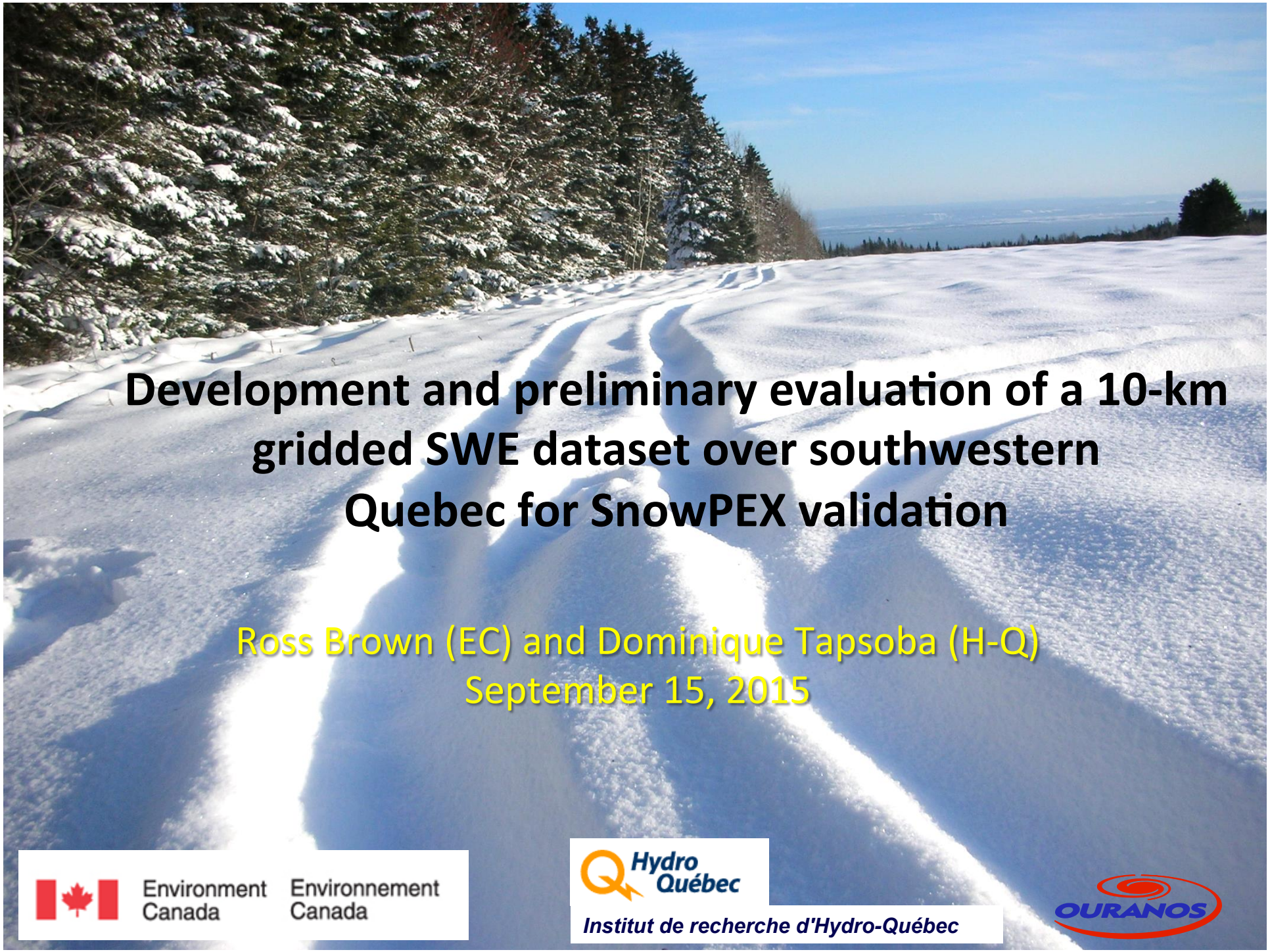

Development and preliminary evaluation of a 10-km gridded SWE dataset over southwestern Quebec for SnowPEX validation

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September 15, 2015

Environment Canada | Environnement Canada

Hydro Québec

Institut de recherche d'Hydro-Québec

OURANOS

Outline

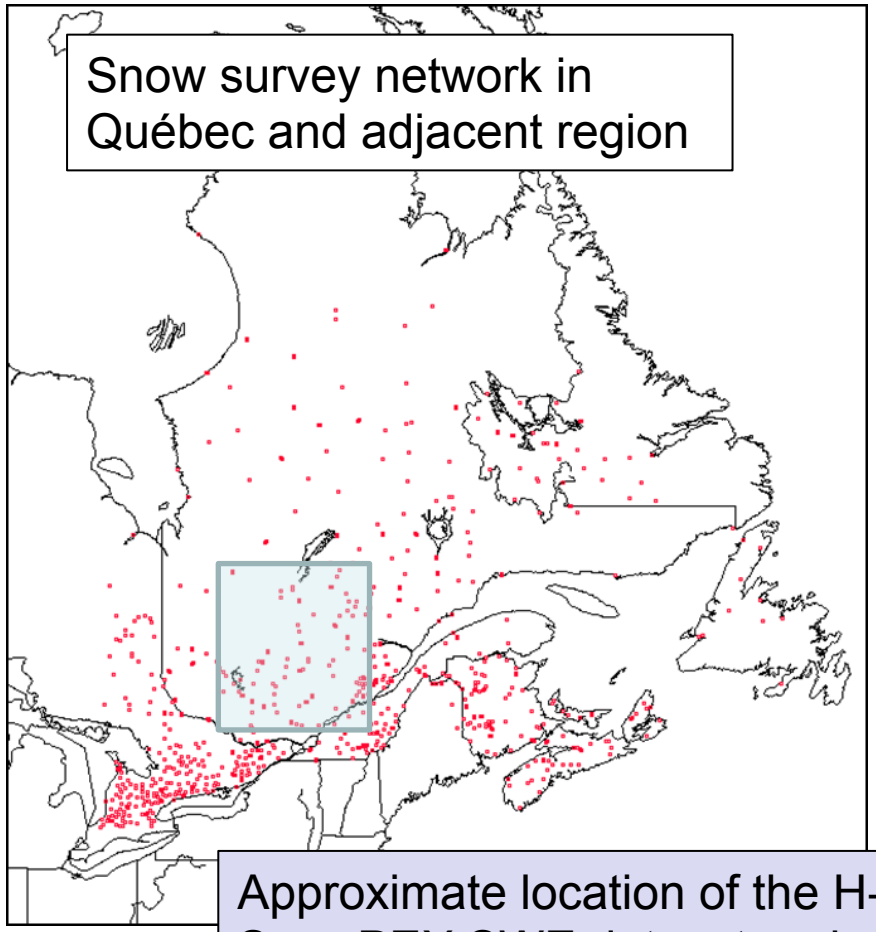
- Objective
- Study area, data sources etc
- Kriging methodology, cross-validation
- Preliminary evaluation results

