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Swiss Confederation

Federal Department of Home Affairs FDHA
Federal Office of Meteorology and Climatology MeteoSwiss

Performances of COSMO at 1km resolution

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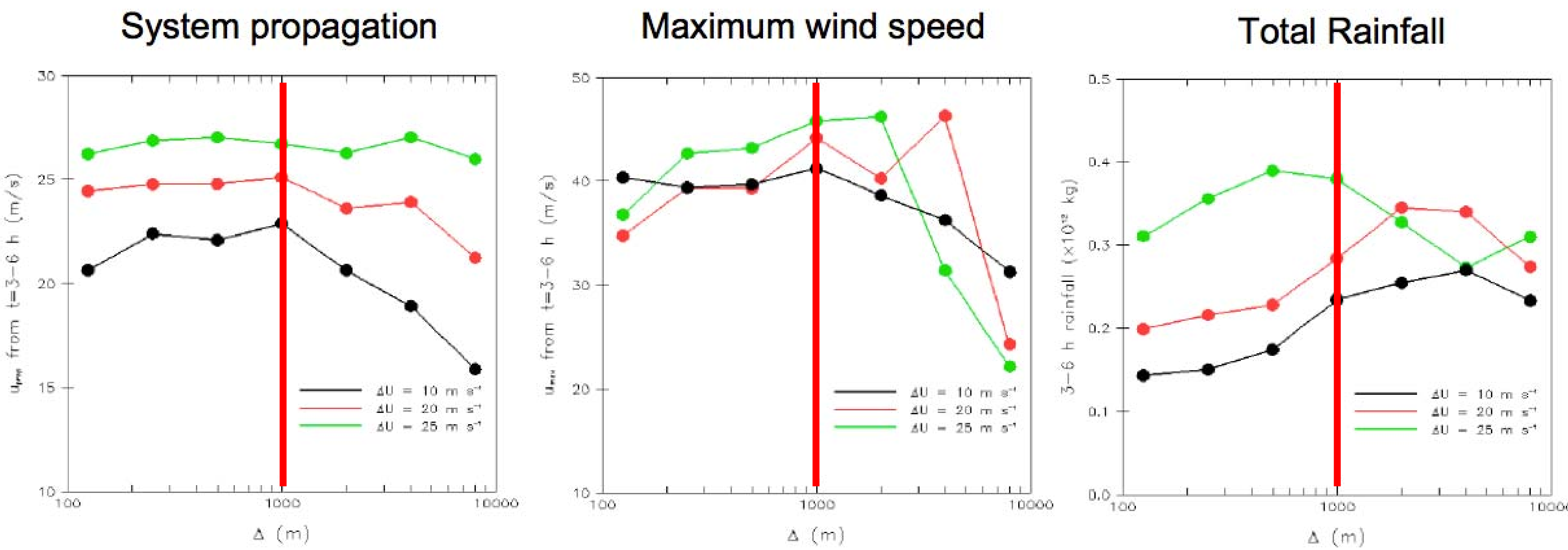
Francis Schubiger

10th International SRNWP-Workshop on Non-Hydrostatic Modelling,
May 13, 2013, DWD, Offenbach

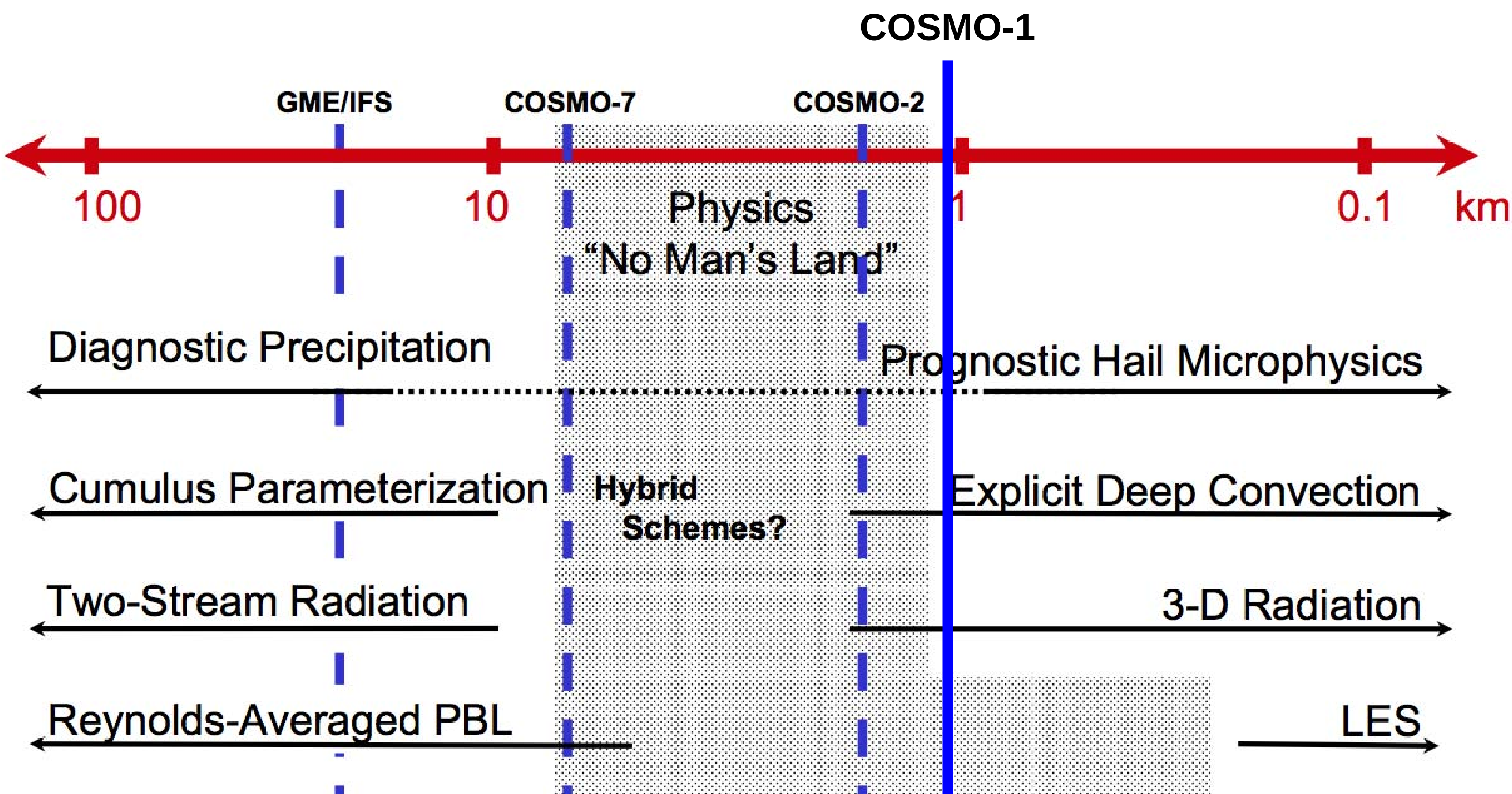
Why a 1 km deterministic forecast?



- Many **bulk properties converge** at O(1 km) resolution
- Many bulk properties have **predictable biases**

Bryan, 2007

Reduced Uncertainty

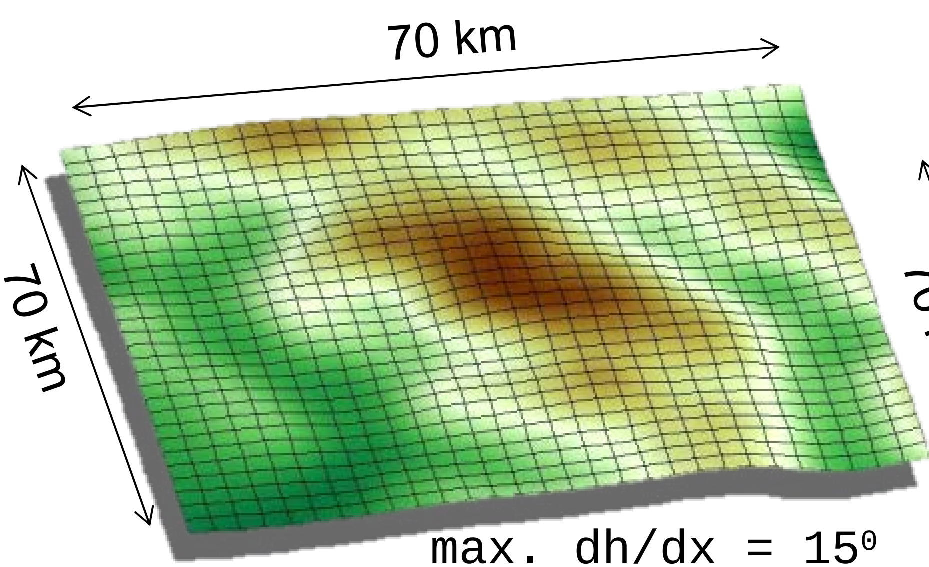


COSMO-1 can steer clear of a large part of the “grey zone” by jumping ahead to Δ=1 km

