



FLEXPART for volcanic applications

M.D. Mulder, D. Arnold, C. Maurer

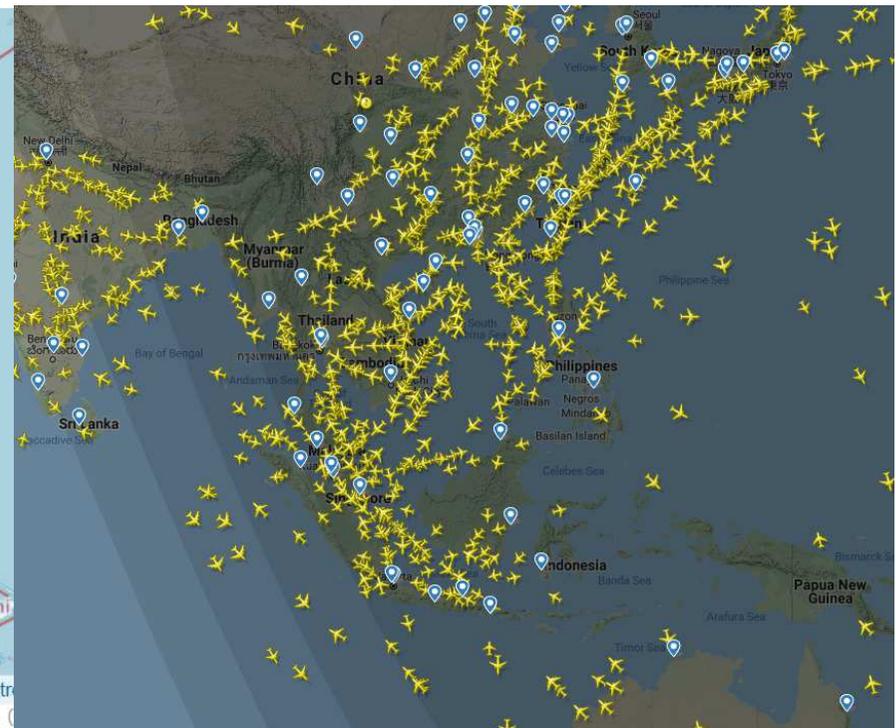
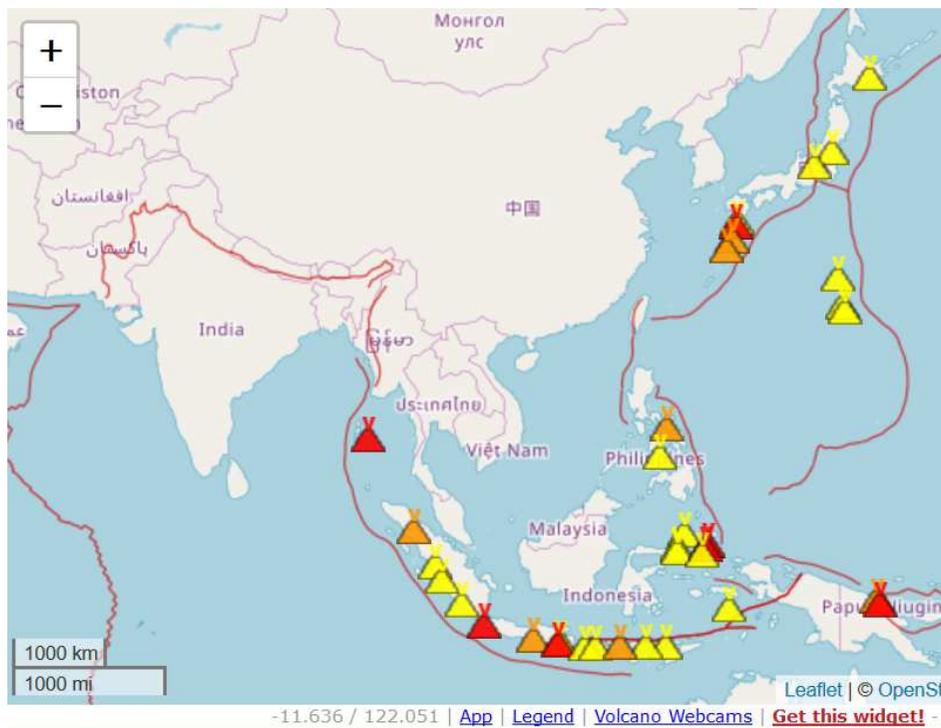


ZAMG
Zentralanstalt für
Meteorologie und
Geodynamik

Introduction: are they important?

8/5/2020
Folie 2

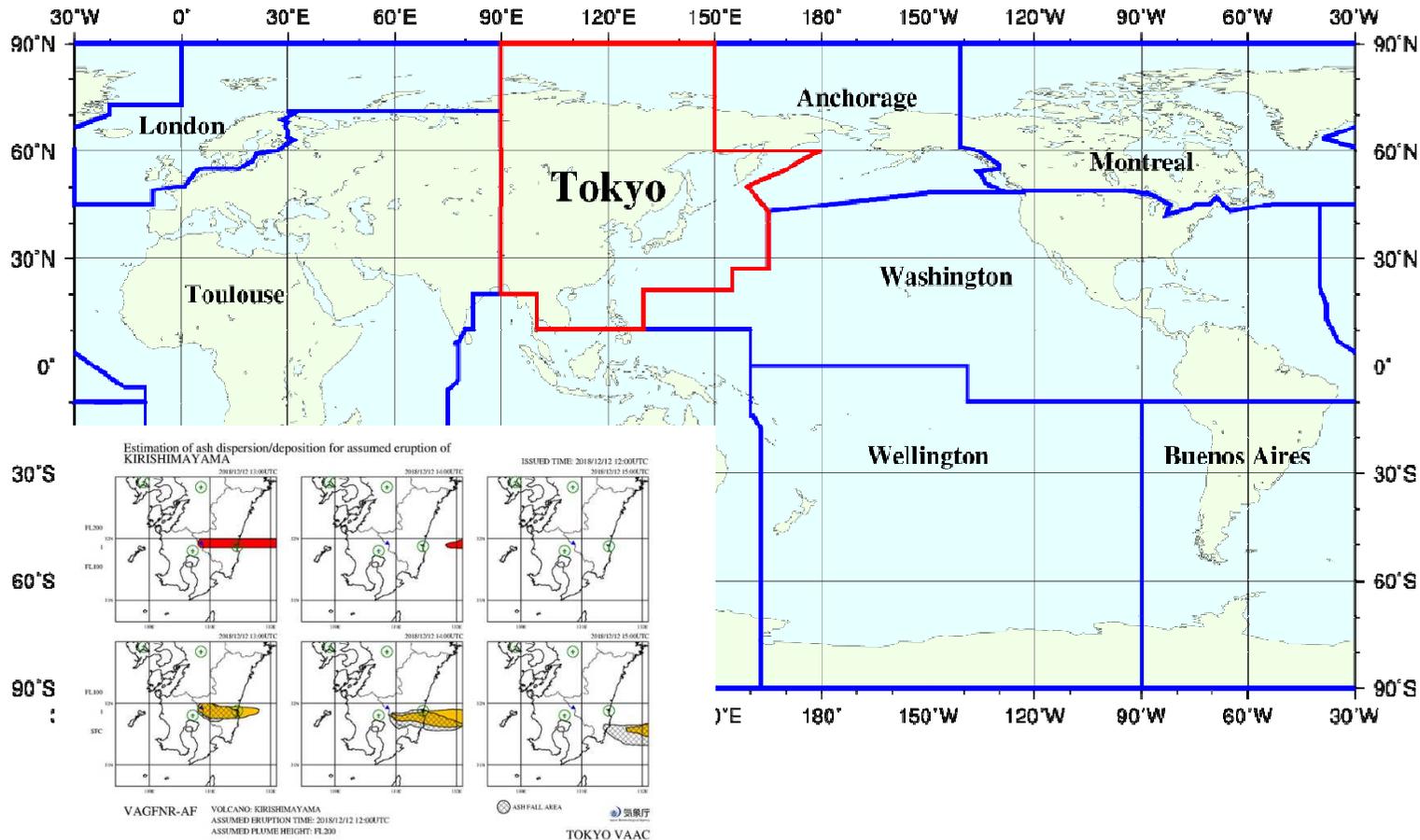
Flightradar information 12.12.2018 at 20:30 Local Time



