

INTRODUCING A SOIL FREEZING SCHEME INTO A LAND-SURFACE MODEL



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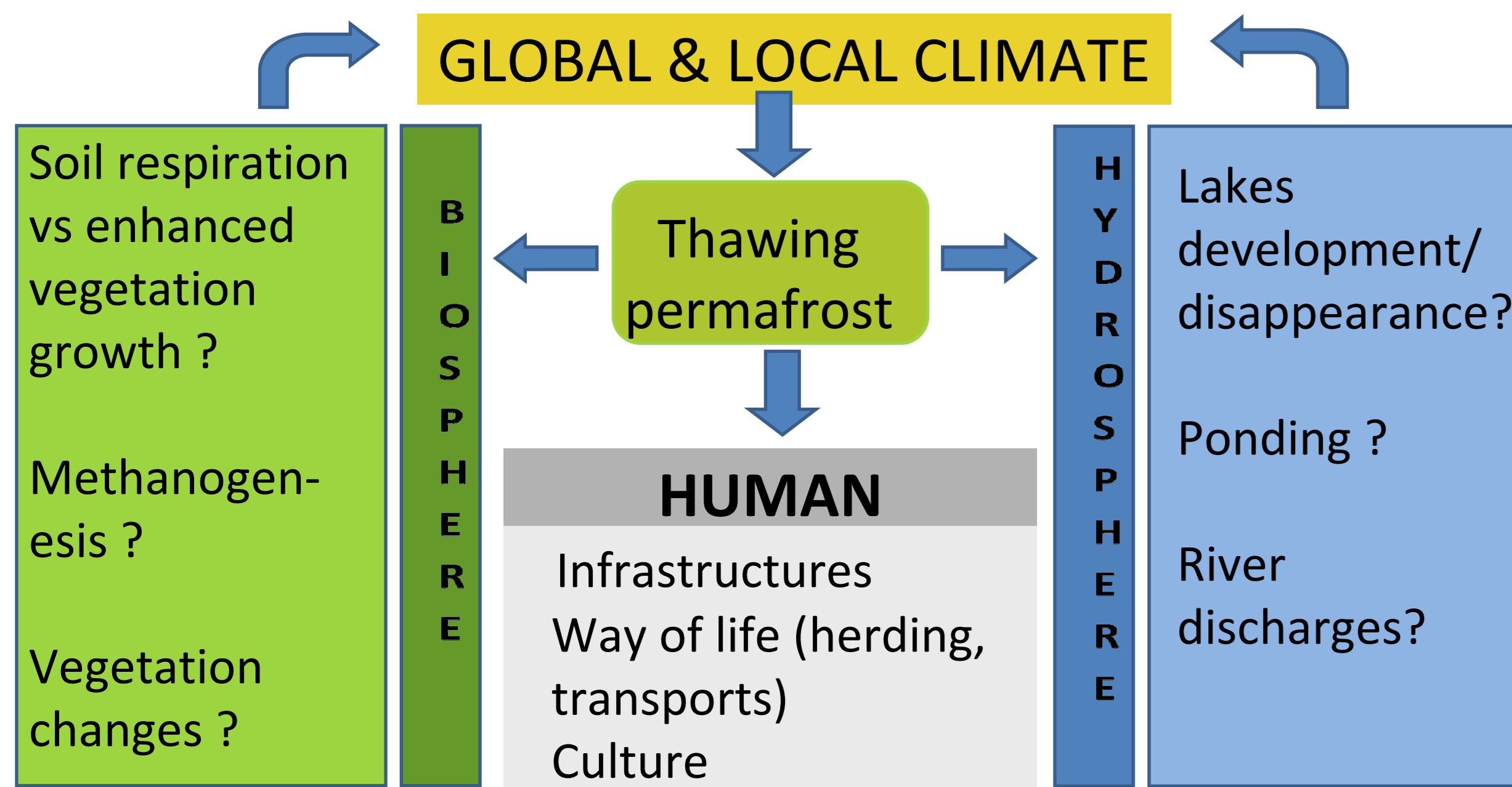
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1. PERMAFROST MODELLING

1.1. WHY ?

Global and local climate feedbacks of thawing permafrost



permafrost concerning wide areas : 25% of the northern hemisphere

We aim at **quantifying permafrost-related climate feedback** by introducing a **soil freezing scheme and organic matter** into the **Land Surface Scheme ORCHIDEE**, part of the **IPSL-ESM4 Earth Climate Model**.

