Development of Earth System Data Records of Ice-Surface Temperature

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Outline

- Introduction/Background
- Multi-Layer MODIS Product of Greenland
- Validation of the IST “layer”
- Why do we need to know IST accurately?
- Conclusion

Introduction and Background

- Surface temperature provides information on the surface melt conditions of a snowpack, and is needed to determine internal snowpack temperatures
- On ice sheets surface temperature largely controls: runoff, internal temperature and basal melt, and must be known in order to model the surface mass balance (SMB)
- Albedo can be closely tied to IST and is related to absorption of solar radiation; the amount of absorbed radiation influences the SMB and meltwater production

Background, cont'd.

- MOD/MYD29 is the standard MODIS Terra and Aqua sea ice IST product (Hall et al., 2004), and is a special IST product of Greenland (Hall et al., 2012)
- MOD/MYD29 derives its heritage from an algorithm developed by Key and Haefliger (1992) and Key et al. (1997), for AVHRR data
- MOD/MYD29 is a split-window algorithm that was first employed to measure SST
- Use of this heritage algorithm facilitates development of an Earth System Data Record (ESDR) and a Climate-Data Record (CDR) for sea ice and ice sheet surface temperature spanning data records from AVHRR, MODIS, and now VIIRS (Tschudi et al.)

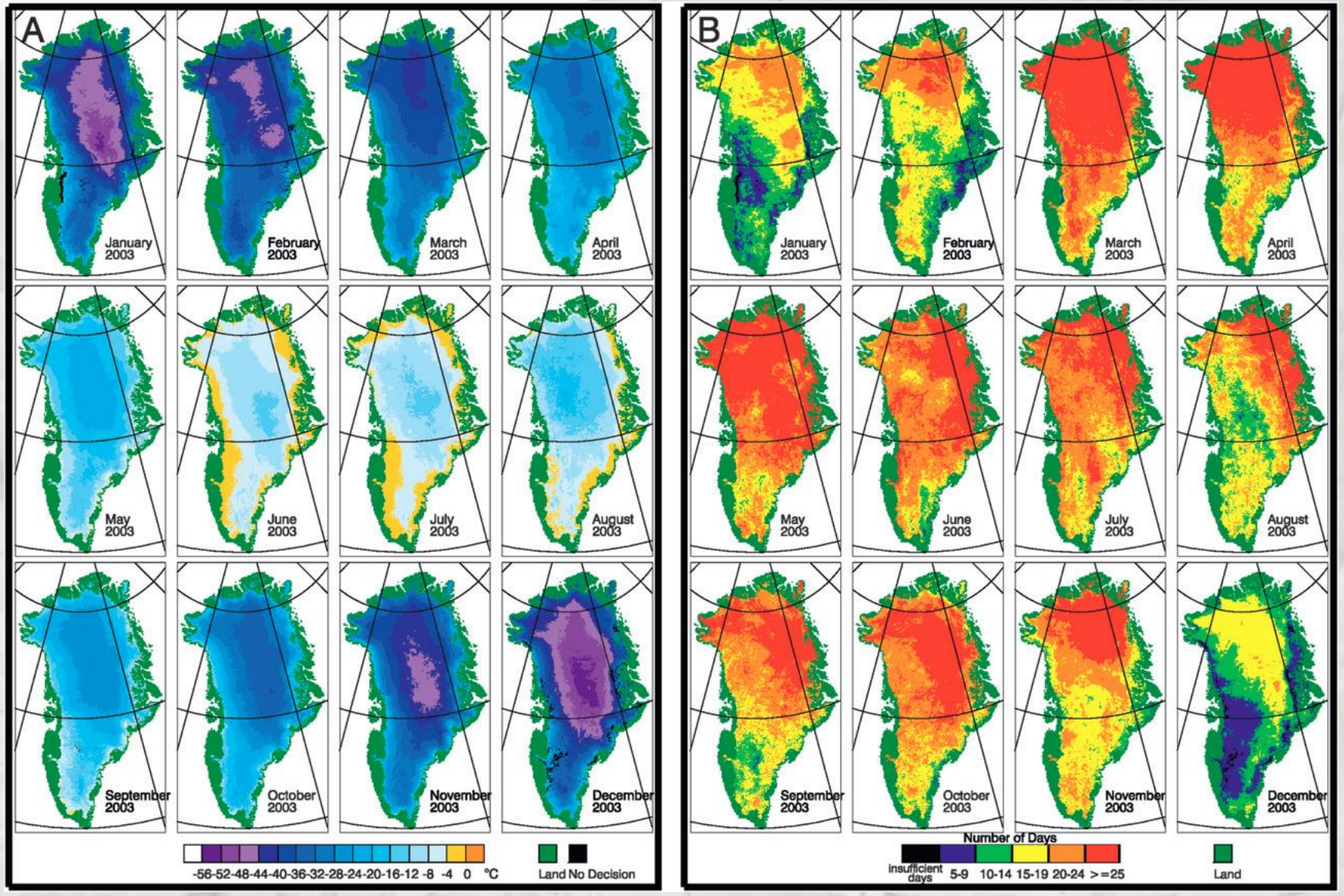
IST algorithm for MODIS Terra & Aqua

$$IST = a+bT11 + c(T11-T12) + d[(T11-T12)(sec(q)-1)]$$

where,
T11 is brightness temperature at 11.03 µm
T12 is brightness temperature at12.02 µm
q is sensor scan angle
a,b,c,d are regression coefficients

IST is calculated with a split-window technique using MODIS bands 31 and 32. Coefficients for the IST equation were derived by Jeff Key / NOAA using MODIS spectral response functions and radiative transfer calculations. Separate coefficients are used for the Northern Hemisphere and Southern Hemisphere.

Monthly IST maps* for 2003 (left), and number of days of data available to create the maps (right); there is a cold bias in the MODIS time series maps

