COSMO physics developments

a short summary of COSMO WG3 recent contributions

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Outline

- **Current PBL issues** *(to be tackled in the short-term):* *Too strong surface fluxes, lack of low level clouds and excessive mixing in strongly stratified conditions.*

  -Re-tuning of minimal diffusion coefficient set up originally to provide an artificial turbolence source to avoid turbulence to die out in very stable situations.

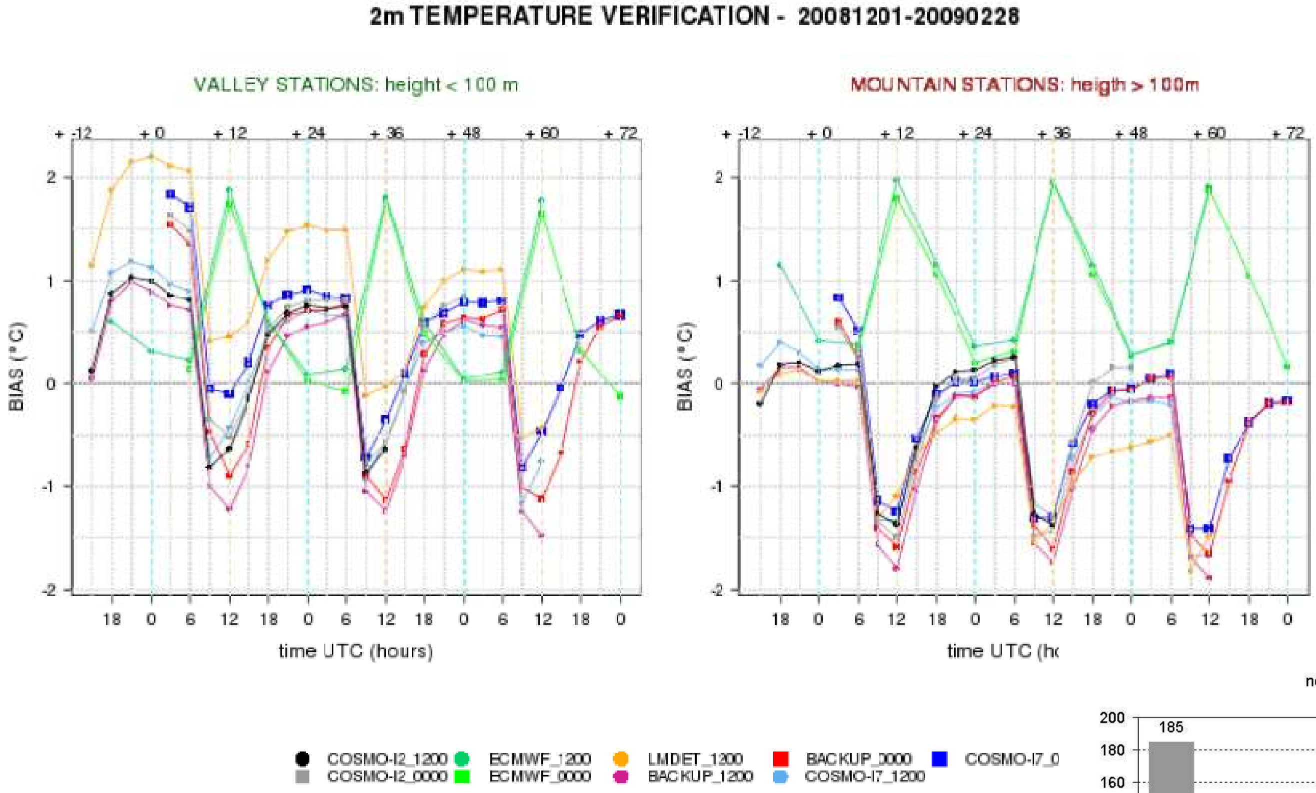
  -Increase interaction and exchange of kinetic energy from of other sub-grid scale phenomena and resolved termo-dynamics with the turbulence scheme (scale separation approach with scale interaction terms)

  -Revision of the surface transfer scheme in order to overcame the problems coming from the treatment and definition of the laminar layer and providing a stronger dependencies of transfer coefficients from stability and Raynold number.

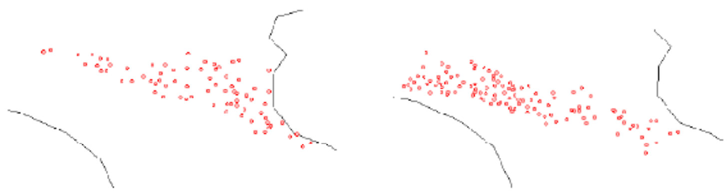
- *Long term plan* : Unified Turbolence Shallow Convection Scheme (UTCS), unique closure assumption for the whole sub-grid scale spectrum of phenomena.

