DTU Space
National Space Institute

DTU Technical University of Denmark

www.space.dtu.dk

Ice_Sheets-CCI: Essential Climate Variables for the Greenland Ice Sheet

R Forsberg, L Sørensen, J Levinsen, R Meister, J Dall, A Kusk (DTU-Space. Denmark), C Ås, D Evansberget (S&T, Norway), R Mottram (DMI, Denmark), S Andersen, M Langer (GEUS), C Hvidberg (NBI, Denmark), K Khvorostovsky (NERSC, Norway), T Nagler, K Scharrer (ENVEO, Austria), A Shepard, F Ticconi (U Leeds, UK)

Products overview

The *CCI_ice_sheet* project will provide selected, consistent, easy-to-use selected ECV's for Greenland, based mainly on ESA EO data (radar altimetry and SAR)

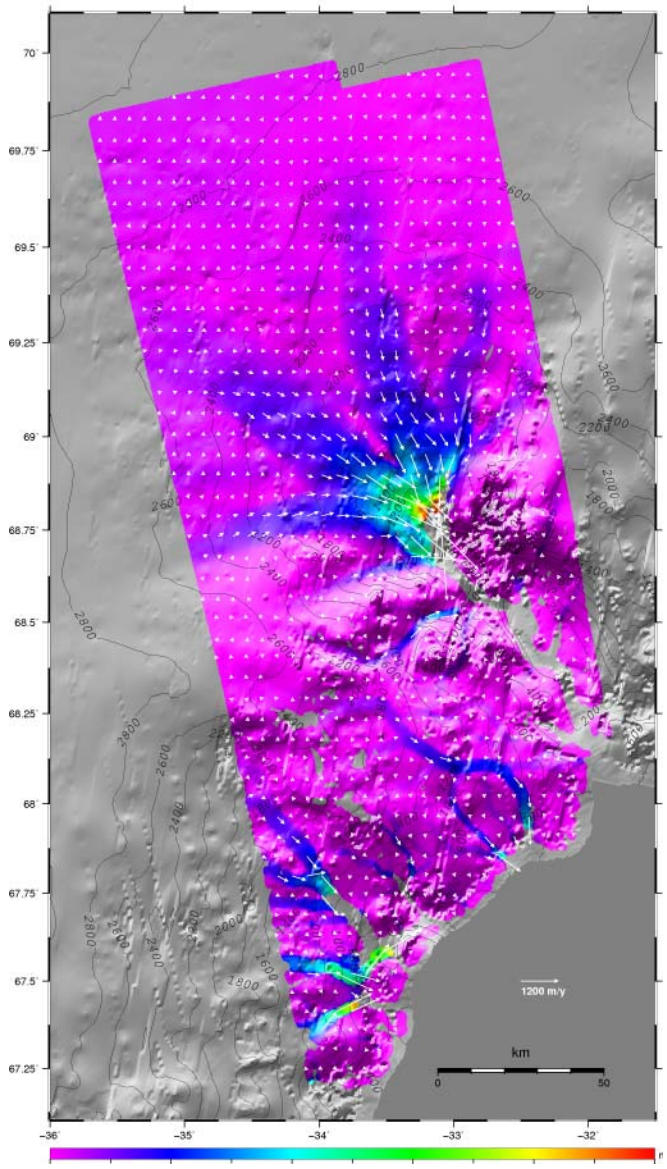
Coverage of ECVs, based on user requirements

ECV Product	Spatial resolution	Temporal resolution	Period	Spatial and temporal coverage, first 3-yr phase
Surface Elevation Change (SEC)	5 km grid	4 per year	1991-present	All ice sheet, 1991-2012 5-year running means
Ice Velocity (IV)	500 m grid	1 per year*	1991-present	Coastal margin (winter 1995/96 and summer 2008) Timeseries on Jakobshavn and Upernavik isbræ; North Greenland interior drainage basin (winter 1991/92)
Calving Front Location (CFL)	250 m shapefile	4 per year	1991-present	19 named major glaciers (some glaciers sampled yearly, depending on data availability)
Grounding Line Location (GLL)	250 m shapefile	1 per year	1991-present	Petermann, Hagen and 79-Fjord Glaciers

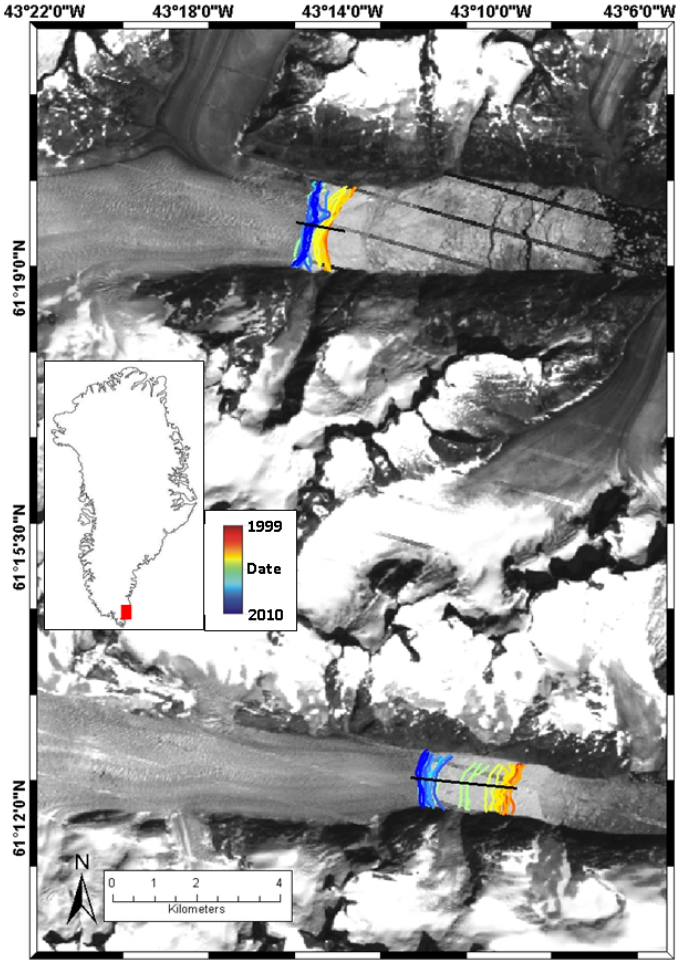
** After CCI phase 1*

Examples: IV and CFL

- Ice velocity and grounding lines determined by SAR feature tracking and interferometry
- CFL and GLL from optical and SAR imagery



