Dispersion modelling and warnings for volcanic ash in the Australian Region

R Potts, R Dare, E Jansons, C Lucas, A Tupper, M Zidikheri

Australian Government
Bureau of Meteorology

The Centre for Australian Weather and Climate Research
A partnership between CSIRO and the Bureau of Meteorology

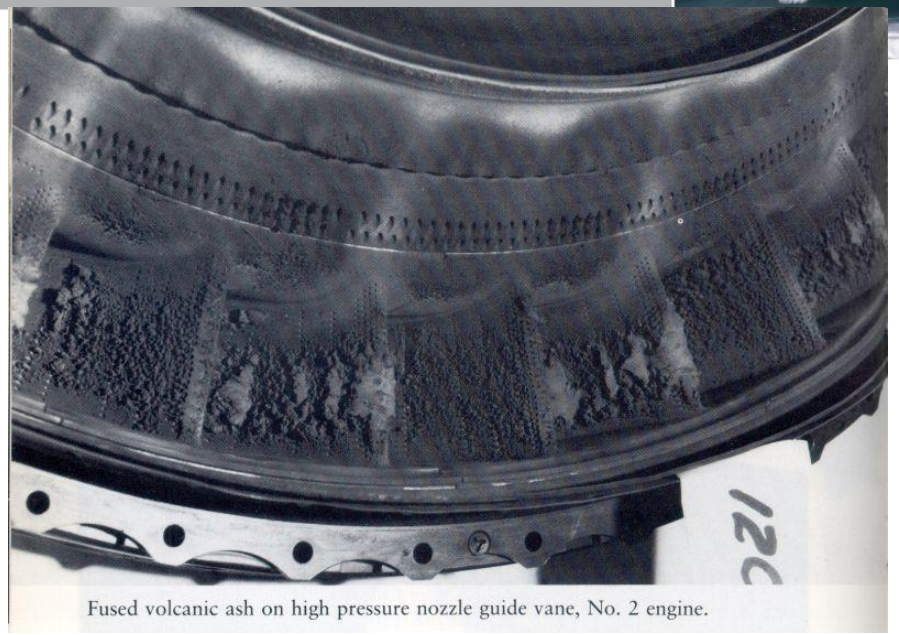
CSIRO

Volcanic ash hazard for aviation
Galunggung Volcano - BA009 ash encounter 24 June 1982

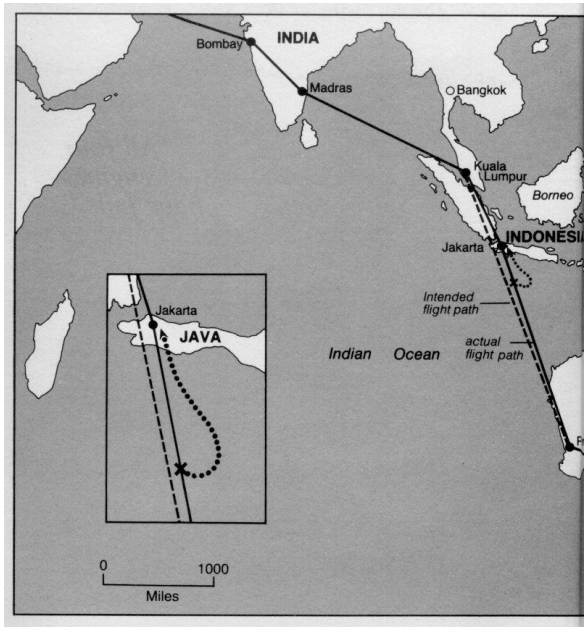
