Icelandic Met Office

# *Remote Sensing of Volcanic Ash: Radar, Lidar and Ceilometer Activities at IMO*

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# Fixed Position C-band Radars

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Fljótsdalsheiði E-Iceland C-band radar.
Photo Geirfinnur S. Sigurðsson 8 October 2012

Keflavík SW-Iceland C-band radar.
Photo Þórður Arason 9 August 2011

# Two Mobile X-band Radars

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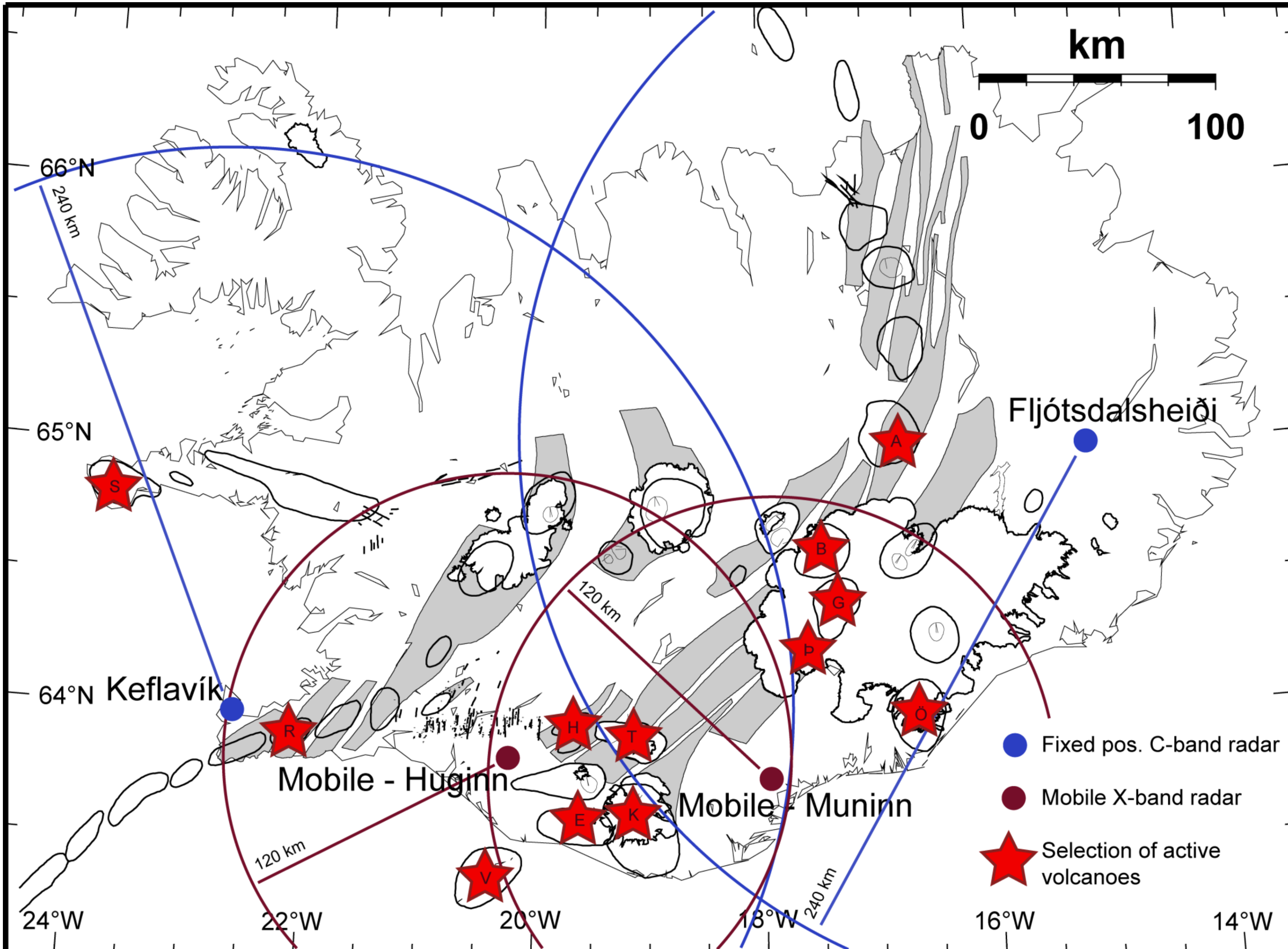
Specially adapted truck to take mobile radar off road.
Photo Geirfinnur S. Sigurðsson 25 September 2012

Mobile radar installed with clear view over
Bárðarbunga before the eruption.
Photo Þorgils Ingvarsson 22 August 2014


km
0
100
66°N
65°N
64°N
24°W
22°W
20°W
18°W
16°W
14°W
240 km
240 km
120 km
120 km
Keflavík
Fljótsdalsheiði
Mobile - Huginn
Mobile - Muninn
S
R
H
T
E
K
V
A
B
G
Þ
Ö
Fixed pos. C-band radar
Mobile X-band radar
Selection of active volcanoes

# Operational Status

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- One of our mobile radars had for a while power generator problems. It automatically shut down after about 1 day of continous operation indicating generator overheating and/or low oil pressure. Neither is true and this has been diagnosed as a sensor/computer problem, which has now been fixed.

- Currently one mobile radar is in Reykjavík for calibration. Will soon be moved to Vatnsfell, 85 km from Bárðarbunga.

- Currently all four radars are believed to be in good health

# Bárðarbunga – Holuhraun

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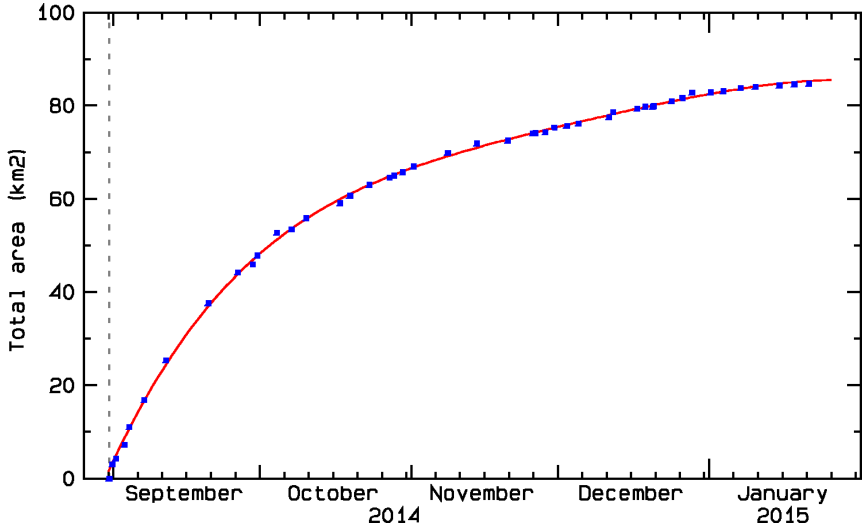