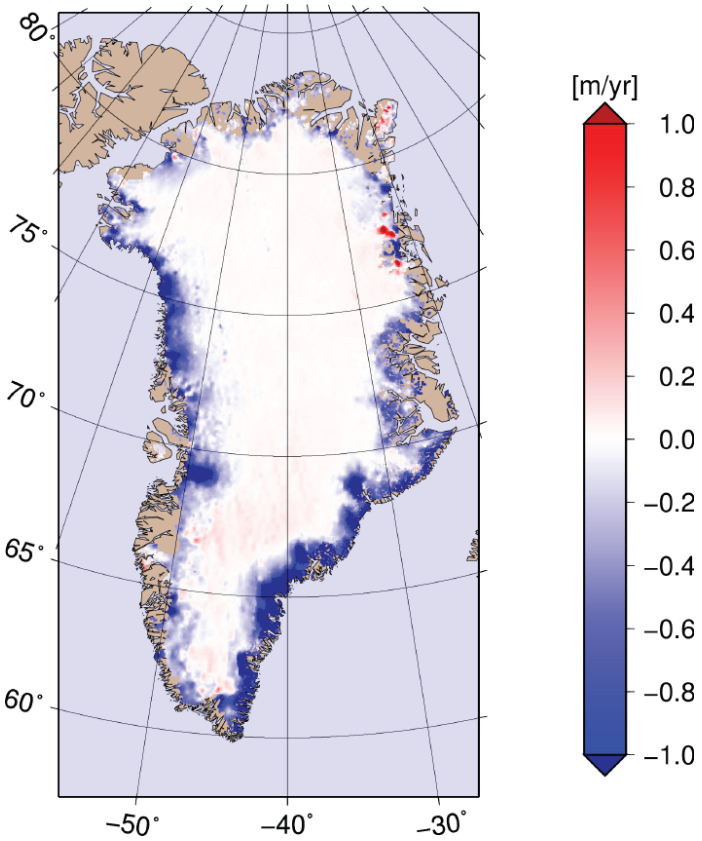
< =
Example of IV for
Kangerlussuaq Glacier,
East Greenland
Nov 2009-Jan 2010
(Merryman, DTU-Space)



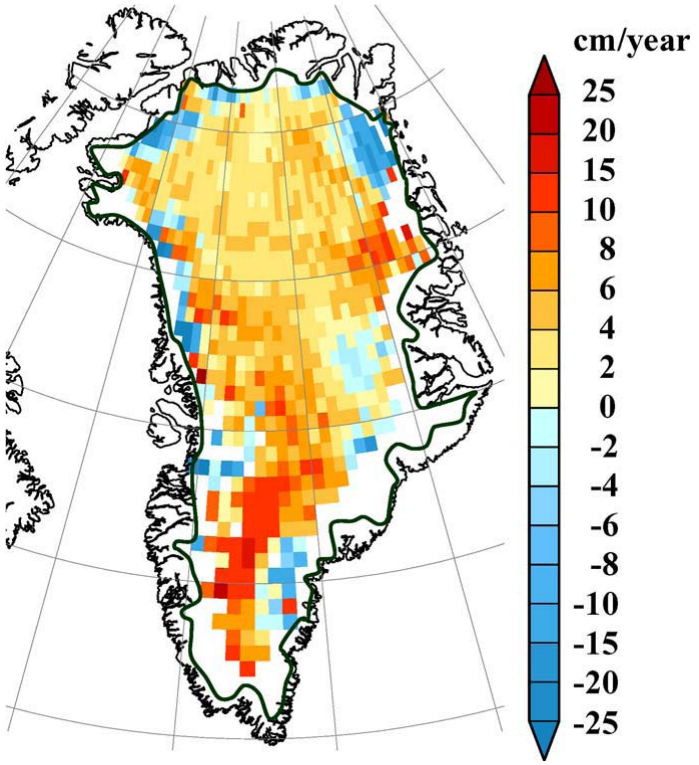
= >
Example of CFL
1999-2010 for
southern glaciers,
East Greenland
(Nagler, ENVEO)

Examples: SEC

The ECV products will build on ERS/Envisat/Sentinel-3 .. with auxillary use of IceSat
Final algorithm selection awaits Round-Robin exersise results ..

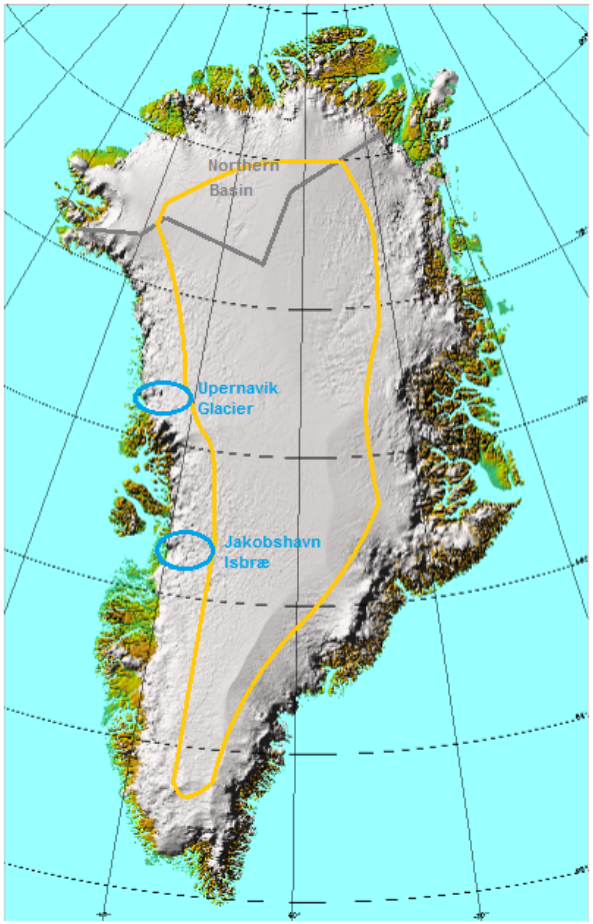


SEC from IceSat data 2003-9 (Sørensen et al, DTU-Space)
Total mass loss ~230 GT/yr, similar to GRACE results



SEC from ERS and Envisat 1992-2008
(Khvorostovsky, NERSC)

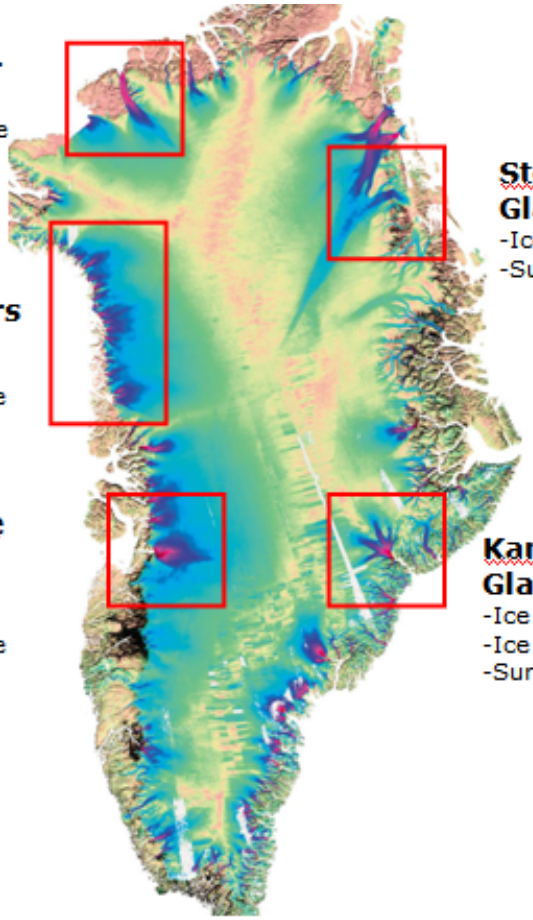
Products – areas and data



Petermann Glacier
-Grounding Line
-Surface Elevation Change
-Ice Velocity

West Coast Glaciers
-Ice Velocity
-Ice Calving Front
-Surface Elevation Change

Jacobshavn Isbrae Glacier
-Ice Velocity
-Ice Calving Front
-Surface Elevation Change



