C-6 Standard Snow and Ice Product Suite: Status, and Evaluation for Science and Modeling Studies

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Outline

- C6 algorithm and product status
- MODAPS and LDOPE testing and evaluation
- Selected science results using C6 algorithms

MODIS Collection-6 Standard Snow-Cover Products

- M*D10_L2 -- 500-m resolution daily snow cover at the swath level
- M*D10GA -- 500-m daily snow-cover tile products – gridded to sinusoidal projection, L2G lite,
- M*D10A1 -- 500-m daily snow-cover tile products
- M*D10C1-- 5-km daily climate-modeling grid (CMG) snow cover
- M*D10A2 -- 500-m 8-day composite snow-cover tile products – gridded to sinusoidal projection
- M*D10C2 -- 5-km 8-day composite climate-modeling grid (CMG) snow cover
- M*D10CM -- 5-km monthly snow cover
- Other – to be discussed later

MODIS Collection-6 Standard Sea Ice Products

- M*D29 – 1-km resolution daily sea ice extent and IST swath;
- M*D29P1D -- 1-km resolution daily daytime sea ice extent and IST gridded;
- M*D29P1N -- 1-km resolution daily nighttime sea ice extent and IST gridded;
- M*D29E1D -- 4-km resolution daily daytime sea ice extent and IST gridded .

Focus of C6 Revisions

- Detecting snow over entire range of the Normalized Difference Snow Index (NDSI) , 0.0 – 1.0, in C6 compared to the lower limit of NDSI 0.4 in the binary snow algorithm used in C5; maximize ability to map snow cover;
    - Algorithm strategy/logic:
        - Definitely snow
        - Definitely not snow
        - Uncertain snow due to
            - Challenging viewing conditions e.g. low reflectance situations
            - Cloud/snow discrimination, use of MOD35_L2 cloud mask
            - Atmospheric conditions
            - Surface mineral features

- Use screens based on reflectance characteristics to prevent false snow detections on non-snow features, which have been effective in many situations and are used to determine QA.

- Increase information/data content of the QA, added bit flags to report screen results

C6 status

•Dropped the surface temperature screen that was used to prevent false snow detection because it was preventing snow detection during spring and summer in some regions; this has increased false snow detections in other situations.

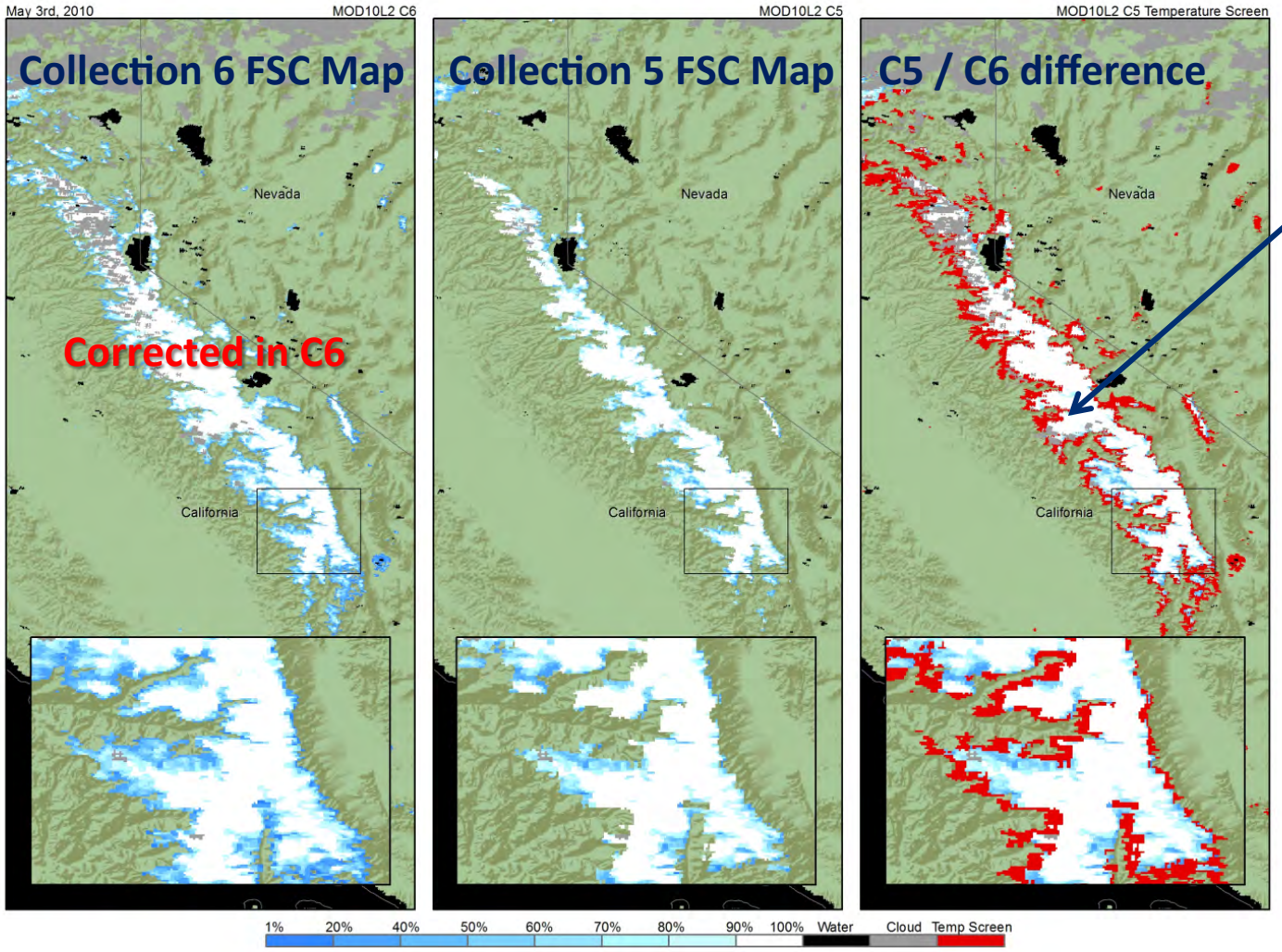
• Implemented the Quantitative Image Retrieval (QIR) algorithm (Gladkova et al.) for Aqua MODIS band 6 (1.6 µm) to provide useful data for the snow algorithm. Terra and Aqua will use same snow algorithm in C6. MODAPS implemented the QIR algorithm for testing and production. (QIR url csdirs.ccny.cuny.edu/csdirs/projects/multi-band-statistical-restoration-aqua)

