

Two adaptive schemes for radiative transfer parameterisations in NWP models

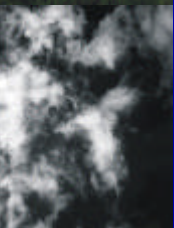
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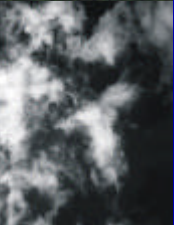


BF/AFOSR2000



Structure

- Problem – adaptive parameterisation scheme
- An adaptive RT scheme
 - Statistical method: local search
- Results
- Future improvements
- Second scheme
 - Statistical method: regression & perturbation
- Other applications
- Summary
- ❖ Preliminary!



Problem

- Parameterisations are indispensable for modelling complex systems
- Climate change studies
 - Less based on the current climate
 - Parameterisations should become more physical
 - Computationally expensive
- High resolution modelling
 - Almost the same calculation is made in neighbouring boxes
 - “The same calculation” within the uncertainty
 - Save computational power

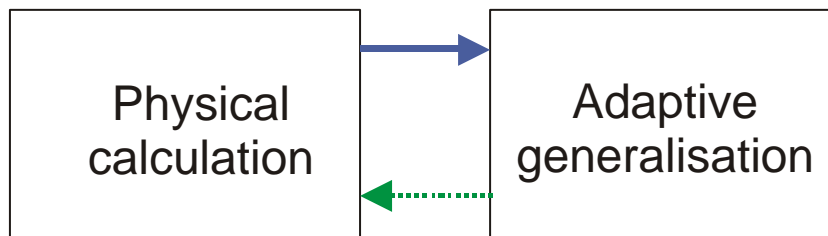
Adaptive parameterisation scheme

Past

Medium complex
parameterisation

Future

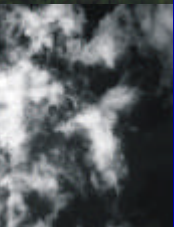
Adaptive parameterisation
scheme



Results physical calculation

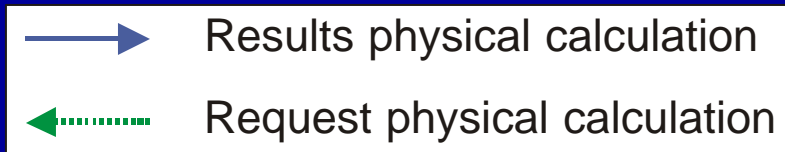
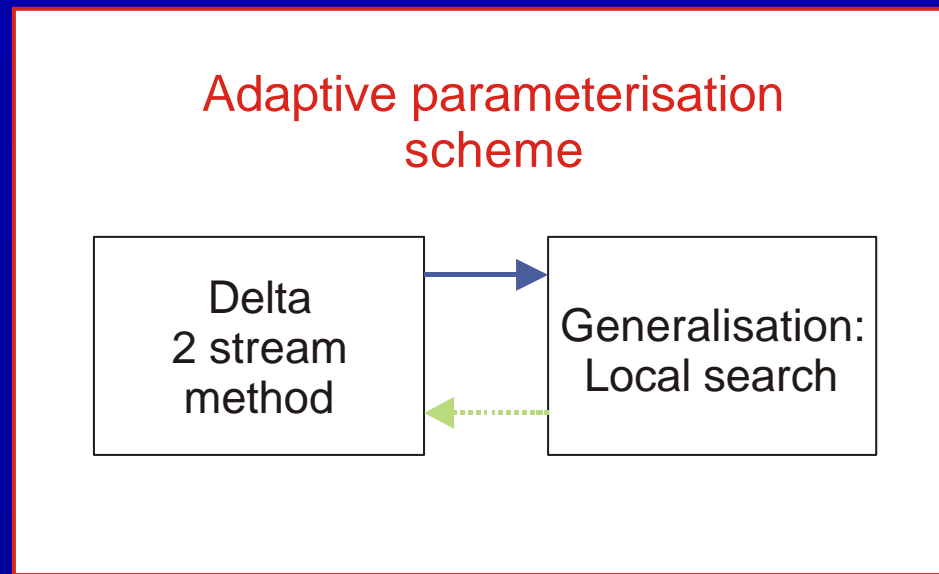


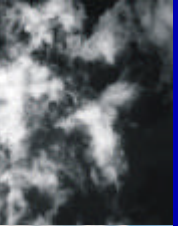
Request physical calculation



Adaptive RT scheme I

- Search for similar cloud fields in the neighbourhood
- Use the radiative flux of the most similar cloud field



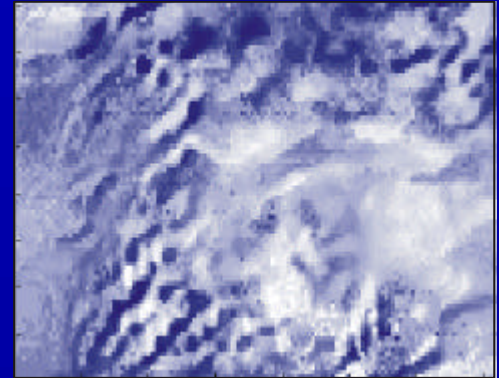
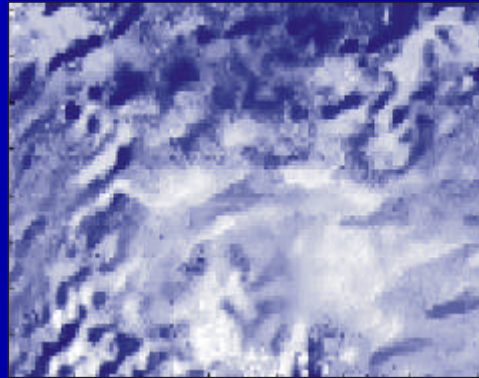


