The Glacier and Ice Surface Topography Interferometer: UAVSARs Single-pass Ka-Band Interferometer

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Outline

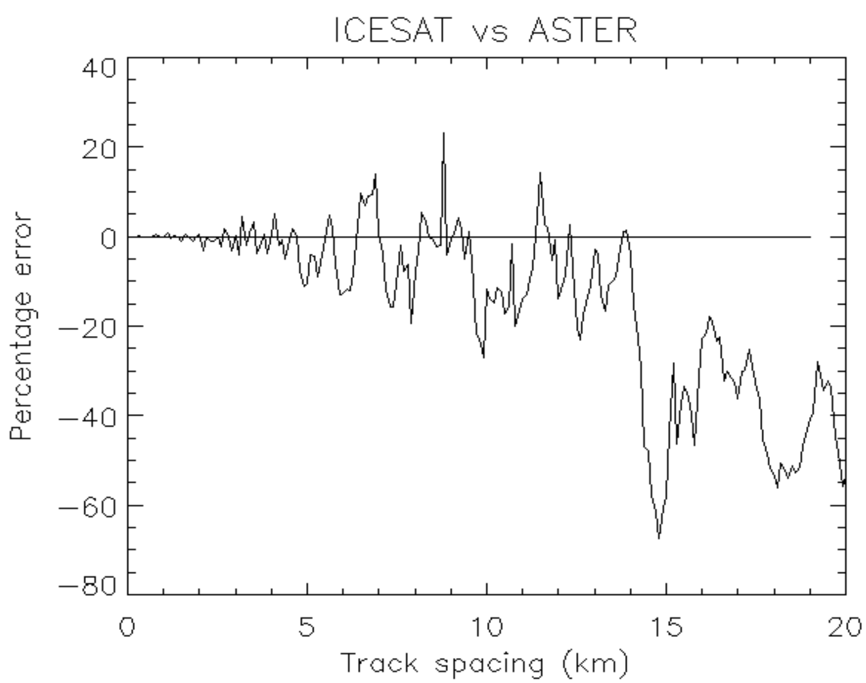
- Science Motivation
- The International Polar Year Greenland Campaign summary
  - Results including relative snow penetration
- GLISTIN-A and GLISTIN-H
  - Upgrade summary
  - Initial results
  - Additional applications/science
  - Plans for Global Hawk

Scientific Motivation for Ice Surface Elevation *Mapping*

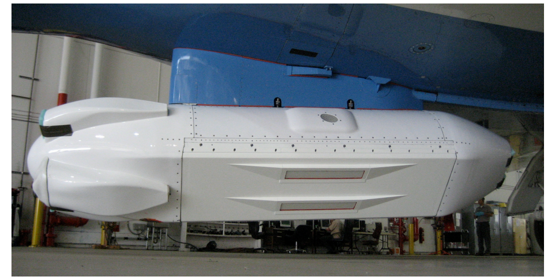
- Under-sampling of the ice by swath-limited sensors, especially in glacial areas can lead to substantial ice volume estimation errors.
- To adequately assess the dynamics and volume changes in glacial/coastal margins of the ice-sheet requires a mapping capability that fills the gaps between altimeter tracks at sufficient resolution.

Mapping in glacier elevation changes is essential

- The Glacier and Ice Surface Topography Interferometer (GLISTIN *not* GLISTEN…) was first proposed as a spaceborne digital beamforming Ka-band space-borne concept



Percentage error of ICESat-II volume change estimates of Helheim Glacier, Greenland versus track spacing (km) simulated using volume changes calculated using ASTER DEMs (courtesy Ian Howat, OSU). This shows that unless the track spacing is less than 5 km, large errors will be made in assessing volume changes of the glacier. Figure credit: Eric Rignot

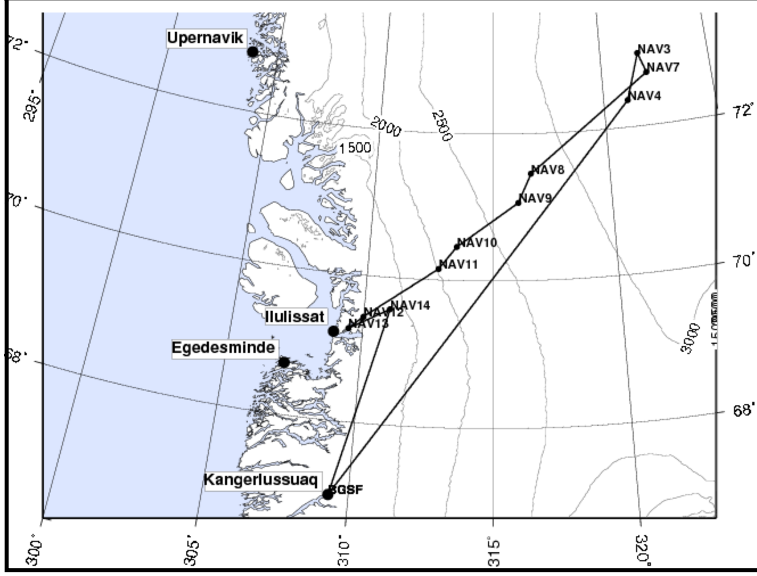


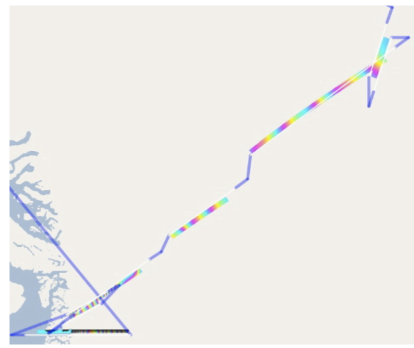
Ka-band antennas installed on the NASA GIII configured for single-pass interferometry

		Requirement	
		Spaceborne	**Airborne**
Coverage		70km (Yields subseasonal complete coverage of Antarctica and Greenland)	>5km swath (10km goal) (IceSAT II track spacing can be 15 km in Greenland)
Coastal	**Accuracy**	1m	0.5m
	Posting	100m x 100m	30m x 30m
Ice Sheet	**Accuracy**	10cm	10cm
	Posting	1km x 1km	100m x 100m

GLISTIN Greenland Campaign Summary

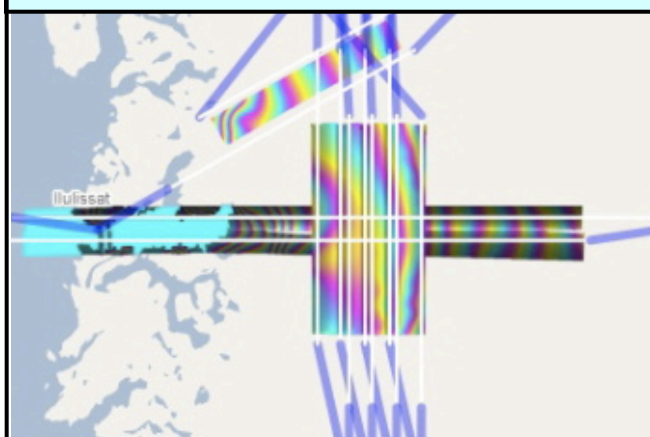
5/5/09 ATM flight path (left) to coincide with GLISTIN **5/4/09** & **5/5/09**

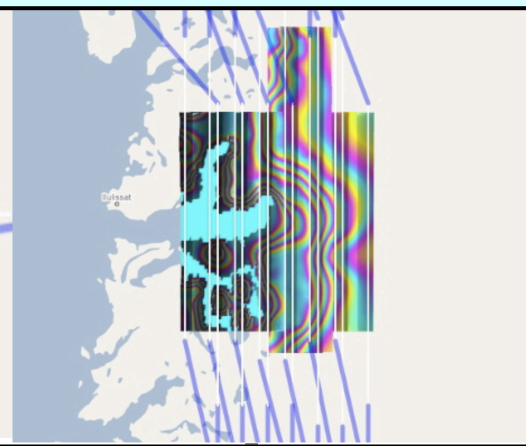




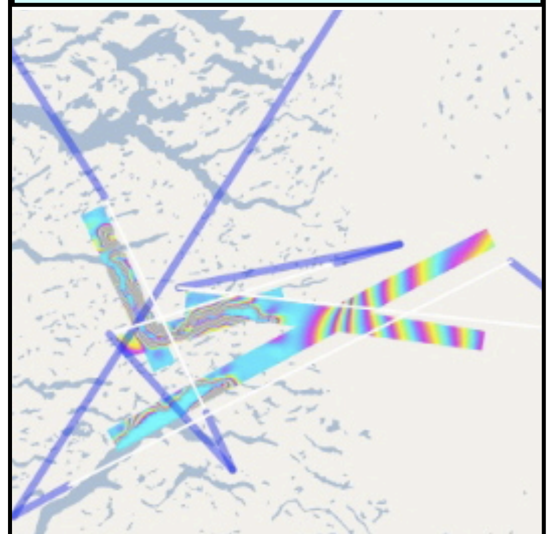
Two calibration sites at Summit and Swiss Camp. Ground (snow) data collected at Swiss Camp. Comparison with ATM will reveal penetration depth of Ka-band