•Increased accuracy of the UMD land/water mask has resulted in increased accuracy in snow products.

•MODAPS integrated observation selection algorithm and snow albedo algorithm to increase code efficiency in MOD10GA, those algorithms had been done in M*D10A1 algorithm in C5

•Snow commission errors on non-snow features revealed during C6 land chain tests resulted in revisions to some of the screens, yet an unacceptable amount of snow commission errors was found in most recent test (after removal of the surface-temperature screen); investigation of these errors is ongoing.

Deleterious Effect of the C5 Surface-Temperature Screen on Spring Snow-Cover Mapping in the Sierra Nevada Mts., USA



3 May 2010

Red shows how much snow was missed due to the C5 tempera-ture screen

C6 status

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•Increased accuracy of the UMD land/water mask has resulted in increased accuracy in snow products.

•MODAPS integrated observation selection algorithm and snow albedo algorithm to increase code efficiency in MOD10GA, those algorithms had been done in M*D10A1 algorithm in C5

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Iterative Testing and Revising

MODAPS and LDOPE have a greater role in this process
than was the case in developing C5

Iterative testing and revising of the algorithms and products process has evolved to be a collaboration with LDOPE and MODAPS having a greater role:

- We develop and analyze algorithm revisions on limited number of granules , then MODAPS integrates code revisions to the algorithm/ products;

- LDOPE conducts the testing of revisions using global data sets, e.g. the land chain tests, and does initial evaluation of results then we do a collaborative evaluation.

LDOPE Tests and Evaluation

C6 Snow Test, land chain test for snow PGEs (04/09/2014): ongoing:

- Accurate detection of snow cover extent in snow covered regions, acceptable quality regarding snow commission and omission errors.

- Significant amount of snow commission error associated with non-snow features (primarily shore/coast lines, water bodies, deeply shadowed vegetated surfaces, in regions where snow is not expected).

Test of new snow products (02/10/2014):

- Land C6 Chain test from L2G down, snow products only (11/12/2013);
- MODIS C6 land chain test (04/19/2013).

New C6 snow products

Production of:

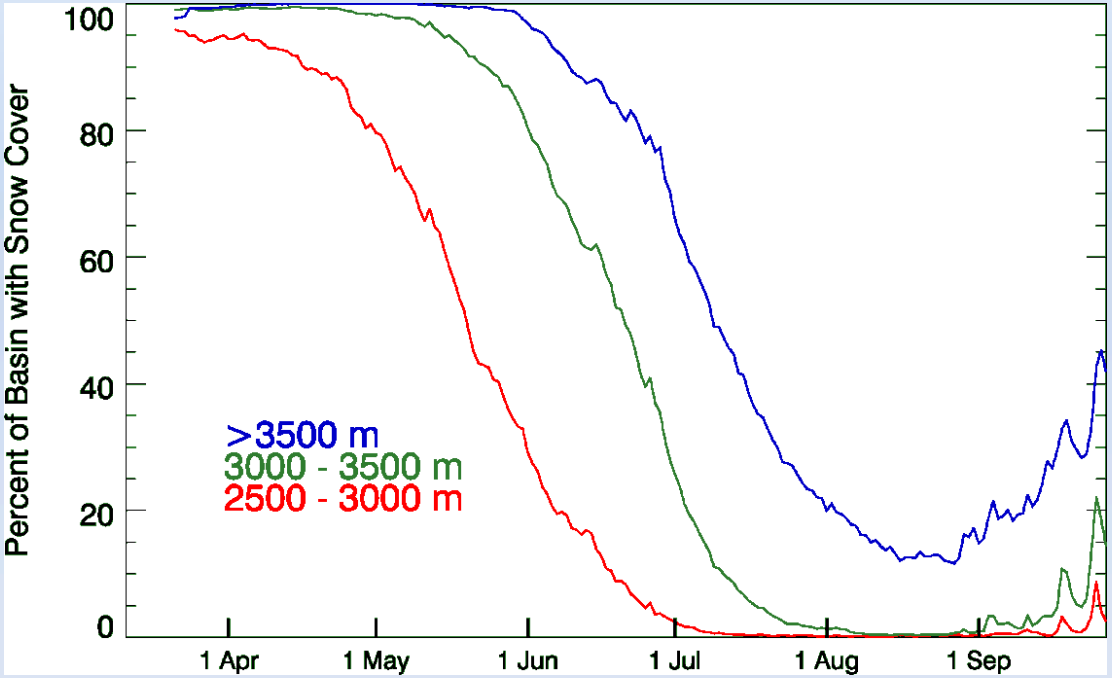
- Daily cloud gap filled (CGF) products at 500-m and 5-km resolution, and,
- Daily snow cover product (MOD10A1S), using surface reflectance input (MOD09GA)

will be requested after the start of C6 processing; these products have no downstream product dependencies.

