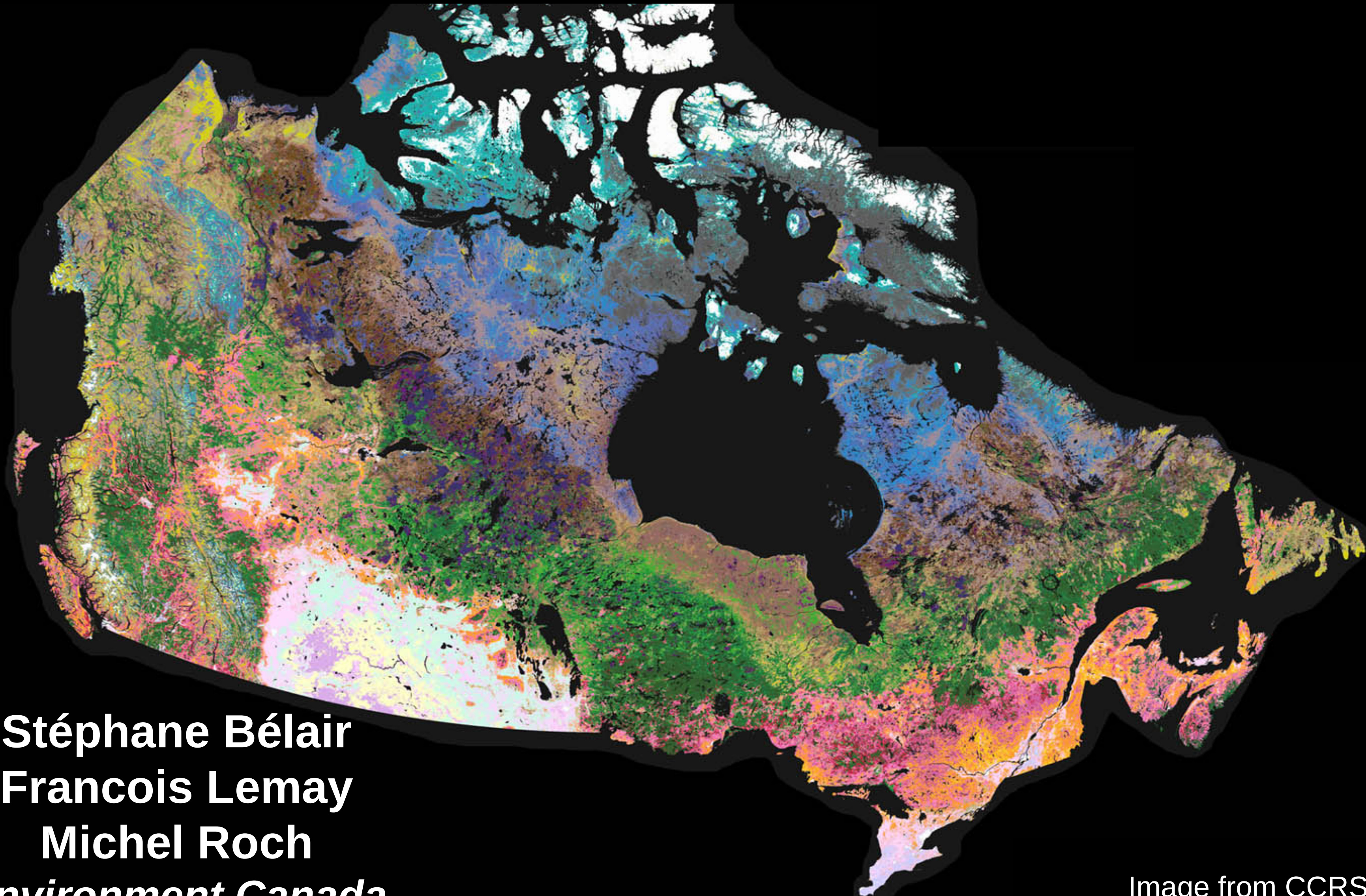
Land Surface in Numerical Weather Prediction Models: Surface and Atmospheric Evaluation



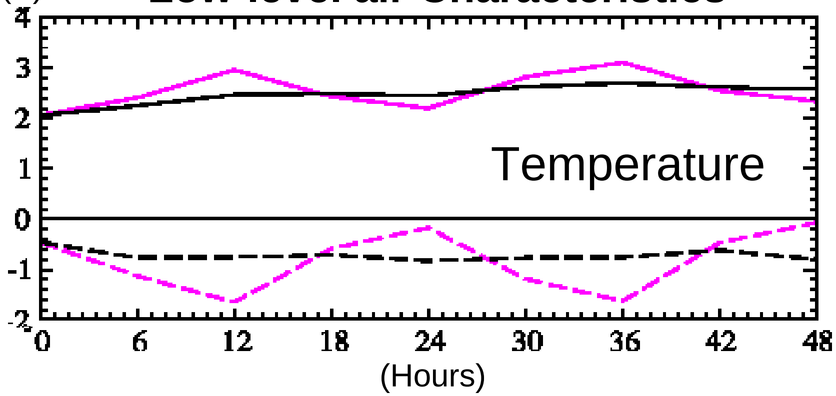
Stéphane Bélair
Francois Lemay
Michel Roch
Environment Canada

Image from CCRS

Impact of Land Surface Schemes on NWP

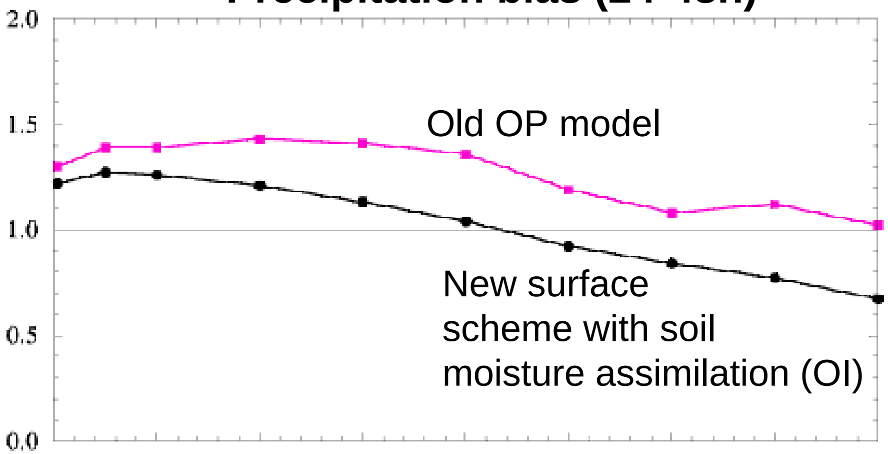
Short range

Low-level air Characteristics



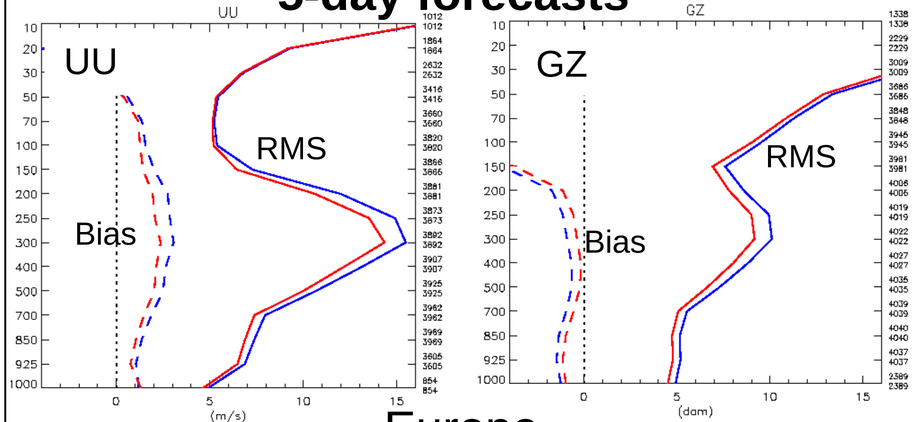
(18 cases)

