# *What can we learn with the comparison between the ERS and Envisat family and Cryosat over ice sheet ?*

Frédérique Rémy and Benoît Legrésy

Legos, 18 av ed. Belin 31401 Toulouse Cedex 9
FRANCE

→Merge the ERS1 and Envisat data with the Cryosat one where the precision is comparable , in the inland part of Antarctica or Greenland (cryosat in low resolution)

→Improve the precise topography or learn more about snowpack characteristics

→Some differences between missions are either a limitation or an opportunity

# Difference between ERS family and Cryosat in LRM mode

| | Envisat | | Cryosat |
|---|---|---|---|
| - altitude : | 800 km | → | 720 km |
| - antenna: | 1.2 m | → | 1.15mX1.4m |
| - sun-synchronous | yes | → | no |
| - inclination | 81.6° | → | 92° |
| - repeat cycles | 35 d | → | 369 d, 30 d sub-cycle |
| - Antenna polarization: | linear,-120° | → | linear,-90° |

→ Are affected the height, the backscattering and the waveform shape via the antenna pattern gain, the slope error, the ratio between surface and volume and the perception of the surface anisotropy….

**We do not look at external effects, such as changes in snow pack properties or high frequency variability**

→ **Part 1 : about the topographies and the slope error**
**(the ≠ are a limitation)**

→ **Part 2 : about instantaneous observations at cross-over**
**(the ≠ could an opportunity)**

## Part 1 : compare the topographies

## (either both precise topography or Envisat and Cryosat topographies)

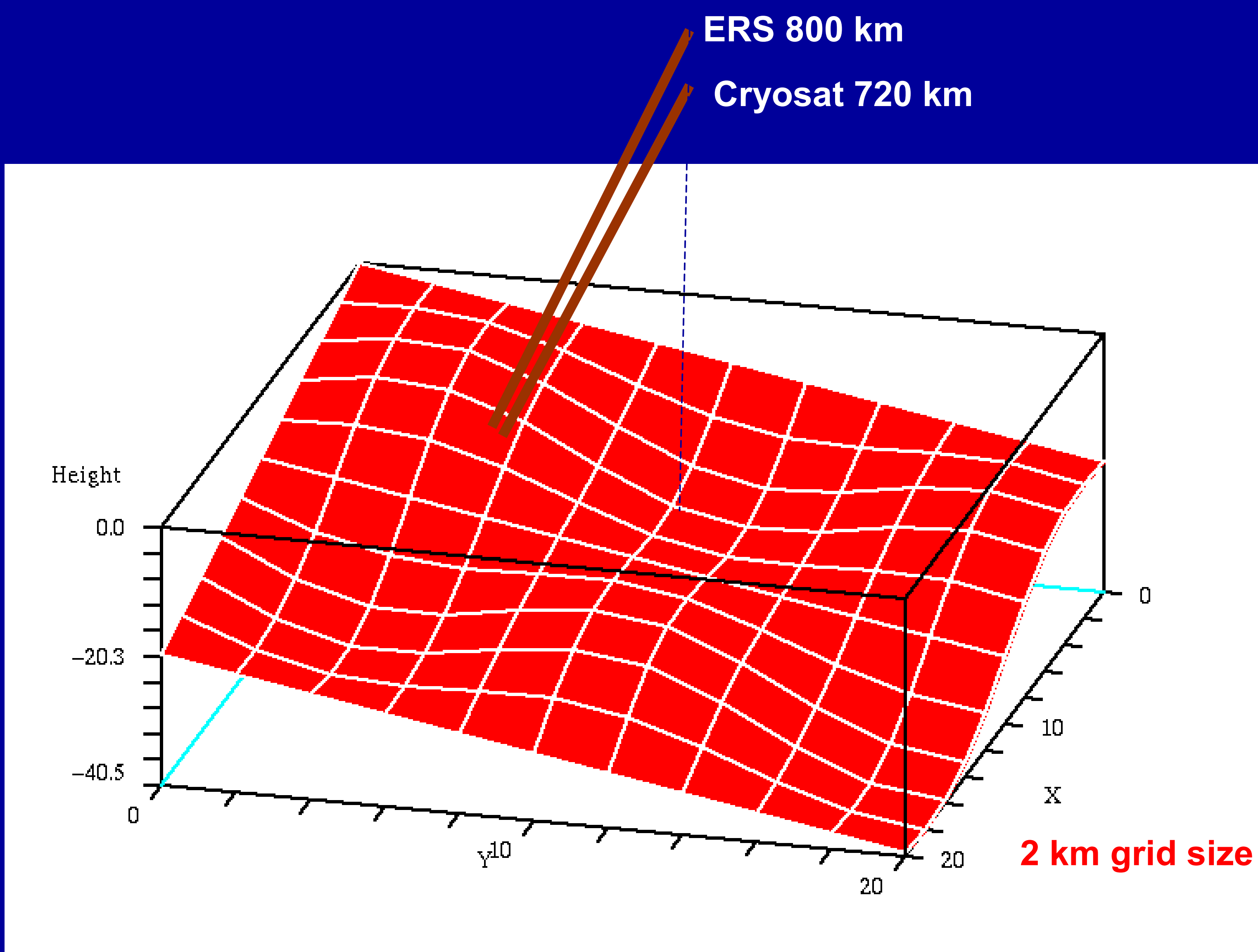
Interests:

- the error budgets for both missions are different and complementary
- depending of the future of altimetric mission above ice sheet a precise calibration between both missions could be needed.
-one can look at the natural variations between the geodetic mission of ERS in 1993 and the one of Cryosat, about 15 years later.

→ The first thing to do is to evaluate the induced error due to the difference in the mission characteristics. One of the greater impact is due to the slope error and the altitude difference.

# Slope error

Due to different slope error induced by different altitude:
- misknowledge of the surface slope (at the good scale)
- misknowledge of surface curvature
- limitation of the methodology, even if taken into account H'' and by iteration



Residual error due to the difference on slope error:
a, the surface slope, c the surface curvature

$h=h0+a\ x+c/2\ x^2$

The slope error is given by: $H/2\ a^2\ (1+cH)$

The residual error due to the difference between slope errors if the precision on the slope is $\delta a$ and the precision of the surface curvature is $\delta c$ is :

$$\delta e = a^2/2\ (H2-H1)\ \delta c\ H \quad + \quad a\ \delta a\ (H2-H1)\ [1+c\ H]$$

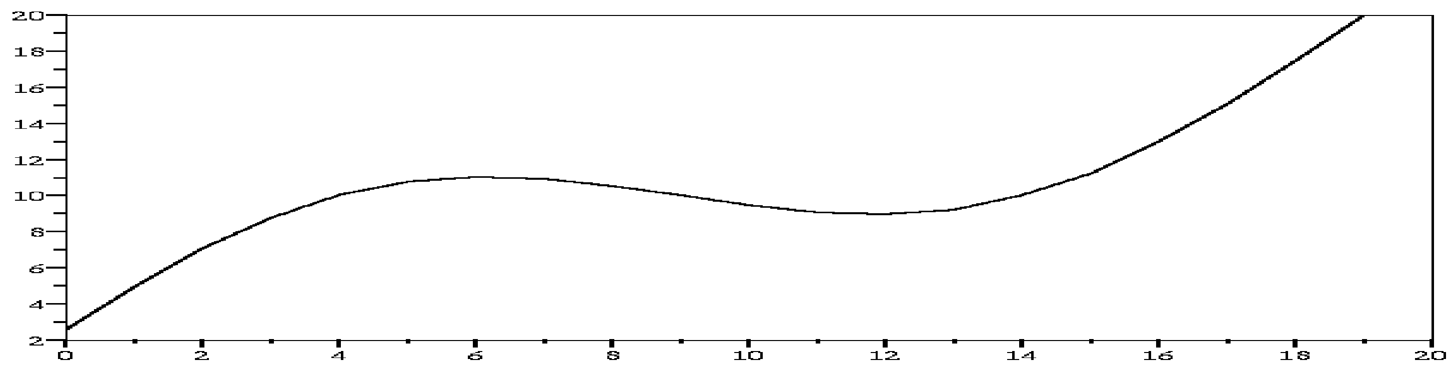
error due to misknowledge of surface curvature

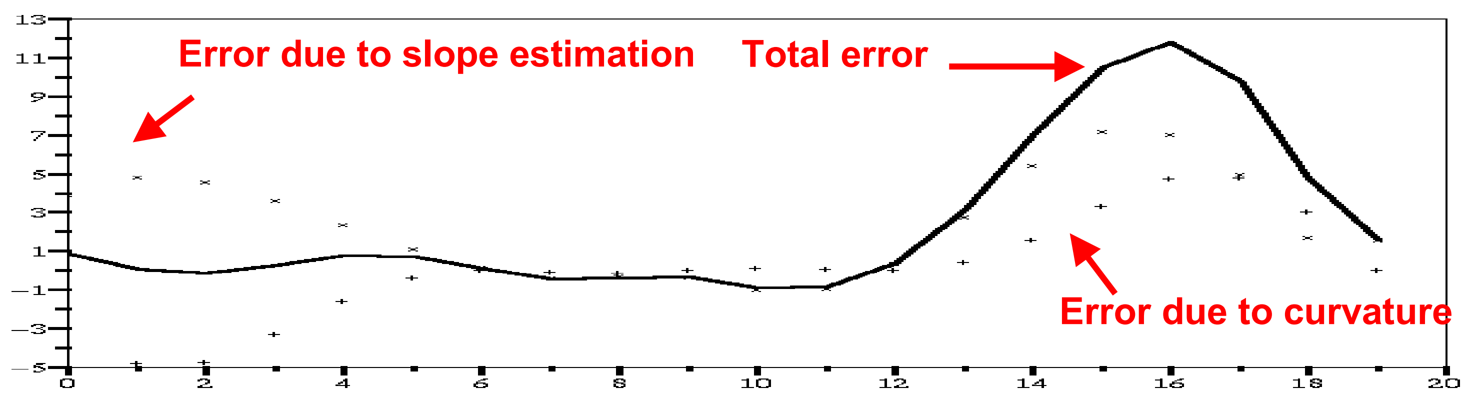
error due to misknowledge of surface slope (scale, topo)

The error on slope is assumed to depend on the grid size, e.g. 2 km ($a+\delta a = a(\pm 1km)$)
We assume that the curvature is (as usual) negliged.
(note that H'' is numerically very noisy)

# Analytical estimation

**Mean slope = 1m/km; Undulation amplitude 5 m; undulation wavelength 20 km**
**The initial difference between slope error varies from 0 to 45 cm**

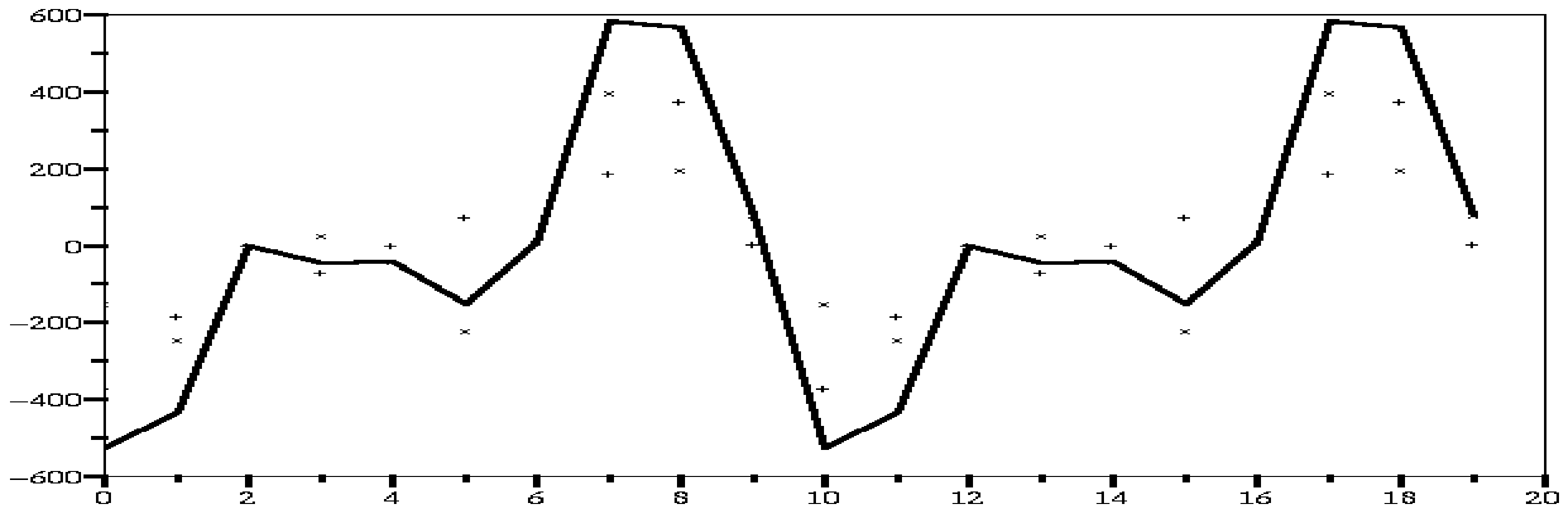





**Residual error after correction:**
**Mean = 2.5 cm, rms = 4 cm**
**→ up to 12 cm for a gentle undulation**

# Analytical estimation

**Mean slope = 2m/km; Undulation amplitude 10 m; undulation wavelength 10 km**
**The initial difference between slope error varies from 0 to 12 m**

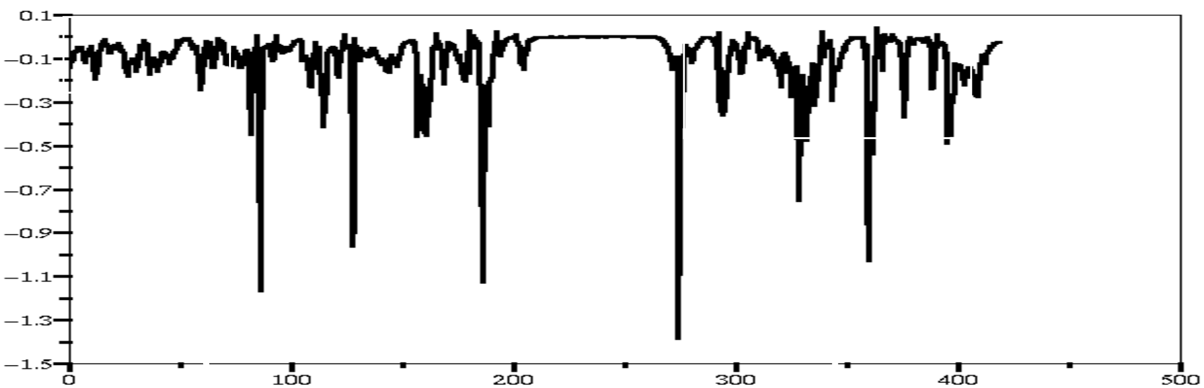


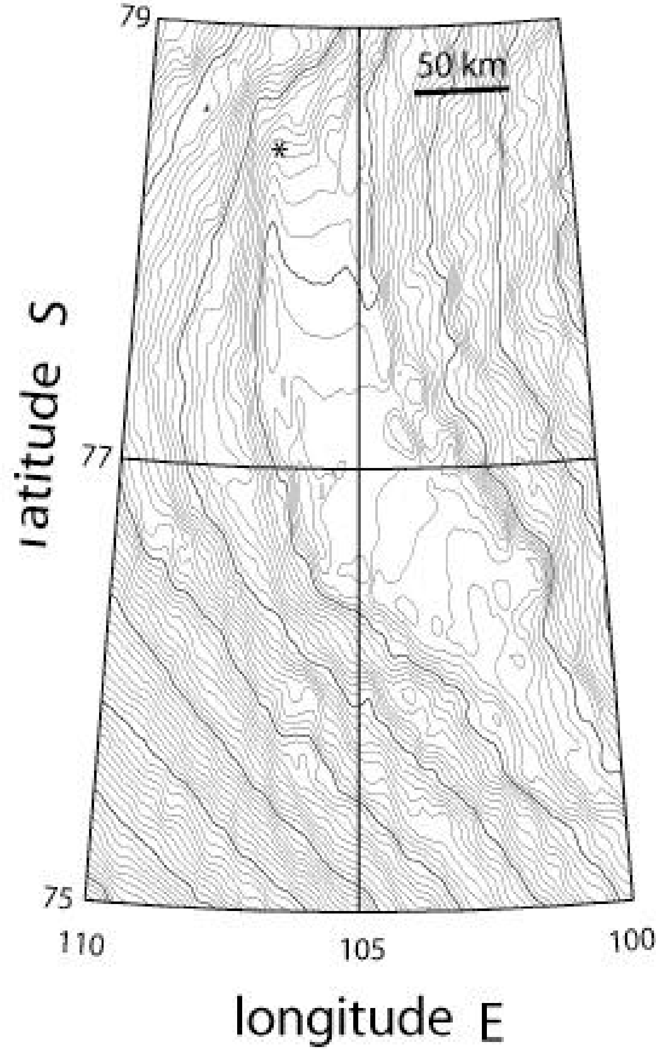

Residual error after correction is

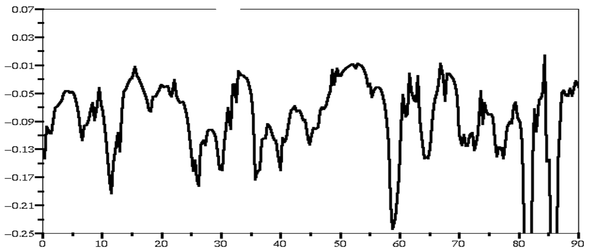
**Mean= 4 cm, rms=3.4 m**
**→ error up to 6 m**

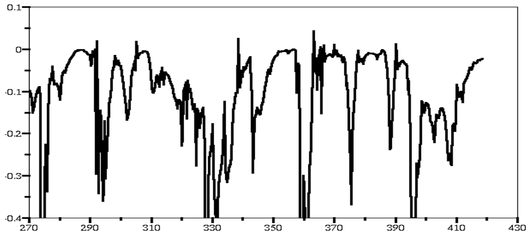
# Numerical simulation
# Swen Roemer

Simulation around Vostok area, with gentle slope
Topography are know with ERS geodetic mission
Simulation of a track as seen by ERS and by cryosat with a known slope
Both are corrected from slope induced error before comparison







Mean = - 10 cm, rms = 12 cm → **In good accordance with previous estimation**

## Summarises

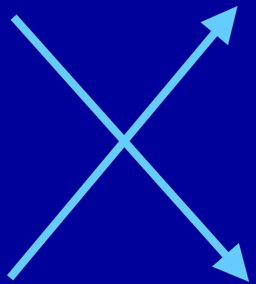
This error, after correction, varies from around 5 cm in the central part to the meter in the sloppy and rough areas.

