Validation of GOES-R volcanic ash products: Near real time operational decision support/hazard analysis

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Plan for 2011-2012

Year 1

- Develop and enhance WRF-Chem and Puff models to deliver volcanic ash concentration forecasts
- Analysis of GOES-R algorithm with other remote sensing methods for ash detection
- Produce tool to allow model to satellite inter comparisons
- Meetings with NWS personnel

Overview of work done

Focused on two aspects: (1) Analysis of thermal infrared remote sensing of cloud top heights and (2) volcanic ash modeling using WRF-Chem and comparison to volcanic ash retrievals.

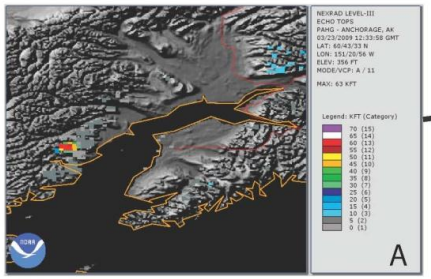
We analyzed three of the major eruptions across the North Pacific, Kasatochi in 2008; Redoubt in 2009; and Sarychev Peak in 2009 as well as the 2010 Eyjafjallajokull events.

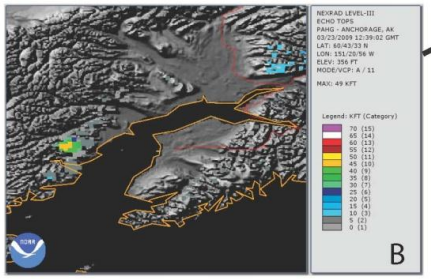
Thermal Infrared cloud/plume heights

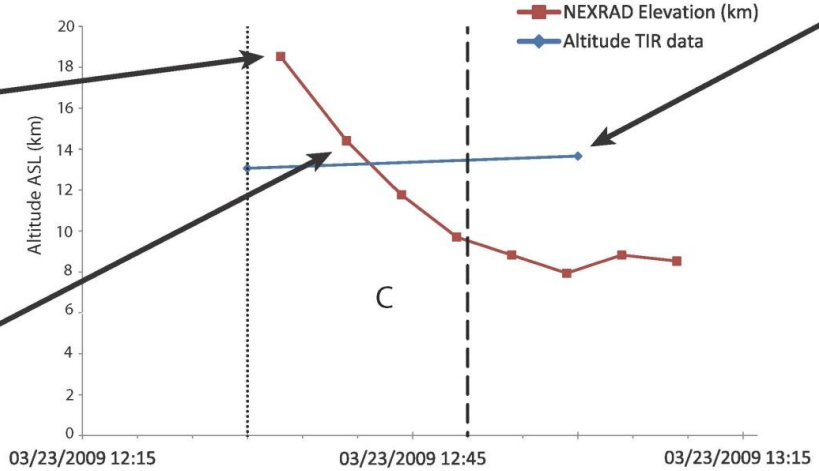
- Requires knowledge of cloud opacity and timing of the measurement relative to the eruption time
- Comparisons to both local radar and MISR data (Ekstrand et al., 2012)
- Timing is critical for inferring if the TIR height is from the drifting ash cloud or the erupting column (Webley et al., 2012)
- This is an essential source parameter for the volcanic ash transport and dispersion (VATD) models used for future location information for the ash cloud and downwind concentrations

TIR (Timing of the data)

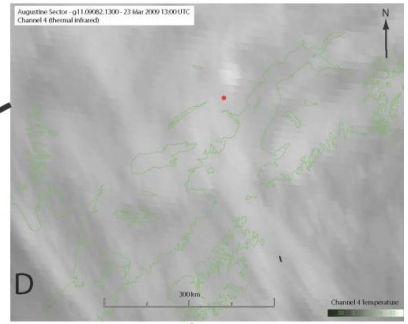
- Plume heights TIR versus radar
- Event lasted 20 Mins
- TIR from AVHRR ~ 55 Mins after start
- Event ended so dispersing cloud
- GOES-R ~ 15 mins so could still be over
- Need to know time of event and time of observation

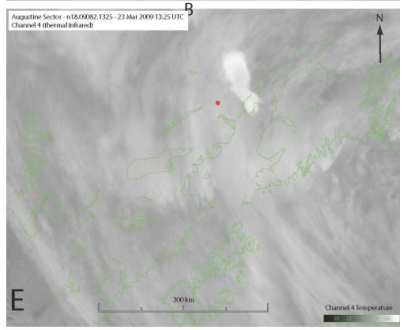






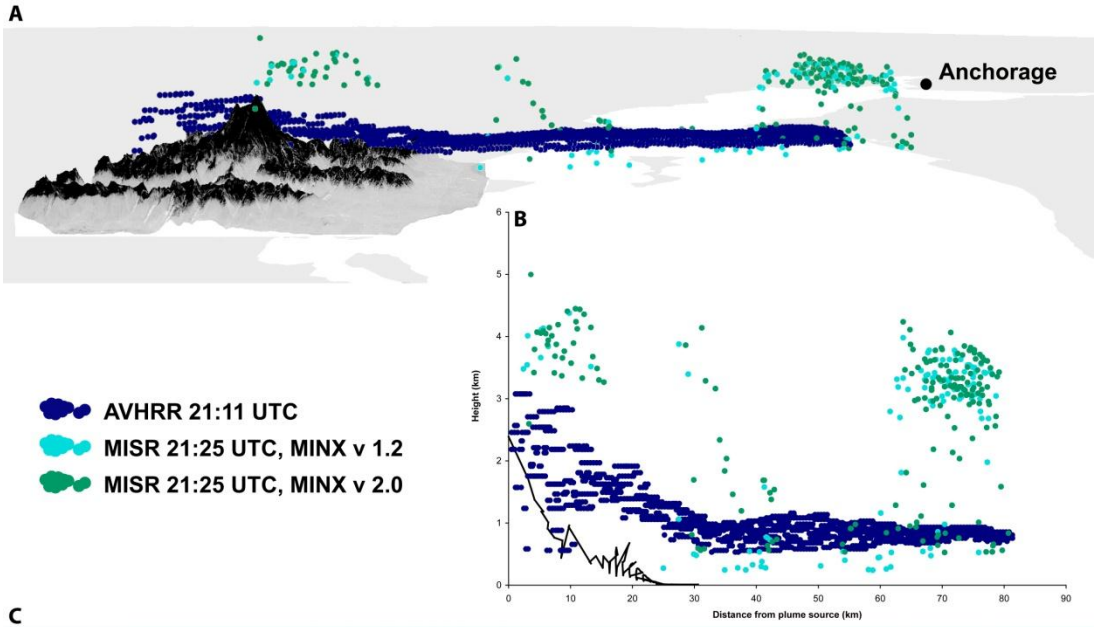
Plume Heights for Event 5 at Redoubt Volcano 2009

