PROGRAMME OF THE EUROPEAN UNION

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Naïve Probabilistic Cloud and Aerosol identification algorithm

Implementation and benefits for the operational Copernicus Sentinel-3 Near Real Time (NRT) aerosol retrieval processor

7th Sentinel-3 Validation Team Meeting 2022

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E. Martins, J. Chimot, S. Jafariserajehlou, L. Spezzi, B. Fougnie, B. Bojkov

EUMETSAT

Context

- **Importance of an adequate cloud screening for** operational Level 2 (L2) aerosol.

- Issues caused by **Cloud mask** in past collection(s) of Copernicus Sentinel-3 NRT Aerosol processor (OSSAR-CS3):
  - Major **aerosol events under-detection over oceans** (*e.g.* Garrigues *et al.*, 2022 + EUMETSAT expert analyses).
  - Large amount of missed broken clouds over warm lands.

- No Sentinel-3 cloud mask product **tailored** to NRT Atmosphere objectives up to today:

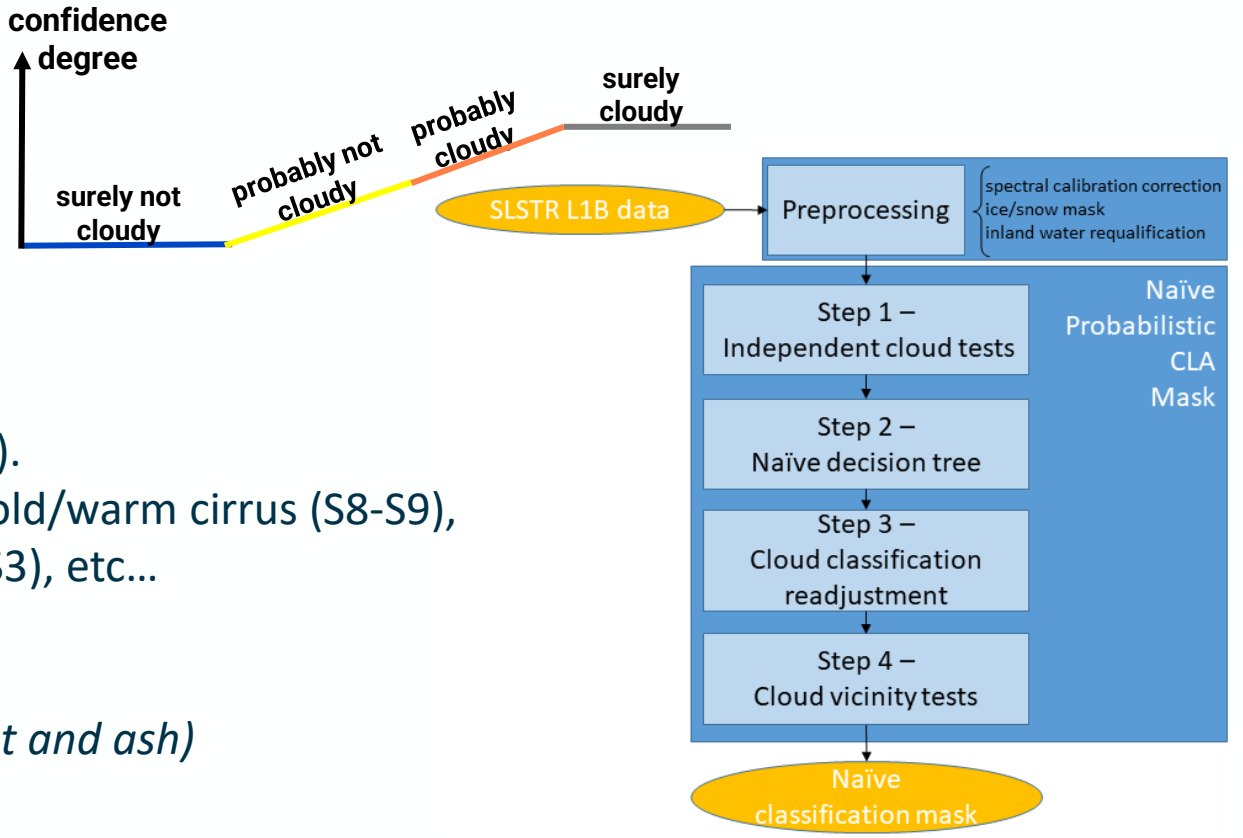
EUMETSAT has developed a new algorithm to fill this gap:
The Naïve Probabilistic Cloud & Aerosol (CLA) identification prototype
(operationally implemented in OSSAR-CS3 → see presentation J. Chimot, Wednesday AM)

- The **Naïve Probabilistic Cloud/Aerosol Mask** has operationally replaced the L1B SLSTR Basic Cloud Mask:
  - **Since Coll.2 (late 2021)** for **lands** : simple version (needs further evolution)
  - **Since Coll.3 (late 2022)** for **oceans** : more sophisticated (imminent release) → **Today's presentation**

Methodology

Simple (*i.e.* "Naïve") Probabilistic approach relying on complete SLSTR spectral coverage + high spatial resolution, with cloud *vs.* aerosol distinction:

- Wide set of proven spectral / spatial tests.
- Spectral synergy Solar + TIR
- Decision tree with simple probabilistic weights
- Aerosol restoral, based on dust/ash detection
- Precautions with cloud vicinity, snow / ice, glint.



Four key steps:

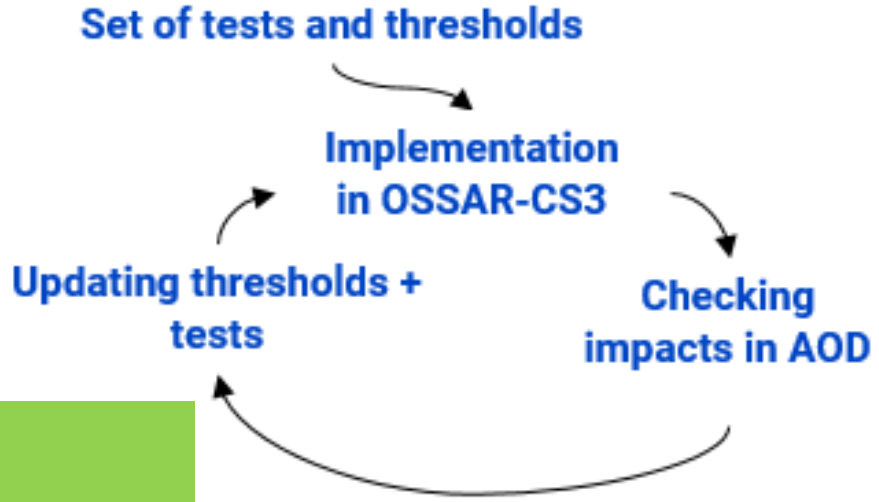
See complete description in ATBD (E. Martins *et al.* –Nov. 2022).

