CYMS Webinar

Storm and Cyclone Monitoring Service with Sentinel-1

2022-05-05

CYMS
with Sentinel-1

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with Sentinel-1

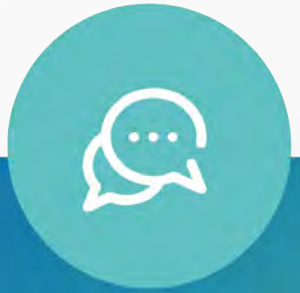
SOME RULES FOR THE WEBINAR

Do not try to turn on your microphone or webcam.

They are automatically switched off.
Organizers may offer to switch them on during the questions/answers.

This webinar is recorded.

The link of the video will be sent to you at the end of the day.



Feel free to ask your questions or comments !

You can chat with our team of experts at any time. They will answer you directly or at the end of the presentation.

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Agenda

9h30 (CET)

1. CYMS project presentation: context, objectives, data processing, description, distribution & perspectives

~ 45 min + 10 min

Romain Husson, CLS

10h25

2. Demonstration (data access & visualization tools)

~20min + 5 min

Vinca Rosmorduc, CLS

10h50

3. USECASE #1: Use of CYMS tropical cyclones measurements by meteorological forecasters

~ 15 min + 5 min

With Météo France La Réunion

11h10

4. USECASE #2: Assimilation of CYMS tropical cyclones measurements in AROME

~ 10 min + 5 min

With LACy

11h25

5. USECASE #3: Assimilation of CYMS polar lows measurements in AROME

~ 10 min + 5 min

With MetNo

11h40

6. Discussion, Q&A

~ 20 min

CYMS project presentation:

Context, objectives, data processing, description, distribution & perspectives

Romain Husson, CLS

The Team

CLS

IFREMER

METNO

ESA

Context and needs

Tropical Cyclones (TC) occur in all ocean basins

20% of the damage and casualties caused by natural hazards

IPCC: "Increase in peak wind intensity and near-storm precipitation in future TCs [...] and increase in the frequency of the most intense storms."

Science: "Probability of intense TCs, on average, more than doubles"

[https://www.science.org/doi/10.1126/sciadv.abm8438]

Monitor and Predict Extreme Winds

Essential steps are **detection** and **observation**. As TCs develop over the oceans, **observing tools are limited**.

Need for Extreme Winds **operational obs. & forecasts** over the **global ocean and during entire lifetime**:
European Sensors & Products for TC Observations

Meteosat (EUMETSAT) - **MeTop ASCAT** (ESA/EUMETSAT) - **SMOS** (ESA, L-band) - **Sentinel-1** (ESA, C-band)

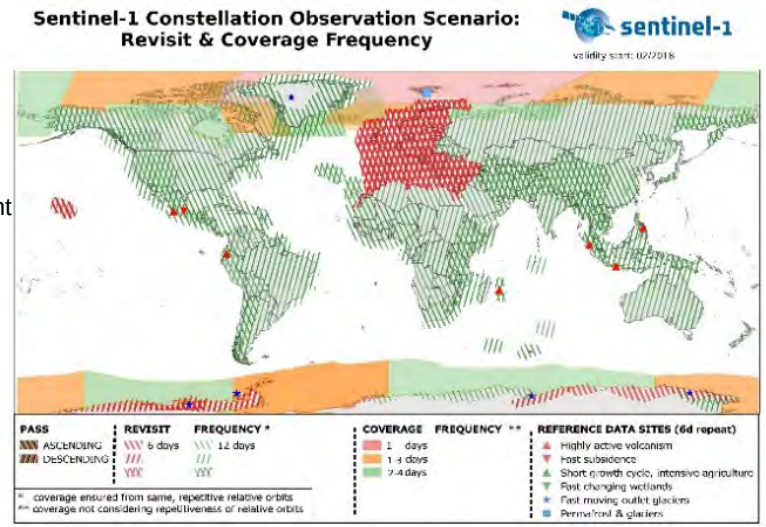
Routine use ... ⟷ *Recent use ...*

CYMS with Sentinel-1

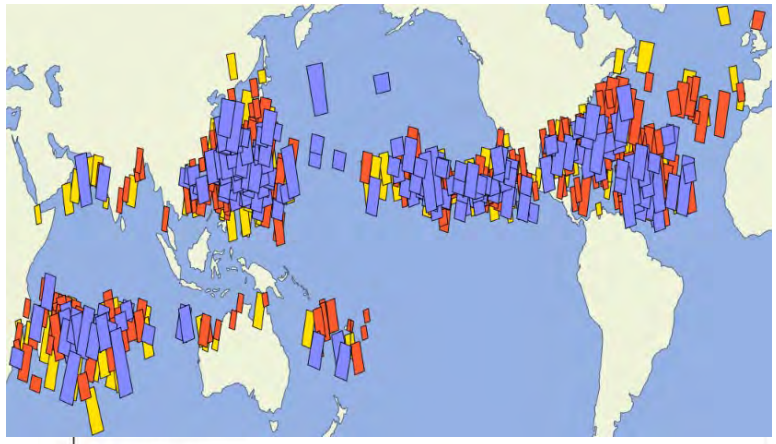
Demonstration Campaign: SHOC

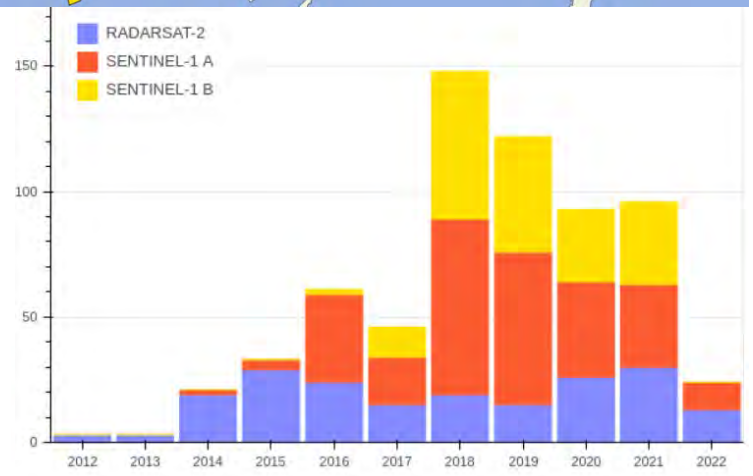
SHOC - Satellite Hurricane Observations Campaign

sentinel.esa.int



- S1 HLOP (High Level Operations Plan) is not compatible with TC monitoring.
- Initiated in 2016, with the support of ESA, IFREMER & CLS proposed to optimize S-1 acquisition plans to maximize the number of observations over TC.
- S1 and RS-2 used with late programming acquisitions for TC monitoring based on ECMWF TC forecast tracks, all along their lifetime.
- TC acquisitions with S1-A: 5 in 2015 vs. 70 in 2018
- → Huge impact of a dedicated TC acquisition strategy
  - Successful new strategy to trigger acquisitions over TC
  → Defined / tested / validated
  - Ever growing database of high-resolution SAR observations over TC
  --> Continue algorithm development
  --> Foster scientific/operational end-user community interest

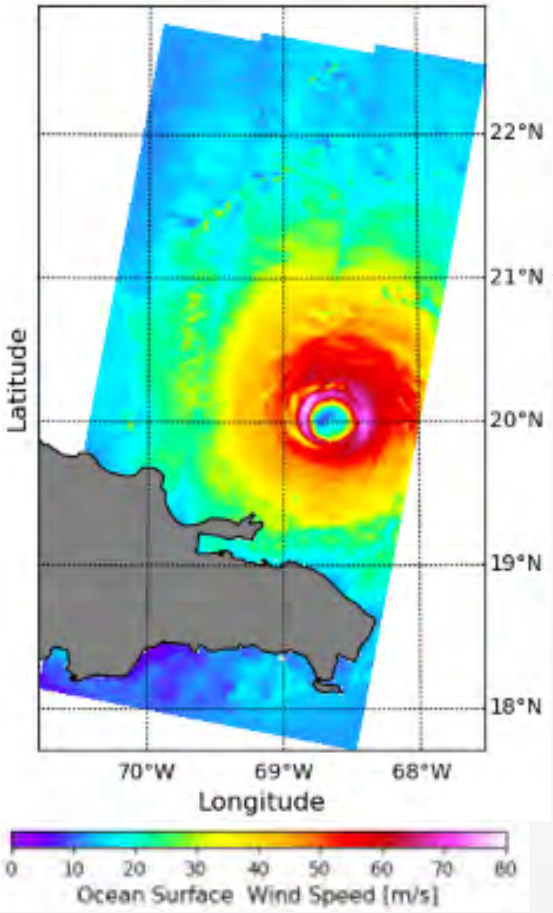




TC acquisition within SHOC since 2012

The SAR way to CYMS: from R&D towards an operational service

1km Winds from Sentinel-1 over Irma on 2017/09/07



2016

1st SHOC Campaign: building TC archive, analyzing R&D

SEOM Program

2017

1st high wind processing chain used for S& over the past acquisitions (e.g. Irma, José, Maria major TCs)

2018

Very active global SHOC Campaign

- Massive SAR database of TC observations
- Consolidation of « service chain »

R&D

2019

CYMS preparation

Consolidation

2020

Operational demonstration + extension to European extreme winds in 2021

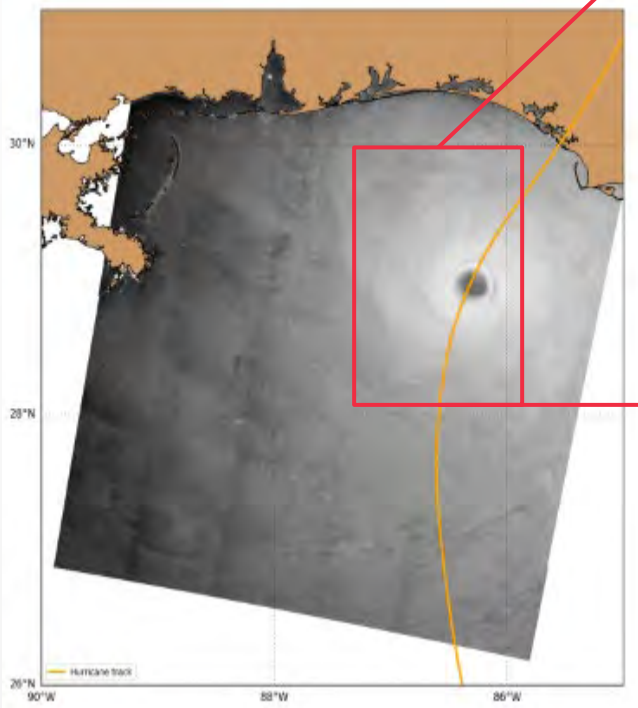
CYMS

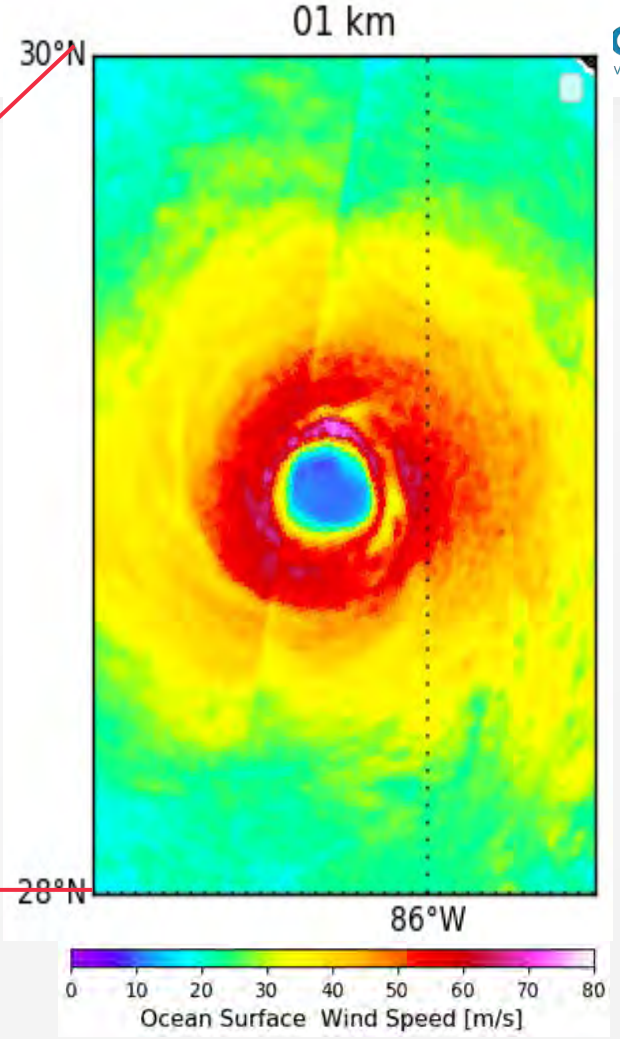
Unique SAR characteristics

The combination of VV and VH channels as measured by SAR at very high resolution allows to provide Ocean Surface Wind measurements from space

- at high resolution

S1A – 2018/10/10
Michael

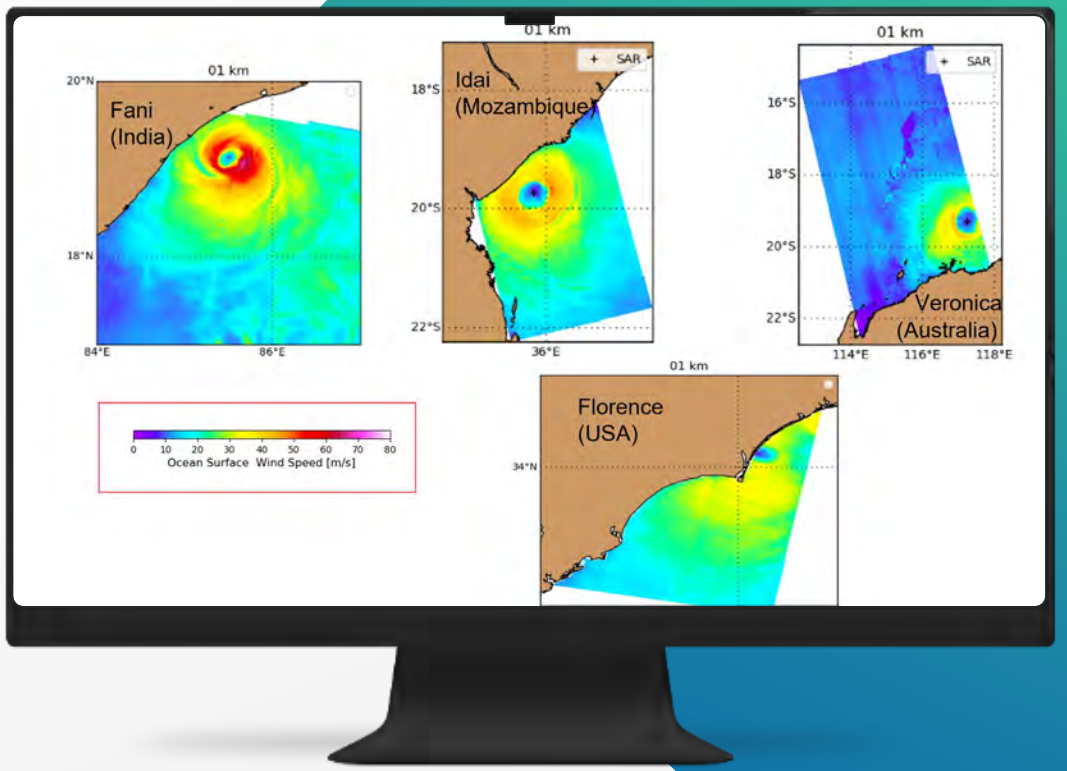




Unique SAR characteristics

The combination of VV and VH channels as measured by SAR at very high resolution allows to provide Ocean Surface Wind measurements from space

- at high resolution
- in coastal areas (unique capability vs. other spaceborne sensors)



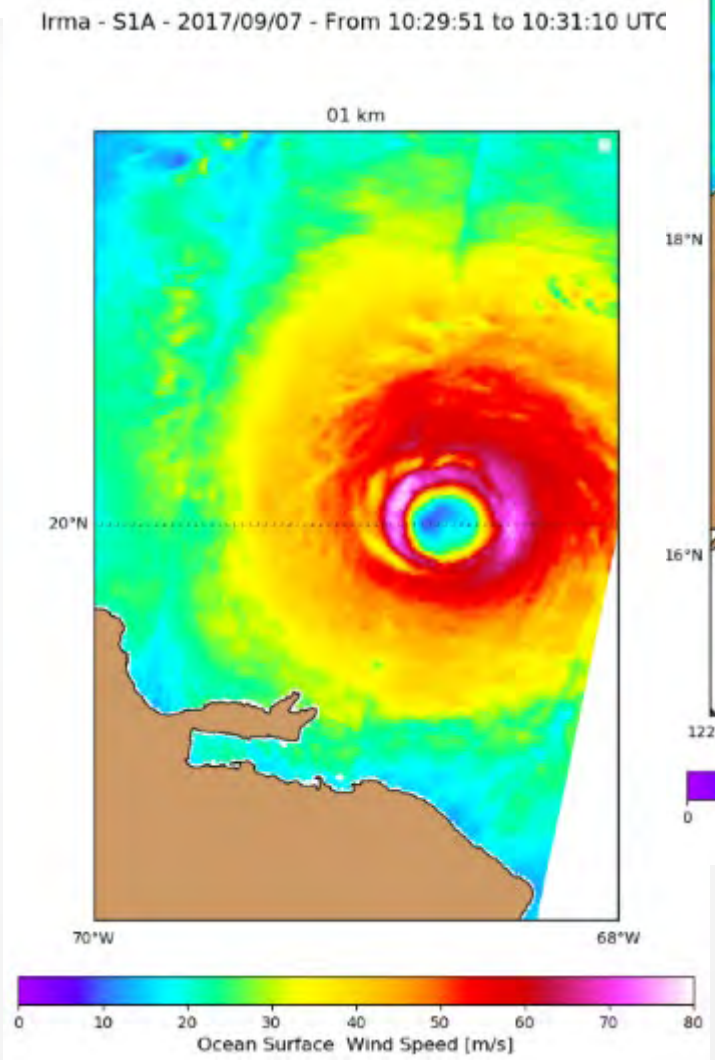
Unique SAR characteristics

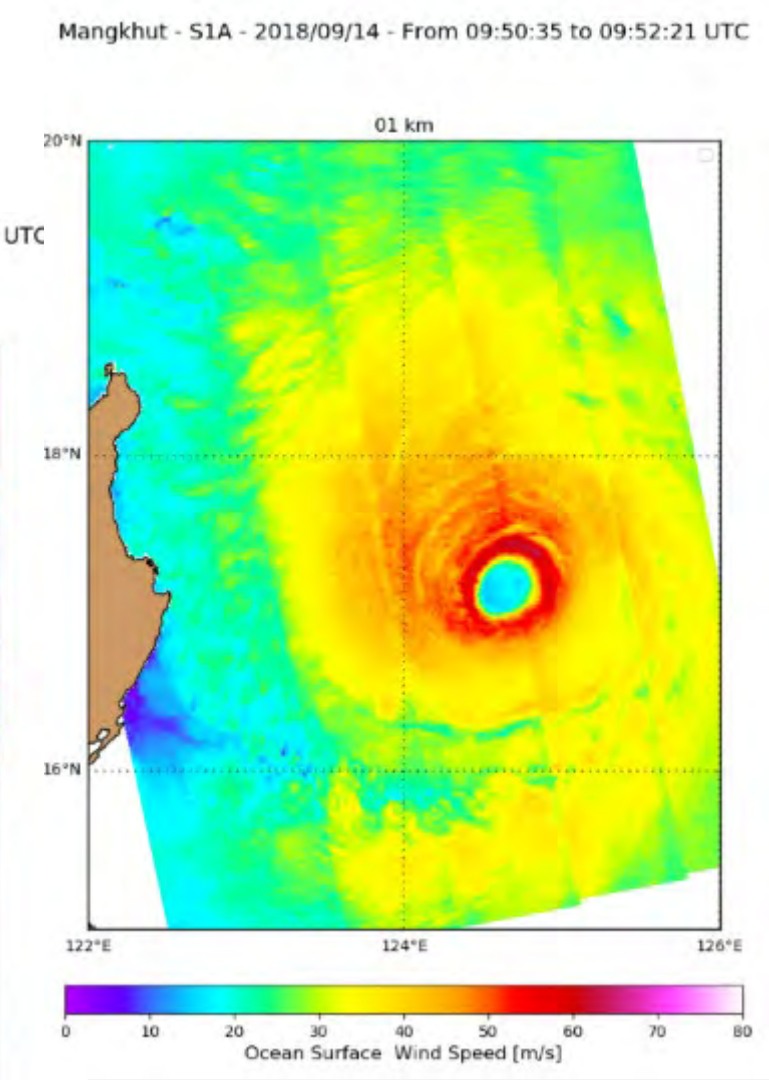
The combination of VV and VH channels as measured by SAR at very high resolution allows to provide Ocean Surface Wind measurements from space

- at high resolution
- in coastal areas (unique capability vs. other spaceborne sensors)
- over extreme Hurricane

Examples of category-5 on the Saffir-Simpson scale:

- **Irma** TC, Sept. 7 2017.
- **Mangkhut** TC, Sept. 14 2018.