Science Results using C6 Snow and Ice Algorithms

Green River at Warren Bridge Basin, Wind River Range, Wyoming

MODIS-Derived Snow-Cover Depletion Curves



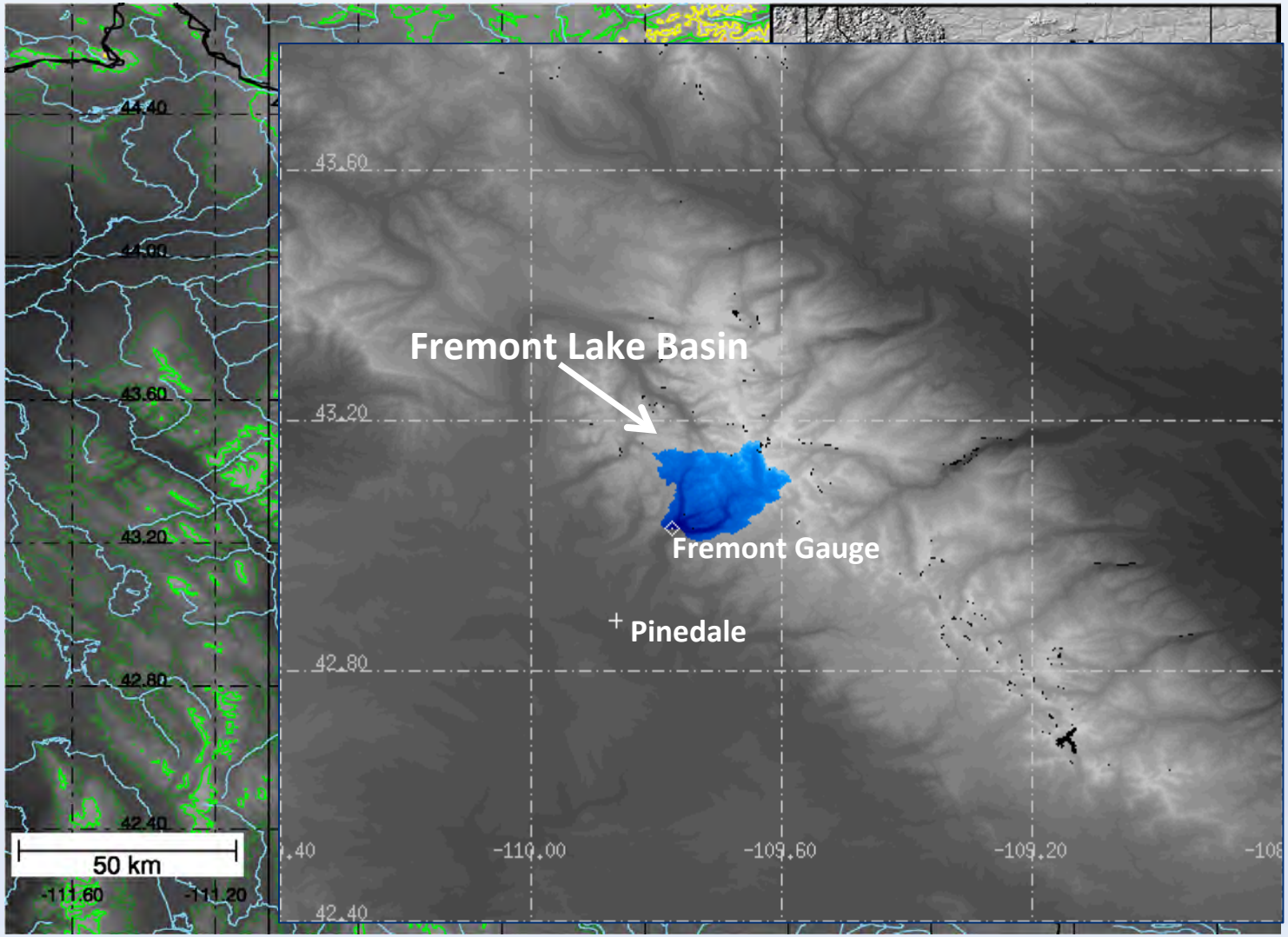
The Green River at Warren Bridge basin is at the headwaters of the Colorado River and is thus key to the water supply for the western U.S.