Precipitation bias (24-48h)



Medium range

5-day forecasts

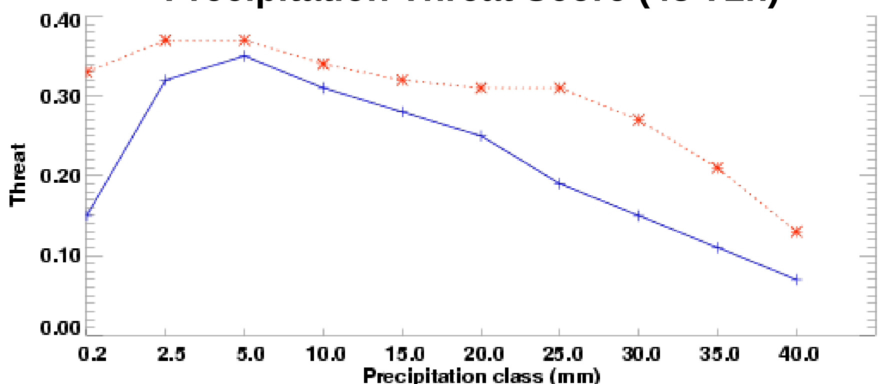


Europe

(65 cases)

Control run
ISBA with sequential assimilation

Precipitation Threat Score (48-72h)



SHEF network - USA

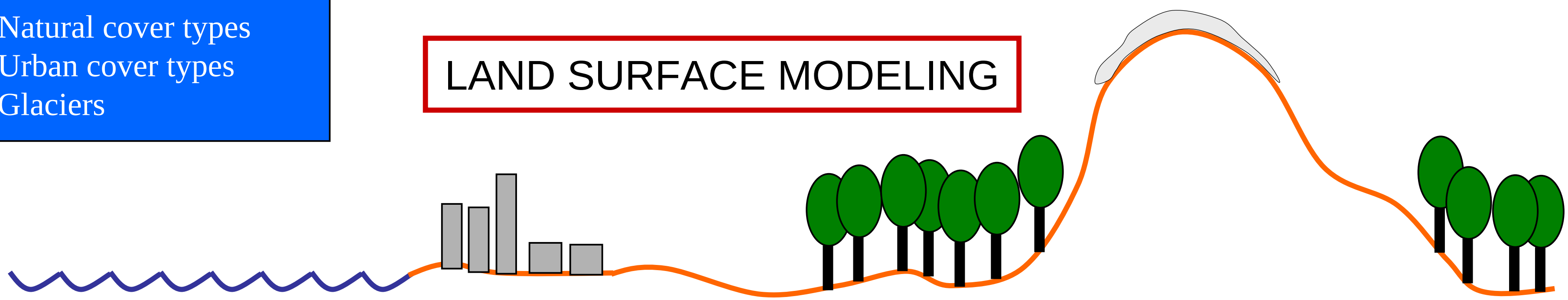
Land Surface Schemes in NWP Models: Possible Sources of Errors

ATMOSPHERIC MODEL

Surface layer
Boundary-layer turbulence
Clouds, precip, evaporation
… and a bunch of other processes including atmospheric numerics and dynamics

LAND SURFACE CHARACTERISTICS

Topography
Roughness
Land/water fractions
Soil texture
Natural cover types
Urban cover types
Glaciers



ATMOSPHERIC FORCING

Near-surface air characteristics (temperature, humidity, winds)
Surface pressure
Incident radiation (solar and infrared)
Precipitation (rain and snow)

INITIAL SURFACE CONDITIONS

Temperatures
Soil water content
Soil ice content
Snow characteristics
Urban surfaces wetness

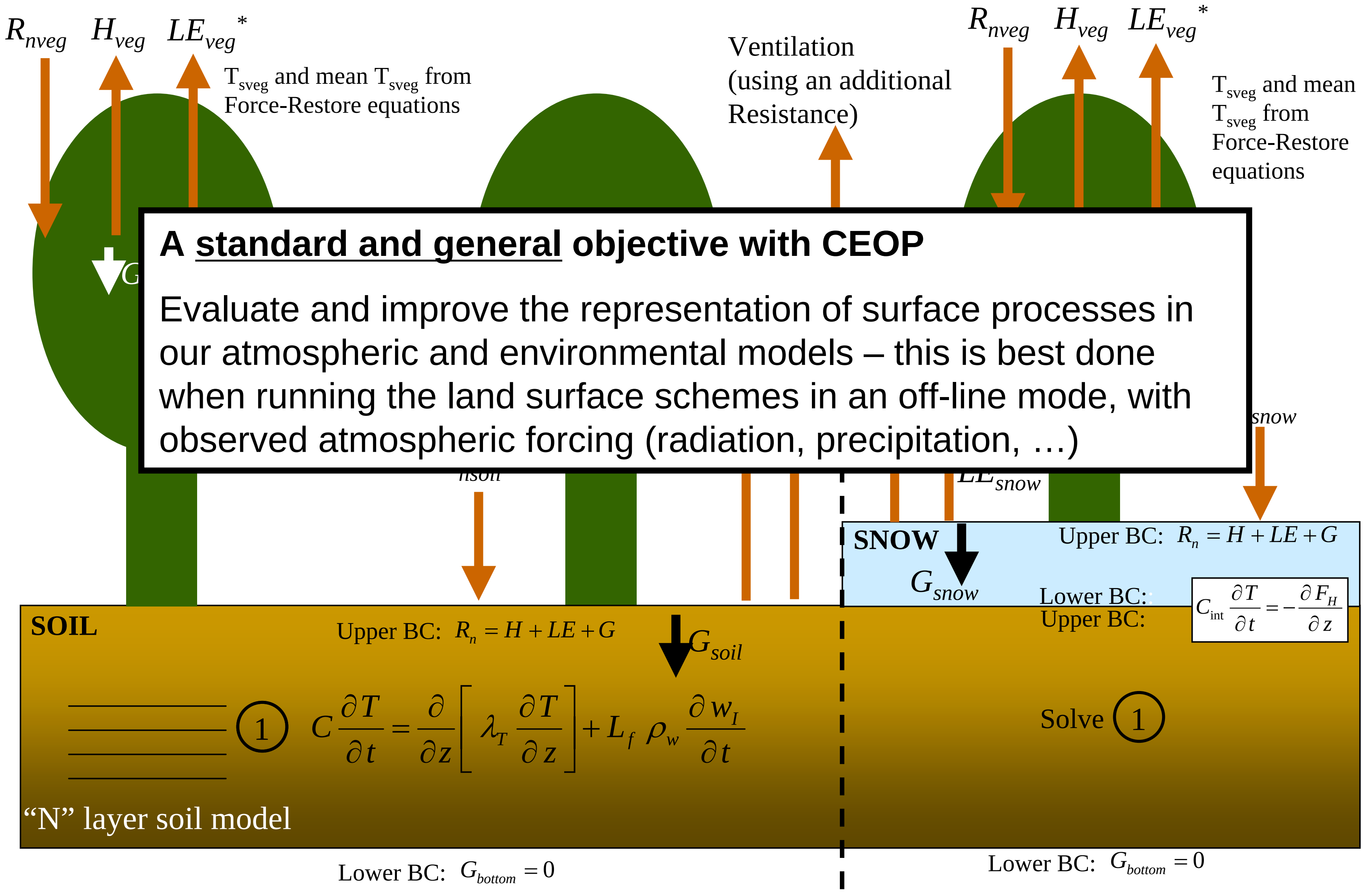
Our Main Objective at Environment Canada

… is to use observational data to reduce errors associated with the representation of surface processes in atmospheric models, i.e., from

- **Land surface modeling**
- **Land surface characteristics**
- **Atmospheric forcing**
- **Initial surface conditions**
- **Atmospheric model**

At this point, the question is: How best could we use CEOP data to achieve this objective?