- Step 1: 8 independent tests, *e.g.*: whiteness ratio (S3/S2), cold/warm cirrus (S8-S9), elevated cirrus (S4), frozen targets (S8), spatial uniformity (S3), etc…
  ➔ Confidence degree manually trained per test.
- Step 2: Decision tree
- Step 3: Cloud classification readjustment *(for restoral of dust and ash)*
- Step 4: Cloud vicinity, Snow / ice mask

Tailored to the NRT aerosol processor needs

- Training specifically tailored to the Copernicus Sentinel-3 NRT aerosol processor (OSSAR-CS3) needs, *i.e.*:
  - Accounting for the **internal defence mechanisms**, *e.g.*:
    - cloud fraction threshold per L2 aerosol pixel,
    - L2 scene radiance homogenizer (*i.e.*, screening abnormally bright pixels),
    - output anomaly diagnosis (*e.g.*, spectral residuals).
  - **Iterative verification with L2 AOD results**

- **Lessons learned** during the development of the algorithm:
  - Probabilistic scheme is key
  - Benefits of Aerosol restoral (dust/ash detection)
  - Critical understanding of OSSAR-CS3 needs

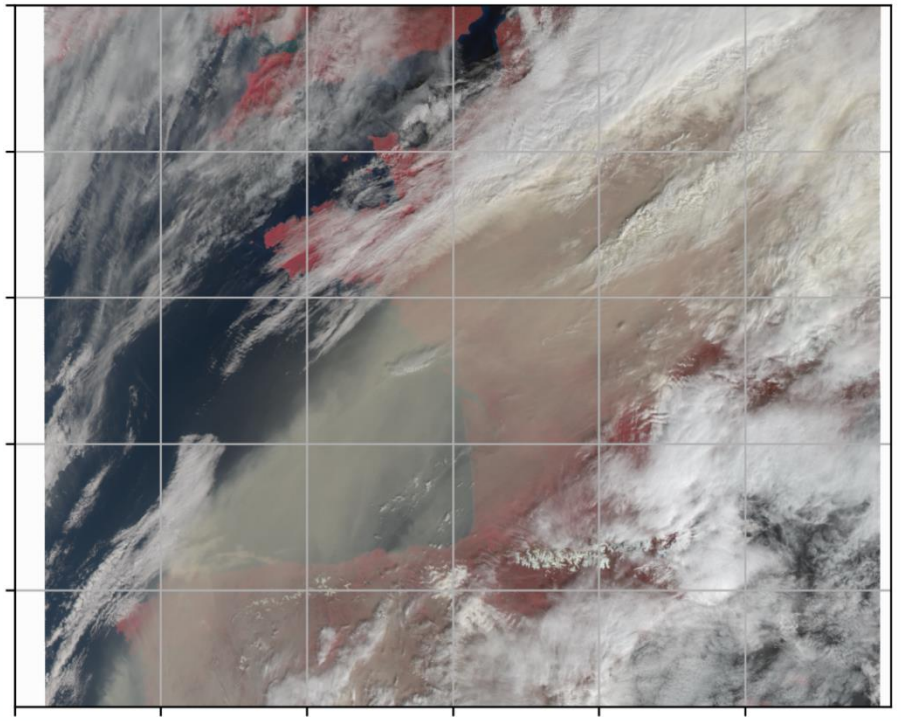


Iterative Validation:

- Holistic analyses of L1 cases (~60 expert cases)
- L2 AOD validation (6 months – Global - A and B)

Illustrating the Algorithm methodology

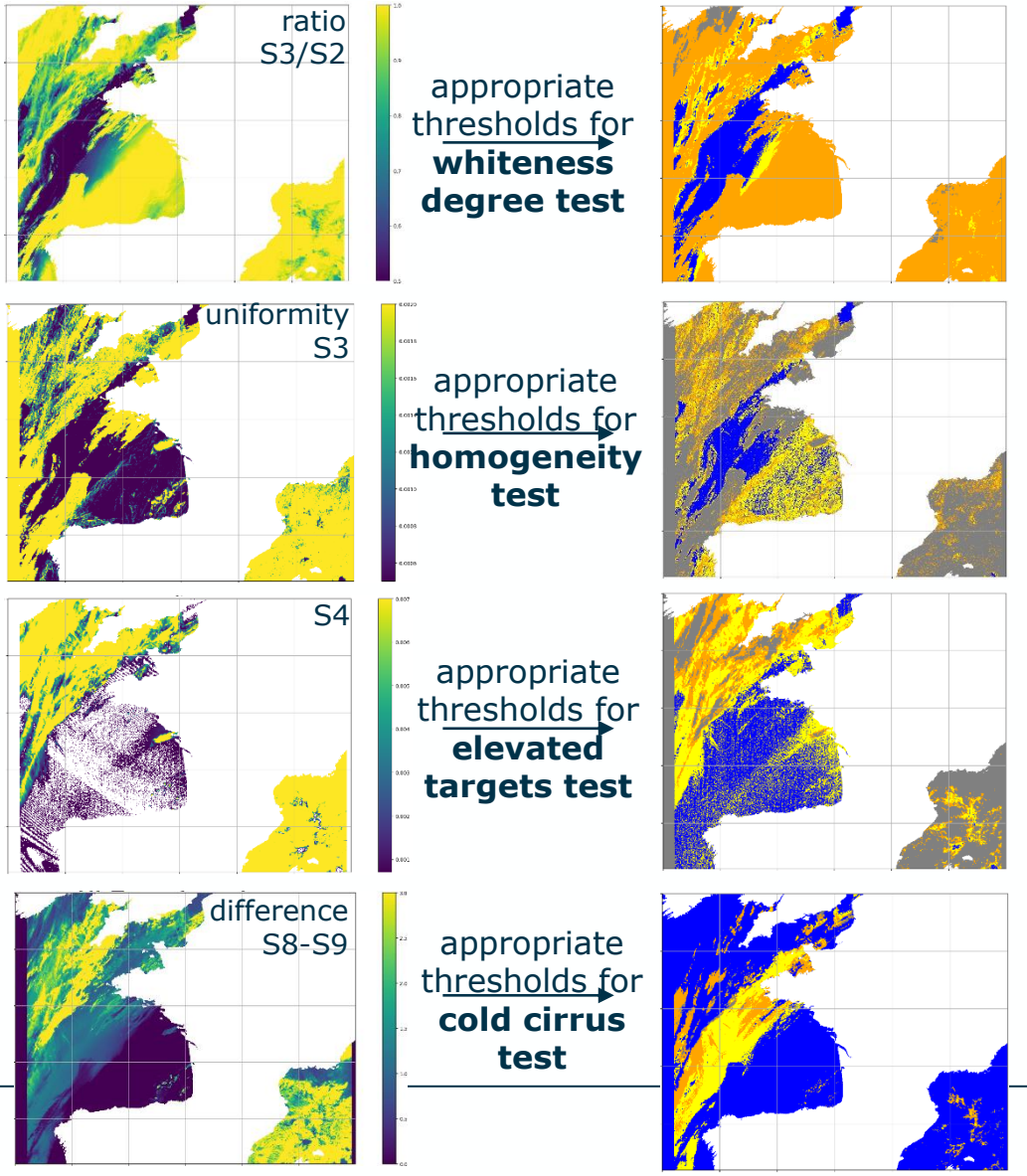
DESERT DUST event (S3B, 20220315T102609)



STEP 1 - 8 independent tests

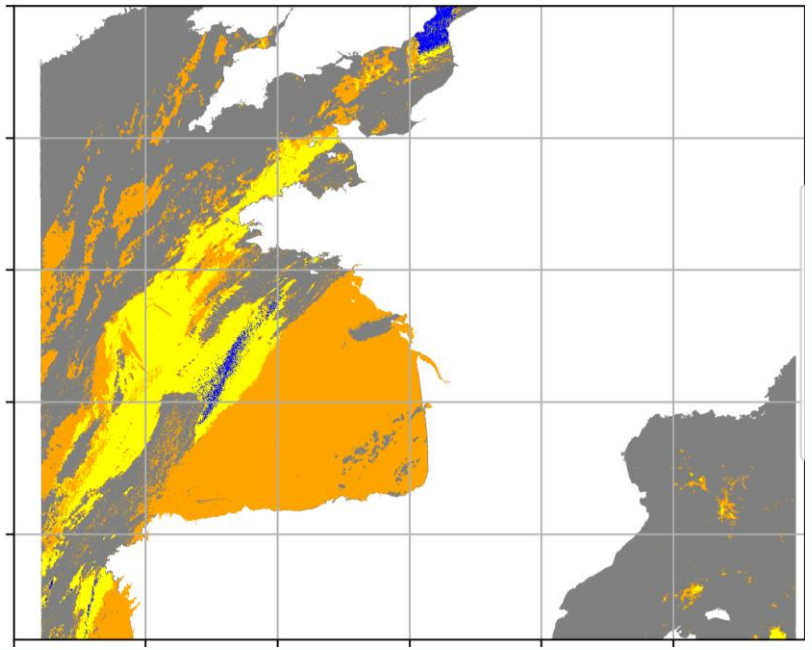
(only 4 shown here)