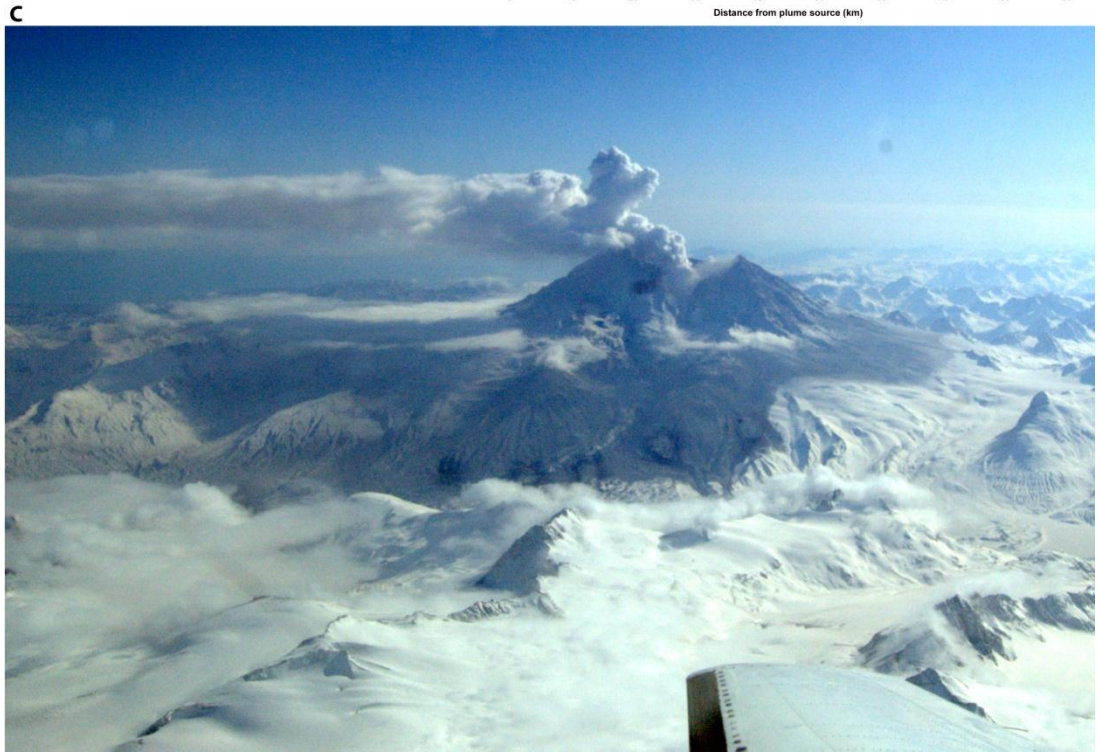




TIR (MISR)

- Plume heights versus MISR
- Direct conversion of TIR to height
- MISR ~ 3.5-4.5 km
- TIR < 3km
- Airborne = 4-5 km
- Need to determine if cloud is fully opaque



