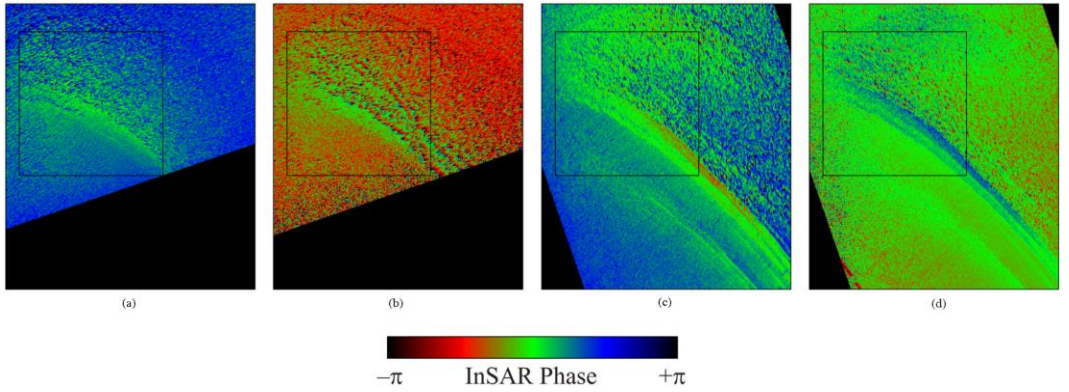
Doppler / Current Retrievals – Part 1: Review

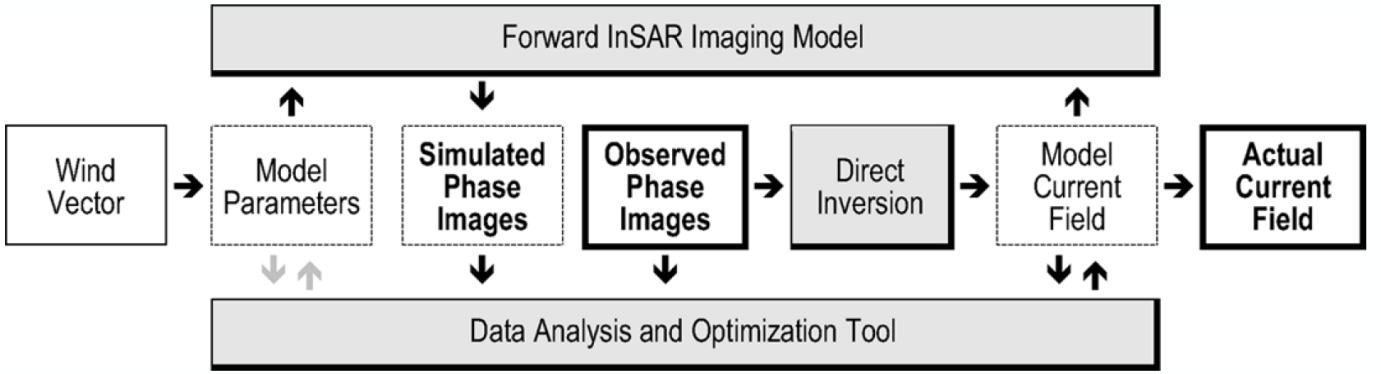
R. Romeiser, F. Lopez Dekker, A. Moiseev and Topic Contributors

