Haustþing Veðurfræðifélagsins 9. nóvember 2017

The problem of predicting ash cloud dispersion in the North Atlantic

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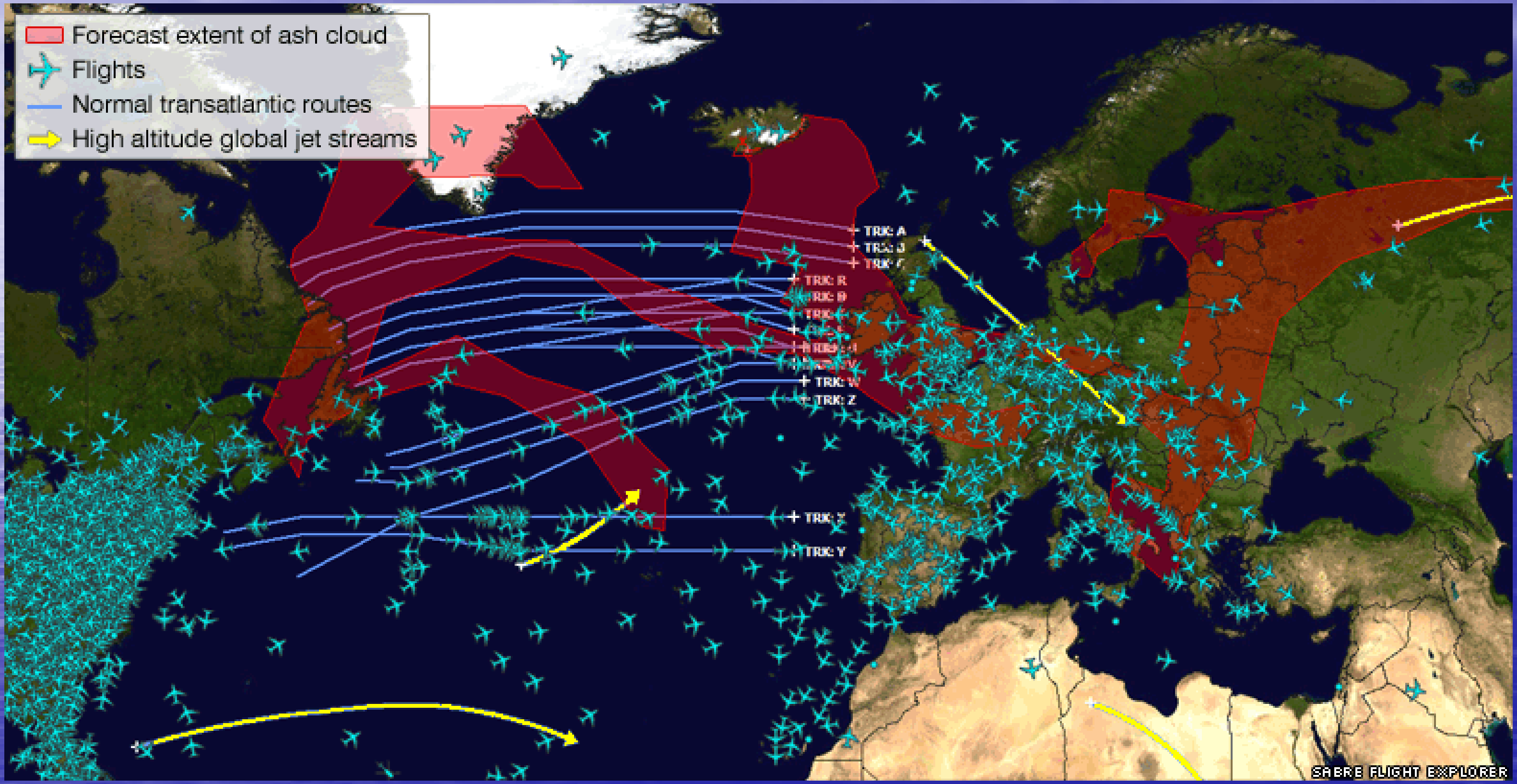
Overview

- Airborne measurements conducted in Iceland and Europe during the Eyjafjallajökull eruption in 2010, Grímsvötn eruption in 2011 and the Sakurajima research program
- Physics of buoyant volcanic plumes
- gravitational flattening and streak fallouts
- Horisontal diffusion approximation
- Error accumulation in diffusion models
- Conclusion

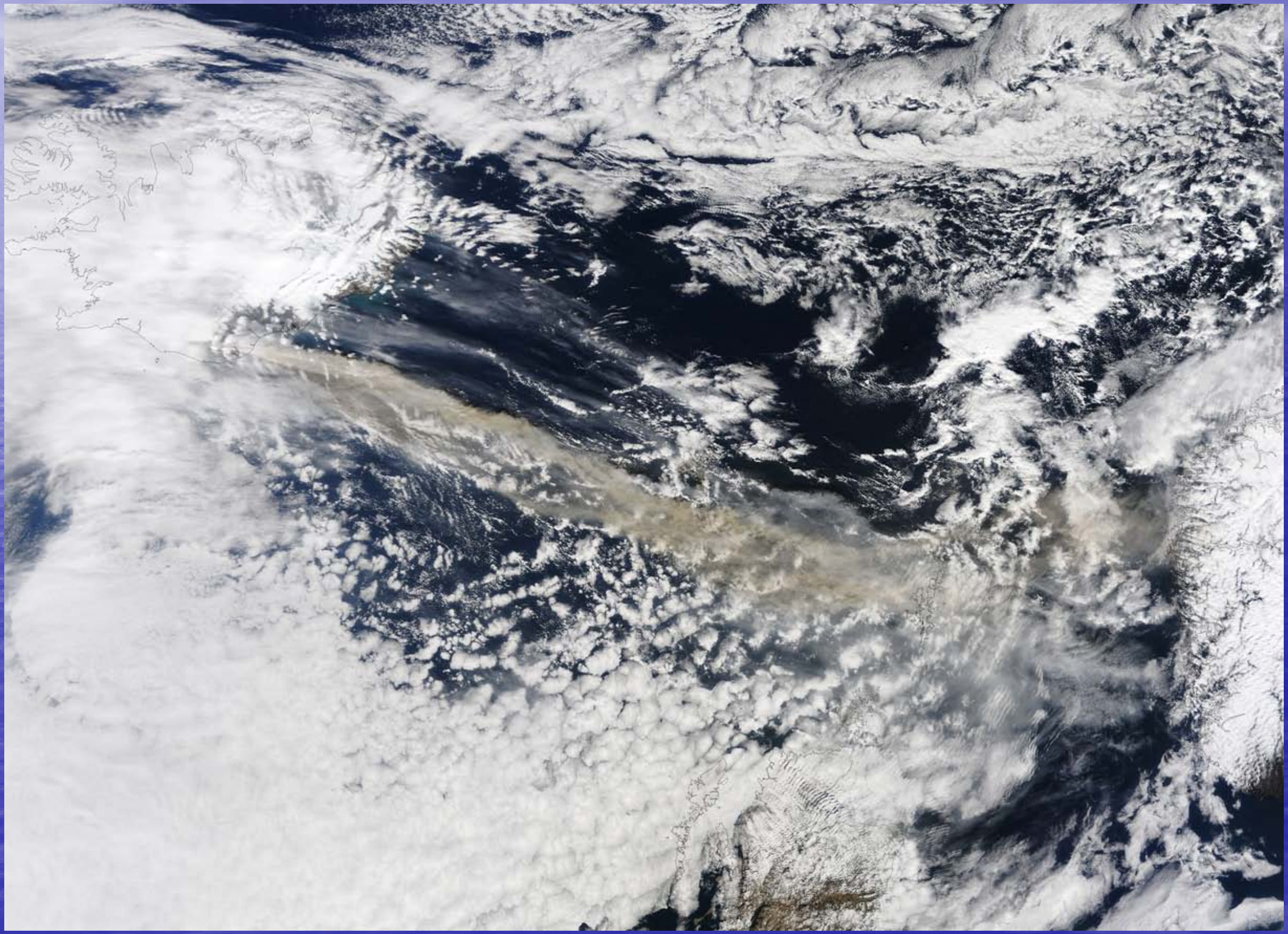
Eyjafjallajökull eruption 2010
BBC news 20.04.2010



