FLEXPART for volcanic applications

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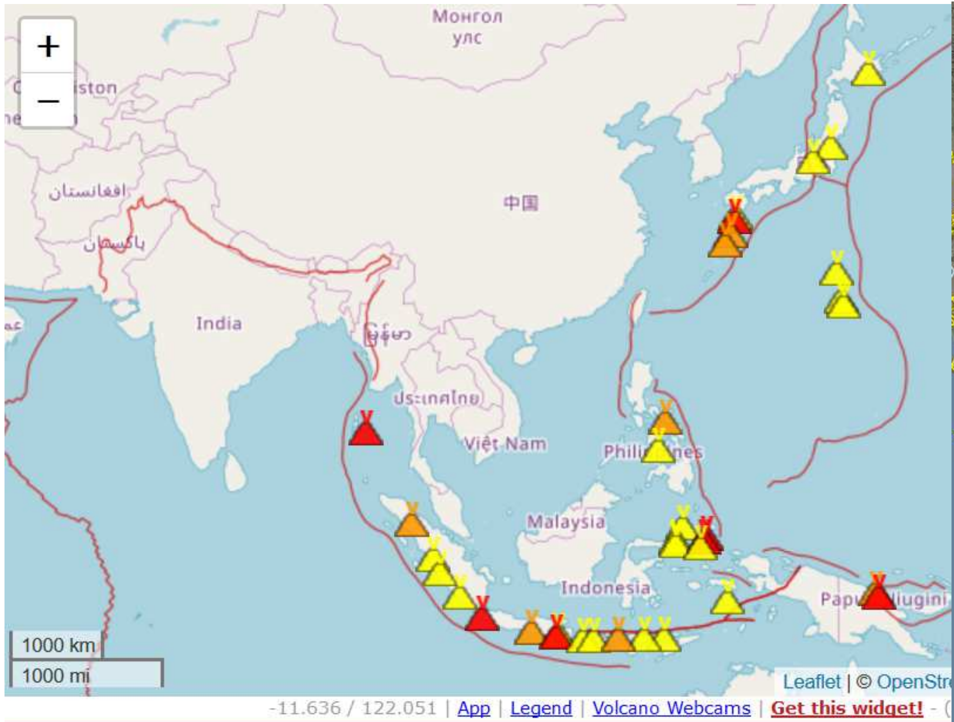
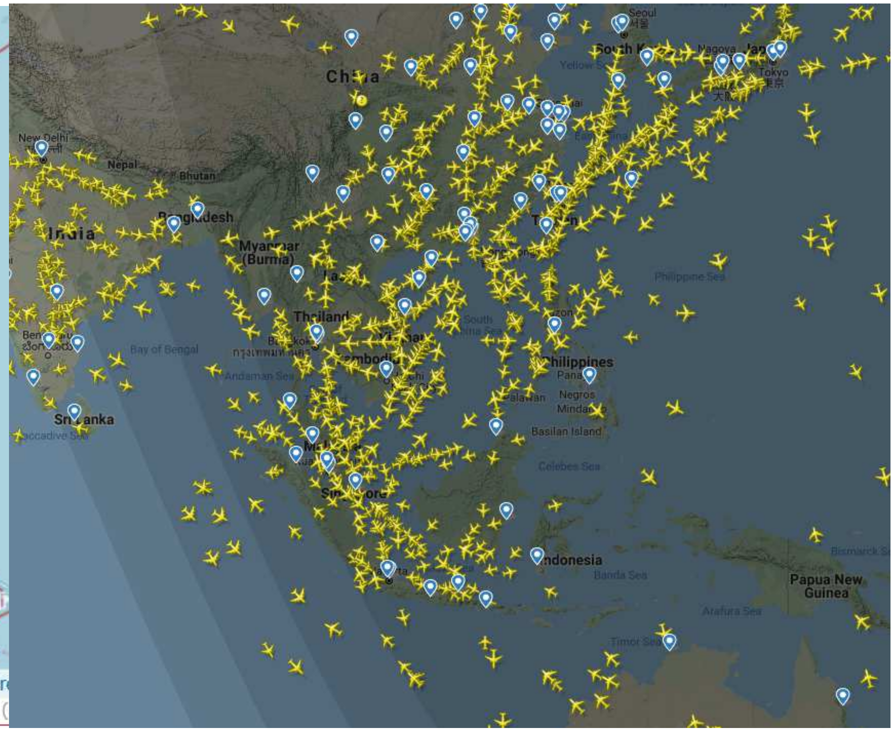
Introduction: are they important?

