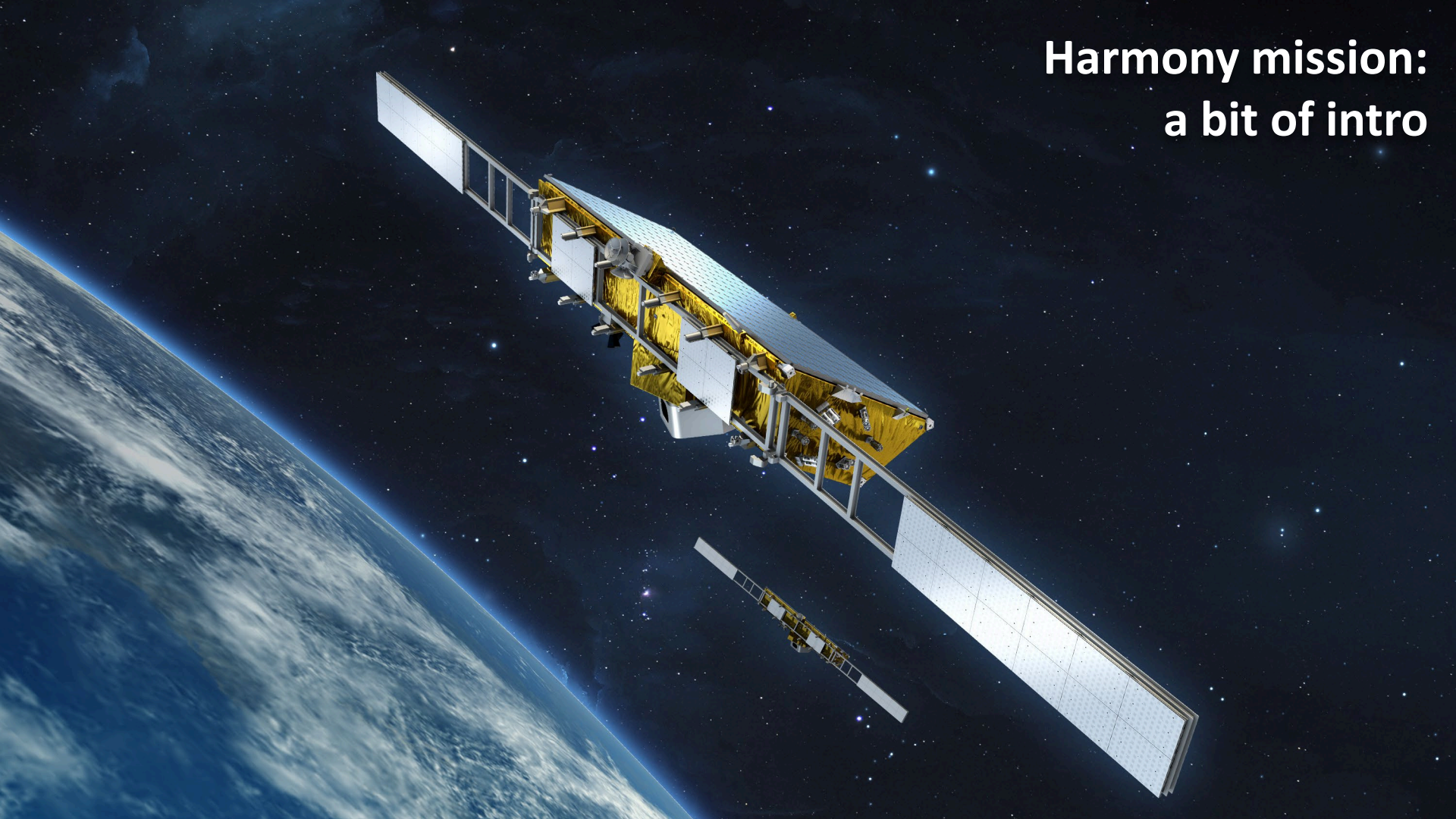

esa
harmony
TO RESOLVE STRESS
IN THE EARTH SYSTEM
Harmony: science status overview

