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Consortium for Small-Scale Modelling

Marco Arpagaus

30^{th} EWGLAM & 15^{th} SRNWP Meeting
6 October 2008, Madrid

Consortium for Small-Scale Modelling

Content

- COSMO Organisation … – and SRNWP Expert Teams
- COSMO Model
- COSMO Operational Applications
- COSMO Activities

COSMO members (chronological order)

DWD	Deutscher Wetterdienst, Germany
MeteoSwiss	MeteoSwiss, Switzerland
USAM	Ufficio Generale Spazio Aereo e Meteorologia, Italy
HNMS	Hellenic National Meteorological Service, Greece
IMGW	Institute for Meteorology and Water Management, Poland
NMA	National Meteorological Administration, Romania
ROSHYDROMET	Federal Service for Hydrometeorology and Environment Monitoring, Russia (Applicant)

Participating regional and military services within the member states:

GeoInfoWBw	Amt für Geoinformationswesen der Bundeswehr, Germany
ARPA-SIMC	Servizio IdroMeteoClima di ARPA Emilia-Romagna, Italy
ARPA-Piemonte	Sevizio Meteorologico di ARPA Piemonte, Italy
CIRA	Centro Italiano Ricerche Aerospaziali, Italy

COSMO Governance: Steering Committee

- Hans-Joachim Koppert (DWD; current Chairman)
- Philippe Steiner (MeteoSwiss)
- Massimo Ferri (USAM)
- Theagenis Charantonis (HNMS)
- Rafał Bąkowski (IMGW)
- Victor Pescaru (NMA; until the end of 2008)

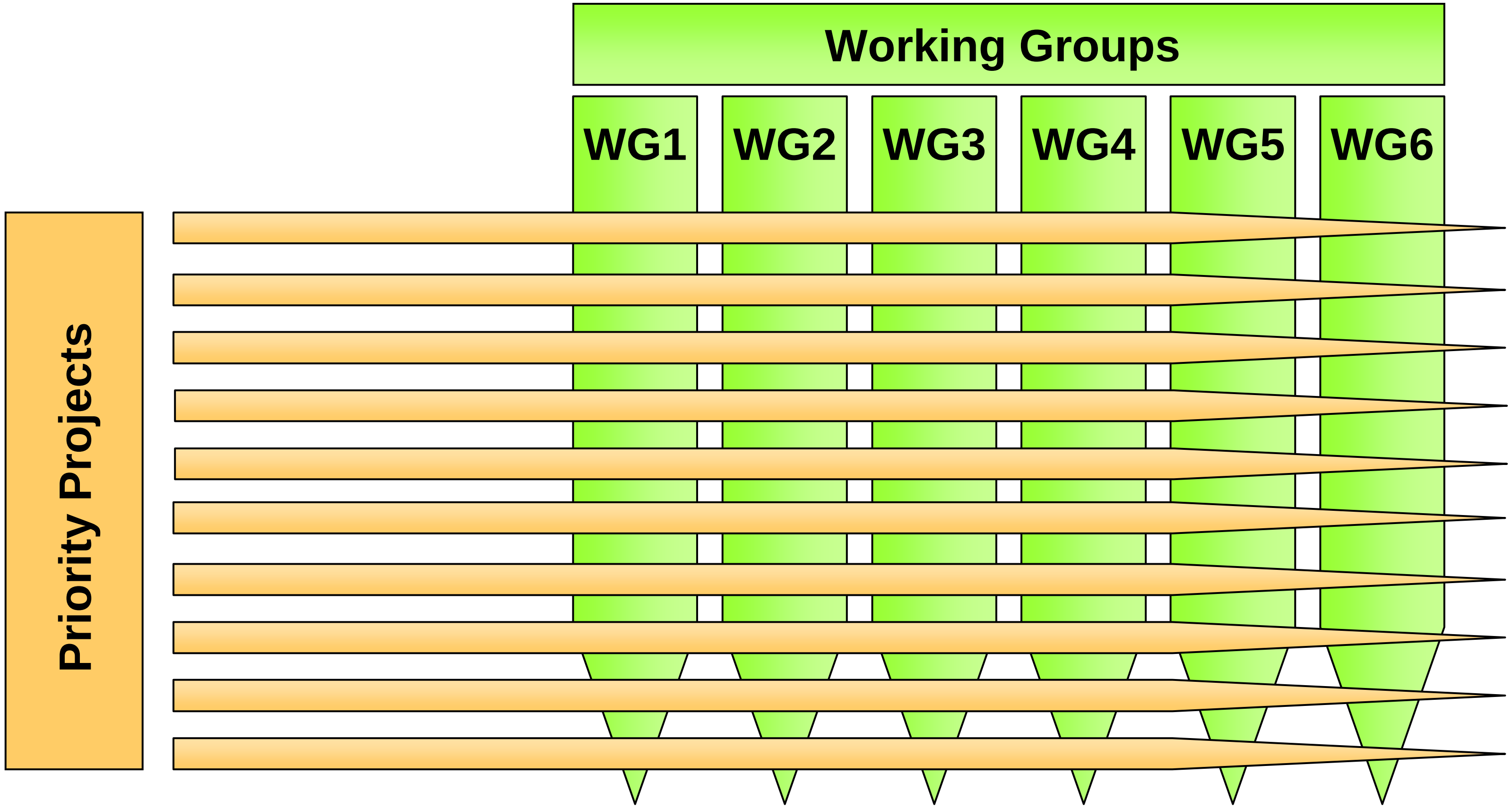
- Dmitry Kiktev (ROSHYDROMET)

Note: There in no (formal) meeting of the directors.

COSMO Governance: Working Groups & WG Coordinators

- **Data Assimilation (WG 1)**
  Christoph Schraff (DWD; christoph.schraff [at] dwd.de)
- **Numerical Aspects (WG 2)**
  Michael Baldauf (DWD; michael.baldauf [at] dwd.de)
- **Physical Aspects (WG 3)**
  Federico Grazzini (ARPA-SIMC; fgrazzini [at] arpa.emr.it)
- **Interpretation and Applications (WG 4)**
  Pierre Eckert (MeteoSwiss; pierre.eckert [at] meteoswiss.ch)
- **Verification and Case Studies (WG 5)**
  Adriano Raspanti (USAM; a.raspanti [at] meteoam.it)
- **Reference Version and Implementation (WG 6)**
  Ulrich Schättler (DWD; ulrich.schaettler [at] dwd.de)

COSMO Governance:
Working Groups & Priority Projects



Every COSMO member needs to provide a minimum of 2 FTEs per year for the Priority Projects.