Flightradar information
12.12.2018 at 20:30 Local Time





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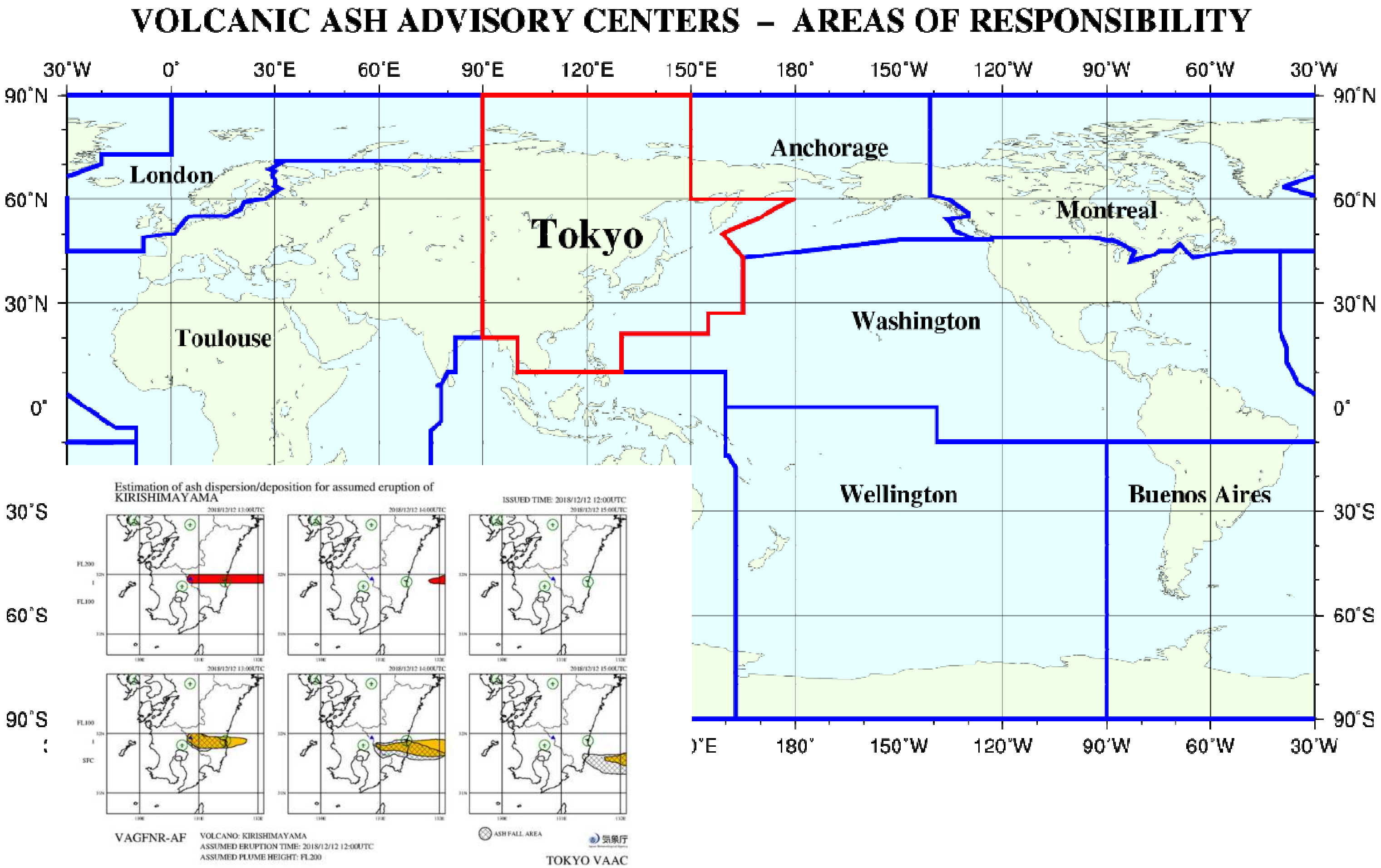
Introduction: VAACS



set up by the International Civil Aviation Organization (ICAO), an agency of the United Nations

Introduction: Involvement of scientific community - EUNADICS

Eyjafjallajökull eruption April – May 2010

Due to the eruption of the Eyjafjallajökull in 2010, **100 000 flights were cancelled** in total.

Grimsvotn remote sensing and flight data - can we use it in operational analyses?

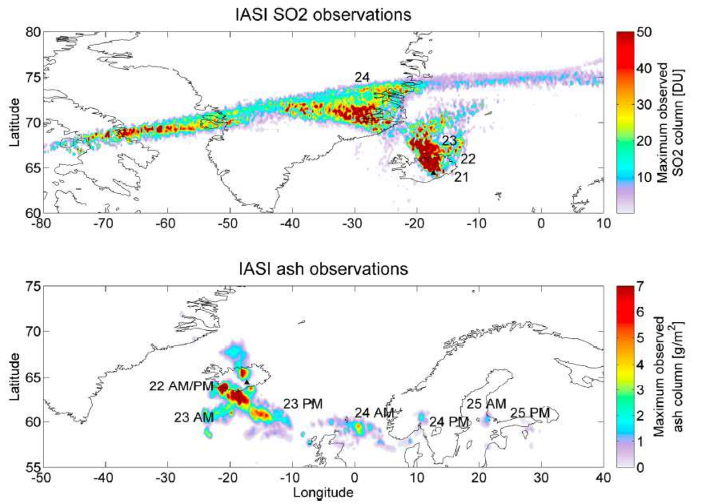
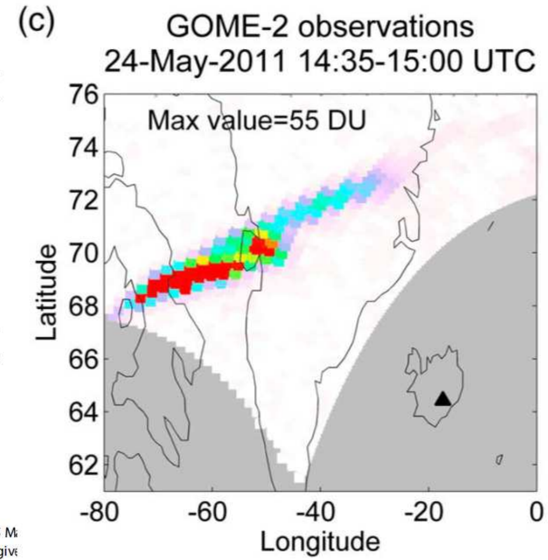
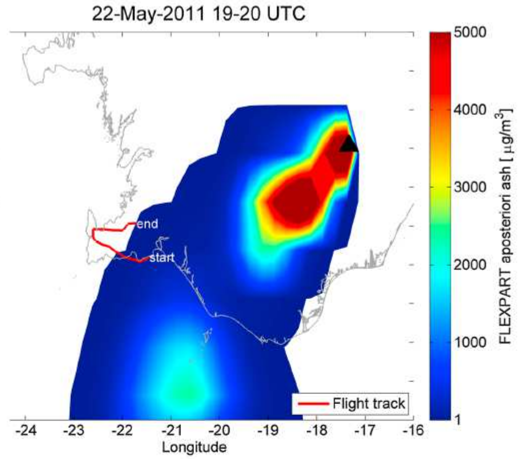
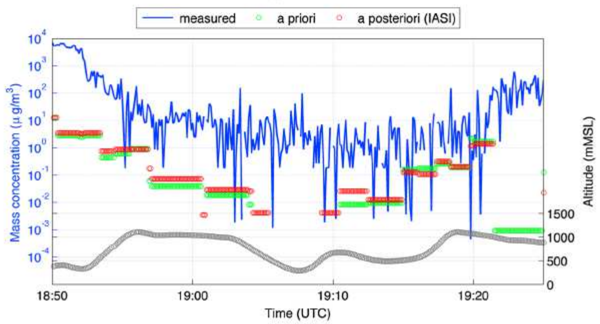
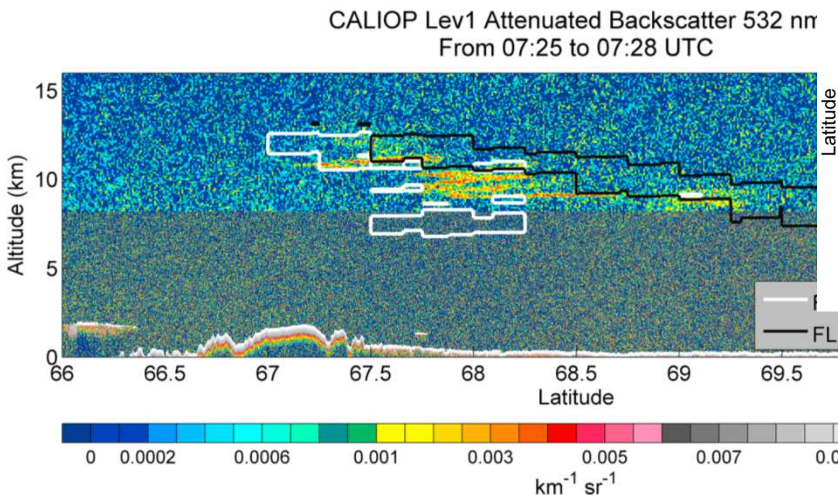