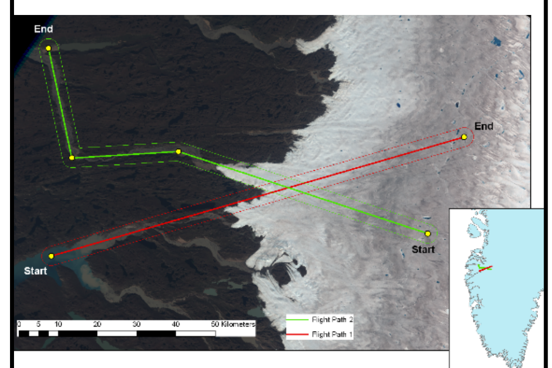
5/5/09 & 5/6/09 mapping over Jakobshavn took place on consecutive days. Flights were repeated six days later **(5/11/09 & 5/12/09**). The ATM flew this region ~1 week prior





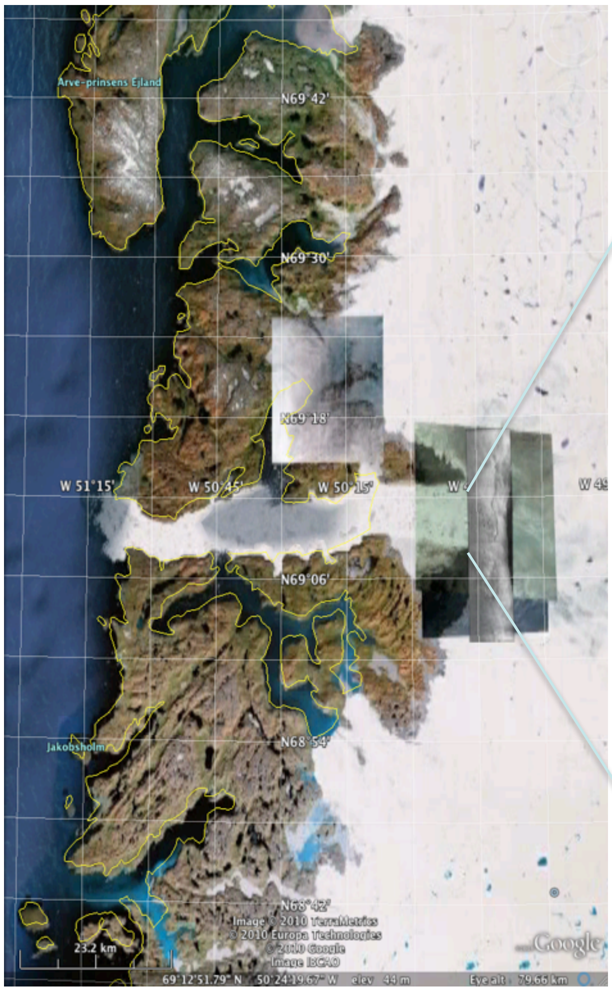
5/7/09 Watson River Glacial lake outlet. Mapping bathymetry and transition onto glacier. Glaciology and hydrology interests and ground activities

