DopSCA ?

ESA MOMS project

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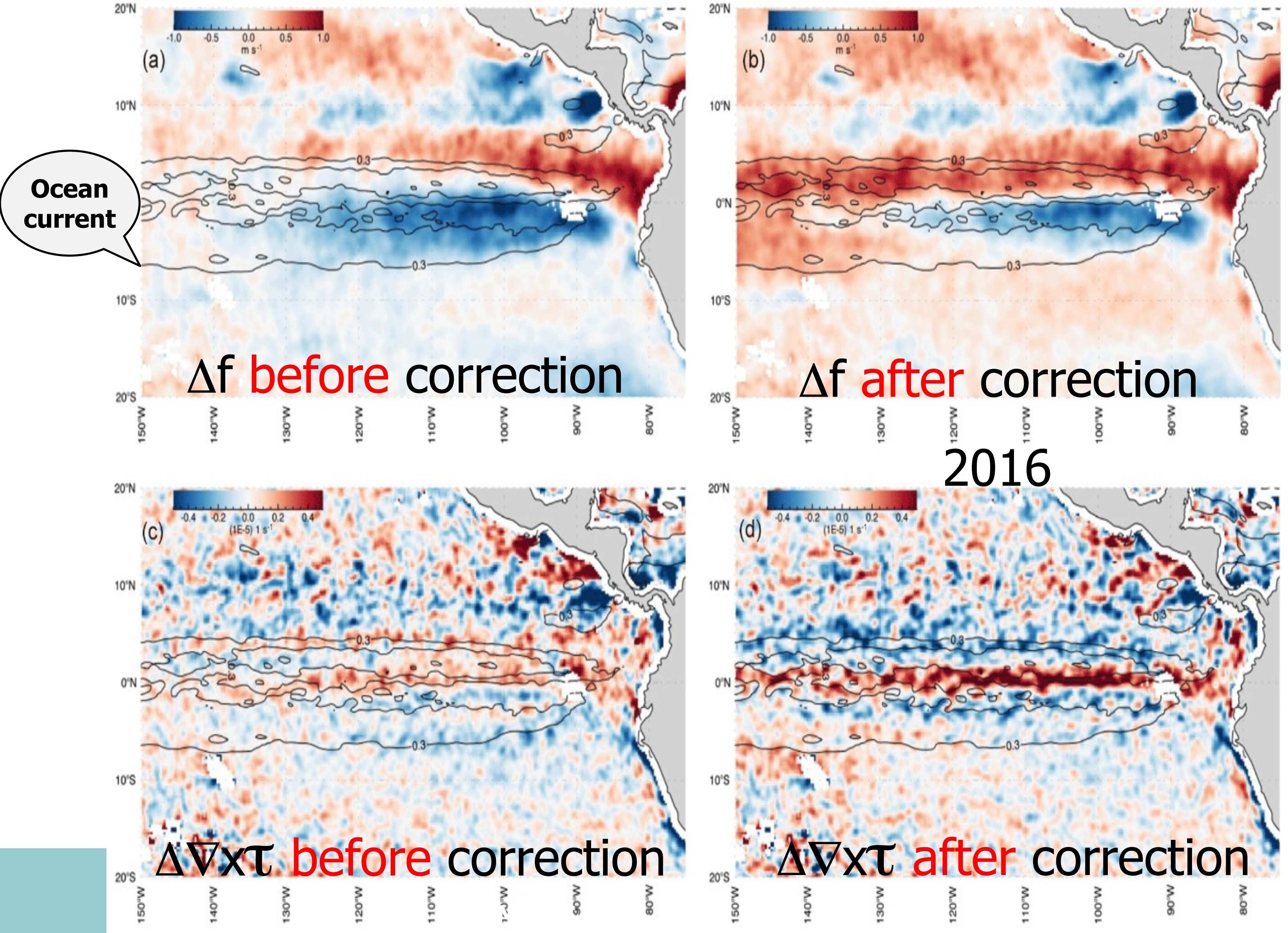
Recap Ocean motion with DopSCA

- The high-quality scatterometer SCA vector winds are used to estimate local wave motion (drift and variance), such that ocean current residual remains
- The digital signal transmitter allows DopSCA waveforms (dual chirps)
- Pointing knowledge may be proven adequate (TBC on ASCAT)
- First simulation studies now provide a feasible concept on SCA with marginal, but potentially useful accuracy, e.g., in hurricane wind conditions or for monthly climatologies
- DopSCA campaign(s) may be envisaged?
- ESA DopSCA study ongoing (MOMS)
- Uses SCA instrument as it is, but needs additional resources for configuration and processing

- A Doppler view is an ocean motion vector component
- Waves are the main source of ocean surface motion
- Ocean current can be estimated if waves are known
- Waves depend on the wind and wave motion may be estimated from wind; SCA has excellent winds

What do we really know about Ocean Currents?



- ❖ Corrected with Copernicus Marine Service currents
- ➢ Errors increase after correction, while they appear closer associated with current gradients
- ➢ Variances on m/s level, not cm/s
- ➢ Currents are not well measured and we understand little about them ☹
- ➢ Very relevant in the tropics to understand climate dynamics, El Nino, MJO, etc.
- ➢ Any measurement helps? DopSCA?
- ➢ Recently also tested ERA6 prototype

Belmonte Rivas and Stoffelen (2019)

Wind Vector Cell Doppler requirements

- SCA exists and will not be changed; DopSCA is a “no-cost” opportunity

Instantaneous direct measurements with Doppler scatterometer

	‘threshold’	‘breakthrough’	‘goal’
random error, σ	~ 1 m/s *	~ 0.5 m/s *	~ 0.05 m/s *
bias	~ 0.3 m/s *	~ 0.15 m/s *	~ 0.015 m/s *
geographical coverage	same as for U_{10s} winds	same as for U_{10s} winds	same as for U_{10s} winds
temporal coverage	same as for U_{10s} winds	same as for U_{10s} winds	same as for U_{10s} winds
spatial resolution	~ same as for U_{10s} winds *	~ same as for U_{10s} winds *	~ same as for U_{10s} winds *
temporal resolution	same as for U_{10s} winds	same as for U_{10s} winds	same as for U_{10s} winds
data timeliness	same as for U_{10s} winds	same as for U_{10s} winds	same as for U_{10s} winds

*: tentative

- Feedback is much appreciated!
  Contact me for MOMS TNs on requirements and specifications

From ASCAT coverage

- Other space-time averages are feasible
- One SCA has 10% more coverage than ASCAT
- Wave motion is taken out instantaneously by the best possible wind proxy (0.5 m/s vector RMS cf. Vogelzang, 2022)
- This leaves a current residual with the smallest possible error
- This error is dominated by SCA (not a dedicated ocean current instrument)
- However, over 20 days currents with SCA can be determined with 6 times smaller SDE by combining 30-40 samples
- This needs to be further explored in MOMS

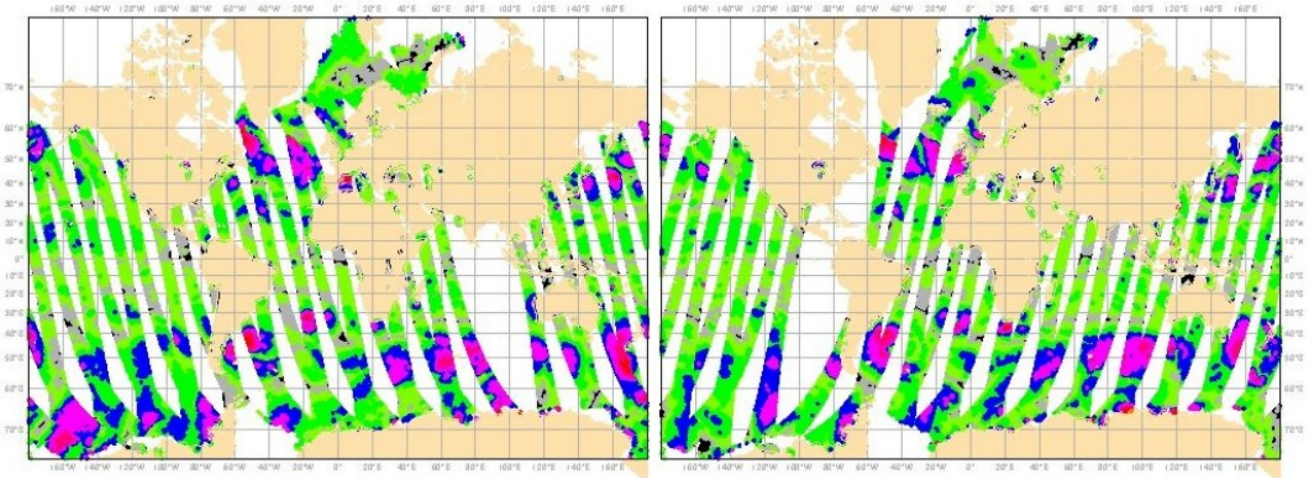


Figure 4: OSI SAF ASCAT-B Coastal product: figures using 22 hours worth of data from Ref. [34], and showing ascending (*left*) and descending (*right*) passes separately. Copyright (2024) EUMETSAT.

