LMU | LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN | Faculty of Physics METEOROLOGY | Meteorologisches Institut München MIM

Heating Rates in 3D Cloud Fields

Fabian Jakub Bernhard Mayer Carolin Klinger

3D Solar Heating Rates

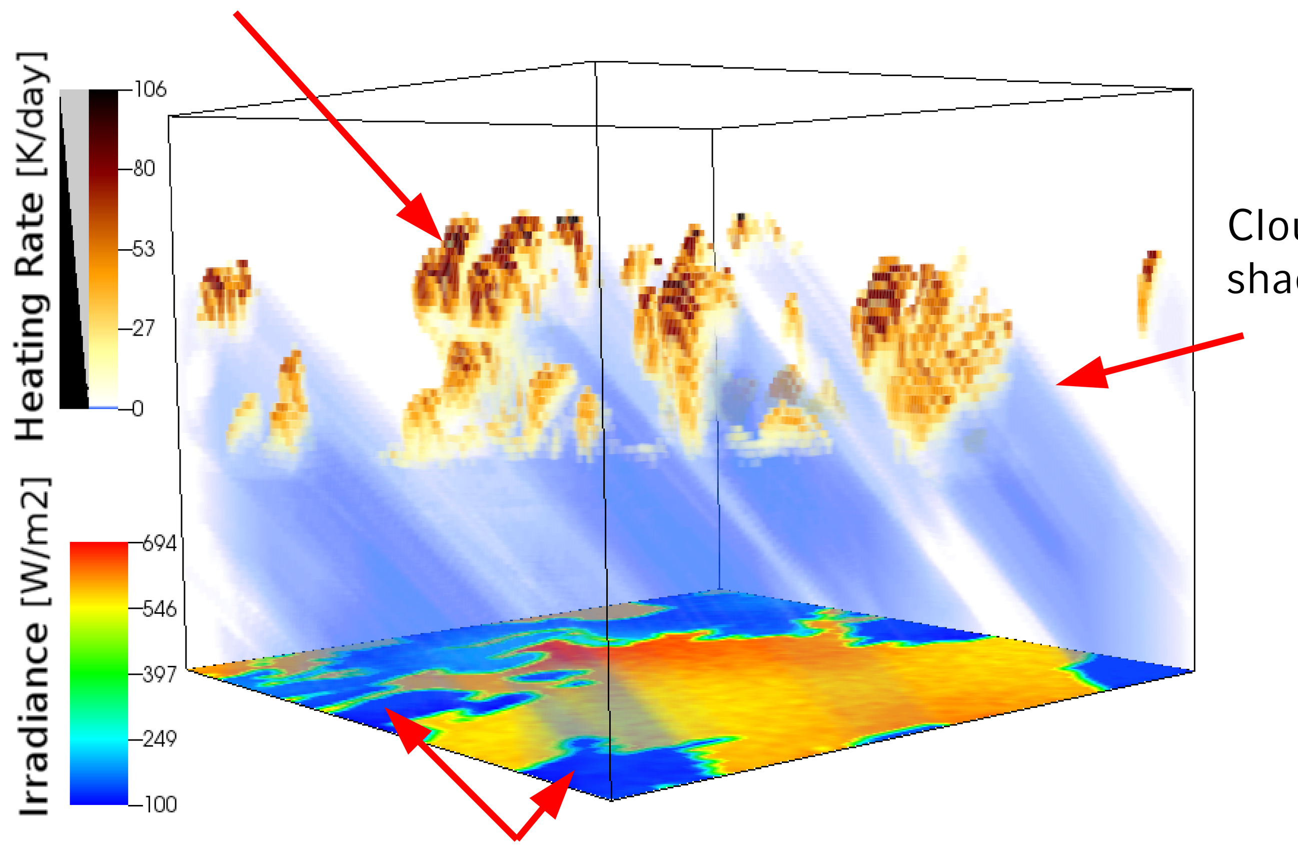
3D Thermal Heating Rates

I3RC Cumulus Cloud Field:

96 * 96 pixels
x/y resolution: 67 m
z resolution: 40 m

Cloud Height: 1.04 - 2.4 km
LWC: 0.004 – 1.82 g/cm^3
R_{eff}: 4 – 14.5 µm

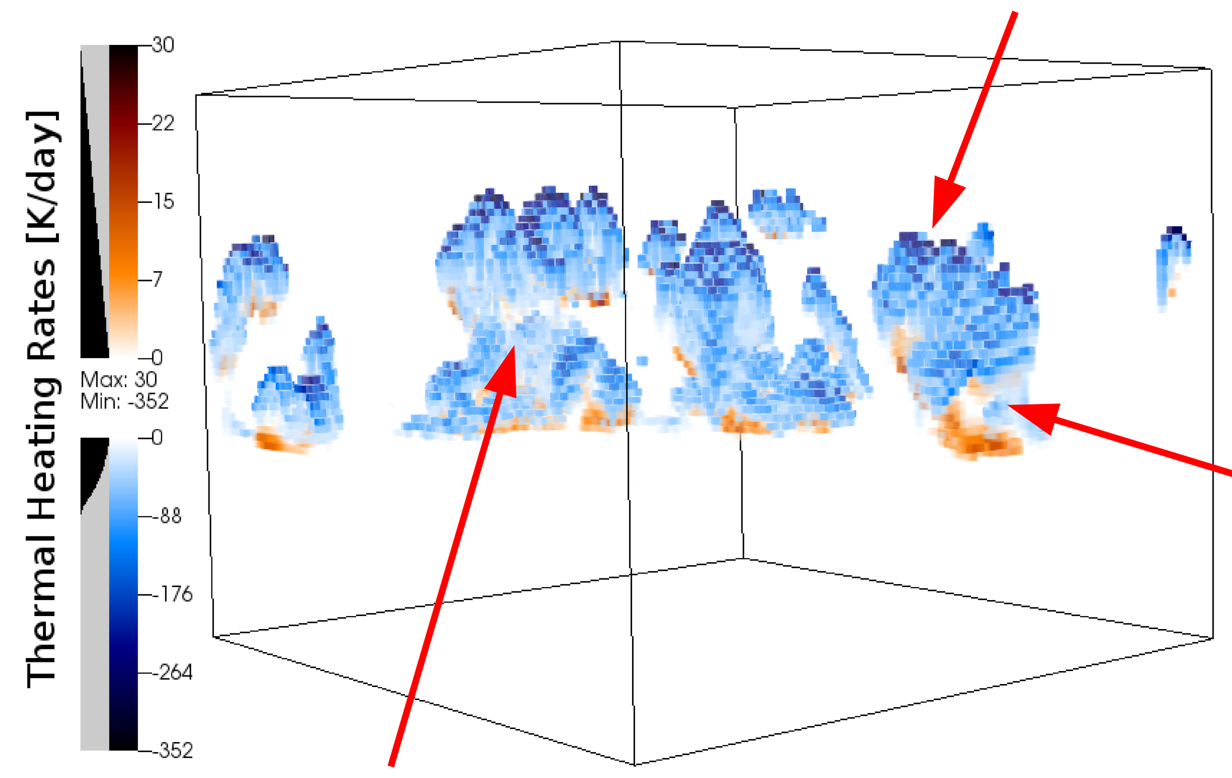
Warming at illuminated cloud side/top



Cloud shadows

Cloud shadows at the surface

Cloud top cooling



Cloud bottom warming

Cloud side cooling

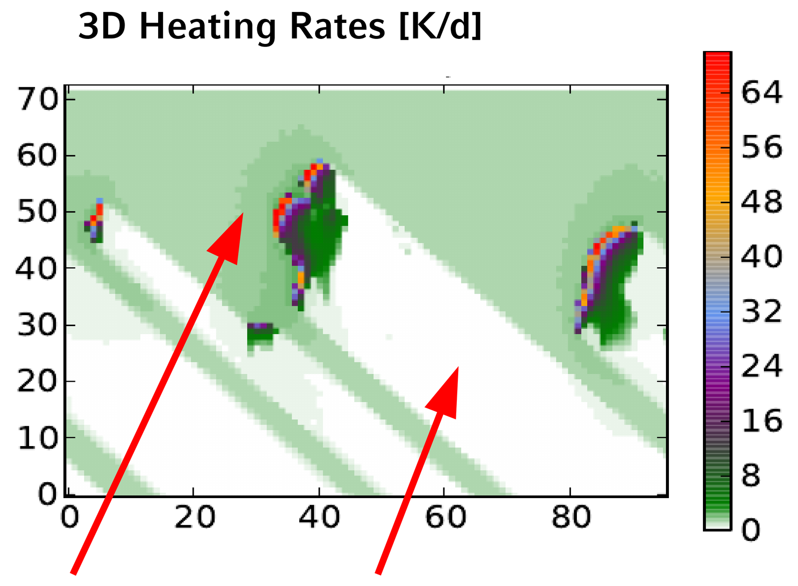
- Clouds reduce the amount of radiation that reaches the surface
- Heat flux from surface to the atmosphere is reduced
- Absorption of solar radiation at illuminated cloud tops/cloud sides → warming effect

