Ocean Surface Wind Retrieval and Quality Control Near Sea Ice

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Sponsor Acknowledgment

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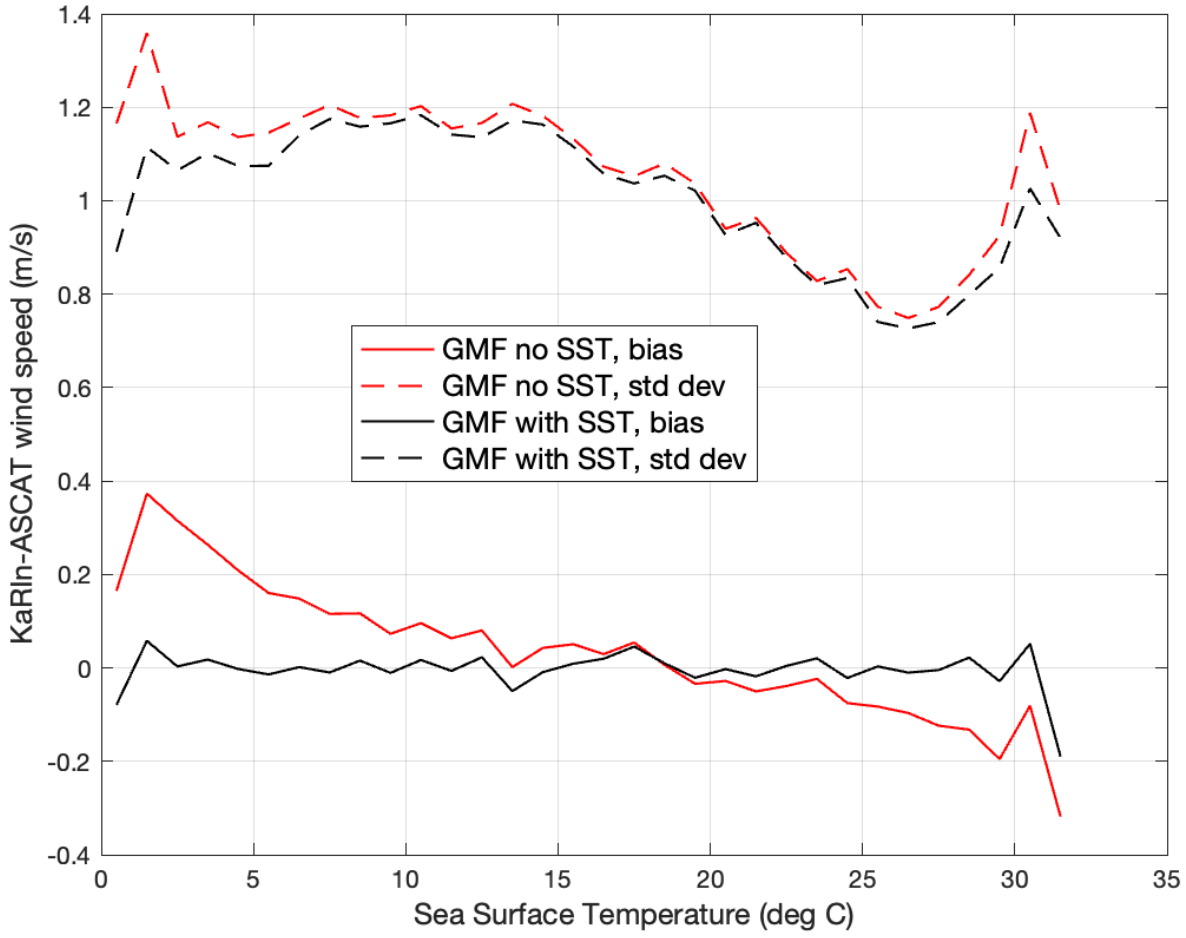
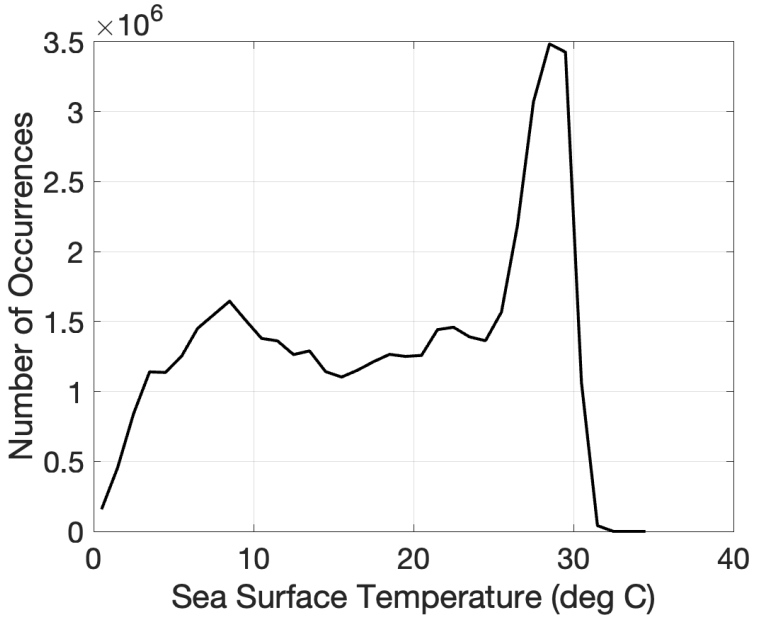
Overview

- Improvements in SWOT wind speeds made with latest version of volumetric correlation
  - Omitting SWH model from the GMF avoids impacts from resolution of SWH model and errors in the SWH model near sea ice
  - Validated using ASCAT
- Improvements in Ice flagging for SWOT
  - Improved volumetric correlation inputs
  - Added Sea Surface Height anomaly and variance as an input
  - Validated using icebergs, ECMWF ice concentration, and wind speed histograms for flagged data

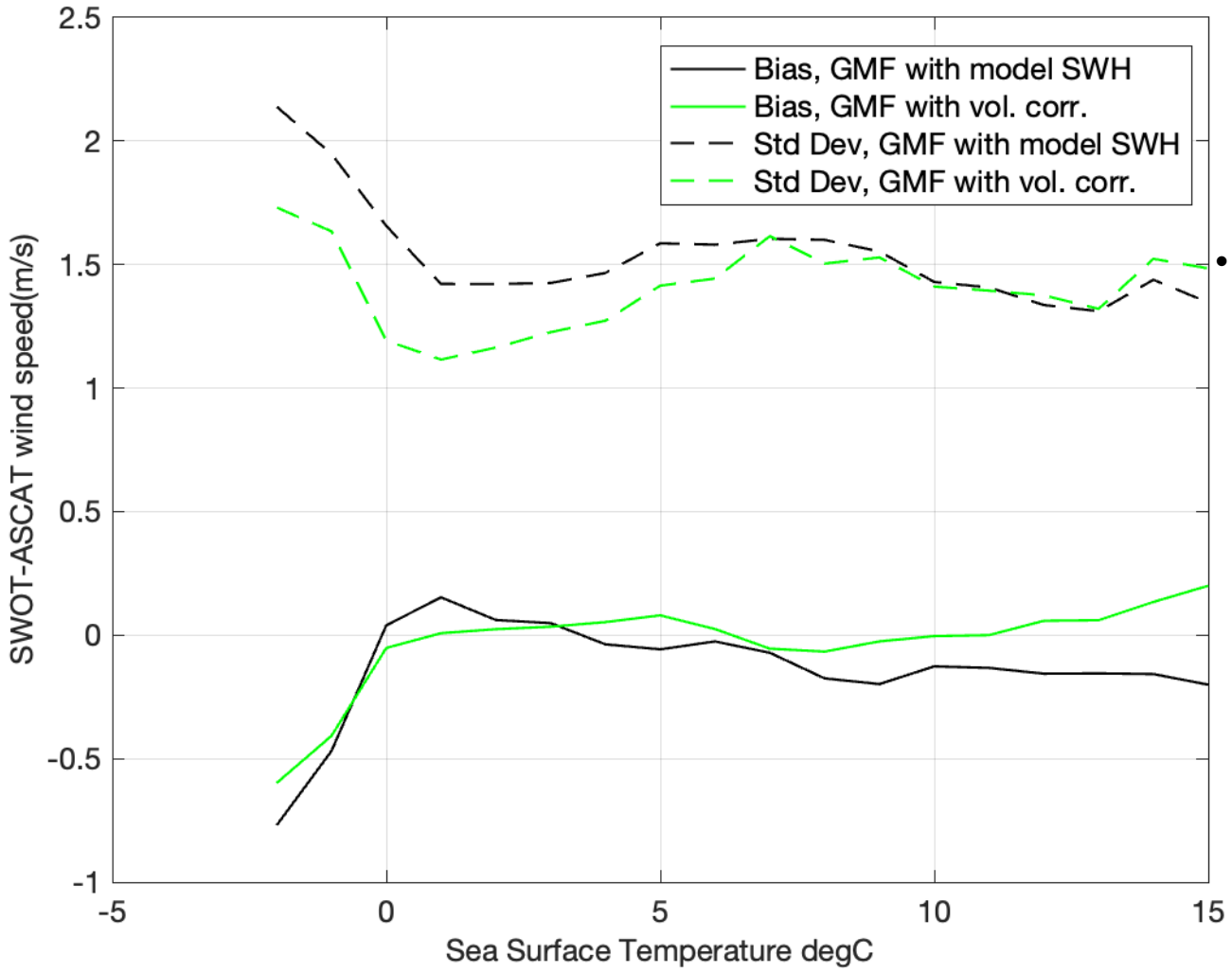
SWOT Wind Speed Neural Network PIC0 version Inputs: radar backscatter, incidence, SWH, SST



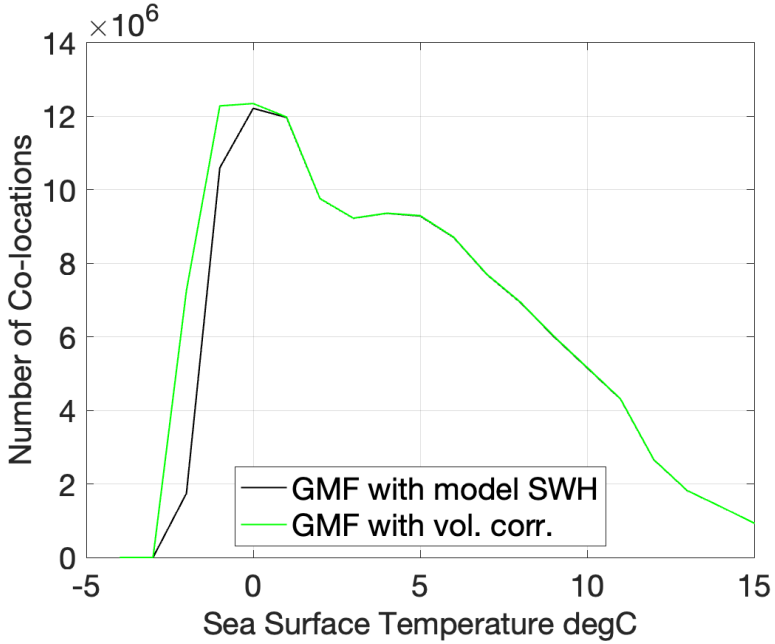
- To avoid sea-ice contamination the data used to make the plots excluded regions poleward of 55 degrees.
- The following data was also omitted
  - ASCAT/SWOT colocations separated by more than 30 minutes
  - Data with 20-km of coast or not over open ocean
  - Data with ssh_karin_2_qual > 0



SWOT Wind Speed Neural Network for PIC2 version Inputs: radar backscatter, incidence, vol. corr., SST



- This plot compares the PIC2 NN with the recalibrated volumetric correlation input to the PIC0 NN that used the model SWH value, for data poleward of 45 degrees with NN3 ice concentration less than 50% (NN3 described in following slides).
- Note that there are places where the model SWH is undefined so only the PIC2 NN has an output, see histogram below.



2 SWOT Ice Flag Neural Network Validation

- Data set: SWOT version PIC2 data from Dec 2, 2024 – Jan 13,2025
- Neural networks were produced to estimate ice concentration from SST and/or SWOT measurements of sigma-0, volumetric correlation and SSHA
- Neural networks were tuned to match ECMWF and NCEP ice concentrations
  - NCEP results were left out due to time constraints and a tendency to overflag as compared to ECMWF.
- Validation metrics
  - RMS ice concentration differences w.r.t ECWMF and NCEP ice concentrations.
    - NCEP results were left out due to time constraints
  - False alarm rates for ECWMF ice free ocean (0-1% ice concentration),
  - Missed detection rates for
    - NOAA Antarctic Iceberg locations within 7 days for icebergs with area greater than 36 km^2
    - ECMWF and NCEP 99-100% ice cover regions.

SWOT Ice Flag Neural Network: PIC2 version

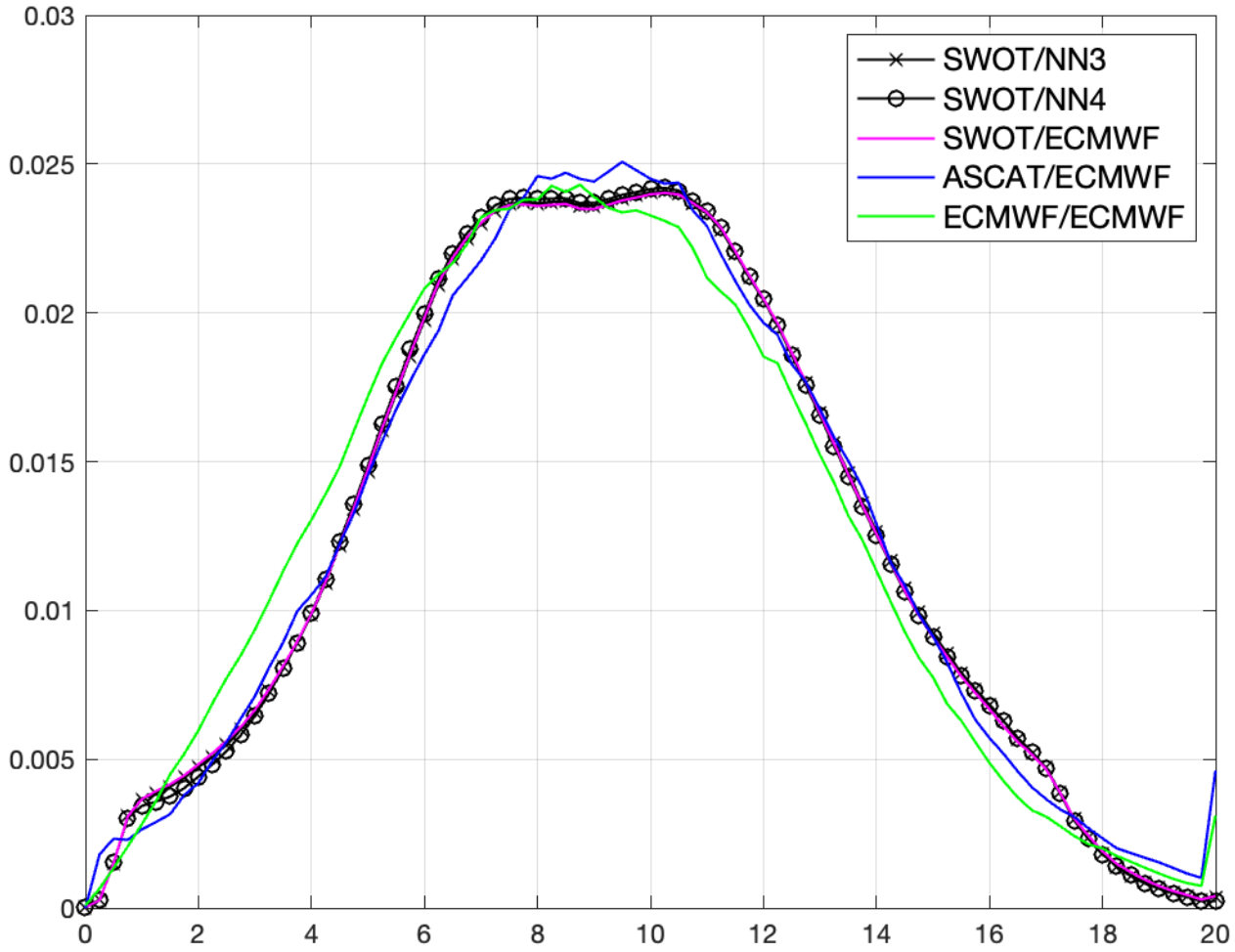
Percentage of SWOT data over ocean flagged poleward of 45 deg

Network Name OR Model name	Percentage flagged with 1% ice concentration threshold	Percentage flagged with 10% ice concentration threshold	Percentage flagged with 20% ice concentration threshold	Percentage flagged with 50% ice concentration threshold	Percentage flagged with 90% ice concentration threshold
NN1: inc, sig0, vol_cor	73.0	35.1	30.5	25.9	15.4
NN2: inc, sig0, vol_cor, vars	53.4	33.6	31.5	28.0	15.5
NN3: inc, sig0, vol_cor, ssha, vars	51.3	33.8	32.1	27.7	15.7
NN4: inc, sig0, vol_cor, ssha, vars, SST	38.8	33.6	31.6	28.3	16.1
ECMWF Ice Concentration	35.5	34.9	34.1	30.7	21.7

SWOT Ice Flag Neural Network: PIC2 version with 10% ice concentration threshold

Network Name:Inputs OR Model name	RMS w.r.t ECMWF (percent) Tuned to ECMWF	False Alarm Percent w.r.t ECWMF ECMWF	Missed Detect Percent w.r.t ECMWF ECWMF	Iceberg Missed Detect Percent, missed /valid ECMWF
NN1: inc, sig0, vol_cor	14.0	7.4	0.22	21.8, 52/238
NN2: inc, sig0, vol_cor, vars	11.4	3.7	0.086	16.8, 40/238
NN3: inc, sig0, vol_cor, ssha, vars	10.5	3.2	0.045	10.9, 26/238
NN4: inc, sig0, vol_cor, ssha, vars, SST	**7.4**	**1.8**	**0.0045**	**9.7, 23/238**
ECMWF Ice Concentration	N/A	N/A	N/A	19.7, 39/198

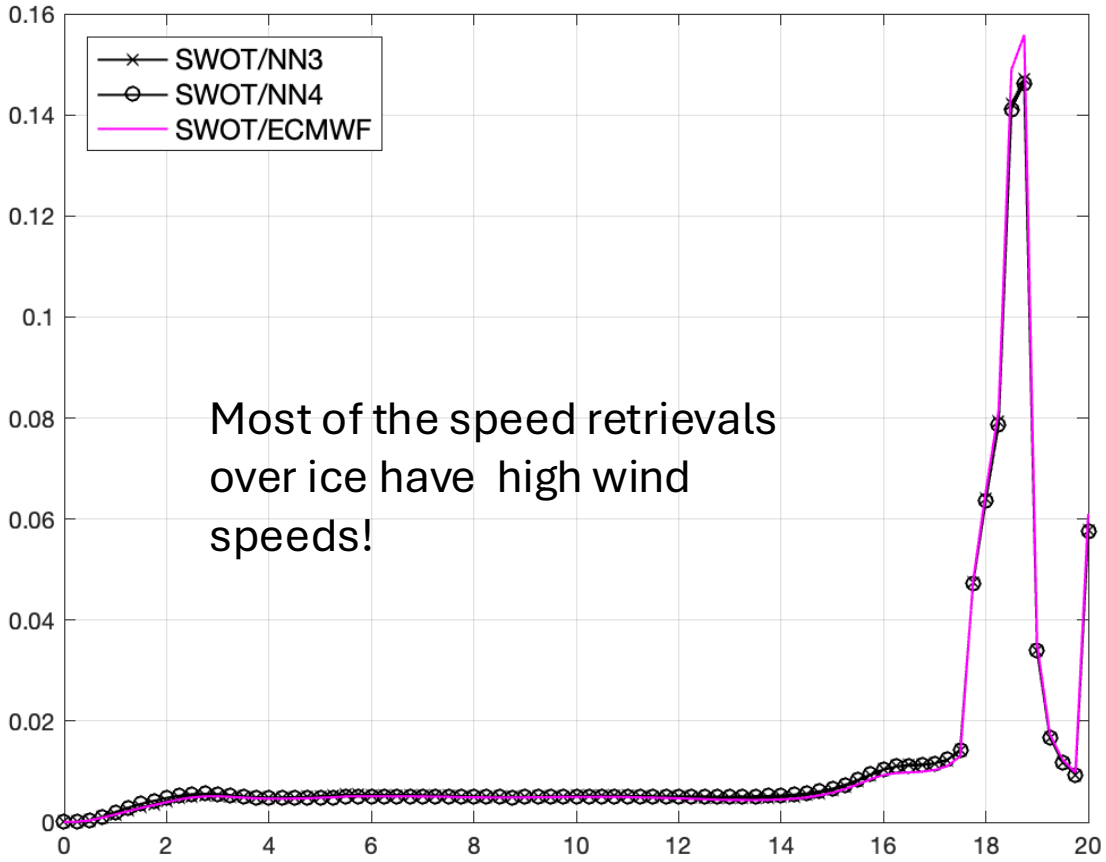
Histogram of SWOT speeds for NN3, NN4, and ECMWF QC with 10% flagging thresholds for ocean poleward of 45 degrees.



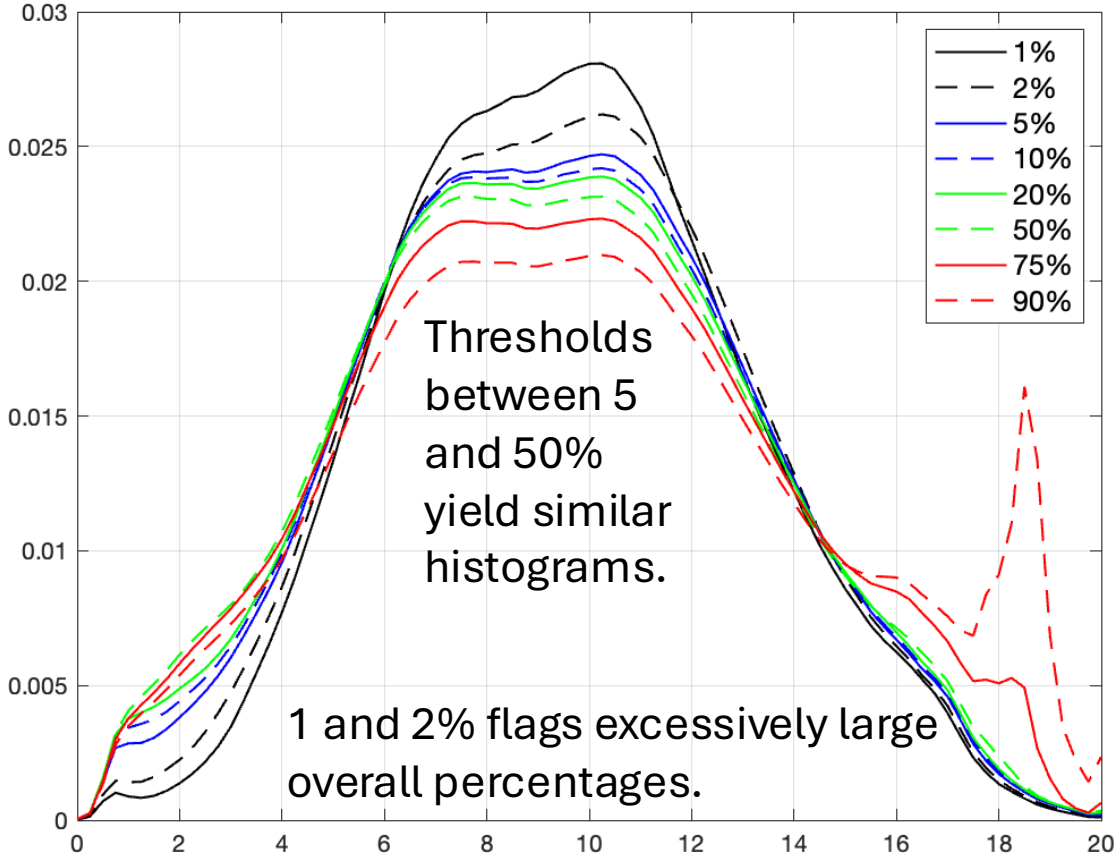
- Legend =Wind Source/Flag Name
- Different flags yield similar histograms for SWOT wind speeds
- SWOT speed histograms agree with ASCAT except for ”pinching” at extremes which may be due to trying to tune 2-km wind speeds which presumably have larger histogram tails to 20-km ASCAT wind speeds.
- There is a small bias between ASCAT and ECMWF as expected.
- See next slide for what the data that failed QC look like, and how the speed histograms vary with NN3 flag threshold.