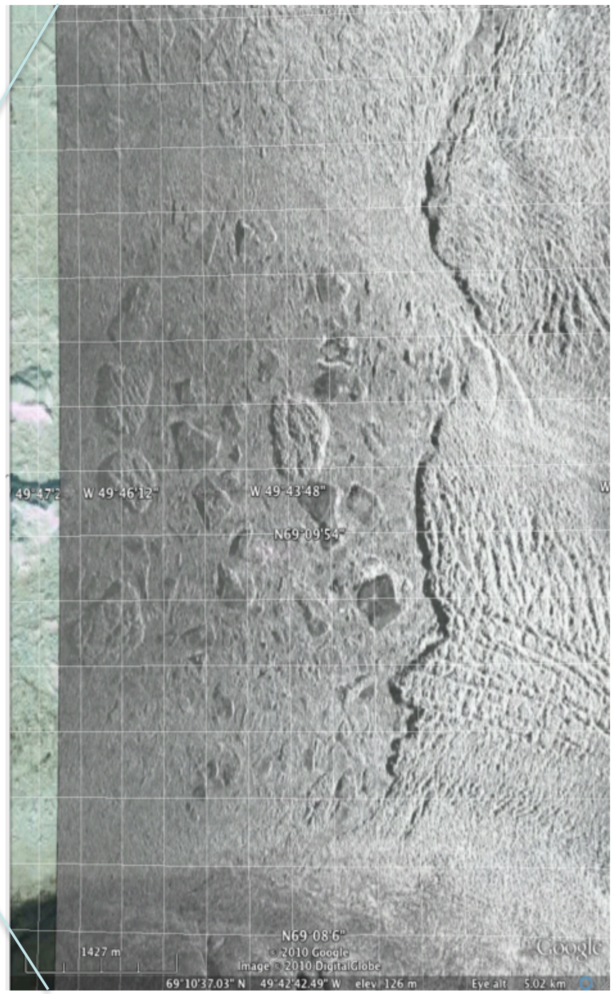




Jacobshavn Glacier Ka-band Imagery

Quick Look Intensity Processing: May 6 and May 12 – Jakobsholm Pass

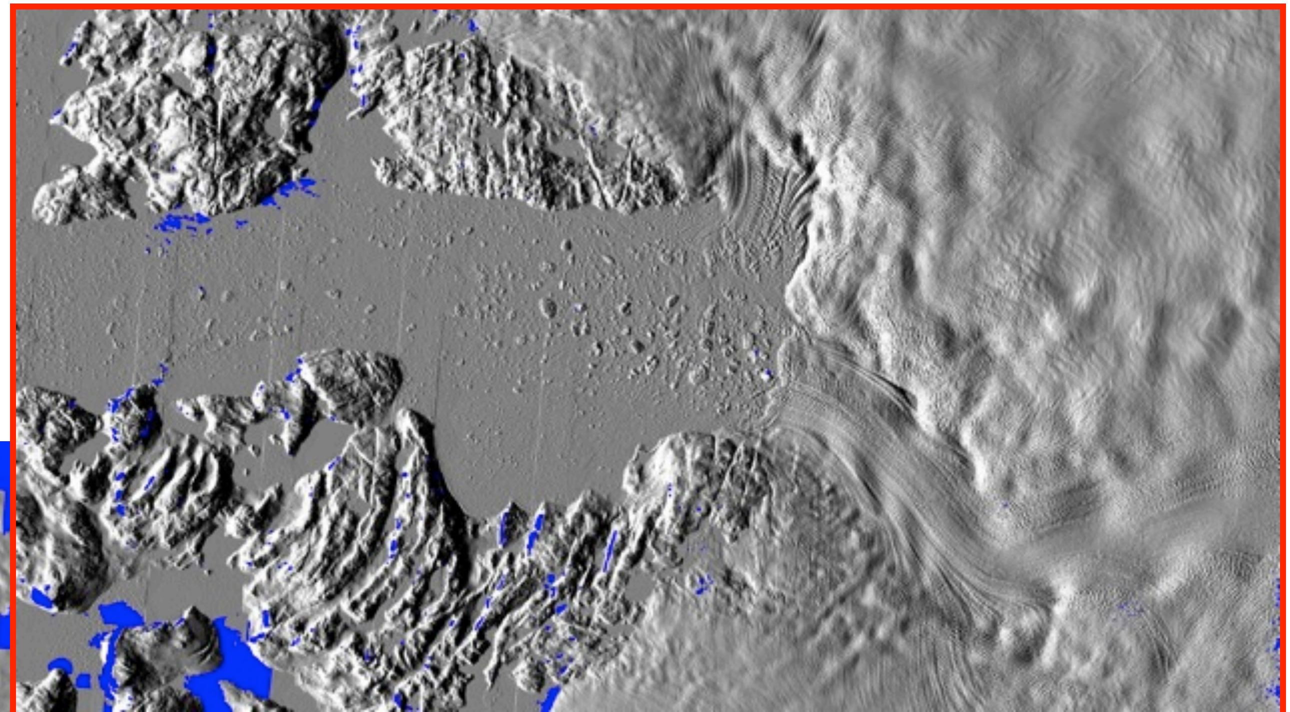


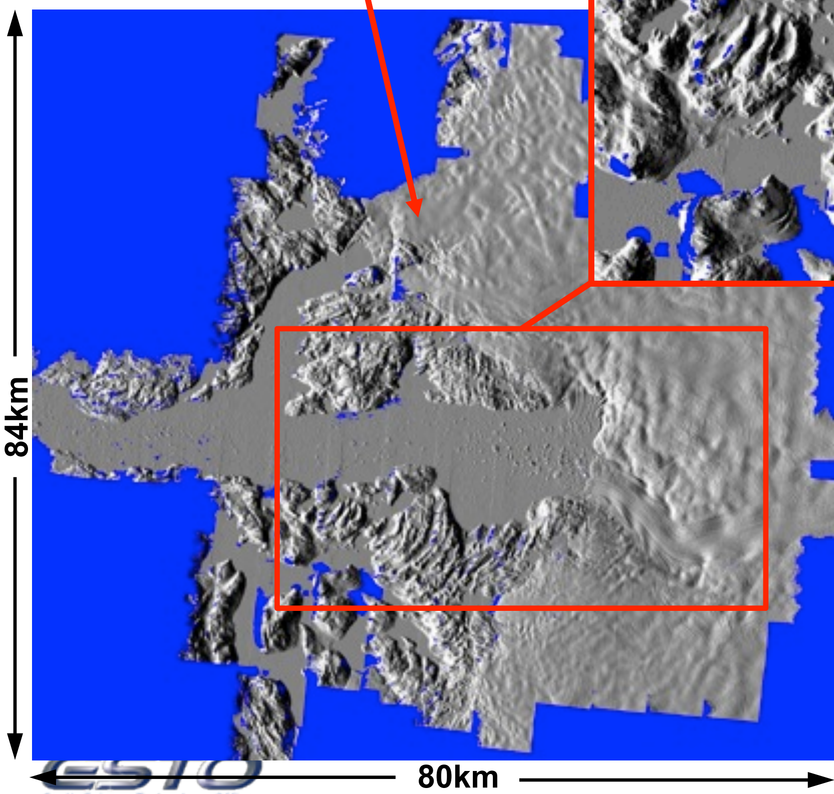


8 km

- Left shows Google Earth view zoomed out to show surrounding region. Quick look processing image is also shown in Google Earth.
- Right images are zoomed in to shown more details in the quick look processing (intensity only) of Jakobsholm pass. They have been imported into Google Earth.
- From the 6th to the 12th (toggle between) the ice sheet retreats ~ 1 km.

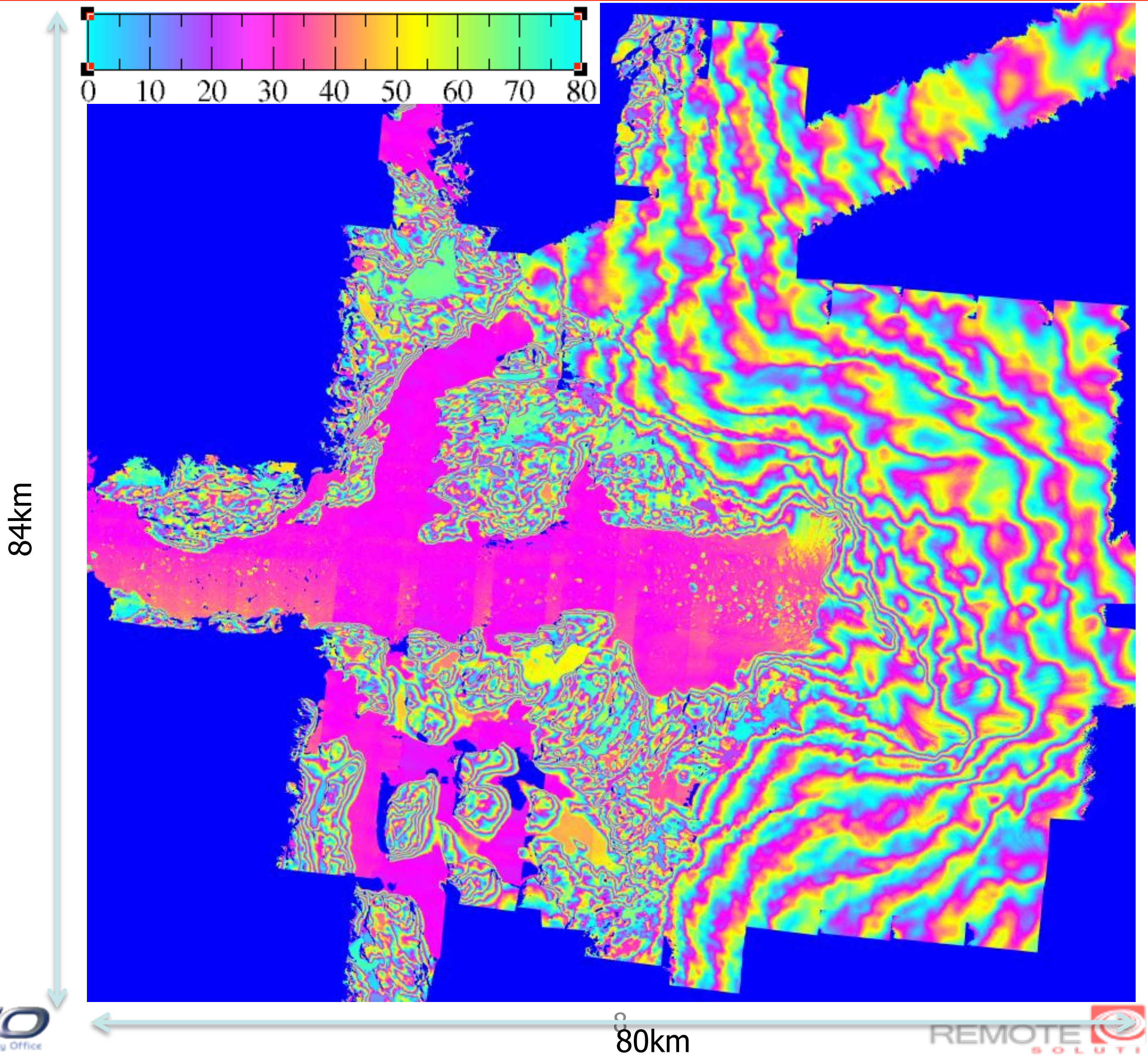
Jakobshavn Isbrae Mosaic: May 5 and 6, 2009 – Shaded Relief