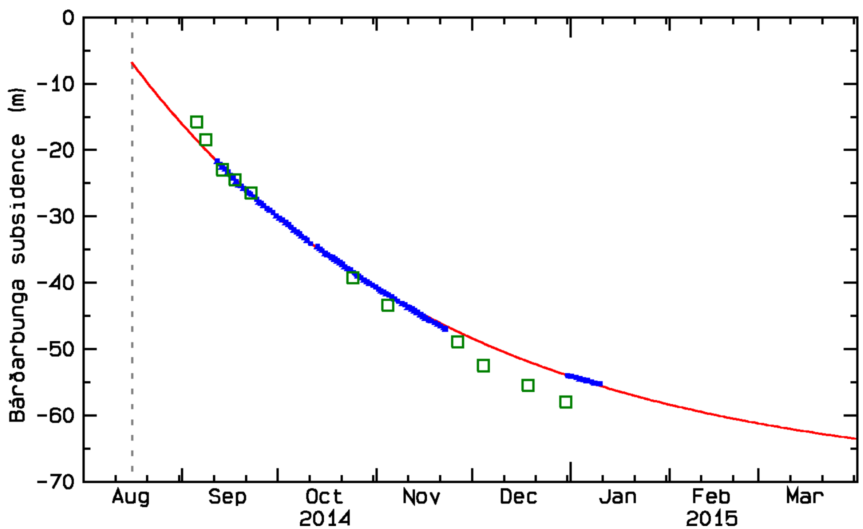


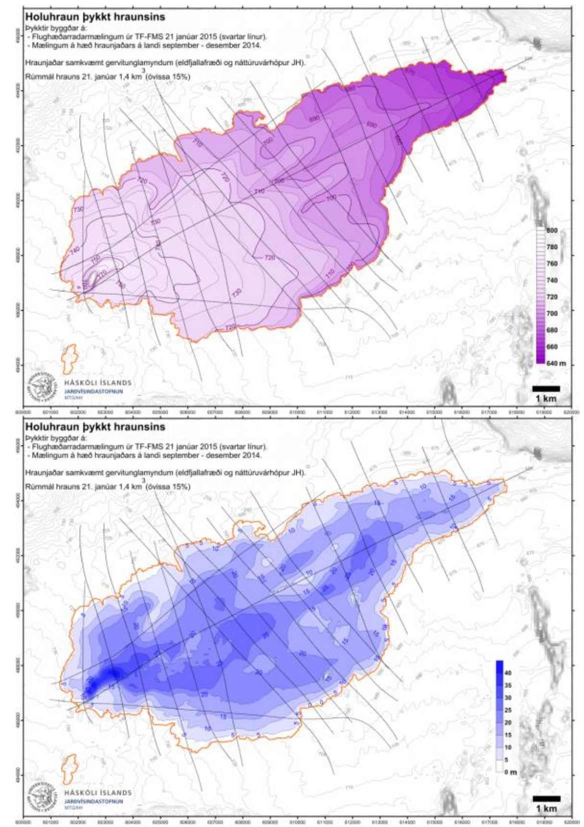


Elevation measured with a flight radar and thickness of Holuhraun lava (21 January 2015). Total volume 1.4 km³. From: jardvis.hi.is

The fissure eruption and juvenile steam and gas plume.
Photo Halldór Björnsson IMO 1 September 2014.

# Python – Open Source Software

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**IMO is planning to install and use Python open source radar software for our radar data analysis. This is not operational.**

- **Wradlib (wradlib.bitbucket.org): An Open Source Library for Weather Radar Data Processing**
- **Baltrad (baltrad.eu)**

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# Lidar and ceilometer measurements at IMO

# LIDAR

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## Outlook

- **co-locate to the NCAS lidar, ceilometer and the X-band radar (Hotel Laki, SE-Iceland)**
- **Real-time data analysis and plotting, assistance FMI (Ewan O'Connor)**

- **Two Leosphere Windcube 200S Doppler lidar with depolarisation channel**
- **SAT August 2014, semi-operational**
- No data analysis
- Depol-function not working on one system
- **One system installed at Keflavík airport**
- **The other one will become mobile on a trailer in 2015**

