Snow and small lake processes at the Arctic forest/tundra transition in the Western Canadian Arctic

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Outline

1. Objectives

3. Study sites

5. 2007/08 data collection program

7. Spatial variability in turbulent fluxes, snowcover and melt
   – Role of vegetation (shrub and tundra) (will not discuss today)

   – Role of snow

   – Year to year variation in snow accumulation and melt

   – Role of lakes

9. Plans for the remainder of this year and next year

1. Objectives

- **Improved understanding of spatial variability in radiative and turbulent fluxes, and runoff, at the tundra-forest transition zone**

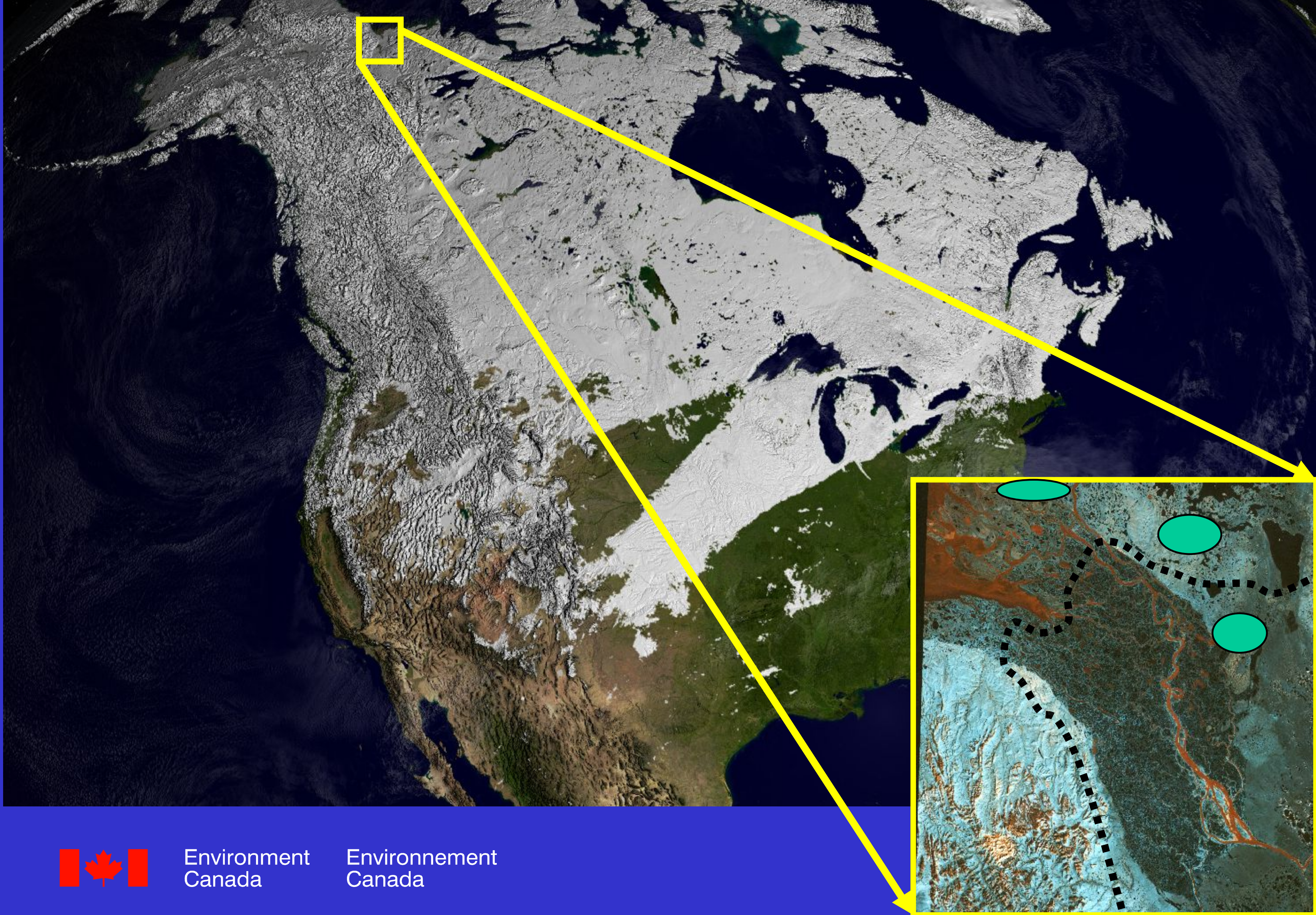
- **Consider scales from point, to small grid (<1 km^2), to** HRU scale (<10 km^2) to GRU scale (>10 km^2)

- **Will consider the role of:**
  - **patchy snow**
  - **slope and aspect**
  - **vegetation (tundra, shrubs, forest)**
  - **soil moisture**
  - **soil temperature**
  - **lakes**

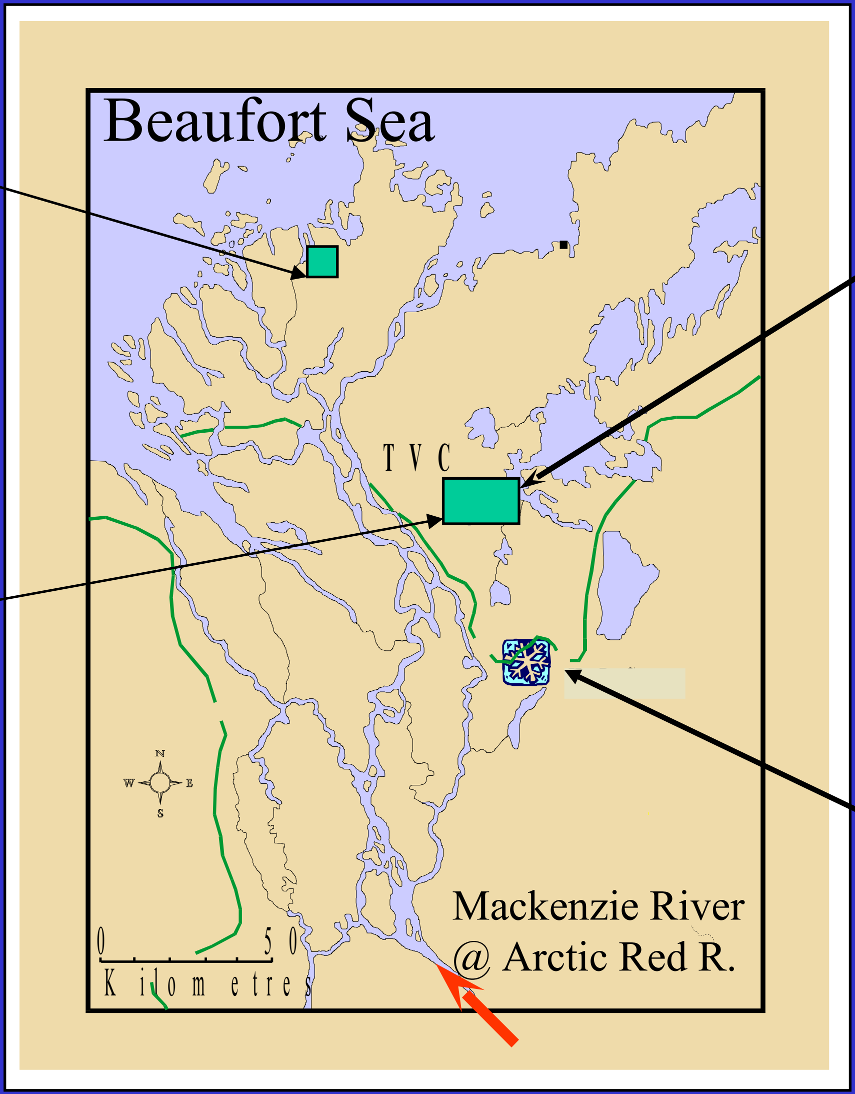
- **Use aircraft and tower flux measurements, micro-met observations, distributed snow surveys, Lidar derived DEM and vegetation heights, satellite images and airphotos, and high resolution modelling**

- **finally, use these data sets to validate and suggest improvements to CLASS and MESH**

