# The Active Tracer High Resolution Atmospheric Model ATHAM: Model concepts and examples

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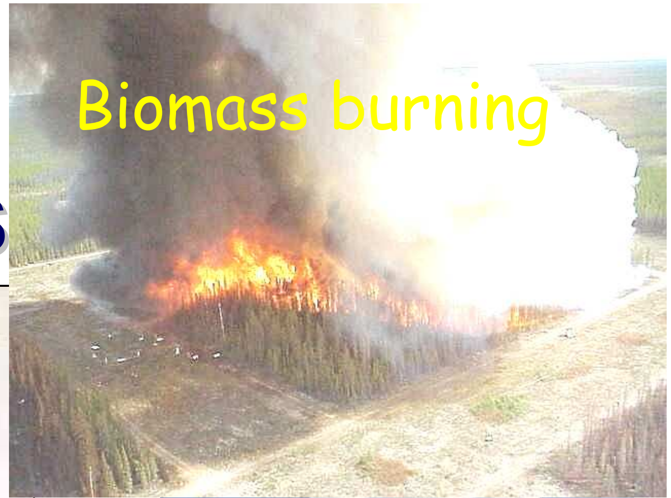
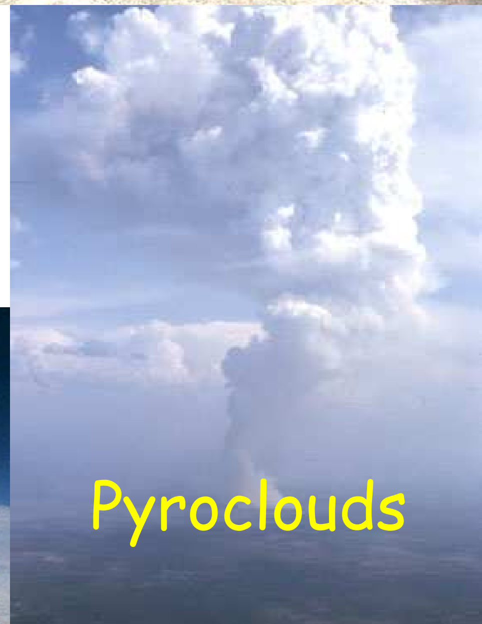
# ATHAM in a nutshell

