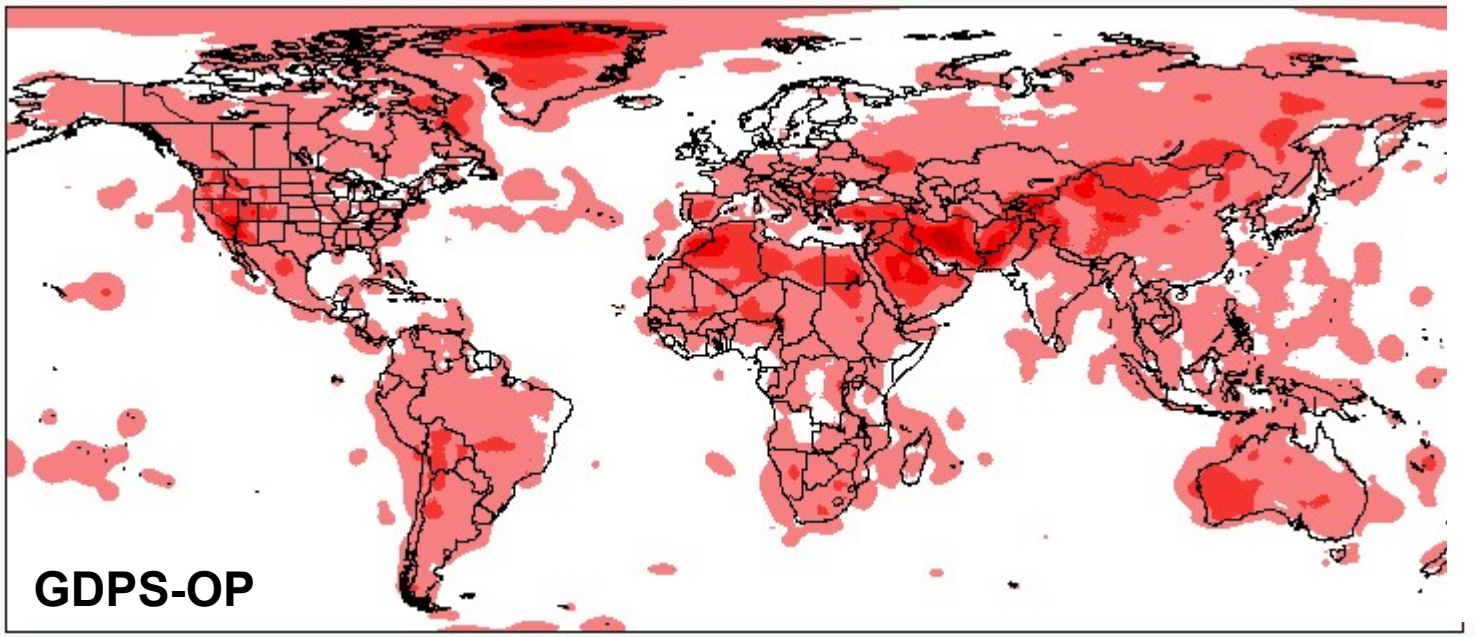
GLOBAL ASSIMILATION of SOIL MOISTURE: MEAN INNOVATIONS for T2m (6h) (Belair et al, in preparation)



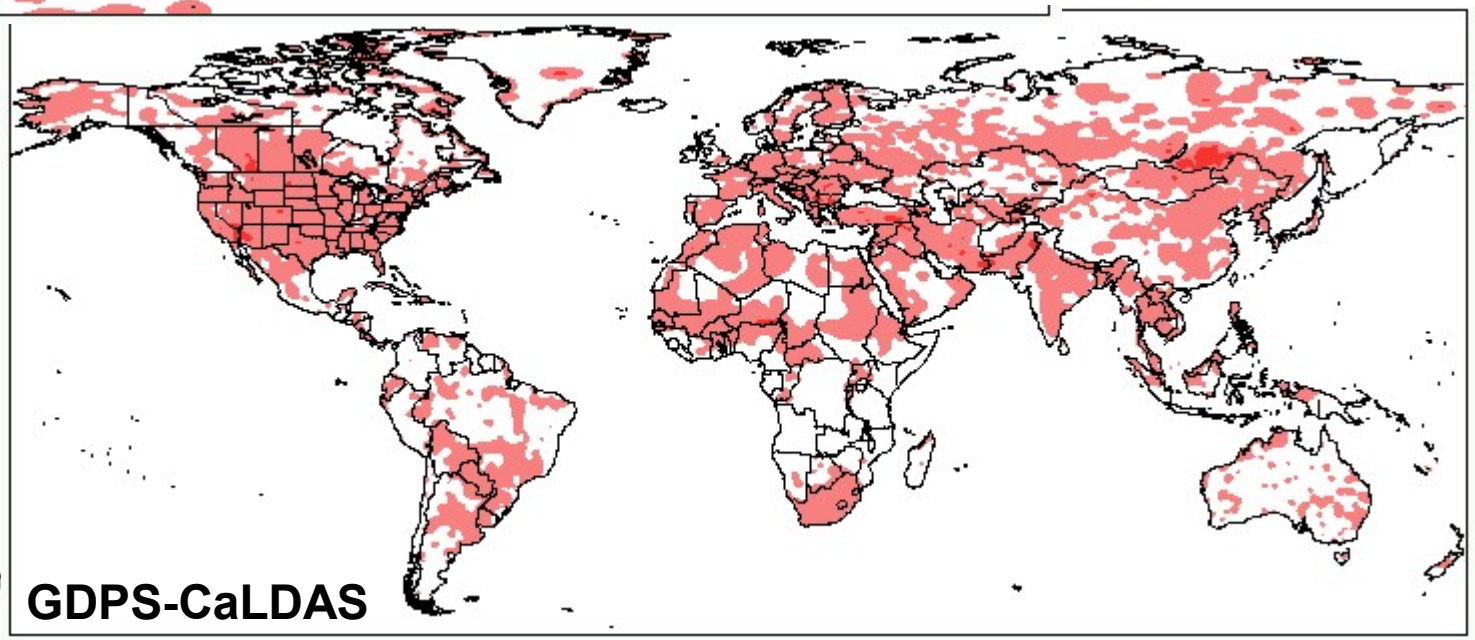
(August 2008)

Environment Canada

GLOBAL ASSIMILATION of SOIL MOISTURE:
STD for T2m INNOVATIONS (6h) (Belair et al, in preparation)



(August 2008)



Environment Canada

ASSIMILATION of SCREEN-LEVEL DATA: IMPACTS (preliminary)