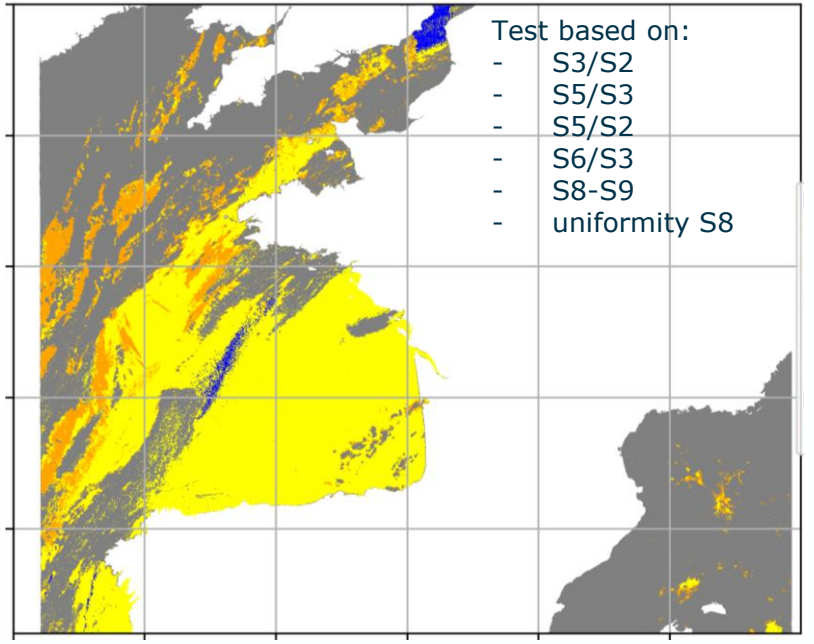
CLASSIFICATIONS

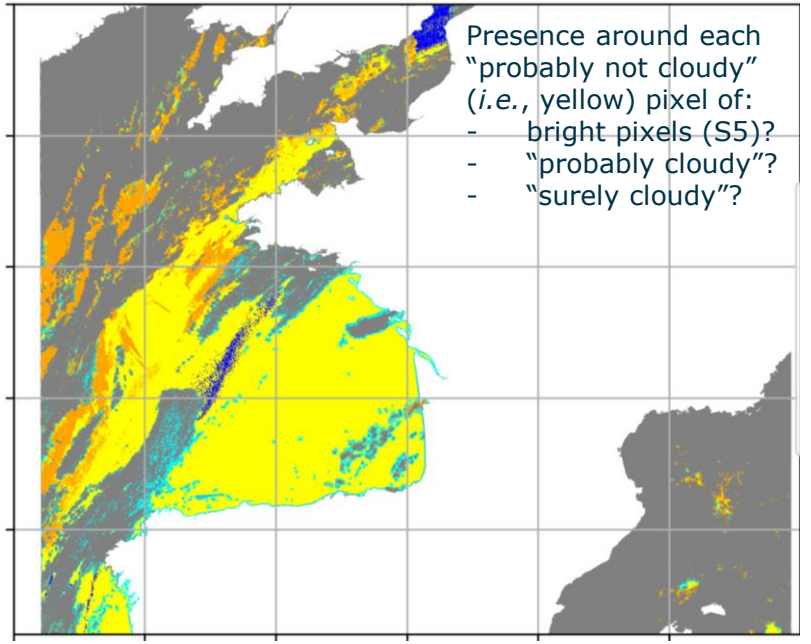


Illustrating the Algorithm methodology

DESERT DUST event (S3B, 20220315T102609)







STEP 1 - 8 independent tests

STEP 2 - Naïve decision tree ("from 8 classifications to a simple 1")

STEP 3 - Classification re-adjustment (for dust & ash plumes)

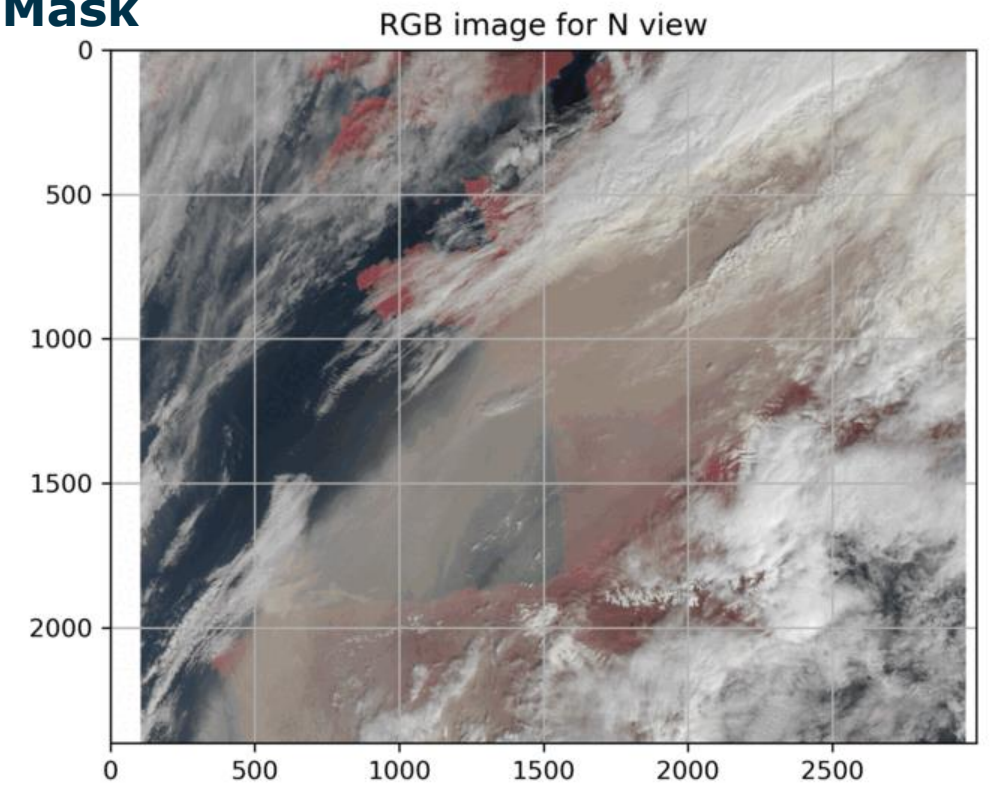
STEP 4 - Cloud vicinity (in windows of 2km*2km)