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

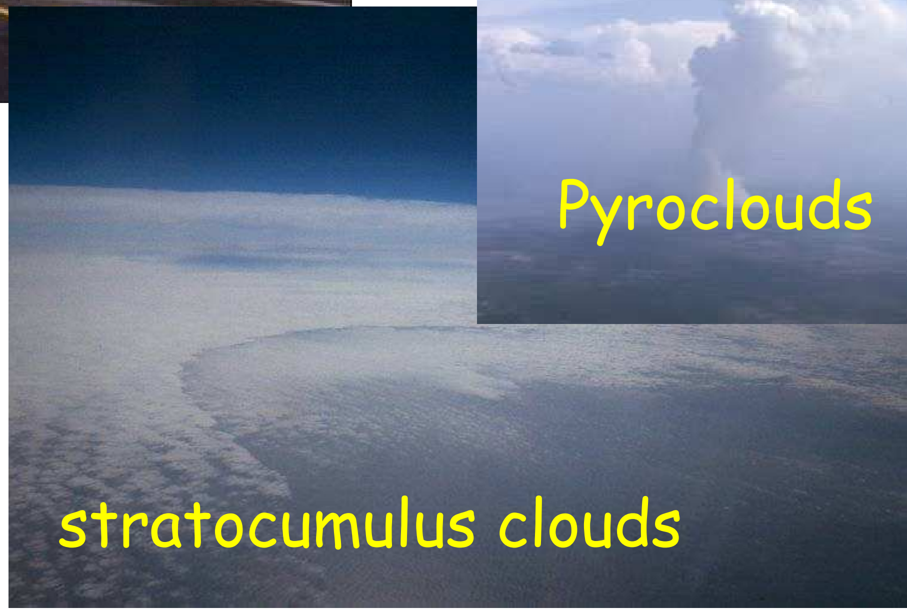
# ATHAM - Applications





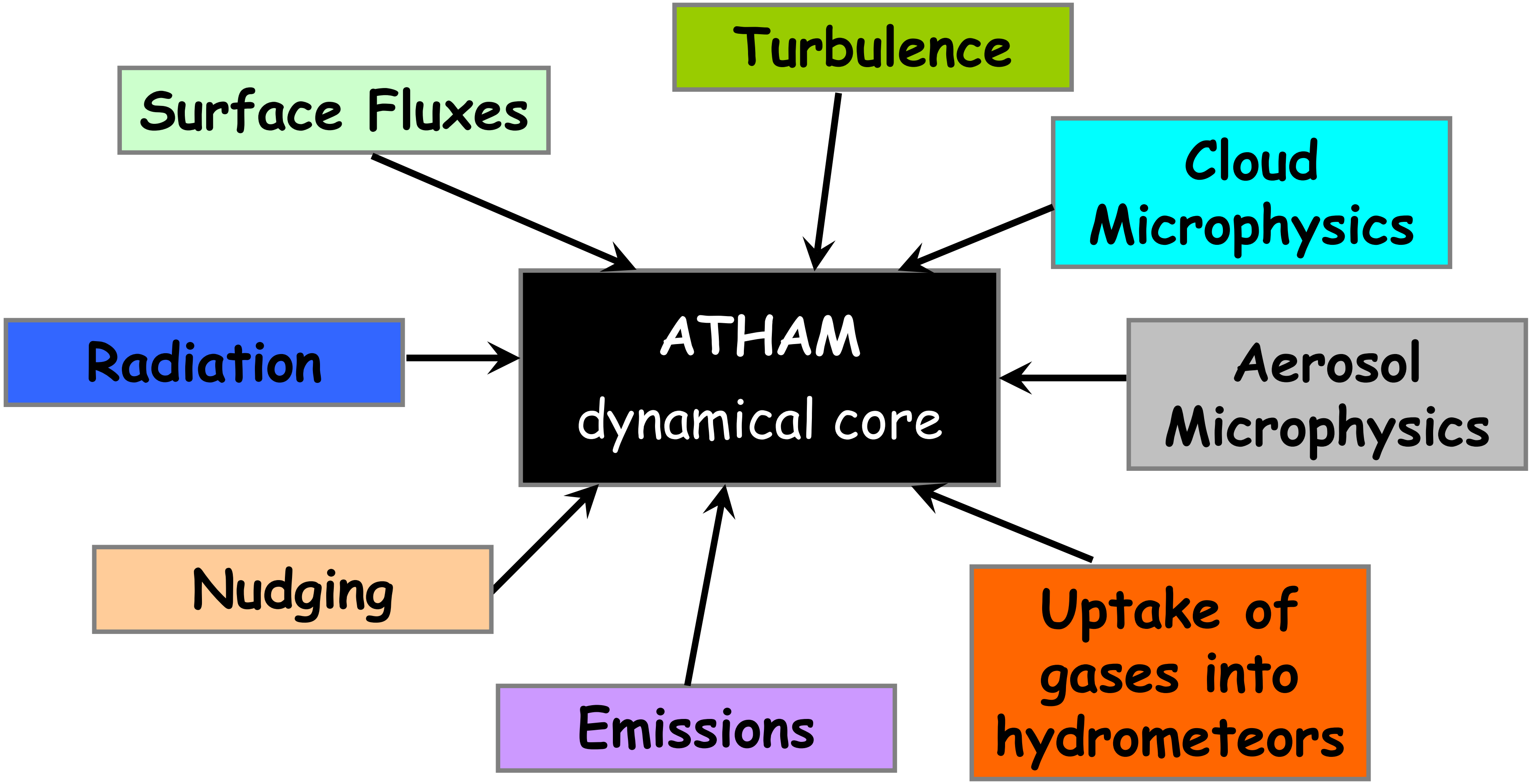



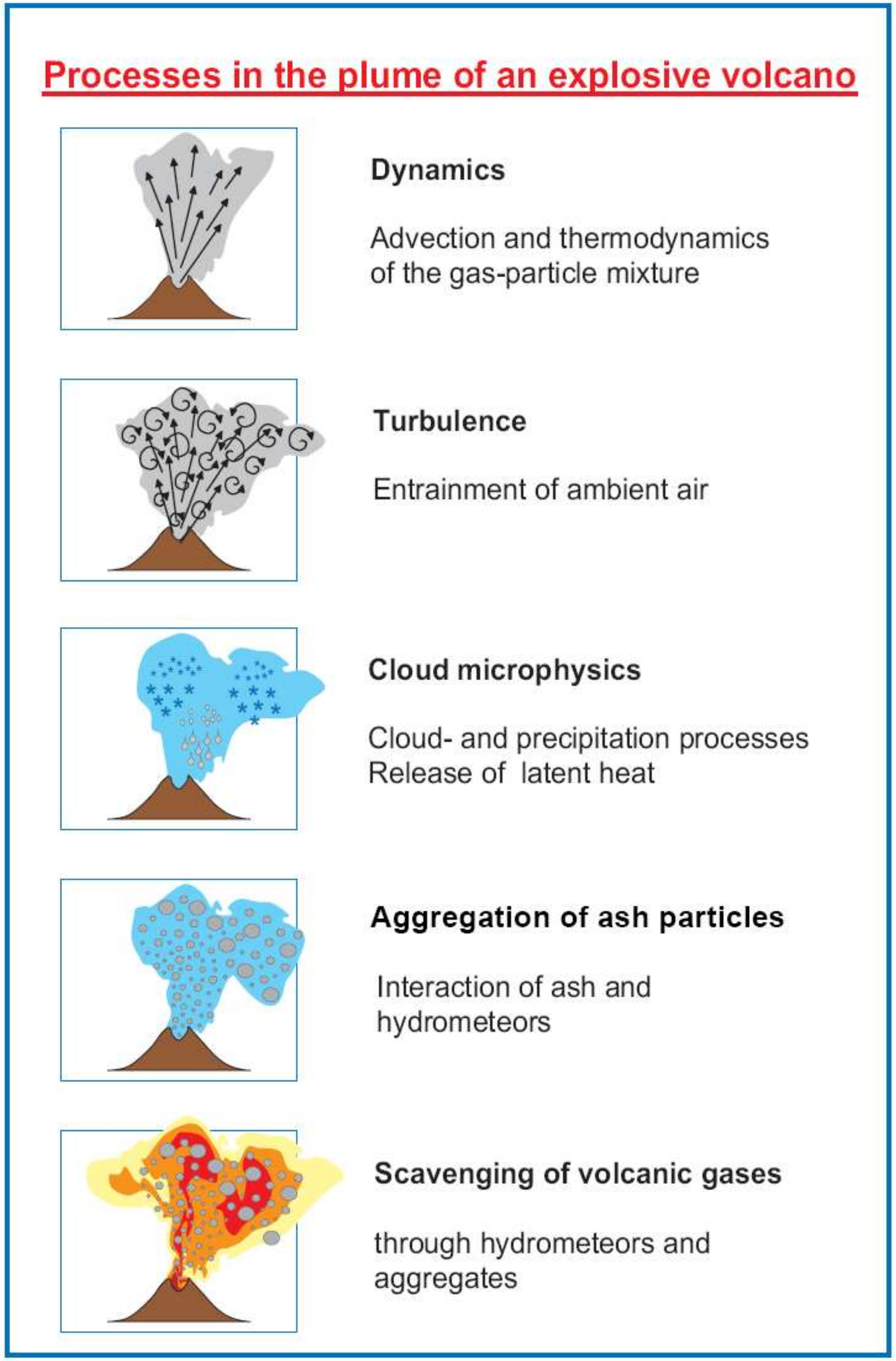




# ATHAM

## Active Tracer High Resolution Atmospheric Model






# ATHAM and Volcanic Plumes

- **forced by conditions at column base:**
  - temperature 800-1000 K
  - particle fraction 90-95 % by weight
  - gas fraction 5-10% by weight
  - vertical velocity 200-400 m/s
  - radius of column base 150-200 m
  - density of mixture 2-5 kg/m$^3$
  - mass eruption rate 10$^8$-10$^9$ kg/s
- **no overpressure at column base:**
  - decompression phase and vent processes not captured
- **no particle-particle interaction:**
  - no description of granular flows
- **active tracers impact bulk density and heat capacity**

The non-hydrostatic model ATHAM is formulated in three dimensions. In addition, two different two-dimensional versions are implemented: one in Cartesian and one in cylindrical coordinates. An implicit time stepping scheme is used, the conservation of mass and momentum is explicitly guaranteed by applying the flux form for the equations of motion and continuity of the tracers.

The initialisation of ATHAM is done by prescribing vertical profiles for horizontal wind, temperature, relative humidity and gaseous species in the background atmosphere. An arbitrary orography, e.g., shape and height of a volcano, can be defined at the lower boundary. The input of material at the source is specified by defining additional vertical velocities, temperature and composition of the ejecta at at least three active grid points.

- ***Dynamic equilibrium:***

we assume instantaneous exchange of momentum between particles and gas. All particles move with their terminal velocity relative to the mixture, which allows for the description of sedimentation.

