

# A GIS-based tool for the estimation of impacts of volcanic ash dispersal on European air traffic

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|         |       |         |           |
|---------|-------|---------|-----------|
| LO 5397 | 15:15 |         | Cancelled |
| LO 763  | 15:15 | 201-244 | Cancelled |
| TP 581  | 15:20 |         | Cancelled |
| LO 5441 | 15:20 |         | Cancelled |
| W6 441  | 15:20 |         | Cancelled |
| OS 624  | 15:20 | 252     | Cancelled |

Cracow  
Munich  
Munich  
Munich  
Moscow  
Moscow  
Milan

AEG

eting  
fice

infor  
infor sk

## **AFTER 2010...**

ICAO International Volcanic Ash Task Force (IVATF)

1st IUGG-WMO Workshop (Bonadonna et al., 2011)

... and many more

## **NOW:**

2nd IUGG-WMO Workshop (Geneva)

Sesar Innovation Days 2013 (Stockholm)

**OPEN ISSUES** (thresholds, graphical output,  
uncertainty, communication)

**RESEARCH INTO OPERATION**



## Monitoring

@Volcano observatories  
and many others...

Satellite  
Ground-based  
Opportunistic

## Management

@Eurocontrol, many others...

Training (VOLCEX)  
Tools (EVITA)  
SRA (Safety Risk Assessment)

## Modeling

@VAACS and many others...  
Different models and strategies





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and many others...

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**LINK** modeling  
and management

# HOW? GIS-BASED TOOL

Results of ash  
dispersal modeling

Air traffic data

**Automated  
GIS-based overlap**

**Expected impacts**

**Where, When, How?**

# ASH DISPERSAL MODELLING

**INPUTS:** Meteorological (wind speed and direction, humidity, temperature, etc.)

Volcanological (column height, duration, grain size, etc.)

**Calculate ash concentration on a 4-D domain**

**OUTPUTS:** **Binary files** (grib, **Netcdf**, HDF5)  
(usually contain a header)

Metadata, but no standard/harmonized output

# How does a Netcdf look like?

chiara@chiara-Latitude-E6430: ~

```
lat = 141 ;
alt = 101 ;
time = UNLIMITED ; // (241 currently)
variables:
  float lon(lon) ;
    lon:units = "degrees_east" ;
    lon:description = "longitude. East of Greenwich" ;
  float lat(lat) ;
    lat:units = "degrees_north" ;
    lat:description = "latitude. North of the Equator" ;
  float alt(alt) ;
    alt:units = "m" ;
    alt:description = "heights (a.s.l.)" ;
  float time(time) ;
    time:units = "h" ;
    time:description = "time after 0000 UTC" ;
  char TIMES(time) ;
    TIMES:units = "YYYY:MM:DD:HH:SS" ;
    TIMES:description = "Time instance" ;
  float TOPOGRAPHY(lat, lon) ;
    TOPOGRAPHY:units = "m" ;
    TOPOGRAPHY:description = "Topography" ;
  float LOAD(time, lat, lon) ;
    LOAD:units = "kg/m2" ;
    LOAD:description = "Particle growth rate" ;
  float THICKNESS(time, lat, lon) ;
    THICKNESS:units = "cm" ;
    THICKNESS:description = "Ground ice thickness" ;
  float C_GRND(time, lat, lon) ;
    C_GRND:units = "gr/m3" ;
    C_GRND:description = "Particle concentration at ground" ;
  float C_PM05_GRND(time, lat, lon) ;
    C_PM05_GRND:units = "gr/m3" ;
    C_PM05_GRND:description = "PM05 concentration at ground" ;
  float C_PM10_GRND(time, lat, lon) ;
    C_PM10_GRND:units = "gr/m3" ;
    C_PM10_GRND:description = "PM10 concentration at ground" ;
  float C_PM20_GRND(time, lat, lon) ;
    C_PM20_GRND:units = "gr/m3" ;
```

Ncview 1.93g David W. Pierce 24 February 2009

variable=C\_FL100  
frame 31/241  
displayed range: 0 to 0.000531301 gr/m3  
Current: (i=4, j=111) 0 (x=-29, y=62.75)