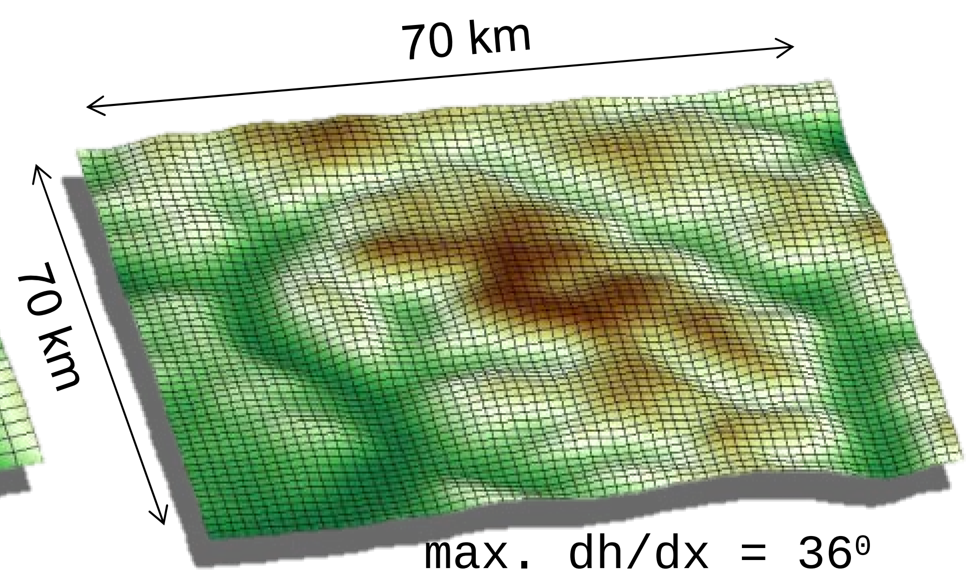
(adapted from Klemp 2007)

Better Topography

- Better near surface wind field (valley winds, Föhn, drag, …)
- Better representation of surface heterogeneity (triggering)
- “Closer match to obs”



COSMO-2



COSMO-1

Overview

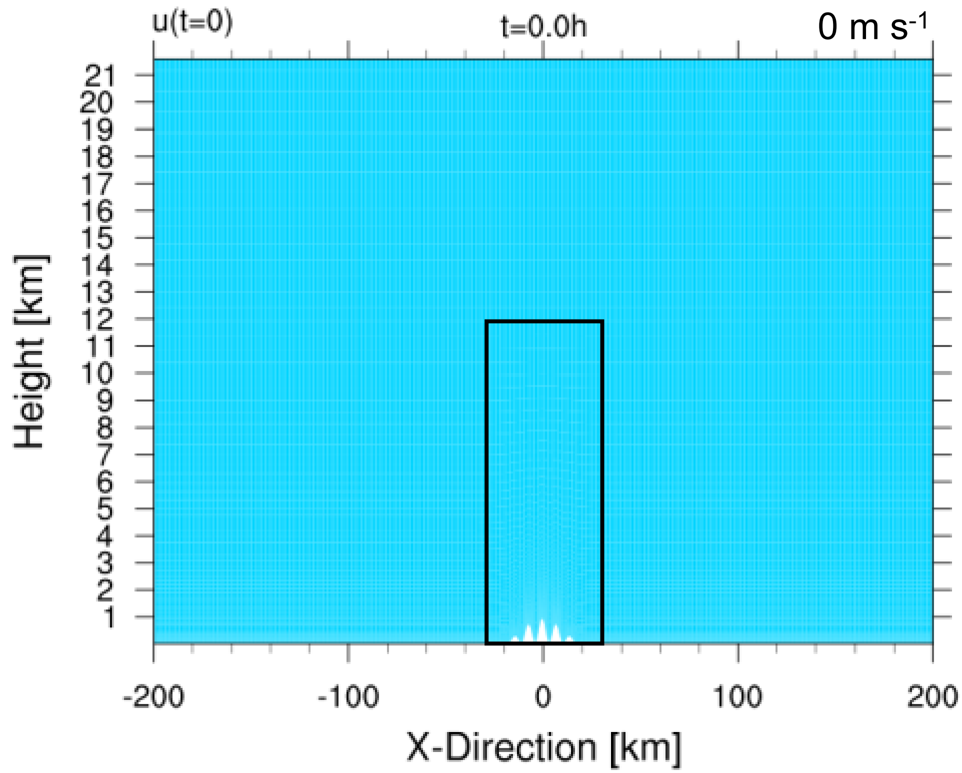
- Motivation
- Part I:
  - Stability of the new dynamical core with idealized experiments
- Part II:
  - Actual settings of the regular runs
  - Verification results for the last 2 seasons
- Summary
- Outlook

Idealized test case I (atmosphere at rest)

- 2-dimensional
- Schaer et al. MWR 2002 topography

$$h(x) = \begin{cases} h_0 \cos^2\left(\frac{\pi x}{\lambda}\right) \cos^2\left(\frac{\pi x}{2a}\right) & |x| \le a \\ 0 & |x| > a \end{cases}$$

- 80 level SLEVE2 coord.
- Δx=1.1km, Lx=401km
- Δz=20-812m, Lz=22km
- Δt=10s
- No humidity; Polytrope temp. gradient=0.0065K/m
- Tropopause at 12km
- Rayleigh sponge (>11.5km)



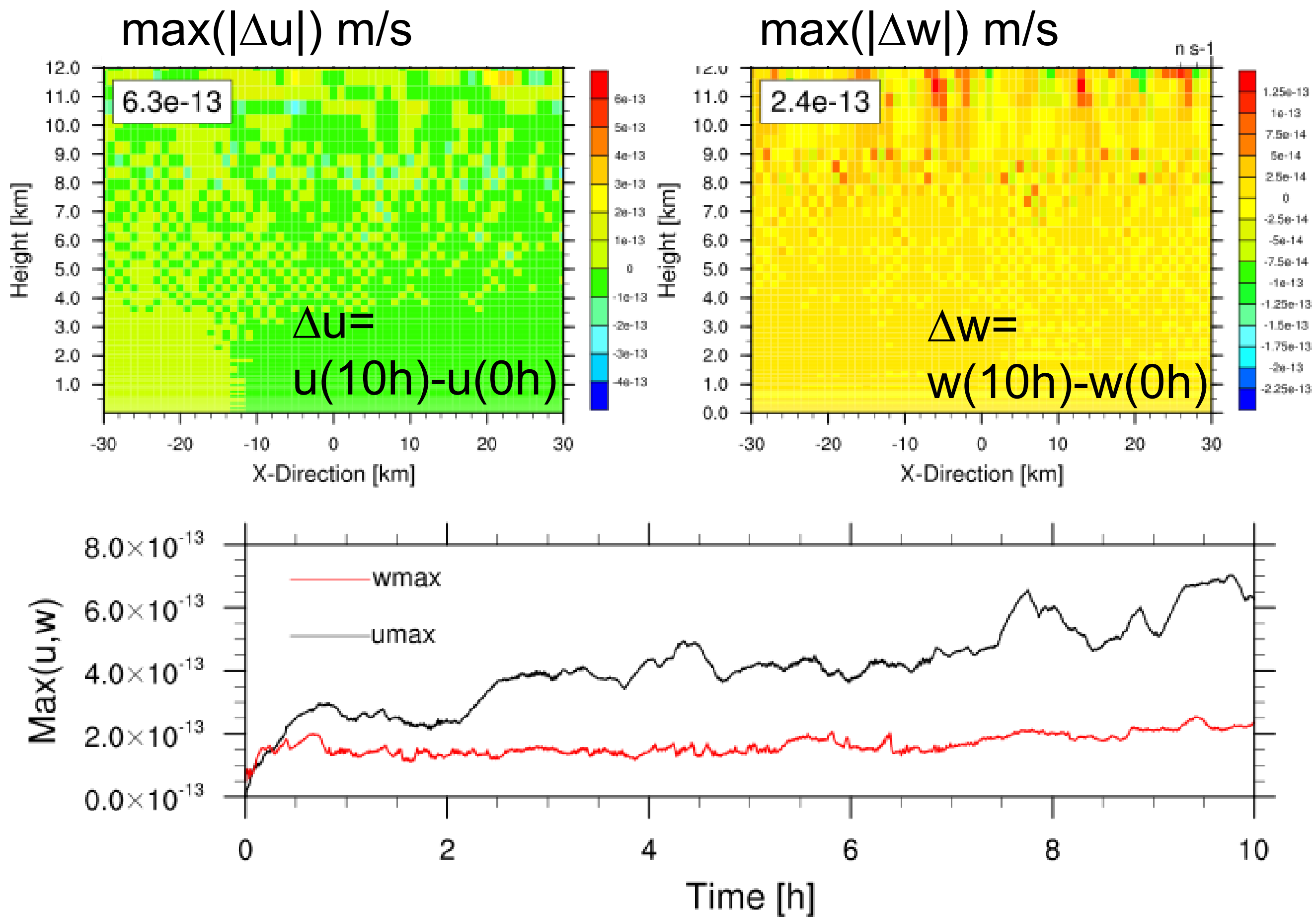
h_0=1000m (max. dh/dx=21°)
h_0=2000m (max. dh/dx=37°)
irk_order=3
iadv_order=5
ieva_order=3