Histogram of SWOT speeds for varying QC

SWOT speed histograms for NN3, NN4, and ECMWF ice concentration **greater** than 10%

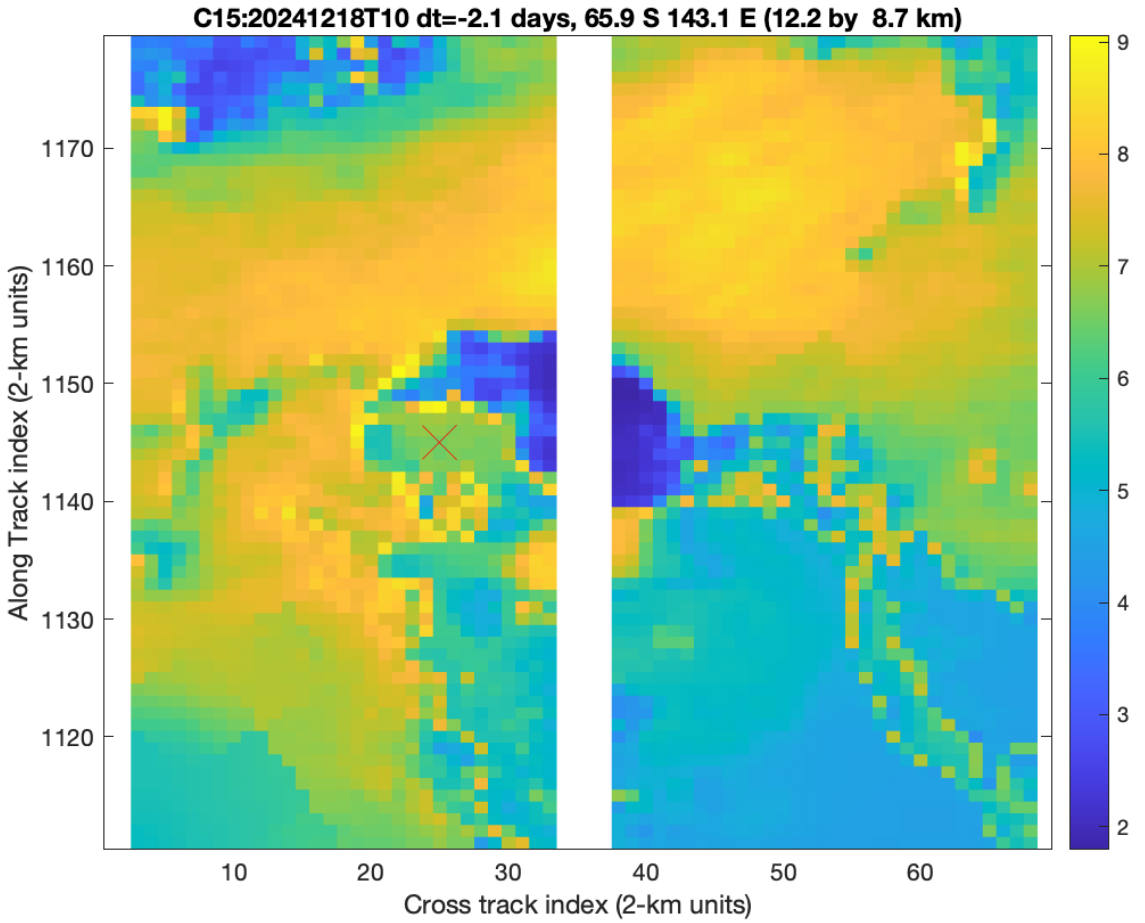


SWOT speed histograms for ice NN3 ice concentration **less than** 1,5,10,20, 50, 75, and 90%

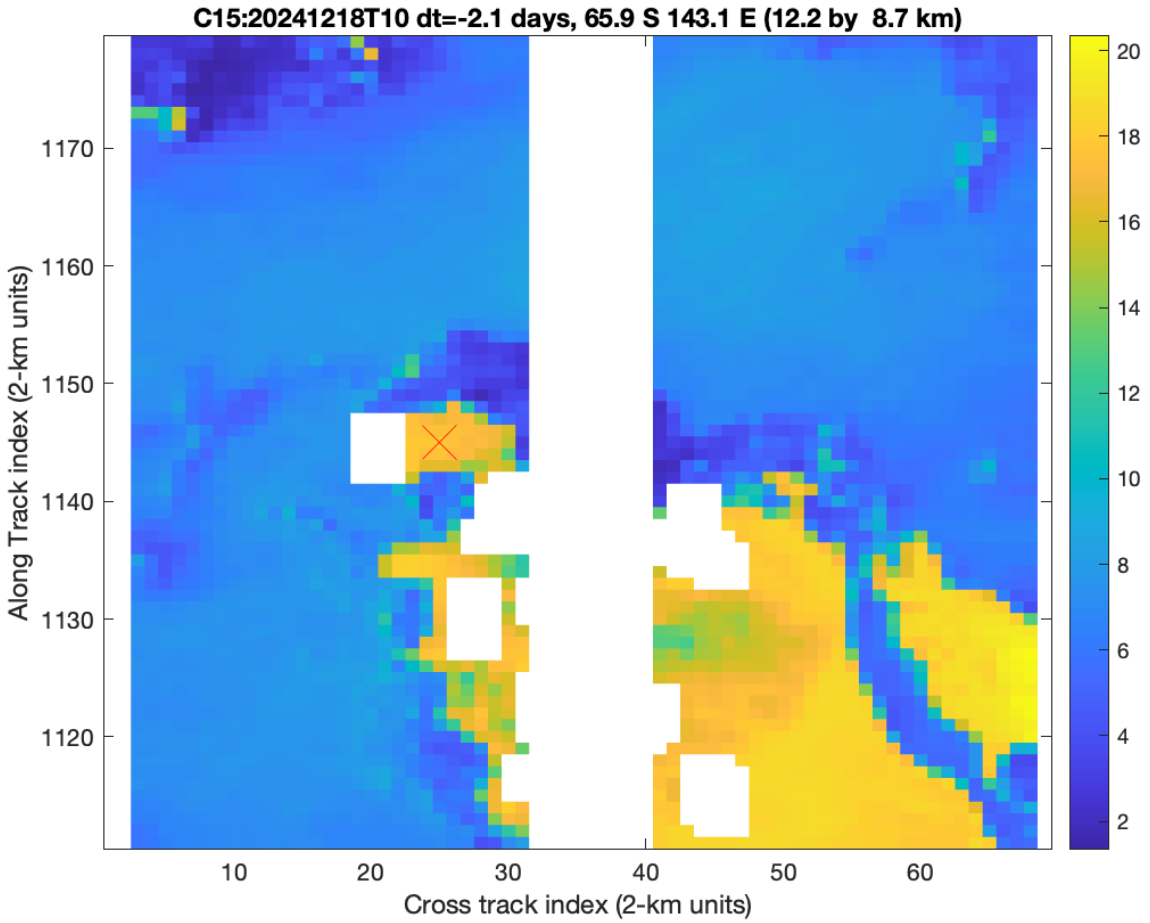


2 SWOT Ice Flag Neural Network Example 1
Iceberg C15, 2024/12/18/10:00 UTC

SWOT retrieved speed PICO NN (m/s), no quality control

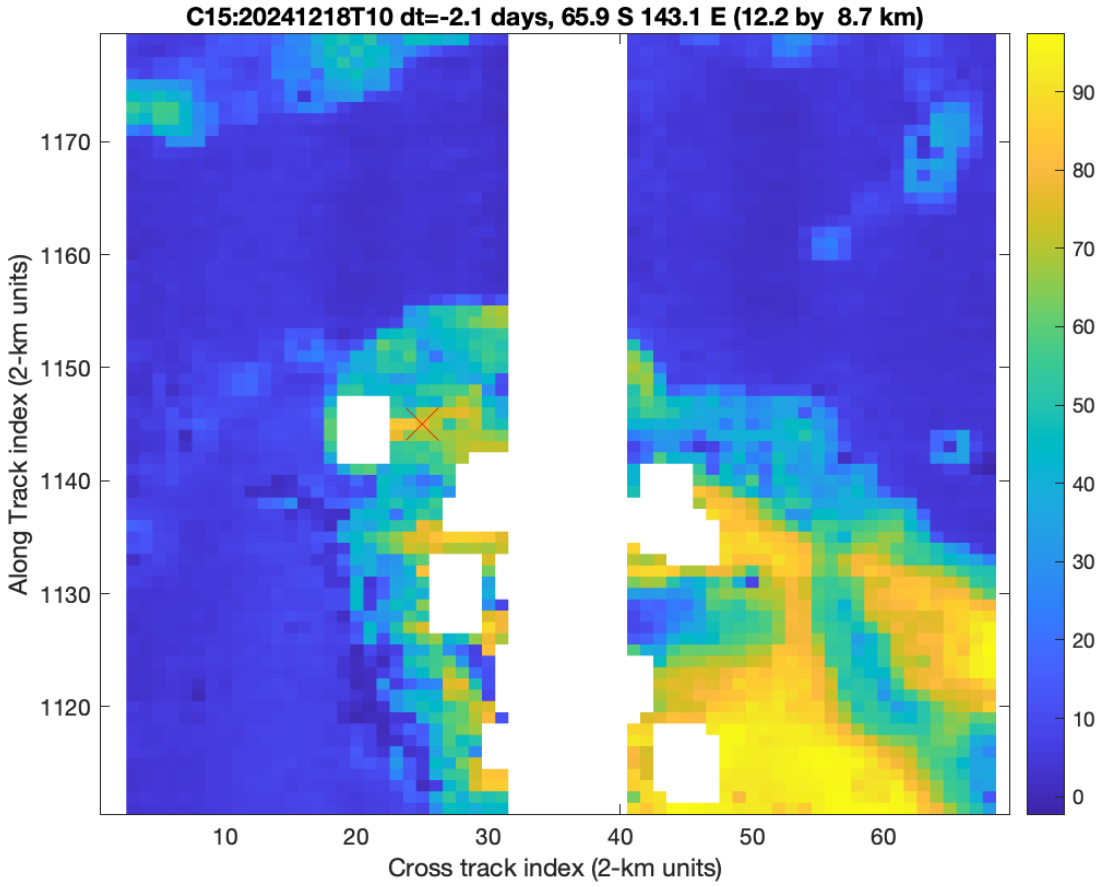


SWOT retrieved speed PIC2 NN (m/s), no quality control

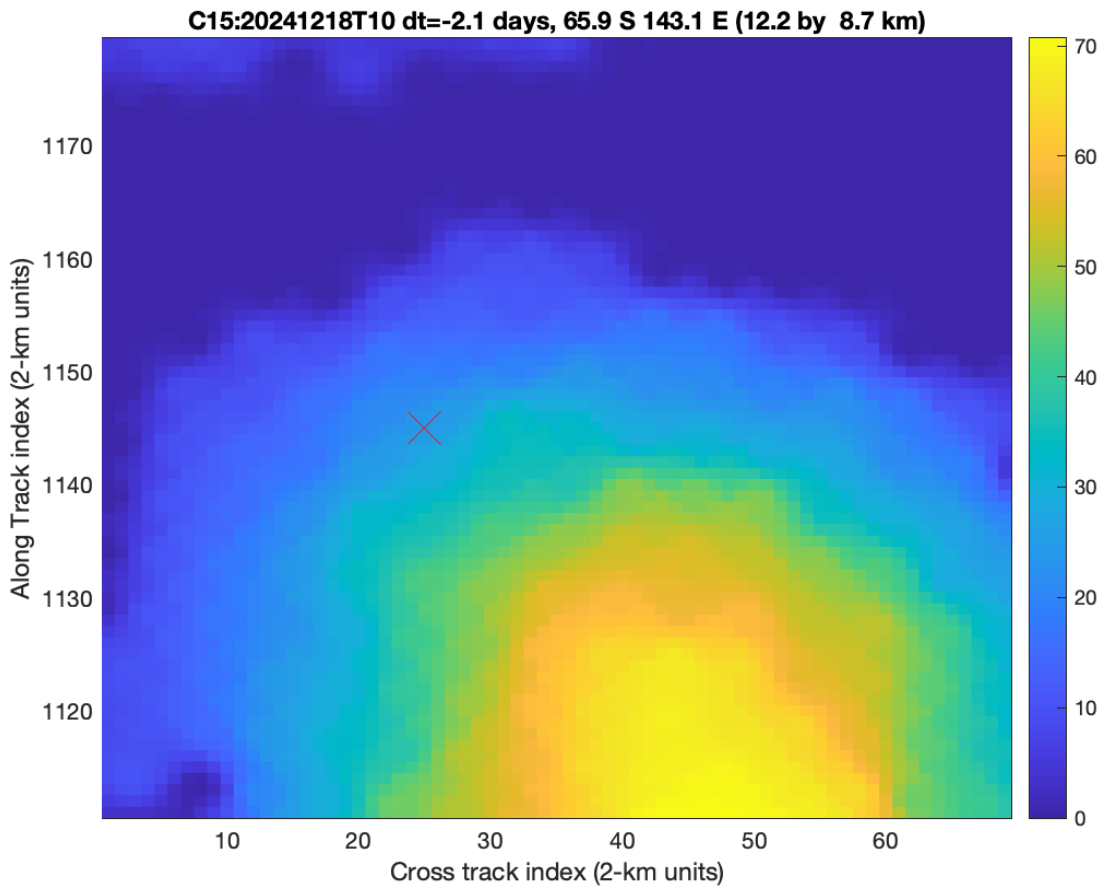


2 SWOT Ice Flag Neural Network Example 1 Iceberg C15,2024/12/18/10:00 UTC

NN3 ice concentration

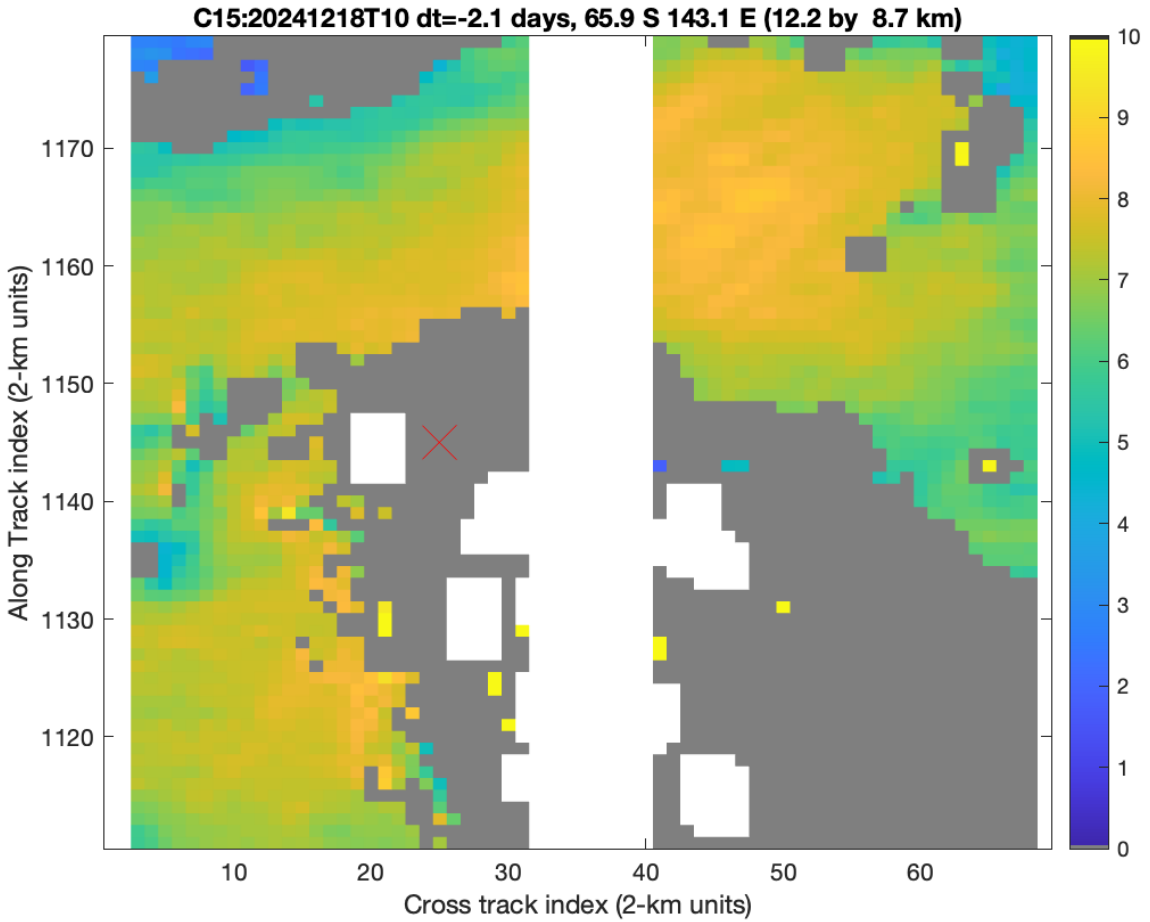


ECMWF Ice Concentration

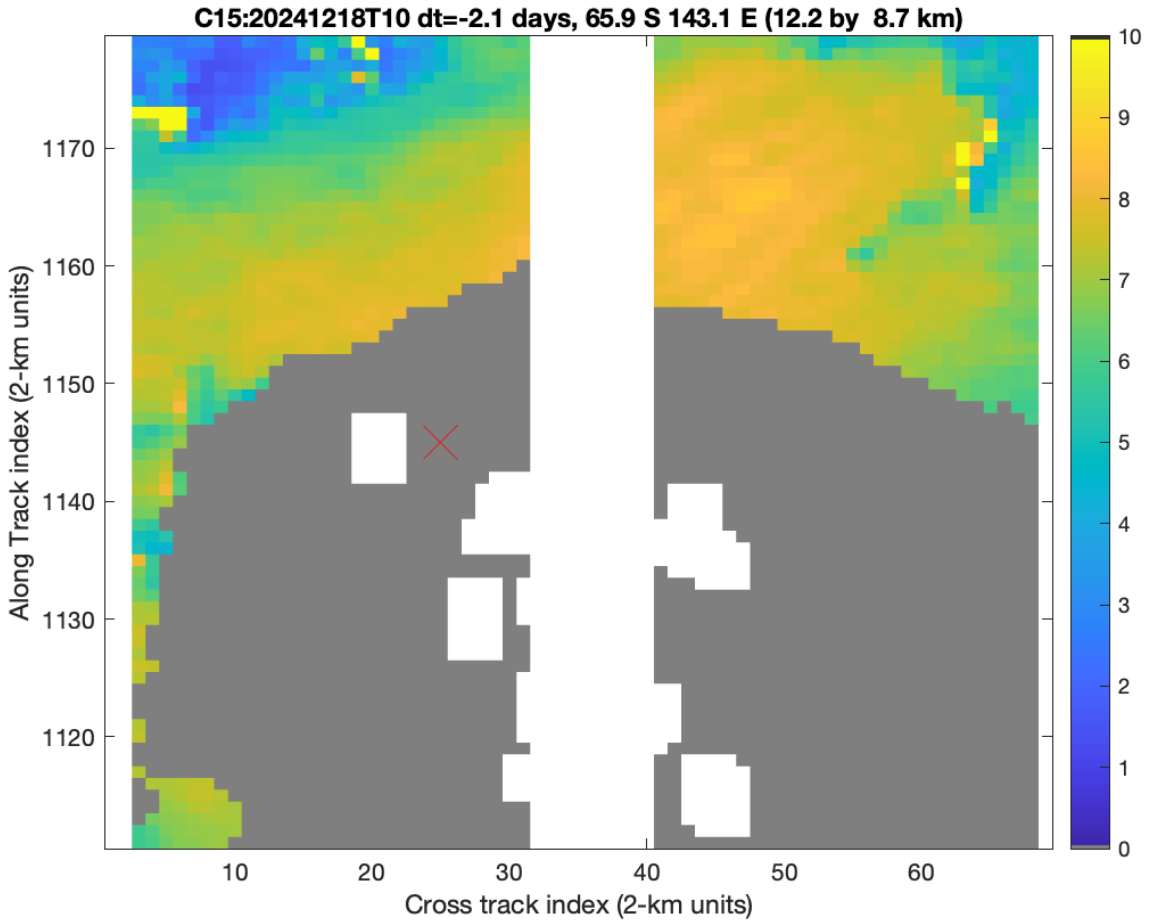


2 SWOT Ice Flag Neural Network Example 1 Iceberg C15, 2024/12/18/10:00 UTC

SWOT retrieved speed PIC2 NN (m/s), with QC= NN3 10% threshold

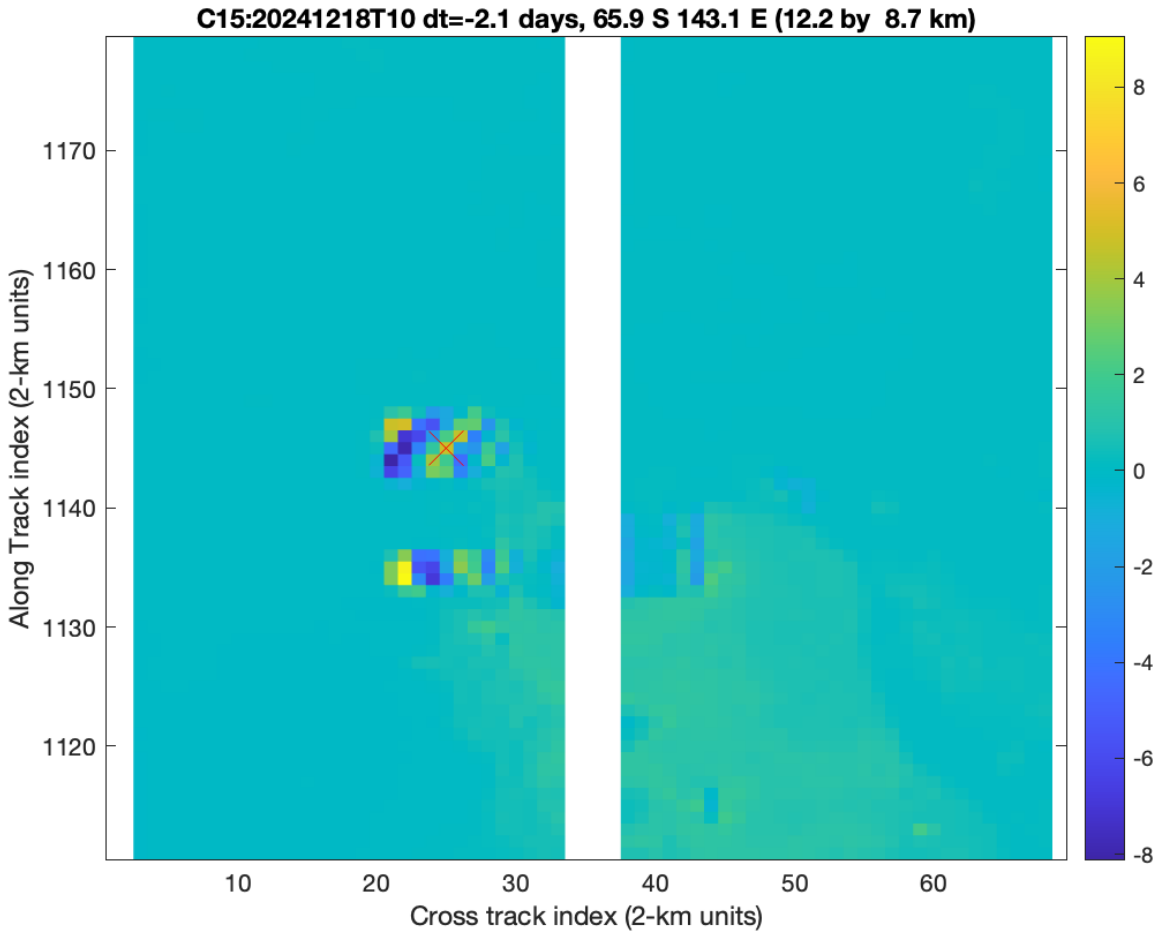


SWOT retrieved speed PIC2 NN (m/s), with QC= ECMWF 10% threshold

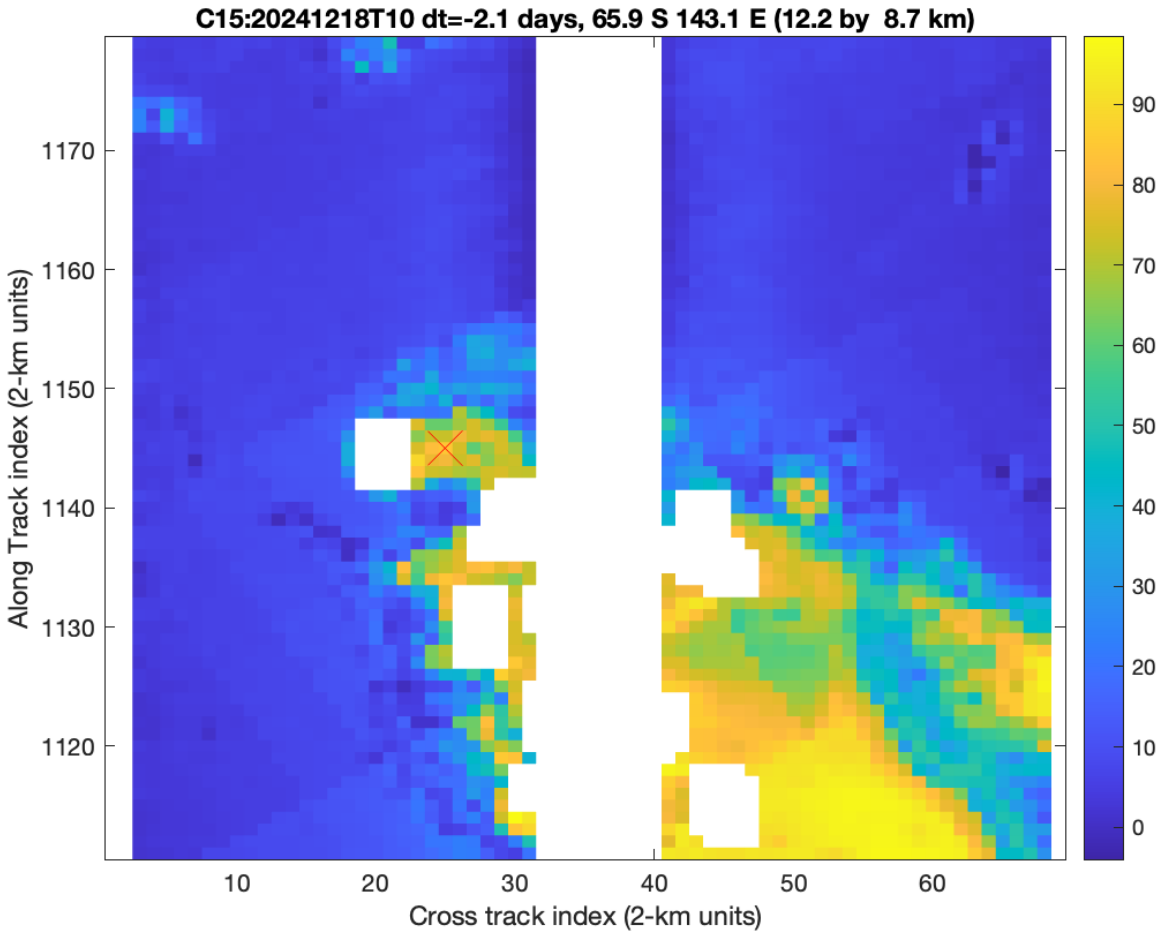


2 SWOT Ice Flag Neural Network Example 1 Iceberg C15, 2024/12/18/10:00 UTC

SWOT SSHA (m)