Introduction: VAACS

VOLCANIC ASH ADVISORY CENTERS – AREAS OF RESPONSIBILITY

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Folie 3

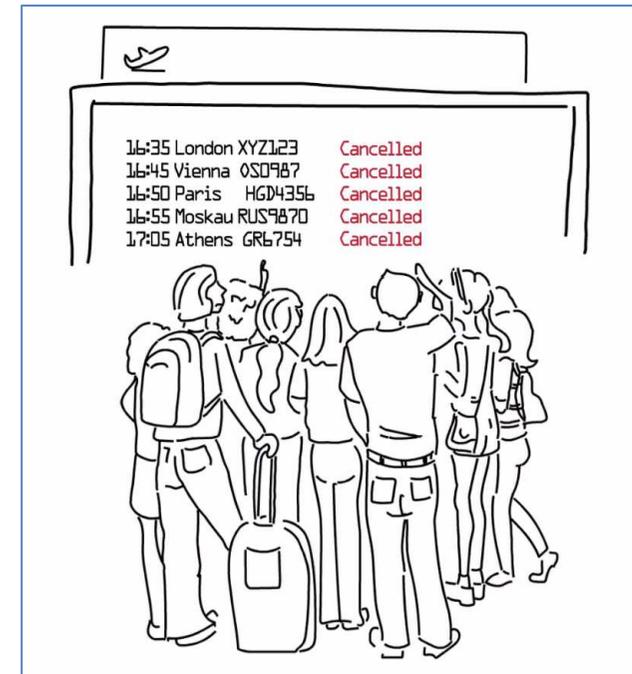
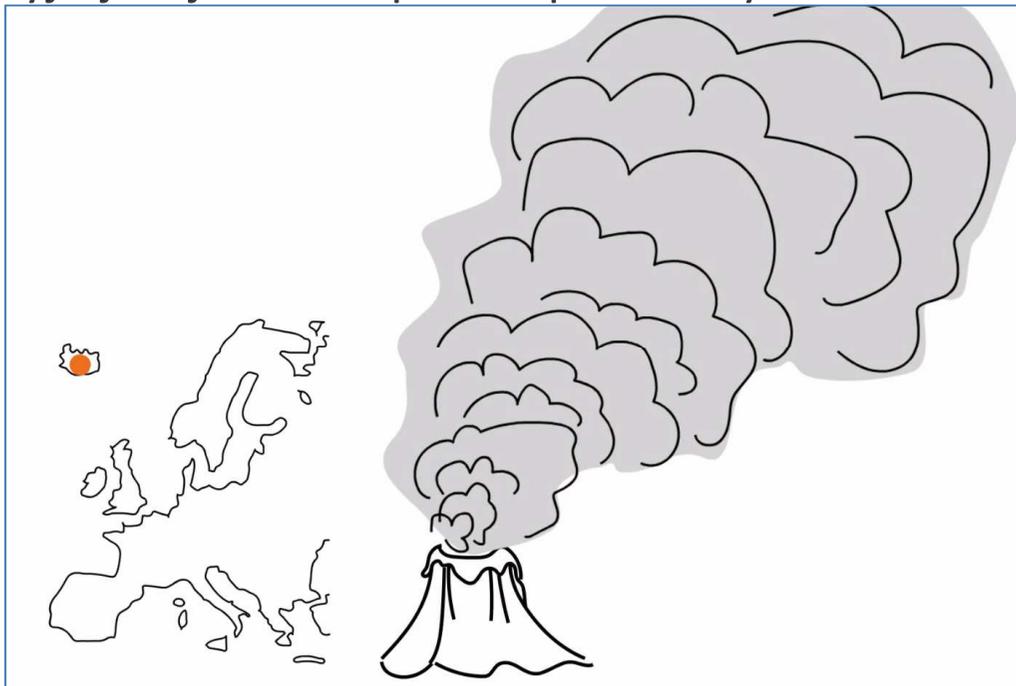


set up by the International Civil Aviation Organization (ICAO), an agency of the United Nations

Introduction: Involvement of scientific community - EUNADICS

8/5/2020
Folie 4

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?