Forecasting of volcanic ash cloud

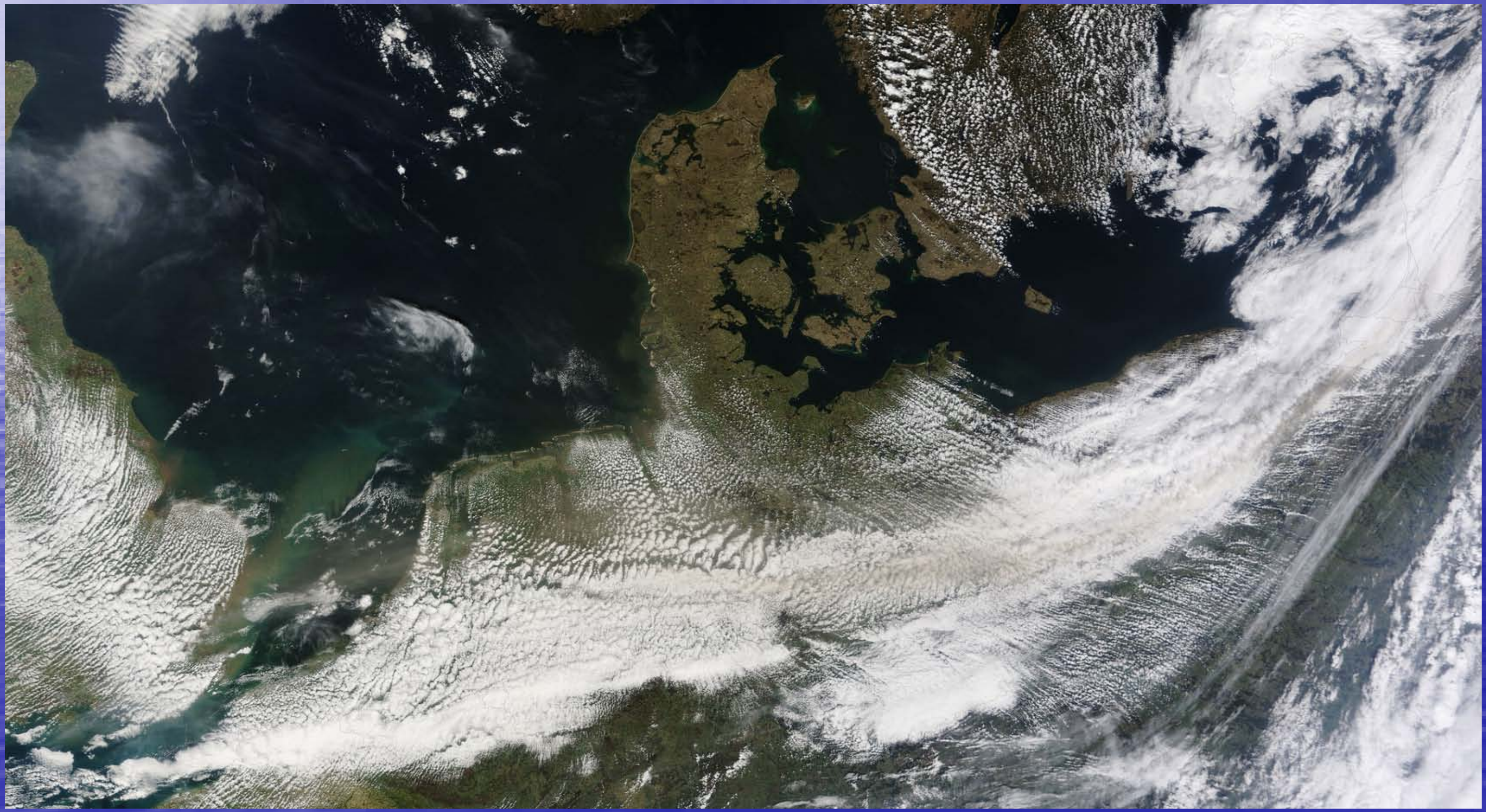
(21 April, 10:00 GMT) (Courtesy Nario Yasuda)

Visible clouds do not look like the predicted clouds



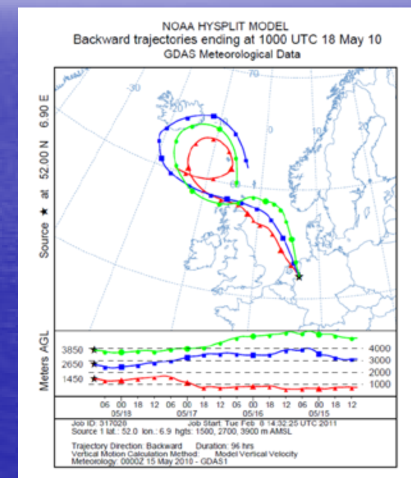
- **Eyjafjallajökull April 15th 2010**

Visible clouds do not look like the predicted clouds



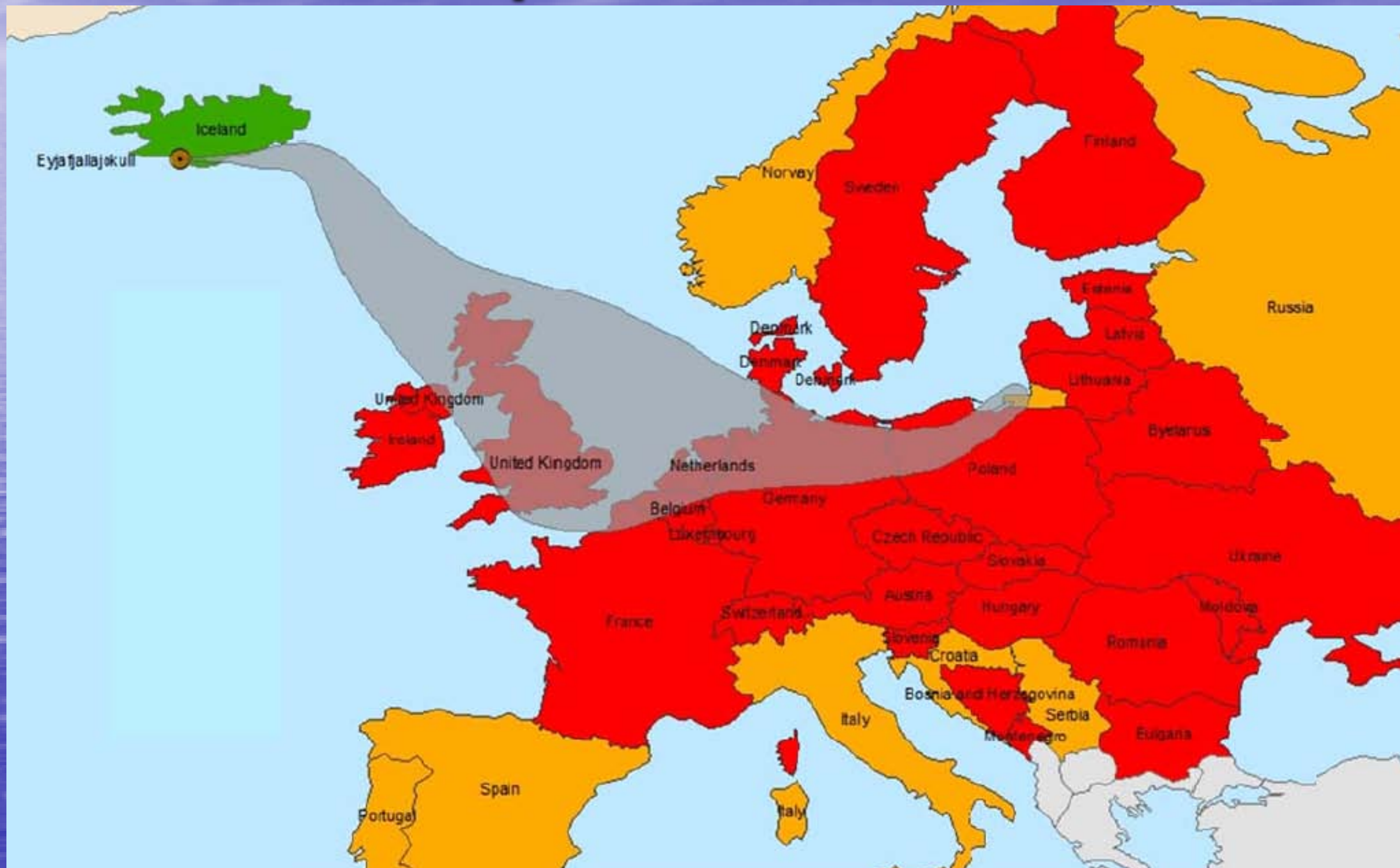
- **Eyjafjallajökull April 16th 2010**

Research flight over Germany at May 18th 2010 during Eyjafjallajökull eruption



Weber and Vogel, UAS Düsseldorf

Visible clouds do not look like the predicted clouds



- **Eyjafjallajökull April 16th, Cyrus Bina**
- **Student University of Texas at Austin**