Harmony mission: a bit of intro



A multi-domain “Earth System” mission

Upper oceans and ocean-atmosphere interactions

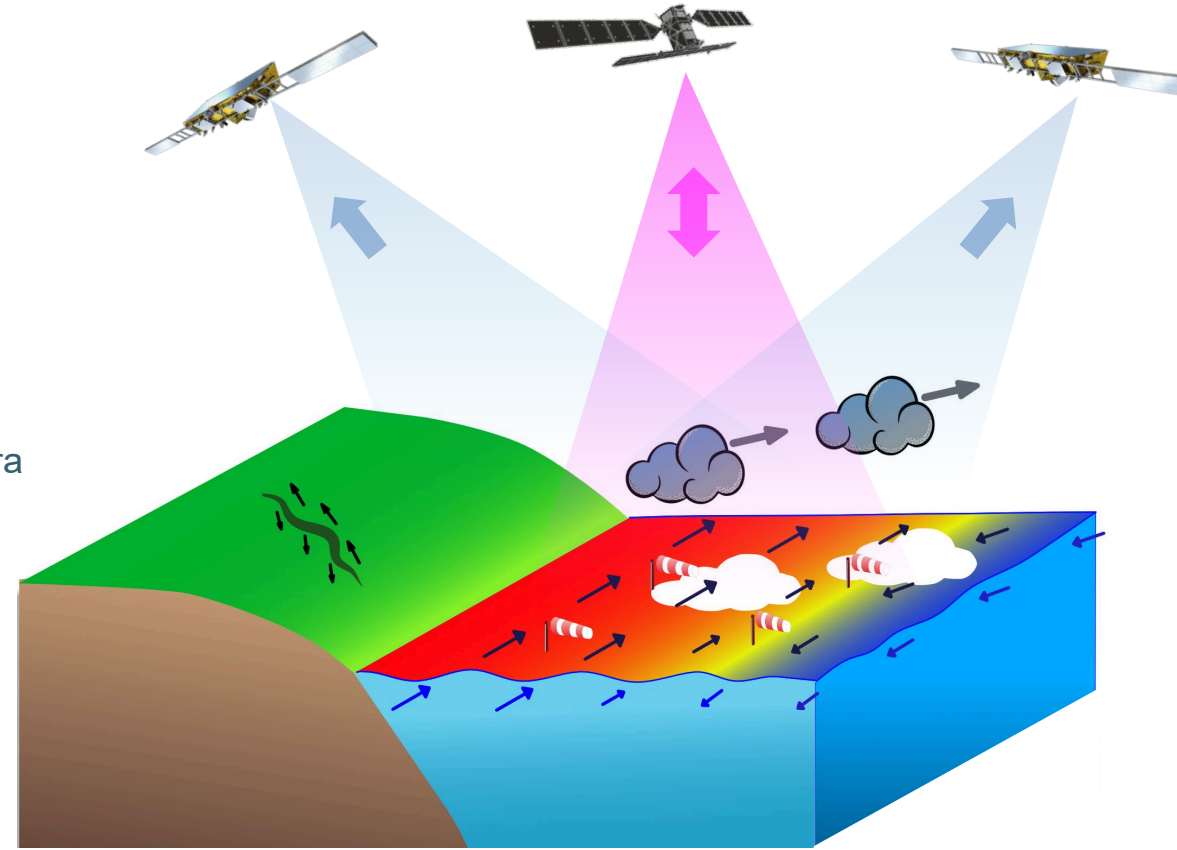
Land ice and sea ice

Tectonic strain and volcanic processes

Observation concept: “stereo” phase

Line-of-sight diversity for high resolution

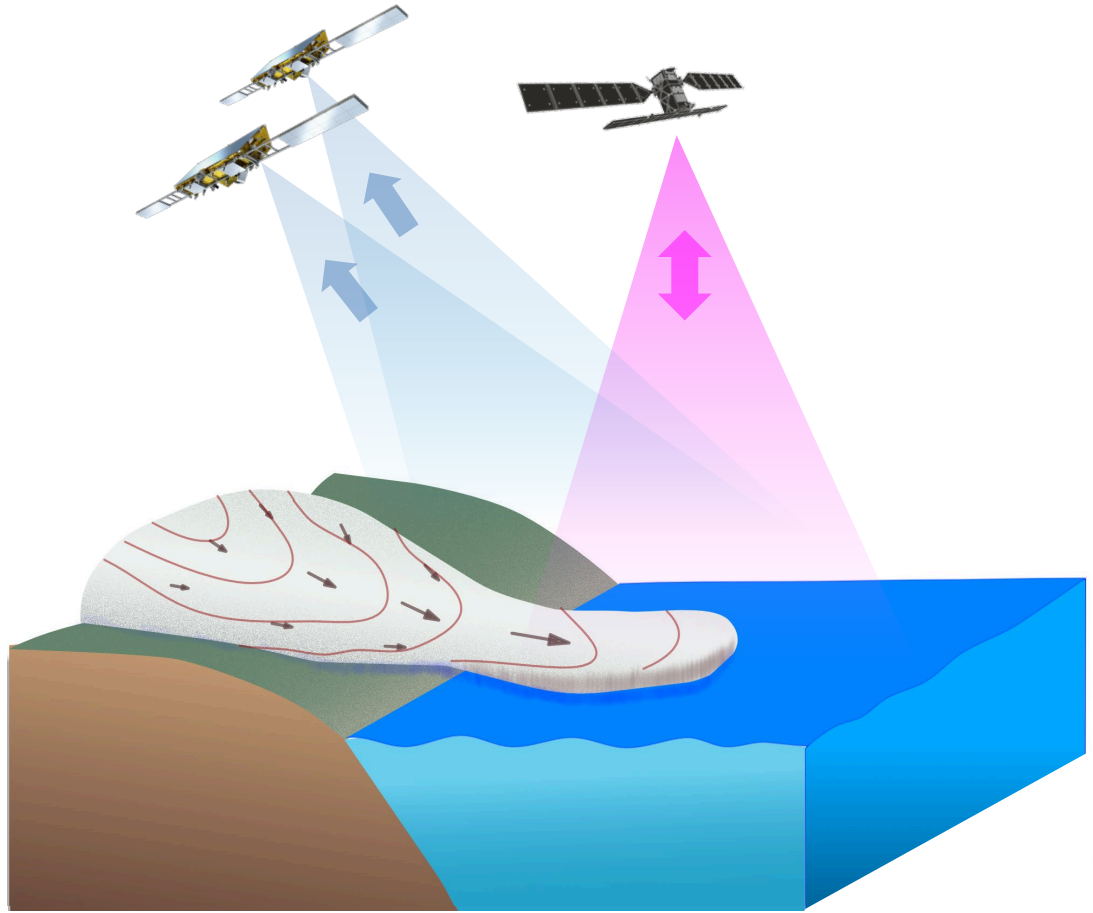
- 3-D surface deformation (DInSAR)
- **Ocean surface motion (Doppler)**
- **Surface winds (scatterometry)**
- Improved directional surface wave spectra
- Sea Surface (skin) temperature
- Cloud-top motion (TIR time-lapse) and height (TIR parallax)



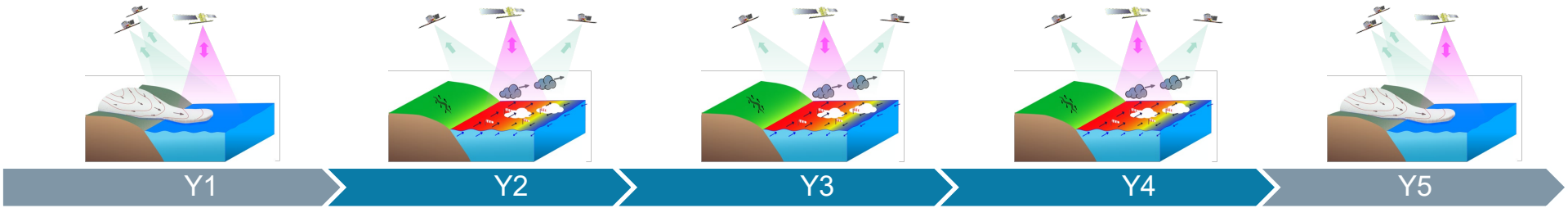
Observation concept: close formation phase

Single-pass cross-track interferometer

- 3-D surface deformation (as in Stereo)
- Surface elevation time-series
    - Glaciers, permafrost, icebergs
    - Volcanoes
- **Ocean-topography (experimental)**