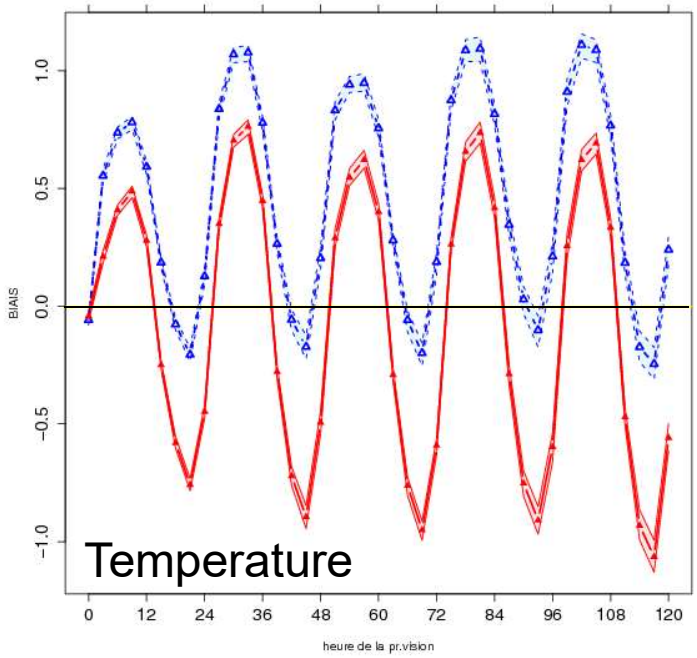
BIAS

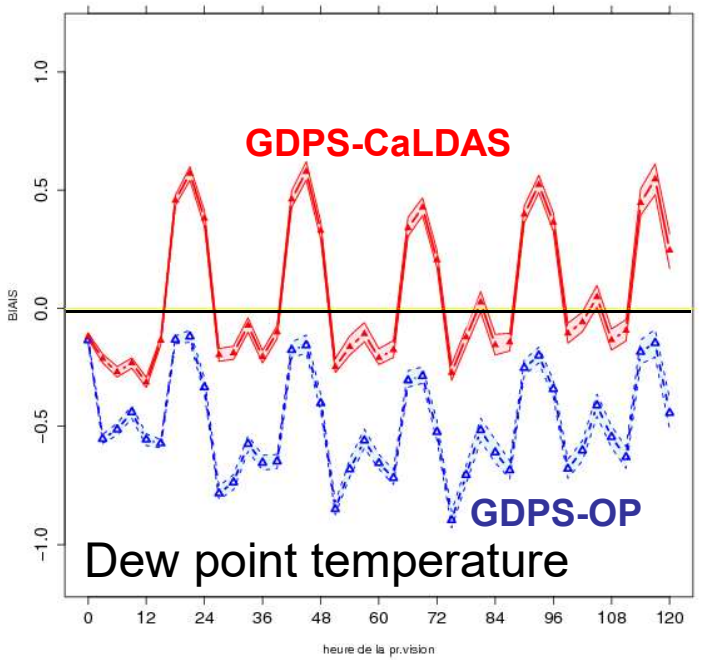
Objective evaluation:

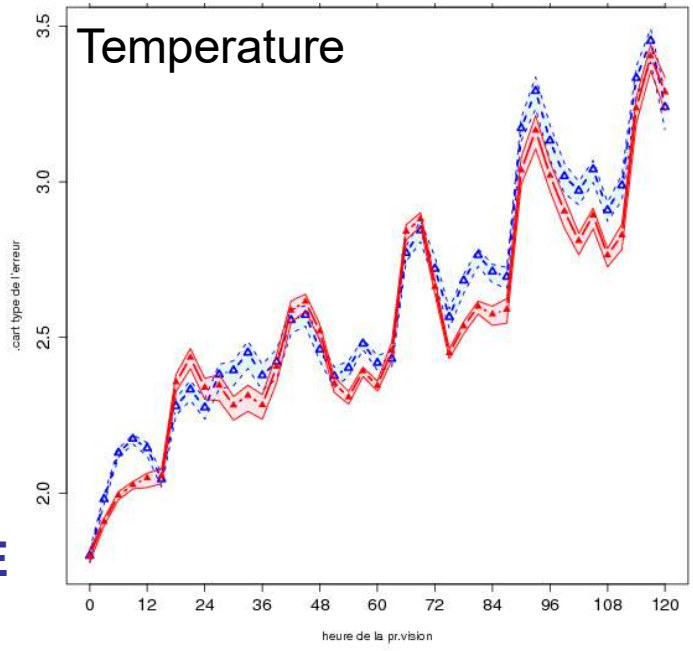
Impact on medium-range prediction of near-surface T and Td

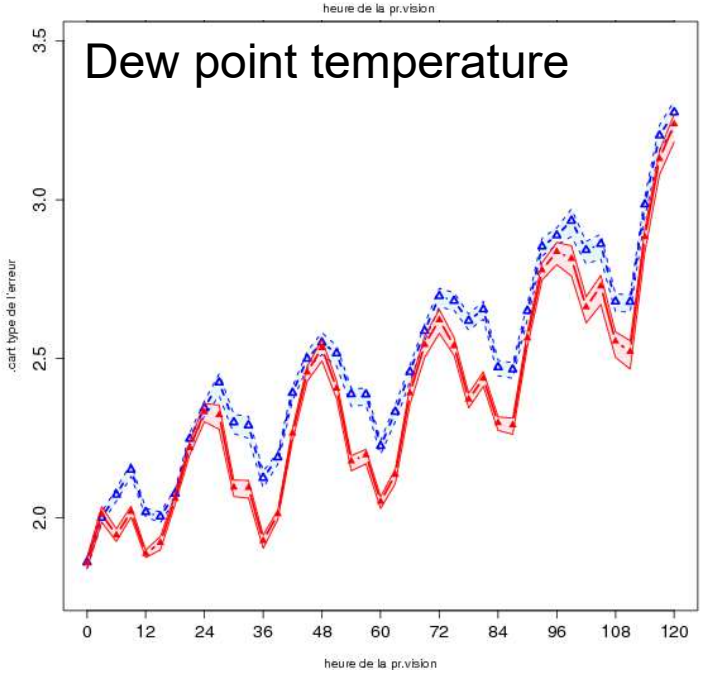
25 cases, from 18 June to 30 August 2008

All surface stations in Canada (~500)





