



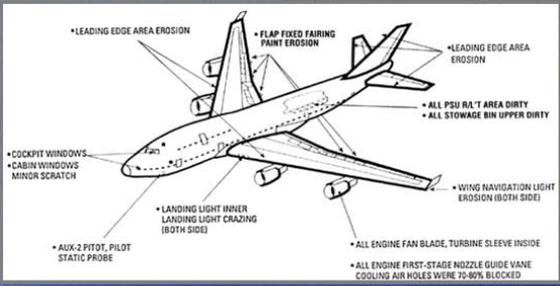
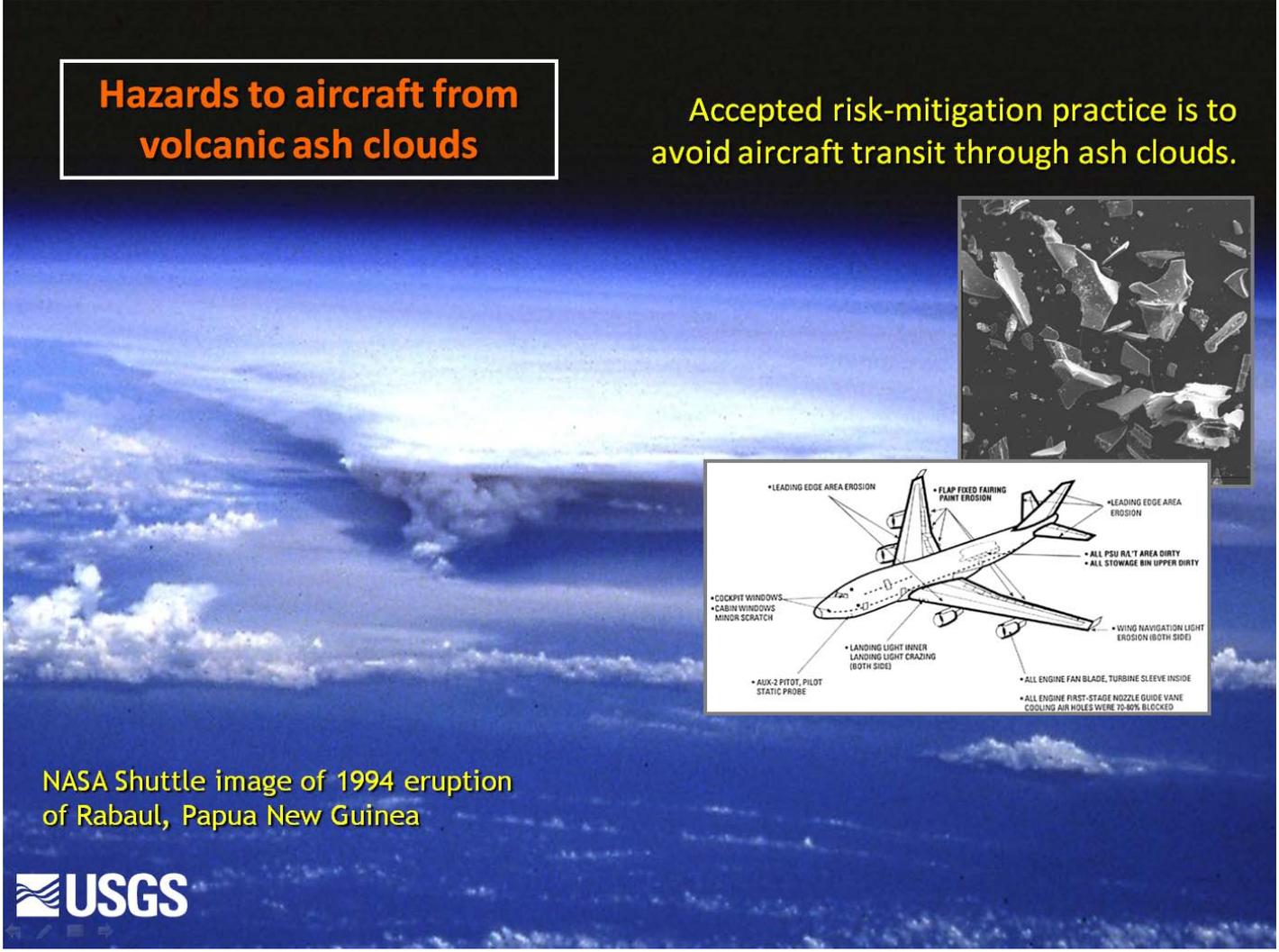
# Volcanic Ash Dispersion Modeling

Barbara Stunder  
Air Resources Laboratory

ARL Laboratory Review  
May 3-5, 2011

# Hazards to aircraft from volcanic ash clouds

Accepted risk-mitigation practice is to avoid aircraft transit through ash clouds.



NASA Shuttle image of 1994 eruption of Rabaul, Papua New Guinea



From USGS presentation to Geological Society of America (for reference, see notes)



## Prevented losses are notoriously hard to quantify, but we do have anecdotal data about costs of known encounters—i.e., when ash avoidance did not work:

- For a suspected encounter: \$\$10,000's to 100,000's to inspect & recertify grounded plane. ( $10^4$ - $10^5$  \$\$)
- For a moderately severe encounter: A few \$million to clean engine, replace windscreen, resurface abraded areas. ( $10^6$  \$\$)
- For a severe engine-damaging encounter: \$10's to \$100's of millions to replace engines and avionics. ( $10^7$ - $10^8$  \$\$)
- For a crash: Unofficial estimate is \$2 billion, including insurance payouts. ( $10^9$  \$\$) How resilient is an air carrier to this?

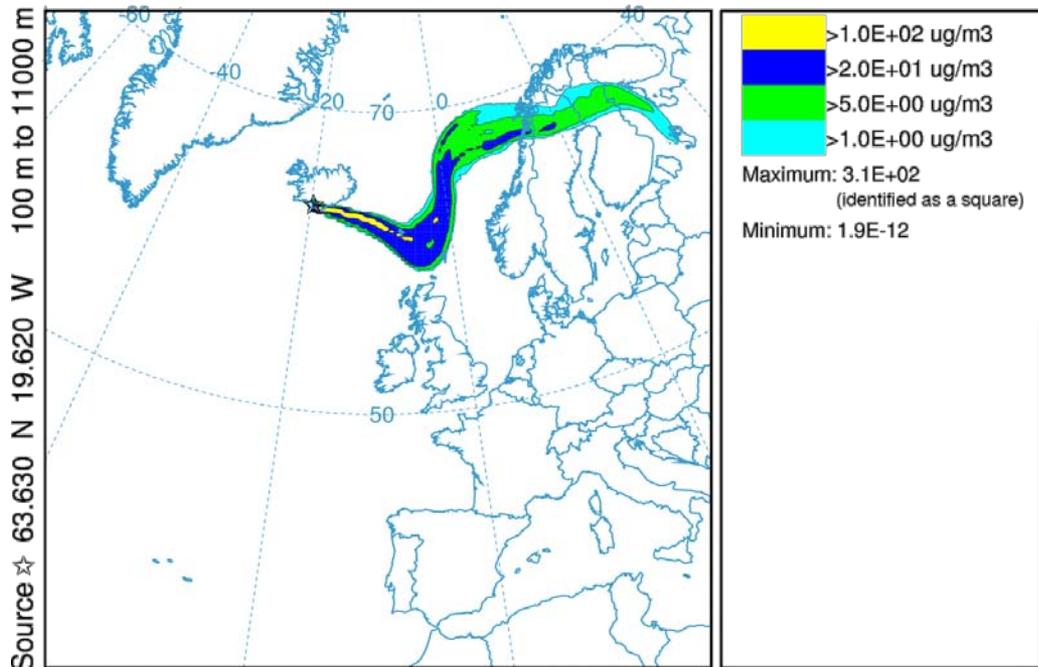


From USGS presentation to Geological Society of America (for reference, see notes)