Runoff Modeling in the Wind River Range, Wyoming, using C6 Snow Cover

- The Snowmelt-Runoff Model (SRM) (Martinec, Rango & Roberts, 2008) simulated discharge in the Fremont Lake basin, 2000 – 2010, with R^2 values >90%;

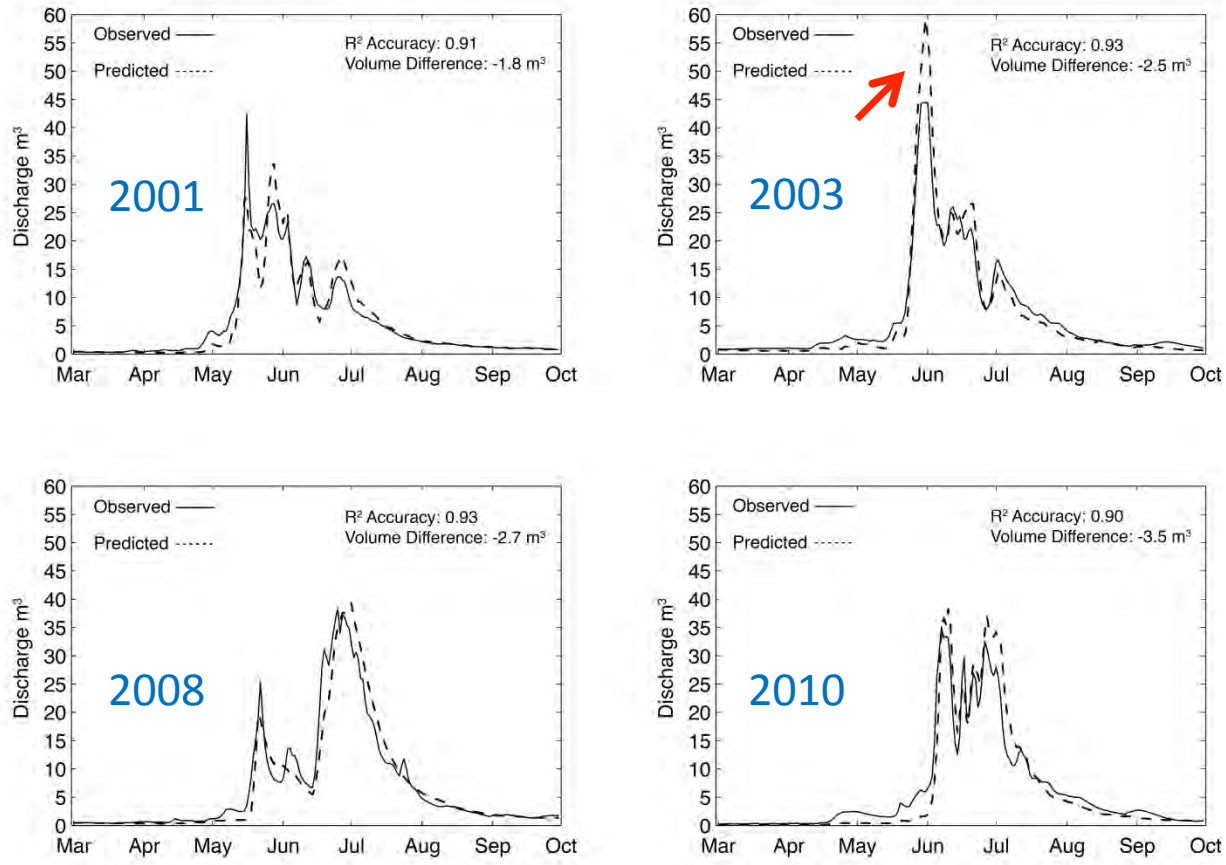
- MODIS C6 fractional snow cover, cloud-gap filled products were used as input.

Fremont Lake Basin, Wind River Range, Wyoming (260.17 km^2)



