Meteorologisches Institut

Universität Bonn

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Results of an Adaptive Radiative Transfer Parameterisation for the Lokal-Modell

LM-User-Seminar

5th – 7th March 2007, Langen

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Outline

- The idea and approach
- Results
  - Improvements in RMSE
  - Improvements in model consistency
- Summary
- Outlook

The Idea: Adaptive parameterisation

calculate **error-estimator** based on a **simple radiation scheme** for each grid point

Grid points where…

…Δ 'large' → Recalculate radiation fluxes with exact scheme

…Δ 'small' → Apply „perturbation method" for surface fluxes

Perturbation method:

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

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

Approach

- **Simple radiation scheme:**

  → Multivariate linear regression

- Predictands:
  - longwave: $L^{\downarrow}_{sur}$
  - shortwave: transmissivity: $c = e^{-\tau}$

- Distinction of 4 categories, with different sets of predictors:

solar cloud free	infrared cloud free
solar cloudy	infrared cloudy

Simple radiation scheme

Predictors: SOLAR

Cloudfree	Cloudy
Cosine of solar zenith angle	LWP
IWV	CLCL
Surface pressure	CLCT
Continental aerosols	Cosine of solar zenith angle
	Cloud thickness
	IWV
	Temperature at cloud base

Simple radiation scheme:

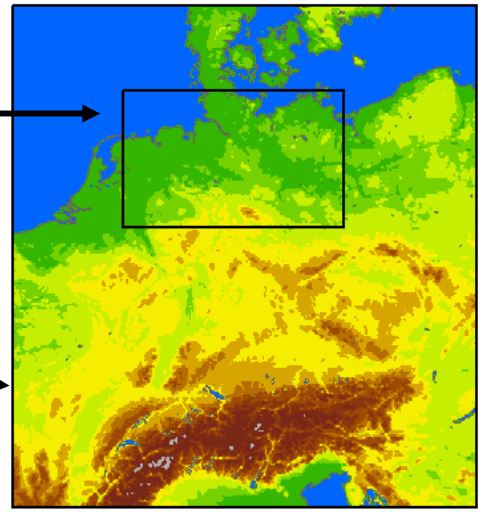
Predictors INFRARED

Cloudfree	Cloudy
IWV	IWV
Surface temperature	Temperature at cloud base
Cosine of zenith angle	Surface temperature
	CLCT
	Cloud thickness
	CLCL
	Cosine of zenith angle
	LWP

Approach

Implementation of adaptive scheme into LM

- First tests and configuration on PC (small model domain)
- After successfull implementation: exemplary cases on LMK-domain on parallel machine at DWD



- Horizontal resolution: 2.8 km
- Frequency of call to adaptive scheme: 2.5 min

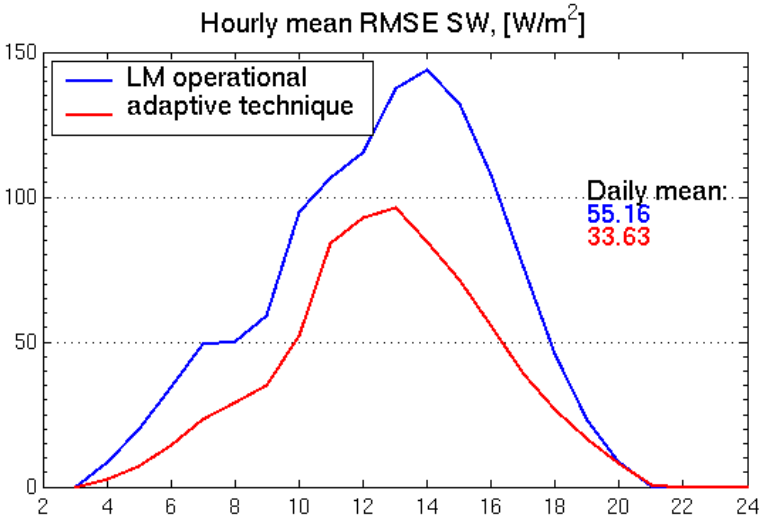
Approach

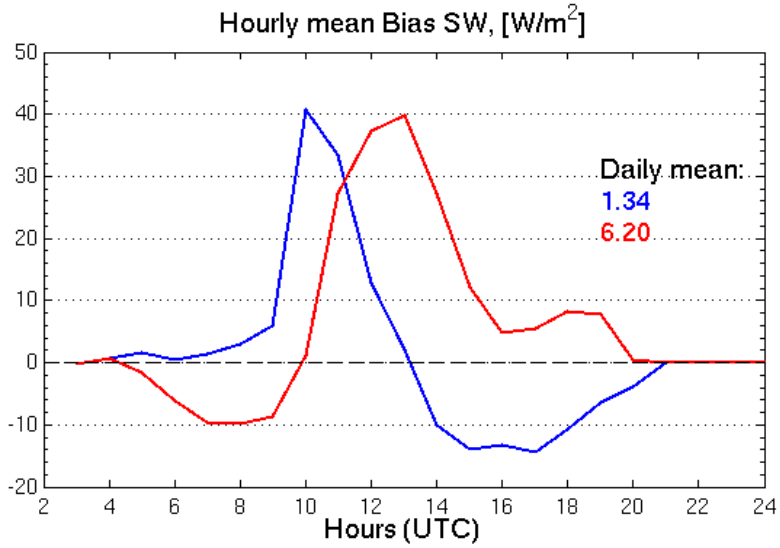
- Problem: Radiation of 3 separate model runs not comparable due to different evolution of cloud field
  → Development of a model version „3 in 1“:
  - Calculation of the radiation fluxes
    - hourly
    - adaptive
    - frequently (every 2.5 min)

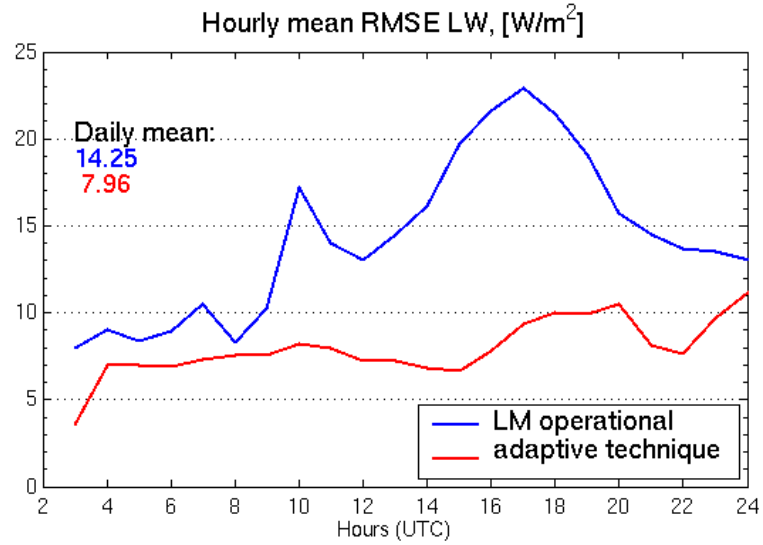
    ... in the same model run
  - Dynamics only influenced by frequent radiation

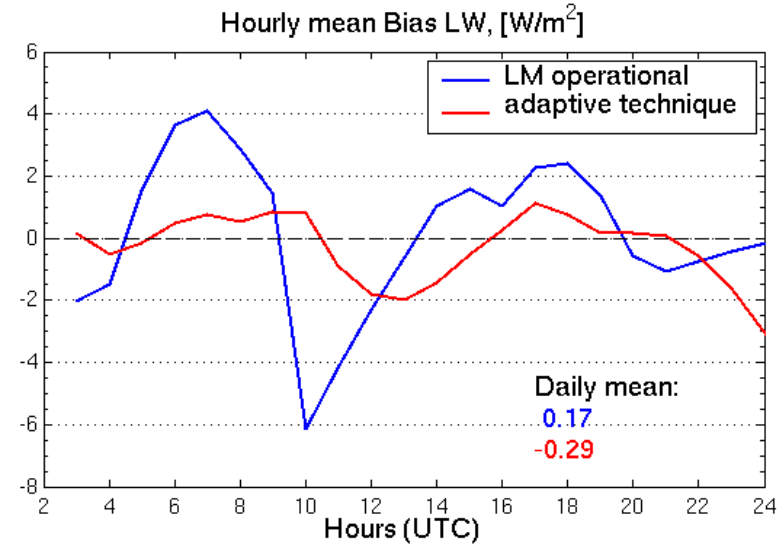
- Test for 3 summer days characterised with much convection

