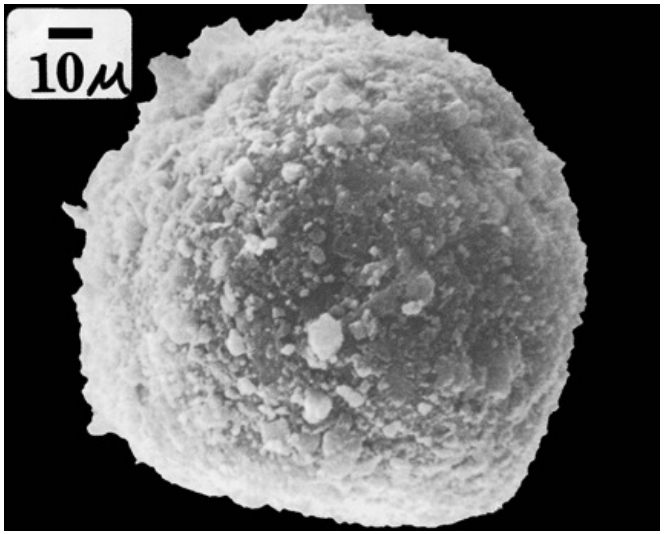
O2.1-09: Ash particle aggregation governed by hydrometeor formation in volcanic clouds

Adam Durant [1,2]

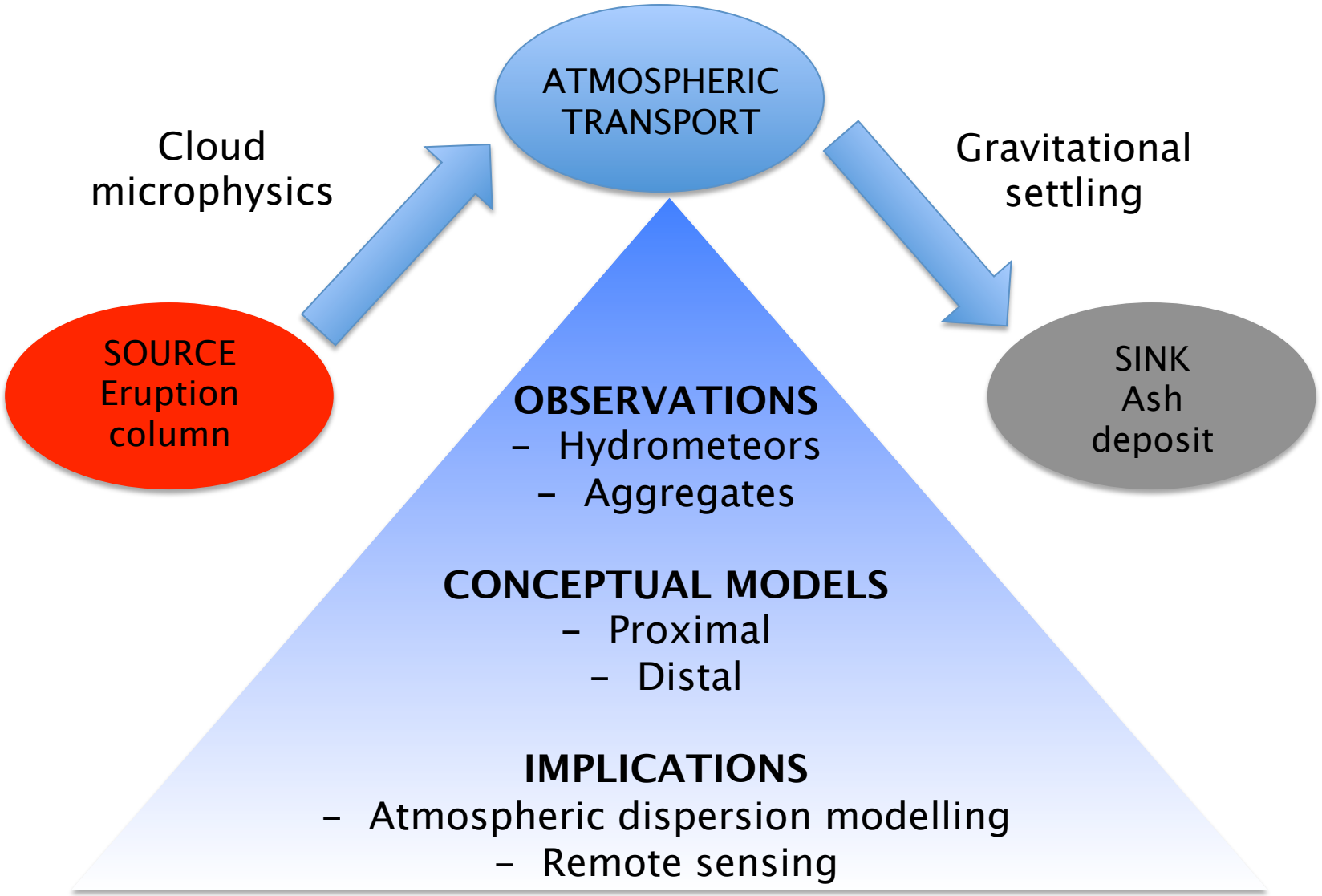
1. Norwegian Institute for Air Research, Norway
2. Michigan Technological University, USA

Acknowledgements: Bill Rose, Costanza Bonadonna, Richard Brown, Gholamhossein Bagheri, Eduardo Rossi, Raymond Shaw, Will Cantrell, Gerald Ernst, Arve Kylling, Andreas Stohl, Nina Kristiansen, Eldbjorg Moxnes, Konradin Weber, Andreas Vogel, Antonio Costa, Arnau Folch, Andrei Sarna-Wojcicki, Steve Carey, Larry Mastin, Alexa Van Eaton

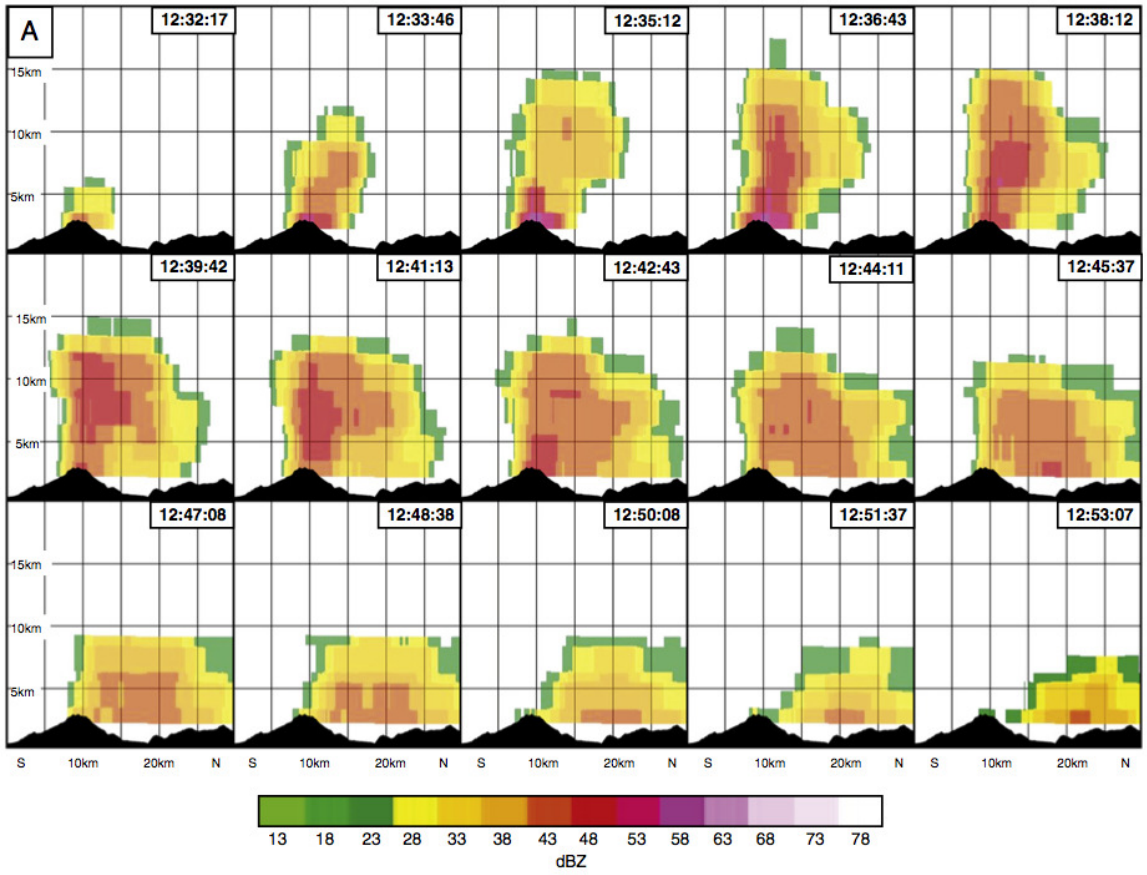
2nd IUGG-WMO workshop on ash dispersal forecast and civil aviation, World Meteorological Organization, Geneva, Nov. 18-20, 2013

