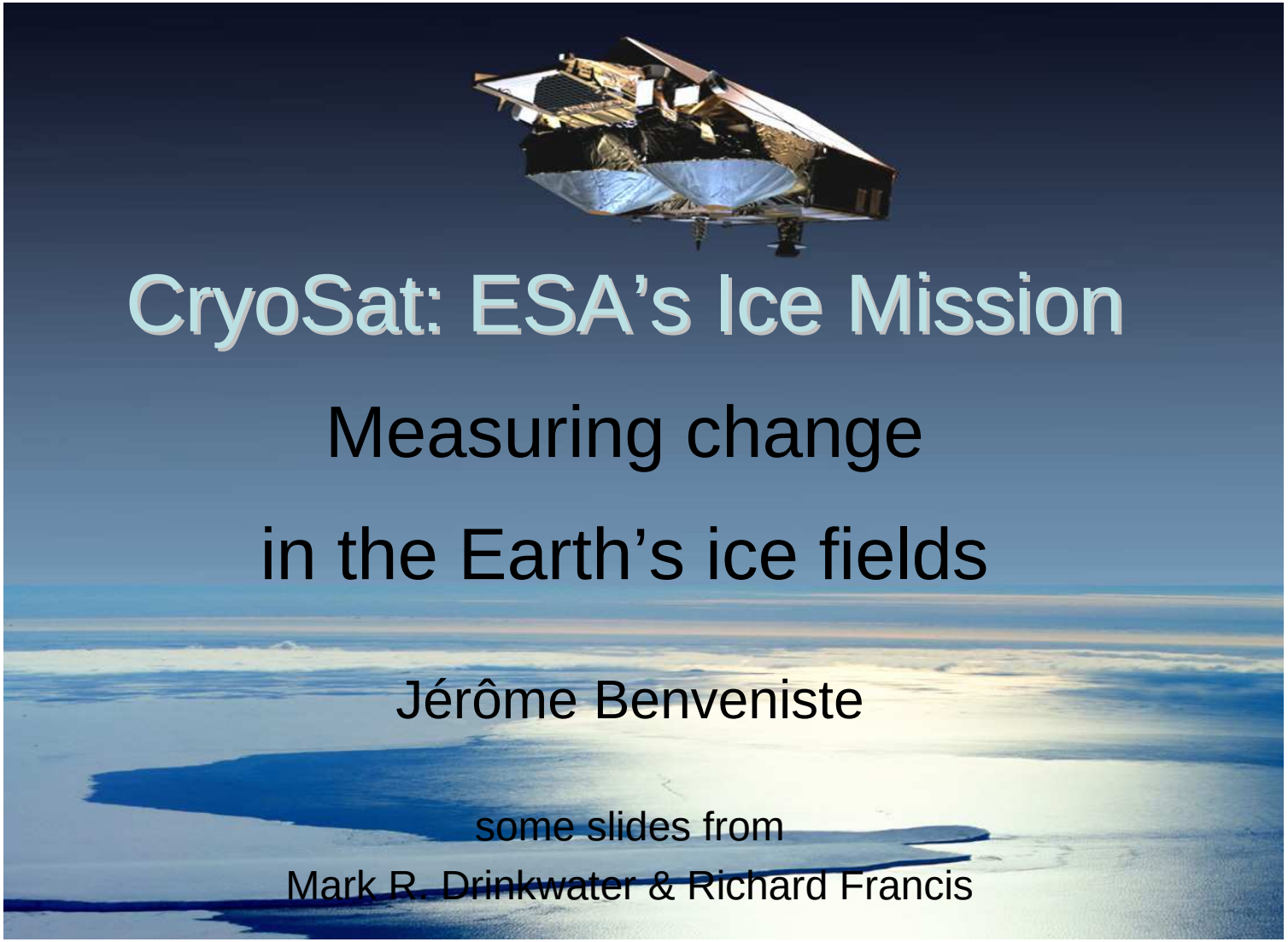


CryoSat: ESA's Ice Mission

Measuring change

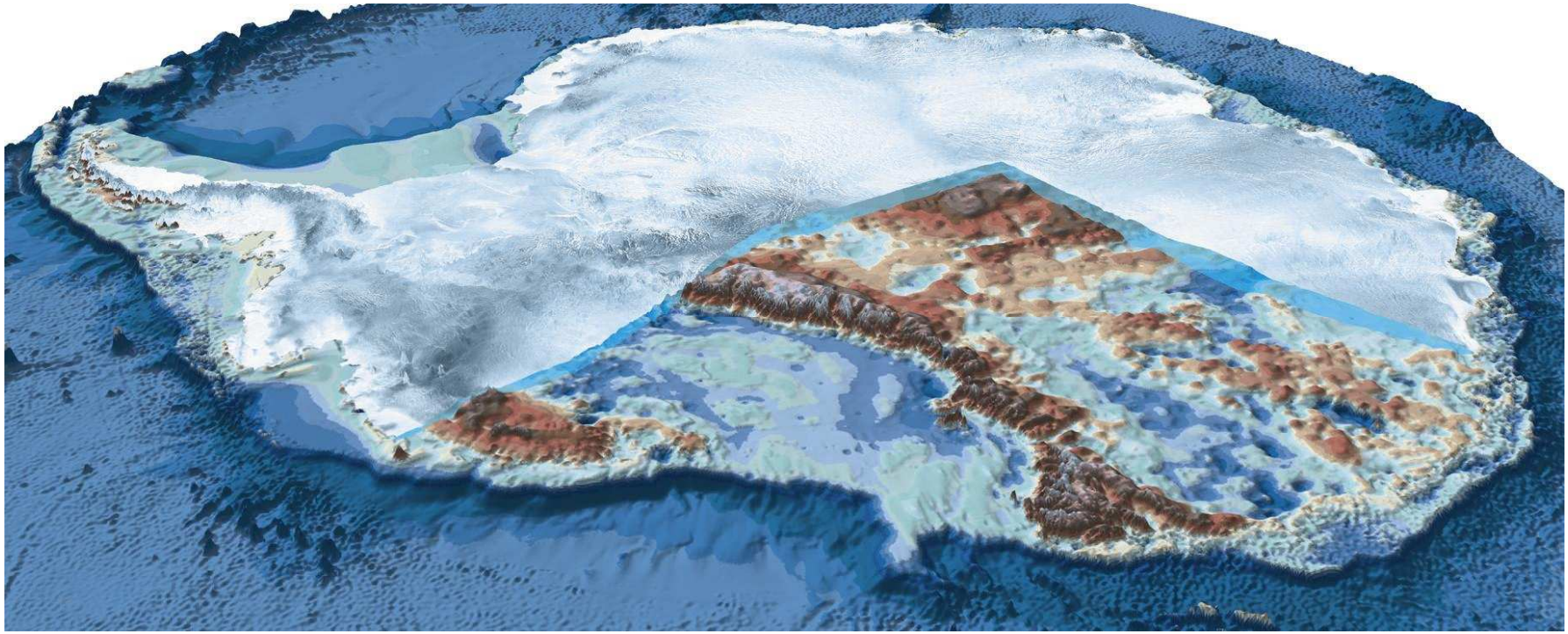
in the Earth's ice fields

Jérôme Benveniste

some slides from

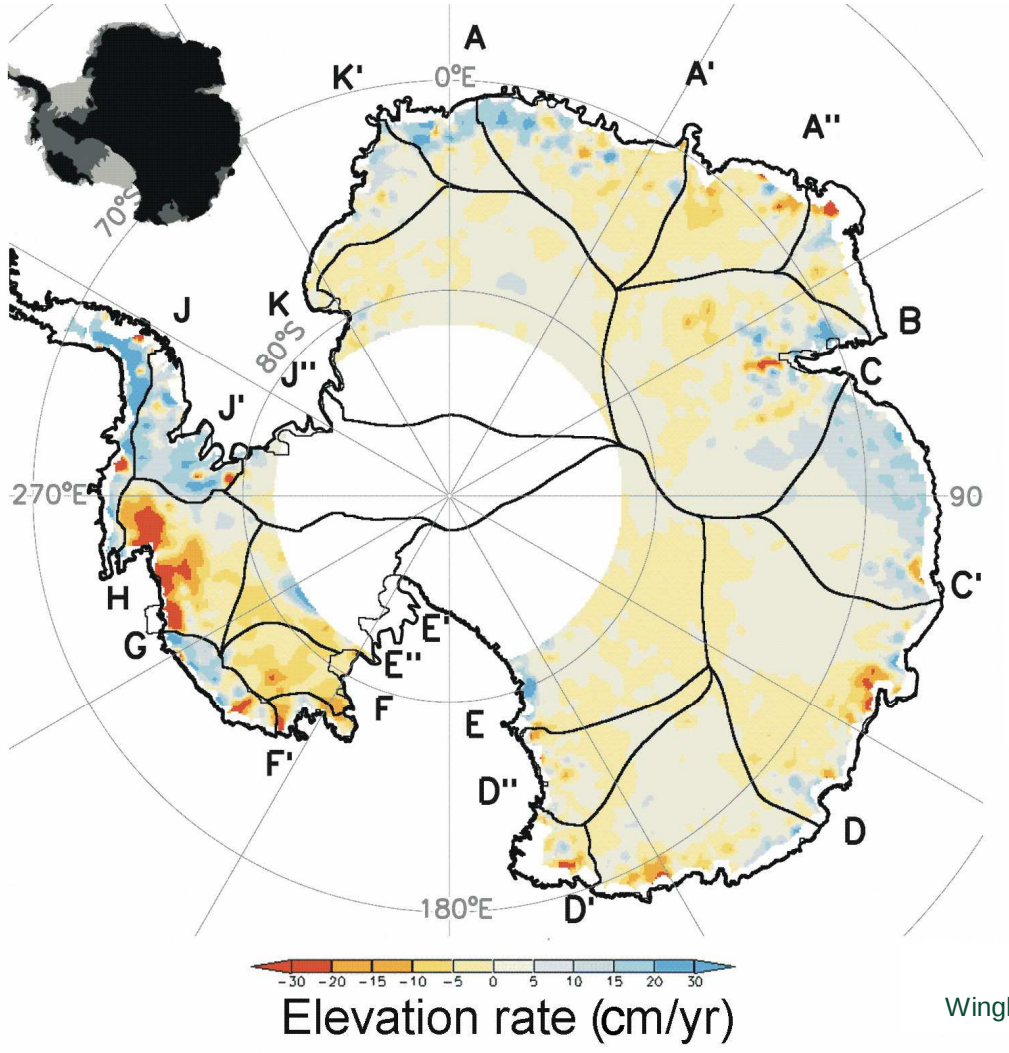
Mark R. Drinkwater & Richard Francis

Antarctic Ice-Cap



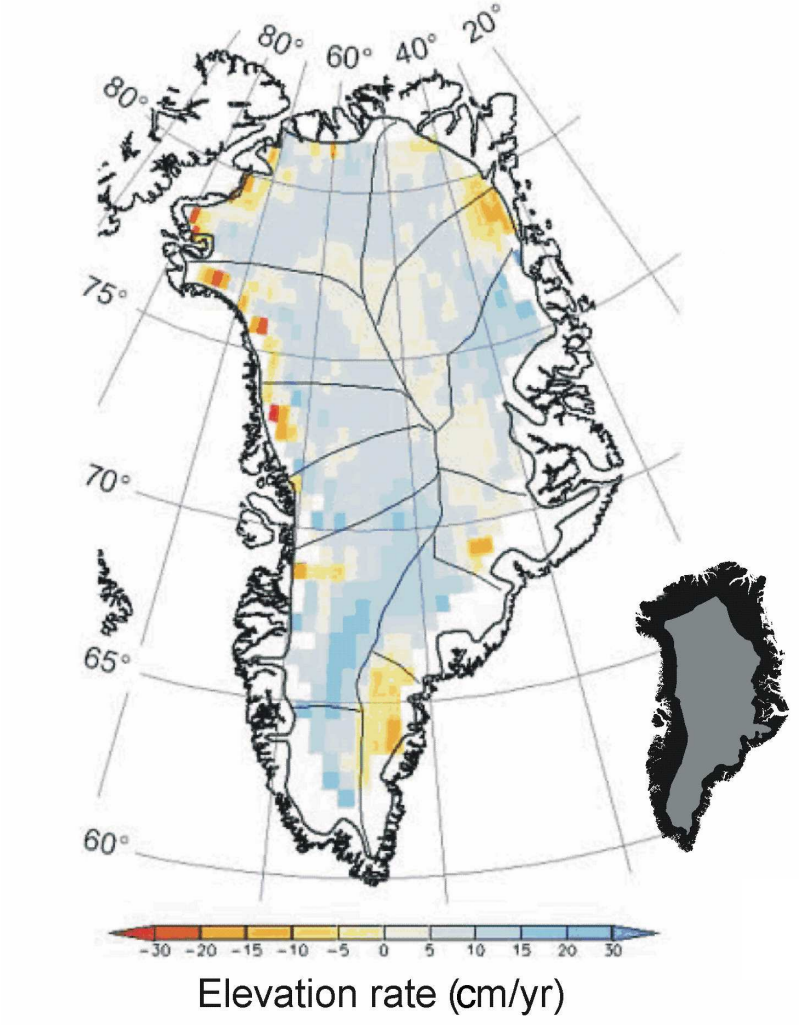
Courtesy National Geographic

Antarctic Elevation Change: 1992-2003



Wingham et al., 2006