# LIDAR – screenshots

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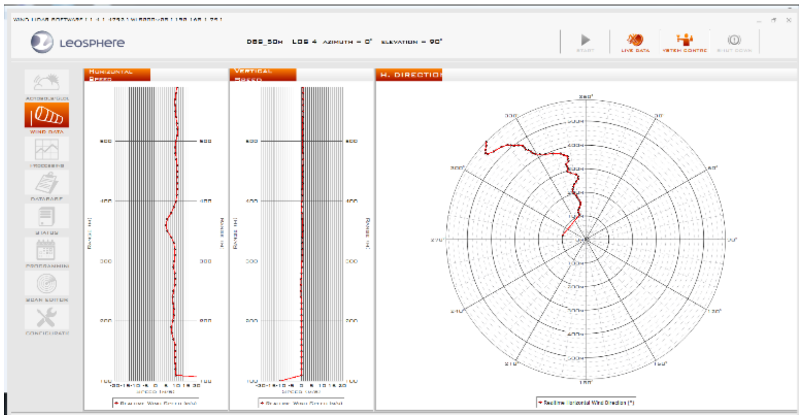
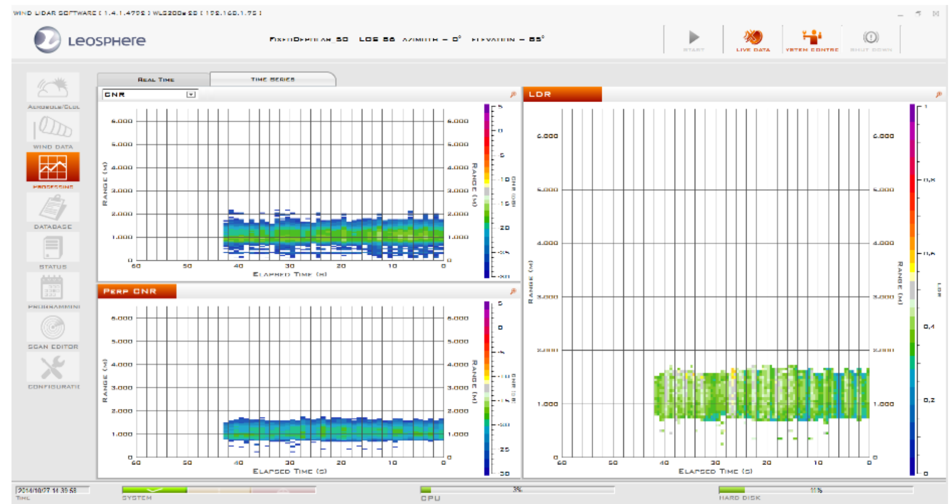
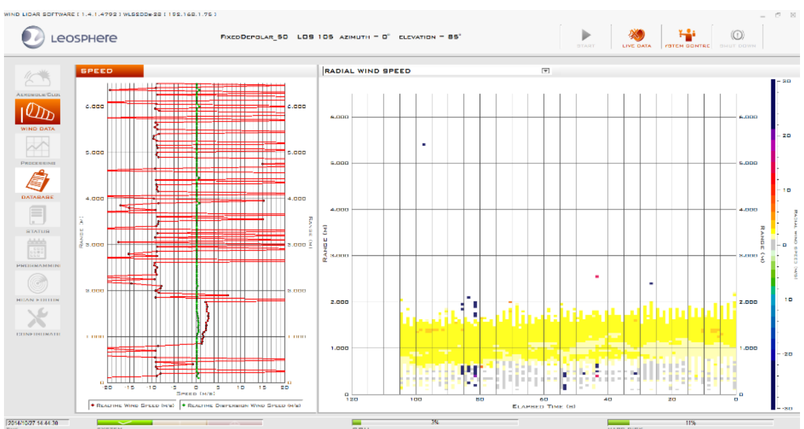
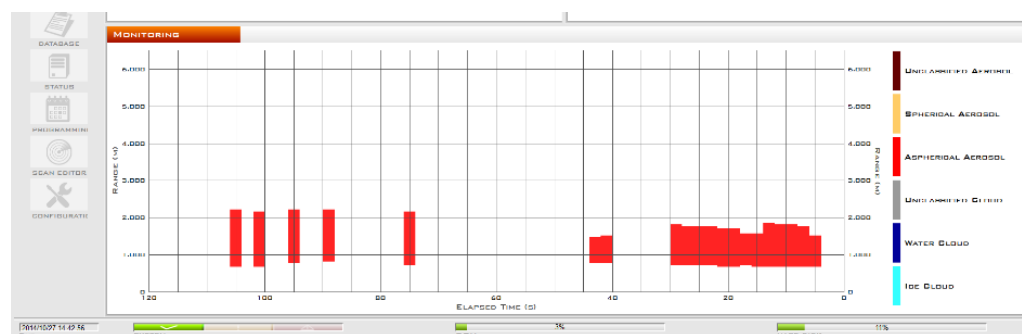
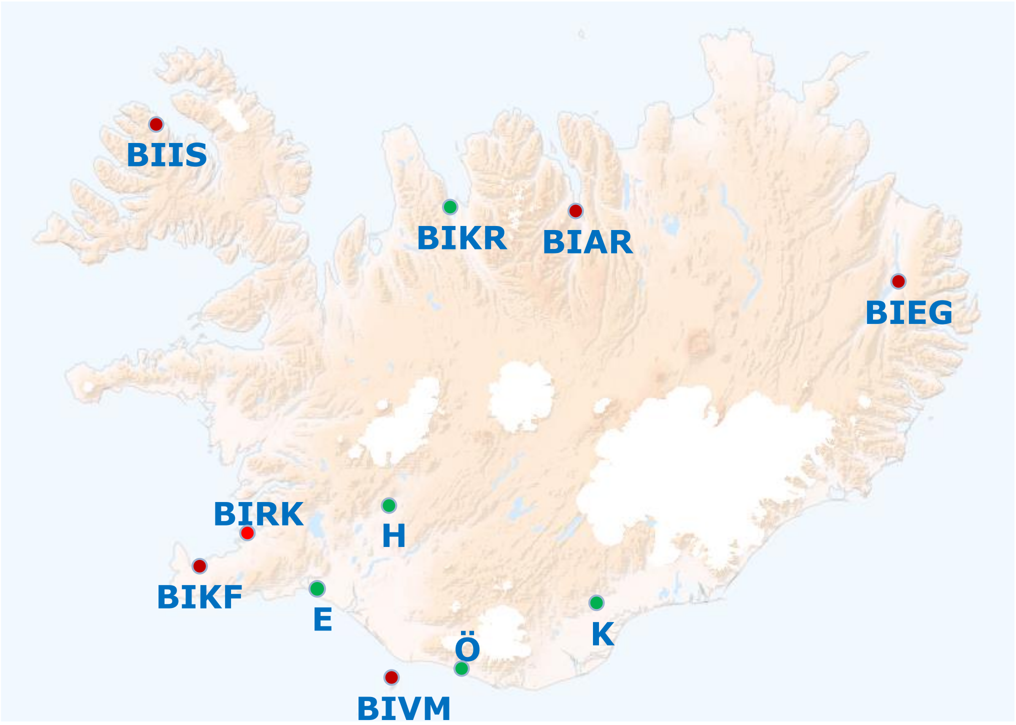