Statistical scheme

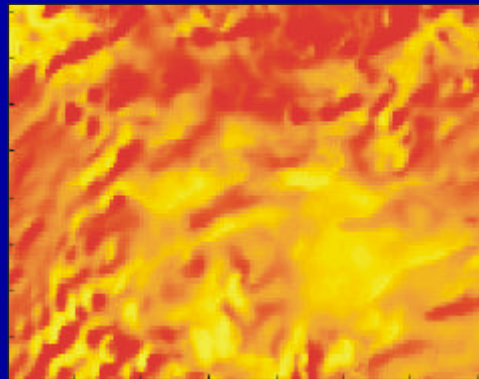
12 h

13 h

Clouds

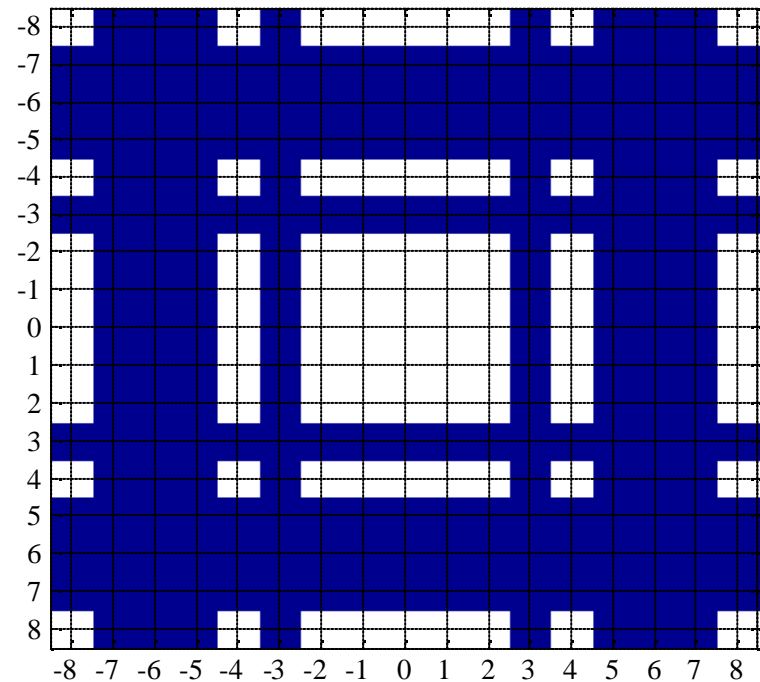


Radiation



Adaptive RT parameterisation I

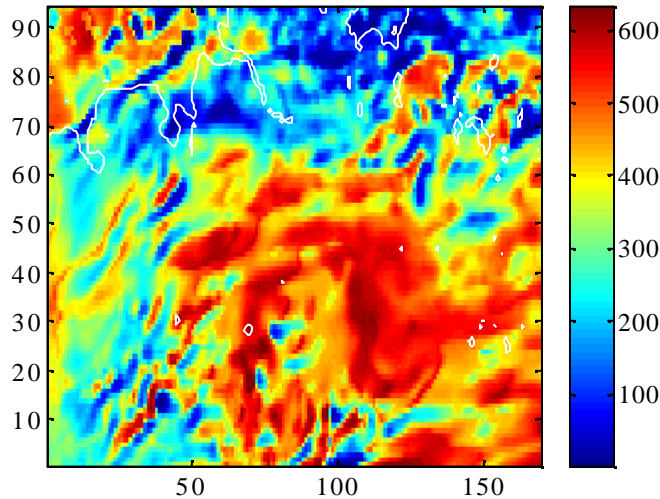
- I = index of similarity
- $I = (100 - \text{TCC}) + w_1 * \text{IWP} + w_2 * \text{LWP}$
 - TCC: Total Cloud Cover
 - IWP: Ice Water Path
 - LWP: Liquid Water Path
 - w_1, w_2 : Two weights
- Search made up to 8 pixels away (0,1,2,4,8)



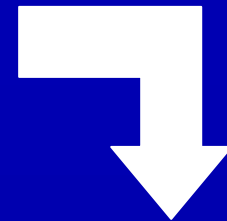
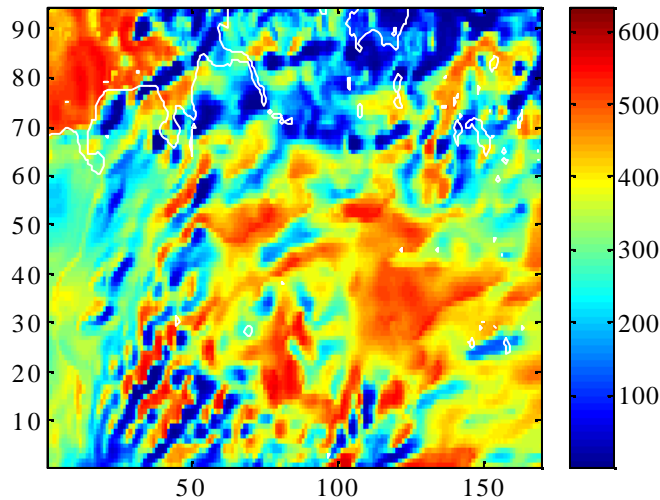
Solar fields - LM vs. Adaptive



Solar flux surface - 1st hour

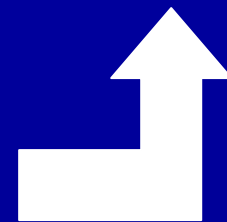
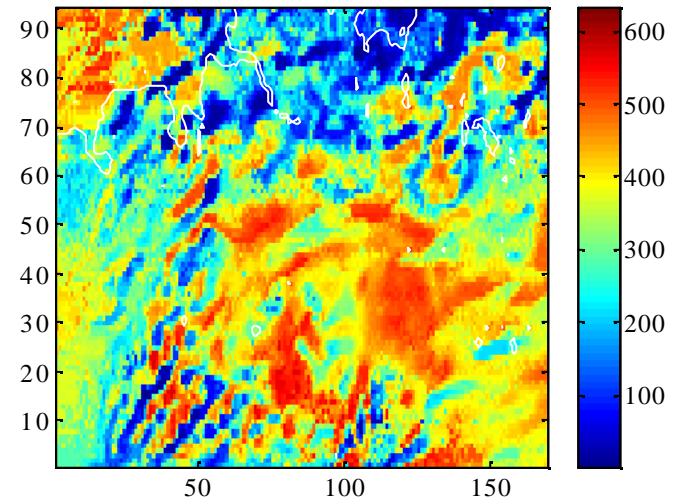