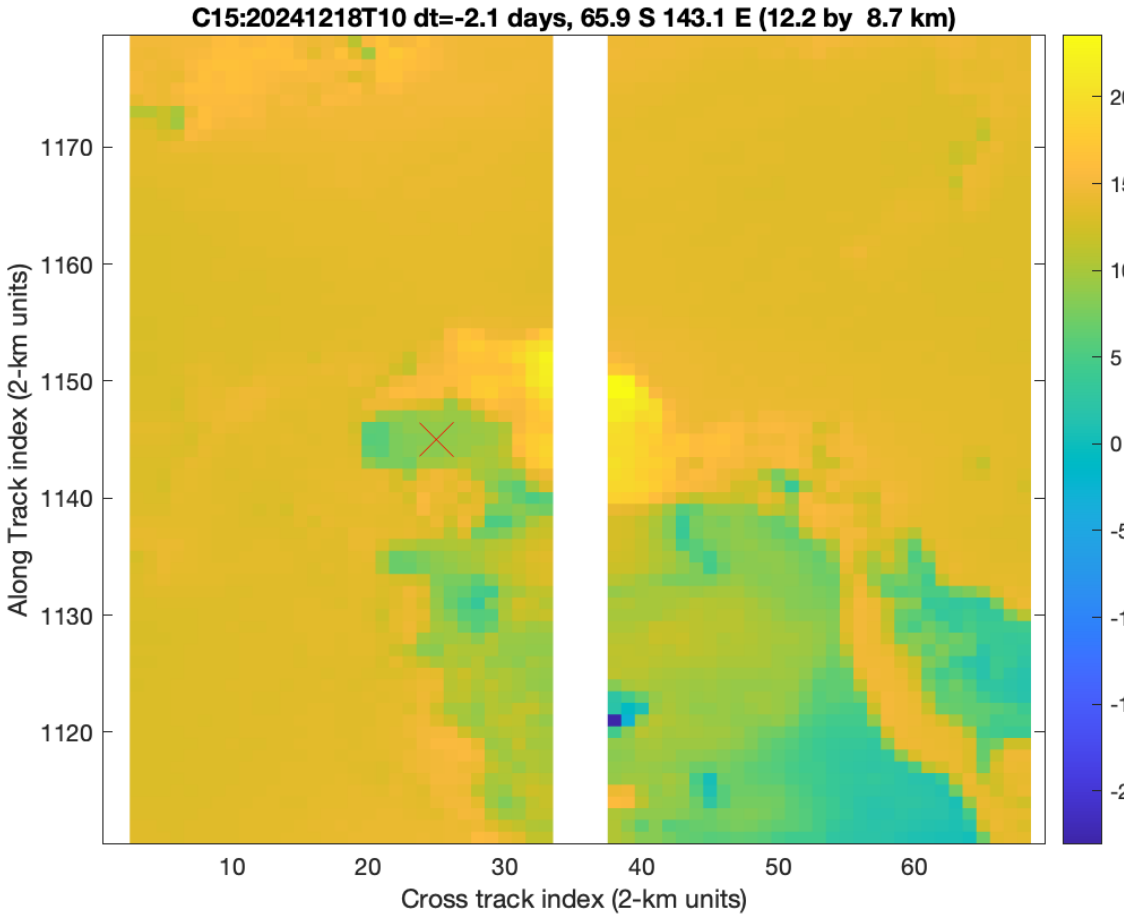


NN4 ice concentration

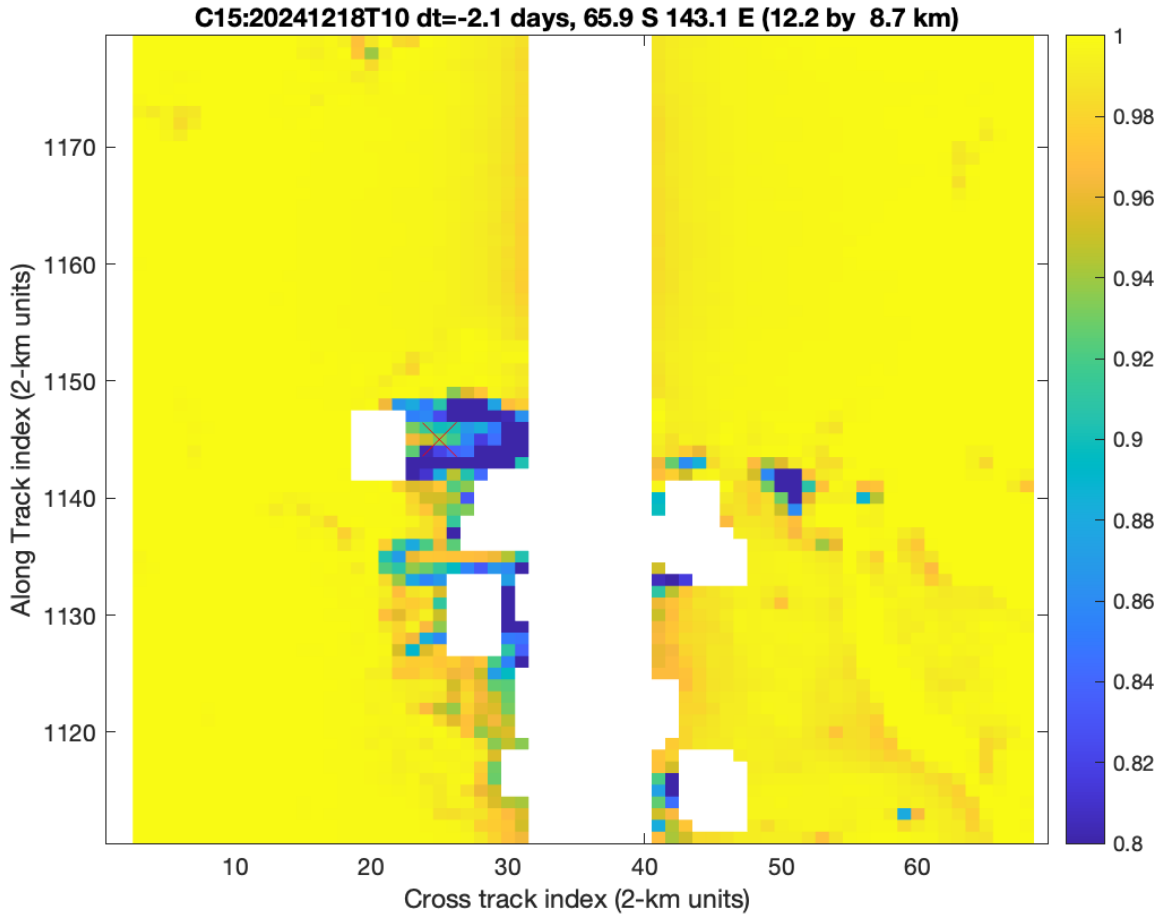


2 SWOT Ice Flag Neural Network Example 1 Iceberg C15,2024/12/18/10:00 UTC

SWOT sigma-0 (dB)



SWOT volumetric correlation (unitless)



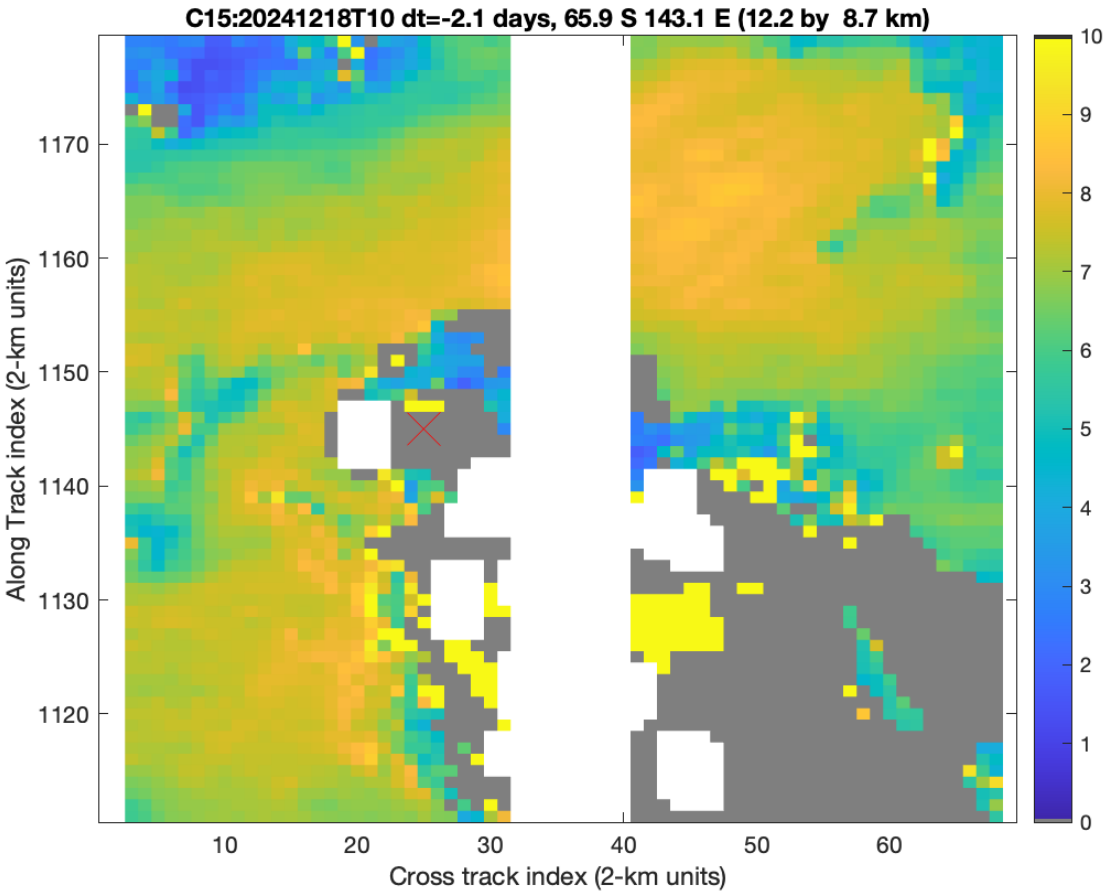
Work over the Next Year

- Make final decision between NN3 and NN4; leaning toward NN3
- Make final decision on recommended threshold, although users of data will be able to choose for themselves
- Run SWOT near-ice wind retrieval and flagging algorithm on full reprocessed version D data set including 1 day repeat cal/val time period and later data up until the end of 2025 at least.
  - Deliver data to PODAAC
- Develop EOS6 near-ice QC algorithm and validate by comparison to SWOT near-ice winds

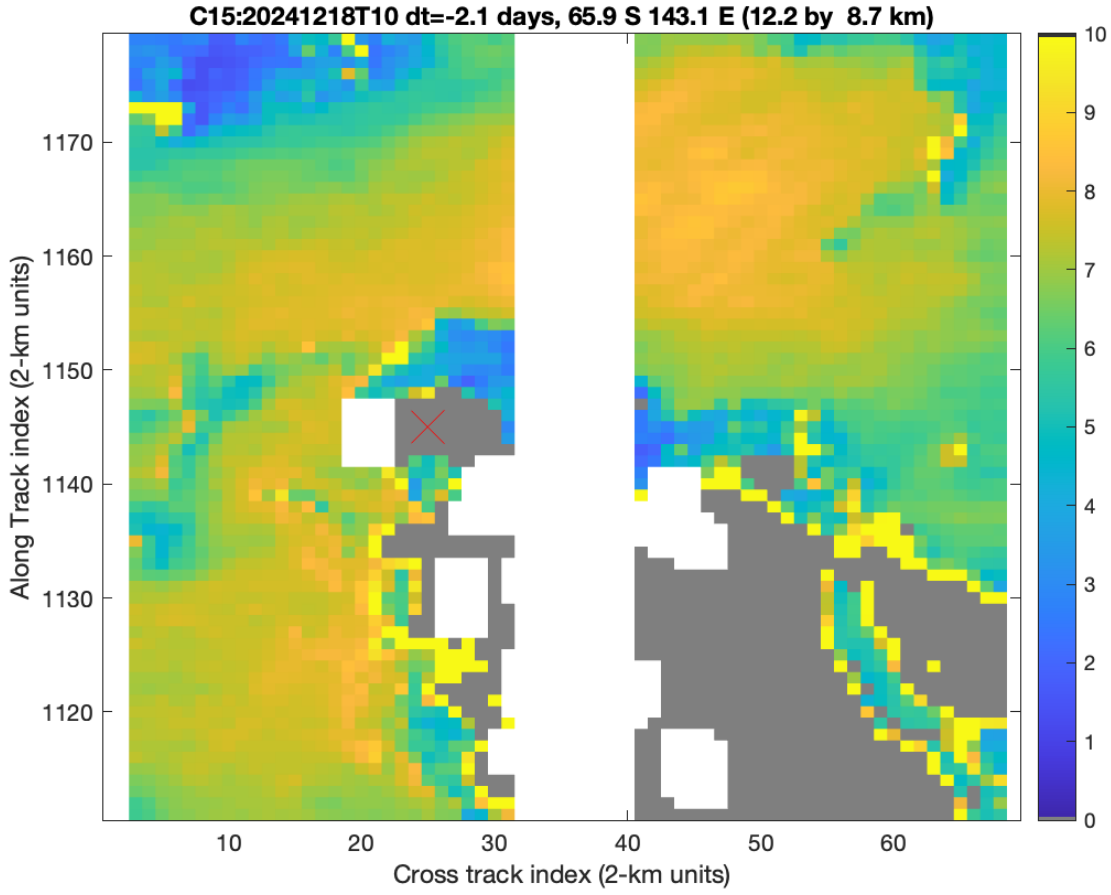
Backup Slides

2 SWOT Ice Flag Neural Network Example 1 Iceberg C15, 2024/12/18/10:00 UTC

SWOT retrieved speed PIC2 NN (m/s), with QC= NN3 50% threshold

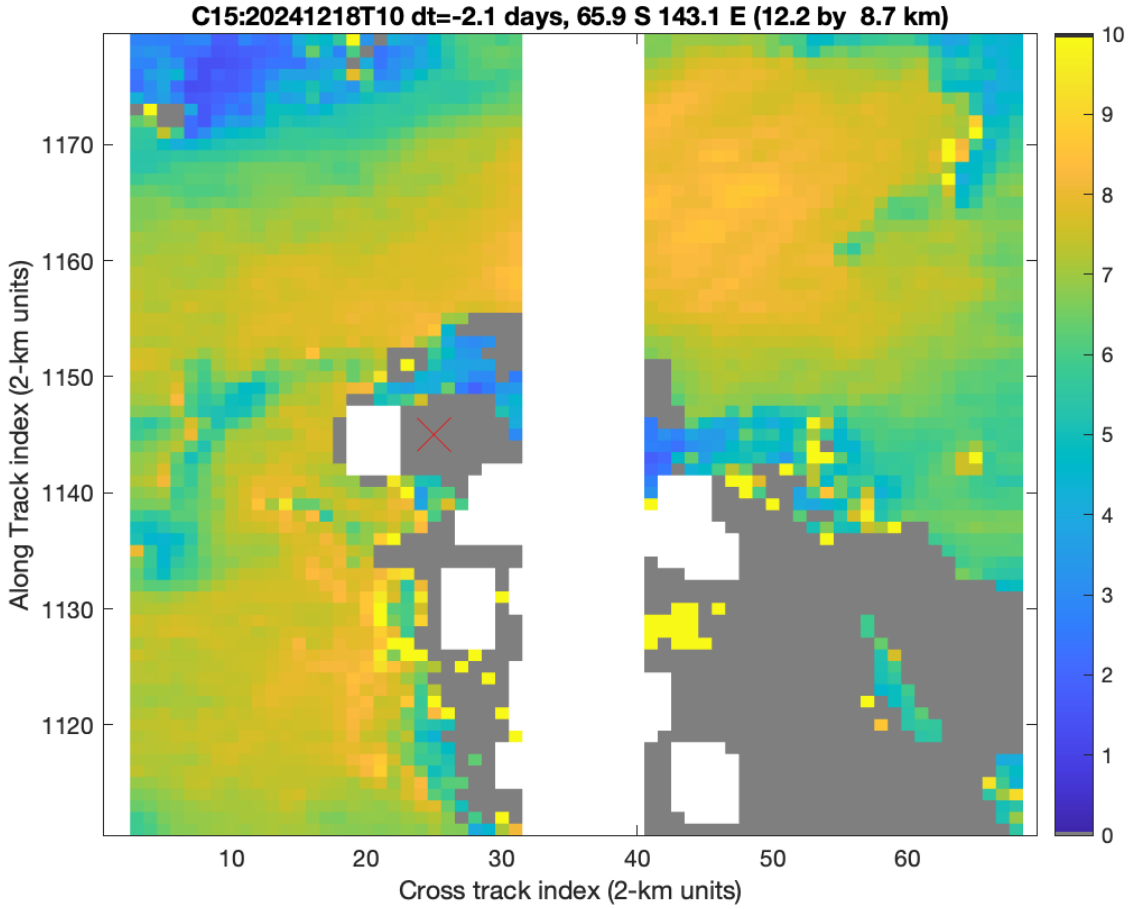


SWOT retrieved speed PIC2 NN (m/s), with QC= NN4 50% threshold

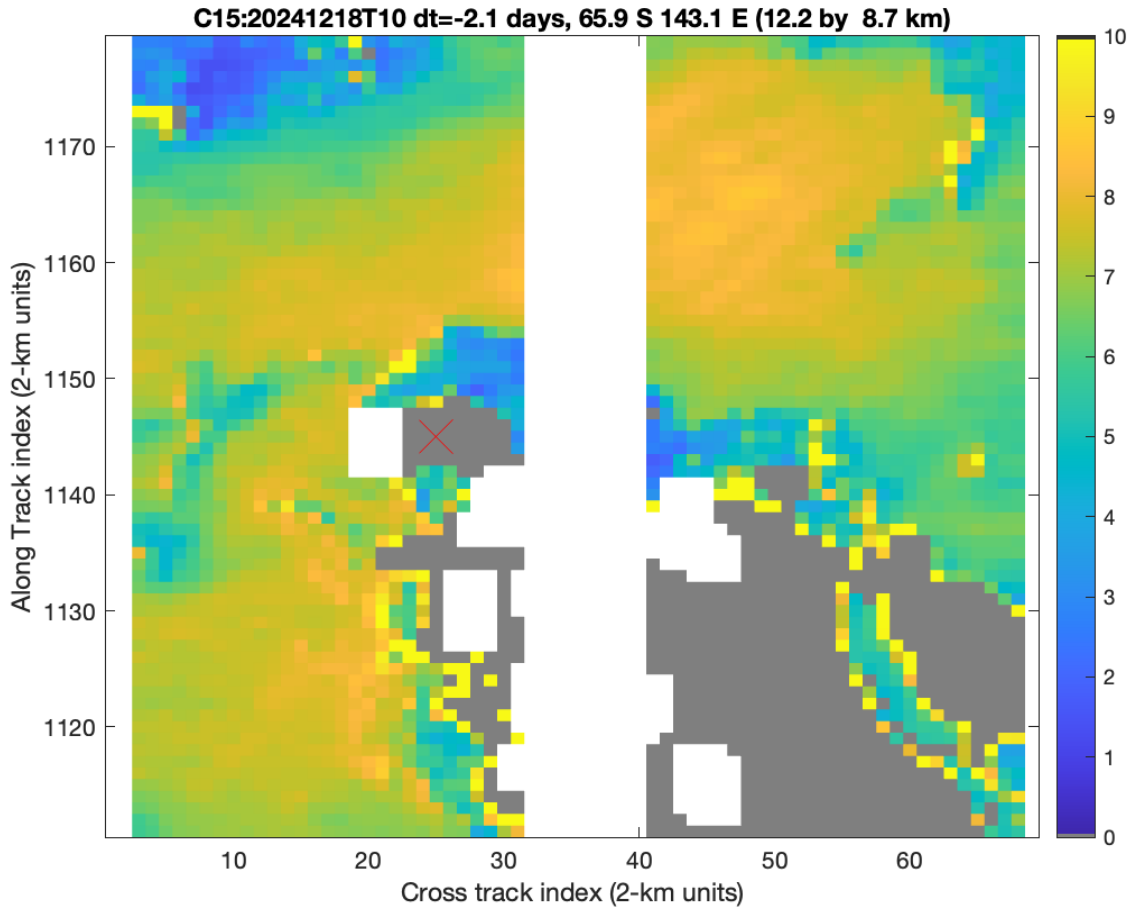


2 SWOT Ice Flag Neural Network Example 1 Iceberg C15, 2024/12/18/10:00 UTC

SWOT retrieved speed PIC2 NN (m/s),
with QC= NN3 50% threshold and speeds over 17 m/s flagged



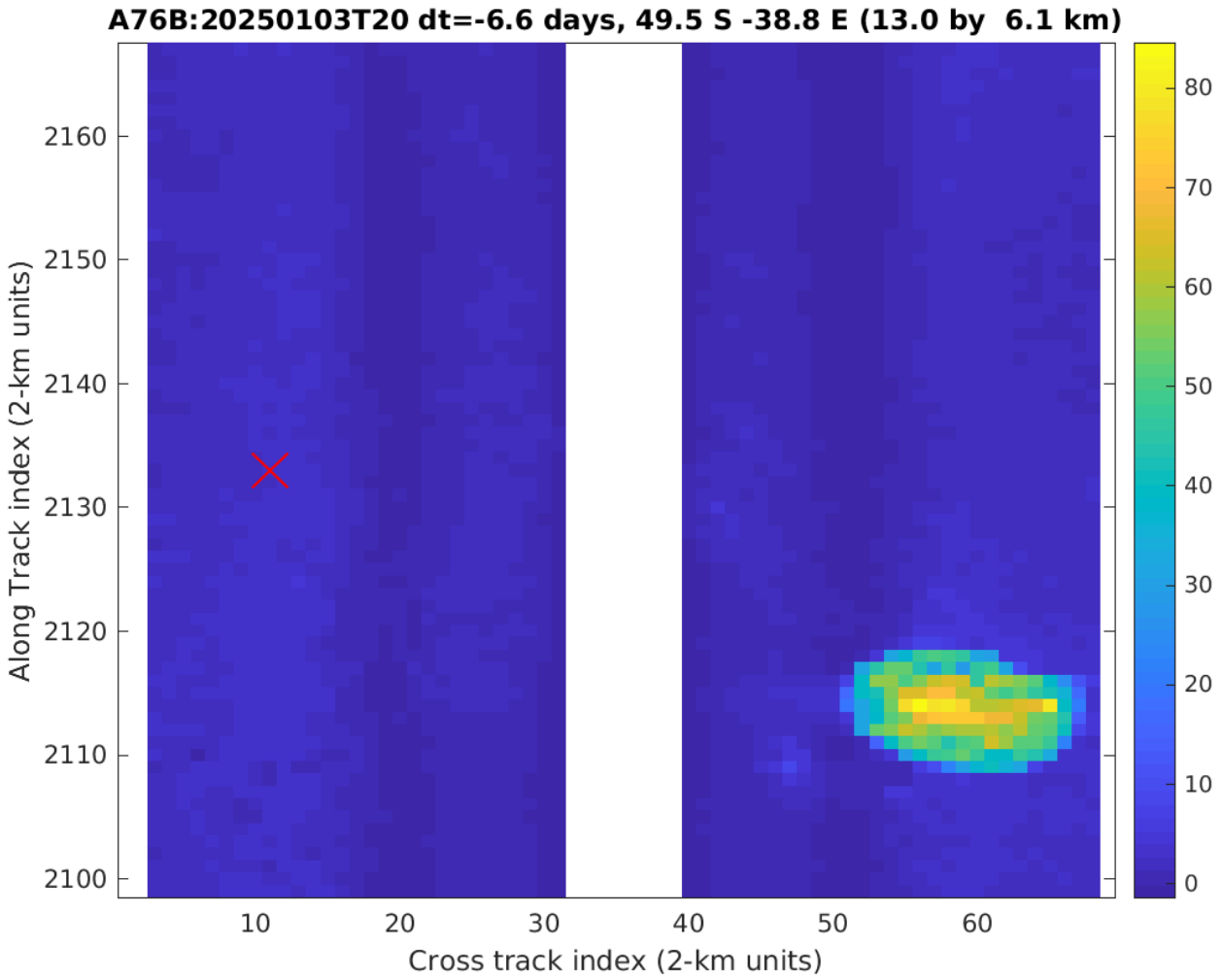
SWOT retrieved speed PIC2 NN (m/s),
with QC= NN4 50% threshold and speeds over 17 m/s flagged



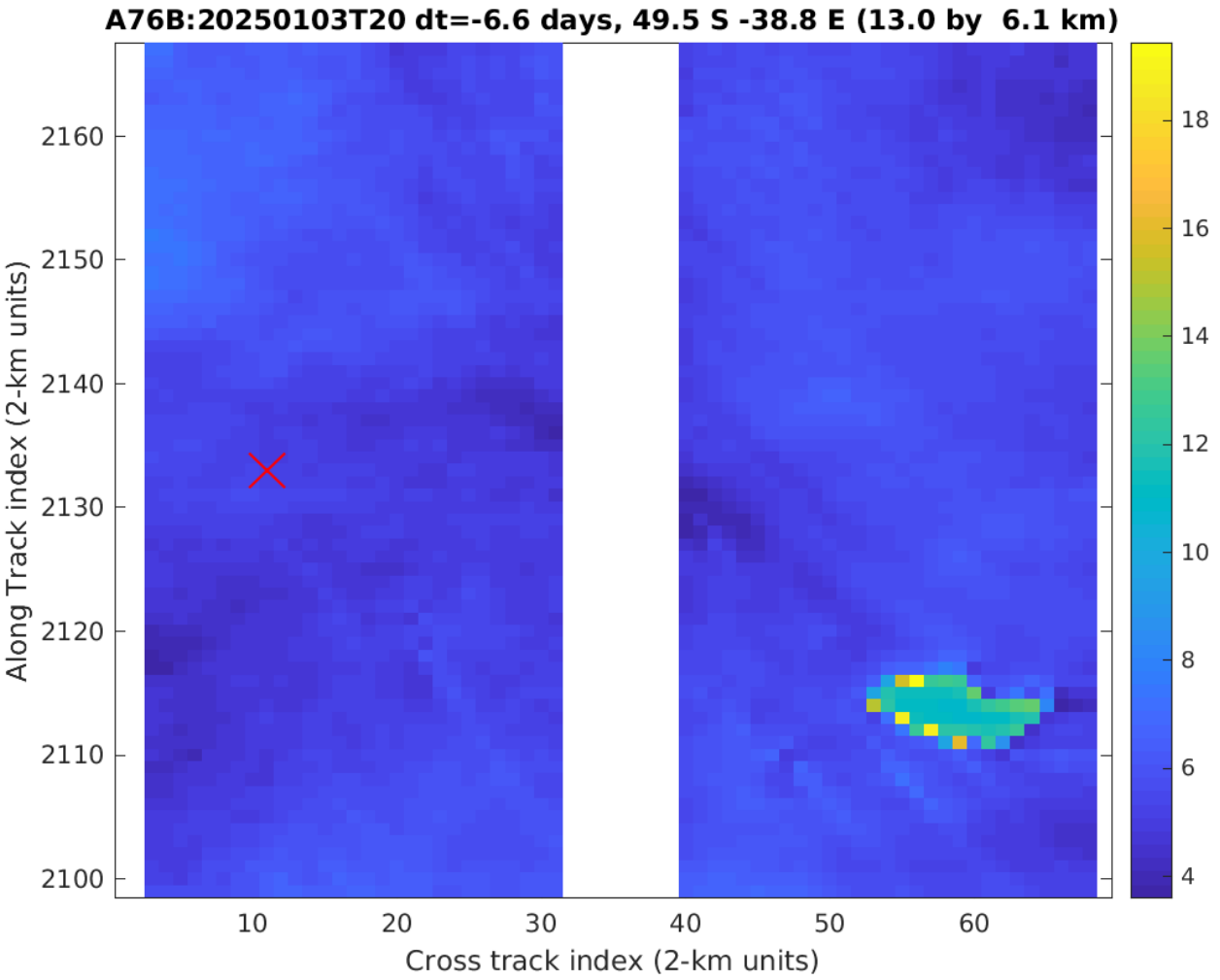
2 SWOT Ice Flag Neural Network: PIC2 version with 50% ice concentration threshold

