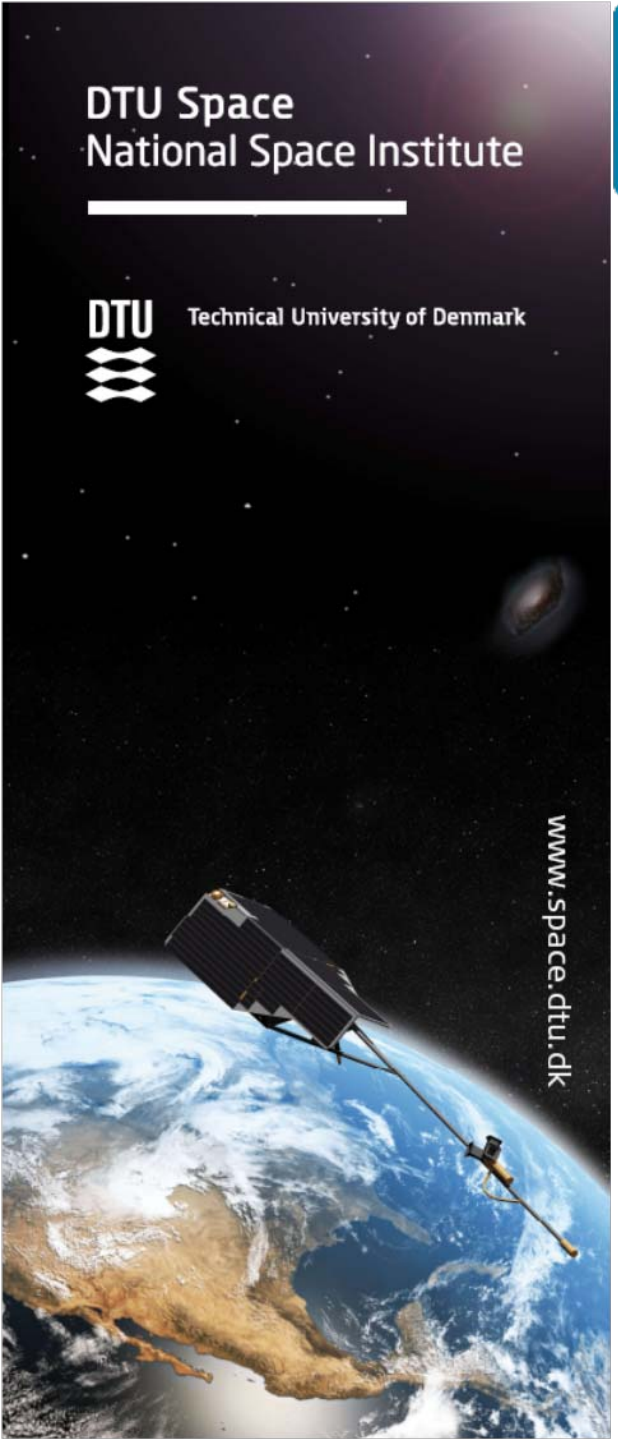


ESA cci_ice_sheets
Essential Climate Variables for the Greenland Ice Sheet

PI: Rene Forsberg, DTU-Space, Denmark
rf@space.dtu.dk
and members of the ECVIS consortium:
*S&T, NERSC (**Norway**), Enveo (**Austria**), ULeeds (**UK**)*
*DMI, DTU-Space, GEUS, NBI (**Denmark**)*

Presentation by
Christine S. Hvidberg, NBI (Denmark)

The ice_sheets_cci team …

DTU-Space, DK (”North”: R. Forsberg, A. Khan, Louise Sørensen – *science lead, Greenland changes)*
(”South”: Jørgen Dall, John Merryman – *SAR interferometry)*

S&T Norway (Christina Ås, Dag Evansberget) – *project management and systems engineering)*

ENVEO Gmbh, Austria (Thomas Nagel, Helmuth Roth – *SAR imagery and systems engineering)*

Nansen Environmental Remote Sensing Center, Norway (Kirill Khvorotovsky – *radar altimetry)*

Geological Survey of Denmark and Greenland (Signe Andersen – *validation*)

Niels Bohr Institute,University of Copenhagen (Christine Hvidberg –*ice sheet modelling and user needs)*

Danish Meteorological Institute (Gudfinna Adelsteinsdottir – *ice sheet modelling and assessment*)

University of Leeds, UK (Andy Shepherd – *radar altimetry and glaciology)*

Climate Research Group …

Dr. Andreas Ahlstrøm, GEUS (lead)

