Challenges in Snow Measurement: Solid Precipitation and Snow Cover

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(with contributions from many colleagues)

Precipitation and Snow Definitions

Precipitation **– Any product of the condensation of atmospheric water vapour which is deposited on the earth's surface is a type of precipitation.**

Rainfall **– the accumulated depth of liquid precipitation over a horizontal unit area between observing periods.**

Snowfall **– the accumulated depth of freshly fallen snow over a horizontal unit area between observing periods.**

Total Precipitation **– the sum of the accumulated depths of the water equivalent of all precipitation over a horizontal unit area between observing periods.**

Snow Cover **– The net accumulation of snow on the ground resulting from solid precipitation deposited as snowfall, ice pellets, hoar frost and glaze ice, and water from rainfall, much of which subsequently has frozen.**

Water Equivalent of Snow Cover (SWE) **– Vertical depth of a water layer which would be obtained by melting a snow cover.**

Snow Depth (Snow on the Ground) **– The total depth of solid precipitation on the ground at the time of observation. The vertical distance between the surface of a snow layer and the ground, the layer being assumed to be evenly spread over the ground which it covers.**

Snow survey **- The depth of snowpack, water equivalent (SWE) and snow density, averaged over a snow course.**

In-situ Measurement of Precipitation and Snow Cover

Instrument / Variable	Standard Rain Gauge	Tipping Bucket Rain Gauge	Nipher Gauge	All Weather Auto Gauge	Ruler	Sonic Depth Sensor	Snow Course
Rainfall	X	X		X			
Rate of Rainfall		XX					
Fresh fallen snow					X	X	
Total Precipitation	X	X	X	X	X		
Depth of Snow on Ground					X	X	
Snow Cover (SWE)							X

X=manual X=autostation

Application Requirements for Precipitation Data

APPLICATION \ DATA	TYPE	TIMING	AMOUNT	AMOUNT ACCURACY	SPATIAL COVERAGE	TEMPORAL HOMOGENEITY
AVIATION FORECASTS	1	1	2	3	2	3
GENERAL PUBLIC	1	1	2	3	2	3
FLOOD FORECASTING	1	1	1	1	1	1
ENGINEERING	1	1	1	1	1	1
RESEARCH	1	1	1	1	1	1
MANUAL OBS AUTOSTATION	↓	↑	↓	↓	↑	↓

1 = very important

2 = important

3 = less important

Good

Bad

THE WMO SOLID PRECIPITATION MEASUREMENT INTERCOMPARISON

Study Objectives

The goal of the intercomparison was to assess national methods of measuring solid precipitation against methods whose accuracy and reliability were known, including past and current procedures, automated systems and new methods of observation. The intercomparison was especially designed to:

- Determine wind related errors in national methods of measuring solid precipitation, including consideration of wetting and evaporative losses;
- Derive standard methods for adjusting solid precipitation measurements; and
- Introduce a reference method of solid precipitation measurement for general use to calibrate any type of precipitation gauge.

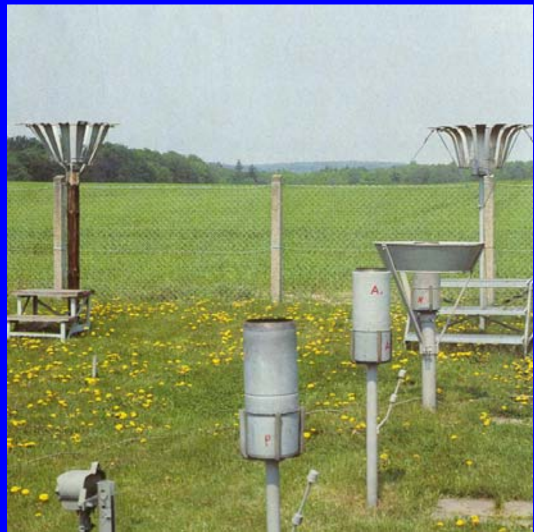
Sources of Measurement Errors

Systematic errors for manual catchment-type gauge:

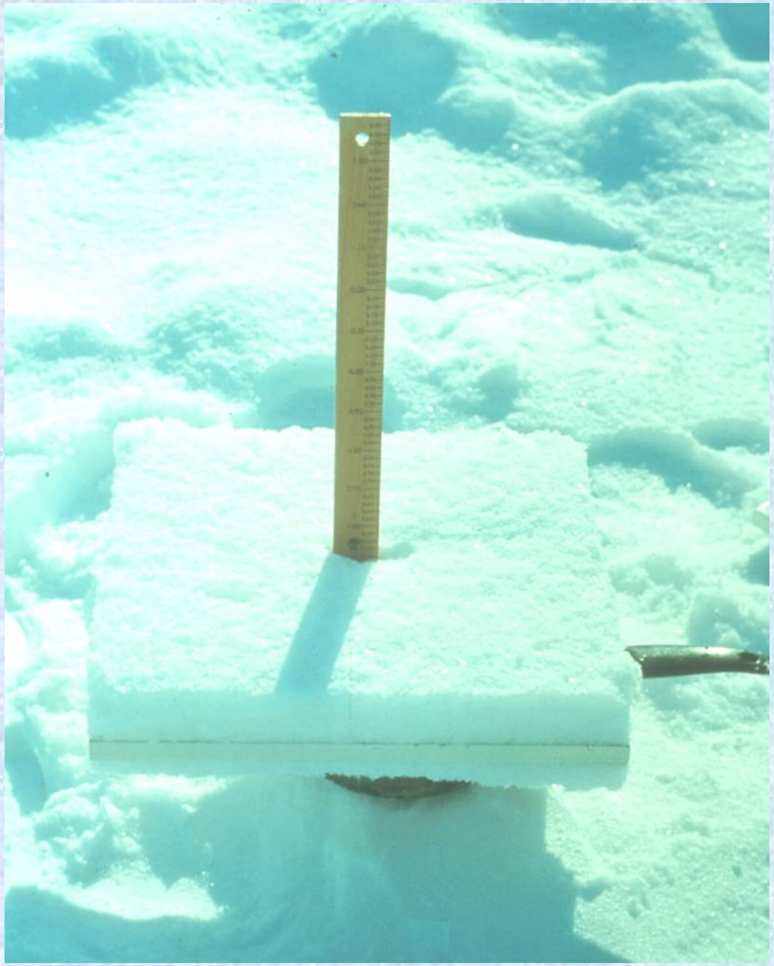
- **WIND (temperature)**
- **wetting loss**
- **evaporation loss**
- **non-zero trace**

- **capping of gauge orifice**
- **blowing snow**

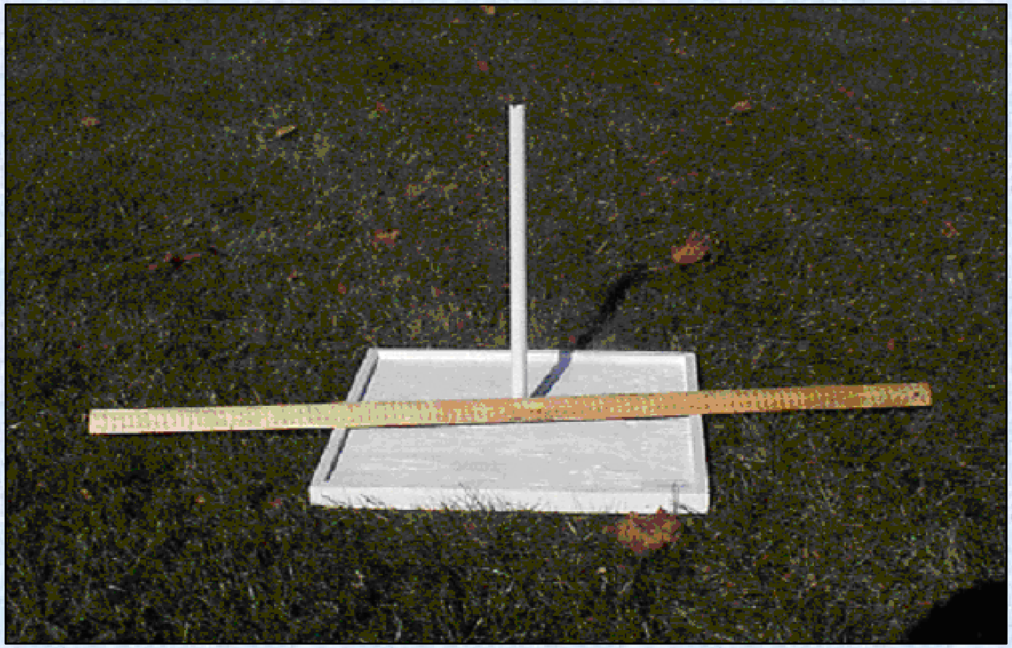
WMO Solid Precipitation Measurement Intercomparison



Measuring freshly fallen snowfall with Snow Boards



Original

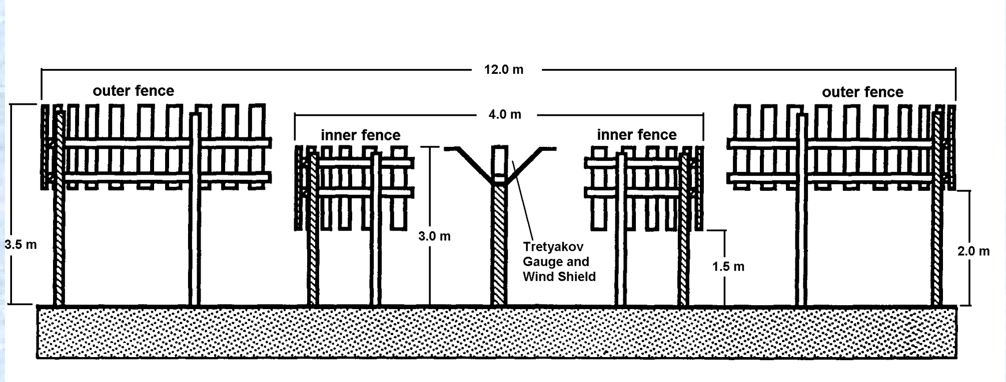


Weaverboard 2000

for use as an Observer's aid

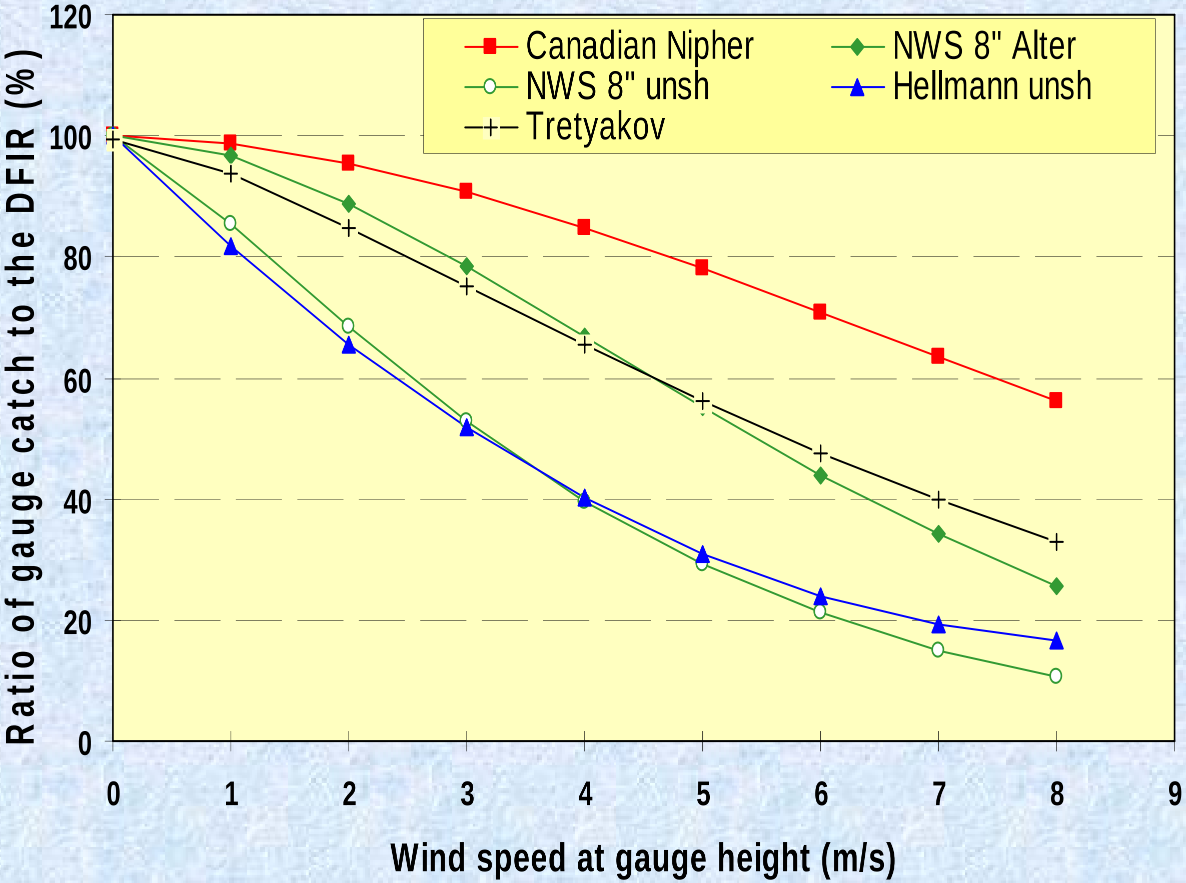
10cm snowfall is 10mm precipitation

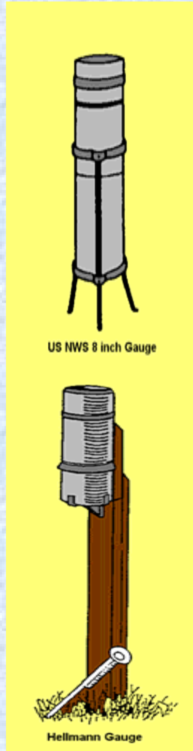
WMO Double Fence International Reference for Solid Precipitation



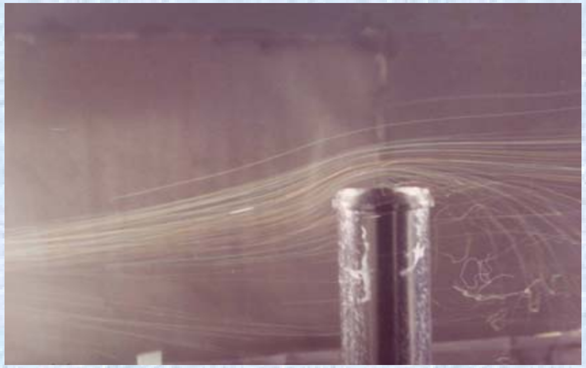
WMO Intercomparison Study Results

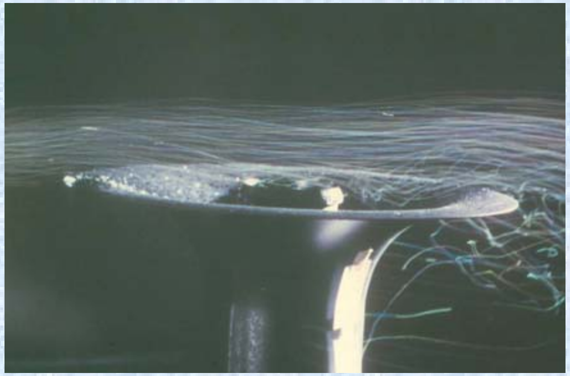
Catch Efficiency vs Wind for the 4 most widely used gauges

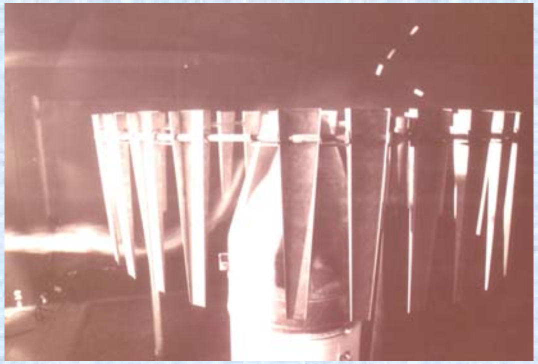


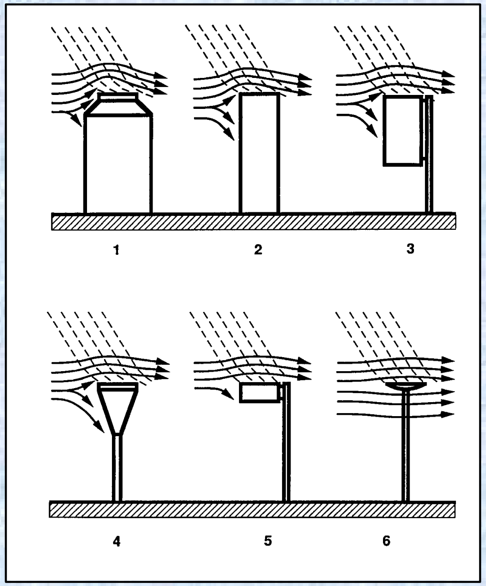


Wind flow effects on gauges



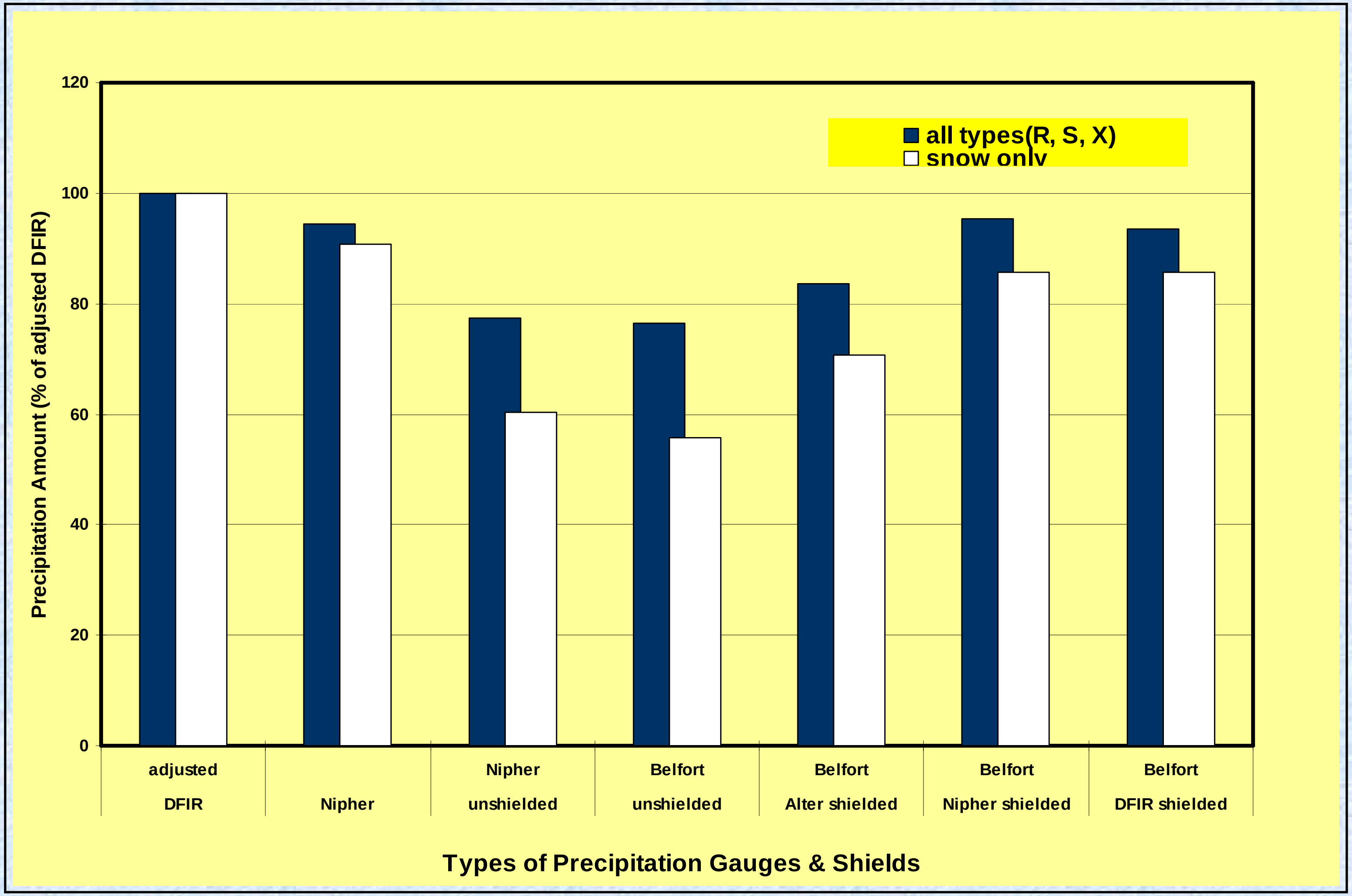






Shapes of precipitation gauge body. The number 1 indicates the shape having the worst aerodynamic properties and the number 6 having the best ones. Arrows show the streamlines and the dashed lines the trajectories of precipitation particles.

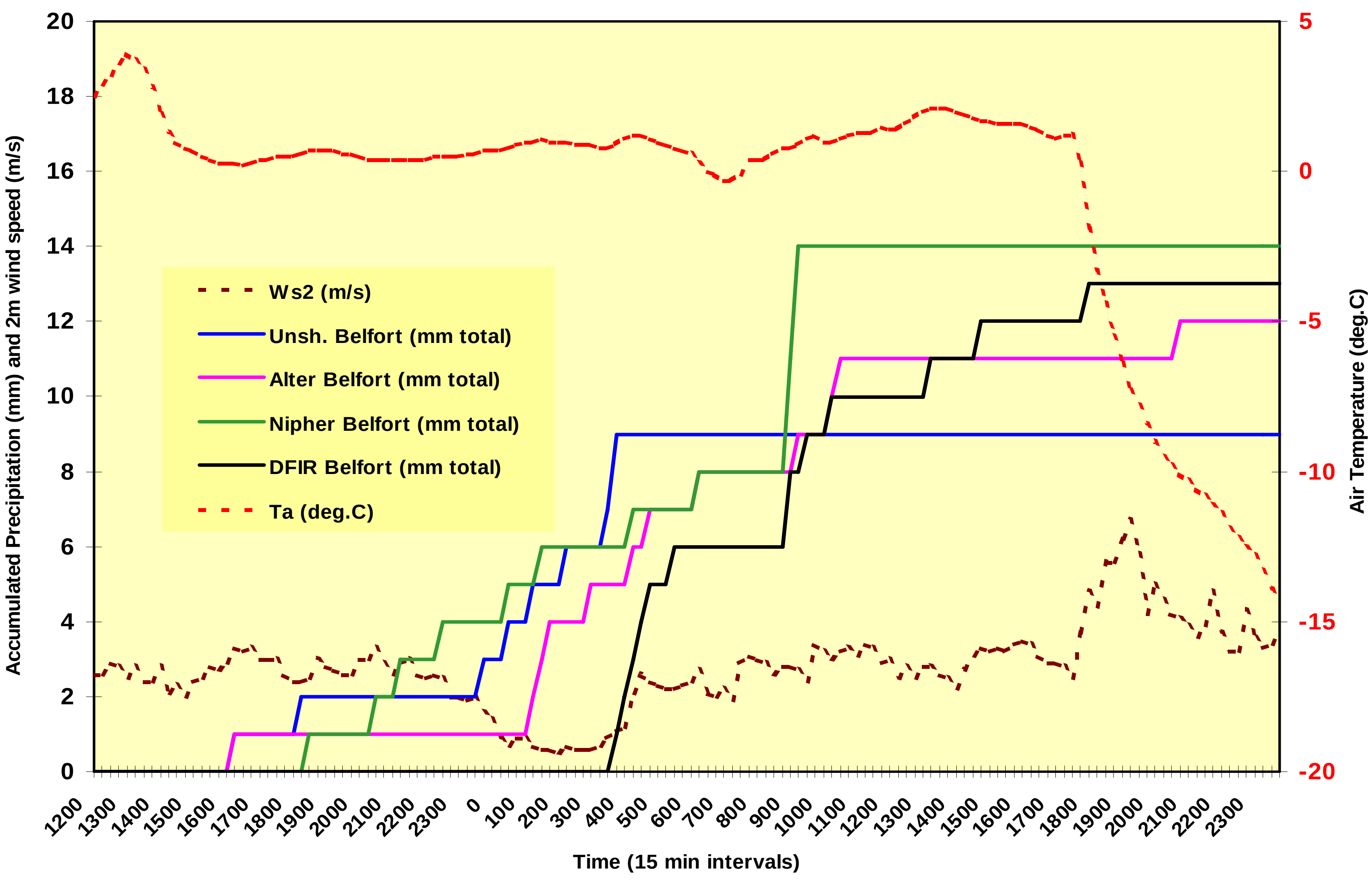
Need for adjustments



Mean annual accumulated winter precipitation ≥ 3.0 mm, of different gauge types and shielding as a percentage of DFIR (adjusted for catch deficiency) at the Canadian Evaluation Station at Kortright Centre, Ontario from 1987-1991.

