Automised evaluation of volcanic source terms (ash and SO_2) from inverse modelling for aviation

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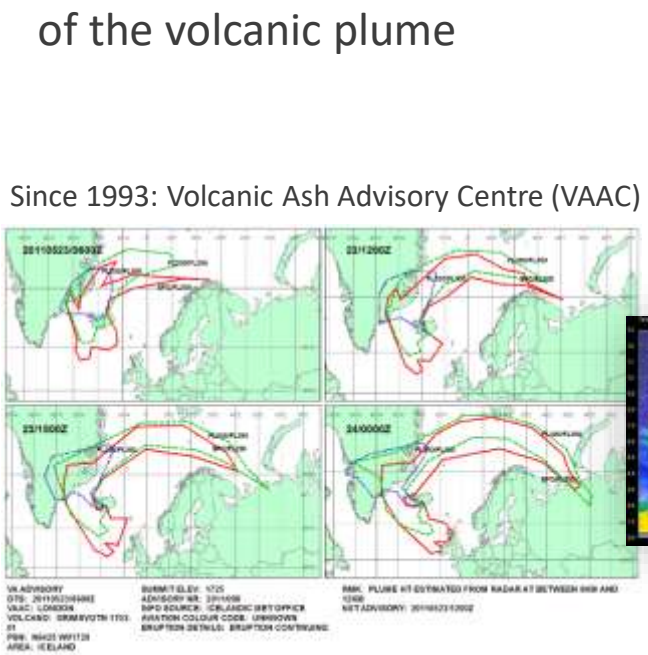
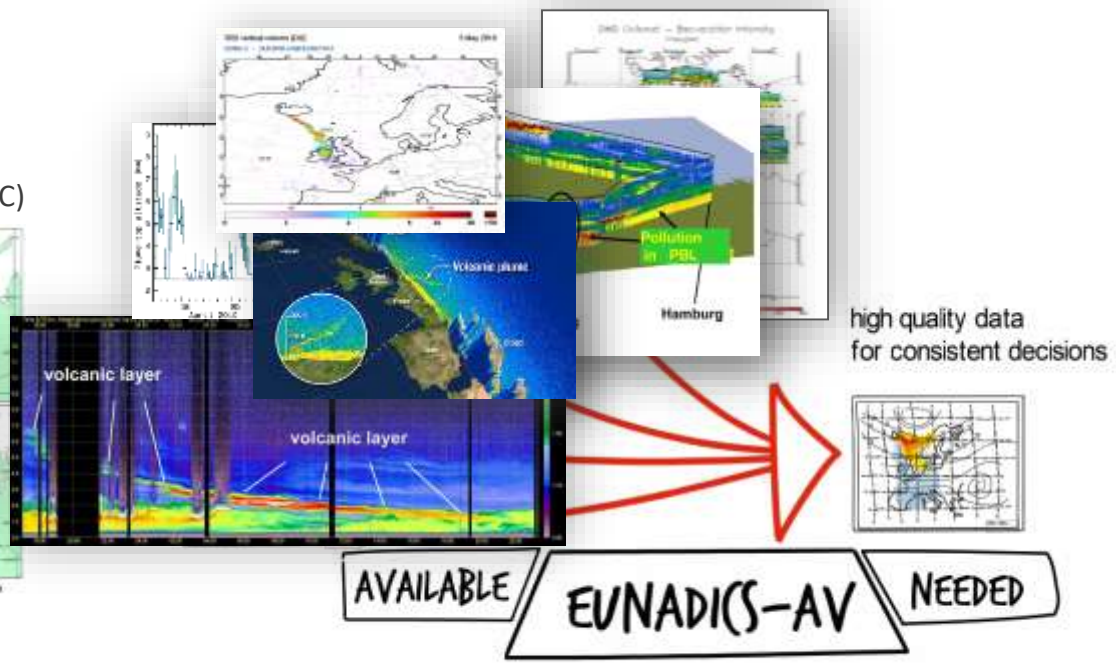
Introduction

- Eyjafjallajökull (2010) and Grimsvötn eruptions (2011) disturbed the air traffic
- Since then international scientific projects to improve information on dispersion of the volcanic plume

Since 1993: Volcanic Ash Advisory Centre (VAAC)