Dr. Michel van Brooke, Univ. of Utrecht, Netherlands

Prof. Heinz Miller, Alfred Wegener Institute, Germany

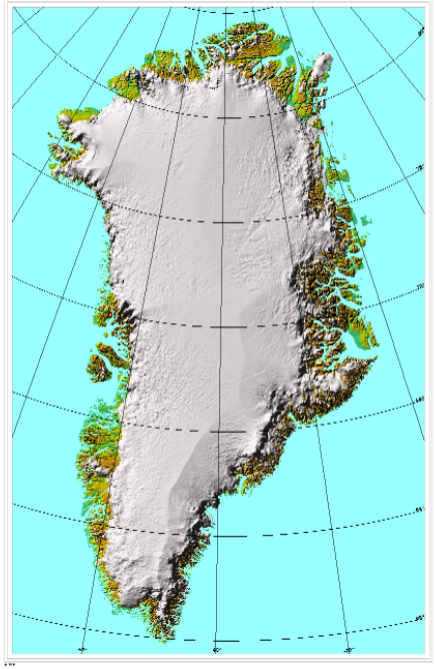
Prof. Jon-Ove Hagen, University of Oslo, Norway

Dr. Ian Howat, Bird Polar Centre, Ohio State University

Dr. Gudfinna Adelsteinsdottir, DMI, Denmark

Dr. Heikki Järvinen, FMI, Finland

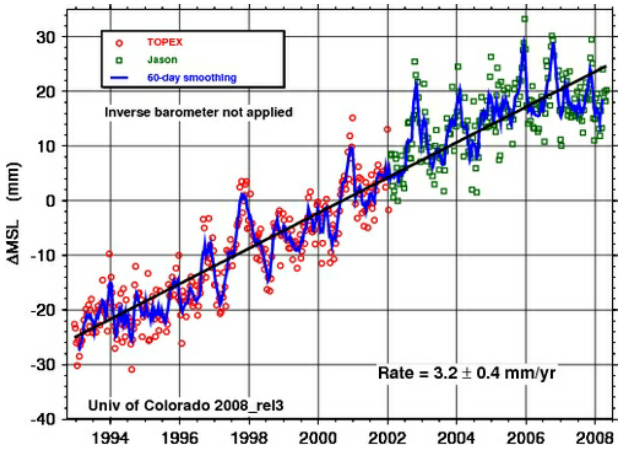
Dr. Ian Joughin, University of Washington, USA



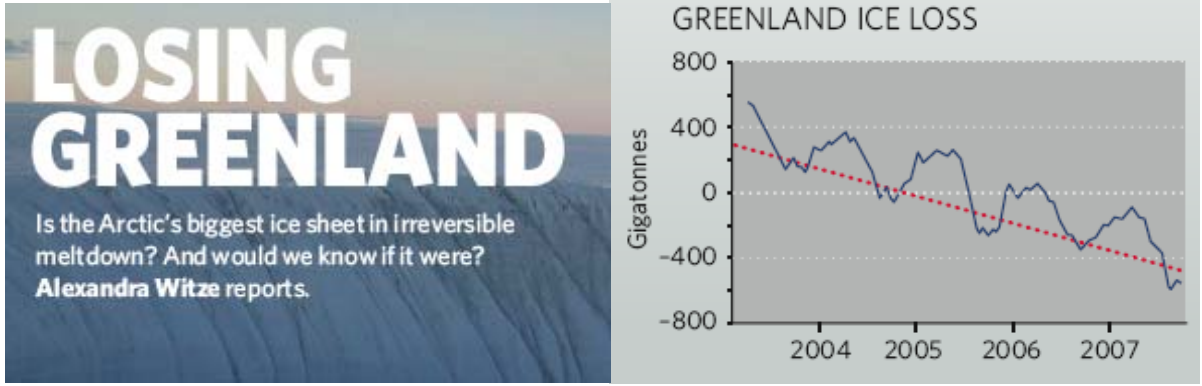
The Greenland ECV ice sheet challenge …

- ECV ice sheet of immediate society interest
  - *mass loss from ice sheets contribute to global sea level rise*
  - *freshwater input may affect ocean currents*

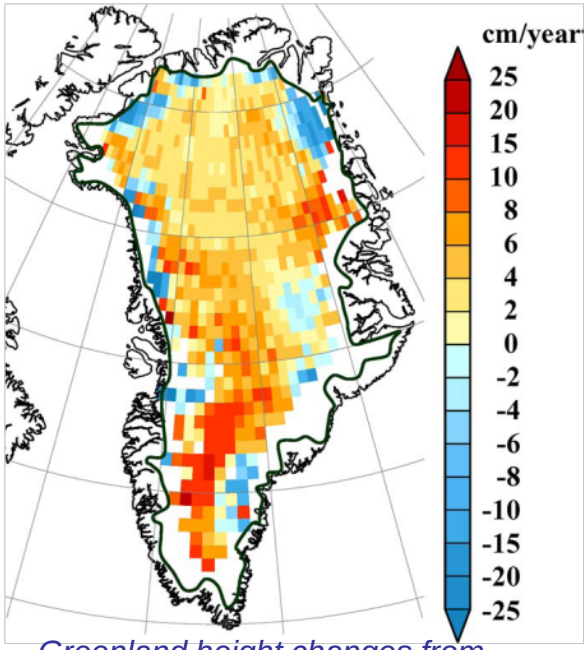
- Many different types of satellite measurements:
  - *melt area (scatterometer)*
  - *height changes (radar and laser altimetry)*
  - *velocity + cross section (SAR interferometry + ice thickness)*
  - *gravity changes (GRACE)*
  - *GPS crustal uplift (GNET)*



