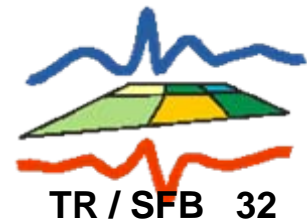


Scale-consistent two-way coupling of land-surface and atmospheric models

COSMO-User-Seminar

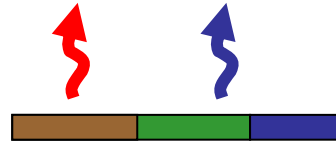
9-11 March 2009

Annika Schomburg, Victor Venema, Felix Ament, Clemens Simmer



Objective

Scale consistent two-way coupling of land-surface and atmospheric models



- Better simulation of the turbulent heat fluxes between these subsystems
- Resolve processes in subsystems atmosphere and surface on their own intrinsic scales
 - account for larger small-scale heterogeneity at surface

Objective

Two effects of surface heterogeneities:

- In small scale models like the COSMO-model the **dynamical effect** of heterogeneity-induced mesoscale circulations can be modeled explicitly to a large degree
- Problem of **nonlinear aggregation effects** remains relevant even at high horizontal resolutions: Scale of surface heterogeneities much smaller than scale of high-resolution weather forecast models

$$\overline{F(x)} \neq F(\bar{x})$$

Objective

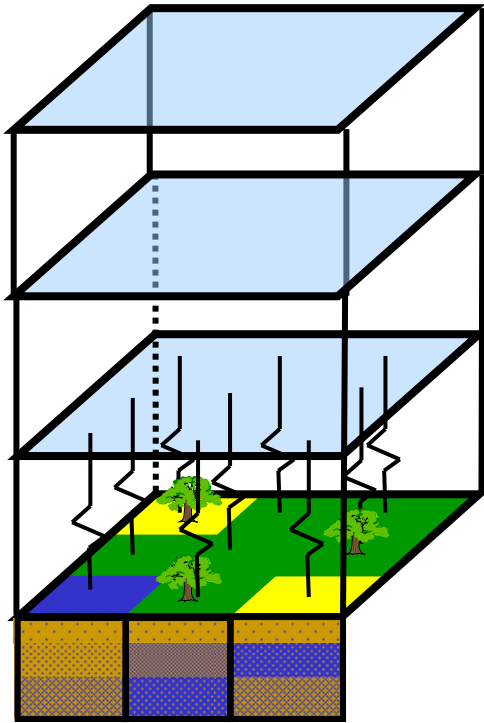
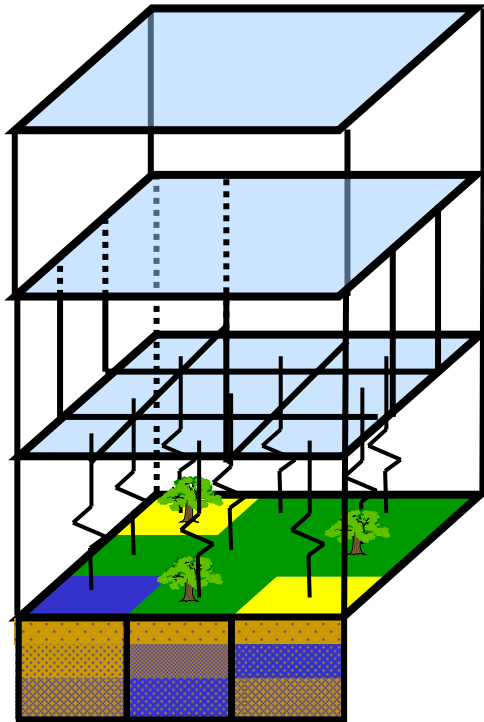


Figure: by F.Ament

- Mosaic approach: Higher horizontal resolution of soil/surface than of atmosphere to account for smaller spatial scales at surface
- Use subgrid information on surface characteristics as orography, land cover, soiltype
 - calculate soil properties and surface fluxes for each subgrid-column separately in soil model

Objective



- Upscaling: Grid box fluxes from surface are obtained by averaging these fluxes
- Usually: Assumption of homogeneous atmospheric forcing

→ **Development of downscaling rules for atmospheric variables on lowest model level**

- to mosaic-resolution
- Rules will depend on small scale surface information (dependent on weather situation)

→ avoid biases due to nonlinear processes

Motivation

- Spatial climate forcing variability one of the factors leading to surface variability
 - Assuming homogeneous atmospheric forcing this aspect is neglected
 - Atmospheric disaggregation should lead to a more realistic input for the soil module
 - should lead again to improvements for the fluxes