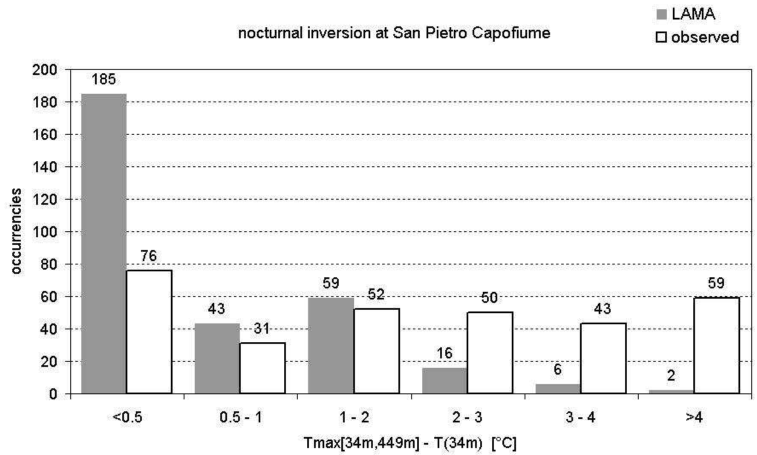
- **Introduction of sub-grid scale orographic effect (SSO)**

- **New parameterizations of ice nucleation and melting of snow**



Around 150
stations
in both
category





ARPA-SIMC Verification report DJF 2009

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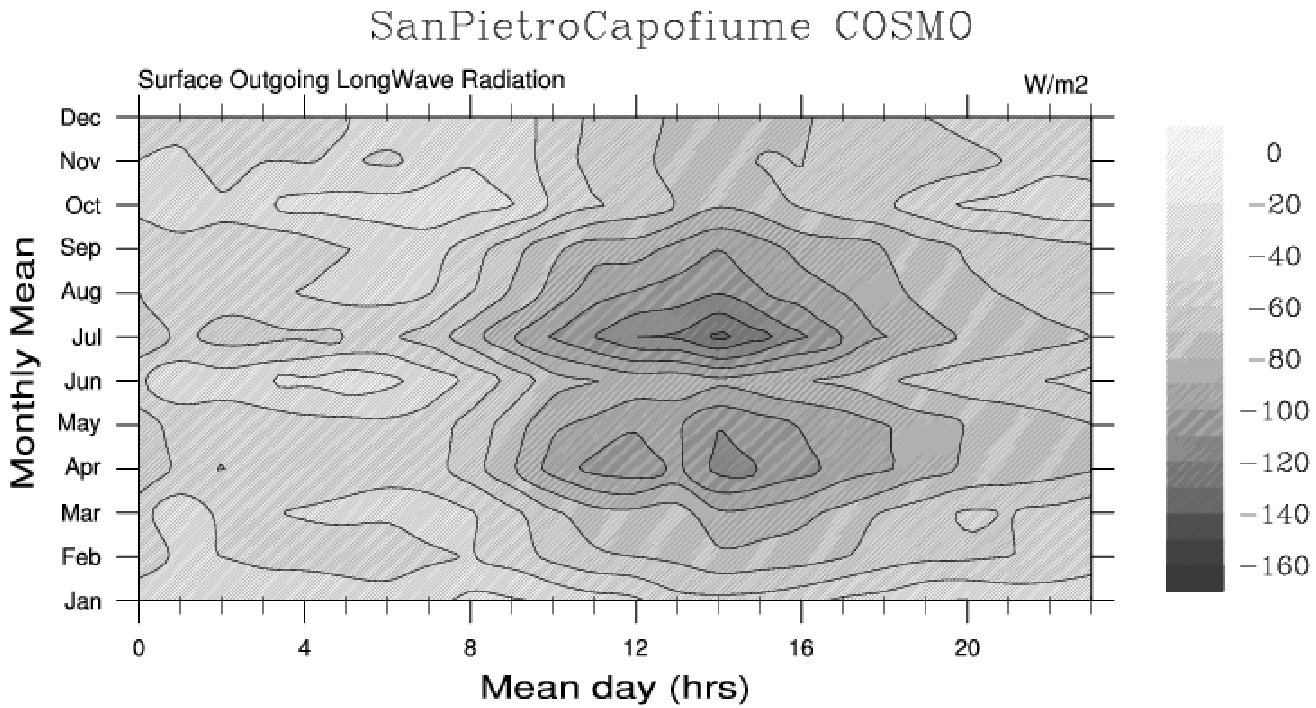