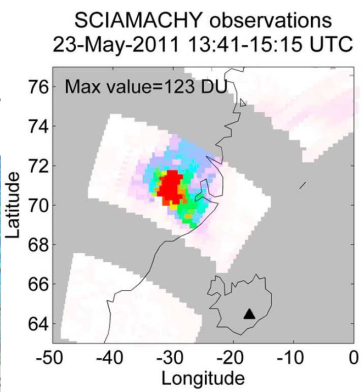
Figure 2. (top) SO_2 and (bottom) ash total columns retrieved from IASI between 21 and 24 May (SO_2) and 22 and 25 M (ash). The data are gridded and for each grid cell, the maximum of the values observed during all overpasses in the giv period is shown. Labels indicate the date when the individual maxima were observed.











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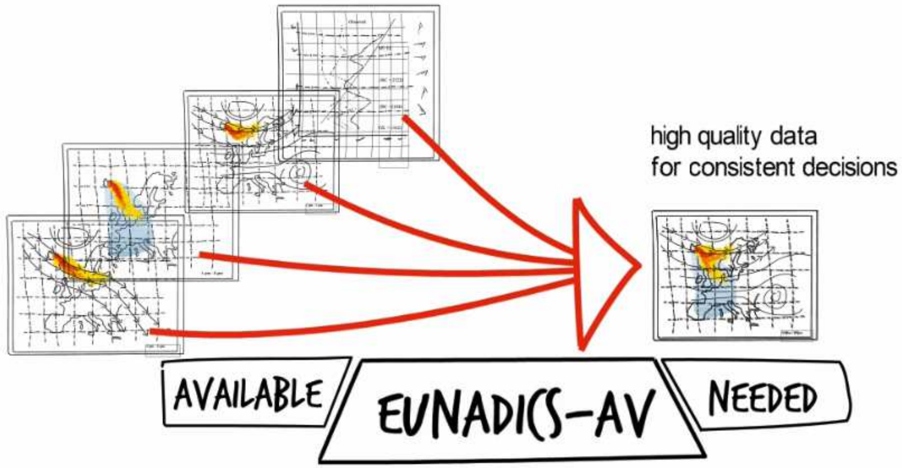
Introduction: EUNADICS



European Natural Disaster Coordination and Information System for Aviation

The project EUNADICS-AV undertakes to 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.

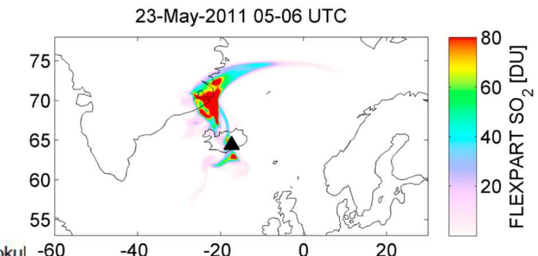
Introduction: Why we use FLEXPART?

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

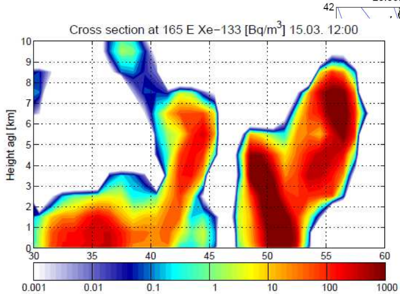
- Fast
- Parallelisation (with v9 trival, with v10 MPI)
- Extensively tested (see literature)
- Global developers community
- Suitable for operational usage
- And many more

Limitations:

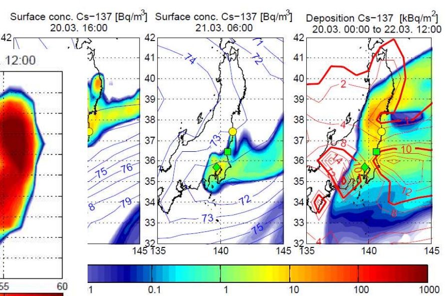
- No ash aggregation -> underestimation
- Online chemistry only with climatological values; v10: preprocessed from Eulerian model



