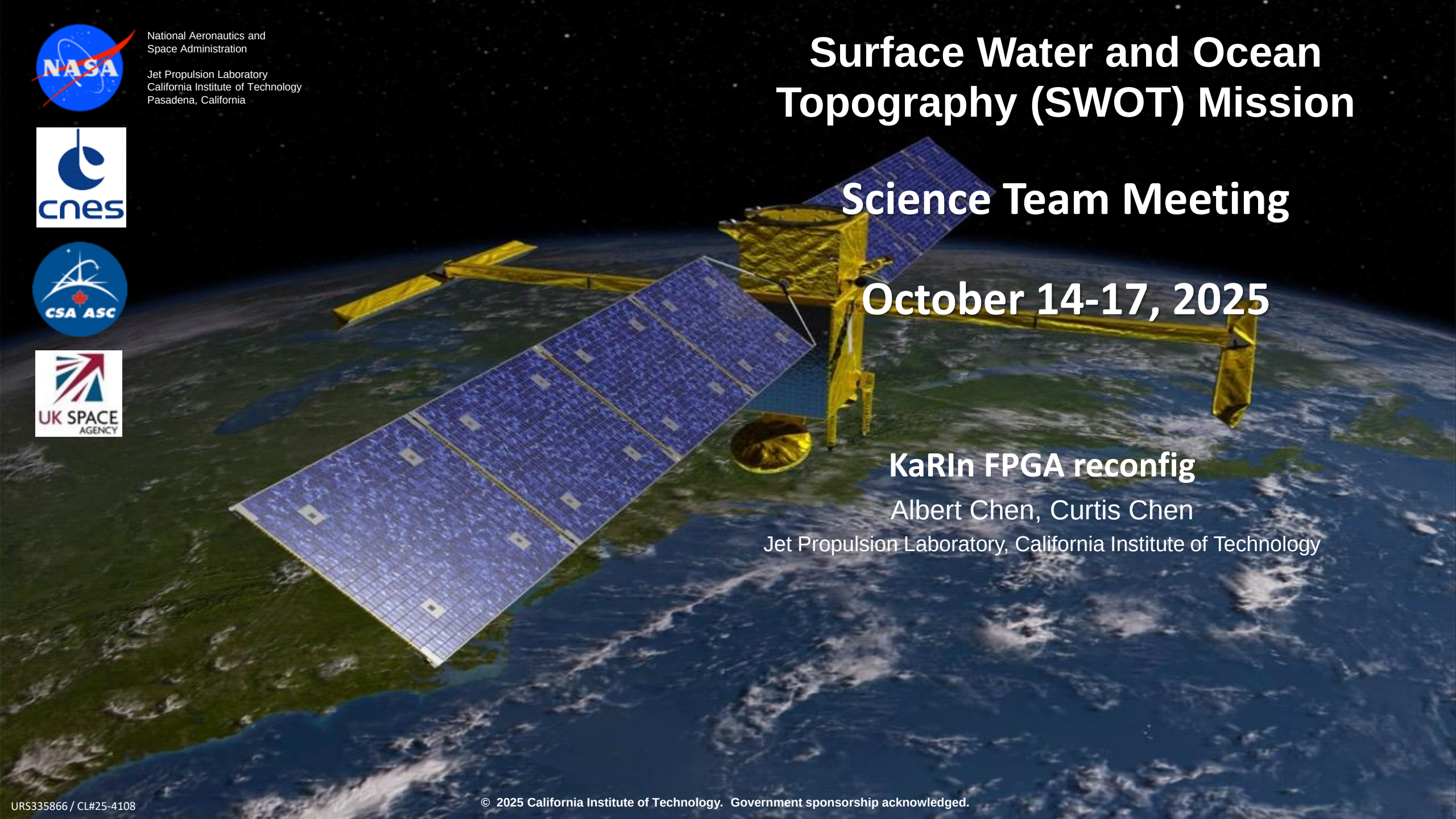

National Aeronautics and Space Administration

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Pasadena, California

# Surface Water and Ocean Topography (SWOT) Mission

## Science Team Meeting

## October 14-17, 2025

### KaRIn FPGA reconfig

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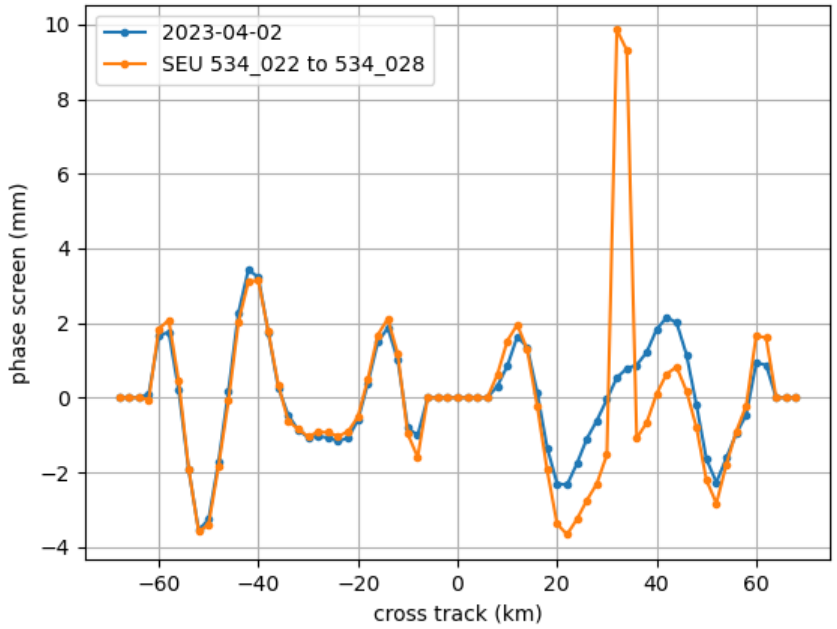
# Overview

- KaRIn on-board processor (OBP) is implemented using electronic field-programmable gate array (FPGA) chips that are somewhat susceptible to upset by ionizing radiation in space.
- An ionizing particle may cause one or more binary bits to be erroneously flipped. This is called a single event upset (SEU). This occurs at random times due to the radiation environment in low-Earth orbit.
  - We show examples of effects on LR data.