COSMO Governance: Priority Projects & PP Leaders (‘*past*’)

- **Assimilation of Satellite Radiances with 1D-Var and Nudging (1D-Var)**
  Reinhold Hess (DWD; reinhold.hess [at] dwd.de)
- **Further Development of the Runge Kutta Method (RK)**
  Michael Baldauf (DWD; michael.baldauf [at] dwd.de)
- **Advanced Interpretation and Verification of Very High Resolution Models (INTERP)**
  Pierre Eckert (MeteoSwiss; pierre.eckert [at] meteoswiss.ch)
- **Development of a Short Range Ensemble (SREPS)**
  Chiara Marsigli (ARPA-SIMC; cmarsigli [at] arpa.emr.it)
- **Verification System Unified Survey (VERSUS 1)**
  Adriano Raspanti (USAM; a.raspanti [at] meteoam.it)

COSMO Governance: Priority Projects & PP Leaders (*'present'*)

- **Km-Scale Ensemble-Based Data Assimilation (KENDA)**
  Christoph Schraff (DWD; christoph.schraff [at] dwd.de)
- **Towards Unified Turbulence-Shallow Convection Scheme (UTCS)**
  Dmitrii Mironov (DWD; dmitrii.mironov [at] dwd.de)

COSMO Governance: Priority Projects & PP Leaders ('*future*')

- **Assimilation of satellite data with clouds and over land (Sat-Cloud)**
  Reinhold Hess (DWD; reinhold.hess [at] dwd.de)
- **Conservative dynamical core (CDC)**
  Michael Baldauf (DWD; michael.baldauf [at] dwd.de)
- **Consolidation of Lower Boundary Conditions (COLOBOC)**
  Jean-Marie Bettems (jean-marie.bettems [at] meteoswiss.ch)
- **Consolidation of COSMO Ensemble (CONSENS)**
  Chiara Marsigli (ARPA-SIMC; cmarsigli [at] arpa.emr.it)
- **Verification System Unified Survey (VERSUS 2)**
  Adriano Raspanti (USAM; a.raspanti [at] meteoam.it)

COSMO Governance: Scientific Management Committee

Members:

- Working Group Coordinators
- Priority Project Leaders
- Scientific Project Manager
- Chairman of the Steering Committee
- One representative for each otherwise not represented member

COSMO Organisation

- Staff:
  - Approximately 125 subscribers to COSMO mailing lists.
  - 20-25 FTEs / year used for Priority Projects.

- Budget:
  - None.
  - However: Efforts to sell model licences. Income will be used for travelling / short-term missions.

SRNWP Expert Team members

see above, plus

- Massimo Bonavita (USAM; bonavita [at] meteoam.it)
- Francis Schubiger (francis.schubiger [at] meteoswiss.ch)
- Lucio Torrisi (USAM; torrisi [at] meteoam.it)
- Detlev Majewski (DWD; detlev.majewski [at] dwd.de)
- Bodo Ritter (DWD; bodo.ritter [at] dwd.de)

COSMO: Model

→ COSMO Web-site

- www.cosmo-model.org
- www.cosmo-model.org/content/model/core/model/default.htm
- www.cosmo-model.org/content/model/documentation/core/default.htm

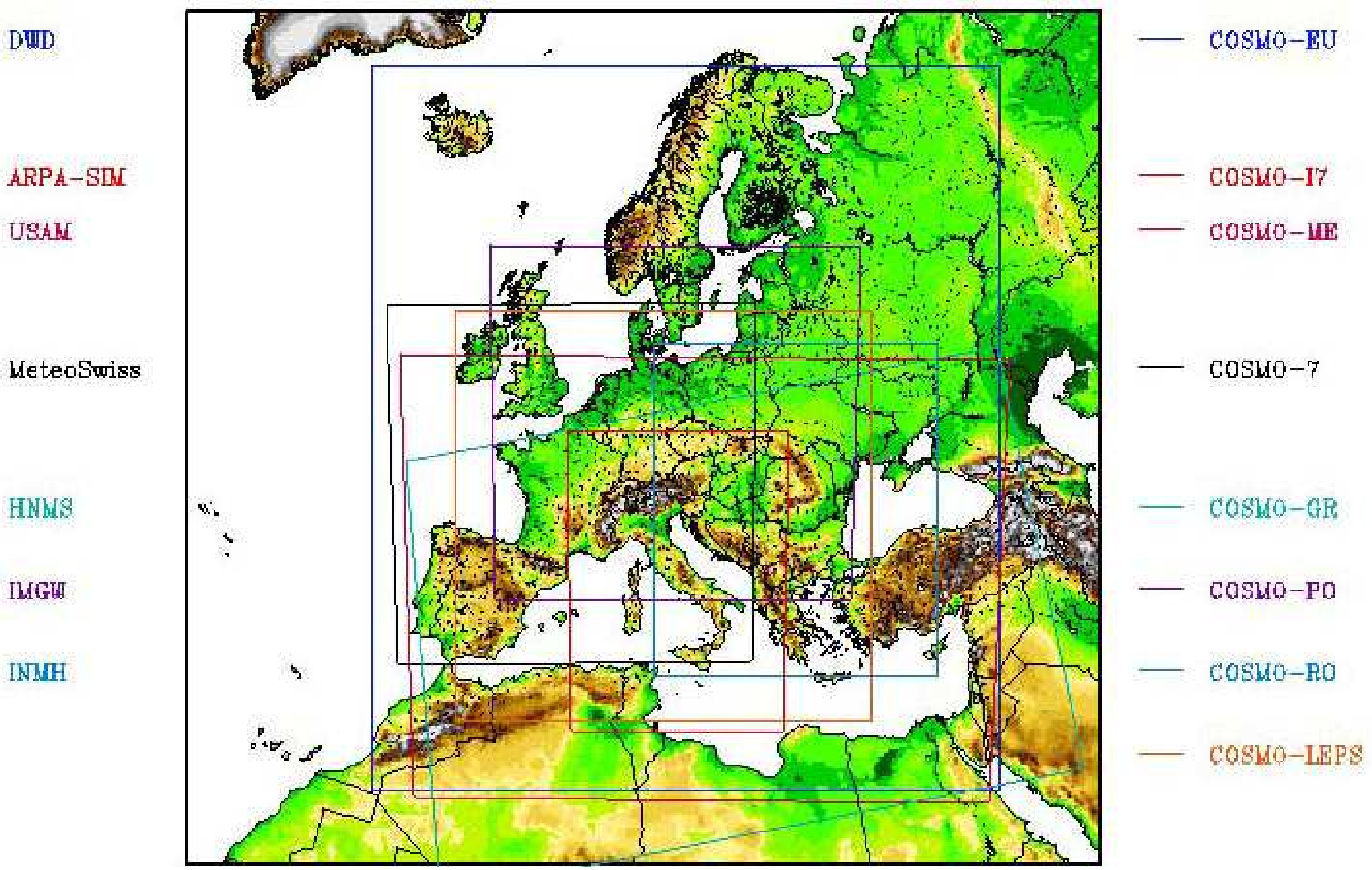
However note:

- Web-site is about to change.
- Quite a few pages are unfortunately not up-to-date …

COSMO: Operational Applications

→ www.cosmo-model.org/content/tasks/operational/default.htm

→ **posters!**



COSMO Activities: Science Plan

Long-term strategy (~2015):

- Stay at the high end of operational NWP model resolution:
  - very high resolution (1 km)
  - short to very-short time-scale
  - deterministic as well as probabilistic (coarser?)
- New: environment modelling
- Also: climate modelling

→ Will approach (some) of the Expert Teams for a review.