Provide consistent, long-term records across different Satellite missions .. Primarily from ESA EO satellite archives
Prepare for future operational system …



Nature, 2008



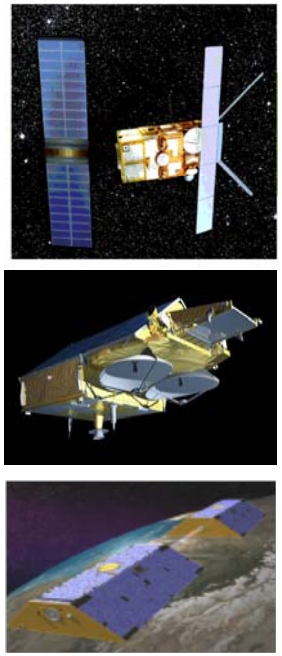
Greenland height changes from ERS/Envisat (1992-2003) (Johannesson, Khvorostovsky...)

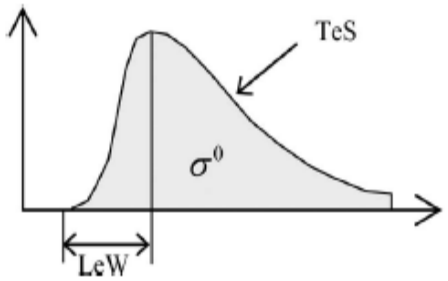
Methods for monitoring the ice sheet ..

Satellite radar altimetry (ERS, Envisat, *CryoSat*)
- *Problems in rapidly changing margin zones*
- *Radar penetration and retracking errors*
- *CryoSat-2 SARIn altimetry to give margin coverage*

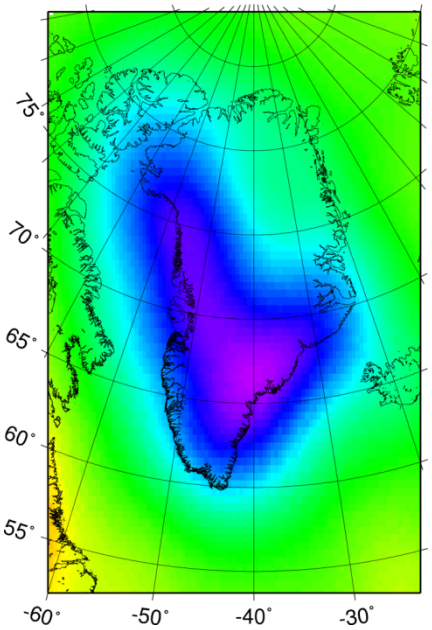
Laser altimetry: ICESat 2003-9
- *Epoch style measurements, cloud problems*
- *Common error: Conversion dh/dt to mass change …*

GRACE mass changes
- *Lack of resolution, GIA errors, ocean leakage ..*

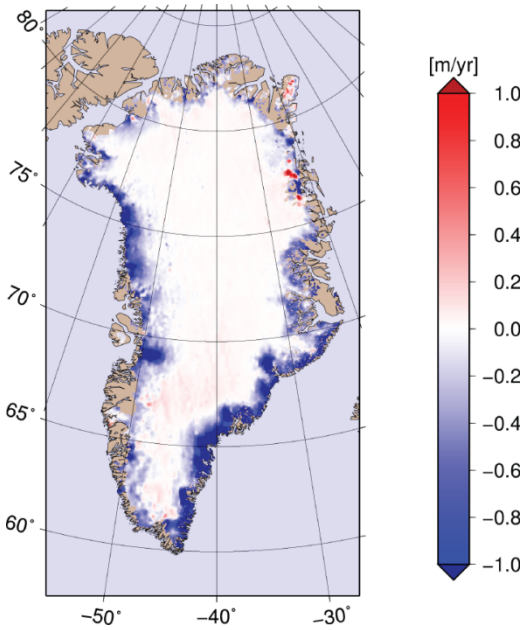




Waveform retracking needed .. radar signals penetrate in snow



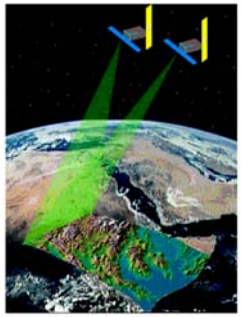
GRACE mass loss (2003-2009) ~ 240 GT/yr (DTU)



ICESAT estimate (2003-2008) ~ 240 GT/yr (DTU)

Ice sheet margin zones melting

Methods for monitoring the ice sheet (2)..

