

Operational support for wave & ice X-band radars

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RVTEC 2024, Durham, NH



UNIVERSITY OF MIAMI
ROSENSTIEL SCHOOL of
MARINE, ATMOSPHERIC
& EARTH SCIENCE



X-band radar program's responsibilities

- Provide vessels with radar processing & storage servers and software.
- Calibrate radars' heading/range/time biases and significant wave height.
- CSTARS radar processing system collects radar raw & ancillary data to produce:
 - Sea surface (and sea ice) mean roughness images,
 - Wave measurements,
 - Near-surface current maps,
 - Sea ice drift maps, ...
- Improve products' visibility through web viewer on ship network.
- Remotely monitor radar operations with error notification and status emails.
- Collaborate with R2R to publicly archive radar products.

TN 2024-07-31 02:13:31 - 02:33:18 UTC
azimuth = 359.158°, range = 179.875 m, time = 0.546 s

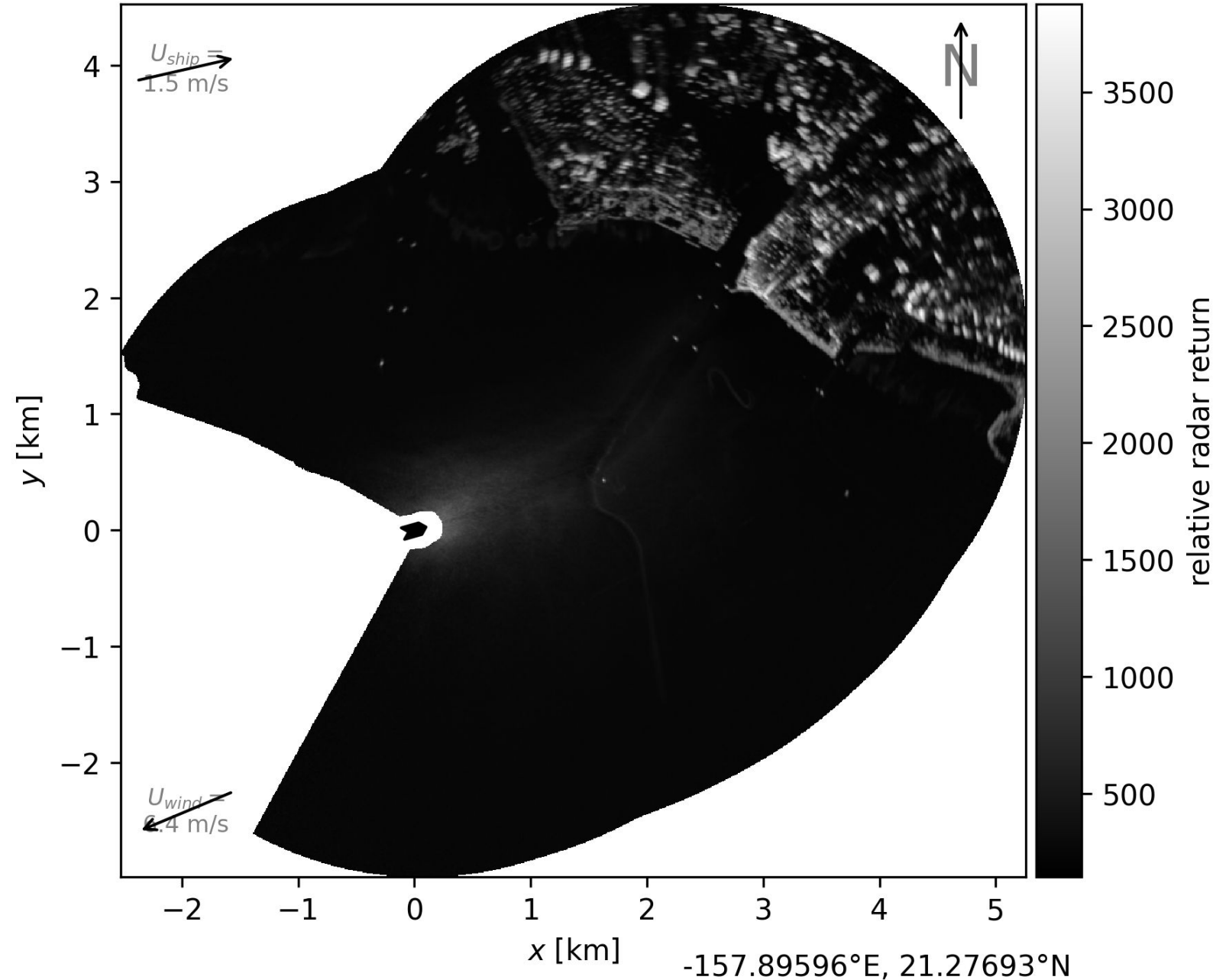
Radar calibration

Finds the radar azimuth, range, and time offsets that maximize the image sharpness.

Requires fixed targets observed from a moving vessel.

Calibrations are repeatable within 0.1° and 0.1 s.

Following McCann & Bell (2018).



TN 2024-07-31 02:33:31 - 02:53:16 UTC
azimuth = 359.109°, range = 179.875 m, time = 0.449 s

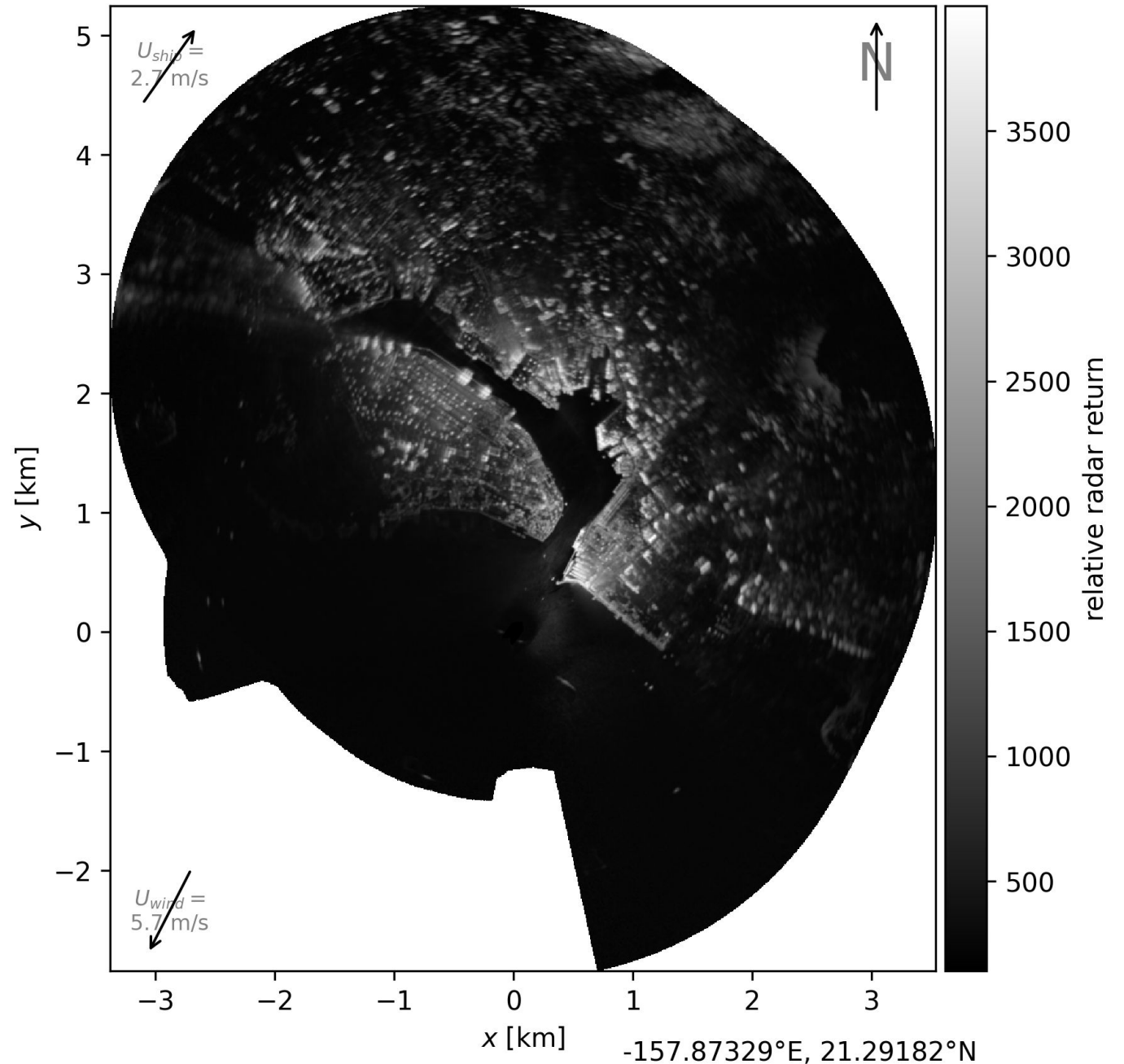
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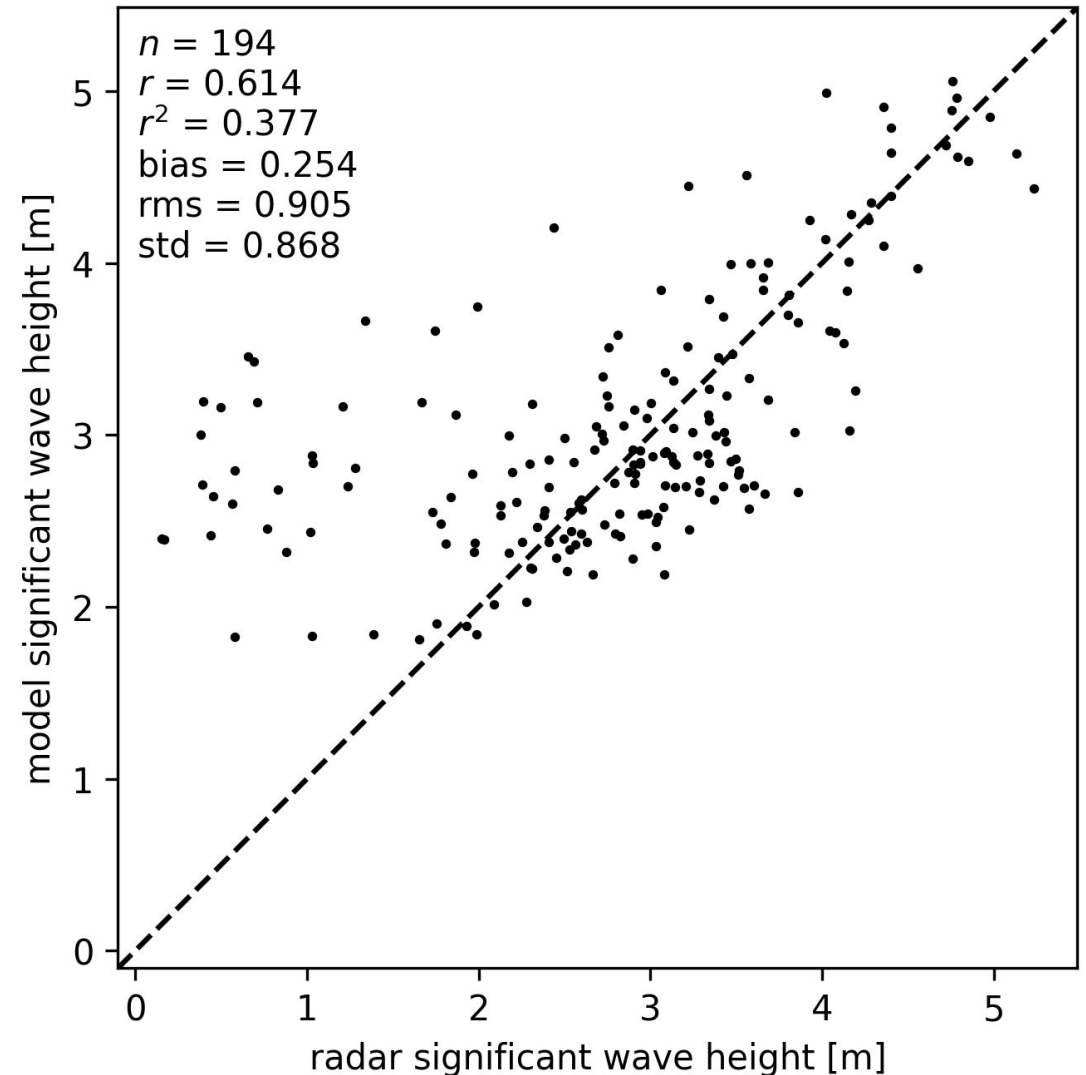
Significant wave height calibration