COSMO Activities: Science Plan, Implications (I)

- Assimilation:
  - appropriate scheme for highly non-linear convective-scale processes
  - ensemble assimilation system
- Dynamics and Numerics:
  - steep slopes
  - closer coupling between the dynamical core an the parameterisations
- Physics
  - basic assumptions / approximations still valid?
  - unified schemes (e.g., turbulence / shallow convection)
  - 3D schemes?

COSMO Activities: Science Plan, Implications (I)

- Ensembles:
  - appropriate perturbations for ICs, BCs, and representation of model errors
  - predictability
- Interpretation and Applications
  - interpretation
- Verification
  - appropriate verification scores, deterministic as well as probabilistic

COSMO Activities: Priority Projects

Data assimilation and use of observations

- **Assimilation of Satellite Radiances with 1D-Var and Nudging (1D-Var)**
  Reinhold Hess (DWD; reinhold.hess [at] dwd.de)
- **Km-Scale Ensemble-Based Data Assimilation (KENDA)**
  Christoph Schraff (DWD; christoph.schraff [at] dwd.de)
- **Assimilation of satellite data with clouds and over land (Sat-Cloud)**
  Reinhold Hess (DWD; reinhold.hess [at] dwd.de)

→ talks by Christoph Schraff and Massimo Bonavita

COSMO Activities: Priority Projects

Dynamics and lateral boundary coupling

- **Further Development of the Runge Kutta Method (RK)**
  Michael Baldauf (DWD; michael.baldauf [at] dwd.de)
- **Conservative dynamical core (CDC)**
  Michael Baldauf (DWD; michael.baldauf [at] dwd.de)

→ talk by Detlev Majewski

COSMO Activities:
Priority Projects

Physical parameterisation (upper air)

- **Towards Unified Turbulence-Shallow Convection Scheme (UTCS)**

  Dmitrii Mironov (DWD; dmitrii.mironov [at] dwd.de)

Task 1b: Balazs Szintai

Goals

- Comprehensive component testing against LES and observational data of the current COSMO-model one-equation turbulence scheme

Key issues

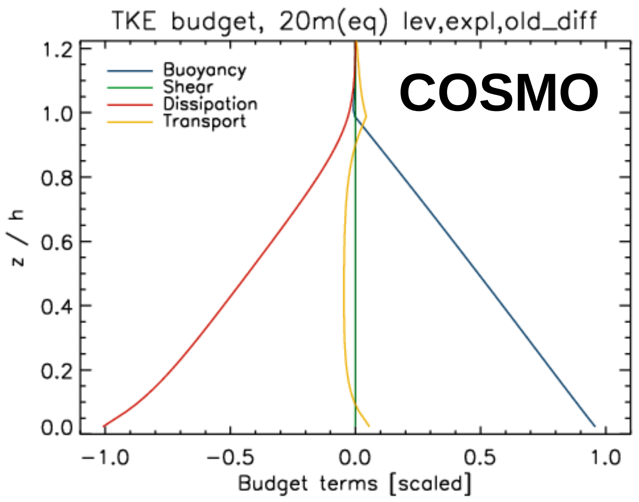
- Stable performance of the scheme
- Entrainment at the boundary layer top

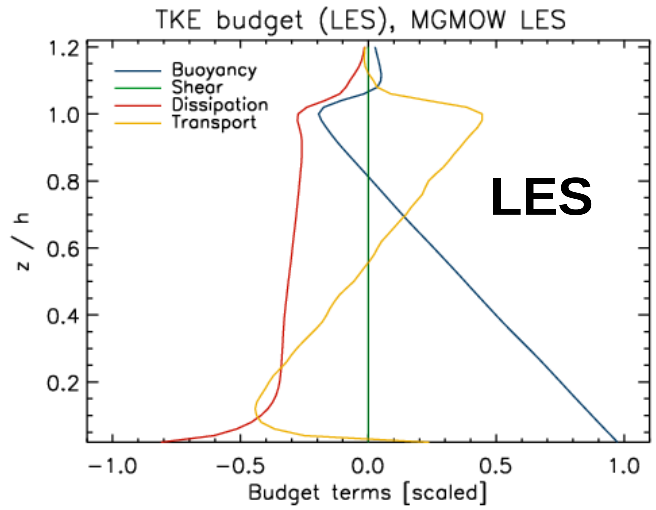
Expected outcome

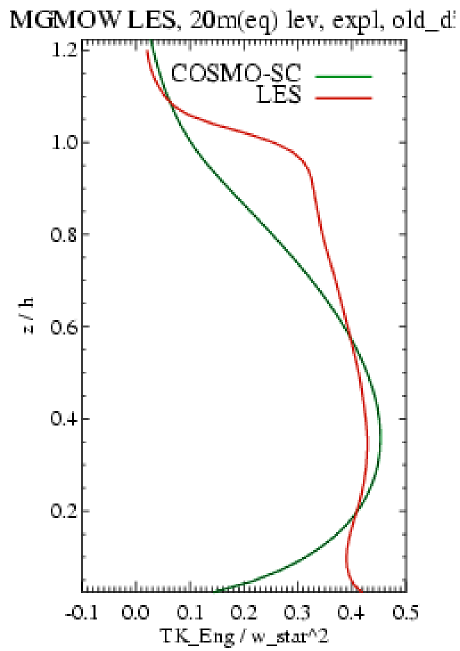
- Improved understanding of the current COSMO-model turbulence scheme
- Recommendations towards the scheme improvement

→ dmitrii.mironov [at] dwd.de

<u>Shear-free convective PBL</u> (LES of Mironov et al. 2000)







- Turbulent transport of TKE is too weak
- Negative buoyancy flux at PBL top is practically missing
- Horizontal velocity variances are poorly described at the PBL top and near the surface

→ dmitrii.mironov [at] dwd.de

Task 1a: Ekaterina Machulskaya and Dmitrii Mironov

Goals

- Development and testing of a two-equation model of a temperature-stratified PBL
- Comparison of two-equations (TKE+TPE) and one-equation (TKE only) models

