The Use of On-Demand Forecasts for Weather Optimization of Aircraft Tracks

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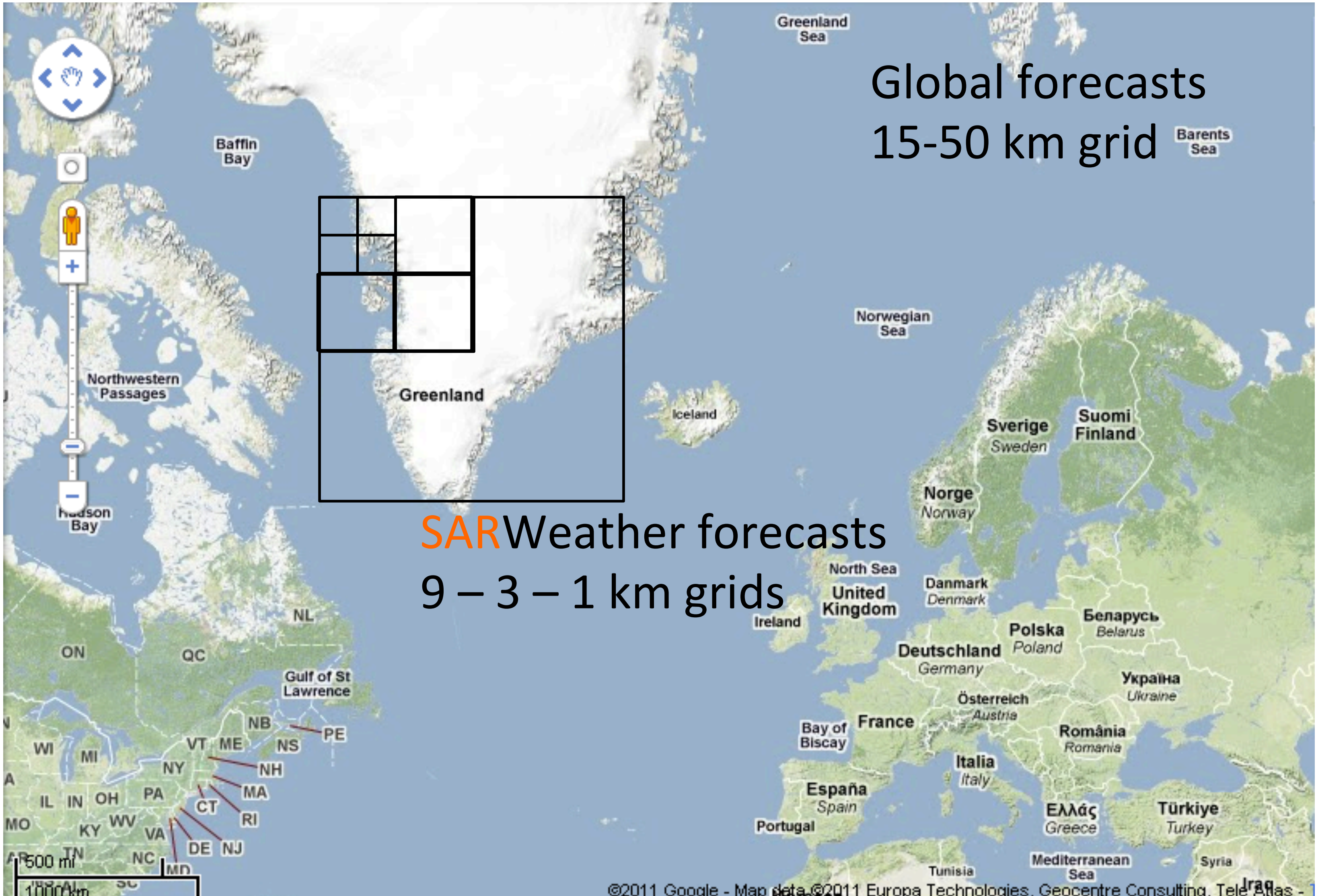
Overview

- Numerical Weather Models
  - Importance of resolution
- Routing optimization using NWM
- Current Crisis Response System
  - SARWeather general description
- Use of observations from UAS's
- On-going research
- Conclusions

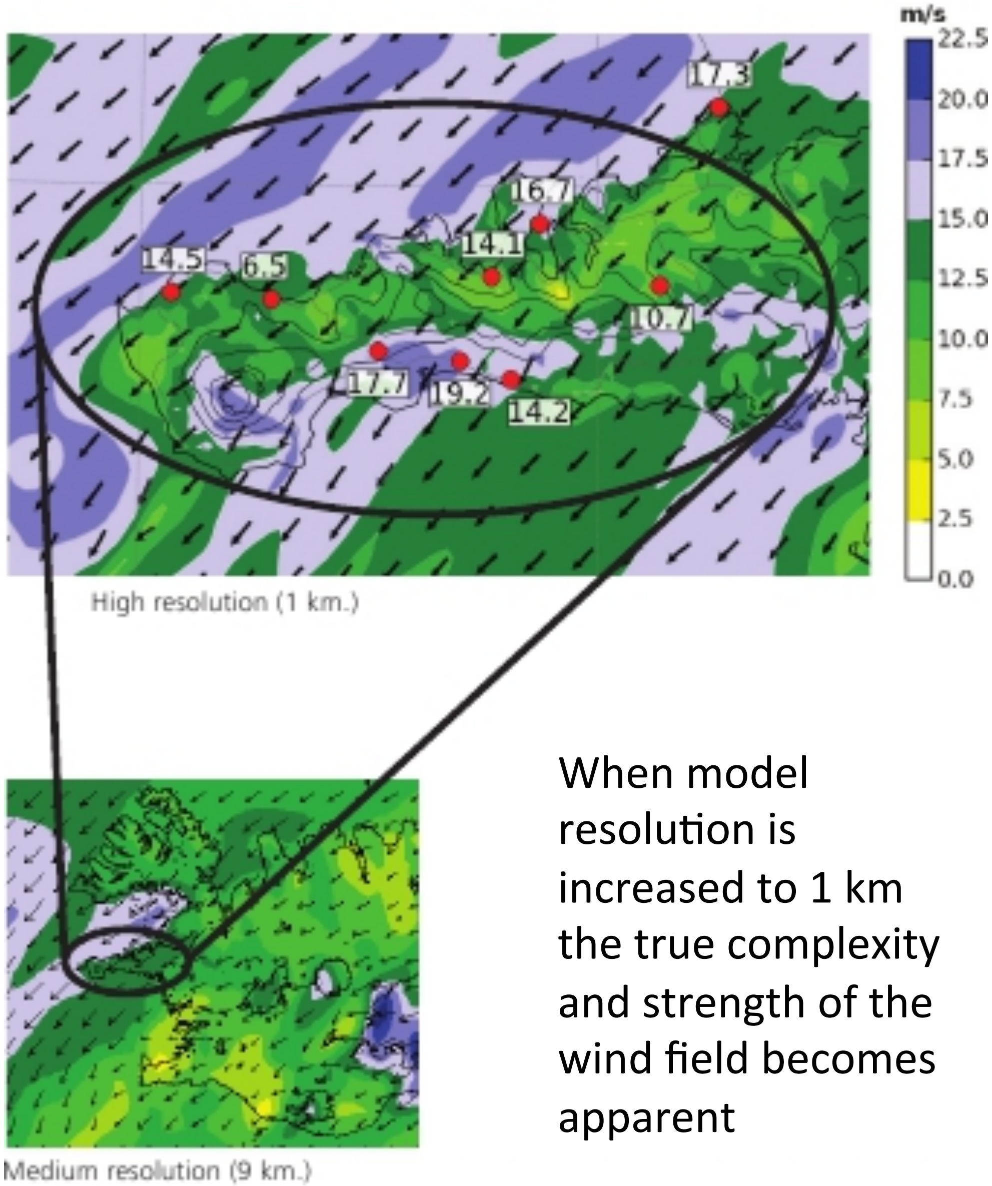
Importance of high resolution



Importance of high resolution

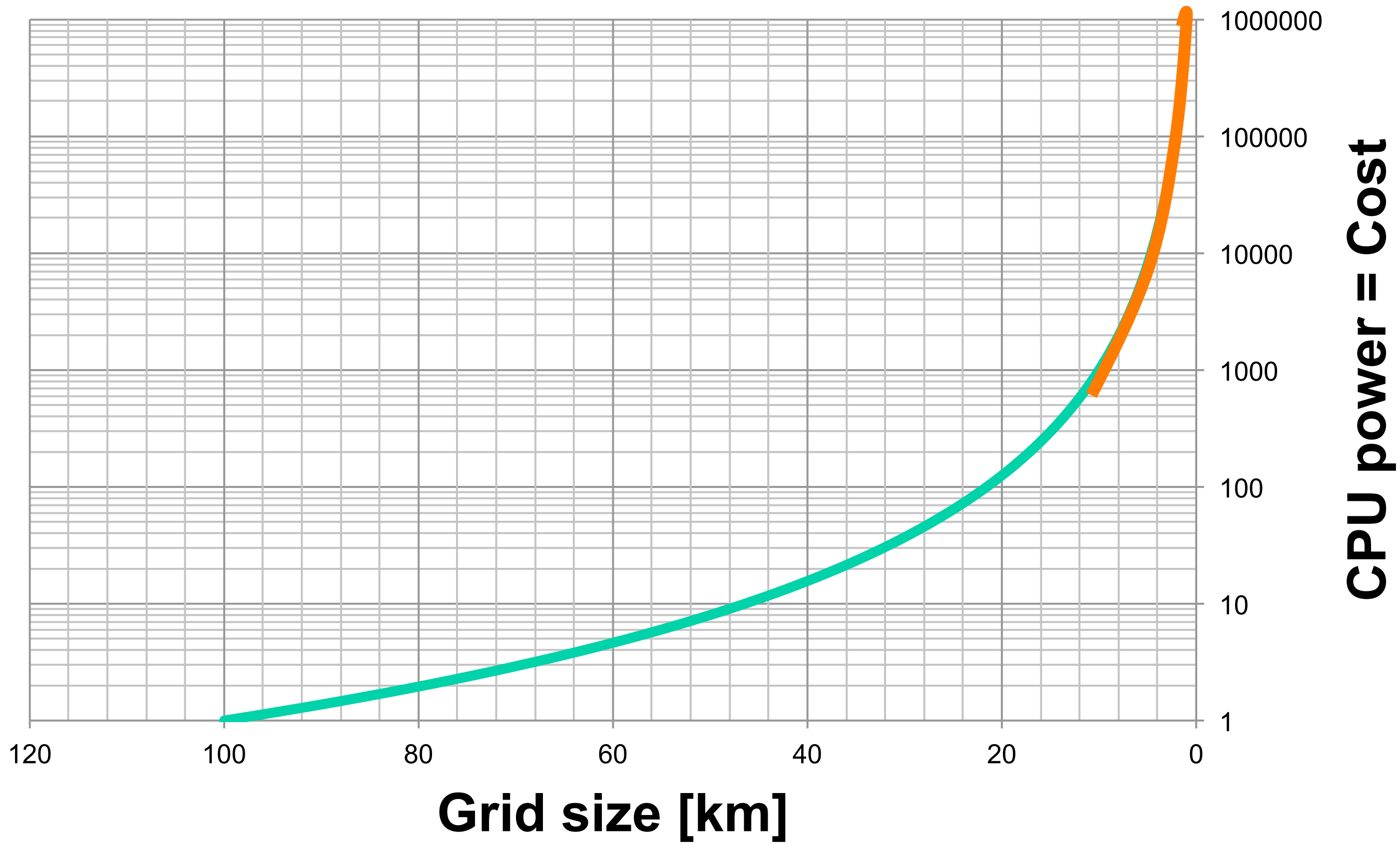
Very high resolution – 1 km

Medium resolution – 9 km



When model resolution is increased to 1 km the true complexity and strength of the wind field becomes apparent

Why not always use 1km resolution?



