Snow land observations: overview, recent developments

M J Sandells

With thanks to:

S. Pullen, C. Charlton-Perez, P. De Rosnay,

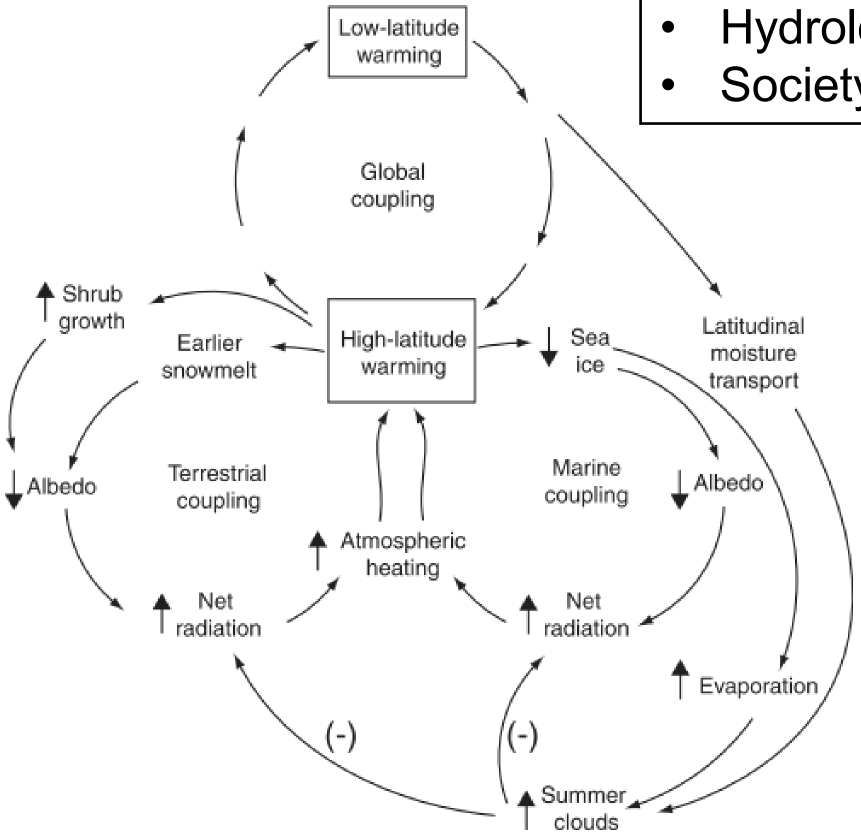
M. Dumont, N. Rutter

Key Messages

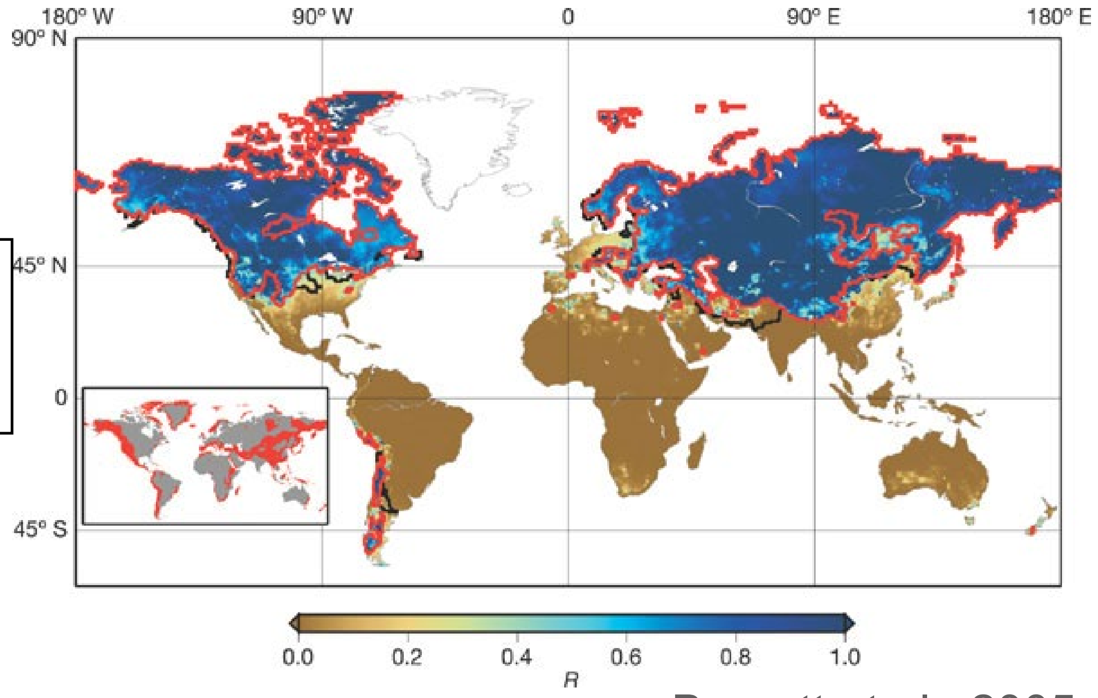
- Snow matters: NWP, climate, hydrology, society
- Reporting of snow data is increasing but ‘no snow’ reports lacking
- In-situ measurements (know a lot about a point) or broader picture from remote sensing
- Currently underutilizing observations BUT exciting opportunities ahead

Why snow matters

- NWP/ Climate
- Hydrology
- Society / Economics



Chapin et al., 2005



Barnett et al., 2005

AGU PUBLICATIONS

Water Resources Research

COMMENTARY

10.1002/2017WR020840

Special Section:
Earth and Space Science is Essential for Society

Key Points:
- Snow is a critical but often-unappreciated resource used by

Water and life from snow: A trillion dollar science question

Matthew Sturm[1], Michael A. Goldstein[2], and Charles Parr[1]

[1]Geophysical Institute, University of Alaska-Fairbanks, Fairbanks, Alaska, USA, [2]Finance Division, Babson College, Wellesley, Massachusetts, USA

Abstract Snow provides essential resources/services in the form of water for human use, and climate regulation in the form of enhanced cooling of the Earth. In addition, it supports a thriving winter outdoor

Sturm et al. (2017)

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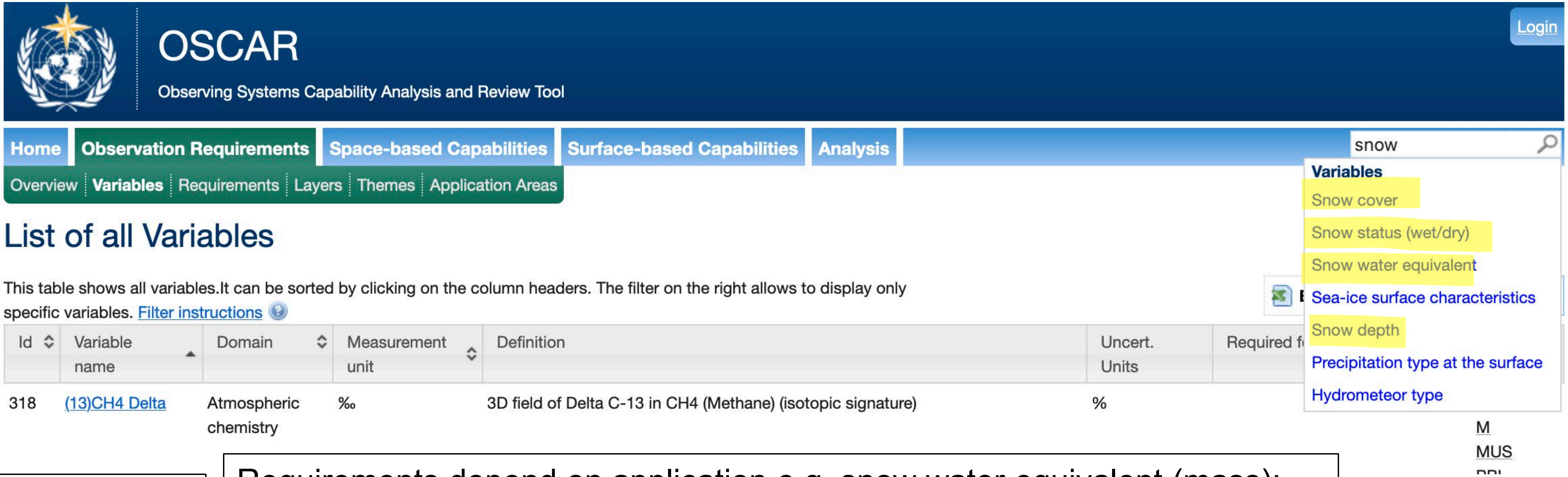
Snow parameters