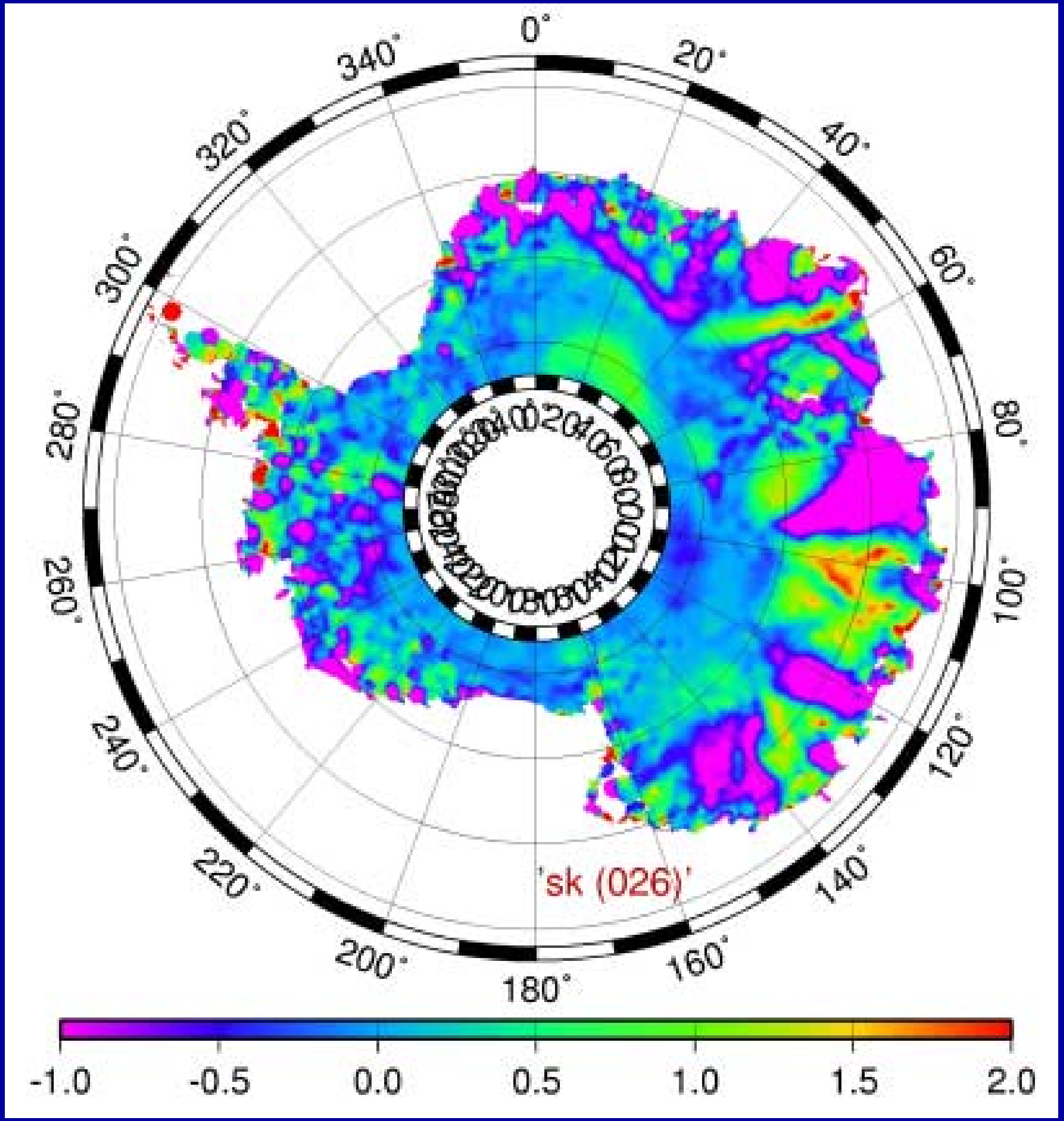
The error due to the difference in antenna pattern gain (altitude and antenna size) is probably around few centimetres and strongly depends on the used retracking.

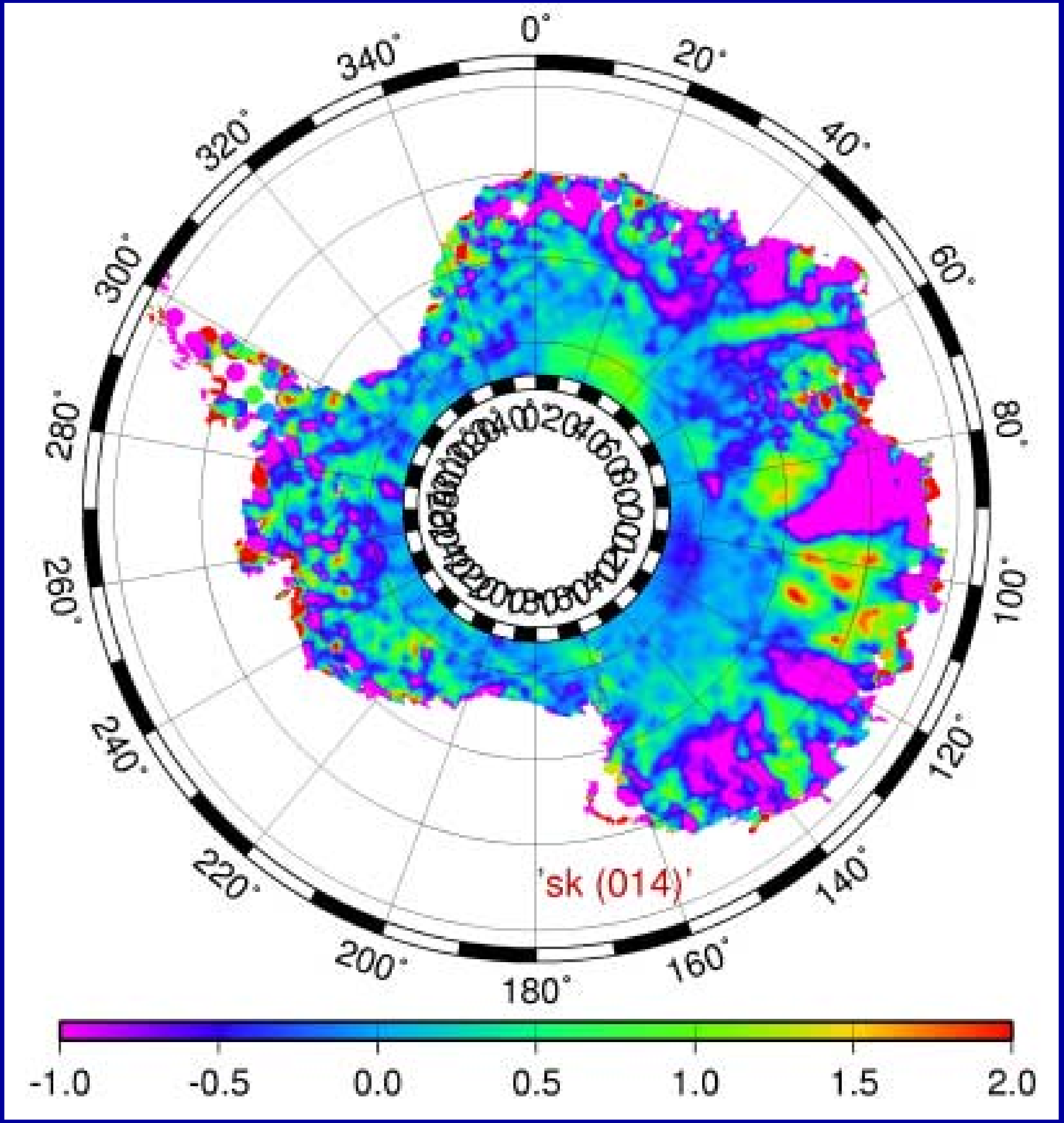
**These errors are not enough important to do not try to compare the data for instance from both geodetic missions. But, without a previous precise analysis no direct comparison between both topographies can be performed.**

**→ The major source of error lies in the difference of the roughness anisotropy due to the antenna polarisation …**

→comparison between descending and ascending track of ERS
Backscattering difference : one of the more complex error in altimetry



