An Overview of Glaciers and Icesheets Mapping Orbiter (GISMO)

Ohio State University
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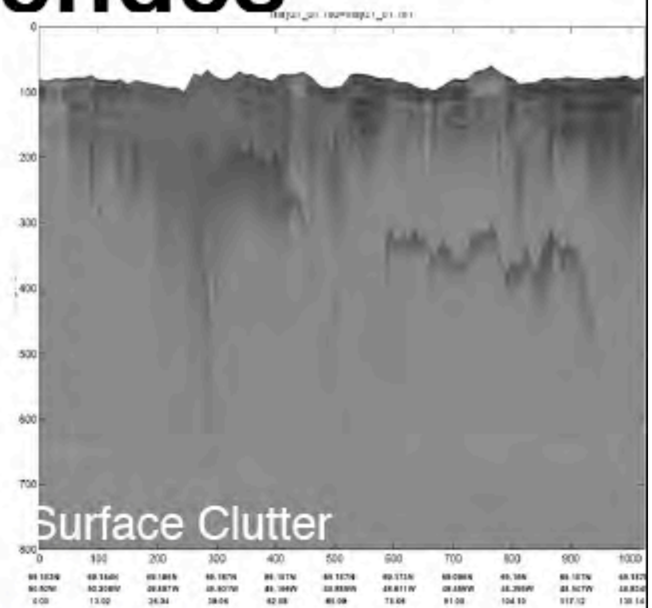
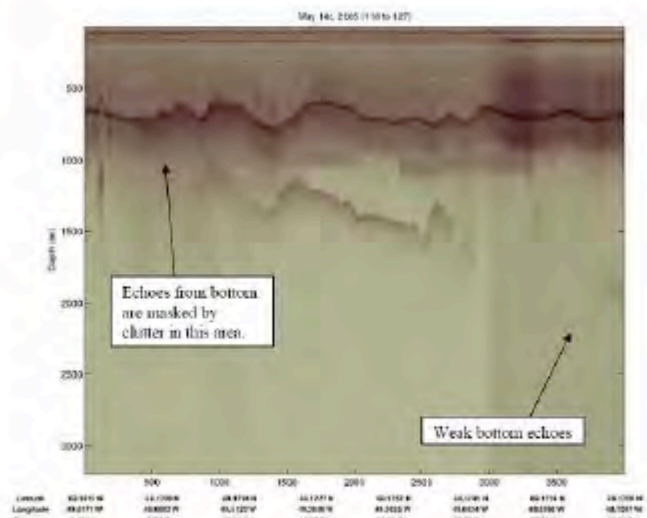
University of Utah
University of New Hampshire

GISMO Technical Challenges

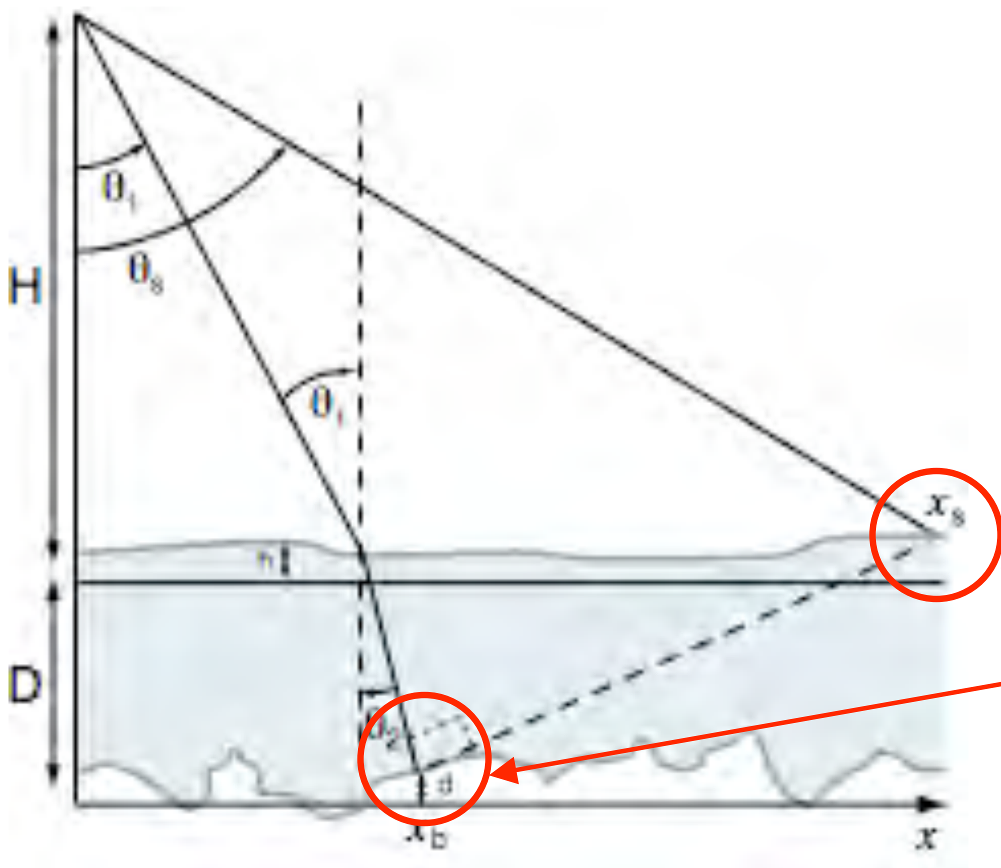
- Obtain Swath Topography and reflectivity data
- Separate basal return from surface clutter





Weak Echoes
Strong Attenuation

Why is Swath Sounding Hard?



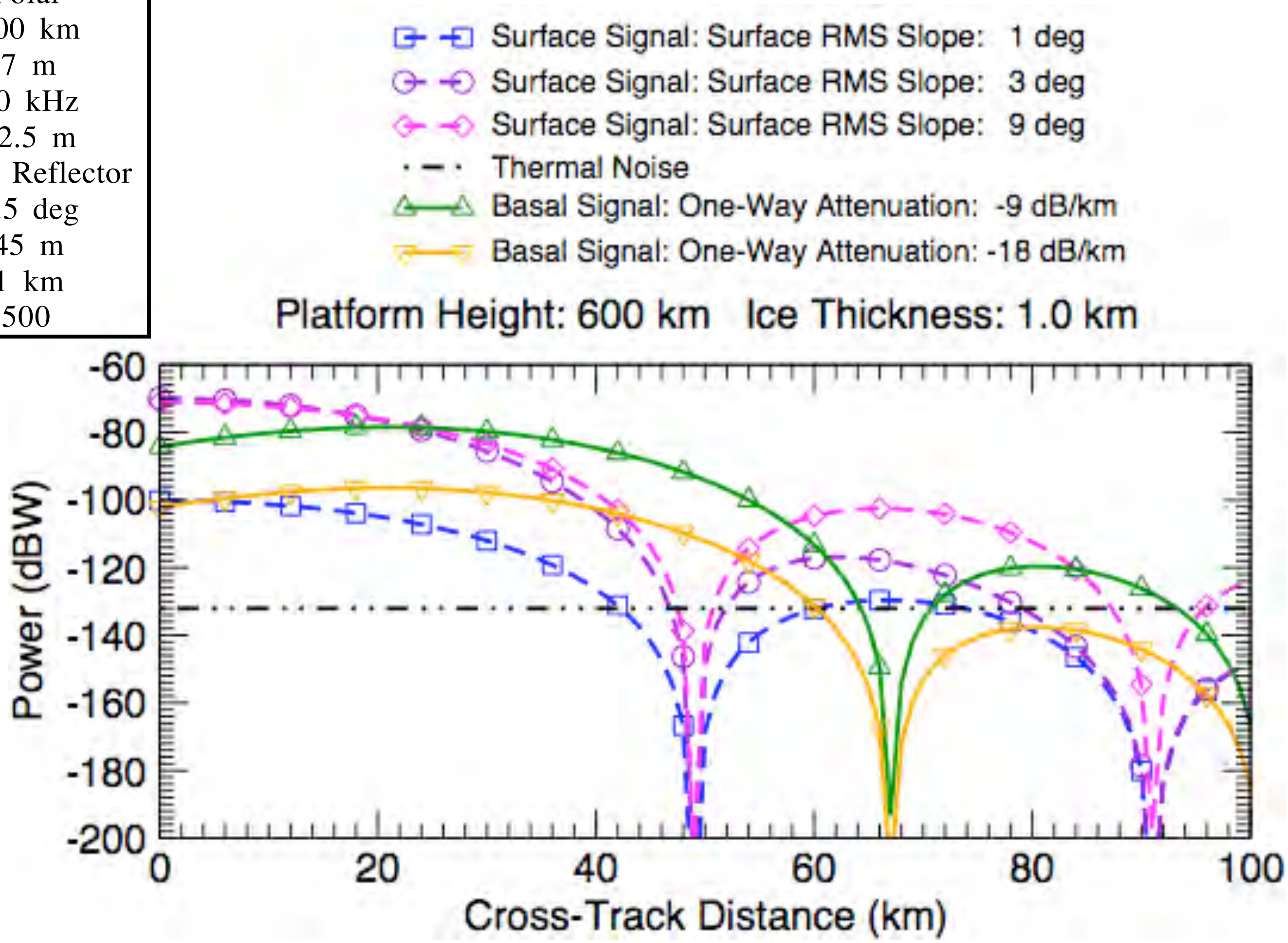
These two returns arrive at the same time and cannot be separated by single antenna timing alone. Need additional information to separate surface and subsurface.

Solution: use interferometry + interferogram filtering

Geometry of the two layer scattering model. H is the spacecraft height above a reference surface; h is the ice surface height above the reference surface; D is the average depth of the basal layer; d is the topographic variations of the basal layer; x_b is the cross-track coordinate of the basal layer point under observation; and, x_s is the cross-track coordinate of the surface point whose two-way travel time is the same as the two-way travel time for x_b.