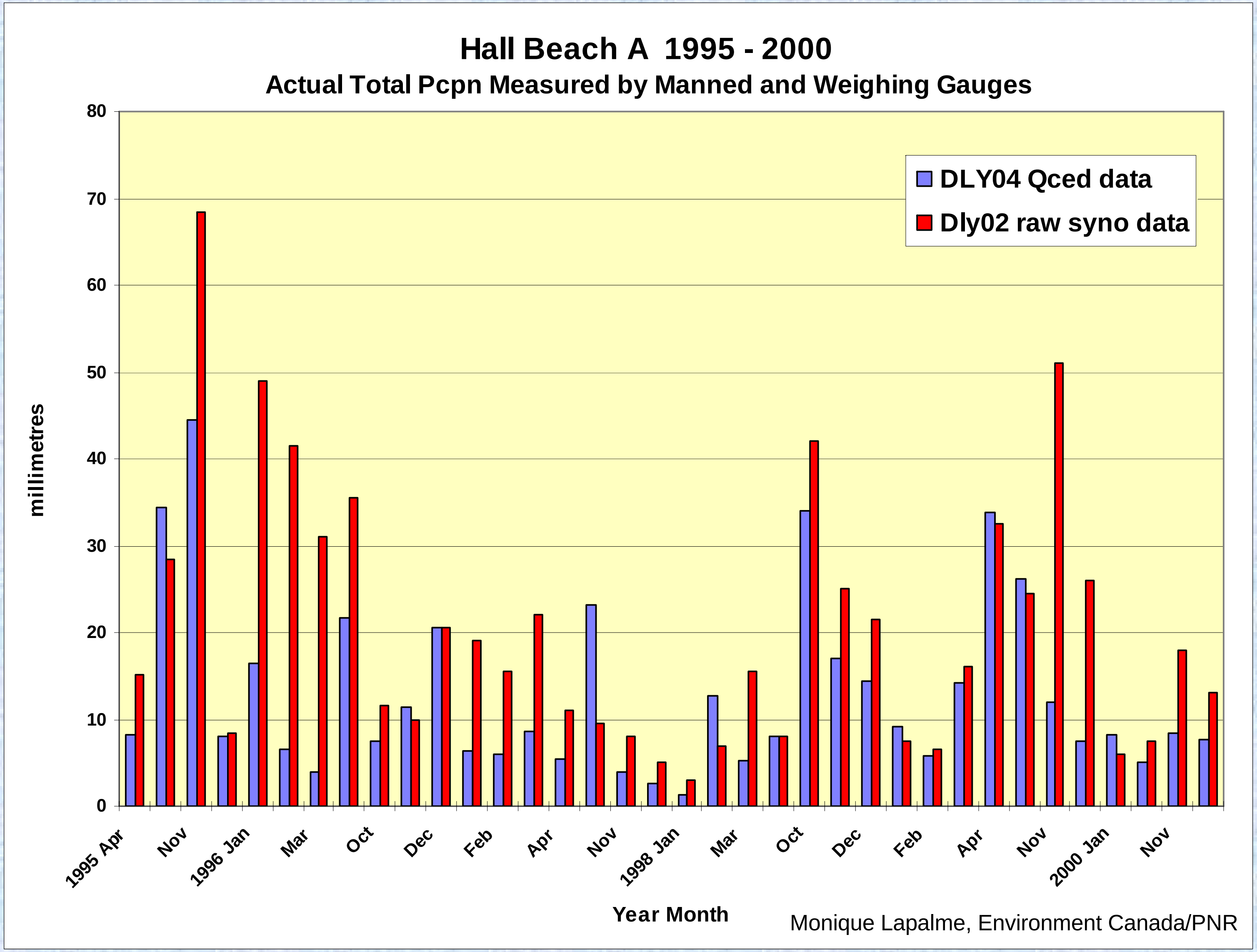
Challenges for auto QA/QC

Automation of precipitation measurements



WMO Study: Timing and catch differences of Belfort Gauges at Kortright, Ontario Feb. 19-20/1988

Hall Beach A — Total Precipitation Manned vs Weighing Gauges

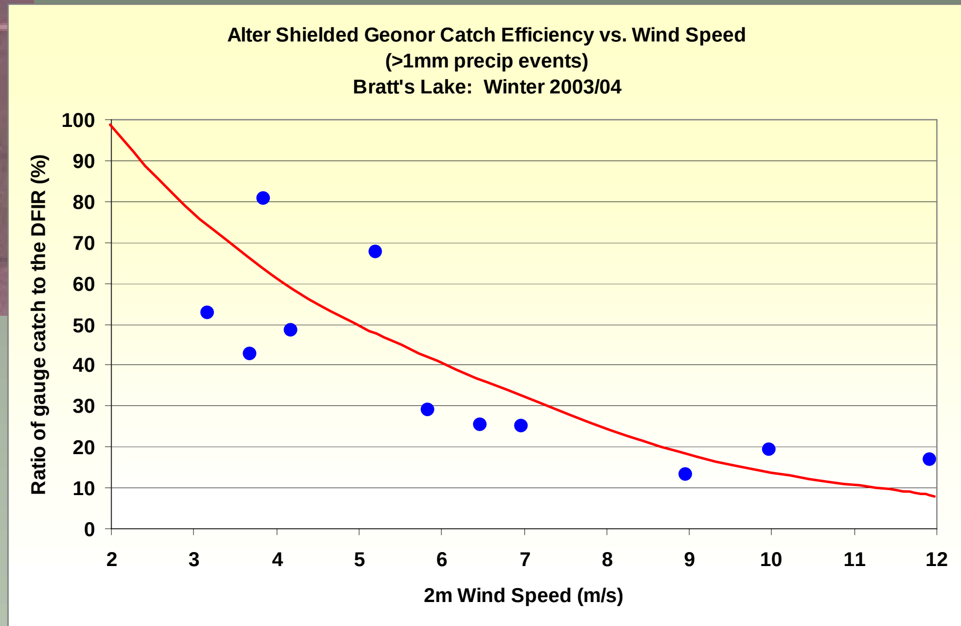


Bratt's Lake Geonor Intercomparison

- Project objective: develop and refine wind under-catch relationships for the Geonor all-weather precip gauge, incorporating new technologies such as the POSS

POSS:

High resolution precip occurrence and typing to be used to refine wind correction relationships



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Development of Bias-Corrected Precipitation Database and Climatology for the Arctic Regions

(NSF project, 2003-2006)

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University of Alaska Fairbanks

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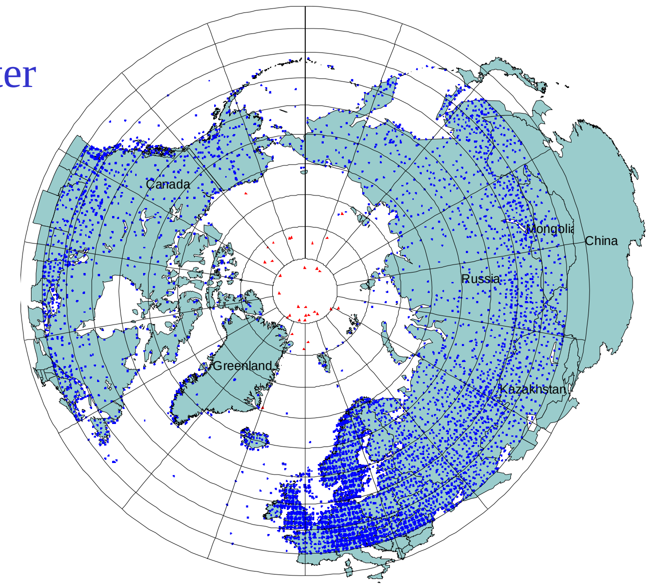
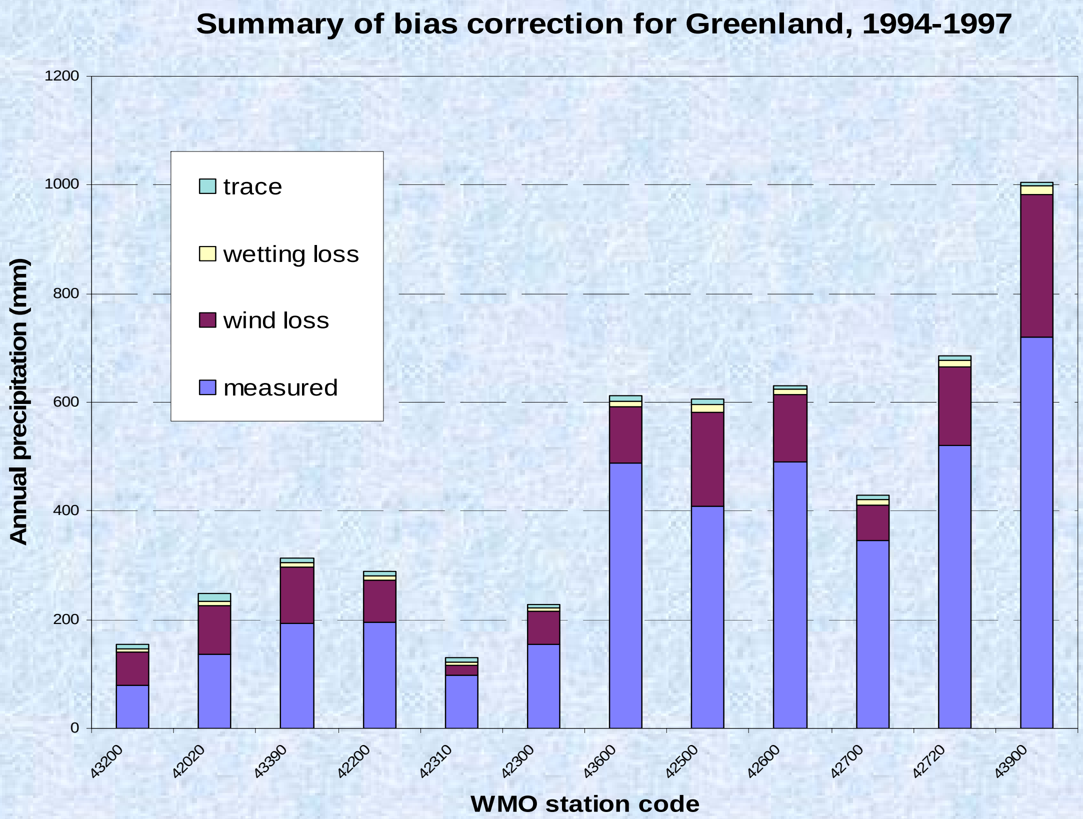


Research Goals

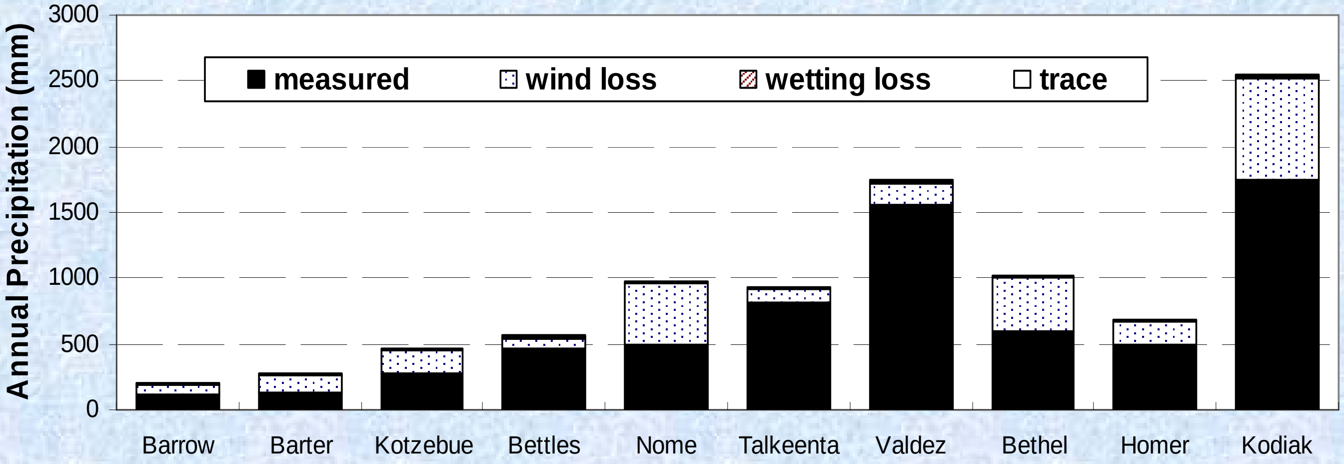
- Evaluate the accuracy of precipitation measurements in the Arctic regions.
- Implement a consistent bias-correction method over the pan-Arctic, i.e. Alaska, northern Canada, Siberia, northern Europe, Greenland, and the Arctic Ocean.
- Develop biased-corrected and compatible precipitation database (including grid products) and climatology for the Arctic regions as a whole.

http://www.uaf.edu/water/faculty/yang/bcp/index.htm

Application of the WMO Results

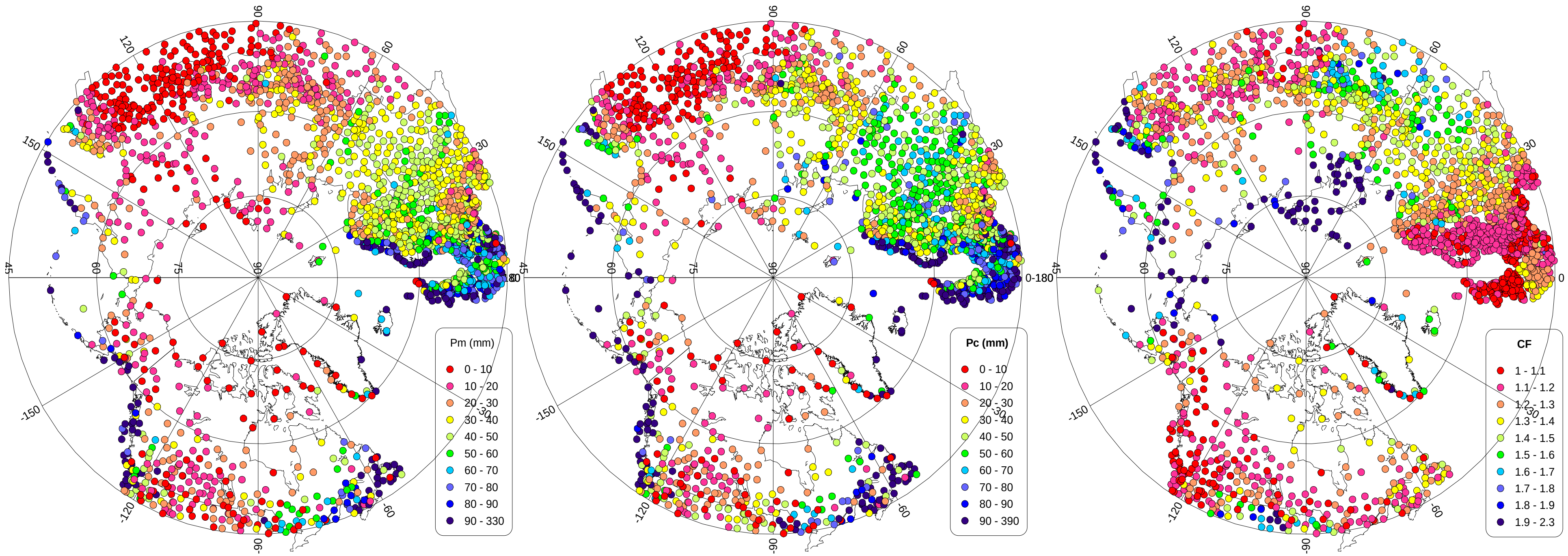


Precipitation correction in Alaska
NWS 8" standard gauges, 1982



Mean Gauge-Measured (Pm) and Bias-Corrected (Pc) Precipitation, and Correction Factor (CF) for January

Yang et al., 2005, GRL

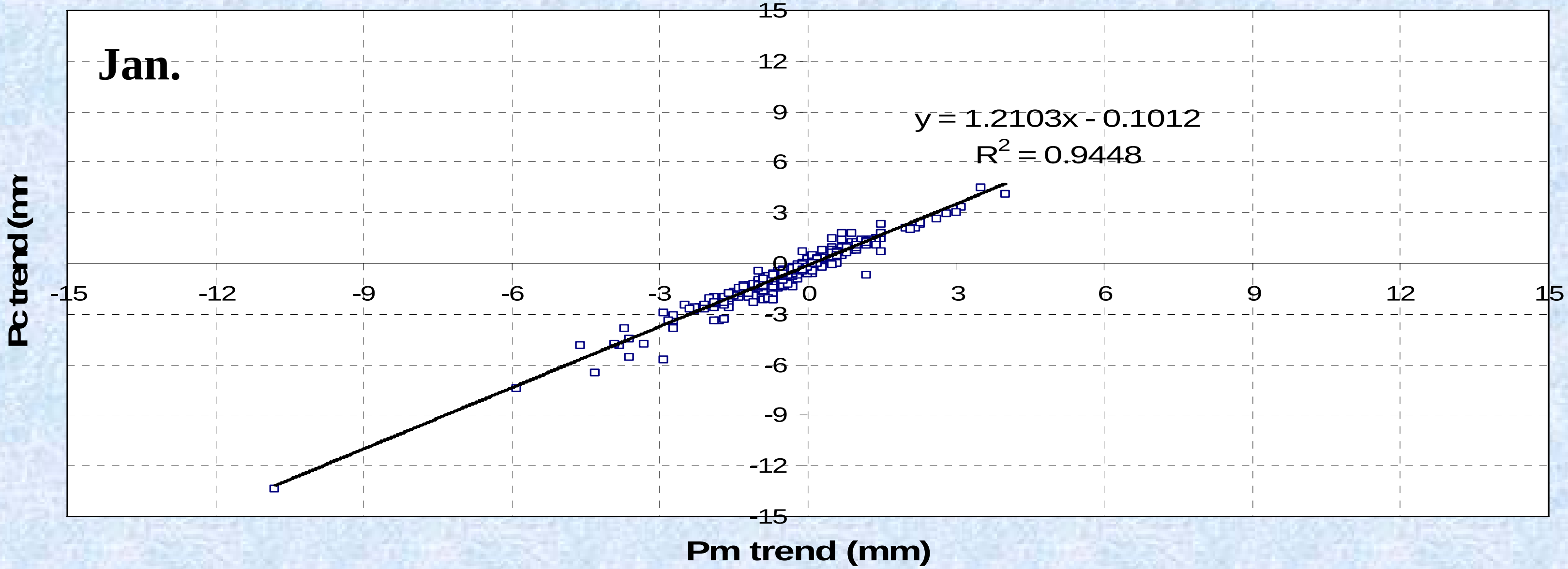


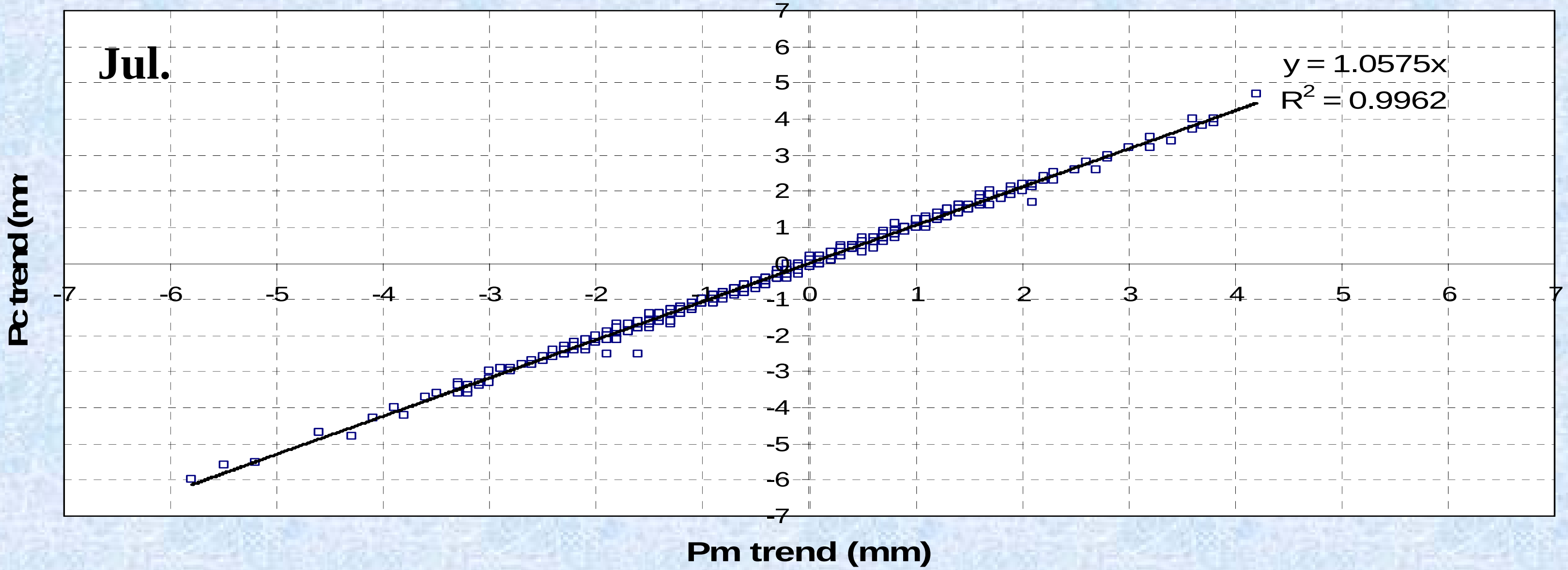
a) Pm (mm)　　*b) Pc (mm)*　　*c) CF*

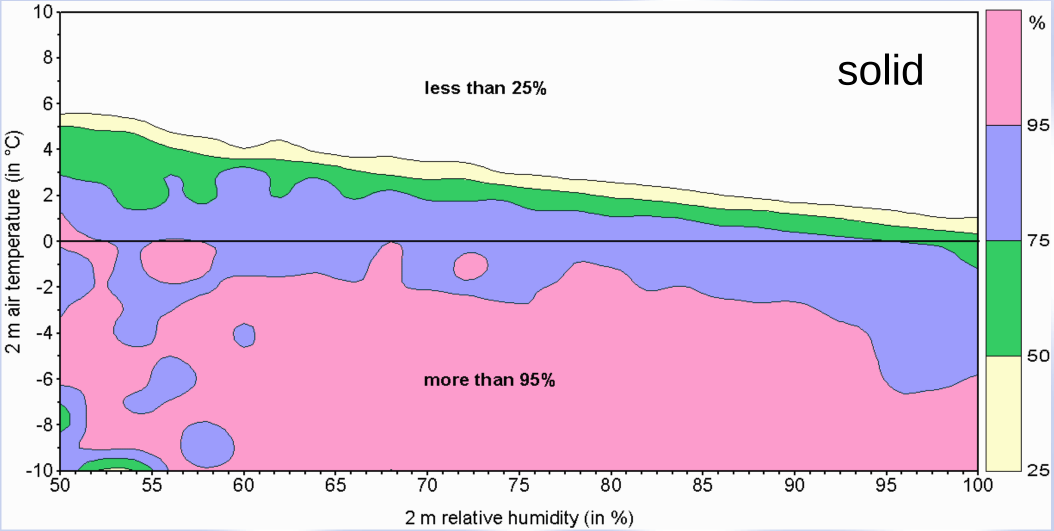
- Total 4827 stations located north of 45N, with data records longer-than 15 years during 1973-2004.
- Similar Pm and Pc patterns – corrections did not significantly change the spatial distribution.
- CF pattern is different from the Pm and Pc patterns, very high CF along the coasts of the Arctic Ocean.