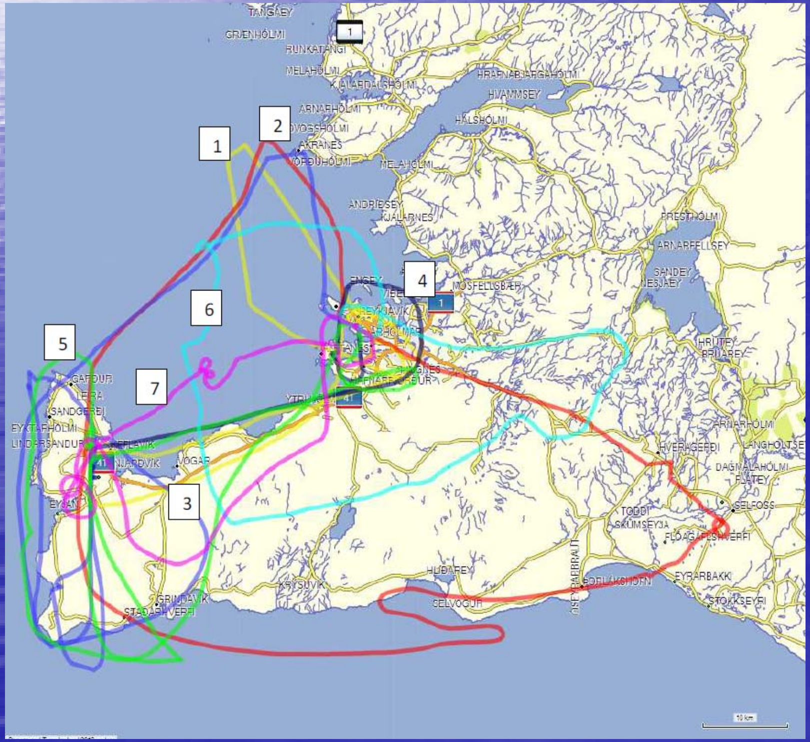
Ash cloud prediction May 11, 2010

Icelandic State TV (RÚV)

Ash cloud predictions were too much on the safe side the size of the predic-ted cloud and the plume were often 40:1

Airport monitoring observations

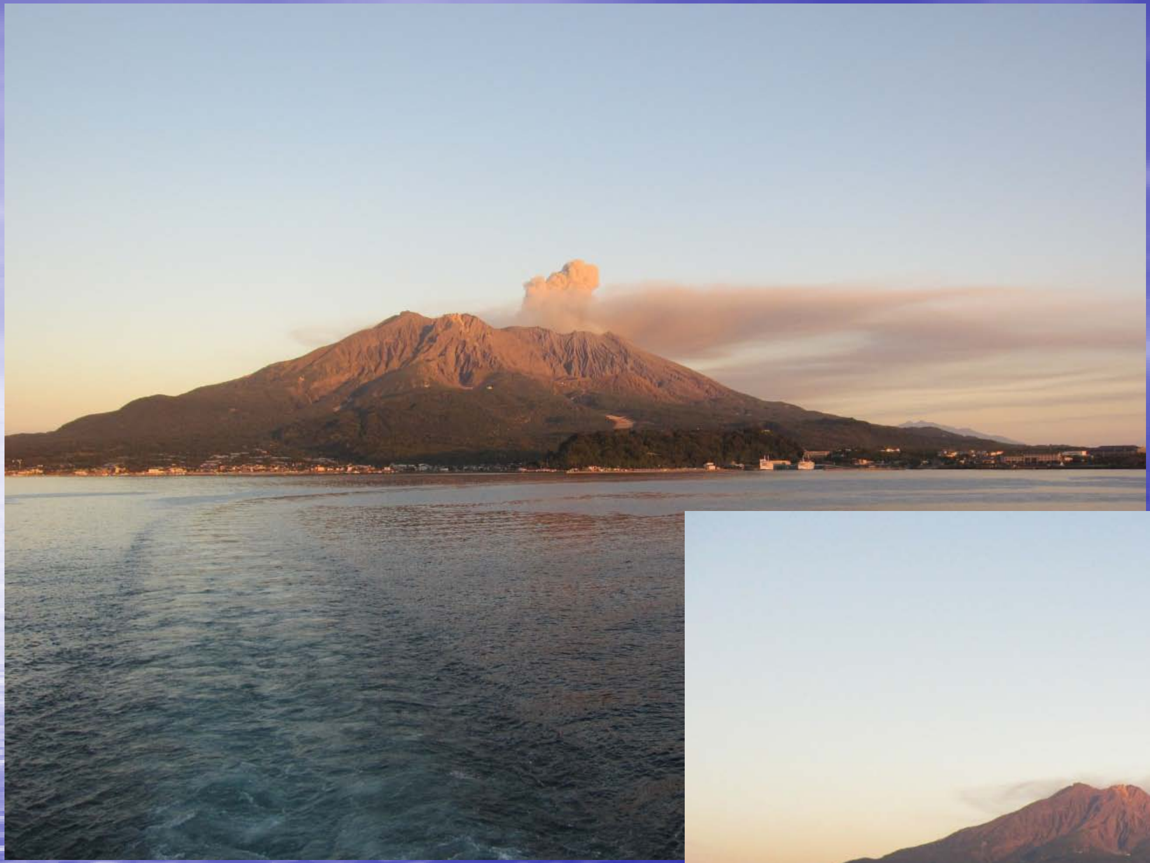
	No 1	No 2	No 3	No 4	No 5	No 6	No 7
Average	7,5	11,6	6,6	6,0	5,9	13,8	8,2
Av. above 500 ft alt.	3,5	9,5	5,1	1,9	5,2	11,9	4,9
St. Deviation	9,8	18,9	8,9	6,6	4,5	20,8	12,2
Maximum	123,1	176,1	187,4	68,0	40,0	227,5	161,3
Minimum	0,9	0,3	0,2	0,0	0,1	0,5	0,0
Ave + 3*stdev	36,9	68,2	33,3	25,8	19,3	76,1	44,9
TSP/PM10	1,2	1,6	1,2	1,2	1,1	1,3	1,5



- Isavia Iceland May 2011 Grimsvotn eruption Observations Campaign May 24 –26. Cessna 206 with two OPC´s. Results used by ANSP for first time. Keflavik int. airport kept open in spite of unfavourable predictions.


Grímsvötn eruption 2011
Courtesy Þorsteinn Jónsson

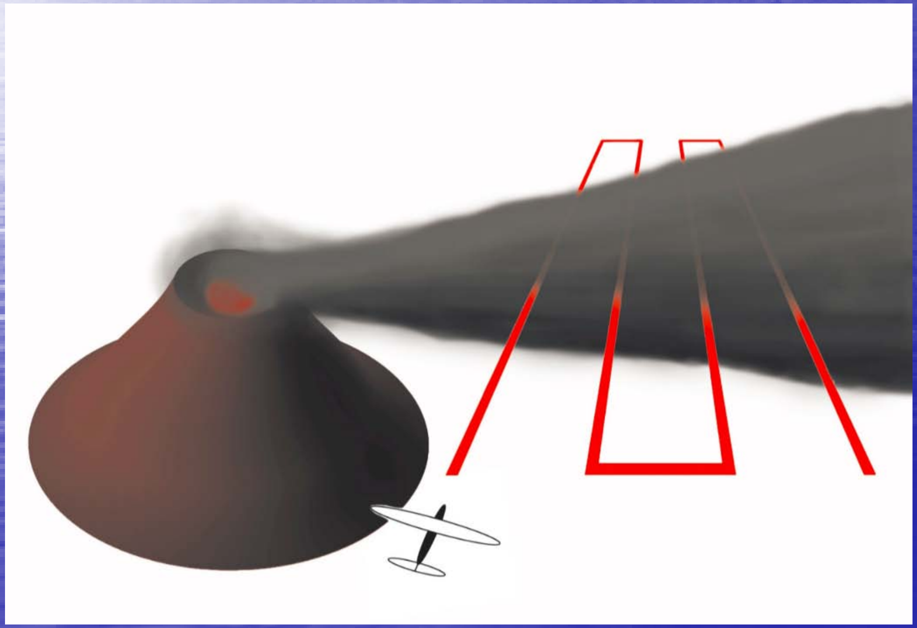
Distant view of Mt. Sakurajima Oct. 24^{th} 2012