1.2. HOW ?

within the land-surface scheme **ORCHIDEE** (IPSL, Paris)

Heat diffusion scheme

$$C \frac{\partial T}{\partial t} = \nabla \cdot (\kappa \nabla T) + \rho_w L \frac{\partial \theta_i}{\partial t}$$

Soil freezing :

- Modified heat capacity and conductivity accounting for ice fraction (Farouki, 1982)
- Latent heat exchange => additional heat capacity (Poutou et al., 2004 ; Smirnova, 1999)

Organic Matter (in future)

- Specific thermal properties
- Additional heat release due to decomposition



Water diffusion scheme

$$\theta_1 \frac{\partial \theta(z,t)}{\partial t} = \nabla \cdot [D(\theta) \nabla \theta(z,t) + K(\theta)]$$

Soil freezing :

- Reduced hydraulic conductivity (Niu and Yang, 2005)
- Infiltration impedance
- Subgrid approach accounting for large-scale features (Cherkauer and Lettenmeier, 2003)

Organic Matter (in future)

- Specific hydrological properties (Bonan and Shugard, 1989)

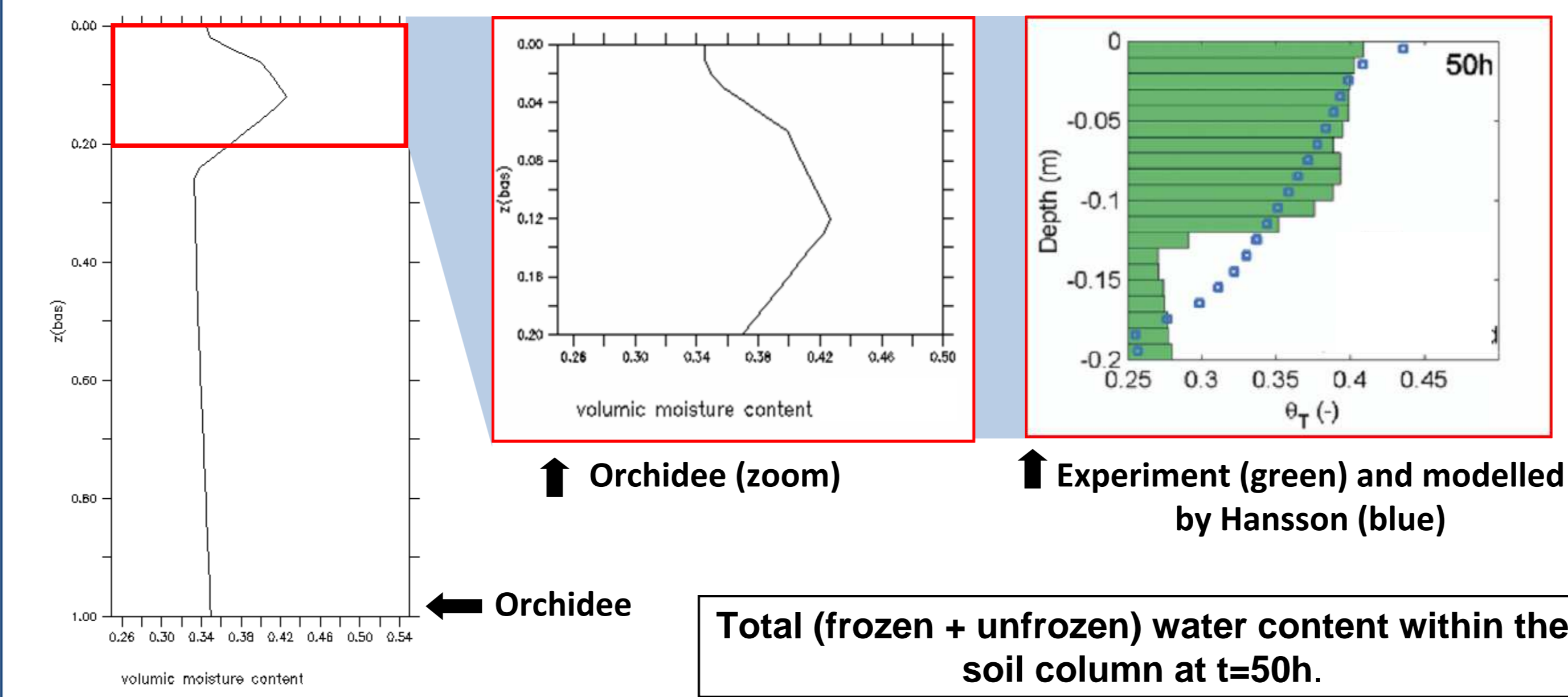
2. FIRST RESULTS

2.1. ON A 1-D LABORATORY EXPERIMENT

Experiment of Mizoguchi, 1990

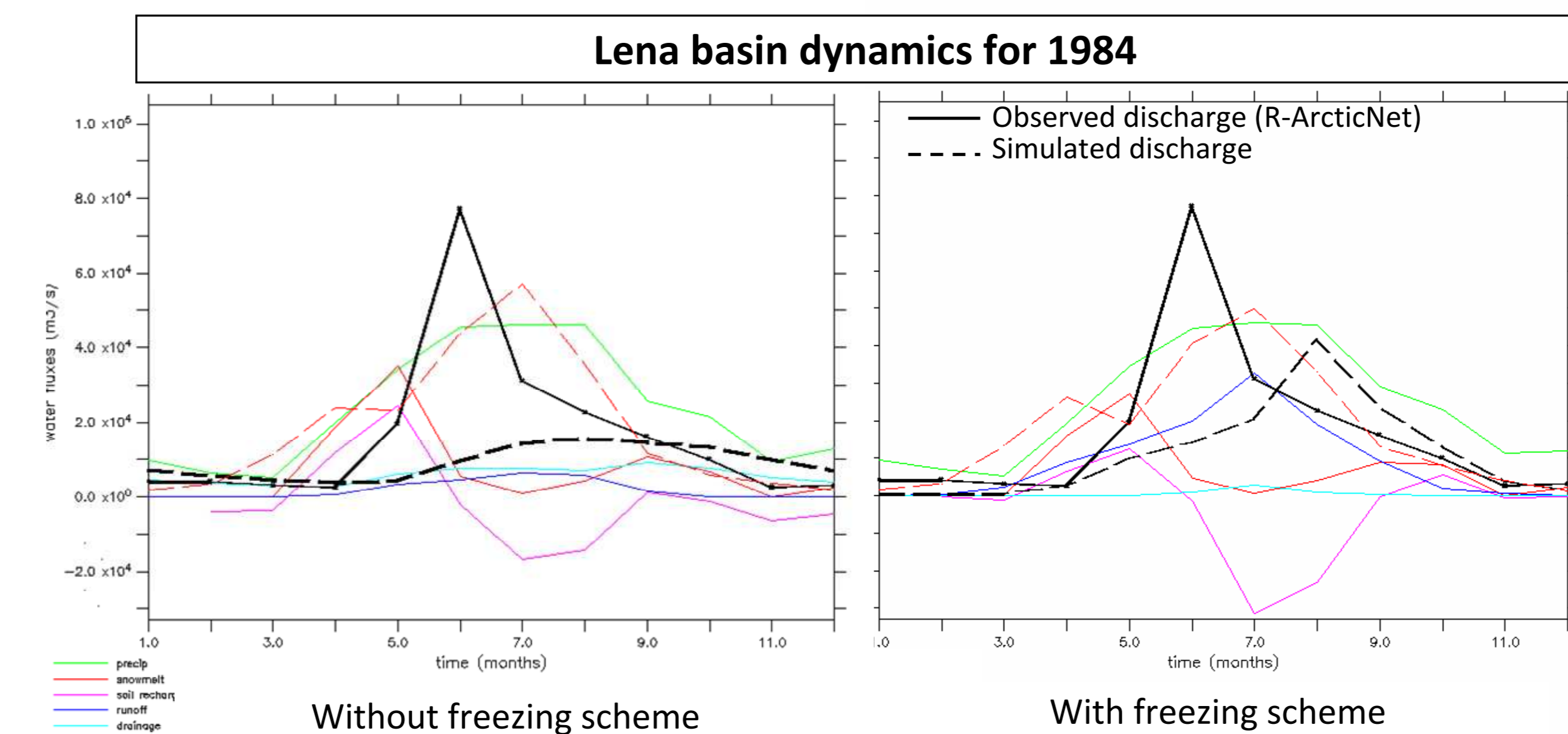
As documented in Hansson et al., 2004.