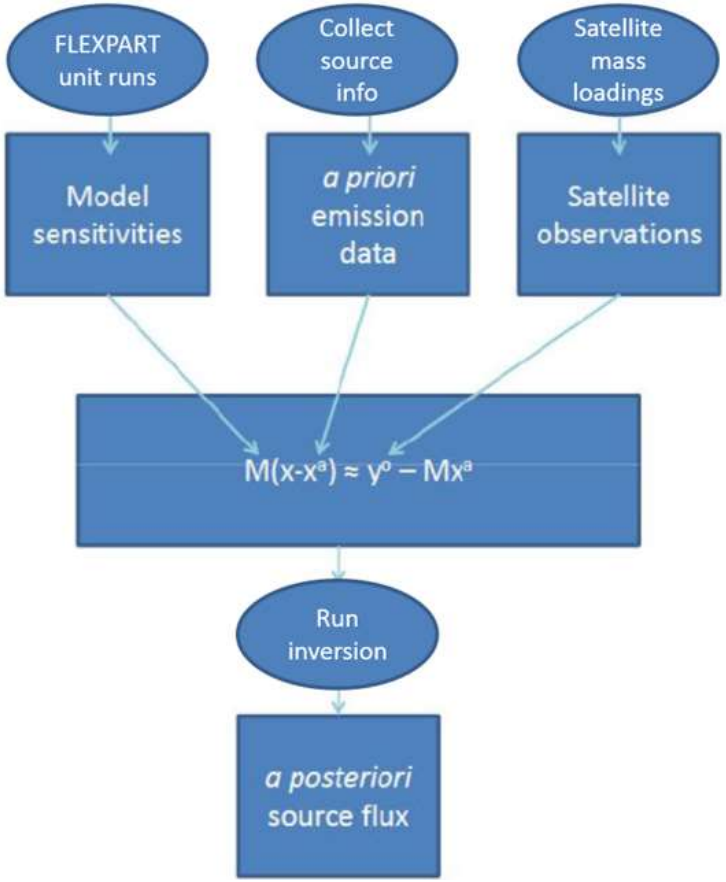


European Natural Disaster Coordination and Information System for Aviation

The project EUNADICS-AV (2016-2019): develop and test a unique system that helps to provide consistent and coherent information to aviation authorities, airlines and pilots in the event of a natural disaster affecting the airspace, which, if successful, would greatly enhance the resilience of one of the most critical infrastructures of the 21st century.

Background on source terms: VAST ad-hoc routines

Volcanic Ash Strategic initiative Team (ESA project 2012 - 2015)



Inversion code estimates emission (x) by making the model match the observations (minimising the differences):
M = model sensitivities
x^a = a priori
y^o = sat obs

Adapted from: Kristiansen, N. I., Arnold, D., Stohl, A, VAST Technical Report: Procedures for volcano inversions using FLEXPART, 2015

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EUNADICS-AV: summarized improvements

H2020 EUNADICS (2016-2019) - Summary of major improvements :

- Parallelized FLEXPART unit runs → *From serial to parallel*
- Run specifications → *From hard-coded to user input list*
- Volcano parameters → *From user input to retrieval from internal ZAMG database*
- *A priori* source term input parameters → *From user input to retrieval from internal ZAMG database*
- Summing, matching and inversion (tuning) parameters → *From hard-coded files to user input list + automised generation of these parameter files*
- Run FLEXPART with *a posteriori* source term → automised visualisation
- Coupling with HAZARD webtool → ST: yes; inversion routines: in progress
- WORK IN PROGRESS: AUTOMISED EVALUATION

ZAMG HAZARD webtool

ZAMG HAZARD WEBTOOL (User input)