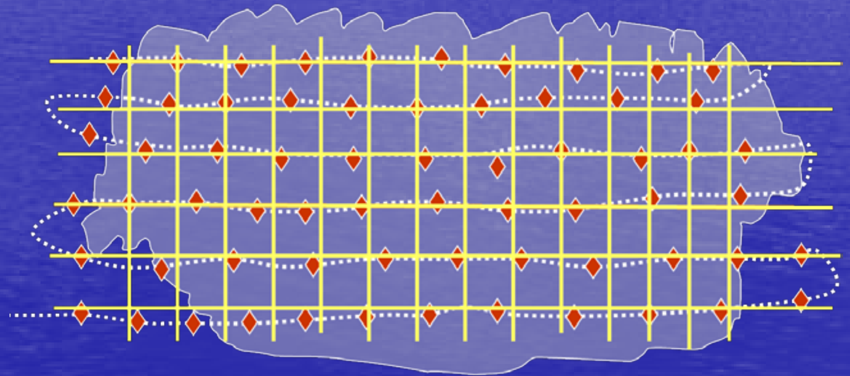


Concentration and flux

Traversing

Cross section

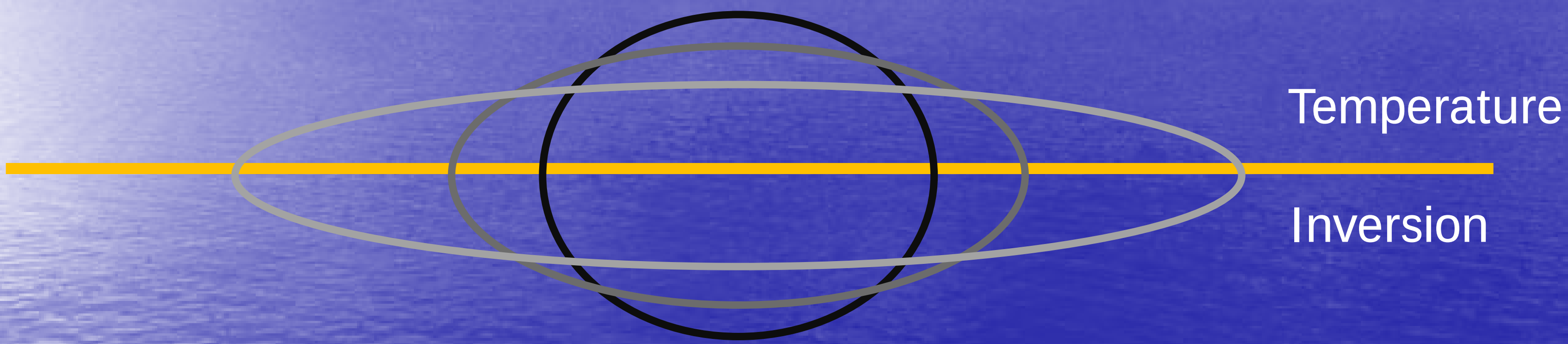




Courtesy Weber and Vogel, UAS Düsseldorf

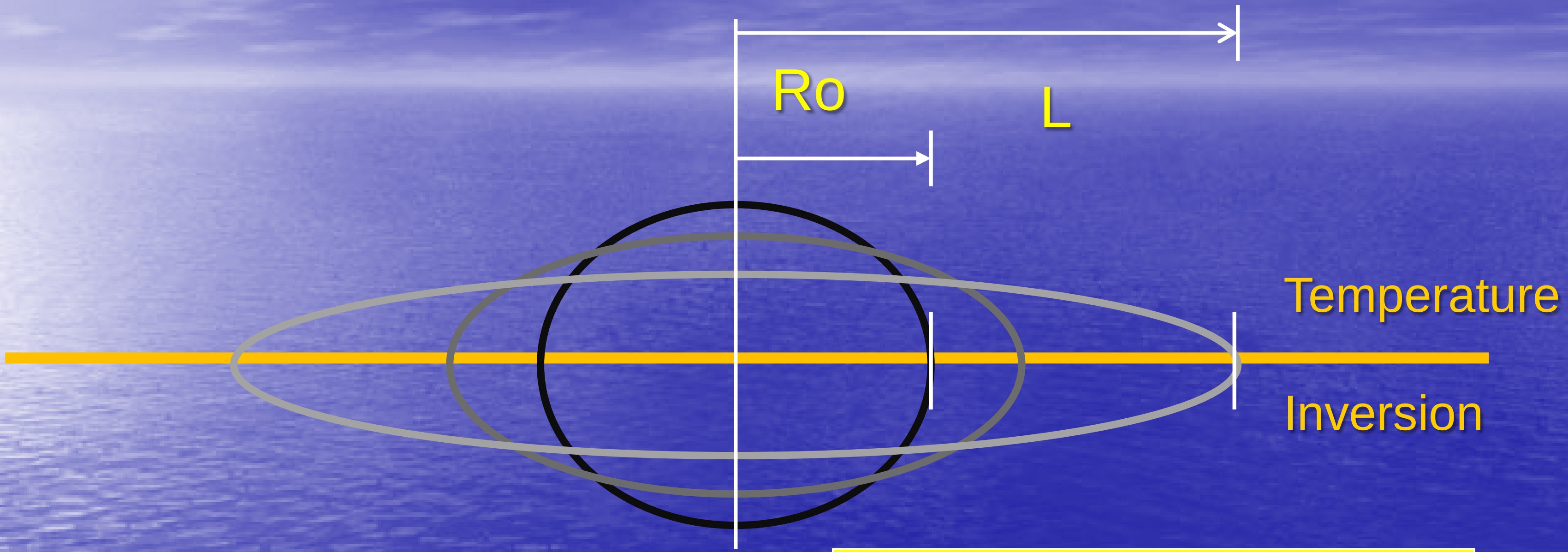
Weak points in ash cloud prediction by source models

Gravitational deformation of plume



- Plumes can spread out like oil slick on water

Gravitational deformation of plume



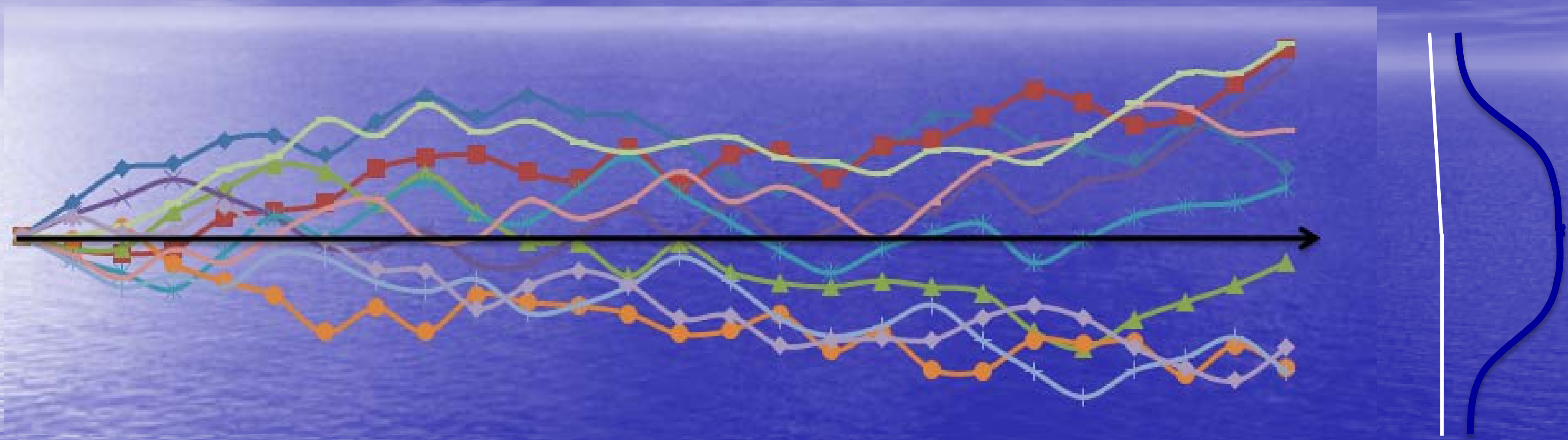
$$L/R_0 = \left[1{,}5\frac{t/T_p + 0{,}733}{1 + 0{,}3\left(L/R_0\right)^{-4}}\right]^{2/3}$$

$$T_p = (R_0/\Delta B g)^{1/2}$$

Plumes can spread out like oil slick on water (pancaking). To model the process temperature and density of plume and ambient air must be measured by radiosondes or airplanes. But satellite photos show visible ash clouds and provide data that can be used in support of ash cloud predictions.