Results: 21 June 2004, small model domain

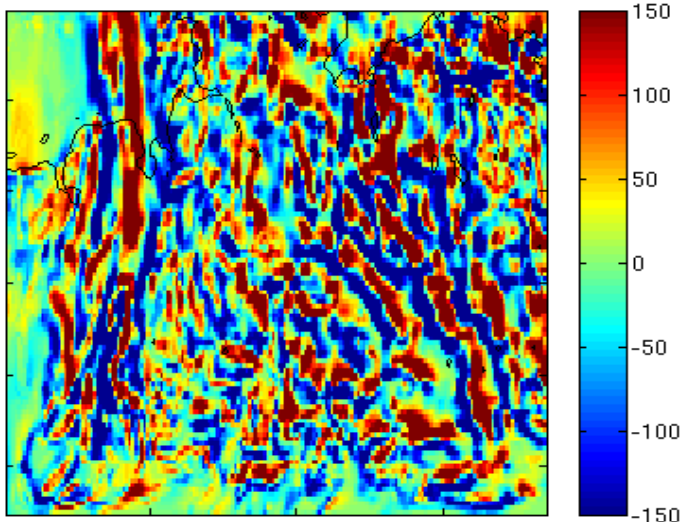






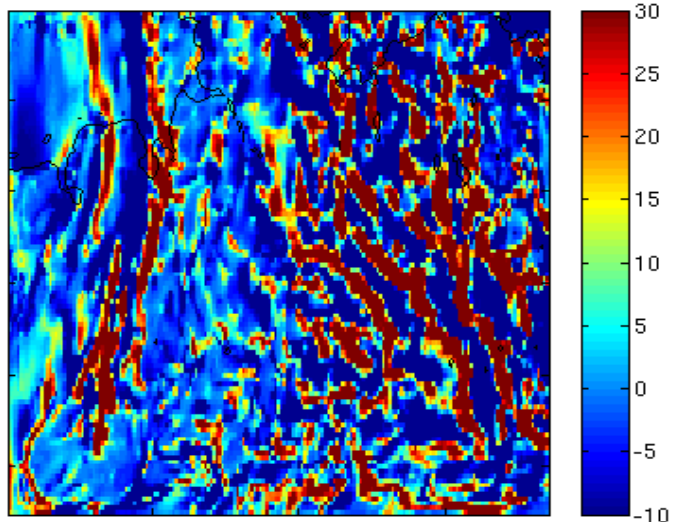


SW: Persistence minus exact [W/m^2]



RMSE: 124.742
Bias: -8.03375
Max: 404.282

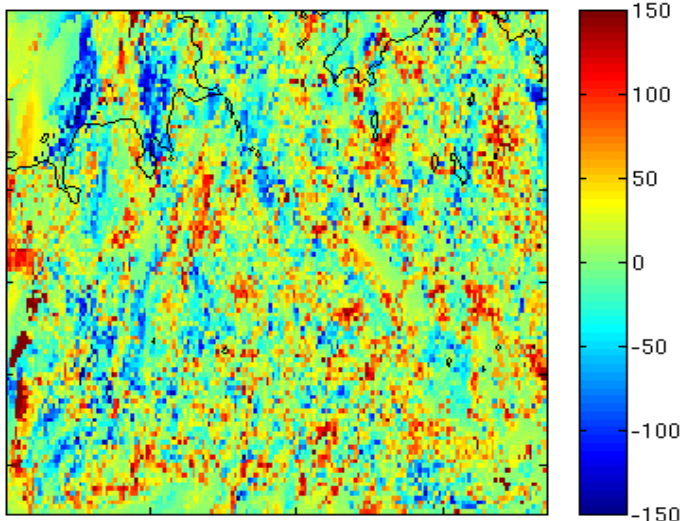
LW: Persistence minus exact [W/m^2]



RMSE: 27.2055
Bias: 1.1977
Max: 96.2182

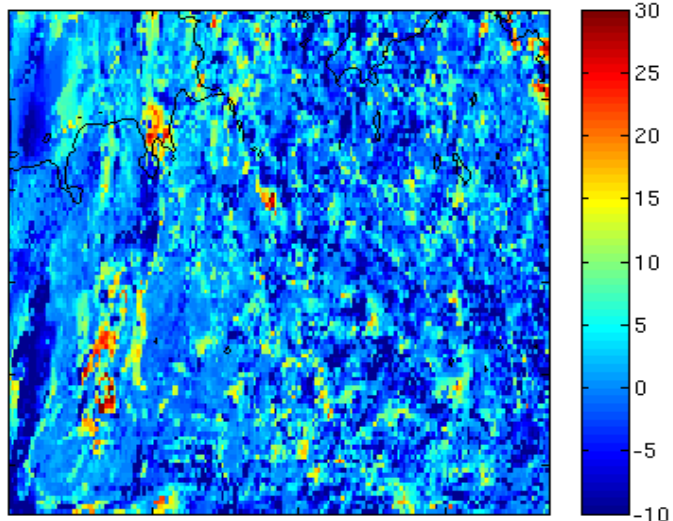
Example-error-fields for 15:30 UTC

SW: Adaptive minus exact [W/m^2]



RMSE: 50.0058
Bias: 7.95416
Max: 254.74

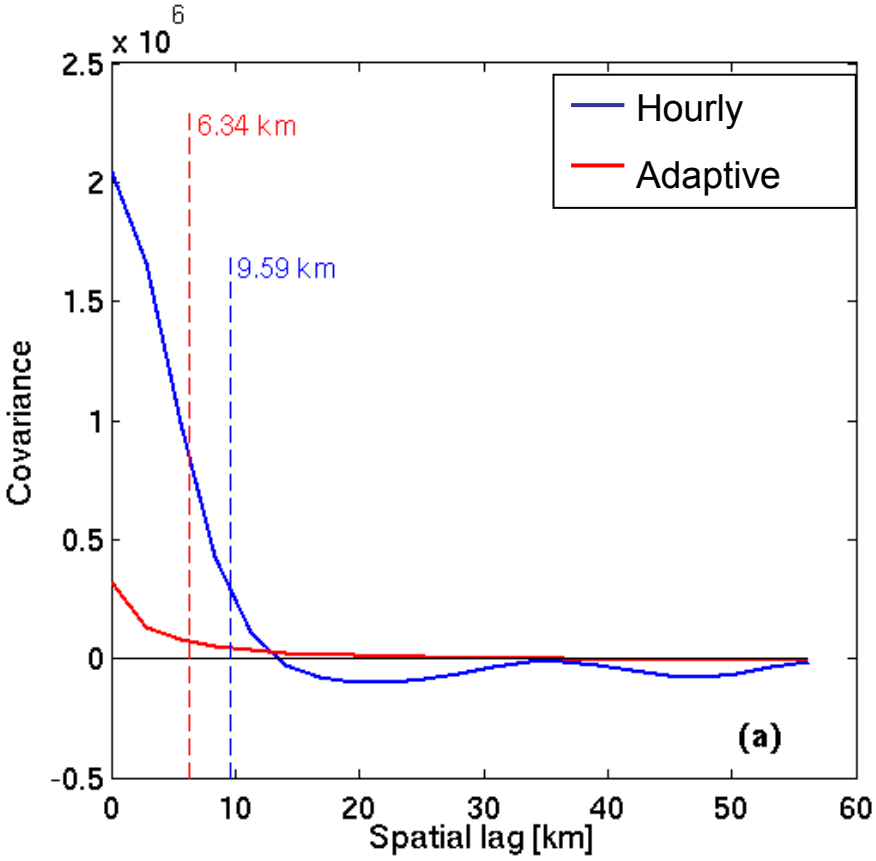
LW: Adaptive minus exact [W/m^2]

