National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Surface Water and Ocean Topography (SWOT) Mission

River Width Developments

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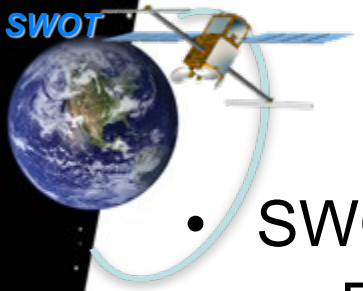
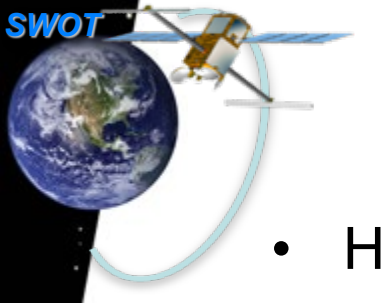


Overview

- SWOT River products generally meet their targeted performance expectations
  - Even at node-level wse is excellent (although there are anomalies)
  - Reach-level slopes are generally good
  - Node and reach widths behave most differently from prelaunch expectations

- SWOT ADT has recently been focusing on river widths in an effort to
  - Better characterize performance
  - Identify the sources of width errors
  - Develop approaches to mitigate remaining issues

- Presentation outline
  - Statistical performance behavior, including as a function of various parameters
  - Examples of known error mechanisms
  - Algorithm improvements beyond Version D



Kinds of Width Assessments

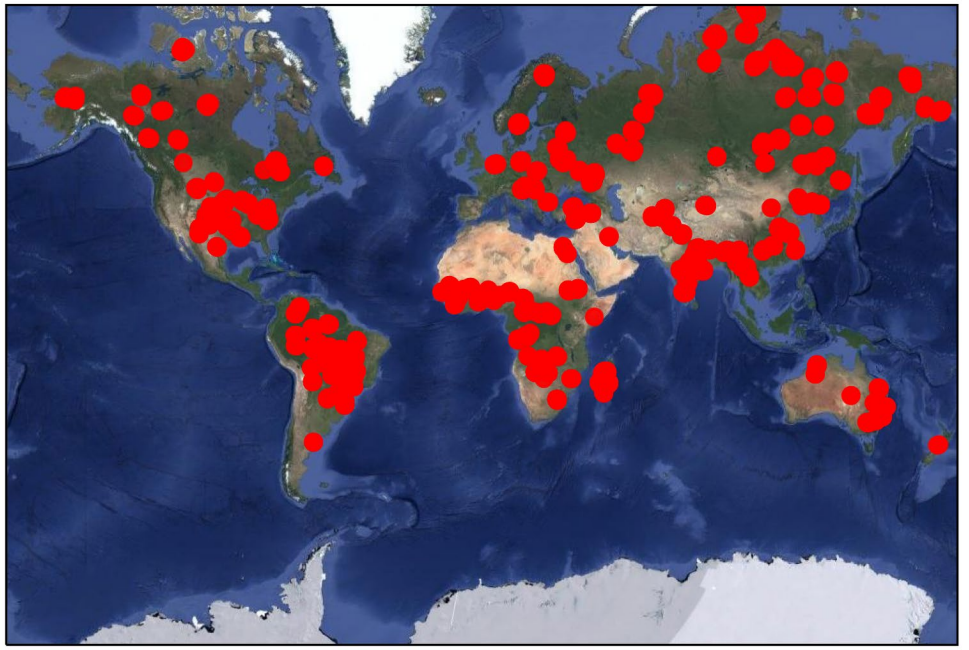
- Have done several classes of assessments (with different levels of scrutiny)
  - Manual investigation of cases as well as statistical assessments
  - “Fine” validation with co-incident high-resolution masks
    - Shoreline walks, NV5…
  - Coarse validation (wrt pekel 50%ile threshold)
  - GLOW-S width collocations
  - DSWx comparisons
  - Multitemporal assessments
    - Self consistency over time and with consistency with expected assumptions (e.g., width and wse should increase together)
    - Performance split by pass-observation etc
- ADT Has focused much of the width assessment effort on DSWx comparisons
  - Can get global representative set
    - Critical because there are several different mechanisms for width errors
  - Large enough set for robust statistics and reliable conclusions

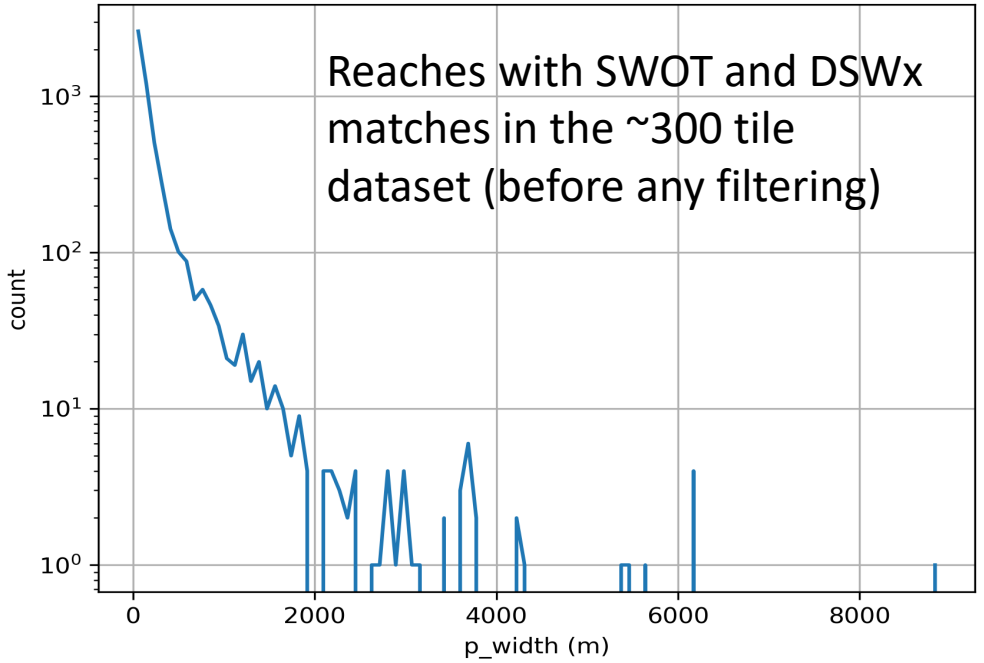
DSWx Width Comparisons

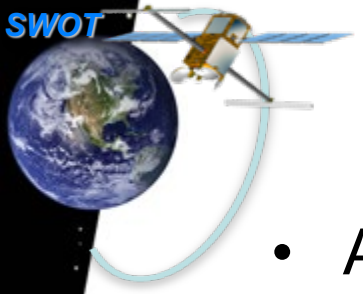
- DSWx collocations with SWOT
  - DSWx-HLS WTR v1.0, from S2
  - SWOT offline Version D-like processing science orbit (node and reach)
- ~ 300 SWOT tiles globally(**) in the science orbit
  - ~30 m resolution masks
  - "Truth" river processing similar to RiverTile processing except
    - Different handling of connectivity
    - Treating clouds as dark_water and filtering on dark_frac (to exclude them from assessments)
  - Collocations <12 hours in time between SWOT and DSWx

- (**)~300 tiles is about the minimum needed to get robust statistics (tested for larger collection of data over Version C dataset)
  - Have identified a separate ~300 tiles to use as future validation of updated algorithms adapted and tuned from the first ~300 tiles

Reaches in Collocated DSWx Set







Quality Filtering for DSWx Width Assessments

- Apply the filter we have been using for both WSE and Width (OIIT)
- DSWx also has quality filtering
  - Exclude clouds in DSWx
  - Exclude DSWx tile clipping

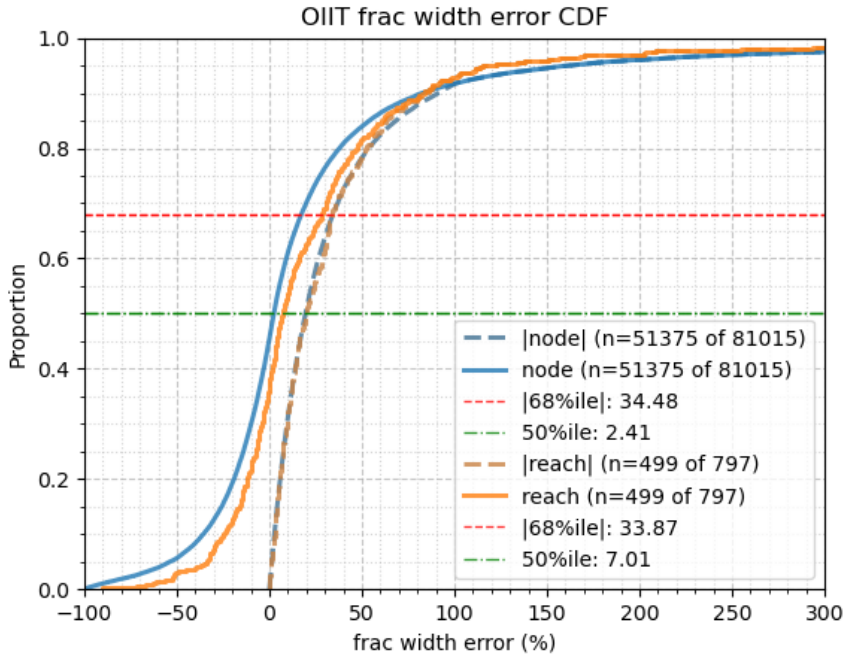
Outer Filter (OI)	
Product Variable	Filtering Criteria
xtrk_dist (cross-track distance)	10 – 60 km
p_width (prior width from SWORD)	>= 80m
p_length (prior reach length from SWORD)	>= 7km
ice_clim_f (climatological ice flag)	Likely not ice covered