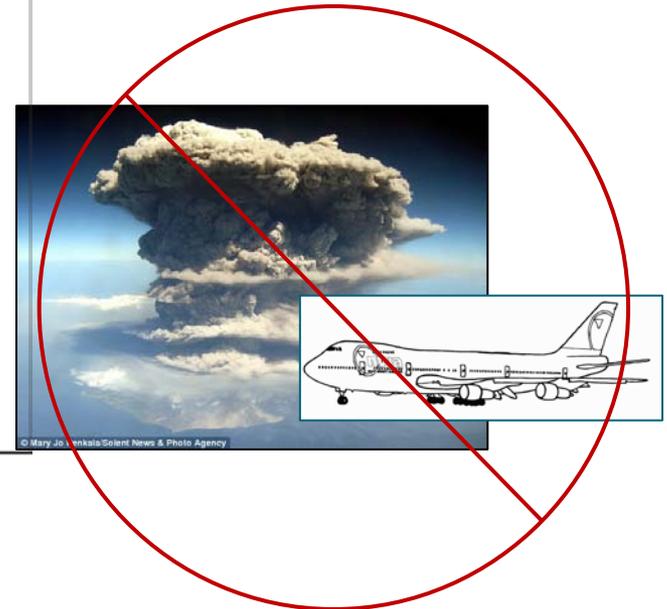
# Goal: Improved forecasts for safe aviation

## NOAA HYSPLIT MODEL

Concentration (ug/m<sup>3</sup>) averaged between 0 m and 10000 m  
 Integrated from 0000 15 Apr to 0100 15 Apr 10 (UTC)  
 SUM Release started at 0000 15 Apr 10 (UTC)



GHDA METEOROLOGICAL DATA

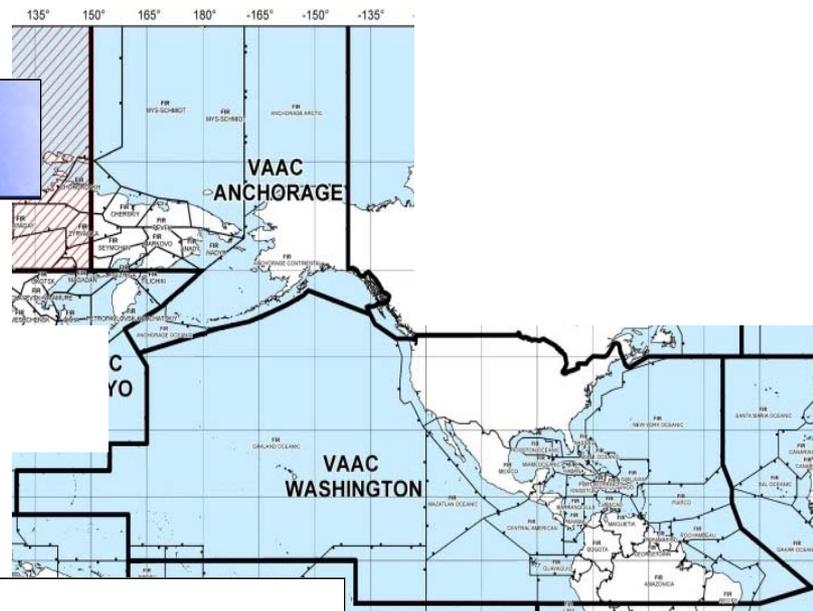




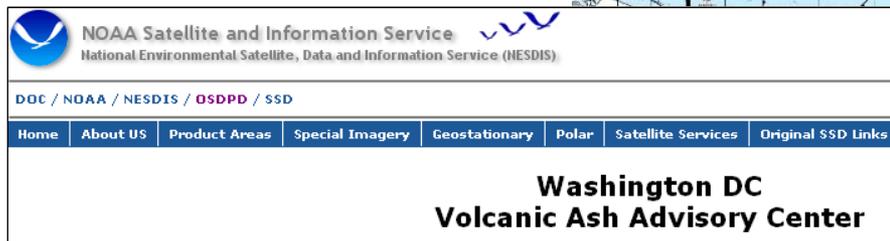
# Approach:

ARL develops improvements based on customer needs, where customers are U.S. Volcanic Ash Advisory Centers (VAAC) (NWS and NESDIS), whose customers are the offices which write SIGMET, FAA, and the airlines.

