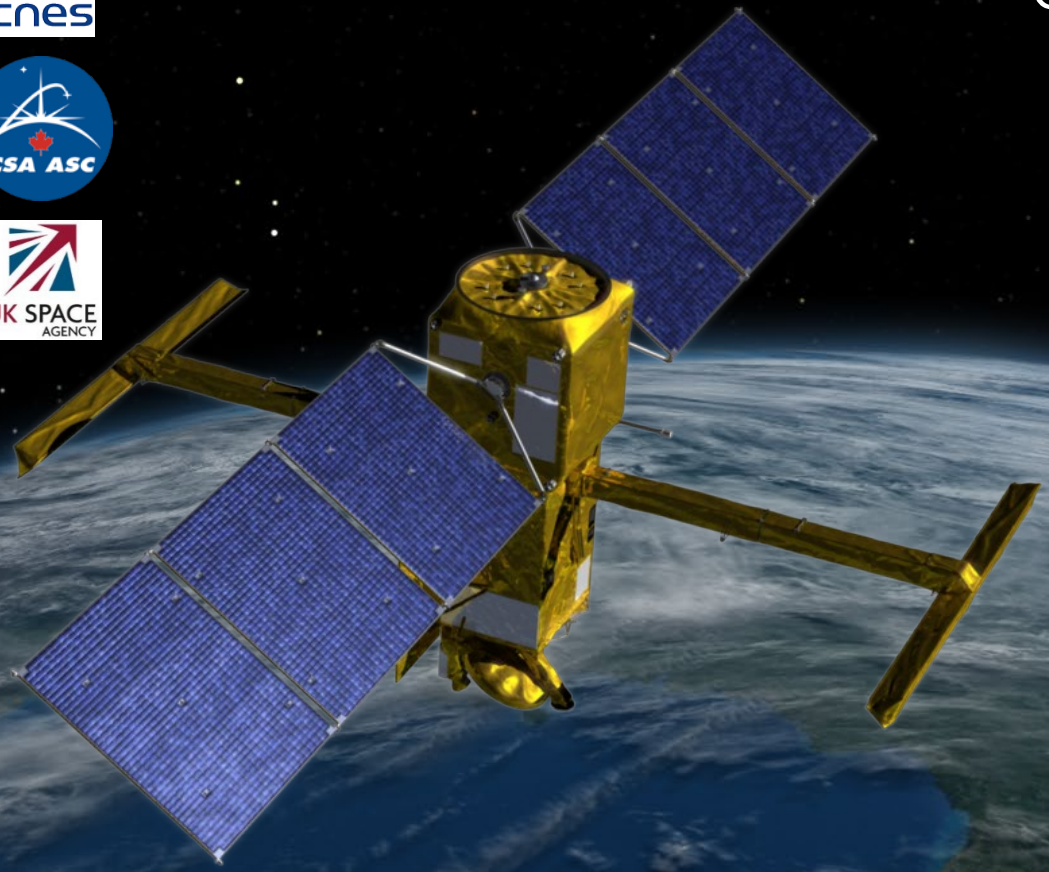
National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Surface Water and Ocean Topography (SWOT) Mission

October 15, 2025



Major Changes to SWOT Products from Version C to D

SWOT Algorithm Team

Product Version D Timeline

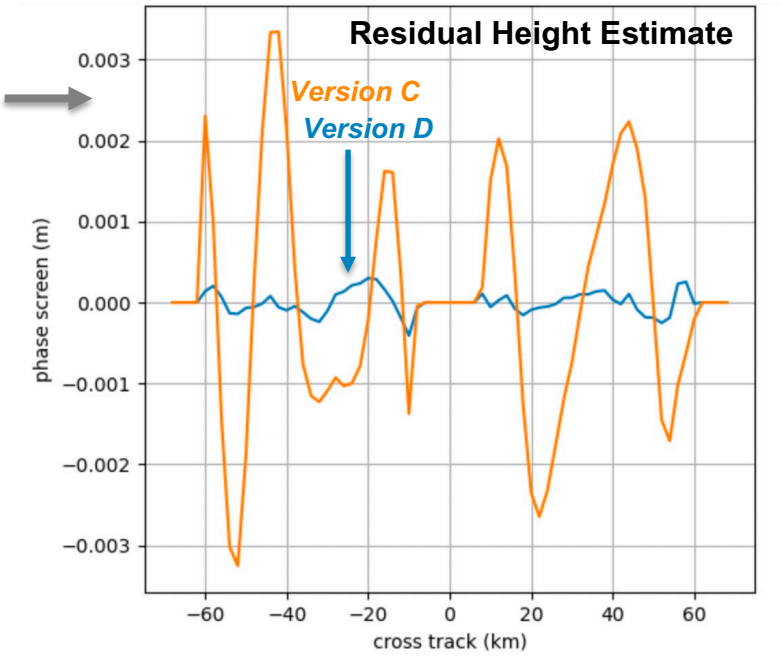
- Forward processing moved to Version D0 configuration for KaRIn data collected from 2025-05-06 to present
  - Version D0 products for data collected from 2025-05-06 onward are available now and continue to be produced with nominal latency
  - Product file names have composite release identifier (CRID) = PID0
- Version D Reprocessing of data collected before 2025-05-06 is ongoing
  - Calibration phase:
    - Reprocessing is nearly complete
    - Most data products are available now, and remaining products are being made available as they are produced
    - Covers KaRIn data collected between 2023-03-30 and 2023-07-11
  - Science phase:
    - Reprocessing is ongoing and expected to complete in early 2026
    - Reprocessing is proceeding in rough chronological order of data collection
    - Products are being made available as they are produced
    - Covers KaRIn data collected between 2023-07-26 and 2025-05-18 (end of cycle 032)
  - Product file names have CRID = PGD0
- All Version C data products (2025-03-30 to 2025-05-05) will continue to be available at least until all Version D reprocessing has been completed
  - Version C0 spans 2025-03-30 to 2024-10-15 (CRID = PGC0 or PIC0)
  - Version C2 spans 2024-10-16 to 2025-05-05 (CRID = PIC2)