Quit ->1 << < || > >> Edit

3gauss Inv P Inv C M X2 Linear A

Var: TIMES TOPOGRAPHY

C\_GRND C\_PM05\_GRND C\_PM10\_GRND C\_PM20\_GRND

COL\_MASS COL\_MASSPM05 COL\_MASSPM10 COL\_MASSPM20

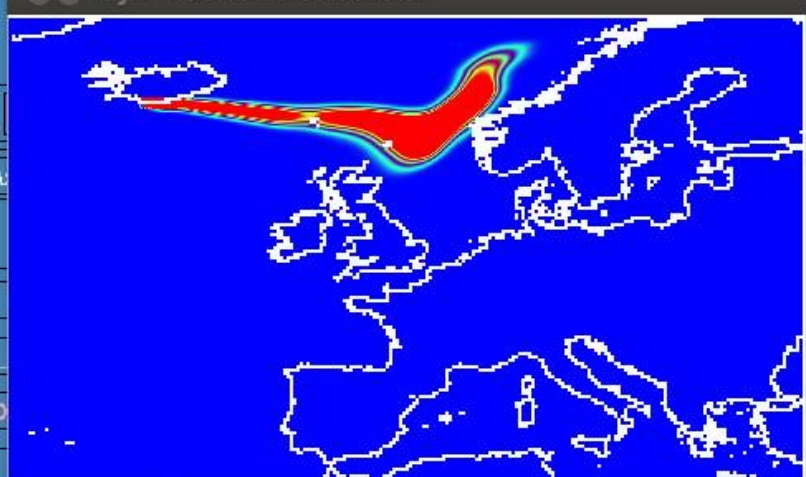
C\_FL050 C\_FL100 C\_FL150 C\_FL200

C\_FL250 C\_FL300 C\_FL350 C\_FL400

AOD CON

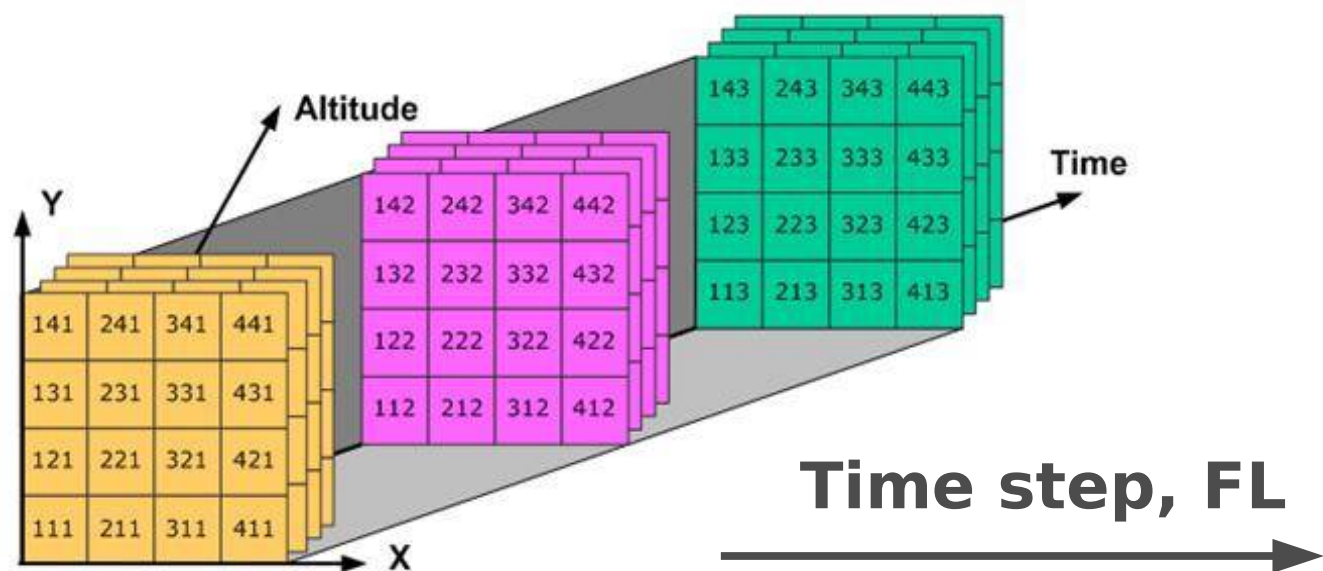
| Dim:  | Name: | Min: | Current: | Max: | Units:        |
|-------|-------|------|----------|------|---------------|
| Scan: | time  | 0    | 30       | 240  | h             |
| Y:    | lat   | 35   | -Y-      | 70   | degrees_north |
| X:    | lon   | -30  | -X-      | 30   | degrees_east  |

Eya-14-24-APR-3-Mas.res.nc



# POST-PROCESSING

Automated post-processing and production of hourly maps



Binary file

15 April 2010 - 22.00 UTC

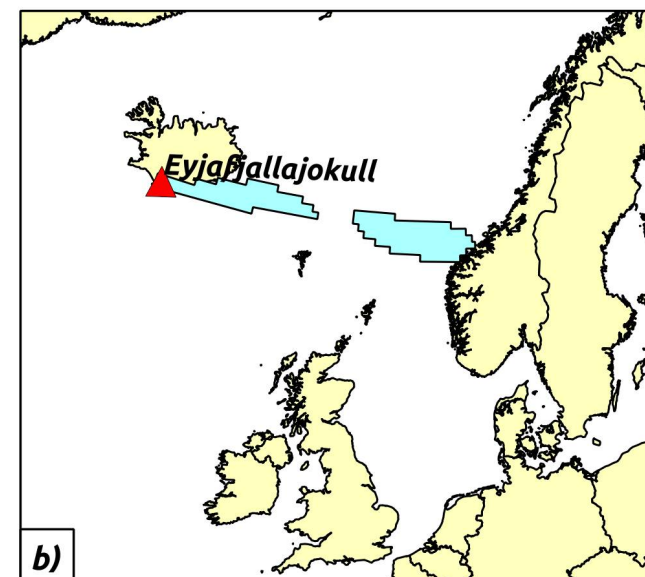
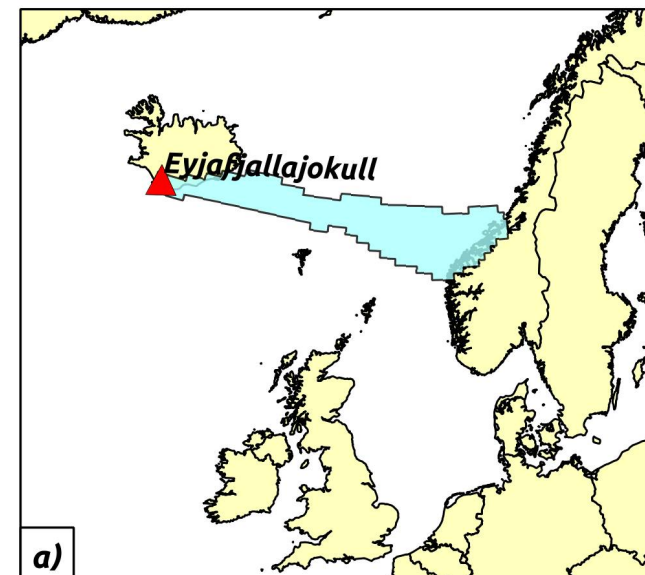
▲ Eyjafjallajokull

■ Ash concentration at FL150

Ash concentration threshold:

a) zero tolerance ( $2 \times 10^{-5}$  mg/m<sup>3</sup>)

b) 0.2 mg/m<sup>3</sup>



0 1000 2000 km

# CASE-STUDY: Eyjafjallajökull 2010

Numerical simulations performed at BSC (Folch et al. 2011)

Ash concentration maps for selected Flight Levels (FLs)