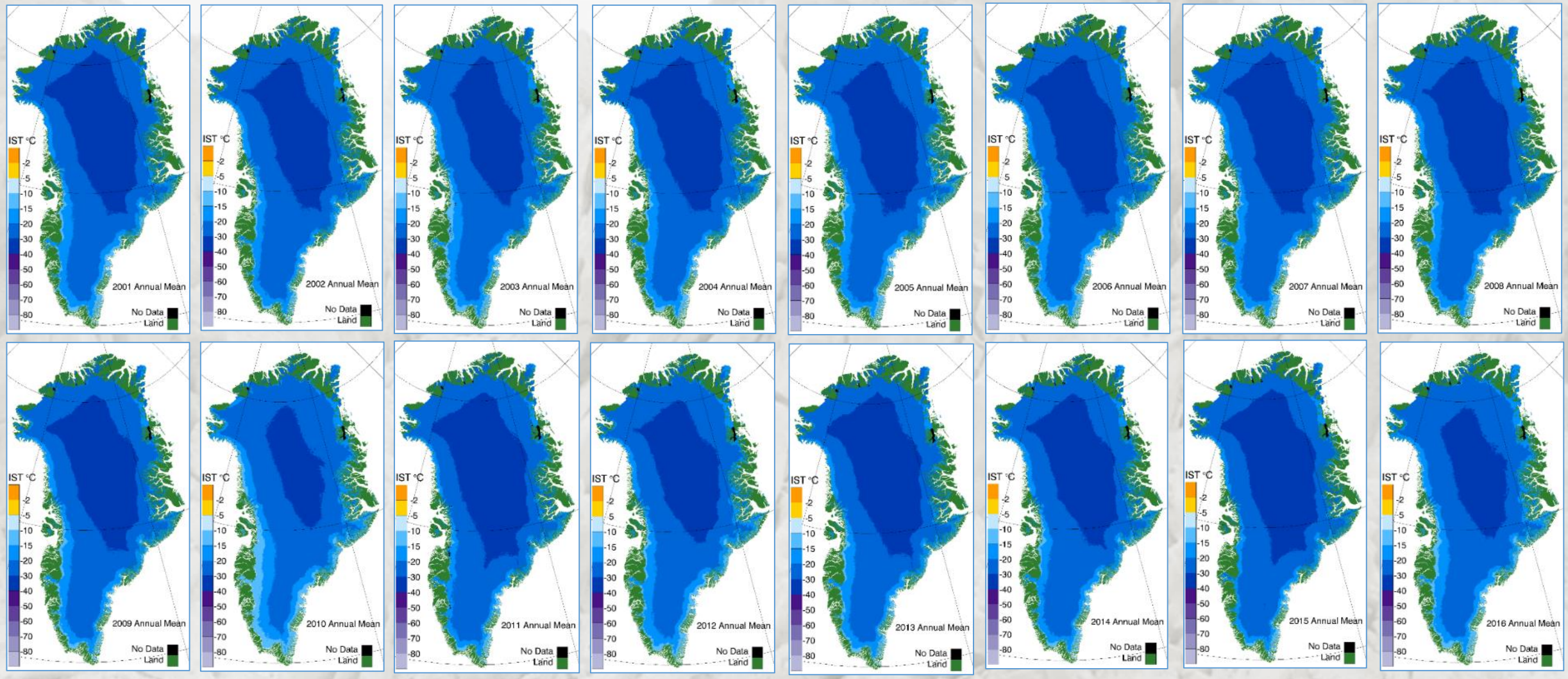


*Clear-sky

Hall et al., 2012, *Jour. of Climate*

Mean*- Annual IST Maps

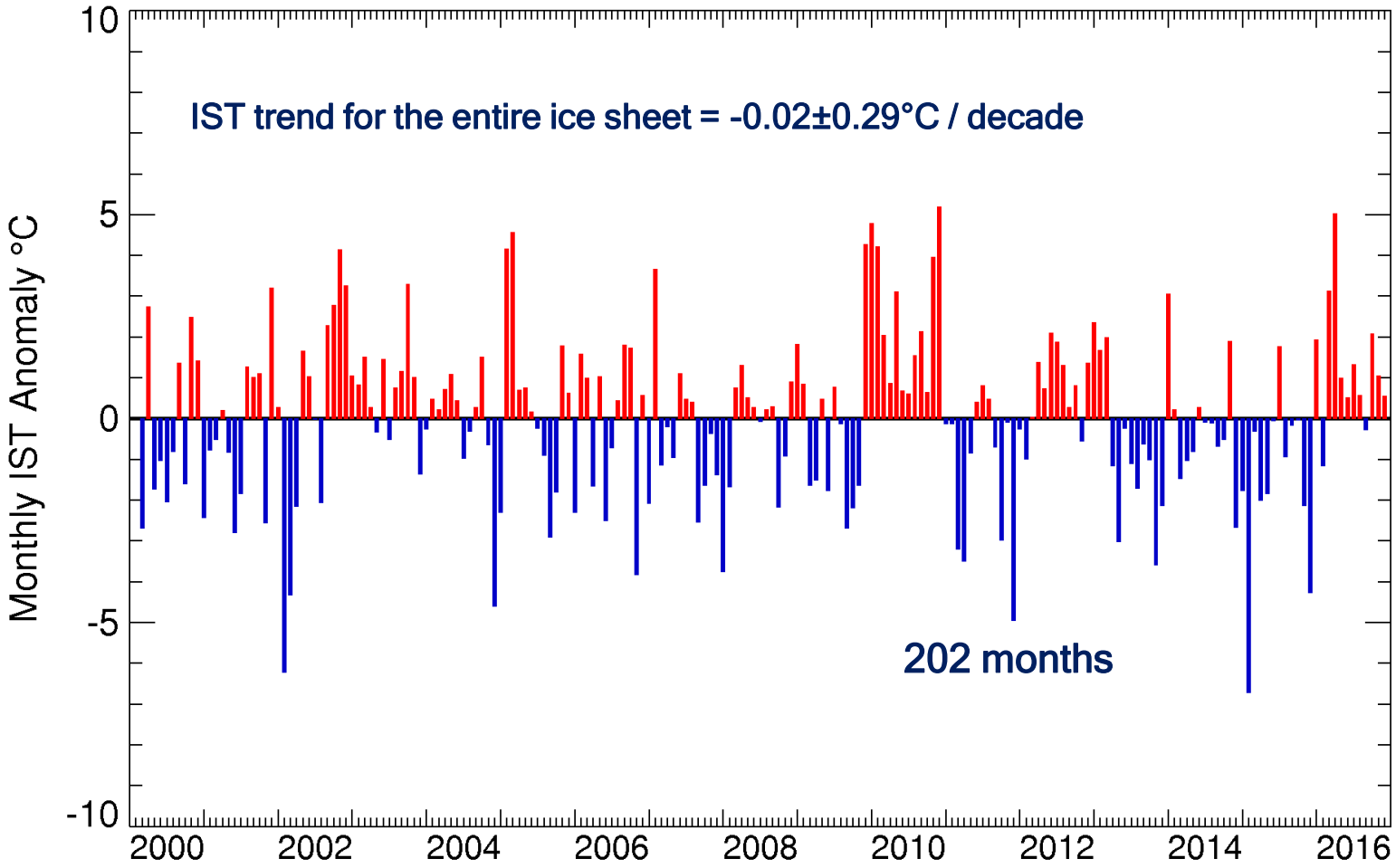
2001 - 2016



*Clear-sky mean

Extended from Hall et al., 2012

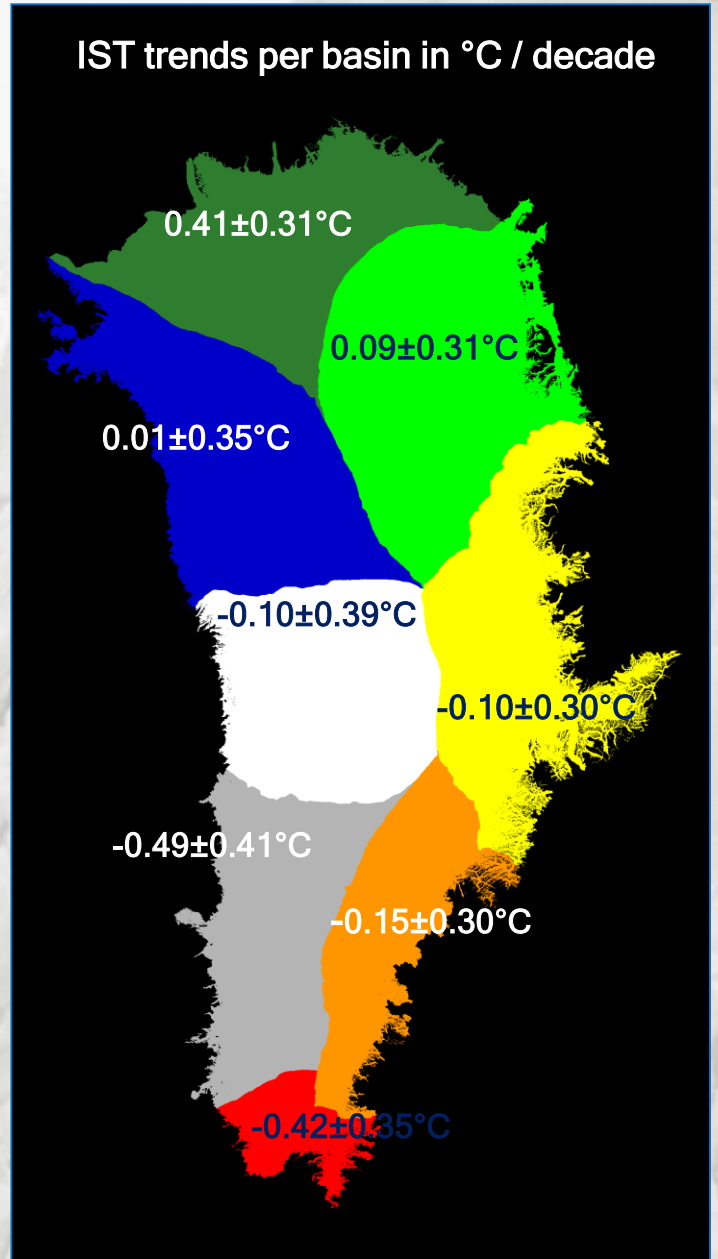