# Ceilometer network



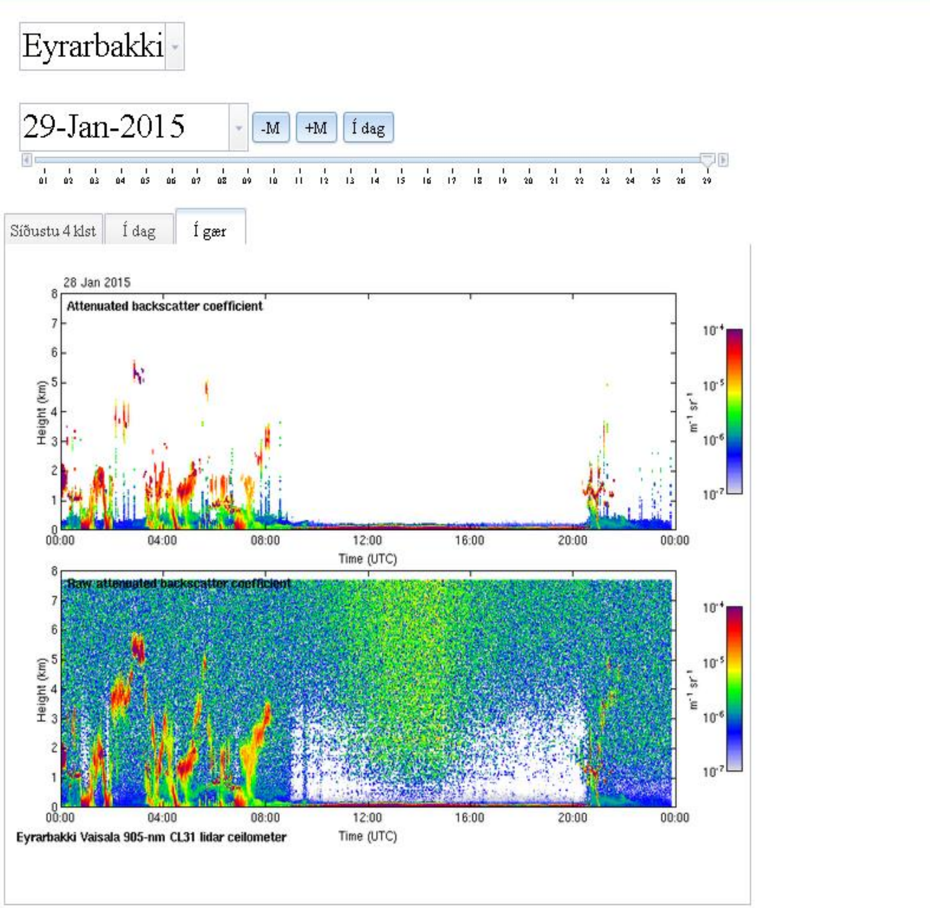

**IMO (CL31)**

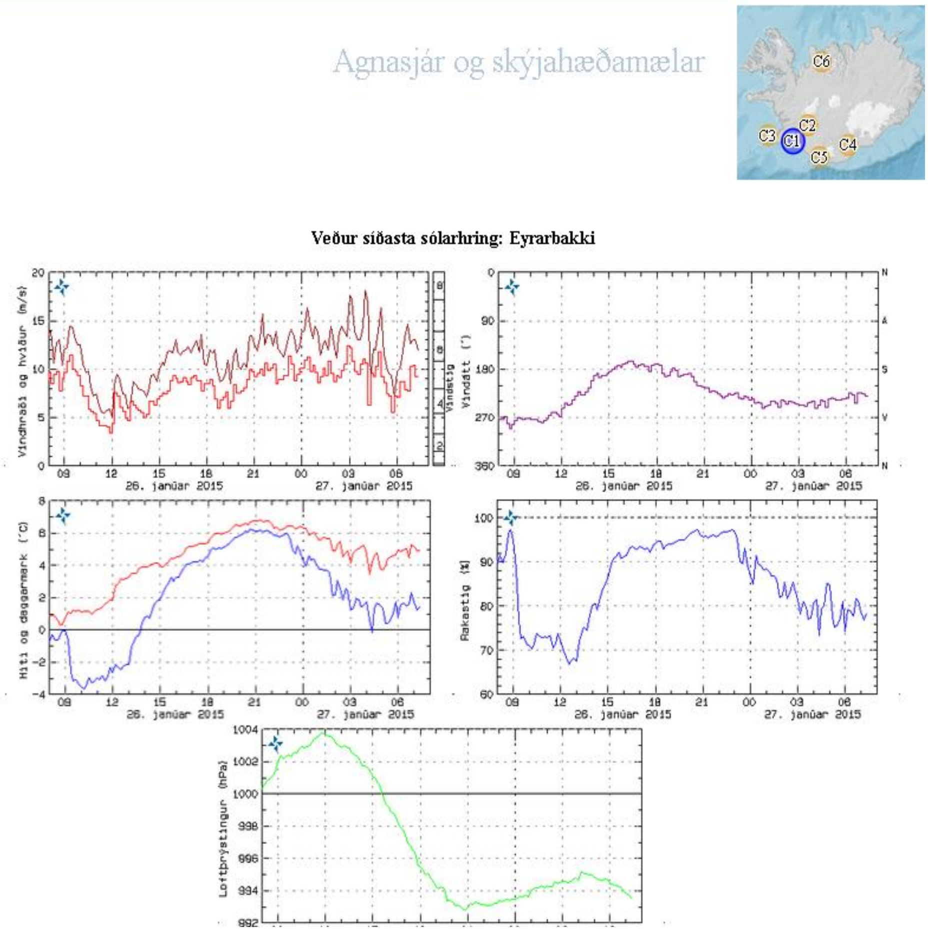
E - Eyrarbakki
H - Hjarðarland
Ö - Önundarhorn
K - Kirkjubæjarklaustur
BIKR – Sauðárkrókur

