DopSCA

ESA MOMS project

Ad.Stoffelen@knmi.nl
Alexandre Payez
Paco Lopez-Dekker
Owen O'Driscoll
EUMETSAT

May 2026, IOVWST

Recap DopSCA

- Europe has a stable and accurate ocean vector wind instrument with ASCAT
- SCA will follow up ASCAT and has improvements in calibration, accuracy, swath coverage and polarization properties
- It allows pulses with frequency chirps embedded in them for ocean Doppler estimation
- Ocean motion and currents informs us about the dynamics of air-sea interaction
- Ocean Doppler is caused by waves and currents and SCA OSVWs allow an accurate estimate of local sea state and wave motion, which is essential to compute an accurate ocean current motion residual
- The residual motion is due to ocean current vector motion and can be accumulated over a longer period (e.g., 20 days), suitable for mesoscale ocean eddy motion measurement on scatterometer scales (25 km)
- The ESA MOMS project develops a plan for DopSCA, aiming to prove its practical feasibility
- SCA is an operational mission and its configuration needs changes to allow Doppler estimation
- A dialogue with ESA and EUMETSAT is ongoing to plan for DopSCA
- The DopSCA plan needs to be endorsed by EUMETSAT

Wind Vector Cell Doppler requirements

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

Ocean motion: 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

- Instanteneous ocean motion measurements require further processing
- 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 vector proxy (0.5 m/s vector RMS cf. Vogelzang, 2022)
- This leaves an ocean current residual with the smallest possible error
- The random motion error is dominated by SCA (not a dedicated ocean current instrument and noisy; O'Driscoll et al., 2025)
- However, over 20 days currents with SCA can be determined with 6 times smaller SDE by combining 30-40 samples
- Accuracy is being further explored in MOMS project

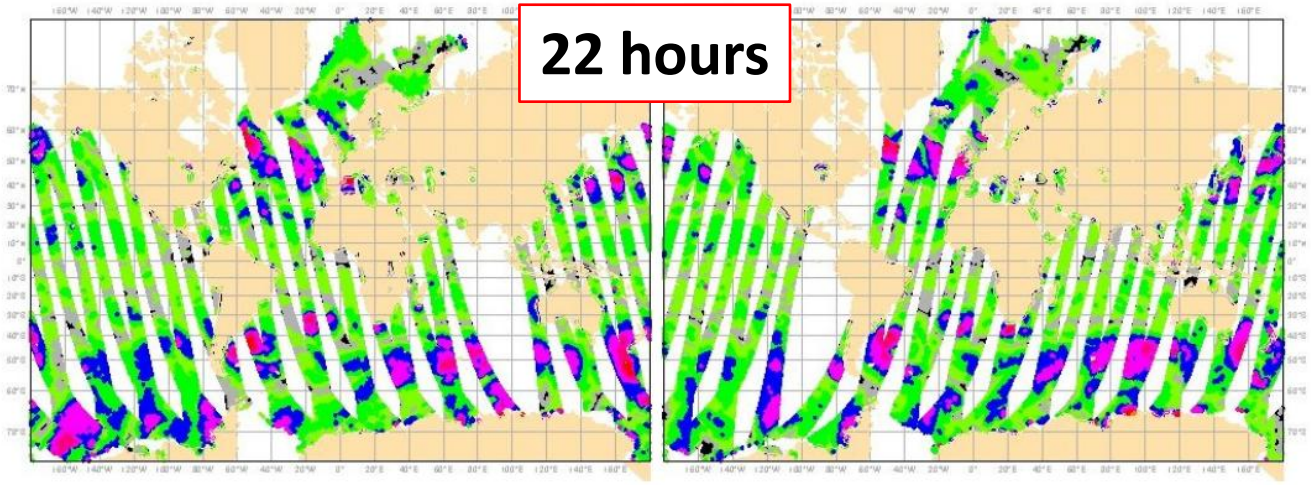


Figure 4: OSI SAF ASCAT-B Coastal product: figures using 22 hours worth of data from Ref. [34], and showing ascending (*left*) and descending (*right*) passes separately. Copyright (2024) EUMETSAT.

