The Arctic Hydrological Cycle

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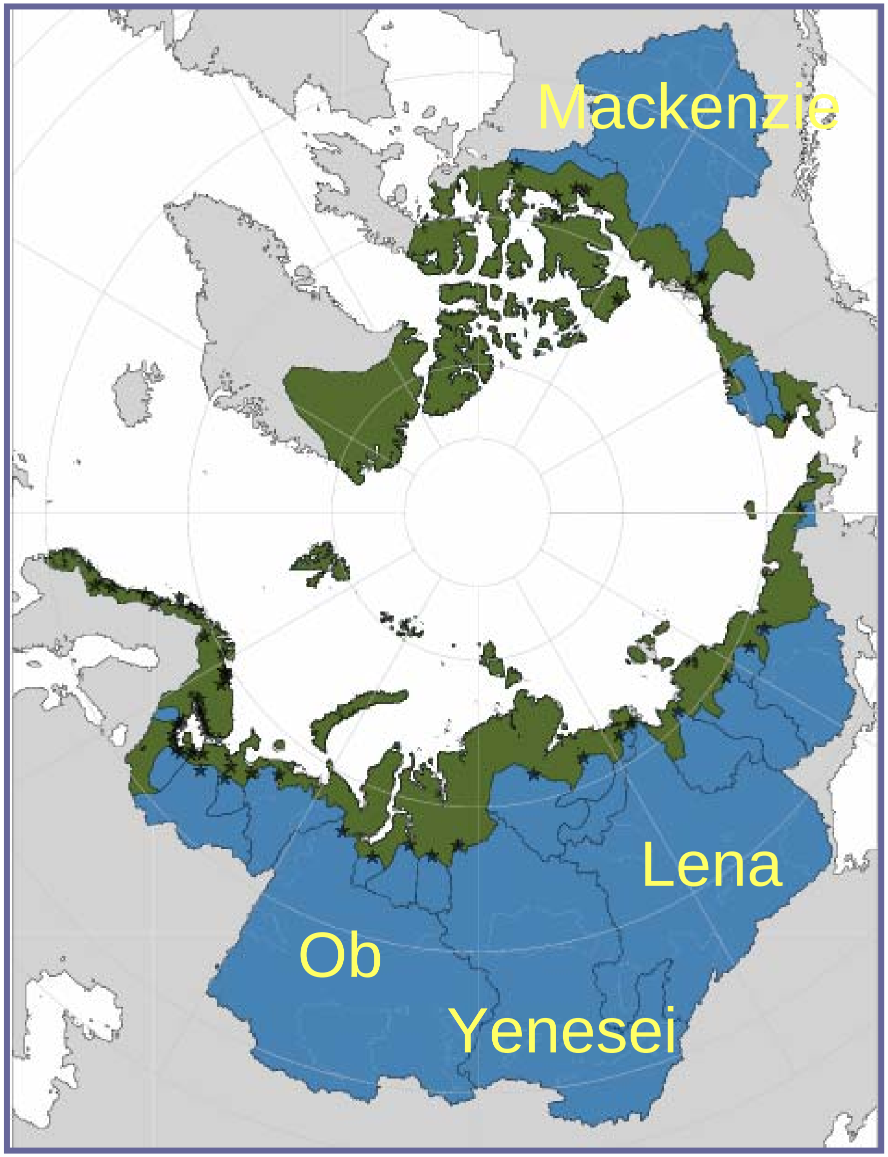
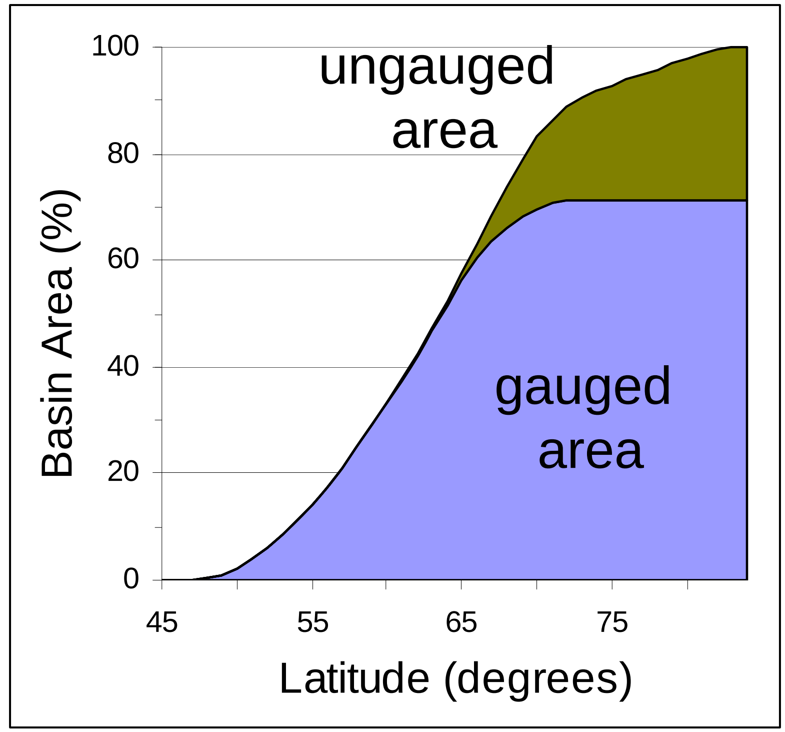
Some key features of the Arctic hydrological cycle