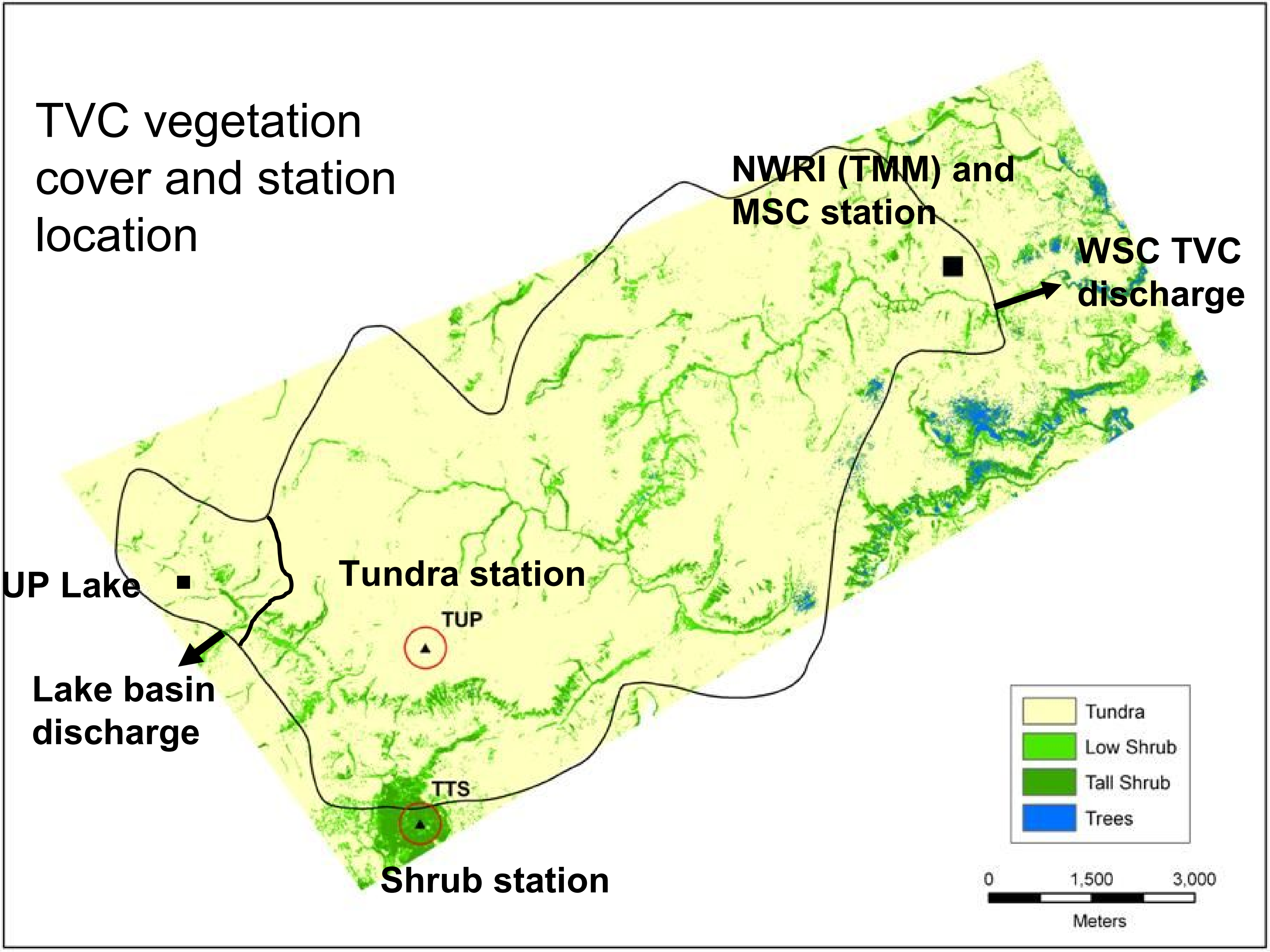
2. Study Sites



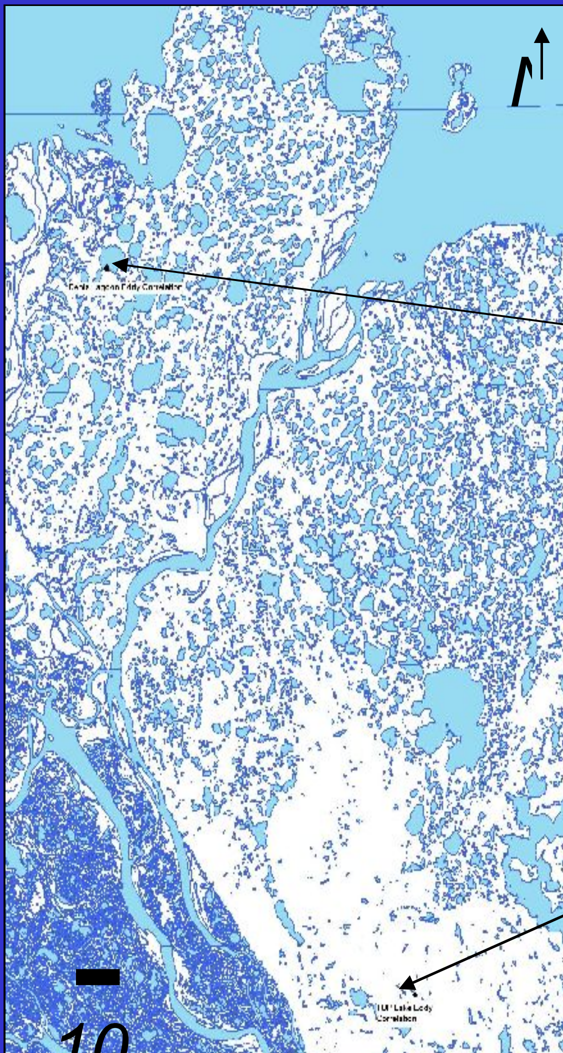
Field Sites - Inuvik, NWT area



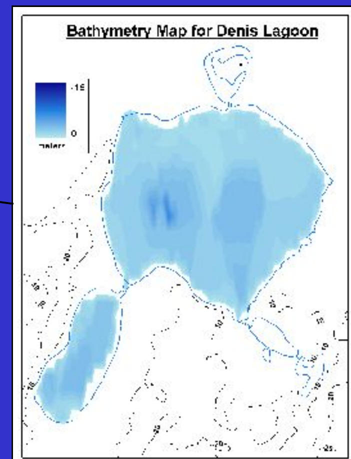
Havikpak Creek


TVC vegetation cover and station location
NWRI (TMM) and MSC station
WSC TVC discharge
TUP Lake
Tundra station
TUP
Lake basin discharge
TTS
Shrub station
Tundra
Low Shrub
Tall Shrub
Trees
0
1,500
3,000
Meters

Lake Study Sites

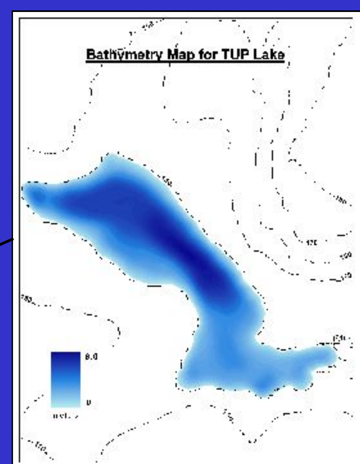


10 km



Denis Lagoon Typical Mackenzie Delta lake

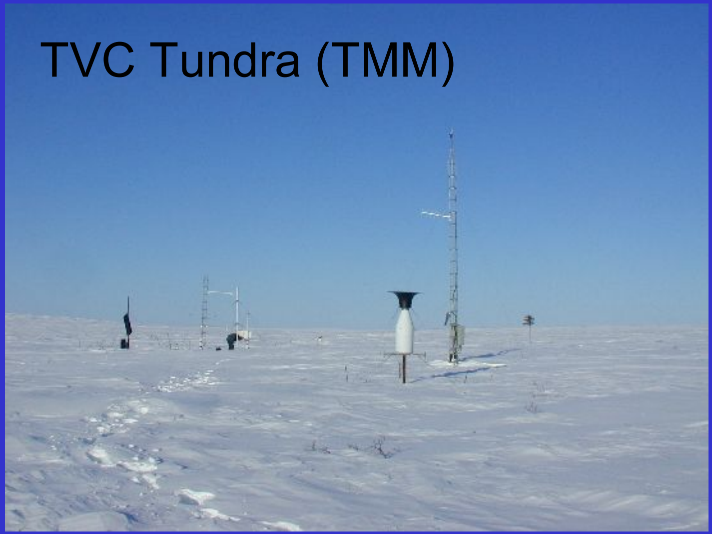
Round (3.0 by 2.7 km); shallow (1 m); circularity 0.78; surface area 6.18 km^2.

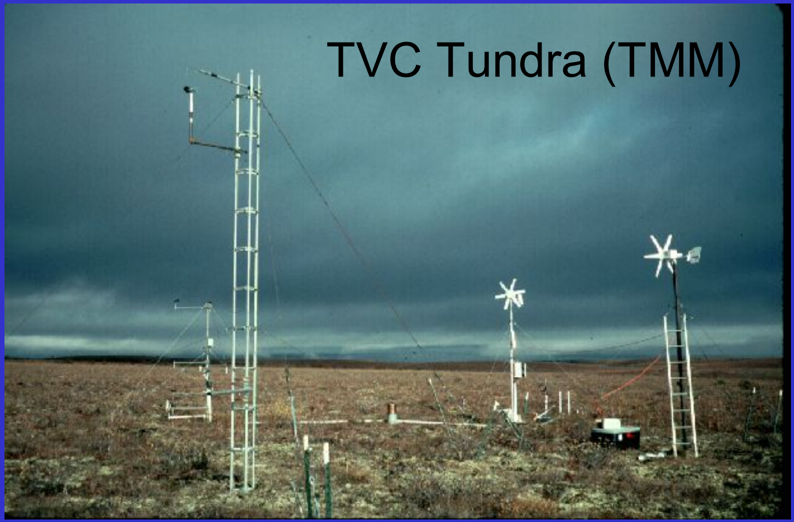


TUP Lake Typical upland lake

Long (778 m); narrow (163 m); deeper (6 m); circularity 0.15; surface area 0.14 km^2.

3. Data Collection Program – 2008: IP3 and IPY +

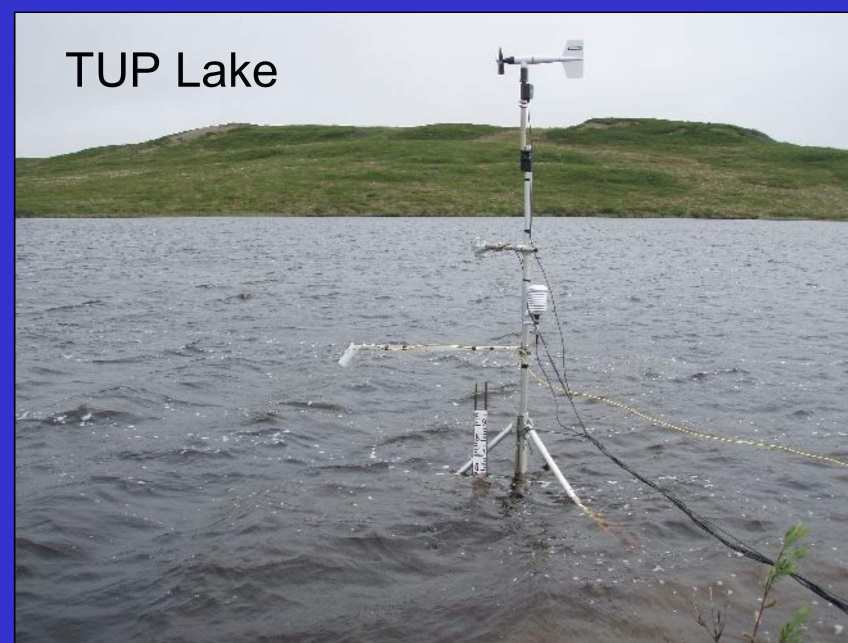




8 stations including:

1. HPC main met,
2. TVC MSC,
3. TVC main met (TMM),
4. TVC shrub (TTS),
5. TVC tundra (TUP),
6. TVC Lake (TUP L.)
7. Denis Lagoon and
8. Big Lake

Lake instrumentation



Snow Surveys

- End of winter vegetation and terrain based snow surveys were conducted at: Trail Valley Creek, Havikpak Creek, TUP Lake, Big Lake, and Denis Lagoon in April /May 2008

- These snow surveys were coordinated with additional ground and aircraft microwave surveys conducted at Trail Valley Creek and Big Lake as carried out by Chris Dirksen of Env. Canada.

- We will collaborate with Chris Dirksen in the analysis of these snow survey data.

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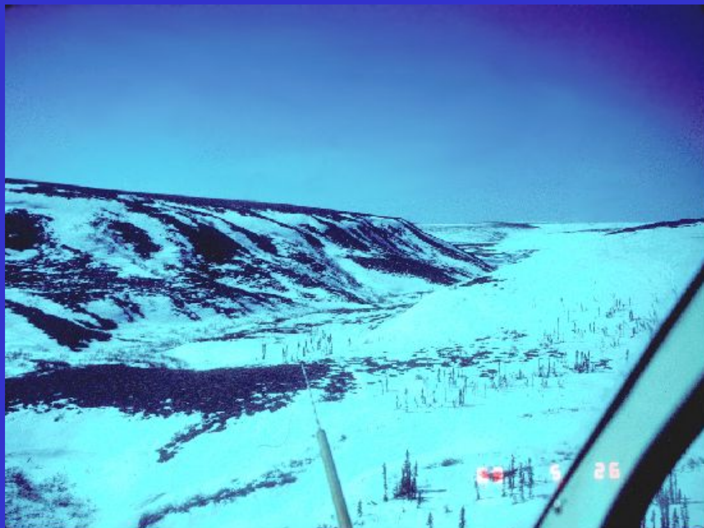
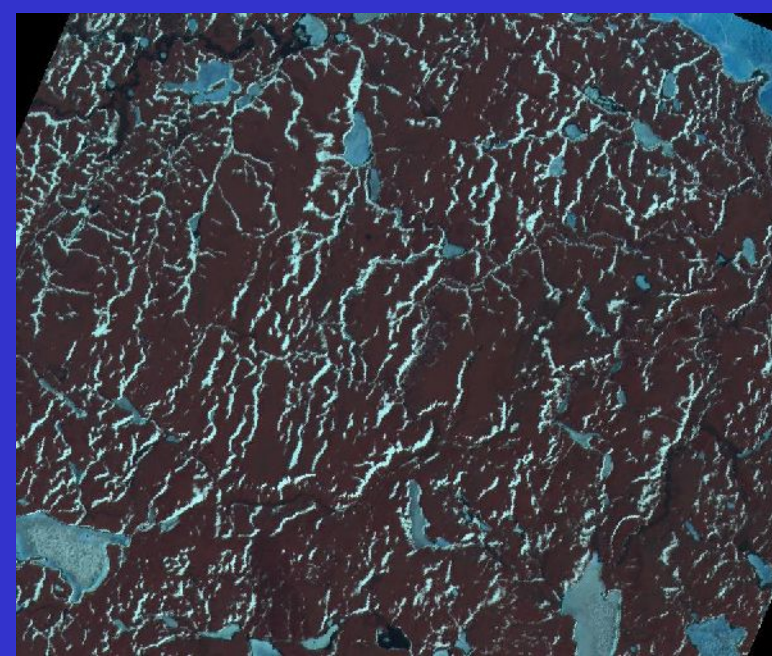
Snow surveys: Large Drifts