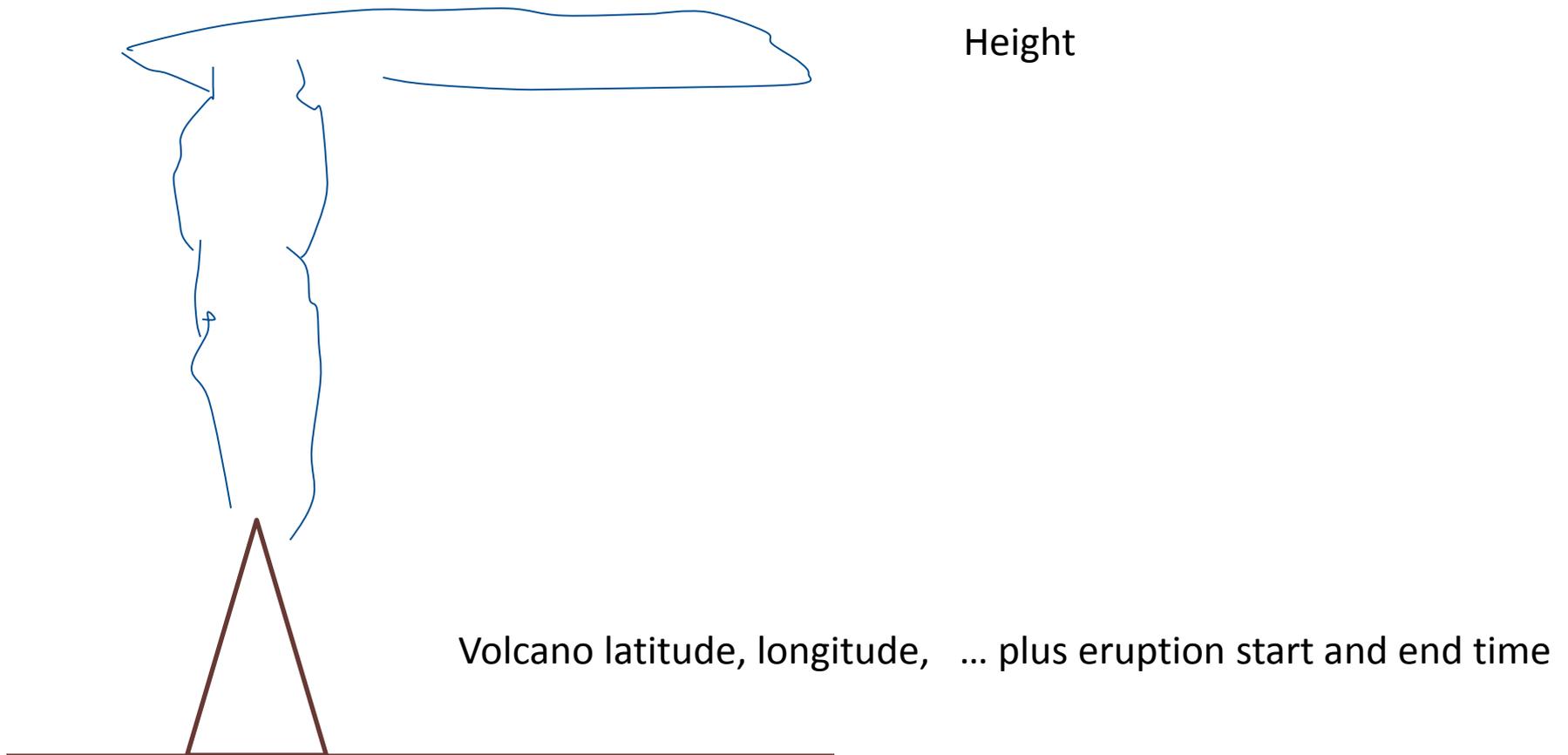
Anchorage, AK, VAAC  
(NWS [non-NCEP])



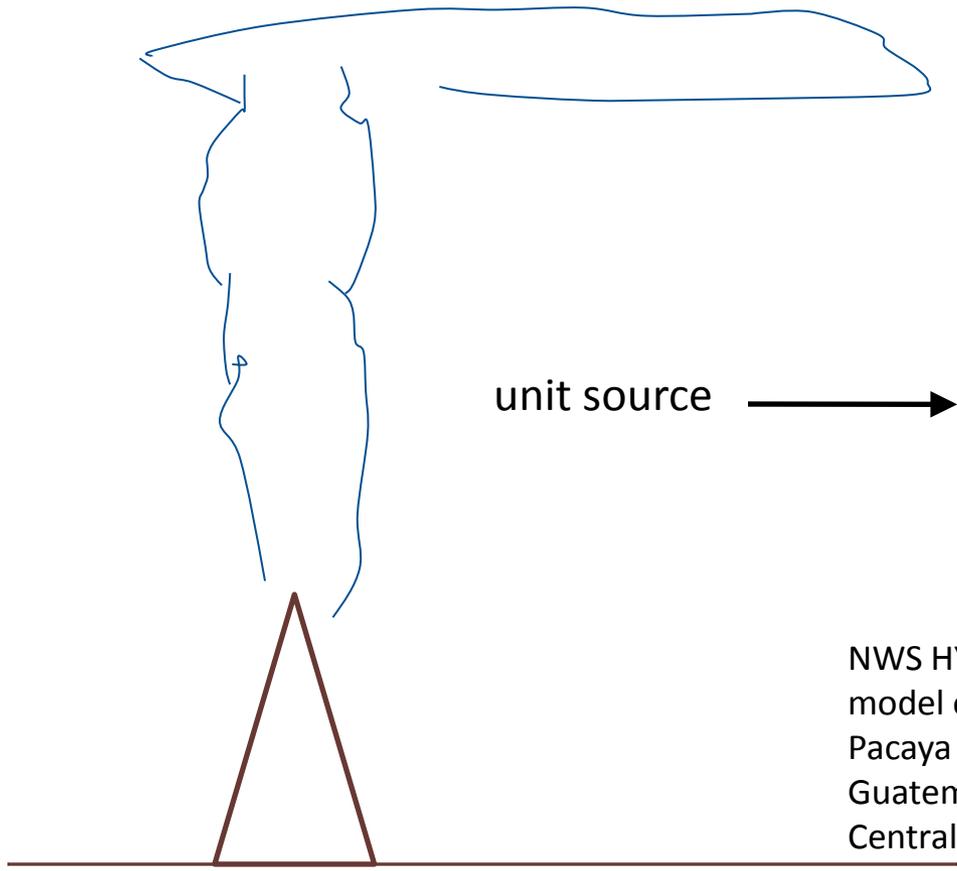
Washington, DC, VAAC  
(NESDIS / NWS [NCEP])



