## Small unmanned airplanes In-situ observations of airborne dust/ash and improved local weather forecasts

Ólafur Rögnvaldsson – IMR/UiB Hálfdán Ágústsson – IMR/UI/IMO Haraldur Ólafsson – UI/UiB/IMO Marius O. Jonassen – UiB/IMR

# Overview

- Atmospheric models
  - Global vs. regional
  - The WRF model
- Importance of resolution
- Use of observations from UAS's
  - The SUMO system
- On-going research
  - SARWeather and SUMO
- Conclusions

#### **Atmospheric models**

Measurements and simulations of volcanic ash for civil aviation



Set of equations that describe the atmospheric flow and need to be integrated forward in time to produce a weather forecast

## The WRF atmospheric model

- Open source model developed in collaboration of
  - NCAR, NOAA, FSL, AFWA, NRL, Univ. of Oklahoma & FAA
- Five development teams with sixteen workgroups
  - More than 160 official developer
  - Additional development by academic and governmental institutions in the US and abroad
  - Very large user community, excellent support
- Non-hydrostatic
- Regional and global applications
- Wide range of scales for both real time and idealized applications
  - Optional data assimilation (3D-VAR, 4D-VAR, and FDDA)
  - Has been modified for volcanic applications
  - Includes a dust module (re-suspension of dust/ash)

### Importance of high resolution of volcanic ash for civil aviation

Measurements and simulations



Measurements and simulations of volcanic ash for civil aviation



Measurements and simulations of volcanic ash for civil aviation

Vatnajökull icecap, max height is 1675m. Top height of Mt. Öræfajökull is only 880m

X geo\_em.d01.nc

At 1km resolution the max height is 2020m. Top height of Mt. Öræfajökull is now 1945m 🗹

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Measurements and simulations of volcanic ash for civil aviation





Simulation results are also affected by the choice of parameterization schemes

Rögnvaldsson, Ó., Bao, J.-W., Ágústsson, H., and Ólafsson, H.: Downslope windstorm in Iceland – WRF/MM5 model comparison, Atmos. Chem. Phys., 11, 103-120, doi: 10.5194/acp-11-103-2011, 2011.



## Why not always use 1km resolution?<sup>Measurements and simulations</sup> of volcanic ash for civil aviation



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

# High resolution not always sufficient Measurements and simulations of volcanic ash for civil aviation

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



#### SUMO and WRF

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



SUMO and WRF



SUMO and WRF

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



## Effects of additional observations

22°W

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

m/s The flow structure 64.5°N <sup>14</sup> is now in much WRF at a <sup>12</sup> better agreement resolution of 500 with available m forced with 10 observations ECMWF-data on model levels and 8 . Esia SUMO data 6 Observed surface 4 winds in red 2 10

21.5°W

#### Effects not just at the surface

#### Simulated flow in N-S section across Mt. Esja



#### Effects can be far reaching

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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. *Monthly Weather Review*, in revision

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



#### 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



#### **Preliminary results**

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#### The SUMO dust sensor has been tested in France and Iceland



#### **Preliminary results**

#### The SUMO dust sensor has been tested in France and Iceland





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

#### Various uses of model output

0.1

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Dry Deposition (normalized by source conc) %



#### **Current research and development**

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(optional)

#### **Current research and development**

Measurements and simulations of volcanic ash for civil aviation



# Conclusions

- The WRF model has a wide variety of applications
- 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
  - Dust sensor could detect low concentrations of ash above airports (fly vs. no fly)
- The SUMO is currently being integrated to the SARWeather, on-demand, forecasting system