Critical ash concentration: zero tolerance, 0.2 and 2 mg/m<sup>3</sup>

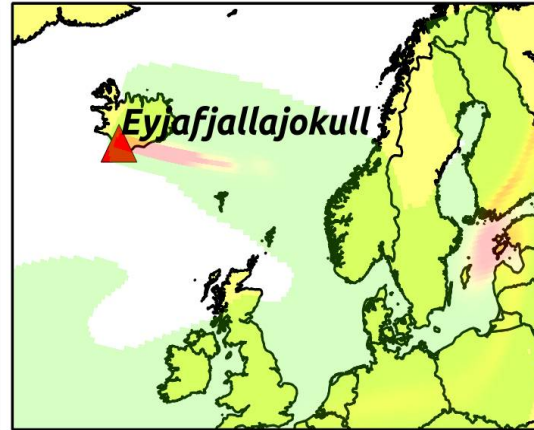
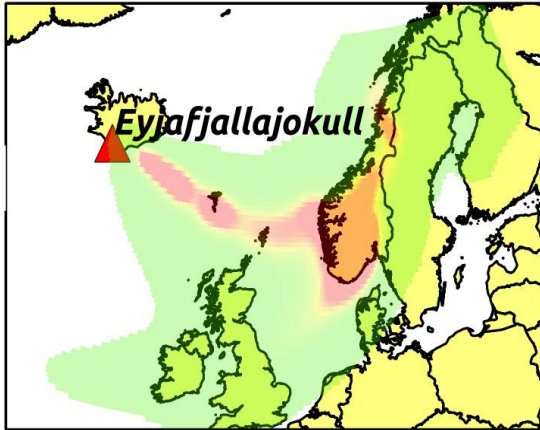


# ASH DISPERSAL MODELLING RESULTS

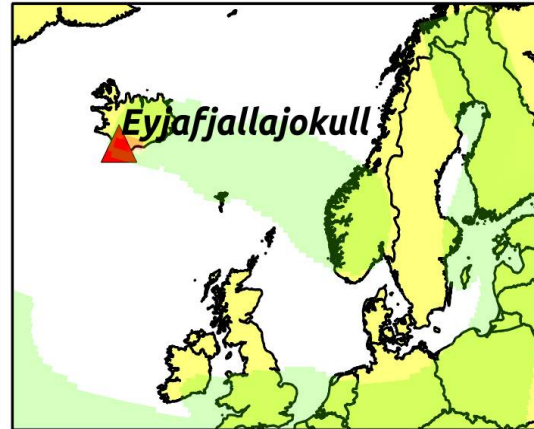
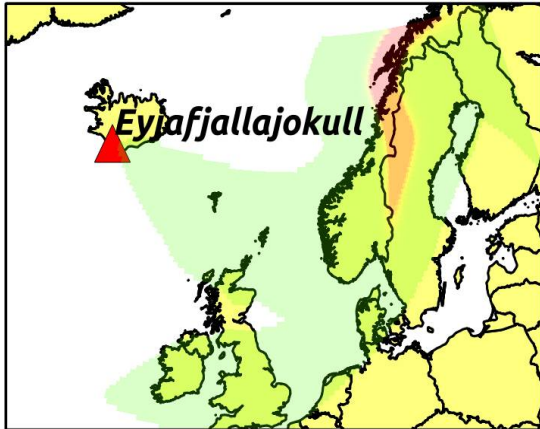
15 April

16 April

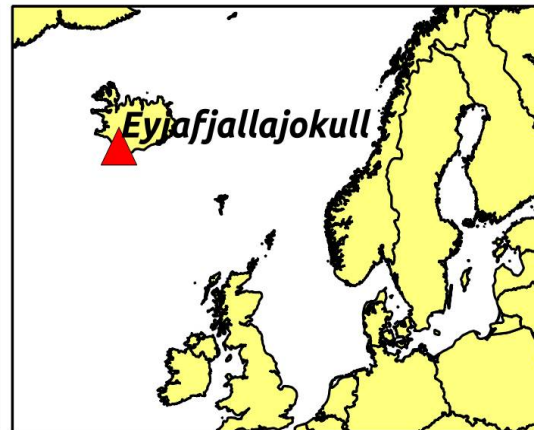
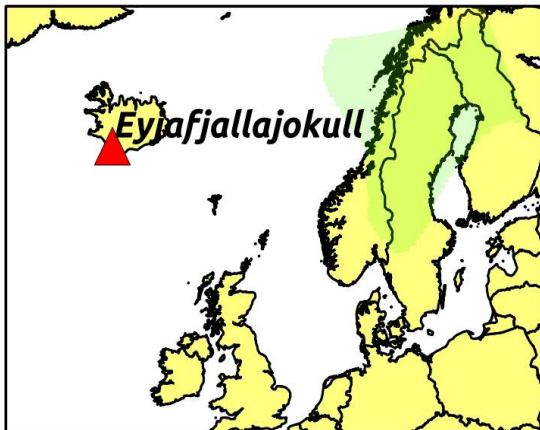
FL100