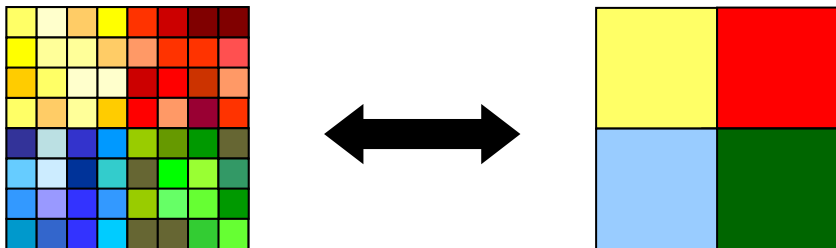
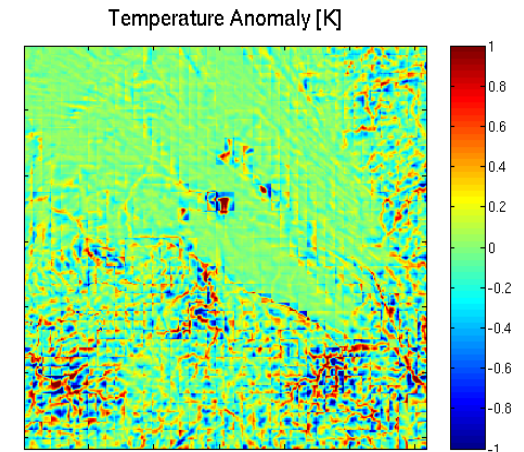
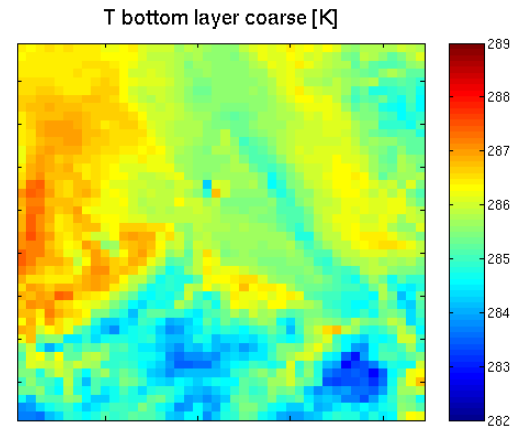
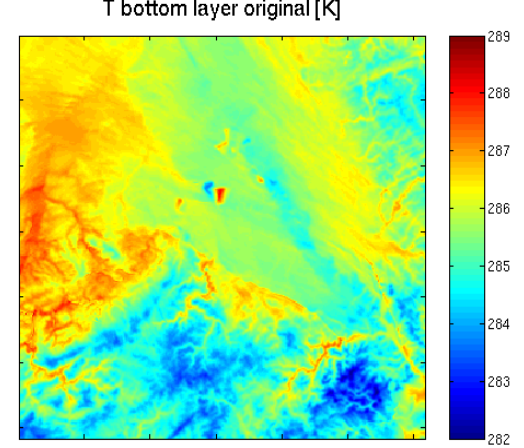
Approach: Variables to downscale

- Variables that are used as input for TERRA:

Temperature (<i>lowest model layer</i>)
Wind speed (<i>lowest model layer</i>)
Specific humidity (<i>lowest model layer</i>)
Shortwave radiation at surface
Longwave radiation at surface
Surface pressure
Precipitation

Approach

- Development and validation of disaggregation scheme by analysing high resolution model runs of different large-scale weather situations
 - 400 m grid spacing
 - compare 400 m information with averaged 2.8 km information → downscaling rules
 - later possible to use 2.8 km resolution with 400 m Mosaic
- main goal: reconstruct variability at small scale!



Approach: Model runs

Date	Hours of model run	Weather situation
20070827	24	changing cloud cover, no precipitation
20071014	48	clear sky
20080310	24	stormy, variable rain and clouds
20080501	48	convective
20080509	48	clear sky
20080607	48	convective
20080721	24	synoptically driven, stratiform rainfall
20080828	24	cloudy, some rain

Downscaling-Strategy

- **3 Steps:**
 1. Smooth field with splines
 2. Downscale field „deterministically“ by regression techniques (use subgrid-scale information like orography)
 3. Add white noise to reproduce original fine-scale variance
- If no rules for step 2. can be found (e.g. for precipitation) apply only step 1. and 3.

Downscaling-Strategy

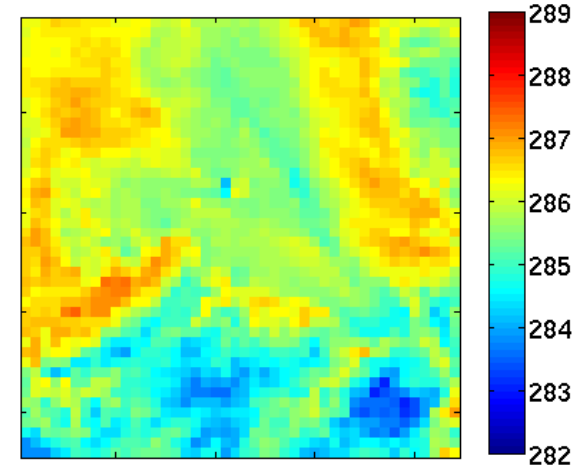
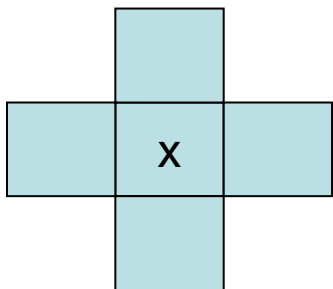
- **3 Steps:**
 1. **Smooth field with splines**
 2. Downscale field „deterministically“ by regression techniques (use subgrid-scale information like orography)
 3. Add white noise to reproduce original fine-scale variance
- If no rules for step 2. can be found (e.g. for precipitation) only step 1. and 3.