No SWE sensor at these resolutions => some in-situ depth + snow cover

Requirements depend on application e.g. snow water equivalent (mass):

Daily, 100m resolution, 5mm uncertainty (Hydrology)

Vs

Hourly, 500m resolution, 5mm uncertainty (high resolution NWP)

Vs

Daily, 1km resolution, 10mm uncertainty (Climate monitoring)

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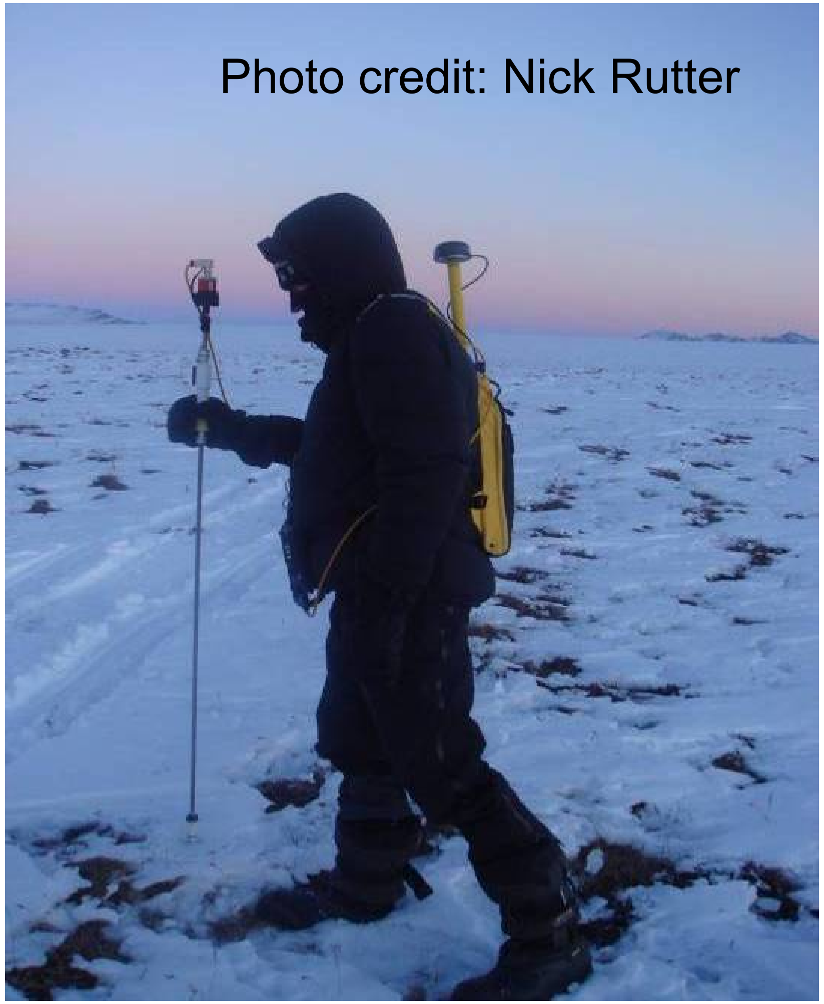
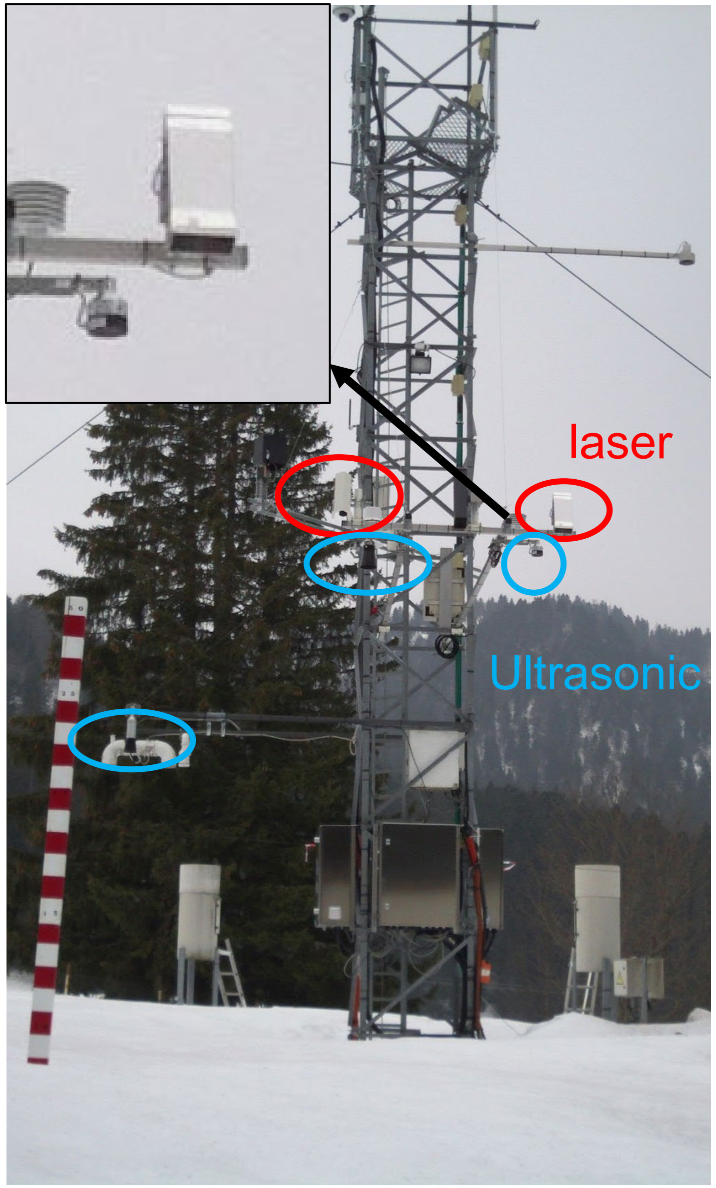
In-situ: snow depth