- Consider domain as Arctic Ocean plus its drainage area (~2/3 Eurasia, 1/3 N America)
- About 2/3 of freshwater flux comes from land, balance from P-E over ocean
- Ocean freshwater balance is negative (unlike other oceans)
- Low net radiation environment, hence low ET – most of Arctic land area would be a desert if at lower latitudes (Average P ~ 400 mm)
- P, ET both generally decline S to north
- Snow redistribution is a key process

Arctic drainage basin



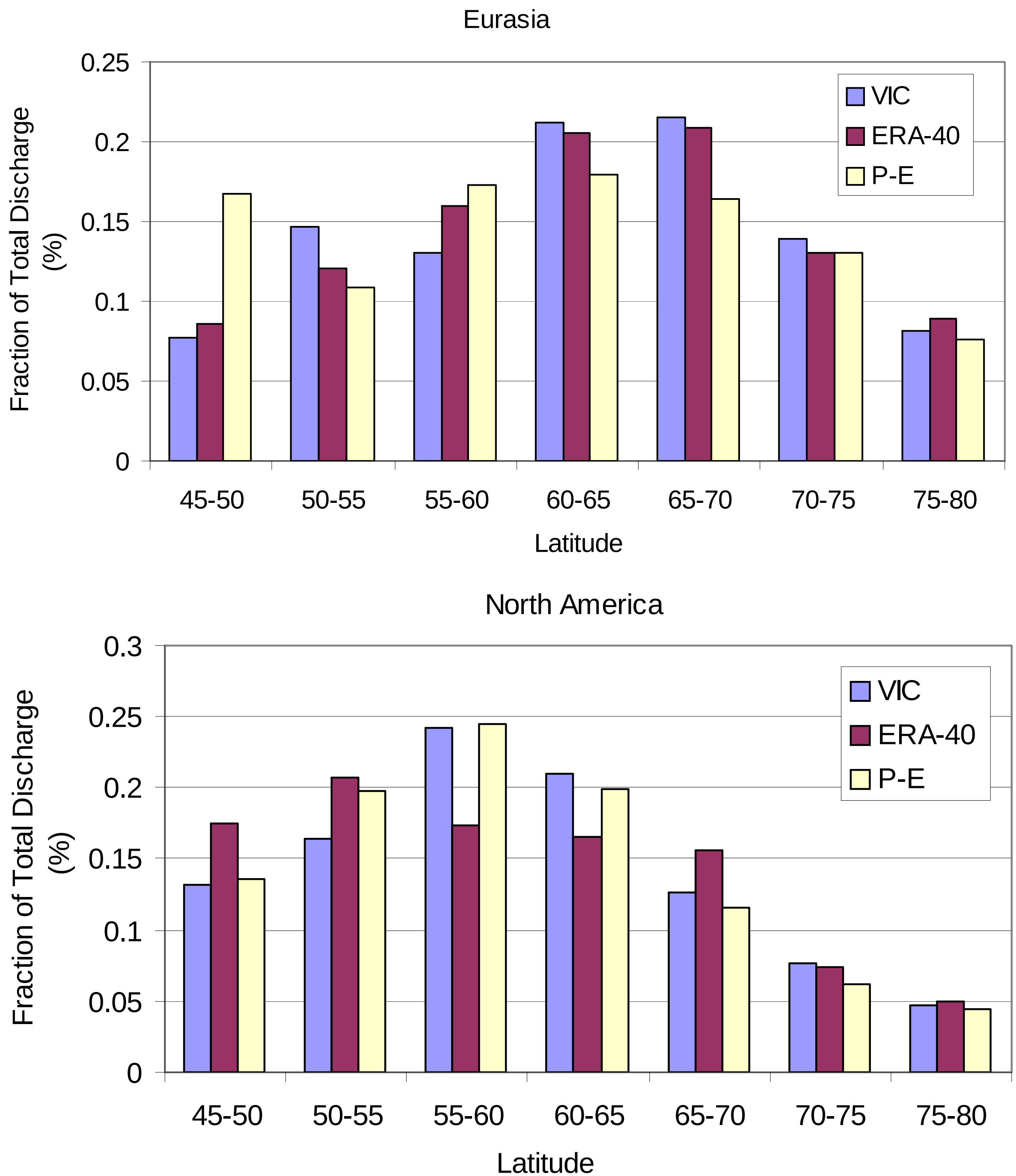


Blowing Snow

Günter Eisenhardt 3.31.2002, Iceland

Key features of the Arctic hydrological cycle (cont.)

- Even at highest (land) latitudes, summer precipitation is substantial portion of annual total (but contributes relatively small part of annual runoff, large part of annual ET due to strong seasonal variation in Rnet)
- Accumulated winter P as spring snow contributes most of the runoff of large rivers (4-5 largest rivers account for ~80-90% of total) – and much of this runoff occurs in a short period following spring ice breakup