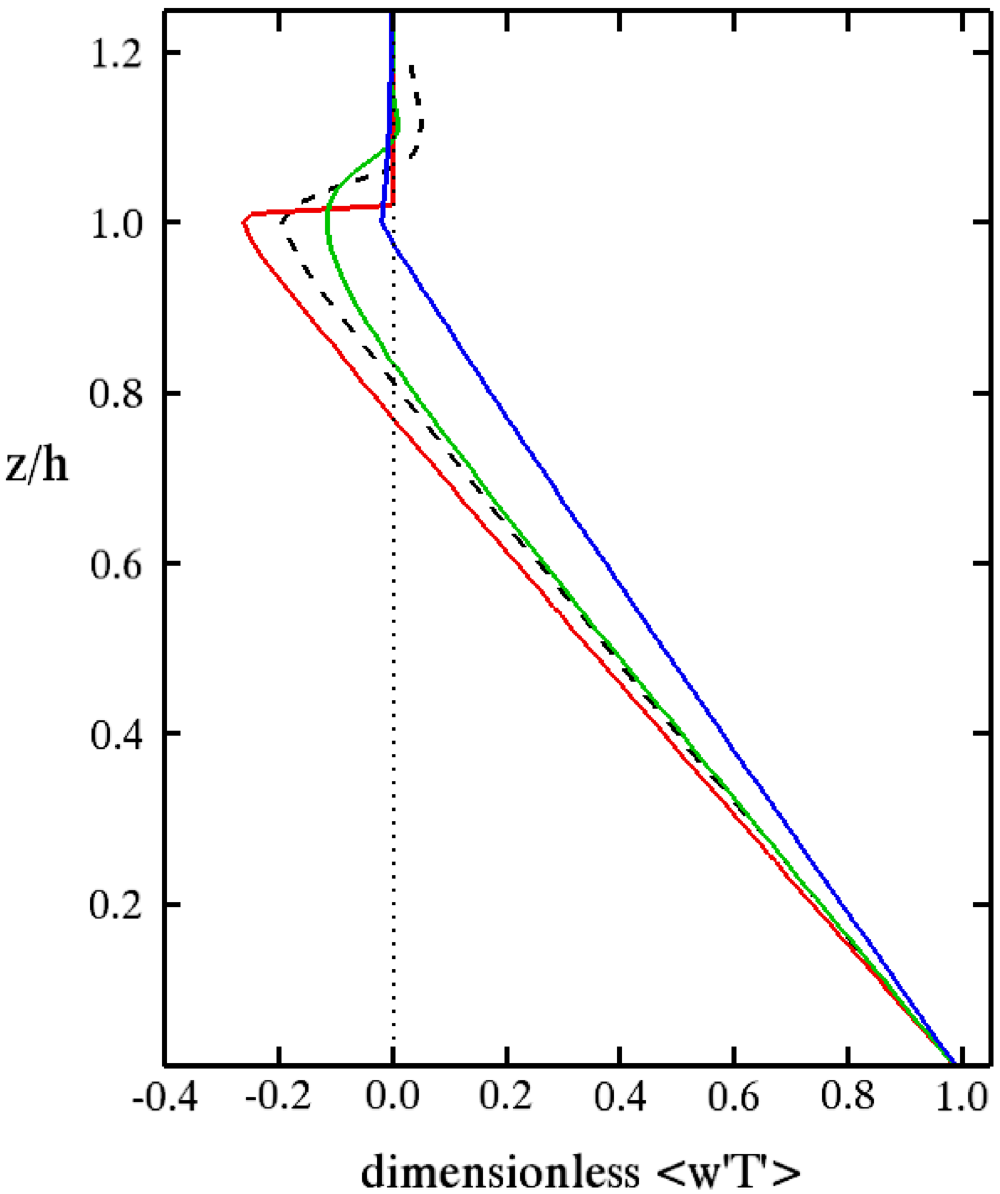
Key issues

- Parameterisation of the pressure terms in the Reynolds-stress and the scalar-flux equations
- Parameterisation of the third-order turbulent transport in the equations for the kinetic and potential energies of fluctuating motions
- Realisability, stable performance of the two-equation model

Expected outcome

- Counter gradient heat flux in the mid-PBL
- Improved representation of entrainment at the PBL top

→ dmitrii.mironov [at] dwd.de



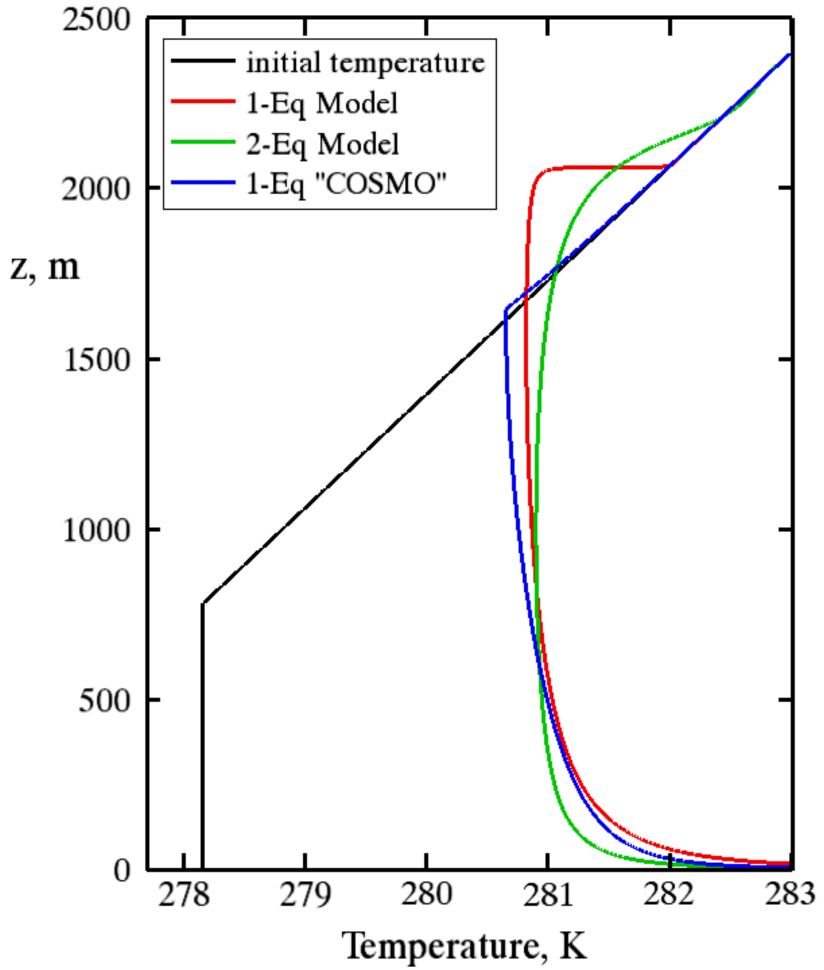
Potential-Temperature (Heat) Flux in Shear-Free Convective PBL

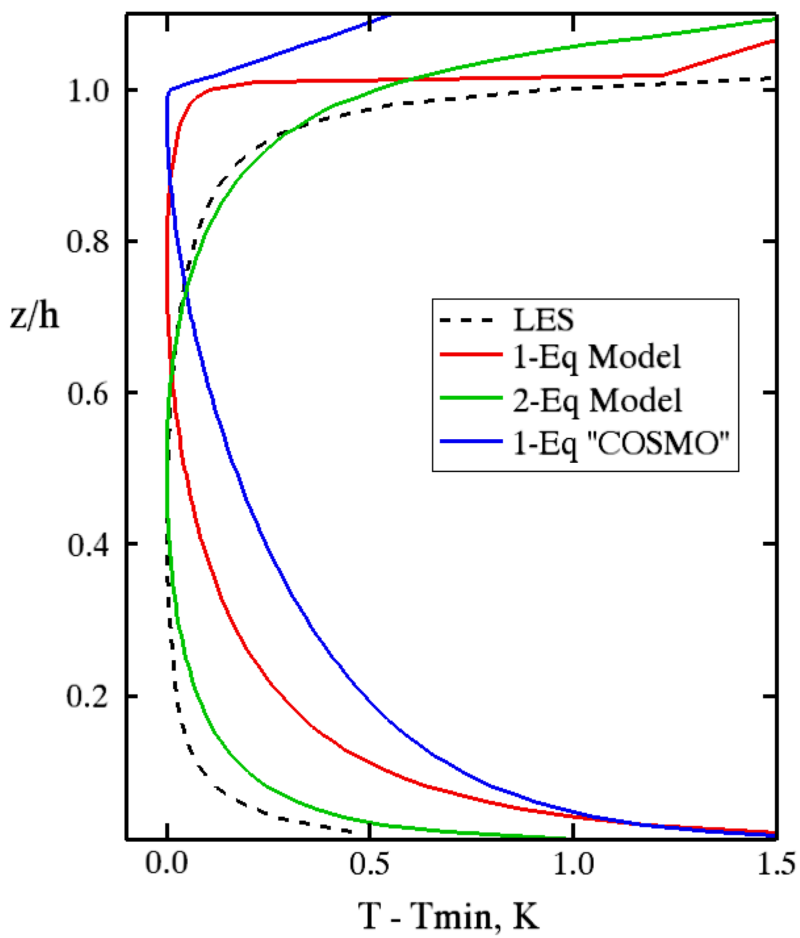
One-Equation and Two-Equation Models vs. LES Data