Fremont Lake Basin, Wind River Range, Wyoming

Snowmelt-Runoff Model (SRM) simulations vs. measured discharge

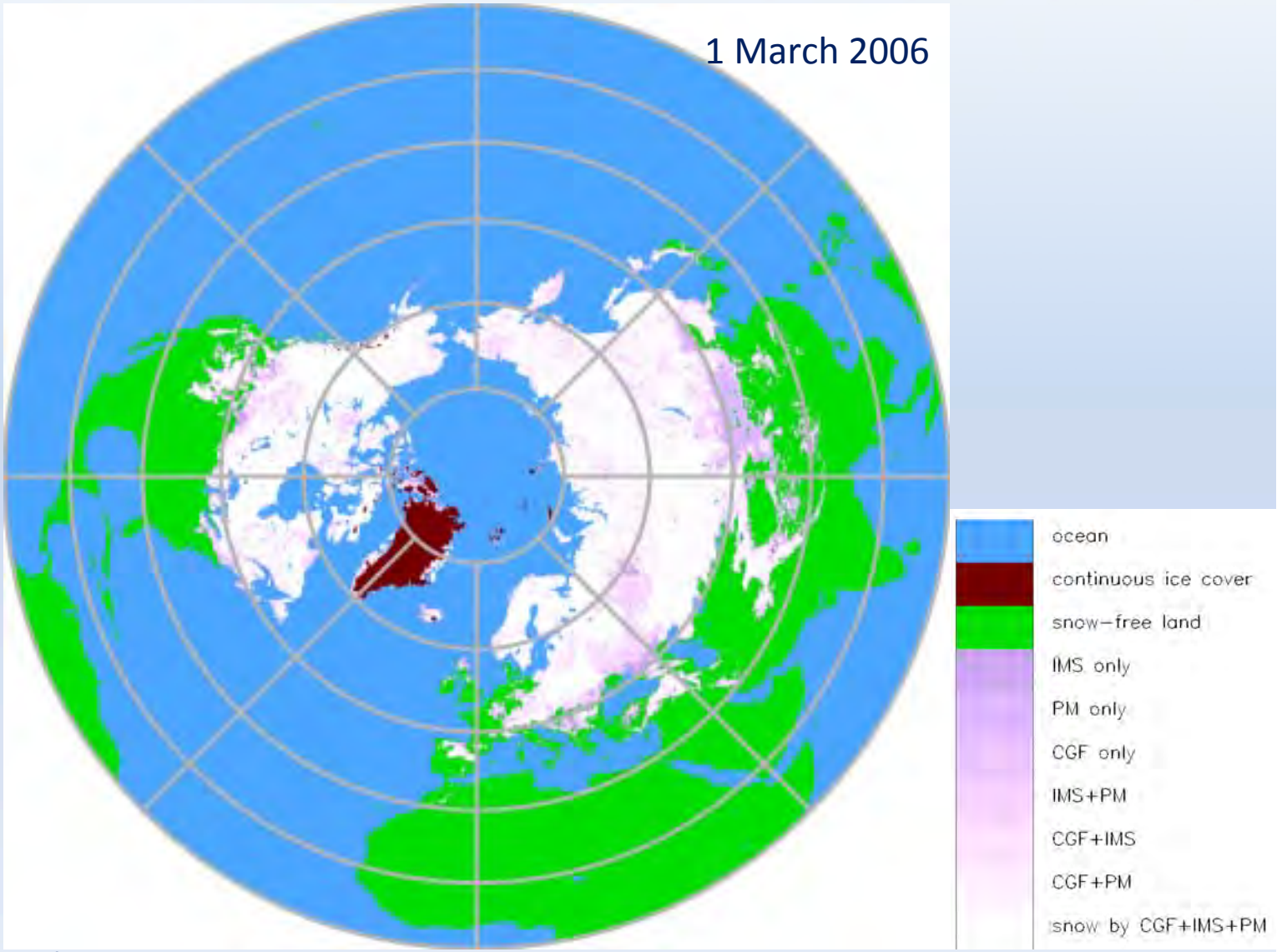


Model runs by Chris Crawford / ORAU

MEaSUREs* Merged Snow Product

Northern Hemisphere Snow Products Blended, 2000 - 2012

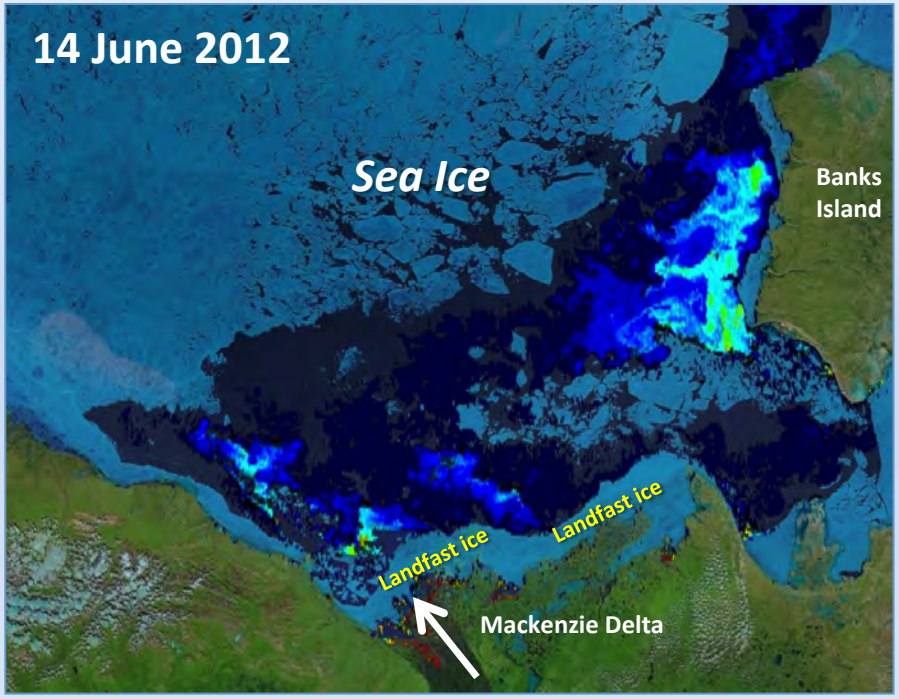
Uses C6 cloud-gap filled (CGF) snow cover snow-cover product , M*D10F