Idealized test case I (atmosphere at rest)

Vertical cross-section
through centre of domain

No mountain
h_0=0m
λ=8km
a=25km
ldyn_bbc=F
divdamp=20

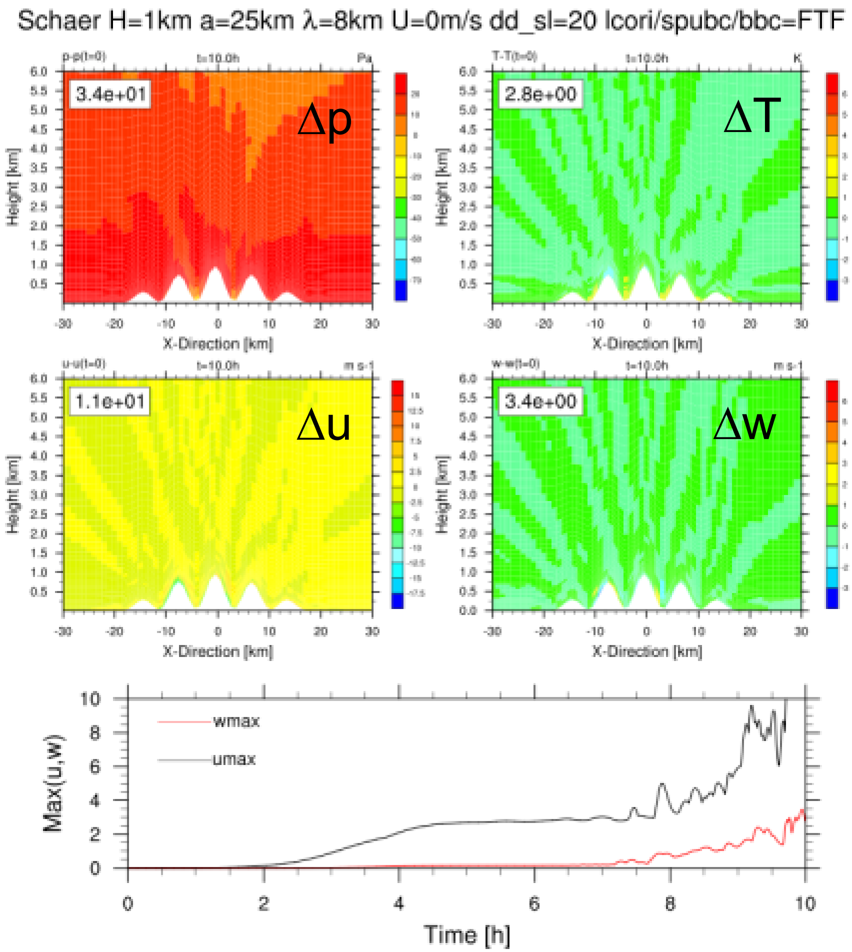
Time series



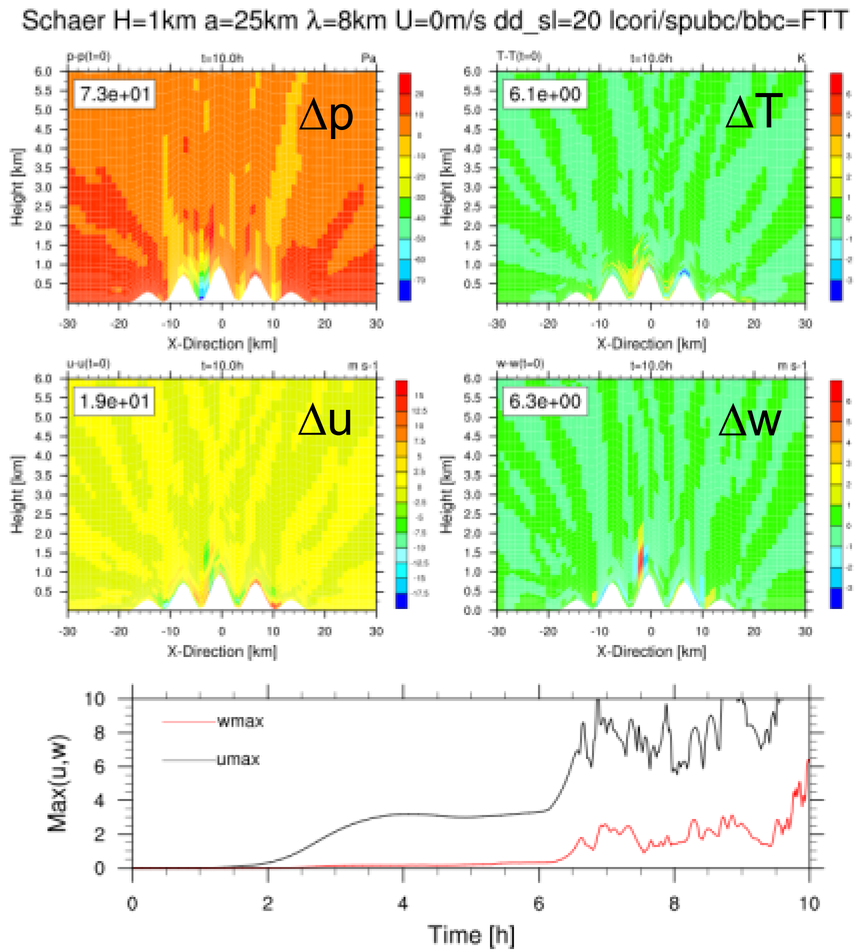
Idealized test case I (atmosphere at rest)

h_0=1000m, divdamp_slope=20, nrdtau=16, svc2=3.5km

New Bottom Bound. Cond.(**114**)