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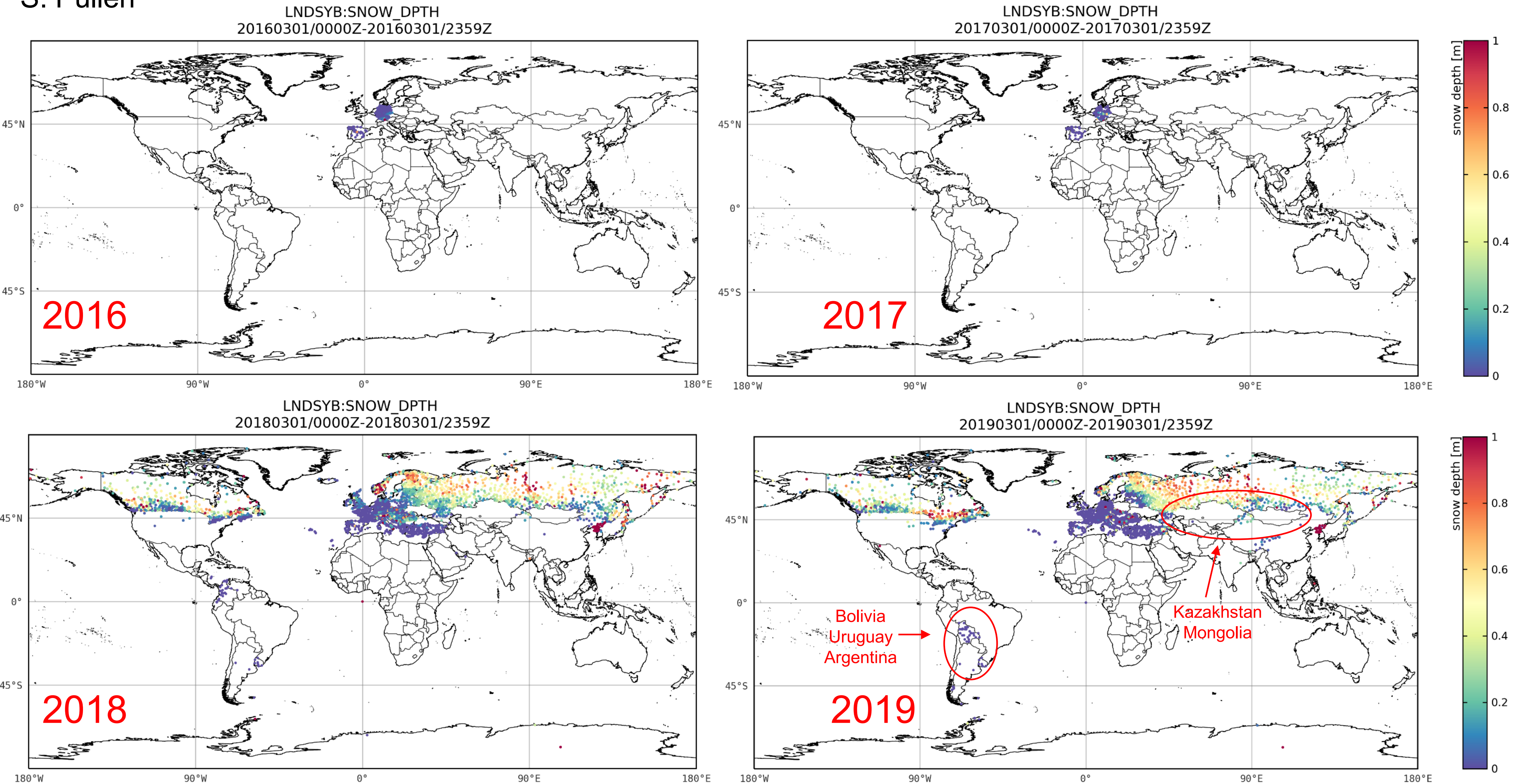
=> How are these data used in NWP?