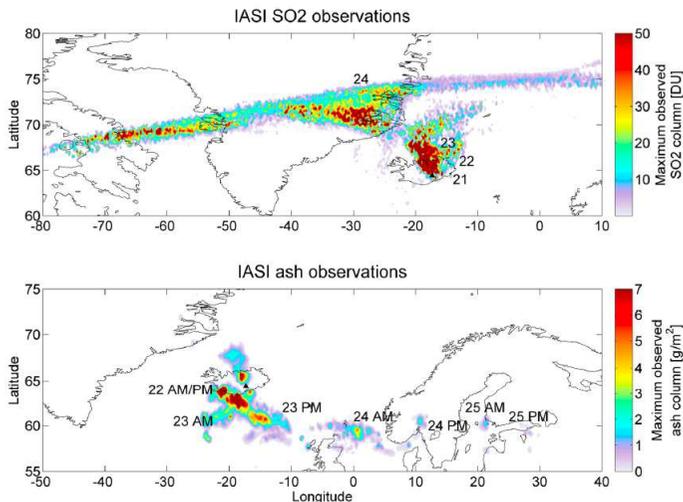
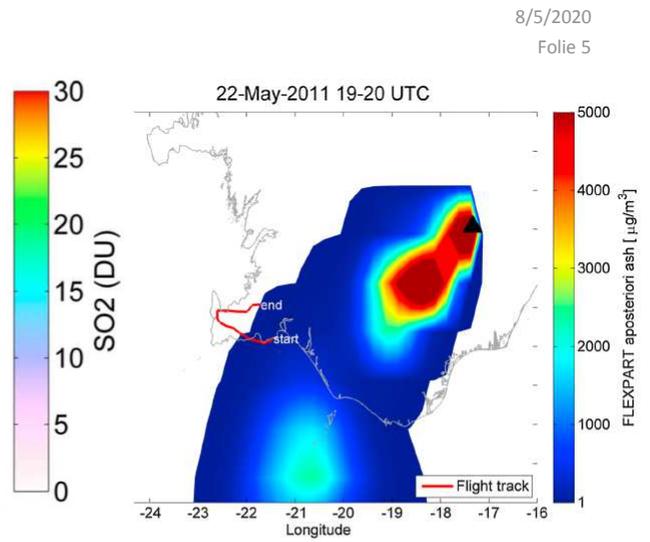
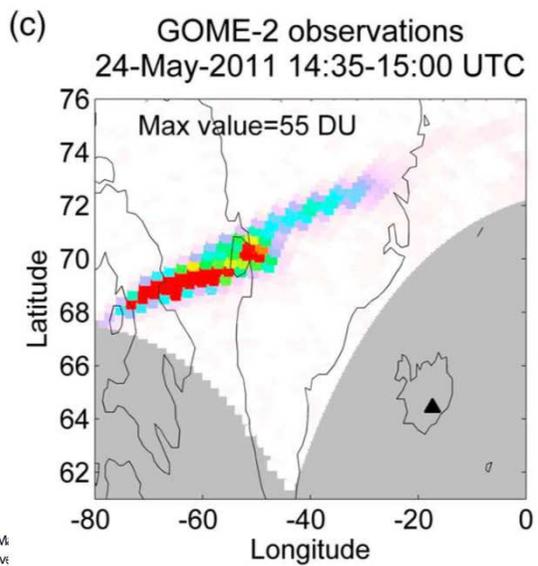
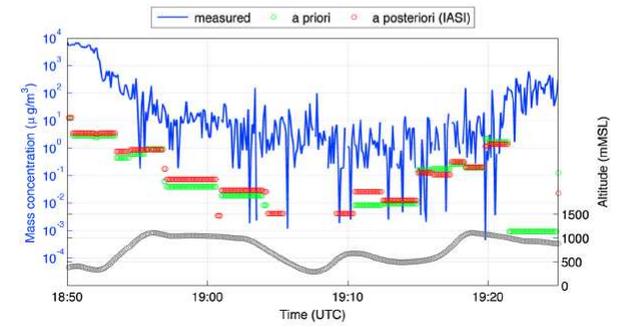
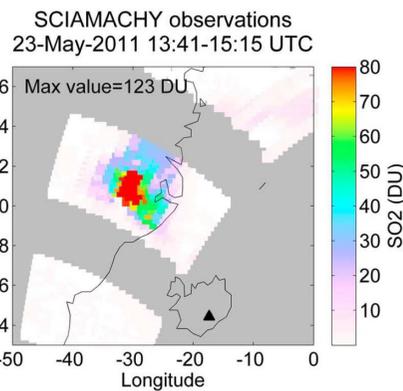
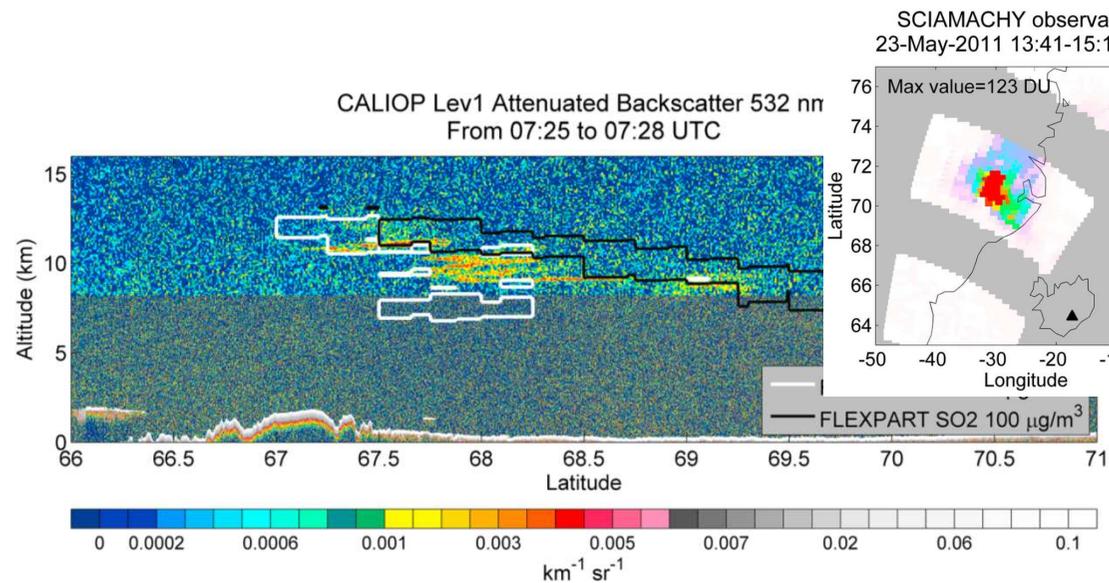


Figure 2. (top) SO₂ and (bottom) ash total columns retrieved from IASI between 21 and 24 May (SO₂) and 22 and 25 May (ash). The data are gridded and for each grid cell, the maximum of the values observed during all overpasses in the given period is shown. Labels indicate the date when the individual maxima were observed.