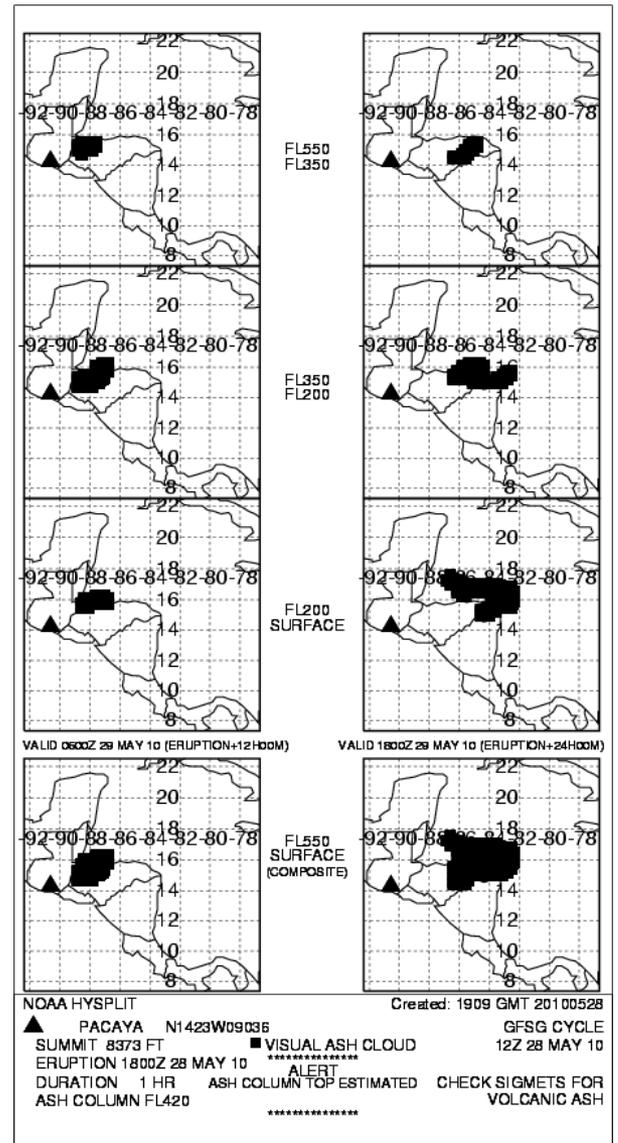
# Model output depends on source term



# Model output depends on source term

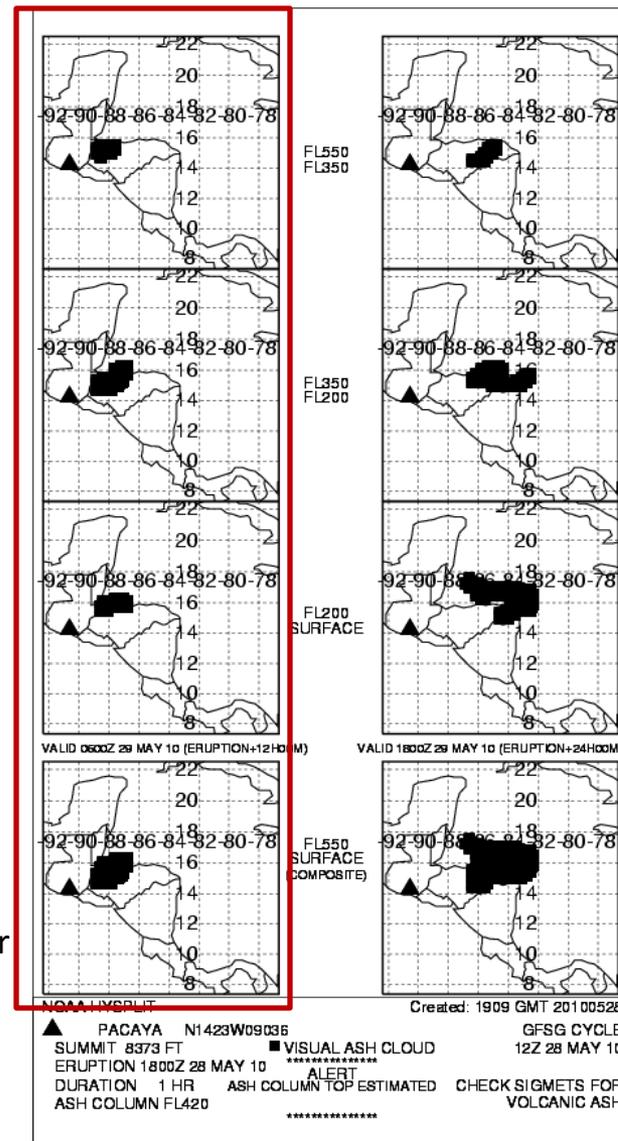


NWS HYSPLIT  
model output for  
Pacaya volcano,  
Guatemala,  
Central America



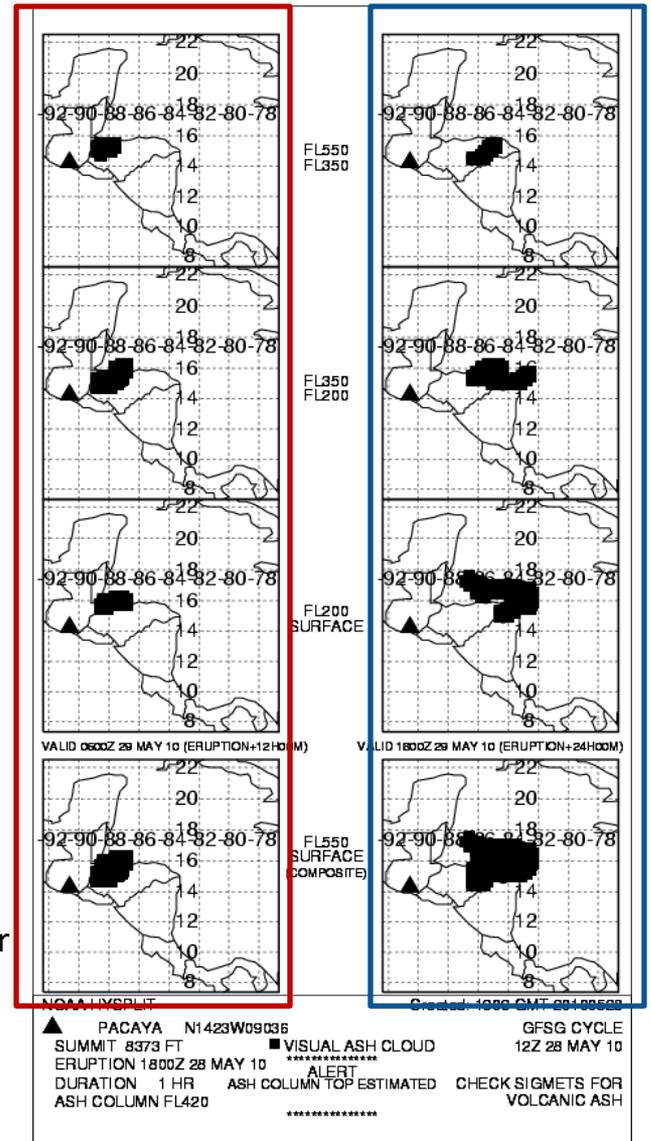
Left-hand column, valid 12-h after eruption start

NWS HYSPLIT  
Model output for  
Pacaya volcano,  
Guatemala,  
Central America

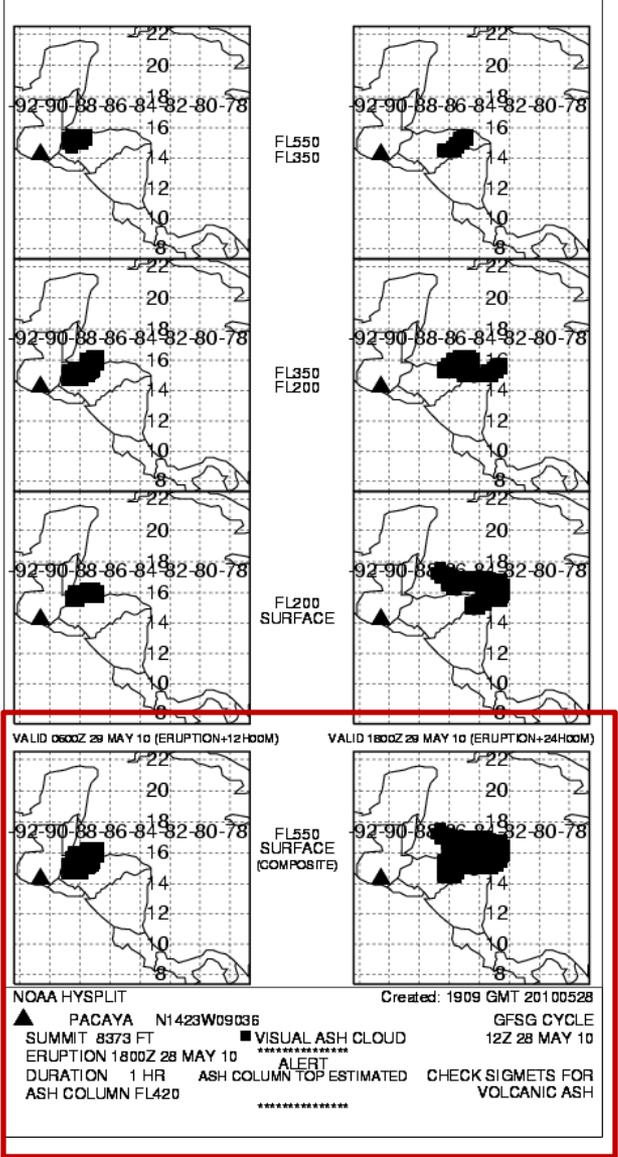


Left-hand column, valid 12-h after eruption start

Right-hand column, valid 24-h after eruption start



NWS HYSPLIT  
 Model output for  
 Pacaya volcano,  
 Guatemala,  
 Central America