Major Changes In Product Version D

Change	C0	C2	D0	Main Impacts
KaRIn height calibration refinement	No	No	Yes	LR+HR: *O*(5 mm) short-wavelength changes in SSH and WSE
KaRIn sigma0 calibration adjustment	No	No	Yes	LR+HR: 2.5 dB change in KaRIn sigma0
Range-Doppler coupling correction	No	Yes	Yes	LR+HR: Fix *O*(3 cm) pass-scale height variations
Update radiometer (AMR) calibration	No	No	Yes	LR: Relative bias between two sides reduced to < 0.2 mm.
Crossover processing update	No	No	Yes	LR+HR: Performance and flagging enhancement
Geoid bug fix	No	No	Yes	LR+HR: Fix *O*(10 cm) errors in reported geoid values
Mean Sea Surface models	No	No	Yes	LR: Updated to CNES/CLS 2023 and DTU21
FES ocean and load tide models	No	No	Yes	LR+HR: Updated to FES2022b
Sea Surface Height Anomaly	No	Yes	Yes	LR: Non-equilibrium long-period ocean tide applied
New variables in L2_LR_SSH	No	No	Yes	LR: SSHA also given at Unsmoothed posting; added mitigation Doppler
LR processing over land	No	Yes	Yes	LR: Fewer height artifacts over land
LR volumetric correlation processing	No	Yes	Yes	LR: Improved KaRIn SWH
HR improved dark-water projection	No	Yes	Yes	HR: Better dark-water and area performance
HR crossover flag handling fix	No	Yes	Yes	HR: Fewer areas with missing crossovers
HR bug fix for non-unwrapped pixels	No	Yes	Yes	HR: Fewer height artifacts and discontinuities
SWORD v17b	No	No	Yes	HR: New reach definitions, improved topology
River processing enhancements	No	Partial	Yes	HR: Improved river width estimates and flagging
PLD v2.02	No	Partial	Yes	HR: Lake catchment areas and reference heights added
Lake processing enhancements	No	Partial	Yes	HR: Improved pixel selection, new bitwise quality flag
Raster algorithm improvements	No	Yes	Yes	HR: Fewer height artifacts in Raster product

KaRIn Calibration Changes (LR+HR)