$<w'\theta'>$ made dimensionless with $w_*\theta_*$. **Black dashed** curve shows LES data, red – one-equation model, green – two-equation model, blue – one-equation model with the Blackadar formulation for the turbulence length scale.

→ dmitrii.mironov [at] dwd.de

Mean Temperature in Shear-Free Convective PBL
One-Equation and Two-Equation Models





Red – one-equation model, green – two-equation model, blue – one-equation model with the Blackadar (1962) formulation for the turbulence length scale. **Black curve** shows the initial temperature profile.

Potential temperature minus its minimum value within the PBL. **Black dashed** curve shows LES data (Mironov et al. 2000), red – one-equation model, green – two-equation model, blue – one-equation model with the Blackadar (1962) formulation for the turbulence length scale.

→ dmitrii.mironov [at] dwd.de

Conclusions and Outlook

- A dry version of a two-equation turbulence-convection model is developed and favourably tested through single-column numerical experiments
- A number of problems with the new two-equation model have been encountered that require further consideration (sensitivity to the formulation of turbulence length/time scale, consistent formulation of “stability functions”, realisability)

Ongoing and Future Work

- Consolidation of a dry version of the two-equation model (c/o Ekaterina and Dmitrii), including further testing against LES data from stably stratified PBL (c/o Dmitrii in co-operation with NCAR)
- Formulation and testing of a moist version of the new model

→ dmitrii.mironov [at] dwd.de

COSMO Activities: Priority Projects

Diagnostics, validation and verification

- **Verification System Unified Survey (VERSUS 1)**
  Adriano Raspanti (USAM; a.raspanti [at] meteoam.it)
- **Verification System Unified Survey (VERSUS 2)**
  Adriano Raspanti (USAM; a.raspanti [at] meteoam.it)

- **Advanced Interpretation and Verification of Very High Resolution Models (INTERP)**
  Pierre Eckert (MeteoSwiss; pierre.eckert [at] meteoswiss.ch)

→ talks by Adriano Raspanti and Marco Arpagaus

COSMO Activities: Priority Projects

Predictability and EPS

- **Development of a Short Range Ensemble (SREPS)**
  Chiara Marsigli (ARPA-SIMC; cmarsigli [at] arpa.emr.it)
- **Consolidation of COSMO Ensemble (CONSENS)**
  Chiara Marsigli (ARPA-SIMC; cmarsigli [at] arpa.emr.it)

Conclusions

- **Ensemble perturbations: Multi Model ICs/BCs & Perturbations on Physics Parameters:**
  - the use of different driving models seems to dominate with respect to physics parameter perturbations as regards the contribution to the spread
  - the selected parameters produce a detectable and comparable spread among members with the same driving model

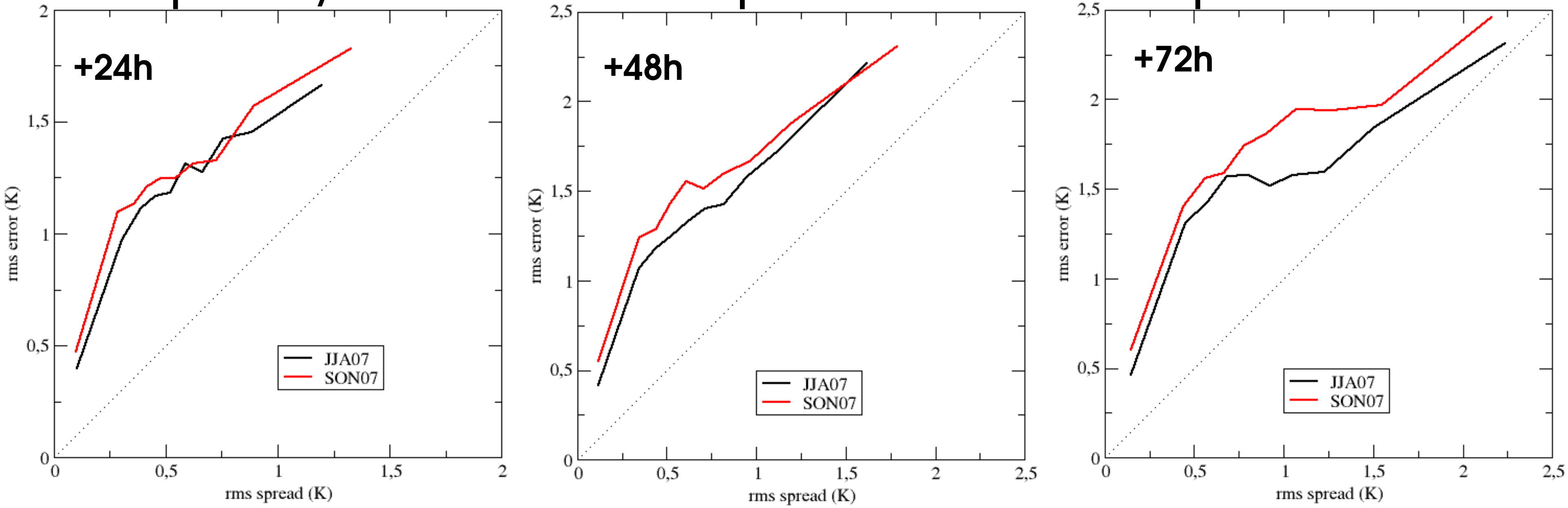
- **Ensemble spread-skill relationship**:
  - there is correlation between error and spread, but the system is under-dispersive -> a better representation of model error is needed

- the **different driving models** contribute differently to the ensemble skill, but in a way strongly dependent on forecast range, season, verification area