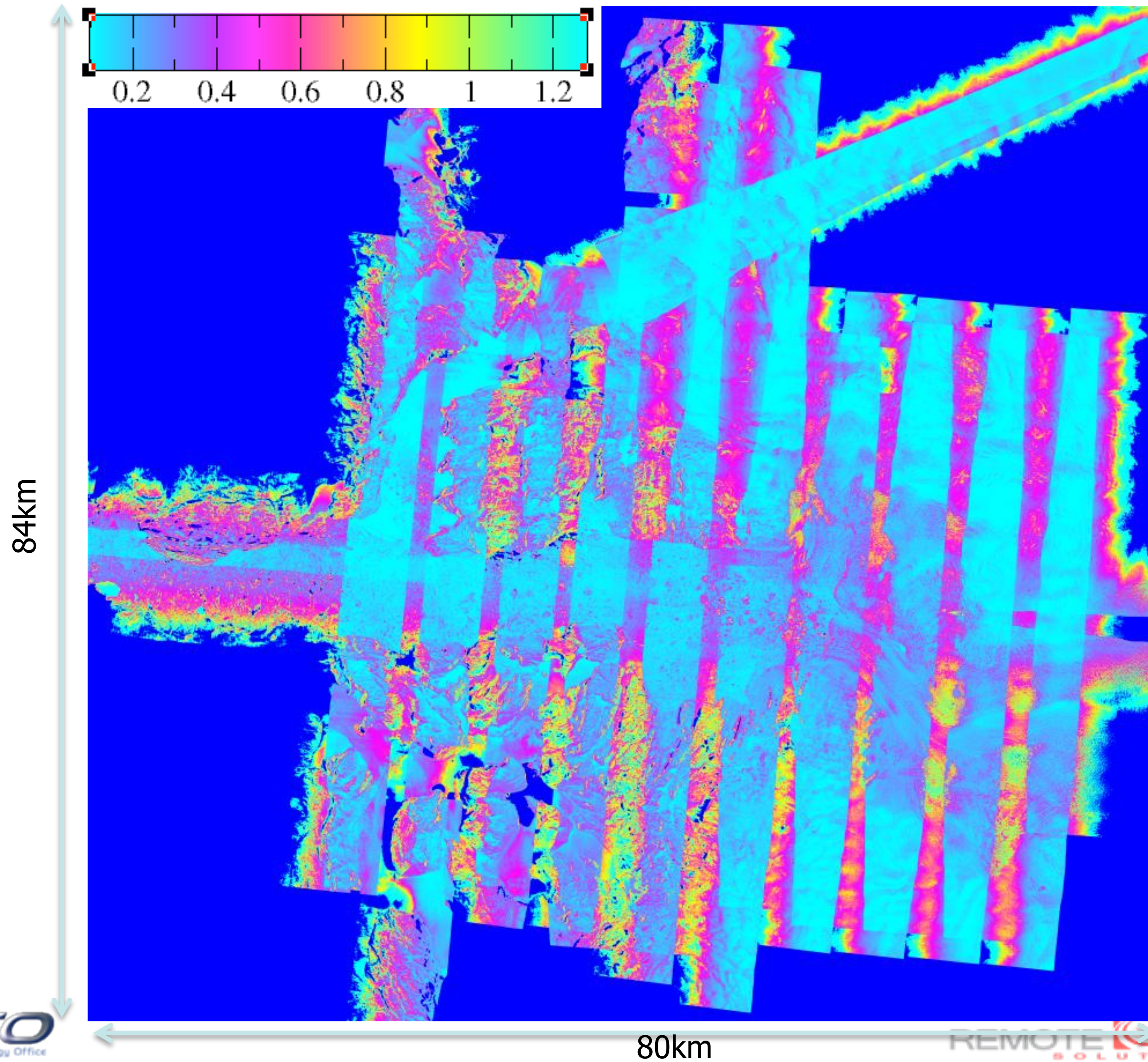


ATM complementary data highly utilized to enable precision processing of the GLISTIN-A IPY collection

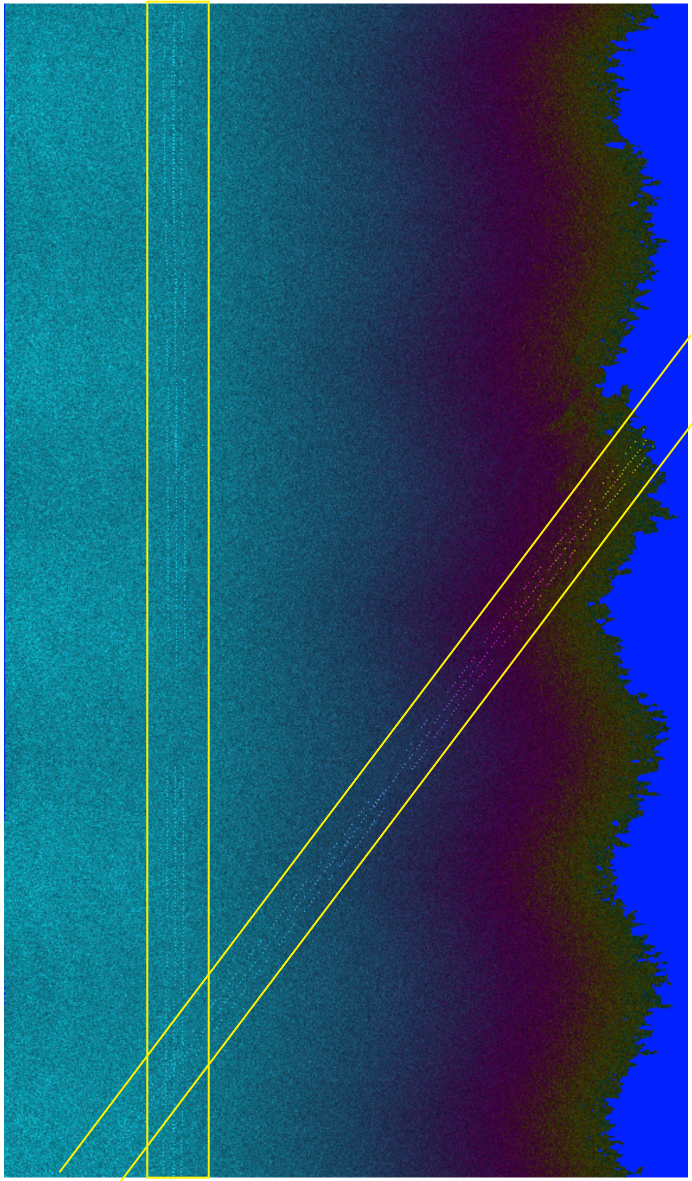
Jakobshavn Isbrae Mosaic: May 5 and 6, 2009 – Height Map 80m Wrap



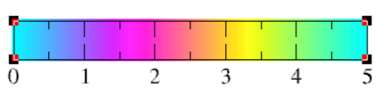
Jakobshavn Isbrae Mosaic 10m posting: May 5 and 6, 2009 – Height Error Map



Ka-band and Lidar Data Comparison: A Bounding Assessment of Penetration



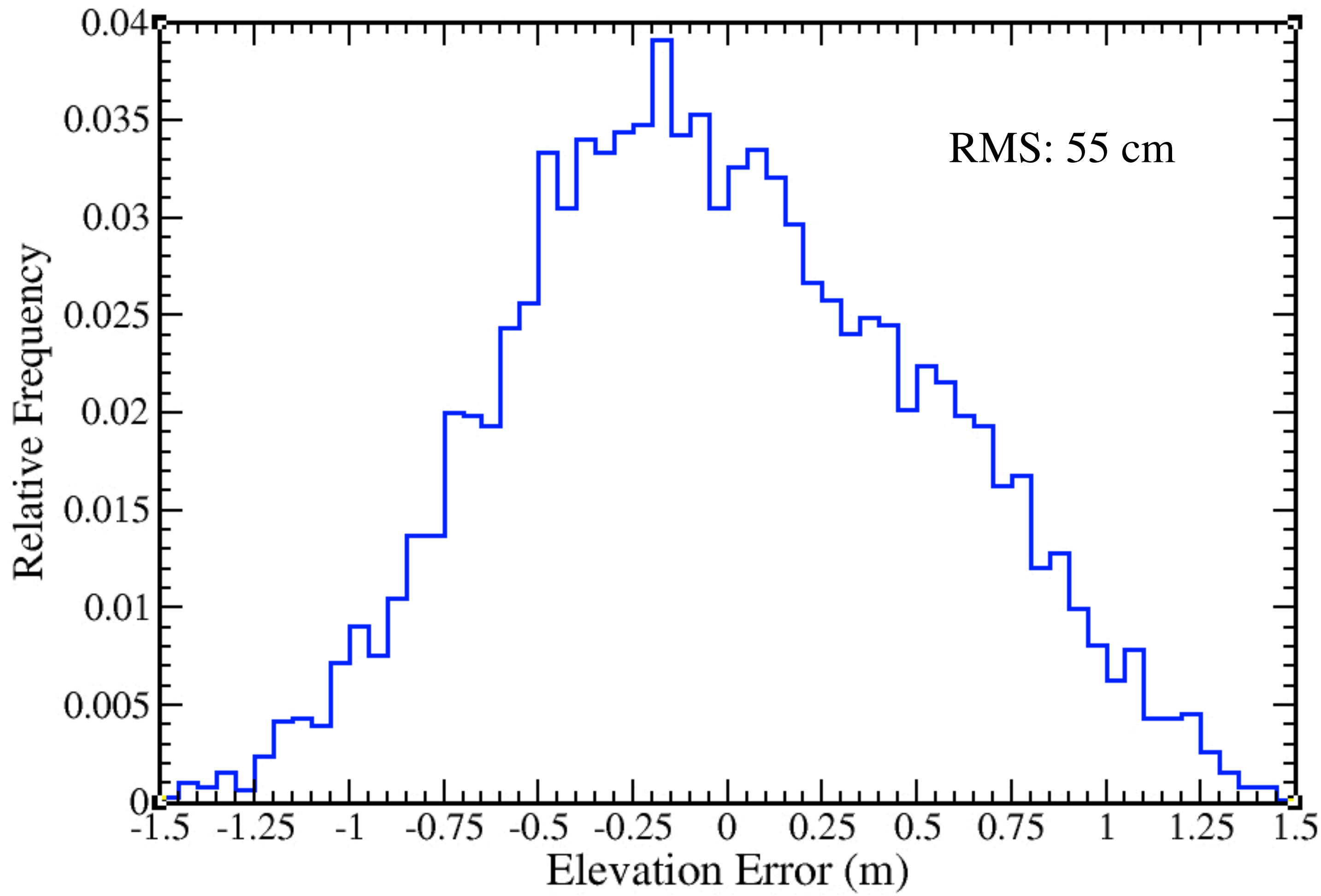
- Ka-band single pass interferometric data was collected at Swiss Camp in Greenland along with ATM lidar data.
- Lidar tracks (~10,000 points/track) are shown overlaid on the Ka-band elevation data in the yellow boxes.
- Interferometric radar measurements allow the estimation of the elevation precision using the correlation.
- Excellent agreement between estimated and measured precisions at the corner reflector locations.
- Restricted analysis to points in the near range where the elevation precisions are around 25 cm.
- Given a lidar measurement accuracy of 20 cm expect an RMS elevation difference of 32 cm for no penetration.



