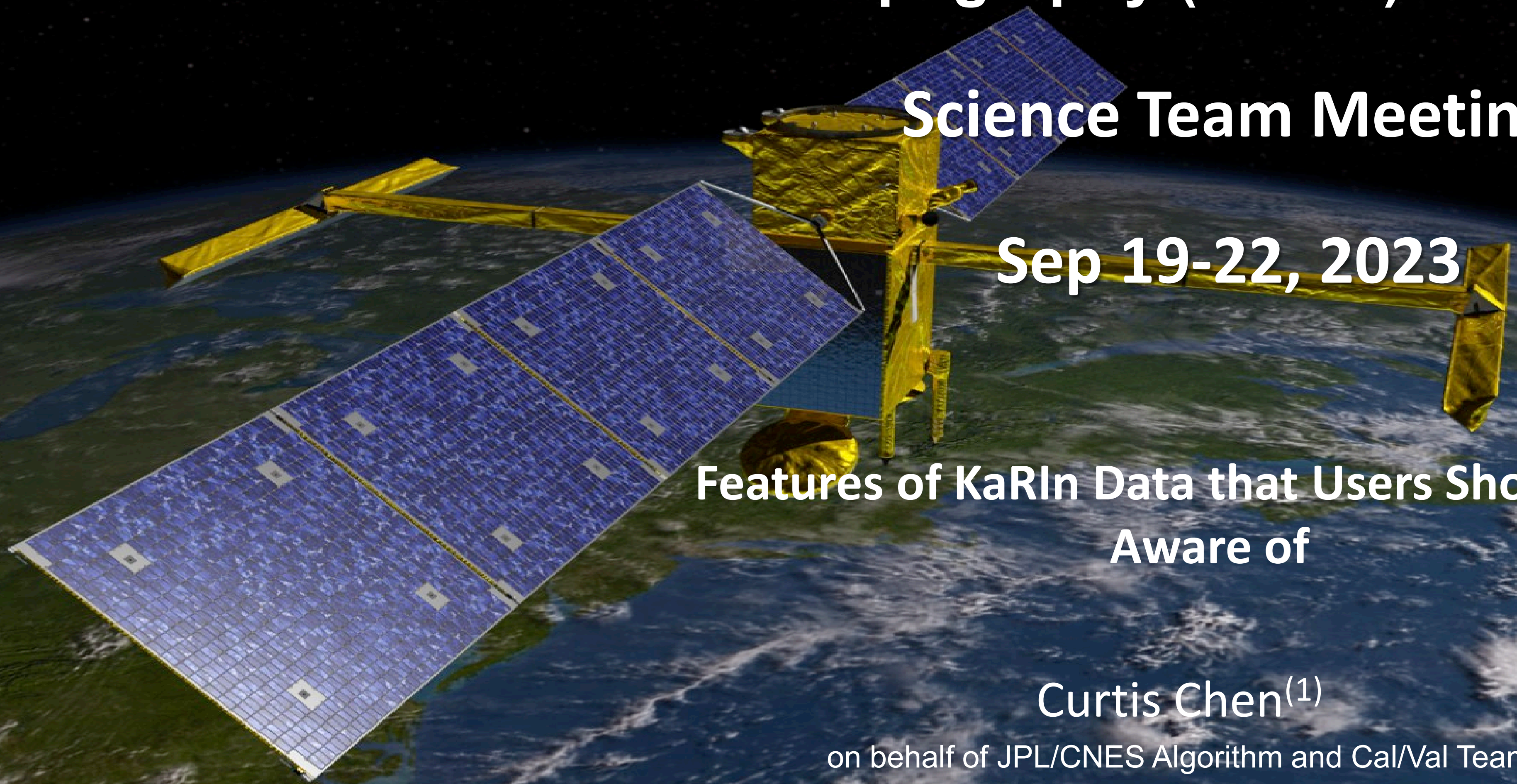
National Aeronautics and
Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

# Surface Water and Ocean Topography (SWOT) Mission

## Science Team Meeting

## Sep 19-22, 2023



# Features of KaRIn Data that Users Should be Aware of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# Introduction

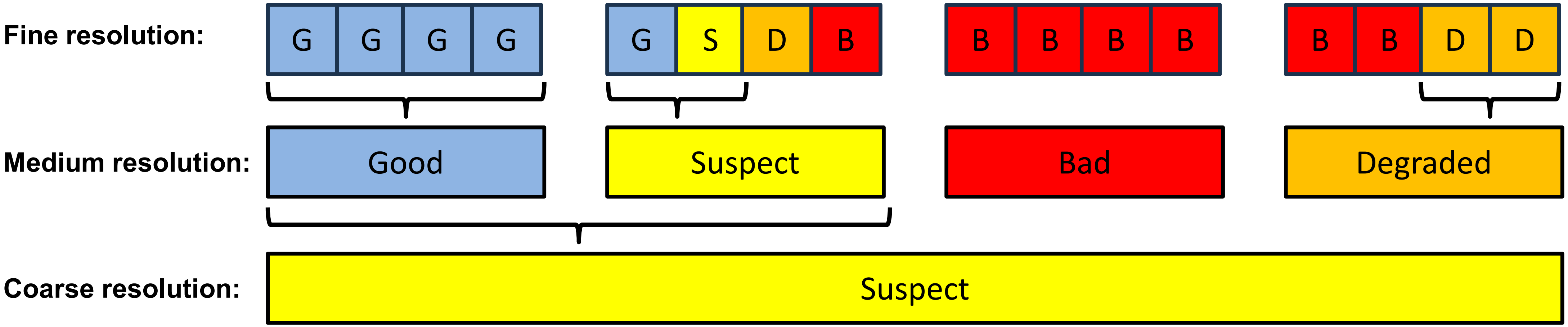
- KaRIn measurement is complicated!
  - Data products attempt to abstract complexities of measurement from users as much as possible, but many items that may not be immediately intuitive remain
  - Knowledge of measurement details can be especially important in trying to interpret pre-validated data products
- This talk addresses practical aspects of interpreting KaRIn data products
  - Answers to frequently asked questions
  - Tips to hopefully avoid misinterpretation and confusion
- General topics:
  - Definitions, conventions, and data representation
  - Data availability
  - Phenomenology to be aware of

# Look at the Quality Flags!

- **Users should pay attention to quality flags in KaRIn products**
  - Measurement values are associated with quality flags
  - Quality flag variables are usually called {measurement_variable}_qual
    - Example: If measurement variable is named height then associated quality flag is usually named height_qual
    - Quality flag variable name for given measurement variable is indicated by metadata in product
      - NetCDF: See the *quality_flag* variable attribute
      - Shapefile: See the *quality_flag* field in the shp.xml file
- Quality flag indicates whether measurement is “good,” “suspect,” “degraded”, or “bad”:
  - “Good”: Processing did not find any reason to disbelieve measurement
  - “Suspect”: Something about measurement was not quite as expected, so measurement may be worse than normal, but may also be fine
  - “Degraded”: Something about the measurement was definitely wrong, so measurement is likely worse than normal (though not necessarily by a lot)
  - “Bad”: Measurement is likely nonsensical (e.g., null filled)

# Quality Flags and Averaging

- Quality flags affect how averaging is done during ground processing
  - Good and suspect data samples are always used when averaging
    - If only good samples are used, then averaged output is marked good
    - If suspect samples are used, then averaged output *may* be marked suspect
  - Degraded data samples are used when averaging only if there are too few good and suspect samples
    - If degraded data samples are used, then averaged output is flagged as degraded
  - Bad data samples are never used when averaging



# Quality Bit Flag Interpretation

- Many quality flags in different KaRIn products are defined as bit flags
  - Bit flag is unsigned integer whose individual bits indicate different off-nominal conditions
  - Allows single variable to contain multiple levels of information
- Simplest interpretation: See if flag is 0 or nonzero
  - If flag = 0, then measurement is “good” (0 always means “good” for KaRIn quality flags)
  - If flag $\neq$ 0, then measurement is not “good”
- Straightforward interpretation: Interpret flag as numeric value and compare to Threshold1 and Threshold2 defined in metadata of flag variable (and PDD):
  - If flag = 0, then measurement is “good” (0 always means “good” for KaRIn quality flags)
  - If flag $\neq$ 0, then
    - If 0 < flag $\leq$ Threshold1, then measurement is “suspect”
    - If threshold1 < flag $\leq$ Threshold2, then measurement is “degraded”
    - If flag > threshold2, then measurement is “bad”
- More sophisticated interpretation:
  - If flag = 0, then measurement is “good” (0 always means “good” for KaRIn quality flags)
  - If flag $\neq$ 0, then decompose nonzero flag value into individual nonzero bits to determine what exactly was not good about measurement (see example on next slide) and interpret measurement accordingly
    - Top-level bit definitions are in metadata of flag variable
    - Additional details on bit definitions are in PDDs