Greenland Elevation Change: 1992-2003



Johannessen et al., 2005

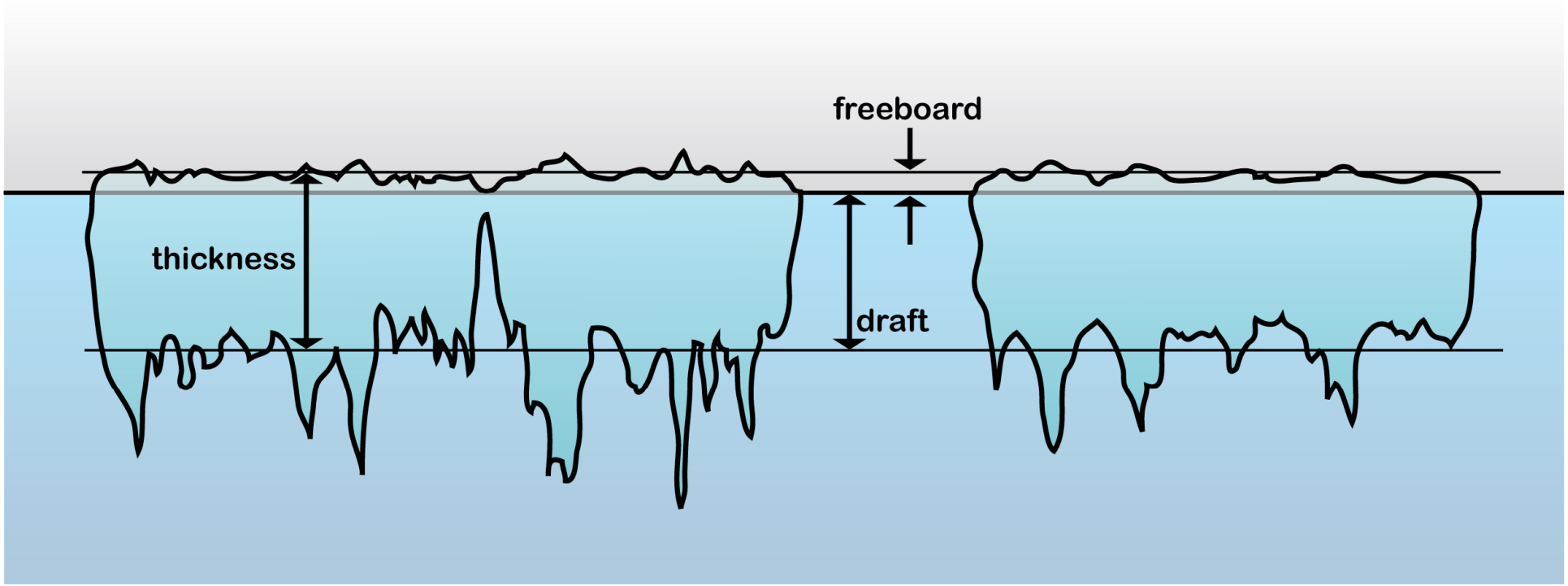
The Rhone Glacier melt down

Arctic Sea-Ice

National Geographic

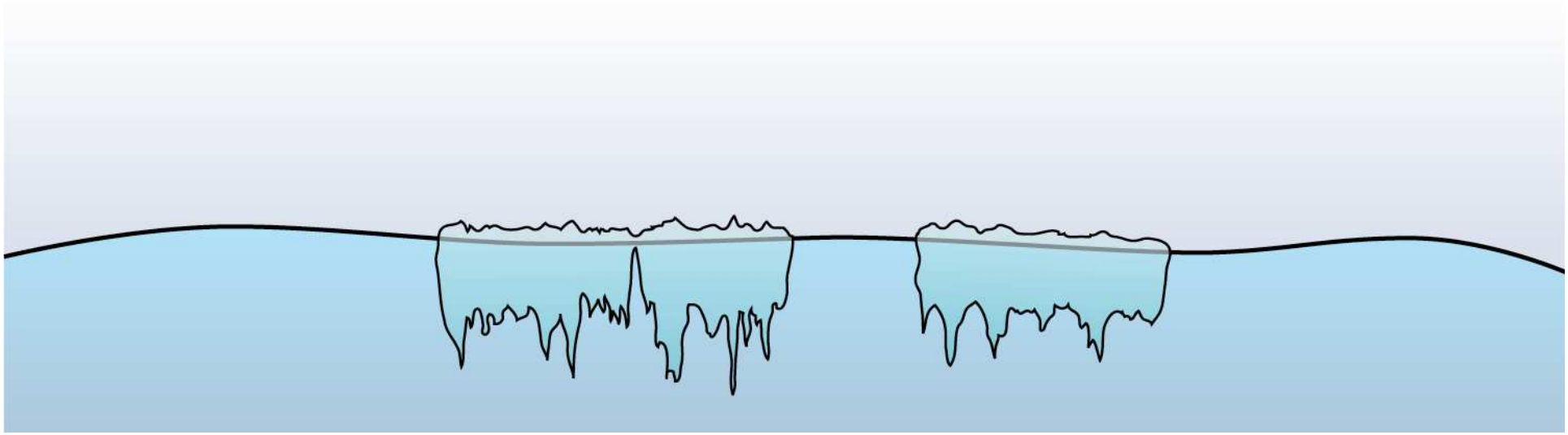
NOAA

Sea-Ice Thickness



Courtesy: R. Francis

Sea-Ice Thickness Measurements from Space



Courtesy: R. Francis

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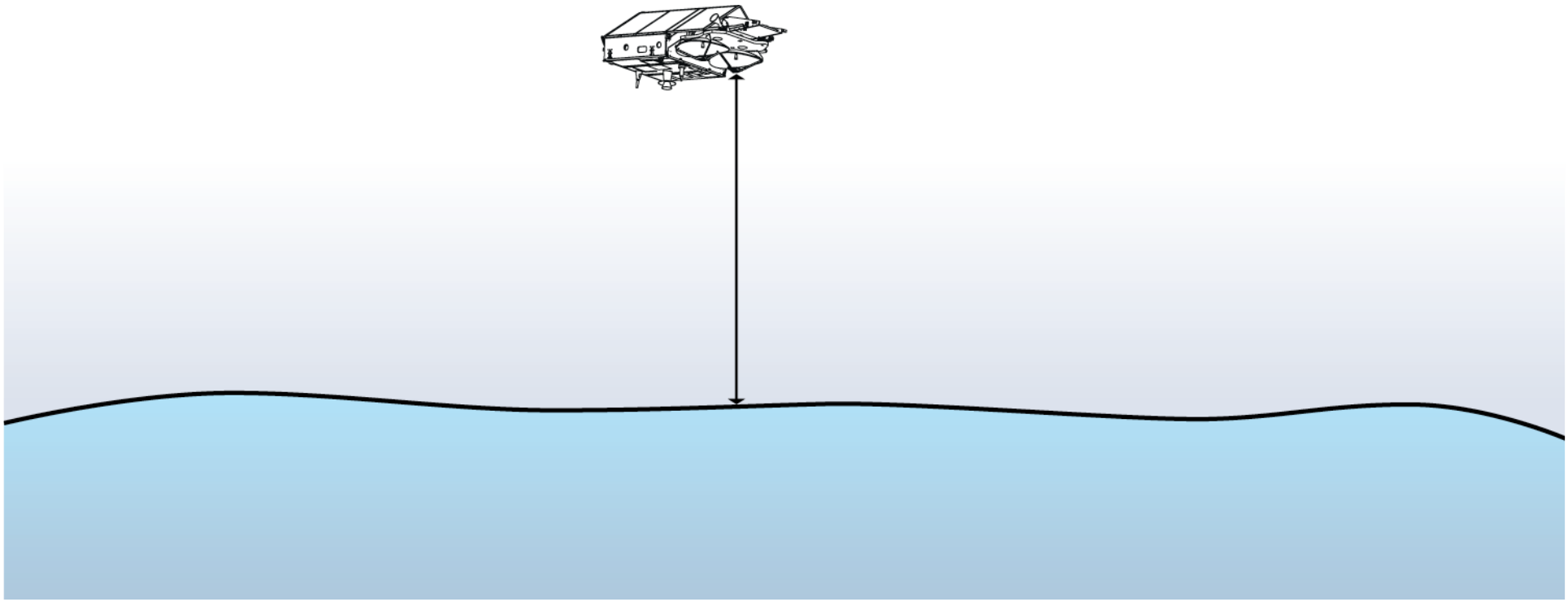
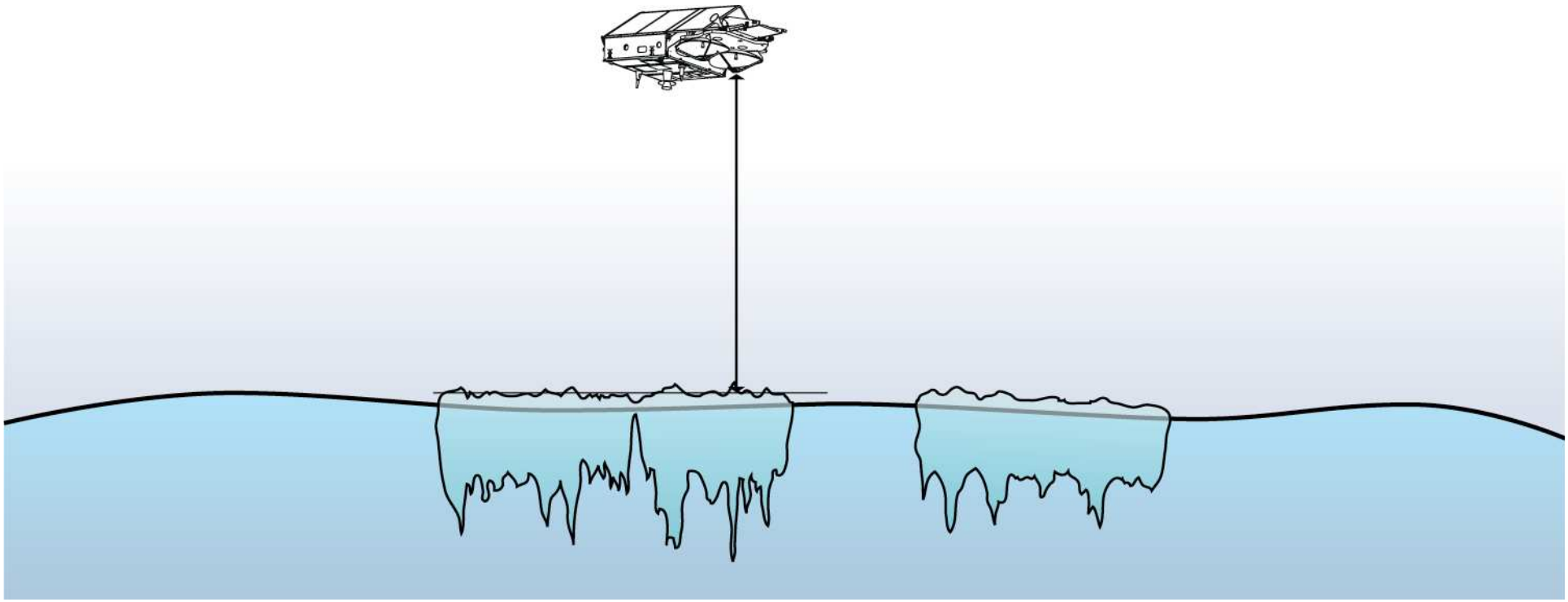