FL200



FL300



Modeling results - 14.00 UTC

▲ Eyjafjallajökull volcano

Ash concentration airborne

■ > 0

■ > 0.2 mg/m³

■ > 0.4 mg/m³

0 1000 2000 km

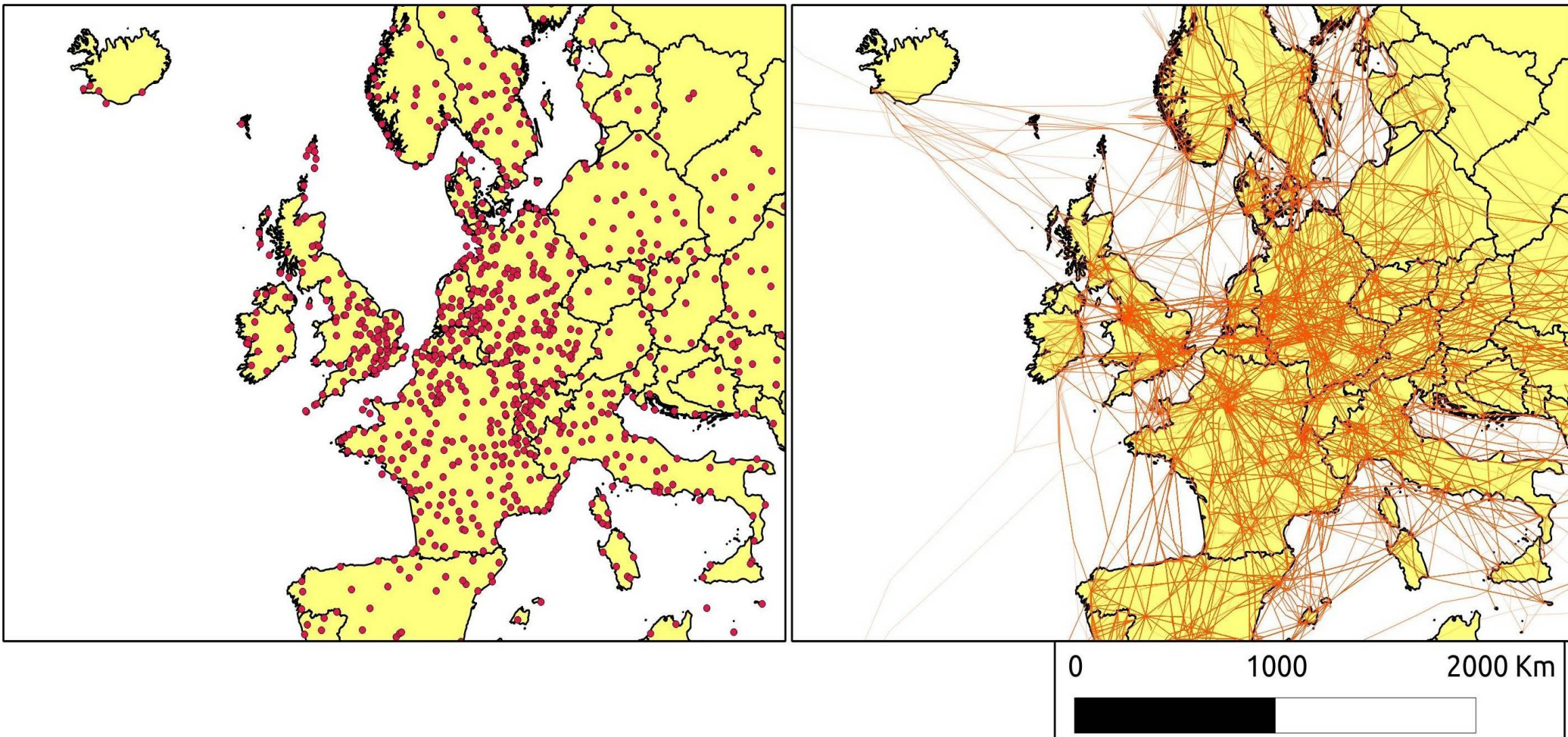


# AIR TRAFFIC DATA

European airports and Intra-European routes

Use of last filed flight plan (Source: Eurocontrol DDR m1so6 database)

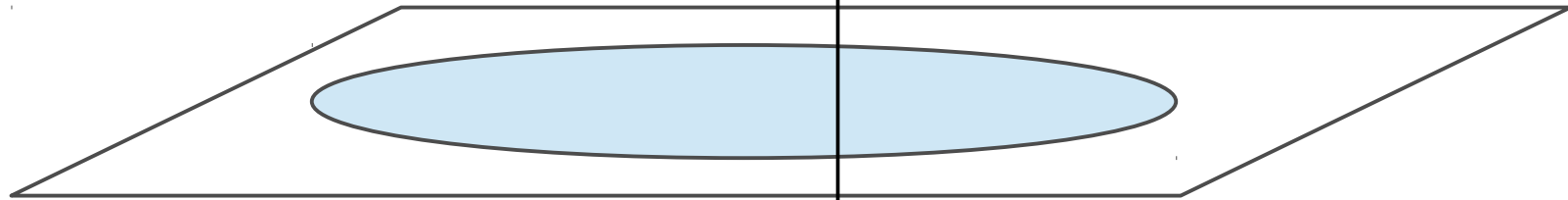
ASSUMPTION: Data for 14/04 can be used to analyze 15-16/04