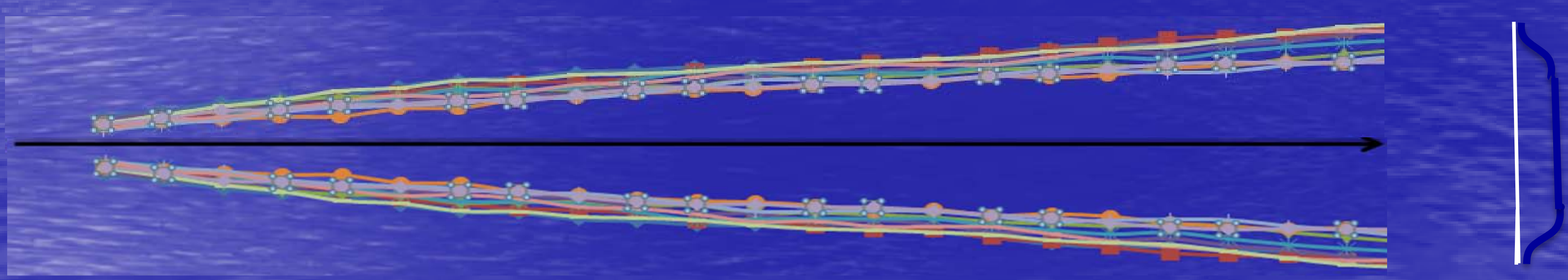
Diffusion vs. gravitational dispersion

Tracks of 10 individual puffs in the diffusion case and gravitational case

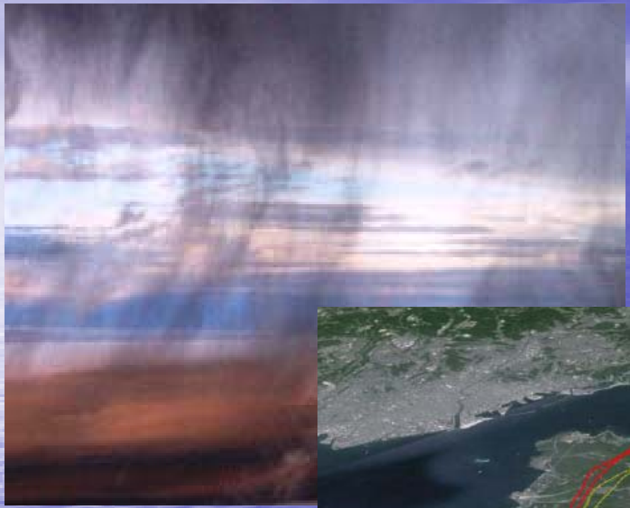


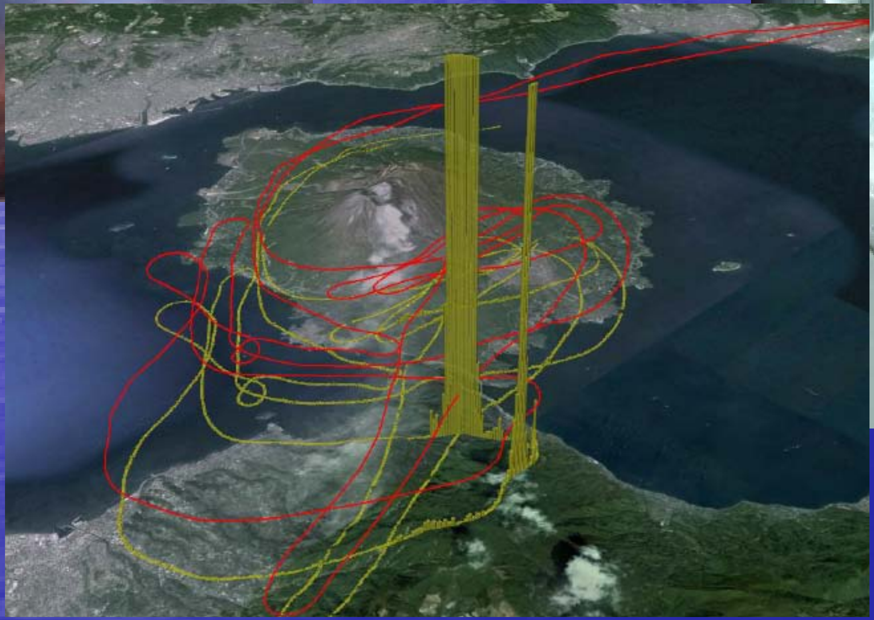
Abve: The cloud is one big horizontal mixng layer. No vertical dispersion

Below: Pancaking section in the middle, narrow mixing layers on the edges



The streak fallout proess 27.07 13





- Streaks increases source term uncertainty

Streak fallout Sakurajima 27.07 13

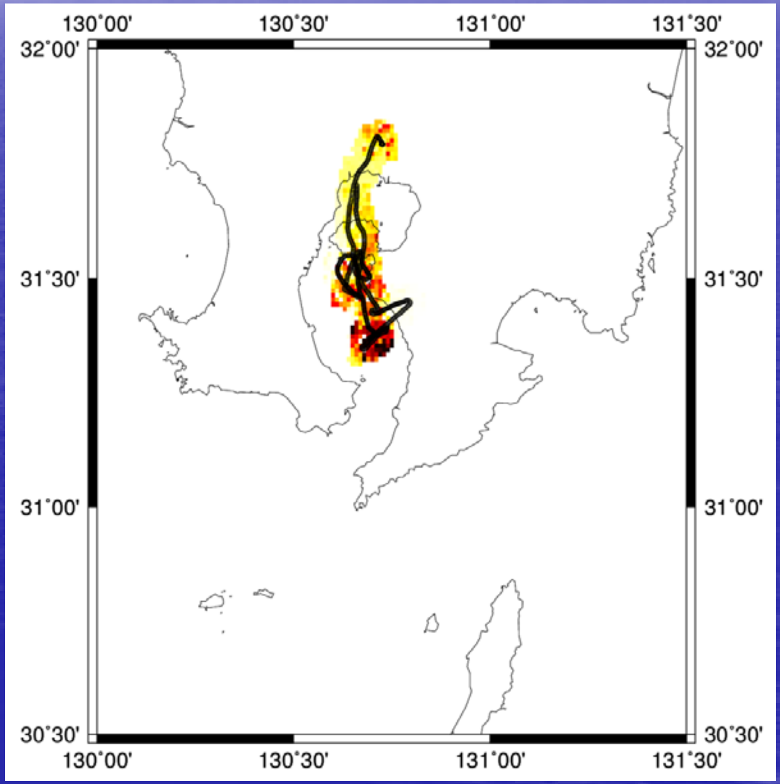
A chunk of cloud is falling down to earth with velocity 0,34 m/s and maximum concentration more than 44 mg/m^3. Picture taken 7 minutes before the measurement. Streaks increases source term uncertainty as they contain all grain sizes

Observation method

Dr. Eliasson (Univ. of Iceland) and their team observed the VA conc. above Sakurajima by using aircraft and skyOPC [Yasuda+2013]