- ***Thermal equilibrium:***

tracers can act as a source of heat, but we expect the system to exchange heat instantaneously, the in situ temperature of the volume mean being identical to the individual in situ temperature of each tracer.

**Model Grid**

| | examples: |
| --- | --- |
| focusing grid | ($\Delta x_{min}$=5m, $\Delta x_{max}$=10km) |
| variable number of grid points | 126 *126*126 |
| variable size of model domain | 200*200*50km$^3$) |
| time step is adapted according to the CFL criterion | ($\Delta t$=0.1-10 sec) |

**Program code of ATHAM**

FORTRAN 90

one code for different model versions controlled with Flags for the Precompiler

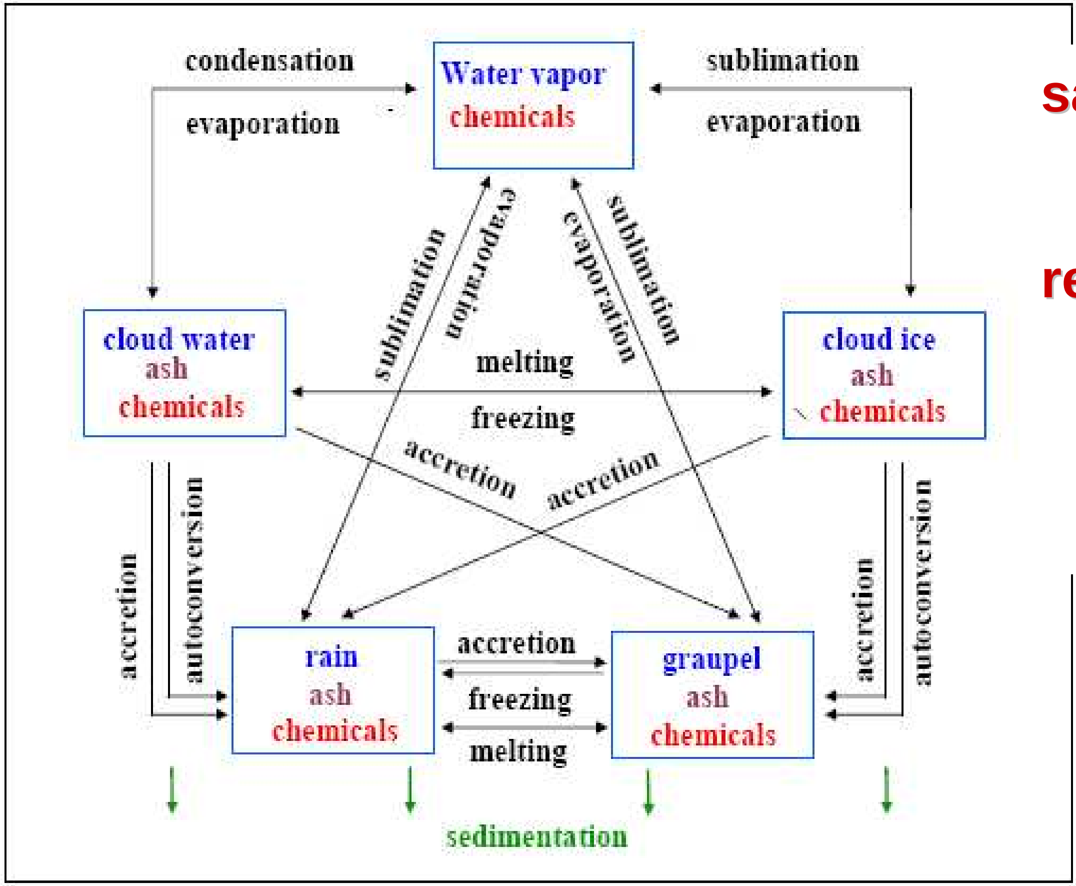
Output files designed for GrADS

Analysis tool qview for GrADS (M. Herzog)

**Modular structure**

- any number of tracers can be added
- new processes are easy to include
- modules of different complexity can be exchanged