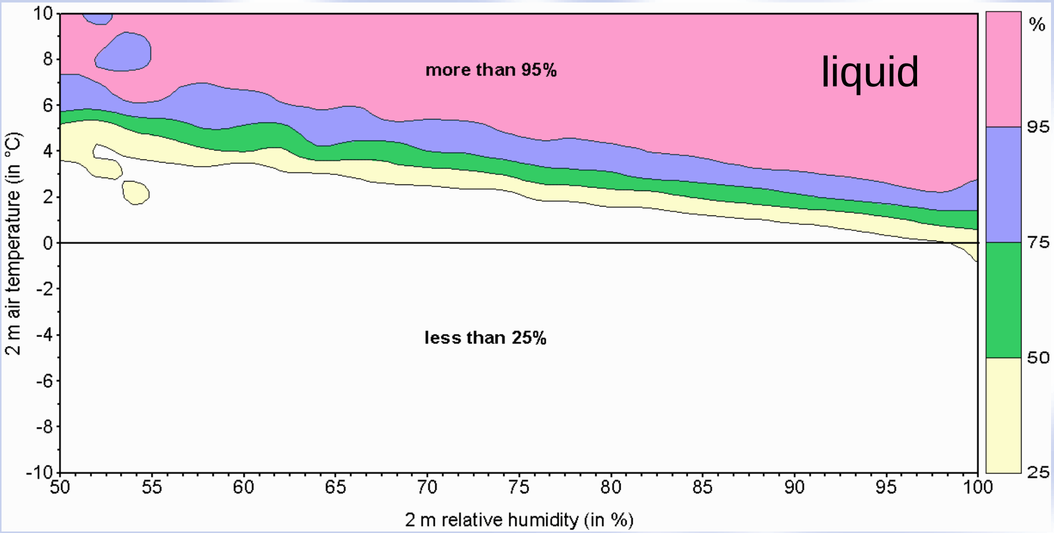
Impact of Bias-Corrections on Precip Trend

Pm & Pc Trend Comparison, Selected Stations with Data > 25 Yrs during 1973-04









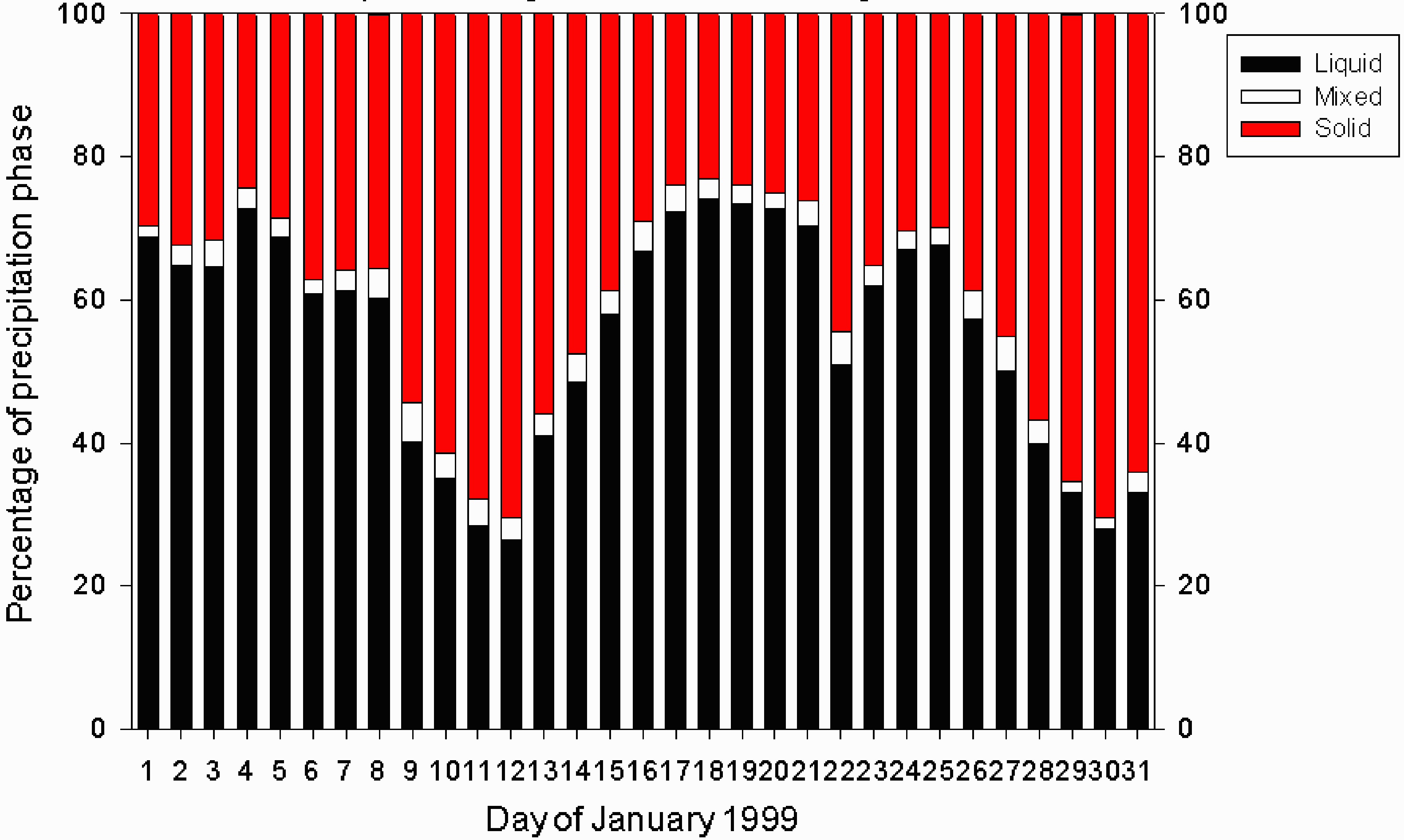
Probability of solid and liquid precipitation as function of air temperature and humidtity

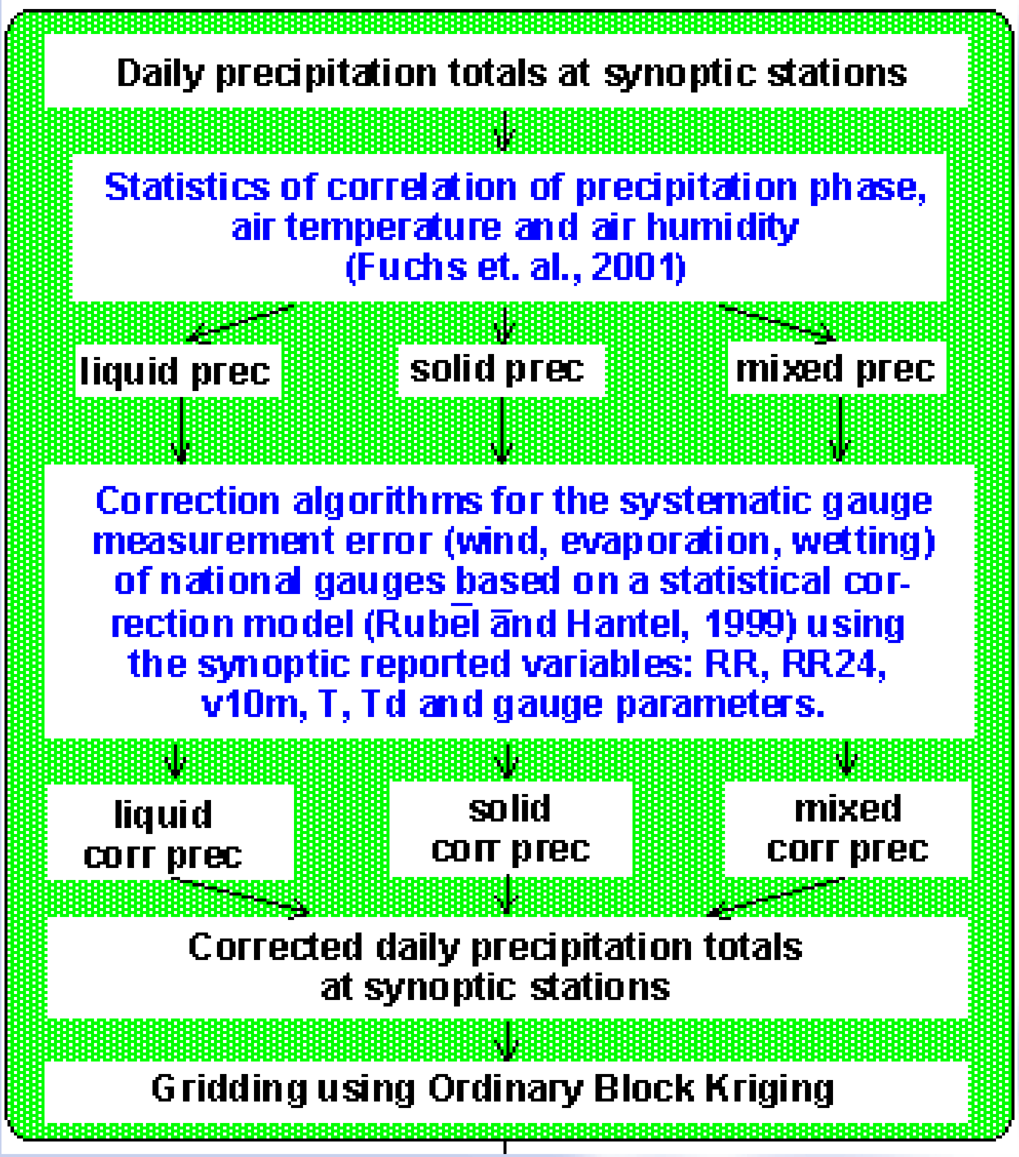
derived from SYNOP data

Fuchs, T., J. Rapp, F. Rubel and B. Rudolf (2001)

Precipitation phases in GTS-SYNOP data of January 1999

Determination of phases using the GPCC scheme; Region: WMO RA VI

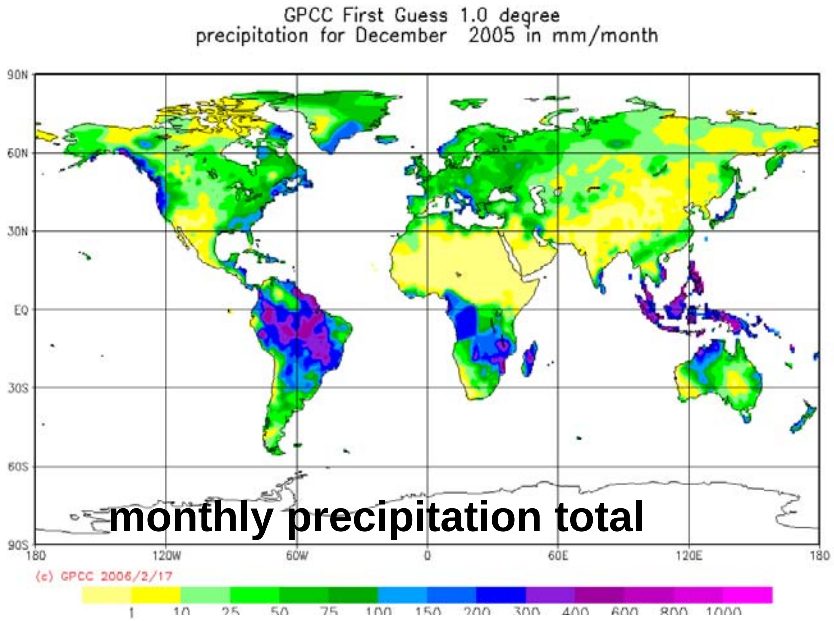


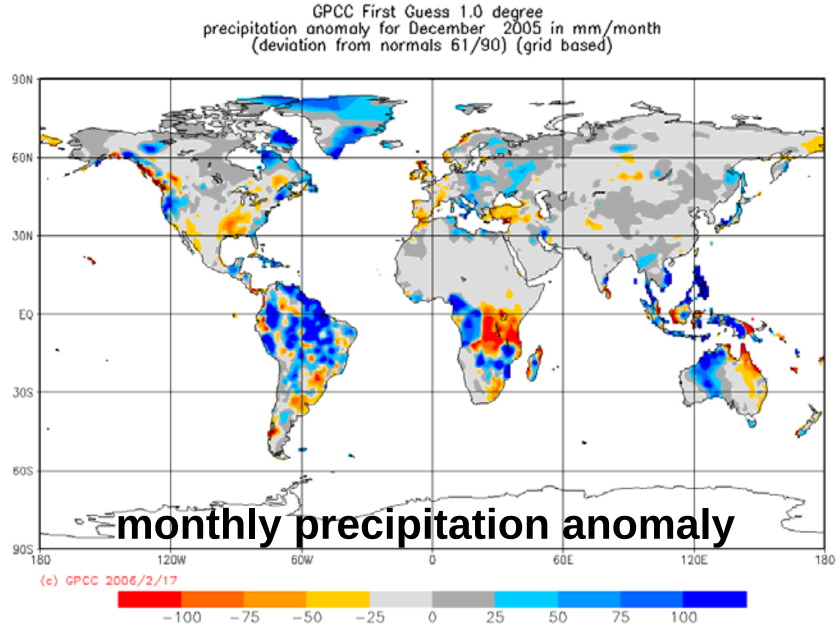


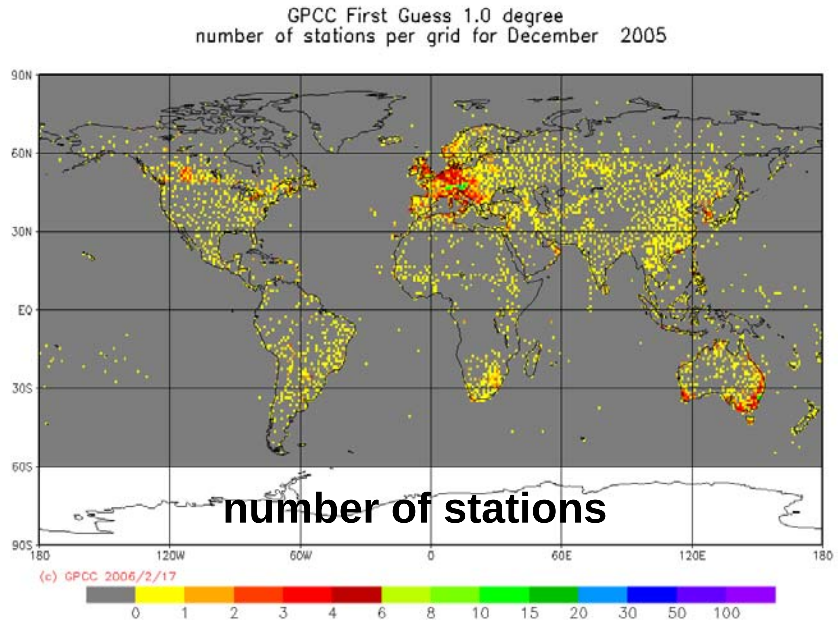
GPCC's data processing scheme for SYNOP reports:

- **Separation of liquid, mixed and solid phase using wwW_1W_2 or T and Td**
- **Correction using a wind speed reduced from v10m.**
- **Calculation of corrected daily precipitation totals.**

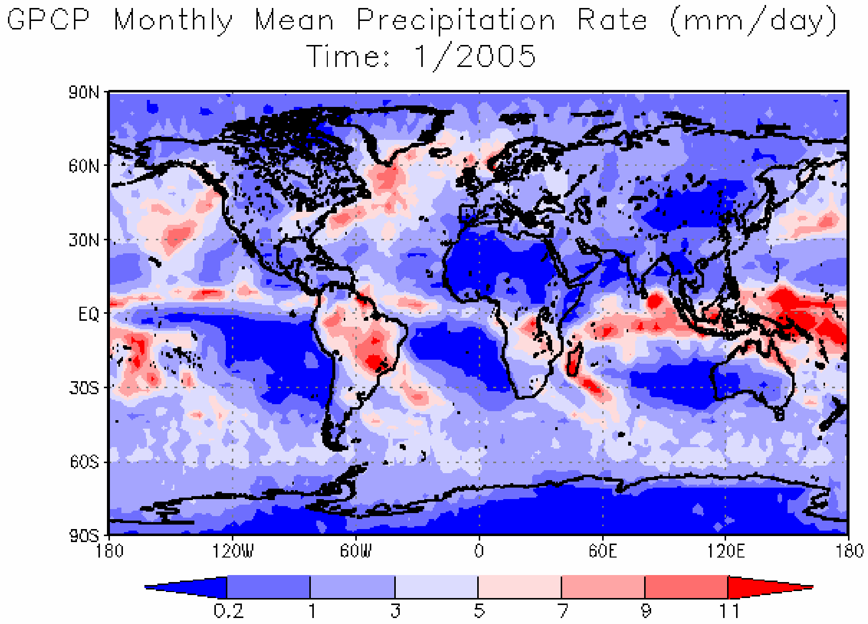
Classical information provided on the grid:

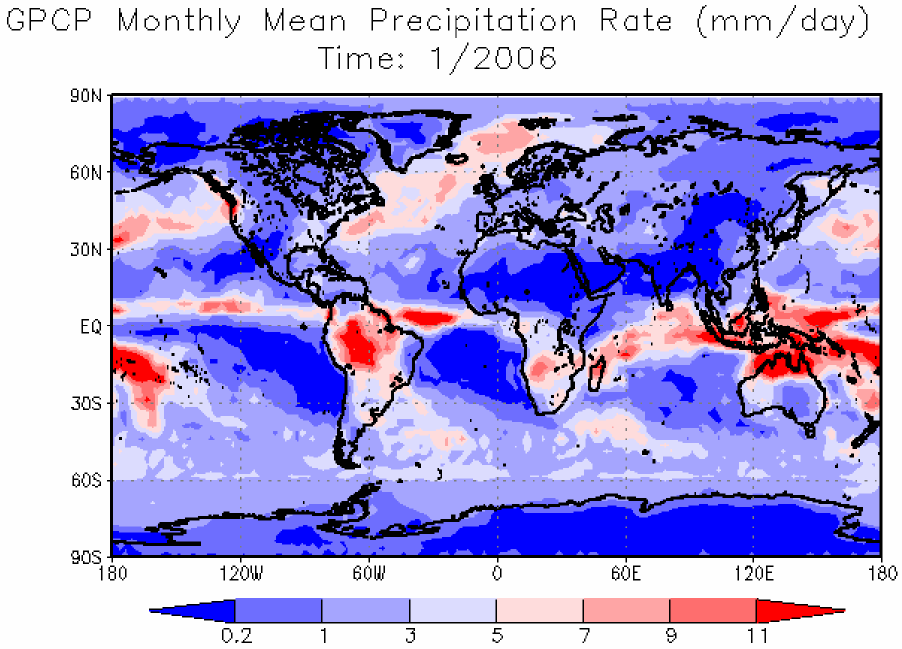




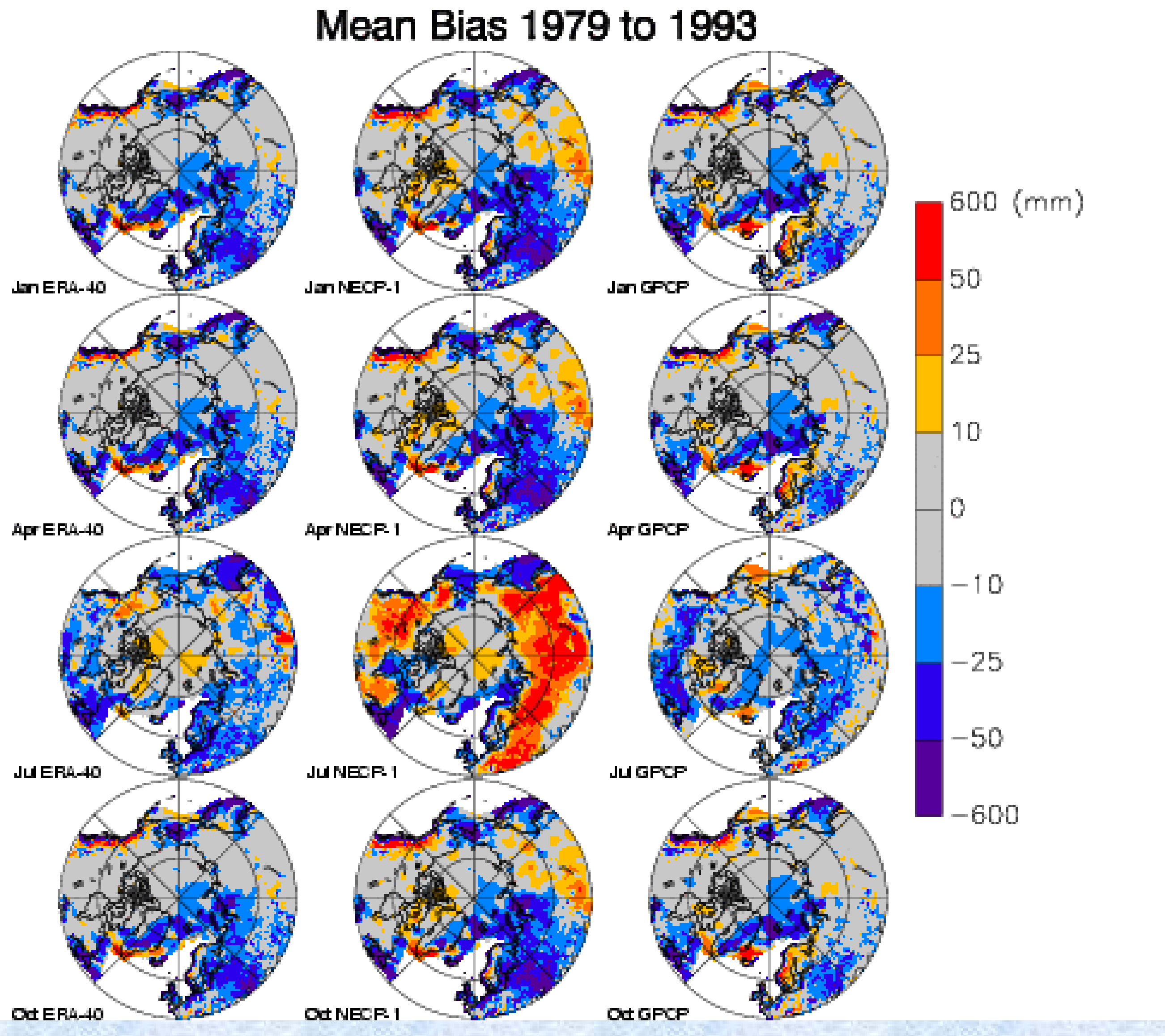


High resolution gridded global precipitation normals are also Available.

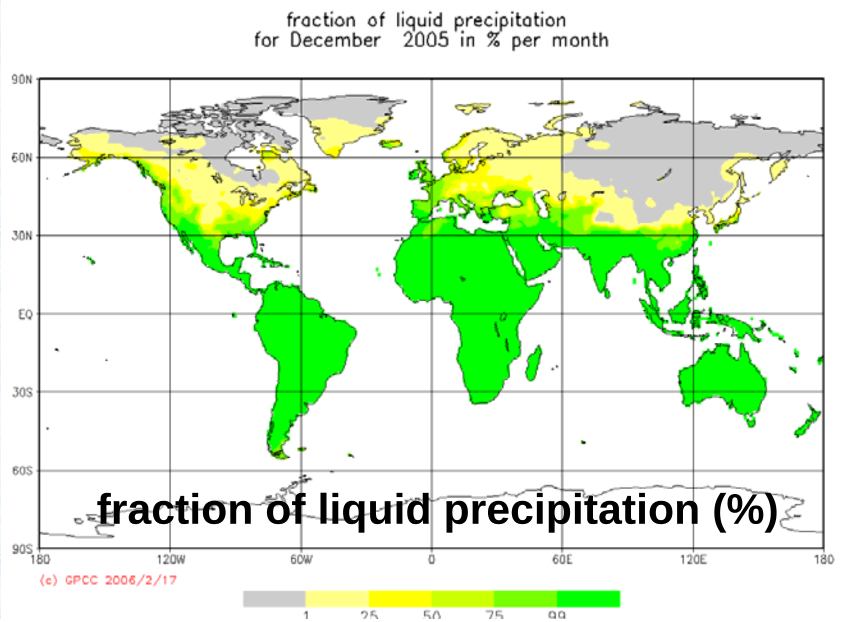

GPCP Monthly Mean Precipitation Rate (mm/day)
Time: 1/2005
90N
60N
30N
EQ
30S
60S
90S
180
120W
60W
0
60E
120E
180
0.2
1
3
5
7
9
11

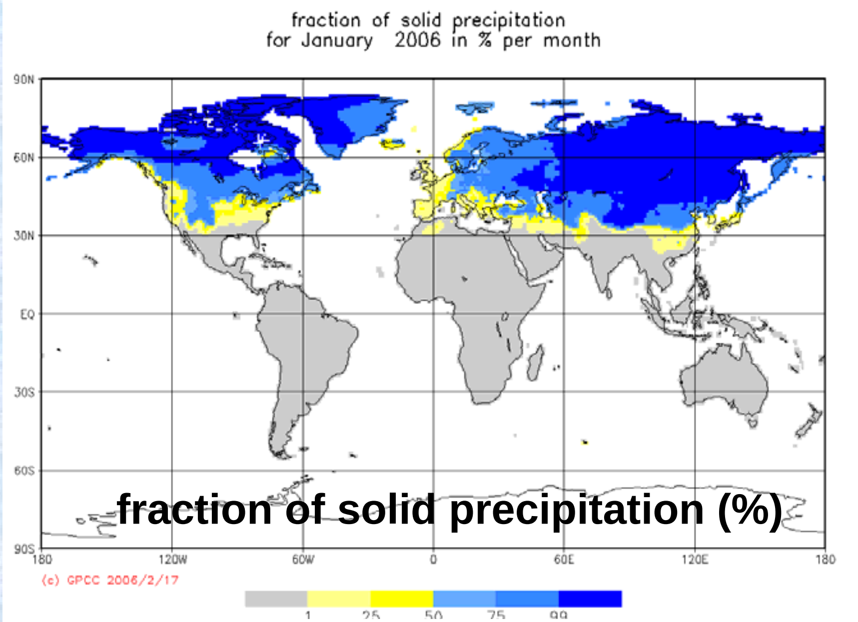

GPCP Monthly Mean Precipitation Rate (mm/day)
Time: 1/2006
90N
60N
30N
EQ
30S
60S
90S
180
120W
60W
0
60E
120E
180
0.2
1
3
5
7
9
11

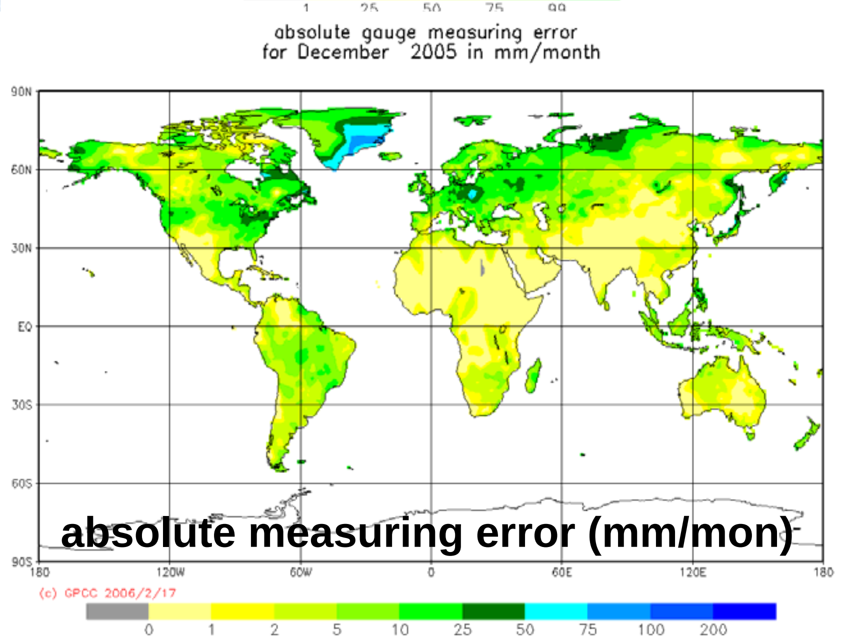
Precipitation Biases: ERA-40, NCEP-1 and GPCP

