EUNADICS-AV

Desert dust as an environmental emergency issue

Barbara Scherllin-Pirscher and the EUNADICS-AV team

14 March 2019
inDust User Workshop on Dust Products for Aviation

www.eunadics.eu

The EUNADICS-AV project has received funding from the European Union's Horizon 2020 research programme for Societal challenges - smart, green and integrated transport under grant agreement no. 723986.

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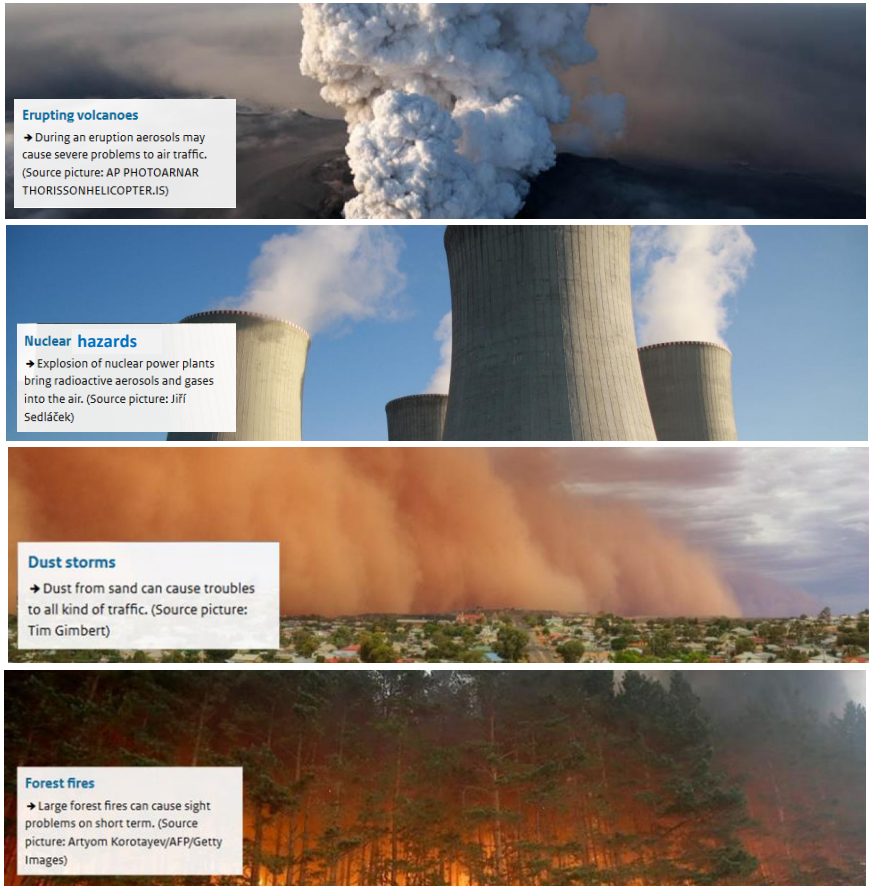
Targeted airborne hazards

- Volcanic eruptions
- Nuclear accidents and incidents
- **Sand storms**
- Forest fires

- Rare events
- High uncertainty in source terms
- Availability of observations



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Air traffic in April 2010

Source: flightradar24, https://www.youtube.com/watch?v=dVkNNV6PORw

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Types of dust storms

Synoptic dust storms (large-scale weather systems)

- Pre-frontal winds
- Post-frontal winds
- Large-scale trade winds

Meso-scale dust storms

- Downslope winds
- Gap flow
- Convection (dust devils and Haboobs)
- Inversion downburst storms

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Problems in aviation

- Poor visibility
- Often associated with strong winds
- Mechanical problems
- Ice nucleation

- Disturbances in airport operations
  - Outside workers
  - Cleanup: remove sand/dust from runways and other critical areas
- Rerouting
- Cancellations of scheduled flights

Source: https://www.dabangasudan.org/en/all-news/article/haboob-blankets-sudan-capital-shuts-down-airport

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Disasters: current situation

- Data from different networks, are not harmonized
- Lack of coordination with regard to special crisis measurements
- Issues with data availability and distribution
- Models/analysis instruments not optimized with regard to data flood during crisis
- Not all stakeholders performing forecasts have access to high-quality analysis

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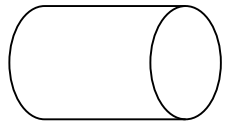
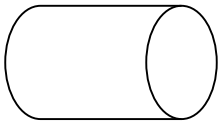
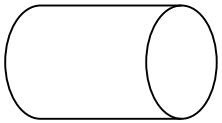
Problem description



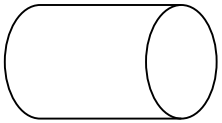
Observations



Tailored obs. products



Obs.-based alerts



Model based products

Different communities:
- Satellite observations
- Ground based observations
- Mod
- …

Different sources:
- ESA
- EUMETNET
- EUNA
- …

Different file formats:
- NetCDF
- HDF5
- GRIB
- …

Different projections:
- Geographic coordinate system
- Projection X
- Projec
- …

Different time intervals:
- Every 5 minutes
- Every hour
- Every
- …

Different data types:
- Grids
- Point
- Timeseries
- …

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EUNADICS-AV

Problem description

Observations

Tailored obs. products

Obs.-based alerts

Model based products

Tailored information:

- Quickly interpretable
- "What, where, how much"
- Properly contextualized
- Available in near real-time
- Option to inspect underlying data

Complete datasets:

- Full access to underlying data
- Ability to subset
- Ability to combine different datasets
- Available during and after events

Aviation community

General public

Sci. community

World Meteorological Organization

National Met. Services

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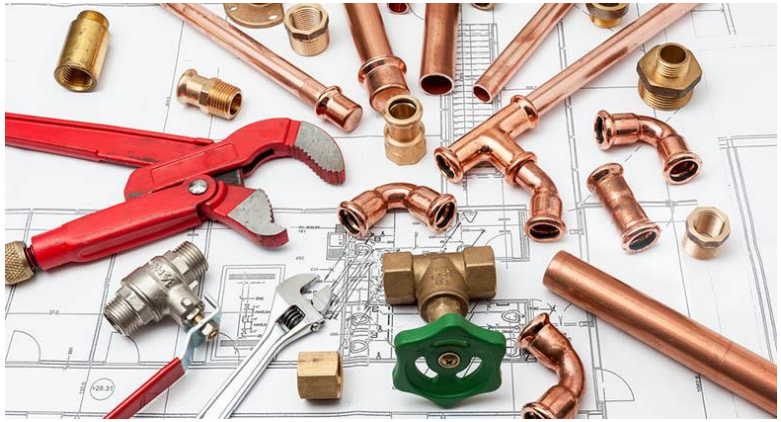

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Solutions

1. Combine and harmonize data from satellite Earth observation, ground-based measurements, and airborne platforms **(talk: H. Brenot)**

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EUNADICS-AV

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EUNADICS-AV

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3. Make data and data analysis products available to all stakeholders (VAACs, RSMCs, national meteorological services, airlines, pilots) through existing channels
4. Realistic air traffic simulations during hazardous events **(short overview: B. Scherllin-Pirscher)**

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EUNADICS-AV

Combined data from satellite, ground-based, and in-situ obs. dedicated to an harmonised Early Warning system (EWS) of natural airborne hazard for aviation

Hugues Brenot and WP3 & WP5 team

14 March 2019
inDust User Workshop on Dust Products for Aviation

BIRA-IASB
Royal Belgian Institute
for Space Aeronomy

www.eunadics.eu

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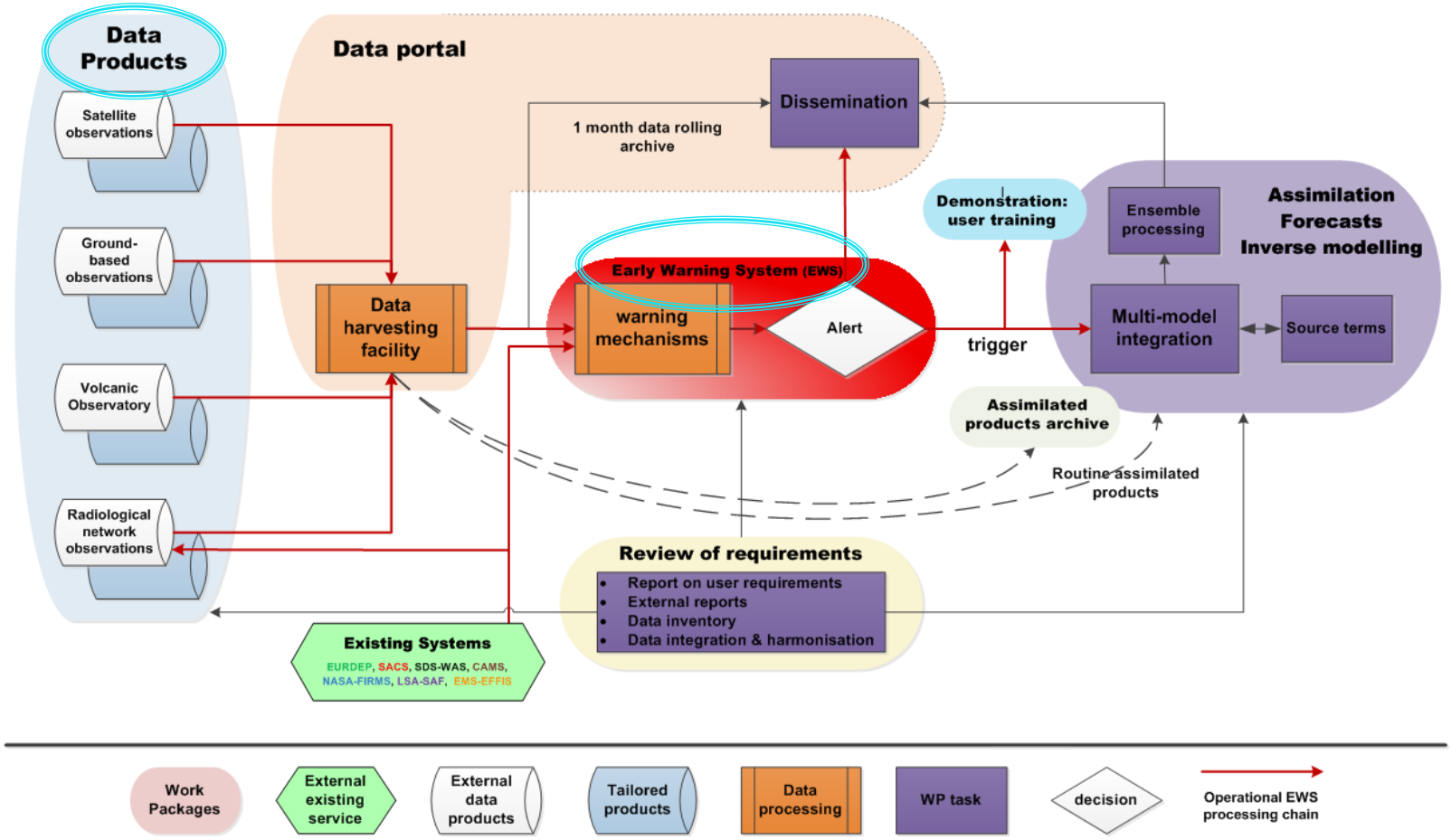
Overview of this presention

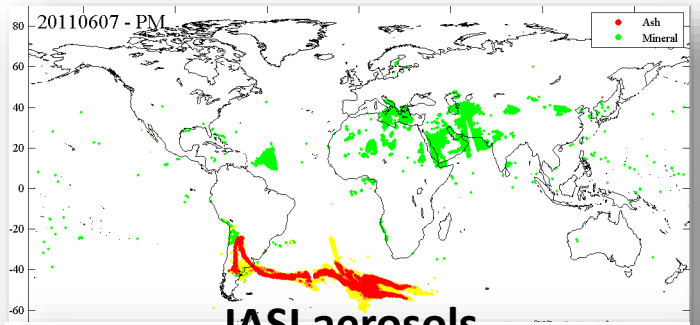
- **Role of combined data and the EWS inside EUNADICS-AV**
- **Overview of the observational system**
- **Mechanism and status of EUNADICS–AV Early Warnig System (EWS)**
- **Cases studies (Hurricane Ophelia & dust storm of spring 2018)**
- **Highlights**

Role of combined data and the EWS inside EUNADICS-AV

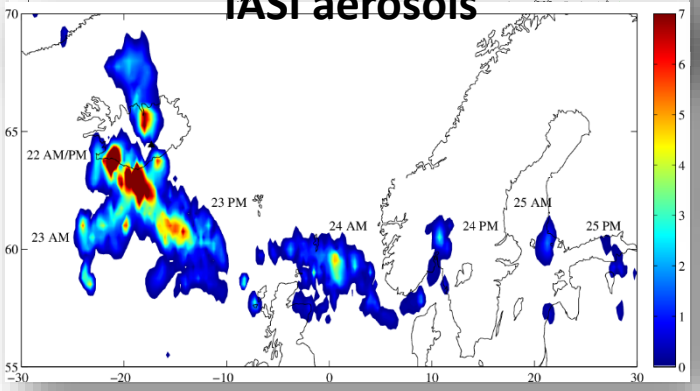


Overview of the observational system

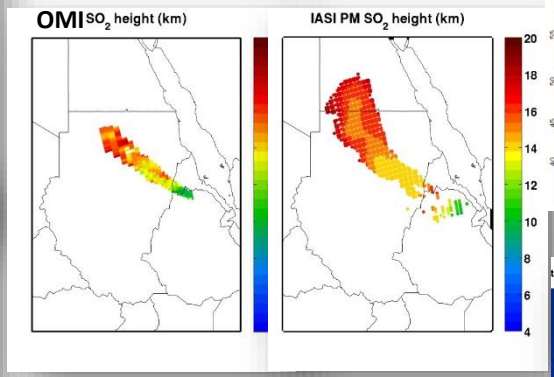
Highlight satellite: optimal for **monitoring** and **alerting**
at global level and model **validation** with high geographical coverage



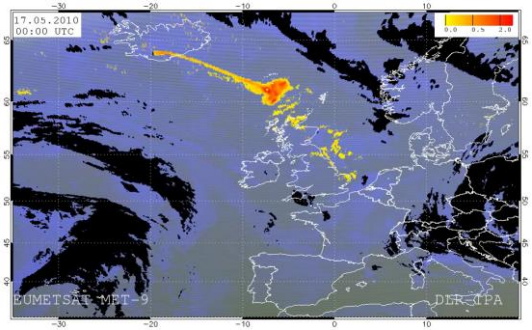
IASI aerosols



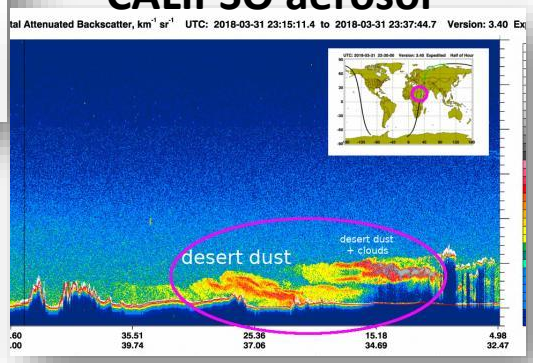
OMI/IASI SO2



SEVIRI ash/dust



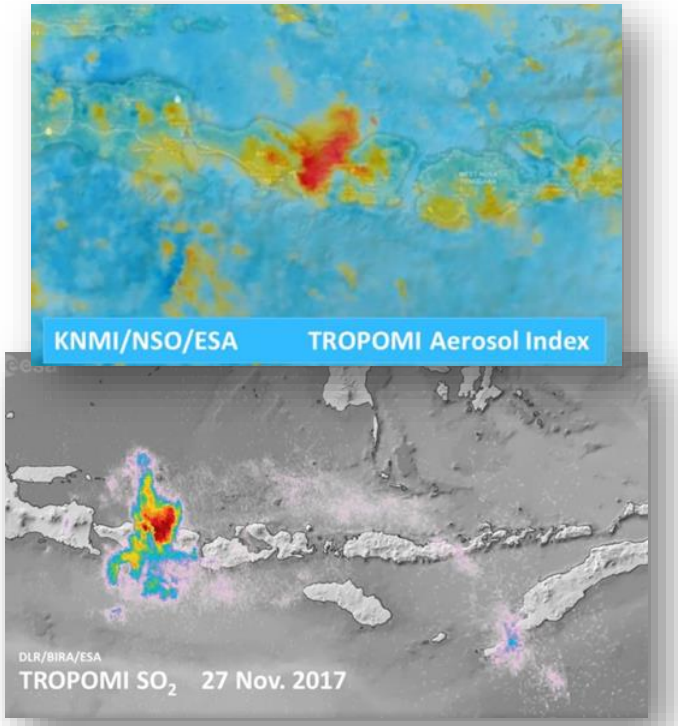
CALIPSO aerosol



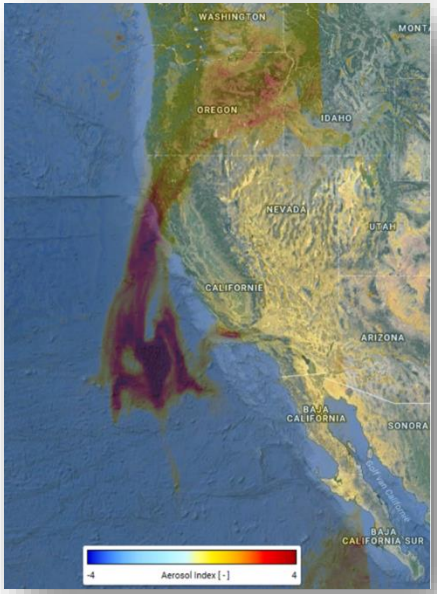
Overview of the observational system

TROPOMI S5P satellite instrument (3.5x7 km²)

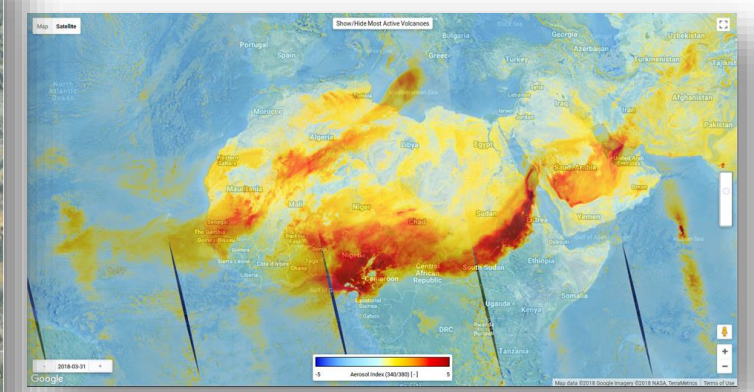
Ash and SO_2 - Agung
Bali, Indonesia, 27 November 2017