Aircraft which uses in observation

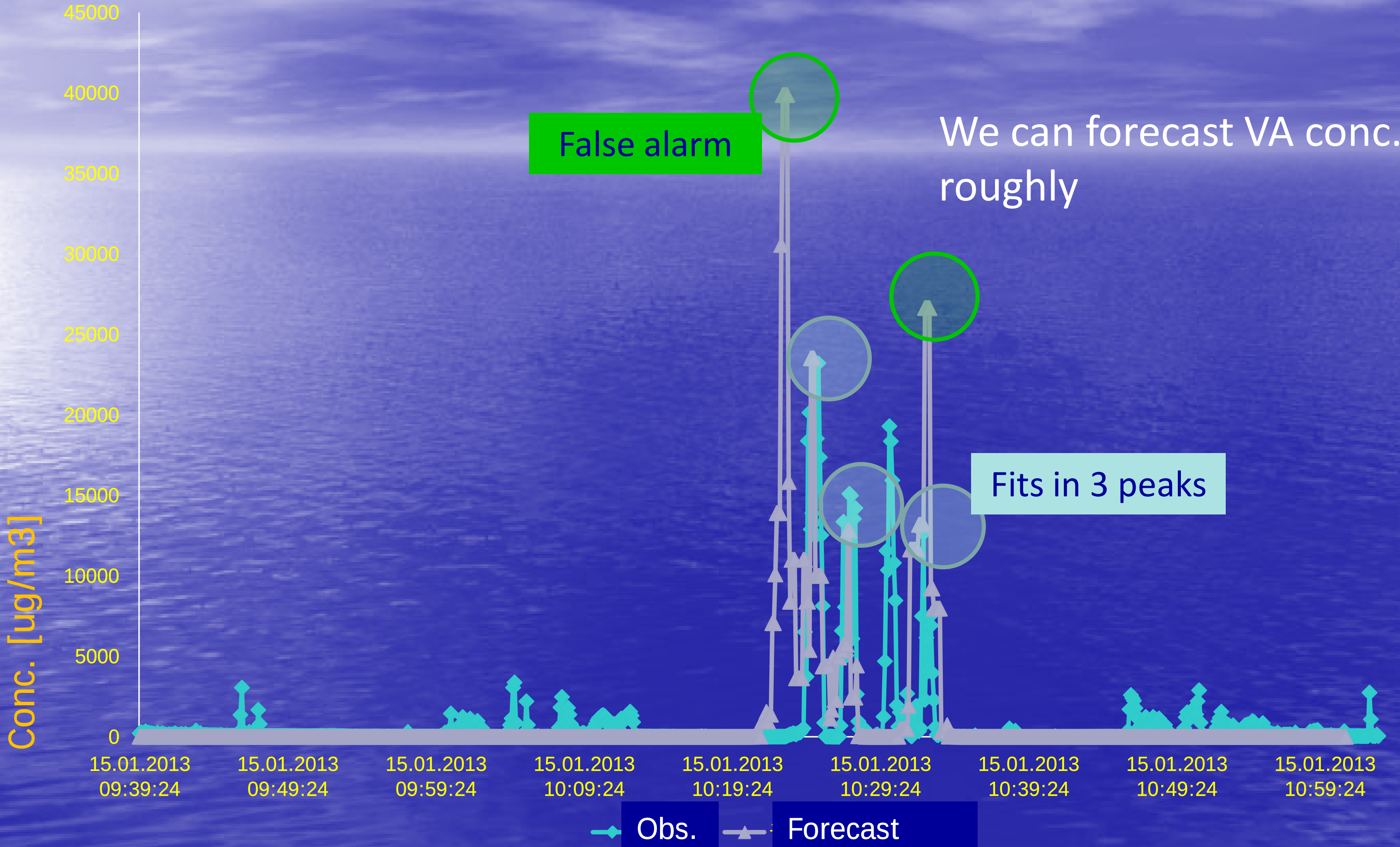
skyOPC (Portable aerosol spectrometer)



Obs. (black line : track of aircraft)

Courtesy of JMA, Tokyo

Result of forecast of concentration.



We can forecast VA conc. roughly

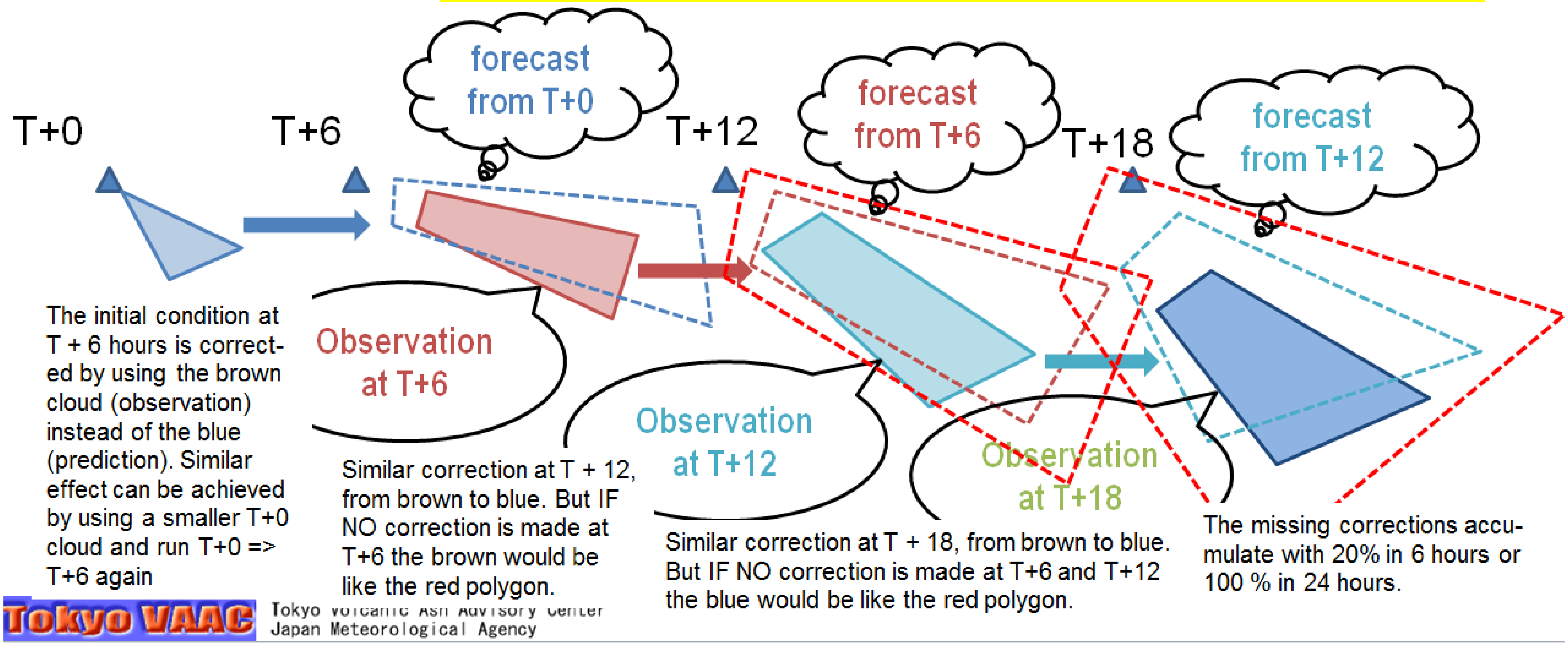
Courtesy of JMA, Tokyo

Tokyo VAAC Tokyo Volcanic Ash Advisory Center
Japan Meteorological Agency

Satellite photo correction for plume size

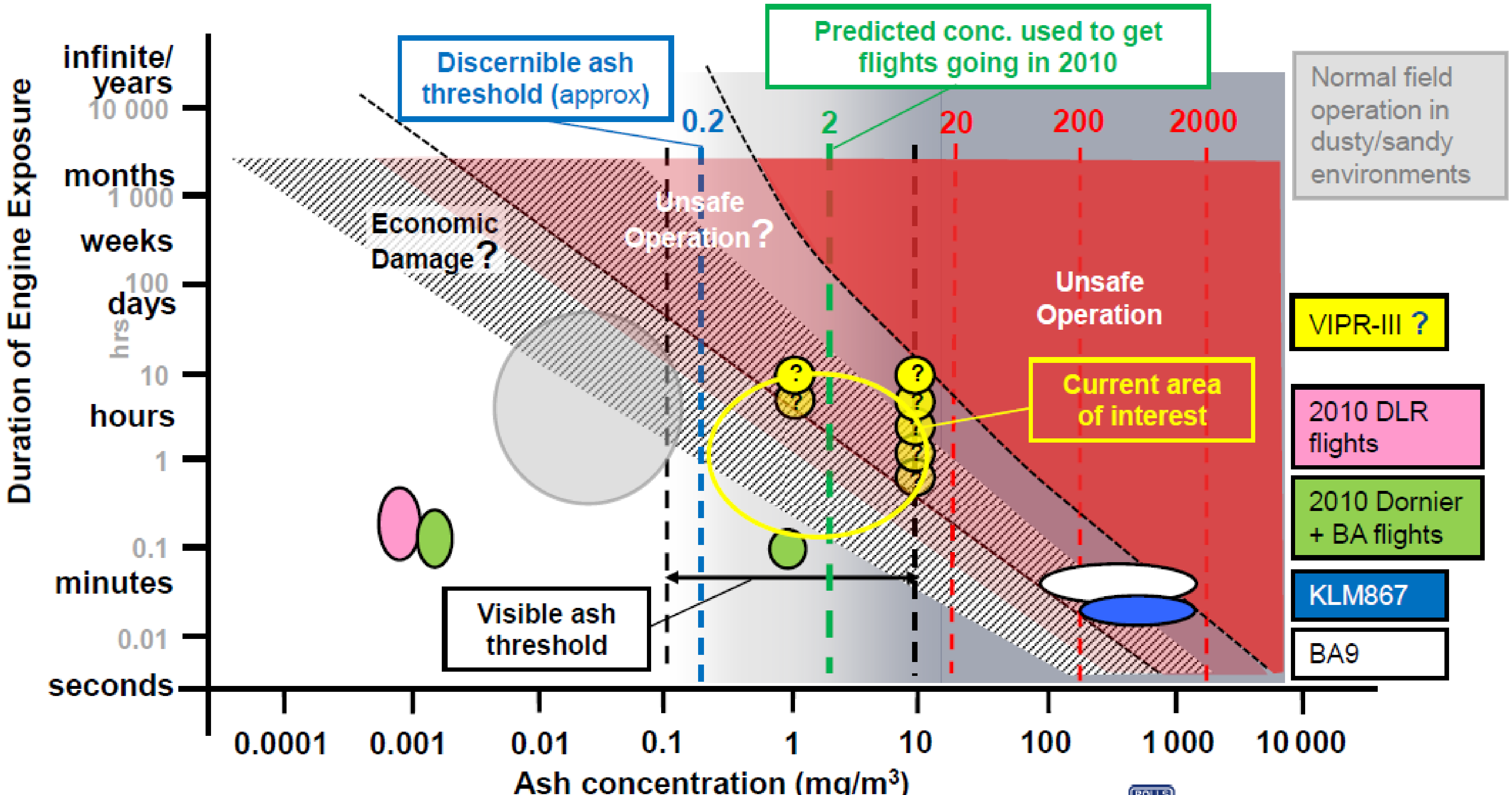
- VAAC Tokyo's 'unique' approach
  - Initial ash particles: use observed ash boundaries
  - Disperse particles from observation time (not from the origin)