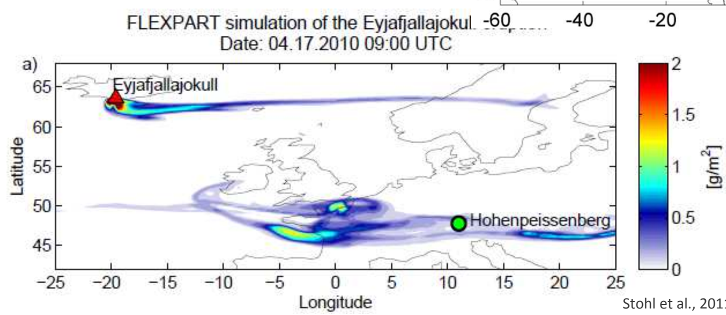
Moxnes et al., 2014



Stohl et al., 2012



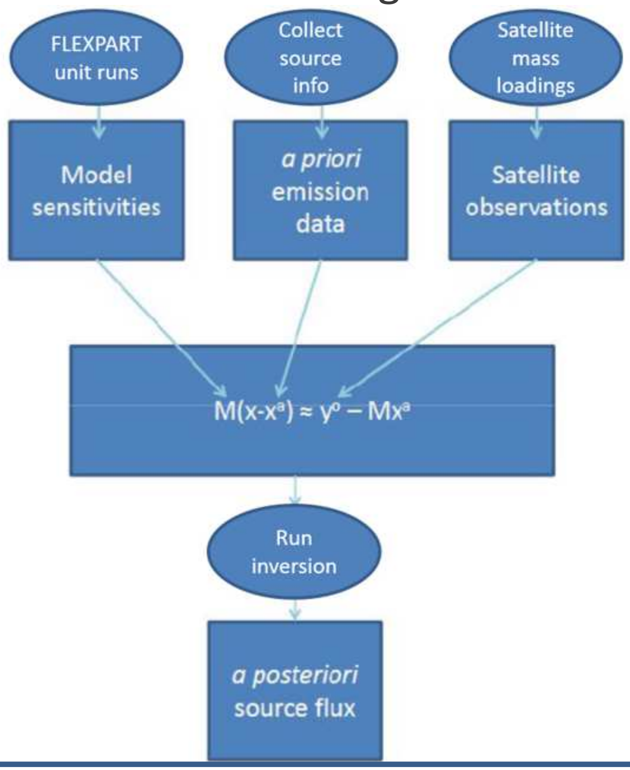
Stohl et al., 2012



Stohl et al., 2011

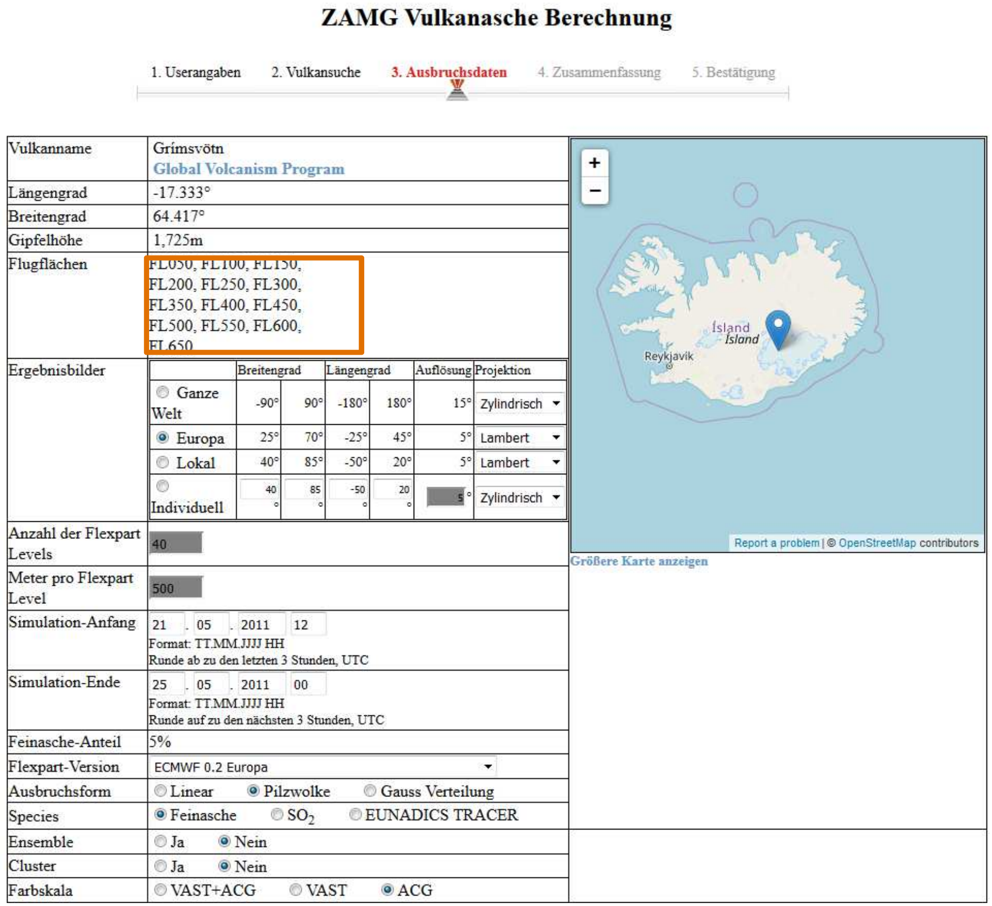
Methods: VAST ad-hoc routines + separate webtool

Volcanic Ash Strategic initiative Team (ESA project 2015-2018, vast.nilu.no)



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



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Methods: VAST ad-hoc routines + separate webtool

A PRIORI source term

What do we know?

- Location
- Plume height

What can we do:

- Mastin et al., 2009 formula
  - 34 eruptions
  - Best-fit line (bold solid line) with mass eruption rate $\dot{M}$ (kg/s) converted to volumetric flow rate $\dot{V}$(m3 DRE* per second):

    $$H = 2.00\ \dot{V}^{0.241}$$
- Or PLUMERIA or other plume models
- Estimate of size distribution