Network Name:Inputs OR Model name	RMS w.r.t ECMWF (percent) Tuned to ECMWF	False Alarm Percent w.r.t ECWMF ECMWF	Missed Detect Percent w.r.t ECMWF ECWMF	Iceberg Missed Detect Percent, missed /valid ECMWF
NN1: inc, sig0, vol_cor	14.0	0.57	0.73	39.9, 95/238
NN2: inc, sig0, vol_cor, vars	11.4	0.83	0.38	29.8, 71/238
NN3: inc, sig0, vol_cor, ssha, vars	10.5	0.59	0.32	28.6, 68/238
NN4: inc, sig0, vol_cor, ssha, vars, SST	**7.4**	**0.09**	**0.05**	**19.7, 47/238**
ECMWF Ice Concentration	N/A	N/A	N/A	44.4, 88/198

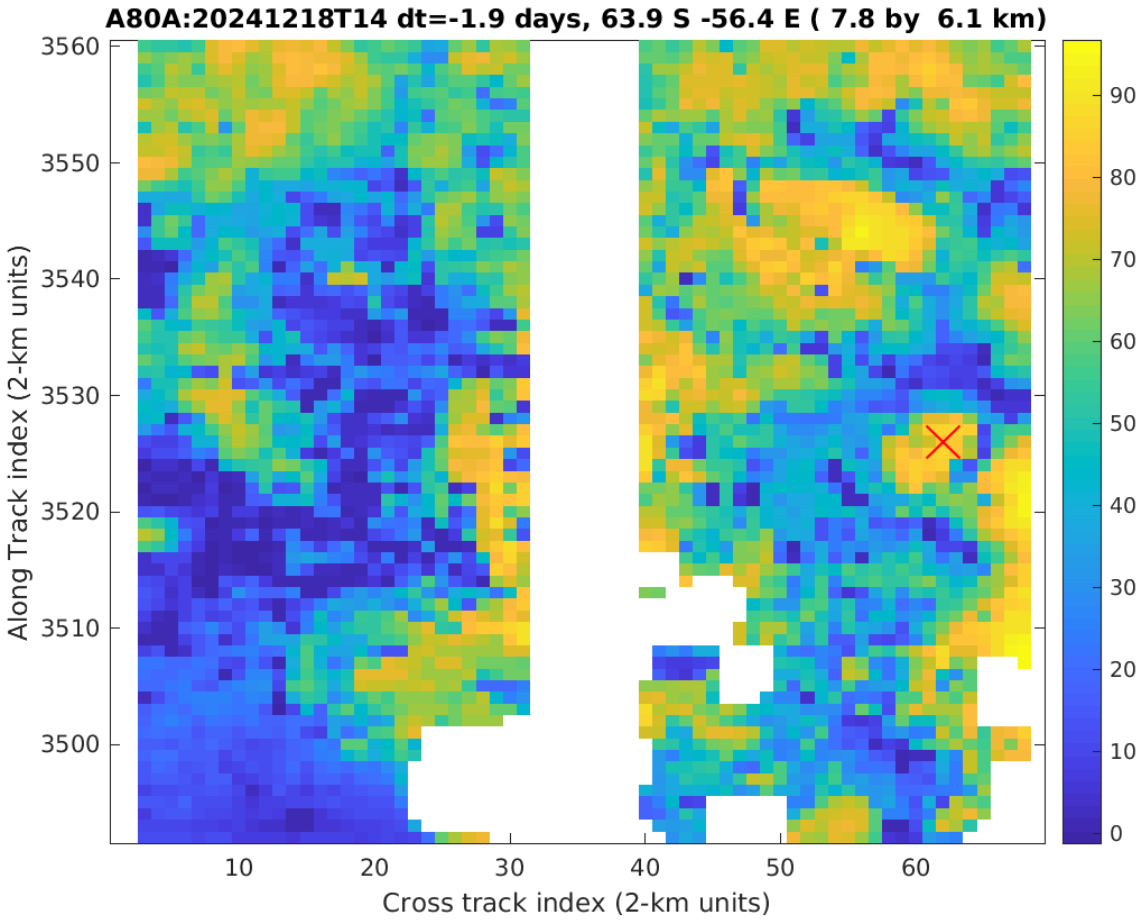
NN3 ice concentration



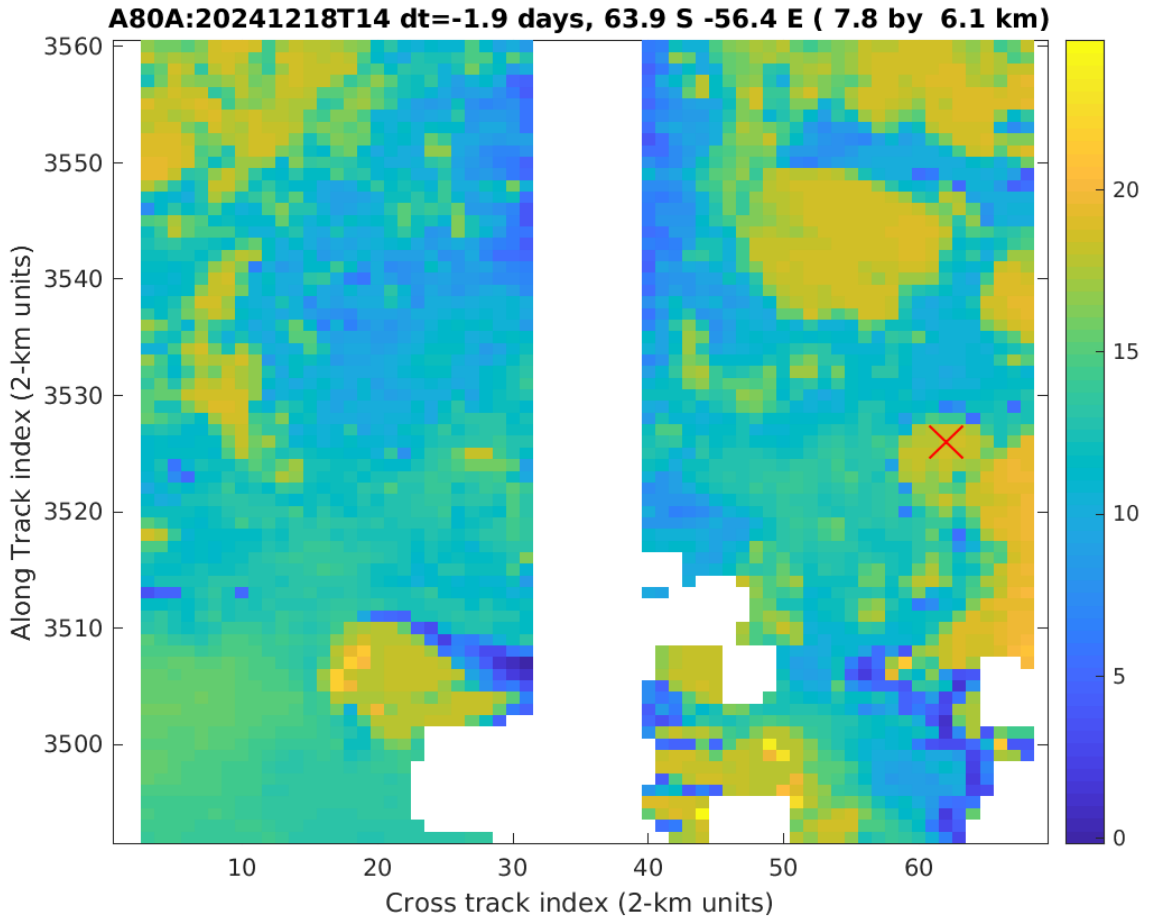
PIC2 NN SWOT wind speed



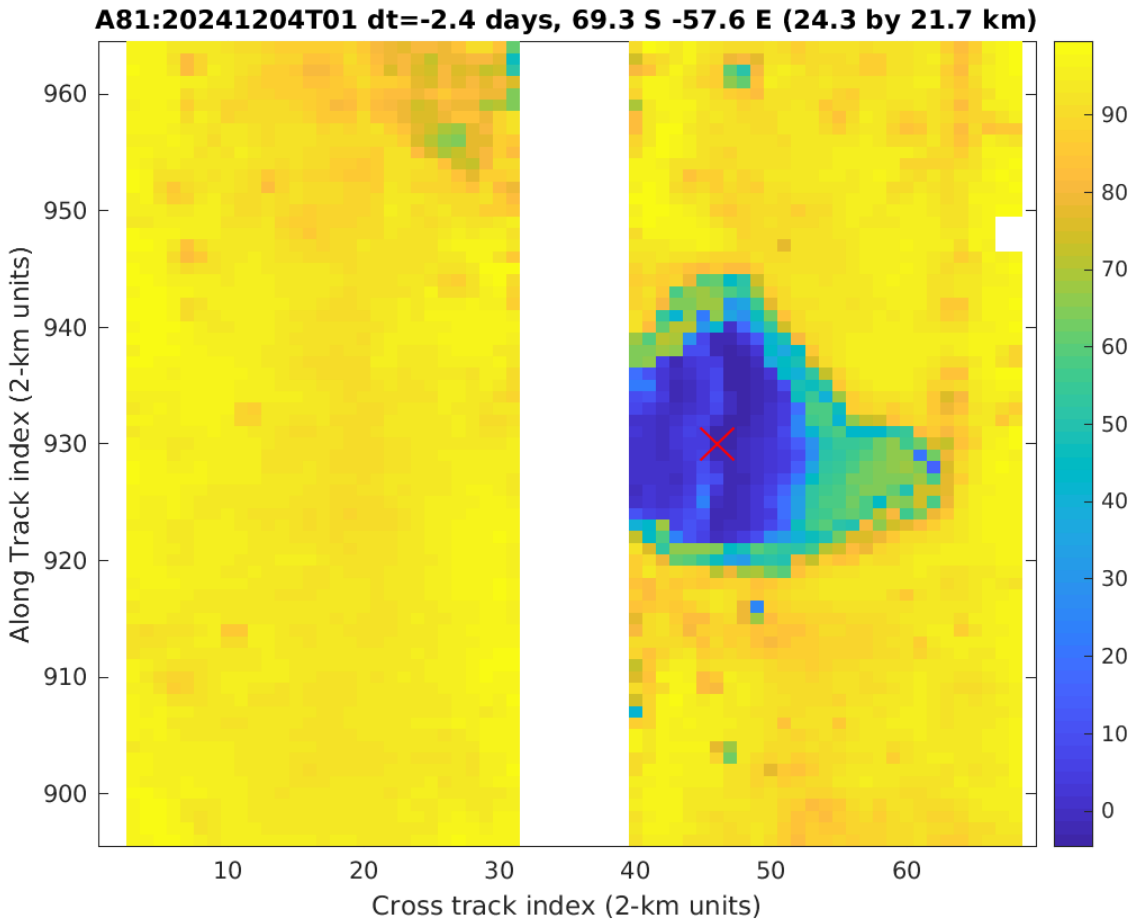
NN3 ice concentration



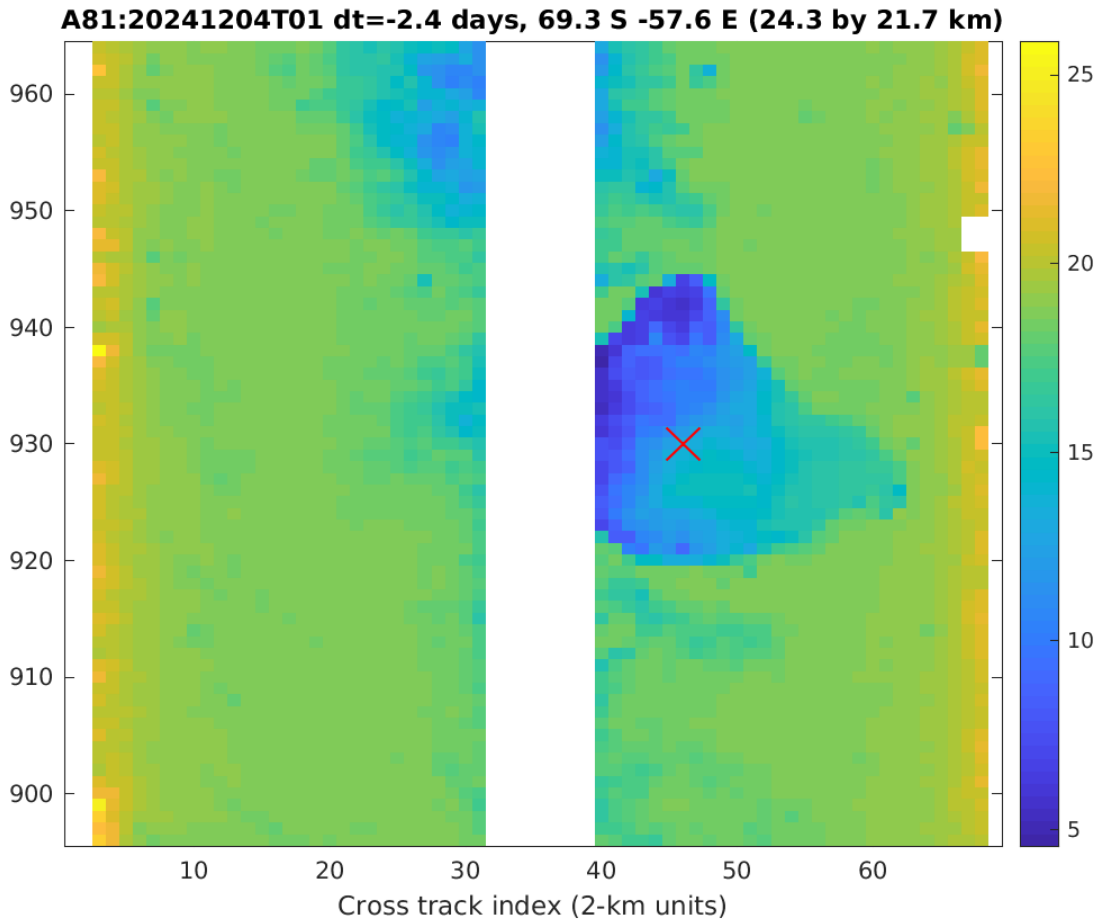
