Assessing the Potential to Observe Volcanic Ash Clouds from Space by

Combining Volcanic Plume Simulations with Microwave Radiometric Remote Sensing Data

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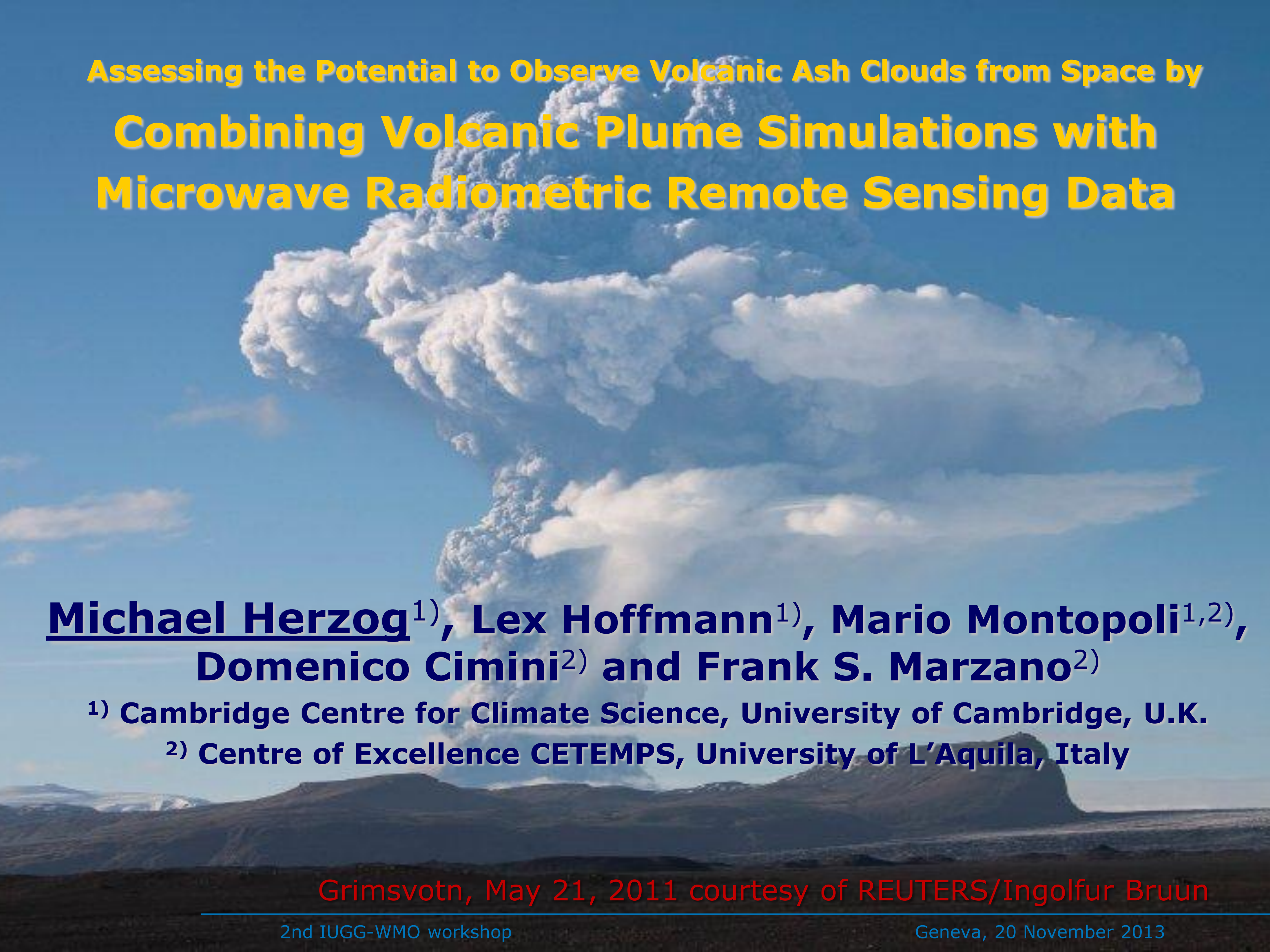


Grimsvotn, May 21, 2011 courtesy of REUTERS/Ingolfur Bruun

Motivation:
The volcanic plume problem

- **no direct (in-situ) observations**
- **indirect measurements:**
  - ground, aircraft, satellite based remote sensing
    - passive radiometers
    - active systems like radar and lidar
  - deposited tephra on ground