Objective

- Develop “best estimate” 10-km gridded SWE dataset from interpolation of surface snow survey data and ancillary information (elevation, land cover) for use in SnowPEX

- Provide estimates of uncertainty in the interpolated values

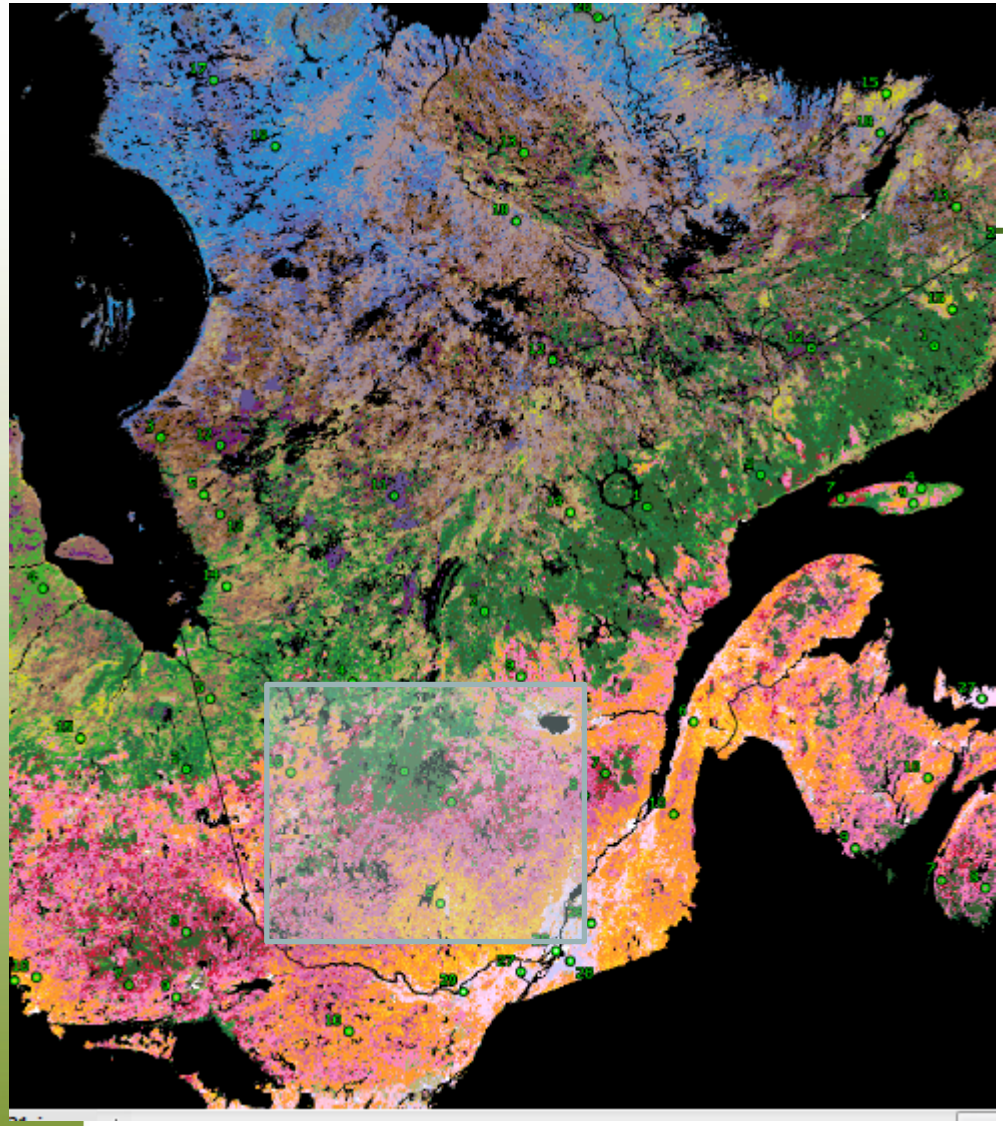
Study Area



Approximate location of the H-Q SnowPEX SWE dataset region

46.3 to 49.2°N, -76.1 to -71.7°W

- Québec a potentially data-rich SnowPEx validation region (high SWE, range of vegetation cover)s
- Initially considered developing a pan-Québec gridded SWE dataset but decided to concentrate on the Saint-Maurice River watershed in southwestern QC
- High density of snow surveys (80-100 per survey period = 1 stn per ~35 km); GMON in situ SWE obs; previous work in area (e.g.Tapsoba et al. 2005)



Land Cover Description

Land Cover Type

Land Cover of Canada (image)