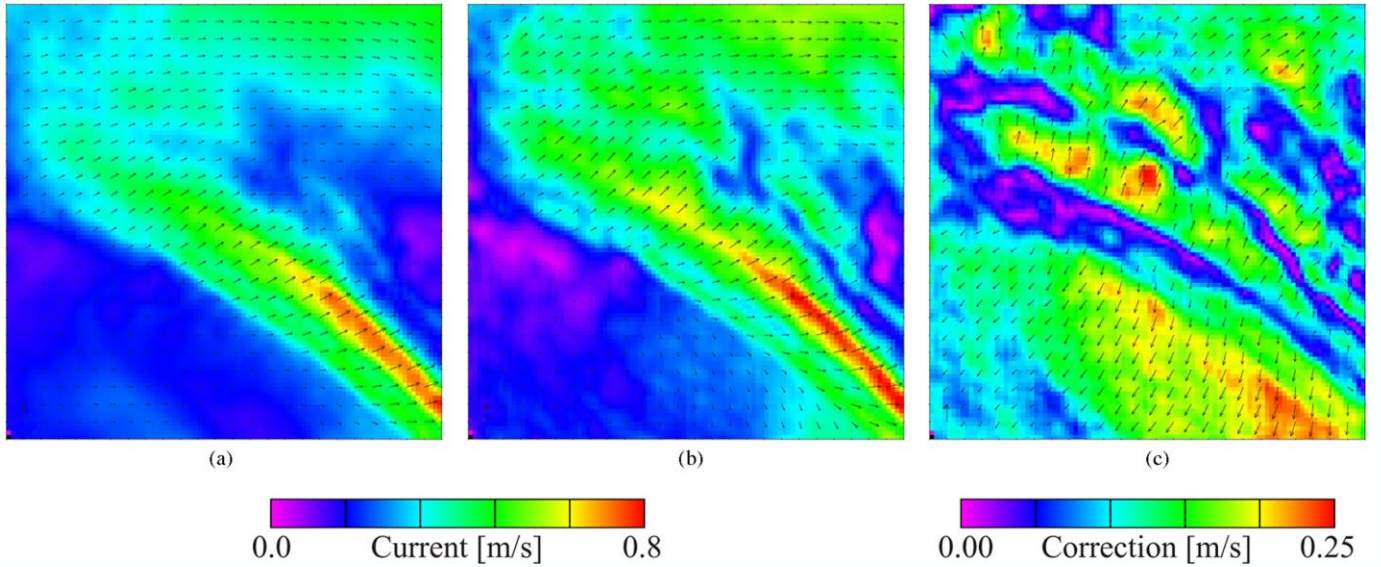
03 May 2023

High-Resolution Vector Current Field Retrieval

Romeiser, IEEE-JOE 2005

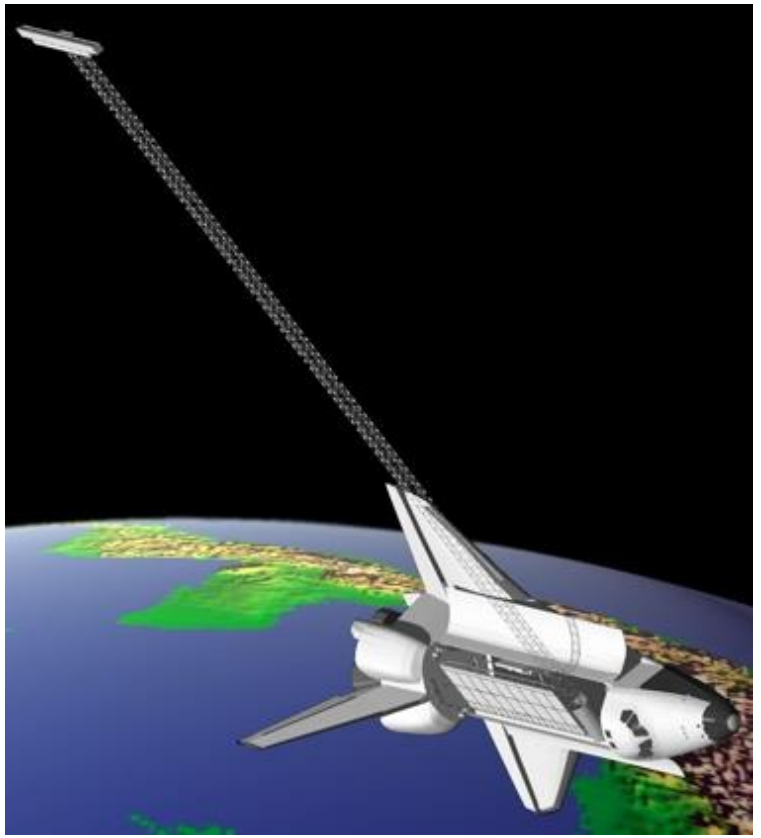


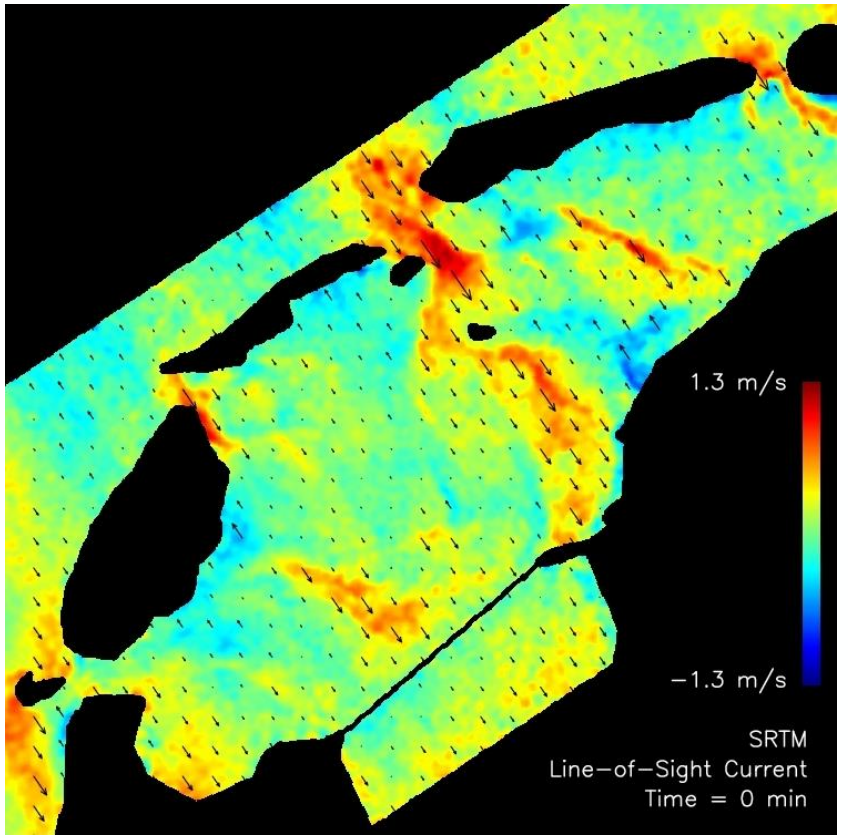




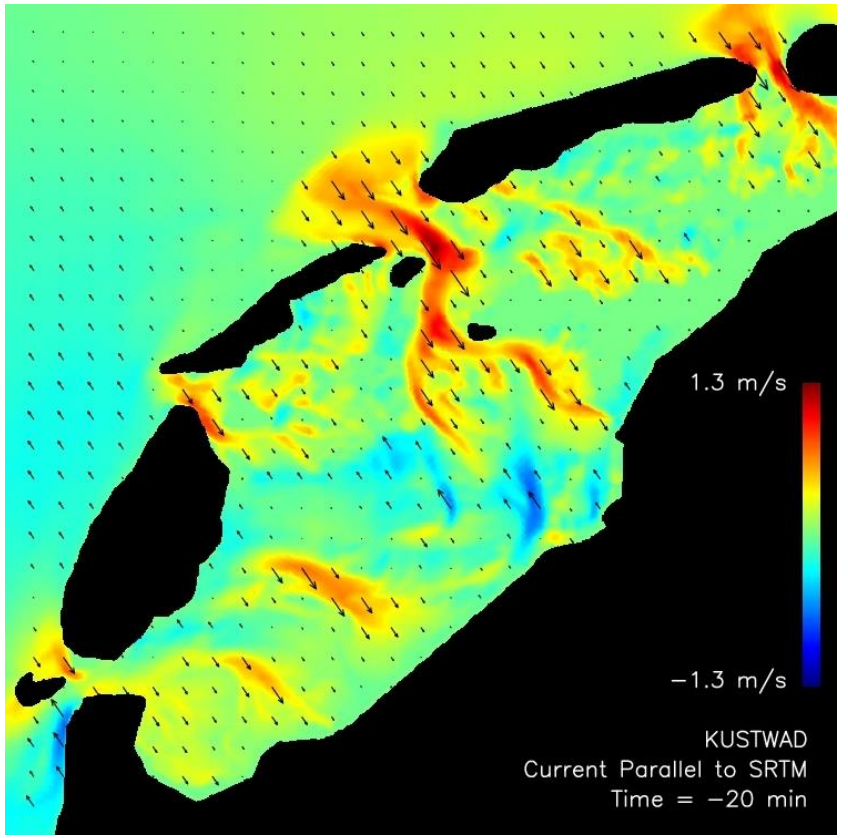
Along-Track InSAR Demonstration With SRTM

Romeiser et al., IEEE-TGRS 2005





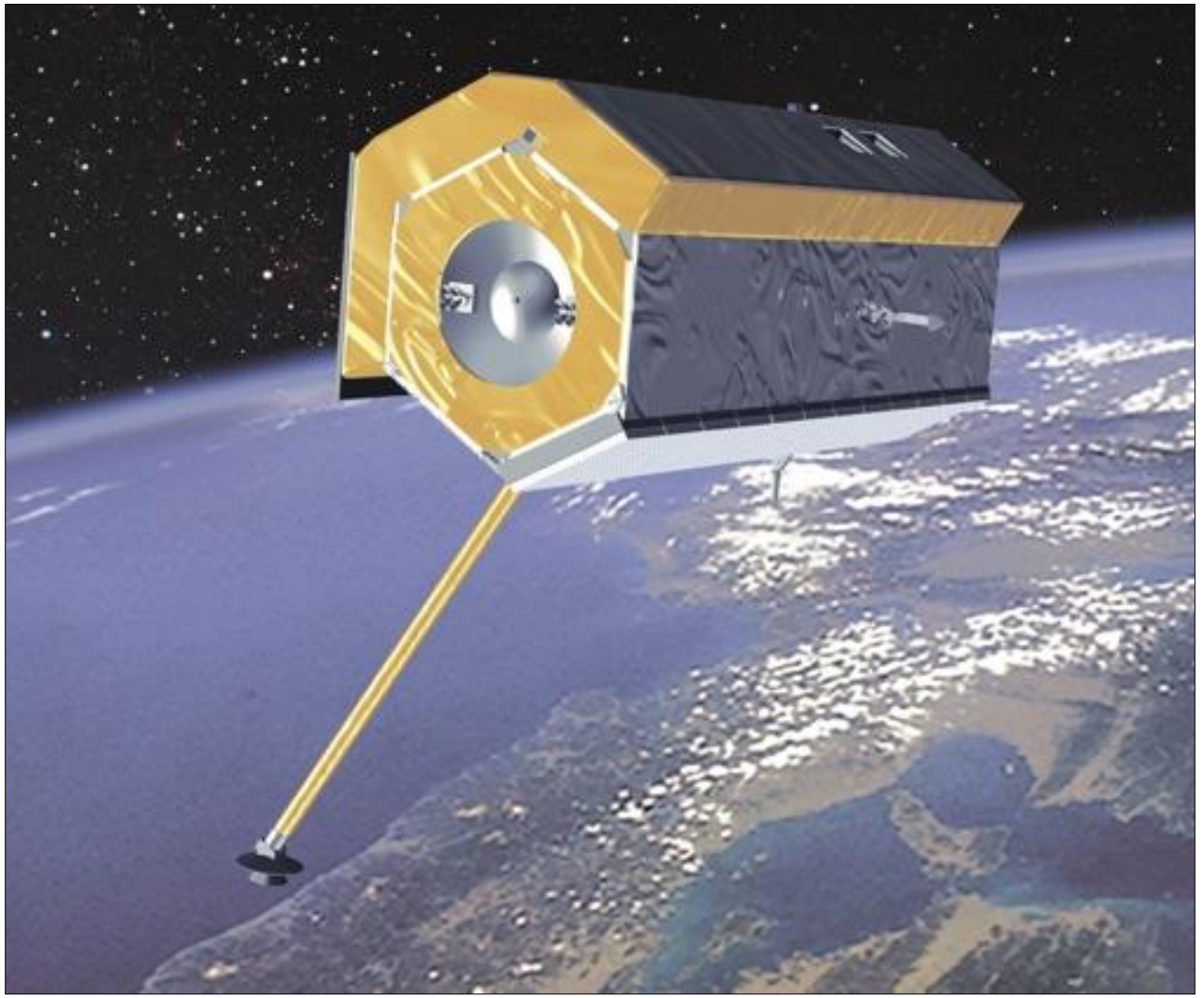
Line-of-sight current from SRTM, (70 km)²

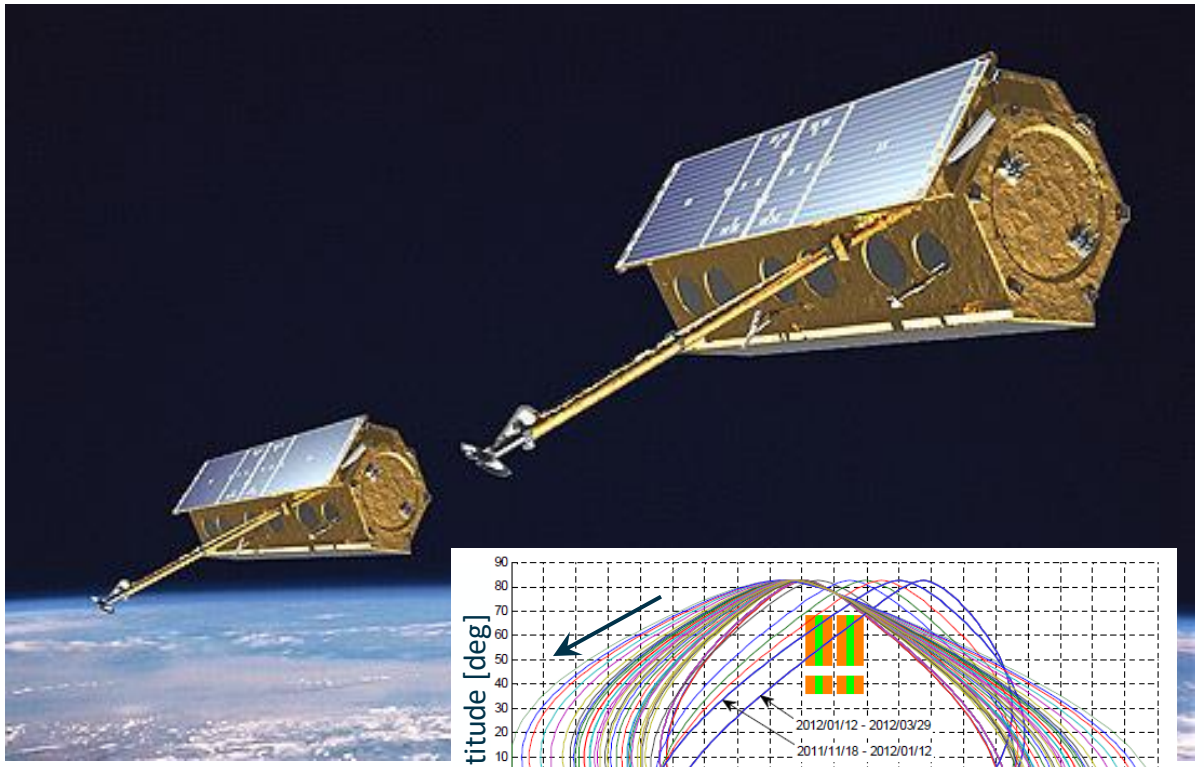


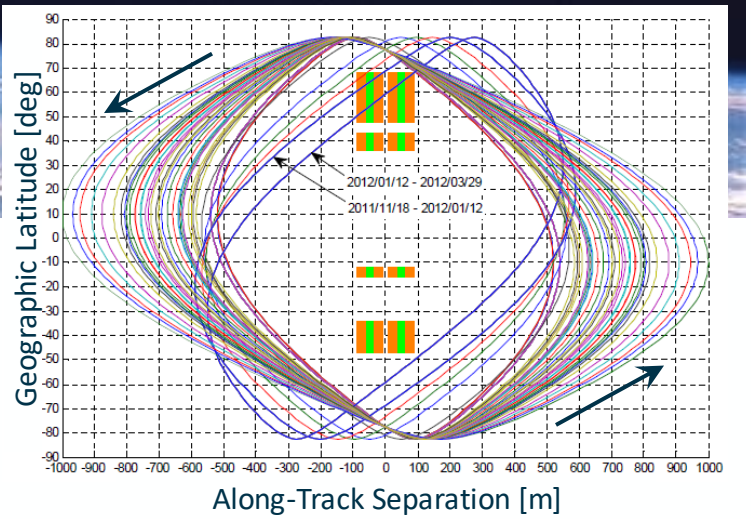
...and from circulation model KUSTWAD

- Good agreement between InSAR-derived line-of-sight horizontal velocity and corresponding component in model result
- Accuracy ≈ 0.1 m/s at 1 km resolution, consistent with theoretical expectations