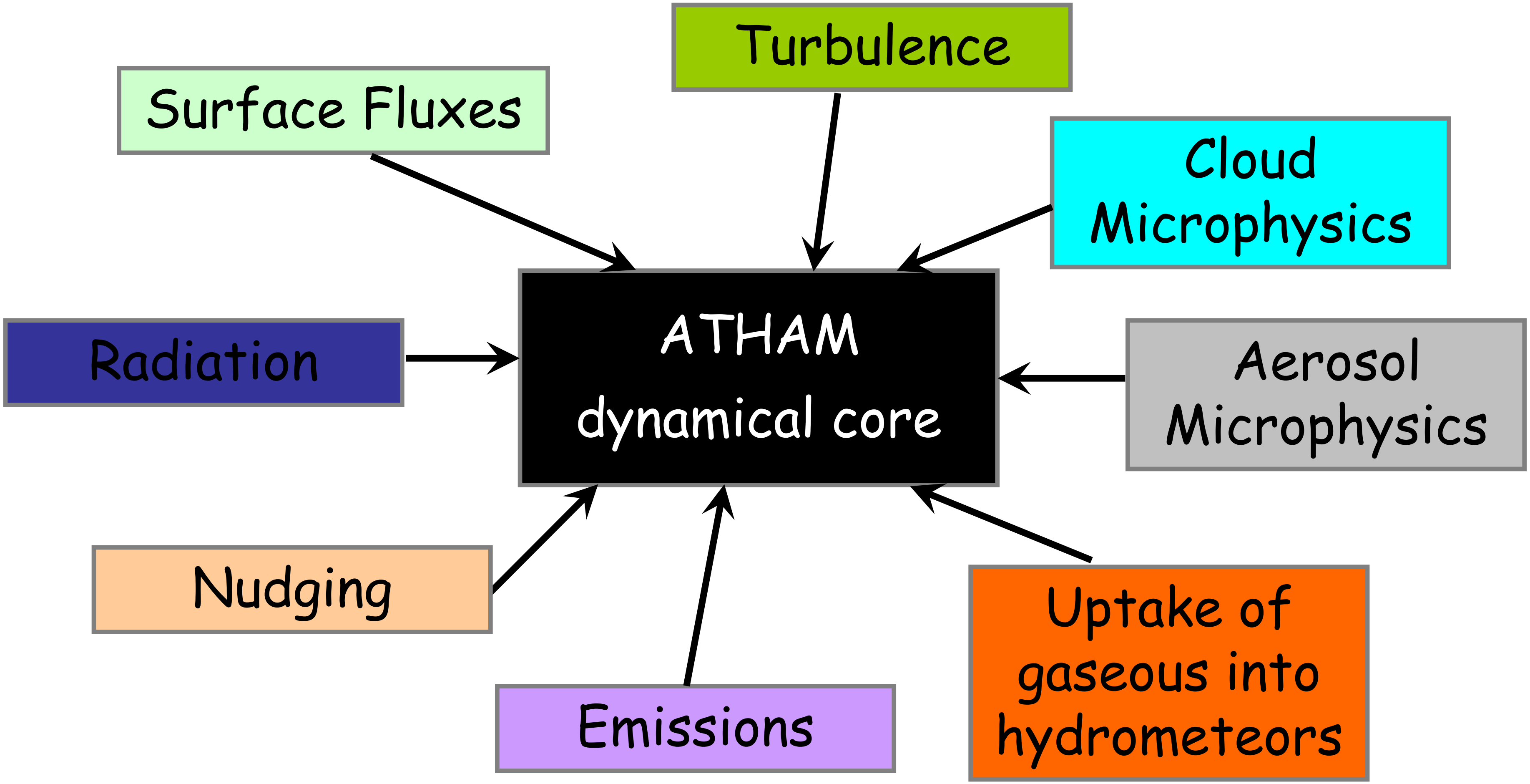
measurements subject to interpretation

complexity makes interpretation difficult

numerical modelling can help

ATHAM

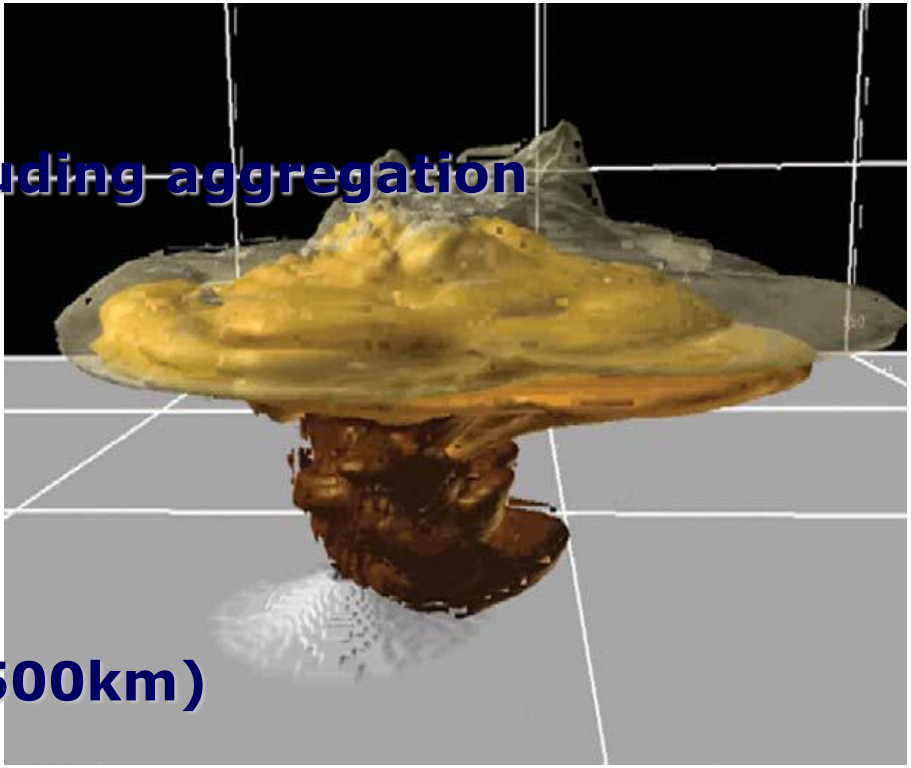
Active Tracer High Resolution Atmospheric Model