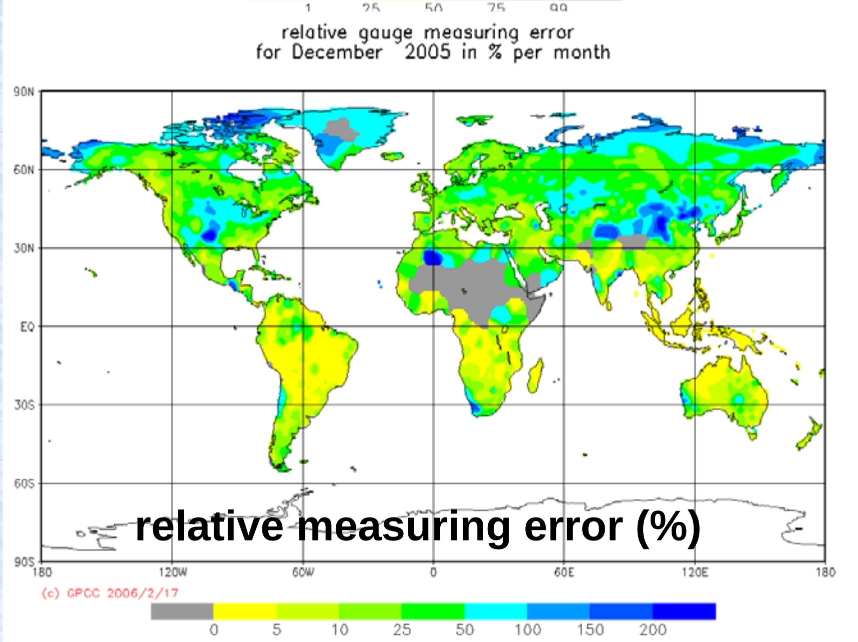


New GPCC products based on synoptic data

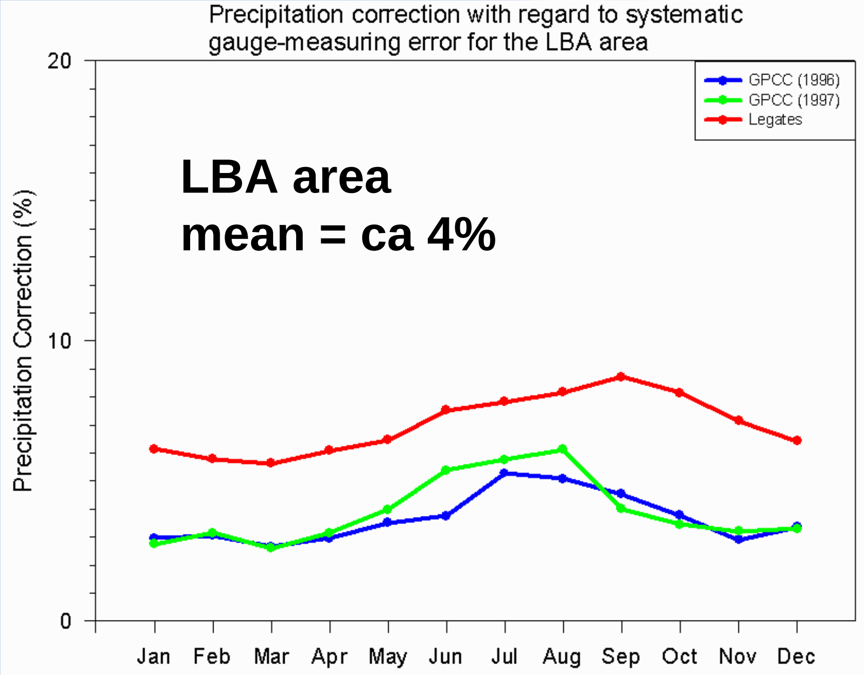


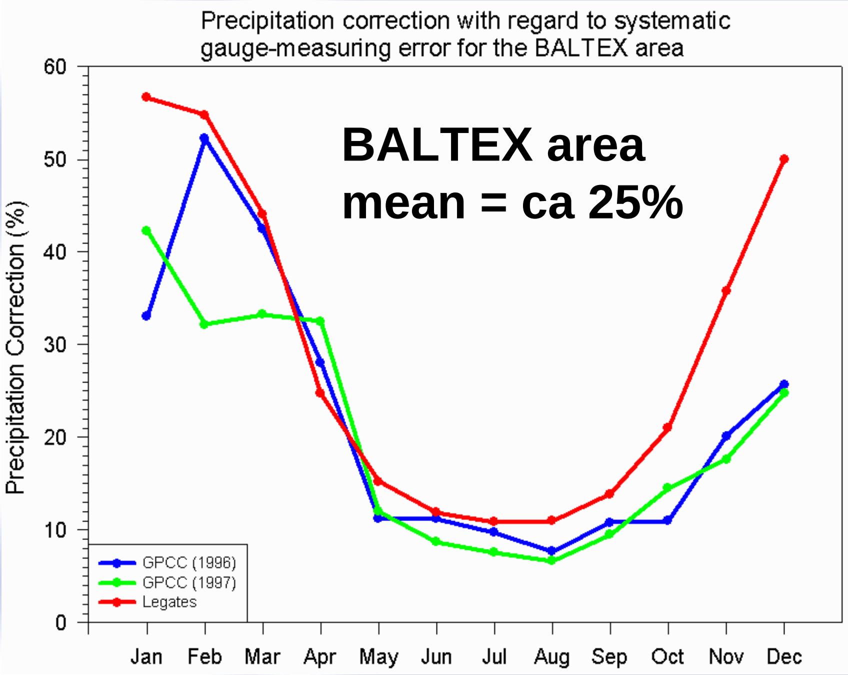






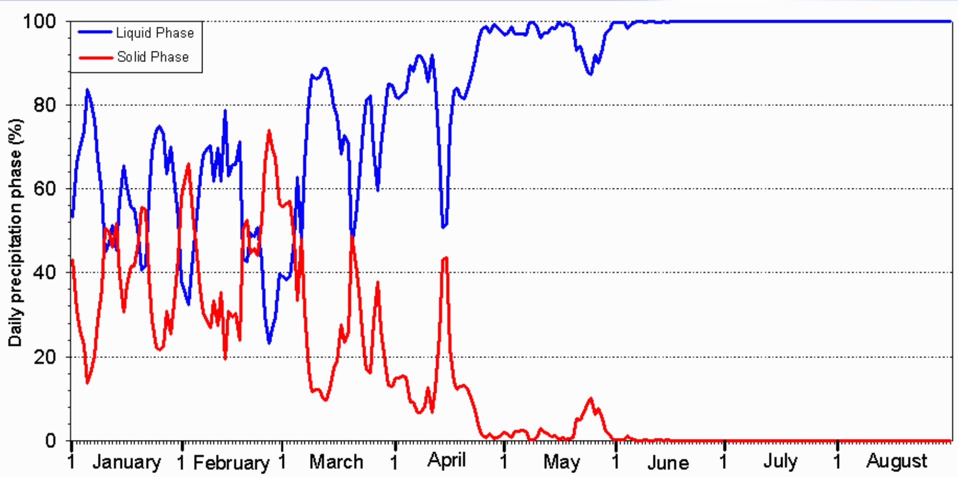
Mean percentual correction for all SYNOP precipitation based on GPCC's new correction method



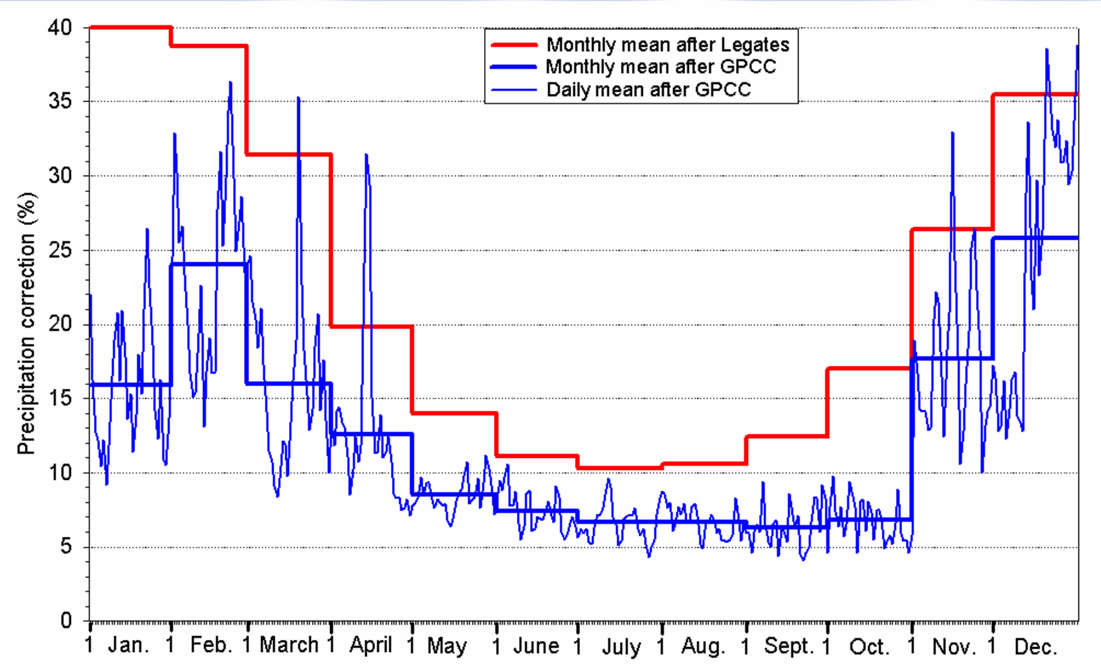


Comparison of monthly percentual corrections in % of observed data derived from daily corrections for the years 1996 and 1997 and long-term mean monthly corrections after Legates 1987

(Ungersböck et al. 2001)



Mean daily precipitation phases in Europe (31°-72°N, 11°W - 44°E) from January until August 2001 based on GPCC's phase scheme.



Mean precipitation corrections in Europe (31°-72°N, 11°W - 44°E) January until December 2001 compared to Legates' mean monthly climatologic corrections

Climate Data Homogenization Recommendations / Part 1

Homogenization

- Climate data need to be assessed for homogeneity before being used for climate change studies.
- Network-wide problems should be addressed first.
- Adjustments should be made with caution to avoid “over-adjusting” the data.
- Detailed documentation of the homogenization procedures and adjustments should be available to all users.

Metadata

- Existence and access to metadata by the research community is absolutely essential for proper climate data homogenization.
- Digitized metadata should be updated on regular basis.
- There is a need to provide standards, collect and archive metadata from other climate observing agencies

IPWG/GPM/GRP Workshop on Global Microwave Modeling and Retrieval of Snowfall October 11-13, 2005

High priority recommendations:

Modelling

- **Encourage the generation of community CRM/NWP model profile databases that represent natural variability.**
- **Intensification of data assimilation studies for the inclusion of precipitation observations in NWP analysis systems**
- **Establishment of modeling chain**
- **Development of high-latitude surface emissivity products (10-200 GHz)**

New technology:

- **The development and further refinement of inexpensive ground-based remote sensing instruments for snowfall should be encouraged (e.g. POSS)**
- **The use of combined active and passive satellite data for snowfall detection/retrieval should be further encouraged.**
- **New passive microwave instruments and new channel combinations need to be studied.**

IPWG/GPM/GRP Workshop on Global Microwave Modeling and Retrieval of Snowfall

Validation:

- High level coordination of international GV programs for snowfall (e.g., through GPM, GEWEX, IPWG) is urgently needed to advance the current state of snowfall retrievals.
- Dedicated validation
- Long term surface based measurements must continue to insure long term continuity for climate assessment and monitoring.

WCRP Workshop Fairbanks
Issues, Gaps and Challenges

- **Adjustment of measured precipitation across national boundaries, collaboratively among nations**
- **Comparison of adjustment approaches for different applications**
- **Error analysis of adjusted products**
- **Adjustment of measured precipitation on a global scale. Validation? Role for GPCC.**
- **Determining precipitation for mountainous regions and ice sheets, e.g. Antarctica. Measured and modelled?**
- **Evaluate the validity of the bias correction procedures for the polar regions. WCRP (CliC) sponsored intercomparisons?**
- **Development of on-line metadata**

WCRP Workshop Fairbanks
Issues, Gaps and Challenges

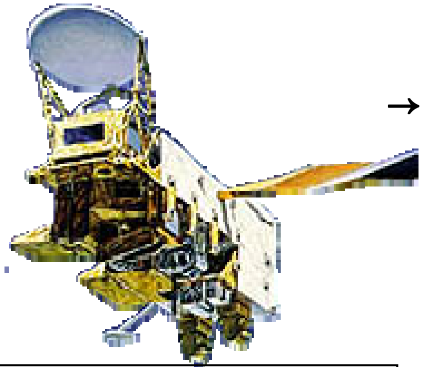
- **Determination of precipitation amount and type in data sparse regions in a changing climate**
- **Automation of precipitation measurements (instruments, errors, adjustment, archiving, GTS data, etc)**
- **Development of gridded, regional precipitation products (scale of RCM, hydrological model) for validation of climate model simulations and for initializing distributed hydrological model**
- **Development of integrated ("fused") precipitation products from in-situ, satellite, radar, models**
- **Human resource capacity, especially for measurement issues**
- **Ability of GPM to "measure" solid precipitation**
- **What can we do for determining precipitation in polar regions for the IPY (March 1 2007-March 1 2009)**
- **What do modellers need to validate precipitation in cold climate regions; can gauge data be confidently used in data assimilation?**

Decrease the UNCERTAINTY in Solid Precipitation:

(1)

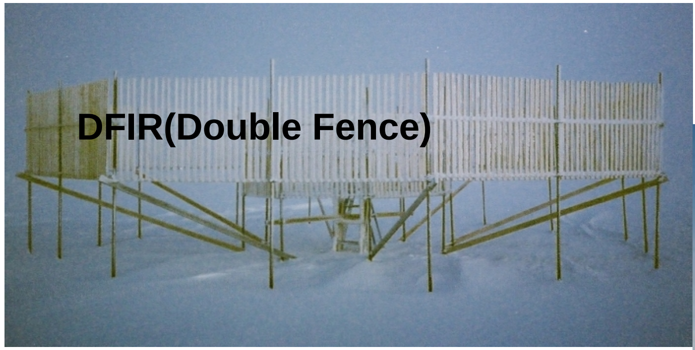
- Correction for past/present data and future monitoring.
- Integrated study from space and land.

Observation at Tiksi, Barrow and/or others

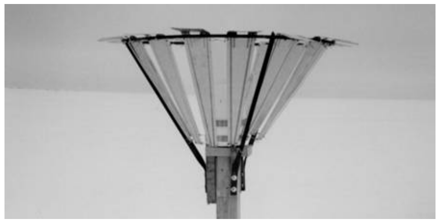


→ GPM

Precipitating snow



Trechakov(Russia, others)

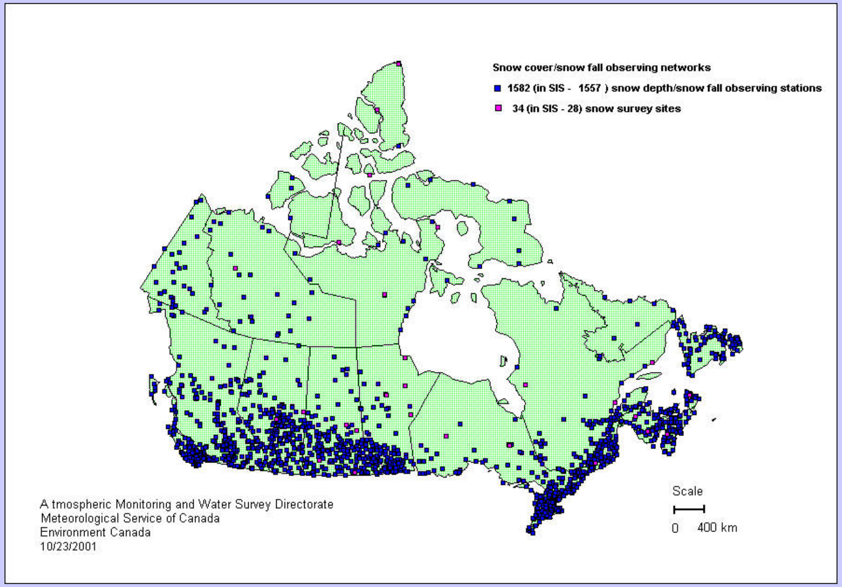


Snow Particle Counter

(1) Verification of remote sensing.

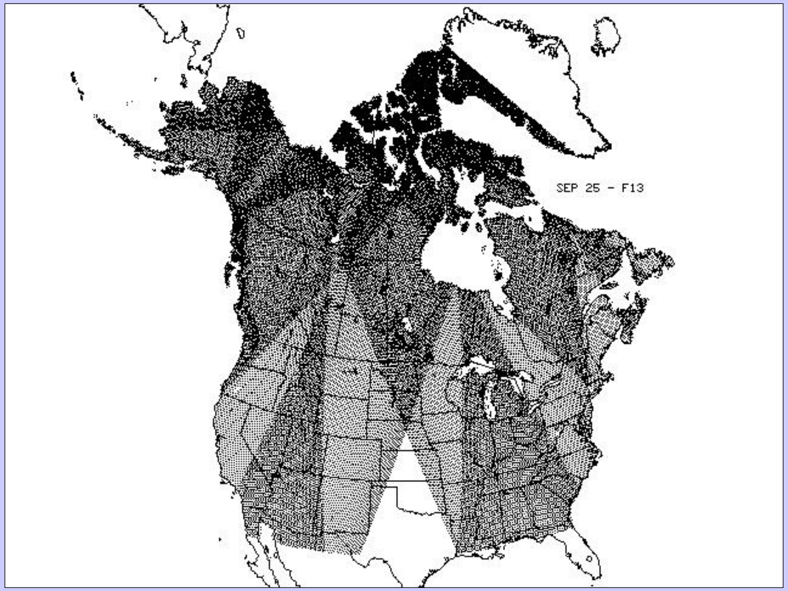
(2) New precipitaion data-set for high altitude.

Snow Cover Information -- *In-Situ* vs Satellite



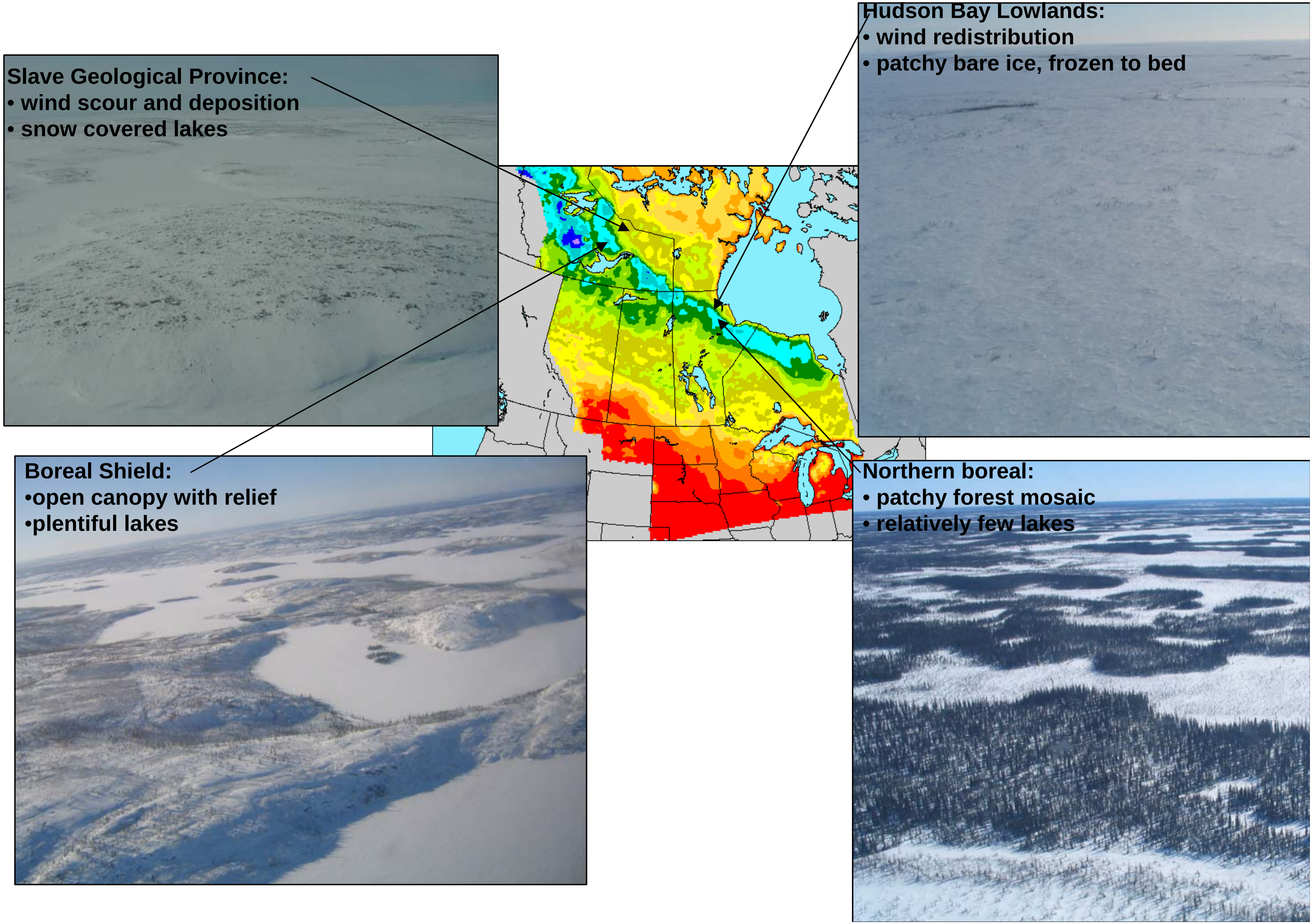
MSC Networks - Snow Cover

SSM / I Data Coverage – 1 day



What is Representative?

The challenge of measurement and modelling



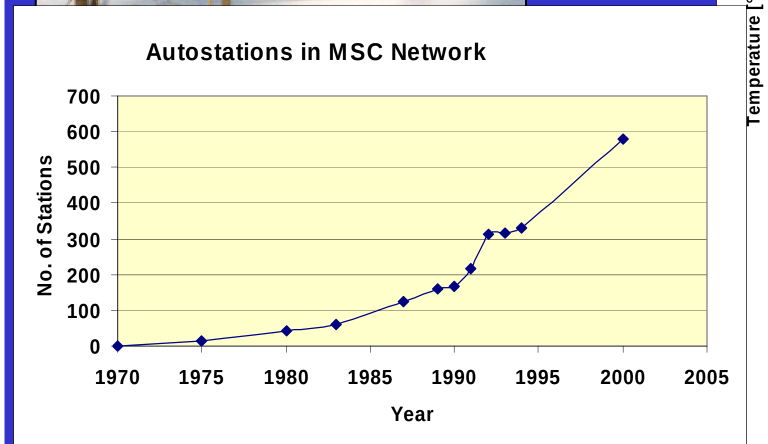
Snow Cover Characteristics:

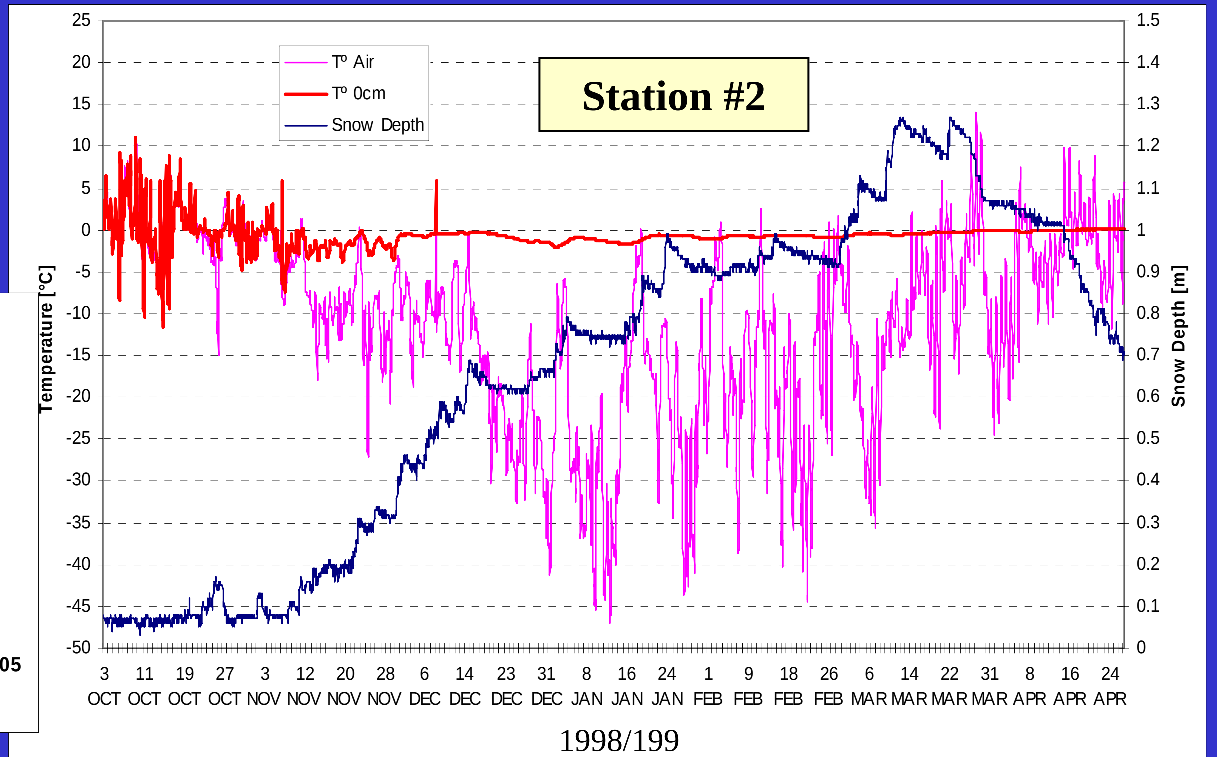
Snow cover structure is complex and highly variable in time and space
Variability depends on many factors:

- **The "parent" weather, their nature and frequency**
- **The weather conditions during the periods between storms—affects metamorphism, ablation and redeposition of snowpack**
- **Surface topography, physiography, and vegetative cover**

Automation

- Loss of observations
- Compatibility and continuity of record
- Collection of data in remote regions
- Change in standards





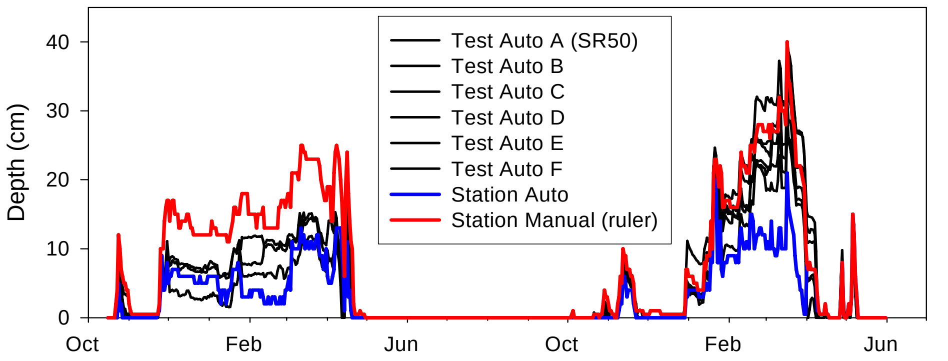
Edmonton Snow Depth Intercomparison

Snow Depth Spatial Variability and Fixed-Point Measurements

Edmonton International Airport
open landscape

✷see a high degree of spatial variability even over a short distance (3 to 300m)

✷of six temporary and a fixed station SR50, and manual ruler measurements, none are statistically similar to each other