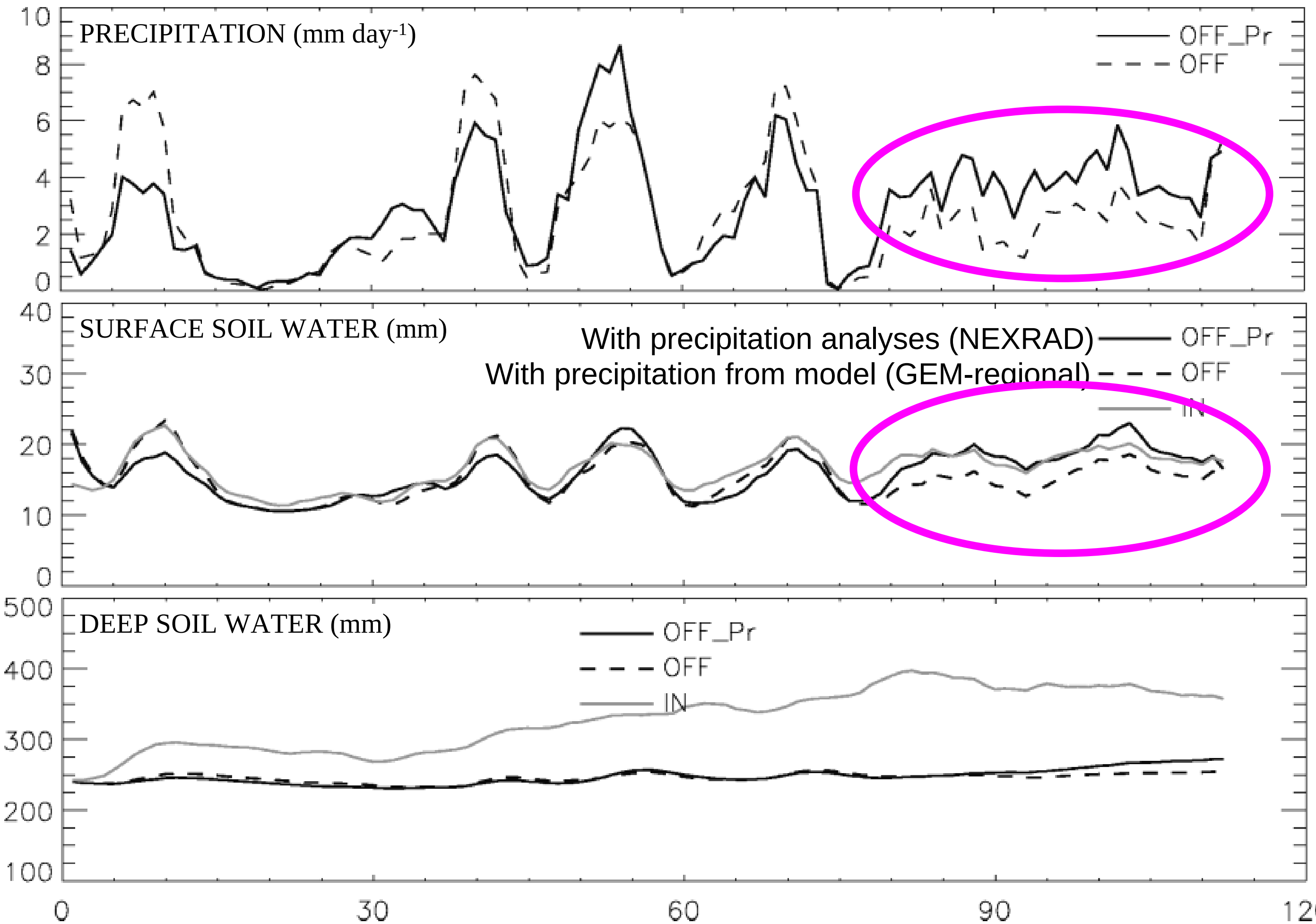
Land Surface Modeling
A) Surface Processes



A <u>standard and general</u> objective with CEOP

Evaluate and improve the representation of surface processes in our atmospheric and environmental models – this is best done when running the land surface schemes in an off-line mode, with observed atmospheric forcing (radiation, precipitation, …)

Land Surface Modeling
B) Atmospheric Forcing

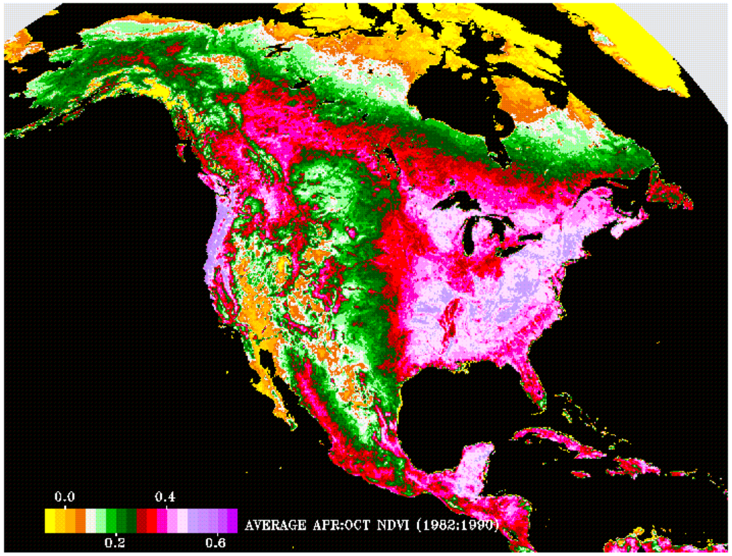


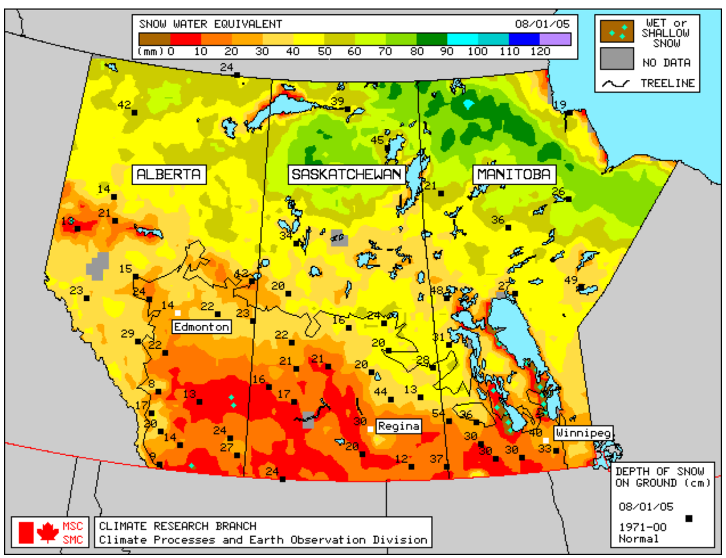
When using more realistic forcing for precipitation, the evolution of soil moisture is closer to a control run (in which soil moisture is adjusted in a data assimilation framework)