ATHAM in a nutshell

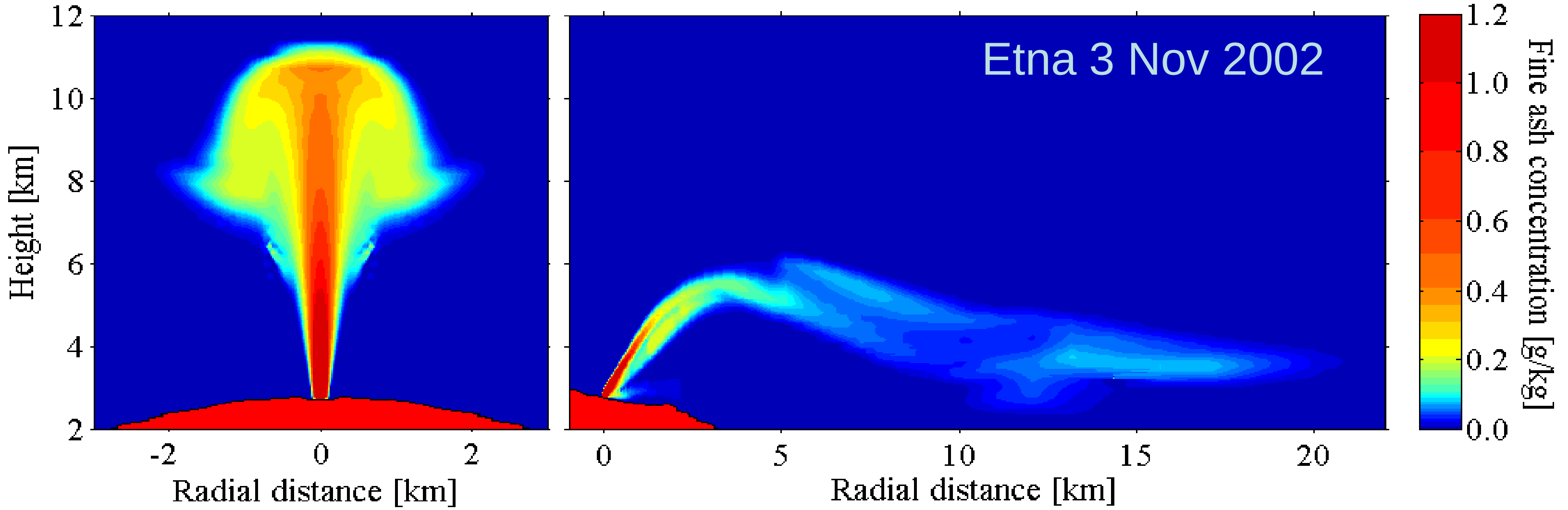
Oberhuber et al. (1998), Herzog et al. (2003)

- **What it is:**
  - non-hydrostatic atmospheric circulation model for particle laden atmosphere
- **What it can do:**
  - internal plume dynamics
  - plume microphysics including aggregation
  - plume chemistry
  - process studies
  - case studies
- **What it can't do:**
  - forecast tool
  - long range transport (>500km)



ATHAM features

- **Active tracer concept**
  - multicomponent system in 3d with arbitrary number of compressible and incompressible tracers of arbitrary concentration
  - active tracers
    - impacts dynamics (e.g. buoyancy) and thermodynamics (e.g. heat content)
    - coupled assuming dynamic and thermodynamic equilibrium
    - one set of dynamic equations for mixture