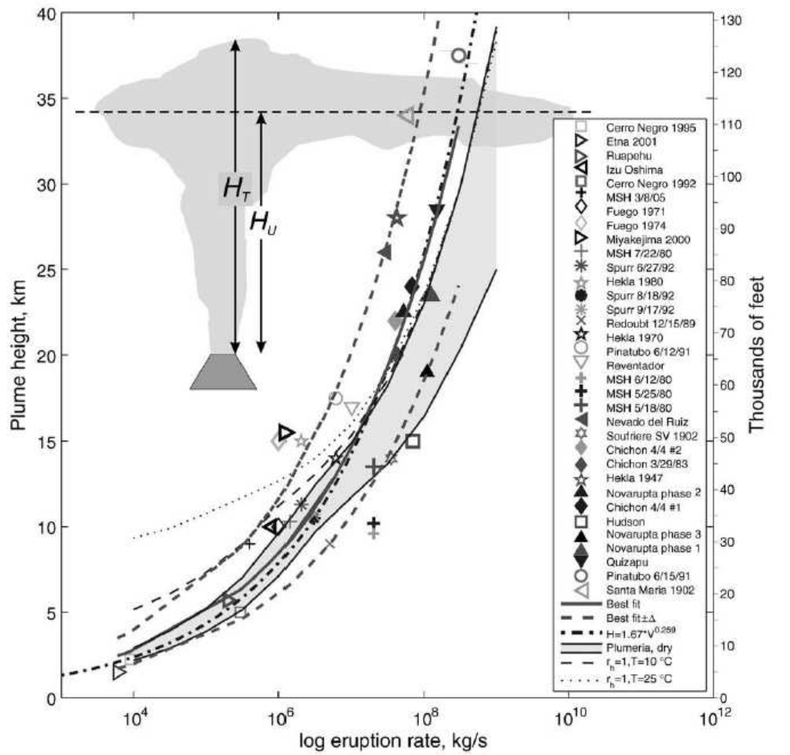
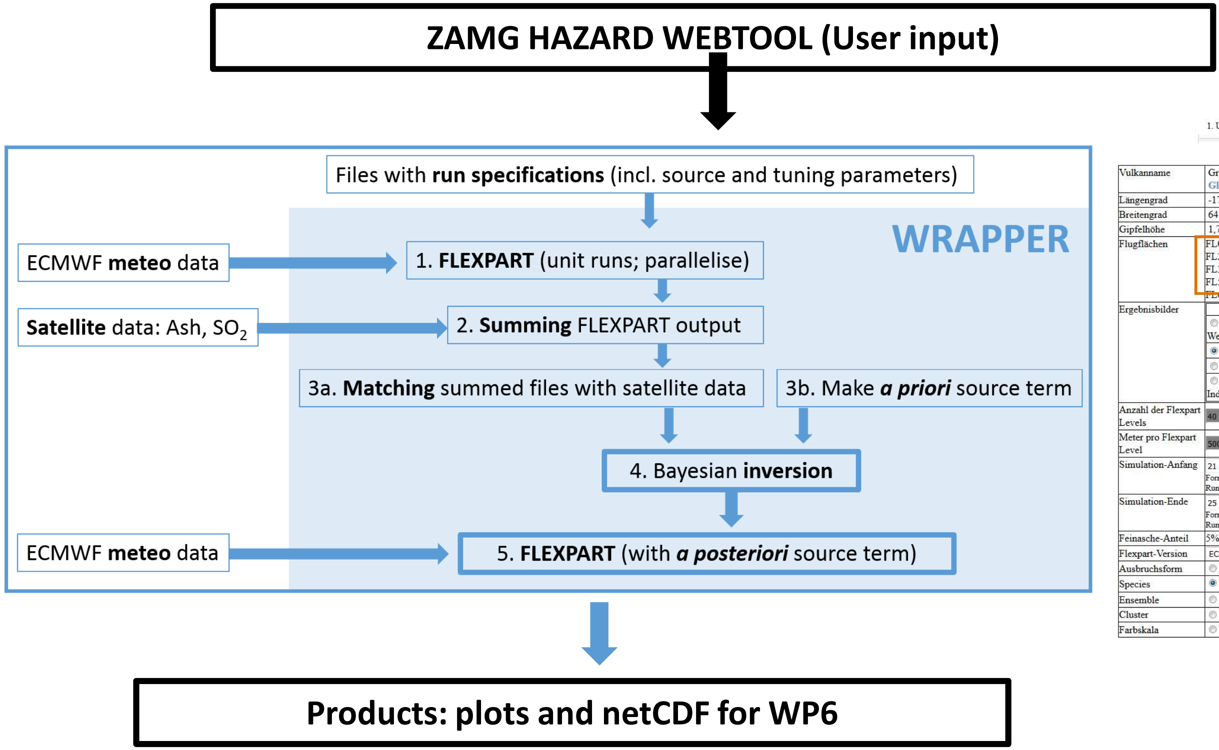


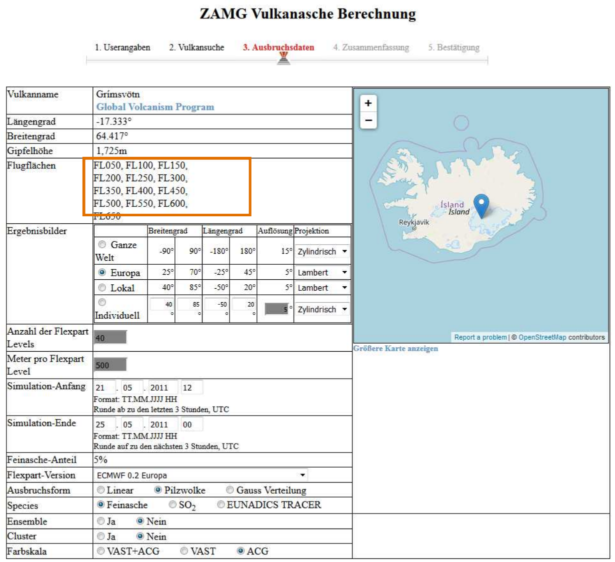
Fig. 1. Plume height above the vent versus mass eruption rate for eruptions listed in Table 1. Symbols for each eruption are given in the legend. The bold sol
the data (Eq. (1)). The bold dashed lines enclose the error envelope (±Δ)calculated by the routine polyval in Matlab® (use of trade names does not constit
products). The error envelope corresponds to a 50% confidence interval, meaning that future observations have at least a 50% probability of falling withi
dashed line is the empirical fit obtained by Sparks et al. (1997, Eq. 5.1). The upper light solid line is a theoretical curve of H_T calculated using the 1-D ste
(Mastin, 2007) using a magma temperature of 900 °C, 3 wt% gas, and a Standard dry atmosphere (United States Committee on Extension to the Standar
lower light solid curve is the elevation of neutral buoyancy, assumed to approximate H_u, calculated from the same model runs. The region between these
dashed light curve represents predictions of H_T by Plumeria using properties of a Standard atmosphere but with 100% relative humidity (r_h) and a temp
10 °C. The light dotted curve is a similar prediction using a relative humidity of 100% and a temperature at ground level of 25 °C. Symbols in the legend ar
highest eruption rate. The Abbreviation "MSH" is Mount St. Helens, "Soufrière SV" is Soufrière of St. Vincent. The figure inset illustrates the difference betwe
the plume (H_T) and the height of the umbrella cloud (H_U). The height H plotted includes both H_T and H_U depending on the method of estimation. Isopleth-ba
solid symbols, give umbrella-cloud height H_U whereas all other methods are thought to give H_T.