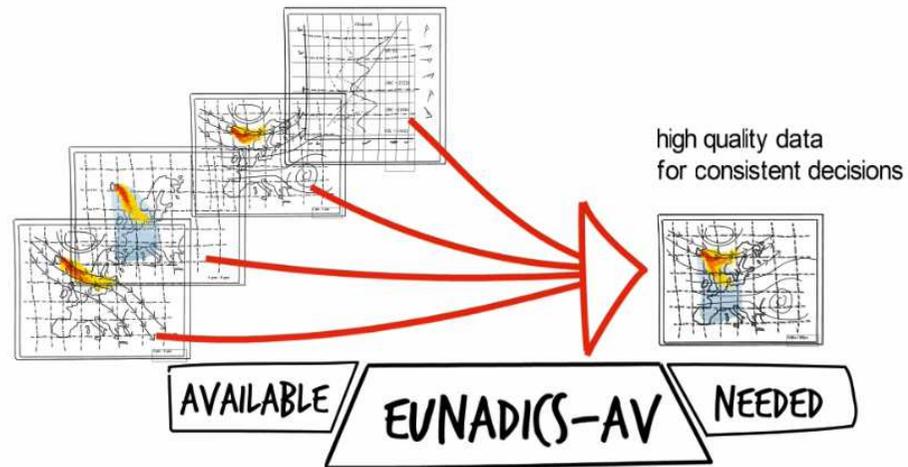


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Folie 5



Introduction: EUNADICS

8/5/2020
Folie 6



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?

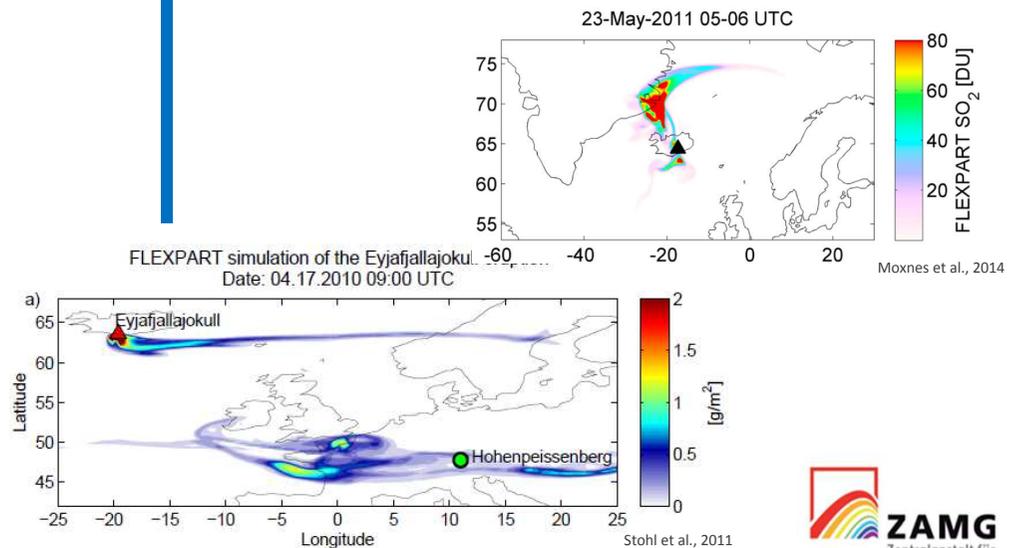
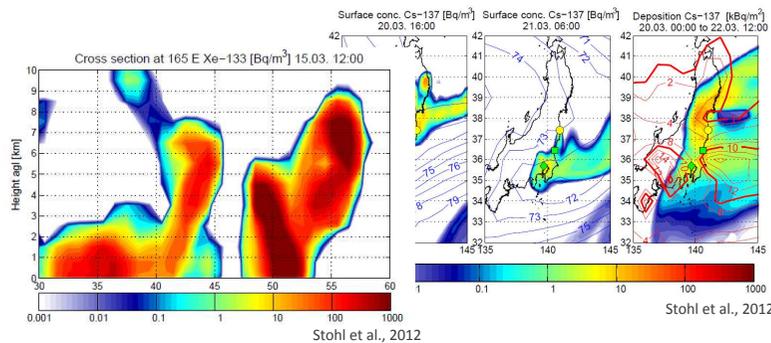
8/5/2020
Folie 7

(Flexible) Lagrangian Particle 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:

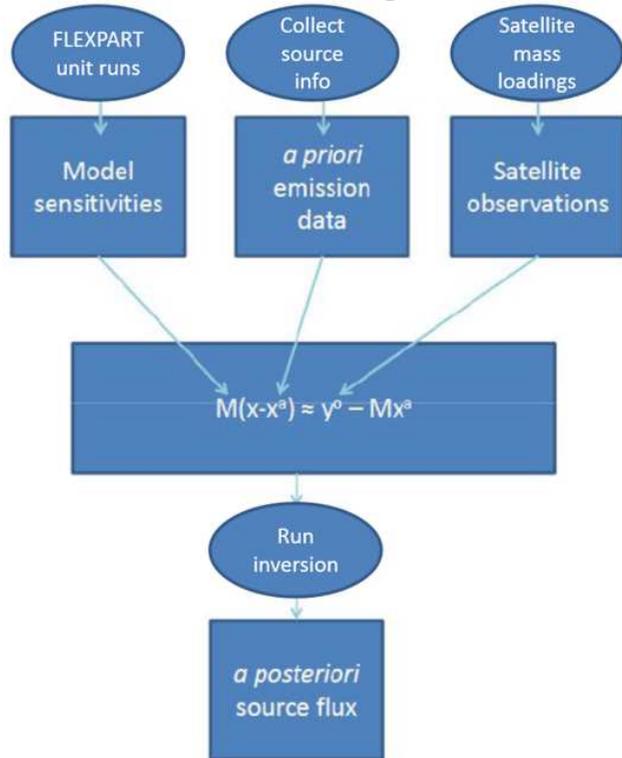
- No ash aggregation -> underestimation
- Online chemistry only with climatological values; v10: preprocessed from Eulerian model



Methods: VAST ad-hoc routines + separate webtool

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

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Folie 8



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

ZAMG Vulkanasche Berechnung

1. Userangaben 2. Vulkansuche 3. Ausbruchdaten 4. Zusammenfassung 5. Bestätigung

Vulkanname	Grímsvötn 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
	<input type="radio"/> Ganze Welt	-90°	90° -180°	180°	15° Zylindrisch
	<input checked="" type="radio"/> Europa	25°	70° -25°	45°	5° Lambert
	<input type="radio"/> Lokal	40°	85° -50°	20°	5° Lambert
	<input type="radio"/> 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	<input type="radio"/> Linear <input checked="" type="radio"/> Pilzwolke <input type="radio"/> Gauss Verteilung				
Species	<input checked="" type="radio"/> Feinasche <input type="radio"/> SO ₂ <input type="radio"/> EUNADICS TRACER				
Ensemble	<input type="radio"/> Ja <input checked="" type="radio"/> Nein				
Cluster	<input type="radio"/> Ja <input checked="" type="radio"/> Nein				
Farbskala	<input type="radio"/> VAST+ACG <input type="radio"/> VAST <input checked="" type="radio"/> ACG				