Solar flux surface - 2nd hour



Cloud and solar flux data

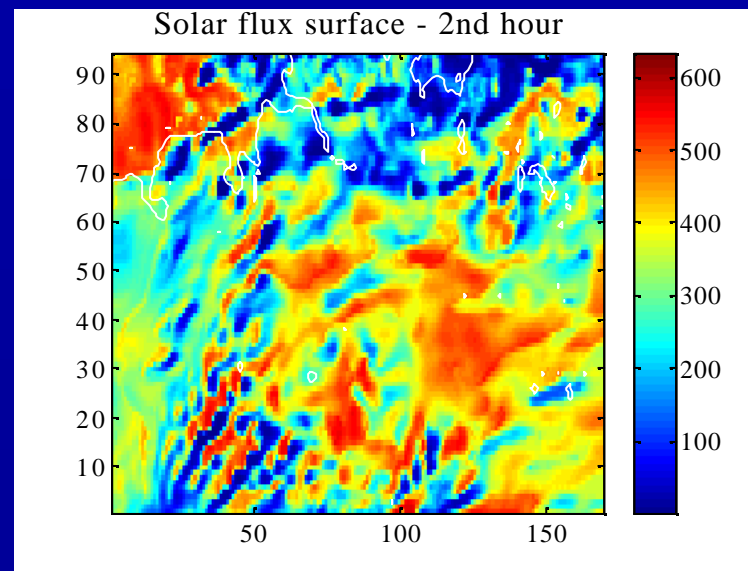
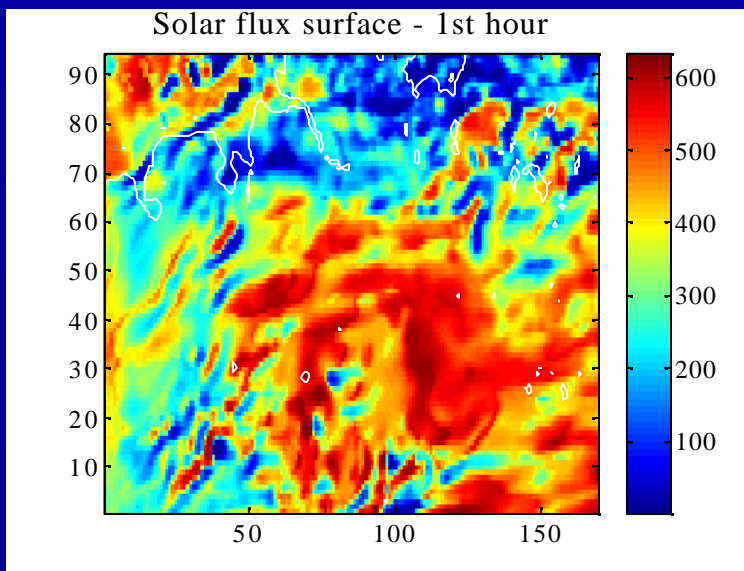
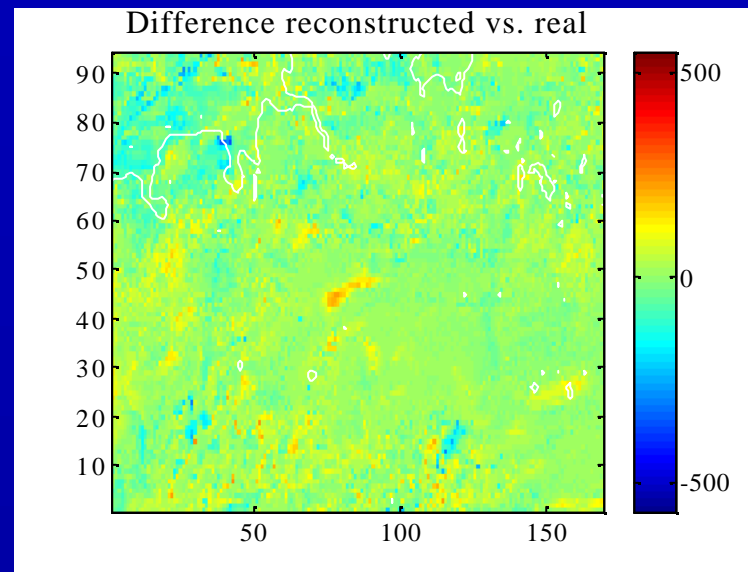
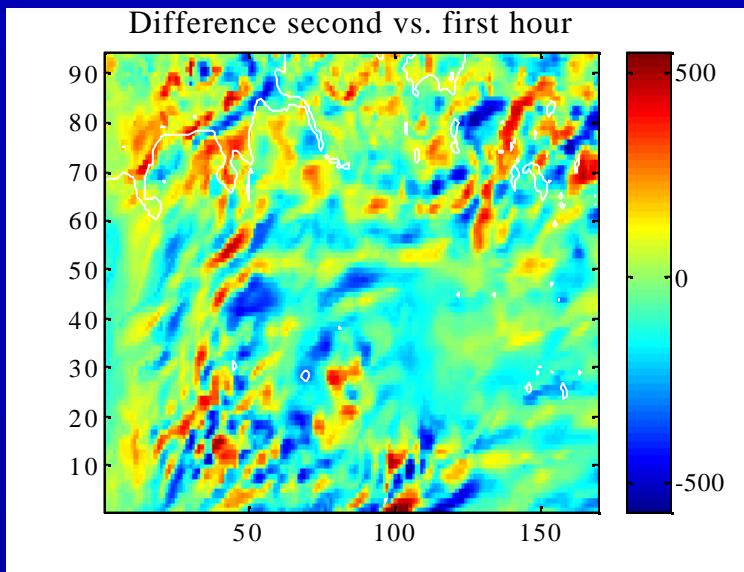
Reconstructed solar flux surface - 2nd hour



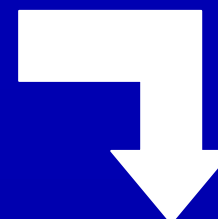
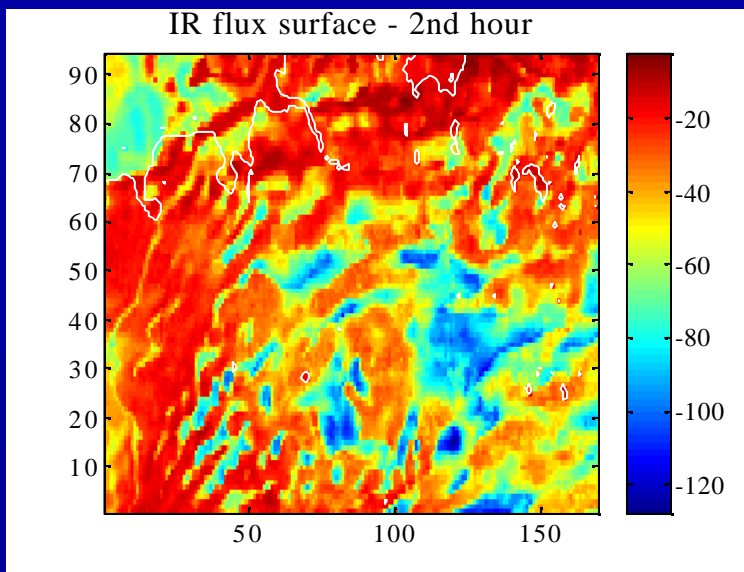
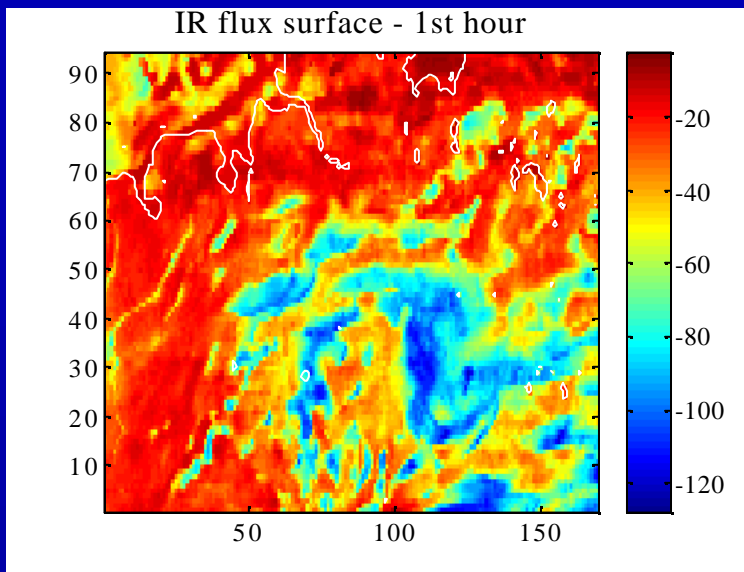
Cloud data