*Erupted volume V (dense-rock equivalent or DRE)

Mastin, L.G. et al., A multidisciplinary effort to assign realistic source parameters to models of volcanic ash-cloud transport and dispersion during eruptions, Journal of Volcanology and Geothermal Research (2009), doi:10.1016/j.jvolgeores.2009.01.008

Methods: VAST source term inversion at ZAMG





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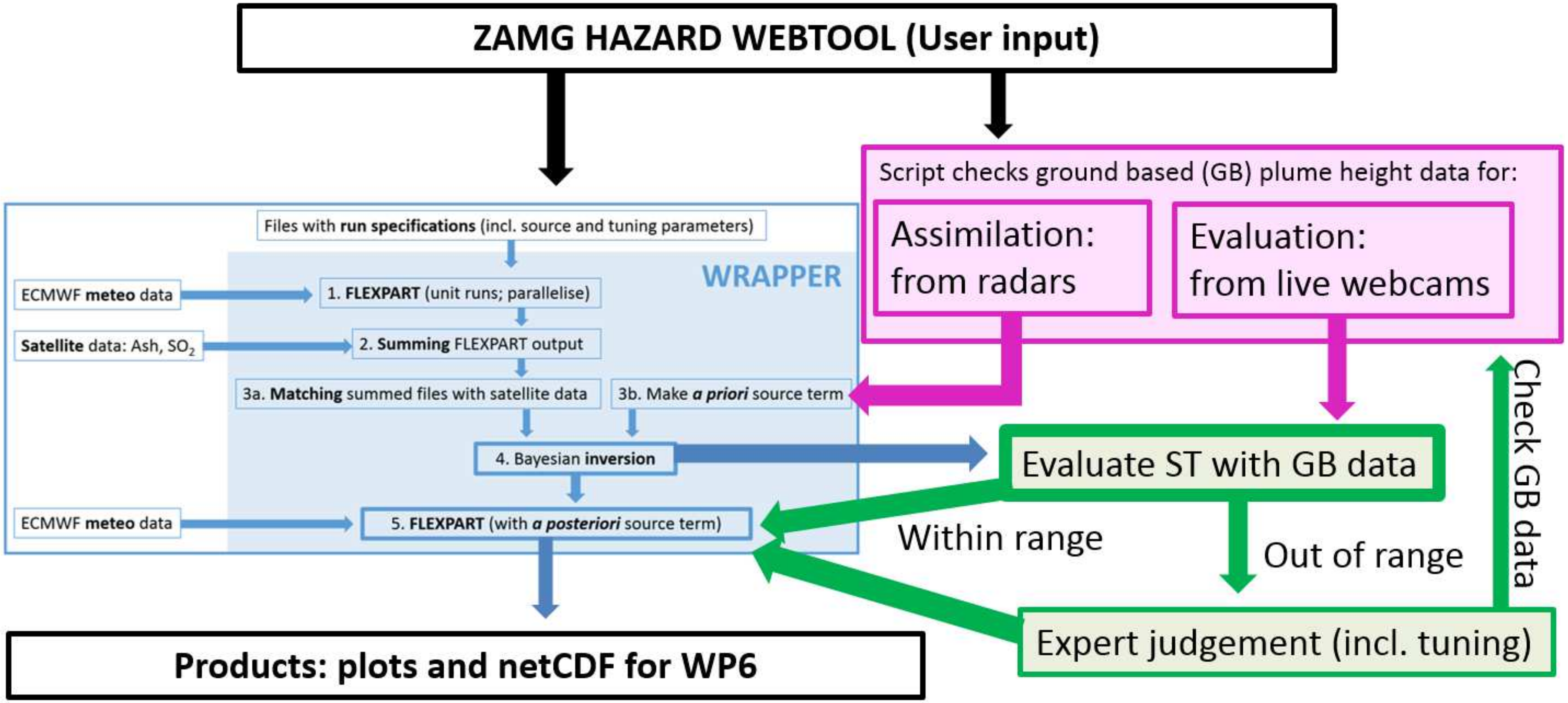
Methods: EUNADICS evaluation of vertical distribution of ash



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Methods: FLEXPART source-term and radar plume heights - Grimsvotn

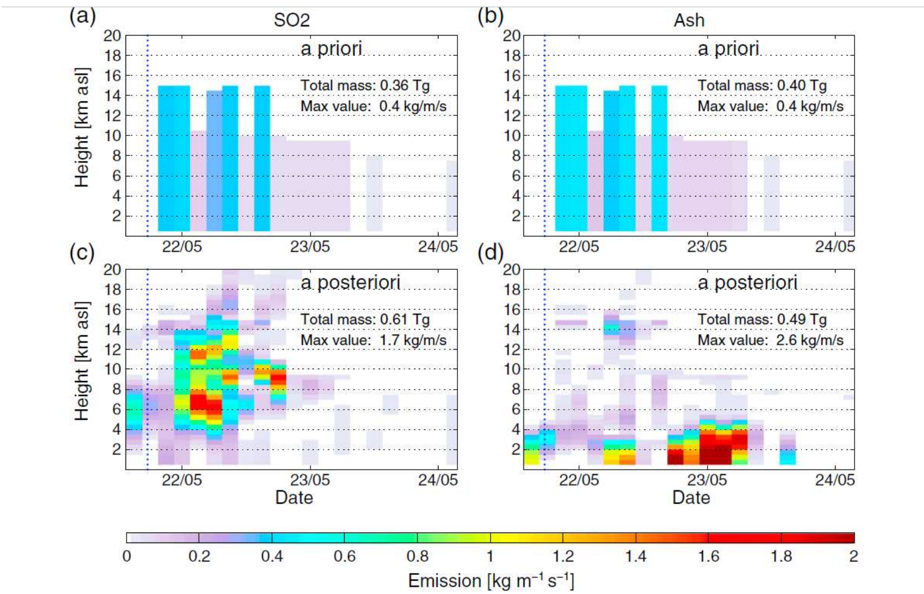
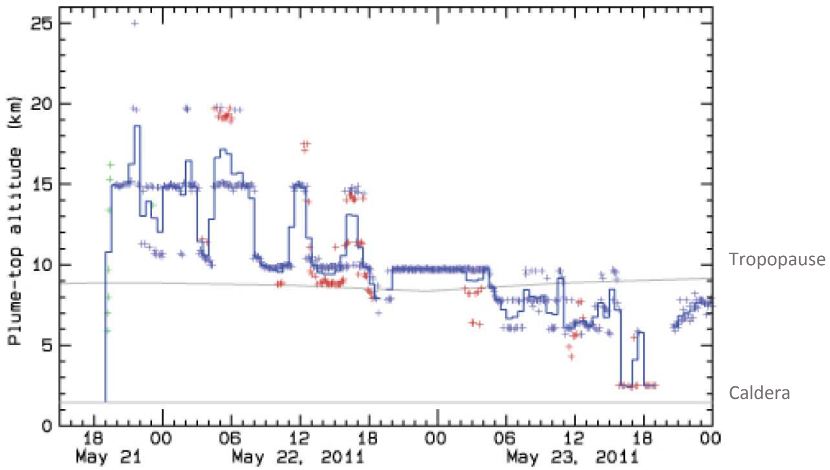