ZAMG Vulkanasche Berechnung

1. Usereingaben | 2. Vulkanasche | 3. Ausbruchsdaten | 4. Zusammenfassung | 5. Bestätigung

Vulkanname	Grimsvötn Global Volcanism Program						
Längengrad	-17.333°						
Breitengrad	64.417°						
Gipfelhöhe	1.725m						
Flugflächen	FL050, FL100, FL150, FL200, FL250, FL300, FL350, FL400, FL450, FL500, FL550, FL600, FL650						
Ergebnisbilder		Breitengrad		Längengrad		Auflösung	Projektion
	Ganze Welt	-90°	90°	-180°	180°	1°	Zylindrisch
	Europa	25°	70°	-25°	45°	5°	Lambert
	Lokal	40°	85°	-50°	20°	5°	Lambert
	Individuell	40 °	85 °	-50 °	20 °	5 °	Zylindrisch
Anzahl der Flexpart Levels	40						
Meter pro Flexpart Level	500						
Simulation-Anfang	21 . 05 . 2011 12 Format: TT.MM.JJJJ HH Runde ab zu den letzten 3 Stunden, UTC						
Simulation-Ende	25 . 05 . 2011 00 Format: TT.MM.JJJJ HH Runde auf zu den nächsten 3 Stunden, UTC						
Feinasche-Anteil	5%						
Flexpart-Version	ECMWF 0.2 Europa						
Ausbruchsform	Linear	Pilzwolke	Gauss Verteilung				
Species	Feinasche	SO_2	EUNADICS TRACER				
Ensemble	Ja	Nein					
Cluster	Ja	Nein					
Farbskala	VAST+ACG	VAST	ACG				

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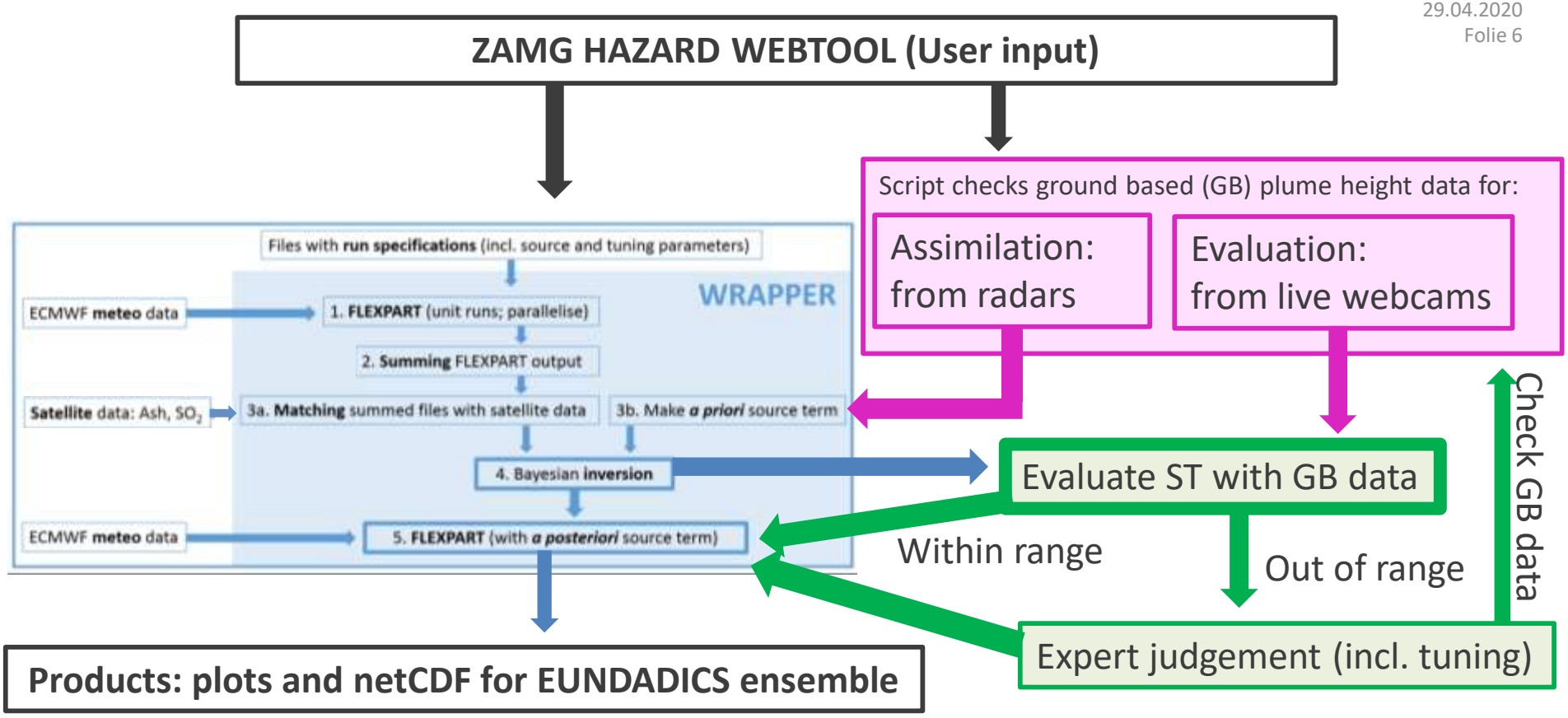
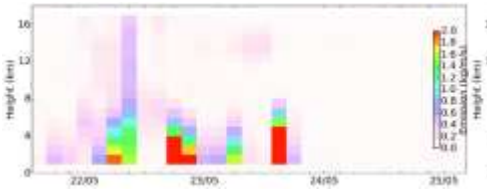
Methods: evaluation of vertical distribution of ash at source location