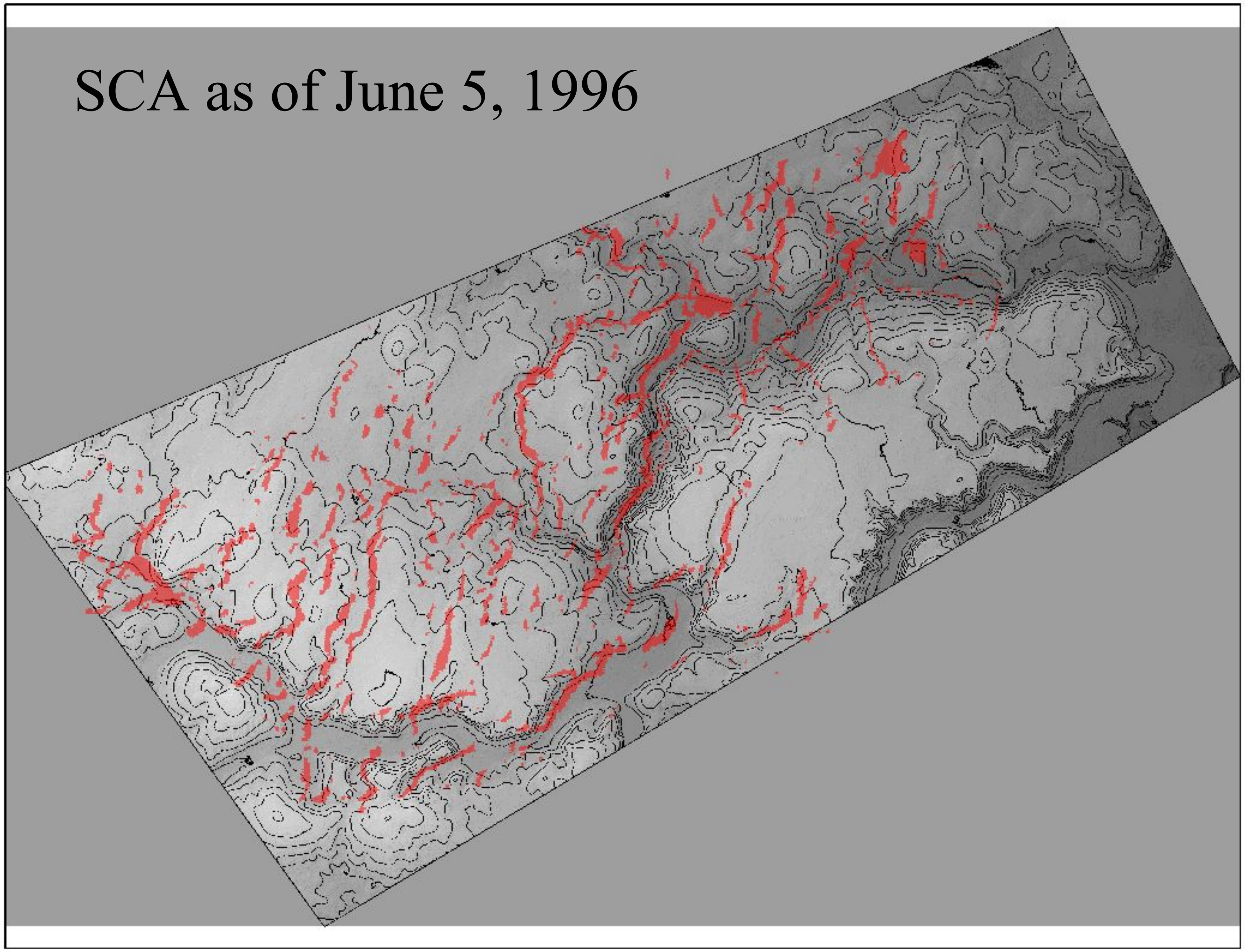


- large drifts may be up to 5 m in depth, and cover about 8% of the basin area, and hold up to 20% of the basin SWE.

- Due to time limitations, our previous studies have only measured a small number of drifts each year. As It has not been clear if this has been sufficient to properly estimate the snow in all drifts, we conducted a more a detailed drift survey during 2008.

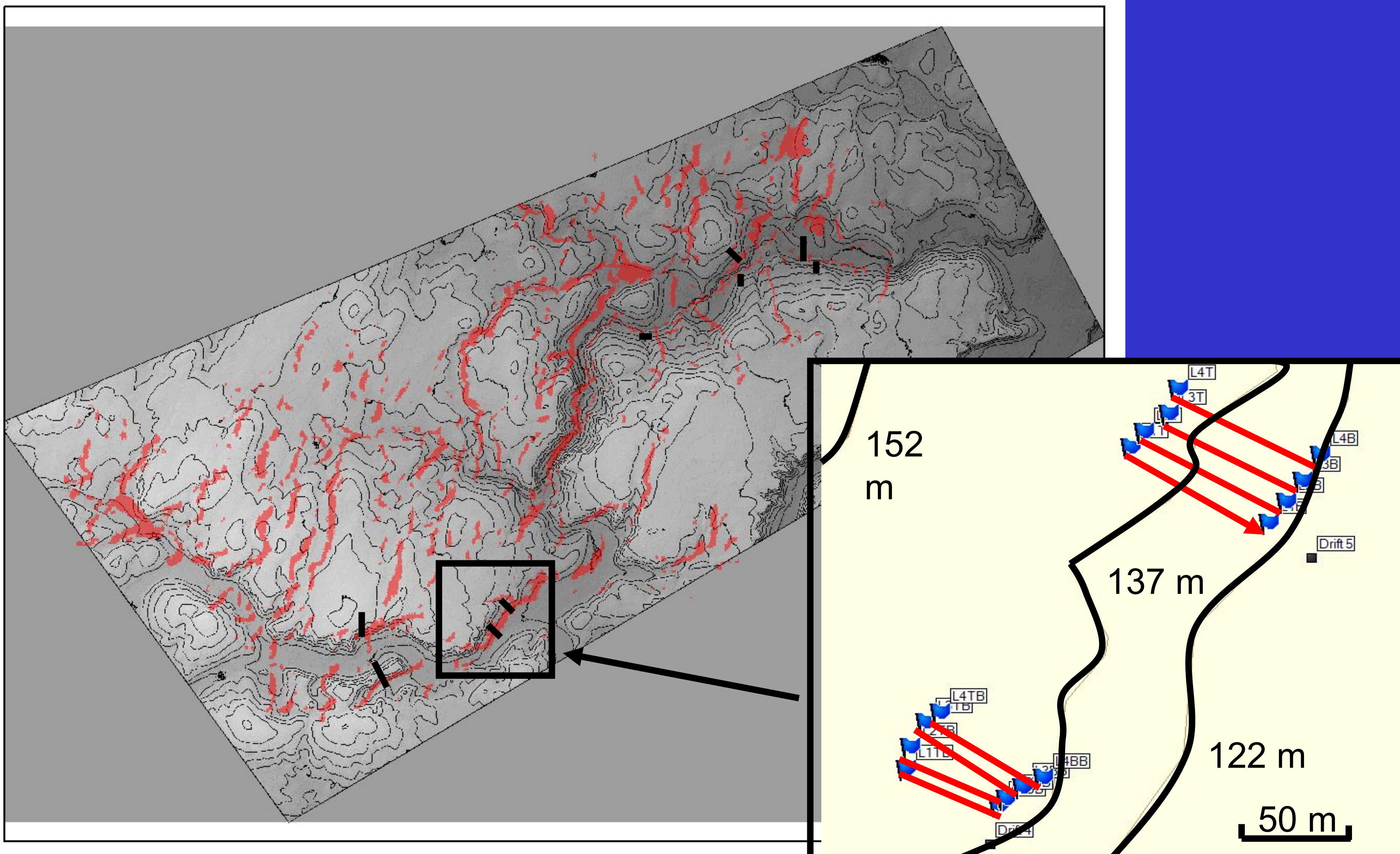


Mapping drift locations

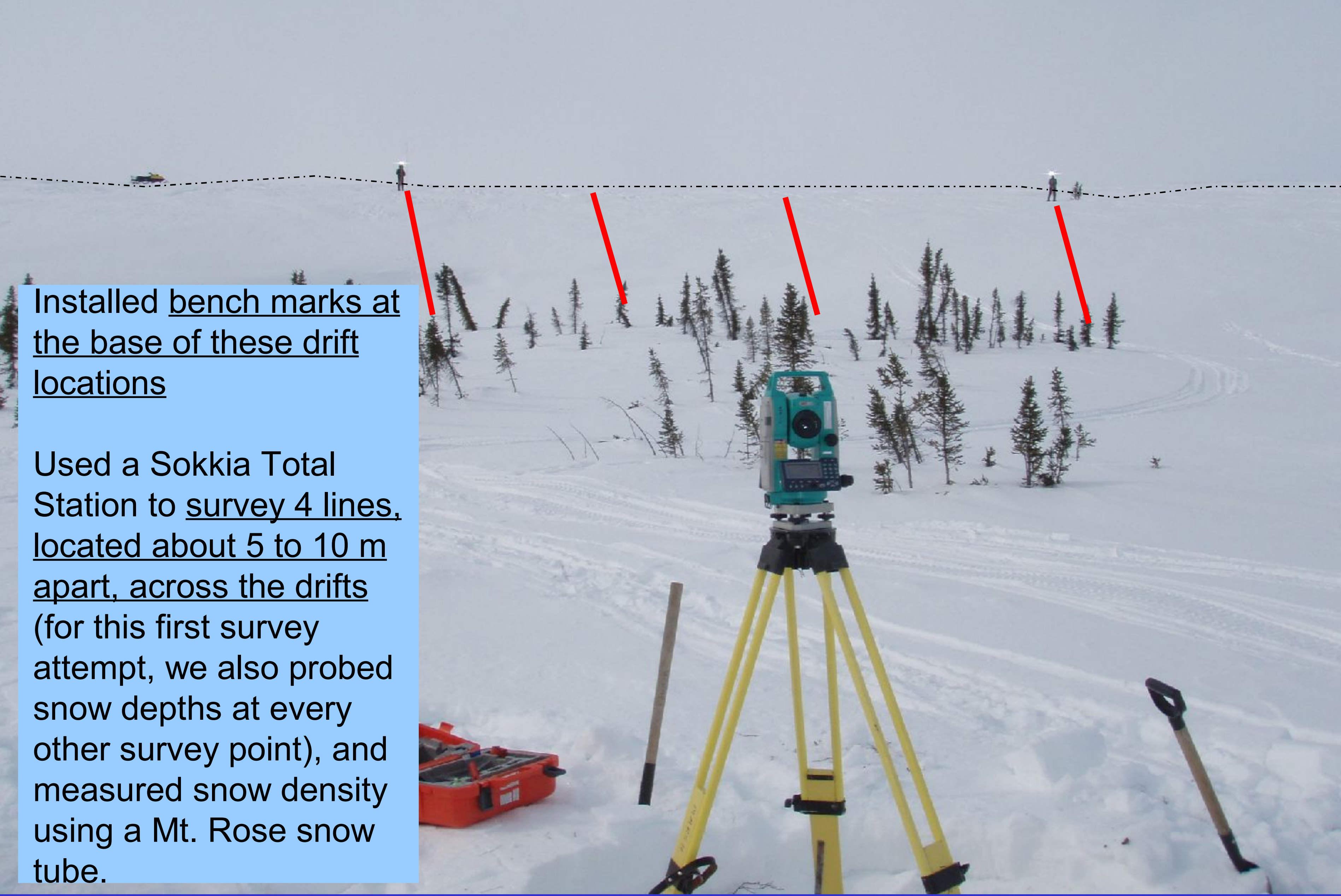


- Used high resolution satellite images late in the melt period, super imposed on a DEM, to identify deep drift locations
- Analyzed these drift locations to determine drift locations by aspect and slope and vegetaton, and then selected a small number of locations that are typical of the range of drift locations

Location of drift surveys at TVC



Drift survey



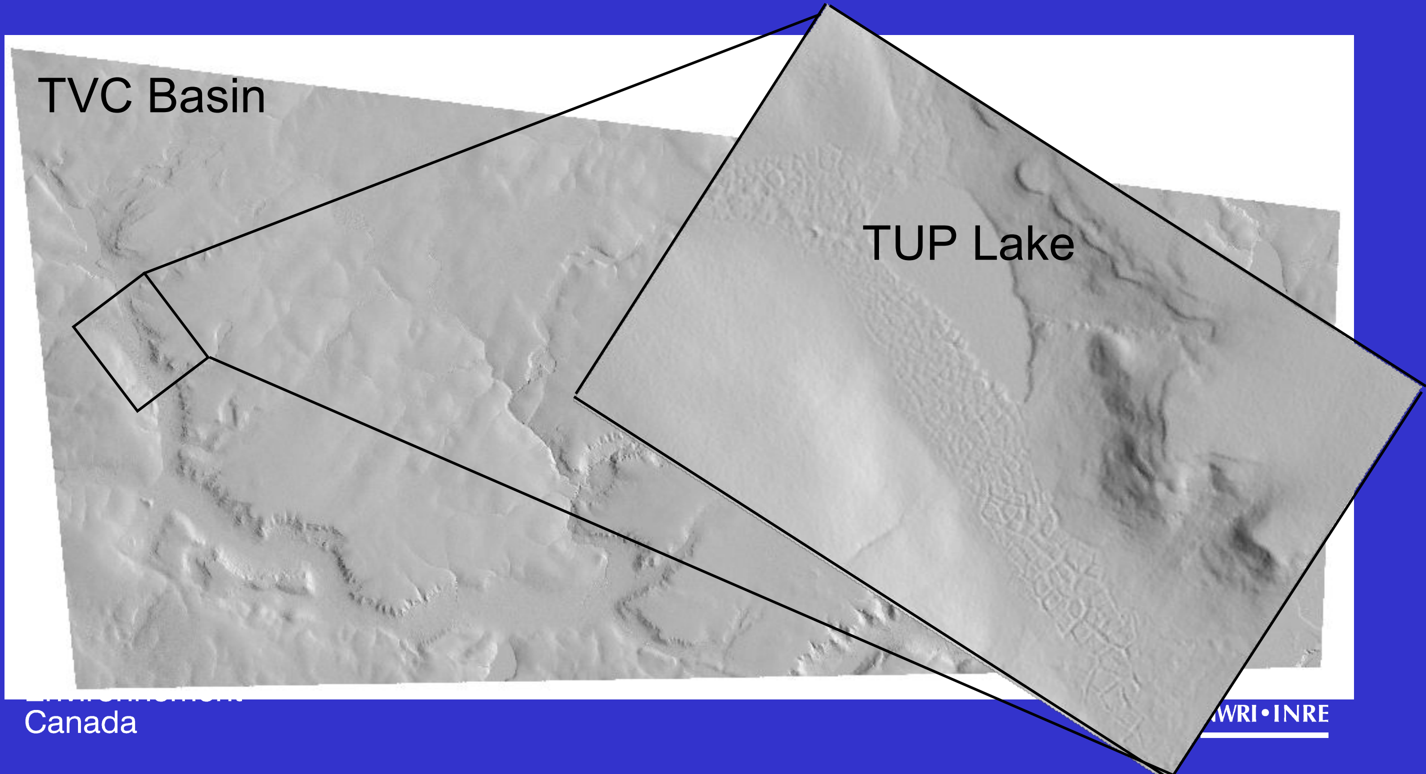
Installed <u>bench marks at the base of these drift locations</u>

Used a Sokkia Total Station to <u>survey 4 lines, located about 5 to 10 m apart, across the drifts</u> (for this first survey attempt, we also probed snow depths at every other survey point), and measured snow density using a Mt. Rose snow tube.