- Coniferous Forest: High Density (1)
- Coniferous Forest: Medium Density - Southern (2)
- Coniferous Forest: Medium Density - Northern (3)
- Coniferous Forest: Low Density - Southern (4)
- Coniferous Forest: Low Density - Northern (5)
- Broadleaf Forest (6)
- Mixed Coniferous Forest (7)
- Mixed Uniform Forest (8)
- Mixed Heterogenous Forest (9)
- Mixed Broadleaf Forest (10)
- Burns: Low Green Vegetation Cover (11)
- Burns: Green Vegetation Cover (12)
- Transition Treed Shrubland (13)
- Wetland/Shrubland: High Density (14)
- Wetland/Shrubland: Medium Density (15)
- Grassland (16)
- Tundra: Lichen and Others (17)
- Tundra: Shrub/Lichen Dominated (18)
- Tundra: Heather and Herbs (19)
- Tundra: Low Vegetation Cover (20)
- Tundra: Very Low Vegetation Cover (21)
- Tundra: Bare Soil and Rock (22)
- Cropland: High Biomass (23)
- Cropland: Medium Biomass (24)
- Cropland: Low Biomass (25)
- Mosaic Land: Cropland-Woodland (26)
- Mosaic Land: Woodland-Cropland (27)
- Mosaic Land: Cropland-Other (28)
- Urban and Built-up (29)
- Water (30)
- Snow/ice (31)

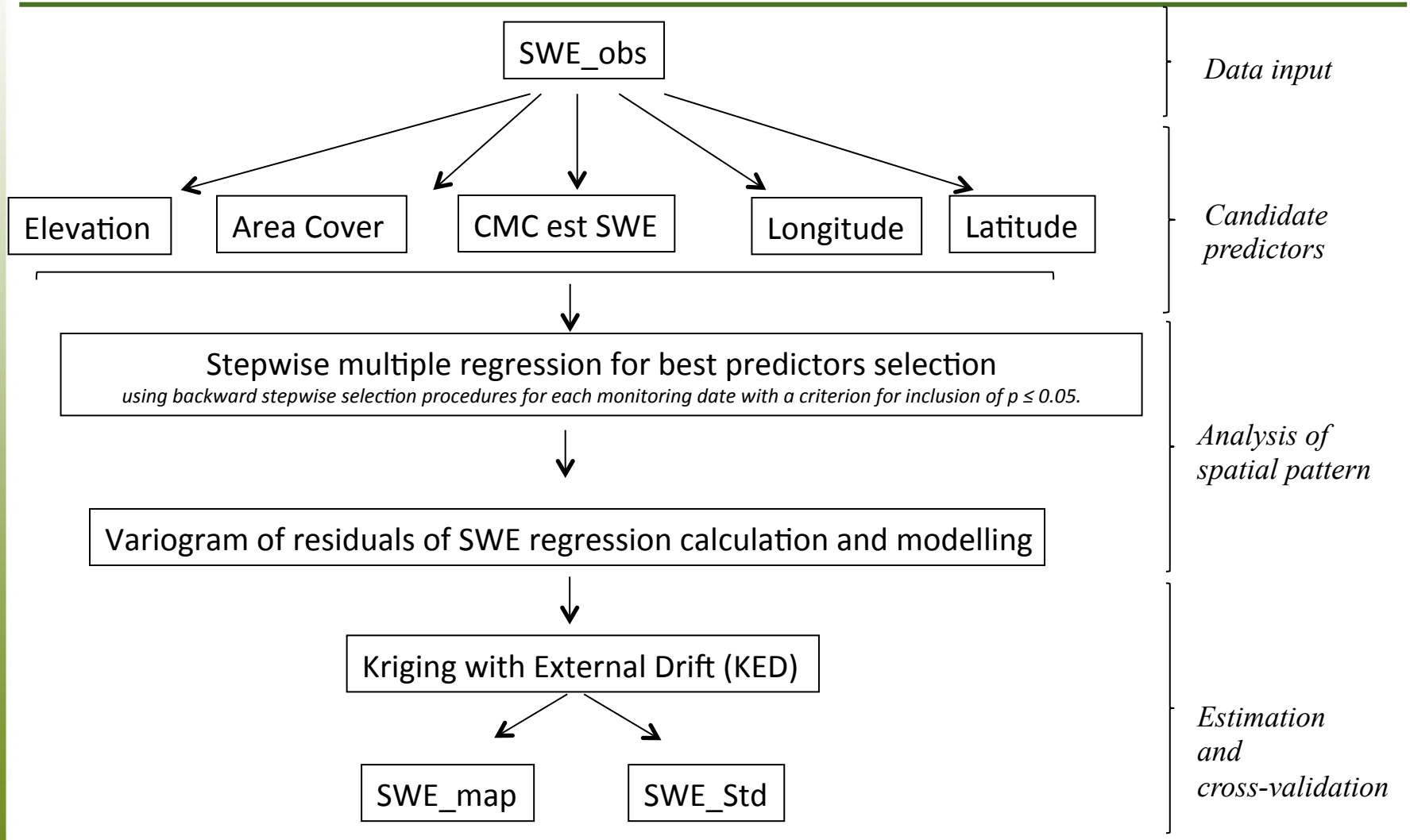
- Region covers the transition zone from mixed broadleaf forest (maple, yellow birch) to southern coniferous forest (pine, spruce, white birch)

Source: Atlas of Canada 6th Edition

Data sources

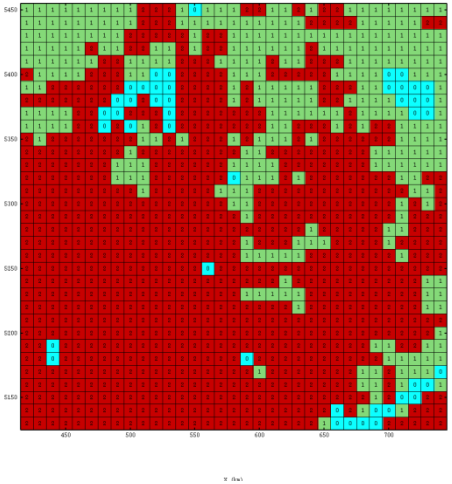
- Hydro-Québec and partner snow surveys for Feb 01, Mar 01, Mar 15, Apr 01 and Apr 15 from 1999-2013. The snow survey dates correspond to the regular snow survey schedule which is designed to observe the maximum accumulation prior to spring melt
- SWE estimates from CMC daily snow depth analysis
- Land cover classification used by H-Q (0=water, 1=open, 2=closed)
- GMON in situ SWE obs and streamflow data also available in the region (proprietary)
- Note: the gridded SWE dataset is freely available to the scientific community