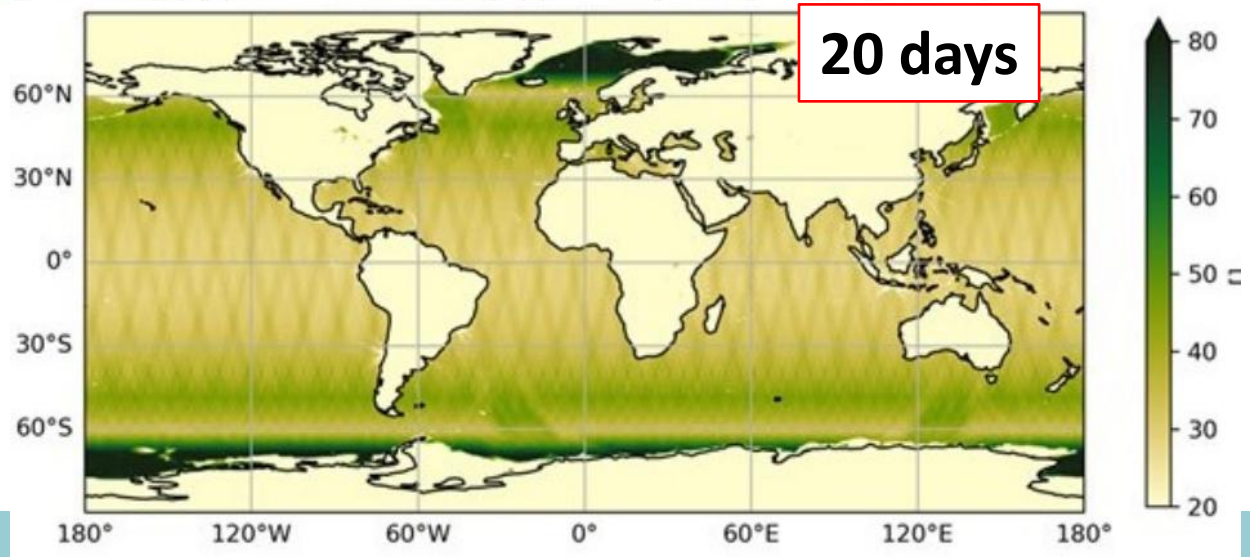


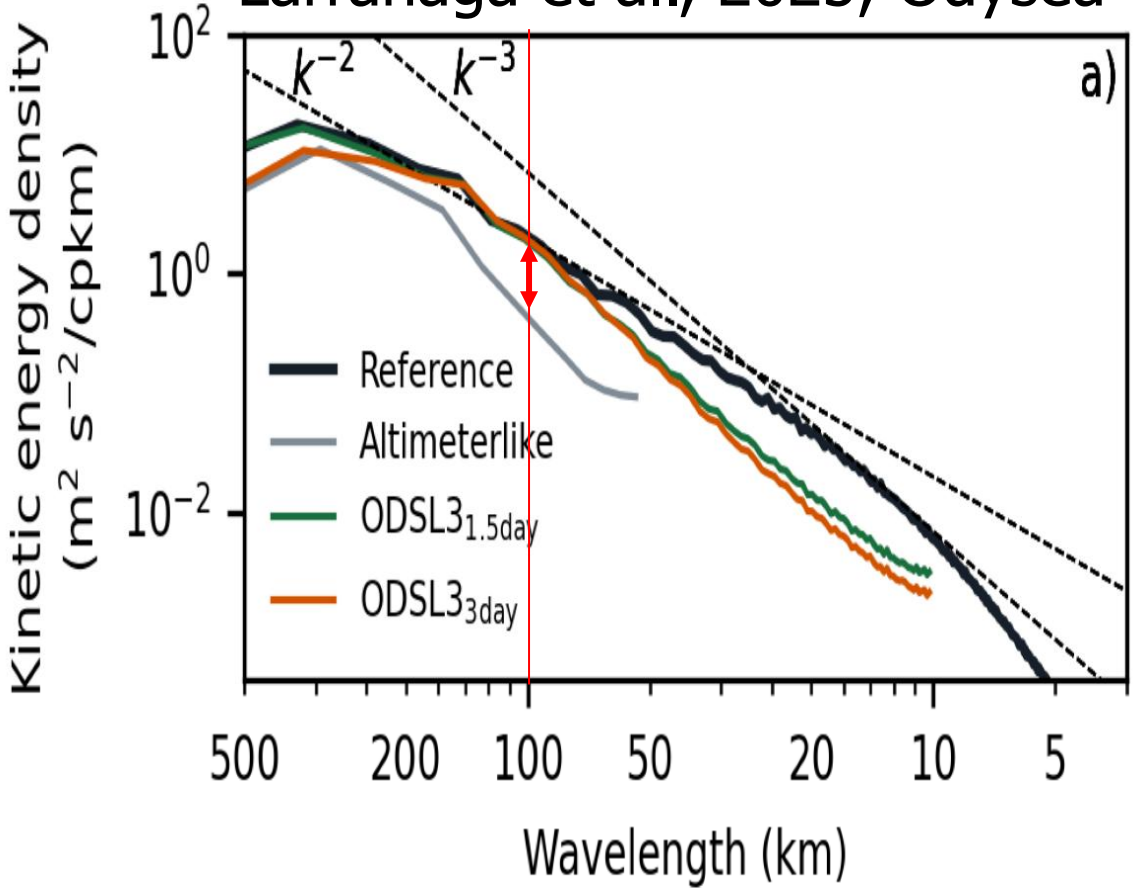
Figure 6: The number of observations for 20 days of ASCAT(0.25 deg.)

Other Ocean Doppler missions

- SCA follow-on in the 2050 time frame
- SeaStar Earth Explorer, not selected by ESA
- Harmony Earth Explorer selected by ESA, S1 coverage
- OSCOM by China, NSOAS HY-2N (>2028)
- NSOAS/CNES CFOSAT follow-on / HY-2L (>2030)
- NASA/CNES Odysea, not selected by NASA

- Typical limitations are :
  - Poor vector winds to estimate wave motion component
  - Limited coverage
  - Limited resolution
  - Limited accuracy, e.g., rain contamination
  - Not approved