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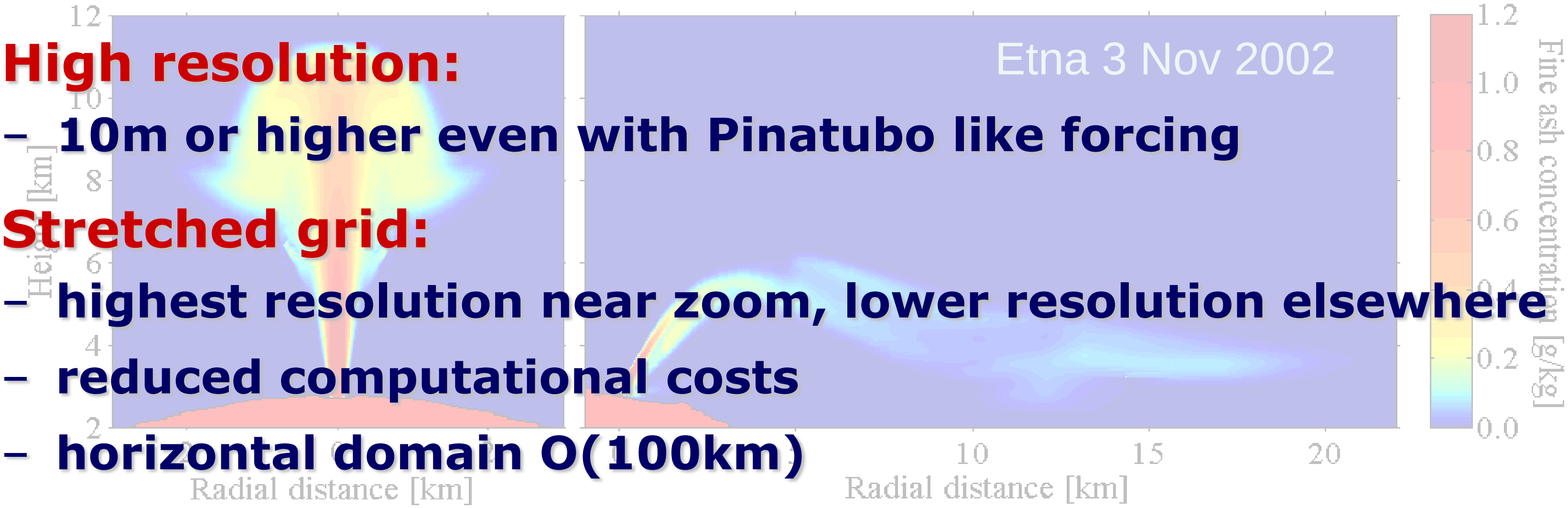
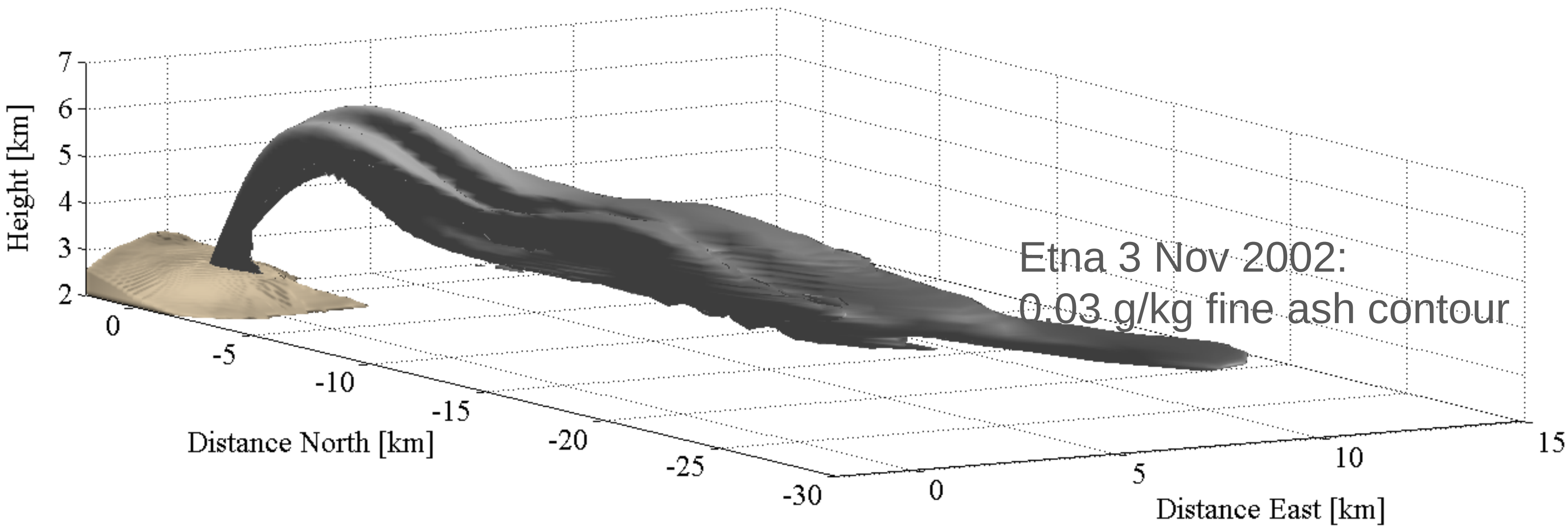
- **High resolution:**
  - 10m or higher even with Pinatubo like forcing
- **Stretched grid:**
  - highest resolution near zoom, lower resolution elsewhere
  - reduced computational costs
  - horizontal domain O(100km)