TerraSAR-X Divided Antenna Mode and TanDEM-X

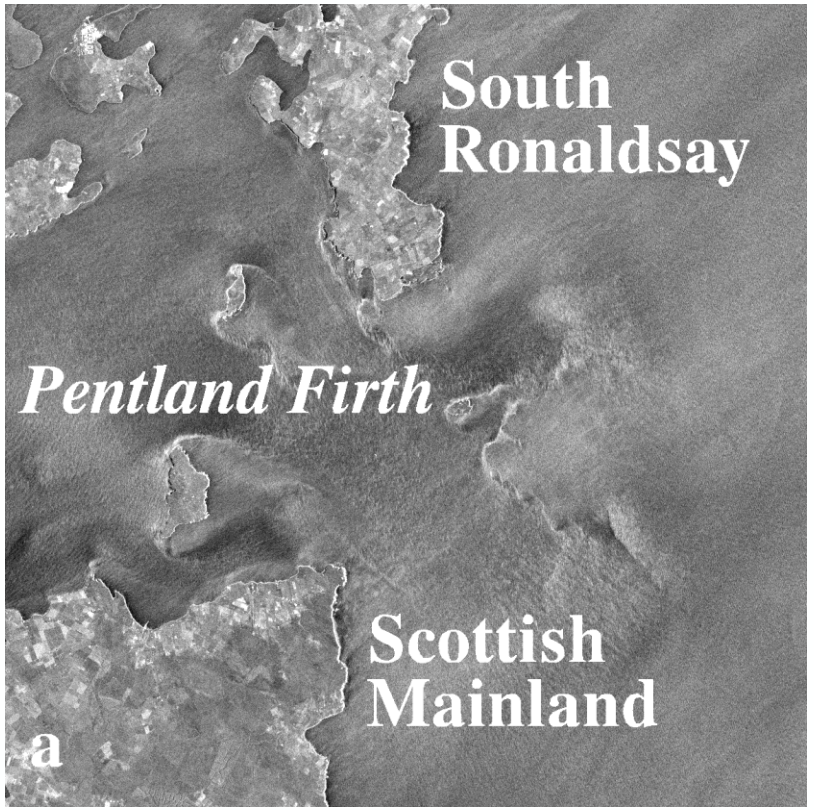




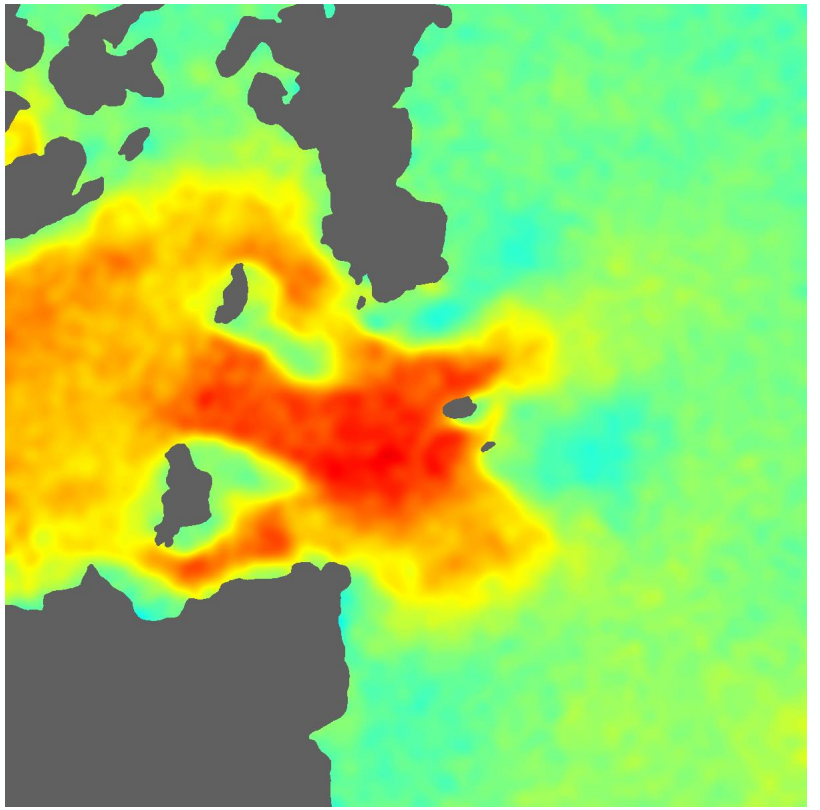


TerraSAR-X Divided Receive Antenna vs. TanDEM-X

Romeiser et al., IEEE-TGRS 2014

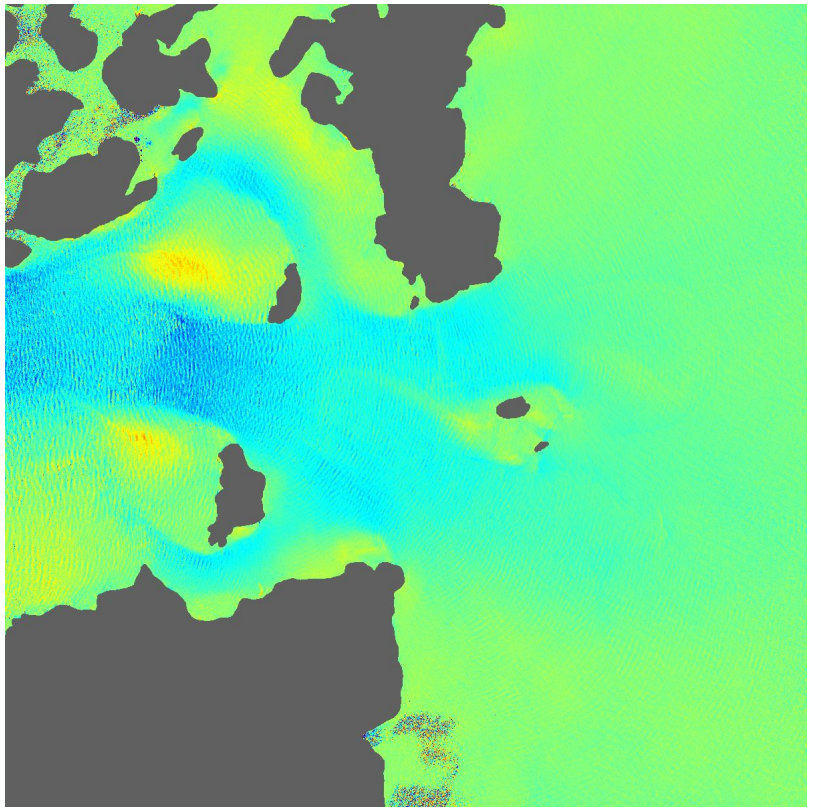


Pentland Firth (Orkney) Test Area
Area size = 30 km × 30 km,
grid cell size = 25 m × 25 m



–5.0 Doppler Velocity [m/s] +5.0

TerraSAR-X Divided Antenna Mode
Eff. along-track baseline = 1.15 m,
speed sensitivity = 200 m/s / 2π

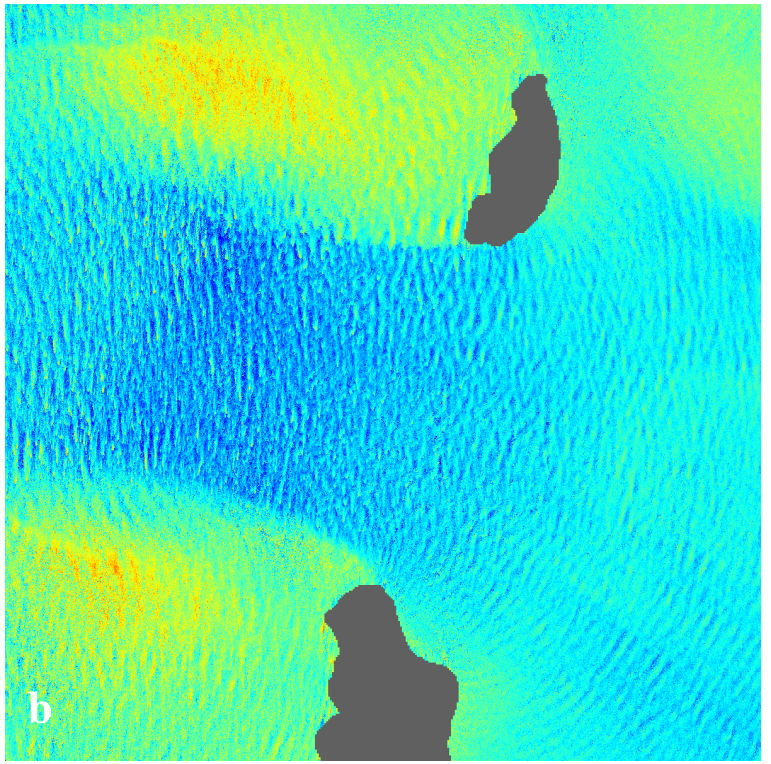


–5.0 Doppler Velocity [m/s] +5.0

TanDEM-X Near-Optimal Baseline
Eff. along-track baseline = 25 m,
speed sensitivity = 9.14 m/s / 2π