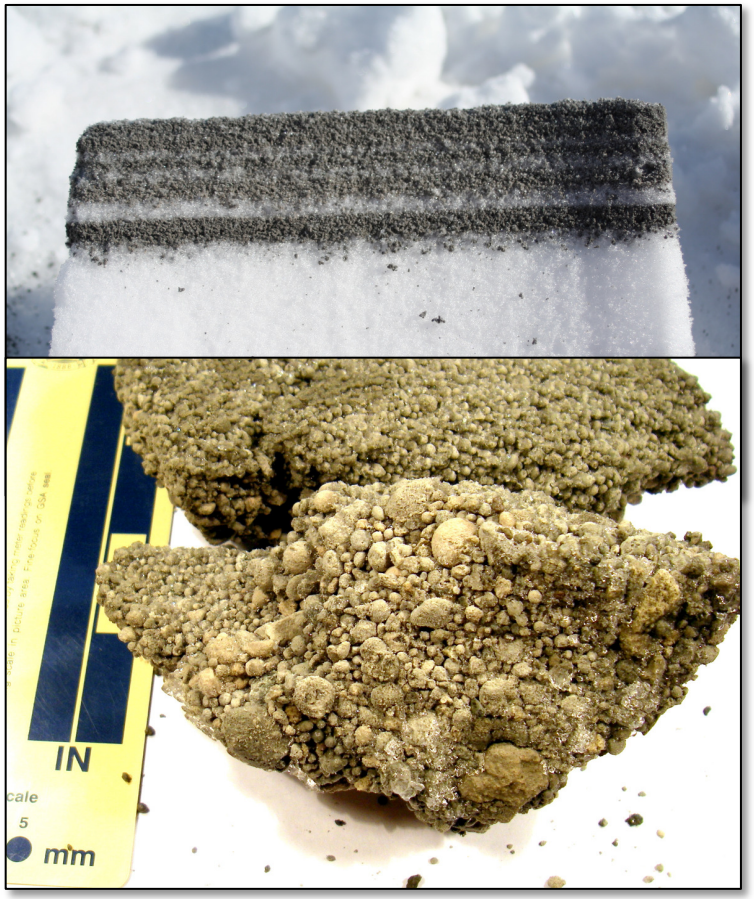


Outline


ATMOSPHERIC TRANSPORT
Cloud microphysics
Gravitational settling
SOURCE Eruption column
SINK Ash deposit
OBSERVATIONS
- Hydrometeors
- Aggregates
CONCEPTUAL MODELS
- Proximal
- Distal
IMPLICATIONS
- Atmospheric dispersion modelling
- Remote sensing

Aggregation timescale ranges from sec to min





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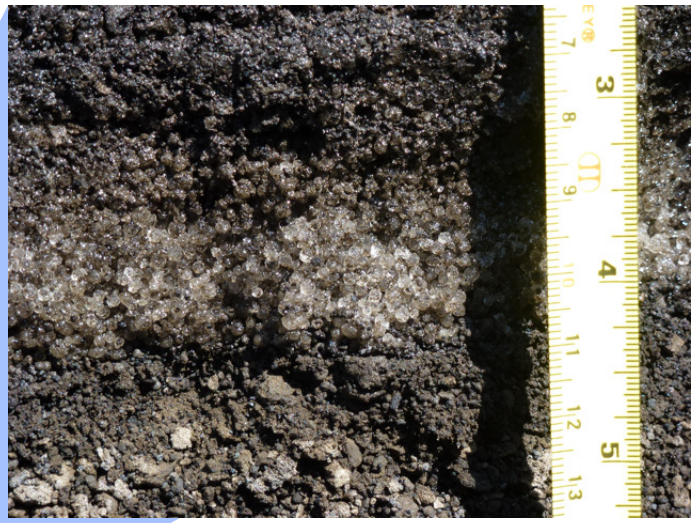
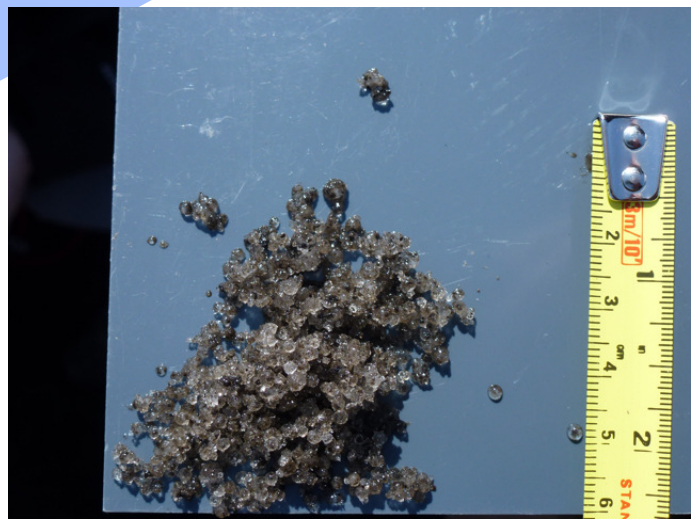
NILU MichiganTech

