A Few Words On Forecasting Snow in the Arctic

Towards a Polar Snowfall Hydrology Mission

26 – 28 June, 2007

Montreal, Quebec

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Environment Canada
Edmonton, Alberta

3. Overview: Forecasting, Parameterization, Prediction Overview and Needs – Chair: Greg Tripoli and Gilbert Brunet

Session objectives: How well are Arctic/Alpine snowfall precipitation systems forecasted and modelled – weather/climate perspective? What is the current state of the art? Where is this going? What are the modelling needs? What are the key issues? How are we doing with addressing them? Observation Needs - temporal, spatial, coverage, phase, intensity, amount?

Regional Arctic Climate Modelling - Rene Laprise/UQAM TBD

Weather Forecasting for the Arctic – Ed Hudson/Ron Goodson/EC TBD

NWP and Data Assimilation - Godelieve Deblonde/EC, Peter Bauer/ECMWF TBC

Microphysical Modelling and Parameterization Issuence - J. Curry/GT

Physical Parameterization - Stephane Belair/EC

Land - Surface Parameterization, Diana Verseghy/EC

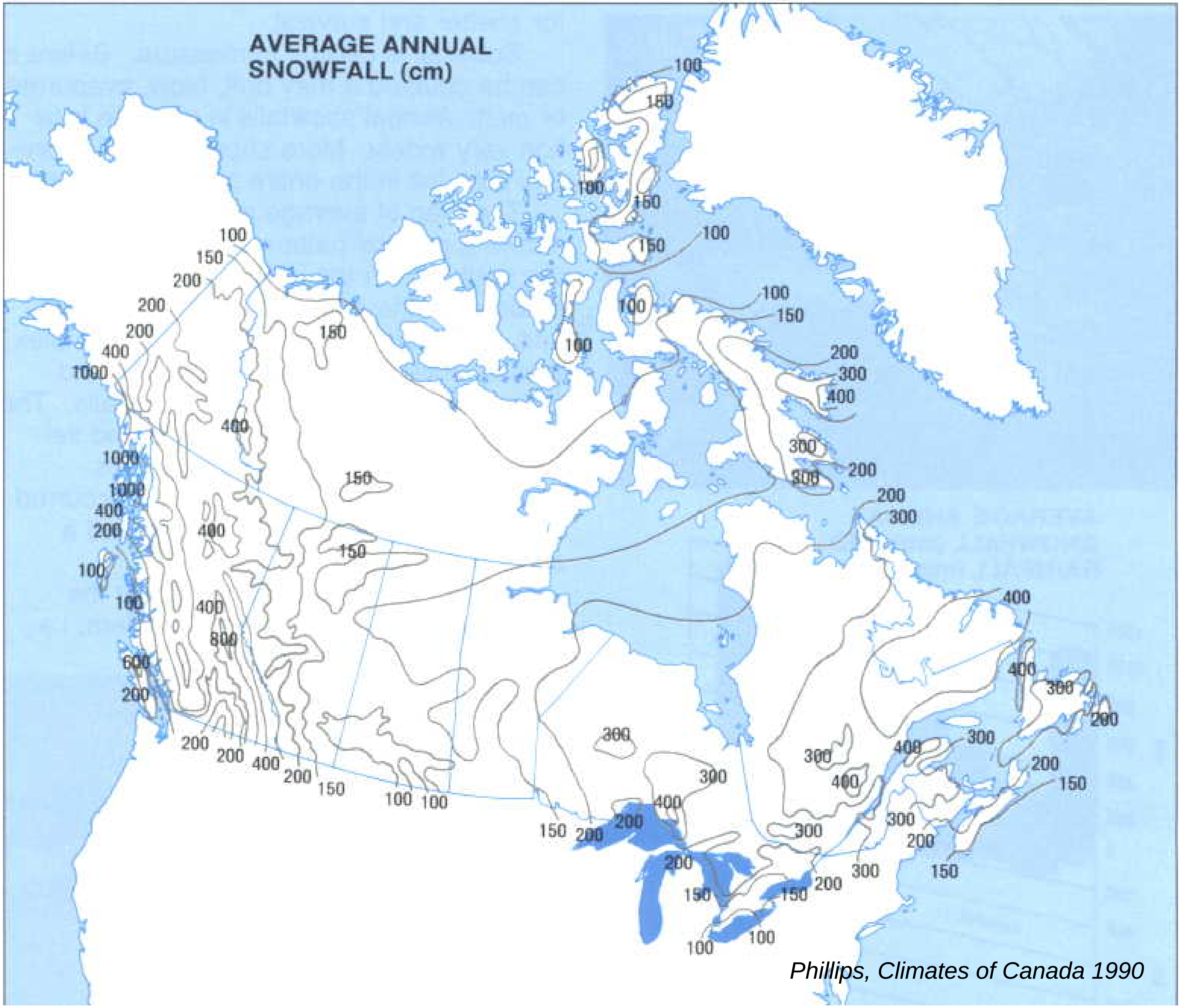
Discussion

Snow Falling From The Sky

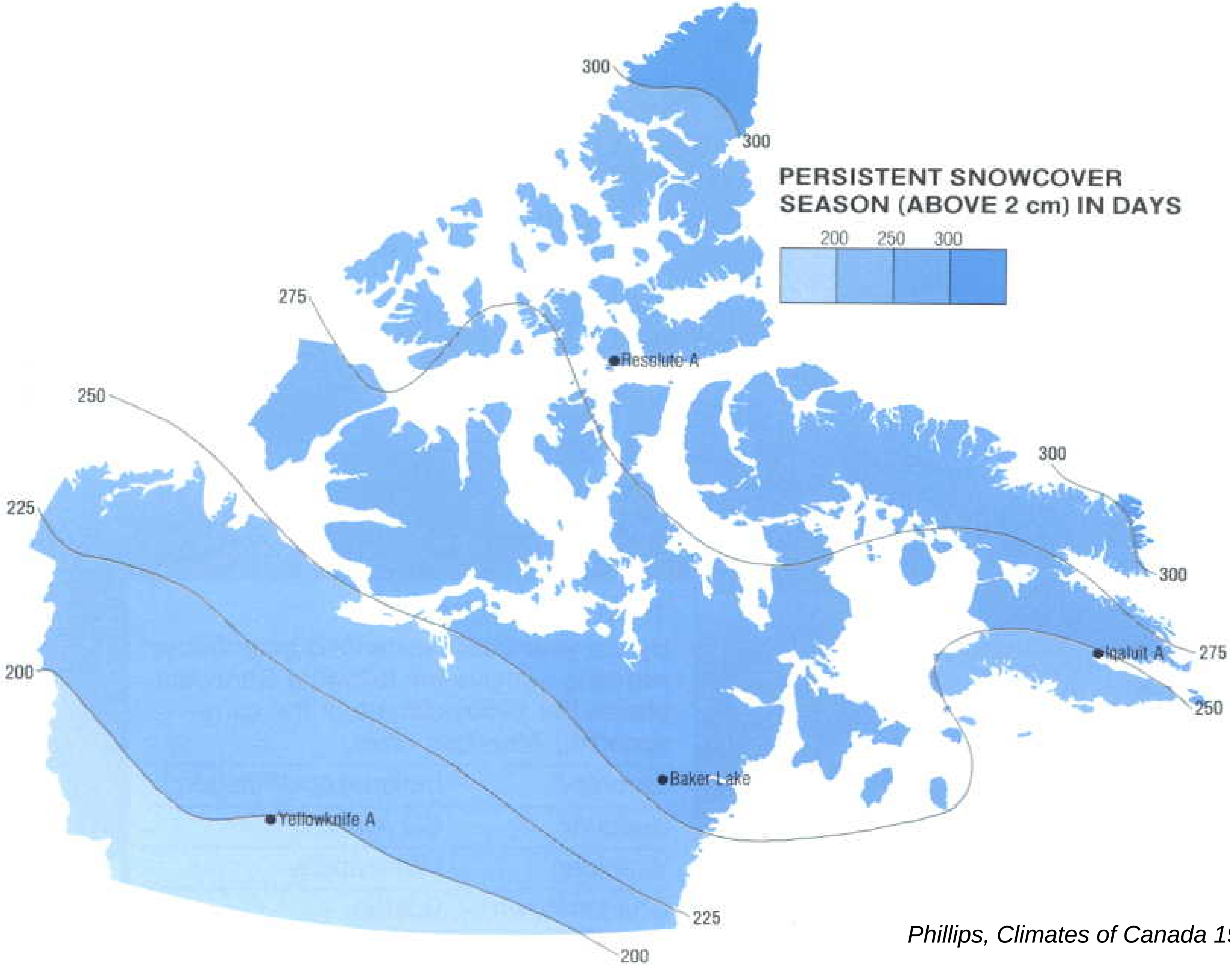
- Will begin with a brief discussion of some weather patterns that produce precipitation

- Will show examples of
  - synoptic snowfall patterns
  - mesoscale influences
  - what forecasters have to “think about”
  - data problems

- A few words about the “tools” used to help forecast precipitation amounts



Phillips, Climates of Canada 1990



Phillips, Climates of Canada 1990

Inverted Troughs

(Nov 15, 2006)

What the forecaster needs to worry about...