NOTE: no data assimilation in OFF and OFF_Pr experiments

This is also true (to a lesser degree though) for radiative forcing

Land Surface Modeling
C) Surface Characteristics





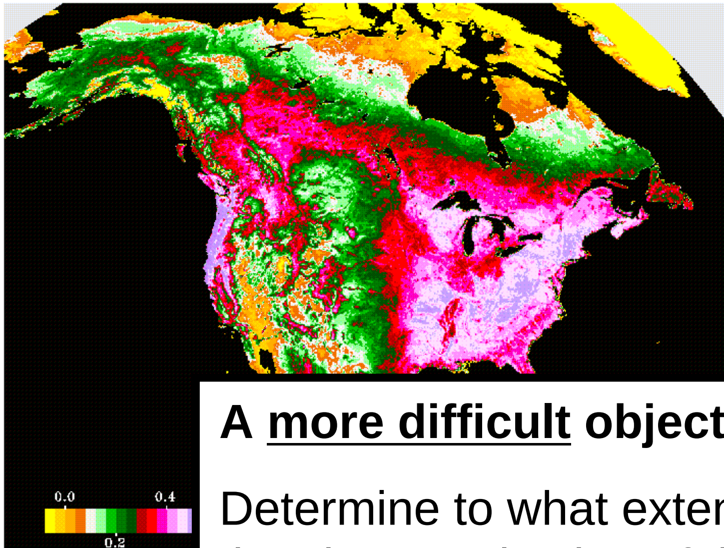
Vegetation

- Vegetation characteristics (LAI, fraction coverage) currently obtained using a 1-km vegetation types database (USGS)
- Pre-determined look-up tables are used to specify the vegetation characteristics
- Seasonal variations are also pre-determined (temporal interpolation using look-up tables)
- Future: Use NDVI from MODIS to specify fractions and LAI

Snow

- First guess provided by a simple off-line snow model
- Assimilation of surface observations (statistical interpolation)
- Sometimes results are funny due to sparse network of observations
- Future: Use microwave and visible satellite imagery to specify snow coverage fraction and snow mass

Land Surface Modeling
C) Surface Characteristics



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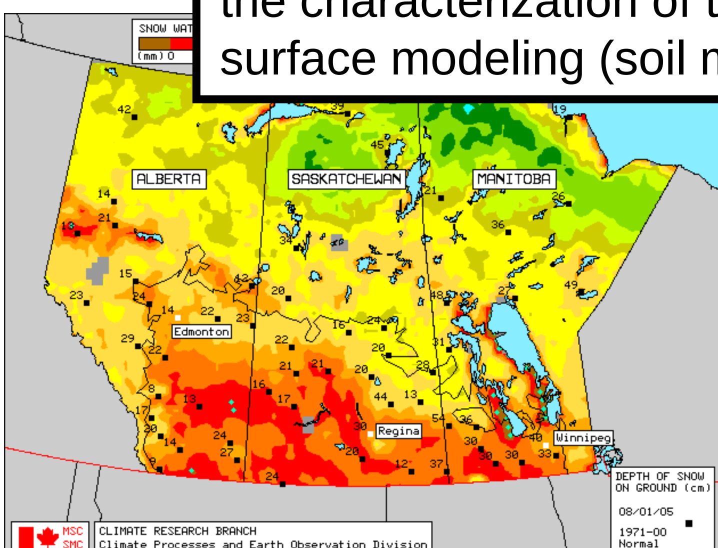
... and

A <u>more difficult</u> objective with CEOP

Determine to what extent errors in the atmospheric forcing and in the characterization of the surface contribute to errors in land surface modeling (soil moisture, surface fluxes, …)



- First guess provided by a simple off-line snow model
- Assimilation of surface observations (statistical interpolation)
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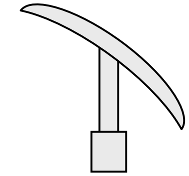
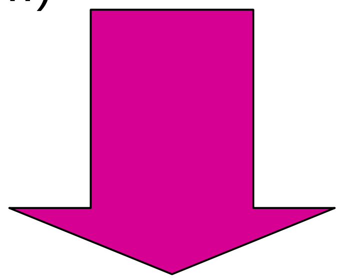
- Future: Use microwave and visible satellite imagery to specify snow coverage fraction and snow mass

Initial Conditions for Soil Moisture
A Few Strategies

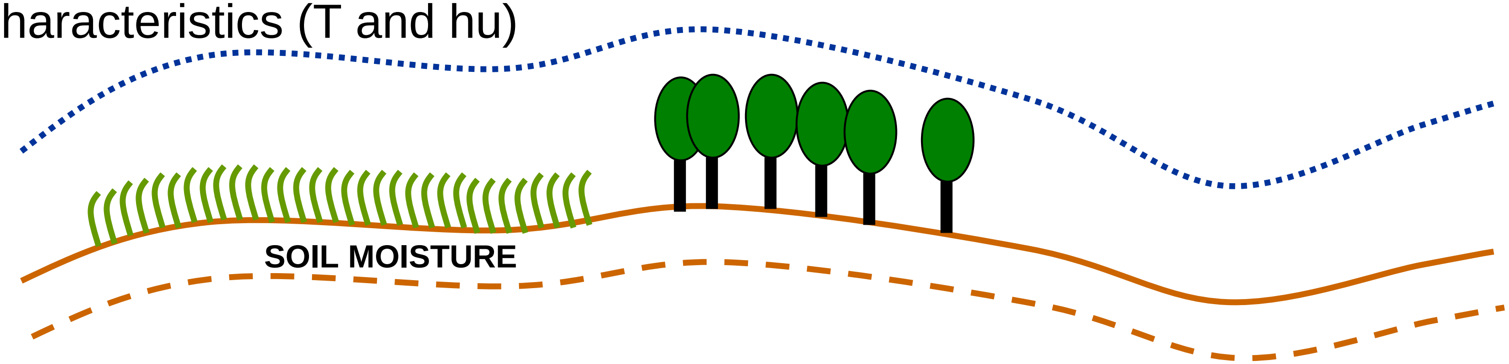


1 Use best estimate for atmospheric forcing (precip, radiation, etc…)

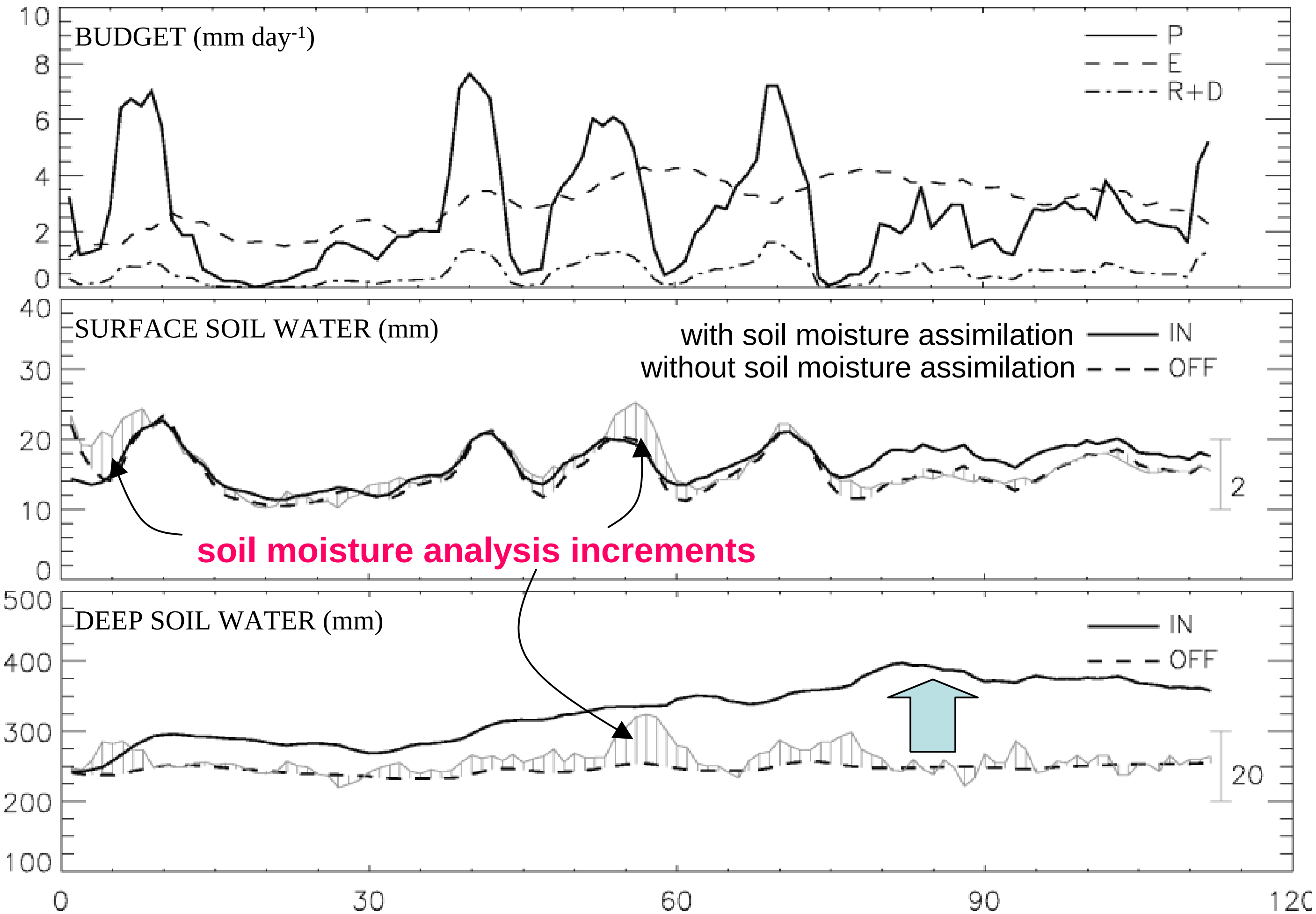
3 Assimilation of microwave remote sensing data