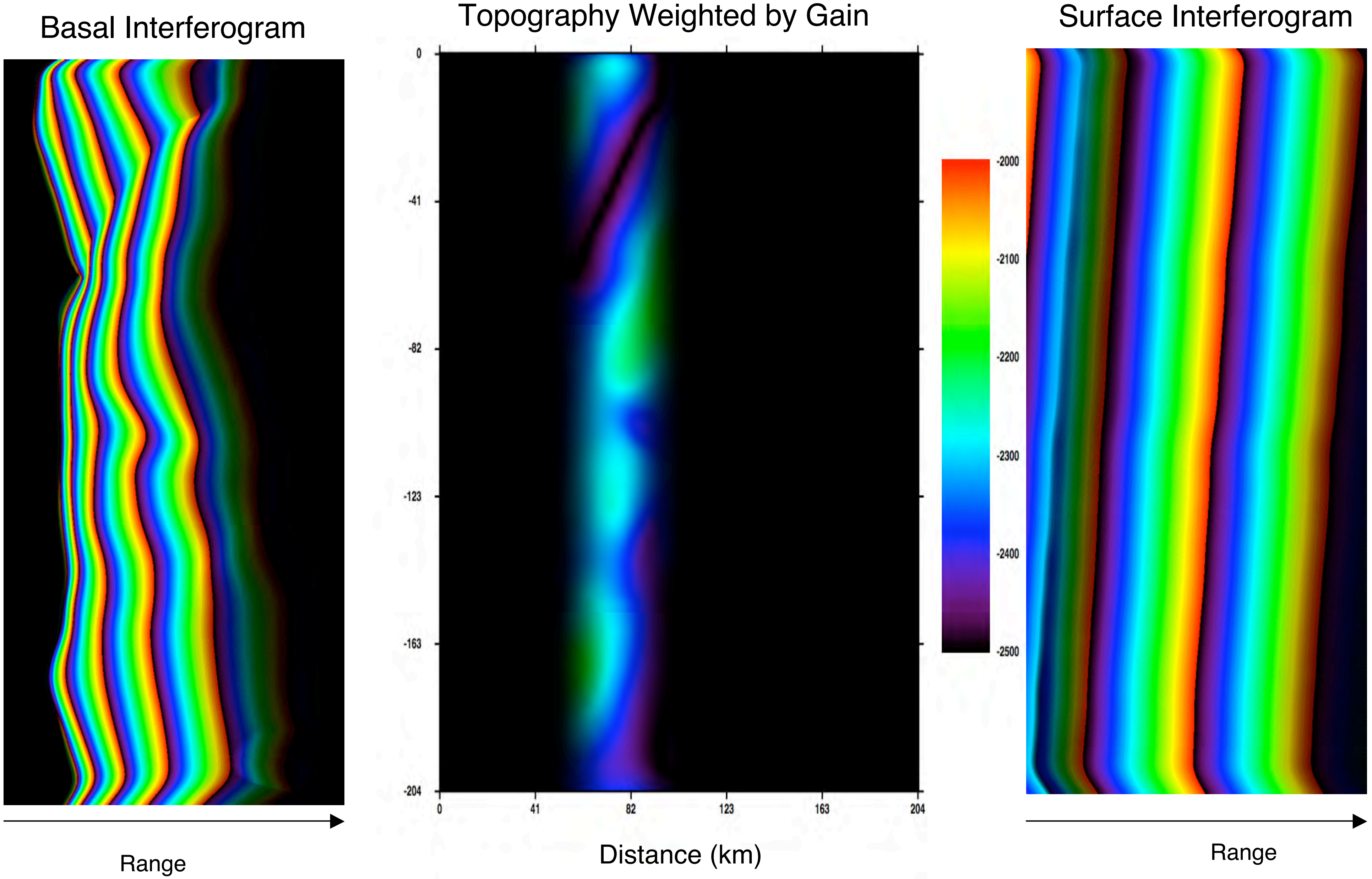
Spaceborne P-band Sounder
1 km Ice clutter

Table 1: Spaceborne System Parameters	Value
Number of channels	4 (polarimetric)
Center frequency	430 MHz
Bandwidth	6 MHz
Pulse Length	20 μsec
Peak Transmit Power	5 kW
Orbit Repeat	2 weeks
Orbit Type	Polar
Platform height	600 km
1-Look Azimuth Resolution	7 m
Pulse Repetition Frequency	10 kHz
Antenna diameter	12.5 m
Antenna Type	Mesh Reflector
Boresight Angle	1.5 deg
Interferometric Baseline	45 m
Resolution after taking looks	1 km
Minimum number of looks	500

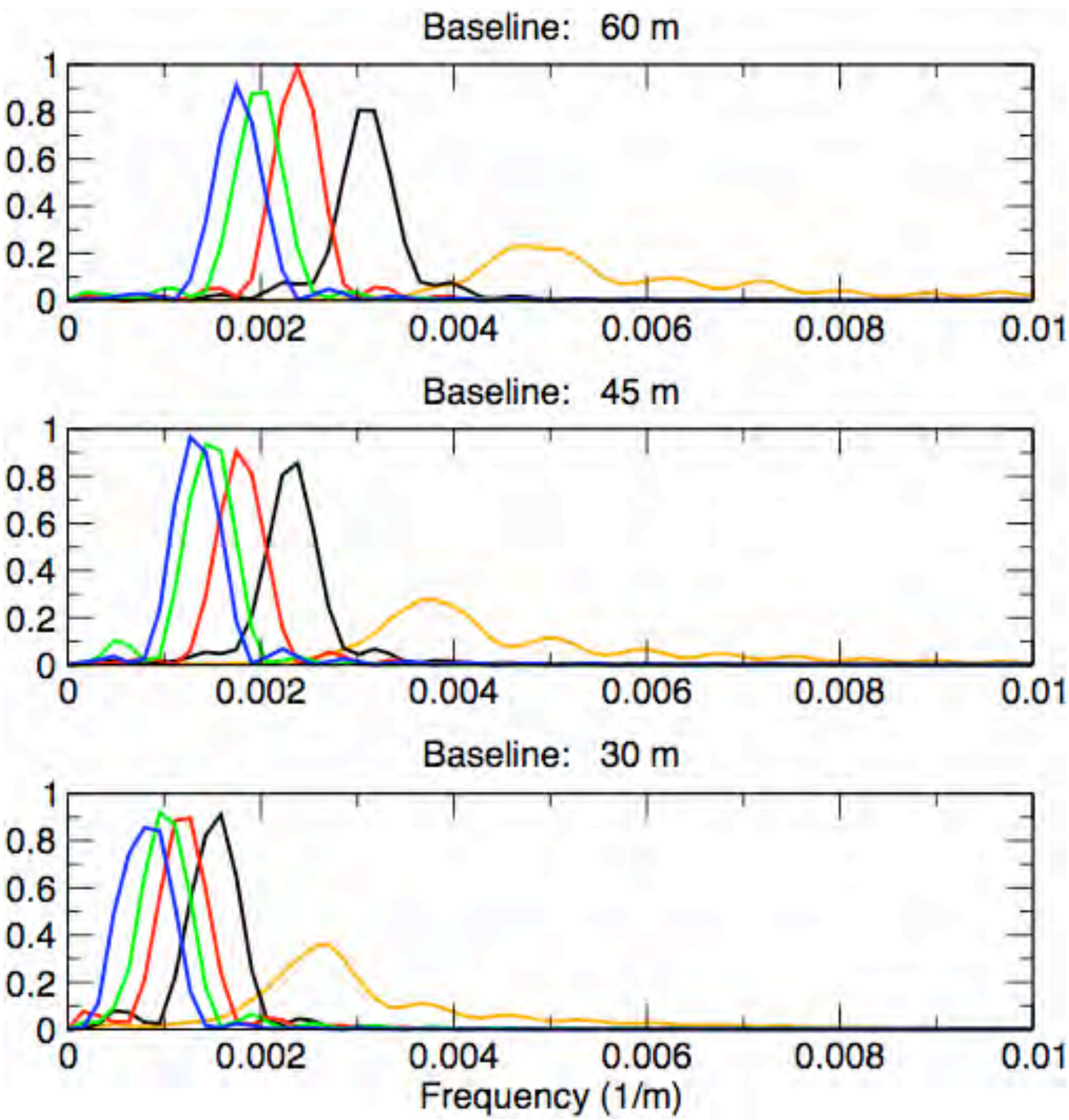


K. Jezek, E. Rodriguez, P. Gogineni, A. Freeman, J. Curlander, X. Wu, J. Paden, and C. Allen. Glaciers and ice sheets mapping orbiter concept. Journal of Geophysical Research, 111(E06S20, doi:10.1029/2005JE002572), 2006.