Need 1000-times more CPU power to simulate a 1 km resolution forecast than a 10 km one for the same region!

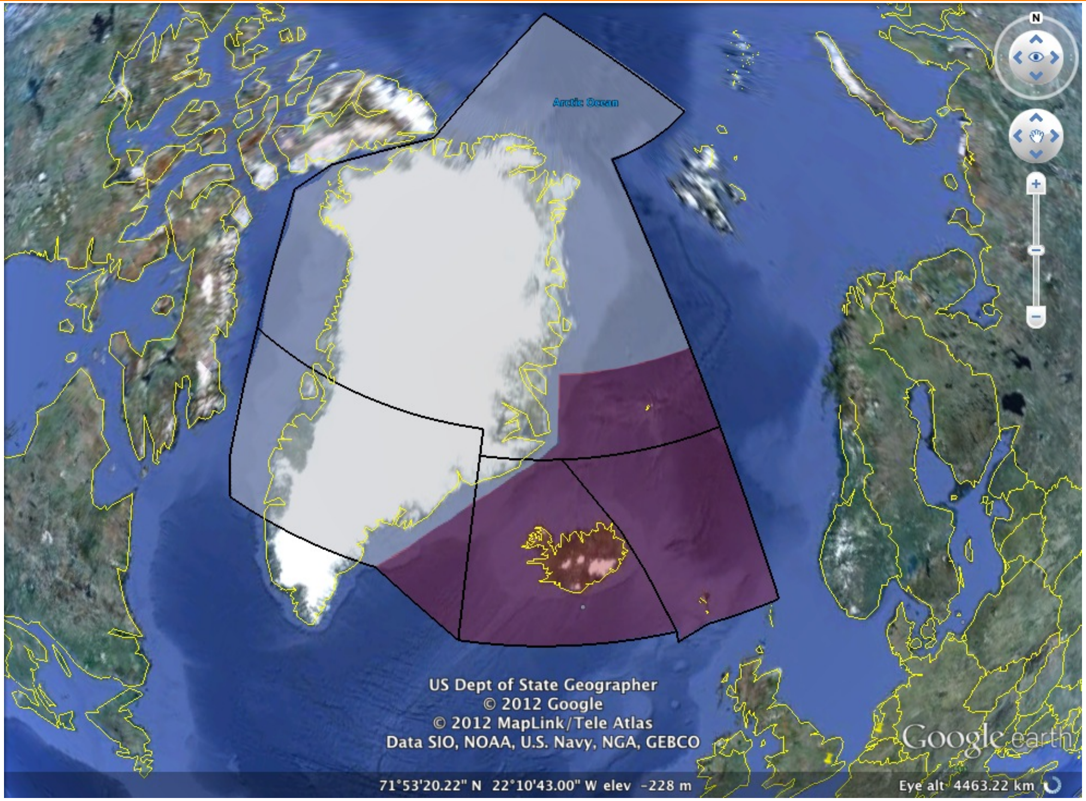
What if

- You only need high very high resolution once in a while?
- Computer clouds (e.g. Azure, EC2 and GreenQloud) are starting to offer HPC service
- Offers great scalability
- Relatively cheap
- And there is already a solution out there ☺

Routing optimization

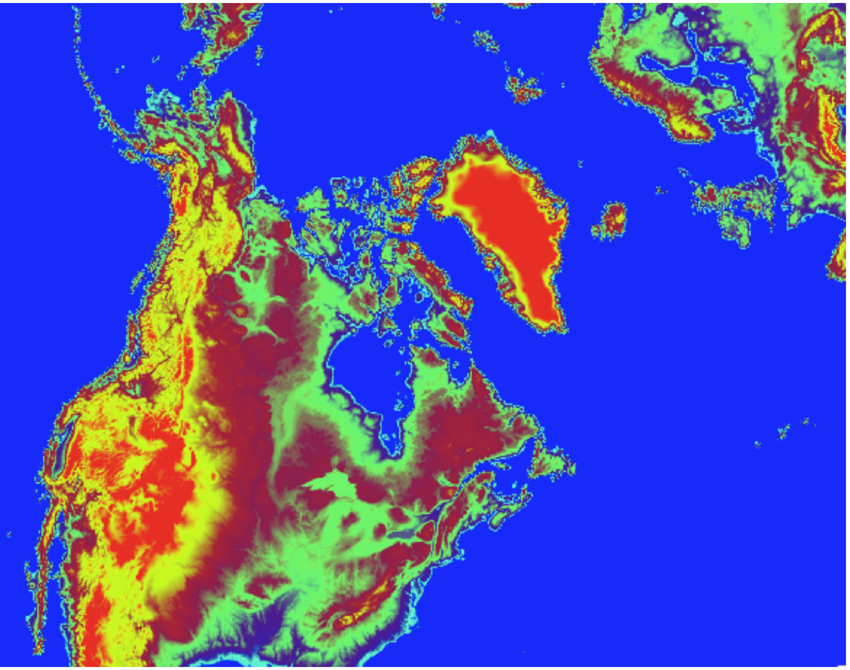
- Recent M.Sc. project at the RU aimed at minimize fuel burn and emissions by optimizing flight tracks with respect to wind
- Used the Dijkstra search algorithm
- Used data from Icelandair
  - Keflavík – New York flight @ 2011-07-14
  - Keflavík – Copenhagen flight @ 2011-07-14
  - Boeing 757-200
- Fuel savings estimated using the BADA model

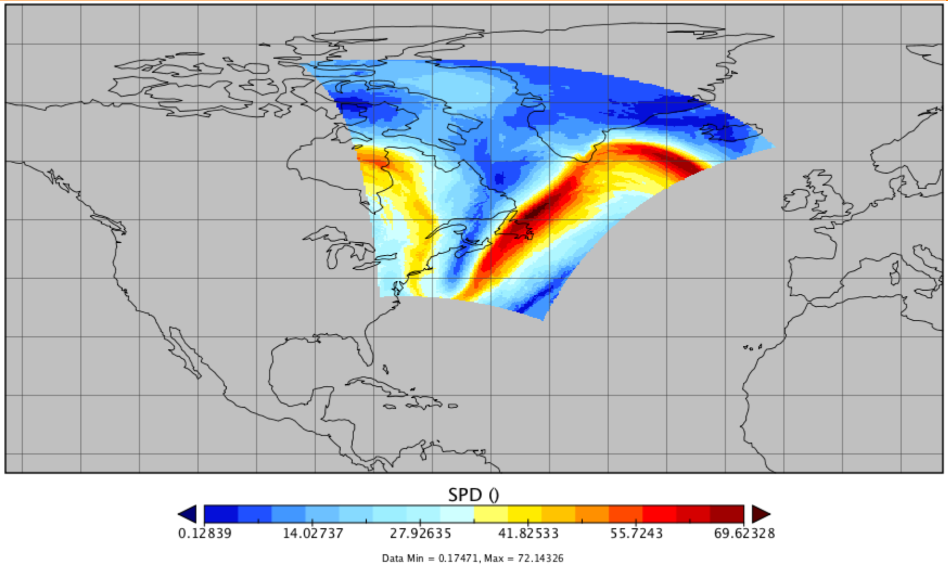
Reykjavík ATC area

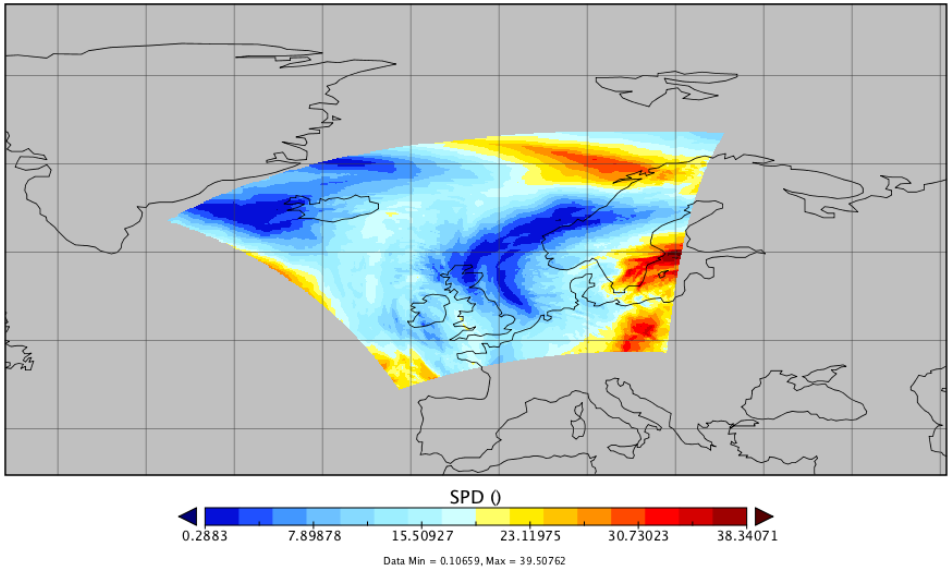


- Reykjavík Air Traffic Control area (BIRD)
- Over 110.000 flights in 2011
- Average time spend within BIRD was 100 minutes
- 1% fuel savings would amount to 6.000 metric tons