- KaRIn OBP periodically does “reconfigs” to clear SEU effects, but these result in missing data in polar regions.

# Single Event Upset (SEU)

- Some LR data is affected by single event upsets (SEUs) in the on-board processor (OBP) hardware.
  - Caused by ionizing radiation in the space environment.
  - Sometimes called “radiation hits”.
- Starts abruptly (but may start over land)
- Ends when the on-board processor automatically resets itself to clear radiation corruption (“FPGA reconfig”).
  - This is done every 7 passes at/near pass boundaries.
- Version D flagging algorithm does not specifically detect these artifacts.



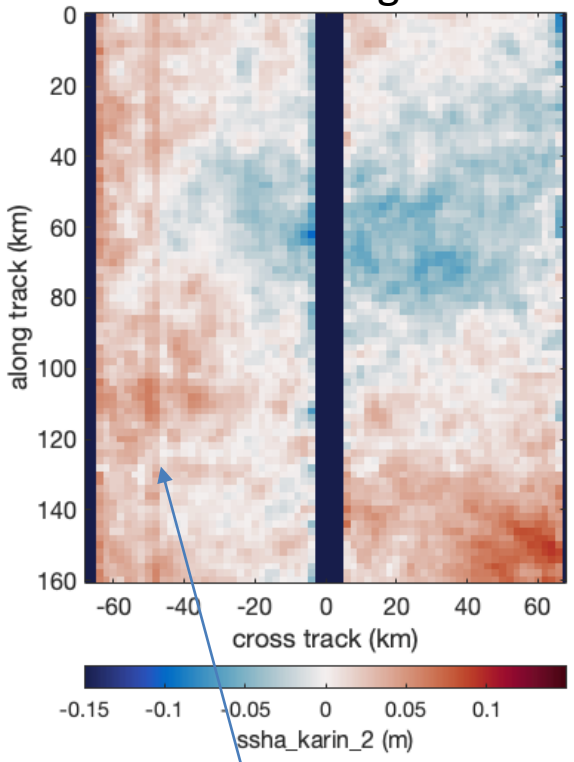

Phase screen computed from data affected by SEU differs from that of unaffected data.

# Single Event Upset (SEU) Example

Example SEU artifact, which affected cycle 010, pass 033 to 039.
Plots show Pass 037 around 32.7°