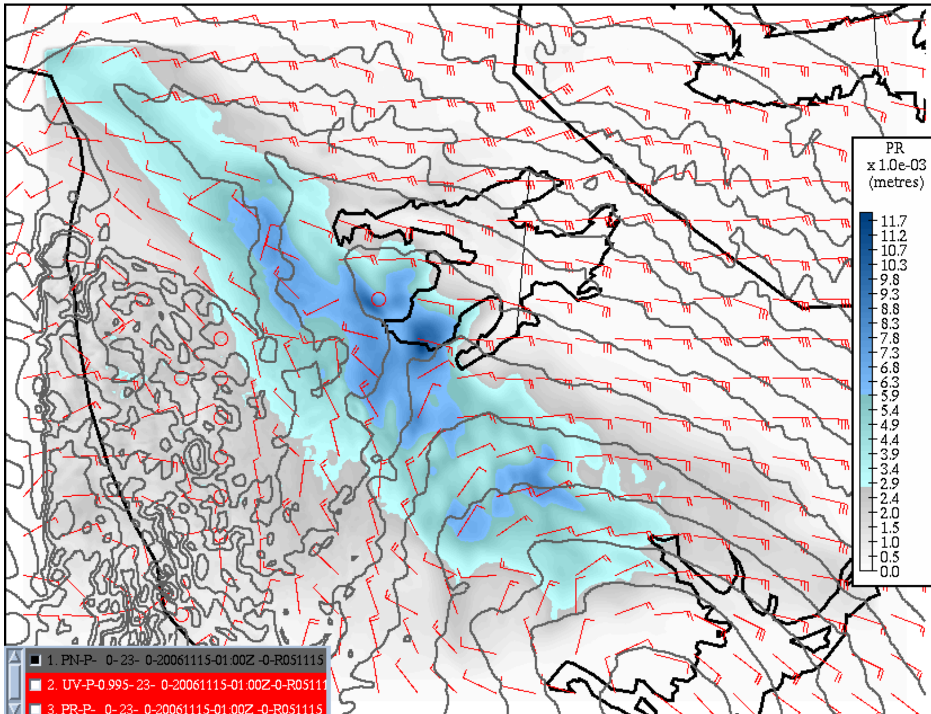
amount of moisture carried northwards by the trough

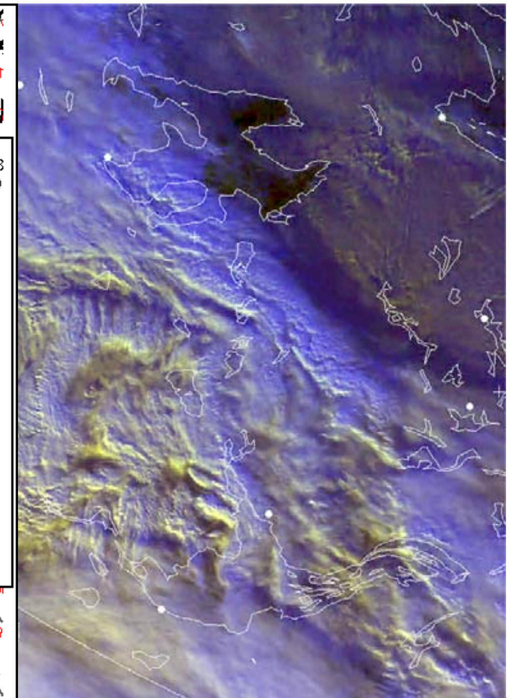
location of trough axis

how much cold air drawn down along the mountains to create convergence zone and lift

strength of moisture flux from Great Bear Lake

potential rain/snow line at higher elevations (depending on season)





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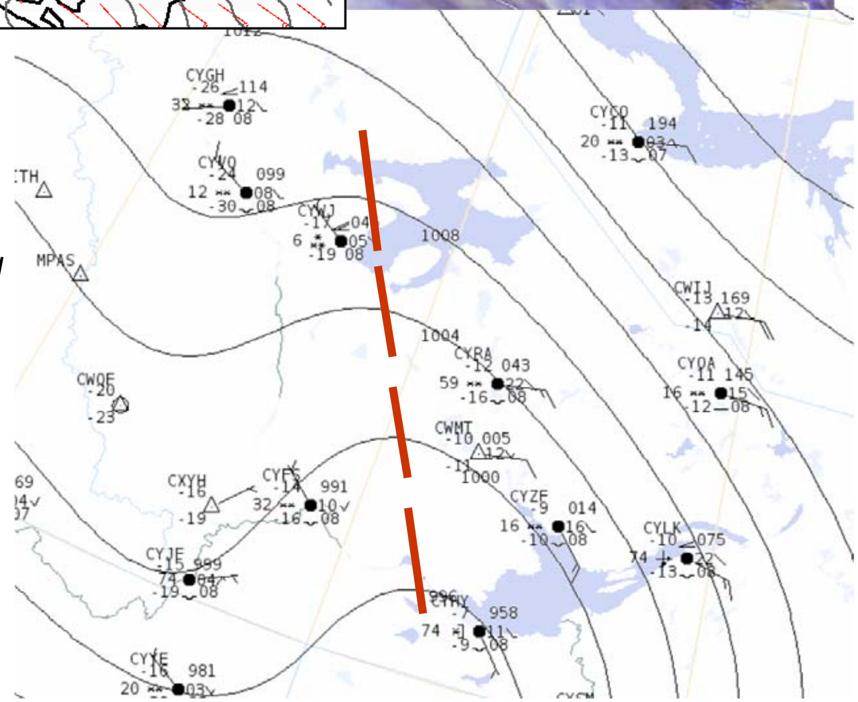


Lows in-and-around Southern Baffin Island

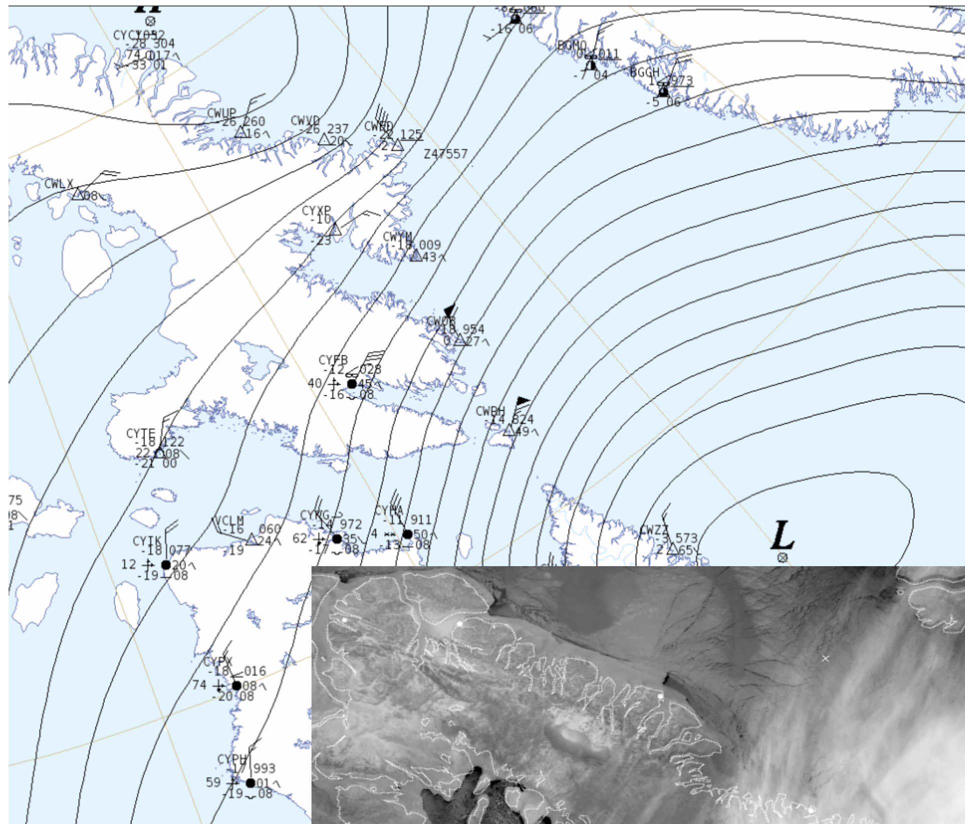
What the forecaster needs to worry about...

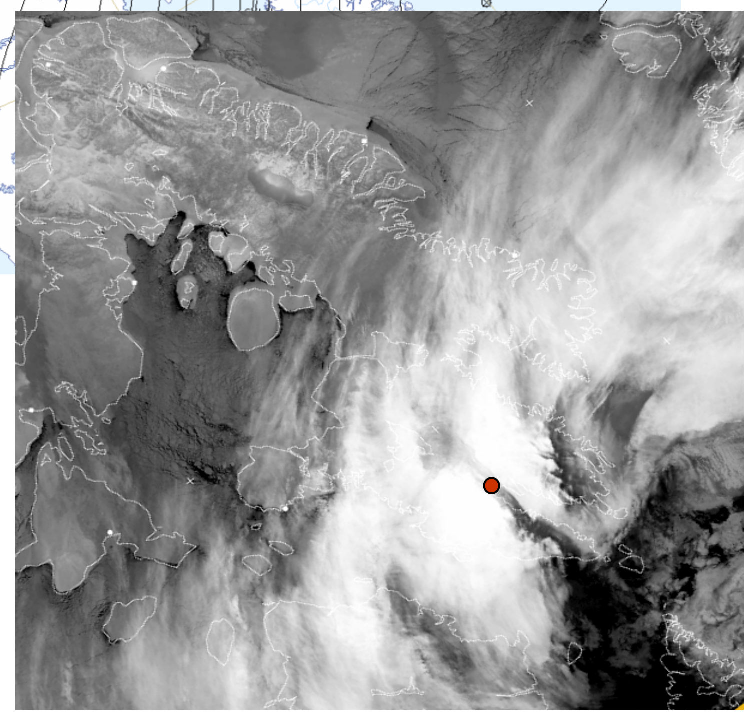
usual large-scale synoptic storm problems of stability, moisture and lift, "feeder-seeder" that influence precipitation amounts

track of surface and upper low - slight changes in track may drastically affect local wind speeds and direction due to interactions with topography

These interactions with local topography can drastically modify local precipitation amounts such as
- upslope along eastern Baffin Island
- downslope for northeast flows at Iqaluit

Observations of S-BS - how much is falling from the sky and how much is blowing (human observations of sky / weather can be tricky in the long-dark winter)

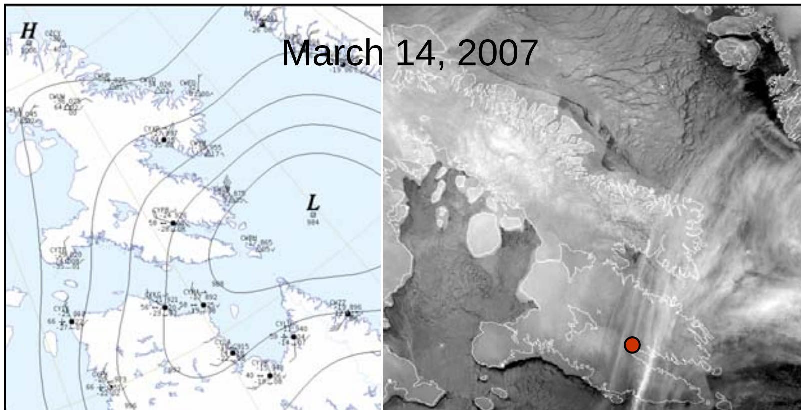




For much of the eastern Arctic, snowfall itself is not the big forecasting problem as typical amounts are < 10cm

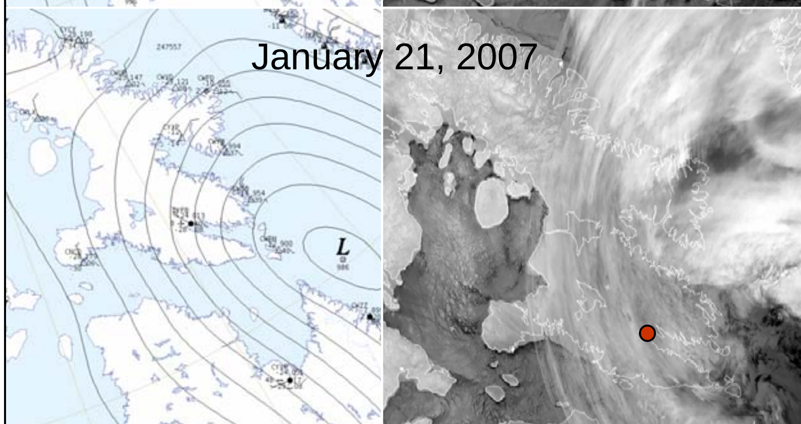
The big forecasting problem is how much snow is available to be blown around causing blizzard conditions.