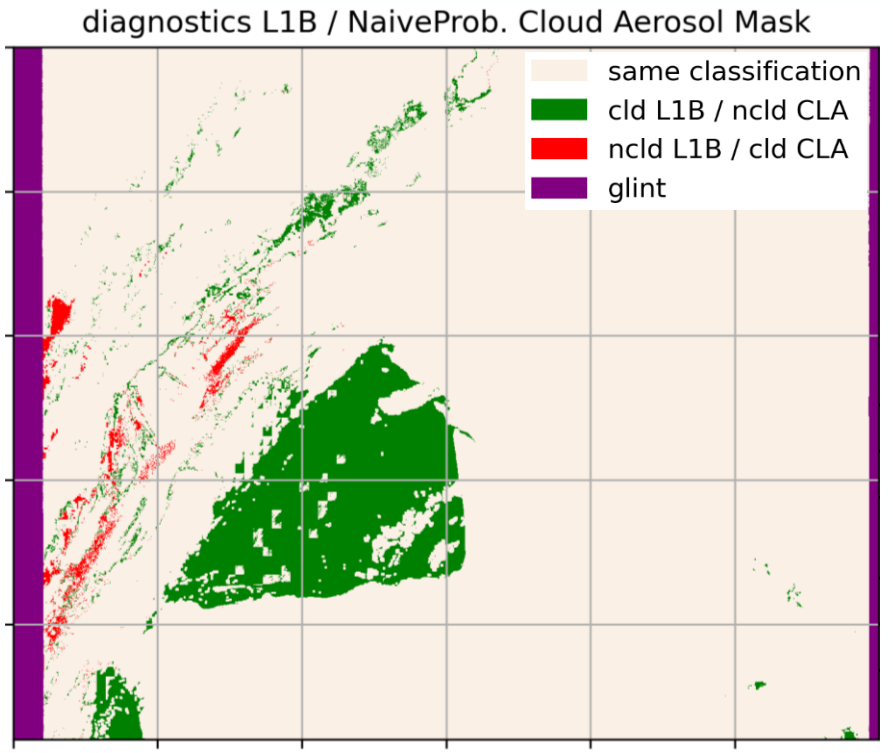
- surely not cloudy
- probably not cloudy
- probably cloudy
- surely cloudy
- lands/borders
- snow/sea-ice
- sun-glint
- cloud-vicinity

Illustrating the Algorithm methodology

DESERT DUST event (S3B, 20220315T102609)

Final Cloud Mask





~95% of the dense dust plume is correctly classified as "Probably NON Cloudy" (restoral).

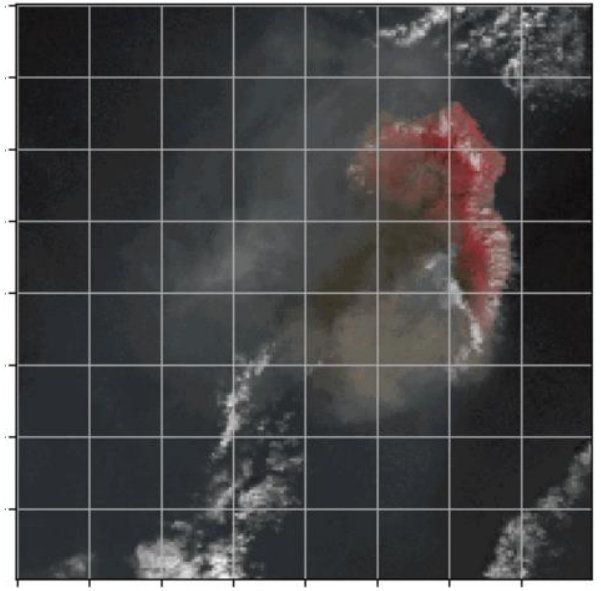
Some sparse cases are missed by the Naïve CLA mask while they appear to be non-cloudy areas.

Illustrating the Algorithm methodology

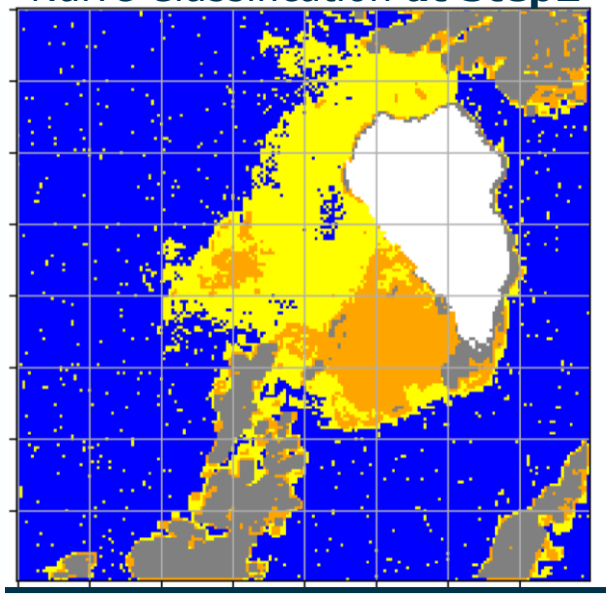
VOLCANIC ASH event (S3A, 20211030T113744)

surely not cloudy
probably not cloudy
probably cloudy
surely cloudy
lands/borders
snow/sea-ice
sun-glint
cloud-vicinity

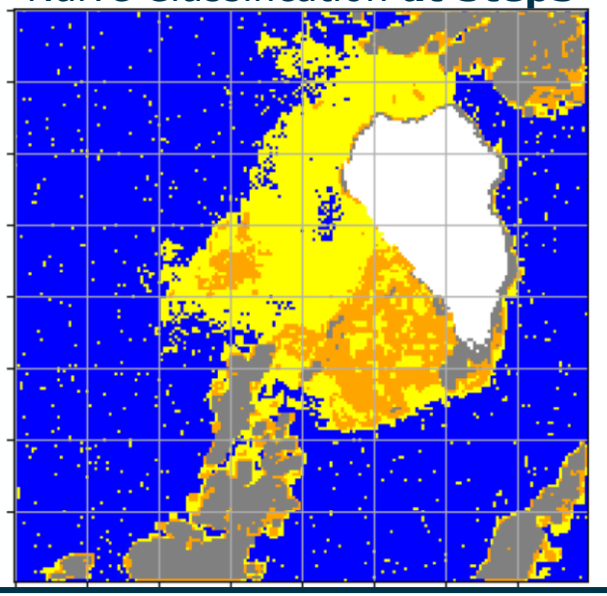
Cumbre Vieja (Canarias Island)