- Winter P accumulation differentially affected by shoulder seasons (fall/early winter, late winter/spring)
- Summer precipitation rarely contributes substantially to discharge of large rivers, but progressively more important as basin size decreases
- Forested area constitutes an important fraction of the Arctic drainage area



Estimates of the fraction of annual total discharge into the Arctic Ocean for each 5° latitude zone from Eurasia and North America based on the VIC R, ERA-40 R, and P-E fields.

Hydrologic implications of a changing Arctic climate

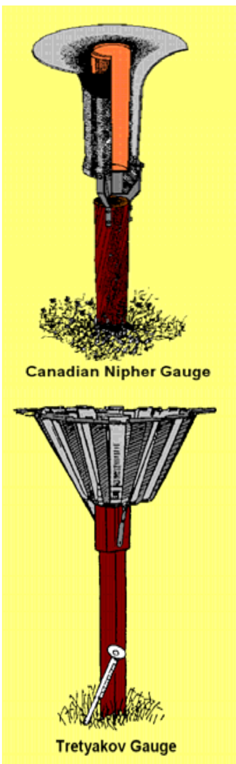
- Differential warming
- Shift in hydrograph earlier in year
- More shoulder season (fall, spring) precipitation
- More summer convective precipitation (shift in balance of extremes relative to basin size?)
- Increase in discharge (but causes still not fully understood)