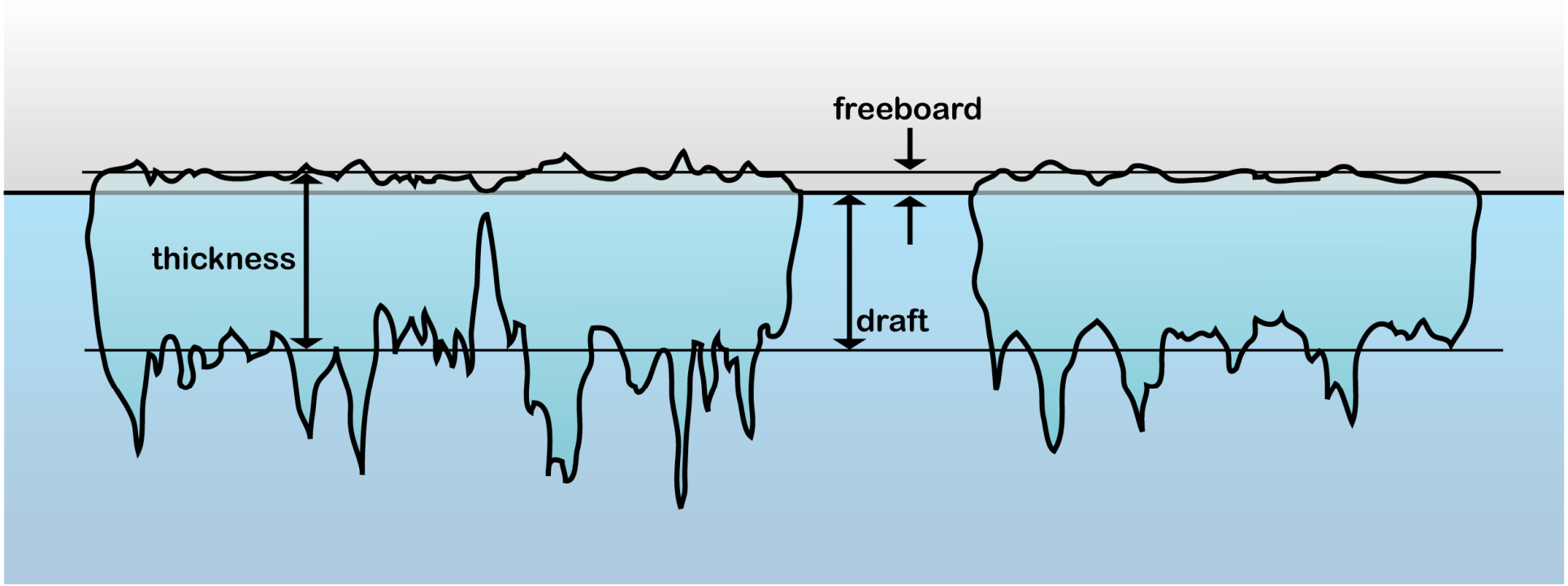
Courtesy: R. Francis

Sea-Ice Thickness Measurements from Space



Courtesy: R. Francis

The Effect of Snow



Courtesy: R. Francis

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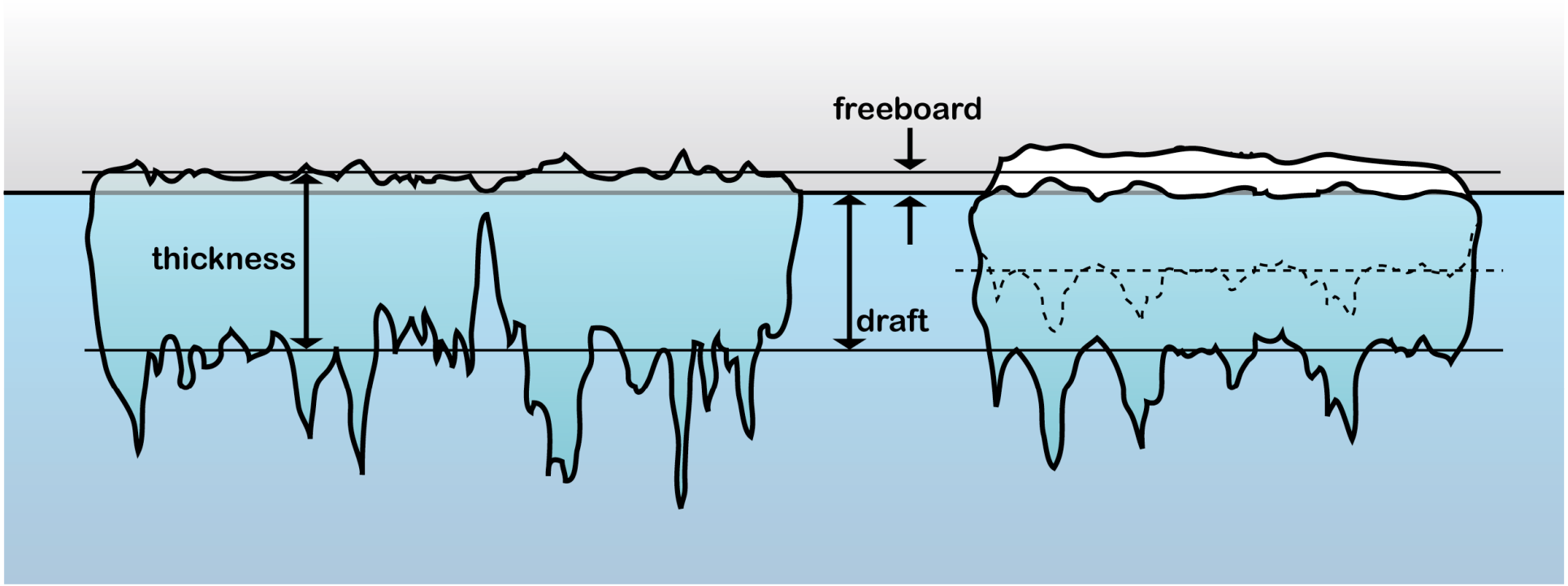
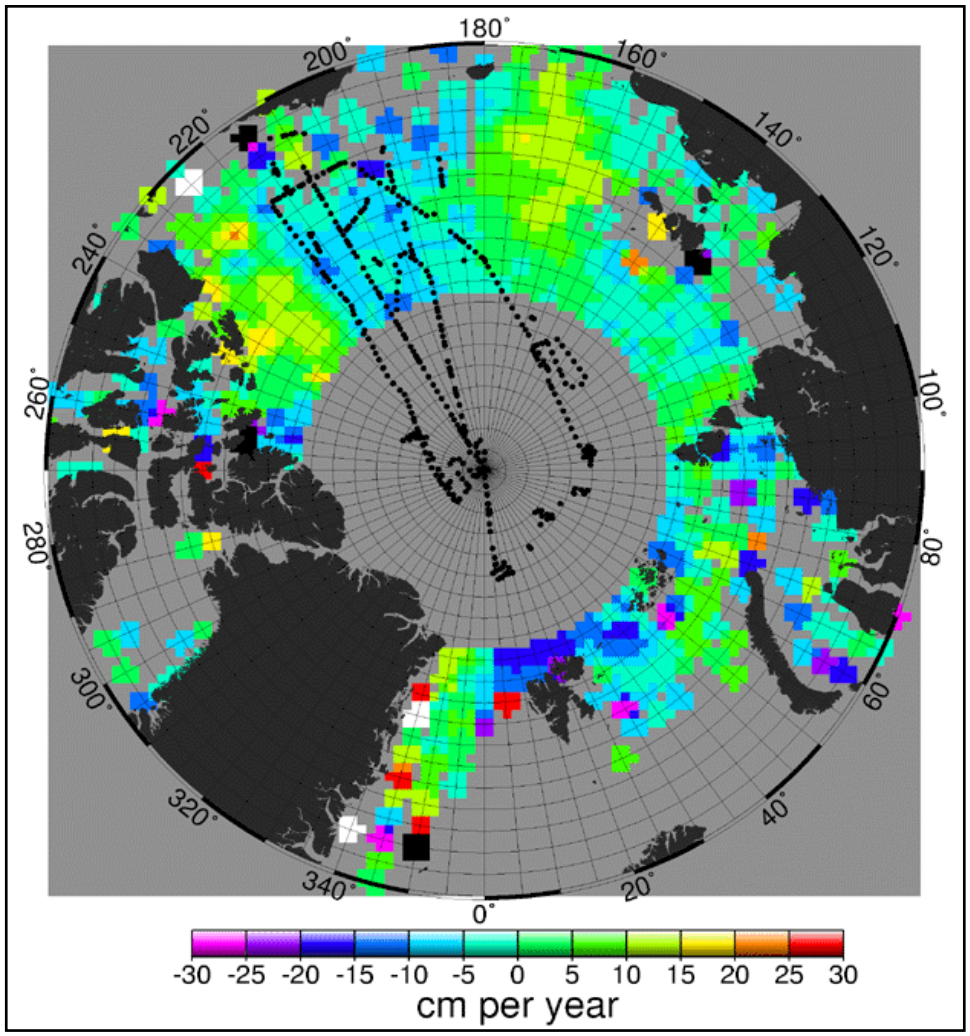


Courtesy: R. Francis

Arctic Sea-Ice Thickness



Courtesy S. Laxon

Limitations of Footprint Size

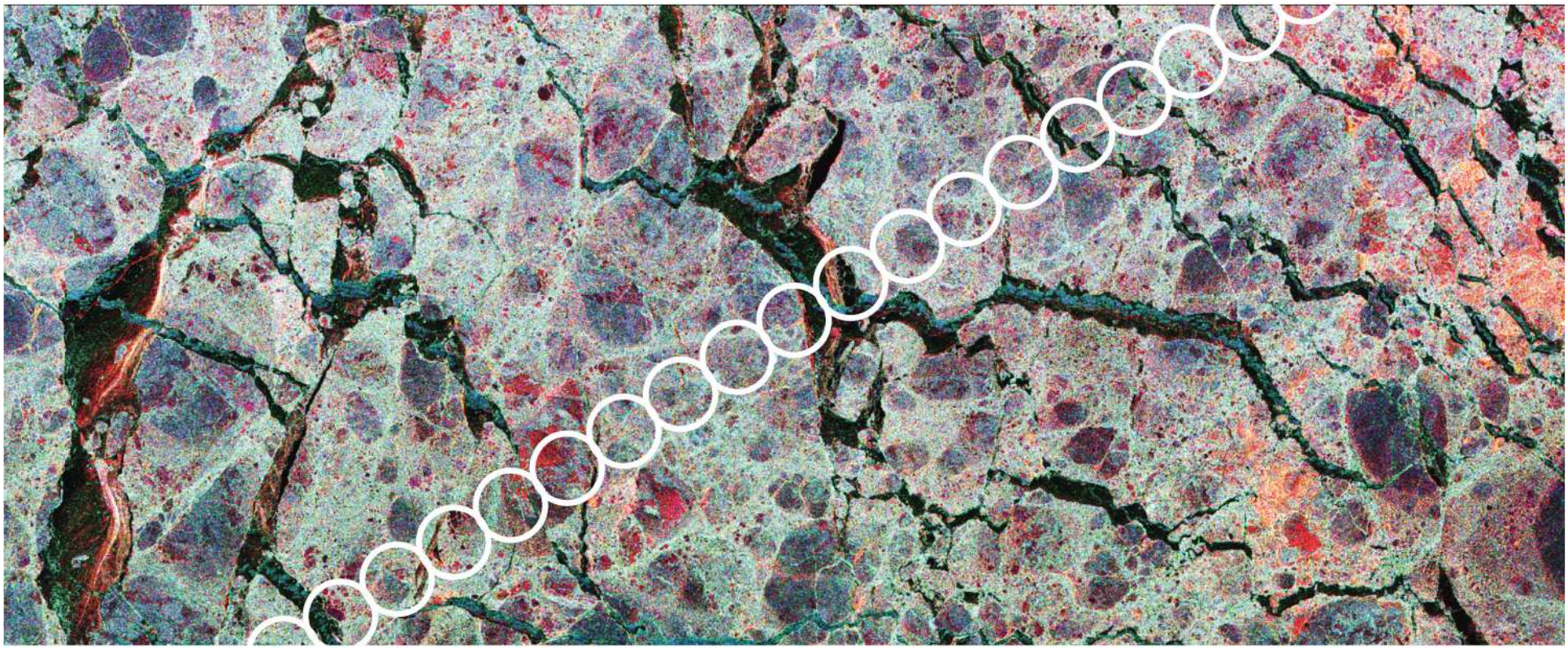
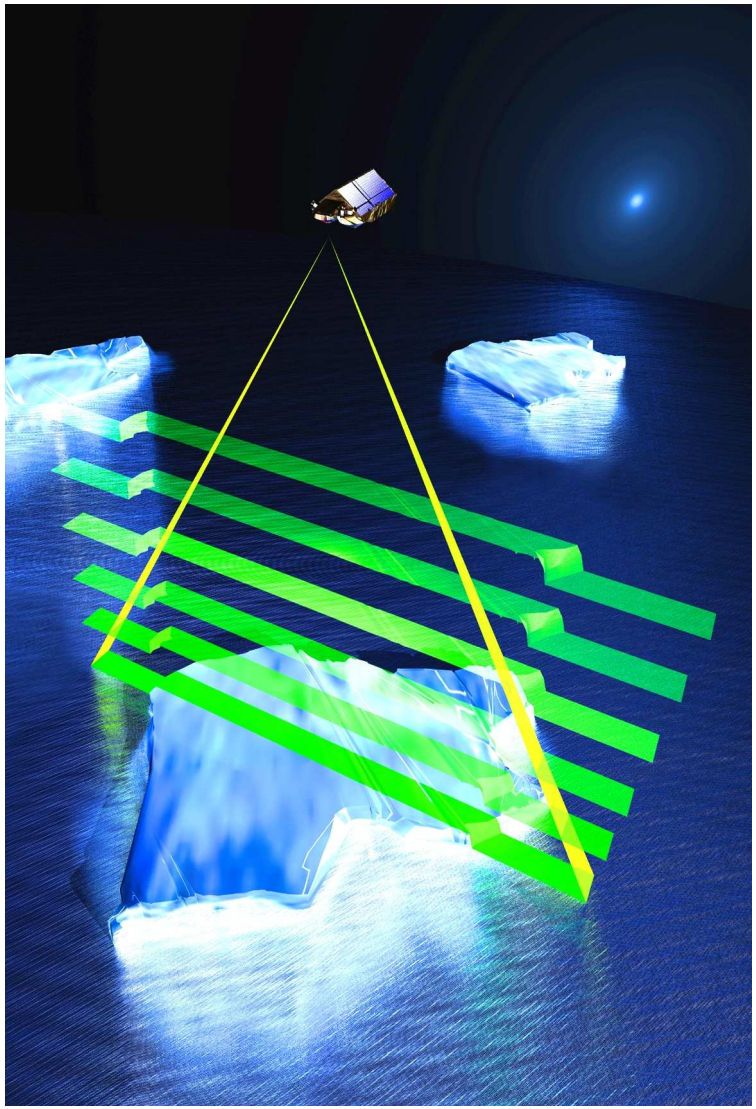