SWOT

# Quality Bit Flag Example

See Appendix B of L2_LR_SSH PDD for details on this example

| Bit (from LSB) | Decimal | Hexadecimal | ssh_karin_qual | ssha_karin_qual | swh_karin_qual | sig0_karin_qual | wind_speed_karin_qual |
|---|---|---|---|---|---|---|---|
| 0 | 1 | 1 | suspect_large_ssh_delta | suspect_large_ssh_delta | | suspect_large_nrcs_delta | |
| 1 | 2 | 2 | suspect_large_ssh_std | suspect_large_ssh_std | | suspect_large_nrcs_std | |
| 2 | 4 | 4 | suspect_large_ssh_window_std | suspect_large_ssh_window_std | | suspect_large_nrcs_window_std | |
| 3 | 8 | 8 | suspect_beam_used | suspect_beam_used | suspect_beam_used | suspect_beam_used | suspect_beam_used |
| 4 | 16 | 10 | suspect_less_than_nine_beams | suspect_less_than_nine_beams | suspect_less_than_nine_beams | suspect_less_than_nine_beams | suspect_less_than_nine_beams |
| 5 | 32 | 20 | | | suspect_rain_likely | | |
| 6 | 64 | 40 | suspect_ssb_out_of_range | suspect_ssb_out_of_range | | | |
| 7 | 128 | 80 | suspect_pixel_used | suspect_pixel_used | suspect_pixel_used | suspect_pixel_used | suspect_pixel_used |
| 8 | 256 | 100 | suspect_num_pt_avg | suspect_num_pt_avg | suspect_num_pt_avg | suspect_num_pt_avg | suspect_num_pt_avg |
| 9 | 512 | 200 | suspect_karin_telem | suspect_karin_telem | suspect_karin_telem | suspect_karin_telem | suspect_karin_telem |
| 10 | 1024 | 400 | suspect_orbit_control | suspect_orbit_control | suspect_orbit_control | suspect_orbit_control | suspect_orbit_control |
| 11 | 2048 | 800 | suspect_sc_event_flag | suspect_sc_event_flag | suspect_sc_event_flag | suspect_sc_event_flag | suspect_sc_event_flag |
| 12 | 4096 | 1000 | suspect_tvp_qual | suspect_tvp_qual | suspect_tvp_qual | suspect_tvp_qual | suspect_tvp_qual |
| 13 | 8192 | 2000 | suspect_volumetric_corr | suspect_volumetric_corr | suspect_volumetric_corr | suspect_volumetric_corr | suspect_volumetric_corr |
| 14 | 16384 | 4000 | | | | | |
| 15 | 32768 | 8000 | degraded_ssb_not_computable | degraded_ssb_not_computable | | | |
| 16 | 65536 | 10000 | degraded_media_delays_missing | degraded_media_delays_missing | | degraded_media_attenuation_missing | degraded_media_attenuation_missing |
| 17 | 131072 | 20000 | degraded_beam_used | degraded_beam_used | degraded_beam_used | degraded_beam_used | degraded_beam_used |
| 18 | 262144 | 40000 | degraded_large_attitude | degraded_large_attitude | degraded_large_attitude | degraded_large_attitude | degraded_large_attitude |
| 19 | 524288 | 80000 | degraded_karin_ifft_overflow | degraded_karin_ifft_overflow | degraded_karin_ifft_overflow | degraded_karin_ifft_overflow | degraded_karin_ifft_overflow |
| 20 | 1048576 | 100000 | | | | | |
| 21 | 2097152 | 200000 | | | | | |
| 22 | 4194304 | 400000 | | | | | |
| 23 | 8388608 | 800000 | | | | | |
| 24 | 16777216 | 1000000 | bad_karin_telem | bad_karin_telem | bad_karin_telem | bad_karin_telem | bad_karin_telem |
| 25 | 33554432 | 2000000 | bad_very_large_attitude | bad_very_large_attitude | bad_very_large_attitude | bad_very_large_attitude | bad_very_large_attitude |
| 26 | 67108864 | 4000000 | | bad_tide_corrections_missing | | | |
| 27 | 134217728 | 8000000 | bad_ssb_missing | bad_ssb_missing | | | |
| 28 | 268435456 | 10000000 | bad_radiometer_corr_missing | bad_radiometer_corr_missing | | bad_radiometer_media_attenuation_missing | bad_radiometer_media_attenuation_missing |
| 29 | 536870912 | 20000000 | bad_outside_of_range | bad_outside_of_range | bad_outside_of_range | bad_outside_of_range | bad_outside_of_range |
| 30 | 1073741824 | 40000000 | degraded | degraded | degraded | degraded | degraded |
| 31 | 2147483648 | 80000000 | bad_not_usable | bad_not_usable | bad_not_usable | bad_not_usable | bad_not_usable |

# Final Note About Quality Flags

- Flagging algorithms are complicated and still evolving
  - New flag bits may be defined
  - Internal thresholds for when to set different flag bits will likely be adjusted
  - Possible that flags may be removed or repurposed
    - Especially if those bits are never raised
  - Threshold1 and Threshold2 for determining suspect vs. degraded vs. bad may change in future product versions
    - But flag interpretation will always remain consistent for a given version
- Flags themselves may have bugs
  - Some known bugs in flags are in “beta pre-validated” products
    - That’s why the products are “beta pre-validated”
  - Project still recommends that users look at flags first

# Uncertainty Estimates

- Many measurement variables are accompanied by uncertainty estimates
  - Uncertainty variables are usually called {measurement_variable}_uncert
    - Example: If measurement variable is named height then associated uncertainty estimate is usually named height_uncert
  - Uncertainty estimates are typically 1-sigma (68th percentile) values
  - Uncertainty estimates often reflect only random error, not systematic error
  - See PDDs and ATBDs for details
- Uncertainty estimates for KaRIn height estimates are usually based on interferometric coherence
- **Validation of uncertainty estimates has been lower priority than validation of measurement variables themselves**
  - Use with caution
  - Do not be surprised if observed systematic errors exceed uncertainty estimates significantly

# L2_LR_SSH “_2” Variables

- L2_LR_SSH product has two versions of SSH and SSHA with different wet troposphere and sea state bias (SSB) corrections:
  - Solution 1 relies more on observations for corrections (may be slightly more accurate)
  - Solution 2 relies more on models for corrections (fewer gaps due to missing corrections)

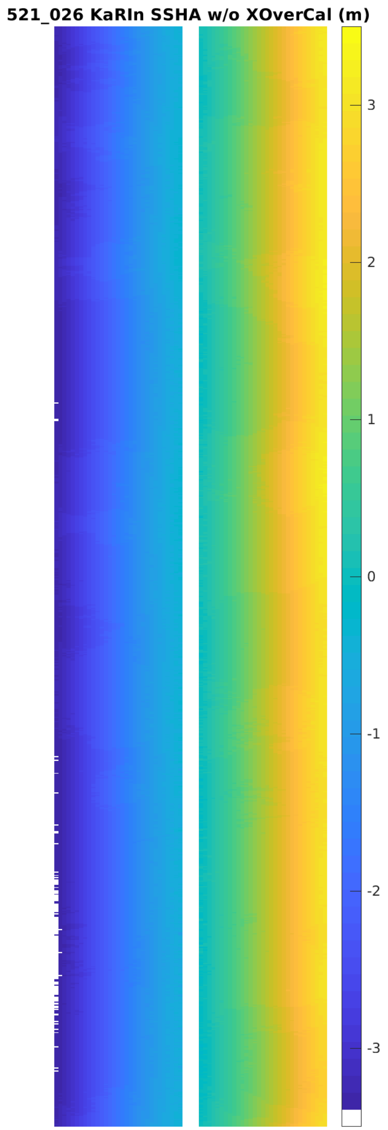
| Property | Solution 1 | Solution 2 |
|---|---|---|
| SSH variable name | ssh_karin | ssh_karin_2 |
| SSHA variable name | ssha_karin | ssha_karin_2 |
| Wet tropo correction source | Radiometer | ECMWF model |
| Variable indicating wind speed used for SSB correction | wind_speed_ssb_cor_source | wind_speed_ssb_cor_source_2 |
| Wind speed source as of Sept 2023 | KaRIn for beta-pre-validated release<br>Nadir altimeter for pre-validated release | ECMWF model |
| Variable indicating SWH used for SSB correction | swh_ssb_cor_source | swh_ssb_cor_source_2 |
| SWH source as of Sept 2023 | Nadir altimeter* | Nadir altimeter* for beta-pre-validated release<br>ECMWF model for pre-validated release |

**Nadir altimeter SWH is smoothed before SSB computation*

- **Input info for SSB correction solutions may continue to change in future product releases**

# Application of Crossover Calibration Correction

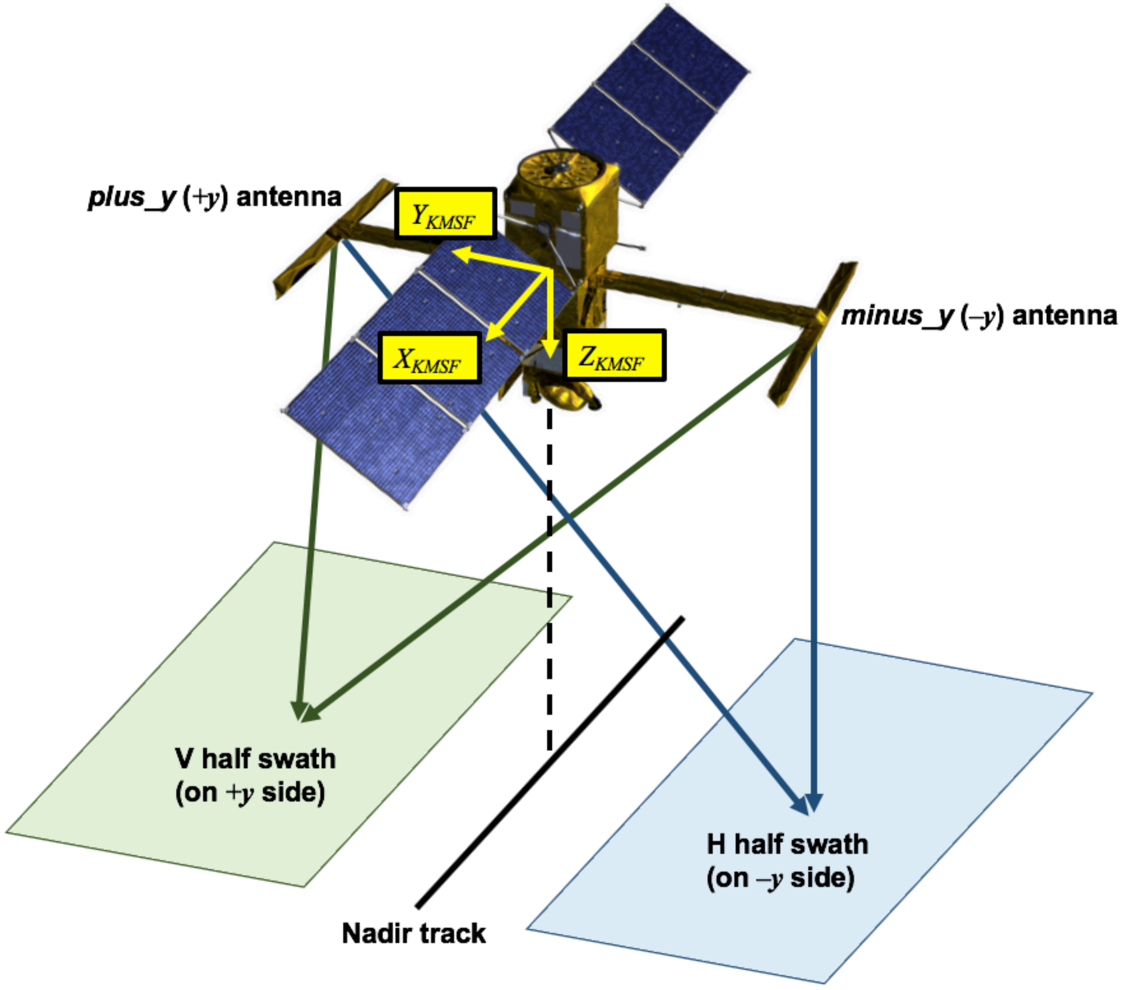
- Correction from crossover calibration (also called XOverCal or “xover”) is reported in L2_LR_SSH product but ***is not*** applied to SSH or SSHA
  - To get corrected SSH, user must compute following himself/herself:
    - ssh_karin_corrected = ssh_karin + height_cor_xover
    - ssha_karin_corrected = ssha_karin + height_cor_xover
    - ssh_karin_2_corrected = ssh_karin_2 + height_cor_xover
    - ssha_karin_2_corrected = ssha_karin_2 + height_cor_xover
  - Crossover correction has its own quality flag in L2_LR_SSH
    - Example: If considering ssha_karin_2_corrected above, should examine both ssha_karin_2_qual and height_cor_xover_qual
- Crossover correction ***is*** applied to height in L2_HR_PIXC and thus also to water surface elevation (WSE) in RiverSP/Avg, LakeSP/Avg, and Raster products.
  - Crossover quality is indicated by bits in relevant height or WSE quality flags in HR products
  - If crossover correction quality flag indicates bad correction, then PIXC result is flagged as “degraded” and uncorrected height is reported