Marine X-band radar significant wave height measurements must be calibrated.

In absence of reference in situ measurements, wave model results can be used.

Scatter plot compares the radar significant wave height after calibration against the global MFWAM wave model.

Time series shows that model and radar wave parameters are in good agreement.



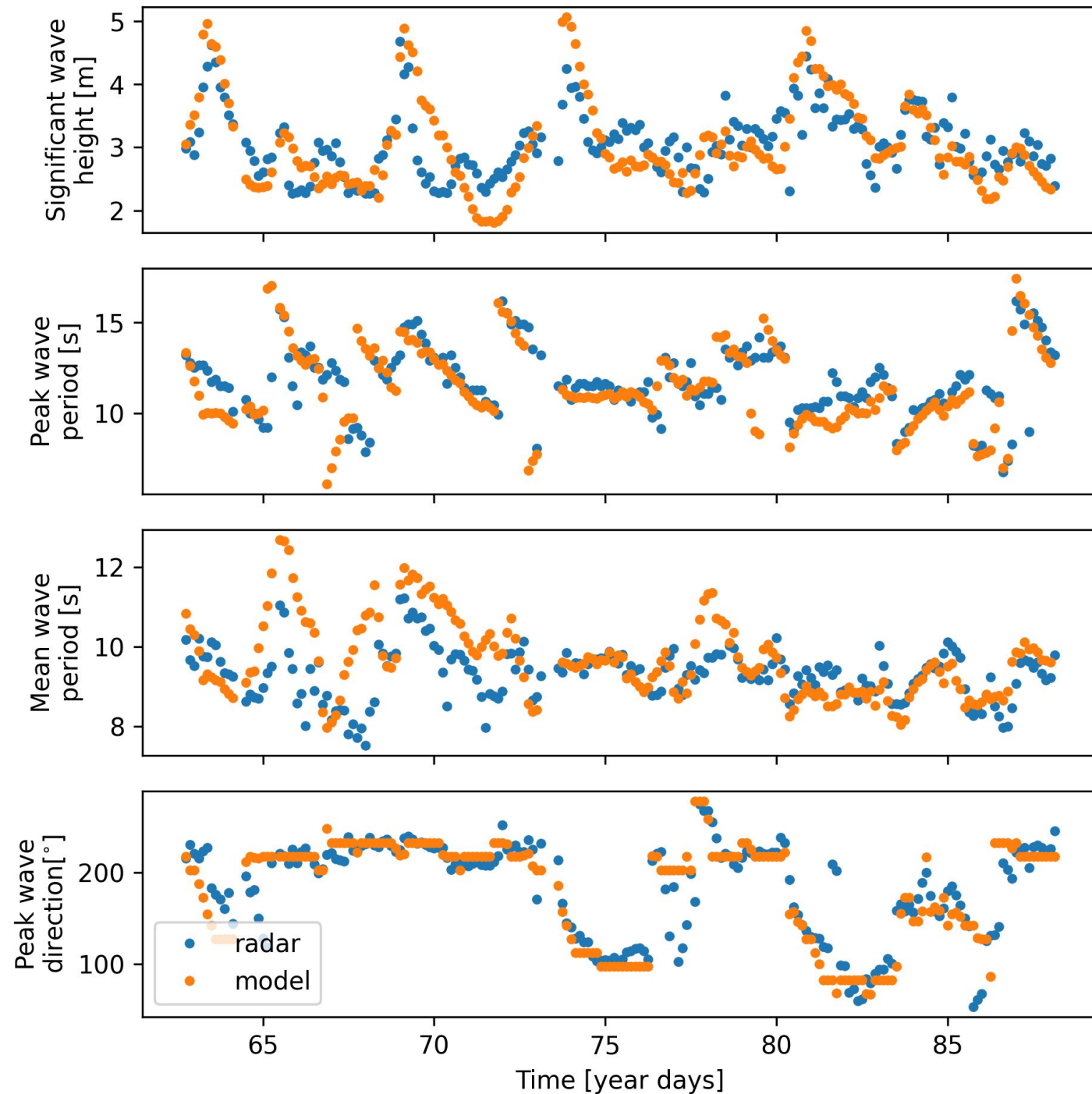
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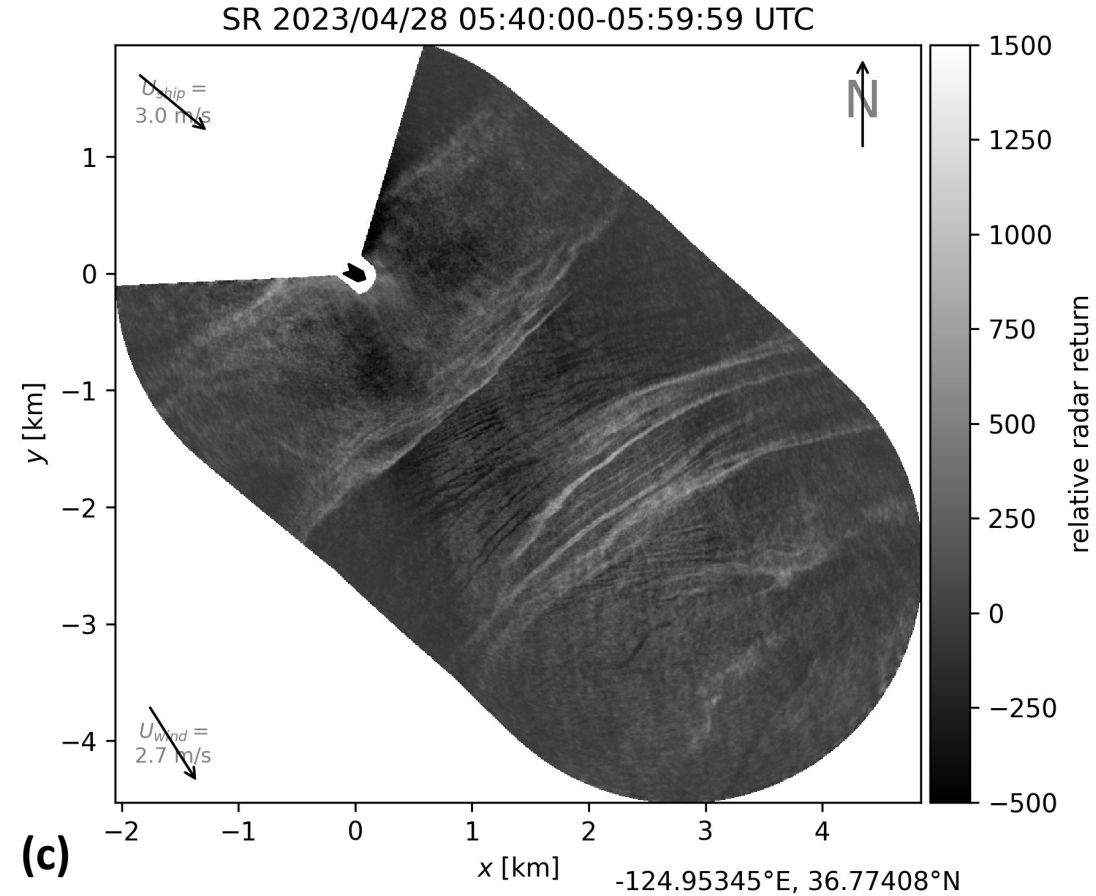
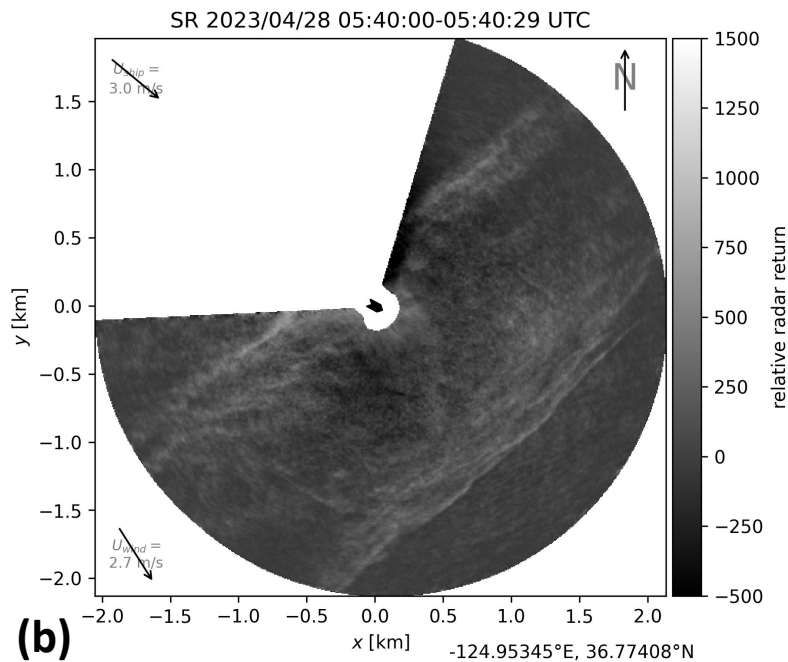
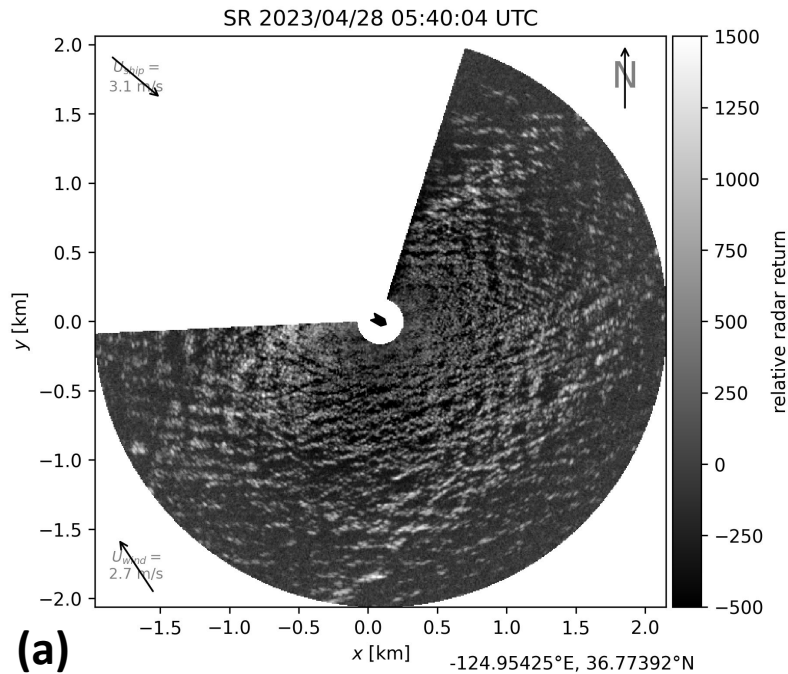