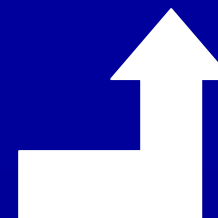
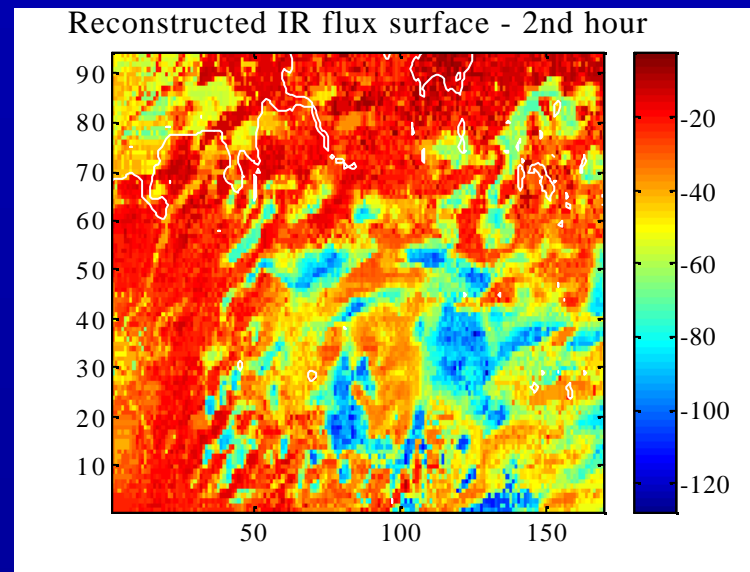
Differences solar flux



IR fields - LM vs. Adaptive

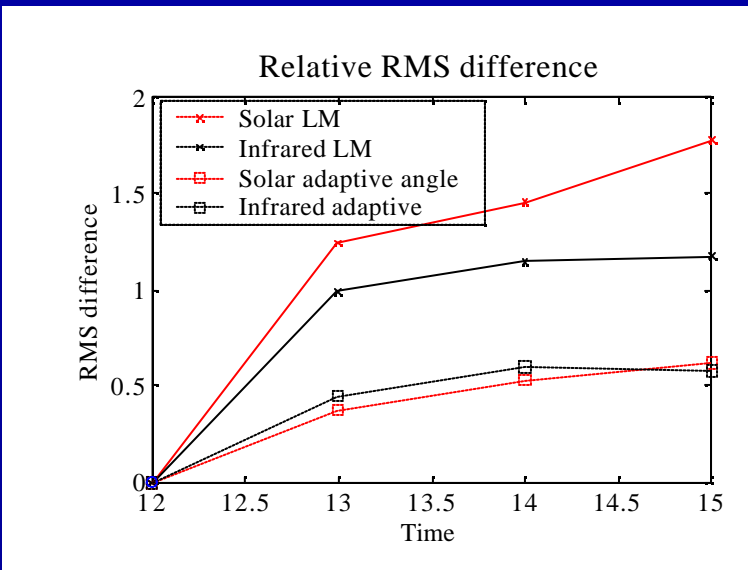
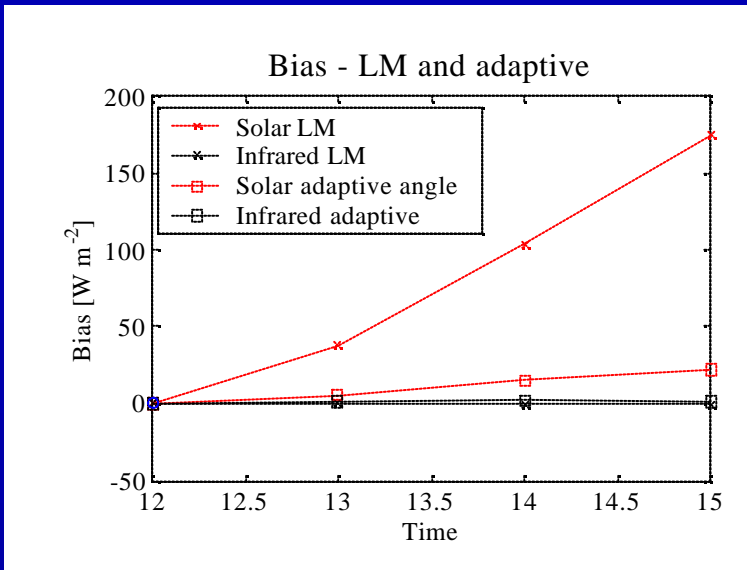
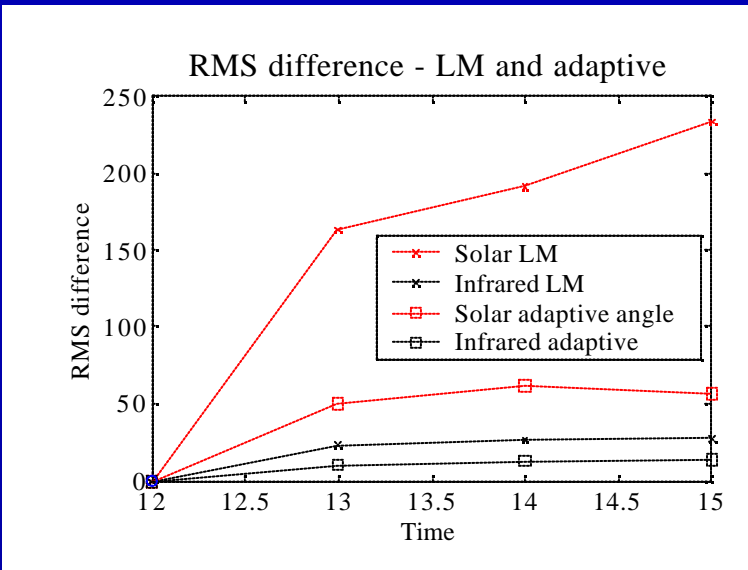