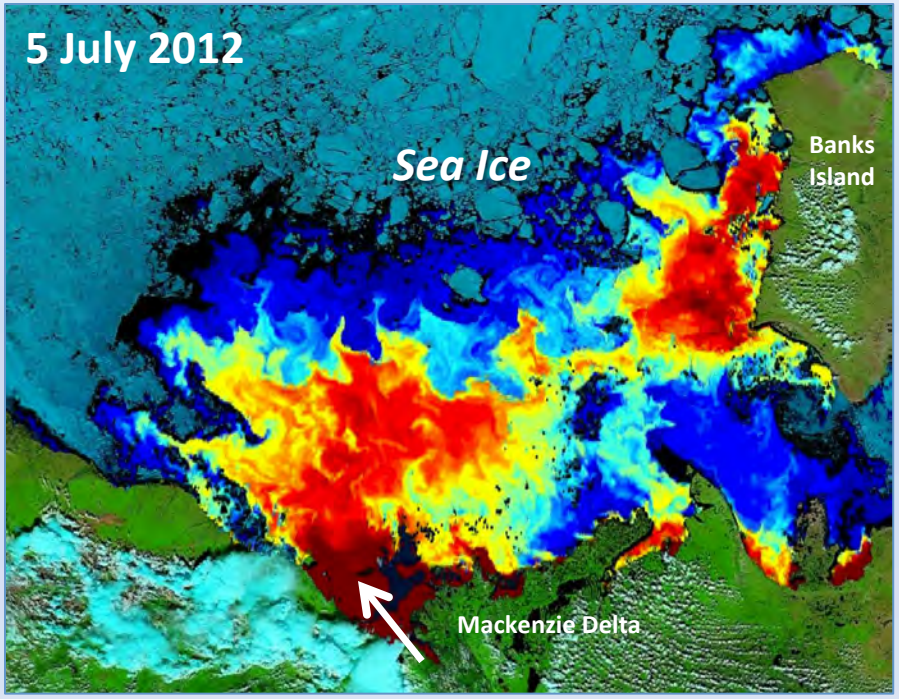


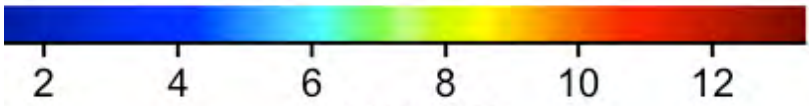
*Making Earth System Data Records for Use in Research Environments

Water temperature from MODIS IST product, MOD29

Left - before the Mackenzie River water broke through the landfast sea ice barrier
Right - after warm water from the Mackenzie River discharged into the Beaufort Sea







IST / SST °C (SST = water temperature)

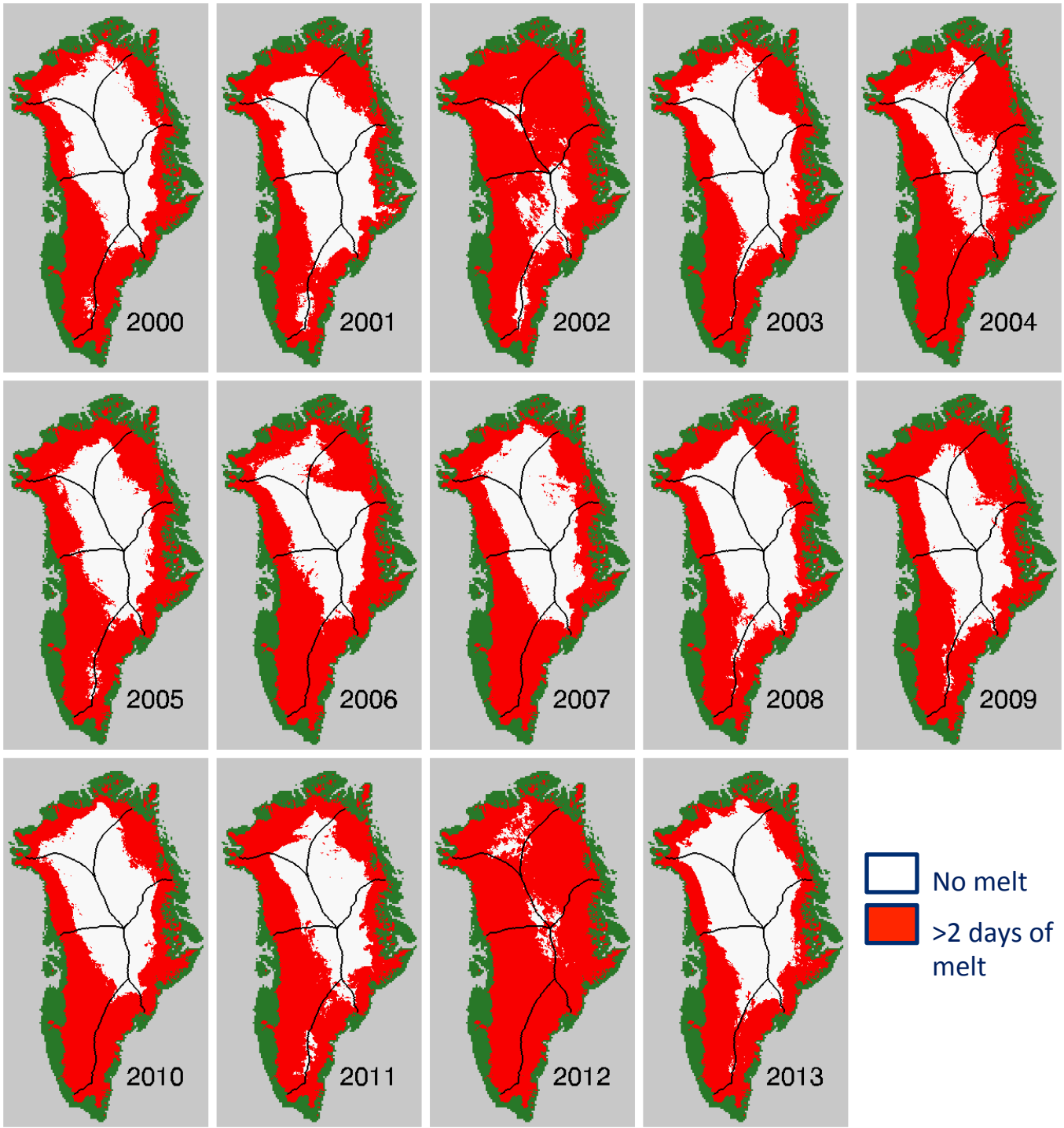
From Nghiem , Hall, Rigor, Li & Neumann, *GRL* (2014)

Greenland Ice Sheet Climate-Quality Data Record

Upgraded to 1.5-km spatial resolution, through March 2014;

Additional cloud masking done for each summer scene, to increase the accuracy of the IST, and melt mapping;