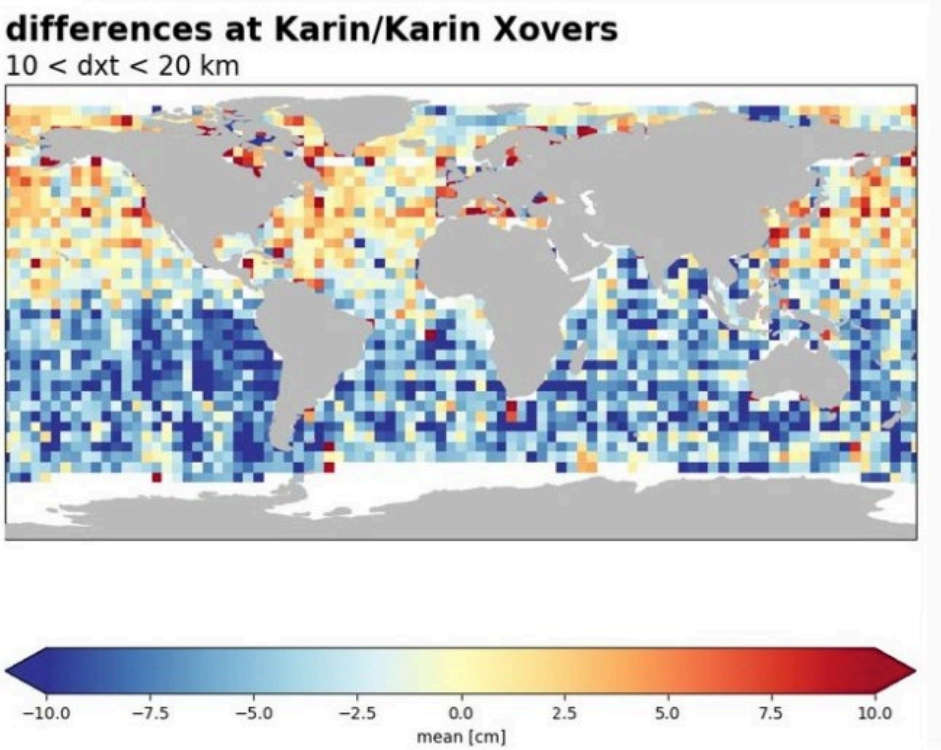
- KaRIn calibration changes (Version D0):
  - LR+HR: KaRIn phase screen calibration change to remove residual cross-track variation of +/- 3 mm
  - LR+HR: Absolute radiometric calibration change to shift sigma0 by 2.5 dB (new sigma0 estimates will be lower than old estimates)
    - Constant bias only (no spatial or temporal variation)
    - Same change all four channels (H+, H-, V+, V-)
    - Other parameters adjusted to compensate, so no impact on height, wind speed, etc.
  - Other minor changes to calibration
    - LR+HR: Change delay vs. phase bookkeeping for H swath only
      - Gives cross-track geolocation shift for H swath only (0.3 HR pixel or ~20 m at 10 km cross track)
      - Small height bias change that depends on spacecraft altitude for H swath only, but expect this to be largely removed by crossover correction
    - LR only: Equalization of LR beams reduces sensitivity of height to sigma0 variations, especially for H swath
    - HR only: Heights adjusted to better match LR over ocean; HR will be ~1.5 cm higher than previously (constant bias spatially and temporally)



Residual height before (orange) and after (blue) phase screen update

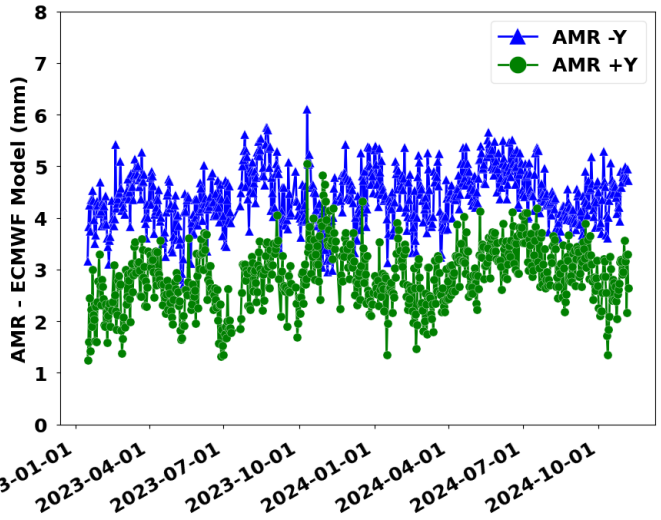
Range-Doppler Coupling (LR+HR)

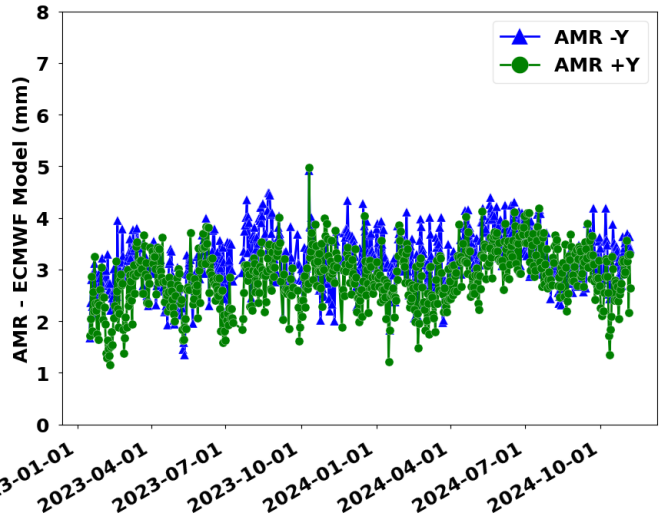
- LR+HR: Missing correction for Range-Doppler coupling added to L1B_LR_INTF and L1B_HR_SLC processing (Version C2)
  - Version C0 had height error in both LR and HR products that depended on vertical component of spacecraft velocity, which depends on whether pass is ascending or descending for given location on Earth surface
  - Magnitude of error was up to 3 cm (before crossover correction) with period of about two cycles per orbit, but was partially compensated by crossover correction in Version C0
  - Error would appear as height variation that varies slowly over latitude with opposite sign for ascending and descending passes; negligible cross-track variation