# Chemical Species in ATHAM



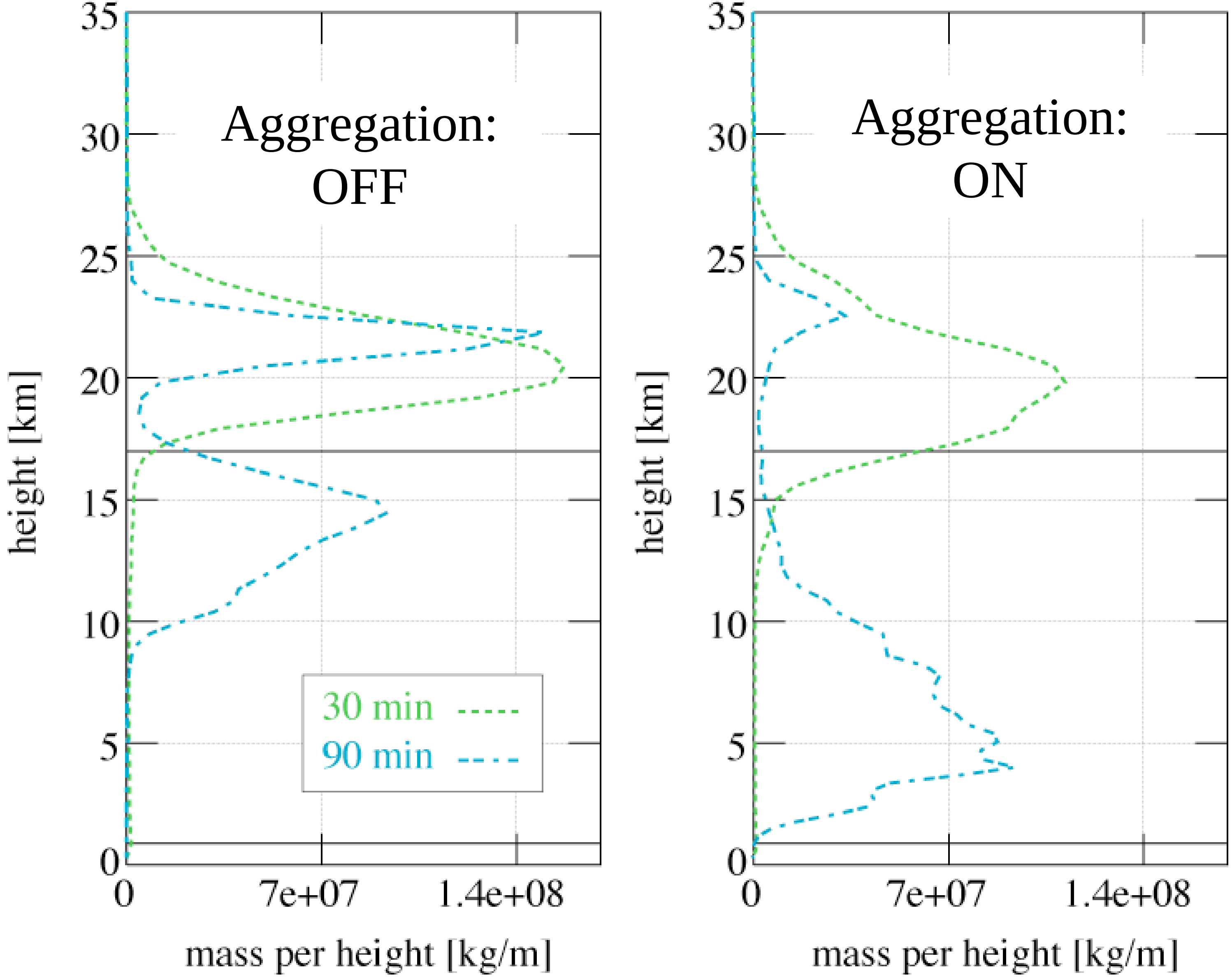

**salinity effects included**

- but difficult to quantify

**relevance for clouds**

- link between gas and liquid phase chemistry included freezing effects

# Aggregates: Impact on Plume



*Tupper et al, 2009, Natural Hazards:* The height of active dispersion (NBH) is much smaller than the top height. Top-hat single column models will fail predicting the NBH. For similar eruption intensity NBH may differ massively depending on atmospheric conditions, mainly for the smaller eruptions. Moister atmosphere leads to higher NBH.

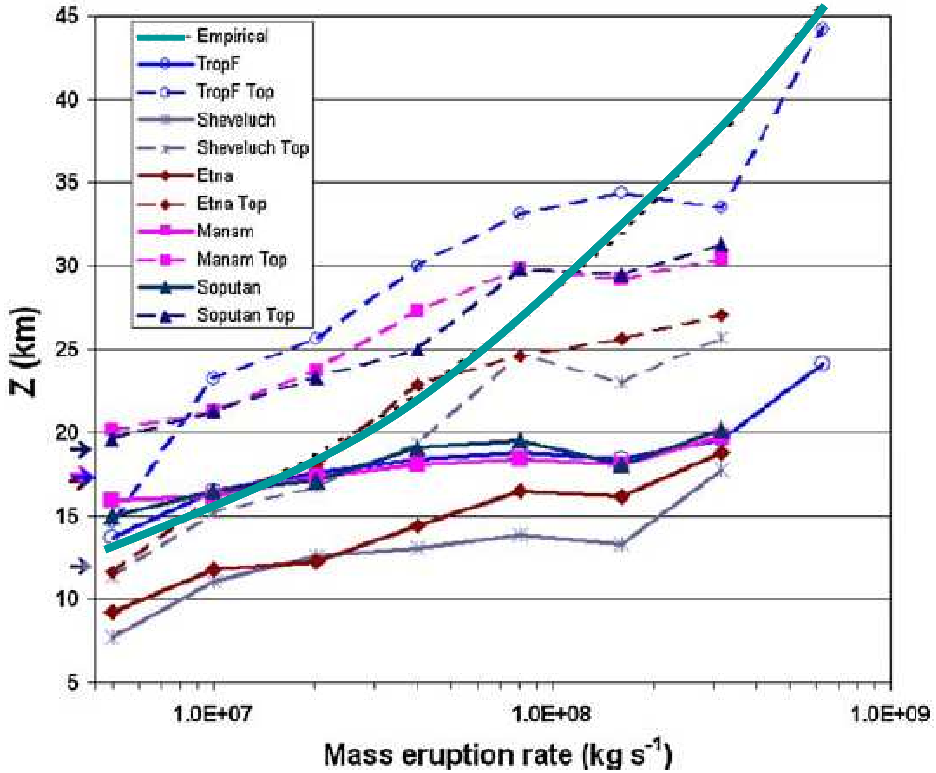



**Fig. 8** Neutral buoyancy (umbrella cloud) height, derived using height of maximum mass per height of $SO_2$ after 1 h of model run time (*solid lines*), and approximate height of top of cloud (*dashed line*). Shown for different mass eruption rates in the atmospheres shown in Fig. 1 and for 'TropF' from Graf et al. (1999), run on a larger domain to allow the highest eruption rate. The *dotted line* is from the empirical relation between mass eruption rate and maximum cloud height given in Sparks et al. (1997). The *arrows* on the *y*-axis indicate cold-point tropopause heights for the (from *bottom*) Sheveluch, Etna/TropF/Manam (clustered), and Soputan atmospheric profiles used