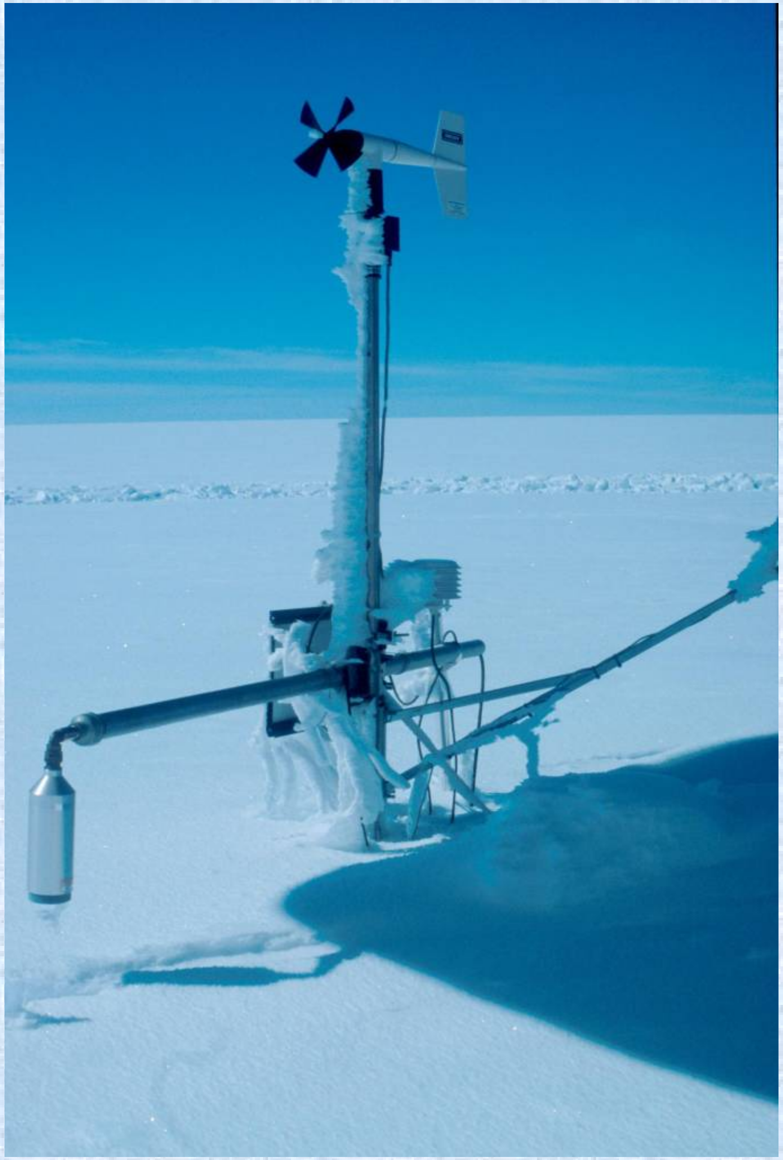


Challenges:

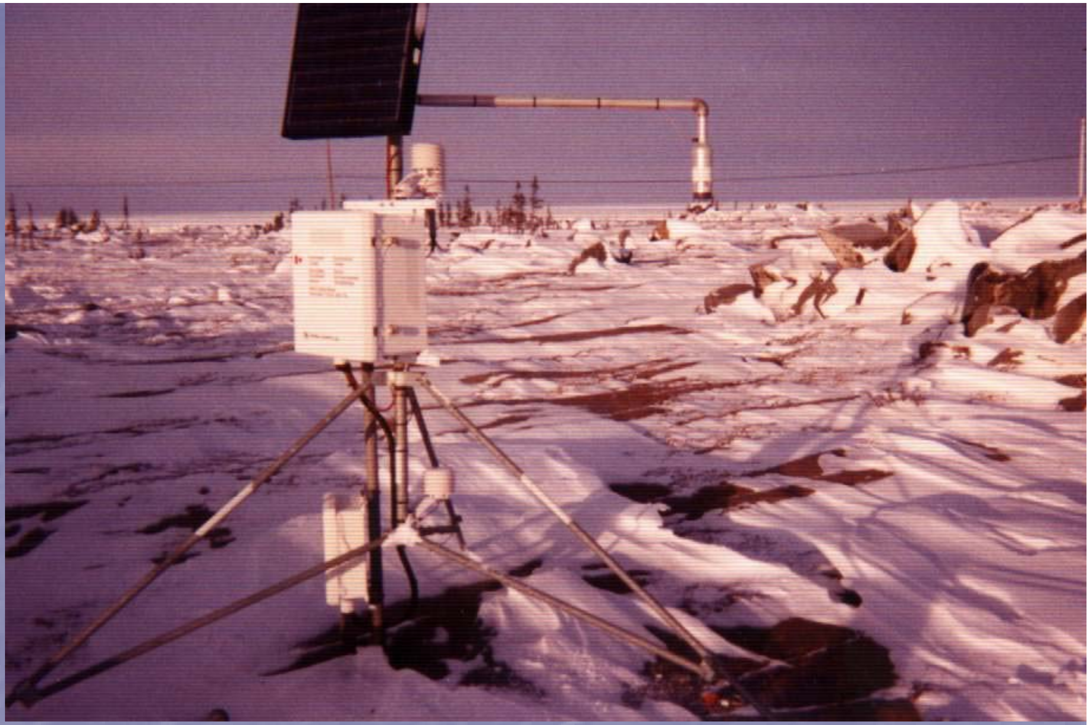
✷*to provide the best quality measurements to the research community*

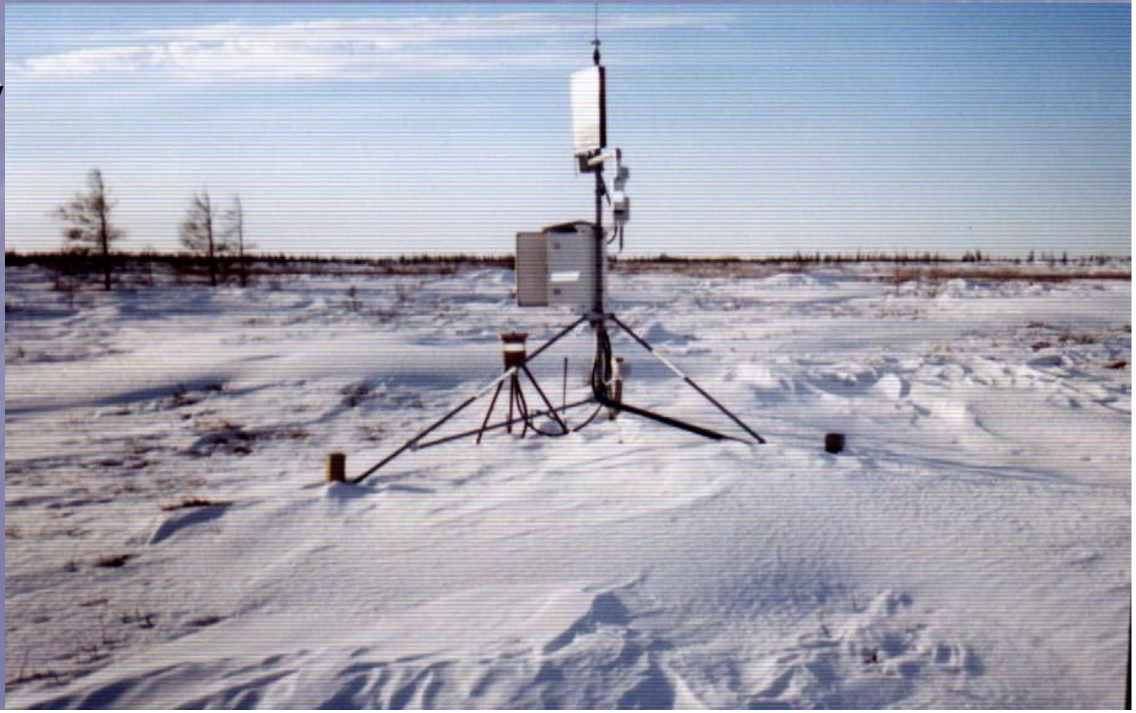
✷*for the research community to recognise these issues when using the data (e.g. comparisons with spaceborne data)*

Penny Ice Cap



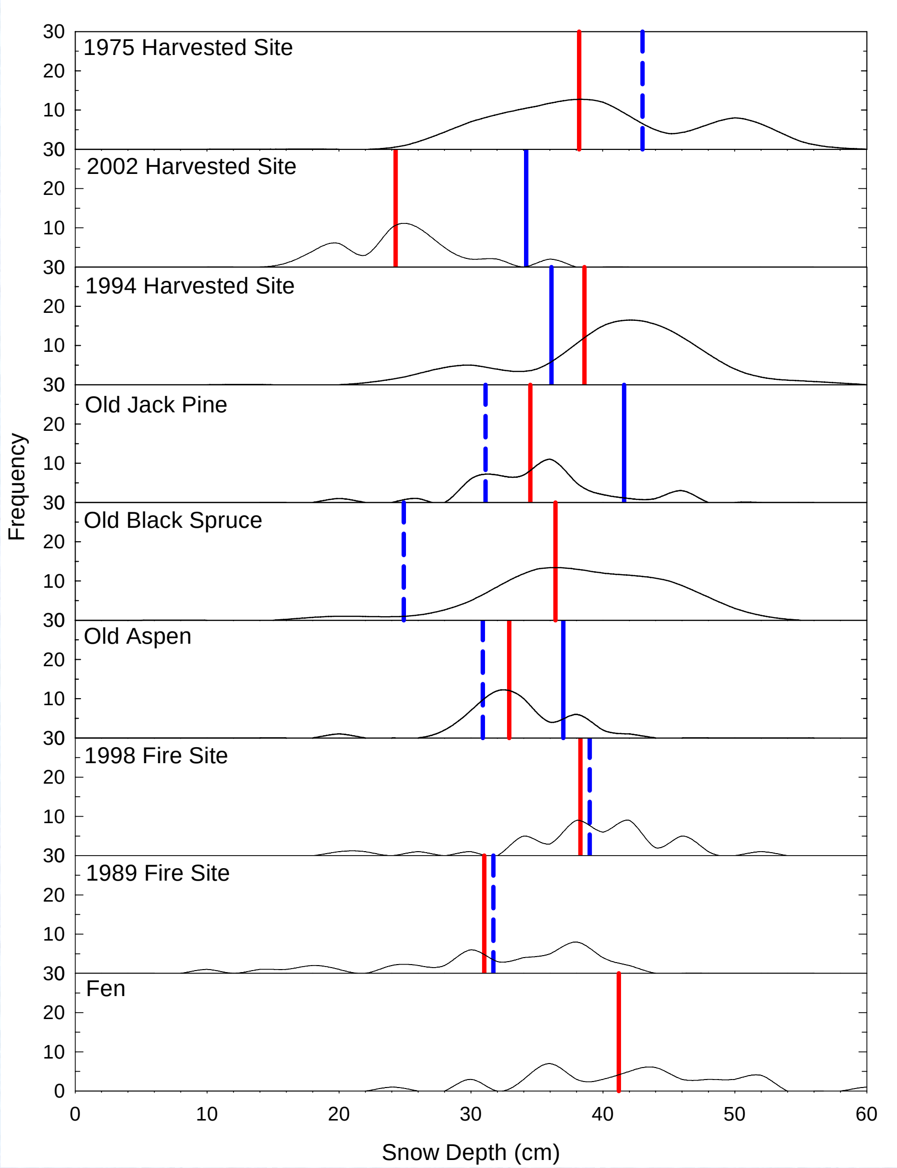
- Churchill RCT1 (top) Dec 2000 Huge rocks create deep drifts, dry patches
- RCT2 (bottom) Mar 2003 Open tundra with small obstacles creates 20-30 cm drifts
- Flagging of trees points away from Hudson's Bay





BERMS Snow Survey

Snow Depth Spatial Variability and Fixed-Point Measurements



Snow depth surveys from a variety of landscapes in the southern boreal forest of Saskatchewan, mid-March 2003.

Results are shown as frequency histograms, with depth along the x-axis.

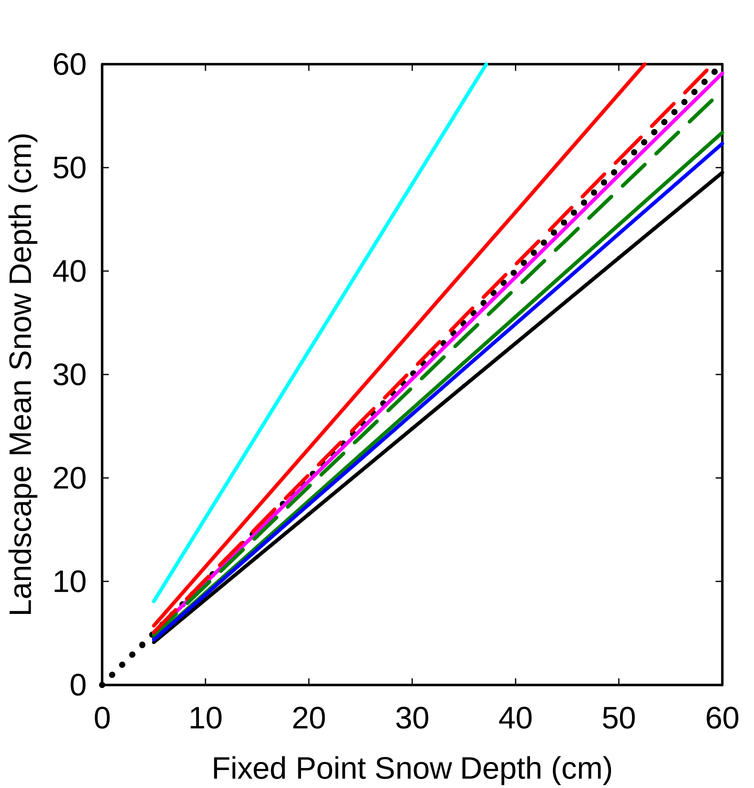
Automated, continuous, fixed-point depth measurements (e.g. SR50) are used to monitor changes in snow depth at a site, but are often restricted to installation near towers or other structures.

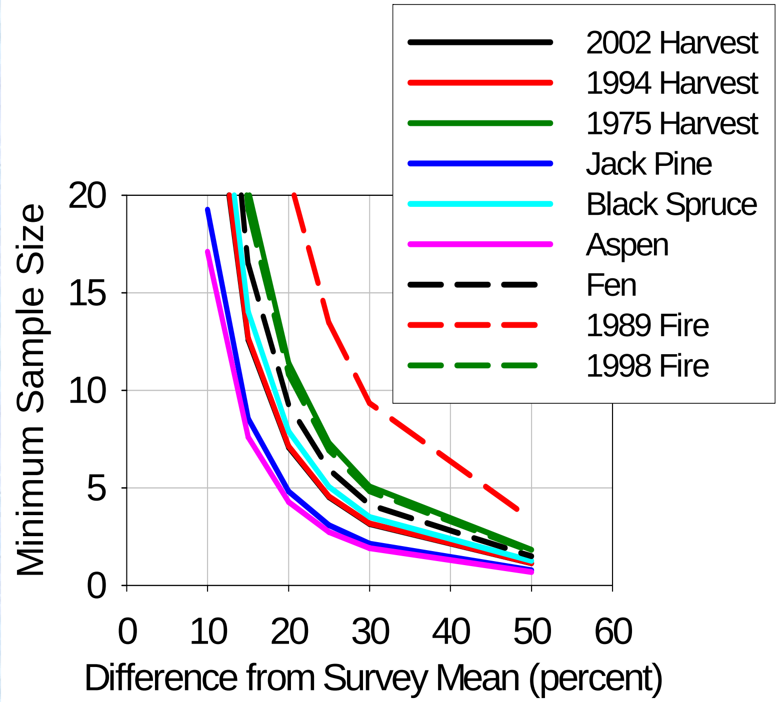
Snow depth is a spatially heterogeneous variable, so it is important to question how well fixed-point measurements represent the spatial variability.

Comparing the fixed-point depth measurements **(clearing = solid blue vertical lines, subcanopy = broken blue)) with the snow survey means (red)** indicates under- and over-representation of the landscape mean at various sites, and good representation at others.

How can this information be used to make the best use of fixed-point depth measurements?

Snow Depth Spatial Variability and Fixed-Point Measurements





Where there are sufficient snow surveys available, able to find a simple linear relationship between fixed-point and landscape mean depths, allowing for "correction" of the point measurements.

Where there are no snow surveys available or where such data collection is too labour- or time- intensive, how many fixed-point measurements would be needed to adequately represent the landscape mean?

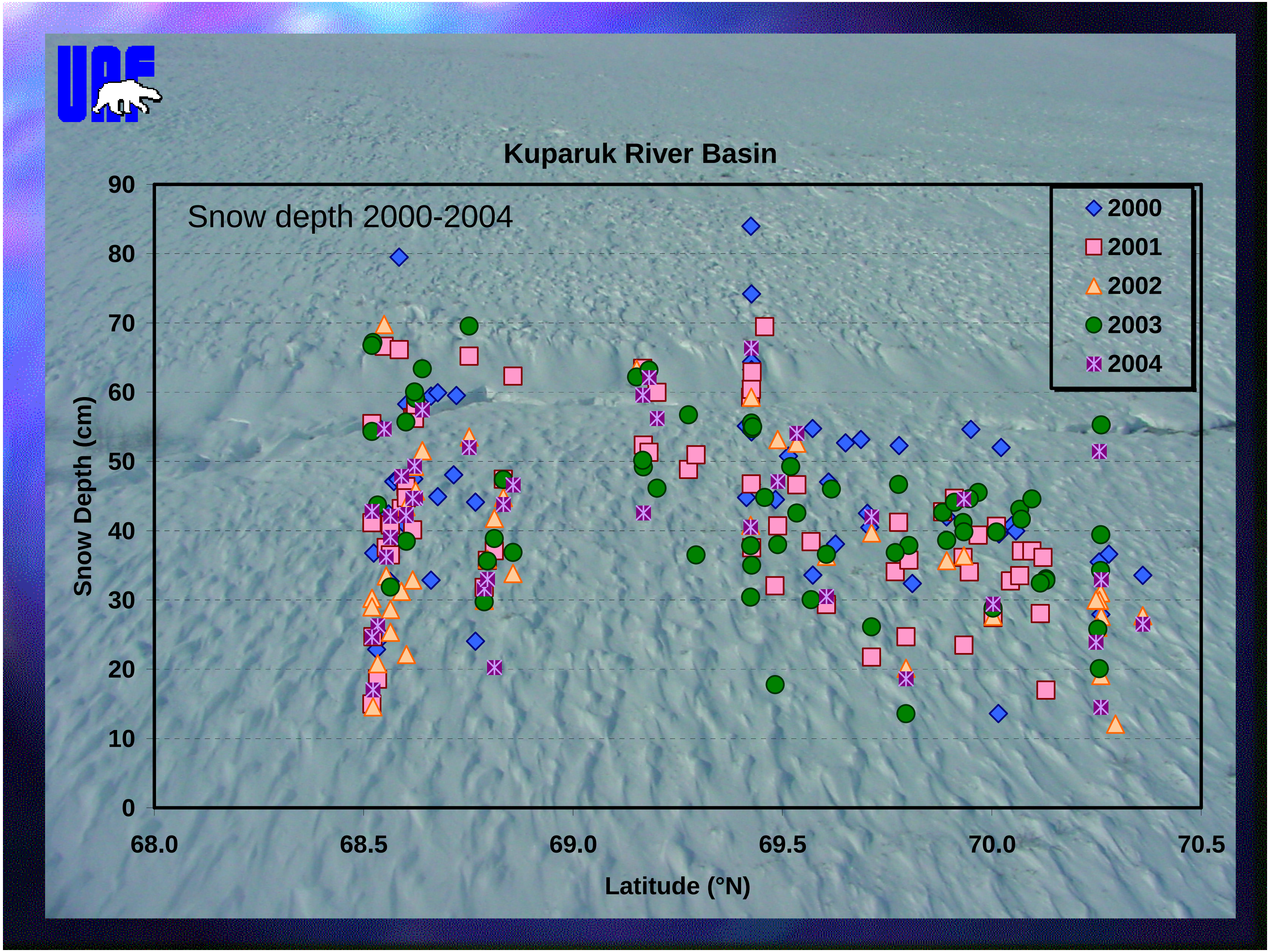
For the boreal forest sites, find that five point measurements (when appropriately installed) will represent the landscape mean within 30%.

Scaling of the crysophere – a problem in cold climate regions

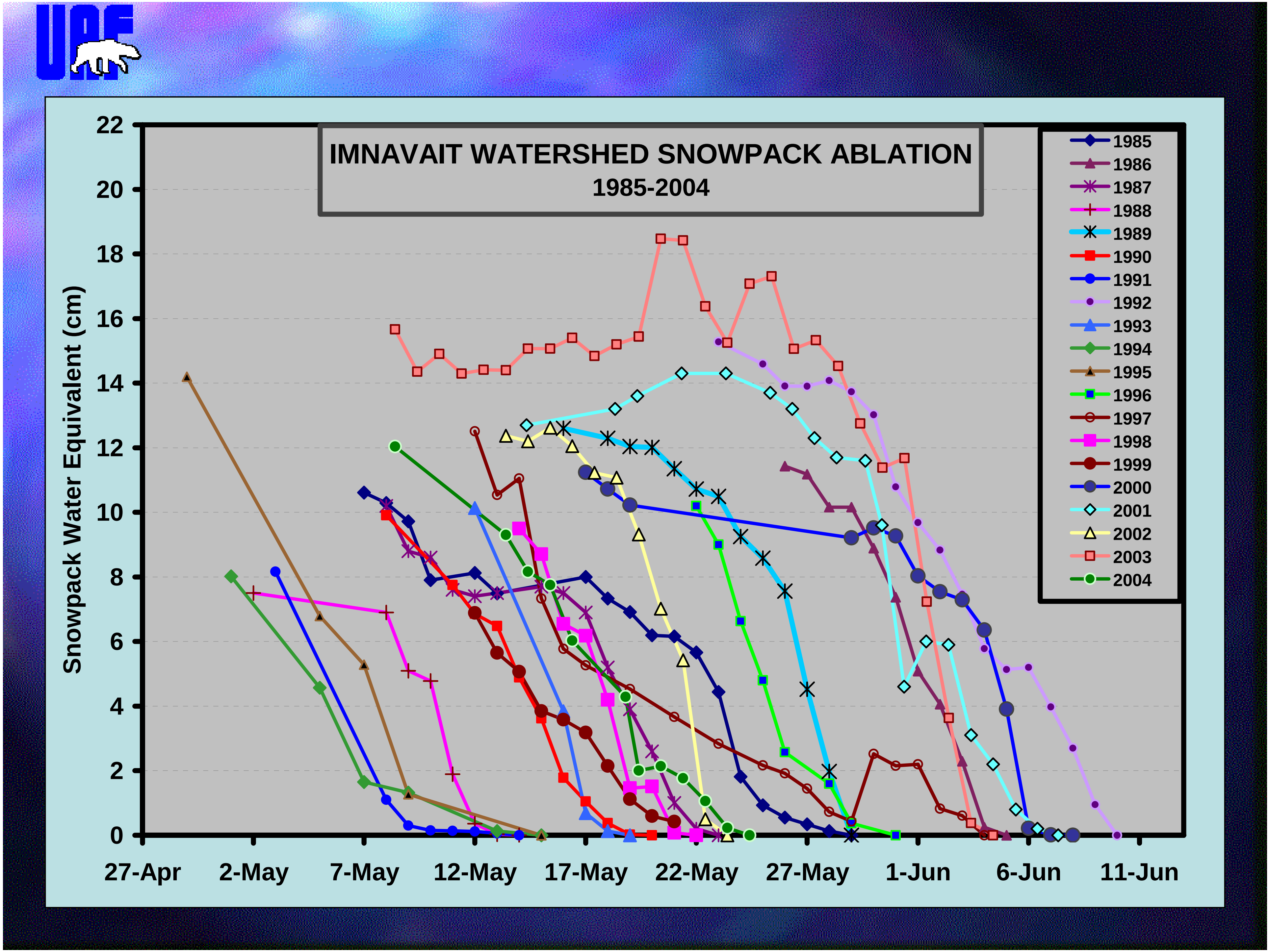
Arctic snowpacks are very heterogeneous due to both micro topography (elevation, aspect and slope) and redistribution by wind coupled with larger topographic features and vegetation. The challenge is to quantify the snowpack distribution over a large watershed , a region, or a grid.