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Sea surface roughness images

- (a) Single scan radar image with wave signatures,
- (b) 1-min averaged radar image with current front,
- (c) 20-min radar image mosaic with current fronts (each pixel is a 30-s average).

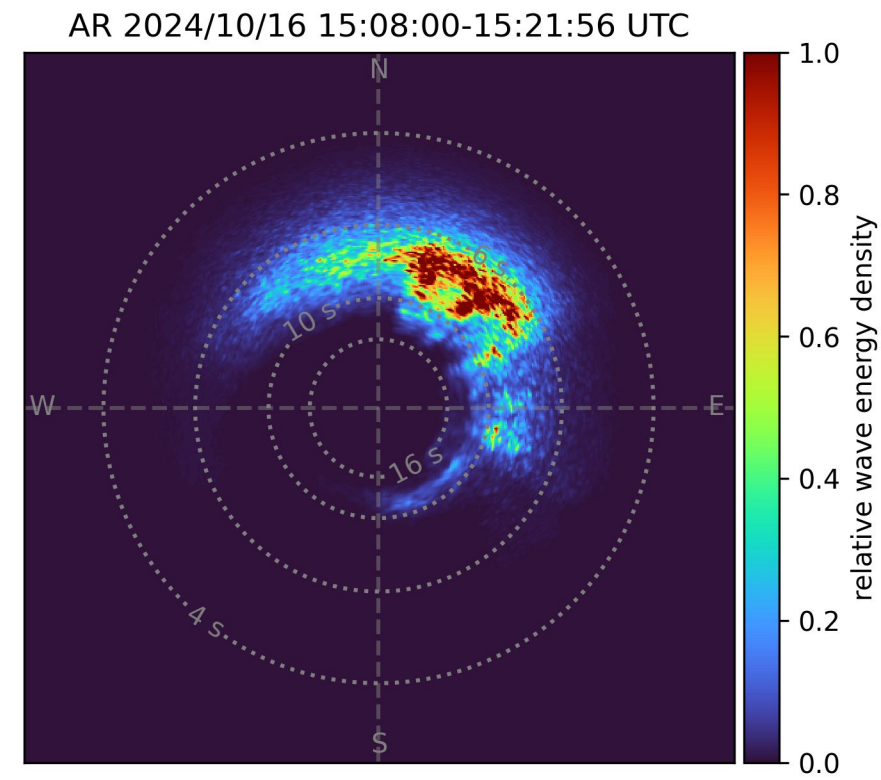
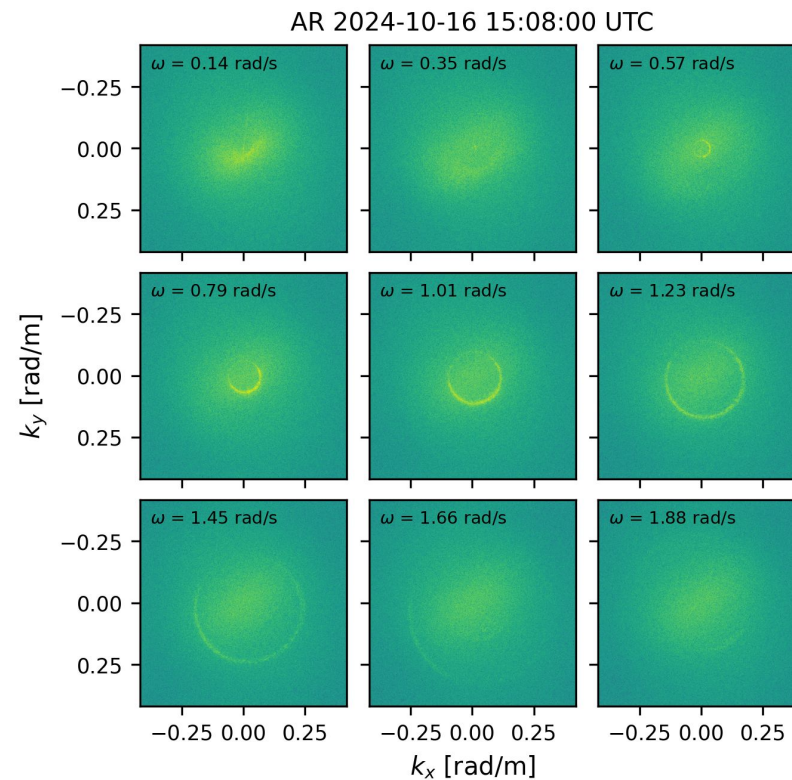
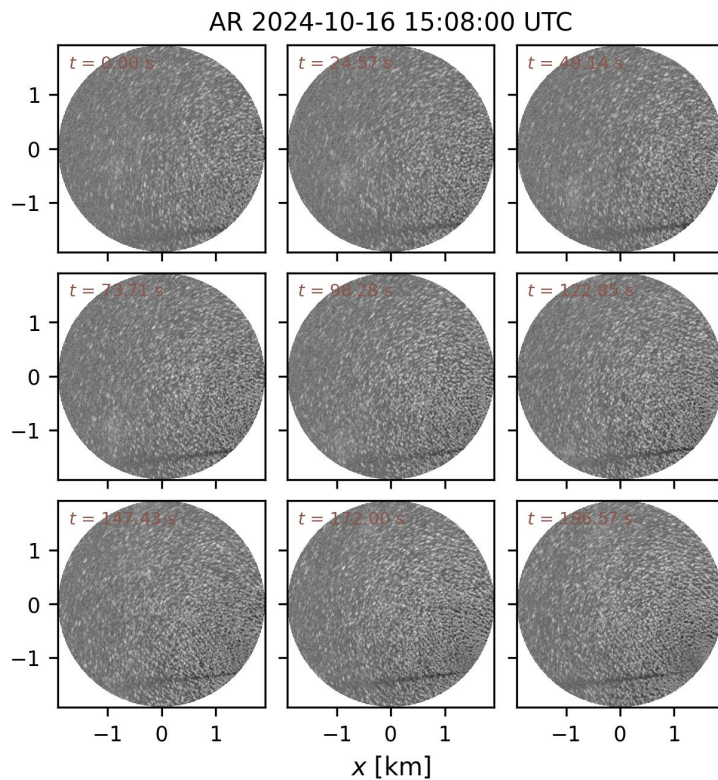
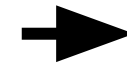
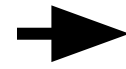


Wave measurements

Sequence of radar images within a circular analysis window.

Corresponding wavenumber frequency spectrum with prominent wave signal.

Two-dimensional wave energy density frequency spectrum via dispersion filter.