Volcanogenic frozen drops, Grímsvötn 2011

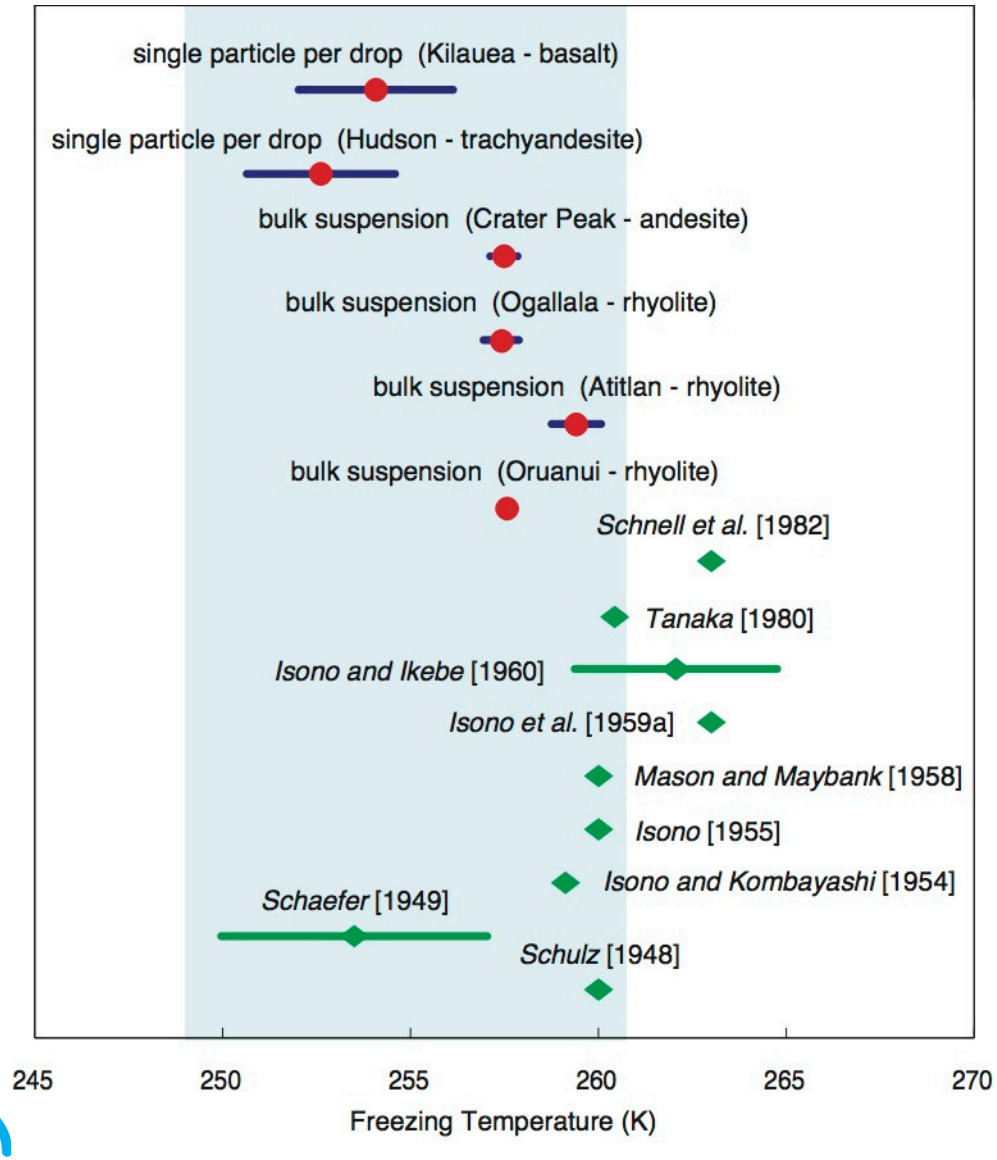
<20 km from source





Thanks: Magnús Guðmundsson

Heterogeneous ice nucleation by volcanic ash



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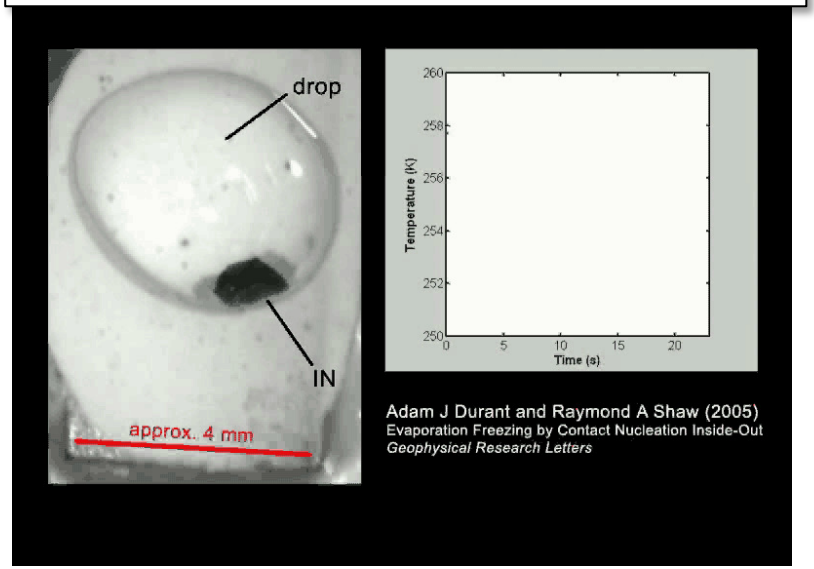

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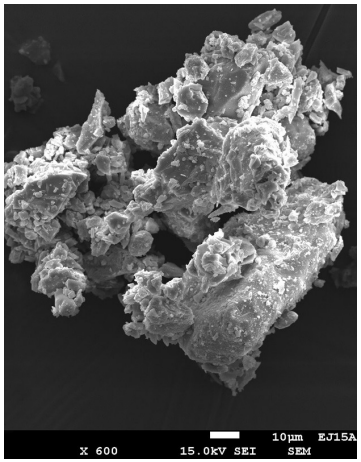
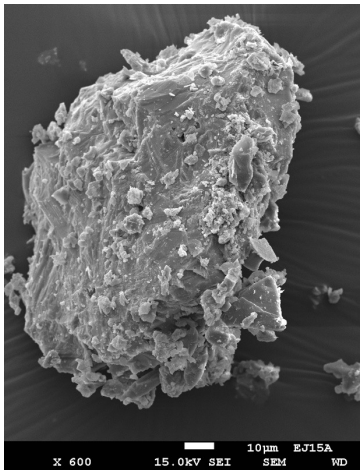
Ash aggregate morphological variability

PARTICLE CLUSTERS

Ash Clusters (PC1)

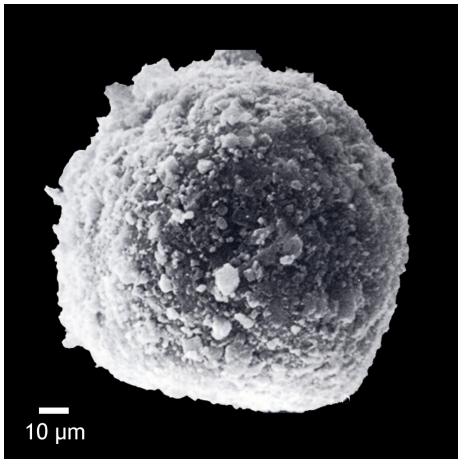


Coated Particles (PC2)

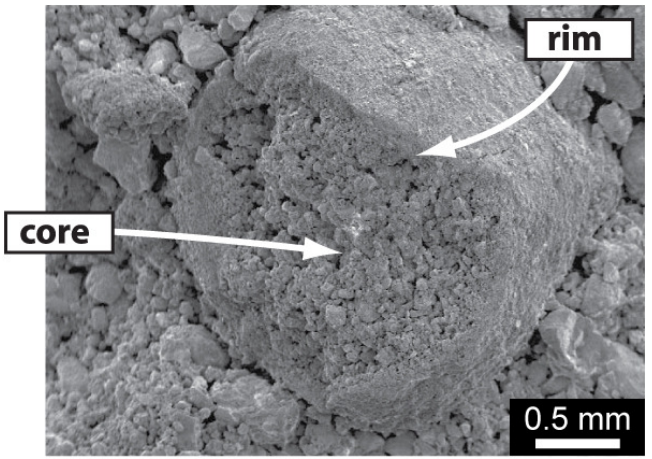


ACCRETIONARY PELLETS

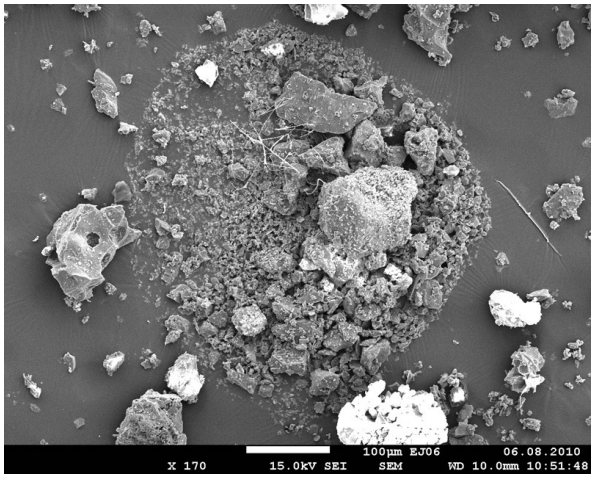
Unstructured pellets (AP1)



Concentric pellets (AP2)



Liquid Pellets (AP3)



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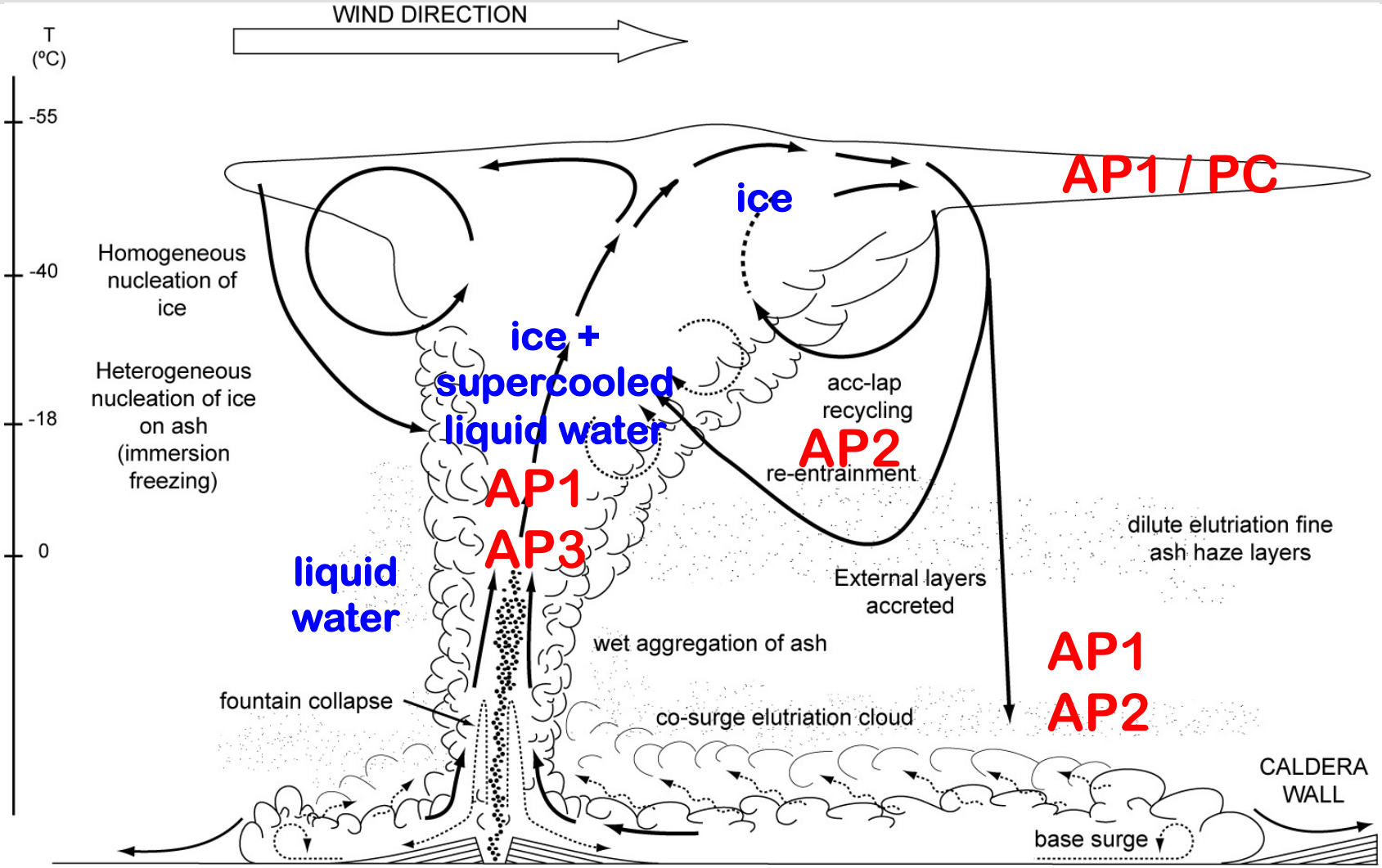
Proximal aggregation: conceptual model