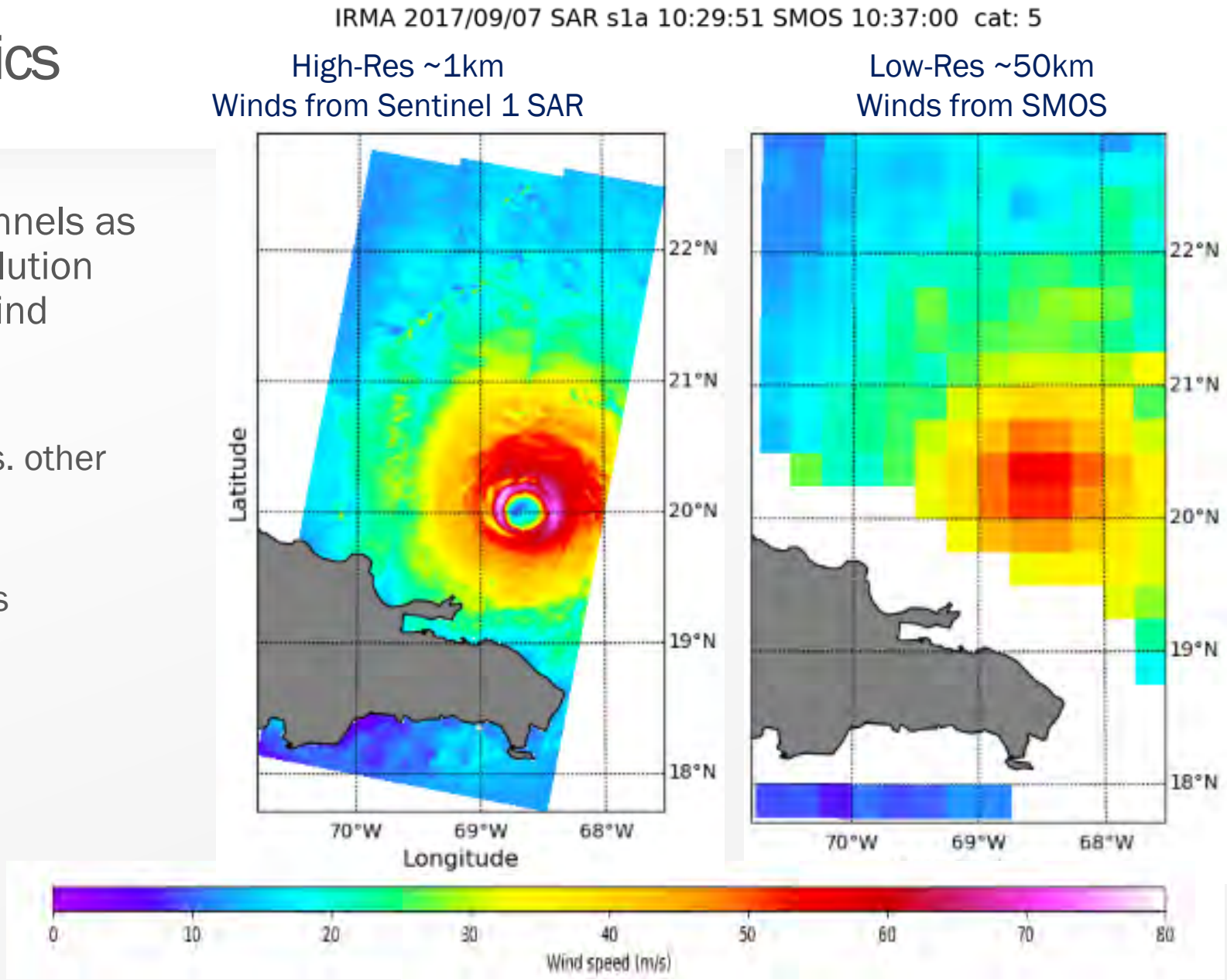




Unique SAR characteristics

The combination of VV and VH channels as measured by SAR at very high resolution allows to provide Ocean Surface Wind measurements from space

- at high resolution
- in coastal areas (unique capability vs. other spaceborne sensors)
- over extreme Hurricane
- bringing synergies with other sensors (airborne & spaceborne)

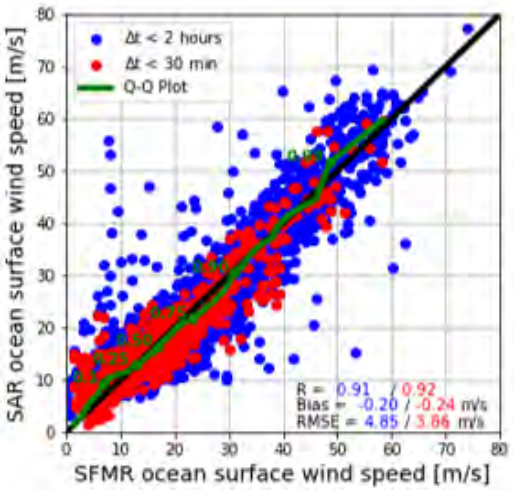


Unique SAR characteristics

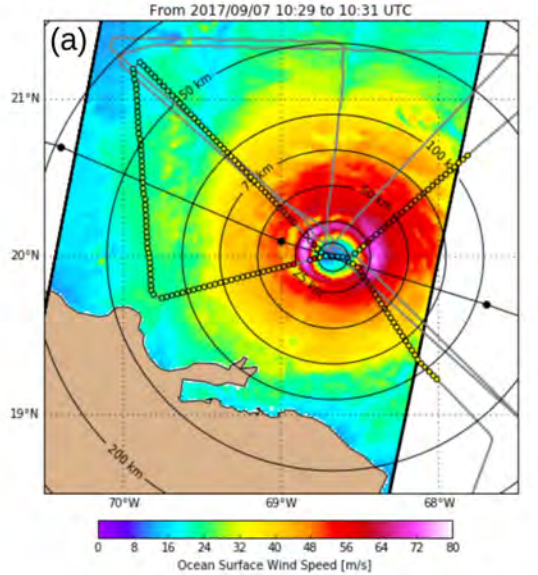
Mature wind speed measurements

- Multiple validation phases with in-situ, airborne and other spaceborne sensors, including strong wind regimes.
- Specific wind processing necessary w.r.t. ESA wind processing

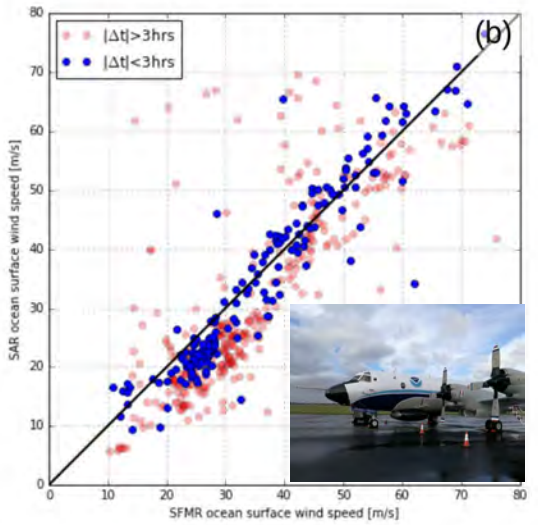
SAR vs. SFMR over several TC
[Combot et al. 2020]



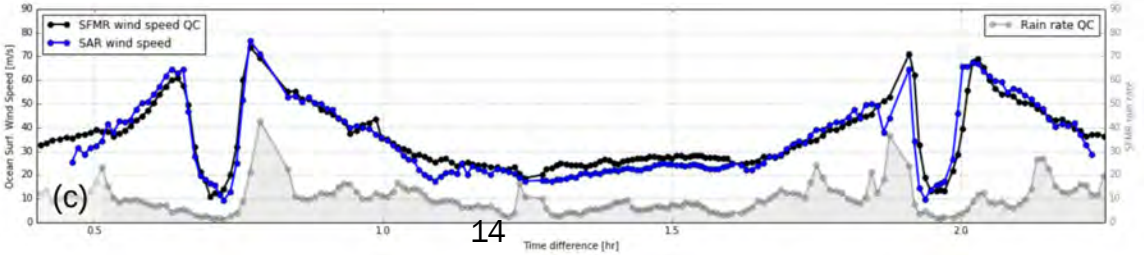
Ocean surface wind speed - Irma



Sentinel 1



Comparison with airborne observations NOAA hurricane hunters airplanes



<u>Scientific references on CYMS data validation</u>

- Combot C. et al. (**2020**). "Extensive high-resolution Synthetic Aperture Radar (SAR) data analysis of Tropical Cyclones: comparisons with SFMR flights and Best-Track". *Monthly Weather Review* , 148(11), 4545–4563. https://doi.org/10.1175/MWR-D-20-0005.1
- Mouche A. et al. (**2019**). "Copolarized and Cross-Polarized SAR Measurements for High-Resolution Description of Major Hurricane Wind Structures: Application to Irma Category 5 Hurricane". *Journal Of Geophysical Research-oceans*, 124(6), 3905-3922. https://doi.org/10.1029/2019JC015056
- Zhao Yuan et al. (**2018**). "Direct Comparison Between Active C-Band Radar and Passive L-Band Radiometer Measurements: Extreme Event Cases". *IEEE Geoscience And Remote Sensing Letters*, 15(6), 897-901. https://doi.org/10.1109/LGRS.2018.2811712
- Mouche A. et al. (**2017**). "Combined Co- and Cross-Polarized SAR Measurements Under Extreme Wind Conditions". *IEEE Transactions On Geoscience And Remote Sensing*, 55(12), 6746-6755. https://doi.org/10.1109/TGRS.2017.2732508

CYMS in a nutshell - Scientific & technical obj. in 2020-21

OBJECTIVE #1

DEVELOP A SUSTAINABLE **ACQUISITION STRATEGY** DEDICATED TO TROPICAL CYCLONES

OBJECTIVE #2

010011
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CONSOLIDATE S-1 END-TO-END **PROCESSING CHAINS** FOR OCEAN SURFACE WIND FIELD WITH DEDICATED AND UP-TO-DATE ALGORITHMS FOR EXTREME EVENTS

OBJECTIVE 3

BUILD AN **ARCHIVE CENTER** WITH HOMOGENEOUS AND CONSISTENT L2 PRODUCTS, FOR THE TC PRODUCT VALIDATION PURPOSE AND SCIENTIFIC APPLICATIONS

OBJECTIVE #4

BUILD A SINGLE INTEGRATED PORTAL EASING **DISSEMINATION AND OUTREACH** ACTIVIES

CYMS service now used by TC WMO regional centers for their operational forecasts

e.g.: JTWC, NOAA, Météo-France La Réunion

Jackson, C. R., T. W. Ruff, J. A. Knaff, A. Mouche, and C. R. Sampson (2021), "Chasing cyclones from space", *Eos, 102,* https://doi.org/10.1029/2021EO159148.

Tropical Cyclone Ophelia on 2017-10-15

2nd storm of the 2017-18 European windstorm season
Largest ever recorded hurricane in East Atlantic
Extreme winds and coastal erosion in Ireland

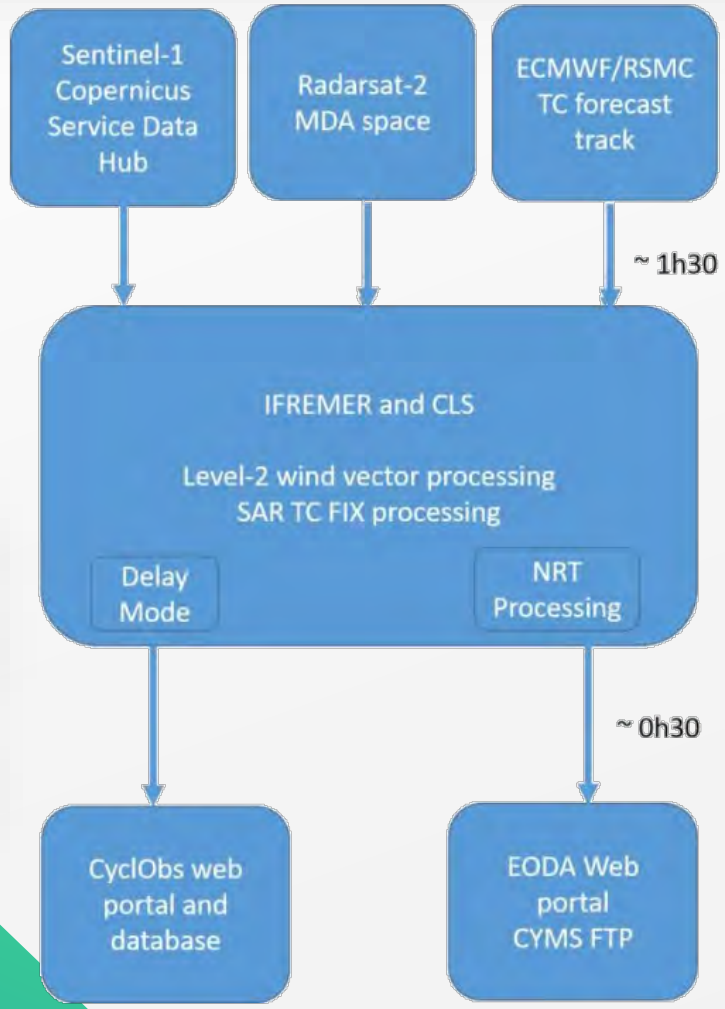
Sentinel-1 & RadarSat-2 specific planning in support of CYMS

CYMS with Sentinel-1

Main steps:

- Specific planning requests for **TC of interest**: Major or Coastal TC (worldwide),
- Following provision of TC forecast track by CYMS partners, S1 and RS-2 mission planners identify and plan the relevant opportunities over the next days,
- Planning of SAR modes made in dual polarisation (VV-VH), preferred mode are EW (S1) and ScanSar Wide (RS-2),
- Related acquisition/ production/ dissemination of Level-1 SAR product is planned in NRT-3H on ESA hubs and MDA ftp,
- CYMS SAR wind products are processed and made available on http://eoda.cls.fr/cyms (**NRT**) and https://cyclobs.ifremer.fr/app/ (**reprocessed products**)
- A new planning loop may be necessary depending on the evolution of TC tracks,

Haishen, 3 Sept. 2020



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CYMS in a nutshell - Scientific & technical obj. in 2021-22

OBJECTIVE #1

Involve new end-users (Maritime transport, insurance, private meteorology…) and develop new applications (Assimilating CYMS products over TC and other intense phenomena met over European waters (e.g. Polar lows, Medicanes, Extra-Tropical Cyclones…)

OBJECTIVE #2

Enrich CYMS processing chain with new products & parameters

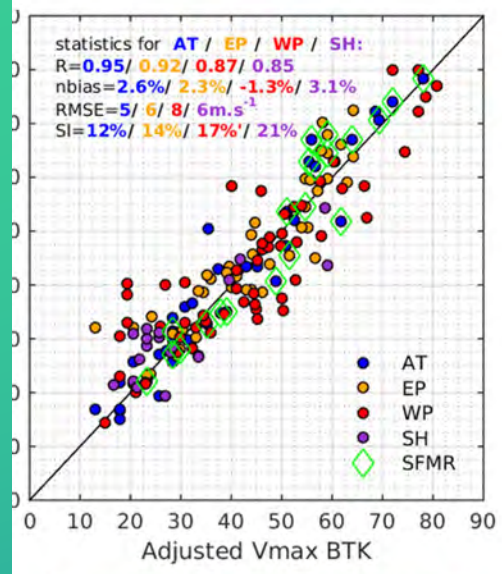
- Maximum Sustained Wind speed (MSW), Radius of MSW (RMW), directions estimated from SAR, rain impact

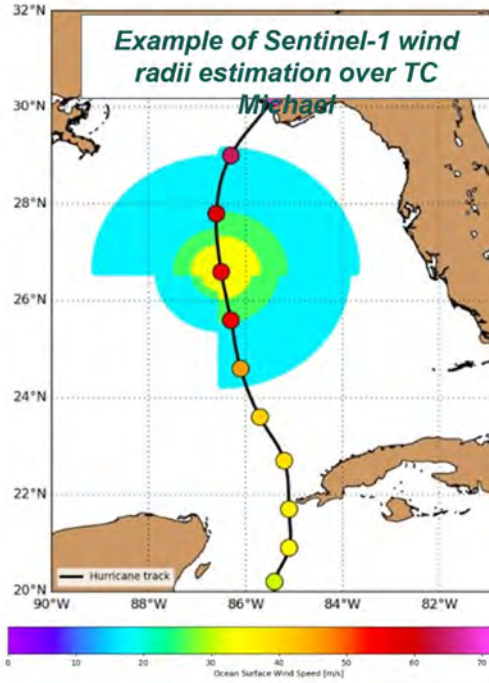
OBJECTIVE #3

Operate the CYMS service for tropical cyclones and other intense phenomena

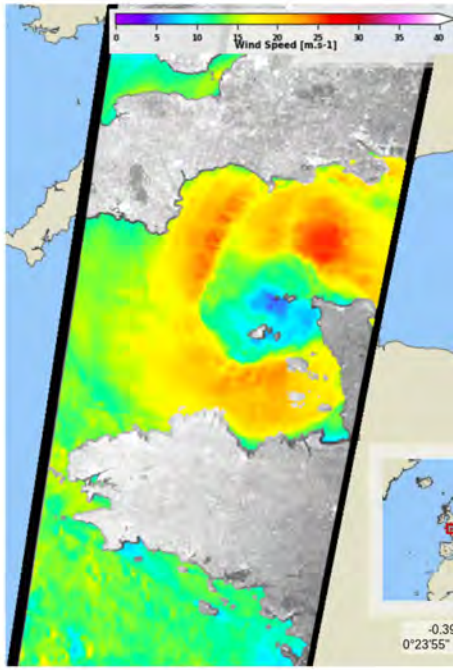
OBJECTIVE #4

Demonstrate CYMS processing on the DIAS platform

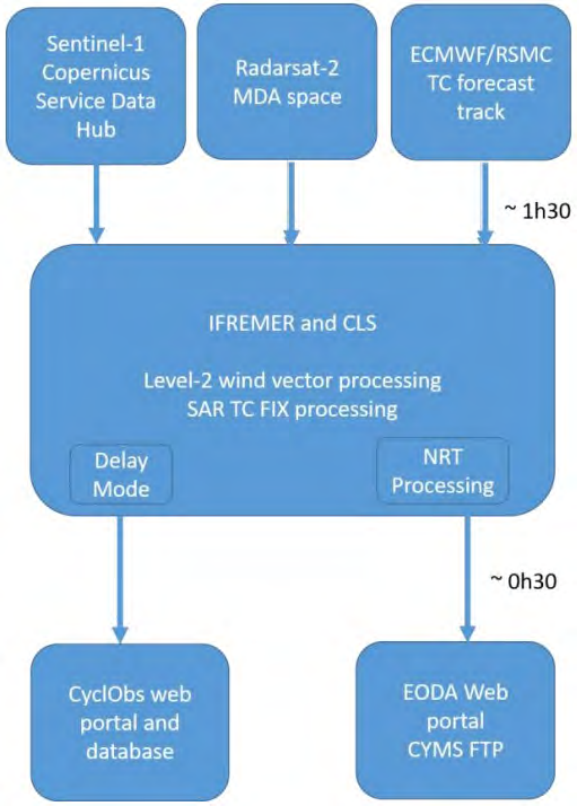




Example of MSW parameters from TC Forecast compared to SAR-derived parameters [Combot et al. 2020].



Sentinel-1 & RadarSat-2 specific planning in support of CYMS



Main steps:

What's new over European waters

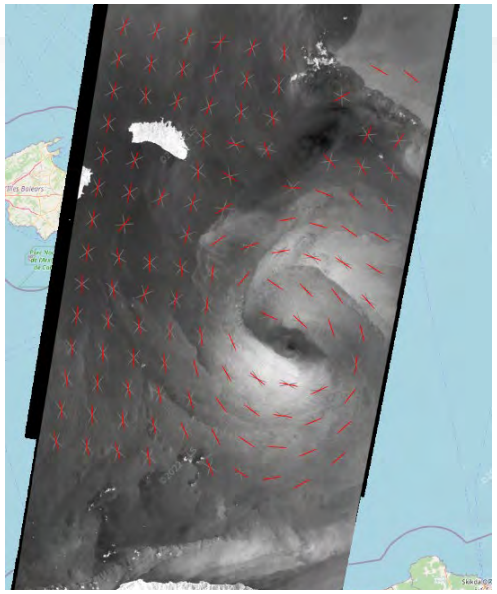
- Default acquisitions for S1 over European waters.
--> S1 product of interest are selected according a minimum threshold on the maximum forecast wind speed, not to process all S1 products (> 15m/s, currently).

- Additionnal planning requests using RS-2 may be performed as a complement over storm events of interest (still manual as no automated ETC forecast tracks).

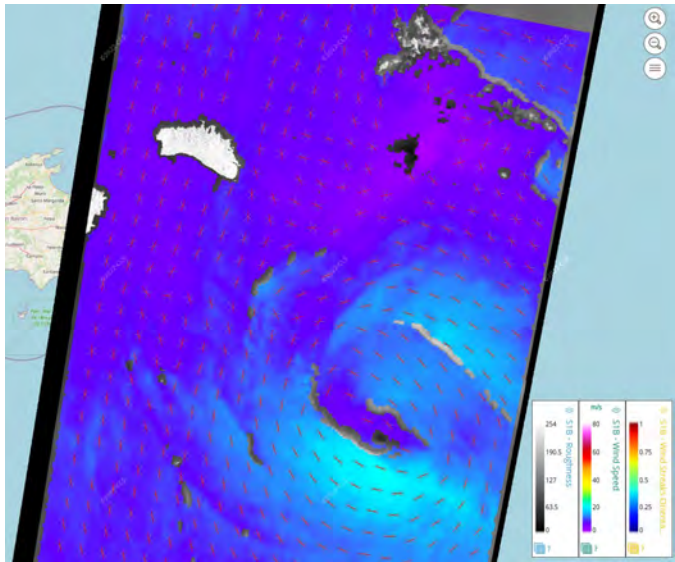
- Related acquisition/production/dissemination of Level-1 SAR product is planned in NRT-3H on ESA hubs and MDA ftp,

- S1 CYMS SAR wind products are processed and made available on http://eoda.cls.fr/cyms (**NRT**)
and https://cyclobs.ifremer.fr/app/ (**reprocessed products**)

- A new planning loop may be necessary depending on the evolution of storm tracks,

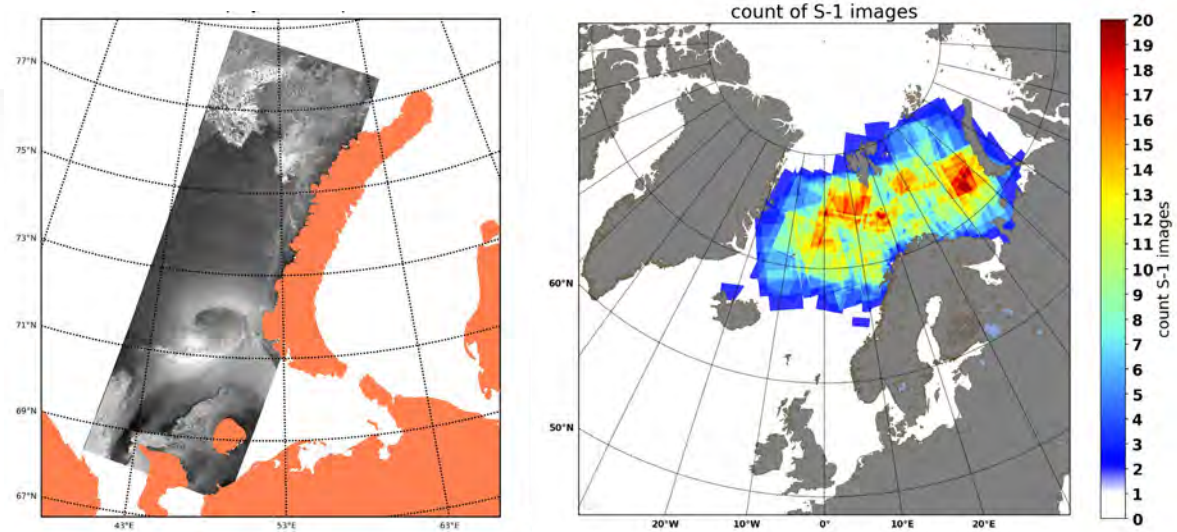


Medicane Blas on 2021-11-13: sea surface roughness on top, wind speed on bottom



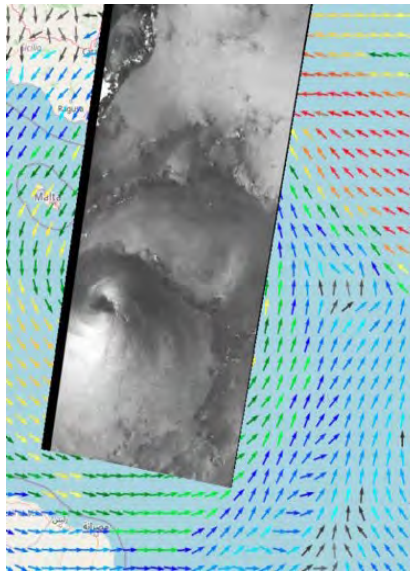
Extreme phenomena of interest over Europe