Fires California
12 December 2017

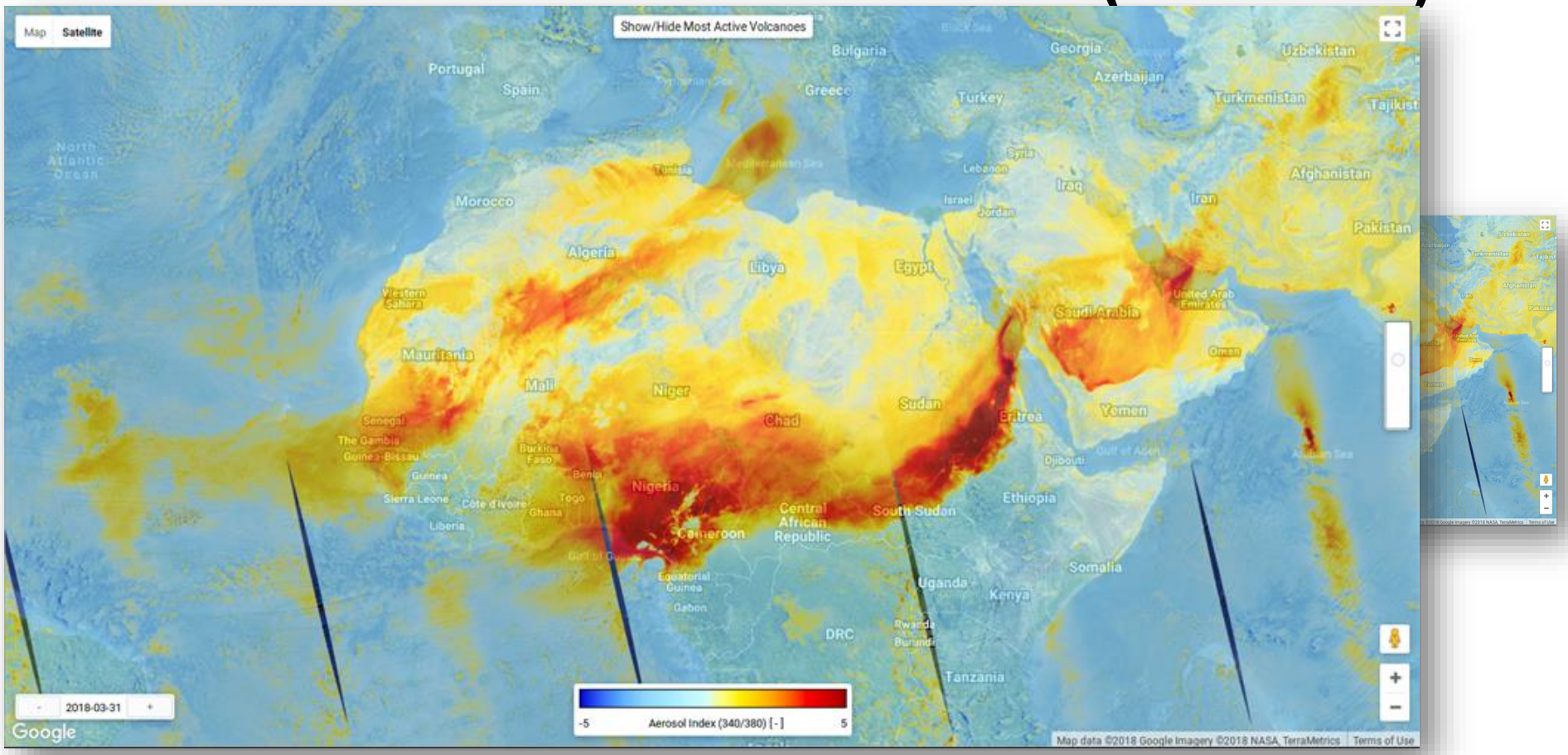


Dust storm
31 March 2018



Overview of the observational system

TROPOMI S5P satellite instrument (3.5x7 km^2)

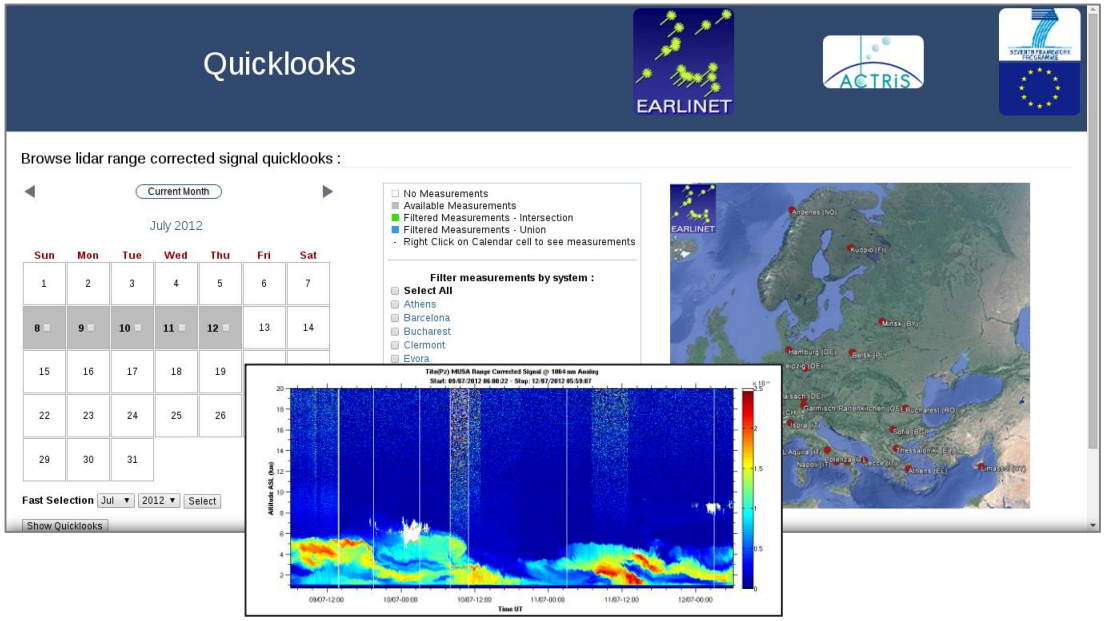


Overview of the observational system

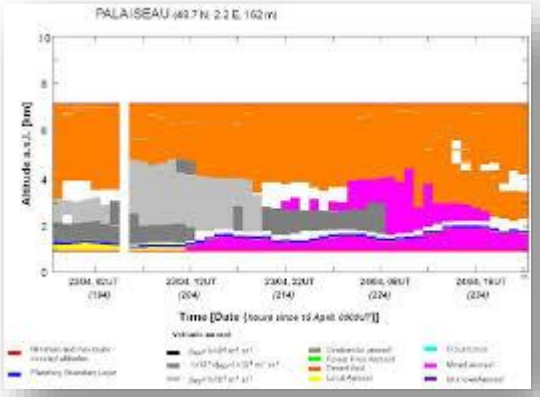
Higher quality provided by **research lidars**

EARLINET

- EARLINET in **ACTRIS Research Infrastructure**
- Quicklook common page almost ready to be public
- NRT demonstrated capability
- up to 40 sites working 24h per day
- Multiwavelength and layer products development as standard products



Standardized quicklook common page

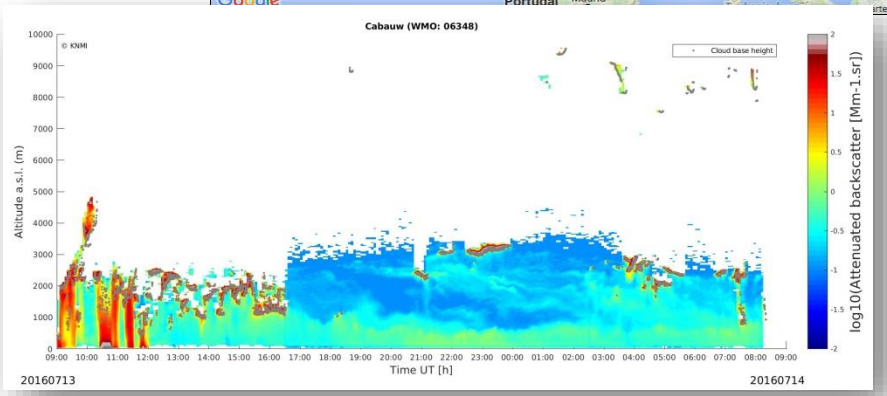


Aerosol masking

Overview of the observational system

EUMETNET set up **E-PROFILE**, for managing the European networks of **radar wind profilers** (RWP) and **automatic lidars and ceilometers** (ALC) for the monitoring of vertical profiles of wind and aerosols including volcanic ash, desert dust and smoke from wild fires.

E-PROFILE data are **calibrated through** the calibration based on **TOPROF** initiative



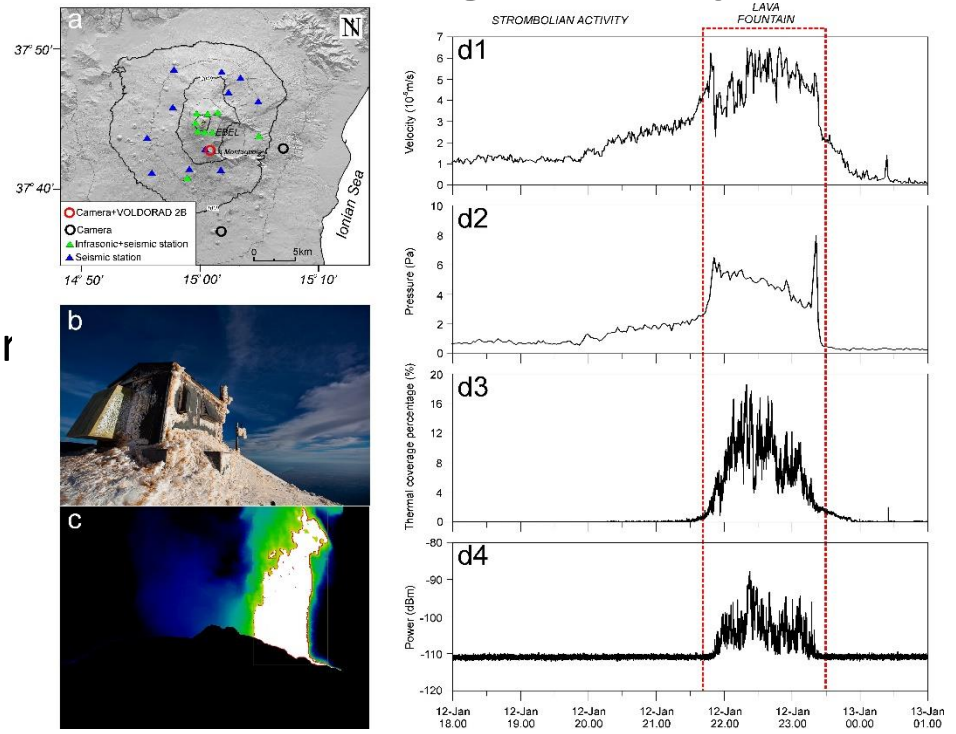
10 stations automatically **calibrated and displayed in real time**.

Overview of the observational system

In-situ observation near the source:

Interesting for **initiating the models**, evaluating the **impact** on different local actors:

- Observatories in Iceland and Sicily
- Eruption onset
- Plume-top altitude estimated by radar
- Seismic and infrasound network
- Aerosol lidar running during events
- Local dispersion modelling

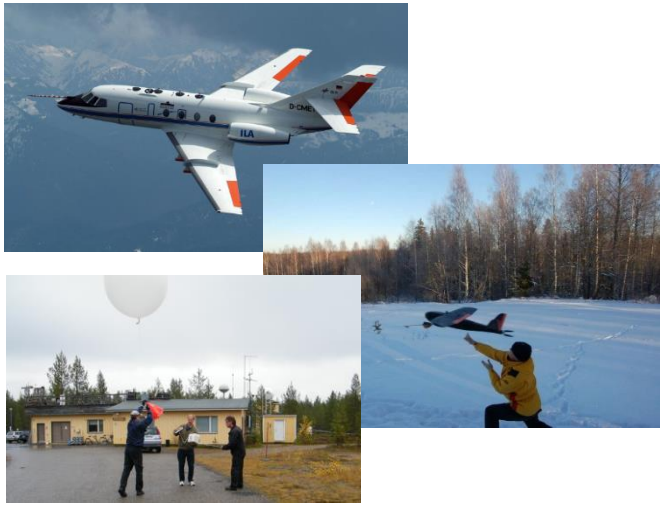


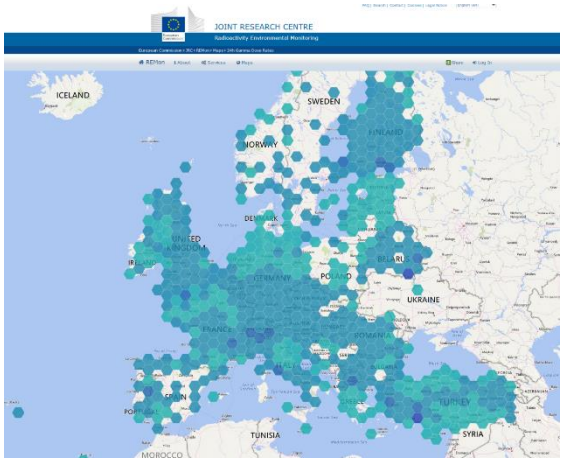
Geophysical signals during a typical Etna explosive eruption

Overview of the observational system

Nuclide measurements

- ✓ Only a few research (2 EUFAR) and civil contingency aircrafts for upper air radioactivity measurements are available in Europe
- ✓ UAV methods in case of the Fukushima nuclear accident have proven to be an important element of radiation surveillance
- ✓ Many UAV system around Europe but a European integrated UAV observation network won't be operational within the next few years.
- ✓ EURDEP centralises appropriate early notification networks of the European Community Urgent Radiological Information Exchange (ECURIE) and the early notification system ENATOM (Emergency Notification and Assistance Technical Operations Manual) of the International Atomic Energy Agency (IAEA).





Overview of the observational system

Tailoring products, three main focal points :

- characterisation of volcanic ash, dust, and smoke, for discriminating these three hazards
- height of layers of volcanic ash, dust, and smoke
- quantitative retrieval of aerosol mass.

Tailoring activities consist of **improving existing algorithms and products**, and of **combining specific products and algorithms** to **improve the usefulness for aviation**

Overview of the observational system

Tailoring activities

- #1 Sulfur dioxide (SO_2)
  - Automated mass calculations over selected volcanoes
  - SO_2 height (spectrally resolved; physical retrieval, possible neural network)
- **#2 Mineral dust**
  - **Vertical profiles ground-based network**
  - **Discrimination from InfraRed wavelengths (broad band & spectrally resolved)**
- #3 Volcanic ash
  - Height from InfraRed wavelengths (physical retrieval, neural network; broad band)
  - Total column mass from InfraRed wavelengths (broad band & spectrally resolved)
  - Height direct from visible wavelength O_2A and O_2B band
  - Height from combined cloud height retrievals and absorbing aerosol index
  - Height from stereoscopy (multi viewing angle)
  - Improved identification accuracy from VIS and/or InfraRed wavelengths
- **#4 Type discrimination**
  - **Use of collocated measurements of SO_2, dust, aerosols, and trace gases, most notably carbon monoxide (CO)**
  - **Allow discrimination for non-selective products using geo-correspondence with pool of previous selective detection**

Mechanisms of EUNADICS–AV EWS

Ash, SO_2, desert dusts, radioactive or fire plumes observations

Alert products from:

- 12 polar orbiting satellites
- 1 geo stationary satellite
- 40 Ground-based stations
- Relay of 7 existing services

Early Warning System aimed at ATM and stakeholders

NRT images

Email notifications

Data files transfer

VAACS
ATM & industry
Pilots
Airlines
Scientists
Observatories

Mechanisms of EUNADICS–AV EWS

- Email notification (essential information) → links to images and alert products

- Alert product (data and tailored products) → standardised format (NetCDF)

- NRT images via SACS and data portal

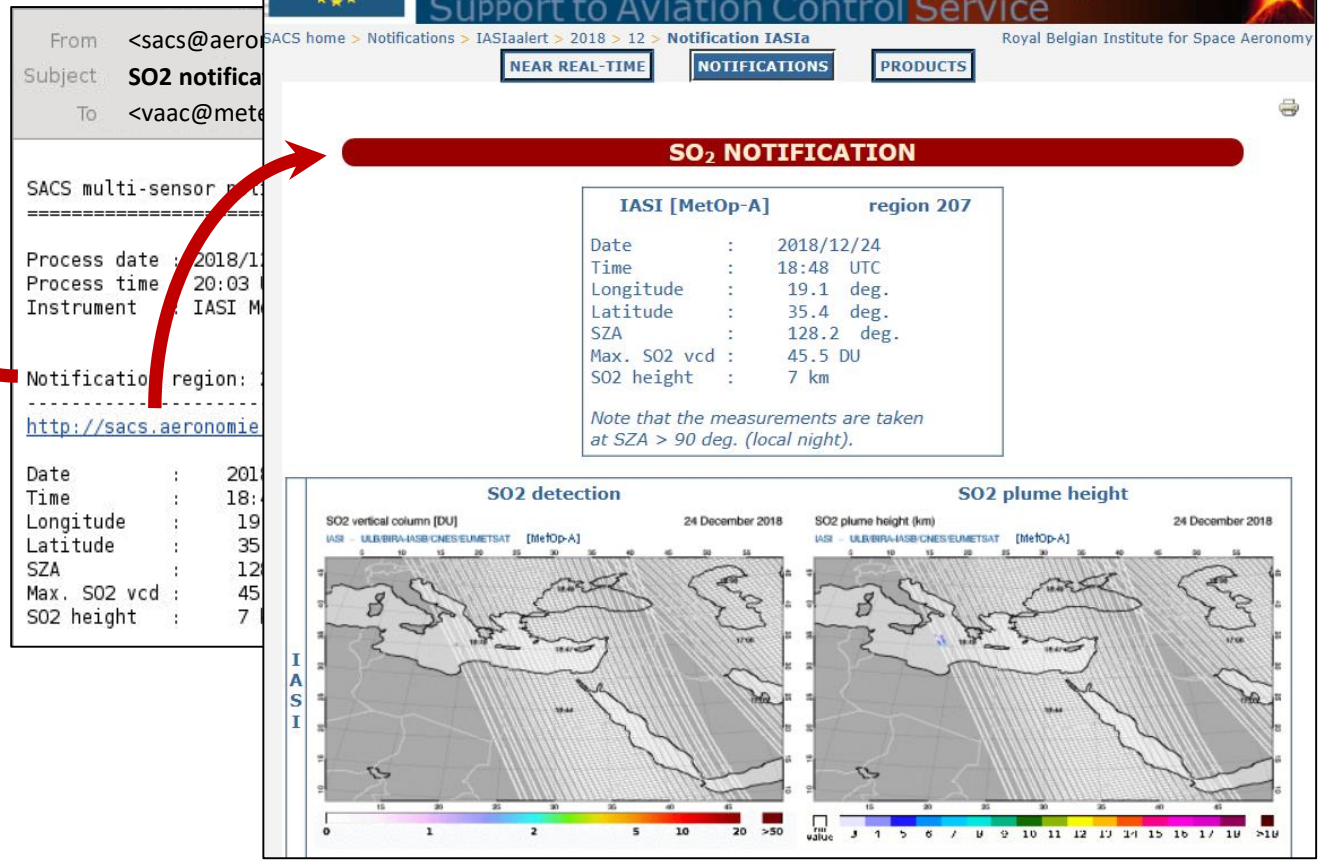
http://sacs.aeronomie.be www.eunadics.eu

Mechanisms of EUNADICS–AV EWS

Etna eruption: 24-31 Dec. 2018

Email notification (essential information)

alert product



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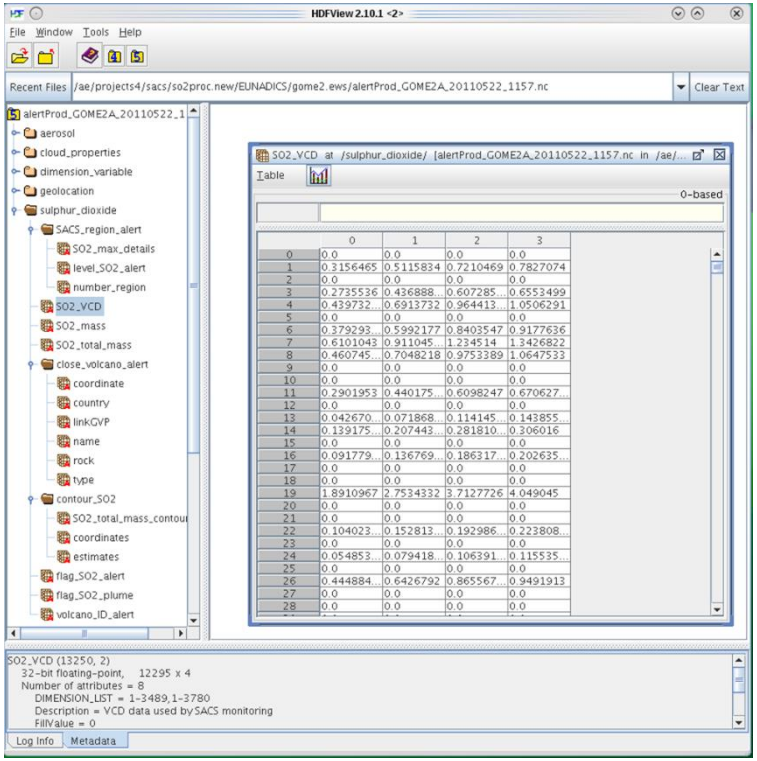