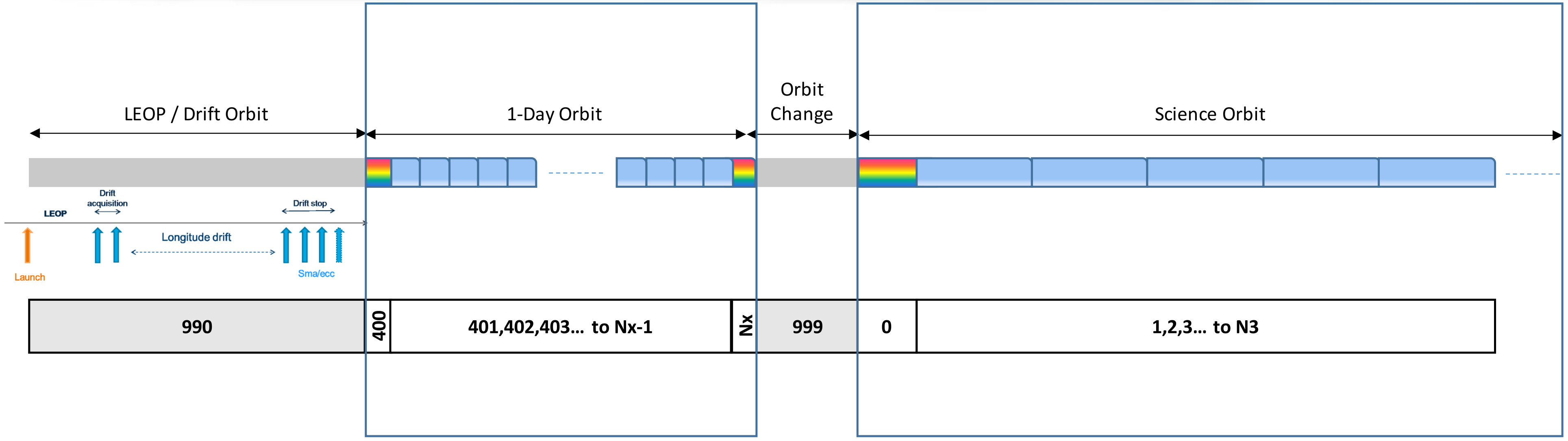

**KaRIn SSHA directly from L2_LR_SSH product shows +/-3 m tilt in cross track without XOverCal correction**

# Left, Right, H, V, Plus Y, and Minus Y

- SWOT spacecraft undergoes 180˚ yaw flips every ~2.5 months
  – Spacecraft thermal design has preferred side to be in sun
  – Beta ($\beta$) angle between orbit plane and sun drifts
  – Yaw flips occur when beta angle goes through zero
- "Left" and "right" swath sides are defined relative to measurement on ground relative to nadir track and do not depend on yaw state
  – End measurement given in terms of left and right sides in data products
- H (horizontal) and V (vertical) polarizations and $+y$ and $-y$ directions in KaRIn frame do depend on yaw state
  – Many L1B product variables and calibration parameters related to physical measurement are given in terms of H, V, +y and -y



# Cycle and Pass Numbering




- Calibration (“1 day” or “fast sampling”) orbit:
  - Cycle numbers increase sequentially from 401 to 578
  - Cycle 401 began 2023-01-15 09:26:13.011 UTC
  - Transition to nominal orbit began 2023-07-11 ~03:00 UTC
  - Repeat period is 0.99349 days (not exactly 1 day)
    - Overpass times of day will drift ~9 min earlier per repeat cycle
  - Calibration orbit has 14 revolutions or 2*14 passes numbered from 001 to 028
- Nominal (“21 day” or “science”) orbit:
  - Cycle numbers increase sequentially from 001
  - Cycle 001 began 2023-07-21 05:33:45.768 UTC
  - Repeat period is 20.86455 days (not exactly 21 days)
    - Overpass times of day will drift ~3 hrs earlier per repeat cycle
  - Nominal orbit has 292 revolutions or 2*292 passes numbered from 001 to 584
- Both calibration and nominal orbit phases:
  - Ascending passes have odd numbers (001, 003, 005, …)
  - Descending passes have even numbers (002, 004, 006, …)
  - Pass duration is ~51 min
  - KaRIn data from drifting orbit phases is not processed

# Height References

- SSH and PIXC height are referenced to ellipsoid
  - Ellipsoid parameters are given in metadata of every single KaRIn product granule
  - As of Sept 2023: WGS84

    :ellipsoid_semi_major_axis = 6378137. ;

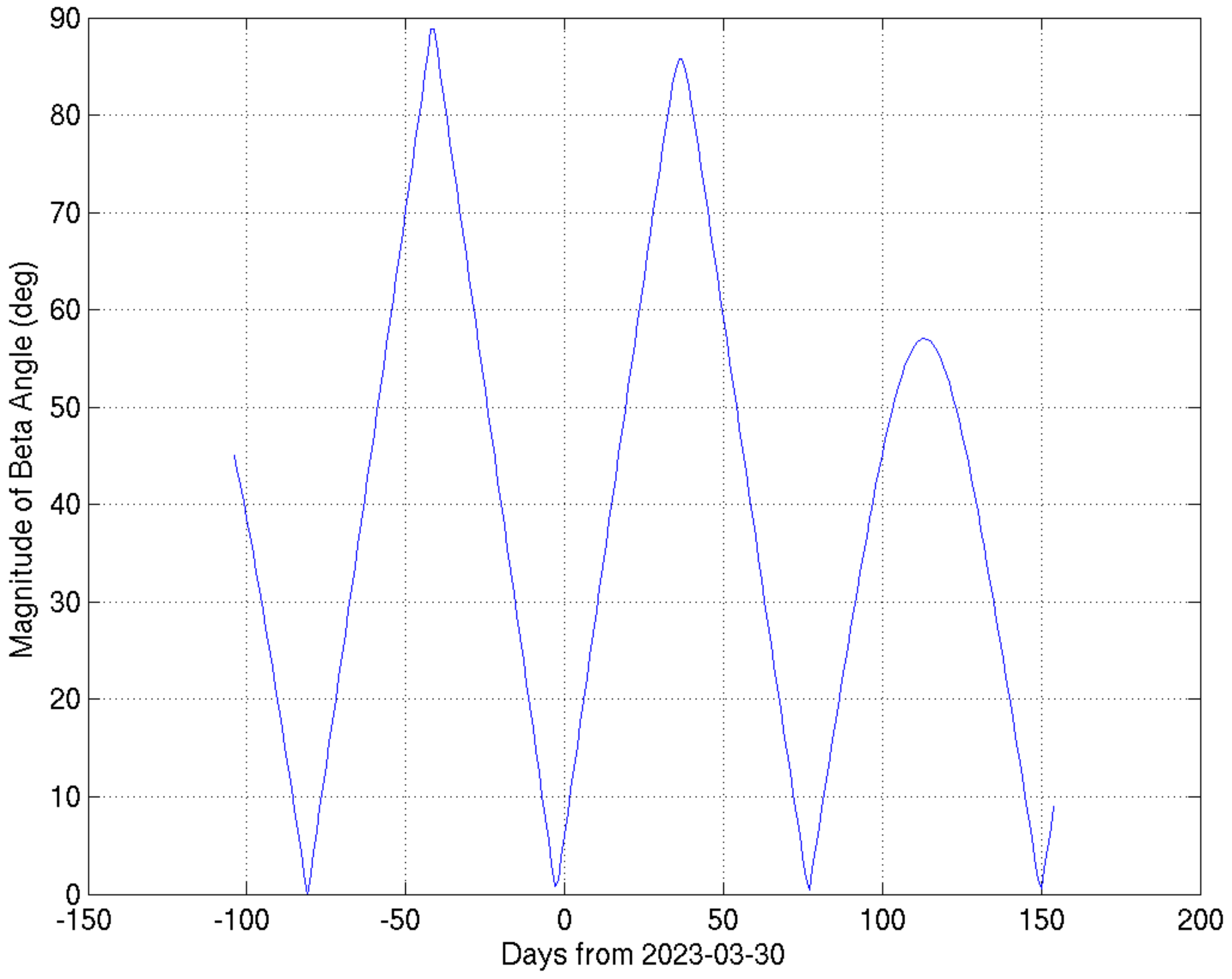
    :ellipsoid_flattening = 0.00335281066474748 ;
- River, lake, and raster water surface elevation (WSE) are referenced to geoid
  - Geoid heights relative to ellipsoid are reported in L2 products at each sample location
  - As of Sept 2023: EGM2008
- SSHA is referenced to mean sea surface (MSS)
  - MSS heights relative to ellipsoid are reported in L2 LR products at each sample location
  - Two MSS models (CNES/CLS and DTU) reported in product, but only one used to compute SSHA from SSH
  - As of Sept 2023, SSHA assumes
    - CNES/CLS 2015 MSS for beta-pre-validated
    - CNES/CLS 2022 MSS for pre-validated

# Truth Definitions

- Truth definitions for SWOT validation may not always agree with specific definitions of quantities used by individual users for particular purposes
  - Definitions are matter of convention for SWOT
  - Consistency in interpretation is most important
  - **Users should be aware of differences in truth definitions and measurement conventions, especially when attempting to “validate” SWOT**
- Example: For validating river products, true or ideal reach slope is defined: *reach_slope = (WSE_at_reach_start – WSE_at_reach_end) / reach_length*
  - Reach length is static and comes from prior river database (SWORD), not from SWOT observation
  - Estimate of reach slope uses measurement data from entire reach to estimate WSE at each end of reach
  - Definition is equivalent to unweighted average of slope over entire reach

# Relevant Time Scales of Variations

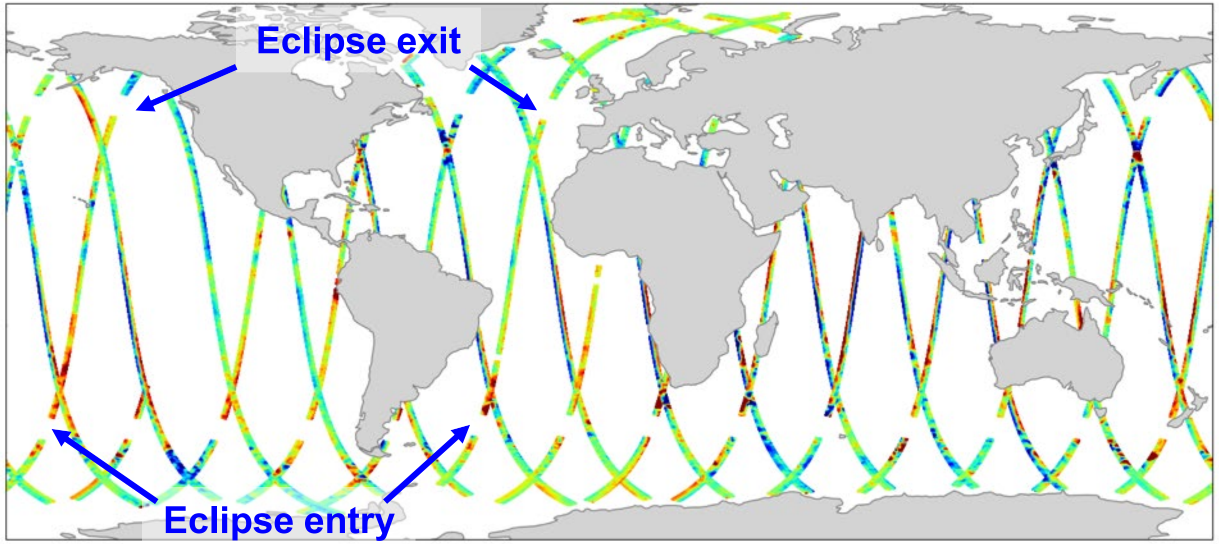
- Users should be aware of time scales of variations that may affect KaRIn data quality
  - Seconds to minutes: KaRIn parameter changes
    - Parameter changes should be compensated by KaRIn internal calibration and processing
  - ~100 min: KaRIn orbit
    - Variations over orbit should be compensated by crossover calibration
  - ~80 days: Beta (half) cycle between yaw flips
    - Changes in KaRIn and spacecraft thermal characteristics may give uncompensated errors