Methodology

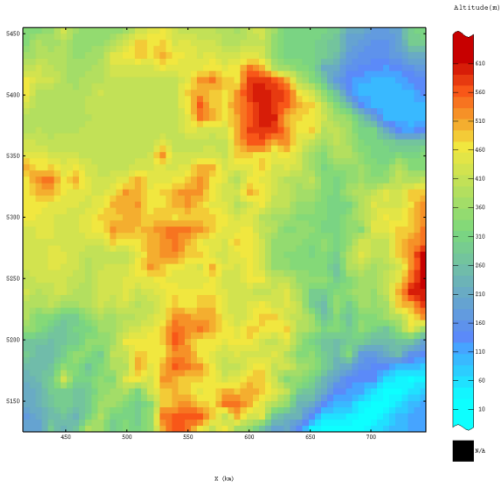


Predictors used in kriging process

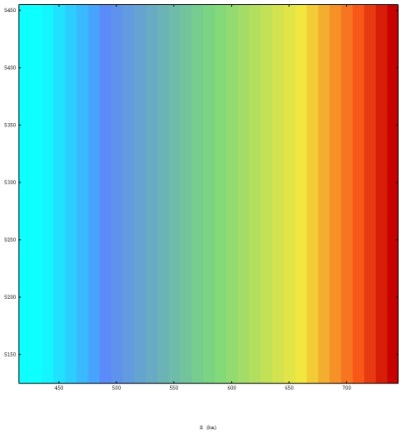
Land use (0,1,2)