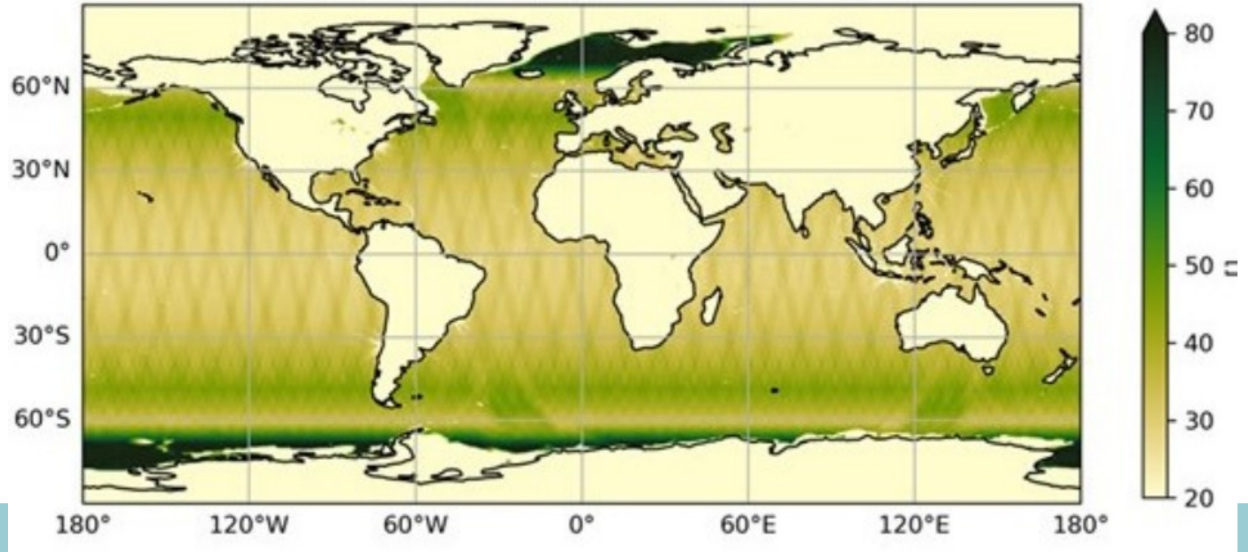
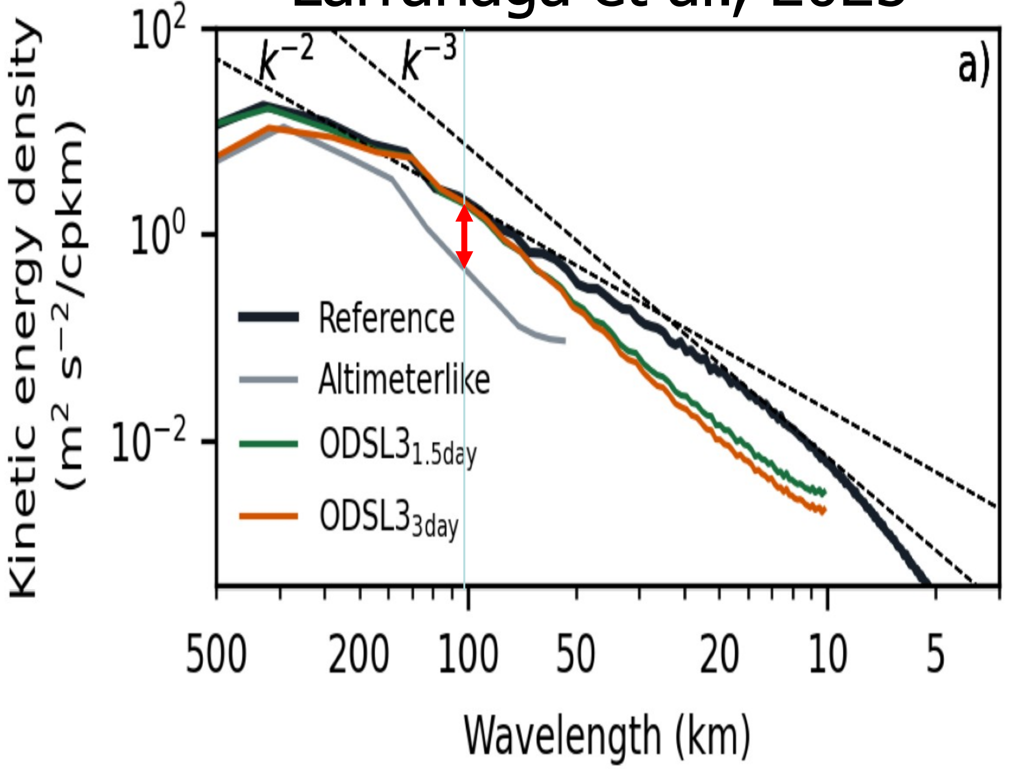


Figure 6: The number of observations for 20 days of ASCAT(0.25 deg.)

Other Doppler missions

Larrañaga et al., 2025



- SCA follow-on in the 2050 time frame
- SeaStar Earth Explorer, not selected by ESA
- NASA/CNES Odysea, proposed
- Harmony Earth Explorer selected by ESA, S1 coverage
- OSCOM by China, CFOSAT follow-on

- Typical limitations are :
  - Poor winds to estimate wave motion component
  - Limited coverage
  - Limited resolution
  - Limited accuracy
- Much synergy between approved missions, as no direct measurements exist yet

Complementarity with SCA

OSCOM (perhaps Odysea, CFOSAT FO)

- More accumulation over a given period
- SCA works in rainy regions
- OSCOM may be a SCA reference for OSVC

Harmony

- Not a global mission, an explorer
- Scenes with high resolution for underlying ocean km-scale processes
- SCA is reference for calibration and vector winds

DopSCA opportunities under study

To be done

- Pulse shape and power (wave form) optimization?
- Pulse sequences?
- Processing chain development
  - Wind use for Doppler?
  - Doppler use for winds?
  - Check oscillator stability over pulse length
  - . . .