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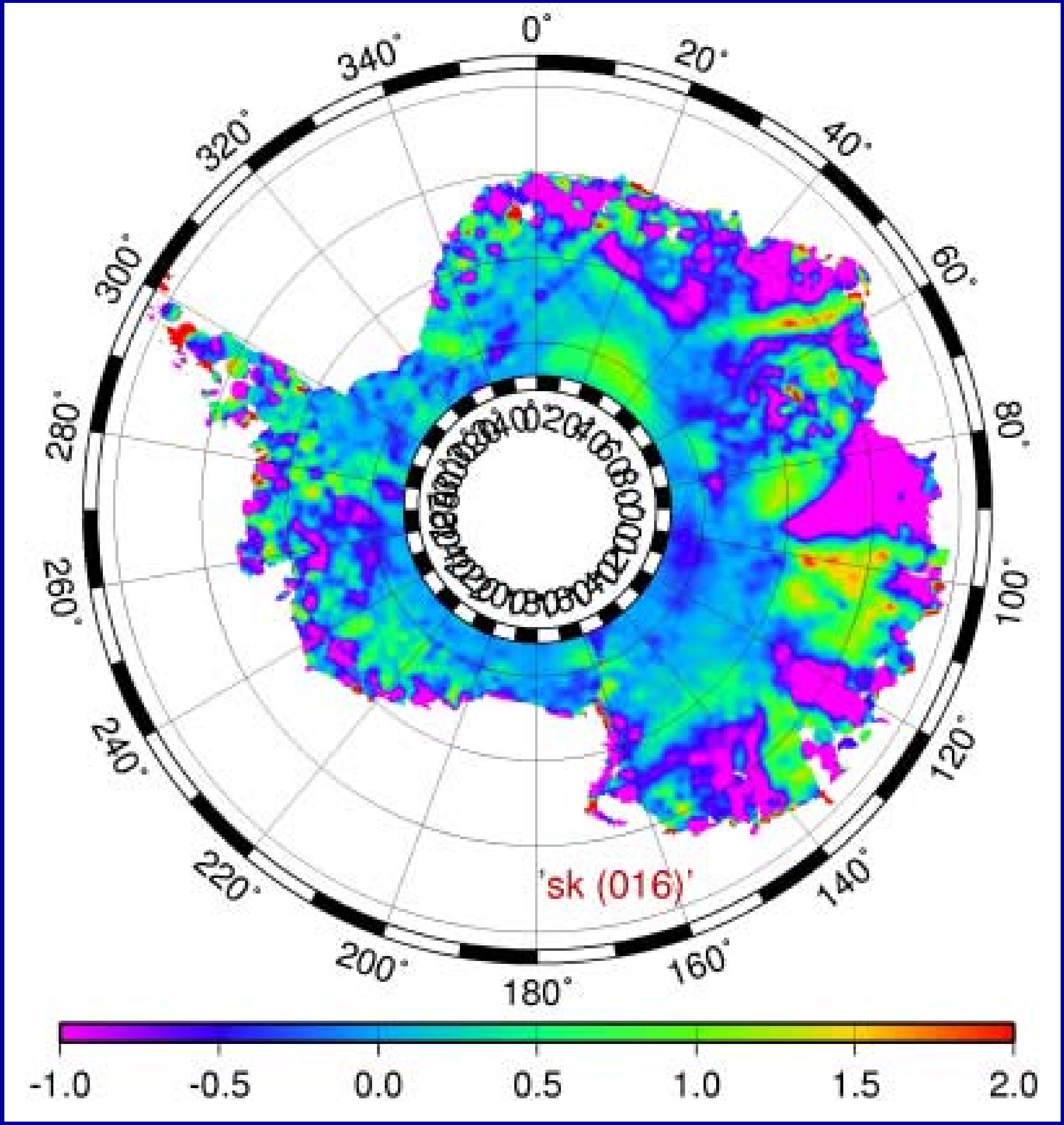
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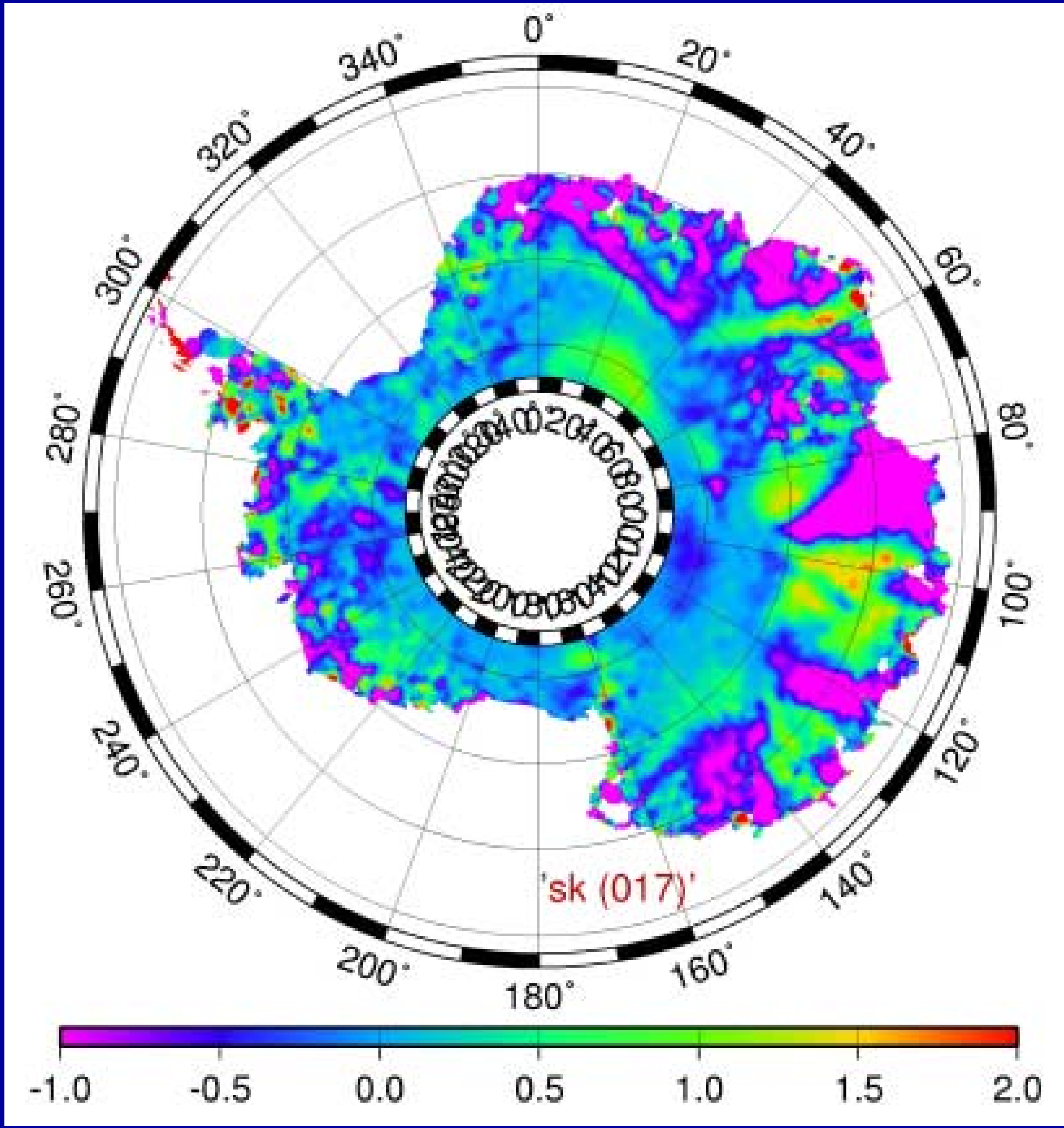
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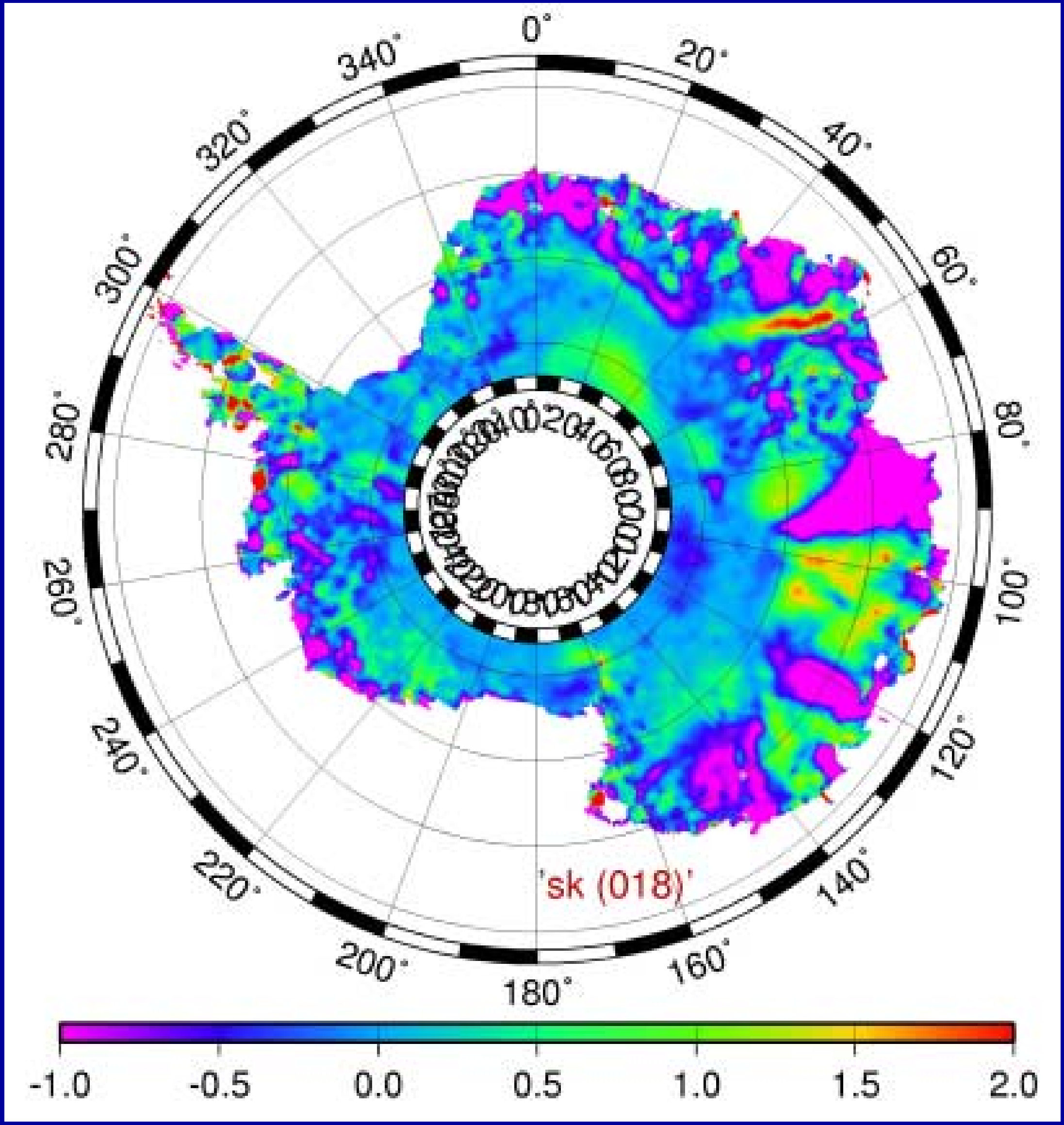
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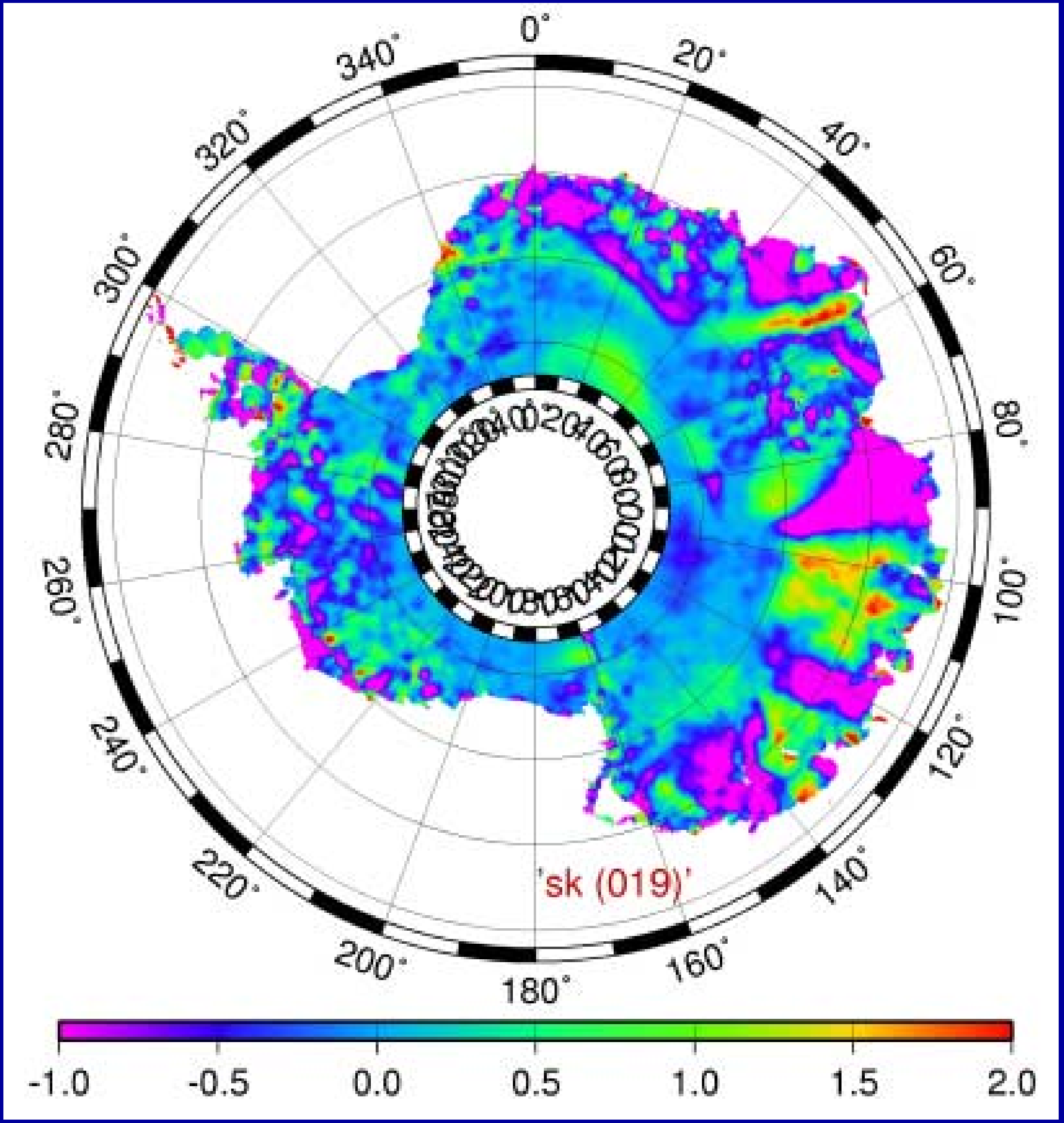
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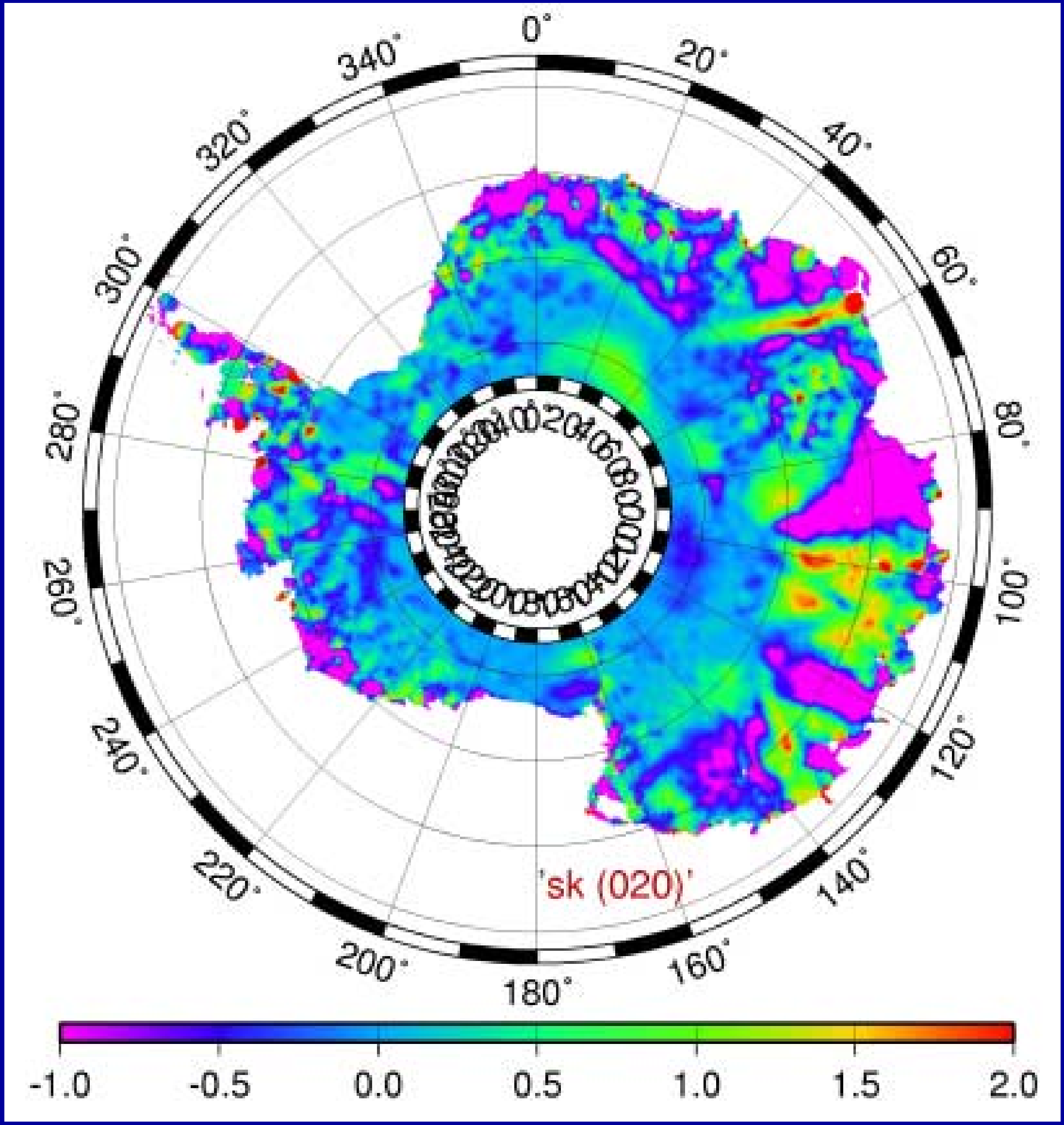
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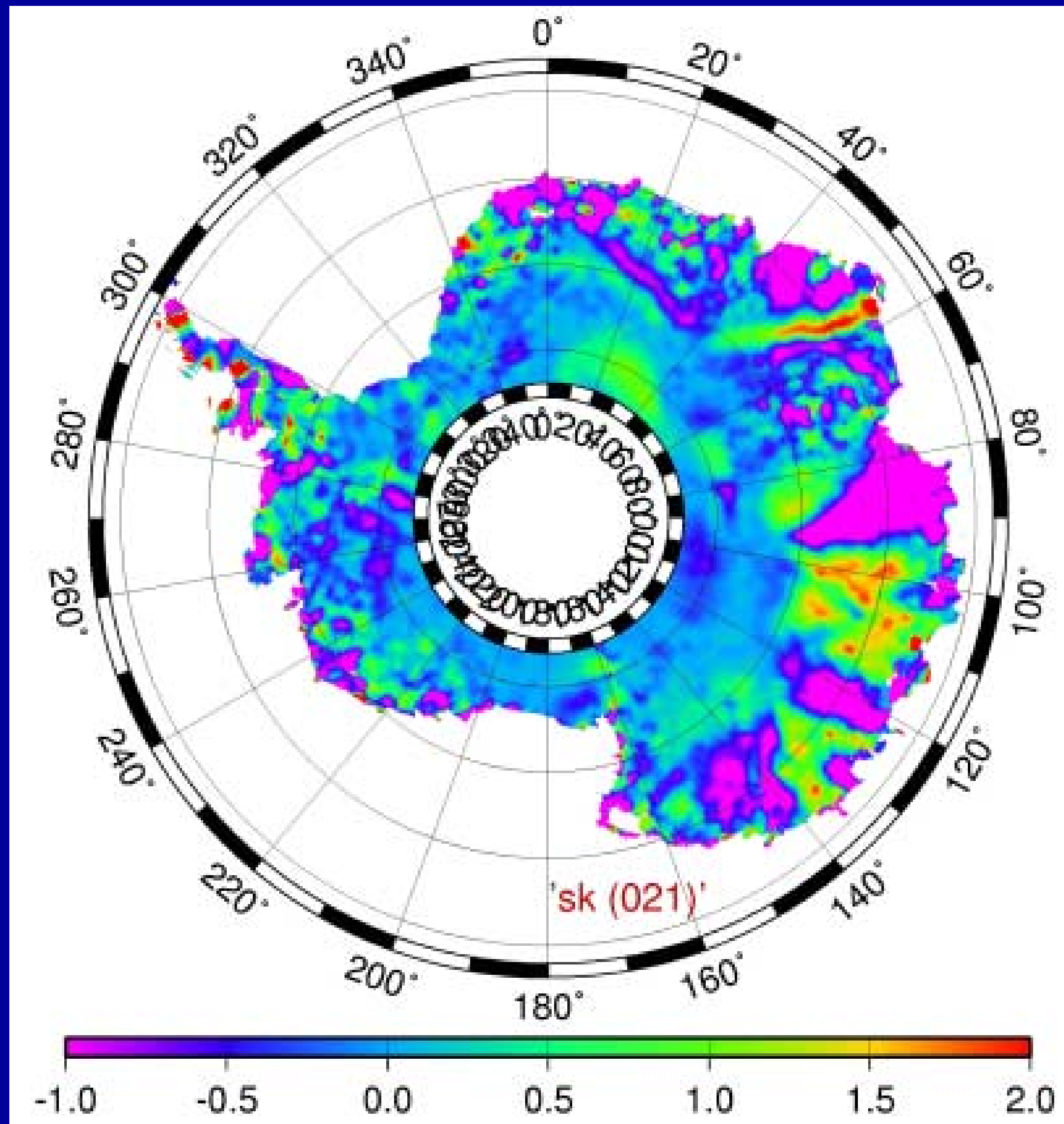
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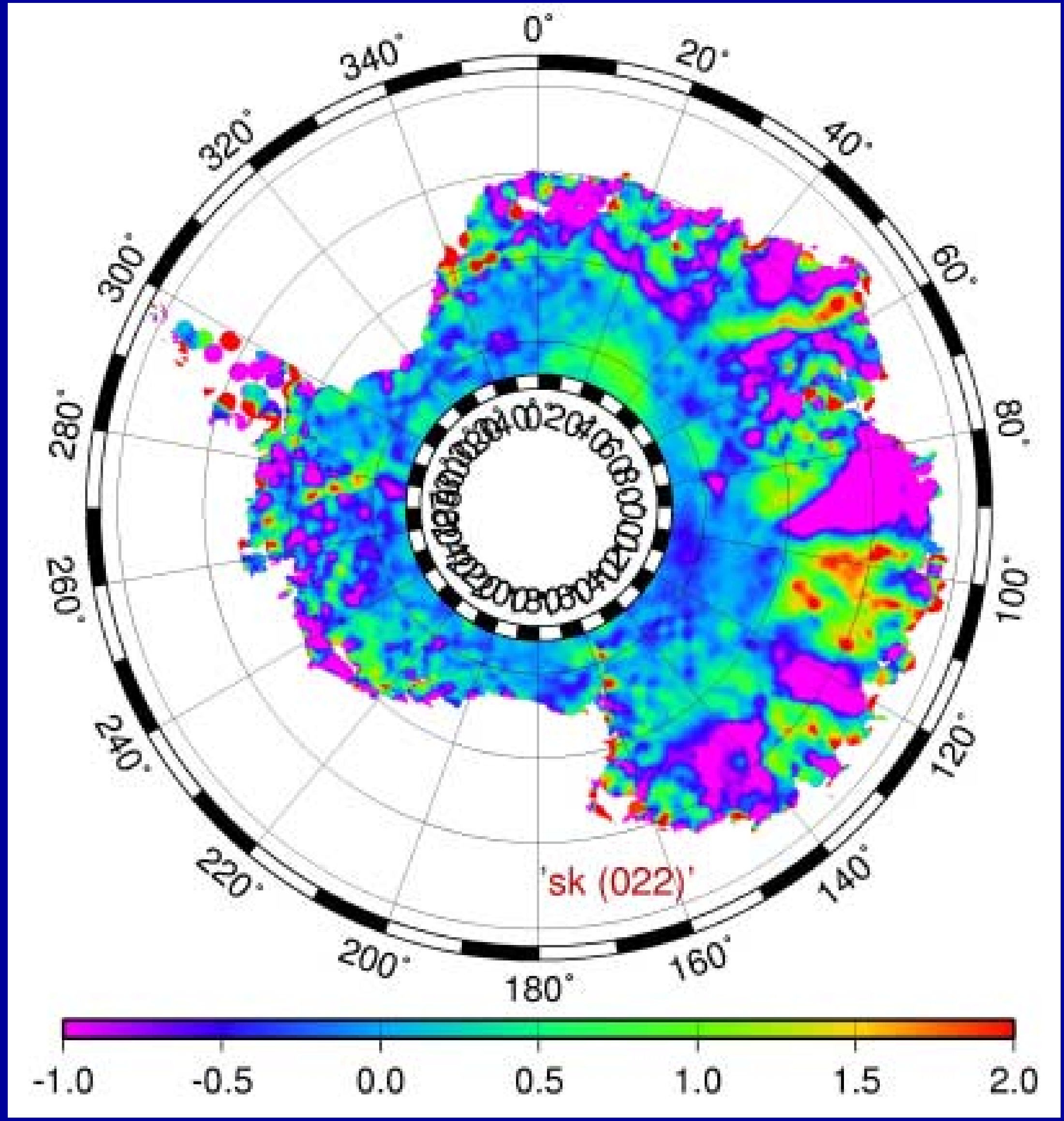
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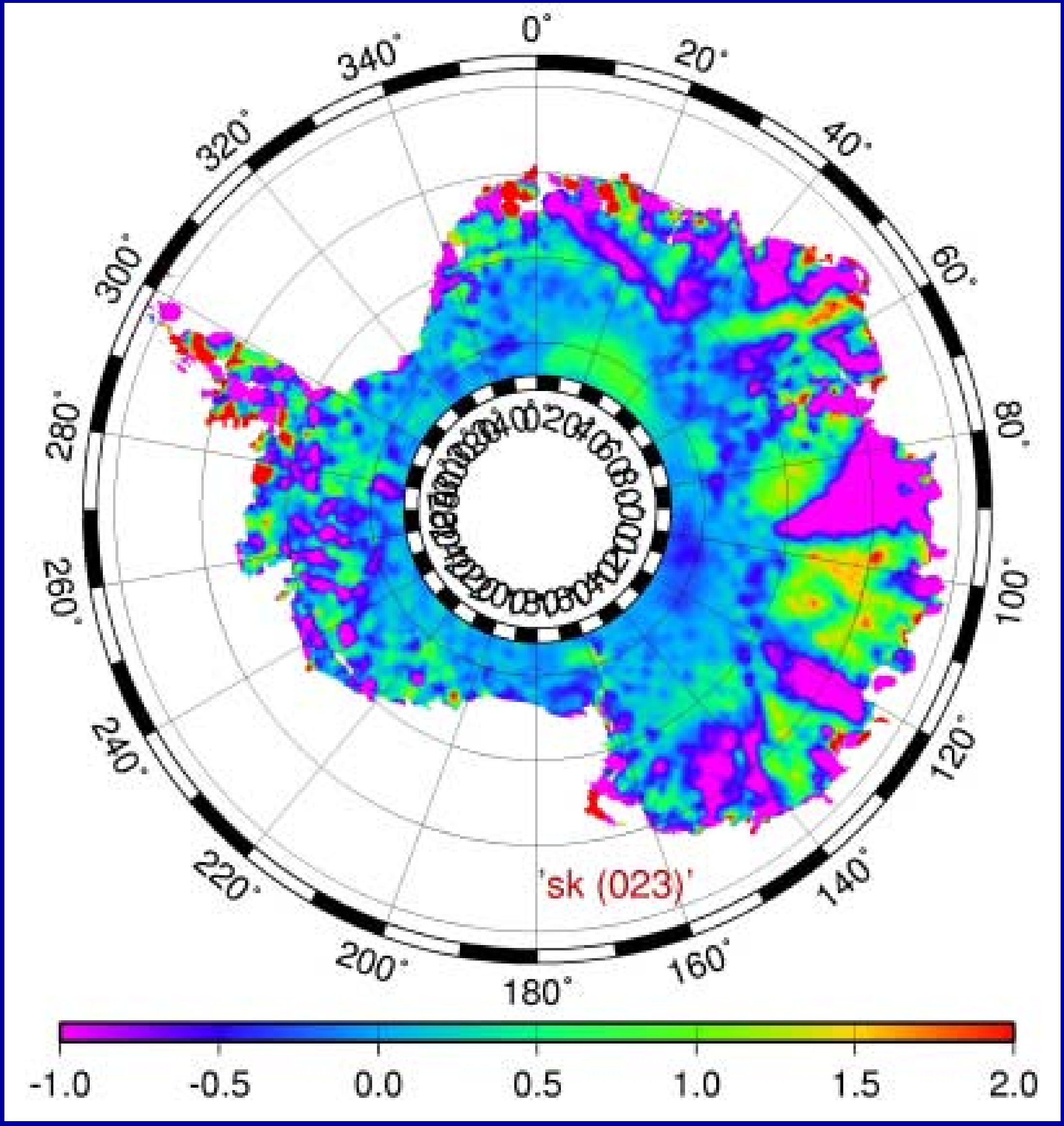
