Measuring High-Latitude Precipitation from Space

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Outline

• Precipitation from space (as it is falling)
  • State-of-the-art
  • Uncertainties
• The ICECAPS project
  • Process studies
  • Arctic EO validation site
IWSSM-4
Fourth International Workshop on Space-based Snowfall Measurement

• Held March 2013, Mammoth
• 50 participants
• Reports back to IPWG, CGMS, WMO
• Detailed recommendations from four working groups:
  1. Applications & Validation
  2. Radiative Properties
  3. Global & Regional Detection/Estimation
  4. Missions & Concepts

Ralf Bennartz, University of Wisconsin
Robin Hogan, University of Reading
Paul Joe, Environment Canada
Gail Skofronick Jackson, NASA GSFC
Graeme Stephens, JPL
Deb Vane, JPL
Jeff Dozier, UCSB
Type

NEXRAD 1638Z

Terra MODIS 1635Z
Observing Clouds with CloudSat

Strengths of CloudSat:

- Active sensor
- Excellent sensitivity
- Near-global coverage
- Coincident measurements from other A-Train sensors

T. L’Ecuyer
Arctic/Antarctic Snowfall climatologies from CloudSat

**Fig. 4.** Reference plot for interpreting the difference plots presented below. Values are for the average $Z_a$–$S$ relationship, with no vertical continuity test, a −10-dBZ$_a$ threshold, and the use of attenuation correction. (top) The snow frequency (precisely, the percent of total CloudSat profiles in each bin considered to be snowing), and (bottom) the mean liquid equivalent snow rate (mm day$^{-1}$).

Hiley, Kulie, Bennartz (JAMC, 2011)
Global Precipitation Measurement (GPM)

- Joint NASA/JAXA mission
- 2013: As soon as NASA finds a launch vehicle...
- **Active**: Dual-frequency Precipitation Radar (DPR) 12/17 dBZ MDS
- **Passive**: Multi-frequency GPM Microwave Imager (GMI): 13 channels (10-183 GHz)

Dual-frequency precipitation radar (DPR) consists of Ku-band (13.6GHz) radar: KuPR and Ka-band (35.5GHz) radar: KaPR

GPM - Courtesy of NASA GSFC
Global Precipitation Measurement (GPM)

- **GPM-DPR**

- “It is estimated that due to its higher detectability threshold, only about 7%/1% of the near-surface radar reflectivity values and about 17%/4% of the total accumulation associated with global dry snowfall would be detected by a DPR-like instrument”

(Kulie & Bennartz 2009, from global CloudSat observations)
FOUR INSTRUMENTS:
DOPPLER CLOUD RADAR
HIGH SPECTRAL RESOLUTION LIDAR
MULTI SPECTRAL IMAGER
BROAD BAND RADIOMETER
CloudSat: 2006 – 2010 Mean

Map showing the distribution of total snow or rainfall in mm/yr on the left, and the fraction of snow on the right, for Greenland.
GPCC: 2006 – 2010
Snowflakes

**FIG 7.** IcePIC ice crystal photographs taken at approximately 17:40 on 21 Sept. In each individual photograph a reference bar of 500 μm length is provided for scale.

Vermont – Bentley (ca. 1902)

Summit Observatory – Greenland Shupe et al. (2012)
Modeling Non-spherical Particles

In the last 5 years significant progress has been made in modeling non-spherical ice optical properties.

What did we learn?

How can we constrain them?
Uncertainty due to habit

**Fig. 7.** (top) Zonally averaged snowfall frequency. (bottom) Zonally averaged mean snowfall rate (mm day$^{-1}$) for average $Z_r$--$S$ relationship (thick line), with the uncertainty range as given by the upper and lower $Z_r$--$S$ relationships shaded. Averages include a full year of data (cold and warm seasons).

Hiley, Kulie, Bennartz (JAMC, 2011)
Comparison to Canadian Surface Observations

Fig. 13. Map of Canada showing locations of surface stations referenced in section 4g and its associated figures.
ICECAPS

HIGH AND DRY
New Observations of Tropospheric and Cloud Properties above the Greenland Ice Sheet


ICECAPS is a new observational campaign to study how the cloudy atmosphere impacts the energy and hydrological budgets of the central Greenland Ice Sheet.

...
ICECAPS

• NSF-funded observatory

• 2010 – 2018

• Von Walden (WSU)

• Matt Shupe (NOAA/ESRL- U-Colorado)

• Dave Turner (NOAA/NSSL, U-Oklahoma)

• Ralf Bennartz (U-Wisc, Vanderbilt)
Atmospheric Properties over the Greenland Ice Sheet

- **Atmospheric State** - temperature and moisture profiles through the troposphere and lower stratosphere
- **Cloud Macrophysics** - cloud occurrence, vertical boundaries, and temperatures
- **Cloud Microphysics** - cloud phase, water content, optical depth, and particle size
- **Precipitation** - precipitation type and rate
- **Cloud Radiative Forcing** - impact of clouds on the surface radiation balance

Elevation 3255 m
72°35’ N
38°25’ W
Suite of Instruments

• MMCR- 35-GHz millimeter-wave cloud radar
• PAERI- Polar Atmospheric Emitted Radiance Interferometer
• 2 MWRs 14 channel water vapor line and 60-GHz oxygen absorption line and 90, 150 GHz
• Radiosondes – 2 per day, 1 GPS
• Ceilometer and Micropulse Lidar- identify cloud base
• POSS - Precipitation Occurrence Sensor System
• SODAR – boundary layer depth
• Hotplate
• Multi-Angle Snowflake Camera
Mobile Science Facility

**Microwave Radiometers:**
Water vapor, cloud water, temperature

**Ceilometer:**
Cloud base height

**Cloud Radar:**
Cloud macrophysics, phase, microphysics, dynamics

**Sodar:**
Boundary layer depth

**Depolarization Lidars:**
Cloud base, phase, microphysics, orientation

**Spectral Infrared Interferometer:**
Cloud phase, microphysics, LW radiation, trace gases
Mobile Science Facility
Low, thin liquid clouds and their impact on the Surface energy balance

Bennartz et al., 2013
Recent Greenland-wide melt event
Low, thin liquid clouds and their impact on the Surface energy balance

Punch line: Low, thin clouds enhance Greenland melt extent

Bennartz et al., 2013
Validation (surface snow accumulation)
SNPP-2 Calibration Validation Details

• Mission Goals:
  – radiometric calibration validation over cold clear scenes
    • Resolve CrIS and IASI differences
  – assess satellite T/q profile retrievals for cold scenes

• Mission Dates and Location:
  – Flights out of Keflavik from March 3-23, 2015
    • Dates are tentative – may change slightly
    • Lots of time over Greenland Ice Sheet
    • Opportunity to coordinate with UKMO Flights out of Goose Bay, CA
    • Opportunity to collaborate with GIS ground sites
Conclusions

• High latitude precipitation is a major gap with current satellite missions but progress is being made with experimental missions (CloudSat, EarthCare)

• There is much to gained by the precipitation and snow on the ground communities working together to outline priorities for future missions and address retrieval issues.

• If we want to observe climate signals, we need to have long-term records. Need for stable, well-calibrated long-term satellite datasets.

• ICECAPS provides an excellent validation site/testbed EO satellites (CloudSat, EarthCare, ADM, ….)