Storstrømmen Glacier
-Ice Velocity
-Surface Elevation Change

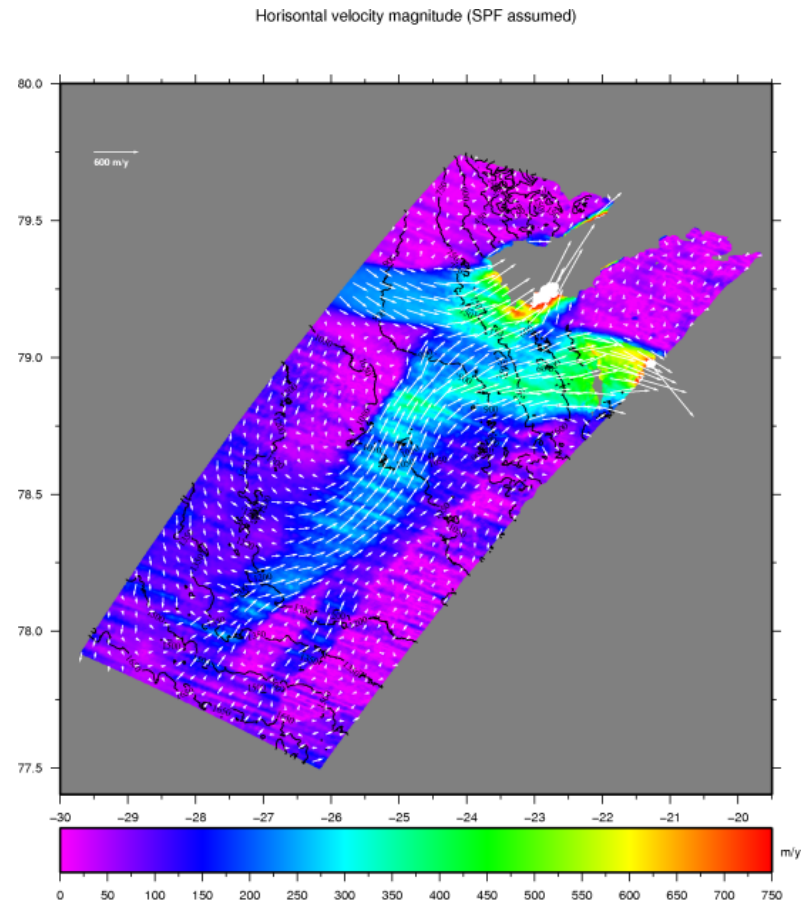
Kangerdlugssuaq Glacier
-Ice Velocity
-Ice Calving Front
-Surface Elevation Change

Example of first phase ECV data coverage: Ice Velocity from SAR interferometry: Coastal regions, northern basin, and time Series on Jakobshavn and Upernavik Glaciers

Key regions for ECV validation from independent satellite, airborne and surface data *(background image: Ice velocities from SAR, from I. Joughin)*

Status: Algorithms and errors

Example: Ice Velocity



79-fjord IV from speckle tracking (GEUS/DTU)

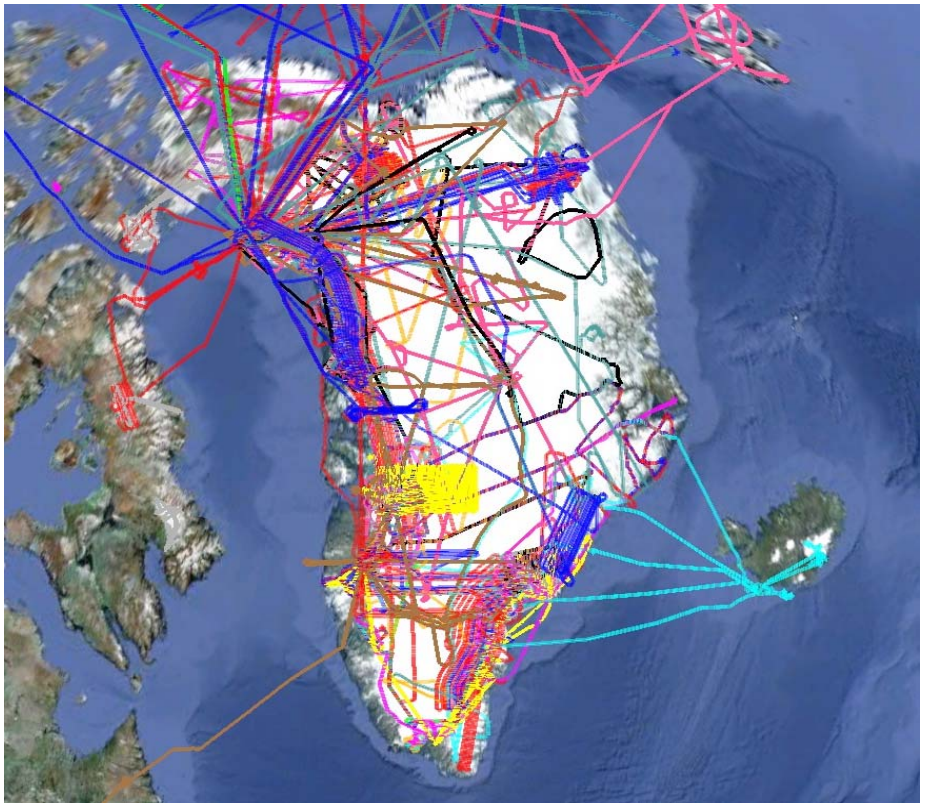
- Ice velocity and grounding lines determined by SAR feature tracking and interferometry – *local + ESA GPOD*

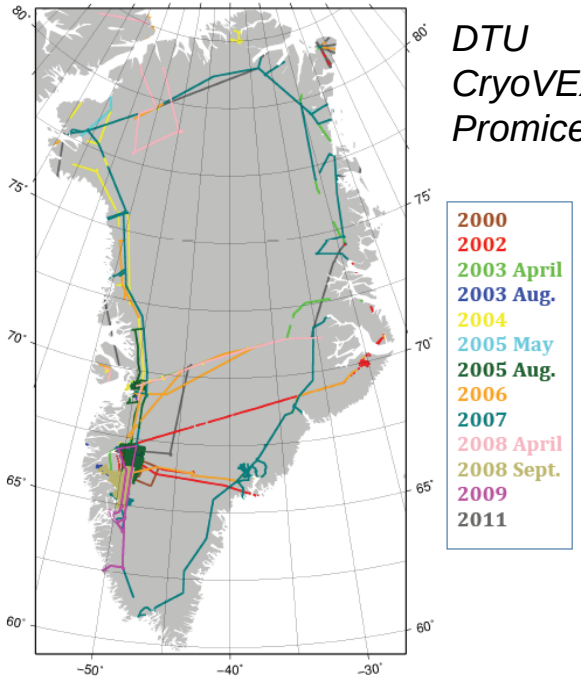
- Three methods - complementary error characteristics:
  - *Speckle tracking*
  - *D-InSAR*
  - *MAI (multi-aperture interferometry)*