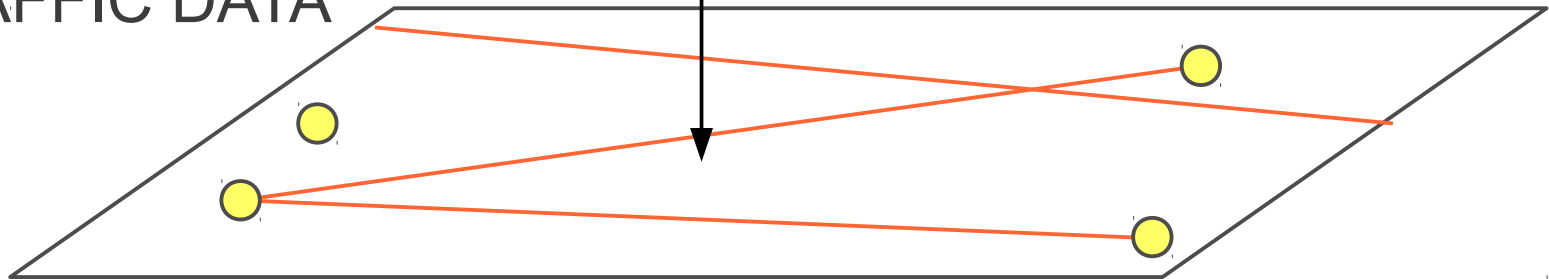
# METHODOLOGY

**GIS-BASED OVERLAP AT FL  
TIME STEP = 1 HOUR**

ASH CLOUD



AIR TRAFFIC DATA



**EXPECTED IMPACTS**

## **Assumptions:**

Airport disrupted only if overlapped by ash at FL050

Flight disrupted only if intersect ash cloud at FLs

Not accounting take-off/landing disruptions

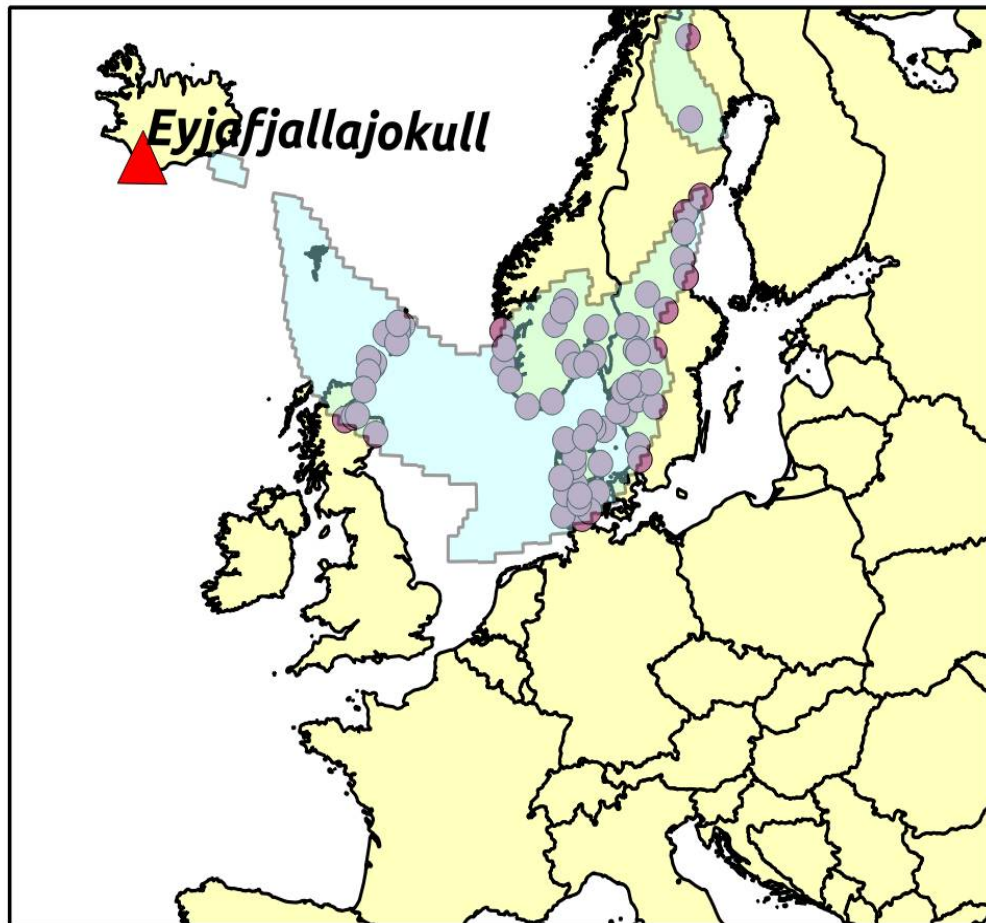
All filed flights plans are operating

# IMPACT ASSESSMENT - Routes

- 1- **Extract flights** (SQL query) at FL interval and time-step
- 2- **Overlap** ash cloud and selected flights
- 3- **Extract way-points and segments** scheduled at time-step
- 4- **Calculate** length of disrupted segments and exposed time

# EXAMPLE - Airports

For each time step (1 hour) and ash concentration threshold  
Identify expected disruptions at airports (FL050)



15 April - 21.00 UTC



Eyjafjallajökull volcano



Ash cloud (0 tolerance) at FL050



Airports impacted

0

1000

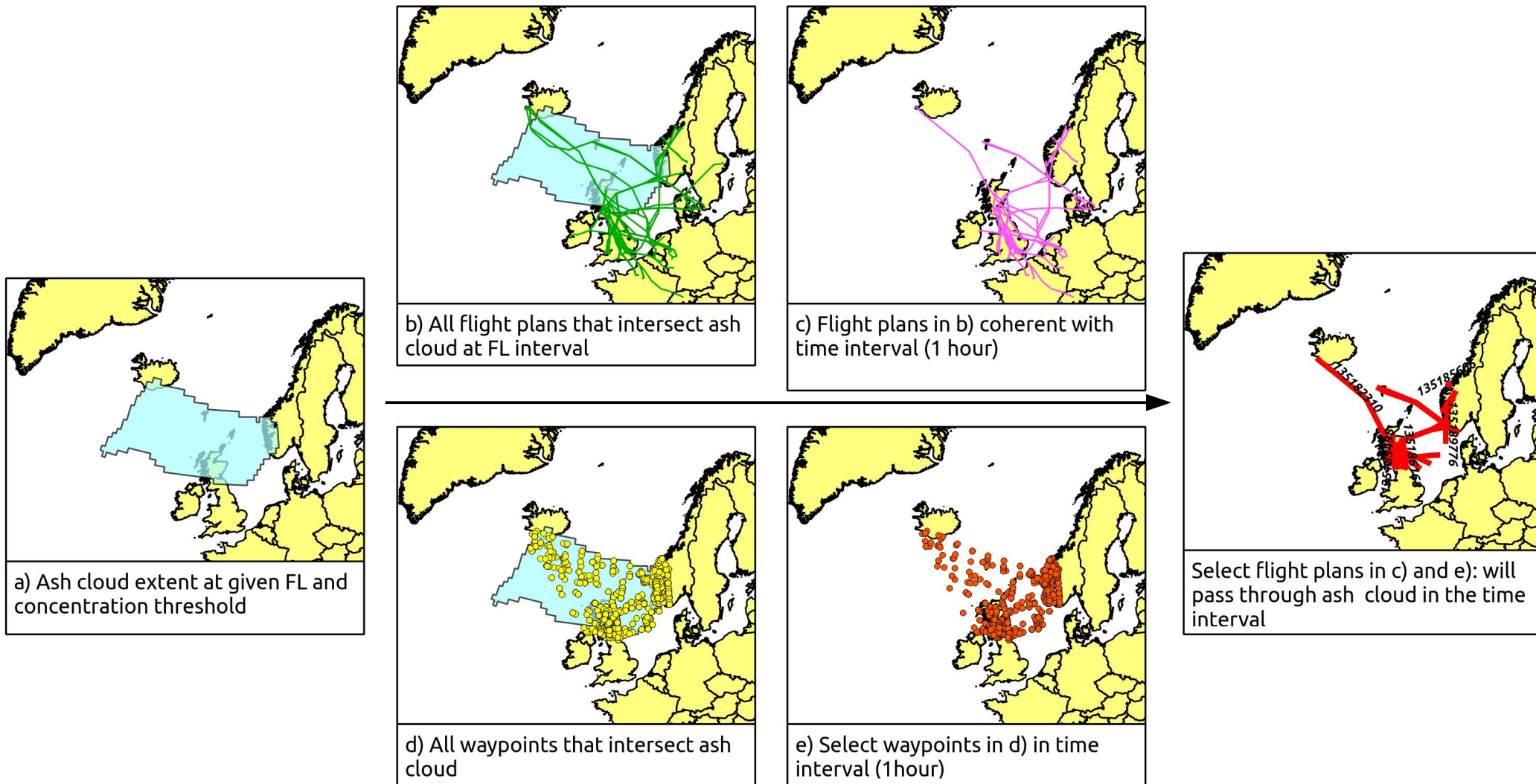
2000 km



# EXAMPLE - Routes

Identify routes expected to be disrupted

For each time step, FL, ash concentration threshold



# IMPACT ASSESSMENT - Routes

## Qualitative impact rating

based on percentage of flight disrupted

Comparative (not absolute) measure of impacts

| Length disrupted x (%) | Impact | Impact rating                                                                           | Strategy        |
|------------------------|--------|-----------------------------------------------------------------------------------------|-----------------|
| $X < 10\%$             | Low    | 1    | Small deviation |
| $10\% < x < 80\%$      | Medium | 2  | Change FL       |
| $X > 80\%$             | High   | 3  | Not flying      |