**ISAVIA (CL31, CL51, CT25K)**

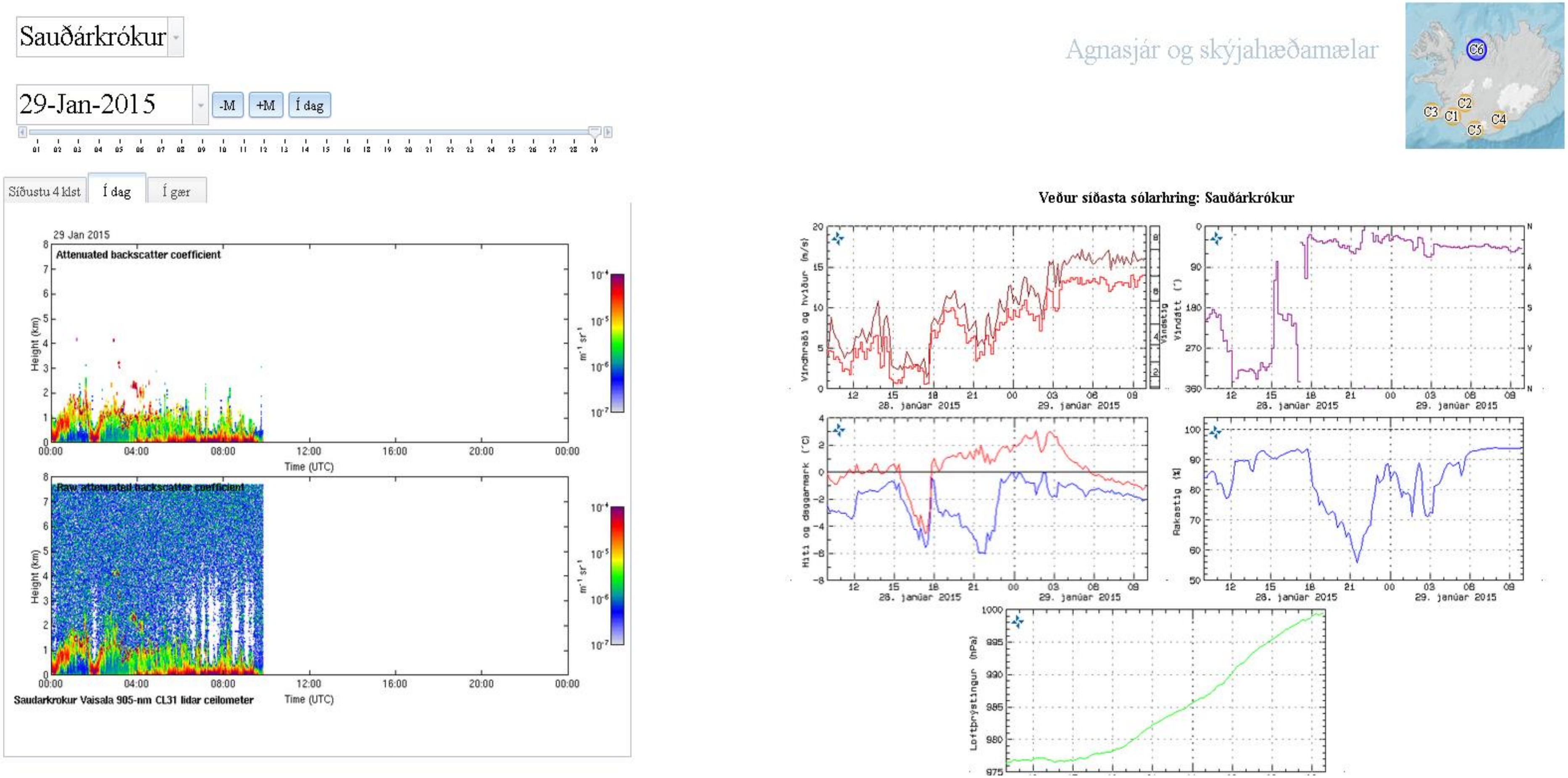
BIKF – Keflavík International Airport
BIRK – Reykjavík
BIIS – Isafjörður
BIAR – Akureyri
BIEG – Egilsstaðir
BIVM – Vestmannaeyjar