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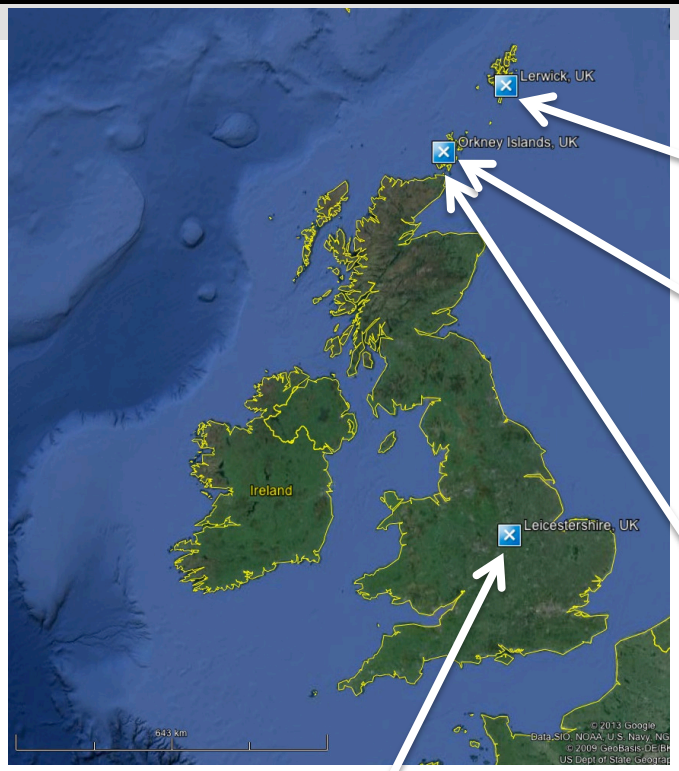
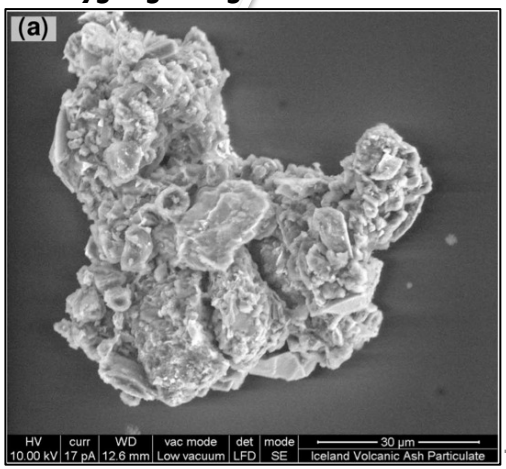
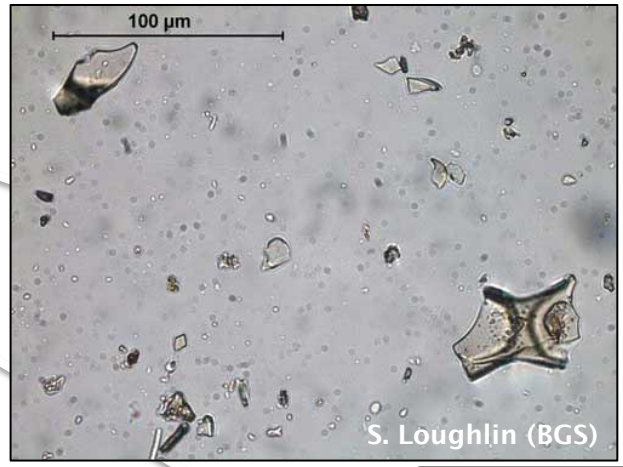
Large particles and aggregates in distal fallout over UK from recent Icelandic eruption clouds



Eyjafjallajökull 2010





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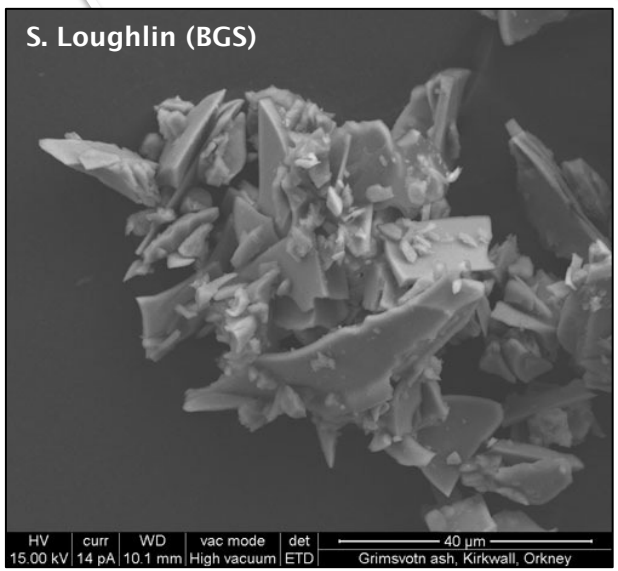
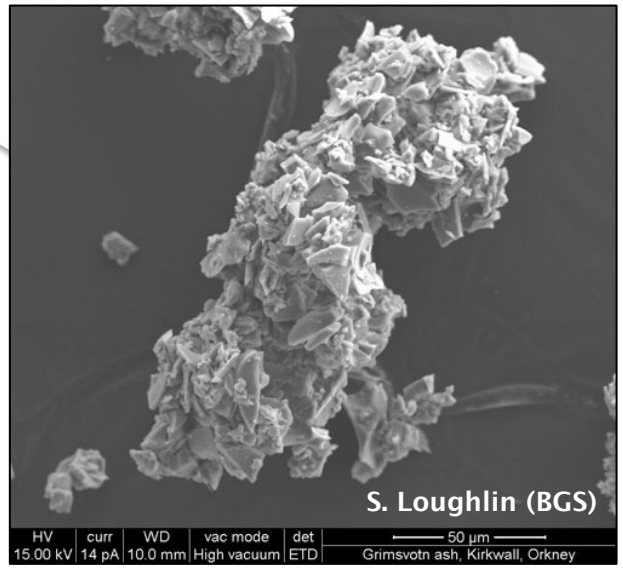
Grímsvötn 2011





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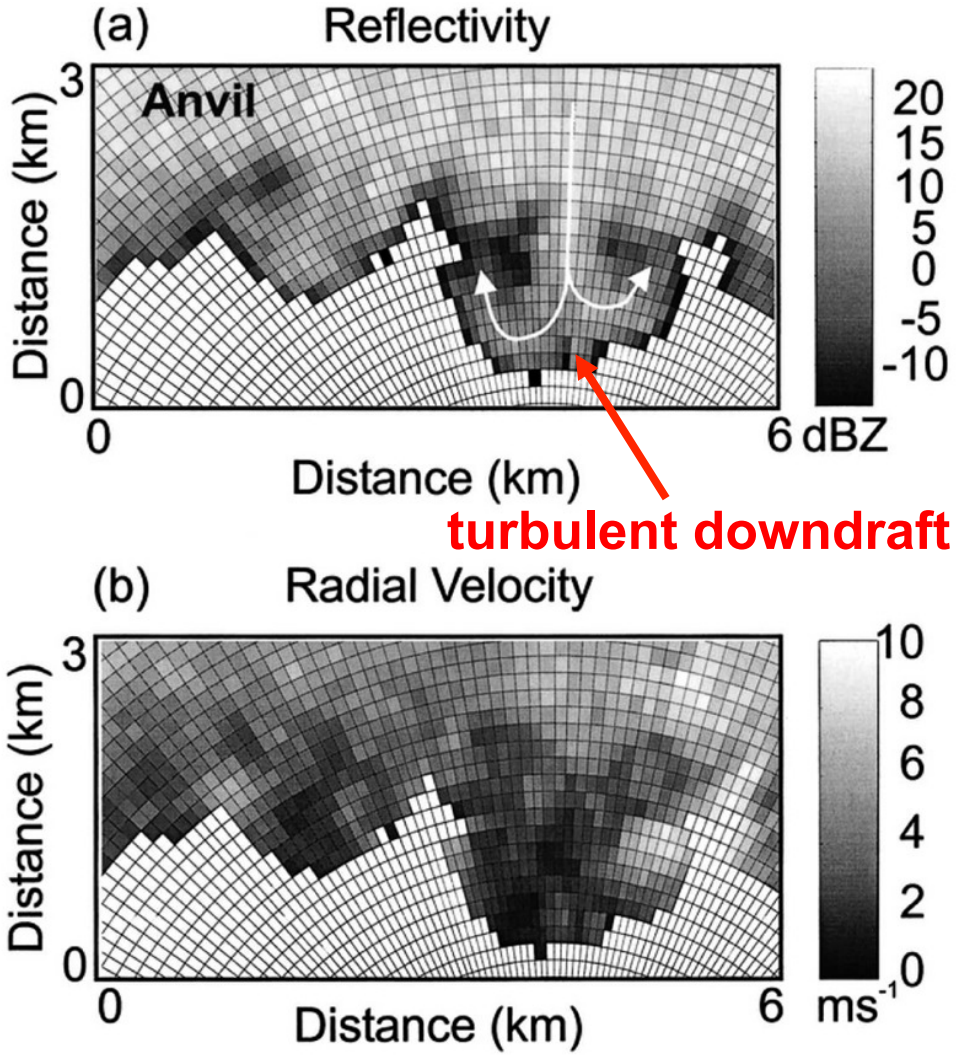
NILU