Its hard to forecast when you are not sure of your history



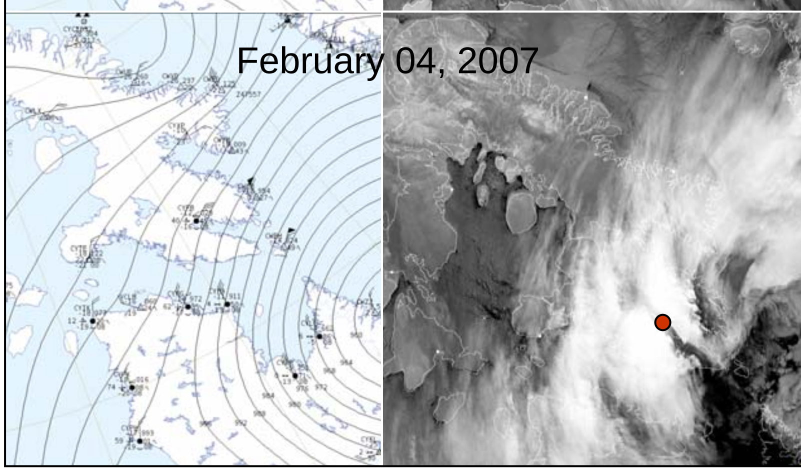
Hourlies – light to moderate northwest winds and light snow

Syno – 5 mm accum.



Hourlies – strong northwest winds and blowing snow

Syno– 15 mm accum.



Hourlies – extreme northeast winds and blowing snow and some light snow

Syno – 42 mm accum. including 12-hour period with 16 mm accum. whilst manned observations reporting drifting snow

Neither the hourly reports or synoptic reports are necessarily that trustworthy.

The lack of reliable data makes it difficult to properly build forecaster experience

And I’ve no idea what the impact is on UMOS output and verification scores

Polar Lows

(Nov 28, 2006)

- We have a reasonable handle on the conditions that could lead to the development of a polar low
- We (forecasters) have no idea if the microphysics / formation of snow within polar lows is any different than within synoptic / convective systems
- However, they move relatively quickly such that accumulations are not large, so this is not a "forecast problem"

Ivujivik

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CYIK 281429Z 34024G29KT 10SM -SN DRSN

CYIK 281500Z CCA 35021G26KT 10SM –SN

CYIK 281600Z 34014KT 3SM -SN DRSN

CYIK 281605Z 35017KT 1/2SM -SHSN DRSN

CYIK 281621Z 01018KT 1/4SM SHSN DRSN

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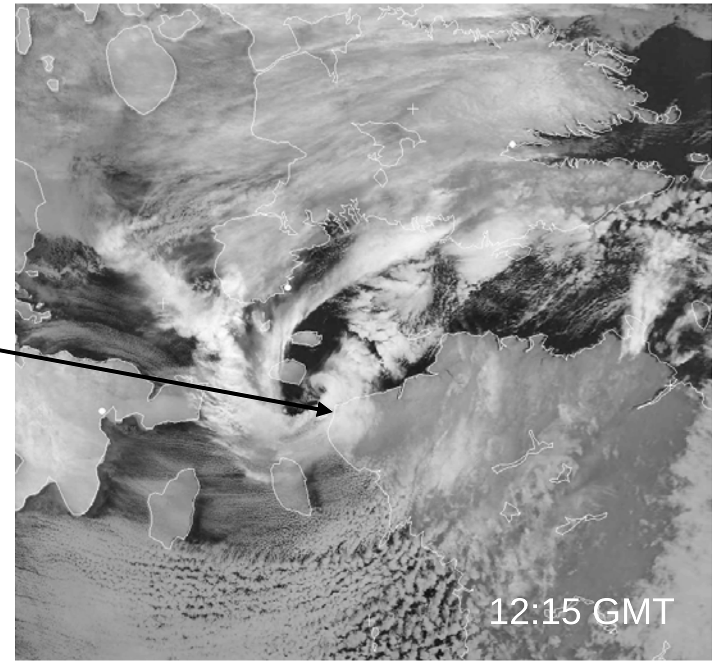
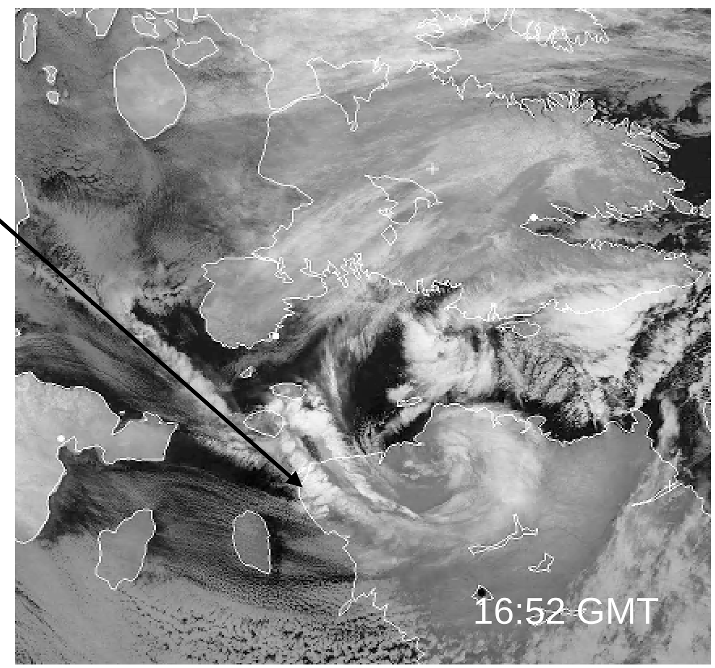




- Predicting polar lows is important because of the (we hope not too unexpected) strong changes in wind speed and direction that can affect the marine community

Cold Lows

(May 21 - 23, 2007)

What the forecaster needs to worry about...

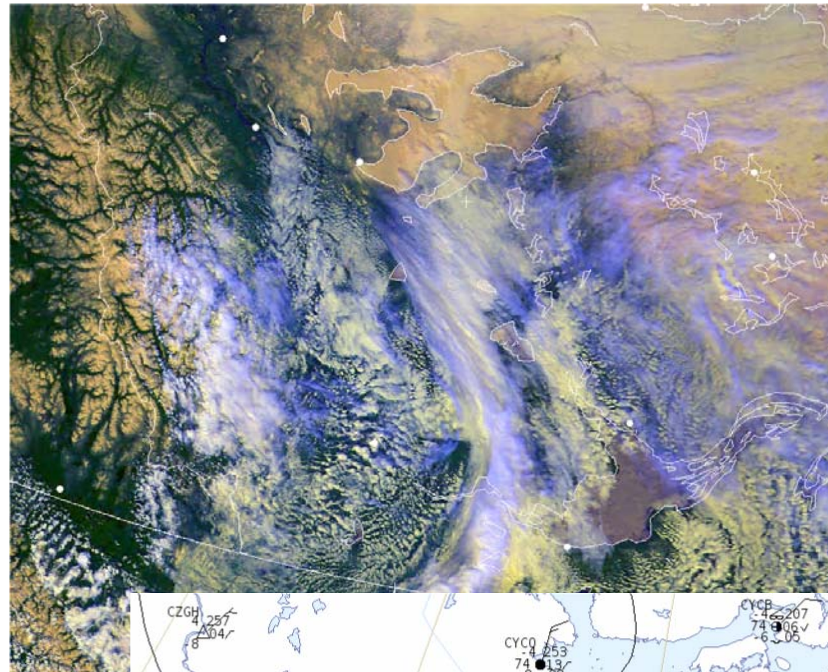
track and speed of low

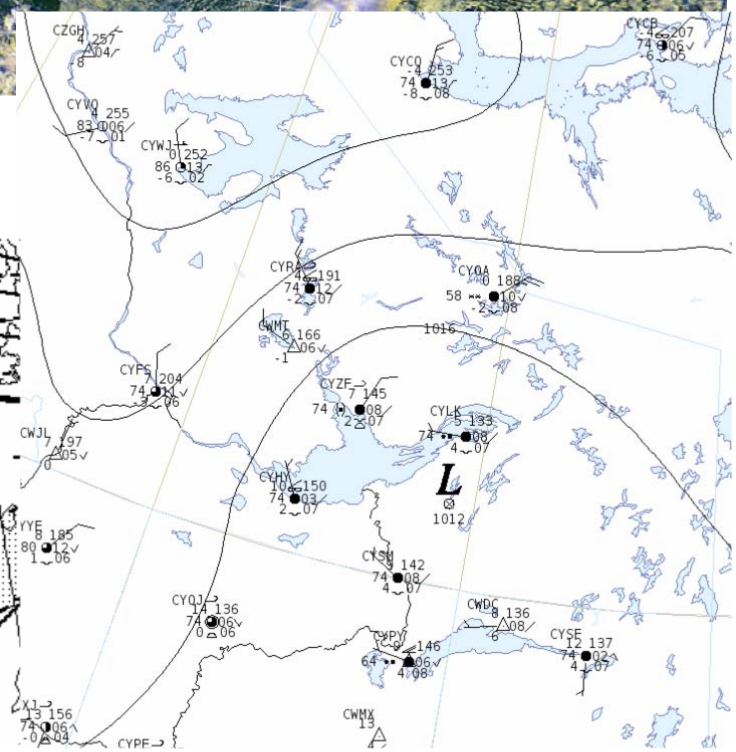
phase and amount of precipitation

snow – water ratio for depth of snow

degree of instability and changes with time

predicting and monitoring strength of embedded convection (with little or no surface / radar data – although highway web cams over northern Alberta proved very useful in this case)





Observations from High Level are for the day after charts shown here – but the same cold low