Image: SIR-C/X NASA JPL

CryoSat's High-Resolution



- Transmits bursts of 64 pulses: sequential echoes are correlated
- Satellite moves 250 m between bursts
- Aperture Synthesis technique gives 250 m along-track resolution, much higher than conventional altimeters (ERS-2/Envisat RA-2)
- SAR Mode used over sea-ice to measure ice-floe freeboards and retrieve thickness

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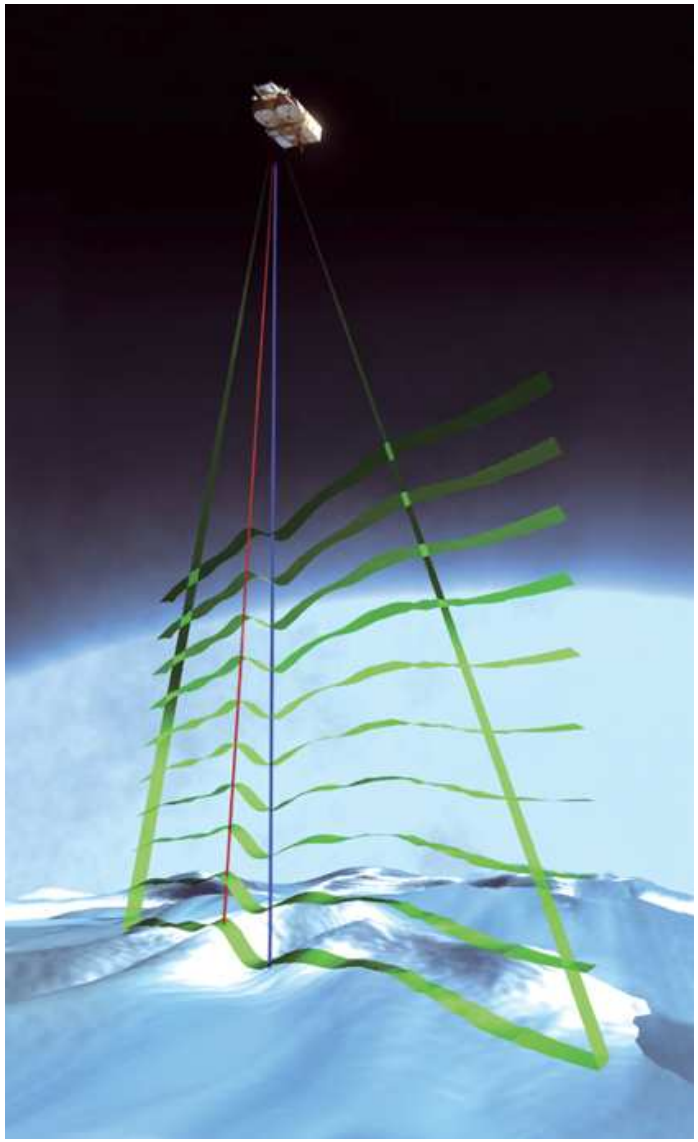

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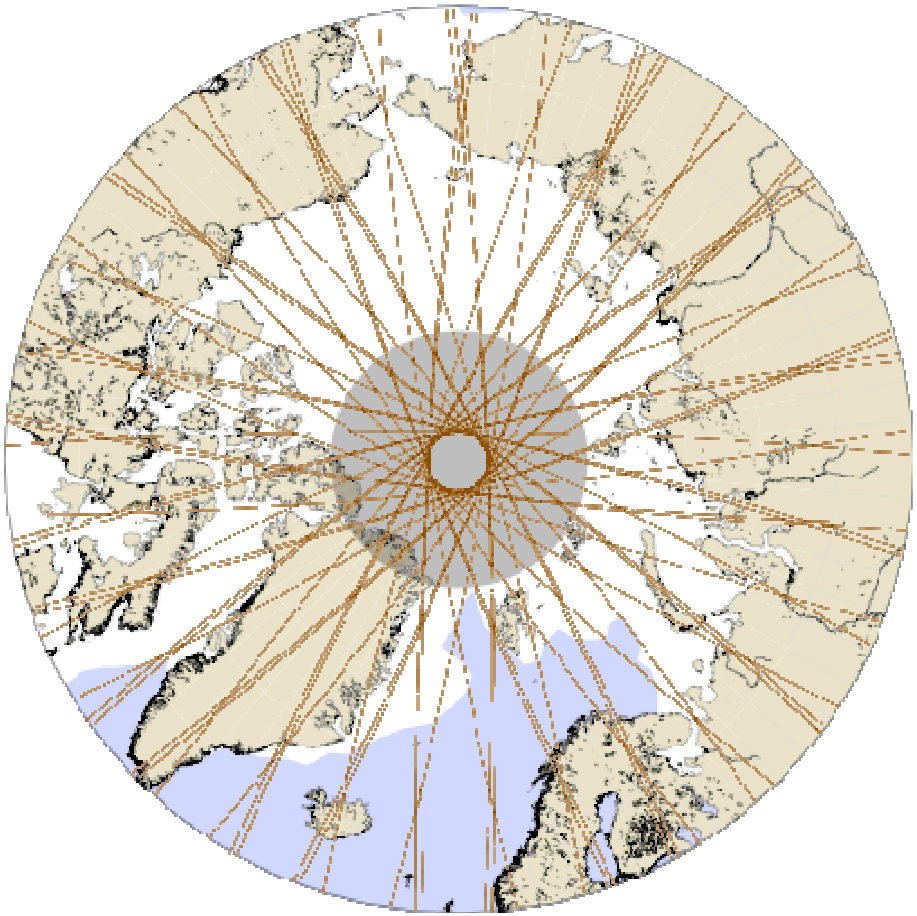
- SARIn mode to measure topographic surfaces: interferometry

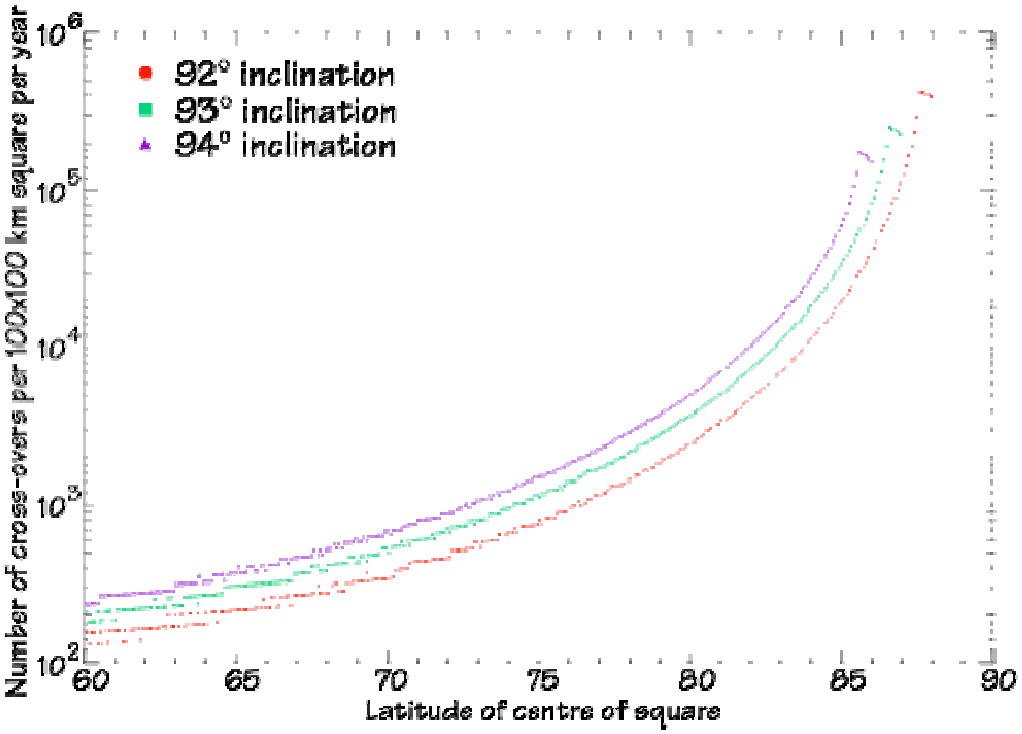
CryoSat's Orbit Coverage



Courtesy: R. Francis

- inclination: 92°
- repeat cycle: 369 days
- sub-cycle: 30 days
- inter-track spacing: 7.5 km
- orbit control: ±1 km
- altitude: 717 km
- *not* sun-synchronous