PIC2 NN SWOT wind speed



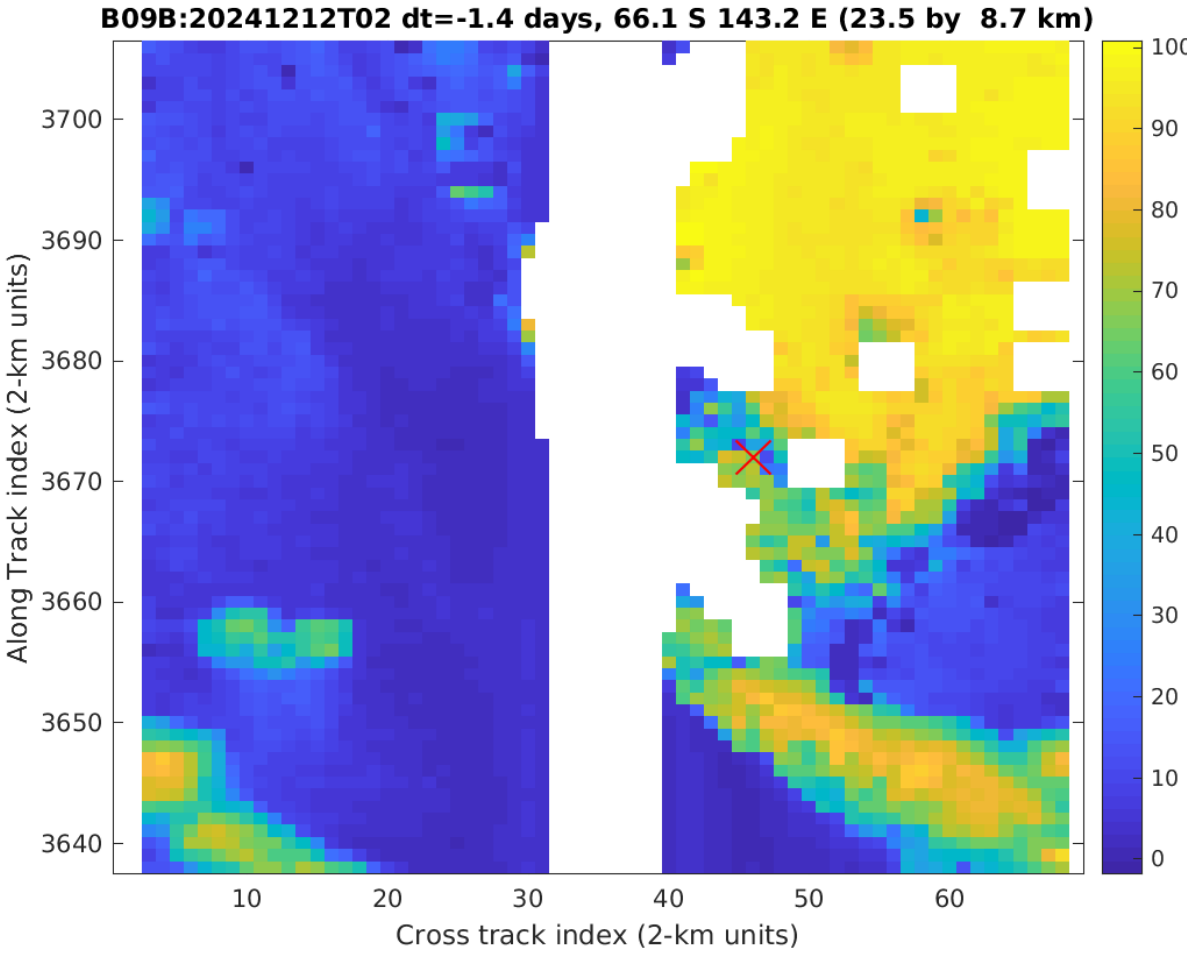
NN3 ice concentration



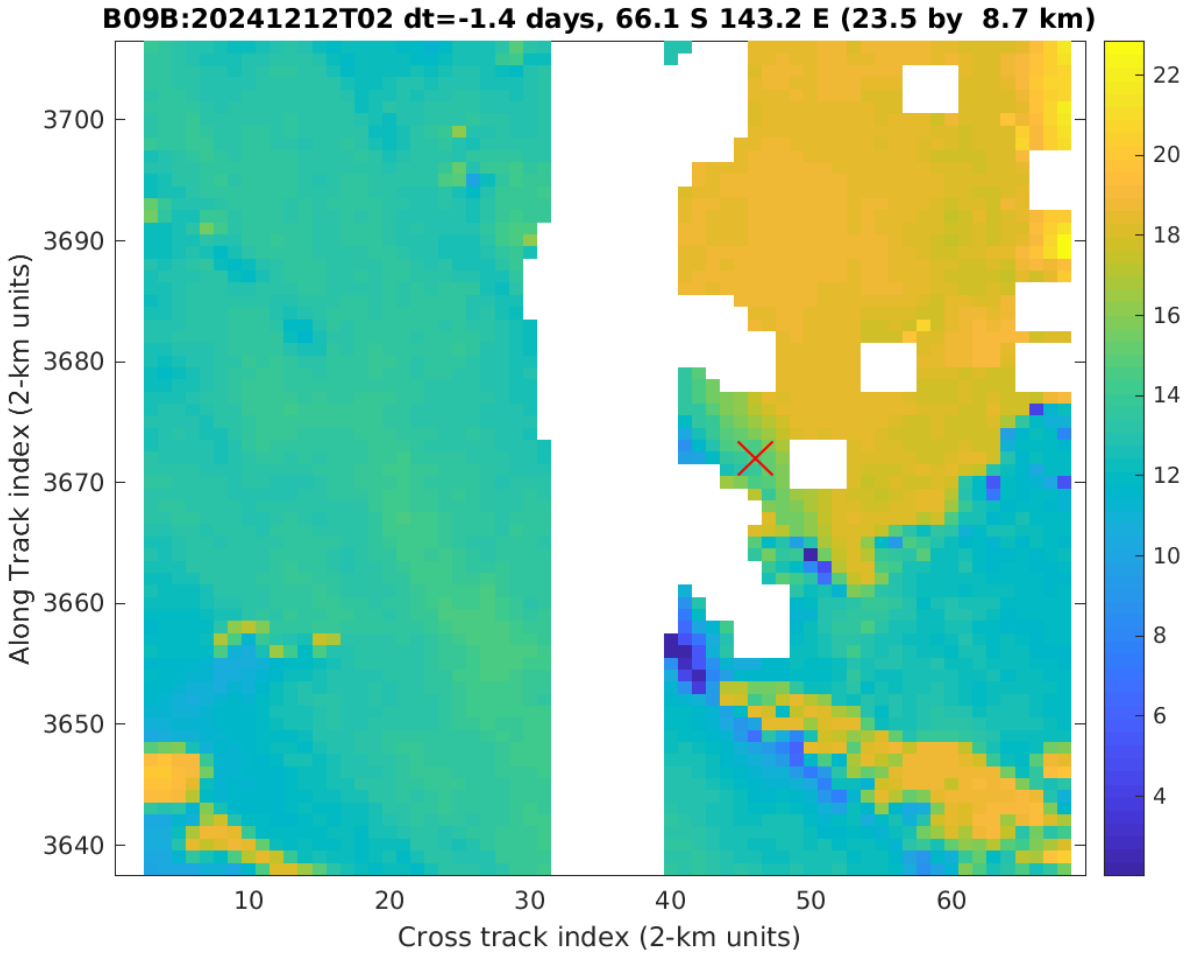
PIC2 NN SWOT wind speed



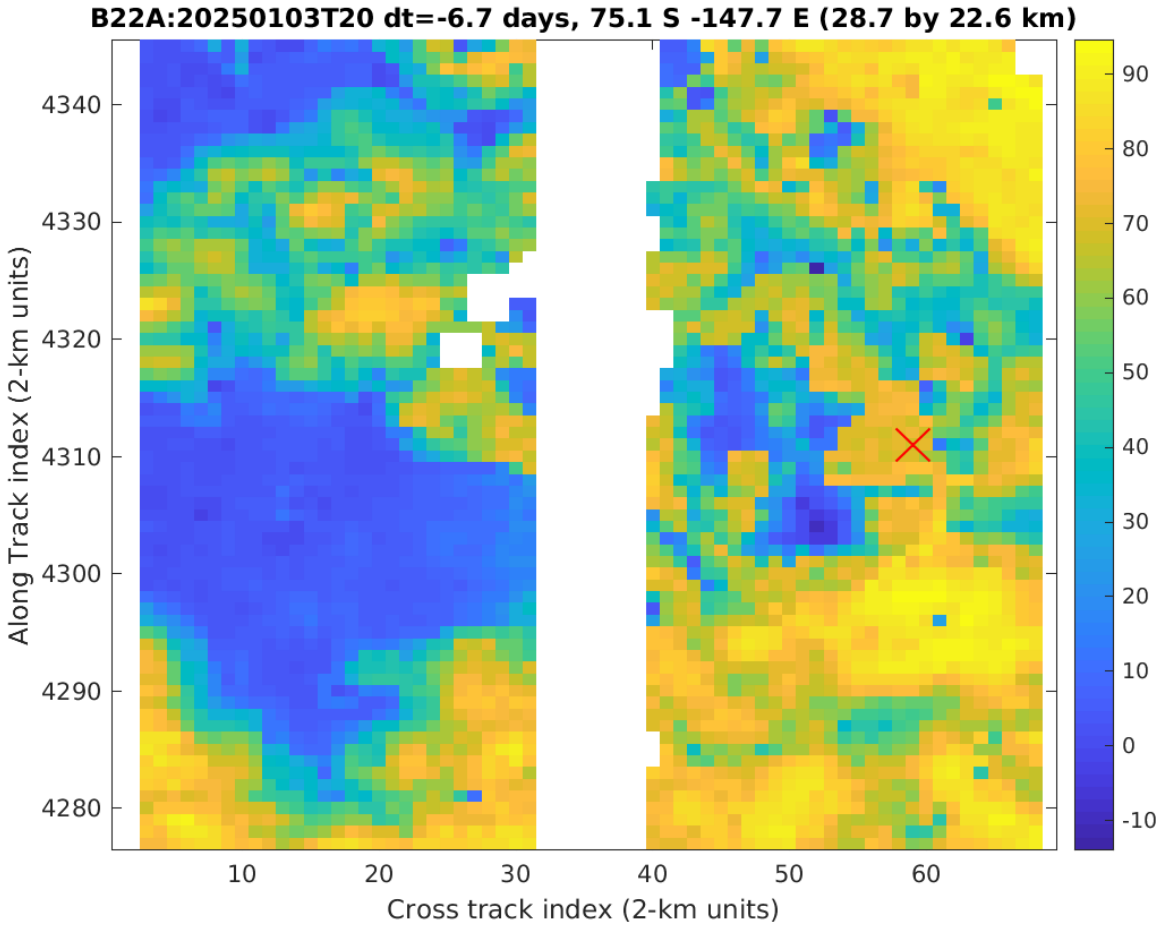
NN3 ice concentration



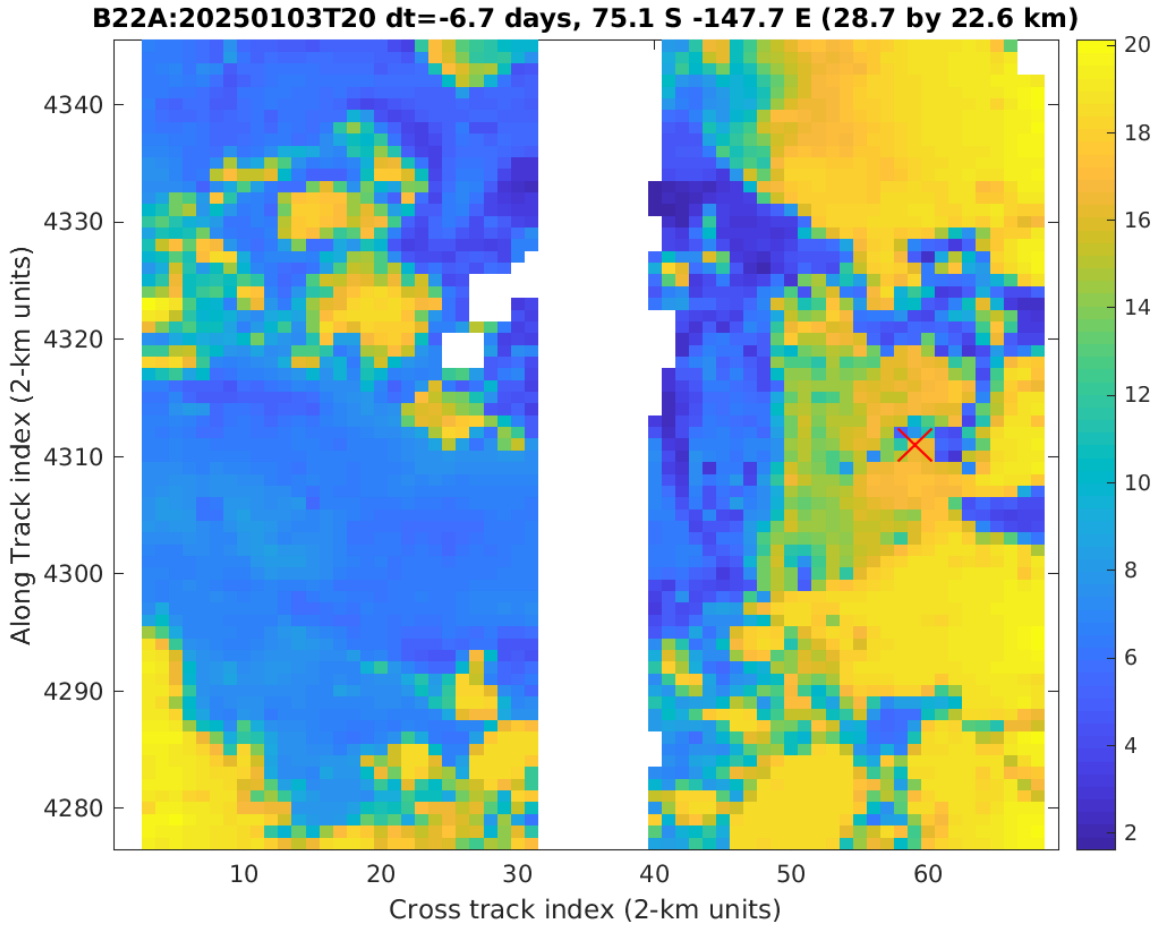
PIC2 NN SWOT wind speed



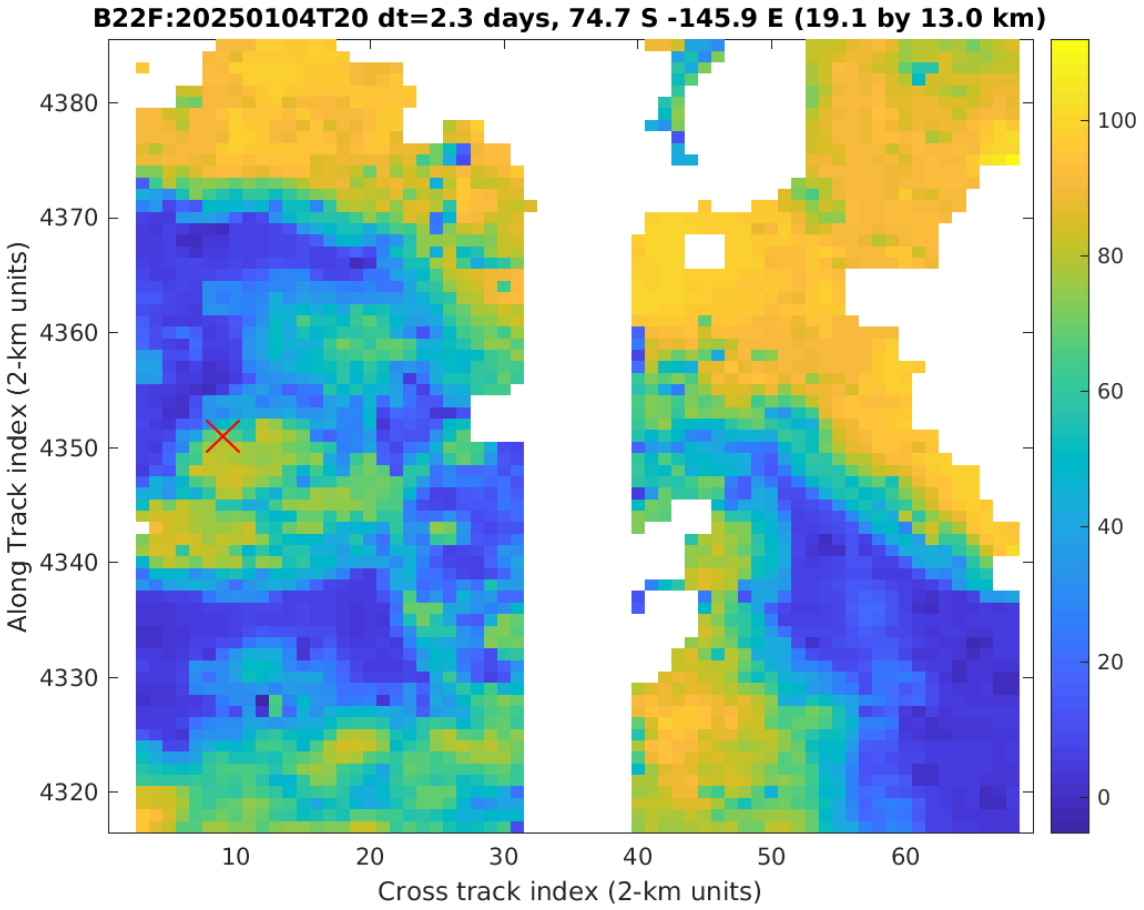
NN3 ice concentration



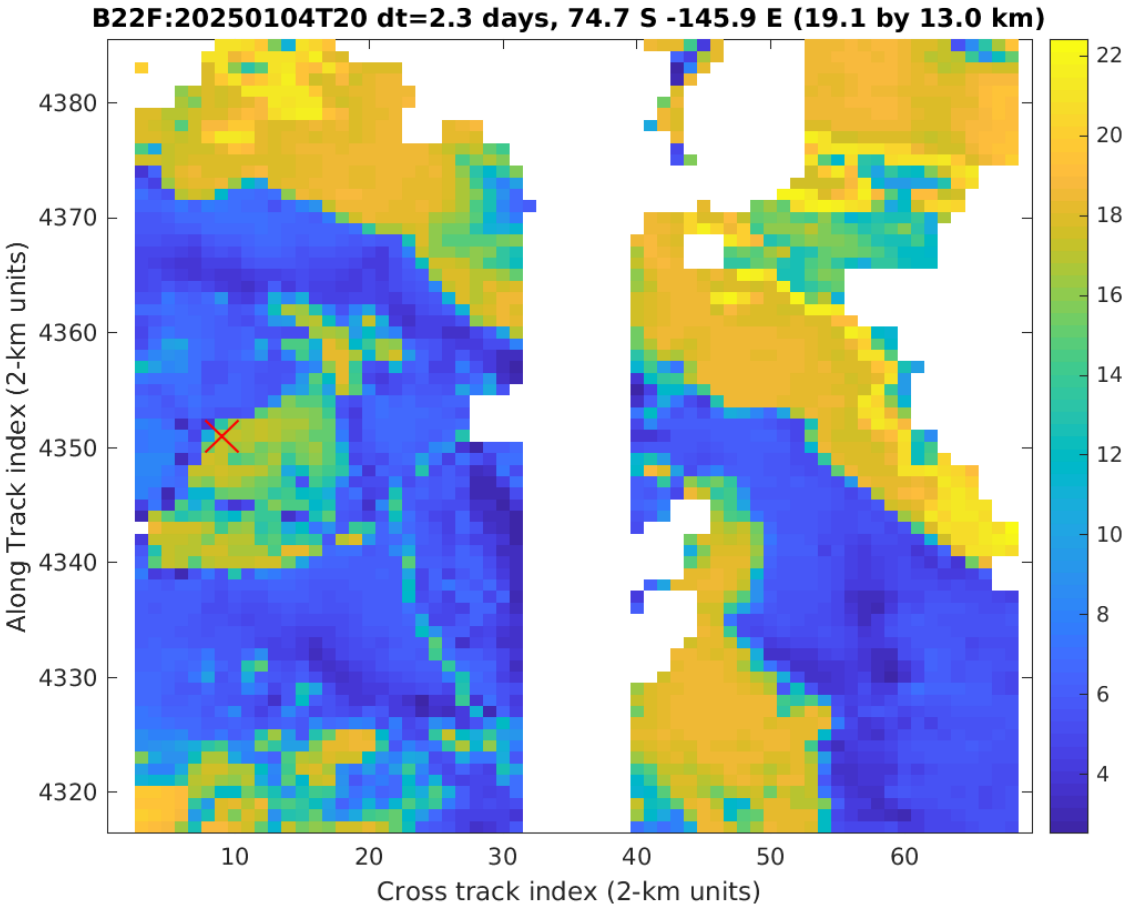
PIC2 NN SWOT wind speed



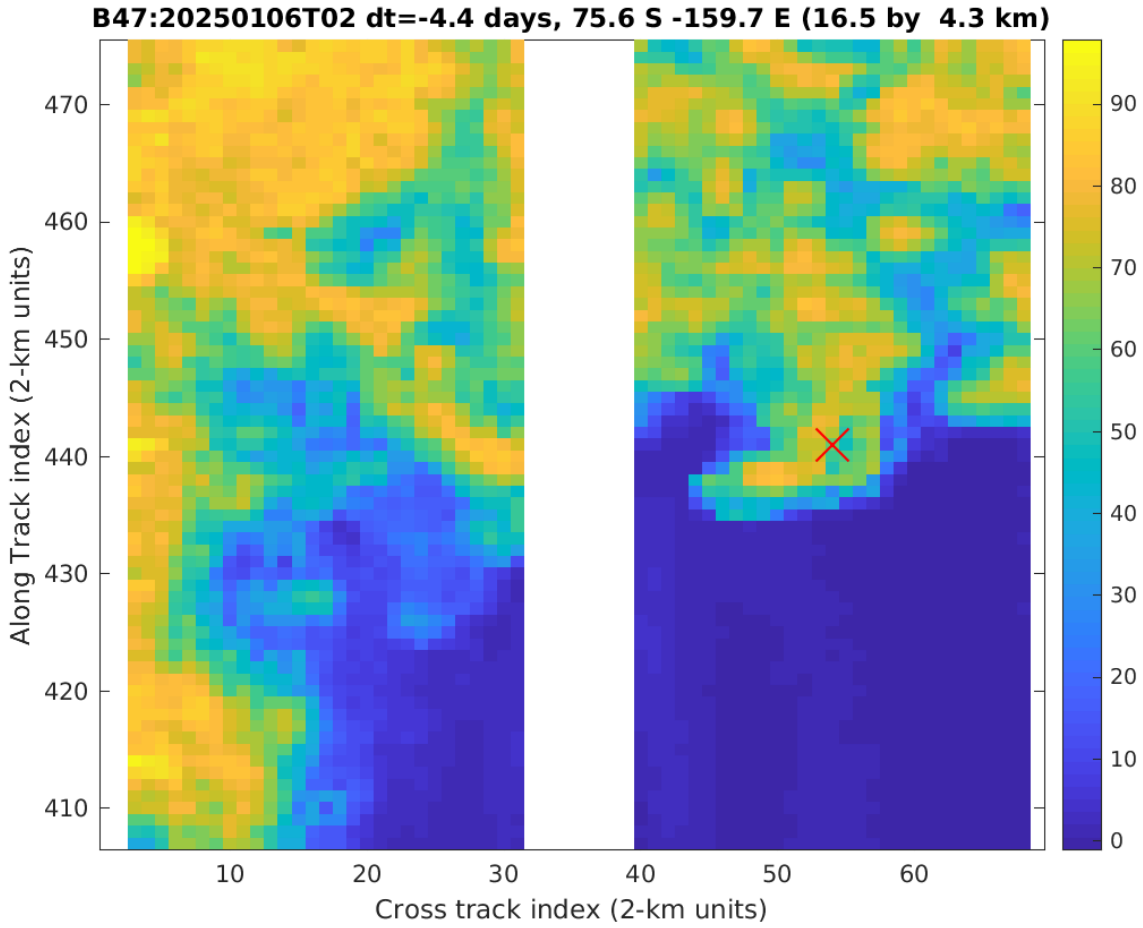
NN3 ice concentration



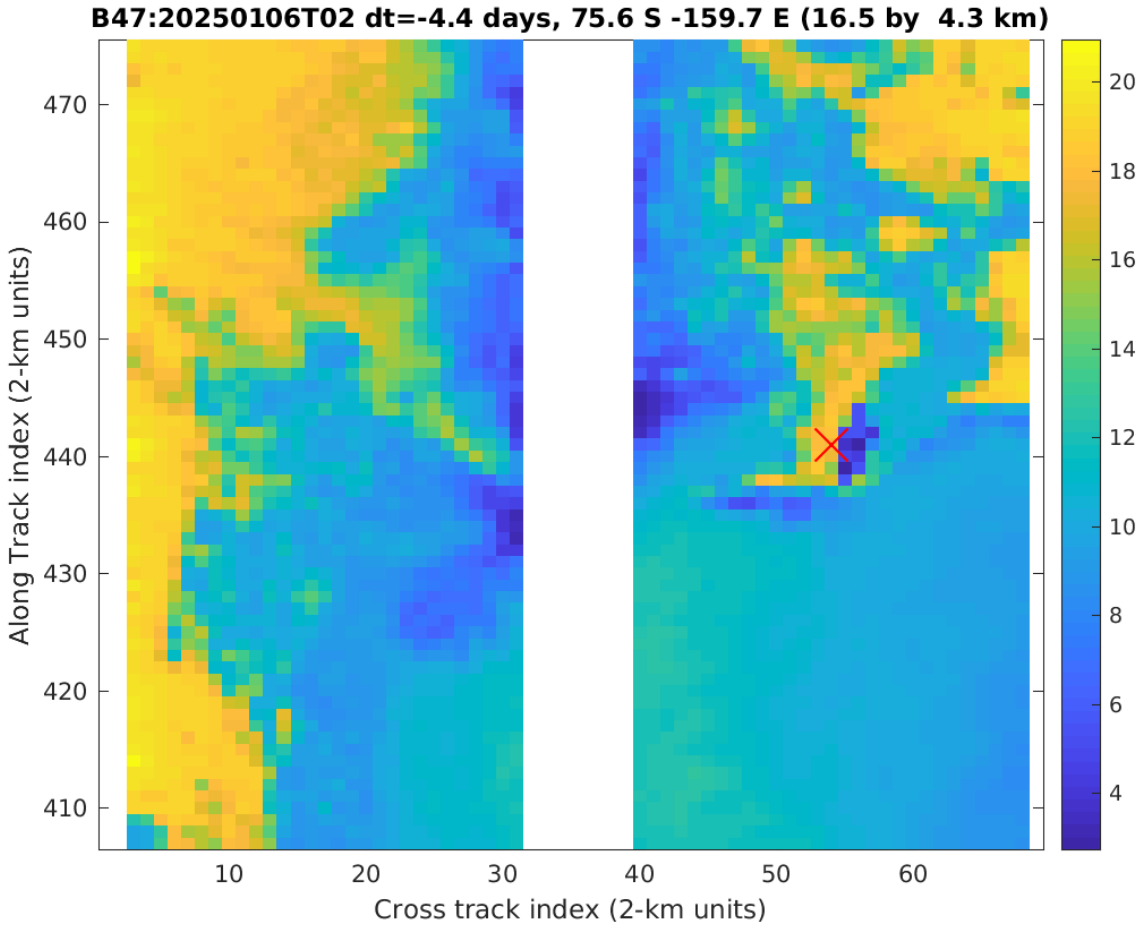
PIC2 NN SWOT wind speed



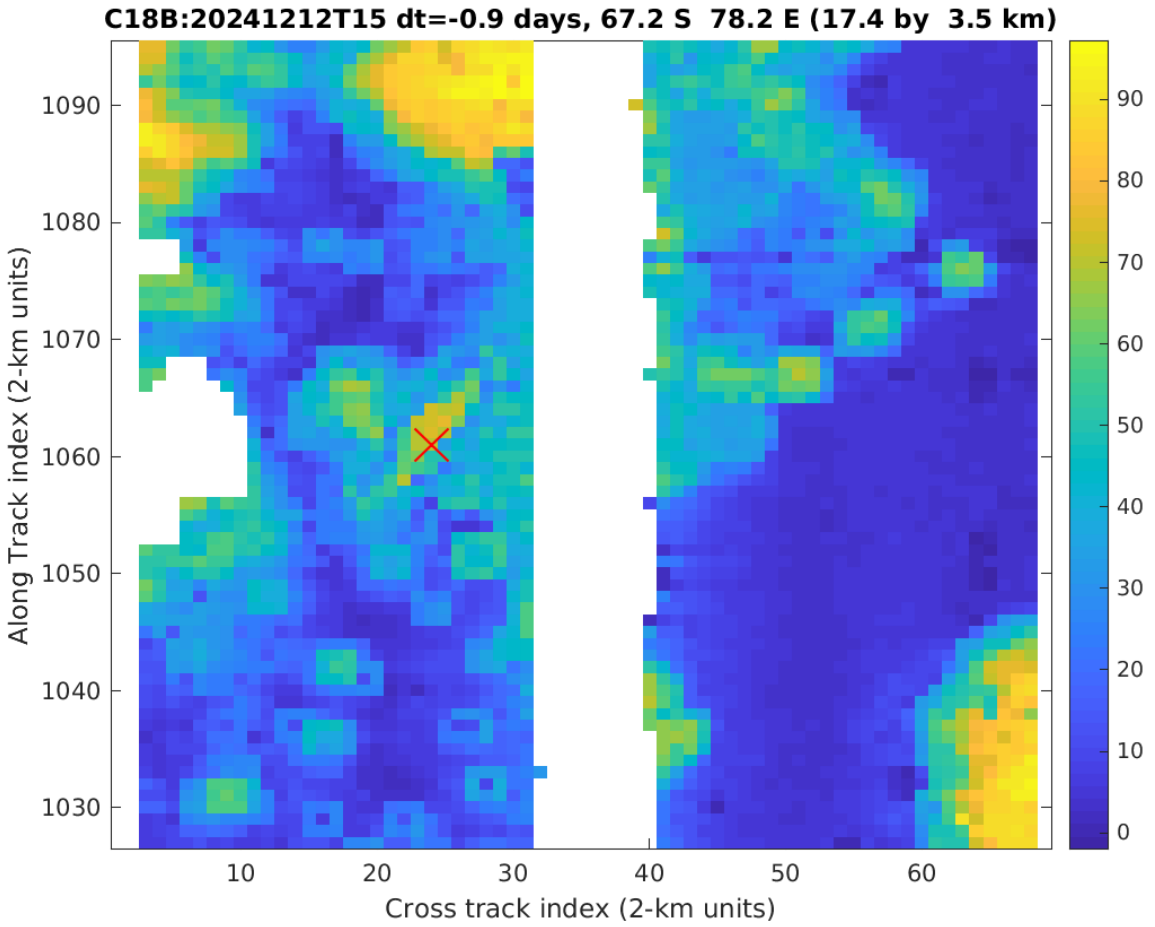
NN3 ice concentration



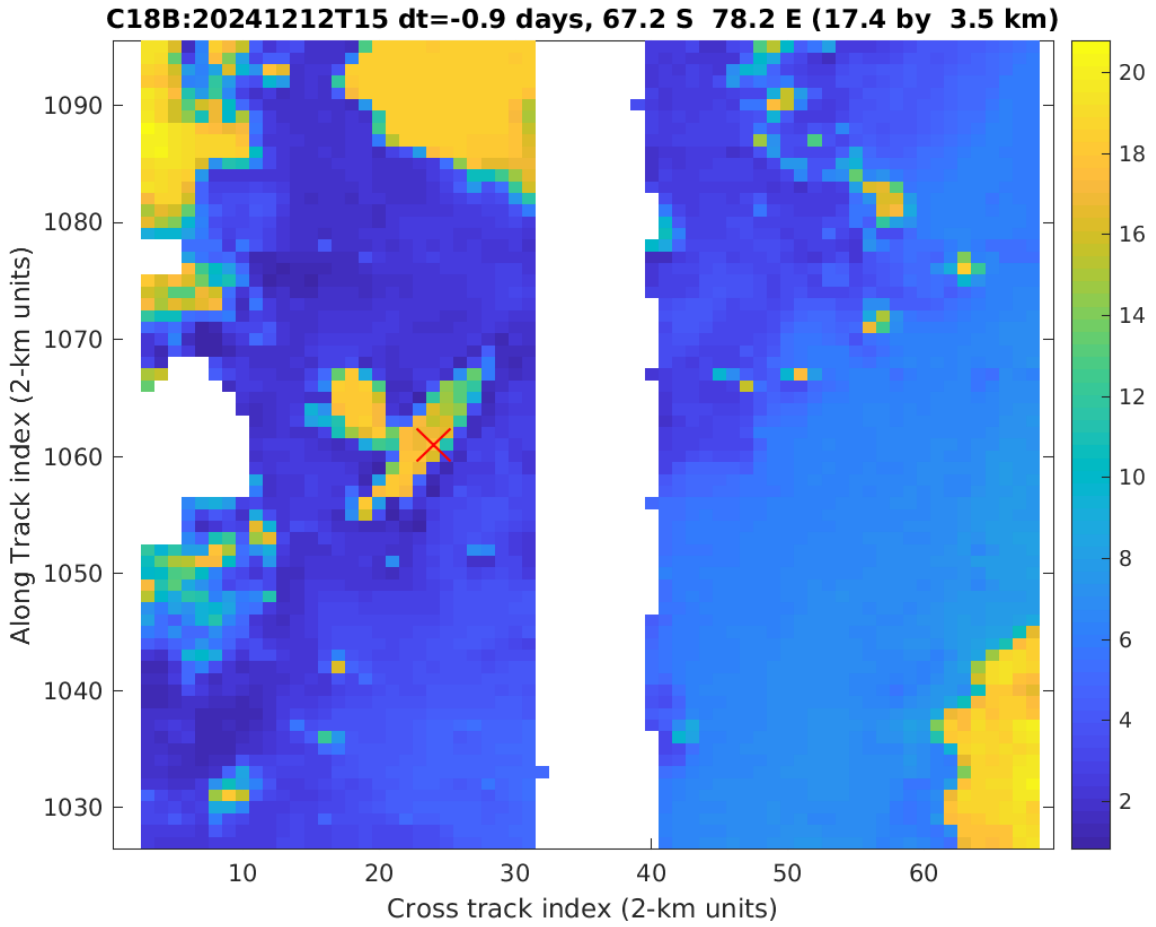
PIC2 NN SWOT wind speed



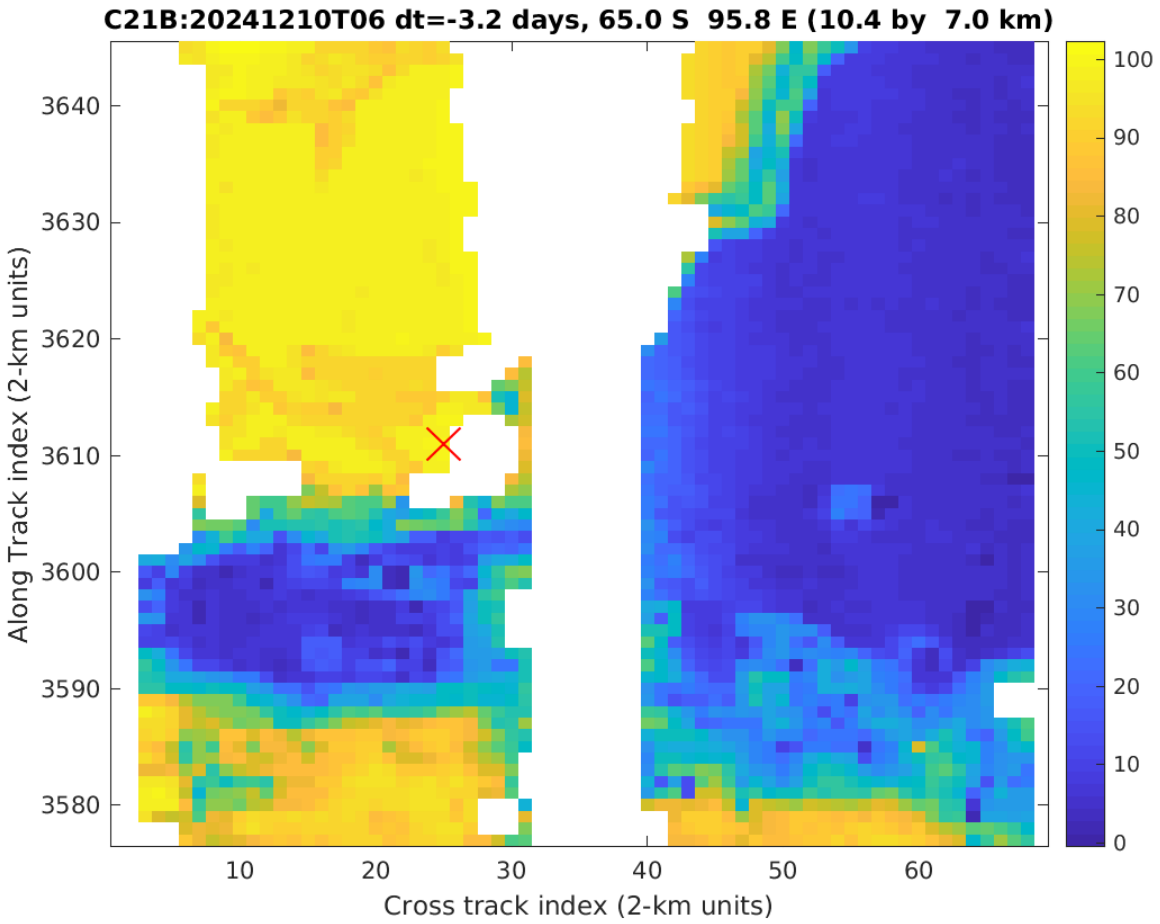
NN3 ice concentration