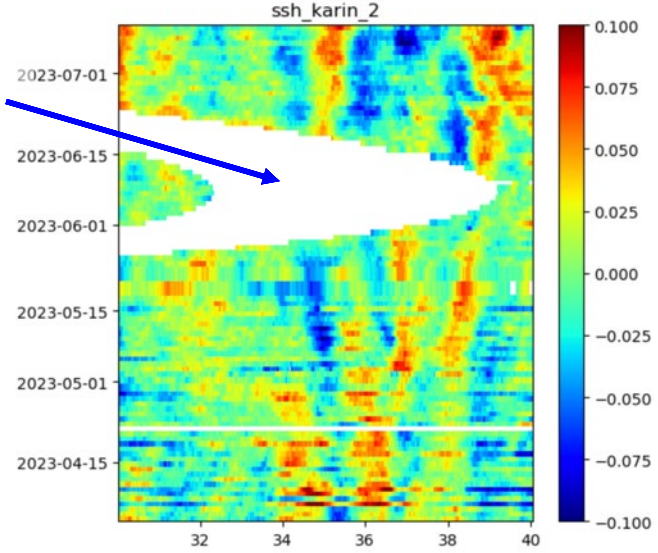


# Spacecraft Events and Data Availability

- Spacecraft events impact availability of KaRIn data
  - Eclipse entry/exit: SWOT spacecraft goes in and out of Earth shadow and experiences thermal transients that can affect KaRIn stability
    - Occurs twice per orbit in similar geographic locations
    - Affects ~2 min of data (~800 km along track) after event
  - Propulsive maneuvers (station keeping, collision avoidance): SWOT needs to fire thrusters to make minor changes to orbit; involves large attitude variations
    - Occurs every several weeks
    - Affects few hours of data after event
  - Yaw flip: 180 rotation in yaw
    - Occurs every ~2.5 months
    - Affects few hours of data after event
  - Solar array rotations: SWOT solar arrays are re-oriented to collect sunlight with changing beta angle
    - Occurs several times every ~2.5 months
    - Affects ~12 min of data after event
- Other data loss:
  - Various issues with storing or downlinking data

**Eclipse example from 2023-04-15 LR coverage**




**Much of data affected by spacecraft events will be flagged “suspect” instead of “bad” (null filled) in pre-validated release, but events may still affect data quality**

*Graphic courtesy of Jinbo Wang*

# Defaulted Fields When Measurement is Bad

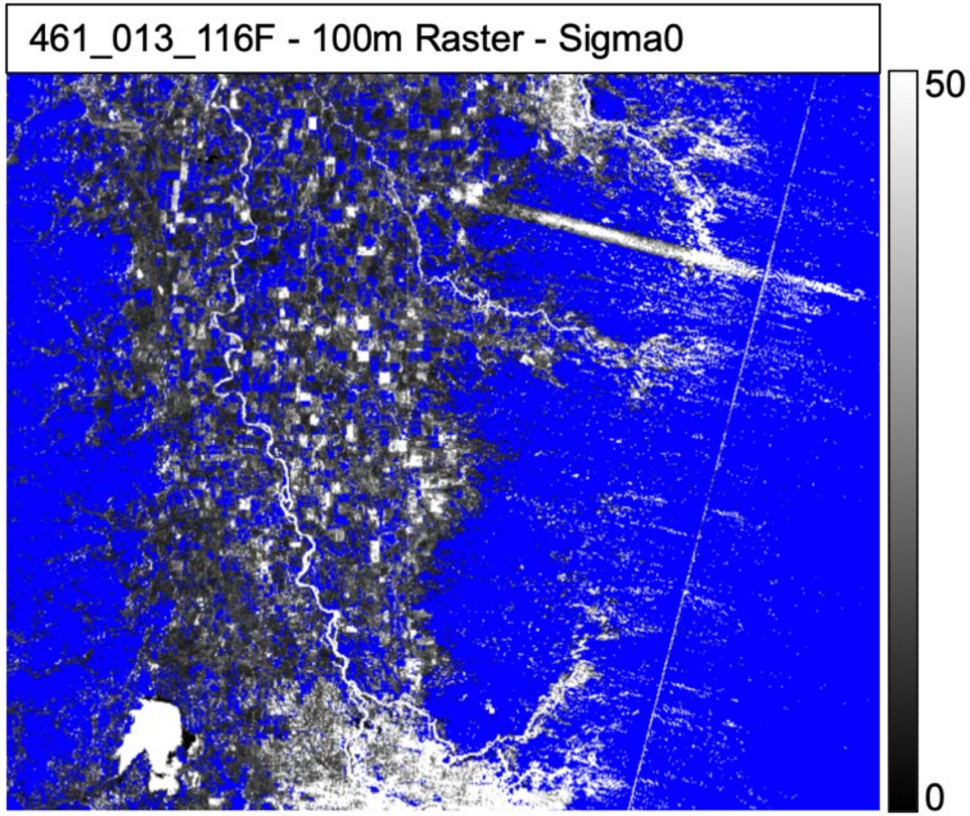
- Typical approach for averaging during ground processing:
  - L2 data products involve averaging many upstream data samples
  - Upstream data samples that are flagged as “bad” are discarded before averaging to compute downstream outputs
  - Time tags reported in L2 outputs are usually times of observation
  - Model corrections are computed at observed geolocation (measured 3-D position)
- If all upstream samples were flagged as “bad”, there are no observations to average for given L2 output sample
  - L2 output sample is flagged as bad
  - Other associated quantities may also be null filled
    - Observation time is null filled if there is no observation
    - Model corrections at geolocation are null filled if measured geolocation does not exist

# No Data vs. No Detection in HR Data

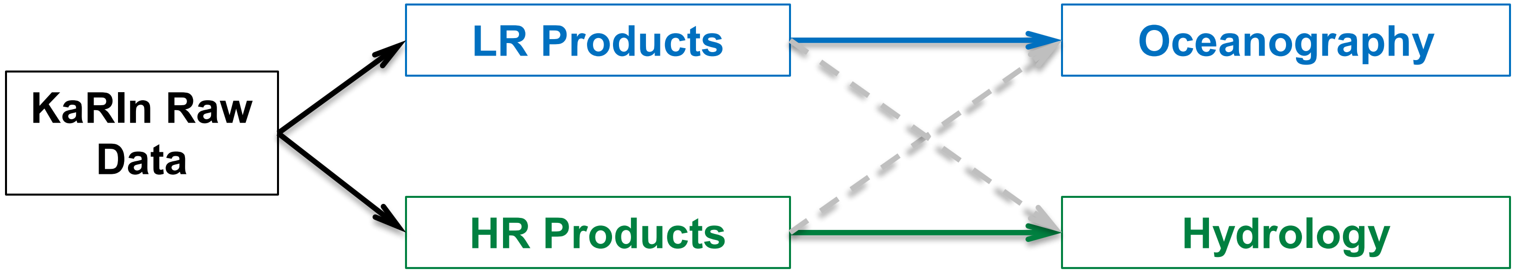
- Most land pixels are discarded from L2 HR products
  - Classification of land vs. water is done by water detection algorithm in L2_HR_PIXC processing
- If L2 HR granule does not contain any water pixels, user may want to know which case happened:
  - SWOT data were collected, but water was not detected (area was observed to by dry)
  - SWOT data were not collected (area was not observed and could be wet or dry)
- L2_HR_PIXC product contains variable pixc_line_qual to indicate whether data were collected
- No equivalent for LR data because water detection does not happen in LR processing

# Filled River/Lake Objects and Sparse Rasters

- RiverSP product and PLD-oriented (Prior) file of LakeSP product contain one entry per database reach/node/lake that *might* be covered by granule
  - Set of reach or lake objects included in given SP continent-pass granule does not vary with cycle number
  - May includes objects up to 80 km from nadir, not just objects from 10-60 km cross track
    - Intent is to be able to report any useful observations rather than have product definition exclude good data
  - Objects are null filled if water is not detected
    - **Objects outside 10-60 km but within 0-80 km cross track may always be null filled**
- Raster product is null filled where water is not detected
  - Flags indicate approximate observation coverage to distinguish no-water vs. no-observation cases



# LR Data Over Inland Water and HR Data Over Ocean




- KaRIn LR and HR data streams are split on board spacecraft in instrument firmware processing
  - Nine-beam LR interferograms are formed on board and spatially averaged before being downlinked
  - HR pulse data are pre-summed (low-pass filtered in along-track) on board before being downlinked
- Ground algorithms and data products are designed around using LR data over ocean and HR data over land, not vice versa
  - LR data for hydrology and HR data for oceanography *may* still be useful
  - But prospective users should gain familiarity with data products and algorithms to determine whether LR data for land and HR data for ocean meet their needs/desires

**Users should *not* assume that LR and HR data differ only in horizontal resolution and height accuracy**

# LR Data Over Inland Water

- KaRIn on-board processor (OBP) uses flat reference surface per swath side
  - Design of on-board reference surface was based on hydro input
  - May still give increased error where there are rapid spatial variations in elevation
- Phase-bias correction in ground processing is sensitive to spatial variations in backscatter and topography at 1–10 km length scales
- LR ground processing does not include many steps that are done in HR processing:
  - Classification (water detection and dark water flagging)
  - Phase unwrapping with respect to HR reference DEM
  - River and lake vector processing
- Crossover-calibration corrections are not applied to LR products, so LR products will contain spatially varying cross-track tilts
  - But crossover-calibration correction terms are reported in product so users can apply themselves
- LR quality flags are designed for ocean and may not be trustworthy
- Validation of LR data over land has not been high priority to date

