A New Dispersion Modelling System at Wellington VAAC

Cory Davis[1], Paul Shucksmith[1], Graham Rye[1], Iman Soltanzadeh[1], Matthieu Bernard[1], Tony Hurst[2], Angus Hines[1]. [1]*Meteorological Service of New Zealand (MetService) Ltd.* [2]*GNS Science*

MetService

Introduction

At Wellington VAAC we have recently implemented a HYSPLIT[1]-based ash dispersion modelling system, which incorporates several recommendations from a WMO VAAC modelling best practices workshop held in 2012[2]. This poster describes the new modelling system and plans for future improvement.

NWP

The automatic use of multiple NWP models for VAAC forecaster initiated simulations allows the consideration of meteorological uncertainty in the resulting VAA, or allows the VAA to reflect the NWP model favoured by the forecast room for a given meteorological situation.

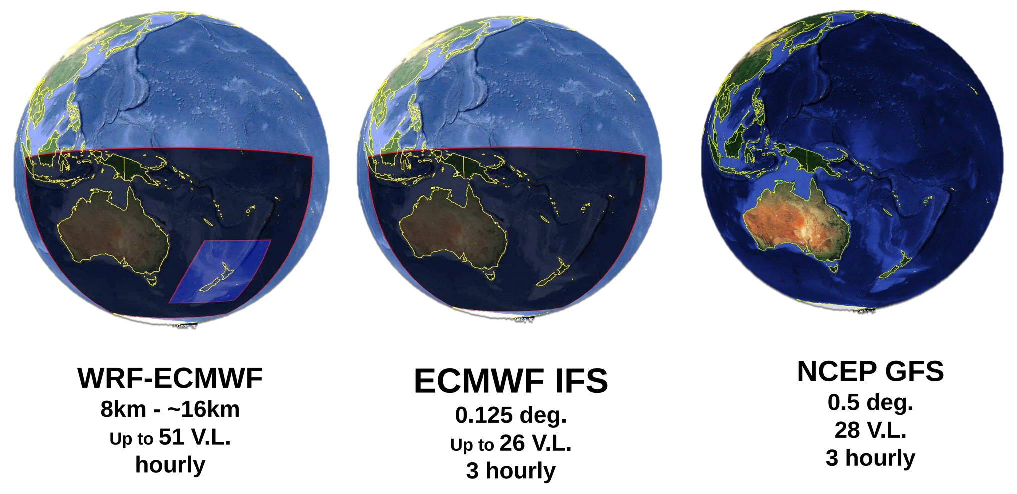

Figure 1: NWP sources and coverage areas. In HYSPLIT, lagrangian particles can be passed between NWP sources, so for WRF, the high-resolution nest, outer nest, and driving global model are all used to extend the spatial range of the simulation and give high resolution where it is needed.

Eruption parameters

We extend the "poor-man's ensemble" approach by also automatically running dispersion simulations for a range of eruption parameters. Initially, when little is known about the eruption, default parameters for small, medium, and large eruptions are used from the USGS eruption parameter database [3]. We are in the process of incorporating the parameters that GNS Science uses for New Zealand volcanoes, which are shown in Table 1.

volcano	possible VEI range	GNS column height (km) high	GNS column height (km) low	USGS column height (km) L	USGS column height (km) M	USGS column height (km) S	GNS tephra volume (km3) L	GNS tephra volume (km3) M	GNS tephra volume (km3) S	USGS Tephra volume (km3) L	USGS Tephra volume (km3) M	USGS Tephra volume (km3) S	ash size distribution	density
auckland	0 to 2	5	3	10	7	2	0.1	0.01	0.001	0.012	0.014	0.0012	Heimay	1500
mayor	1 to 4	10	3	15	11	5	5	1	0.1	0.234	0.035	0.0070	Hatepe	1200
white	1 to 3	5	3	15	11	5	0.01	0.001	0.0001	0.216	0.032	0.0065	Vesuvius	1300
haroharo	1 to 4	25	3	not in our database			10	5	1	not in our database			Hatepe	1200
tarawera	1 to 4	25	3	not in our database			5	2		not in our database			Hatepe	1200
tarawera	1 to 4	10	3	not in our database					0.1	not in our database			Hatepe	1200
taupo	3 to 8	25	3	15	11	5	10	10	0.1	0.234	0.035	0.0070	Hatepe	1200
tongariro	1 to 4	20	3	15	11	5	1	0.1	0.001	0.216	0.032	0.0065	Vesuvius	1300
ngauruhoe	1 to 3	10	4	15	11	5	0.1	0.01	0.001	0.216	0.032	0.0065	Vesuvius	1300
ruapehu	1 to 3	20	4	15	11	5	1	0.01	0.001	0.216	0.032	0.0065	Vesuvius	1300
taranaki	1 to 4	15	4	15	11	5	1	0.05	0.01	0.216	0.032	0.0065	Vesuvius	1300