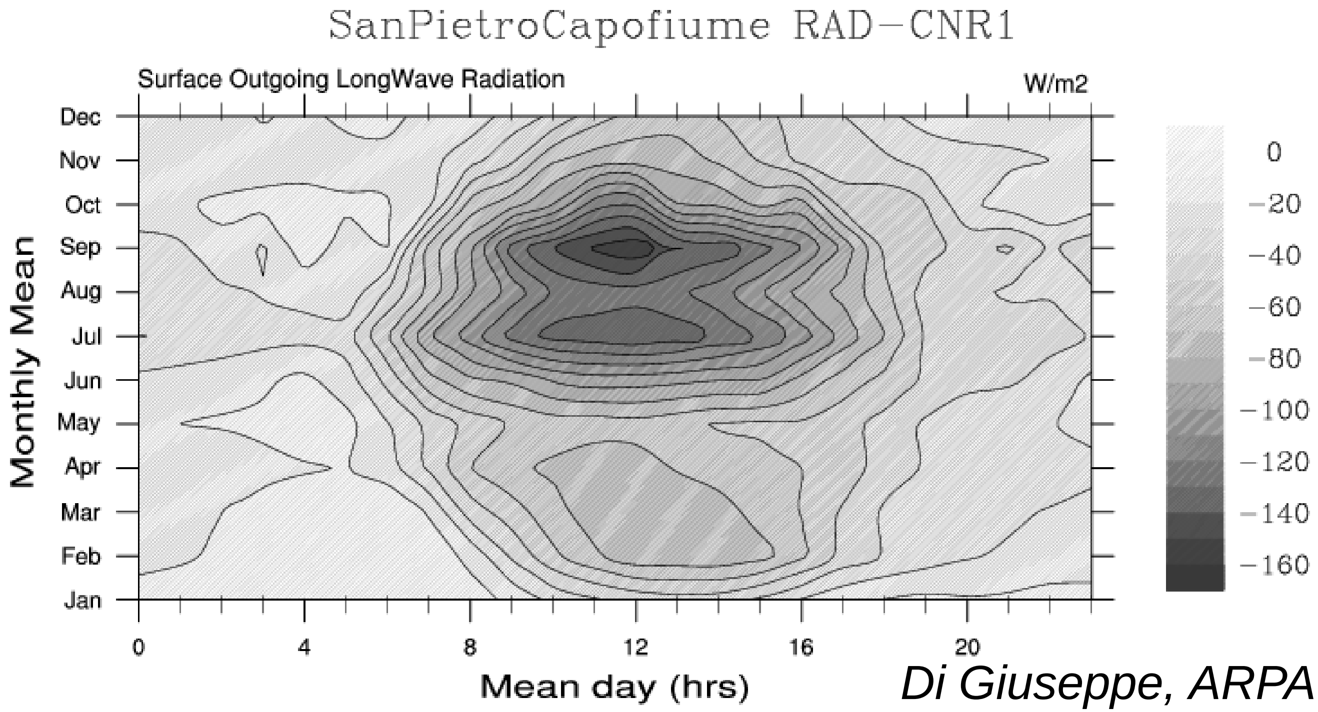

Seasonal versus daily outgoing longwave radiation at SanPietroCapofiume location as measured by the CNR-1 radiometer and as predicted by the COSMO-I7 analysis. The data are averaged over two years 2007-2008.

It is evident a seasonal shift, which is superimposed to the delay in the daily cycle. The model appears to be too conductive and thus unable to buid-up in thermal energy during the summer. The weak daily cycle and its offset of few hours is responsible for a warm nighttime bias and a cold daytime bias.