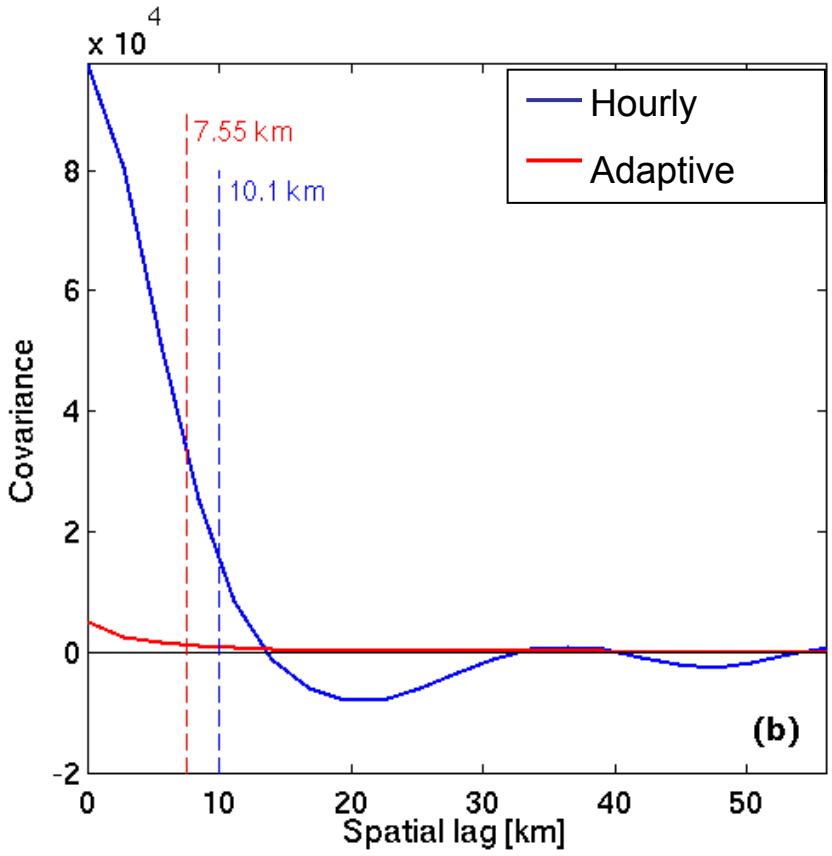


RMSE: 6.13857
Bias: 0.0375747
Max: 32.0265

Initialisation at 02:00 UTC

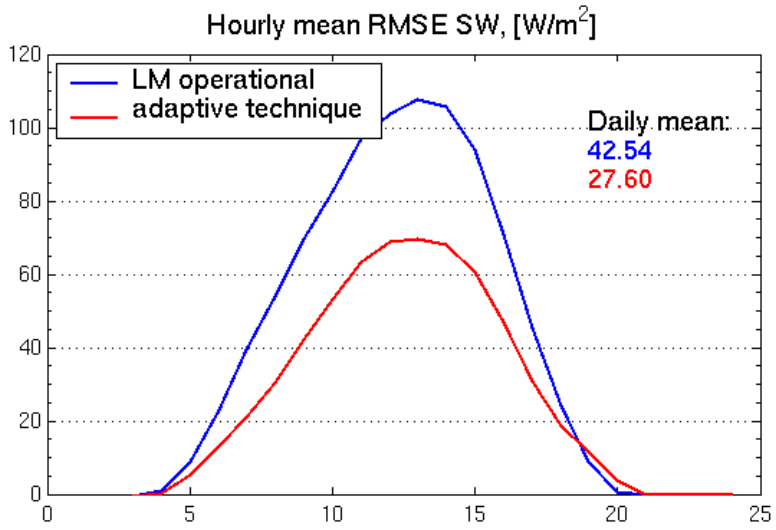
Correlation lengths for error fields (15:30 UTC)

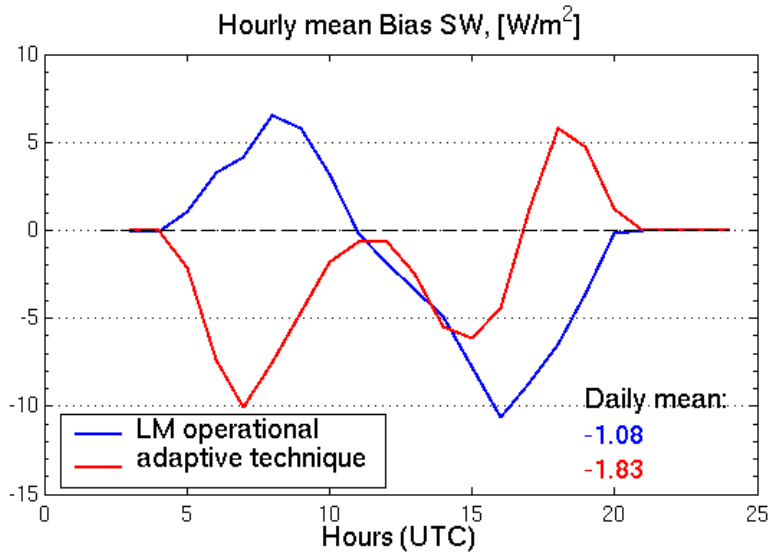


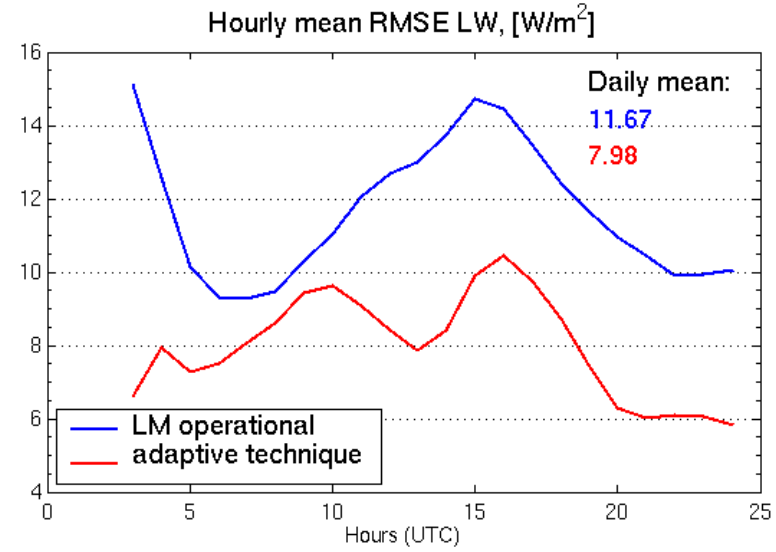


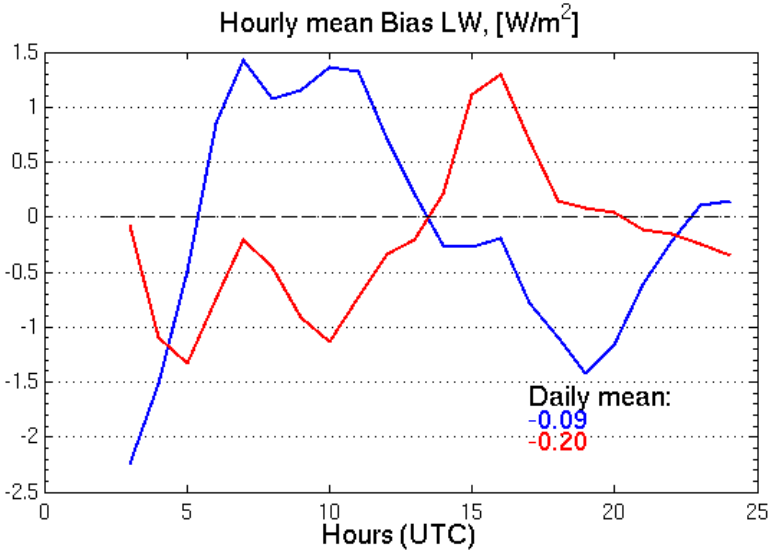
The covariance functions of the errors in the solar (a) and infrared (b) fluxes at the surface.