- Polar-lows: Norway and Sweden
- Medicanes: Italy, Greece, Croatia
- Extra tropical cyclones / winter storms: Ireland, UK, France, Spain, Portugal, Netherlands, Denmark, Germany
- Tropical Storms: France & Netherlands (overseas), Spain & Portugal

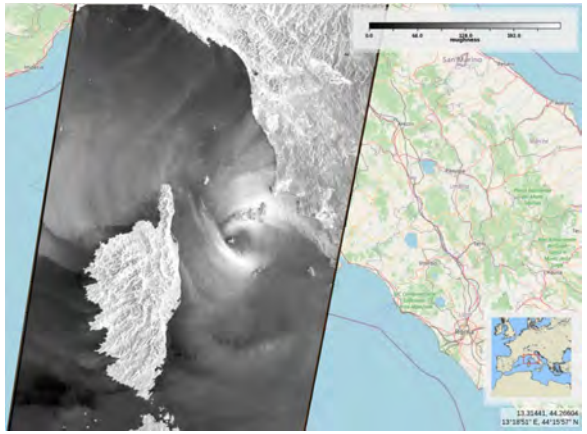


Left: Example of Sentinel-1 observation over Polar Low. Right: Total number of Sentinel-1 acquisitions over Polar Lows available since Sentinel-1 A launch

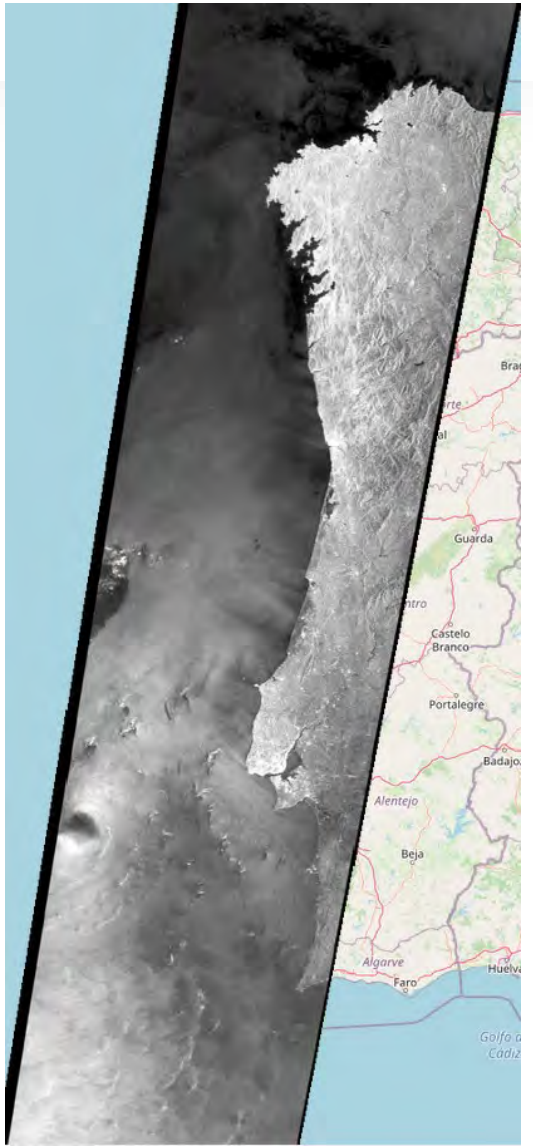
Region of interest for European extreme winds processing



Medicane Apollo caused heavy rainfall and intense winds in Sicily (here on 2021-10-26)



Medicane Albenga
2021-11-15 05:27

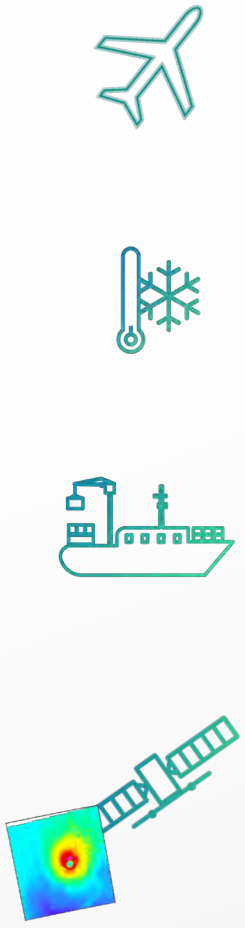


Sub-tropical storm Alpha on 2020-09-18 before hitting Portugal
First recorded landfalling (sub)tropical cyclone in mainland Portugal

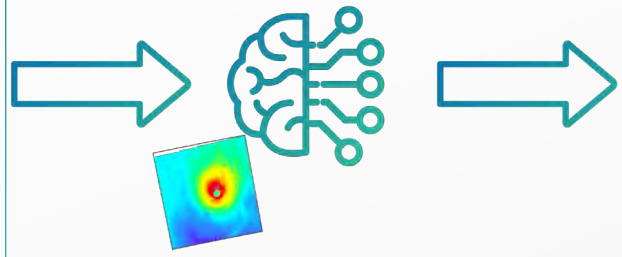
Extreme winds & associated services

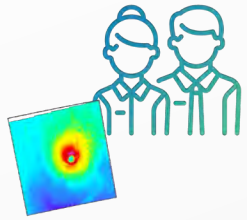
CYMS
with Sentinel-1

Where SAR-based extreme winds observations can be useful:

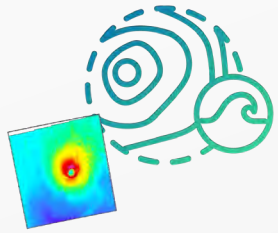


Input data sources





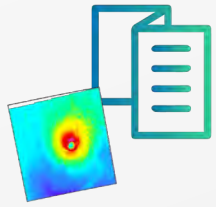
Derive alerts & bulletins



Forecasts

Operational

R&D



Scientific Publications

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What's in CYMS products ?

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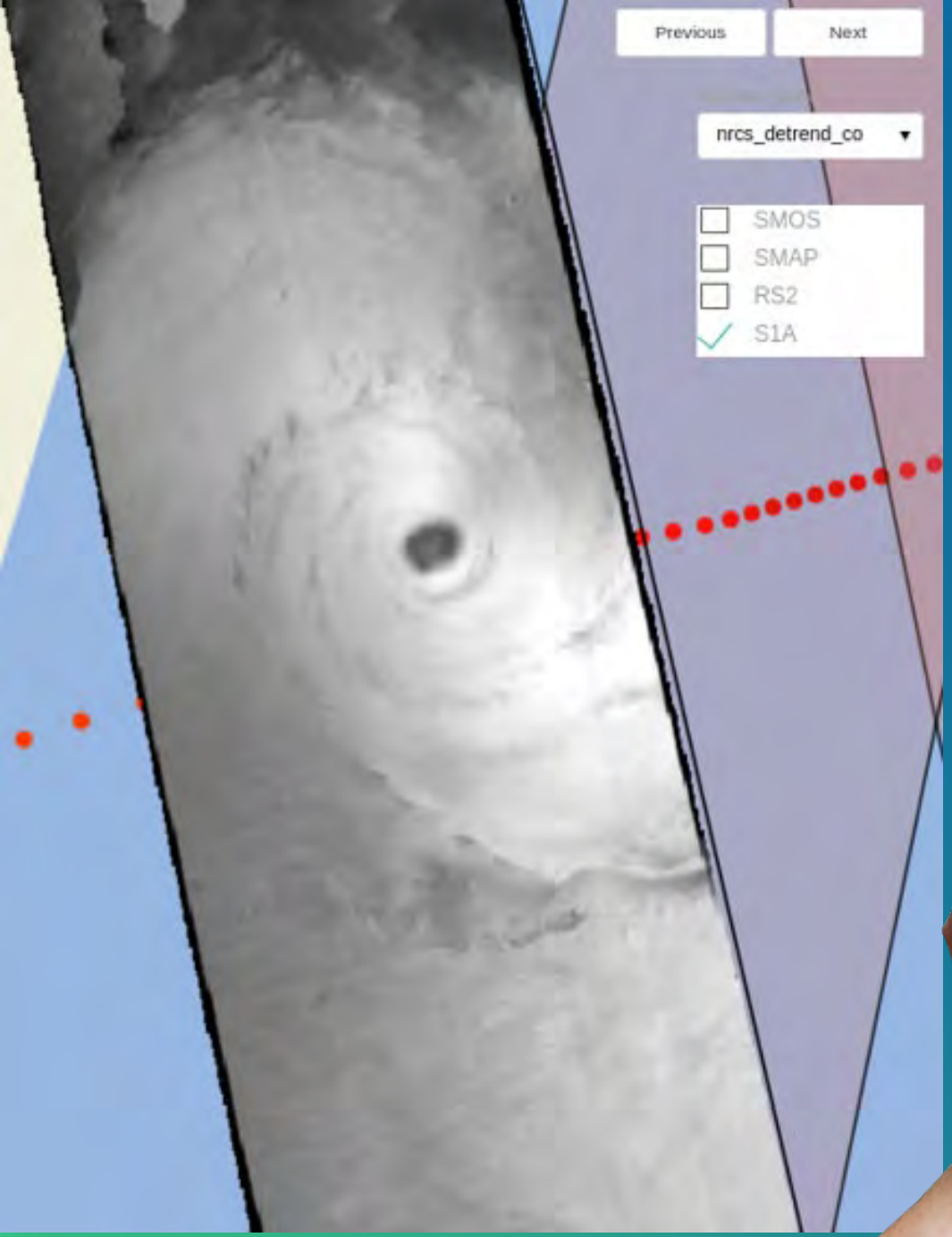
What’s in CYMS products ?

L2 wind maps + L2 Fix products
(tropical cyclones only)



What's in CYMS products?

CYMS with Sentinel-1

L2 wind maps

- Level-1 information: **Normalized Radar Cross Section (NRCS) for co- (VV)** and cross-polarization (VH) channels
- SAR-derived geophysical information: SAR wind speed + direction (mainly driven by model) + SAR wind orientation (wind streaks orientation, 180° ambiguity)
- Model information: ECMWF wind speed + direction
- Masks: Validity mask, Heterogeneity mask

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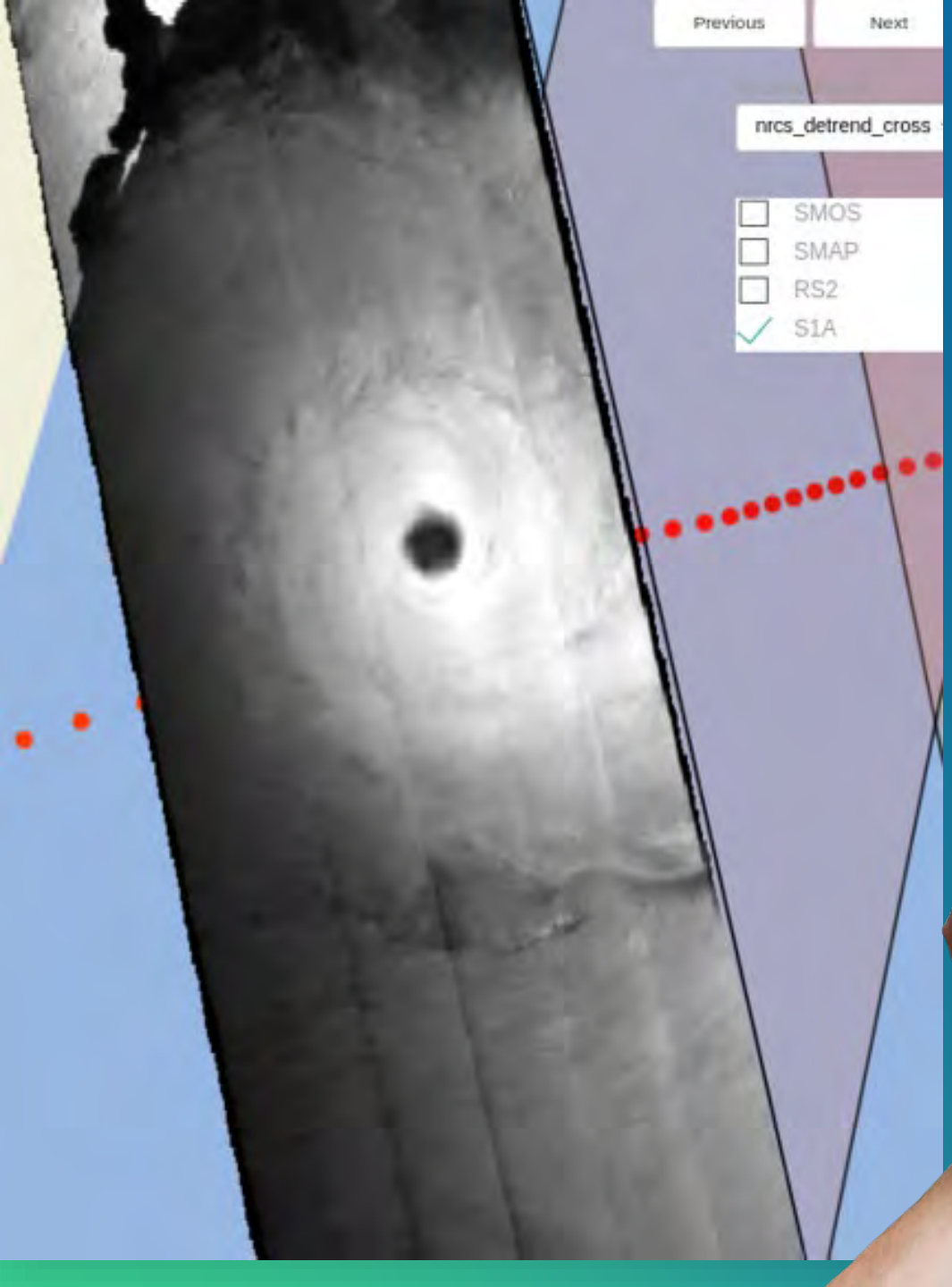

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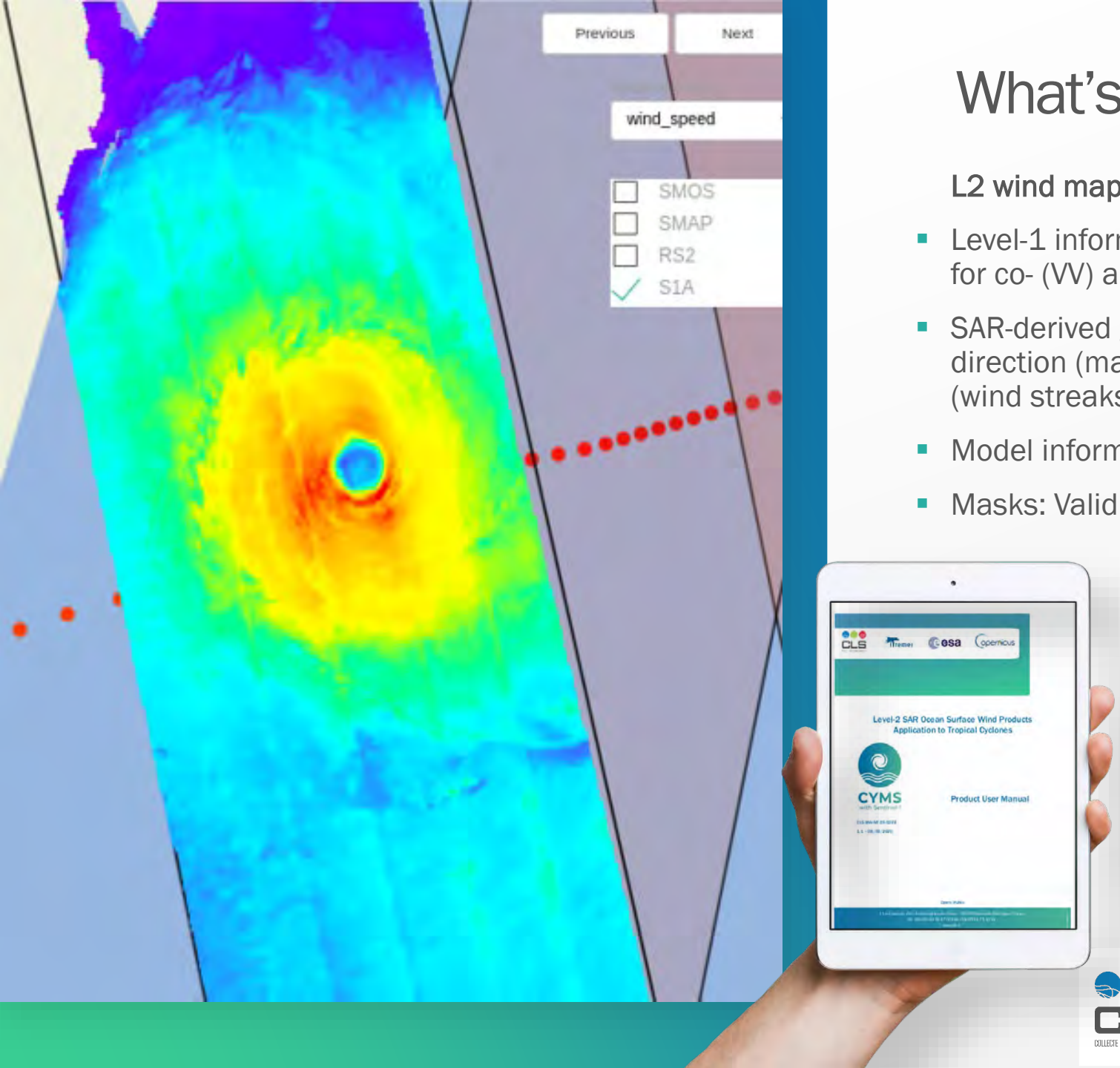

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What's in CYMS products?

CYMS with Sentinel-1

L2 wind maps

- Level-1 information: Normalized Radar Cross Section (NRCS) for co- (VV) and cross-polarization (VH) channels
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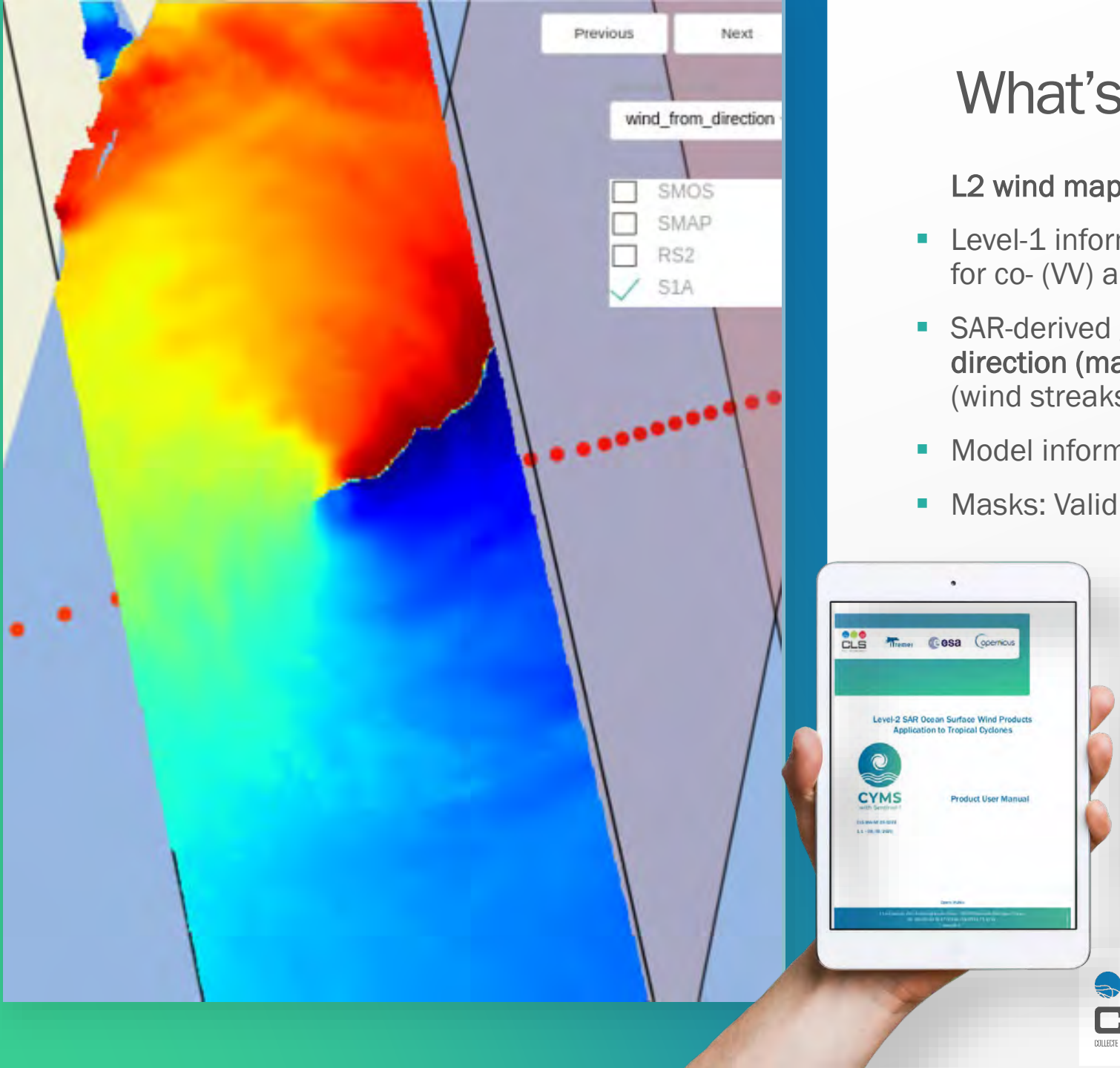