Di Giuseppe, ARPA-SIMC

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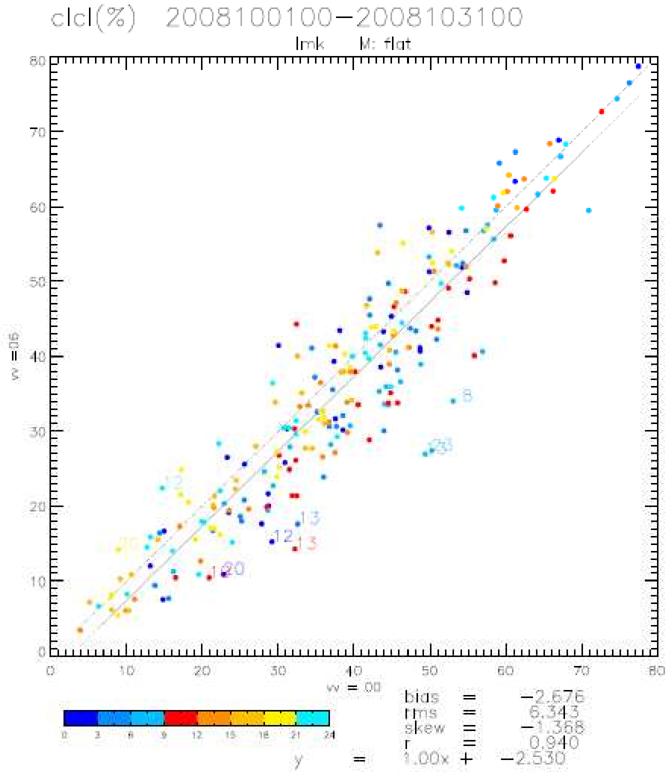
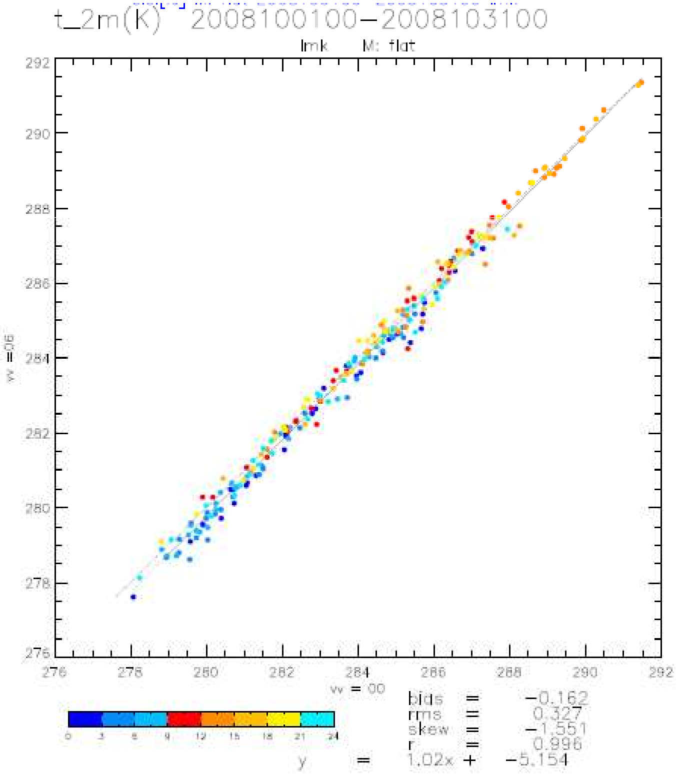
Problem with simulating PBL clouds

Underestimation of boundary layer clouds?
20081001-20081031, CLCL and T2m
06h-Forecast vs. 00h forecast COSMO-DE

Every dot represents a domain average of a forecast at a given target date (00, 03, 06, 09, 12, 15, 18 und 21 UTC) vs. the reference (00h forecast) at the same instance





Patrick Volker COSMO GM 2009

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Experiment using reduced minimal diffusivity

Reduction of the minimal diffusion coefficient.

In the operational model we use for the minimal diffusion coefficients (heat and momentum) the value of 1 m^2/s, which in a stable stratified Layer, causes artificial mixing. This might lead to a break up of the boundary layer clouds.

Experiment Information:

Period:	20090103-20090114	
Model:	COSMO-EU	
Initialisation:	00h und 12h	
Forecast:	78h	
Changed:	K_m^{min}	$\rightarrow 0.01\ m^2/s$
	K_H^{min}	$\rightarrow 0.01\ m^2/s$

Results of EXP (reduced diffusion coefficients)

POSITIVE:

In entire COSMO-DE domain:

- The tendency of the PBL clouds to disappear decreases

Lindenberg:

- **Surface temperate** fits **better** the observations
- **Long wave radiation budget** fits **better** the observations
- **Sensible heat flux** fits **better** the observations
- **Temperature Profile** fits **better** the observations

NEGATIVE:

In entire COSMO-DE domain:

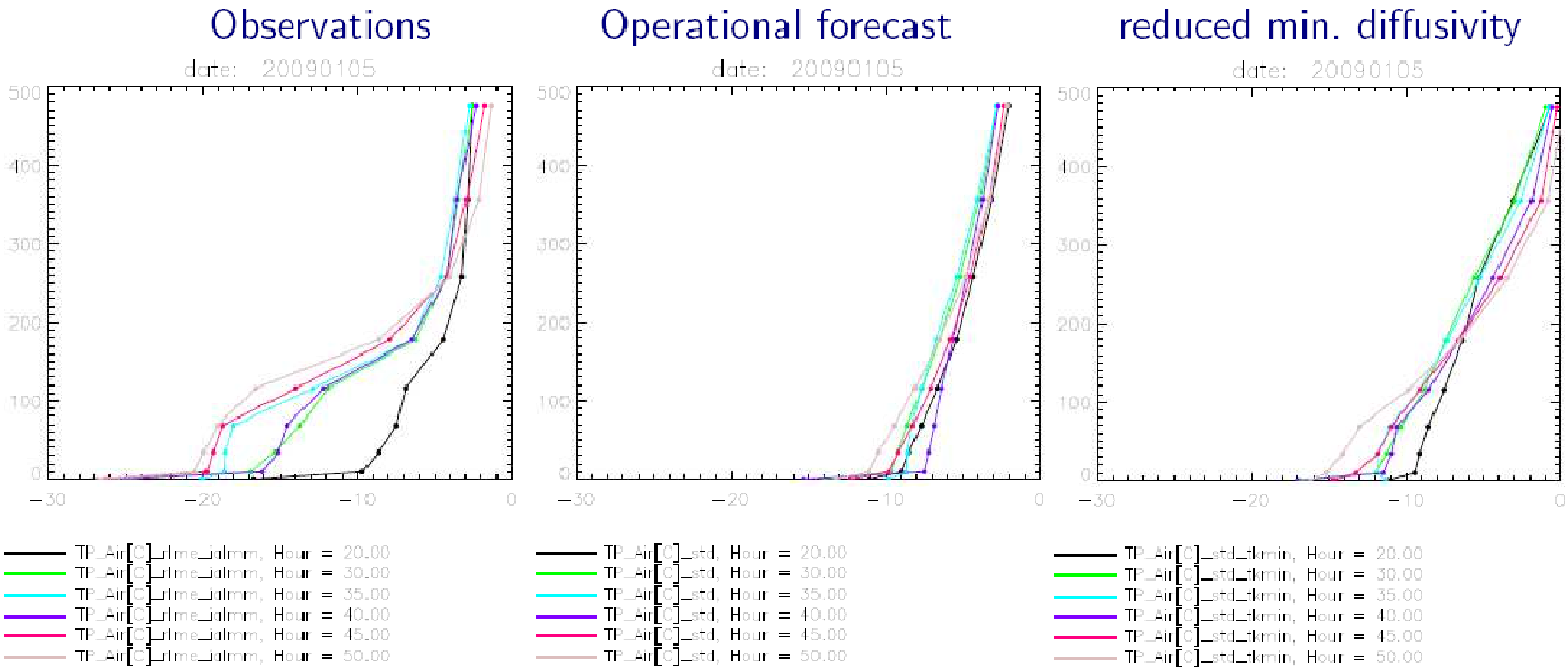
- **Negative Bias in T2m**
- RMSE in T2m slightly increased

Patrick Volker COSMO GM 2009

SCM: sensitivity to reduced minimal diffusivity (2009010512-2009010712)

The measure field of the observatory was completely snow covered (8cm)

First the θ-**Profile** of the operational forecast where compared to observations



Reduced minimal diffusivity give a more realistic θ profile

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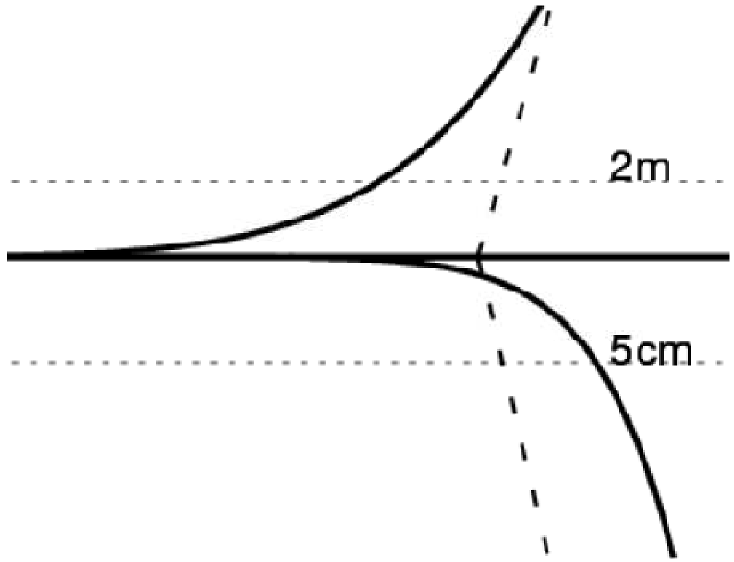
Too diffusive atmosphere, too conducive soil

Cosmo vs. Lindenberg data (20081001-20090531)

A long term analysis shows a too diffusive atmosphere and a too conductive soil (at least at Lindenberg).

E.g. in a stable stratified PBL we can expect a schematic temperature profile near the surface:

Model:	Dashed
Observations:	Solid line



If we use the two meter temperature difference to correct the soil temperature we risk to make the soil temperature bias even bigger. We have to be careful to the correction parameters.

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Recent extensions of the COSMO TKE scheme related to the interaction with non turbulent scales

- **Separation between turbulence and non turbulent sub grid scale circulations**

  ⇩
- **Additional scale interaction terms in the separated TKE budget**
- **Parameterization and effect of 3 important scale interaction terms with separated:**
  - **Horizontal shear modes** (e.g. at frontal regions)
  - **Wake modes from SSO blocking** (over mountains)
  - **Buoyancy forced thermal circulations** (e.g. due to shallow convection or sub grid scale katabatic flows)
- **Considering of non turbulent sub grid scale circulations in the statistical condensation scheme (including non Gaussian effects)**

Raschendorfer, DWD

Impact of additional interaction terms:

- **Non turbulent** sub grid scale modes interact with **turbulence** through additional **shear production** in the **TKE equation.**

- **3D-shear terms** have got a significant effect **only**, when formulated as a **scale interaction term** producing TKE by shear of a **separated horizontal shear mode** with its **own length scale.**

- **Wake production** of TKE by **blocking** can be formulated as a **scale interaction term** as well and can be described by **scalar multiplication** of the **horizontal wind vector** with its **SS0-tendencies** yielding some effect above mountainous terrain.