Area	***Accu-racy***	***Sensors***	***Method***
Ice sheet interior	<10 m/y	ERS SAR	Calibration with balance velocities D-InSAR and MAI techniques
Ice sheet margin	10 to 30 m/yr	ERS SAR, ASAR, PALSAR	Calibration with stationary control points on bedrock. Speckle-tracking (highest accuracy) and feature-tracking (lowest accuracy)

SEC Validation data

Validation of Surface Elevation Change: NASA IceBridge and ESA CryoVEx



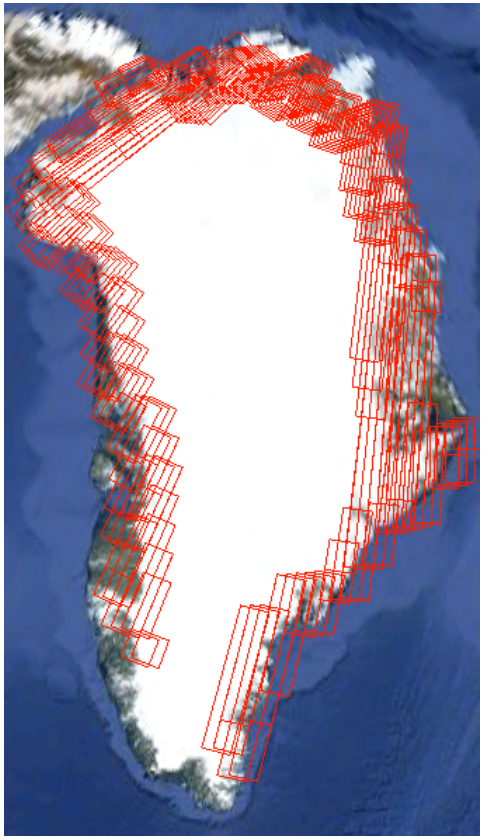


DTU CryoVEx / Promice

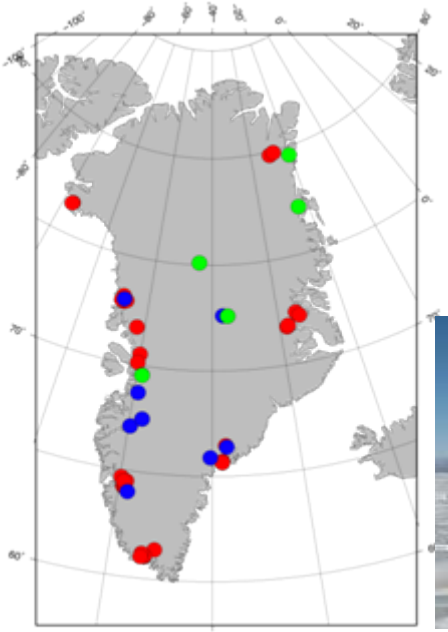
NASA Parca / IceBridge

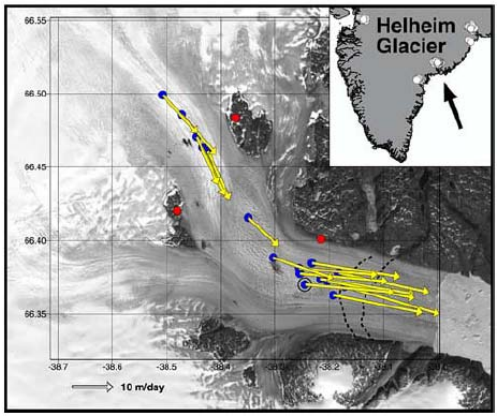
IV and CFL validation data

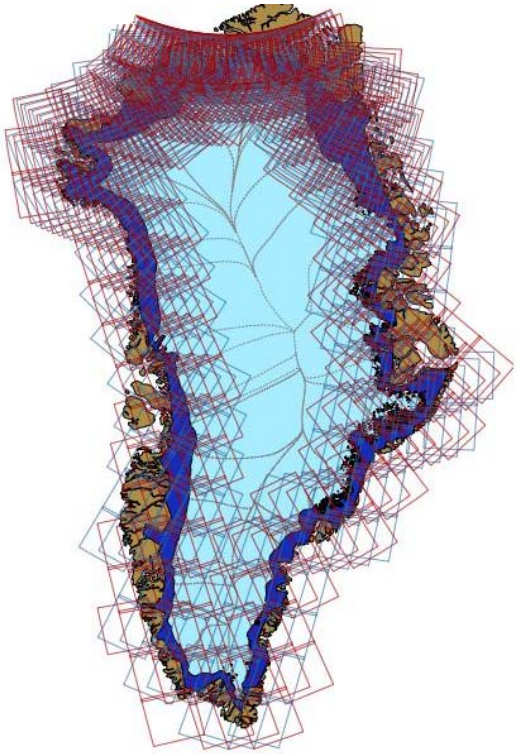
Validation data .... *GPS velocity (IV) and Landsat (CFL)*



Envisat ASAR summer 2008 (ECV production data)







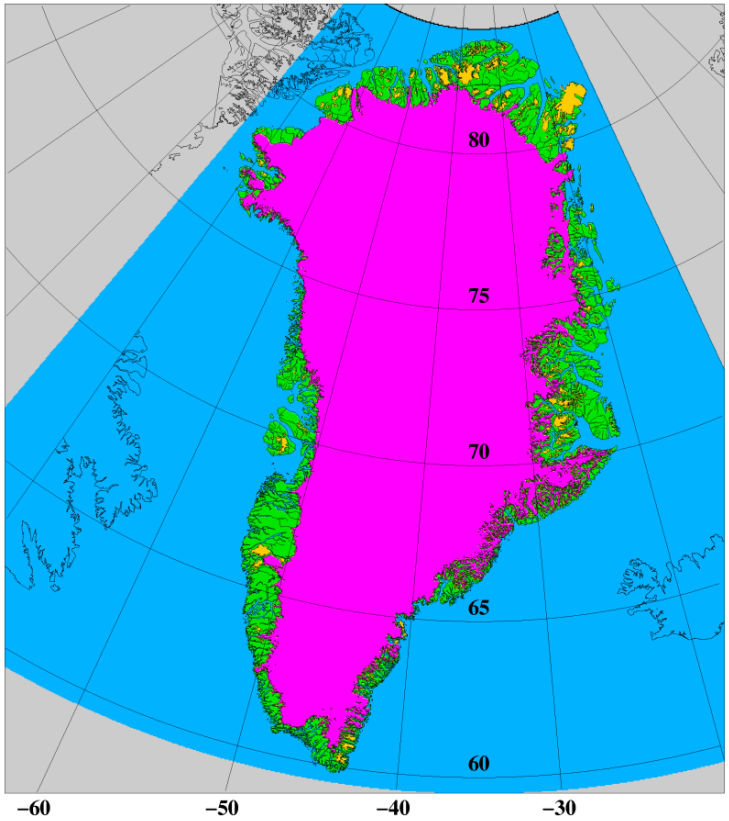
Landsat data coverage for Calving Front validation