Table 1: Plume heights and volumes assumed by GNS Science for N.Z. volcanoes

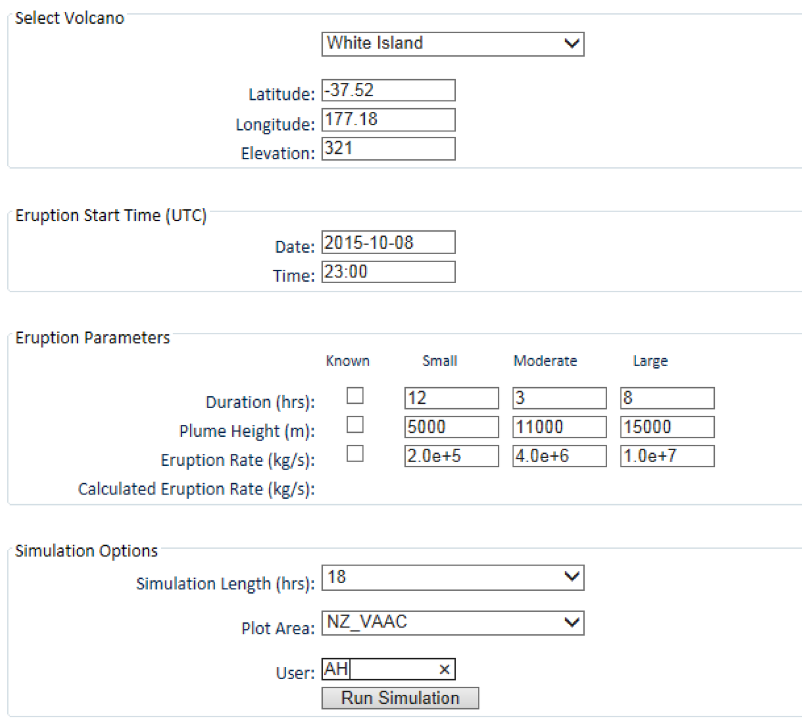

Figure 2: User interface showing default parameters for White Island.

When the plume height, h, is known, the default mass eruption rate, $\dot{M}$, is determined by inverting the Mastin Equation[4]:

$$h = 2.00\dot{V}^{0.241}, \qquad (1)$$

assuming a dry equivalent rock density of 2500 $\mathrm{kg\,m^{-3}}$. The fraction of erupted mass belonging to particles less than 63 μm in diameter, which is the fraction of the erupted mass that we actually model, is considered as a constant value of 0.05.

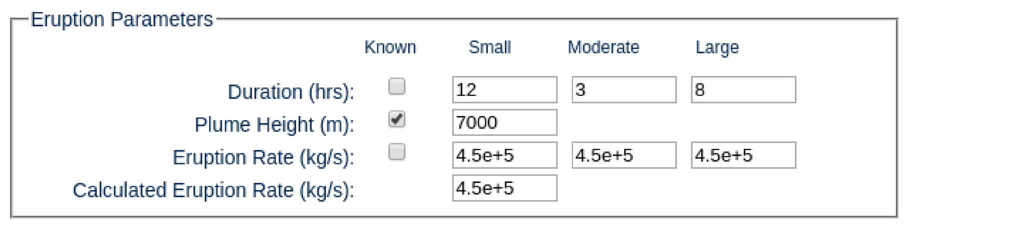

Figure 3: As information about the eruption becomes known, these parameters can be easily adjusted, and the range of parameters in the subsequent simulation reduced.