Monthly IST anomalies



Extended from Hall et al., 2012, *Jour. of Climate*

IST Trends in Drainage Basins 2000 - 2016

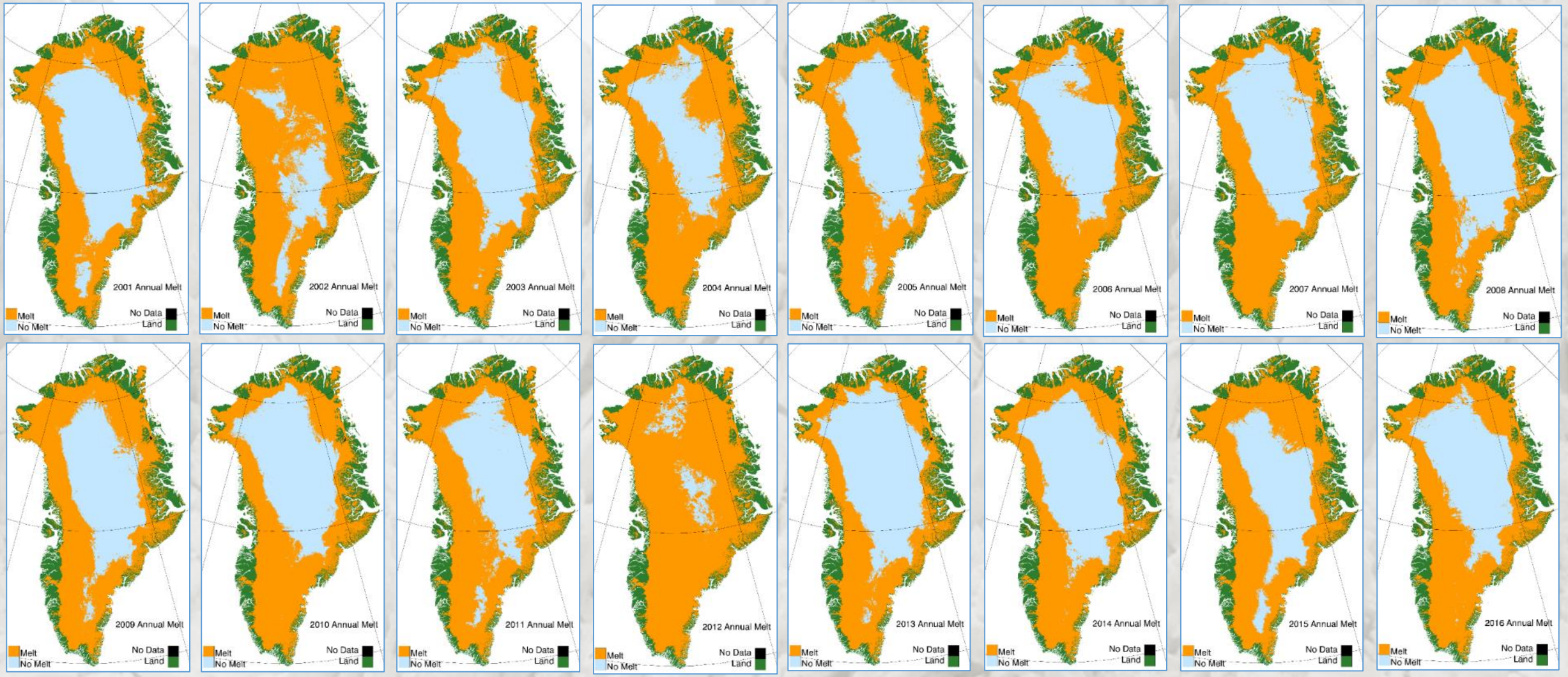
Ice-surface temperature trends in °C per decade are shown within the drainage basin boundaries