# Ceilometer quicklook webpage



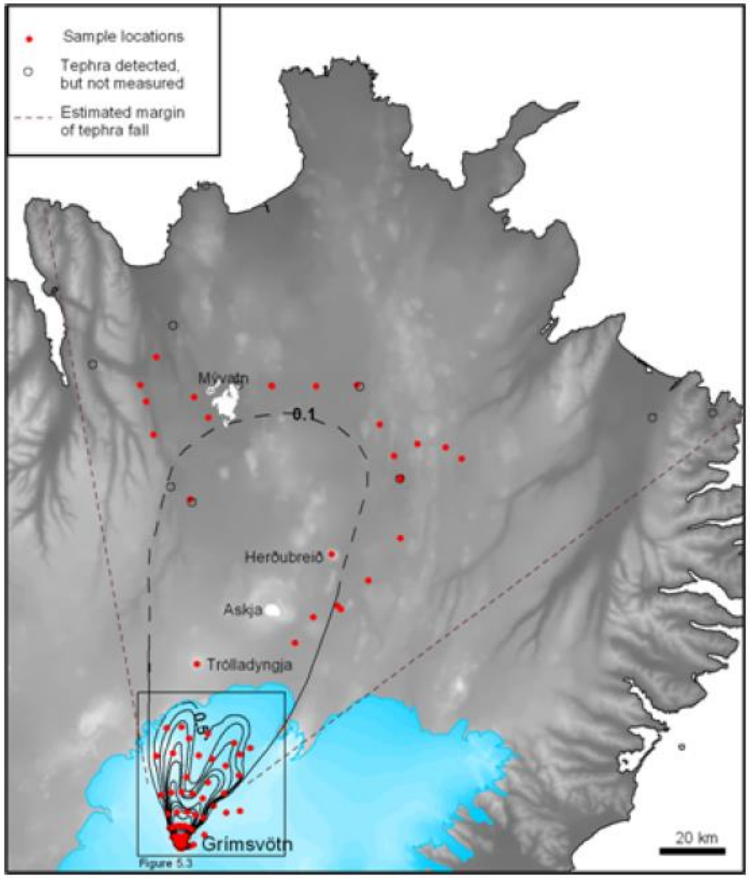
# Ceilometer quicklook webpage 2

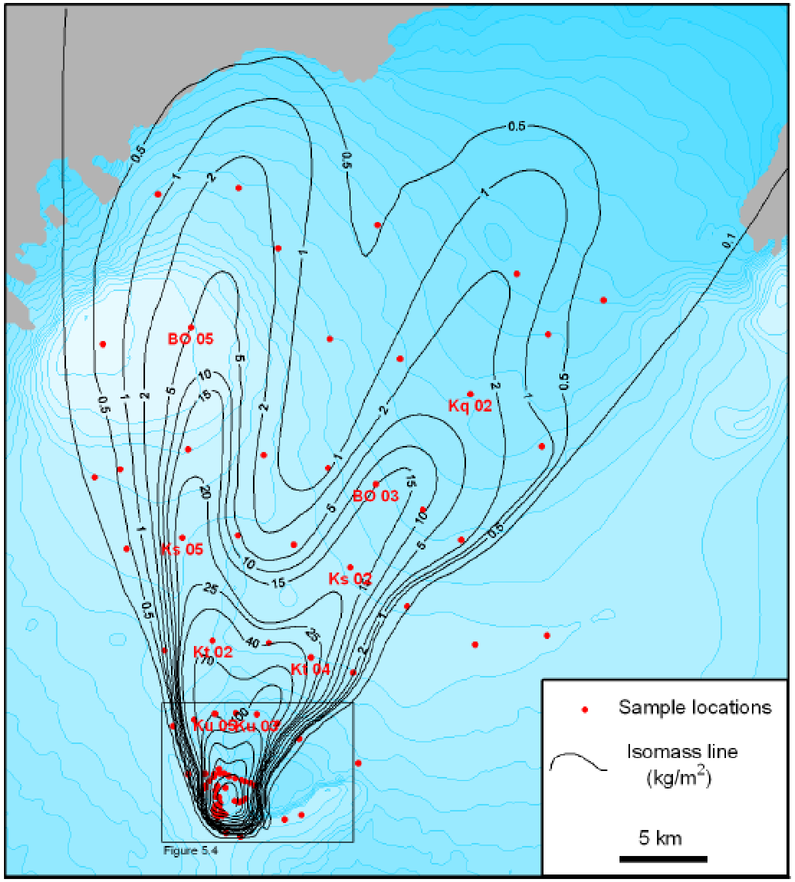


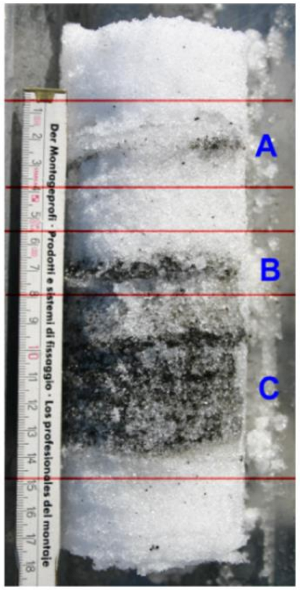
# Validation

# Grímsvötn 2004

## Sampling of ash deposits and estimates of ground mass loading (kg/m²)

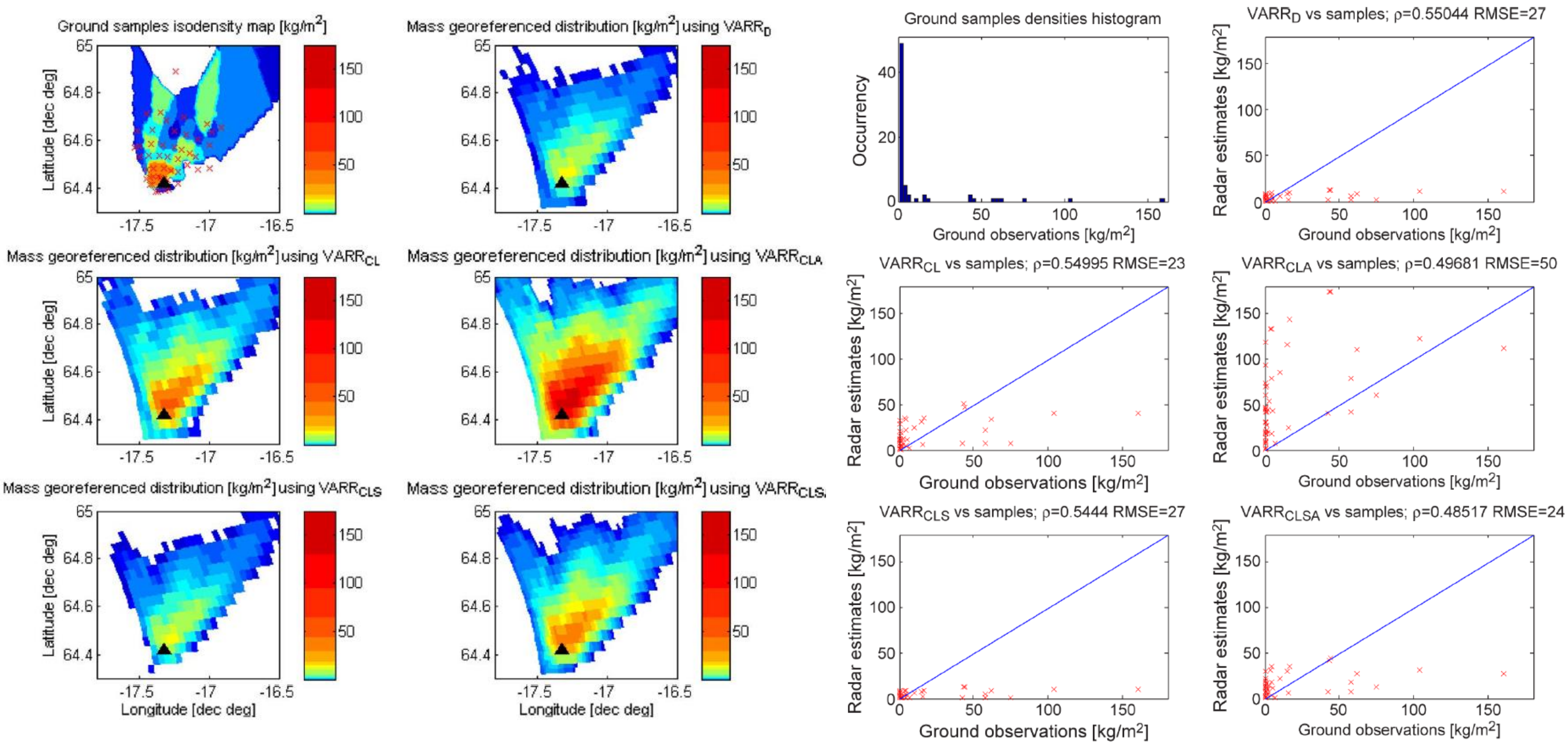



Oddsson, B. (2007), The Grímsvötn eruption in 2004: Dispersal and total mass of tephra and comparison with plume transport models, MS Thesis, Univ. Iceland.