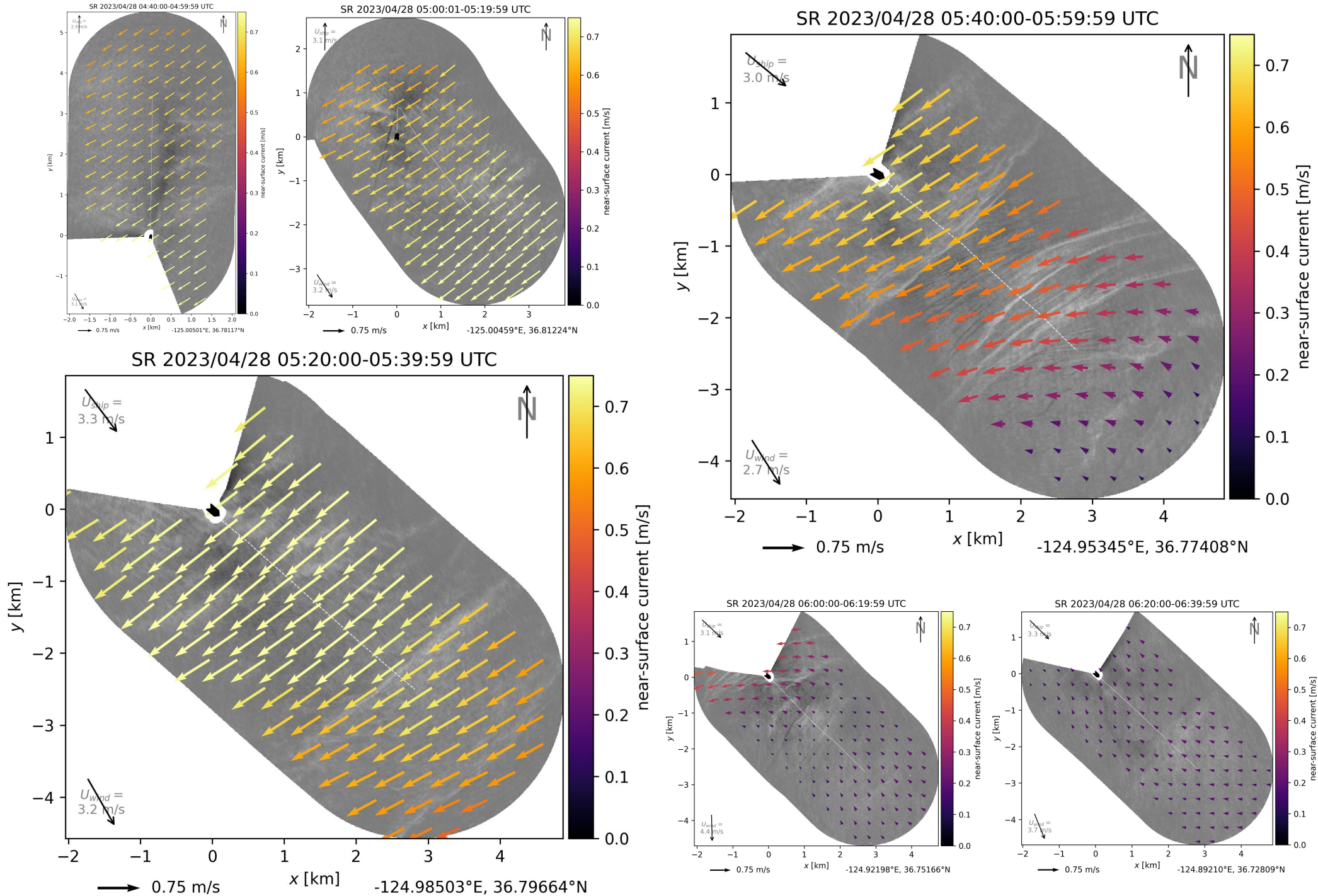


See Lund et al. (2016) for details on the method and a model comparison: <https://doi.org/10.1007/s10236-016-0961-z>.

Near-surface current maps

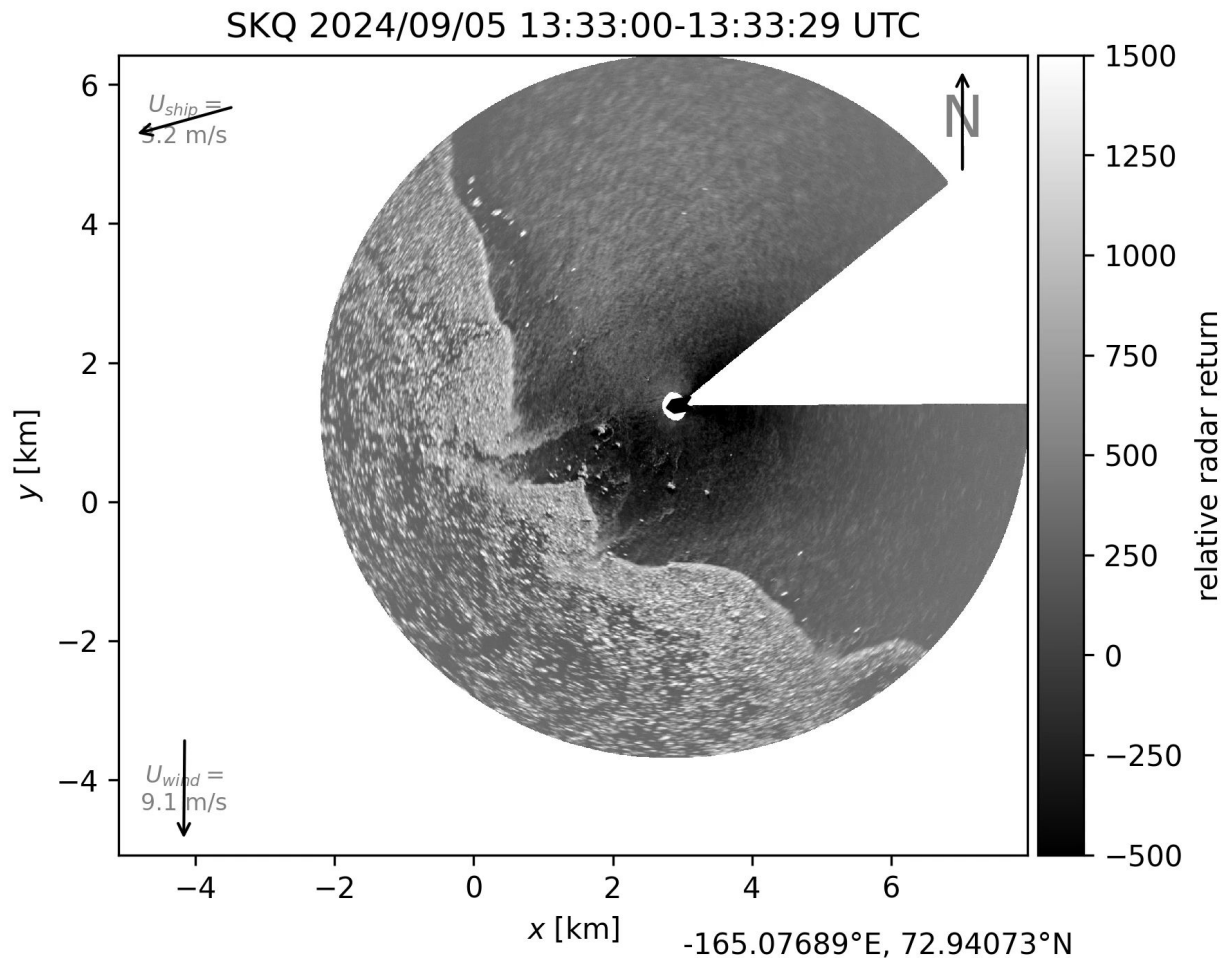
Time series of radar near-surface current maps from R/V Sally Ride (Apr 2023) over radar image mosaics with ship tracks as white dashed lines.

See Lund et al. (2018) for details on the method and a drifter-based validation: <https://doi.org/10.1175/JTECH-D-17-0154.1>

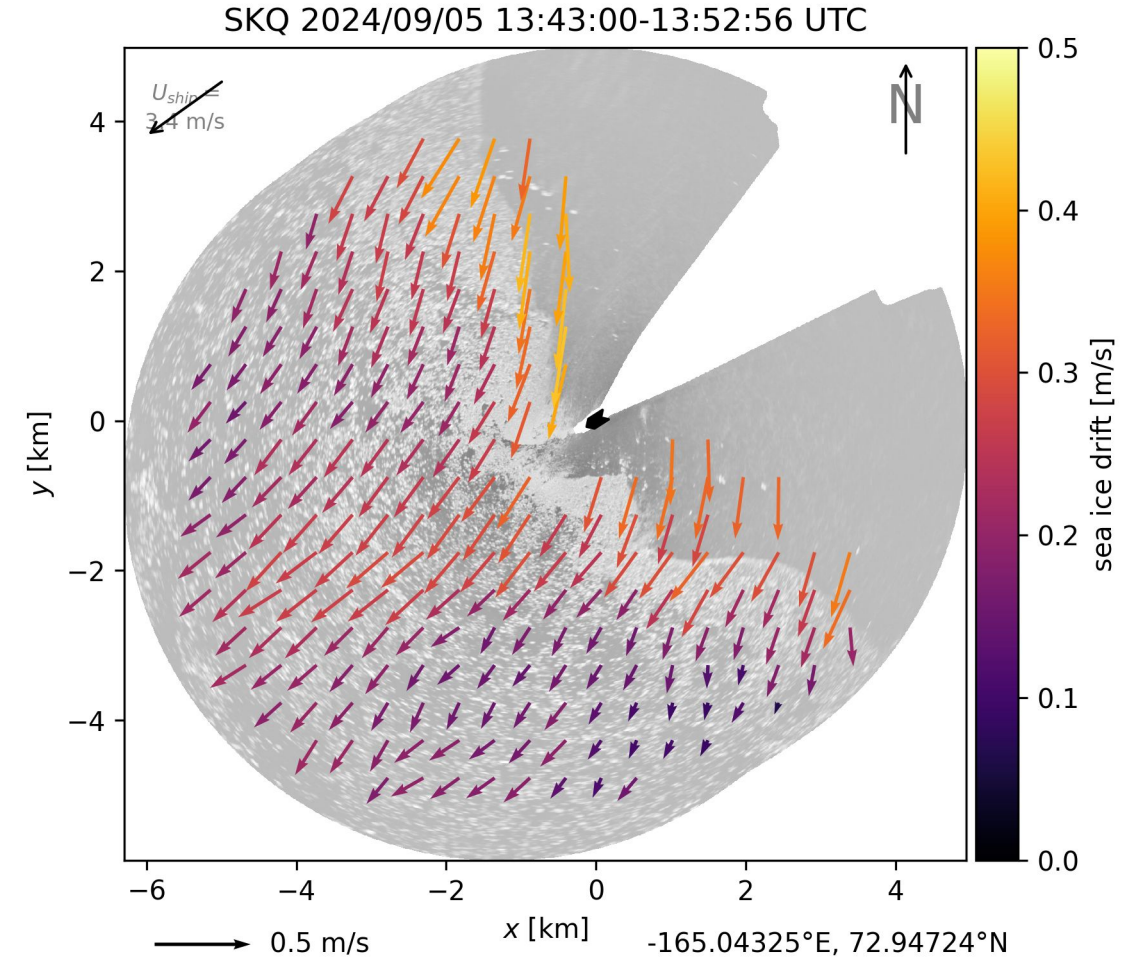


Sea ice drift maps

Movie of 30-s averaged marine X-band radar sea ice images from R/V Sikuliaq.