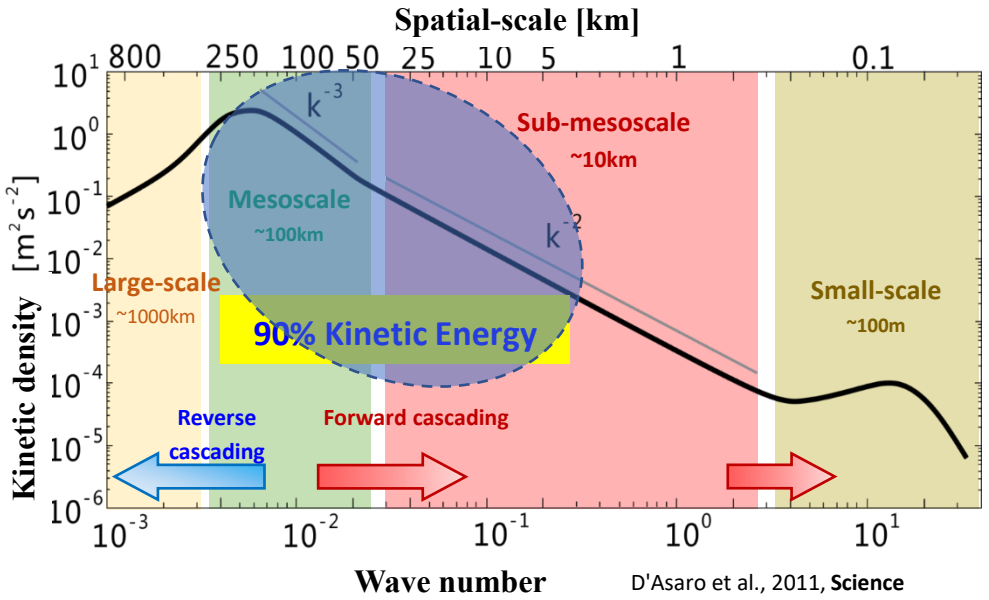
Larrañaga et al., 2025, Odysea



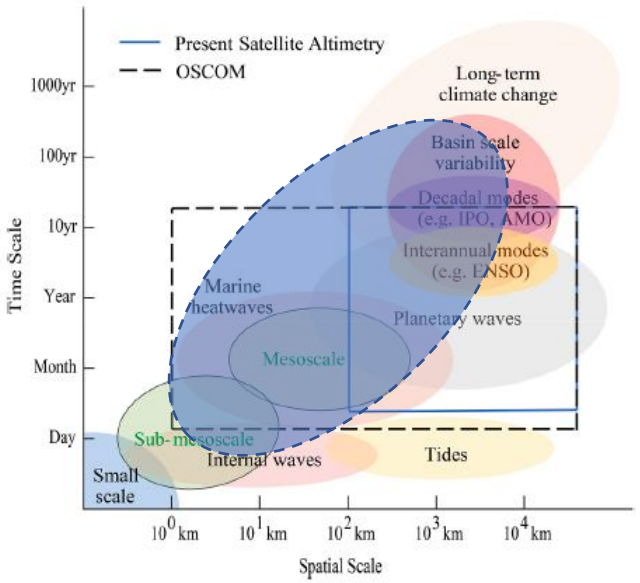
- Much synergy between missions, when approved, as no direct measurements exist yet

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 waves and currents?

DopSCA opportunities under study

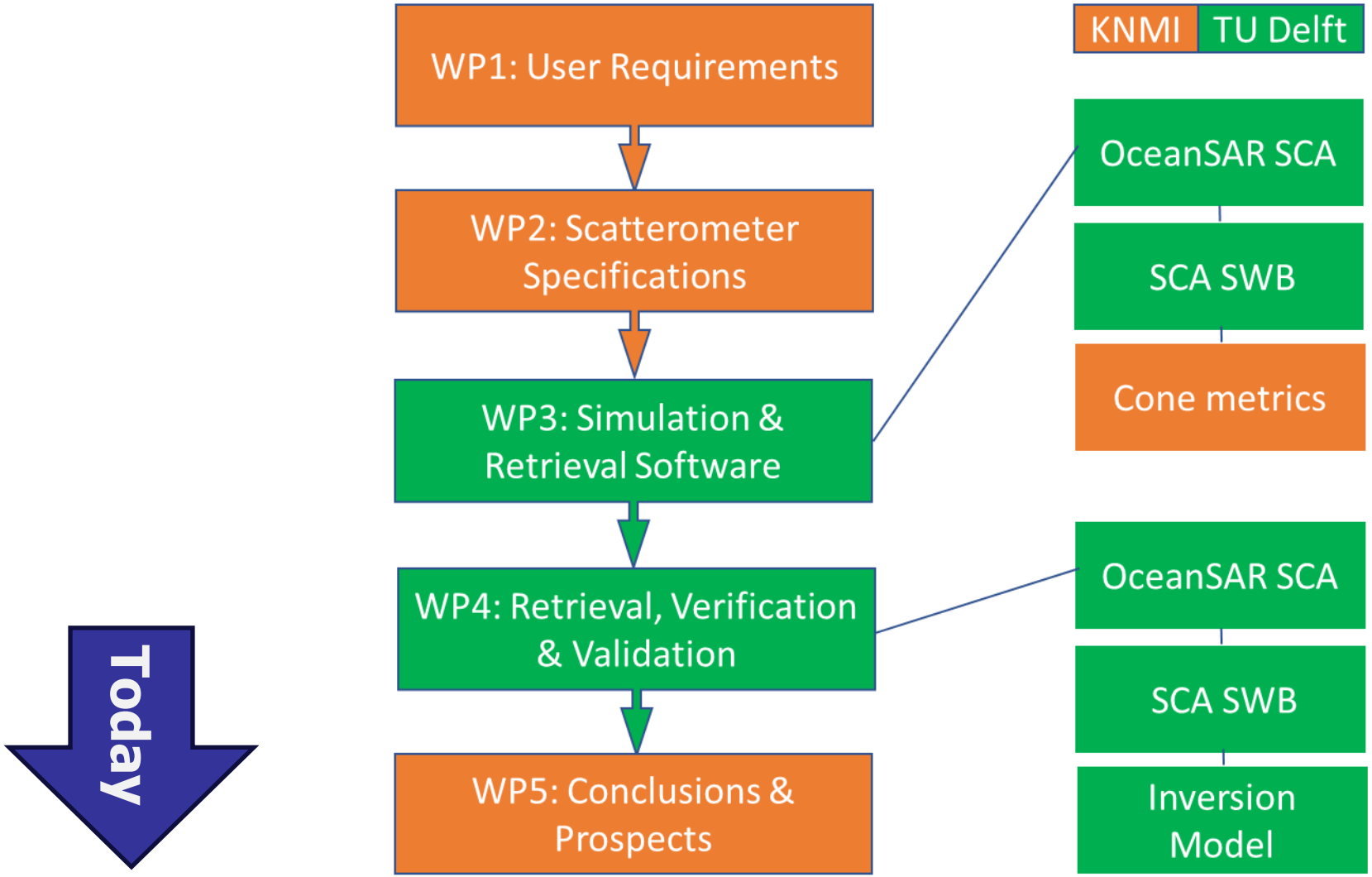
Ongoing topics:

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

Operations

- Continuity of the SCA wind mission is prime!
- Explore further use of pulses and prove (limited) loss of wind quality or resolution
- VH / HV pulses ? ASCAT, without VH, has proven superior performance in hurricanes, Ni et al., 2024, 2022
- Discuss possible technical trade-offs with SCA SAG (land, ice) and SCA experts at EUMETSAT, ESA
- Proposal for EUMETSAT member states for DopSCA experiment, needed to develop DopSCA products