'All four engines have failed'

The True and Triumphant Story of Flight BA 009 and the 'Jakarta Incident'

by BETTY TOOTELL



Fused volcanic ash on high pressure nozzle guide vane, No. 2 engine.



Effect of erosion on IP. 1, 2, 3 & 4 rotor blade.

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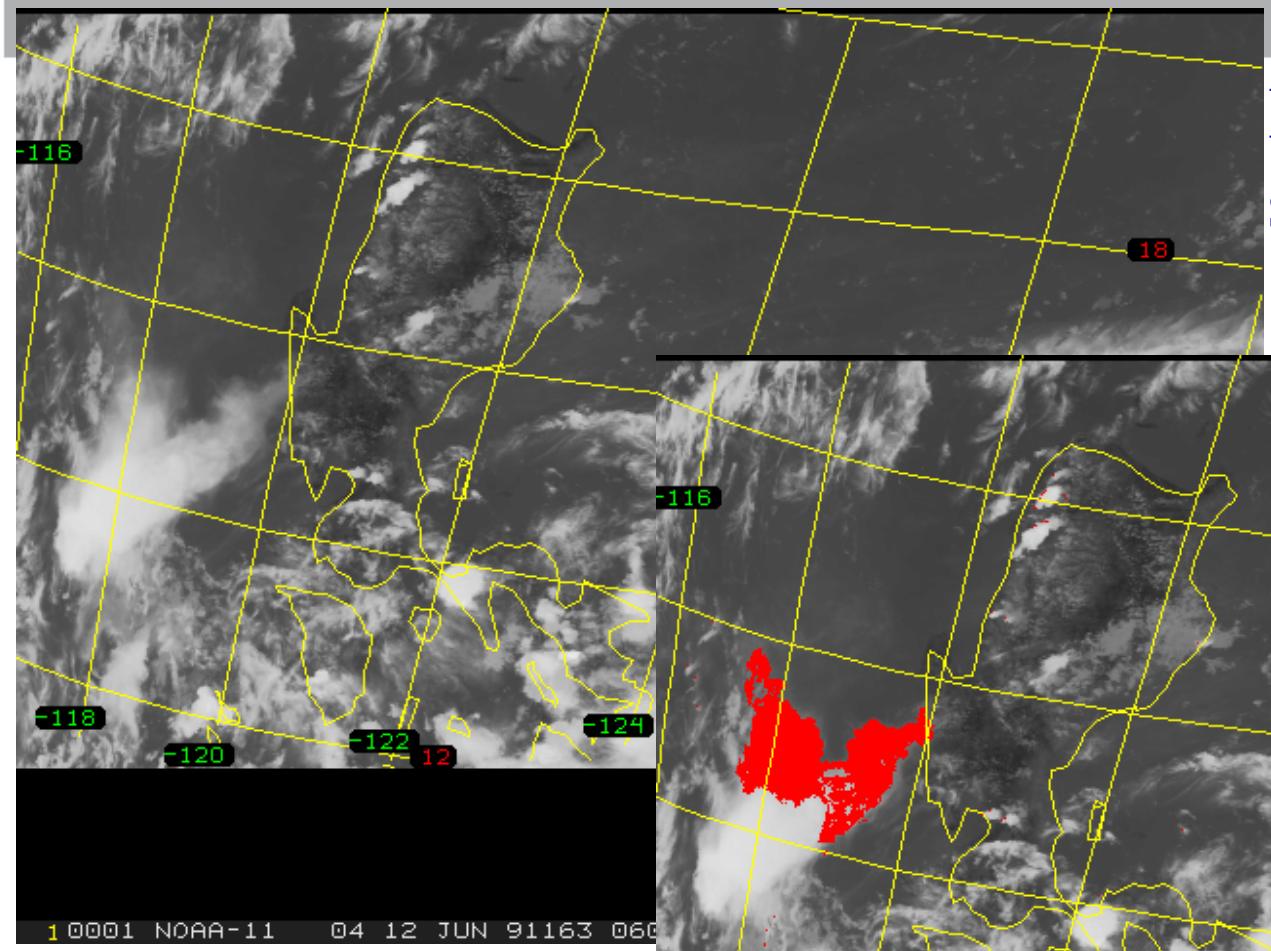
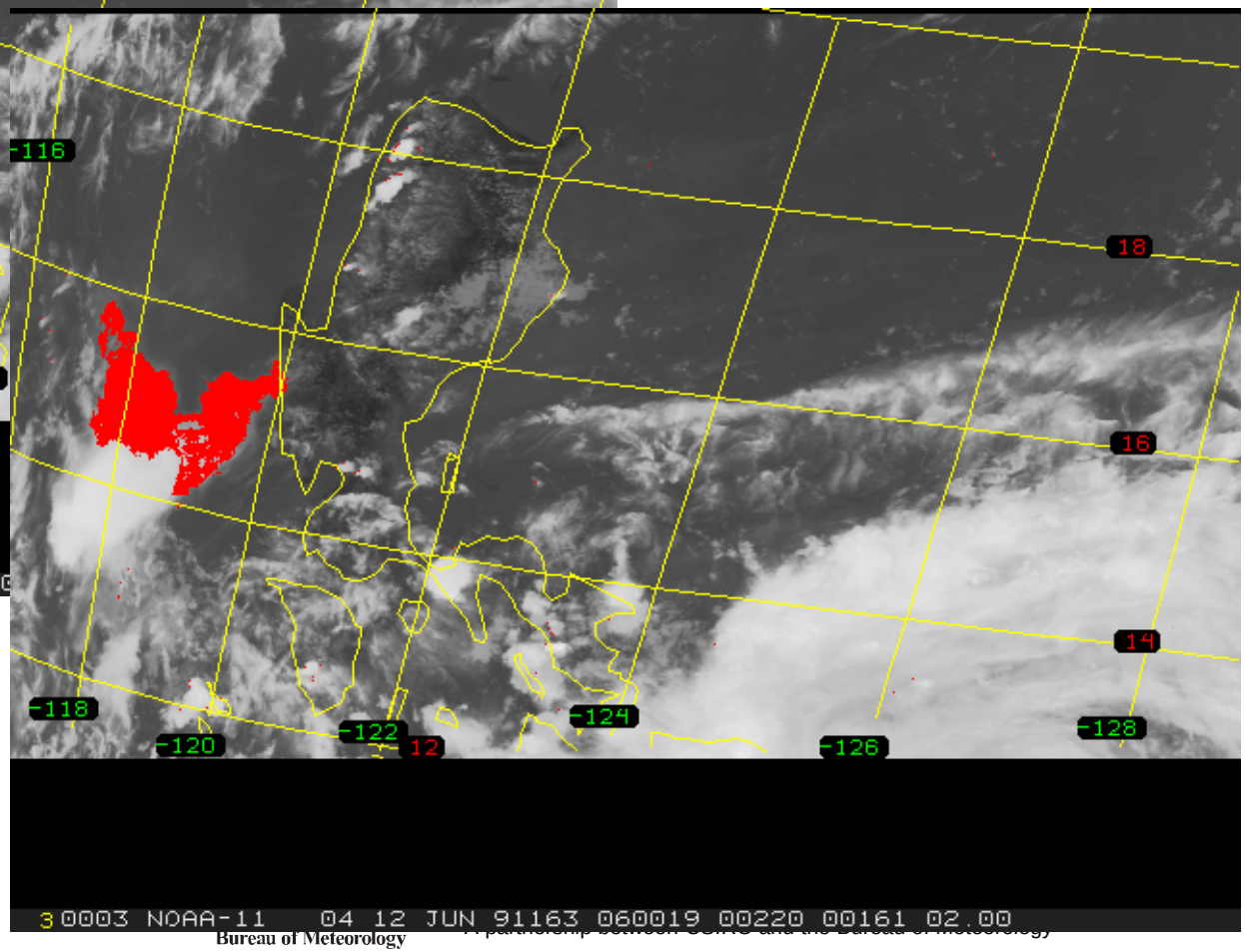
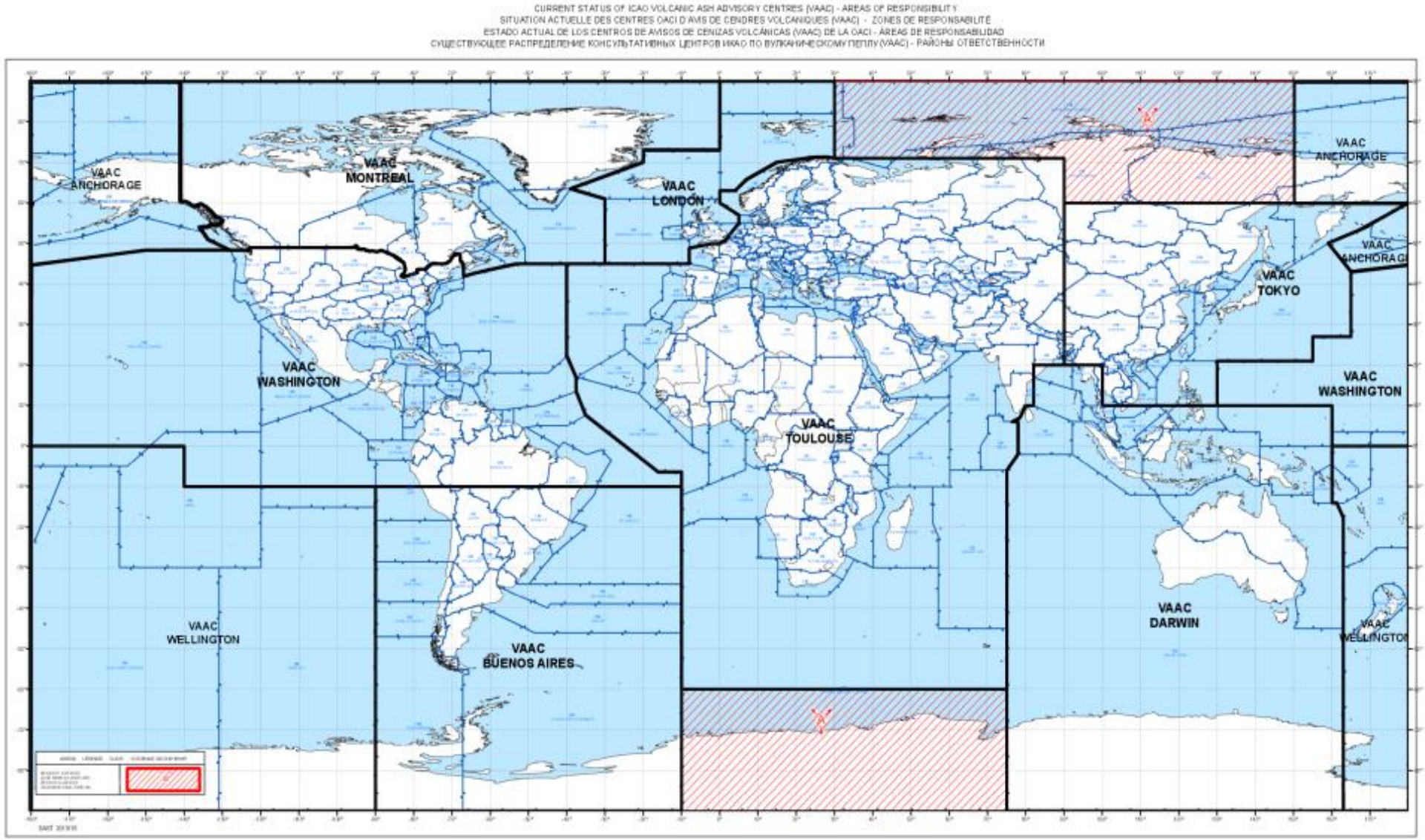
Pinatubo 12 June 1991, 0600 UTC