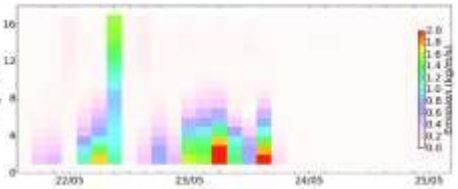


Methods: sensitivity tests (incl. tuning)

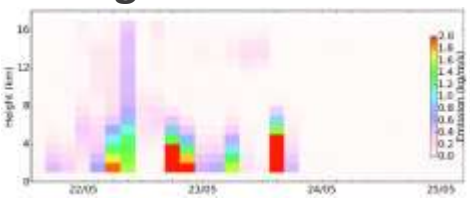
1. Reference



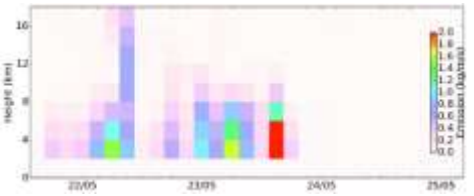
2. Bin sizes 4 → 9



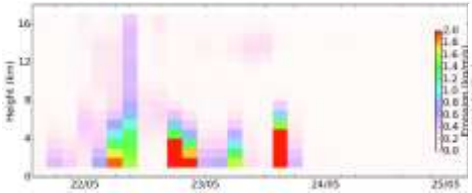
3. Longer ash life time



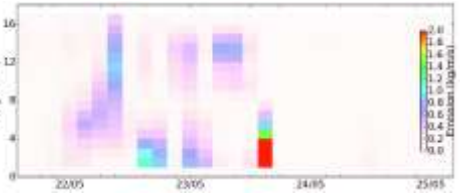
4. Halved vertical levels



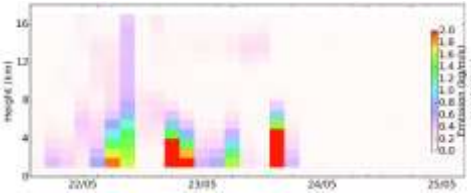
5. ECMWF vent height



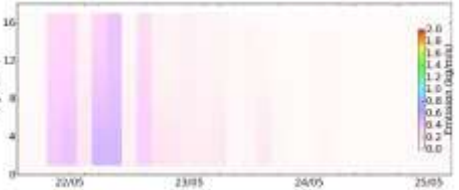
6. Meteo 0.5° → 1.0°



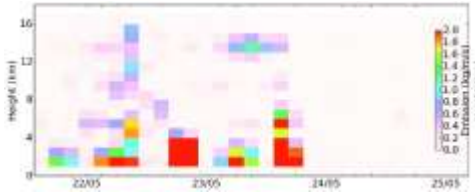
7. Particles/10



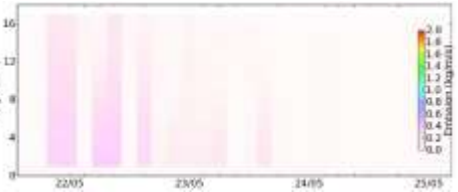
8. *A priori*: more weight



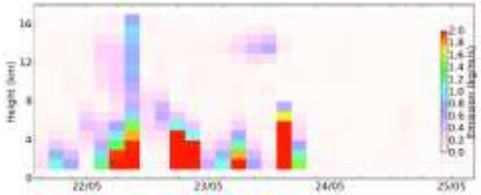
9. *A priori*: less weight



10. Model: less weight



11. Model: more weight



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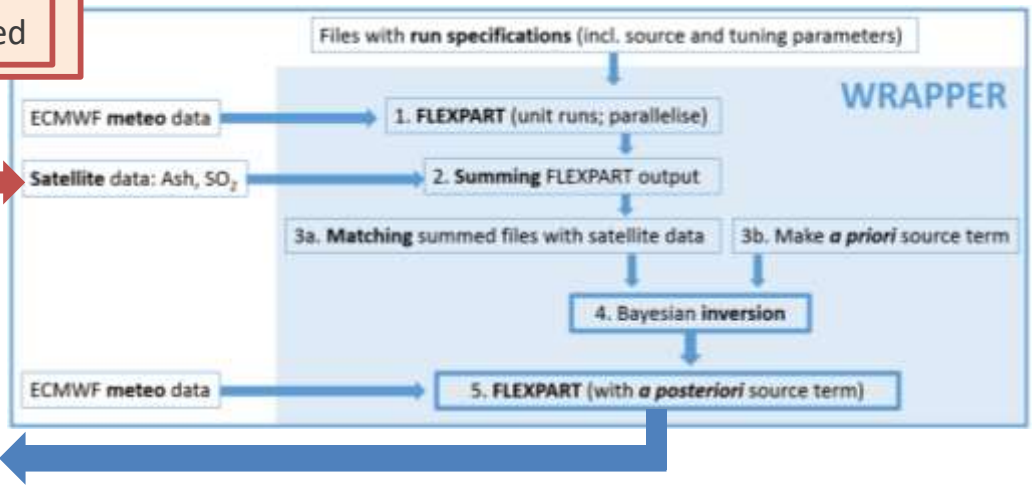
Methods: evaluation of horizontal distribution of ash

ZAMG HAZARD WEBTOOL (User input)

Script checks for satellite data (EUNADICS portal) for:

- Evaluation (currently SEVIRI) → re-grid + time averaged
- Assimilation (currently IASI) → re-grid + time averaged



Evaluate FLEXPART output with satellite data

Out of range

Within range

Check satellite data

Expert judgement (incl. tuning)

