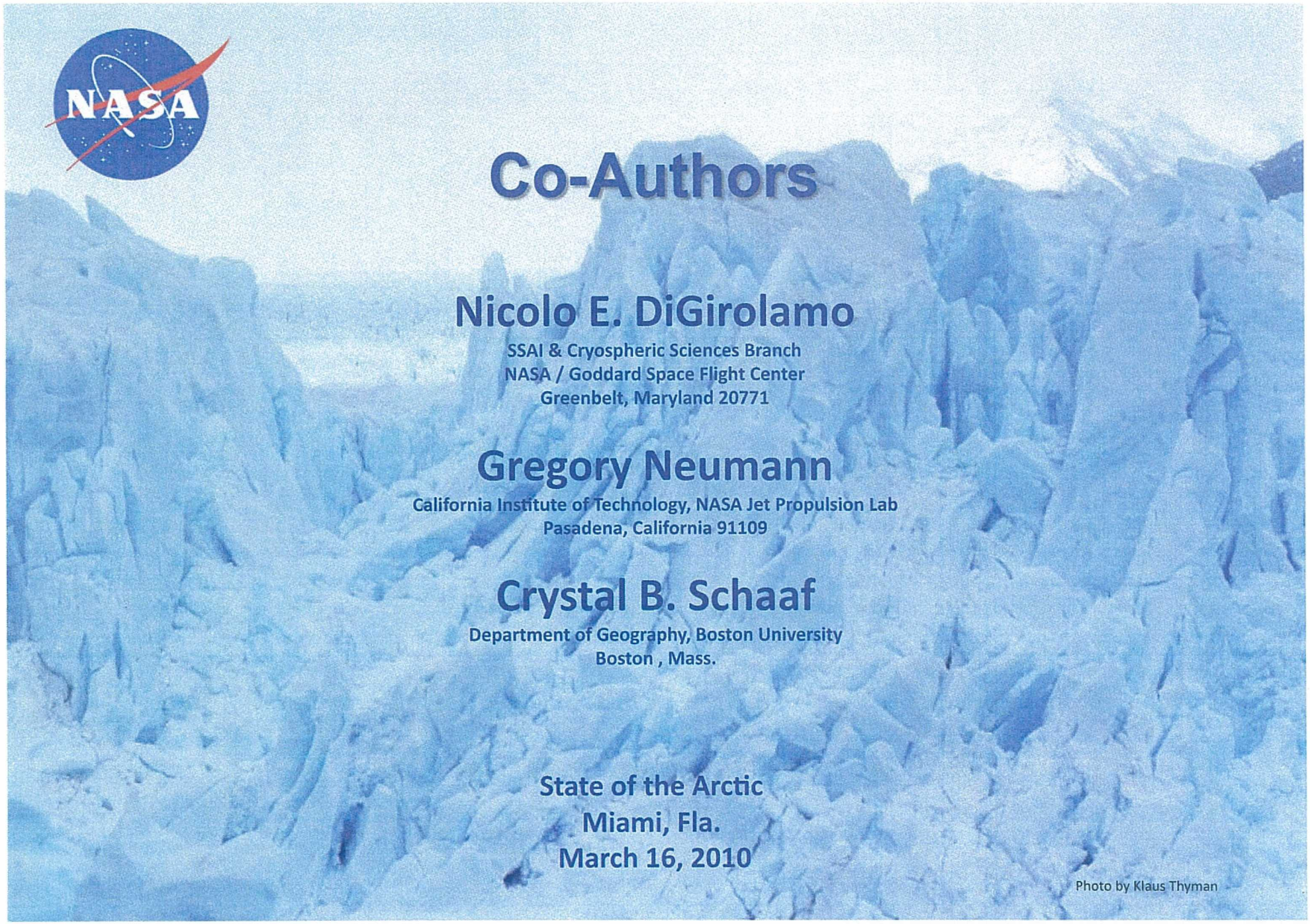
Delineation of Surface and Near-Surface Melt on the Greenland Ice Sheet using MODIS and QuikSCAT data

Dorothy K. Hall
Cryospheric Sciences Branch
NASA / Goddard Space Flight Center
Greenbelt, Maryland 20771
dorothy.k.hall@nasa.gov

Son V. Nghiem
California Institute of Technology, NASA Jet Propulsion Lab
Pasadena, California 91109
Son.v.nghiem@jpl.nasa.gov

State of the Arctic
Miami, Fla.
March 16, 2010

Photo by Klaus Thyman



Co-Authors

Nicolo E. DiGirolamo

SSAI & Cryospheric Sciences Branch
NASA / Goddard Space Flight Center
Greenbelt, Maryland 20771

Gregory Neumann

California Institute of Technology, NASA Jet Propulsion Lab
Pasadena, California 91109

Crystal B. Schaaf

Department of Geography, Boston University
Boston , Mass.