NOAA11 AVHRR satellite data

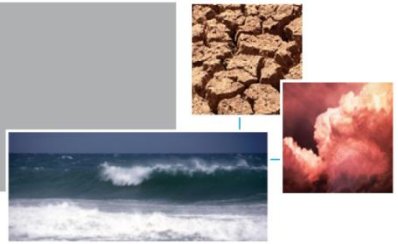




Volcanic Ash Advisory Centers



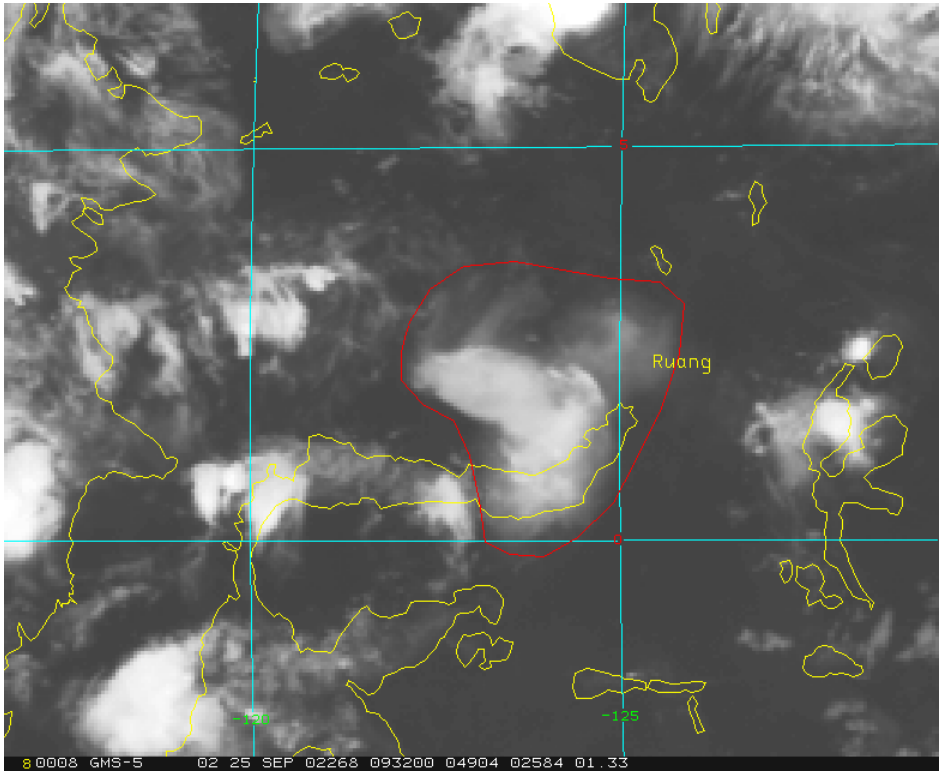
Science / technical challenges

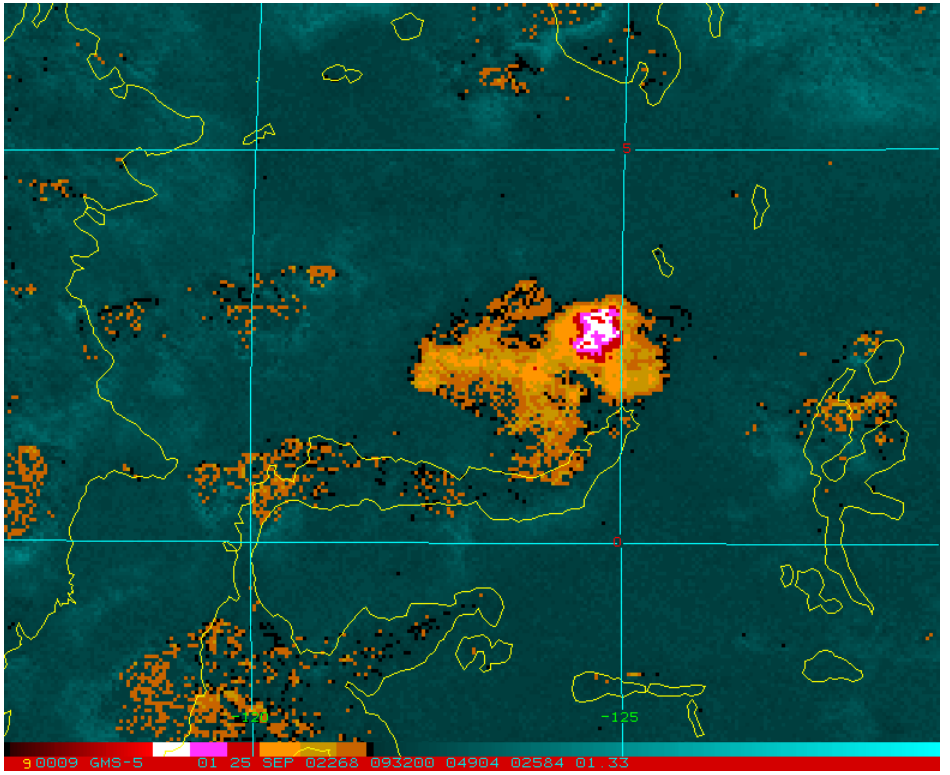


- What concentration is a hazard
- Timely report / detection of eruption / ash cloud
- Satellite detection of volcanic ash
  - Discrimination of ash from water/ice **
  - Vis / IR data – MTSAT-2, AVHRR, MODIS
  - IR channel difference (T_{11}-T_{12})
  - Missed detections
  - False alarms
  - Navigation errors
  - Sensor response function
  - Spatial / temporal resolution
  - Measurement precision
  - Calibration
  - Channel registration
- Dispersion models
  - Source term definition – MER, height, PSD, mass distribution, aggregation [assume a gas]
  - Uncertainties in base NWP model – [ACCESS]
  - Uncertainties in dispersion model – [HYSPLIT]
  - Utilisation / visualisation of output
- Timely issue of volcanic ash warnings
  - More automation

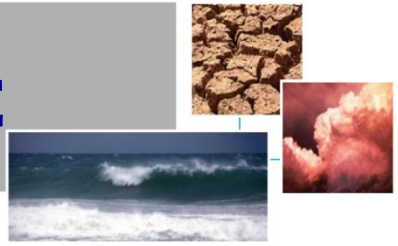
Ruang volcano - 25 September 2002, 0345 UTC

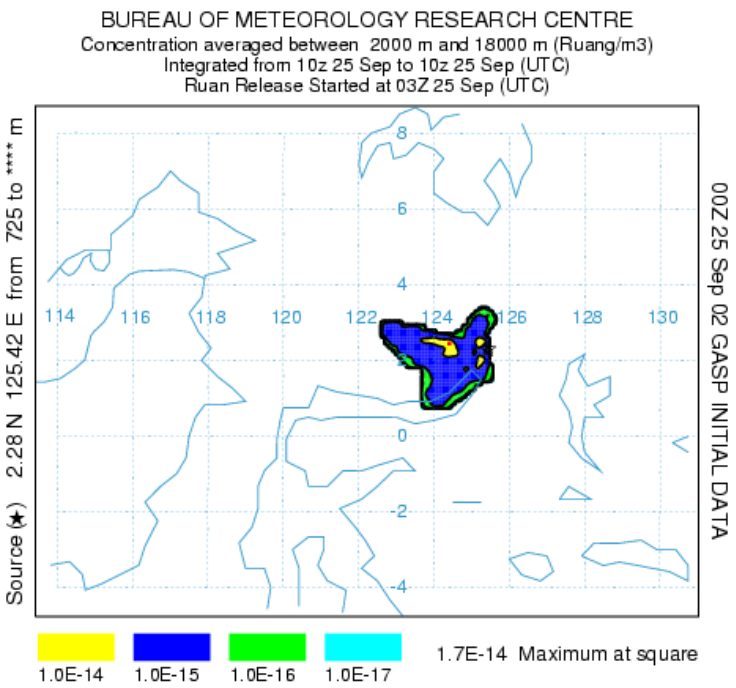
GMS5 satellite data, 25 Sept 2002, 0930 UTC

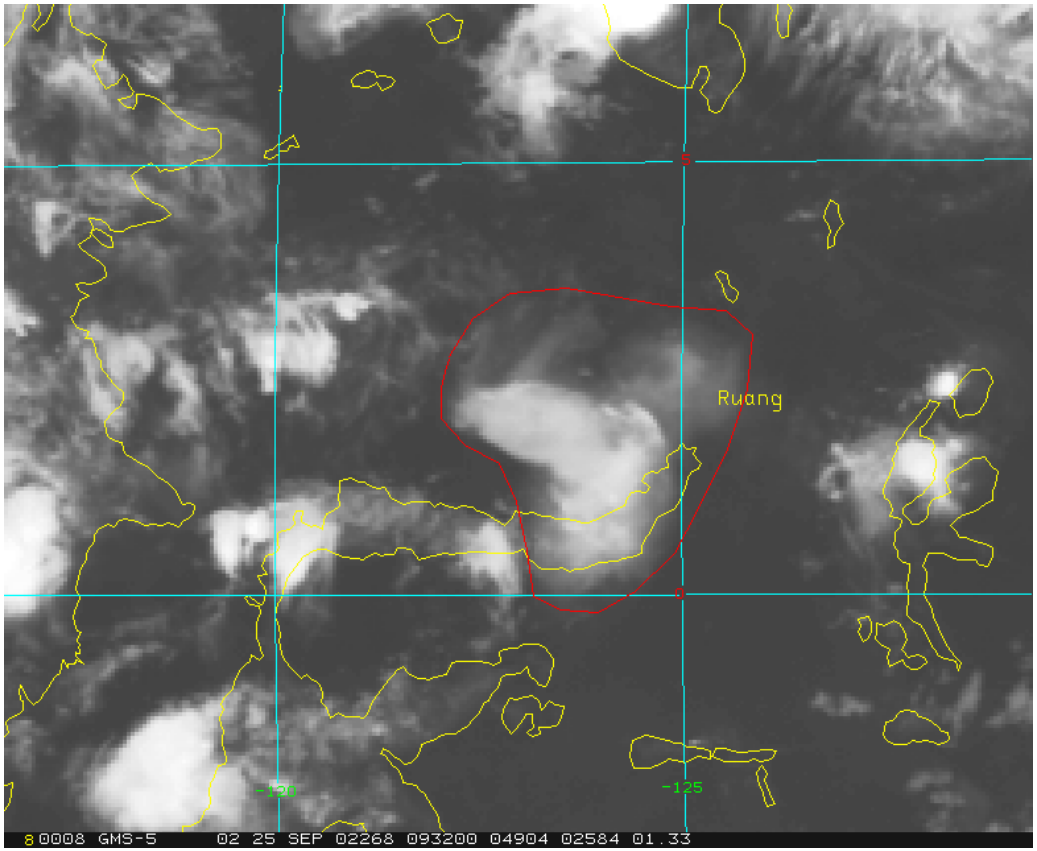




Ruang volcano - 25 September 2002, 0345 UTC



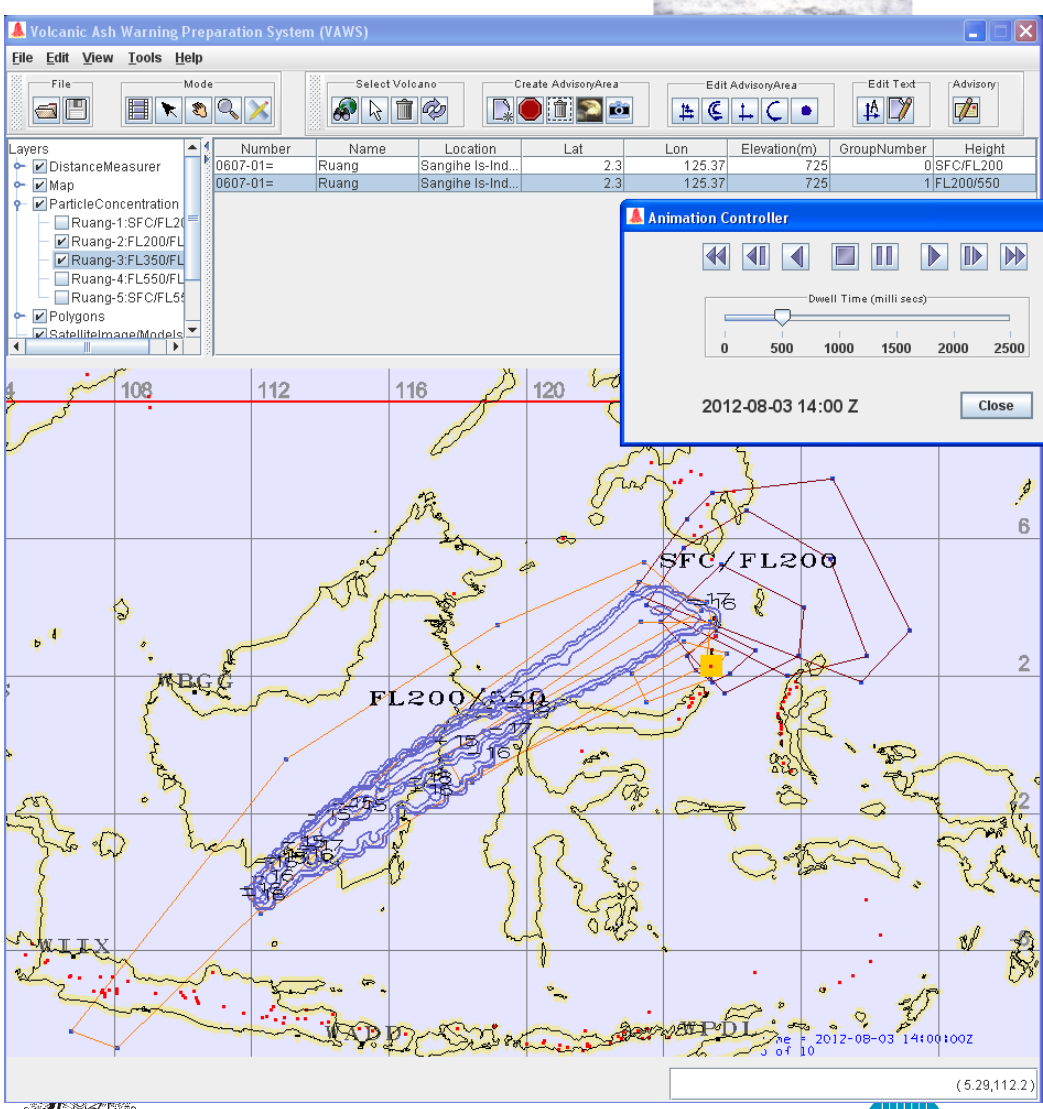




Ruang volcano - 25 September 2002, 1000 UTC

Volcanic Ash Warning Preparation System (VAWS)