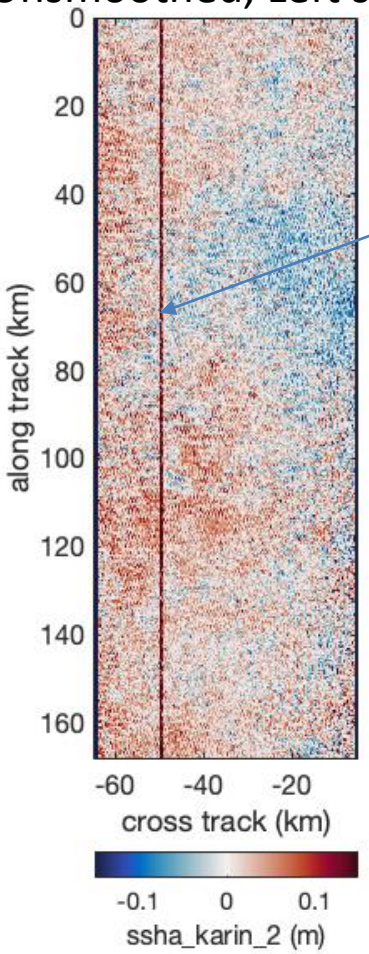
Basic/Expert

Left swath Right swath

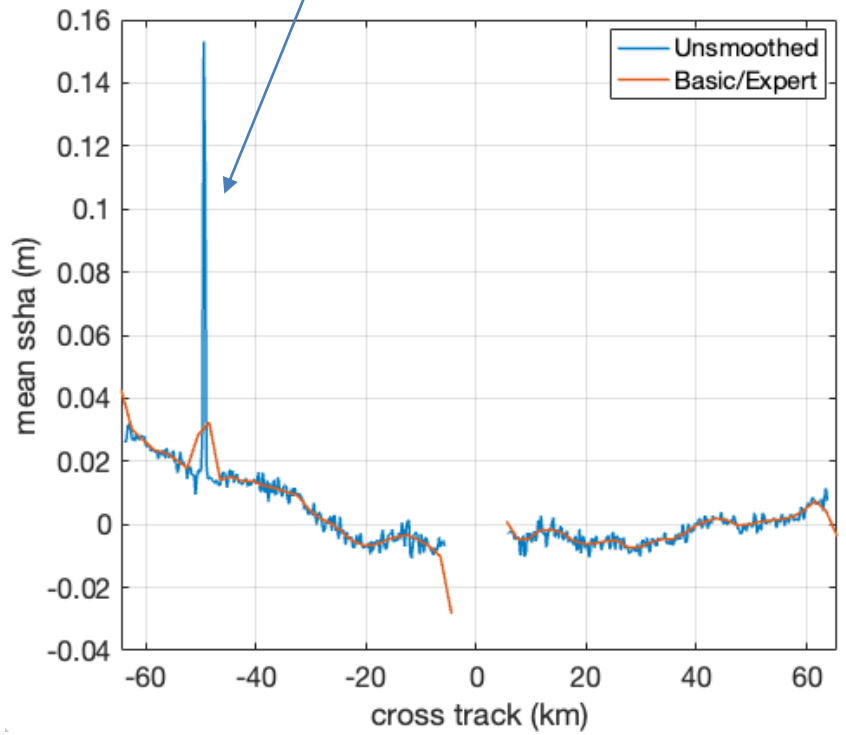



~1 cm height error in Basic/Expert

Unsmoothed, Left swath




~13 cm height error in Unsmoothed, ~1 cm height error in Basic/Expert

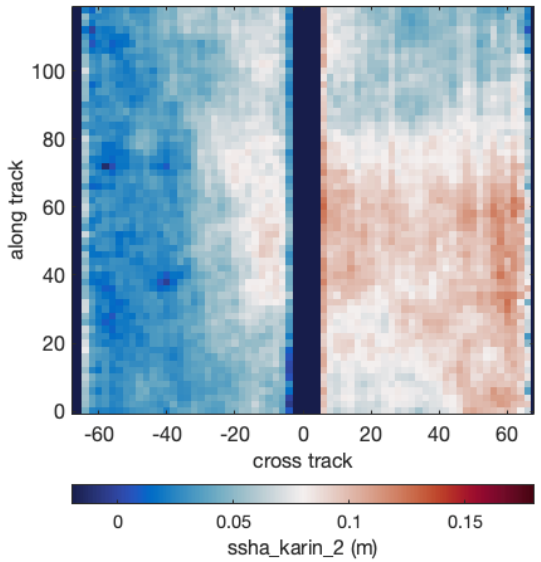


# Single Event Upset (SEU) Example

Example SEU artifact, which affected cycle 003, pass 365 to 368.
Plots show pass 365 around 26.5° S, 36.3° W (in South Atlantic Anomaly)