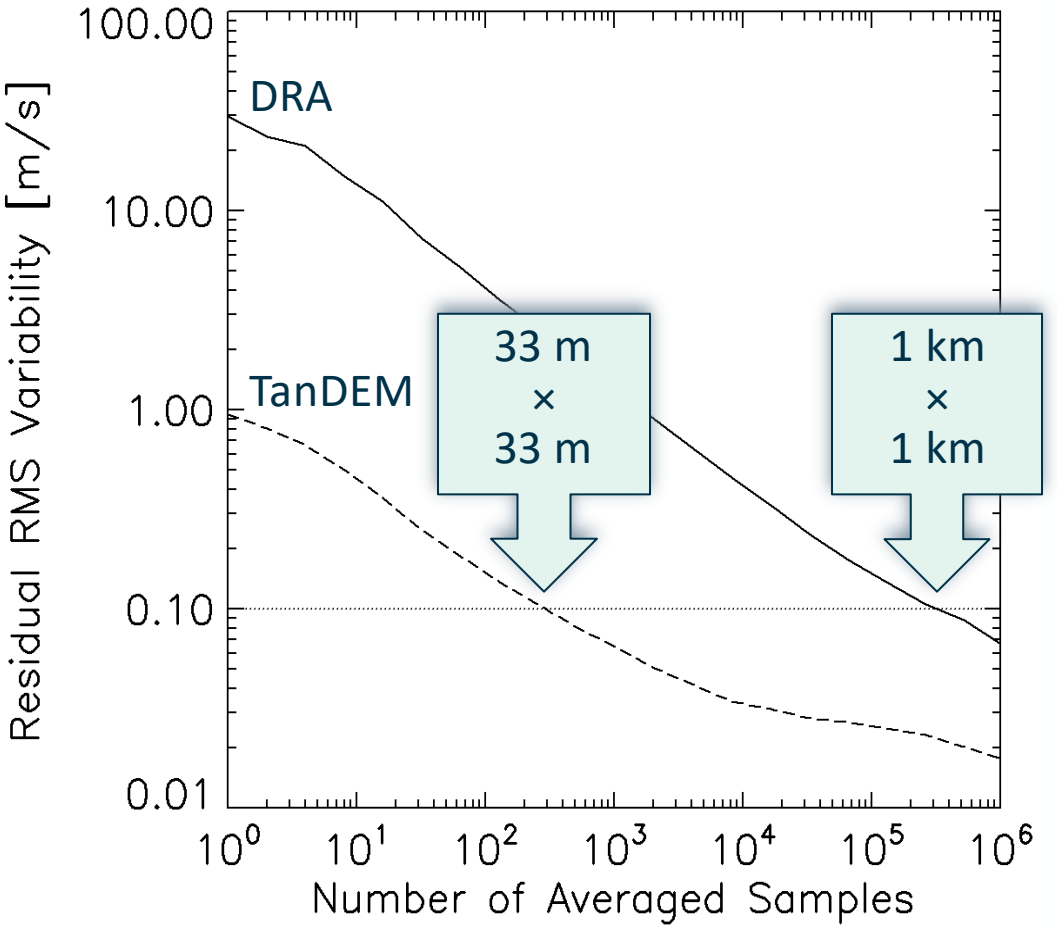
Doppler Velocity Uncertainty vs. Spatial Resolution

Romeiser et al., IEEE-TGRS 2014



–5.0 Doppler Velocity [m/s] +5.0

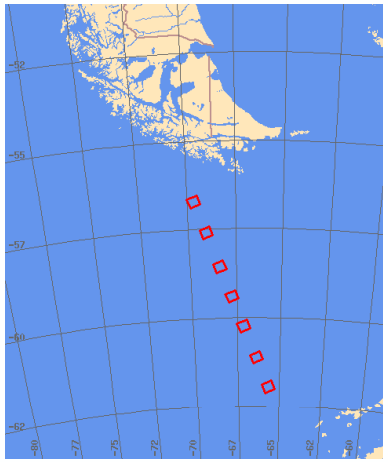
10 km × 10 km subsection of the TanDEM-X Doppler velocity field, grid cell size = 8.40 m × 8.46 m



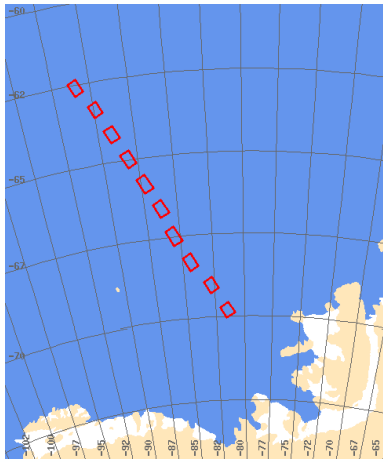
Velocity uncertainty reduction by averaging over increasing pixel numbers

Coherence vs. Time Lag Experiment With TanDEM-X

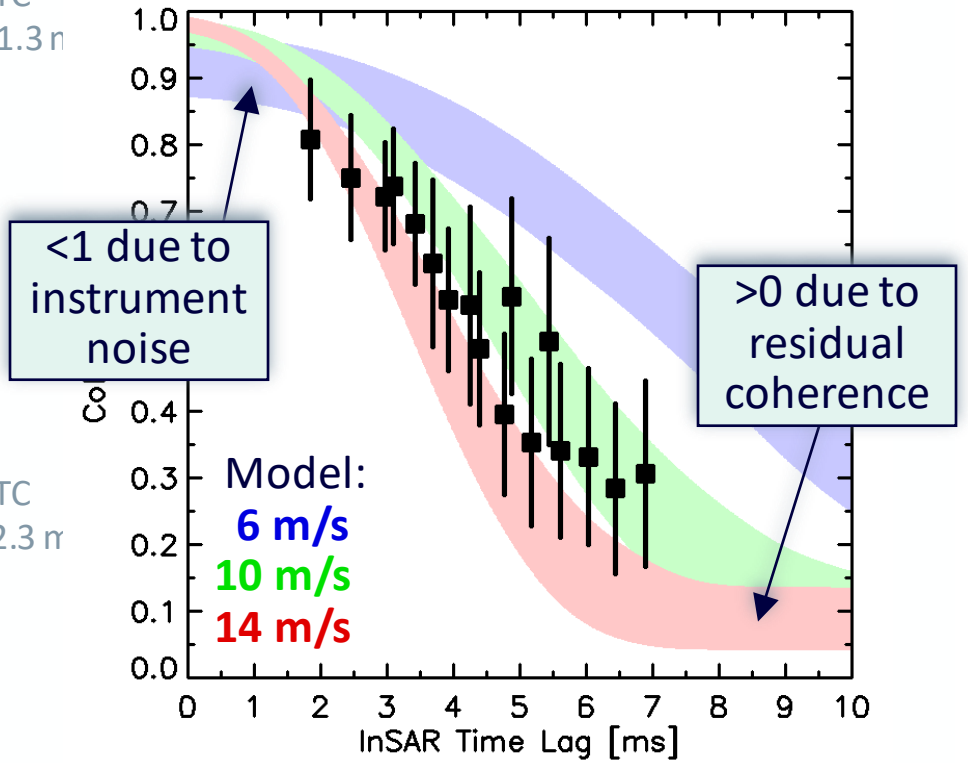
Romeiser and Runge, EUSAR 2014



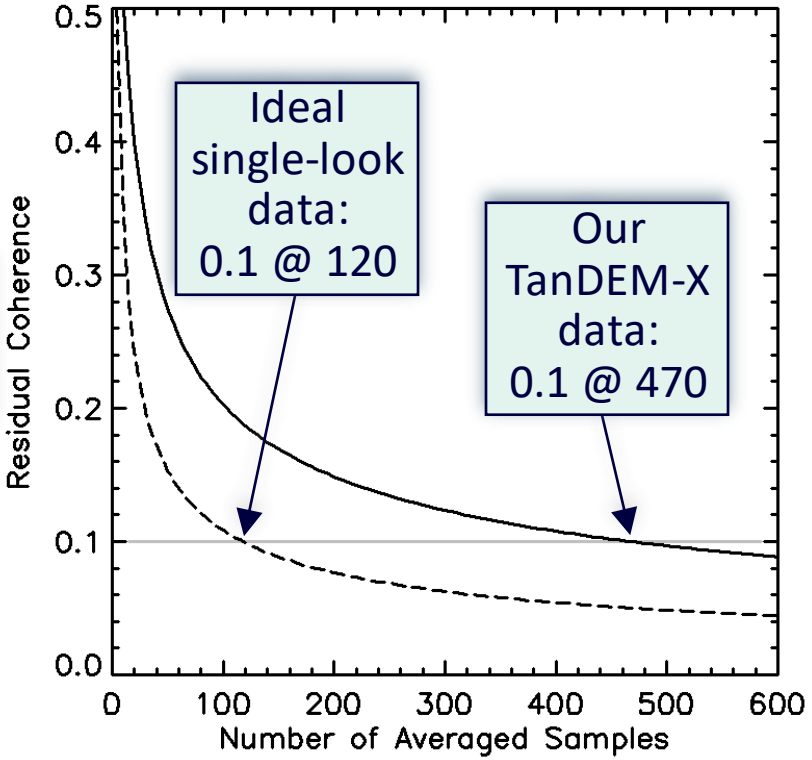
March 23, 2012
23:41:53-23:43:25 UTC
Eff. baseline = 14.0-41.3 m