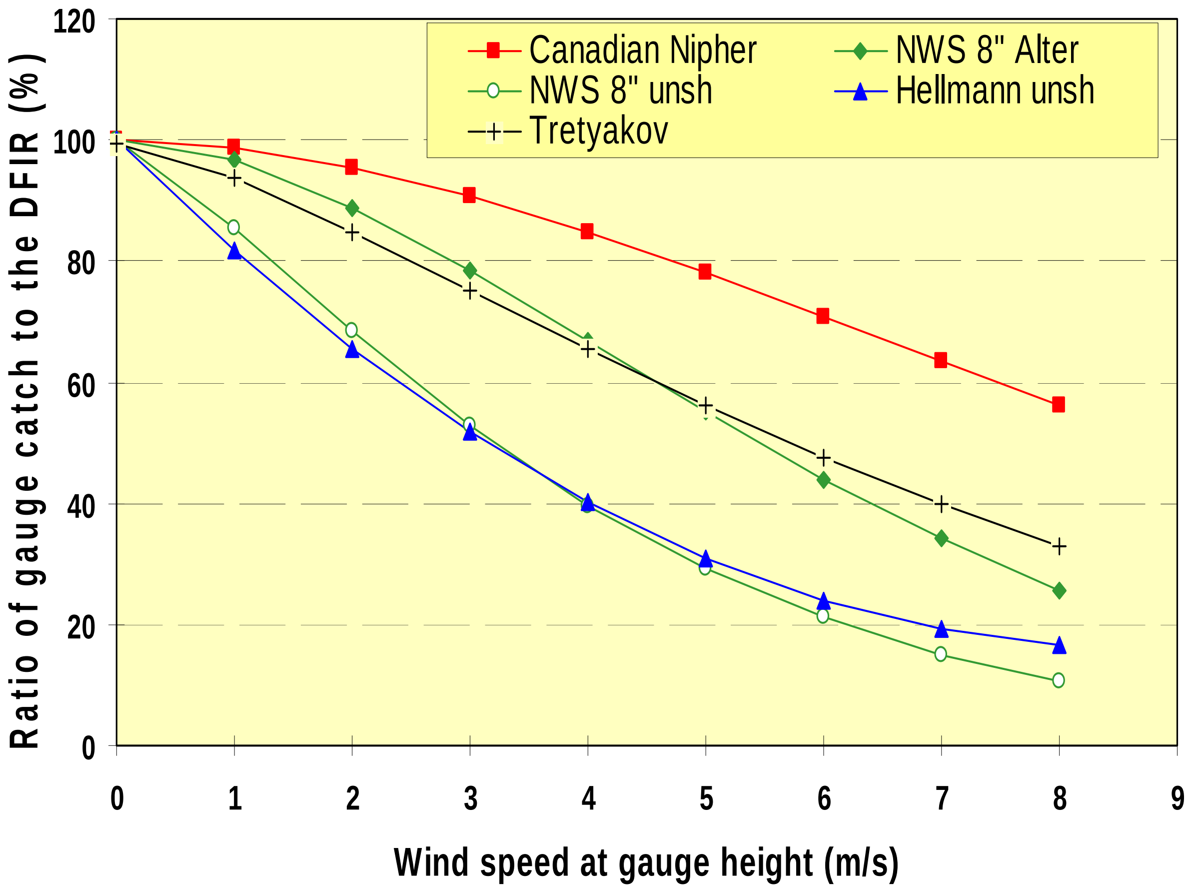
Measurement difficulties

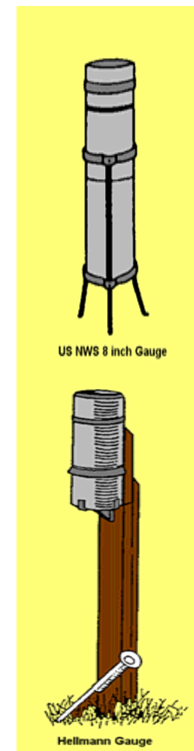
- Most of the region is remote, access difficult (e.g., expense of running USGS stream gauges in Alaska -- ~ 5-10 x relative to lower 48).
- Station densities (especially precipitation) tend to be where the population is (hence major gaps in Arctic interior)
- Extreme environment, hard on instrumentation
- Solid precipitation measurement extremely difficult due to wind effects on gauges (alternate strategy is to measure accumulated snow on ground)
- Result of which is that gauge distribution (in space) is highly uneven