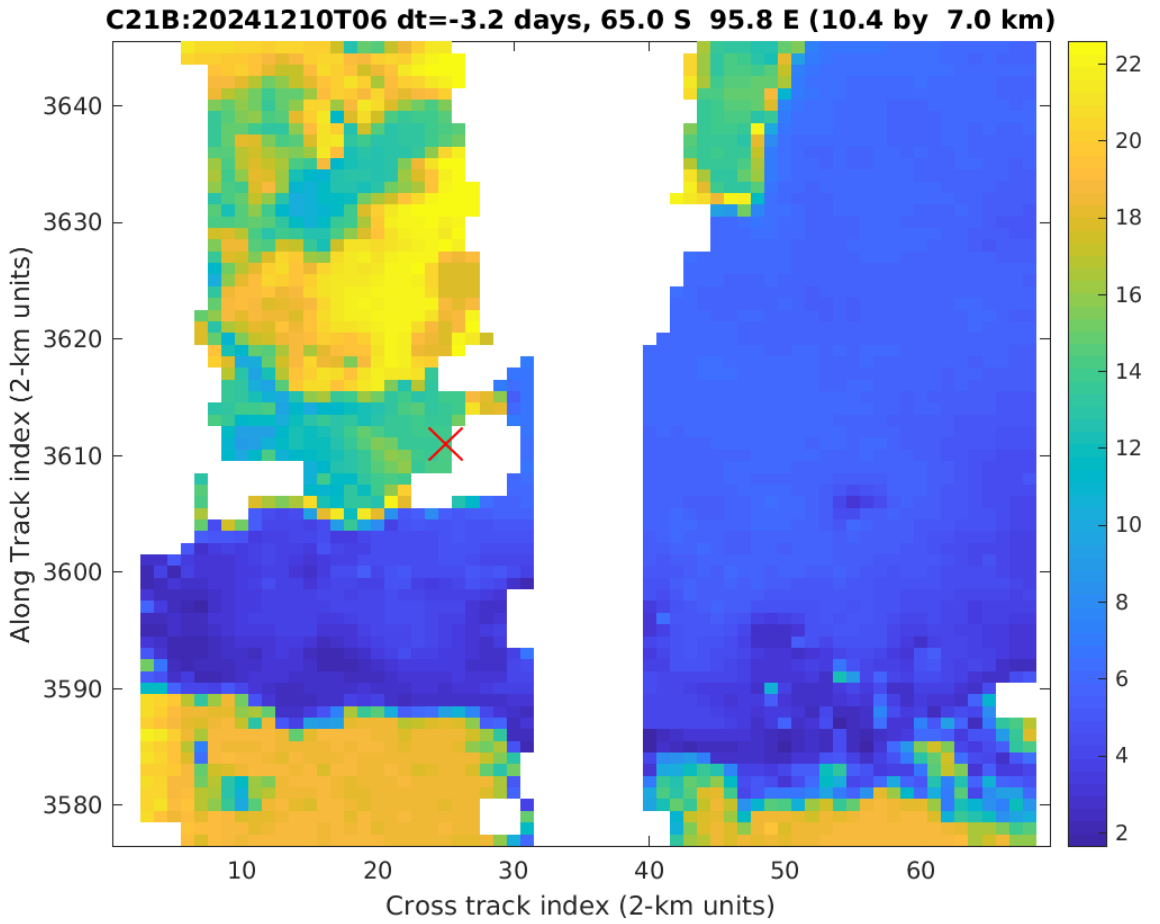
PIC2 NN SWOT wind speed



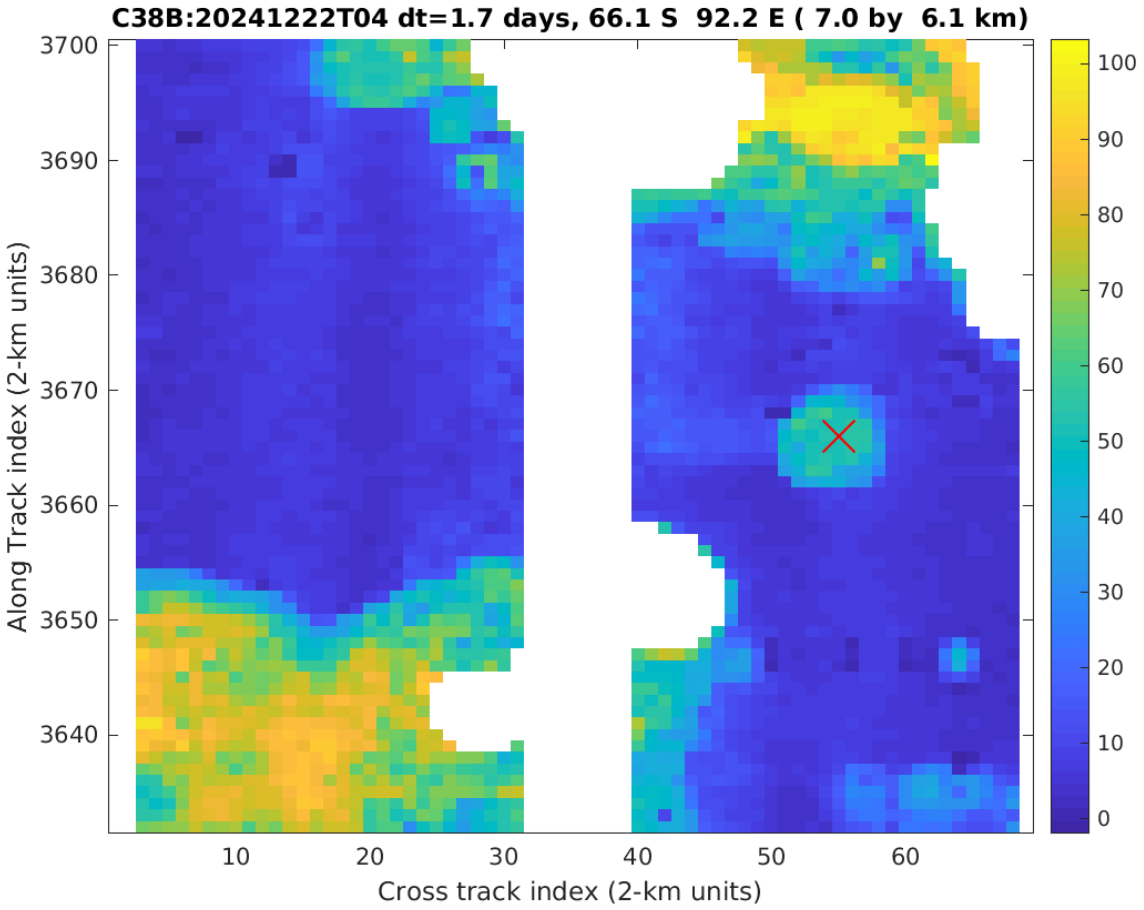
NN3 ice concentration



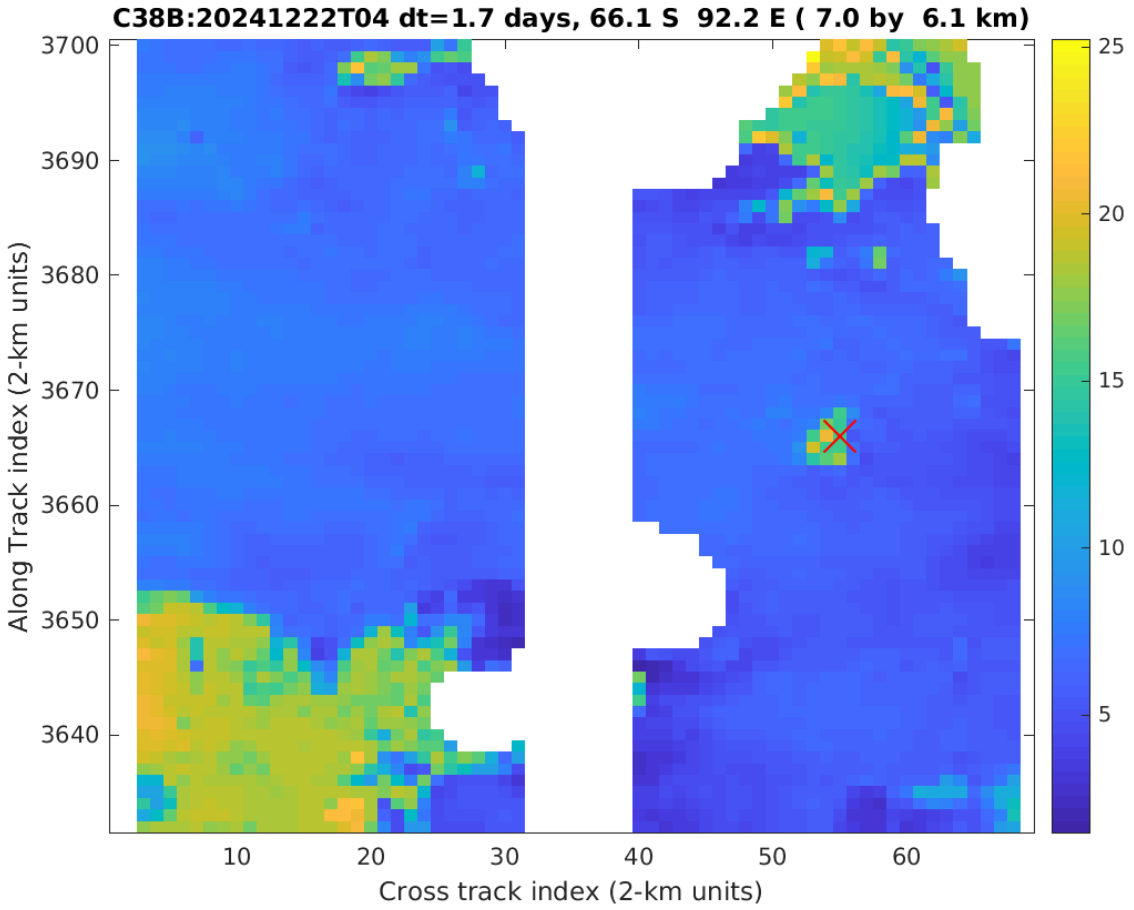
PIC2 NN SWOT wind speed



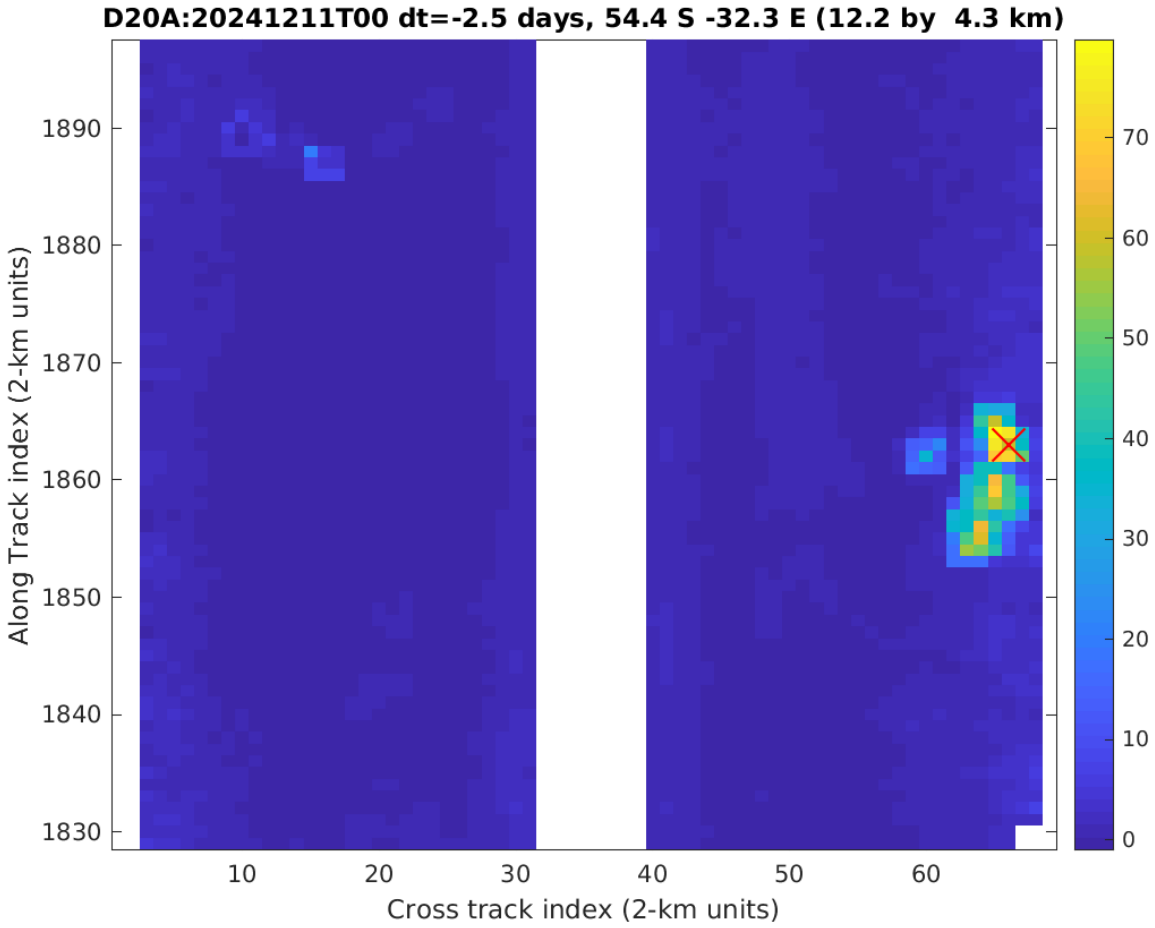
NN3 ice concentration



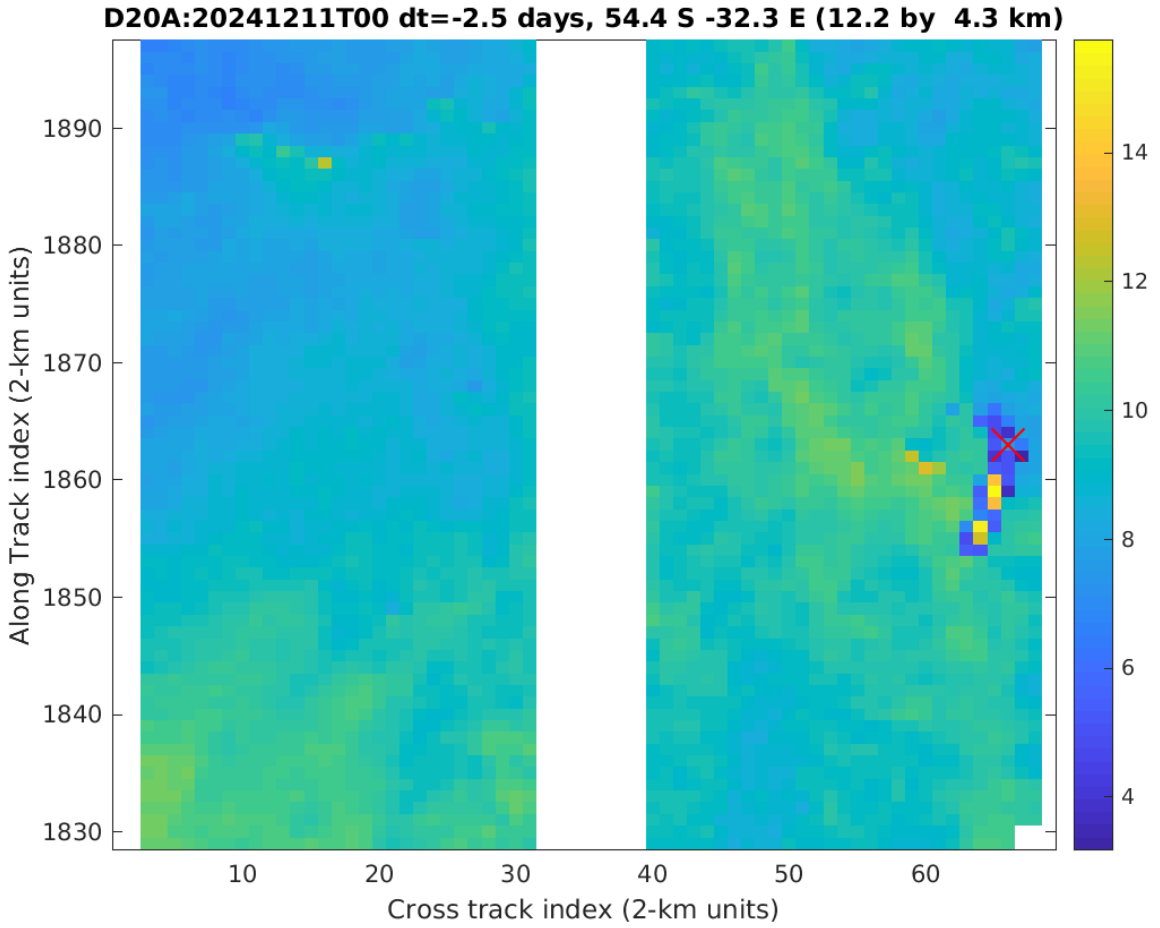
PIC2 NN SWOT wind speed



NN3 ice concentration

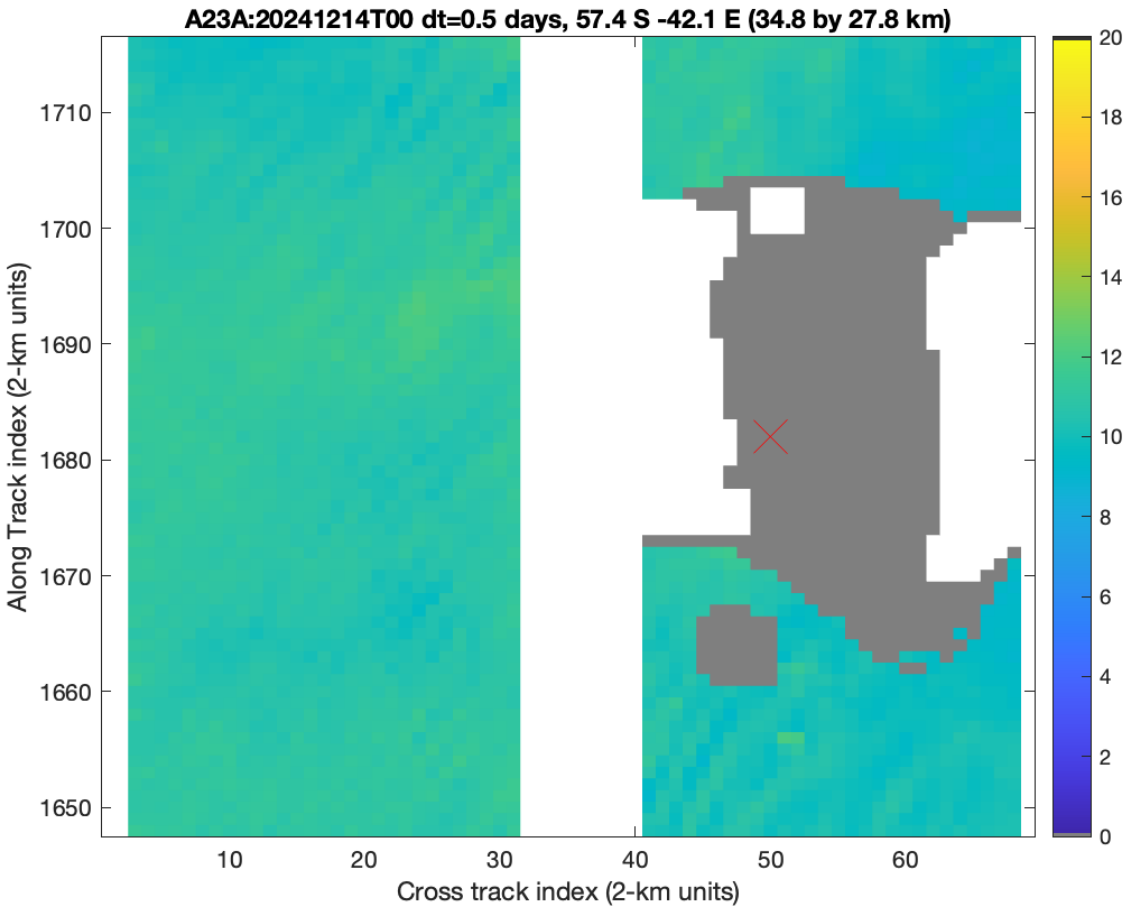


PIC2 NN SWOT wind speed

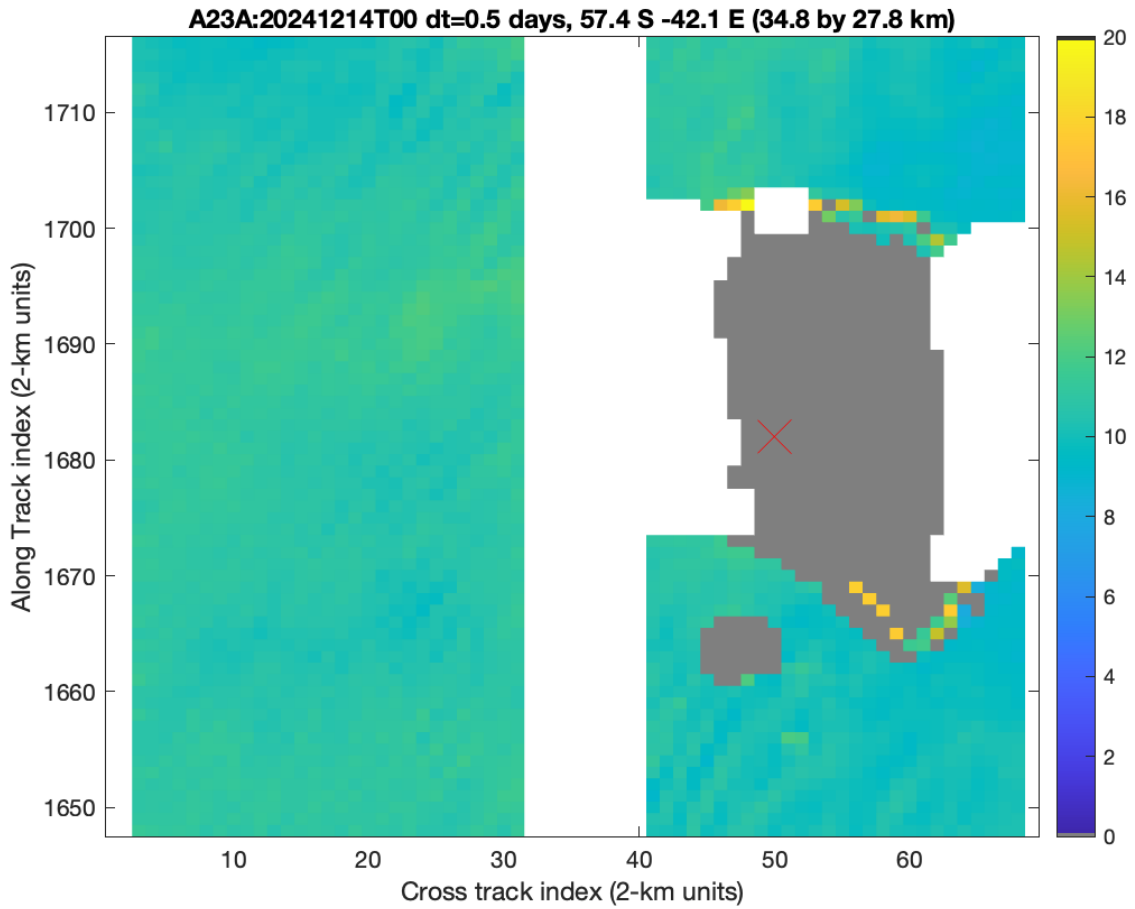


2 SWOT Ice Flag Neural Network Example 1 Iceberg A23A, 2024/12/14/0:00 UTC

SWOT retrieved speed PIC2 NN (m/s), with QC= NN3 20% threshold

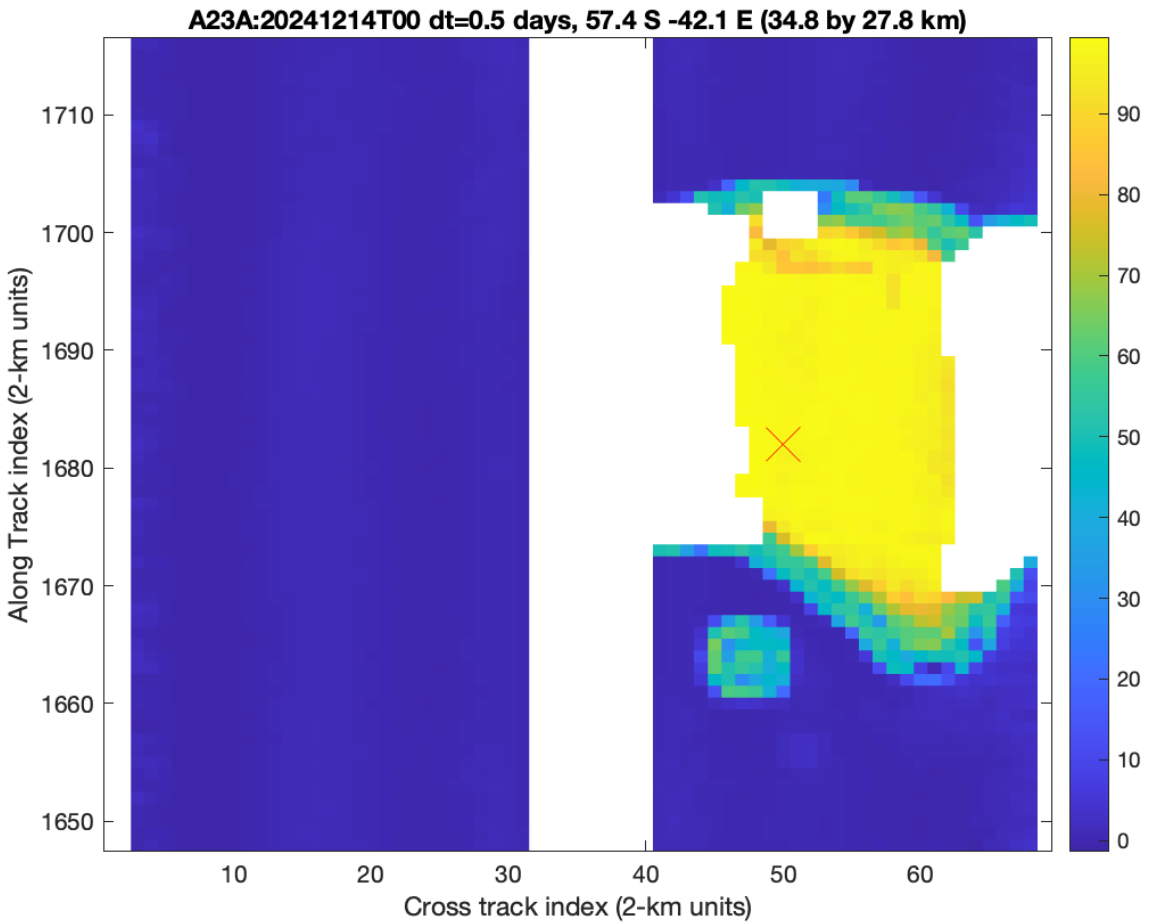


SWOT retrieved speed PIC2 NN (m/s), with QC= NN4 20%

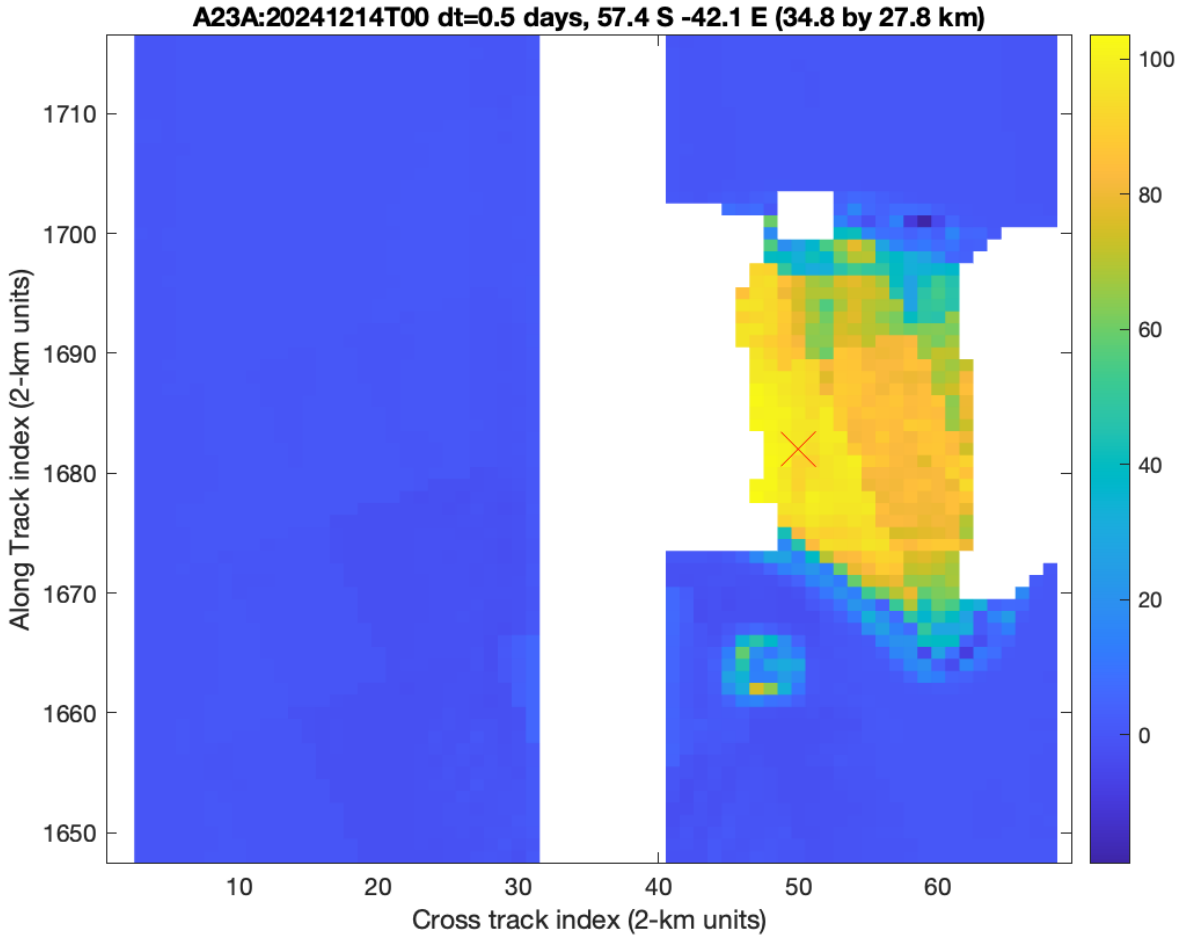