Cloud and solar flux data



Cloud data

Results - statistics

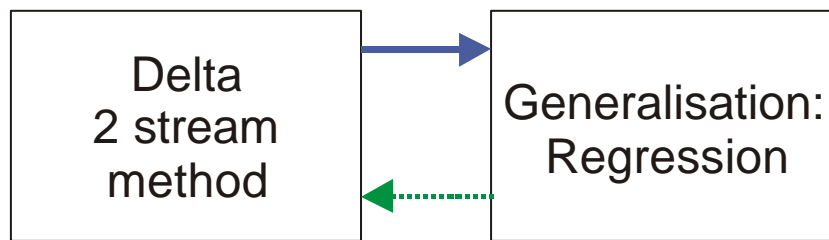


Future plans

- Include temperature for IR
- Include mean advection in search
- Local interpolation instead of nearest neighbour
- physical calculations
 - Reduce the number calls per time step
 - Increase the number of time steps
 - For example, 6 x h, 1/9 columns
- $\Delta I = \Delta(\text{LWC} + w_1 * \text{IWP}) + w_2 * \Delta\text{TCC} + w_3 * \Delta T + w_4 * \Delta D$
- Implement requests for physical calculations from adaptive subsystem

Adaptive RT parameterisation II

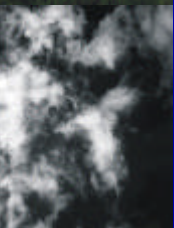
Adaptive parameterisation scheme



Results physical calculation

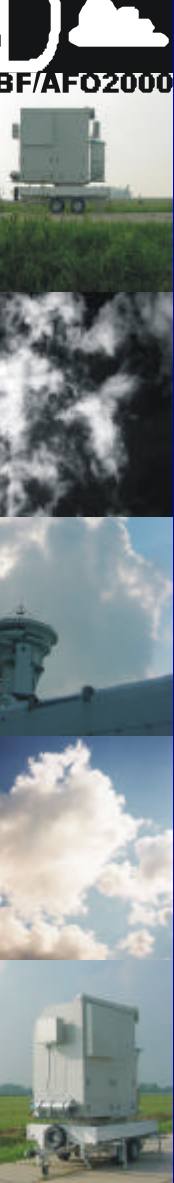


Request physical calculation

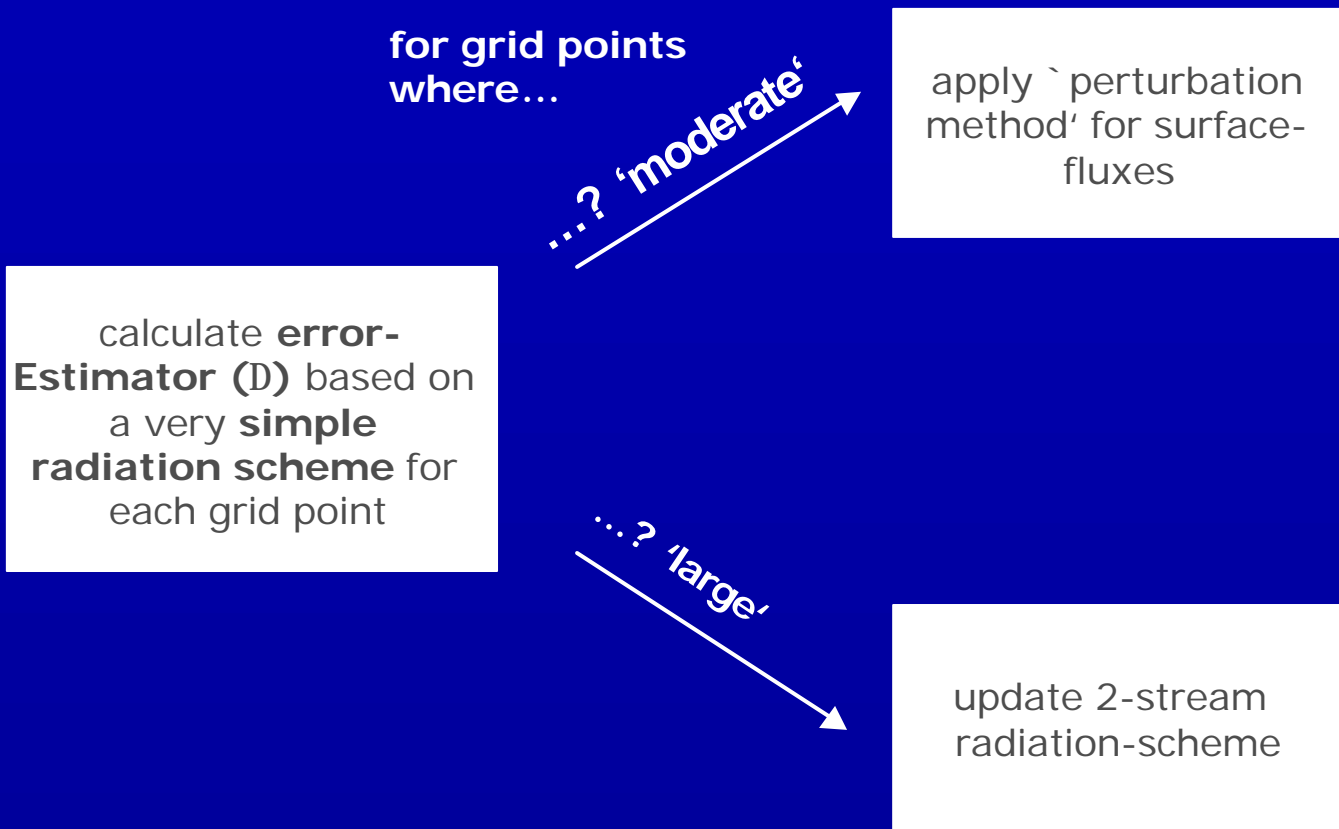


Adaptive RT parameterisation II

- Exploits temporal correlations
- Adaptive generalisation: simple regression algorithm
 - CLC_{Low} , CLC_{Total} , cloud thickness, cloud base, T_{base} , $T_{surface}$, LWP, IWP
- Status: to be combined to an adaptive parameterisation scheme



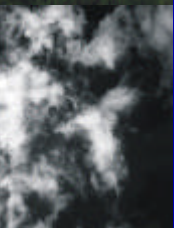
Adaptive RT parameterisation II



Perturbation method:

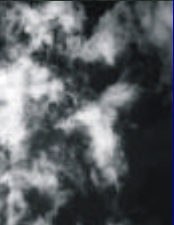
$$F^{\downarrow}(t + \Delta t) = F^{\downarrow exact}(t) + \Delta F^{\downarrow simple}$$

$$\Delta F^{\downarrow simple}(t + \Delta t) = F^{\downarrow simple}(t + \Delta t) - F^{\downarrow simple}(t)$$



Fields of application

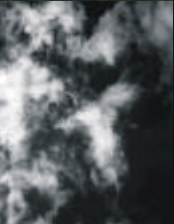
- Parameterised small scale processes
- Physical calculation must be significantly better
- The generalisation must correlate
 - Spatially
 - Temporally
 - In the physical parameters



Examples - physical calculations

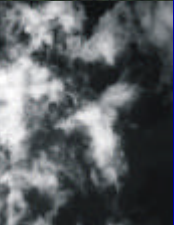
- Aerosol models nested in NWP model
- Cloud model: cloud cover or LWC PDF
- Ground module with more levels
- Chemistry/aerosols in some cells of a LES
- Detailed spectral drop size calculation in a convective cloud model

- Consisted physics: LES / CRM to calculate the clouds, turbulence, exchange, ...
 - Super parameterisations: small 2D ‘CRM’



Cloud feedback effect

- Start of my thinking
- In principle adaptive parameterisations allows to investigate cloud feedback effects
- Feedbacks
 - Large scales to smaller: physical calculation
 - Small scales to larger: generalisation
- Problem: the strength of the feedback becomes ‘subjective’
 - Cloud feedback depends on the intelligence of the adaptive algorithm
 - Sensitivity study: increasing # physical models
 - Hopefully this would converge

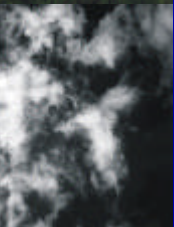


Summary

- Adaptive parameterisation scheme
- Illustrated it for Radiative Transfer
 - Adaptive regression method
 - Adaptive local search algorithm
- Two views
 - Two-stream accelerator
 - Decreased biases
 - Decreased RMS error by factor 3
 - Roadmap to make parameterisations more physical
 - Now all weather services can use 2-stream calculations and still a small enough time step
- General idea useful for other parameterisations



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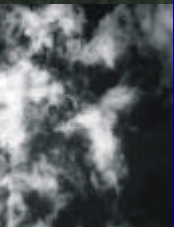
More information

- http://www.meteo.uni-bonn.de/venema/themes/adaptive_parameterisations/
- Google: adaptive parameterisations
- Google: Victor Venema



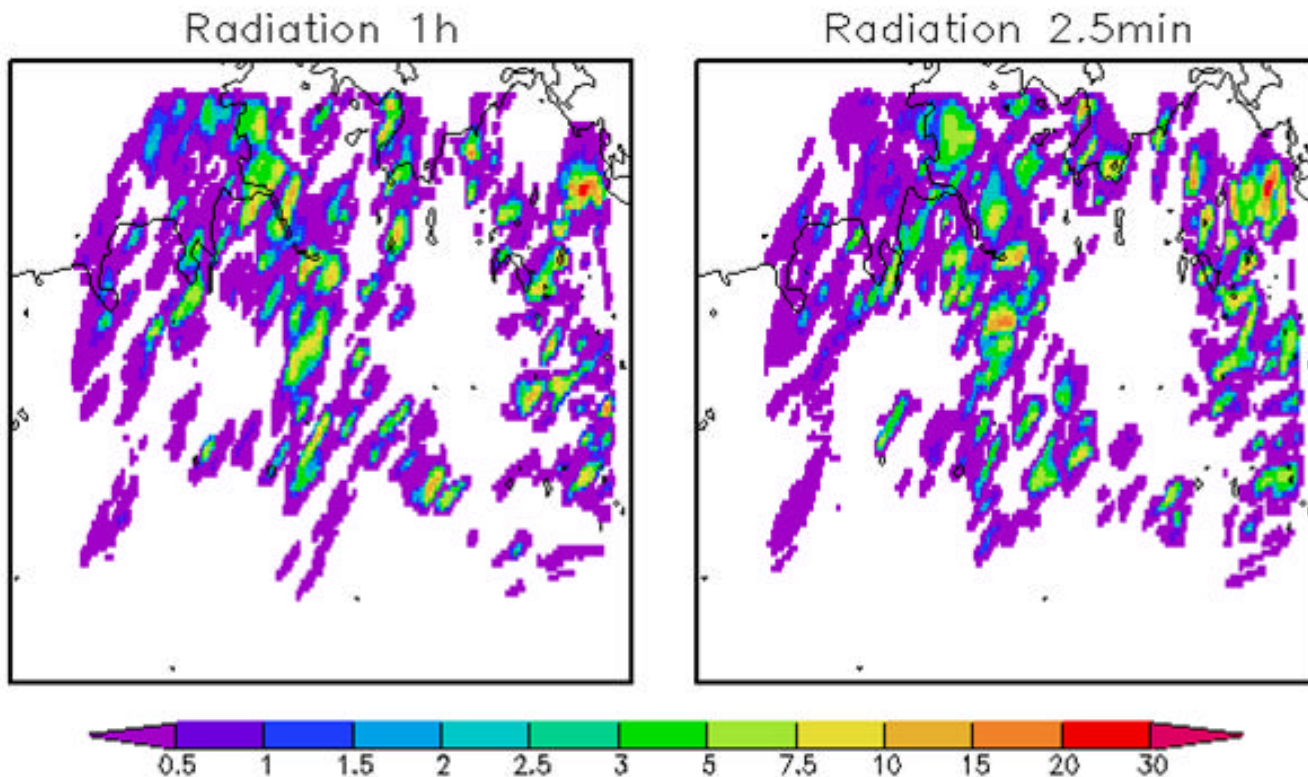


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Motivation: Sensitivity study

21/06/2004 14:00, Hourly precipitation [mm]



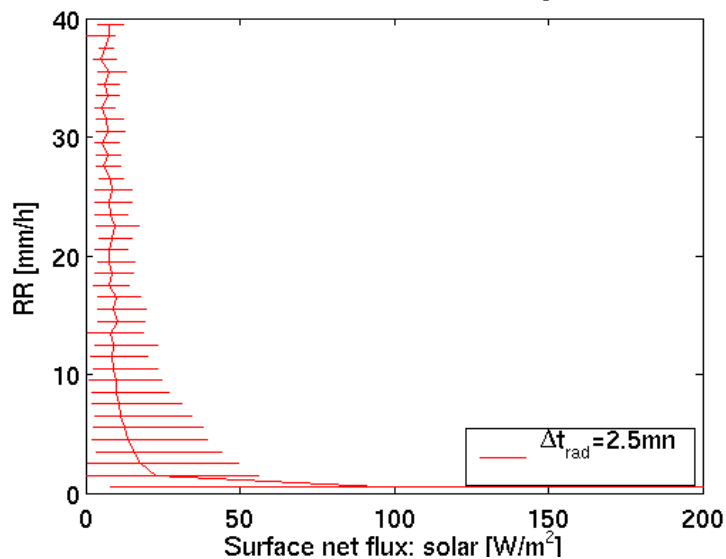
- Precipitation field similar on large scales
- Clear differences on small scales.