Step 1: Smoothing by splines

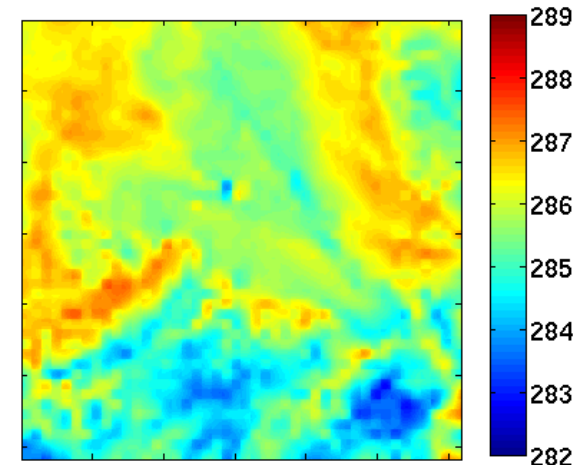
- Done for avoiding sharp edges
- Bi-quadratic-splines in x and y direction (piecewise polynomials with certain constraints at common points of adjacent pieces)

$$f(x, y) = a_1 + a_2x + a_3y + a_4x^2 + a_5y^2$$

- 5 unknowns → need of 5 constraints
 - Derivatives at edges should be equal
 - Mean value should be conserved



Temperature: Coarse field



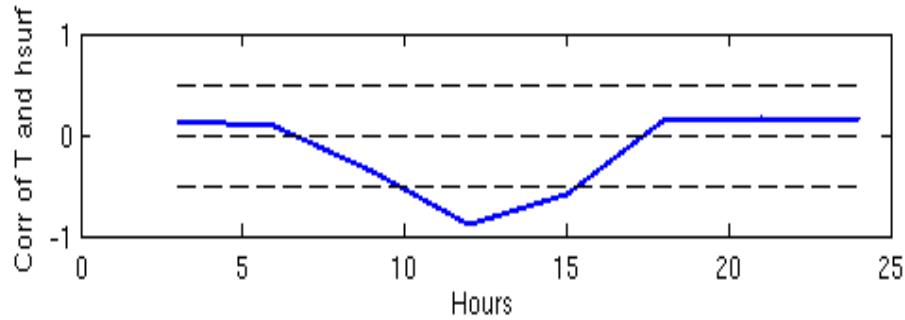
Smoothed field

Downscaling-Strategy

- **3 Steps:**
 1. Smooth field with splines
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 3. Add white noise to reproduce original fine-scale variance
- If no rules for step 2. can be found (e.g. for precipitation) only step 1. and 3.

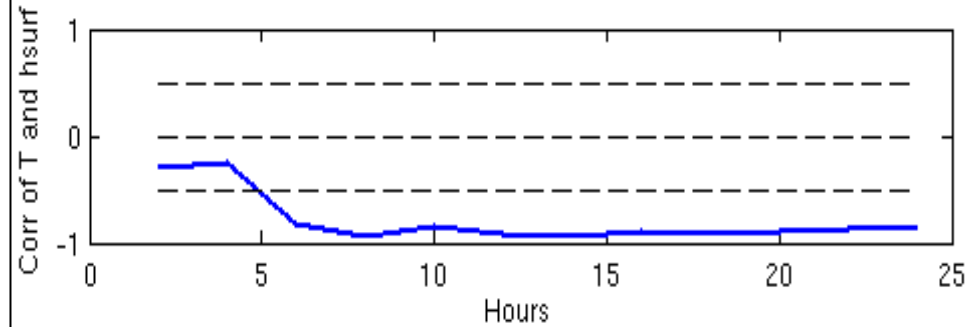
Mean Correlation vs time

Correlations: T with orography

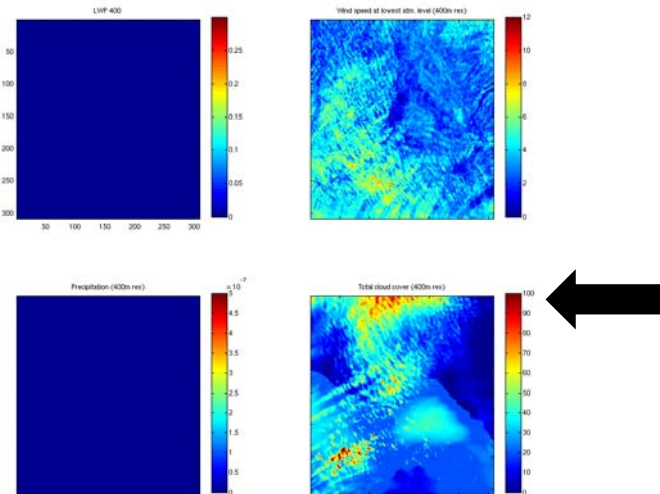


20071014: radiation day

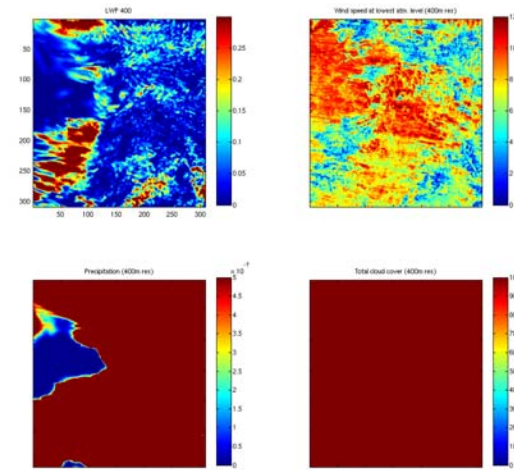
Correlations: T with orography



20080721: synoptically driven



LWP	Wind speed
Precipitation	Cloud Cover



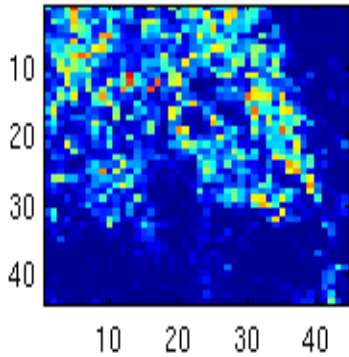
Temperature: 2D Correlations

20071014 (clear sky)