**LR data products are *not* simply less-noisy, coarser-resolution versions of HR products**

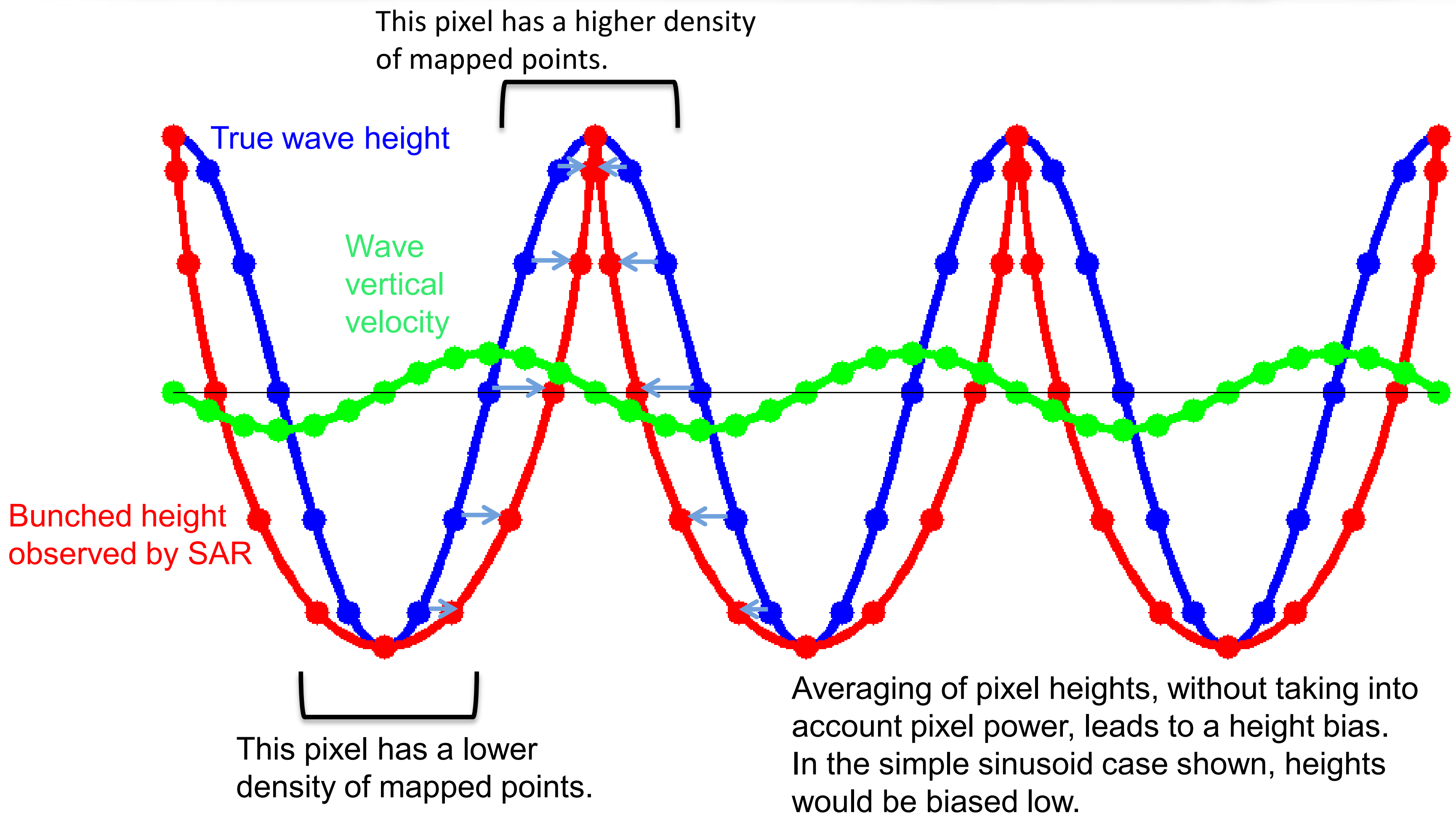
# HR Data Over Ocean

- Pre-summing in OBP implies loss of information in downlink
- HR ground processing does not do very much spatial averaging
  - HR data may be sensitive to wave-bunching effects observed on AirSWOT unless specialized post-processing is applied
- HR data products do not include ocean tide or sea-state bias (SSB) corrections
- Prior-based river and lake outputs may exist but be empty over ocean where there are no database features
- HR quality flags are designed for inland water and may not be trustworthy
- Validation of HR data over ocean has not been high priority to date

- Note: Cal/Val team uses HR data over ocean, but only for specific calibration purposes and only after customized offline processing (not available generally)

**HR data products are *not* simply noisier, finer-resolution versions of LR products**

# Height Distortion From Wave Bunching



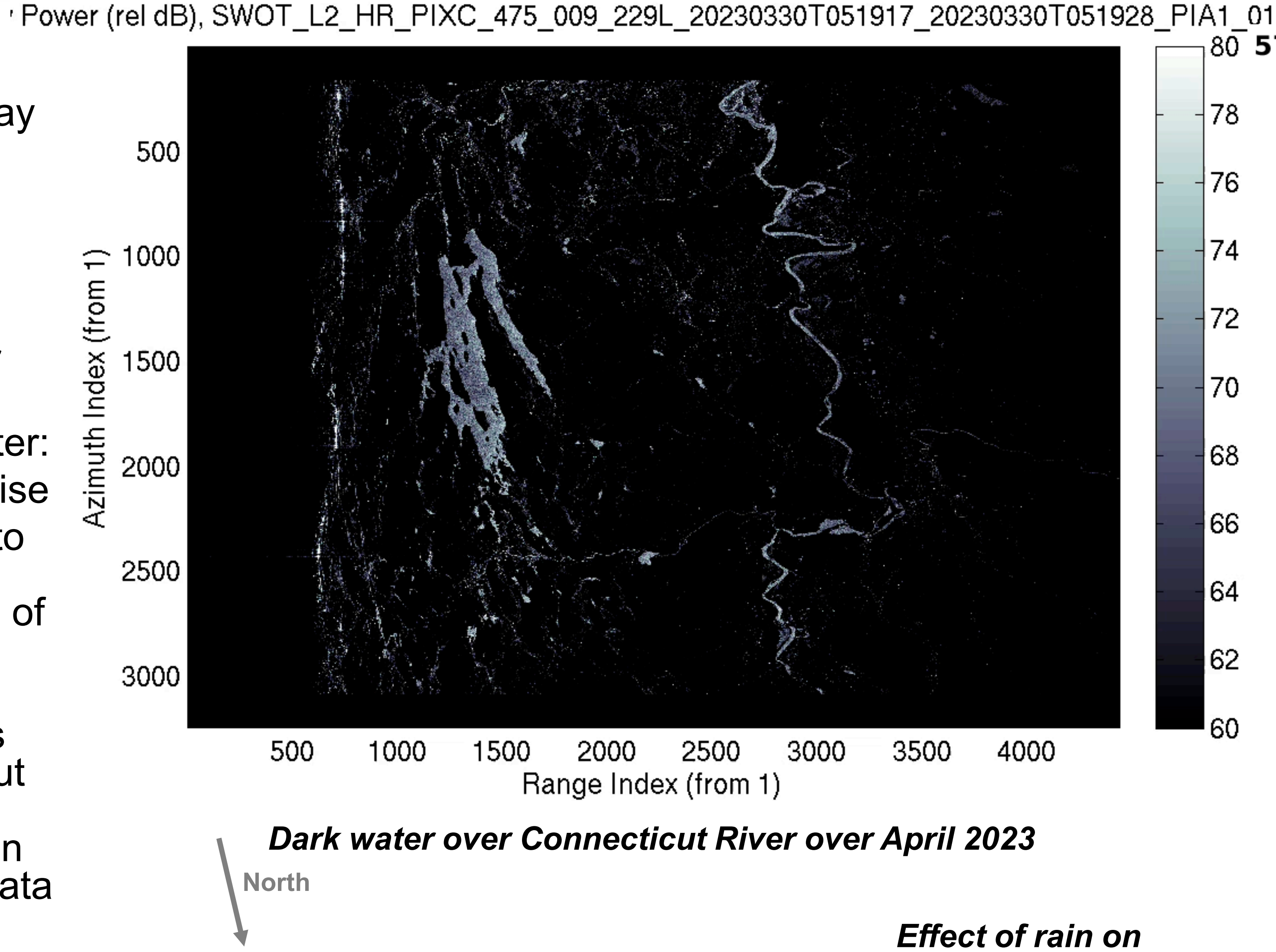

Azimuth shift is proportional to line-of-sight target velocity, which is mainly due to wave vertical velocity for near-nadir viewing geometry

Averaging of pixel heights, without taking into account pixel power, leads to a height bias. In the simple sinusoid case shown, heights would be biased low.

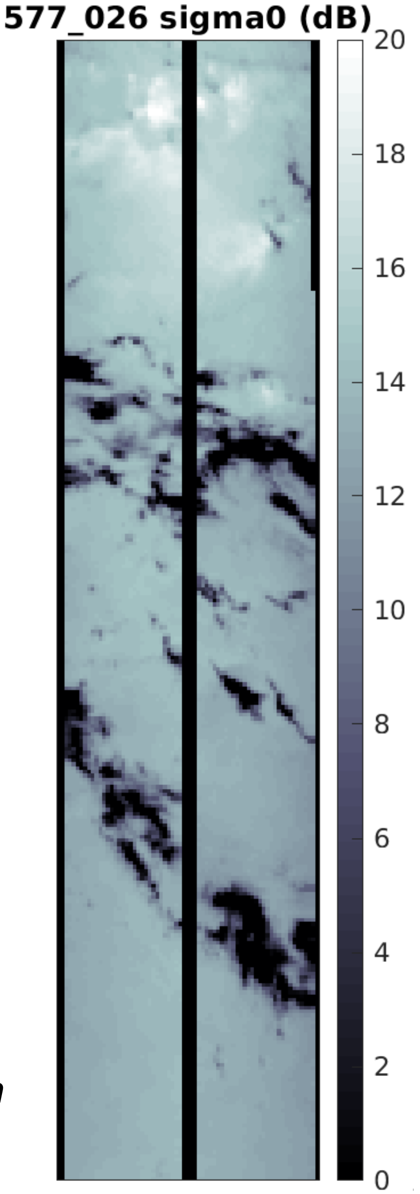
**Wave bunching is non-linear distortion, so spectrum of observed heights can exhibit energy at spatial frequencies that are not present in the true wave field**

# Dark Water

- Backscatter of water may be dark for different reasons:
  - Rain
  - Highly specular reflections (more significant issue for inland water)
- Effects of low backscatter:
  - Greater random noise
  - Greater sensitivity to systematic errors from contamination of nearby targets
  - Dark water not directly detected as water in HR data but may be flagged as dark water based on prior (not SWOT) data