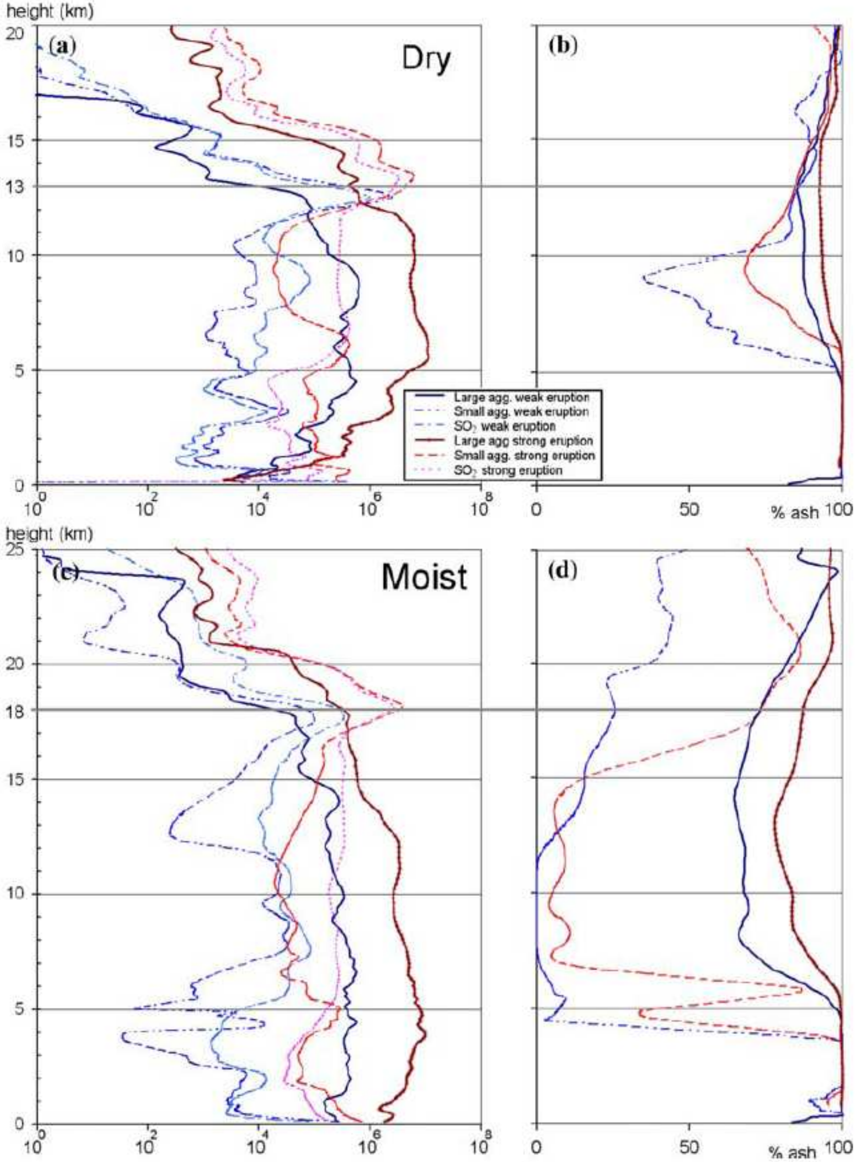
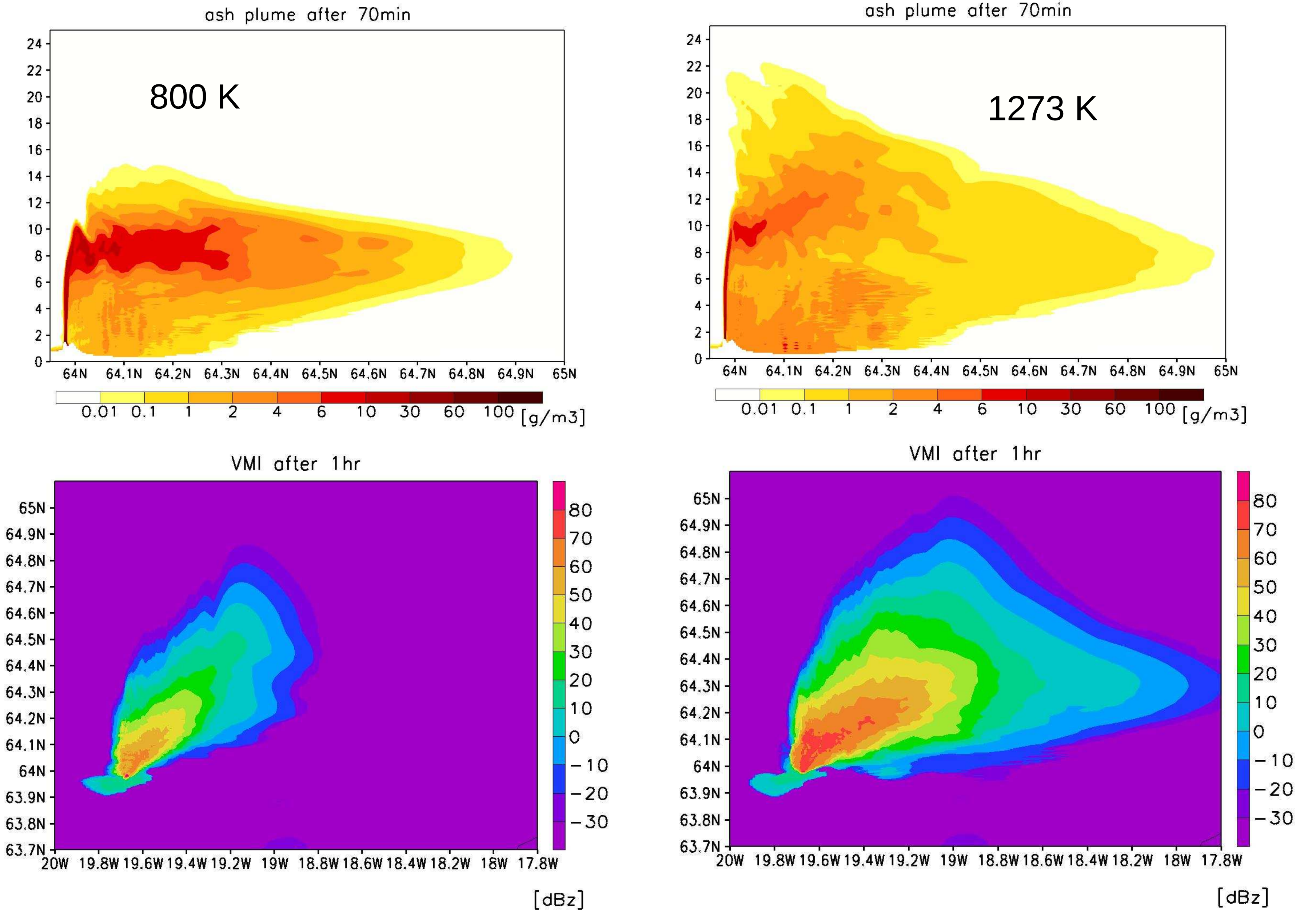


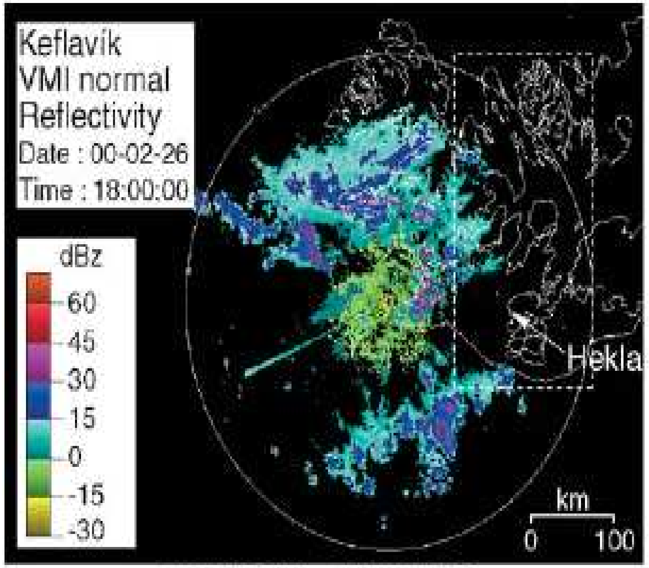

Fig. 7 a and c $SO_2$, small and large aggregate vertical distributions for dry 'Sheveluch' and moist 'Manam' soundings for eruption rates of $2.00 \times 10^7$ kg s$^{-1}$. ('weak') and $1.60 \times 10^8$ kg s$^{-1}$ ('strong'), 30 min after cessation of a modelled eruption. Units for particles are kg m$^{-1}$ and for $SO_2$ mol m$^{-1}$. **b** and **d** are the ash fractions of the small and large aggregates for these modelled eruptions. The *grey lines* at 13 and 18 km indicate the approximate mean positions of the umbrella clouds from these eruptions