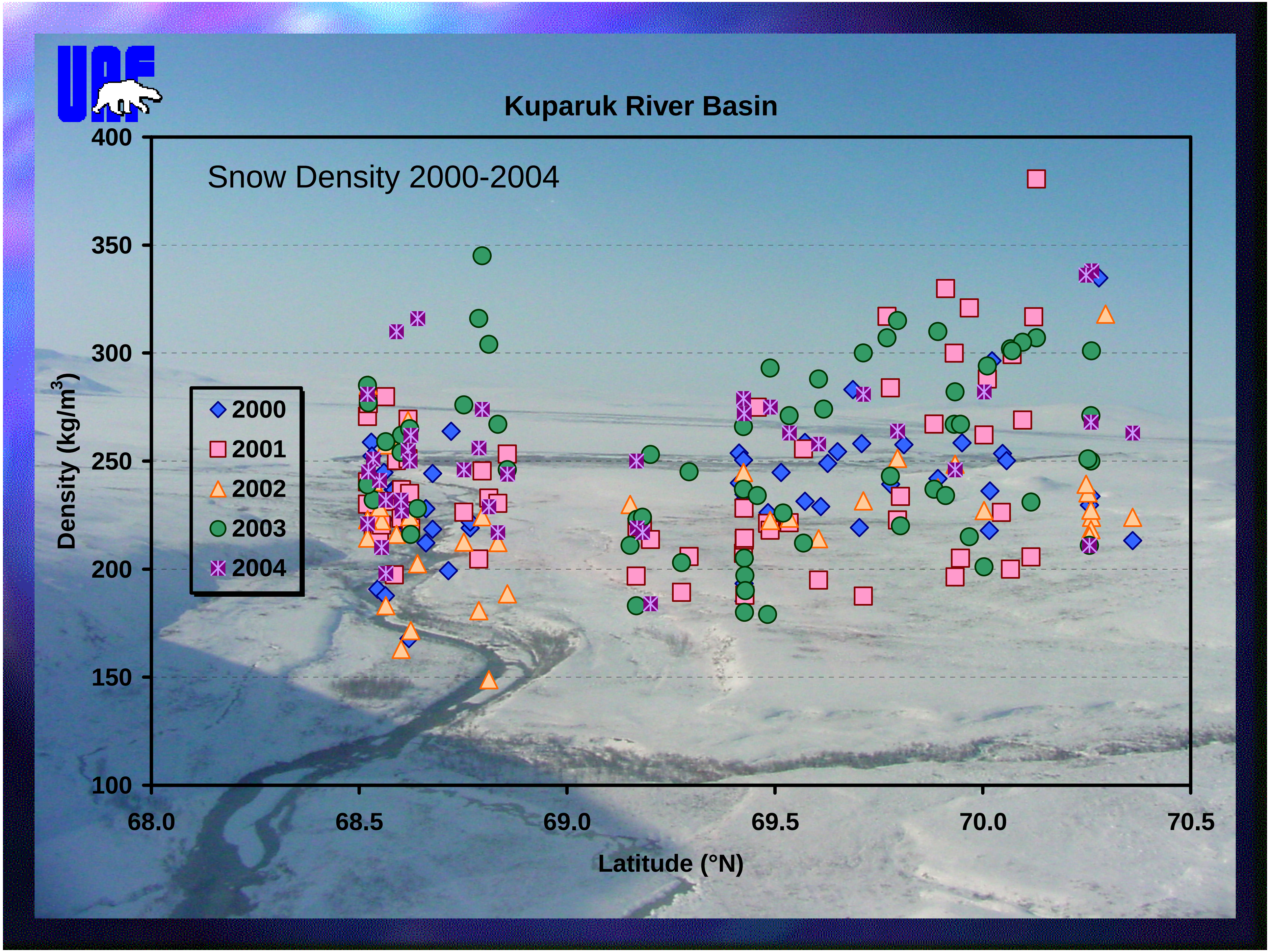
The development and ablation of a snow cover in the Arctic are interesting and important hydrologic processes that are difficult to quantify at the watershed scale. Both __energy and mass fluxes__ play a role in these processes, but are also impacted by these processes.

How do we get high quality, spatially distributed snowpack data for use in water balance closure and input into hydrologic models at the watershed scale (2 to 10,000 km^2 or larger)?

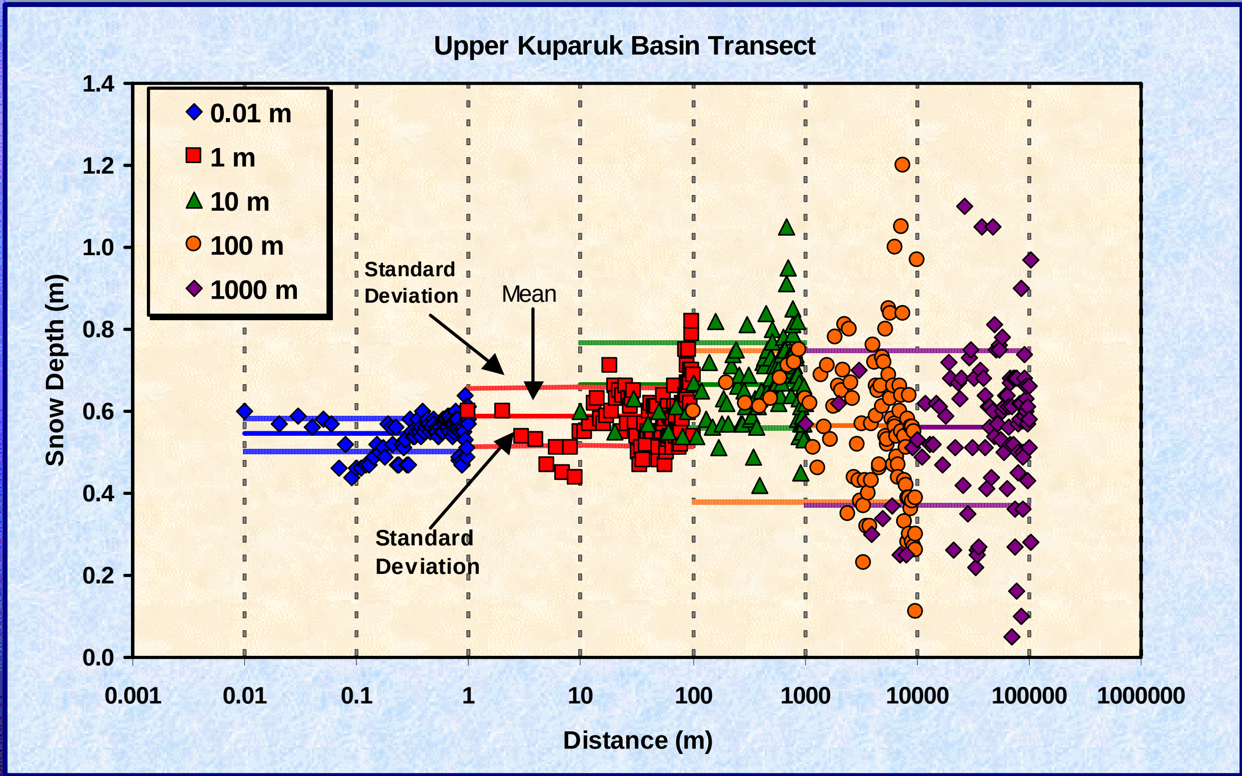


Kuparuk River Basin
Snow depth 2000-2004
2000
2001
2002
2003
2004
Snow Depth (cm)
0
10
20
30
40
50
60
70
80
90
68.0
68.5
69.0
69.5
70.0
70.5
Latitude (°N)

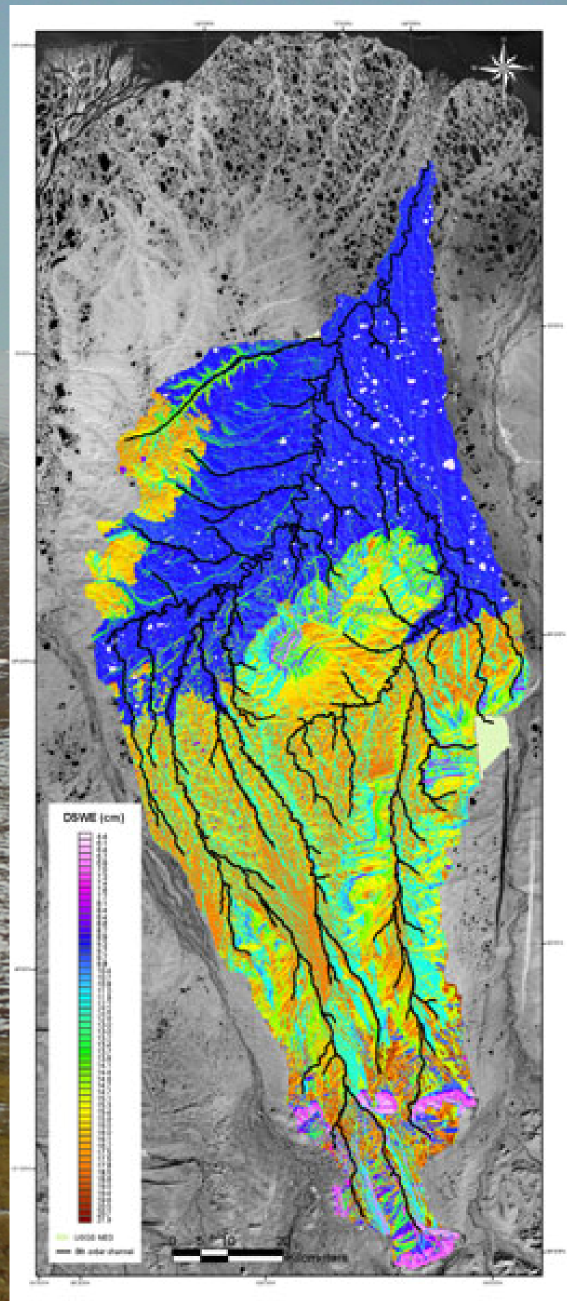

IMNAVAIT WATERSHED SNOWPACK ABLATION
1985-2004
Snowpack Water Equivalent (cm)
0
2
4
6
8
10
12
14
16
18
20
22
27-Apr
2-May
7-May
12-May
17-May
22-May
27-May
1-Jun
6-Jun
11-Jun
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004



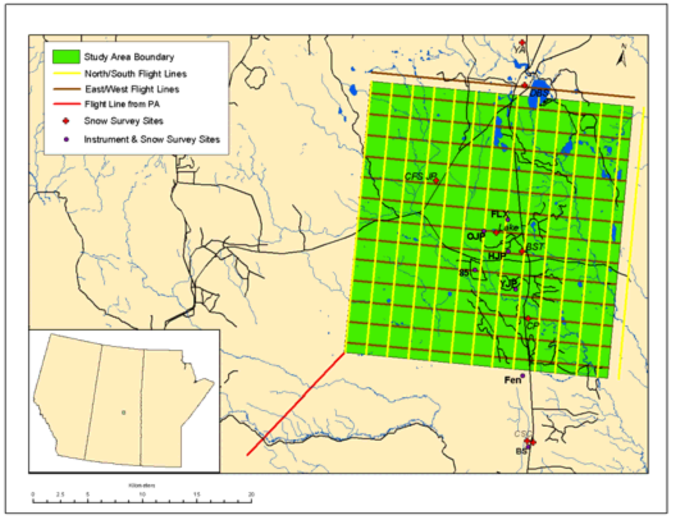
Kuparuk River Basin
Snow Density 2000-2004
Density (kg/m3)
Latitude (°N)
400
350
300
250
200
150
100
68.0
68.5
69.0
69.5
70.0
70.5
2000
2001
2002
2003
2004

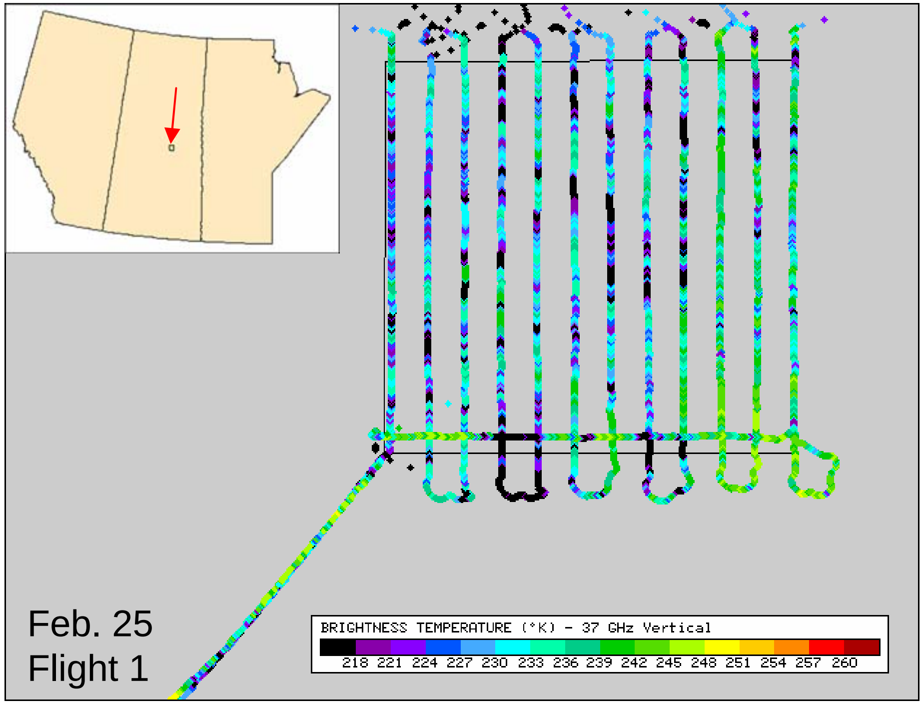


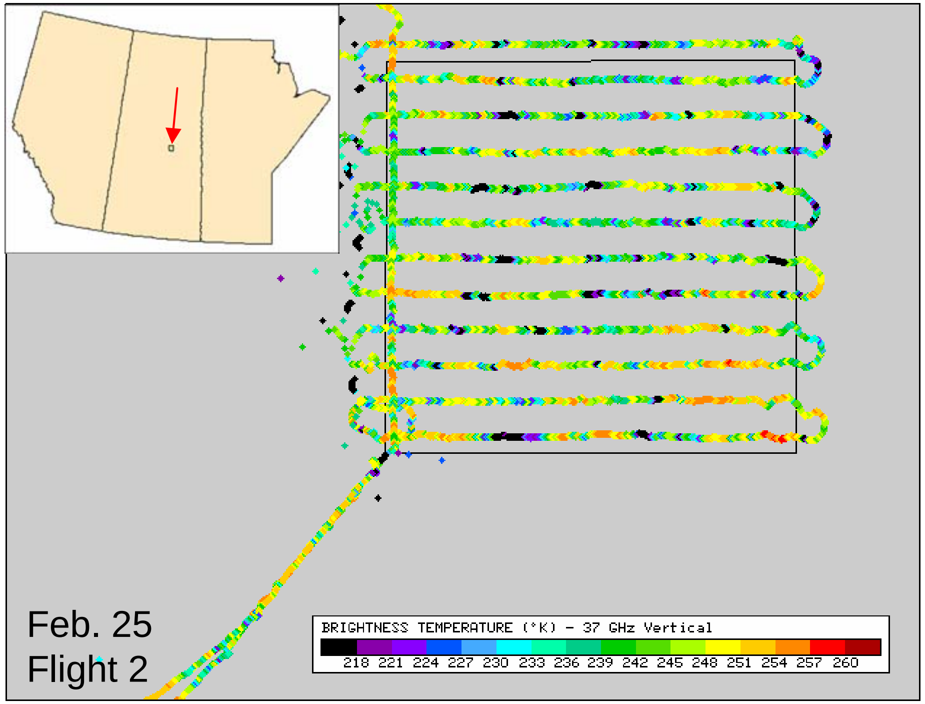
Upper Kuparuk Basin Transect
0.01 m
1 m
10 m
100 m
1000 m
Standard Deviation
Mean
Standard Deviation
Snow Depth (m)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.001
0.01
0.1
1
10
100
1000
10000
100000
1000000
Distance (m)



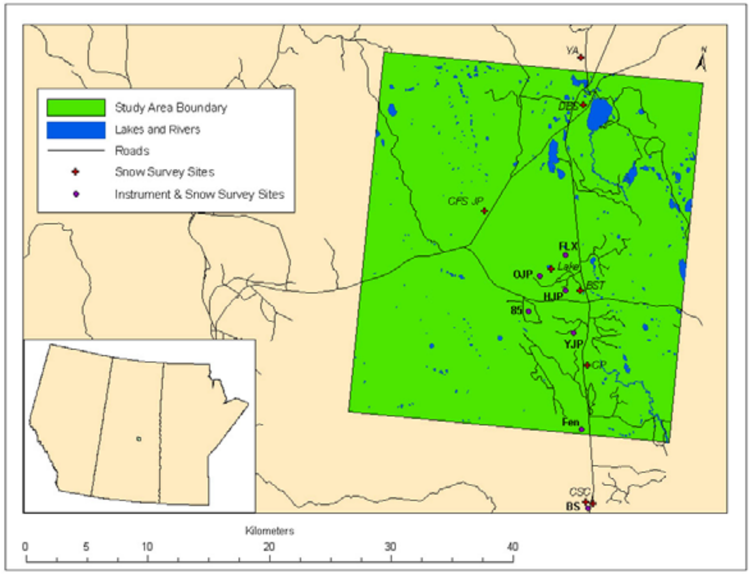
Airborne Passive Microwave Data

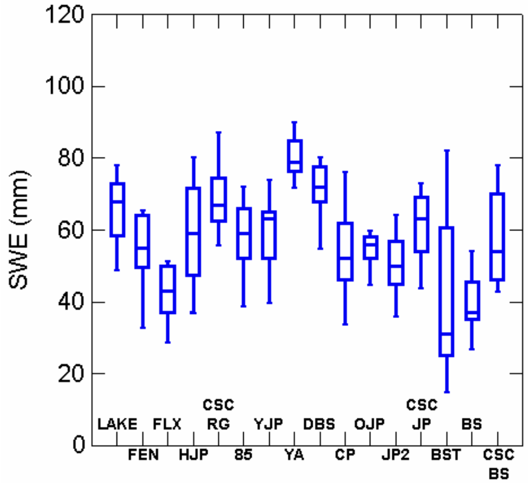


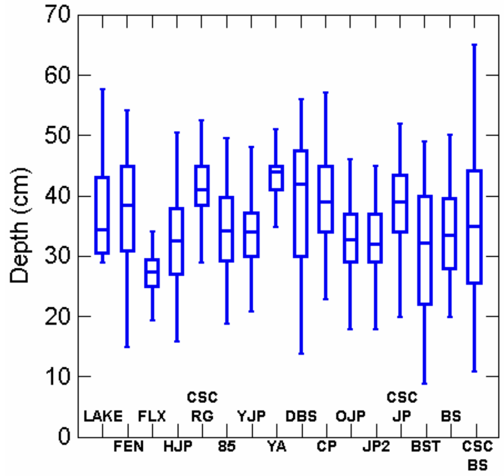




Boreal Forest SWE Scaling





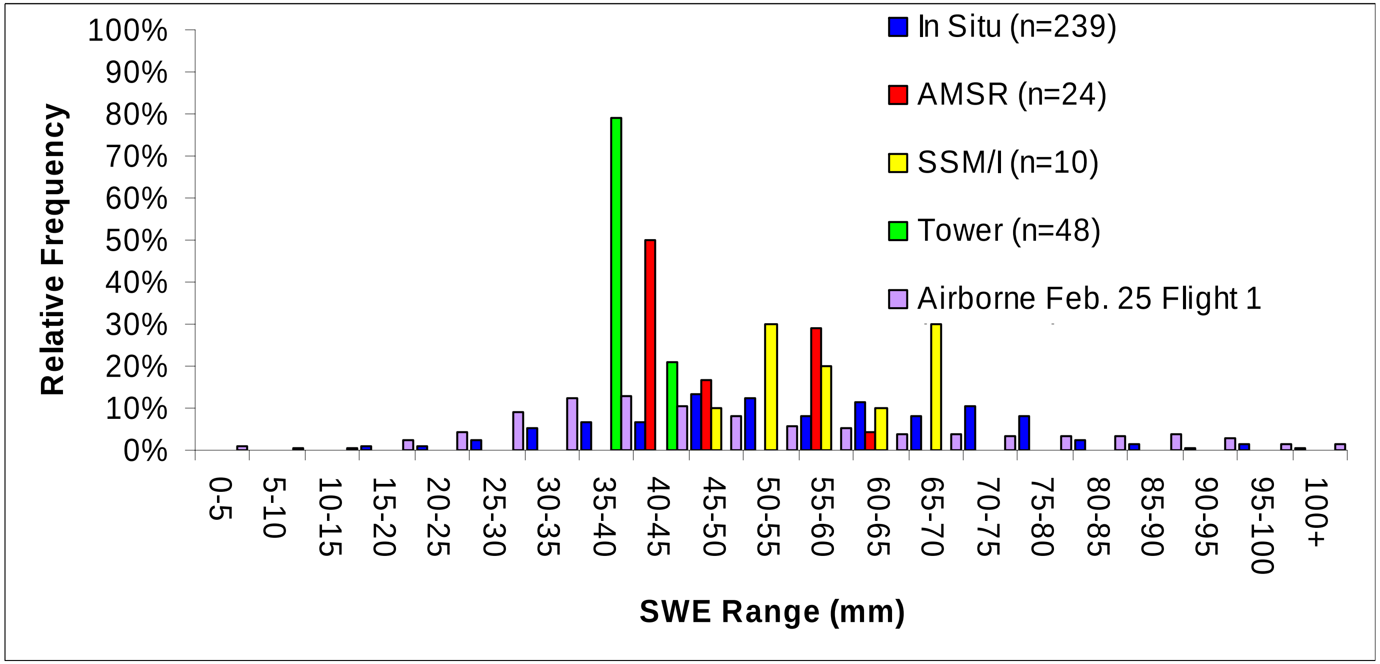


➢ High level of within and between site SWE variability

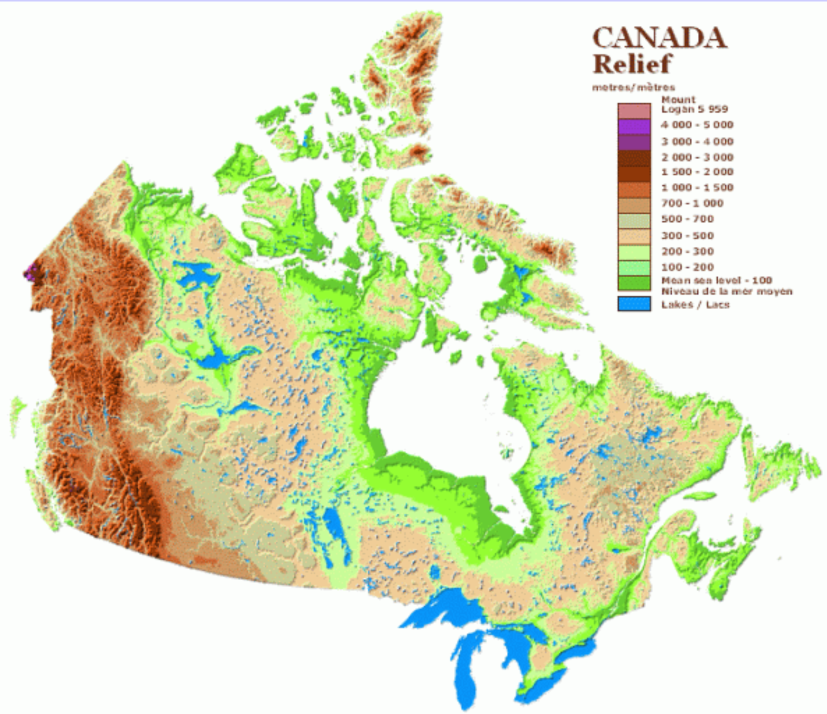
➢AMSR and SSM/I derived SWE retrievals (MSC coniferous algorithm) fall into center of normally distributed *in situ* measurements.

➢ AMSR SWE retrievals tend to be ~ 10 mm lower than SSM/I.

➢ Airborne passive microwave SWE retrievals capture the full range of *in situ* measurements.