# RESULTS - Hourly tables

Impacted flights

Expected disruption (length, duration, %)

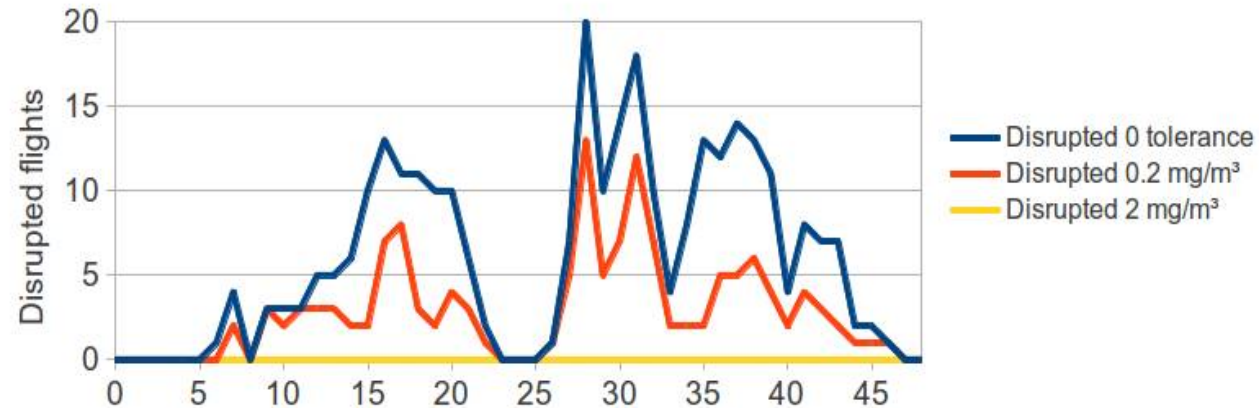
| Flight ID | Time tot (min) | Length tot (km) | Length dis (km) | Time dis (min) | Length dis (%) | Impact |
|-----------|----------------|-----------------|-----------------|----------------|----------------|--------|
| 135199866 | 36             | 251             | 17              | 2              | 7              | 1      |
| 135195266 | 268            | 974             | 1724            | 47             | 18             | 2      |
| 135199526 | 40             | 425             | 280             | 26             | 66             | 2      |
| 135200495 | 32.83          | 247             | 221             | 29             | 89             | 3      |

(excerpt of impacted routes for 15 April 2010 - FL150 – 14.00 to 15.00 UTC)