AMR Calibration Change (LR, Version D0)

- AMR calibration updates to reduce bias between two sides from ~1.5 mm to < 0.2 mm.
  - Calibration change primarily on AMR –y channel, making wet path delay corrections wetter by ~1.5 mm.
- Makes SSH and SSHA for KaRIn H swath when computed with radiometer correction (*ssh_karin* and *ssha_karin*) ~1.5 mm higher.
  - Small impact for KaRIn V swath
- No impact for KaRIn SSH and SSHA solutions that use ECMWF model (*ssh_karin_2* and *ssha_karin_2).*

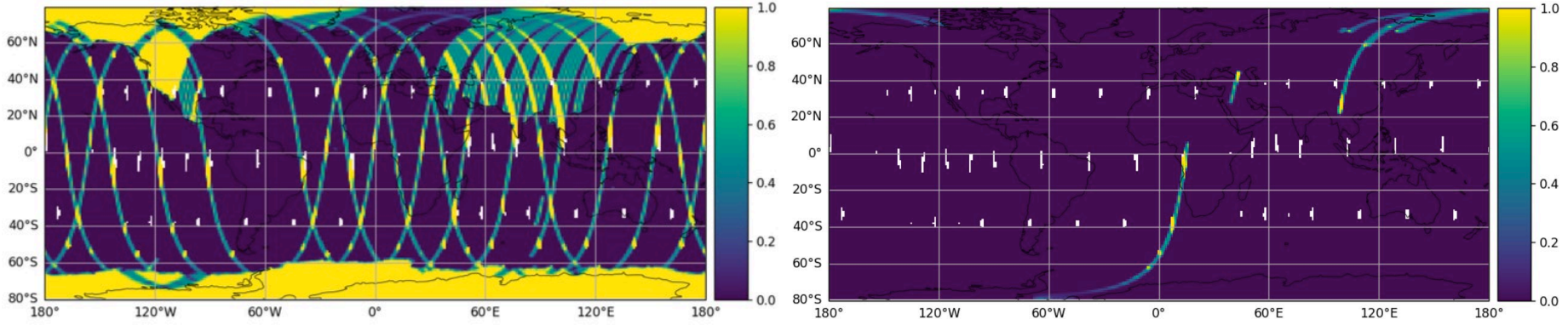




Crossover Processing Changes (LR+HR)

- LR+HR: Crossover processing updated (version D0)
  - Changes described here affect science orbit only because L3 solutions are used for reprocessed data from calibration orbit
  - Slight improvement in solution quality (reduction in residual variance)
  - Flagging of crossover data should be more correlated with expected crossover error
  - Much less data over land flagged as suspect
- *Reminder: Crossover solutions are applied to HR height/WSE but only reported (not applied) to LR SSH/SSHA--no change to this*

Fraction of Crossover Data Flagged



Version C2 **Version D0**

Geophysical Model Changes (LR+HR)

- Changes to geophysical models
  - Bug fix in values of EGM 2008 geoid value reported in product and used to compute HR WSE (Version D0, LR+HR)
    - For Version C products, interpolated geoid values were offset by 0.5 x 0.5 arcmin in latitude and longitude, giving errors that vary slowly spatially and are constant in time (max ~40 cm but usually < 5 cm)
    - Fix also applied to SWOT nadir altimeter products
  - FES 2022b tide model (Version D0, LR ocean and load tide, HR load tide only)
  - CNES/CLS/SIO/DTU 2023 hybrid mean sea surface used to compute SSHA (Version D0, LR)
  - DTU21 mean sea surface reported (Version D0, LR)
  - CNES/CLS 2024 mean dynamic topography (Version D0, LR)
  - Modified population of tide fields over land (Version D0, LR)

LR Product Changes

- Non-equilibrium long-period ocean tide applied to SSHA (Version C2)
- New variables in L2_LR_SSH Unsmoothed file (Version D0)
  - SSHA (two solutions) and associated flags and selected corrections
  - Mitigation Doppler (experimental and unvalidated)
  - Removed mitigation power (same info available in L1B) and MSS (available offline) to offset increase in data volume from above additions
- Volumetric correlation added to Expert and Unsmoothed files (Version C2)
- Spacecraft event info added to Expert file (Version D0)