(initialized at 0:00)

Motivation: Solar Surface Flux vs. Rainrate

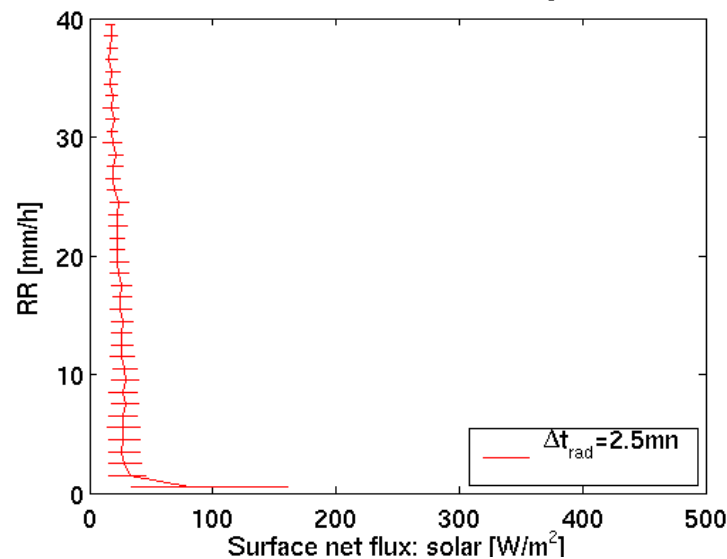
13/08/2004

Median and 0.25-quantiles



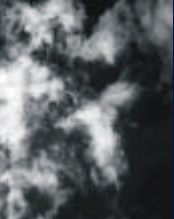
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Median and 0.25-quantiles