Methods: VAST ad-hoc routines + separate webtool

8/5/2020
Folie 9

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

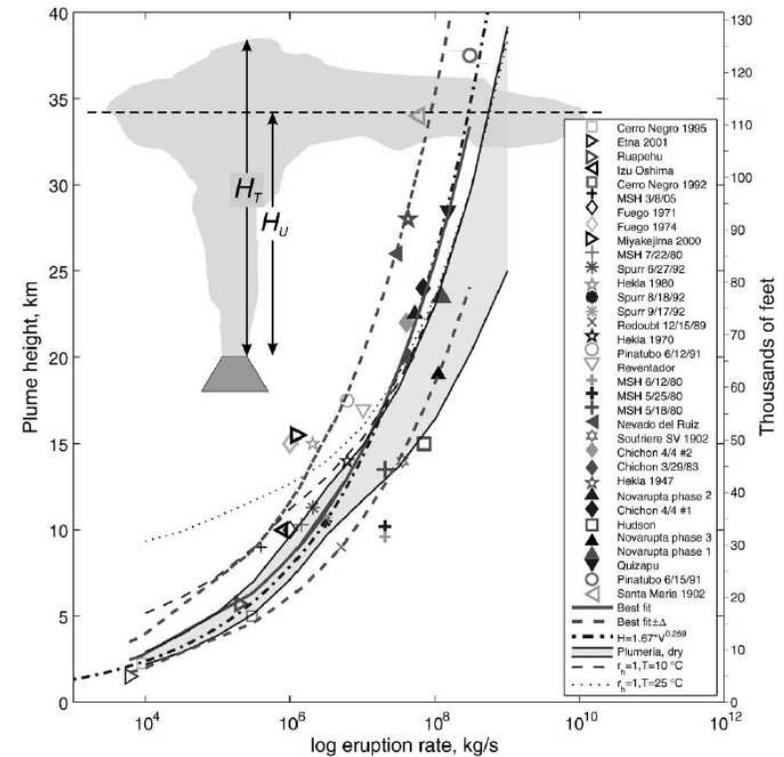
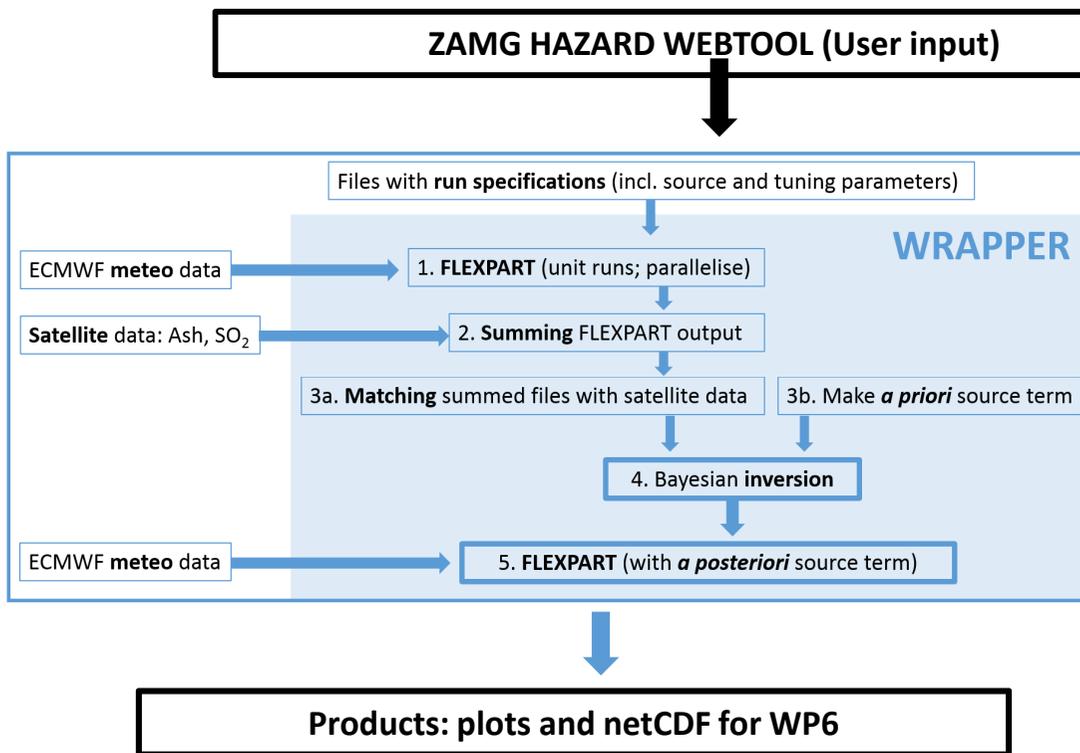


Fig. 1. Plume height above the vent versus mass eruption rate for eruptions listed in Table 1. Symbols for each eruption are given in the legend. The bold solid line is the best fit to the data (Eq. (1)). The bold dashed lines enclose the error envelope ($\pm \Delta H$) calculated by the routine polyval in Matlab® (use of trade names does not constitute endorsement). The error envelope corresponds to a 50% confidence interval, meaning that future observations have at least a 50% probability of falling within the 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 Steiner (Mastin, 2007) using a magma temperature of 900 °C, 3 wt% gas, and a Standard dry atmosphere (United States Committee on Extension to the Standard Atmosphere). The 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 two dashed light curves 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 are: (○) Carro Negro 1905, (△) Etna 2001, (□) Ruapehu, (◇) Izu Oshima, (○) Carro Negro 1992, (◇) MSH 3/8/05, (◇) Fuego 1971, (◇) Fuego 1974, (◇) Miyakejima 2000, (◇) MSH 7/22/80, (◇) Spurr 9/27/92, (◇) Hekla 1980, (◇) Spurr 8/18/92, (◇) Spurr 9/17/92, (◇) Redoubt 12/15/89, (◇) Hekla 1970, (◇) Pinatubo 6/12/91, (◇) Reventador, (◇) MSH 6/12/80, (◇) MSH 5/25/80, (◇) MSH 5/18/80, (◇) Nevado del Ruiz, (◇) Soufriere SV 1902, (◇) Chichon 4/4 #2, (◇) Chichon 3/29/83, (◇) Hekla 1947, (◇) Novarupta phase 2, (◇) Chichon 4/4 #1, (◇) Hudson, (◇) Novarupta phase 3, (◇) Novarupta phase 1, (◇) Quizapu, (◇) Pinatubo 6/15/91, (◇) Santa Maria 1902. Legend symbols: (—) Best fit, (---) Best fit $\pm \Delta$, (---) $H = 1.67 \dot{V}^{0.259}$, (---) Plumeria, dry, (---) $r_h = 1, T = 10$ °C, (---) $r_h = 1, T = 25$ °C.