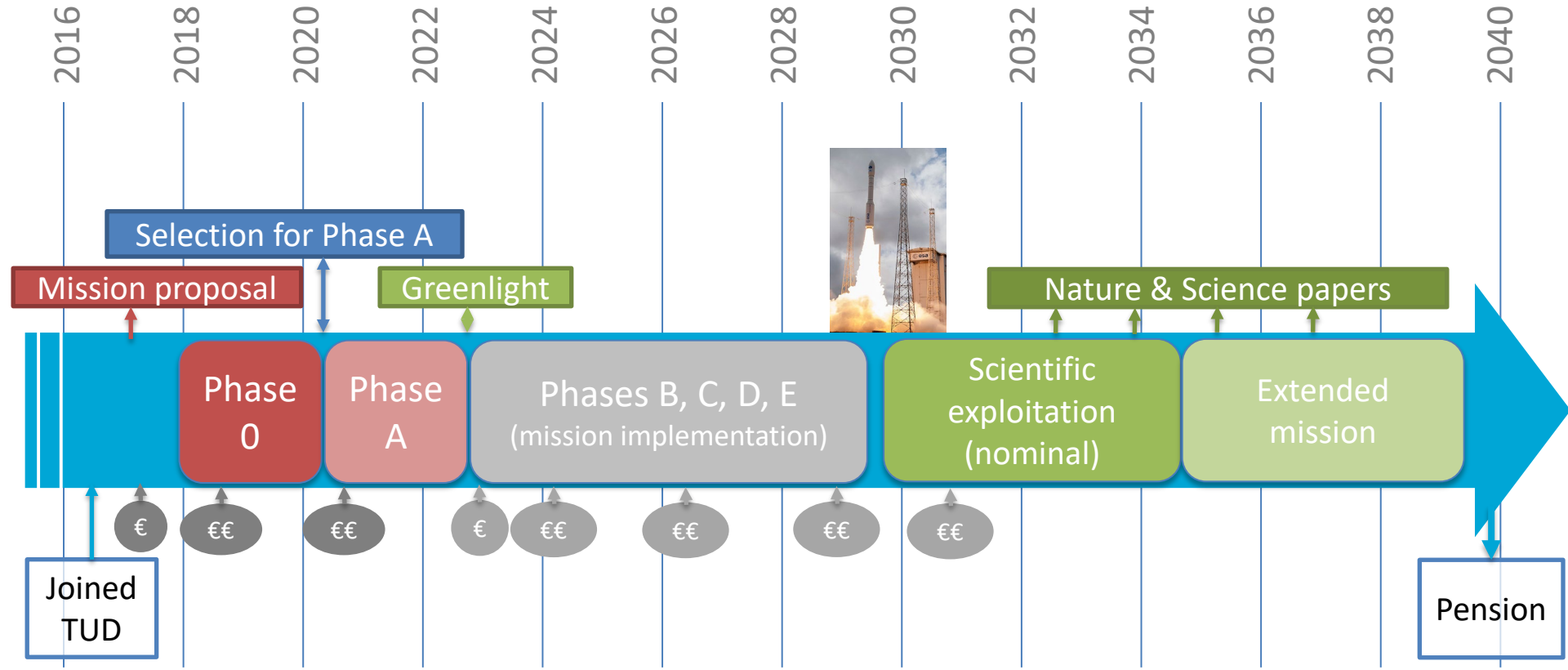


Mission Timeline

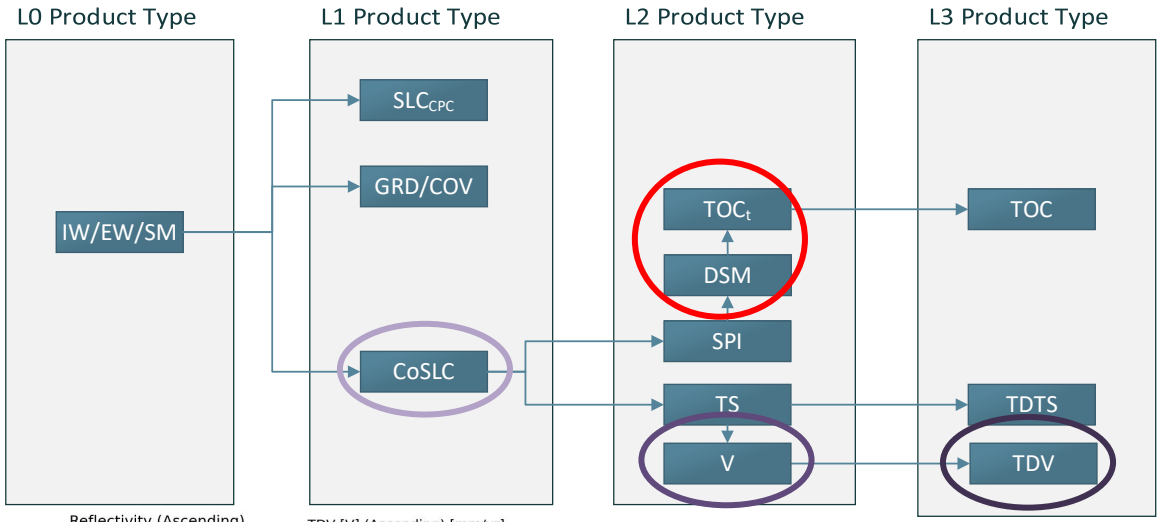


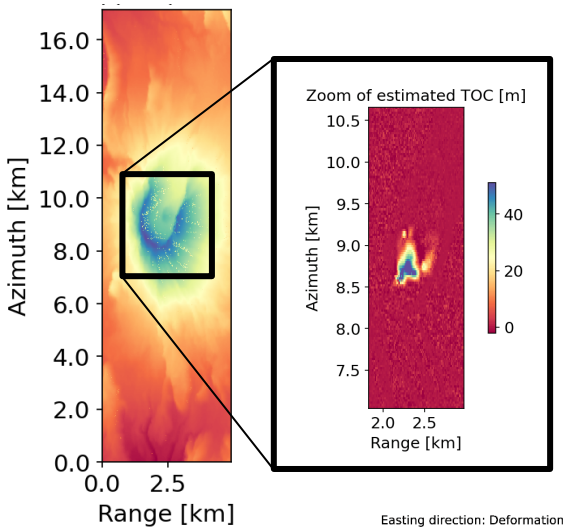
Ice Volume change **Glacier dynamics**		**Ice Volume change** **Glacier dynamics**
	3-D Ice surface motion	
	Air-sea interactions	
Exp. Ocean topography	**Atmosphere-ocean-extemes (Tropical Cyclones, Polar lows, etc)**	Exp. Ocean topography
	Upper ocean dynamics	
	Tectonic Strain (3-D deformation)	
Vol. change (volcanoes)		Vol. change (volcanoes)
Iceberg volume	Sea-ice instantaneous motion/deformation	Iceberg motion

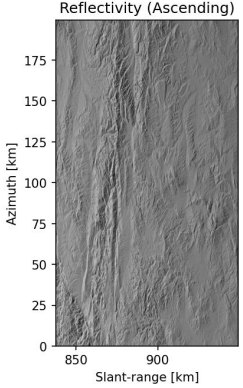
Timeline

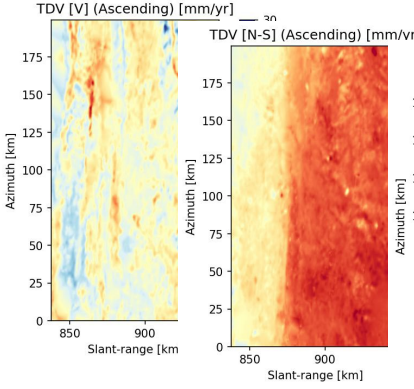

2016
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Selection for Phase A
Mission proposal
Greenlight
Nature & Science papers
Phase 0
Phase A
Phases B, C, D, E
(mission implementation)
Scientific exploitation (nominal)
Extended mission
€
€€
€€
€
€€
€€
€€
€€
Joined TUD
Pension