Alert products
in standardised format (NetCDF)

* Data
* Tailored products
  - *alert pixels*
  - *level of severity (LOW, HIGH)*
  - *extended plume of hazard*
  - *surface (and mass loading)*
  - *contours (surface, mean, max, mass)*
  - *info. source , SACS region, max values*
  - *traceability of event (START → END)*
  - *links image alert and SACS notification*
  - *links images other instruments*

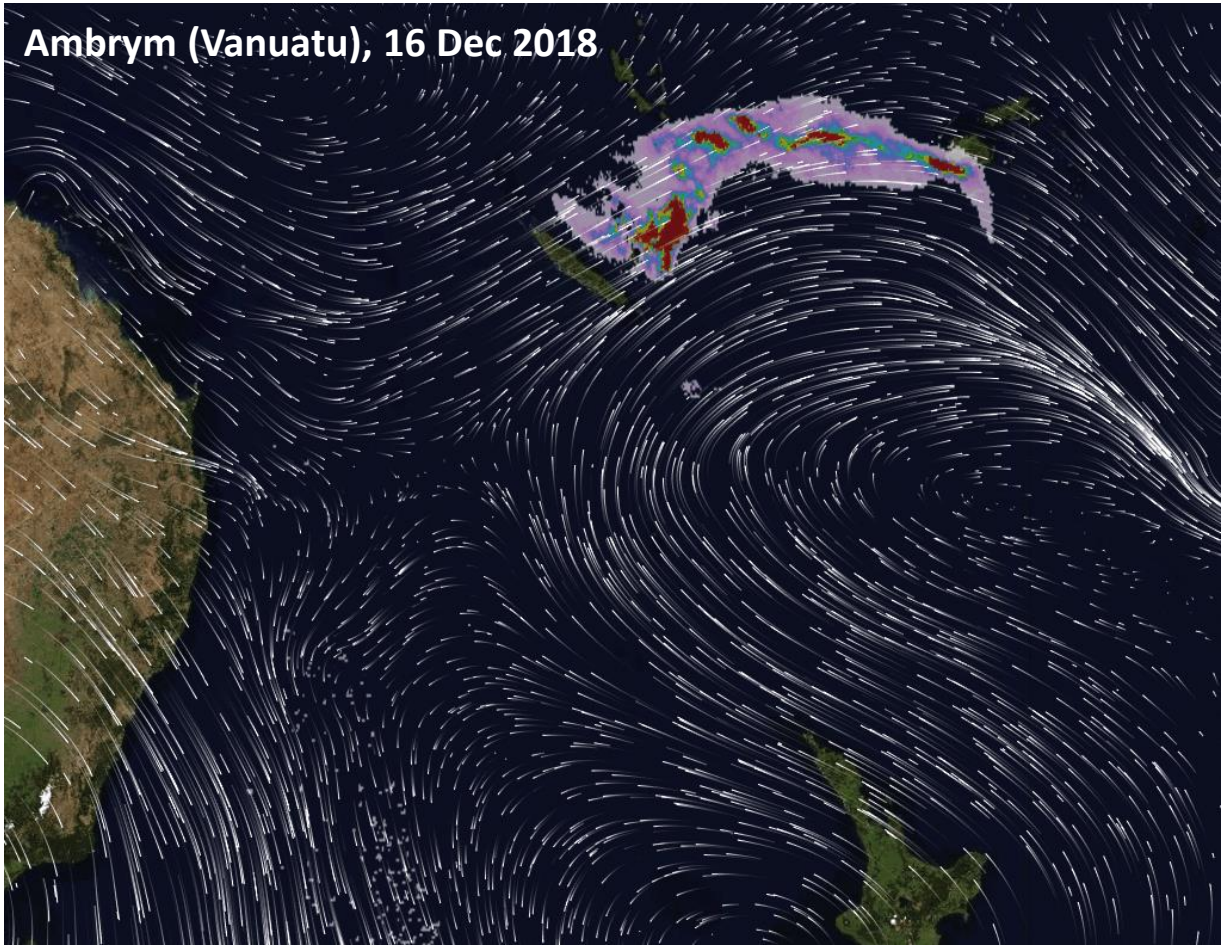
Mechanisms of EUNADICS–AV EWS

TROPOMI SO_2

+

Wind

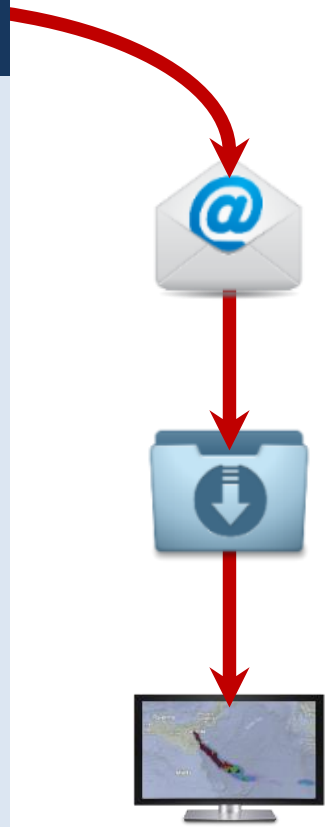
http://sacs.aeronomie.be



Development of a new webinterface with wind direction

Status of EUNADICS–AV EWS

Instruments [GB]	Instruments [SAT]	Instruments [IS]	Observations	Sources alert	Alert products
Lidar (EARLINET)			Vol. depolarisation ratio	Volcano / Dust	Existing
Automatic lidar & ceilo. (AERONET)			Attenuated backscatter coeff.	Volcano / Dust / Smoke	May 2019
Radar & auto. lidar & ceilo. (E-PROFILE)			Wind prof. / Att. backs. coeff.	Volcano / Dust / Smoke	May 2019
UV spectrometer network			SO_2 profiles	Volcano	May 2019
Radar			Plume height	Volcano	Existing
AIRS / IASI-A & -B			Ash index / SO_2	Volcano	Existing
OMI / OMPS / GOME2-A & -B / TROPOMI			SO_2	Volcano	Existing
OMI / OMPS / GOME2-A & -B / TROPOMI			Aerosol Absorbing Index	Volcano / Dust / Smoke	Existing
IASI-A & -B			Aerosol classification	Volcano / Dust	May 2019
IASI-A & -B			SO_2 height	Volcano	Existing
SEVIRI			Ash / Ash height	Volcano	May 2019
SEVIRI			Aerosol Optical Depth	Volcano / Dust / Smoke	May 2019
SEVIRI			Dust index	Dust	May 2019
MODIS-Terra & -Aqua			Aerosol Optical Depth	Volcano / Dust / Smoke	May 2019
SLSTR			Aerosol index / Aerosol height	Volcano / Dust / Smoke	May 2019
MODIS-Terra & -Aqua / VIIRS			Thermal anomaly	Smoke	Existing
SIL seismic network			Seismicity	Volcano	Existing
Network of detectors			Gamma radiation	Nuclear	Existing



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OMI / OMPS / GOME2-A & -B / TROPOMI			SO_2	Volcano	Existing
OMI / OMPS / GOME2-A & -B / TROPOMI			Aerosol Absorbing Index	Volcano / Dust / Smoke	Existing
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SEVIRI			Ash / Ash height	Volcano	May 2019
SEVIRI			Aerosol Optical Depth	Volcano / Dust / Smoke	May 2019
SEVIRI			Dust index	Dust	May 2019
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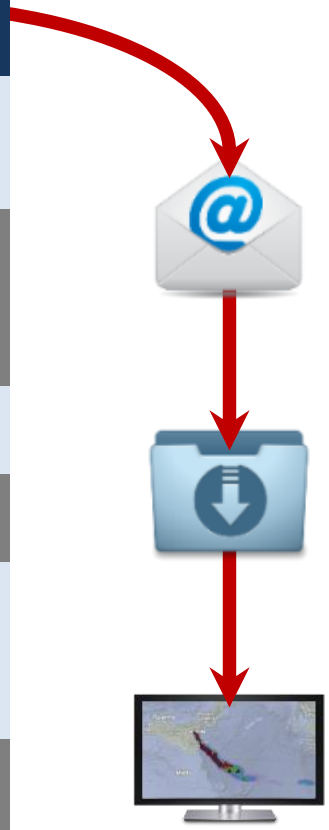
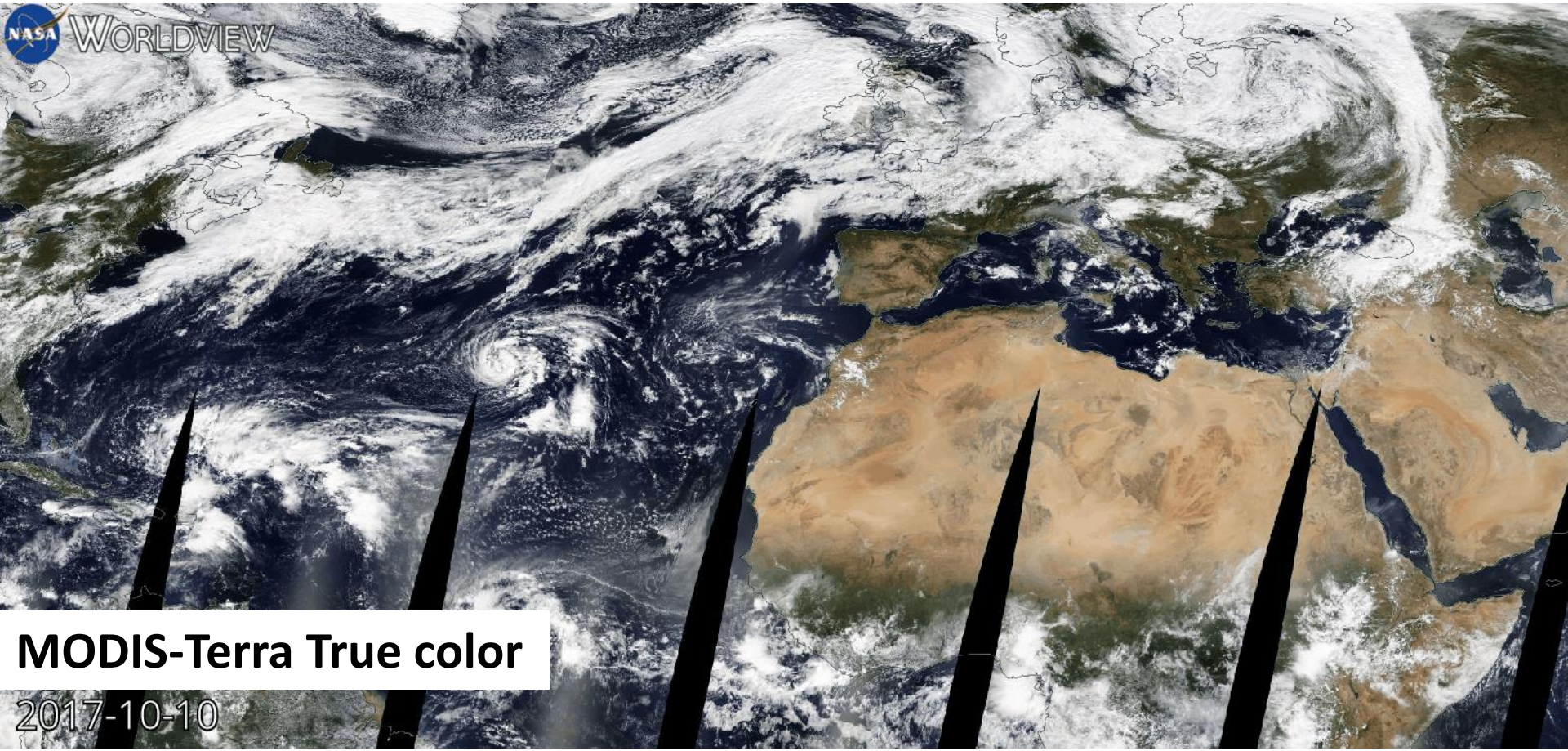
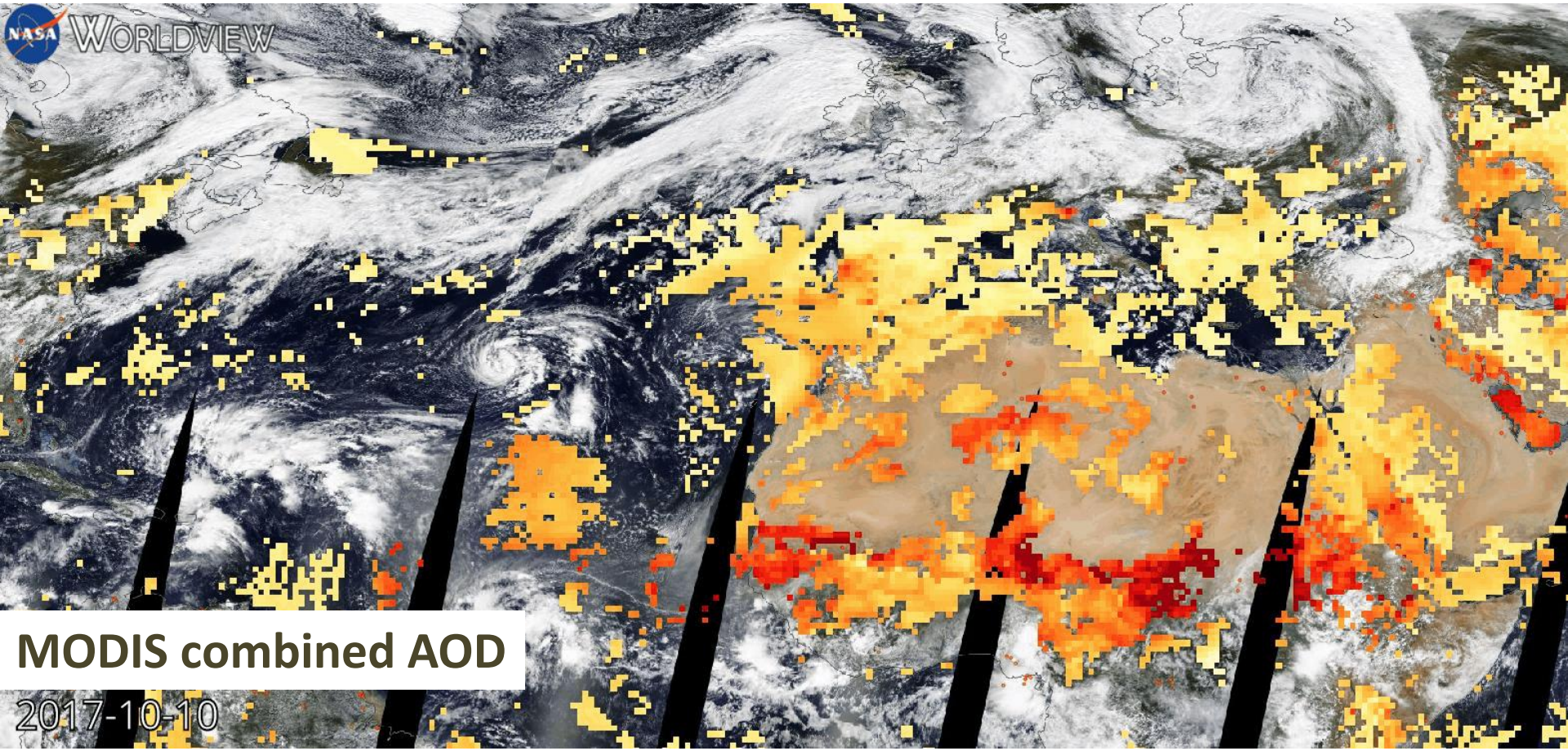