Extended from Hall et al., 2013, *GRL*

Annual Maximum Melt Maps

2001 - 2016



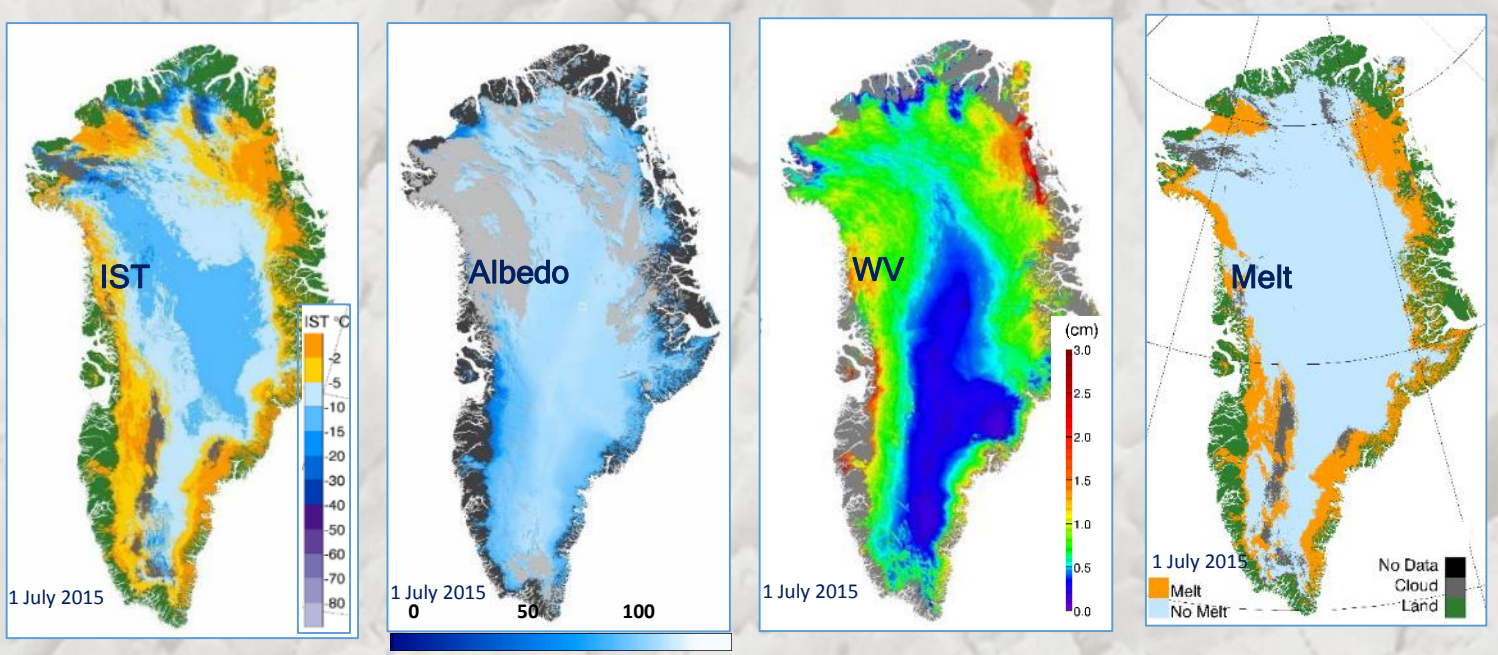
Extended from Hall et al., 2012

A Multilayer IST-Surface Melt-Albedo-Water Vapor Product of Greenland from MODIS

Dorothy K Hall[1], Richard I. Cullather[1], Nicolo E. DiGirolamo[2], Josefino C. Comiso[3], Sophie M. Nowicki[3] and Brooke C. Medley[3]

[1]ESSIC / University of Maryland, College Park, MD 20740; [2]SSAI, Lanham, MD 20706; [3]NASA / Goddard Space Flight Center, Greenbelt, MD 20771

The multi-layer product of Greenland (March 2000 through December 2016) was developed to meet the needs of the ice sheet modeling community. Swath-based, daily, monthly and annual maps are provided on a polar stereographic grid at ~0.8-km resolution in netCDF.

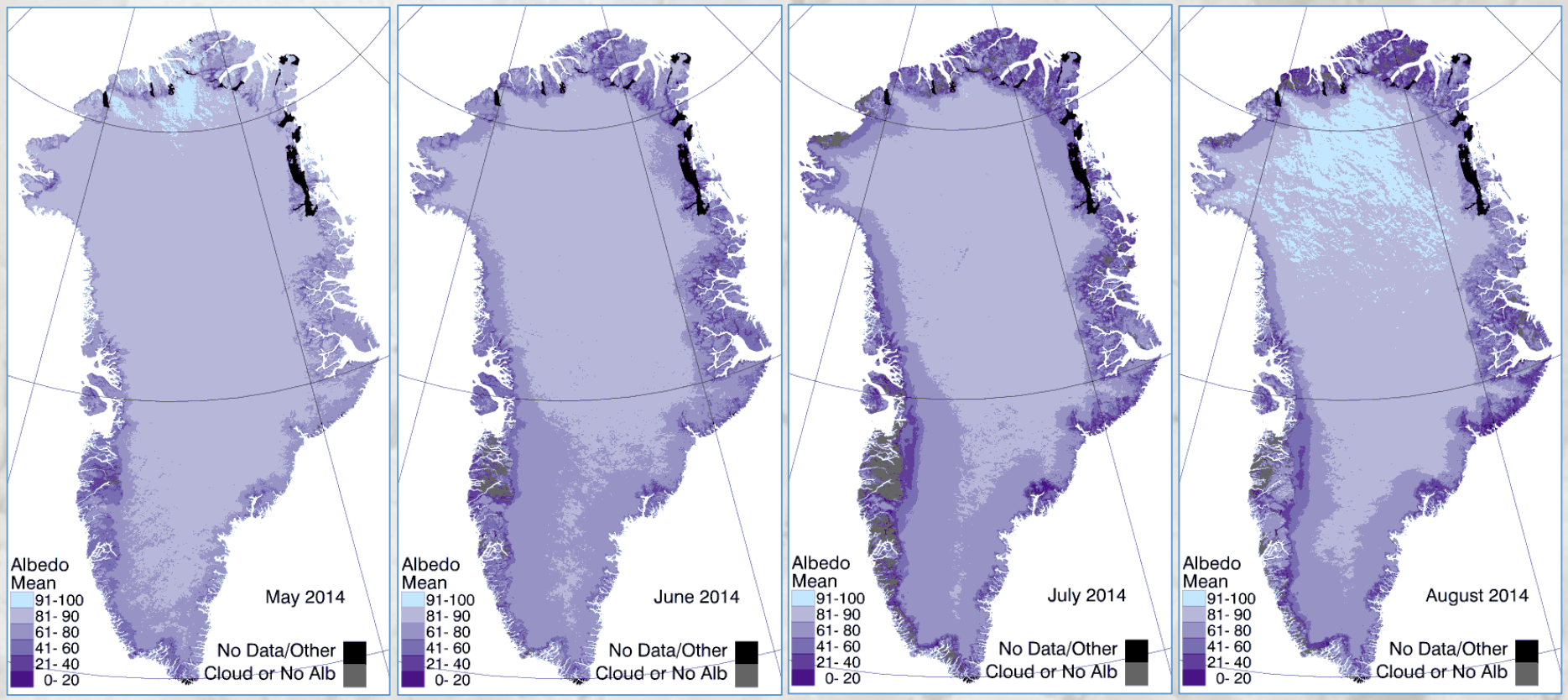


Rationale for Multi-Layer Product

- To facilitate studies of relationships between IST or melt and albedo, and water vapor, melt and clouds
- To evaluate reanalysis products such as from: MERRA, MERRA-2, ASR, ERA-I, CFSR
- To compare with other satellite data, e.g., AIRS & VIIRS