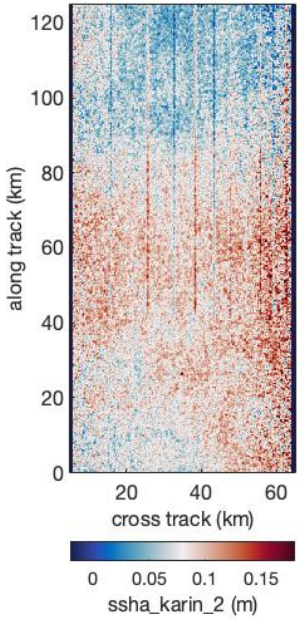
Basic/Expert

Left swath Right swath



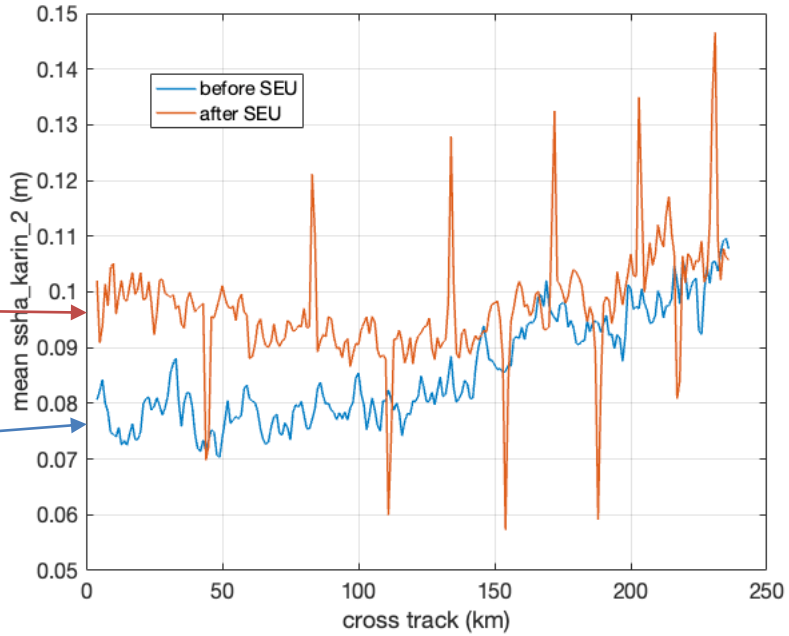

S/C flight direction

Unsmoothed Right swath




Start of artifact

Along-track mean of unsmoothed ssha, Right swath

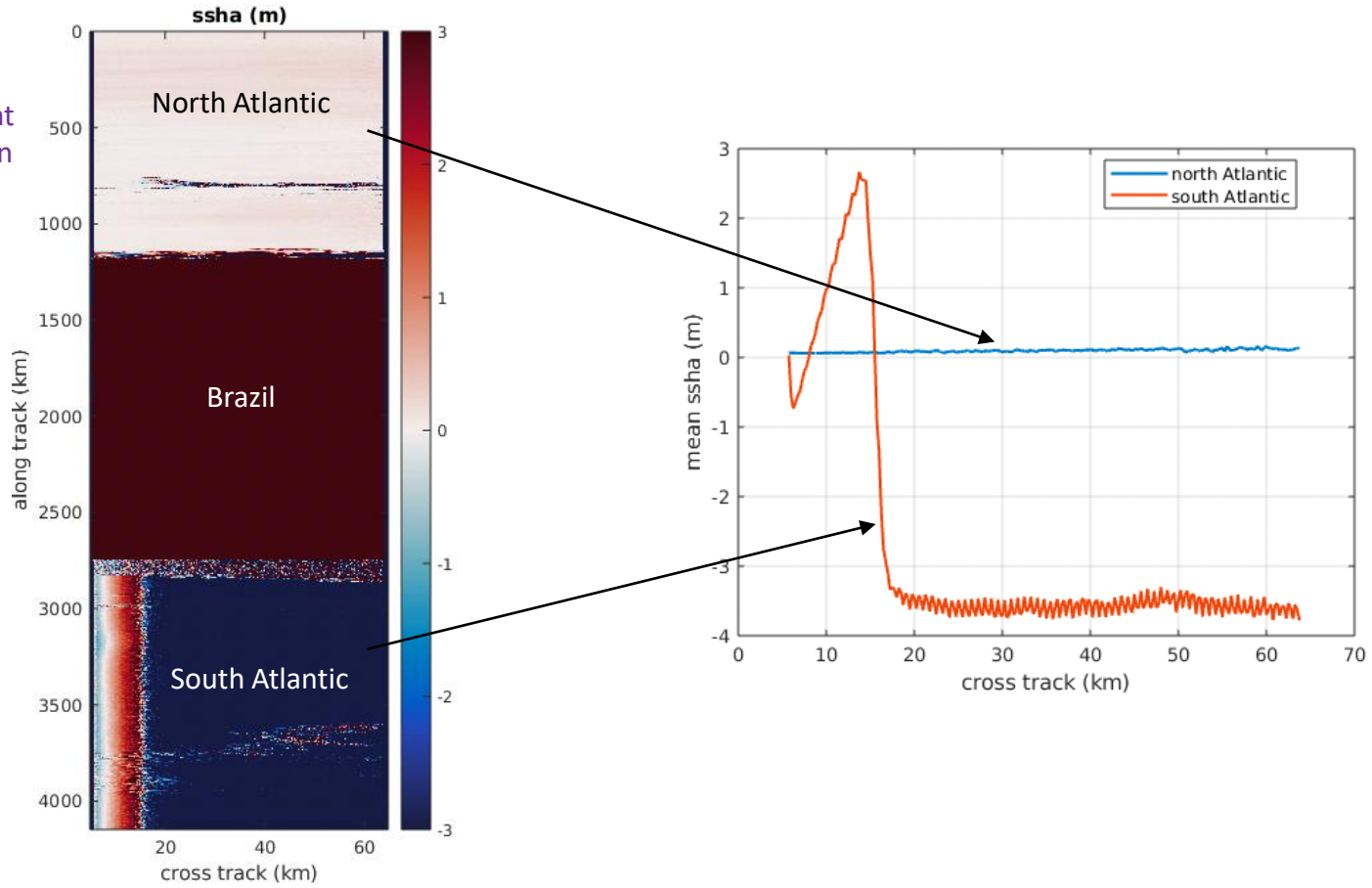


# Single Event Upset (SEU) Example

Example SEU artifact, which affected cycle 031, pass 352 to 354.
Plots show pass 352 between 10° N and 35° S.