Mammatus: Mount St. Helens 1980 eruption cloud



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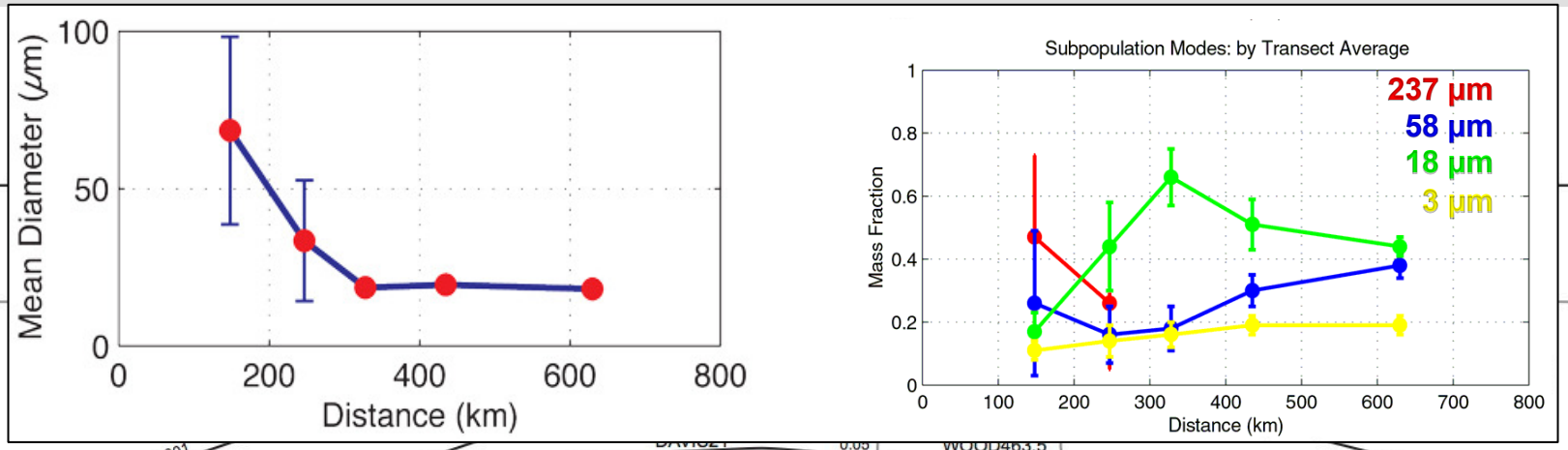
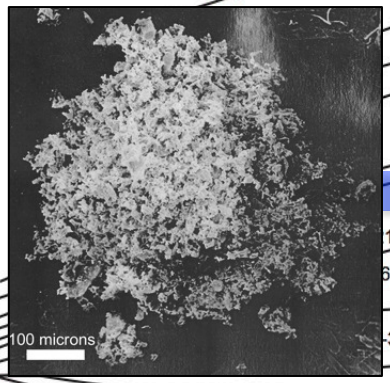
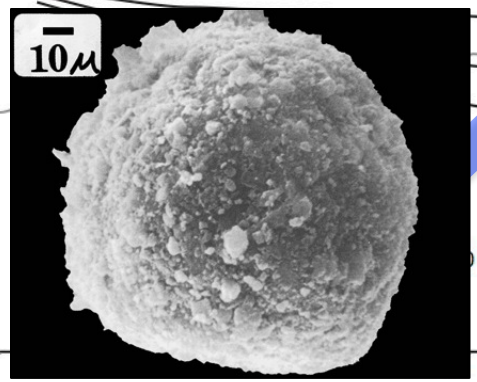
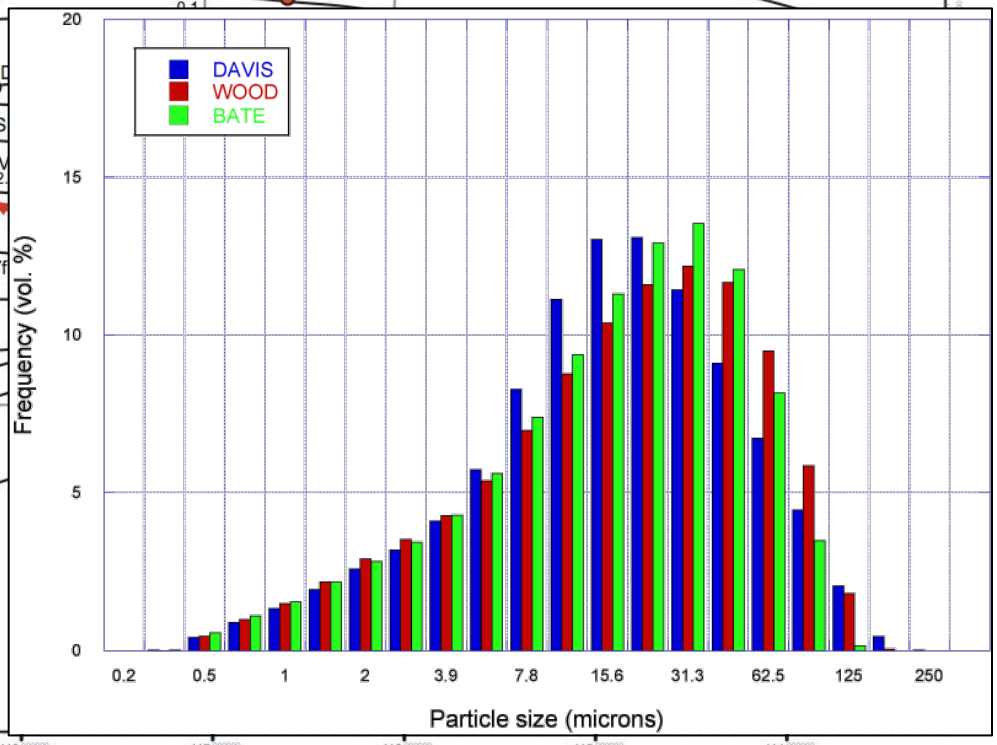
Durant, Rose, Sarna-Wojcicki, Carey, Volentik (2009), **Hydrometeor-enhanced tephra sedimentation: Constraints from the 18 May 1980 eruption of Mount St. Helens,** *J. Geophys. Res.*,114, doi:10.1029/2008JB005756