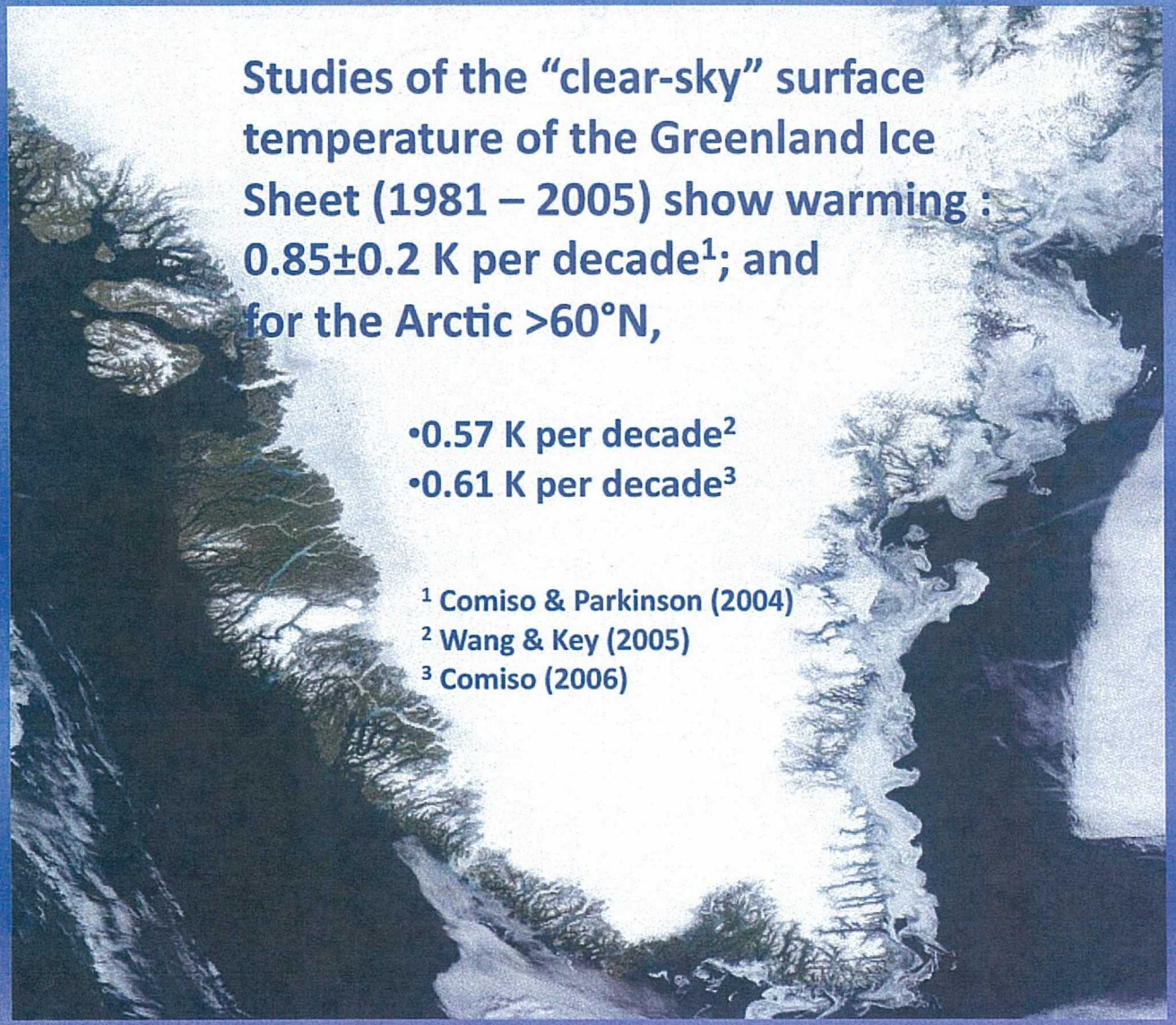
State of the Arctic
Miami, Fla.
March 16, 2010

Photo by Klaus Thyman

Objective and Results

- To refine the measurement of melt extent on the Greenland Ice Sheet using MODIS surface temperature, albedo and QuikSCAT melt products
- Results generally show excellent agreement between MODIS and QuikSCAT melt products with interesting differences related to sub-surface melt

Background



Studies of the "clear-sky" surface temperature of the Greenland Ice Sheet (1981 – 2005) show warming : 0.85±0.2 K per decade[1]; and for the Arctic >60°N,

- 0.57 K per decade[2]
- 0.61 K per decade[3]

[1] Comiso & Parkinson (2004)
[2] Wang & Key (2005)
[3] Comiso (2006)

Various methods have been used to study melt on the Greenland Ice Sheet, including:

- Mote & Anderson (1995) & Mote (2007) - MW emission model
- Abdalati & Steffen (2001) passive-MW XPGR
- Nghiem et al. (2001) – diurnal change in backscatter
- Tedesco (2007) – diurnal-amplitude variation in MW emissivity
- Comiso (2003) & Hall et al. (2006) – surface temperature from satellite

however, they often don't agree on the total amount of melt measured.