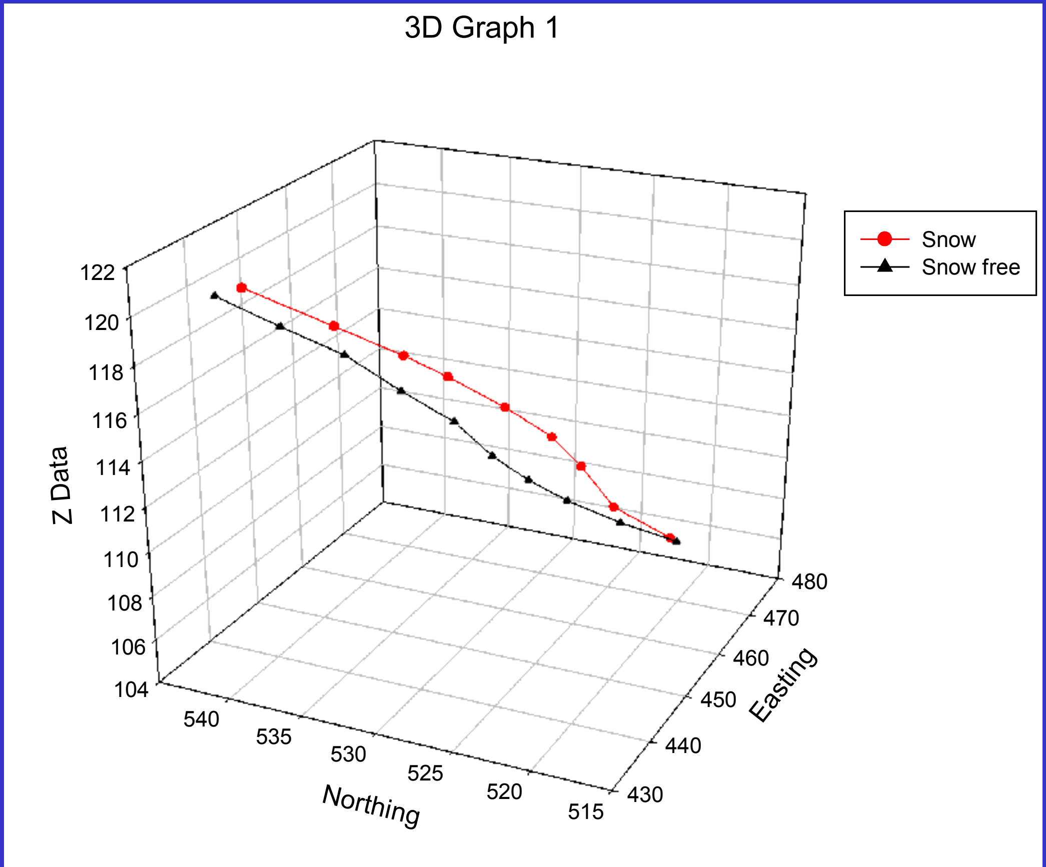
Ground surface survey

- in the snow free period, used a survey quality GPS to determine the location of the benchmarks at each drift site, and then used a Sokkia Total Station to survey the ground surface along each of the late winter survey lines. These will be compared to the Lidar DEM for TVC

- We will then determine total snow depth by comparing the snow surface survey lines to the ground surface identified by: (1) Sokkia Total Station survey lines, and (2) the bare ground elevation from Lidar



Example of one of the drift snow survey lines



Change in snow cover area during melt at TVC

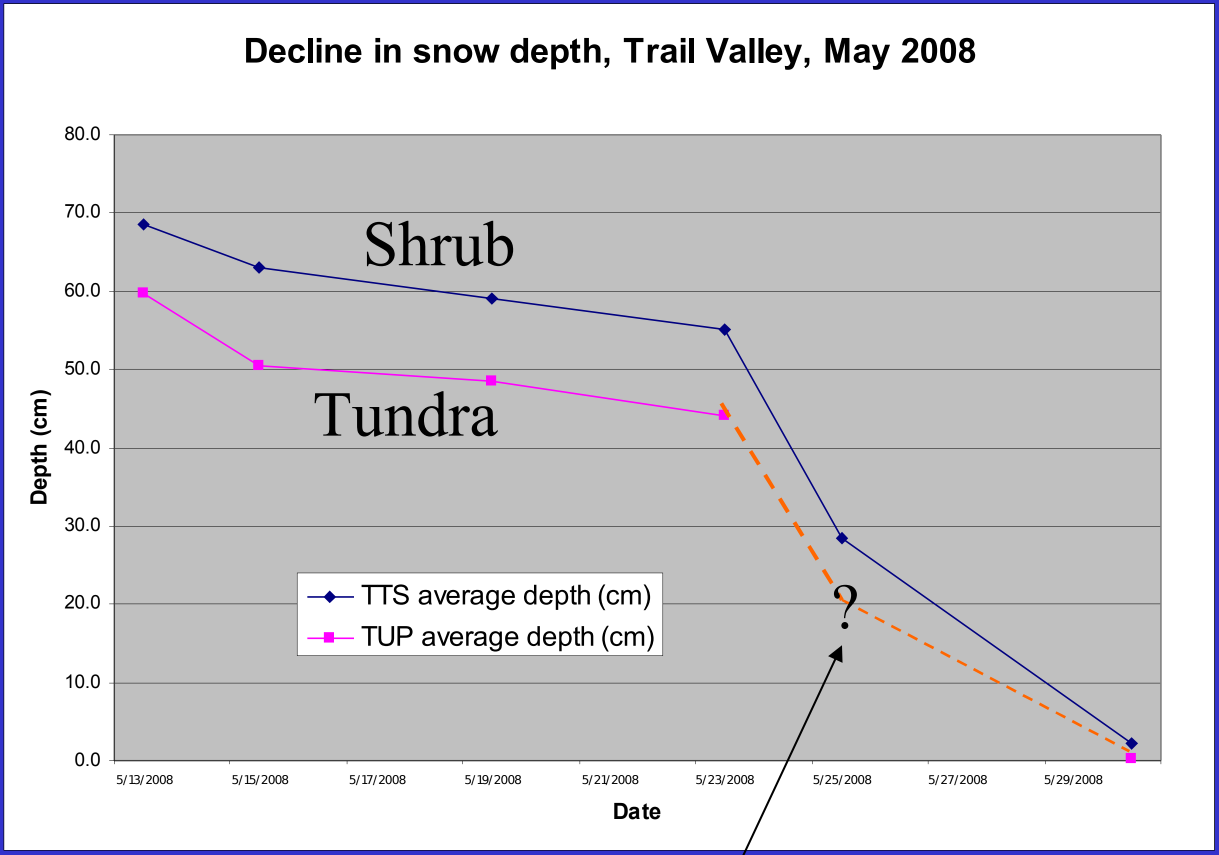
During May and June 2008 we obtained:

- SPOT 5 m and 10 m images of TVC on 20 different days

- high resolution air photos on 6 days
    - standard 9x9” negative air photos with photogrammetric quality camera
    - these photos are being scanned at high resolution to obtain digital versions for image analysis

- both SPOT and air photos will then be analyzed to determine snow covered area

Change in snow depth at a tundra and shrub site in TVC (from 250 point snow survey)



Missing data point

Environment Canada Environnement Canada

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2008 Satellite (SPOT) and Aerial Photos of Trail Valley Creek during melt

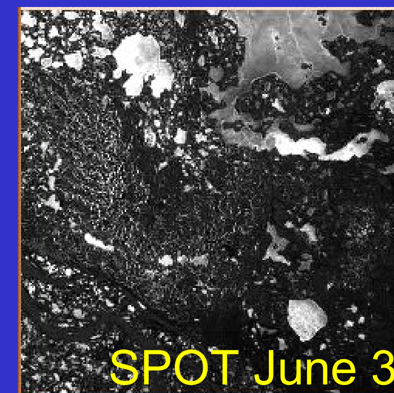
Air photo May 23

Air photos yet to be scanned and processed

Air photo June 2

Air photo May 25

Air photo May 27



Air photo May 26

Air photo June 4

Additional SPOT images available until end of June when all drifts have melted

Changes in snow cover during melt

- A number of snow surveys were carried out within TVC basin during the snow melt period at representative sites.

- These include:
  - Tall Shrub site (TTS)
  - Tundra site (TUP)

- When combined with
  - SPOT/air photos of change in basin SCA,
  - Eddy correlation measurements
  - Meteorological conditions at 4 sites within the basin, and
  - Lidar DEM and vegetation data,

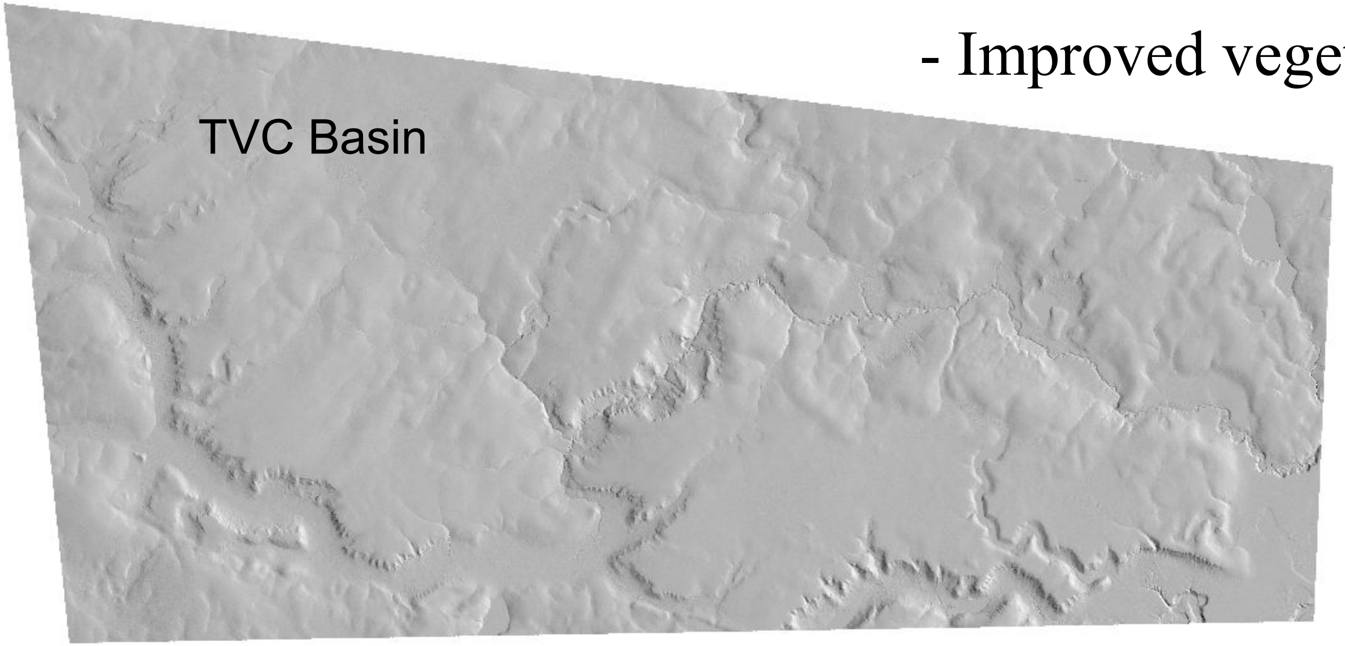
  - these data will provide an excellent data set of change in snow cover for use in validating models for use in this environment

TVC Lidar data set

1. Last year I noted problems with our existing TVC Lidar data

2. As part of our IPY Delta and PERD programs, we obtained Lidar data for segments of the Mackenzie Delta, and using Env. Canada funds, we were able to obtain new Lidar for TVC.