NWM area

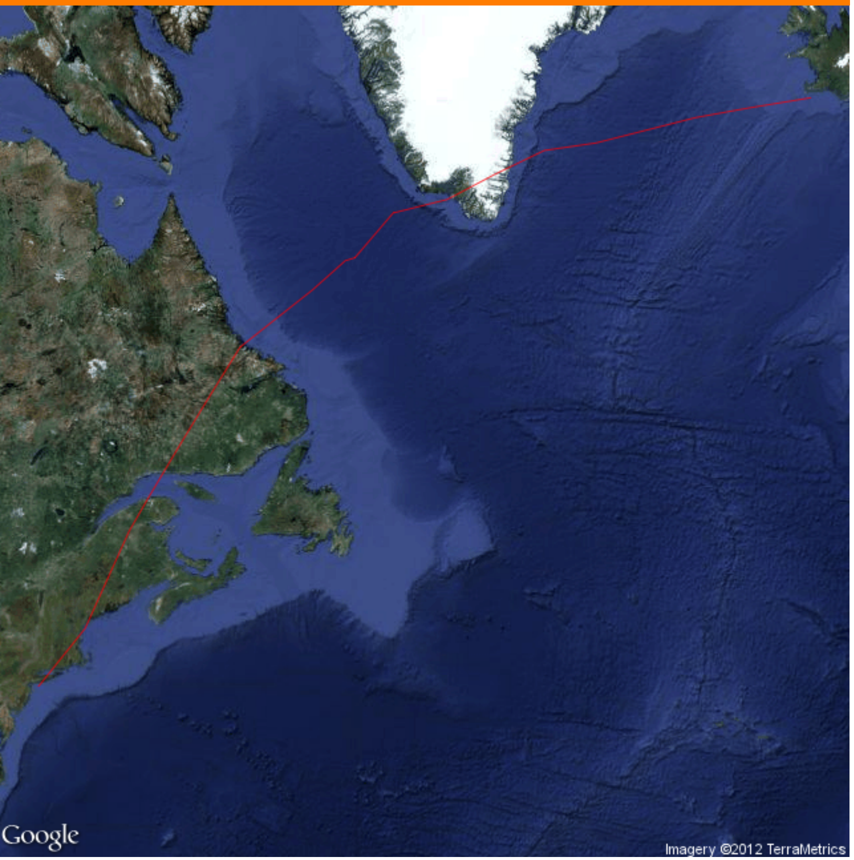


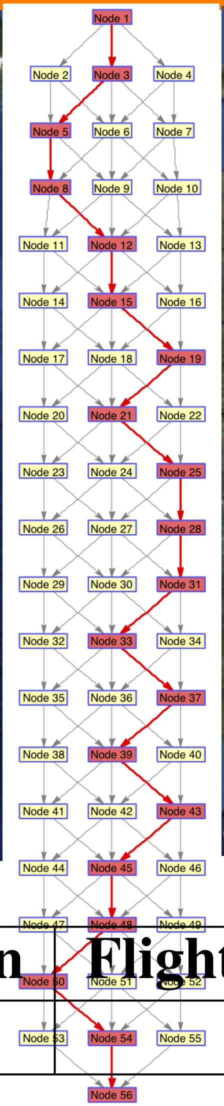


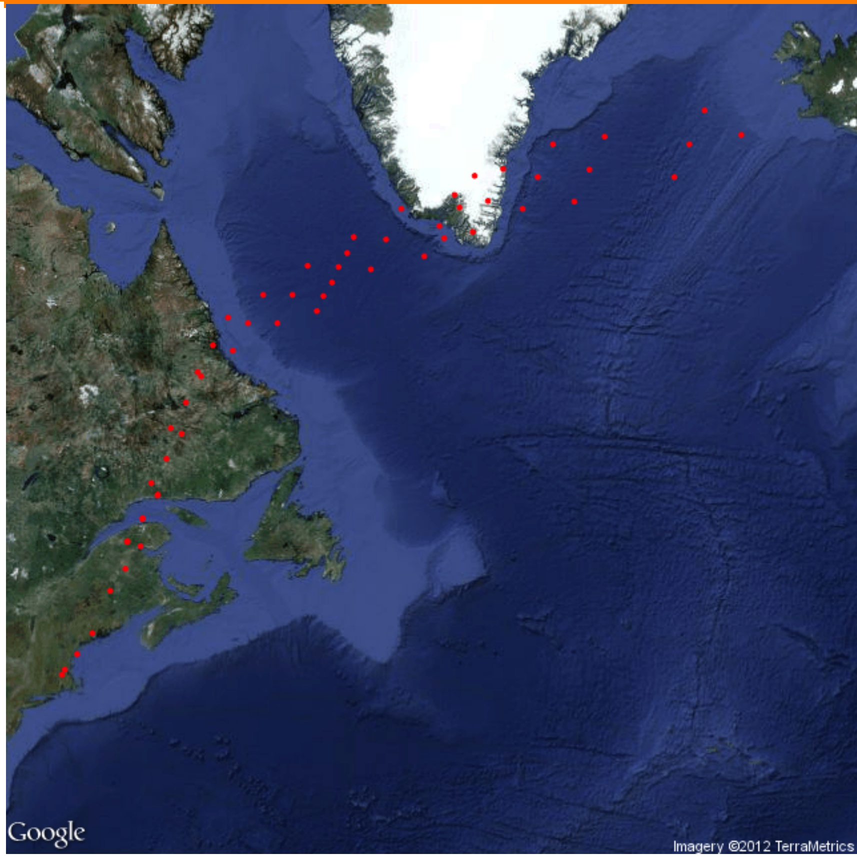


- Weather was simulated over a large region @ 9km resolution
- Part of domain used to optimize the routes between Keflavík and New York and Keflavík and Copenhagen

Flight ICE615 – Keflavík New York



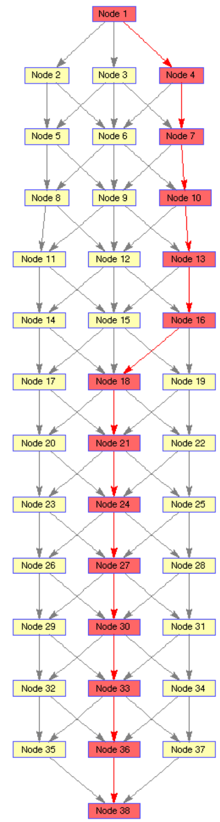


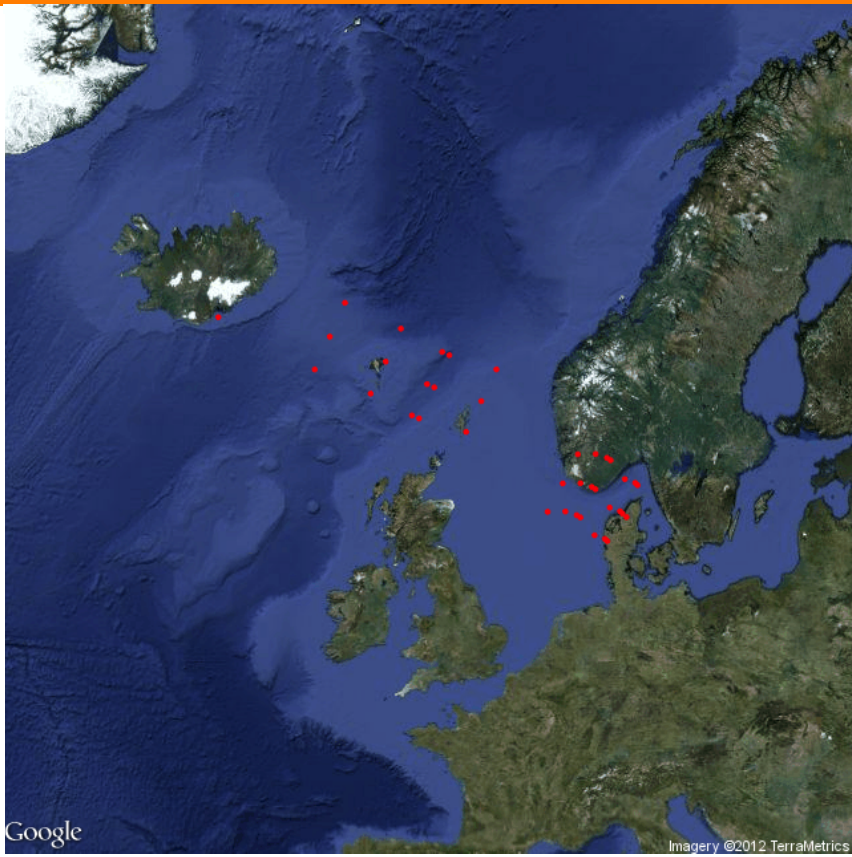


Flight	Dijkstra Path in min	Flight plan in min	Fuel saved in kg
ICE615	294.7	297	132

Flight ICE204 – Keflavík/Copenhagen

- Similar results found for another flight @ 2011-07-14
- Approximately 1% fuel savings for the whole flight
- Note that there was not “much” weather during this day
- Perhaps more to be gained in stronger winds?





Flight	Dijkstra Path in min	Flight plan in min	Fuel saved in kg
ICE204	123.3	124.5	66.8

Crisis Response System

- Good weather information help improve decision making
- Current CRS uses the WRF model and consists of a
  - Backend and Frontend
- Frontend is called SARWeather
  - Easy to use
  - Fast
  - Flexible model output and presentation
    - CF and ArcGIS compliant output files
    - Interactive and static maps

SARWeather

Give the forecast a name

Type in Lat/Lon or click on the map

Choose resolution: 1, 3, or 9 km

Title

Vienna – medium resolution

Location

Latitude: N48°11'

Longitude: E16°23'

Type

Res	Size	Time	Cost	
1 km	30 km	12 hr	14 cr	○
		24 hr	24 cr	○
		36 hr	36 cr	○
1 km	84 km	9 hr	24 cr	○
		12 hr	42 cr	○
		24 hr	72 cr	○
3 km	125 km	24 hr	14 cr	○
		48 hr	24 cr	○
		72 hr	36 cr	○
9 km	1000 km	24 hr	8 cr	○
		48 hr	10 cr	○
		72 hr	14 cr	○
		96 hr	24 cr	●

Options

- [ ] CF compliant netCDF files
- [ ] ArcGIS compatible netCDF files
- [x] Accept terms