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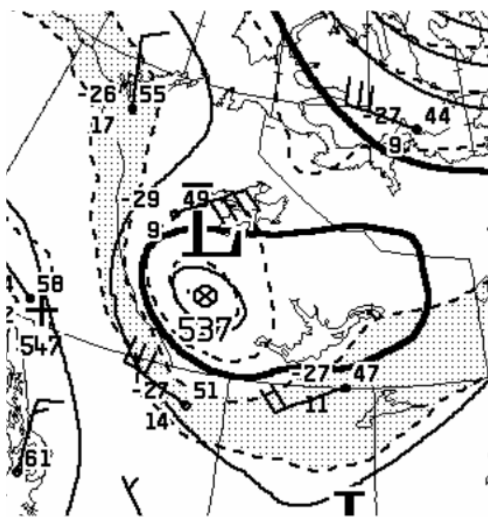
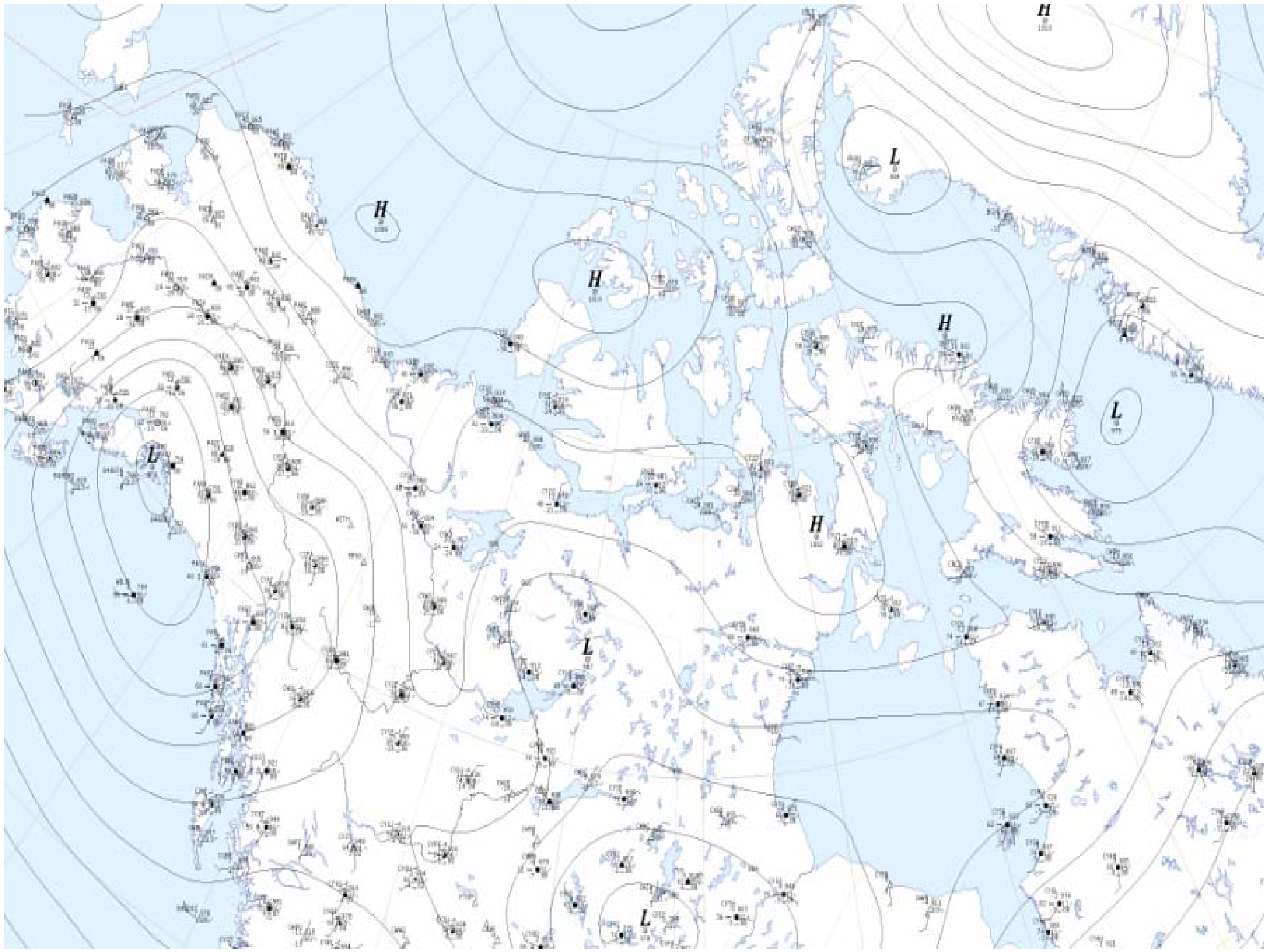


... And More

- There are many other examples, ranging from synoptic to mesoscale
- Each has their own forecast challenge
- Synoptic
  - short waves moving from the Gulf of Alaska to the Yukon with lows (re)forming in the Mackenzie region
  - lows moving across the Beaufort Sea
  - lows moving westward across the top of Greenland and Ellesmere Island
  - lows moving across the Kivalliq region and Hudson Bay
- Synoptic / Mesoscale
  - barrier jets along the east coast of Baffin Island that form in response to lows in Davis Strait / Baffin Bay affecting (possibly) the location / amount of precipitation
  - we shall never know due to lack of observations
- Mesoscale
  - snow streamers downstream from lakes or over the open water downstream from cold land-areas
  - persistent, but amorphous, areas of light snow or drizzle from ever-present stratus cloud over the water and coastal areas from spring through fall.

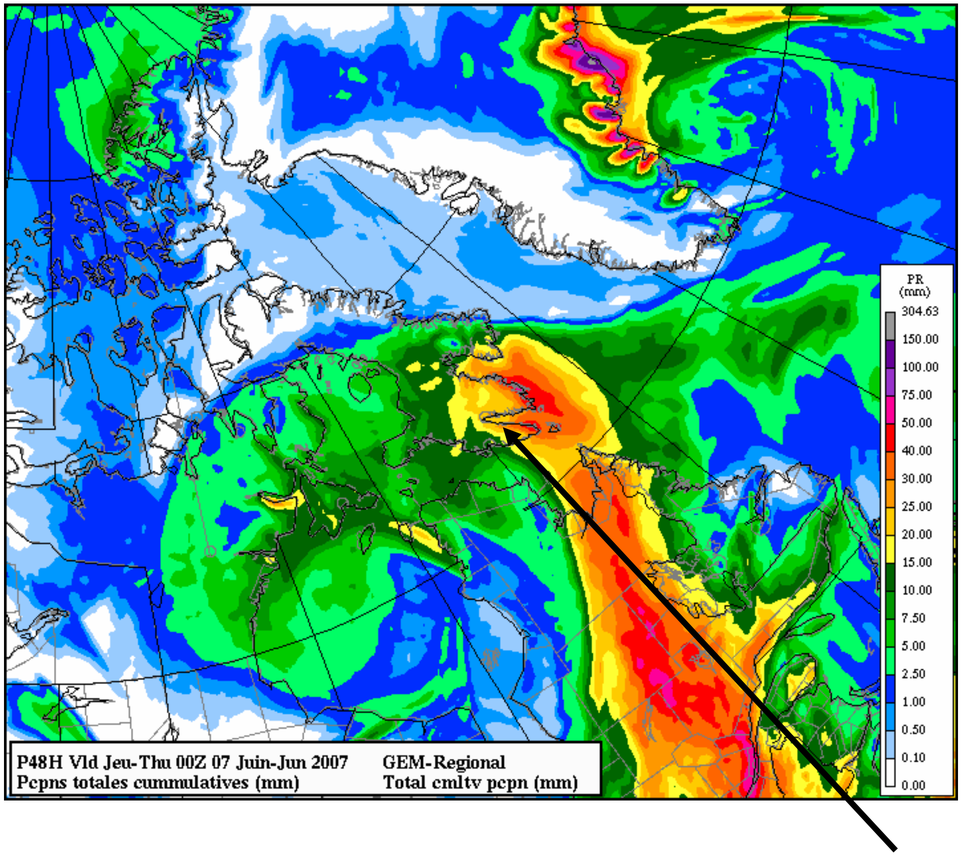
How many of these patterns can you spot in 3 months worth of weather

January – March, 2007



Tools - NWP

- GEM-15 is good at forecasting elements that lead to precipitation
  - synoptic forcing
  - overall estimate of moisture in a column
- GEM-15 is not so good at many of the mesoscale interactions that are important at some Arctic locations
- In general, winter precipitation amounts (and mid-level RH) from the GEM-15 are too high
- GEM precipitation types generally OK
- There is low expectations for GEM ability to forecast blobs of stratus / drizzle / light snow in the north in an operationally useful sense (especially for aviation), therefore not used
- I leave it to others to describe potential improvements to the GEM for polar regions
  - such as improved land-ocean-ice scheme

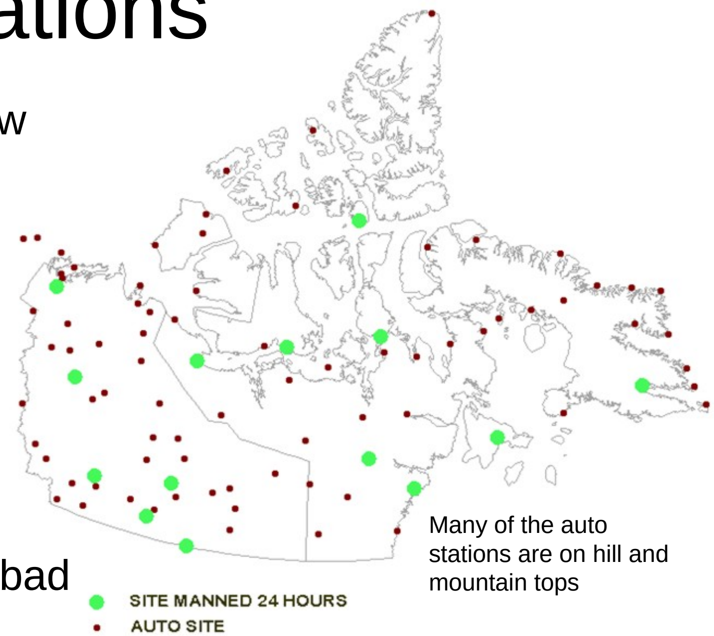


predicted > 20mm for Iqaluit, but received only 9mm (but I'm cheating here, as this was a mixed rain-snow event)