Version C Product

double time(num_lines)
double time_tai(num_lines)
int latitude(num_lines, num_pixels)
int longitude(num_lines, num_pixels)
unsigned short latitude_uncert(num_lines, num_pixels)
unsigned short longitude_uncert(num_lines, num_pixels)
char polarization_karin(num_lines)
int ssh_karin_2(num_lines, num_pixels)
unsigned int ssh_karin_2_qual(num_lines, num_pixels)
unsigned short ssh_karin_uncert(num_lines, num_pixels)
float sig0_karin_2(num_lines, num_pixels)
unsigned int sig0_karin_2_qual(num_lines, num_pixels)
float sig0_karin_uncert(num_lines, num_pixels)
short total_coherence(num_lines, num_pixels)
int mean_sea_surface_cnescls(num_lines, num_pixels)
float miti_power_250m(num_lines, num_pixels)
float miti_power_var_250m(num_lines, num_pixels)
unsigned byte ancillary_surface_classification_flag(num_lines, num_pixels)

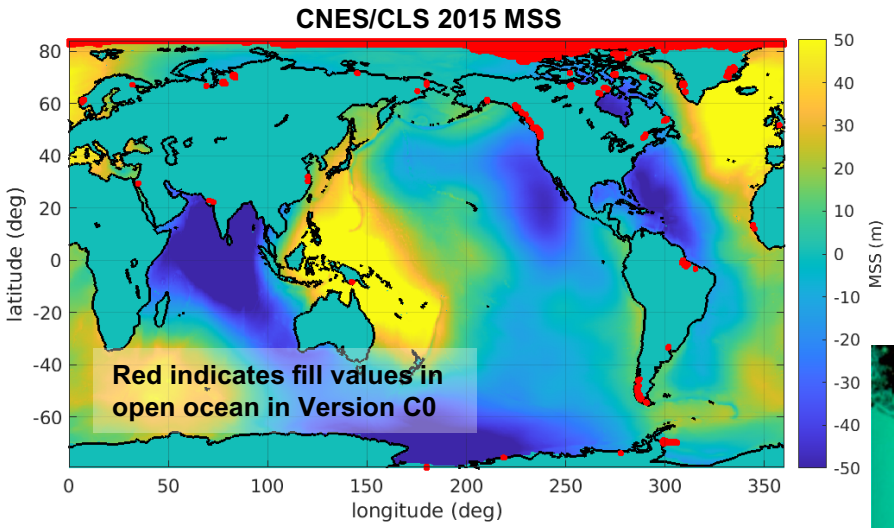
Differences in Unsmoothed file of L2_LR_SSH product

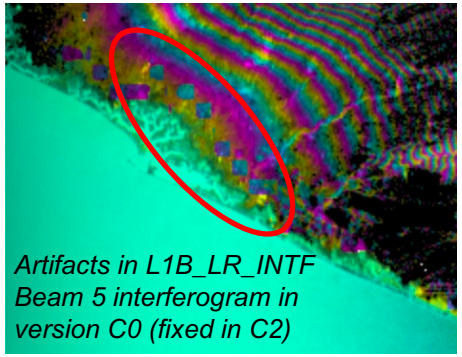
Version D Product

double time(num_lines)
double time_tai(num_lines)
int latitude(num_lines, num_pixels)
int longitude(num_lines, num_pixels)
unsigned short latitude_uncert(num_lines, num_pixels)
unsigned short longitude_uncert(num_lines, num_pixels)
int ssh_karin(num_lines, num_pixels)
unsigned int ssh_karin_qual(num_lines, num_pixels)
unsigned short ssh_karin_uncert(num_lines, num_pixels)
int ssha_karin(num_lines, num_pixels)
unsigned int ssha_karin_qual(num_lines, num_pixels)
int ssh_karin_2(num_lines, num_pixels)
unsigned int ssh_karin_2_qual(num_lines, num_pixels)
int ssha_karin_2(num_lines, num_pixels)
unsigned int ssha_karin_2_qual(num_lines, num_pixels)
char polarization_karin(num_lines)
float sig0_karin_2(num_lines, num_pixels)
unsigned int sig0_karin_2_qual(num_lines, num_pixels)
float sig0_karin_uncert(num_lines, num_pixels)
unsigned byte ancillary_surface_classification_flag(num_lines, num_pixels)
float cross_track_distance(num_lines, num_pixels)
int height_cor_xover(num_lines, num_pixels)
unsigned byte height_cor_xover_qual(num_lines, num_pixels)
short sea_state_bias_cor(num_lines, num_pixels)
short sea_state_bias_cor_2(num_lines, num_pixels)
int volumetric_correlation(num_lines, num_pixels)
unsigned int volumetric_correlation_uncert(num_lines, num_pixels)
short total_coherence(num_lines, num_pixels)