- Interactive user interface to streamline preparation of volcanic ash warnings
- Integrated environment for display of satellite, dispersion model and delineation of analysed and forecast threat areas
- Generation of VAA + VAG
- Stable framework for implementation of improved analysis and forecast methodologies
- Platform independence



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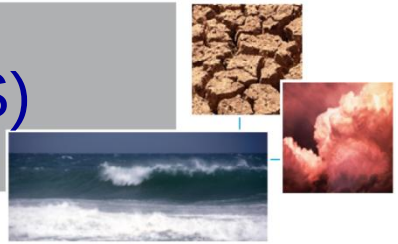
Volcanic Ash Warning Preparation System (VAWS)



VA ADVISORY
DTG: 20120803/0313Z
VAAC: Darwin

VOLCANO: Ruang 0607-01=
PSN: N0218 E12522
AREA: Sangihe Is-Indonesia
SUMMIT ELEV: 725M

ADVISORY NR: 2012/2
INFO SOURCE: report of eruption
AVIATION COLOUR CODE: NIL
ERUPTION DETAILS: eruption of volcano

OBS VA DTG: 03/0300Z
OBS VA CLD:
SFC/FL200 N0205 E12555 - N0150 E12525 - N0210 E12455 - N0235 E12440 - N0320 E12530 - N0245 E12640 - N0205 E12555
FL200/550 N0205 E12305 - N0300 E12435 - N0240 E12550 - N0155 E12520 - N0115 E12330 - N0115 E12330 - N0205 E12305

FCST VA CLD +6HR: 03/0900Z
SFC/FL200 N0235 E12755 - N0130 E12545 - N0335 E12355 - N0515 E12540 - N0400 E12805 - N0235 E12755
FL200/550 N0220 E12515 - S0105 E11805 - S0020 E11740 - N0335 E12320 - N0335 E12520 - N0220 E12515
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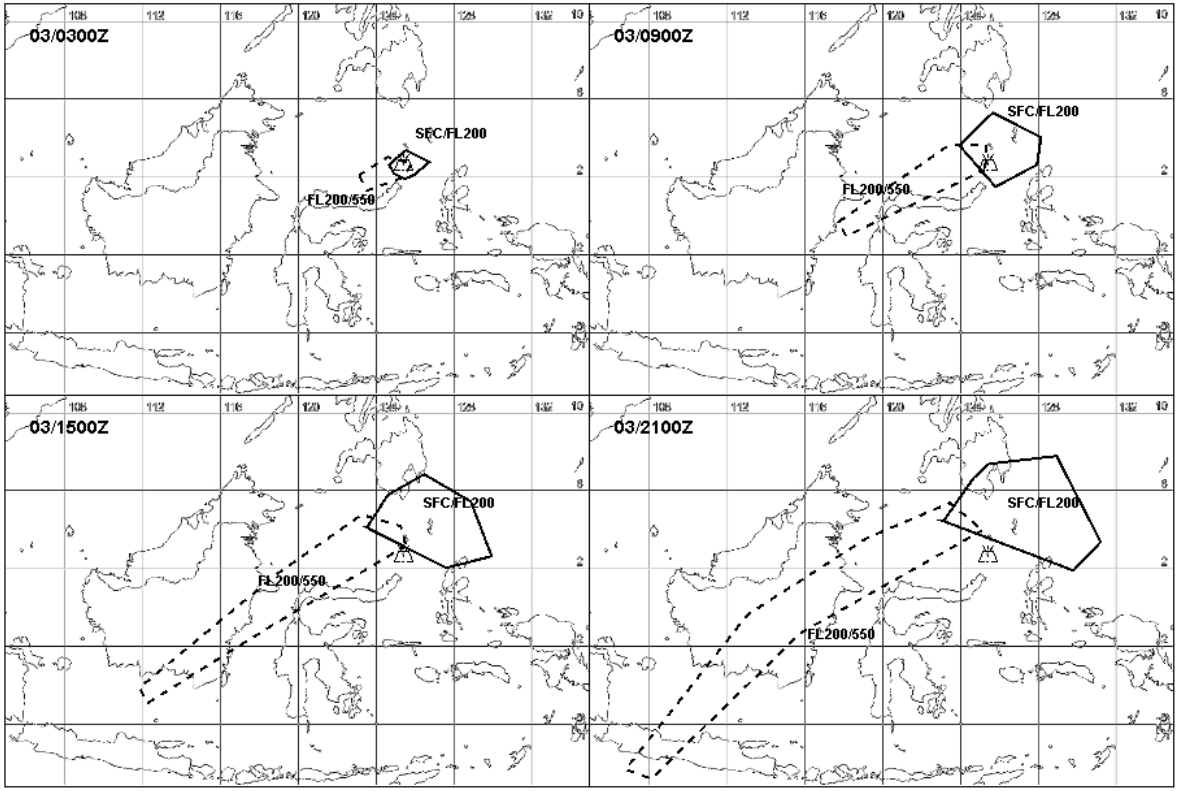
FCST VA CLD +18HR: 03/2100Z
SFC/FL200 N0720 E12525 - N0720 E12525 - N0745 E12855 - N0320 E13110 - N0150 E12945 - N0425 E12305 - N0425 E12305 - N0635 E12440 - N0720 E12525
FL200/550 N0355 E12505 - S0120 E11545 - S0850 E10805 - S0820 E10645 - S0025 E11300 - N0330 E11910 - N0520 E12325 - N0355 E12505

RMK: Graphic at [lower case]
http://www.bom.gov.au/info/vaac/advisories.shtml
NXT ADVISORY: NO LATER THAN 20120803/0900Z



VOLCANIC ASH ADVISORY
DTG: 20120803/0313Z
VAAC: Darwin
VOLCANO: Ruang 0607-01=
AREA: Sangihe Is-Indonesia

SUMMIT ELEV: 725M
ADVISORY NR: 2012/2
INFO SOURCE: report of eruption
AVIATION COLOUR CODE: NIL
ERUPTION DETAILS: eruption of volcano

RMK:
NXT ADVISORY: NO LATER THAN 20120803/0900Z

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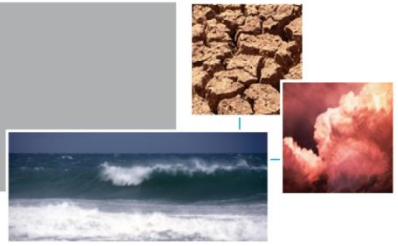
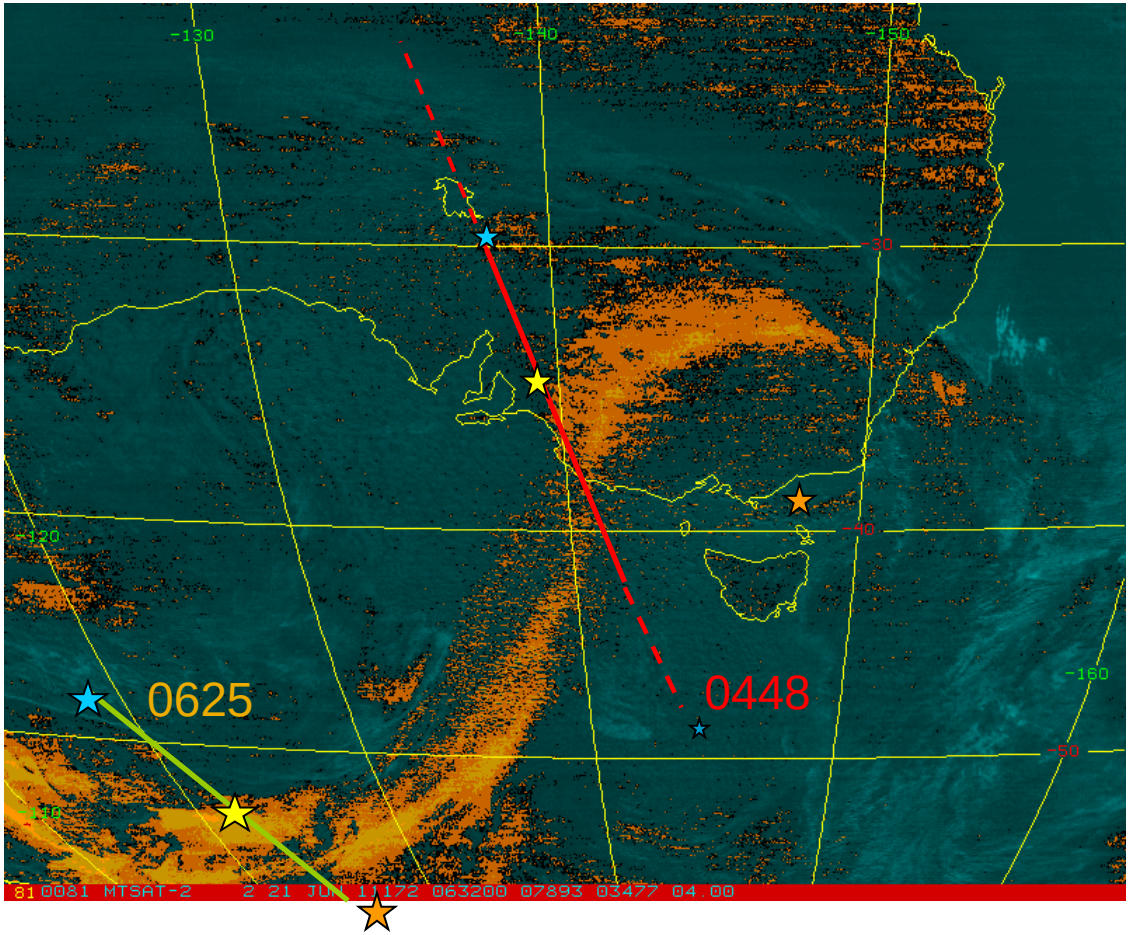
Improved Volcanic Ash Detection and Prediction