2 SWOT Ice Flag Neural Network Example 1 Iceberg A23A, 2024/12/14/0:00 UTC

NN3 Ice Concentration

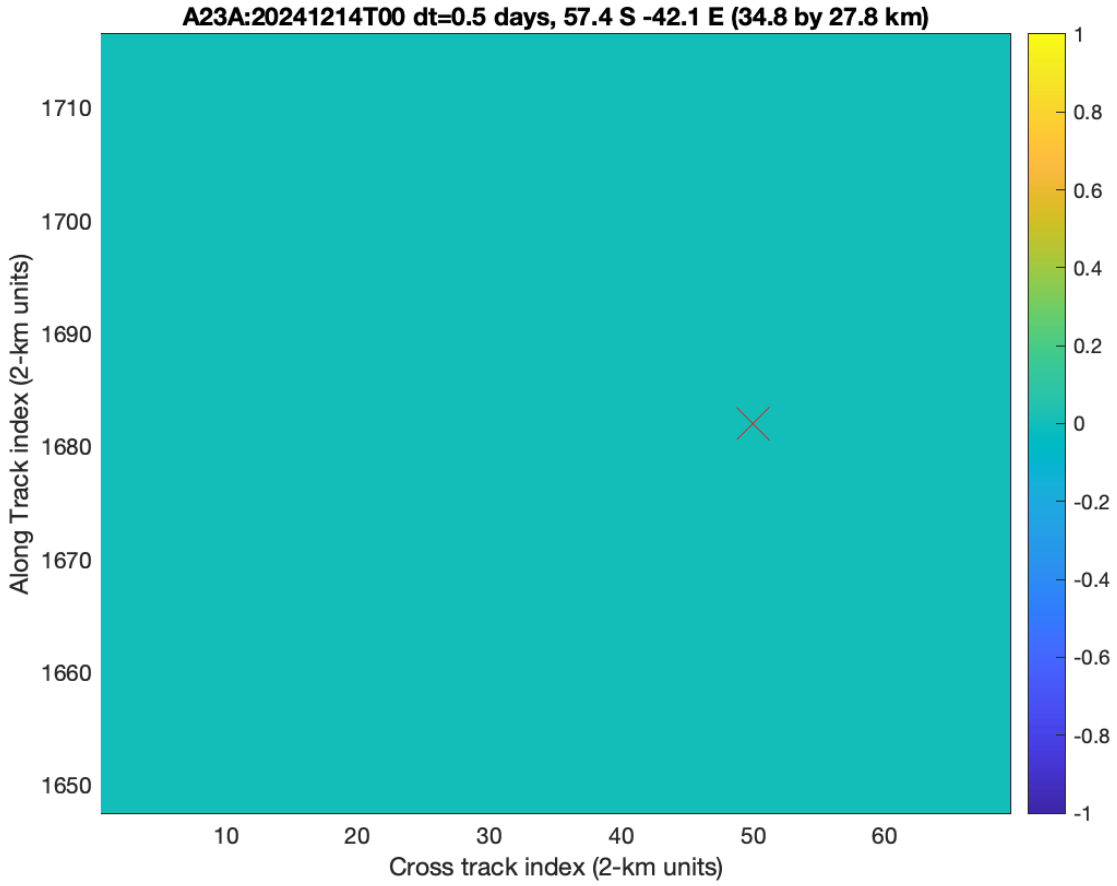


NN4 Ice Concentration

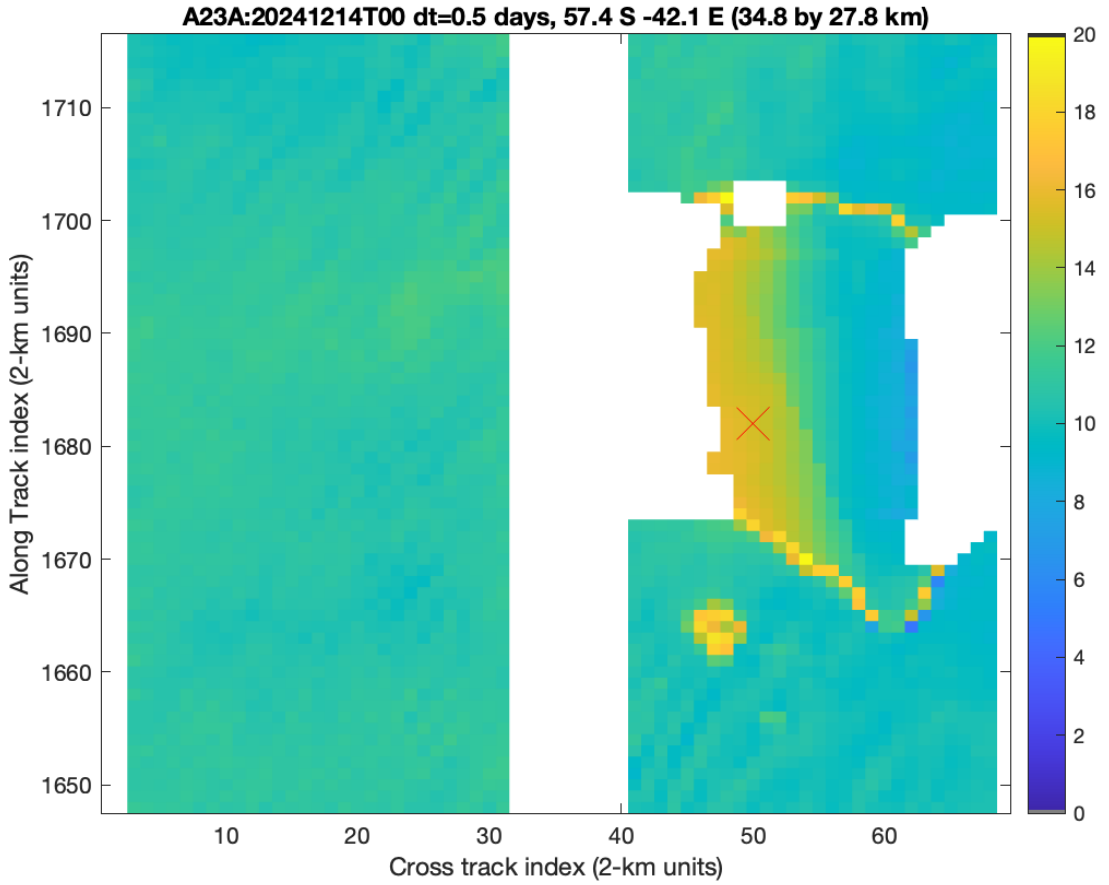


2 SWOT Ice Flag Neural Network Example 1 Iceberg A23A, 2024/12/14/0:00 UTC

ECMWF Ice Concentration

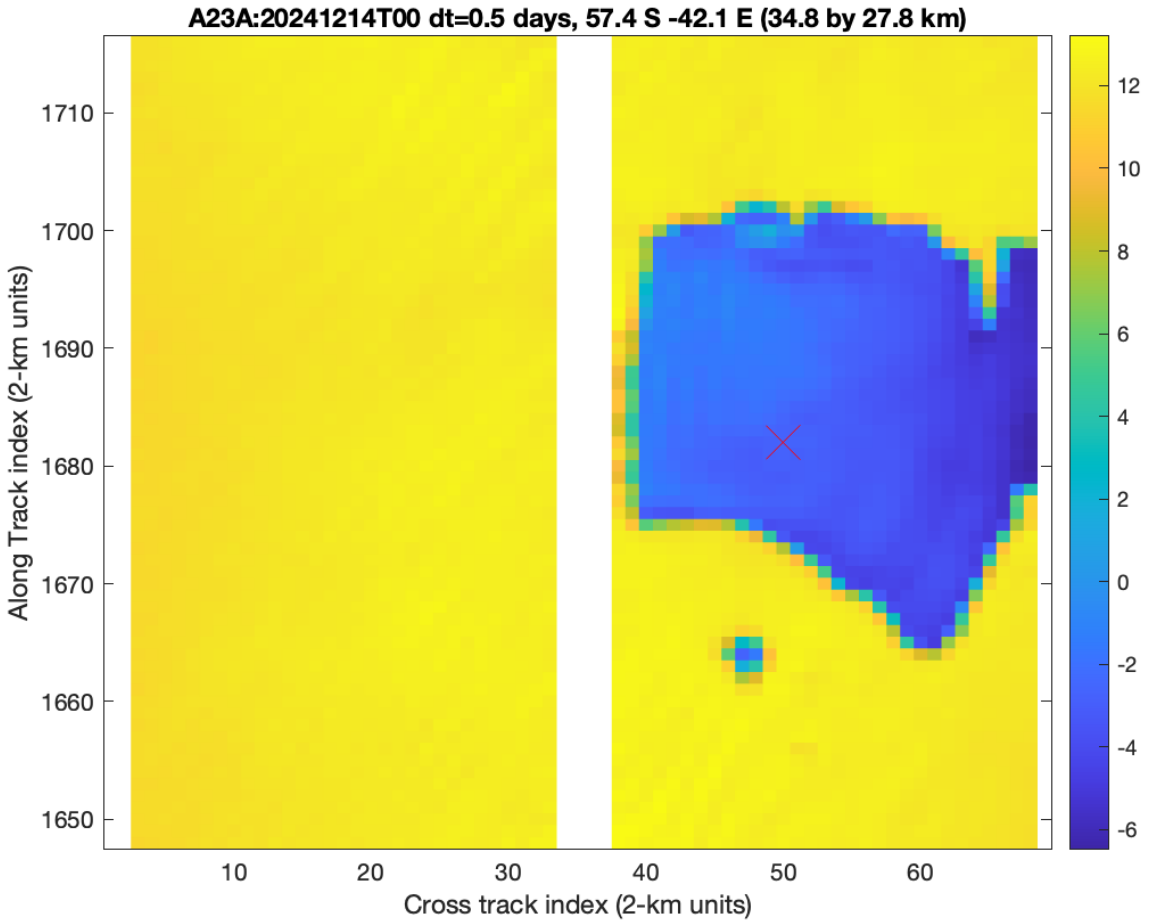


SWOT retrieved speed PIC2 NN (m/s), with no flagging

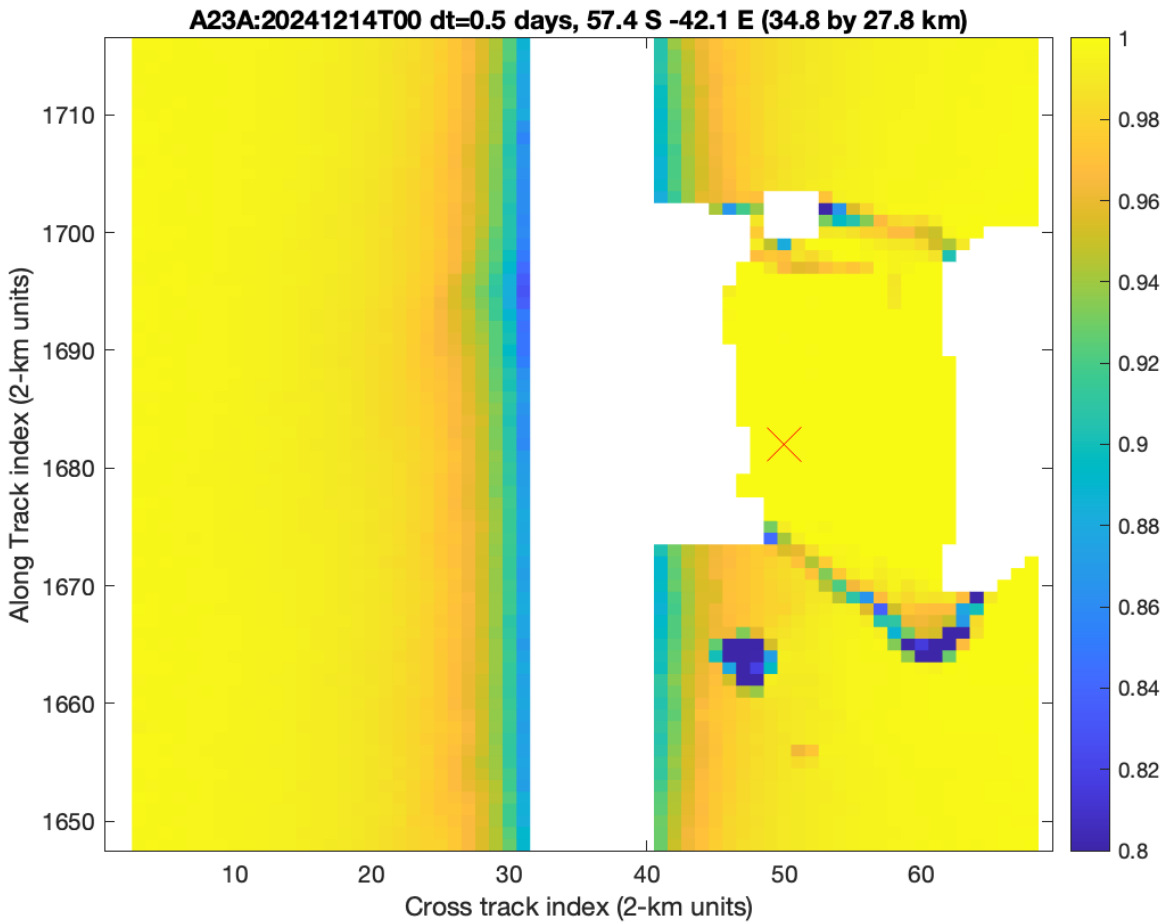


2 SWOT Ice Flag Neural Network Example 1 Iceberg A23A, 2024/12/14/0:00 UTC

Sigma-0 (dB)

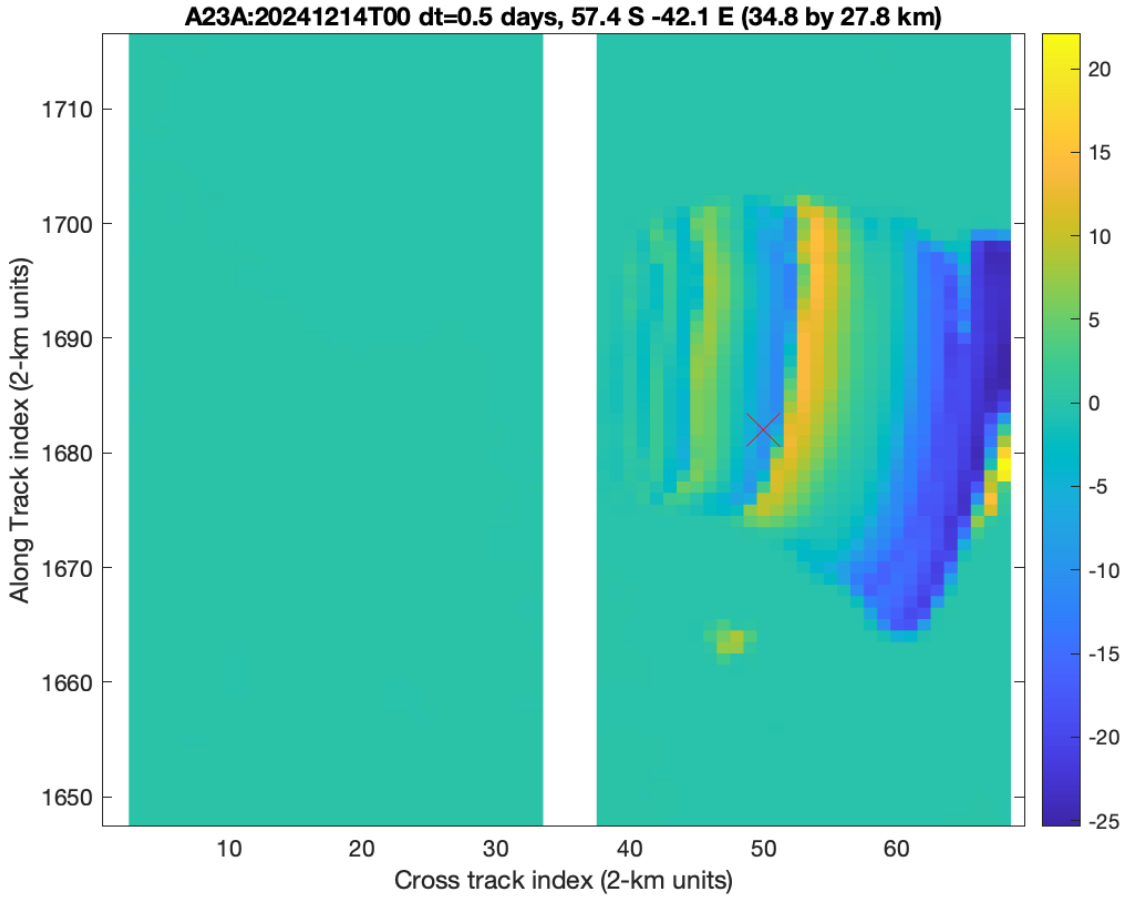


Volumetric Correlation

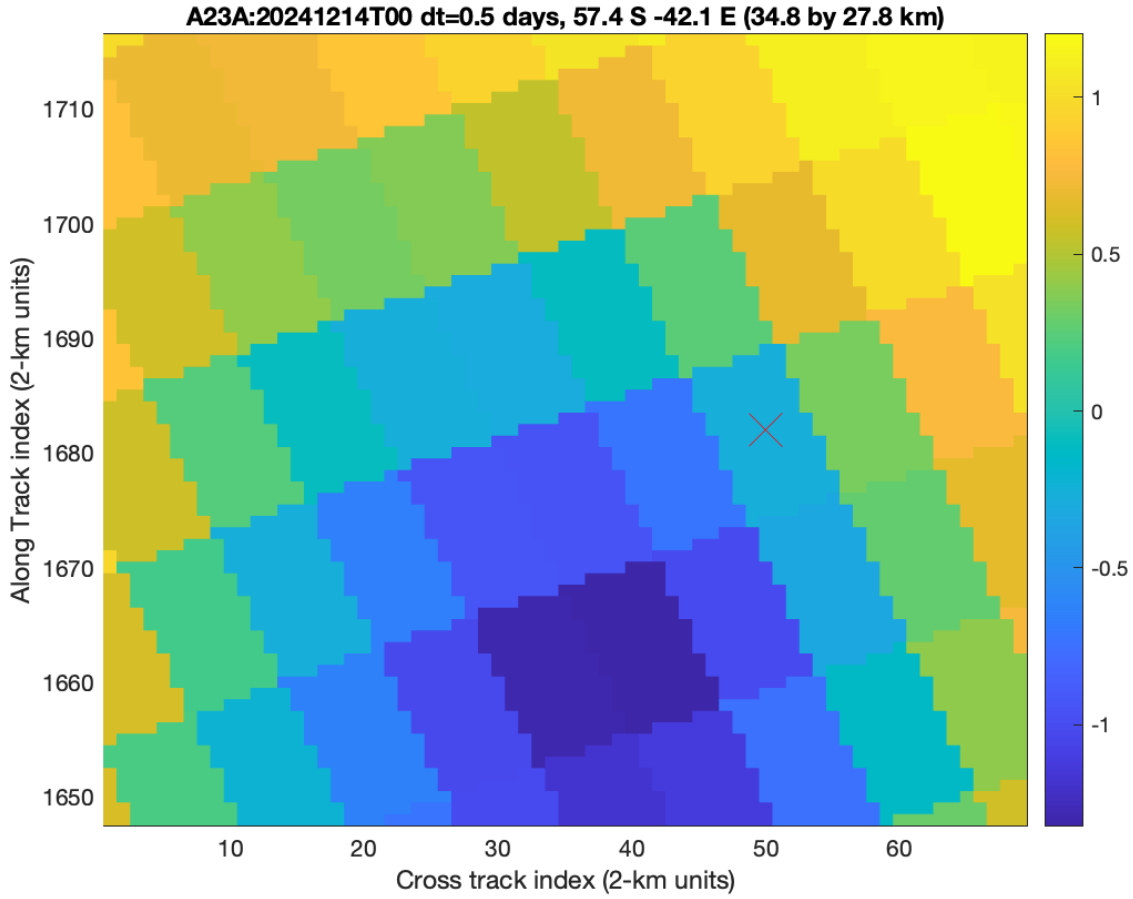


2 SWOT Ice Flag Neural Network Example 1 Iceberg A23A, 2024/12/14/0:00 UTC

SSHA (m)

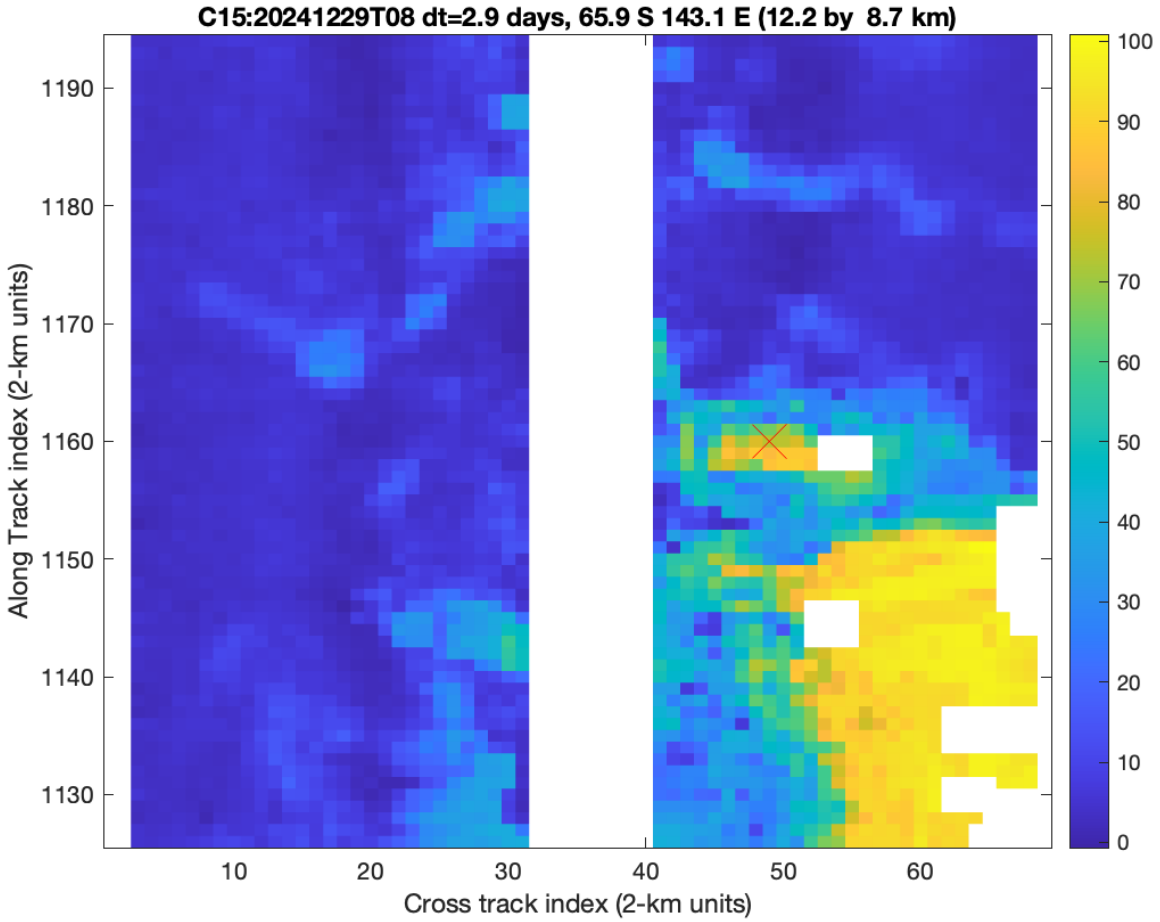


SST (deg C)