A soil column sample with initially uniform volumetric water content of 0.33 is exposed to a -6.7°C fluid at its upper end at t=0. Volumetric water content is measured at different times.



- **Cryosuction works**, but not directly beneath the surface due to time-step vs space discretization ratio.
- Too rapid an advance of the freezing front, possibly due to uncalibrated thermal properties

2.2. ARCTIC RIVER DISCHARGES SIMULATIONS



- Snowmelt water runs-off instead of infiltrating, leading to **less soil recharge in spring and dryer soils in summer**
- Failure at reproducing the basin's discharge volume and seasonality may proceed from an underestimated snowcover as suggested by a comparison with ETAC_snow data (not shown).

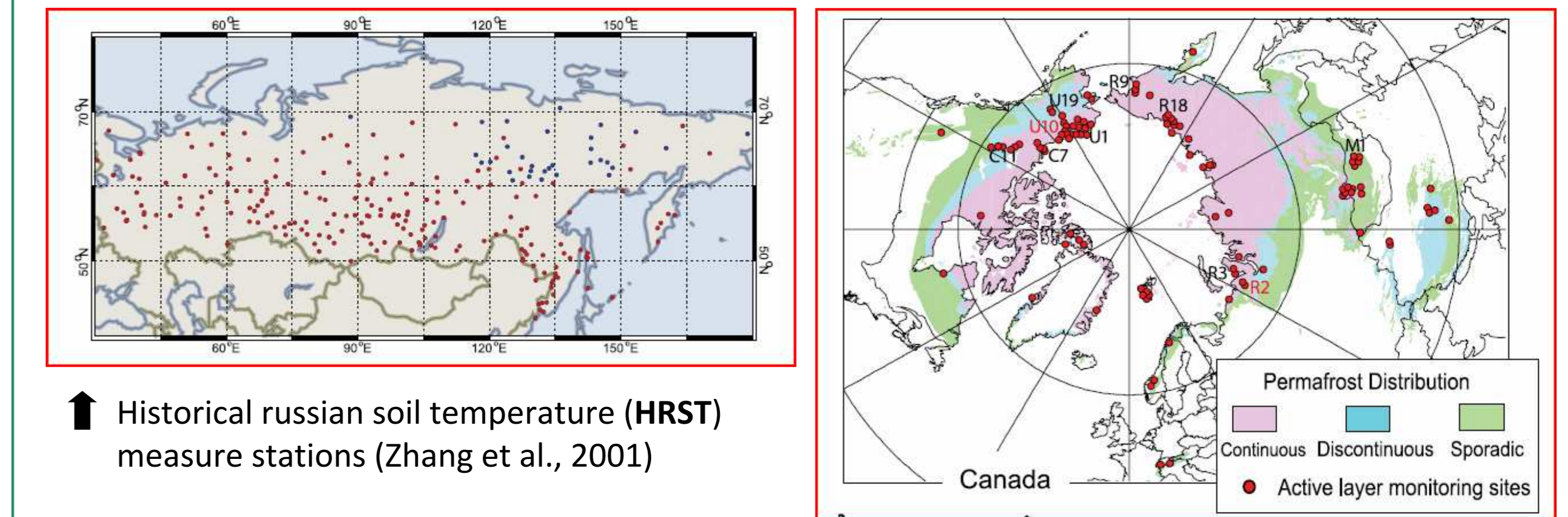
3. FURTHER PROSPECTS

3.1. TOWARDS IMPROVED SOIL TEMPERATURES AND ARCTIC HYDROLOGY REPRESENTATIONS

Accurate **ACTIVE LAYER THICKNESS** and **MOISTURE CONDITIONS** representation is crucial for C-cycle implications of permafrost thawing.