Mean-Monthly* Albedo Maps

Examples from 2014

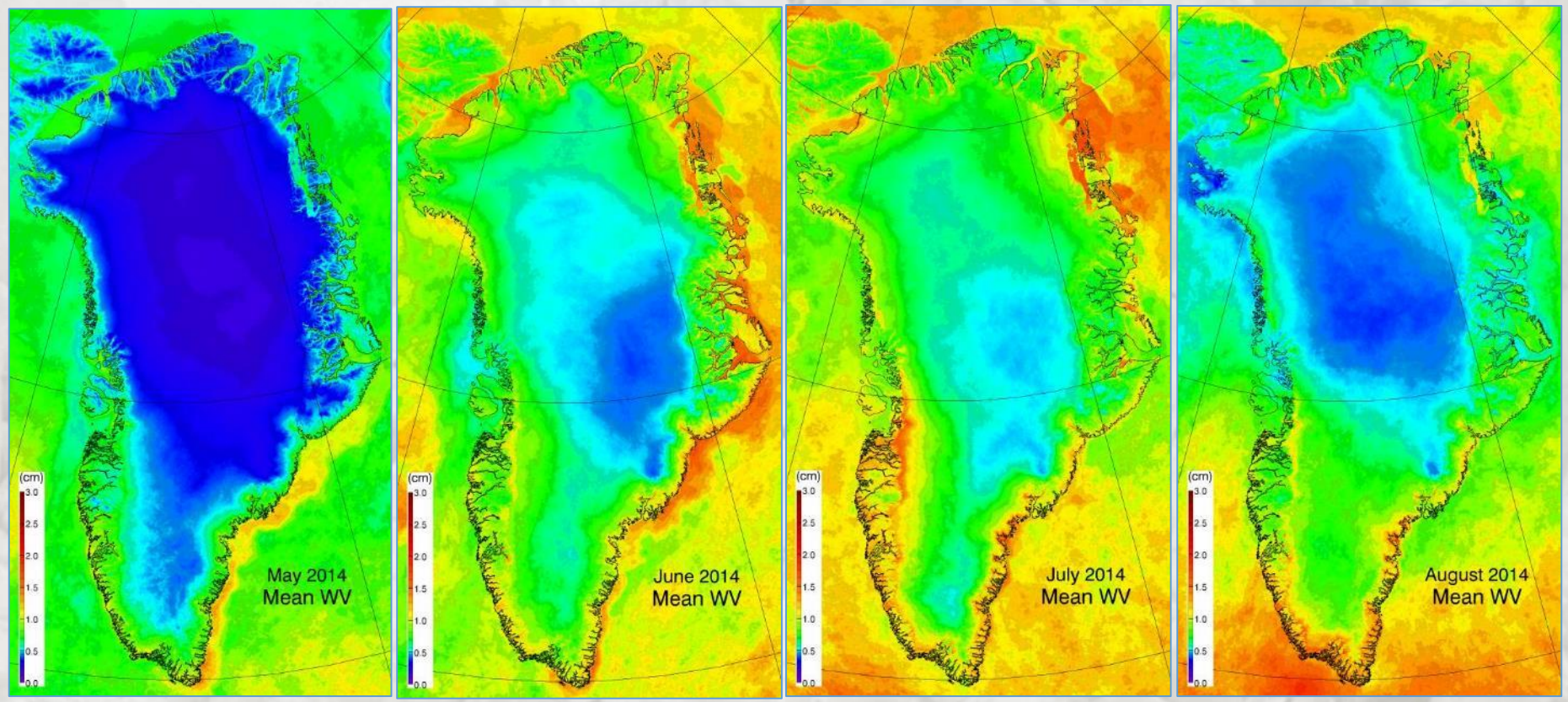


Hall et al., 2002
Klein and Stroeve, 2003
Riggs et al., 2006 and 2016

*Clear-sky mean

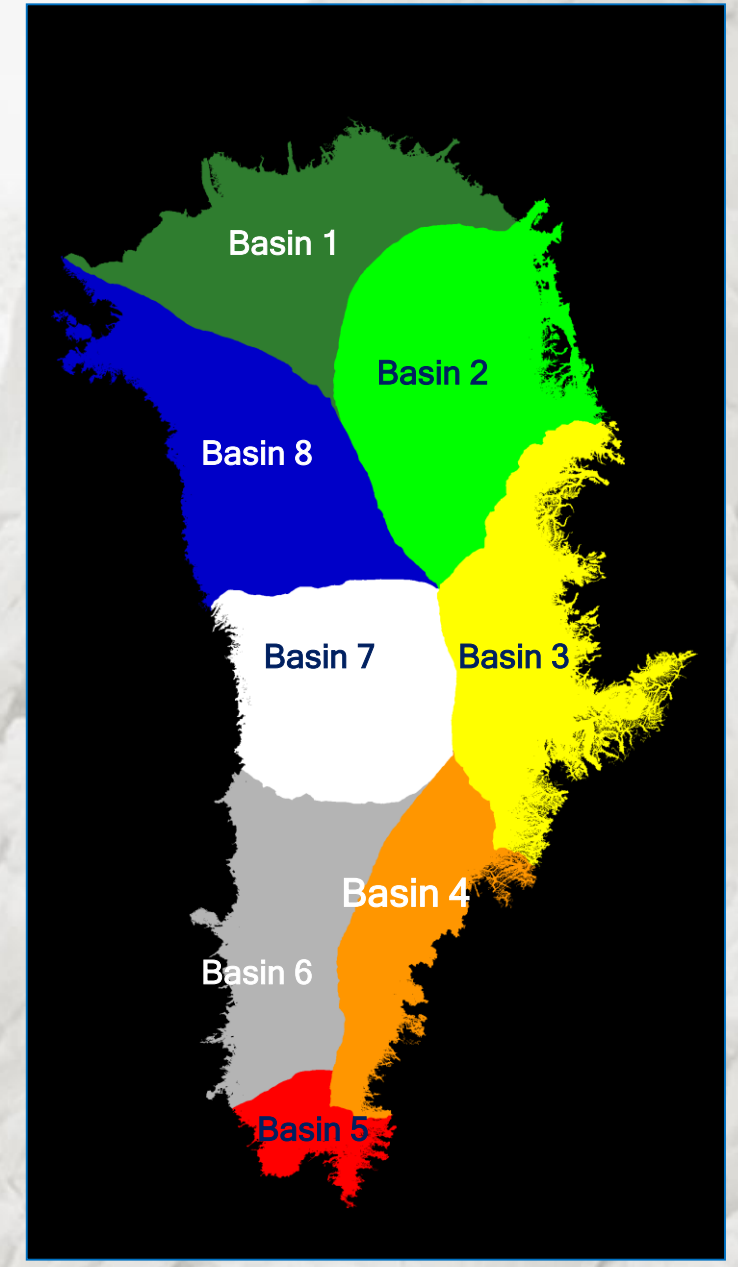
Mean Monthly Water Vapor Maps

Examples from 2014