- Eyjafjallajökull Mar 2010; Merapi Nov 2010; Cordon-Caulle Jun 2011

- Improve satellite remote sensing
  - Improve ash detection - plume height, mass loading – GEOCAT
  - Better quantify uncertainties
  - HIMAWARI-8 – Japanese geostationary satellite – operational 2015
- Dispersion modelling
  - Better quantify sensitivities and uncertainties – what is "truth"
  - Source term parameters – plume height, particle size distribution, MER
  - Initiation with distal ash cloud
  - Inverse modelling – more effective use of satellite data and dispersion model
  - Ensemble forecasts – probabilistic forecasts – AGREPS
  - Model intercomparisons – HYSPSLIT / UKMO NAME
  - Improved microphysics
- VAWS application – improve functionality, replacement system
- Operationalization
- 'Best Practice' Workshops

Cordon-Caulle eruption 4 Jun 2011





MTSAT-2

11-12 μm brightness temp difference

0632 UTC, 21 Jun 2011

Also shown are ‘close’ CALIPSO overpasses

0448 UTC and 0625 UTC

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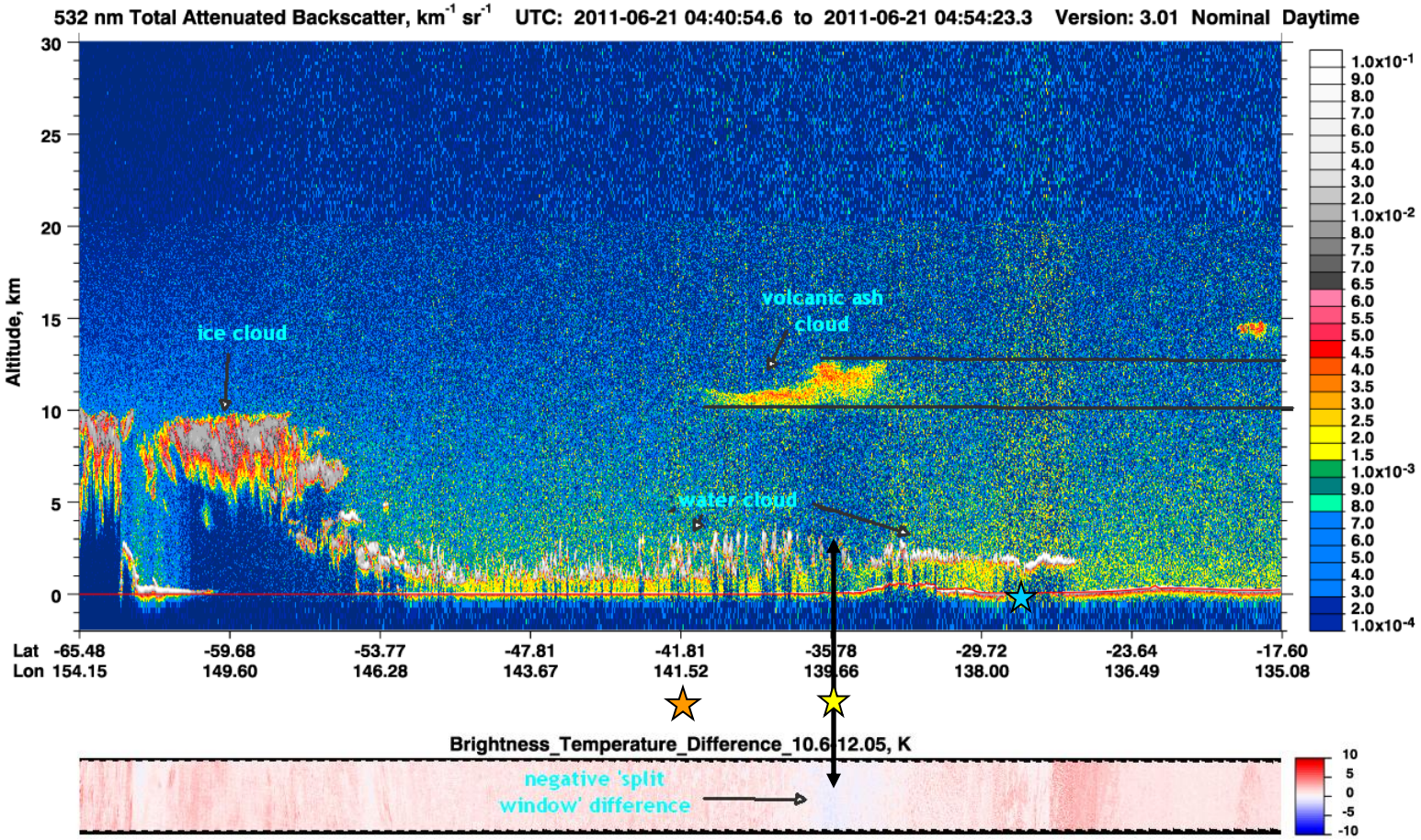
Cordon-Caulle eruption 4 Jun 2011



0448 UTC CALIPSO overpass

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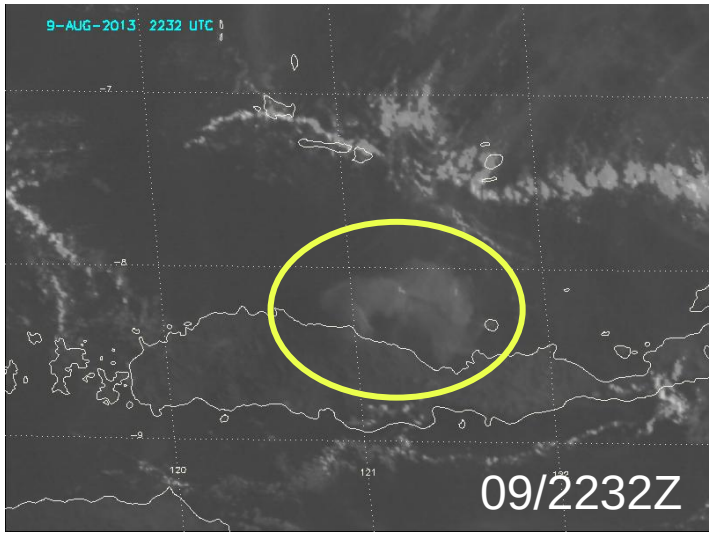
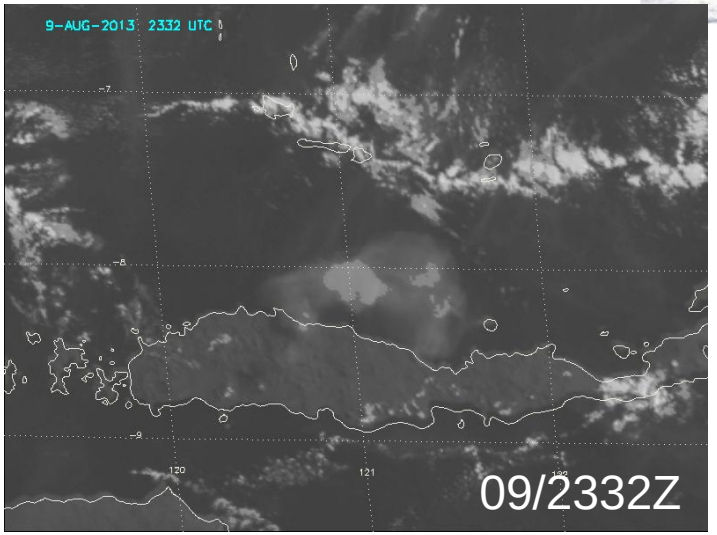
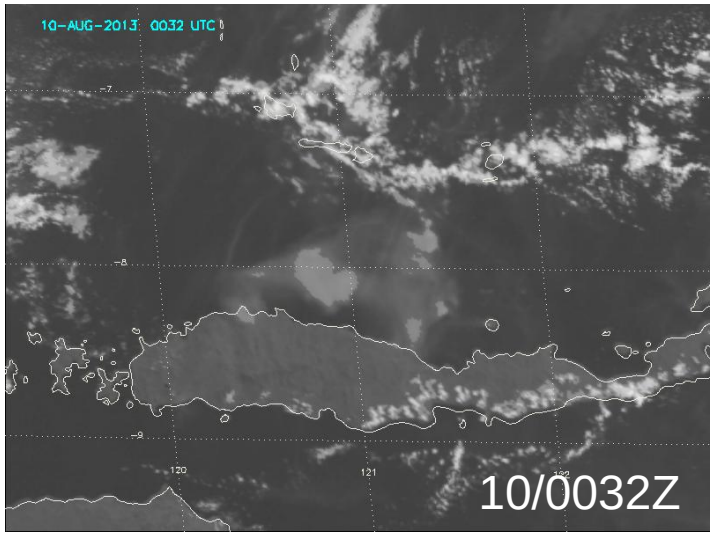
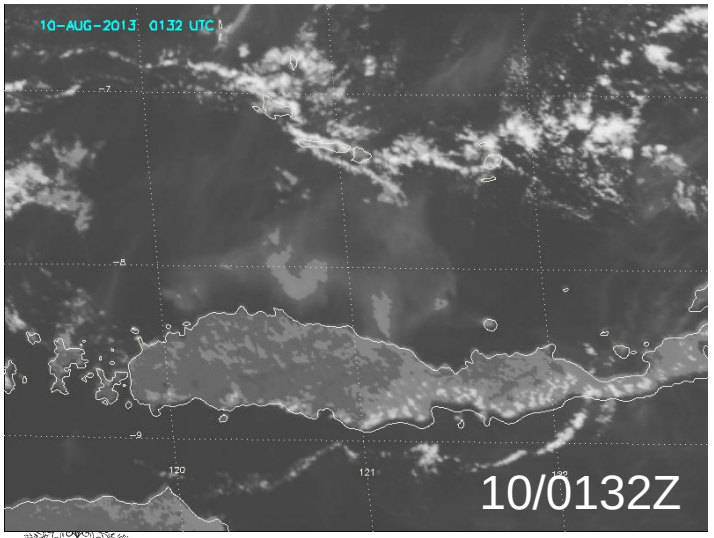
Paluweh Eruption 2027 UTC, 9 August 2013