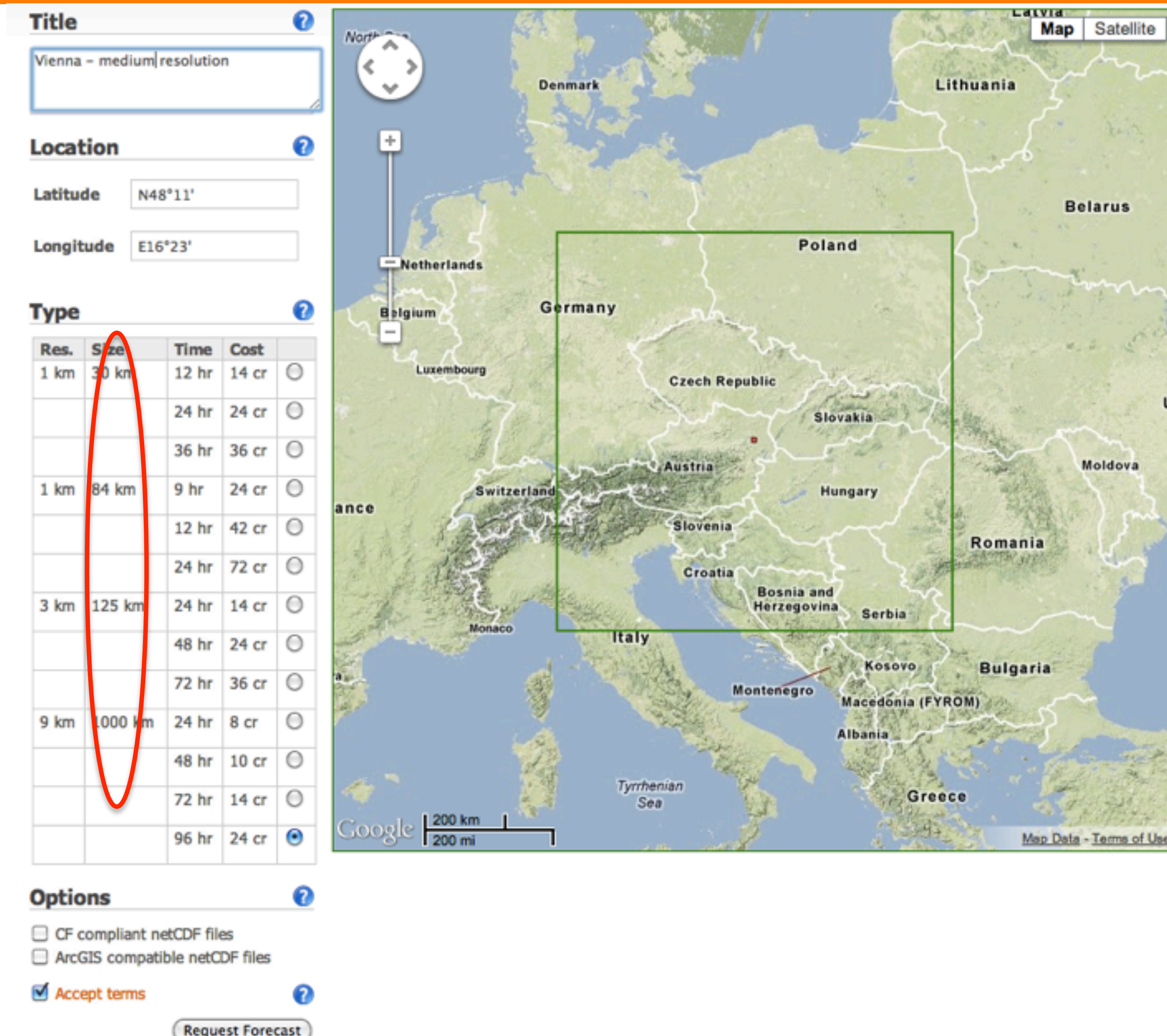
Request Forecast

SARWeather

Give the forecast a name

Type in Lat/Lon or click on the map

Choose domain size

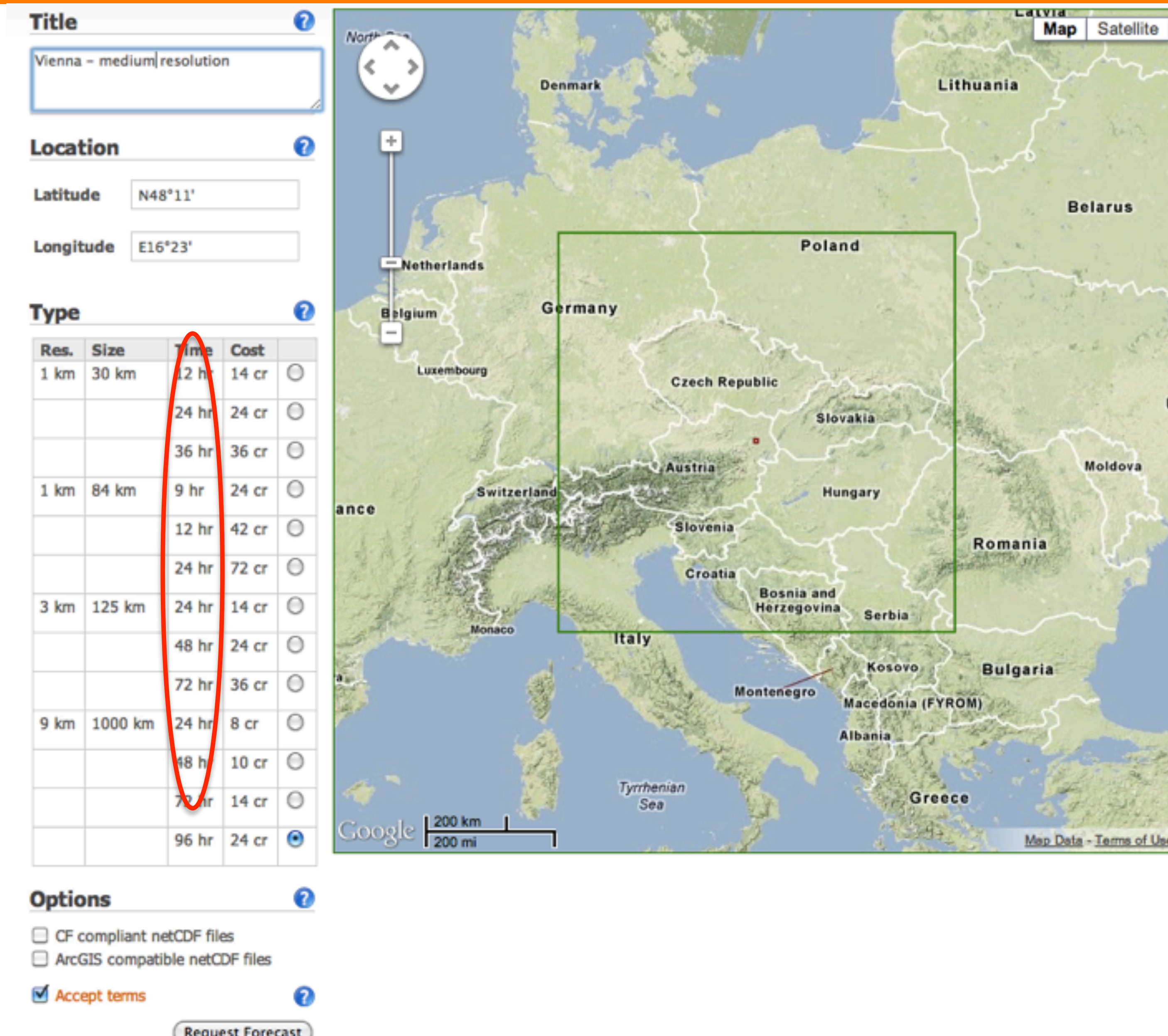


SARWeather

Give the forecast a name

Type in Lat/Lon or click on the map

Choose forecast duration



Res.	Size	Time	Cost	
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		48 hr	10 cr	○
		72 hr	14 cr	○
		96 hr	24 cr	◉

SARWeather

Give the forecast a name

Type in Lat/Lon or click on the map

1km resolution, 84x84 km domain and 24 hr forecast

Do you need CF or ArcGIS compliant output files?

Title

Vienna – 1km resolution

Location

Latitude N48°13.000'

Longitude E16°21.000'

Type

Res.	Size	Time	Cost	
1 km	30 km	12 hr	14 cr	○
		24 hr	24 cr	○
		36 hr	36 cr	○
1 km	84 km	9 hr	24 cr	○
		12 hr	42 cr	○
		24 hr	72 cr	◉
3 km	125 km	24 hr	14 cr	○
		48 hr	24 cr	○
		72 hr	36 cr	○
9 km	1000 km	24 hr	8 cr	○
		48 hr	10 cr	○
		72 hr	14 cr	○
		96 hr	24 cr	○

Options

☐ CF compliant netCDF files

☐ ArcGIS compatible netCDF files

☐ Accept terms

Request Forecast

When all is set, run forecast

SARWeather

Time from initiation:

30 sec – computer node up’n running

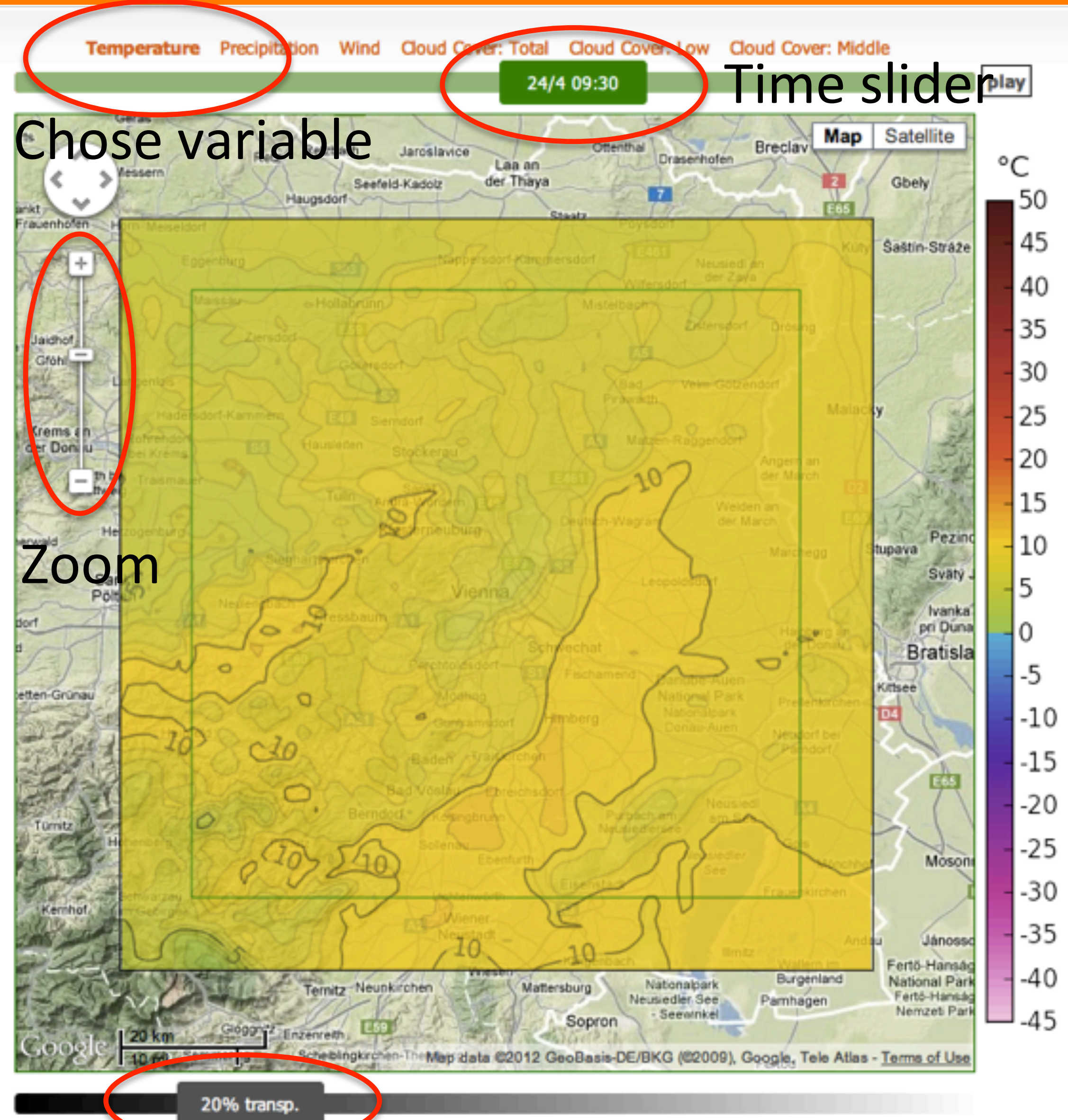
2 min 40 sec – pre-processing done and model starts running

5 min 50 sec – first frame ready on screen

51 min 50 sec – 24 hr forecast ready

54 min 20 sec – “static” post-processing done

Typical response time for SAR operators is 30 min or less



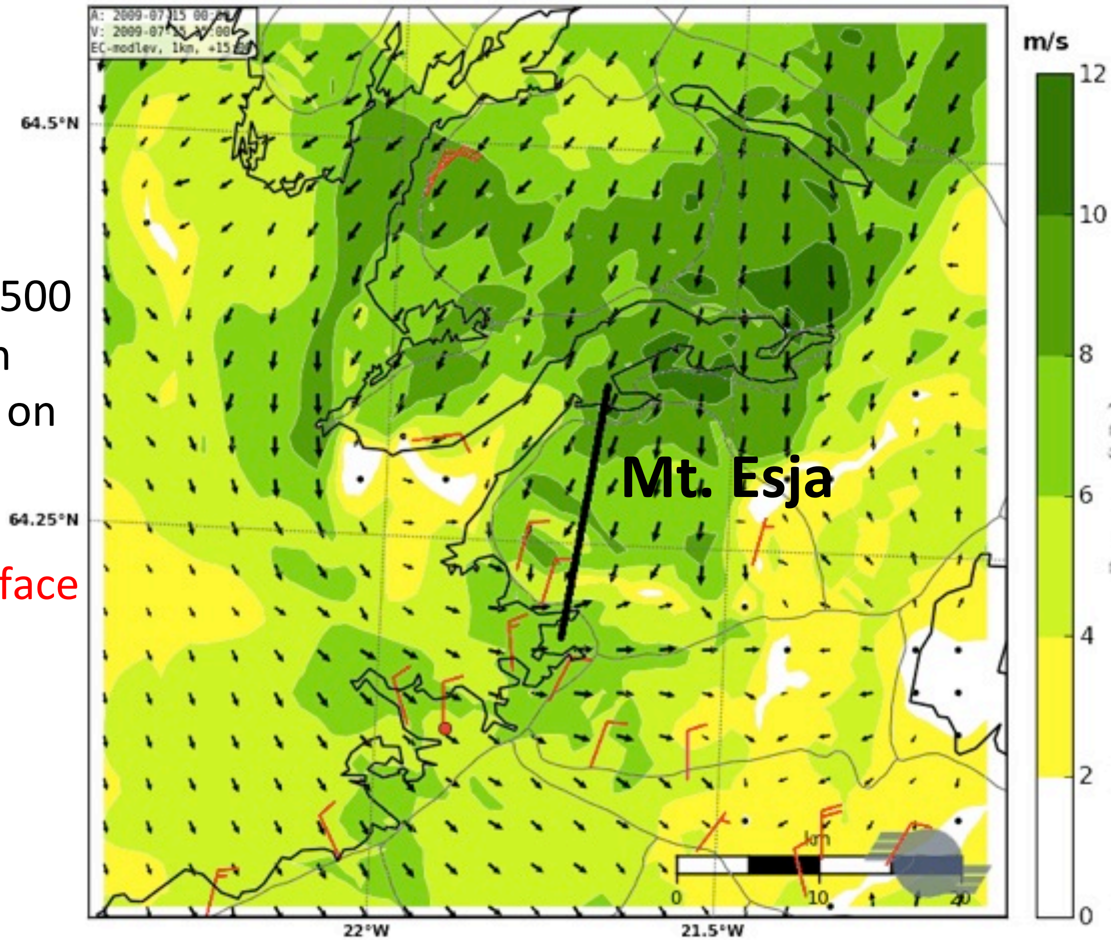
Control transparency

High resolution not always sufficient

Simulated and observed surface winds on 15 July 2009 at 13 UTC

WRF at a resolution of 500 m forced with ECMWF-data on model levels.