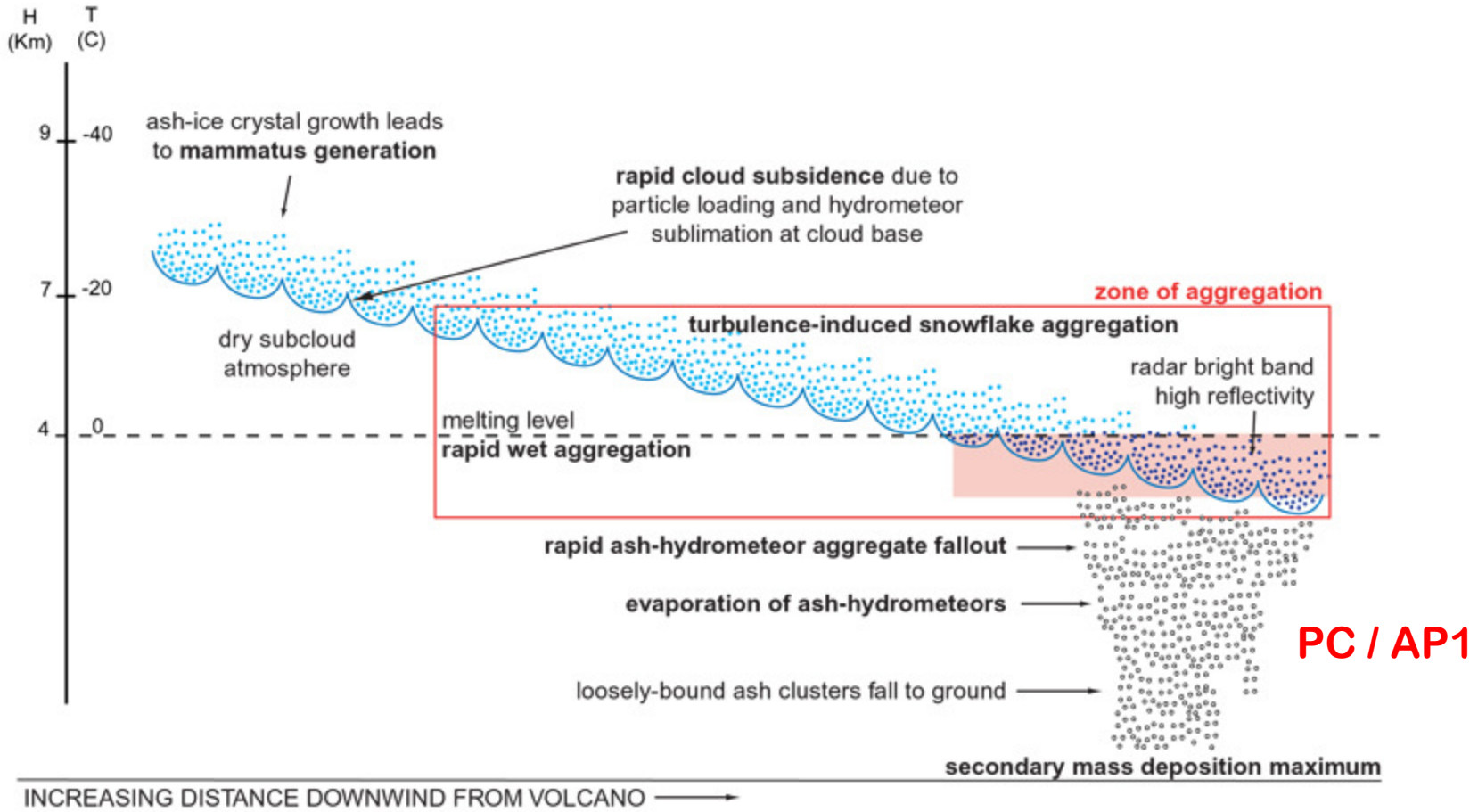








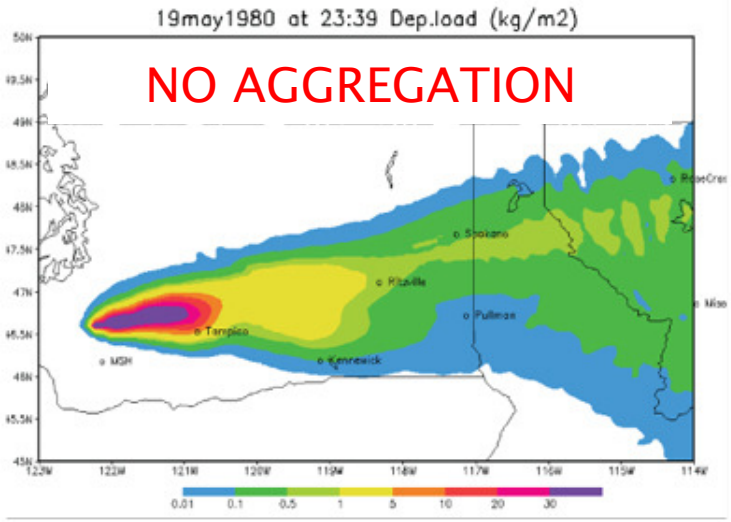
Distal aggregation: conceptual model

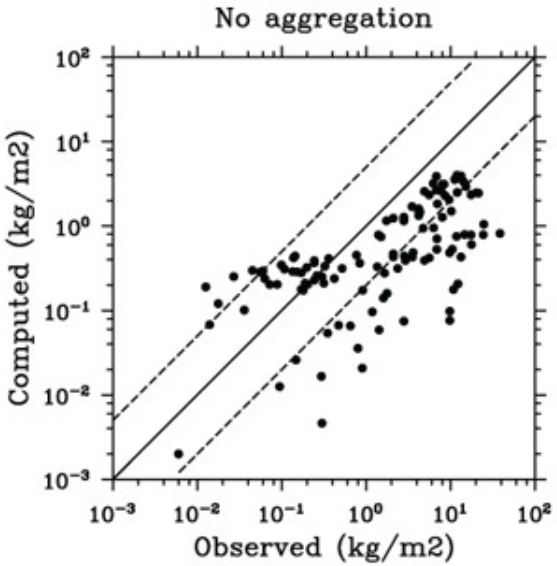


PC / AP1

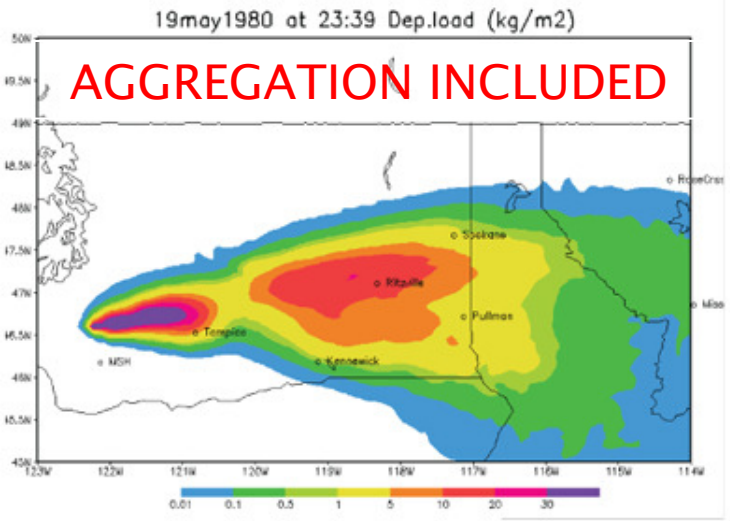
Durant AJ, Rose WI, Sarna-Wojcicki AM, Carey S, Volentik ACM (2009), **Hydrometeor-enhanced tephra sedimentation: Constraints from the 18 May 1980 eruption of Mount St. Helens**, *J. Geophys. Res.,114, doi:10.1029/2008JB005756*

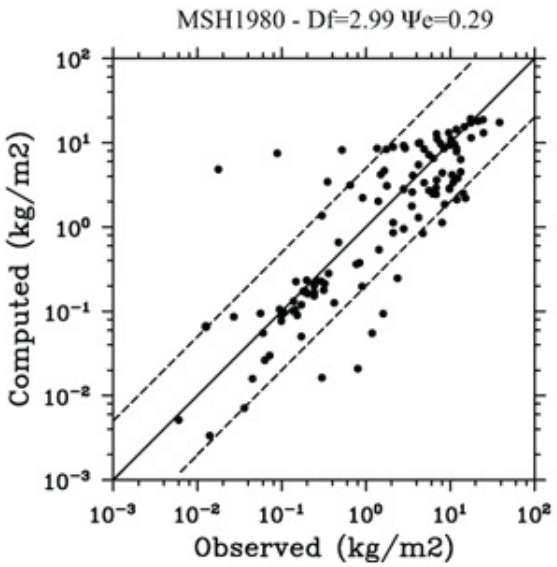
Aggregation model validation





Costa A, Folch A, Macedonio G (2010), **A model for wet aggregation of ash particles in volcanic plumes and clouds: 1. Theoretical formulation**, *J. Geophys. Res.*, 115(B9), B09201





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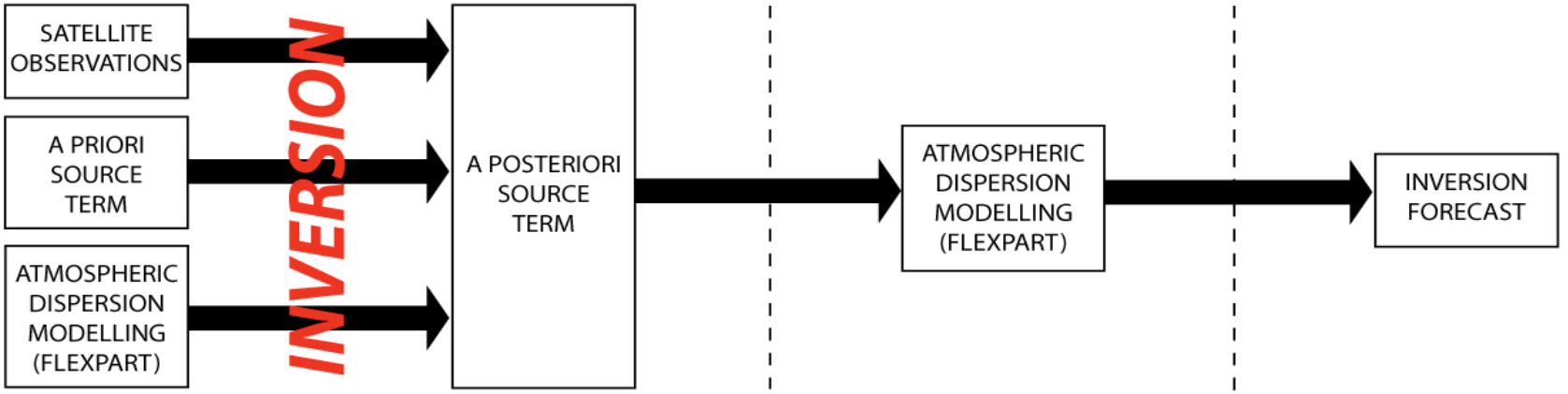