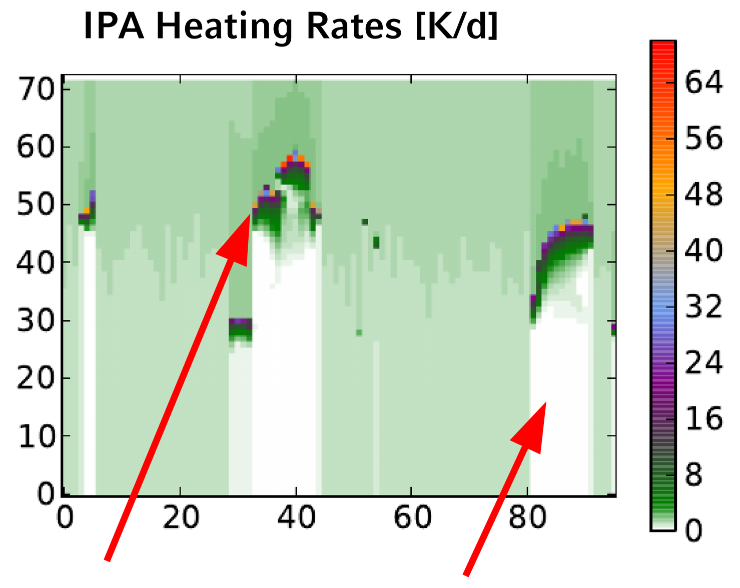
Influence on:
- Cloud microphysics
- Dynamics
- Cloud development

- Main interactions: thermal absorption and emission of the clouds and the atmosphere
  → Cloud side and cloud top cooling
  → Cloud bottom warming

Independent Pixel Approximation

Comparision of **3D** calculation and the commonly employed **independent pixel approximation** (IPA) in the solar spectral range for the **I3RC cumulus cloud field**.





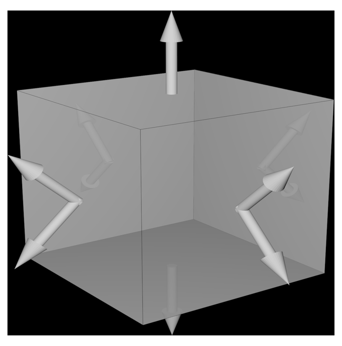
Strong warming at illuminated cloud top/side