- **Buoyancy forced** (convective) **circulations** can be described either by a **mass flux** approach or **2-nd order closure**. The according **TKE production** term is related to the **circulation buoyancy heat flux**.
  Interaction of those circulations with the **statistical saturation adjustment** (cloud scheme) can be formulated by "**convective modulation**".

Prospect:

- We intend to implement the **revised** formulation of the **circulation term** together with the "**convective modulation**" of the **statistical cloud scheme** and to derive a similar **scale interaction term** from the current **convection scheme** as well.

- Further we plan to consider the **circulation scale fluxes** in the **1-st order budgets** leading to **additional non local mixing tendencies** of the prognostic variables.

UTCS project

Priority Project "UTCS"
Towards Unified Turbulence-Shallow Convection Scheme

Project leader: Dmitrii Mironov (DWD)

Motivation
[……] The project is aimed at (i) parameterising boundary-layer turbulence and shallow non-precipitating convection in a unified framework, and (ii) achieving a better coupling between turbulence, convection and radiation.
Boundary-layer turbulence and shallow convection will be treated in a unified second-order closure framework. **Apart from the transport equation for the sub-grid scale turbulence kinetic energy (TKE), the new scheme will carry at least one transport equation for the sub-grid scale variance of scalar quantities (potential temperature, total water).** The second-order equations will be closed through the use of a number of advanced formulations, where the key point is the non-local parameterisation of the third-order turbulence moments. The proposed effort is expected to result in an improved representation of a number of processes and phenomena, including non-local transport of heat, moisture and momentum due to boundary-layer turbulence and shallow convection, triggering of deep cumulus convection, and stratiform cloud cover. This in turn is expected to lead to an improved forecast of several key quantities, such as the rate and timing of precipitation and the 2m temperature.

http://www.cosmo-model.org/content/tasks/priorityProjects/utcs/default.htm

UTCS tasks

✓ Task 1: Analytical derivation of a new second-order turbulence-shallow convection closure scheme, including transport equations for the sub-grid TKE and for the sub-grid scalar variances.

✓ Task 2: Coupling of a new closure scheme with the sub-grid scale statistical cloud scheme.

✓ Task 3: Development of a one-dimensional code of a new turbulence-shallow convection closure scheme, testing the new scheme through single-column numerical experiments, comparison with available empirical and numerical data.

- Task 4: Implementation of a new turbulence-shallow convection closure scheme into the COSMO model

- Task 5: Investigation of the interaction of a new closure scheme with the radiation and the grid-scale precipitation schemes.

- Task 6: Testing the new scheme in the COSMO model through numerical experiments, fine tuning of disposable parameters of the new scheme, evaluation of results.

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UTCS preliminary results

- A two-equation turbulence closure model for dry PBL has been coded (prognostic equations for the TKE and for the potential temperature variance) and favourably tested through single-column numerical experiments.

- A skewness-dependent parameterisation of the temperature-variance turbulent transport is implemented and tested (physically, the skewness-dependent formulation is a mass-flux formulation for the scalar transport due to shallow convection recast in terms of ensemble-mean turbulence moments).

- The model reveals a stable performance on a relatively coarse grid (Δz_{min}=10 m, Δt well over 40 sec).

- A non-local second-order closure model (parameterisation scheme) for moist PBL, including prognostic equations for the scalar variances, is formulated; first single-column numerical experiments are performed.

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Introduction of Sub-grid Scale Orographic effects

Dignostic studies did show an underestimation of cross-isobaric flow in the PBL attributable to a lack of surface drag.