For example, the trend in total area of melt found by Mote (2007) for 1974-2007: +17,600 km^2 per yr (Mote, 2007) differs from the trend found by Tedesco (2007) for 1992-2005: +40,000 km^2 per yr* by ~22,400 km^2 per yr.

Sometimes melt extent is determined if a pixel experiences *any* melt even on a single day.

We have developed a consistent method of delineating melt on Greenland

*These studies using different time periods, techniques and different passive-MW instruments to measure melt.

Algorithms used in this work were already developed & validated

- Moderate-Resolution Imaging Spectroradiometer (MODIS)
  - Daily 1-km snow albedo product (MOD10A1) (Klein & Stroeve, 2002; Hall et al., 2002)
  - 1-km Land Surface Temperature (LST) product (Wan et al., 2002)
- SeaWinds scatterometer (13.4 GHz) on Quik Scatterometer (QuikSCAT)
  - 25-km special melt product (Nghiem et al., 2001)
- MODIS and QuikSCAT instruments are sensitive to different physical properties

References:

Hall, D.K., S.V. Nghiem, C.B. Schaaf, N.E. DiGirolamo and G. Neumann (in press), "Evaluation of surface and near-surface melt characteristics on the Greenland Ice Sheet using MODIS and QuikSCAT data," *JGR - Earth Surface*.

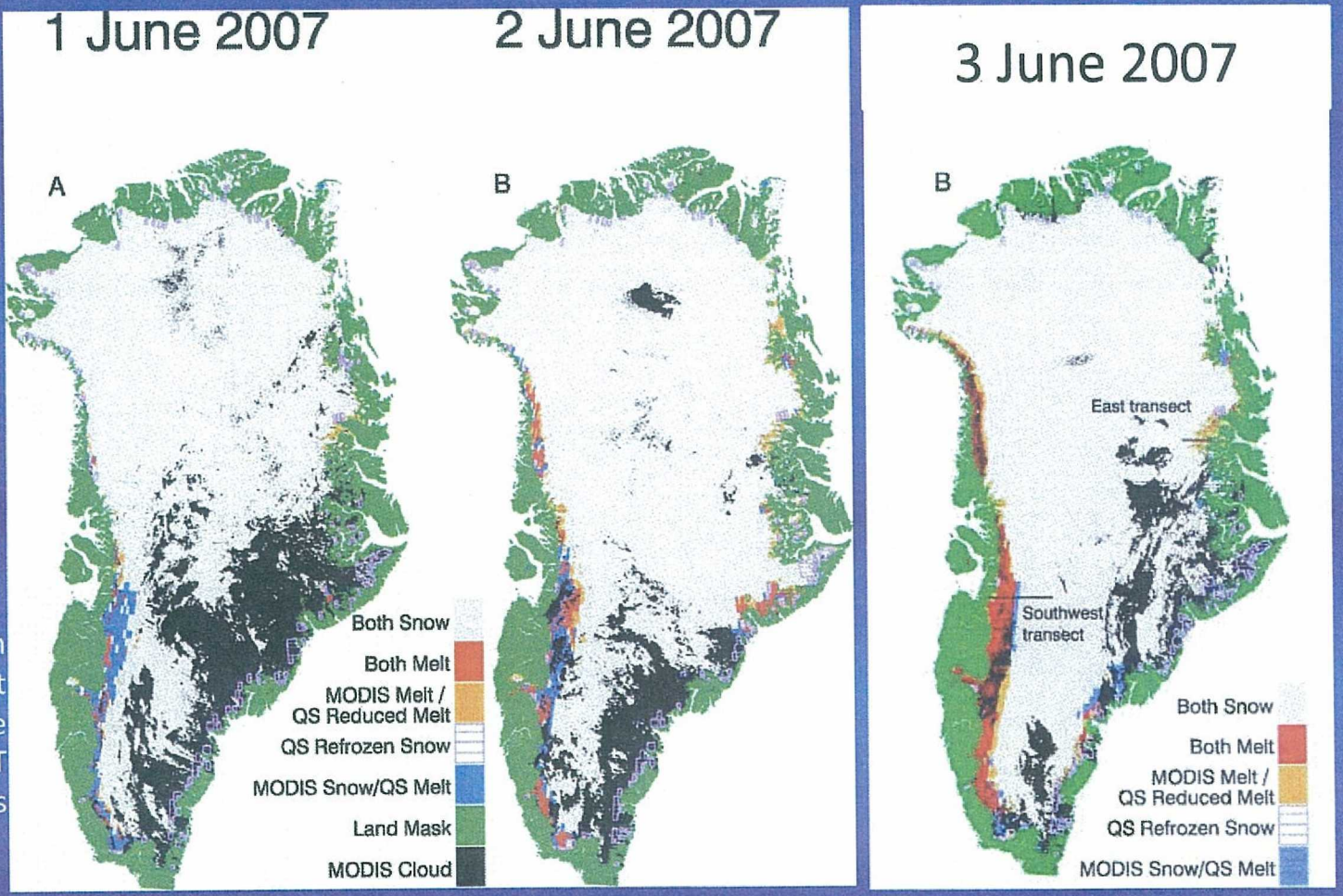
Klein, A. G., and J. Stroeve (2002), Development and validation of a snow albedo algorithm for the MODIS instrument, Ann. Glaciol., 34, 45– 52, doi:10.3189/172756402781817662.