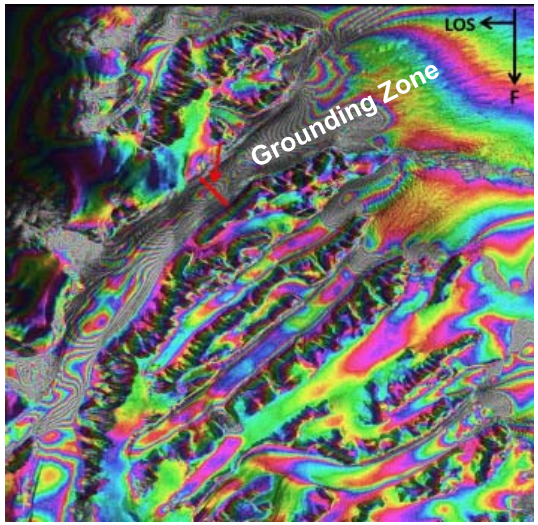


SAR interferometry

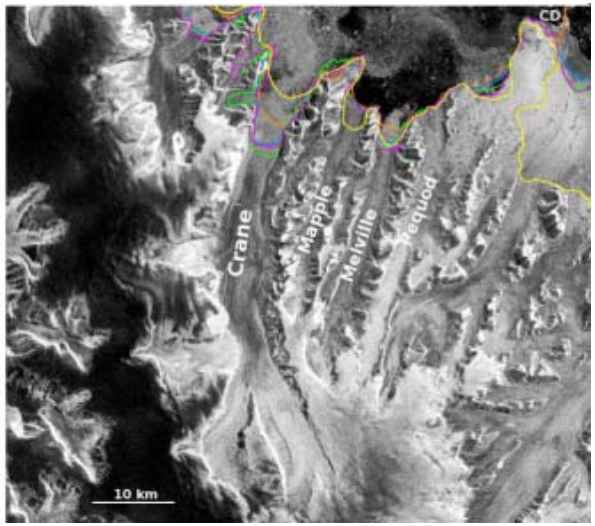
- *Estimation of ice velocities*
- *Combination with ”outlet gates” yield mass loss*
- *Errors due to unknown thickness, accumulation ..*
- *Grounding line location on tidewater glaciers*

Outlet glacier geometry from SAR/optical imagery

- *Calving front location*

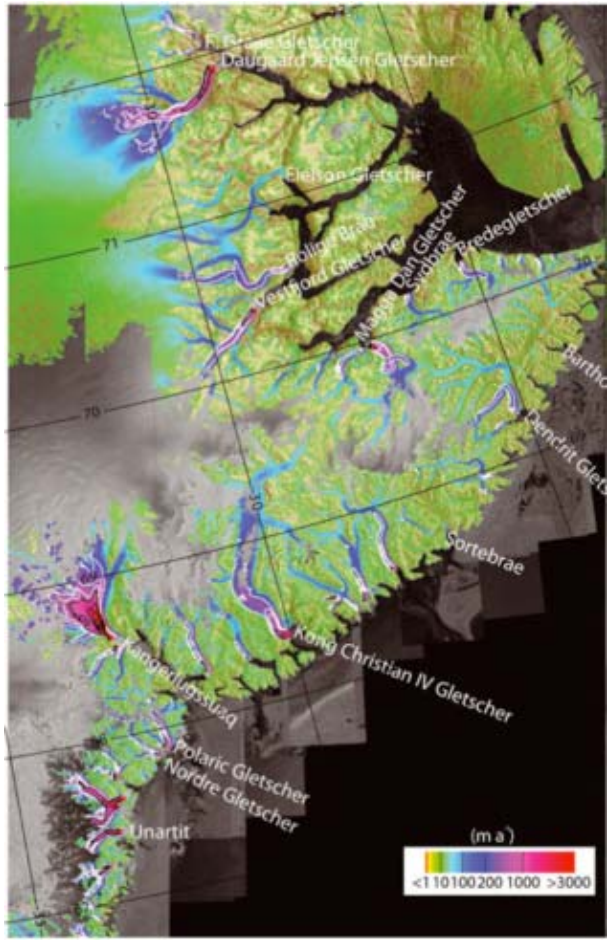


Grounding Llne Location from ASAR



Calving Front Location from ASAR

Antarctic Peninsula, Larsen-B outlet glaciers (ENVEO)



East Greenland glacier velocities (Joughin)

Ice_Sheet_CCI key parameters:

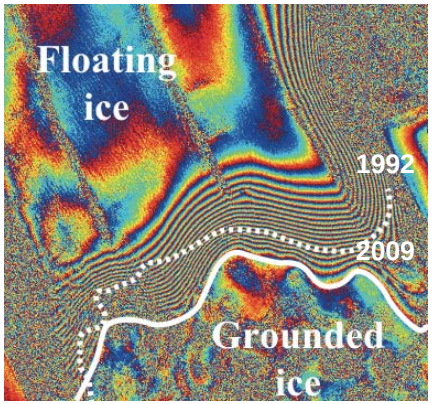
Primary:

Variable/ Parameter	Application		Horizontal Resolution	Temporal Resolution	Accuracy	Stability
Surface Elevation Change (SEC)	Mass balance	GCOS Target	100m	30days	0.1m/yr	0.1m/yr
		*Current capability.**	5km.†	35 days.‡	<0.1m/yr.§.	<0.1m/yr. **
Ice Velocity (IV)	Mass balance	GCOS Target	1km	30 days	10m/yr	10m/yr
		Current capability.††	25m – 500m.‡‡.	3-35 days.§§	3-30m/yr.***	stable

Secondary:

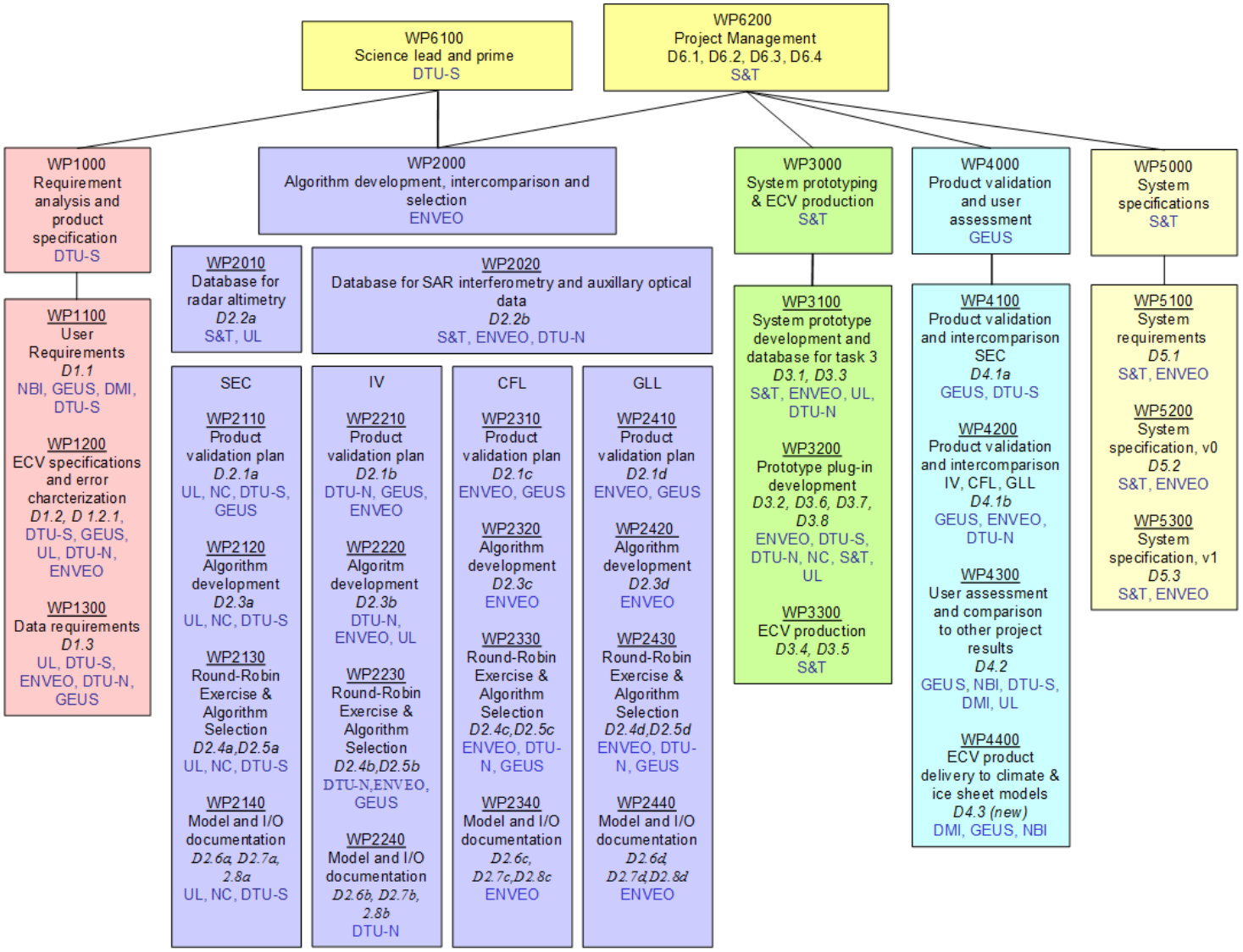
Variable/ Parameter		Horizontal Resolution	Temporal Resolution	Accuracy
Grounding Line Location (GLL)	IGOS Target	1 km	1 years	1 km
	*Current capability.**	20 m	intermittent.†	50-100m

Variable/ Parameter		Horizontal Resolution	Temporal Resolution	Accuracy
Calving Front Location (CFL)	*Current capability.**	20m-150m.†	≤35 days.‡	50m-300m



Peterman Glacier GLL
N Greenland (Shepard)

IS-CCI Task/WP structure ..