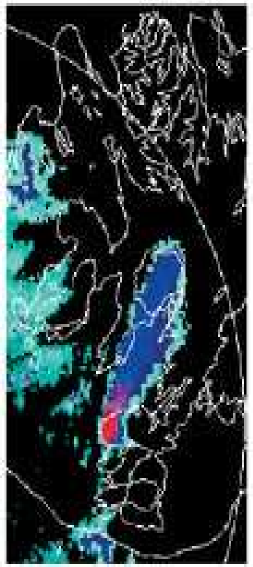
Atmospheric ash loading depends highly on atmospheric moisture: In a dry atmosphere ash content in small aggregates is high. This effect is stronger for weaker eruptions. Highest ash content is in larger aggregates, which sediment out more rapidly.

Ash plume height (top) and horizontal dispersion (bottom) depend strongly on initial temperature at vent due to turbulence, initial buoyancy and wind pattern.



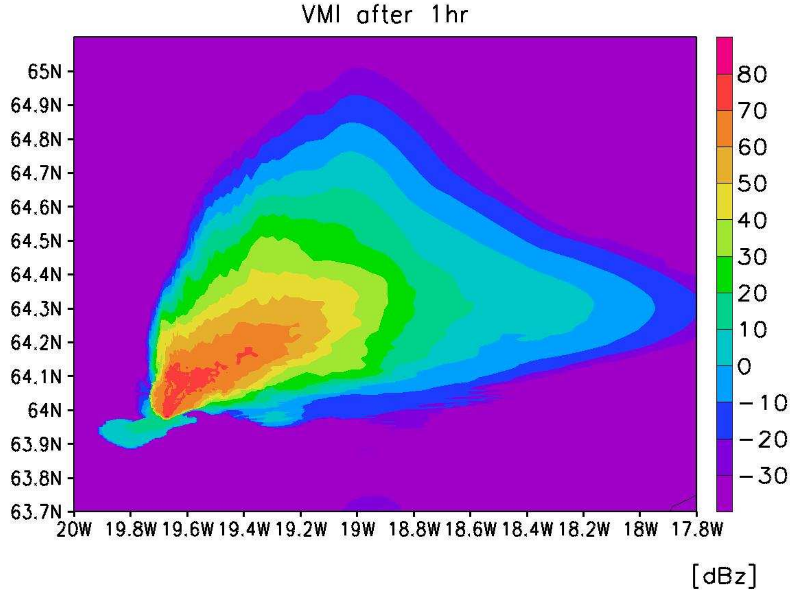
# Hekla 2000 eruption: simulated and observed radar signals