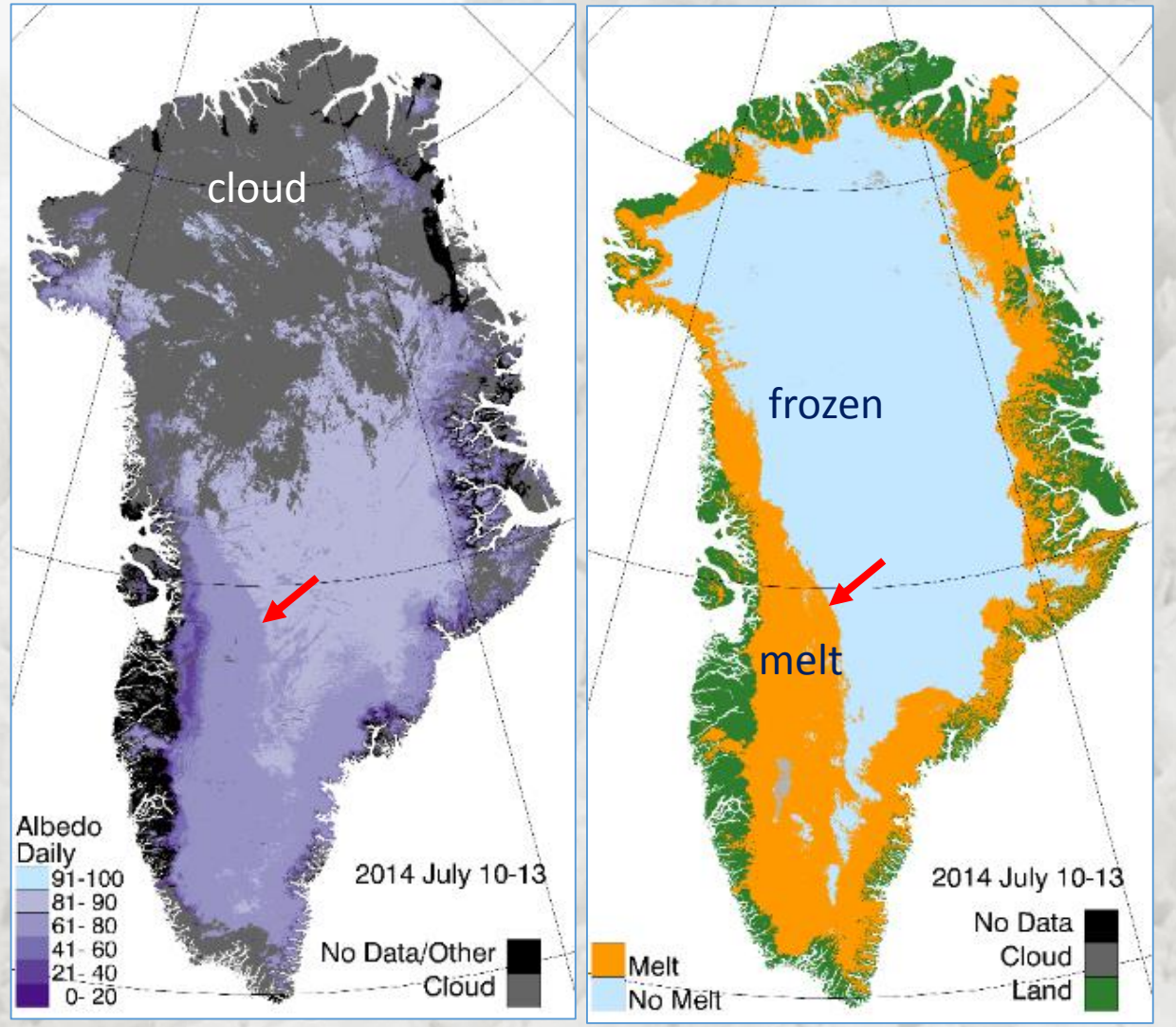
Gao and Kaufman, 2003

Ice Mask and Drainage Basins



From:
Howat et al., 2014
Zwally et al., 2012

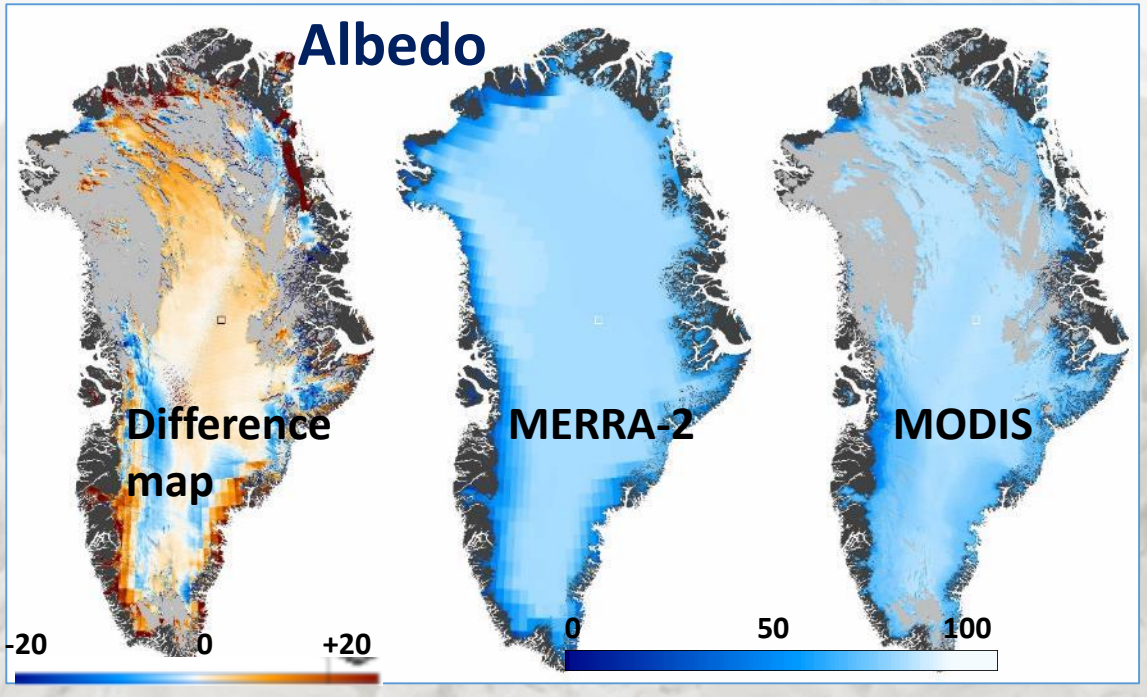
The multi-layer product allows relationships, e.g., between surface melt and albedo to be explored easily