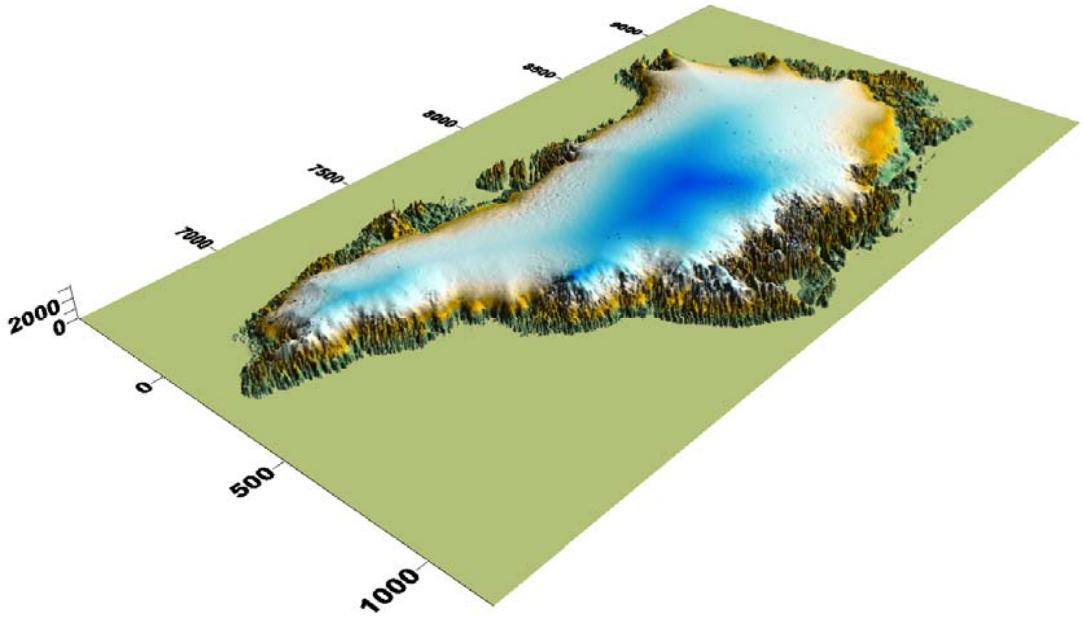
In-situ GPS data from PROMICE and various outlet glacier projects

Auxillary data

Improved DEM of Greenland from digital mapping, ASTER, ERS/ICESat and (soon) CryoSat

- Reference for SEC and IV .. resolution 200 m-1 km, polar stereographic or UTM
- Land/ice masks … including outlying glaciers and ice caps

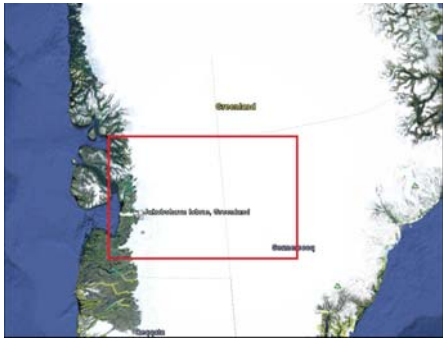




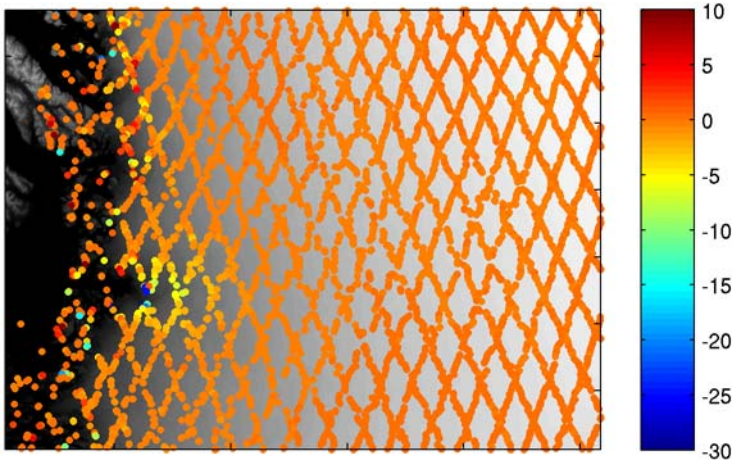
Status: Round-Robin excersize

Round-Robin: External tests for best methods .. *Common areas, time span, data*
Participants: *SEC: 10 researchers; IV: 11; CFL: 4; GLL: 0 (!)*

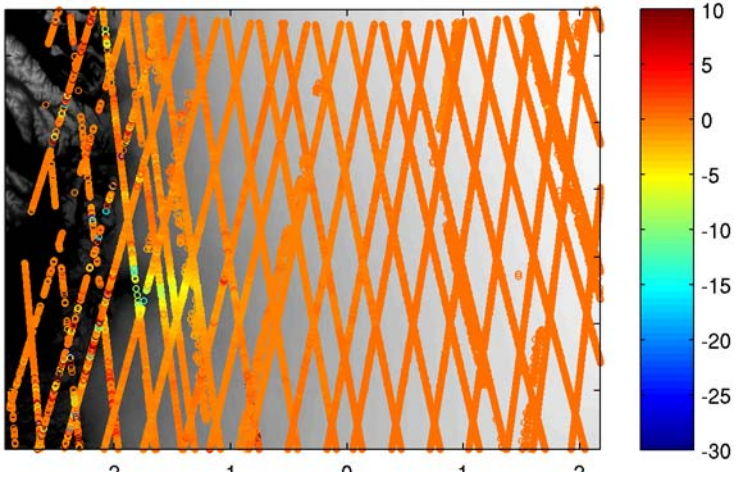
Example: Surface Elevation Change – ICESat and EnviSat / x-over and repeat-track methods



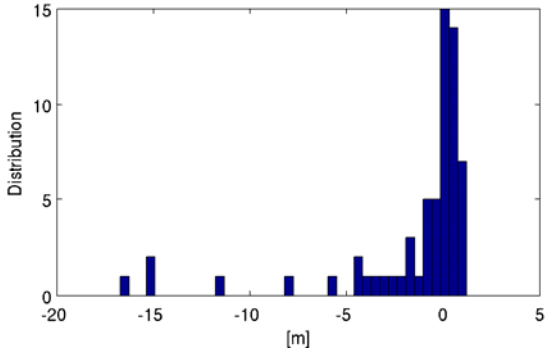
Area:
Jakobshavn Isbræ
drainage basin



Envisat SEC
(T Flament)