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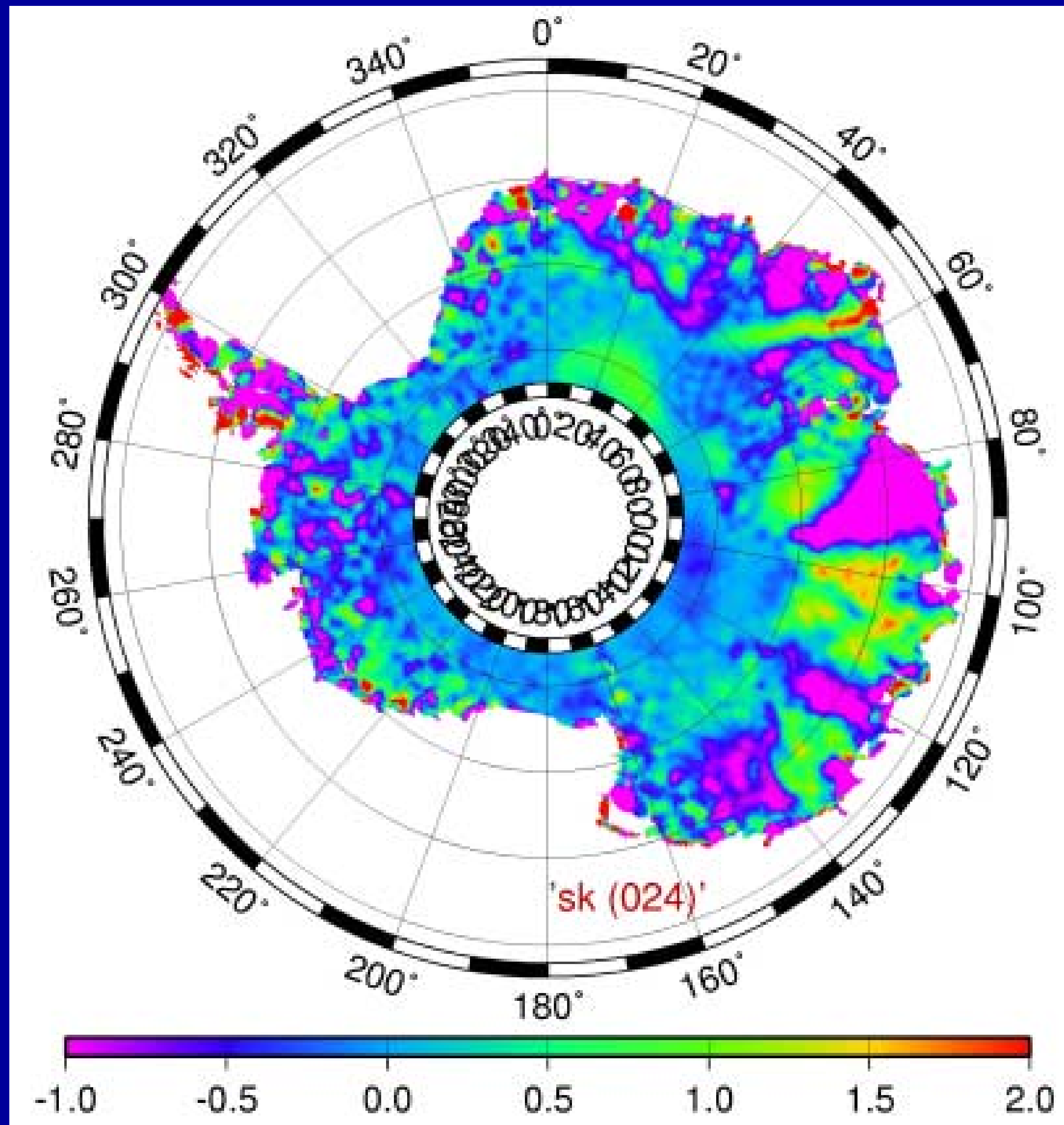
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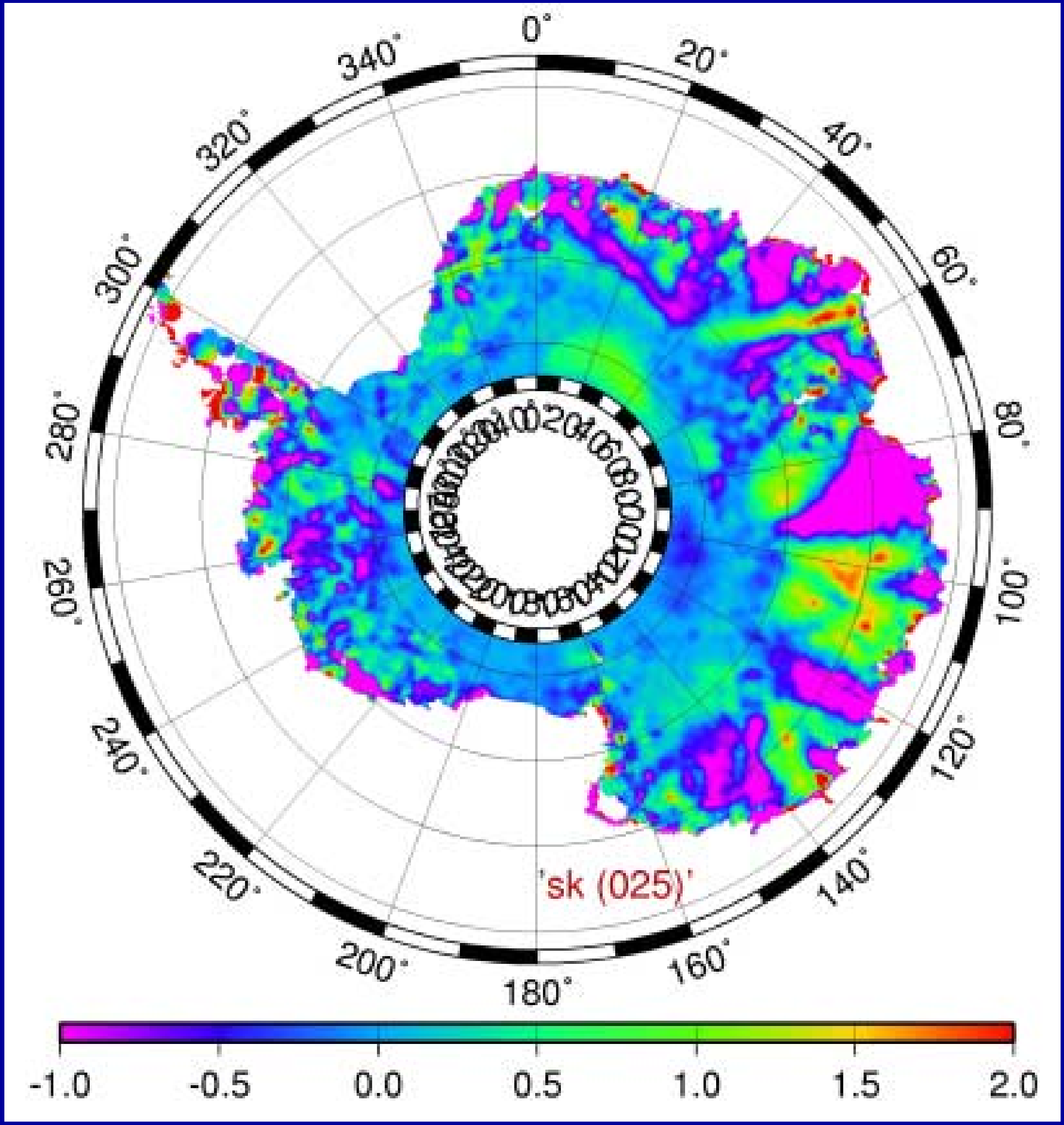
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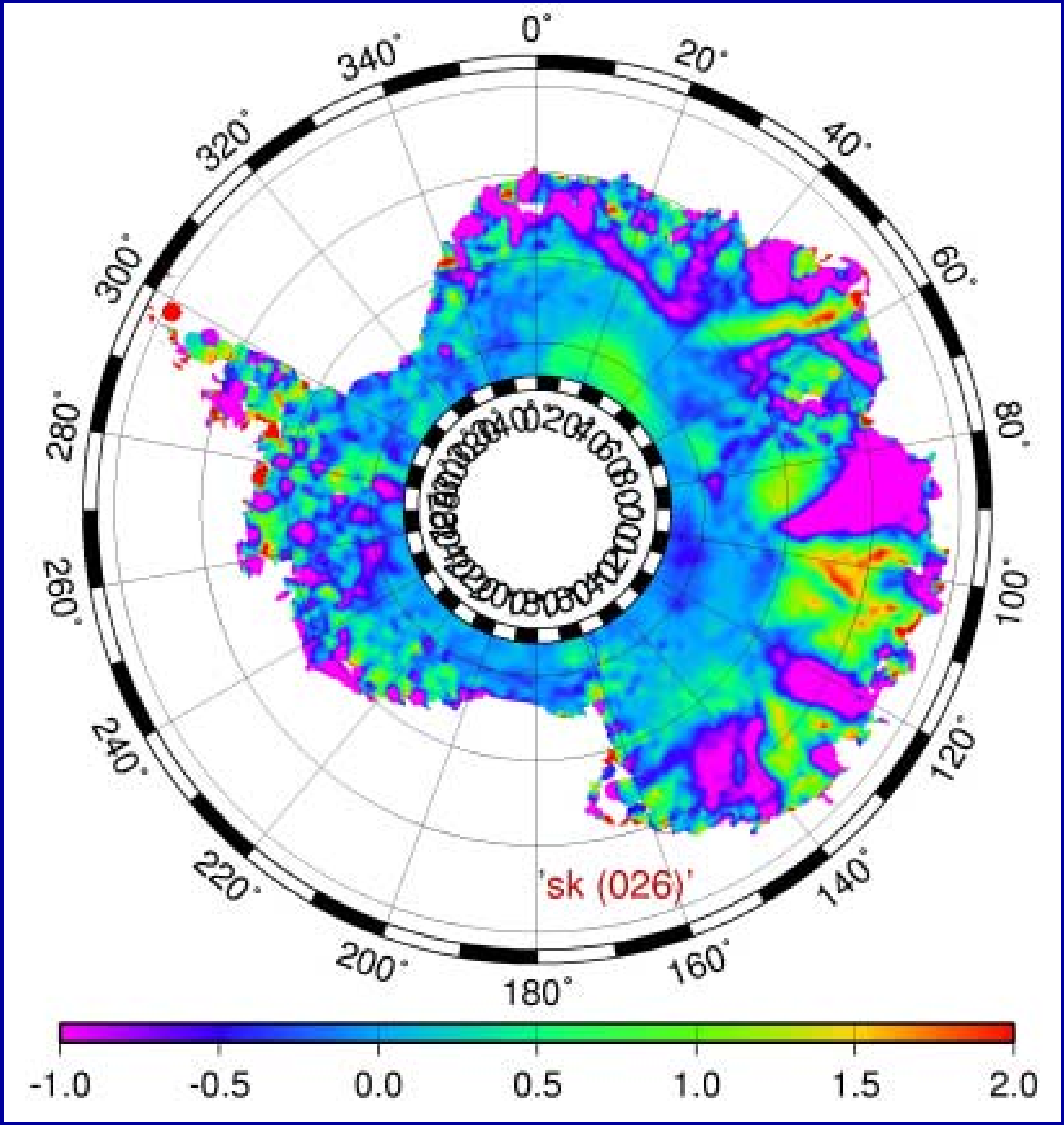
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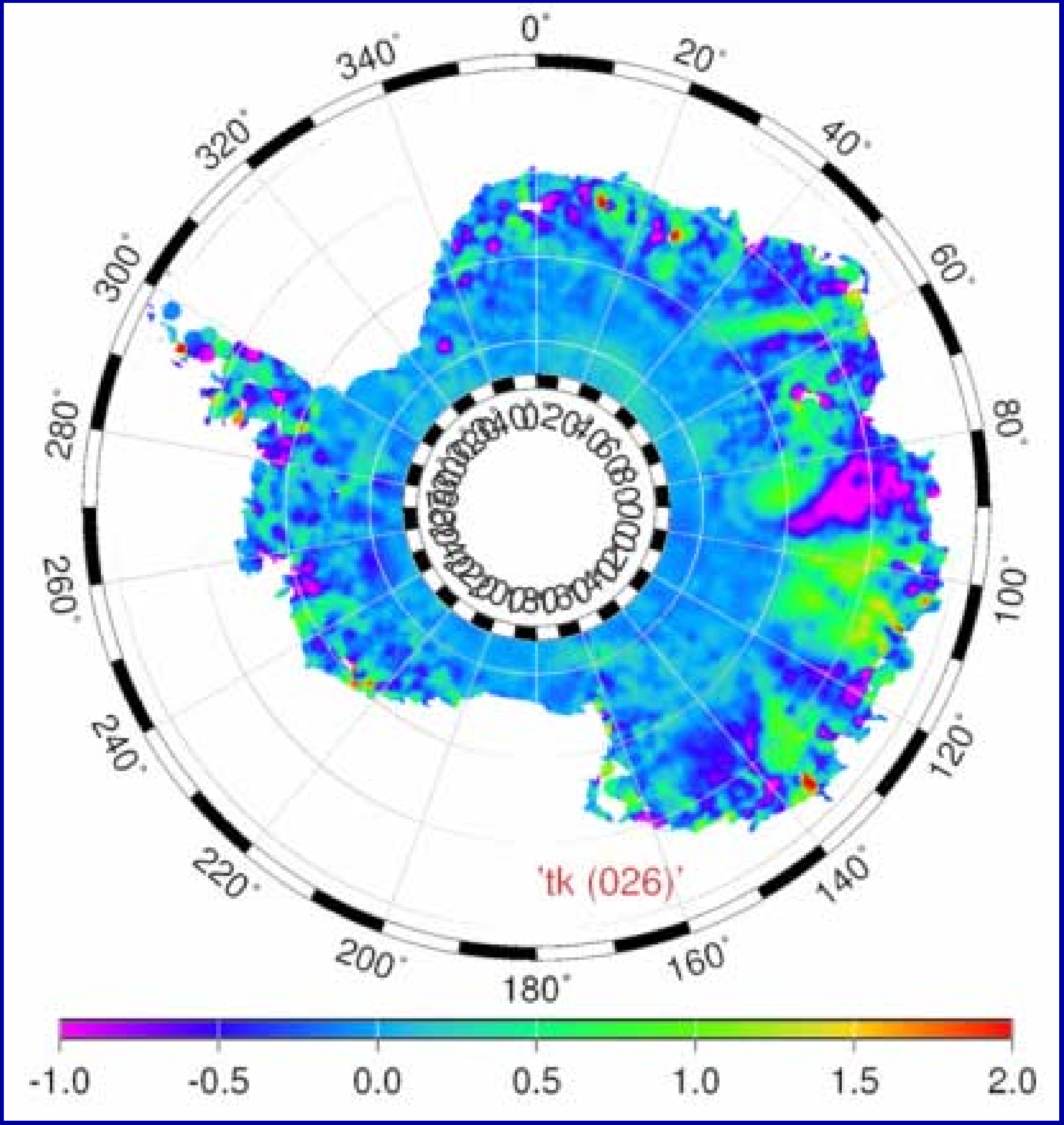
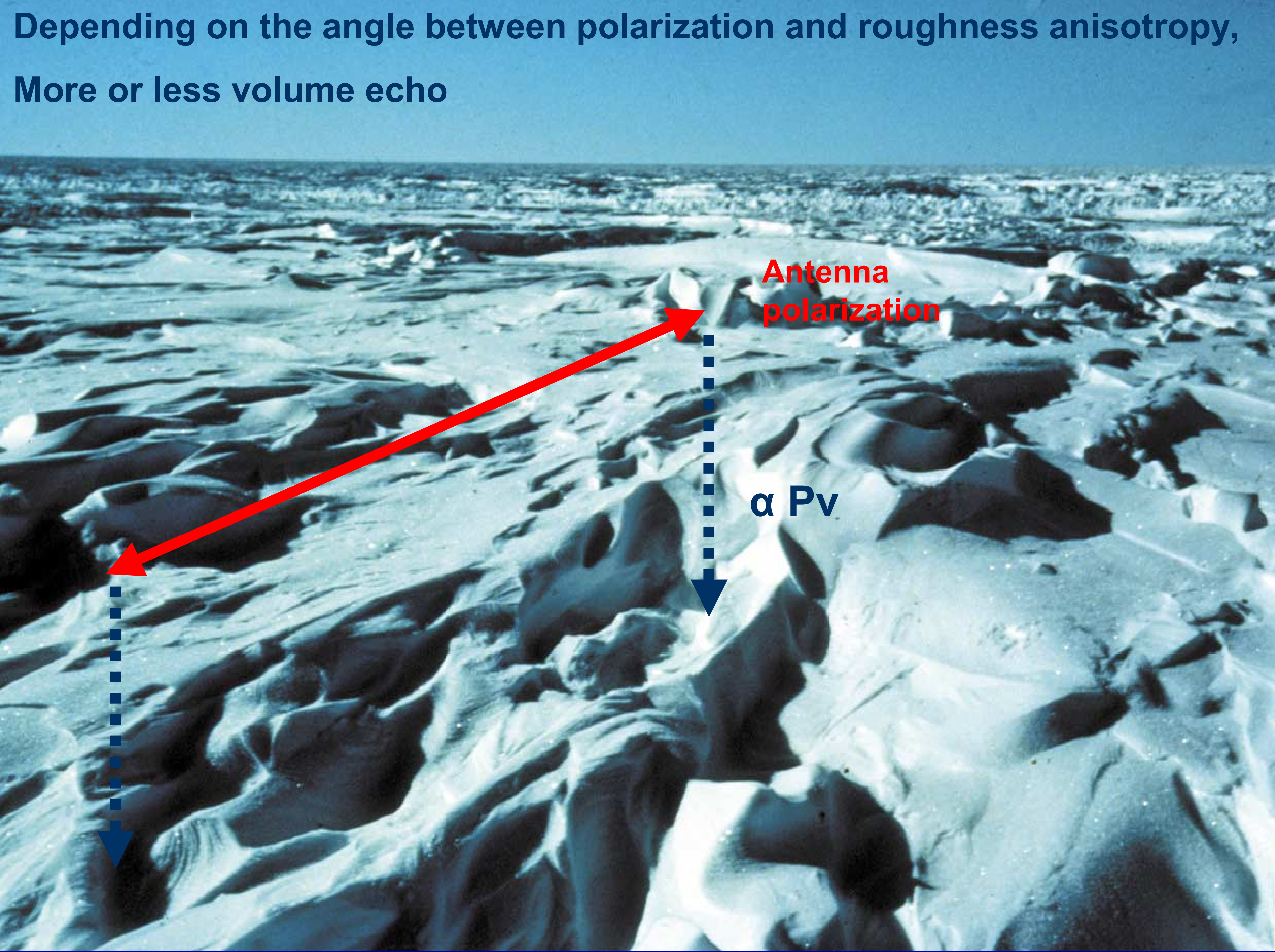
This difference in backscattering directly acts on the waveform shape and on the height retrieval  [-1 m; 1 m] . Dominant source of error in term of elevation
 (no cross-over analysis, pb with long term trend, complicate the comparison between different altmeters).