Canada - Challenges for SWE Determination



- large country with diverse climates and landscapes (e.g. topography, vegetation cover)
- lack of conventional measurements for validation in remote areas (e.g. north)
- spatial variability in snow cover characteristics
- no single passive microwave SWE algorithm will be applicable for all areas
  - ➲ regional approach to algorithm development

Assessment of Spring Snow Cover Variability over Northern Canada from Satellite Datasets

Dataset	Period	Resolution	Description
In situ	1979-2004		Daily snow depth measurements at a point
NOAA snow charts	1979-2004	190.5 km	Digitized weekly charts of snow cover derived from visual interpretation of visible satellite imagery
NOAA IMS charts	2000-2004	25 km	Incorporates additional data sources but is still largely based on manual interpretation of visible imagery
Passive Microwave	1979-2004	25 km	SWE retrieved using EC open environments algorithm (37V-19V) SWE converted to SCD* using 1 mm threshold
QuikSCAT	2000-2004	8-10 km	Ku-band measurements Information on spring SCD* inferred from the melt onset signal (small amount of liquid water content in snow causes a decrease of more than 5 dB in backscatter)

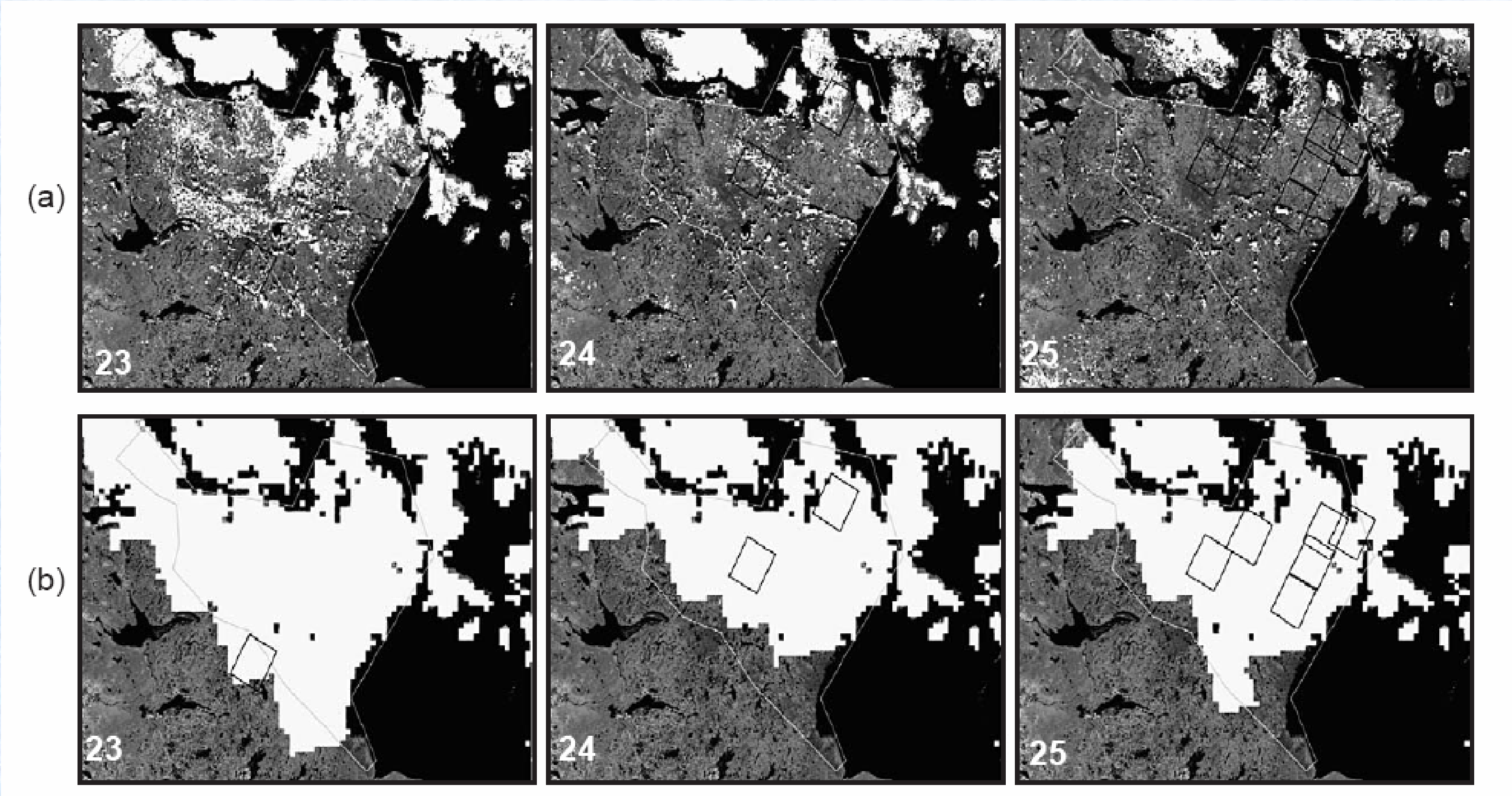
SCD=Spring Snow Cover Duration: number of days with snow cover from 1 April – 31 July

Motivation – Wang et al. (2005) [*Rem. Sens. Env*., **95**, 453–463]

"NOAA weekly dataset consistently overestimated snow cover extent during the spring melt period, with delays of up to 4 weeks in melt onset"

AVHRR

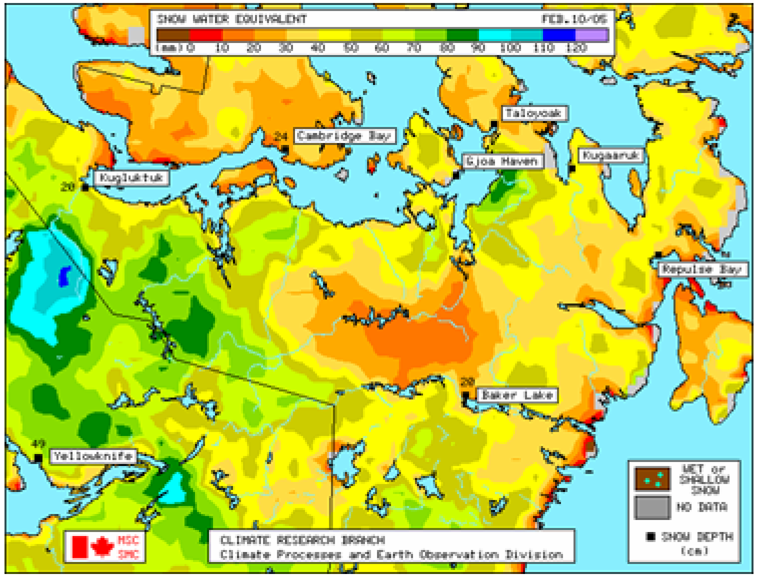
NOAA



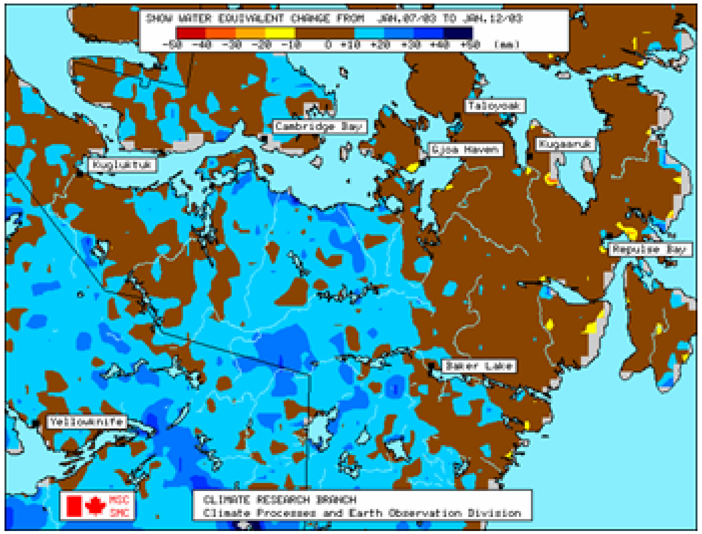
Comparison of weekly snow cover maps derived from AVHRR and NOAA for weeks 23–25 in the spring of 1997

Current Passive Microwave Capabilities in Tundra Areas

SWE

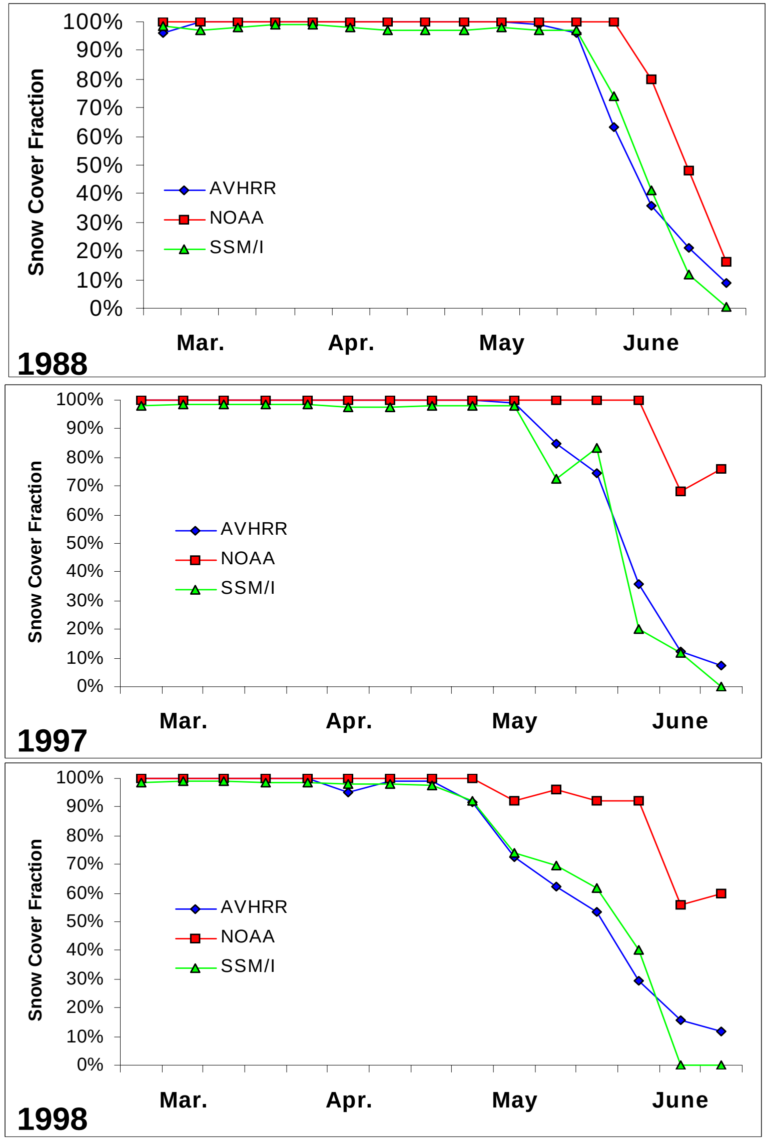


➢ Systematic underestimation in SWE magnitude



➢ Greater utility in identifying event related ΔSWE

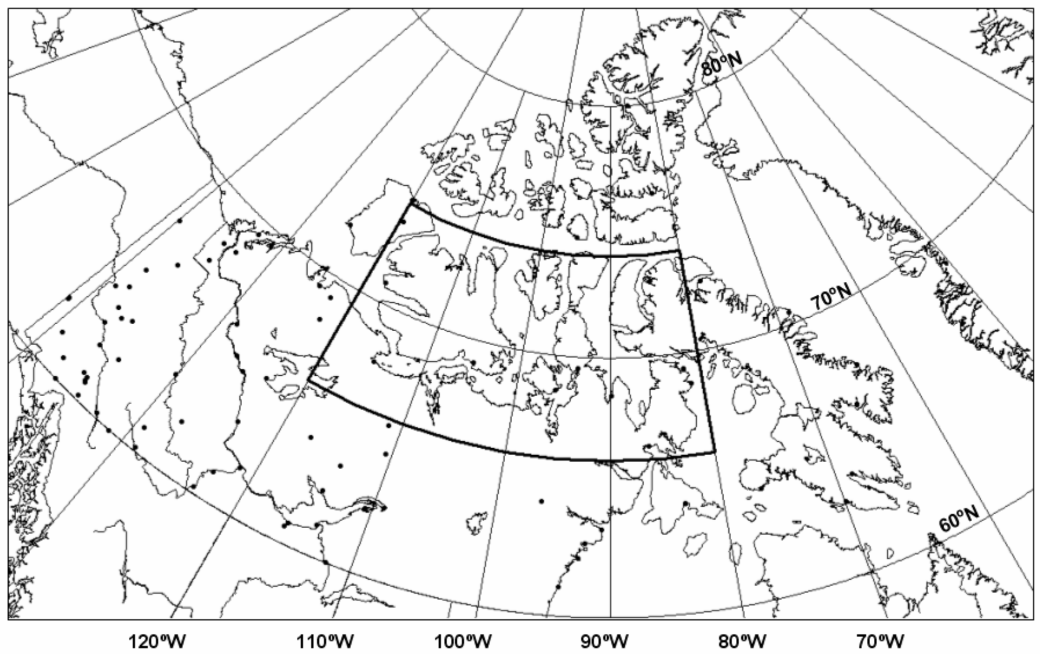
Snow Extent/Melt Timing



➢ Snow extent during melt agrees well with optical data

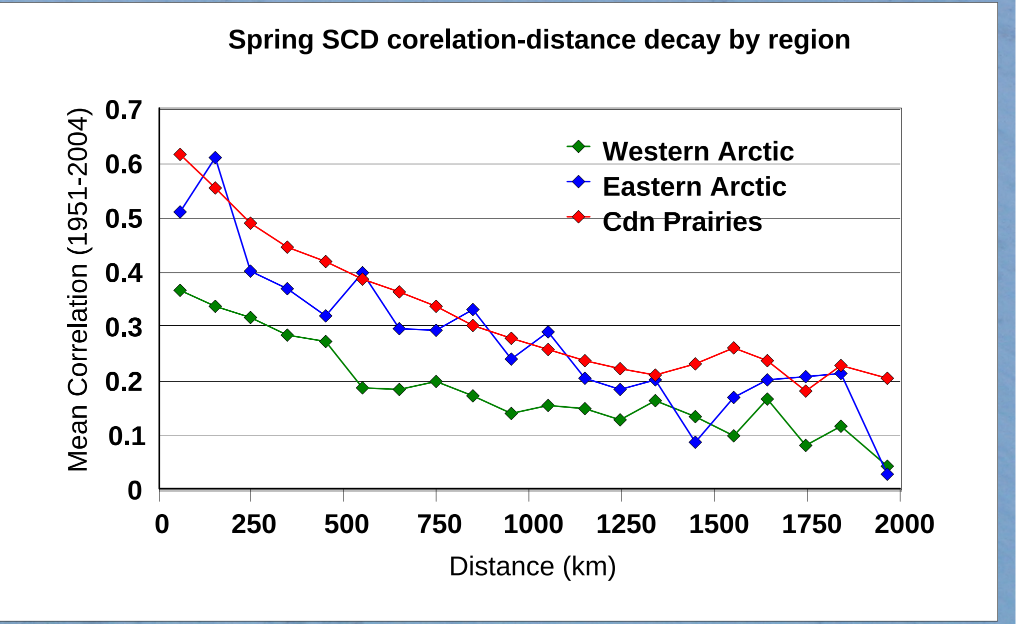
Wang et al., *Remote Sens. Environ*. In press.

In situ Network

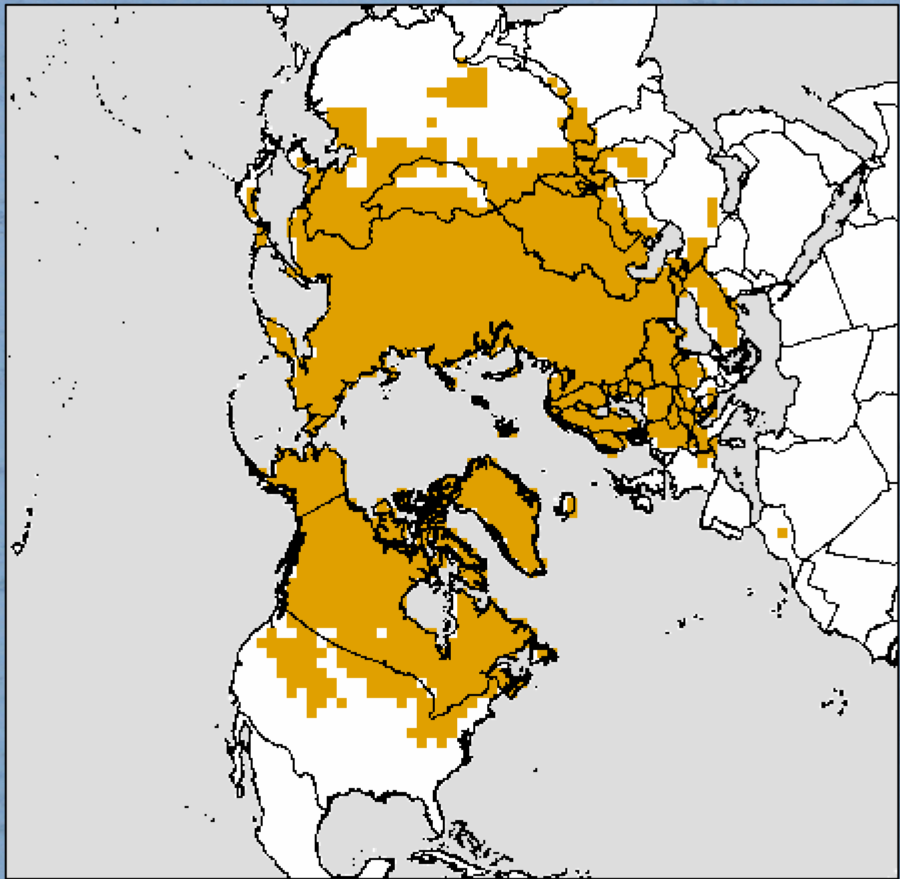


Location of surface stations with at least 3 years of complete spring snow cover data, 2000-2004. Central Canadian Arctic study area is outlined in bold.

- **Current observing network is sparse, and biased to the western Arctic and coastal locations**
- **2 cm threshold selected for SCD determination: avoids discontinuity in 1975 when Canadian reporting switched from whole inches to whole centimetres**
- **Significant inter-station correlations in spring SCD over distances of several hundred kilometres**.

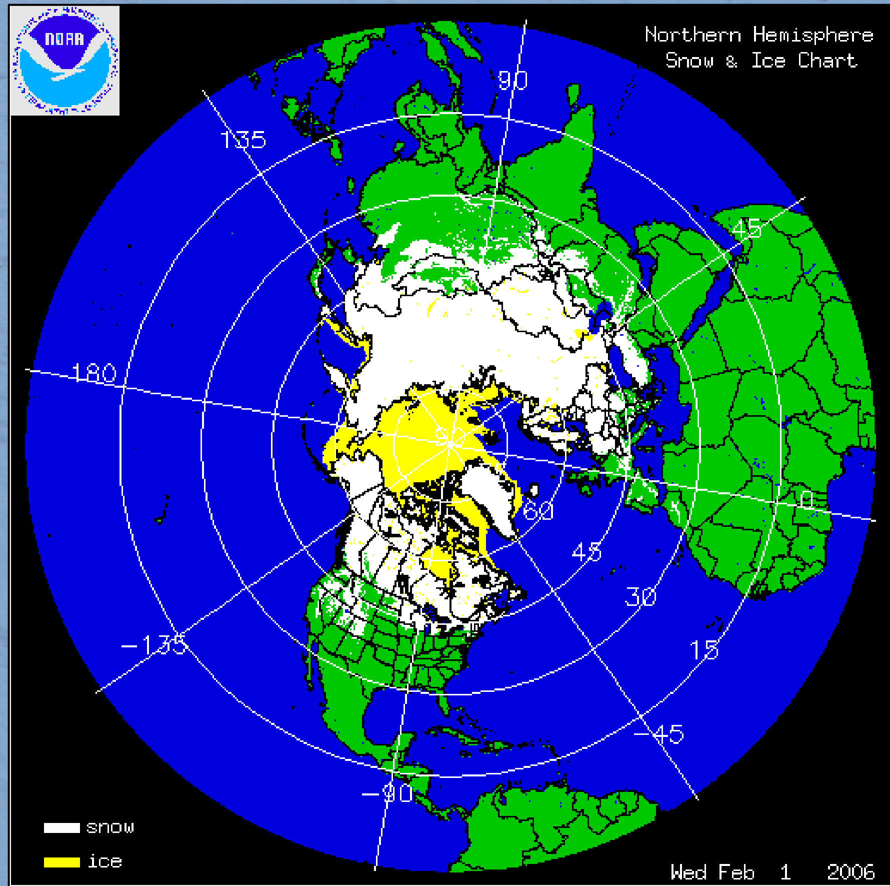


NOAA Visible Satellite Products



Snow Chart: Jan. 29-Feb. 4 2006
(Rutgers University Global Snow Laboratory)

- presence/absence of snow based on 50% coverage threshold
- weekly, 190.5 km resolution
- available 1967 - present



IMS Product: Feb. 1 2006
(NOAA/NESDIS)

- presence/absence of snow based on 50% threshold
- daily, 25 km resolution
- available 2000 - present

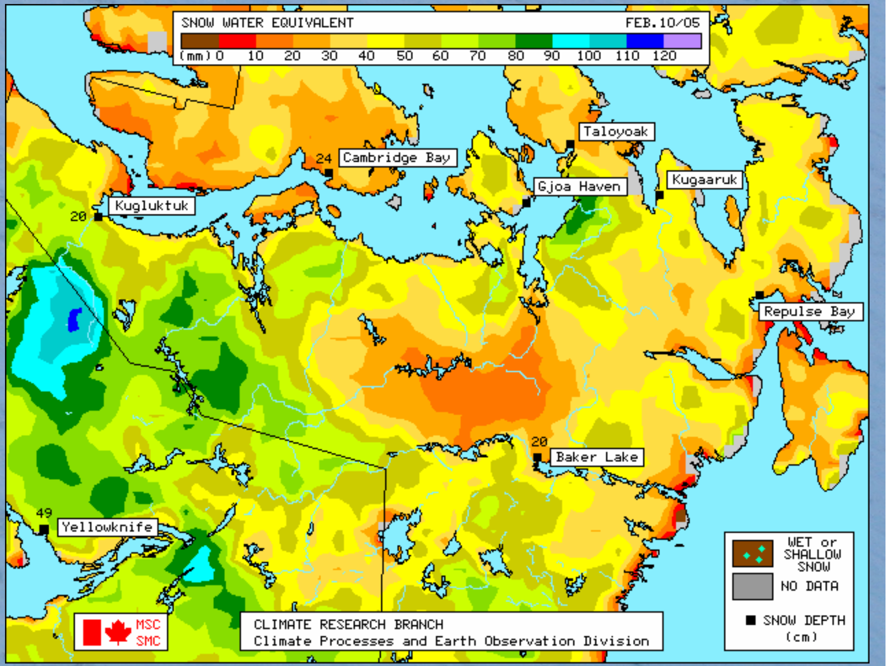
Passive Microwave Time Series

- Weekly averaged EASE-Grid brightness temperatures processed with the Environment Canada open environments SWE algorithm (Goodison and Walker, 1995) (based on brightness temperature difference between 37 and 19 GHz)

- Scanning Multichannel Microwave Radiometer (SMMR; 1978-1987) and Special Sensor Microwave/Imager (SSM/I; 1987-2004) data combined using the brightness temperature standardization coefficients of Derksen and Walker (2004)

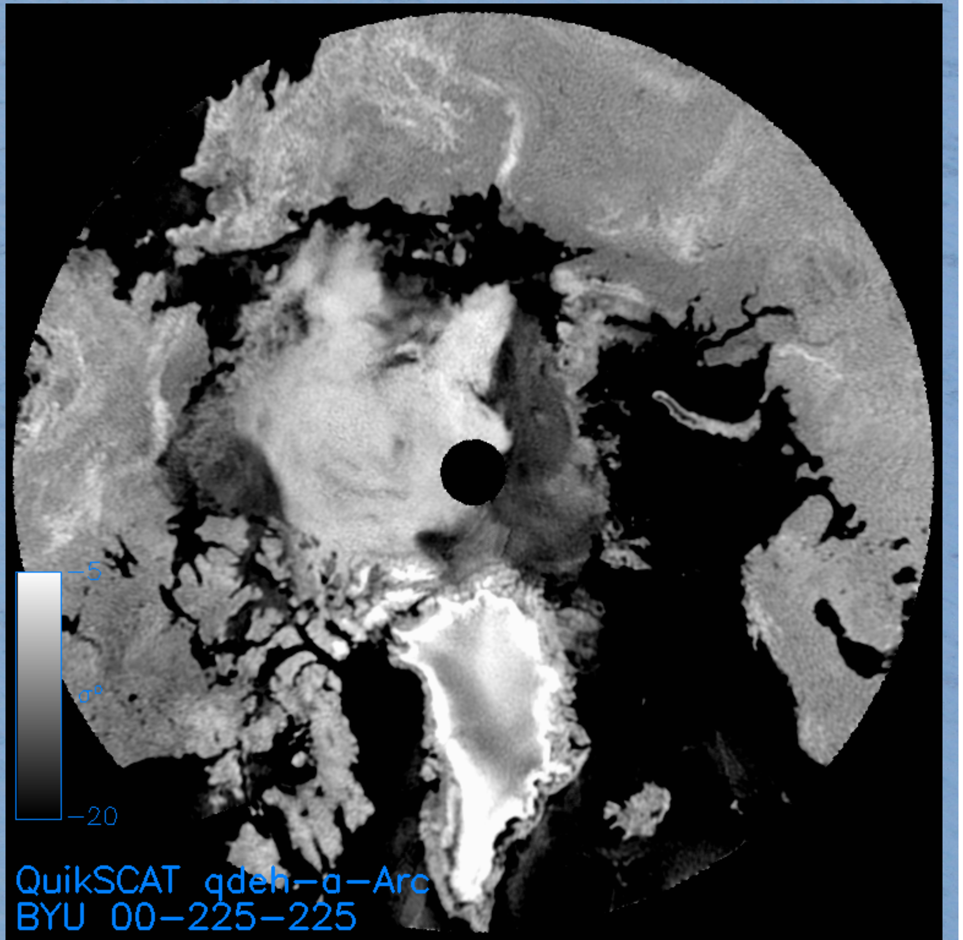
- SWE algorithm not considered reliable over mountainous and dense forest; over open tundra SWE retrieval is affected by highly variable snow distribution, wind slab, and lake ice; wet snow also an issue

- Comparisons against AVHRR data and model simulations showed good agreement over tundra when SWE retrievals were converted to SCA; gave superior performance to the adaptive brightness temperature threshold approach of Mialon et al., 2005 (EARSeL Proceedings, 215-225)



SeaWinds Scatterometer on QuikSCAT

- Operates at Ku-band frequency (13.4GHz)
- Constant incidence angles: 46º for H-pol, 54 º for V-pol
- Original Resolution: ~7 x 25 km
- Available from July 1999 – present.
- Due to wide swath and orbit geometry, QSCAT observes the polar regions multiple times each day, allowing reconstruction of surface backscatter at finer spatial resolution
- Dynamic threshold method developed by Wang et al. (2005) for high Arctic ice caps was modified for terrestrial snowmelt signal
- Spring SCD estimated from snowmelt onset by applying an empirically-derived constant which represents the time from melt onset to disappearance



BYU Egg-based SIR product on 4.45km * 4.45 km grid

Wang, L., M. Sharp, B. Rivard, S. Marshall, and D. Burgess. 2005. Melt season duration on Canadian Arctic ice caps, 2000-2004. *Geophysical Research Letters*, **32**, doi:10.1029/2005GL023962.