CryoSat's Orbit Cross-Overs



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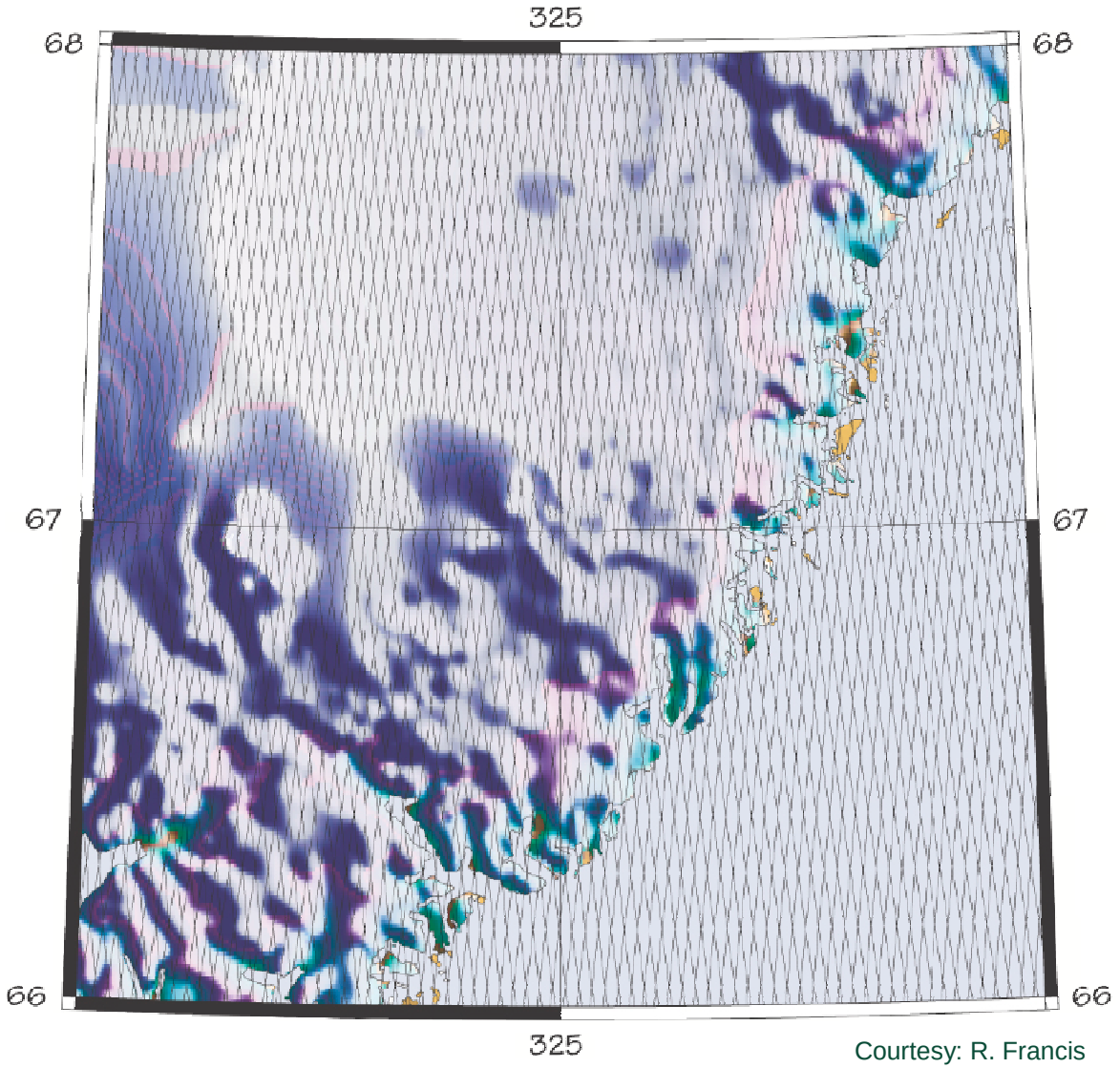
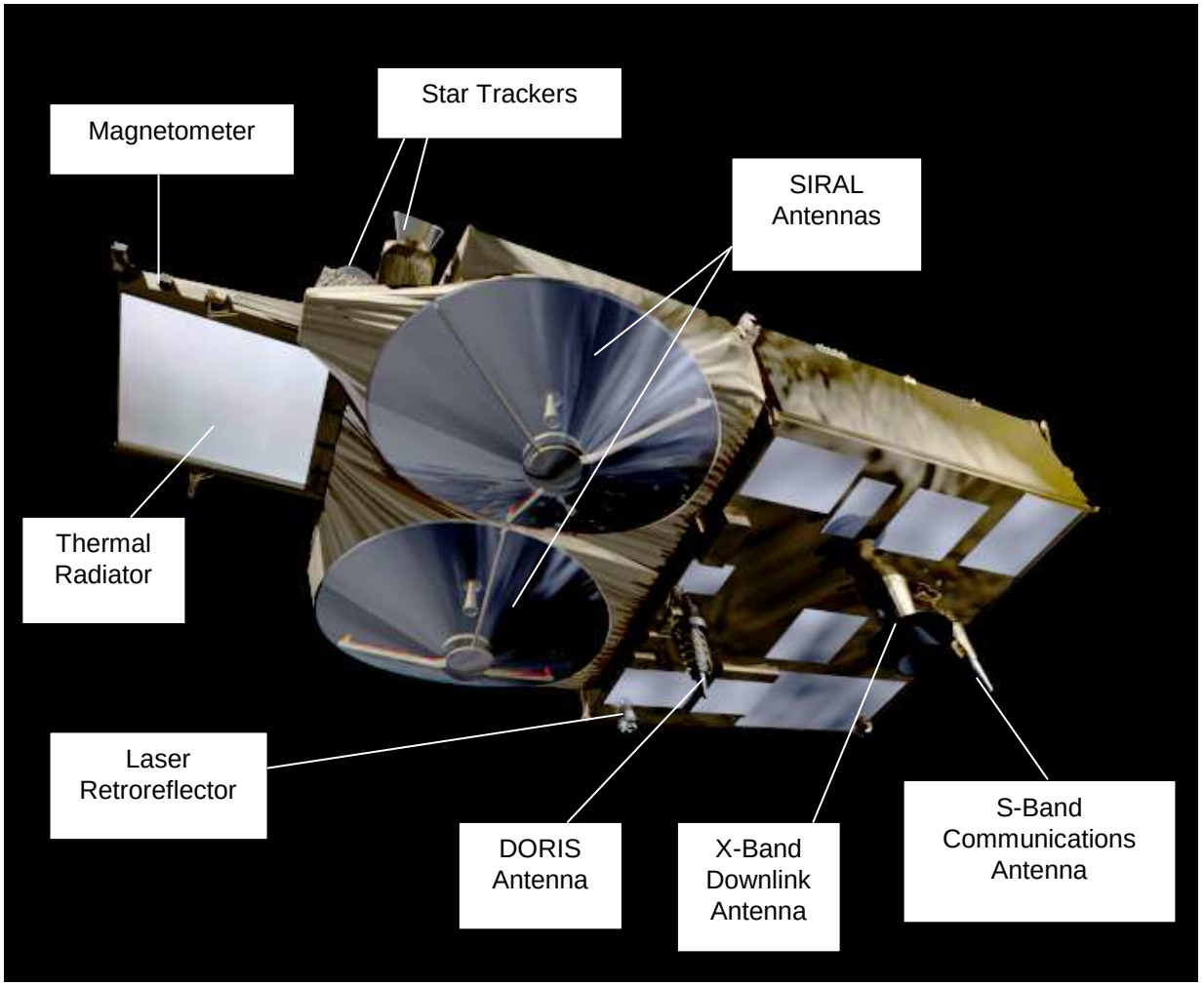
Courtesy: R. Francis

CryoSat's Orbit Coverage



Courtesy: R. Francis

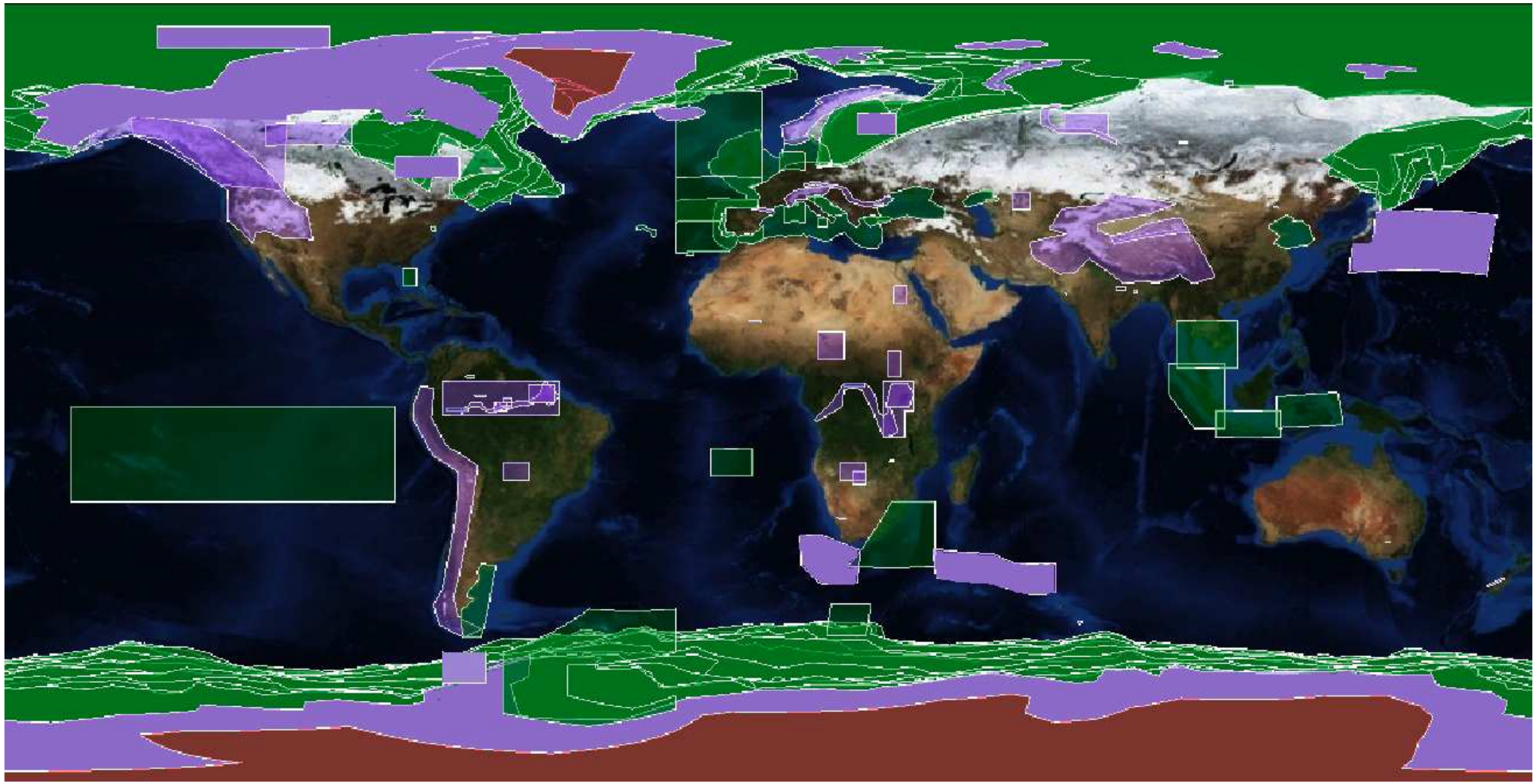
CryoSat Instruments



Cryosat-2

- ESA Earth Explorer mission;
- Launched 8 April 2010
- LEO, non sun-synchronous
  - ✓ 369 days repeat (30 d sub-cycle)
  - ✓ Mean altitude: 717 km
  - ✓ Inclination: 92°
- Prime payload: SIRAL
  - ✓ SAR/Interferometric Radar Altimeter
  - ✓ Modes: Low-Res / SAR / SARIn
- Ku-band only; no radiometer
- Design life:
  - ✓ 6 months commissioning + 3 years

SIRAL Mode Operation



Synthetic Aperture Radar (SAR) (green)
SAR Interferometric (SARIn) (purple)
Low Resolution Mode (LRM) (red and elsewhere)

On Ground Data Processing

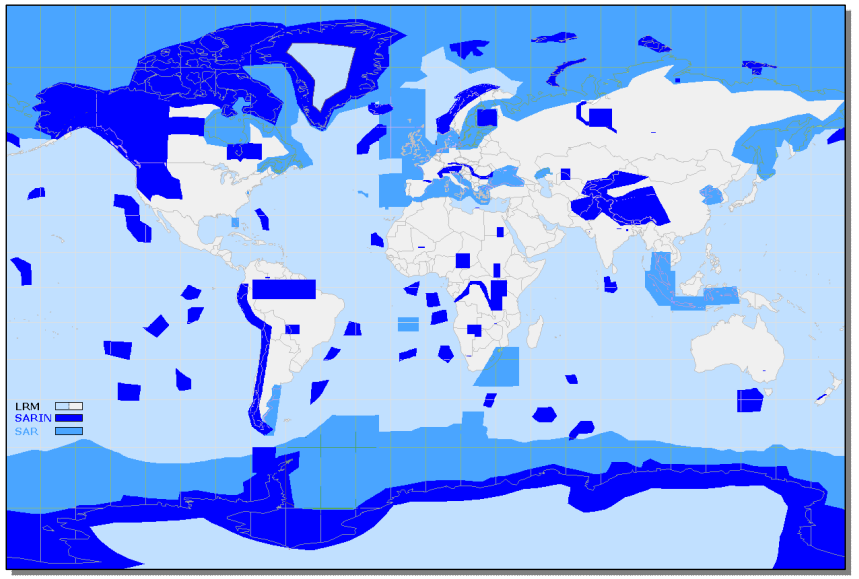
- Large data acquisition flow:
  - Cryosat: 430 Gbits/day (for 1 instrument) *(=50 GBytes/day)*
  - Envisat: 2000 Gbits/day (for 9 instruments)
- Large data processing (and archiving) flow:
  - Level-0: ~ 430 Gbits/day *(instrument data)*
  - Level-1b: ~ 3 Gbits/day *(measurement processing)*
  - Level-2: ~ 20 Mbits/day *(Geophysical processing)*
- Reduced data distribution flow
  - Only Level-1b & Level-2
  - Reduced Full-Bit-Rate distribution for Cal/Val

What is avaliable?