Unsmoothed
Right swath

S/C flight direction




Artifact starts somewhere over Brazil

Unrealistic SSHA lasts until next FPGA reconfig

Note: This example looks very different from the others. SEU effects are unpredictable and depend on which bit(s) in OBP got flipped.


# FPGA reconfig

- The FPGA that implements the On-Board Processor (OBP) gets reconfigured (“FPGA reconfig”) every 7 passes (~6 hours). This is also known as “FPGA reload”. (See also SWOT User Handbook, Sec. 9.2.4.)
- During FPGA reconfig, KaRIn does not produce any data. Each reconfig takes about 90 sec, and results in an LR data gap approximately 600 km long.
- The reconfigs happen in polar regions, to avoid missing data over oceans and terrestrial hydrology targets.
- As of Version D, L2_LR_SSH Expert data samples that are missing because of FPGA reconfigs are flagged as bad, but the quality flag does not explicitly indicate whether the sample is bad due to an FPGA reconfig or a different reason. Unsmoothed files with missing data at the beginning/end due to FPGA reconfig have fewer lines than nominal Unsmoothed files.

FPGA = Field Programmable Gate Array

# Reconfig passes

Cal/Val Orbit

FPGA reconfig happens at the ends of these passes:

7, 14, 21, 28

Science Orbit

FPGA reconfig happens at the ends of these passes:

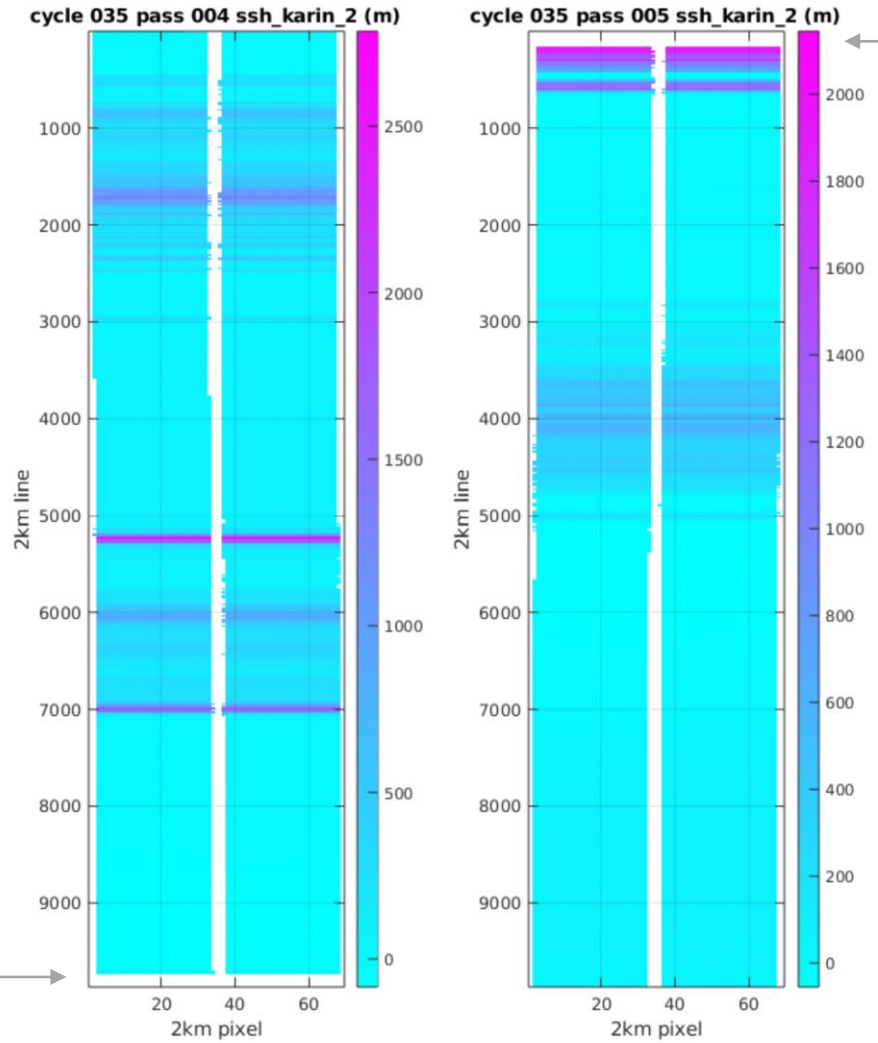
4, 11, 18, 25, 32, 39, 46, 53, 60, 67, 74, 81, 88, 95,102,109, 116, 123, 130, 137, 144, 151, 158, 165, 172, 179, 186, 193, 200, 207, 214, 221, 228, 235, 242, 249, 256, 263, 270, 277, 284, 291, 298, 305, 312, 319, 326, 333, 340, 347, 354, 361, 368, 375, 382, 389, 396, 403, 410, 417, 424, 431, 438, 445, 452, 459, 466, 473, 480, 487, 494, 501, 508, 515, 522, 529, 536, 543, 550, 557, 564, 571, 578, 583

This is every 7 passes, *except* between 578 and 583, and between 583 and pass 4 of the next cycle. There are 84 total reconfigs in each cycle.