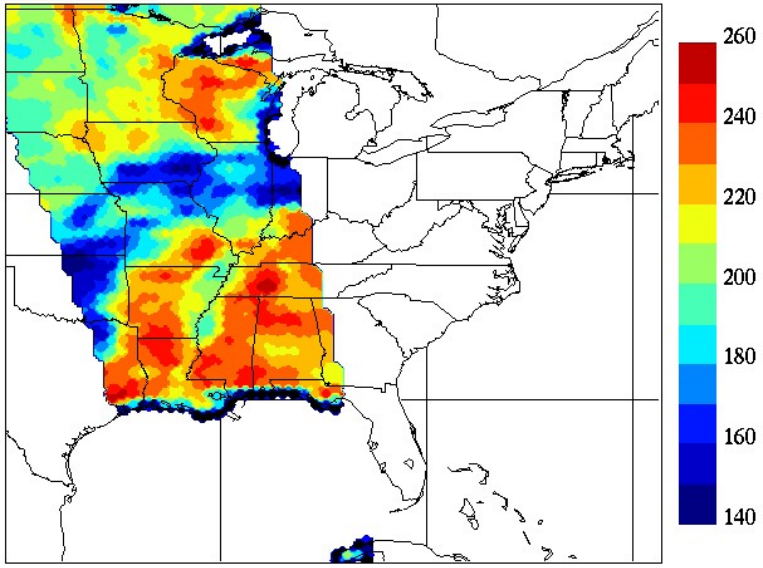


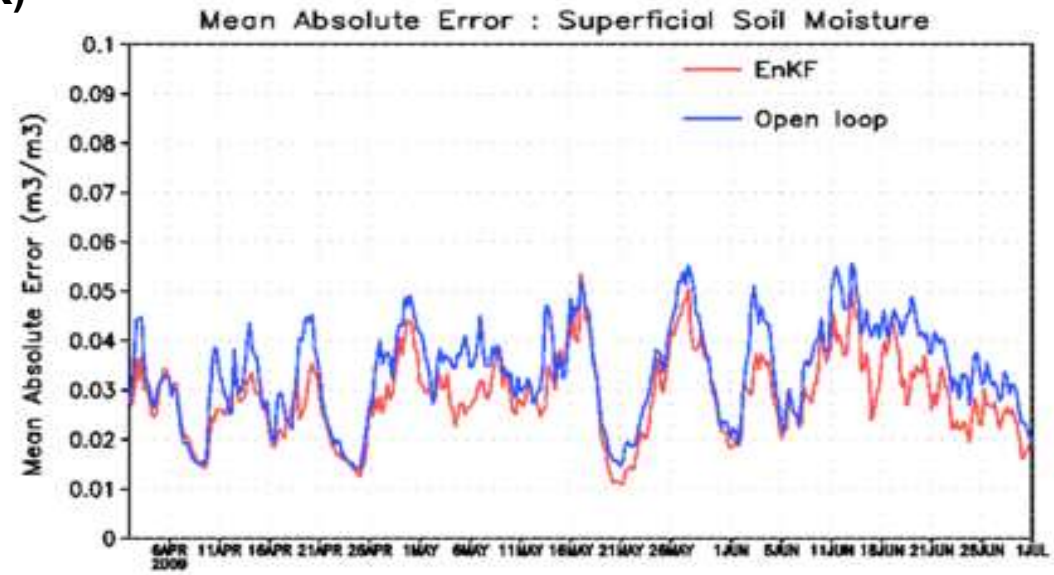


STDE
Environ Canada

SYNTHETIC ASSIMILATION of L-Band PASSIVE DATA for SOIL MOISTURE (Carrera et al., in preparation)

SYNTHETIC Tb L-band (H-pol) at 40º (K)





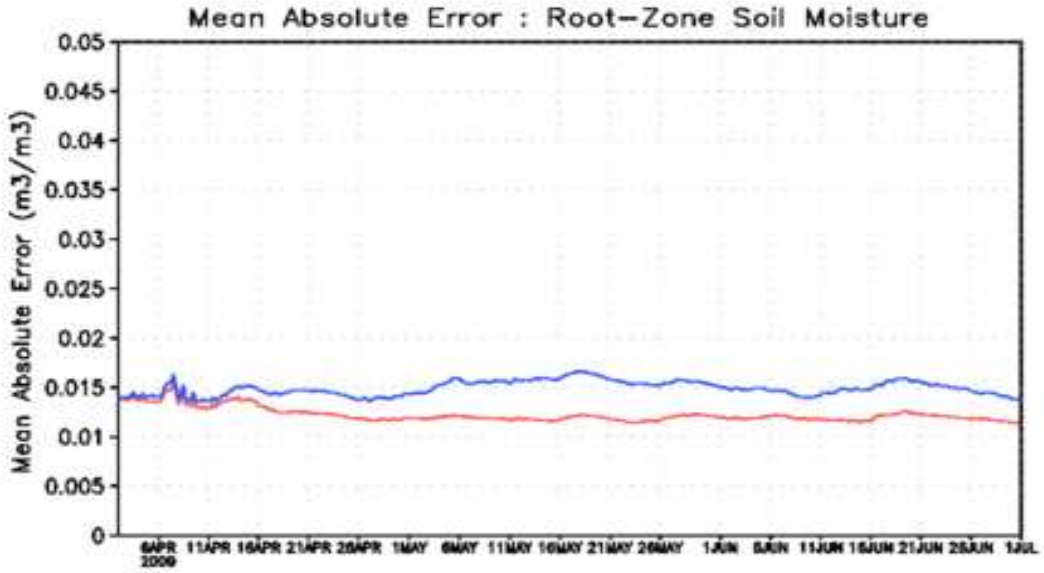
Synthetic L-band TBs from 1km nature/reality run

Average at 40km and perturbed

Assimilated in CaLDAS

Comparison against "reality"

Useful for setting up CaLDAS configurations



Environment Canada Environnement Canada

Canadian Experiment for Soil Moisture in 2010 (CanEX-SM10)

- Originated as an experiment for Canadian researchers to support SMOS Cal/Val activities over land and to develop soil moisture retrieval algorithms.
- Experiment was expanded to include pre-launch validation and algorithm development for SMAP through a collaboration with US scientists.

- **Period** : 31 May – 17 June 2010

- **Study Sites** :

- (i) **Kenaston agricultural site (~ 80 km south of Saskatoon) (33 km x 71 km).**

- (ii) **BERMS (Boreal Ecosystem and Research and Monitoring Sites) in northern Saskatchewan (33 km x 71 km).**

CanEX-SM10

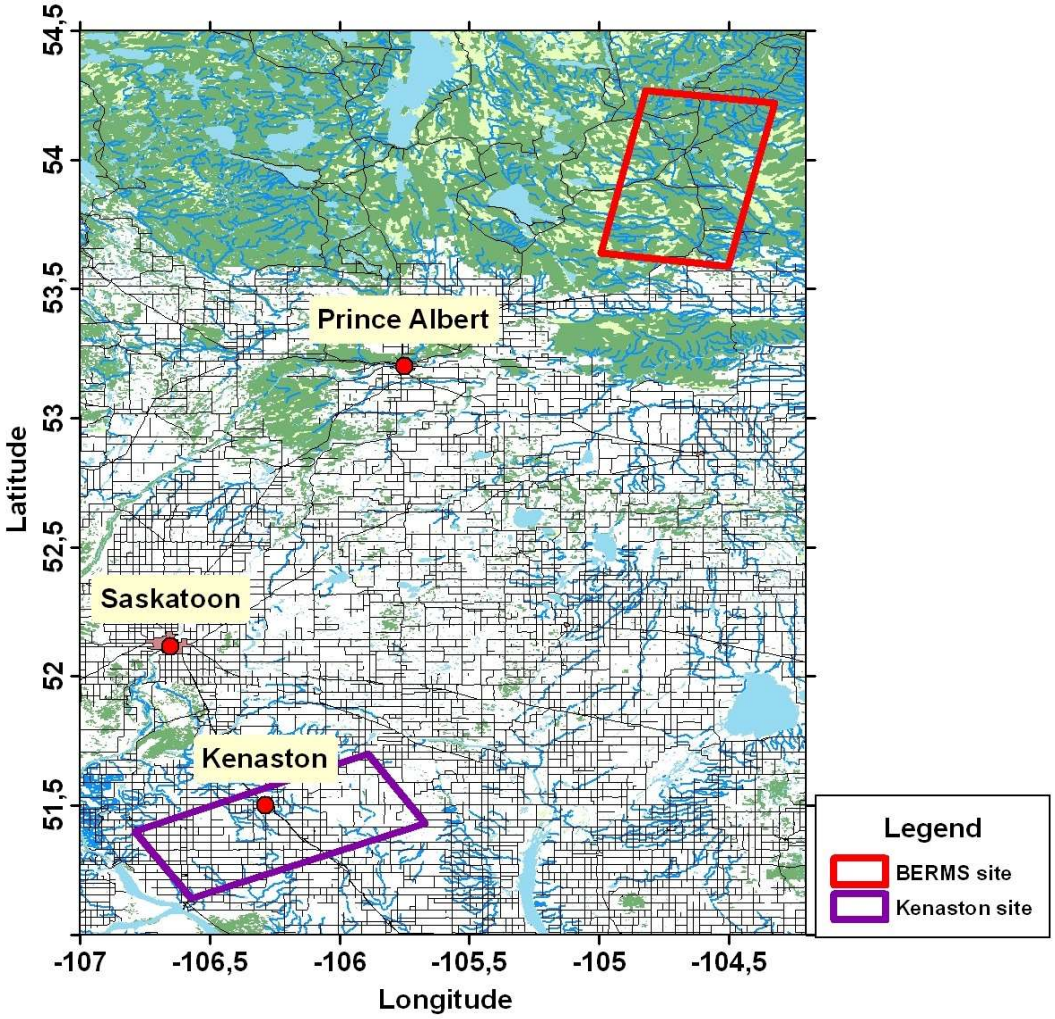


Image courtesy R. Magagi

Environment Canada Environnement Canada

Kenaston Site :

• High-density network : 24 permanent Environment Canada monitoring sites with measurements of soil moisture at depths of 5, 20 and 50 cm.