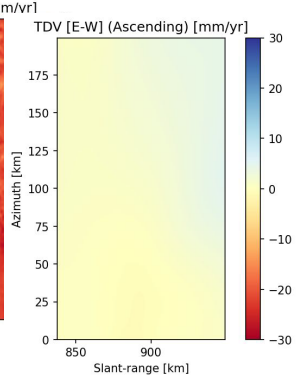
Land Products

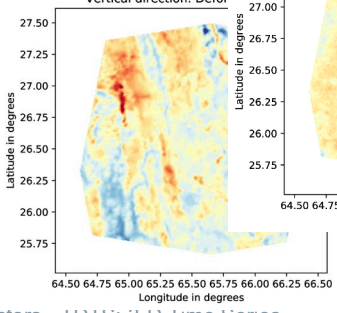


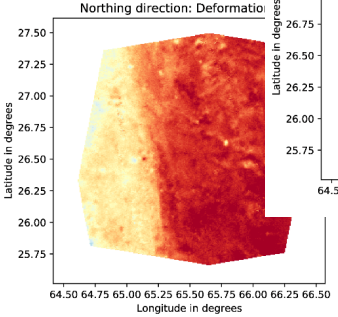


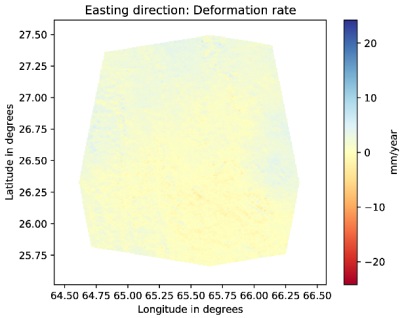












DSM: Digital Surface Model - TOC: Topography Change - TDV: 3-D Velocity Vectors - TDTS: 3-D Time Series

Challenges for Land Applications

End-to-End Simulation, Processing, Calibration

- System calibration, especially clock synchronization, XTI and ATI baseline calibration
- Calibration of L1/L2/L3 products
- Efficient simulation of raw products including more representative instrument characterization and scenes generation
- Efficient SAR image formation under large bistatic angles

Science

- Refine priority areas for all applications taking into account system constraints
- Cal/Val strategy

Way Forward for Land Applications

HEEPS/Terra: End-to-End Simulation

- Improve system characterization (instrument, antenna, orbit, attitude)
- Improve forward models (snow/ice, dispersive ionosphere)
- Accurate reverse processing kernel for raw data generation of extended scenes (topography, antenna)

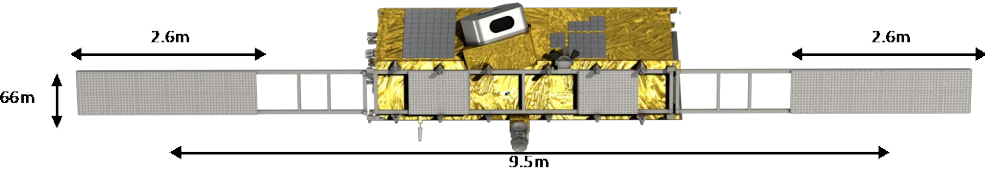
L1/L2/L3 Algorithms

- Consolidate ATBDs
- Implement breadboard processors: L1, InSAR chain, DEM retrieval chain, PSI chain
- Investigate calibration approaches for L2/L3 products (DEM calibration, penetration bias, residual synchronization errors)

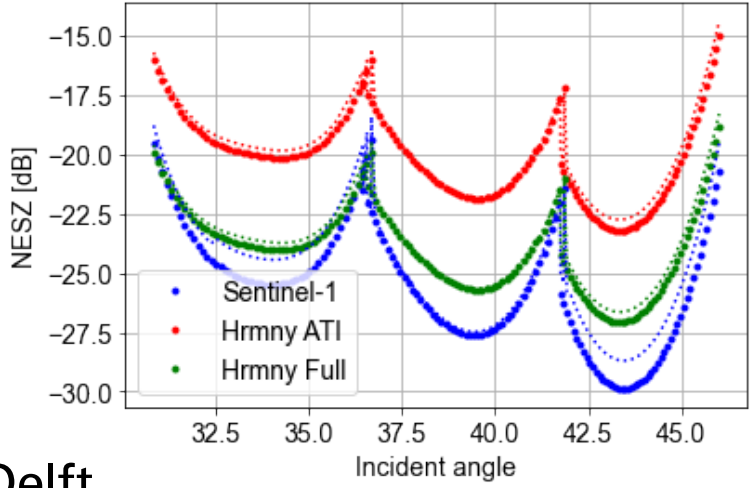
Science

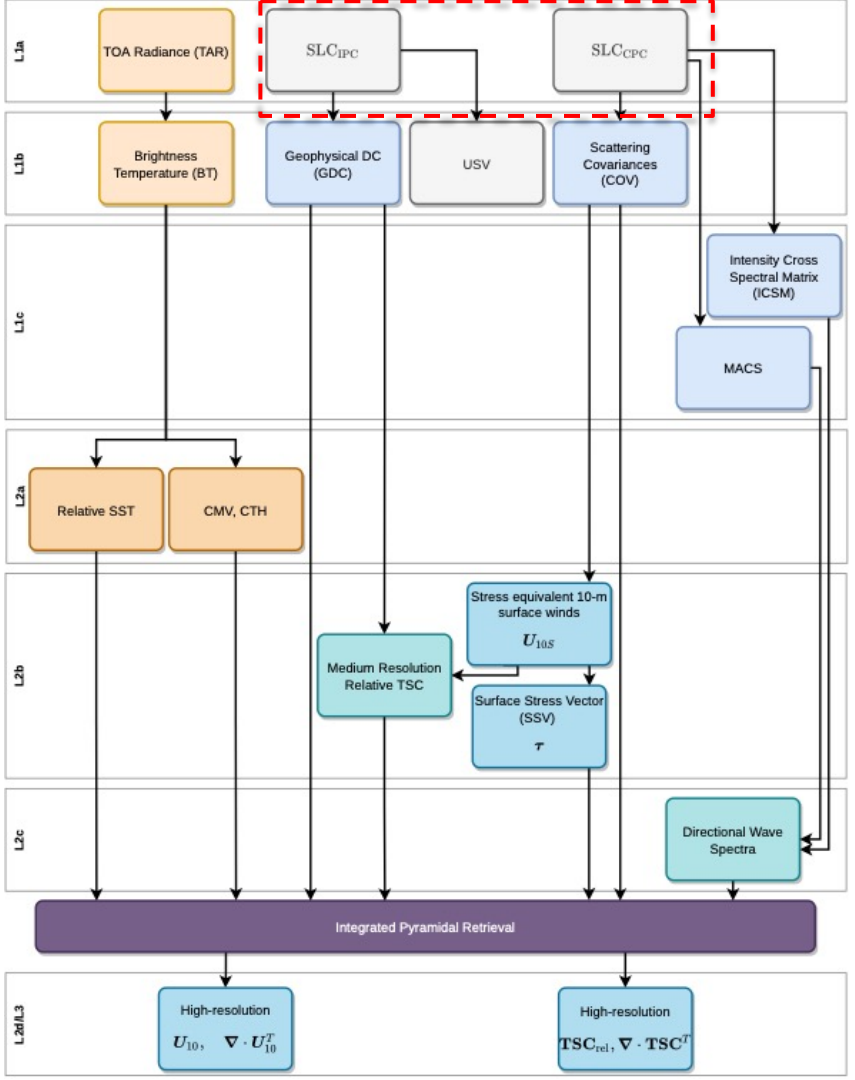
- Consolidate requirements: refine priority areas (masks), temporal sampling requirements, seasonal dependency, complementarity with other sensors (e.g., altimetry for inland regions for land ice)
- Consolidate helix formation and DEM acquisition strategy for XTI phase
- Consolidate representative scenarios and scenes for the end-to-end simulation
- Conduct performance campaign in view of system CDR