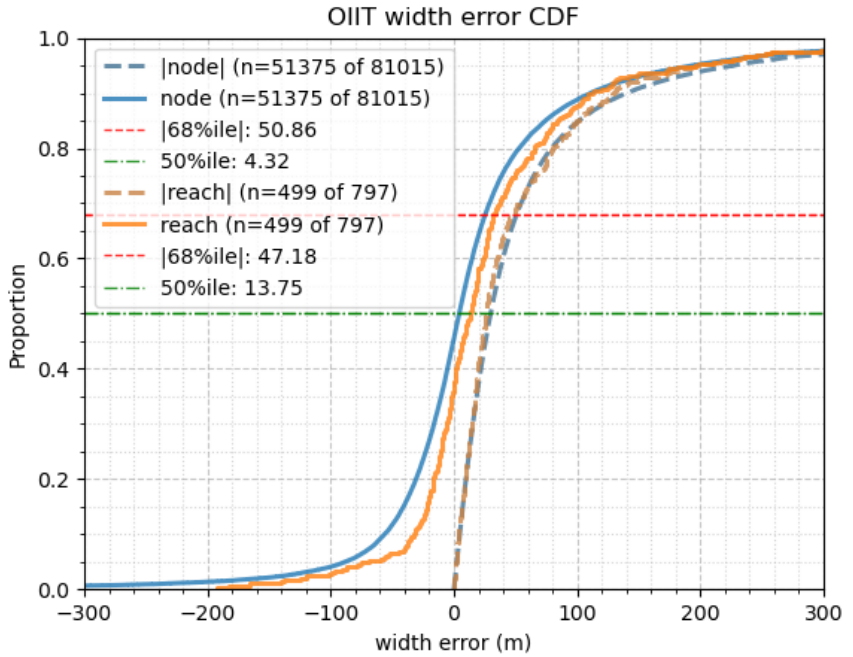
Inner Filter (OIIT)	
Product Variable	Filtering Criteria
dark_frac (dark water fraction)	<= 0.4 (40%)
obs_frac_n (fraction of nodes with valid WSE)	>= 0.5 (50%)
node_q (summary node quality indicator)	Good, Suspect and Degraded
reach_q (summary reach quality indicator)	Good, Suspect and Degraded
node_q_b (bitwise node quality indicator)	<= 2097152
reach_q_b (bitwise reach quality indicator)	<= 2097152
xovr_cal_q (crossover calibration quality indicator)	<= 1
area_total (total water surface area)	>= 0

DSWx Statistical Comparisons

- Bulk results
  - Many errors seem to occur near river banks, so focus on width error metric (in meters)
  - Width errors (focus on OIIT)
    - low bias (<5m for nodes, <15m for reach)
    - ~50m 1-σ errors
  - Not clear how much error is SWOT vs DSWx contributions

- Limitations with this approach:
  - ~30m resolution limitations on edges and small water bodies
  - Truth processing behaves in many ways like the SWOT processing, potentially hiding some classes of algorithm error
  - Almost every observation is for a different node/reach (not many observations of the same reach over time)

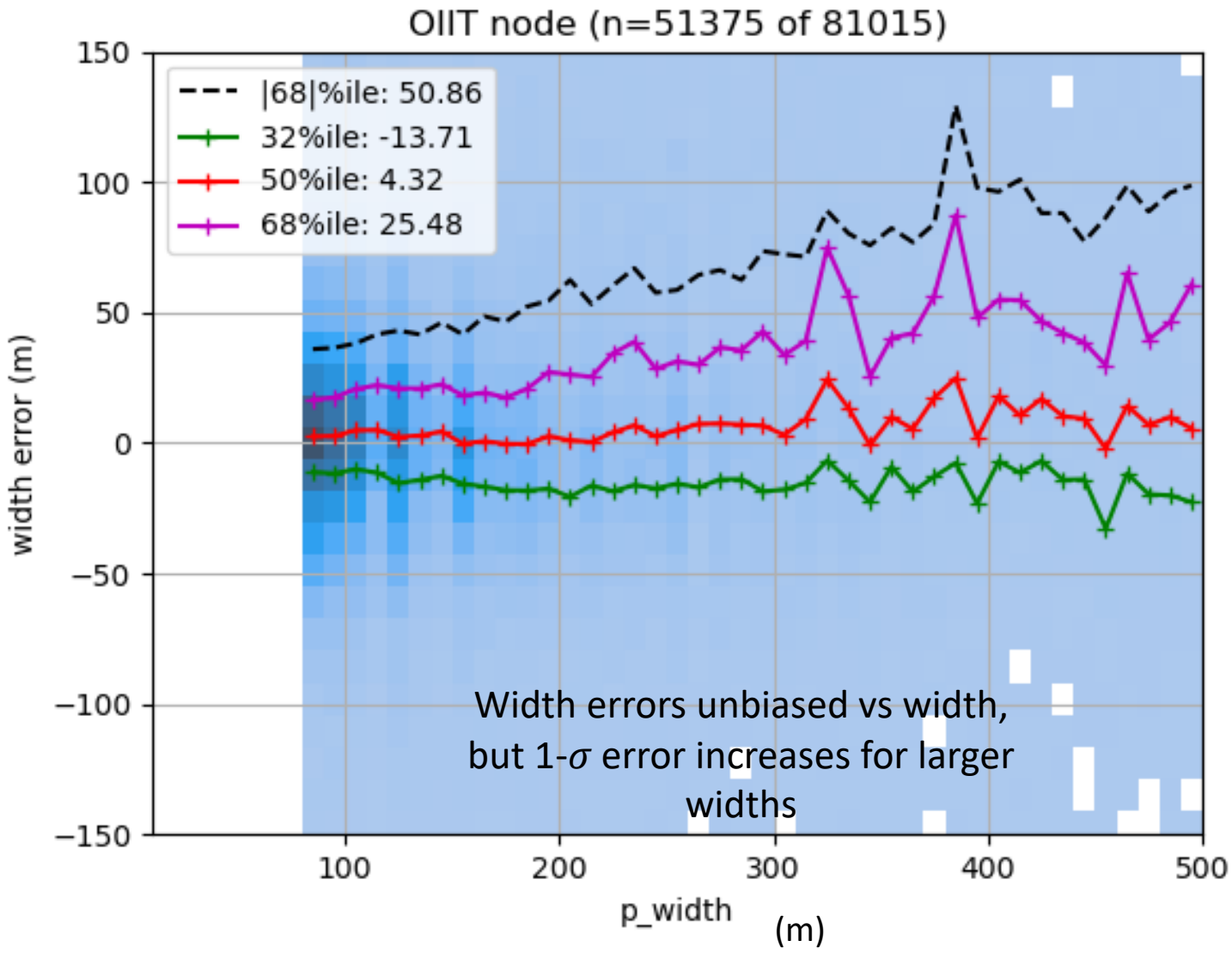




Width Error vs Width

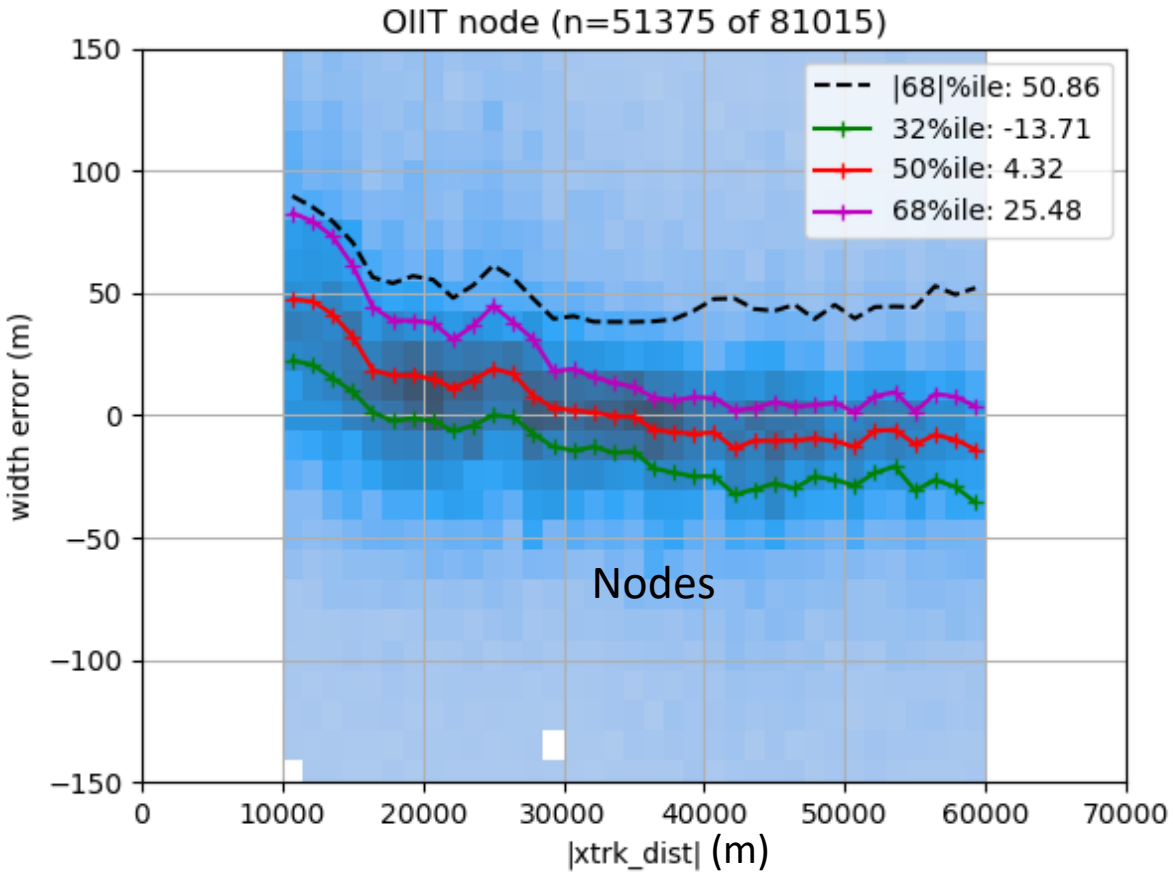
- Width errors are not a strong function of the width
  - Bias (50%ile, red line) is flat
  - 1-σ error (dashed-black line) does have a trend