All CryoSat **systematic** data acquired over the mission reference zones:

1. Level 1b: *FDM, LRM, SAR, SARIN
2. Level 2: *FDM, LRM, SAR, SARIN
3. GDR: LRM+SAR+SARIN

*FDM: Product for oceanographic use



Product	Main Characteristics
Level 1b (FDM, LRM, SAR, SARIN)	Multi-look echoes – Waveform power data and phase (i.e. SARIN) averaged Full engineering and geophysical correction applied
Level 2 (FDM, LRM,SAR, SARIN)	Time-ordered elevation values and, in the case of sea-ice, it will included also freeboard after one year
GDR	Concatenated LRM, SAR, SARIN Level2 products over an orbit, consolidated from ANX to ANX

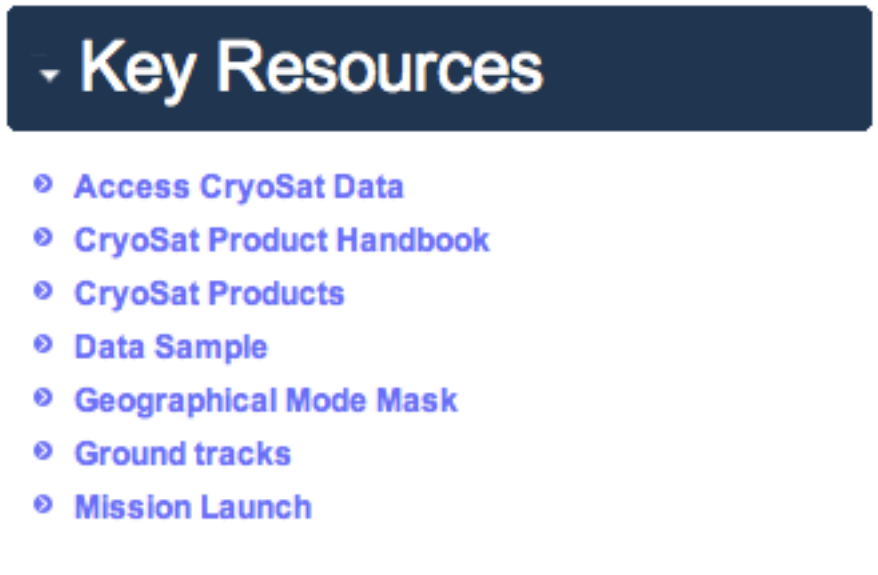
How to access data?

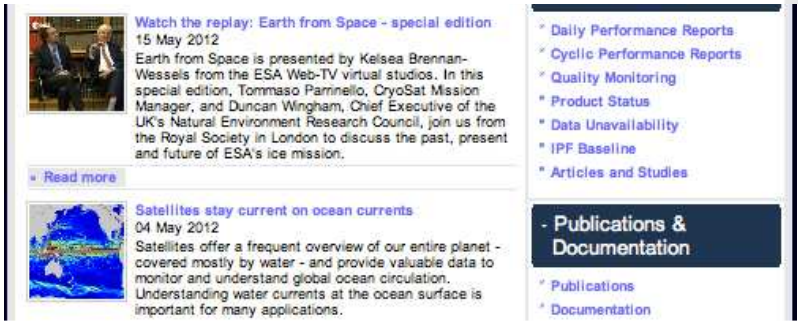
- All Cryosat systematic data are free available to all registered users via the CryoSat dissemination ftp server:
  ftp://science-pds.cryosat.esa.int

- Simple on-line registration is achieved via the EOPI Portal:
  http://eopi.esa.int/esa/esa

- More information available on the Cryosat Mission Portal:
  http://earth.esa.int/cryosat

- For any other requests, user may contact **eohelp@esa.int**





http://earth.esa.int/cryosat

Access to CryoSat data
CryoSat Products Overview

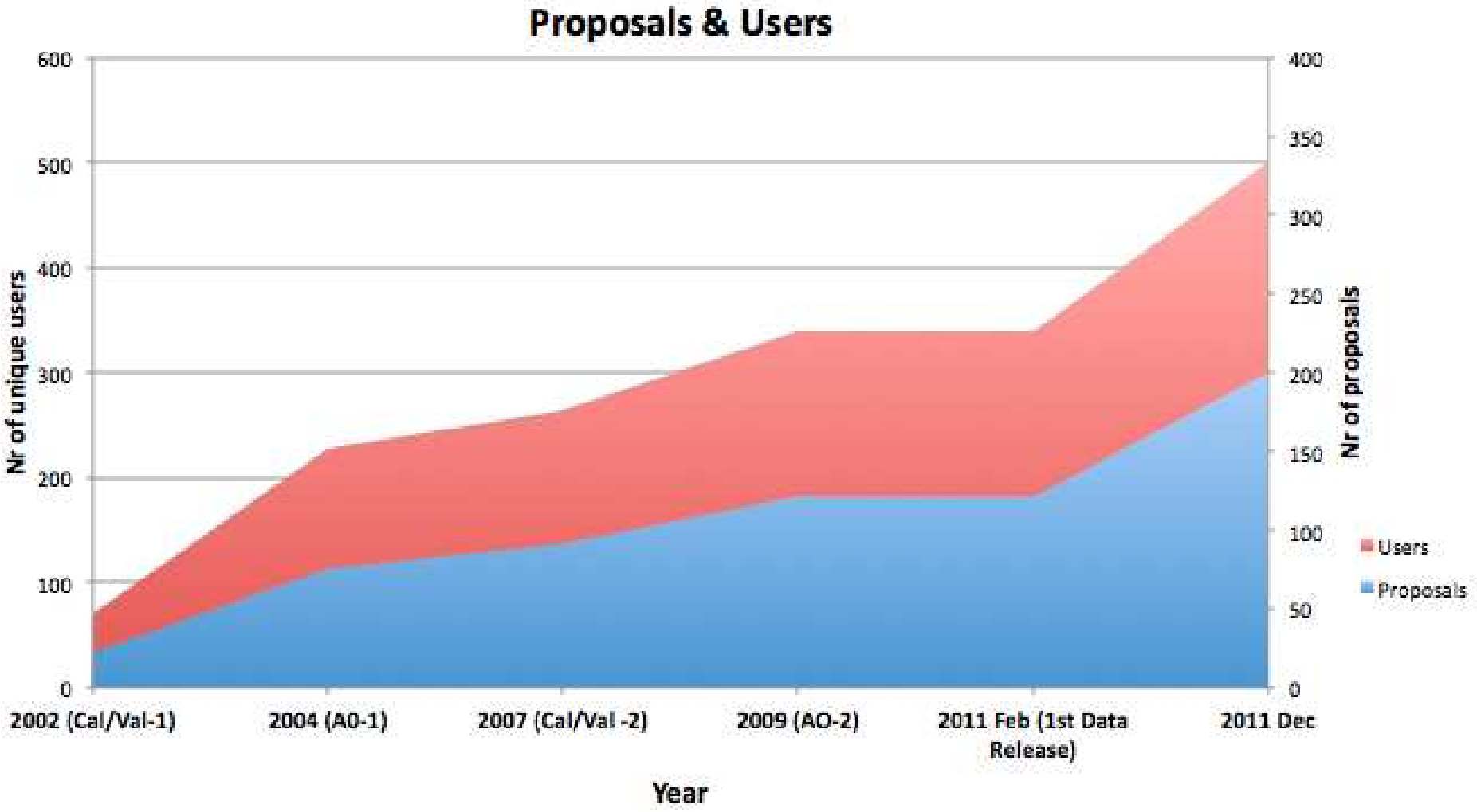
Access to Data Sample

Download Geographical Mode Mask

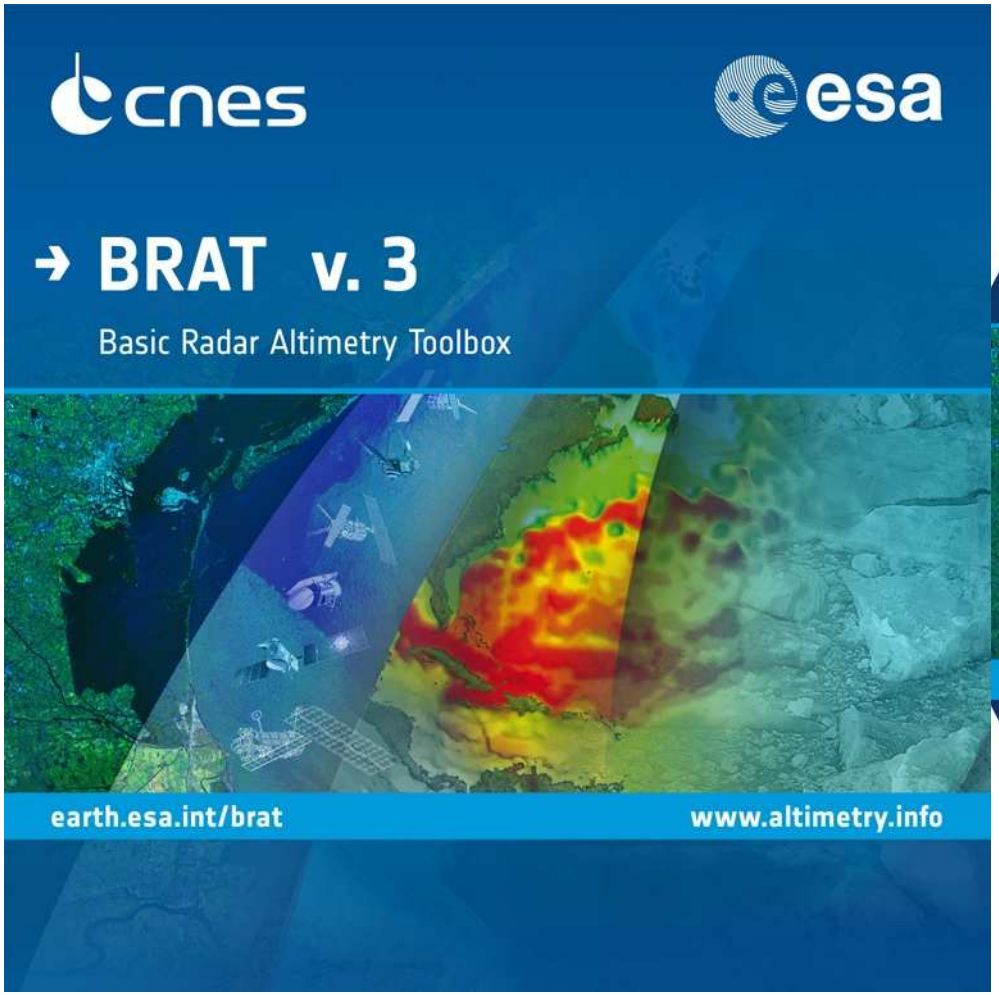
Download Ground Tracks

…*plus* tools to read and download data, software routines, data quality, news, etc