Nghiem, S., K. Steffen, R. Kwok and W.-Y. Tsai (2001), "Detection of snowmelt regions on the Greenland ice sheet using diurnal backscatter change," *Jour. Glaciol.*, *47*(159), 593-547.

Wan, Z., Y. Zhang, Q. Zhang, and Z.-L. Li (2002), Validation of the land surface temperature products retrieved from Terra Moderate Resolution Imaging Spectroradiometer data, Remote Sens. Environ., 83, 163– 180, doi:10.1016/S0034-4257(02)00093-7.

Blended melt maps from the MODIS LST and the QuikSCAT melt products

QuikSCAT often detects melt before the MODIS LST does

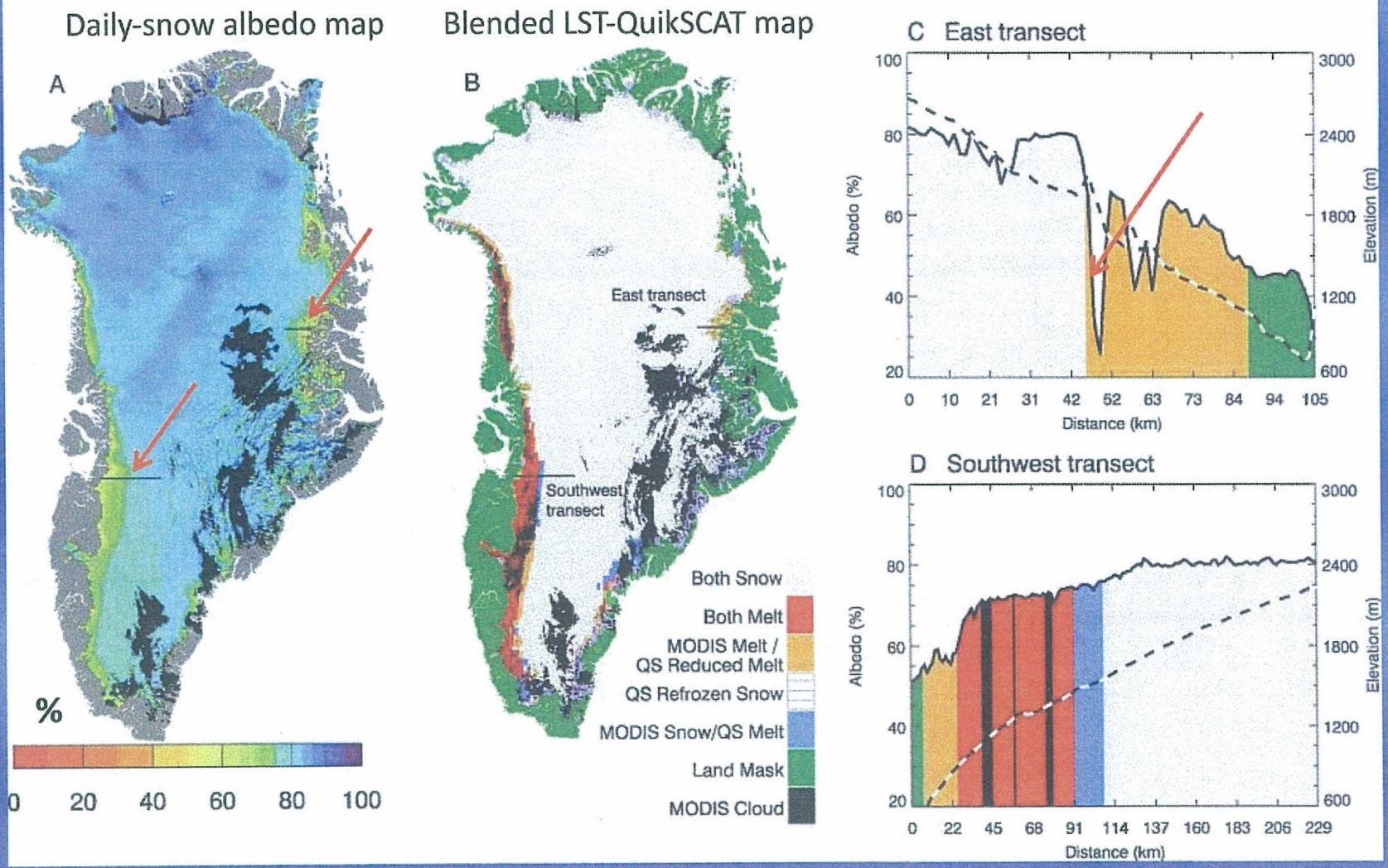


Hall, D.K., S.V. Nghiem, C.B. Schaaf, N.E. DiGirolamo and G. Neumann, 2009: EvaQuikSCAT luation of surface and near-surface melt characteristics on the Greenland Ice Sheet using MODIS and data, *JGR - Earth Surface.*, 114.