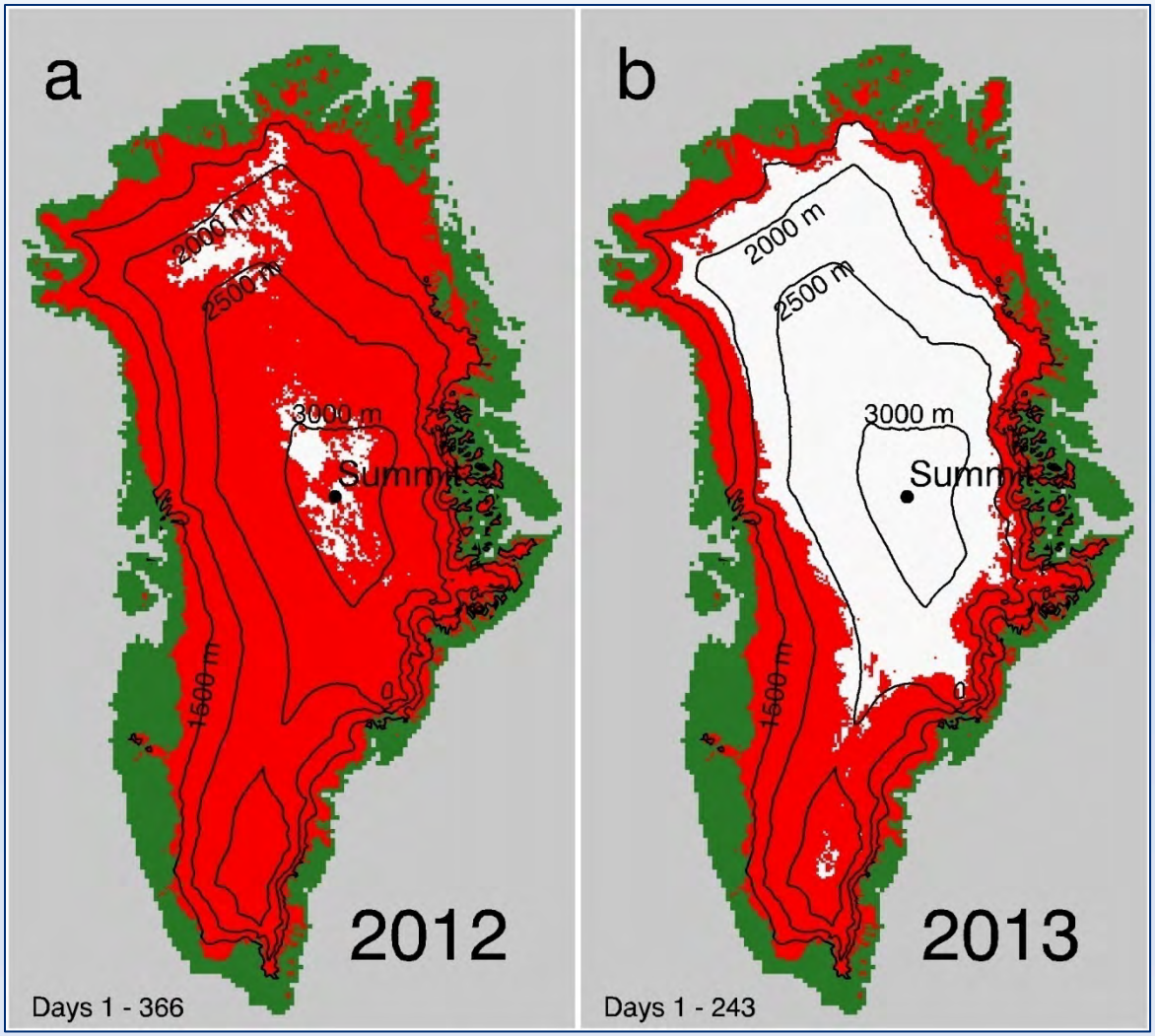
Dataset will be available to download by summer 2014.