Corresponding radar-derived sea ice drift maps.



See Lund et al. (2018) for details on the method and a buoy-based validation: <https://doi.org/10.1029/2018JC013769>

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Control Panel

CSTARS MR Viewer

Controls


Dark Mode: ▾

Orientation: ▾

Live Tracking

Speed in Knots

Update Rate: ▾

Vector 

Range (m/s):

Data **Map History**

Vessel Info: ▾

Sea Roughness:

Current/Sea Ice Vectors:

Data **Graphs History**

Current: ▾

Sea Ice Drift: ▾

Waves: ▾

Info

Last Update: 2024-09-05 21:06:01

Location: -165.070170, 72.942205

Bearing: 235.00 degrees

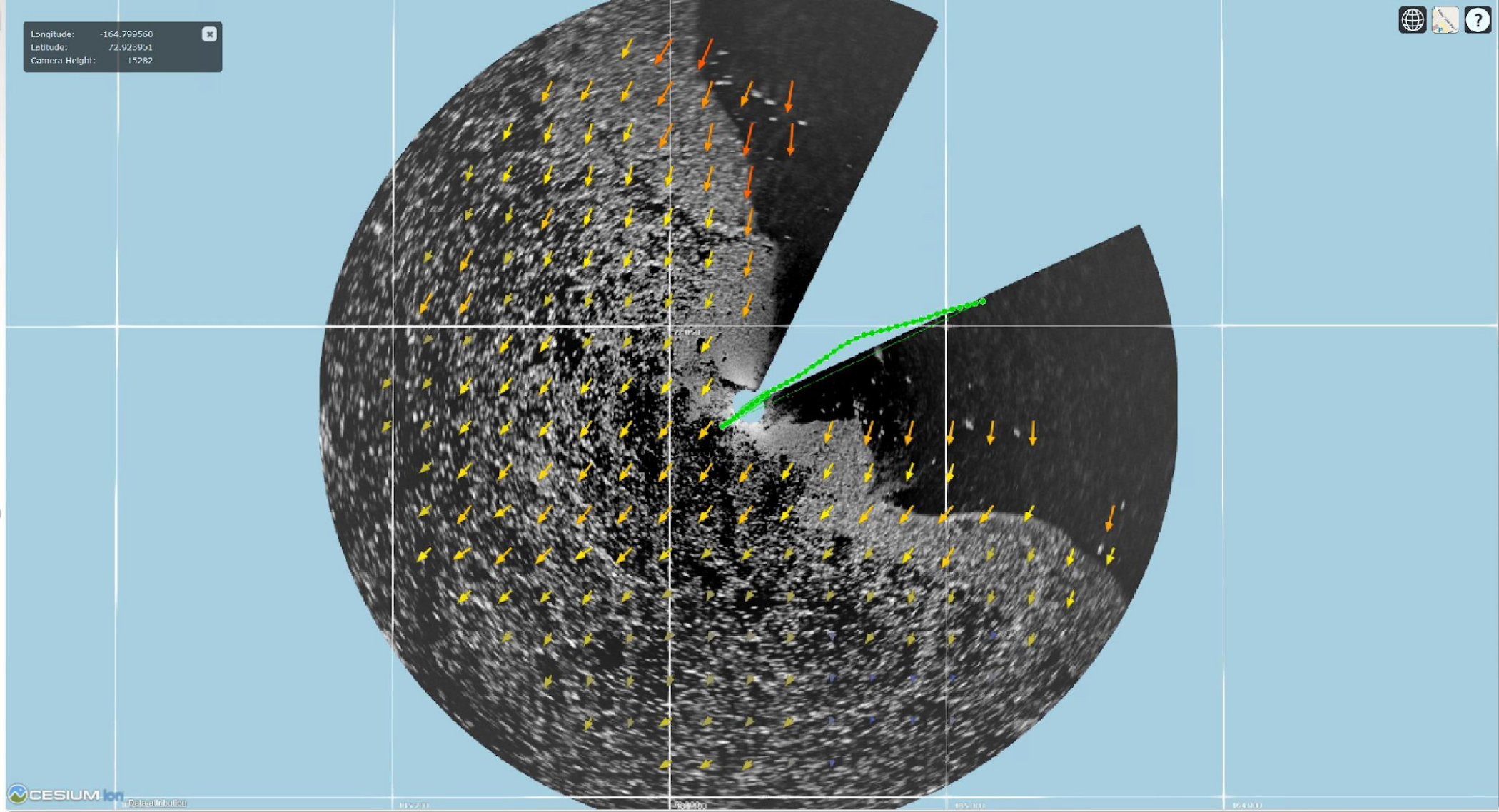
Current: -

Sea Ice Drift: 0.22 m/s, 210.00 degrees

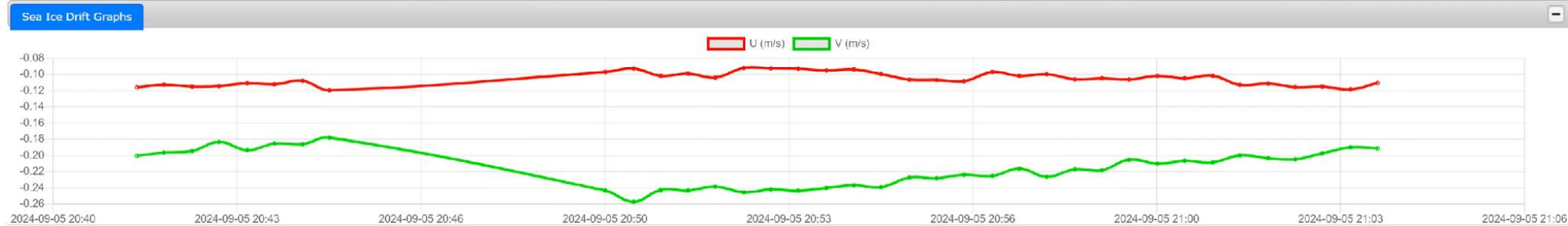
Peak Waves: -

Plots

Select data to plot ▾



MarineRadarViewer 2.1.0



Longitude: -146.652150
 Latitude: 57.124265
 Camera Height: 14562

Controls

Dark Mode: Off

Orientation:

Live Tracking

Speed in Knots

Update Rate: sec

Vector Range (m/s): to

Data **Map History**

Vessel Info: 20 min

Sea Roughness:

Current/Sea Ice Vectors:

Data **Graphs History**

Current: min

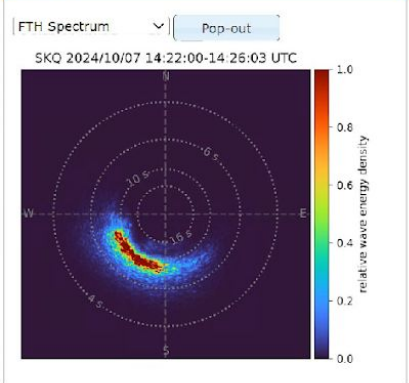
Sea Ice Drift: min

Waves: min

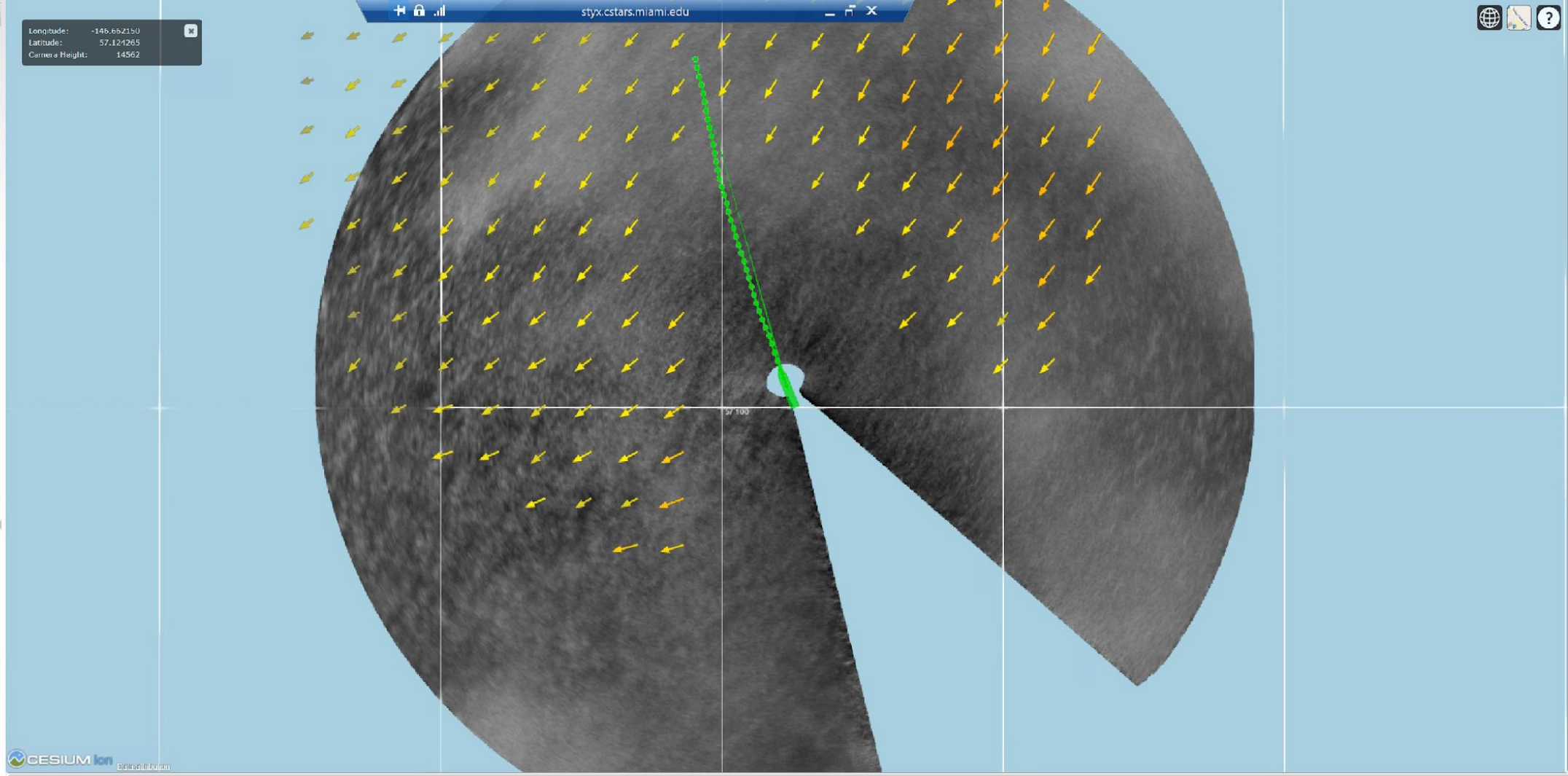
Info

Last Update: 2024-10-07 14:32:01
 Location: -146.788504, 57.102350
 Bearing: 338.00 degrees
 Current: 0.24 m/s, 220.93 degrees
 Sea Ice Drift: -
 Peak Waves: 214.99 degrees (8.42 s period)

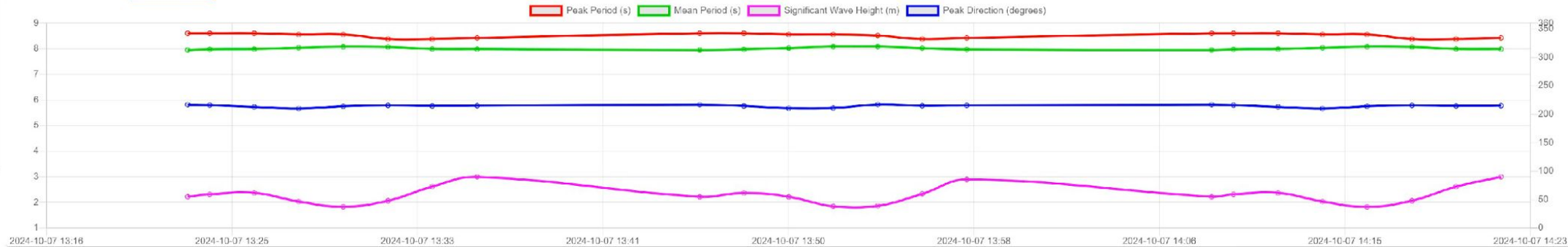
Plots



MarineRadarViewer 2.1.1



Wave Graphs



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System status monitoring

Sample system status emails from R/V Sikuliaq (status “good”) and R/V Neil Armstrong (status “ERROR”).

Remote access allows us to resolve issues when they occur.

[EXTERNAL] SKQ radar acquisition status at 2024/10/16 12:58 +0000 (status: good) - Lund, Bjoern - Outloo...

about:blank

Delete Archive ↶ ↷ 🔍 Zoom 📧 📁 📧 📧 ...

[EXTERNAL] SKQ radar acquisition status at 2024/10/16 12:58 +0000 (status: good)

Marine Radar Viewer Status - 2024-10-16 12:58:05 UTC

Position

Path	File	Message
/datalocal/raw/serial/seapath/*.log	2024-10-16_seapath.log	Most recent GGA entry from 2024-10-16_seapath.log: 2024-10-16_12-58-03.074488 \$GPGGA,125803.06,4422.482770,N,12454.862361,W,2,09,0.9,-2.84,M,-23.05,M,1.2,0001*50 Open in Google Maps

Storage

Disk	Used [GB]	Total [GB]	Free [GB]	Used [%]
/datalocal	5015.33	7392.19	2376.86	67.85
/	163.81	432.10	268.29	37.91
/synology	25906.64	71479.68	45573.04	36.24
/dev/shm	5.50	125.76	120.26	4.38

Acquisition Files

Path	Latest File	Last Accessed
/datalocal/raw/polar/*.pol	/datalocal/raw/polar/20241016125750sik.pol	2024/10/16 12:57:58 +0000
/datalocal/raw/serial/seapath/*.log	/datalocal/raw/serial/seapath/2024-10-16_seapath.log	2024/10/16 12:58:03 +0000
/datalocal/raw/udp/wind/*.log	/datalocal/raw/udp/wind/2024-10-16_wind_gill_fwdmast_true.log	2024/10/16 12:58:02 +0000
/datalocal/raw/serial/mgc2/*.log	/datalocal/raw/serial/mgc2/2024-10-16_mgc2.log	2024/10/16 12:58:02 +0000

Acquisition Info

Type	Message
Polar radar image range	2024-10-15 12:58:03 -> 2024-10-16 12:57:41
Mean pulse repetition frequency	1534.848 Hz
Std pulse repetition frequency	50.575 Hz
Min pulse repetition frequency	1357.093 Hz
Max pulse repetition frequency	1631.807 Hz
Cartesian radar image range	2024-10-15 12:58:04.010373 -> 2024-10-16 12:57:38.916270
Median antenna rotation period	1.257s
Number of acquired radar scans	67867
Number of missed radar scans	858 (1.264%)

Database Info

[EXTERNAL] AR radar acquisition status at 2024/10/16 13:10 +0000 (status: ERROR) - Lund, Bjoern - Outloo...

about:blank

Delete Archive ↶ ↷ 🔍 Zoom 📧 📁 📧 📧 ...

[EXTERNAL] AR radar acquisition status at 2024/10/16 13:10 +0000 (status: ERROR)

Database Lag

Table	Column	Delay [min]
parse_nmea.gps	datetime	Lag of -2770296482 min
parse_pol.pol	start_datetime	Lag of 0 min
pol_to_car.car	start_datetime	Lag of 0 min
imaging.car_avg	start_datetime	Lag of 1 min
waves.spec	start_datetime	Lag of 19 min
car_to_spec.spec	start_datetime	Lag of 216 min > threshold of 30 min
sea_ice_drift.sea_ice_drift	start_datetime	Failed to fetch table lag row

Processing Info

Table / Name	Message
parse_nmea.gps / parse_nmea.py	7292-01-09 13:12:20, Longitude: -59.637683°, Latitude: 66.804472°, Heading: 320.9°
parse_nmea.wind / parse_nmea.py	2024-10-16 13:09:57, Wind Speed: 4.63m/s, Wind Dir: 153.9°
parse_pol.pol / parse_pol.py	2024-10-16 13:09:50, Pulse Frequency: 3000.37Hz
pol_to_car.car / pol_to_car.py	2024-10-16 13:09:49
imaging.car / imaging.py	2024-10-16 13:09:02
waves.waves_mean / waves.py	2024-10-16 12:32:01, H: 2075.01m, HS: 0.58m, TP: 11.73s, TM: 7.25s, DP: 151.62°, UX: 0.06m/s, UY: -0.31m/s
cur_bathy.currents / cur_bathy.py	2024-10-16 09:34:01, H: 1991.66m, UX: -0.15m/s, UY: -0.1m/s
sea_ice_drift.sea_ice_drift / sea_ice_drift.py	No data found

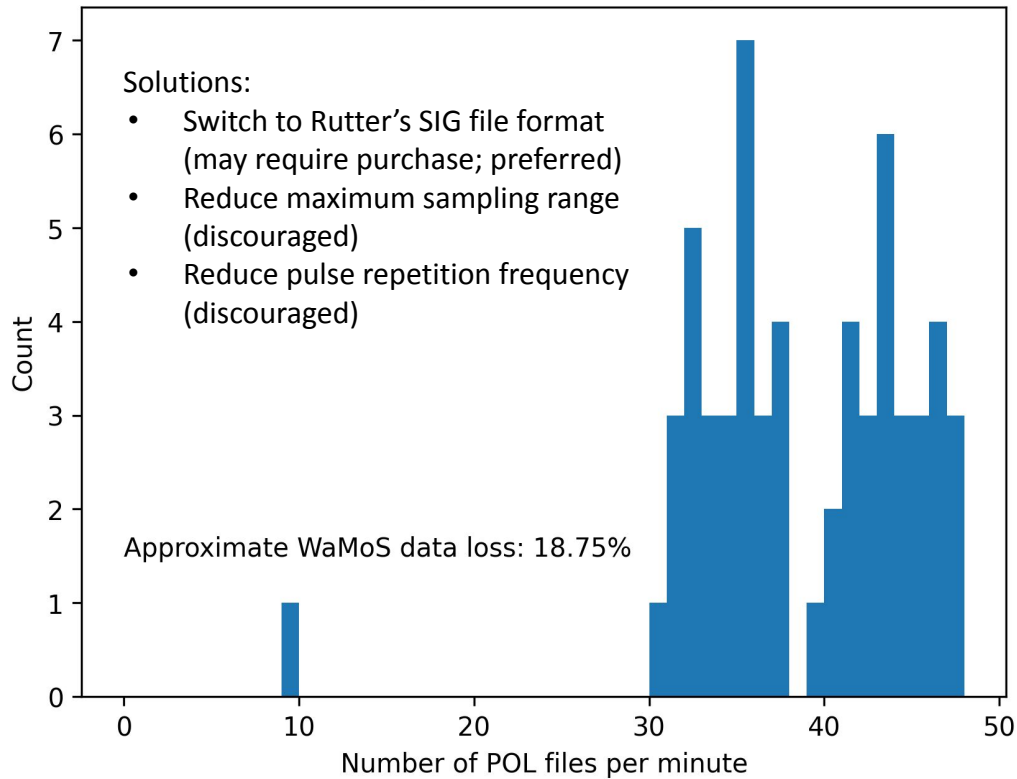
Processing

Name	Workers	PID	ETimes [s]	CpuTime [s]	Cpu [%]	Mem [MB]	Mem [%]
parse_nmea.py		317740	132,195	3,520	2.6	212.281	0.0
parse_pol.py		317873	132,193	30,056	22.7	240.16	0.0
pol_to_car.py		317881	132,188	11,220	8.4	609.723	0.2
pol_to_car.py	3		132,188	39,226	29.67	612.59	0.24
imaging.py		317888	132,186	18,663	14.1	4330.48	1.6
waves.py		317908	132,181	4,843	3.6	3500.953	1.3
waves.py	4		132,181	23,918	18.09	2719.586	1.06
car_to_spec.py		317917	132,176	3,801	2.8	3146.223	1.2
car_to_spec.py	4		132,176	6,513	4.93	617.746	0.24
cur_bathy.py		317924	132,174	128	0.0	237.227	0.0