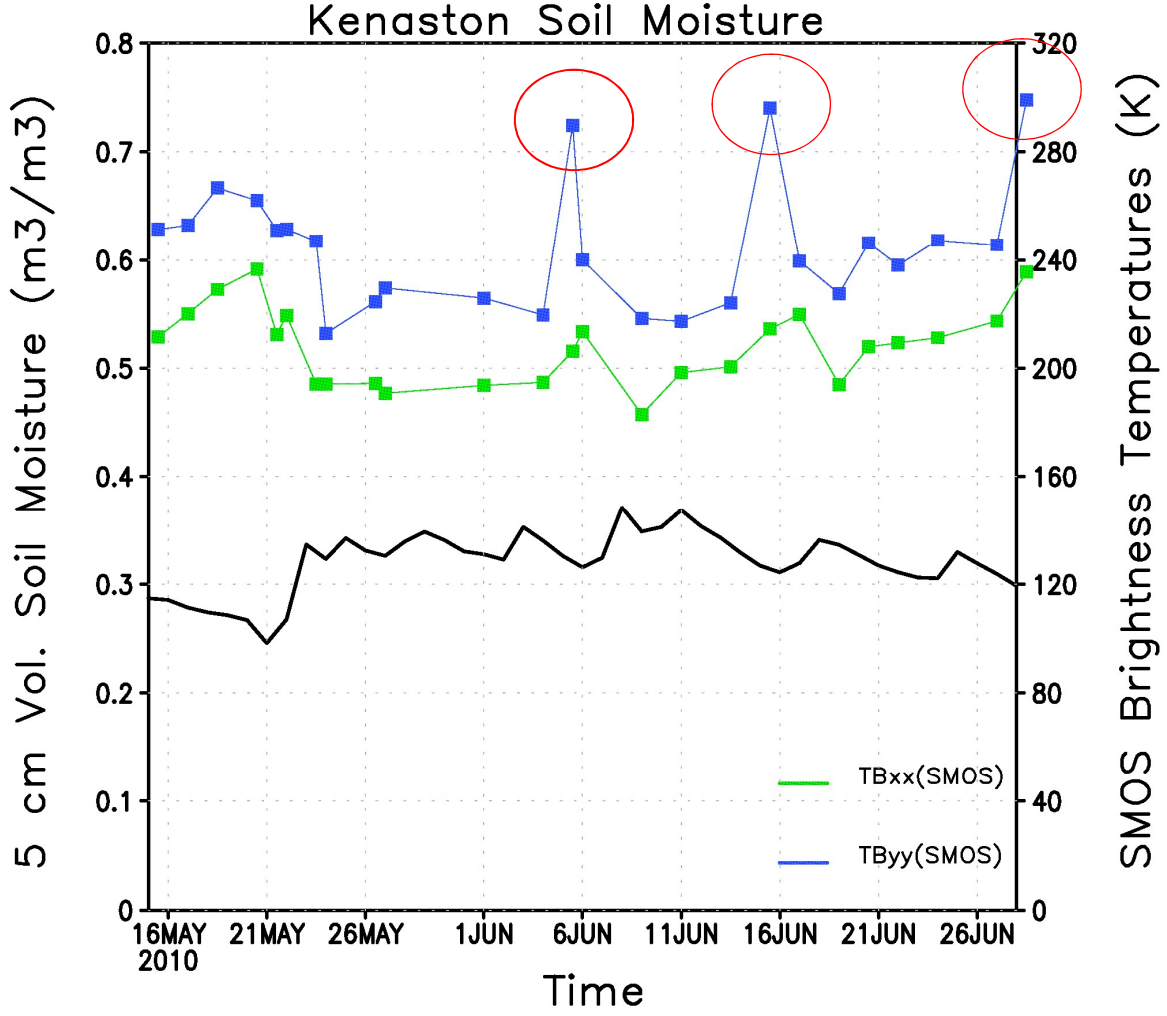
• Low-density network : 16 sites operated by the University of Guelph recording soil moisture at depths of 5, 20 and 50 cm.

• Additional 20 manual survey sites were added for CanEX-SM10 which record soil moisture at a depth of 6 cm.

• National Research Council Twin Otter aircraft equipped with a passive microwave radiometer measuring emission in L-band at 40° incidence angle. NASA UAVSAR fully polarimetric L-band radar.

Canada

SMOS Level 1C Brightness Temperatures (40º Incidence Angle) – Exclusive alias free zone