Reasons for Disagreement between MODIS LST and QuikSCAT Melt Results

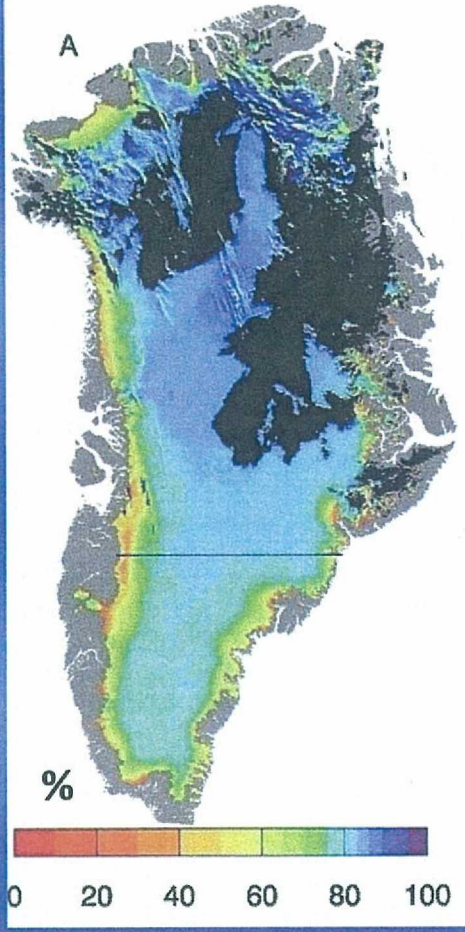
- QuikSCAT scatterometer can detect sub-surface melt
- QuikSCAT algorithm is a diurnal algorithm wherein melt occurring anytime during the day is detected; the MODIS algorithm is based on a snapshot in time each day on the ice sheet
- The QuikSCAT scatterometer is more sensitive to melt than is an IR instrument; there were no cases of melt on MODIS and "no melt" on QuikSCAT

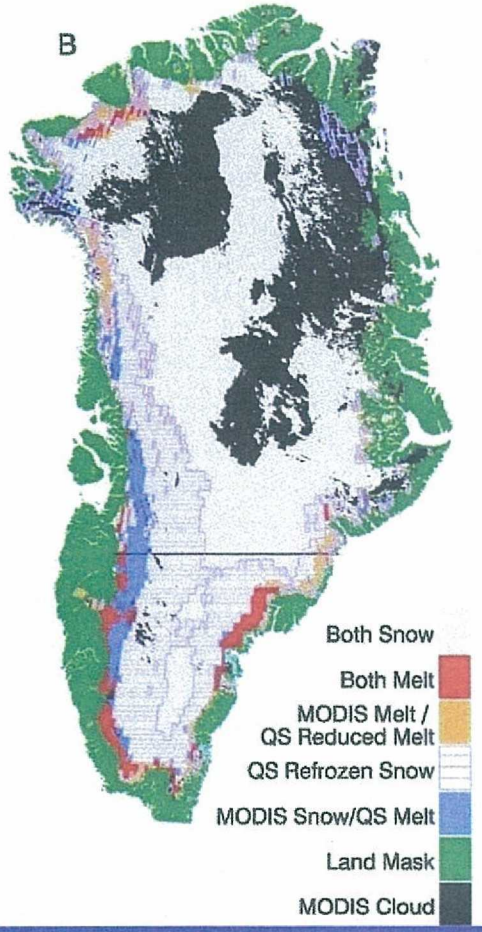
3 June 2007

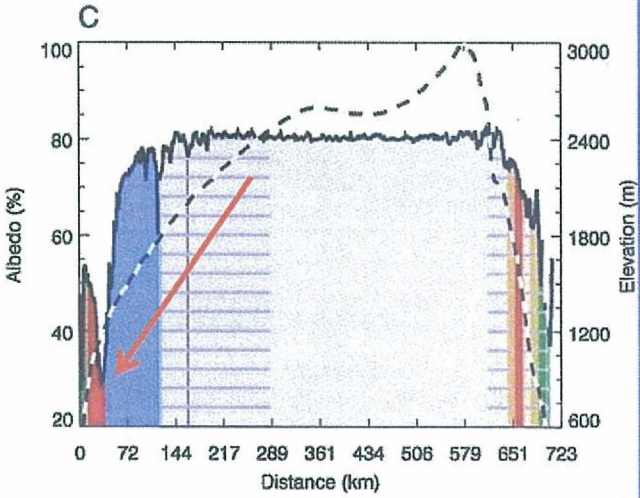


Hall, D.K., S.V. Nghiem, C.B. Schaaf, N.E. DiGirolamo and G. Neumann, 2009: Evaluation of surface and near-surface melt characteristics on the Greenland Ice Sheet using MODIS and QuikSCAT data, *JGR - Earth Surface.*, 114.