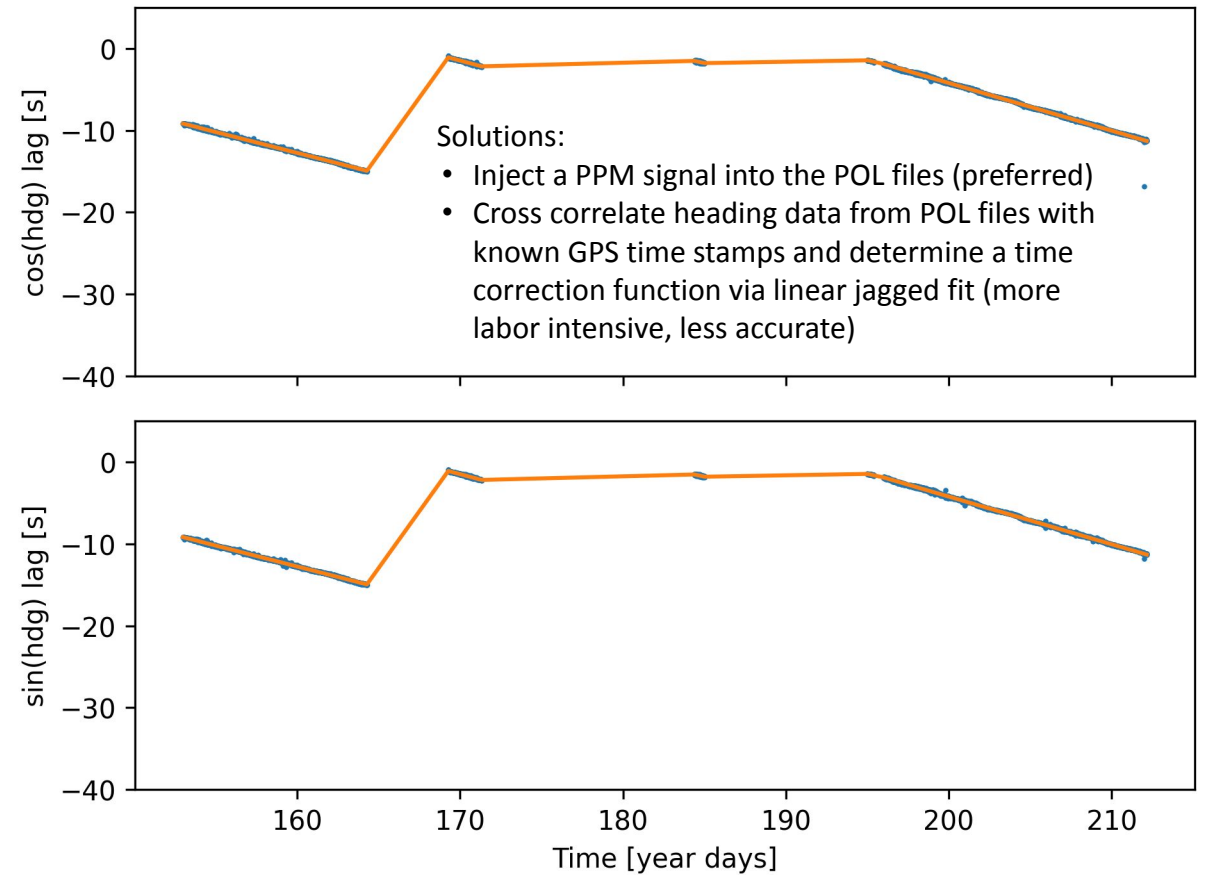
Troubleshooting fleetwide WaMoS issues

Frequent radar raw data (POL file) loss at irregular intervals

Histogram of the number of POL files per minute between 2024-09-26 00:00:02 and 2024-09-26 00:58:20 (expected value = 47)



Drifting radar raw data (POL file) time stamps despite NTP synchronization



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Radar product sharing and raw data archiving

- Marine X-band radar data volumes (assuming 250 sea days/year):
 - Radar products on R/V Sikuliaq: ~12 GB/day, ~3 TB/year.
 - Radar products on R/V Neil Armstrong ~20 GB/day, ~5 TB/year.
 - WaMoS radar raw data on R/V Sikuliaq: ~450 GB/day, ~113 TB/year.
 - Hereon radar raw data on R/V Neil Armstrong: ~530 GB/day or ~133 TB/year.
- Radar products:
 - Will be stored in NetCDF format following the Climate and Forecast (CF) metadata conventions.
 - Will be included in the cruise data set & added to the R2R catalog.
 - More than 90% of the data volume is due to roughness images; it can be reduced by lowering their update rate or storing mosaics only.
- Radar raw data:
 - Radar raw data are archived using pairs of Synology NAS servers with ~96 TB capacity per unit.
 - Shipboard technicians swap Synology when full and ship to CSTARs where we archive the radar raw data to tape.
 - We are exploring options for a public long-term radar raw data archive using the WMO CF Radial standard.

X-band radar program's timeline (abridged)