# Grímsvötn 2004
## Single polarization C-band radar data
## VARR-models

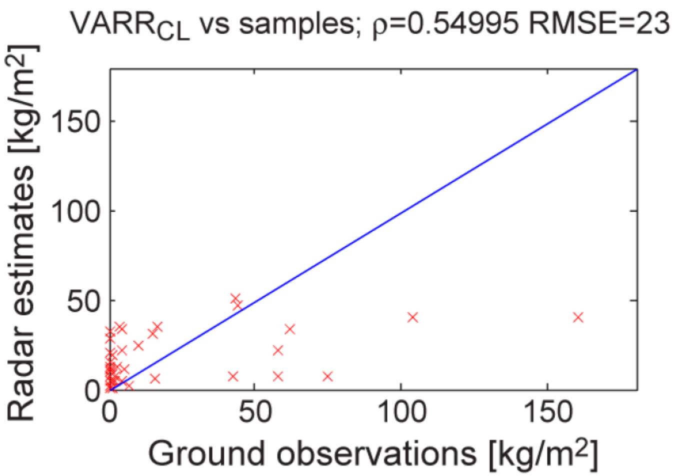


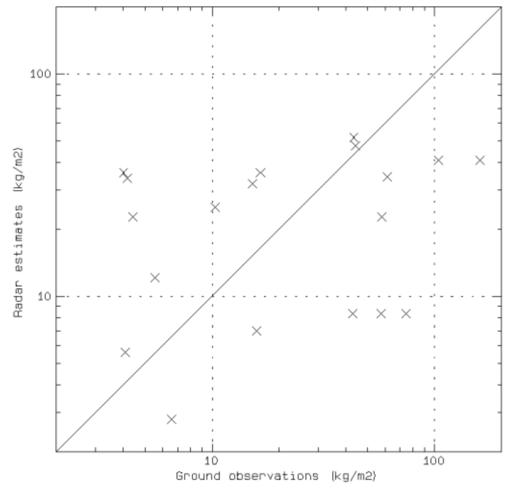


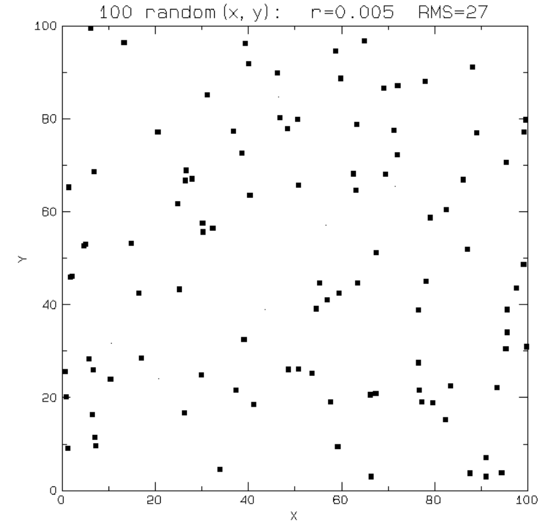
Marzano, F. S., M. Lamantea, M. Montopoli, B. Oddsson & M. T. Guðmundsson (2012), Validating subglacial volcanic eruption using ground-based C-band radar imagery, *IEEE Transactions on Geoscience and Remote Sensing*, **50**(4), 1266-1282.

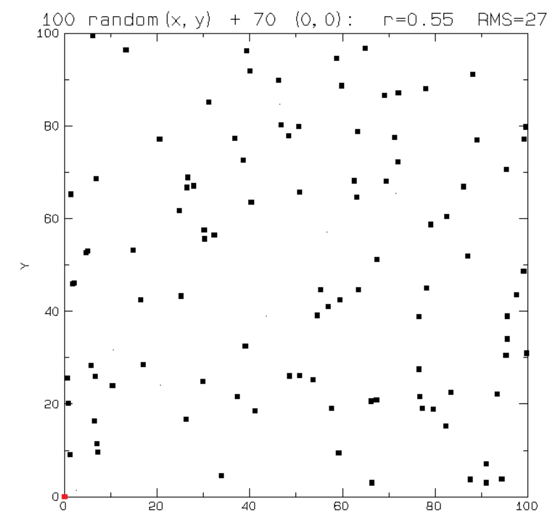
# Is there a correlation?

## i.e. bewteen mass loading of ground observations and the VARR-model?




Variance of the ground observations (i.e. for >2 kg/m²) about the mean is lower than the variance of the difference between the model and observations. This is true for both the linear and logarithmic viewpoints.

**The model does not explain any of the variability in the observations about their mean!**

# Additional observational data sets are needed for validation

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# Types of Grains

# Variations in Physical Properties

- **Volcanic ash**
  - Grain shape
  - Water coated ash
  - Ice coated ash
  - Ash-infused hail
- **Water drops**
- **Ice**
- **Hail – Graupel**

**The Radar Equation**

$$\frac{P_r}{P_t} = \left\{\frac{\pi^3 c\, \tau\, G^2 \varphi\, \theta}{1024\ \ln 2\ \lambda^2\, r^2}\right\} |k|^2 N\, D^6$$