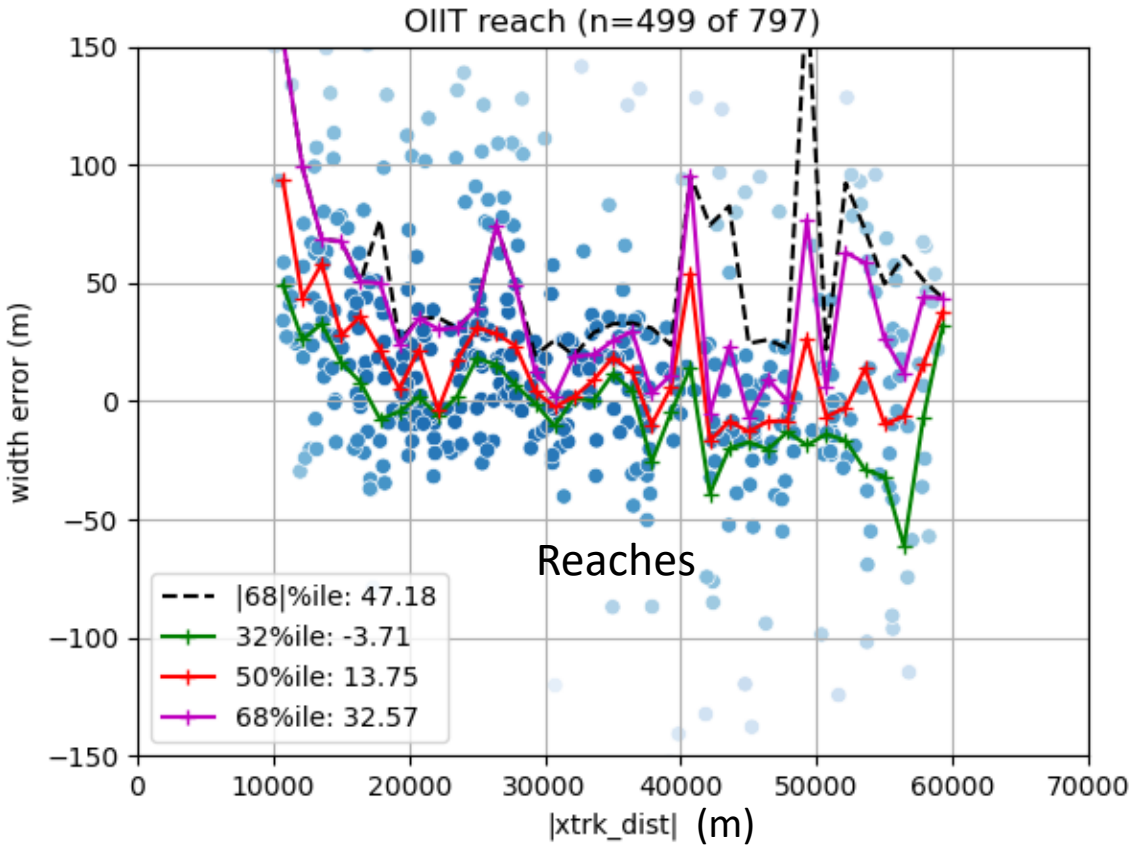
- Width error in meters is a better metric than fractional error to quantify width error
  - More relatable to physical mechanisms of width error
  - Fractional errors are dominated by the smaller rivers because they are so much more abundant



Cross-track Bias in Width Error

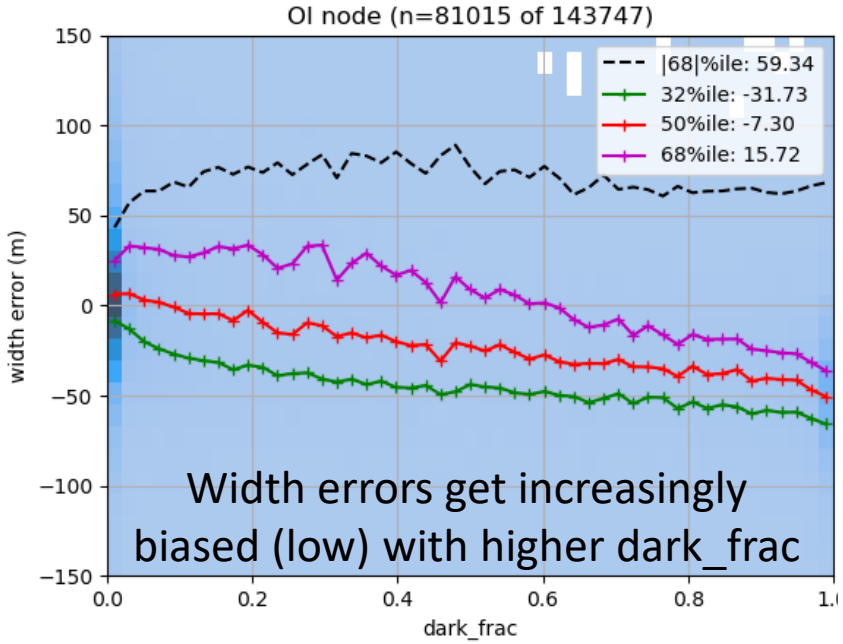
- There is a width error bias vs cross-track (in both nodes and reaches)
  - Positive bias in the near swath (~+50 m at 10 km)
  - Negative bias in the far swath (~-10 m, at 60 km)

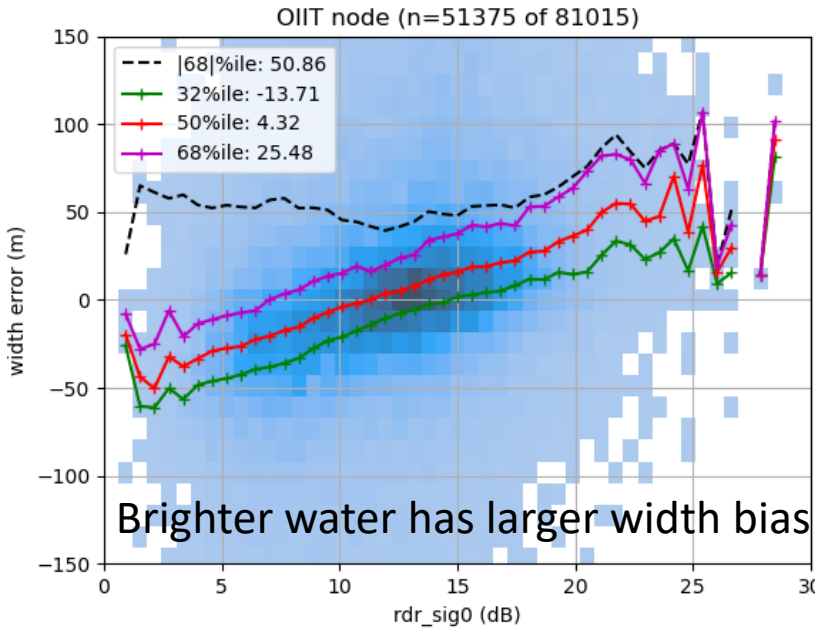


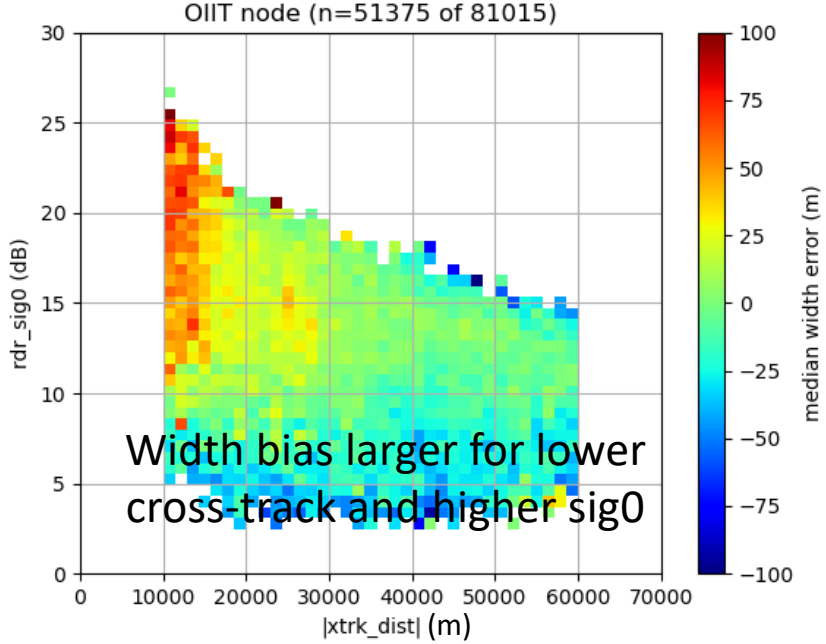


Width Error Relationships

- Width errors (both the bias and the 1-σ error) are a function of various parameters that exist in the river products
- Many of these are coupled with each other making it difficult to identify mechanisms of error
  - E.g., sig0 bias trend may be due to dependence with cross-track and/or with dark_frac