Precision (m)

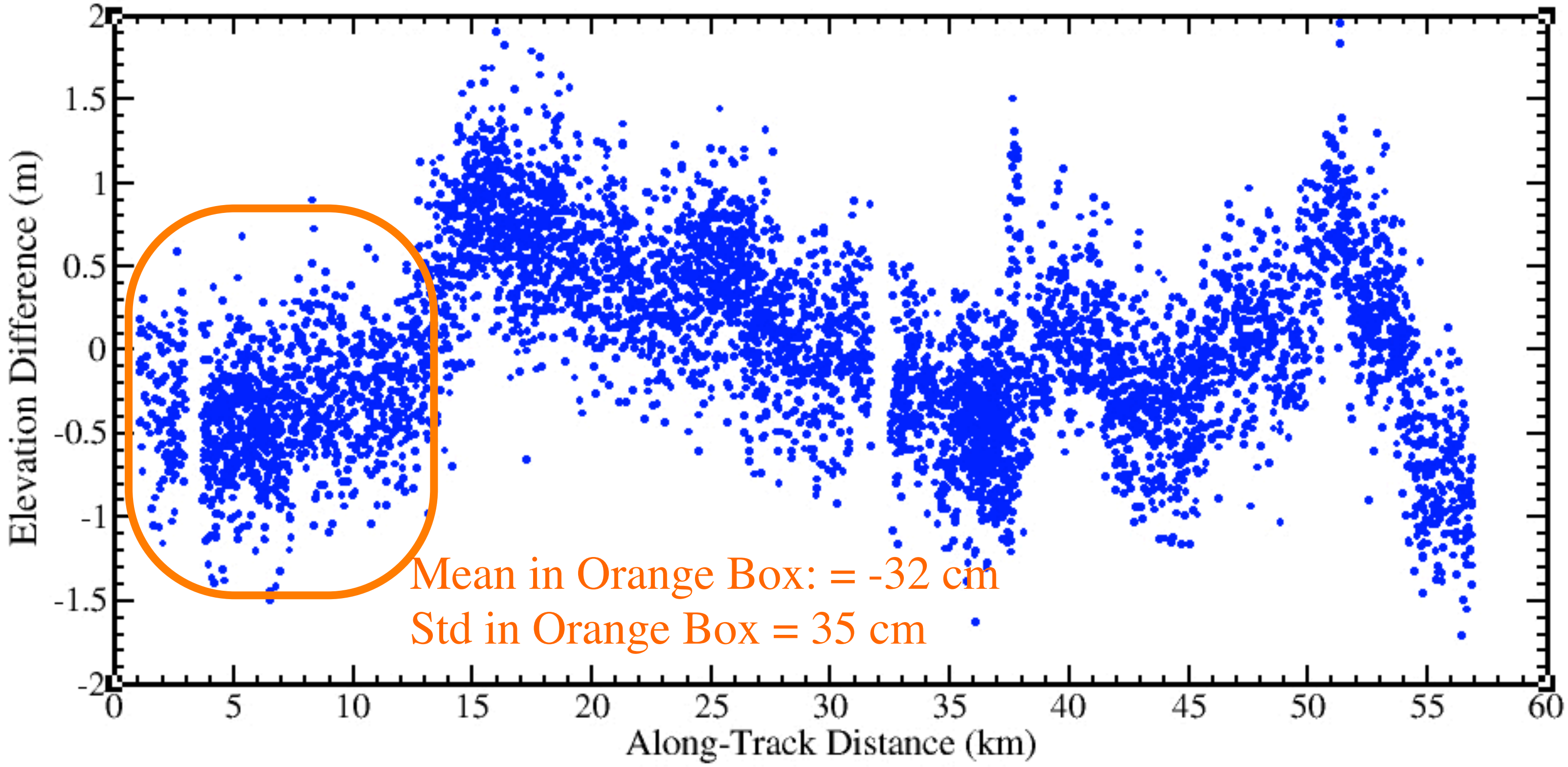
Lidar/Radar Elevation Difference Histogram

- Histogram of elevation differences between lidar and radar for points in the near range.
- Measured RMS of 55 cm (mean difference of 1.4 cm) is slightly larger than the expected value of 32 cm for no penetration.



Elevation Difference vs Along-Track Position

- There may still be a small calibration error resulting in some systematic elevation differences that is not indicative of radar penetration.
  - Positive elevation differences larger than the combined measurement precisions are signature of potential calibration issues.
- Maximal penetration is bounded from above at 44 cm with a much lower value if the systematic trends in the plot below are removed.
- Currently reanalyzing data after resolving some residual calibration issues



GLISTIN-A/H Upgrades

GLISTIN-H Upgrades

Parameter	Unit		IPY	GLISTIN-A	GLISTIN-H
Peak transmit power (at antenna)	W		40 (TWTA)	80 (SSPA)	**80 (SSPA)**
Receive Losses	dB		5	2	**2**
Ping-pong			No	Yes	**Yes**
Height precision (30x30m posting)*	m	15^{o}	0.06	0.13	**0.12**
		31^{o}	0.14	0.17	**0.20**
		49^{o}	0.50	0.54	**0.55**
Nominal flight altitude (AGL)	km		7	12	**13.7**
	kft		24	41	**45**
Nominal Swath	**km**		**6**	**11**	**12**

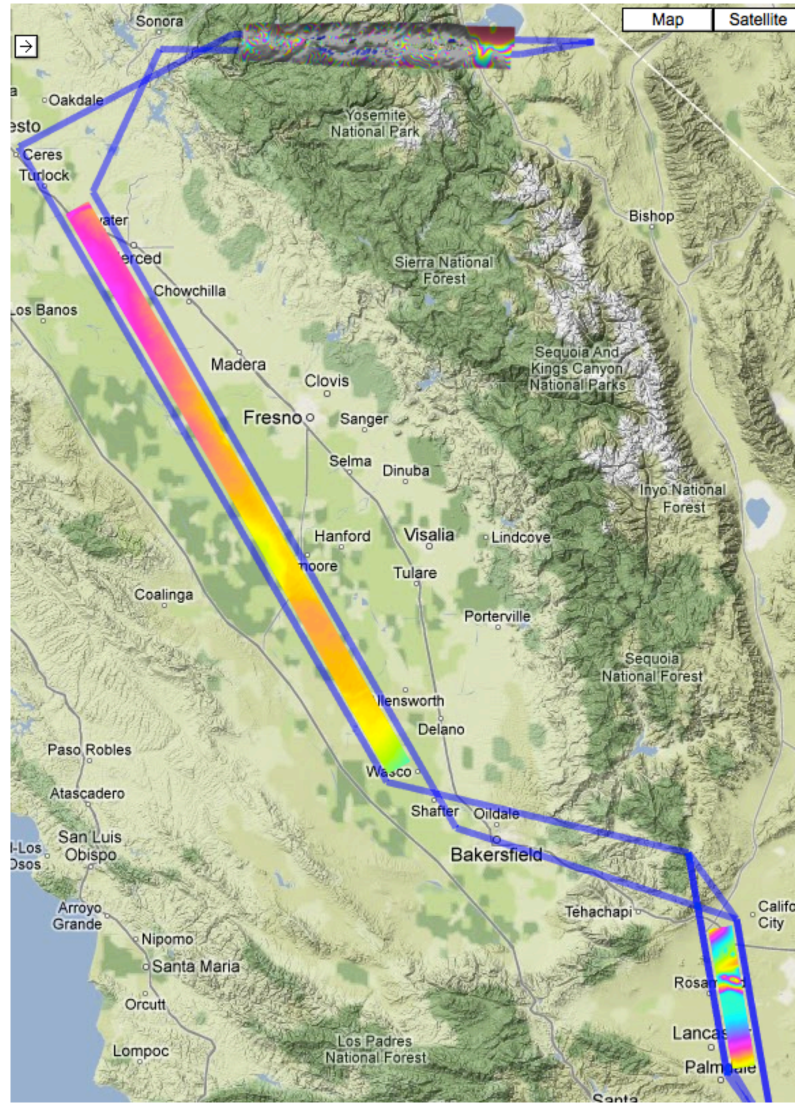
Upgrades allow higher altitude of flight -> increased swath -> decreased acquisition time for the same coverage and performance

- New RF front-end to include ping-pong
  - Minimum 80dB isolation
  - Cal-loop integrated with UAVSAR
- SSPA for pod-only configuration
  - Transmit power equivalent but reduced receive losses
- Capable of GH operation once UAVSAR is migrated
- GLISTIN-A and GLISTIN-H identical with exception of antenna boresite. (31 and 36 degrees respectively)