Interferometric Basal and Surface Signals Have Different Phase Rates

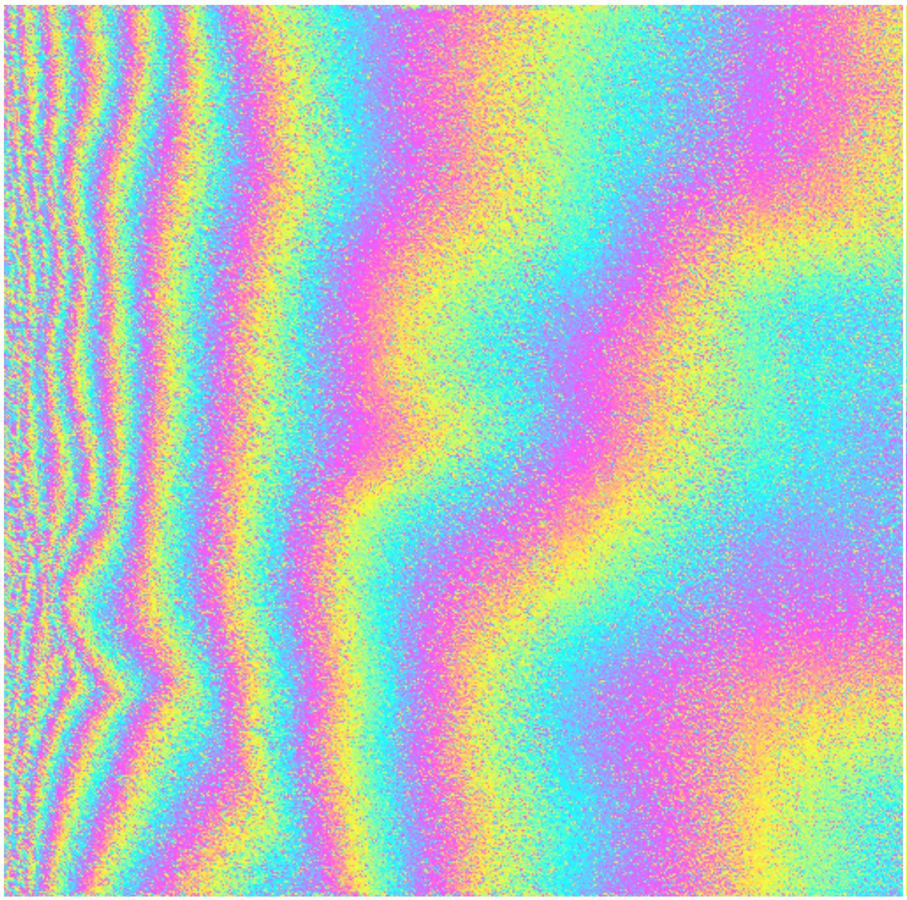


UHF Fringe Spectrum
No Antenna Pattern

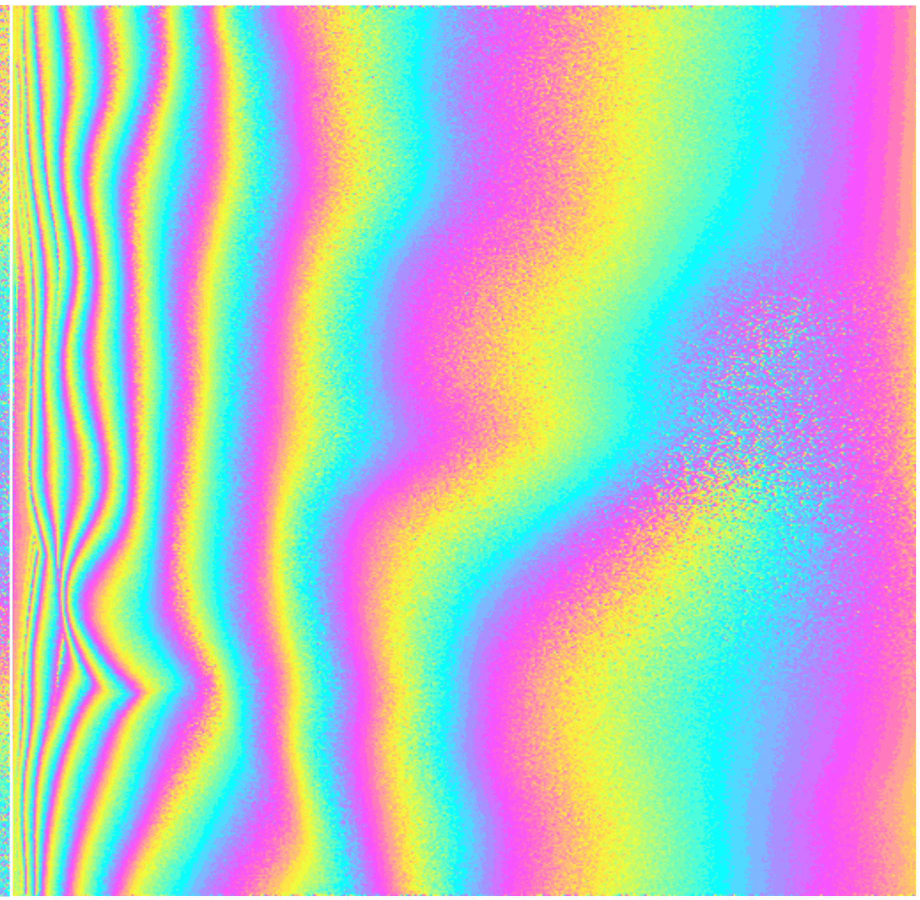


Interferogram spectra for signal to clutter ratio of 1, radar frequency of 430MHz, bandwidth of 6MHz, for the first 50 km of x_b. The basal spectrum is colored orange. The remaining curves show the surface spectra for
D = 1 km (black),
D = 2 km (red),
D = 3 km (green),
D = 4 km (blue). Notice that the basal fringe spectrum depends very weakly on depth

Results of Interferogram Filtering Simulation



True basal interferogram

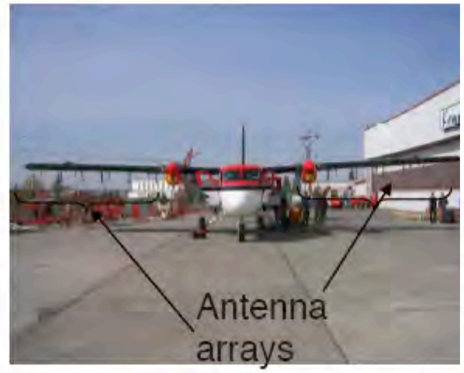


Extracted basal interferogram from band-pass filtering

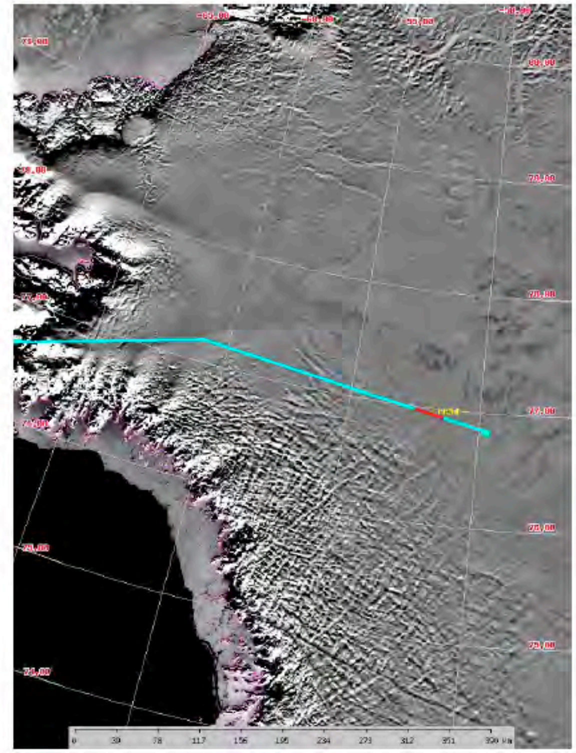
Background

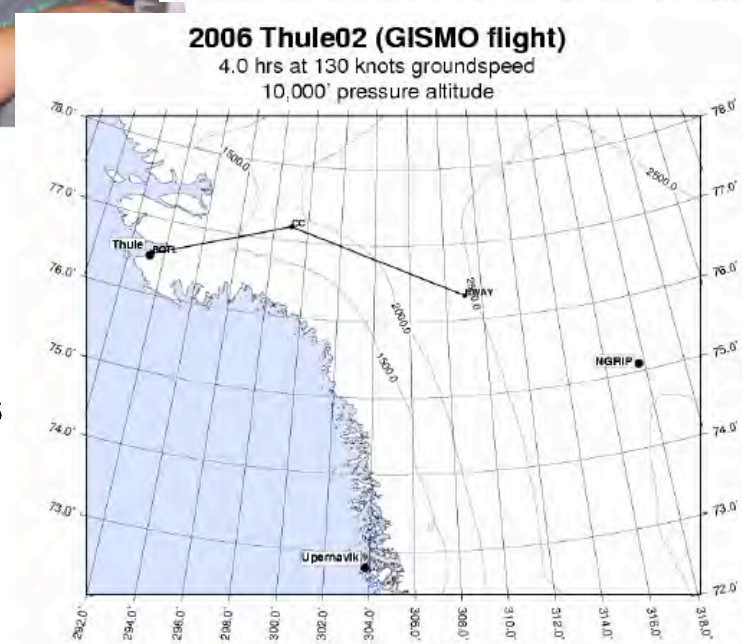
- Radars
  - Installation in Calgary
    - Measure antenna pattern
  - to measure ice thickness, image ice bed and map layers at depth