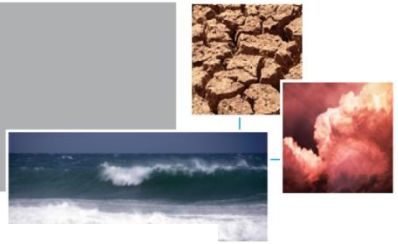




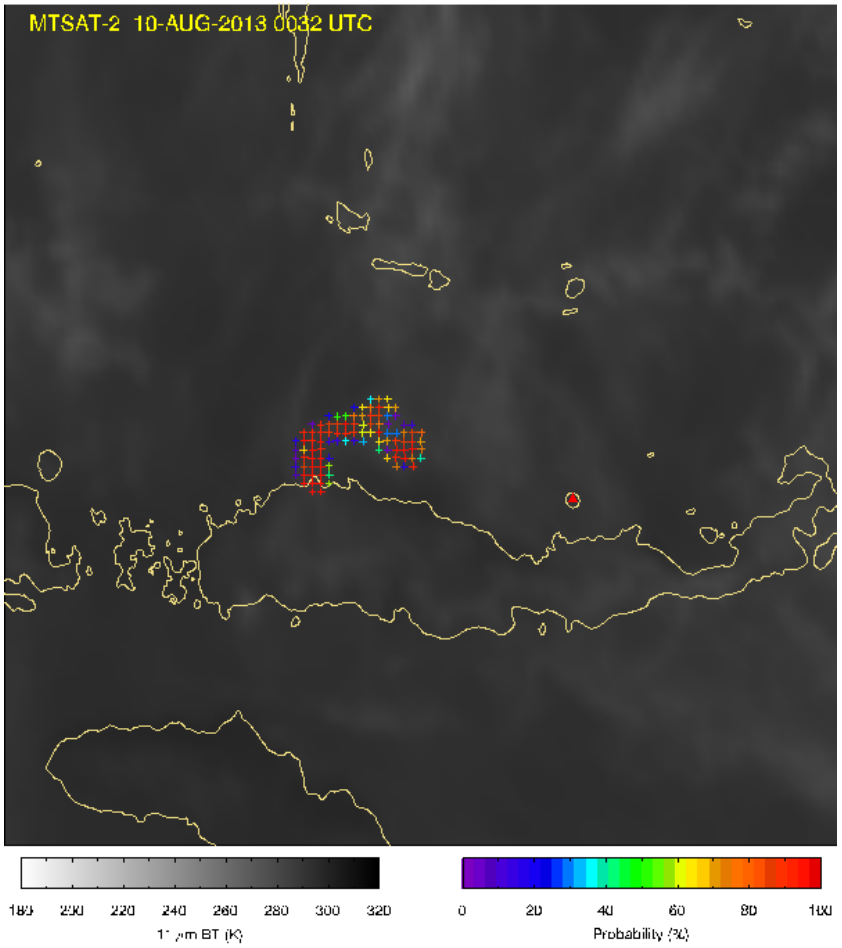
MTSAT-2 visible imagery

CSIRO

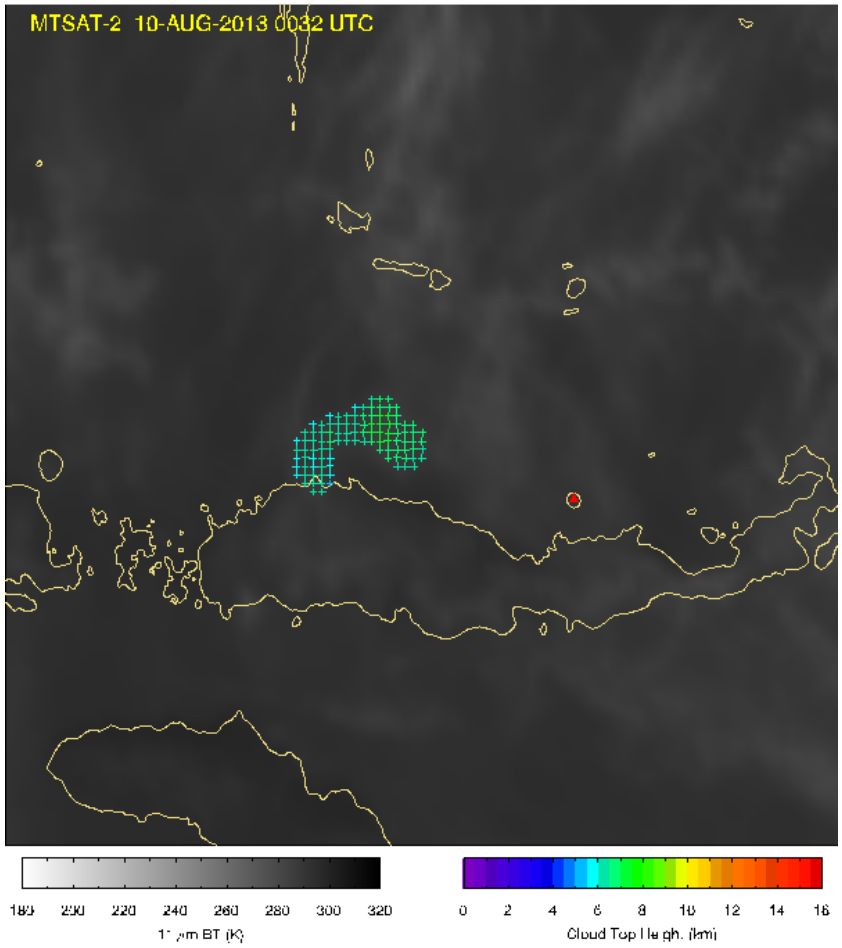
Paluweh Eruption 2027 UTC, 9 August 2013



IR Imagery and Ash Probability



IR Imagery and Ash Cloud Top Height



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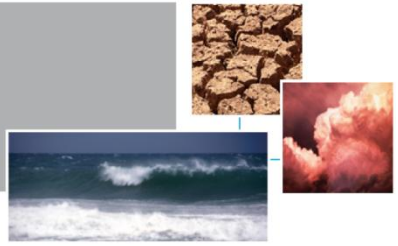
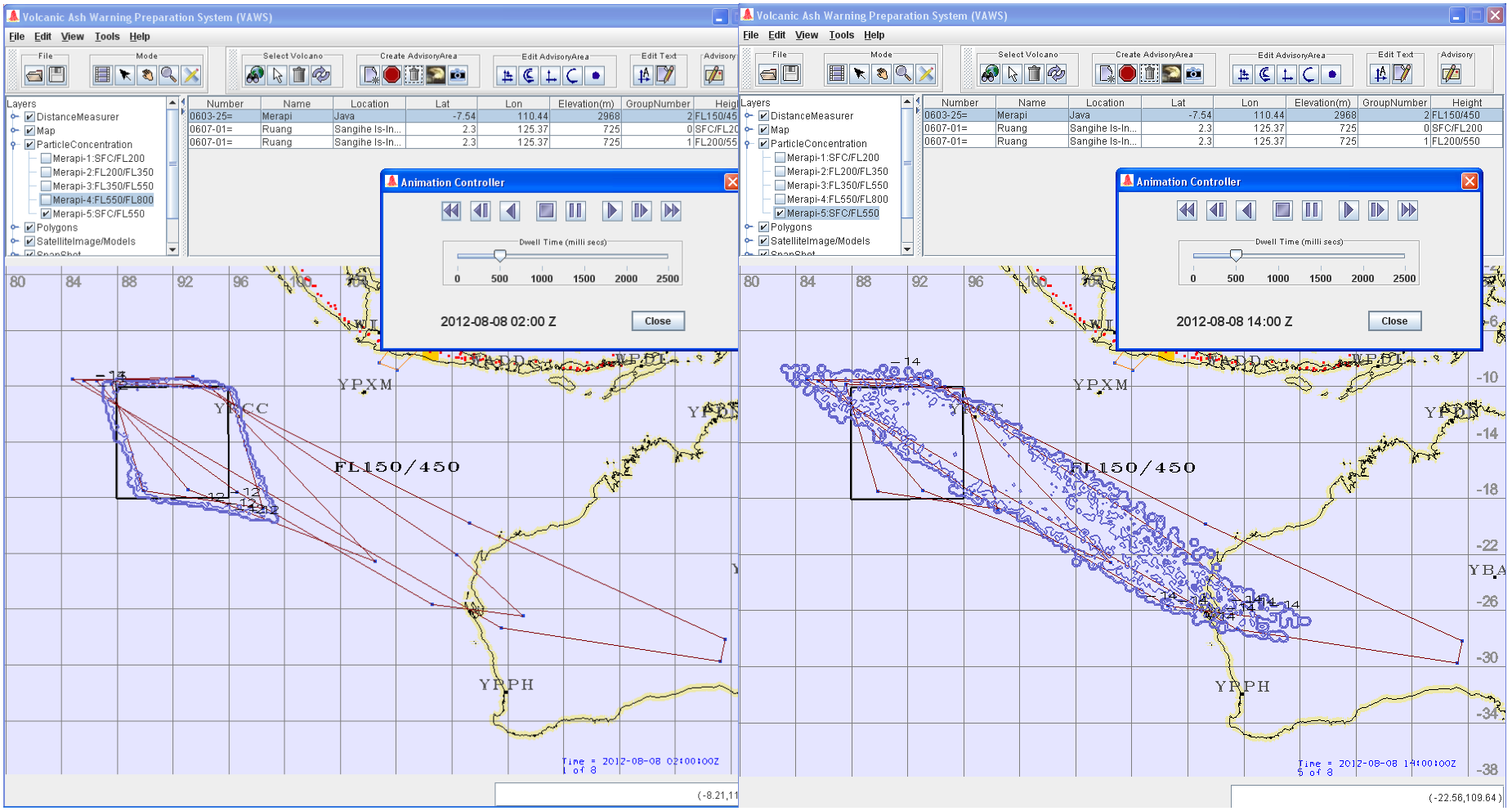
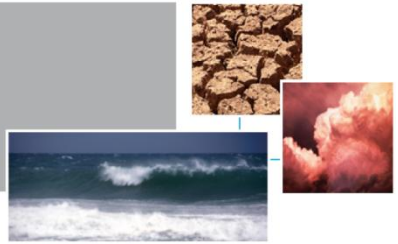
Initiation of HYSPLIT with distal ash cloud