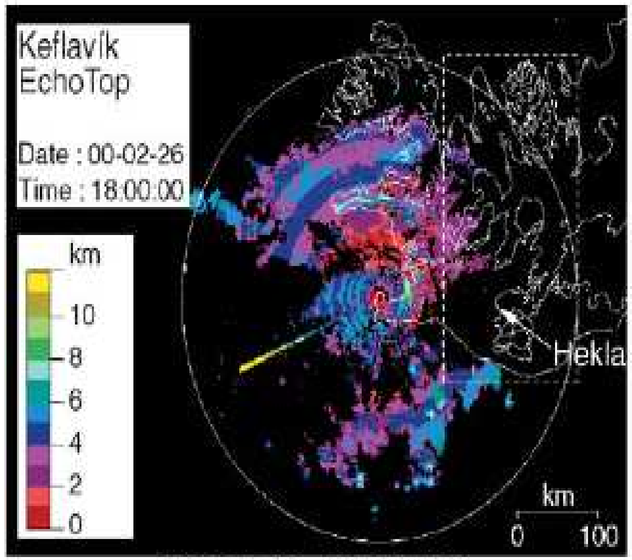


26 FEB 00 - 18:00 UTC

19:20

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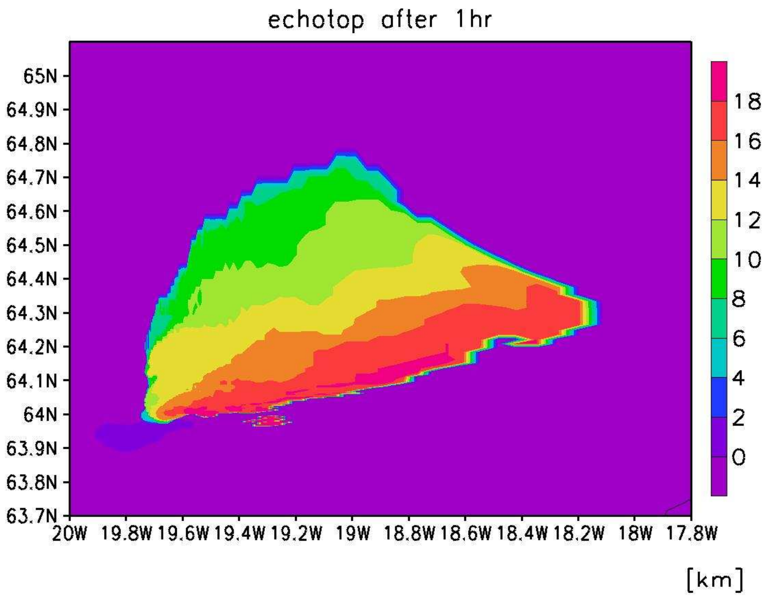
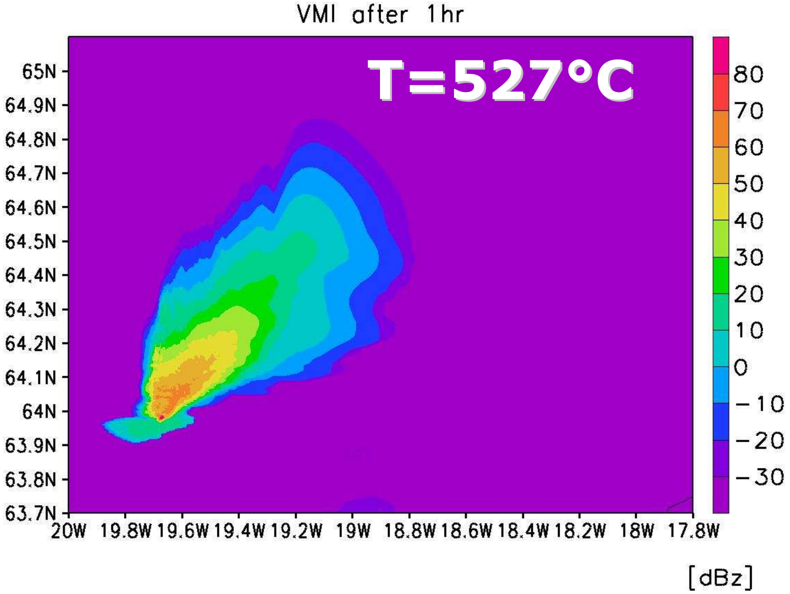
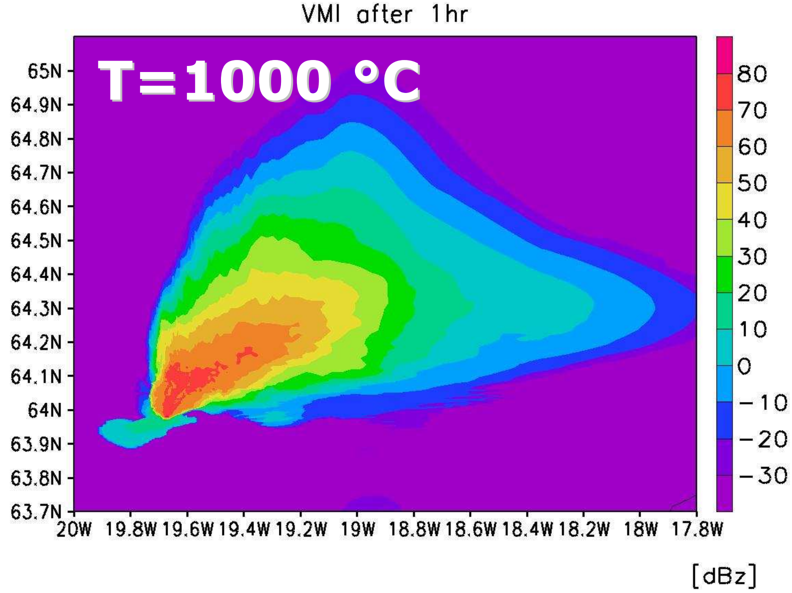
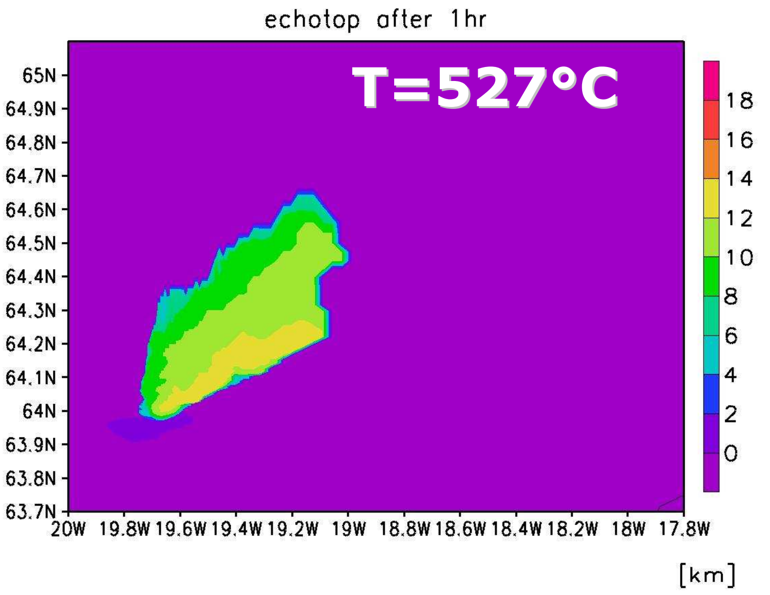