- Antennas
  - Twin Otter

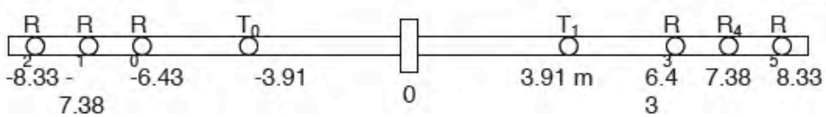


Equipment
rack





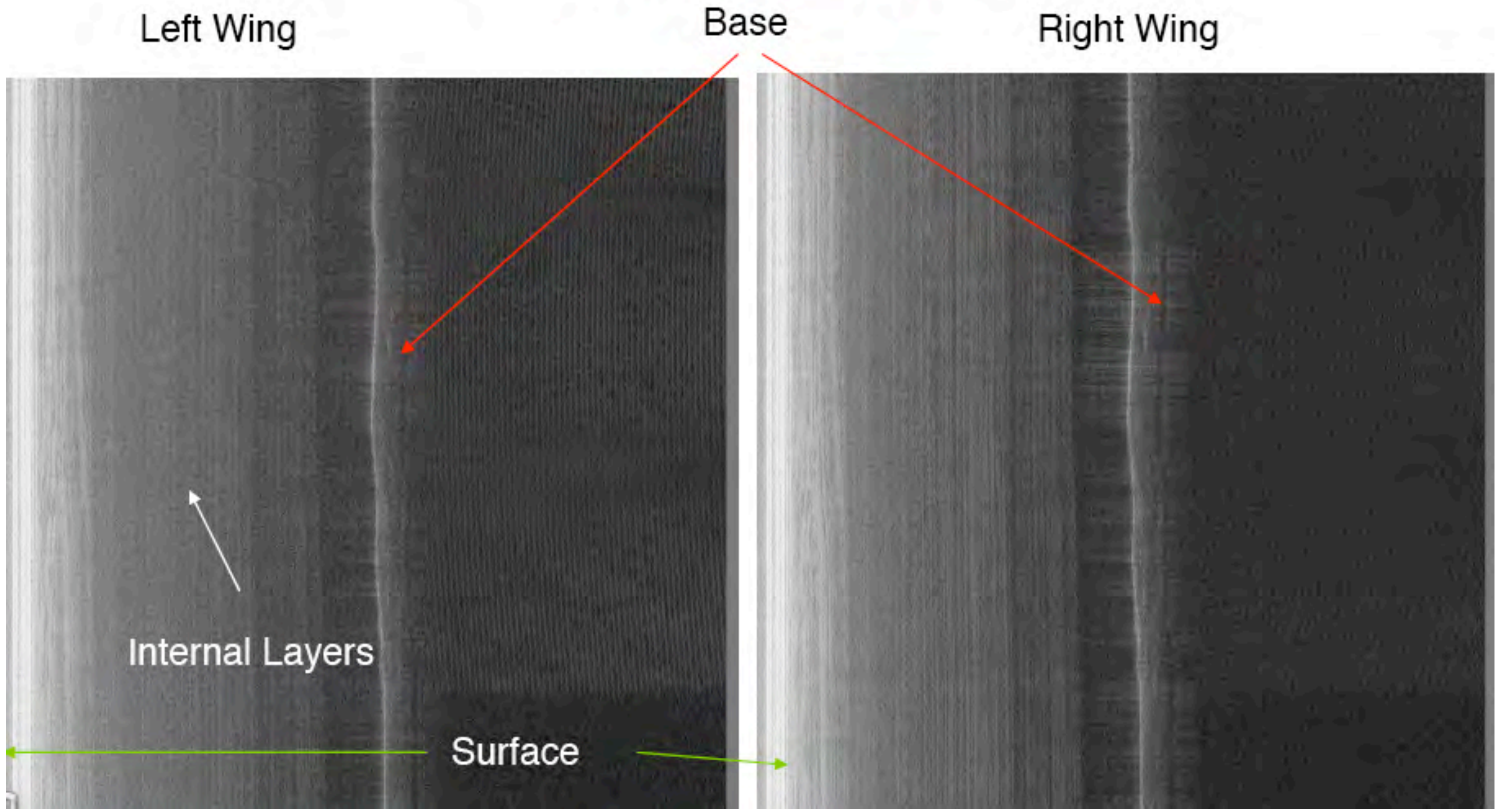
May '06 Flights



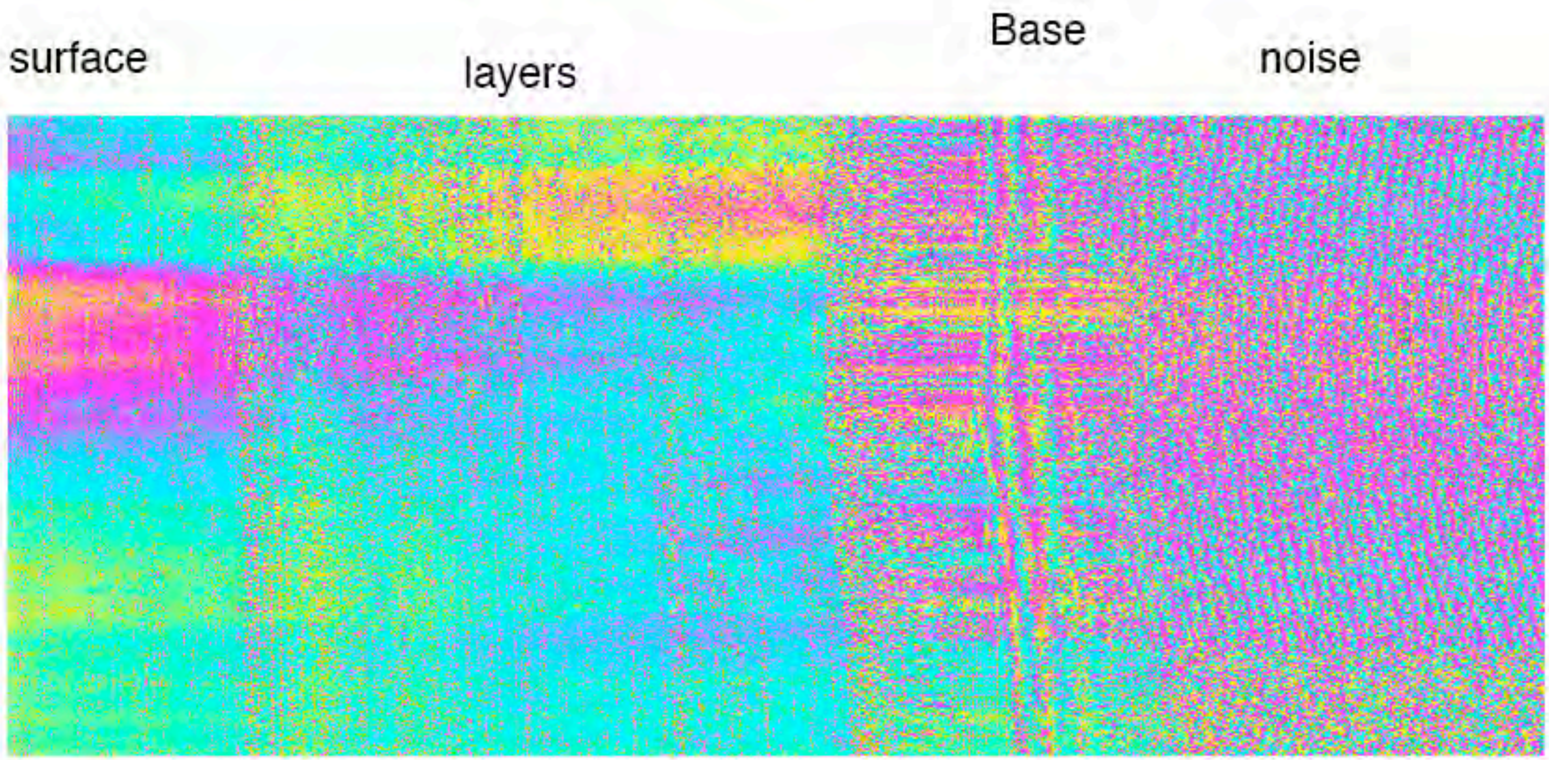
First Airborne SAR Images of the Base of the Greenland Ice Sheet

Range and Azimuth Compressed Slant Range Images (log scale)

5200 m along track



First Airborne SAR Interferogram of the Base of the Ice Sheet



Interferograms from two adjacent channels

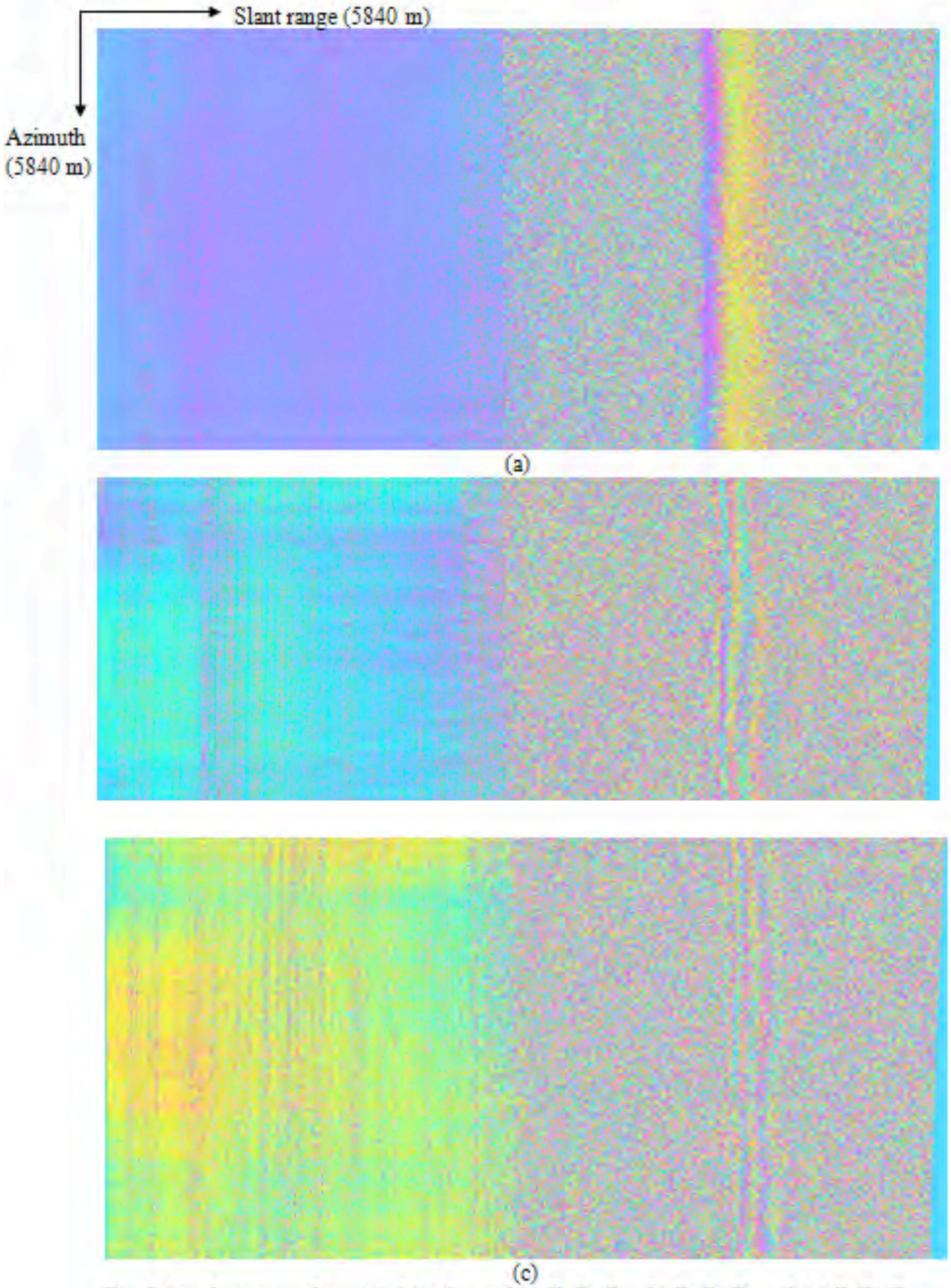
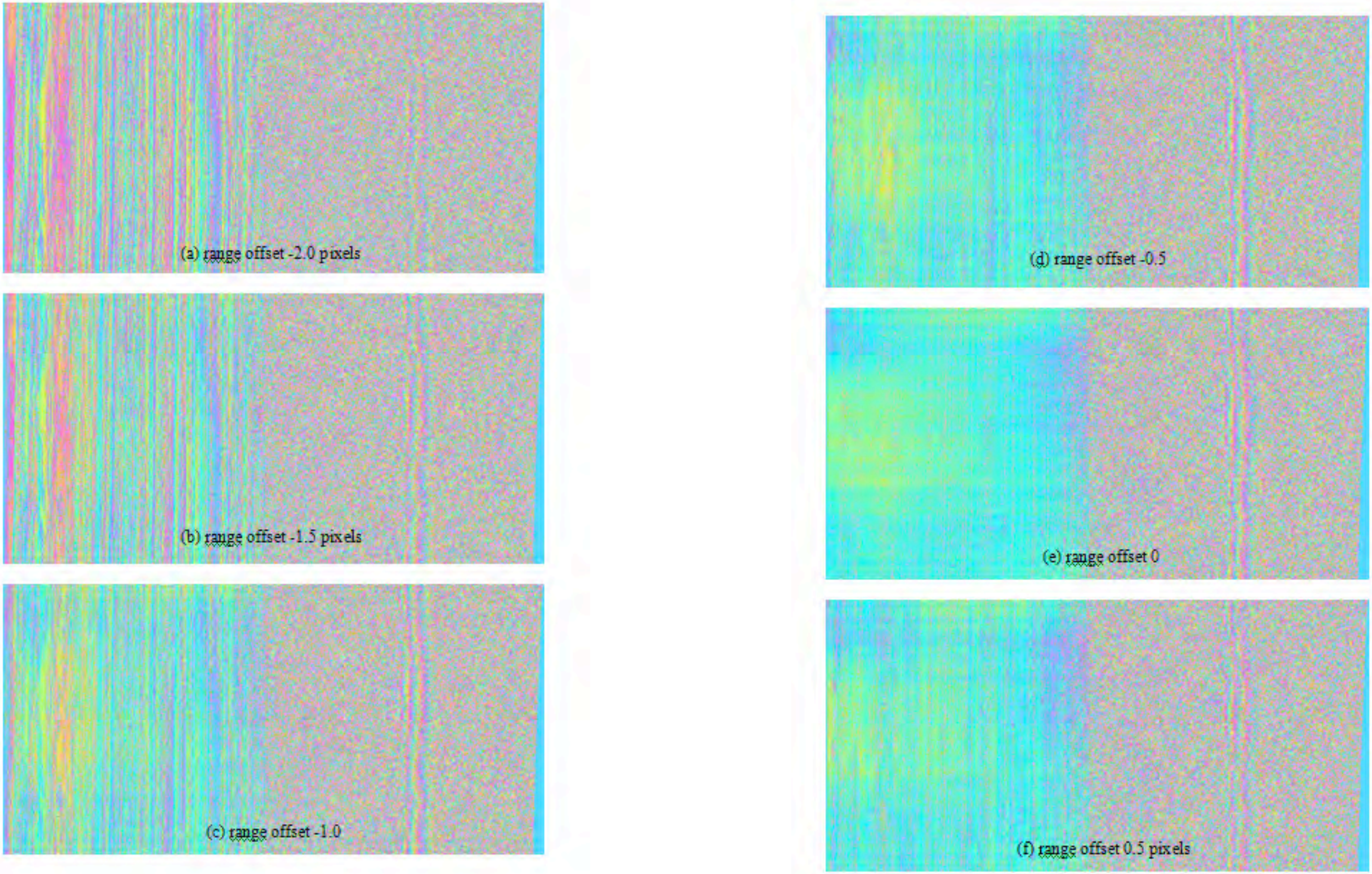


Fig. 7 interferograms from combinations of (a) $T_0/R_0/R_2$, (b) $T_0/R_0/R_3$ and (c) $T_0/R_2/R_5$. The equivalent baselines of these combinations are 0.95 m, 6.43 m and 8.33 m, respectively. The azimuth looks number is 2 and range look number is one.