- Introducing organic matter should help
- Simulations with **forced snow** might stress the necessity of improving our **representation of snow** in ORCHIDEE.

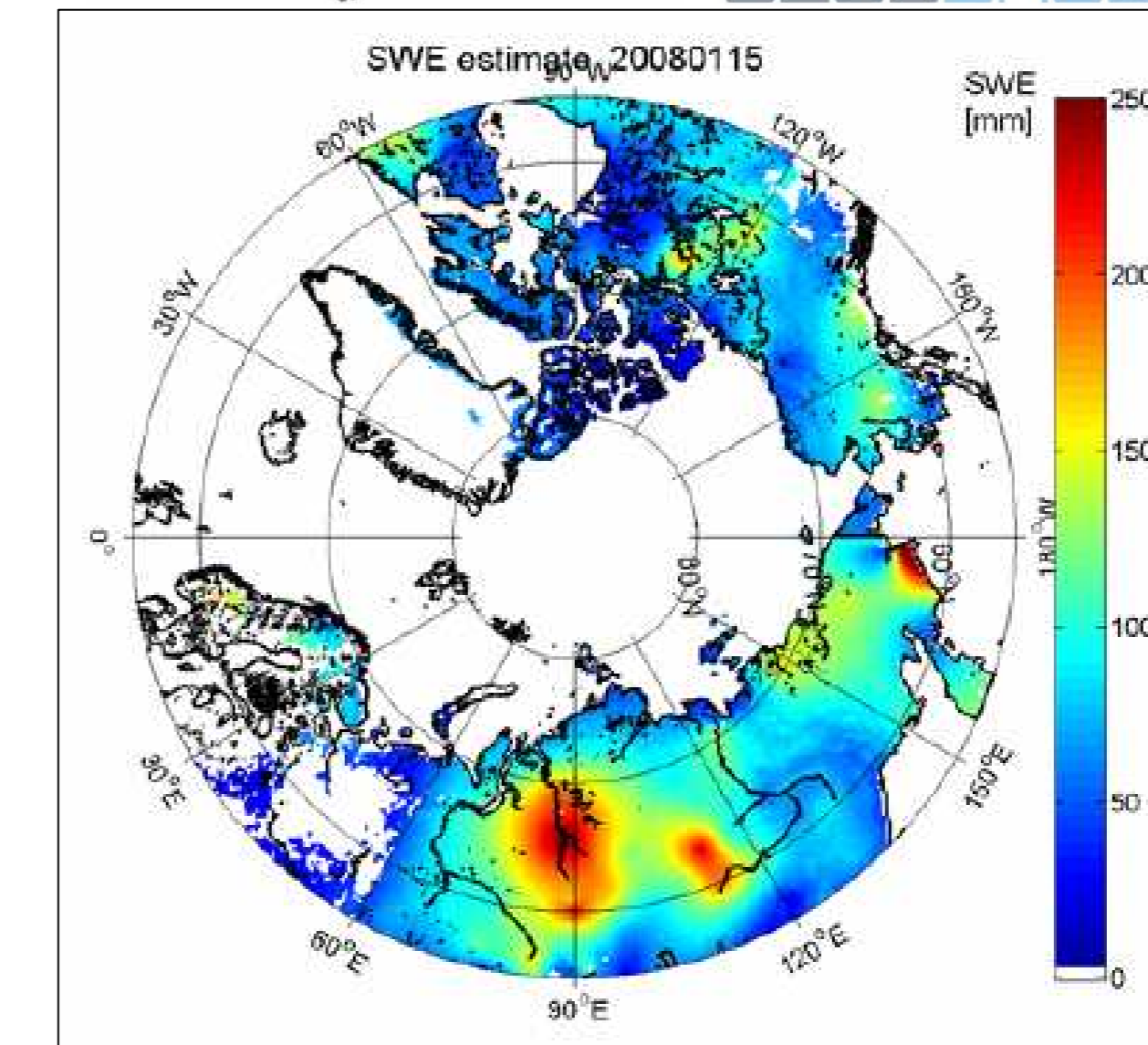
soil temperature and active layer thickness data



Historical Russian soil temperature (HRST) measure stations (Zhang et al., 2001)