Results for 13 August 2004 (LMK domain)

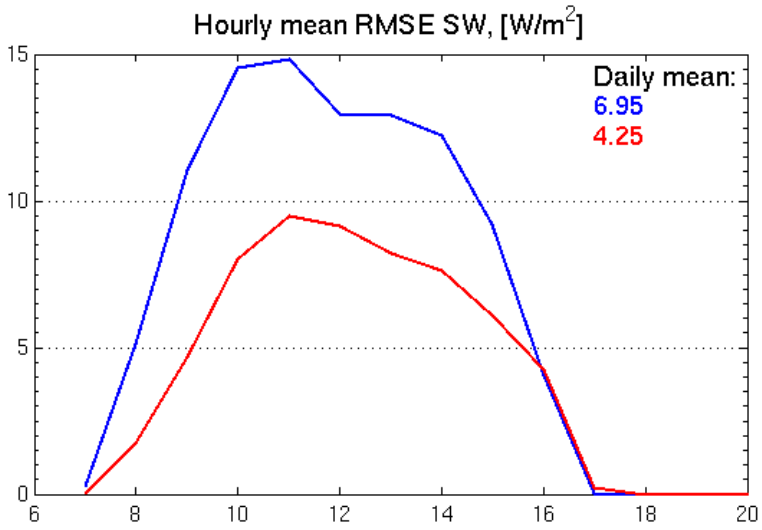


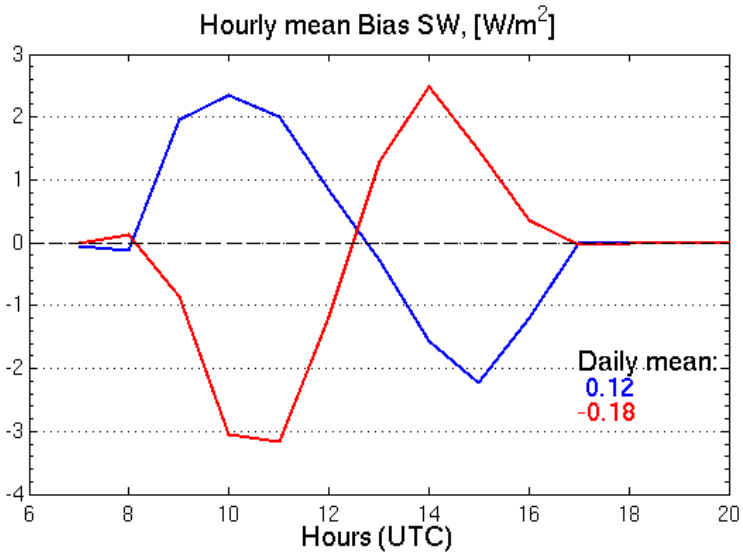


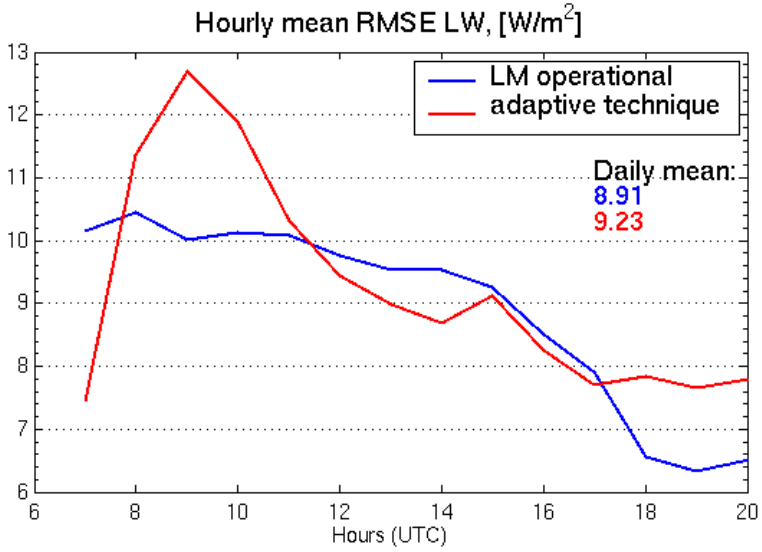


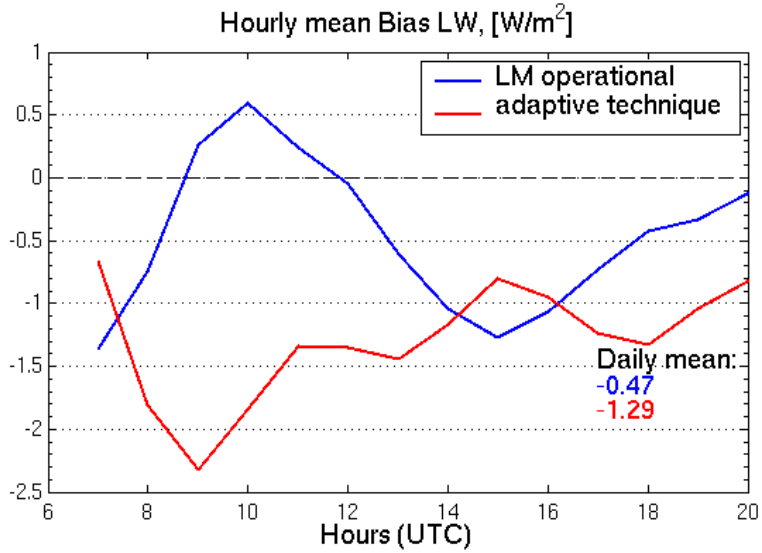


Results for stratiform winter day: 22 December 2005

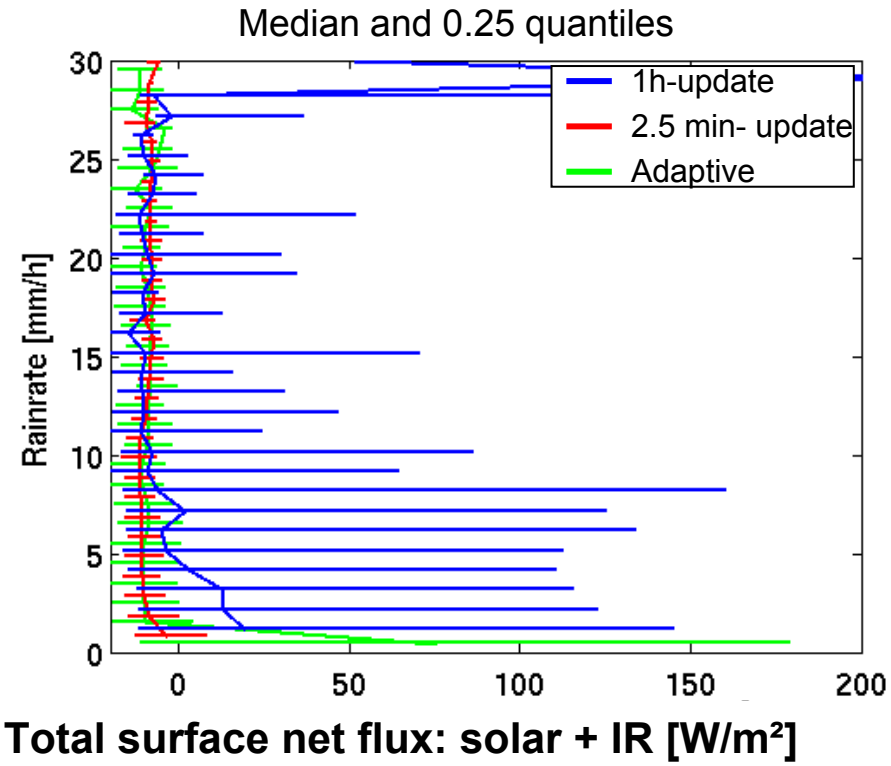




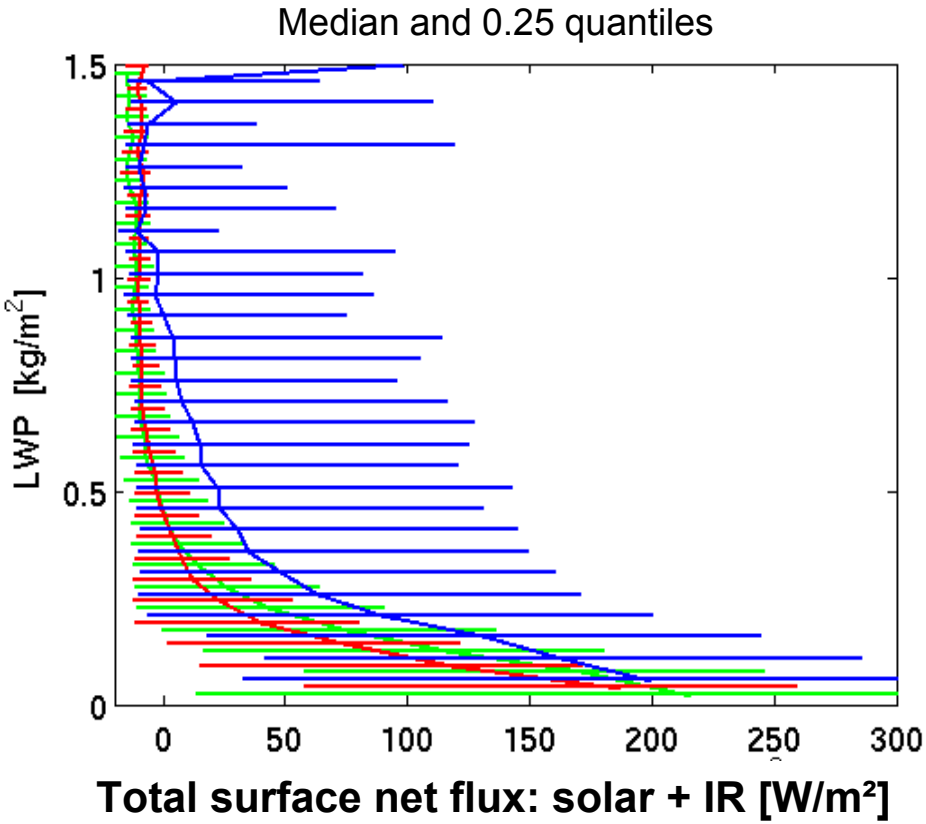




Results: Improvements of model consistency



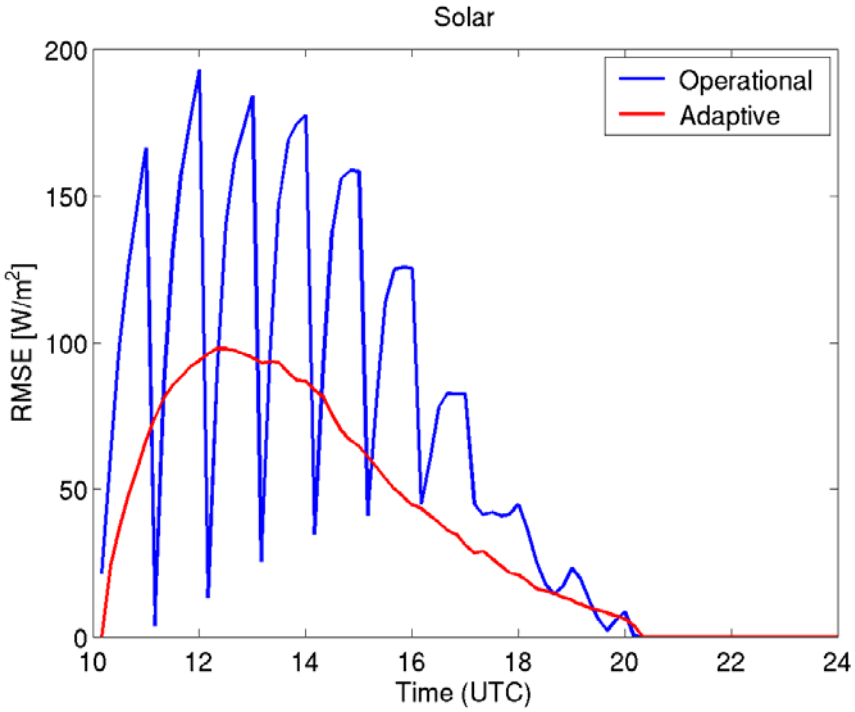
21 June 2004

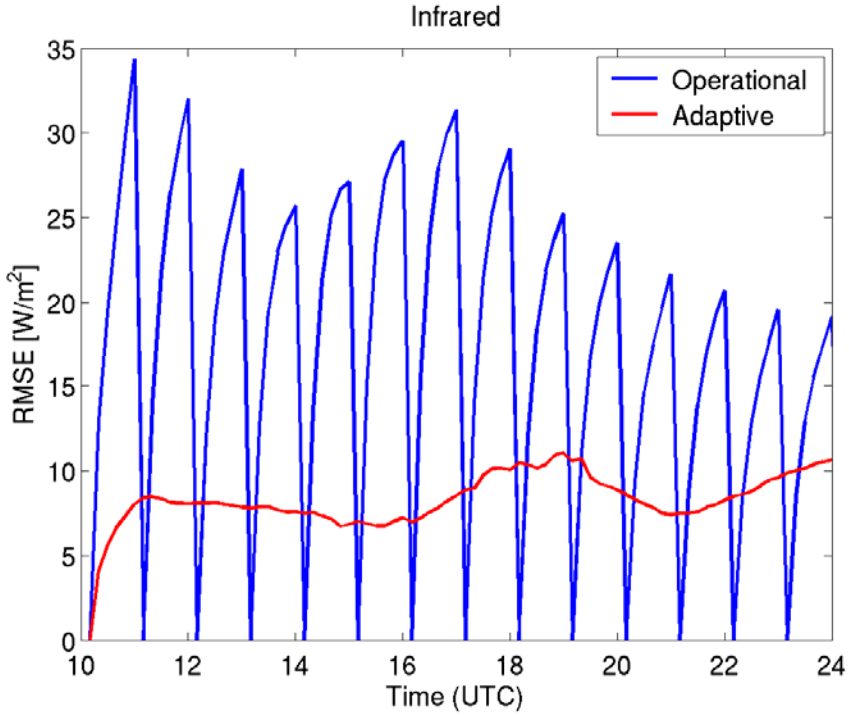


Adaptive approach leads to a considerable reduction of unrealistic situations

Instantaneous RMSE

21June 2004

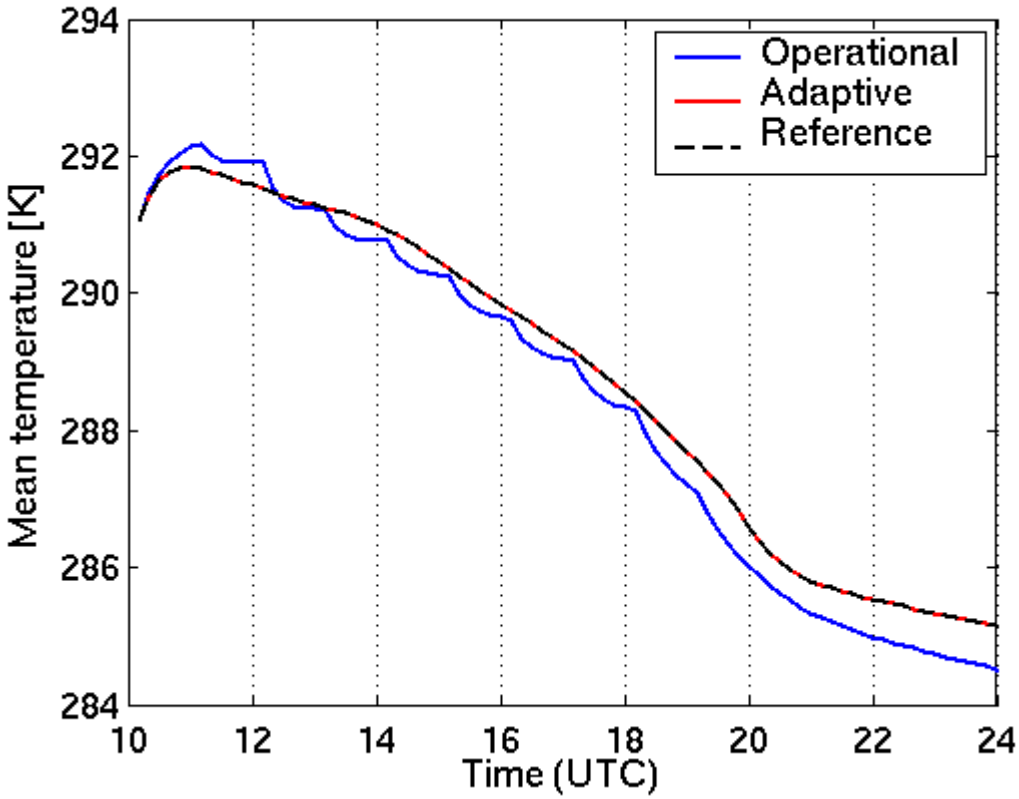




with adaptive scheme smoother error curves

Smoother developing of model variables with time

Surface temperature



21 June 2004

Adaptive approach prevents „wavy“ structure of developing of variables with time

Summary

- Improvements of RMSE:
  - 30% to 40% for SW,
  - 13% to 44% LW fluxes
- for one exemplary stratiform winter day
  - 40% improvement for solar fluxes
  - 4% detoriation for infrared fluxes
- Daily biases worse than in operational mode
- More self-consistent and smoother model runs

Outlook: improvement opportunities

- Separate regressions for winter and for summer
- „Online learning“ regression
- Other simple radiation scheme instead of regression :
  - very simple physical scheme
  - neural network
- Application to whole vertical column, not only on surface fluxes
- Comparison to LMK radiation update configuration
- Application to other parts of model physics

Thank you for your attention!