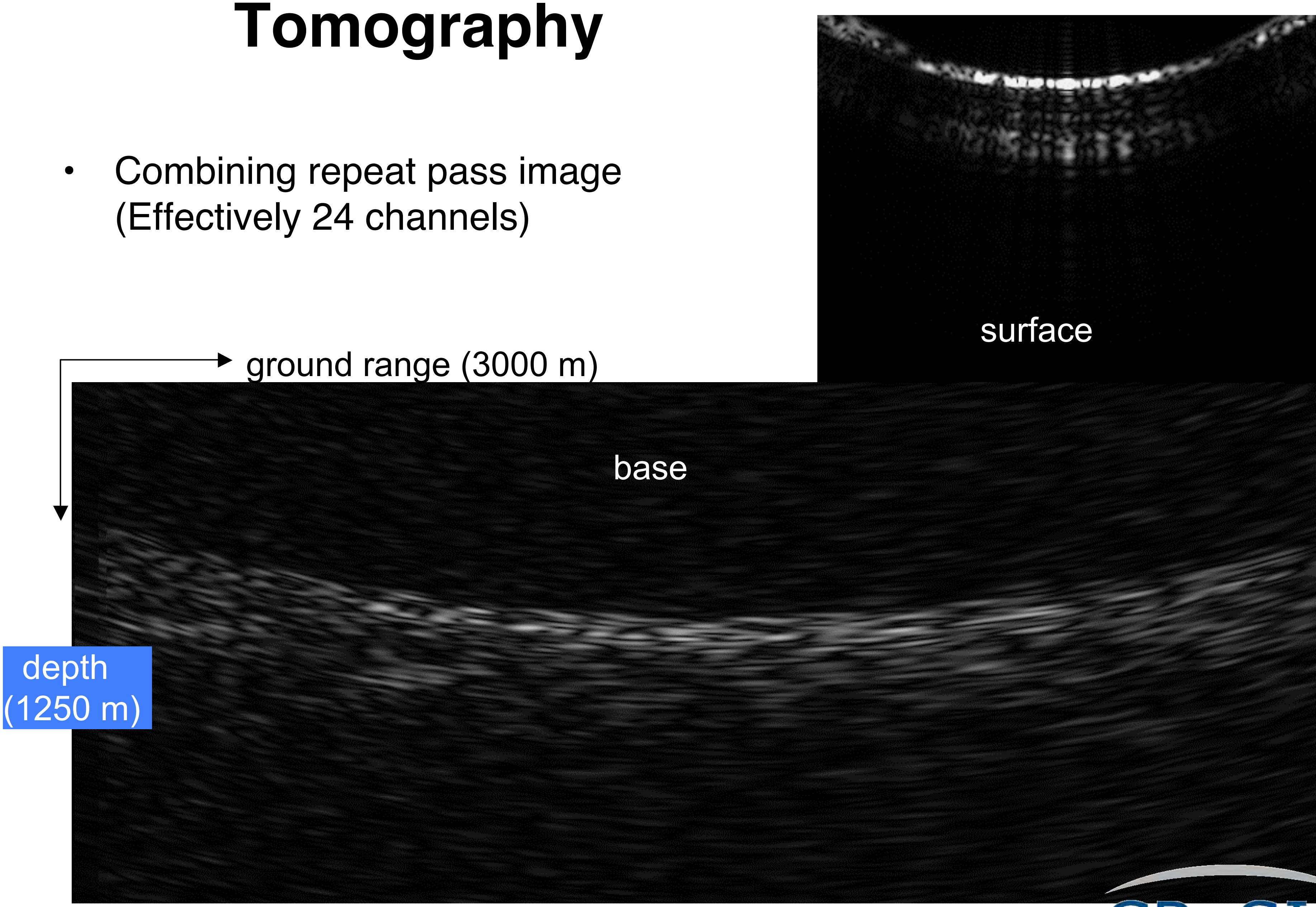
Range Offset Sensitivity

Image separation is to small to use traditional image cross correlation techniques so registration optimized by manually sliding the images in range

CReSIS
Center for Remote Sensing of Ice Sheets

Tomography

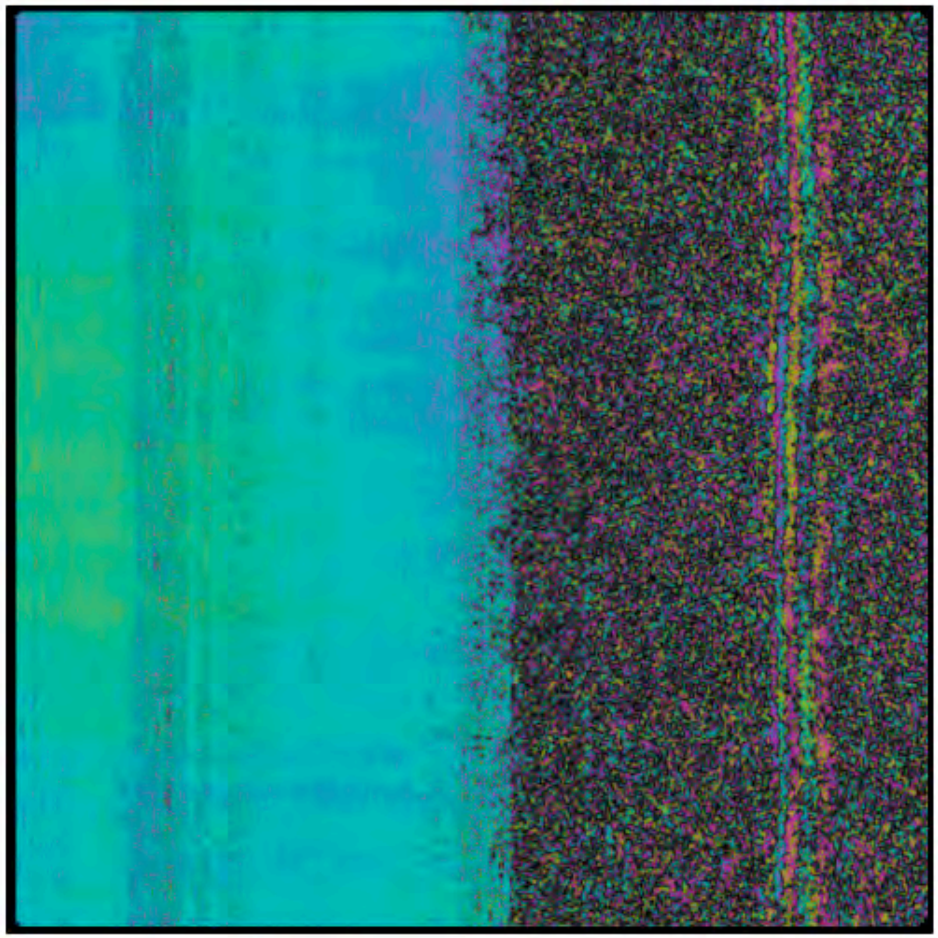
- Combining repeat pass image (Effectively 24 channels)



CReSIS
Center for Remote Sensing of Ice Sheets

Filtered Interferogram – Intensity modulated with coherence

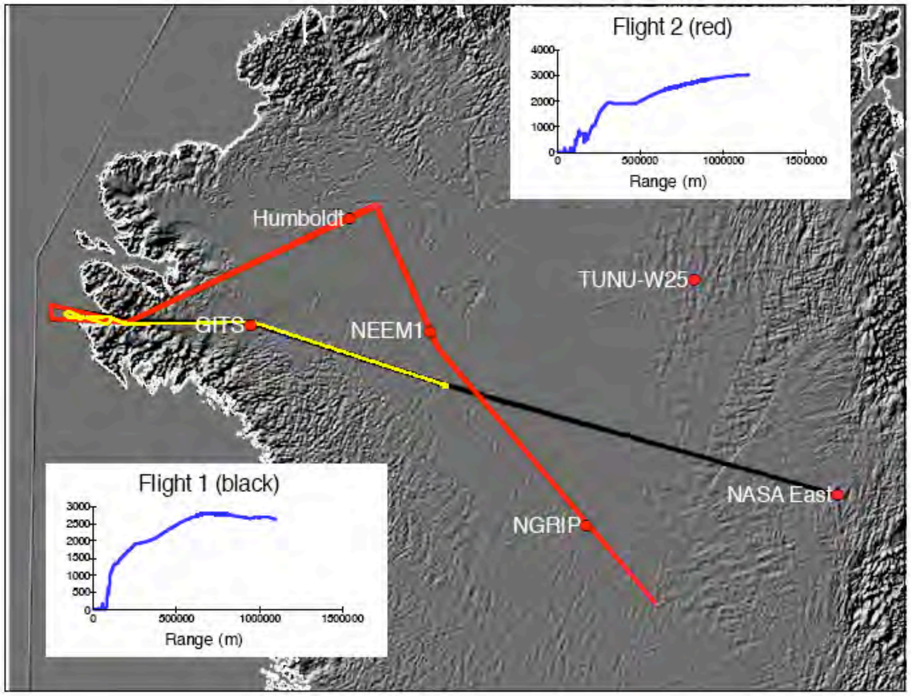
First step towards computing swath topography



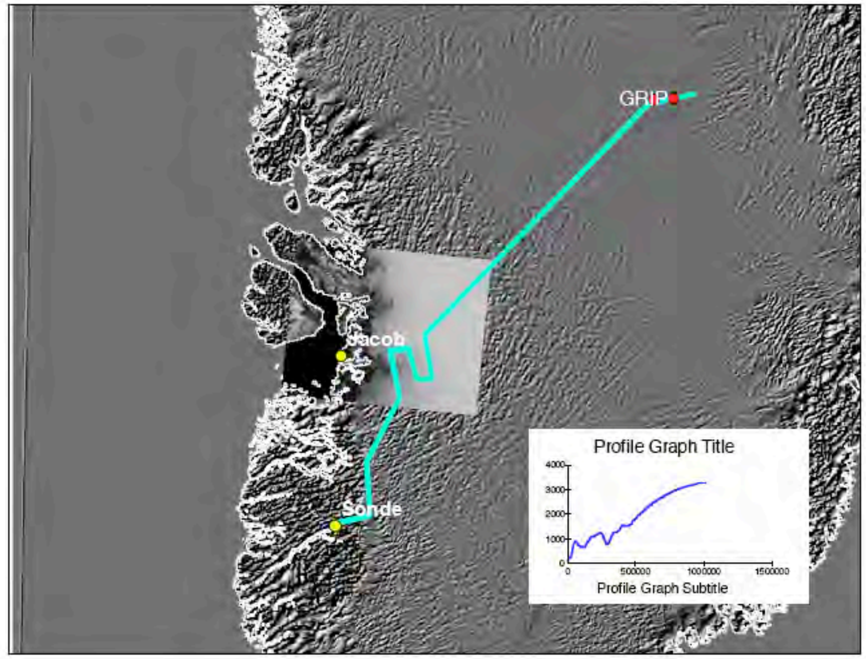
Technical Objectives for '07

- 1) Acquire data over the May 2006 flight line to compare high and low altitude observations and to compare interferometry acquired with different baselines. *Are results consistent with theory?*
- 2) Acquire data at 140 MHz and 440 MHz along every flight line and compare backscatter and interferometric frequency response? *Are the results consistent with theory?*
- 3) Acquire data over areas where we expect to find subglacial water. *Is water detectable either from backscatter maps or from topography?*
- 4) Acquire data over regions of increasing surface roughness. This may require observations over heavily crevassed shear margins such as those found around Jacobshavn Glacier. *Can we successfully implement interferogram phase filtering?*
- 5) Acquire data for tomographic analysis
- 6) Investigate repeat pass interferometry over repeat periods of days.
- 7) Verify volume clutter is weak (all snow zones)
- 8) Collect data over thick and thin ice to test for absorption effects