For oceans & air-sea



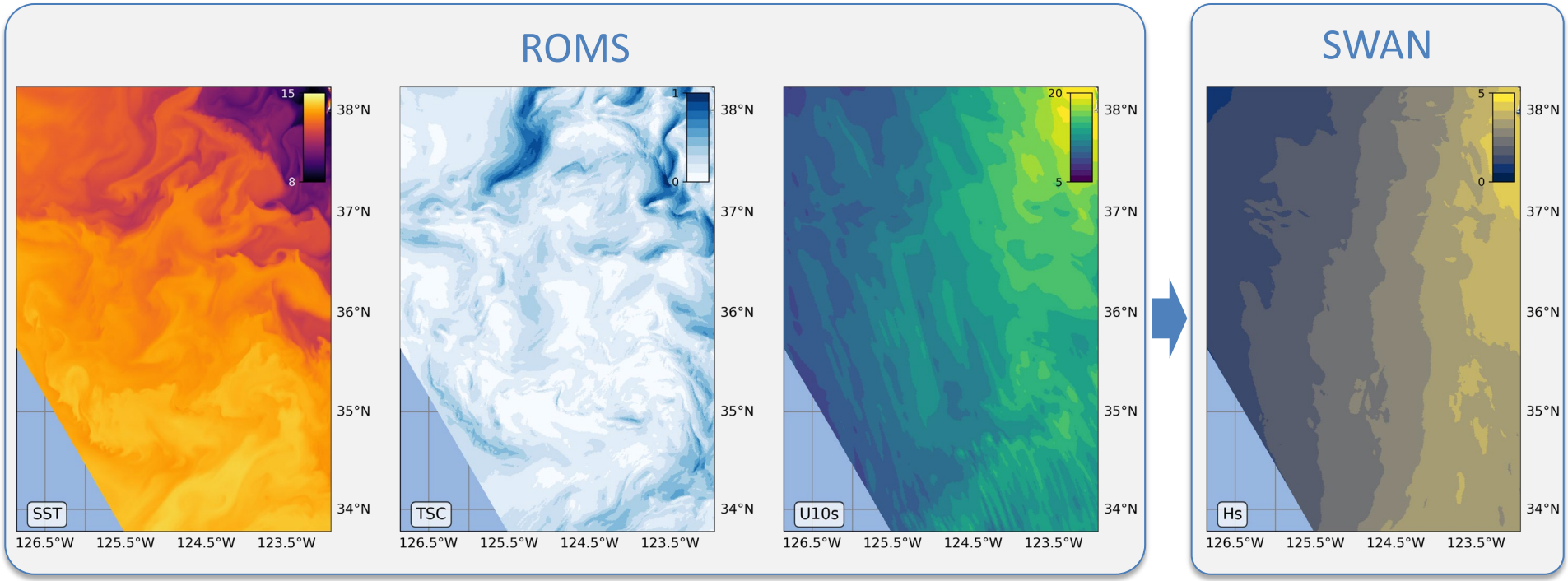
- Two types of SLC
  - Individual Phase Center → ATI
  - Combined (DBF) → everything else