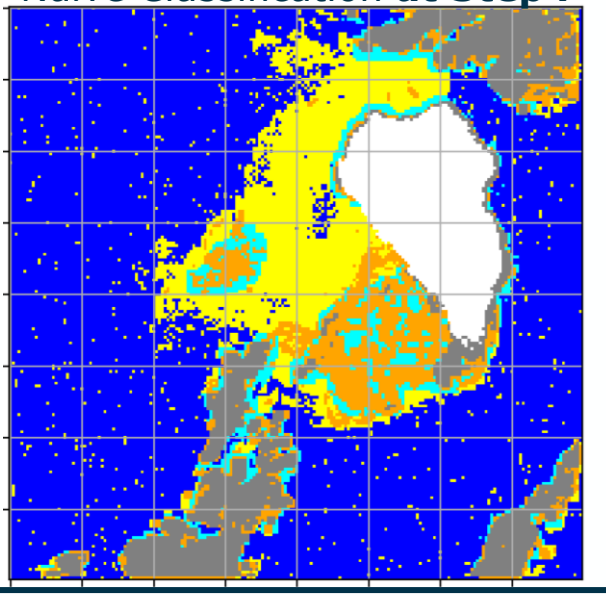
Naïve Classification **at Step2**



Naïve Classification **at Step3**

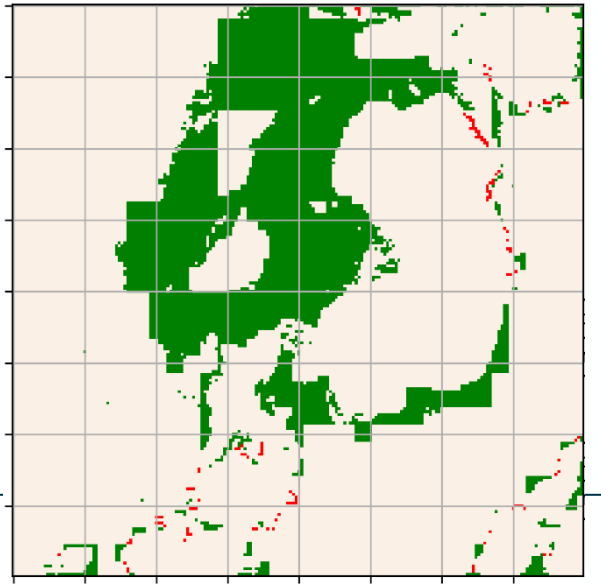


Naïve Classification **at Step4**



diagnostics between masks
L1B / Naïve Prob. CLA

same classification
cld L1B / ncld CLA
ncld L1B / cld CLA
glint



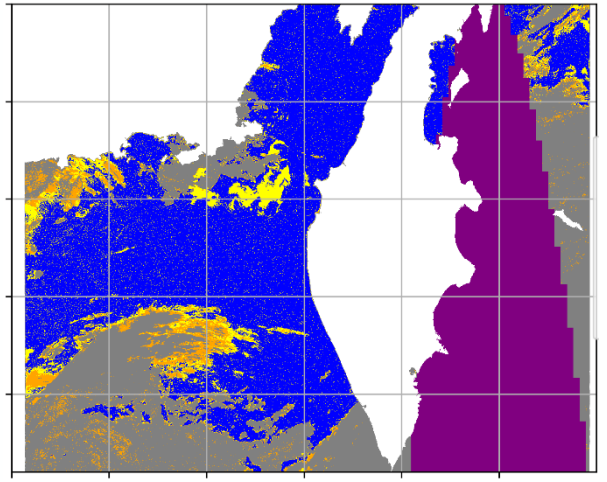
Most of the ash plume is not screened-out and is correctly classified as "Probably NON Cloudy" (restoral) by the Naïve CLA Mask
(however, not the denser part).

Illustrating the Algorithm methodology

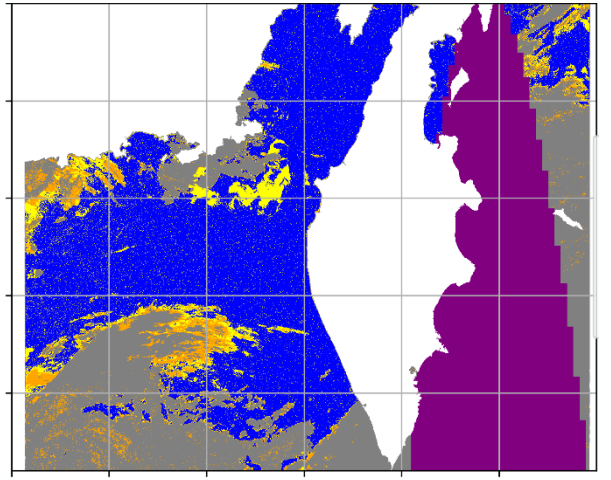
SMOKE event (S3A, 20220722T001144)

surely not cloudy
probably not cloudy
probably cloudy
surely cloudy
lands/borders
snow/sea-ice
sun-glint
cloud-vicinity

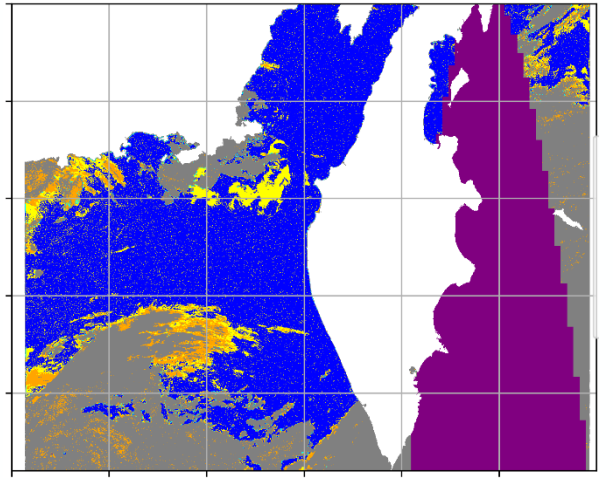
Naïve Classification **at Step2**



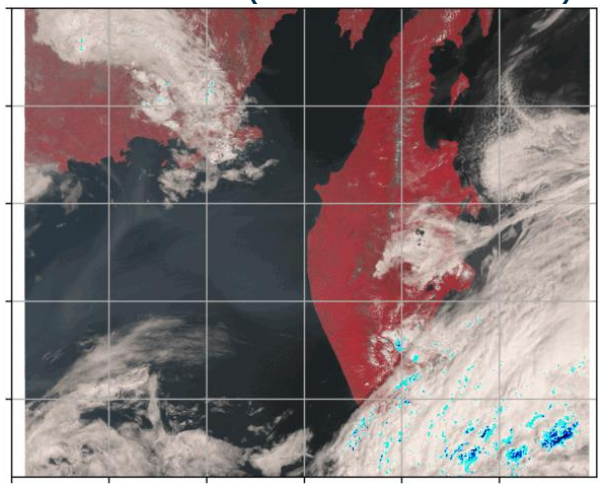
Naïve Classification **at Step3**



Naïve Classification **at Step4**

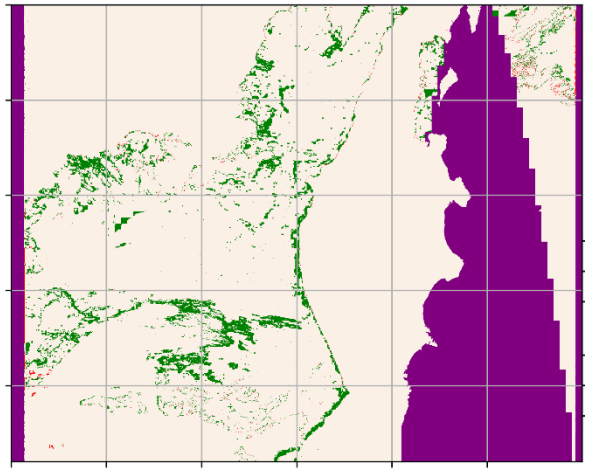


Kamtchatka (Far East Siberia)