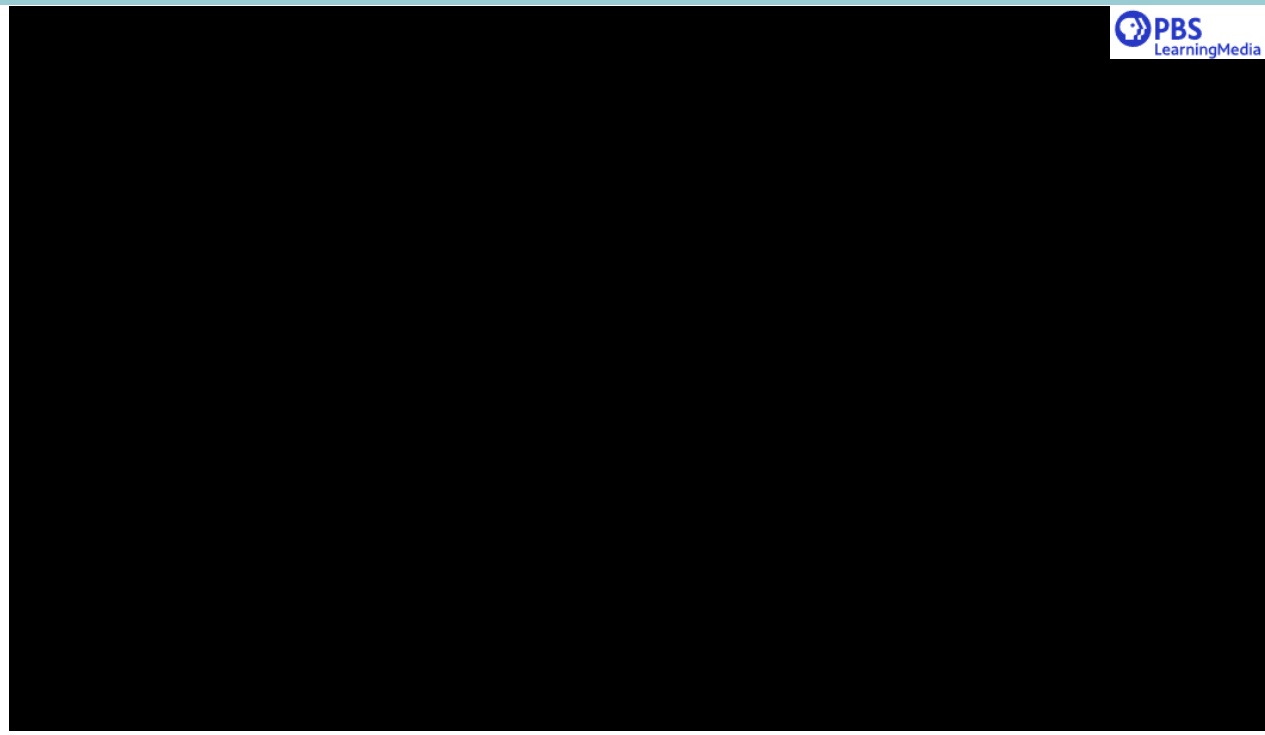
MOMS WP overview



Backup slides

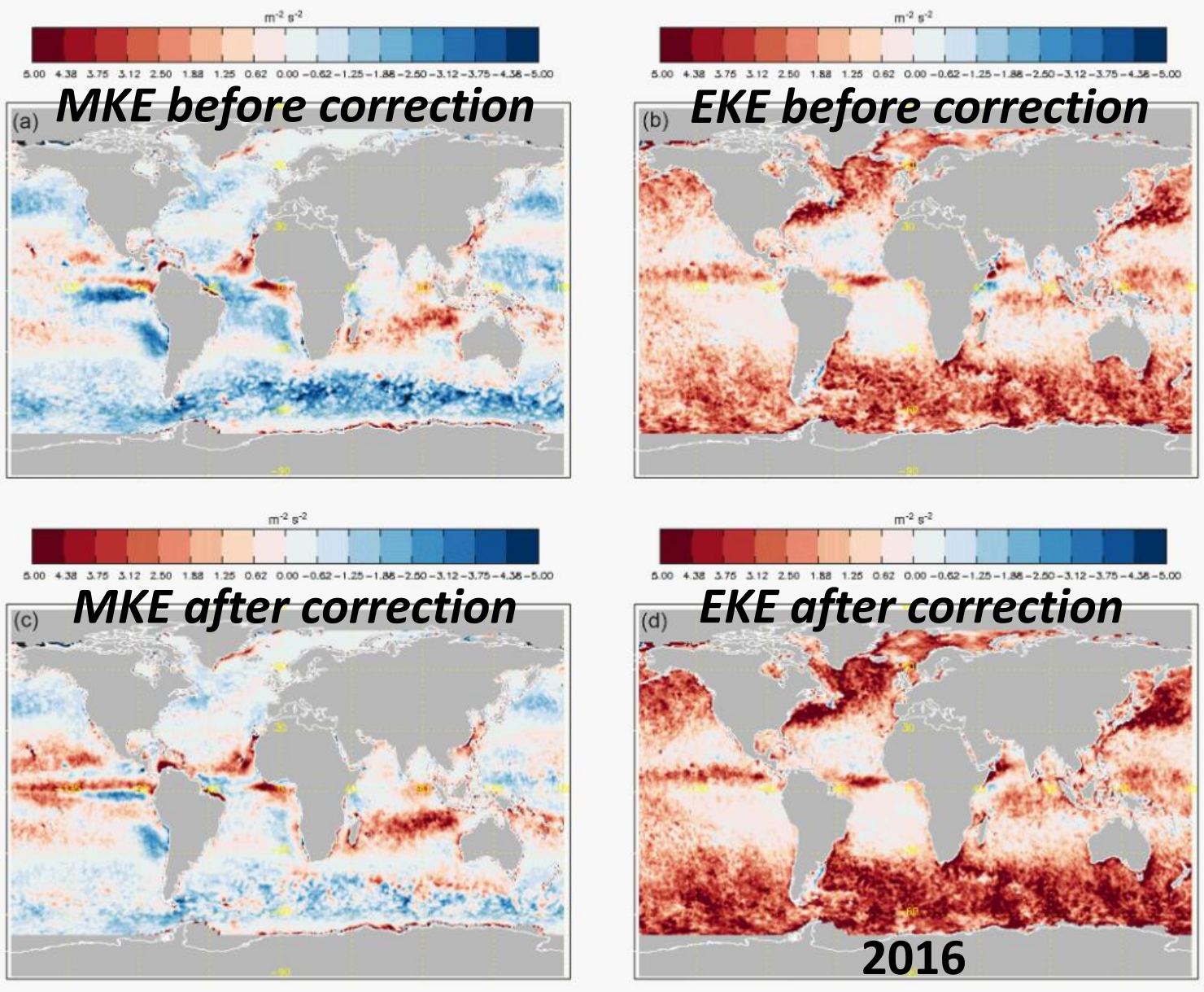
Recap Ocean motion with DopSCA

- 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 the required DopSCA pulse waveforms (dual chirps embedded)
- Pointing knowledge may be proven adequate (TBC on ASCAT and using cone metrics)
- 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
- ESA DopSCA study (MOMS) uses SCA instrument as it is, but allows additional R&D to suggest campaigns, configuration and (novel) processing