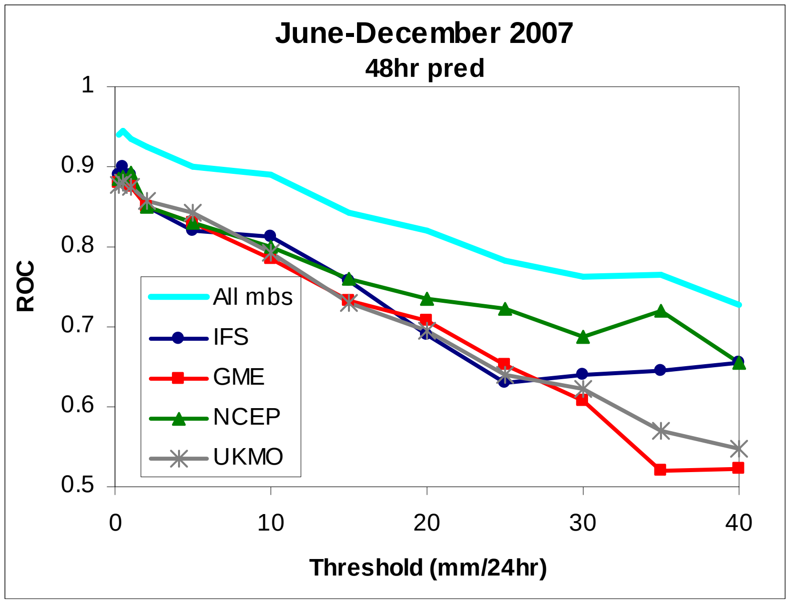
- the **different perturbations** contribute differently to the ensemble skill as well

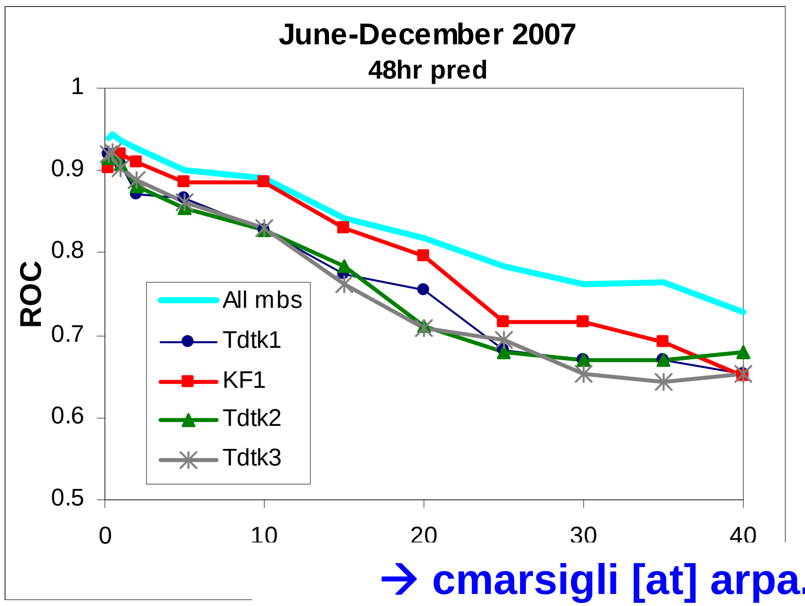
→ **cmarsigli [at] arpa.emr.it**

Spread/skill relationship - T850 on an alpine area



Ensemble skill – 24h tp over Greece (SYNOP)





→ cmarsigli [at] arpa.emr.it

COSMO Activities: Priority Projects

Predictability and EPS

- **Development of a Short Range Ensemble (SREPS)**
  Chiara Marsigli (ARPA-SIMC; cmarsigli [at] arpa.emr.it)
- **Consolidation of COSMO Ensemble (CONSENS)**
  Chiara Marsigli (ARPA-SIMC; cmarsigli [at] arpa.emr.it)

→ Merge COSMO-LEPS and COSMO-SREPS to obtain an ensemble system for days 2-5.
→ Boundary conditions for COSMO-DE-EPS

→ additional talk by Detlev Majewski on COSMO-DE-EPS

COSMO Activities: Priority Projects

Surface and soil processes

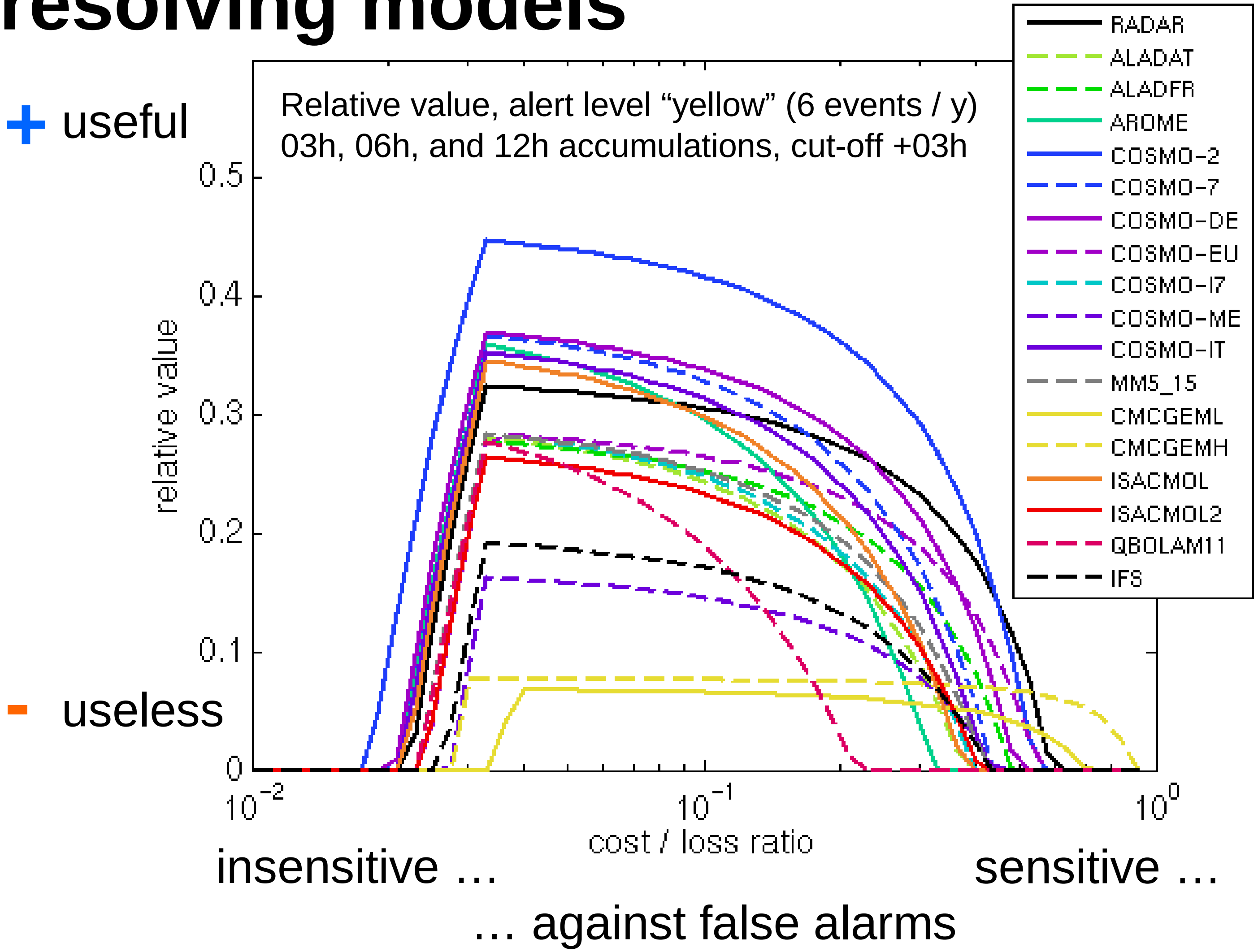
- **Consolidation of Lower Boundary Conditions (COLOBOC)**