4 August 2007



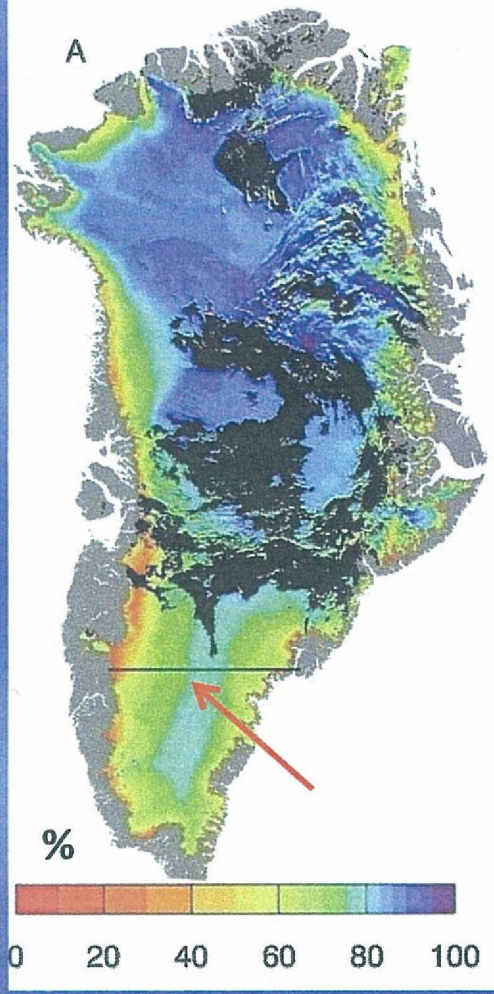


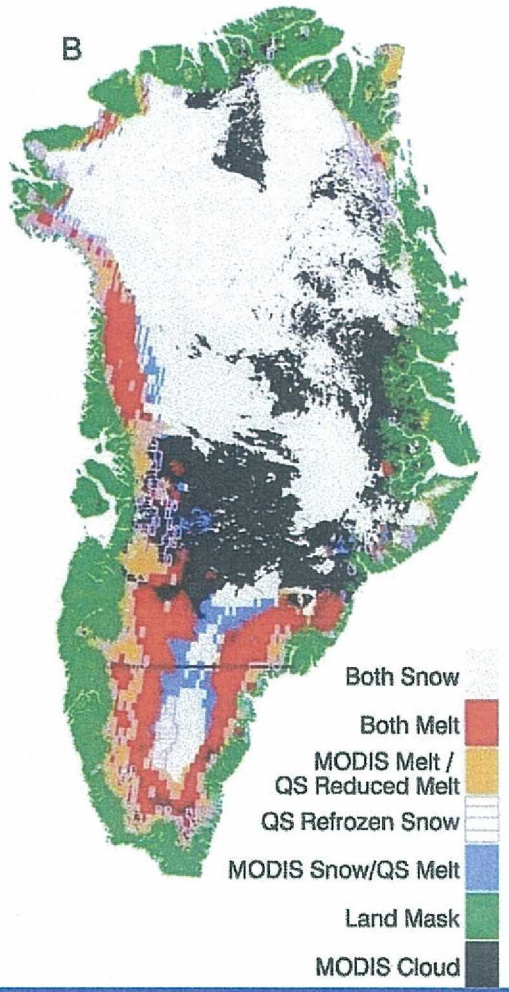


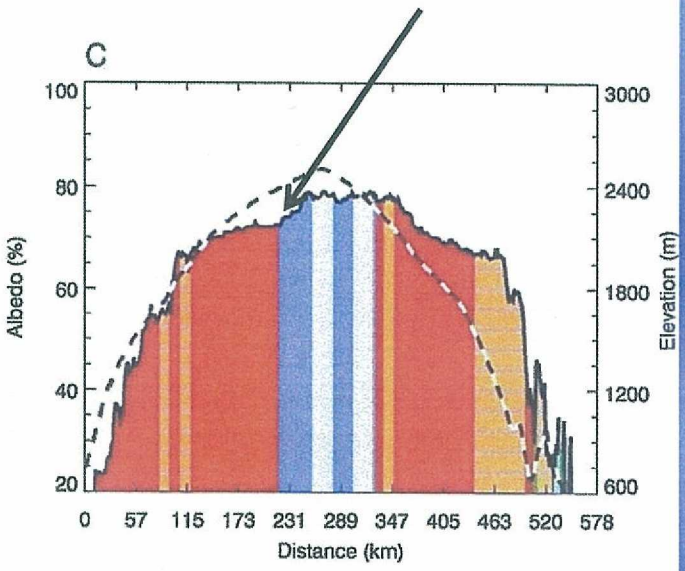
The sudden increase in albedo at arrow corresponds with the LST product showing "no melt" thus the blue area probably represents subsurface melt detected by QuikSCAT since the MODIS products detect only surface properties

Hall, D.K., S.V. Nghiem, C.B. Schaaf, N.E. DiGirolamo and G. Neumann, 2009: Evaluation of surface and near-surface melt characteristics on the Greenland Ice Sheet using MODIS and QuikSCAT data, *JGR - Earth Surface.*, 114.