case	Available observations h	Available observations d	Satellite Ash Cloud Area	HYSPLIT eruption parameters	runs
1	×	×	×	Run default parameters (magnitude 1,2, and 3) for appropriate volcano type (M/S). For U0 type use M1 and M2.	3
2	×	✓	×	As in case 1, except use d observation	3
3	✓	×	×	Set h, $\dot{M}$ from Equation 1, run for the d of each category.	3
4	✓	✓	×	As in case 3, except use d observation	1
5	×	×	✓	As in case 1. From closest match to satellite obs.,adjust h, $\dot{M}$, and d to give a closer match to satellite obs.	> 3
6	×	✓	✓	As in case 2. From closest match to satellite obs.,adjust h and $\dot{M}$ to give a closer match to satellite obs.	> 3
7	✓	×	✓	As in case 3. From closest match to satellite obs.,adjust $\dot{M}$ and d to give a closer match to satellite obs.	> 3
8	✓	✓	✓	As in case 4. From closest match to satellite obs., adjust $\dot{M}$ to give a closer match to satellite obs.	1

Table 2: Logic for setting Eruption Source Parameters: plume height, h, eruption duration, d, and mass eruption rate, $\dot{M}$, depending on what observational information is available.

Quantitative outputs → Forecaster Visualisation System (IBL Visual Weather) → VAA/VAG

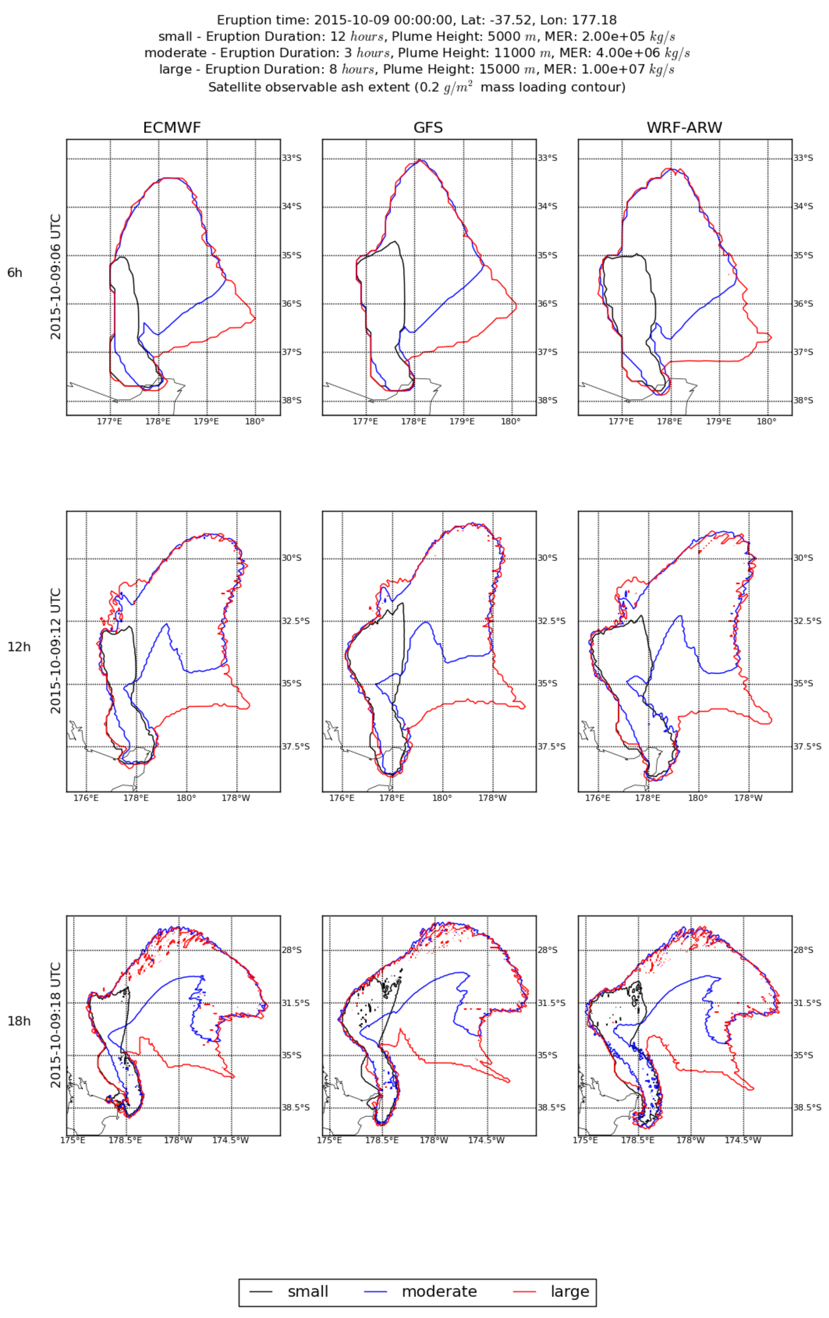

Figure 4: We provide a first-look chart of column mass loading for all ensemble members, so that the forecaster can quickly evaluate the range of outcomes. Modelled mass loading can be verified against satellite observations, leading to revised eruption parameters.