diagnostics between masks
L1B / Naïve Prob. CLA

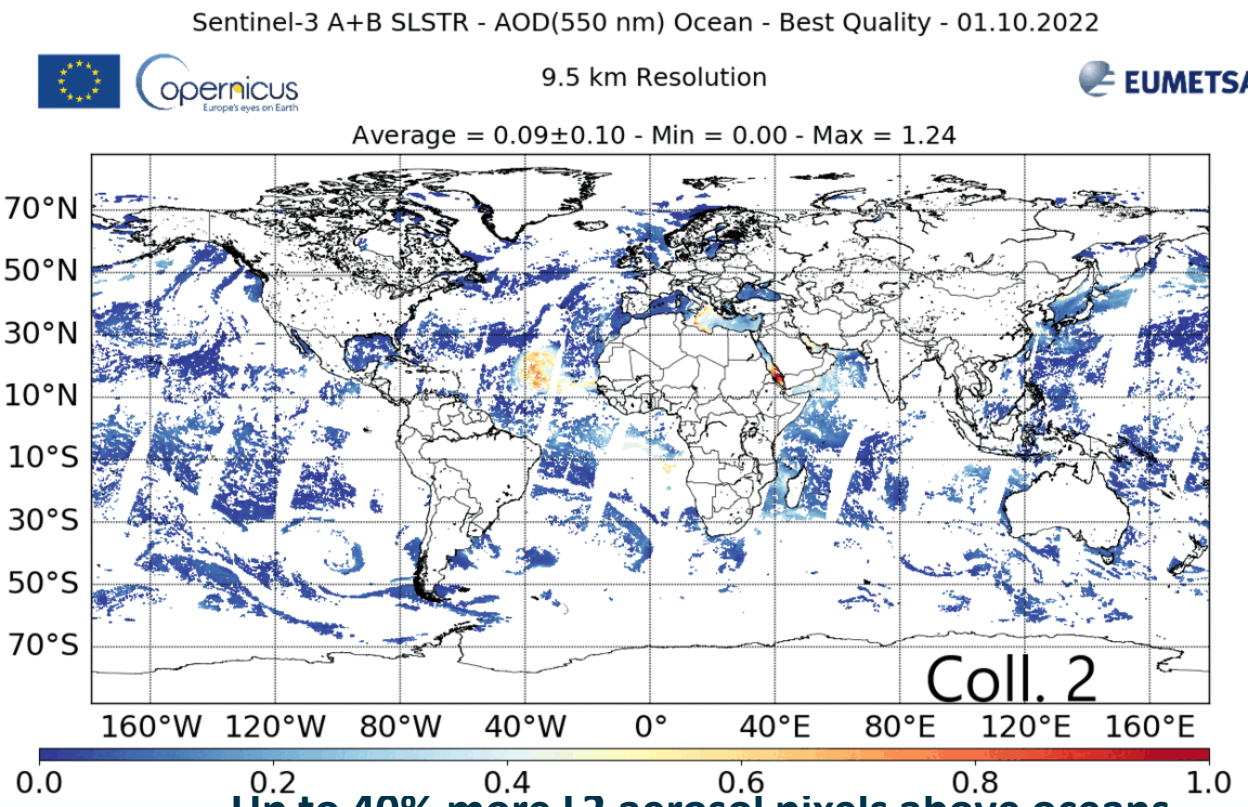
same classification
cld L1B / ncld CLA
ncld L1B / cld CLA
glint



The **smoke** is not screened-out and is correctly classified as "Probably NON Cloudy" (restoral) by the Naïve CLA Mask.

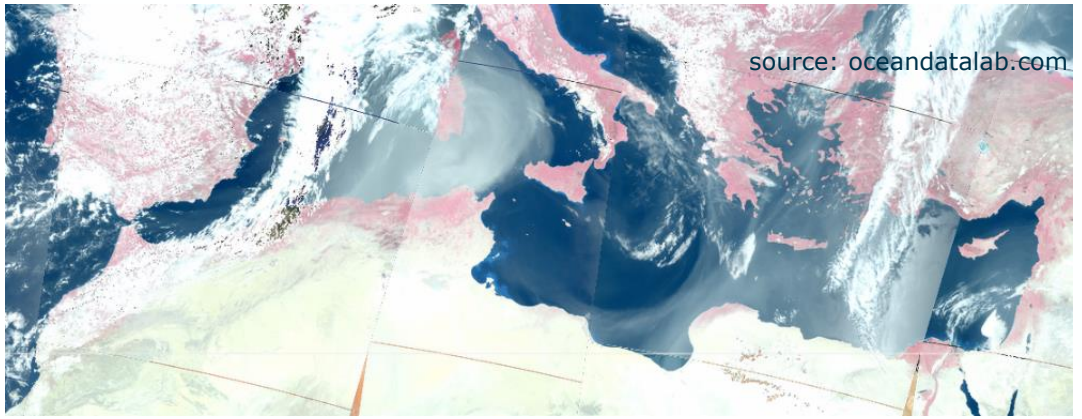
Some key results (L2)

OSSAR-CS3 (retrieval of AOD at global/regional scale)

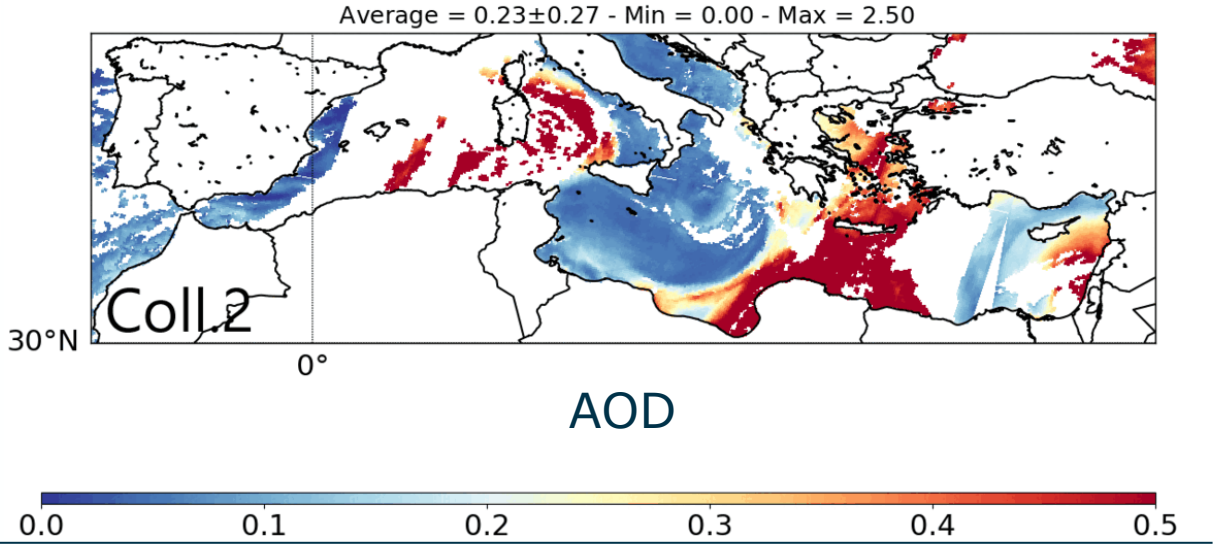


Up to 40% more L2 aerosol pixels above oceans
between Coll.2 and Coll.3 of OSSAR-CS3

In Coll.3 of OSSAR-CS3:
Wider regions of homogeneous patterns,
Much less areas with broken cloudy scenes



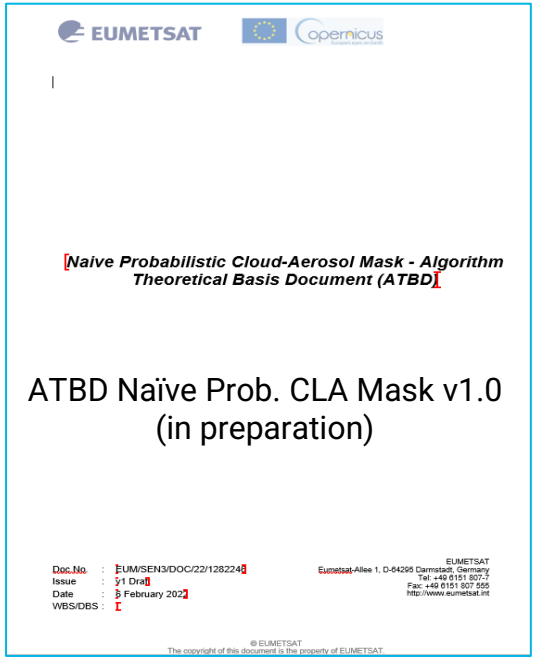
(courtesy J. Chimot)