ATHAM improvements

- **improved numerics**
  - **updated advection scheme**
  - **improved consistency in treatment of momentum, heat and tracer**
  - **improved boundary conditions**



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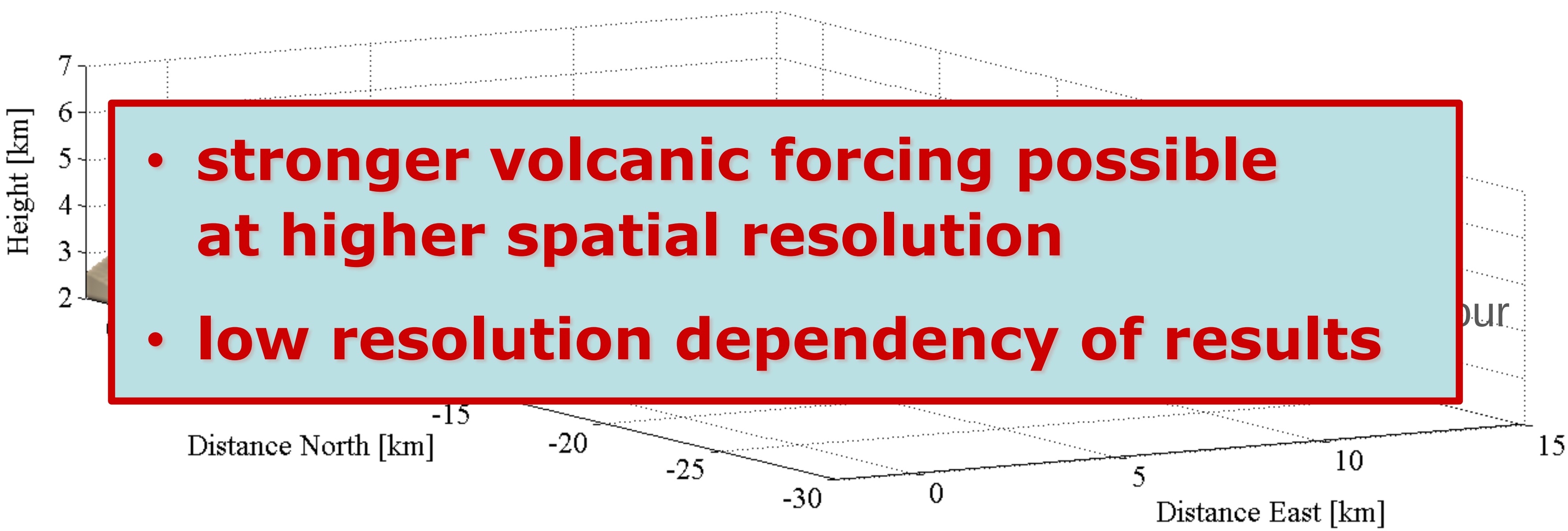
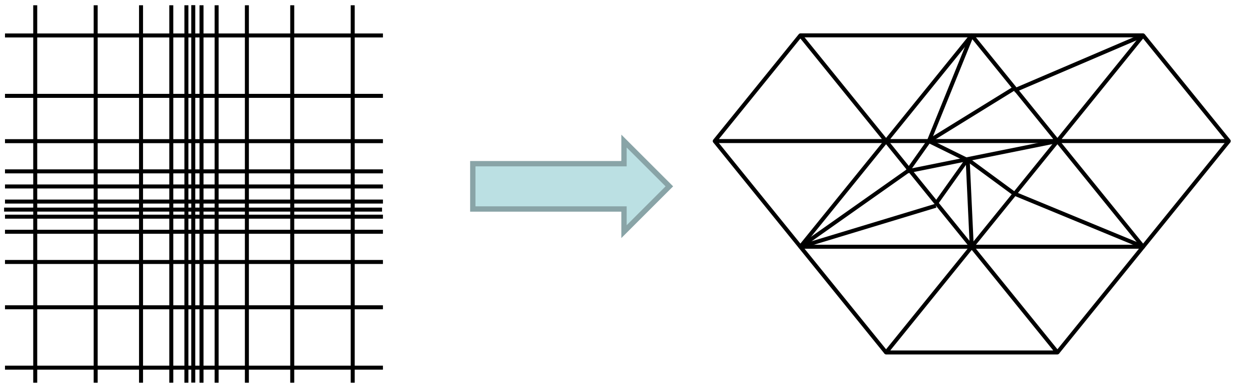