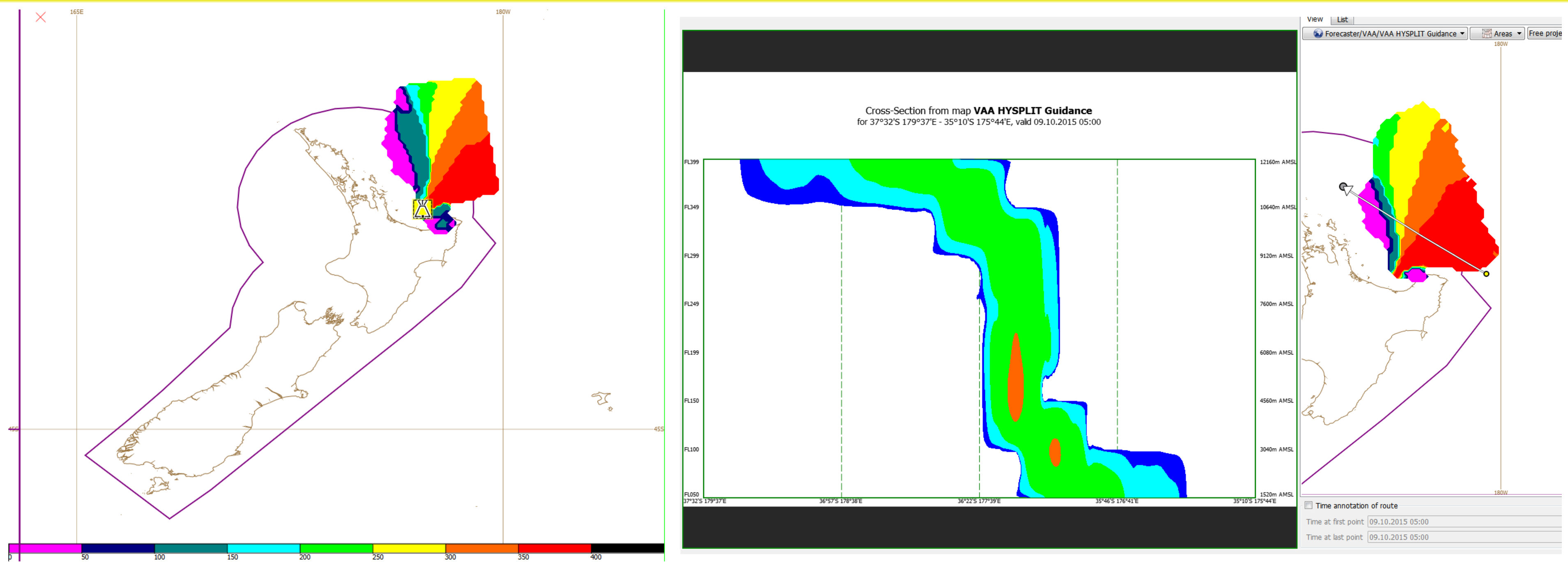

Figure 5: The complete output, including mass loading, concentration at flight levels, ash cloud height, ash cloud base, and surface deposition, are made available in GRIB1 format to IBL Visual Weather.