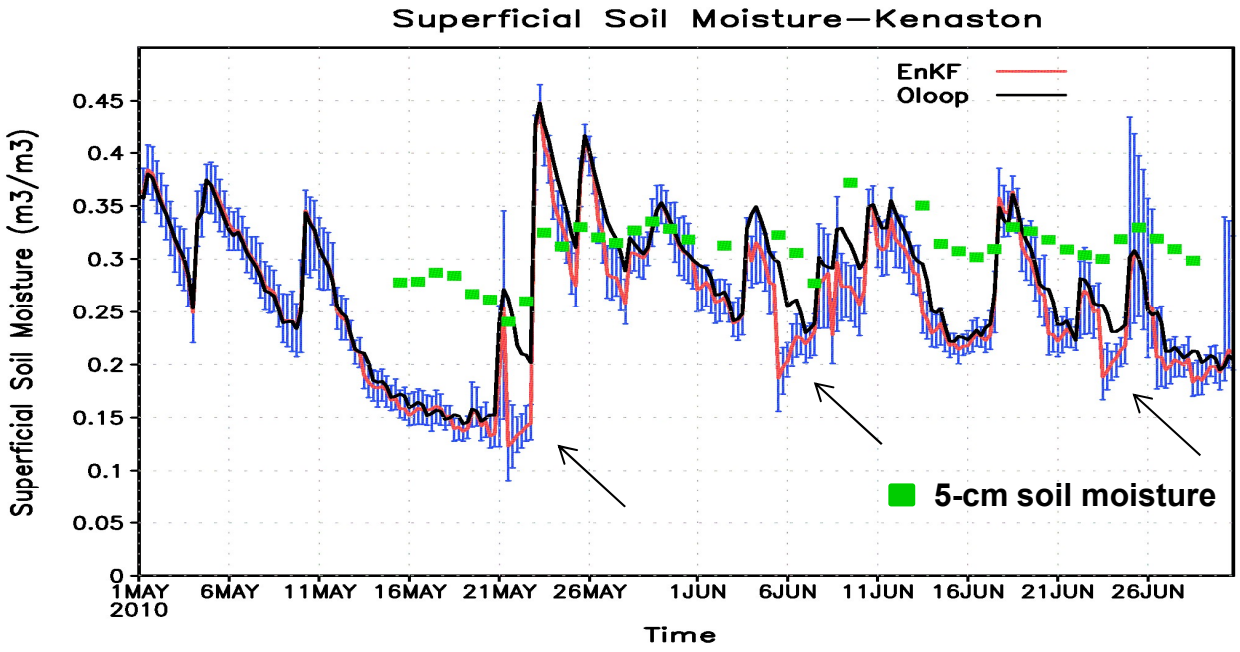


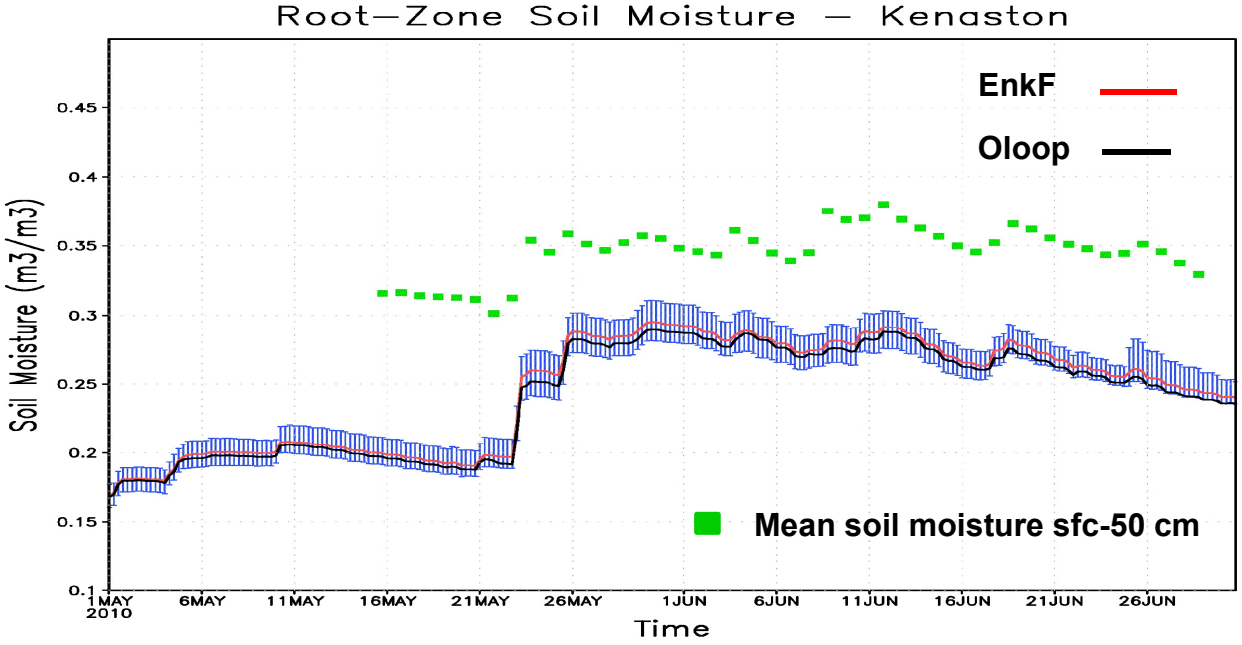
Very wet conditions on the ground.

Temporal trends in soil moisture captured well by SMOS.

Considerable inter-field variability in superficial soil moisture values.

Very Wet Soil Conditions : Assimilation in a near saturated environment



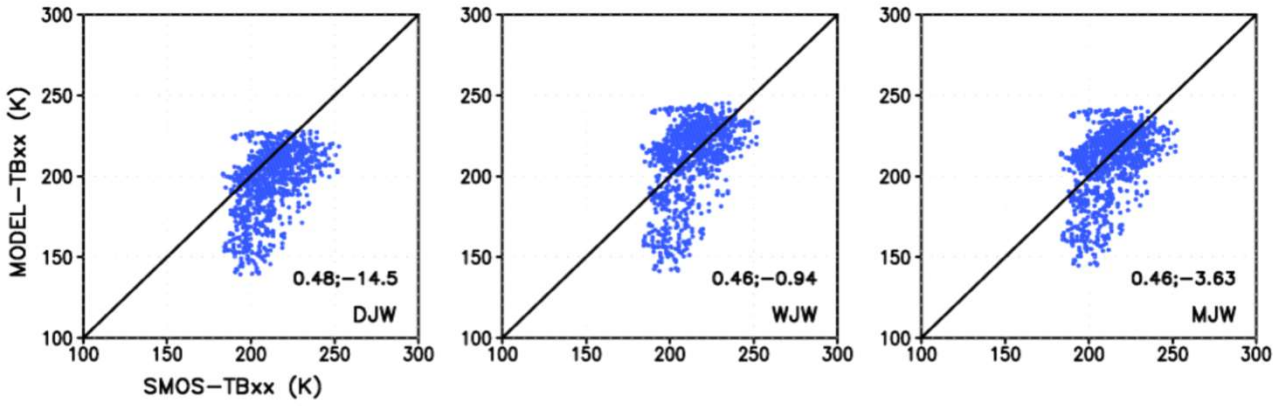


Dry-Downs are too rapid and strong in the EnKF run.

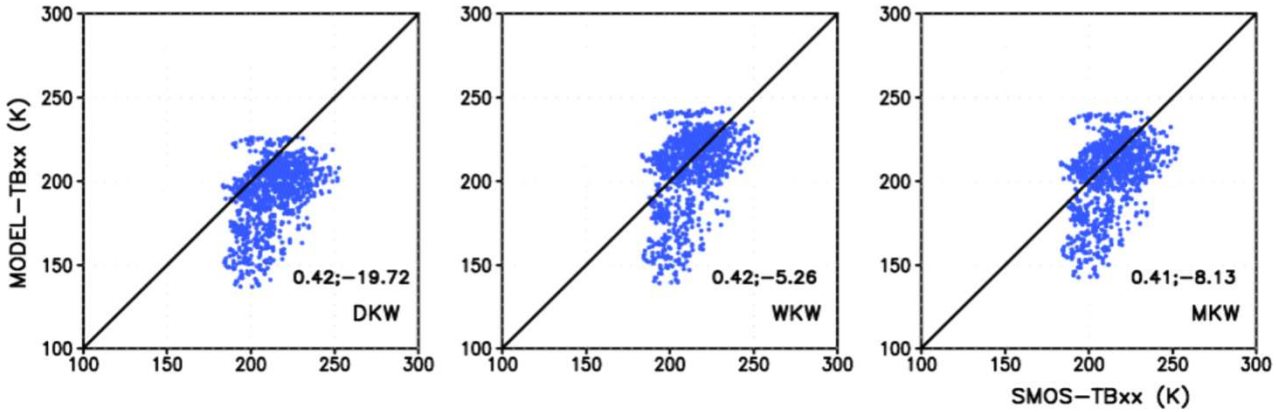
Problem : Persistent negative soil moisture increments. Indicates that work needs to be done on the quality-control side.