For further information see also:

www.meteo.uni-bonn.de/venema/themes/adaptive_parameterisations/

Motivation: Sensitivity Study

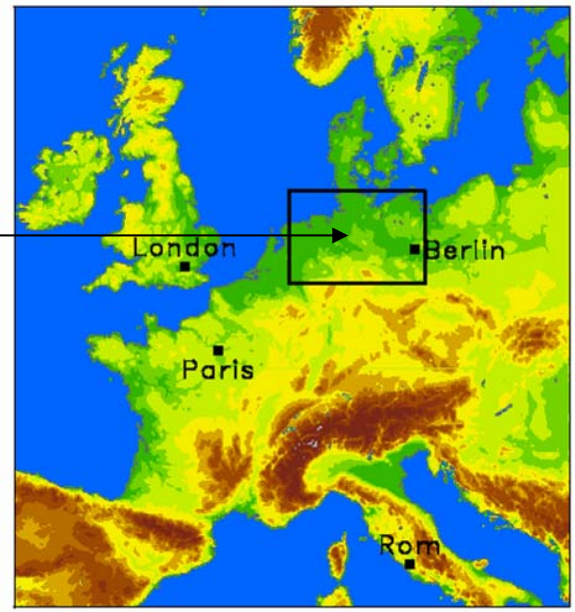
- Comparison:

LM with
hourly radiation

LM with
Radiation
every 2.5 min

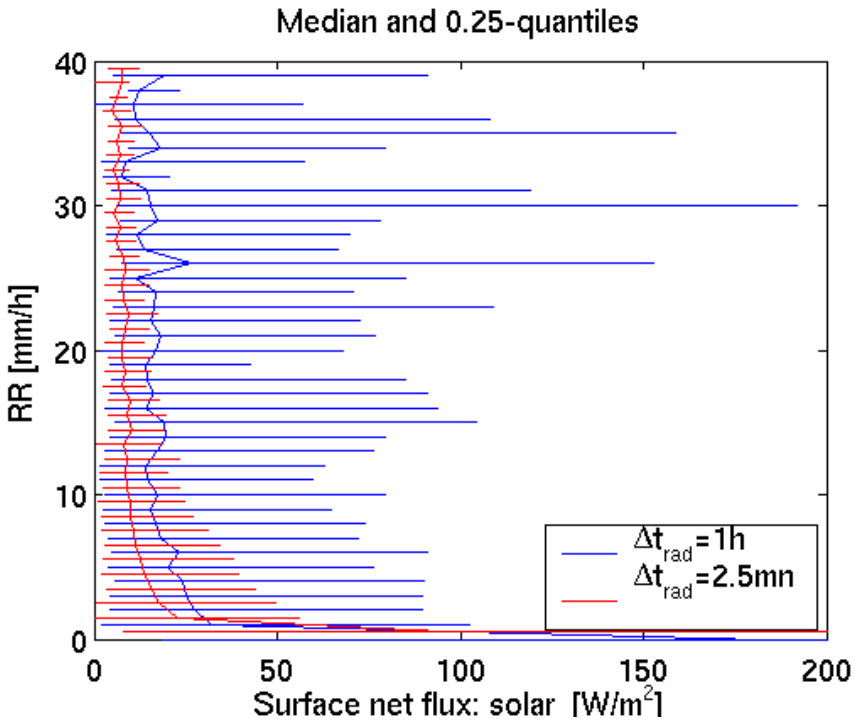
Model domain:

Horizontal
resolution: 2.8 km



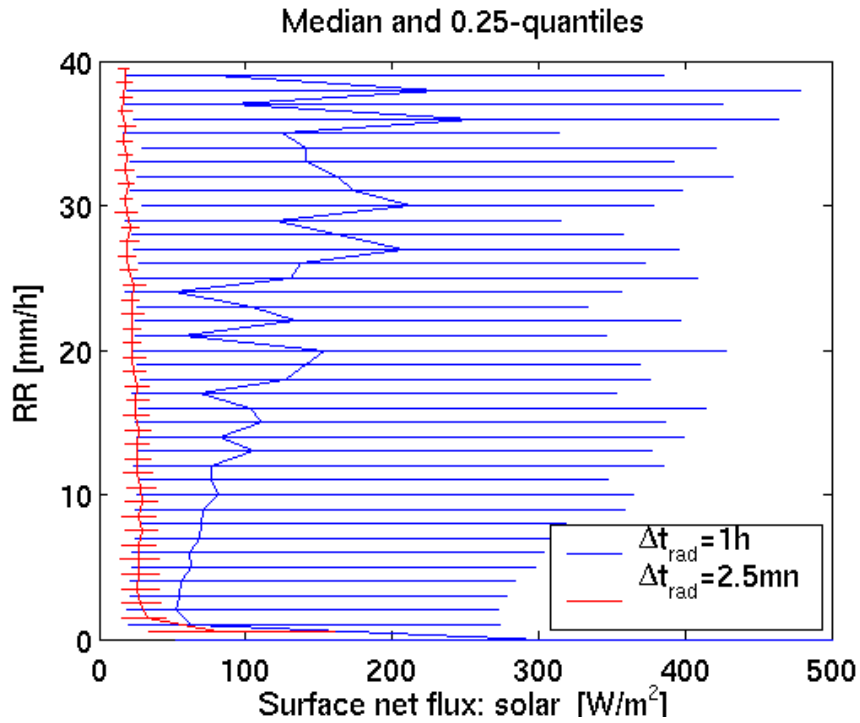
Motivation: Solar radiation flux vs. rainrate