2 Assimilation of low-level air characteristics (T and hu)



Assimilation of Screen-Level Air Characteristics (Operational at Environment Canada)

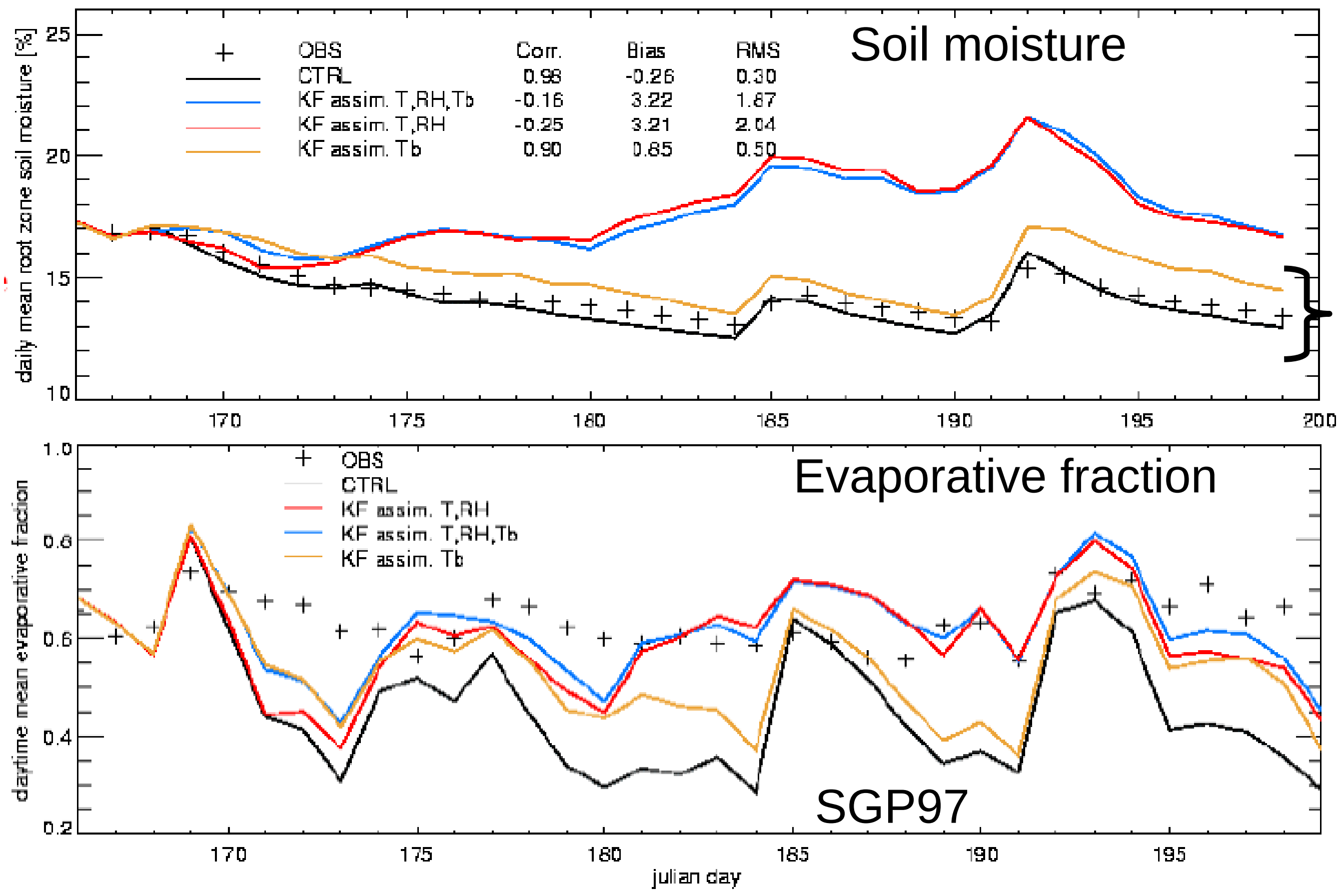


In order to minimize the modeling errors on low-level air characteristics, soil moisture is modified in a significant manner.

The "analysed" soil moisture could thus greatly differ from results obtained in an off-line experiment in which no data is assimilated and the land surface evolves freely without constraints from a data assimilation system.

It is not clear how well the soil moisture obtained with this analysis system corresponds to reality

Assimilation of Brightness Temperature



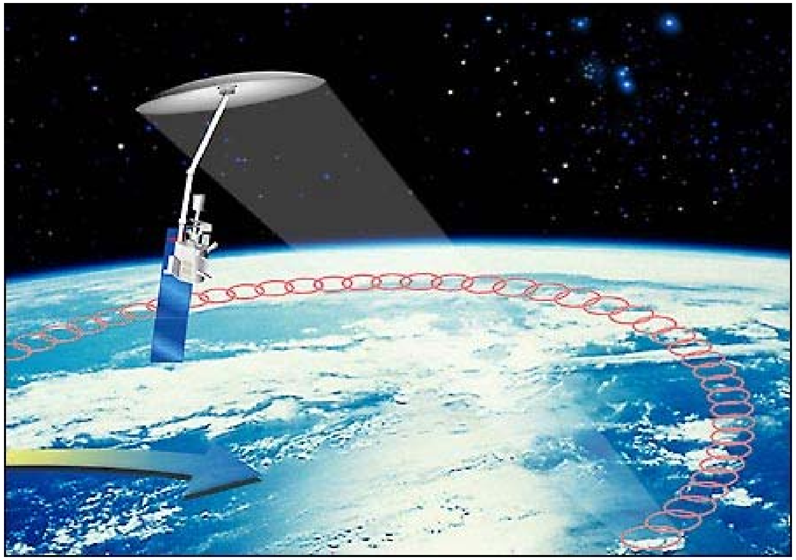
(From Ettema, ECMWF/ELDAS workshop on land surface assimilation, 2004)

Assimilation of Tb leads to good representation of soil moisture

But it does not necessarily lead to better surface fluxes

Conversely, the assimilation of screen-level air characteristics leads to better surface fluxes, but soil moisture is far from the observed values.