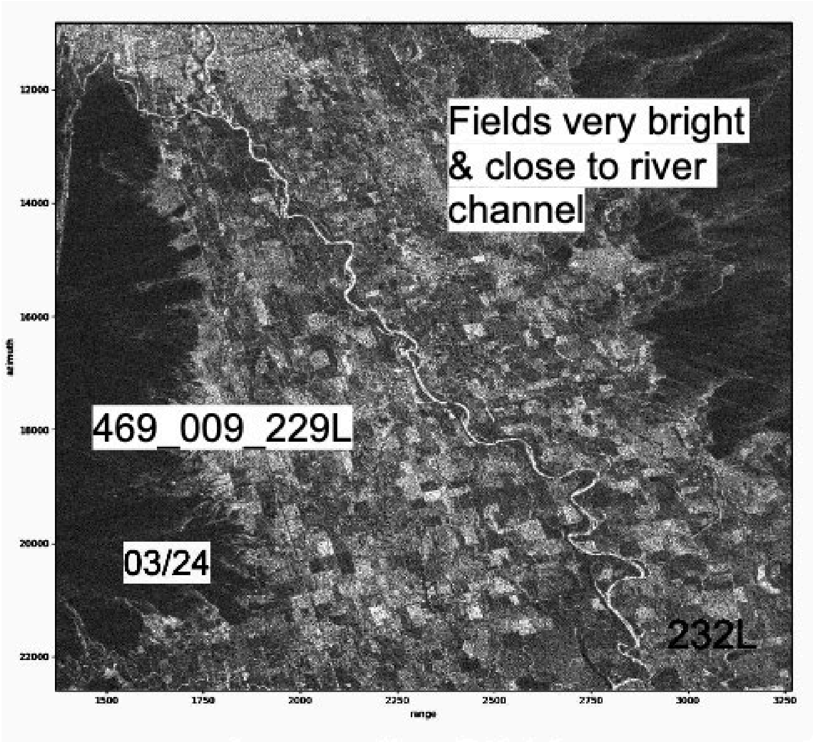

*Dark water over Connecticut River over April 2023*




*Effect of rain on backscatter over ocean*

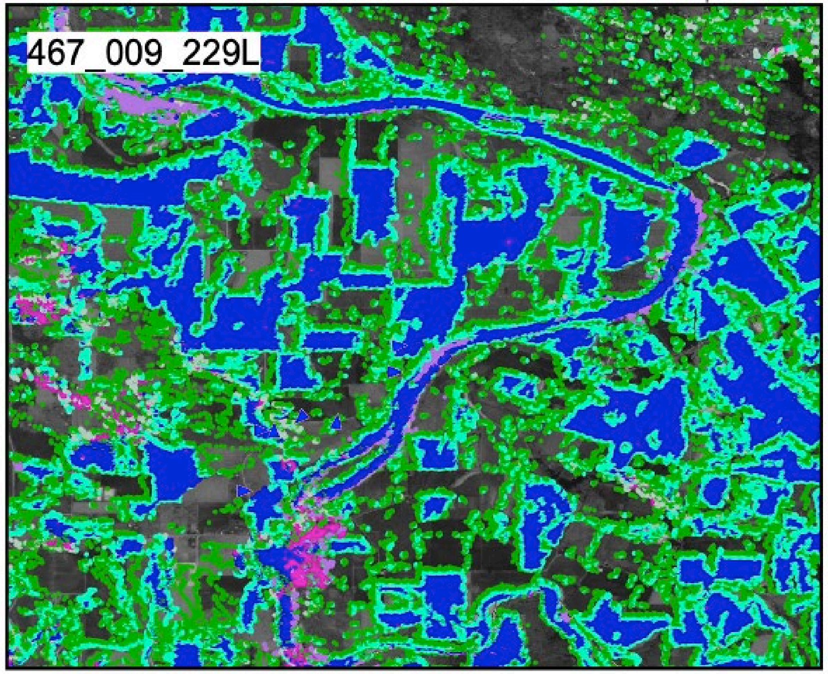
# Willamette River Bright Fields Example

- Agricultural fields near Willamette River Cal/Val site are bright and are incorrectly detected as water, especially in winter/early spring data
  - Overdetection of water affects pixel mapping to river and therefore corrupts river height, slope, and area estimates
  - Fields in other areas are not as bright
  - Willamette fields became less bright going into summer
  - Overall impact to river height, slope, and area estimates needs further assessment after additional calibration work, comparison to field data, and algorithm tuning




Contrast-adjusted SLC image

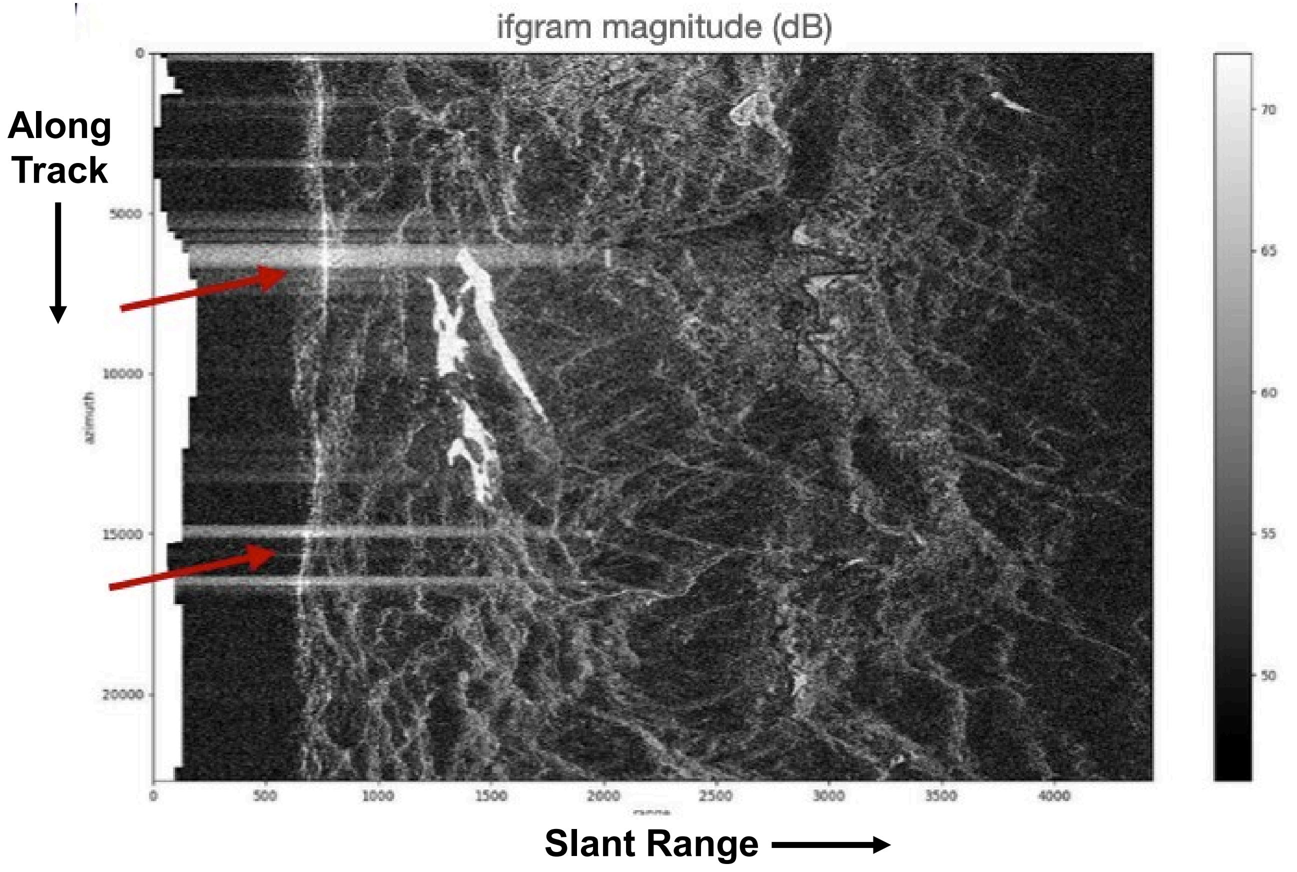
Ground truth transect over PIXC water detection map




blue=interior water; cyan=water-near-land;
pink=layover class (i.e. low coh)
purple=dark water

# Bright Nadir Returns

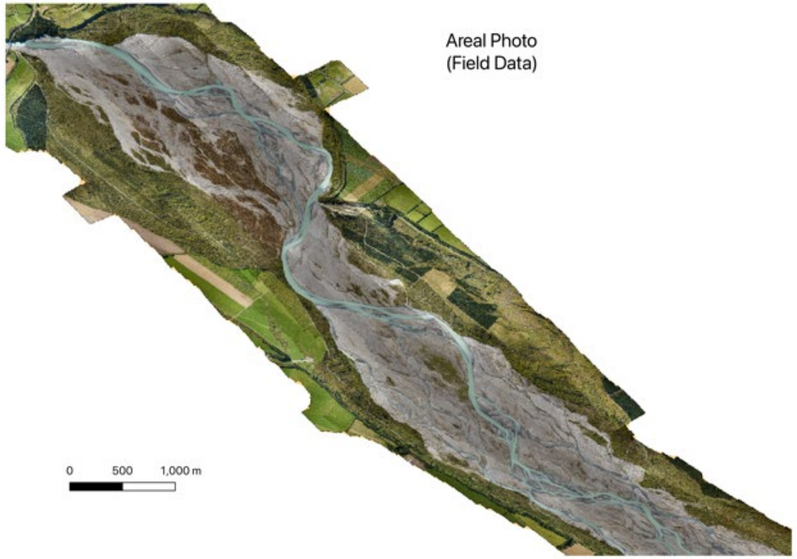
- Specular echoes from nadir are sometimes so bright that range sidelobes of point-target response corrupt other parts of images
- Algorithms have been updated to flag and ignore corrupted pixels
  - But not in beta-pre-validated release

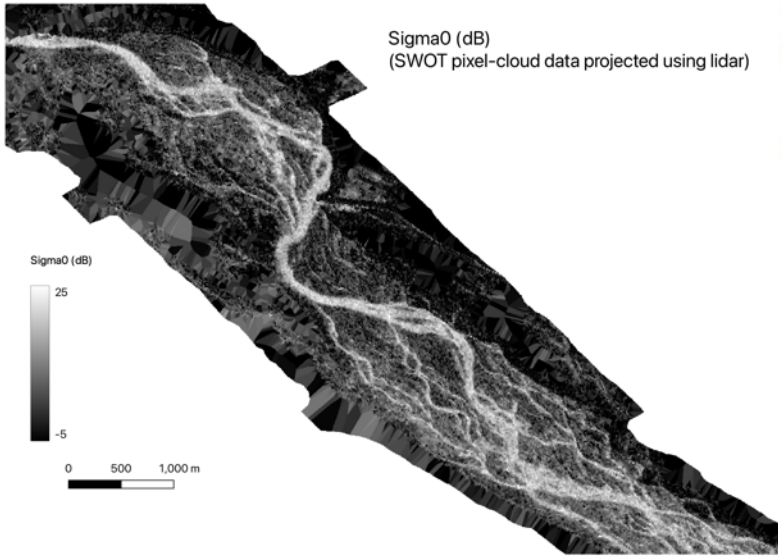


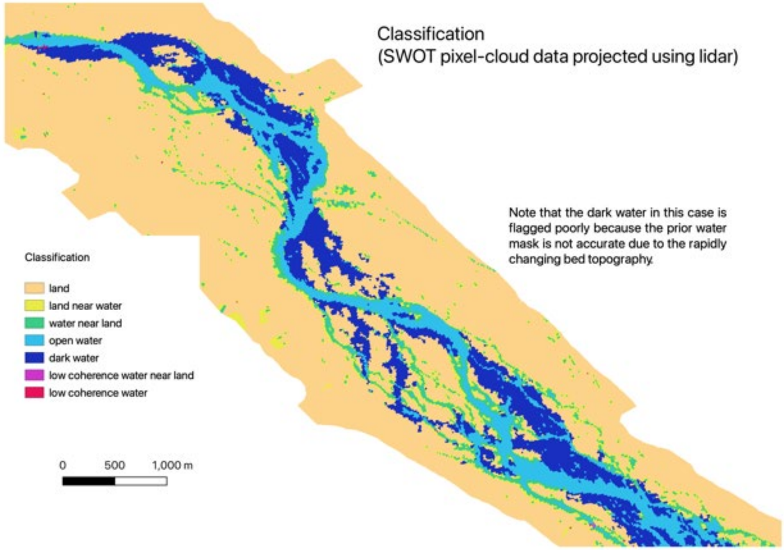

*Connecticut River example with bright nadir echoes (and dark water on river)*

# Waimakariri River Example

- Detection of real water works quite well over Waimak
- Dark water flagging does not work well because rapid migration of river channels causes smearing in prior water probability map