Correlation with

Orography

surface
temperature

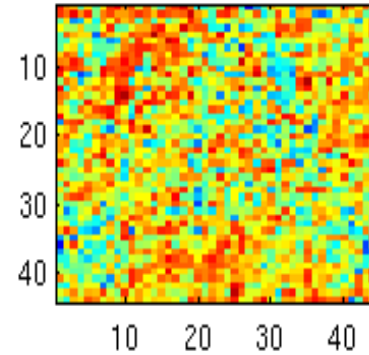


12 UTC

Correlation with

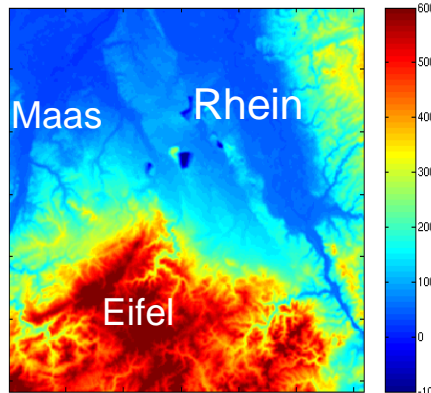
Orography

surface
temperature



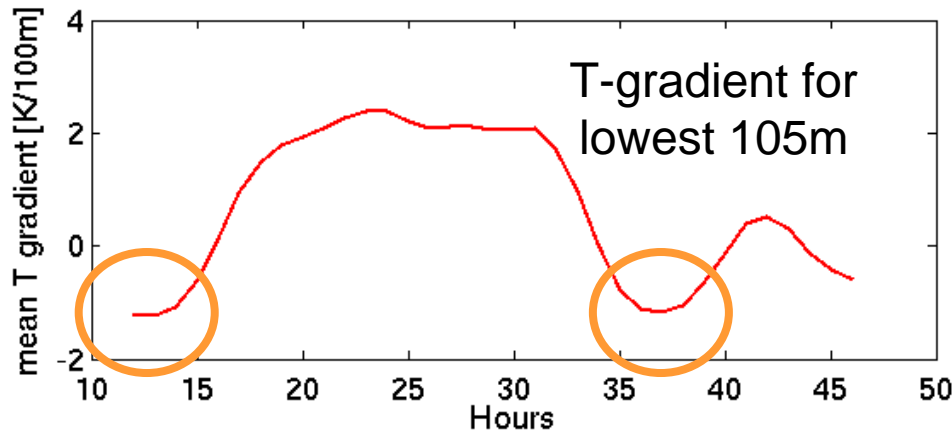
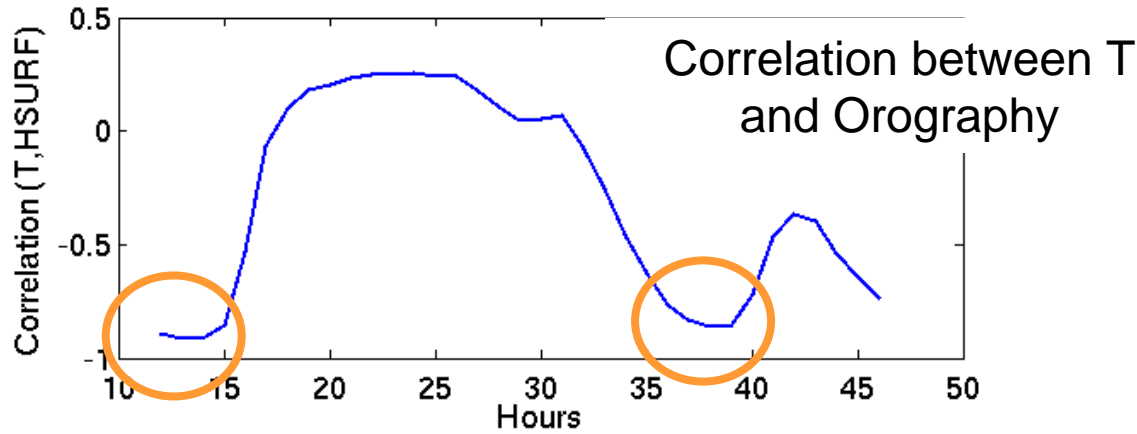
21 UTC