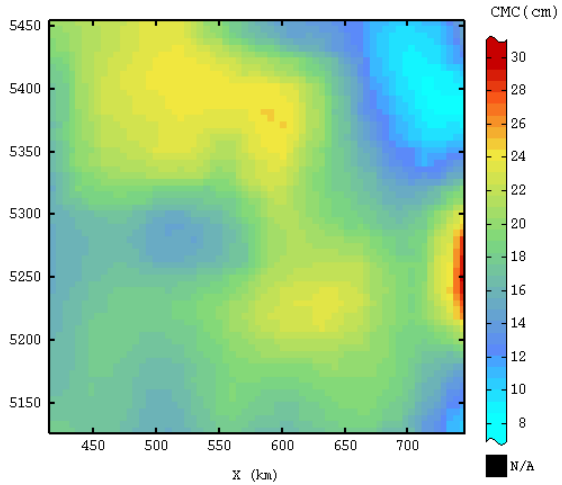
Elevation



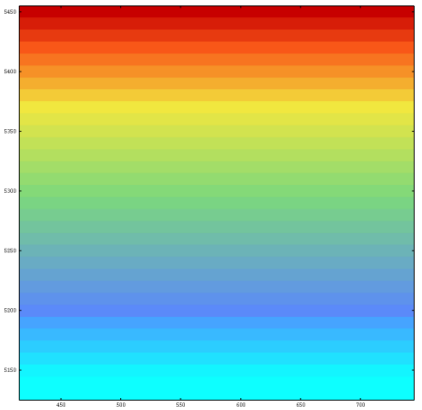
Longitude



CMC estimated SWE

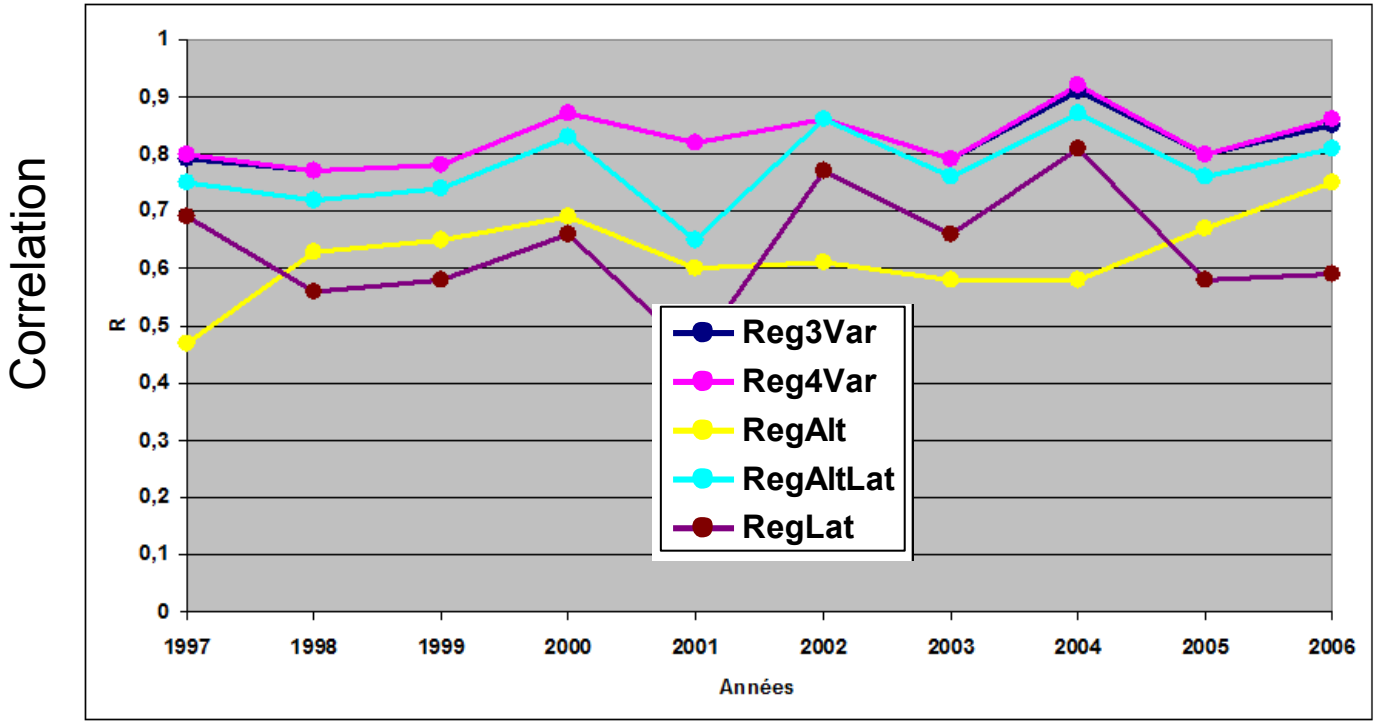


Latitude



Canada

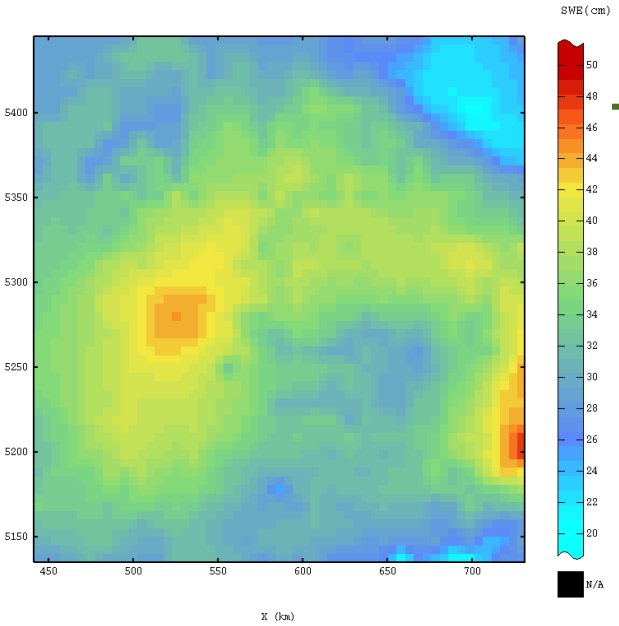
Cross validation results March 15



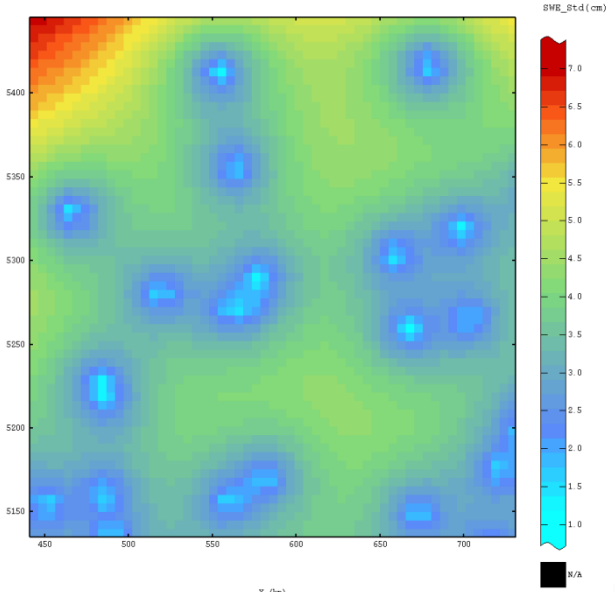
Best results obtained with four predictors (Reg4Var):

land cover, elevation, latitude, longitude

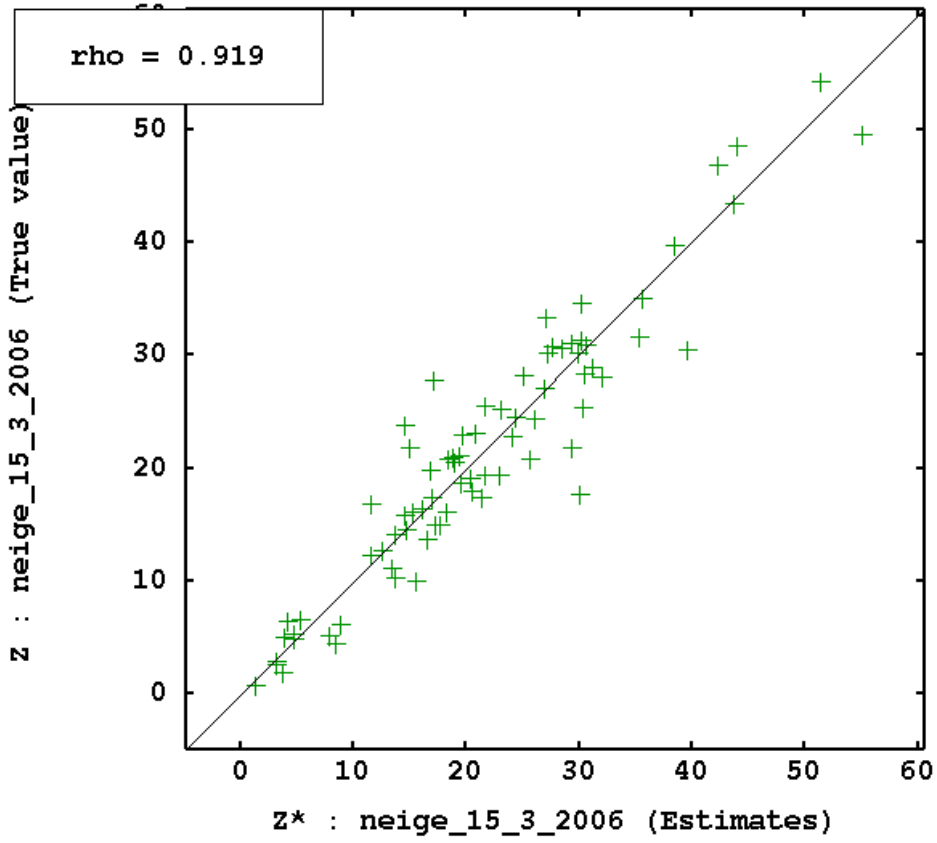
SWE (cm)



SWE-Std (cm)