  Jean-Marie Bettems (jean-marie.bettems [at] meteoswiss.ch)

  → Merge all (well advanced) activities related to the lower boundary condition and consolidate these developments

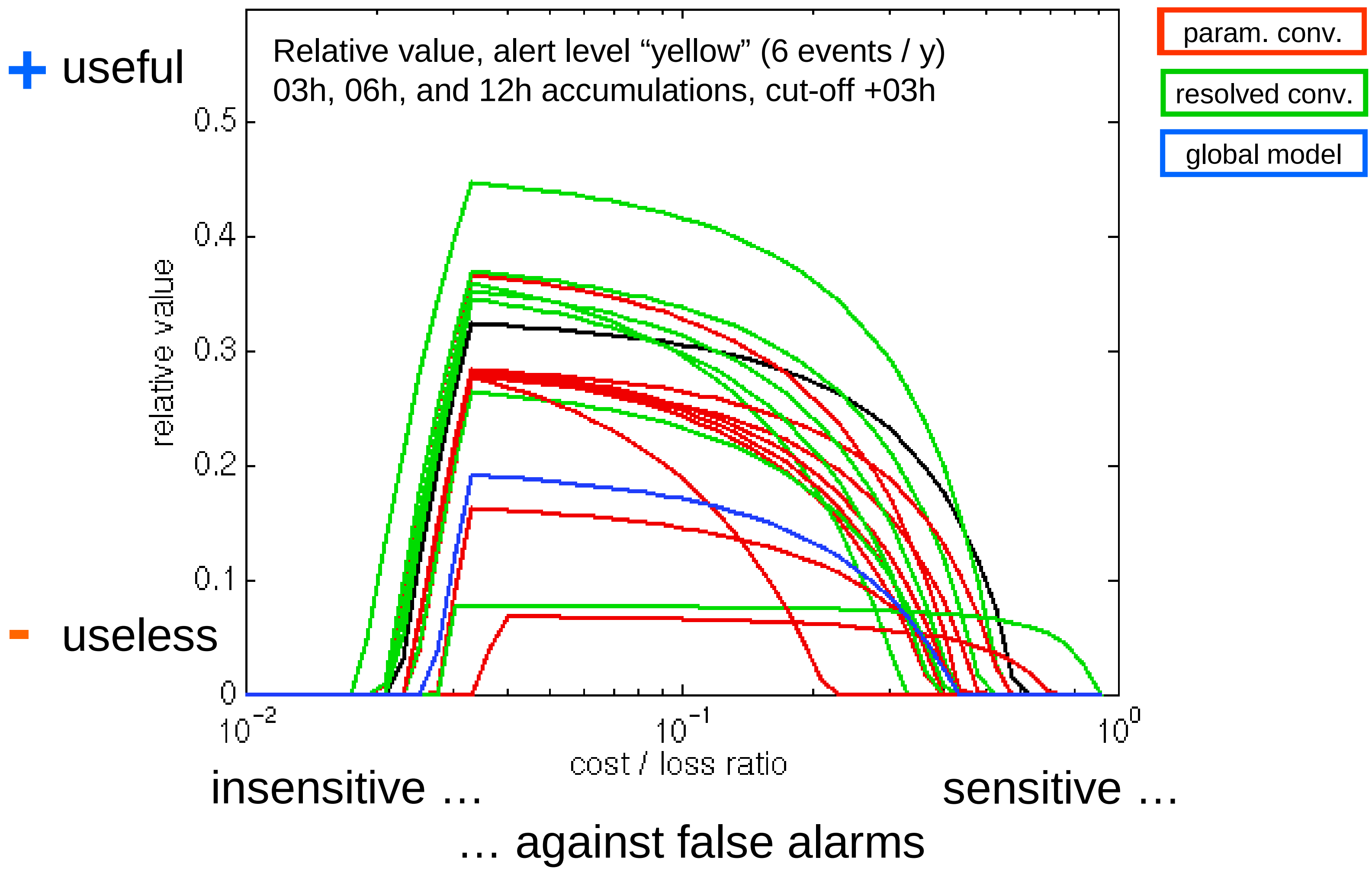
  - external parameters
  - TERRA (coupled, stand-alone, SCM)
  - snow
  - urban module
  - mosaic/tile

D-PHASE: Advantage of convection resolving models



→ **felix.ament [at] zmaw.de**

D-PHASE: Advantage of convection resolving models



→ **felix.ament [at] zmaw.de**

Component testing

Prognostic equation for TKE:

$$\frac{\partial e}{\partial t} + U_j \frac{\partial e}{\partial x_j} = -\beta g_i \overline{u_i'\theta_v'} - \overline{u_i'u_j'} \frac{\partial U_i}{\partial x_j} - \frac{\partial (u_j' e)}{\partial x_j} - \frac{1}{\overline{\rho}} \frac{\partial (\overline{u_i' p'})}{\partial x_i} - \varepsilon$$

I. II. III. IV. V. VI. VII.

- <u>Budget terms:</u>
  - I. : Local tendency
  - II. : Advection by the mean wind
  - III. : Buoyancy production term
  - IV. : Shear production term
  - V. : Turbulent transport of TKE
  - VI. : Pressure correlation term
  - VII. : Dissipation

Balázs Szintai (balazs.szintai@meteoswiss.ch)

Governing Equation, Truncation, Closure Assumptions

- Prognostic equations are carried for the TKE (trace of the Reynolds stress tensor) and for the potential-temperature variance
- Equations for other second-order moments (the Reynolds stress and the temperature flux) are reduced (truncated) to the diagnostic algebraic relations (by neglecting the time-rate-of-change and the third-order moments)
- Slow pressure terms in the equations for the Reynolds-stress and for the temperature-flux are parameterised through the Rotta return-to-isotropy formulations; linear parameterisations for the rapid pressure terms are used
- The TKE dissipation rate is parameterised through the Kolmogorov formulation
- The temperature-variance dissipation rate is parameterised assuming a constant ratio of the temperature-variance dissipation time scale to the TKE dissipation times scale (alternatively, the time scale ratio can be computed as function of the temperature-flux correlation coefficient)
- The third-order transport terms in the TKE and the temperature-variance equations are parameterised through the simplest isotropic gradient-diffusion hypothesis (alternatively, a "generalised" non-isotropic gradient-diffusion hypothesis can be used)
- The system is closed through an algebraic formulation for the turbulence length (time) scale that includes the buoyancy correction term in stable stratification

Turbulence Length Scale

An algebraic expression for *l*,

$$\frac{1}{l} = \frac{1}{\kappa z} + \frac{1}{l_\infty} + \boxed{\frac{N}{C_N e^{1/2}}}, \quad \kappa = 0.40, \quad C_N = 0.76, \quad l_\infty = 200\,\text{m}.$$

Estimates of l_∞ range from 100 m to 500 m.