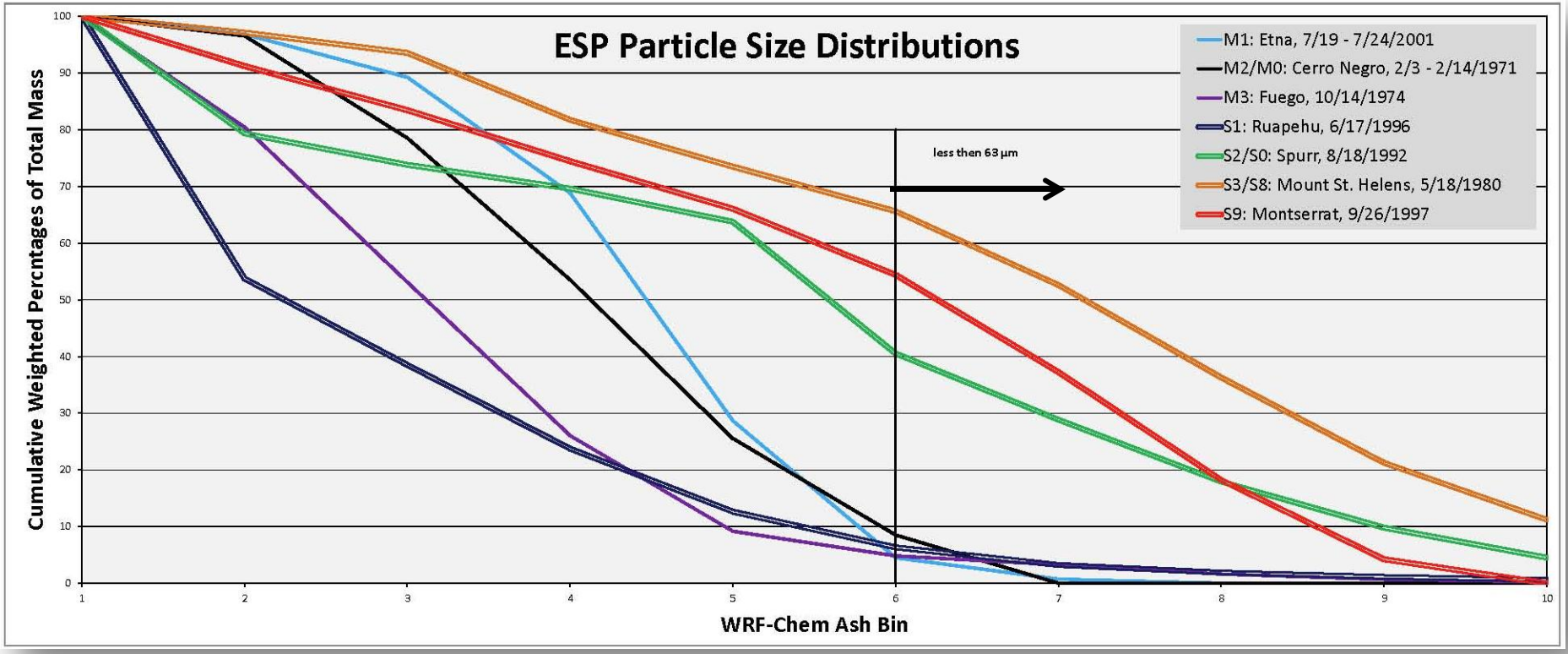


Volcanic ash and WRF-Chem

- Puff and Weather Research Forecasting within inline Chemistry (WRF-Chem) models
- Show the eruption rate and particle size distribution (PSD) to be the critical parameters
- Compare the modeled ash clouds to volcanic ash retrievals from the GOES-R algorithm, on MODIS and SEVIRI data, as well as other volcanic ash retrieval tools which can be applied to all TIR data
- Most VATD models use a set of default eruption source parameters and this can be applied to the VATD models used in this project
- Assessed the sensitivity of the eruption rate and PSD on the downwind concentrations
- Developing tools to allow both a spatial and point-to-point comparison between the volcanic ash satellite retrievals and VATD model simulations

Model inputs: Particle size Distribution

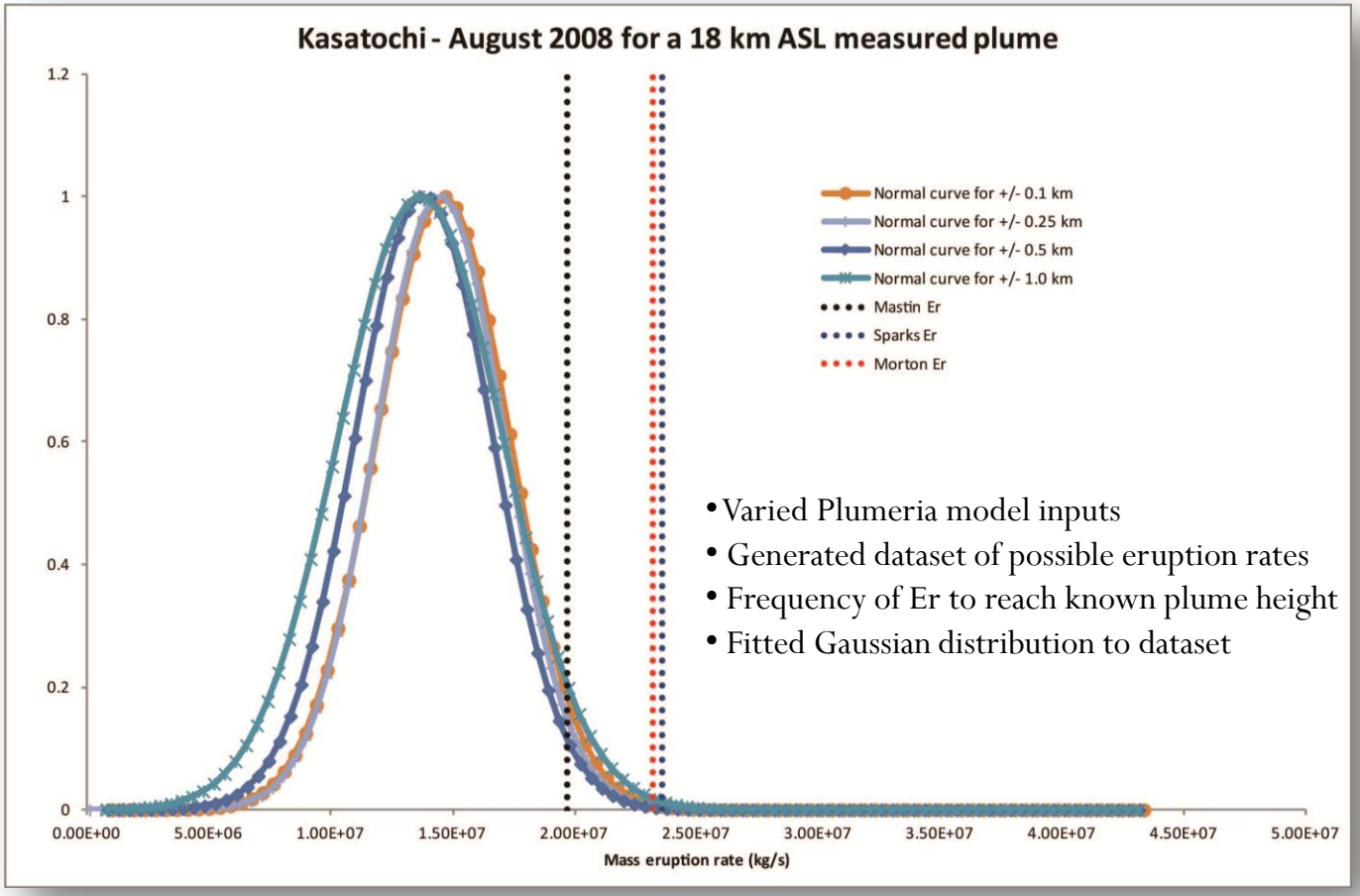
- Use the assigned ESP PSD from Mastin et al. (2009)



Model inputs: Eruption rate

- Eruption rate: Empirical relationship $H\ (km) = 1.69*V^{0.259}$, where V=Volume flow rate (km^3/s) . Use ash density to get eruption rate (kg/s)

Determine probability of eruption rate given measured plume height



- Varied Plumeria model inputs
- Generated dataset of possible eruption rates
- Frequency of Er to reach known plume height
- Fitted Gaussian distribution to dataset