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

Methods: VAST source term inversion at ZAMG

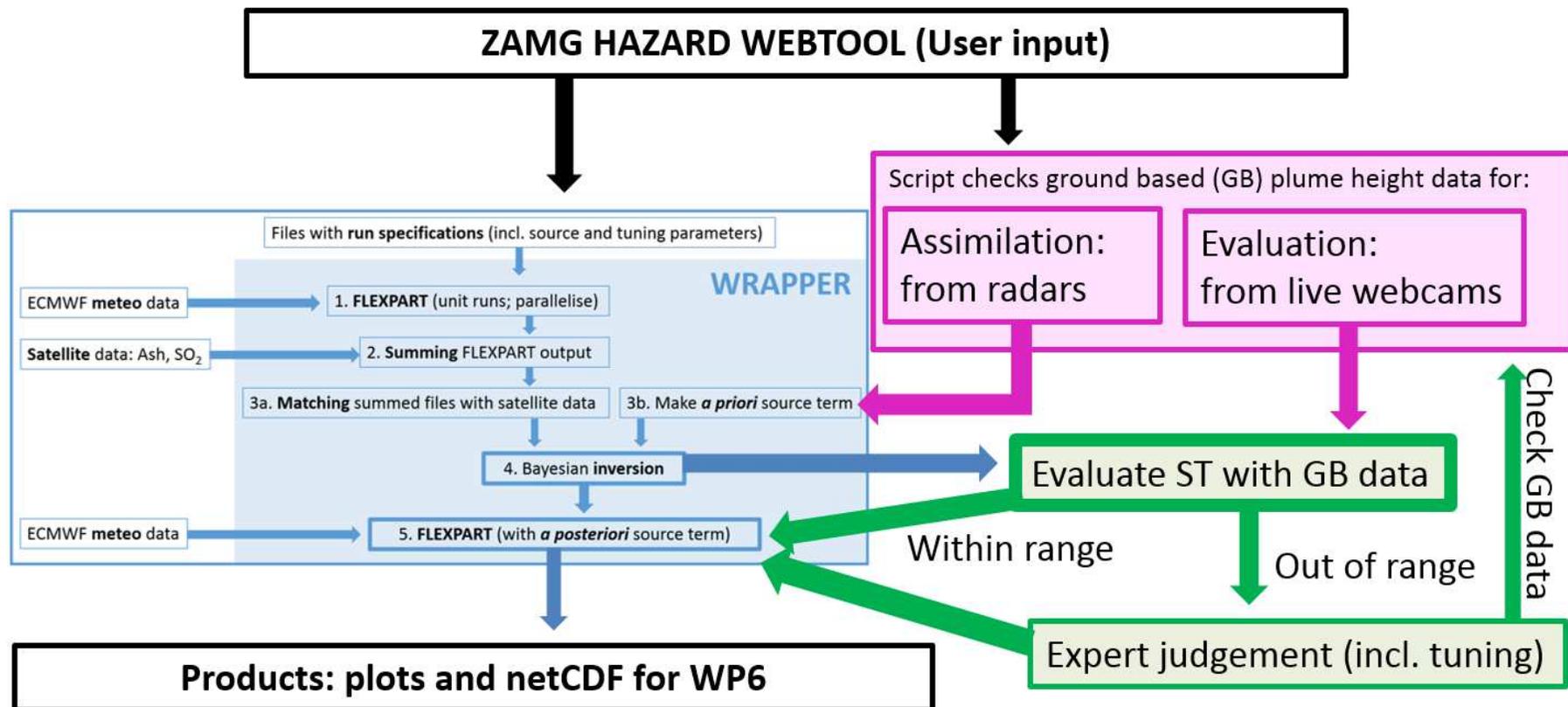


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Ensemble	<input type="radio"/> Ja <input checked="" type="radio"/> Nein			
Cluster	<input type="radio"/> Ja <input checked="" type="radio"/> Nein			
Farbskala	<input type="radio"/> VAST+ACG <input type="radio"/> VAST <input checked="" type="radio"/> ACG			

Methods: EUNADICS evaluation of vertical distribution of ash



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

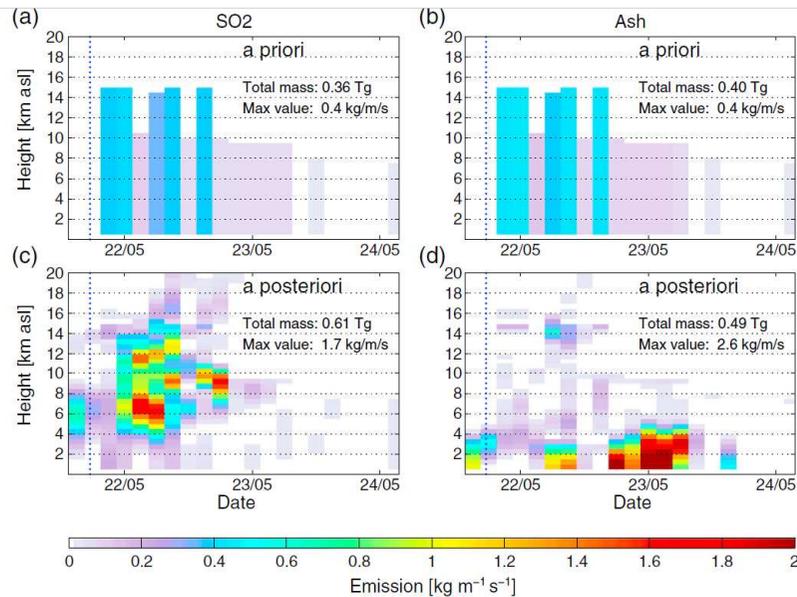
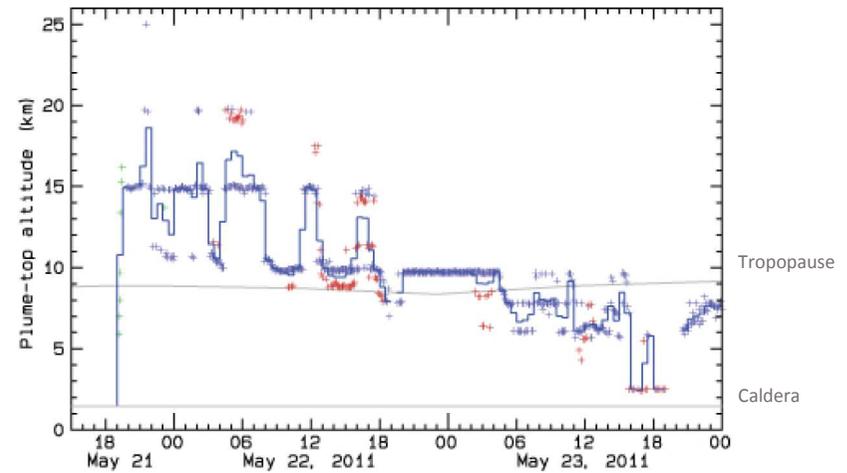