Comparison of in situ and satellite SCD pairs

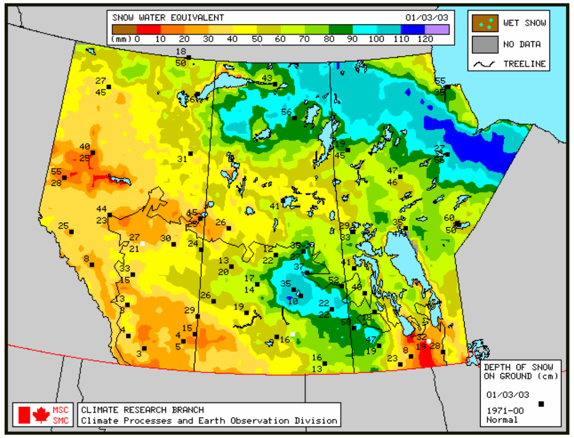
Satellite	Period	No. Pairs	Avg Separation (km)	Bias (SAT-STN)	Slope	rmse	r^2
NOAA	2000-2004	125	63.8	24	0.63	31.0	0.39
PMW	2000-2004	354	10.1	13	0.51	21.1	0.49
IMS	2000-2004	347	10.3	26	0.70	32.4	0.45
QSCAT	2000-2004	326	1.6	-7	0.56	19.5	0.42
NOAA	1979-2004	683	63.8	22	0.91	27.4	0.60
PMW	1979-2004	1985	10.1	8	0.46	22.4	0.37

- For the 2000-2004 period, all datasets have similar r^2 values
- NOAA and IMS have similar positive bias but highest slope values (i.e. best representation of the spatial gradient in spring SCD over northern Canada)
- 3-4 week positive bias in IMS and NOAA likely related to cloud cover effects
- Microwave results influenced by forest cover and mountainous terrain

Summary

- A comprehensive inter-comparison of melt season SCD datasets derived from satellite data was conducted for high latitude NA for the spring seasons of 1979 – 2004
- NOAA, IMS and QSCAT data were successful at capturing the ***spatial variability*** in **<u>mean</u>** spring SCD over the Canadian Arctic (passive m/w affected by forest and mountains)
- However, the passive m/w was better than the NOAA dataset at capturing the ***interannual variability*** in spring SCD over the central Canadian Arctic
- The NOAA dataset also exhibited weaker correlations with NCEP air temperatures than passive m/w
- The results suggest that considerable care be exercised when using the NOAA dataset in summer months when snow cover variability is controlled by smaller high latitude regions such as the central Cdn Arctic that are subject to extensive cloud cover
- The high resolution QuikSCAT product showed some promise for mapping spring snow cover variability over high latitudes
- And YES we will be including MODIS in this evaluation now that the 0.25º climate grid products have been released

Regional SWE Products for Research and Operational Applications



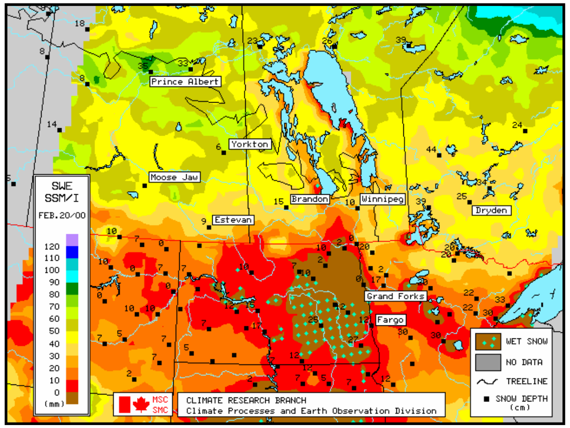
Canadian Prairies

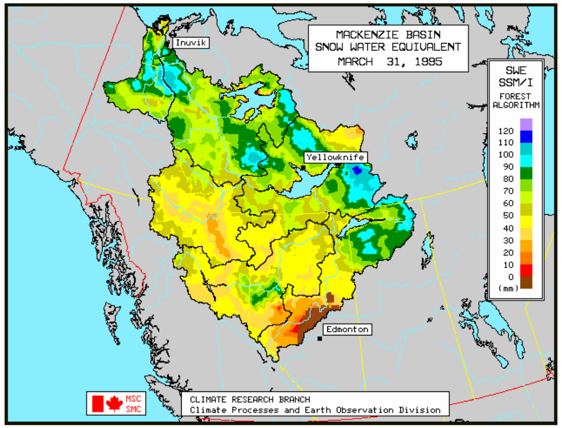
-weekly maps produced and sent to users (federal, provincial agencies, private industry) who have a requirement for regular monitoring of snow cover in western Canada

- available to public on www.socc.ca (State of Canadian Cryosphere)

Manitoba – Red River watershed

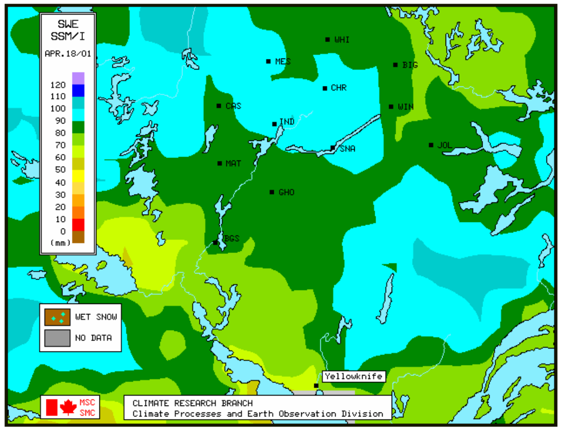
- specialized maps sent to provincial water resource agencies focussed on priority river basins for forecasting spring runoff and flood risk





Mackenzie Basin

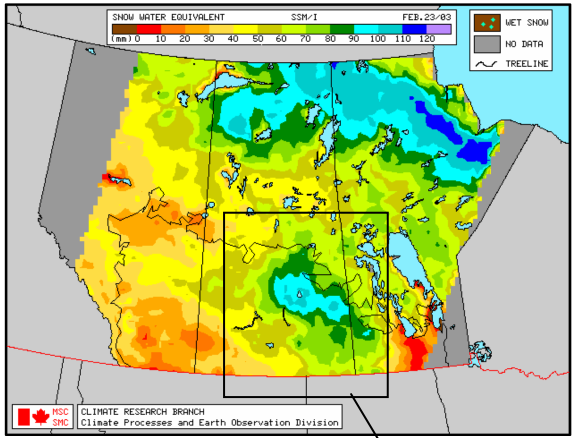
- MAGS research on snow cover variations, RCM evaluation



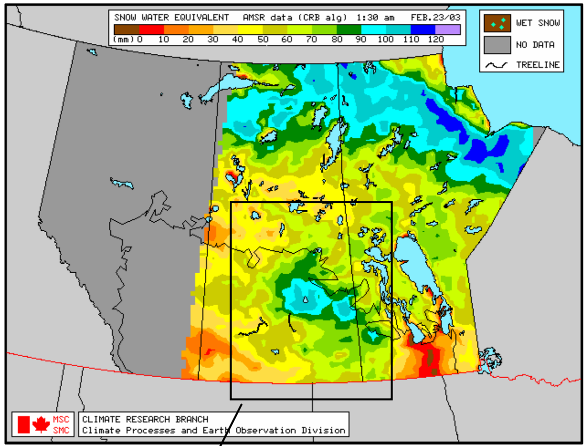
Snare River Basin – NWT

- maps for hydro companies (e.g. NWT Power Corp.) in support of planning hydroelectric power operations

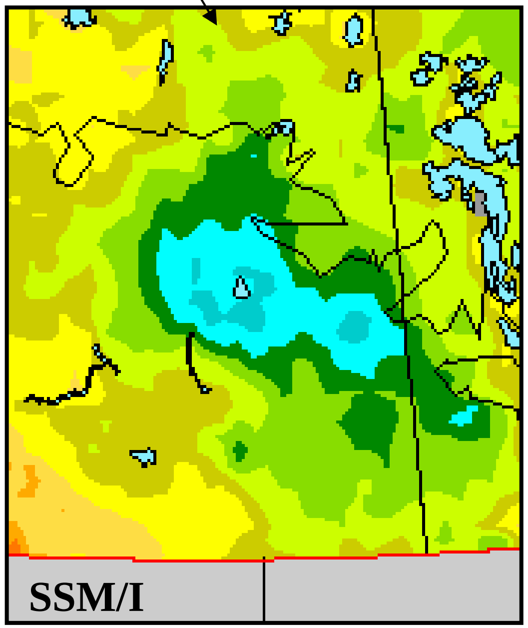
Comparison of AMSR-E and SSM/I SWE Products (CRB SWE Algorithm)

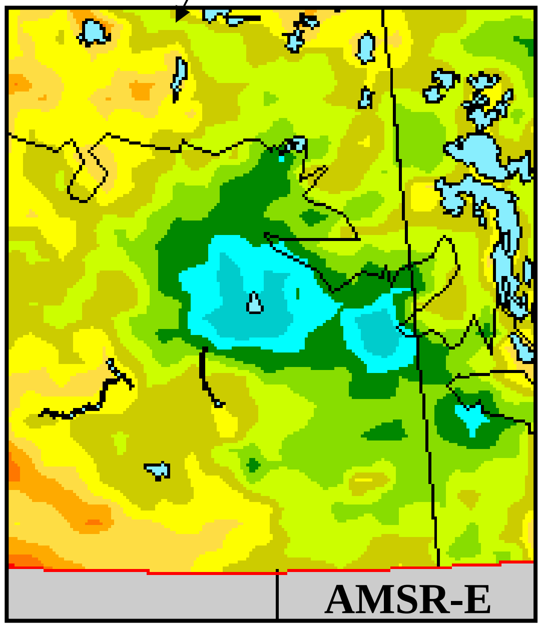


SSM/I SWE – MSC SWE algorithm

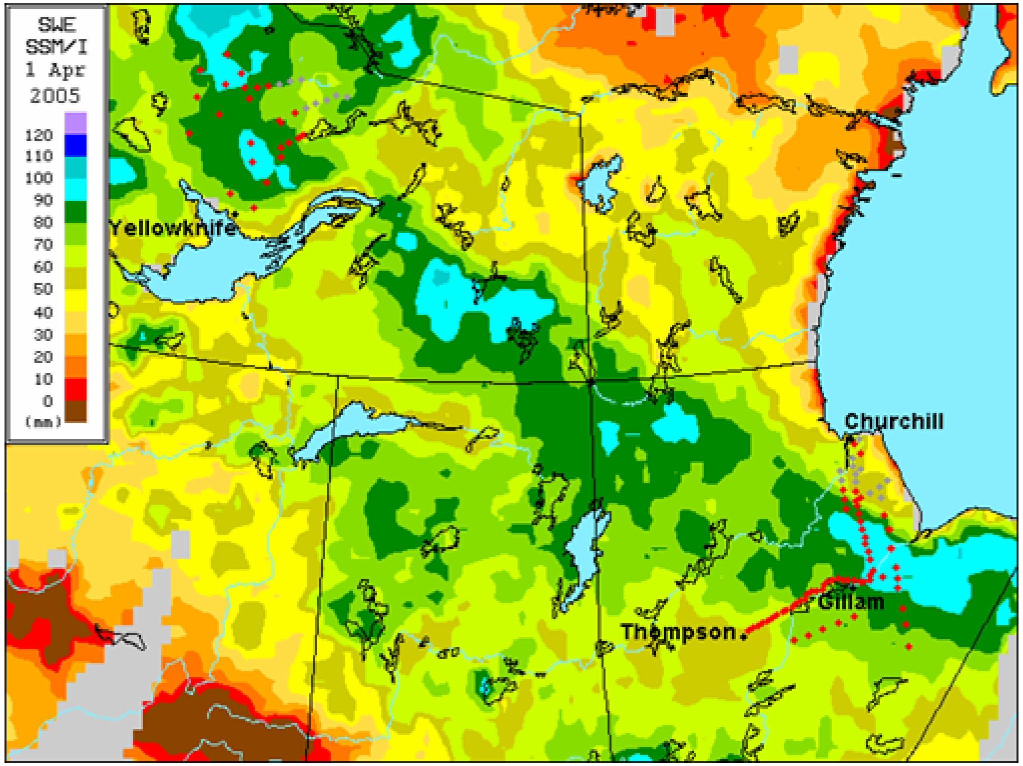


SWE derived from AMSR-E using MSC algorithm

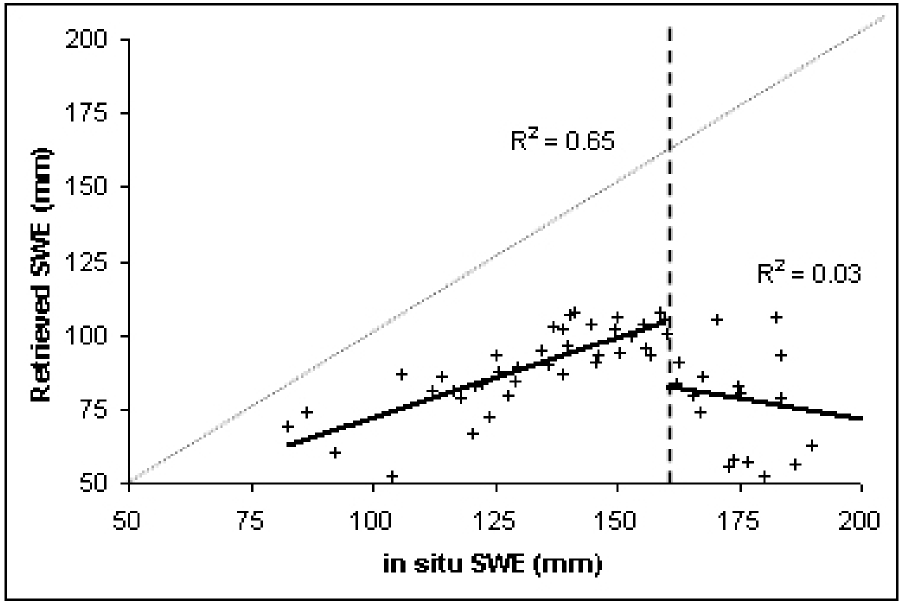


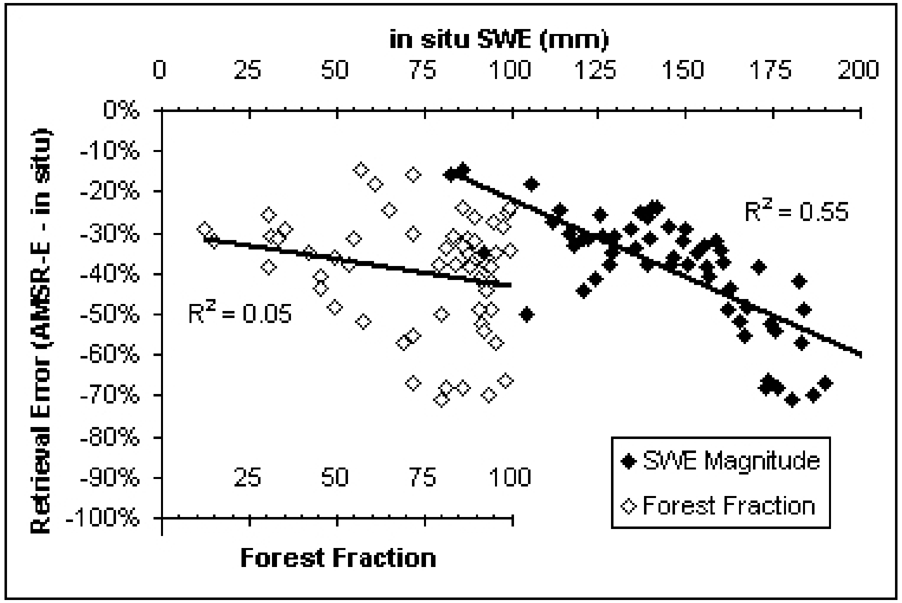


- ***Spatial patterns of SWE are similar***
- ***More detailed information with higher resolution AMSR-E***



Field Validation: 2005 Results

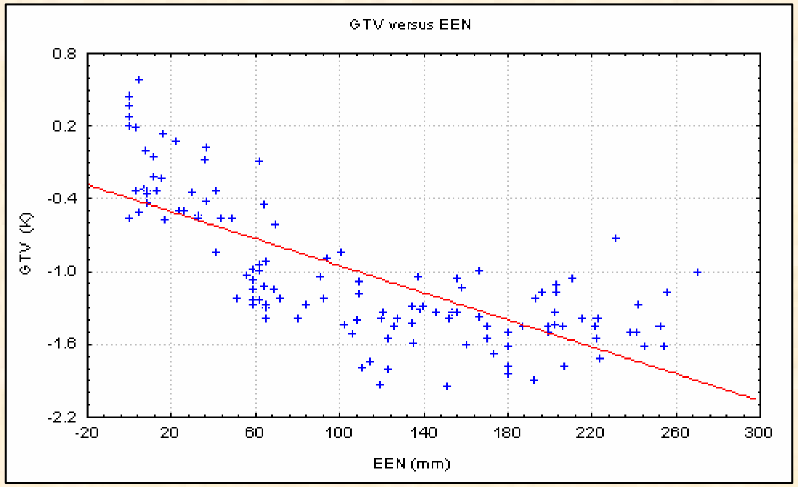


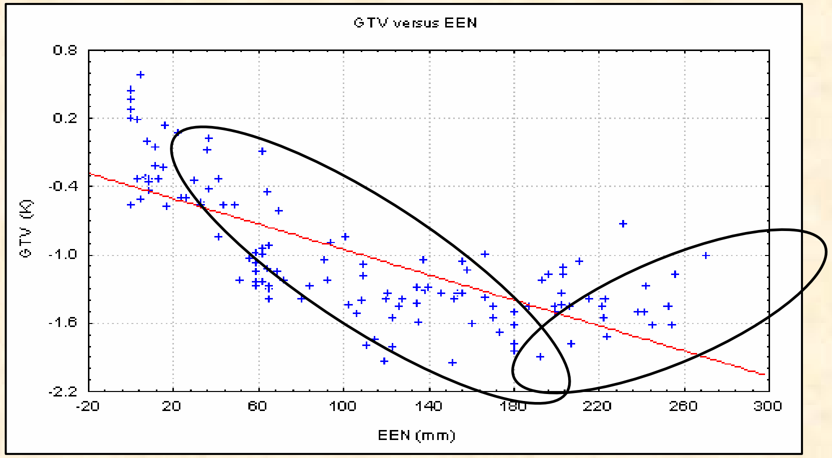


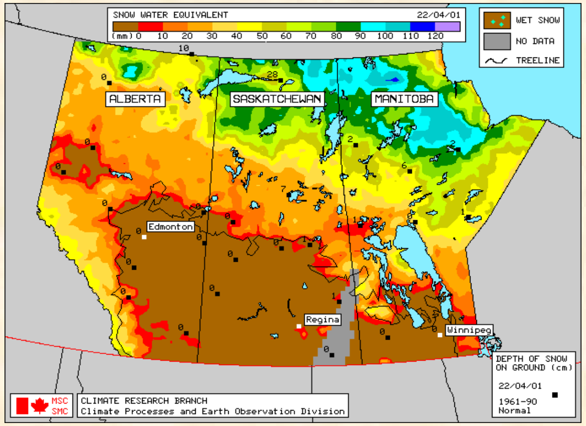
SWE underestimation in the open canopy northern boreal forest is a function of retrieval 'saturation' and is less dependant on the influence of vegetation.

Conventional brightness temperature difference algorithms are accurate up to ~160 mm SWE.

Snow Water Equivalent from SSM/I data







$$GTV = \frac{Tb_{37v} - Tb_{19v}}{f_{37v} - f_{19v}}$$

(Source : IREQ, Danielle De Sève, 2003)

Université du Québec
Institut national de la recherche scientifique

Welcome to the

State Of the Canadian Cryosphere

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SNOW

LAKE & RIVER ICE

SEA ICE

GLACIERS & ICE CAPS

PERMAFROST & FROZEN GROUND

snow cover | sea ice extent | lake ice | glaciers & ice caps | permafrost / frozen ground

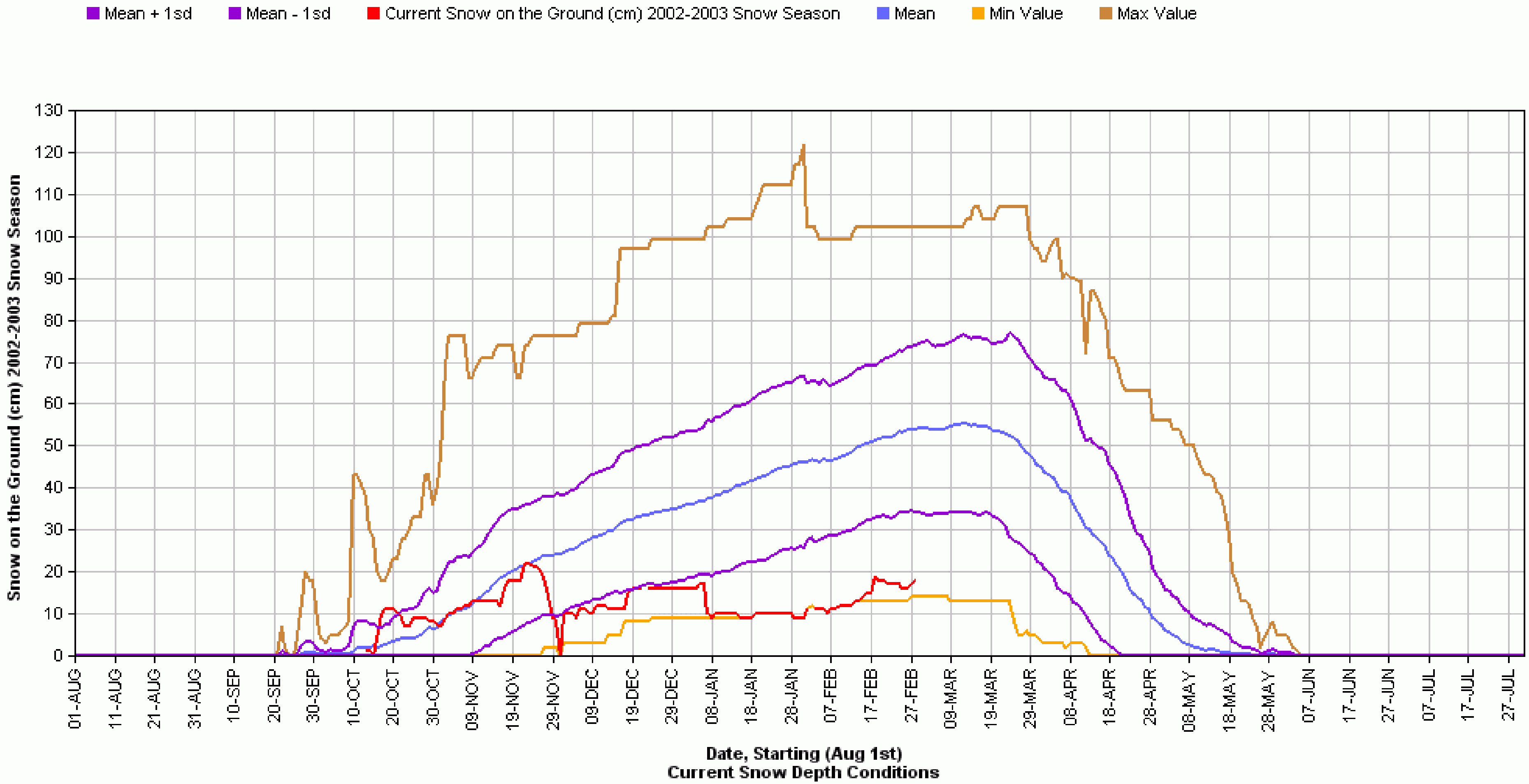
CRYOSPHERE SYSTEM IN CANADA CRYSYS

Take me to... GO!

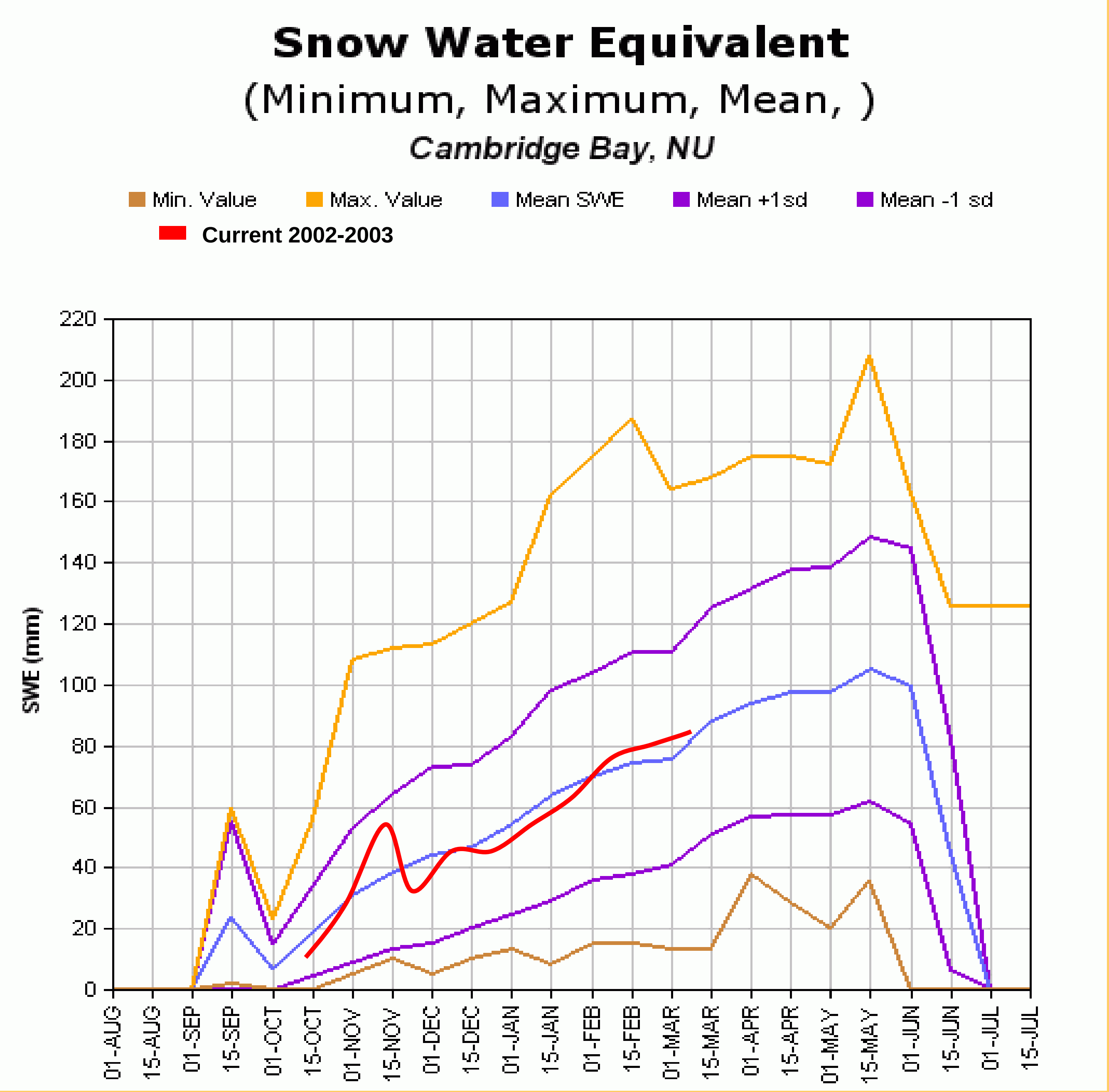
Current Snow Depth Conditions

(Minimum, Maximum, Mean, Mean +-1sd, Current)

HAY RIVER A



Compare current SWE with previous observations



Networks and Lessons Learned

- **automation** is a major challenge
- **networks aren't sexy**… hard to attract the investment needed to keep current networks operating – long term monitoring costs should not be under estimated, including decommissioning
- Funding is often short term – data monitoring is long term
- **Who should operate** monitoring networks – operational agencies who have the mandate – eg WMO members
- don't underestimate the **resources needed to maintain an effective national data archive**
- unless data and information are easy to obtain (e.g. online free access) and have well-documented meta-data, the huge investment in observing systems is being wasted
- **avoid custom solutions** to data management; open source is the way to go.
- **Partnerships** in operating provide significant opportunities in a northern environment


Thank you
Questions ?