Other estimates of C_N should be tested, ranging from 0.76 to 3.0.

Formulations for Turbulence Length (Time) Scale

Teixeira and Cheinet (2004), Teixeira et al. (2004),

$$l = \kappa z \exp(-0.01z) + \tau_0 e^{1/2}[1 - \exp(-0.01z)], \quad \tau_0 = \mathrm{Min}\left(600\mathrm{s}, \frac{C_N}{N}\right).$$

Does not satisfy the logarithmic boundary layer constraint, $l=\kappa z$ as $z \to 0$. This defect is easy to fix, e.g.

$$l = \kappa z \exp(-0.01z) + \tau_0 e^{1/2}\left(1 - \exp\left[-(0.01z)^{1+\alpha}\right]\right), \quad \alpha > 0.$$

A more flexible formulation (cf. Teixeira and Cheinet 2004),

$$l = \kappa z \exp(-10z/h) + \tau_0 e^{1/2}\left(1 - \exp\left[-10(z/h)^{1+\alpha}\right]\right),$$

where $$\tau_0 = \mathrm{Min}\left(\frac{h}{w_e}, \frac{C_N}{N}\right), \quad w_e = \left(\frac{10}{3} h^{-1} \int_0^h e\,dz\right)^{1/2}.$$

Formulations for Turbulence Length (Time) Scale (cont'd)

A simple interpolation formula (cf. Teixeira and Cheinet 2004, Teixeira et al. 2004),

$$l = \frac{\kappa z \tau_0 e^{1/2}}{\left[(\kappa z)^2 + \tau_0^2 e\right]^{1/2}}, \quad \tau_0 = \mathrm{Min}\left(\frac{h}{w_e}, \frac{C_N}{N}\right).$$

Asymptotic behaviour

$l = \kappa z$ near the surface,

$l = \frac{h}{w_e} e^{1/2}$ away from the surface in unstable stratification,

$l = C_N \frac{e^{1/2}}{N}$ away from the surface in (strongly) stable stratification.

Problems Encountered

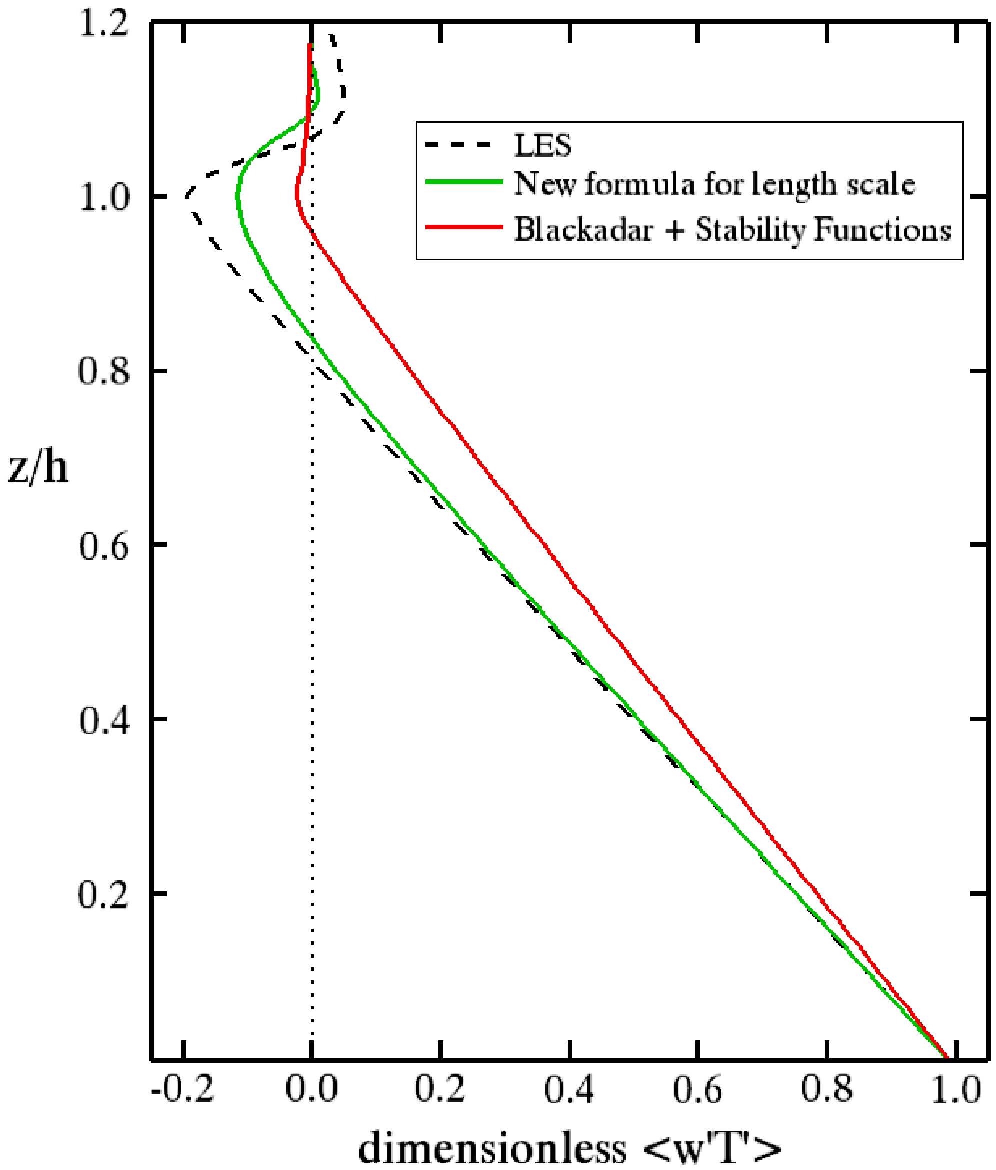
- Formulation of turbulence length (time) scale
- (The so-called) stability functions

Stability functions in the shear-free convective PBL,

$$\overline{w'\theta'} = \Phi_\theta \left[-\frac{2}{3} C_{u\theta} \tau_\varepsilon e \frac{\partial \overline{\theta}}{\partial z} + C_{u\theta} \left(1 - C_{\theta b}^{p}\right) \tau_\varepsilon g \alpha \overline{\theta'^2} \right],$$

$$\Phi_\theta = \frac{1}{1 + C_\Phi \tau_\varepsilon^2 N^2}, \quad C_\Phi = \frac{4}{3} \frac{\left(1 - C_b^u\right)}{C_\theta^u}, \quad N^2 = \frac{g}{\theta_{ref}} \frac{\partial \overline{\theta}}{\partial z},$$

where τ_ε is the TKE dissipation time scale.



Potential-Temperature Flux in Shear-Free Convective PBL

Stability Functions

$\langle w'\theta' \rangle$ made dimensionless with $w_*\theta_*$. **Black** dashed curve shows LES data (Mironov et al. 2000), green – two-equation model with "new" formulation for turbulence length scale and no stability functions, red – two-equation model with the Blackadar (1962) formulation for the turbulence length scale and with stability functions.