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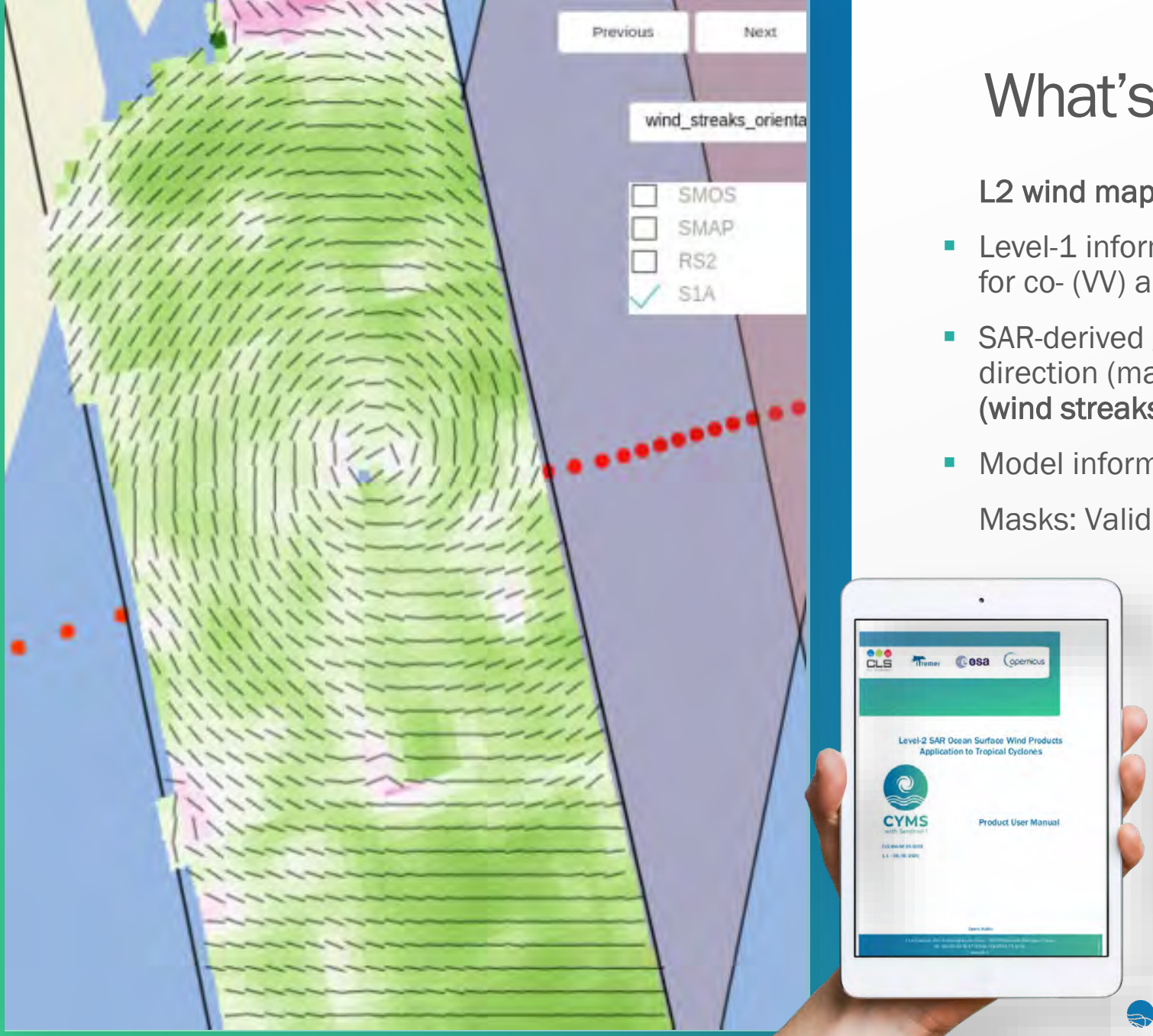

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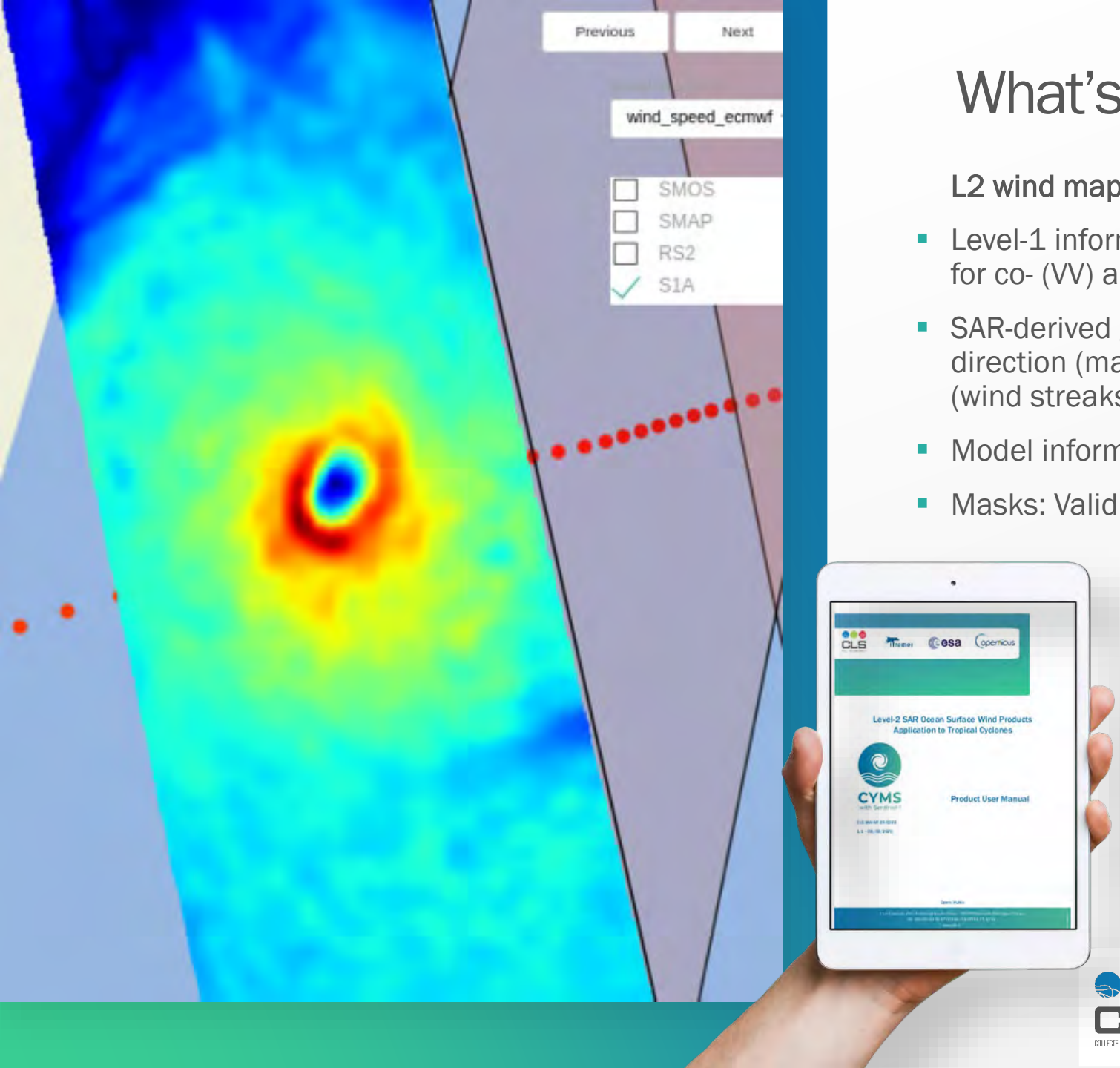

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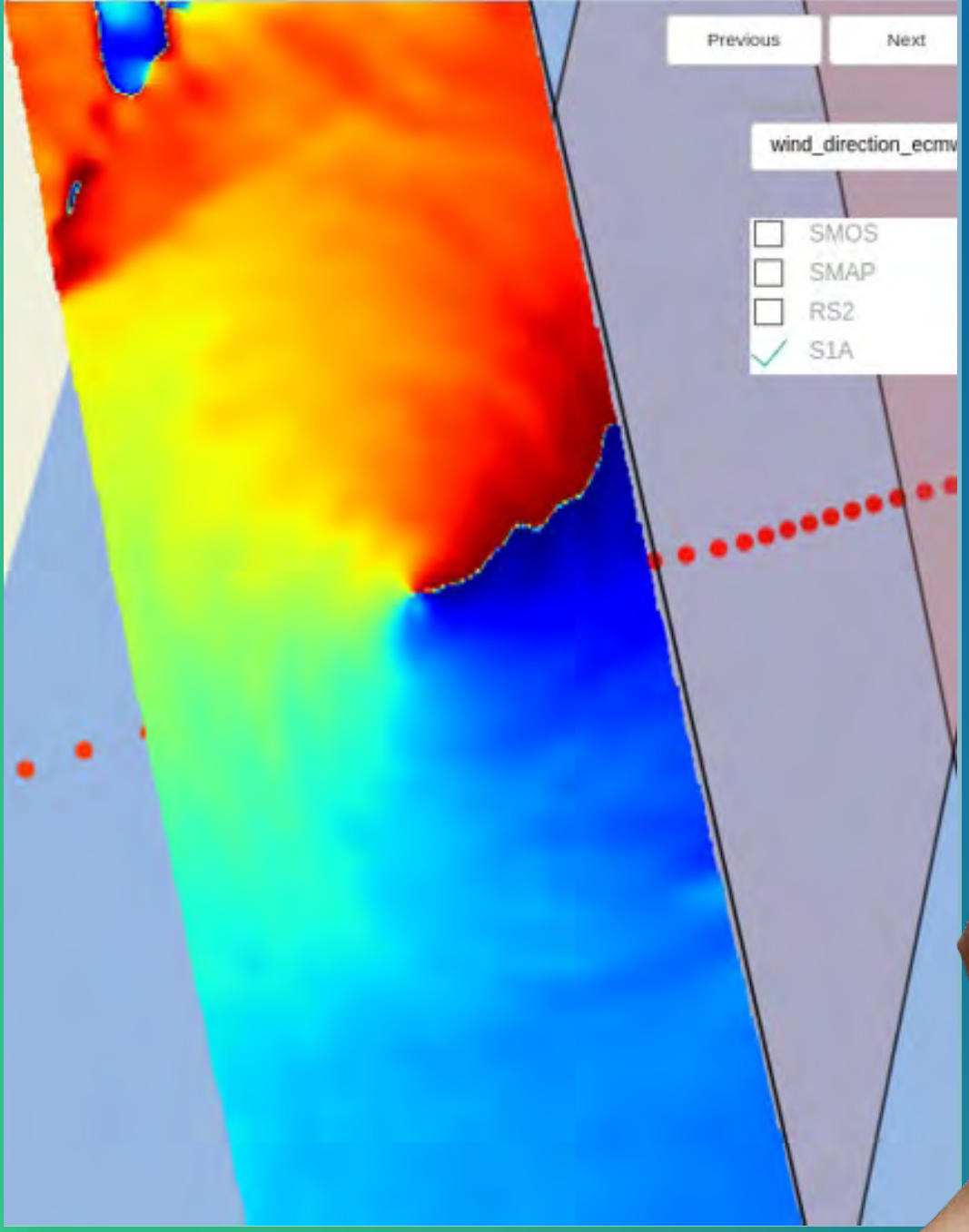

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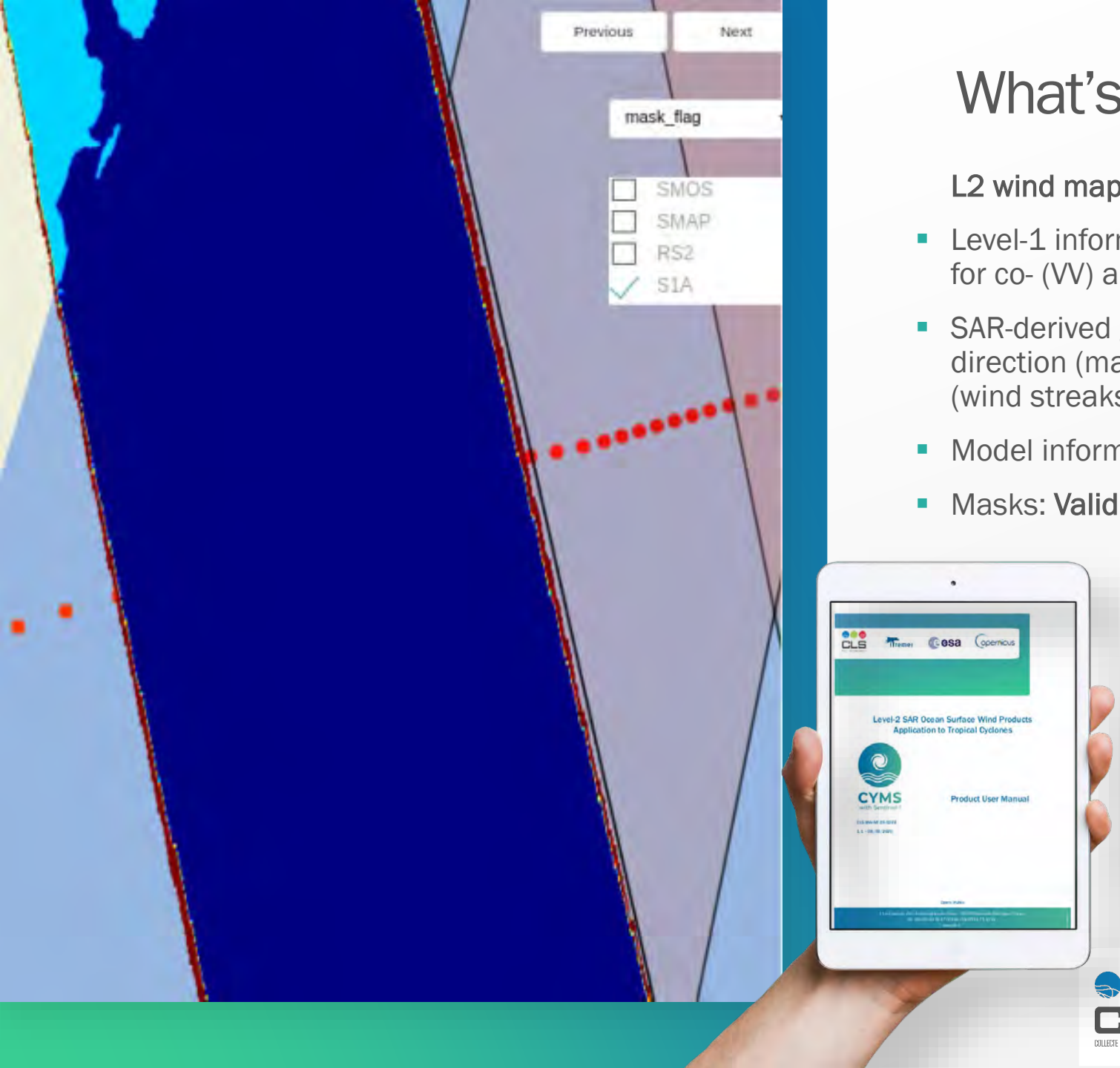

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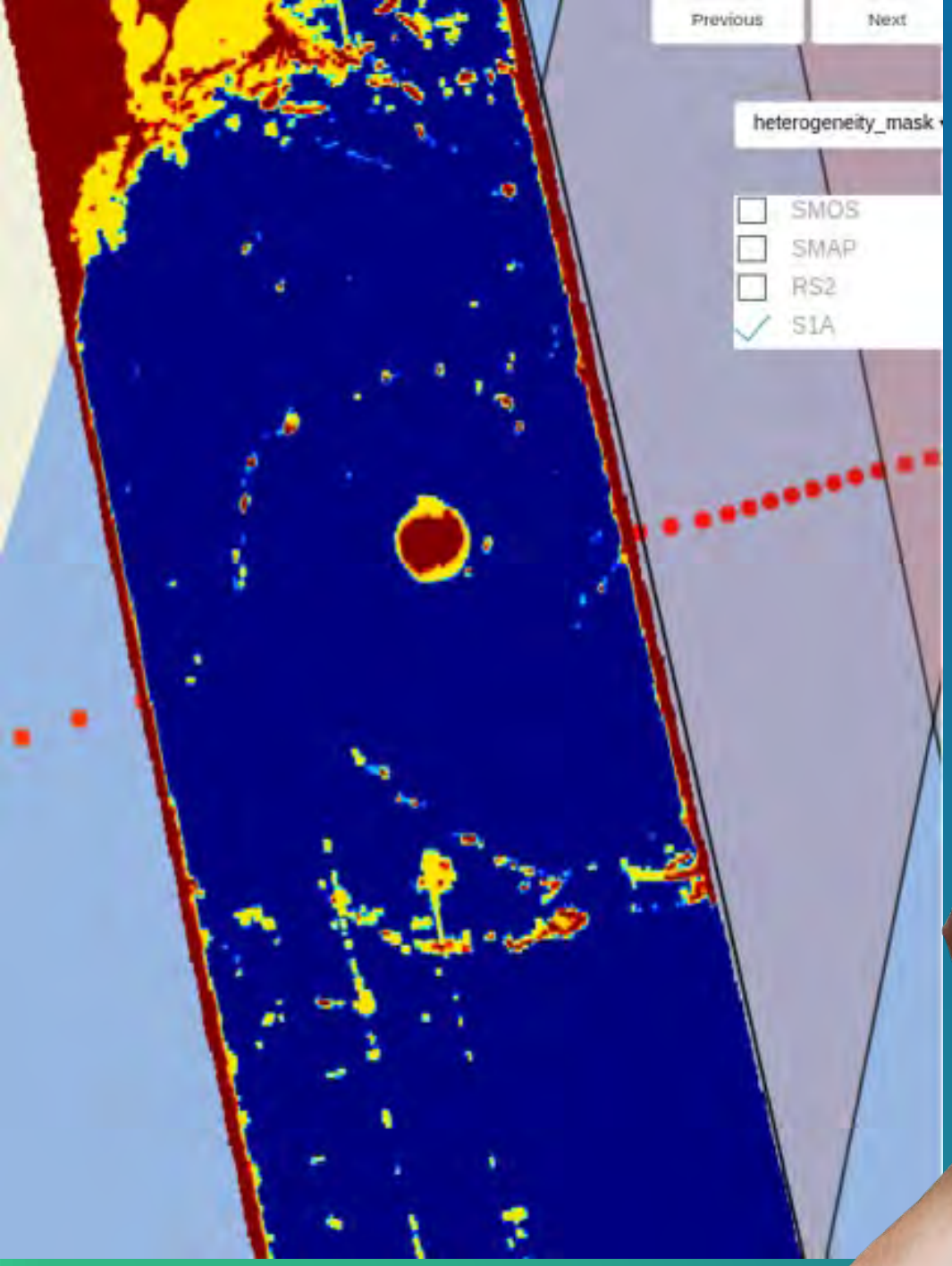

What's in CYMS products?

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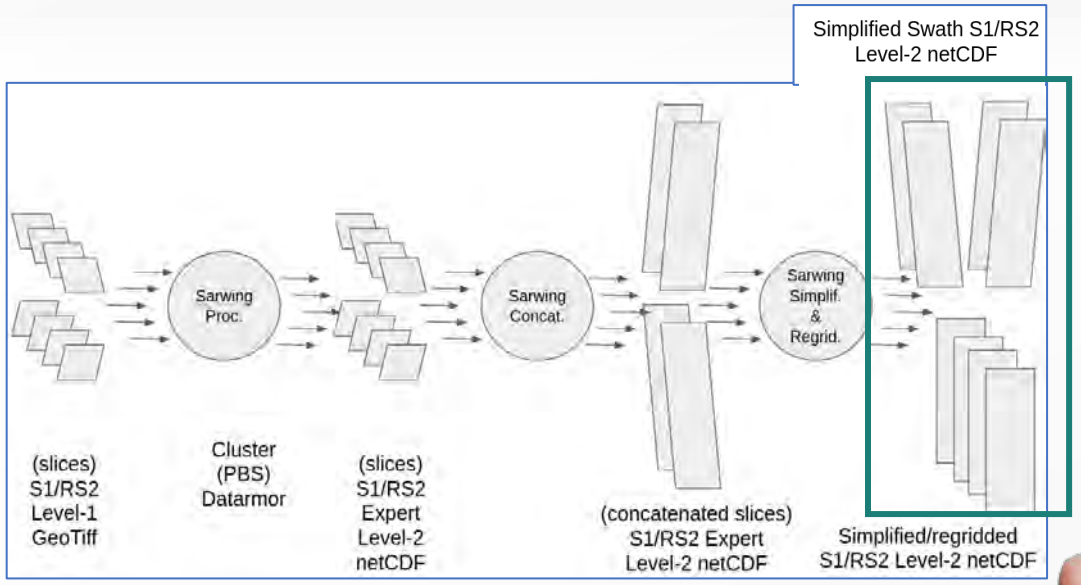

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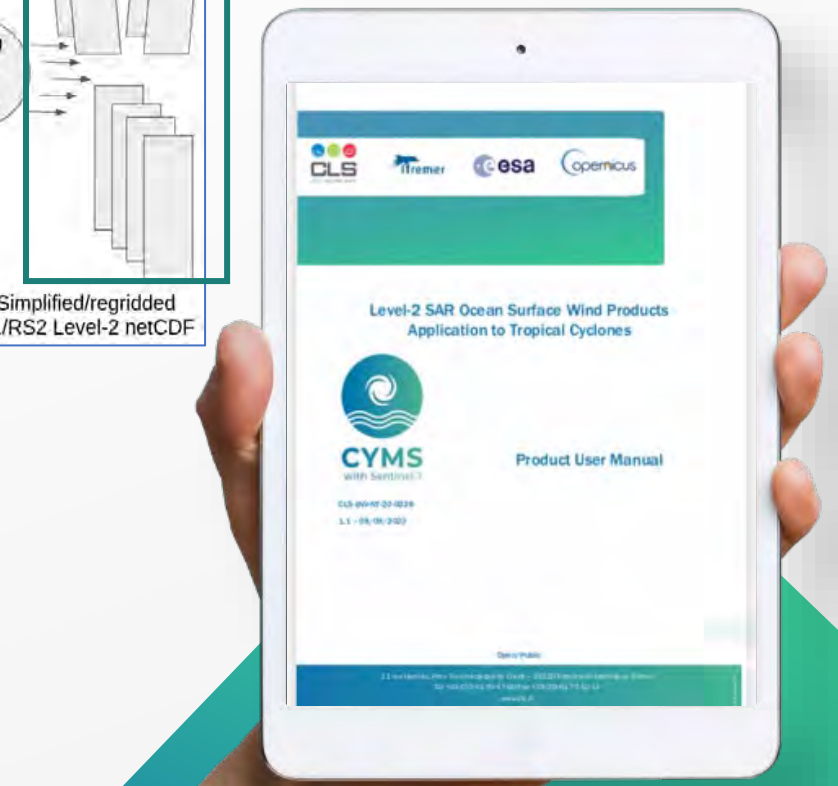


User oriented wind product

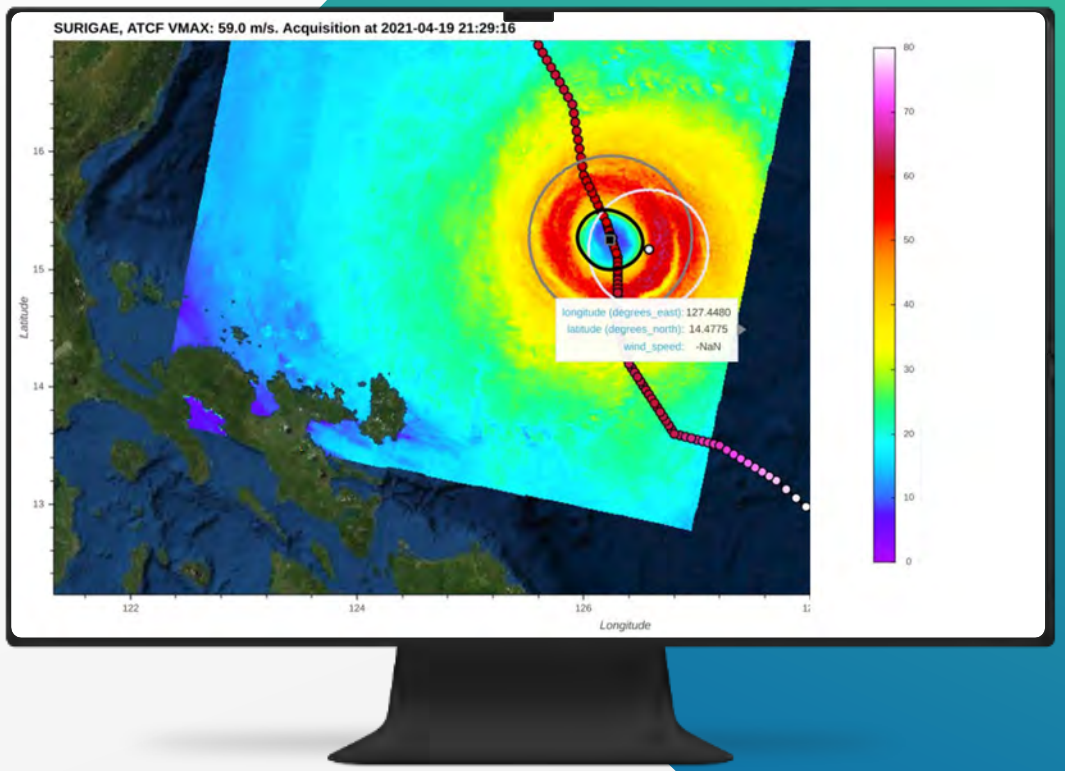
- High-wind processing chain
- Slice concatenation: to provide a single concatenated product from SAR slices
- Swath & Gridded Product: Geographical and regular grid (lon and lat)
- Product User Manual [PUM] (CMEMS Template)
  - Defines data content, format, access
  - Defined in collaboration with end-users
  - Formatted following the CF-1.6 convention to facilitate usage

=> A new CYMS product distributed in NRT and in re-processing.