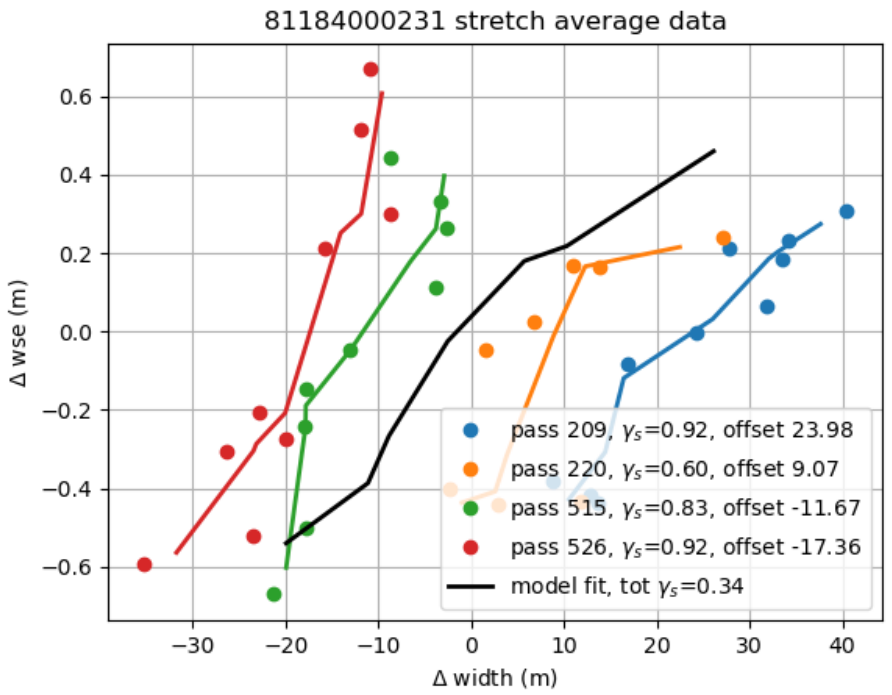


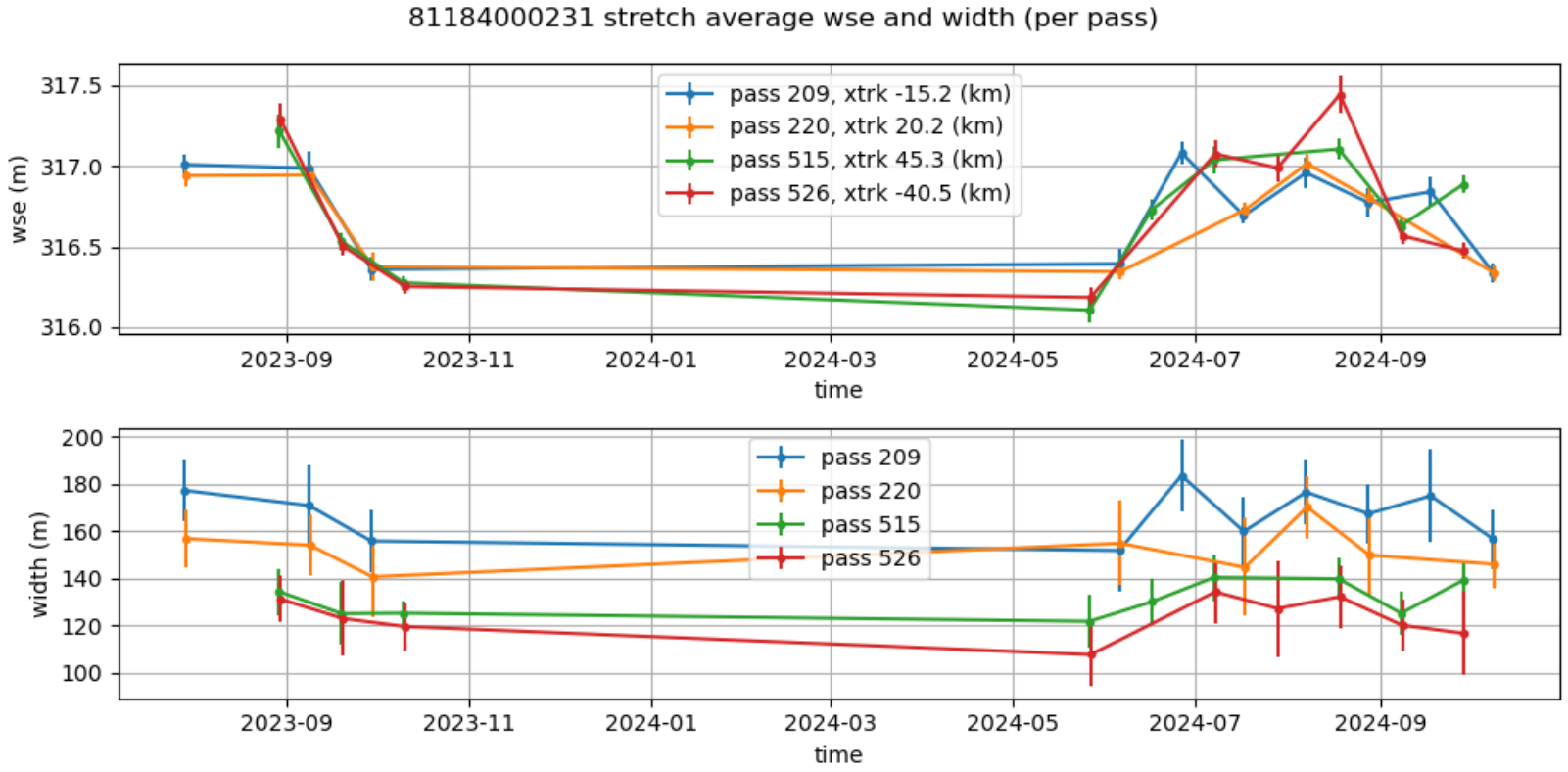


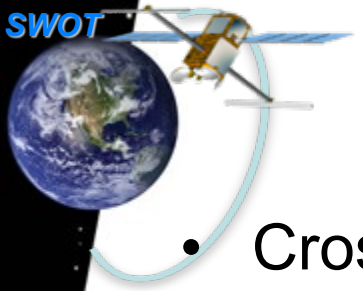
Per-pass Bias: Multitemporal Analysis

- Time series shows bias that depends on pass number in cycle (PxC0 data)
- Seems related to the cross-track bias
- Will still be in the Version D data

- We are actively working on:
  - Understanding the mechanisms that cause the cross-track/per-pass bias
  - Developing algorithms for correcting/mitigating those mechanisms
  - Empirical bias correction is also being considered



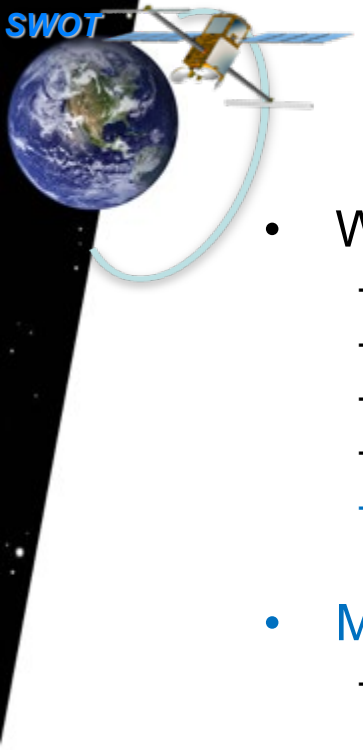




Finding Error Mechanisms

- Cross-track bias and other statistical trends
  - help understand the characteristics of the errors in the data
  - but do not directly point to specific error mechanisms
  - nor indicate which mechanisms are most important to fix

- Potential approaches to identify error mechanisms
  - Look through cases manually (maybe filtering on specific error magnitude ranges)
    - We have done some amount of this and have a list of known issues
  - Hypothesize mechanisms that are causing the biggest problem, figure out how to flag or fix them, then test how they impact the overall error statistics
    - i.e., given an error mechanism and a way of identifying it in the data, we can directly test sensitivity of the errors to that mechanism