Tools – Remote Sensing

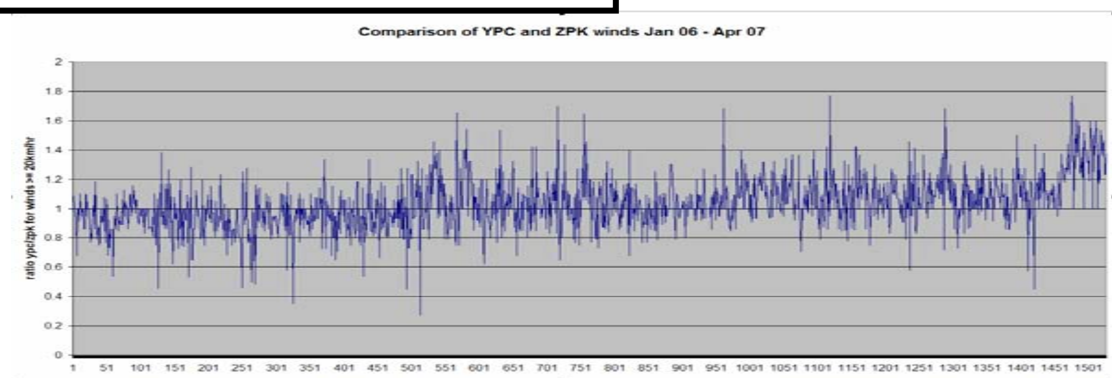
- Satellite Imagery is a major diagnostic tool
  - used to monitor evolution of weather
  - used to infer validity of GEM
  - top-down view only
- POES most commonly used
  - good spatial resolution (1km)
  - poor temporal resolution – up to 6 hour gap over a region
- GOES used to monitor overall cloud-outline evolution
  - useful up to 65 – 70 N although obviously without details
- No radar in the north, so no spatially/temporally coherent "bottom-up" view
- Other, potentially useful, remote-sense data such as precipitable water from microwave (over oceans) are under-utilized (for various reasons)
  - SWE from microwave are used for other purposes
- WebCams can be useful (if not truly remote sensing)
  - frequent update
  - low cost
  - near-direct observation
- A every-hour every-where CloudSat image would be nice ...

Tools – Observations

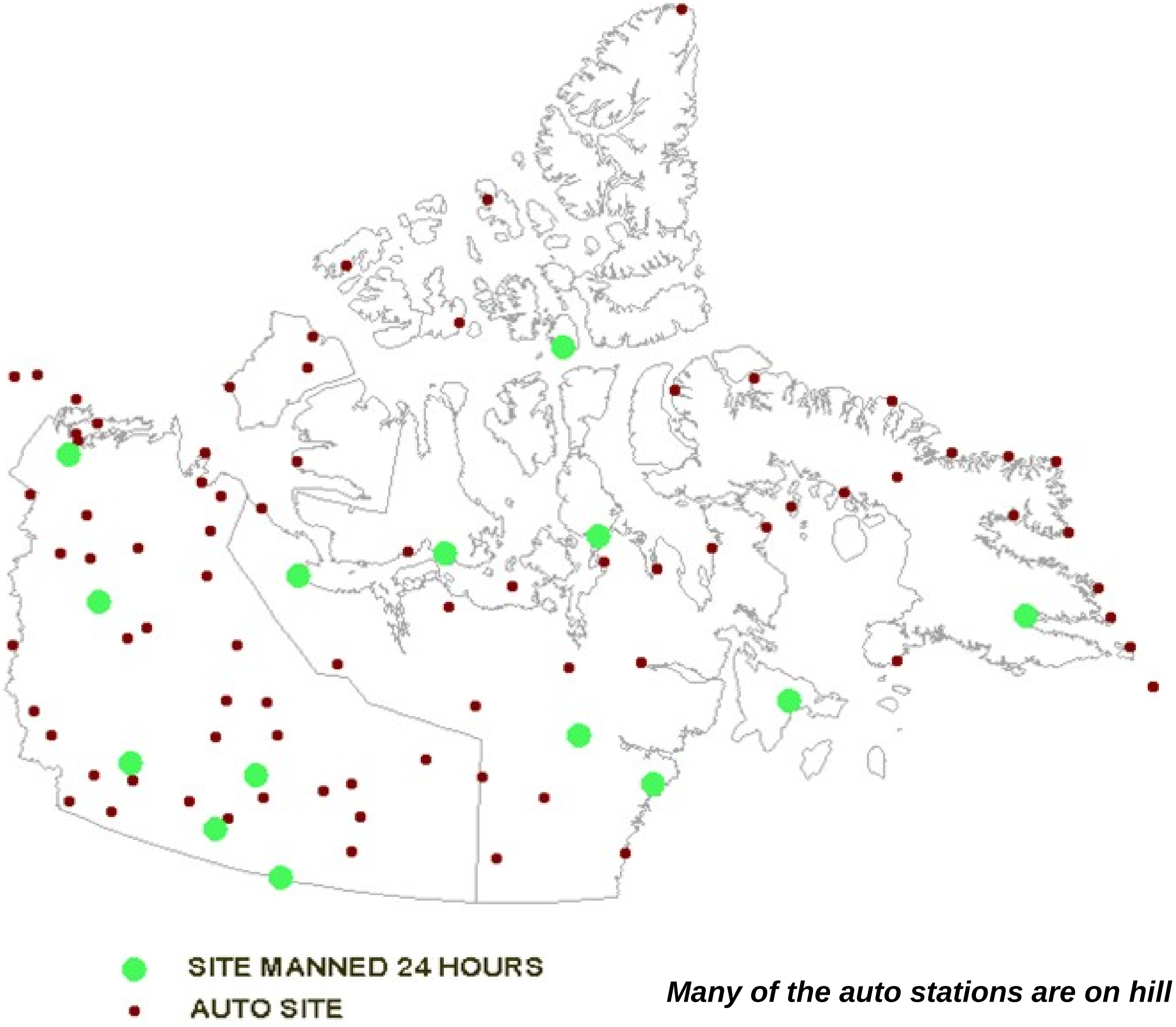


Many of the auto stations are on hill and mountain tops

- Number and density of surface weather stations is low
- Many stations have no manned observations
- Many stations do not operate at night
  - some may have automatic reports
- Many stations do not operate on the weekend
- Some stations will close operations when weather is bad
- Quality of observations is sometimes suspect, such as
  - ceiling heights during darkness
  - fine snow versus ice crystals
  - amount of snow falling from sky versus blowing snow
- Important, commonly used back-up tool is called the “telephone”
- Interval between site visits for maintenance can be lengthy, even when problems are known to exist



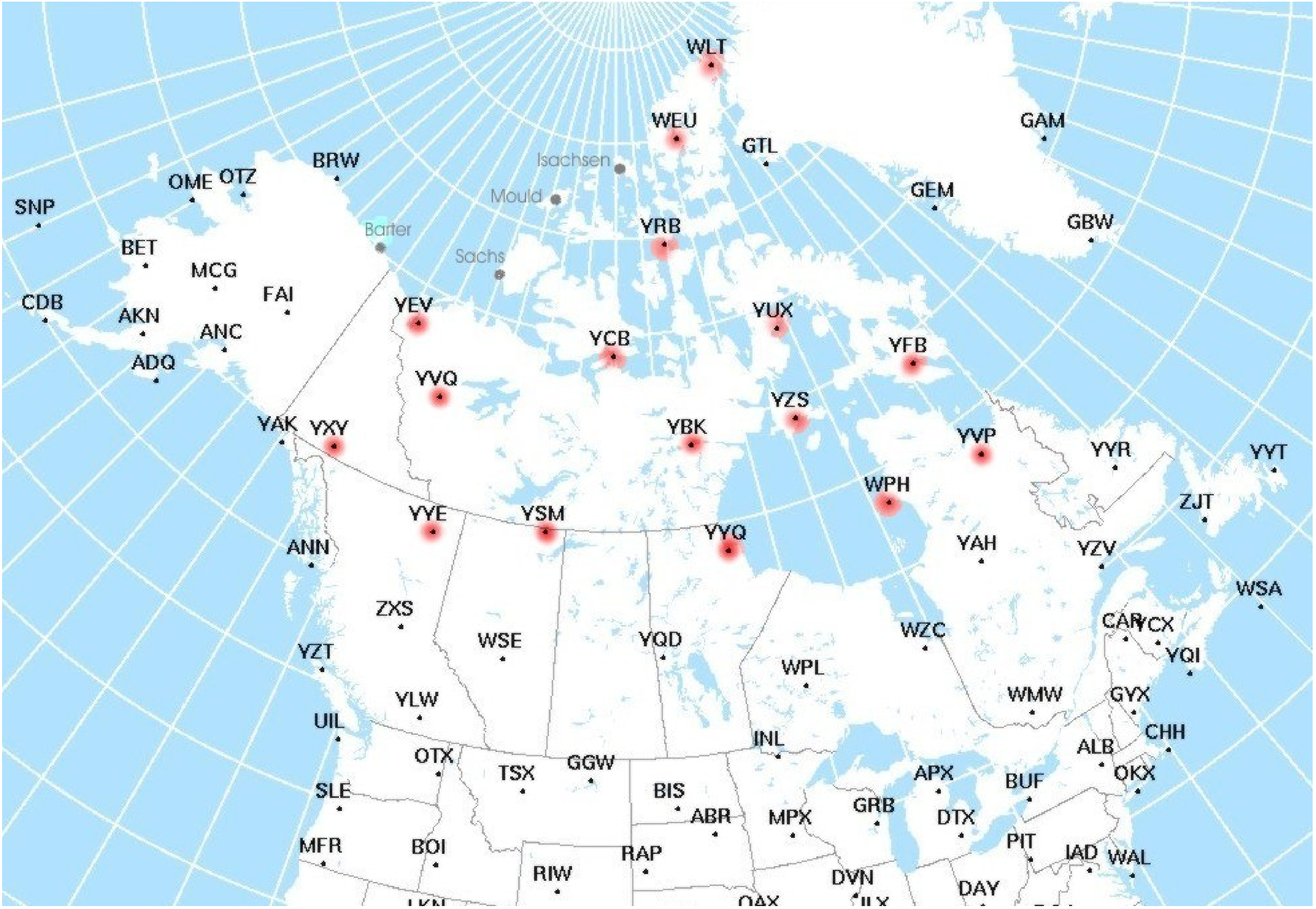
Observing Network



Many of the auto stations are on hill and mountain tops

courtesy of Ed Hudson

Upper Air Network



courtesy of Ed Hudson

So, How Do We Estimate Precipitation Amounts

judgment based on history of storm – how much snow it has produced in the past, and how it has differed from NWP