- New larger domain
- Improved vegetation height



4. Spatial variability in turbulent fluxes, snowcover and melt

Role of:

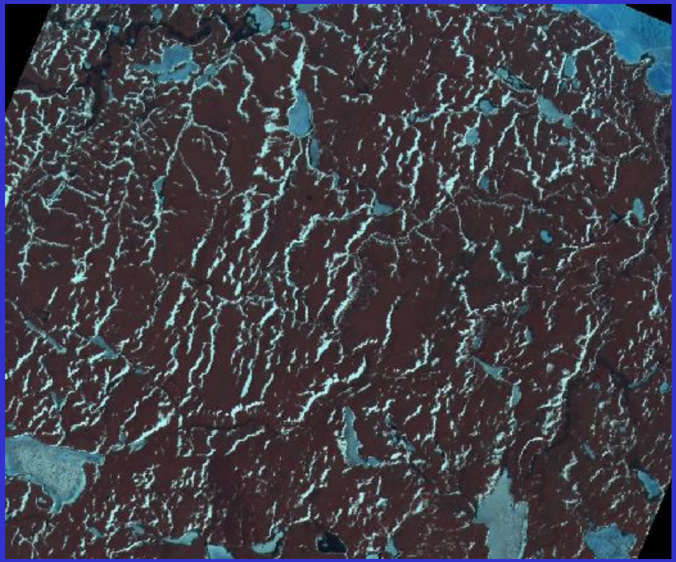
c) **Vegetation (shrub and tundra)**
   - **Ongoing studies with Murray Mackay and Paul Bartlett**
   - **will not discuss today**

- **Snow**

- **Year to year variation in snow accumulation and melt**

- **Lakes**

4b. Role of snow in controlling spatial variability at a range of scales



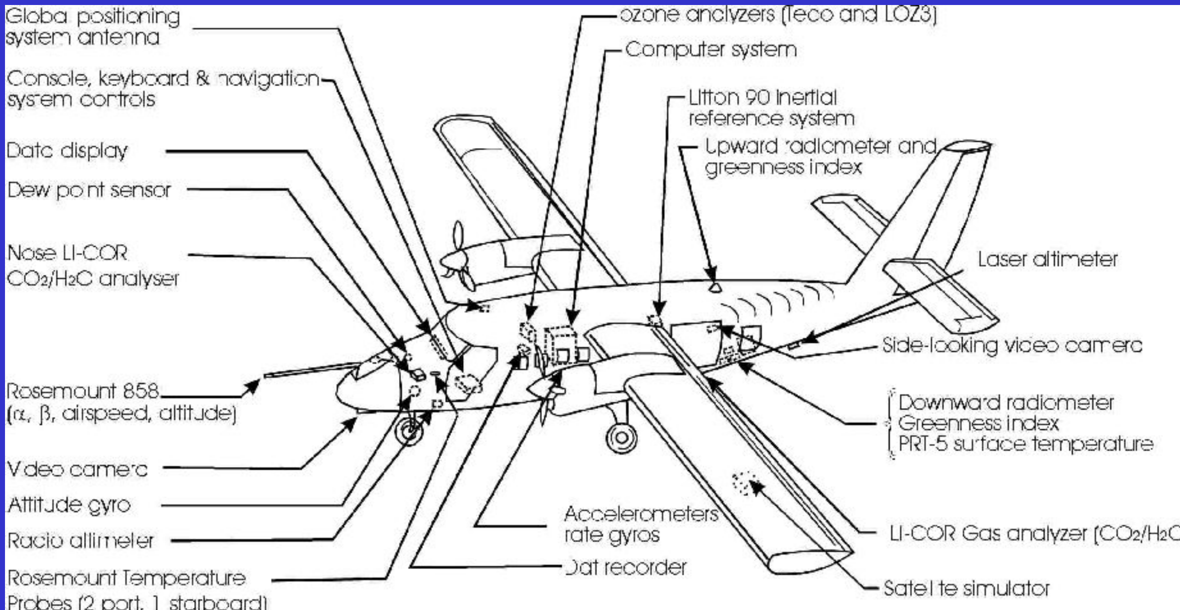
- spatial variability of sensible and latent heat flux at TVC during, and immediately after, snow melt, at a range of scales from 100 m, to 3 km, to 10 km

- to consider 100 m scale variability in fluxes required the use of a suite of high resolution gridded models (Micromet-GEOtop-Snowtrans3D)

- The next step will use MESH and/or CLASS to consider sub-grid variability in order to estimate grid average values.

- further details available in a poster by Endrizzi et al. on Friday night

Mackenzie GEWEX Study (MAGS) 1999 - NRC Twin Otter Flux Aircraft



<u>Parameters</u>

- Air temperature
- Incident short wave
- Reflected short wave
- Infrared surface temp
- Calculated net rad.
- Sensible heat flux
- Latent heat flux

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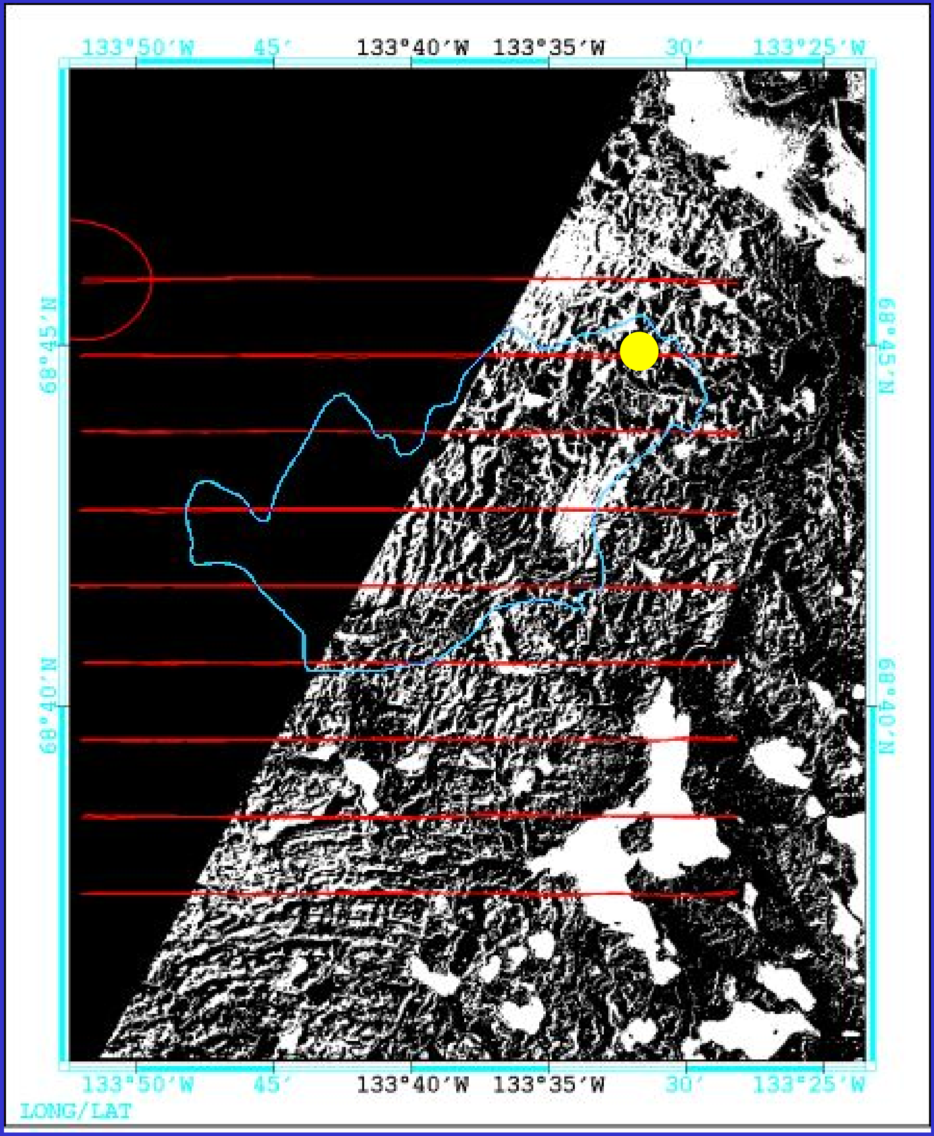
Fluxes: Basin average, and gridded



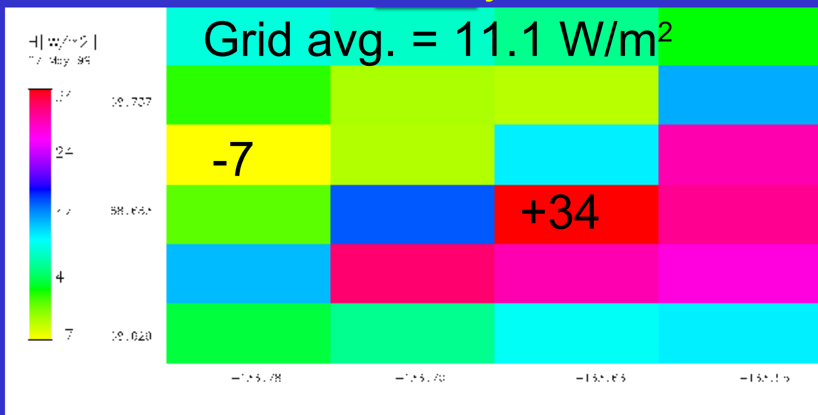
- Flight altitude: approx. 60 m above ground level
-Nine 16 km transects spaced 2 km apart
- flux tower located along grid line # 8

Aircraft flux data analysis

- Using the approach of Mauder at al. (2008), Mauder and Desjardins:
  - applied the wavelet transform method and, using footprint models,
  - produced maps of turbulent fluxes at the resolution of 3 km
  - highest spatial resolution possible, while still maintaining the fluxes random errors, proportional to the length of the flight, at a reasonable value (around 15-25%).

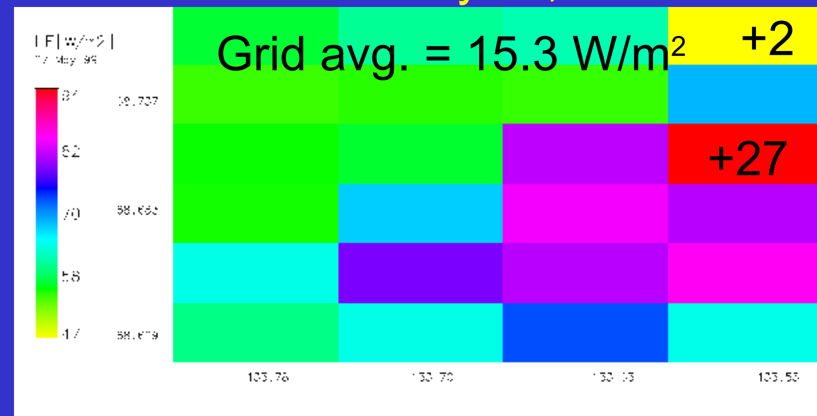
Gridded aircraft derived fluxes
(3 km x 3 km grids over Trail Valley)