Figure 3. SO₂ and ash source terms for the 2011 Grimsvotn eruption showing the time, altitude, and strength of the emissions. (a, b) The a priori source term used as input to the inversion for SO₂ and ash. (c, d) The a posteriori source term estimated by the inversion method constrained by SO₂ and ash 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 Grimsvotn eruption, *J. Geophys. Res. Atmos.*, 119, 7477–7501.

Petersen, G. N., H. Bjornsson, P. Arason, and S. von Lowis (2012a), Two weather radar time series of the altitude of the volcanic plume during the May 2011 eruption of Grimsvotn, Iceland, *Earth Syst. Sci. Data*, 4(1), 121–127

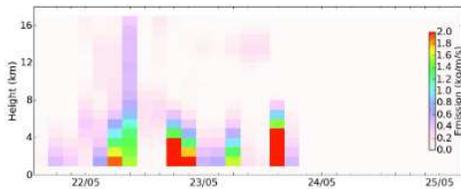
Methods: EUNADICS sensitivity tests



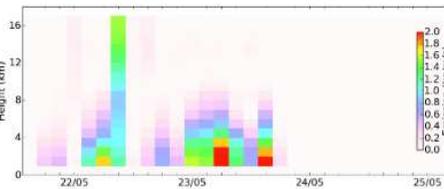
Tuning of several run specifications; arrows indicate most relevant ones

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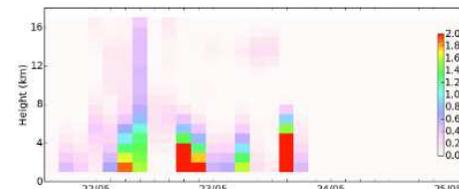
1. Reference