- Doppler SCA campaign(s) are envisaged to allow L2 ocean motion processor development



- 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 vector winds

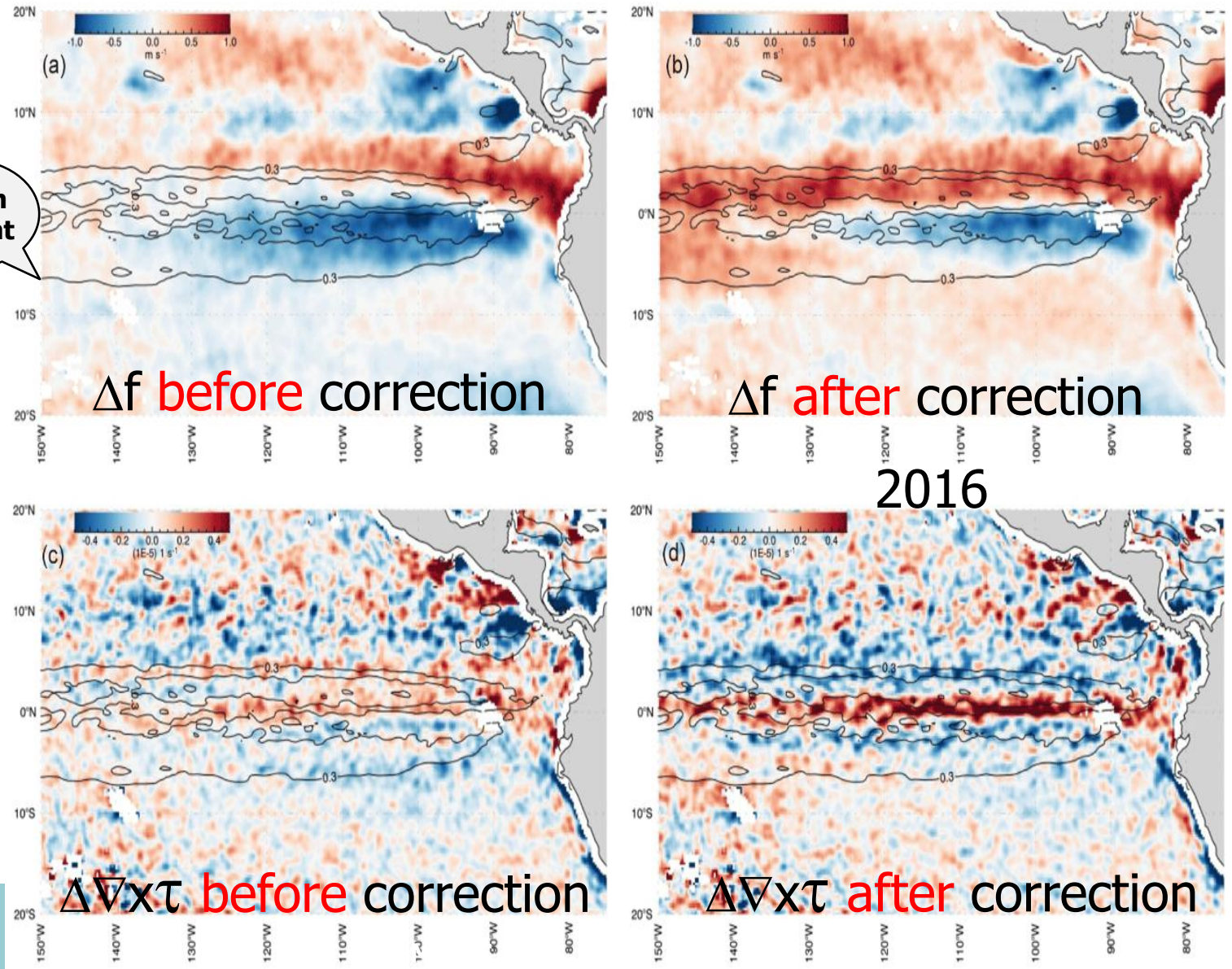
What do we really know about OSC?



- These currents generally deteriorate the deterministic differences between scatterometer and ERA5 model
- Repeated with ERA6
- KNMI in EU CHERRI proposal on ERA7 development

- Variances on m/s level, not cm/s

What do we really know about Ocean Currents?