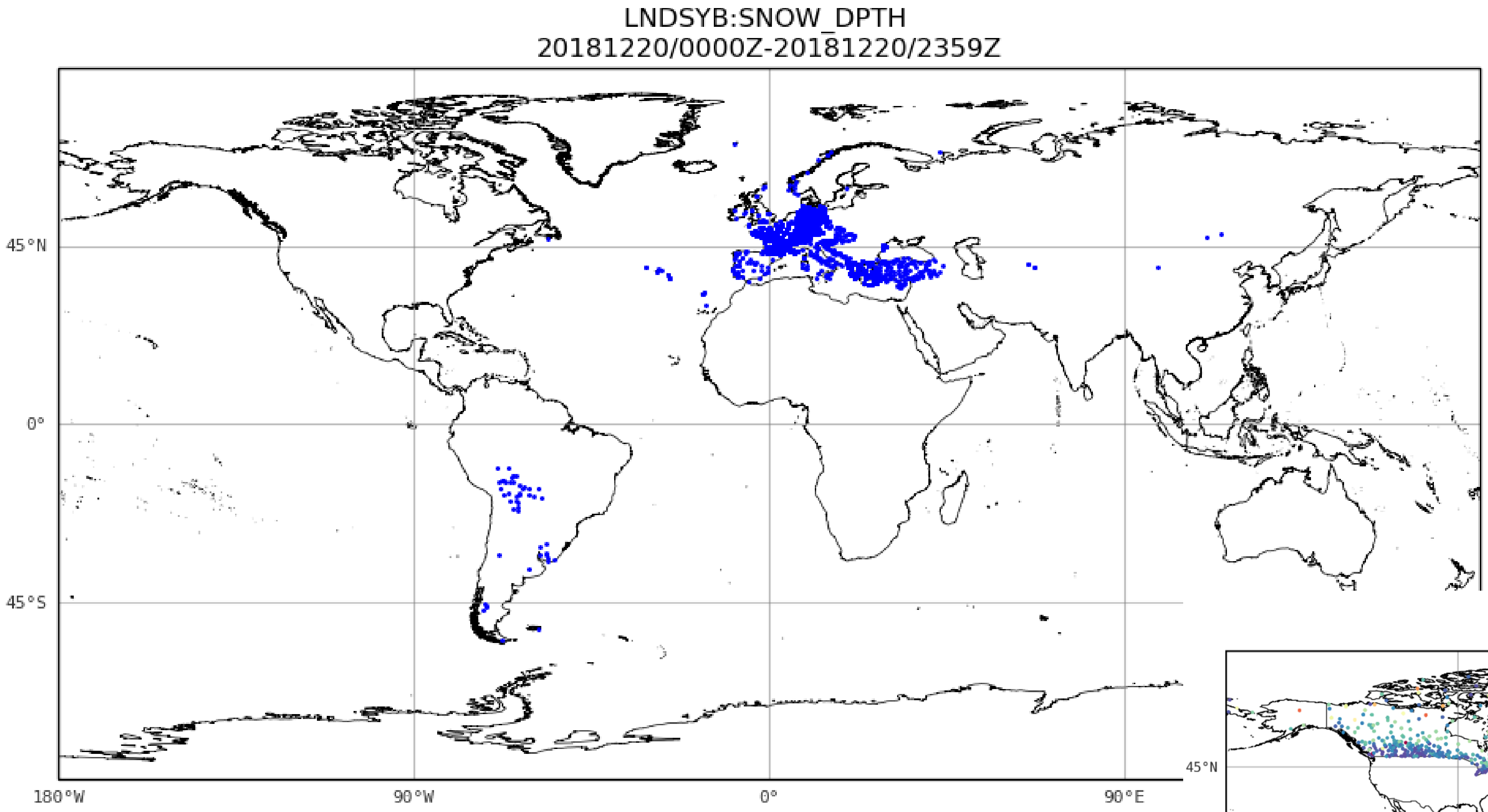
Global SYNOP BUFR reporting

Met Office
S. Pullen



Global reporting of zero snow depth

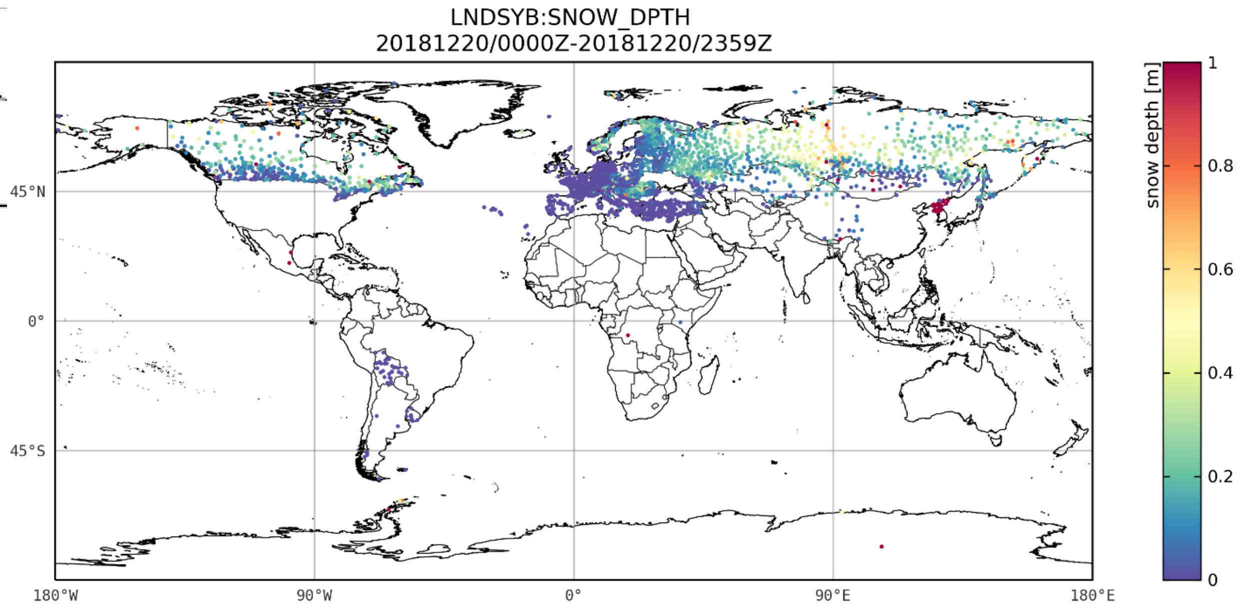
S. Pullen



December 2018

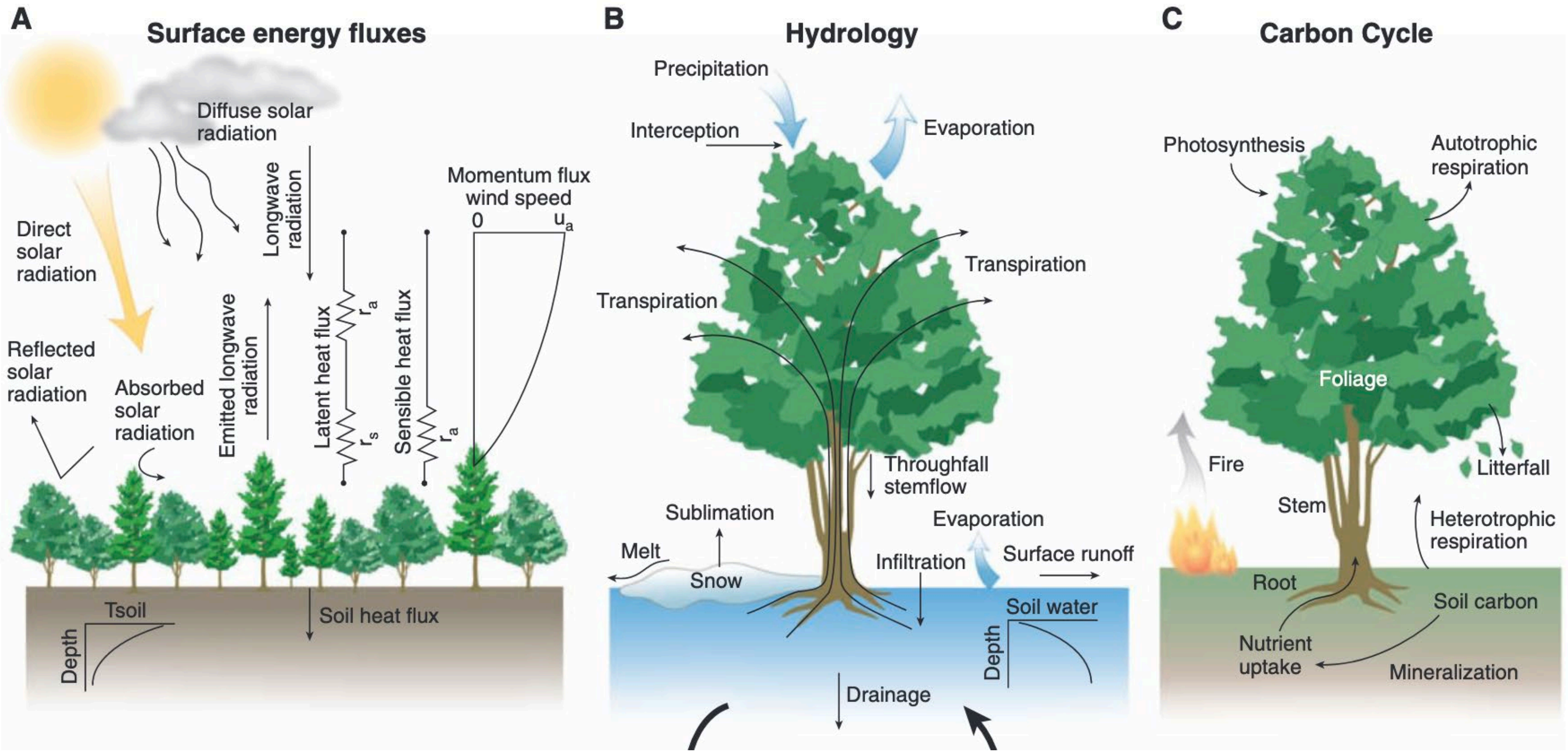
Good uptake in Europe

Some in China, S. America



=> Why does zero snow depth reporting matter?

Why getting the snow right matters



Bonan et al. (2008), Science

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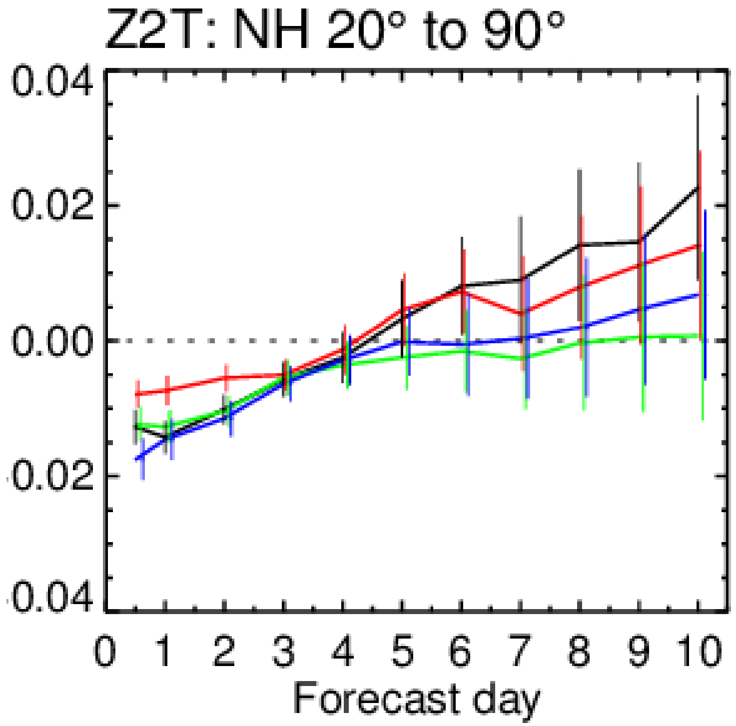
ECMWF

Snow data assimilation OSEs

P. De Rosnay

Winter 2014-2015 (December to April) - Assess the impact of the snow observing system

Expts	SYNOP	National Data	IMS snow cover
0- OL (no snow data assimilation)			
1- Snow DA: SYNOP+IMS	✓		✓
2- Snow DA: SYNOP+Nat (all in situ)	✓	✓	
3- Snow DA SYNOP+Nat+IMS (all)	✓	✓	✓