then adjust for mesoscale influences and forecaster site-specific experience

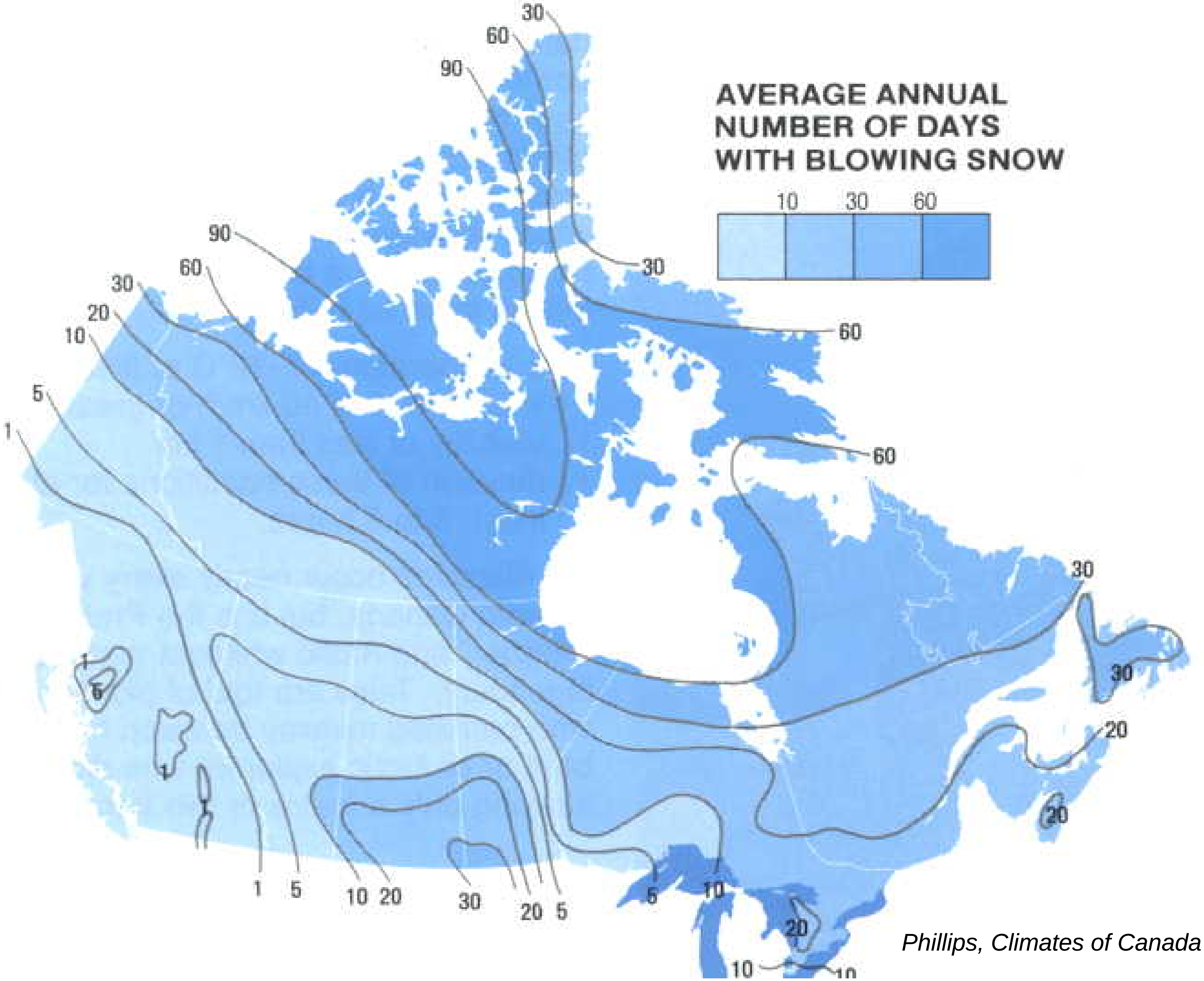
check NWP QPF. If amounts large (10cm) will generally reduce them to < 5cm

the lack of rigor in the above speaks to deficiencies in both the observations and NWP

SCRIBE – software which presents model-based output for site-specific weather elements, used to construct the public forecast

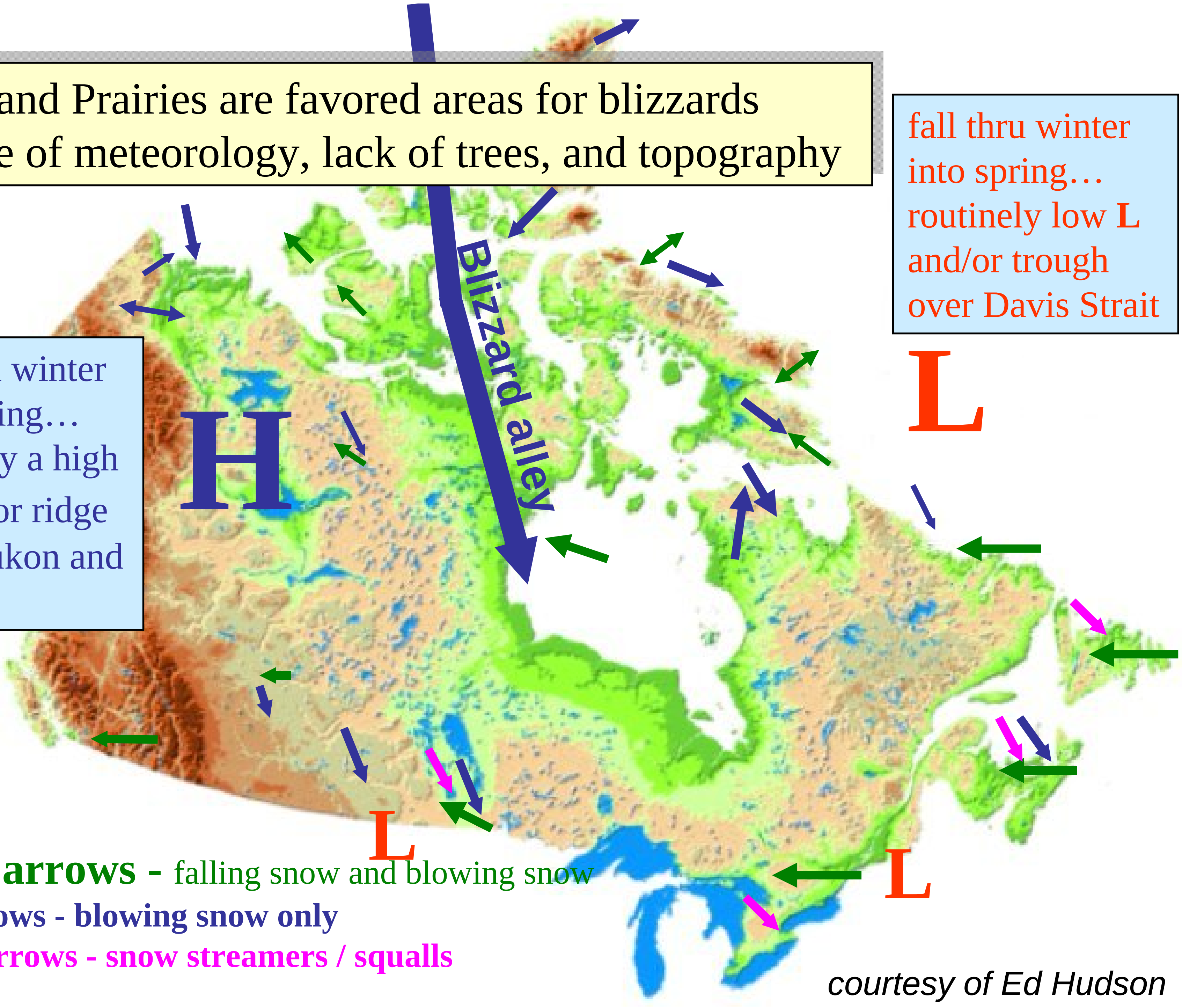
Snow That Blows Around

- Will begin with a brief discussion of some of the common weather patterns that lead to blizzards
- Will show examples of
  - synoptic patterns
  - mesoscale influences
  - what forecasters have to “think about”
- A few words about the “tools” used to help forecast the likelihood of a blizzard



Phillips, Climates of Canada 1990

Arctic and Prairies are favored areas for blizzards because of meteorology, lack of trees, and topography

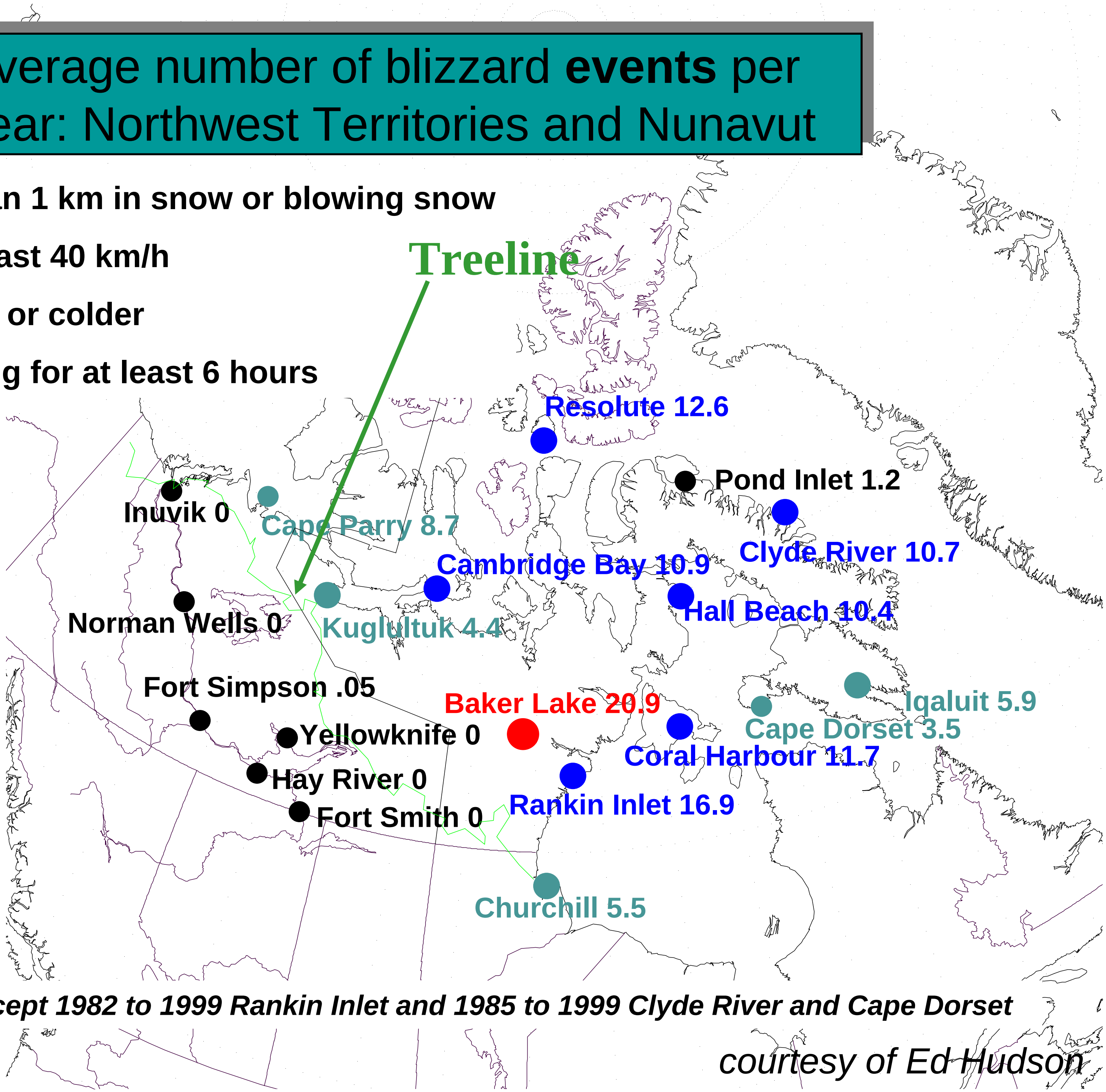


Green arrows - falling snow and blowing snow
Blue arrows - blowing snow only
Purple arrows - snow streamers / squalls