IceSat
(several)



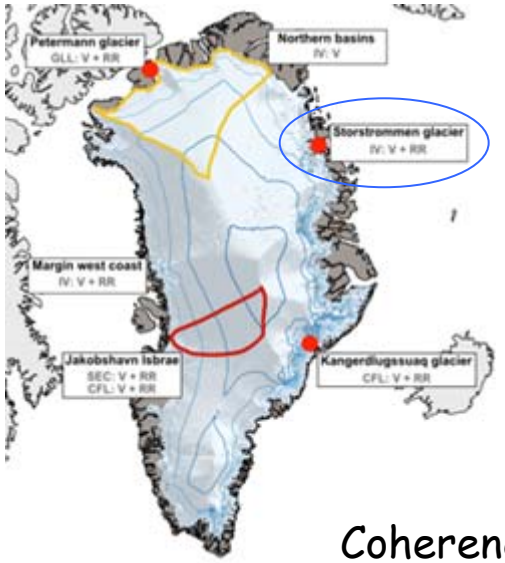
x-over
vs
repeat-
track
(IceSat)

Status: Round-Robin - IV

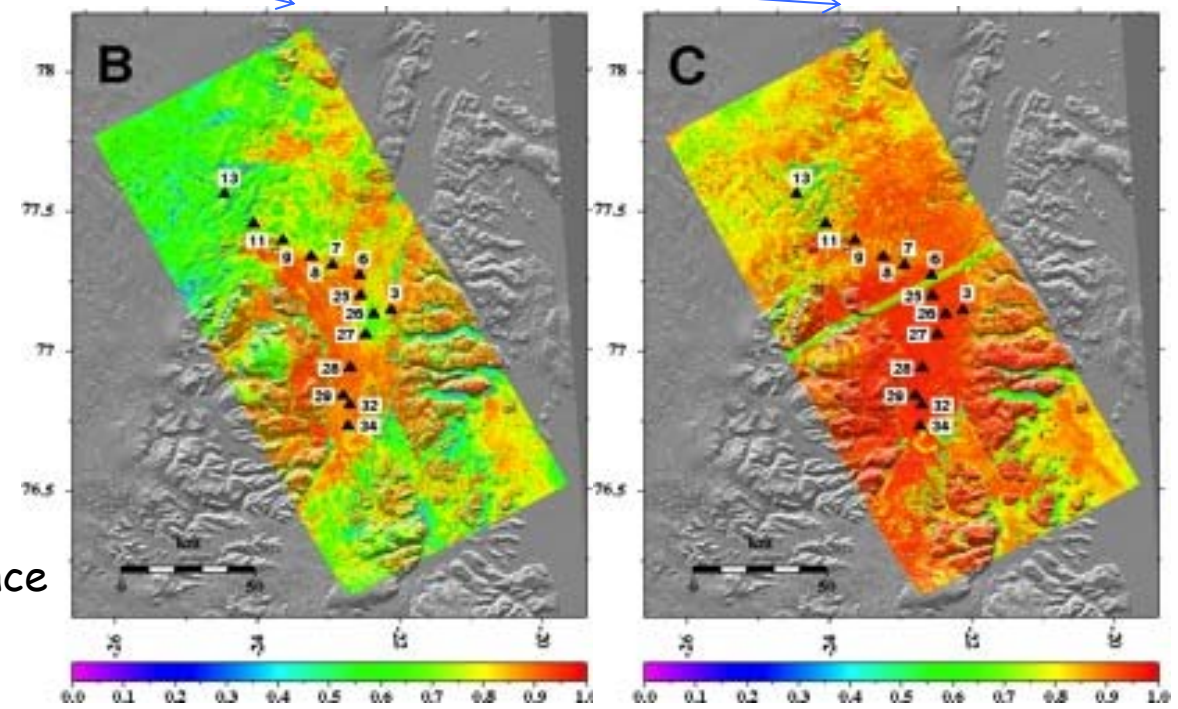
Round Robin Dataset

Id	Sensor	Acquisition date	Bperp [m]	Dfdc [Hz]	Btemp [days]
Pair 1	ERS-1	31 Jan. 1996	140	0	1
	ERS-2	01 Feb. 1996			
Pair 2	ERS-1	10 Apr. 1996	-20	245	1
	ERS-2	11 Apr. 1996			