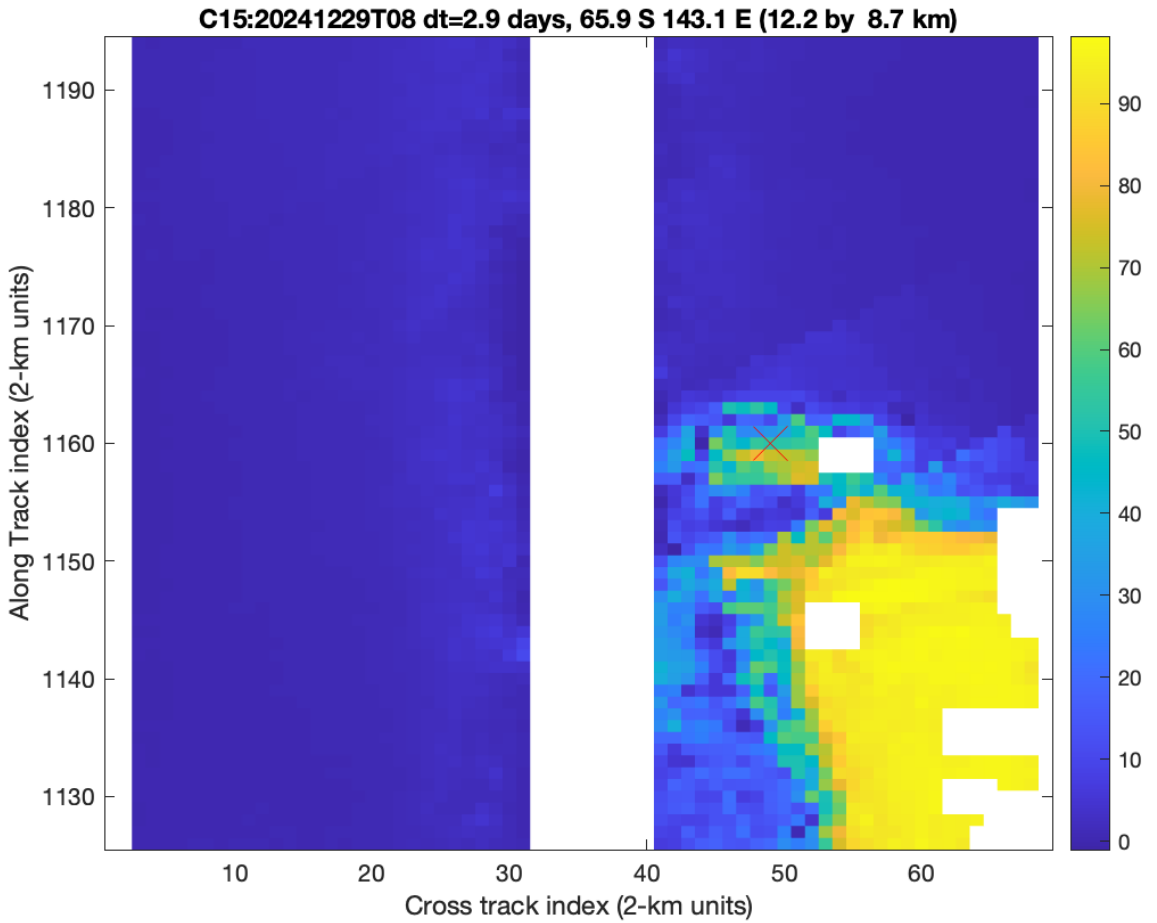


2 SWOT Ice Flag Neural Network Example 1 Iceberg C15,2024/12/29/08:00 UTC

NN3 ice concentration



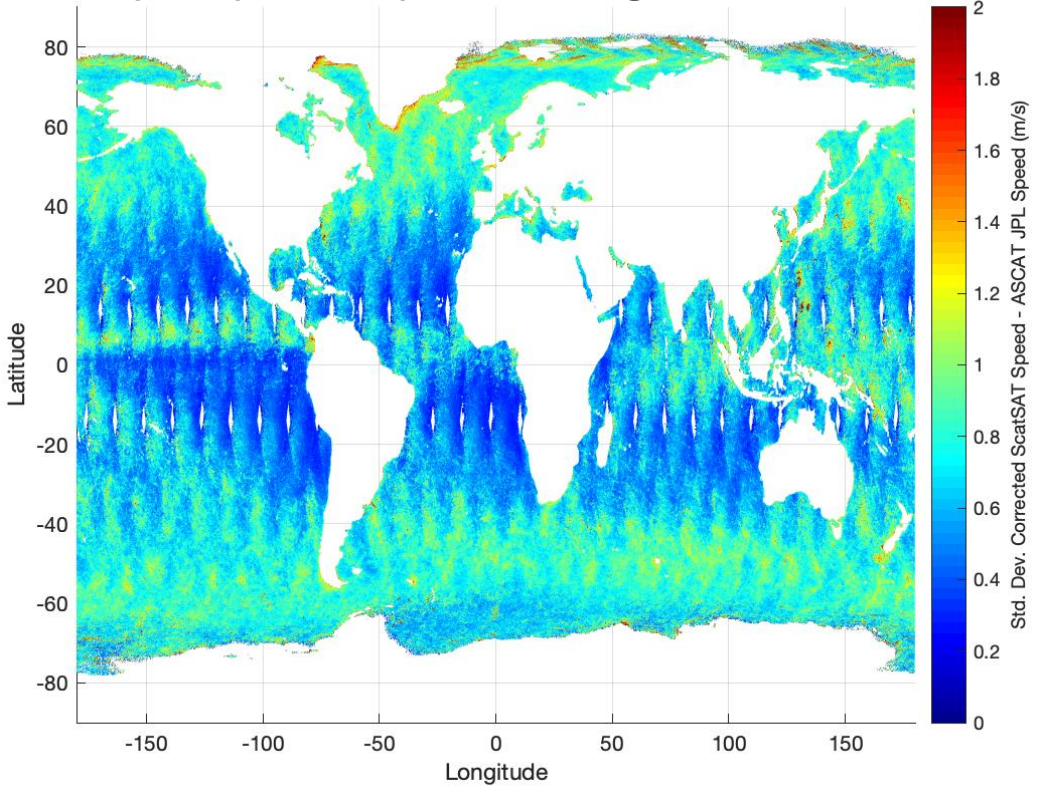
NN4 Ice Concentration



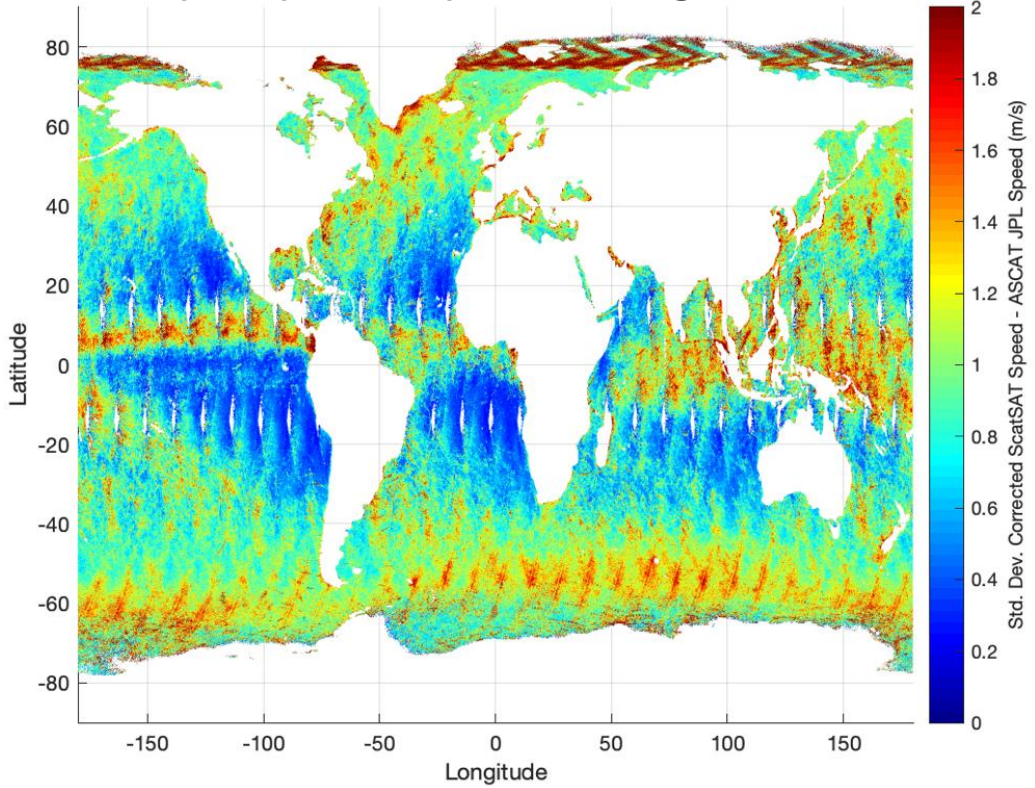
3 QuikSCAT/ScatSAT wind speed correction neural network

- Inputs: sigma-0 4 azimuths/polarizations; brightness temp, cross track distance, original retrieved wind speed
- Speed correction neural network originally meant for rain reduced artifacts near ice for ScatSAT and QuikSCAT

ScatSAT yearly wind speed average with rain correction



ScatSAT yearly wind speed average without rain correction



3 QuikSCAT/ScatSAT wind speed correction neural network

One-Year Scatterometer Wind Speed Statistics with respect to ERAInterim for latitudes poleward of 60 degrees

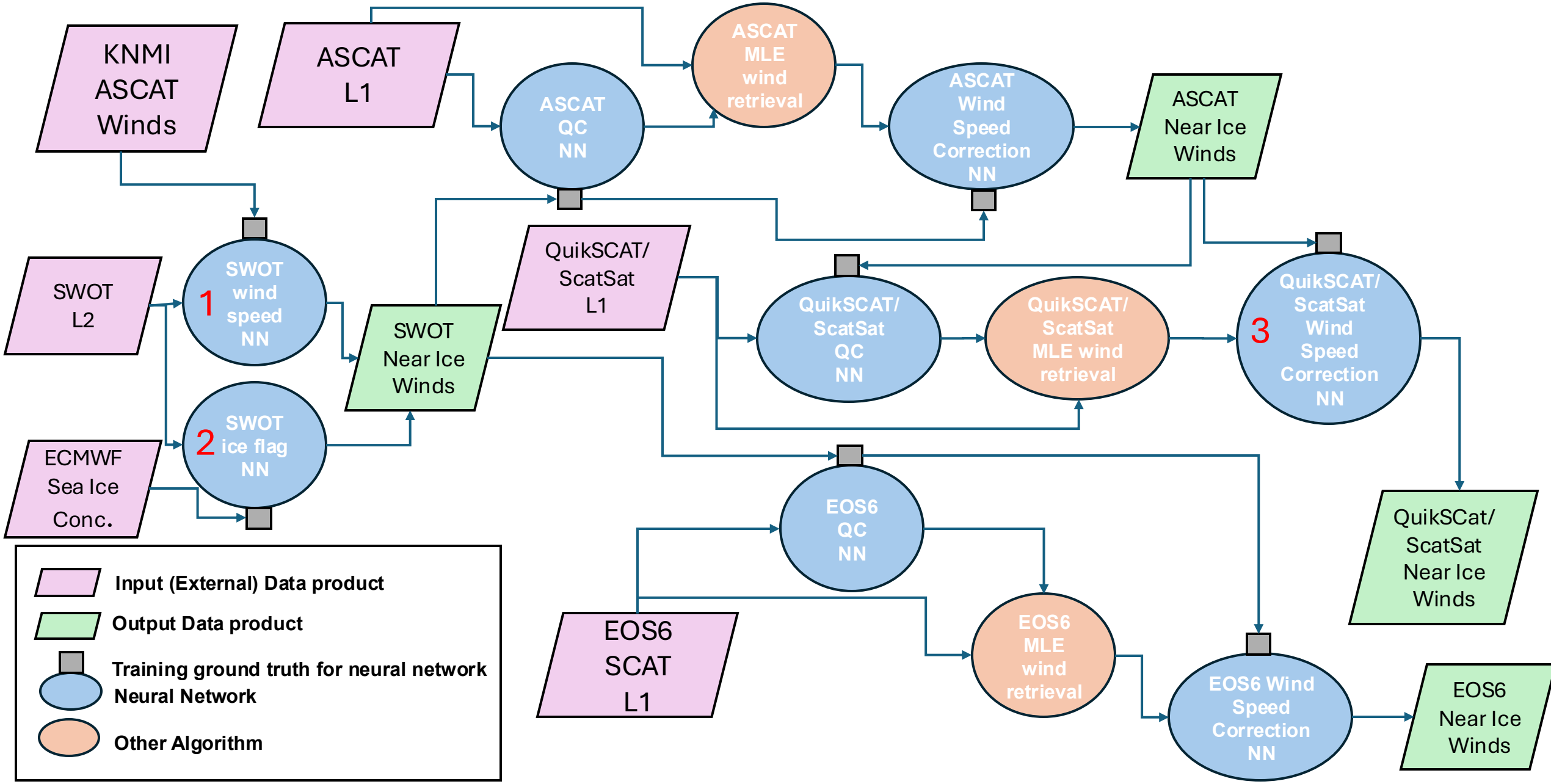
RMS=Root mean square difference (m/s), RSF = Relative Sampling Frequency, Q1 = High Quality, Q2=Medium quality, Q3=All retrieved winds

Platform	Year	Latitude Range	Rain Corrected?	RMS Q1	RMS Q2	RMS Q3	RSF Q1	RSF Q2	RSF Q3
QuikSCAT	2008	60-90	Yes	2.41	14.7	22.24	0.676	0.878	0.924
QuikSCAT	2008	60-90	No	2.42	17.32	31.96	0.676	0.878	0.924
ASCAT A	2008	60-90	No	1.96	2.16	2.47	0.511	0.615	0.665
ASCAT B	2019	60-90	No	1.66	1.76	1.95	0.487	0.599	0.664
ScatSat	2019	60-90	Yes	1.84	2.38	2.51	0.703	0.901	1
ScatSat	2019	60-90	No	1.96	3.21	25.05	0.703	0.901	1

References and Publicly Available Software Repo

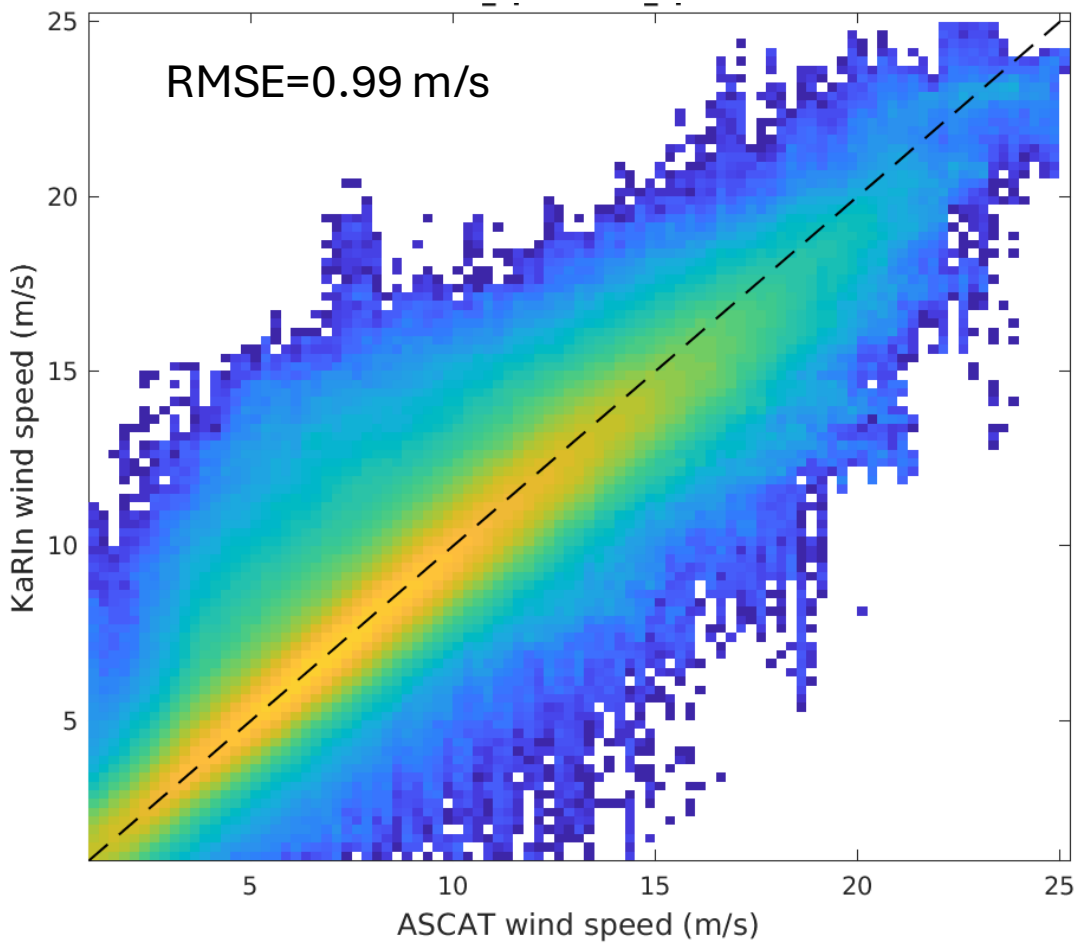
- B. W. Stiles *et al.*, "Ocean Surface Wind Speed Retrieval for SWOT Ka-band Radar Interferometer," *IGARSS 2024 - 2024 IEEE International Geoscience and Remote Sensing Symposium*, Athens, Greece, 2024, pp. 1422-1425, doi: 10.1109/IGARSS53475.2024.10640472.
- B. W. Stiles, Richard E Danielson, W Lee Poulsen, "Optimized Tropical Cyclone Winds From QuikSCAT: A Neural Network Approach," in *IEEE Transactions on Geoscience and Remote Sensing*, vol. 52, no. 11, pp. 7418-7434, Nov. 2014, doi:10.1109/TGRS.2014.2312333.
- A. G. Fore, B. W. Stiles, A. H. Chau, B. A. Williams, R. S. Dunbar and E. Rodríguez, "Point-Wise Wind Retrieval and Ambiguity Removal Improvements for the QuikSCAT Climatological Data Set," in IEEE Transactions on Geoscience and Remote Sensing, vol. 52, no. 1, pp. 51-59, Jan. 2014, doi: 10.1109/TGRS.2012.2235843.
- B. W. Stiles and R. S. Dunbar, "A Neural Network Technique for Improving the Accuracy of Scatterometer Winds in Rainy Conditions," in IEEE Transactions on Geoscience and Remote Sensing, vol. 48, no. 8, pp. 3114-3122, Aug. 2010, doi:10.1109/TGRS.2010.2049362.
- MLE Wind and Salinity Retrieval Code Repo: https://github.com/jplwindssalinity/v3proc
- Neural Network Wind Retrieval Code Repo: https://github.com/jplwindssalinity/neuralnetwindret

Flowchart of Near-Ice Wind Processing

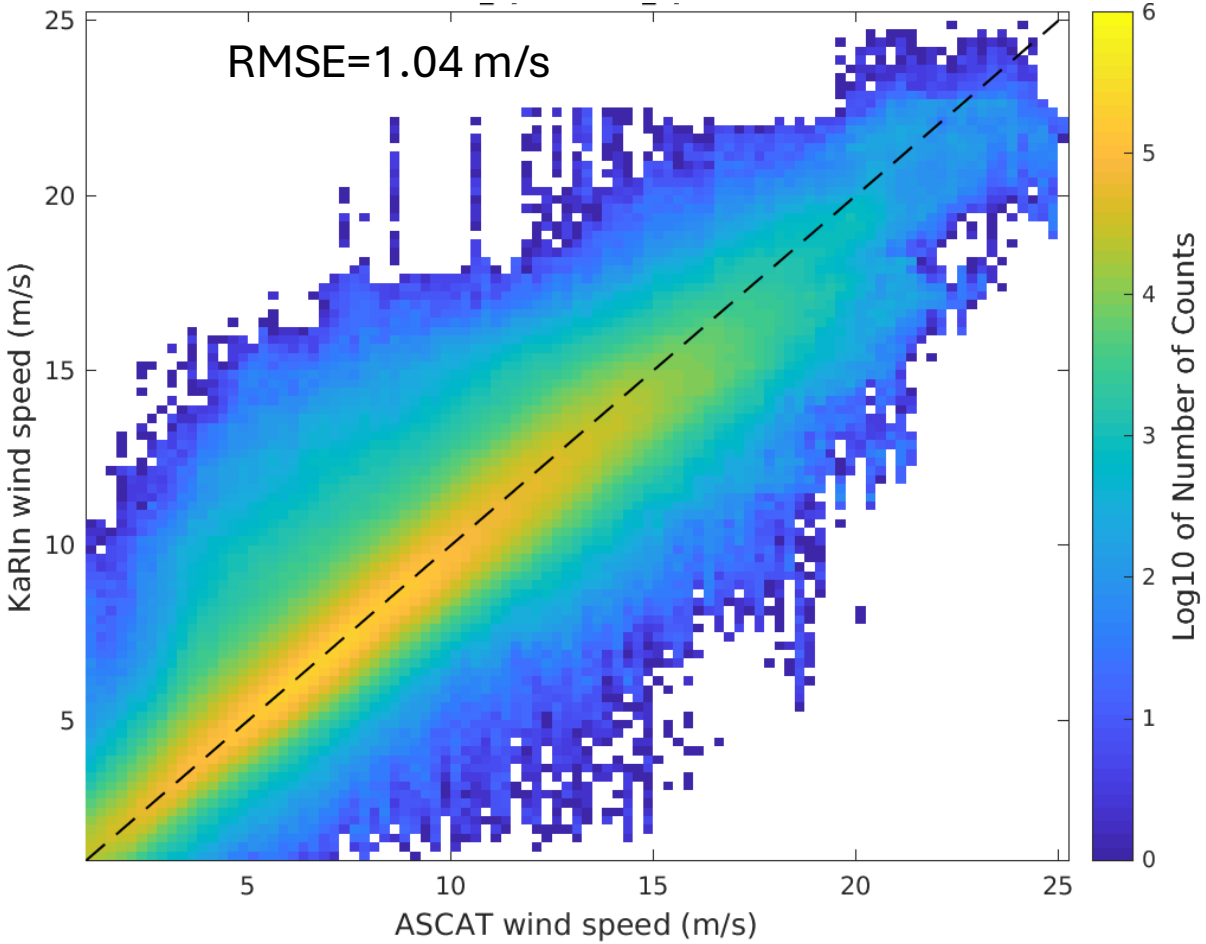


1 SWOT Wind Speed Neural Network Inputs: radar backscatter, incidence, SWH, SST

SST Included, ASCAT within 30 min



No SST, ASCAT within 30 min



2 SWOT Ice Flag Neural Network: PIC0 version

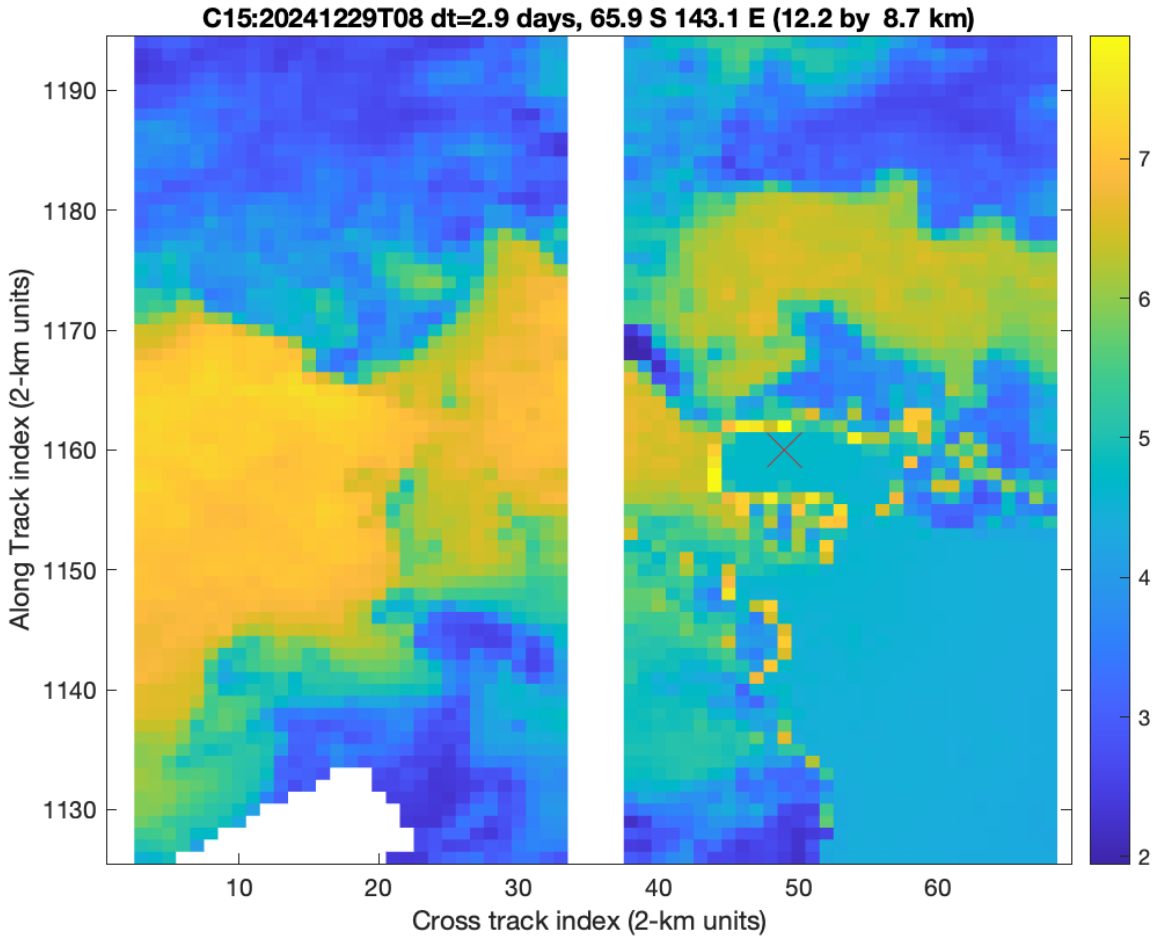
* Note this NN detects all but 2 icebergs with valid NCEP flags and detects the one NCEP missed detection. It also detects all the icebergs that the ECMWF flag detects.

* Note this NN detects all but 4 icebergs with valid NCEP flags including the one NCEP missed detection. It also detects 13 icebergs that the ECMWF flag misses while only missing 3 that ECMWF detects.

Network Inputs OR Model name	RMS w.r.t ECMWF (percent) Tuned to ECMWF (NCEP)	RMS w.r.t NCEP (percent) ECMWF (NCEP)	False Alarm Percent w.r.t ECWMF ECMWF (NCEP)	Missed Detect Percent w.r.t ECMWF ECWMF (NCEP)	False Alarm Percent w.r.t NCEP ECMWF (NCEP)	Missed Detect Percent w.r.t NCEP ECMWF (NCEP)	Iceberg Missed Detect Percent, missed /valid ECMWF (NCEP)
inc, sig0, vol_cor	16.8 (16.9)	22.2 (21.0)	15.1 (14.7)	0.31 (0.64)	21.3 (20.6)	0.16 (0.40)	23.4, 43/184 (24.5, 45/184)
inc, sig0, vol_cor, vars	11.8 (12.2)	20.0 (18.2)	4.1 (6.3)	0.034 (0.056)	11.1 (13.3)	0.022 (0.040)	24.5, 45/184 (24.5, 45/184)
inc, sig0, vol_cor, ssha, vars	11.6 (12.0)	17.3 (16.4)	4.2 (6.2)	0.035 (0.050)	9.9 (11.7)	0.042 (0.052)	23.9, 44/184 (23.9, 44/184)
inc, sig0, vol_cor, ssha, vars, SST	**8.3** (9.6)	13.3 **(12.2)**	**2.0** (6.0)	0.0088 **(0.0018)**	**3.7** (7.4)	0.030 **(0.0058)**	20.7, 38/184* **(10.9, 20/184)***
ECMWF	N/A	11.2	N/A	N/A	1.5	0.0078	28.4, 48/169
NCEP	11.2	N/A	4.0	0.69	N/A	N/A	1.47, 1/68

2 SWOT Ice Flag Neural Network Example 1 Iceberg C15,2024/12/29/08:00 UTC

SWOT retrieved speed PICO NN (m/s), no quality control



SWOT retrieved speed PIC2 NN (m/s), no quality control