What's in CYMS products ?

L2 Fix products (tropical cyclones only) - V1

- TC center location
- Maximum sustained wind speed
- Wind Radii
- Radius of maximum wind speed



- Cyclone ATCF interpolated track
- High wind speed research area
- Low wind speed research area
- Eye shape
- First guess (from interpolated ATCF track)
- High wind speed barycenter
- Low wind speed barycenter
- Center of eye shape

What's in CYMS products ?

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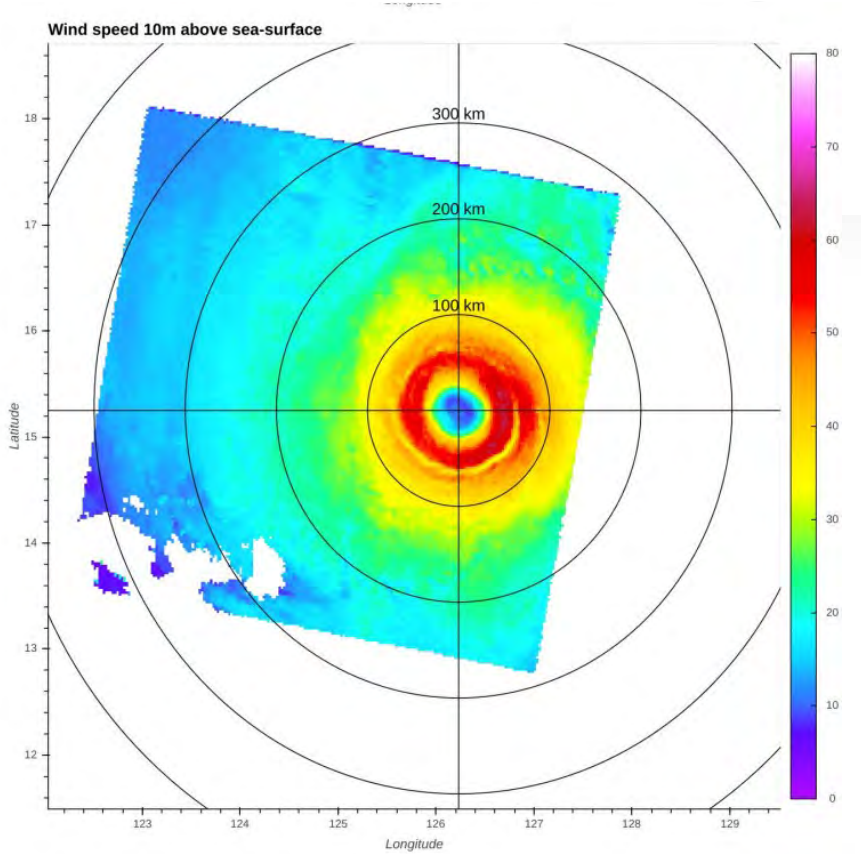
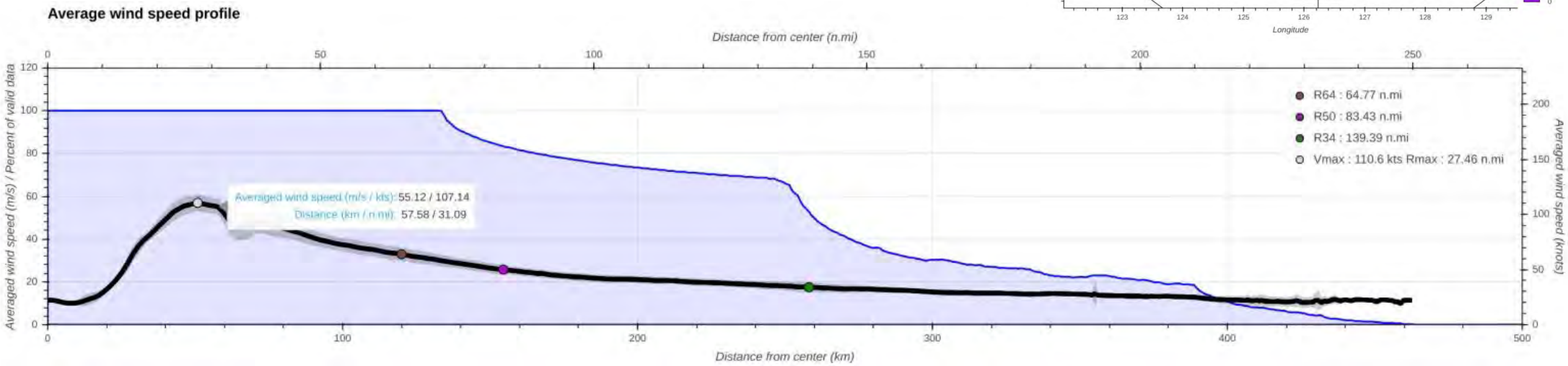
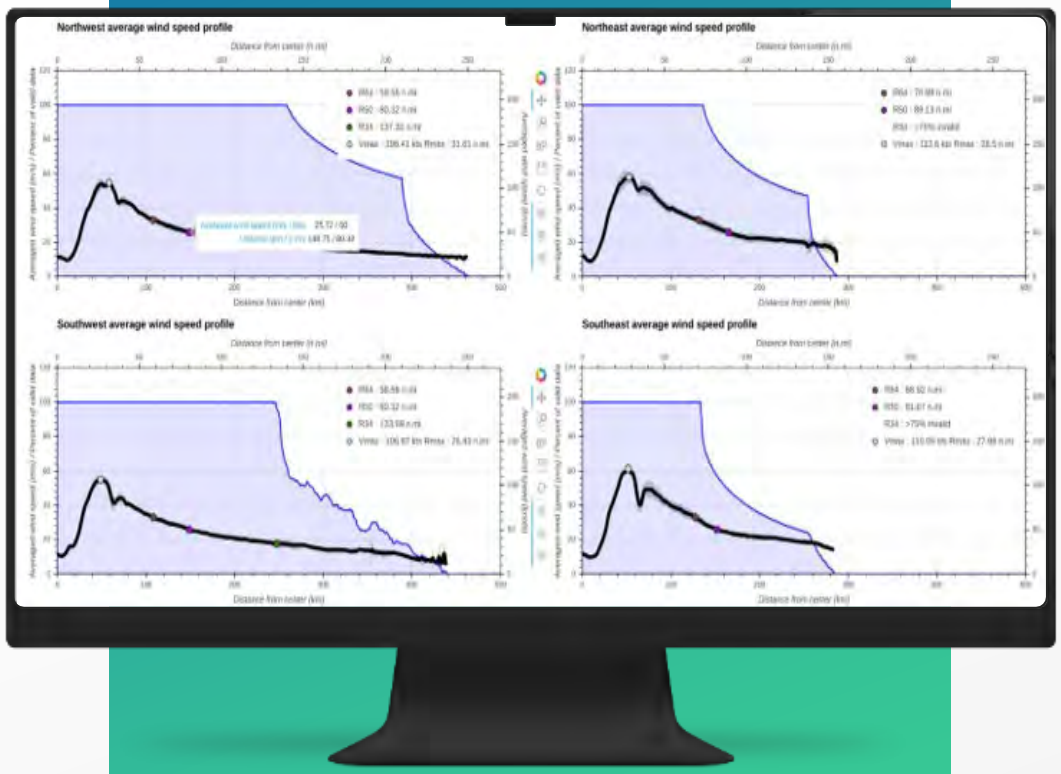




CYMS
with Sentinel-1

What's in CYMS products ?



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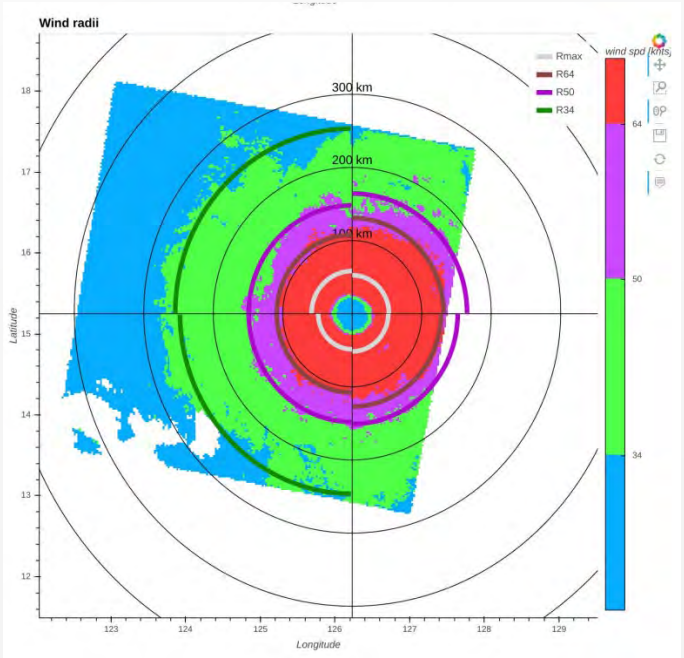

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Some references & data access

Point of Contact: contact@esa-cyms.org

General website: http://esa-cyms.org

Twitter account: https://twitter.com/CYMS_S1

Documentation: (Scientific articles, project description, technical documentation) :

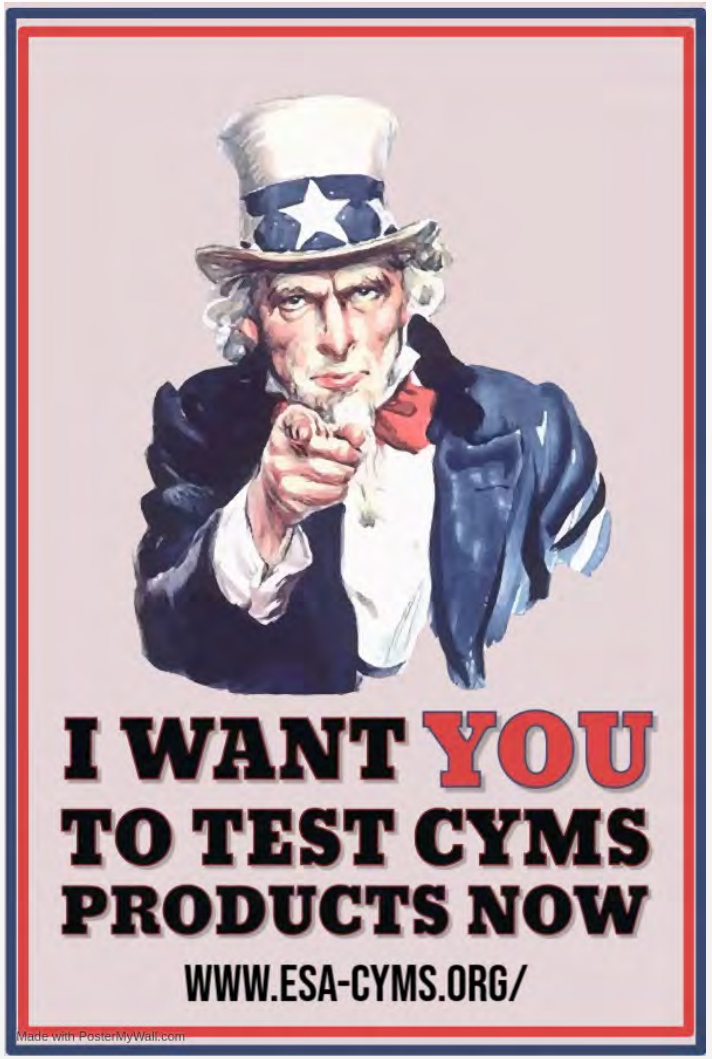
https://www.esa-cyms.org/documentation/

Data access & visualization (NRT and Archive):
https://www.esa-cyms.org/data-access/

- WebGIS platform for **NRT products:** https://eoda.cls.fr/cyms or https://datastore.cls.fr/seewater-cyms
- Data archive center for **reprocessed products:** https://cyclobs.ifremer.fr/app/

Any questions?

More perspectives
for future in next slides...



Demonstration

Data access & visualization tools

Vinca Rosmorduc, CLS

CYMS
with Sentinel-1

Demonstration (data access and visualisation tool)

Archive Center

- Tropical cyclone (example of Bastirai)
  - Visualisation
  - Data download
  - Statistics & additional information provided
- Polar lows pages
- Extra-Tropical Cyclones (example of Medicane Apollo)

NRT center ("SeeWater" interface (beta version)):

- European extreme wind events:
  - How to select roughness, wind speed and streaks, ovelay in different data layers
  - Date/time selection
  - Examples of Bora winds (Adriatic Sea), Winter Northern Winds over Egean Sea, Medicane Albenga

NRT data download via SFTP

Data access

CYMS provides with Sentinel-1-derived ocean surface wind field products acquired along Tropical Cyclone forecast tracks through a single integrated portal. It also provides data over polar lows and extratropical cyclones.

- Ocean surface wind estimates day and night at high spatial resolution and over wide images for hurricane-force winds, additional key information on Tropical Cyclone structure: maximum wind speed, eye diameter, wind radii, eyewall replacement cycle... from Sentinel-1,
- complementary existing observations (geostationary imagery, radiometry) for a full overview,
- Customized, validated and fully acknowledged products,
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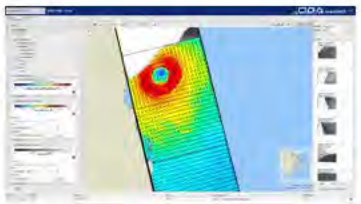
- WebGIS platform and archive center,
- Near real-time information

See the Product User Manual for information on the data format and access

Near-Real Time Tropical Cyclone data access



EODA webGIS portal enables to visualize and download latest NRT wind surface products.

A SFTP server to download data files (netCDF) is available at:
sftp://ftp.vigisat.cls.fr/CYMS_products/
login: CYMS
pwd: CYMSentinel1
port: 2222
(open on e.g., Filezilla)

A beta version of a new graphical interface is also available.

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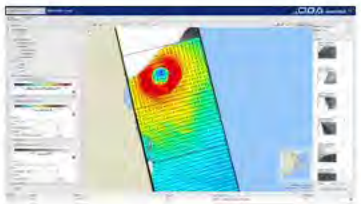

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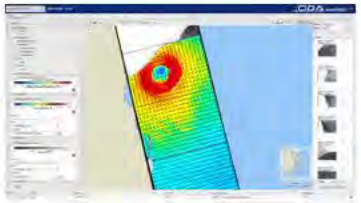

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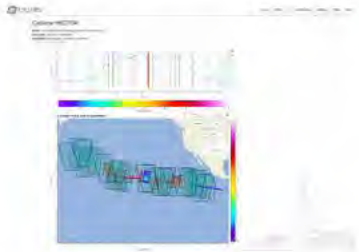
Archive data access for Tropical Cyclone, polar lows and extratropical cyclones



Cyclobs archive center provides a complete and homogenous dataset to the Tropical & extratropical Cyclone Community. Reprocessing archive center delivering a complete, state-of-the-art and homogeneous dataset since the Sentinel-1 launch. CyclObs updates are data-driven

Any Questions?

Reminder

CYMS with Sentinel-1

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USECASE #1

Use of CYMS tropical cylcones measurements by meteorological forecasters

With Tarik Kriat from Météo France La Réunion

METEO FRANCE

CYMS with Sentinel-1

Use Case #1 - TC forecasters

Météo-France La Réunion is a Regional Specialized Meteorological Center (RSMC): it is responsible for the TC monitoring for WMO in the Southern Indian Ocean region.

TC forecasters are on hold during the TC season to analyze the meteorological situation and provide meteorological bulletins operationally.

Region of interest for MF RSMC

WORLD METEOROLOGICAL ORGANIZATION

CYMS with Sentinel-1

Use Case #1 - TC forecasters

Satellite/ sensor	Source	Software	Use	Comments
Geostationary [MSG-1] IR/Vis/WV/RGB	Eumetsat MF Sat Met Center	Meteo France (MF) software ('Synopsis')	Routine	High Res. Vis. Imagery (1km) Himaxari-8 (eastern part of the basin), MSG-4 (westernpart of the basin) and FY-G as back-up
Scat – ASCAT B	- Eumetsat OSI SAF (KNMI) - Regional reception - Internet	- MF software ('Synopsis') - KNMI website for ASCAT-C, HY-2B/HY-2C - NOAA STAT (manati) for BYU, NRCS products - NRL website	Routine	Next: ASCAT-C visualisation
SMAP / SMOS	- IFREMER - Internet	- Internal MF - NRL	Routine	Poor near real time availability but improving
SAR	- IFREMER / CLS - Internet	- Cyclobs / eodus web platform - NOAA/STAR/SAROPS - NRL	New products	Poor near real time availability but improving. New product – lack of guidelines to optimize operational use
AMSR-2				
Microwave 37; 85-91 GHz **OTHER …**	- MF Satellite Center - Internet	- MF software ('Synopsis' + 'Synergie Cyclone' → SSMI/S, AMSU-B - NRL → GMI, AMSR2	Routine	Next: AMSR2 and GMI imagery on our internal software

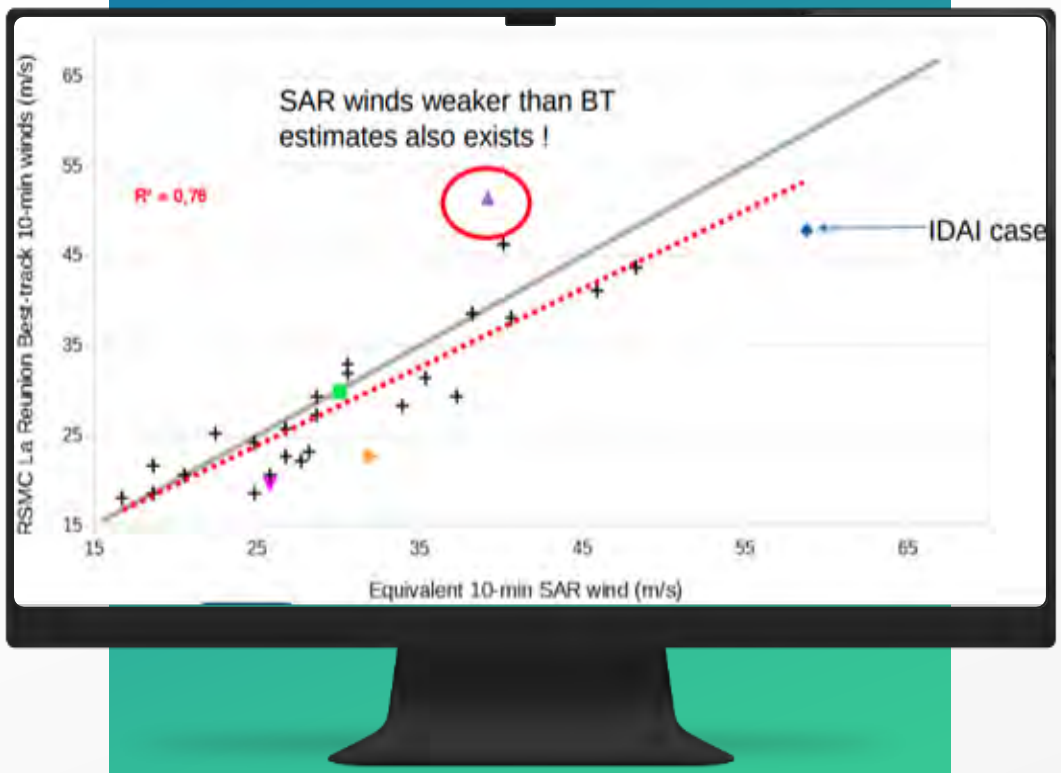
They use various data sources and associated techniques to best estimate/forecast the TC intensity .

After the TC season, they also perform an annual re-analysis to re-evaluate the data sources and associated methodologies.

Satellite/sensors used by MF RSMC for their analysis

Use Case #1 - TC forecasters

Comparison between equivalent 10min SAR maximum winds and the RSMC La Reunion BTMW.