Input:
- Level 0 (RAW) data
- Precise state vectors (Delft)
- 90 m DEM

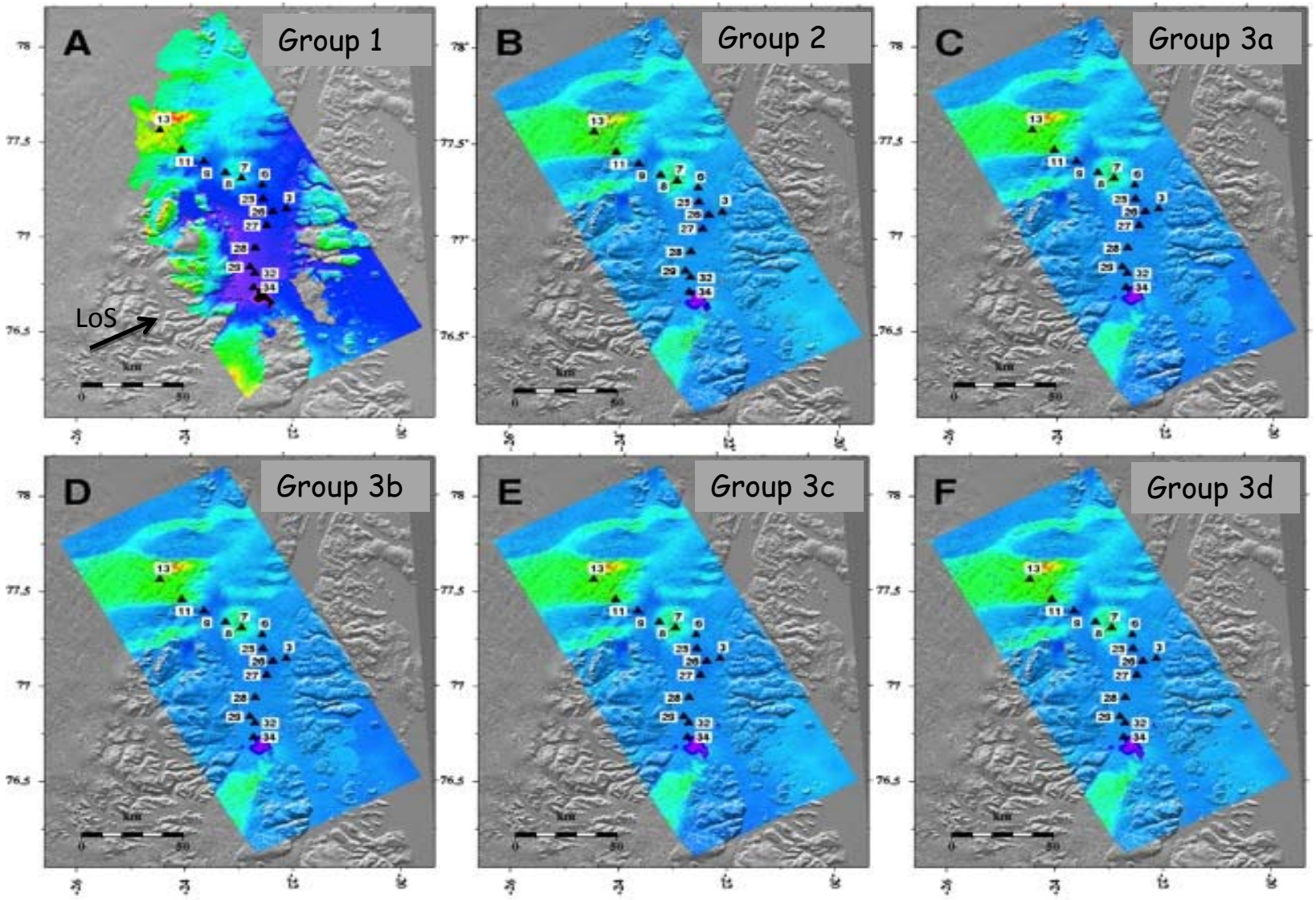


Coherence



Goal: derive slant-range velocity map using DEME (two-pass) or DD (four-pass)

Status: Round-Robin - IV



▲ = GPS

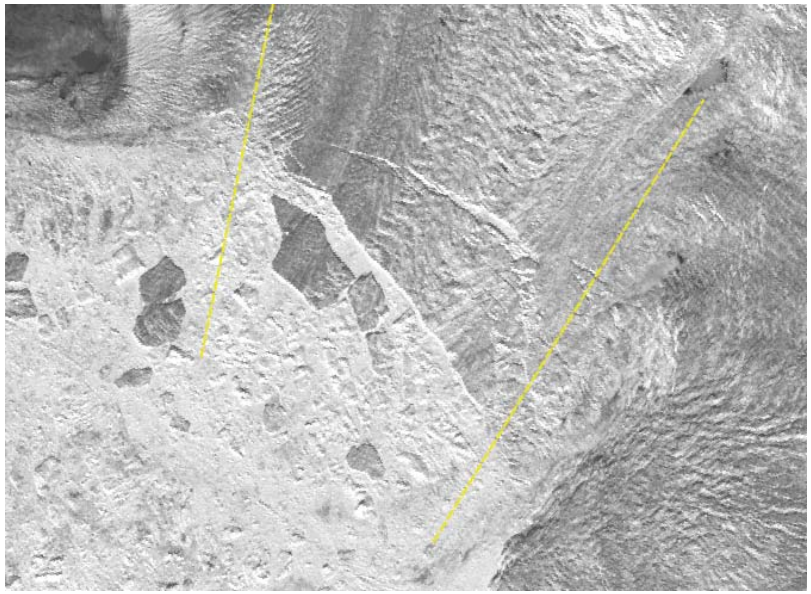
Slant-range Velocities

-100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160 180 200

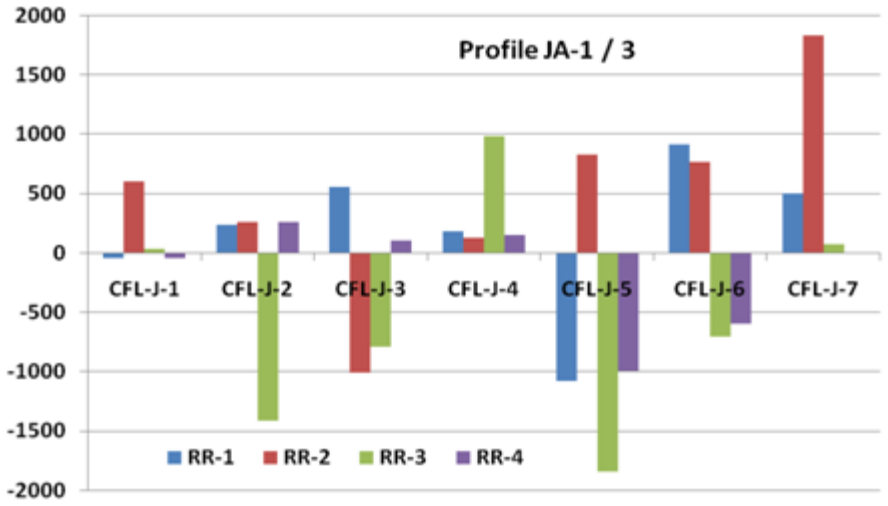
Storstrømmen Glacier

Status: RR Calving Fronts

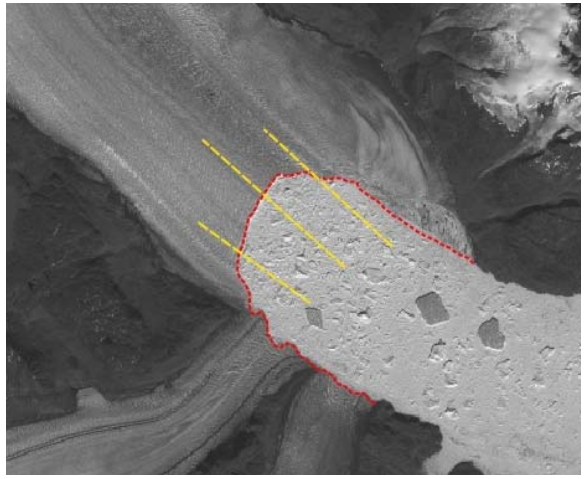
Areas: Jakobshavn and Kangerlussuaq (East) – *manual digitalizations / SPOT "ground truth"*

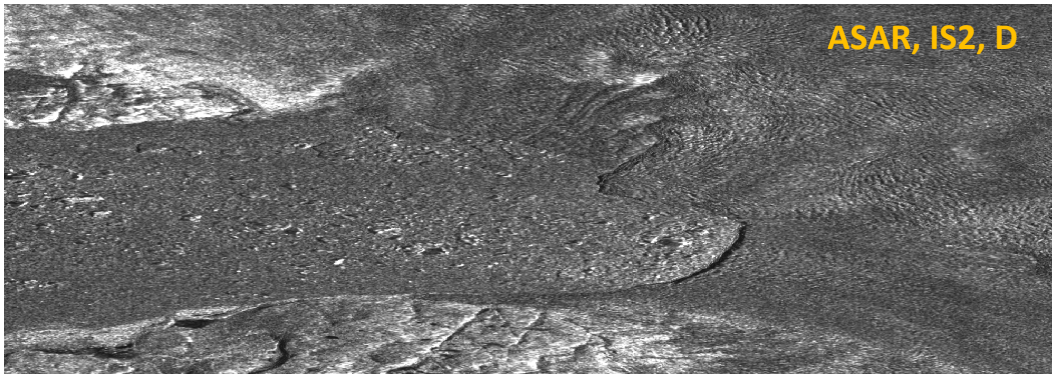


Jakobshavn northern part: where is the CFL?