***Special challenges*:** *huge data volumes (SEC: Level-1B reprocessing, IV: Level-0 processing; 20 yrs+)*
Output for users in adequate grid / line formats … SARin data only available at irregular intervals

Main tasks in Phase 1 of Ice_Sheet_CCI project 2012-14:

Task # 1

First 6 months:

- User requirements (questionaire/consultations ..) – *URD*
- ECV specifications and data requirements – *DARD + PSD*
- Error characterization - *CECR*

Next 6 months:

#2

- Get data to data bases ..
- Algorithms to be described .. Specify evaluation principles
- Round Robin Excersizes .. open to all interested parties
- Select ”best” algorithm

Year 2:

#3

- Prototype development and data bases
- ECV production – R&D context, not industry-standard processing chain

Complete coverage of coast-near region 1995/96 and 2008 ”golden year”

#4

Year 3:

- Product validation
- User assessment
- Overall changes compared to other satellite data (e.g., GRACE)

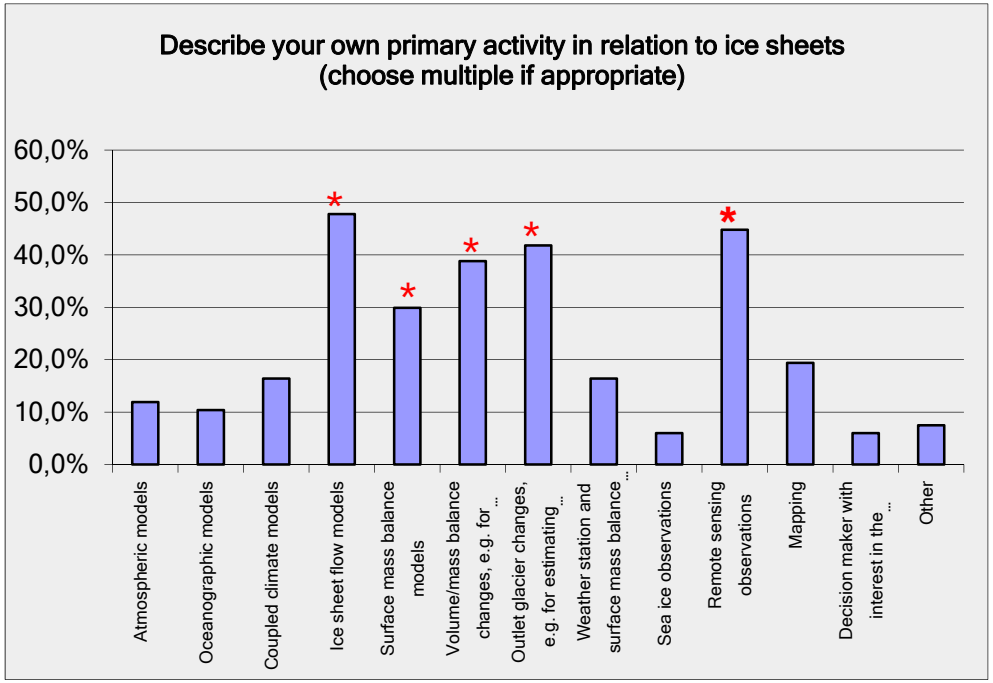
#5

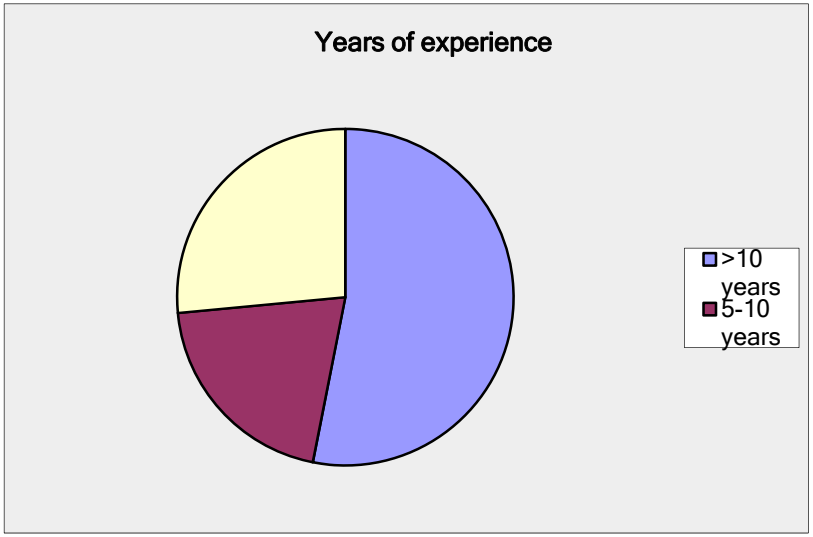
- ECV product usefulness to modellers
- System specification for operational production system

Phase 2: 2015-17: operational system implementation .. + Antarctica??

Phase 3: Transfer of operational system to users … (GMES?)

Short summary of the user survey (67 respondents)





Main user groups: Ice sheet flow models
Volume and mass balance changes/Remote sensing observations
Outlet glacier changes (dynamic changes, discharge, etc)
Surface mass balance models

User resommendations and priorities:

Generally:

-The preferred priority is to have high-resolution in margin areas (SEC and IV) and low-resolution in the central parts.