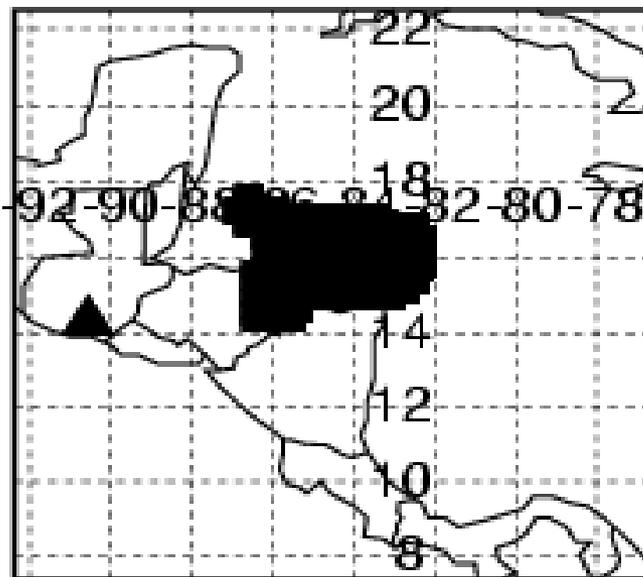
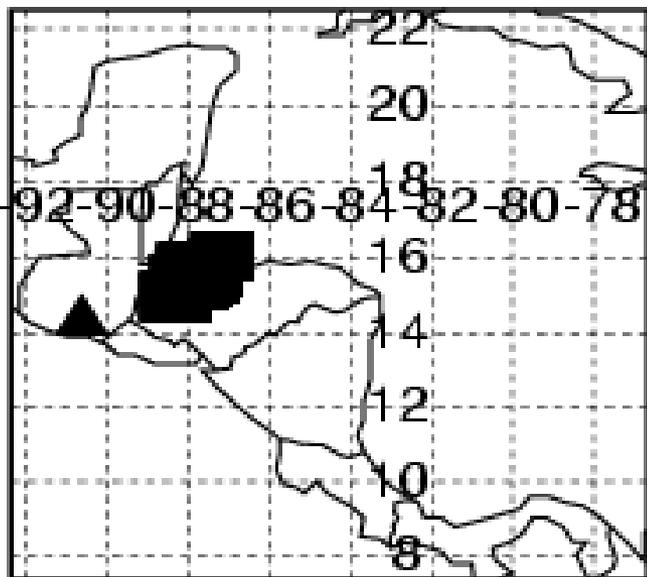
NWS HYSPLIT  
Model output for  
Pacaya volcano,  
Guatemala,  
Central America



FL550 ≈ 55,000 ft

VALID 0500Z 28 MAY 10 (ERUPTION+12H00M)

VALID 1800Z 28 MAY 10 (ERUPTION+24H00M)



FL550  
SURFACE  
(COMPOSITE)