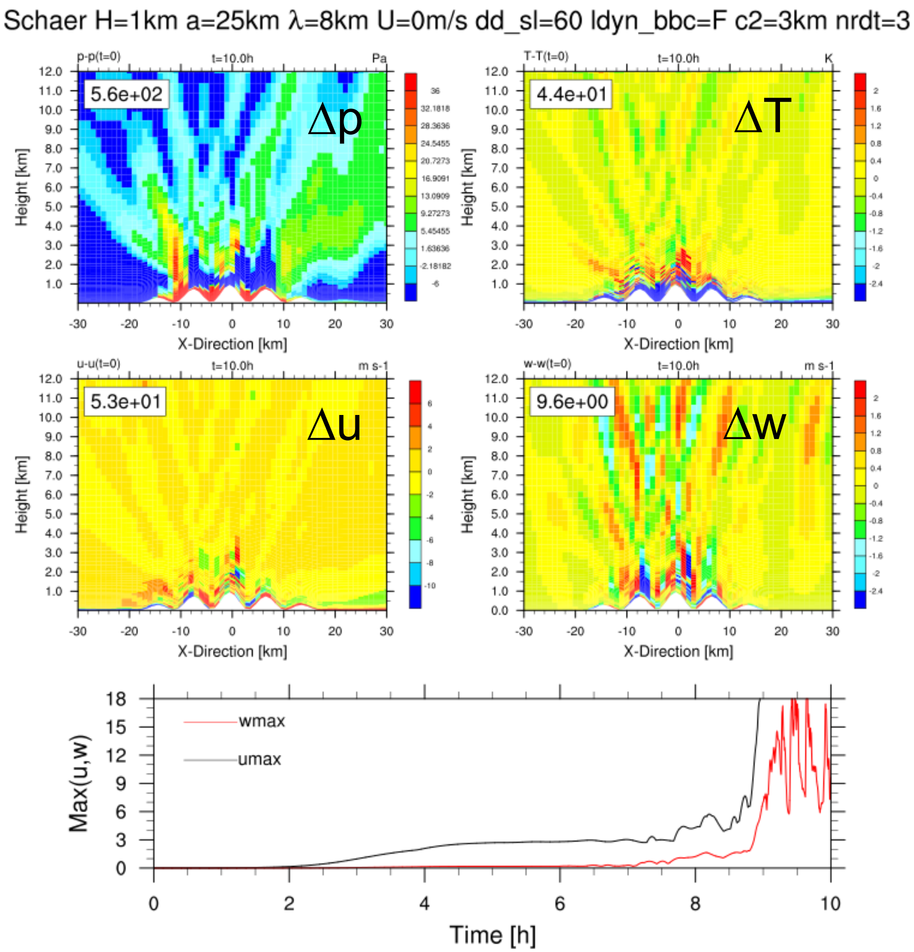
Old BBC **for w**

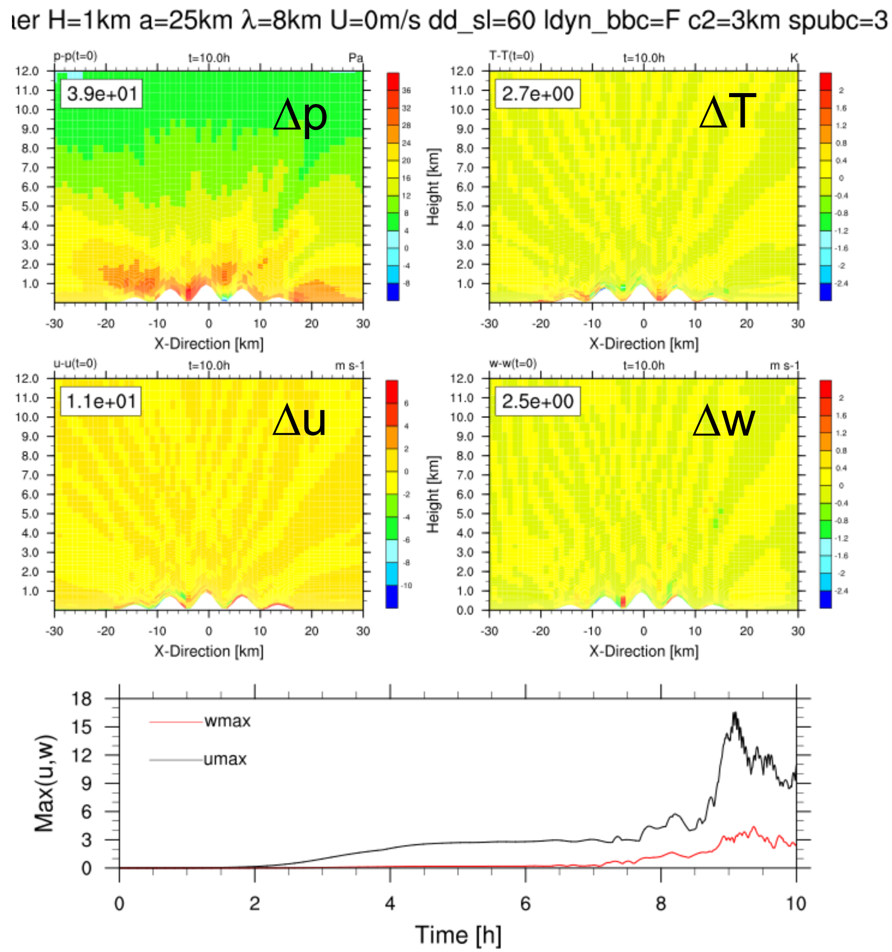


Idealized test case I (atmosphere at rest)

h_0=1000m, divdamp_slope=60, nrdtau=3, svc2=3km

Damping all var. @ upper boundary | **Only w** (Klemp,2008; itype_spubc=3)

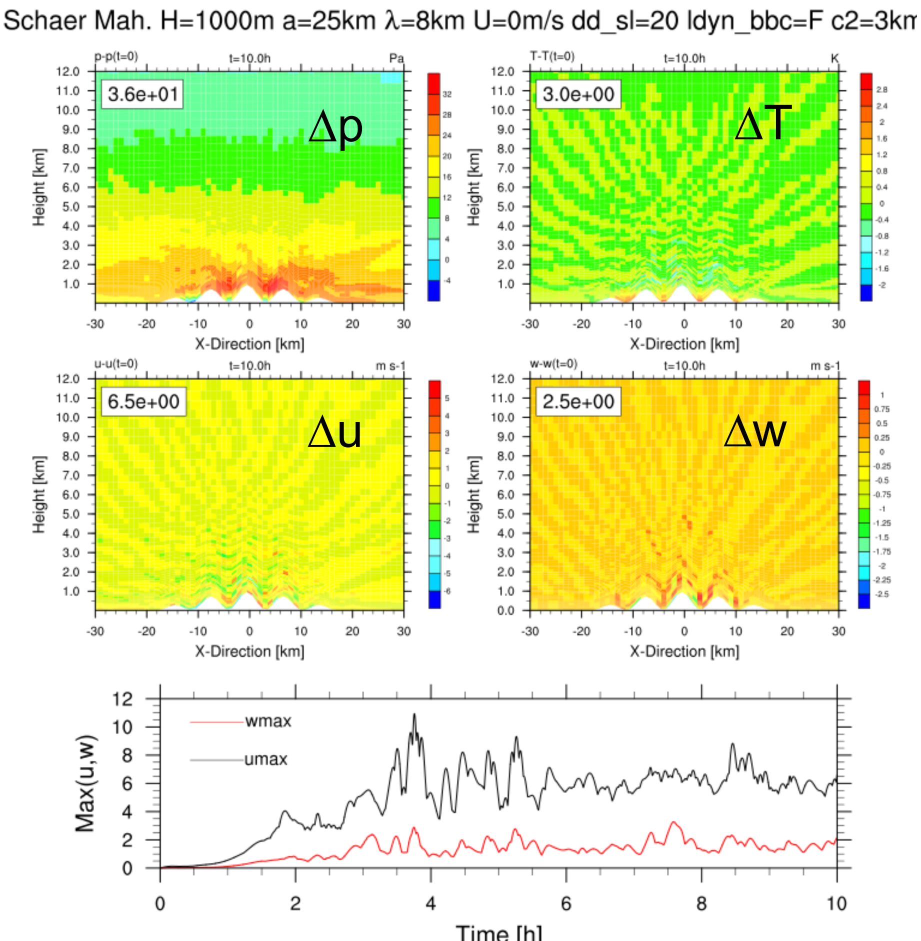


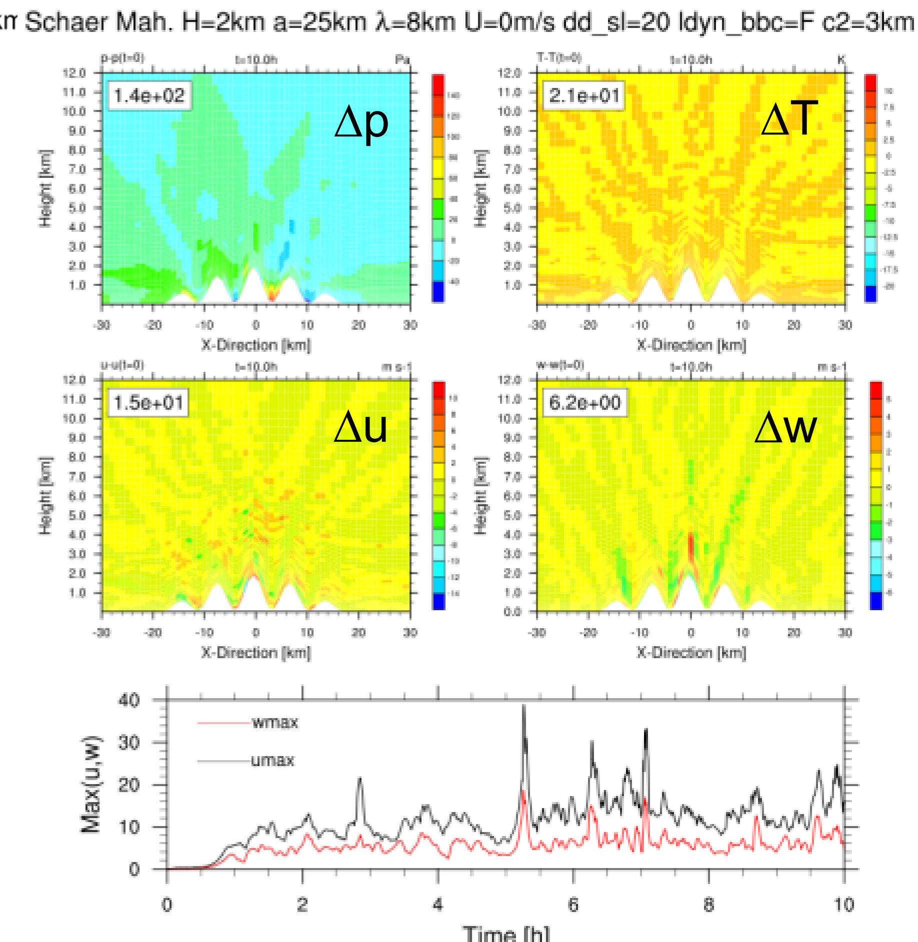


Idealized test case I (atmosphere at rest)