13/08/2004



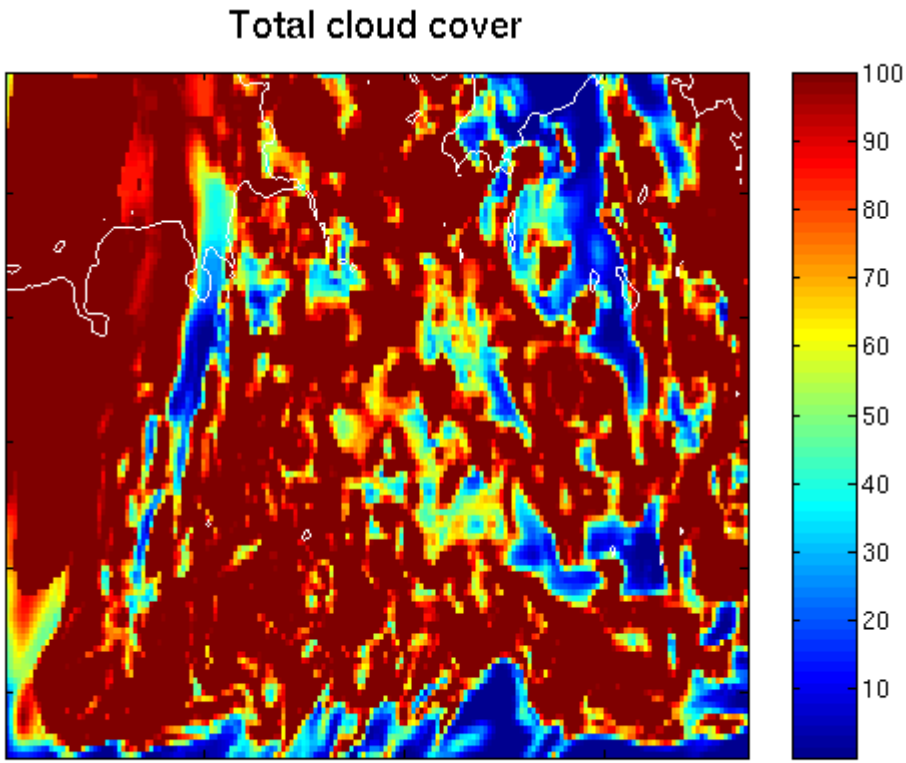
Prognostic precipitation

21/06/2004



Diagnostic precipitation

Cloud field 15:30 UTC

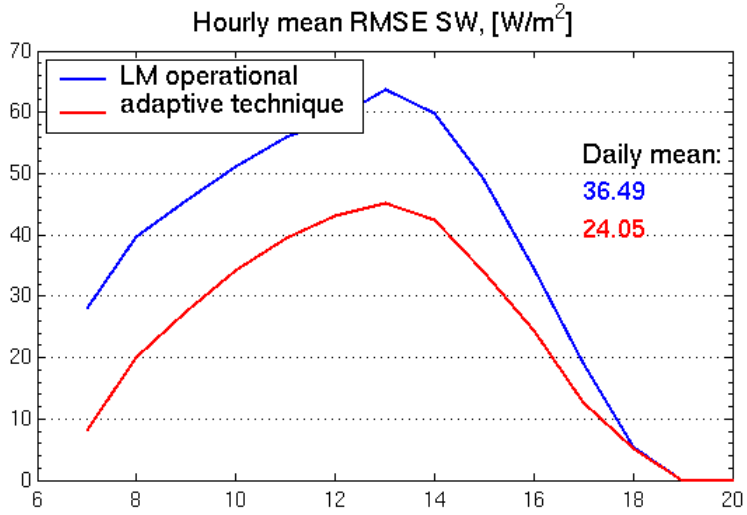


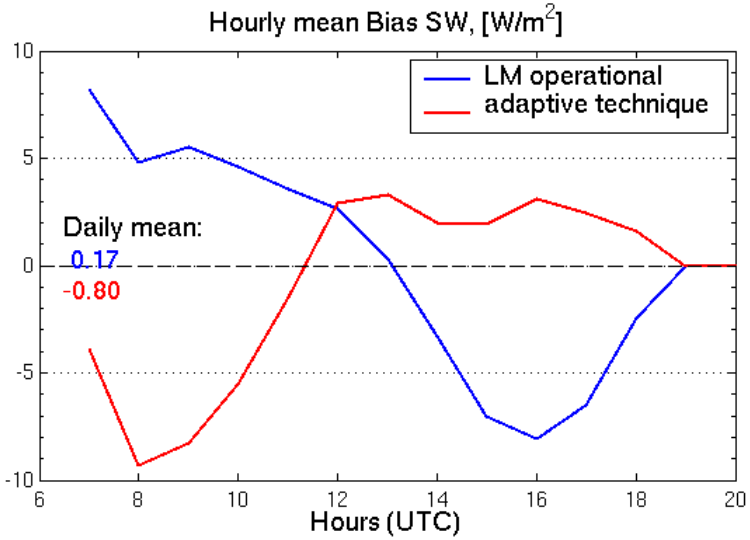
Parallel Mode

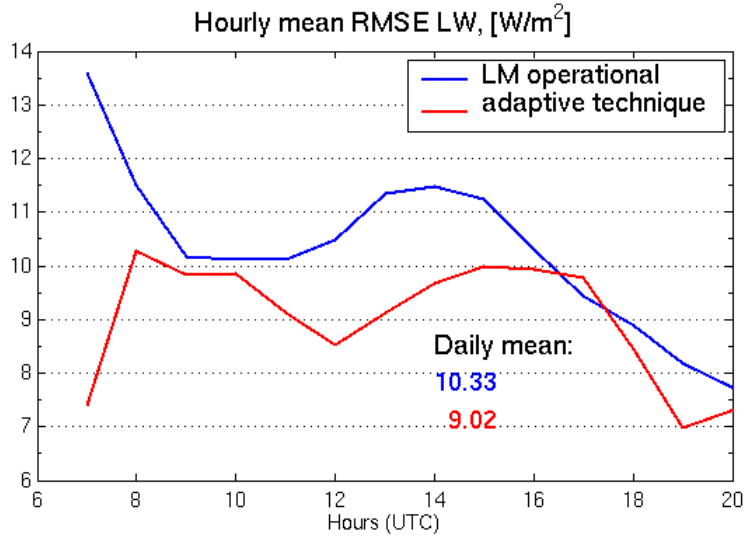
- Number of allowed updates is prescribed, therefore computation of error estimator for whole model domain and recalculation of „worst“ gridpoints
- Communication between processors required
- Processors have to wait for each other
- Adaptive selection for whole model domain too expensive!

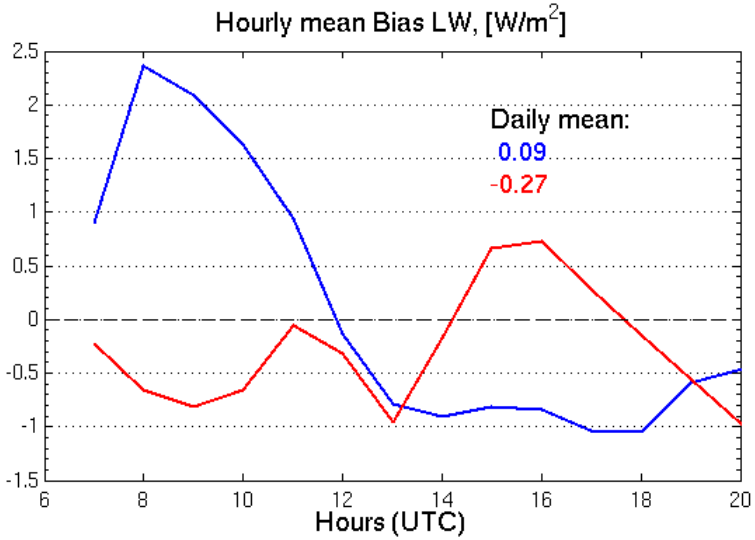
- ⟹ Adaptive selection related to subdomains

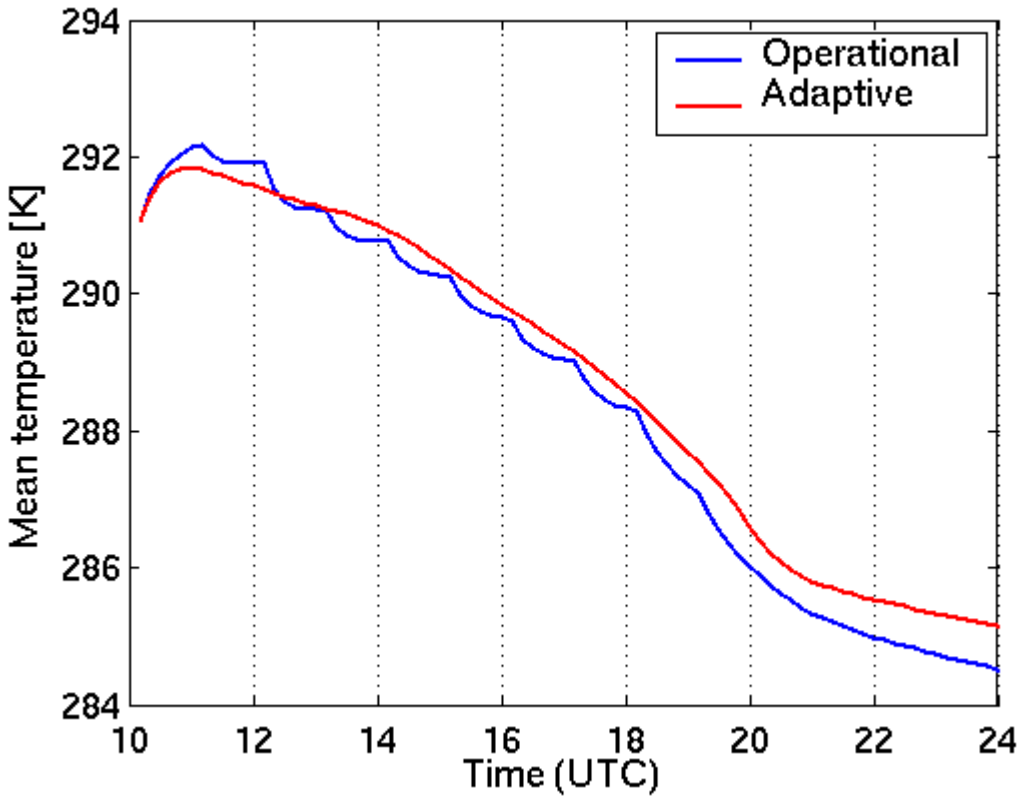
Results for 19 September 2001, large model domain