Initiation of HYSPLIT with distal ash cloud



VA ADVISORY
DTG: 20120808/0255Z
VAAC: Darwin

VOLCANO: Merapi 0603-25=
PSN: S0732 E11026
AREA: Java
SUMMIT ELEV: 2968M

ADVISORY NR: 2012/3
INFO SOURCE: report
AVIATION COLOUR CODE: NIL
ERUPTION DETAILS: eruption

OBS VA DTG: 08/0245Z
OBS VA CLD:
FL150/450 S0950 E08735 - S1010 E09600 - S1845 E09825 - S1730 E08950 - S0950 E08735

FCST VA CLD +6HR: 08/0845Z
FL150/450 S0935 E08630 - S1000 E09440 - S2235 E10630 - S1725 E09305 - S0935 E08630
FCST VA CLD +12HR: 08/1445Z
FL150/450 S0935 E08535 - S0920 E09325 - S2205 E11220 - S2630 E11705 - S2540 E11035 - S1735 E09635 - S0935 E08535
FCST VA CLD +18HR: 08/2045Z
FL150/450 S0930 E08445 - S0930 E09245 - S1950 E11315 - S2810 E13135 - S2945 E13115 - S2720 E11530 - S0930 E08445

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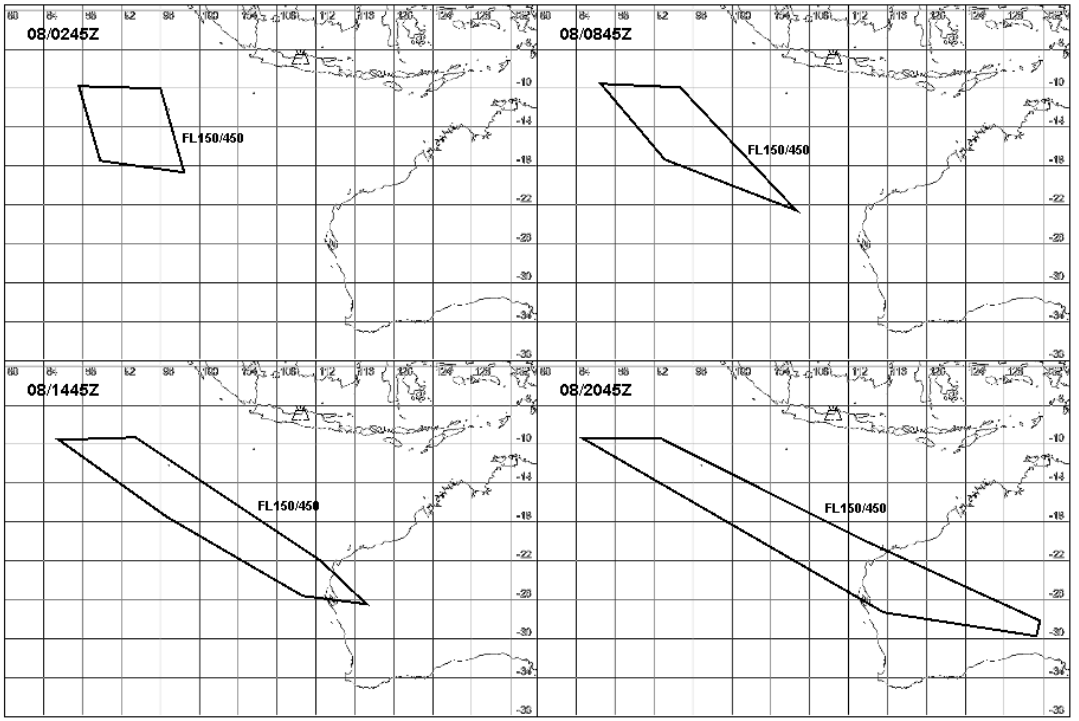
http://www.bom.gov.au/info/vaac/advisories.shtml
NXT ADVISORY: NO LATER THAN 20120808/0845Z



VOLCANIC ASH ADVISORY
DTG: 20120808/0255Z
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VOLCANO: Merapi 0603-25=
AREA: Java

SUMMIT ELEV: 2968M
ADVISORY NR: 2012/3
INFO SOURCE: report
AVIATION COLOUR CODE: NIL
ERUPTION DETAILS: eruption

RMK:
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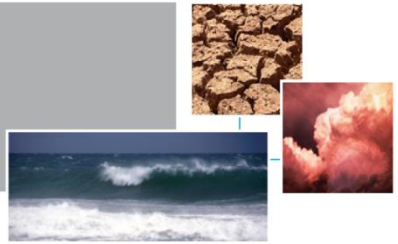
Inverse modelling



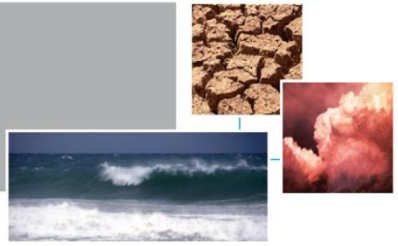
- Use of satellite data to optimise current model
- Minimise function $f(\lambda_1, \lambda_2, \lambda_3 .. \lambda_n) = 1 - r(\lambda_1, \lambda_2, \lambda_3 .. \lambda_n)$

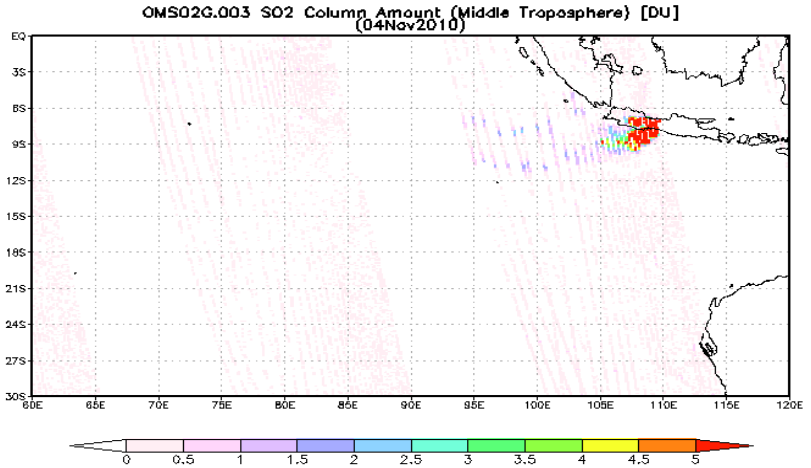
[*r* is pattern correlation between observation (X) and simulation (Y). λ represents HYSPLIT model parameters.]

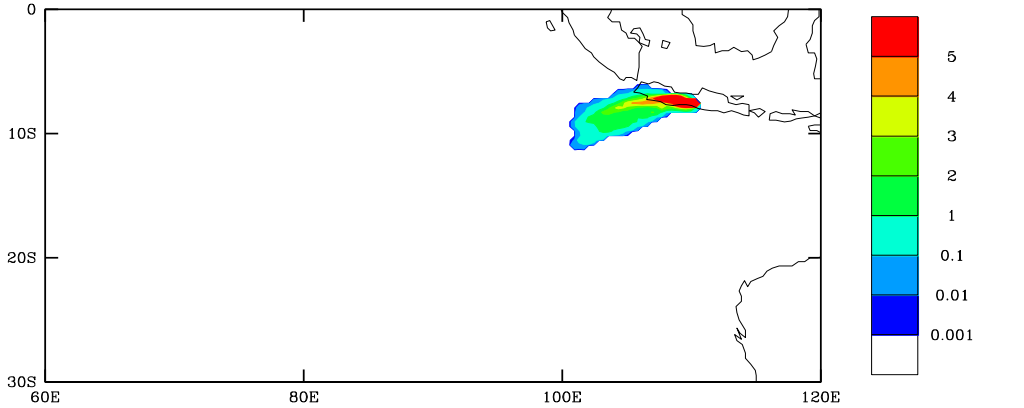
- Merapi Nov 2010 event - OMI sulphur dioxide data
- One-dimensional version of inverse model with source height as the variable (other model parameters are specified)