Mahrer pressure gradients, divdamp_slope=20, svc2=3km

h_0=1000m **h_0=2000m**





(max. dh/dx=21⁰) (max. dh/dx=37⁰)

Idealized test case I (atmosphere at rest)

- 2 different 80 level SLEVE2 coordinate systems

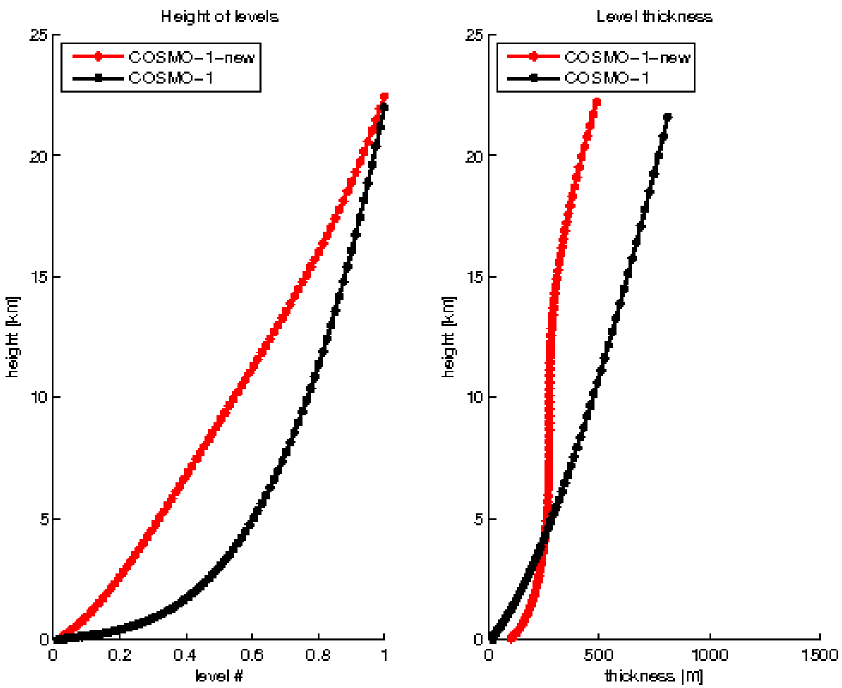
with different layers thicknesses:

Δz=101-490m, Lz=22.4km

or

Δz=20-812m, Lz=22km

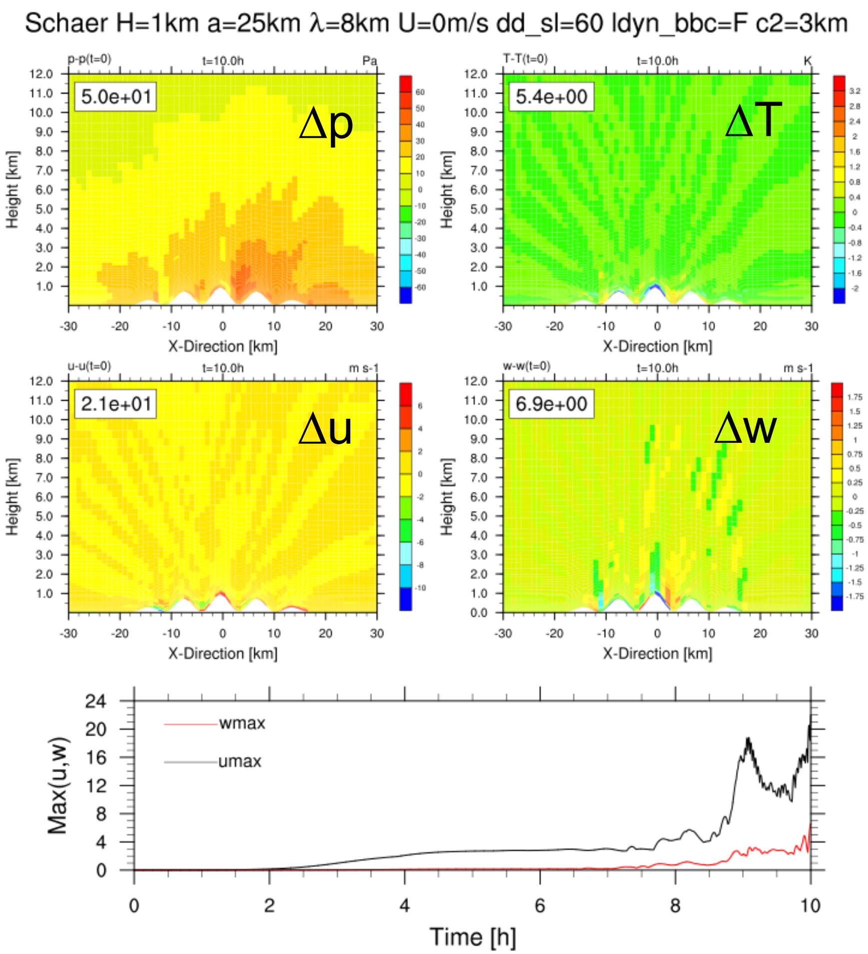
(same mean thicknesses)

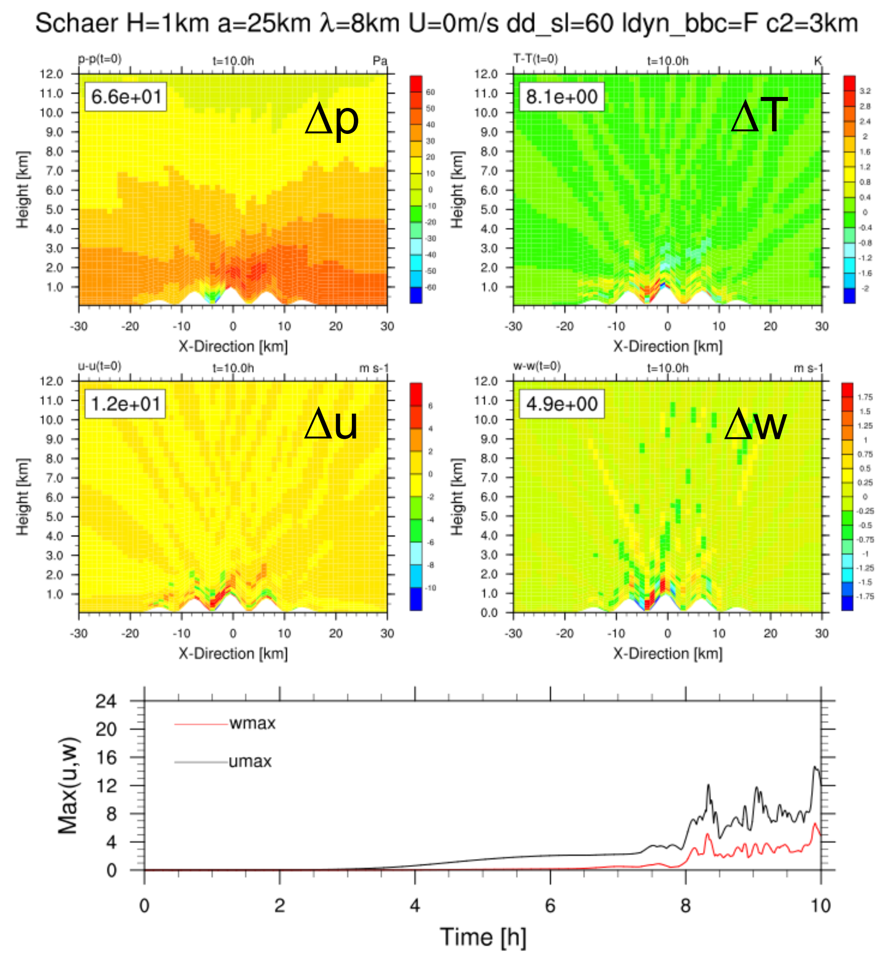


Idealized test case I (atmosphere at rest)