CryoSat PIs

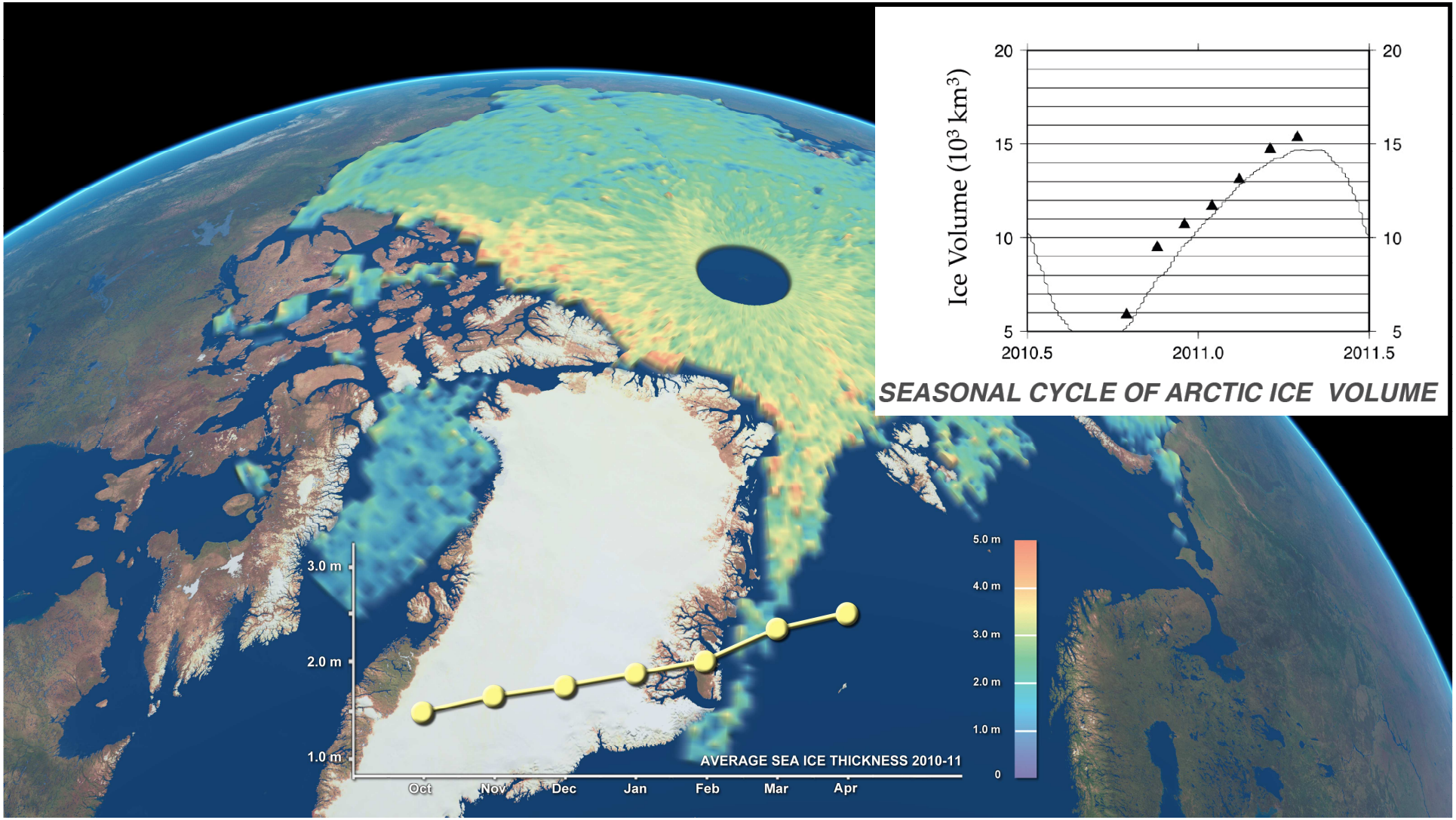

Proposals & Users
600
500
400
300
200
100
0
Nr of unique users
400
350
300
250
200
150
100
50
0
Nr of proposals
Users
Proposals
2002 (Cal/Val-1)
2004 (A0-1)
2007 (Cal/Val -2)
2009 (AO-2)
2011 Feb (1st Data Release)
2011 Dec
Year

BASIC RADAR ALTIMETRY TOOLBOX
RADAR ALTIMETRY TUTORIAL



http://earth.esa.int/brat

Seasonal cycle of Arctic ice thickness ! October 2010 to April 2011!



CryoSat+ Cryosphere

05 June 2012 - **New call for proposals:**
A new call for proposals named "CryoSat+ Cryosphere" under the STSE Programme, addressing innovative science and new applications to exploit novel capabilities of the CryoSat mission, has been issued.
The call focuses on two main themes:
•Ice sheet grounding line location, ice thickness and ice mass flux
•Regional glacial isostatic adjustment and elevation rate corrections

Proposals may suggest alternative themes exploring innovative applications and novel potential areas for the exploitation of CryoSat data.

To find more information visit STSE news or ESA EMITS.

CryoSat+ Cryosphere

ESA Open Invitation To Tender
AO7158

Title: STSE-CRYOSAT+ CRYOSPHERE

Open Date: 01/06/2012
Closing Date: 26/07/2012

Prog. Ref.: EOEP-3 Supp Sci Elem
Special Prov.:
B+DK+F+D+E+S+CH+GB+IRL+A+N+FIN+POR+GR+LUX +CZ
Price Range: 200-500 KEURO
Establishment: ESRIN
Directorate: Directorate of EO Programmes
Department: Science, Appl & Future Technologies Dept

→ EARTH OBSERVATION AND CRYOSPHERE SCIENCE

Advancing Knowledge of Cryosphere-Atmosphere-Ocean Interactions from Space

13-16 November 2012 | ESA-ESRIN | Frascati (Rome), Italy


esa
→ CRYOSAT THIRD USER WORKSHOP
12-14 March 2013 | Dresden University | Dresden, Germany

CryoSat space segment status

- Space segment very stable
- SIRAL functioning very well with no issues since April 2011
- DORIS is providing “state of the art” orbits
- Fuel consumption: < 10 grams / week
- Housekeeping manoeuvres: every 6 weeks, slight increase due to rise of solar activity
- Expected life time > 3+2 years
- CryoSat extension proposed in EOEP-4

CryoSat space segment status

- Ground segment is functioning well
- Around 3 GB of data per day is delivered to the international community
- User community has increased by 65% since launch
- New baseline of products was released on the 1st Feb 2012
- Some anomalies still present in products
- Reprocessing of CryoSat data from July 2010 – January 2012 is about to start
- New Geographical Mode Map released 7th May 2012 – NEW Proposal issued from CryoSat +
- Mission performance (i.e. Mission data return) exceeding 97%

Summary

- Are humans really changing the polar environment?
- CryoSat – ESA's first dedicated satellite for study of the polar regions – is focused on answering this question.
- CryoSat will deliver quantitative data on the rates of change of ice sheet and marine ice masses.

The Space Segment

CryoSat Design Drivers

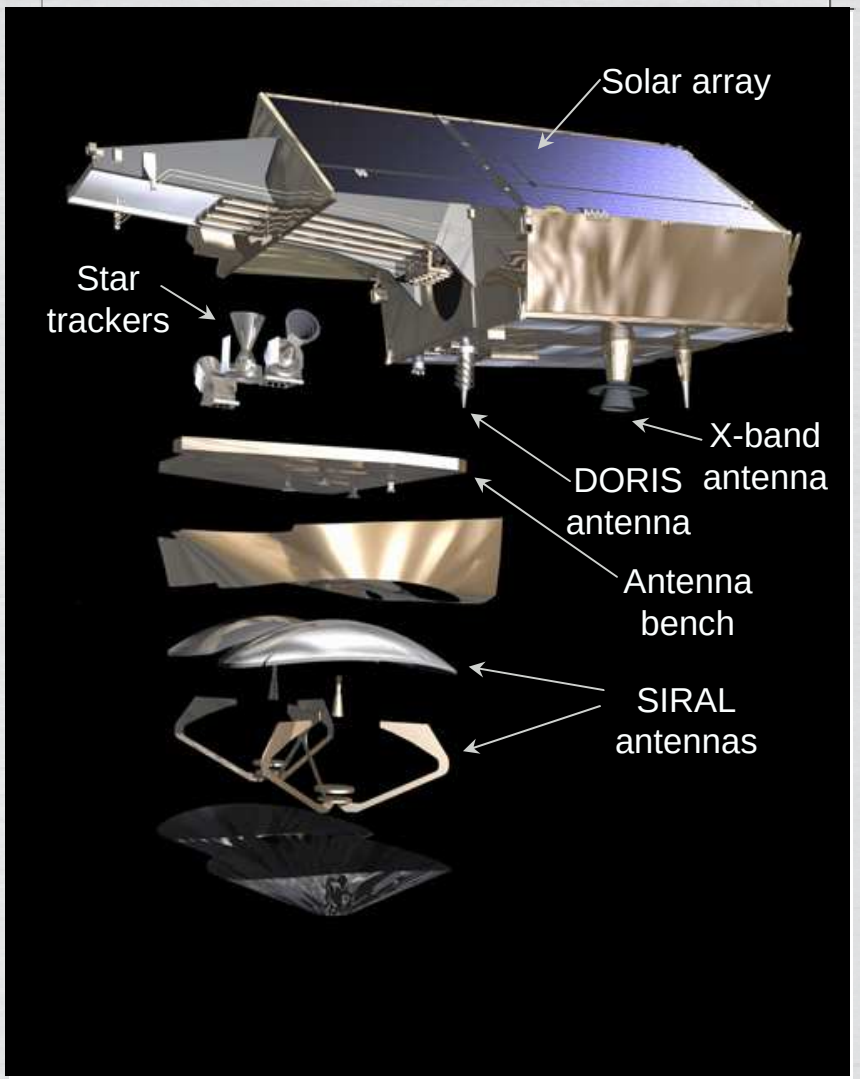
- Mission constraints:
- non sun-synchronous orbit;
- interferometer stability;
- data volume and dump strategy;
- small launch vehicle.
- Programmatic constraints:
- low cost;
- fast development.

Design Approach

- Simplified design:
- robust structure;
- no moving parts;
- simple attitude control system.
- Recurrent hardware:
- almost all platform equipment is recurrent from other programmes.
- Reduced model philosophy:
- satellite – proto-flight hardware;
- SIRAL – breadboard and engineering models;
- extensive use of simulation.

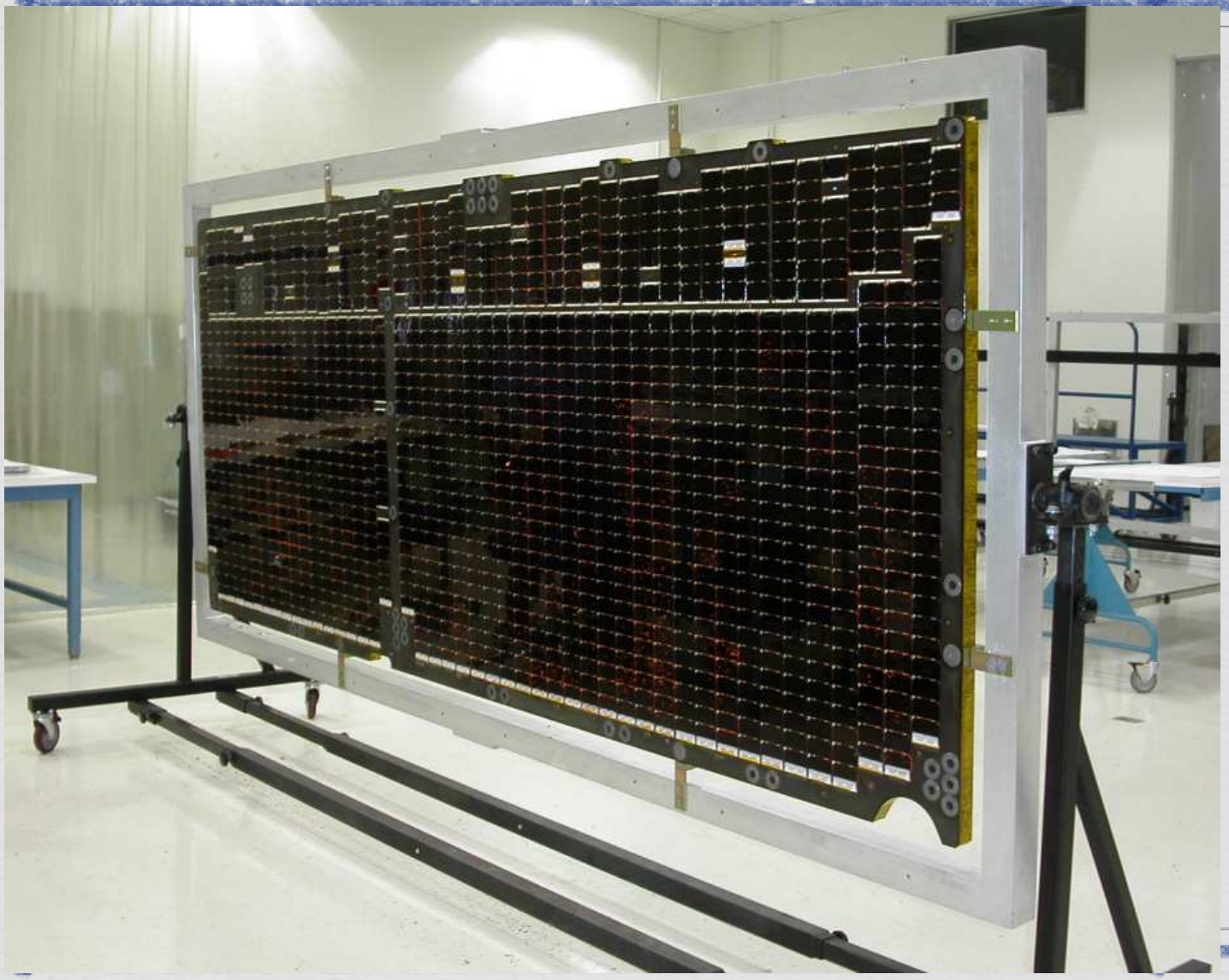
CryoSat Design

- High efficiency (24%) GaAs solar array.
- Stable SIRAL antennas (CFRP) with thermal protection.
- Rigid, stable antenna bench.
- Star trackers mounted directly on bench.
- DORIS antenna near CoG.
- Isoflux X-band antenna.