April 18, 2013
01:23:22-01:25:22 UTC
Eff baseline = 26.0-52.3 m



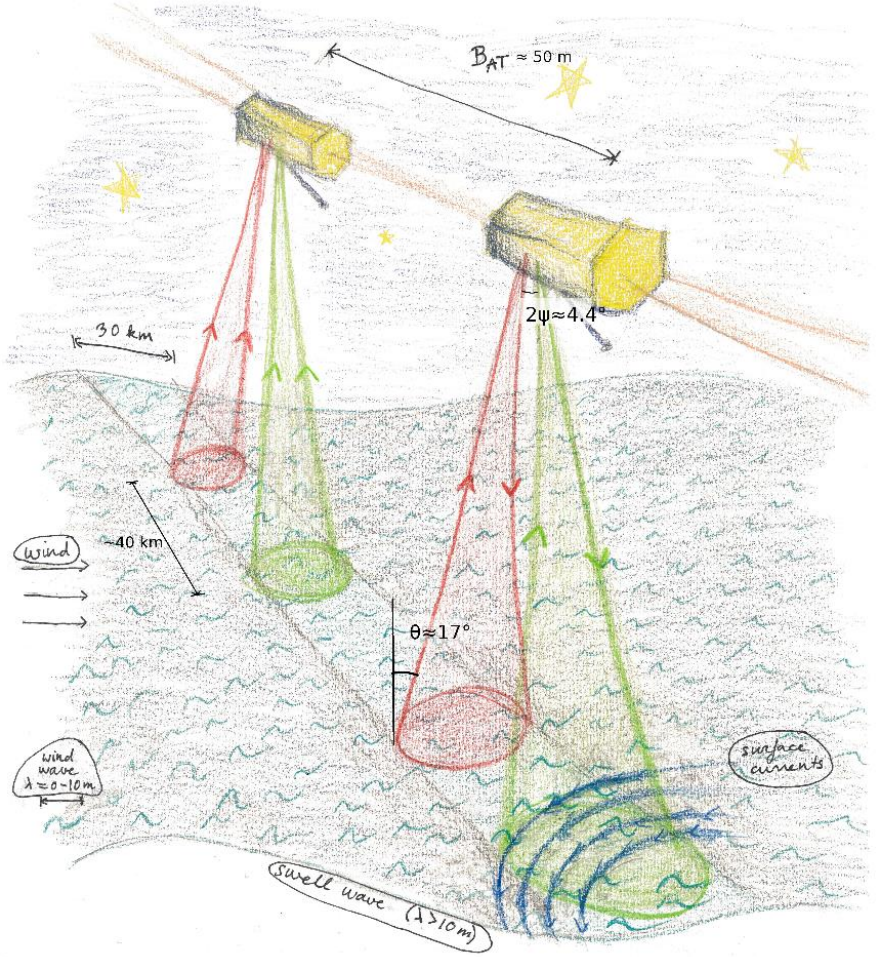
Coherence vs. InSAR time lag



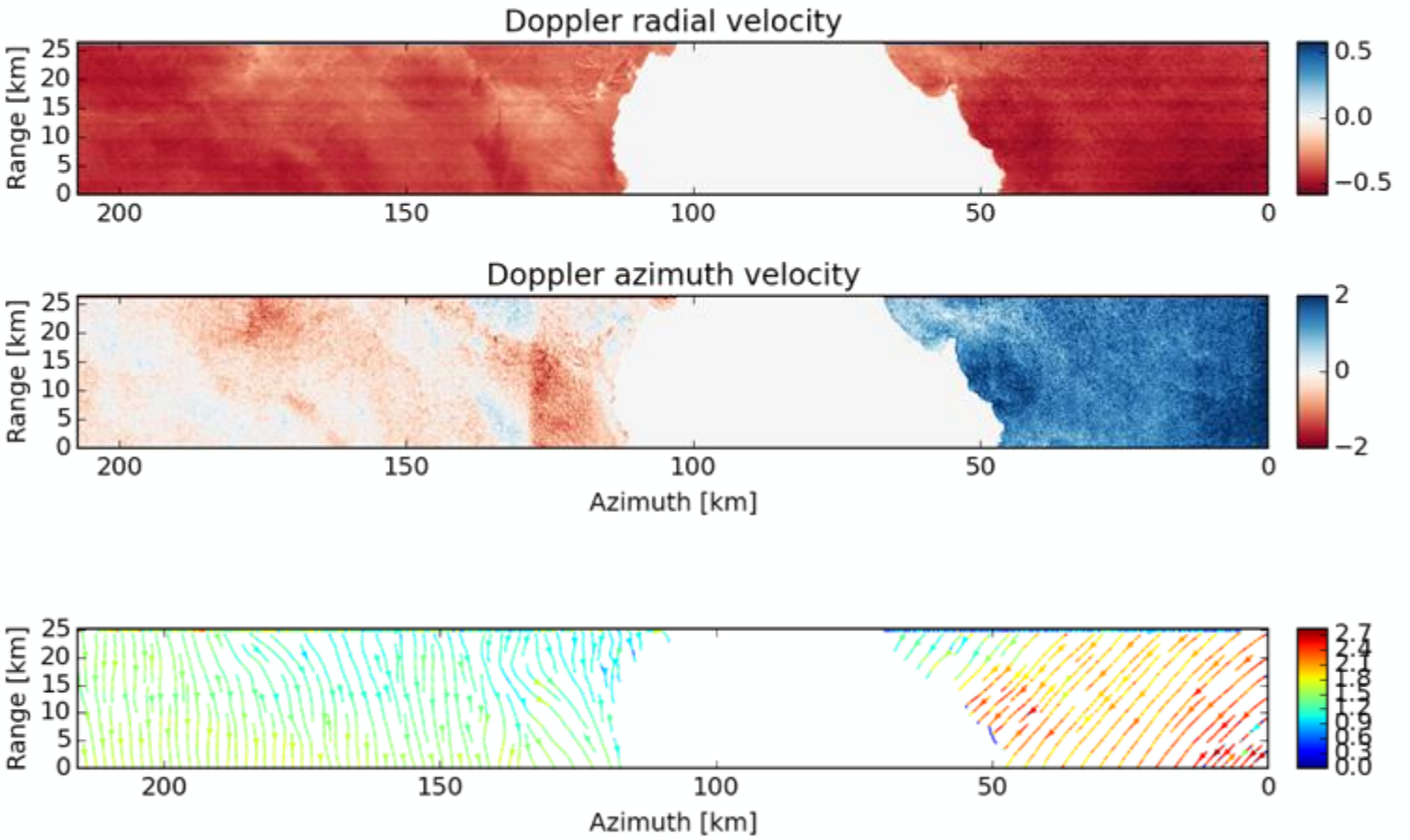
Effective number of looks analysis

Dual-Beam ATI Experiments With TanDEM-X

Figures from Paco Lopez Dekker, DLR / TU Delft

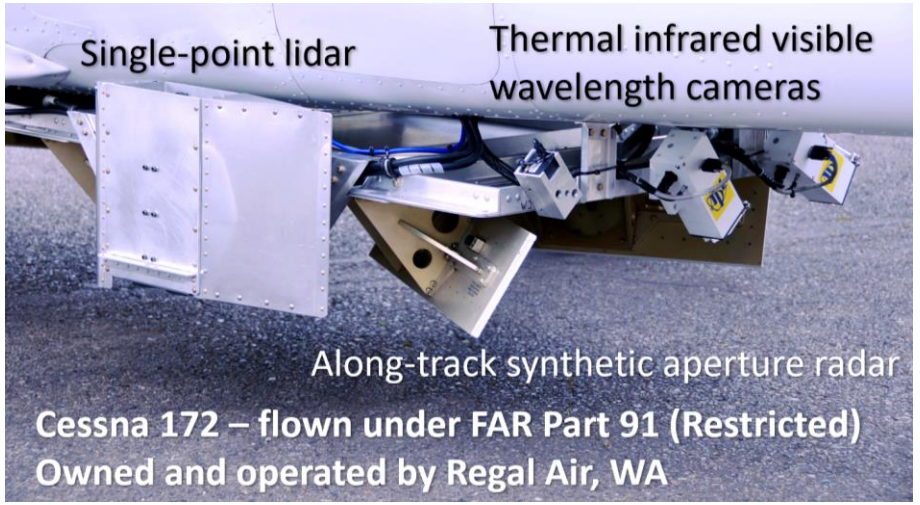


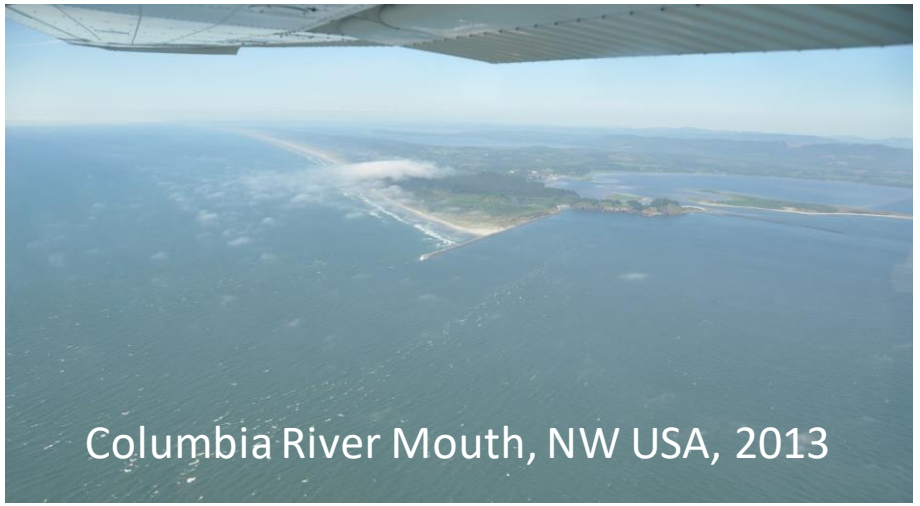
© Nina Caldarella

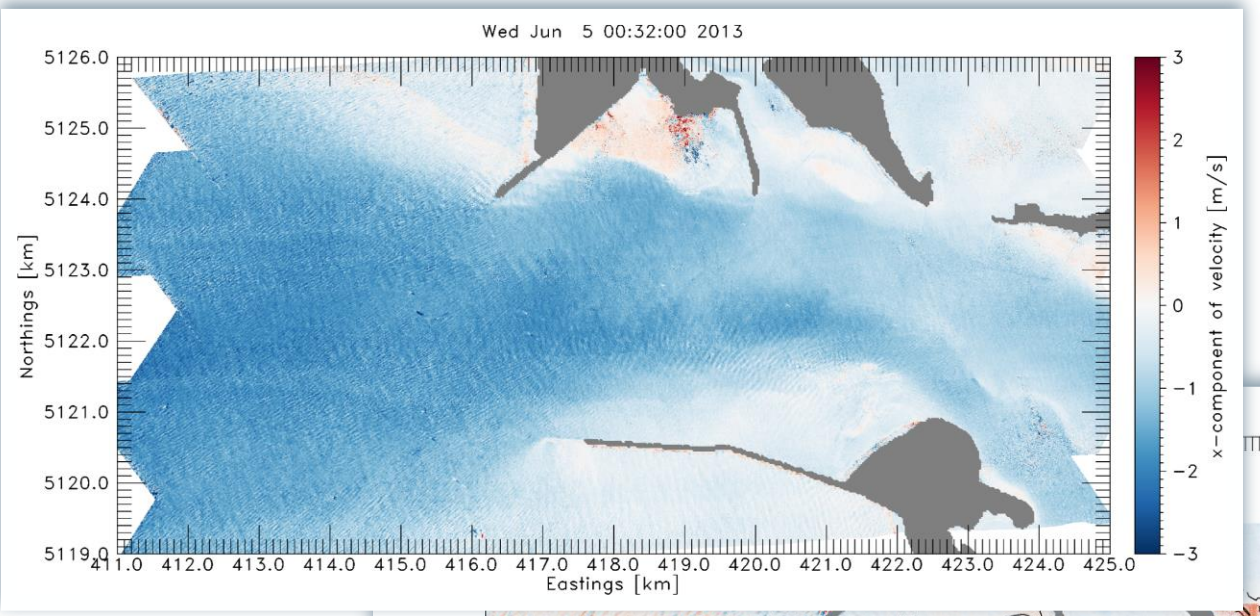


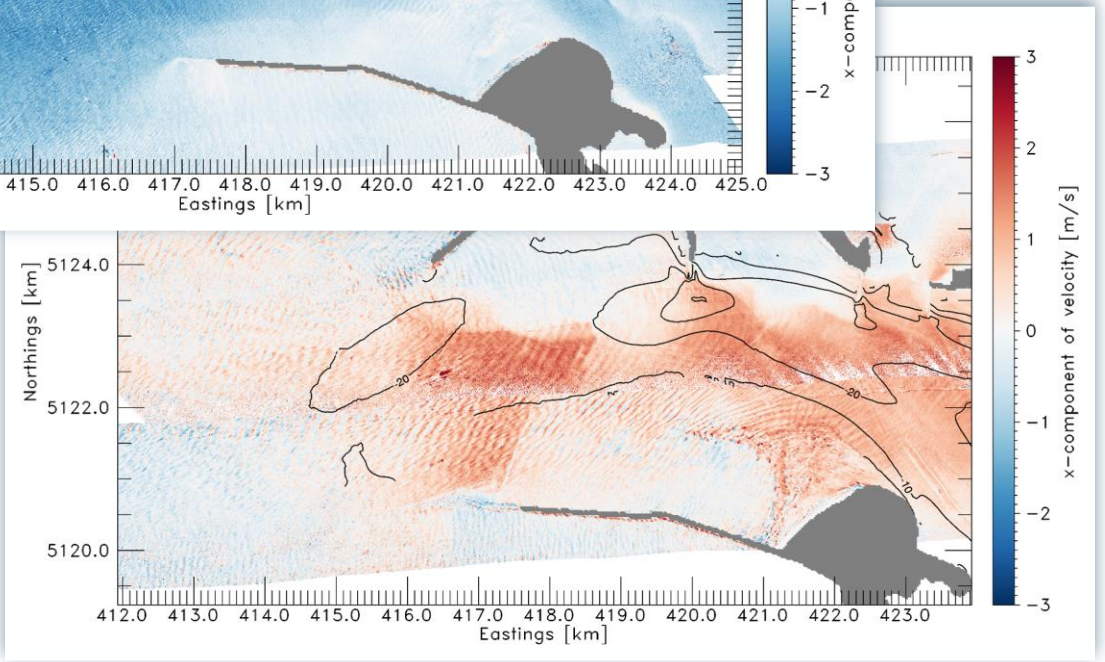
Airborne Dual-Beam Along-Track InSAR Experiments