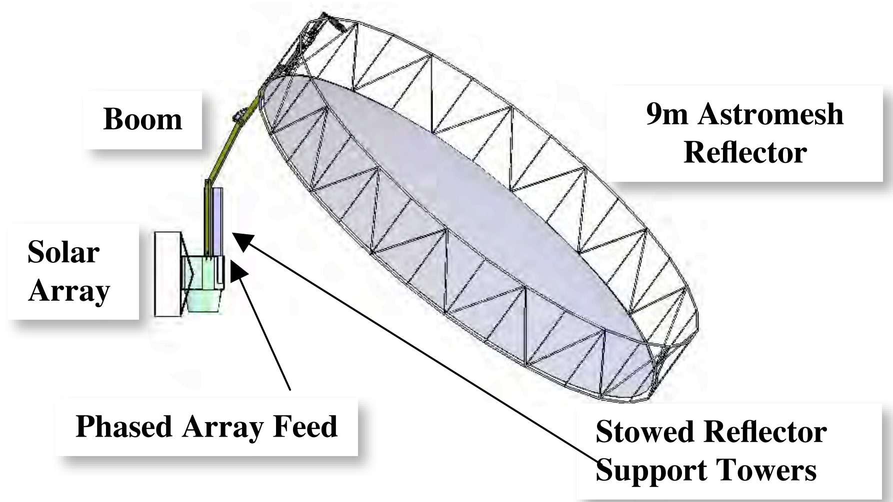
Flight 1 and 2



Flight 3



P-band Radar Instrument Concept
(for Veg. 3-D structure)



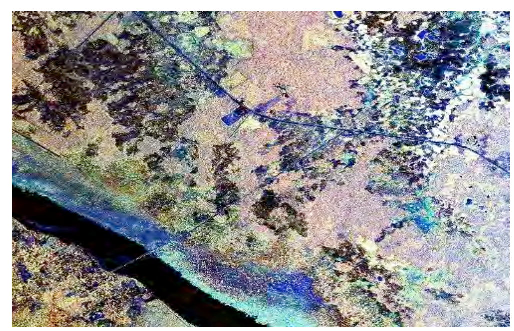
Instrument Features

- Pointing: 25° cross-track (right) of nadir
- P-band (435 MHz), 6 MHz Bandwidth
- Polarimetric (HH,HV,VH,VV)
- 25° illumination angle
- 62 km swath
- 100 m resolution (20 looks)
- Reflector Diameter: 9 m
- Reflector Width: 7 m
- Geolocation Accuracy: < 10 m
- Calibration: 1 - 1.5 dB absolute,
  0.5 - 1.0 relative
- Noise Equivalent σ^0: < -30 dB

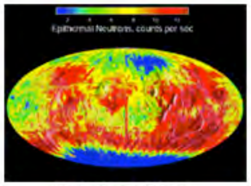
Technology

- No technology development required
- Astromesh Antenna technology provides 10-15 year lifetime (TRL 9)
- Phased Array Feed (TRL 6)
- Heritage:
  - MBSat 12-meter reflector
  - INMARSAT 9-meter reflector

Airborne Simulation of P-band Polarimetric Data



Eagle Scout Mission



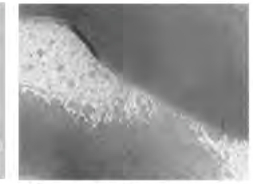
Origin of Ice

Duricrust vs. Bedrock

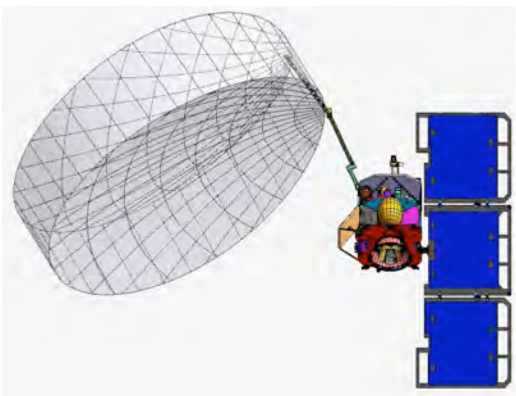
Hydrologic Cycle

Penetrating Dust

Probing the Poles

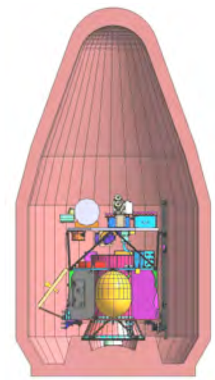


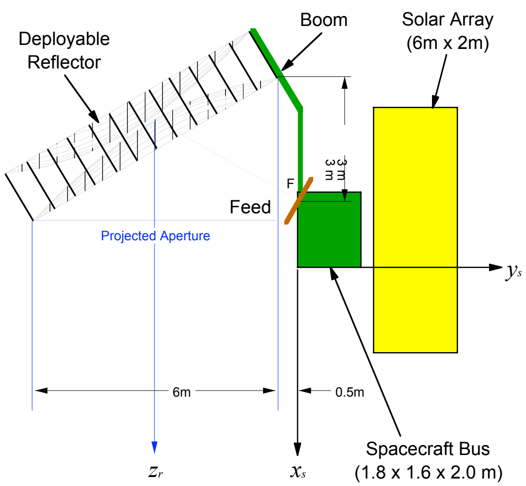
Recent Transport?



Mission Characteristics

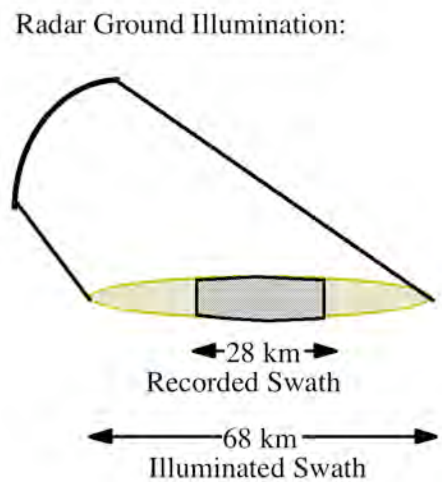
Mission Element	Characteristic
Length of Primary Mission	27 months
Launch Vehicle	Delta 2925
Trajectory Type	Type II
Launch Period	2011
Launch C3 (Max.)	17 km^2/s^2
Arrival Period	2011
Arrival V-infinity (Max.)	2.6 km/s
Mapping Orbit Altitude	240 × 320 km
Mapping Orbit Eccentricity	0.011
Mapping Orbit Period	112.0 min
Mapping Orbit Inclination	92.8 deg
Mapping Orbit Node Local Time	3:30-5:00 pm





P-Band SAR

Parameter	Value
Imaging Geometry	a) Look angle 37° (off-nadir) b) Nadir-pointing
Wavelength	63 cm
Polarizations	Full polarimetric capability
Number of science modes	4
Spatial resolution	100 m/30 m
Swath width	8 to 28 km
Mass (CBE)	76.9 kg
Stowed antenna dimensions	176 × 33 × 33 cm
Electronics box dimensions	20 × 30 × 40 cm
Power needs (average)	93.3 W
Data rates	0.75 to 2 Mbps
Pointing accuracy requirement	0.75 °

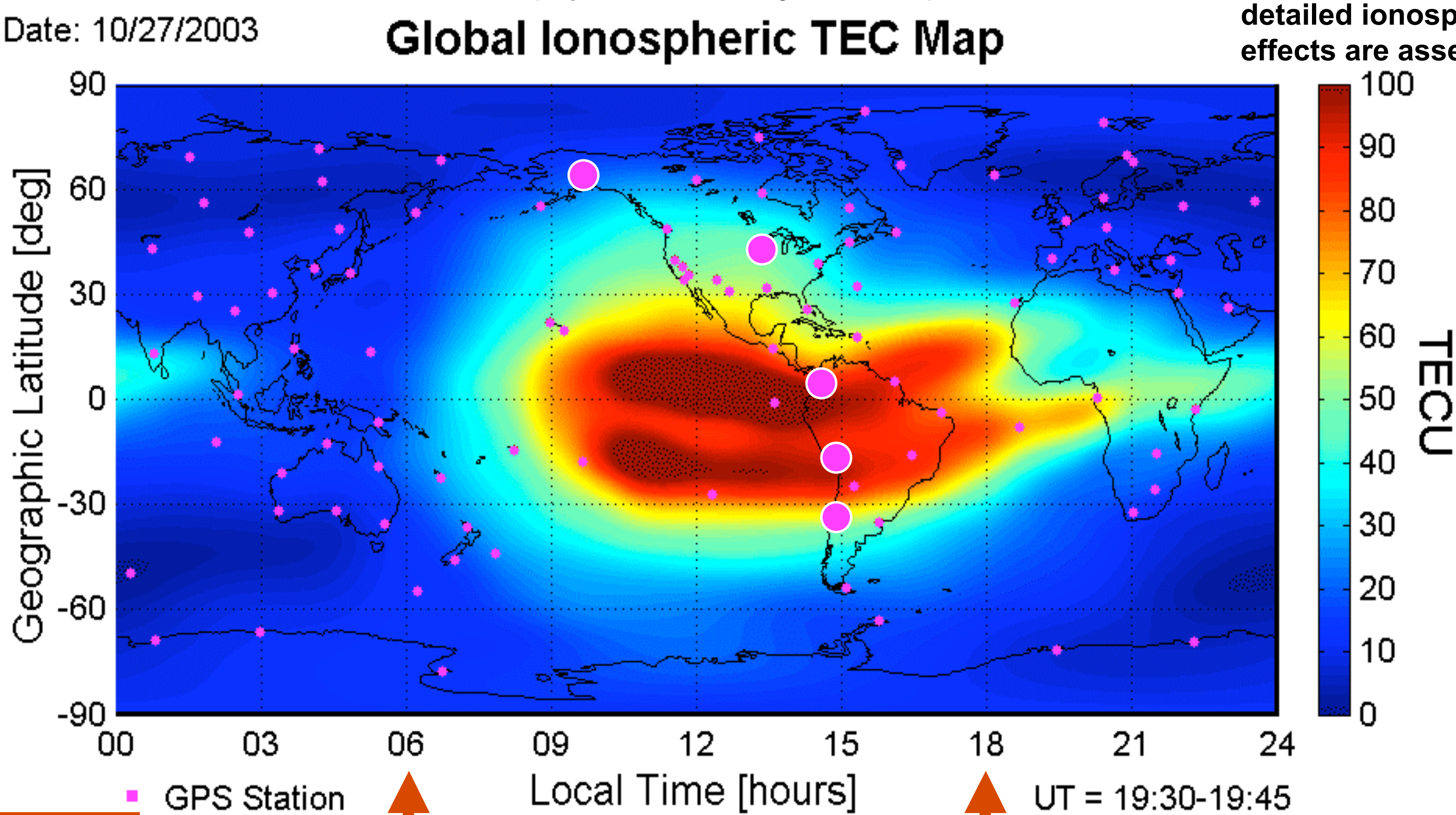


Combines Polarimetry and Repeat-pass Interferometry to characterize Martian subsurface

Latitudinal Variation of the Ionosphere
A Concern at Low and Mid Latitudes

(Updated every 5 mins)

Locations where some detailed ionospheric effects are assessed



Dawn (ascending)