Notes:

- All reconfigs begin near the end of the pass, continuing into the beginning of the next pass, except for cal/val pass 28, which starts a bit earlier in the pass.
- Reconfigs are alternating Arctic/Antarctic.

# Example of reconfig missing data

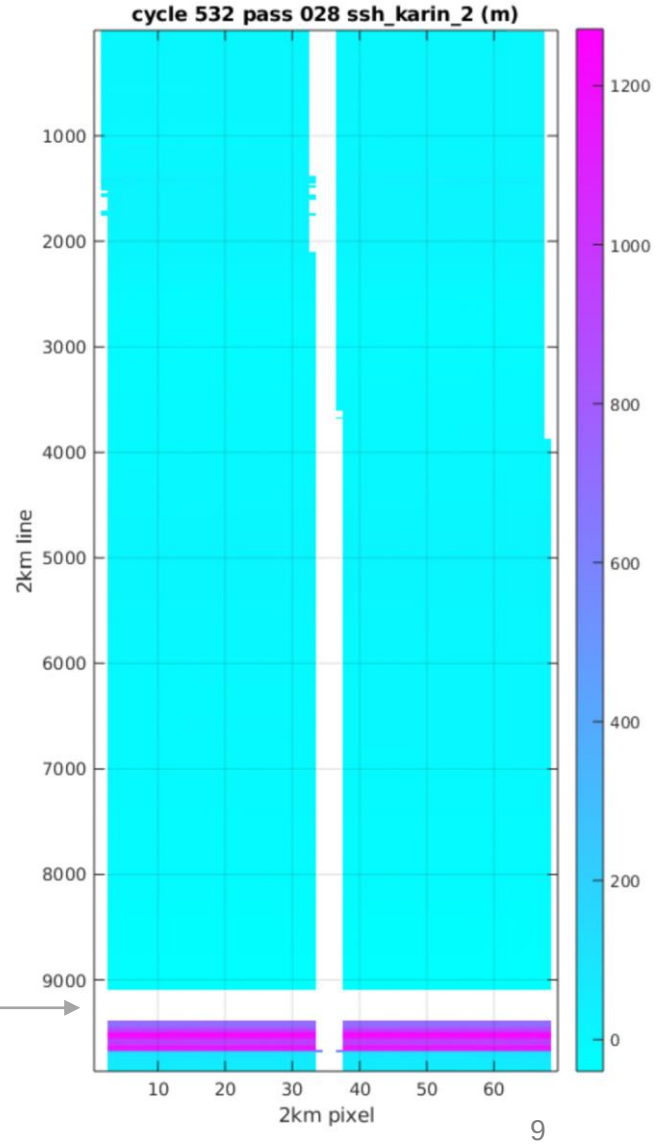






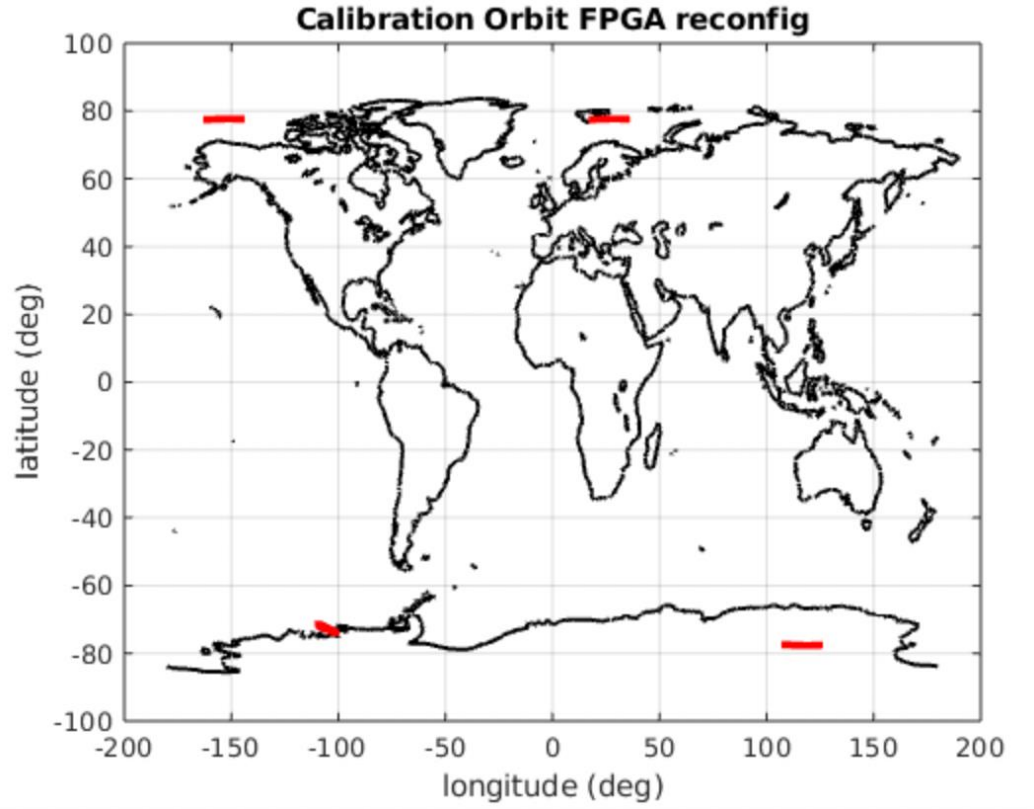
Reconfig finishes at beginning of pass 5