13 August 2007



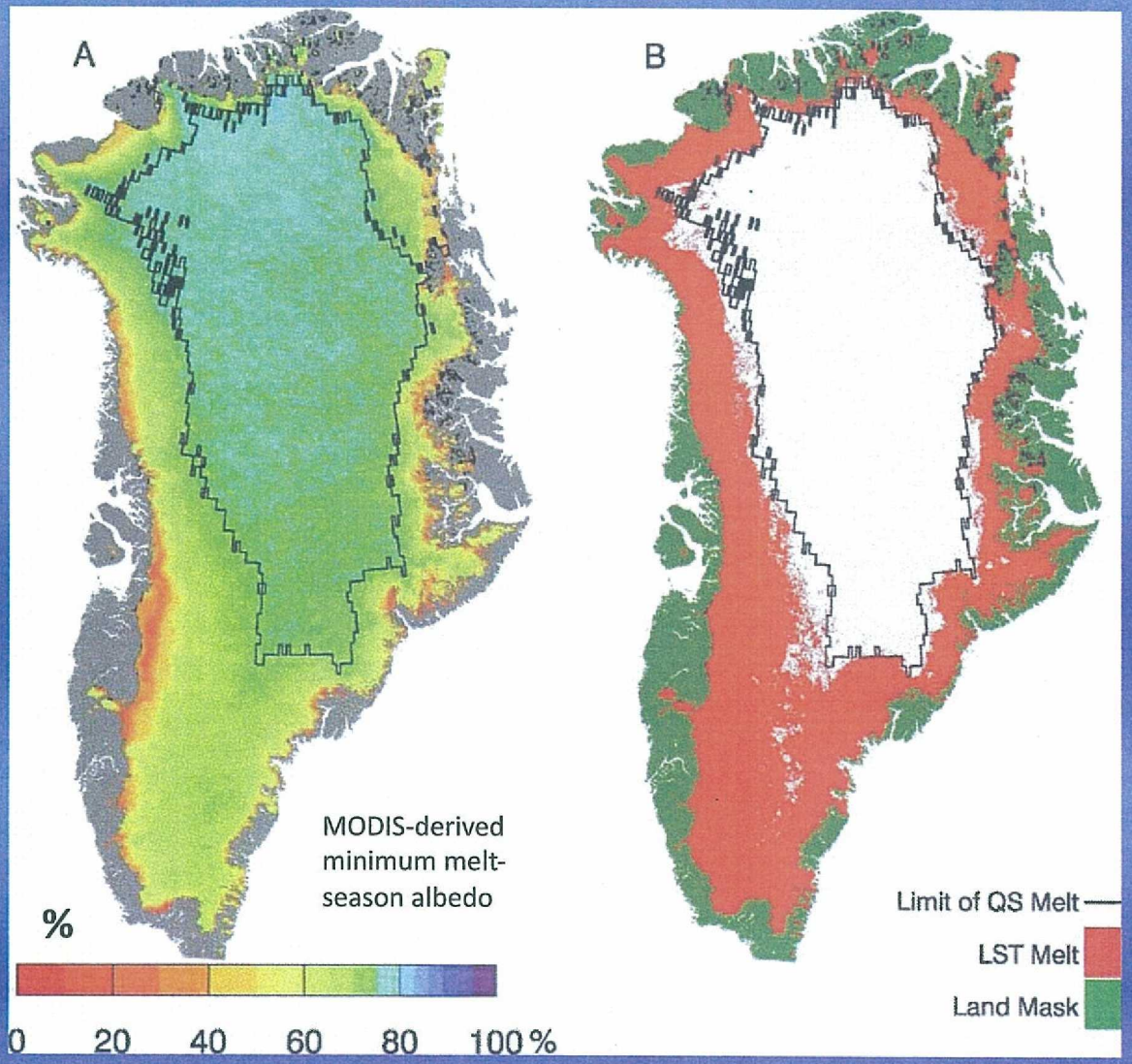




A large melt event occurred in southern Greenland on 13 August 2007; note the increase in albedo between the red and blue (at arrow)

Hall, D.K., S.V. Nghiem, C.B. Schaaf, N.E. DiGirolamo and G. Neumann, 2009: Evaluation of surface and near-surface melt characteristics on the Greenland Ice Sheet using MODIS and QuikSCAT data, *JGR - Earth Surface.*, 114.