`divdamp_slope=60, svc2=3km, nrdtau=16`

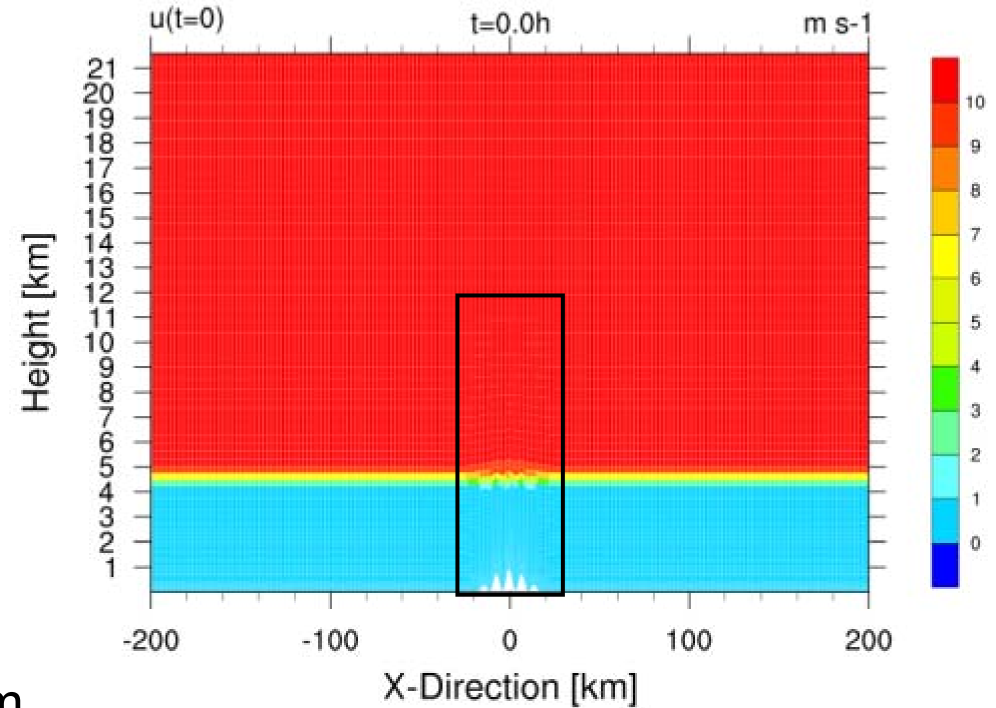
Big changes of Δz | **Small changes of Δz**





Idealized test case II (shear flow)

- 2-dimensional
- Schaer et al. MWR 2002 topography
- 80 level SLEVE2 coord.
- Δx=1.1km, Lx=401km
- Δz=20-812m, Lz=22km
- Δt=10s
- No humidity; polytrope temp. gradient=0.0065 K/m
- Tropopause at 12km
- Rayleigh sponge (>11.5km)



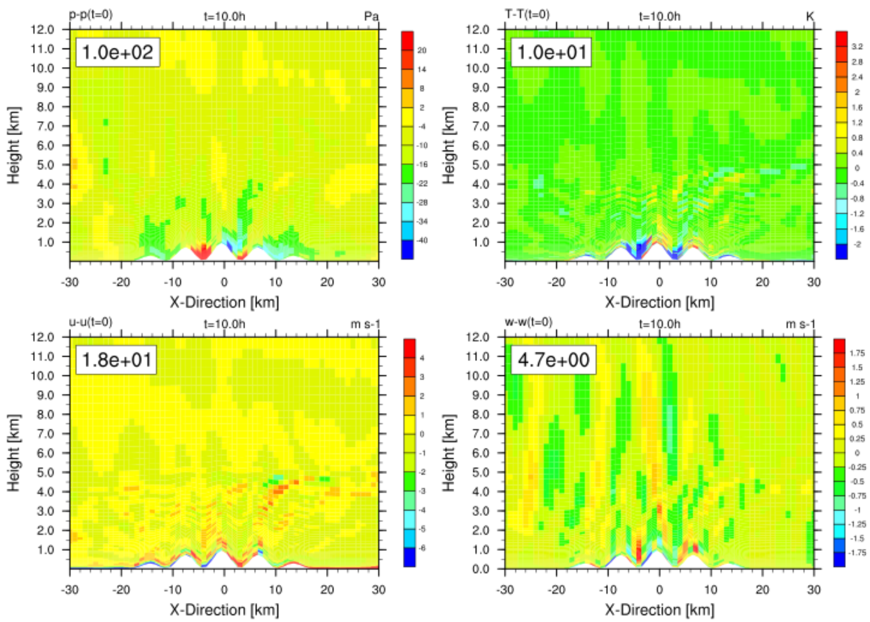
10m/s west wind above 5km height

Idealized test case II (shear flow)

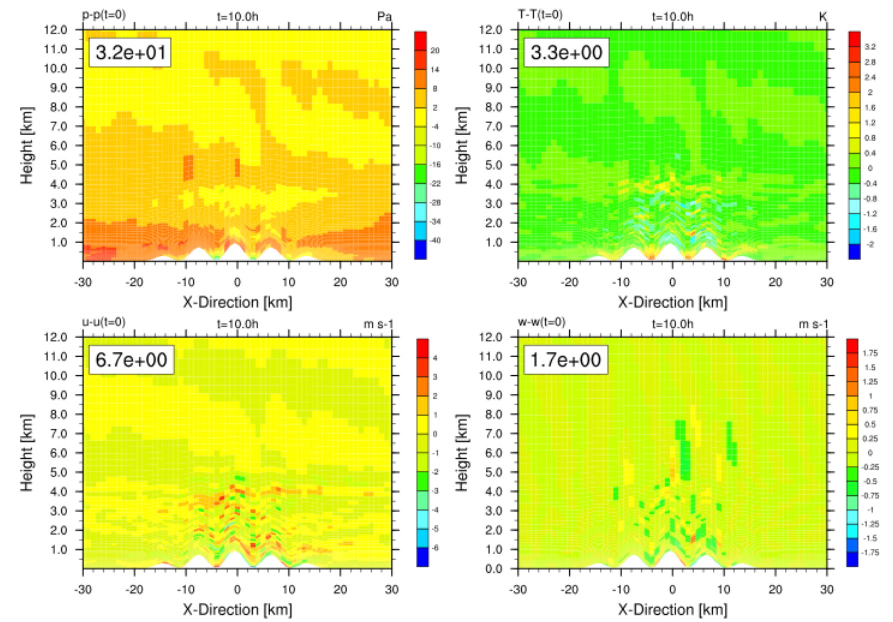
divdamp_slope=20, svc2=3km, nrdtau=16

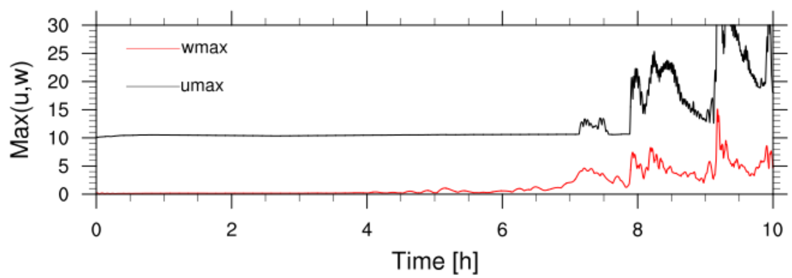
Standard | **Mahrer pressure gradients**

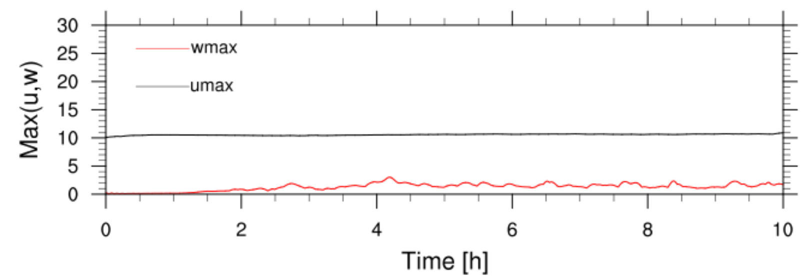
Schaer H=1km a=25km λ=8km U=10m/s dd_sl=20 ldyn_bbc=F c2=3km