WMO Intercomparison Study Results

Catch Efficiency vs Wind for the 4 most widely used gauges



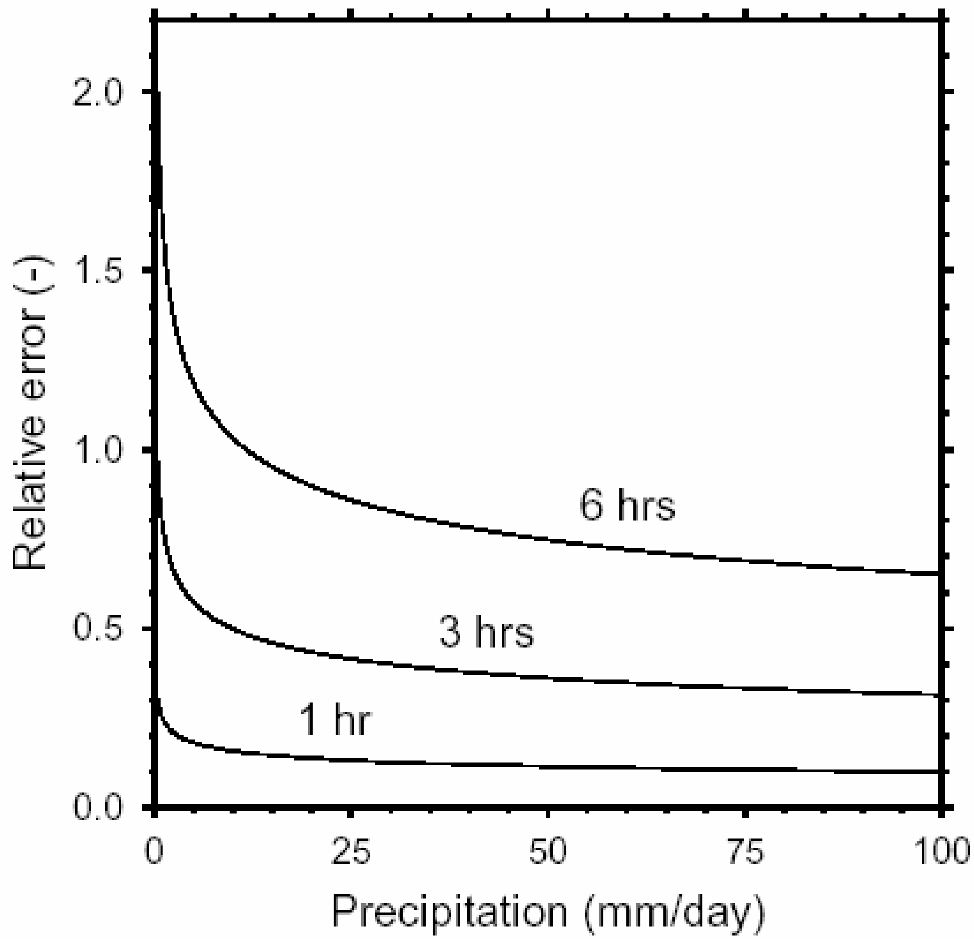


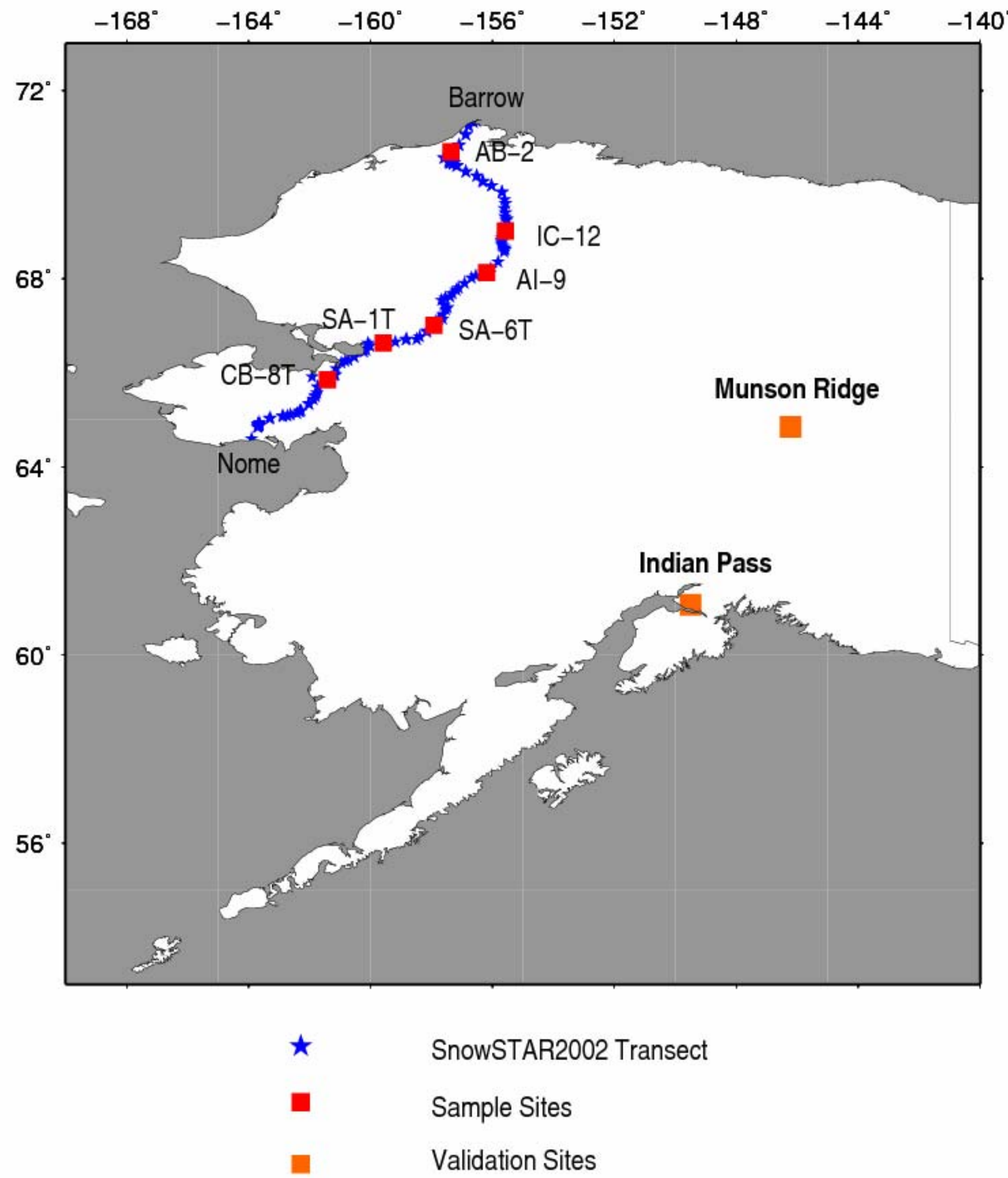


Strategic issues (from the standpoint of macroscale hydrology)

- What processes are most critical, and how can the observational base best be improved?
- Rivers – major rivers are reasonably well gauged (notwithstanding budget pressures, and complications of estimating discharge during ice breakup, etc) – however "interior" gauge network is sparse, and under continuing pressure, generally number of Arctic gauges has declined over land ~20 years. Possible role of swath altimetry (complications include ice cover, overpass interval)
- Snow on ground – some in situ measurements, but vast area – remote sensing offers promise (focus of Cold Lands Mission), and some success already with DMSP passive microwave sensors (most algorithms use 19/37 GHz channels). Complications include mixed pixels (especially forest), and topography, among others.
- Evapotranspiration – usually by difference, possibility for indirect inference and measurement of key variables (Ts, vegetation indicators) via remote sensing
- Precipitation – role of GPM? Sampling issues? Strategies for data assimilation?