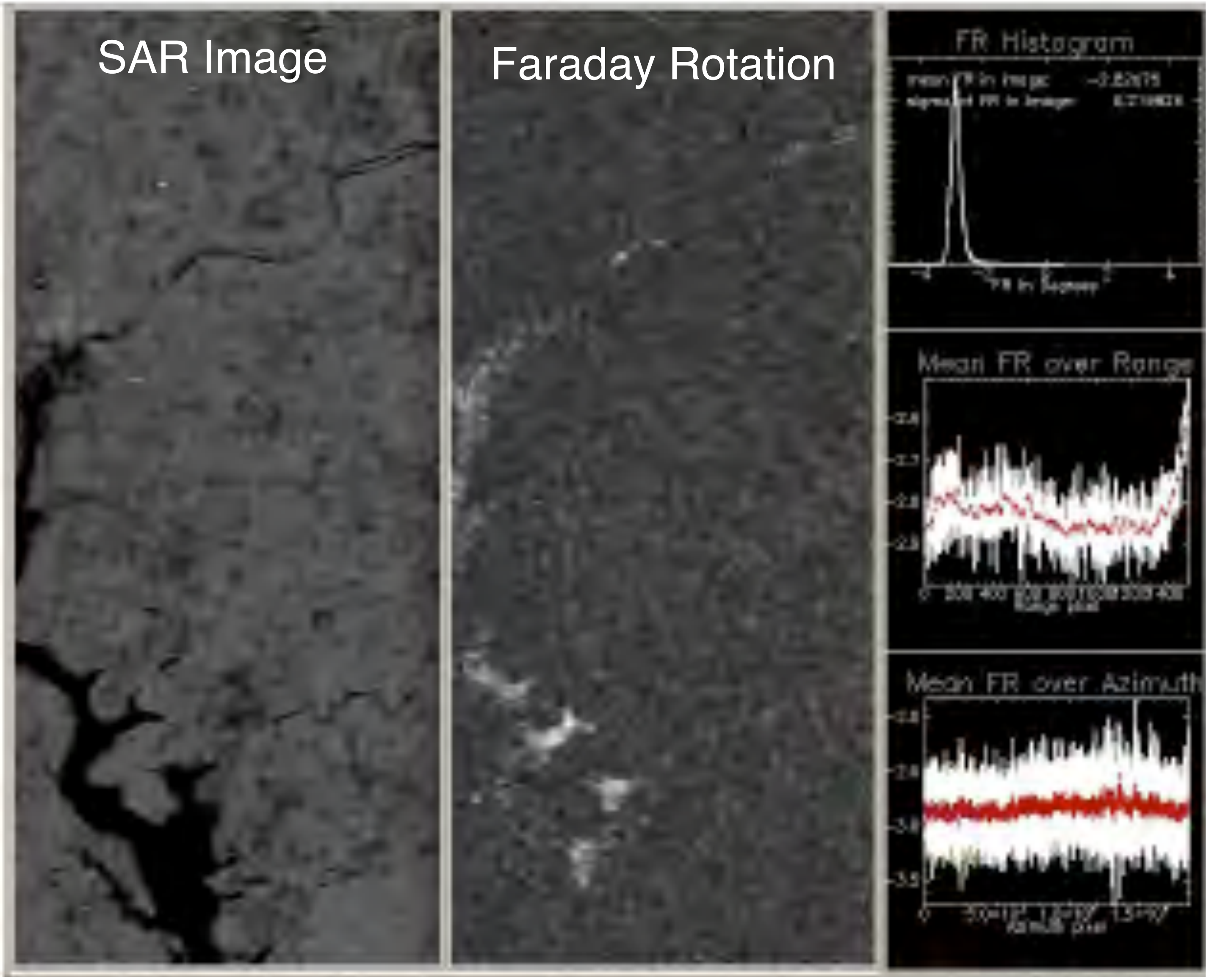
Dusk (descending)

A year similar to the target launch year - 2014

Most of blue areas are not a concern for the Faraday rotation effect at L-band (but may be at P-Band)

Source : http://iono.jpl.nasa.gov/

Faraday rotation estimated from L-Band polarimetric PalSAR data over Washington, DC



(courtesy Jeremy Nicoll, Alaska SAR Facility)

Faraday rotation estimated at

Ω= 2.83 (+/- 0.22)

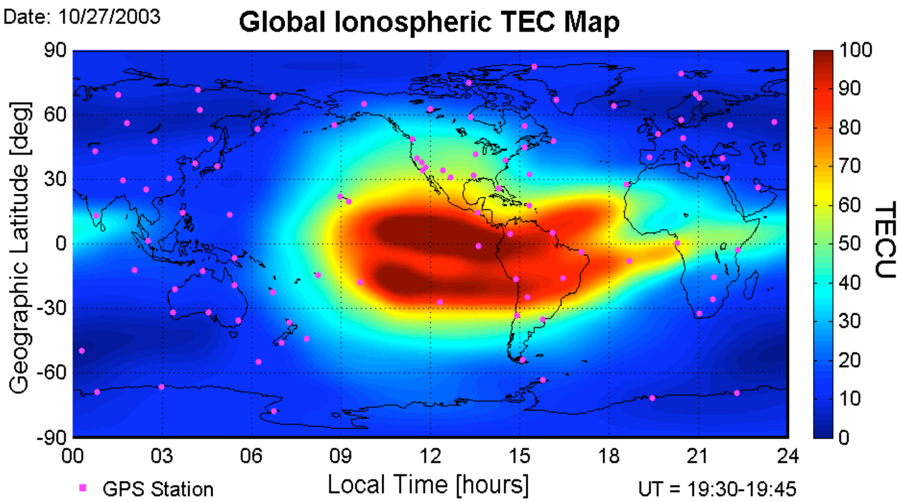
compares well with prior estimate based on GPS-based TEC maps

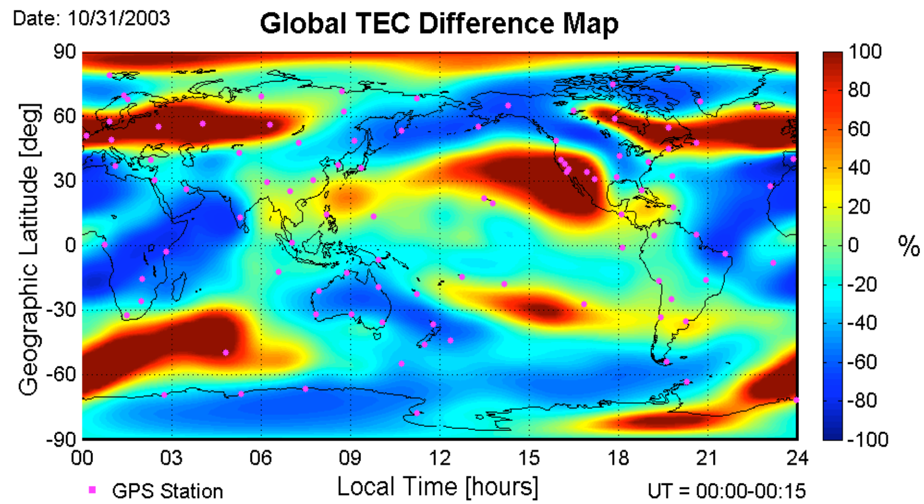
Ω = 4.0

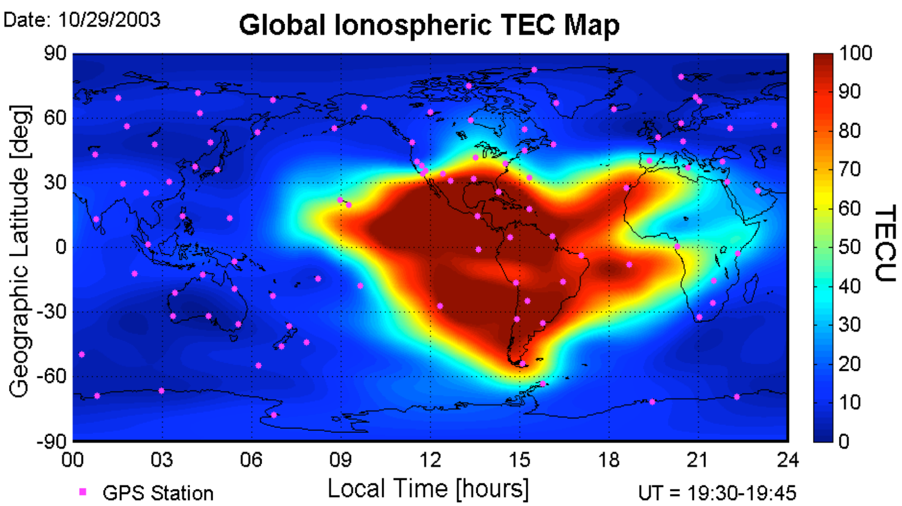
Little range or azimuth dependence in this example

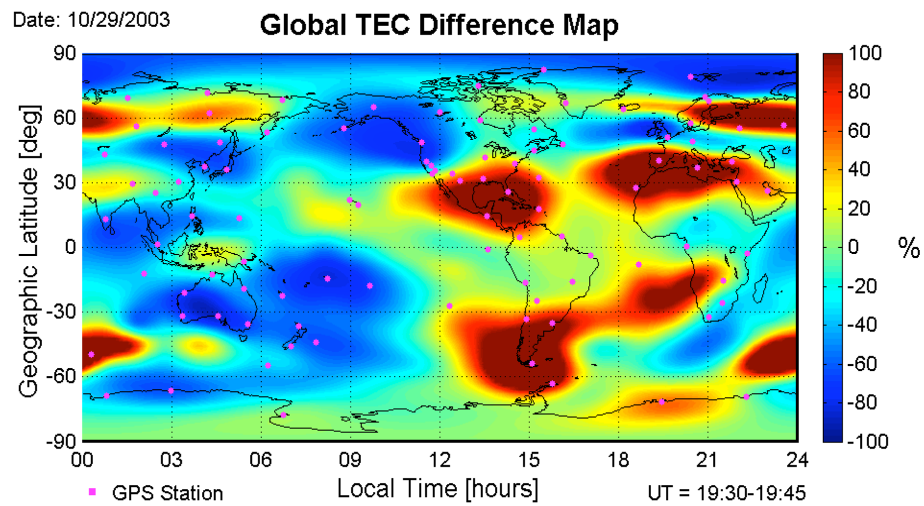
Estimation algorithm for Ω performs well except in low SNR areas