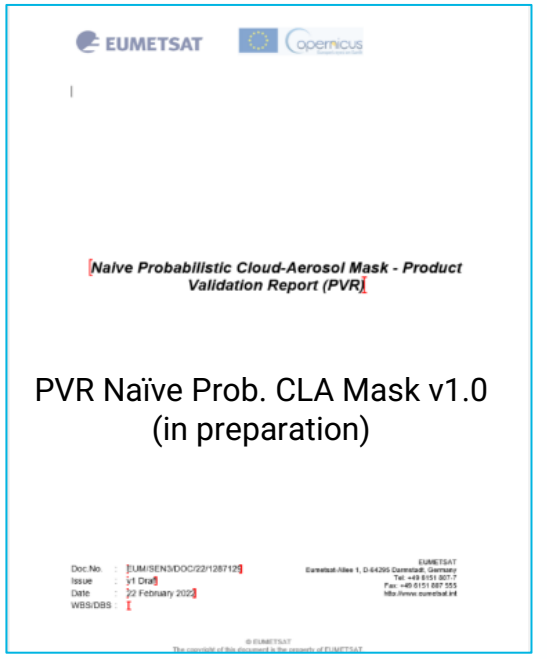
AOD

Coming soon

- Prototype v1.0 finalized – routinely running in EUMETSAT off-line premises.
  - Product for now internal.
  - External user testing / feedbacks welcome
    (Please contact us if interested)
- Implemented in operational OSSAR-CS3:
  - Deployment with Collection 3 imminent.
- Documentation under finalization (~Nov. 2022)
  - ATBD and PVR to be published on EUMETSAT website
- Evolution in progress (for future v2.0):
  - Extension to Land areas: probabilistic scheme, dust/ash.
  - Smoke detection *(under investigation)*
  - Sparse odd patterns in high latitudes *(under investigation)*
  - Comparison/validation towards other similar cloud masks products



ATBD Naïve Prob. CLA Mask v1.0
(in preparation)



PVR Naïve Prob. CLA Mask v1.0
(in preparation)

Take-away key messages

EUMETSAT **initiated the development of cloud/aerosol identification algorithms**

to overcome issues of current SLSTR cloud mask w.r.t. atmospheric applications → the **Naïve Probabilistic CLA algorithm**

- **V1.0 ready** → implemented in Coll.3 of Copernicus Sentinel-3 NRT Aerosol processor (**see presentation J. Chimot, Wed AM**)
- V2.0 under further evolution.

Prototype based on :
- use of proven tests,
- probabilistic scheme,
- decision tree,
- dust/ash detection,
- cloud vicinity,
- new snow / ice masks.

Prototype tailored to the needs of operational aerosol processor and accounting for its **defence mechanisms** (strengths/weaknesses) :
- Not intended as a stand-alone product, but as internal algorithm to current NRT L2 processor (replacing L1B basic cloud mask)
- Complementary to the SYNergy Cloud-mask (→ foreseen as a future L2 product)

see presentation R. Quast, Tue PM

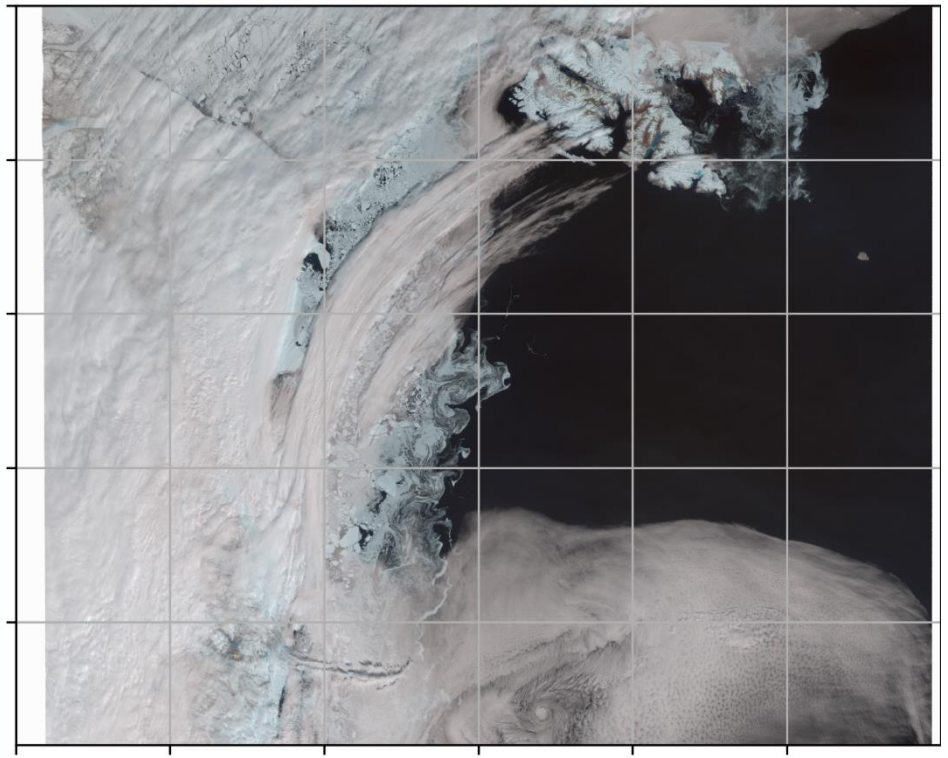
Promising results: **enhanced representation of aerosol events** (~40% more pixels above oceans) – few residuals caused by Arctic fog & white caps (under monitoring)

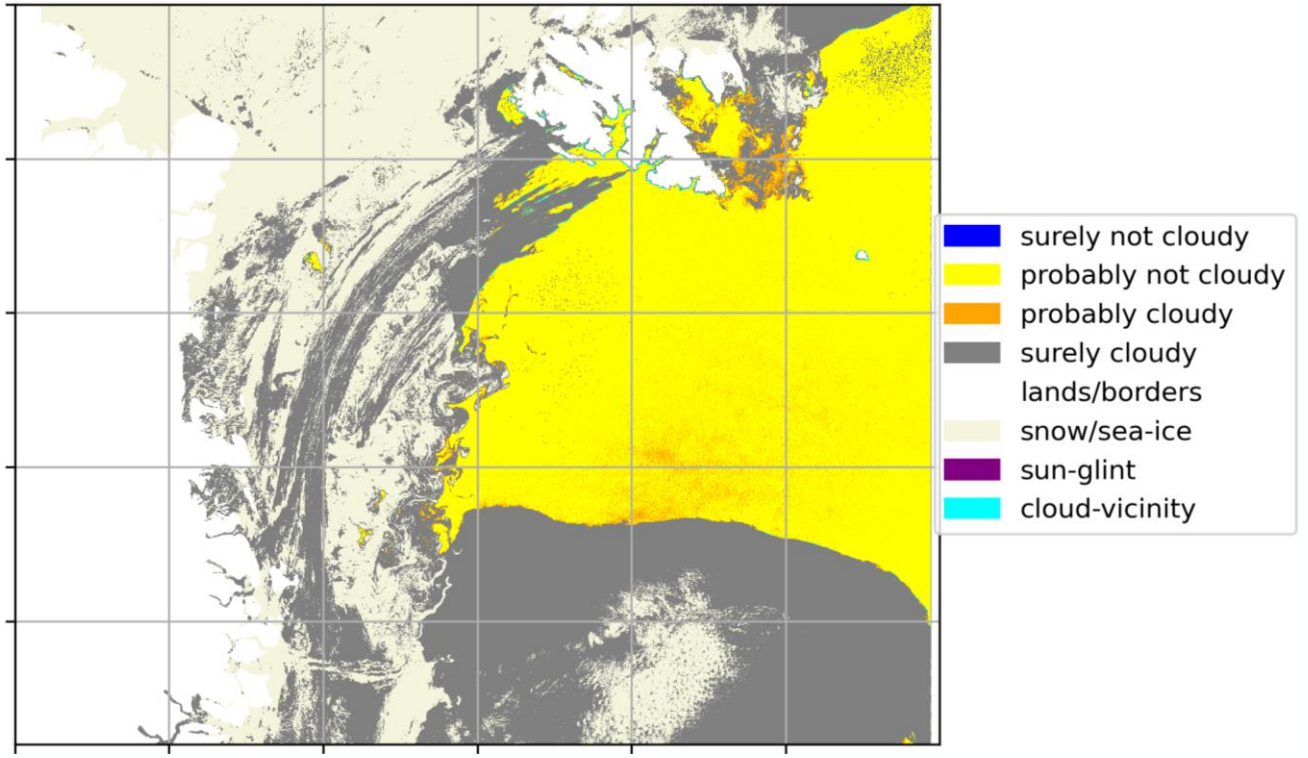
Iterative Validation:
- Holistic analyses of L1 cases (~60 expert cases)
- L2 AOD validation (6 months – Global - A and B)

ATBD and PVR to be released in Nov. 2022 on EUMETSAT webpages.