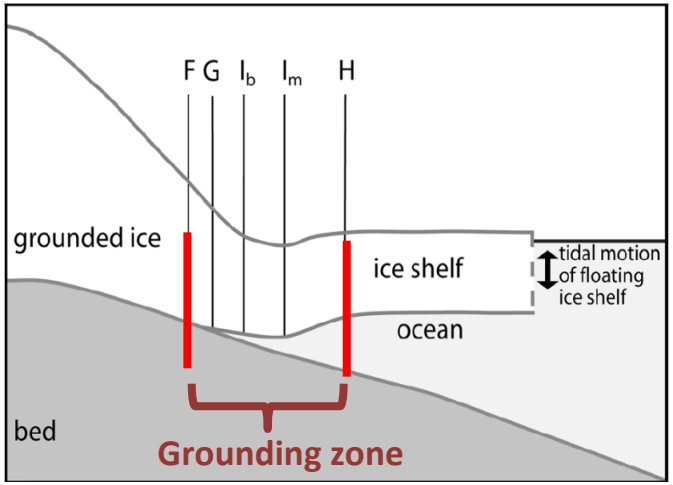


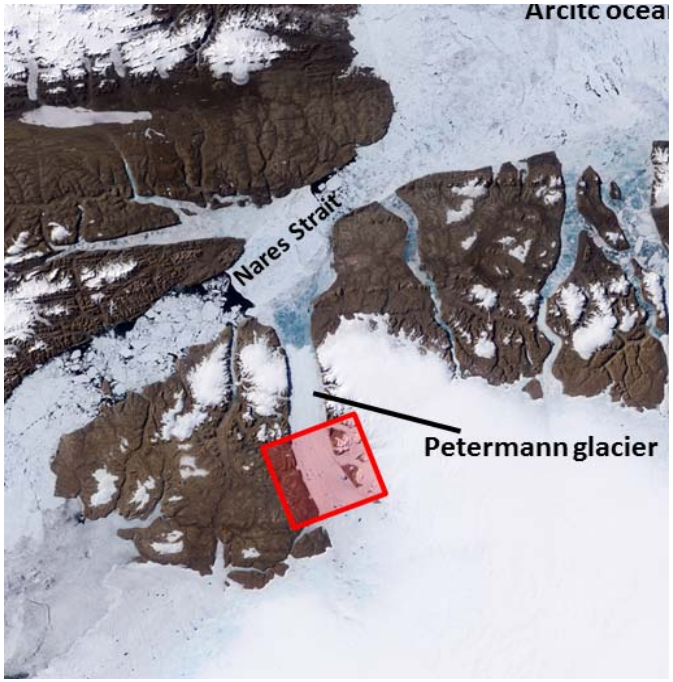
Kanger-lussuaq

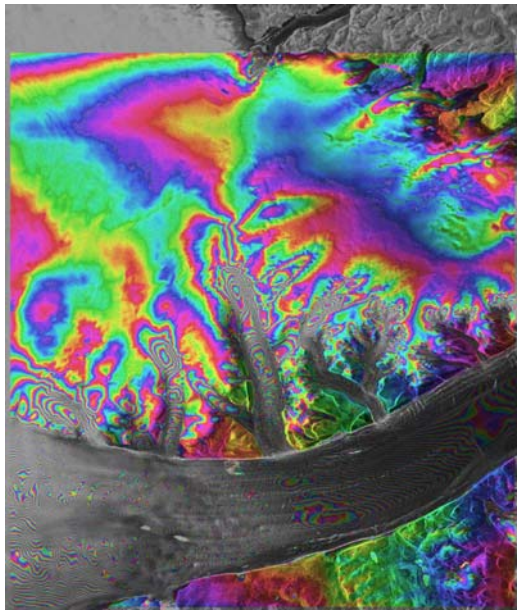




Status: RR grounding lines





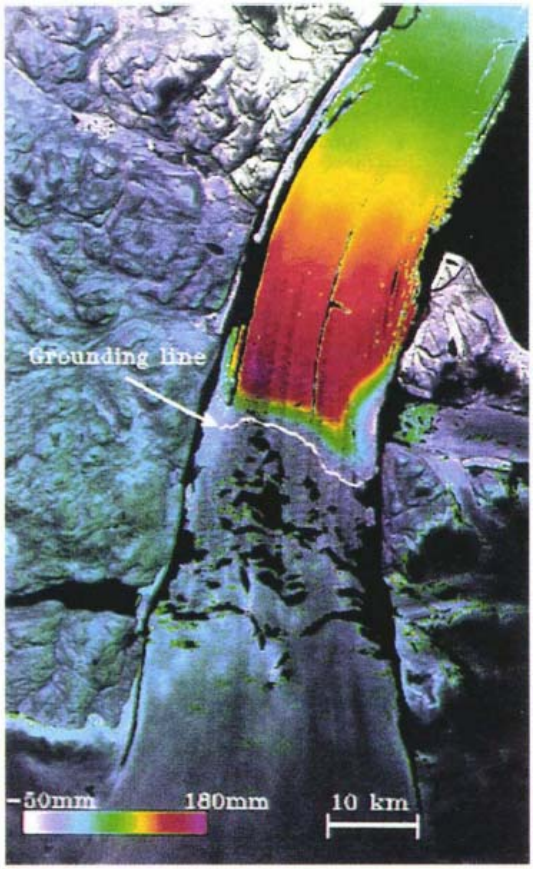


Master: 28/02/1992
Slave: 02/03/1992
B_{perp}: 1 m
+ 3 more scenes distributed

No external participants
.. but nearly same data used by Rignot (1996)

GPS ground truth anyone?
Internal experimental validation: TanDEM-X repeat (ENVEO)

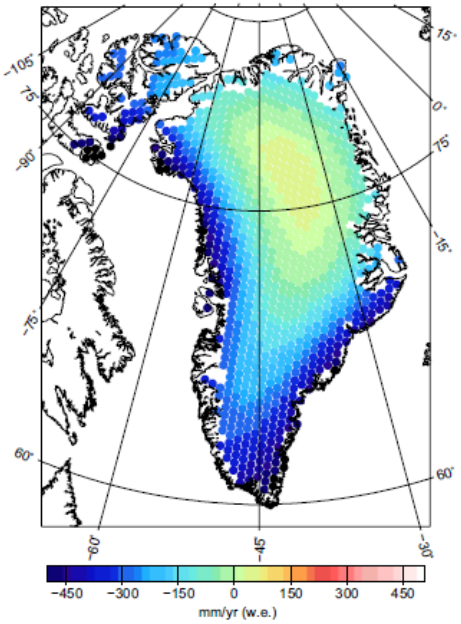
Antarctica experiment upcoming (Fimbul Ice Shelf, DML)



- PVASR, IODD+DPM
- *System documents (SRD, SSD) in prep*

Living Planet release of first prototype ECVs

Antarctica preparatory project (1 yr) – PI U Leeds
- Sentinel-1 preparation for IV (1.5 yr) – PI Enveo
- CryoSat-2 for bridging SEC Envisat gap – PI DTU



GRACE mass loss 2003-12 (DTU-Space)