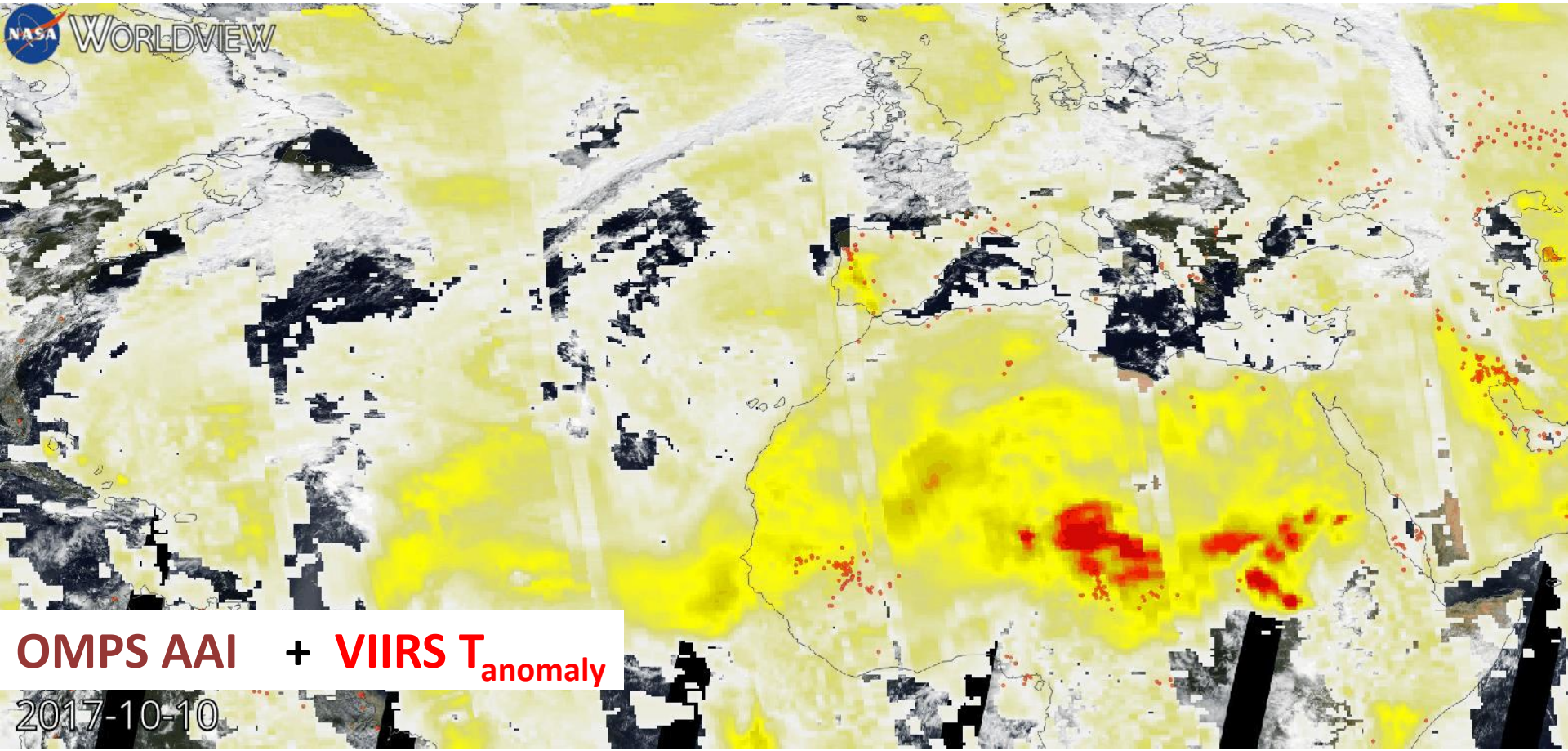
Case study of Hurricane Ophelia



Case study of Hurricane Ophelia

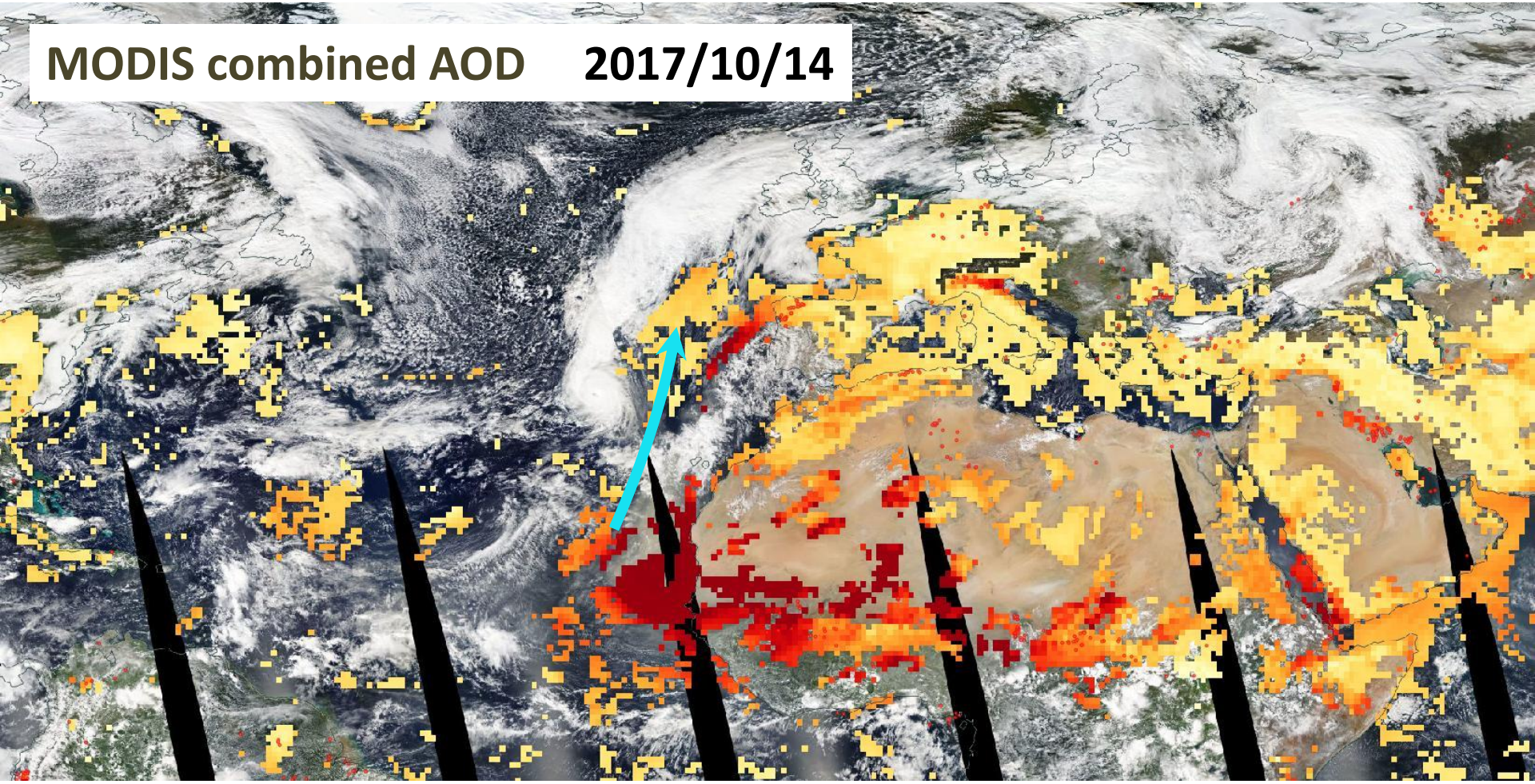


Case study of Hurricane Ophelia



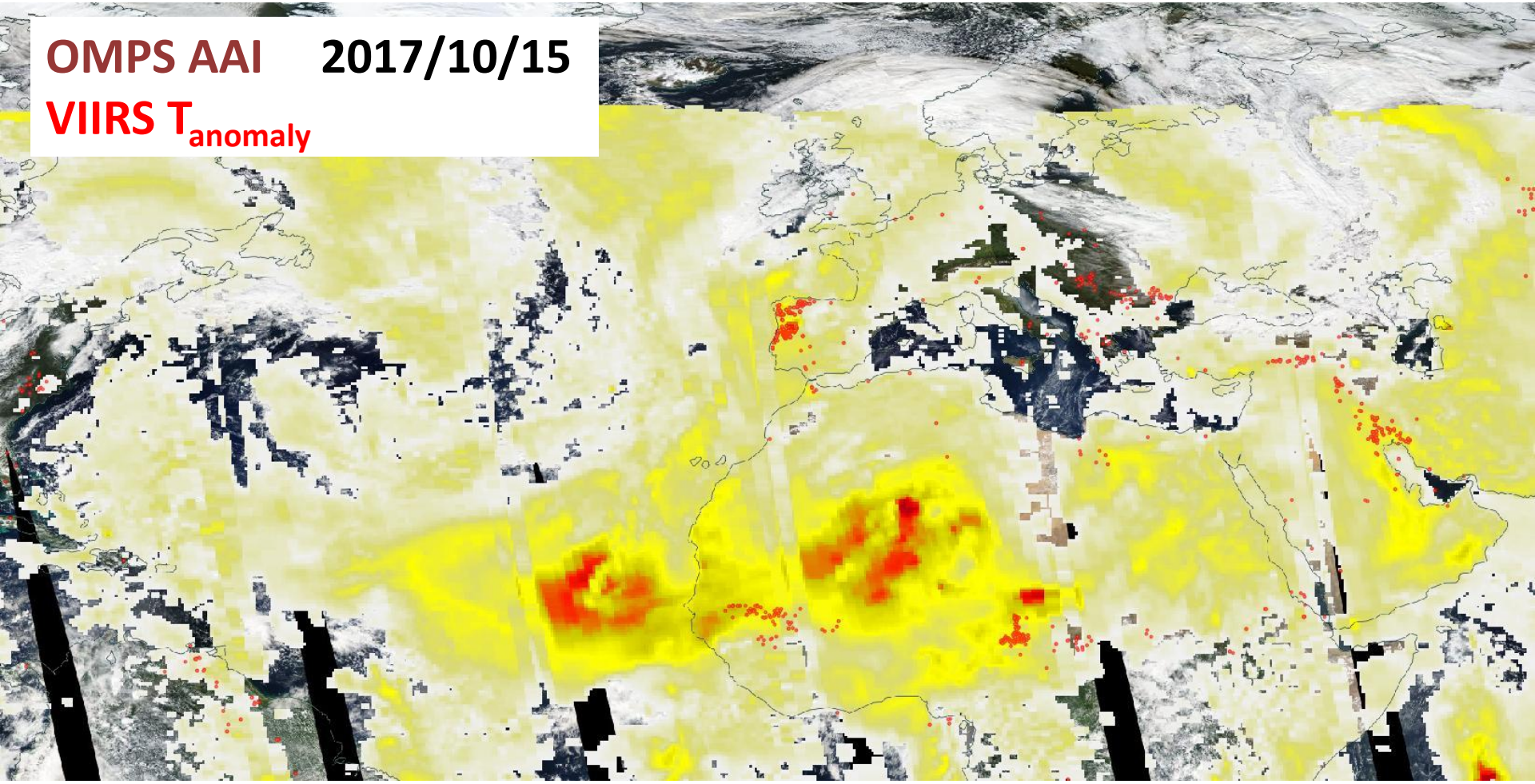
Case study of Hurricane Ophelia

→ Dust



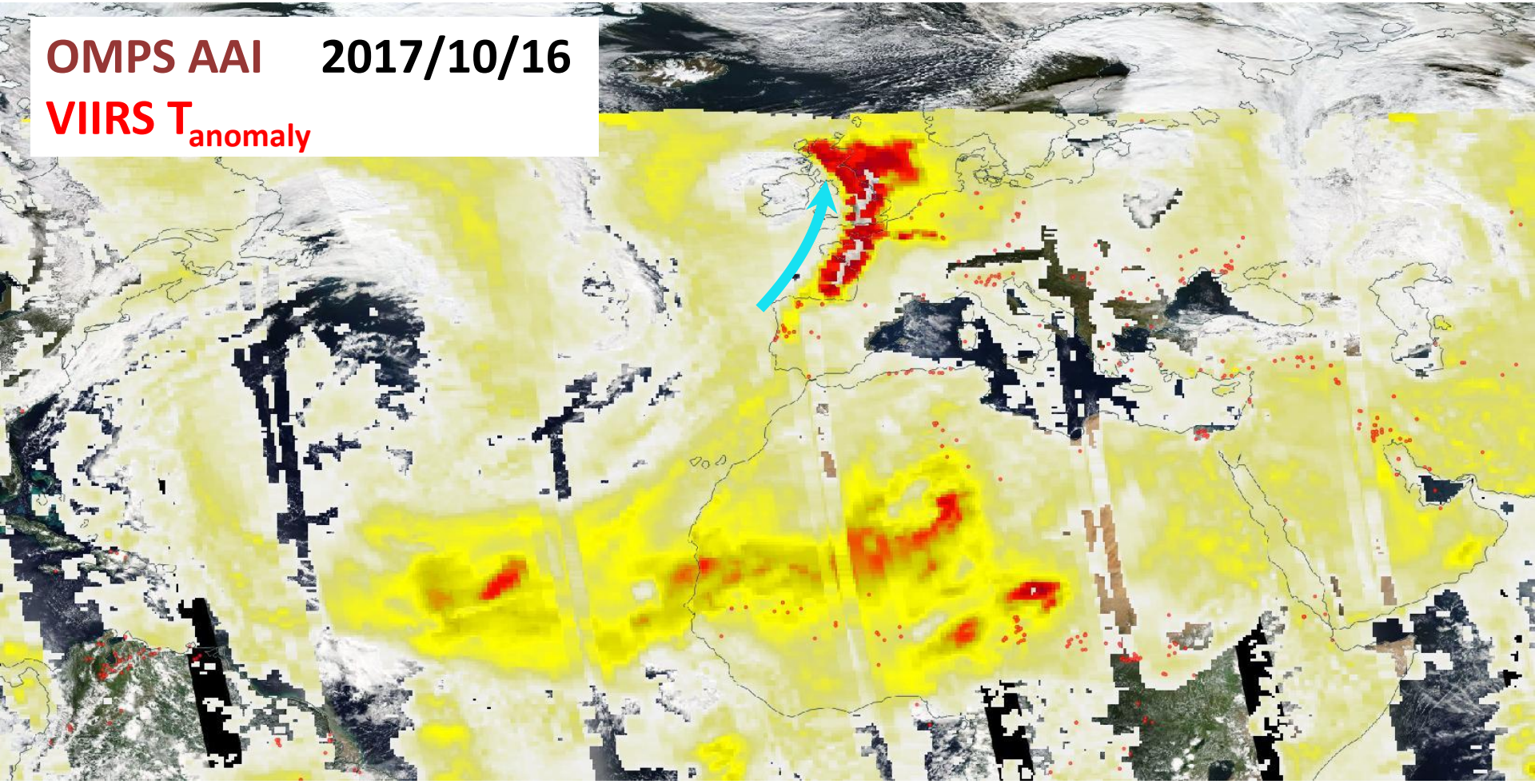
Case study of Hurricane Ophelia

→ Dust



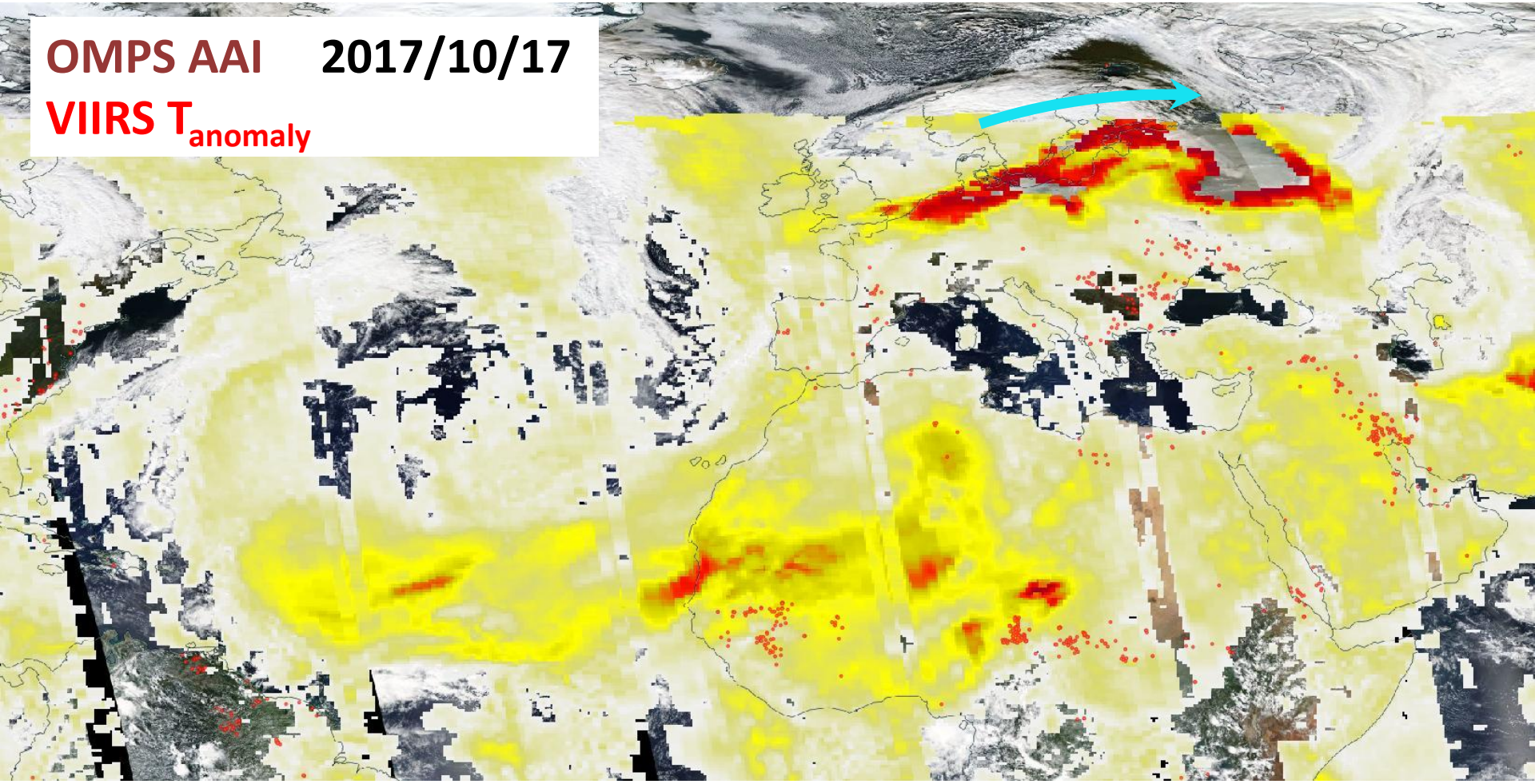
Case study of Hurricane Ophelia

→ Dust & Smoke



Case study of Hurricane Ophelia

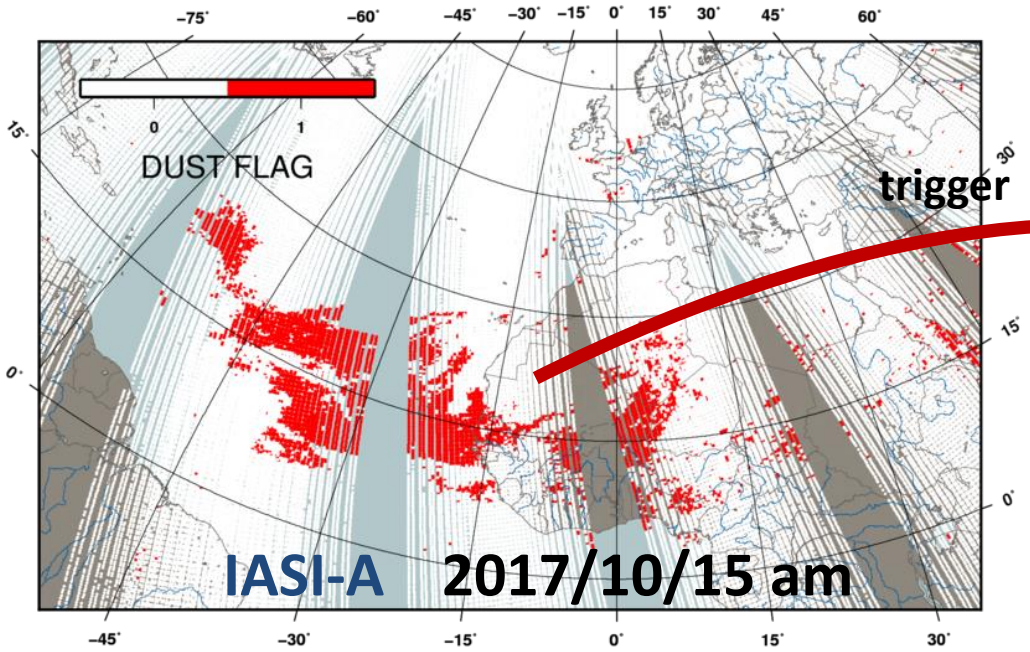
→ Dust & Smoke



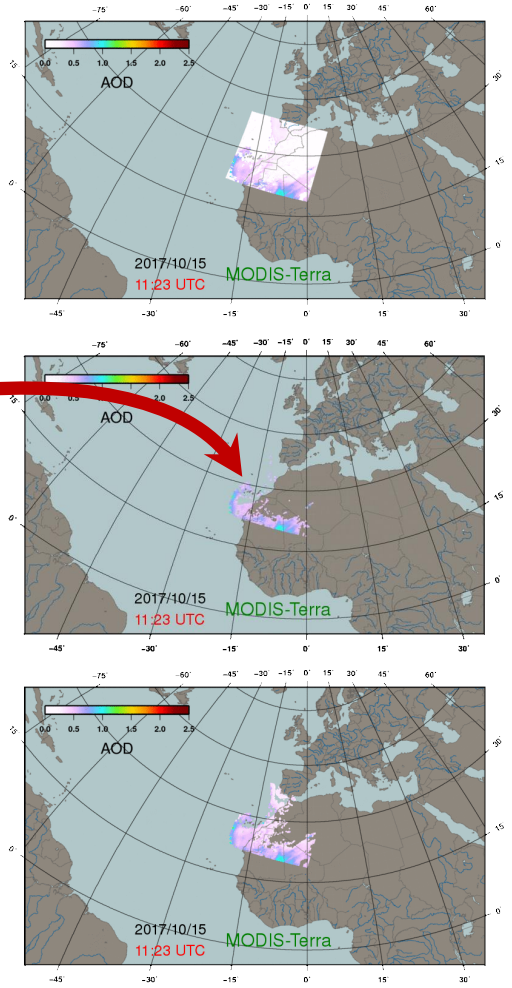