# Simulated radar signals: Effect of at vent temperature

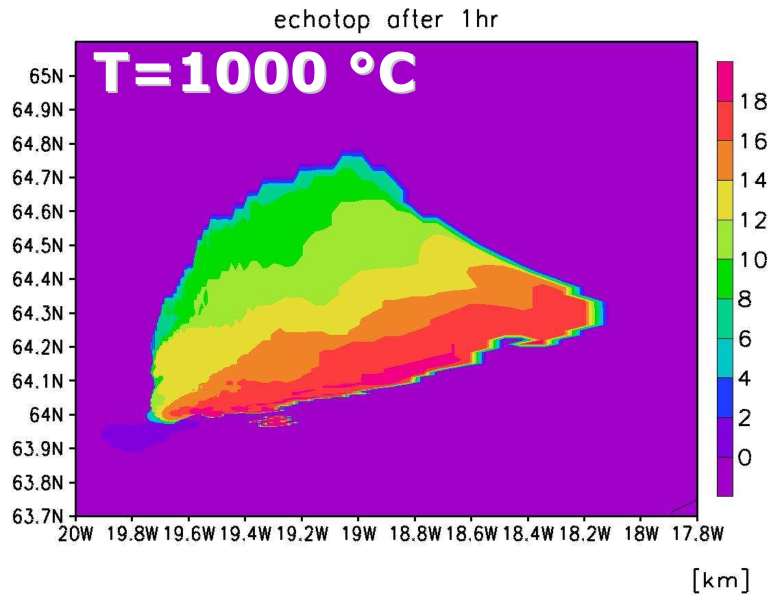


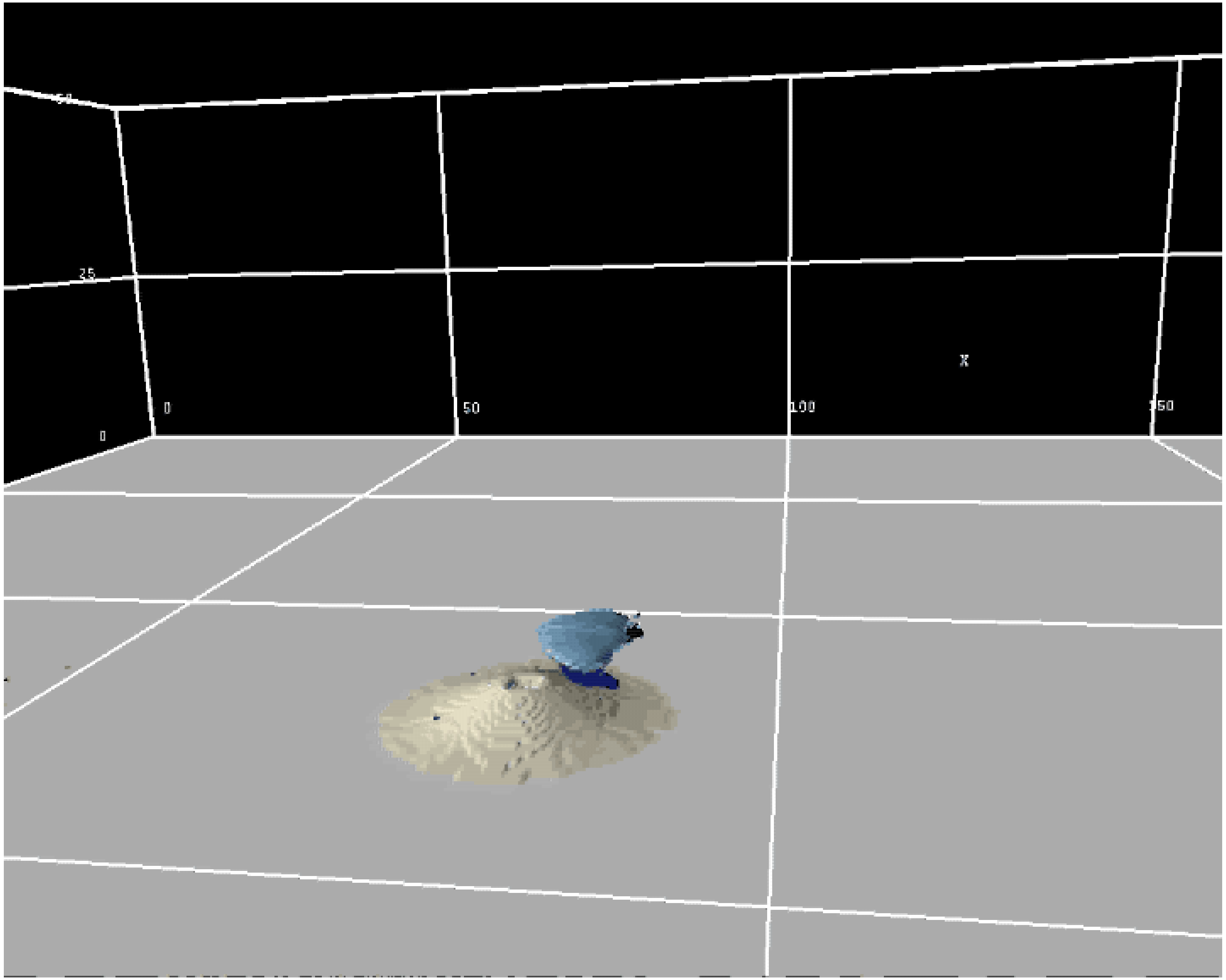

**VMI: vertical maximum signal**



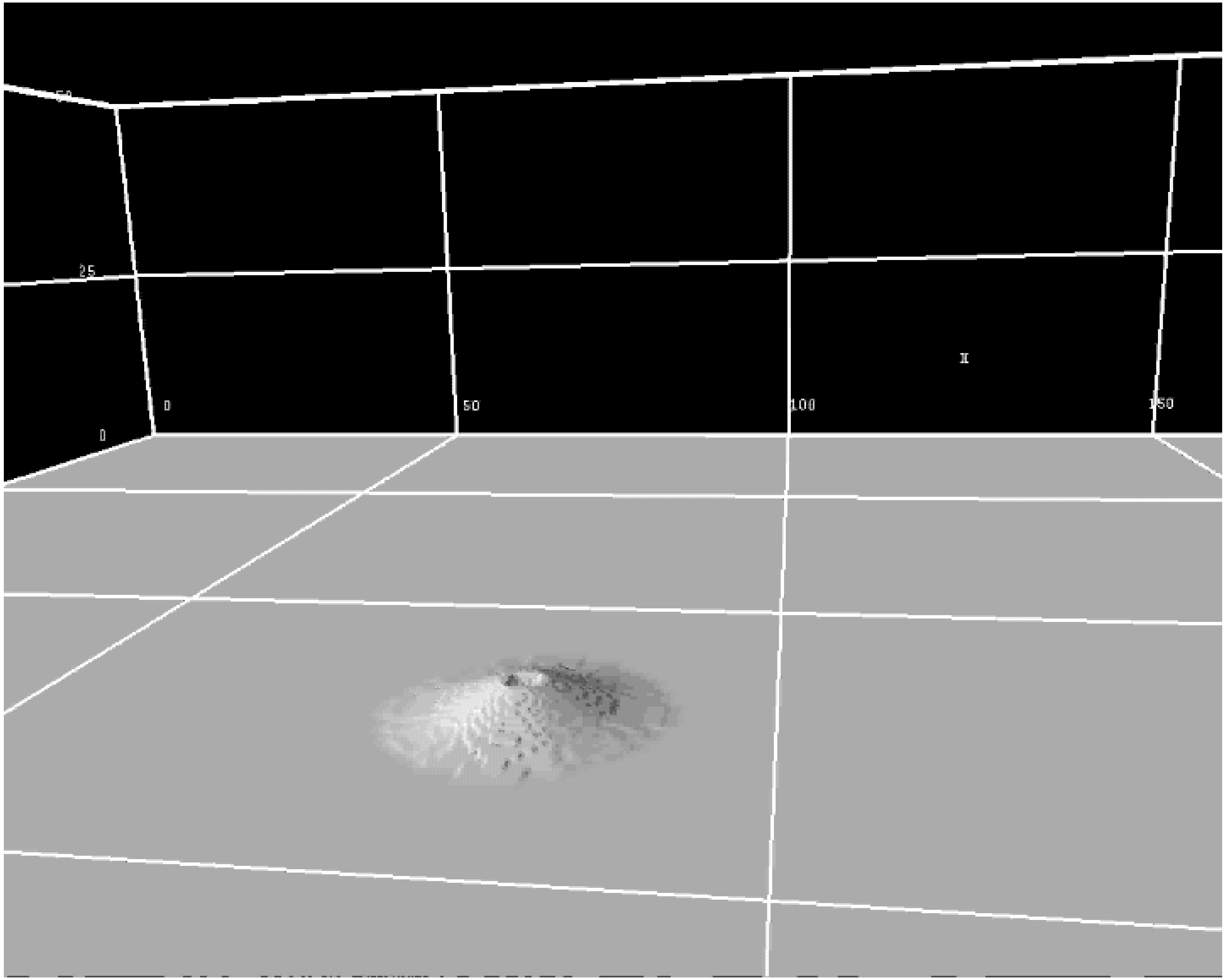




**Echotop: maximum height of 0 dBz**





25
0
0
50
100
150
X


50
25
0
0
50
100
150
x

*Thanks!!*