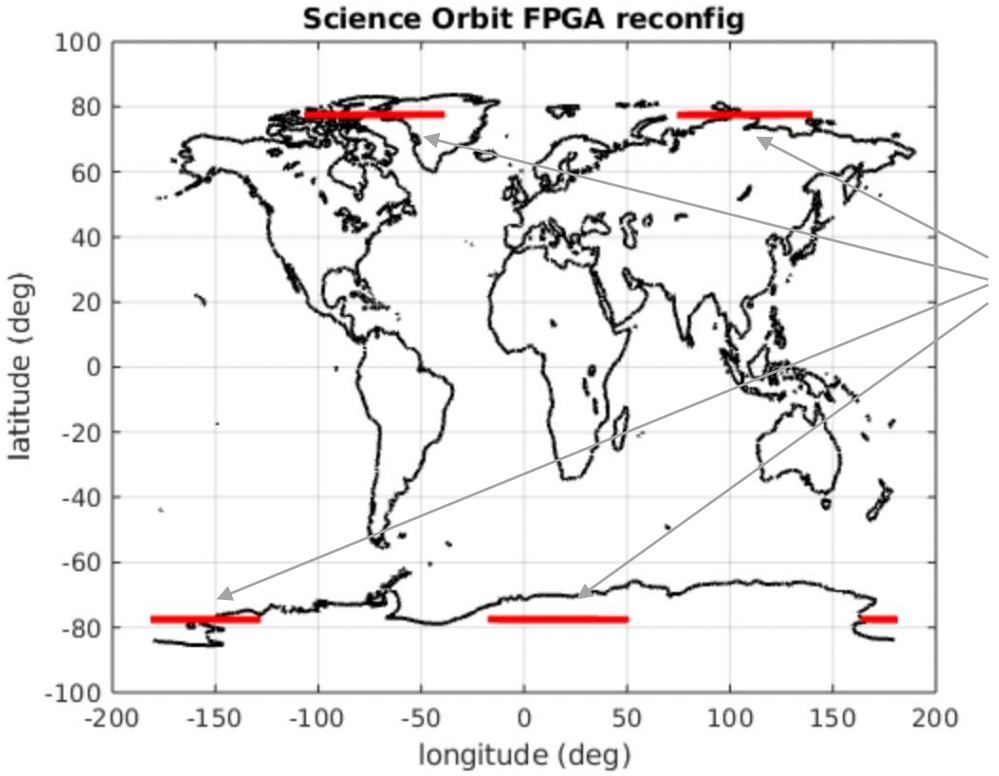
Sci orbit Reconfig starts end of pass 4




Cal/Val orbit pass 28 has reconfig here.