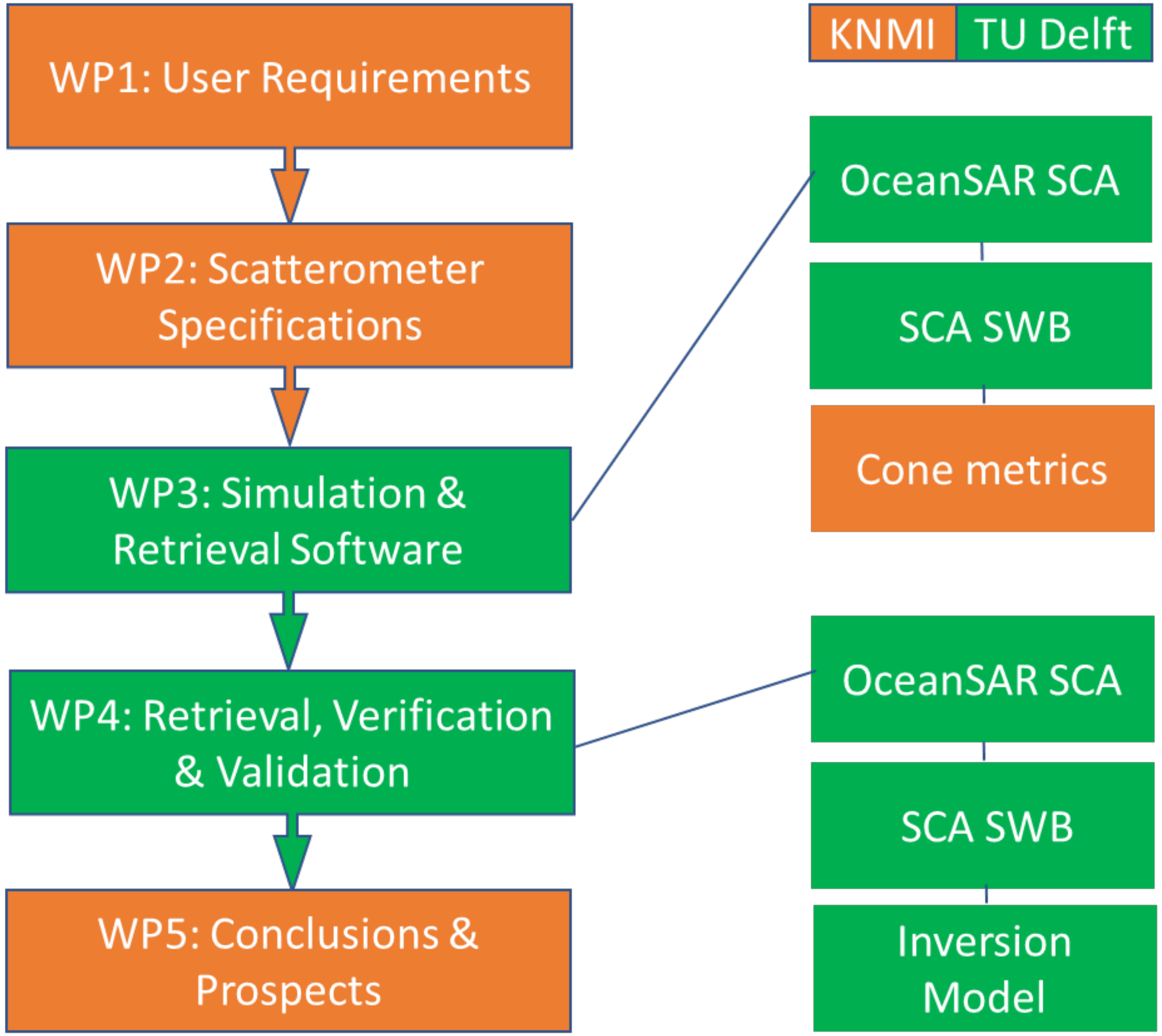
Operations

- Continuity of the SCA wind mission is prime!
- Explore further use of pulses and prove (limited) loss of wind quality or resolution
- Discuss possible technical trade-offs with SCA SAG and SCA experts at EUMETSAT, ESA

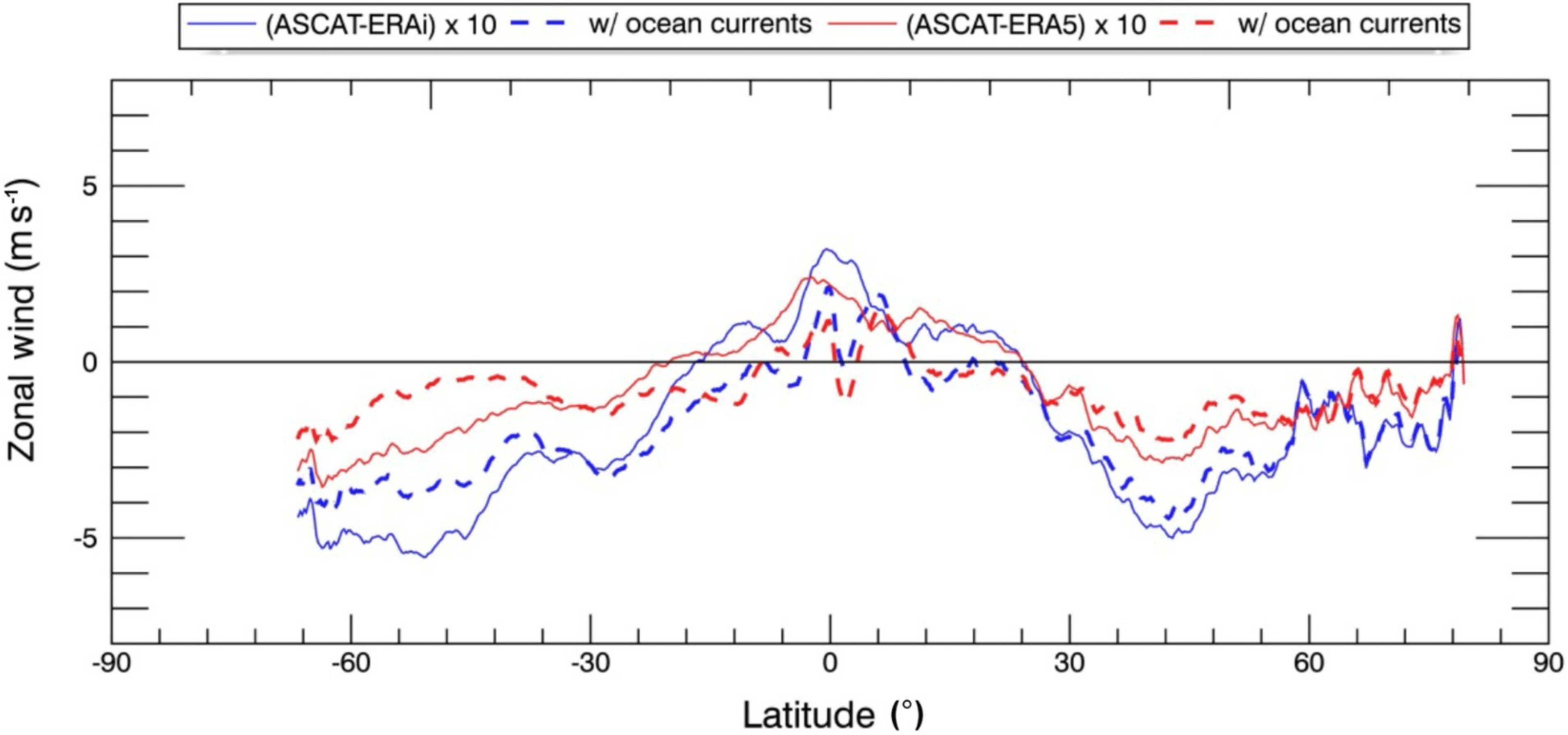
- Prepare a proposal for EUMETSAT member states for DopSCA

Backup slides

MOMS WP overview

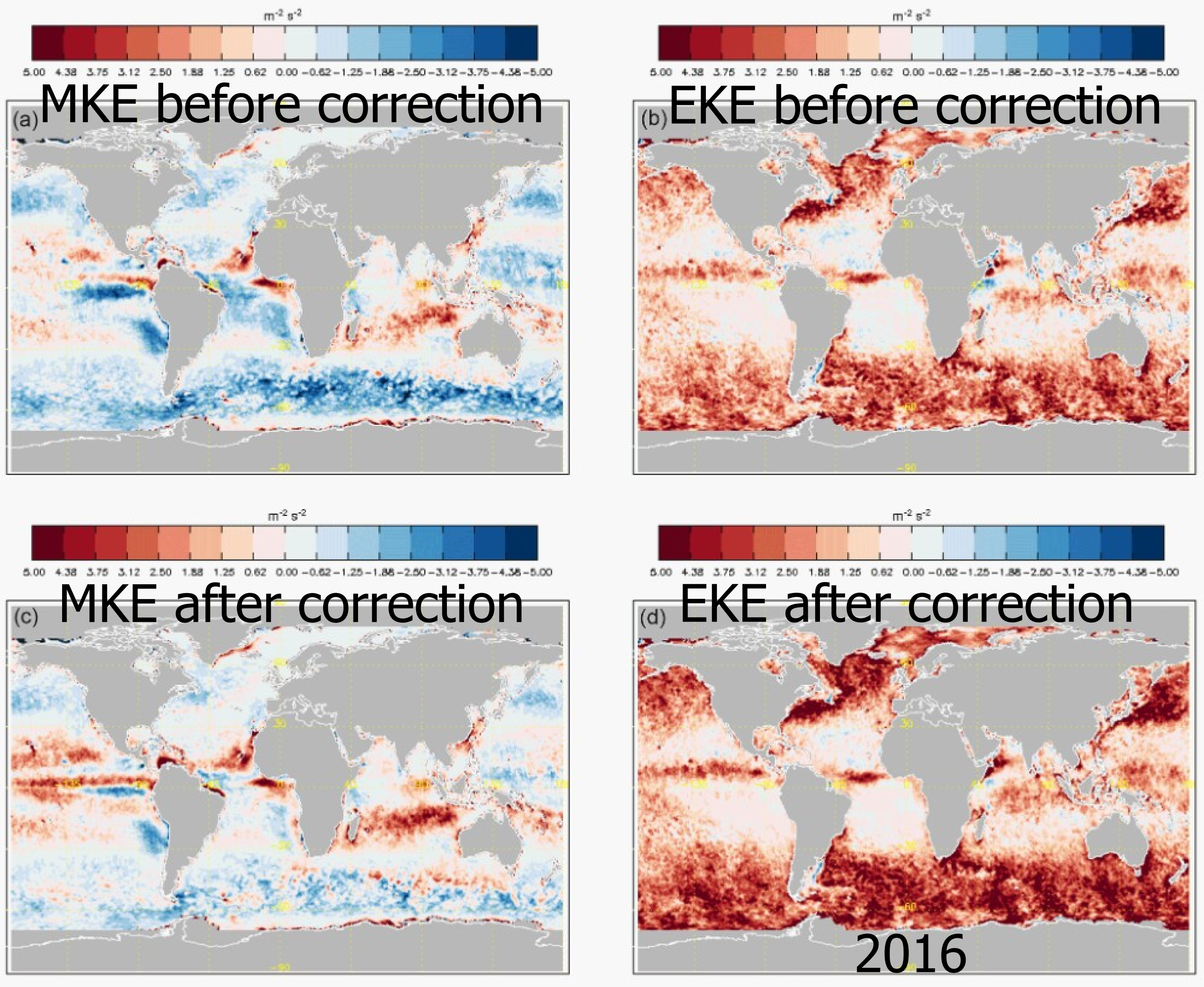


What do we really know?