Sensible heat flux May 27, 1999



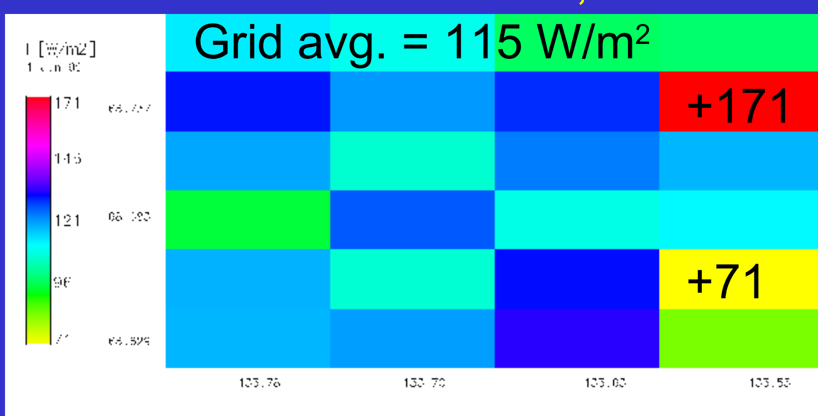
SCA = 40%

Latent heat flux May 27, 1999



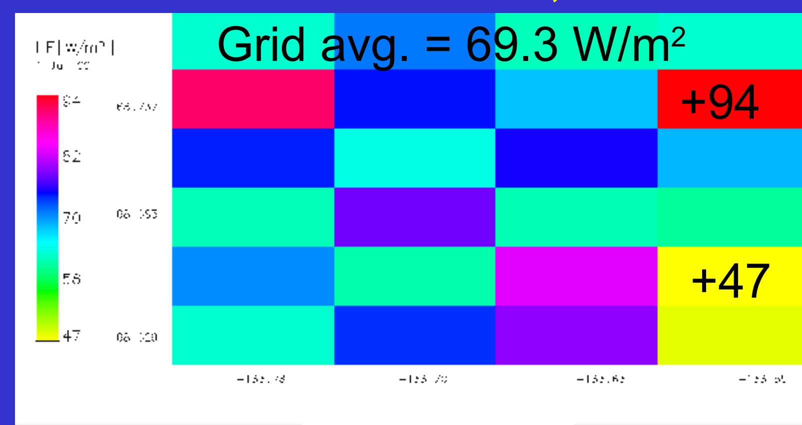
SCA = 40%

Sensible heat flux June 1, 1999



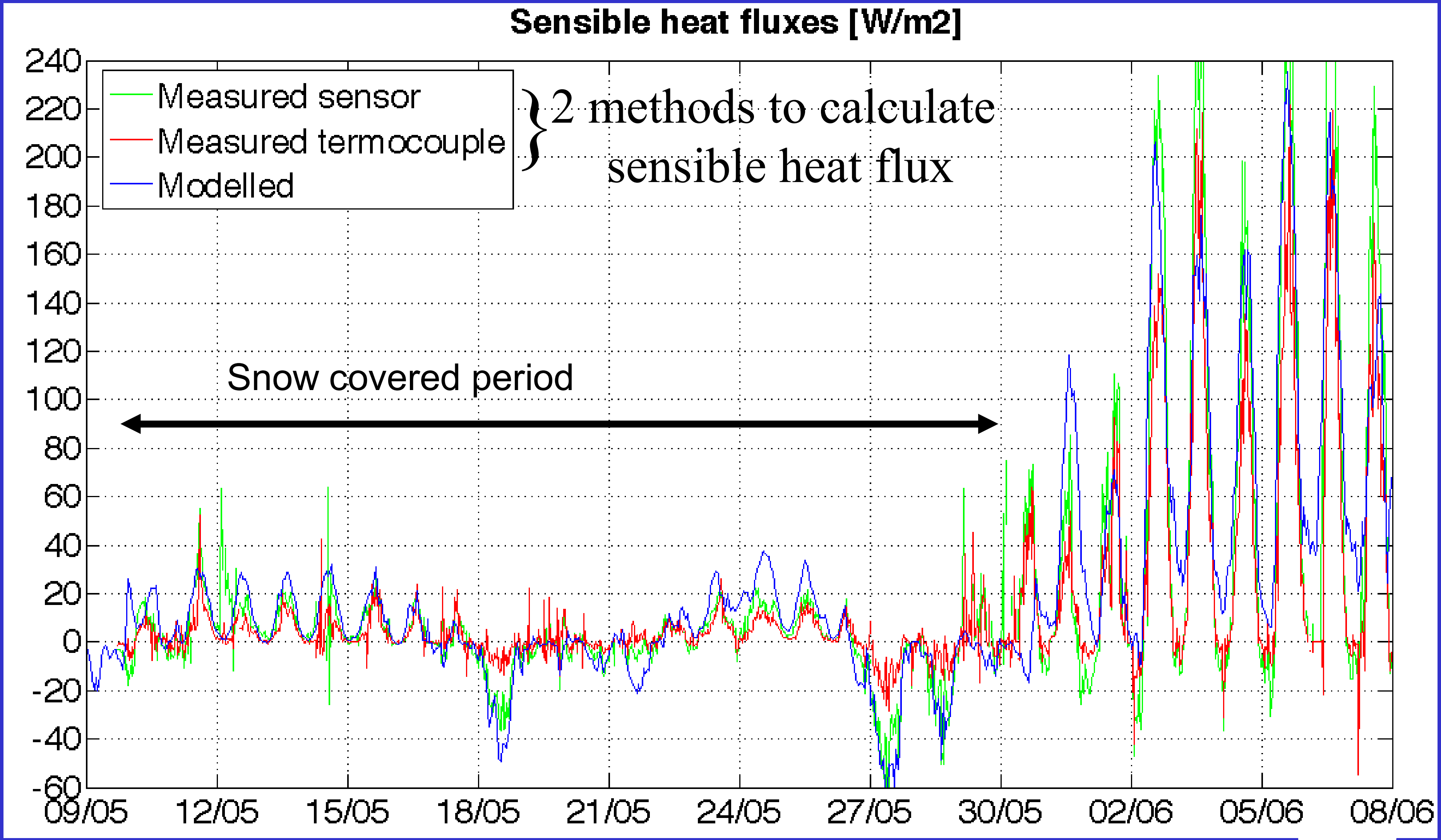
SCA = 10%

Latent heat flux June 1, 1999

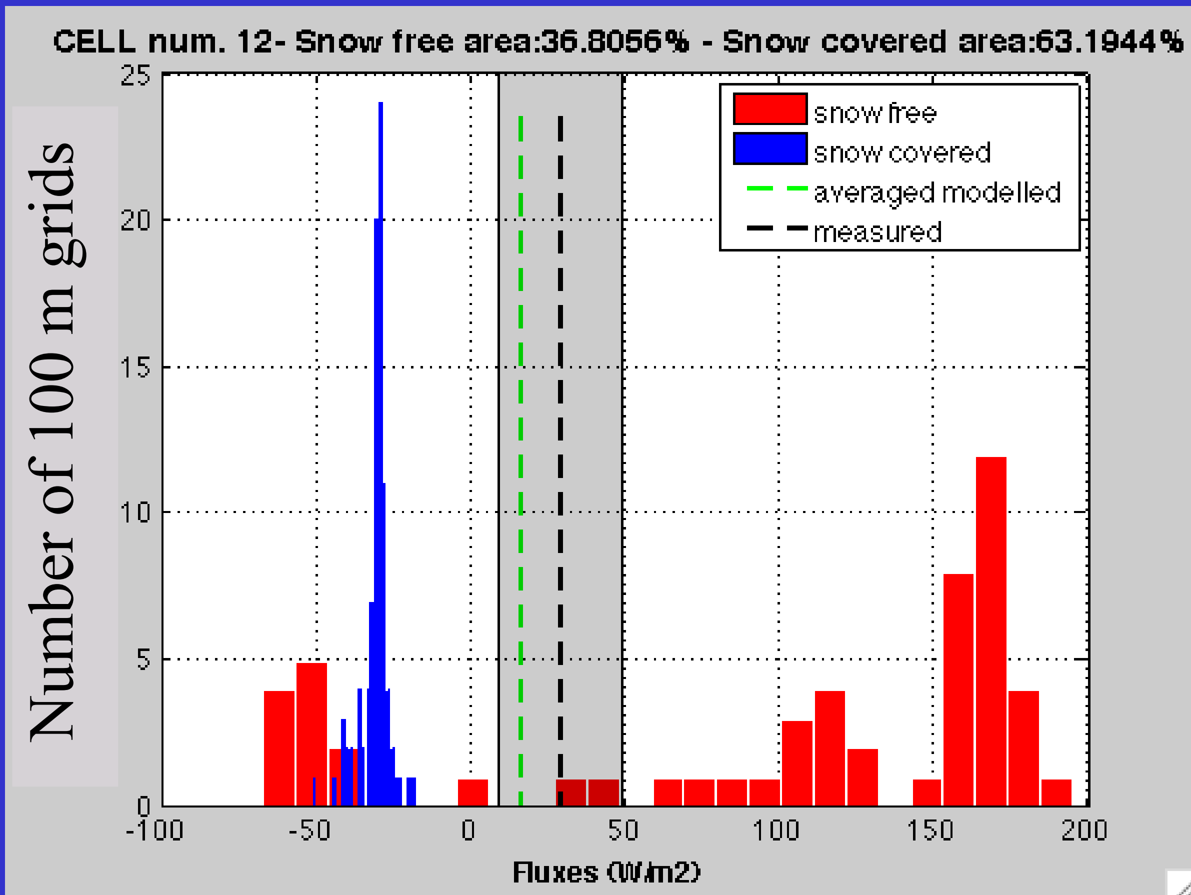


SCA = 10%

Modelled (Micromet-GEOtop-Snowtrans3D) point fluxes vs. 2003 TUP tower observation



Variability in sensible heat within one "typical" 3 km grid (May 27)



For additional examples and further explanations see poster by Stefano Endrizzi et al. on Friday night

- Note large spatial variability in sensible heat from snow free area. Due to differences in soil moisture, aspect and slope, and surface temperature.

- We will consider aircraft obs of surface temp as a possible validation of the wide range of turbulent fluxes from snow free sites

4c. Year to year variations in snow accumulation and melt

- this portion of the study will consider year to year variability in snow conditions, and our ability to model snow processes and runoff under a range of conditions

- First step is to test the MicroMet – SnowModel - SnowTrans3D for years with sufficient validation data

- as in the earlier component of the study, this combination of models allows high resolution (< 100 m) required to consider the sub-grid spatial variability

- the next steps will be:

    - run Micromet – SnowModel – SnowTrans3D for a variety of years between 1996 and 2008, to cover a range of large/small winter precip, winter wind conditions and hence blowing snow, and early/late melt events

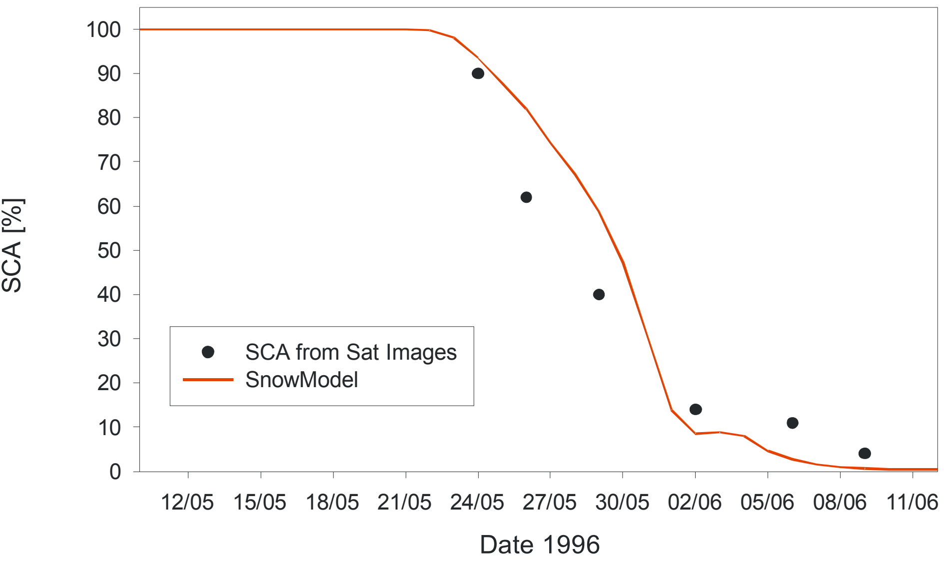
    - test MESH and/or CLASS to this period of record

Change in basin average snow covered area

- For two years with SPOT satellite images to estimate SCA

- model estimates change in SCA reasonably well. However, it appears to eliminate the drifts too early. This is likely due to under estimating the SWE within the large drifts in TVC