Orography of model domain

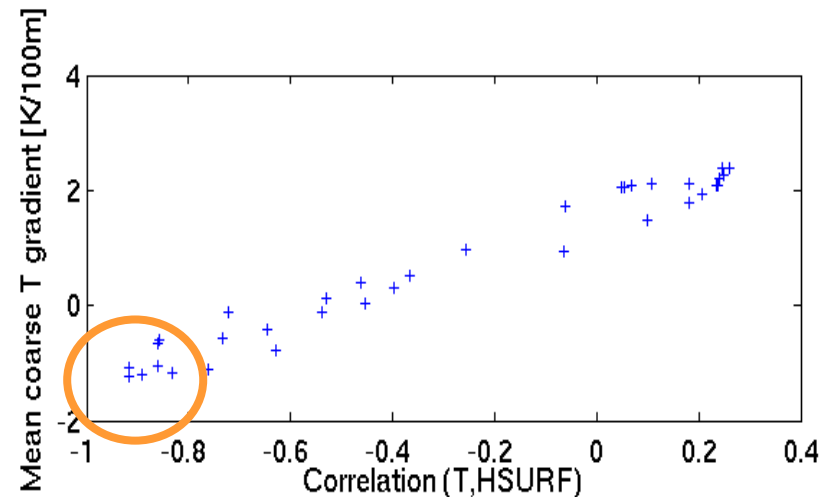


T-gradient as indicator

14/15-10-2007



For (over-)adiabatic T-gradient
good correlations between
temperature and orography!



Downscaling-Strategy

- **3 Steps:**
 1. Smooth field with splines
 2. Downscale field „deterministically“ by regression techniques (use subgrid-scale information like orography)
 3. **Add white noise to reproduce original fine-scale variance**
- If no rules for step 2. can be found (e.g. for precipitation) only step 1. and 3.

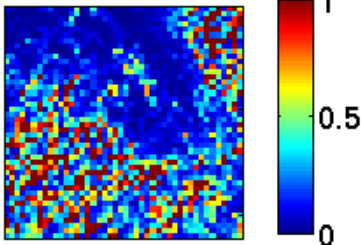
Step 3: Add noise

- Question: How much additional variability is needed?

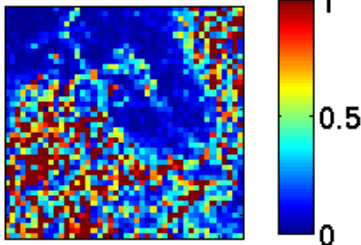
Subgrid-scale variability: Temperature (radiation day)

09-05-2008

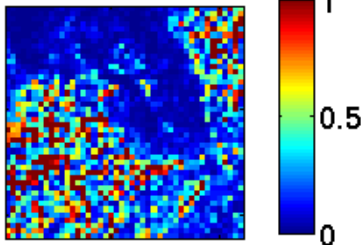
T2:00 UTC



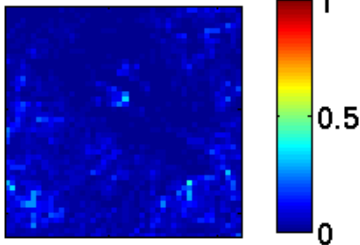
T4:00 UTC



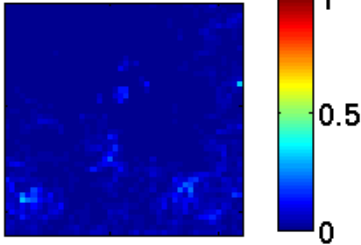
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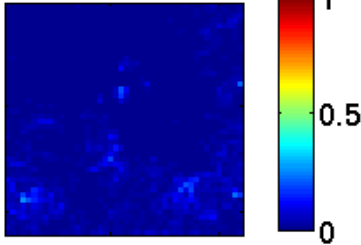
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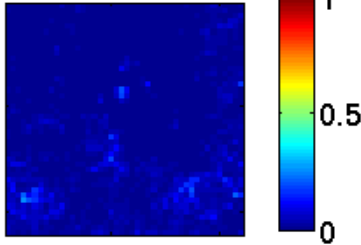
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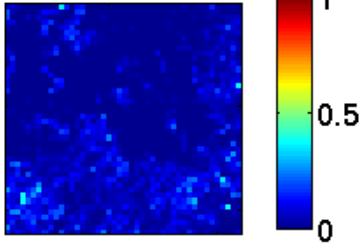
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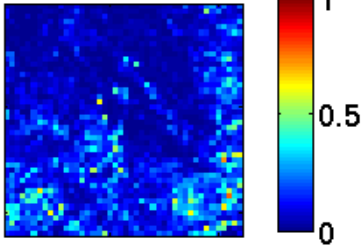
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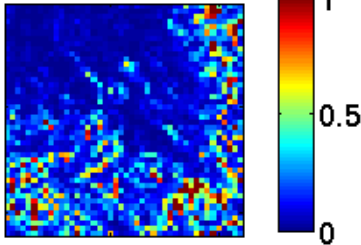
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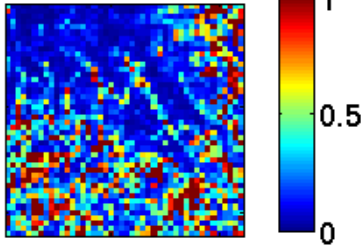
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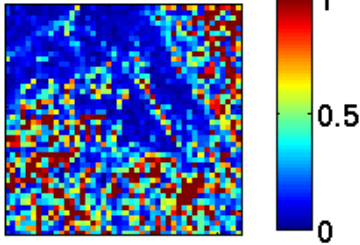
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T22:00 UTC