Case study of Hurricane Ophelia

→ Dust

Dust flag from IASI becomes a trigger for MODIS AOD pixels



trigger

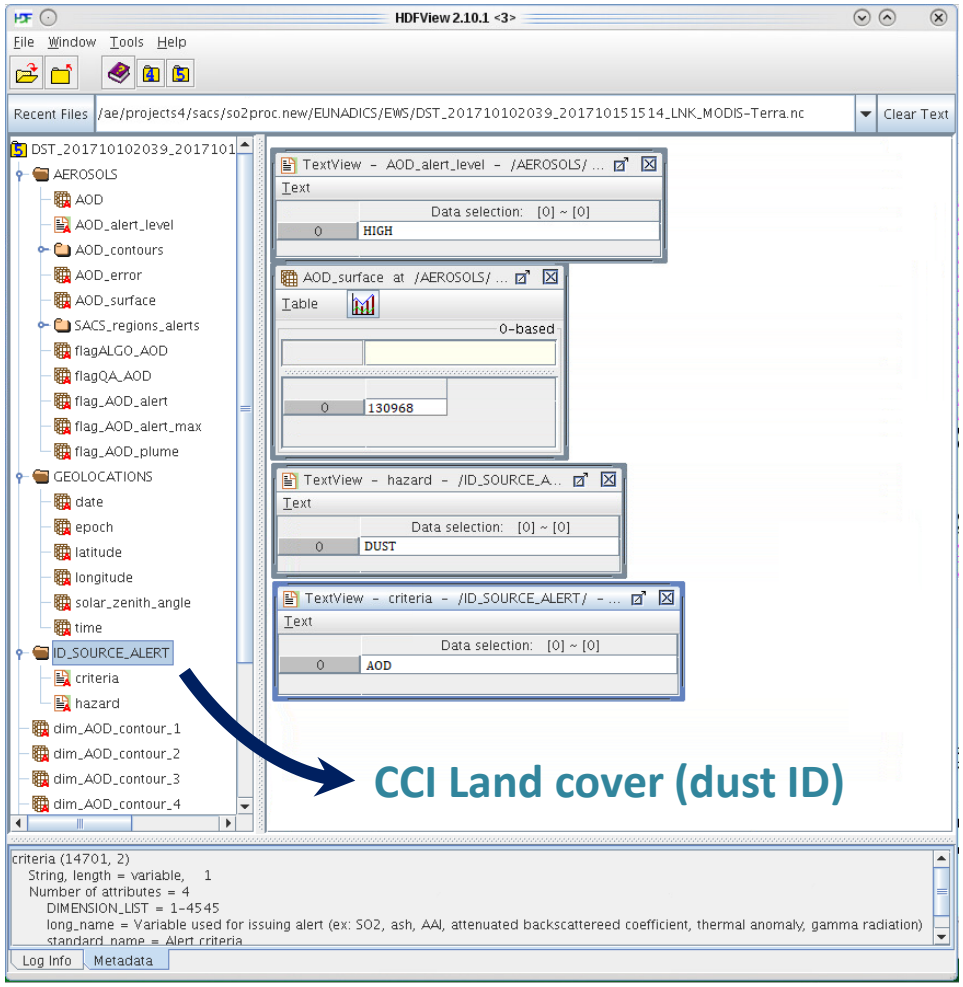


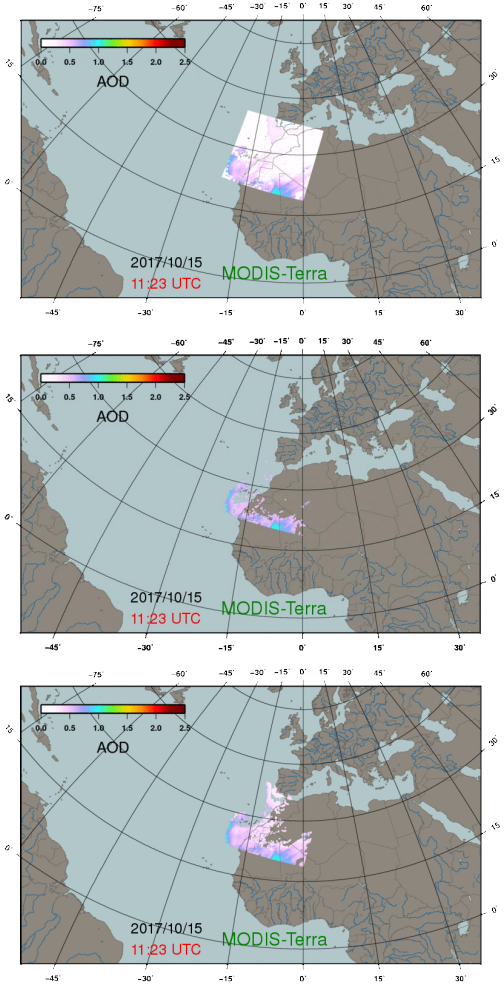
MODIS-Terra
2017/10/15
11:20 – 11:25
all pixels

alert pixels

extended plume

Case study of Hurricane Ophelia



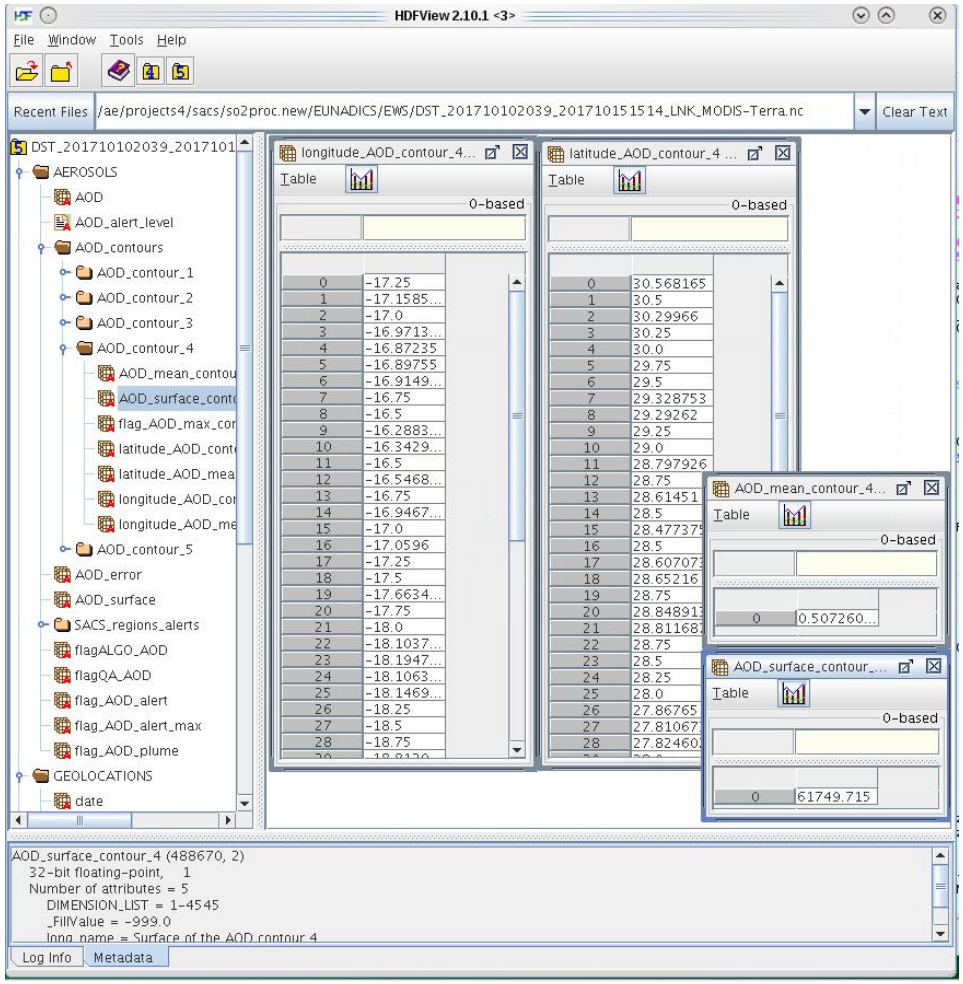


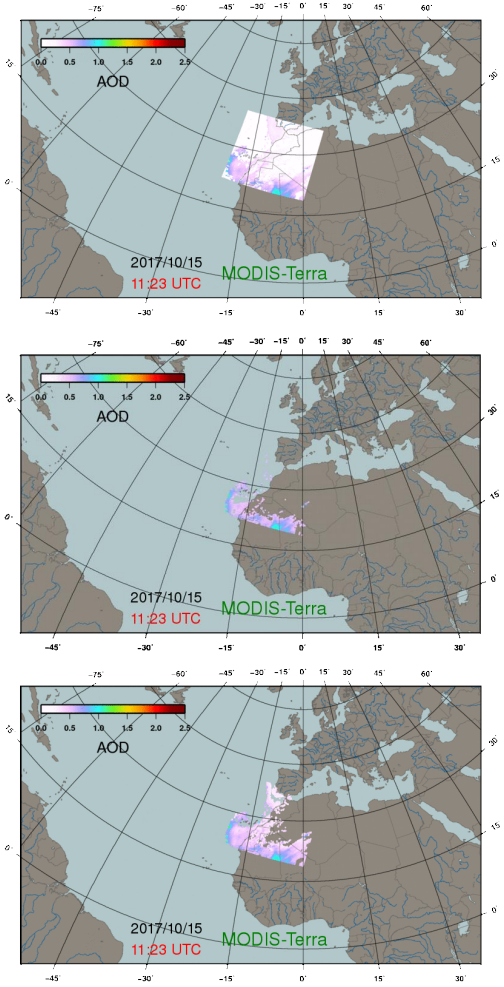
MODIS-Terra
2017/10/15
11:20 – 11:25
all pixels

alert pixels

completed cloud

Case study of Hurricane Ophelia





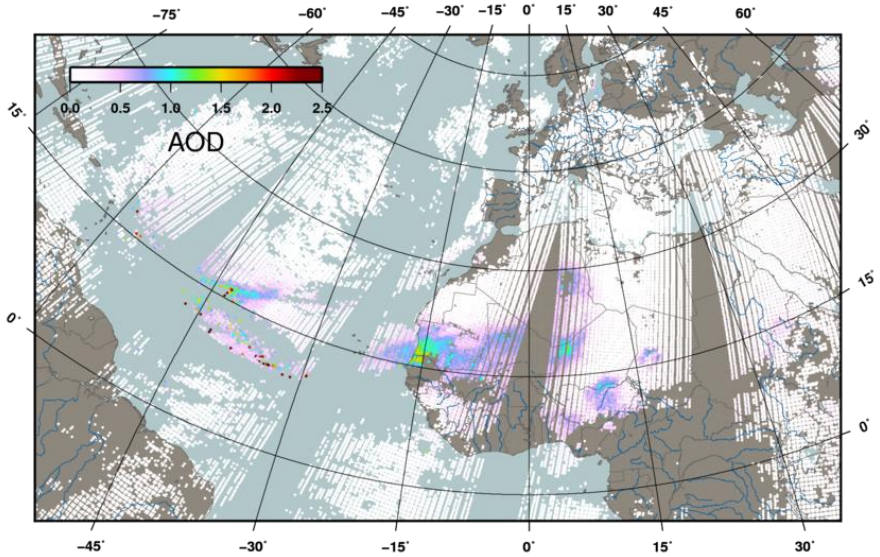
MODIS-Terra
2017/10/15
11:20 – 11:25
all pixels