- stronger volcanic forcing possible
  at higher spatial resolution
- low resolution dependency of results

ATHAM developments

- **ATHAM-Fluidity:**
  - collaboration with Imperial College, London
  - new dynamical core
    - unstructured grid with adaptive grid capability
    - improved conservation properties
    - massive parallel computing environments
  - prototype available
  - new ERC funding for 4 years for work on extreme precipitation events in coastal areas



Combining Plume Simulation and Remote Sensing

- **ATHAM-COSP**
  - **CFMIP Observation Simulator Package**
    http://cfmip.metoffice.com/COSP.html
  - **Cloud Feedback Model Intercomparison Project**
  - **potentially useful for near vent plume and thin ash layers**
- **ATHAM-SDSU**
  - **Satellite Data Simulator Unit**
    (Masunaga et al., 2010)
  - **useful for dense, near-source plume**

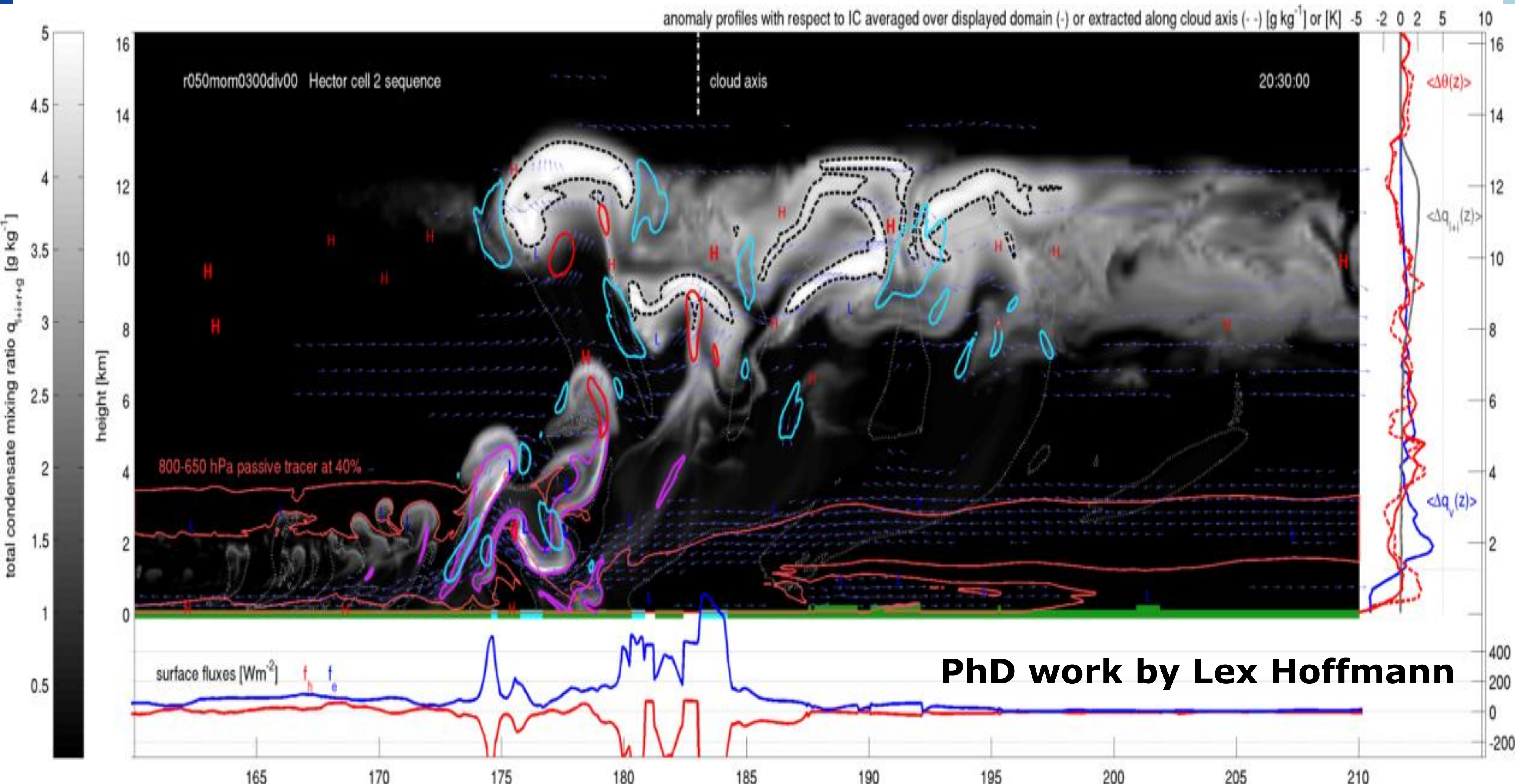
COSP Simulator

- **facilitates exploitation of A-train data in numerical models**
  - compare models with observations
  - compare models with models
  - focus on cloud properties, however, aerosol component straightforward
- **included satellites:**
  - ISCCP, MISR, MODIS, CloudSat, Calipso
  - same instruments also used for ash detection
- **uses model output to produce cloud quantities available from satellite observations**
- **radiative transfer code available for brightness temperatures of passive microwave sensors**

Grimsvötn 22 May 2011, MODIS

Simulated Hector Cloud:

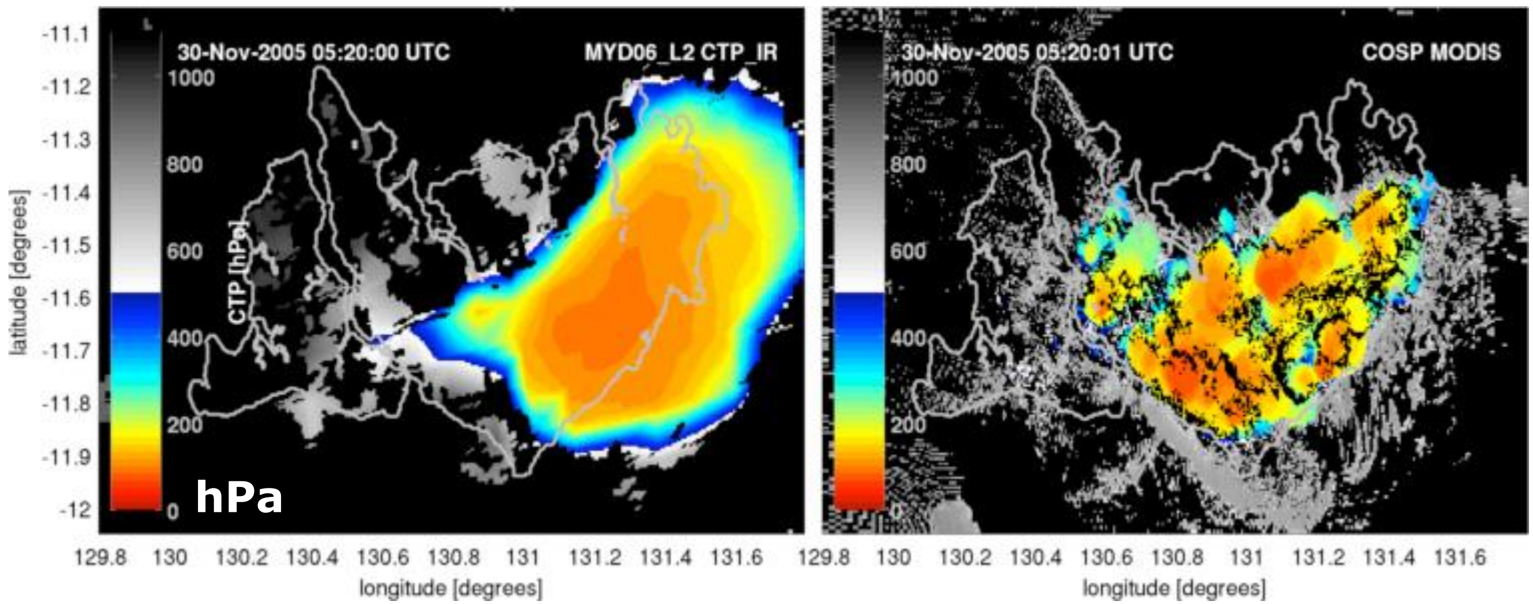
2d Atham, 50m horizontal resolution snapshot of cloud at 20:30 LT