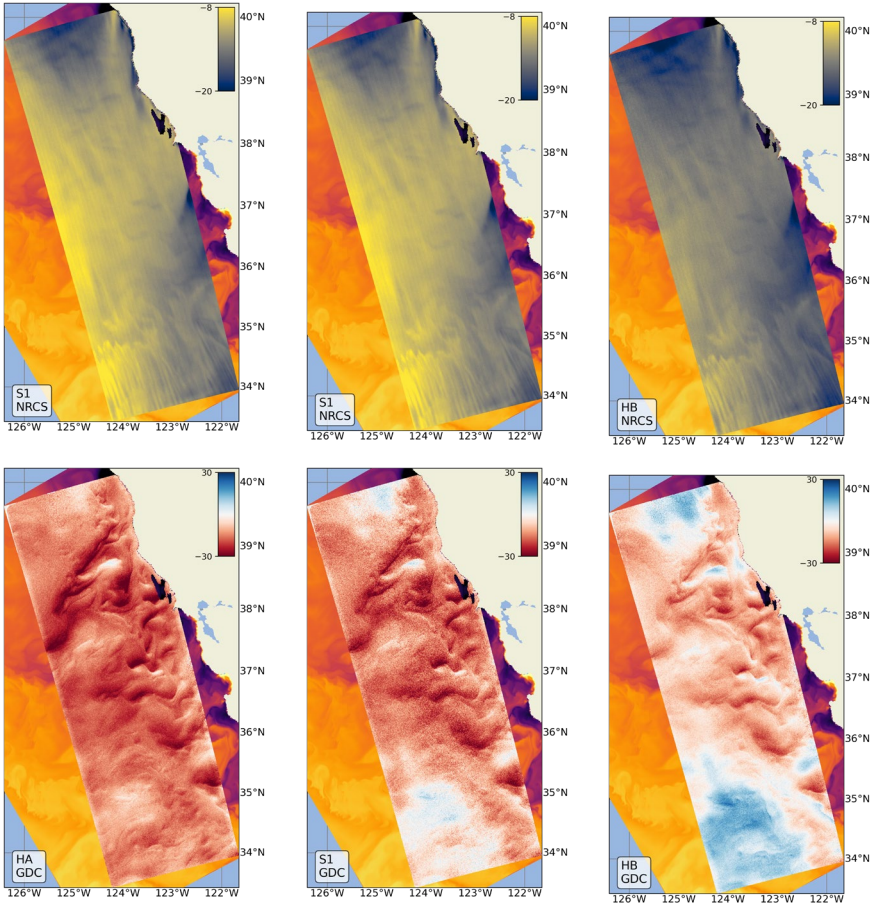


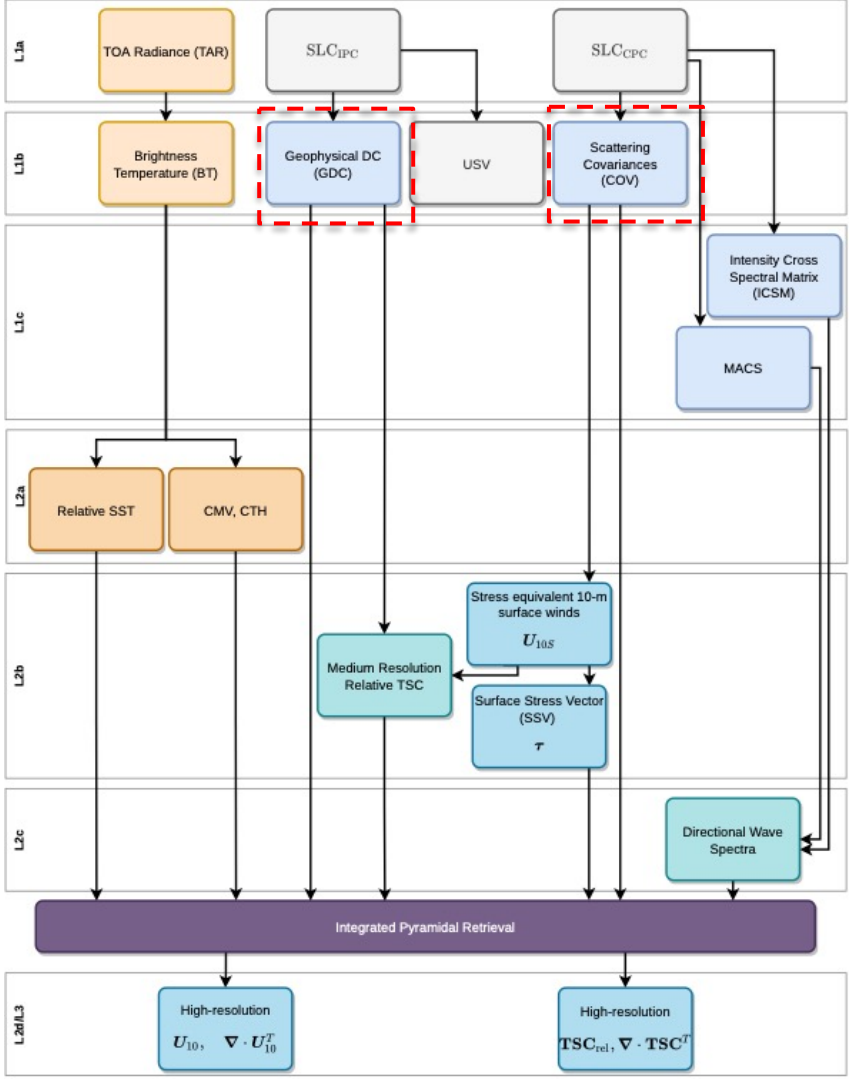
TU Delft

Example input: California Coastal System ROMS



For oceans & air-sea: L1b-c

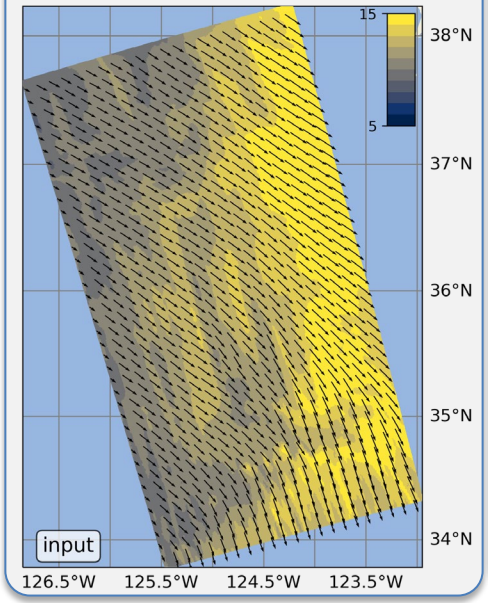




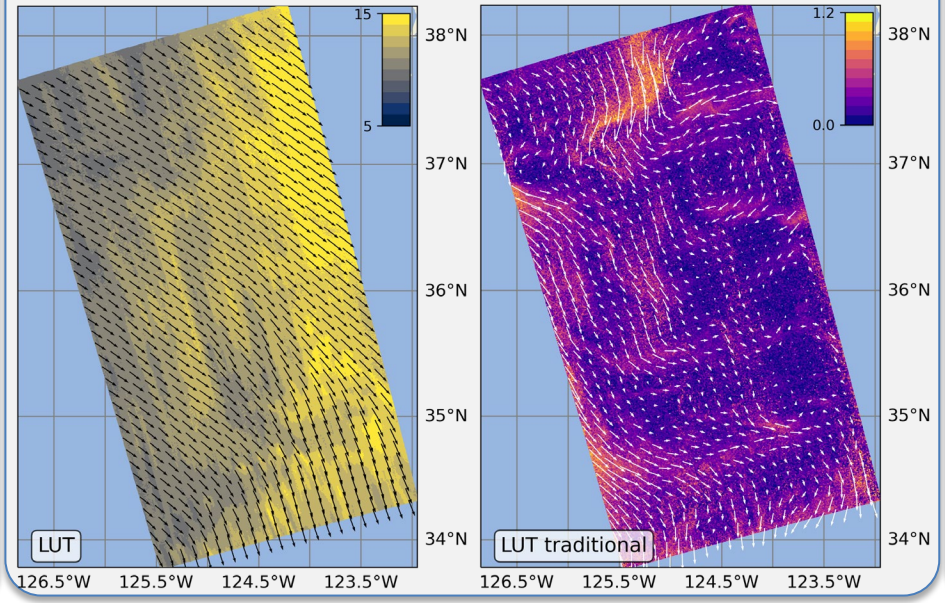
TU Delft

Retrieval

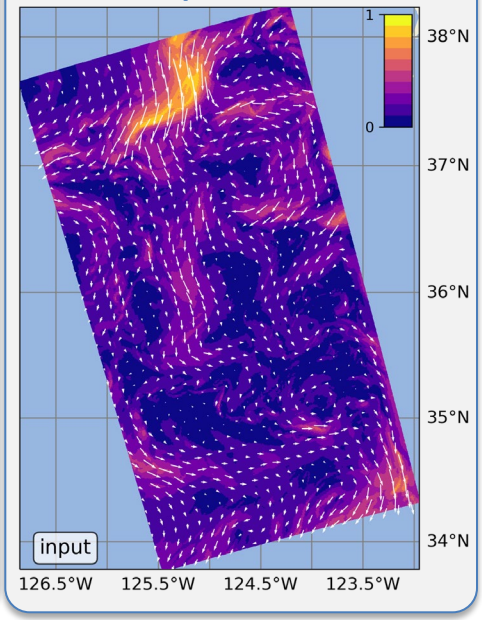
Input U_{10s}



Naive GMF-based forward/inverse



Input TSC

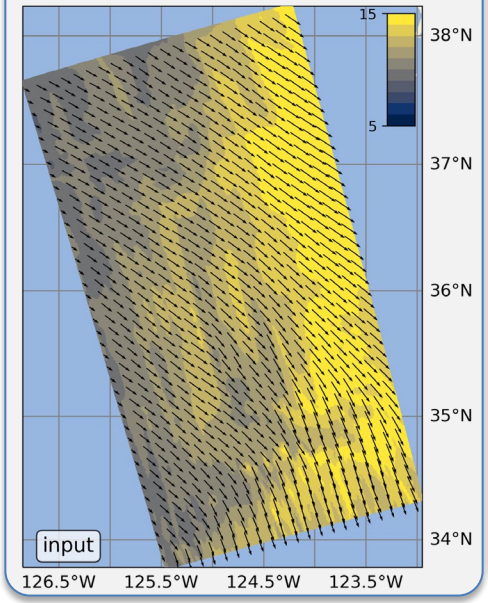


Instrument (SNR, geometry) performance:

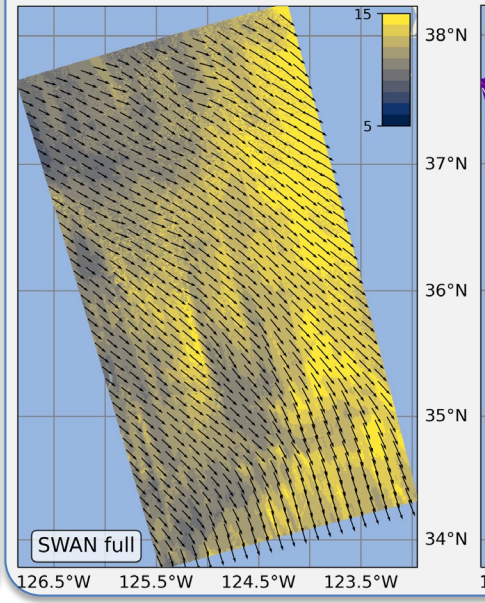
- TSC: O(15 cm/s) at 2x2 km^2
- U_{10s}: O(5%) at 1x1 km^2

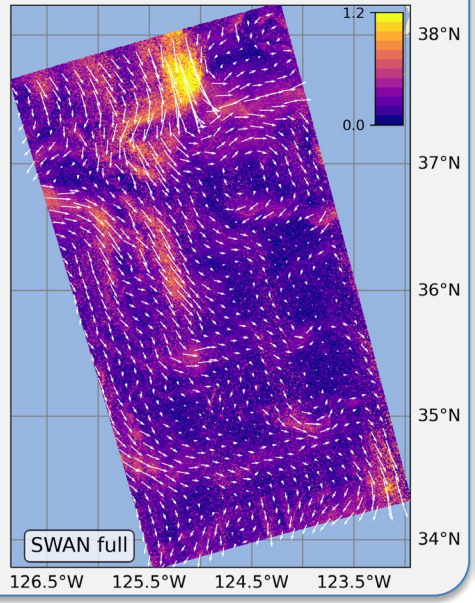
Retrieval

Input U_{10s}

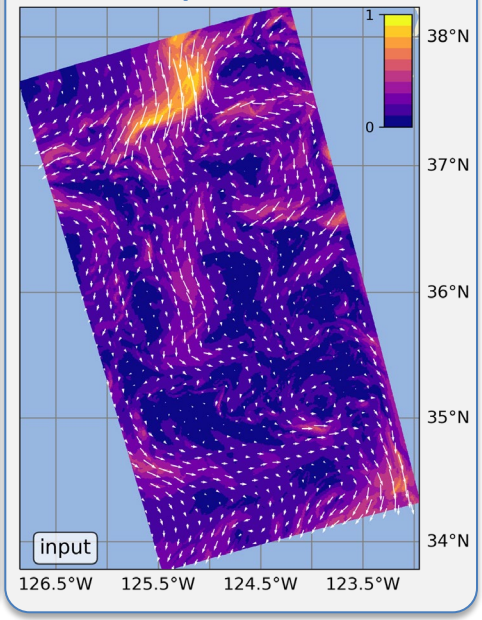


Full forward, best-effort retrieval



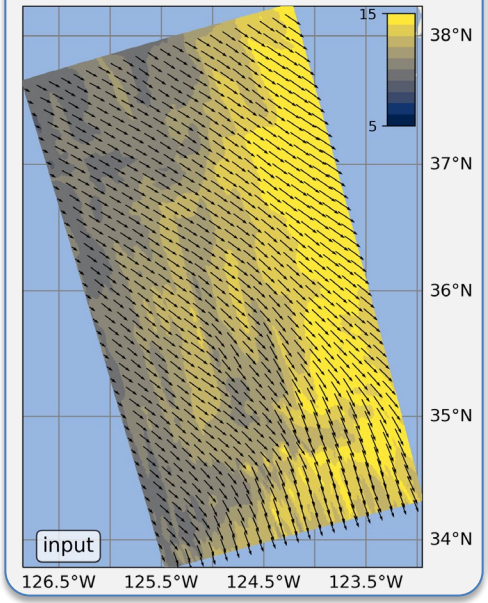


Input TSC

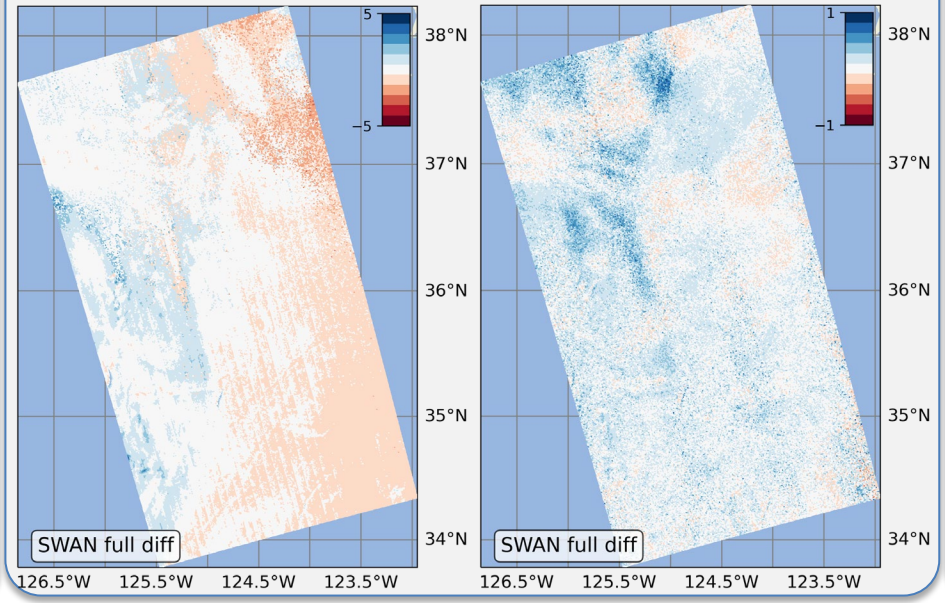


Retrieval

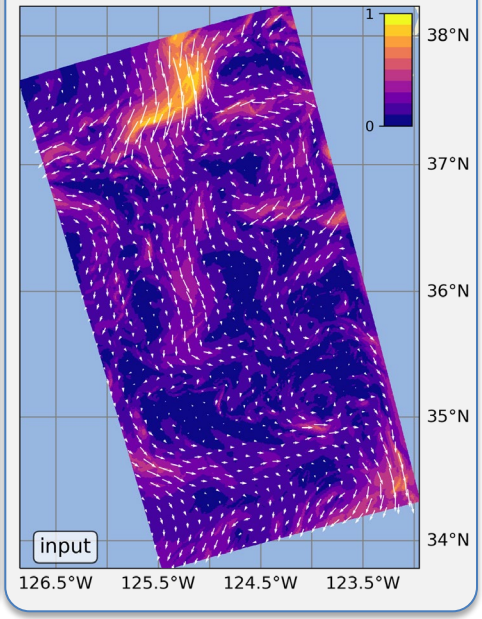
Input U_{10s}



U_{10s} and TSC magnitude errors



Input TSC



- Performance mostly limited by difficulties in inversion near strong gradients.
- To be expected, but to be worked on.