Figures from Gordon Farquharson, UW-APL, Seattle, 2012-2017



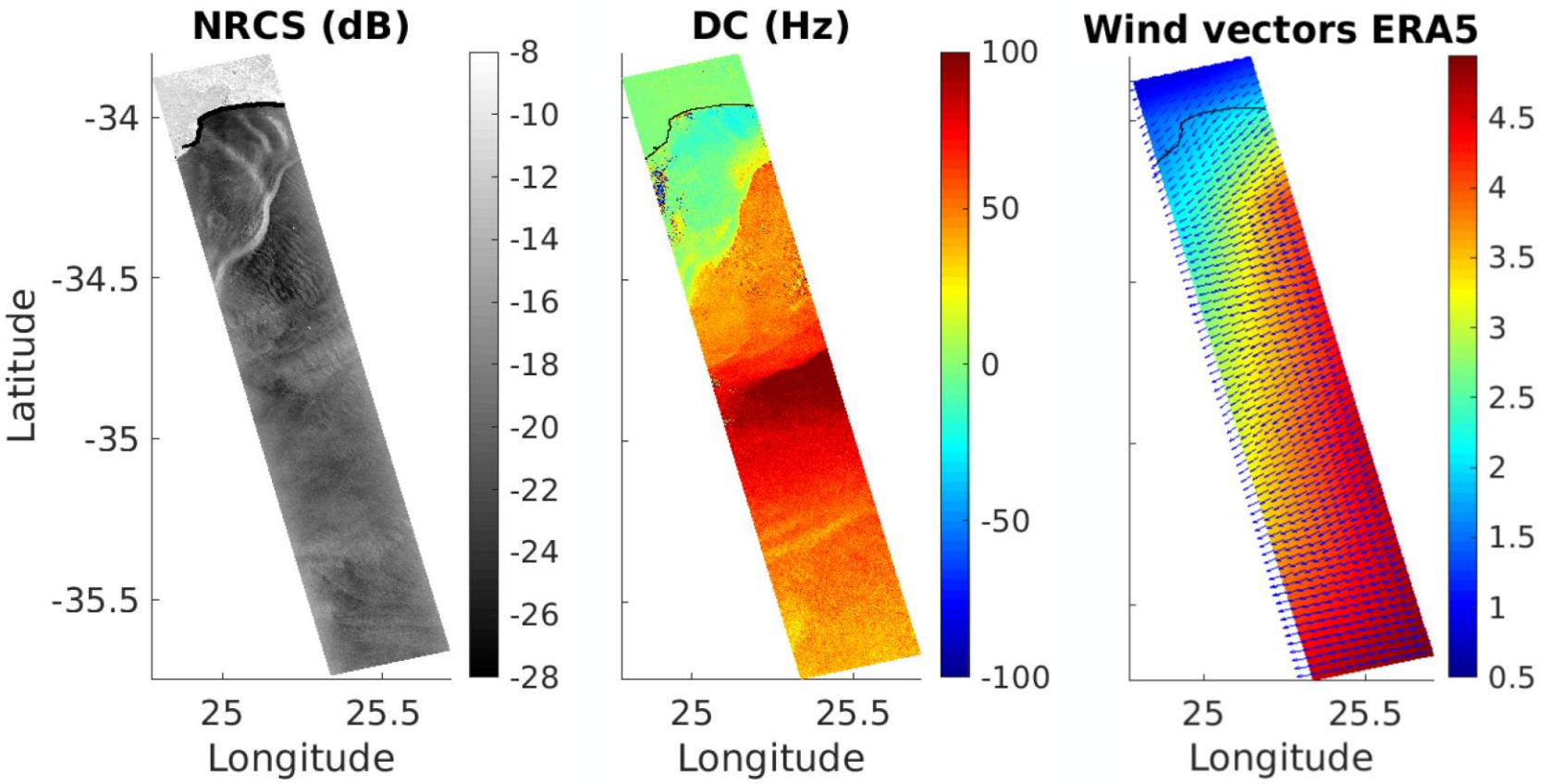


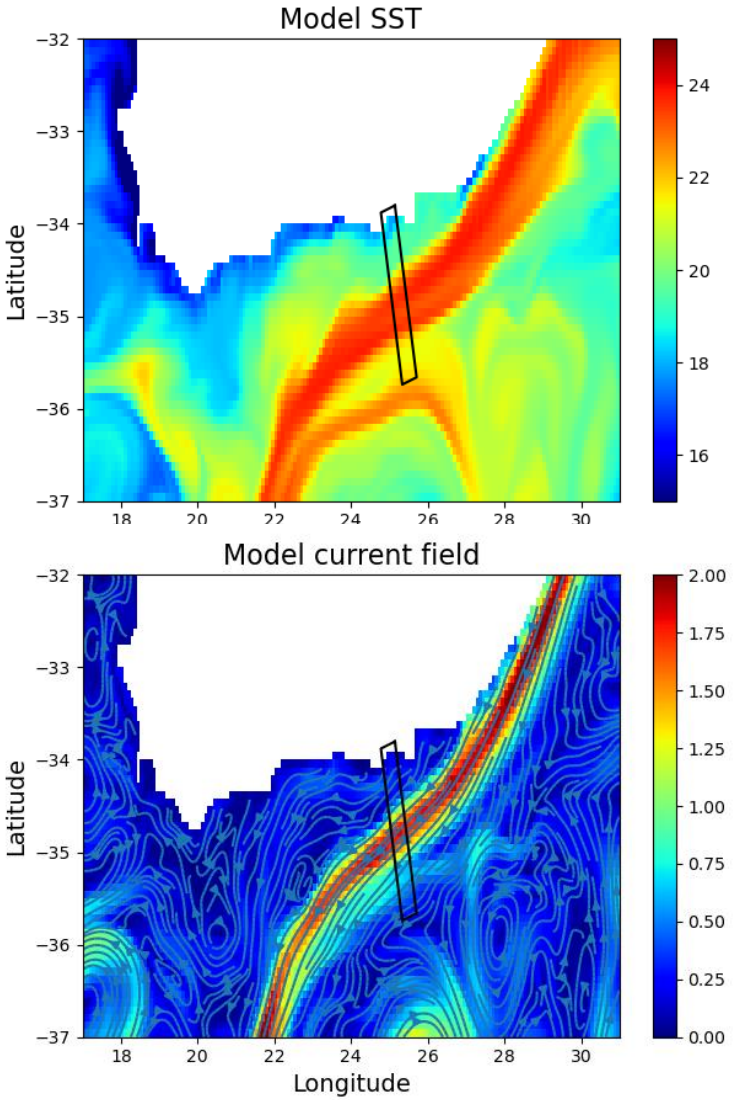




TanDEM-X Agulhas Current Study

Slides from Anis Elyouncha, Chalmers University of Technology, Gothenburg

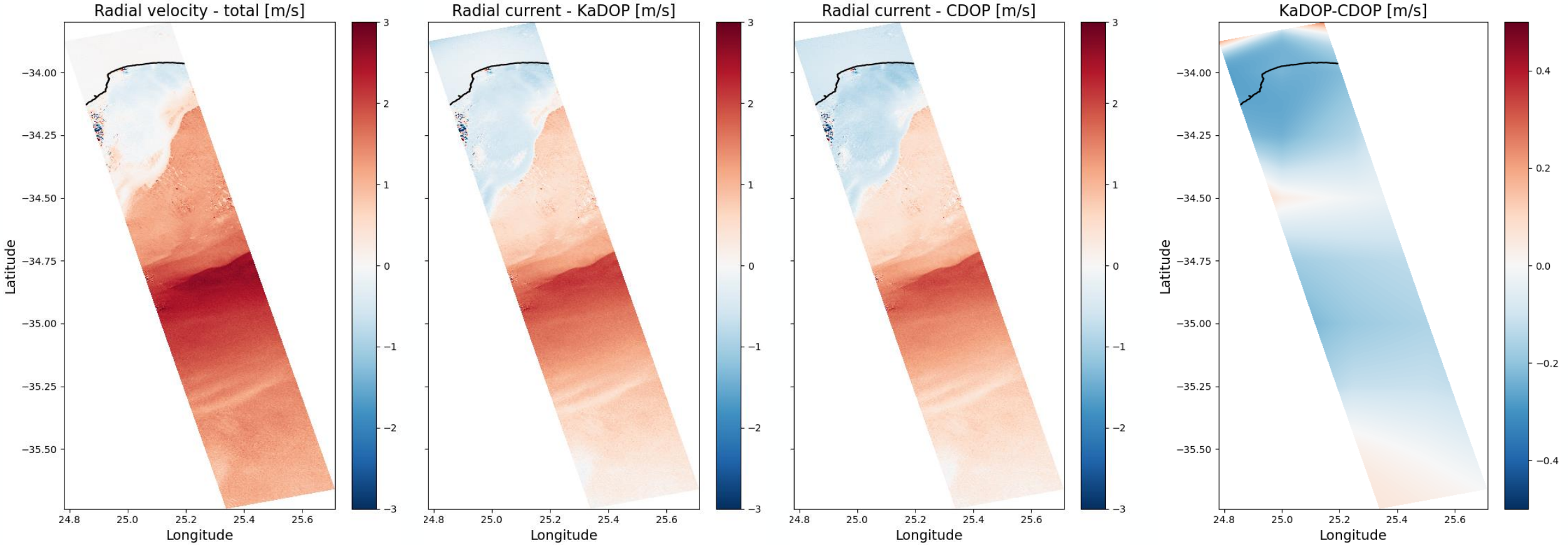




- NRCS derived from TerraSAR-X and DC derived from TanDEM-X ATI phase
  - Scene consists of 5 SAR images concatenated, 2015-11-05
- NRCS modulations, wave-current interaction at current gradients / fronts
- DC modulation wind and current, high DC in the core of the Agulhas current

TanDEM-X Agulhas Current Study

Slides from Anis Elyouncha, Chalmers University of Technology, Gothenburg



- Total radial velocity includes current and wind-wave induced DC, values up to 3 m/s
- Correction using wind-wave induced DC models, KaDOP (Yurovsky et al. 2019), CDOP (Mouche et al. 2012)