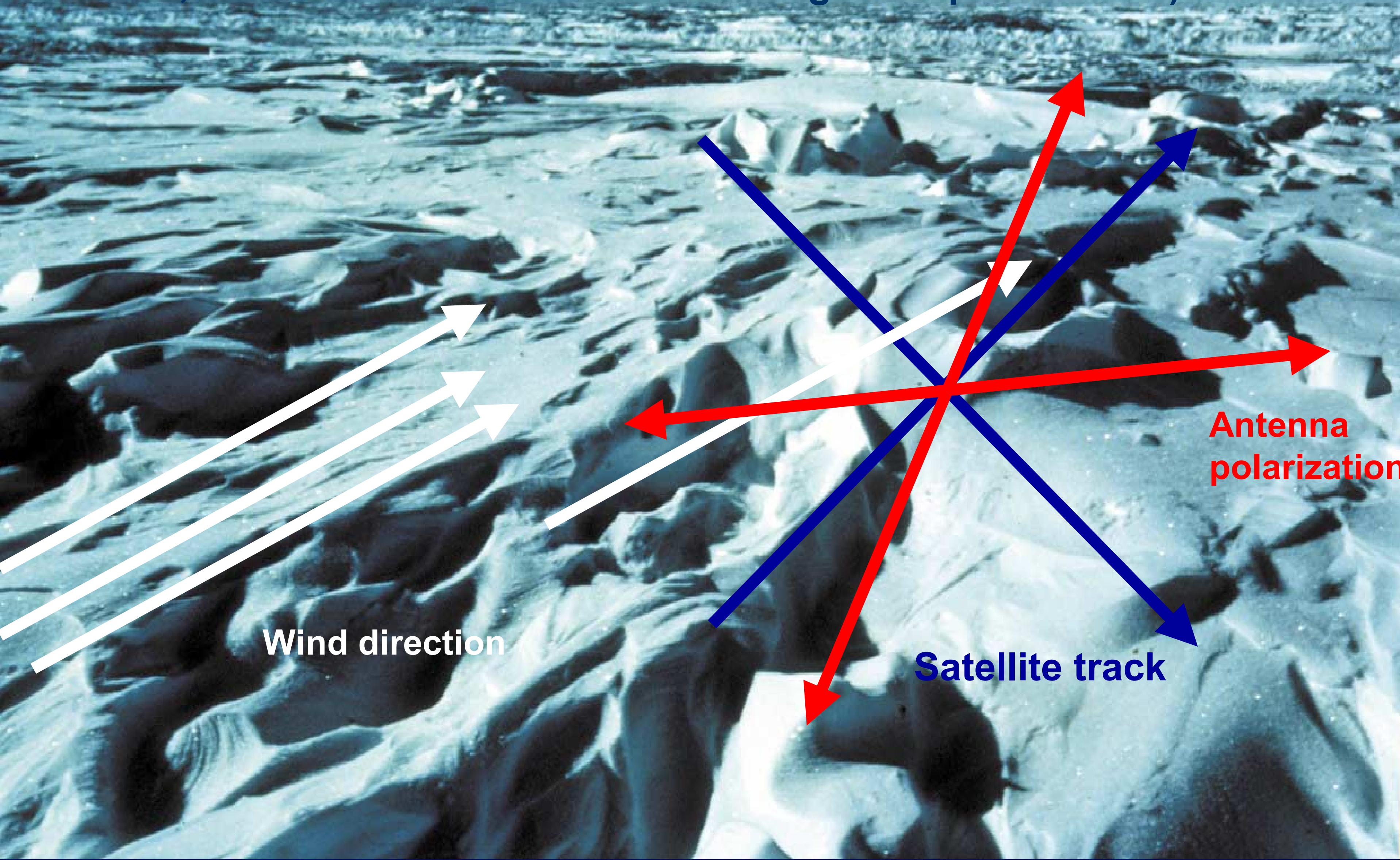


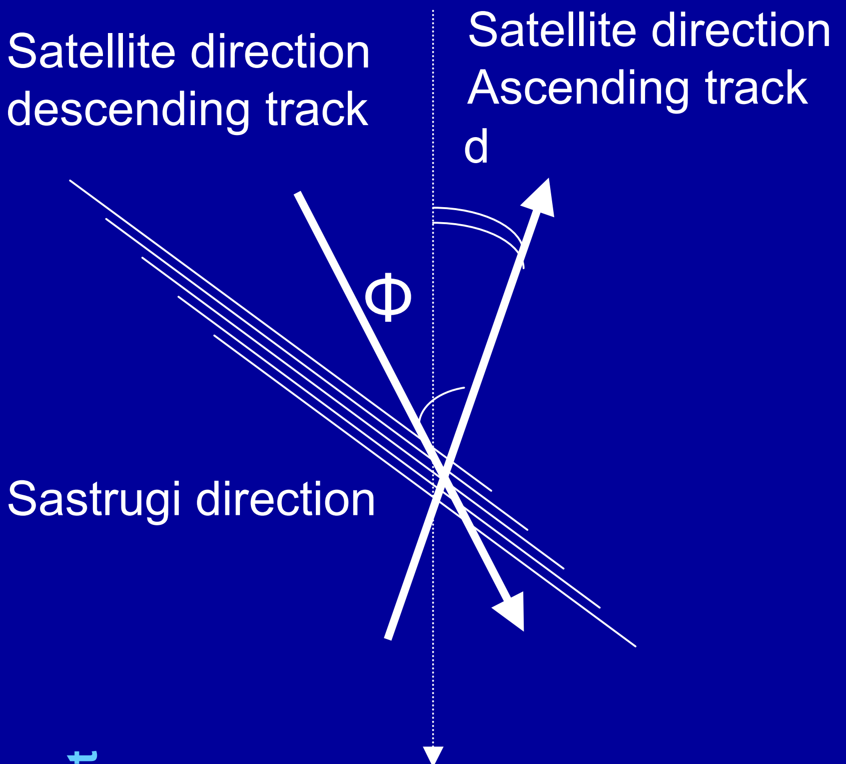
Depending on the angle between polarization and roughness anisotropy,