alert pixels

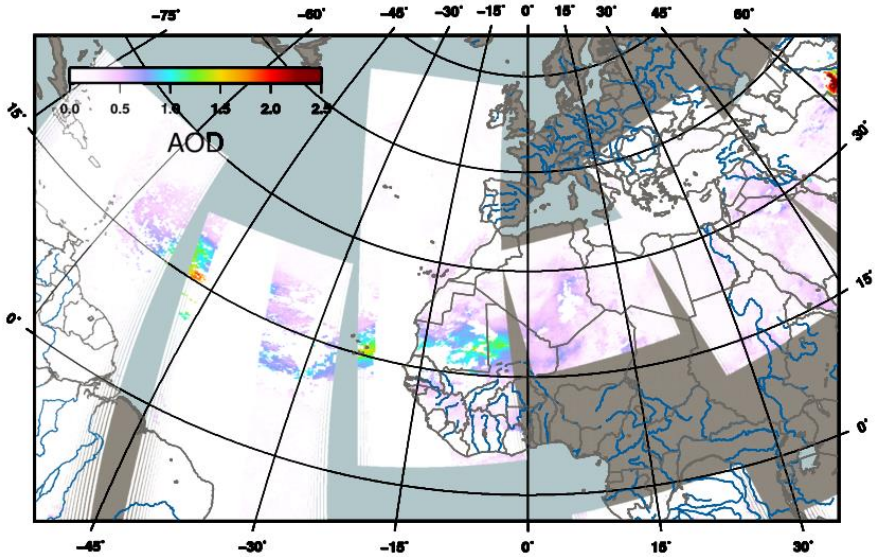
completed cloud

Case study of Hurricane Ophelia

IASI 2017/10/17 pm



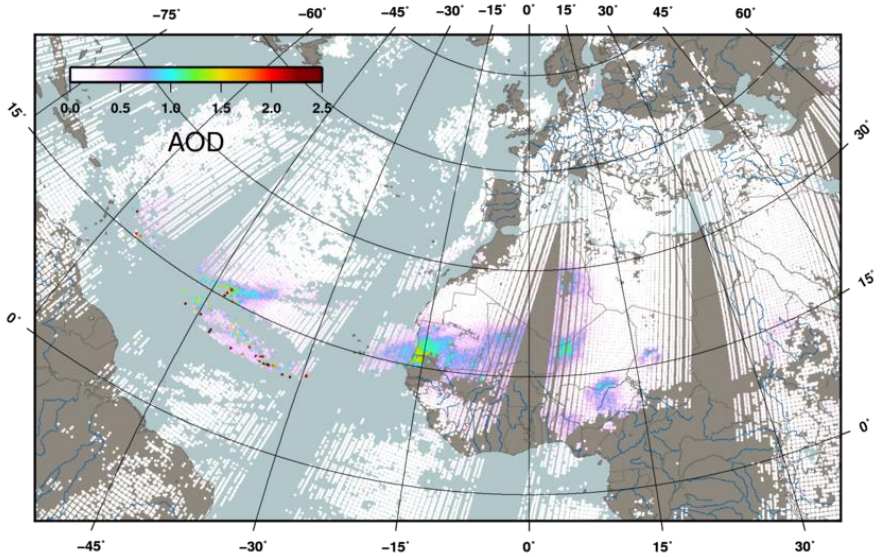
MODIS 2017/10/17



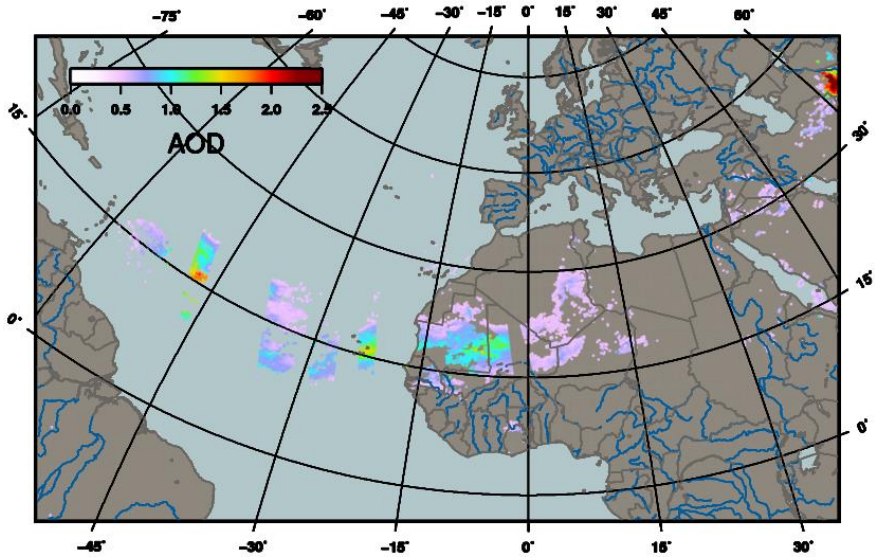
all pixels

Case study of Hurricane Ophelia

IASI 2017/10/17 pm



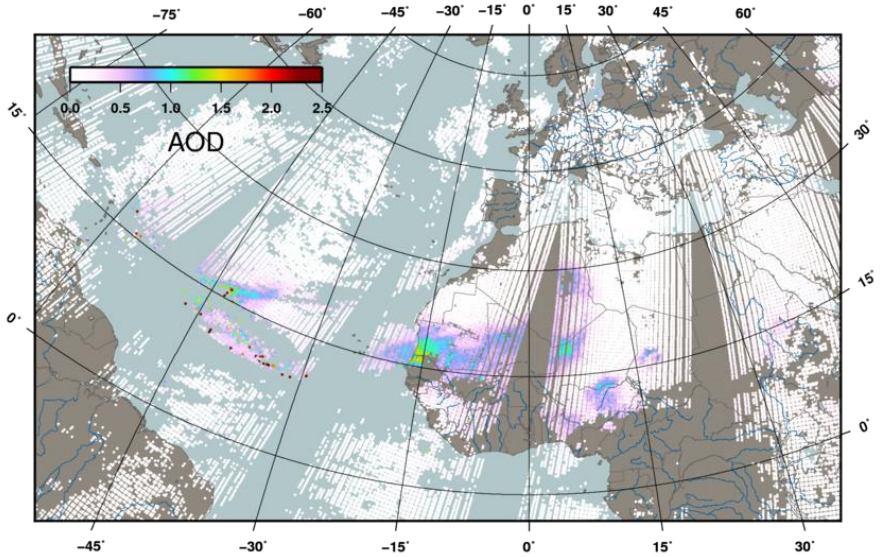
MODIS 2017/10/17



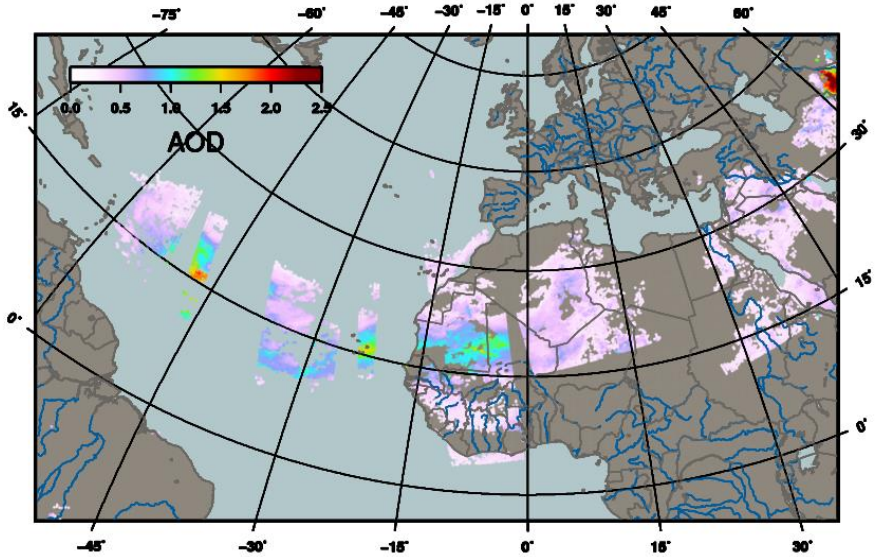
alert pixels

Case study of Hurricane Ophelia

IASI 2017/10/17 pm

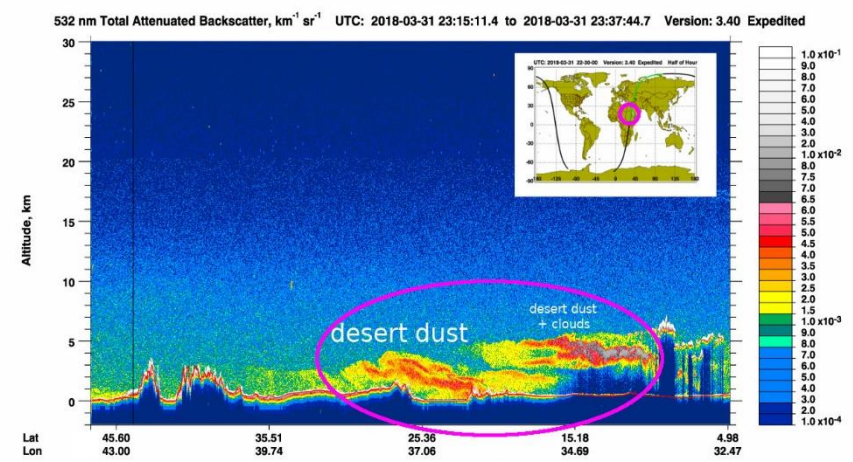


MODIS 2017/10/17

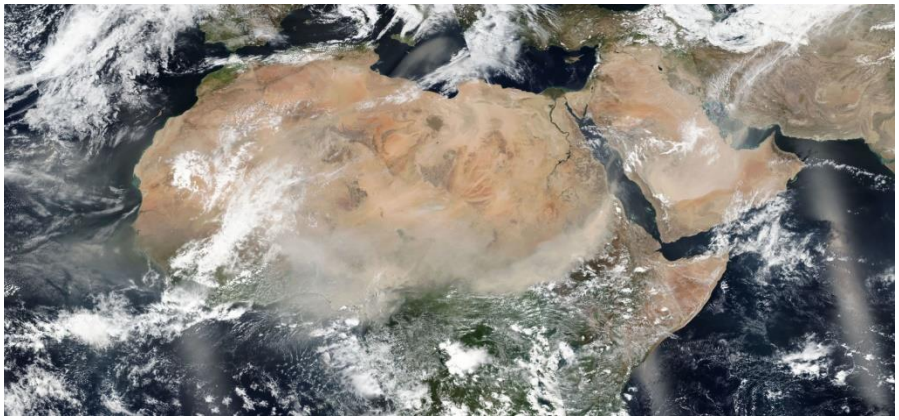


completed cloud

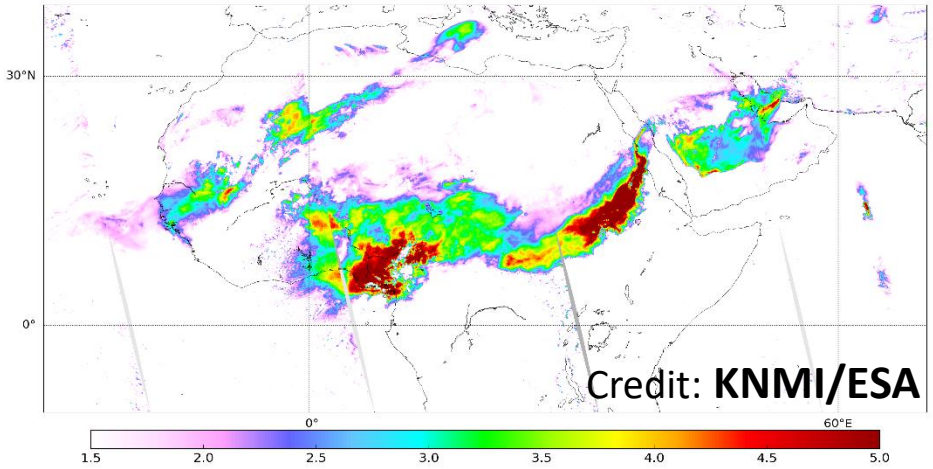
Saharan sub-Sahel dust storm of Spring 2018



VIIRS corrected reflectance (true color), 2018-03-31

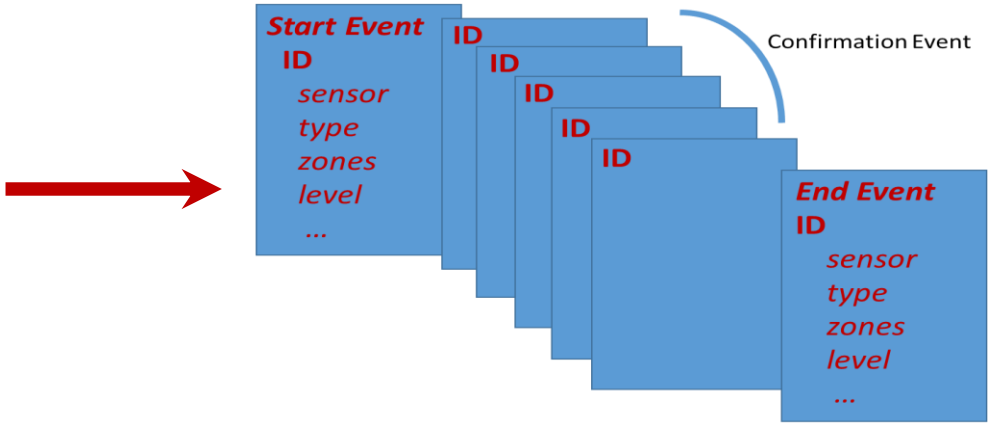


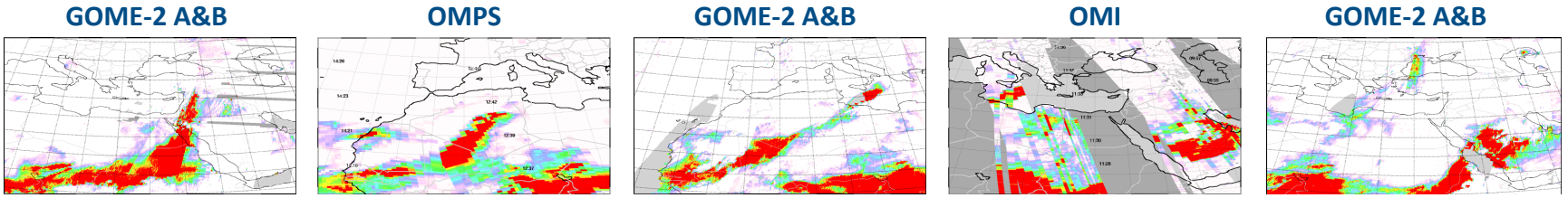
TROPOMI Absorbing aerosol index
2018-03-31



Saharan sub-Sahel dust storm of Spring 2018

Our global multi-sensor system allows time-space tracking of natural airborne hazard clouds





EUNADICS-AV system can follow the chronology of an event and the displacement of dust cloud using it's ID

Highlights

inDust

International Network to Encourage the Use of Monitoring and Forecasting Dust Products
COST Action CA16202
Period: 14 Nov 2017 – 14 Nov 2021

InDust aims to provide a comprehensive catalogue of Desert Dust observations on Global Scale.

The idea is to:

➔ realise a **dynamical catalogue**

(updated and replying to the expressed need of specialised measurements for Dust particles)

➔ provide in NRT **alert products** from our EWS

EUNADICS-AV

Modelling approach

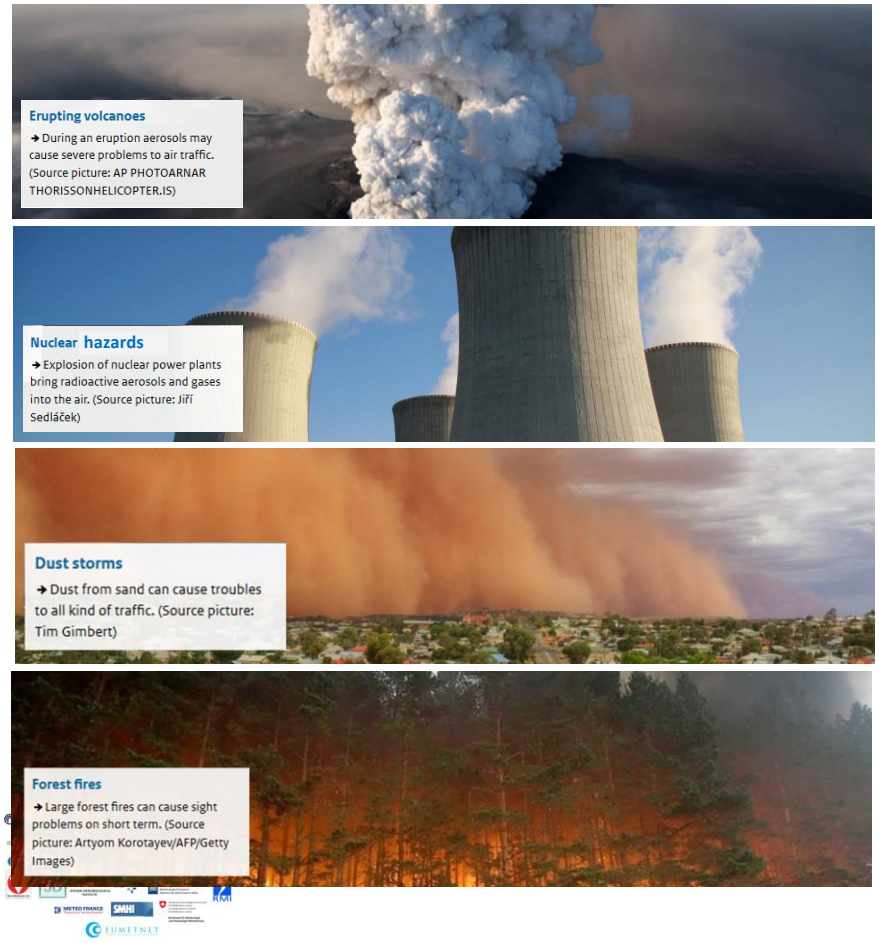
M. Sofiev, M. Plu, D. Arnold, A.Uppstu, C. Maurer, L. Robertson, M. Mulder, A. Carvalho

COST InDust aviation workshop
14.3.2019, Cranfield, UK

www.eunadics.eu

The EUNADICS-AV project has received funding from the European Union's Horizon 2020 research programme for Societal challenges - smart, green and integrated transport under grant agreement no. 723986.

Objectives: 4 hazards



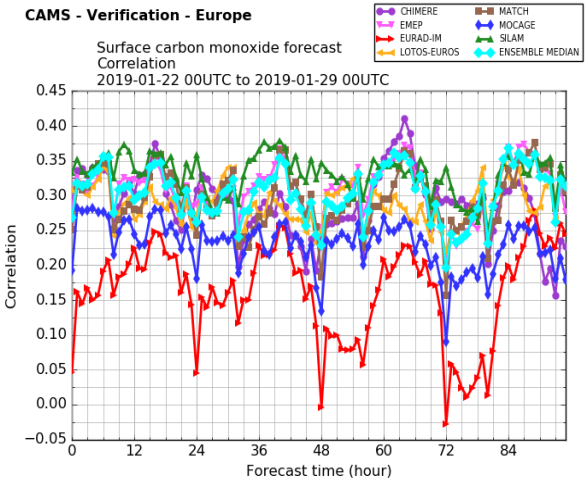
Key challenges for modeling these hazards:

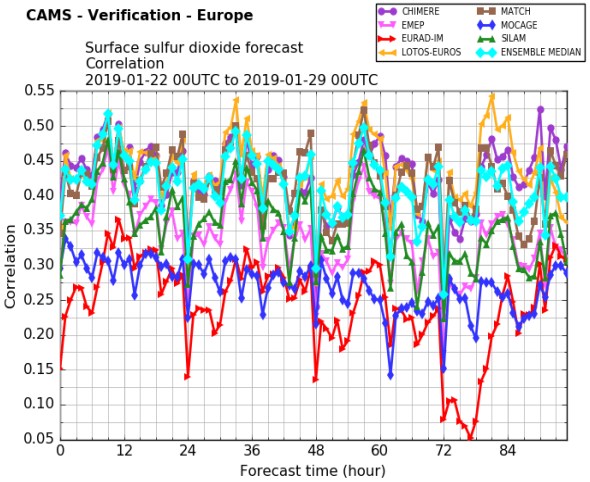
- Rare events,
- High uncertainty in source terms,
- Sensitivity to dispersion model,
- Availability and variety of observations to integrate,
- Identifying the key products that stakeholders would make use of.

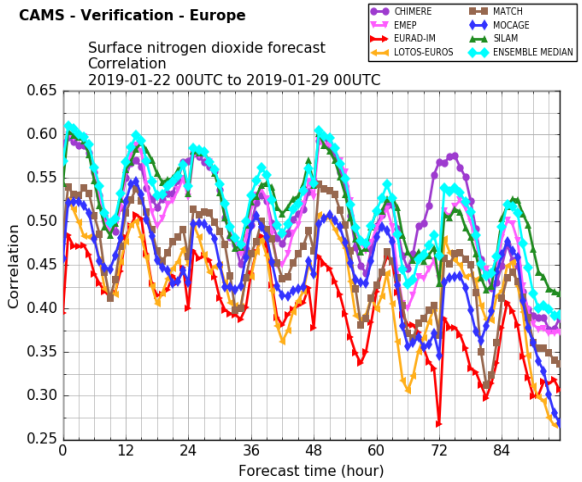
EUNADICS-AV modelling concept

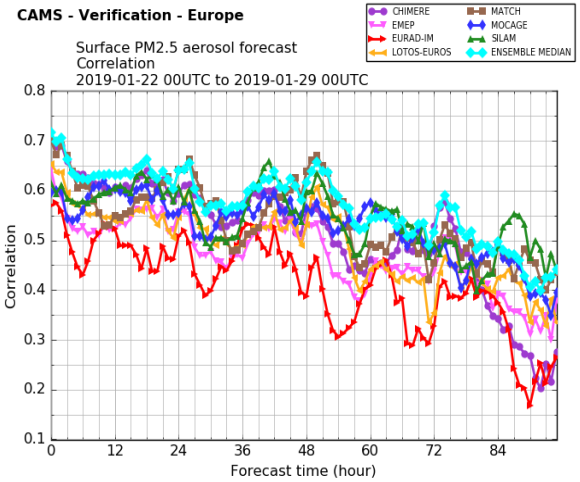
- Assimilation
  - models, technologies:
    - FLEXPART (ZAMG, source inversion)
    - MATCH (SMHI, 4D-VAR)
    - MOCAGE (MF, 3Dvar)
    - SILAM (FMI, EnKF)
    - WRF-Chem (ZAMG, special tasks)
  - new observations
    - lidars
    - aircraft-based sensors
    - radioactive dose rate
- Ensemble
  - EnKF ensemble: SILAM, 140-512 members
  - multi-source: 2-4 sources estimated by the modelling teams
  - multi-model: EUNADICS models

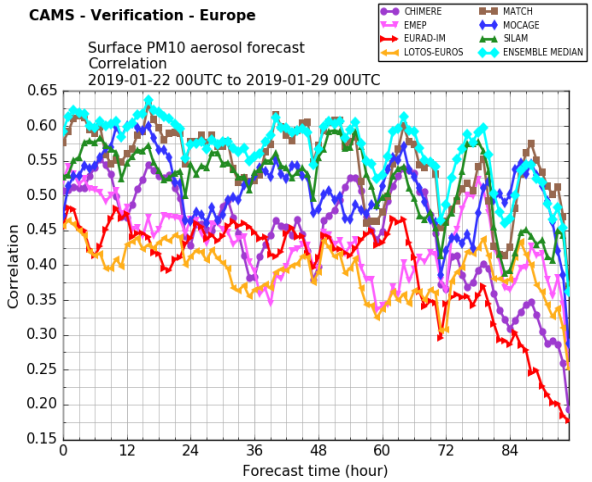
Why ensemble? Example: AQ fcst skills, Europe, correlation coeff

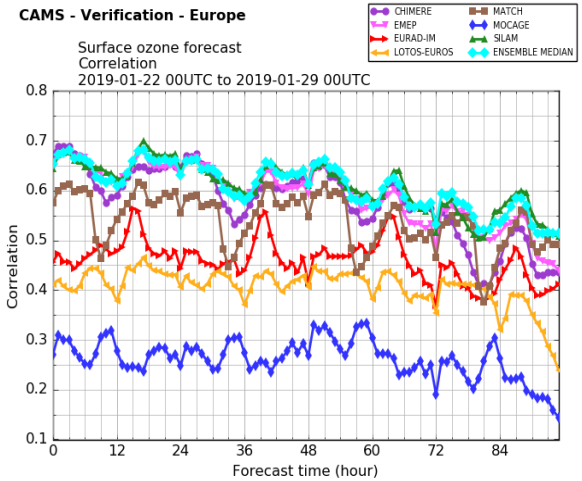




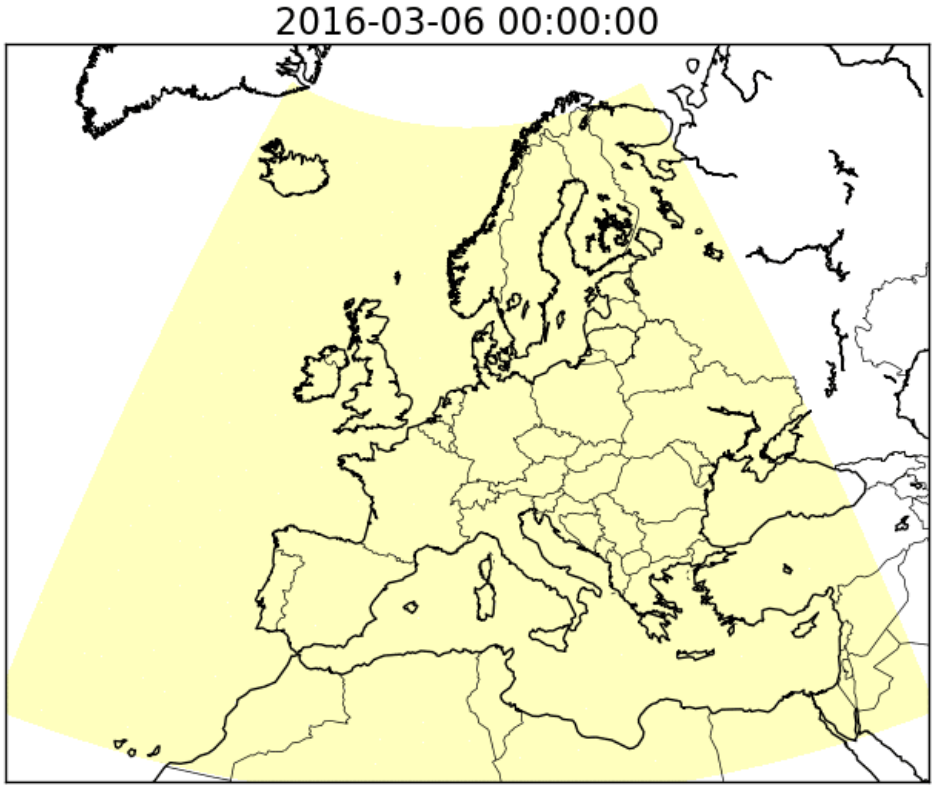








Ensemble for highly localised sources ?