courtesy of Ed Hudson

Average number of blizzard **events** per year: Northwest Territories and Nunavut

- ✓ **Visibility less than 1 km in snow or blowing snow**
- ✓ **Wind speed at least 40 km/h**
- ✓ **Temperature 0°C or colder**
- ✓ **Conditions lasting for at least 6 hours**



1980 to 1999 data except 1982 to 1999 Rankin Inlet and 1985 to 1999 Clyde River and Cape Dorset

courtesy of Ed Hudson

Snow on the Move

(Feb 06, 2006)

What the forecaster needs to worry about...

wind speed

will snow fall from the sky

when did it last snow

how much snow fell, locally and upstream

character of snow on the ground

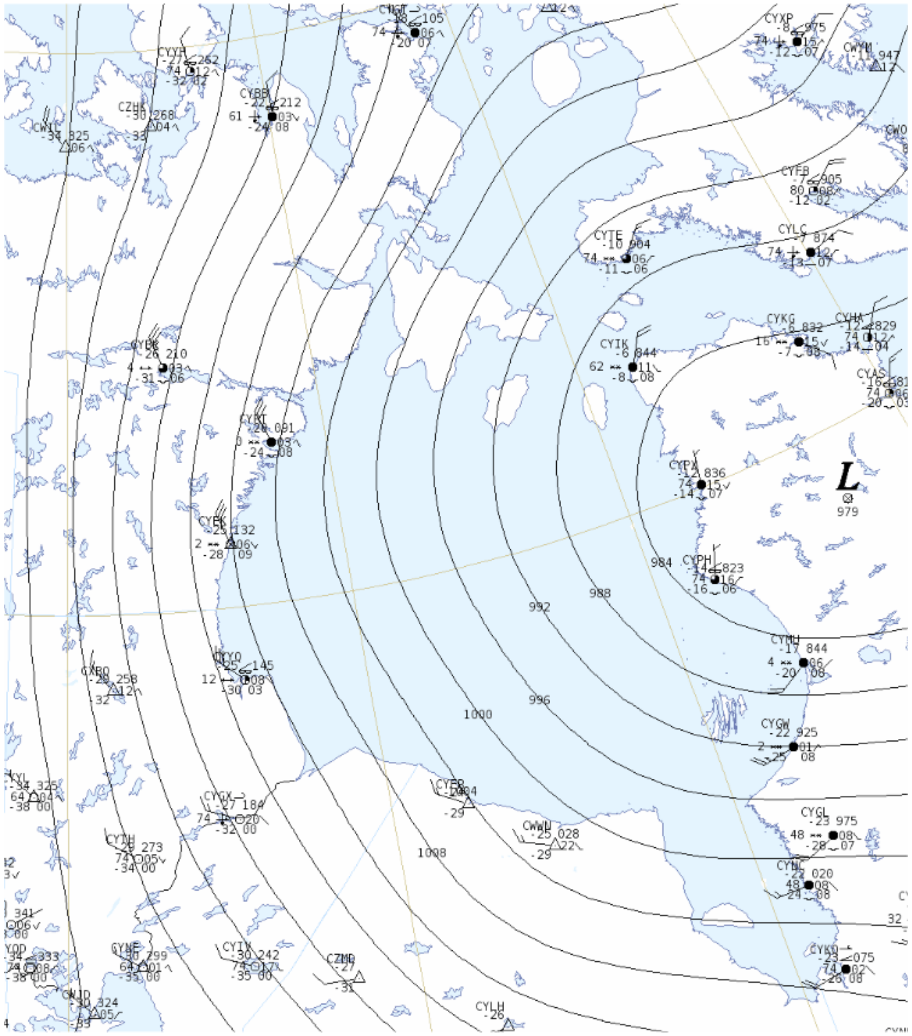
temperature changes since last snow fall

any rain since last snow fall

“fetch” of available snow-to-blow

underlying surface – tundra, trees, ice

site experience – some locations are more/less prone to blizzards based on wind direction / speed

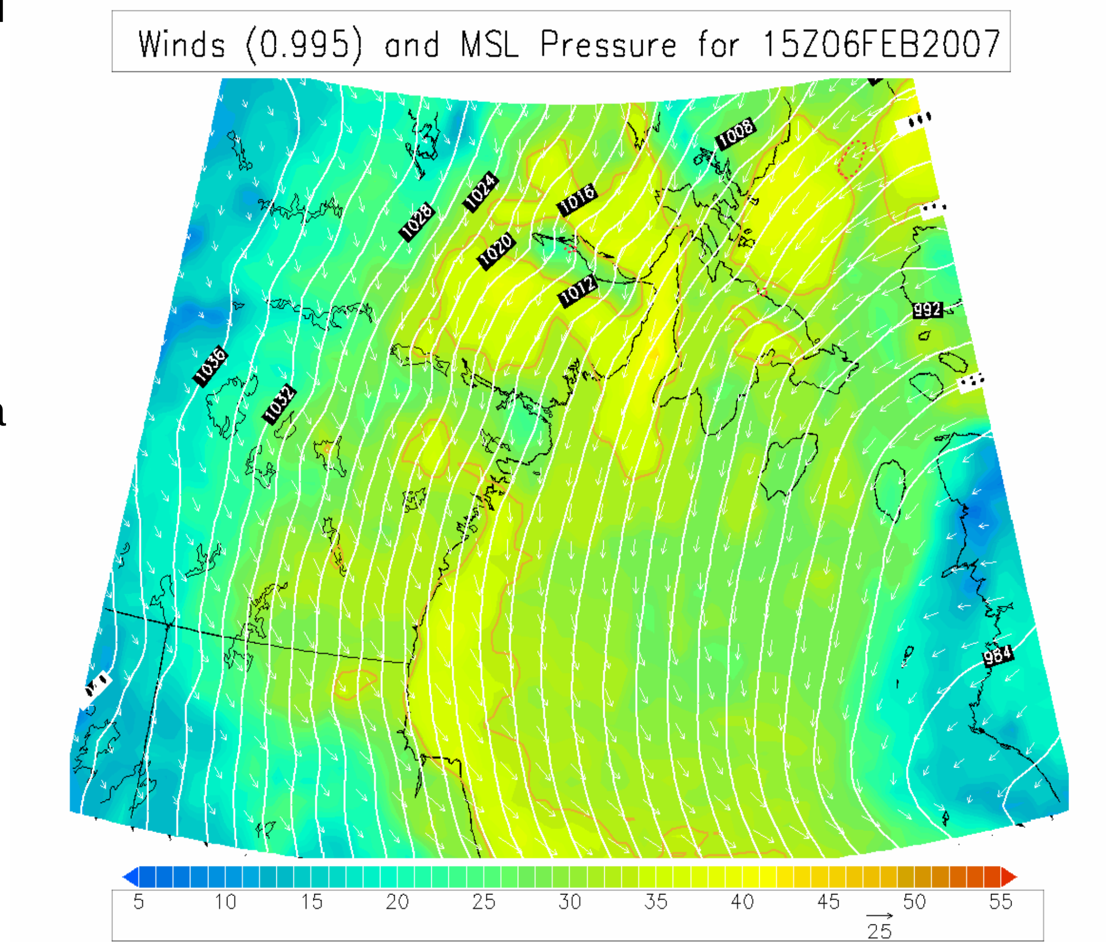


Visibility at Baker Lake was < 1 km with winds 35 km/hr to 60 km/hr for over 4 days.

What mass of snow was transported? No idea, but it must have been very large.

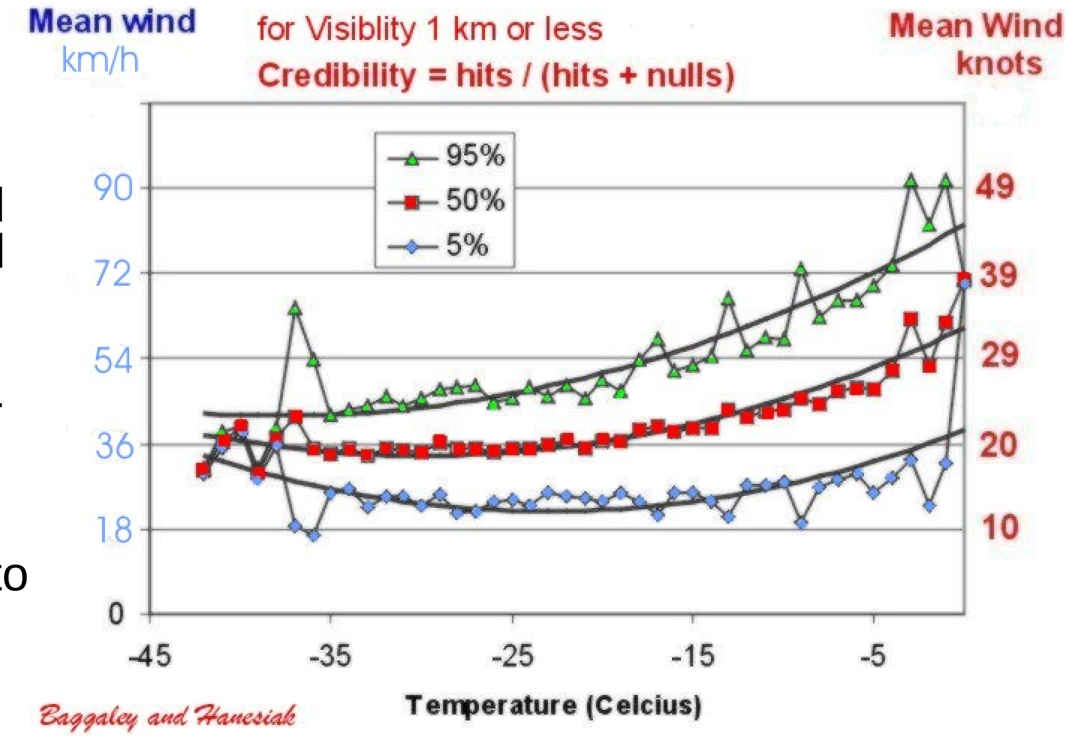
Tools - NWP

- In regions without strong mesoscale influences, the GEM is reasonably good for the all-important wind speeds
- We are hopeful that higher resolution GEMLAM will help in regions where mesoscale influences are important
- Human experience is used on a site-by-site basis to adjust the winds with possibilities of blizzards in mind
- We've already discussed how comfortable the forecaster is with GEM QPF to answer the "will snow fall from sky" question
- We do not make use of, or have any experience with blowing-snow models