Products: plots and netCDF for EUNDADICS ensemble

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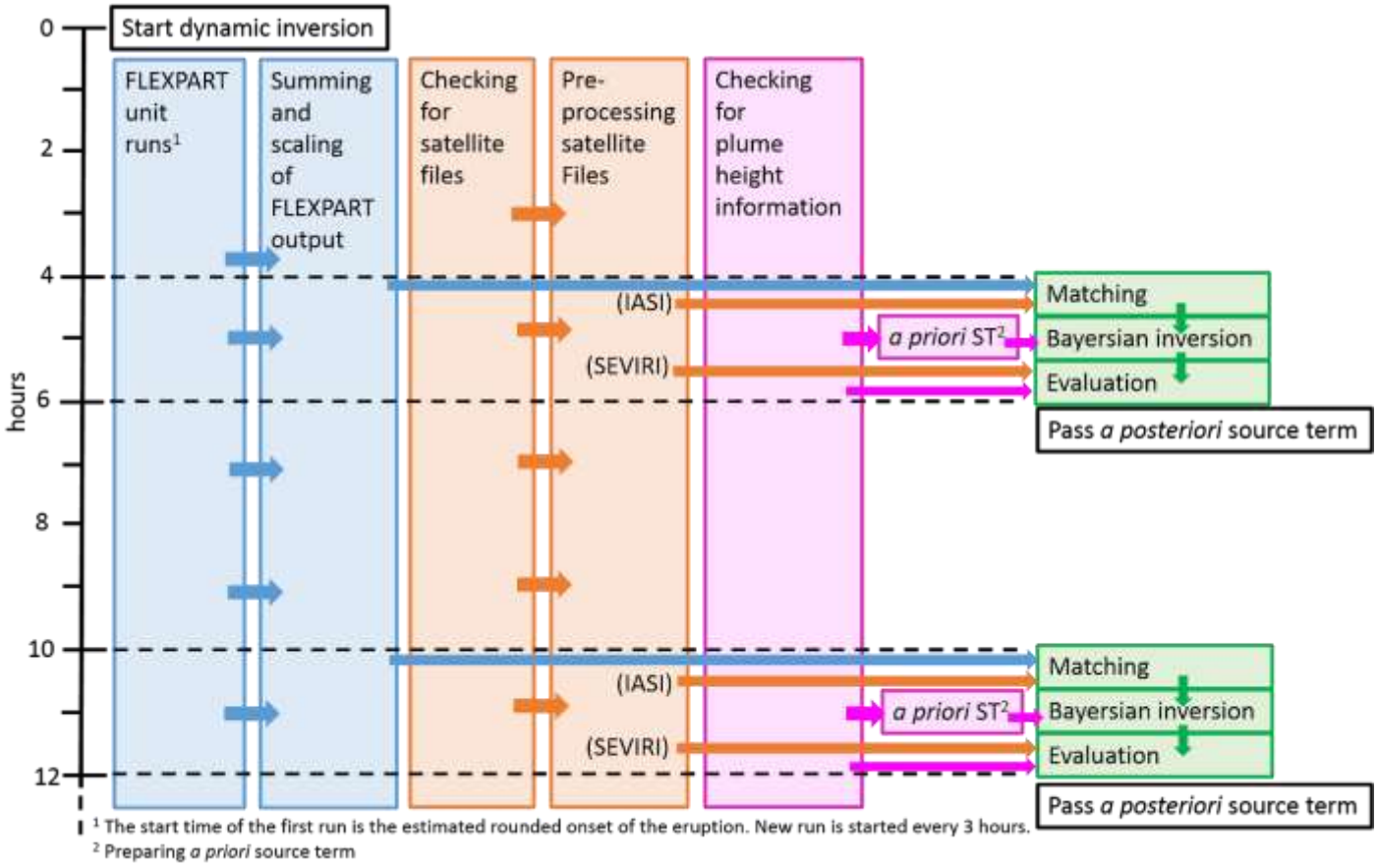
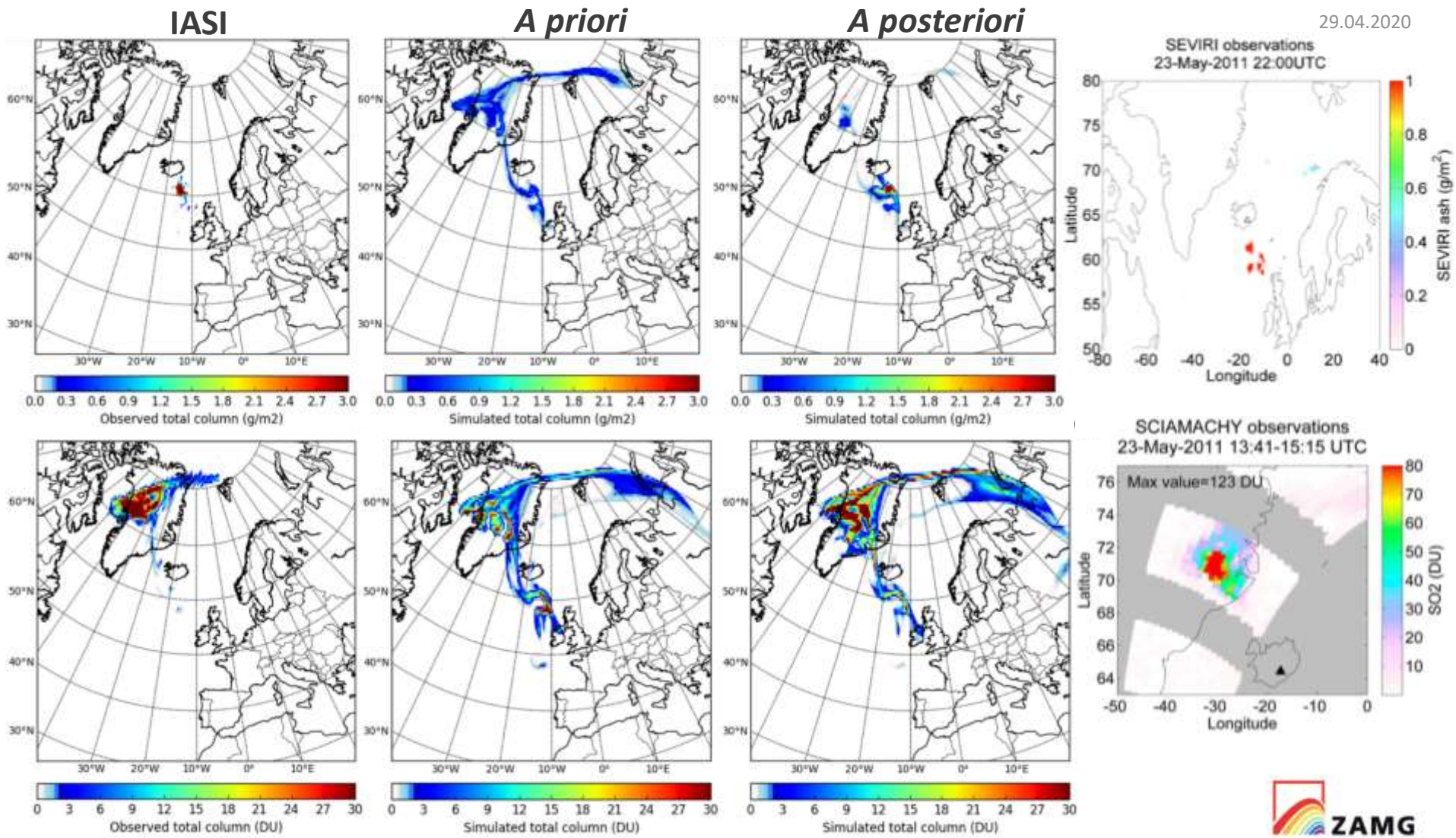
Design for operational set-up