Ionospheric Storms
A Threat to L- & P-Band InSAR Missions



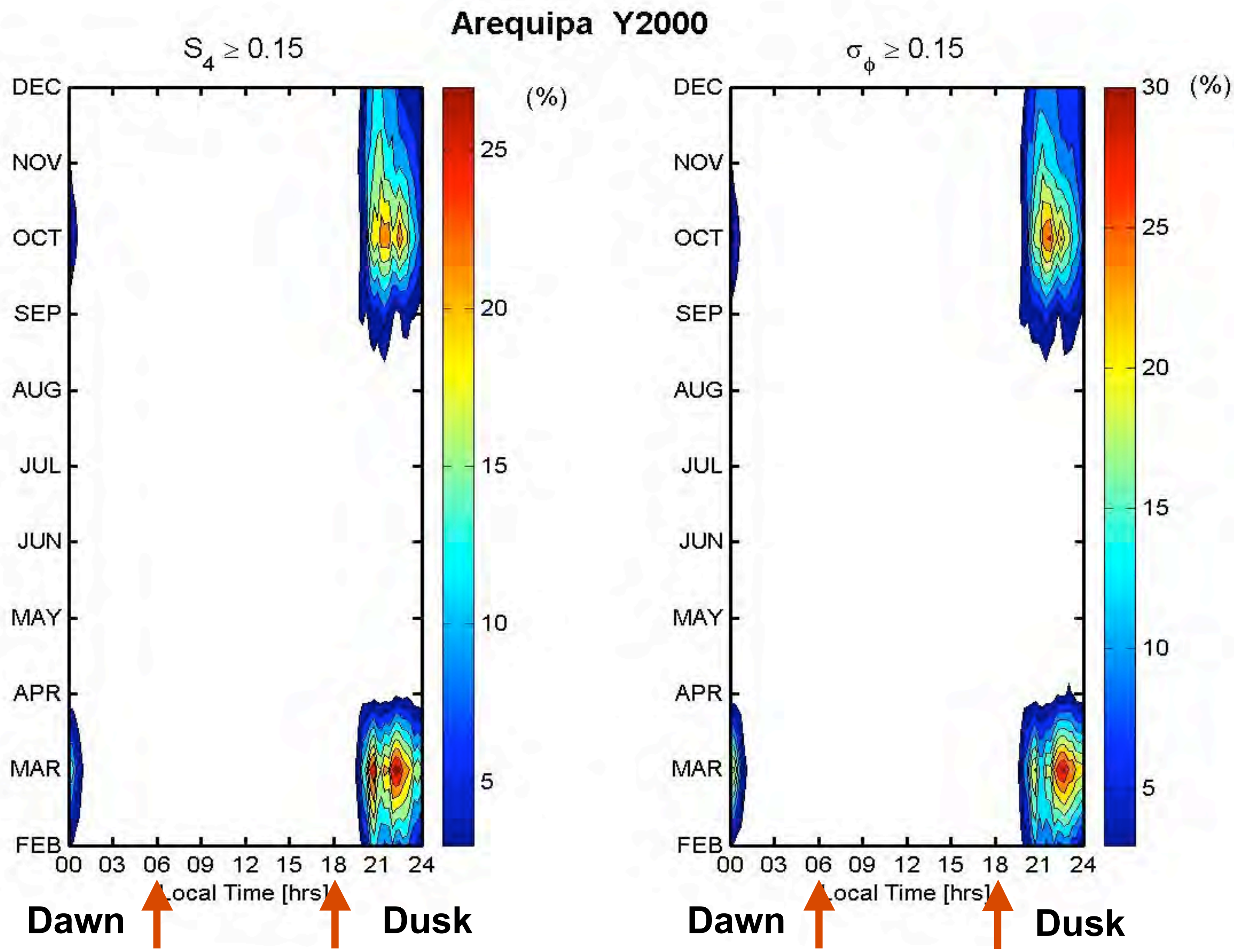




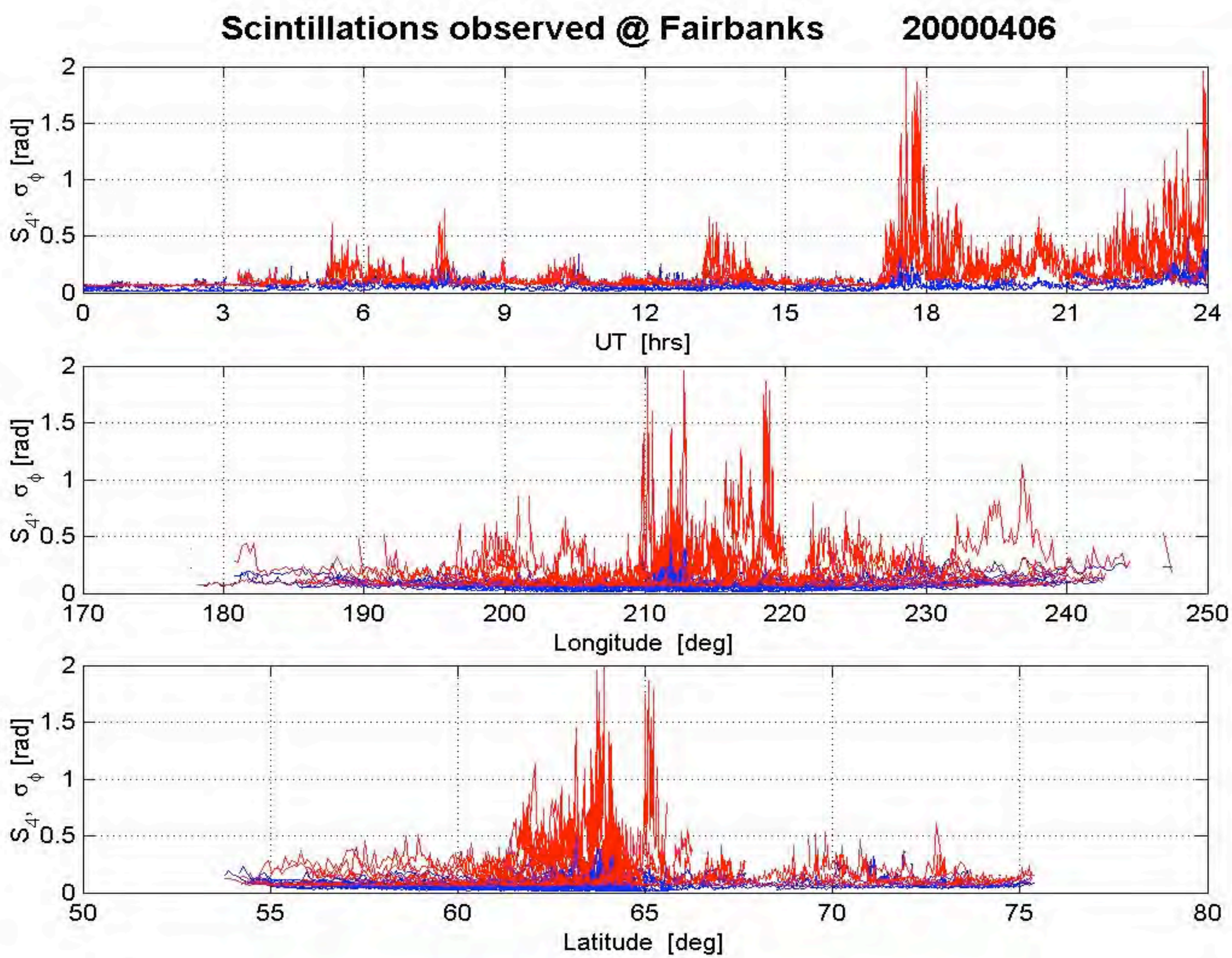


TEC difference is relative to a quiet-time average using data before the storm day.

L-Band Scintillation at Low Latitudes
Not a Concern for a Dawn-Dusk Orbit

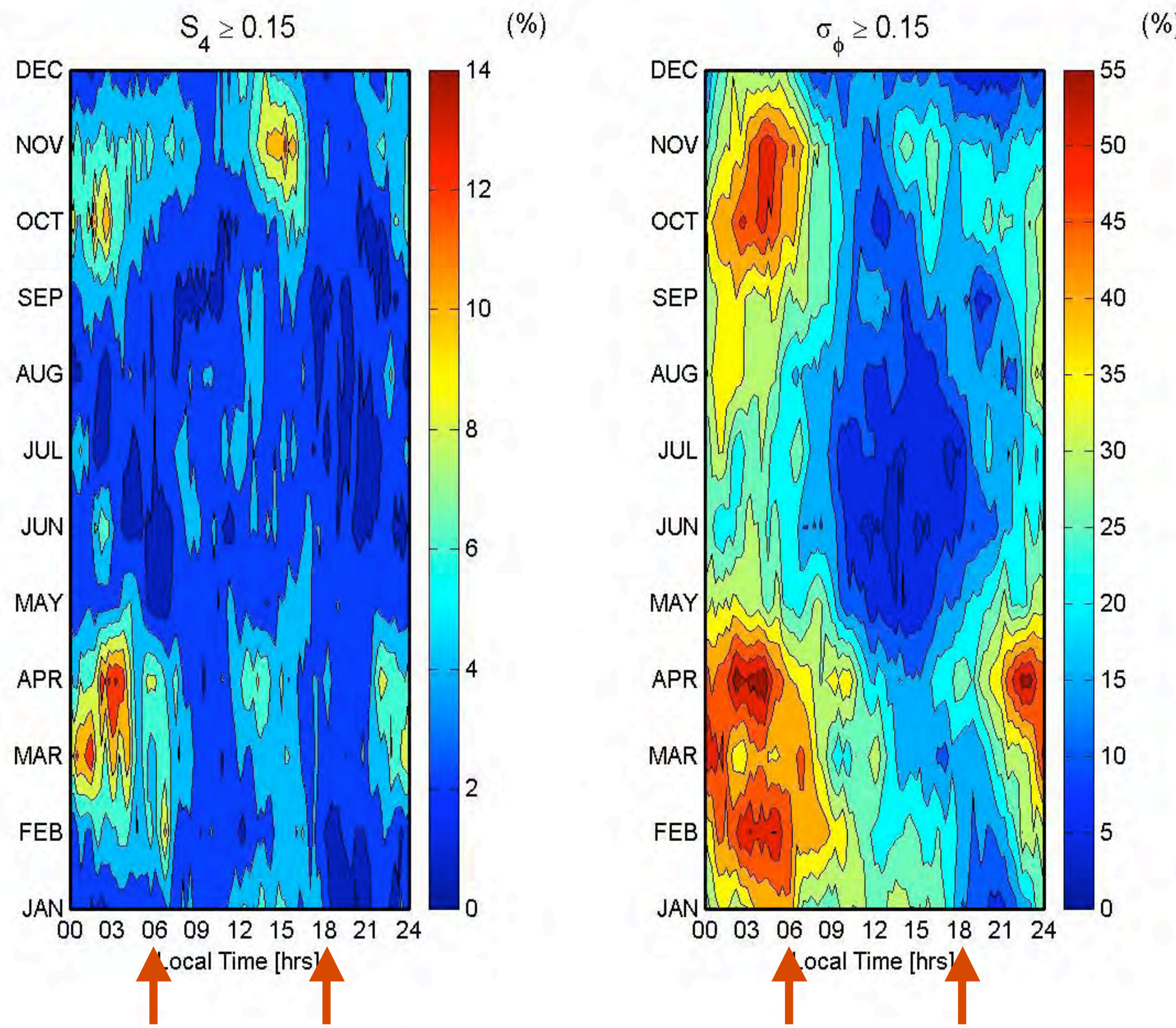


Example of Ionospheric Scintillation Scales at High Latitudes during a Geomagnetic Storm



Scintillation Effects in the Auroral Zone
A Concern to Dawn Passes

- **Occurrence patterns of L-band ionospheric scintillation at Fairbanks, Alaska**
- **The two-way scintillation statistics is obtained by processing GPS data (50-Hz L1 signal intensity and phase, *f* = 1.57542 GHz) collected during 2000**



GISMO

- **Conclusions:**
  1. 1st interferogram from base of Greenland Ice Sheet
  2. P-Band sees base and layering in the ice sheet
  3. Still have to show interferogram filtering works to suppress clutter (main aim of flights later in ‘07)
  4. Faraday rotation can be measured quite effectively using polarimetric data (and corrected) ==> we can live with Faraday rotation
  5. Ionospheric scintillations can cause severe distortions, but we can design the mission orbit/operations to avoid the worst