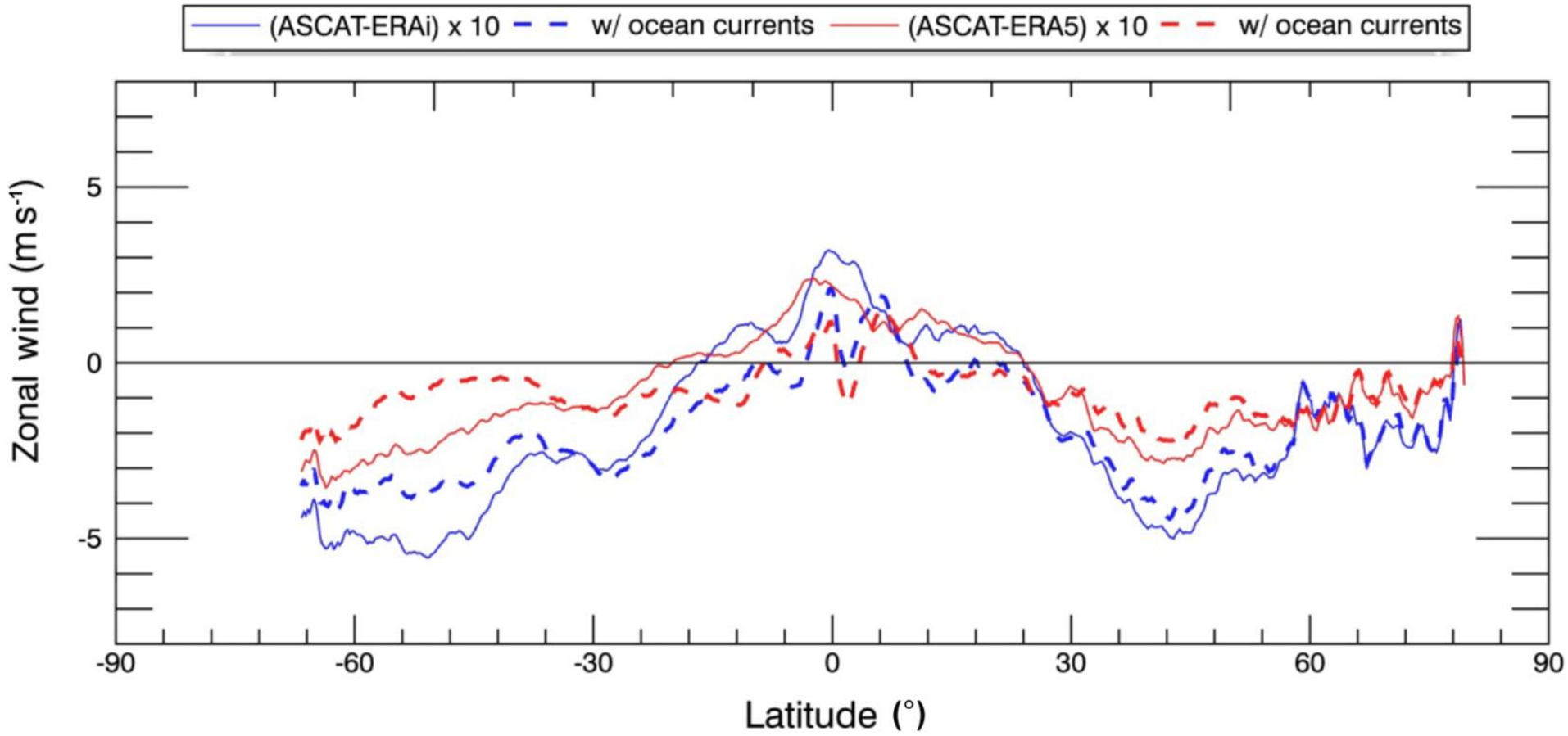


Ocean current

- 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, involved in ERA7

Belmonte Rivas and Stoffelen (2019)

What do we really know?



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

Belmonte Rivas and Stoffelen (2019)

ScienceAdvances

Current Issue First release papers Archive About

HOME > SCIENCE ADVANCES > VOL. 10, NO. 6 > PHYSICS-BASED EARLY WARNING SIGNAL SHOWS THAT AMOC IS ON TIPPING COURSE

RESEARCH ARTICLE | OCEANOGRAPHY

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

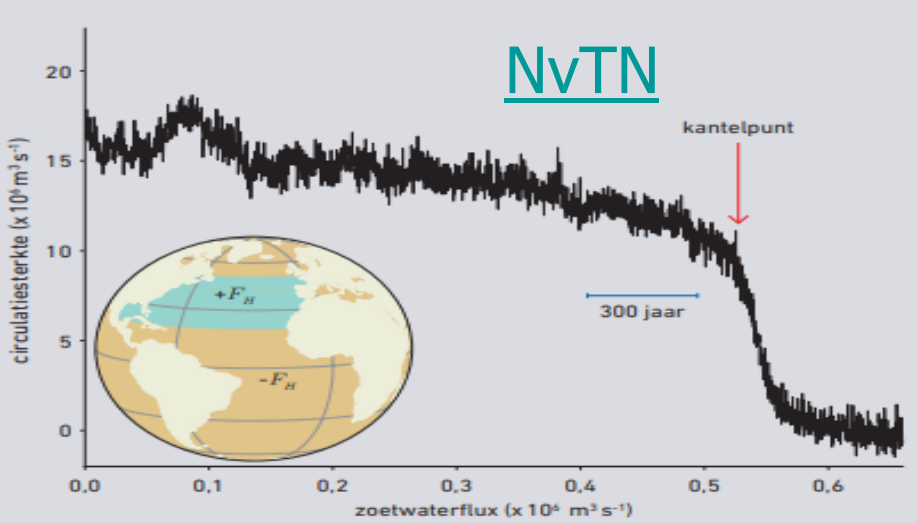
RENÉ M. VAN WESTEN, MICHAEL KLIPHUIS, AND HENK A. DIJKSTRA Authors Info & Affiliations