- Copernicus Marine Service mean ocean currents typically reach 0.2 m/s
- Basin-scale biases are (only) partially removed

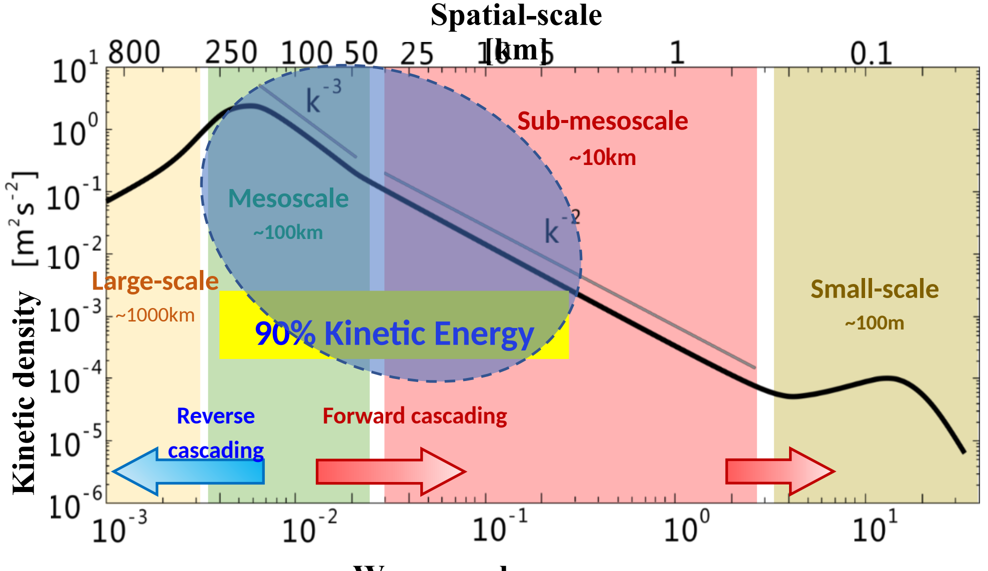
What do we really know about OSC?



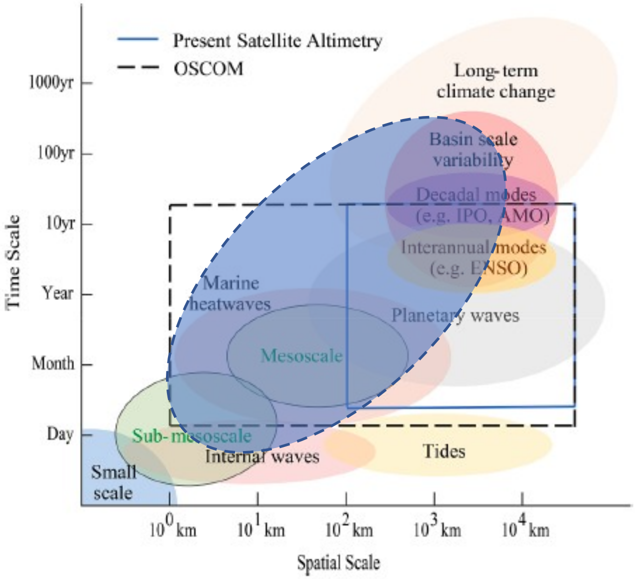
- These currents generally deteriorate the deterministic differences between scatterometer and ERA5 model
- Variances on m/s level, not cm/s

Ocean Surface Current multiscale Observation Mission (OSCOM)

Scientific issues: ① Multi-scale dynamical process interaction and energy cascades



D'Asaro et al., 2011, **Science**

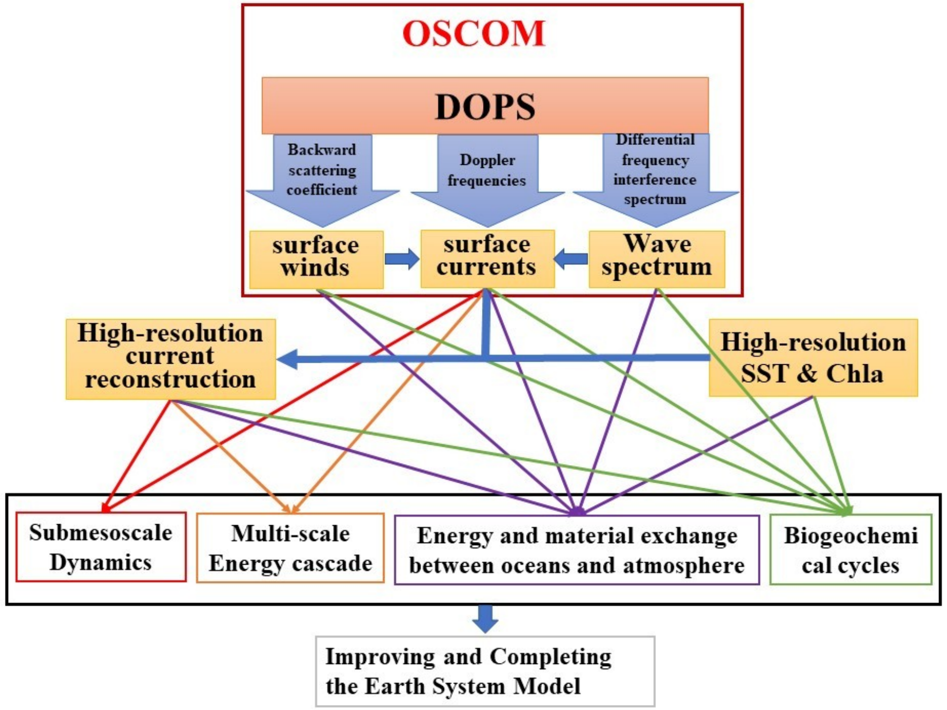


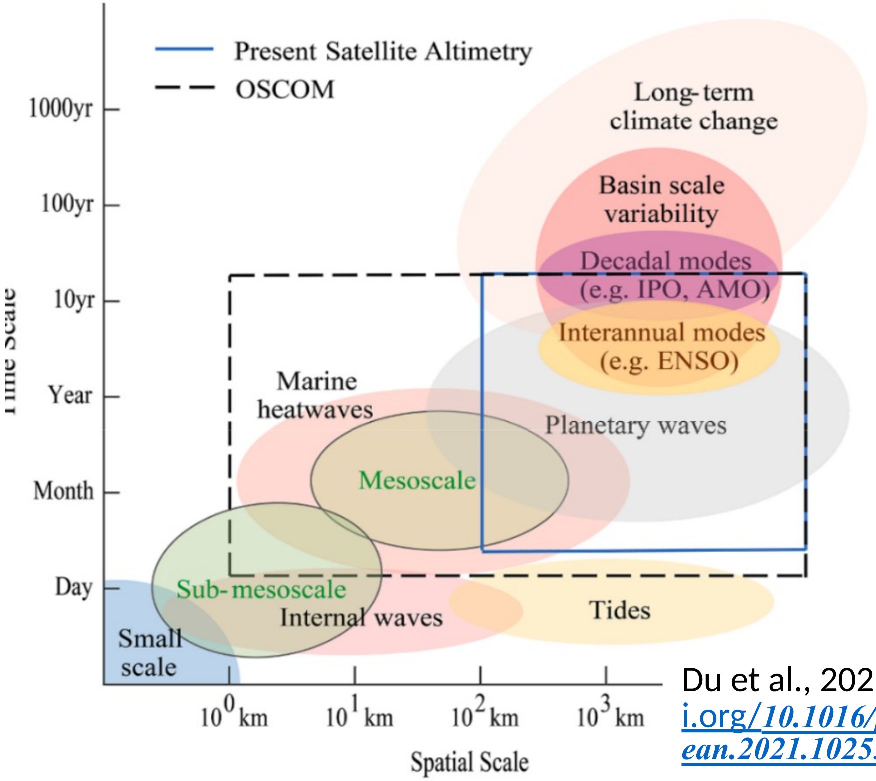
- How to separate multi-scale processes in the global ocean surface total currents?
- What constitute the unbalanced ocean dynamic processes?
- How do mesoscale and sub-mesoscale processes in the ocean interact with each other and transform energy?
- How does the energy of surface wind input and convert to ocean currents and waves?