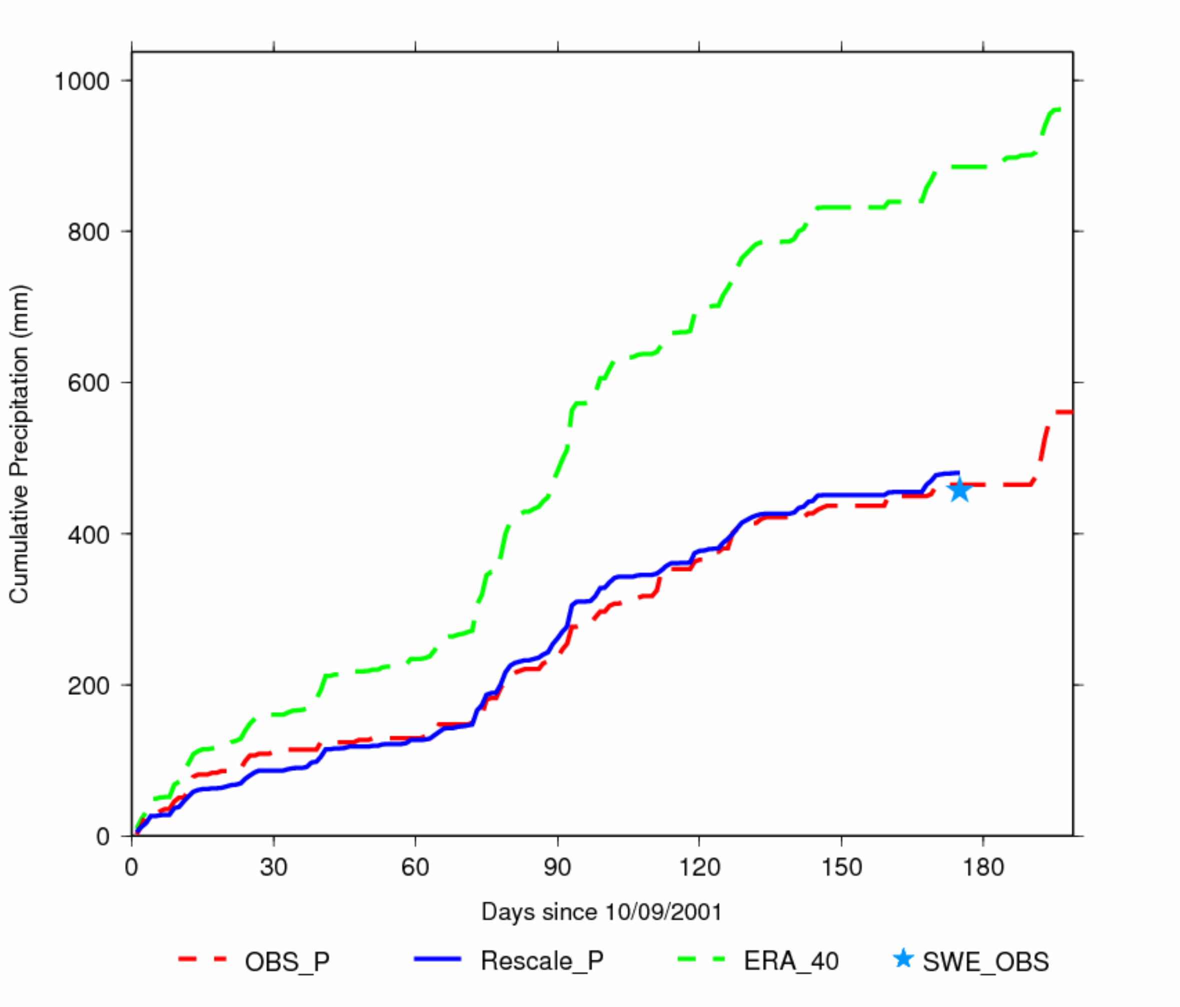
Relative RMSE in daily precipitation from a TRMM-like radar averaged over 2500 km2 for 1, 3, and 6-hour overpasses (from Nijssen and Lettenmaier, 2004, based on error model of Steiner et al, 2003)





−168˚
−164˚
−160˚
−156˚
−152˚
−148˚
−144˚
−140˚
72˚
68˚
64˚
60˚
56˚
Barrow
AB−2
IC−12
AI−9
SA−1T
SA−6T
CB−8T
Nome
Munson Ridge
Indian Pass
SnowSTAR2002 Transect
Sample Sites
Validation Sites

Simulated and observed SWE at Indian Pass, AK, winter 2001-02



Challenges to the workshop

- Identify the research questions
- What is the technological potential, and what is realistically achievable
- Where is the intersection of the science (and applications) needs, and the technology?