Observed surface winds in red



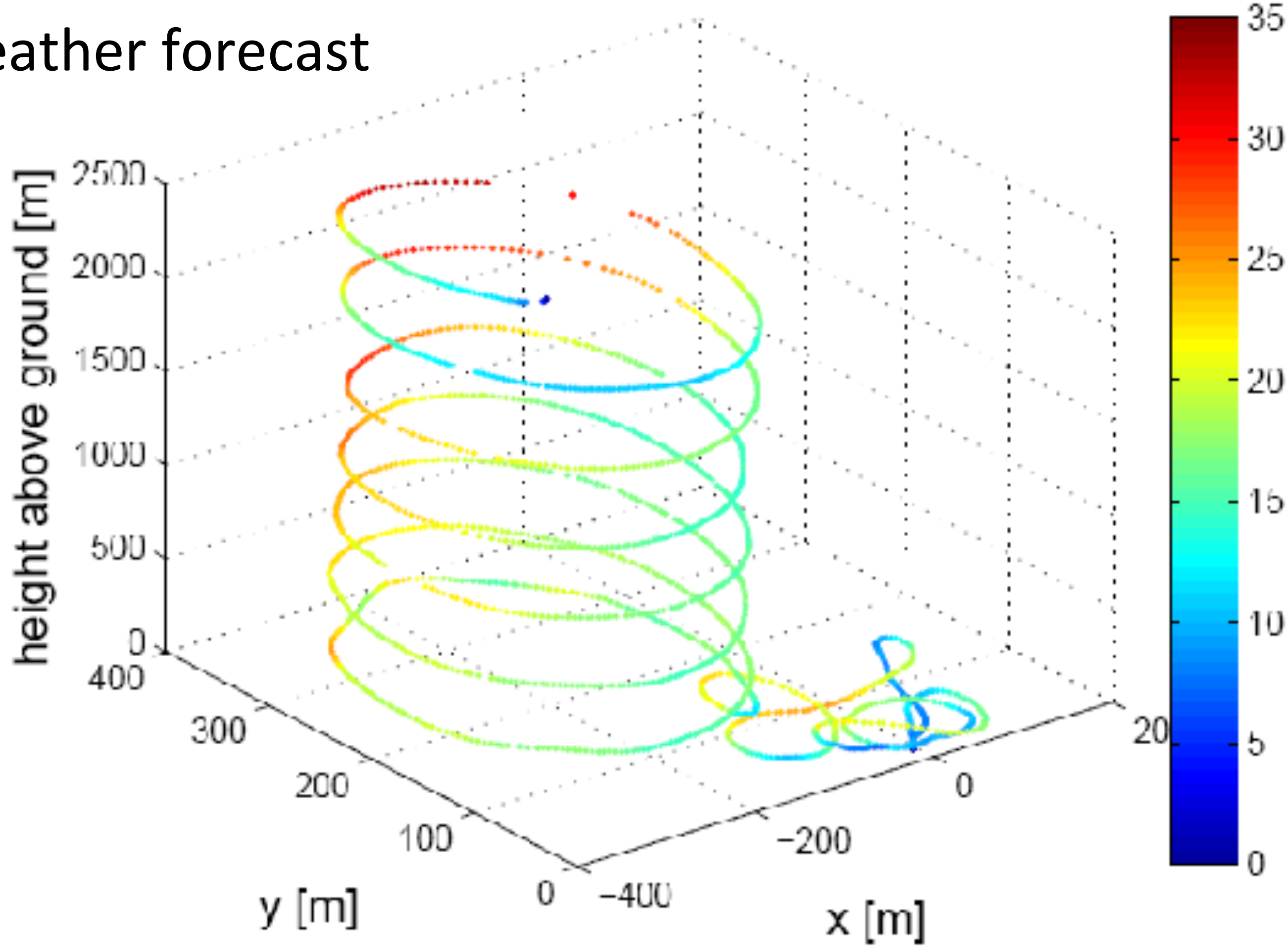
Model simulates a see-breeze that is not seen in observations

SUMO and WRF

The SUMO (Small Unmanned Meteorological Observer) can measure winds, humidity, pressure, and temperature in a vertical profile up to a 4km height

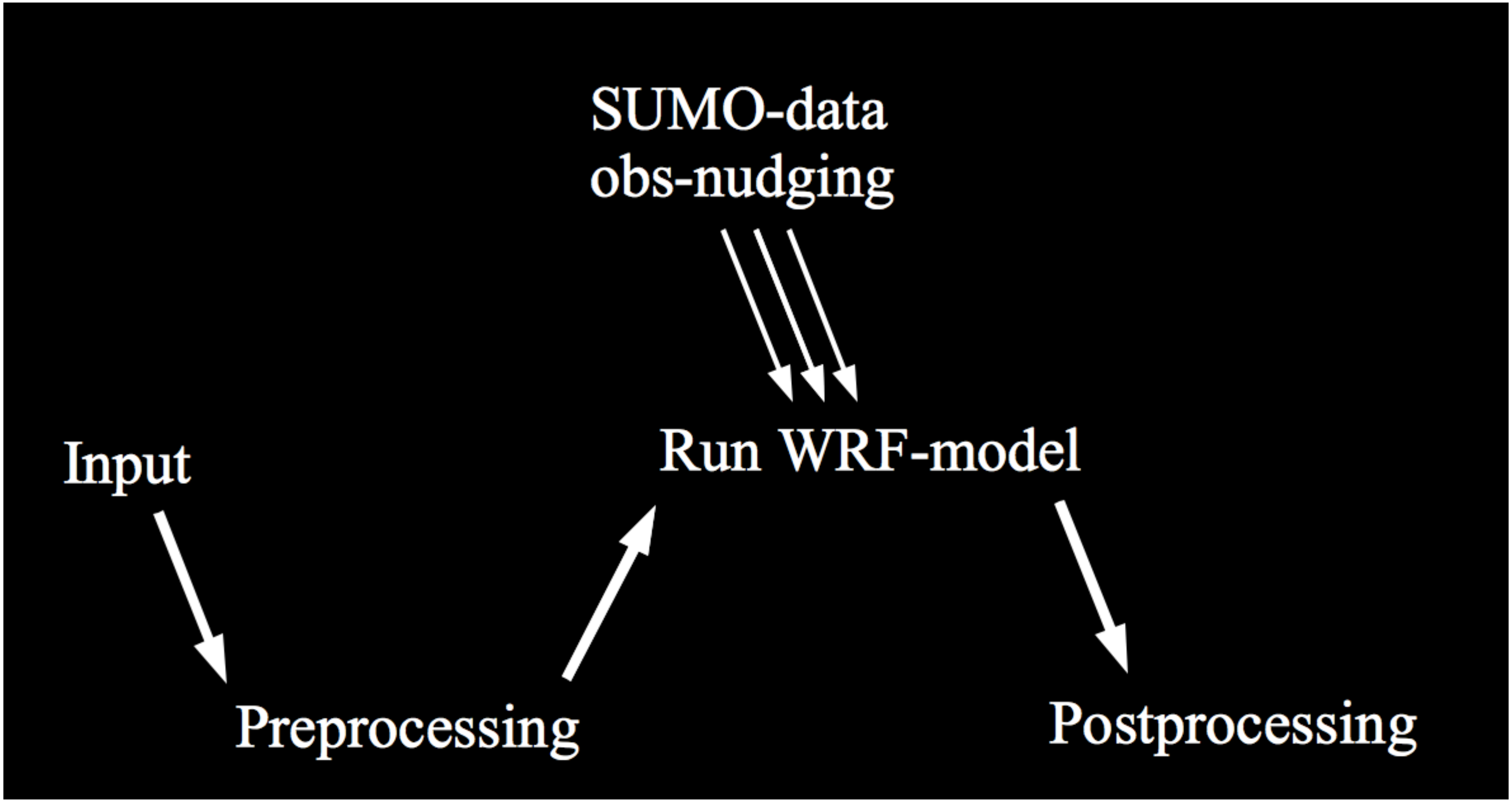
SUMO and WRF

This data can be assimilated with the WRF weather forecast



SUMO and WRF

The SUMO-data is incorporated into the WRF-simulation, via obs-nudging

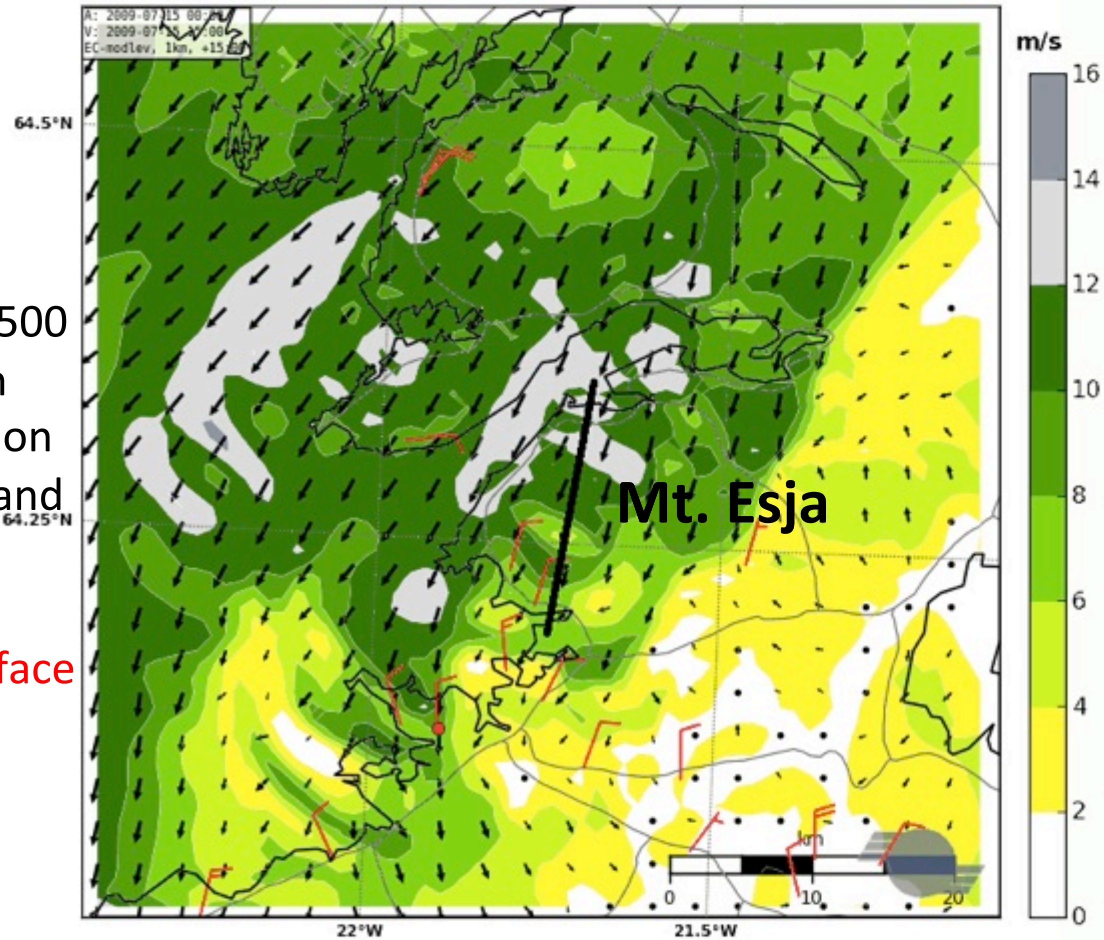


Effects of additional observations

Simulated and observed surface winds on 15 July 2009 at 13 UTC

WRF at a resolution of 500 m forced with ECMWF-data on model levels and SUMO data

