An improved adaptive radiative transfer scheme

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1 Introduction

We introduce the term

"adaptive parameterisation scheme"

for a scheme, which uses multiple parameterisations (simple & efficient and complex & accurate), which aid each other to make the scheme accurate and efficient.
This poster presents an adaptive radiative transfer (RT) parameterisation scheme, which has been implemented and tested in COSMO.
The general idea is probably applicable to many parameterisations in complex geophysical models.

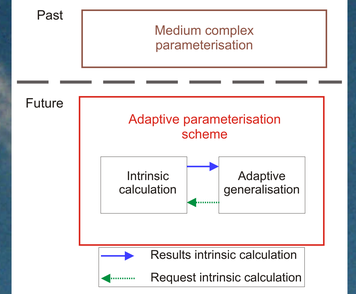
2 Adaptive parameterisation scheme

An adaptive parameterisation has two parts:

Intrinsic calculation of subscale processes
- Called in fraction of the time steps, columns or grid boxes
- More complex and physical
- Can be called by the adaptive generalisation (not used here)

Simple (statistical) adaptive generalisation
- Generalises the results to the full domain
- Utilises nearby intrinsic results to avoid biases (exploiting atmospheric spatio-temporal correlations)

3 Adaptive parameterisation scheme

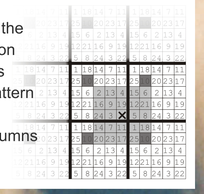


4 Radiative transfer scheme

- *COSMO model uses the delta 2-stream radiative transfer approximation*
  →Liquid and ice cloud water, cloud cover profile, gas absorption, aerosols, ground albedo
  →COSMO-DE: Called every 15 minutes, 2x2 columns are averaged
  →Costs about 5 % of calculation time
- *Infrequent call and averaging lead to*
  →Errors in radiation (plate 7, 8, 9)
  →Other weather development (plate 10)

5 Spatial adaptive scheme

- This scheme uses spatial correlations (mainly in the cloud field)
- In every 5x5 intrinsic region, one intrinsic (2-stream RT calculation) is performed every 2.5 minutes
- In which column the intrinsic calculation is called depends on the regular pattern to the right
- For the other columns see plate 6



6 Spatial local search method

- The spatial adaptive scheme computes the radiation at the other 24 columns by searching for similar column in the vicinity
- Search region 5x5 pixels
- Similarity index to be minimised:

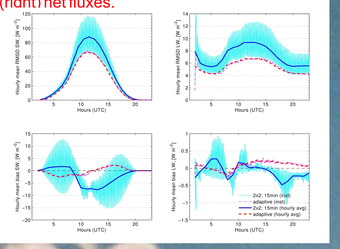
$$\delta = w_1\Delta CCL + w_2\Delta CCT + w_3\Delta LWP + w_4\Delta IWV + w_5\Delta\alpha + w_6\Delta t + w_7\Delta d$$

with, w_i weights, *CCL*: cloud cover (low clouds), *CCT*: cloud cover (all clouds), *LWP*: total column cloud water, *IWV*: integrated water content, α: surface albedo, *t*: time, Δd: distance

- The weights are optimised
- The result is not sensitive to the weights

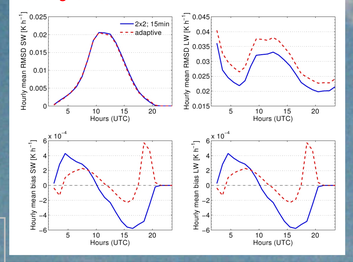
7 Diurnal cycle surface net flux

The root mean square error (top) and bias (bottom) of the shortwave (left) and longwave (right) net fluxes.



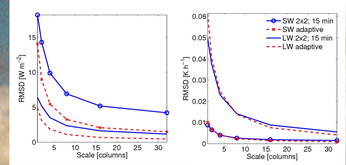
8 Diurnal cycle of heating rates

The same as plate 7 for the atmospheric heating rates.



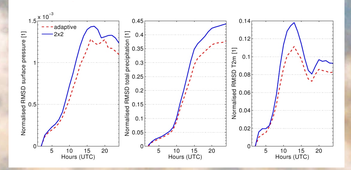
9 Scale dependence of errors

Plate 7 & 8 are computed at the model resolution. At coarser resolutions, the adaptive scheme performs better relative to the operational scheme increases for the flux (left) and heating rates (right). Large scales are likely dynamically more important.



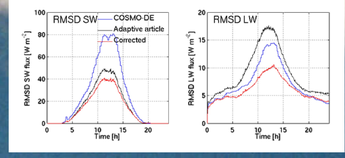
10 Deviations in single runs

This plate compares three free runs: 1. The reference run with a 2.5 min radiation time step at the model resolution (2.8 km). 2. The operational 2x2 scheme (time step 15 minutes). 3. Adaptive scheme.
The adaptive scheme deviates least.



11 Correction surface net flux

The optically important properties (LWP, cloud cover, albedo, etc.) of the selected most similar column will typically still differ (the selection is from a limited number of local computations). Correcting the surface flux for such deviations by multiple linear regression, reduces the RMSD.

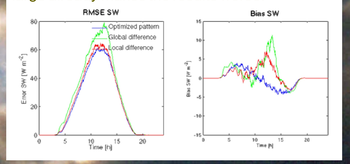


12 Further investigations I

* A similar correction as for the surface flux (plate 11) does not work for the atmospheric heating rates. It does work for the lower model layers individually, but these thin layers explain only a few percent of the total variance. A more general statistical model for all (lower) layers explains even less. On the positive side, if these adjustments are so hard to predict, they may also not influence model dynamics that much.
* The bias has a diurnal cycle for all schemes. This bias for the adaptive scheme can be reduced by 40% by subtracting one minute from the time before performing the solar zenith angle correction.

13 Further investigations II

* The column in which an intrinsic computation is performed follows a fixed pattern (plate 5). It could have made sense to perform these computations were the atmosphere changes most. However, making these computations where changes in surface fluxes themselves are large already makes the results worse.



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