Canada

Bias Correction : Forward Modelling Comparisons
Comparisons First-Guess TB vs SMOS TBs : Kenaston Agricultural Site
CMEM : Community Microwave Emission Model



Sensitivity to Dieletric Mixing Model Jackson Vegetation



Sensitivity to Dieletric Mixing Model Kirdyashev Vegetation

Dielectric Mixing Models : **D** (Dobson), **W** (Wang and Schmugge), **M** (Mironov)
Vegetation Model : **J** (Jackson and Schmugge), **K** (Kirdyashev)
Soil Roughness Model : **W** (Wigneron et al. 2007); **Ws** (Wigneron et al. 2001)

Bias Correction : Forward Modelling Comparisons
Comparisons First-Guess TB vs SMOS TBs : Kenaston Agricultural Site
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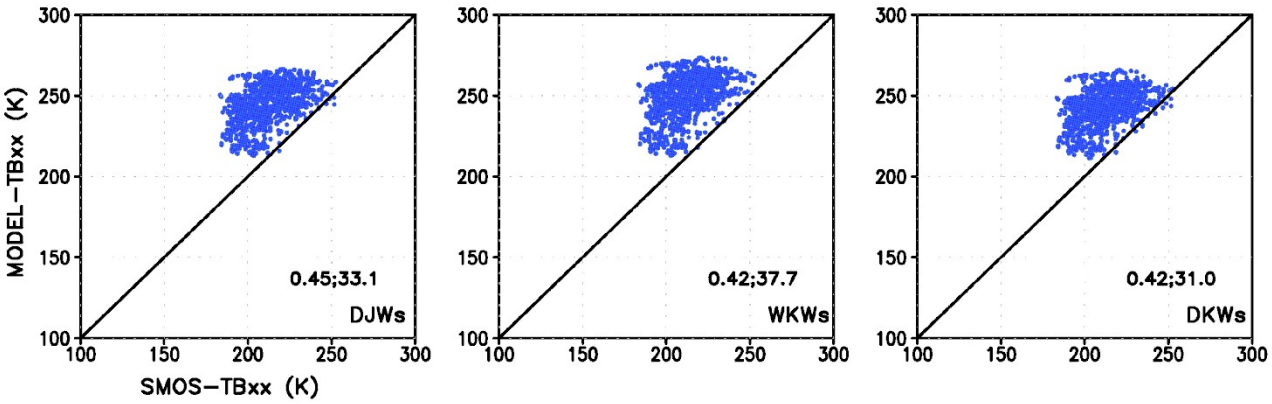
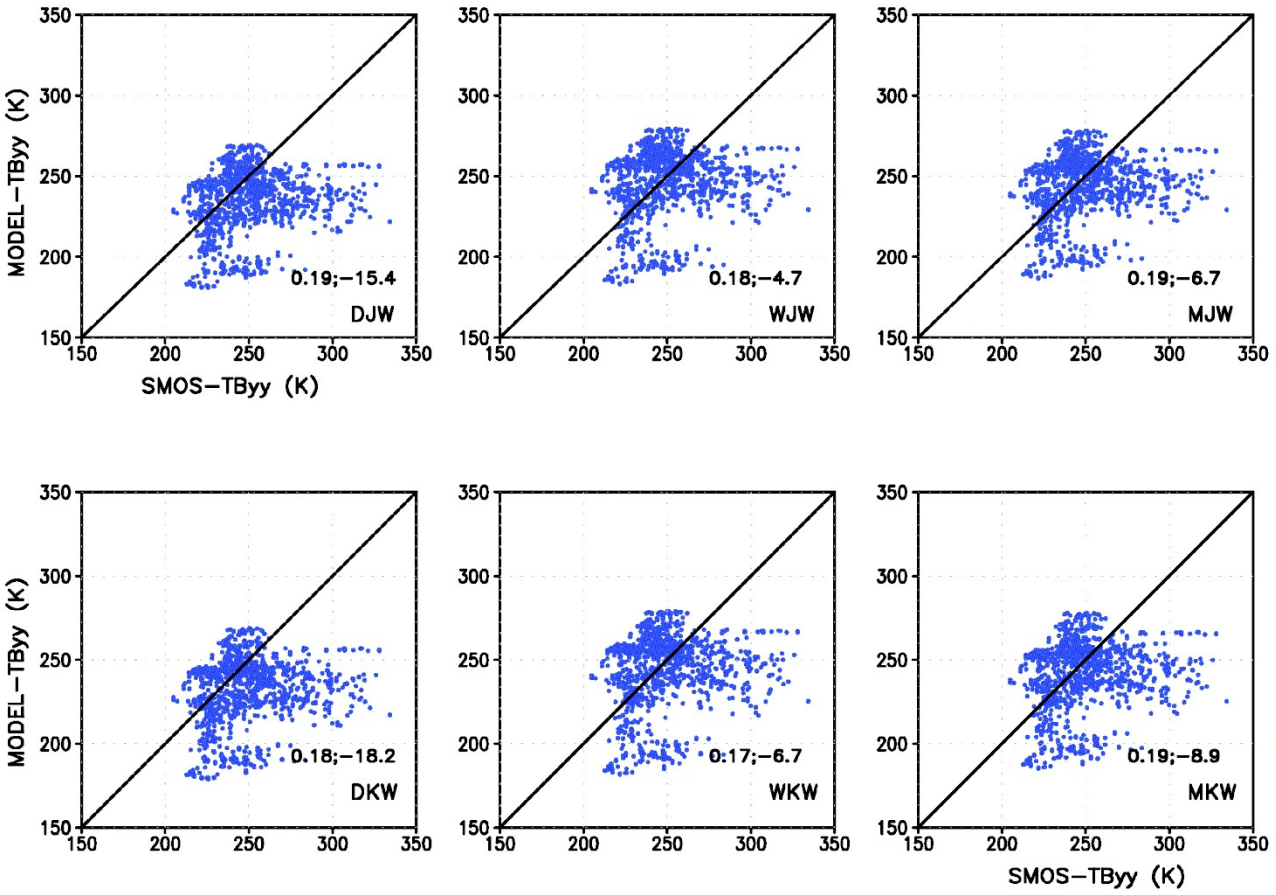


Strong sensitivity to soil roughness model
Wigneron et al. (2007) vs Wigneron et al. (2001)

Bias Correction : Forward Modelling Comparisons
Comparisons First-Guess TB vs SMOS TBs : Kenaston Agricultural Site
CMEM : Community Microwave Emission Model

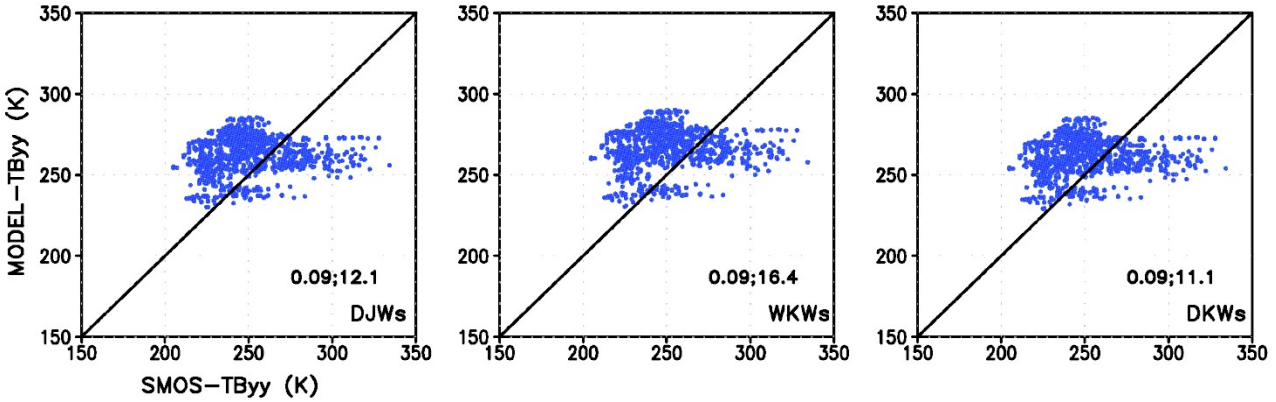


Sensitivity to Dieletric Mixing Model Jackson Vegetation

Sensitivity to Dieletric Mixing Model Kirdyashev Vegetation

Agreement for TByy is not as good as TBxx.