Ocean Surface Current multiscale Observation Mission (OSCOM)

Requirement and Achievement

OSCOM will directly measure ocean surface currents with a very **high horizontal resolution of 5–10 km and a 3-day global coverage**. The **accuracy of currents is 0.1m/s** in speed and 15° in direction.





Du et al., 2021 doi.org/10.1016/j.pocean.2021.102531

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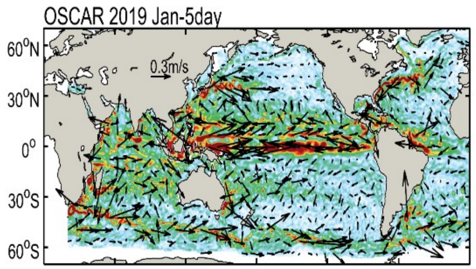
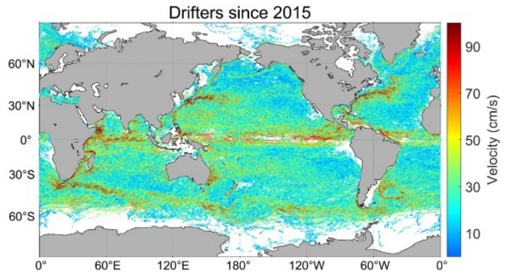
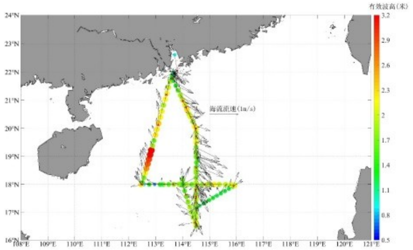
Ocean Surface Current multiscale Observation Mission (OSCOM)

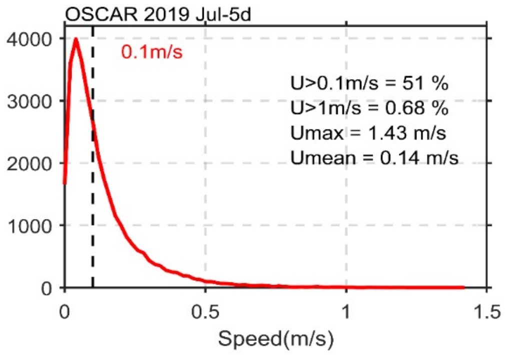
Global ocean surface velocity: OSCAR, Argos, ADCP, Radar

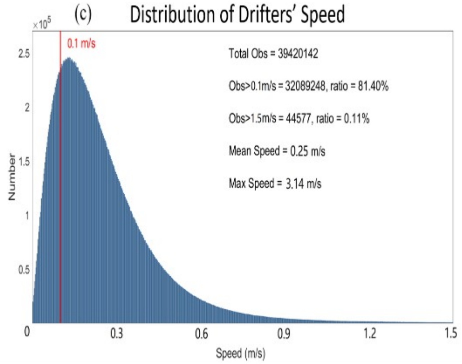
- 5-day mean OSCAR currents: Currents with speed ≥0.1m/s account for 51% of the global currents
- 6-hour mean Argos currents: Currents with speed ≥0.1m/s account for 81% of the global currents
- **In-situ observed currents (2021): Currents with speed ≥0.1m/s account for 95% of the currents**

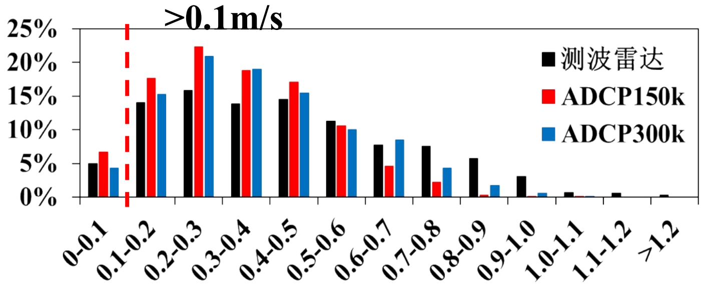






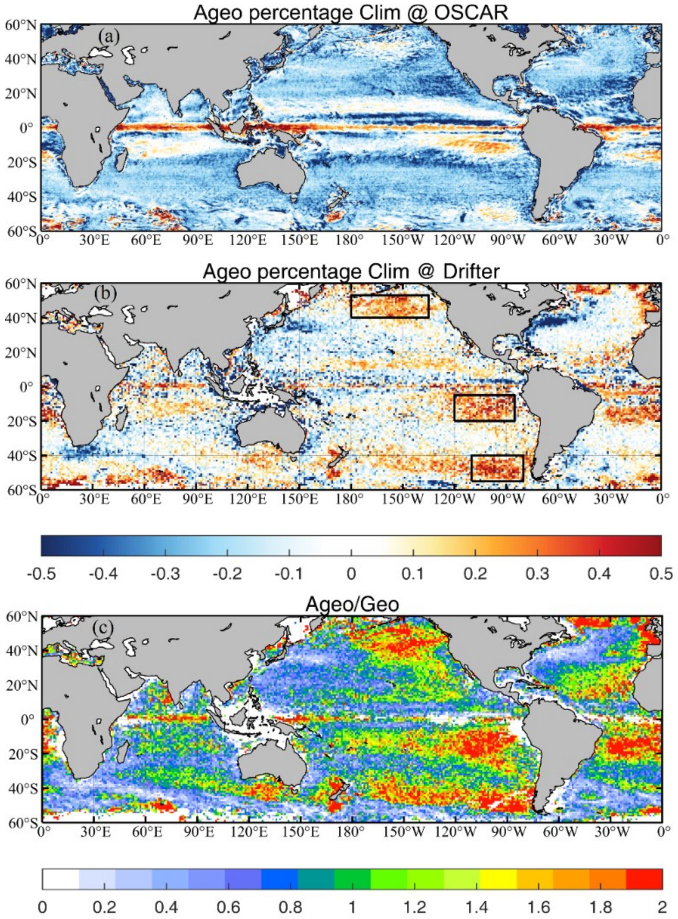




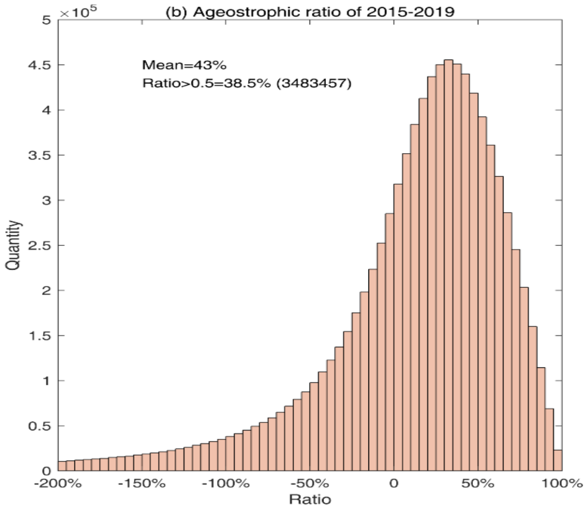


Ocean Surface Current multiscale Observation Mission (OSCOM)

Importance of the non-geostrophic currents



- The non-geostrophic currents determine the directions of the total currents in the near-equatorial trade winds and mid-latitude westerly winds prevailing regions, where the maximum non-geostrophic speed can reach twice the geostrophic speed and exceed 60% of the total current.
- The OSCAR data cannot reveal the non-geostrophic processes in these regions and underestimate the weakening effect of the non-geostrophic process in the strong western boundary currents and the Antarctic Circumpolar Current.