* Assumes dry snow cover

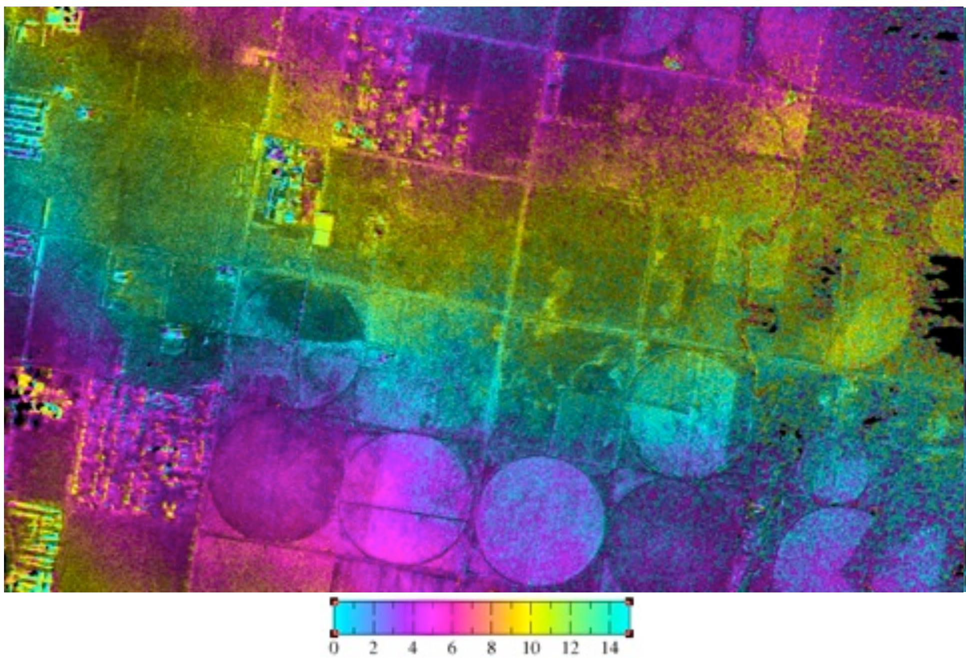
Recent Activities and Near-term Timeline

- Two local engineering flights were flown on the GIII in August 2012
- Decided to delay the remainder of the GIII engineering flights due to synergy with further upgrades for GLISTIN-H
- Test-flights on the GIII January and Feb 2013 with the GH like configuration
- GH flights Fall 2013

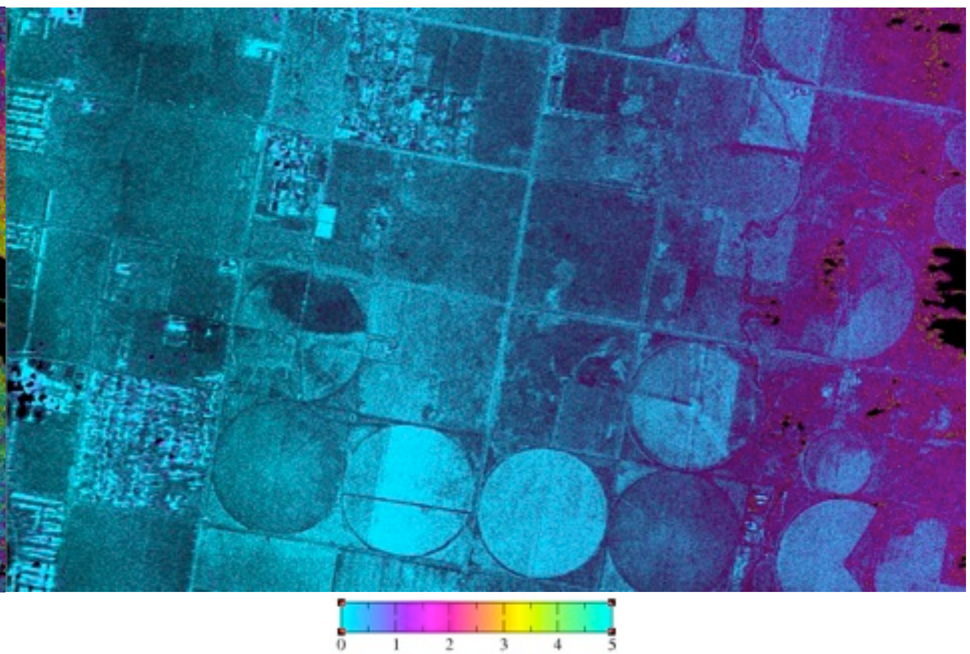


Ping-Pong Data

- Elevation and elevation precision imagery obtained over Rosamond Lake area with the GLISTIN-A system (DATA IS NOT CALIBRATED) at a flight altitude of about 9.2 km.
  - Elevation data are posted at 3 m.
  - Multi-path and switch leakage seem quite small. More work is need to quantify fully.
  - Elevation precision based on interferometric correlation is close to a priori design parameters for the ping-pong mode.



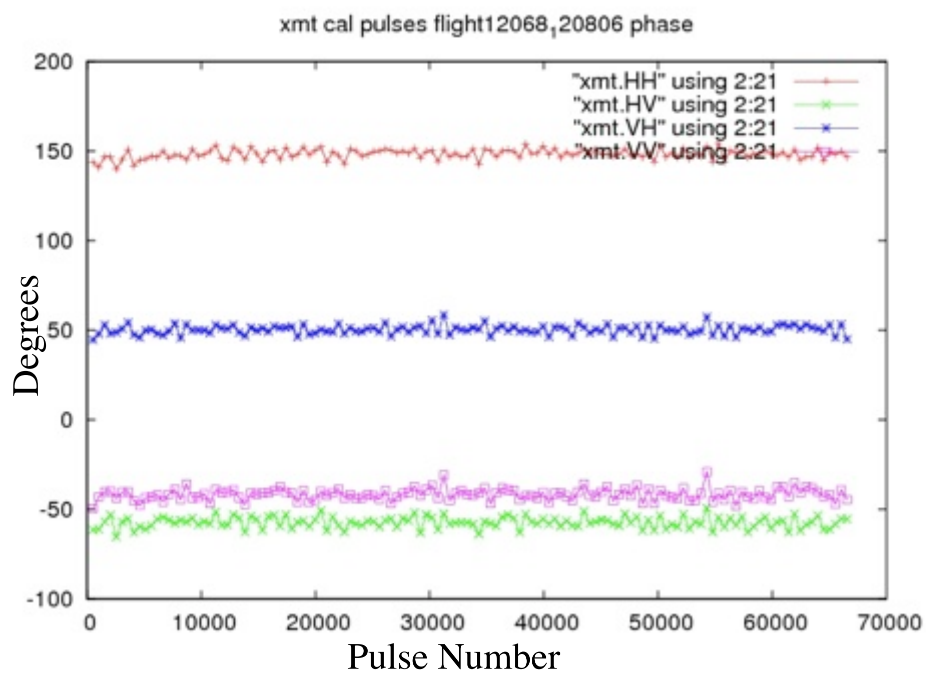
Elevation Wrap (m)

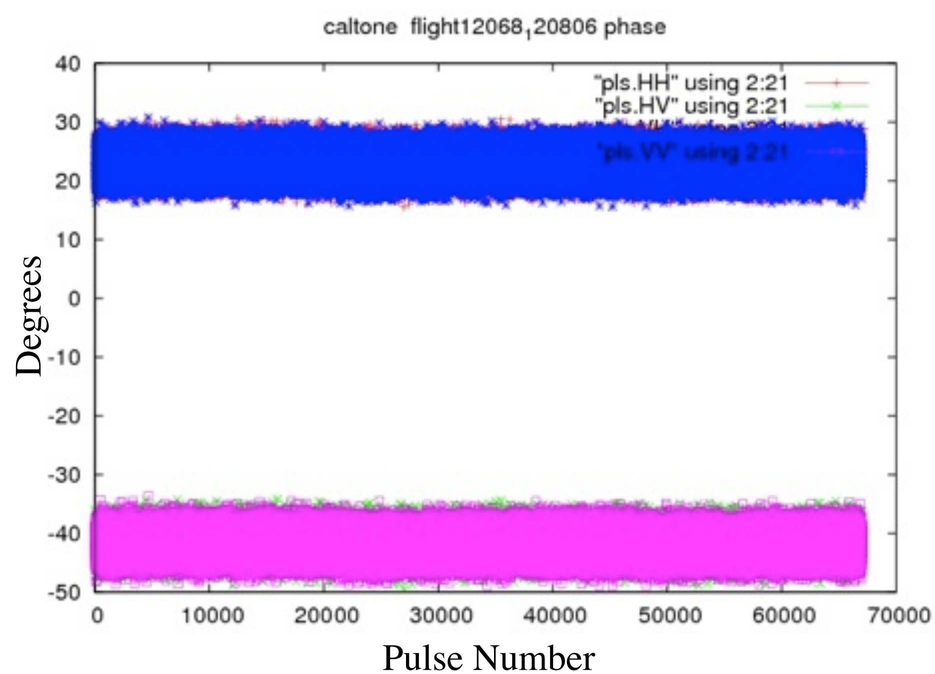


Elevation Precision (m)

Calibration Signals

- Calibration data is collected during each pass to compensate for phase drift between channels during a data collection.
  - Stability of signals is key to having a well calibrated instrument.
  - Signals look clean and stable and no along-track trending in elevations have been observed so far indicating the system is performing well. Additional evaluations are ongoing.