PhD work by Lex Hoffmann

Cloud Top Pressure from MODIS

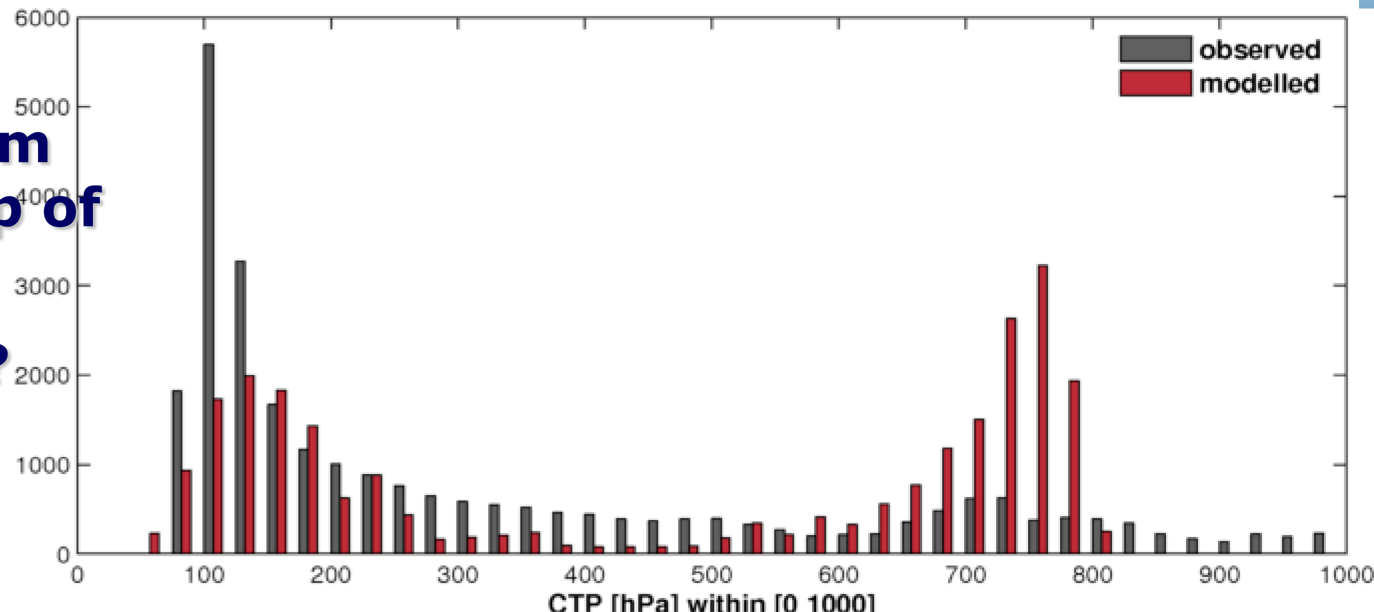
MODIS



ATHAM

cloud top spectrum could describe top of volcanic plume

but does it mean?



ATHAM-SDSU: Grimsvötn Eruption, 22 May 2011

Montopoli et al. (2013)

Special Sensor Microwave Sounder aboard DMSP, US Air Force

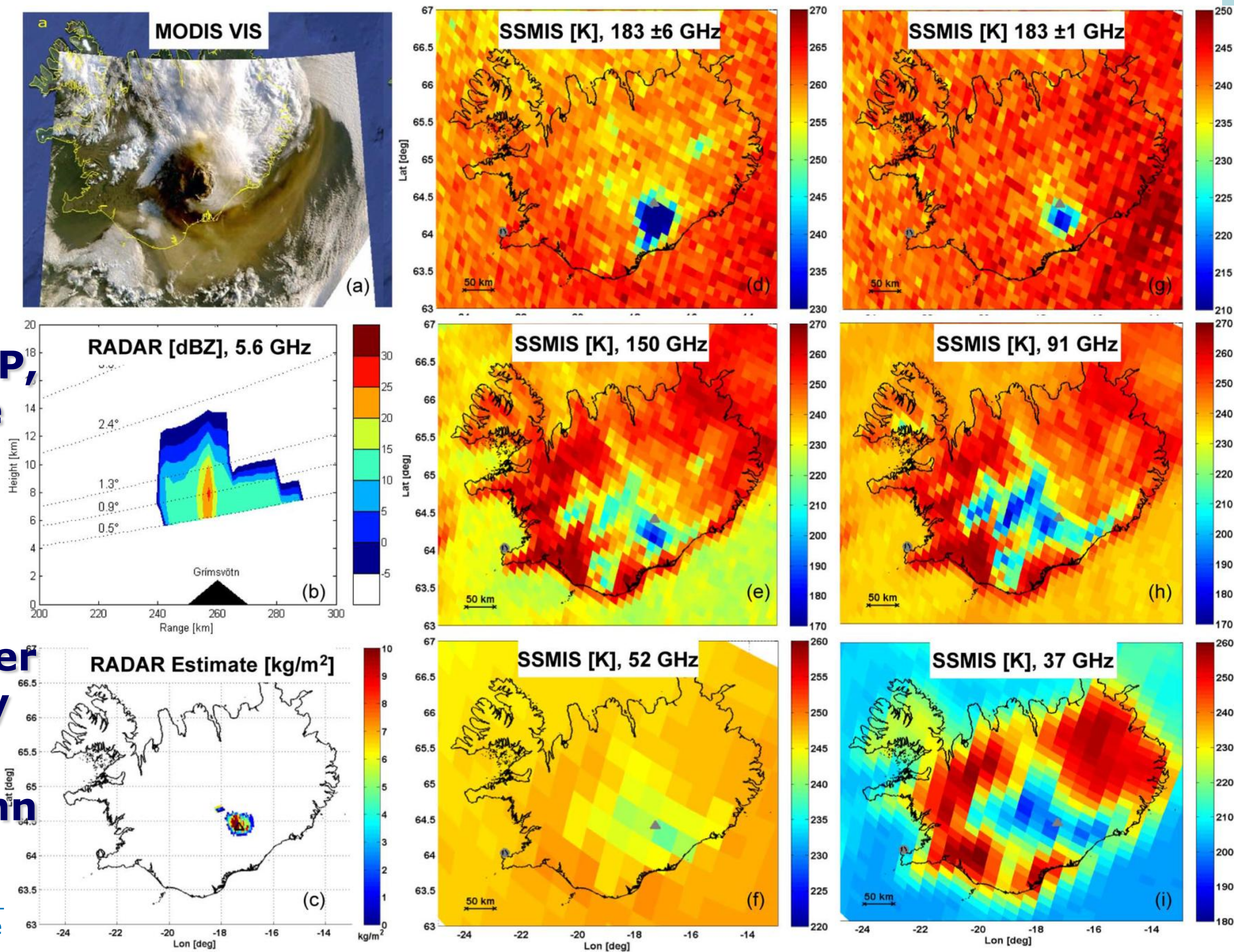
Low-Earth-orbit

μ-wave:

doesn't suffer from opacity

sensitive to whole column

Brightness Temperature [K]