Example of cross-validation results for March 15th 2006

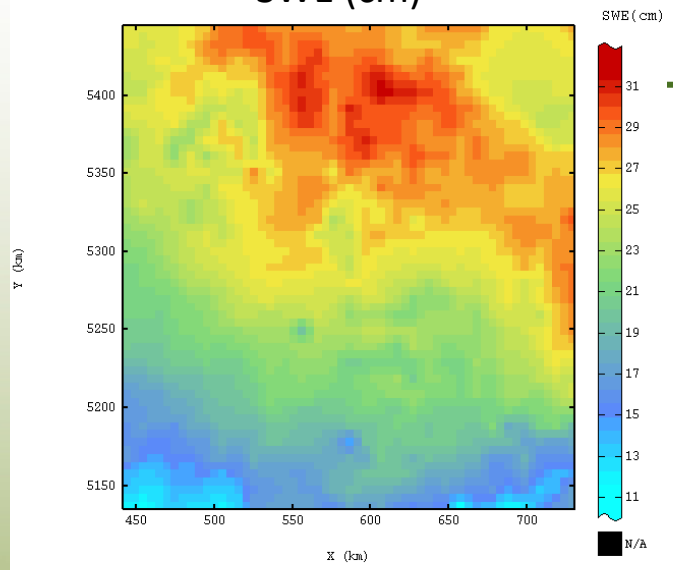


SWE (cm)

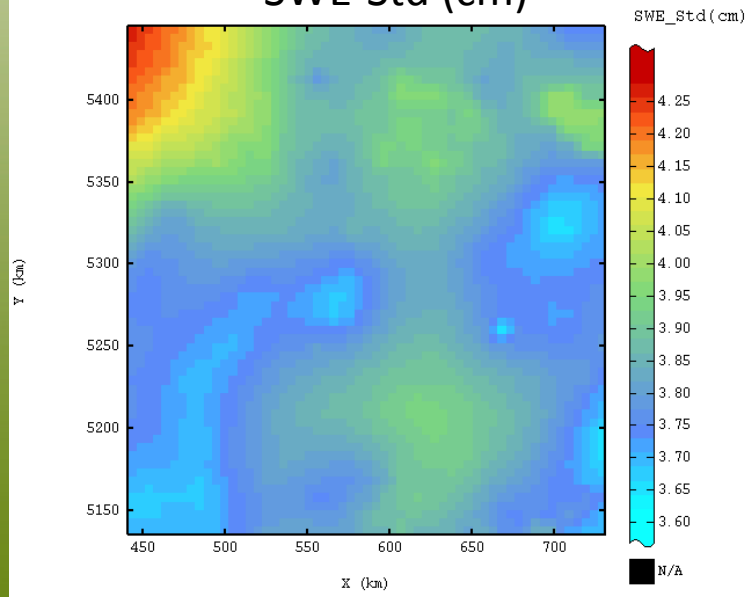
Canada

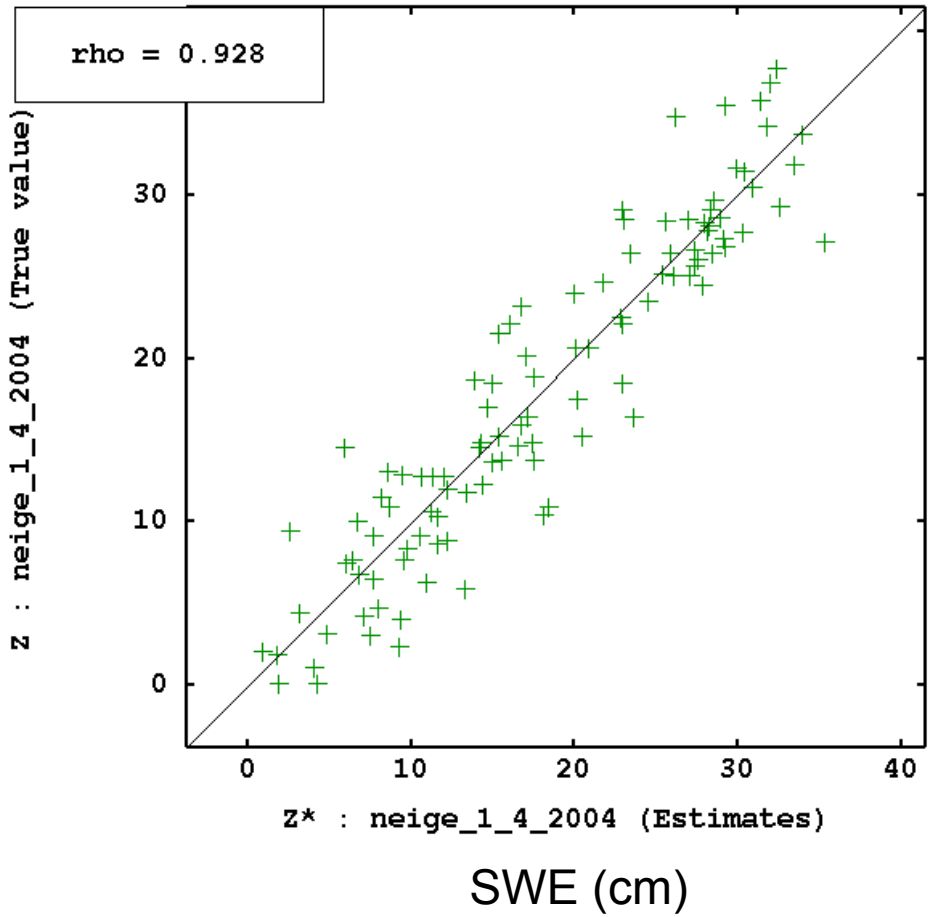
Example of cross-validation results for April 1st 2004

SWE (cm)



SWE-Std (cm)





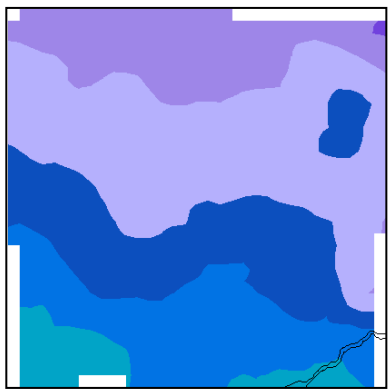
SWE (cm)