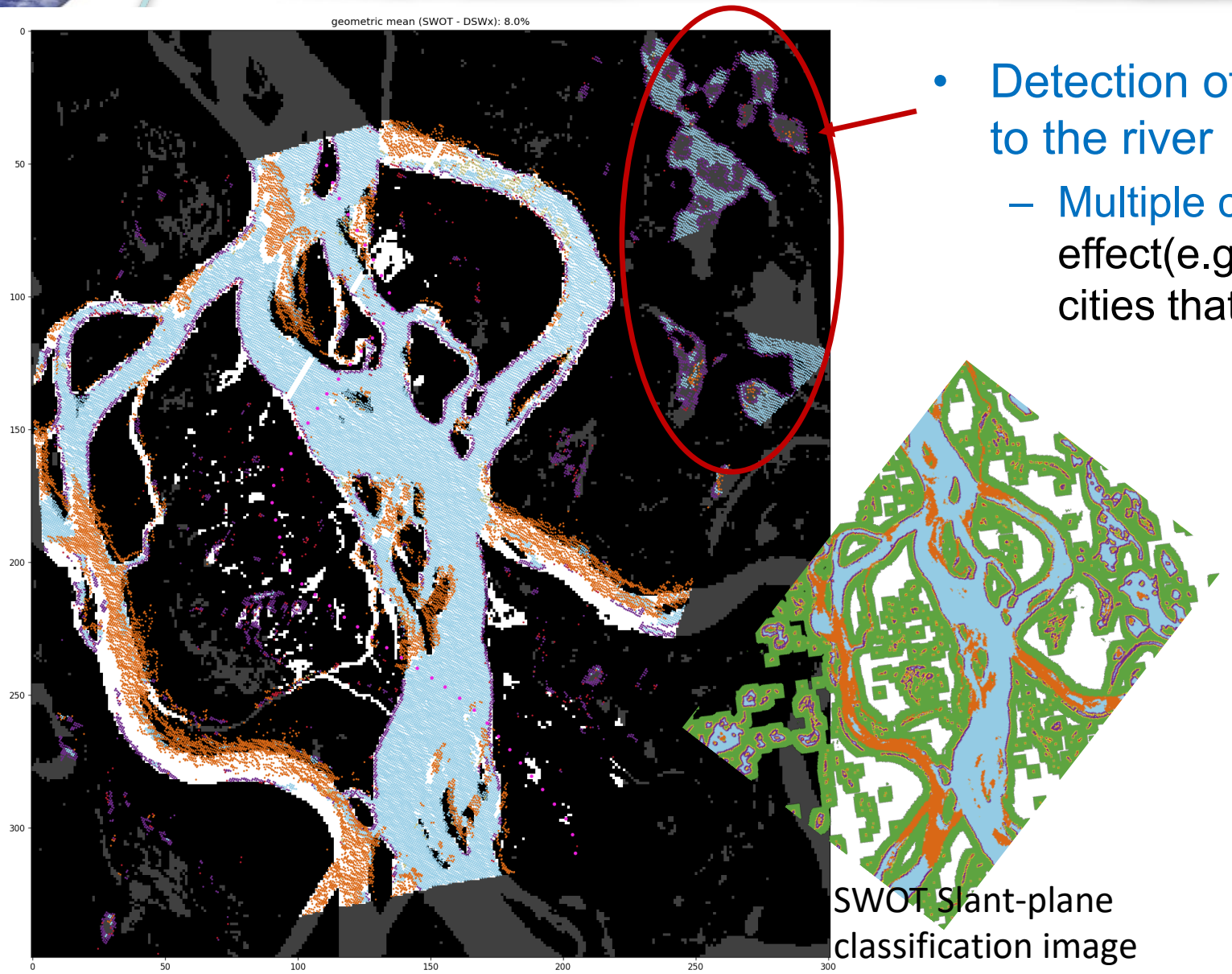
Known Classes of Width Error

- Water detection and dark water flagging errors
  - False detection of bright non-water (cities, ice/snow etc)
  - Errors in the prior occurrence
  - Errors in projecting and co-registering the prior mask with the slant-plane images
  - Errors in selecting the occurrence threshold
  - These occur in PIXC processing

- Misassignment of non-river-water pixels to nodes
  - Assigning extra non-river pixels
    - Neighboring lakes
    - False detected cities, bright fields, or sand bars
    - Other bright non-river features coupled with SWORD extreme distance too large
  - Not assigning river pixels
    - SWORD centerline offsets
    - SWORD extreme distance clipping
  - These occur in river processing (pixel-to-node)

- Anomalies affecting node-to-reach aggregation
  - Node-level width outlier rejection is difficult on a per-pass basis
  - Quality flags and uncertainty measures for width/area are still rudimentary
  - These occur in river processing (node-to-reach aggregation)

Example: Extra Pixel Assignment Errors

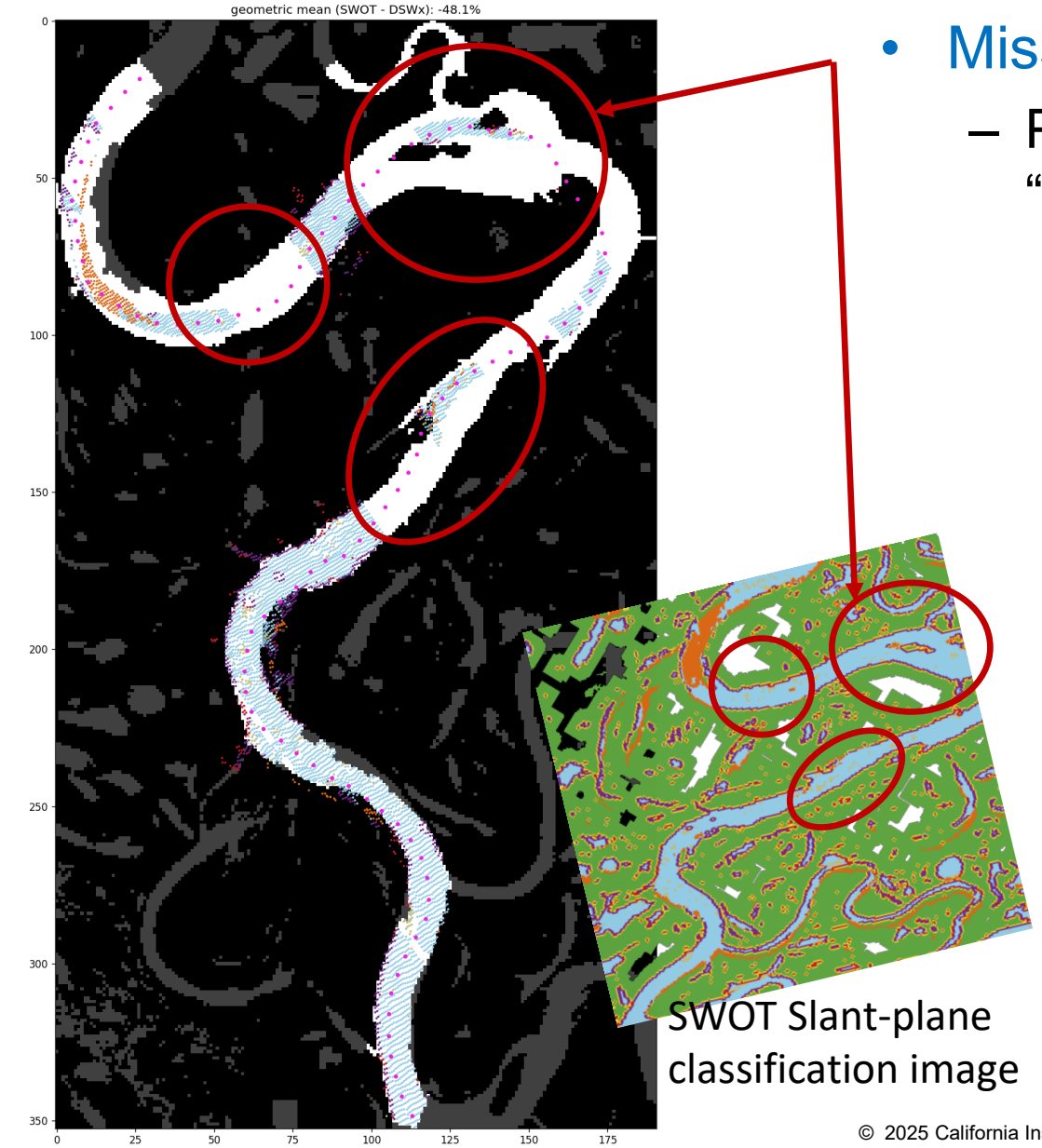


- Detection of non-river-water that gets assigned to the river
  - Multiple causes of this “overdetection” effect(e.g., lakes close to river, flooded fields, cities that are bright and detected as water etc)

SWOT Slant-plane classification image

- White: DSWx water in reach
- Gray: DSWx water not in reach
- Black: DSWx non-water
- Blue: SWOT detected water
- Orange: SWOT dark water
- Purple: SWOT water-near-land
- Yellow: SWOT land-near-water
- Green: SWOT land
- Red: SWOT low coherence water
- Pink: SWORD centerline

Example: Missed Pixel Assignment Errors



SWOT Slant-plane classification image

- Missed assignment causing gaps in SWOT data
  - Possibly multiple mechanisms that can cause this "slicing" effect
    - E.g., Specular ringing, phase unwrapping region on wrong ambiguity, SWORD clipping in multibranch sections