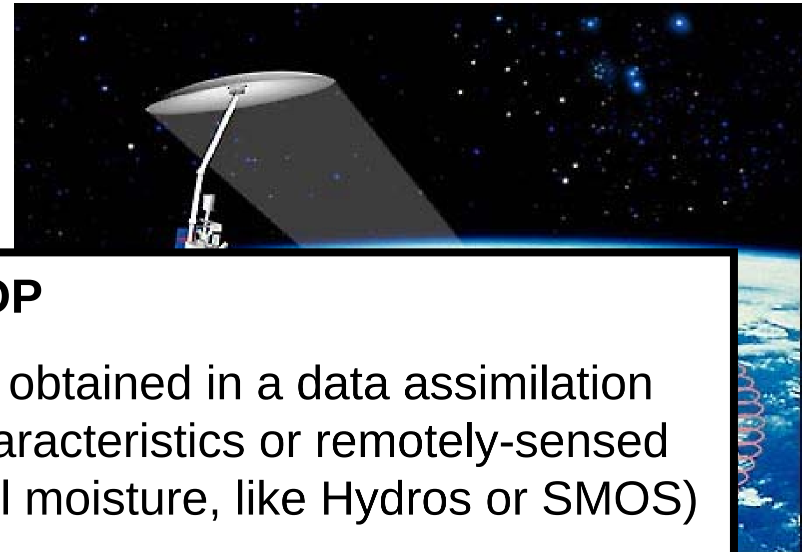
Hydros
Soil Moisture and Freeze/Thaw



- Pathfinder exploratory measurements
- L-band passive and active measurements (sensitive to soil moisture and freeze/thaw state)
- Spatial resolution: ~ 40 km for the radiometer; ~ 1-3 km for the radar; ~ 10 km for combined soil moisture product; ~ 3 km for freeze/thaw state
- Orbit: circular, polar, sun-synchronous, ~670 km above the Earth, ~6am/pm Equator crossing
- Swath width ~ 1000 km, revisit time 2-3 days global
- Environment Canada is on the science team

	2004	2005	2006	2007	2008	2009	2010	2011	2012
Phase	**Phase A/B**				**Phase C**		**Phase D/E**		

Hydros
Soil Moisture and Freeze/Thaw



Interesting objectives with CEOP

in situ verification of soil moisture obtained in a data assimilation system (using screen-level air characteristics or remotely-sensed data more directly sensitive to soil moisture, like Hydros or SMOS)

Establish the relationship between the quality of the soil moisture assimilation and forecasting errors for near-surface air characteristics

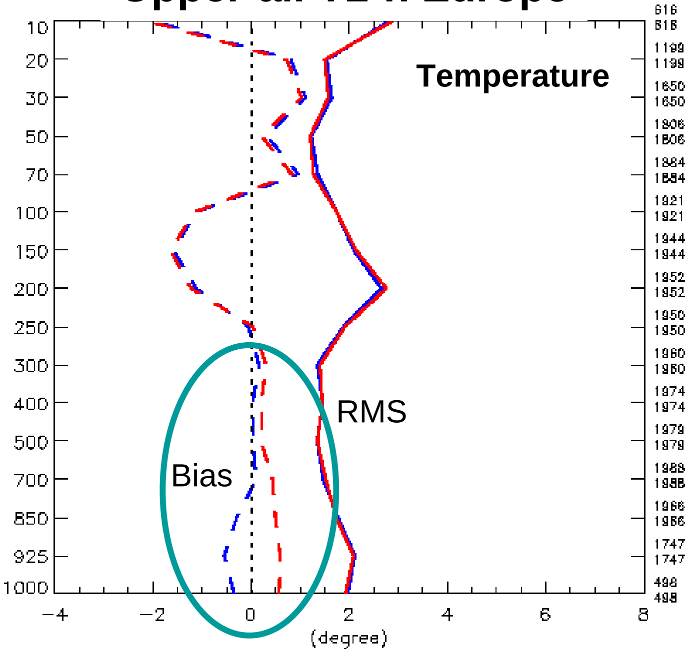
If better soil moisture does not lead to better forecasts of low-level air characteristics, why?

- Pathf
- L-ban meas moist
- Spati ... km for co
- Orbit ... m Equa
- Swath width ~ 1000 km, revisit time 2-3 days global
- MSC is on the science team

	2004	2005	2006	2007	2008	2009	2010	2011	2012
Phase	Phase A/B				Phase C		Phase D/E		

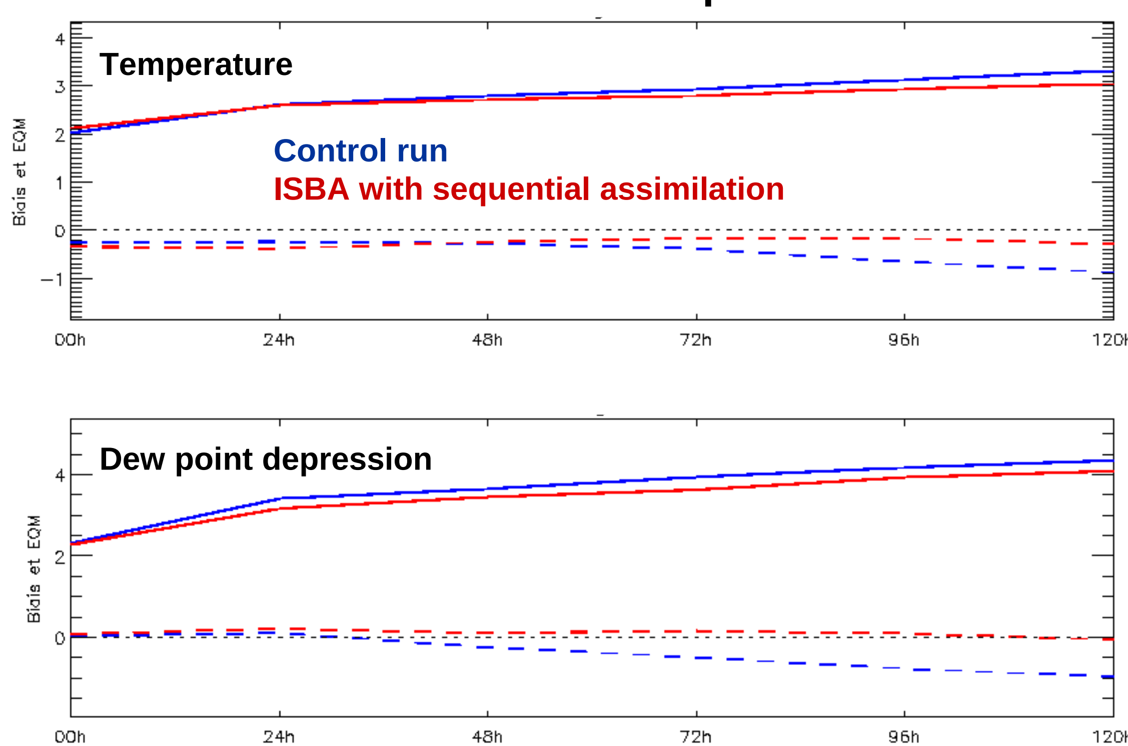
Atmospheric Modeling

Upper-air 72-h Europe



New land surface scheme with sequential assimilation reduce the errors at the screen level, but leads to warming of the troposphere