- **The non-geostrophic currents in the global ocean account for ~43% of the total current**

$$P_1 = \frac{|S| - |S_G|}{|S|}, P_2 = \frac{|S| - |S_G|}{|S_G|}$$

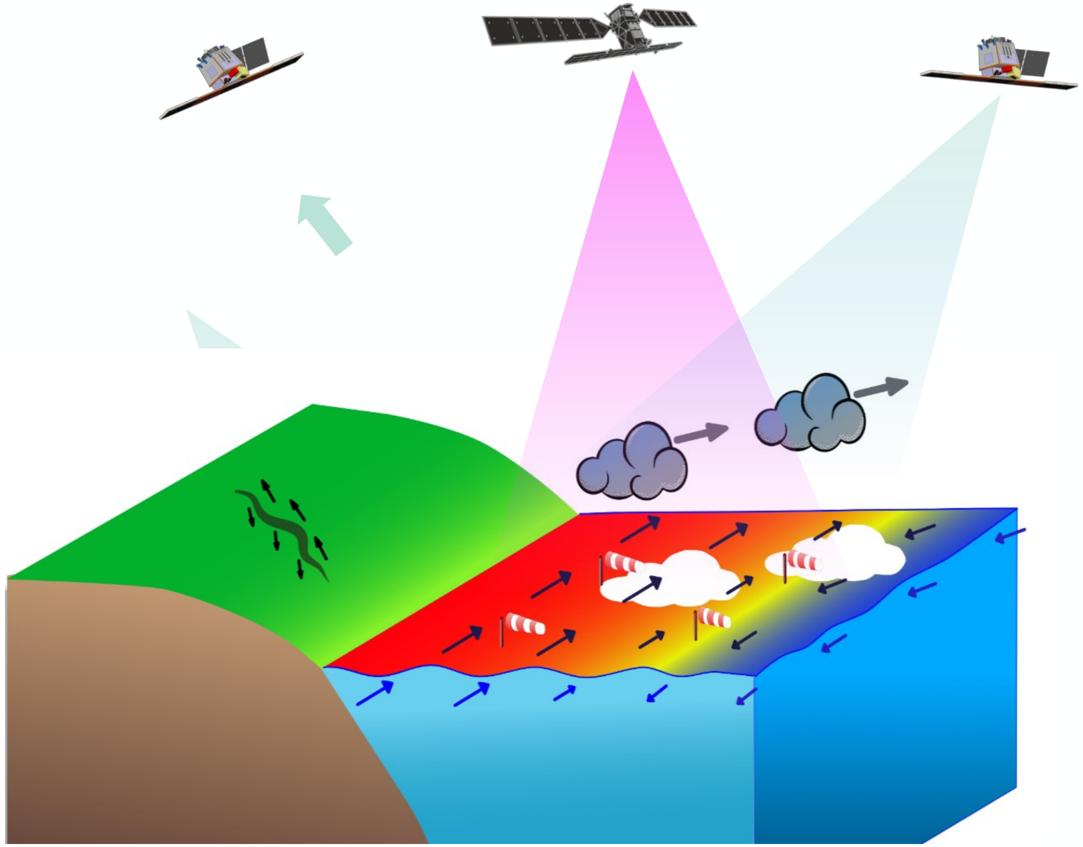
EE10 HARMONY observation concept: stereo phase

Exploit Sentinel-1

Add tandem satellites

Line-of-sight diversity for **high resolution (km)**

- Ocean surface **vector** motion (Doppler)
- Surface **vector** winds (scatterometry)
- Improved directional surface **wave spectra**
- Sea Surface (skin) Temperature (**SST**)
- Cloud-top **motion** (TIR time-lapse) and **height** (TIR parallax)
- Sea Ice / cryosphere application
- 3-D surface deformation (DInSAR)



Approved for 2029

- Focus on km-scale processes
- Regional explorer mission
- Limited calibration for NRCS/Doppler

Ocean Surface Current multiscale Observation Mission (OSCOM)

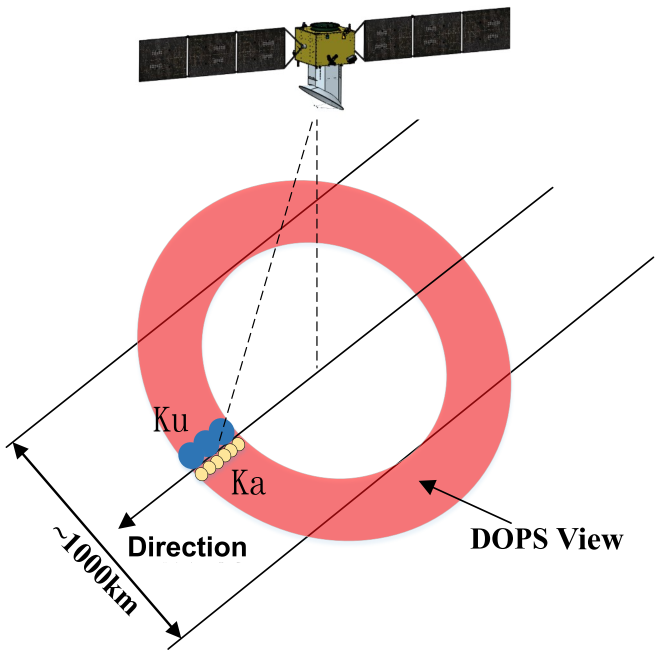
Configurations and measurement principles

Payload: **Doppler Scatterometer (DOPS)**

Variables:

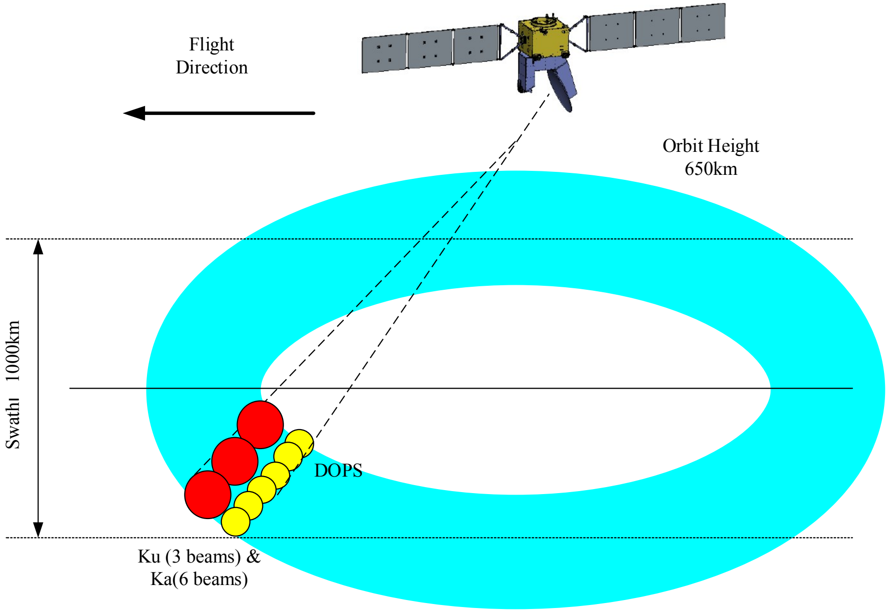
Ocean surface currents (OSC) ,
Ocean surface vector winds (OSVW),
Ocean surface wave spectrums (OSWS)

Parameter	Values
Wave band	Ka+Ku
Polarization mode	Ka： VV Ku： HH 、 VV
Swath	＞1000km
Resolution	5km （OSC, OSVW） 10km （OSWS）
Accuracy	0.1m/s （OSC） 1.5m/s （OSVW） 15° （OSC， OSVW）
Rotating speed	~15rpm
Antenna diameter	1.5m

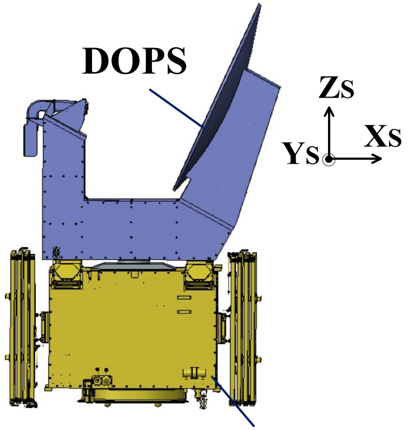


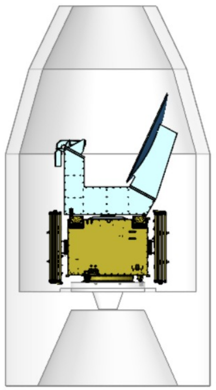
Ocean Surface Current multiscale Observation Mission (OSCOM)

Ka & Ku Dual Frequency Doppler Scat onboard OSCOM



Payload	Payload Parameter	Technical Indicator
Ka+Ku DOPS	**Dual Band：Ka+Ku; incidence: 46°-49°; Polarization: Ka-band: VV, Ku-band: HH & VV;**	**Resolution ：** 5 km (OSC, OSVW) **Swath：** >1000 km **Accuracy:** 0.1m/s (OSC) ≤15° (OSC, OSVW)





The main system parameters are shown in Table I.