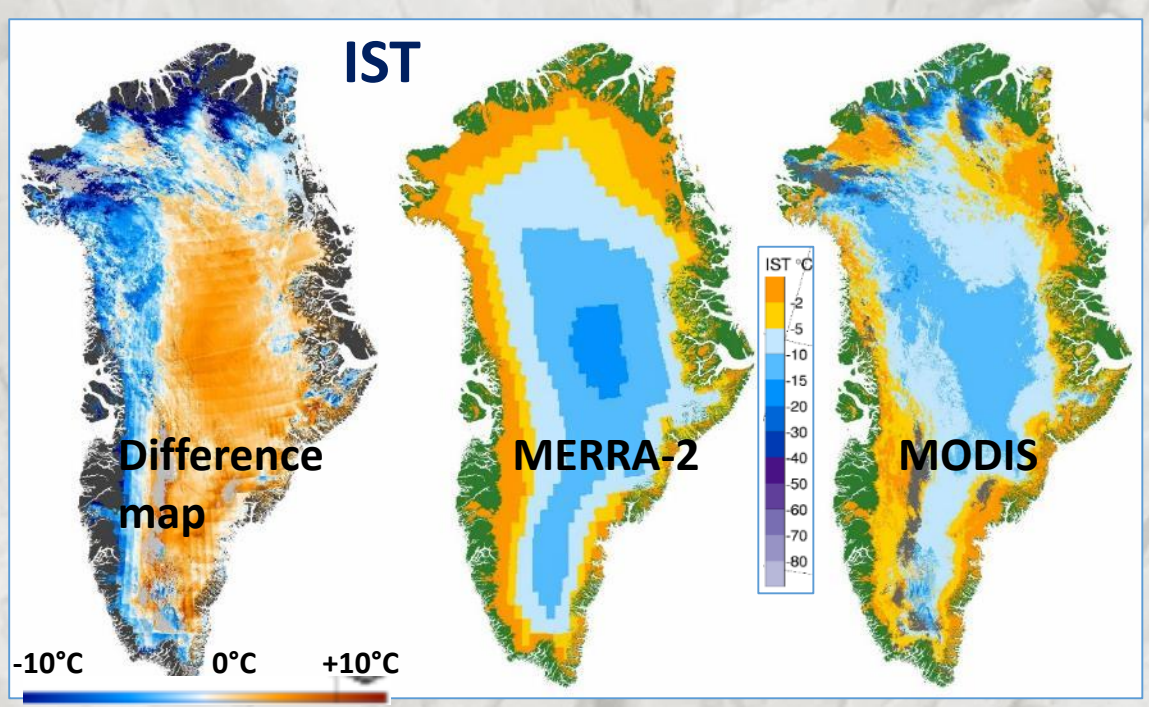


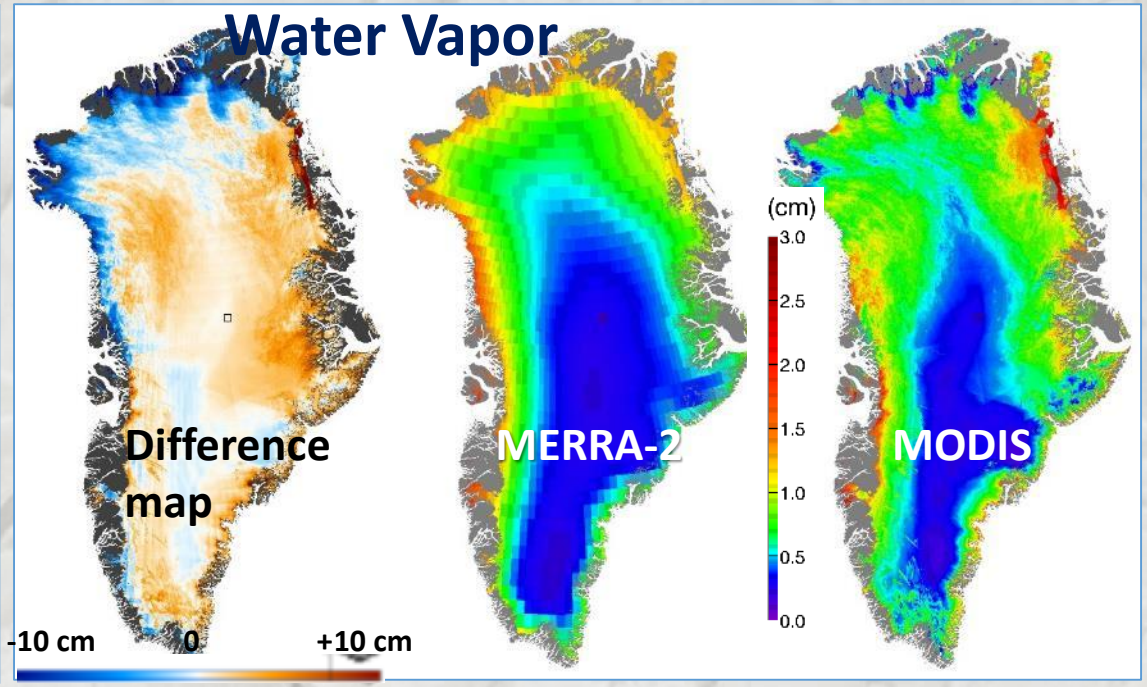
Hall et al., 2017, *Proc. IEEE IGARSS'17*

Different layers can be used to evaluate reanalysis products

MERRA-2 vs MODIS comparisons
1 July 2015*





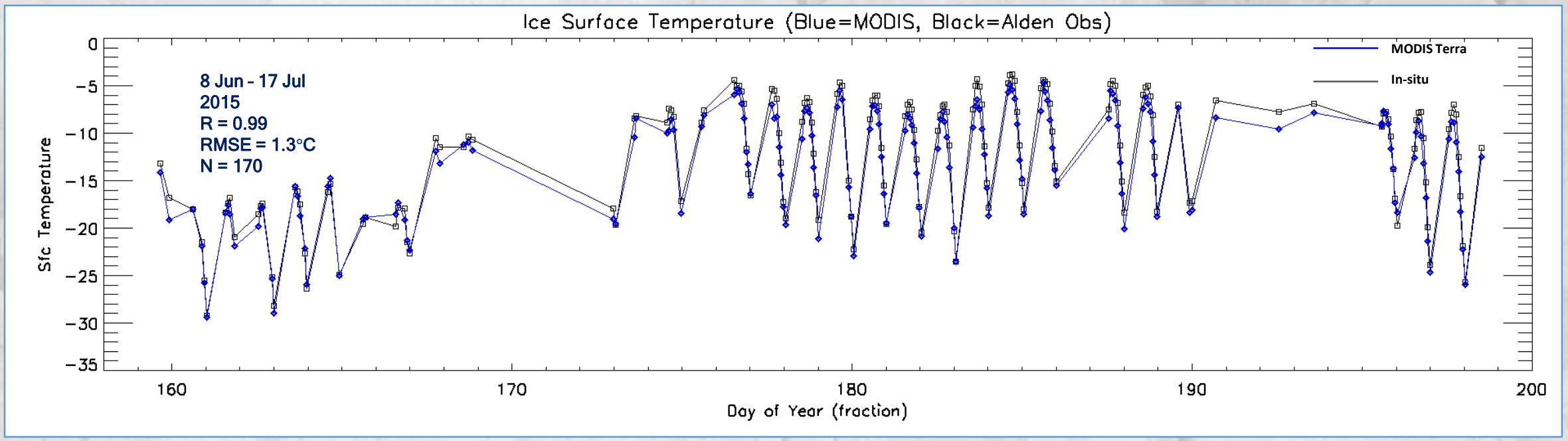


* day 182

Validation of IST in the Multi-Layer Product

Much validation work has been accomplished for the MODIS IST product (MOD/MYD29) over sea ice, snow cover and the Greenland Ice Sheet. 2-m air temperature is often used to "validate," but is significantly different from snow/ice skin temperature and is not useful for absolute accuracy studies.