Schaer Mah. H=1km a=25km λ=8km U=10m/s dd_sl=20 ldyn_bbc=F c2=3km







Summary Part I

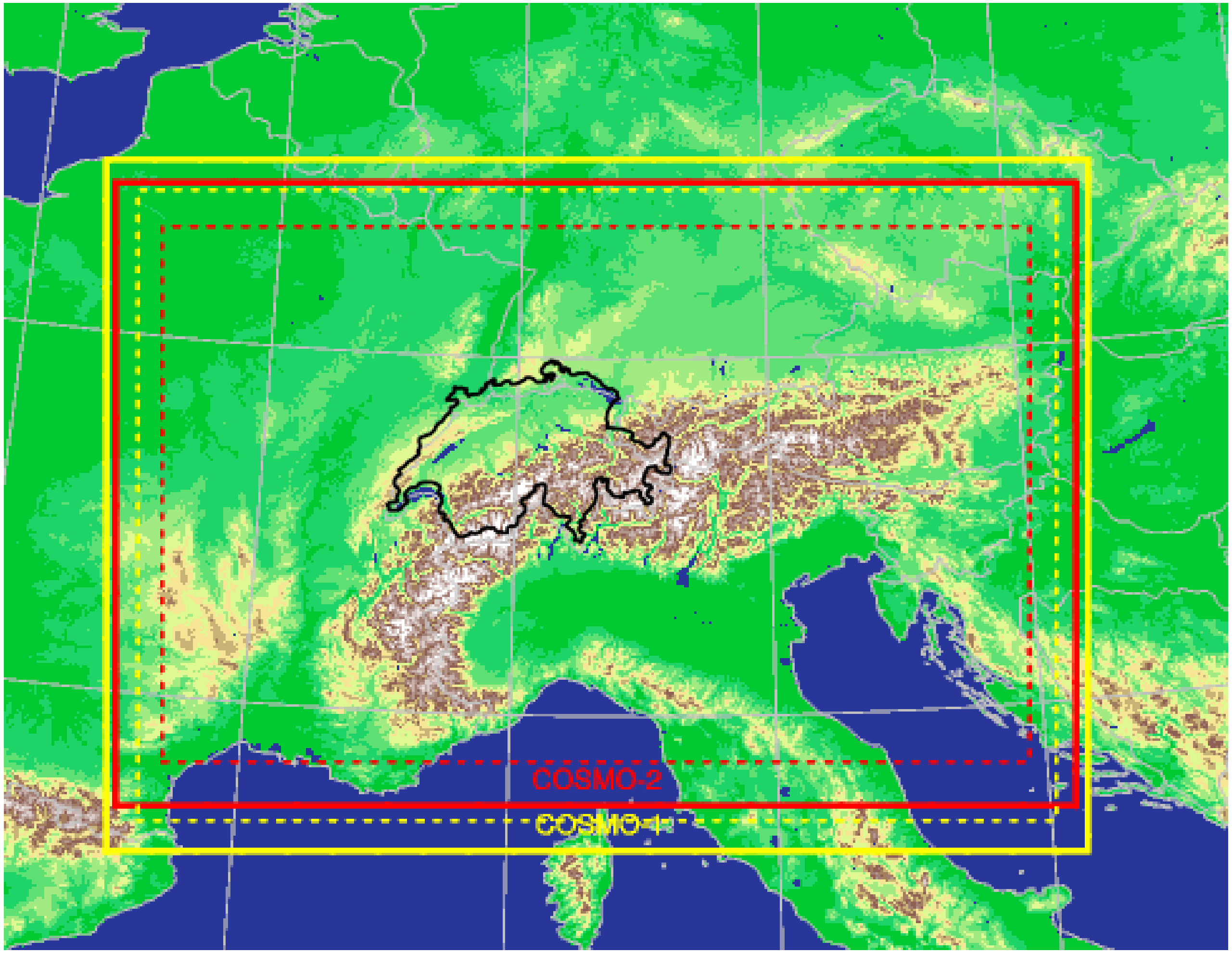
- The stability can be analysed by using a selection of possible choices (e.g. the kind of lower or upper boundary conditions, the amount of divergence damping, etc.)
- The choice of the vertical levels (changes of layer thicknesses, SLEVE2 parameters) can have an impact on the stability of the model
- A truly horizontal pressure gradients following Mahrer (1984) shows **better results**
- **But not all settings translate directly to the real world !**

Part II: Experimental Run: Setup

- **Continuous 1km-assimilation cycle** since end of August 2012 (including latent heat nudging and snow analysis)
- **Two** forecasts per day (00/12 UTC) to **+24h**
- Driven by the operational COSMO-7km forecasts
- Run at CSCS in approx. 1h45’ elapsed time
  with 2470 cores (60%) on CRAY XE6
- Visualization, monitoring and verification for evaluation purposes but not for production!

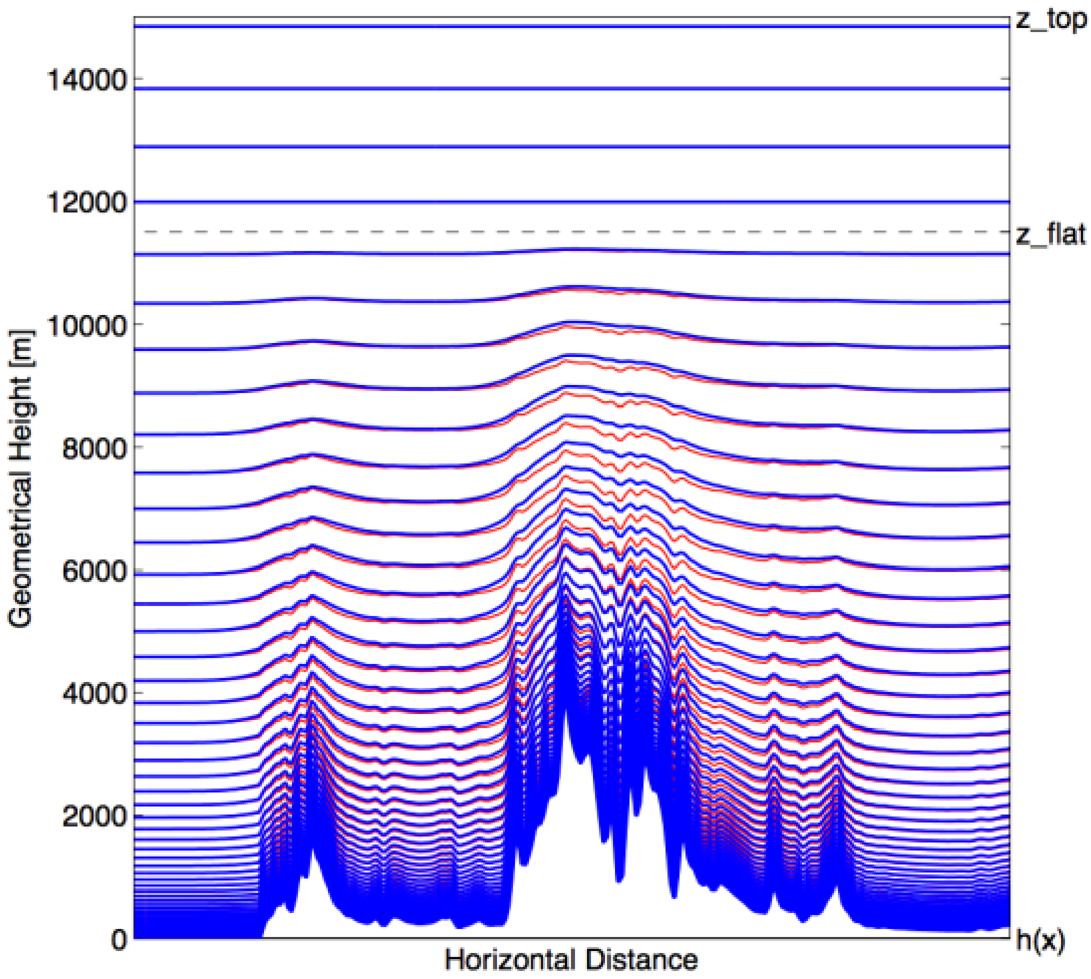
COSMO-1 Domain

- lon × lat × lev = 1062 × 774 × 80



New Coordinate Transformation

- Generalized **SLEVE** (after Leuenberger et al. 2010) (ivctype=4, svc1=10km, svc2=3.5km, nfltvc=100, n=1.35)