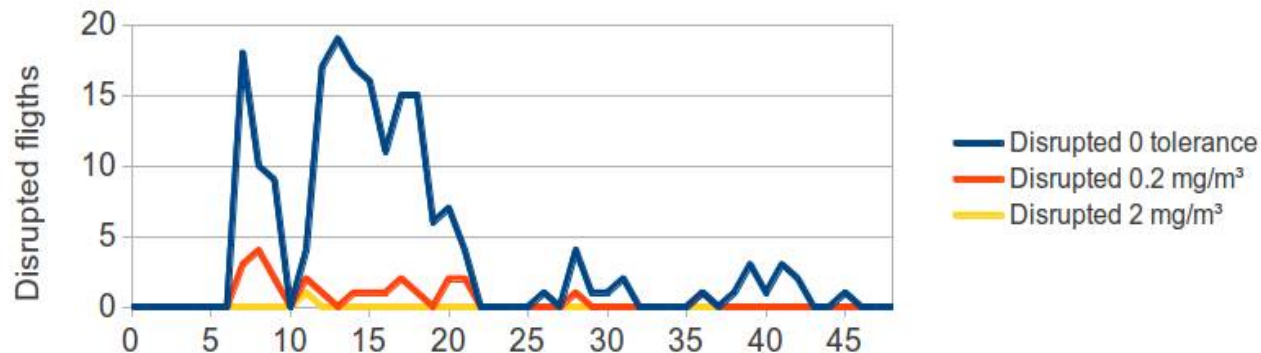
# RESULTS - Time series

Impacted flights for each hour at considered FLs

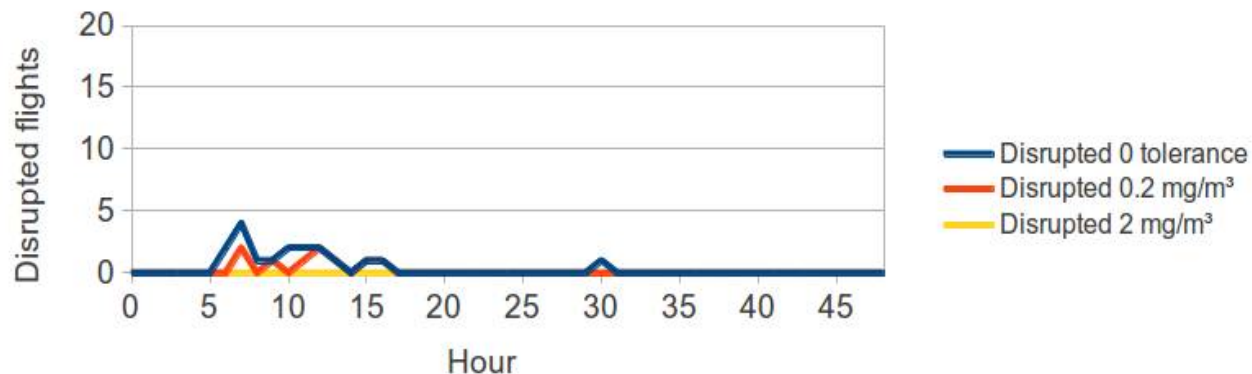
FL150



FL200



FL250



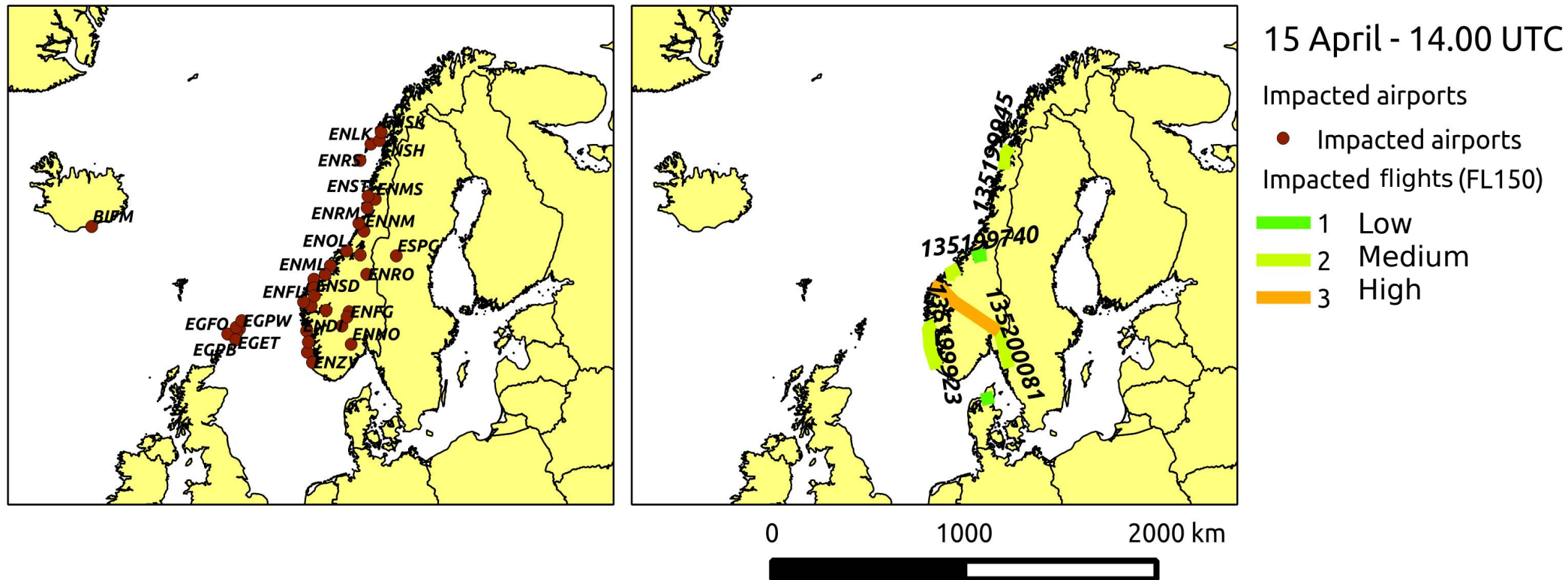
# RESULTS - Graphical output

Digital maps (GIS) of disrupted airports and flights

Visualization of impacted flights

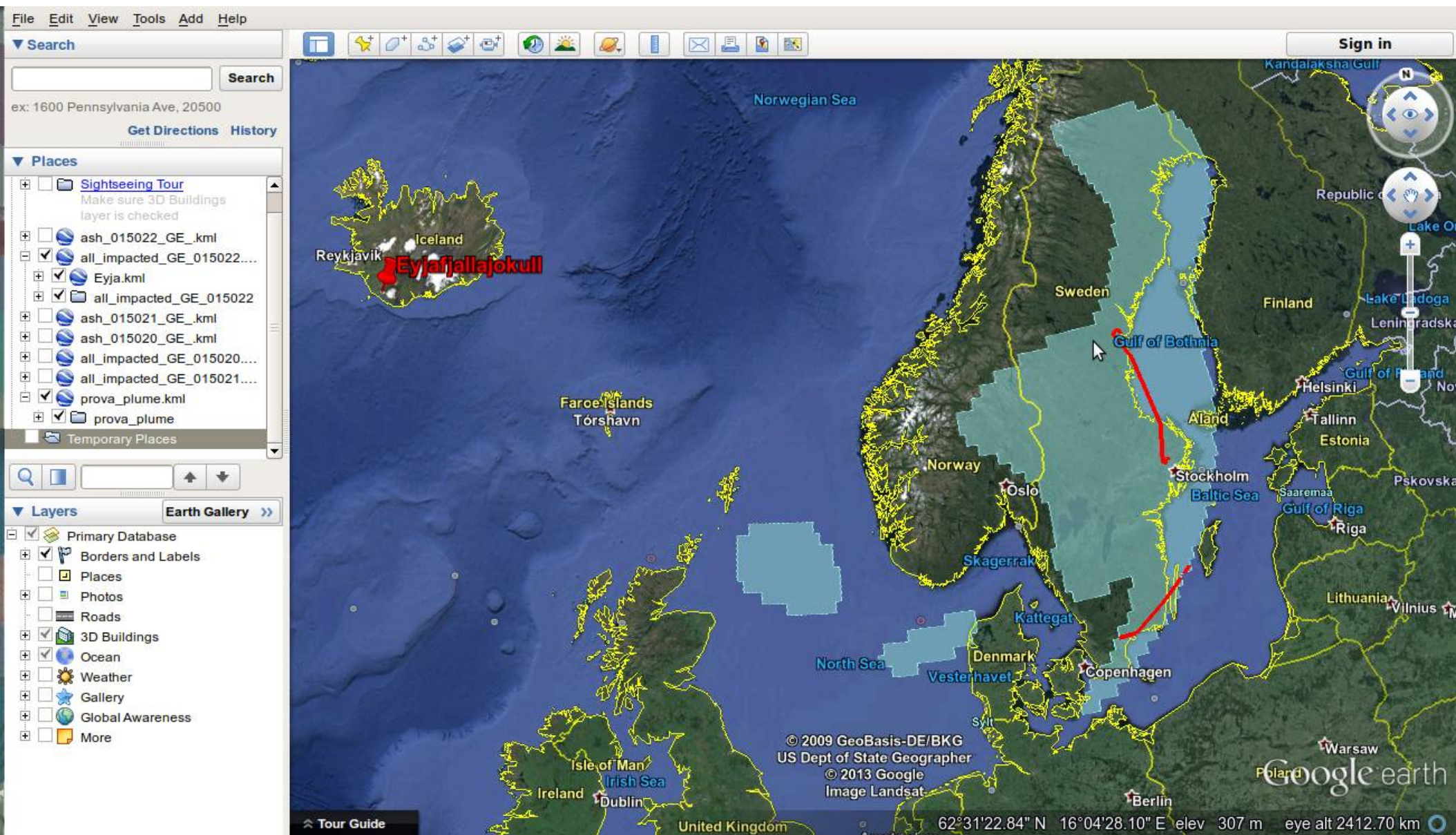
Impact assessment rating

**Advantage:** supports further spatial analysis



# RESULTS - Google Earth video (screenshot)

**Advantage:** user friendly, easy to share



# MAIN FINDINGS

Substantial **impacts** at lower FLs, but low at upper FLs

**Possible rerouting** especially in case of low columns

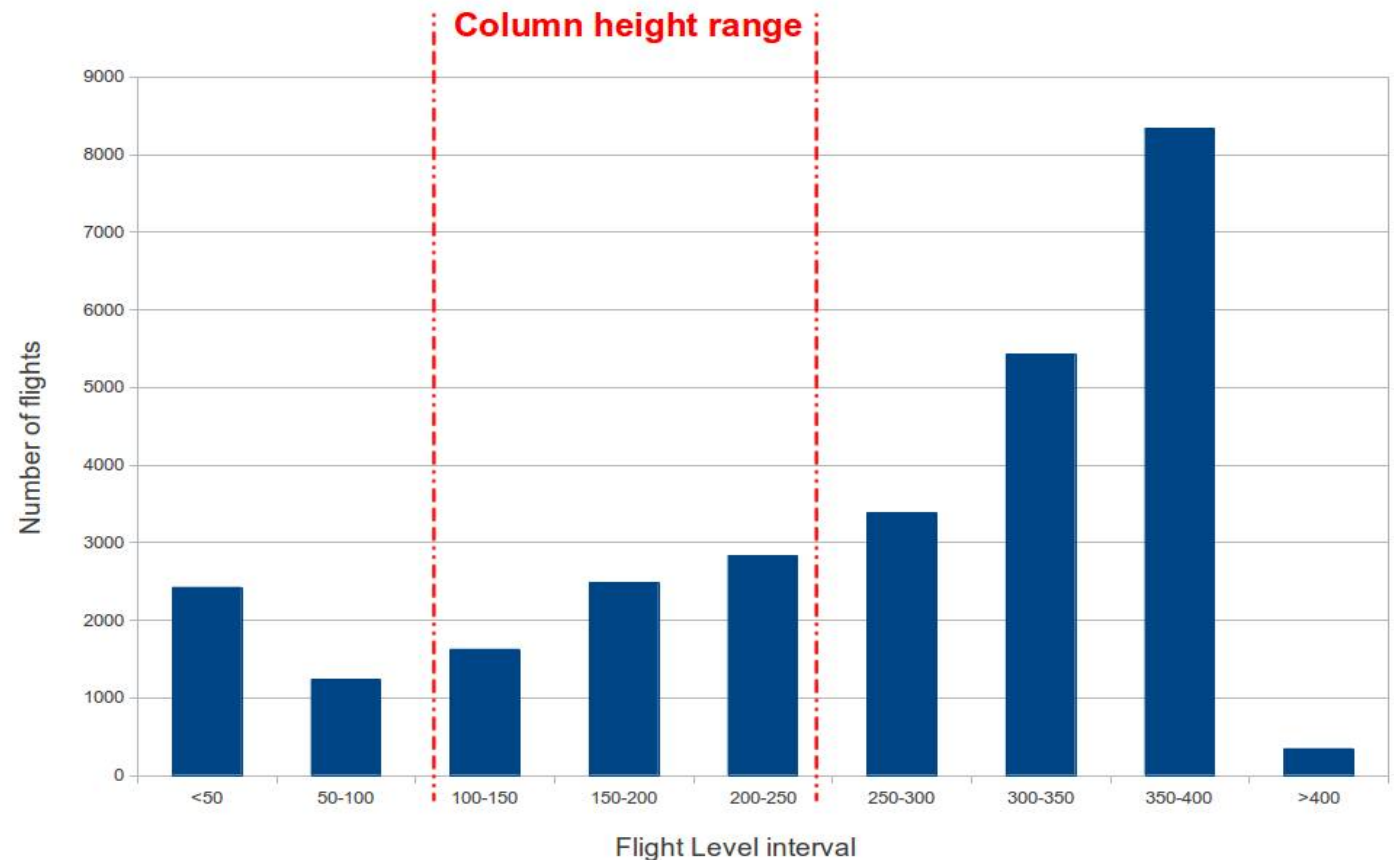
Most affected FLs:

100 ÷ 250

**BUT**

Most congested

FLs: 300 ÷ 400



# DISCUSSION:

Comparison with 2010 shows a reduction of impacted flights

**BUT:**

Strong assumptions in methodology (all filed flight plans are operating, not considering disruptions due to airport closure)

In 2010, precautionary closure of great part of Central European airspace

Secondary disruptions (fleet and crew allocation, ...)

Differences in the expected impacts from those in 2010  
(better characterization of input parameters, improved modeling strategies)

**A direct comparison with 2010 is therefore biased!**

# FURTHER WORK AND PERSPECTIVES:

| LIMITATIONS        | ADVANTAGES                    | IMPROVEMENTS                   |
|--------------------|-------------------------------|--------------------------------|
| Strong assumptions | Link modelling and management | Economic aspect                |
| Not operational    | Synthesis                     | Become operational             |
| Uncertainties      | Hourly analysis               | Include probabilistic forecast |
|                    | Model-independent             | Include satellite retrievals   |

**Lot of work to be done!!!**

Account for closed airports

Spatial and temporal uncertainties

Stakeholders feedback – SURVEY to be performed

# CONCLUSIONS

Improved **post-processing** of ash dispersal modeling results

**Automated impact assessment at higher temporal resolution**

**Simplified** but **multidisciplinary** approach improves air traffic management during volcanic eruptions

Importance of **team-working** and diversity



**Thank you :)**

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