More or less volume echo



**Depending on the angle between polarization and roughness anisotropy, there is more or less volume scattering (Legresy et rémy, 1999)➔ Difficulty of estimate and correct for this error (need of the wind direction, of the volume echo and of the degree of polarisation)**






$$P_t = (1-\alpha)\,(P_s+P_v) + \alpha \cos \Phi \, P_v$$

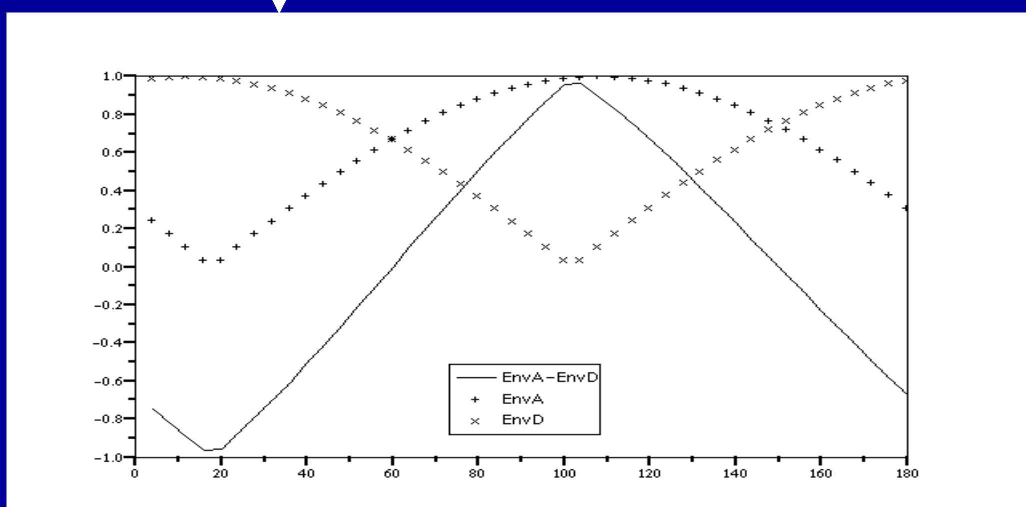
(Legrésy and Remy, 1999)
α degree of polarisation between 0-1

Φ = < roughness anisotropy, antenna polarization >

$$P_{ta}-P_{td} = \alpha P_v \,[\cos \Phi_a - \cos \Phi_d]$$

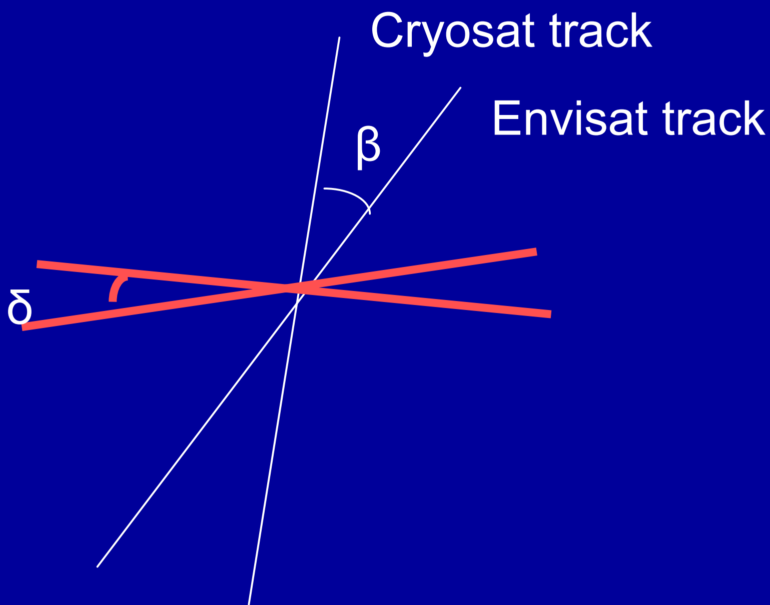
→ effect decreases with latitude

Relative intensity of the effect




Sastrugi field orientation (°)

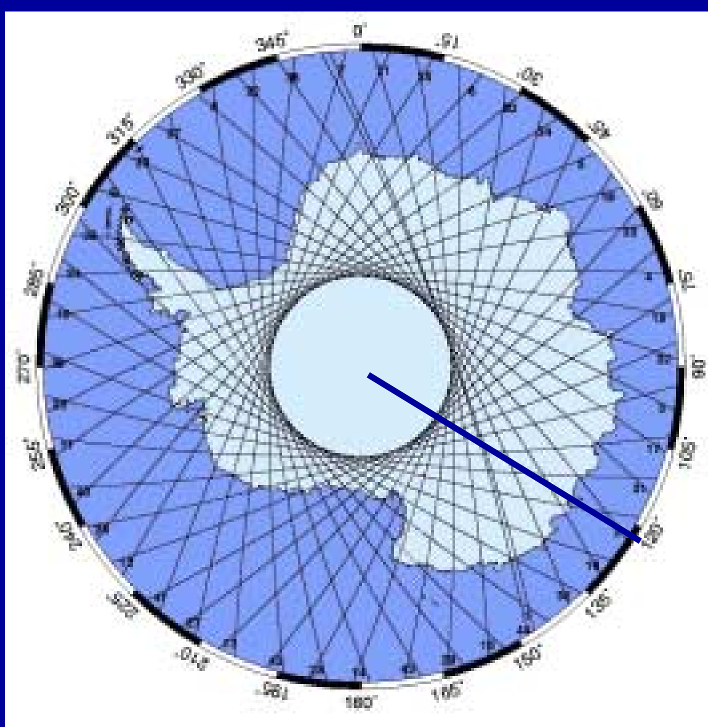
Cos Φa ,cos Φb and
cos Φa -cos Φb
at atitude 70°S for
ERS

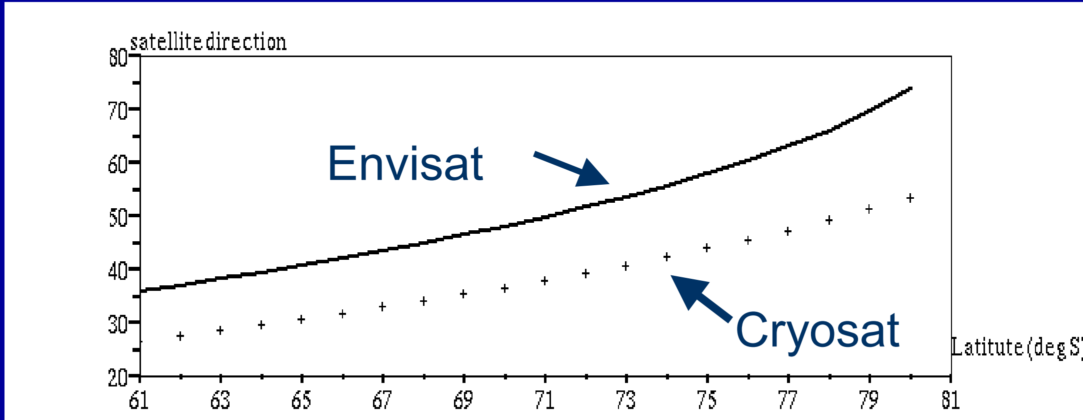


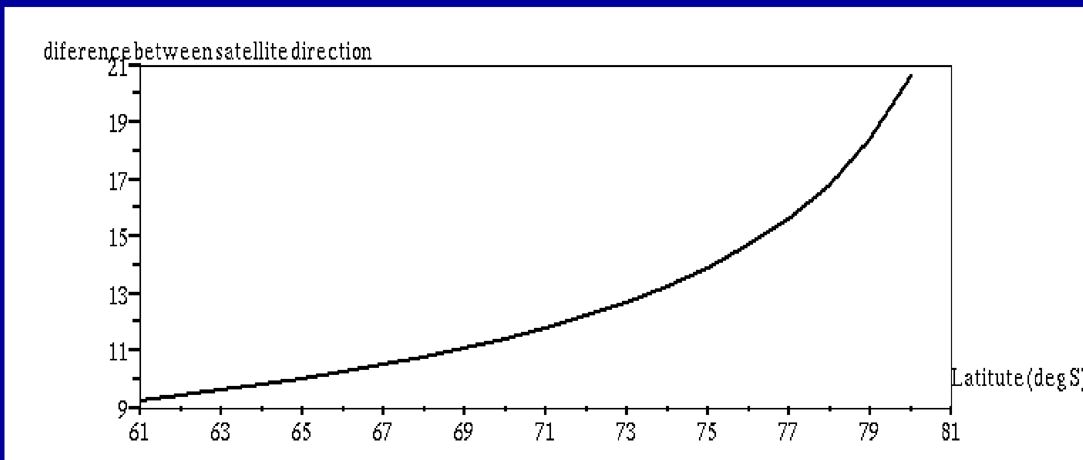

Angle between satellite and meridian

$d = \lambda_s * \cos(\arcsin(\lambda / \lambda_s))$

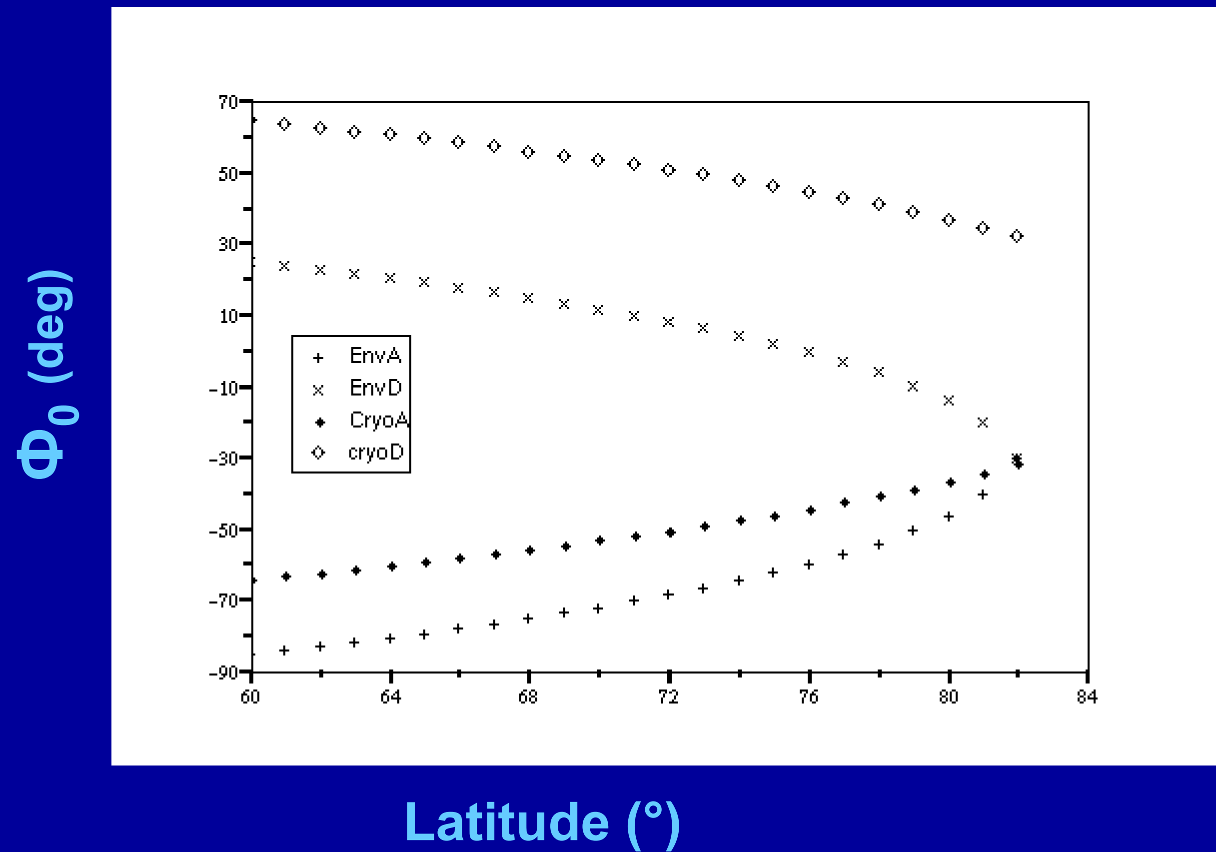
And $\lambda_{cryo} = 88°$, $\lambda_{env} = 81.6°$