CryoSat Structure

Solar Array



X-Band Antenna

Attitude and Orbit Control

- No moving parts (wheels or gyros).
- Low-thrust (10, 40 mN) cold gas reaction control system.
- Dual use of payload (DORIS and Star Trackers).
- Fine Pointing Mode (local normal pointing, yaw steering):
  - attitude measurement by Star Tracker;
  - position determined by DORIS navigator;
  - torque by magneto-torquers/cold gas thrusters (10 mN);
  - performance: 0.1° (pitch, roll), 0.2° (yaw).
- Coarse Pointing and Safe Mode (Earth pointing):
  - attitude measured by Combined Earth Sun Sensor;
  - torque by magneto-torquers/cold gas thrusters (10 mN).

Data Handling

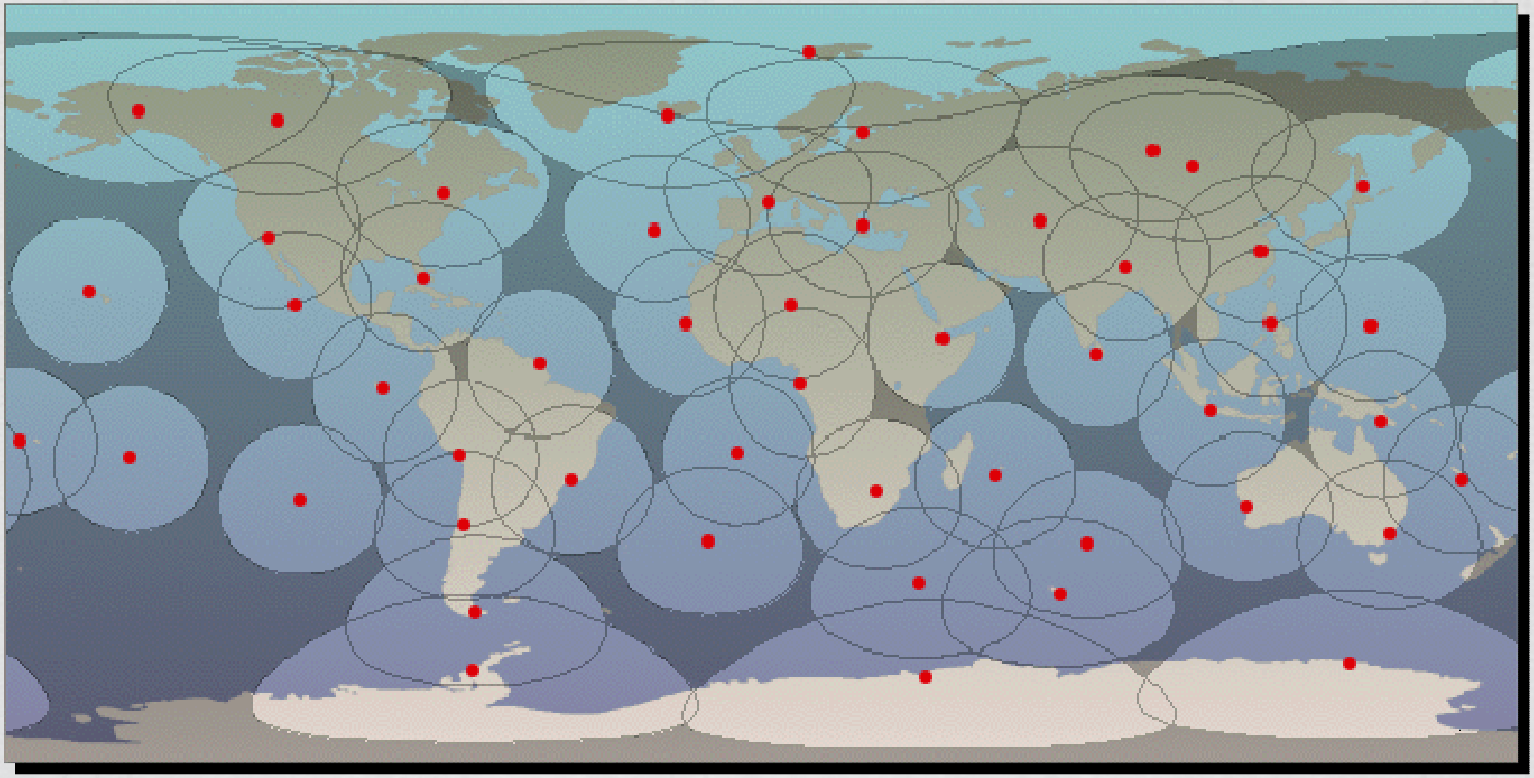
- On-board science data storage:
- 2 × 128 Gbit solid-state mass memory;
- 7 separate filestores;
- flexible data-handling.
- Data downlink:
- 100 Mbps X-band (8.1 GHz) downlink.
- Command and Control:
- S-band TT&C link (2 and 4 kbps).
- Powerful and autonomous central control computer.

Nadir Panel

Payload: DORIS

- Up-link RF tracking system based on Doppler from worldwide beacon network.
- Dual frequency (2036.25, 401.25 MHz) for ionospheric corrections.
- DORIS provides:
- Doppler tracking data for precise orbit determination;
- real-time navigator data for AOCS and near-real time data products (<1 m radial);
- on-board time synchronised to TAI (5 μs).

DORIS Beacon Network



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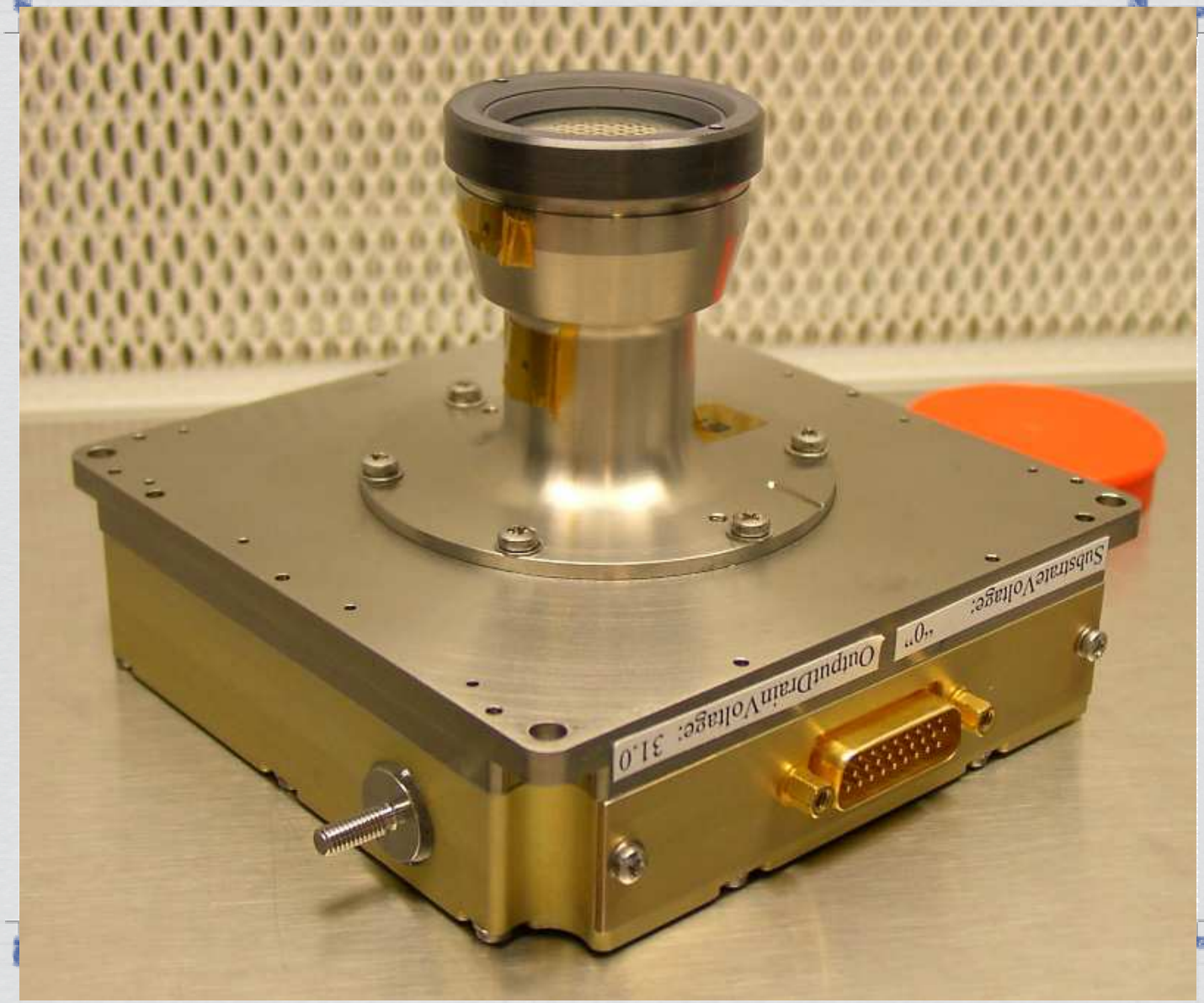
Payload: Laser Retroreflector

Payload: Star Trackers

- Three autonomous Star Trackers:
- accommodation to avoid simultaneous Sun and Moon blinding (0° and ±65° to zenith);
- fixation with CFRP and titanium to antenna bench;
- determine interferometer baseline *and* 3-axis attitude sensor for AOCS.
- 1024 × 1024 pixel CCD; field of view 22° × 22°.
- Sun exclusion angle 30°.
- Autonomous acquisition in 2 – 3 s.
- Attitude updates at 1.7 Hz.

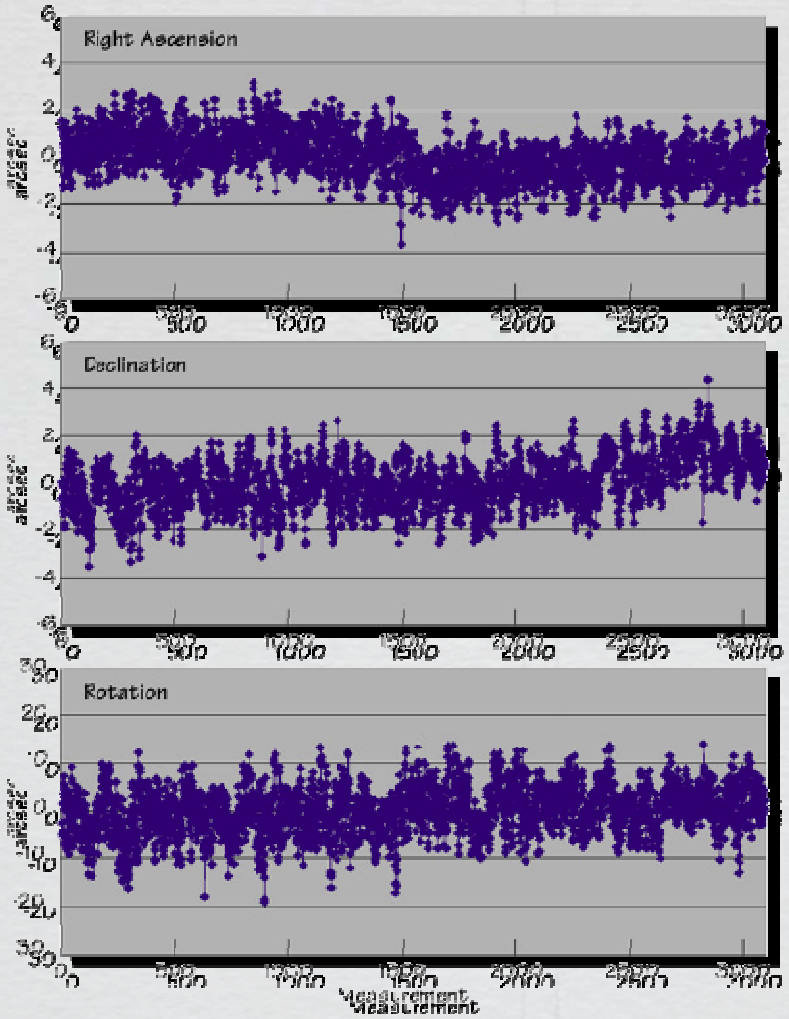
Star Tracker Camera Head



Antenna Bench

Star Tracker Night Sky Test

Star Tracker Night Sky Test



0.96 arc sec (1σ)

1.08 arc sec (1σ)

4.91 arc sec (1σ)