NOAA HYSPLIT

Created: 1909 GMT 20100528

▲ PACAYA N1423W09036

GFSG CYCLE

SUMMIT 8373 FT

■ VISUAL ASH CLOUD

12Z 28 MAY 10

ERUPTION 1800Z 28 MAY 10

\*\*\*\*\*

DURATION 1 HR

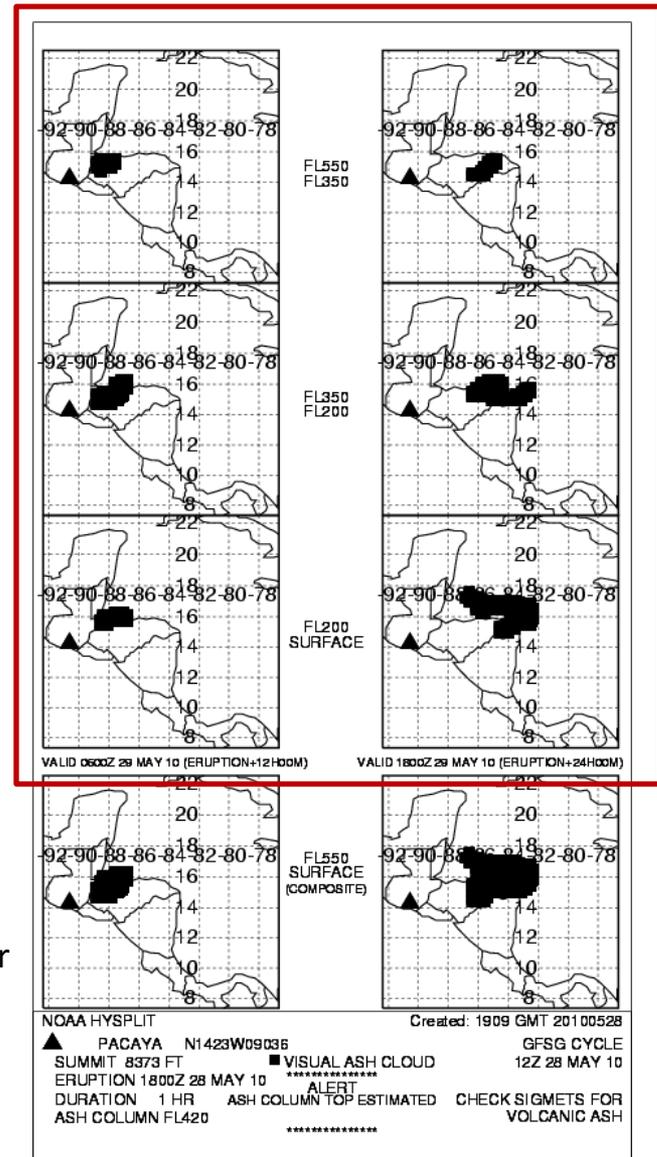
ALERT  
ASH COLUMN TOP ESTIMATED

CHECK SIGMETS FOR

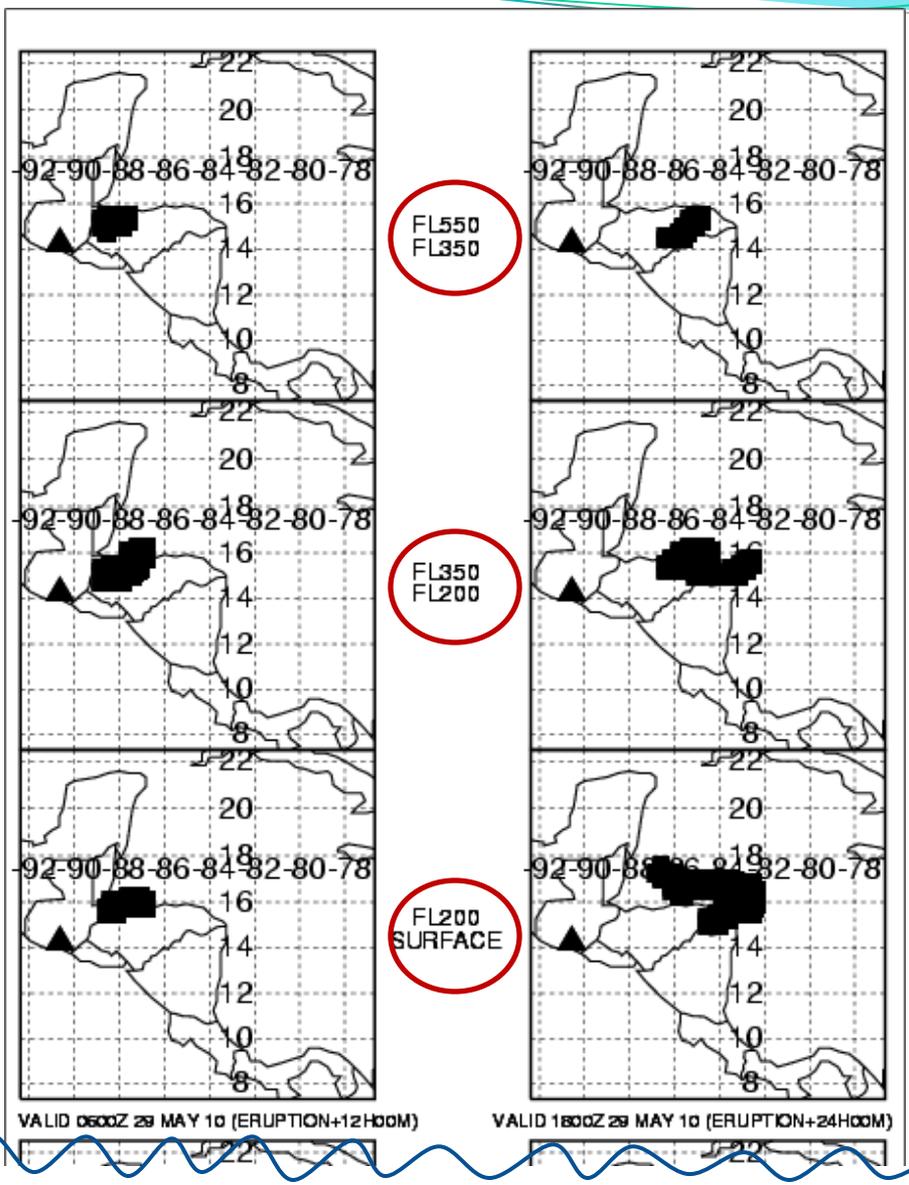
ASH COLUMN FL420

\*\*\*\*\*

VOLCANIC ASH

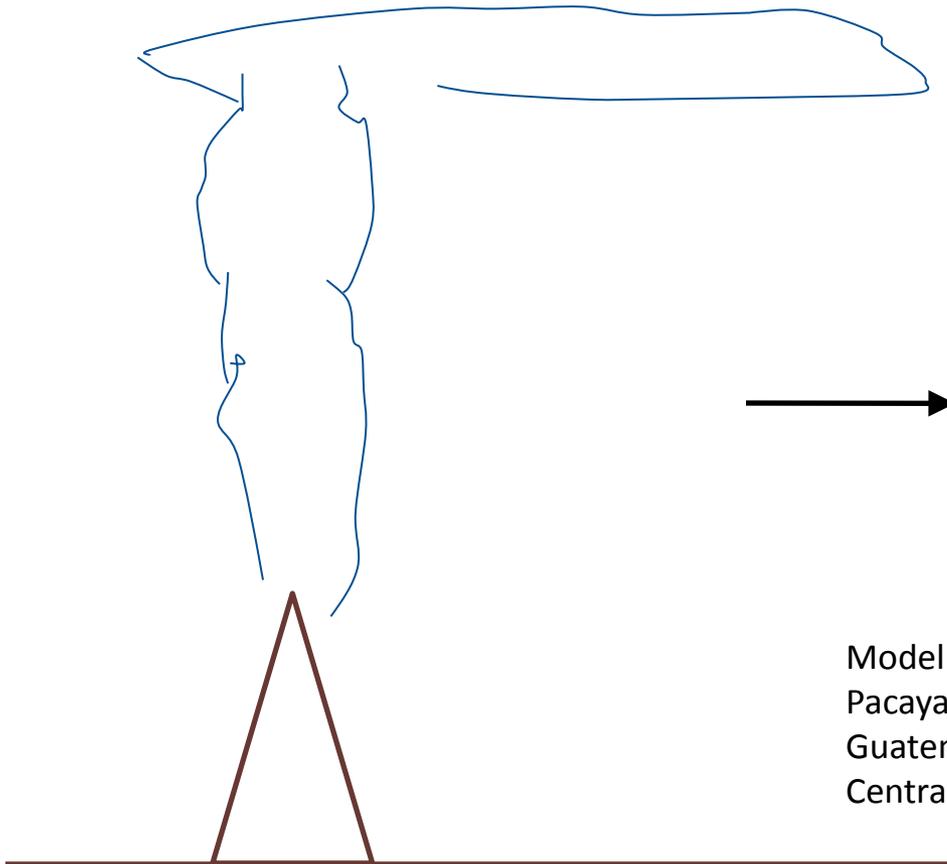


NWS HYSPLIT  
Model output for  
Pacaya volcano,  
Guatemala,  
Central America

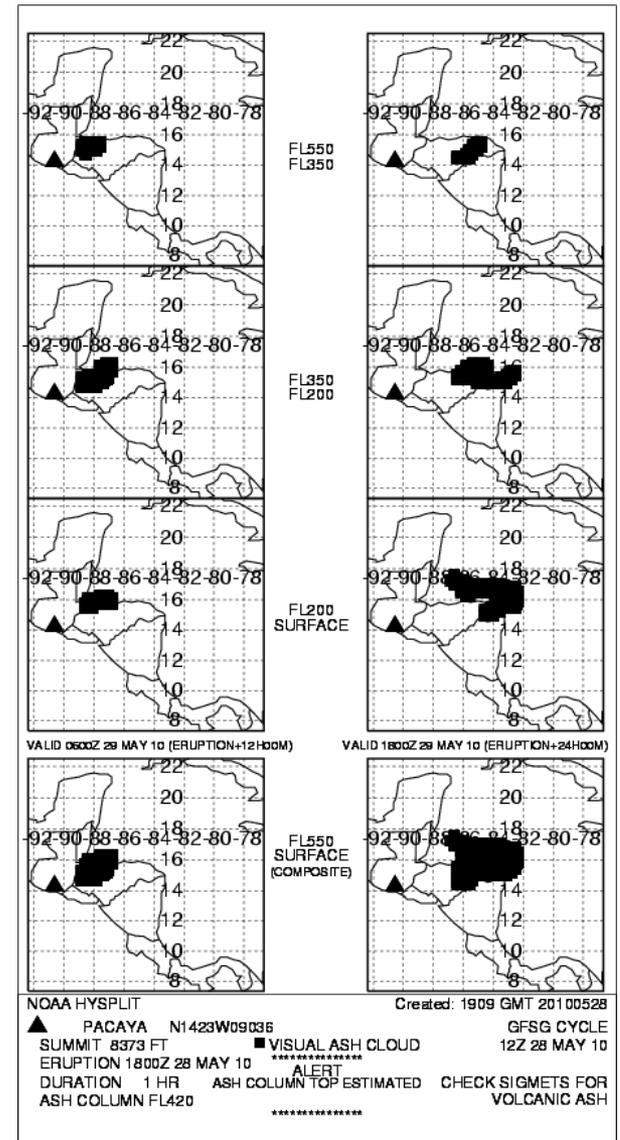


3 layers

# Model output depends on source term



Model output for Pacaya volcano, Guatemala, Central America





## Approach:

ARL develops improvements based on customer needs ....

... and with partners, is developing improvements to the HYSPLIT volcanic ash source term, including methods to account for its uncertainty

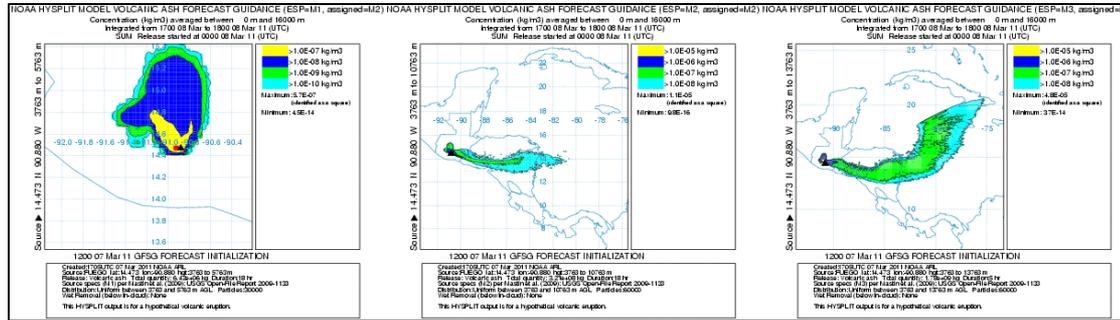