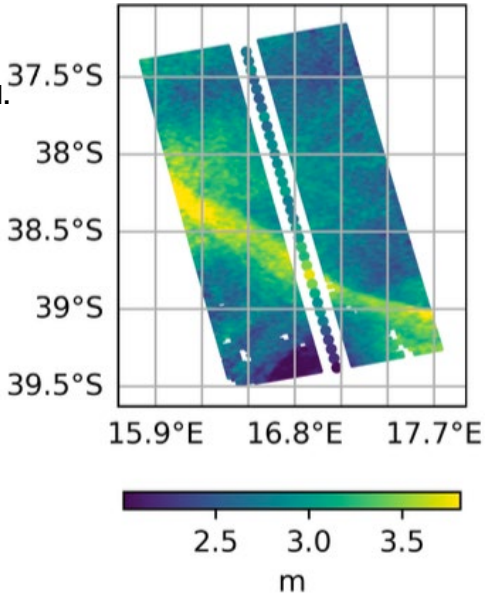
LR Algorithm Changes

- Fewer artifacts in LR SSH over land and near coasts (Version C2)
  - Multiple changes (reference surface, interpolation algorithm, bug fixes)
  - But LR data over land may still be unreliable, especially for smaller water bodies
- New algorithms for estimating KaRIn volumetric correlation and SWH give 2-D information over swath (Version C2)



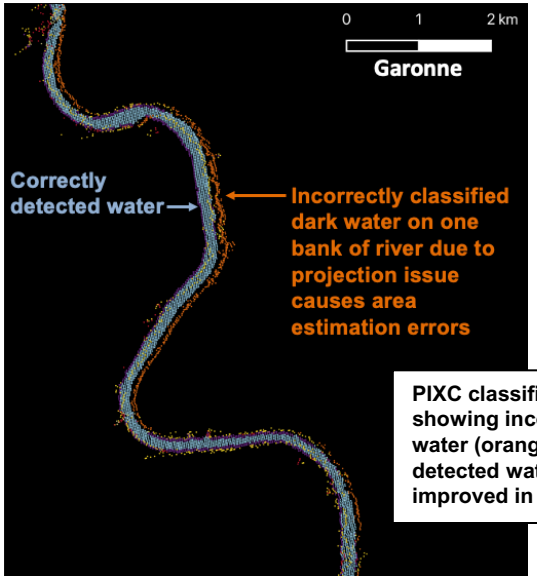


SWH estimated from KaRIn (from Bohe, et al. 2025, in press)

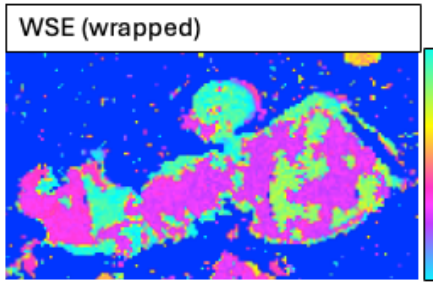


HR Pixel Cloud Changes
(Also Affect River, Lake, Raster)

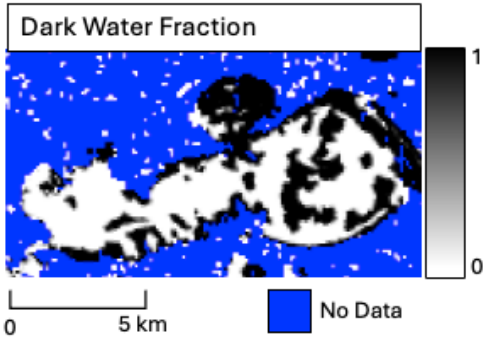
- Improved dark-water projection algorithm (Version C2)
  - Algorithm gives greater robustness to reference DEM errors when projecting between ground-plane and slant-plane during pixel-cloud processing
  - Gives more accurate classification, giving better estimates of river width and lake area
  - Fewer artifacts where water feature is “doubled” (data show two shifted copies of same feature on ground)
- Crossover flag handling fix (Version C2)
  - Some crossover data that had been flagged at “suspect” was being treated as “bad” and discarded in pixel-cloud processing; now fixed
- Bug fix for non-unwrapped pixels (Version C2)
  - Heights of pixels that were not phase unwrapped might have been computed incorrectly due to bug in previous versions; now fixed
  - Typical example of problem would be discontinuity in height between dark water and bright water in same feature



PIXC classification showing incorrect dark water (orange) at edge of detected water (blue); improved in C2

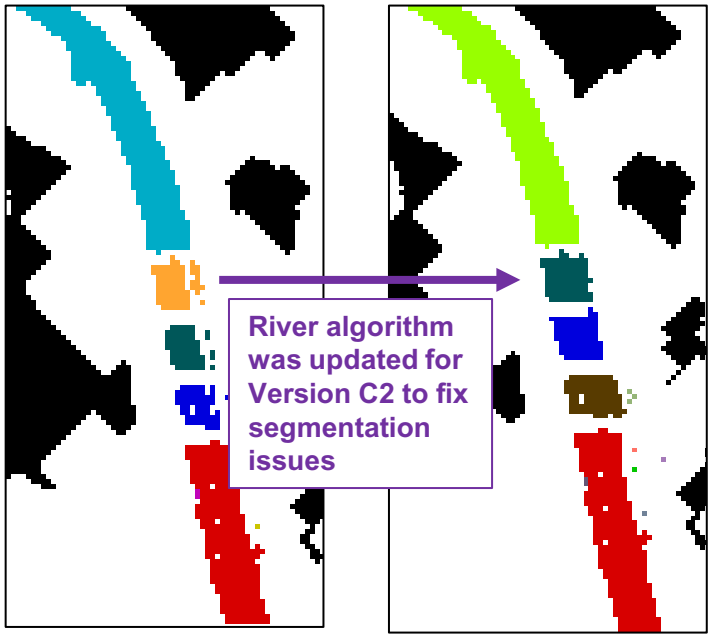


Raster example showing WSE artifacts for non-unwrapped dark-water pixels due to PIXC bug; fixed in C2