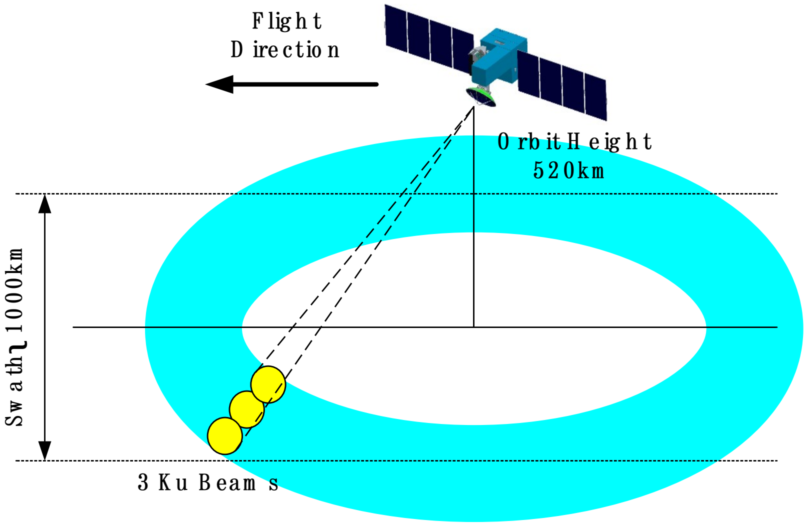
Table I System Parameters of Airborne Doppler Scatterometer

Incidence Angle	50°
Flight Height	3000m
Carrier Frequency	35.9GHz
Signal Bandwidth	5MHz
Signal Form	Chirp Signal
Pulse Width	4us
Pulse Interval	4us
Central Frequency of IF	14MHz
Sampling Frequency	56MHz
Pulse Period	100us
Antenna Rotation Speed	40°/s

Burst

CFOSAT follow-on DopSCAT proposal

Ku band Doppler Scat onboard Wind-Wave Satellite



Payload	Payload Parameter	Technical Indicator
Ku-DOPS	**Frequency**: **13.256GHz (Ku); incidence: 46°-49°; Polarization: HH &VV;**	**Resolution**: 12.5 km (OSC, OSVW) **Swath**: >1000 km **Accuracy:** 0.2m/s (OSC) 1.5m/s (OSVW) ≤15° (OSC, OSVW)

- CFOSAT SCAT transmit/receive was thermally unstable
- **Wind-wave Satellite** is the follow-on missions of CFOSAT.
- The Scatterometer will upgrade to Ku band Multi-beam Doppler Scatterometer for the Ocean Surface Current observation.
- Ocean Surface Current accuracy: 0.2m/s
- Resolution, Wind vector accuracy will be improved

Odysea (previously WaCM)

- Pencil beam scatterometers
  - Ku-band (10 km nominal resolution; provided by ISRO)
  - Doppler Ka-band (5 km nominal resolution for winds; JPL)
- Ocean current measurements
  - Spatial resolution: <25 km
  - Temporal resolution: <10 days
  - Vector velocity accuracy: 5 cm/s – 10 cm/s

Limitations

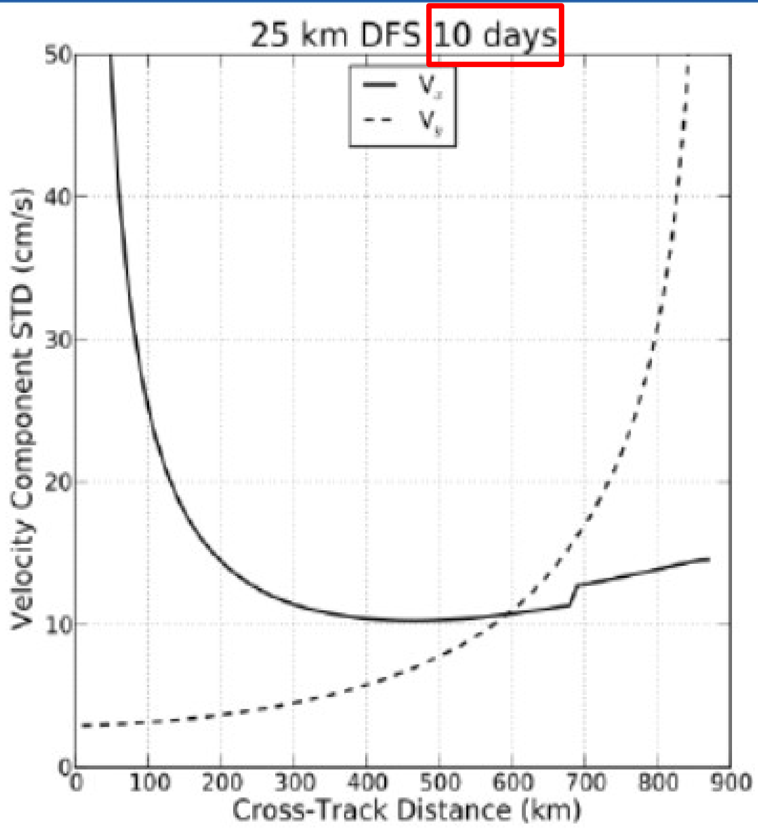
- Not yet approved

- High noise at low winds (tropics)

- Cloud and rain Doppler problem for, e.g., cold pool ocean dynamics

- 10 days averaging

Wind-Averaged Velocity Component Errors at Ku-Band



Ka-band has improved sensitivity by a factor of 2.7

To avoid lack of sensitivity at low wind speeds, restrict surface current (but not wind) retrievals for winds above 5 m/s.

Account for this in the number of samples in 10 days by assuming a Rayleigh distribution for the winds.

Graphic from Ernesto Rodriguez

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RESEARCH ARTICLE | OCEANOGRAPHY

Physics-based early warning signal shows that AMOC is on tipping course

RENÉ M. VAN WESTEN , MICHAEL KLIPHUIS, AND HENK A. DIJKSTRA Authors Info & Affiliations

SCIENCE ADVANCES • 9 Feb 2024 • Vol 10, Issue 6 • DOI: 10.1126/sciadv.adk1189

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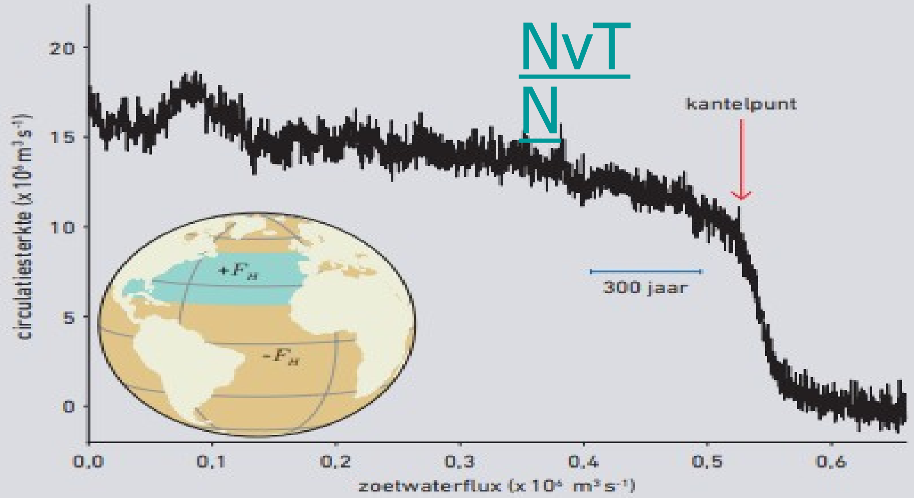
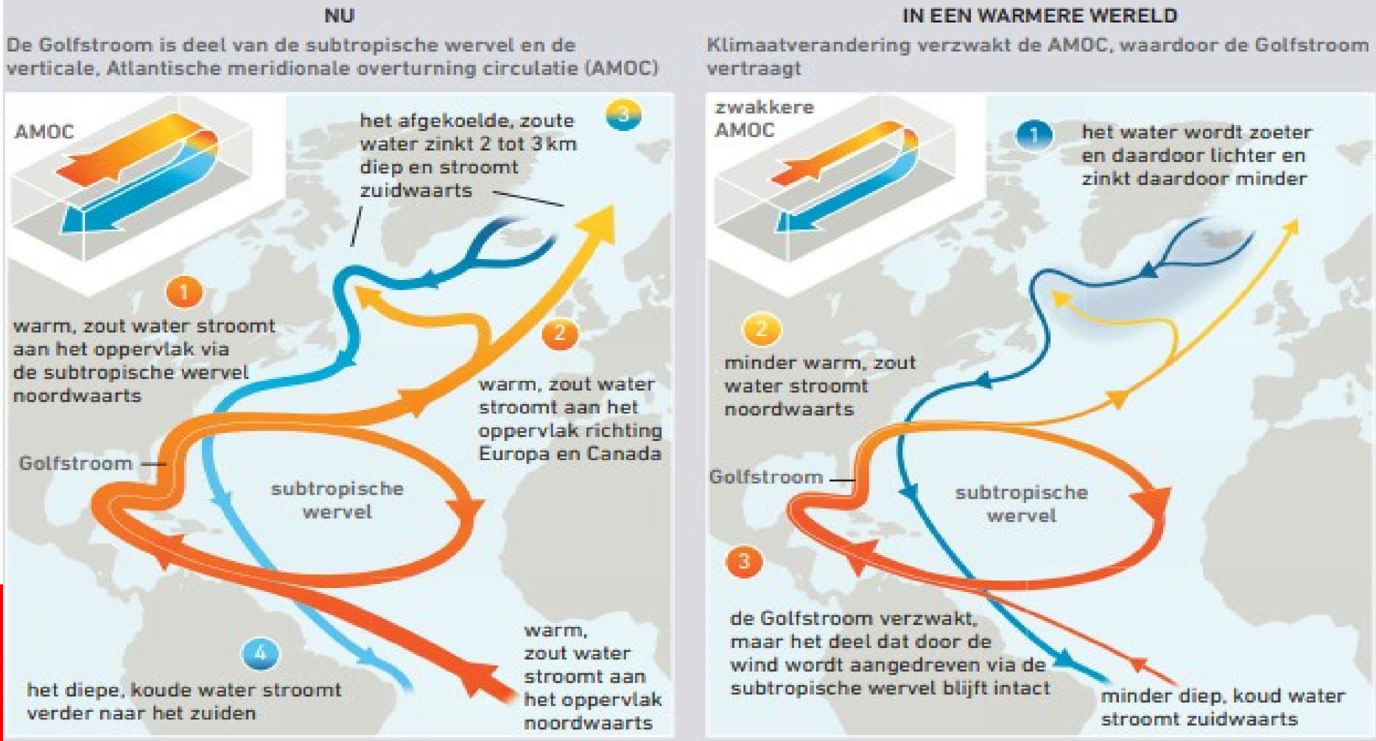