- Radial current (after wave DC removal), the two models give slightly different results (differences up to 0.5 m/s)

Doppler Centroid Anomaly Analysis Using ENVISAT

No contributions received,

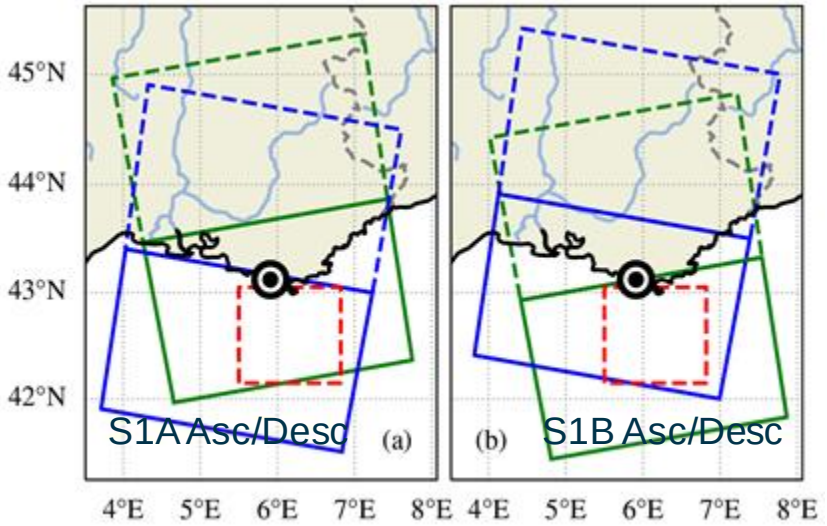
but this topic will be covered in our white paper

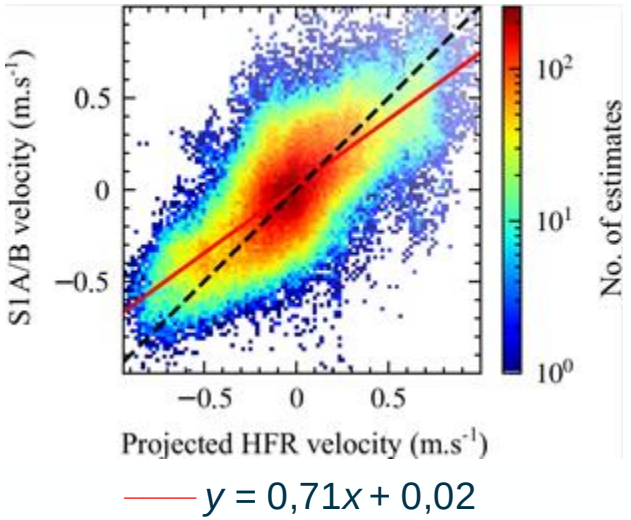
To be covered by Artem Moiseev

in his part of this main presentation

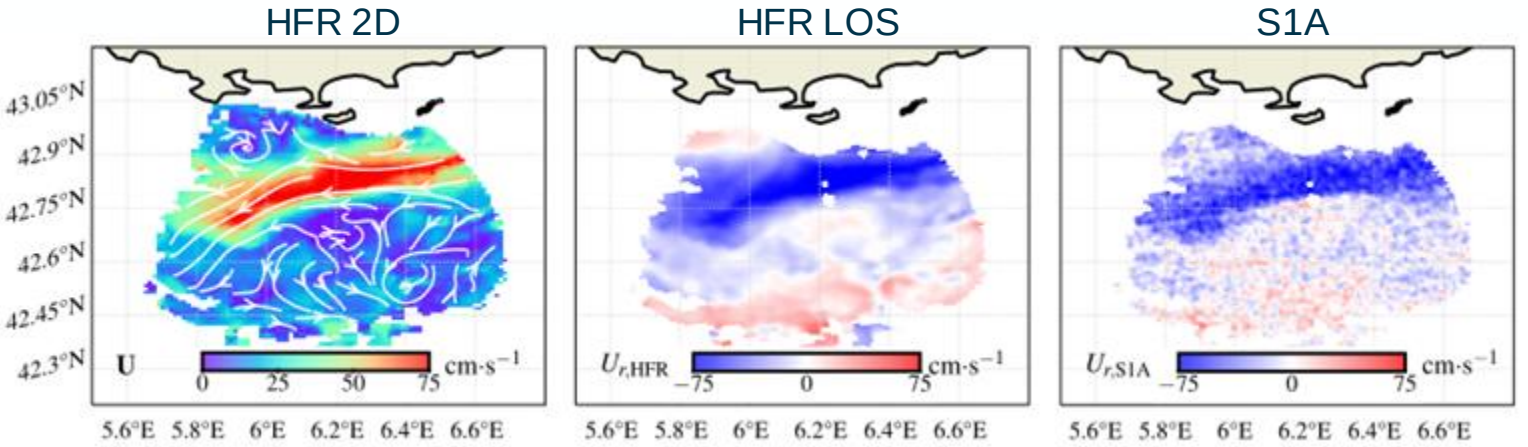
Using HF Radar to Evaluate S1 Doppler Currents

Slides from Baptiste Domps, Degreane Horizon / VINCI Énergies, Cuers, France, et al.





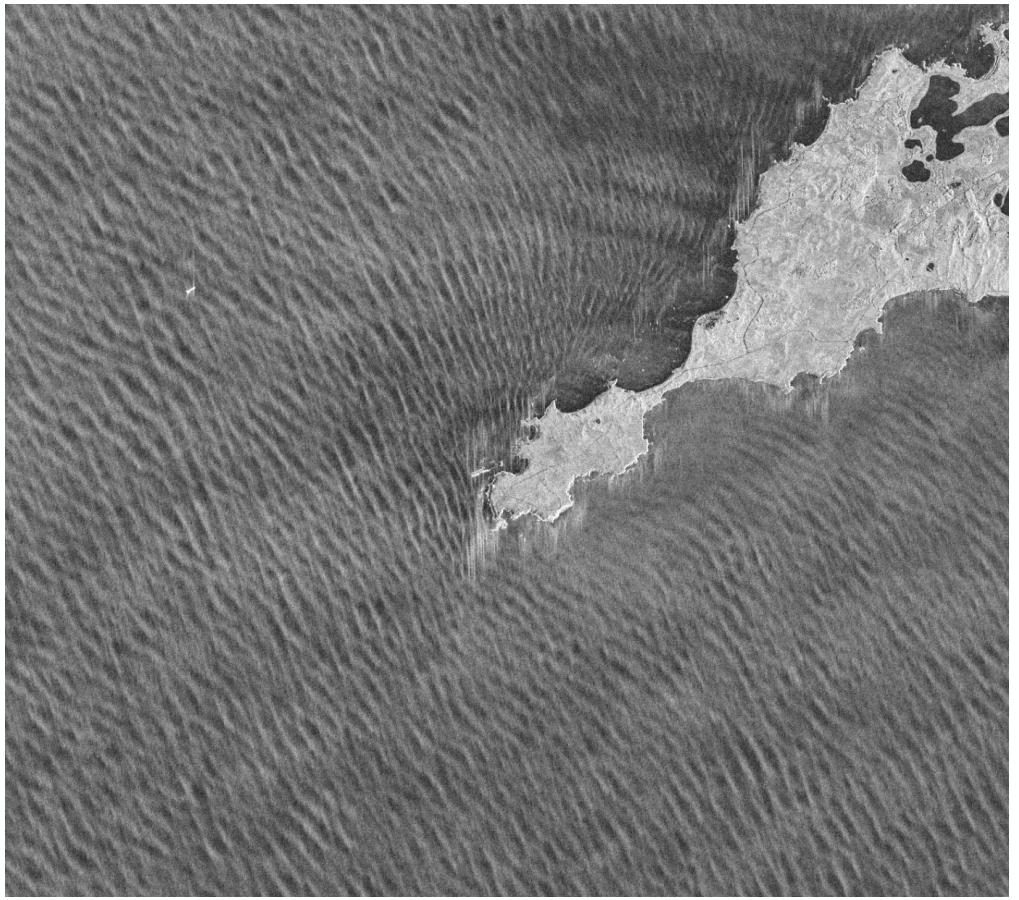
- Assuming same vertical integration depth
- Multistatic HF Radar Network of Univ. Toulon, south of France (Prof. C.A. Guérin), calibrated using drifters [Dumas et al., 2021]
- 6 months of measurements (July 2020 to March 2021)
- Approx. 150,000 pixel-to-pixel comparisons: RMSE of 21 cm s^{-1}
- E.g. Northern Mediterranean Current on March 1, 2021, 1730Z