HR River Changes

- SWORD v17b (Version D0)
  - Improved river topology
  - New reaches
  - Reach and node identifiers differ from Version C0/C2
- River processing enhancements
  - Algorithm refinements affecting segmentation, node-to-reach aggregation (Version C2) improve width estimates
  - Area normalization to match width normalization (Version D0)
  - Updated quality flag handling to reduce number of *degraded* reaches (Version D0)
  - Bug fixes affecting measurement time and tile boundaries (Version D0)
- "Smoothed" node heights after Bayes reconstruction added to L2_HR_RiverSP product (Version D0)



$$W = \frac{\sum_n A_n}{\sum_n L_n}$$

Reach width *W* is estimated by dividing total observed area *A* (summed over nodes) by reach length *L*

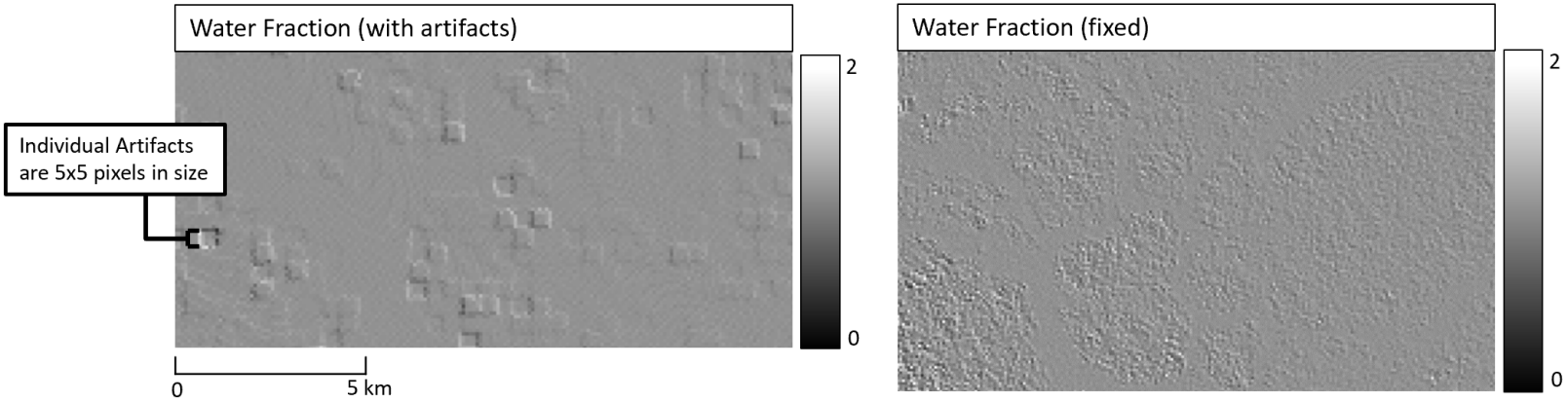
- Version C2 adjusts denominator to account for missing nodes
- Version D0 re-normalizes reported area to reflect estimated area over full reach even if some nodes are missing
- Changes also deal with details of detected vs. total area, quality flag handling, etc.

HR Lake Changes

- PLD v1.06 (version C2)
  - Additional lakes, updated lake catchment areas
- PLD v2.02 (version D0)
  - Reference lake elevations based on median LakeSP_Prior elevations
- Lake processing enhancements
  - Updated quality flag and introduction of bitwise flag (version C2)
  - Exclusion of pixels flagged as specular ringing from water surface area and elevation computations (version C2), as well as certain other pixels based on classification and quality flags (version D0)
  - Refinement of the cross-track distance to better filter pixels outside the 10-60 km swath (version D0)
  - Correction of the computation of the overlap attribute in the _Obs file and some other bug fixes (version D0)

HR Raster Changes

- Raster algorithm improvements (Version C2)
  - Updated algorithm to reduce “boxy” artifacts
  - Fixed issue with water being geolocated on incorrect swath side
  - New quality flag bits to provide more information on specular ringing and dark water
- Minor bug fixes (Version D0)