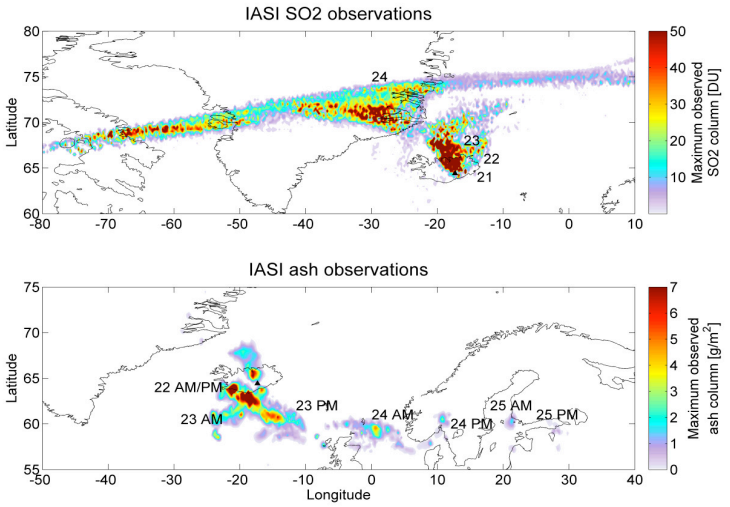

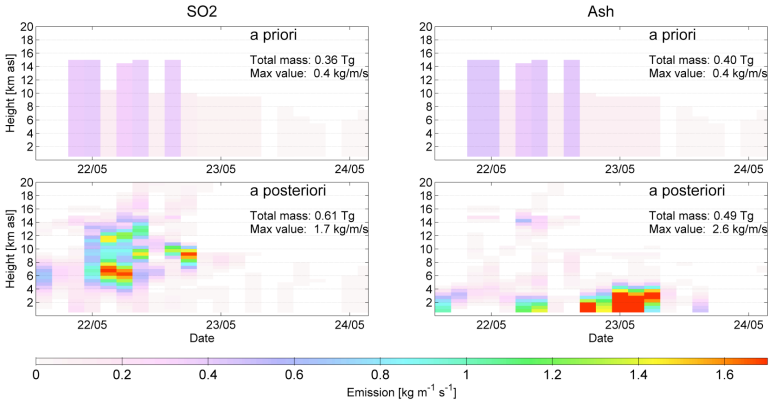

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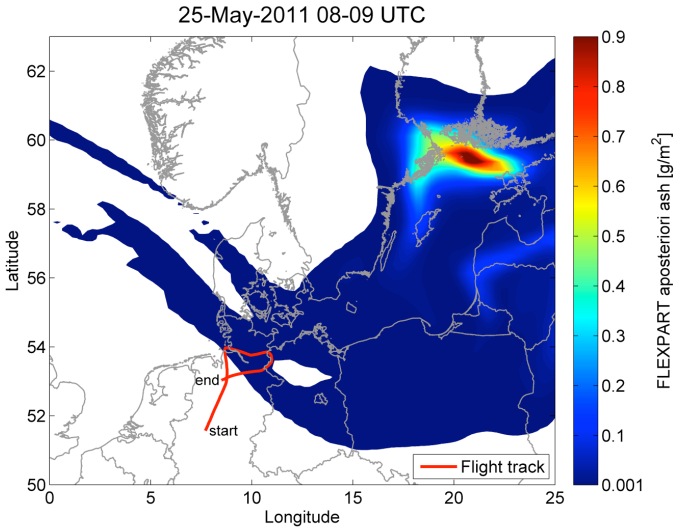
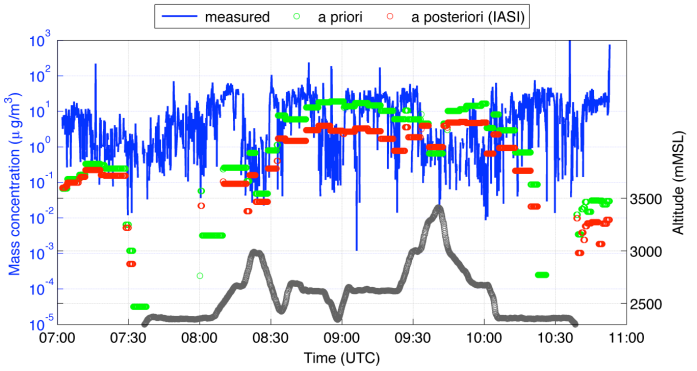
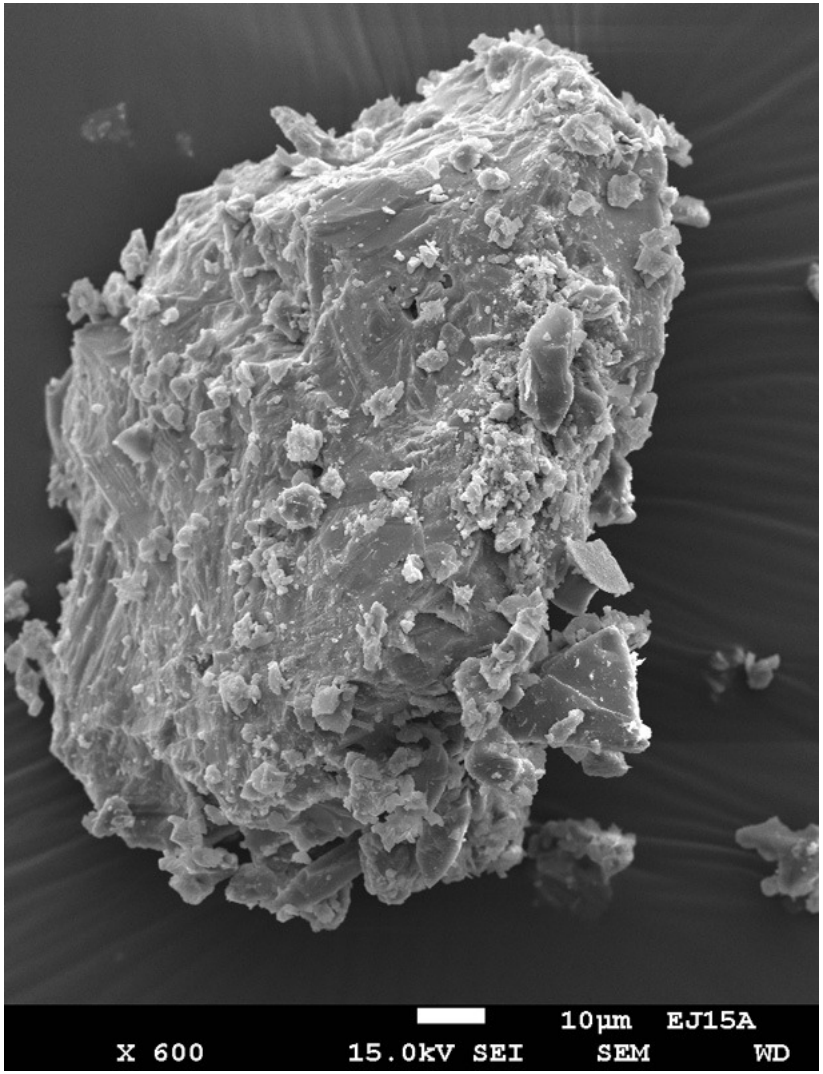
See Kristiansen et al. poster 13