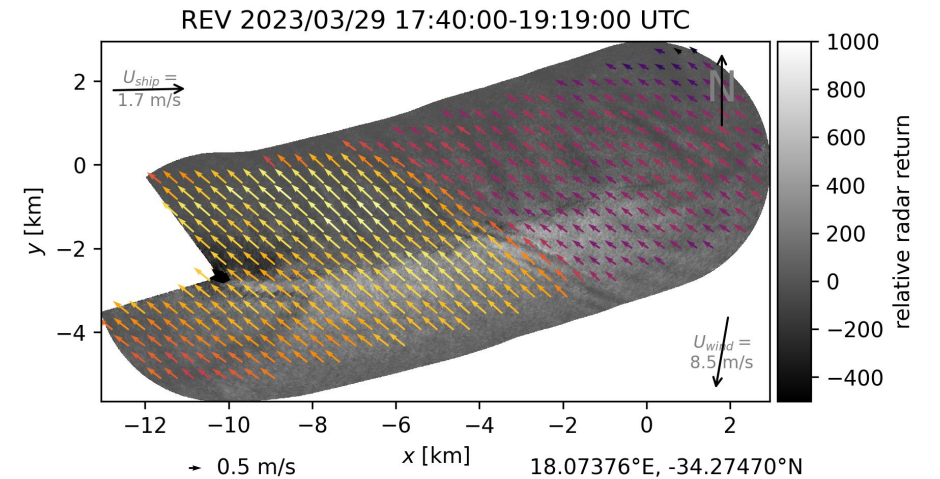
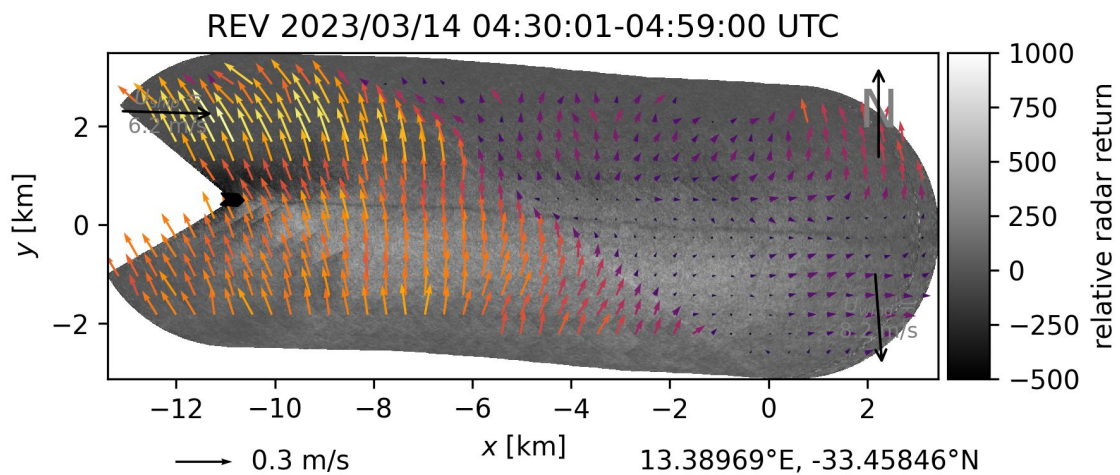
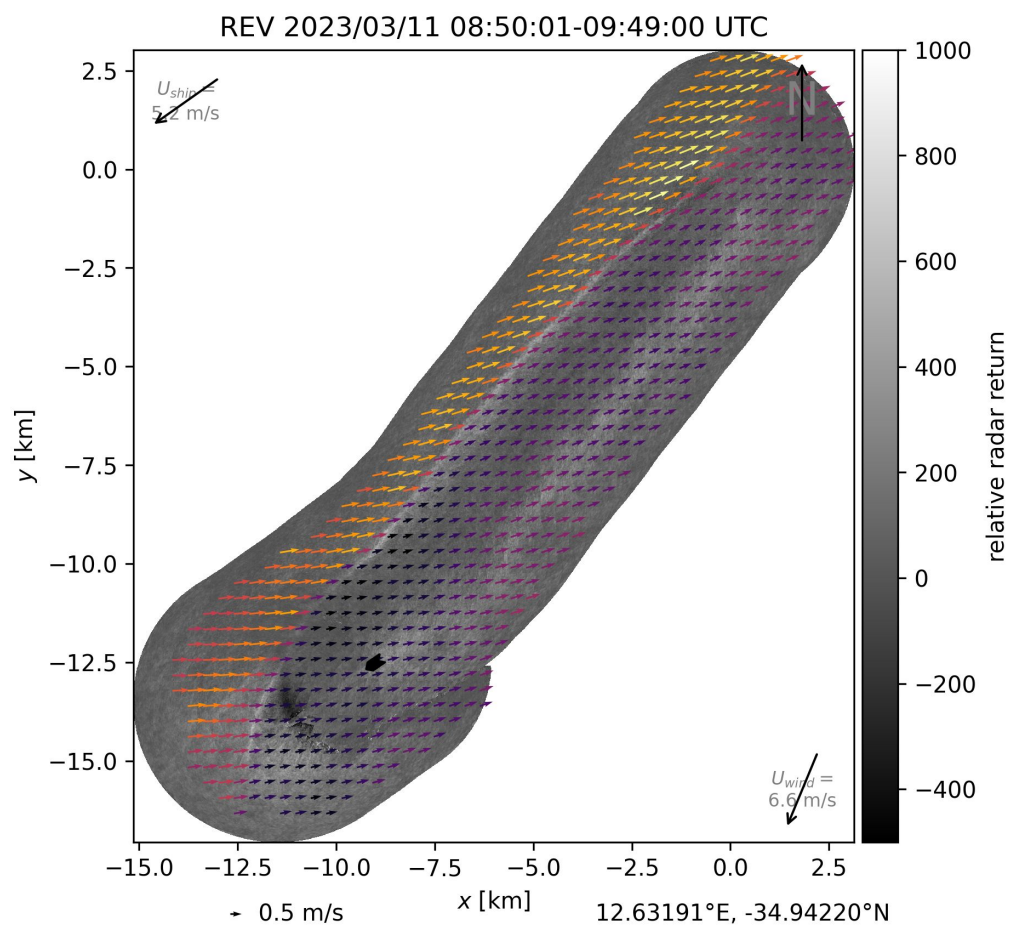
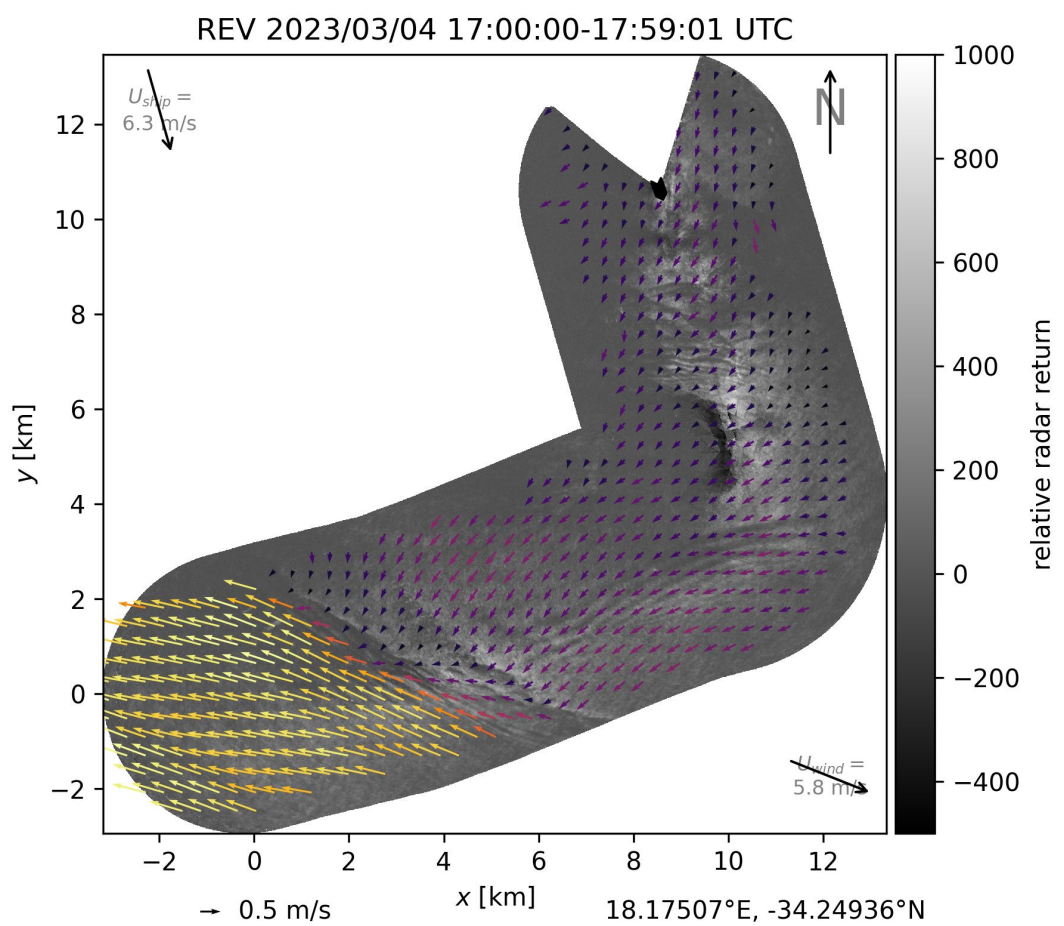
- PY1 (Sep 2023 – Aug 2024):
 - Upgraded Hereon radar input card & radar motor on R/V Neil Armstrong.
 - Installed new radar processing & storage servers on R/Vs Sikuliaq & Neil Armstrong.
 - Calibrated radars in terms of azimuth/range/time offsets and significant wave height.
 - Continuously updated our radar processing software & added a fully operational sea ice drift mapping program.
 - Started archiving radar raw data from R/Vs Sikuliaq & Neil Armstrong at CSTARs.
- PY2 (Sep 2024 – Aug 2025):
 - Add radar products to cruise data set and R2R catalog.
 - Develop documentation and open-source software to ease radar data access.
- PY3 (Sep 2025 – Aug 2026):
 - Extend radar support to other radar-equipped research vessels.
 - Identify long-term archive for radar raw data.

Best practices & questions

- Record GPS and accurate heading data at high temporal resolution (>1 Hz) via serial feed.
- Enable regular radar calibrations by recording radar raw data while departing from and returning to port.
- Synchronize the radar acquisition server with the ship's time server.
- **Interested in enhancing your shipboard X-band radar's capabilities?**
- **Have suggestions for big data storage, transfer, & public archiving?**
- **Contact marineradar@cstars.miami.edu or blund@cstars.miami.edu.**

Near-surface current maps

Sample radar near-surface current maps from R/V Roger Revelle (Mar 2023) over radar image mosaics.



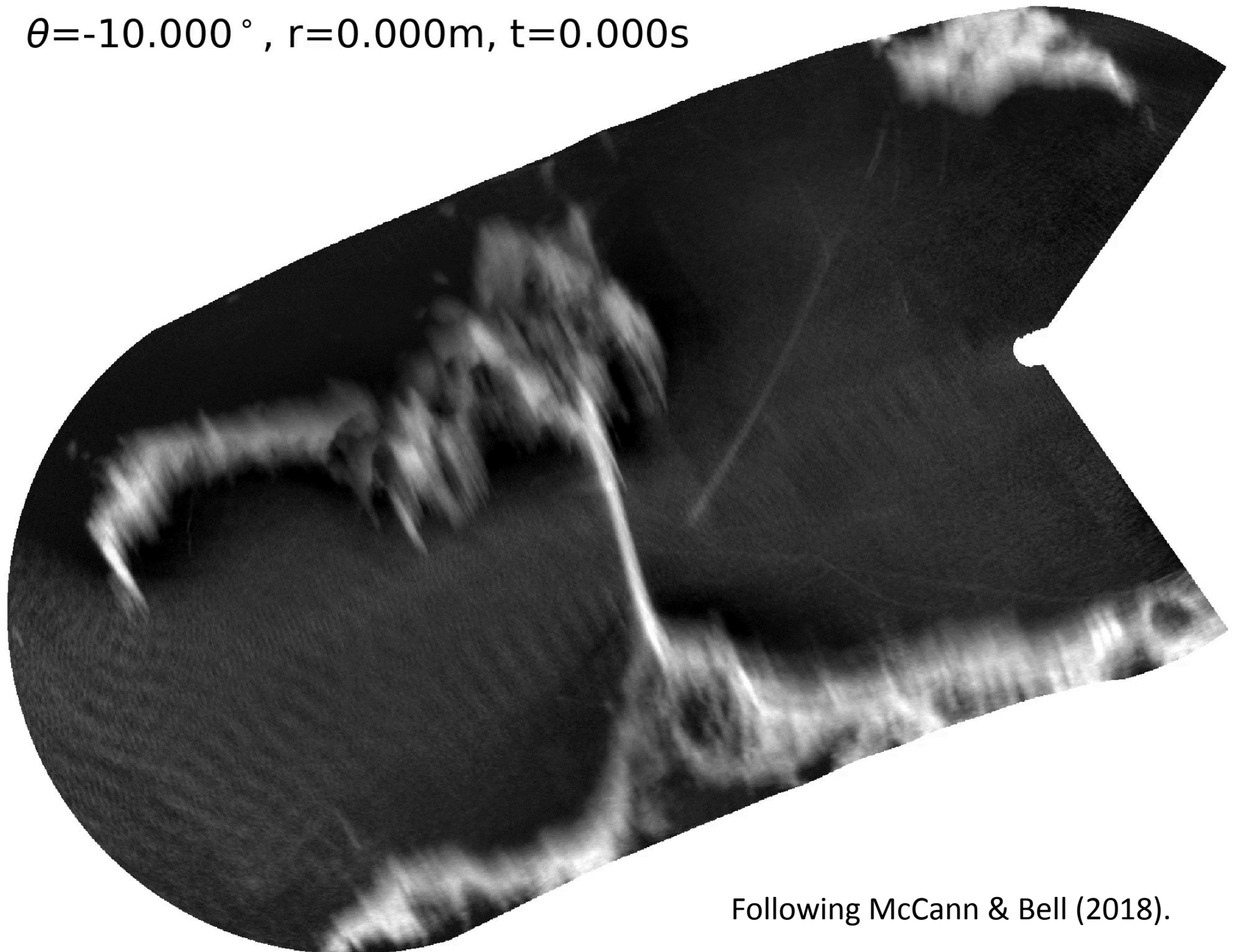
$\theta = -10.000^\circ$, $r = 0.000\text{m}$, $t = 0.000\text{s}$

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