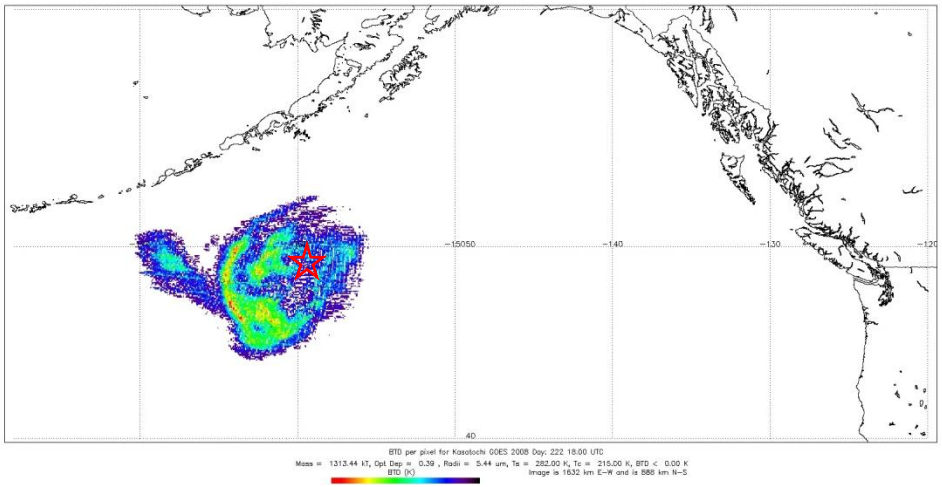
Kasatochi 2008

- August 7 – 11, 2008
- 3 volcanic eruptions with volcanic ash up to 18 km ASL
- MODIS data with GOES-R
- GOES data with UAF-GI VAR
- WRF-Chem
  - 1st run Sparks et al. (1997) ER and S2 PSD
  - 18 km spatial resolution
- To come: Vary spatial res, ER method and PSD
- Puff to WRF-Chem to Satellite derived

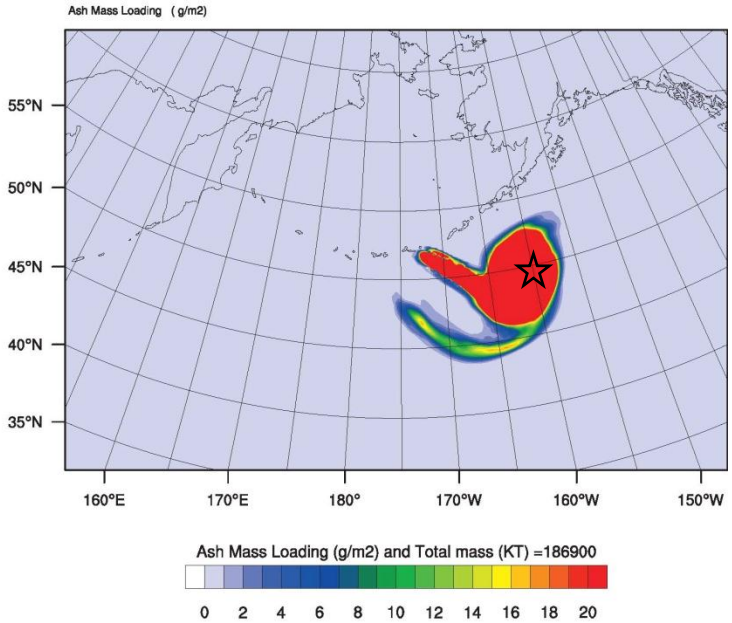
Mass loading : Satellite & WRF-Chem

Mass Loading (BTD < 0 K)

Mass ~ 1300 KT

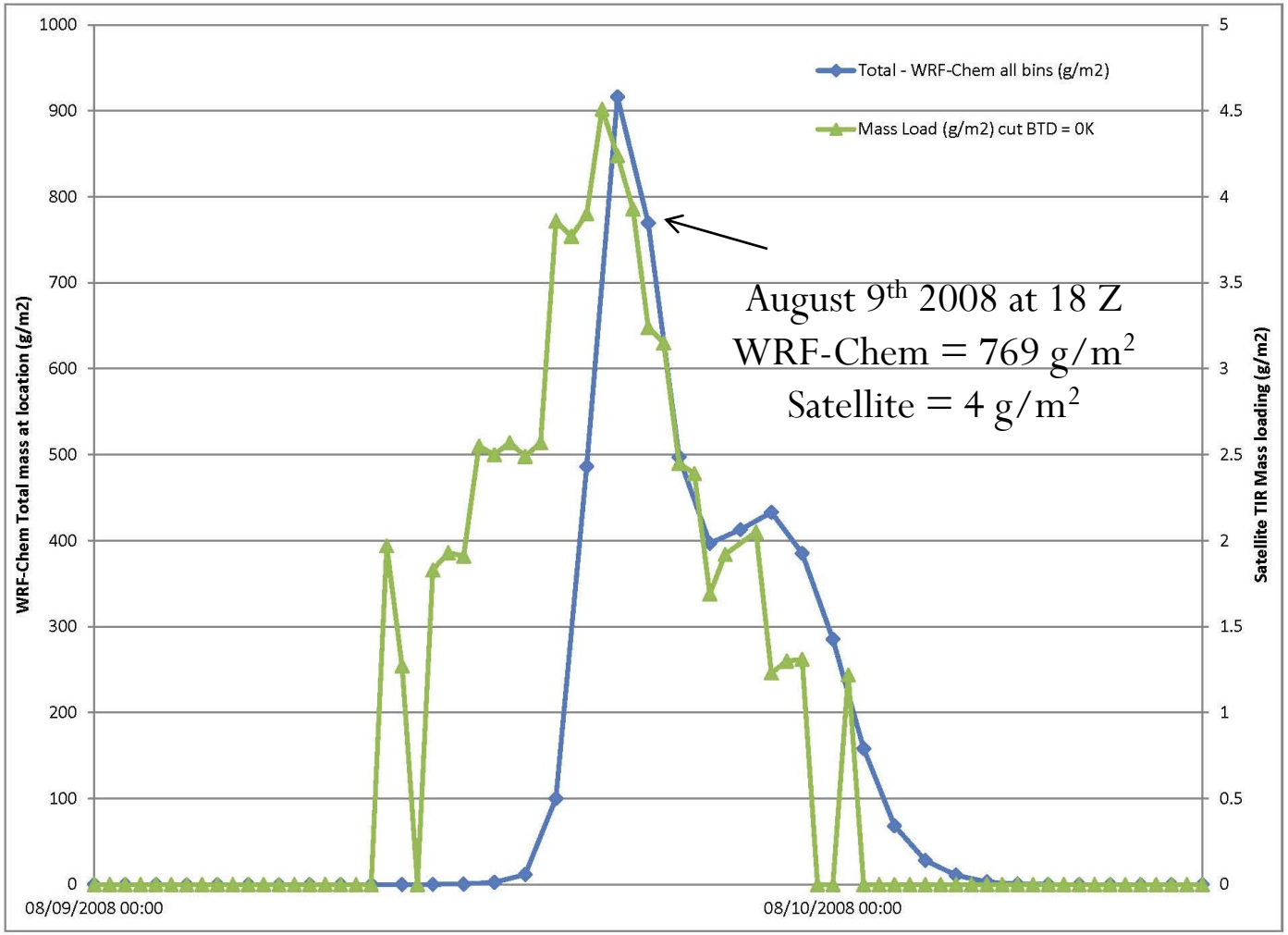


Mass Loading (WRF-Chem)