Current GLISTIN Technical Status

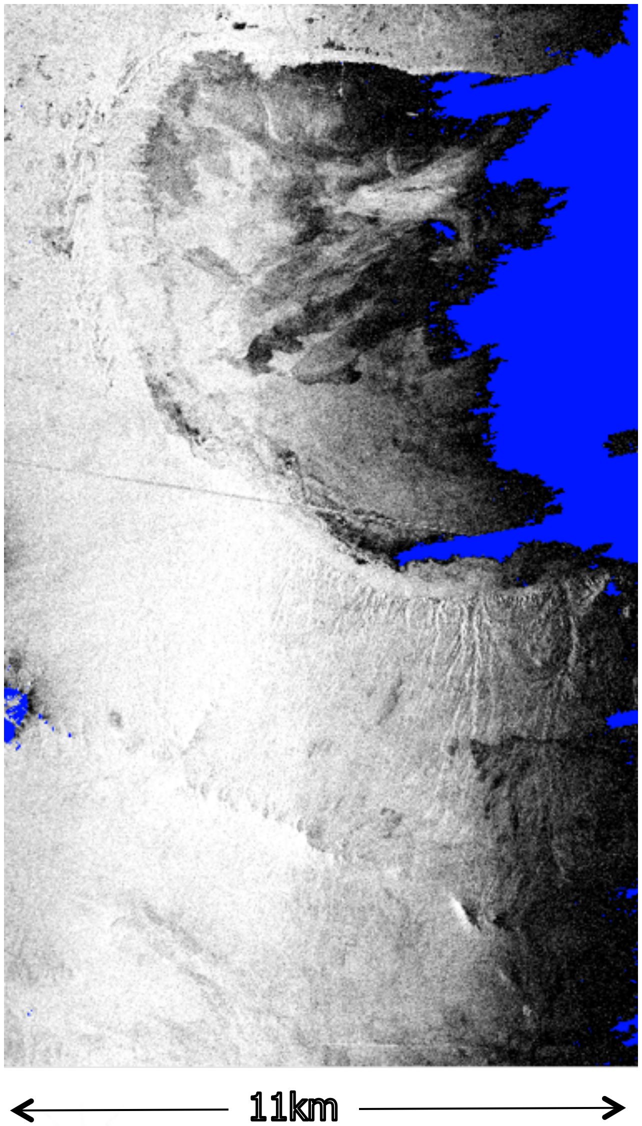
- Additional SSPA power combined, integrated and tested
  - Achieved power of 80W over bandwidth
- Antenna fairing modified for Global-hawk and GIII antenna mounting and compatibility
- GIII configuration now almost identical configuration as for the GH (only antenna angles change)
- GIII engineering flights complete.
  - detailed calibration and operational processor finalization is ongoing

GLISTIN-A ready for science campaigns!

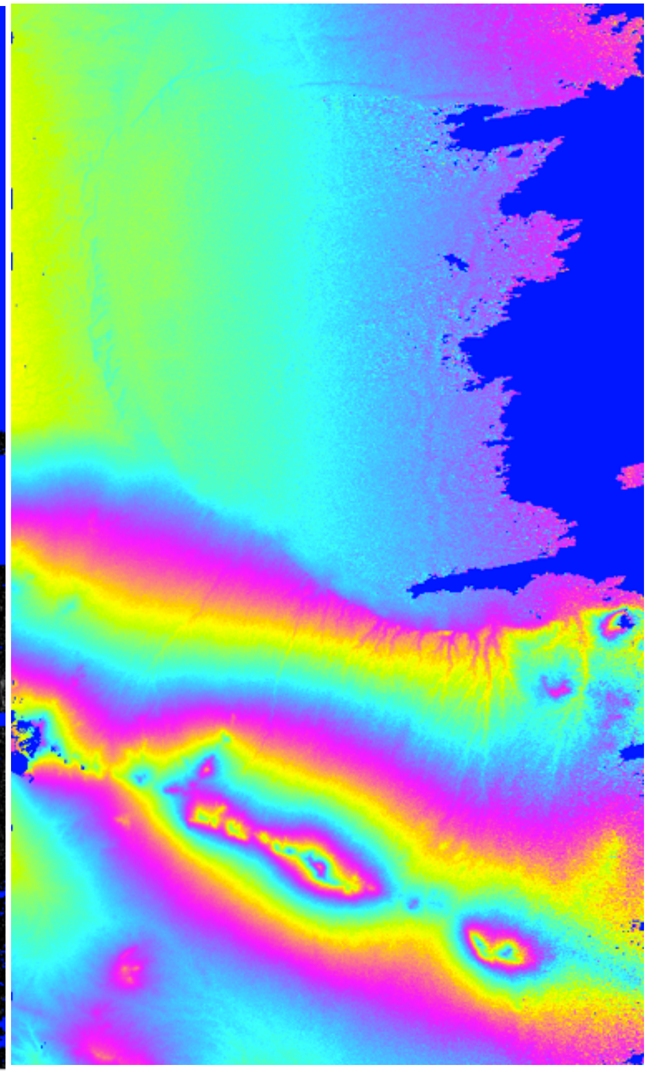
Compatible with DFRC GIII and with airworthiness assessment the JSC GIII.

Performance Assessment

Rosamond Lake Magnitude



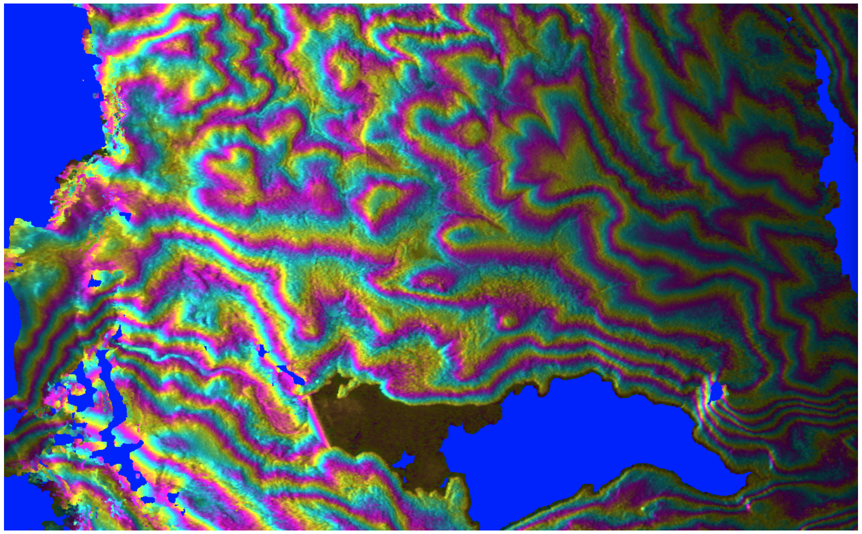
Rosamond Lake Height (80m wrap)



- Data collection at 41kft (12km)
- Errors range from 30cm near-range to 3-4m in far range for 3x3m posting
- Favorable to the sub-50cm accuracy requirement for 30x30m
- 11km swath except over very dark regions
- Snow σ_0 expected to be several dB (wet) to 10dB brighter (dry)
- Phase screen and calibration yet to complete
- Multipath phase artifacts now mitigated

Additional Science/Applications

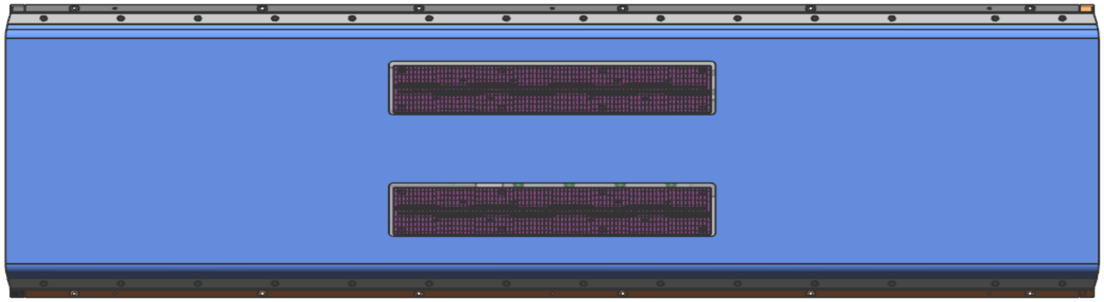
- Snow inventory assessment
  - Tuolumne Meadows flown in August over Airborne Snow Observatory (ASO – Tom Painter PI) region (“snow-off” collected August).
  - April repeat during “snow-on” in coordination with ASO airborne and ground activities and AirSWOT/ KaSPAR.

