Development of an ensemble-based volcanic ash dispersion model for operations at Darwin VAAC

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Outline

• VAAC operations
• Research
• Dispersion Ensemble Prediction System (DEPS)
• Conclusions and future work
Volcanic Ash Advisory Centres (VAAC) area of responsibility
Warnings for volcanic ash

- Advice or detection of an eruption
- Interpretation of satellite data
- Dispersion model guidance
- Generation of VAA and VAG for ash cloud 0h, +6h, +12h and +18h.
Research objectives

Improve information systems and guidance for operations in the Darwin VAAC

Eyjafjallajökull eruption 2010 → guidance on spatial variation in ash concentration and uncertainties

• Satellite remote sensing
  ▪ Discriminate ash from water/ice, plume height, mass load – Pavolonis et al (2015a,b)
  ▪ Himawari-8 – operational since 2015 – improved spatial, temporal and spectral resolution

• Dispersion modelling
  ▪ HYSPLIT coupled with ACCESS NWP model
  ▪ Source term parameters – line / umbrella source, MER, mass distribution, uncertainties
  ▪ Improved microphysics – particle size distribution, particle fall speed, wet deposition
  ▪ NWP ensemble models – quantify uncertainties
  ▪ Integrated use of satellite data to calibrate forecasts - inverse modelling
Kelut, 1930Z, 13 Feb 2014, MTSAT-2

(+3 hr after eruption. Ash probability (%) and mass load (g/m²))
Kelut, 0130Z, 14 Feb 2014, MTSAT-2

(+9 hr after eruption. Ash probability (%) and mass load (g/m2))
## Specification of “Himawari-8/9” Imager (AHI)

<table>
<thead>
<tr>
<th>Band</th>
<th>Central Wavelength [μm]</th>
<th>Spatial Resolution</th>
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<tbody>
<tr>
<td>1</td>
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<td>9</td>
<td>6.89 - 7.01</td>
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<td>10</td>
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<td>11</td>
<td>8.44 - 8.76</td>
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<td>12</td>
<td>9.54 - 9.72</td>
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<td>14</td>
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<td>15</td>
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<tr>
<td>16</td>
<td>13.2 - 13.4</td>
<td>2Km</td>
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</tbody>
</table>

### Water Vapour

- **SO₂**
- **O₃**
- **Atmospheric Windows**
- **CO₂**

- **MSG/EUMETSAT**

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### Full Color Disk Image

- Every 10 minutes

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### as of MTSAT-1R/2

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<tr>
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<tbody>
<tr>
<td>1</td>
<td>0.55 – 0.90</td>
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<td>2</td>
<td>3.50 – 4.00</td>
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<tr>
<td>3</td>
<td>6.50 – 7.00</td>
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<td>4</td>
<td>10.3 – 11.3</td>
<td>4Km</td>
</tr>
<tr>
<td>5</td>
<td>11.5 – 12.5</td>
<td>4Km</td>
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</tbody>
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  ▪ Microphysics – particle size distribution, particle fall speed, wet deposition, aggregation
  ▪ NWP ensemble models – quantify uncertainties
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Wet deposition

- Removal of ash by rainfall
- Heavy seasonal rainfall in Darwin VAAC area
- Significant seasonal impact on ash mass loading
- There has been relatively little investigation on this
Vertical emission rate - Kelut

VOLCAT mass load at 13/2330

Optimal vertical mass emission rates

Simulation at 13/2330 UTC with uniform source

Simulation at 13/2330 UTC with optimal source
Dispersion Ensemble Prediction System (DEPS)

• Web application that runs HYSPLIT coupled with Bureau's 24 member ACCESS-GE ensemble system [+ deterministic models ACC-G, ACC-R, NOAA-GFS]
• Defined eruption source parameters
  – height
  – line / umbrella source
  – duration of eruption
  – MER and fine ash fraction (Mastin etal 2009, Webster etal 2012)
  – wet vs dry sedimentation
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Line</th>
<th>Umbrella</th>
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<tbody>
<tr>
<td></td>
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<td>Source a</td>
</tr>
<tr>
<td>Eruption time</td>
<td>1600Z, 13 Feb 2014</td>
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<tr>
<td>HYSPLIT model initialization time</td>
<td>1600Z, 13 Feb 2014</td>
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<tr>
<td>Eruption duration</td>
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<td></td>
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<tr>
<td>Wet deposition</td>
<td>On</td>
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<table>
<thead>
<tr>
<th>Parameter</th>
<th>Line</th>
<th>Umbrella</th>
<th>Source a</th>
<th>Source b</th>
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<tbody>
<tr>
<td>Base (km)</td>
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<td>1.731</td>
<td>14</td>
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<tr>
<td>Top (km)</td>
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<td>26</td>
<td>19</td>
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<td>Diameter (km)</td>
<td>10</td>
<td>10</td>
<td>100</td>
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<tr>
<td>Fine ash fraction</td>
<td>0.1</td>
<td>0.1</td>
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<tr>
<td>MER (kg/s)</td>
<td>$7.88 \times 10^6$</td>
<td>$3.94 \times 10^6$</td>
<td>$3.94 \times 10^6$</td>
<td></td>
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</table>
Kelut eruption, 1600Z, 13 Feb 2014
Ash load at 0100Z, 14 Feb 2014 (+9 hr after eruption)
Based on ACC-R
a) Cylinder source (3.5 kg.m$^{-1}$)  
   (current operational guidance)
b) Umbrella source (1.8 kg.m$^{-1}$)
Kelut eruption, 1600Z, 13 Feb 2014
Ash load at 0100Z, 14 Feb 2014 (+9 hr after eruption)
Based on ACC-GE11
a) Cylinder source (3.1 kg m\(^{-1}\))
b) Umbrella source (2.8 kg m\(^{-1}\))
Kelut eruption, 1600Z, 13 Feb 2014
Forecast for 0100Z, 14 Feb 2014
(+9 hr after eruption)
[fine ash fraction 0.1]
Percentage of 27 members with ash load > 4 g.m\(^{-2}\)

a) Cylinder source
b) Umbrella source
Kelut eruption, 1600Z, 13 Feb 2014
Forecast for 0100Z, 14 Feb 2014 (+9 hr after eruption)

**fine ash fraction 0.001**

Percentage of 27 members with ash load > 4 g.m$^{-2}$

a) Cylinder source
b) Umbrella source
Conclusions

• Ensemble output shows spread of outcomes for dispersion of ash – guidance on uncertainty with meteorology
• Simple umbrella source provides improved representation of ash dispersion for large eruption reaching tropopause when compared with satellite observations
• Mass load in DEPS output too high compared to observed satellite estimate by significant factor
  – MER for initialization of DEPS is too high for observed height of eruption column – based on Mastin empirical relation (associated with latent instability in tropical environment)
  – Fine ash fraction too high
  – Poor representation of cloud and precipitation in tropics in NWP models
Outstanding problems and future directions

• Improve utility of satellite products for operations
• Integration of observational data in dispersion modelling
• Optimize use of ensemble models
  – Subsets
  – New inputs (e.g. EC, GFS ensembles)
Thank you