Red polygones by JE: Estimated forecast with no correction



Courtesy of JMA, Tokyo

Jet Engine Research



Rolls-Royce

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Thank you for listening

Ash left by streak fallouts
Grimsvotn 2011: Thorsteinn Jonsson

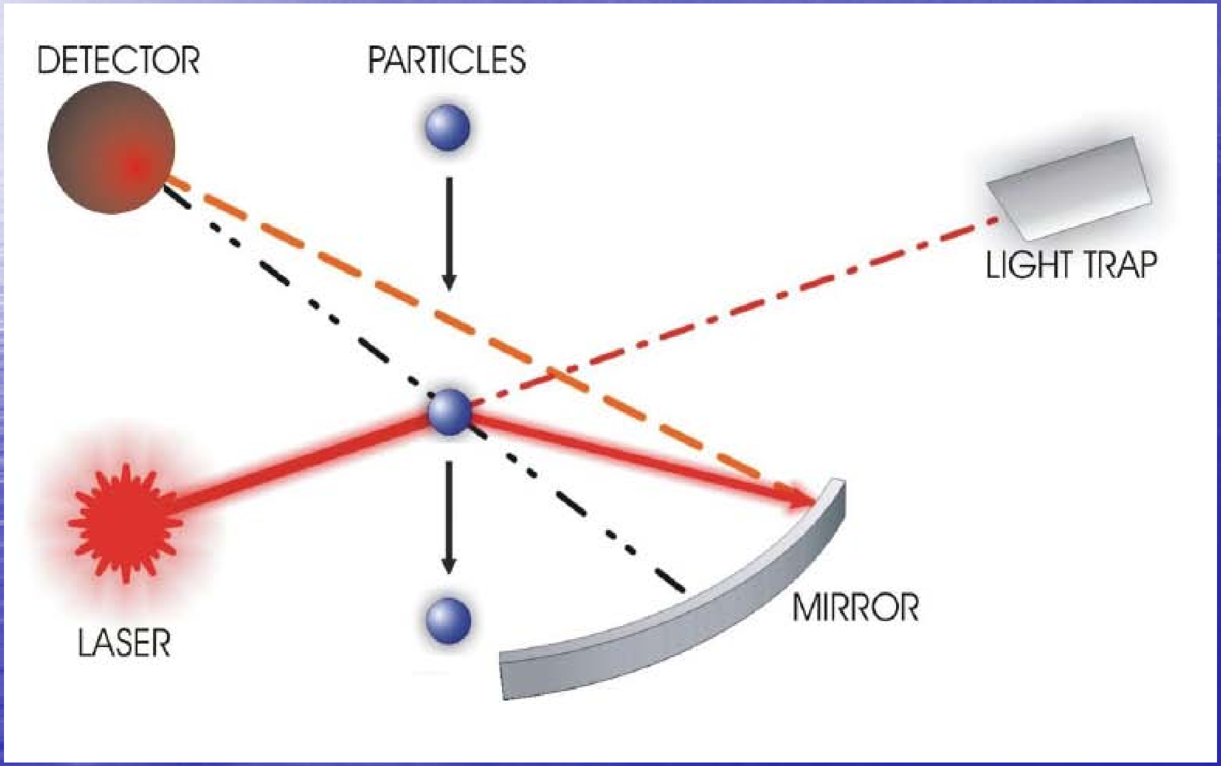
Installation in a (very) light aircraft

- Experimental aircraft for easy testing of 3 optical particle counters in parallel in the open atmosphere

Isokinetic inlet tubes without slipstream arrangement. Diameters have to fit the airspeed and quality control of results is important.

Courtesy Weber and Vogel, UAS Düsseldorf

Optical Particle Counter



Orthogonal laser scattering

Number of blinks counted

Duration of blink size indicator

Size of particles is approx only but improved esti-mates are being researched

Weak points in ash cloud prediction by source models

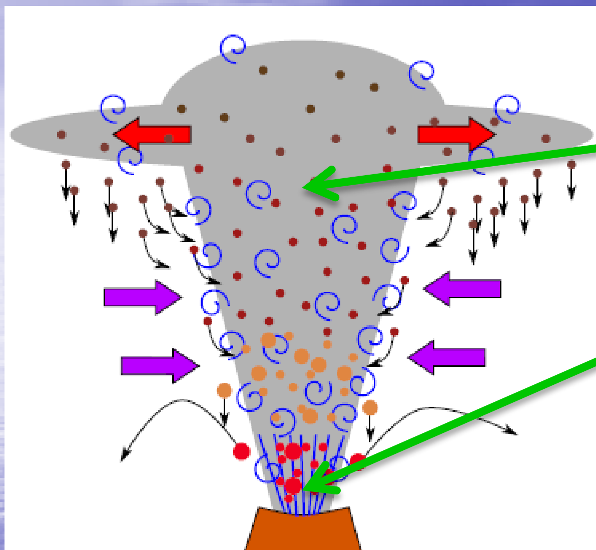
- Gravitational deformation of plume
- The streak fallout proess
- Turbulence and temperature data rare
- This has to be researched if source models are to be used in Air Navigation Service
- Source term uncertain by orders of magnitu.
- Purpose: Improve the predictions

Neutrally buoyant volcanic plumes

ΔT ° C	0,01	0,1	1	10
Air Δ o/oo	0,036	0,37	3,66	36,63
C mg/m^3	40	380	3.810	38.100
Max*flux kg/s	1	12	120	1.197
W_s, m/s B=1	0,6	1,9	6,1	19,1
d, μm	83	149	265	472
W_s, m/s B = 0,1	0,2	0,6	1,9	6,1
d, μm	47	84	149	265