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

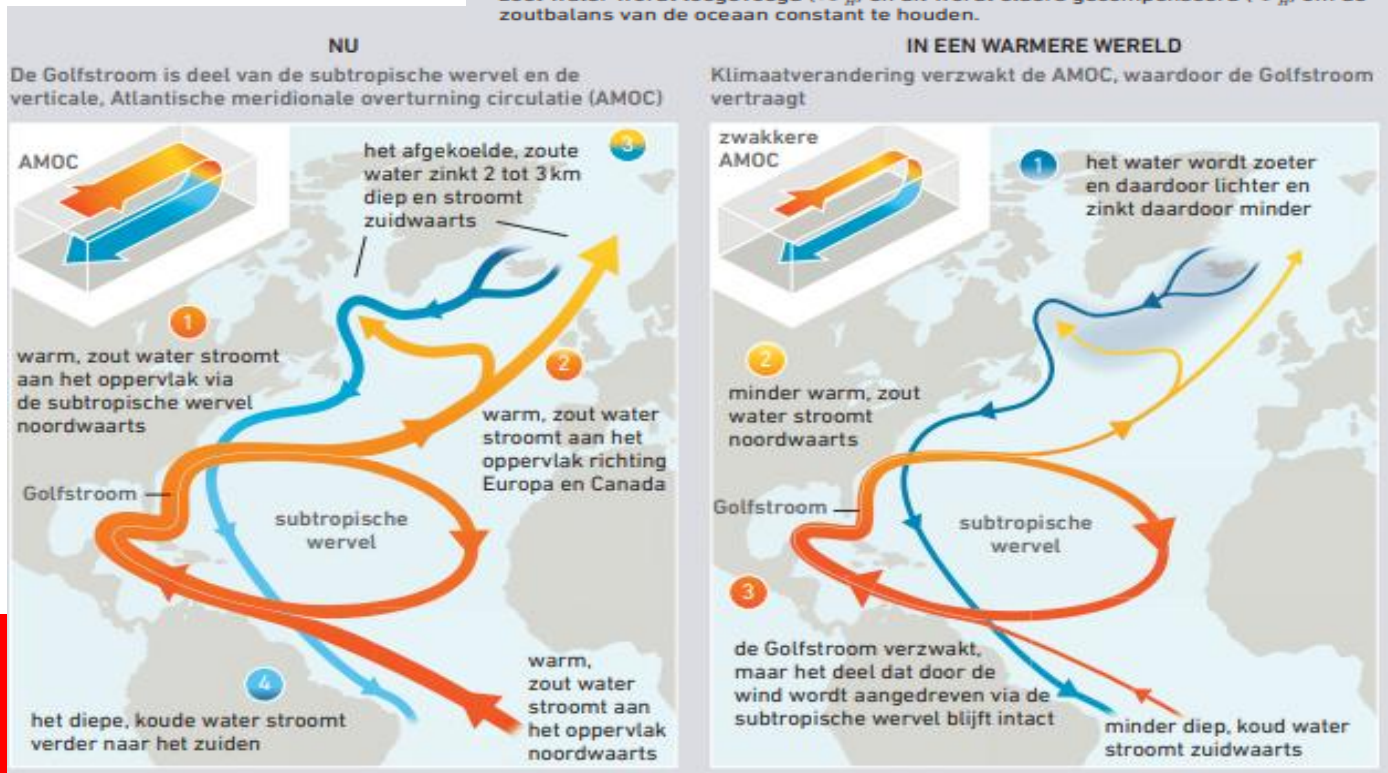
- Model study to show slowing down process of Atlantic Meridional Circulation (AMOC)
- Key indicators show that the real world moves towards the modelled AMOC collapse
- A collapse would happen relatively fast and would be particularly disastrous for Western Europe

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

NvTN



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.



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].

Complementarity with DopSCA

HY2 (perhaps CFOSAT FO)

- More accumulation over a given period
- SCA works in rainy regions
- HY2N may be a SCA reference for OSVC

Harmony

- SCA is a global monitoring mission, Harmony an explorer
- Harmony scenes with high resolution for underlying ocean km-scale processes
- SCA is reference for Harmony calibration and vector winds

DopSCA outreach

2025:

- EUMETSAT
- IOVWST talk (@ EUMETSAT)
- LPS DopSCA talk and poster
- Paper:

  O. O'Driscoll, P. López-Dekker and A. Payez, Phantom Motion of the Ocean: Leakage of Geometrical Doppler Into Geophysical Motions Observed With Doppler Scatterometers, TGRS, https://www.doi.org/10.1109/TGRS.2025.3589713

2026 proposal:

- IOVWST update (17-21 May, Miami)
- EUMETSAT conference

MOMS WP progress

Agenda later today:

14:00	-14:15	Ad	Overview MOMS
14:15	-14:45	Paco/Owen	OceanSAR-SCA
14:45	-15:15	Paco/Owen/	SWB-SCA, optimal pulse shape with subpulses
15:15	-15:30	Stefan	Oscillator stability
15:30	-16:30	All	Discussion on DopSCA feasibility and SCA sampaign
	17:00		Leave for airport

MOMS technical notes for OceanSAR-SCA and SWB-SCA are the topic of the meeting:
OceanSAR-SCA: https://surfdrive.surf.nl/s/Xzn44yPtCaZdk4w
SWB-SCA: https://surfdrive.surf.nl/s/9DawDxkd8ziLPLp

In particular, specifications of SCA and concerns on the Phase-Locked Oscillator will need to be addressed.

Note that the simulation software and data will be delivered, as well as guides to use them. These will also be discussed.