Shadow depending on solar zenith angle

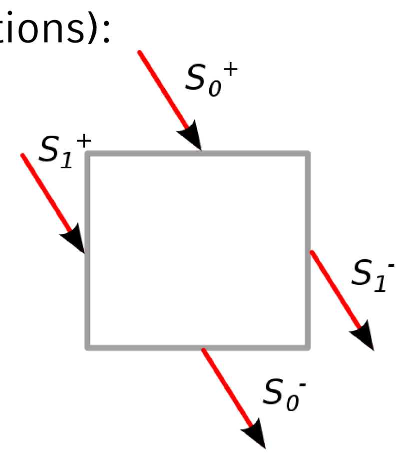
Warming weaker, no cloud side effects

Shadow always directly below the cloud

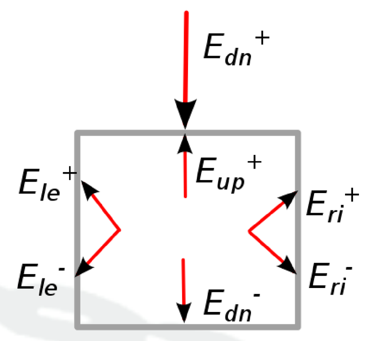
Concept for Fast 3D-RT Solver



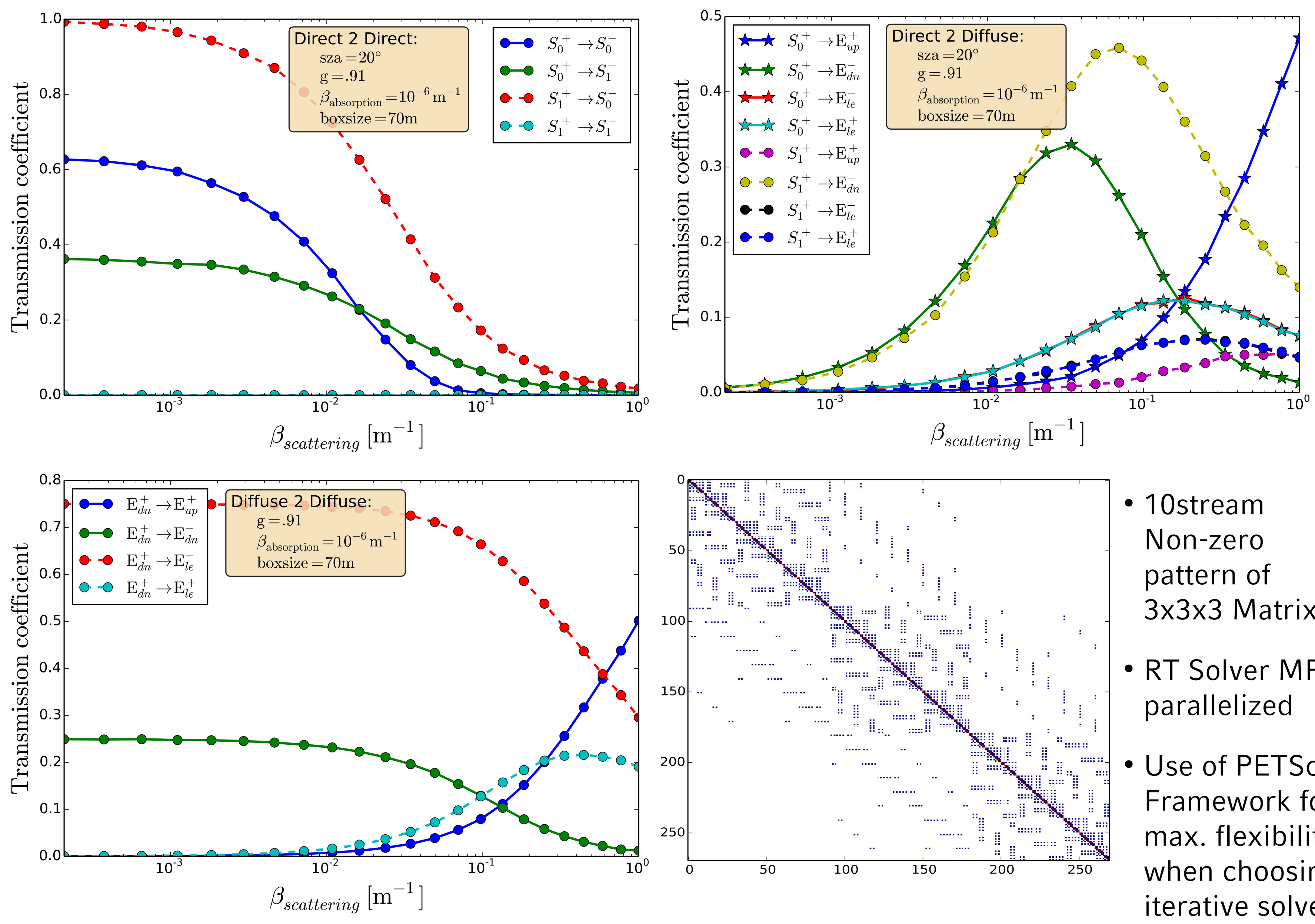
- Generalization of the twostream method to 3 dimensions
- Minimum required streams for 3D-RT(directions):
  - 3 streams for direct radiation ($S_{0,1,2}$)
  - 10 streams for diffuse radiation ($E_{dn,up,...}$)



- Obtain transport coefficients for arbitrary geometries and optical properties with exact Monte Carlo methods and store in LookUpTable
- Degrees of freedom of transport coefficients for one box are aspect ratio, optical properties (absorption / scattering coefficients and asymmetry parameter) and sun angles (zenith and azimuth)
- Couple streams in linear equation system and solve iteratively