- White: DSWx water in reach
- Gray: DSWx water not in reach
- Black: DSWx non-water
- Blue: SWOT detected water
- Orange: SWOT dark water
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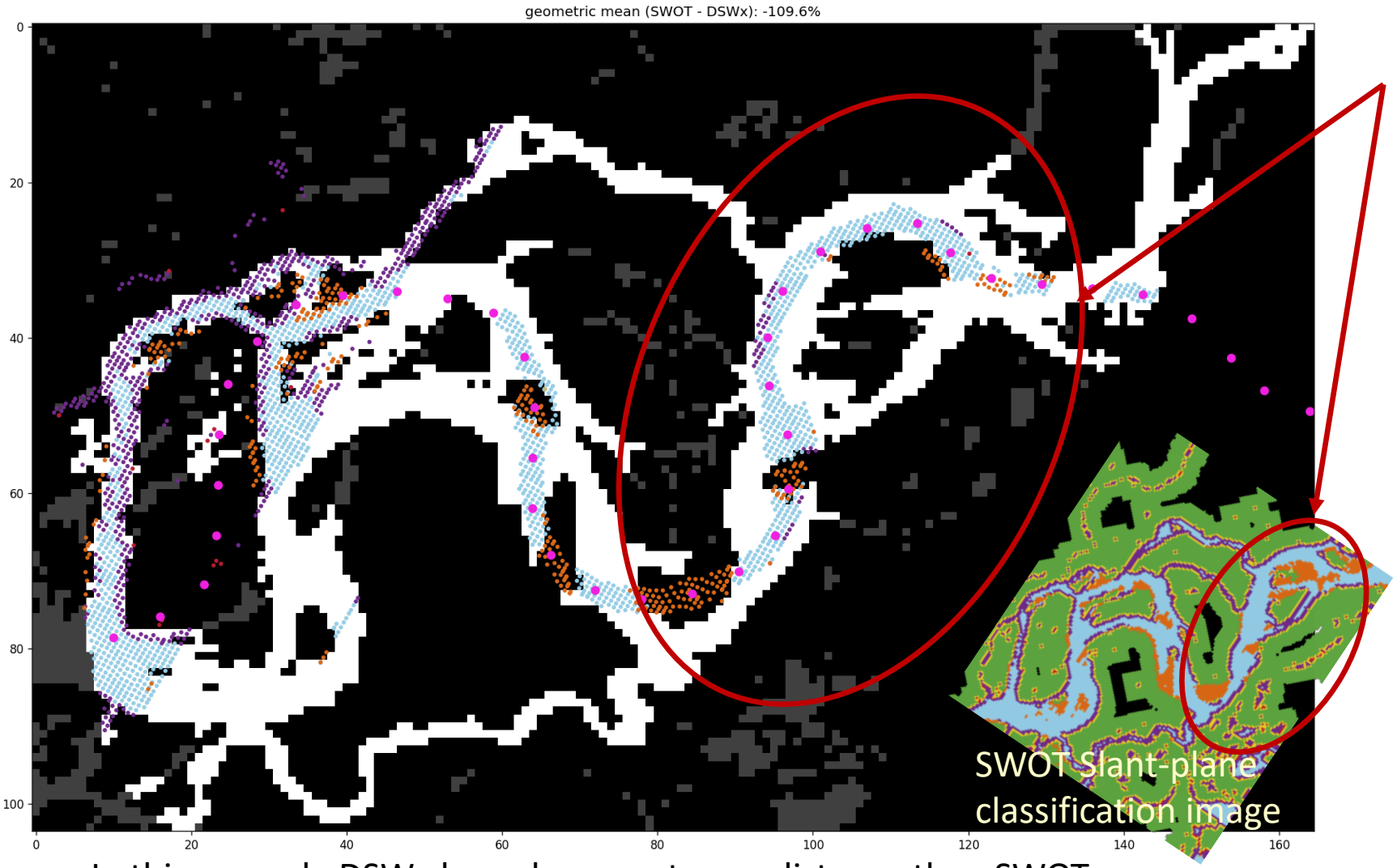
- Pink: SWORD centerline

Example: SWORD clipping



In this example DSWx has a larger extreme distance than SWOT

- SWOT pixels outside of SWORD extreme distance get clipped out and not assigned
  - Can be obvious like this case or more subtle (small differences near riverbanks)

- White: DSWx water in reach
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- Green: SWOT land
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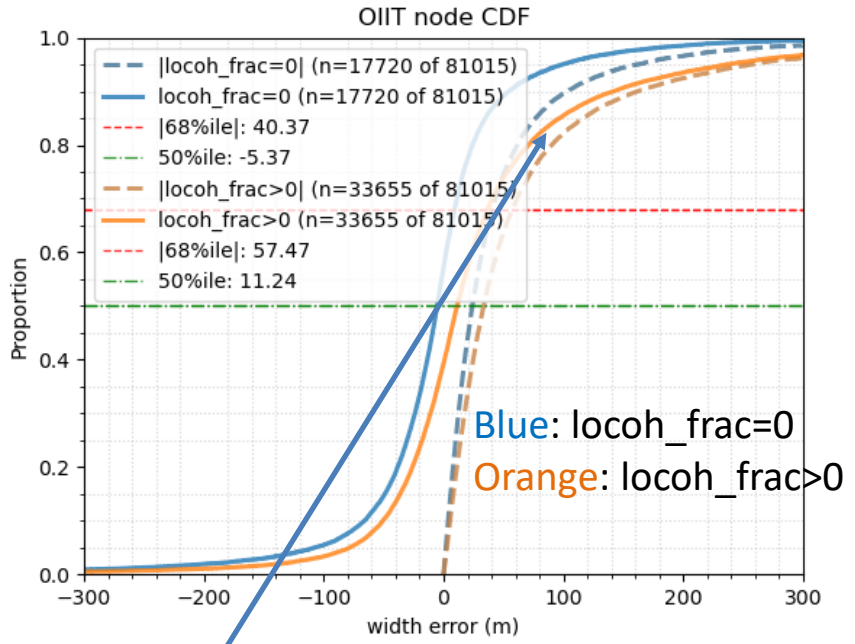
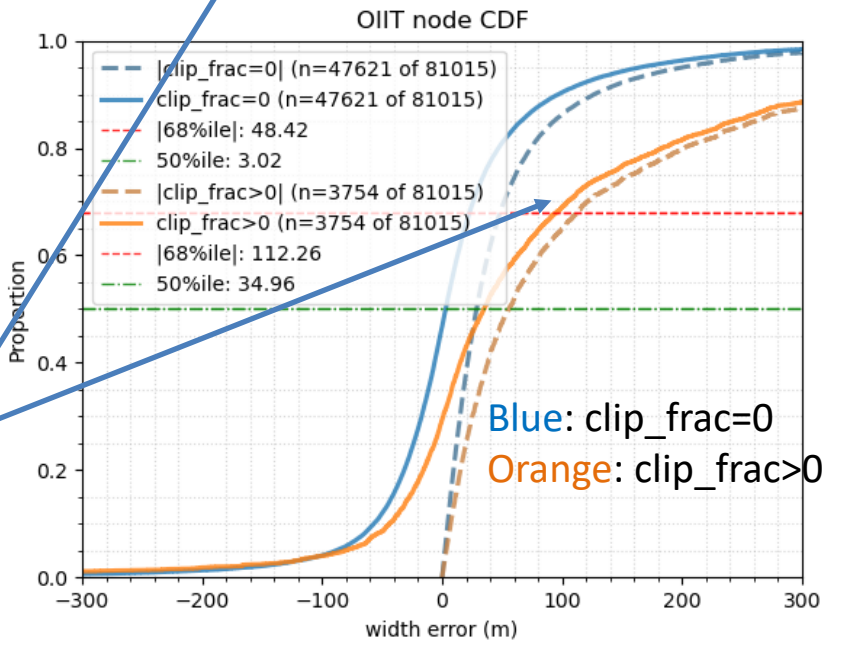
- Pink: SWORD centerline

Exploring Additional Algorithms

- Have explored width outlier filtering
  - Difficult even with entire multitemporal stack
- Developing node-level and reach-level quantities that can indicate when nodes/reaches are less reliable
  - Can use in node-to-reach aggregation to deweight/exclude nodes with bad dubious widths (see other slides for details?)
  - Can use as information for additional quality filtering
- Some experimental metrics (not available in Version D) that seem to be useful
  - **locoh_frac**: fraction of pixels in a node that have low-coherence classification
  - **clip_frac**: fraction of pixels in a node that were excluded because they are farther than the “extreme distance” threshold
  - Orange lines (non-zero locoh_frac and clip_frac) are significantly skewed right meaning they capture a larger percentage of the large positive width errors