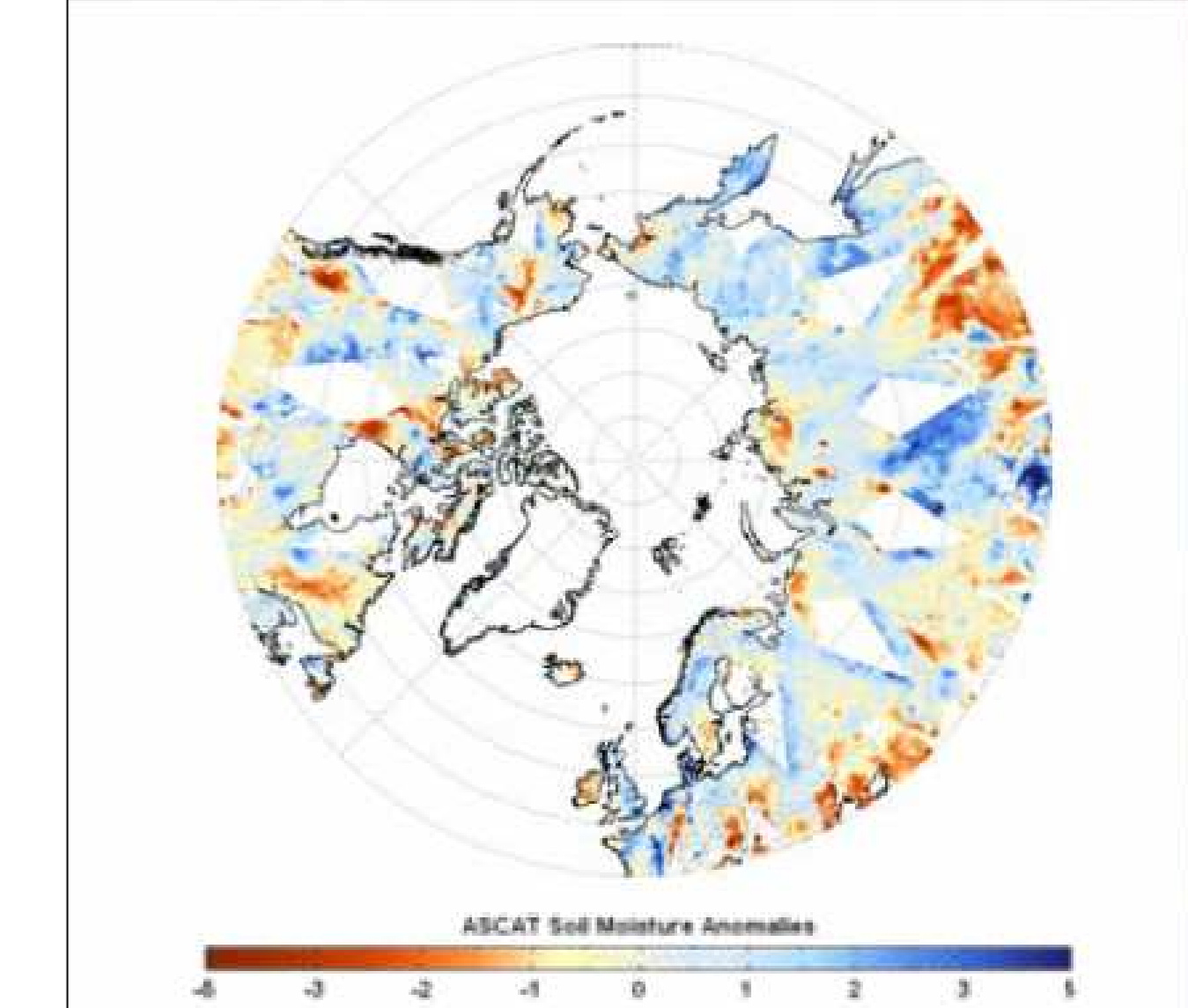
Circum-polar active layer monitoring sites (CALM) (Brown et al, 2000)

snow water equivalent data



Snow water equivalent for January, 2008 from the GLOBSNOW dataset.

soil moisture and status data



Pan-arctic anomaly of soil moisture from METOP ASCAT data of July, 2007.

3.2. TIMELINE