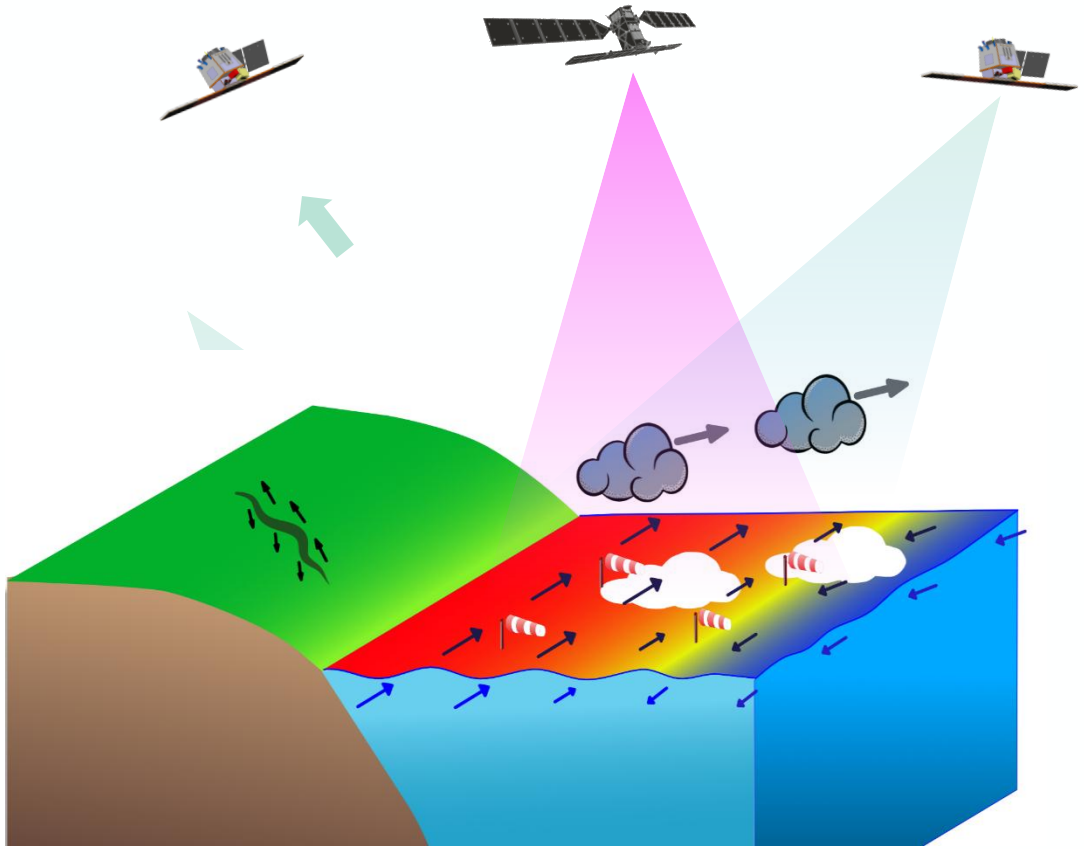
EE10 HARMONY observation concept: stereo phase

Exploit Sentinel-1

Add tandem satellites

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

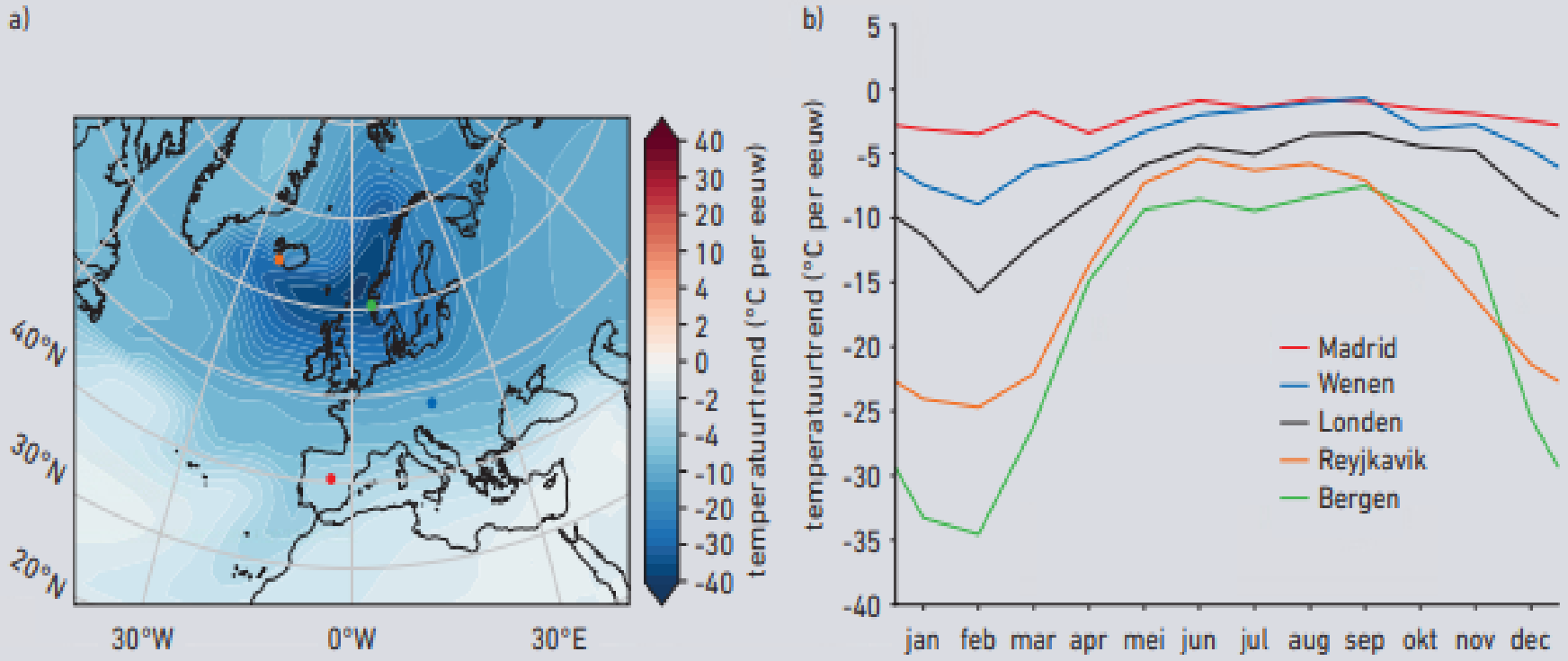
- Ocean surface **vector** motion (Doppler)
- Surface **vector** winds (scatterometry)
- Improved directional surface **wave spectra**
- Sea Surface (skin) Temperature (**SST**)
- Cloud-top **motion** (TIR time-lapse) and **height** (TIR parallax)
- Sea Ice / cryosphere application
- 3-D surface deformation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



Approved for 2029

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

What disaster?



Figuur 3. De februari-temperatuurtrend tijdens het instorten van de AMOC (a). De stippen zijn vijf steden en voor deze steden is de temperatuurtrend voor elke maand weergegeven in de grafiek ernaast (b).

- 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

Old 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