Figure 3. SO_2 and ash source terms for the 2011 Grímsvötn eruption showing the time, altitude, and strength of the emissions. (a, b) The a priori source term used as input to the inversion for SO_2 and ash. (c, d) The a posteriori source term estimated by the inversion method constrained by SO_2 and ash total columns retrieved from IASI data. The dashed blue vertical line represent the start time of the eruption as reported by IMO (21 May 2011 17:30 UTC).



Time series of the 5-min detected plume-top altitude (km a.s.l.) from the:

- **C-band weather radar** → go into *a priori* ST
- X-band mobile radar → for evaluation
- initial rise of the plume estimated from photographs
- 30-min average plume-top altitude of all the estimates is shown by the curve.

Moxnes, E. D., N. I. Kristiansen, A. Stohl, L. Clarisse, A. Durant, K. Weber, and A. Vogel (2014), Separation of ash and sulfur dioxide during the 2011 Grímsvötn eruption, J. Geophys. Res. Atmos., 119, 7477–7501.
Petersen, G. N., H. Bjornsson, P. Arason, and S. von Löwis (2012a), Two weather radar time series of the altitude of the volcanic plume during the May 2011 eruption of Grímsvötn, Iceland, Earth Syst. Sci. Data, 4(1), 121–127

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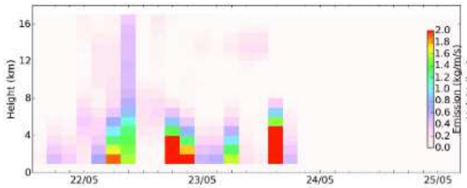
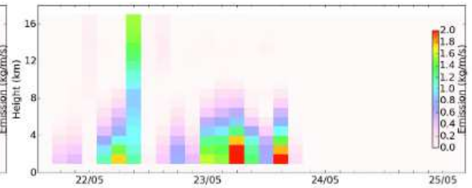
Methods: EUNADICS sensitivity tests