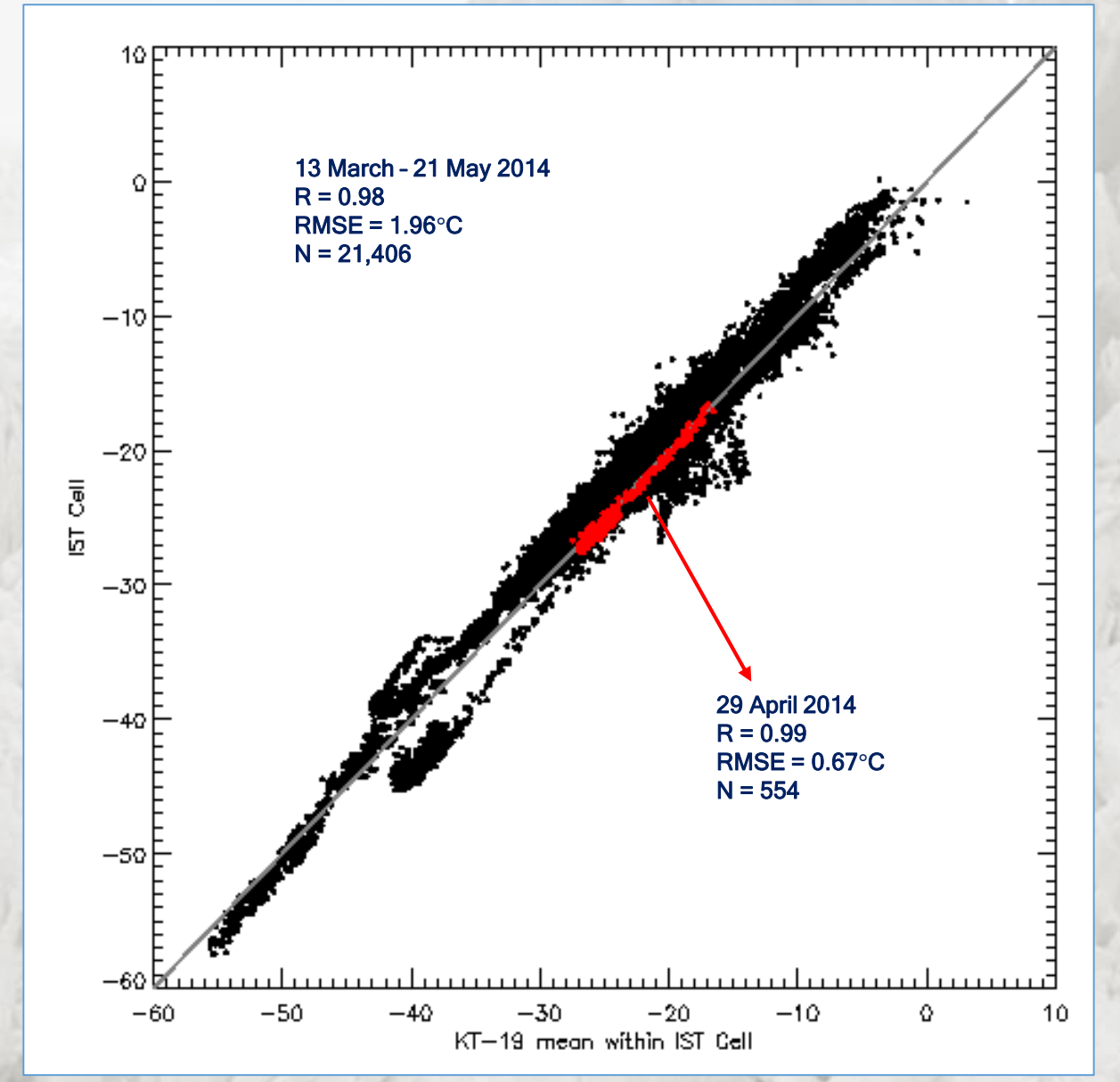
Validation of IST using in-situ data near Summit Station



Field measurements acquired by Alden Adolph / Dartmouth University* using a Campbell Scientific Apogee Precision IR radiometer mounted ~60 cm from the surface.

*now St. Olaf College

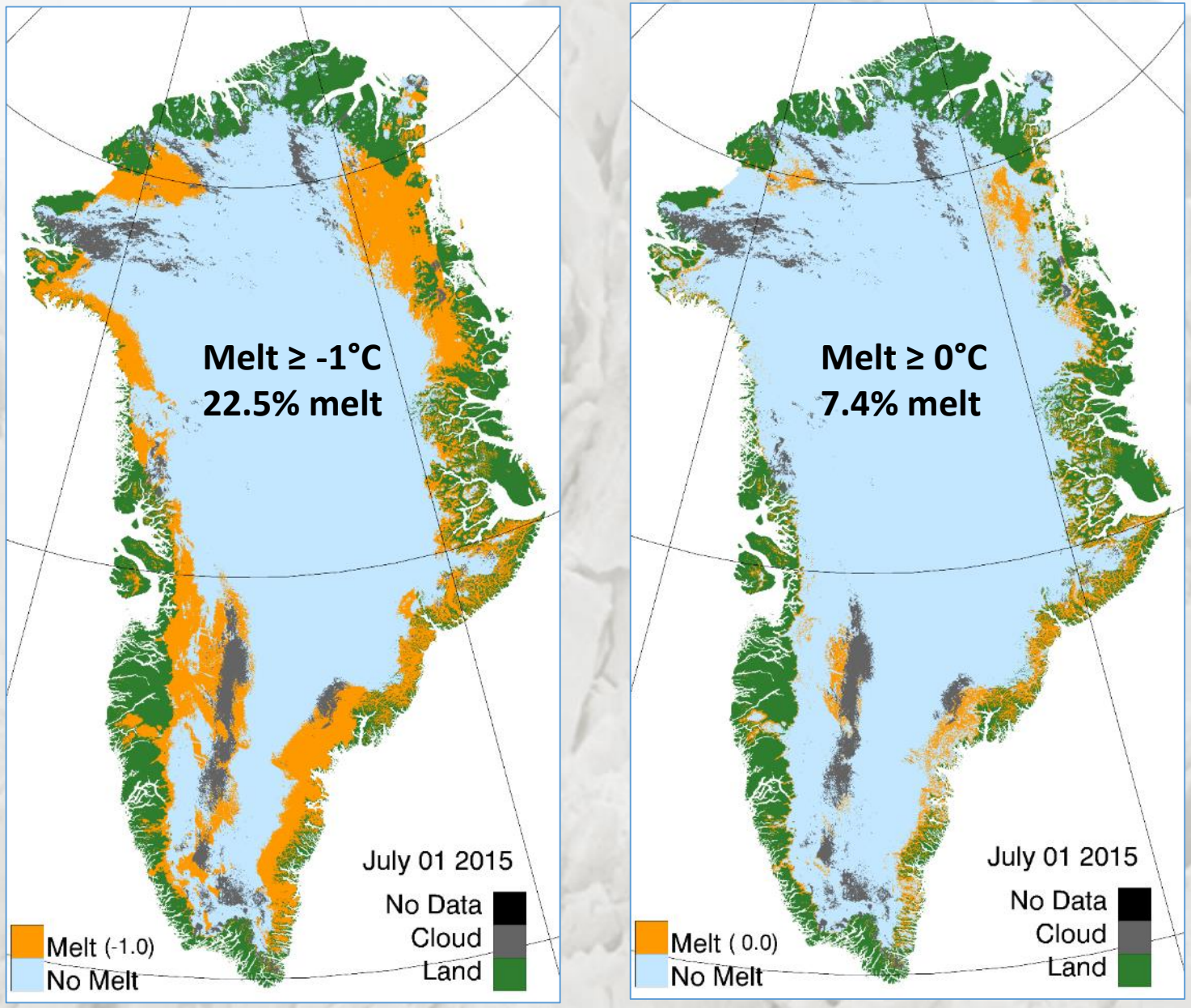
Validation of IST using IceBridge KT-19 Data



Why do we need to know the IST accurately?

- For snowpacks, IST is needed to ensure that distributed snow models are accurately calculating the energy balance, and to determine outgoing irradiance
- For ice-sheet surface-temperature trend calculations, a systematic bias can be introduced if measurements are not accurate
- If the IST is off by even 0.5°C that makes a large difference in the determination of melt onset, and for calculation of melt extent

Melt maps are very sensitive to the IST threshold



Conclusions

- Development of an IST ESDR and ultimately a CDR requires use of a consistent algorithm, and ideally overlapping data records from different instruments (e.g., AVHRR to MODIS to VIIRS)
- Instrument differences can affect the continuity of the data record, such as differences in spectral channels and spatial resolution
- MODIS-derived IST over homogeneous areas like the Greenland Ice Sheet can be accurate to <1°C; the biggest source of uncertainty is undetected clouds and fog