# Geographical Locations

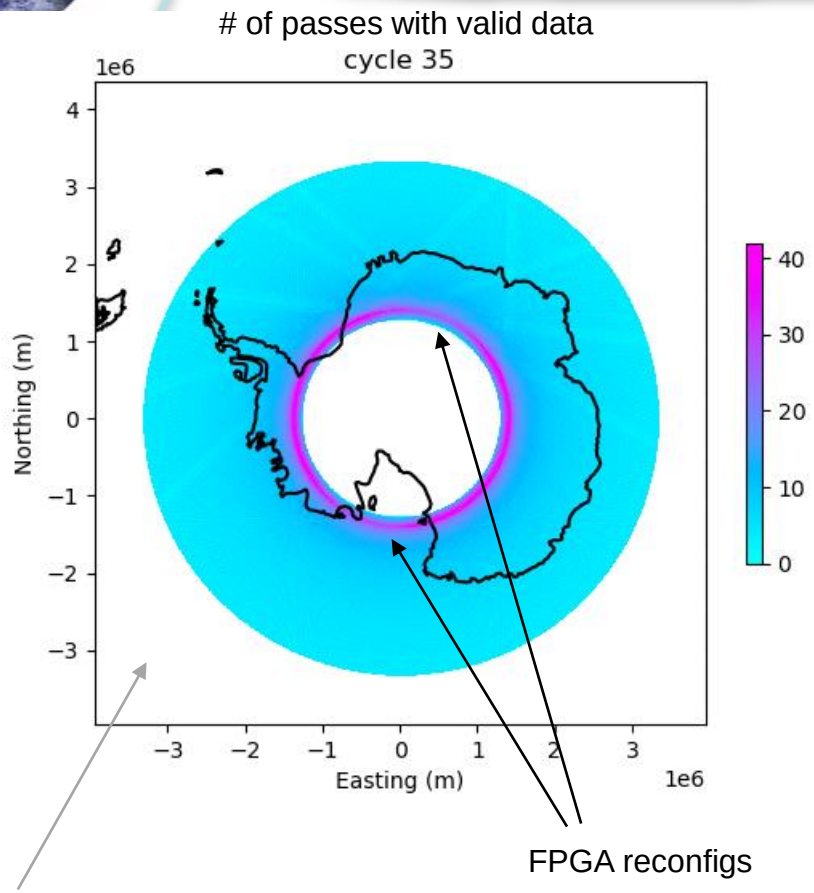



21 reconfigs occur in each geoghraphical region

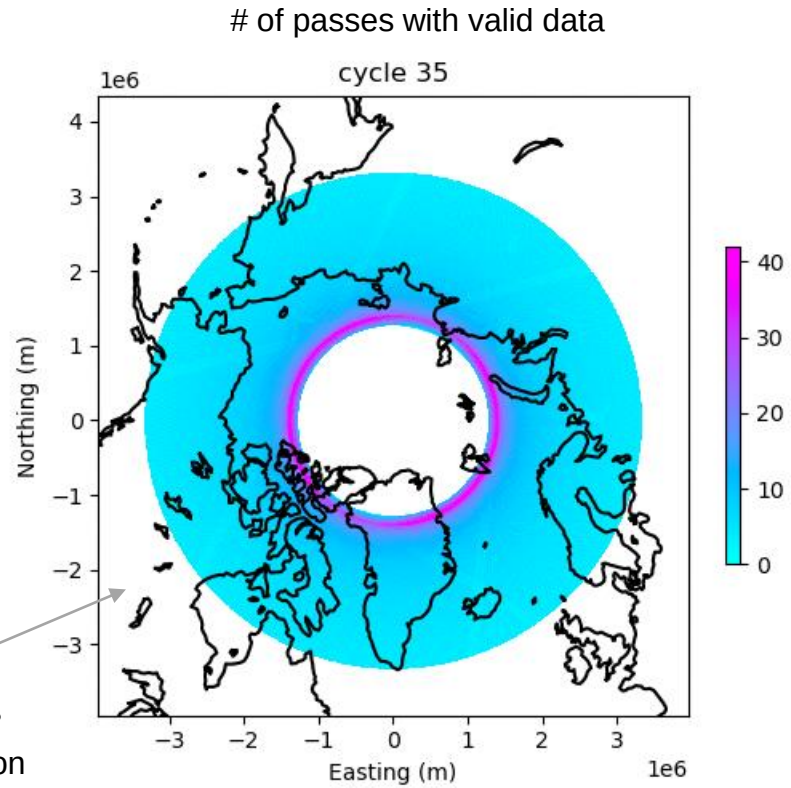
Note: For science orbit, although reconfigs occur in the red areas, those areas are still observed during multiple other passes without reconfigs, so data are still available (see next slide).

# Geographical coverage

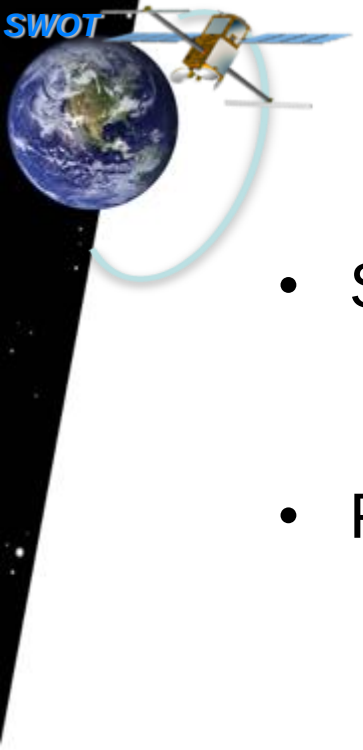



Note: Data north of −60° latitude are not shown on this plot.

- The plots shows maps of how many KaRIn passes have valid data over each point in the polar regions for cycle 35.
- There is less coverage in the areas where FPGA reconfigs happen, but we still have at least one pass everywhere.




Note: Data south of 60° latitude are not shown on this plot.




# Conclusion

- SEUs cause occasional errors, especially in LR data.
  - The processors do not have an algorithm that flags these errors.
  - SEU error characteristics are unpredictable but can be very large.
- FPGA reconfigs ensure SEU errors last less than 6 hours.
  - FPGA reconfigs imply some unavailability of data from selected passes over polar regions.
  - However, those polar areas are amply covered by other passes.