From the start of the dynamic inversion, every 6 hours an *a posteriori* source term is passed on to the ZAMG hazard webtool and made available to EUNADICS modelling groups. [Test phase: IASI for inversion, SEVIRI for evaluation; later other way around]



Results for May 23, 22 UTC: IASI, a priori ST, a posteriori ST, SEVIRI



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Outlook

- Observations of volcanic ash + SO_2:
  - Include lidar and aircraft data
  - Also lidar data for evaluation
  - …
- Automise processing (re-grid and time average) of level 2 sat data
- Switch to FP10
- Decide which data to use for assimilation (in inversion) and which for evaluation
- Testing of evaluation criteria: time range (3 hr shift is acceptable, 6 hr discussable), spatial range

→ How to handle sensitivities in operational environment?

Expert judgements will always be needed !!

Thank you for your attention!

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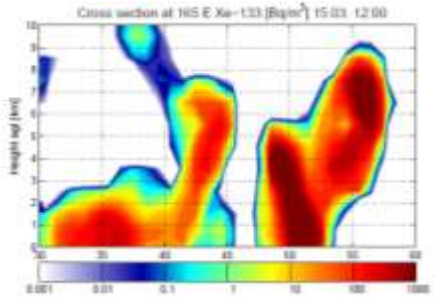
Methods: Why we use FLEXPART?

(**Flex**ible) Lagrangian **Part**icle Dispersion Model is:

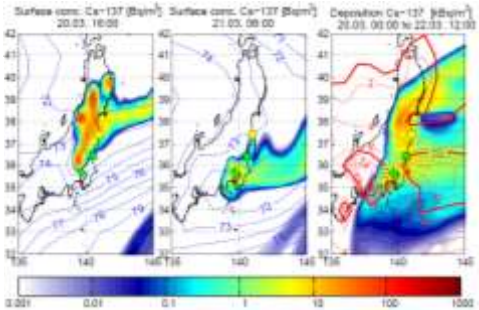
- Fast
- Parallelisation (with v9 trival, with v10 MPI)
- Extensively tested (see literature)
- Global developers community
- Suitable for operational usage
- And many more

Limitations:

- No ash aggregation -> underestimation
- Online chemistry only with climatological values