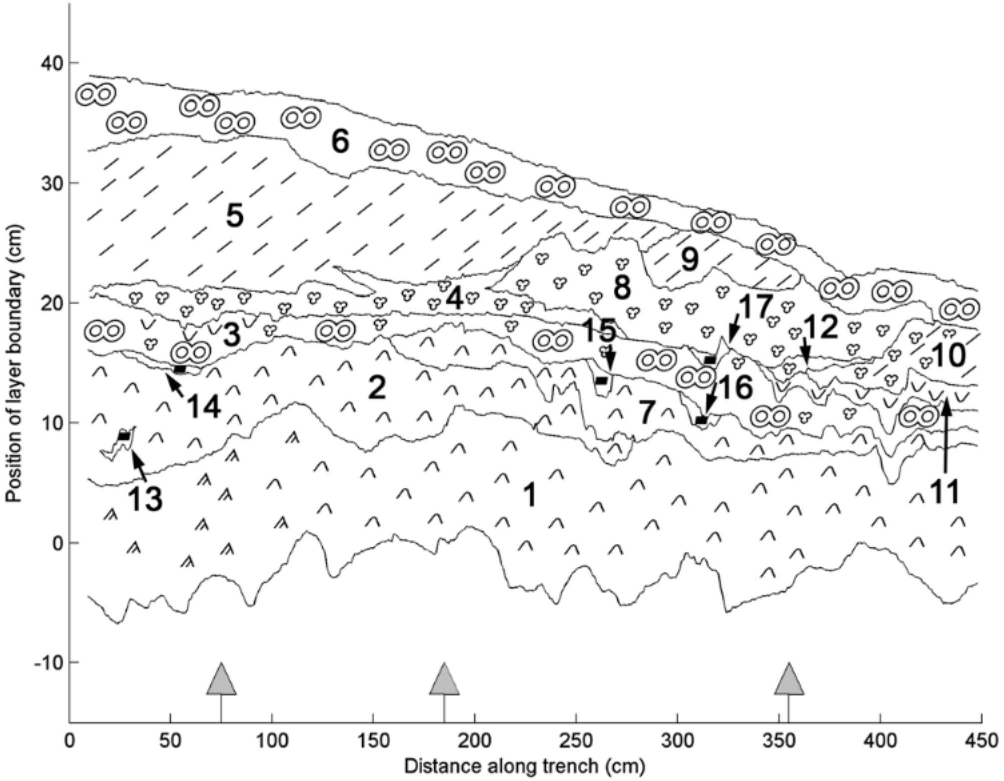
Impact on T2m Forecasts:
Normalized RMSE for T2m FC difference compared to the reference (no snow DA)

Ref (no snow DA)
SYNOP+IMS (1-0)
SYNOP+Nat (2-0)
SYNOP+Nat+IMS (3-0) -> oper

=> Patricia De Rosnay
Weds 3pm

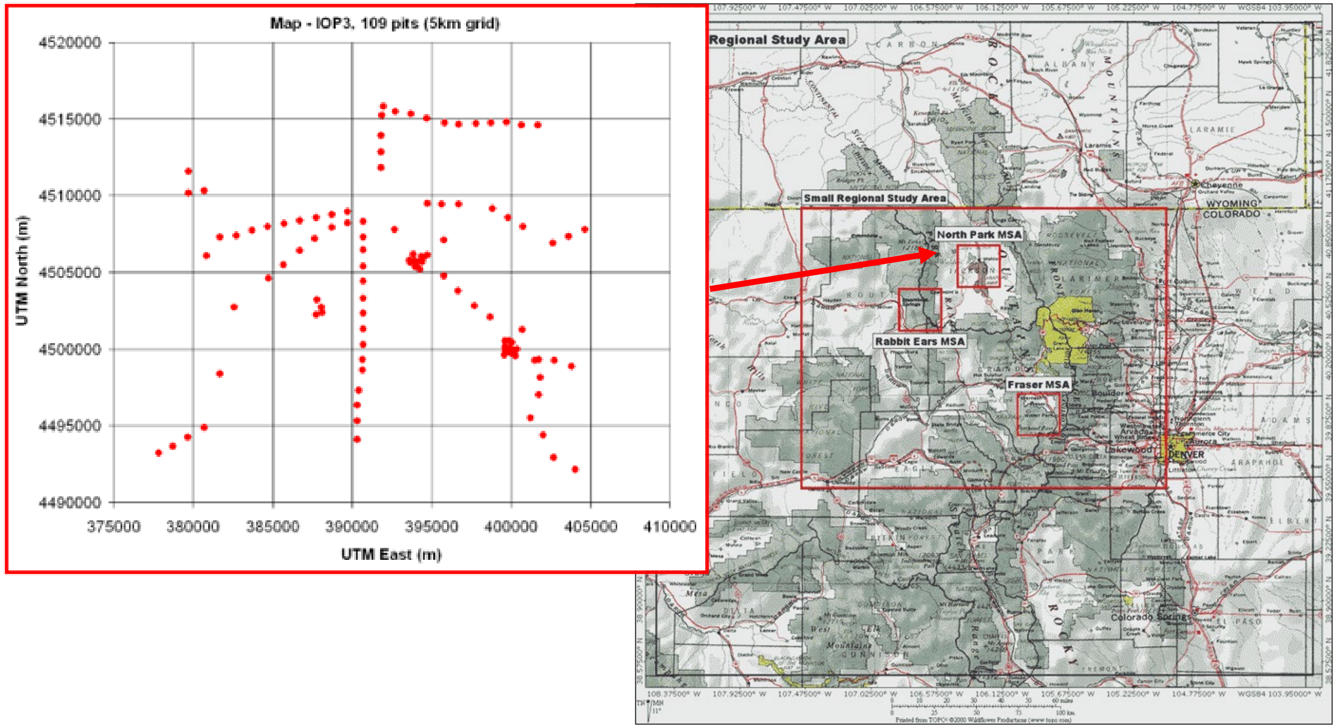
Best T2m Forecast when all observations, combining in situ and IMS, are assimilated.

In-situ vs remote sensing



Rutter et al., JGR-Earth Surface (2014)

- Can know a lot about a little snow (in-situ) but may not be representative of larger area e.g. SNOTEL sites



Cline, D., R. Armstrong, R. Davis, K. Elder, and G. Liston. 2002, Updated July 2004. *CLPX-Ground: ISA Snow Pit Measurements*

=> Remote sensing offers (global) measurements at more useful scales….

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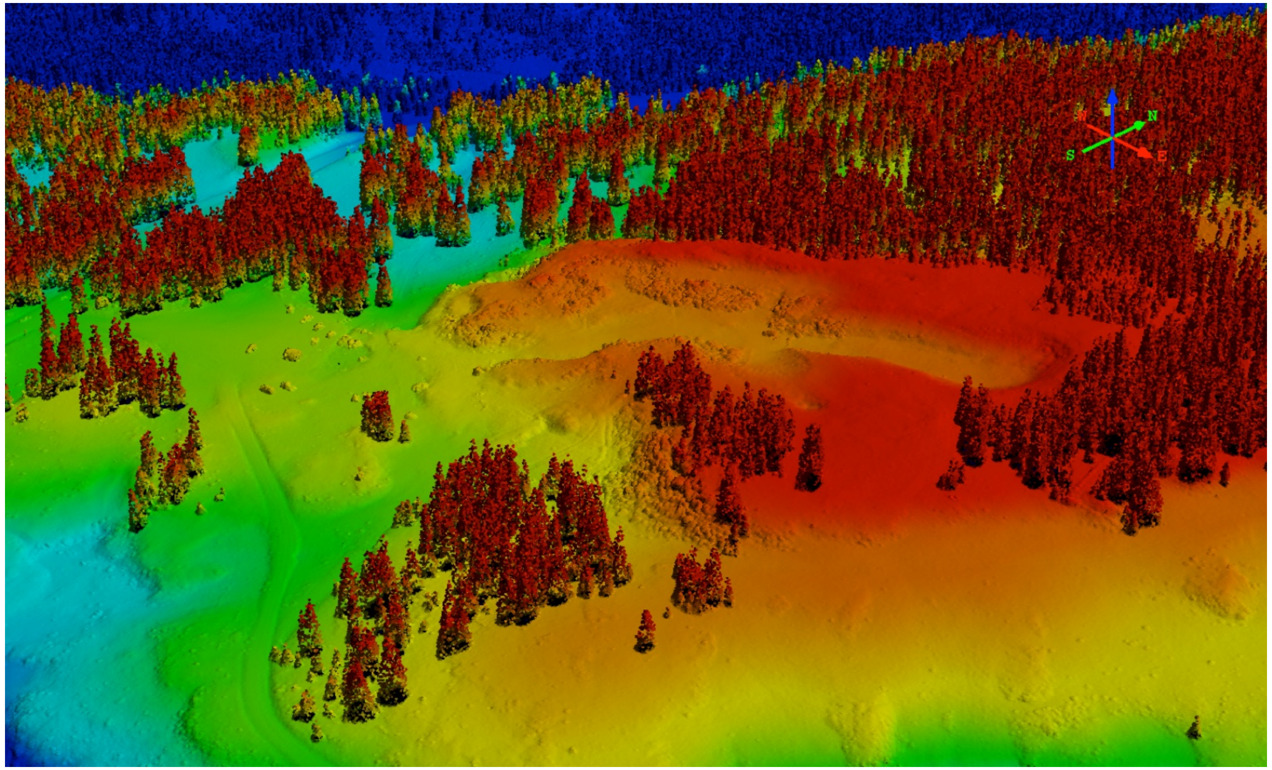
Remote sensing: snow depth