Example:

- a fake eruption of Etna
- SILAM model applied
- two meteorological drivers
  - blue: ERA-Interim
  - orange: IFS operational
  - dark colour: overlap

A hint:

- for localised sources, median may be a bad idea
- probabilities, percentiles, envelopes, overlaps, …

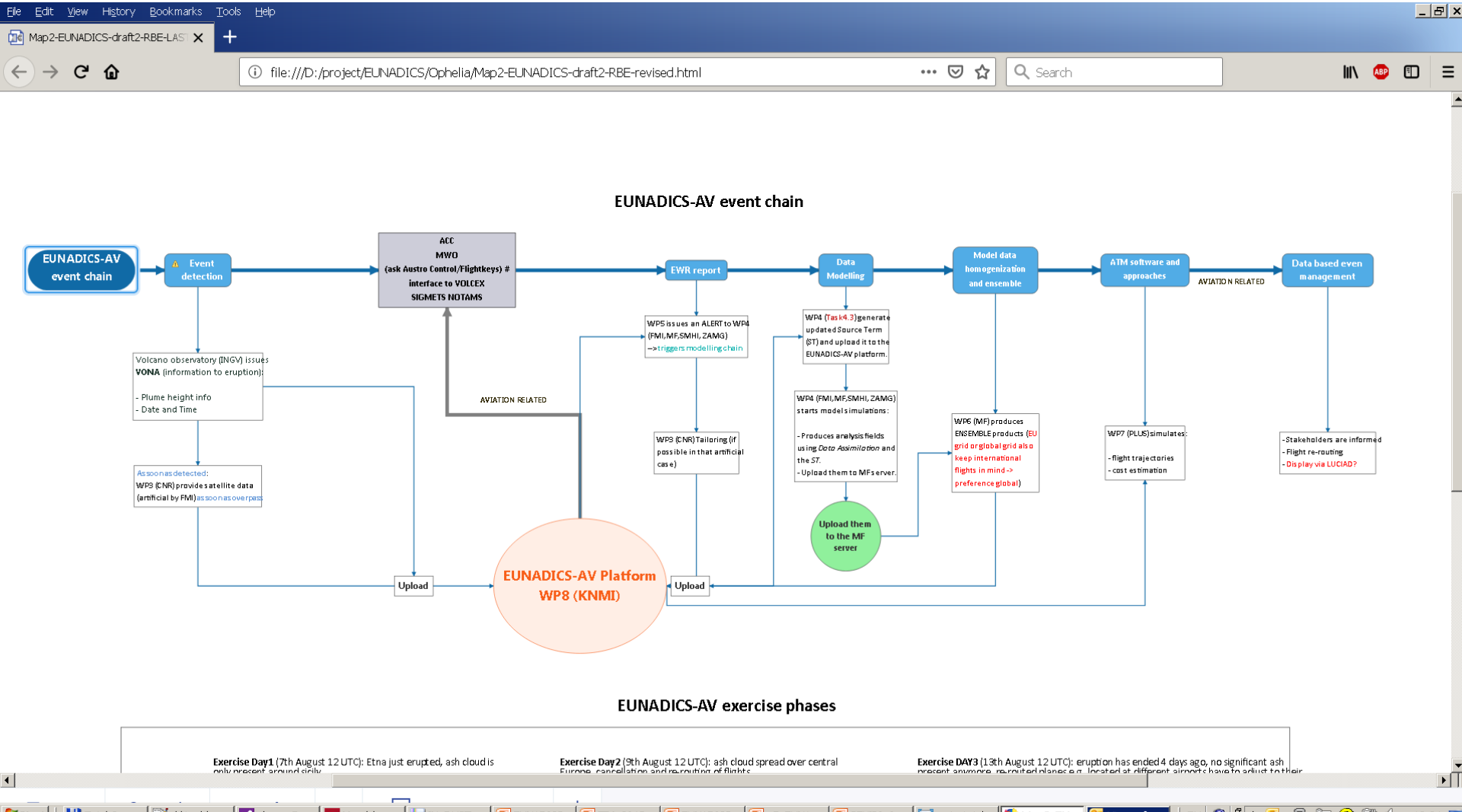
What is the “ensemble output”?

- Ensemble gives many answers (results of individual models)
  - all answers are equal
  - some may be “more equal” than others
- Ensemble answer?
  - “consensus”: mean / median of all models
  - “worst-case”: max of all models (actually, 99%)
  - “uncertainty”: difference, e.g. 75% - 25%
  - …

Examples of case studies

- Exercise 2018
  - Artificial Etna eruption
  - Artificial nuclear attack
- Ophelia storm

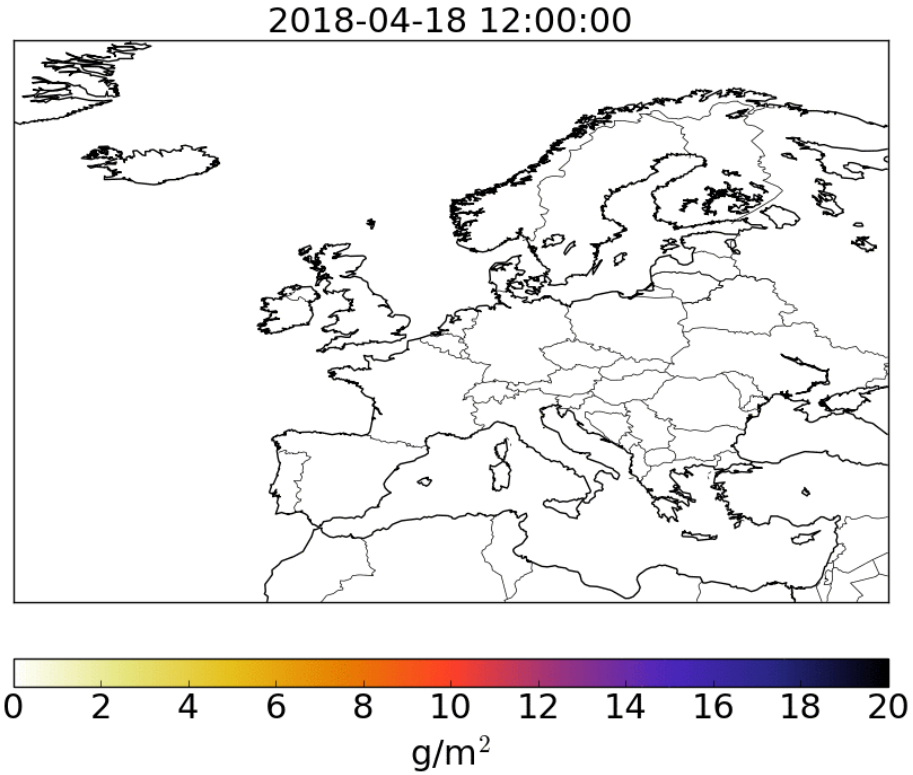
EUNADICS-AV exercise: volcano and nuclear



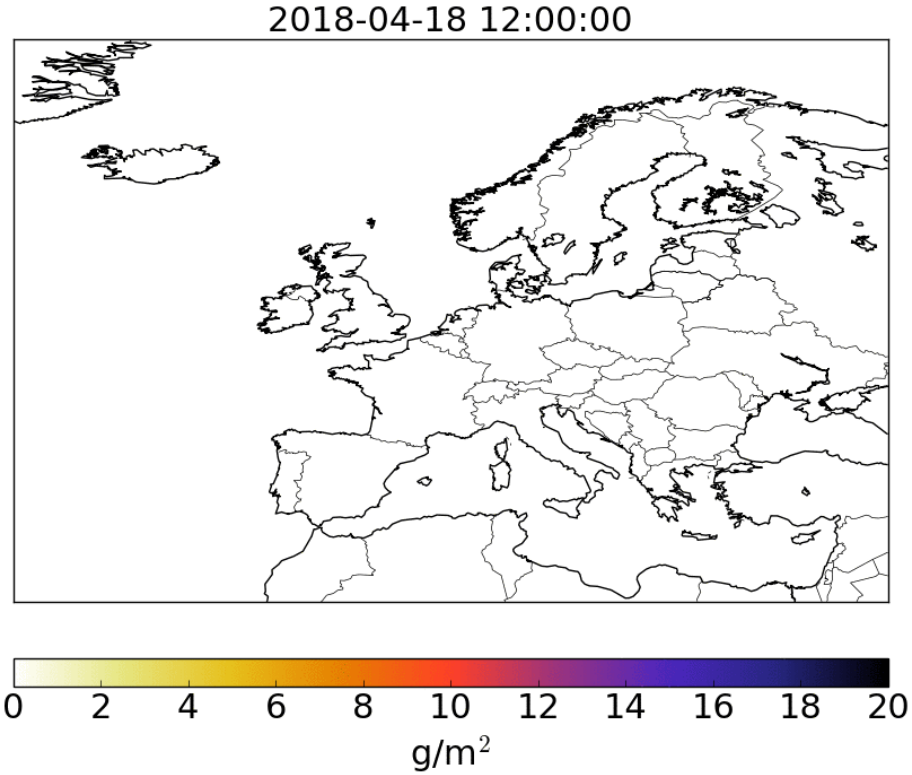
XE-133	X	X		X		3

Ash load, full period, with assimilation

25th percentile

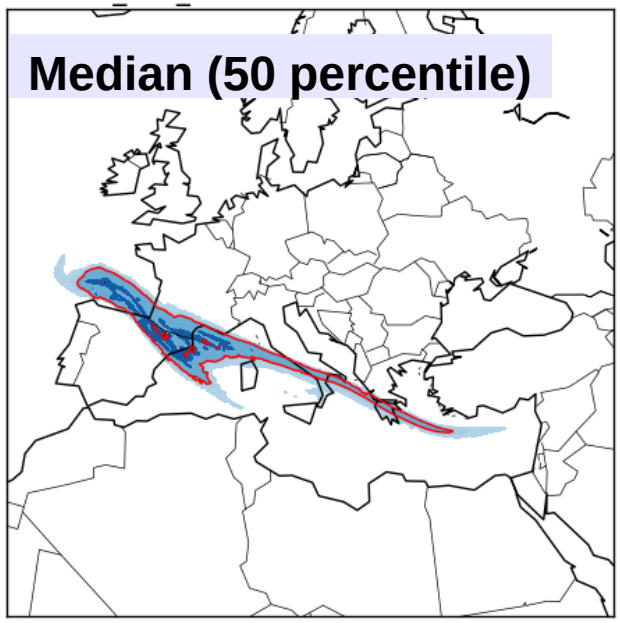


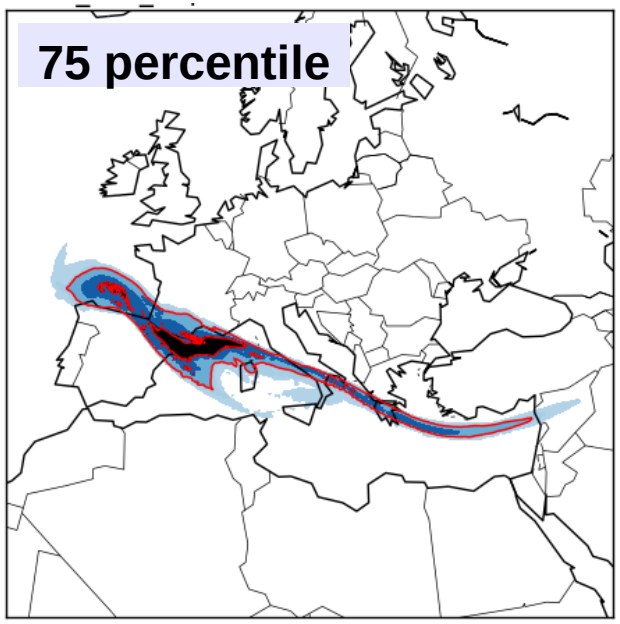
75th percentile

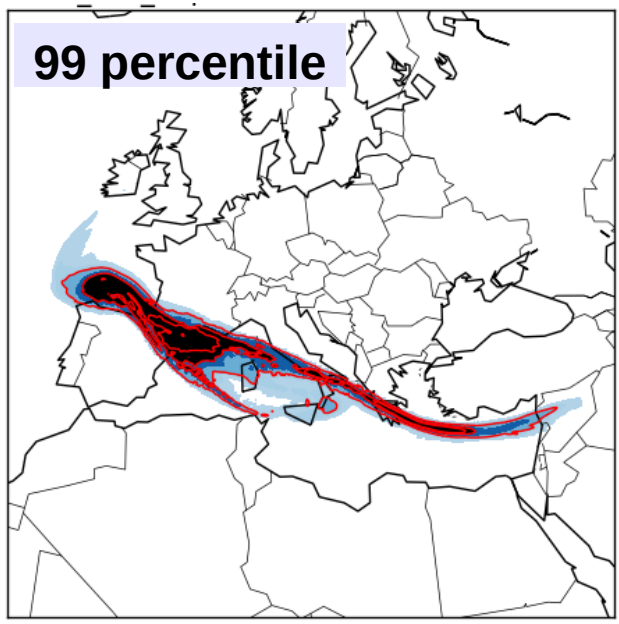


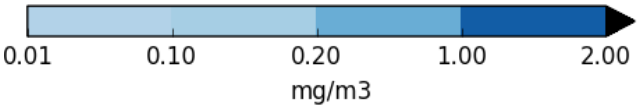
Etna case: results

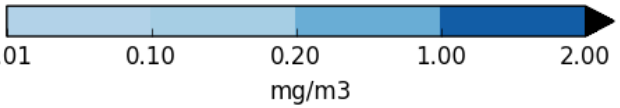
FL425 – volcanic ash

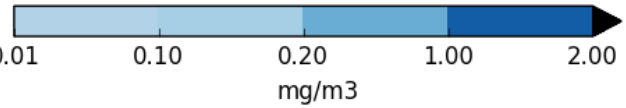












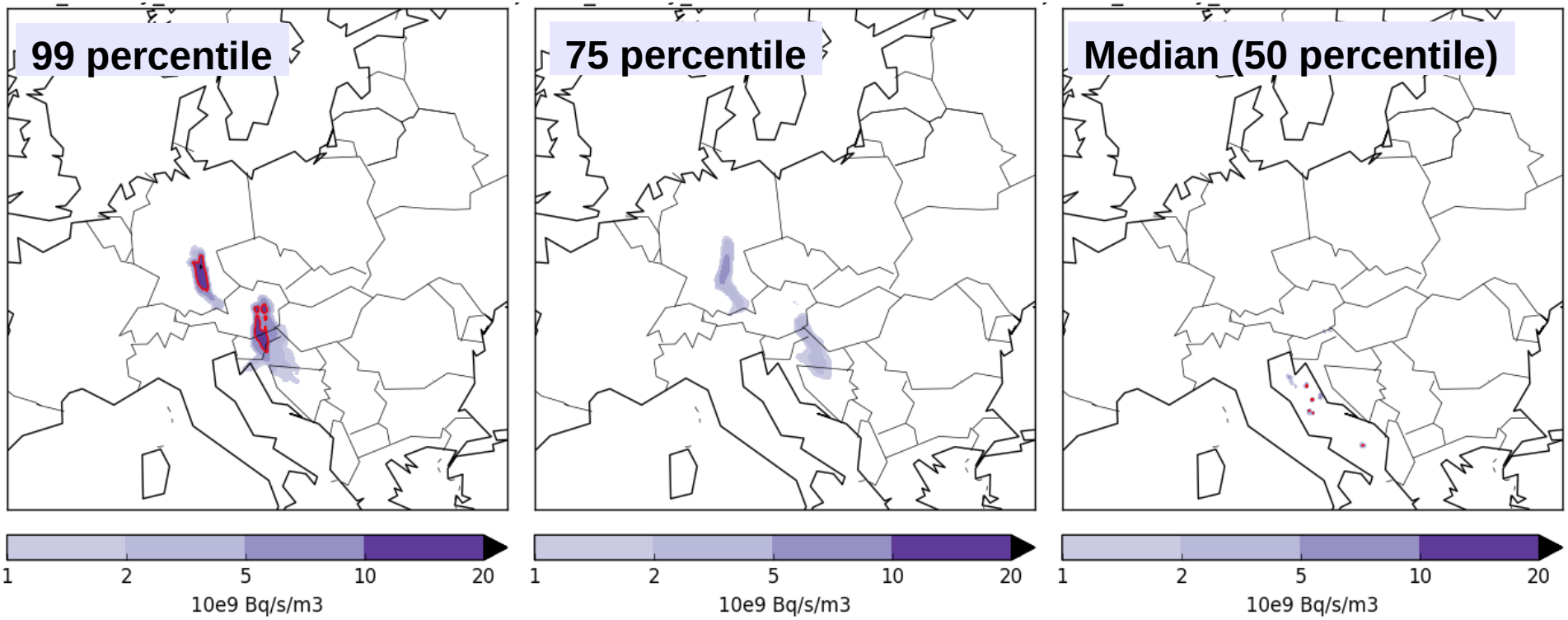
A “central scenario”