-in the upcoming year, we will use the 2008 melt information



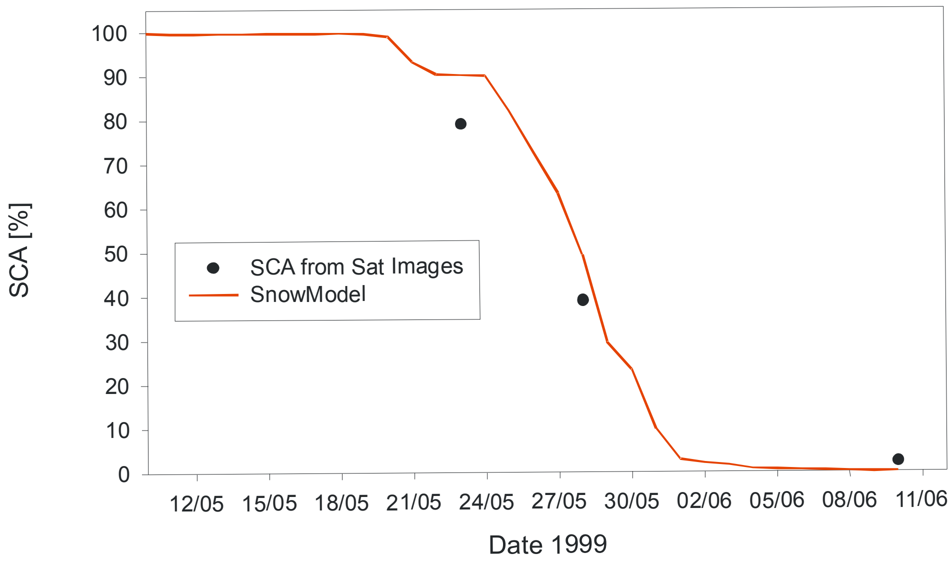
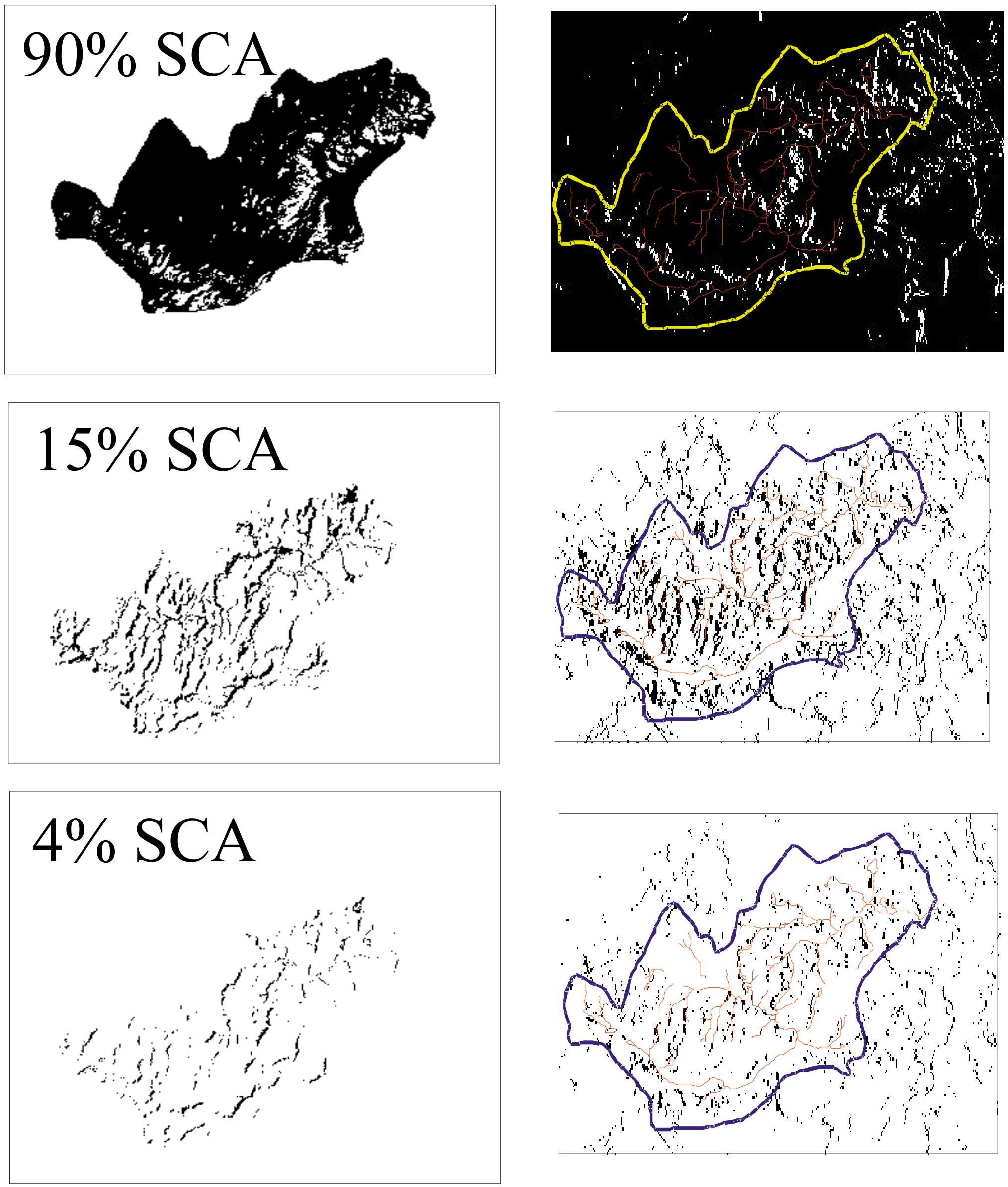


Fig. 3 Snow cover depletion curves for 1996 and 1999

Observed SCA Modelled SCA



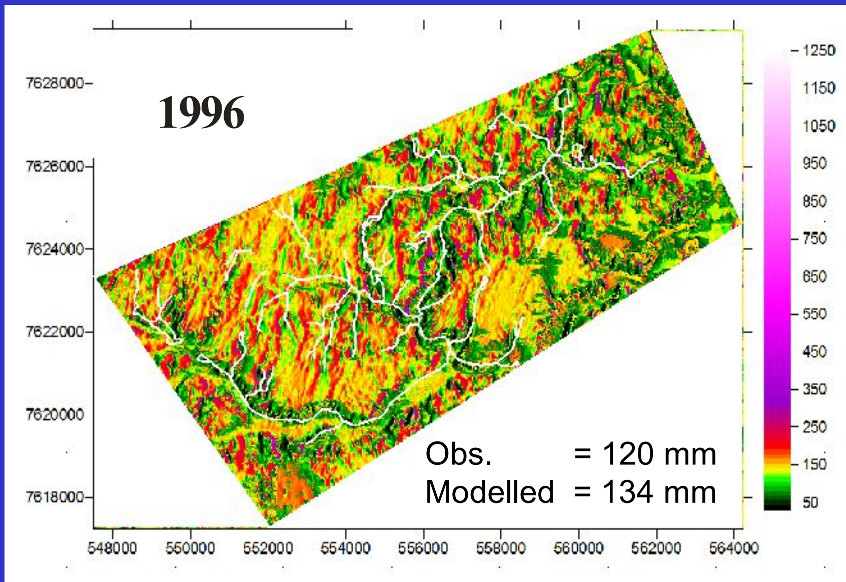
Change in spatial pattern of snow cover during spring melt 1996

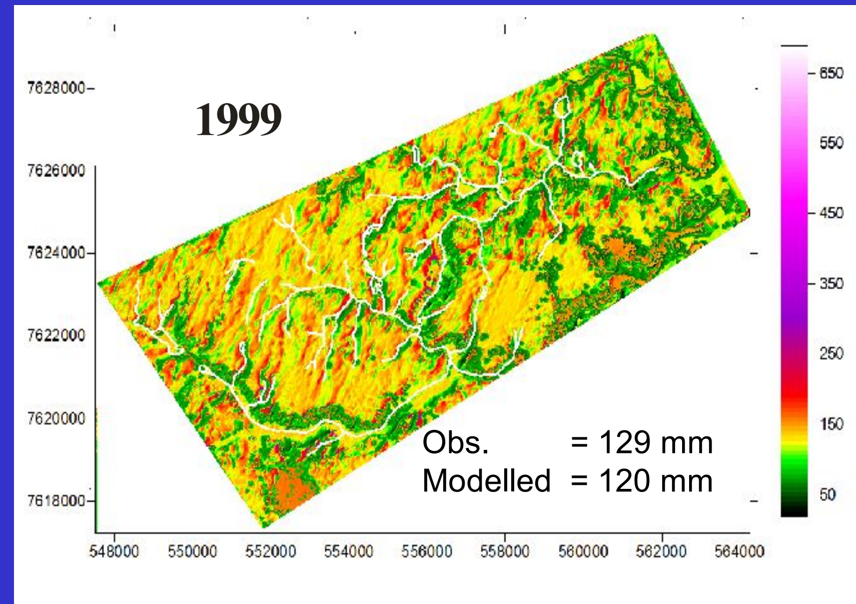
- For further details see poster by Pohl et al. at the Friday poster session

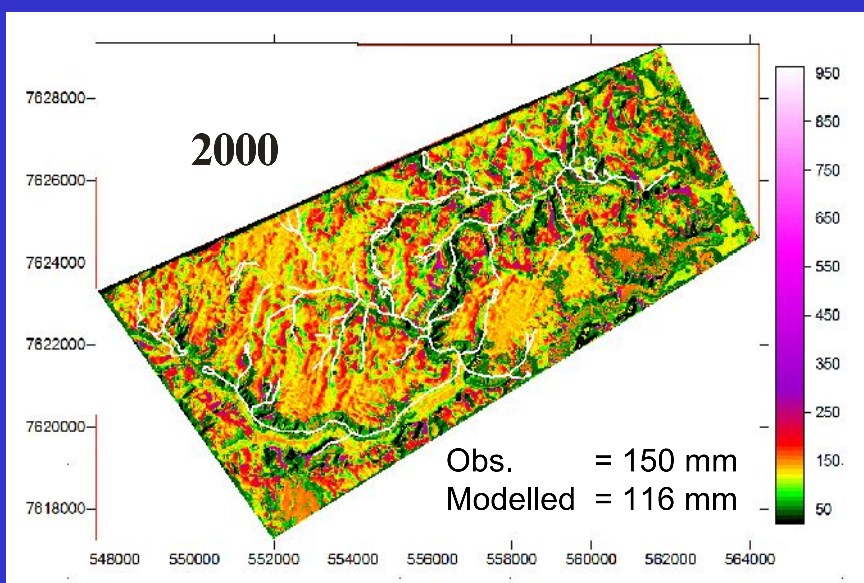
NOTE:

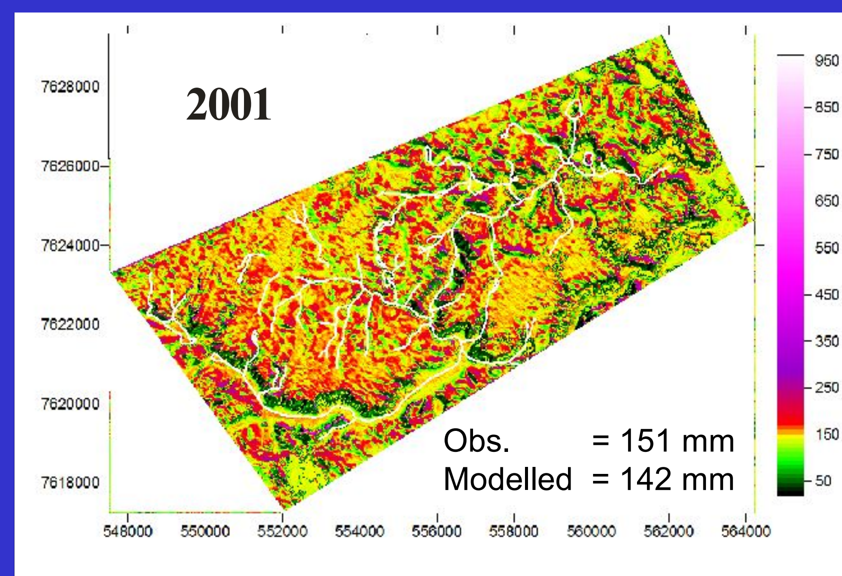
- Black = snow
- White = bare ground

End of winter snow distribution







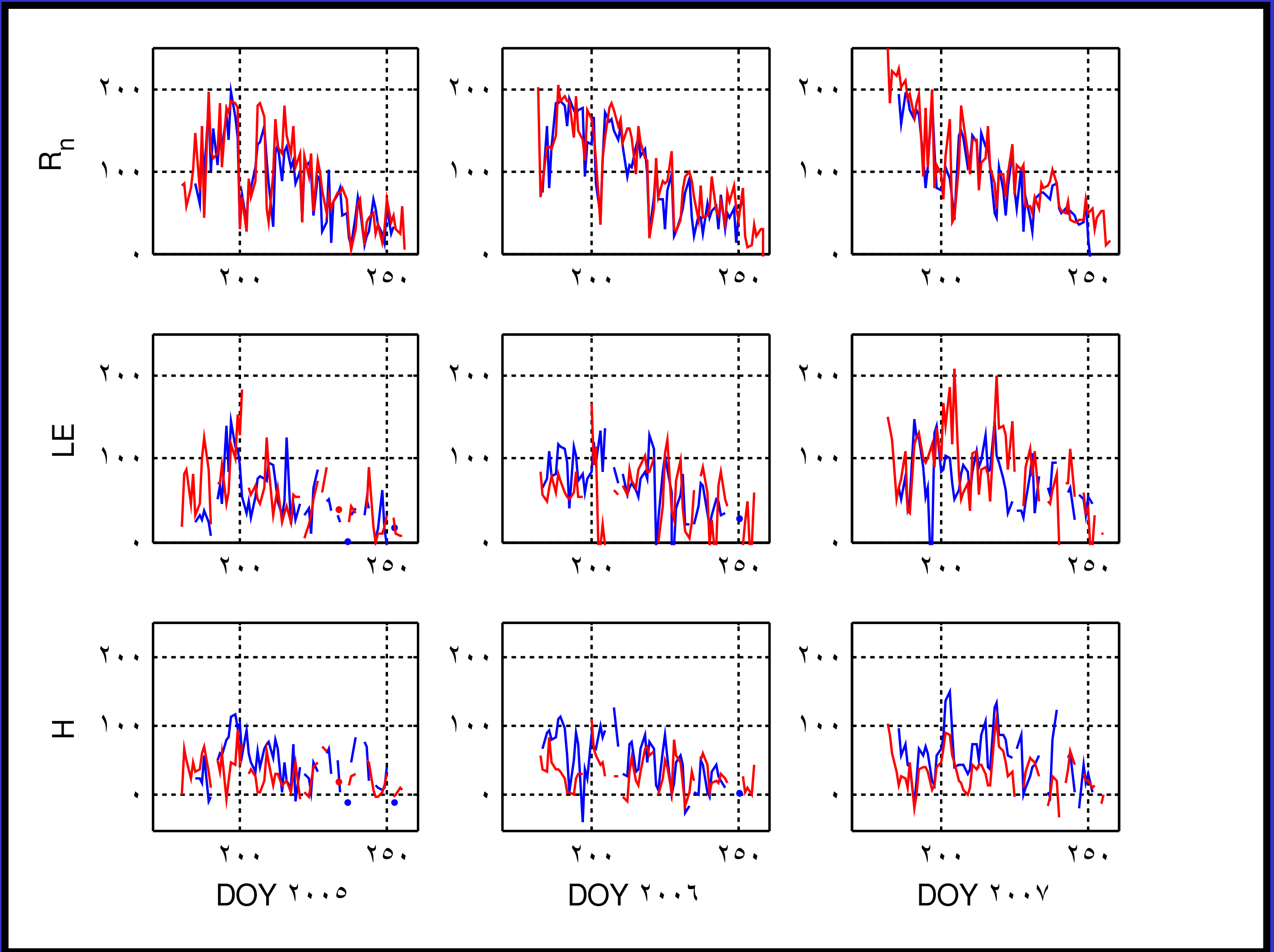


4d. Role of Lakes in controlling spatial variability

- How does the magnitude and controls of lake evaporation vary across the study area?

- As a first step we will compare/contrast two different small lakes: round and shallow vs. long and deeper; northern and southern, to help address this question.

24-hr mean energy balance components (net radiation, latent and sensible heat; W m-2) for Denis (blue) and TUP (red).



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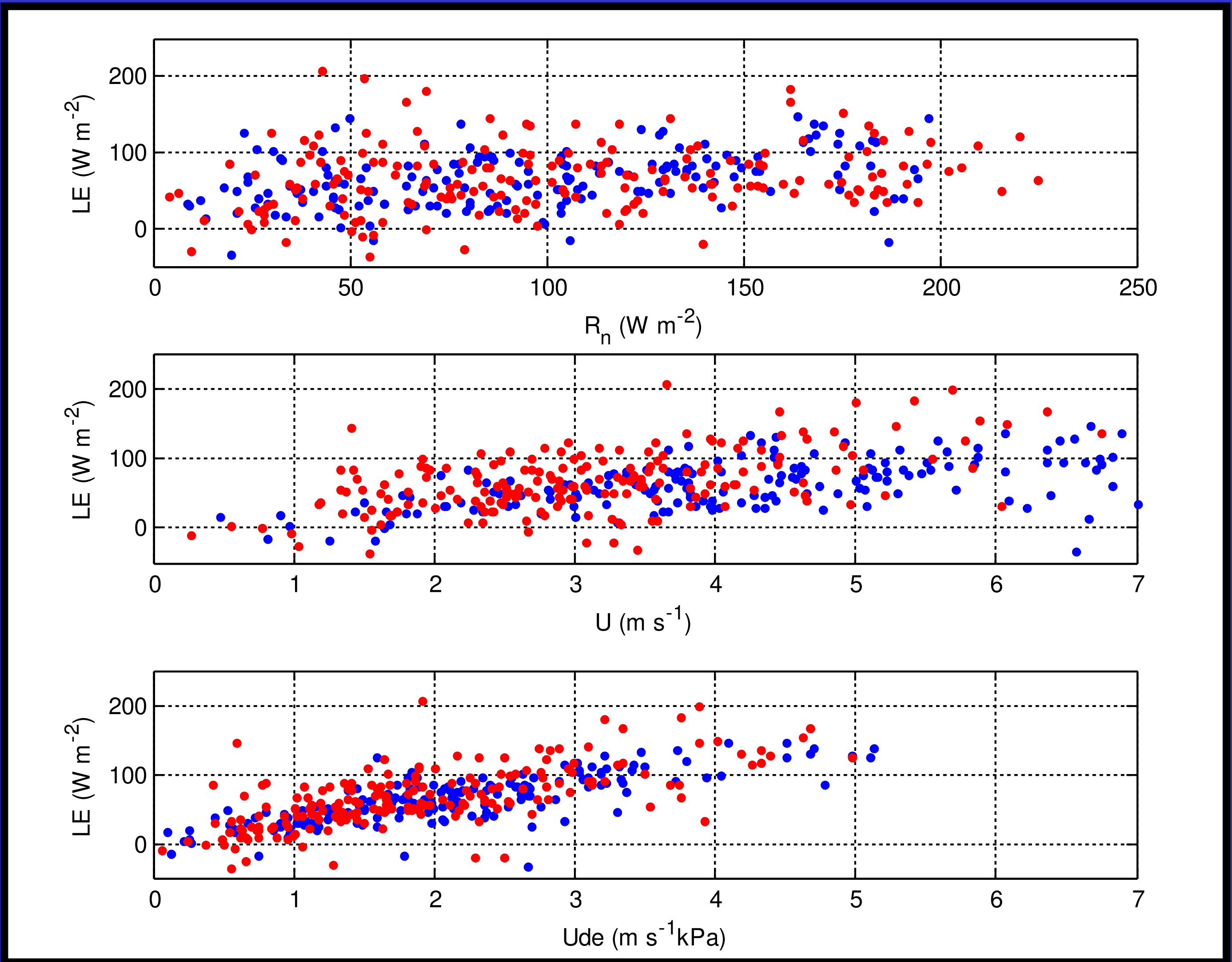
Controls on the 24-hr mean latent heat flux from Denis (blue) and TUP (red): net radiation; horizontal wind speed; product of horizontal wind speed and the difference between water surface and atmospheric vapor pressure.



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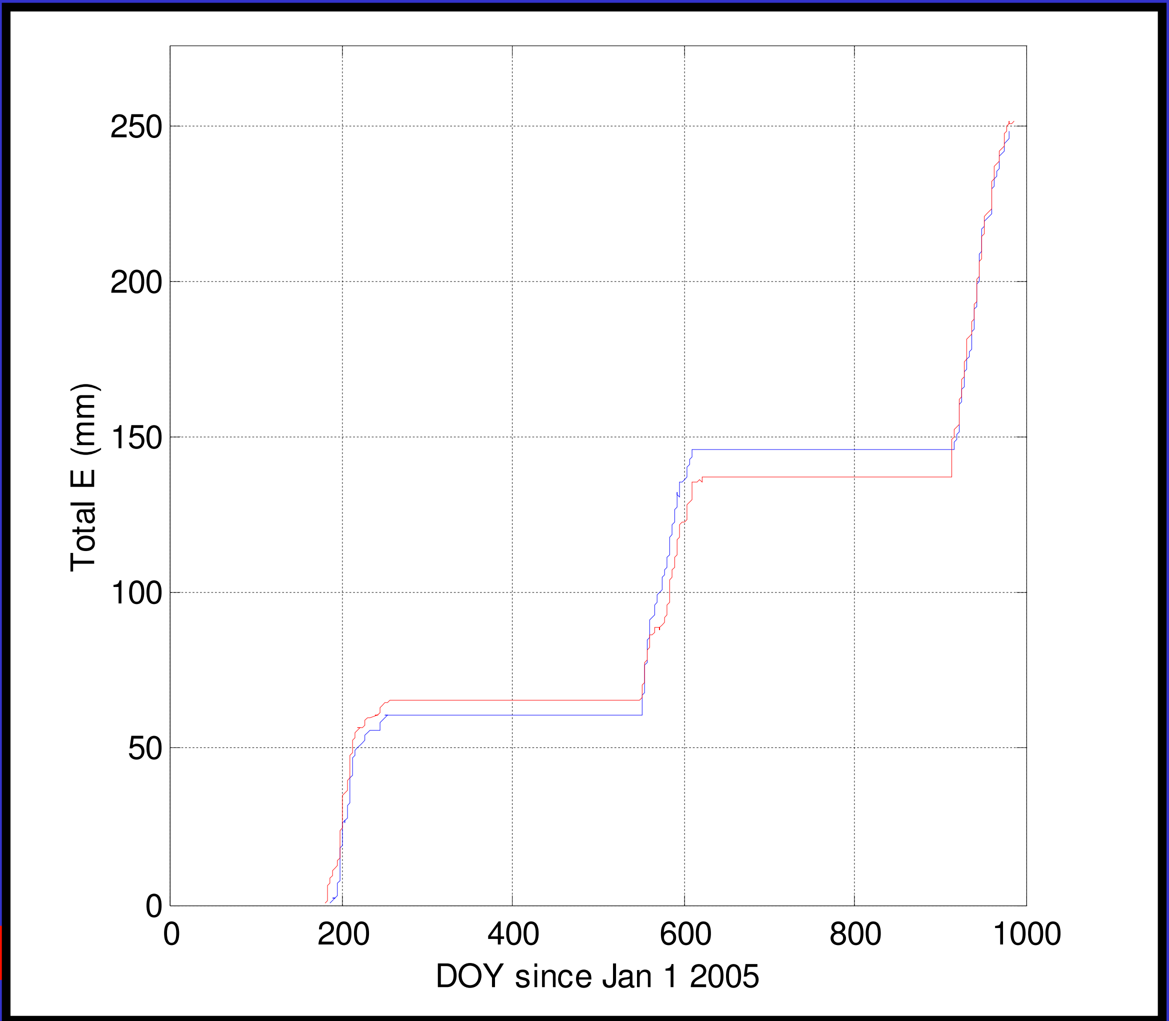
After three years, the total evaporative water losses were 249 (Denis-blue) and 251 mm (TUP-red) .



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- Except for wind speed and direction (which varied between the 2 sites), met. conditions and net radiation were indistinguishable at TUP Lake and Denis Lagoon despite 90 km N-S separation.
- Although low correlation between *LE* between sites, the best predictor of *LE* was *Ude* (product of wind speed and difference in vapour pressure between the air and surface) at both sites.
- Despite differences in location, size, shape, and depth, nearly identical evaporative water losses over the 3 year observation period.
- Future work will look into the possibility of testing the lake model under development by Murray Mackay.

For full details, see poster by Blanken et al. on Friday night

5. Planned activities over the next year

- We are currently working with Murray Mackay (MSC) and Paul Bartlet (MSC) to use CLASS to better understand factors controlling melt at a shrub and tundra site at Trail Valley Creek

- Collaborate with Bill Quinton to consider the links between snow, active layer depth, organic soils, and runoff at Trail Valley Creek

- The combination of field data, aircraft flux data, and satellite and air photo information, in conjunction with the validated high resolution modelling studies, provides a tremendous data set for testing MESH and CLASS.

- Develop plans to run MESH/CLASS or collaborate with other groups running these models.

- We plan to continue our collaboration with Peter Blanken (U. of Colorado Boulder) to analyze our lake flux data, and consider the impact of small lakes on sub-grid scale processes

- discuss with Murray Mackay to test his newly developed lake model for TUP Lake and Denis Lagoon

- Discuss with Raoul Granger whether to test his lake evaporation parameterization to the Inuvik area study sites

- We will continue our collaboration with Drs. Ray Desjardins and Matthias Mauder to analyze the NRC aircraft data for the flight lines over TVC, and to explore the option of similar analysis for lake rich regions near Inuvik

THE END