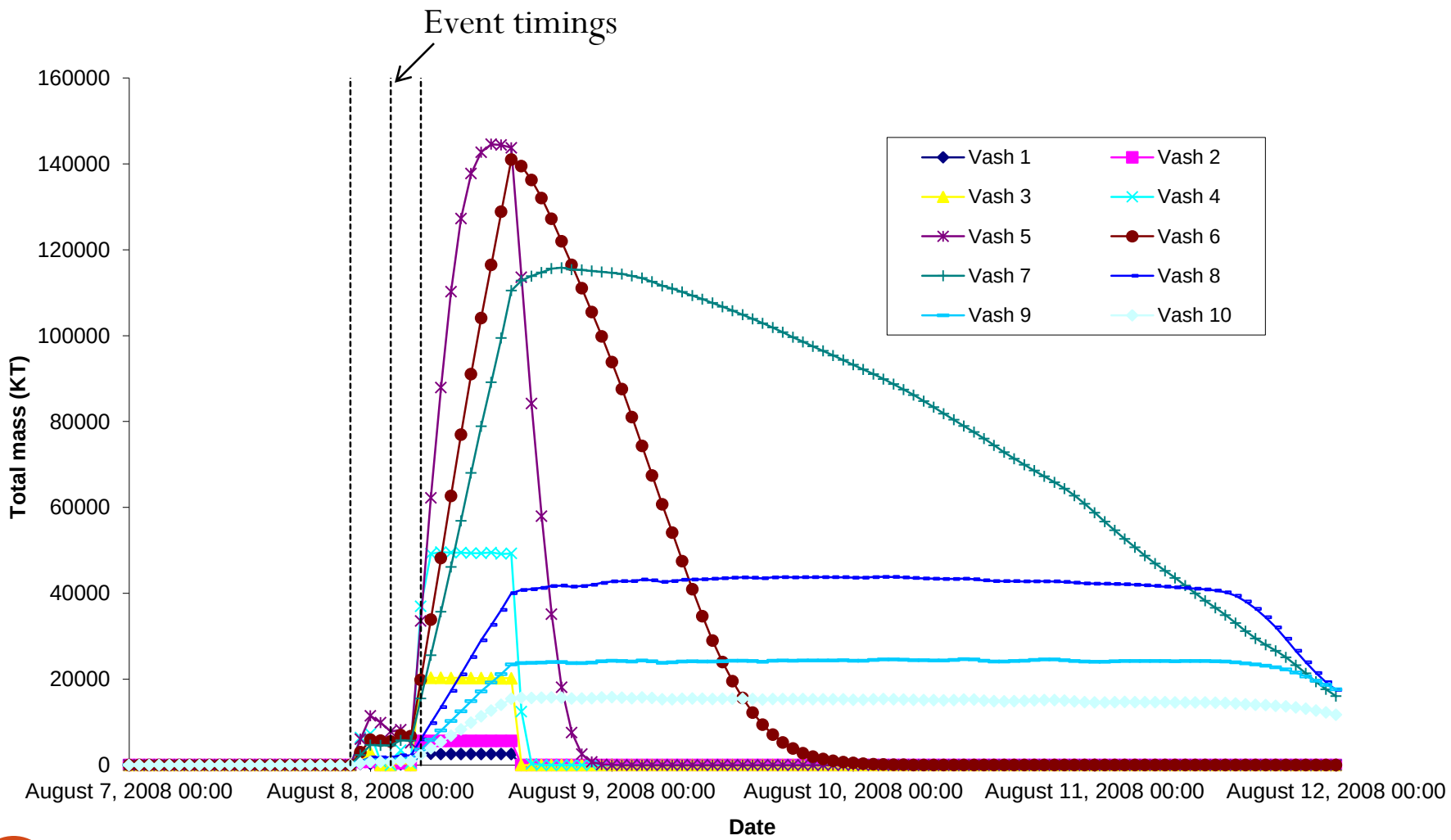
August 9th 2008, 18Z

Mass loading at 50N, 160W – Time Series



- Too much fine and eruption rate is too high
- Next to run, 5km res, with less fine ash and Plumeria method eruption rate

Kasatochi 2008 : WRF-Chem: Total mass per bin



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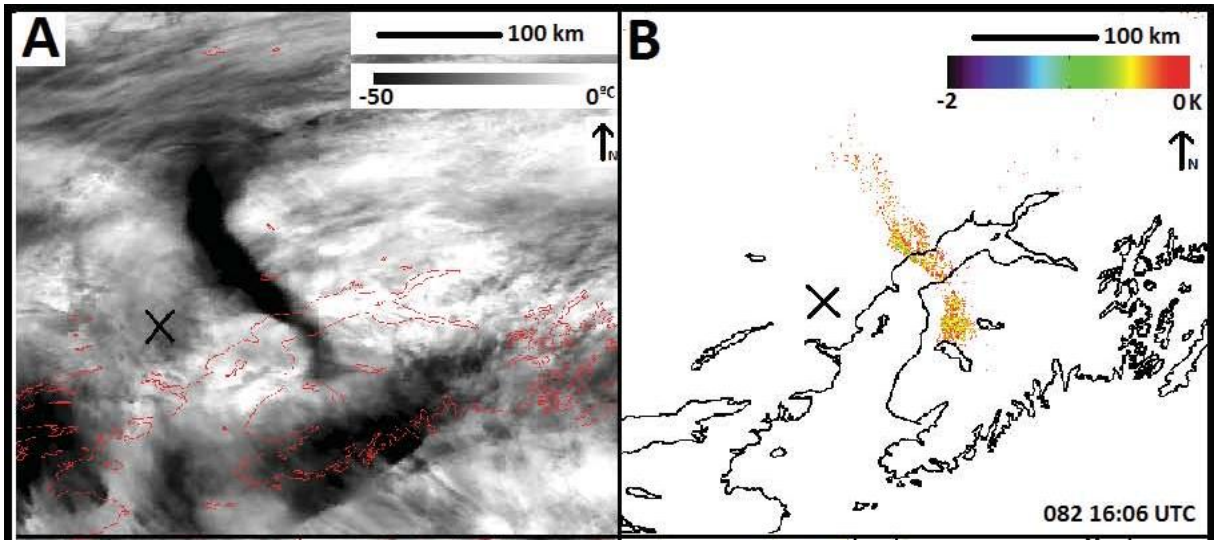
Redoubt 2009