The colored symbols correspond to: the pink triangle with d ownward point refers to TC CARLOS (February 2017), the green square refers to TC GELENA (February 2019), the orange triangle with rightward point refers to TC FRANCISCO (February 2020), the purple triangle with upward point refers to TC JOANINHA (March 2019), and the blue diamond refers to TC IDAI (March 2019).

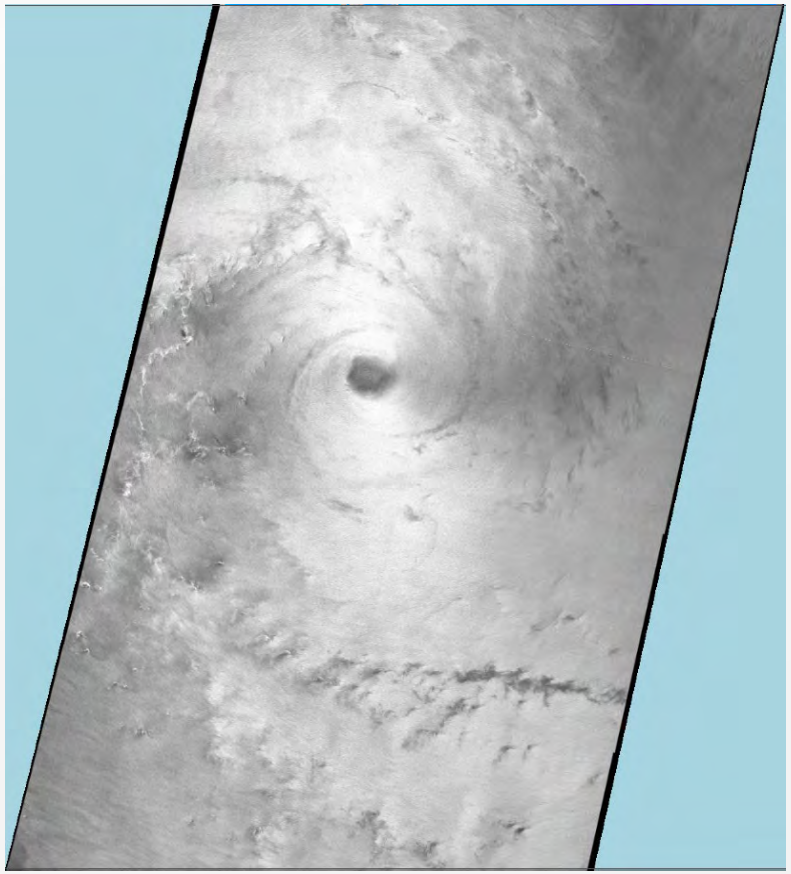
- The following feedback from the forecasters team, directed by Philippe Caroff, was gathered by Sébastien Langlade.
- A thorough re-analysis between February 2017 and March 2020, for cases where the location of maximum wind (Rmax, for Radius of max. wind) was sampled by CYMS data.
- It compares their usual reference data, the Best-Track data of Maximum Winds (BTMW), interpolated at SAR acquisition time to the SAR-derived MSW estimate (Maximum Sustained Wind speed).
- This analysis is part of the prepared publication Duong et al. 2021: https://doi.org/10.3390/atmos12050576.
- This re-analysis is very important as it assesses the possible inclusion of CYMS products in forecasters current analysis methodologies.
- Overall, they are in good agreement and can sometimes lead to a re-estimation of the initial MSW.
- Yet, in 50% cases, disagreements were found.

Use Case #1 - TC forecasters

These disagreements are attributed to heavy rains and/or incorrect calibration

- **Heavy Rains**
  - Usually well filtered for wind speed 0-20 m/s but less for higher regimes,
  - Can lead to under/over-estimation of the Radar signal and thus resulting wind speed if not well filtered

- **Incorrect Calibration**
  - **SAR** calibration (including noise correction): regularly improving, coordination with Sentinel-1 Mission Performance Center. Eg: wind speed discontinuities at subswath edges, EW1 (smallest incidence angle)
  - **GMF** calibration: updates possible with increasing CYMS L1 data archive. Expected improvements less sample conditions:
    - lowest/largest incidence angles,
    - highest winds,
    - sensor dependent (S1A / S1B / RS2),



SAR-derived wind speed over TC Emnati on 2022-02-19 showing large rainbands swirling around the TC eye

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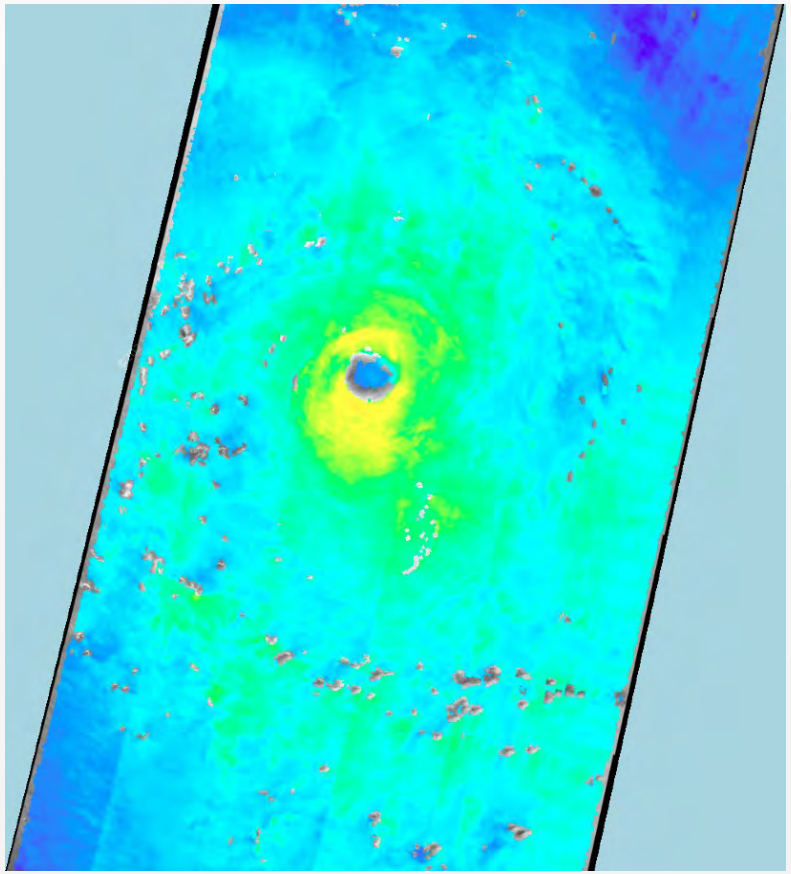


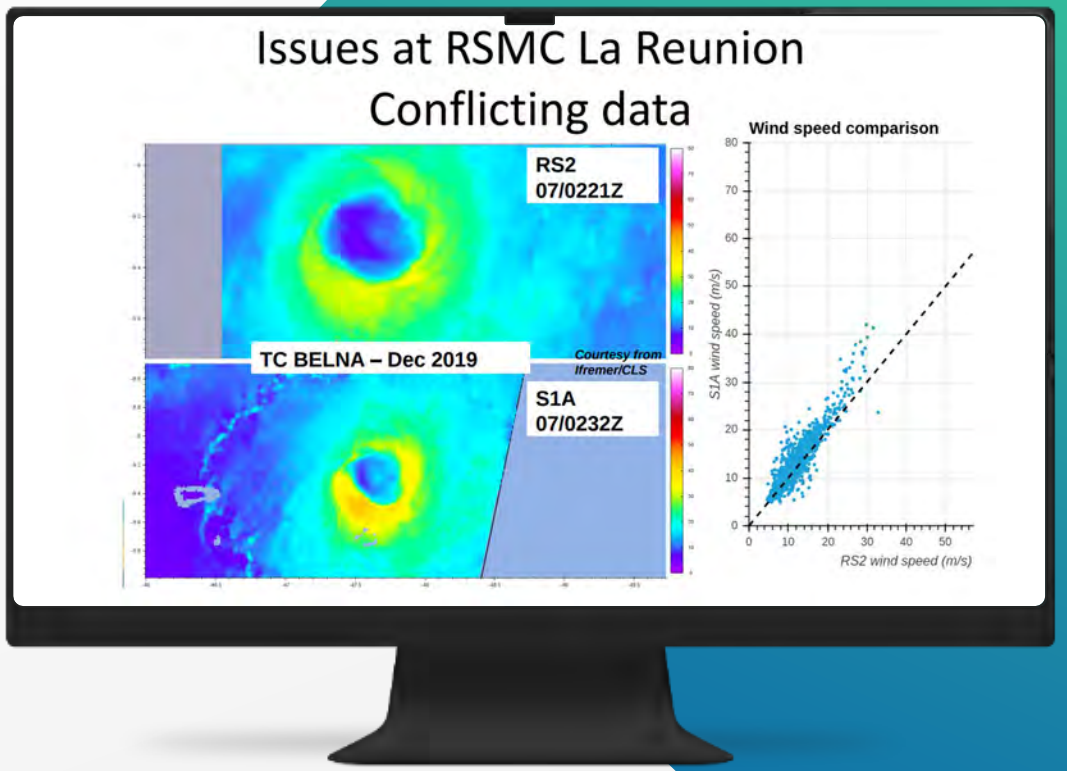
SAR-derived wind speed over TC Emnati on 2022-02-19 showing large rainbands swirling around the TC eye

Use Case #1 - TC forecasters

How to compare CYMS products among them?

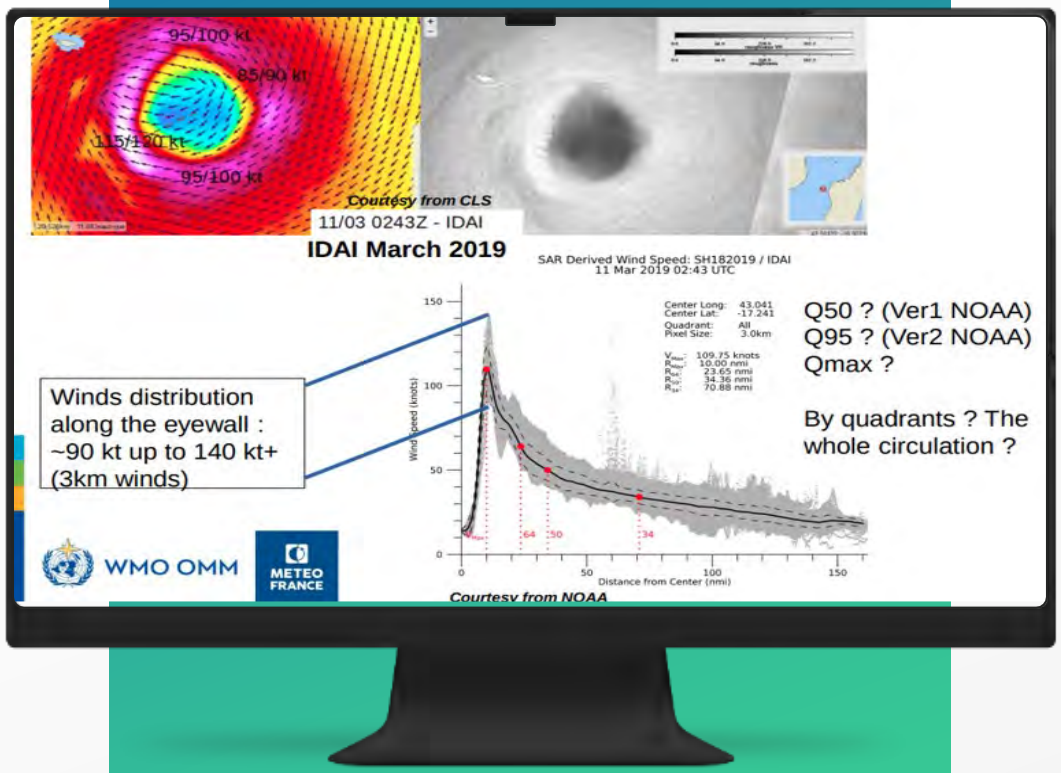
- ~ 15/20 kts difference in terms of max winds on this two passes only 10 minutes apart
- Sub-swath issue at low incidence angle? (likely for the S1A), rain effect ?
- Subjective Dvorak close to RS2 / Objective Techniques close to S1A

→ What's the decision?



Use Case #1 - TC forecasters

Issues at RSMC La Réunion
Intensity definition with SAR



How to compare CYMS products wrt. to other information ?

- Estimation of MSW from S1A product can be sensitive to its definition, partly also due to the SAR high resolution
  - Is the information used at 1 km resolution or down-sampled ?
  - How does it compare with 1min vs. 10min average winds?
- Depending on the estimation
  - Sub/Obj guidance at **100kt ± 5 kt** (1' winds).
  - S1-A at **123 kt** (3 km winds -Q50 max by quadrant)

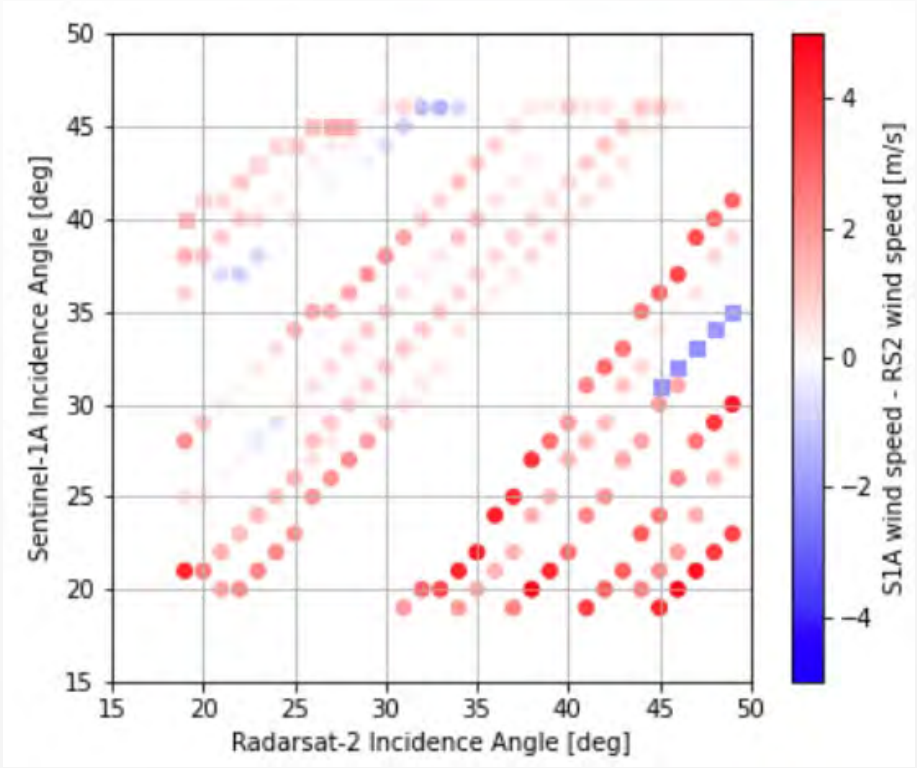
--> Leads to a re-estimation to 10 kts higher value of the MSW

Use Case #1 - TC forecasters – perspectives...

Investigating the consolidated CYMS archive and its co-location with reference data (SFMR, SMAP/SMOS):

- Further analysis has to be done on the radar signal and in particular to its dependency to incidence angle, but also wind speed, polarization and sensor
- Processing date (for S1) and sensor (to separate S1 and RS2) also need to be considered

=> New GMF shall be developed



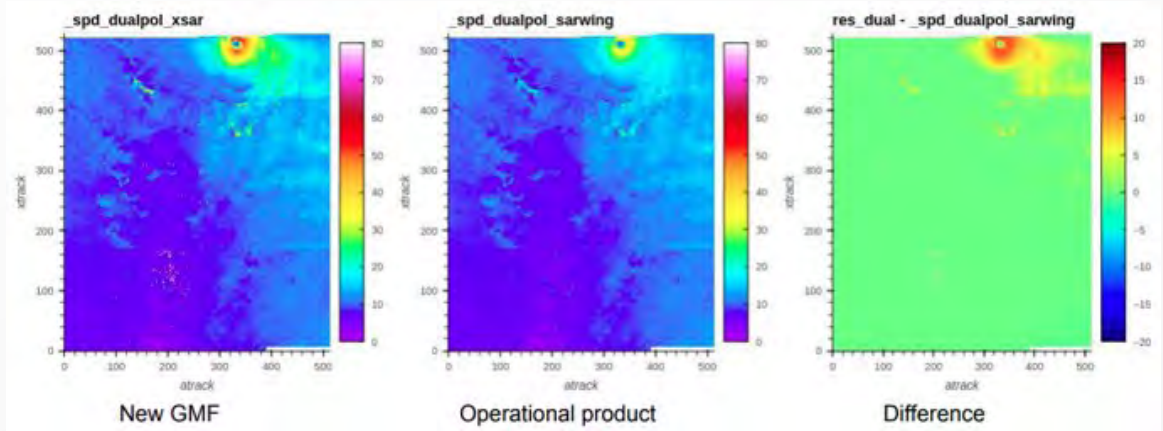
Mean wind speed difference between Sentinel-1A and Rardarsat-2 missions with respect to incidence angles of the two SAR missions. dots and squares stand for Sentinel-1 data acquired in EW and IW modes, respectively.

Use Case #1 - TC forecasters – perspectives...

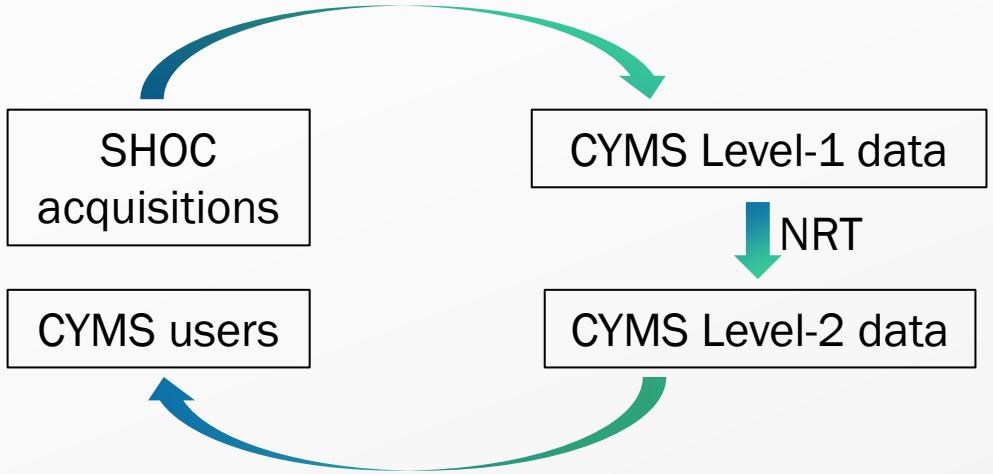
Preliminary new GMFs under development, tested over Batsirai, over 2 co-located cases, 18 min apart.

- Based on **RS2** co-locations with SFMR and SMAP
  - **Higher** wind speed values
  - The new VMAX for RS2 is about **57 m/s** wrt. **37 m/s**,
  - More in line with TC expert estimate, but stronger.

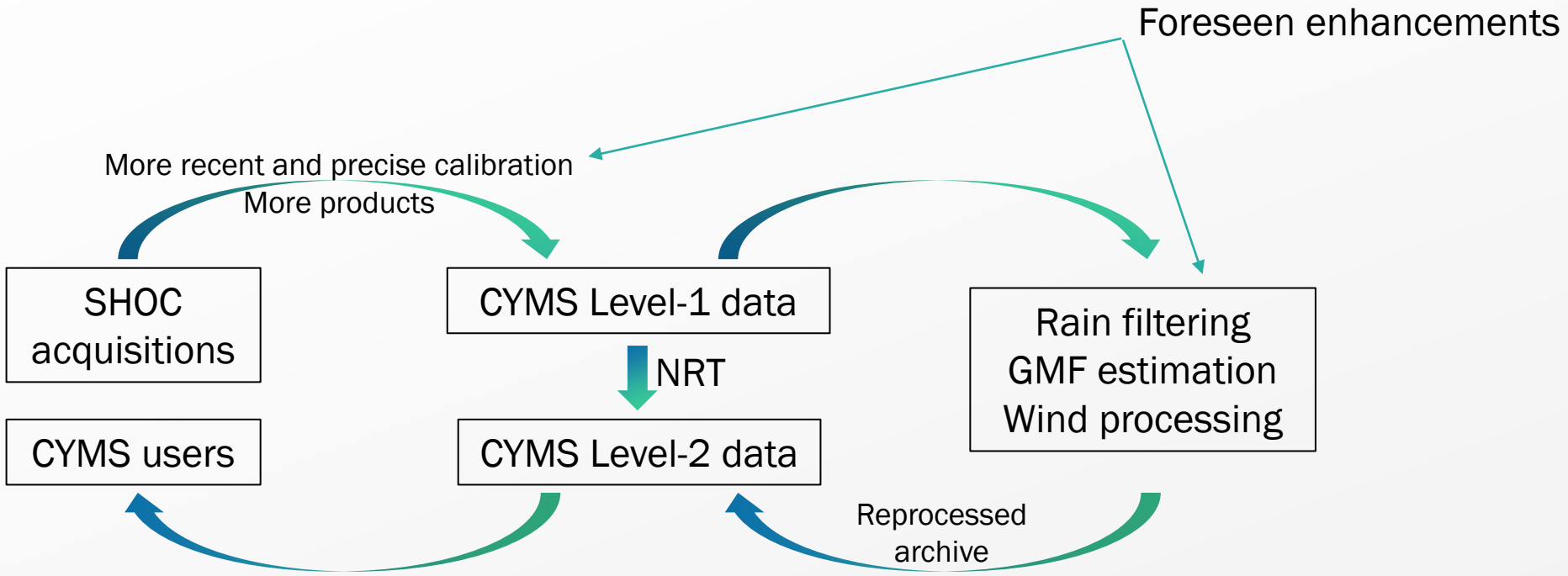
- Based on S1A (EW) co-location with SFMR and SMAP
  - **Lower** wind speed values,
  - The new VMAX for S1A is about **61 m/s** wrt. **68.5 m/s**,
  - More in line with TC expert estimate, but stronger.



Use Case #1 - TC forecasters – perspectives...



Use Case #1 - TC forecasters – perspectives...



Any Questions?