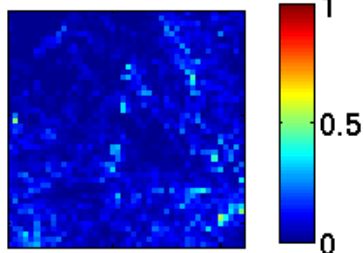
T24:00 UTC



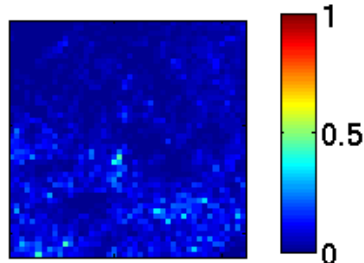
Subgrid-scale variability: Temperature (stratiform clouds)

21-07-2008

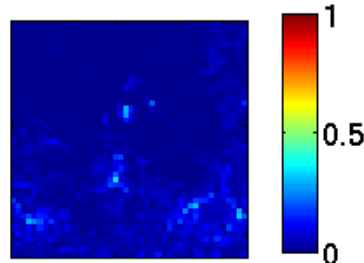
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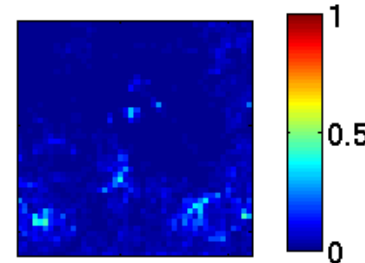
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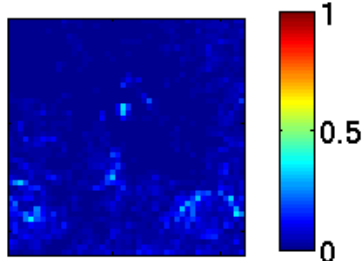
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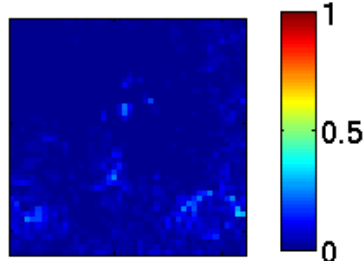
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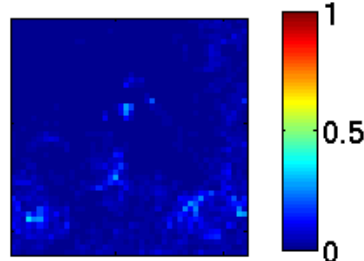
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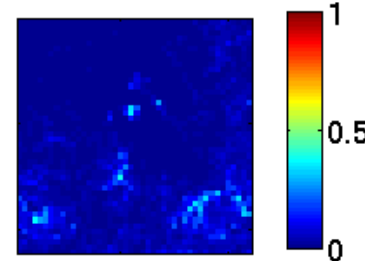
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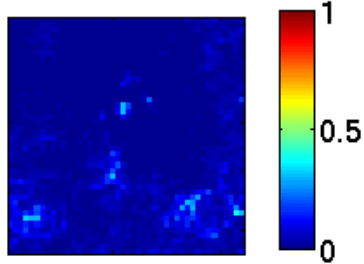
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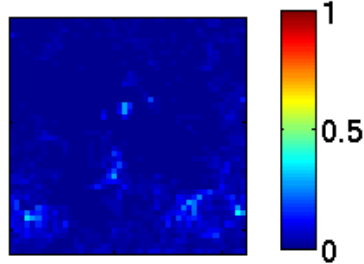
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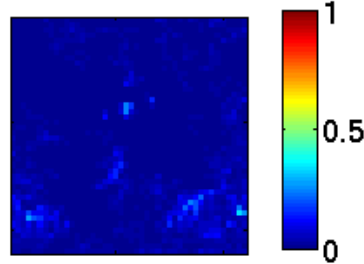
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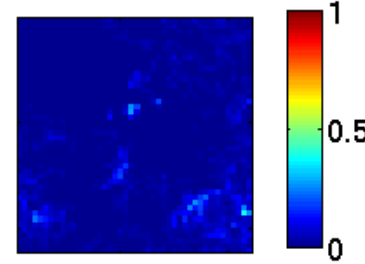
T20:00 UTC