# Source term approaches . . . initialization at the volcano

(small)

(medium)

(large)

(1)



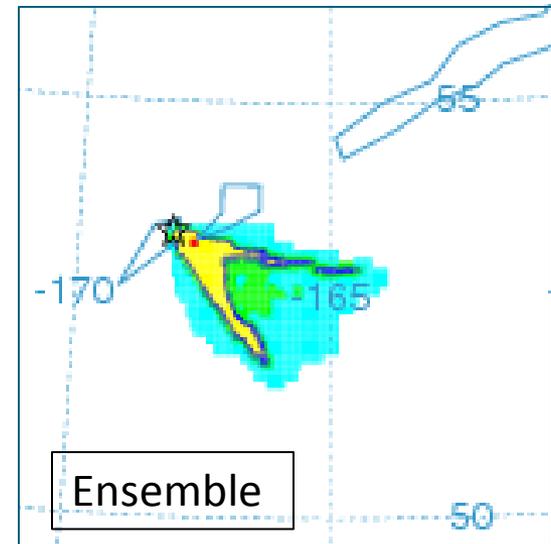
“Preliminary Spreadsheet of Eruption Source Parameters for Volcanoes of the World”

(2)

$$H \text{ (km)} = 0.41 M \text{ (kg/s)}^{0.222}$$

& mass fraction of fines

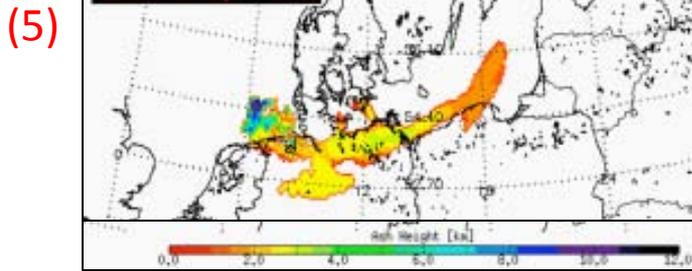
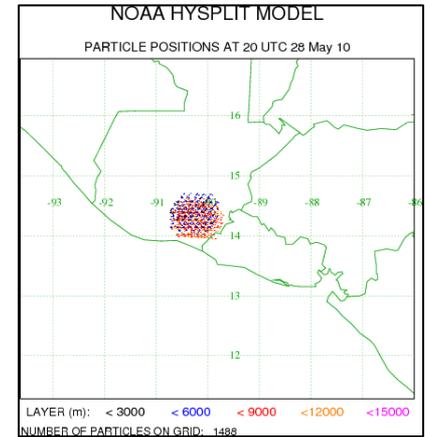
(3)



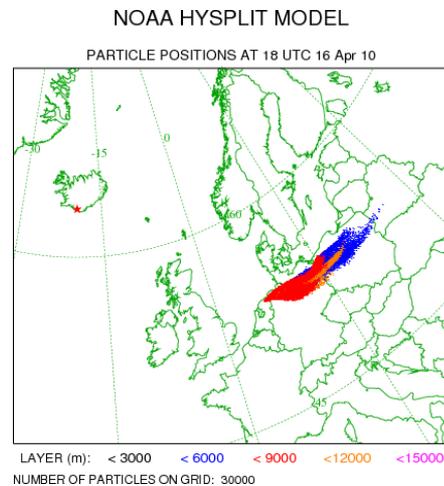
# Source term approaches (cont) ... initialization with downwind observations

(4) OBS VA DTG: 28/1845Z  
 OBS VA CLD: SFC/FL420 N1438 W09008 - N1427 W09001 -  
 N1411 W09010 - N1413 W09034 - N1419 W09038 - N1428  
 W09044 - N1437 W09038 - N1438 W09008

(location information only)



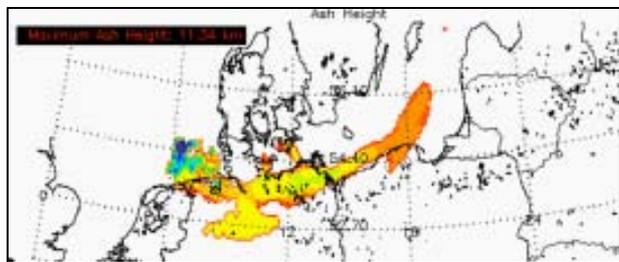
(location and mass loading)



# Accomplishment:

ARL developed interim solution for HYSPLIT initialization and delivered it to NWS for operational implementation