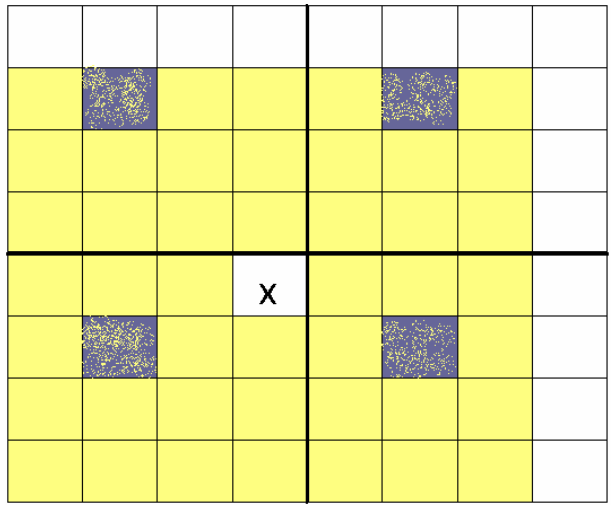





294
292
290
288
286
284
Mean temperature [K]
10
12
14
16
18
20
22
24
Time (UTC)
Operational
Adaptive

Adaptive RT parameterisation II: “Search Scheme”

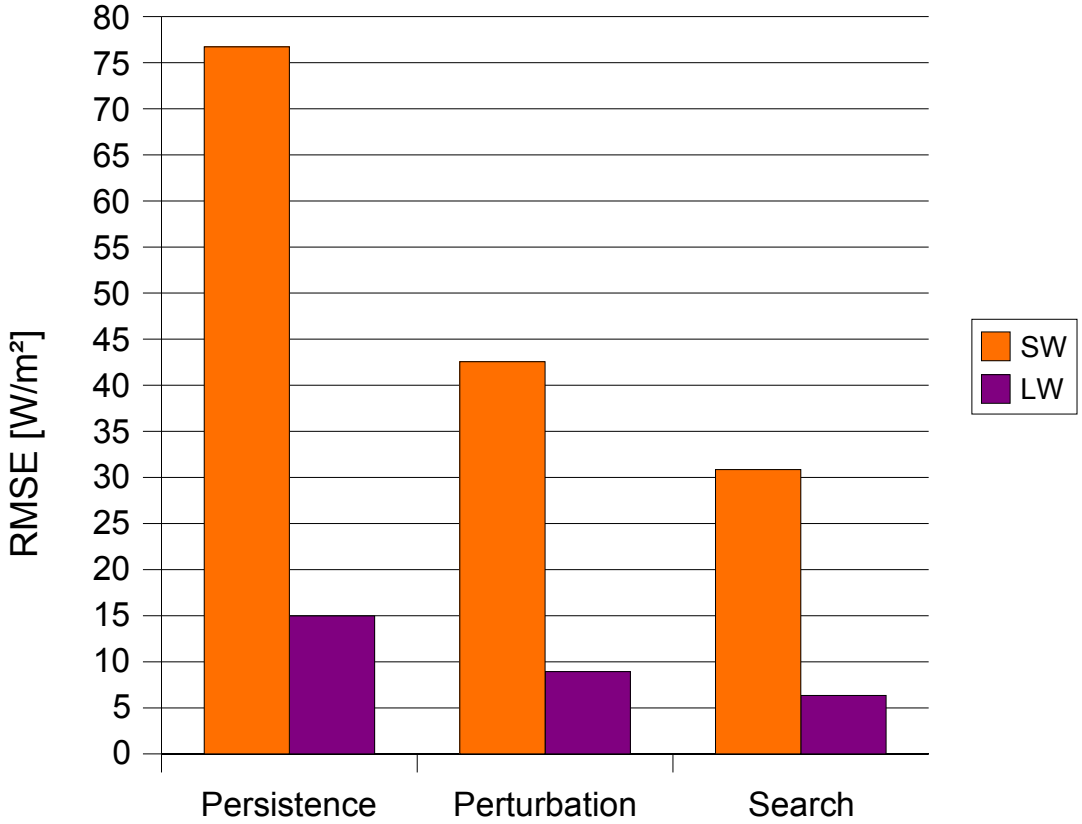
- uses spatial correlations
- update every 5 minutes one out of 4x4 columns
- for other 15 columns: search for similar column in the vicinity (search region 7x7 pixels)
- similarity index to be minimised:

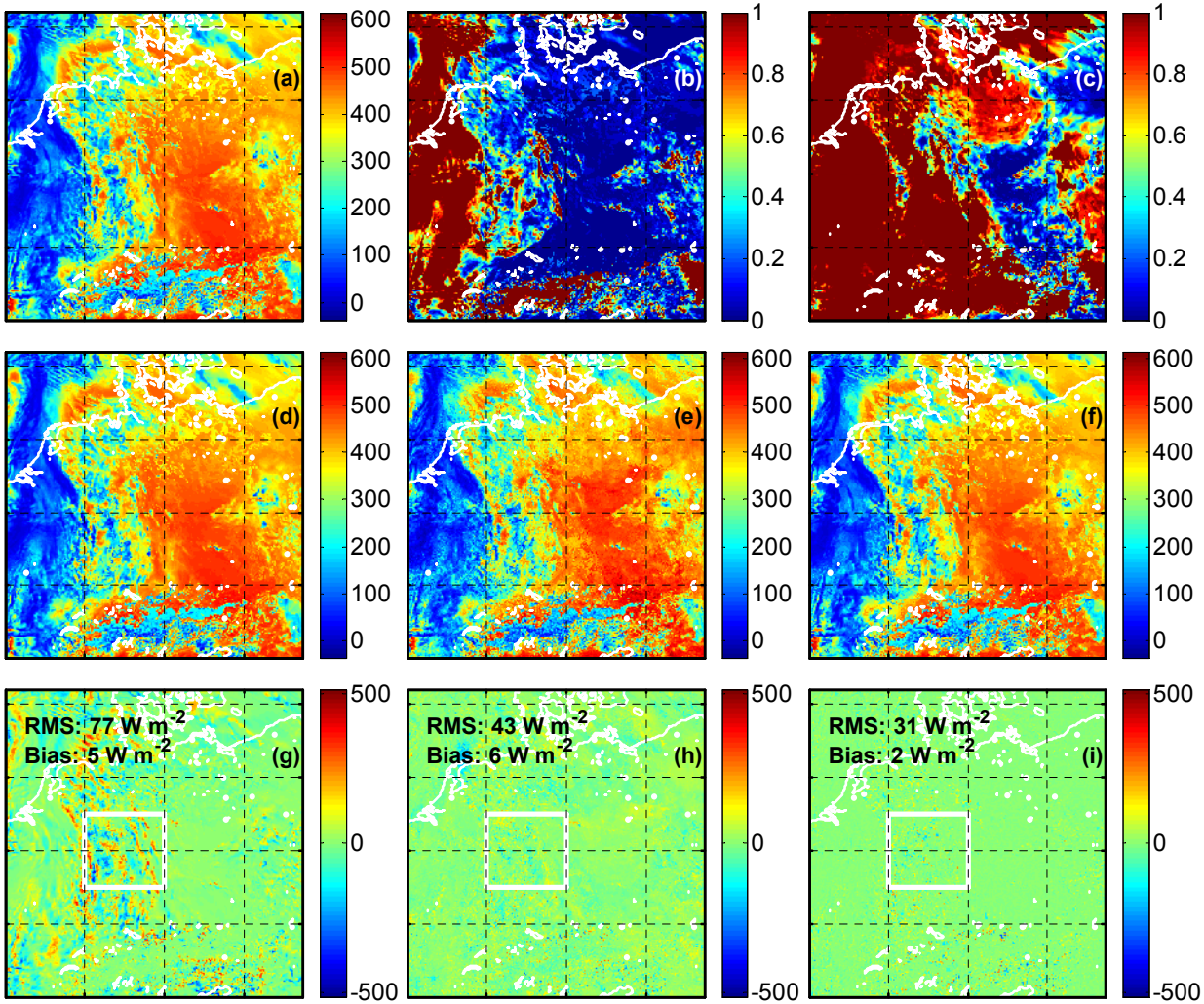


$$\delta = w_1 \Delta CCL + w_2 \Delta CCT + w_3 \Delta LWP + w_3 \Delta \alpha + w_4 \Delta t$$

Comparison of adaptive schemes for a case study

19 September 2001, 12:30 UTC,
offline versions





Errors in the solar heating rates (W m-2) in the LM at the surface for 12.30 h UTC.
(a) The two-stream calculation of the solar surface flux is the reference field
(b) Cloud cover of low clouds
(c) Total cloud cover
(d) the 1-h persistence assumption,
(e) the adaptive perturbation scheme,
(f) the adaptive search scheme. The corresponding errors are shown in the same order in the third row.