Figuur 2. Verandering van de AMOC-sterkte onder invloed van de toenemende zoetwaterflux in de Noord-Atlantische Oceaan. De inzet laat de gebieden zien waar zoet water wordt toegevoegd ($+F_H$) en dit wordt elders gecompenseerd ($-F_H$) om de zoutbalans van de oceaan constant te houden.

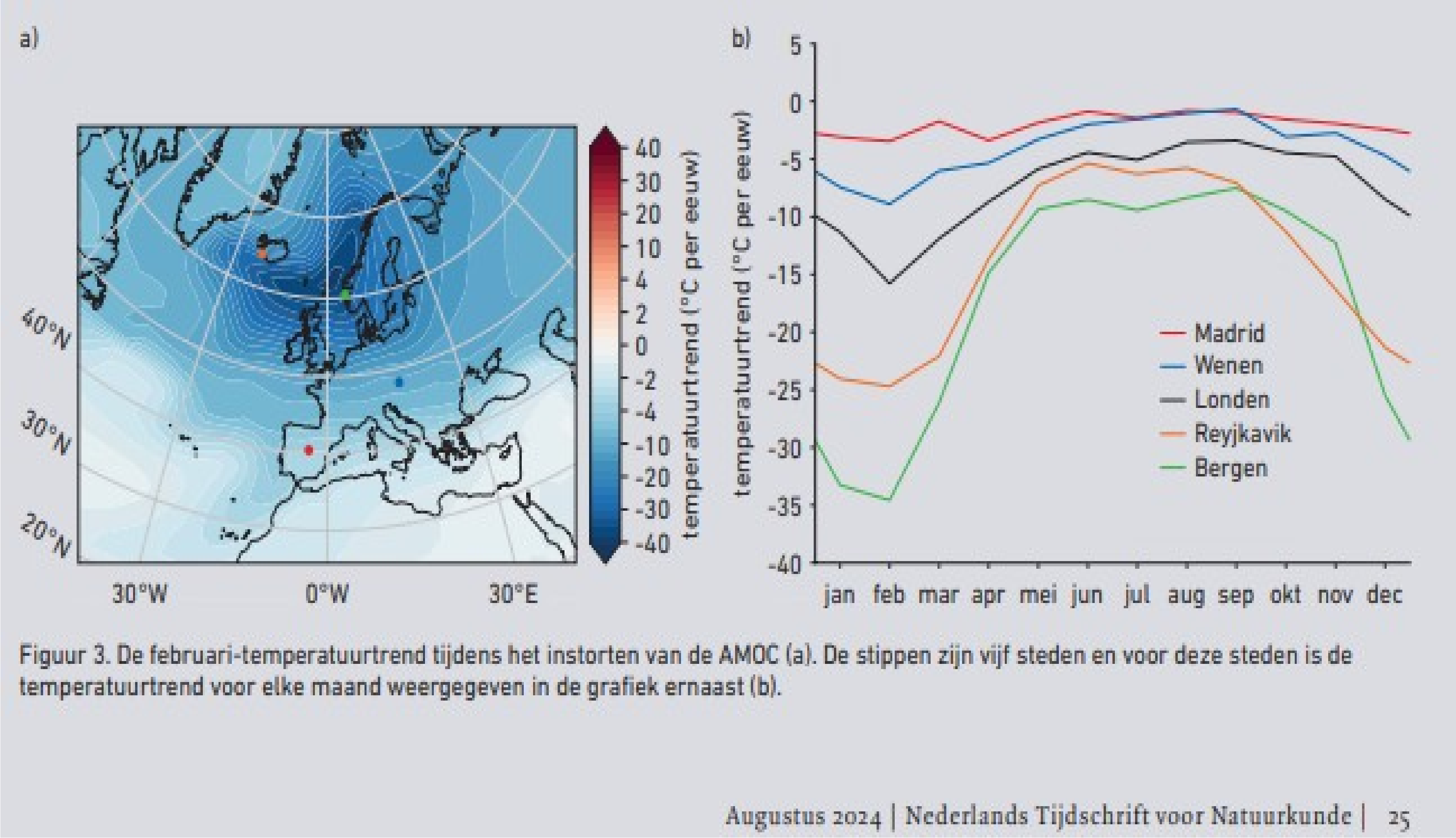
- ➢ Model study to show slowing down process of Atlantic Meridional Circulation (AMOC)
- ➢ Key indicators show that the real world moves towards the modelled AMOC collapse
- ➢ A collapse would happen relatively fast and would be particularly disastrous for Western Europe



Figuur 1. Schematische weergave van de huidige (links) Atlantische Oceaancirculatie en in de toekomst (rechts) als de circulatie sterk verzwakt. De rode pijlen representeren de stroming nabij het oppervlak en de blauwe pijlen op grote diepte [5].

➢ **How to deal with unknown risk & high impact => R&D**

What disaster?



- New model with linear increase in influx of sweet water, triggering the destabilizing mechanism
- More realistic than earlier model runs
- Corresponds to more run-off and melting glaciers (Greenland)
- Implies circulation changes during the onset and collapse
- Earth system dynamics of ocean, atmosphere, cryosphere and land

We really know very little about Ocean Currents

- No direct current measurement system exist yet
- Geostrophic measurements appear unable to inform mesoscale currents
- Much ocean motion is generated by the wind and associated waves, which change rather fast, hence collocated measurements of high-quality wind and current are very beneficial
- Seeing only large-scale currents will be useful to correct coupled atmosphere-ocean models on a timescale of months to years
- Existing requirements appear more based on goals than on thresholds or breakthroughs
- Requirements have been evaluated in ESA MOMS DOPSCA TN1

DopSCA simulation

Peter Hoogeboom, Emeritus TU Delft

- Dual chirp of approximately 0.115 ms, separated by approximately 0.011 ms
- Echo cancellation

Time delay between transmit pulses in ms	Precision in m/s Combined pulse responses	Precision in m/s Echo cancelled pulse responses	Precision in m/s Echo cancelled pulse responses, 50 x50 km WVC
0.115	1,23	0,80	0,39
0.1265	1,09	0,67	0,34
0.138	1,02	0,72	0,37
0.1495	1,03	0,73	0,36
0.161	1,04	0,84	0,42

- The result shows that it should be possible to obtain 0.5 m/s precision on the surface for a single 50 x 50 km WVC
- SCA will be 15 km spatial resolution and other space-time averages are feasible
- Now simulated in an a more realistic simulator in the ESA MOMS DopSCA project