Too strong reduction of wind speed over the Alpine region

Deutscher Wetterdienst

DWD

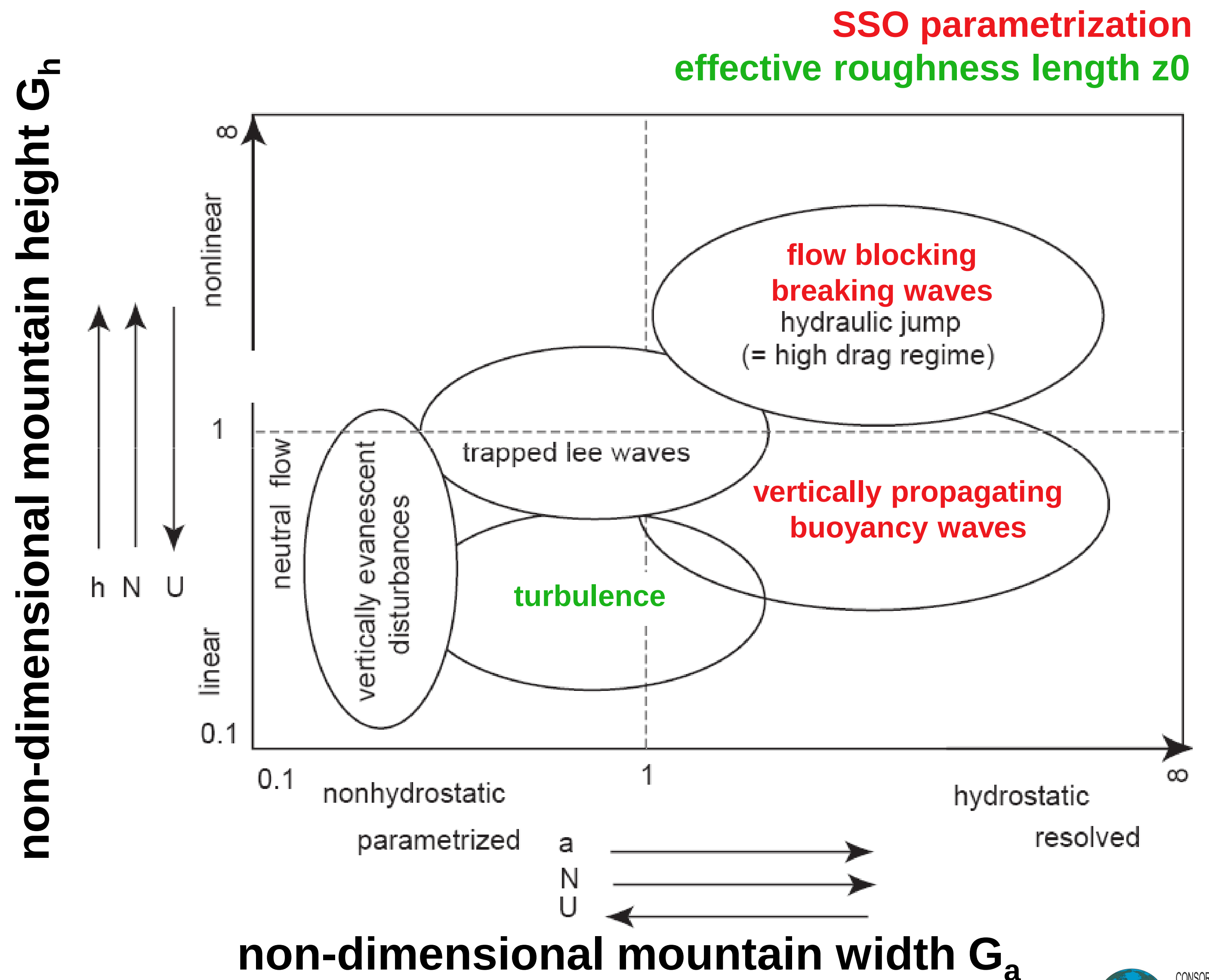
Conclusions

The sub-grid scale orography scheme by Lott and Miller (1997) was implemented in the COSMO model. It shows the following improvements in COSMO-EU in the period 26 Feb. – 17 Mar. 2008:

- The positive bias of the surface wind speed is removed.
- The positive bias of the surface wind direction and the RMSE of the vector wind are reduced.
- The negative bias of the mean sea level pressure is reduced.
- The RMSE of the mean sea level pressure is significantly reduced, the variance of the pressure is substantially reduced by more than 13%. This means that the pressure patterns are much better captured by the model. A similar improvement of this quantity has not been achieved by any other model modification during the last years.
- Upper air verification shows a similar improvement.

Thanks to Ulrich Damrath and Ulrich Pflüger, DWD, for their verifications.