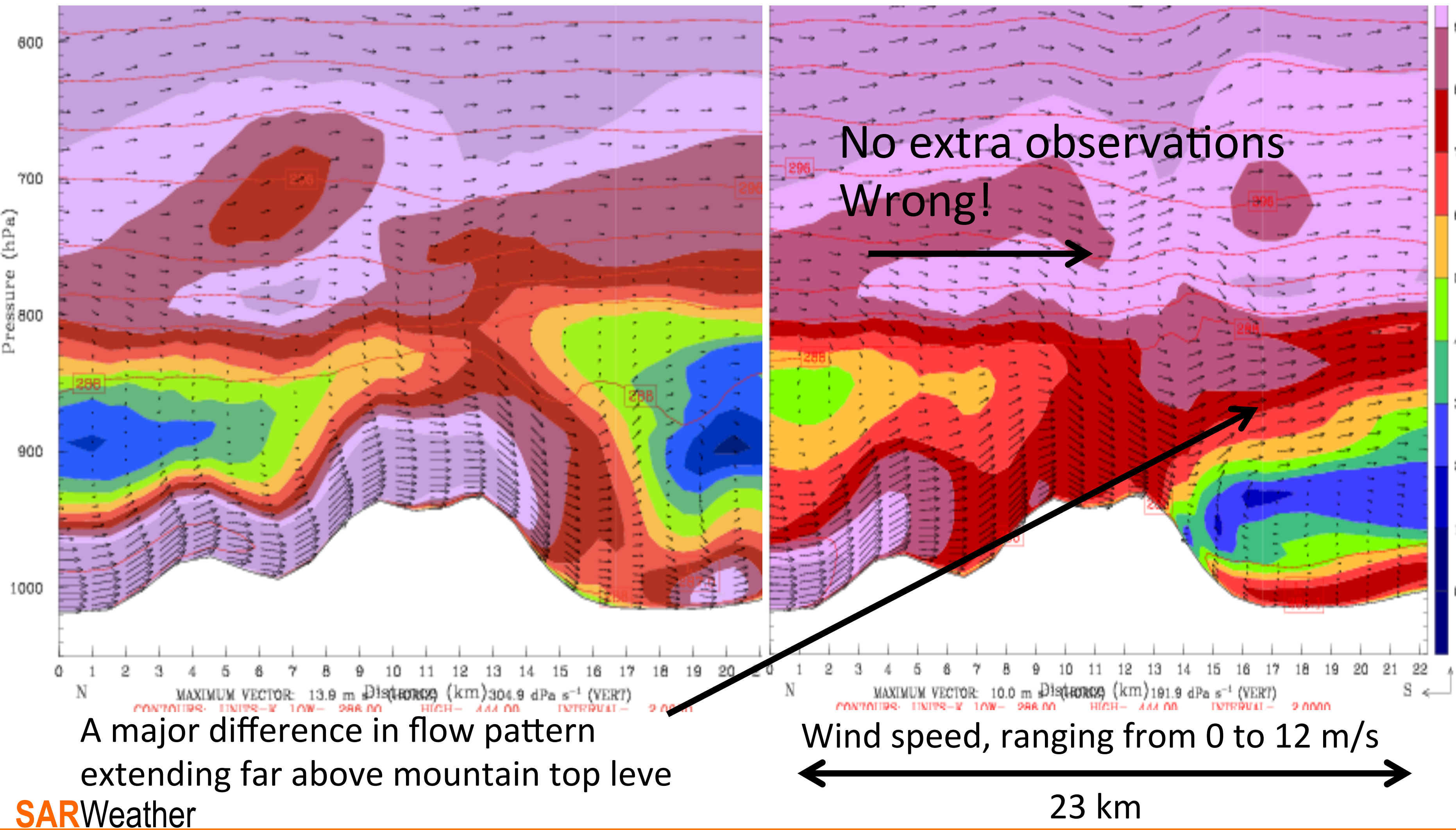
Observed surface winds in red



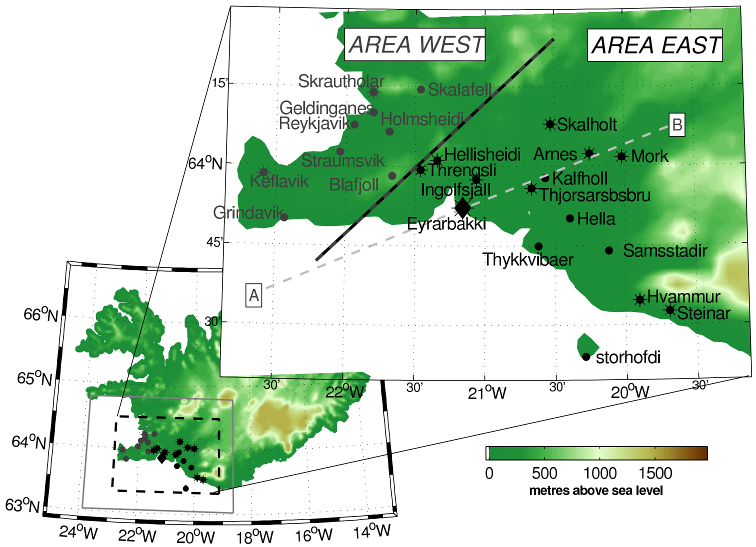
The flow structure is now in much better agreement with available observations

Effects not just at the surface

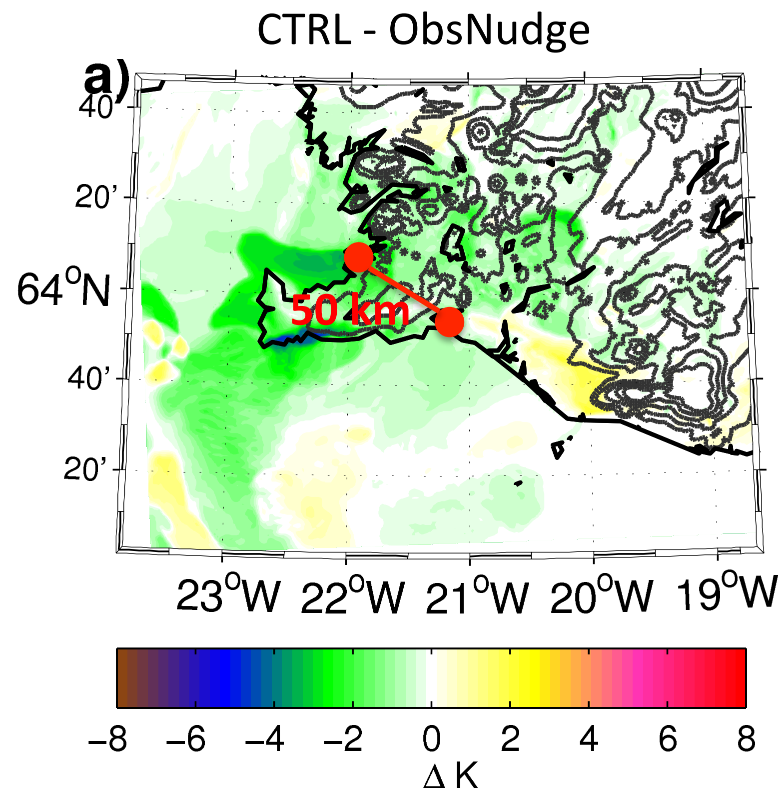
Simulated flow in N-S section across Mt. Esja



Effects can be far reaching



"Substantial improvements of winds, temperatures and humidity in the region are achieved"



Marius O. Jonassen, Haraldur Ólafsson, Hálfdán Ágústsson, Ólafur Rögnvaldsson, and Joachim Reuder (2012). Improving a high resolution numerical weather simulation by assimilating data from an unmanned aerial system. Accepted for publication in *Monthly Weather Review*

Additional sensors

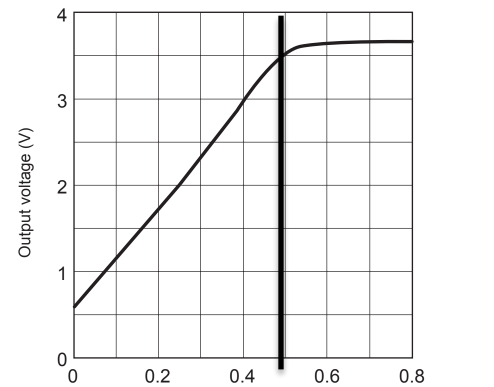
The SUMO has been equipped with an optical dust sensor

GP2Y1010AU0F is a dust sensor by optical sensing system:

- An infrared emitting diode (IRED) and an phototransistor are diagonally arranged into the device
- It detects the reflected light of dust in air
- Especially effective to detect very fine particle
- In addition it can distinguish smoke from house dust by pulse pattern of output voltage