Bias Correction : Forward Modelling Comparisons
Comparisons First-Guess TB vs SMOS TBs : Kenaston Agricultural Site
CMEM : Community Microwave Emission Model



Very poor correlations for the Wigneron et al. 2001 roughness parameterization.

PROPOSED APPROACHES for CaLDAS

Currently operational: *assimilation of screen-level data to analyze surface temperatures and soil moisture*

Proposed-1: *joint assimilation of screen-level, brightness temperatures, and backscatters for surface temperatures and soil moisture*

Proposed-2: *sequential assimilation... screen-level data for surface temperatures and SMAP data for soil moisture*

Proposed-3: *hybrid approach... screen-level data used as forcing (stronger constraint on first guesses) and SMAP data assimilated for soil moisture*

ASSIMILATION of PASSIVE / ACTIVE SMAP OBSERVATIONS
OPTION: HIGH-RESOLUTION ASSIMILATION (LOCAL/REGIONAL)

HIGH-RESOLUTION (1-3 km)

LOW-RESOLUTION (10km-40km)

Ensemble at high resolution

$\mathbf{x}_{a\,\mathrm{HR}}^{t-\Delta t}$ HR model $\mathbf{x}_{b\,\mathrm{HR}}^{t}$

Active obs at high resolution

$\mathbf{y}_{\sigma}$ $\mathbf{y}_{HR}$

Passive obs at low resolution

$\mathbf{y}_{Tb}$ *Downscaling*

$\mathbf{B}_{\mathrm{HR}}$, $\mathbf{R}_{\mathrm{HR}}$

Analysis at high resolution

$$\mathbf{x}_{a\,\mathrm{HR}}^{t} = \mathbf{x}_{b\,\mathrm{HR}}^{t} + \mathbf{K}_{\mathrm{HR}}\left[\mathbf{y} - H\left(\mathbf{x}_{b\,\mathrm{HR}}^{t}\right)\right]$$

PREVIOUS ANALYSIS

BACKGROUND and OBSERVATIONS

NEW ANALYSIS

ASSIMILATION of PASSIVE / ACTIVE SMAP OBSERVATIONS
OPTION: MEDIUM-RES ASSIMILATION (GLOBAL)

MEDIUM-RESOLUTION (10 km)

Ensemble at medium resolution

$$\mathbf{x}_{a\,\mathrm{MR}}^{t-\Delta t} \xrightarrow{\text{MR model}} \mathbf{x}_{b\,\mathrm{MR}}^{t}$$

Analysis at medium resolution

$$\mathbf{x}_{a\,\mathrm{MR}}^{t} = \mathbf{x}_{b\,\mathrm{MR}}^{t} + \mathbf{K}_{\mathrm{MR}}\left[\mathbf{y} - H\left(\mathbf{x}_{b\,\mathrm{MR}}^{t}\right)\right]$$

$\mathbf{B}_{\mathrm{MR}}$, $\mathbf{R}_{\mathrm{MR}}$

$\mathbf{y}_{AP\_SM}$

Active / Passive retrievals

PREVIOUS ANALYSIS

BACKGROUND and OBSERVATIONS

NEW ANALYSIS

HOW we ARE PROCEEDING

Continue current approach for the assimilation of screen-level data (implementations in 2012-2013)

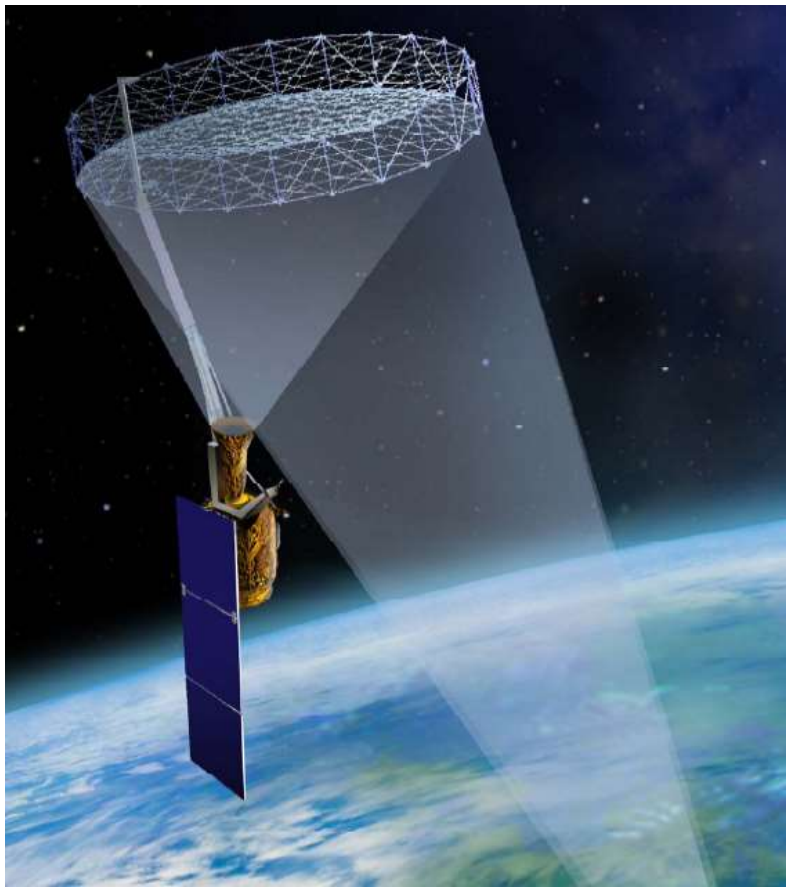
Synthetic tests for passive and active L-band data (prior to launch)