Canada

Results of preliminary evaluation with some existing SWE datasets

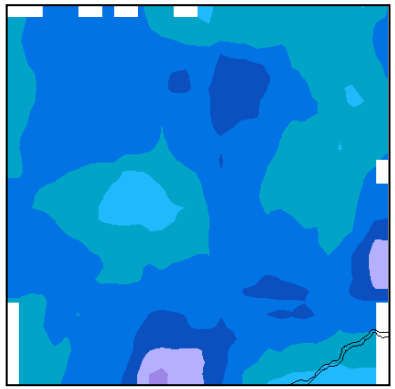
MERRA, CMC, GlobSnowV2

Evaluation of spatial pattern in mean SWEmax (1999-2010)



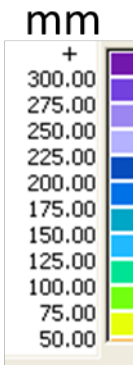
HQ 10 km kriged

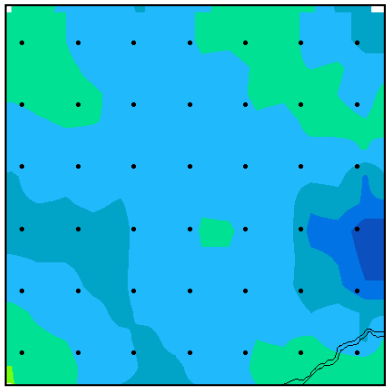
Avg = 221.1 mm
Min = 154.0
Max = 278.5



CMC elev adj

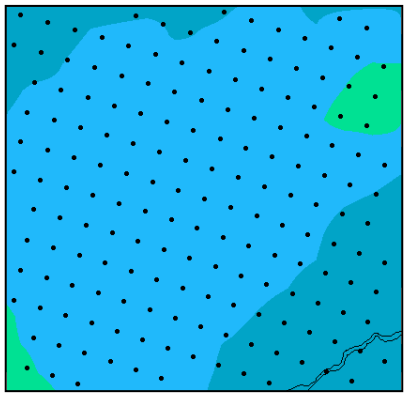
Avg = 180.0 mm
Min = 134.3
Max = 256.4





MERRA Land

Avg = 137.5 mm
Min = 99.3
Max = 218.4

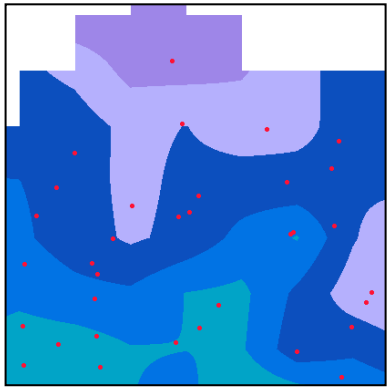


GlobSnow v2.0

Avg = 142.6 mm
Min = 40.9
Max = 176.5

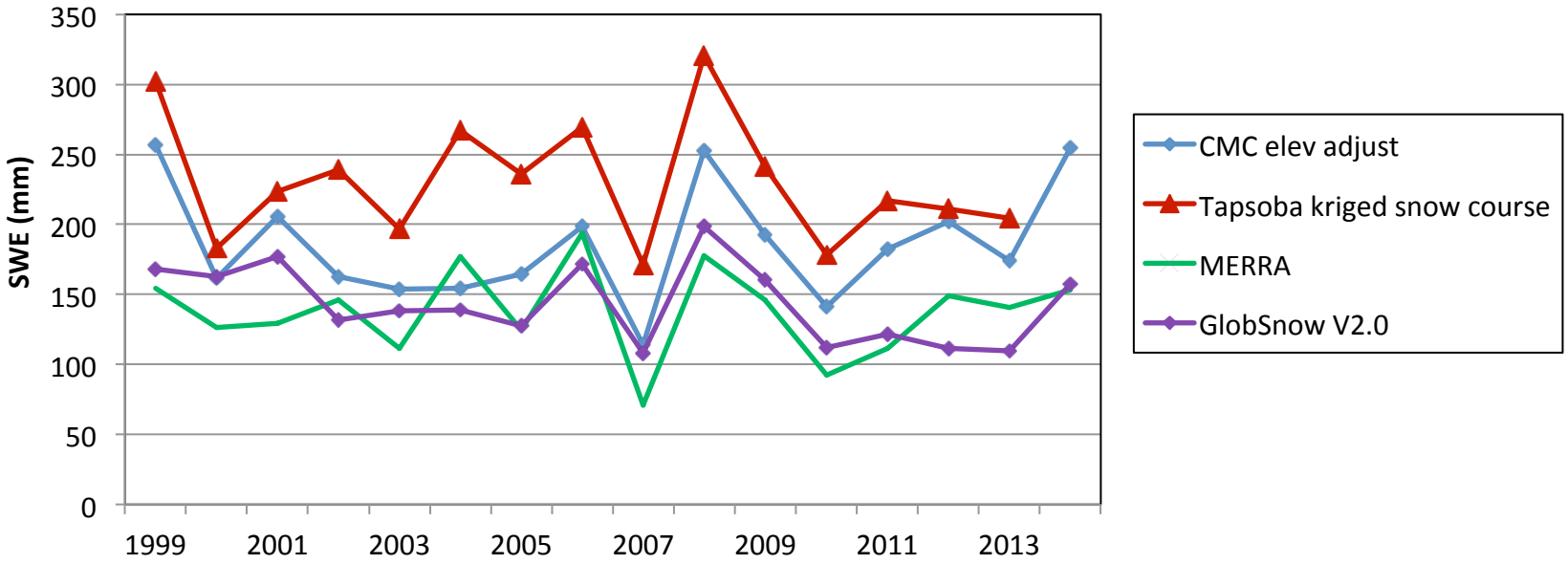
March 15 snow surveys

Avg = 199.8 mm
Min = 56.0
Max = 440.0



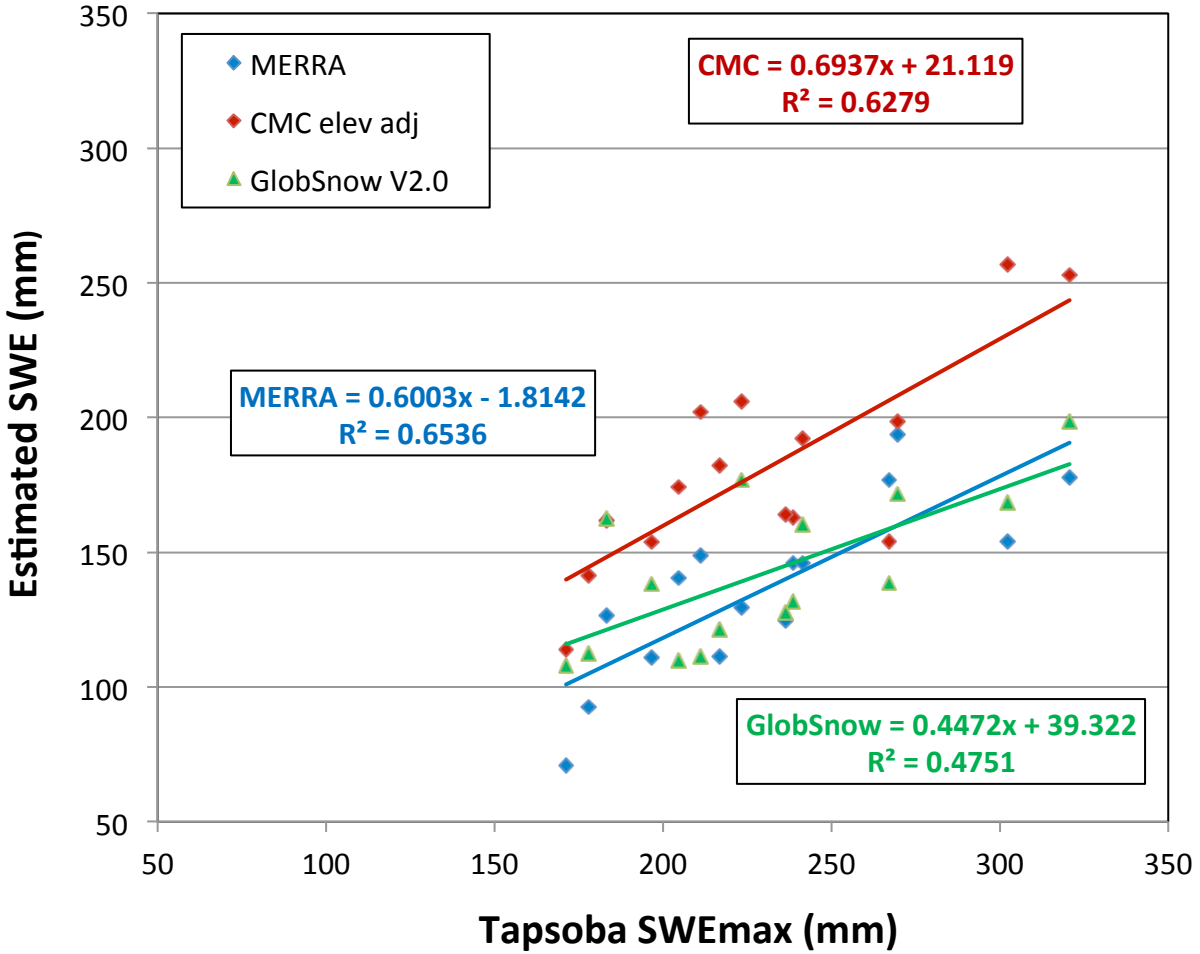
Interpolated using Shepard method with 50 km grid and 100 km search radius. Red dots are locations of snow survey SWE measurements within +/- 7 days of March 15, 1999-2010. Results are the average of all obs falling in the window which is not the same as the 12-year average plotted for the other datasets.

Annual variation in SWEmax over HQ SnowPEX region, 1999-2014



- MERRA is the most closely correlated to H-Q (r=0.81) followed by CMC (r=0.79)
- GlobSnow (r=0.69) is less well correlated to the H-Q dataset but is more consistent with MERRA over time than CMC
- Evidence of discontinuity in CMC after 2007 (resolution increase in forecast precipitation input to snowpack model used in first guess field)

1999-2013 SWEmax comparison with H-Q kriged snow course data over SW Quebec



All 3 datasets systematically underestimate SWEmax over the region

Conclusions

- A 10-km gridded SWE dataset was developed over the Saint-Maurice River watershed from kriging of snow survey observation for the period of maximum SWE (Feb-April) for a 15 year period (1999-2013) - can be combined with previously kriged data for 1970-2005 to cover 1970-2013.