Useful scenarios:

-**For Surface Elevation Change (SEC):**

long time records are important. A scenario with low resolution over the entire ice sheet, long time series would be useful for comparing volume changes with estimated mass change from surface mass balance models.

-**For Ice Velocity (IV):**

a snapshot of the surface velocity would be particularly useful for ice sheet modellers and studies of outlet glacier changes.

High-resolution velocity at specific fast-flowing glaciers would be particularly useful for process-oriented studies and studies of outlet glacier changes.

User resommendations and priorities, continued:

-**Open access to data is critical.** NSIDC or similar ressources are suggested. If not, many users will continue to use publicly available dataset.

-File formats is an important issue for some users, particularly climate modellers. **NetCDF-format** is by far the most preferred format, but there is also a request for simpler file formats. Most users use Matlab or Fortran.

- Request for **high-level data products**.

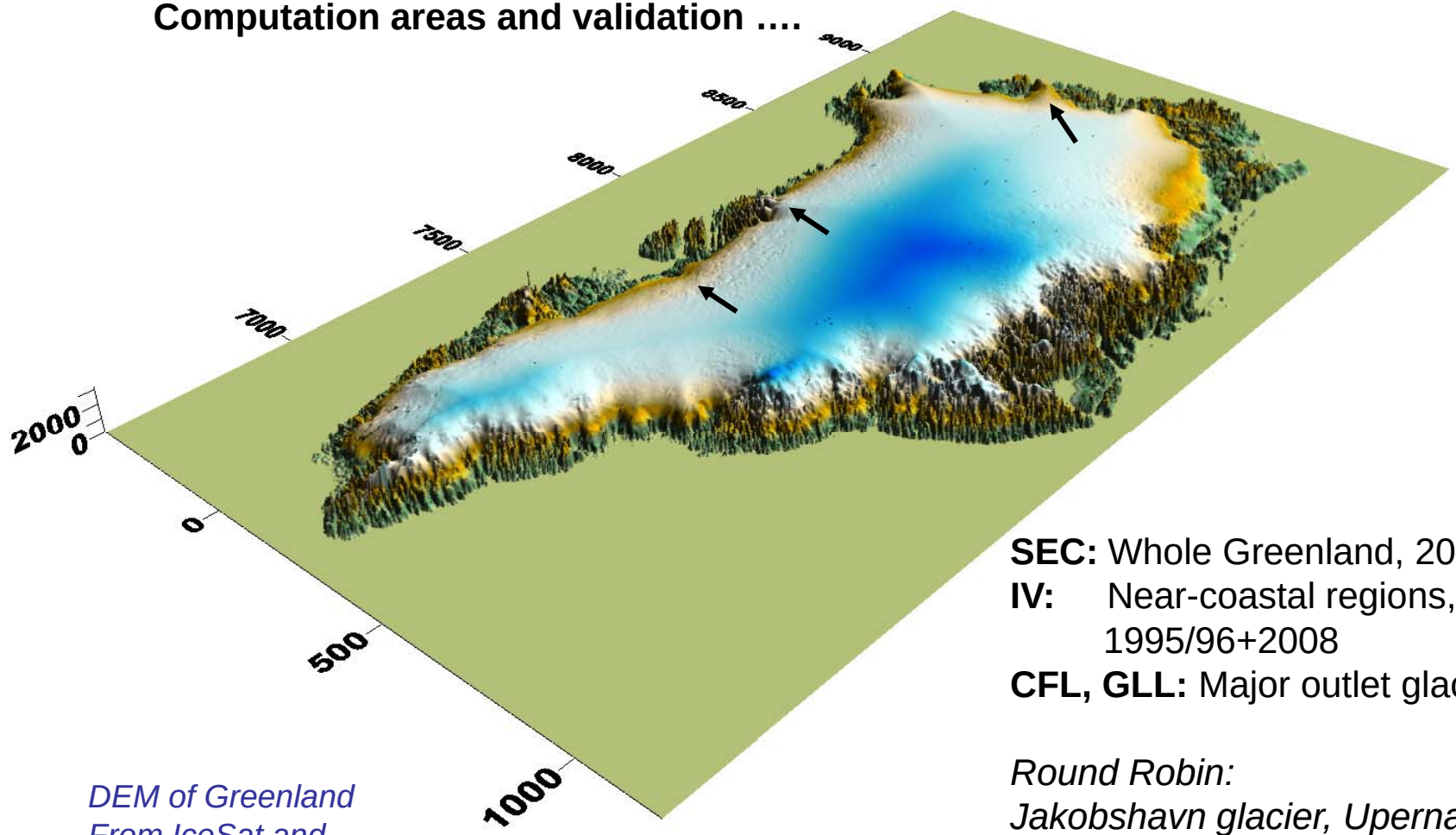
-**Ensuring long records** is an important issue that most be taken into account when planning future satellite missions.