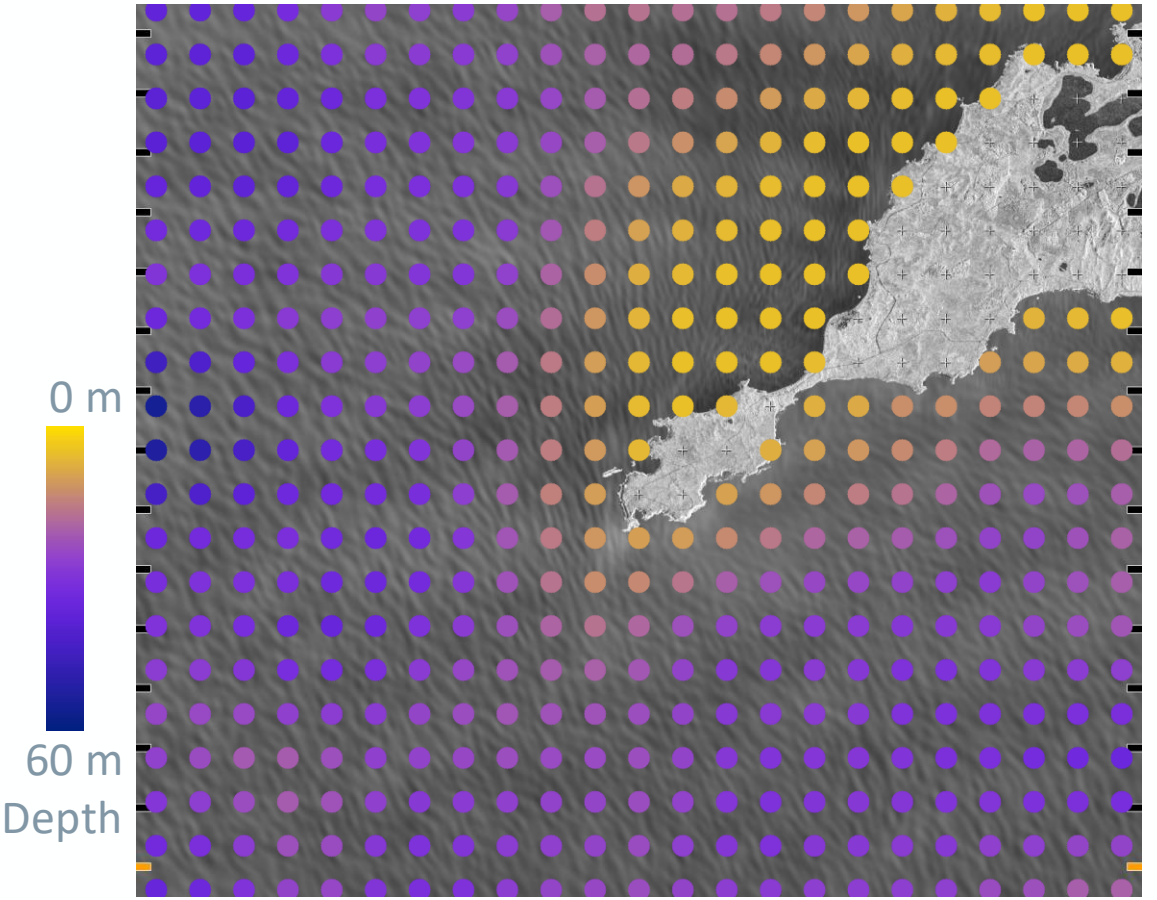
- Playground for Cal / Val and new processing techniques

Moving Wave Patterns From Spotlight Mode Data

Romeiser and Graber, EUSAR 2021



TSX Sliding Spotlight Mode (Rottnest, Australia);
area = 11740 m × 10400 m, pixel = 1.19 m × 1.27 m,
total SAR integration time = 1.22 s

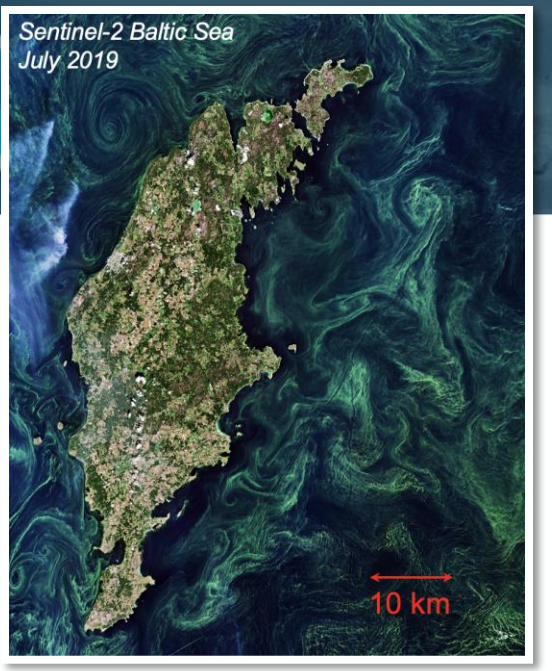


Derived moving wave patterns
and water depths

The same methodology could be used for current vector retrievals!

Future Missions: Earth Explorer 11 SeaSTAR

Slides from Christine Gommenginger, NOC, Southampton



One of four candidates to EE 11, currently in Phase 0 (Phase A Decision: Oct / Nov 2023)

Focus on small-scale ocean surface dynamics in coastal & shelf seas and marginal ice zones

Primary Objectives

1. Measure 2D images of Total Surface Current Vectors (TSCV) and Ocean Surface Vector Winds (OSVW) at 1 km resolution with high accuracy
2. Quantify the magnitude, spatial distribution and temporal variability on daily, seasonal, and multi-annual time scales
3. Deliver high-order derivative products like gradients, divergence, vorticity, and strain
4. Investigate relations between small-scale dynamics and marine productivity using synergy with in-situ data and other satellite sensors
5. Validate high-resolution and coupled models and support the development of new parameterisations to improve operational forecasts and reduce uncertainties in climate projections

SeaSTAR Primary Products (Level 2)
Total Surface Current Vector (L2-TSCV)
One continuous swath ≥ 100-150 km
Horizontal posting (resolution) ≤ 1 km
TSCV Uncertainty @ 1km ≤ 0.1 m/s or 10%
Ocean Surface Vector Wind (L2-OSVW)
Same swath as TSCV
Same horizontal posting as TSCV
OSVW Uncertainty @ 5km ≤ 1 m/s or 10%

Future Missions: Earth Explorer 11 SeaSTAR

Slides from Christine Gommenginger, NOC, Southampton

First squinted along-track interferometric SAR in space

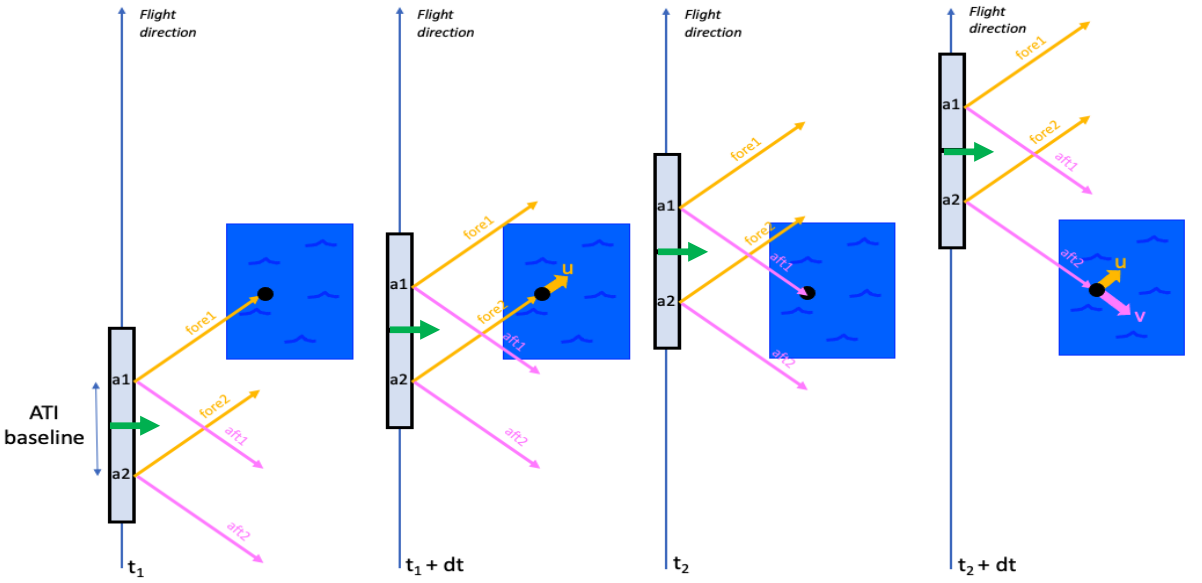
- Ku-band
- Physical baseline ~ 15 metres (dt ~ 1ms)

Three azimuth directions in ASCAT-type configuration

- One ATI pair pointing 45º forward
- One ATI pair pointing 45º backward
- One DCA or ATI pointing broadside

Moderate incidence angles: 20-50º

- High incidence angles = greater sensitivity to currents (horizontal) and lower Doppler wave velocity



Doppler and NRCS data in three directions enable retrieval of TSCV and OSVW in a single pass

Directional swell spectrum (broadside)*

HH/VV polarisation (broadside)*

Directional wave spectrum (squinted beams)**

* Subject to EE11 cost cap

** Subject to SRL

To be covered by Paco Lopez Dekker

Future Missions: Doppler Scatterometers

- Fois et al. [JGR-Oceans 2015]:
  Mission concept DopSCAT, Dopplerized European-style wind scatterometer
- Rodriguez et al. [MDPI Remote Sensing 2018, 59 pp.]:
  Comprehensive study on American-style (rotating pencil beam) Doppler scatterometer
- Rodriguez et al. [Front. Mar. Sci. 2019]:
  Winds and Current Mission concept (WaCM)
- Wineteer et al. [MDPI Remote Sensing 2020]: Airborne implementation
- Now known as ODYSEA
  - USA-France partnership
  - Covers >90% of the ocean in <1 day, spatial resolution <5 km
  - Launch possible around 2030 [Fabrice Ardhuin, personal communication]