T22:00 UTC



T24:00 UTC



Step 3: Add noise

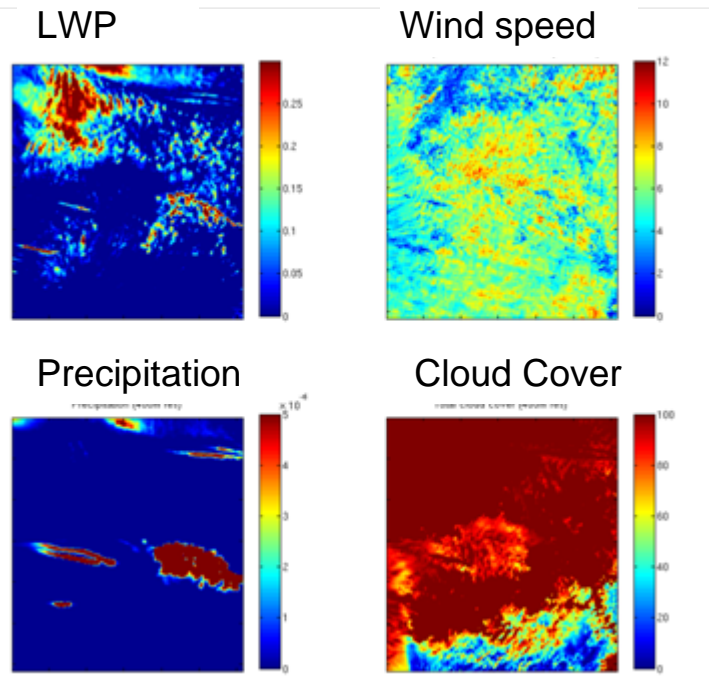
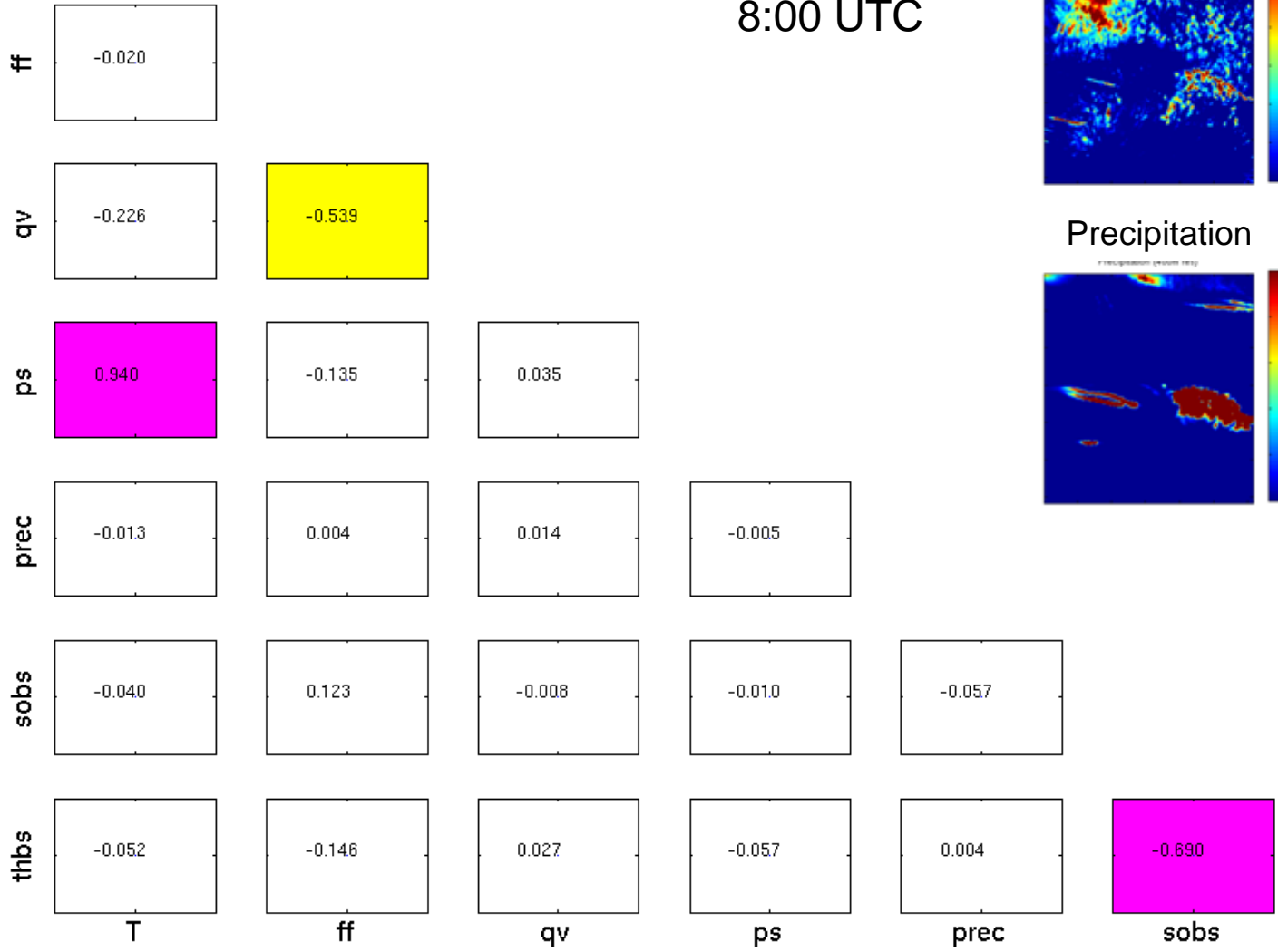
- Question: How much additional variability is needed?
- Find measures of subgrid-scale variability, e.g.:
 - coarse variance (3x3 coarse pixel)
 - coarse value
 - surface pressure
 - temperature gradient
- Take into account for noise generation:
 - Auto-correlations
 - model the small-scale variability as autoregressive process