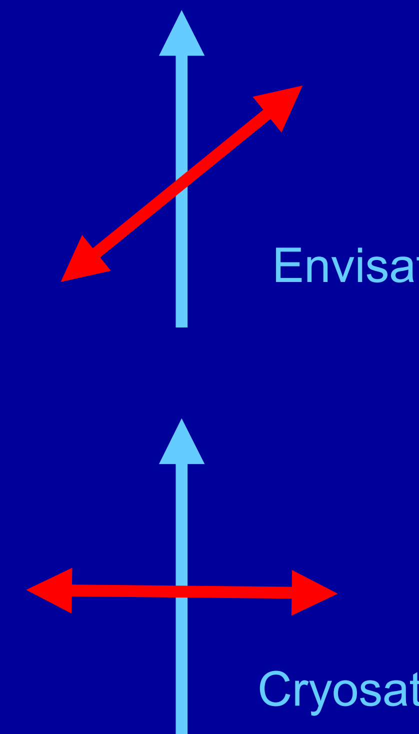




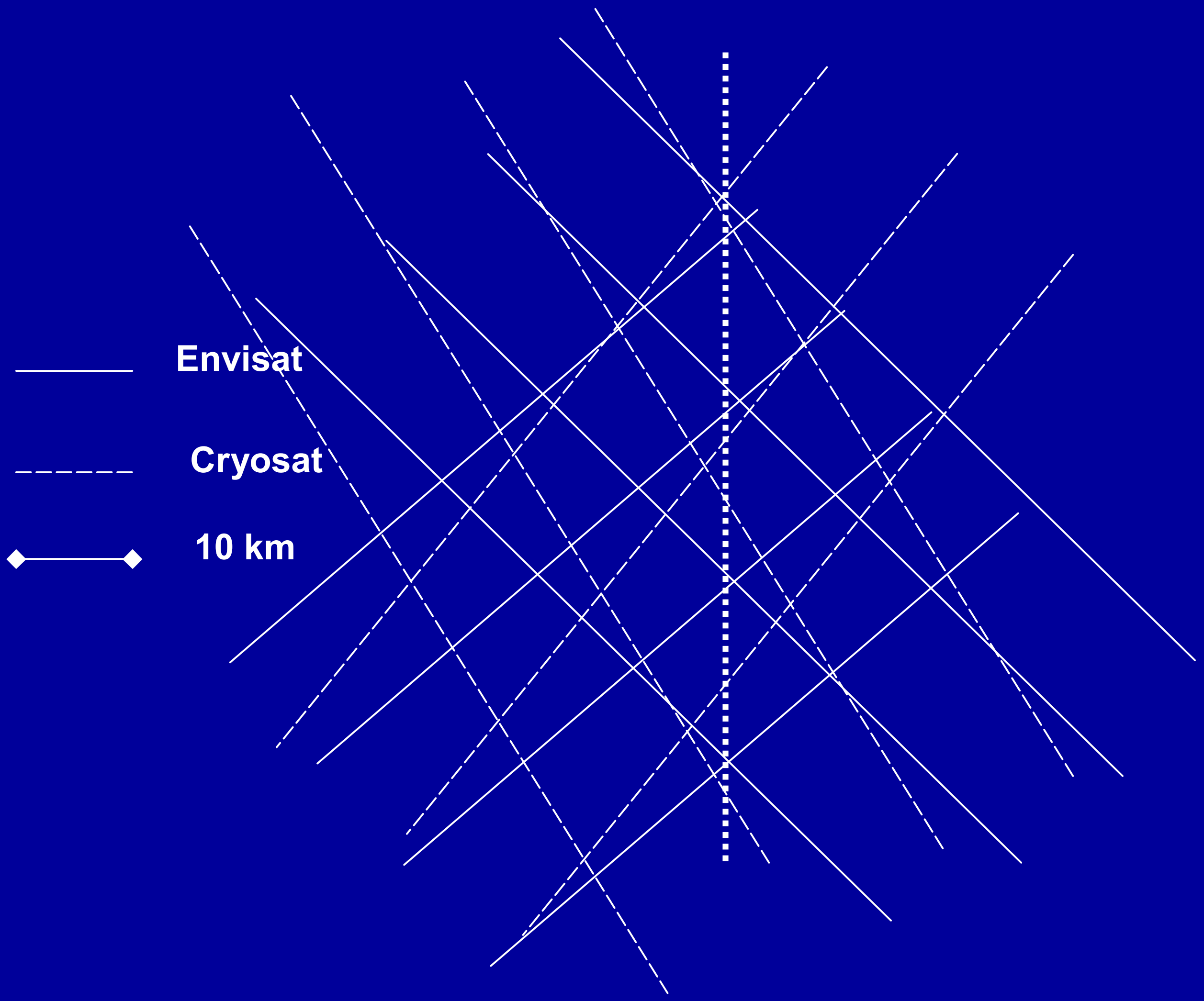



Direction of polarisation for cryosat 90° and 120° for Envisat

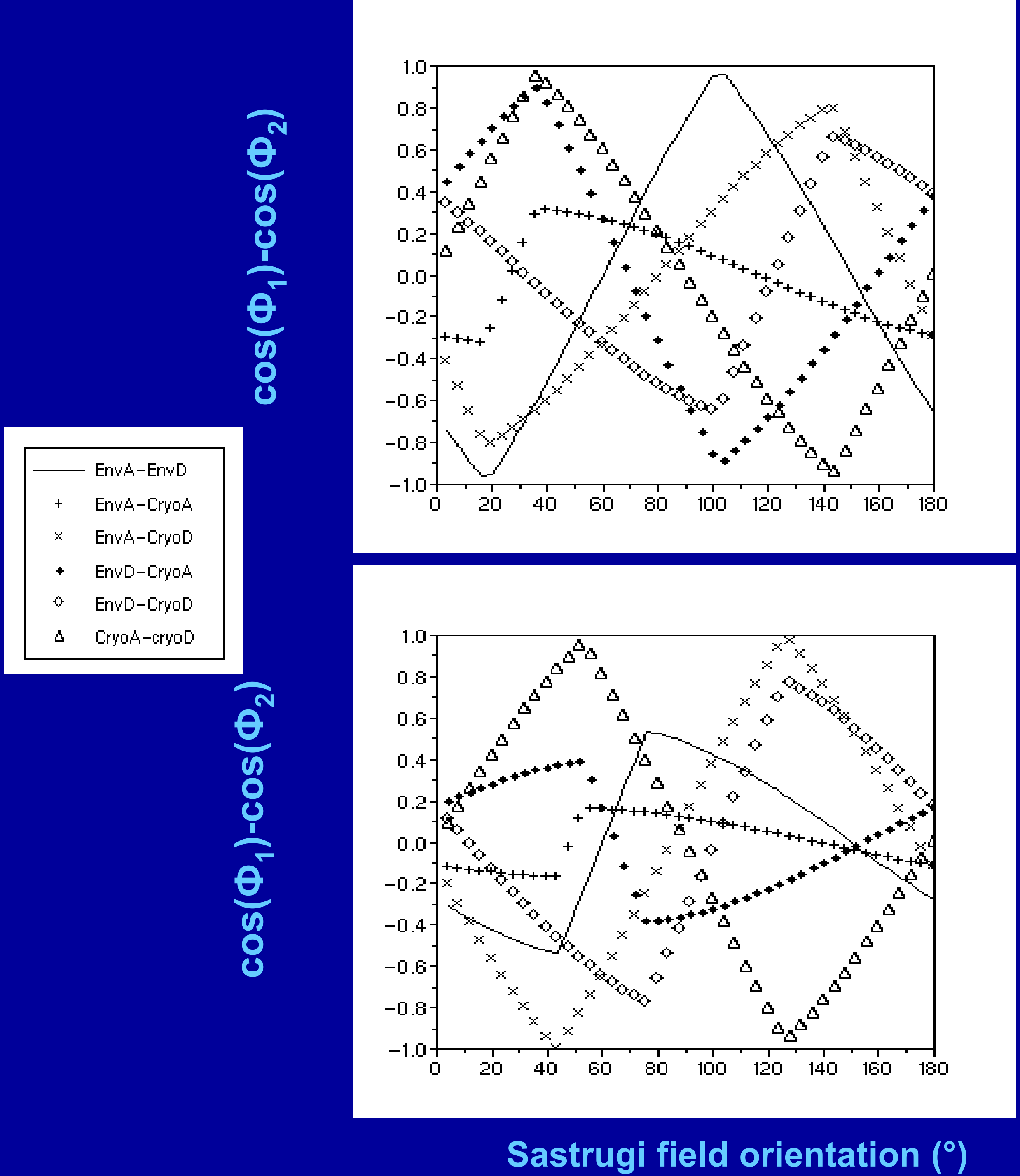



→ Evolution of the angle between the antenna polarization and the meridian with respect to latitude




one 35 d cycle of Envisat + one 30 d sub-cycle of Cryosat
→ 6 combinaisons of cross-over



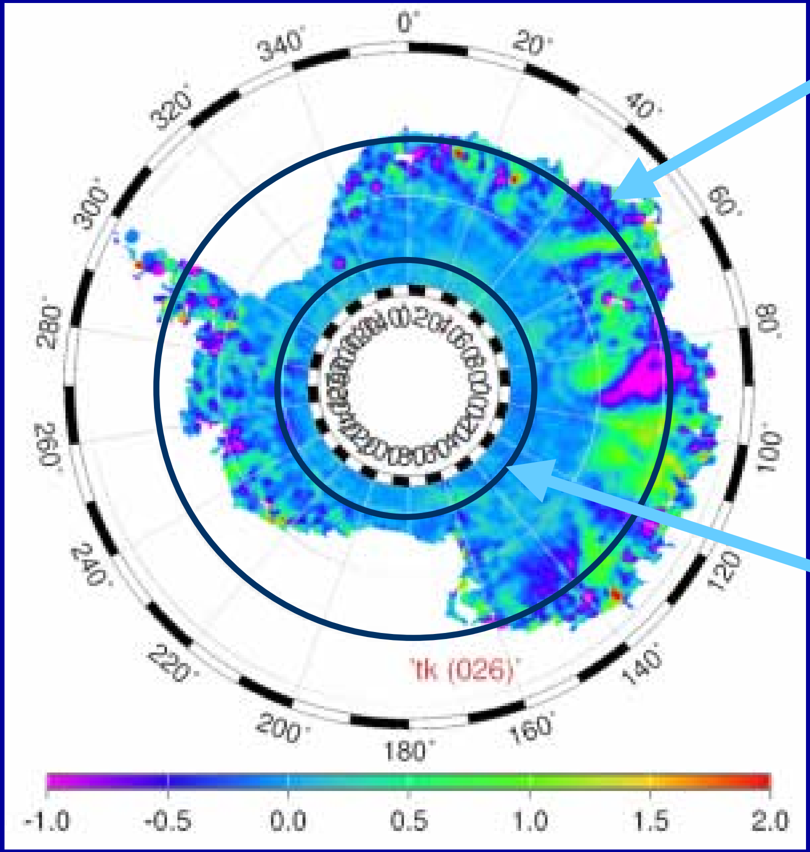

***a) latitude = 70° S***

Only effect with EnvA-CryoA is 40% the nominal effect at 70°S

***b) latitude = 80° S***

Effect with EnvA-EnvD decreases, and cryoA wiht both Env. CryoA-cryoD is still very important

# Summurize of the different effects with respect to latitude and cross-over points



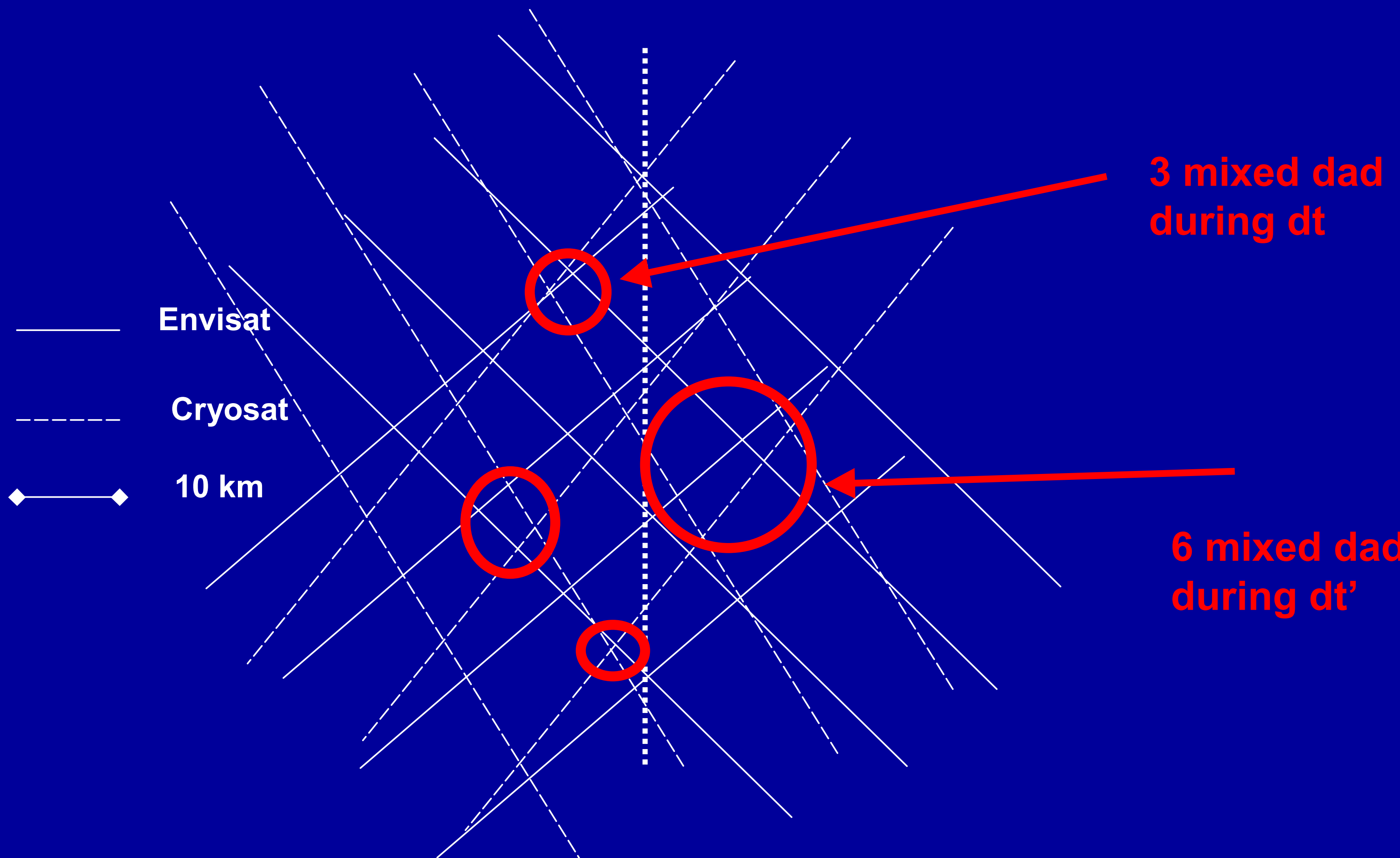

At latitude 70°S same effects for dad Envisat, cryosat , e.g. σ : [-1.5;1.5] ; H : [-1,1] (except envA-cryoA)

At latitude 80°S no effect for dad Envisat, but still very important with cryosat and between Env and cryosat

→ Effect is prohibitive for any comparison between cryosat and envisat over the whole continent and for apply cross-over correction for Cryosat

The modulation of backscattering due to roughness anisotropy is given by α cos Φ Pv

→ 2 unknown, the sastuggi field direction and α Pv




→ Few combinaisons depending on the choosen space and time resolution

→ Toward an inversion of the system

In theory, 2 different cross-over points are enough
In practical, no because of the noise

1) Simulation for sastrugi direction between [0°,180°] and α Pv = 1 (linear) and for different croos-over difference noises

$\Delta$ P t (track 1) = α Pv cos ($\Phi_1$) (1 + Noise)

2) Estimation of the six cross-over points effects

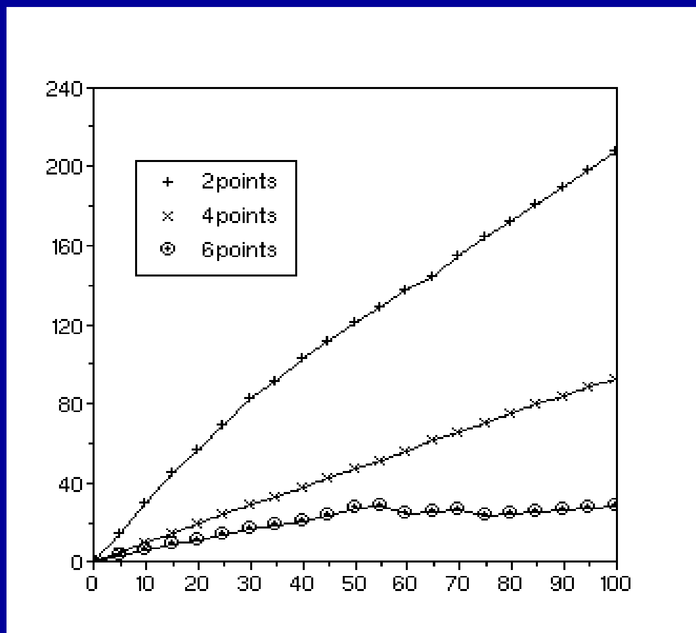
3) Inversion taking into account 2, 4 or 6 cross-over points

4) Results in term of restitution precision with respect to initial noise

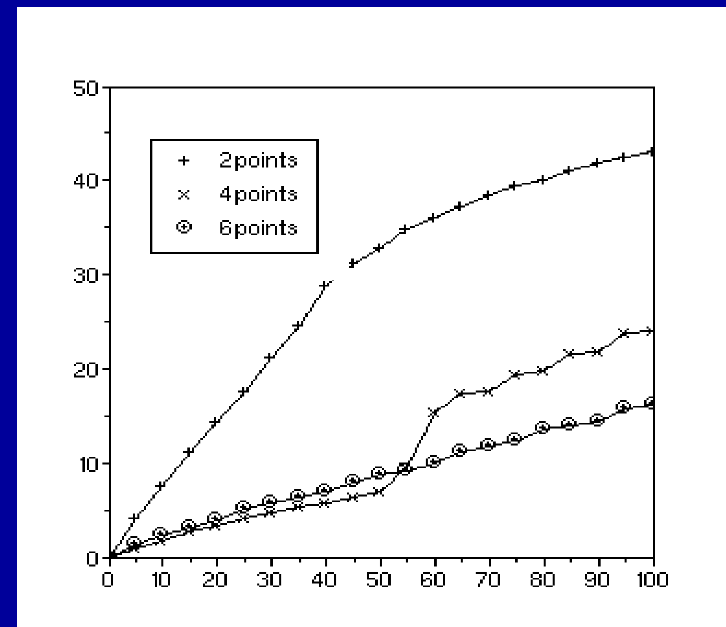
We perform the simulation for the backscattering.