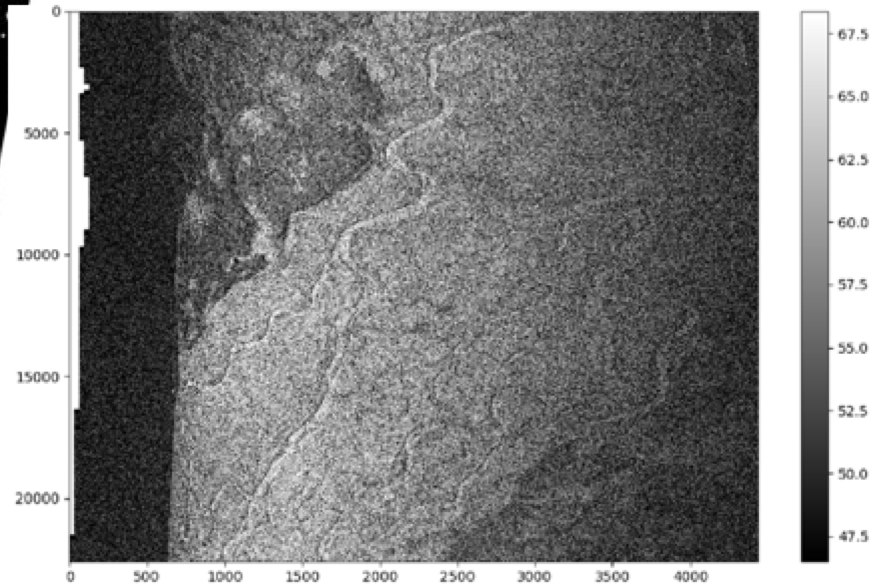



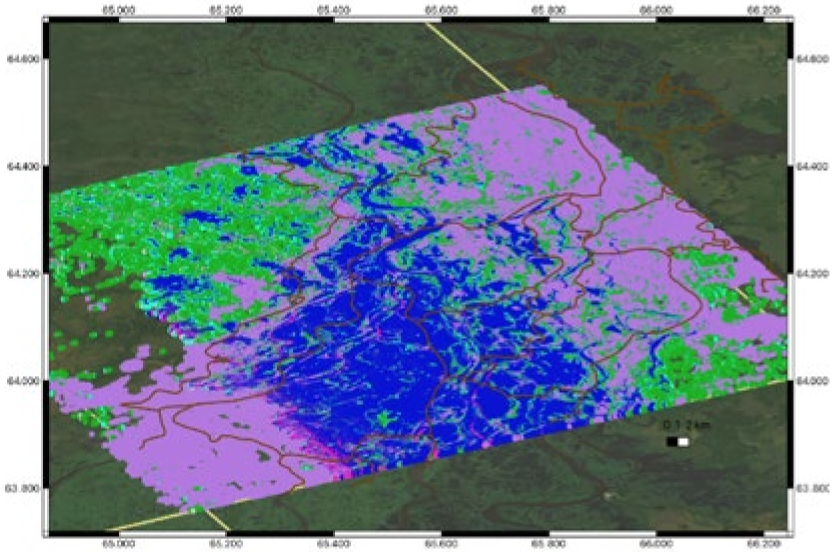
# Ice

- Ice can appear bright and be detected as water, but resulting height measurements may not be reliable
- KaRIn data may have potential for cryosphere science, but validation of performance is not primary priority for current project work
- Ice flags exist in both LR and HR data products