Orographic related processes affecting the flow

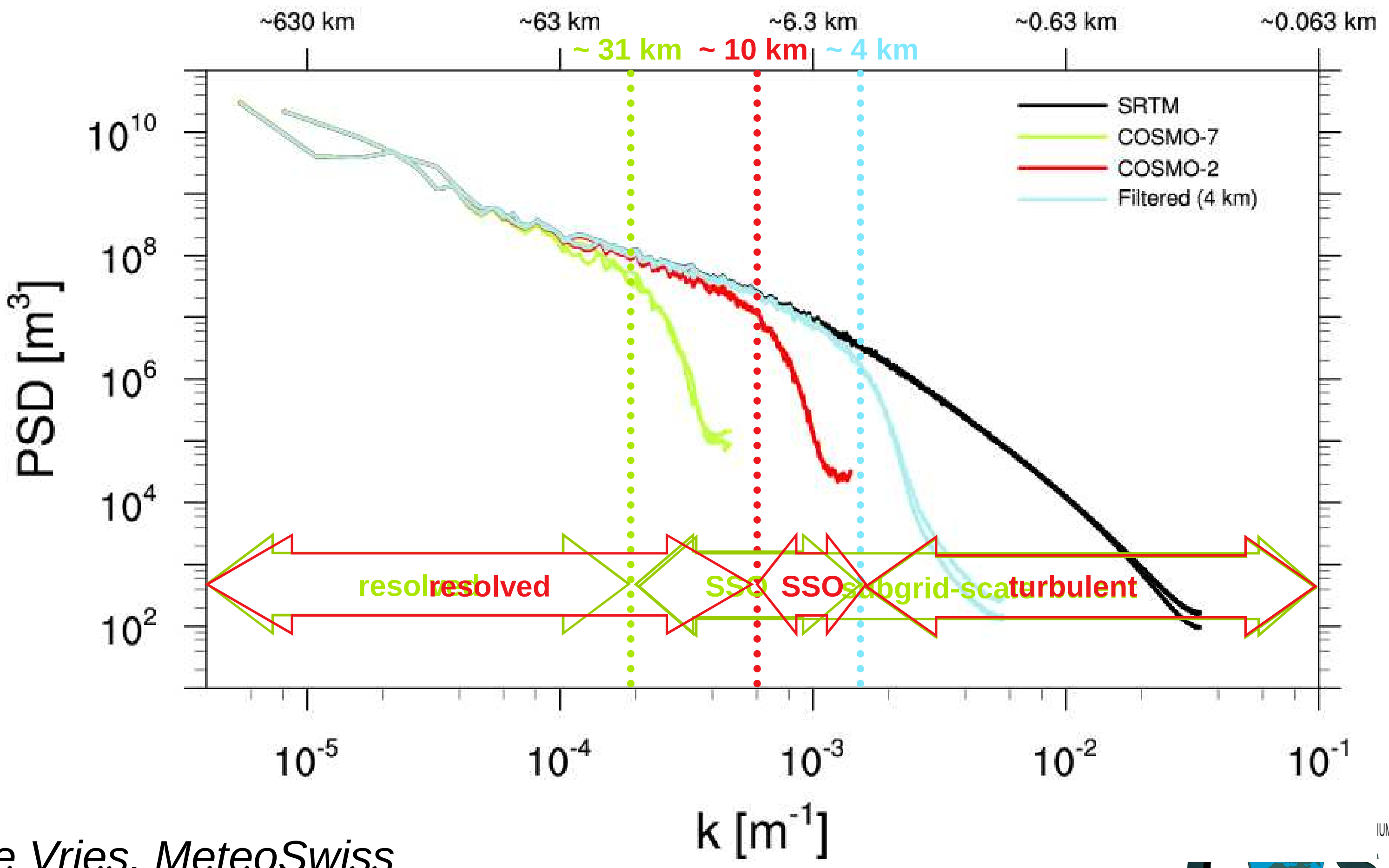


Fuhrer, de Vries, MeteoSwiss

Refinements of SSO scheme with the introduction of scale separation concept

Need to separate turbulent and mesoscale unresolved drag

Power
Spectral
Density



Fuhrer, de Vries, MeteoSwiss

New parameterizations of ice nucleation and melting of snow

- Currently the COSMO model uses very simple empirical (statistical) parameterization for the number of ice particles.

➔ A new microphysics scheme is currently being developed which makes use of new measurements and parameterizations

- Currently the COSMO model cannot represent the melting layer very well leading to uncertainties and biases in the prediction of precipitation phase

➔ A new microphysics scheme is currently being developed which uses the liquid water fraction of snowflakes to achieve a better representation of the melting process and the melting layer.

➔ **Both project are at the beginning and first results can be expected next year. An operational implementation might be possible 2011 or 2012.**

Seifert et al., DWD

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Tuning of convection permitting implementations

- COSMO2 had a very limited diurnal cycle, the afternoon maximum was very weak.

- DWD introduced turlen=150m together with a modification of the subgrid cloudiness q_krit=1.6, clc_diag=0.5. For Germany this change has a quite positive impact, with more small scale convection, which is in many cases more realistic. Also the diurnal cycle has been improved. However there is still a tendency underestimate the frequency of convective systems in weakly forced cases. Convection is a bit too strong in strongly forced situations. Also the organization, propagation and lifetime of convective systems sometimes it is not good enough in non-equillibrium situations. In 2009 also the initiation of convection was much better.(Seifert, DWD).

- At MeteoSwiss they find a negative impact of the reduced mixing length getting to much convection over the Alps.They have now operationally introduced turlen=250m combined with q_krit=1.6, clc_diag=0.5.

- At ARPA-SIMC we recently upgraded to version 4.9, running I2 with turlen=250m. This had a quite remarkable impact on the diurnal cycle of scattered convection with a substantial increase in number of cells. Distribution and frequency looks realistic now, the intensity seems a bit too strong.

NEW

- In collaboration with ETH a IFS convection scheme library was prepared mainly for climatological simulation. It will be also tested in NWP mode in COSMO (7).

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