Tuning of several run specifications; arrows indicate most relevant ones

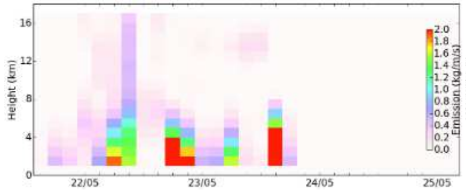
1. Reference



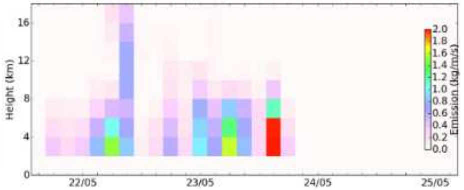
2. Bin sizes 4 → 9



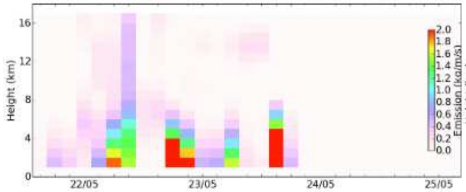
3. Longer ash life time



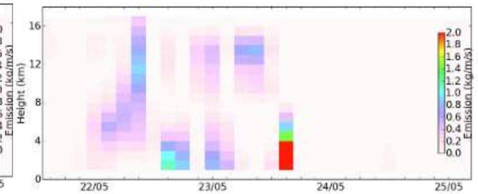
4. Halved vertical levels



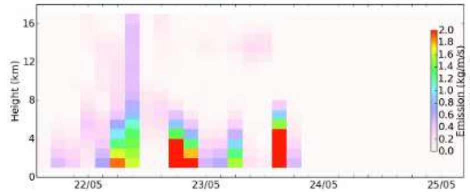
5. ECMWF vent height



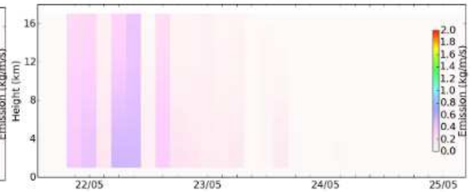
6. Meteo 0.5° → 1.0°



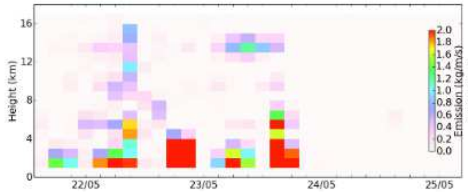
7. Particles/10



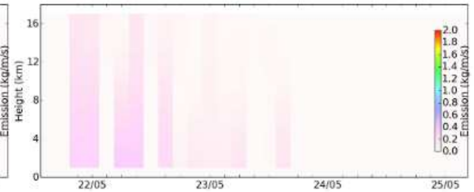
8. *A priori*: more weight



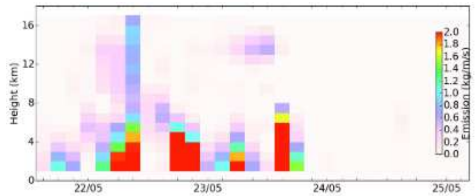
9. *A priori*: less weight



10. Model: less weight



11. Model: more weight



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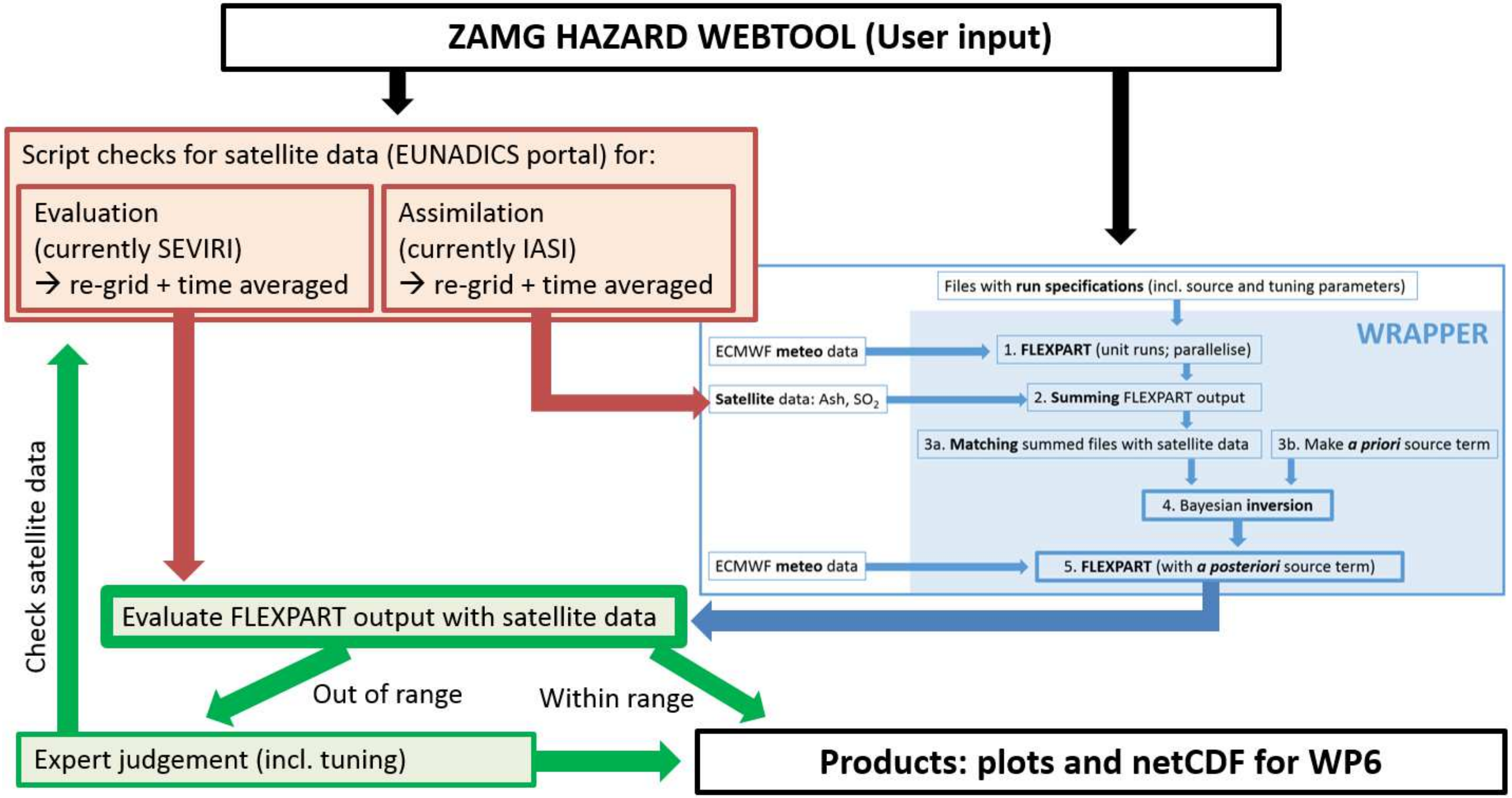
Methods: EUNADICS evaluation of horizontal distribution of ash



Extra slides

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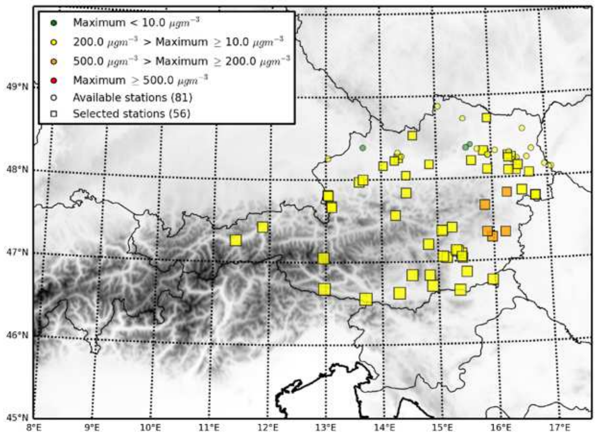
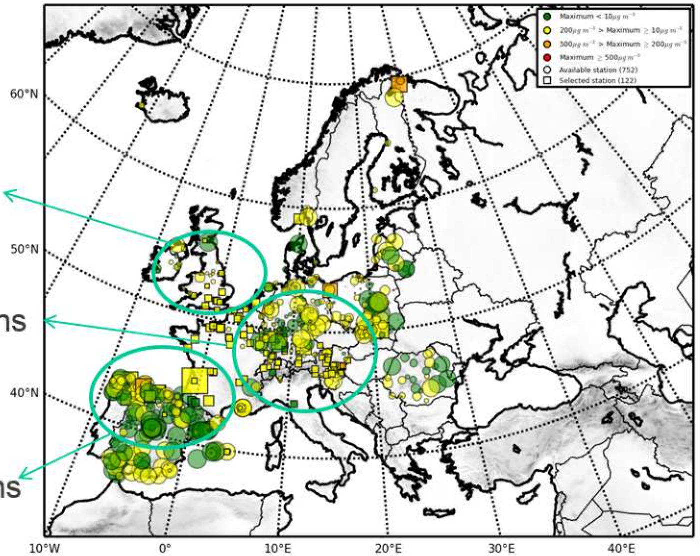
The Holuhraun Sept-Oct 2014 eruption

The Holuhraun eruption in Europe – SO2 emissions



- What led to all those exceedances?
- Were we able to simulate this? (model evaluation)
- Was it posing some thread?



1 – first detections

2 – central Europe detections

3 – later detections

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