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USECASE #2

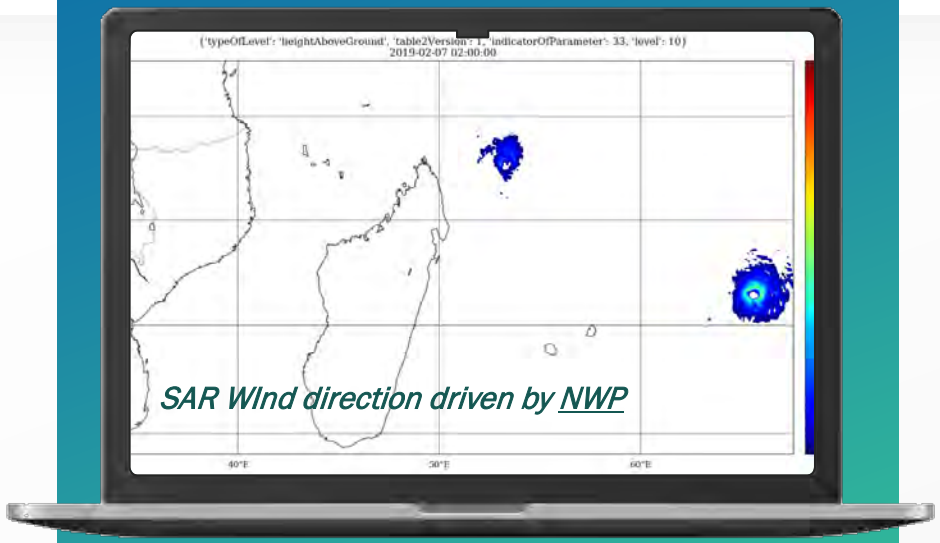
Assimilation of CYMS tropical cyclones measurements in AROME

With Quoc-Phi Duong from LACy

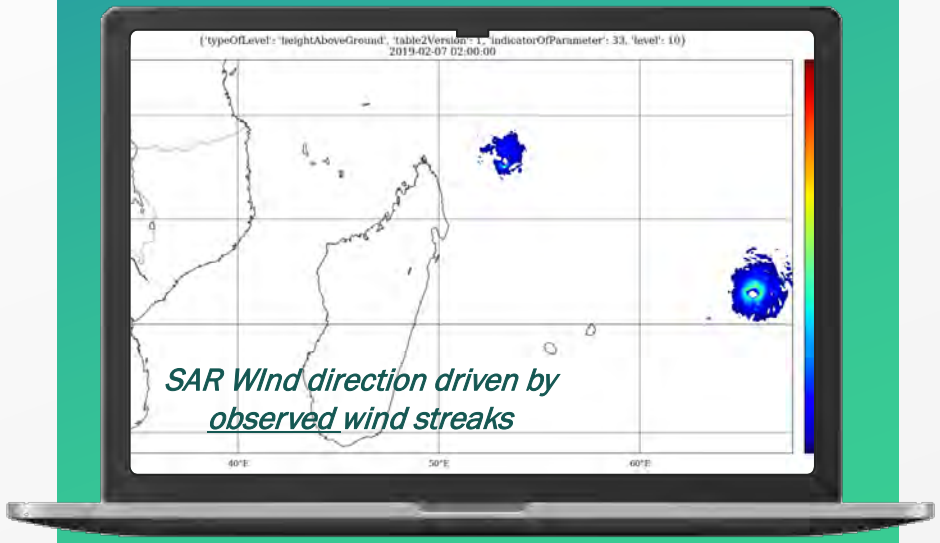
Use Case #2 - TC assimilation

- LACy, Cyclones and Atmosphere LAboratory, Cyclone team, directed by Sylvie Malardel. --> Improve the knowledge and the tropical cyclone modelling in the South-West Indian Ocean (SWIO).
- This work is also available in Duong et al. 2021: "C-band SAR Winds for Tropical Cyclone monitoring and forecast in the South-West Indian Ocean": https://doi.org/10.3390/atmos12050576.
- Tropical Cyclone (TC) monitoring and forecasts in the SWIO basin remain challenging, notably because of the lack of direct observations.
- During 2018-2019 cyclone season, CYMS products acquired as part of the ReNov'Risk campaign --> Unprecedented detailed TC wind structure description without wind speed limitation.
- Assessment of CYMS data quality and their capability to correct TC position and structure in Limited Area Model (LAM) analyses is investigated by assimilating them in the convection-permitting, AROME 3D-VAR Indian Ocean model, developed for research purpose on TC forecasts.
- The impact of SAR assimilation in AROME OI 3D-Var is assessed through 2 TC case studies: Gelena and Idai

Use Case #2 - TC assimilation



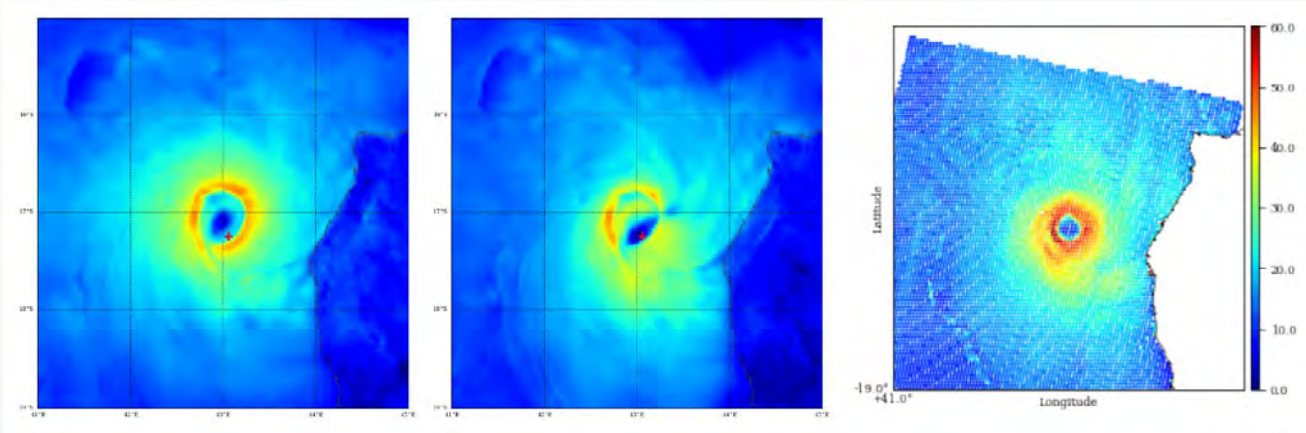
Analysis evolution on 07/02 from 02 UTC to 09 UTC



- In TC GELENA case, it leads to a **better TC positioning** and an improved representation of **inner and outer vortex** structures. The TC intensity reduction in the analysis **propagates** through subsequent analyses and it has an impact on forecasts for around 12 h.
- Using **wind streaks orientation** (derived from the SAR image) rather that from an a priori information such as a NWP model better preserves the TC structure and impacts the assimilation for a much longer time period.
- On top of the wind field modification, SAR data assimilation is also responsible for analysis increments of **pressure, temperature and humidity** at sea surface and upper levels in the eye and eye-wall area.

Use Case #2 - TC assimilation

- In TC IDAI case, the 3D-VAR does not manage to reproduce TC intensity captured by SAR
- In the 3D-Var background, the TC is well organised with strong winds in the eyewall. However, the **TC eye** diameter of the background is approximately **twice larger** than in the SAR image and SAR wind speed are much more intense in the inner vortex.
  - TC center is displaced southward by the assimilation --> better matching the position estimated by BT.
  - Winds are reinforced in the southern part of the outer vortex --> the outer vortex wind structure closer to the SAR observations in the analysis.
  - The inner vortex wind structure in the analysis is very different from the one given by the SAR image. --> the 3D-var assimilation fails to remove completely the initial eyewall, misplaced in the background, and it is not able either to construct a new thick eyewall as seen in the SAR image.



Background without SAR (left) and analysis with SAR assim. (middle) on 11 March 2019 03:00Z and SAR wind speed observations (right) at 02:46Z

Red cross is the estimated TC center position

Use Case #2 - TC assimilation

- Sensitivity tests show that these results are robust to different observation errors and thinning.

- Future research perspectives at LACy:
  - A new AROME model: 3DEnVar then 4DenVar
  - AROME Model will be coupled an oceanic model.
  - Then Assimilation tests will resume

Any Questions?

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USECASE #3

Assimilation of CYMS polar lows measurements in Harmonie-AROME

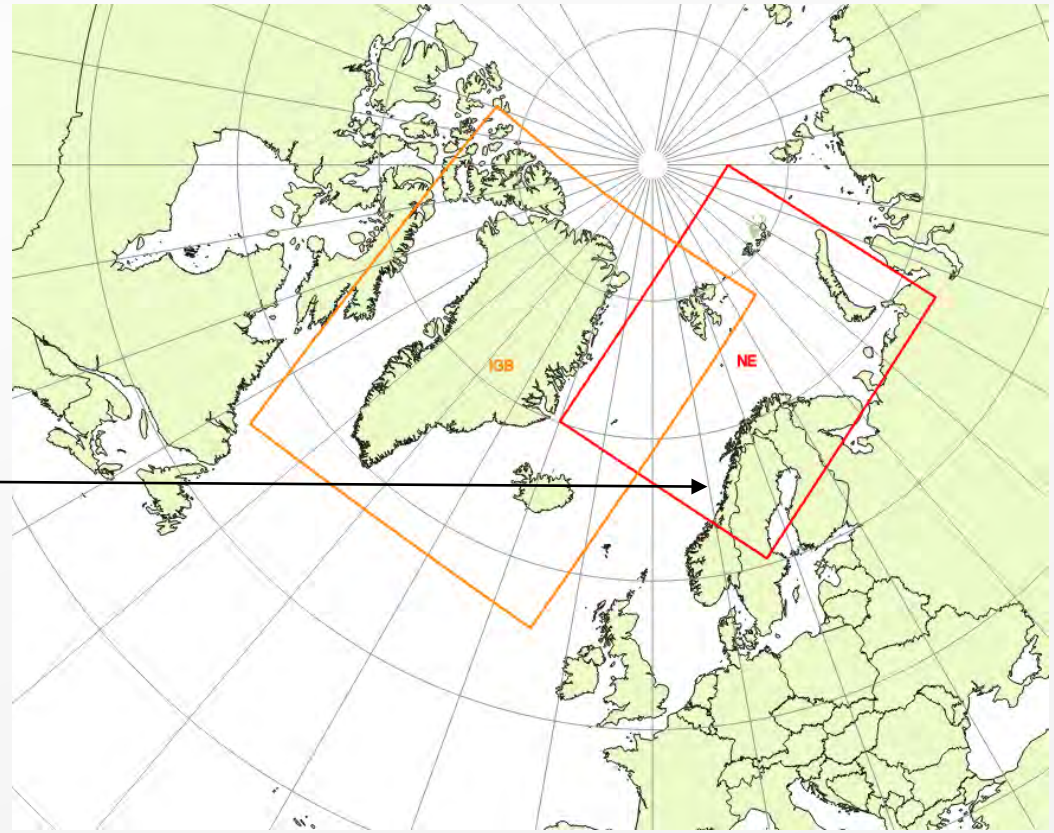
With Per Dahlgren, Roger Randriamampianina, from MET NORWAY

Use Case #3 – Polar Low assimilation

HARMONIE-AROME system

- Copernicus Arctic Regional ReAnalysis (CARRA) system (CARRA reanalysis data set 1990-2021)
- 3D-Var
- 3-hour cycles, analysis every third hour 00,03,06,09,12,15,18,21 UTC

The SAR test was done on NE domain

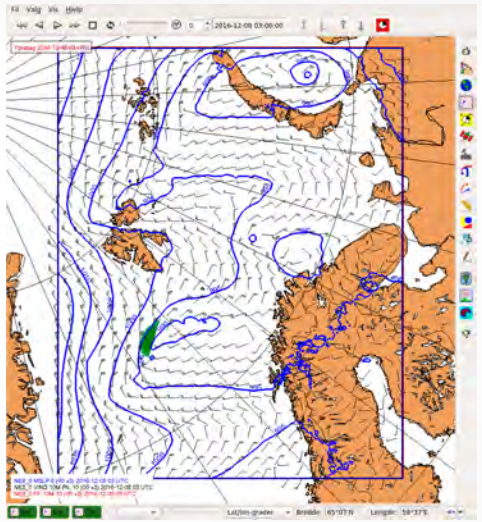


SAR Assimilation

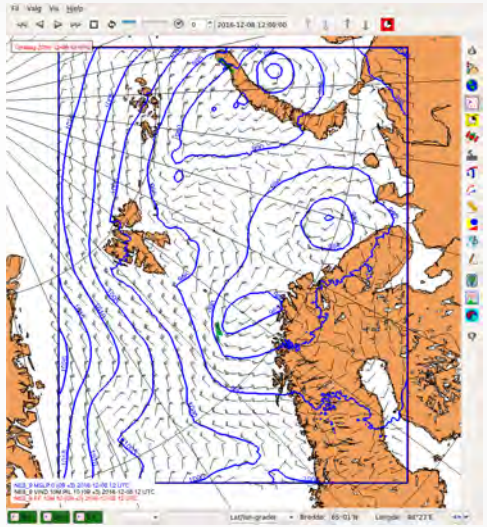
- Code updates for assimilation of SAR winds were provided by MF via Roger Randriamampianina
- The updates were phased into the CARRA system
- SAR data were assimilated in a case study on 8 December 2016, an intense mesoscale development
- SAR data thinned to 50 km

Use Case #3 – Polar Low assimilation

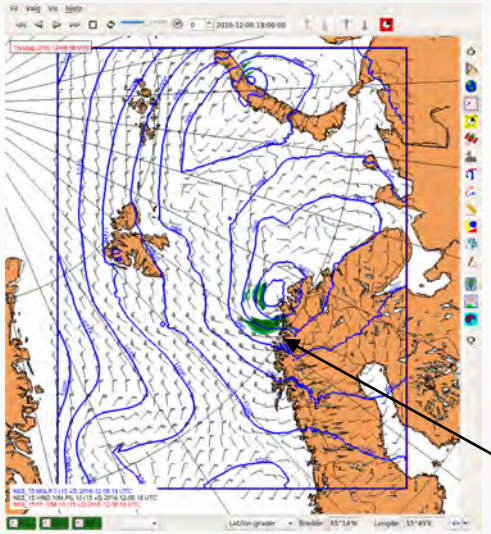
03UTC



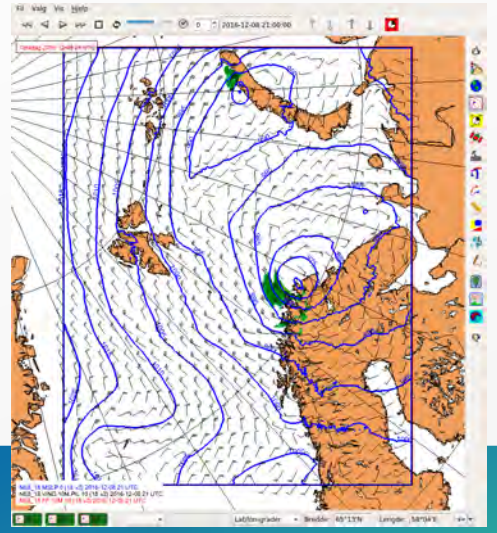
12UTC



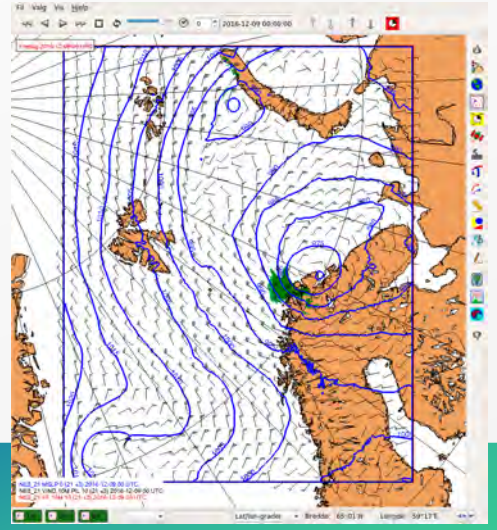
18UTC



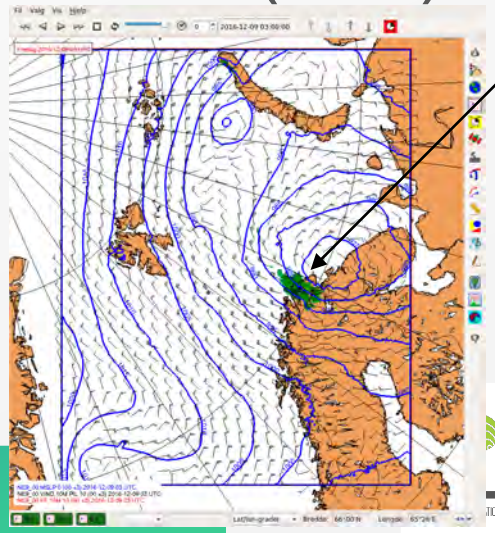
21UTC



00UTC (9Dec)



03UTC (9Dec)



Storm case 8 Dec 2016

Green color shade indicate where wind speed is greater than

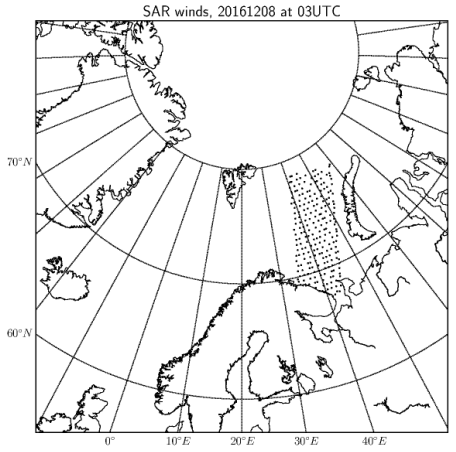
20 m/s

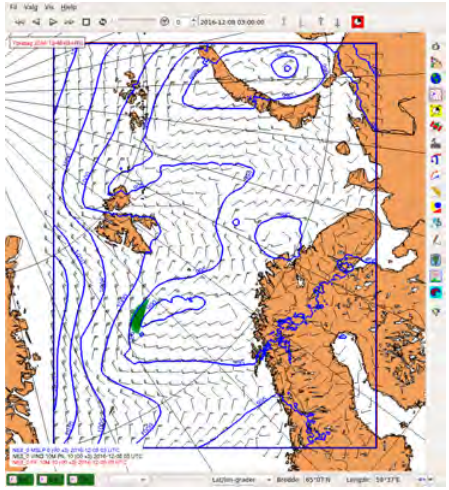
Use Case #3 – Polar Low assimilation

Availability of SAR winds

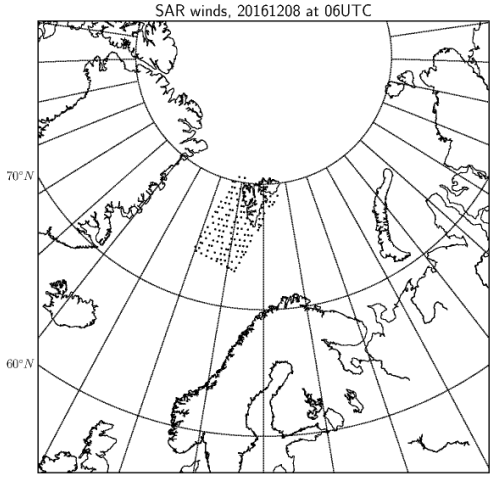
CYMS with Sentinel-1

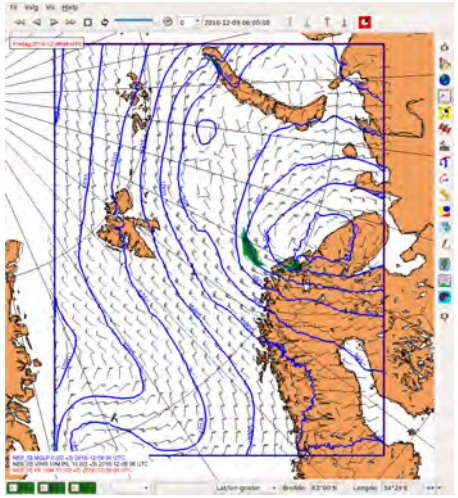
03UTC



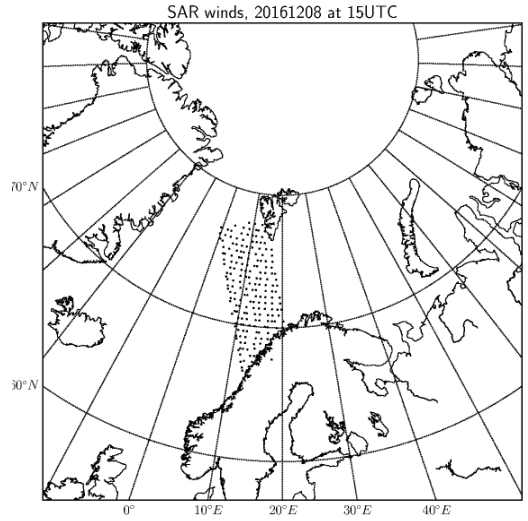


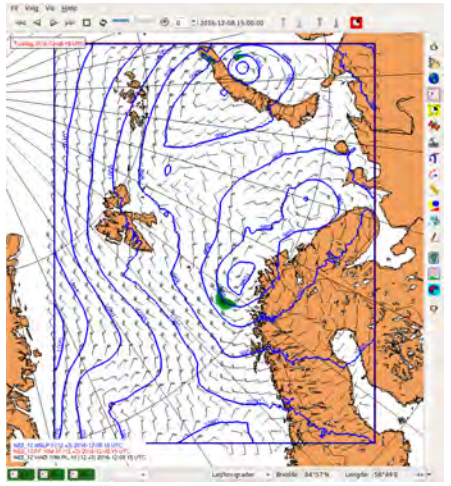
06UTC





15UTC





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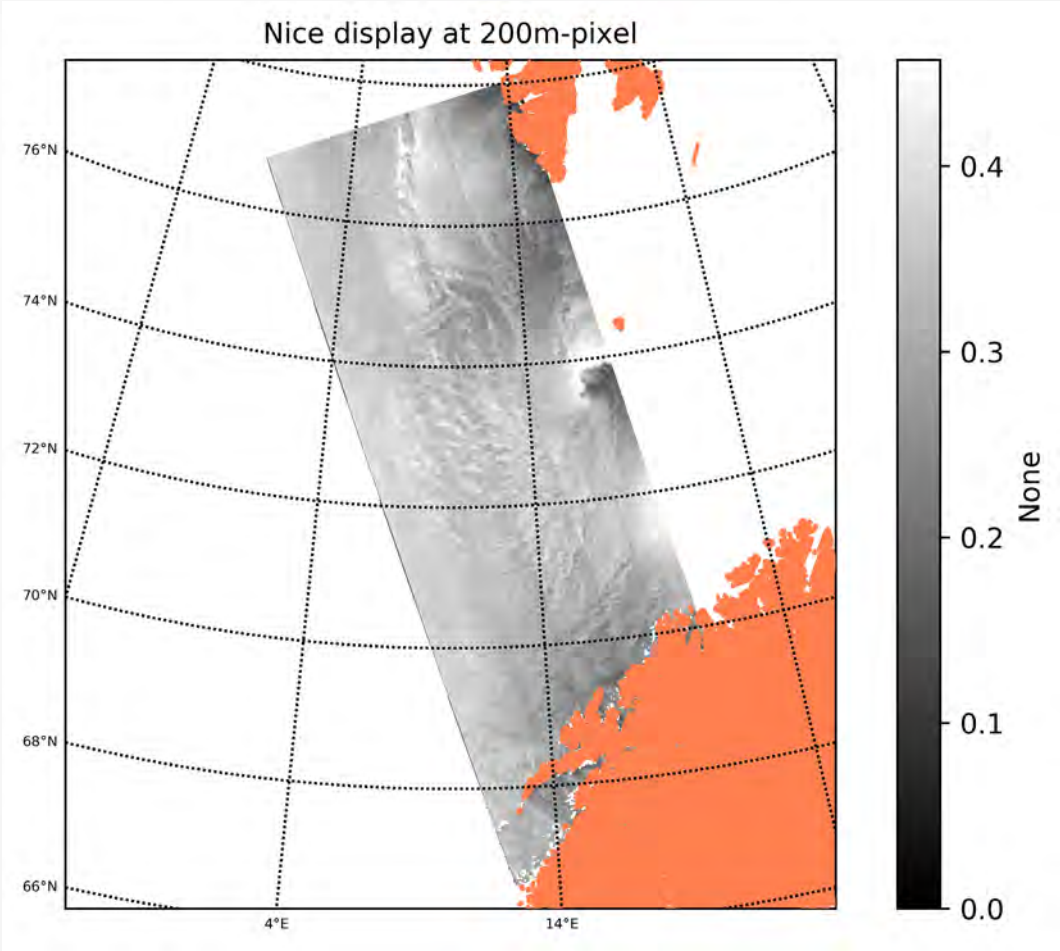
Case study simulations