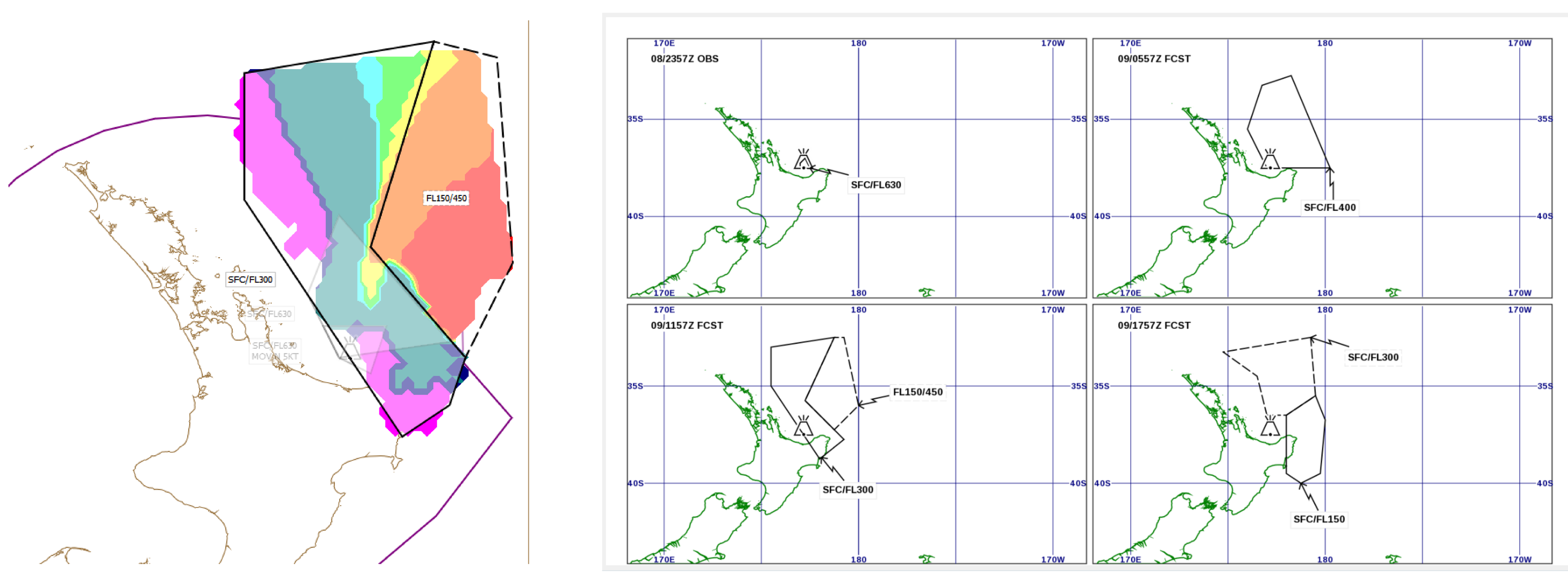

Figure 6: The HYSPLIT output in Visual Weather is then used to guide the creation and publication of the final VAA/VAG.

Ash Fall

GNS Science provide Ash Fall warnings for NZ eruptions. These are provided using their ASHFALL model[5]. ASHFALL is currently limited to assuming a 1D wind field corresponding to the vertical wind profile at the vent. We are adapting our HYSPLIT implementation to provide routine deposition simulations for the GNS standard set of eruptions in Table 1.

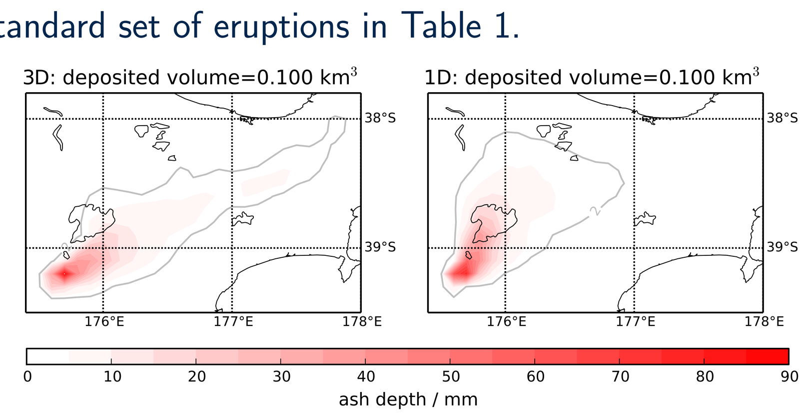

Figure 7: The assumption of 1D wind fields used in ASHFALL can have a significant negative impact in some cases, such as this Ruapehu eruption.