Correspondence of Different Melt Algorithms for the 2007 Melt Season*

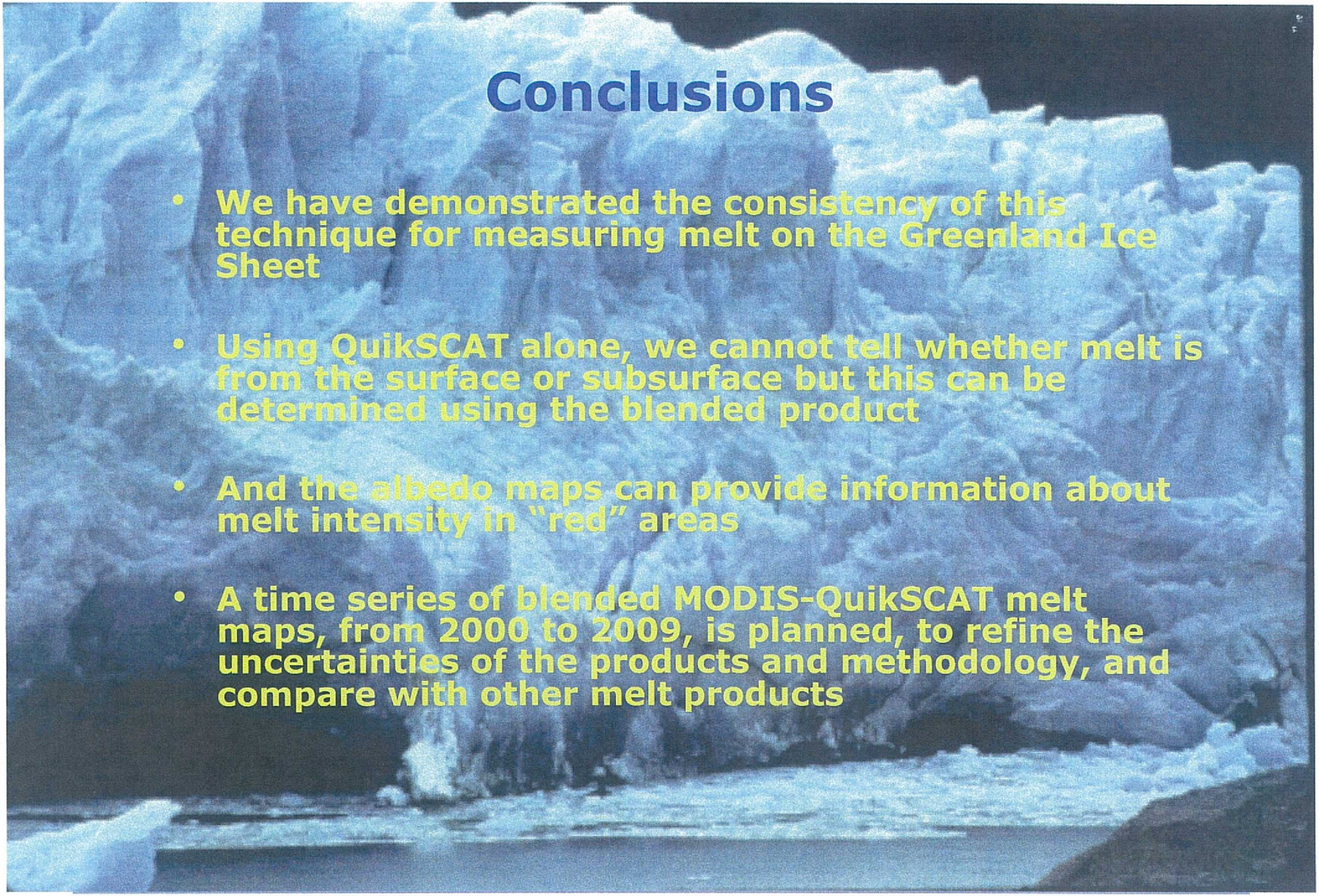


Total extent of seasonal snow melt from the MODIS LST (766,184 km^2 ±8%), and QS (862,769 km^2 ±3%) melt products, a difference of ~11%

Also, QuikSCAT detects melt under all sky conditions; surface tends to be warmer under clouds, hence more melt

*days 121-225

Hall, D.K., S.V. Nghiem, C.B. Schaaf, N.E. DiGirolamo and G. Neumann, 2009: Evaluation of surface and near-surface melt characteristics on the Greenland Ice Sheet using MODIS and QuikSCAT data, *JGR - Earth Surface.*, 114.



Conclusions

- We have demonstrated the consistency of this technique for measuring melt on the Greenland Ice Sheet
- Using QuikSCAT alone, we cannot tell whether melt is from the surface or subsurface but this can be determined using the blended product
- And the albedo maps can provide information about melt intensity in "red" areas
- A time series of blended MODIS-QuikSCAT melt maps, from 2000 to 2009, is planned, to refine the uncertainties of the products and methodology, and compare with other melt products