Airborne Snow Observatory

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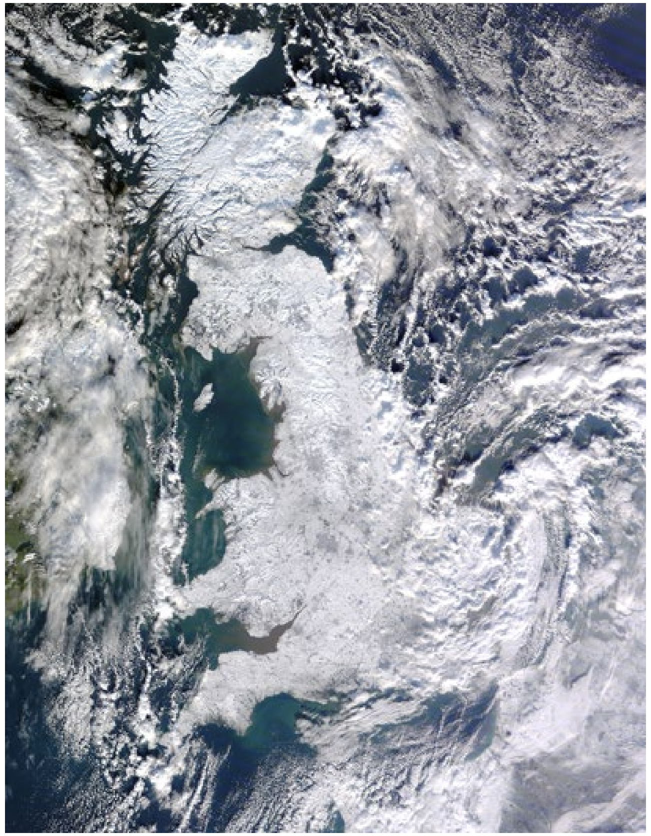
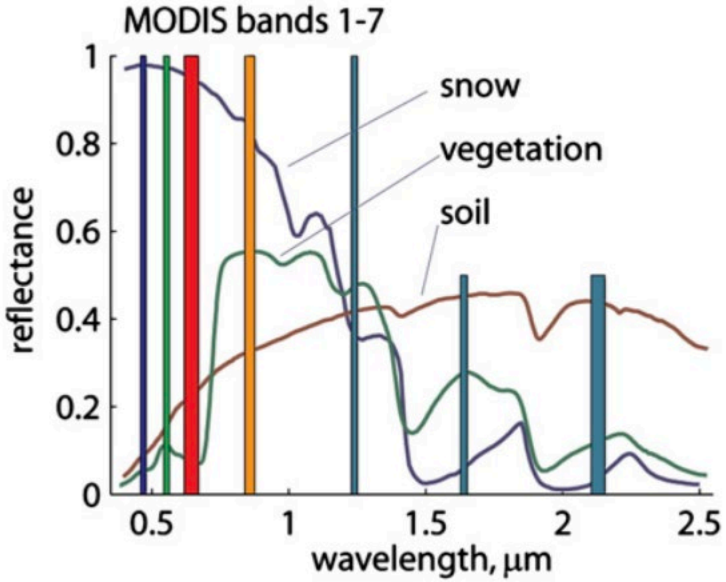
Remote sensing: snow cover



@NASA Terra 7th Jan 2010



Painter et al., RSE, 2009

- Daytime, cloud-free conditions
- Resolution 10-100s metres
- Can use spectral mixing theory to get fractional snow covered area