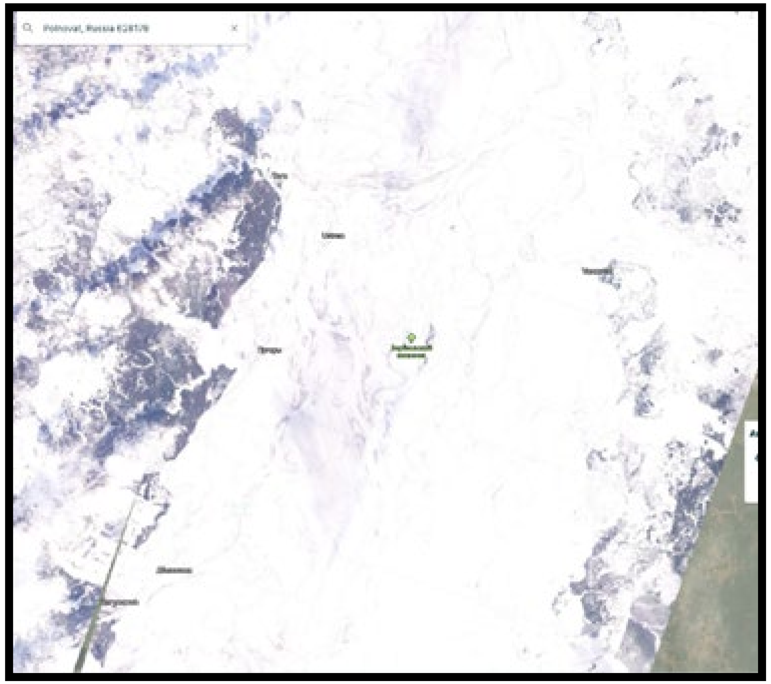
**Backscatter**




**Classification**



**Planet RGB Optical Image**



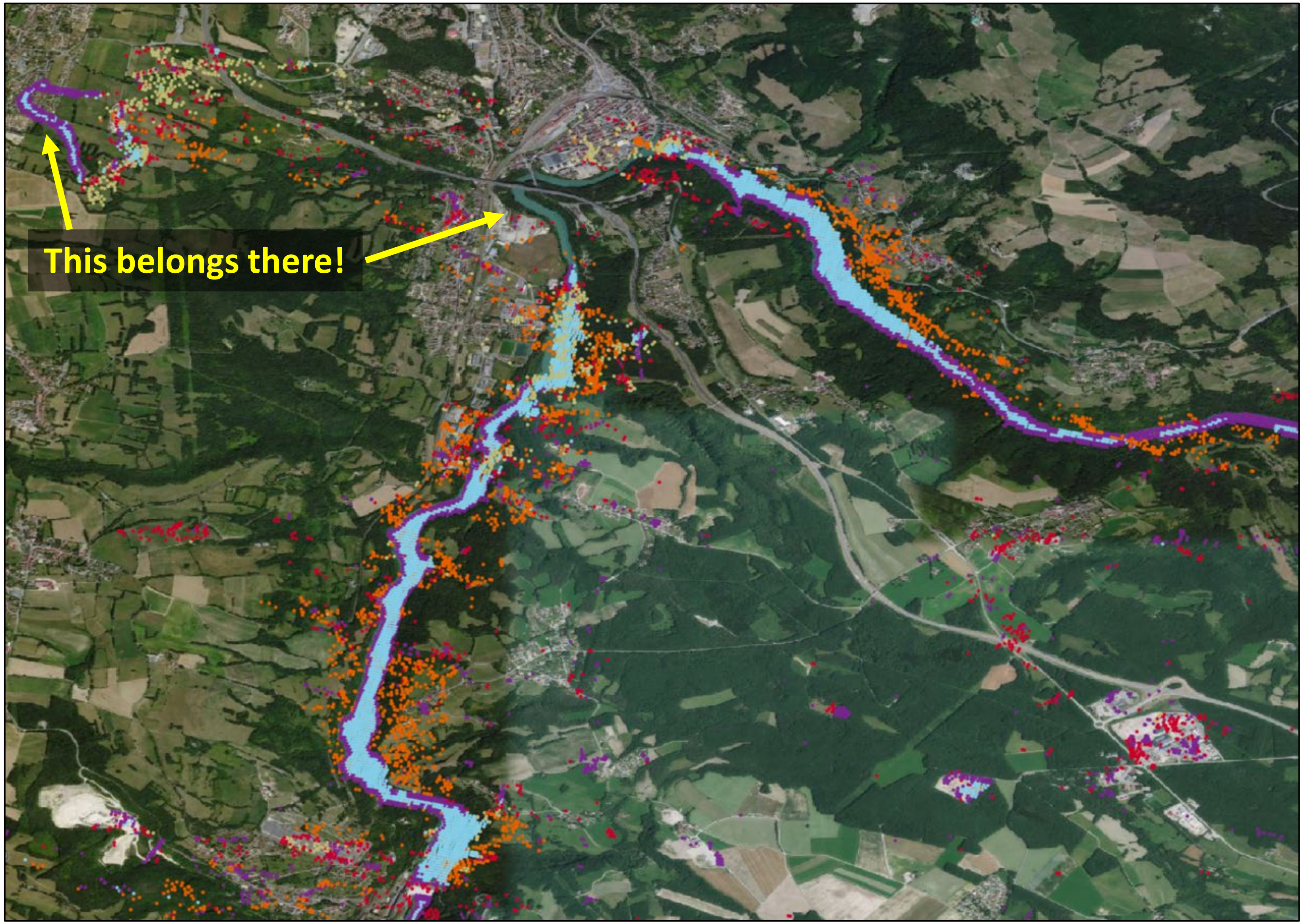
Ob River, 406_010_040L

Note: Data is from before antenna alignment and processing is not calibrated

# Phase Unwrapping Errors

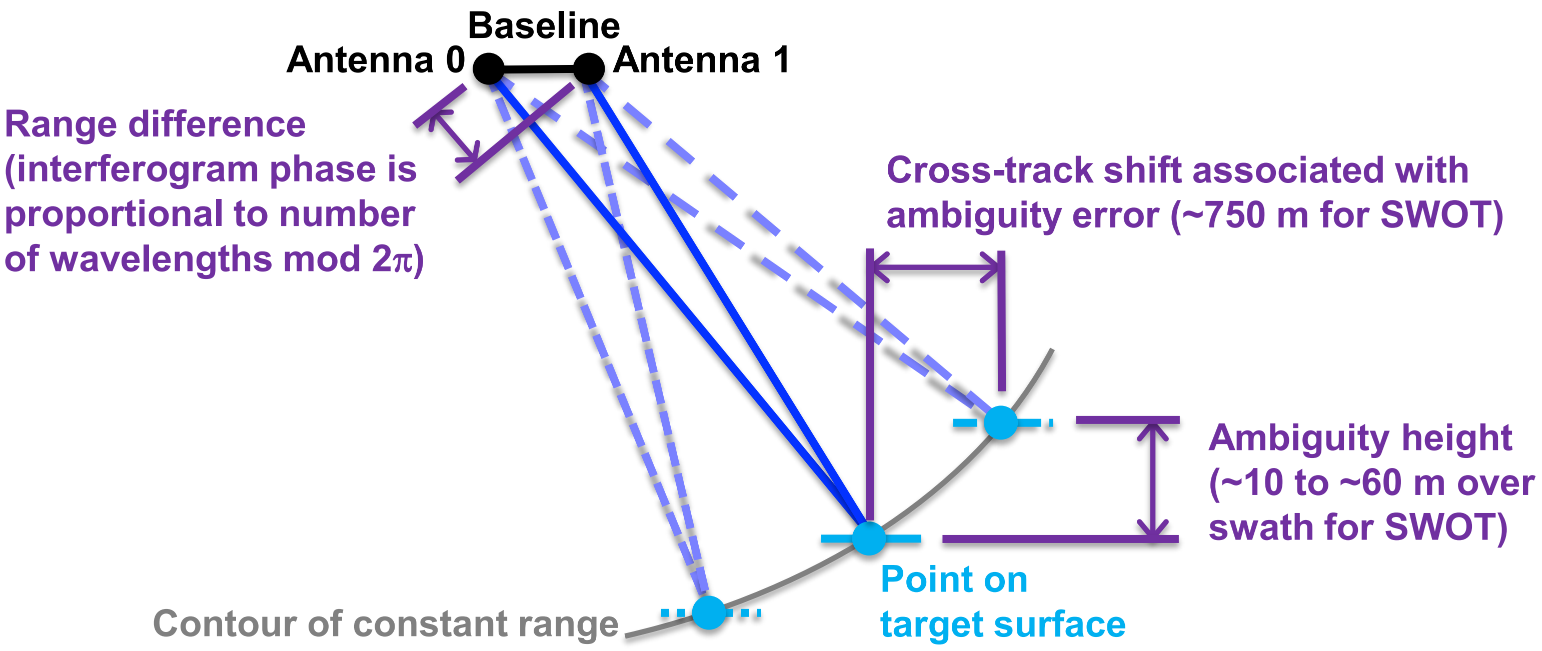
Image shows HR pixel geolocations projected onto ground and overlaid on optical layer for illustration; colors represent pixel classification values

Phase unwrapping errors can cause large cross-track shifts, large height errors, and noticeable cross-track slope errors in HR data




*Rhone River, reach 21602600391, 523_003_235L*

# Phase Unwrapping



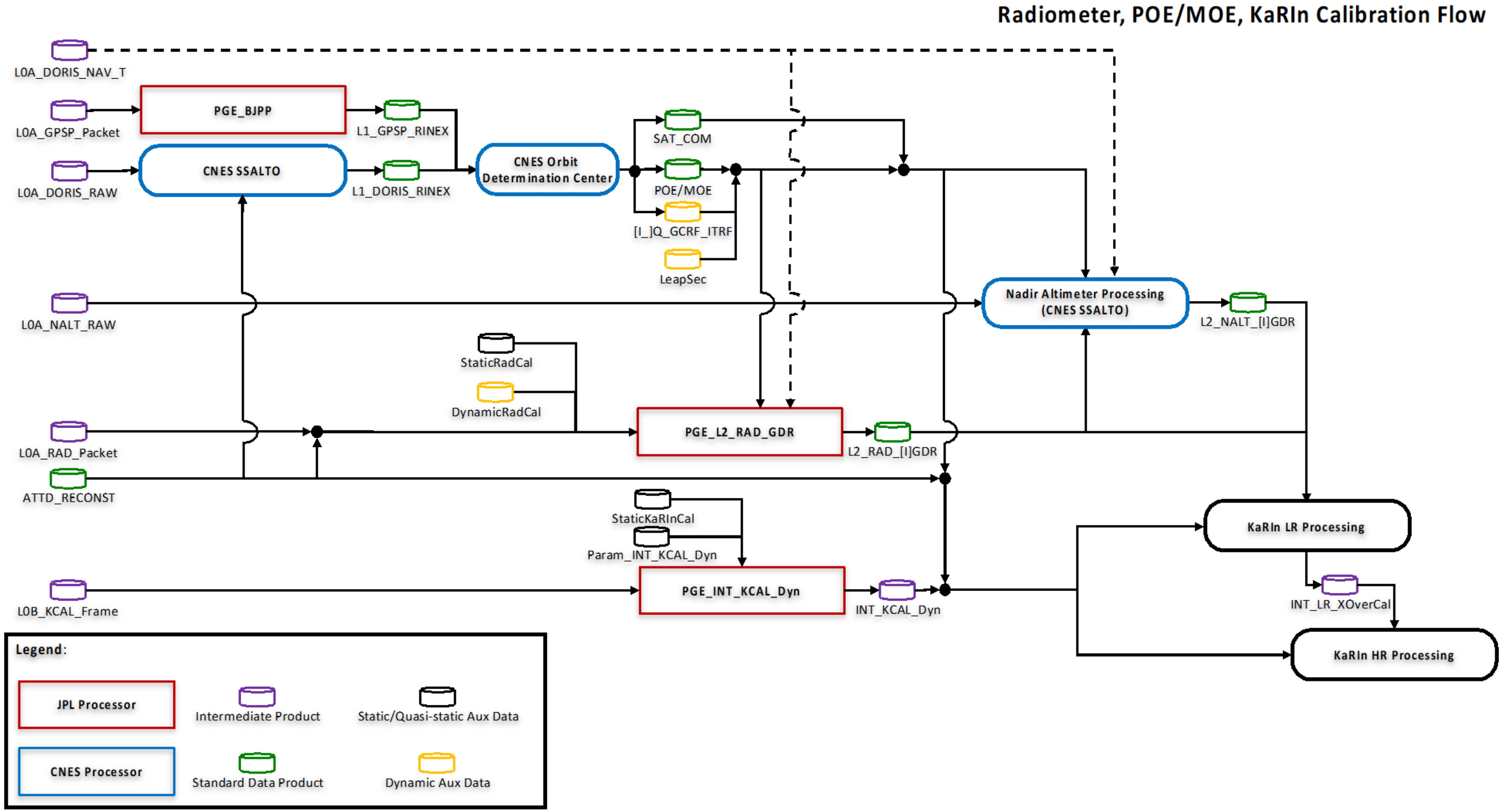

- Interferometric phase is precise measure of difference in range between point on ground and two radar antennas separated by known baseline
- Phase can only be determined modulo $2\pi$ radians
  - Multiple points in space have same range and interferometric phase; target location is ambiguous
  - Target location is geolocated incorrectly if incorrect phase ambiguity is assumed

# Conclusions

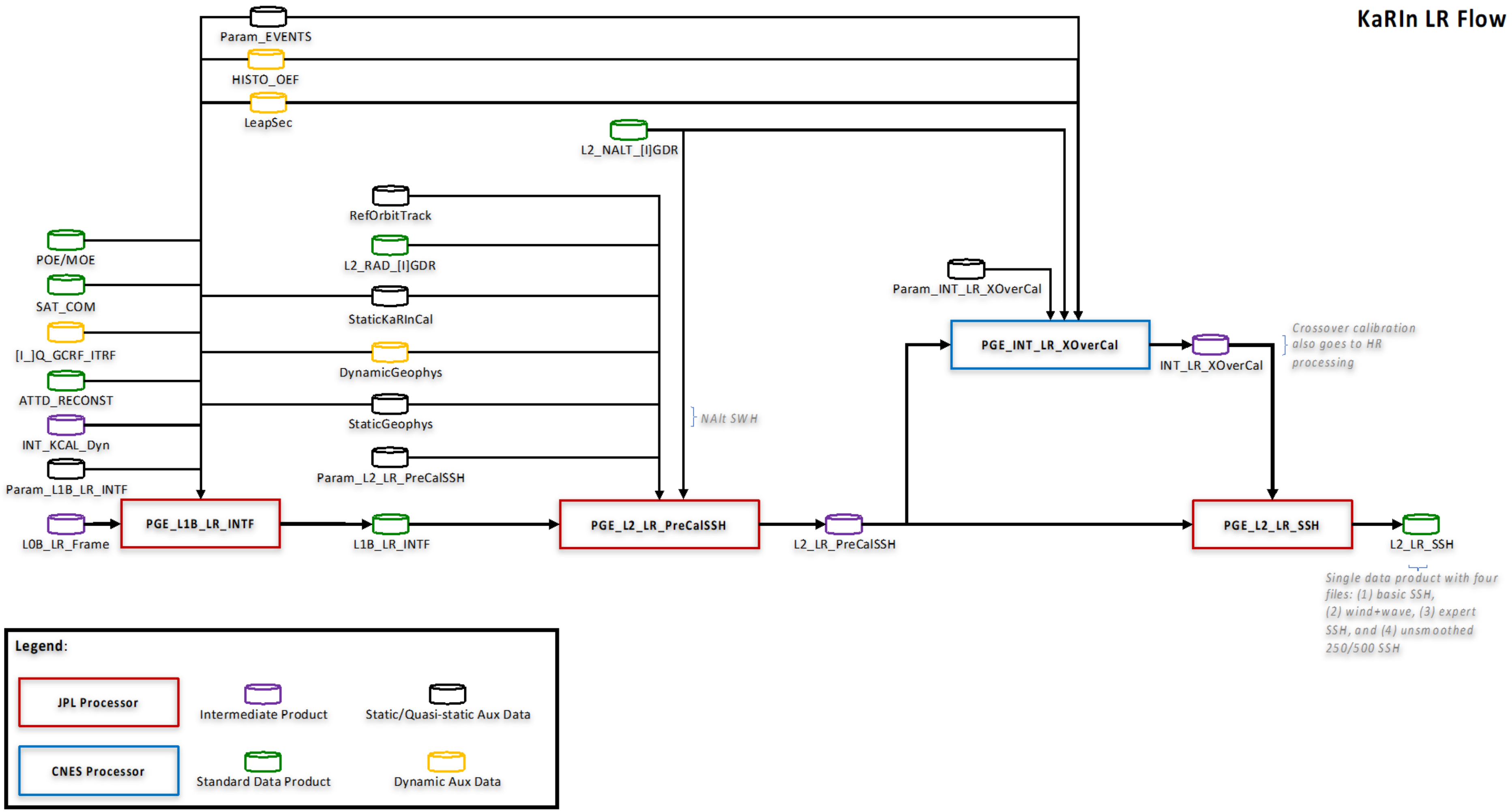
- KaRIn measurement is complicated
- Users seeking to validate SWOT measurements may benefit from seeking to understand measurement and conventions
  – If measurement process is viewed as black box, validation feedback may not be very helpful to project
  – Specific definitions and conventions can have significant implications on validation results
- Many sources of additional details are available:
  – Metadata of product files
  – Product description documents (PDDs) and algorithm theoretical basis documents (ATBDs)
    - https://podaac.jpl.nasa.gov/swot?tab=datasets

# Backup

# Top-Level Algorithm Flow



# LR Algorithm Flow



# HR Algorithm Flow