- March 23 and April 4, 2009
- To do: MODIS data via GOES-R
- AVHRR and MODIS data with GIVAR
- WRF-Chem: Sparks Er and S2 PSD
- Vary spatial resolution
- Satellite volcanic ash v Puff v WRF-Chem comparisons
- To do: spatial qualitative comparisons

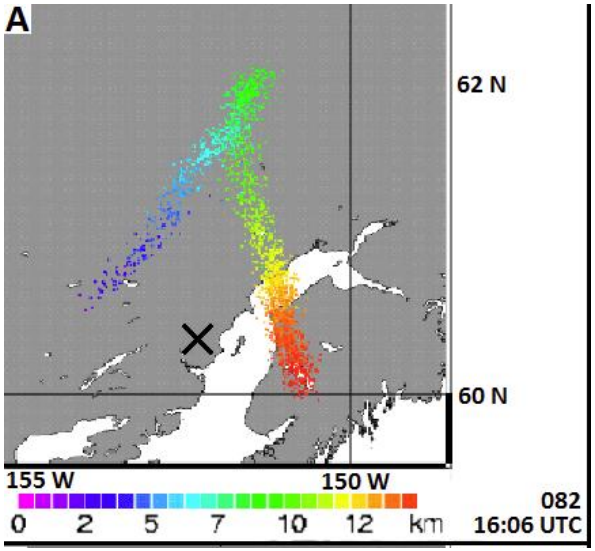
Satellite data v Puff: March 23 2009



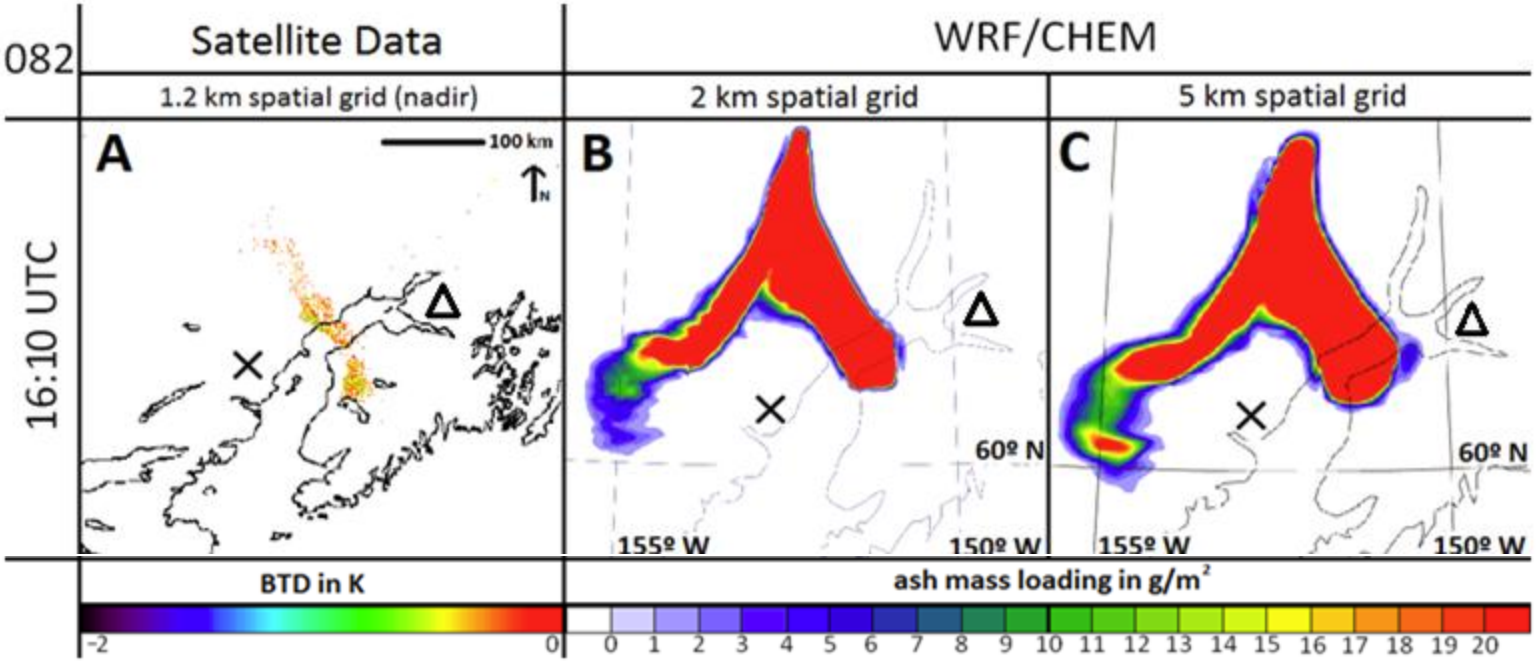
TIR Data

BTD Data

Puff Model



Satellite data v WRF-Chem: March 23 2009

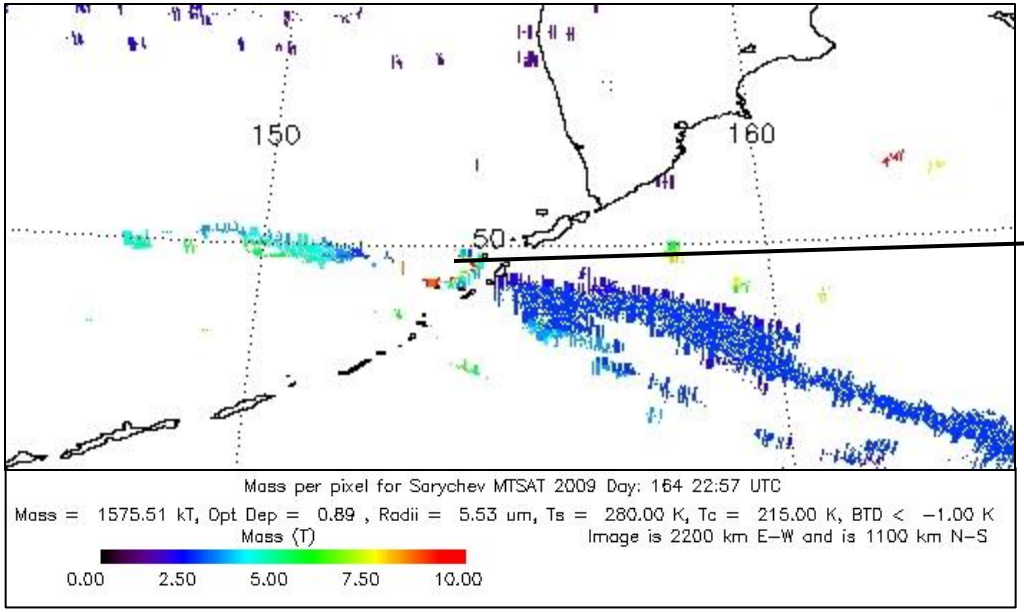


Initial PSD had too much fine (used default ESP of S2)
Initial Eruption rate too high (used Sparks Eruption Rate)
Lack of BTD to the north-west due to local cloud cover

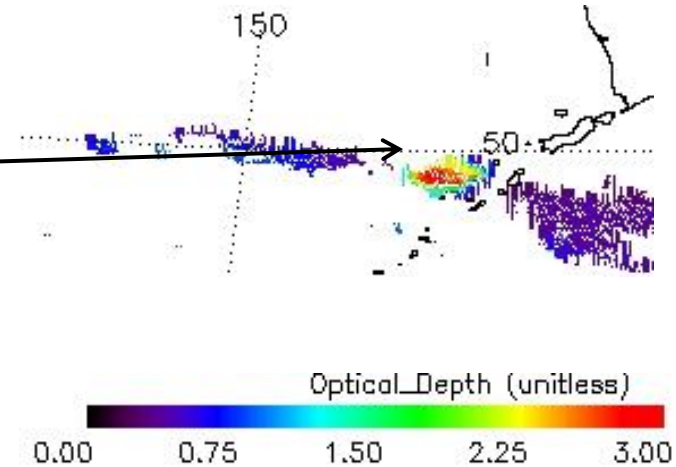