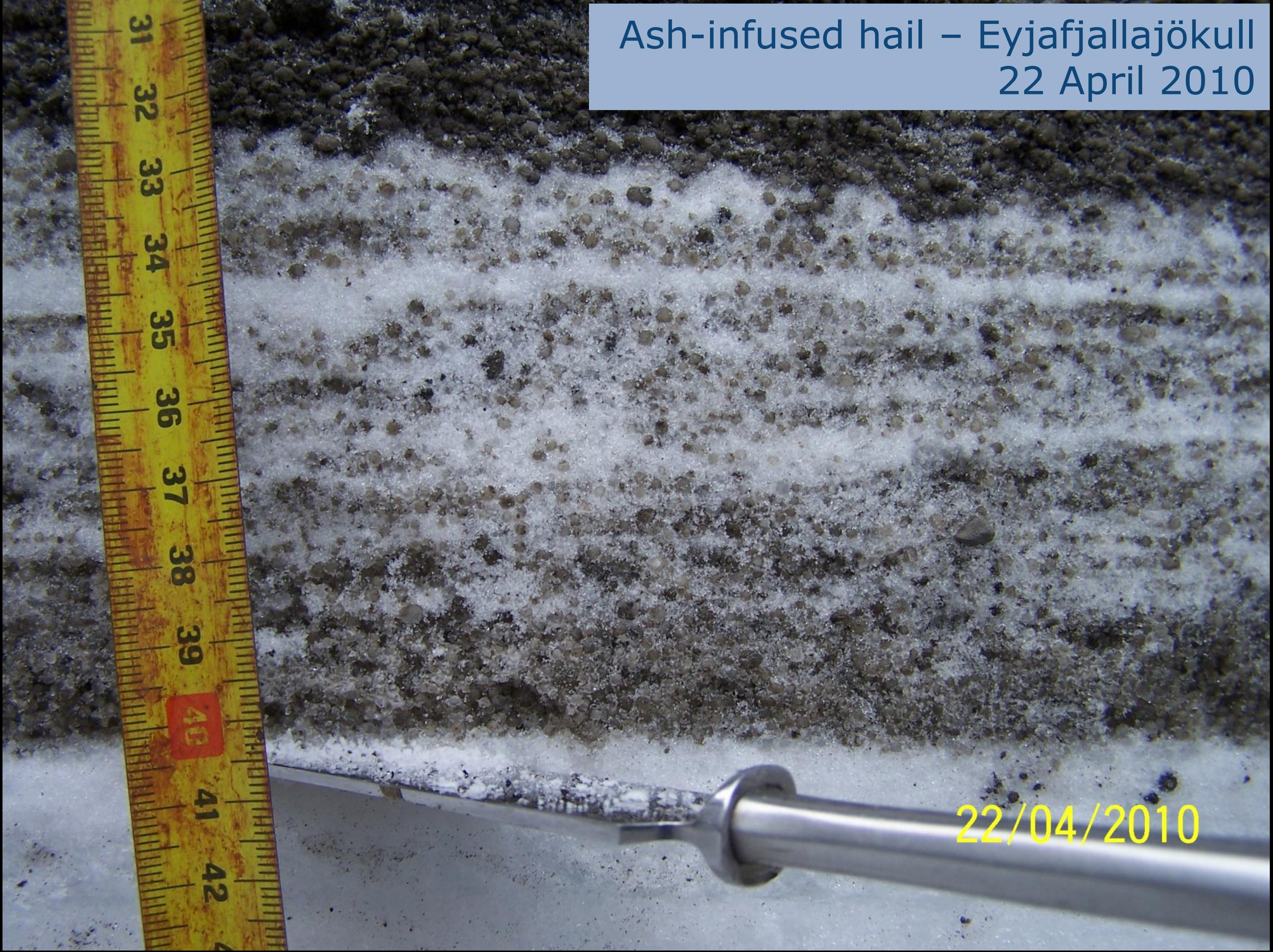
$$|k|^2_{ice} = 0.197, \quad |k|^2_{ash} = 0.39, \quad |k|^2_{water} = 0.93$$

# Eyjafjallajökull eruption April 2010

Plume lightning seen from a distance of 72 km
Notice the characteristic fibrous anvil shape of the plume top

Photo Þórður Arason 17 April 2010 at 04:47:09

# Ash-infused hail – Eyjafjallajökull
22 April 2010




Ash-infused hail on the glacier about 5 km east of the Eyjafjallajökull crater
Photo Thor Thordarson 22 April 2010

15 km
10 km
Tr
5 km
Gr
Grímsvötn eruption
May 2011
Photo Bolli Valgarðsson 21 May 2011 at 19:20

# 3 km from Grímsvötn crater

Hagl-01: Grímsvötn 2011 ash section 3 km from the crater

Photo Þórður Arason 11 June 2011


Grímsvötn 2011 – Hagl-02

Macro-photo Þórður Arason 11 June 2011

Grímsvötn 2011 – Hagl-01

Macro-photo Þórður Arason 11 June 2011

# Radar detection of ash vs. ash-infused hail

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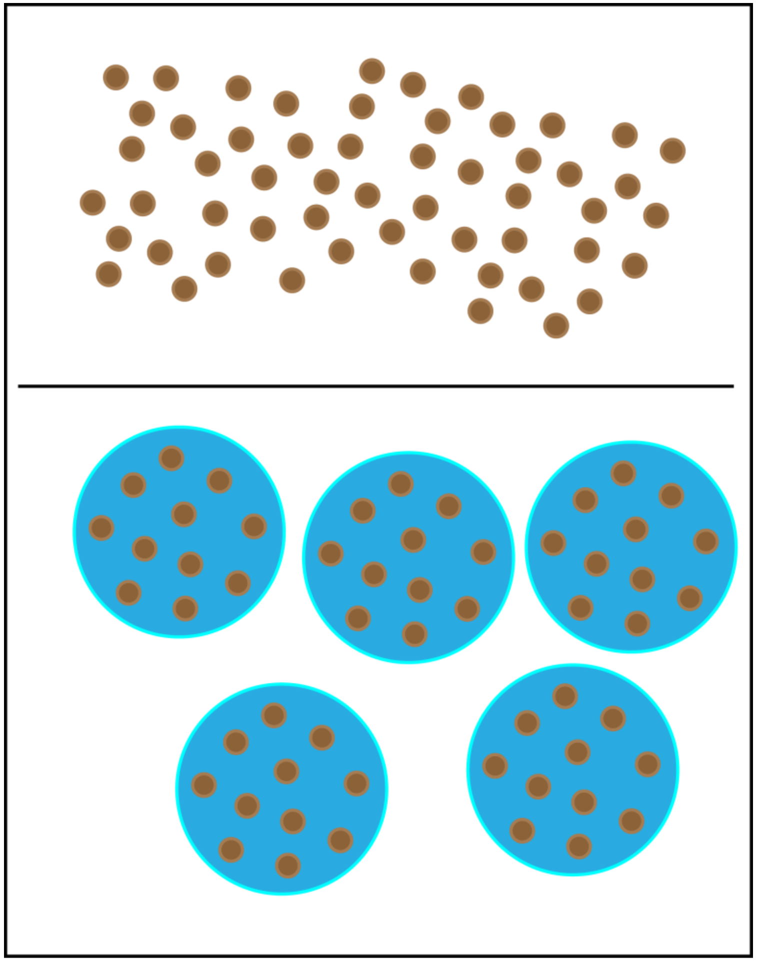

**Ash grains embedded into much larger hail, lead to stronger received radar signal.**

**On the ground we may observe the fine ash grain size distribution after the hail has melted.**

**Mass concentration in the plume, assuming the observed ash grain size distribution, may be overestimated by a factor of 10-100.**