Transport Coefficients for Single Box

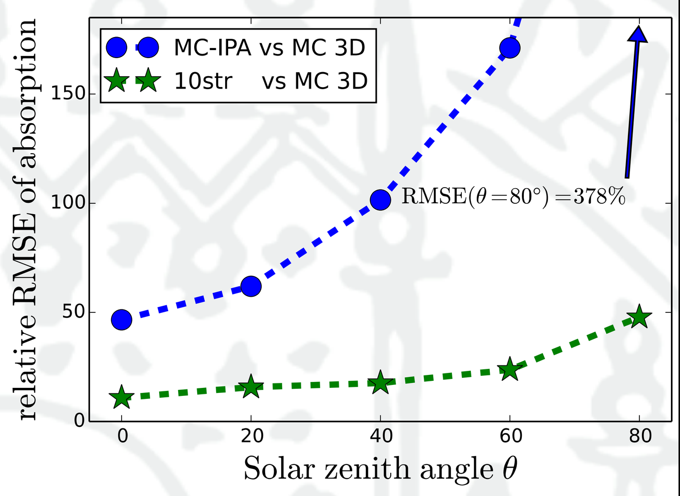


- 10stream Non-zero pattern of 3x3x3 Matrix
- RT Solver MPI-parallelized
- Use of PETSc Framework for max. flexibility when choosing iterative solver

Performance of New Solver

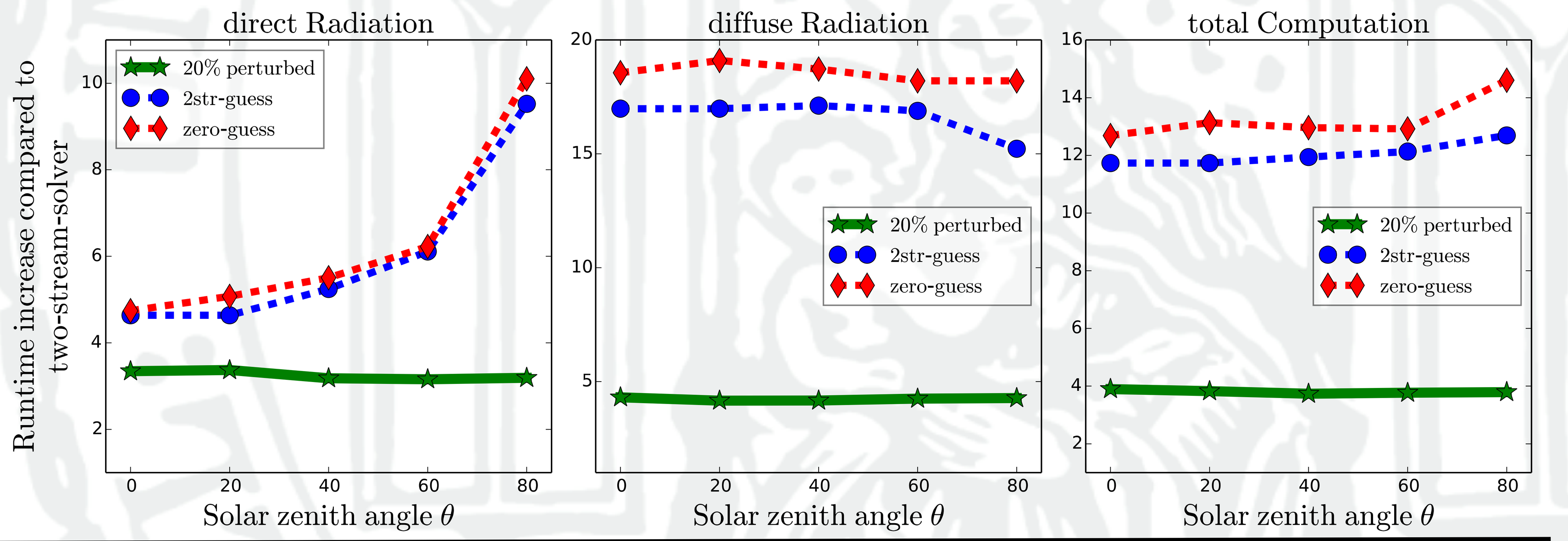
Can it calculate 3D absorption?

- Root-Mean-Square-Error shows significant improvement (here shown is the RMSE for I3RC scene from above)
- Decrease in precision for high solar zenith angles due to numerical diffusion in direct part



What are the computational costs?

- Calculations done on workstation with 8 cores
- Dashed lines (zero-guess) show an approximative increase of total runtime by a factor of 12
- If started with a good initial guess (e.g. last time step +20%noise perturbation), computation may be significantly faster



http://www.meteorologie.lmu.de