Sarychev 2009

- Focus on June 13 – 16, 2009
- MODIS data with GOES-R
- MTSAT data with GIVAR
- WRF-Chem
  - Sparks ER and S1 PSD
  - Plumeria ER and S1 PSD
  - 5 km spatial resolution
- To come: Vary spatial resolution and PSD

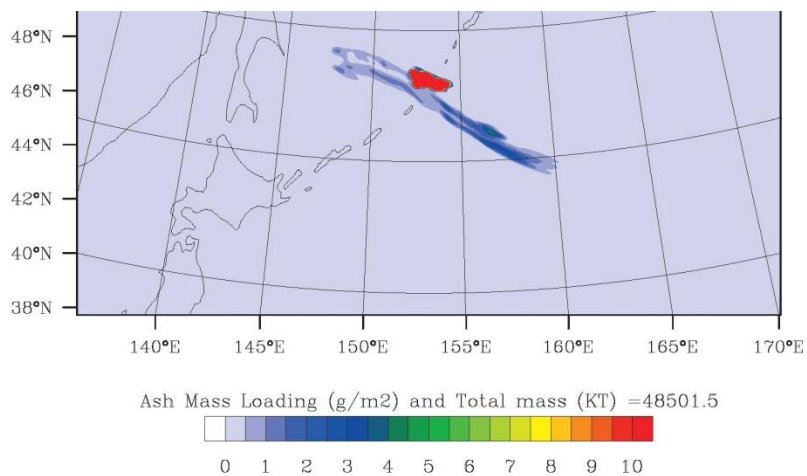
Sarychev: Satellite Ash versus WRF-Chem runs



New event



MTSAT: June 13th 2009 at 22:57 UTC



25 _____ 125 _____ 250 T/pixel

Plumeria Eruption Rate and S1 PSD

WRF-Chem: June 13th 2009 at 23:00 UTC

$1\ g/m^2 = 25T$ per pixel

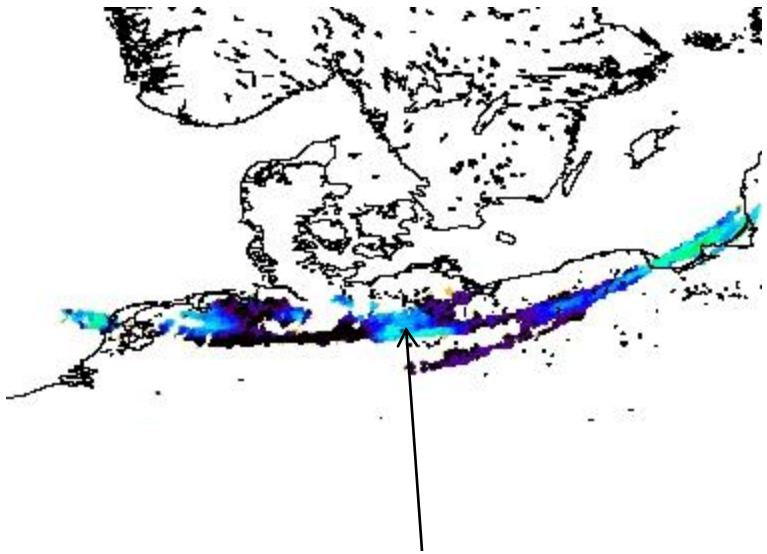
Eyjafjallajökull 2010

- April 14 – 19, 2010
- SEVIRI data via GOES-R
- SEVIRI data with VAR
- WRF-Chem
  - Sparks Er and S2 PSD
- Comparison to LIDAR