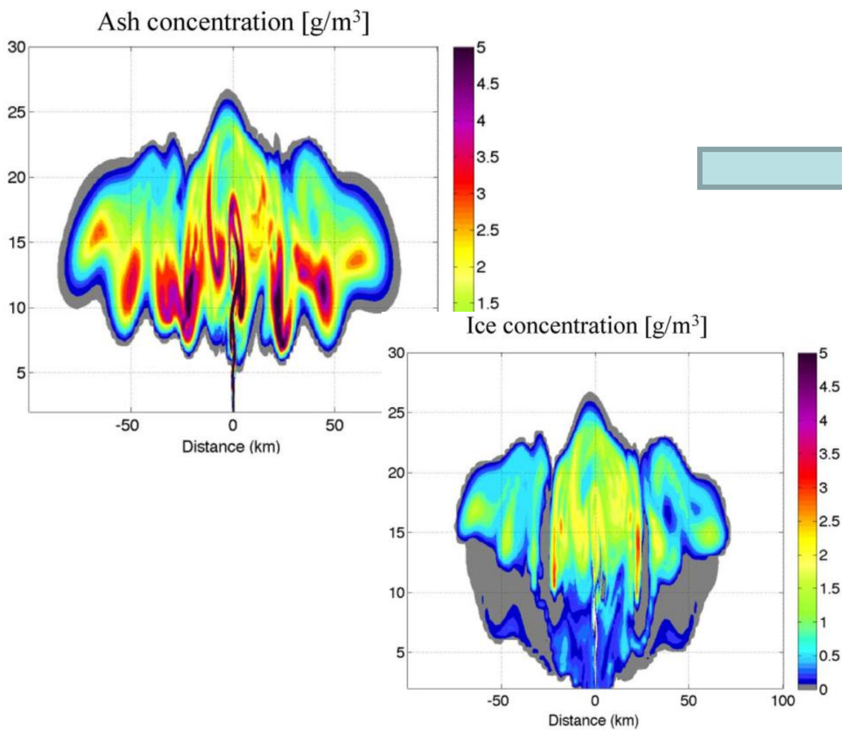


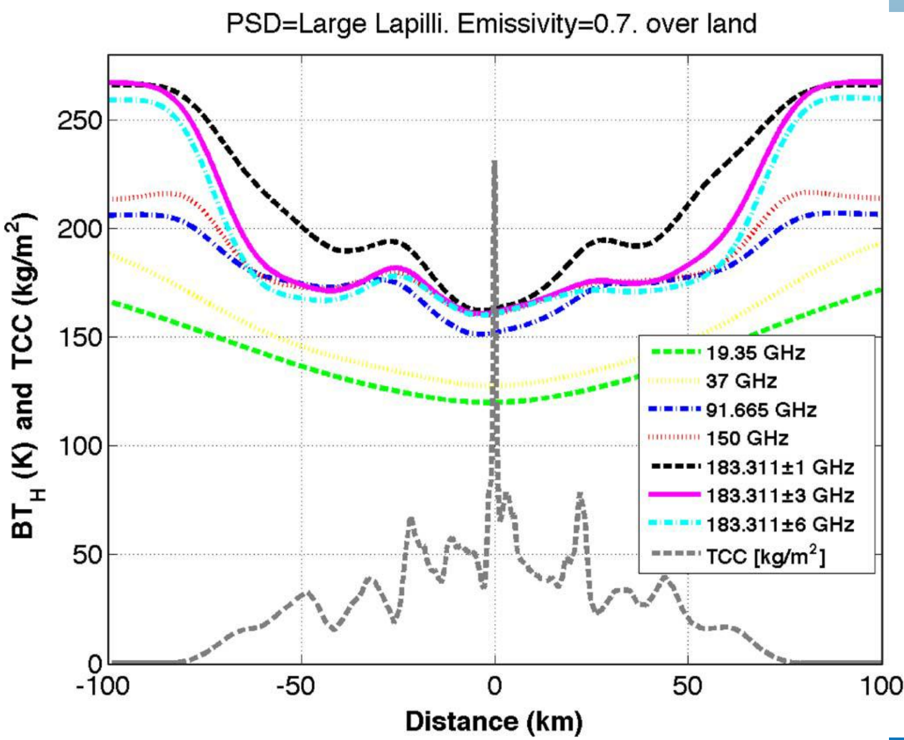
Michael He

Interpretation of Microwave Remote Sensing

Montopoli et al. (2013)

Use ATHAM and modified SDSU radiative transfer code to derive relationship between total column concentration and brightness temperature at different frequencies and for given size distribution





Summary

- **ATHAM is powerful tool
to study volcanic plumes in detail**
- **Combined with remote sensing data ATHAM can help with interpretation of observations**
- **COSP can help if extended to ash clouds**
- **microwave data allow for estimates of
total ash column concentrations**
  - **apriori knowledge of
size distribution and hydrometeor content**
  - **assumption hydrometeor ash interaction**
  - **influence of particle aggregation**