Tools - Statistics

- John Hanesiak (U. of Manitoba) and Dave Baggaley have used station climatology to construct charts of the likelihood of blizzard conditions given temperature and wind speed
- Others have done similar in other regions
- Verification of these methods is, to me, unknown

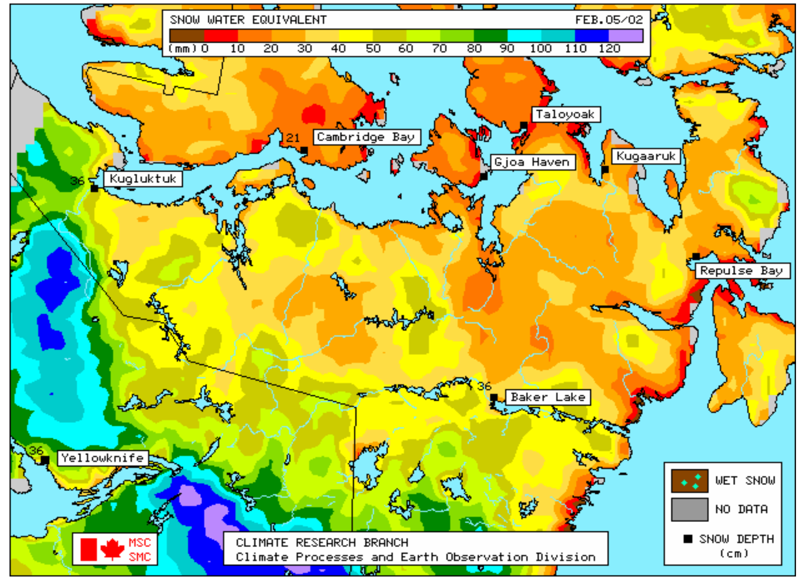


	Drifting	Blowing	Blizzard
Wind Speed - General	less than 35 km/h	35 to 39 km/h	40 km/h or greater (visibility less than 1 km)
Wind Speed - Arctic Basin per Radionov, V.F. et al, 1997	greater than 22 km/h (6m/sec)	winds of 25 to 29 km/h (7 to 8 m/sec)	
Wind Speed - Antarctica		winds of 36 km/h or more (10 m/sec or more)	
Wind Speed - U.S. National Weather Service			56 km/h (explainable as visibility is visibility lower than 0.4 km

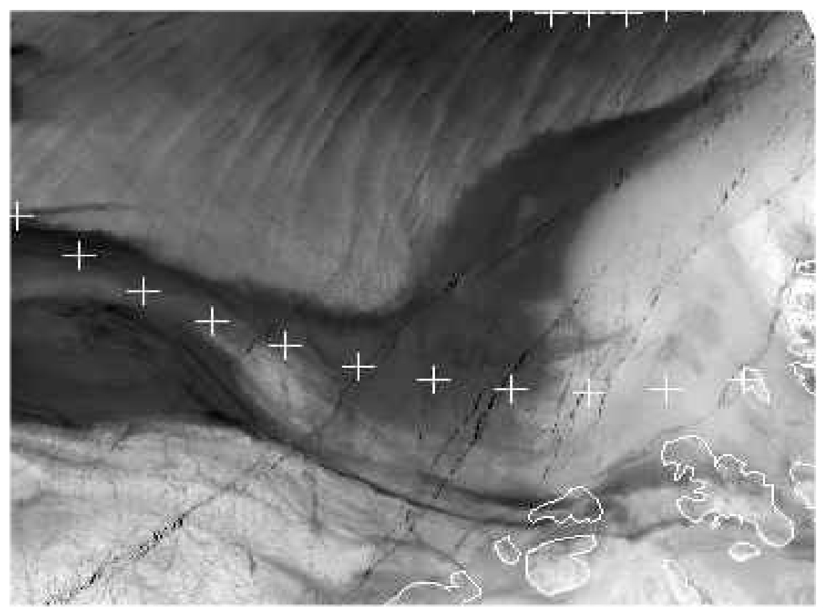
figures courtesy of Ed Hudson

Tools – Remote Sensing

- Snow Water Equivalent charts derived from microwave are used to attempt to monitor changes in snow depth and snow cover
- These are provided by Climate Research Branch (Anne Walker)
- I defer to CRB to comment on the accuracy / utility of these charts in a later session

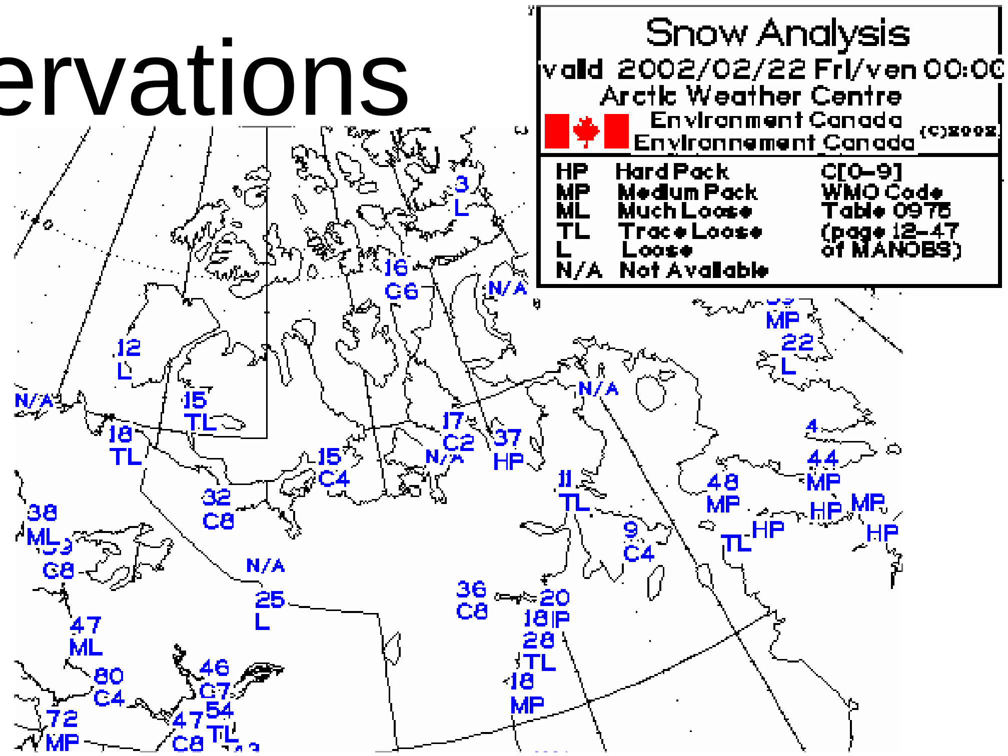


- Banding on POES imagery indicate blowing snow
- Generally only seen over the ice
- A diffuse area over land also indicates blowing snow but this is only rarely observed

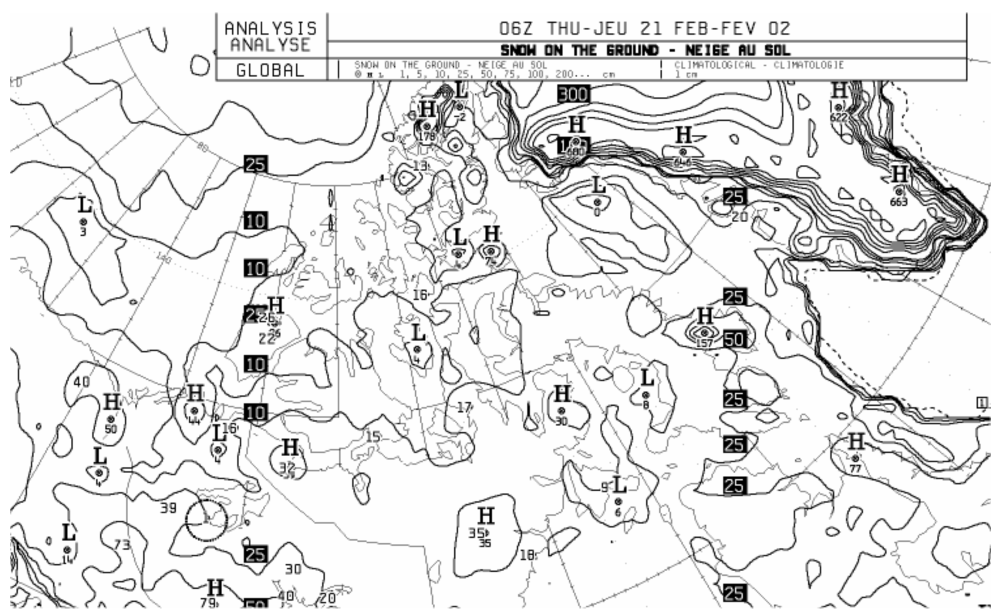


Tools – Observations

- first and last observations of the day give snow depth and information about snow pack
- At the SPC-PNR, these observations are extracted and put into graphical form
- These are very important pieces of information for the forecaster



- other snow depth analyses are used as well



So, How Do We Estimate If Snow Will Move Around (Blizzards)

first guess for wind speeds from NWP

then adjust for mesoscale influences

then determine if there is any snow-to-blow

determine end time by when winds speeds drop or run out of snow

(sounds easy, eh)

Questions?
Thank You
and
The End