-Satellite observations are not sufficient to identify key processes controlling ice sheet dynamics. Other data (in situ or radio echo data) are needed.

A challenge for the future space exploration programs:

Extend the current radar techniques and initiate development of **new instruments to measure internal ice sheet properties from space.** (e.g. ice penetrating radar, for example POLARIS proposed by DTU-N)

Computation areas and validation ….



DEM of Greenland From IceSat and Photogrammetry (DTU-Space).

Arrows show Round-Robin areas

SEC: Whole Greenland, 20 yrs
IV: Near-coastal regions, 1995/96+2008
CFL, GLL: Major outlet glaciers

Round Robin:
Jakobshavn glacier, Upernavik, Petermann glacier & Northern Basin

Validation data:
- Optical/SAR imagery feature tracking
- GPS in-situ networks
- IceSat / CryoSat-2 altimetry
- Airborne lidar: IceBridge, CryoVEx ..

ECV product specifications …. based on user requirements

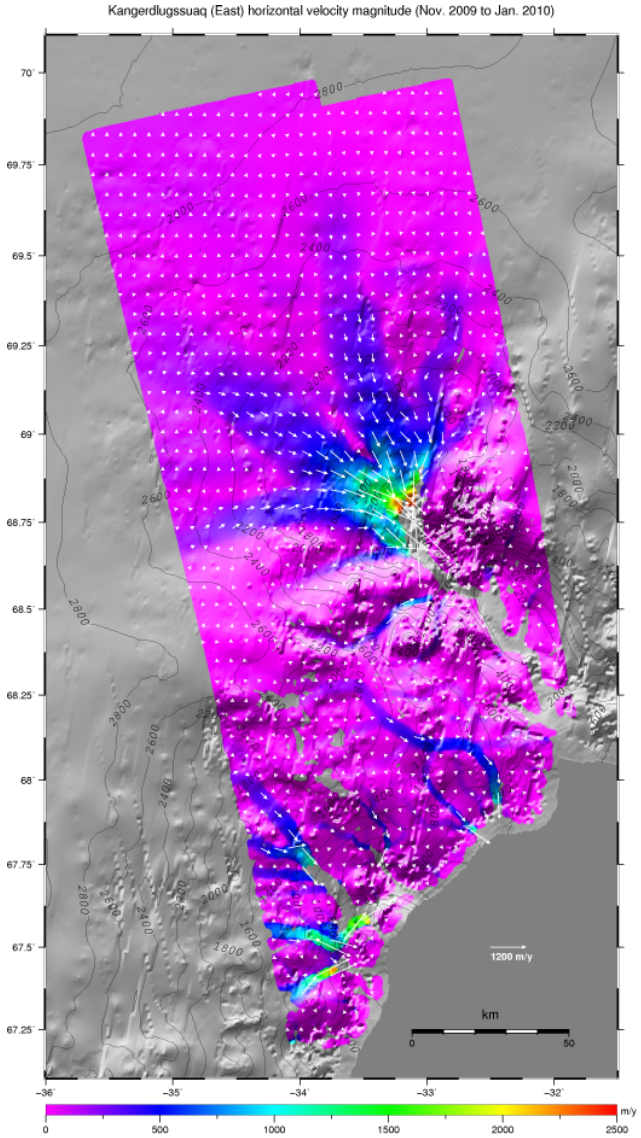
ECV parameter	Time sampling	Period	Spatial sampling	Satellite sensors
Ice velocity (IV)	1 / year	1991-present	500 m grid	ERS, Envisat, ALOS/Palsar, RadarSat? (2012-)
Surface elevation change (SEC)	4 / year	1991-present	5 km grid	ERS, Envisat, CryoSat (2012-)
Calving Front Location (CFL)	4 / year	1991-present	250 m shapefile	ERS, Envisat, optical (Landsat, Modis)
Grounding Line Location (GLL)	1 / year	1991-present	250 m shapefile	ERS, Envisat, Radarsat?

Grid format: *NetCDF (with supplementary simple ASCII files)*
Linefiles: Shapefiles (+ ASCII supplements)
Map projection: *Polar Stereographic (with auxillary transformation software to geographic/UTM)*

Links to other CCI-projects .. www.esa-cci.org

Sea-ice CCI (NERSC) - *sea-ice thickness (same satellites …)*
Sea-level CCI (CLS) – *some satellite overlap, calibration of cryosphere data over oceans*
Glaciers CCI *(Zurich) - same satellites ..*

The other CCI projects:
Ocean Colour
Sea Surface Temperature
Soil Moisture
Fire
Land cover
Greenhouse Gases
Aerosols
Ozone
Cloud Cover



(Merryman / DTU-N)

Related project to Ice Sheets:
IMBIE – International Mass Balance Intercomparison Experiment (ESA-NASA)
10 US-European teams .. 6 months 2011/12 …
IPCC paper for Greenland and Antarctica changes
– GRACE, IceSat, InSAR + GIA comparisons
Lead: Andy Shepard (UL), Erik Ivins (JPL)


Thank you for the attention …