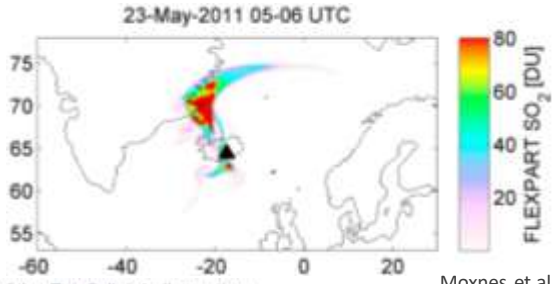


Stohl et al., 2012

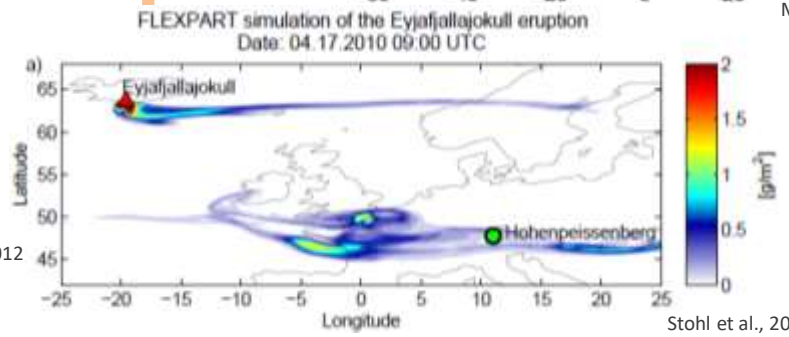


Stohl et al., 2012

Flexpart.eu



Moxnes et al., 2014



Stohl et al., 2011

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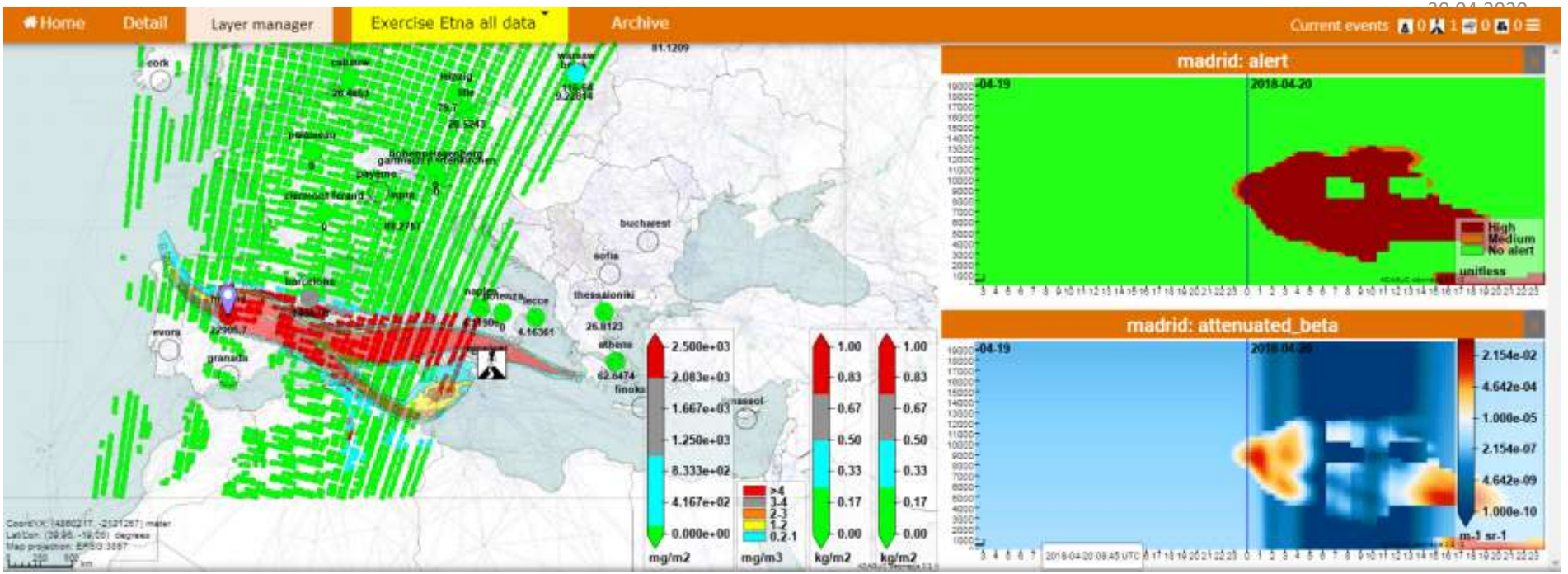
EUNADICS-AV portal



Project results and show cases of the data products are disseminated and exploited via the EUNADICS-AV portal. The products will be provided through stakeholder specific interfaces and as INSPIRE compliant web services. Specific target groups (aviation community, EACCC, intermediate users as VAACs) are addressed by different communication channels.

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Cost based avoidance

Example trajectories (red) for flight Paris – Athens, sorted by total cost:

A (blue) passes through low concentration
- lowest total cost

B (green) passes both low and medium
- lowest fuel/time cost

C (magenta) avoids contamination entirely
- lowest maintenance cost

Dose-based avoidance can be applied, offering more information and trajectory options to airlines.