Back-up slides

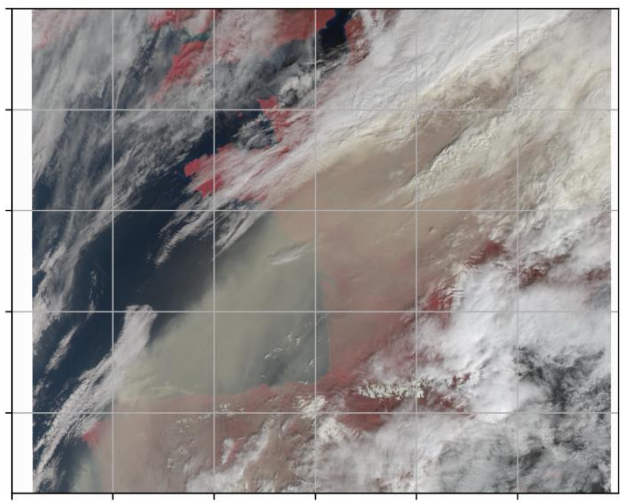
Snow/ice mask

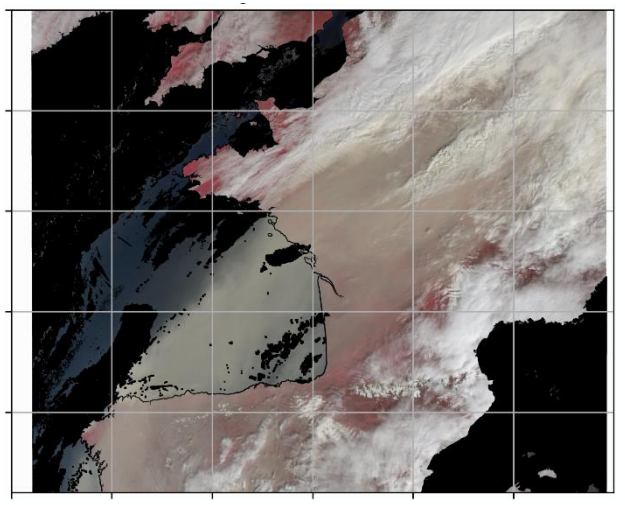


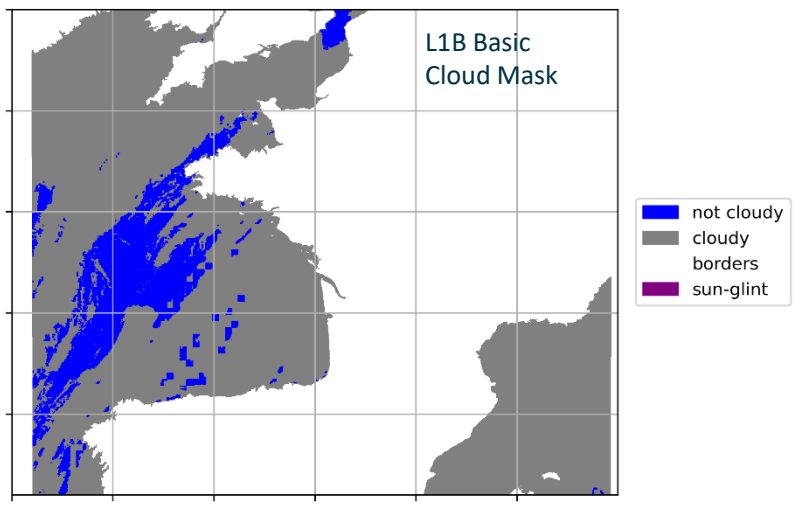


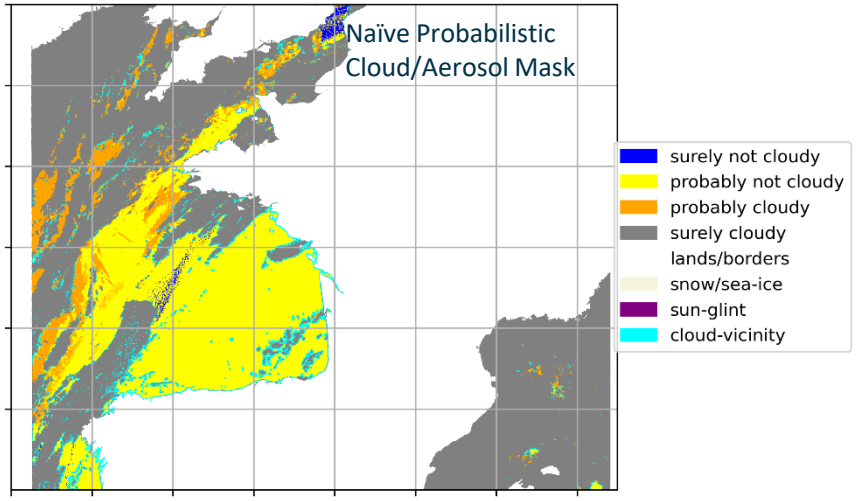
Greenland + Svalbard island (S3B, 20220531T120203)

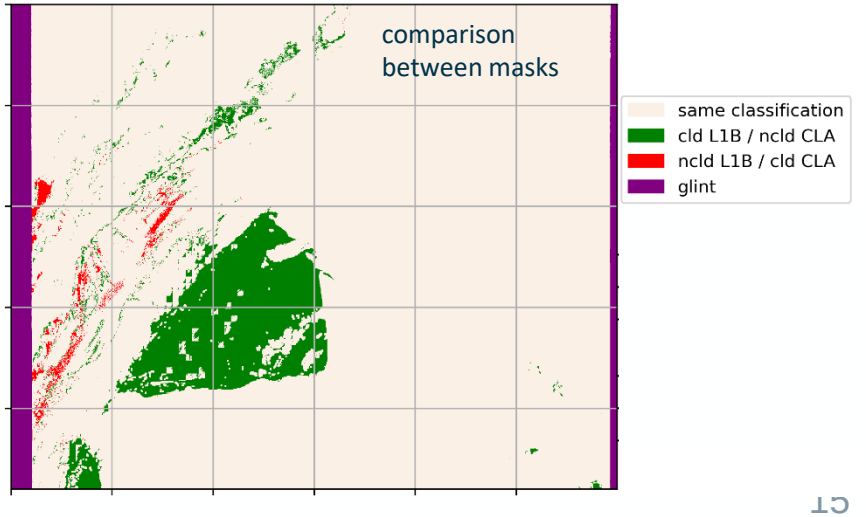
Case of **huge dust event** in Bay of Biscay (S3A, 20220315T102609)











Case of **volcanic eruption** in Canarias Islands (S3A, 20211030T113744)