* Hypothetical plume US st. atmosphere, R ≈ 1 km, U 10 m/s

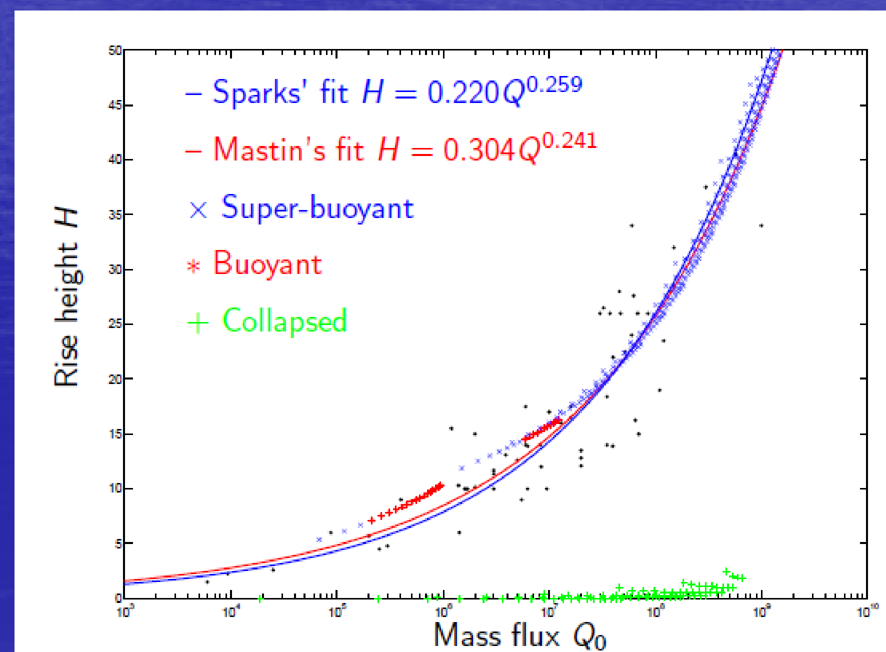
Spark– Mastin formula too high



Is probably valid up here

Should show emission down here

Difference entrained air



Theory provides Q ~ H^4 only

Coefficients logaritmic regression

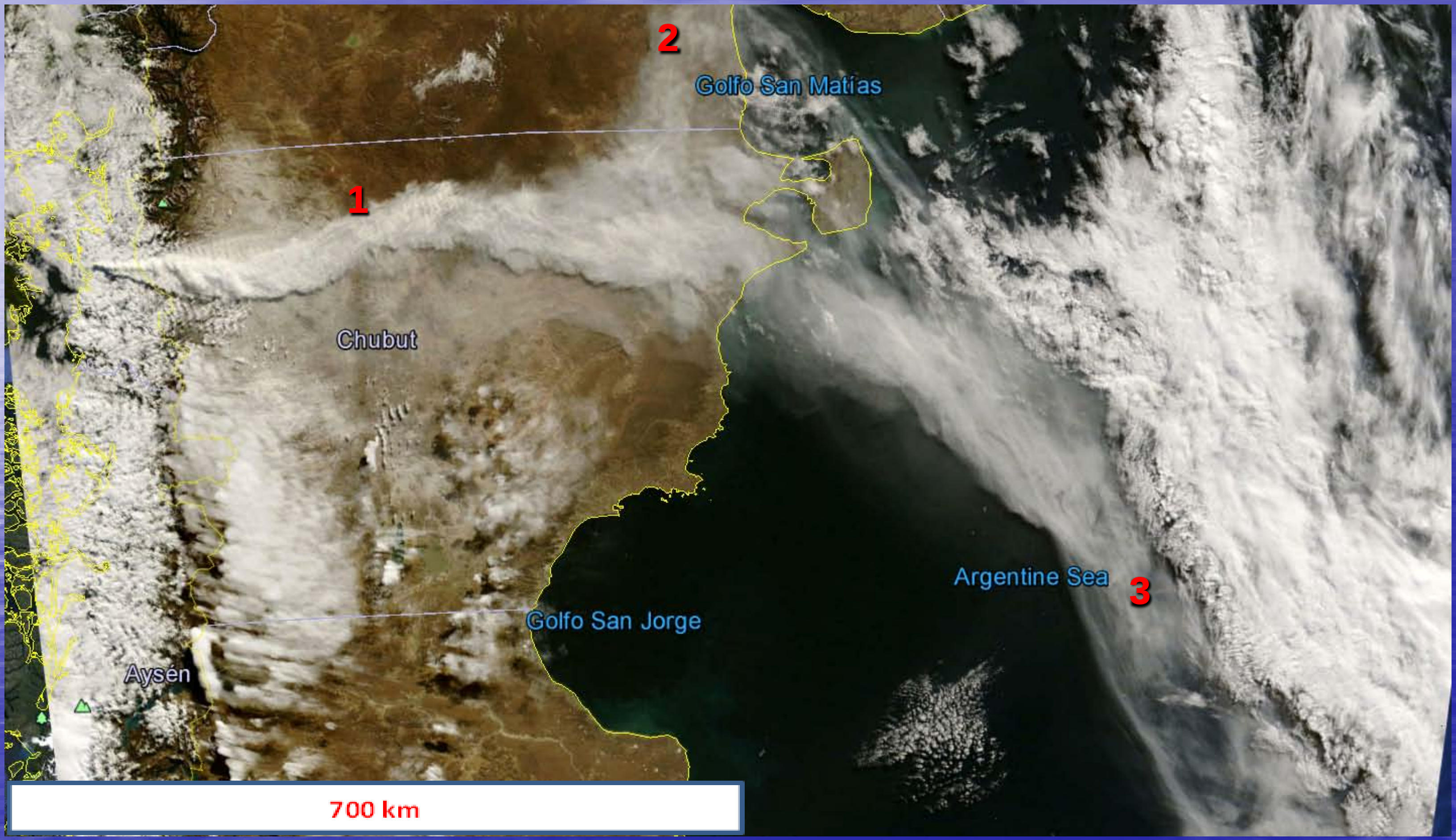
If data includes entrained air, so does formula.

Pictures by Woodhouse 2011

Numerical simulation of ash plumes

- Lagrangian or Eulerian adv.-diffusion eq. used, source data is plume height and S/M equation, wind data from NWP models
- All weak points cause ash load increase.
- Correction using satellite photos necesssary
- Change of method needs measured data not available from NWP data.
- => Too inaccurate: New technology based on calibration by measurements needed

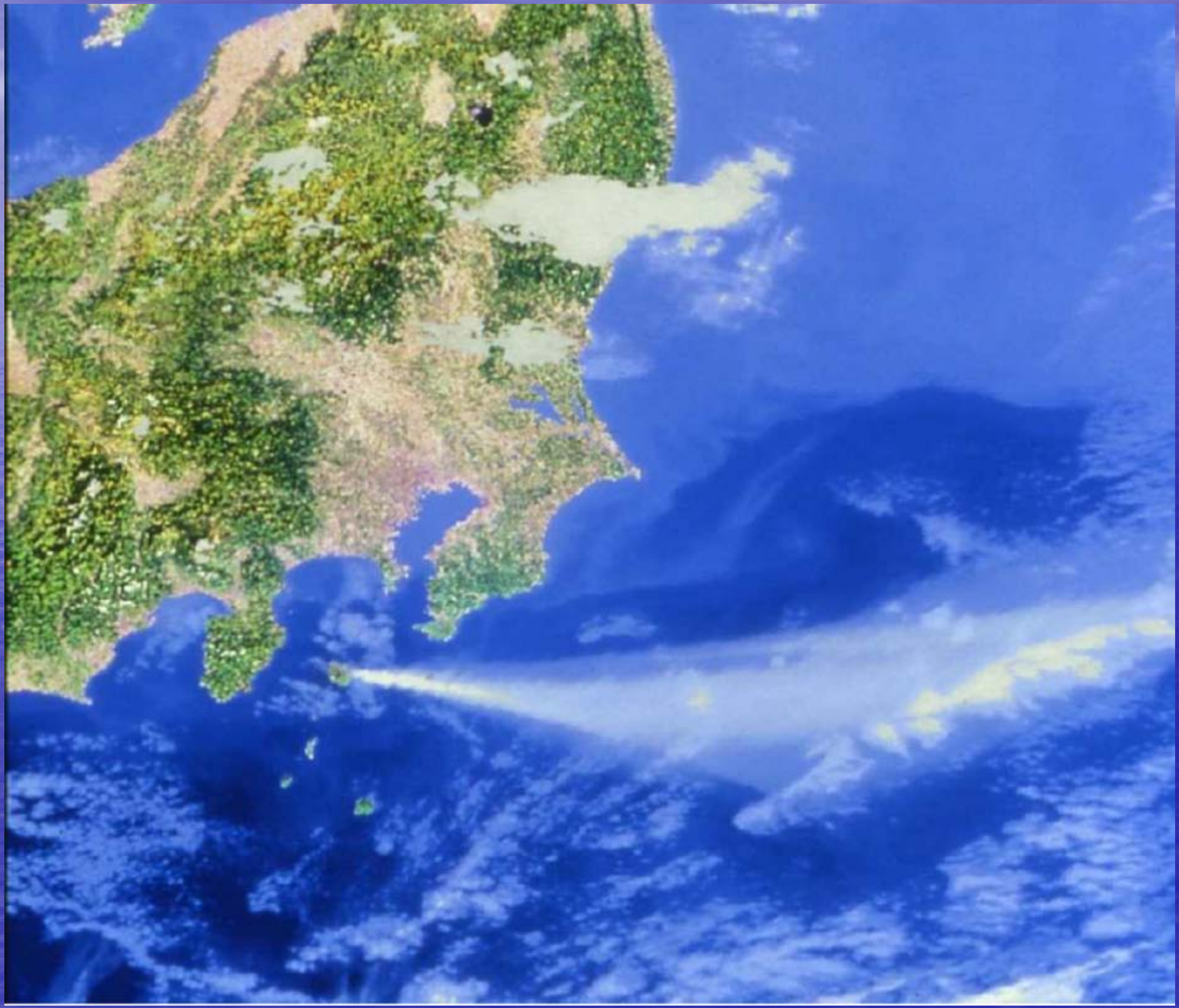
Chile’s Chaitén Volcano 2008



We see landscape effects 1, graviational crossflow 2 and frontal influence 3

Nasa (Modis) on Google Earth

Izu-Oshima Nov. 21st 1986



Plume riding in an inversion with windshear (NOAA)