# → Toward an inversion of the system

Error on amplitude (%)




Error on angle (deg)




Error on data (%)

Error on data (%)

→The system could be inverted with a very good precision, then for the first time we can map anisotropy direction and we can apply a correction (knowning the relation between backscattering and elevation modulations)

Interest of a mixed product ERS-Envisat and Cryosat : summarize

**I. Compare the ERS and Cryosat topographies over the central part of the Antarctic.**

<u>3 kinds of errors</u>

-Slope error, can be corrected for but residual errors will be still important
- antenna pattern gain error, depend on the used retracking, can be very important is the retracking are different
- roughness anisotropy, can be corrected for but with a not negligible residual errors

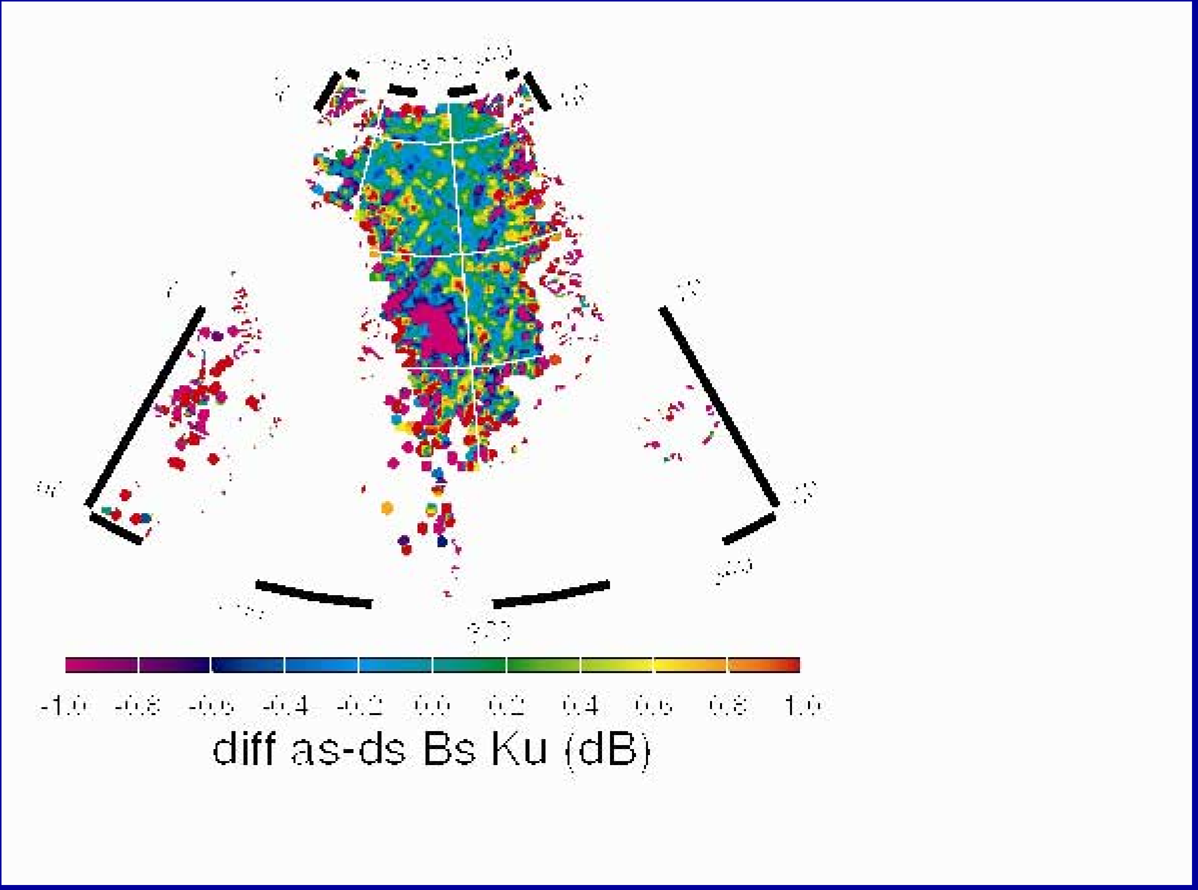
→ could be done but with care

**II. Instantaneous cross-over analysis**

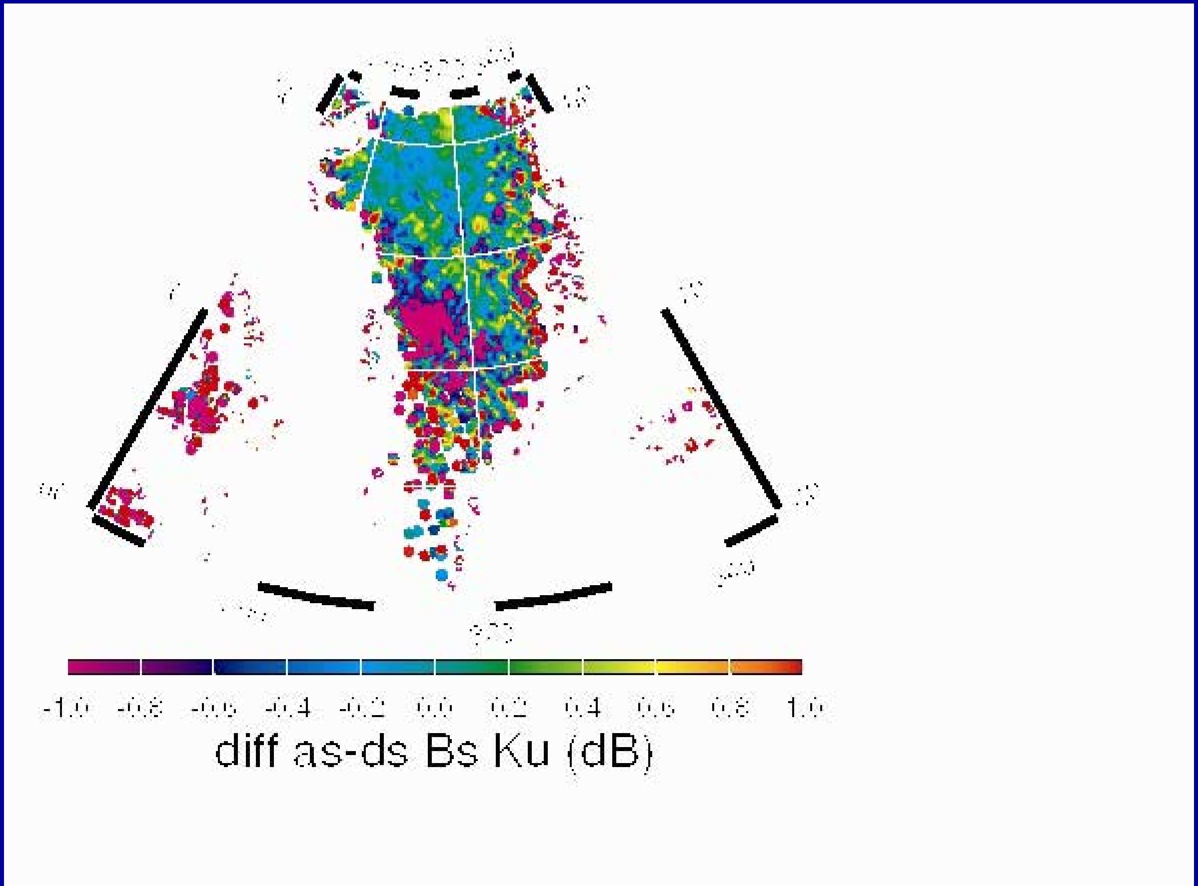
Cryosat, Envisat and mixed cross-over points are strongly affected by roughness anisotropy -> dominant effect + it prevents from using any cross-over analysis
- Opportunity to estimate roughness anisotropy direction at a very good scale
- Opportunity to estimate the induced modulation
- Opportunity to correct for the altimetric data (both ERS, Envisat and cryosat)
- Opportunity to very carefully map the central part of the Antarctica with Cryosat

→ This methodology can be applied everywhere anisotropy and volume exist

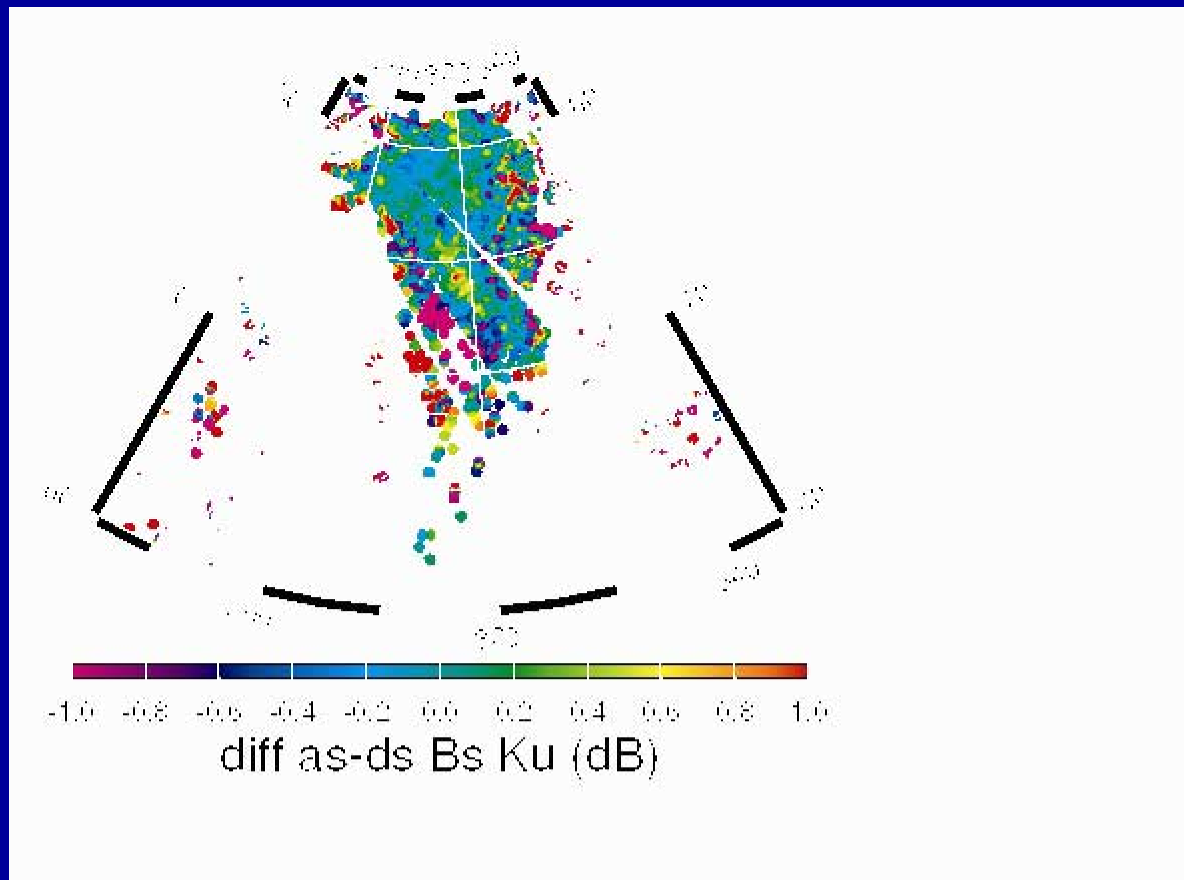
# Cycle 20



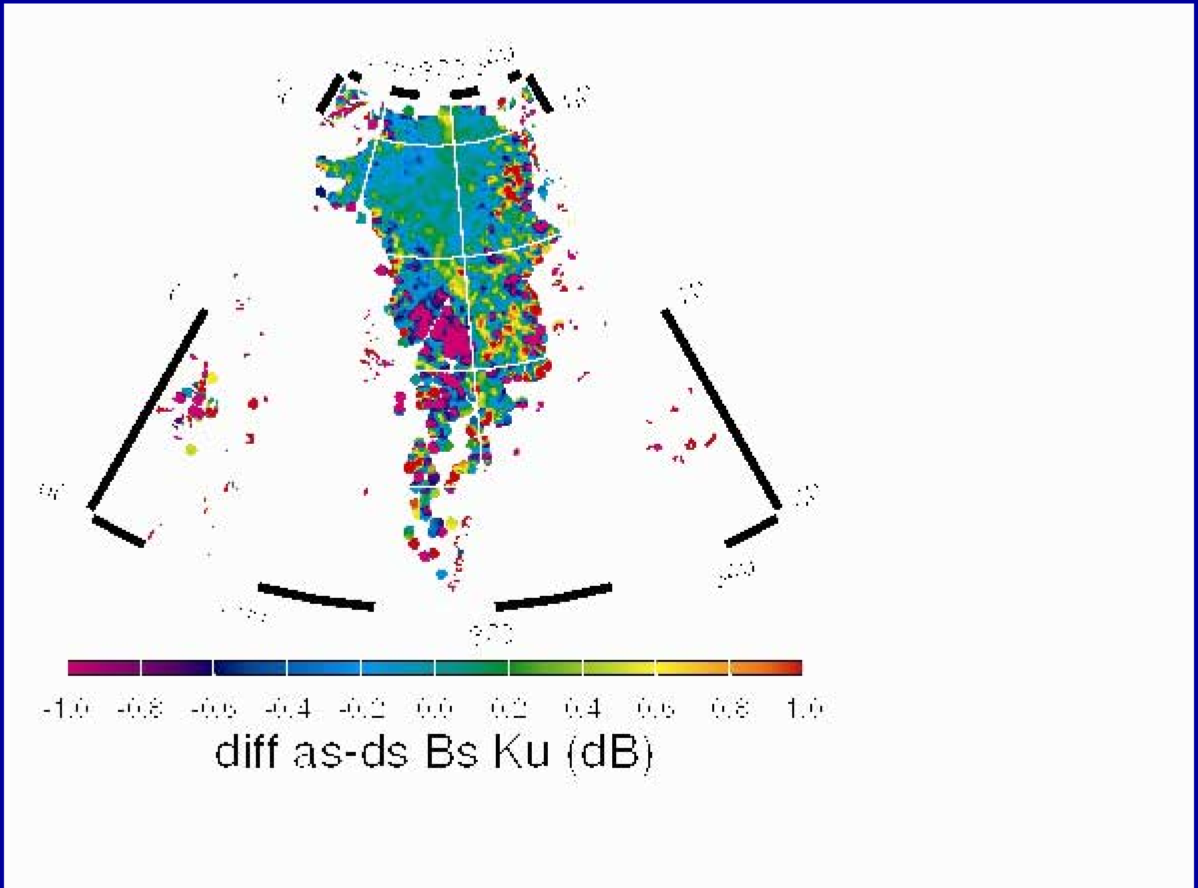
Cycle 21



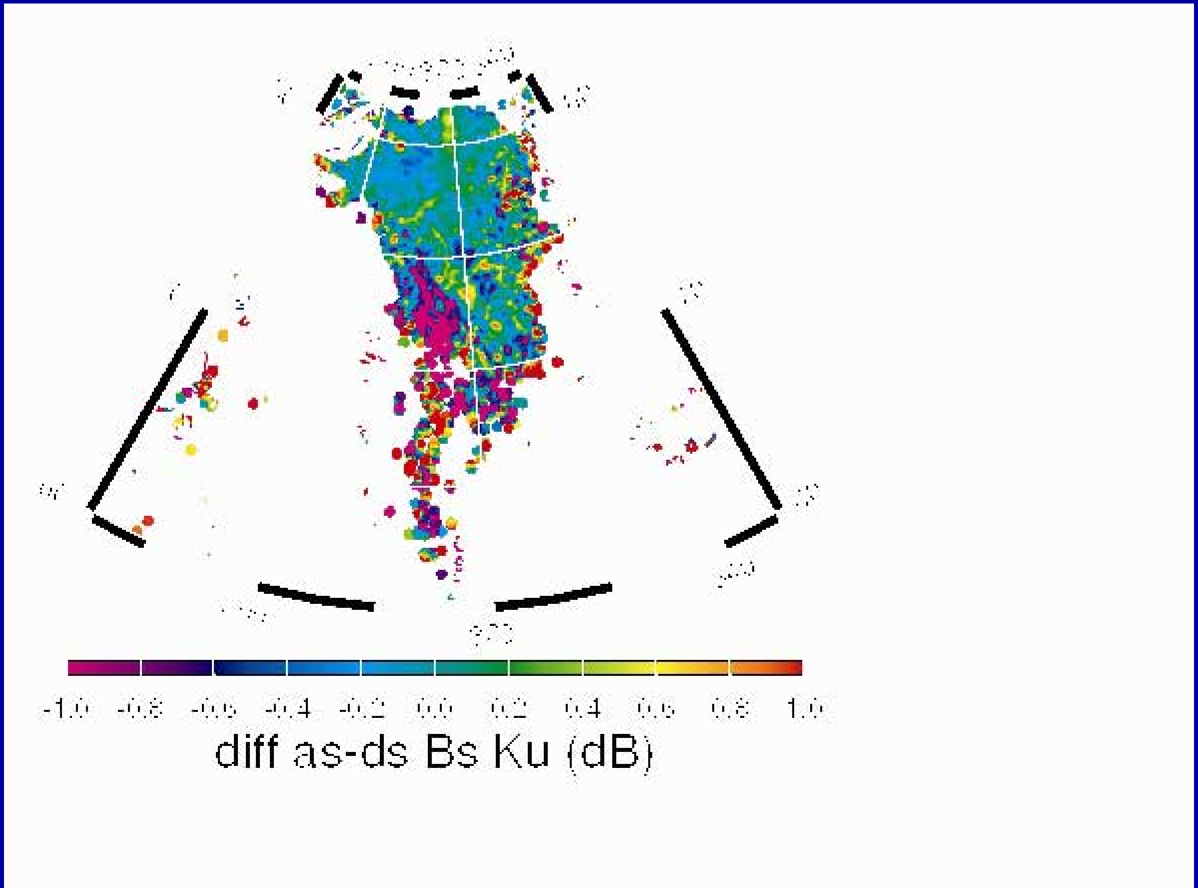
# Cycle 22



Cycle 23



Cycle 24



Cycle 25