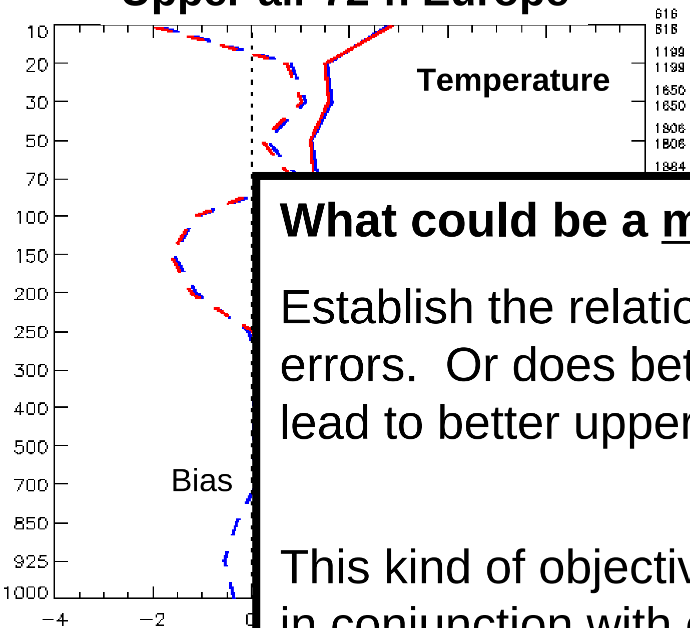
Surface Europe



This discrepancy between low-level air characteristics and upper-air results is believed to be related to other weaknesses of the atmospheric model (e.g., coupling between surface and the atmosphere, turbulent diffusion)

Atmospheric Modeling

Upper-air 72-h Europe



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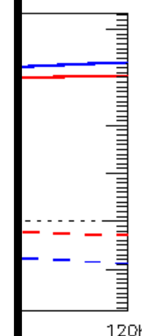
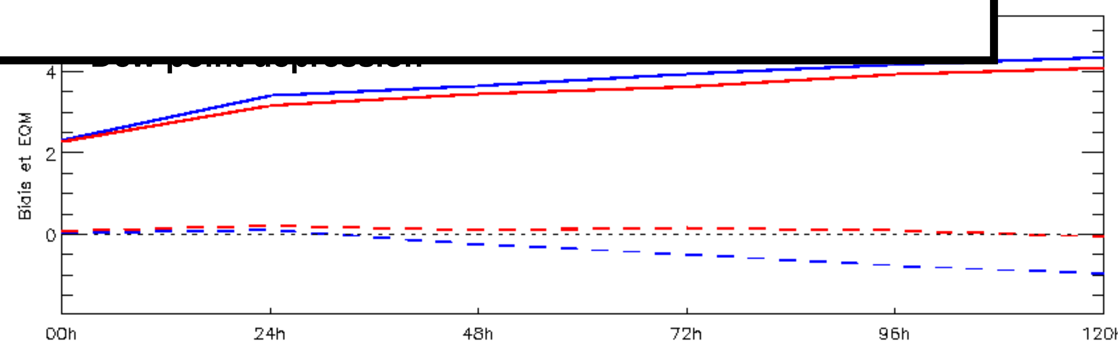


What could be a <u>most difficult</u> objective with CEOP

Establish the relationship between upper-level and near-surface errors. Or does better forecasts of low-level air characteristics lead to better upper-air forecasts? If not, why?

This kind of objective can only be achieved if CEOP data is used in conjunction with other types of data already available for the objective evaluation of NWP models (e.g., radiosondes and upper-air analyses)

This discre... level charac... results is believed to be related to other weaknesses of the atmospheric model (e.g., coupling between surface and the atmosphere, turbulent diffusion)



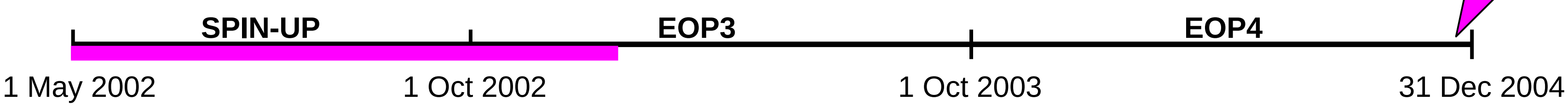
Our Modeling Strategy for CEOP

MODELING SYSTEM:
Based on the new mesoscale version of the Global Enrvironmental Multiscale (GEM) model that is currently being developed at MSC for medium-range weather forecasts

- 800x600x58L (~33 km at 50º lat);
- 4-schemes for the representation of clouds
  - Kain-Fritsch for deep convection
  - Kuo Transient for shallow convection
  - Sundqvist for grid-scale condensation
  - Simple scheme for PBL clouds
- 4 types of surface schemes (including ISBA over land + other schemes over water, sea-ice, and glaciers)

EOP3 and EOP4 should be completed before the end of this year

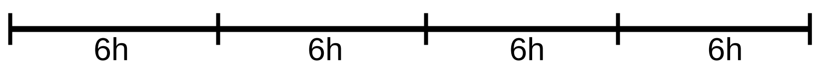
PERIOD of INTEGRATION:



CYCLING and ASSIMILATION STRATEGY:

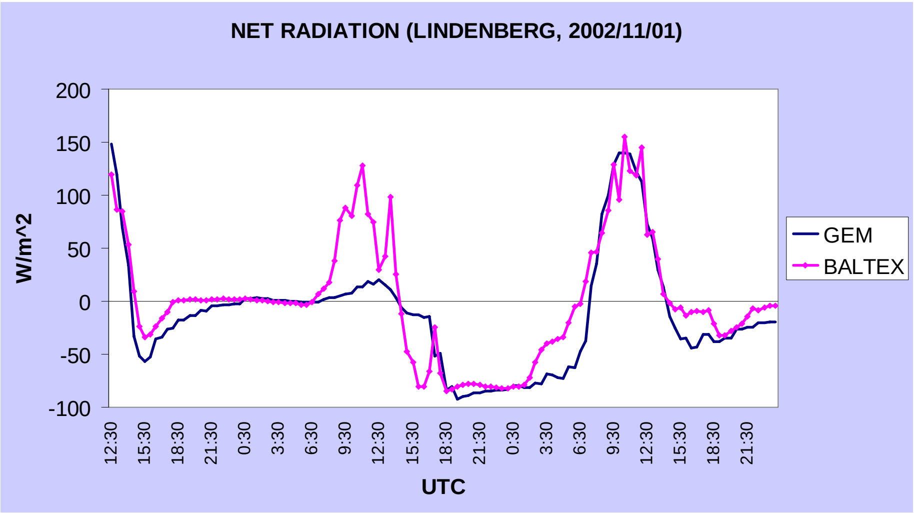
Upper-air component of the analyses is directly obtained from CMC's archive, i.e., no 3DVAR will be performed for atmospheric observations

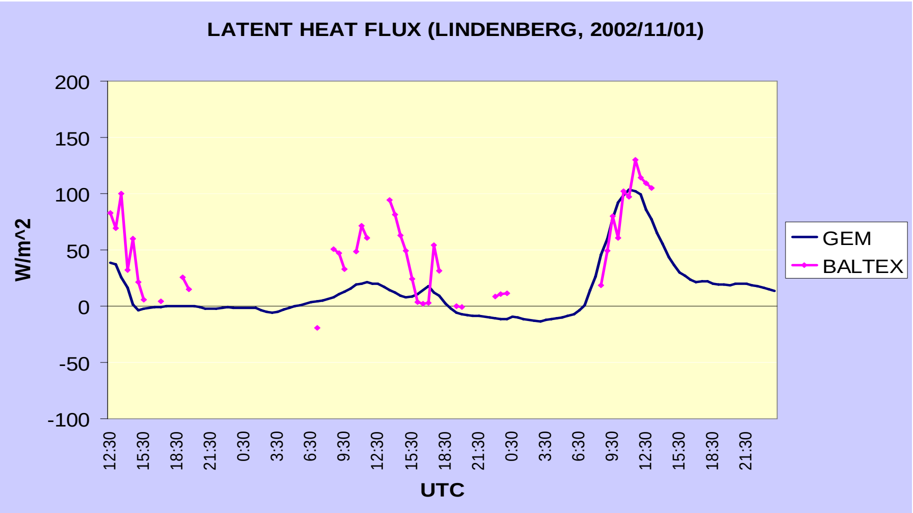
Grid-scale cloud water content is cycled from the previous 6-h forecast, to avoid spin-up problems which could have negative impacts on surface processes