$$x_{t+1} = \phi(x_t) + \varepsilon_{t+1}$$

- Cross-correlations between different small-scale variables

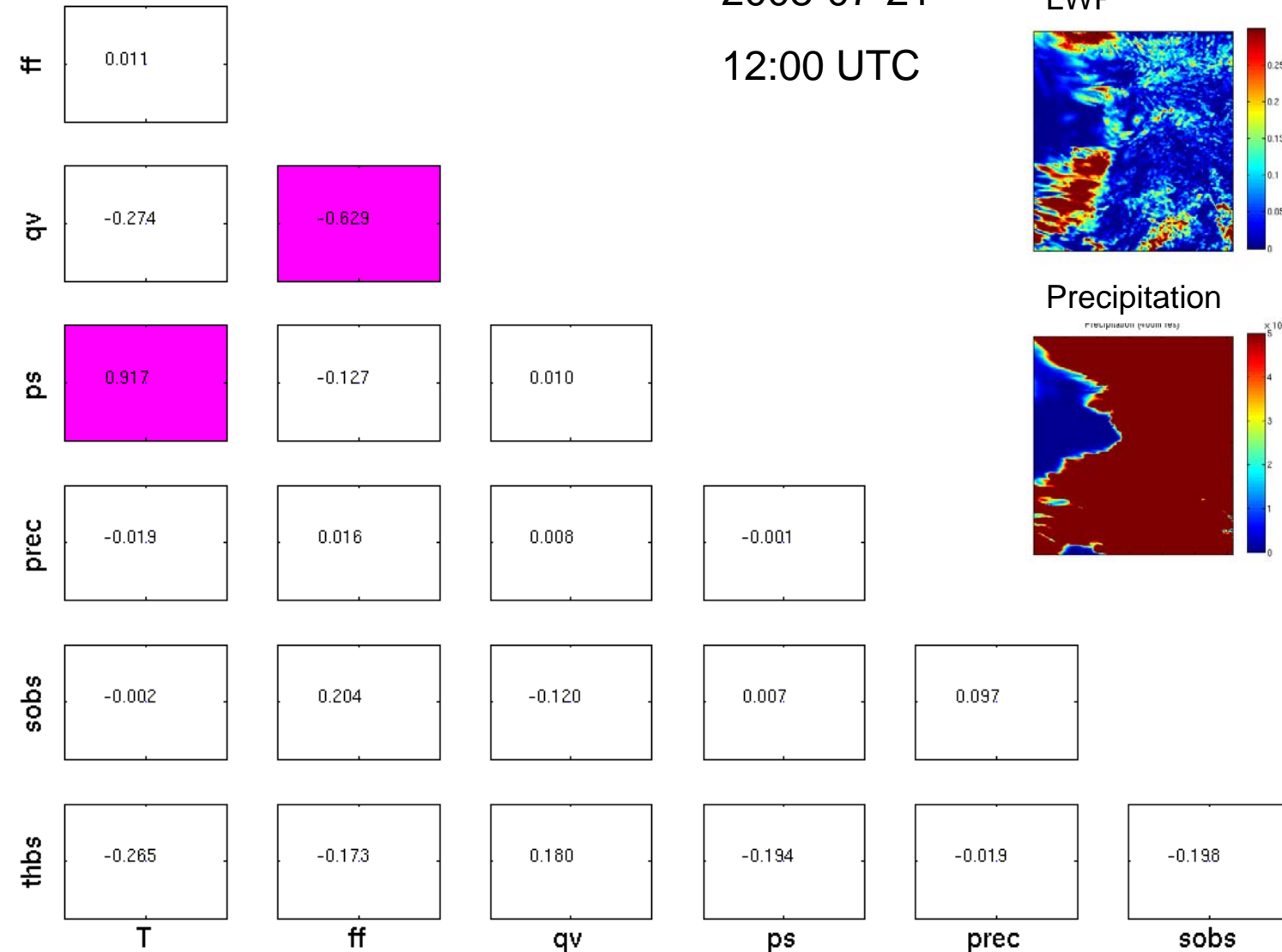
Cross-Correlations between small-scale variables

2008-07-21
8:00 UTC

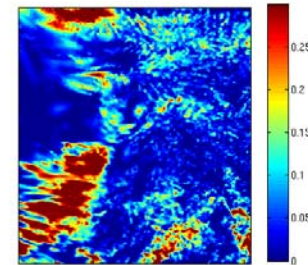


Cross-Correlations between small-scale variables

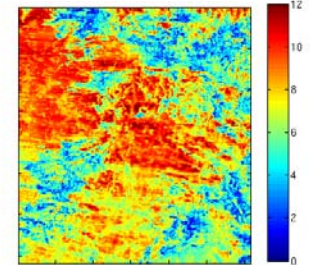
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12:00 UTC



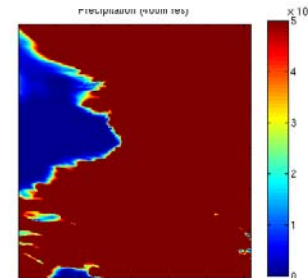
LWP



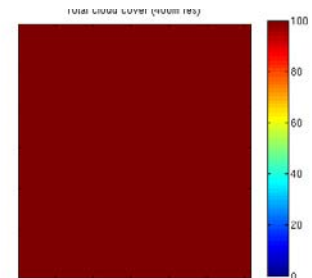
Wind speed



Precipitation



Cloud Cover



Conclusions / Outlook

- A **downscaling system** for the variables at the lowest model level, to be used in combination with the **mosaic approach**, is under development, consisting of three steps
 - Including deterministic regression rules associated with high-resolution surface information and white noise conserving temporal and cross-correlations
- Currently: Combining these three steps, to test the system firstly „offline“ on model output, later implemented into **COSMO-SUBS** (from F.Ament) and tested „online“
- This downscaling system could also be used as intermediate step for generating high-resolution **input for hydrological models** (apply downscaling to atmospheric model output)

Thank you for your attention!

Step 2: „deterministic“ downscaling

- Find rules and correlations for disaggregation variables at lowest atmospheric level
- Need of indicators for using different predictors
 - in different weather situations
 - or time of the day