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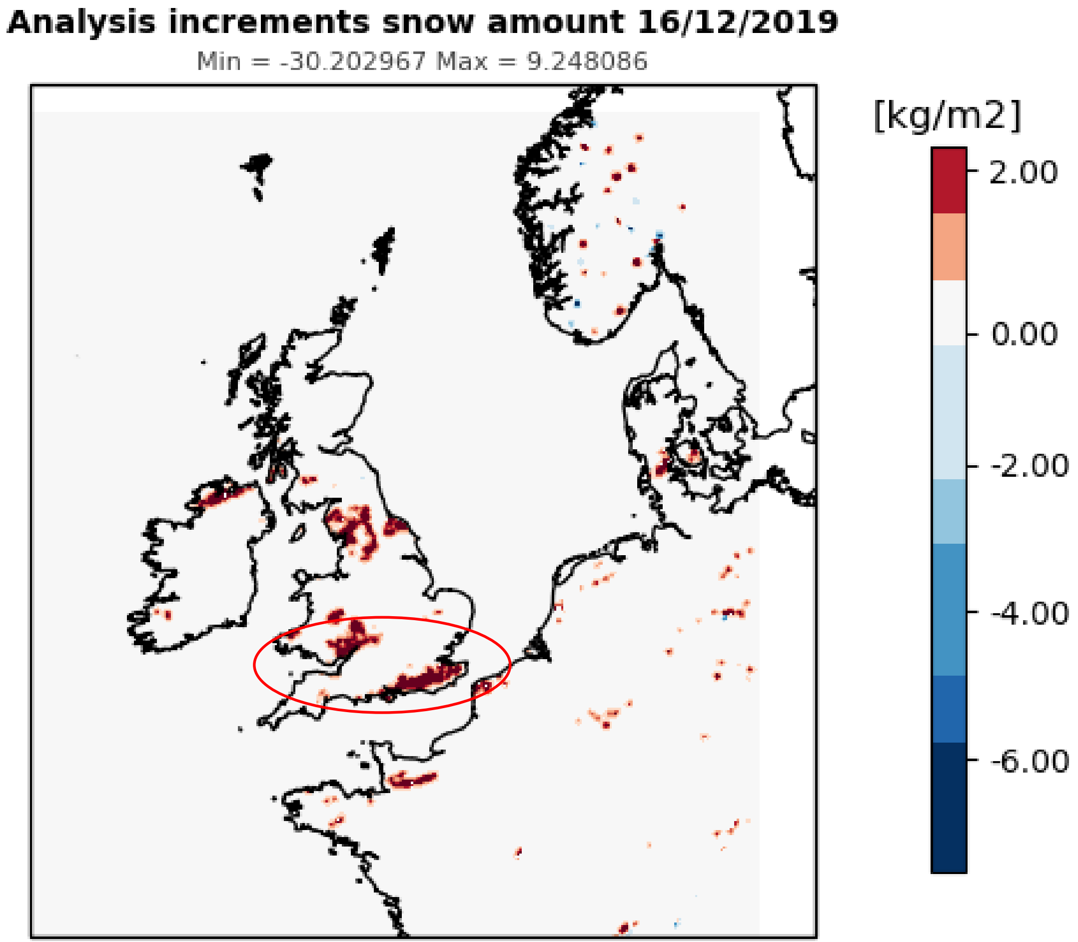
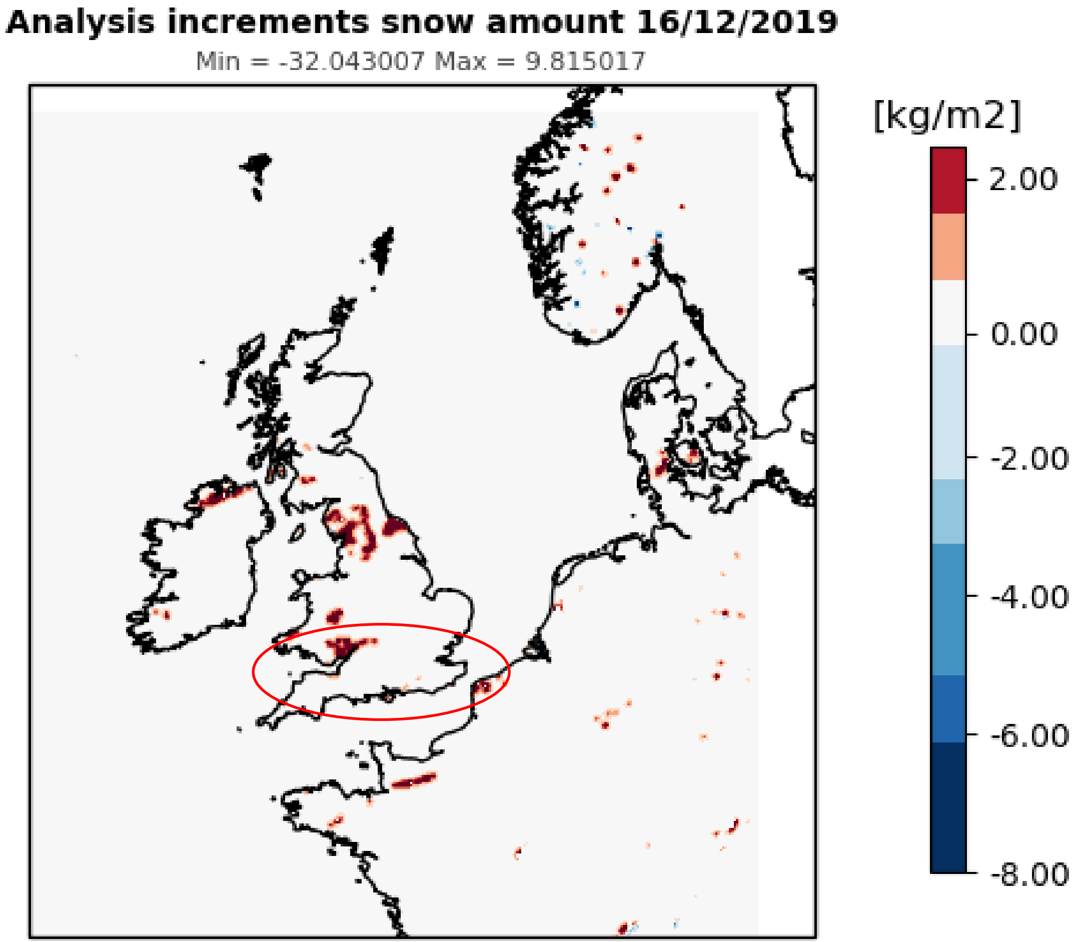
- Control (06Z)

Trial (06Z)





Ground-based Synop network

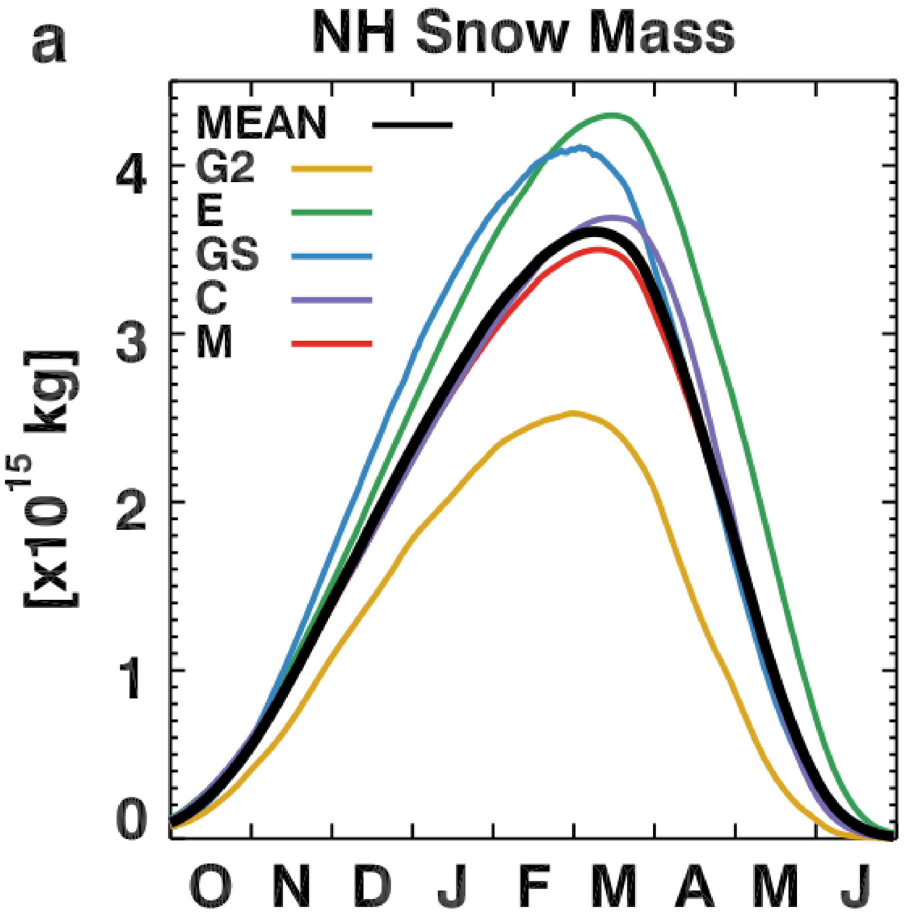
- snow depth
- state of ground (snow or no snow)

Satellite data from MSG-SEVIRI

- EUMETSAT H-SAF (H31) daily snow cover product

What about snow mass?

Mudryk et al., J. Climate, 2015



GlobSnow: passive microwave + assimilation of station snow depth (microstructure estimate)

Dataset	Abbreviation	Snow scheme	Land model	Forcing data	Resolution
GlobSnow	GS	Satellite passive microwave + in situ[a]			25 km
ERA-Interim/Land	E	Simple	HTESSEL	ERA-Interim	$3/4° \times 3/4°$
MERRA	M	Intermediate	Catchment	MERRA	$1/2° \times 2/3°$
Crocus	C	Complex	ISBA	ERA-Interim	$1° \times 1°$
GLDAS-2	G2	Simple	Noah 3.3	Princeton Meteorological	$1° \times 1°$

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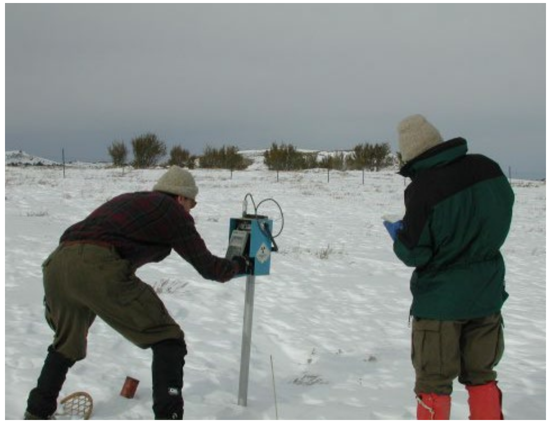
In-situ observations: snow density