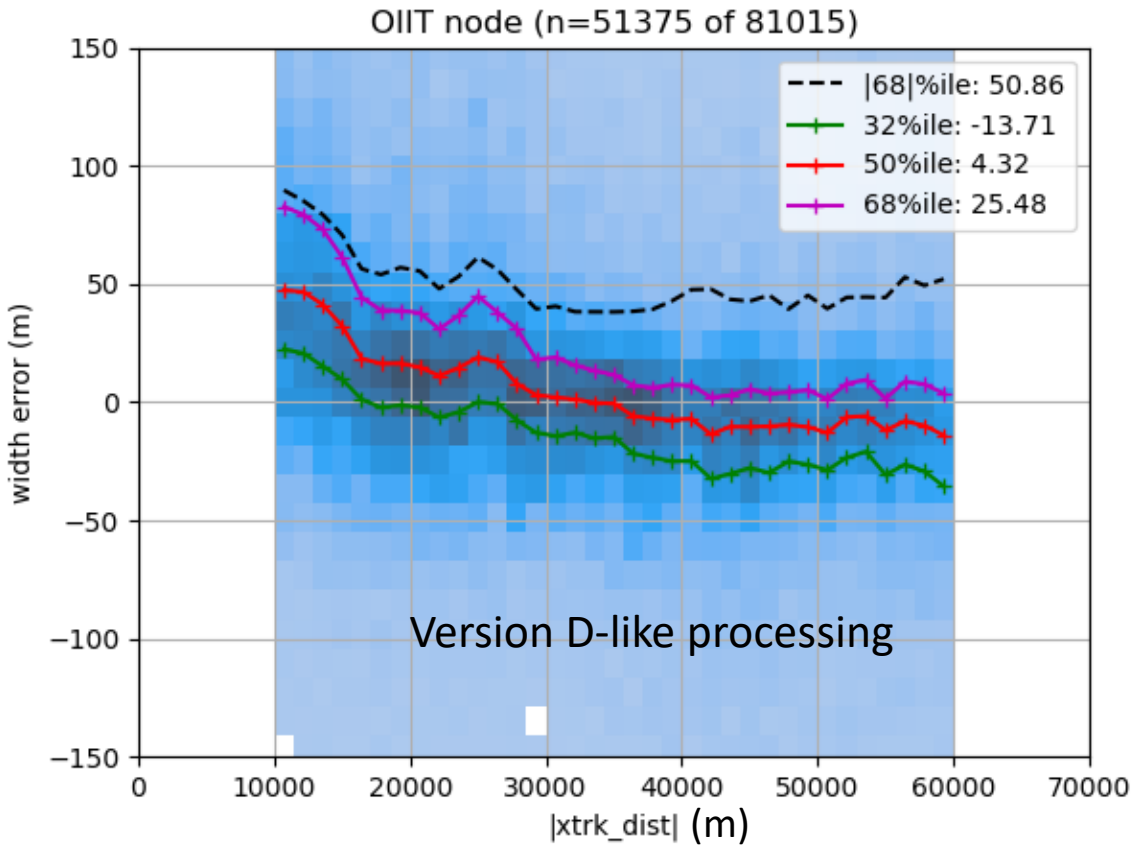


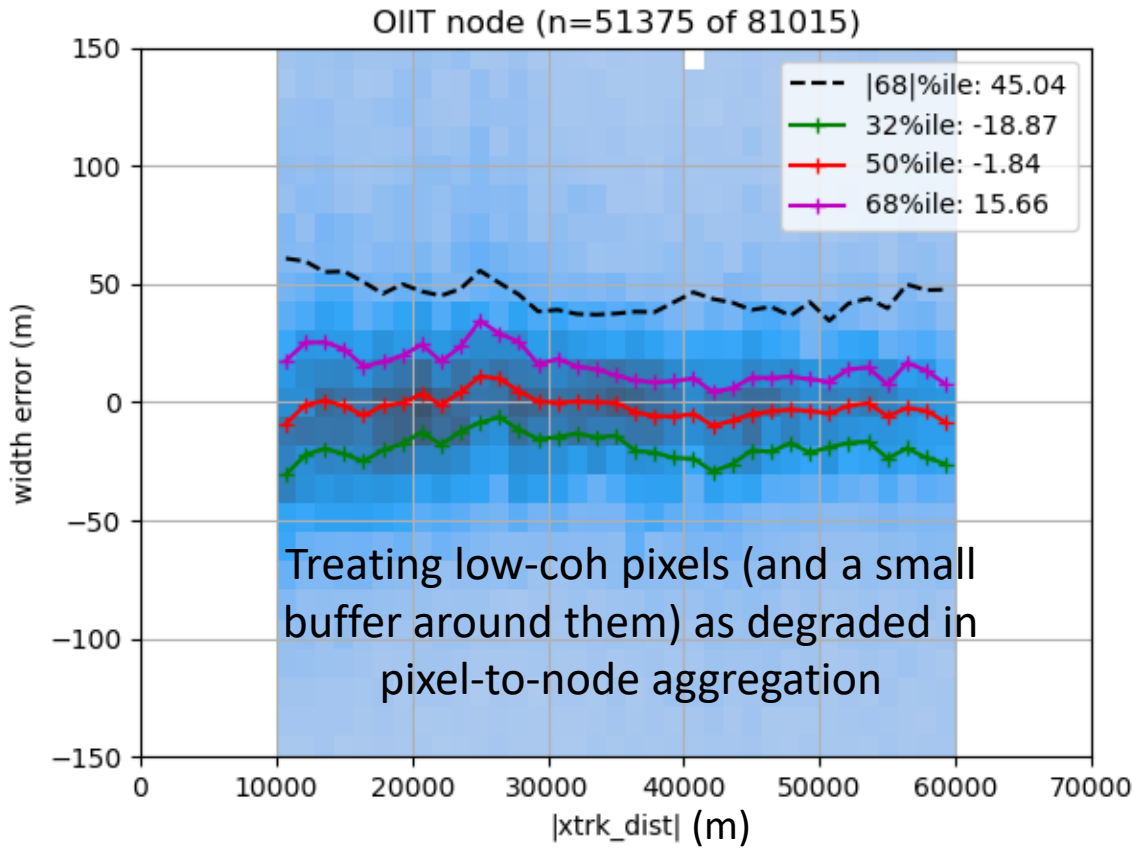


Exploring Additional Algorithms

- Treating low-coherence pixels as degraded
  - Reduces the cross-track dependence
  - Could reduce the number of nodes that pass OIIT fllter

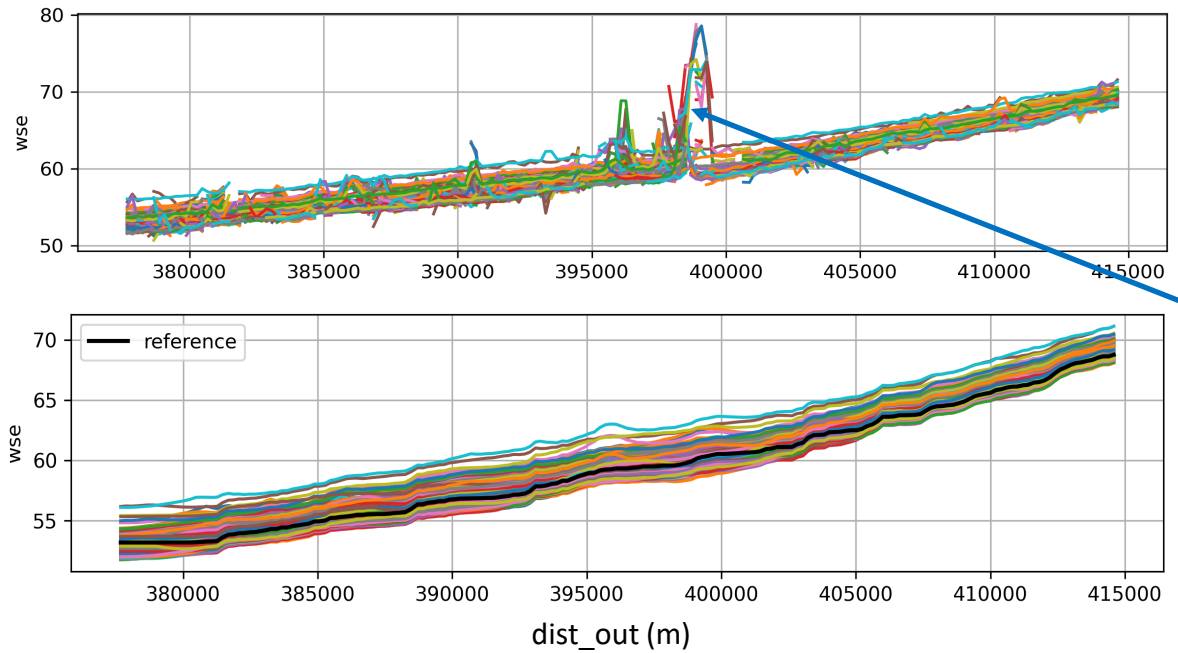
- Does not completely resolve the cross-track bias
- There are likely multiple mechanisms that contribute to the cross-track bias