Synthetic evaluation of impacts on NWP (and possibly hydrological) systems

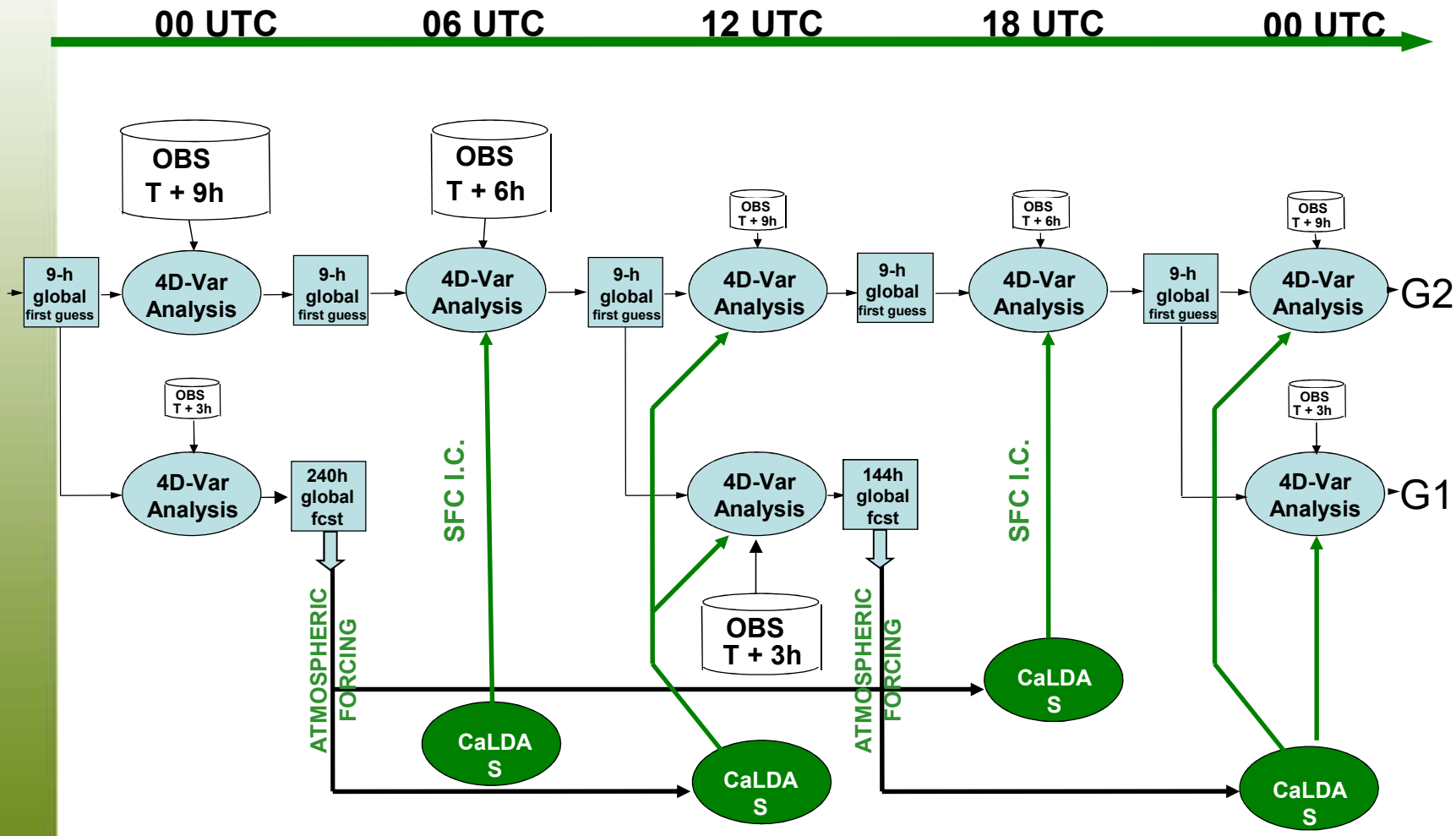
Assimilation of real SMAP data (post-launch)

Generation of Canadian products for SMAP

THANK YOU for your ATTENTION



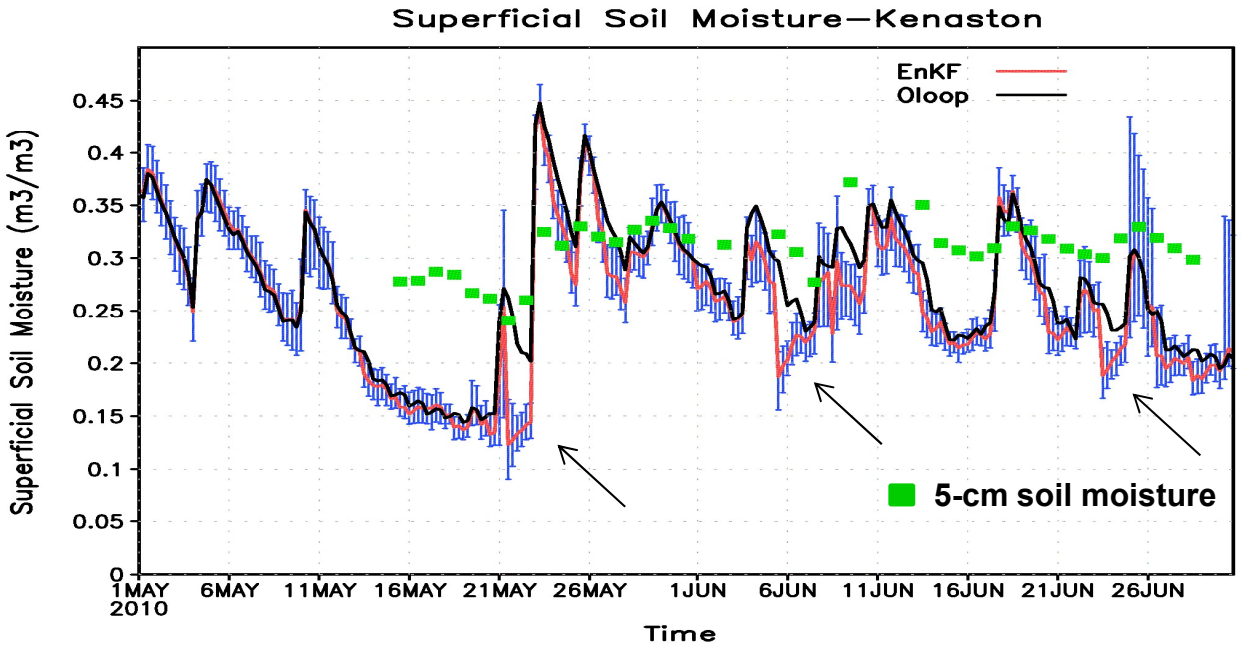
CaLDAS within the Global model data assimilation cycle



Environment Canada | Environnement Canada

G2 = Global Assimilation Cycle
G1 = Global Forecast Run

Canada



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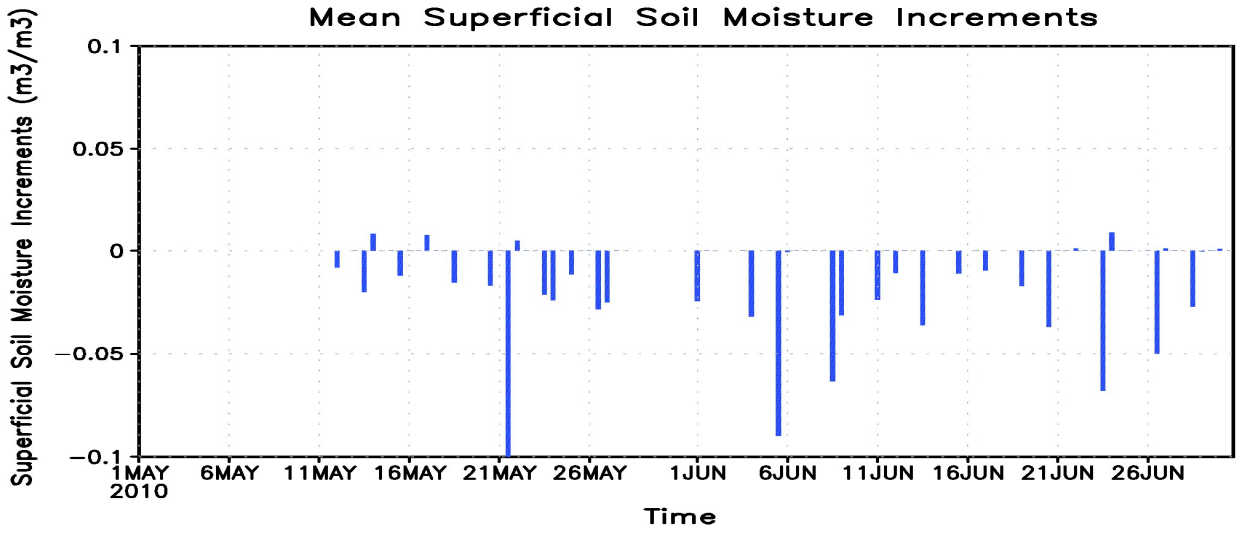

Problem : Persistent negative soil moisture increments. Indicates that work needs to be done on the quality-control side.