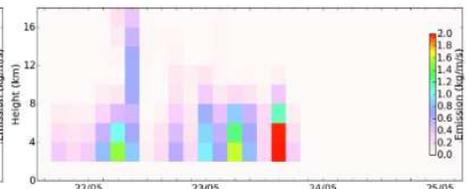
2. Bin sizes 4 → 9



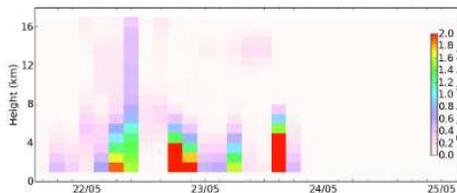
3. Longer ash life time



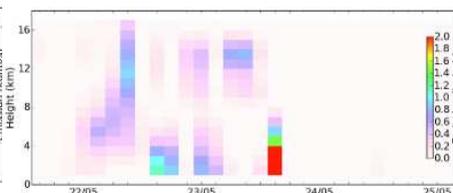
4. Halved vertical levels



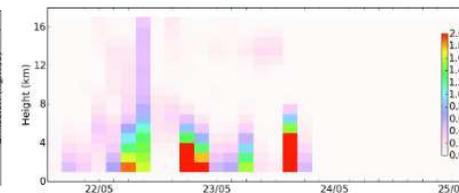
5. ECMWF vent height



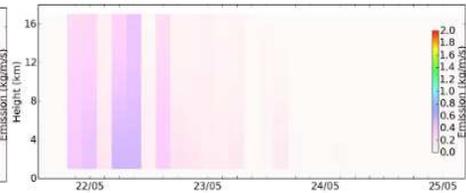
6. Meteo 0.5° → 1.0°



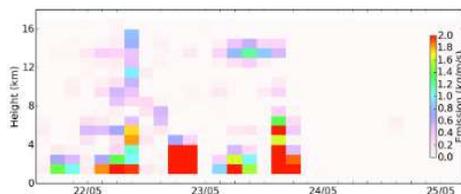
7. Particles/10



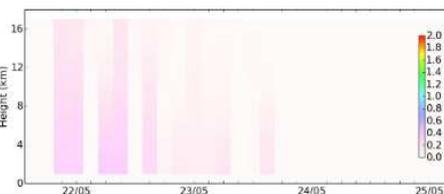
8. A priori: more weight



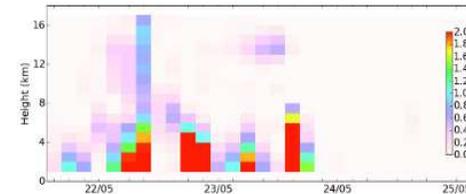
9. A priori: less weight



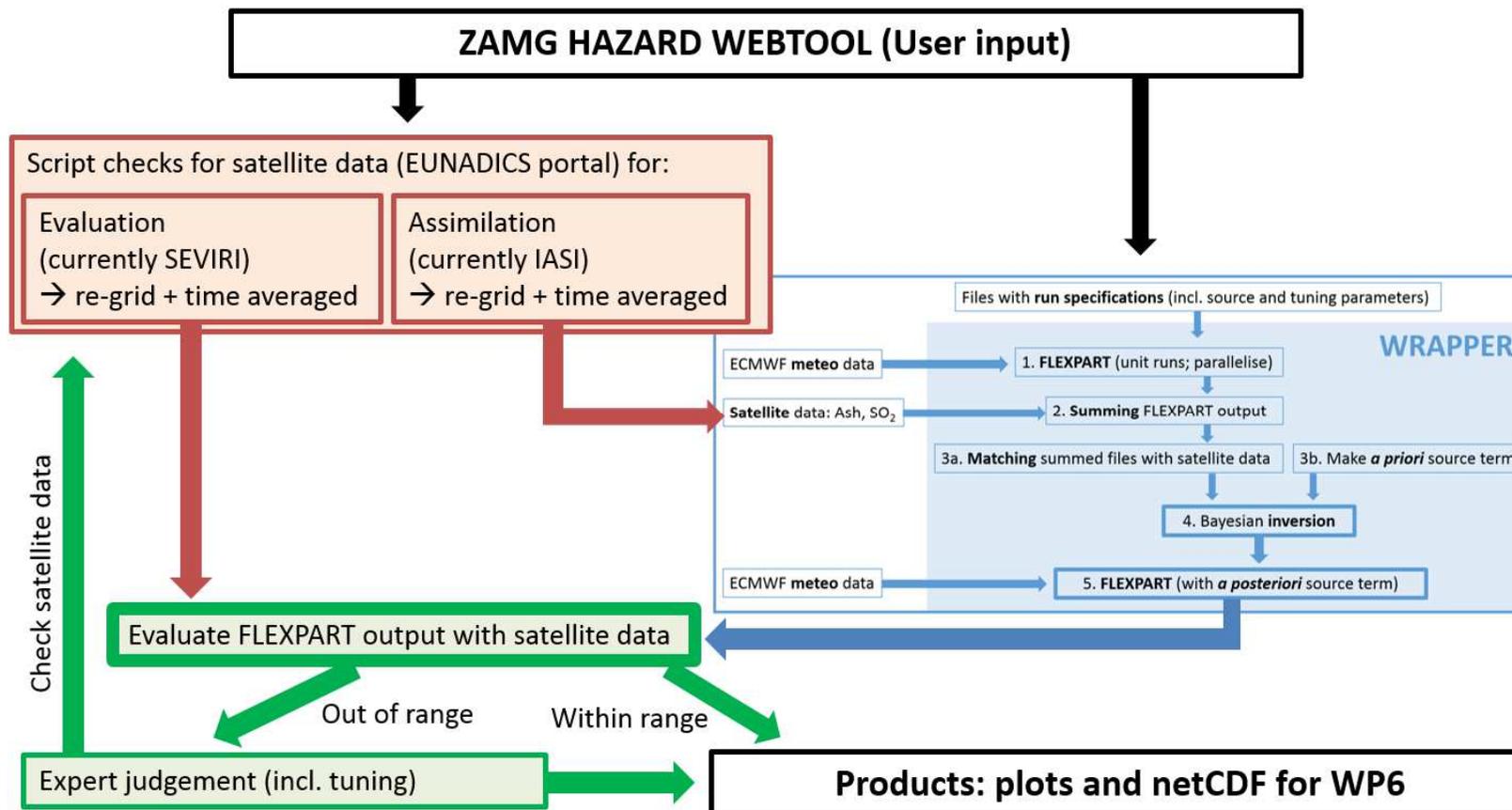
10. Model: less weight



11. Model: more weight



Methods: EUNADICS evaluation of horizontal distribution of ash



Extra slides



8/5/2020

Folie 15

The Holuhraun Sept-Oct 2014 eruption

8/5/2020
Folie 16

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Gas-spewing Icelandic volcano stuns scientists

Supernatural eruption defies preparations for an easy blast.

Alexandra Witte

28 October 2014

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What's that smell? Fumes from Iceland's Bardarbunga volcano reach Ireland

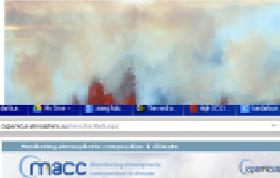
Highly-above-normal levels of sulphur dioxide reached Ireland over the weekend.

Sep 28, 2014, 11:58 AM 10,588 Views 18 Comments

Share 01 Tweet 25 Email 17

CHANGING WEATHER PATTERNS mean that low quantities of dangerous gases from Iceland's Bardarbunga volcano are no longer blowing into Irish airspace – right now, at least.

Higher levels of sulphur (SO₂) than normal were late on Saturday evening



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MACC-III supports French anti-furriers on elevated SO₂ values

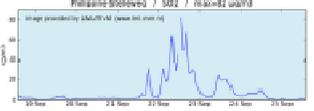
In the matter of European Union Europe countries were contacted by manufacturers of high sulphur diesel combustion at ground level. SO₂ is known as a pollutant for health and also acts as an irritant to the respiratory system as well as being a precursor of sulphate aerosol. Such a policy might affect the EU industry to reduce SO₂ emissions, high concentrations of SO₂ are also reported in transport lanes, though in specific areas affected by industrial or shipping emissions. So what was going on?

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ZAMG
Zentralanstalt für Meteorologie und Geodynamik

Aktuell Wetter Klima Umwelt Geophysik Forschung Produkte

Hohe SO₂-Werte in Teilen Österreichs durch isländischen Vulkan

Am Montag, 23.9.2014, wurden in einigen Regionen Österreichs ungewöhnlich hohe Schwefeldioxid-Werte (SO₂) gemessen. Nach Berechnungen der Zentralanstalt für Meteorologie und Geodynamik (ZAMG) wurde das SO₂ mit häufigem Nordwestwind vom isländischen Vulkan Bardarbunga nach Mitteleuropa transportiert. Diese SO₂-Konzentrationen stellen keine Gefährdung der Gesundheit dar.

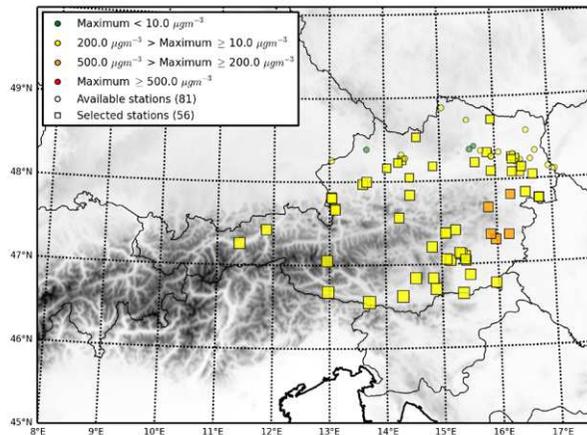
Zahlreiche Luftgüte-Messstellen in Österreich registrierten am Montag stark erhöhte Schwefeldioxid-Werte (SO₂). Besonders hohe Konzentrationen wurden am Apenstradl-Gemeinde, wo zwei Messstellen in der nordöstlichen Steiermark (Nasenberg mit maximal 247 µg/m³ und Hartberg mit maximal 229 µg/m³) den Grenzwert des Immissionschutzgesetzes-Luft (mehr als 500 Halbstundenmittelwerte pro Tag über 200 µg/m³) überschritten. Konzentrationen über 200



The Holuhraun eruption in Europe – SO₂ emissions



8/5/2020
Folie 17



1 – first detections

2 – central Europe detections

3 – later detections

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