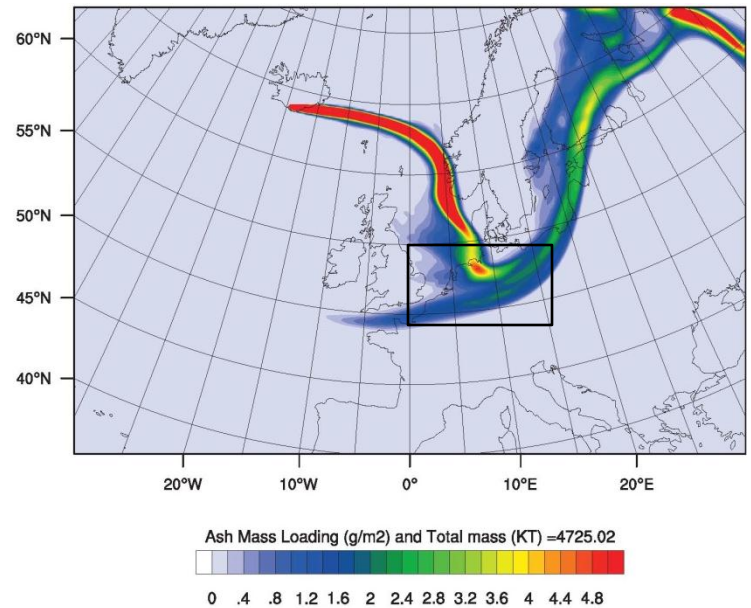
Focused on
April 14 – 19, 2010 period

Start time	Duration (hrs)	End time	Height ASL (km)	Eruption rate (kg/s)
4/14/2010 09:00	10	4/14/2010 19:00	9	5.71E+05
4/14/2010 19:00	9	4/15/2010 04:00	5.5	3.87E+04
4/15/2010 04:00	39	4/16/2010 19:00	6	6.44E+04
4/16/2010 19:00	35	4/18/2010 06:00	8.25	3.65E+05
4/18/2010 06:00	17	4/18/2010 23:00	5	2.17E+04
4/18/2010 23:00	1	4/19/2010 00:00	4	4.93E+03

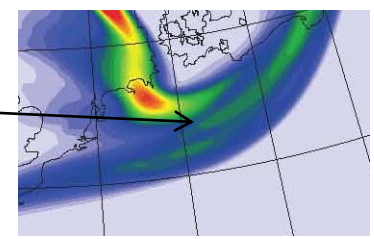
Eyjafjallajokull: GOES-R v WRF-Chem

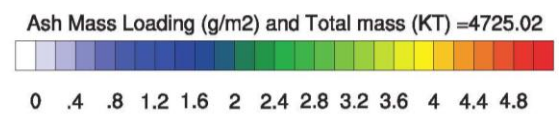


2 T → ~ 0.1 g/m^2



2 g/m^2



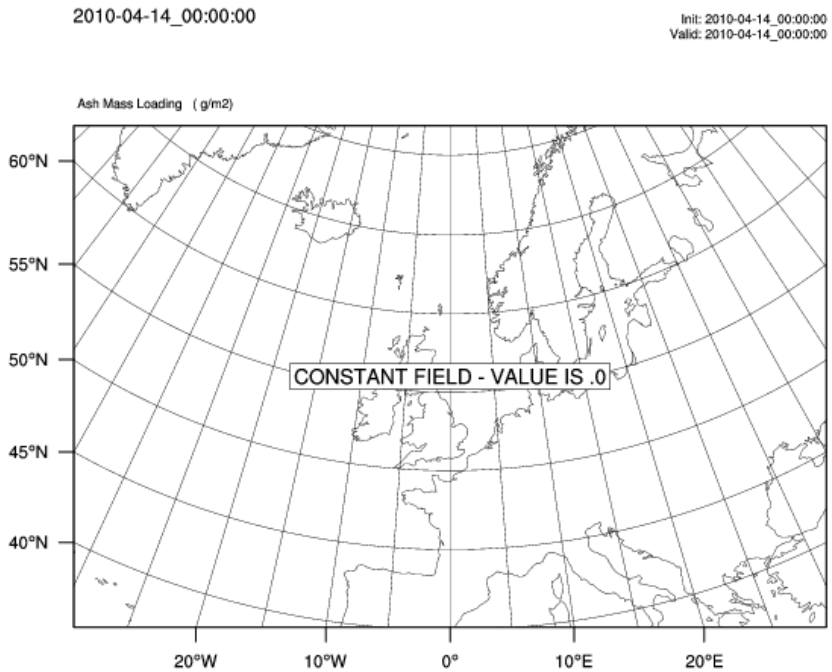


<u>Next</u>

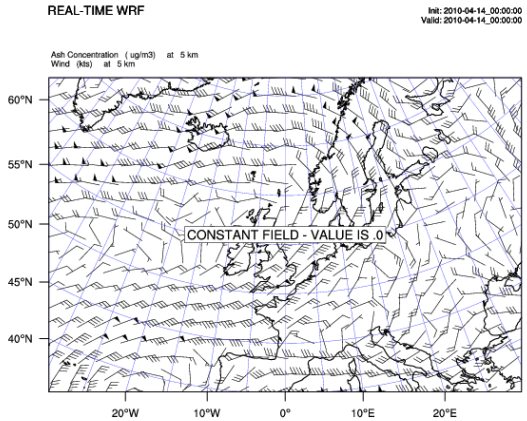
- Point analysis with time
- Spatial comparison

WRF-Chem Mass Loading: Eyjafjallajökull 2010

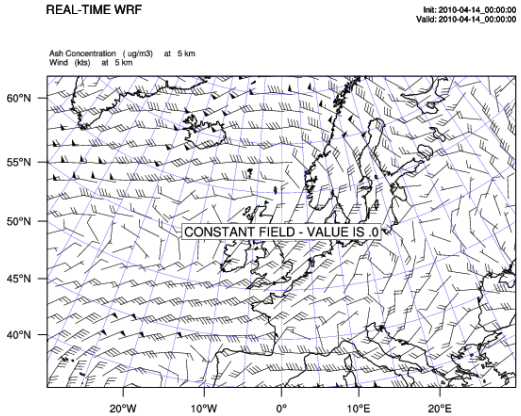
Total ash mass loading



Ash mass (vash 6) at 5 km ASL



Ash mass (vash 10) at 5 km ASL



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What is next? – Year 2 → 3

Continue

- Provide GOES-R height product analysis capability compared to other methods
- Continue tool developed to compare satellite to model products

New

- Assess VATD model results compared to GOES-R ash algorithm products
- Improve WRF-Chem modeled data product latencies
- Display the VATD model products within AWIPS
- Develop new model inputs to improve eruption source parameters

Alert on plume heights from GOES-R algorithm

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Inverse 1D plume model for likely plume eruption rate

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Trigger WRF-Chem model forecasts for Ops