Maps of annual maximum *clear-sky* melt extent from MODIS IST data from MOD29*

Six major drainage basins are outlined in black

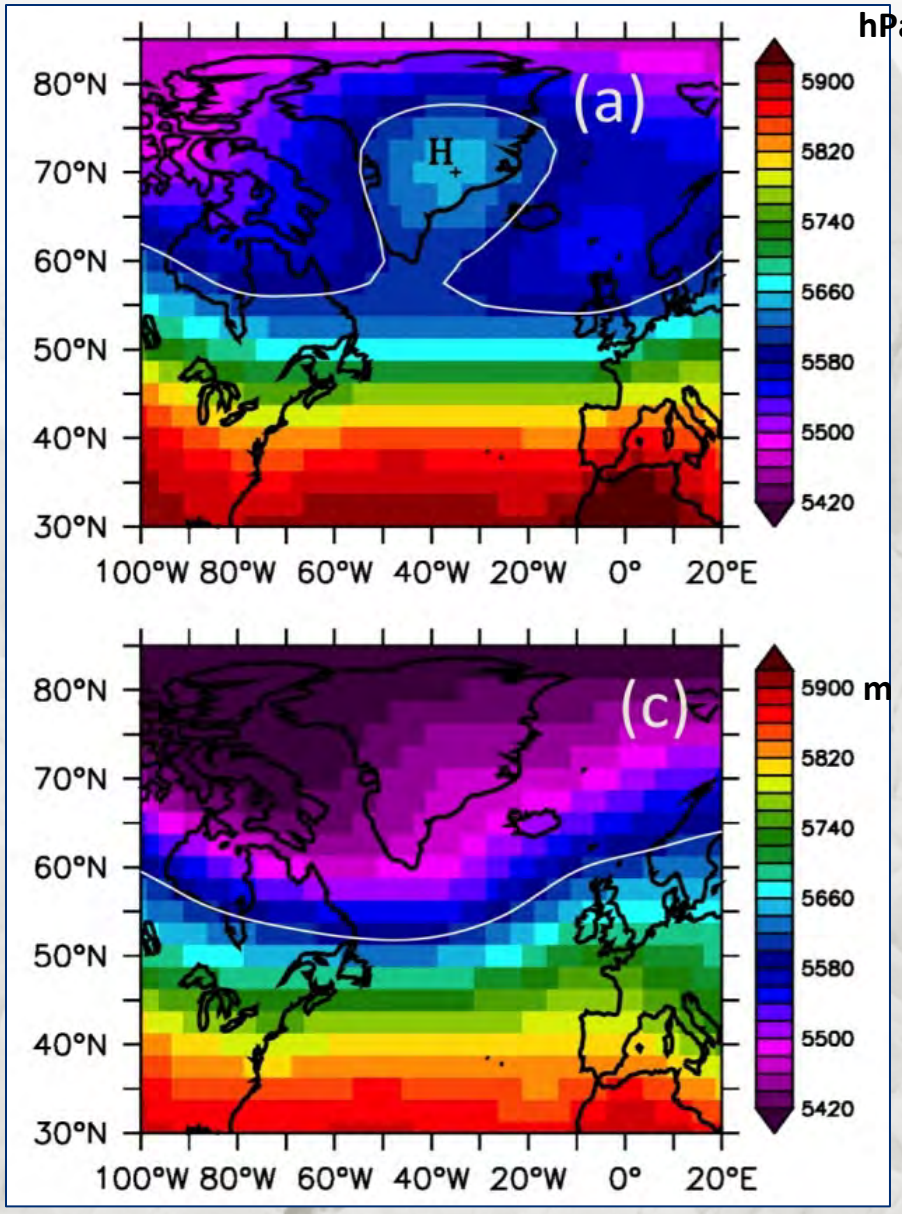
Extended from: Hall, D.K., J.C. Comiso, N.E. DiGirolamo, C.A. Shuman, J.E. Box and L.S. Koenig, 2013: Variability in the surface temperature and melt extent of the Greenland ice sheet from MODIS, *GRL*.

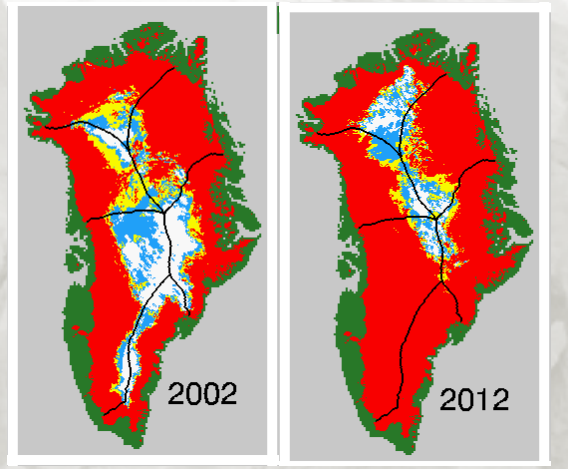

a
2000 m
2500 m
3000 m
Summit
1500 m
2012
Days 1 - 366
b
2000 m
2500 m
3000 m
Summit
1500 m
2013
Days 1 - 243

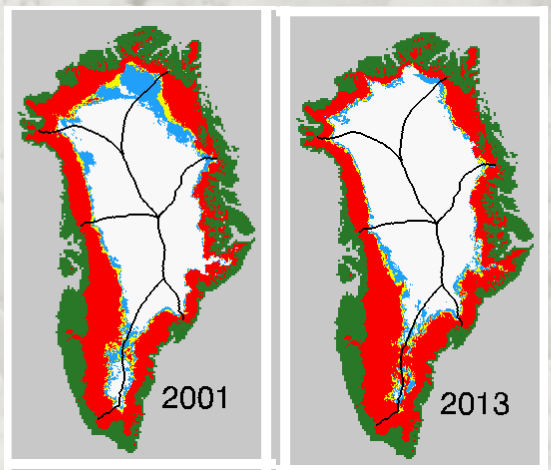
Atmospheric blocking patterns bring warm subtropical air over the ice sheet, controlling daily surface temperatures and melt

Top – Atmospheric blocking lasting 5 or more days can cause major melt episodes on the ice sheet (e.g., 2002 and 2012).

Bottom – Blocking patterns, absent in 2001 and 2013 (e.g. zonal flow) indicating they are needed to initiate extensive melt especially at higher elevations.







Häkkinen, S., D.K. Hall, C.S. Shuman, D.L. Worthen & N.E. DiGirolamo, in press, *GRL.*

Conclusions

- Snow cover and sea ice algorithms were mature in C5, but improvements have been made;
- New products will be added to C6:
  - Cloud-gap filled snow maps;
  - Maps based on surface reflectance (instead of TOA).
- Standard snow product improvements:
  - Removed surface temperature screen;
  - Added screens to reduce snow commission errors.
- Science results using C6 products include:
  - Snowmelt-runoff modeling in the Wind River Range using MOD10A1;
  - Use of MOD29 to map sea surface temperature and help explain sea ice minimum of 2012;
  - Use of MOD29 to map IST and melt over Greenland.