Prognostic
precipitation

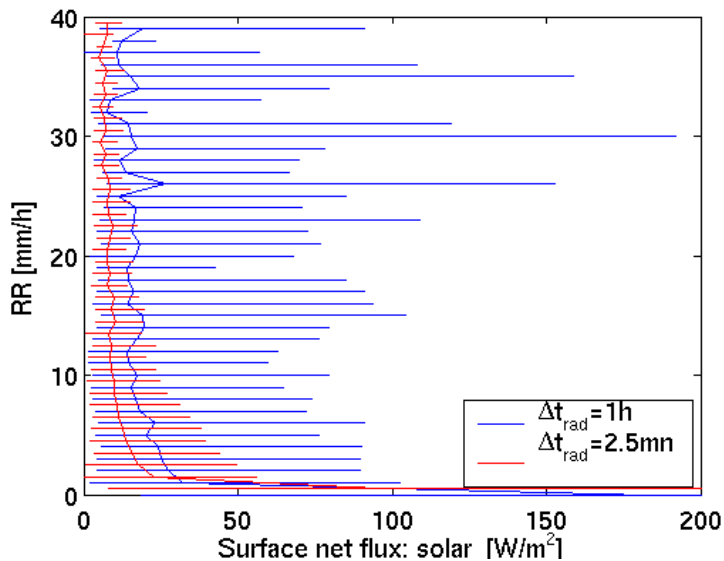
Diagnostic
precipitation



Motivation: Solar Surface Flux vs. Rainrate

13/08/2004

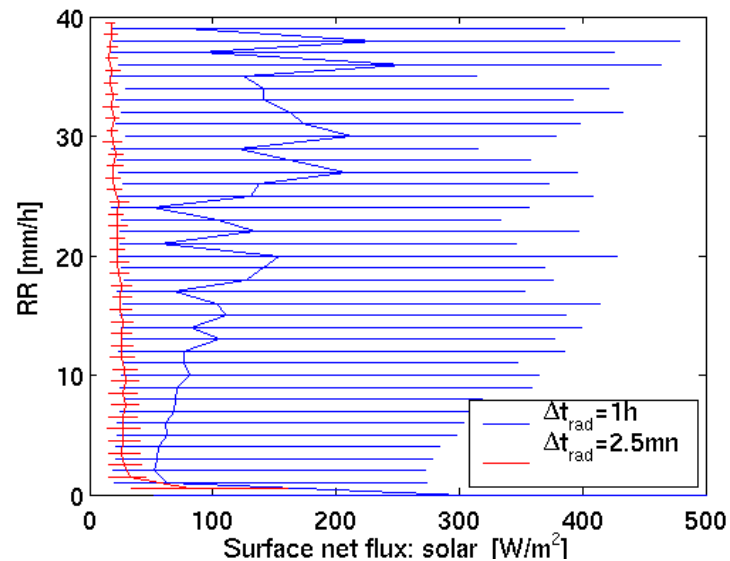
Median and 0.25-quantiles



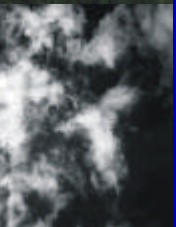
Prognostic
precipitation

21/06/2004

Median and 0.25-quantiles



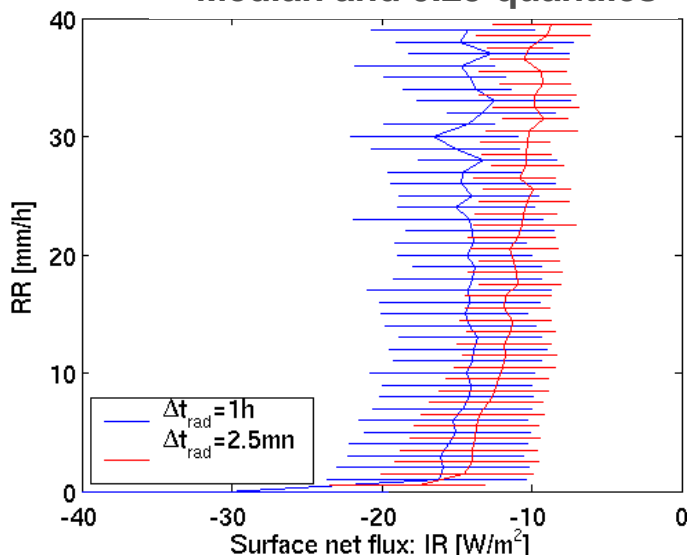
Diagnostic
precipitation



Motivation: Thermal Flux vs. Rainrate

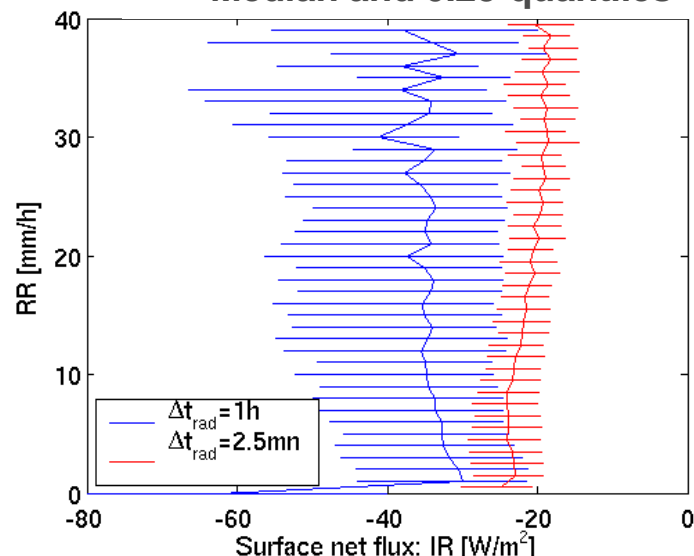
13/08/2004

Median and 0.25-quantiles



21/06/2004

Median and 0.25-quantiles



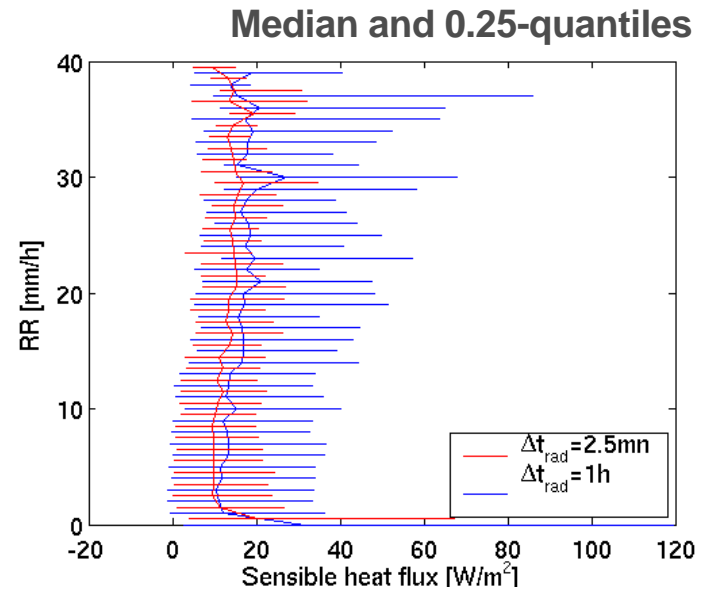
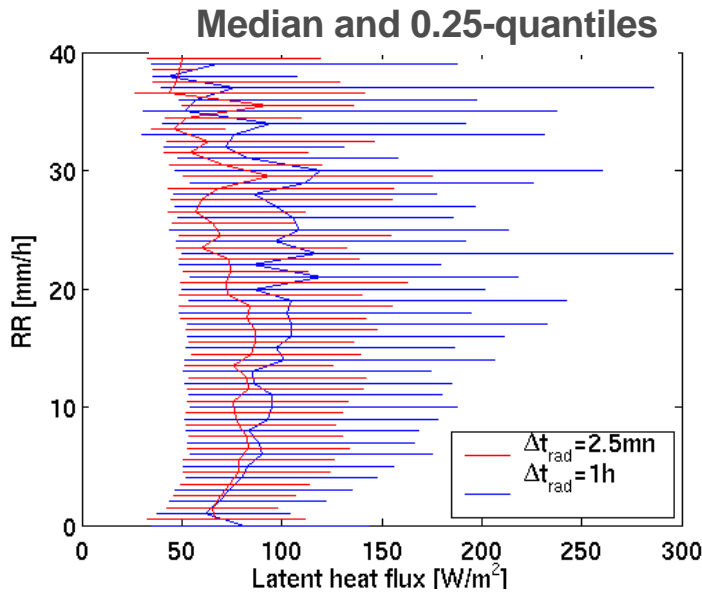
Prognostic
precipitation

Diagnostic
precipitation

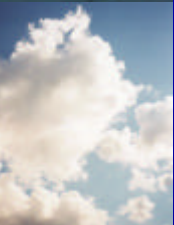
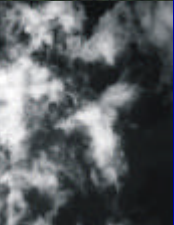


Motivation: Turbulent Fluxes vs. Rainrate

13/08/2004

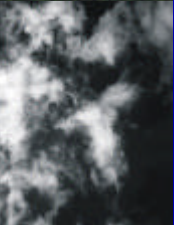


Prognostic
precipitation



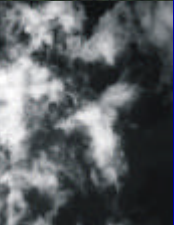
2-Stream RT parameterisation

- Physical calculation: 2-stream RT parameterisation of the LM
 - Ice and water clouds profiles
 - Water content and cloud fraction
 - Aerosols and gasses
 - Surface albedo
 - Several spectral bands
- Computationally expensive for NWP
 - One computation per hour
 - Small part of the needed space-time volume
- Pragmatically: saved development of the physical calculation



Scientific agenda

- Get away from the grid
- Treat processes at their spatial and temporal scales and their 'complexity'
- Parameterisation will not go away soon
 - 7 km to 1 km: $7 \times 7 \times 7 \times 2 \sim 700$, or to 100m: 10^7
 - Moore law: doubling every 1.5 years
 - Thus this would take 19, or 38 years, resp.
- Also at these scales there are still processes that need to be parameterised!



Adaptive generalisation

- Learning algorithm to learn weights
- Fitness: Prediction of the results, e.g. c_f
- Using results and the model state from the other detailed models
- Flexible weighting
 - Spatial Cartesian
 - Spatial Geophysical
 - Dynamical, meteorological
 - Similar soil type(s), ...
- Computational load generalisation is part of the cost function
 - Default hierarchy

Adaptive parameterisation

- Physical calculation in part of the model field
 - Adaptive generalisation to obtain a full field
-
- Physical calculation
 - More computationally expensive as the normal parameterization
 - Much more advanced parameterisation
 - Nested higher resolution model
 - Adaptive generalisation
 - Uses the high quality calculations
 - Simple adaptive algorithm
 - Assimilation type problem