- The dataset was provided to the SnowPEX SWE evaluation team on July 17
- Initial evaluation of MERRA, CMC and GlobSnow with the datasets showed reasonable temporal coherence but systematic underestimates of SWE and poor agreement in mean SWEmax spatial patterns
- Estimates of the uncertainty in the SWE estimates are in progress using the *Turning Bands Method* (Lantuejoul, 2002) to generate a set of maps (realizations) of the spatial distribution of SWE.
- A paper describing the dataset is in preparation


Thank you for
your attention!

Kriging with external drift (KED) methodology

- **The problem**

How to combine point snow course observations and spatial information from the predictor(s) in an optimal way to interpolate SWE at other locations?

- **KED estimation of SWE at location (x) is made from**

$$SWE(x) = a_0 + a_1 S(x_1) + a_2 S(x_2) \ldots + R(x)$$

Deterministic external-drift

Random residual

- S(x) is based on the linear regression of SWE observations with the external drift predictor variables

- R(x) is defined from the modelled variogram of the residuals from the regressions

Selection of predictors

- *Based on method presented in Tapsoba et al. (2005) Can. J. Civ. Eng., 32, 289-297*
- *Uses a stepwise procedure based on a partial F-test (Draper and Smith, 1981) to select candidate predictor fields that are informative and significant*
- *The stepwise procedure ensures that each selected predictor is linearly independent from the others*
- *KED process carried out with observed snow course data for Feb 01, Mar 01, Mar 15, Apr 01 and Apr 15 snow survey dates over 1999-2013 period*