Compact Optical Dust Sensor

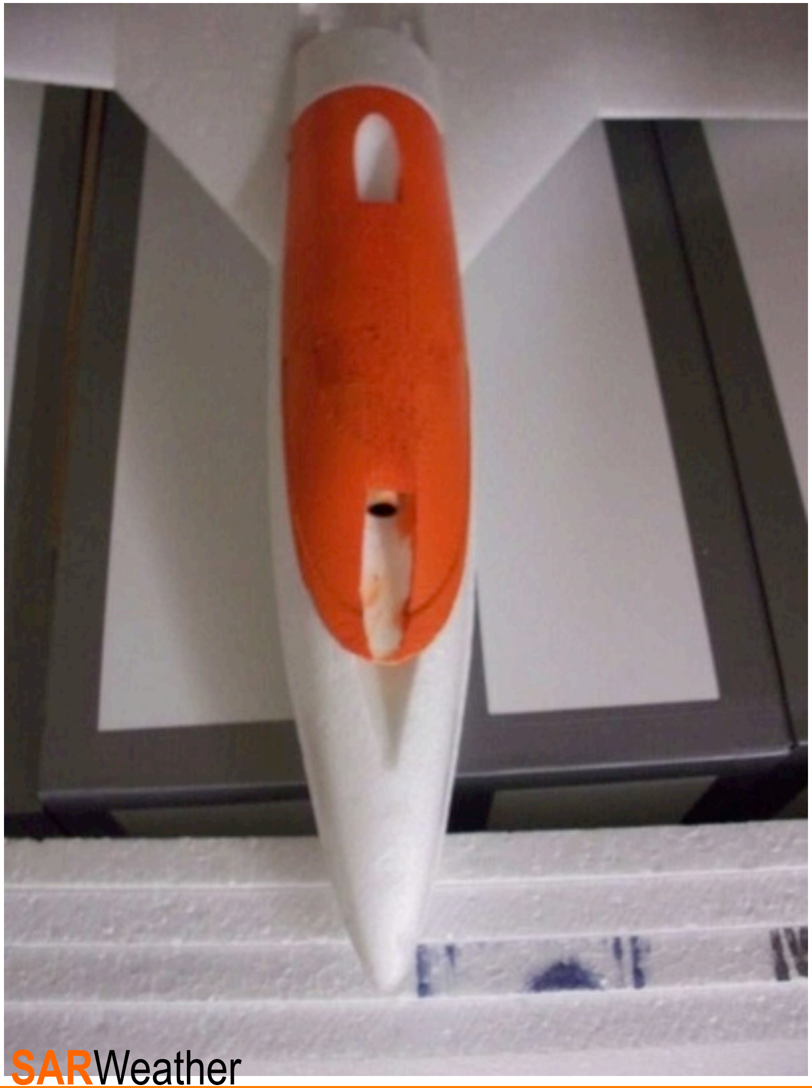
Output Voltage vs. Dust Density

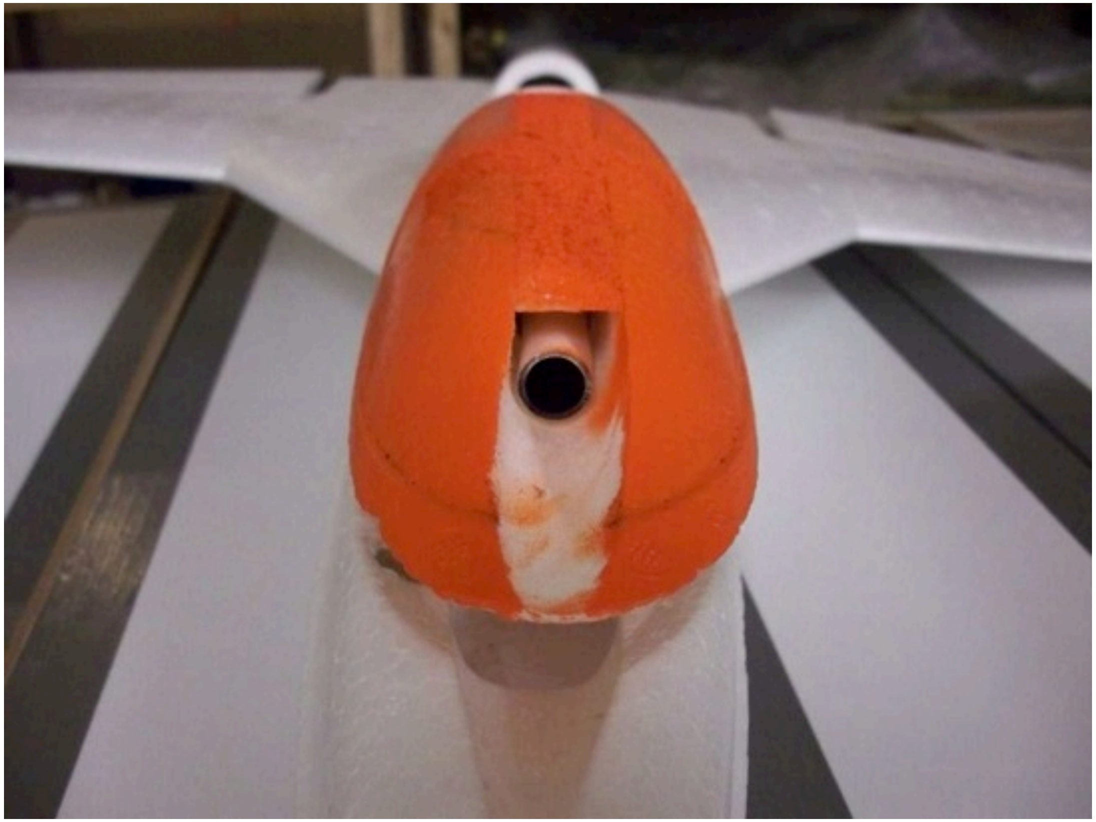


Saturation at about 500µg/m^3

Preliminary results

The SUMO dust sensor has been tested in France and Iceland



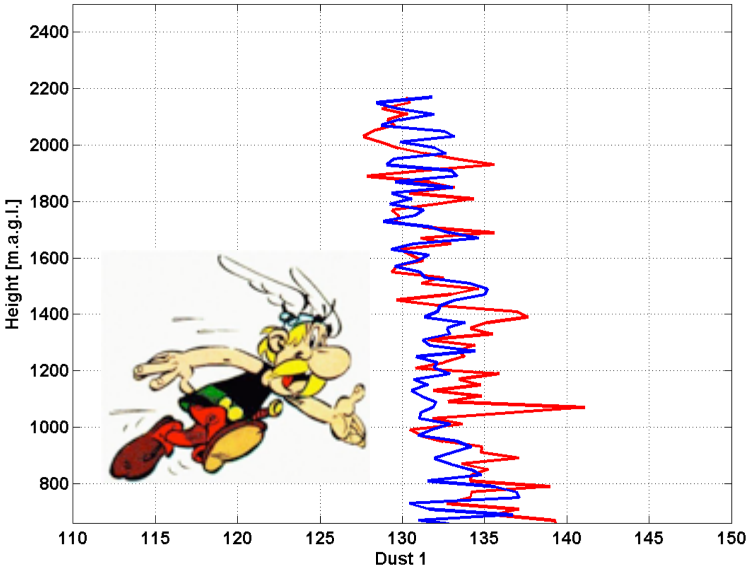


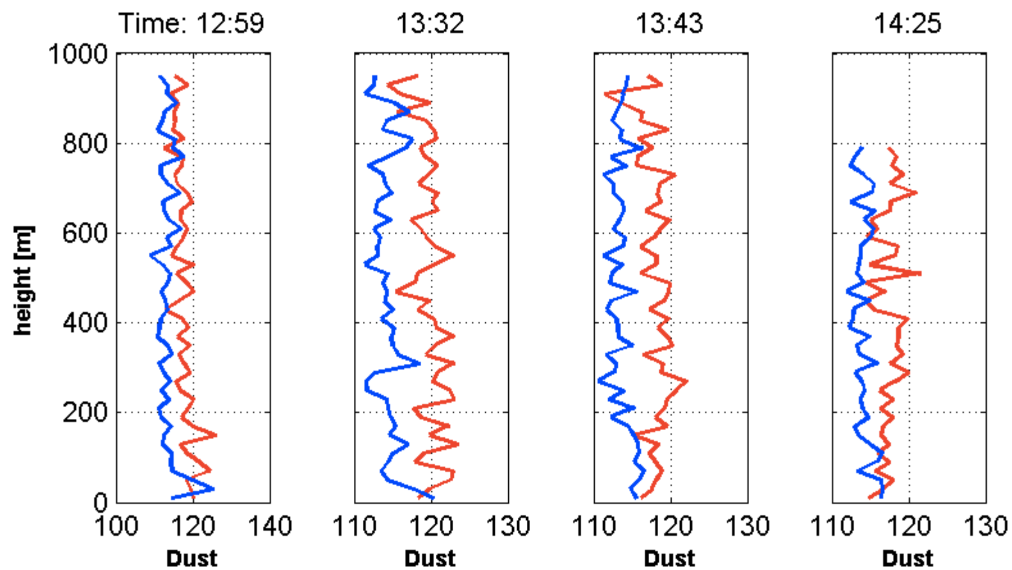
Preliminary results

The SUMO dust sensor has been tested in France and Iceland

Ascending

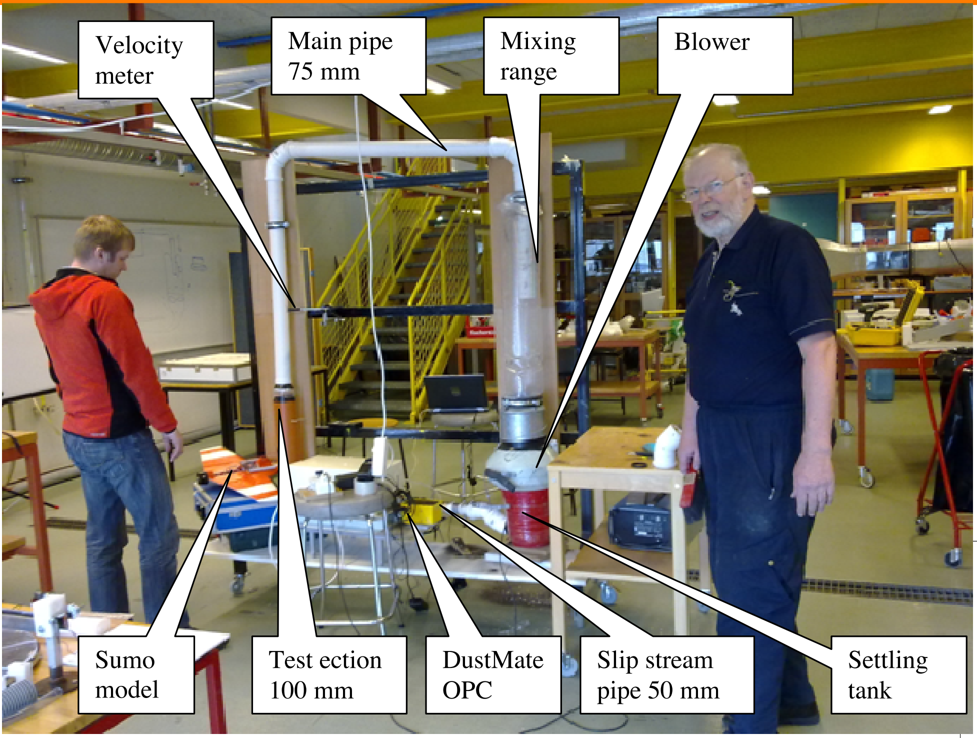
Descending



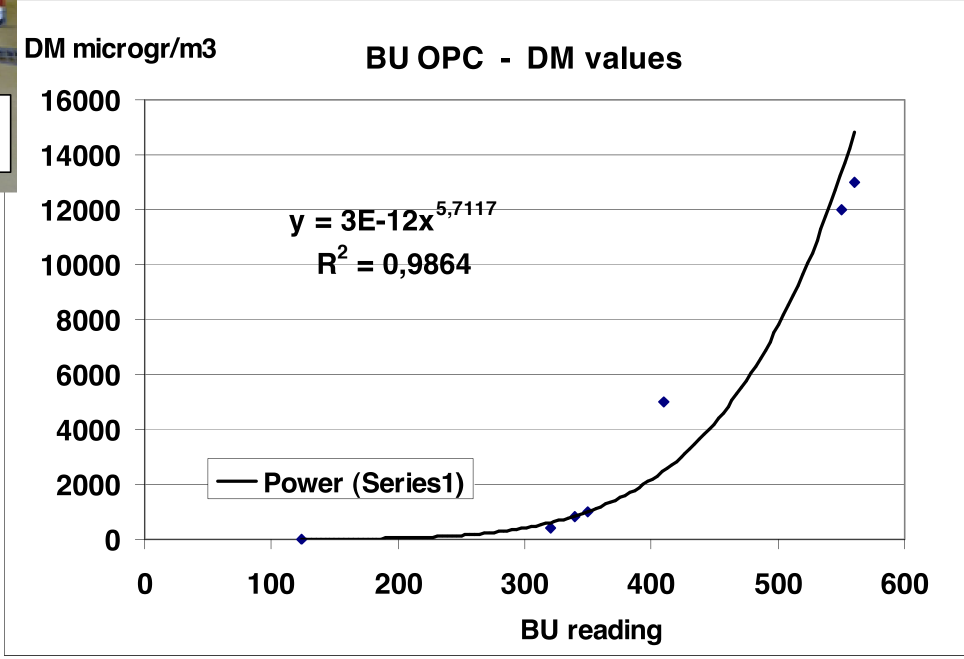


Sensor is now being calibrated and tested with ash from Mt. Eyjafjallajökull

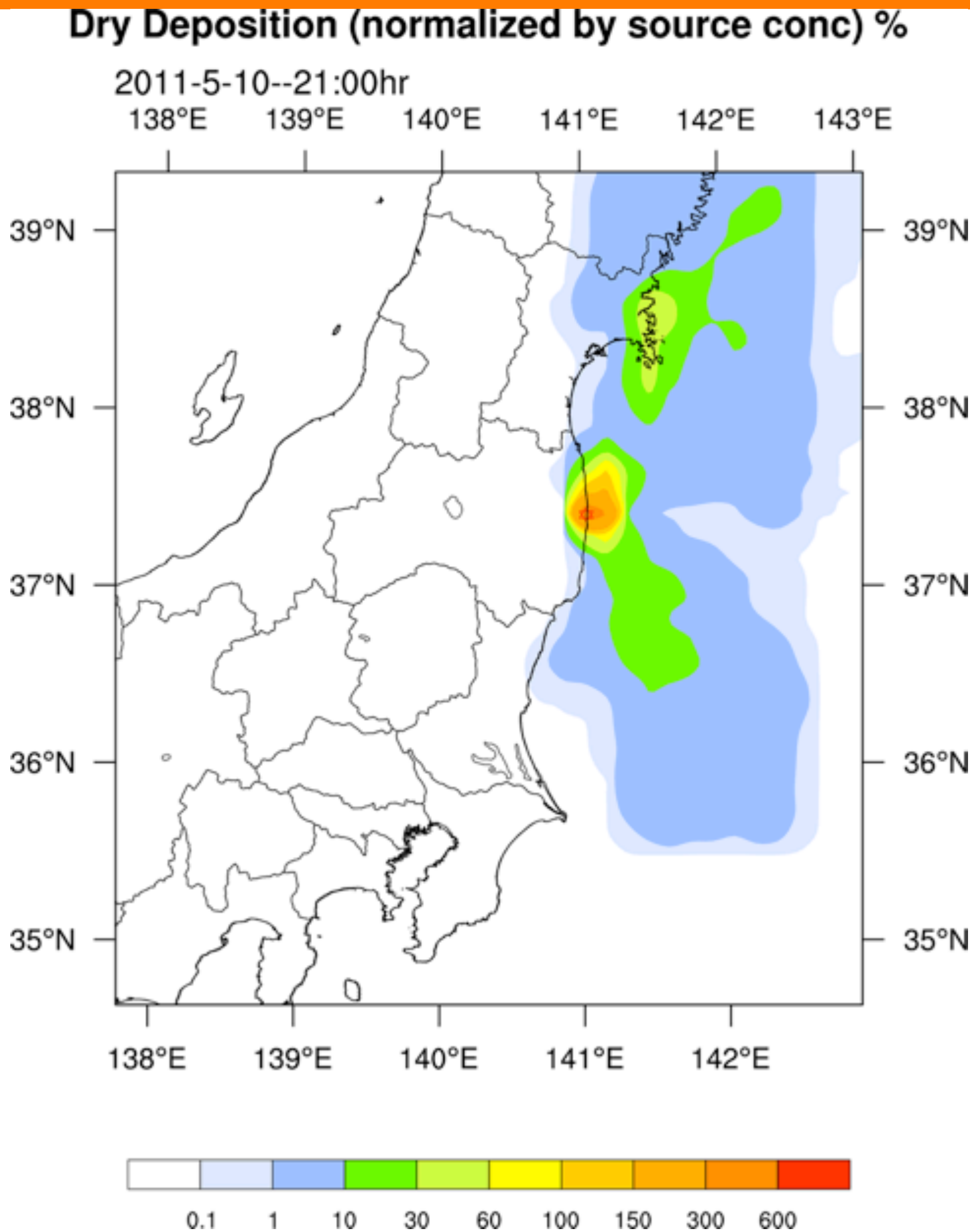
Calibration – preliminary results



- The sensor (BU) readings show high sensitivity in the range 125 – 300. After that the sensitivity is rather low in the range 350 to 700.
- Using the meter for ash surveillance for jet aircrafts, the best thing would be to designate below 300 as "safe" but above 400 as "unsafe"



Various uses of model output

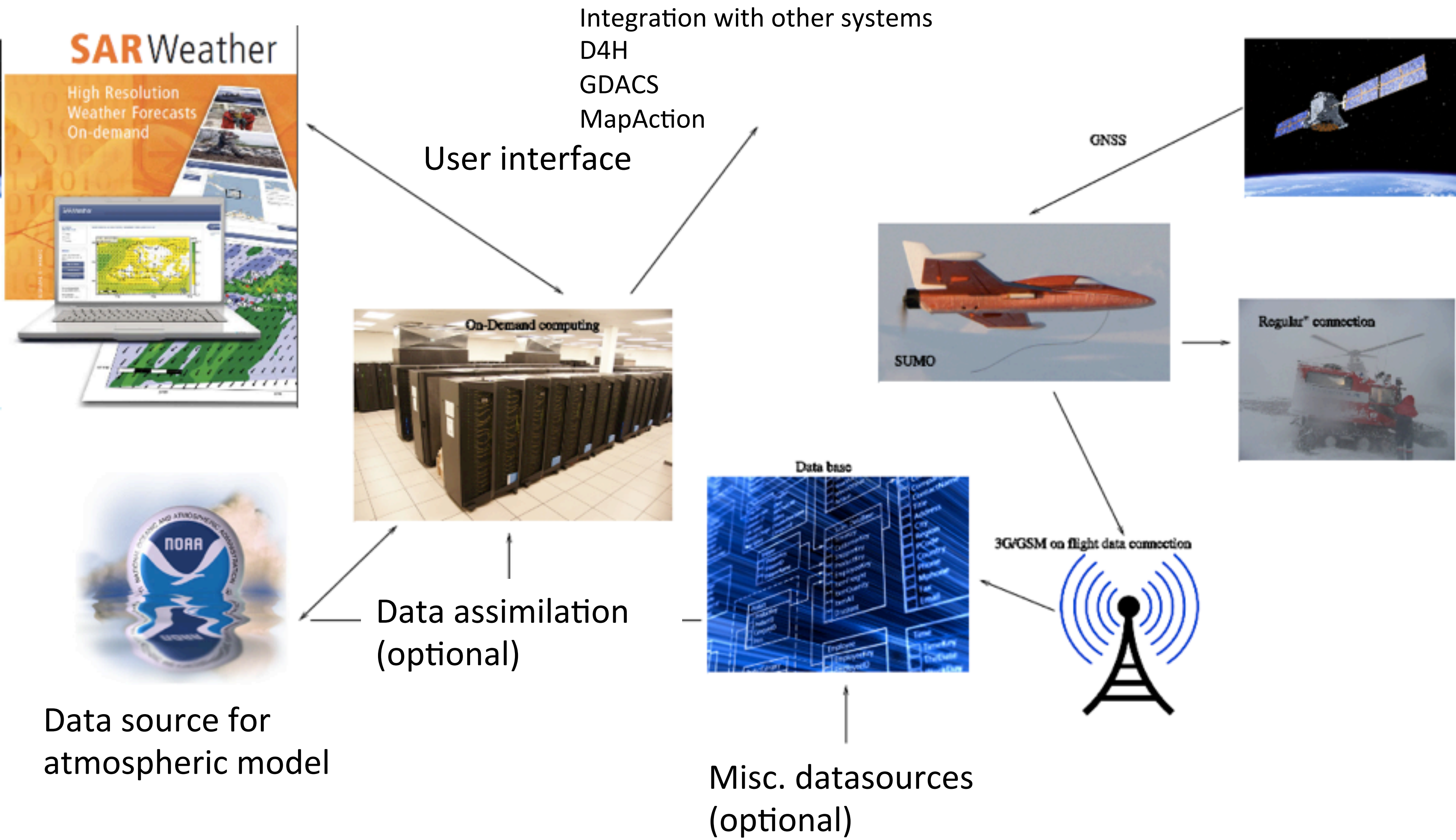


To correctly simulate distribution of pollutants, it is very important to correctly simulate the atmospheric conditions close to the source.

Data courtesy of Prof. Saji Hameed at the University of Aizu, Fukushima.

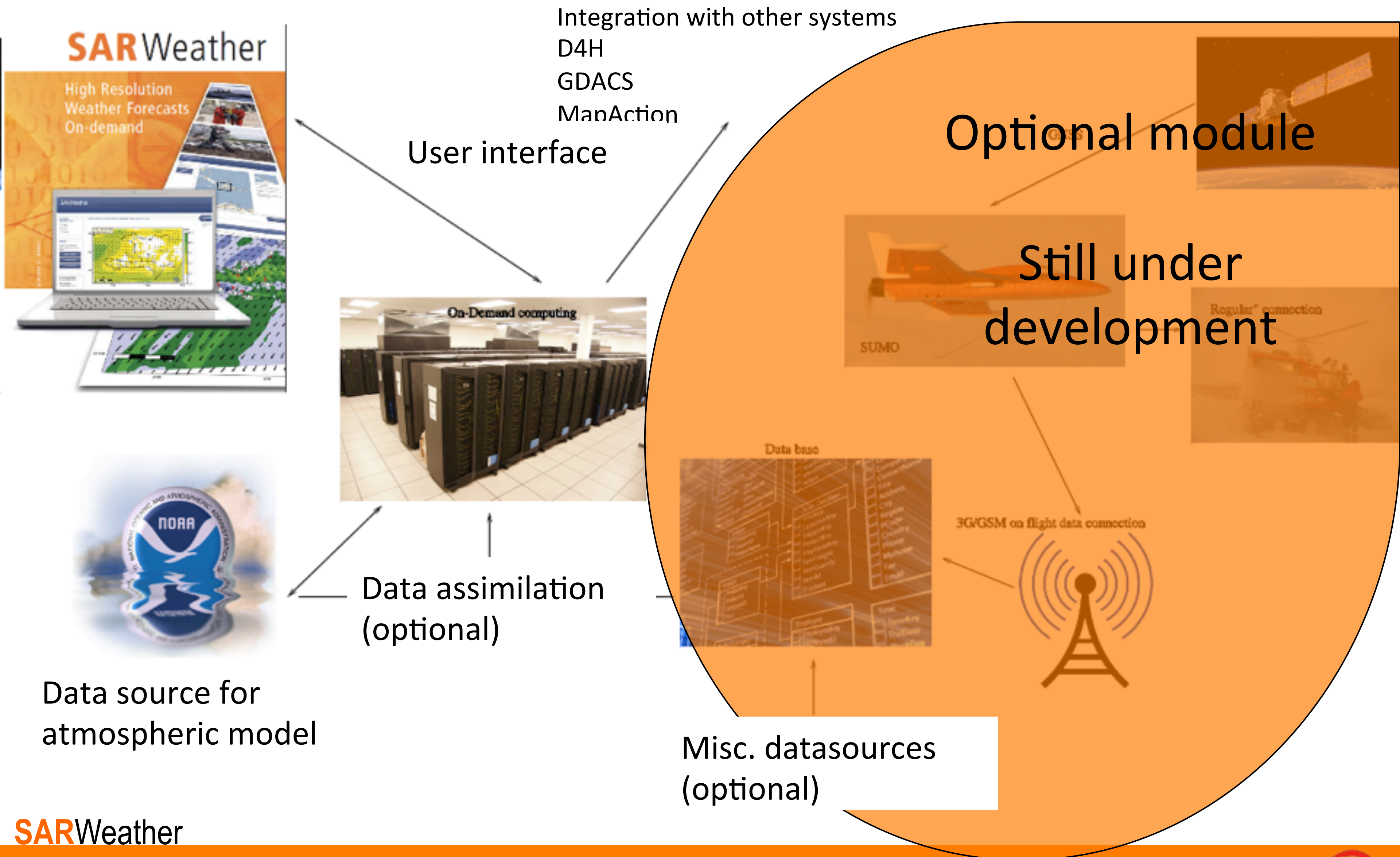
Current research and development

System schematics



Current research and development

System schematics



Conclusions

- Model resolution is important
  - Especially in the vicinity of complex terrain
- Additional observations can improve the simulation
  - Vertical profiles made by the SUMO
- The SUMO is a low-cost system with many advantages
  - Proof of concept before investing in a more durable and expensive UAS
  - Additional sensors are being added to the system
- Fast response time is crucial in SAR operations
  - SARWeather meets these needs
  - Good weather information help improve decisions
- The SUMO is currently being integrated to the SARWeather, on-demand, Crisis Response System

Acknowledgement

- SARWeather is a joint research project led by IMR/Belgingur, in collaboration with NOAA/ESRL, the University of Bergen, and the private companies GreenQloud and DataMarket. To ensure maximum usability for SAR operators, SARWeather is developed in close collaboration with ICE-SAR and the Civil Protection Department of the Icelandic Police.
- SARWeather was initially funded in part by grant number 550-025 (Vejrtjeneste for Søberedskab) from NORA and by the European Commission under the 7th Community Framework Programme for Research and Technological Development (GalileoCast). GalileoCast is managed by GSA, the European GNSS Supervisory Authority.
- Current development of SARWeather is funded in part by the Icelandic Technical Development Fund – RANNÍS
- Development related to the SUMO has in part been funded by the COST project ES0802