Raster water fraction before and after fix of “boxy” artifacts

Documentation Updates

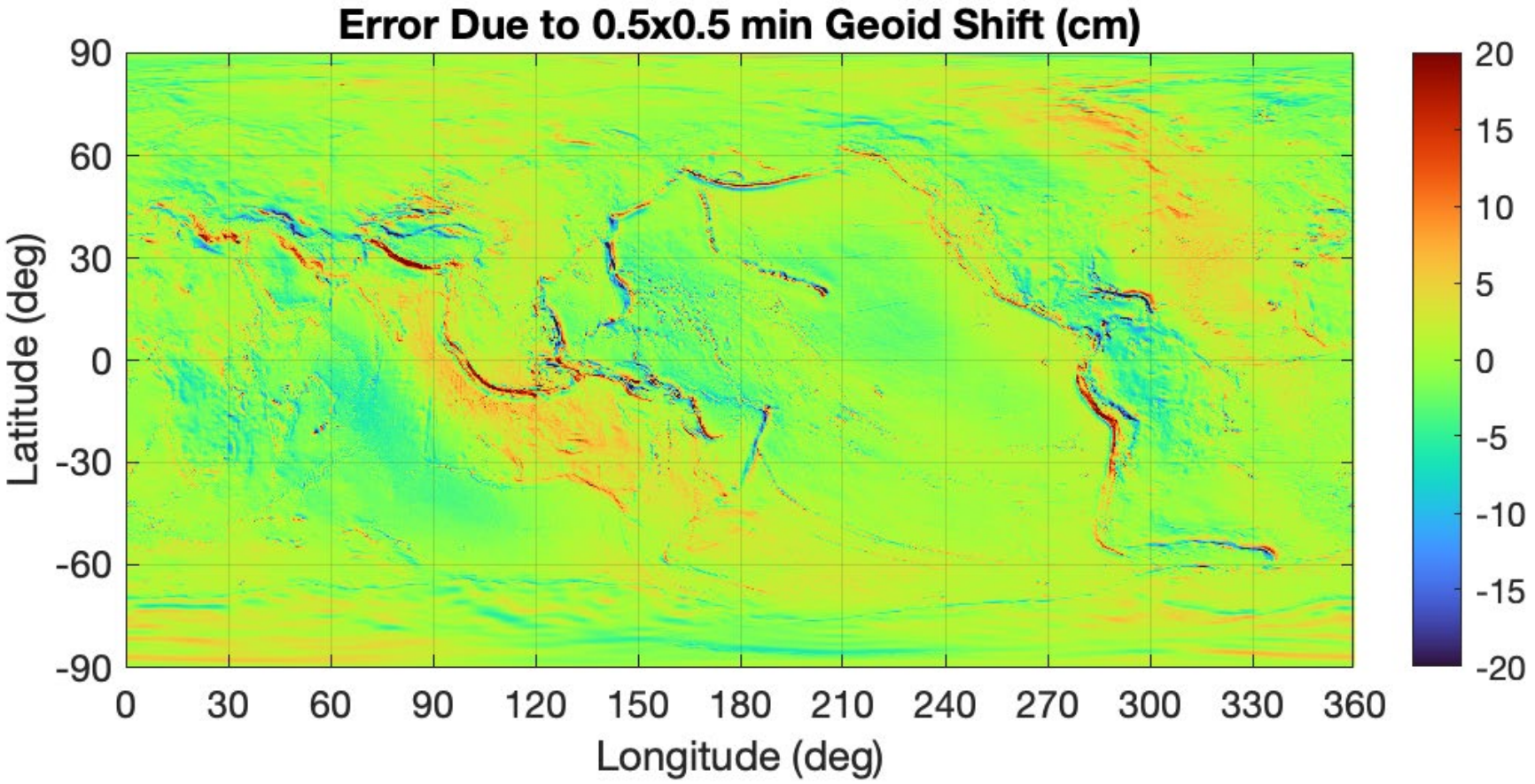
- Users are strongly encouraged to read the documentation available at:

  https://podaac.jpl.nasa.gov/swot?tab=datasets-information&sections=about

- Includes:
  - Small updates to:
    - User Handbook
    - Product Description Documents for all KaRIn and Nadir altimeter products.
- Version D release note.
  - Summarizes major changes from Version C0, to C2, to D0.
  - Known issues in each of C0, C2, and D0 products.
  - Changes to data access locations for Version D as compared to Version C.
    - For PODAAC, can search as follows:
      - Version D: https://search.earthdata.nasa.gov/search?q=SWOT_*_D
      - Version C: https://search.earthdata.nasa.gov/search?q=SWOT_*_2.0
    - Similar locations for CNES AVISO and hydroweb.next

Backup

Error Due to 0.5 x 0.5 arcmin Geoid Issue



Magnitude of error due to geoid shift can be larger than 20 cm at specific locations but is less than 5 cm for great majority of planet surface. Fixed in Version D0