Uncertainty depends on the difference with median

The “worst-case” scenario

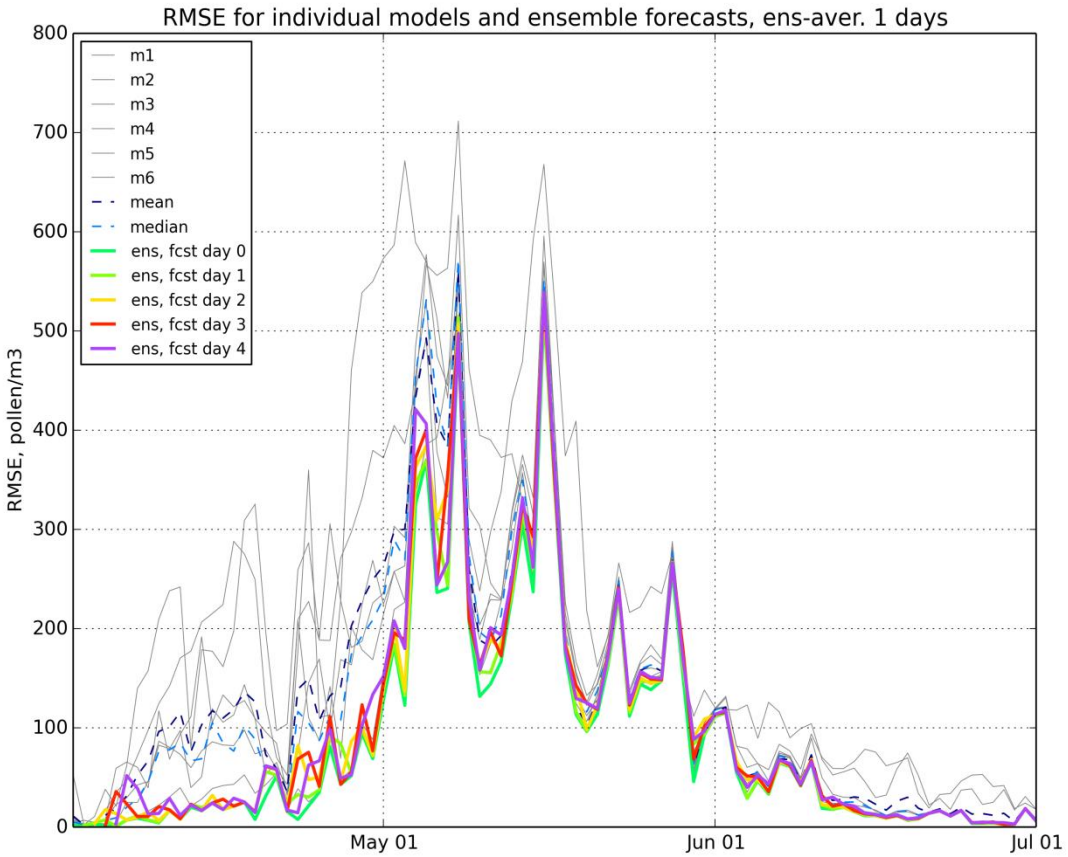
Nuclear case: results

FL25 – Activity concentration



Use of the ensemble: future…

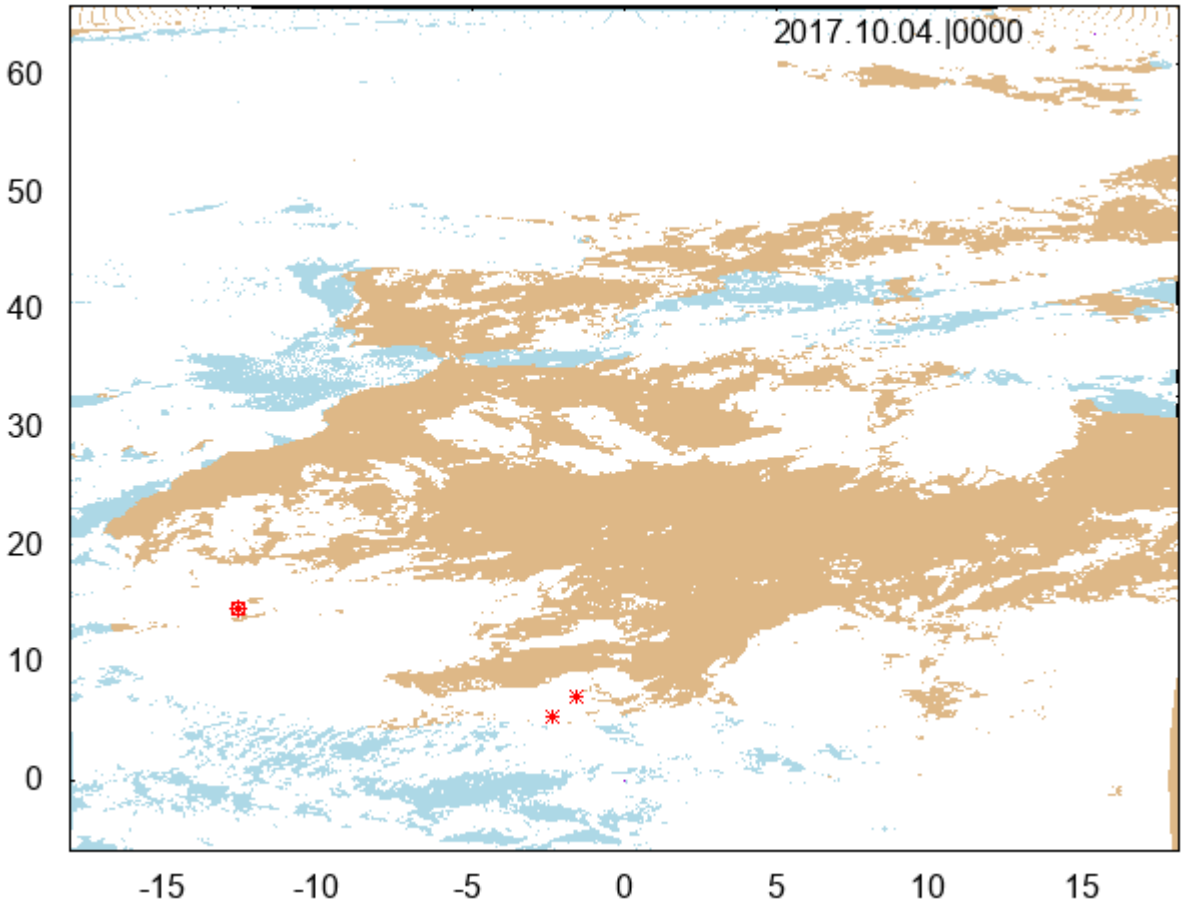
Error of the **fusion ensemble**
(thick coloured lines)
vs
individual models
(thin grey lines)
and
mean/median ensemble
(thick dashed lines)



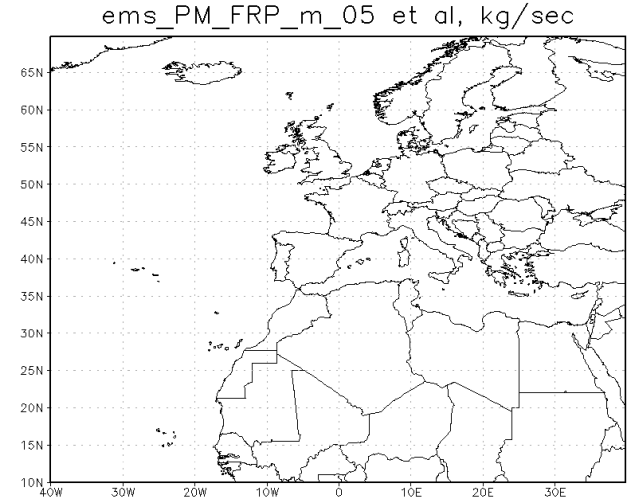
More: (Sofiev et al, ACP, 2017)

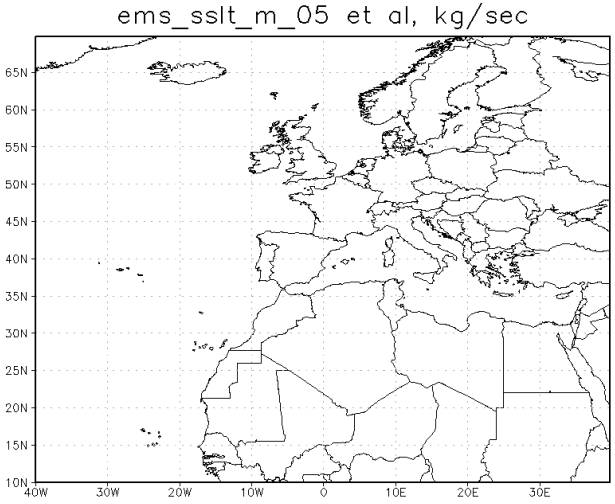
Ophelia case study: October 2017

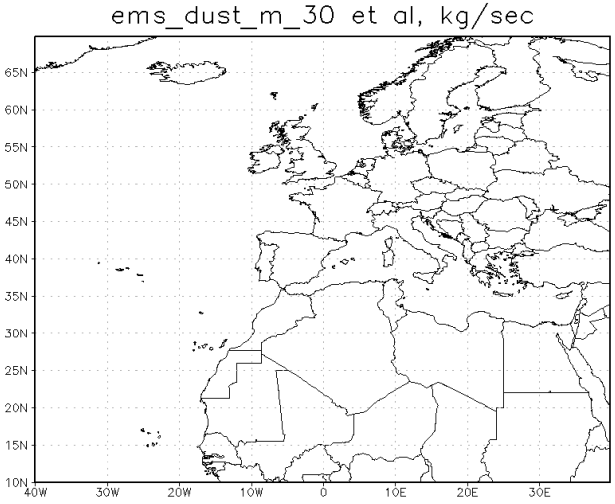
An event that brought together two of EUNADICS-AV hazards: desert dust and fire smoke

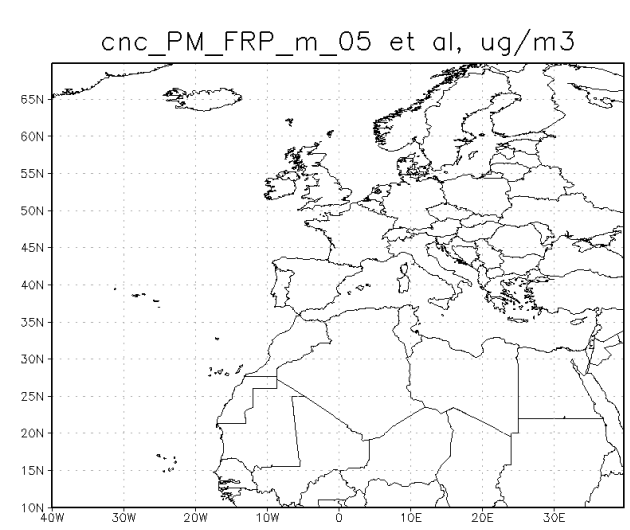


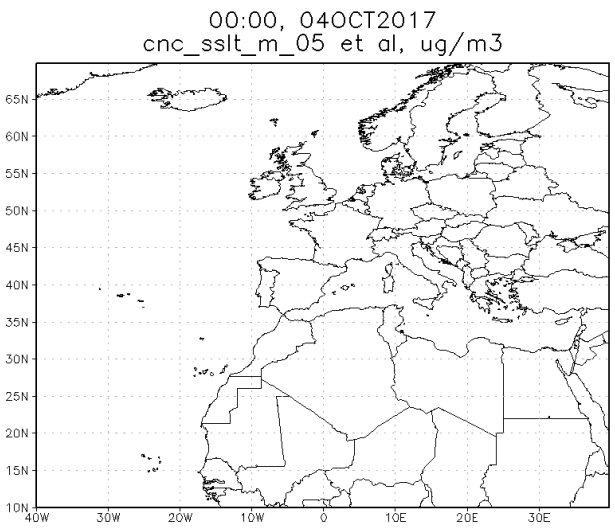
Development of the case: dust, fires, sea salt

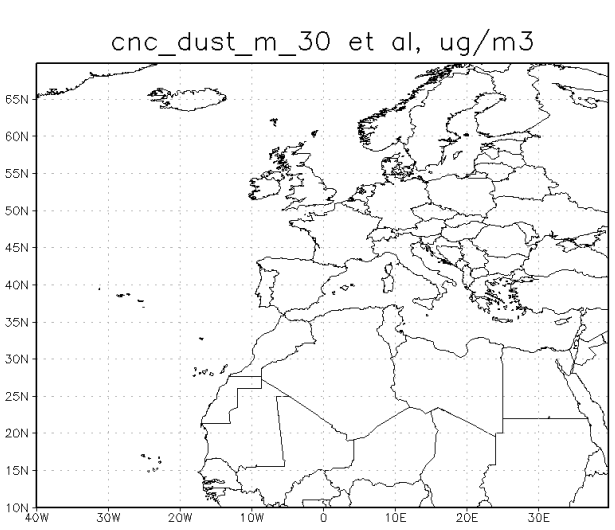












Ophelia case: invitation to a dance

- EUNADICS-AV is studying the case with its technology, source terms, assimilation, etc.
- collaboration with other dust- and fire- modelling groups is highly appreciated
- COST inDust community is invited to contribute to the exercise
  - details can be discussed to make contributions easy for the collaborators

Air traffic simulations during hazardous events

Barbara Scherllin-Pirscher and the EUNADICS-AV team

14 March 2019
inDust User Workshop on Dust Products for Aviation

www.eunadics.eu

The EUNADICS-AV project has received funding from the European Union's Horizon 2020 research programme for Societal challenges - smart, green and integrated transport under grant agreement no. 723986.

Project MET4LOWW

Low visibility has a big impact on airport capacity

Source: https://www.ndtv.com/offbeat/watch-runway-barely-visible-pilot-lands-plane-during-sandstorm-in-saudi-arabia-1844227

Low Visibility Procedures (LVP)

LVP state	RVR	Ceiling	Spacing	Capacity
normal			2.5 NM	>40
LVP	< 600 m	BKN<200 ft	4.0 NM	25
LVP CAT III	< 350 m		6.0 NM	18

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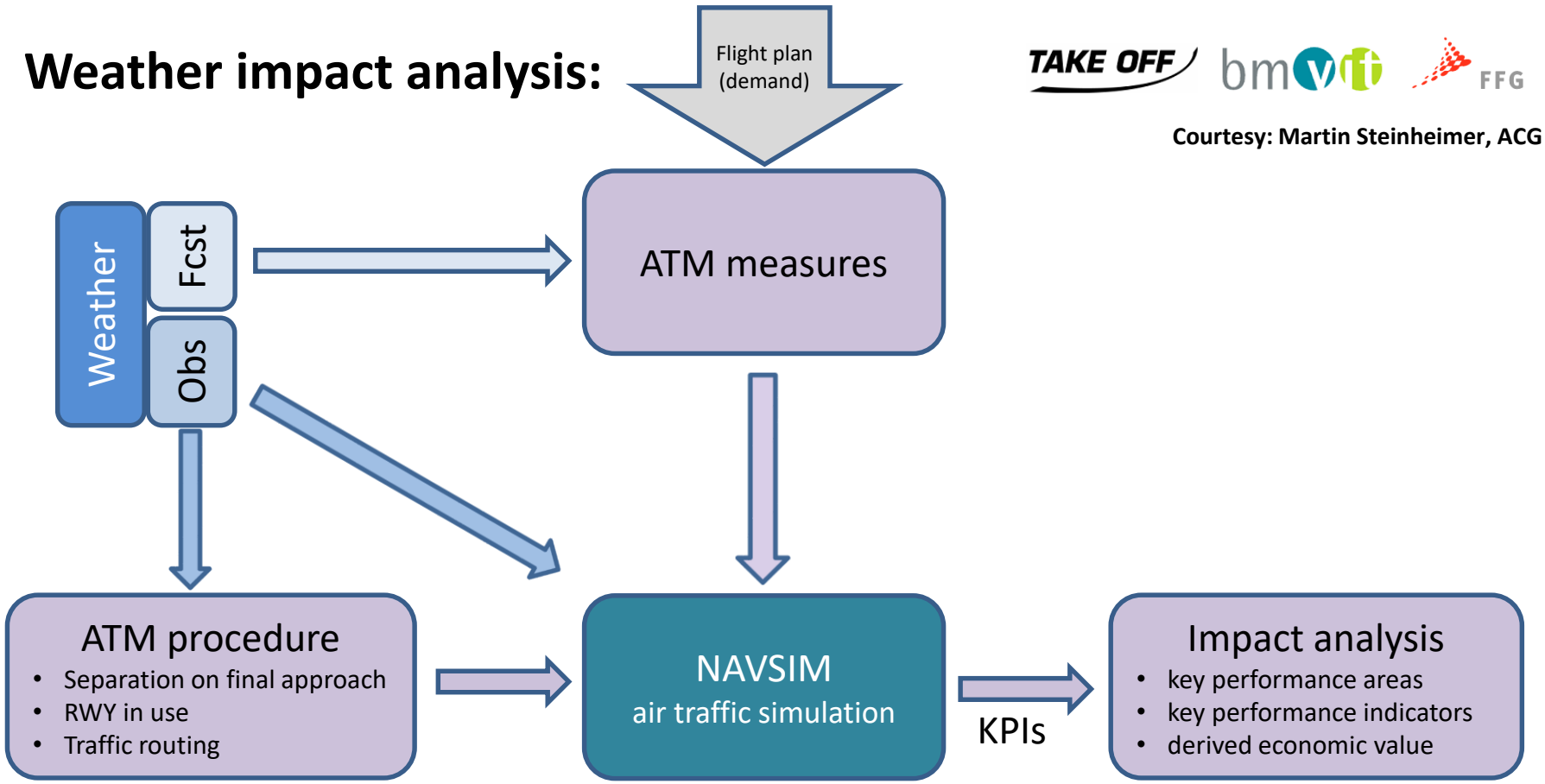
Weather impact analysis:



Courtesy: Martin Steinheimer, ACG

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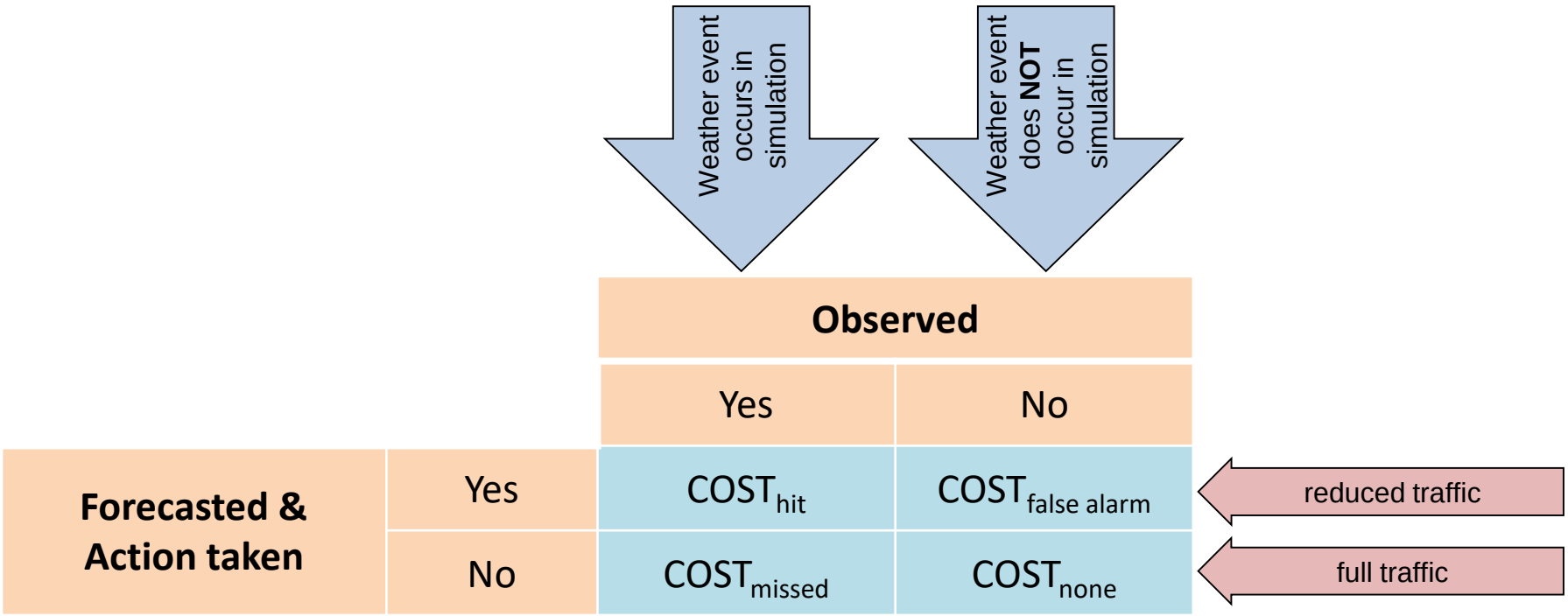
Cost matrix:

based on air traffic simulations

Courtesy: Martin Steinheimer, ACG



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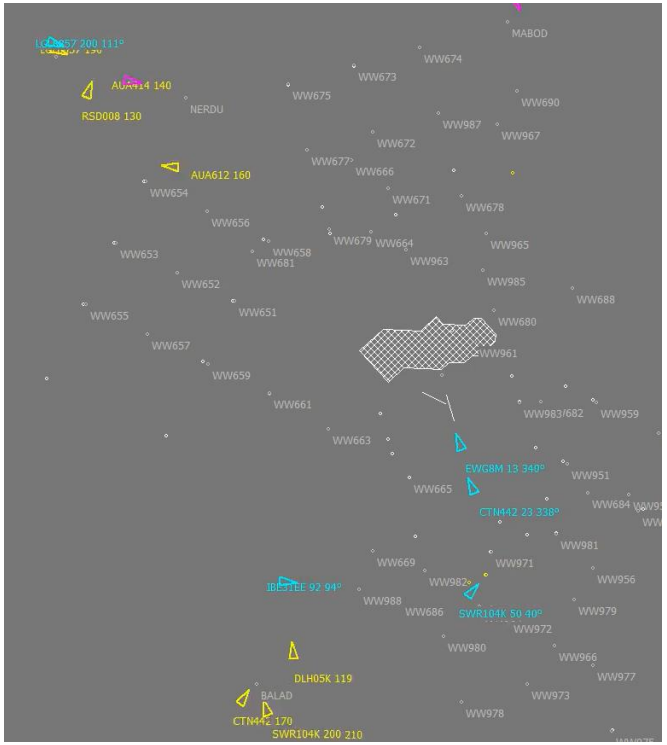
NAVSIM: air traffic simulation

- More than 100000 aircraft can be simulated simultaneously
- Simulation is initialized with traffic at endpoints of standard arrival route
- Weather is realistically considered



Source: Carl-Herbert Rokitansky

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Project MET4LOWW

Evaluation

Courtesy: Martin Steinheimer, ACG

- Key Performance Areas: KPA
  - Capacity, environmental impact/flight efficiency, cost effectiveness, traffic complexity
- Key Performance Indicators: KPI
  - Must be specific, measureable, proper with regard to weather forecast,…
  - Trackmiles, holding time, delay,…

Better weather forecasts increases air traffic efficiency and safety

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EUNADICS-AV

Thank you for your attention!

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