Reference, or baseline, simulation

- Starts 00 UTC on 8 Dec 2016
- Warm start from the CARRA reanalysis (First guess from CARRA reanalysis)
- Ends 00 UTC on 9 Dec 2016 (analysis every 3:rd hour)
- No scatterometer data

Experiment simulation with SAR data

- Same as reference, but SAR data assimilated at 03, 06 and 15 UTC



Co-pol detrended NRCS from S1B on 20161208t161427

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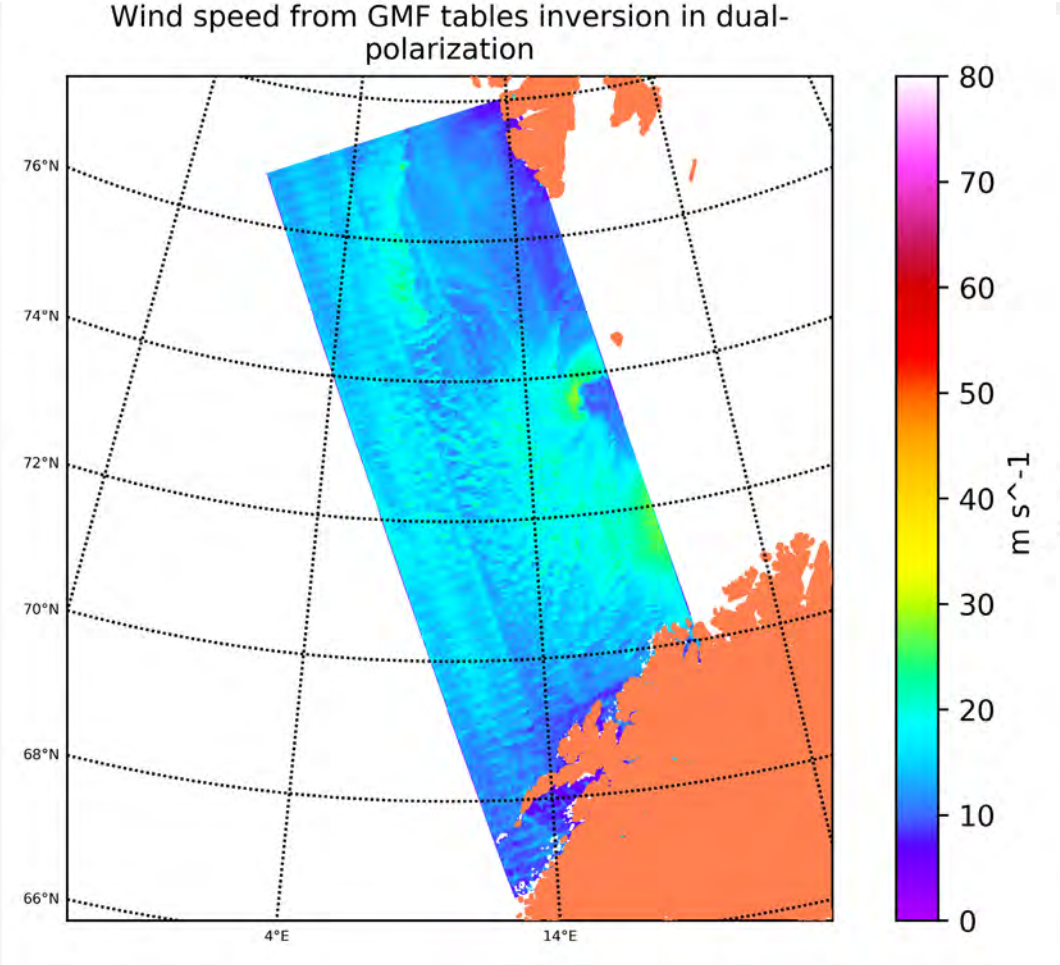
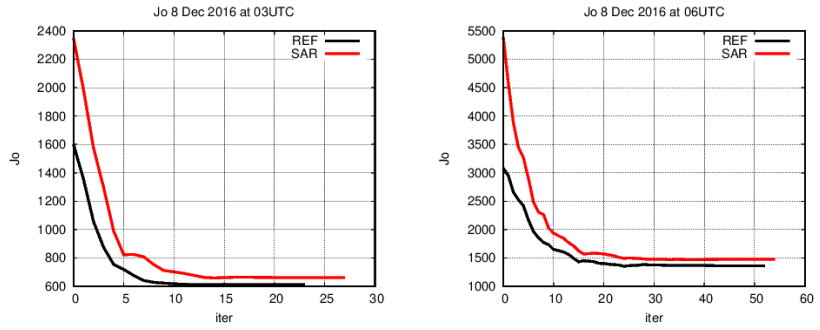
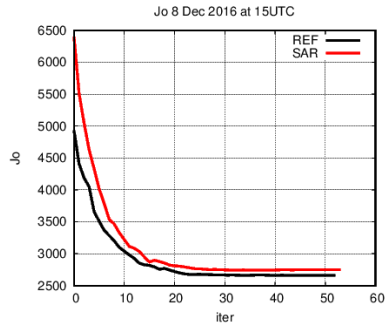


Wind Speed from S1B on 20161208t161427

Case study simulations

Jo costfunction minimization





Minimizes smoothly, but takes a few more iterations when SAR data is included

8 Dec 2016 at 15 UTC

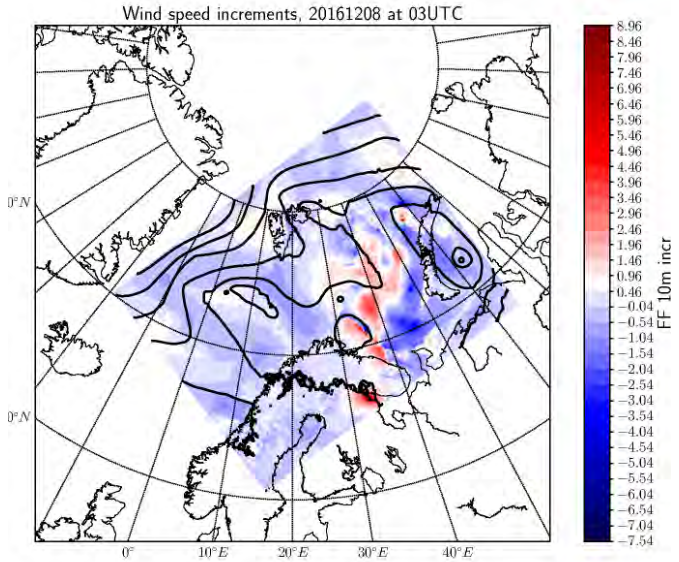
ASCAT comparison

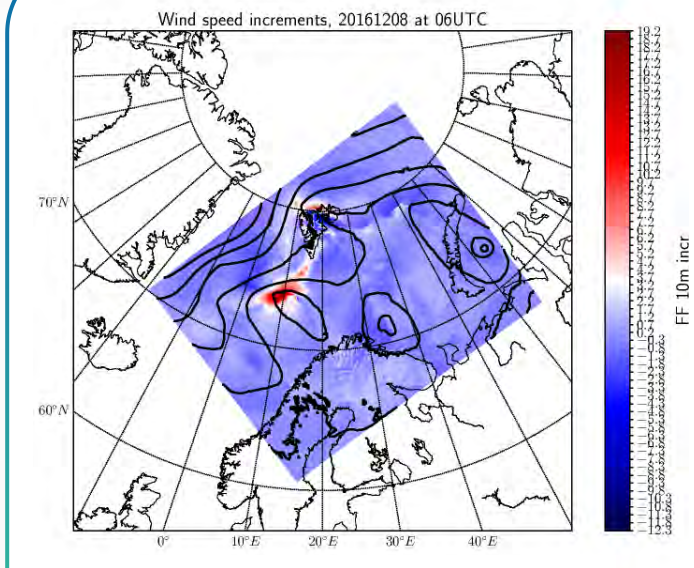
- CARRA reanalysis used similar amount of ASCAT data
- Cost minimization function for SAR (1466) much larger than for ASCAT (816)
- SAR obs errors might need tuning

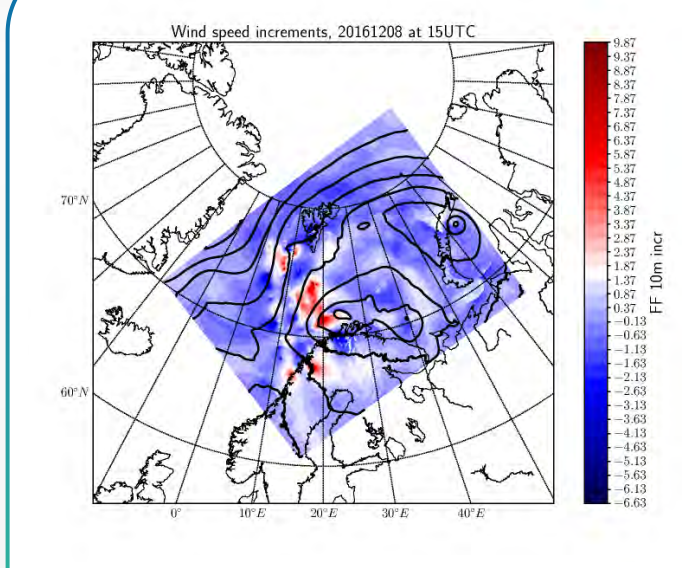
CARRA ASCAT	Obs count	Jo	Jo/N
1:st iter	418	816	1.95
Last iter	418	35	0.09

SAR Exp	Obs count	Jo	Jo/N
1:st iter	414	1466	3.54
Last iter	414	89	0.22

10m wind speed increments, analysis - first guess







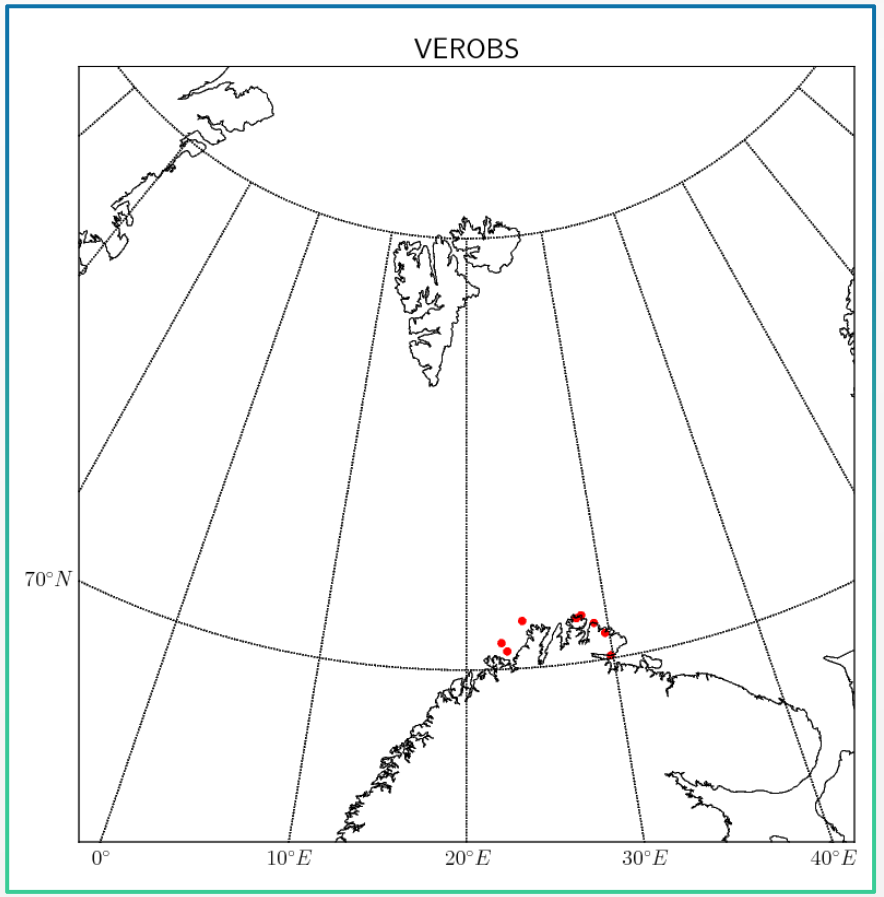
Impact

Other observation denial studies were performed for this period (with the CARRA system) and the performance is generally good when observations are taken out of the data assimilation

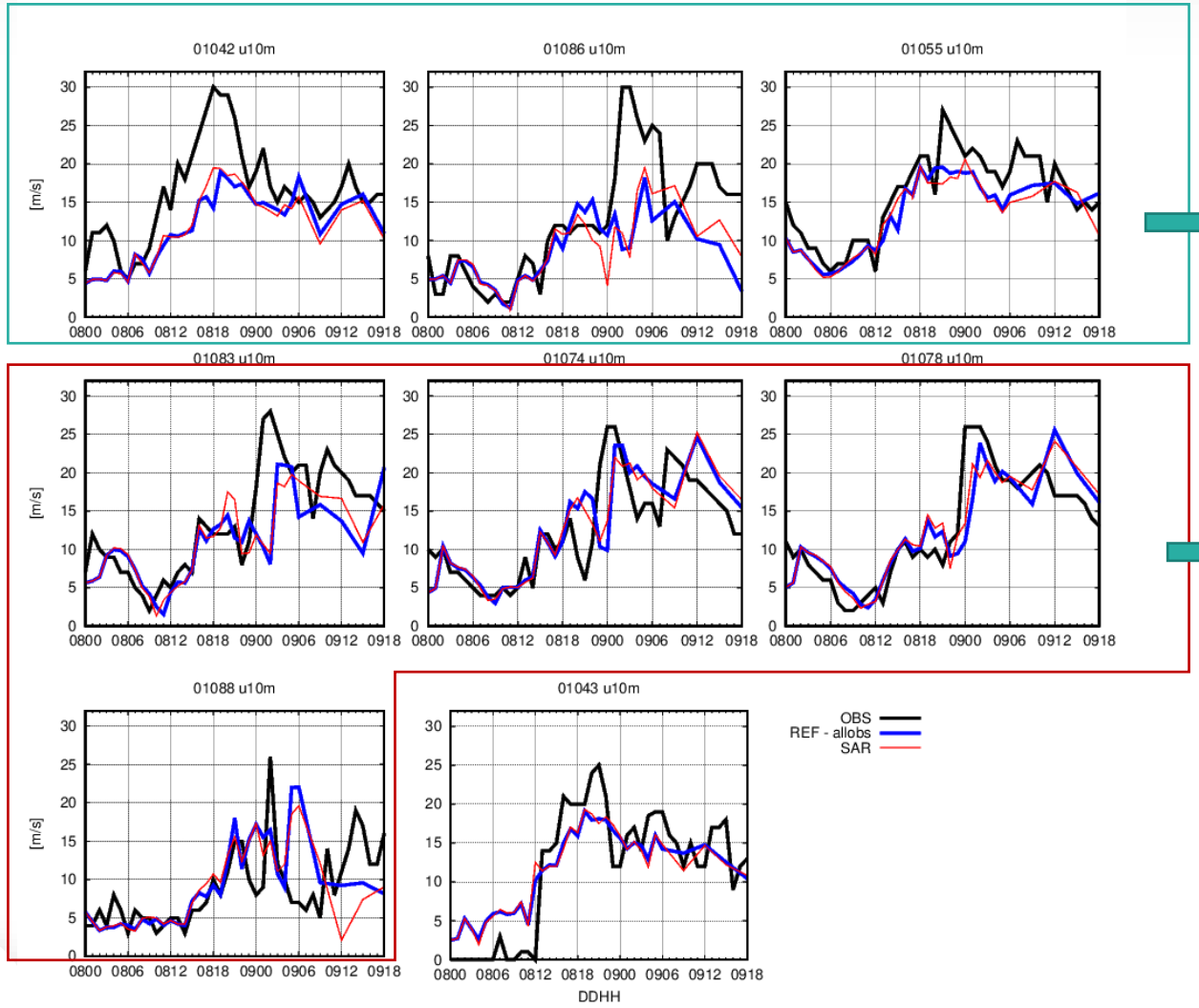
==> The CARRA system is quite **robust** in this case

We have selected 8 observing stations that reported >25m/s (storm)

2 stations even reported 30 m/s



Results



SAR data **improves** NWP performance for **higher wind speeds**

SAR Exp with SAR data is **worse** than Reference for **lower wind speeds**

WP 220: Assimilation by atmospheric modelers

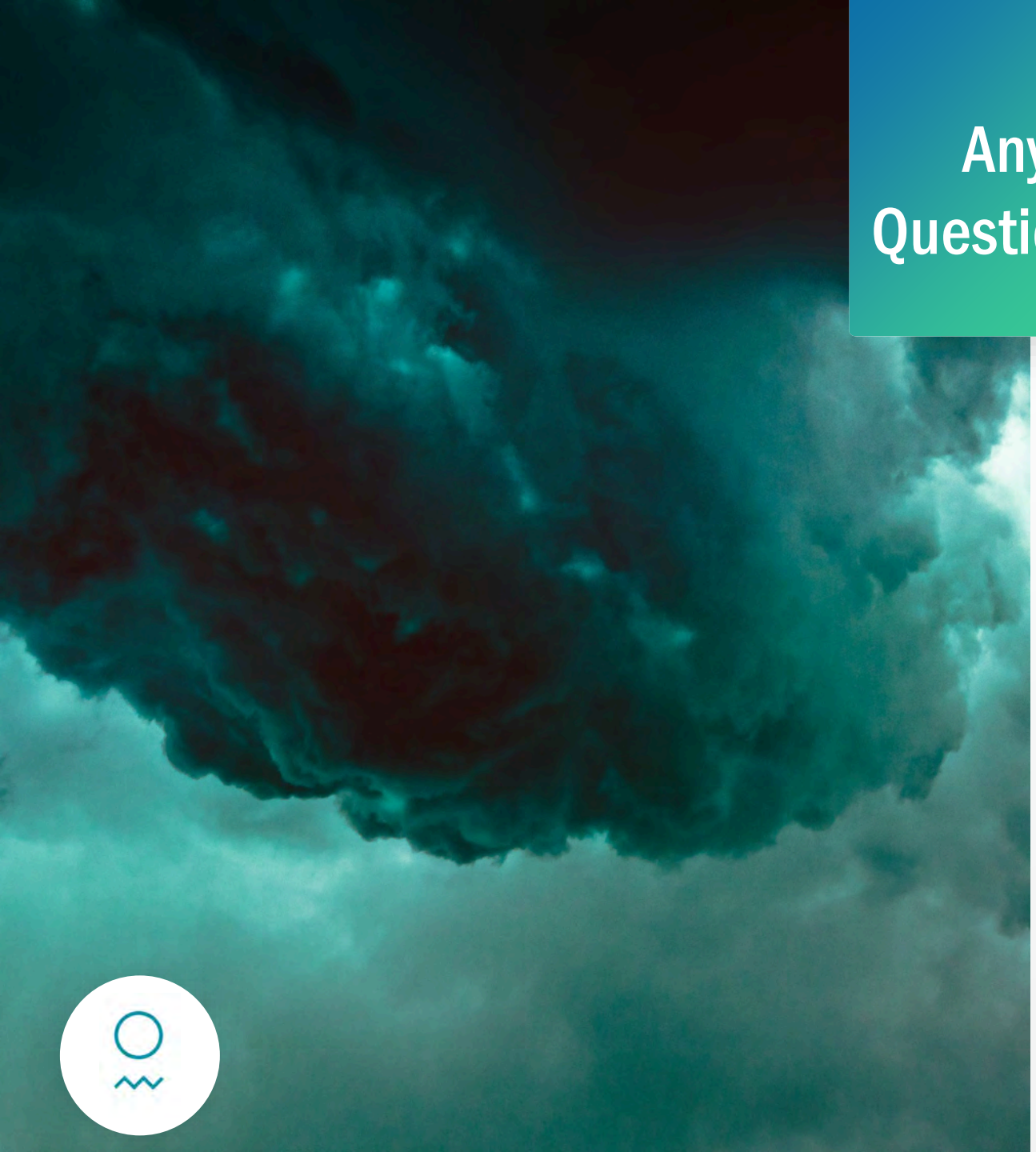
Summary

CARRA, an AROME based reanalysis system, has been prepared to assimilate SAR winds

- Remarks:
  - Observation errors need to be tuned
  - Quality control should be investigated
  - Methodology: thinning used now. Instead: superobbing …

Methodology refinement needed to see better impact on NWP performance

Impact on one intense storm case was small but the experiment is quite robust.



Any Questions?

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Discussion

Feel free to turn on your cameras and microphones

Some references & data access

Point of Contact: contact@esa-cyms.org

General website: http://esa-cyms.org

Twitter account: https://twitter.com/CYMS_S1

Documentation: (Scientific articles, project description, technical documentation) :

https://www.esa-cyms.org/documentation/

Data access & visualization (NRT and Archive):
https://www.esa-cyms.org/data-access/

- WebGIS platform for **NRT products:** https://eoda.cls.fr/cyms or https://datastore.cls.fr/seewater-cyms
- Data archive center for **reprocessed products:** https://cyclobs.ifremer.fr/app/

Thank You

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What's next ?

You will receive:

- Presentation pdf
- Webinar Replay
- Questions & Answers recap'

- Your continuous feedback is key !

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