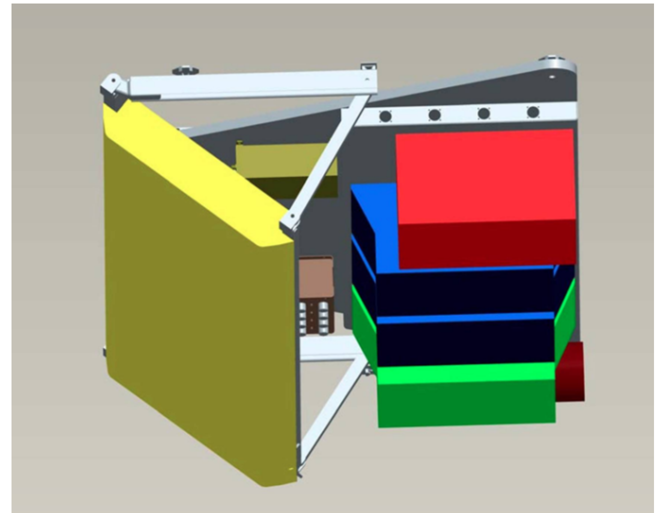


Height map over portion of Tuolumne site collected August one week after ASO collections.

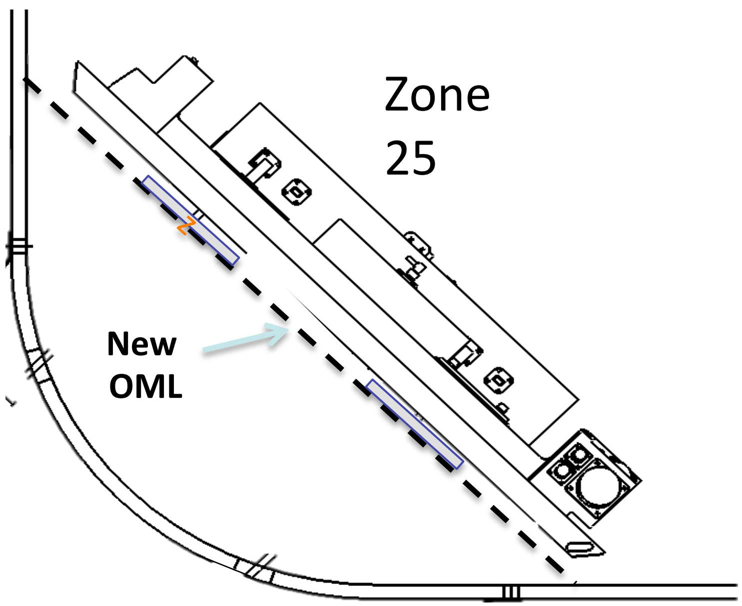
- Generation of Digital Surface Models for aviation data-bases
- Sea-ice wide-scale mapping and possible freeboard measurement (need proof of concept)
- Complementary canopy height measurements (Ka-band interferometry complementary with L- and P- Band)
- Volcanic field topography

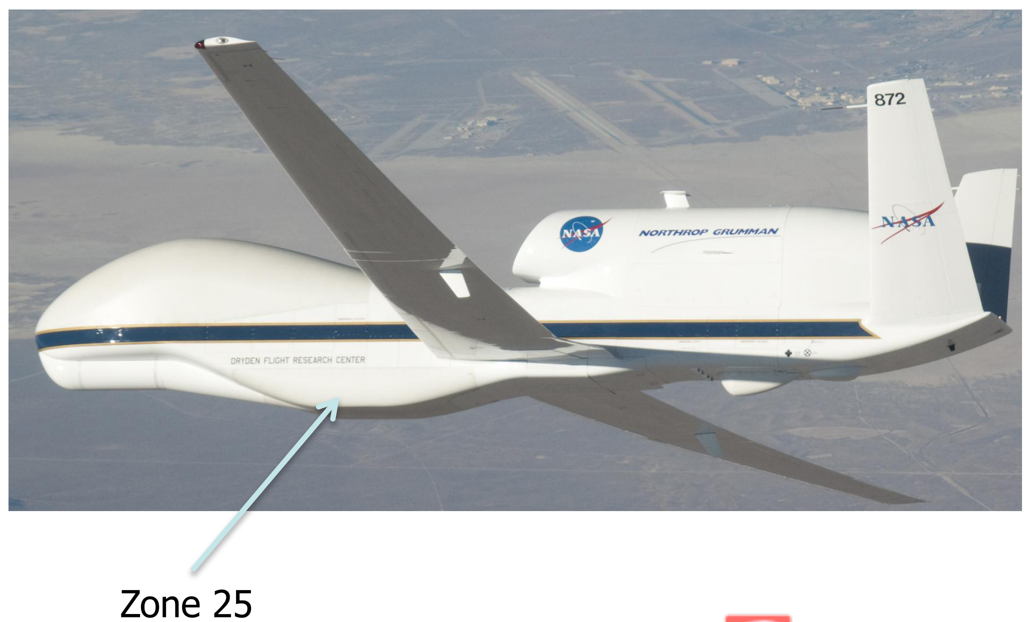
GLISTIN-H Global Hawk Radome Modification





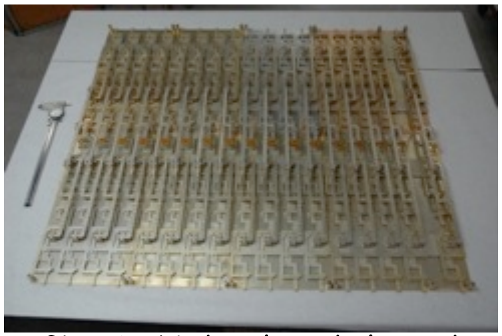
Global Hawk long-duration capability could enable observations and large scale mapping of cryospheric regions currently too remote, e.g. Antarctica.





GLISTIN-A Technology/Programmatic Heritage and Infusion

GLISTIN: IIP (2004)

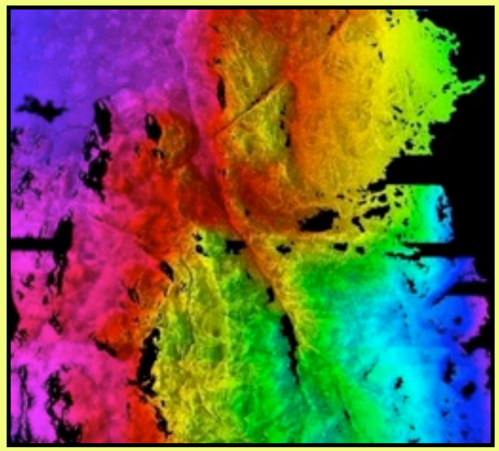


GLISTIN developed slotted waveguide array and Ka-band 16 channel digital beamformer.

DESDynI SweepSAR Airborne Demonstration

Scale demonstration on DC8 of SweepSAR for DESDynI using GLISTIN DBF and antenna technology

GLISTIN-A/H: NASA IPY & AITT (2009)



First demonstration of mm-wave SAR interferometry

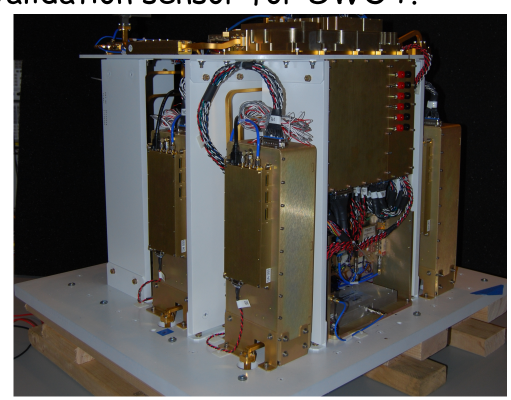
- *technology development & technique demonstration*
- *Processor development is direct heritage for KaSPAR/AirSWOT*
- *Near-nadir interferometric surface water data successfully collected and processed*

HiWRAP: NASA SBIR(2004) & IIP (2004)

Multichannel, high-throughput digital system capable of autonomous unpressurized operation

AirSWOT's KaSPAR: NASA SBIR (2009) & ESTO (2011)

Multibaseline Ka-band near-nadir interferometric calibration/ validation sensor for SWOT.



Thank you!

Questions?