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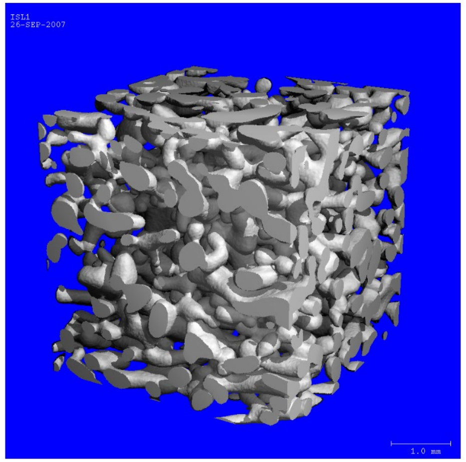
Remote sensing: snow mass

- Snow scatters microwave radiation
- Sensitive to snow mass + microstructure
- New models (e.g. SMRT) to understand microwave scattering
- New microstructure measurement techniques (SMP, micro-CT, infrared reflectance)

⇒ **Interpret satellite observations**
(past + present)



⇒ Alan Geer
Fri 4pm

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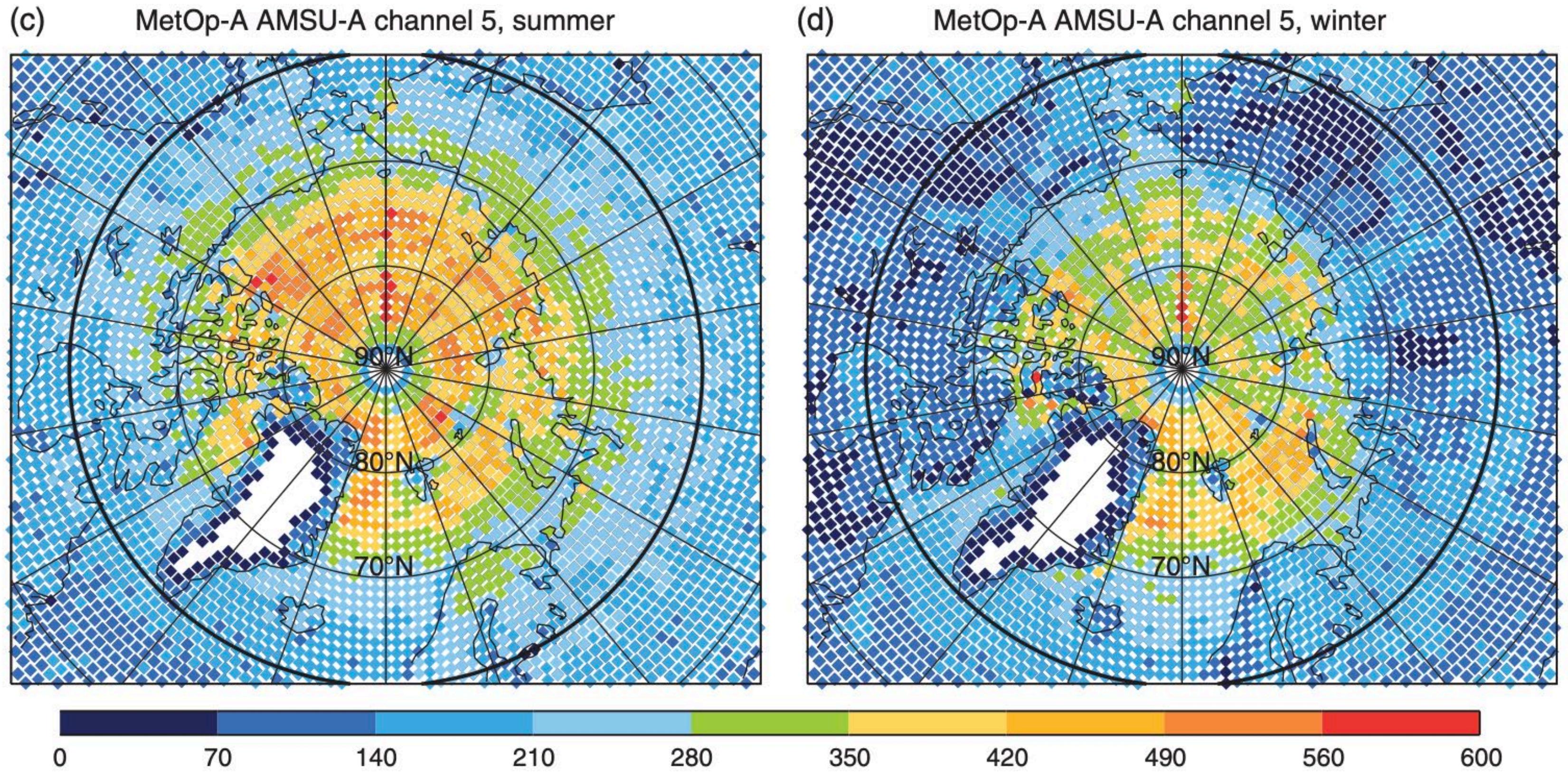
Underutilization of data

54 GHz



Lawrence et al., QJRMS, 2019

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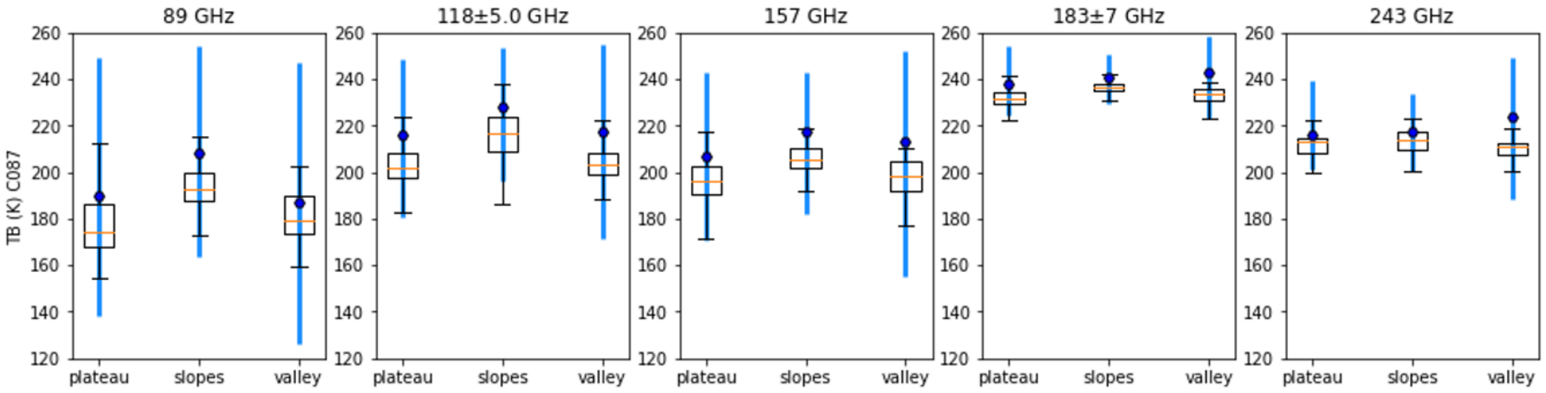
Snow emissivity 89-243 GHz

In-situ snow properties + SMRT + ARTS atmosphere
=> good comparison with airborne data



Coupled land-atmosphere data assimilation?

Summary + Perspectives

- Get snow right! => mass / energy atmosphere exchanges
  - zero snow depth reporting matters!
- In-situ measurements: know a lot about a point, representative?
- Remote sensing data: greater coverage but hard to interpret
- 100m-1km SWE requirements challenging but new sensors on horizon
- Microwave observations are underutilized for NWP
- We are making huge advances in understanding snow (mature enough for coupled DA)
- We have 40+ years of microwave data: invest in people to use it

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