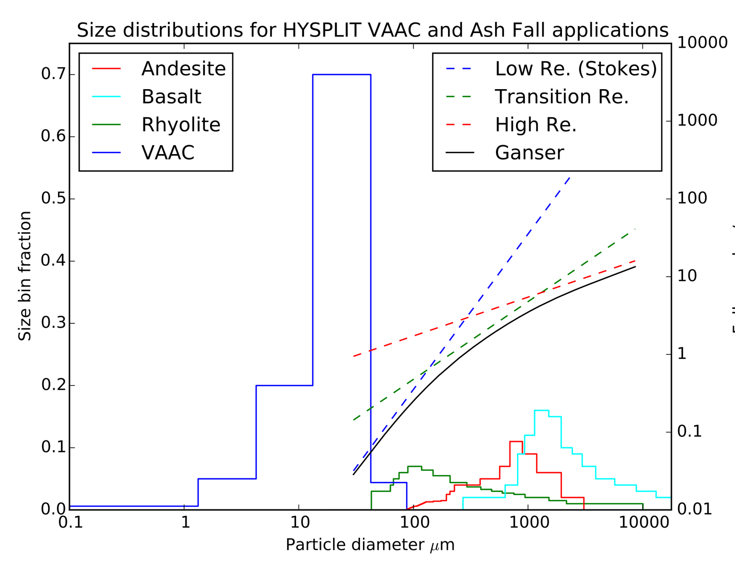

Figure 8: The size distributions for the ash fall application are much larger than that used for VAAC simulations. The Stokes' fall speed calculation in HYSPLIT (blue dashed curve above) is only suitable for low Reynolds numbers, so is not suitable for these larger particles. Richard Dare[6] implemented the Ganser fall speed equation[7] in HYSPLIT, which is in good agreement with the three Re. regime proposed in [8].

Implementation Details

All NWP data is processed routinely as soon as it is available, so that forecaster triggered dispersion runs are not delayed by pre-processing. The system is based on HYSPLIT(r593), with some patches, including the Ganser fall-speed equation. The over-arching software was developed in Python (2.7) using various 3rd-party Python libraries, including numpy, pygrib, netCDF4, matplotlib, and Flask.

Further Work

The recent deployment of JMA's Himawari-8 satellite comes at the perfect time to complement our improved dispersion modelling capability. We are now looking to obtain volcanic ash products from the Advanced Himawari Imager: ash detection and mass loading in particular, to allow validation of our HYSPLIT output.

References

[1] Draxler, R.R., and G.D. Hess, 1997: Description of the HYSPLIT_4 modeling system. NOAA Tech. Memo. ERL ARL-224, NOAA Air Resources Laboratory, Silver Spring, MD, 24 pp.

[2] WMO, 2012: VAAC 'Inputs and Outputs' (Ins and Outs) Dispersion Modelling Workshop, FINAL REPORT. https://www.wmo.int/aemp/archive.

[3] Mastin, L.G., Guffanti, M, Ewert, J.W., Spiegel, J. 2009. Preliminary Spreadsheet of Eruption Source Parameters for Volcanoes of the World. Open-File Report 2009–1133. U.S. Geological Survey, Reston, Virginia.

[4] Mastin, L.G., M. Guffanti, R. Servranckx, P. Webley, S. Barsotti, K. Dean, A. Durant, J.W. Ewert, A. Neri, W.I. Rose, D. Schneider, L. Siebert, B. Stunder, G. Swanson, A. Tupper, A. Volentik, and C.F. Waythomas. 2009. A multidisciplinary effort to assign realistic source parameters to models of volcanic ash-cloud transport and dispersion during eruptions. *Journal of Volcanology and Geothermal Research.*

[5] Hurst, A.W. 1994: ASHFALL – A Computer Program for estimating Volcanic Ash Fallout. Report and Users Guide. Institute of Geological and Nuclear Sciences Science Report 94/23. 22 pp.

[6] Dare, R.A., 2015. Sedimentation of volcanic ash in the HYSPLIT dispersion model. CAWCR Technical Report No. 079. Centre for Australian Weather and Climate Research, Melbourne, Australia.

[7] Ganser, G.H., 1993: A rational approach to drag prediction of spherical and nonspherical particles. Powder Technology, 77, pp 143-152.

[8] Bonadonna, C., Ernst, G.G.J., Sparks, R.S.J., 1998. Thickness variations and volume estimates of tephra fall deposits: the importance of particle Reynolds number. *Journal of Volcanology and Geothermal Research*, 81, pp 173-187.

Acknowledgements

Thanks are due to Richard Dare for implementing the Ganser fall speed equation in HYSPLIT and making this available. We are also thankful to the developers of HYSPLIT for making this software available, and to Larry Mastin for helpful advice on eruption parameters.