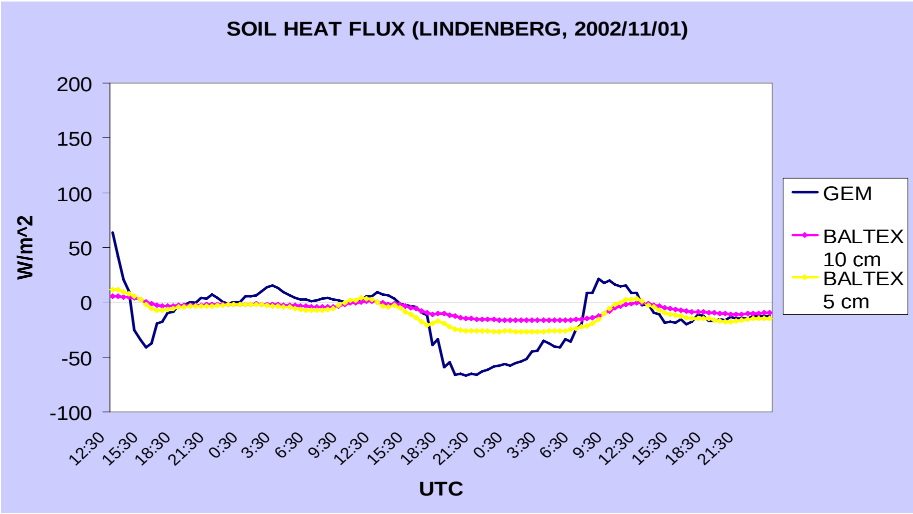


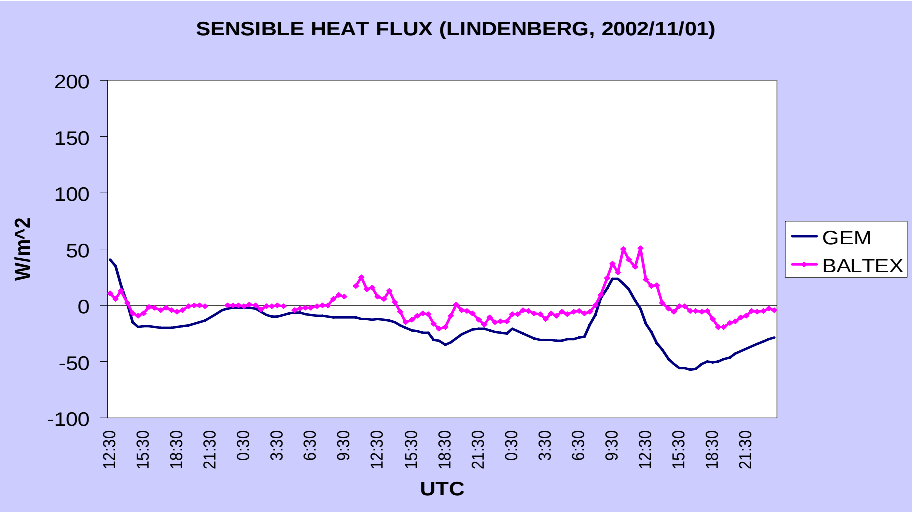
Surface component of the analyses is cycled from the previous 6-h forecast, with sequential assimilation of soil moisture and surface temperature

Preliminary Results: Energy Budget at Lindenberg

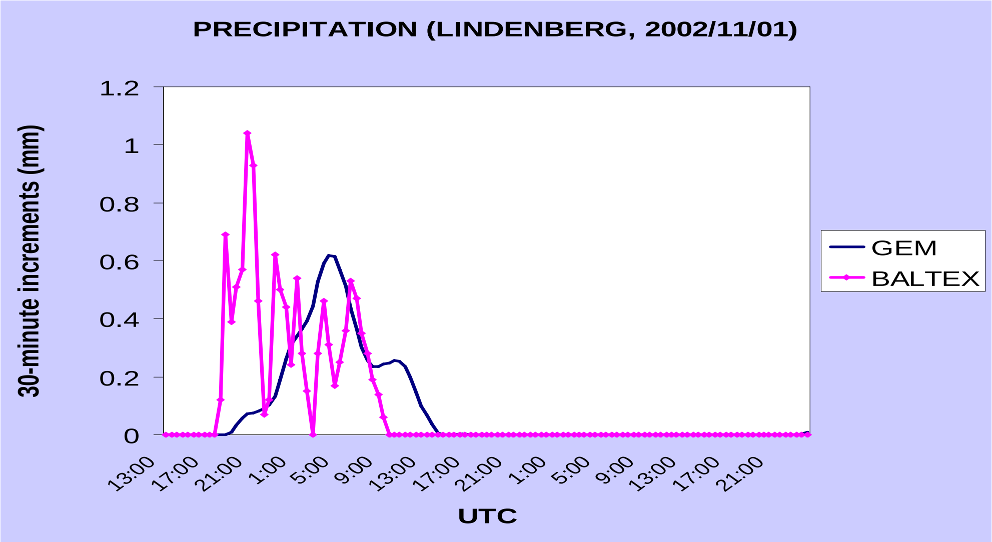


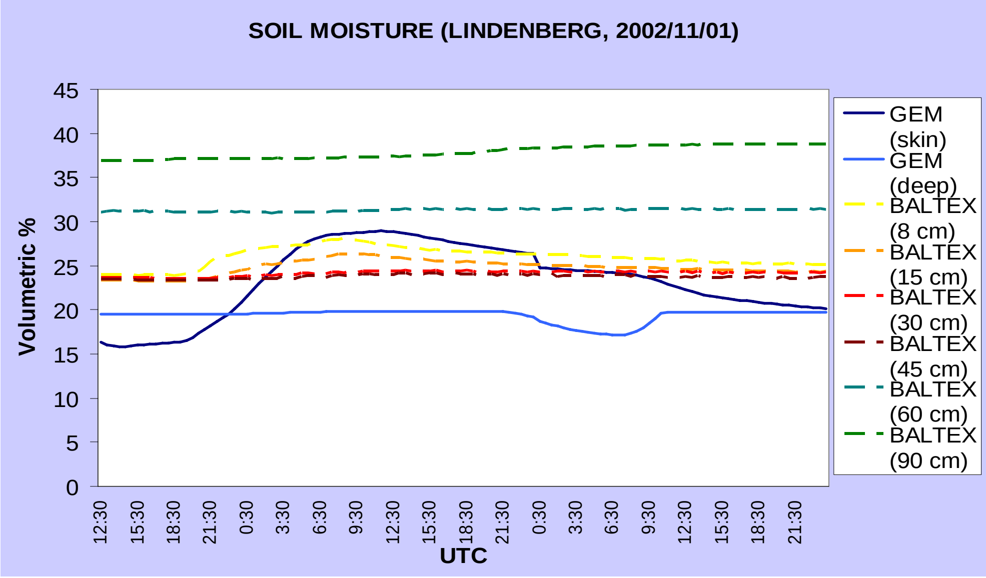






Preliminary Results: Water Budget at Lindenberg





Preliminary Results: Water Budget at Lindenberg

PRECIPITATION (LINDENBERG, 2002/11/01)

Conclusions

CEOP data will be included into our statistical (objective) evaluation. The objective is to use the complementary aspect of this data to evaluate and optimize the impact that the land surface assimilation and modeling system has on global weather forecasting.

In particular, we are interested in errors associated with:

- **Land surface modeling (including also surface characteristics)**
- **Atmospheric forcing**
- **Soil moisture (analyses and forecasts)**
- **Coupling surface-atmospere**