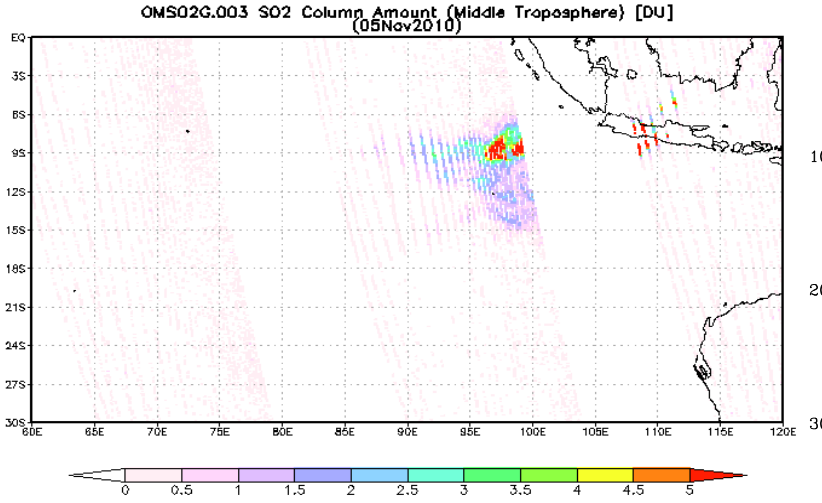
	Nov 4	Nov 5	Nov 6	Nov 7	Nov 8
height (km)	13.106	13.915	12.826	12.693	12.780
r	0.82	0.69	0.63	0.41	0.43

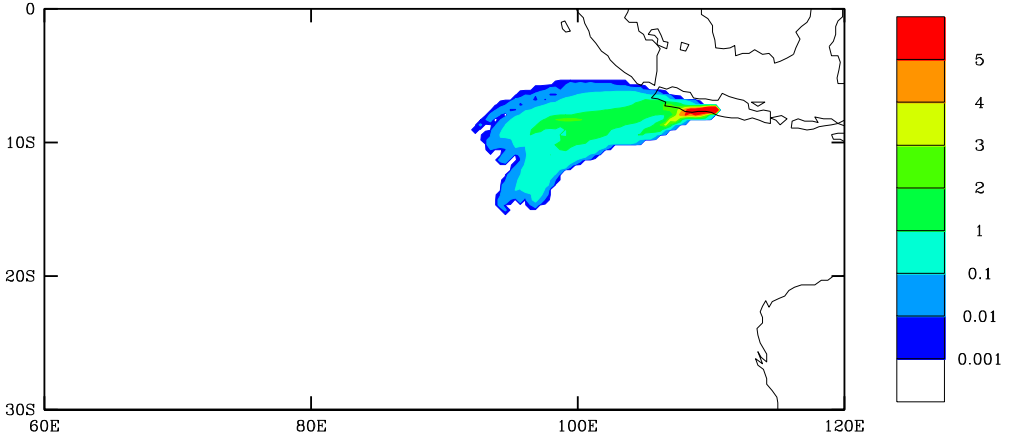
Point source model











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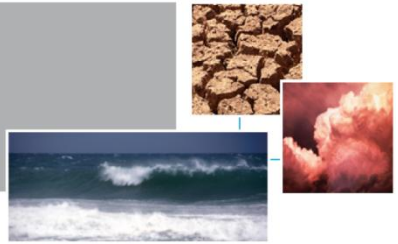
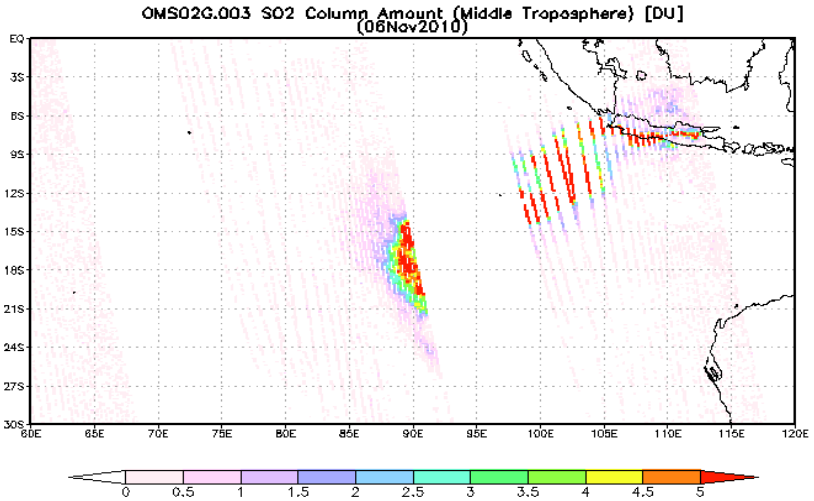
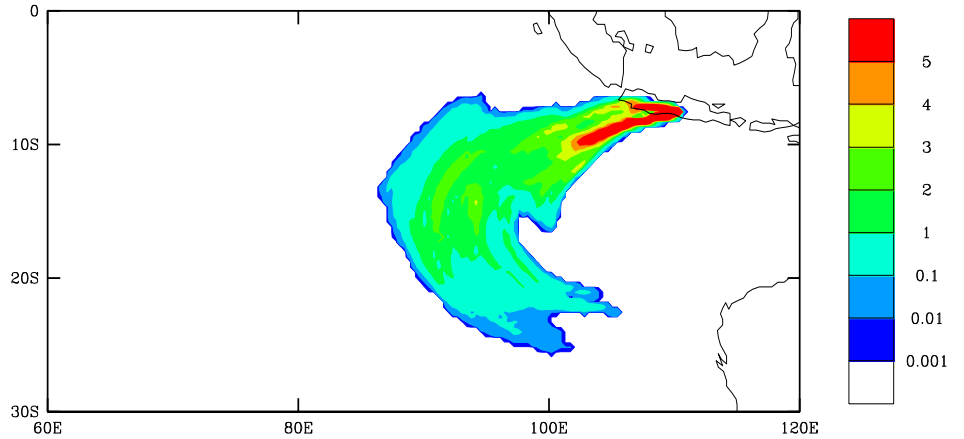
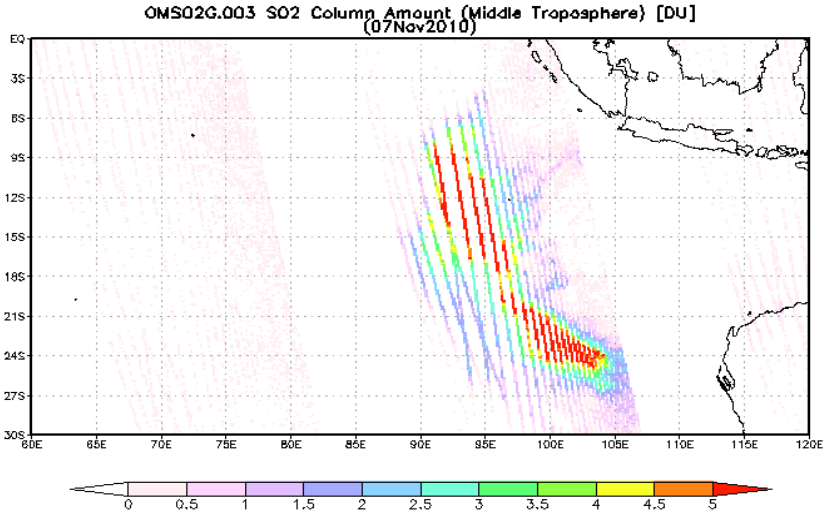
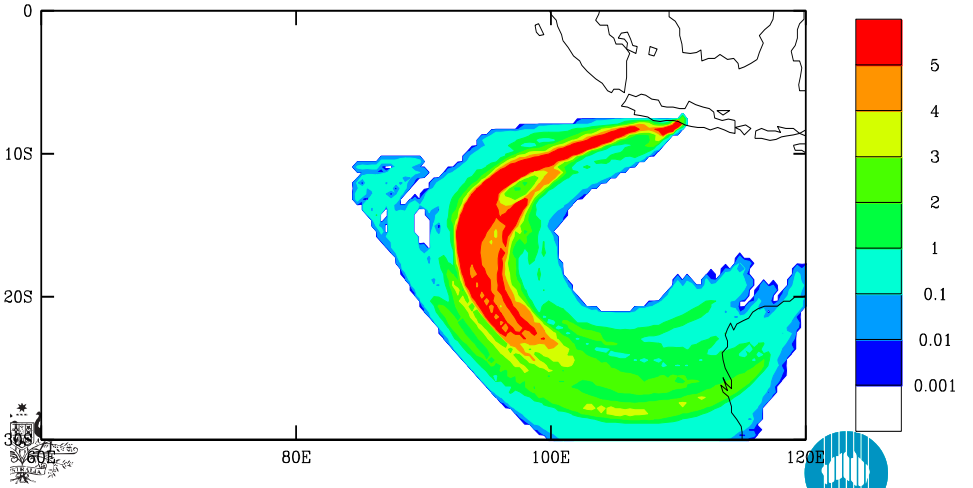
Point source model











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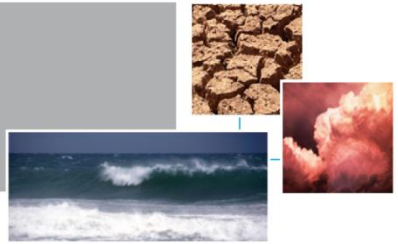
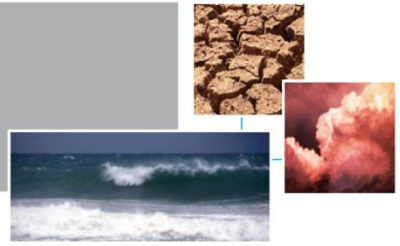
Next steps



- Welcome collaboration with others working on volcanic ash
- More evaluation of satellite data processing algorithms
  - Uncertainties in detection and retrieved parameters
- Better physical representation of ash in dispersion model
  - Uncertainties in meteorology, source term and physical processes
  - Probabilistic forecasts
- Need for integrated use of satellite and model data
- Translate research outcomes to operations
  - Product development



The End