Challenges for ocean and air-sea applications

System level

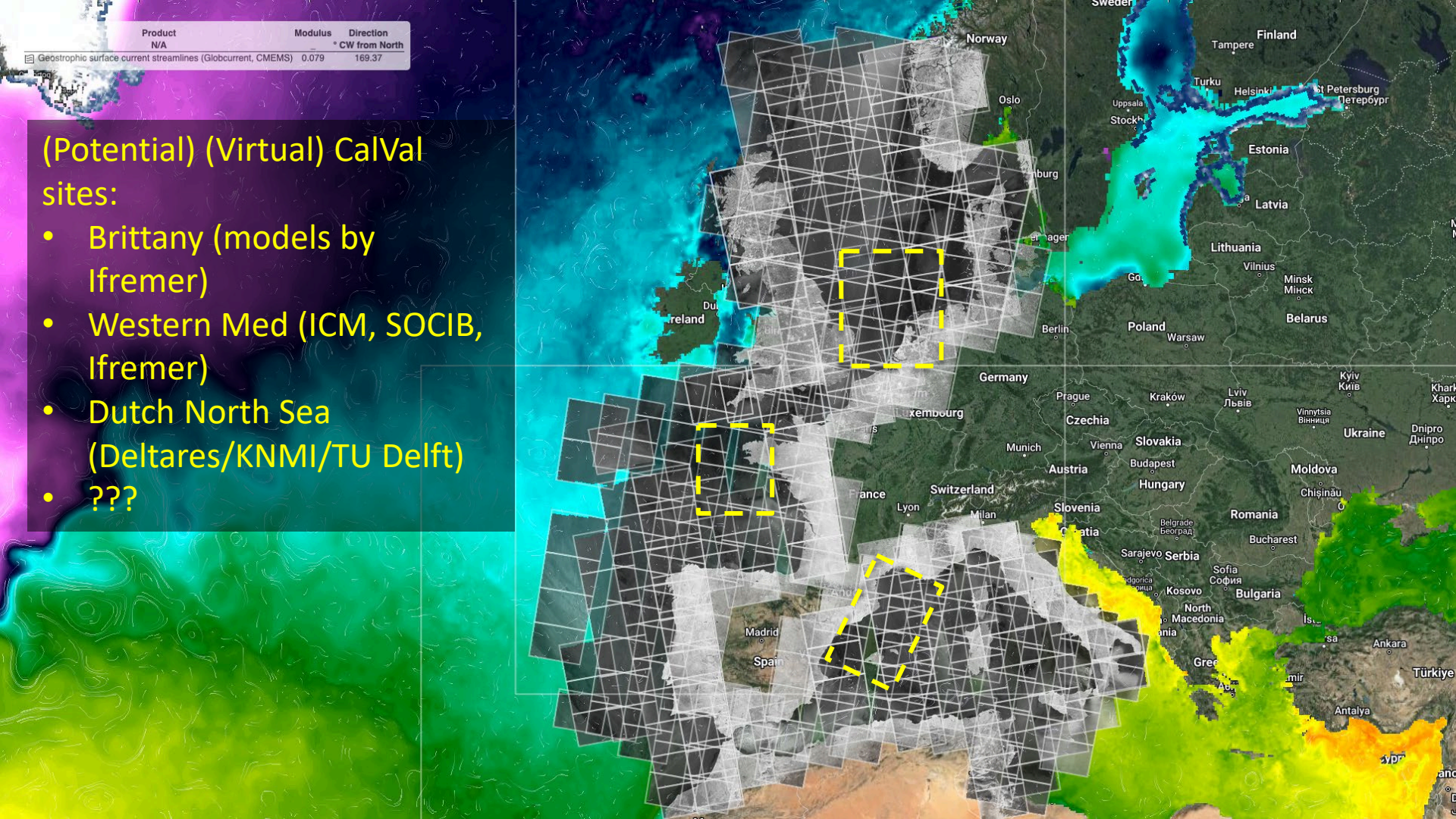
- Pointing → ATI phase errors → Velocity errors
- Synchronization
- Calibration → wrong NRCS → biased U_{10s}

Science (inversion)

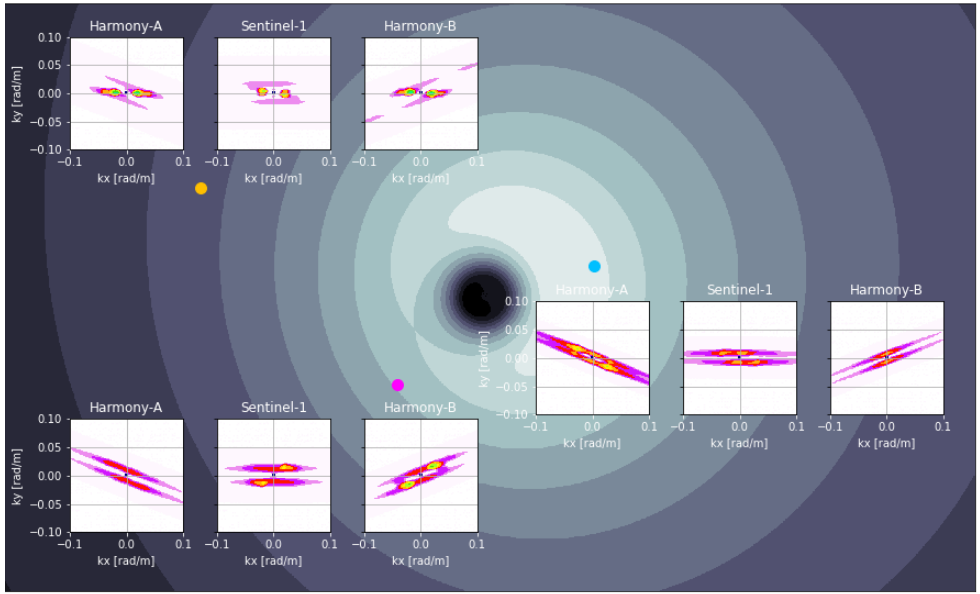
- Lack of accurate Geophysical Model Functions:

$$\vec{\sigma}_0, \vec{v}_{\mathrm{Dop}} = \mathrm{G}(\vec{U}_{10s}, \vec{V}_{\mathrm{TSC}}, \text{wave age}, \ldots, \text{geometry})$$

- Corresponding uncertainty in inversion
- Residual calibration issues


Product
N/A
Modulus
Direction
° CW from North
Geostrophic surface current streamlines (Globcurrent, CMEMS) 0.079 169.37
(Potential) (Virtual) CalVal sites:
• Brittany (models by Ifremer)
• Western Med (ICM, SOCIB, Ifremer)
• Dutch North Sea (Deltares/KNMI/TU Delft)
• ???
Norway
Oslo
Finland
Tampere
Turku
Helsinki
Uppsala
Estonia
Latvia
Lithuania
Vilnius
Minsk
Belarus
Poland
Warsaw
Berlin
Germany
Prague
Kraków
Lviv
Czechia
Slovakia
Ukraine
Munich
Vienna
Budapest
Austria
Hungary
Moldova
Switzerland
Lyon
Milan
Slovenia
Romania
Bucharest
Belgrade
Sarajevo
Serbia
Sofia
Bulgaria
Kosovo
North Macedonia
Madrid
Spain
Ankara
Türkiye
Antalya

Also for ocean-atmosphere extremes



Potential observations of the TC core

Potential observations of a TC wake