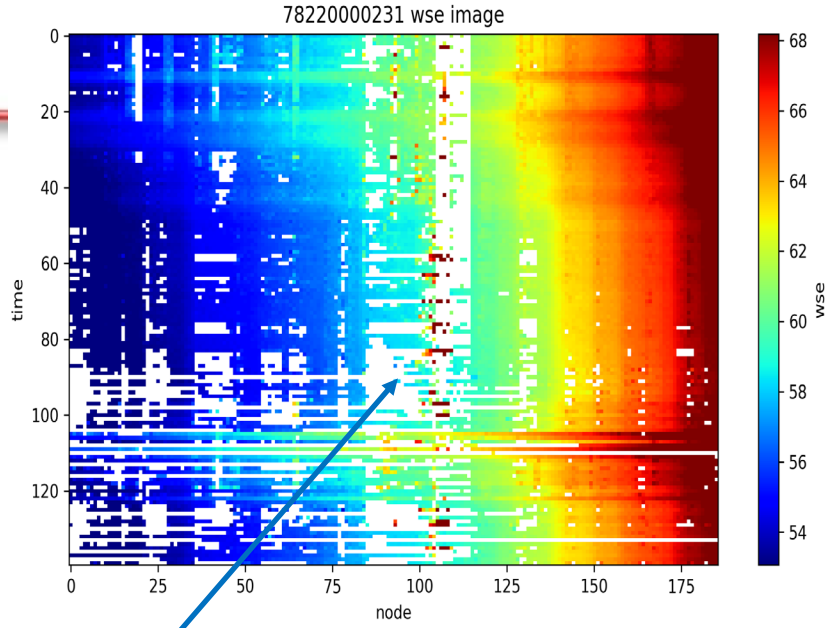


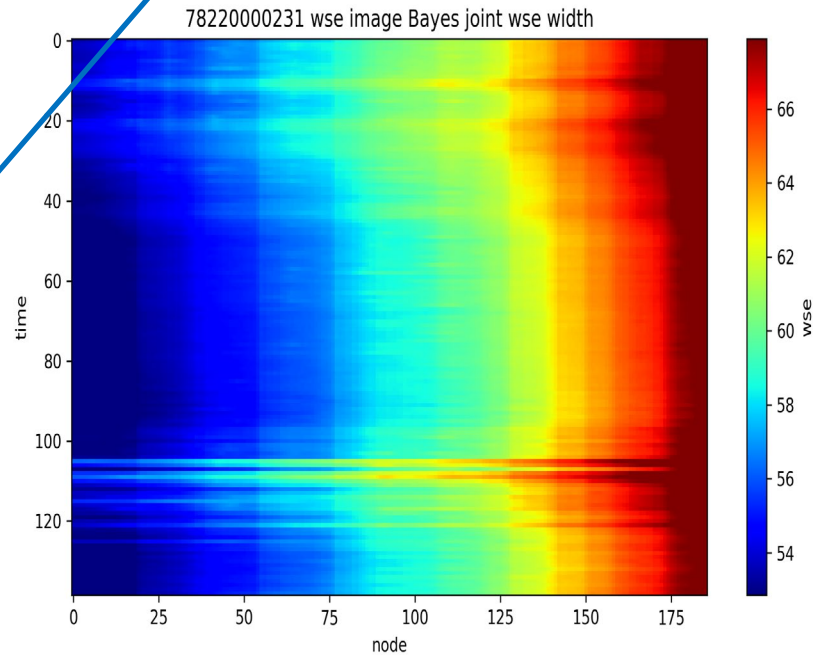


Multitemporal Info as Priors

- Already have Bayes reconstruction for WSE in RiverSP
  - Currently only applies to WSE and uses a linear fit as the prior WSE profile and coarse guesses for spatial correlation scales
- Extend to use priors from multitemporal stack of SWOT data
  - Reference WSE and width along-river profiles to get actual non-linear profile shape
  - Height/width relationship models
  - Spatial-scale/correlation length estimates
  - Seasonally varying priors
- Available in this repo https://github.com/SWOTAlgorithms/river-spatial-scale







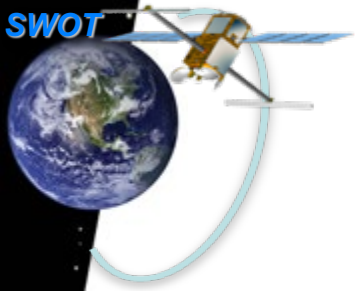
Can help in outlier rejection as well as produce quality estimates at every node (with reliable uncertainties)

Summary

- SWOT river performance is good, but ADT is focusing on improving widths

- Width errors compared to DSWx
  - Show relatively low overall bias and ~50m (1-σ) errors
  - There is a bias vs cross-track (and is coupled with sig0 and dark_frac etc)
  - The cross-track bias manifests as a per-pass bias in multitemporal width timeseries and height/width analyses

- ADT is working on
  - Identifying sources of the width errors (especially the cross-track bias)
  - Developing additional quality indicators
  - Improving/fixing known issues algorithmically



Backup

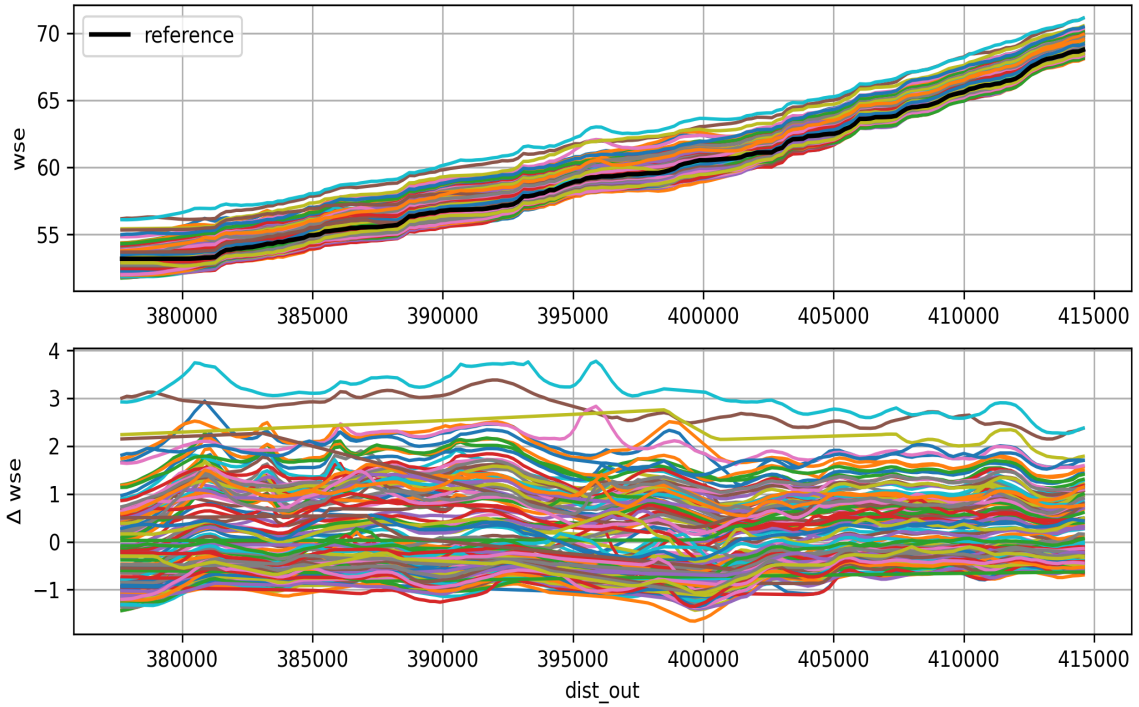
DSWx Details

- Truth processing uses the “orig” aggregation method, which differs from what’s used in forward processing. Don’t know what the implications of that are, however.

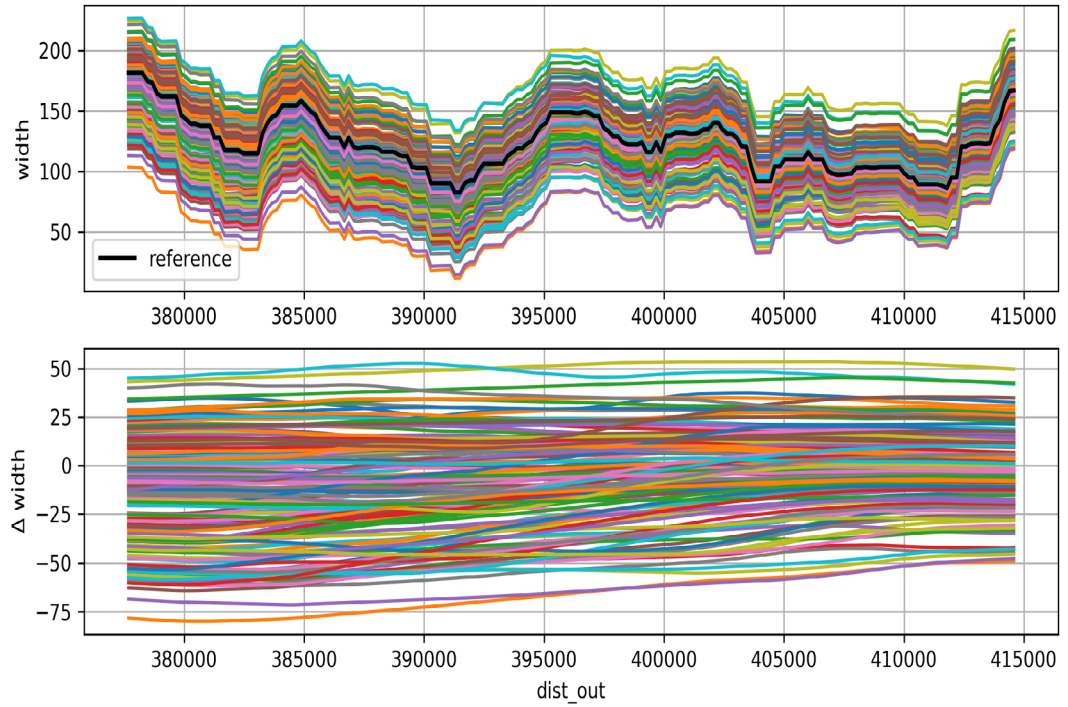
- Cal/Val comparison also used LandSAT, but science-orbit does not.

BayesData

78220000231 Bayes joint wse width



78220000231 Bayes joint wse width



- Bayes reconstruction can be done for both WSE and width (and joint/together)
- Can also incorporate height/width model (though not applied in this example)
- Width reference profiles are not too smooth, but deviations around them are
- Potentially different spatial scales of deviation from reference profiles for WSE and for width