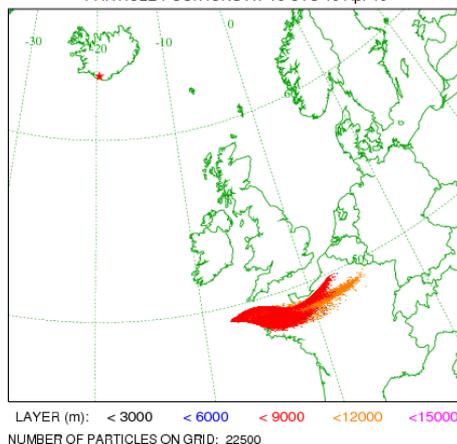
(6)



(observed location)

+

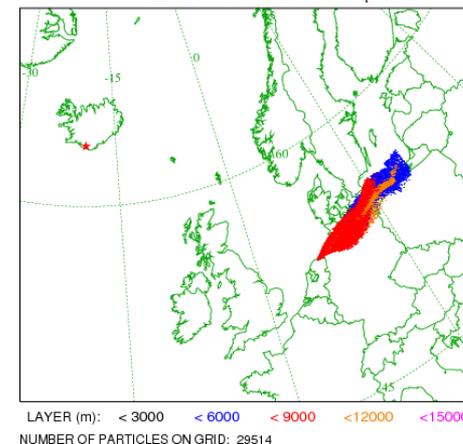
NOAA HYSPLIT MODEL  
PARTICLE POSITIONS AT 18 UTC 16 Apr 10



(model output)

=

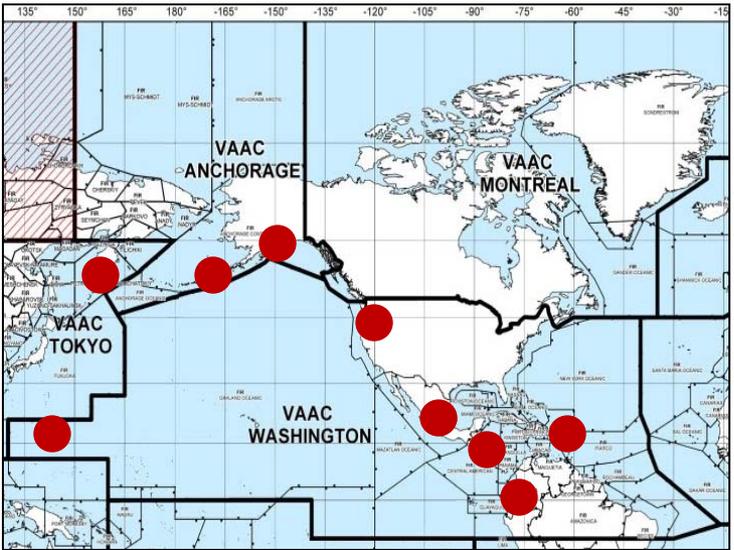
NOAA HYSPLIT MODEL  
PARTICLE POSITIONS AT 18 UTC 16 Apr 10



(adjusted model output becomes initialization for forecast)

# Need a verification database:

- source term
- observations
- analysis meteorology
- statistics program



● = historically active volcano





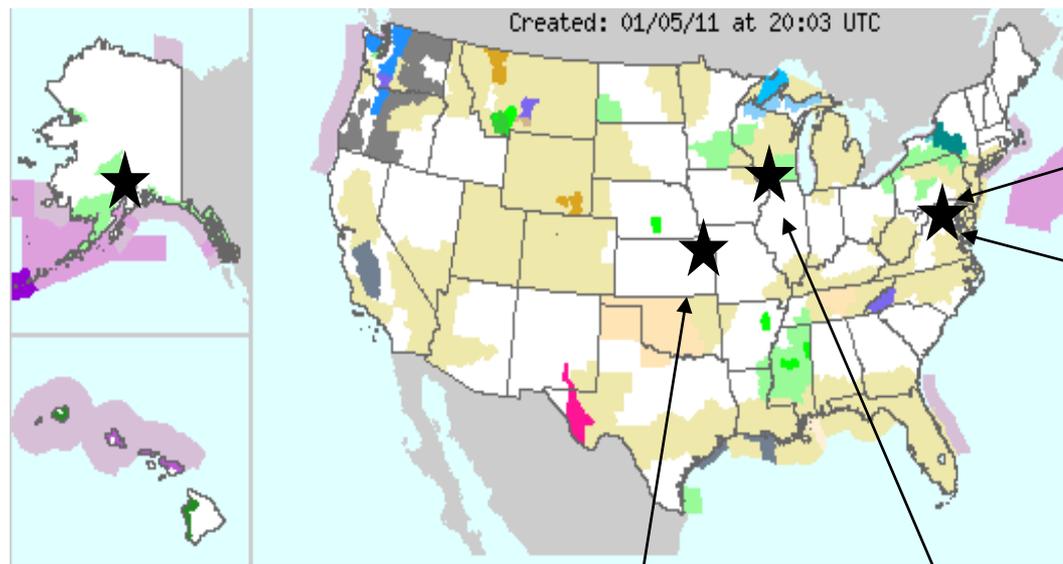
# Partners:



Innovate, Incubate, Integrate  
**noaa research**  
NOAA's OFFICE OF OCEANIC AND ATMOSPHERIC RESEARCH

 **NOAA Satellite and Information Service**  
National Environmental Satellite, Data and Information Service (NESDIS)

NWS/AR →



NWS/HQ  
ARL  
NWS/NCEP  
NESDIS

NWS/AWC

NESDIS



## Partners (cont):



Environment  
Canada



## Indicators of success:

- HYSPLIT volcanic ash model output is issued by the NWS
  - eruptions occur frequently, most are small;
  - about 3% of text Advisories issued have an associated HYSPLIT product issued (~50 HYSPLIT forecasts/year)
- Publications
  - Weather and Forecasting, Journal of Volcanology and Geothermal Research
- Weather Services International (WSI) uses HYSPLIT products
  - WSI is one of NWS's private industry partners
- HYSPLIT installed at
  - Air Force Weather Agency
  - Buenos Aires, Argentina, Volcanic Ash Advisory Center
  - Bureau of Meteorology, Australia



## Future directions for improving volcanic ash dispersion forecasts

- improved HYSPLIT initialization
  - with observations as given in Volcanic Ash Advisory
  - with satellite-derived microphysics
- create model evaluation database
- data assimilation

## The end

“In Iceland, they were used to volcanic activity, ... some 200 km west of ... Reykjavik,... spewing red hot lava, dust, ash ... into the air. For eight months the eruptions continued...”



“In the town of Selbourne, in Hampshire, Gilbert White wrote:

*The summer of 1783 was an amazing and portentous one, ... the peculiar haze or smokey fog, that prevailed for many weeks, ... was a most extraordinary appearance... . The sun, at noon, looked as black as a clouded moon...”*

from Halford, P., 2004: Storm Warning – The Origins of the Weather Forecast, Sulton Publishing Ltd., 295 pp.