Andreas Stohl talk



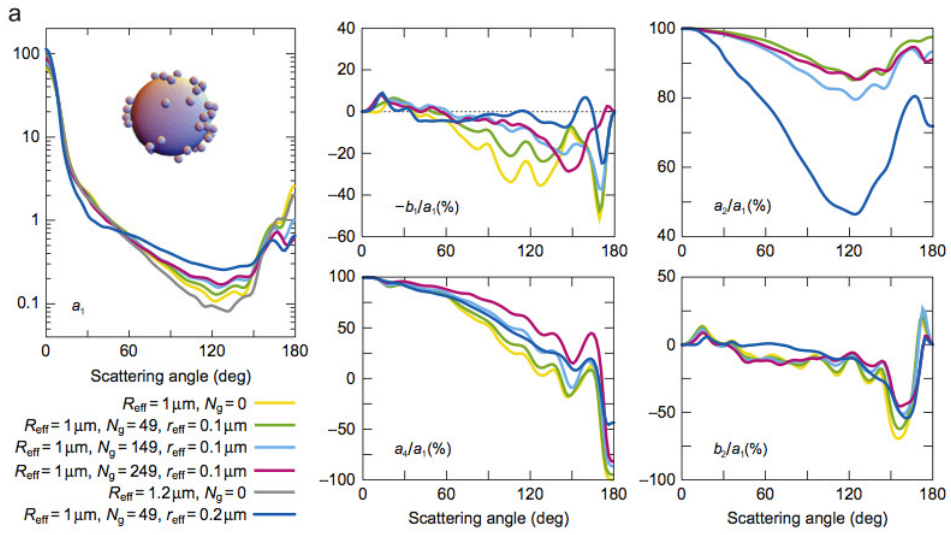


Ash particles in volcanic clouds are probably always present as some form of aggregate



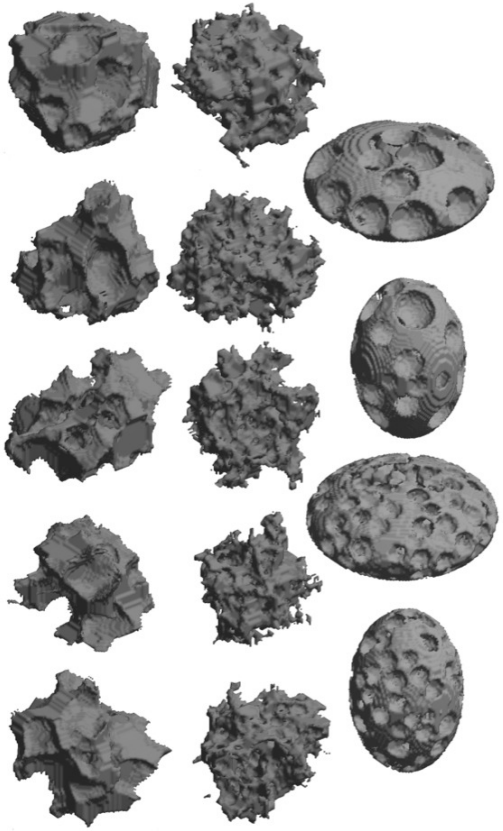
Particle Clusters – Coated Particles (PC2)

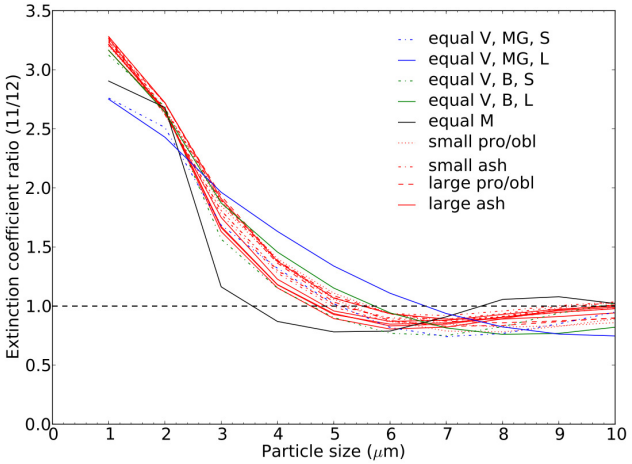
- Includes any particle (juvenile, crystal or lithic) that has smaller particles adhering to the surface
- PC2 diameter spans ash size class (<1-2000 μm)
- Particle size <1-40 μm
- Poor preservation potential



m	r_{eff}/R_{eff}	N_g	C_{ext} (μm^2)
1.55+i0.0003	–	0	6.314
1.55+i0.0003	0.1	49	6.607
1.55+i0.0003	0.1	149	7.358
1.55+i0.0003	0.1	249	8.214
1.55+i0.0003	0.2	49	10.670
1.55+i0.3	–	0	6.464
1.55+i0.3	0.1	49	6.845
3+i0.1	–	0	7.355
3+i0.1	0.1	49	7.448

Dlugach, Mishchenko, Mackowski (2012), **Scattering and absorption properties of polydisperse wavelength-sized particles covered with much smaller grains**, *J. Quant. Spec. Rad. Trans.*, 113, 2351–2355.





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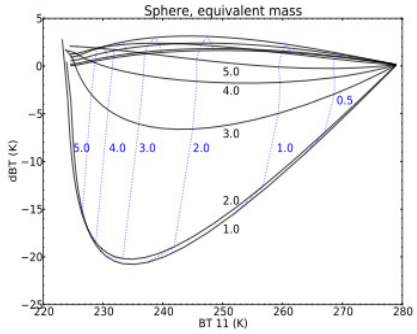
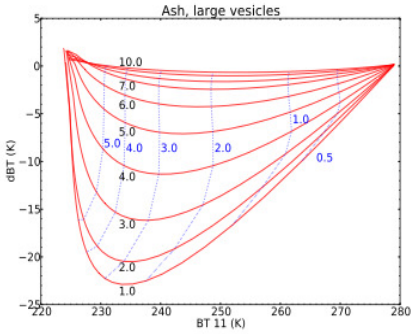
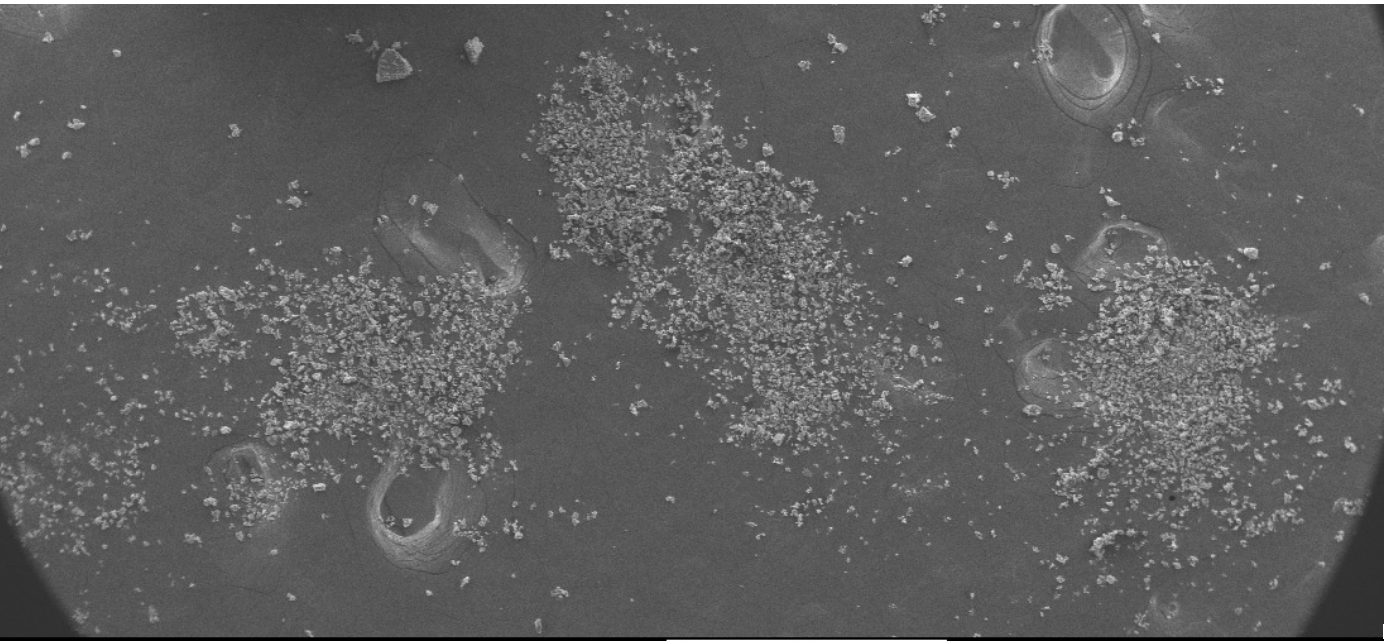




Sakurajima measurement intercomparison 2013



SEM Image: G. Bagheri

Led by: Costanza Bonadonna and group; *Coordinated with*: Konradin Weber, Andreas Vogel, J. Eliasson

Concluding remarks

- Aggregation is not limited to the plume (the part of the cloud attached to the vent) and occurs where particles interact, even in long-lived clouds that have been transported 1000s km, days after emplacement
- Aggregation occurs on timescales of seconds and extensively modifies the particle size distribution and speeds up fine particle removal
- Hydrometeor formation plays a key role in particle removal by acting as a binding agent to form aggregate particles with larger mass and settling velocity than single constituent particles