Gal-Chen
Δz_{min} = 13.1 m
ivctype=2

SLEVE
Δz_{min} = 15.6 m

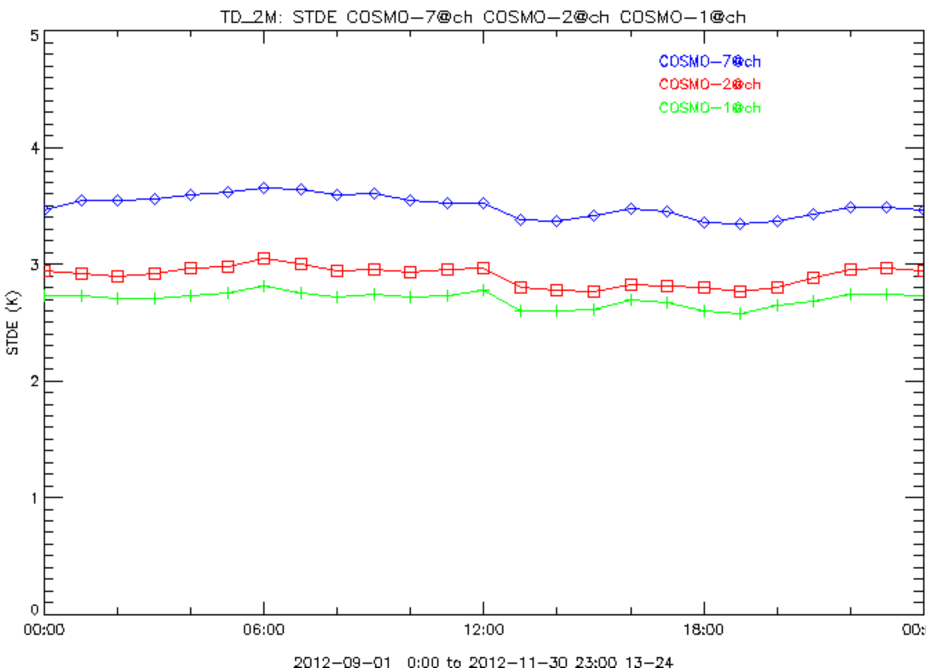
Settings for dynamics and physics

- **New fast waves solver** (consistent 2^{nd}-order accuracy, strong conservation form of divergence operator, increased divergence damping)
- Horizontal non-linear **Smagorinsky** diffusion
- **No** artificial horizontal diffusion
- Rayleigh damping of **all** variables at upper boundary (test running with condition on w **only** looks very similar)

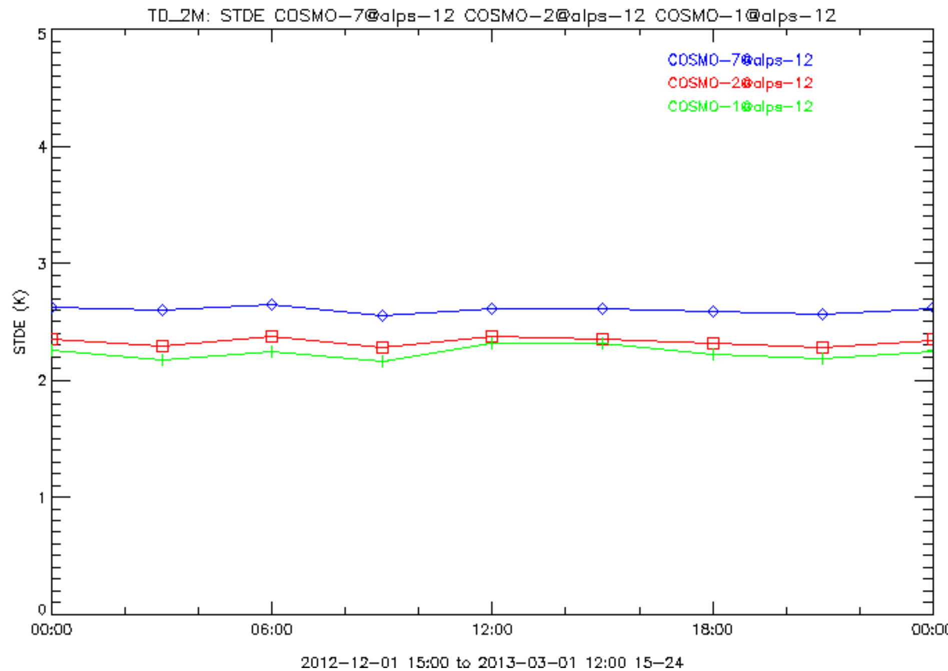
- 6 category microphysics including **graupel** (as COSMO-2)
- **Standard** turbulence and multilayer soil module
- **Explicit** deep convection but Tiedtke shallow convection (C-2)
- Ritter-Geleyn radiation every 6’
- Roughness length only from land use ($Z_0 \leq 1$m)
- No sub grid scale orography

Dew Point Temp. at 2m of **COSMO-1** for
SON 2012 DJF 2013

Standard Deviation CH +13-24h



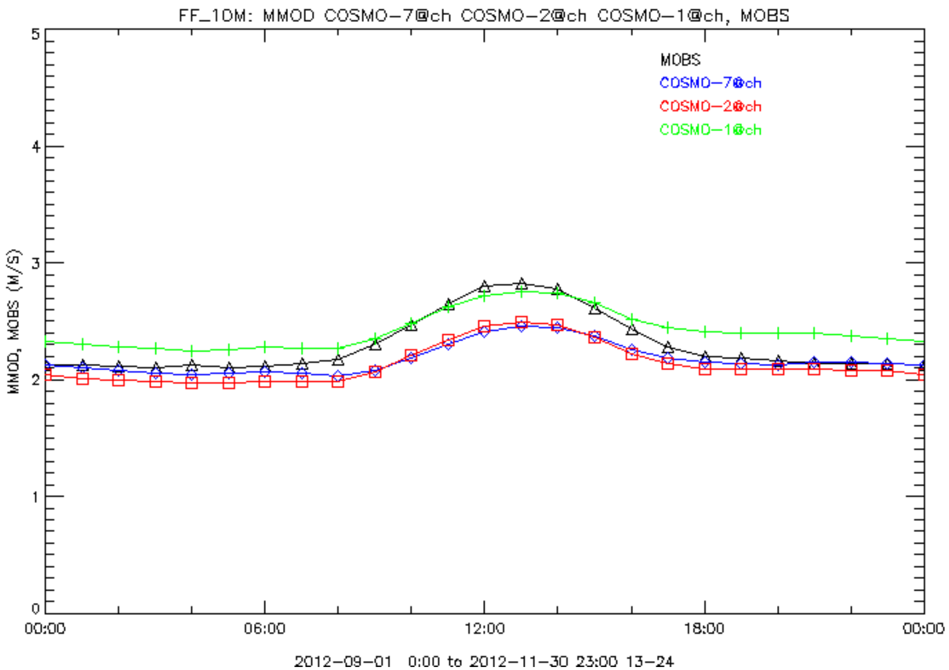
Standard Deviation Alps +15-24h

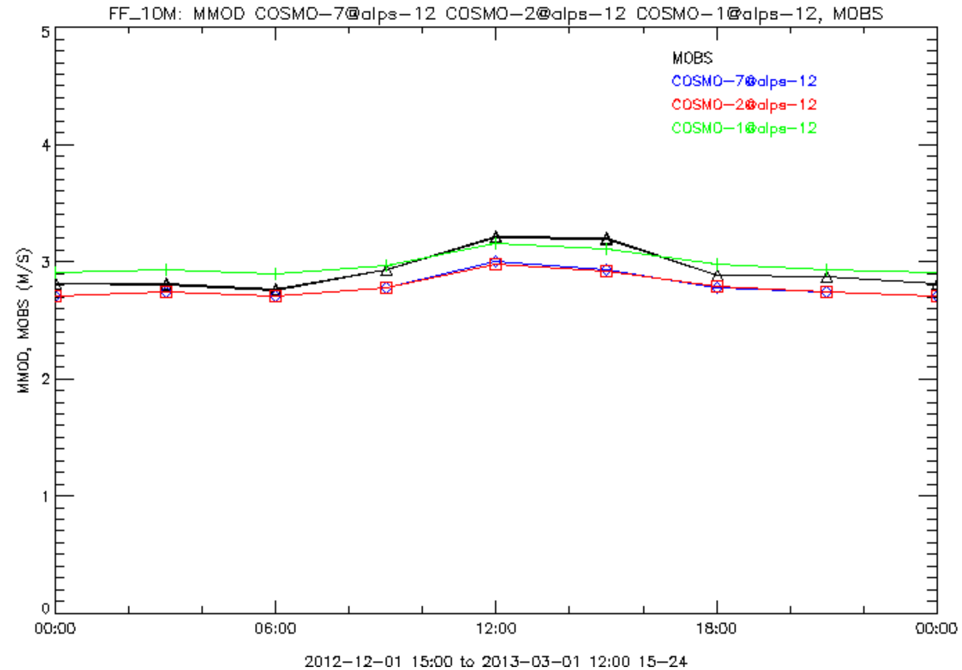


COSMO-7
COSMO-2
COSMO-1

10m Wind Speed of COSMO-1 for
SON 2012 DJF 2013

Swiss domain +13-24h Alps +15-24h

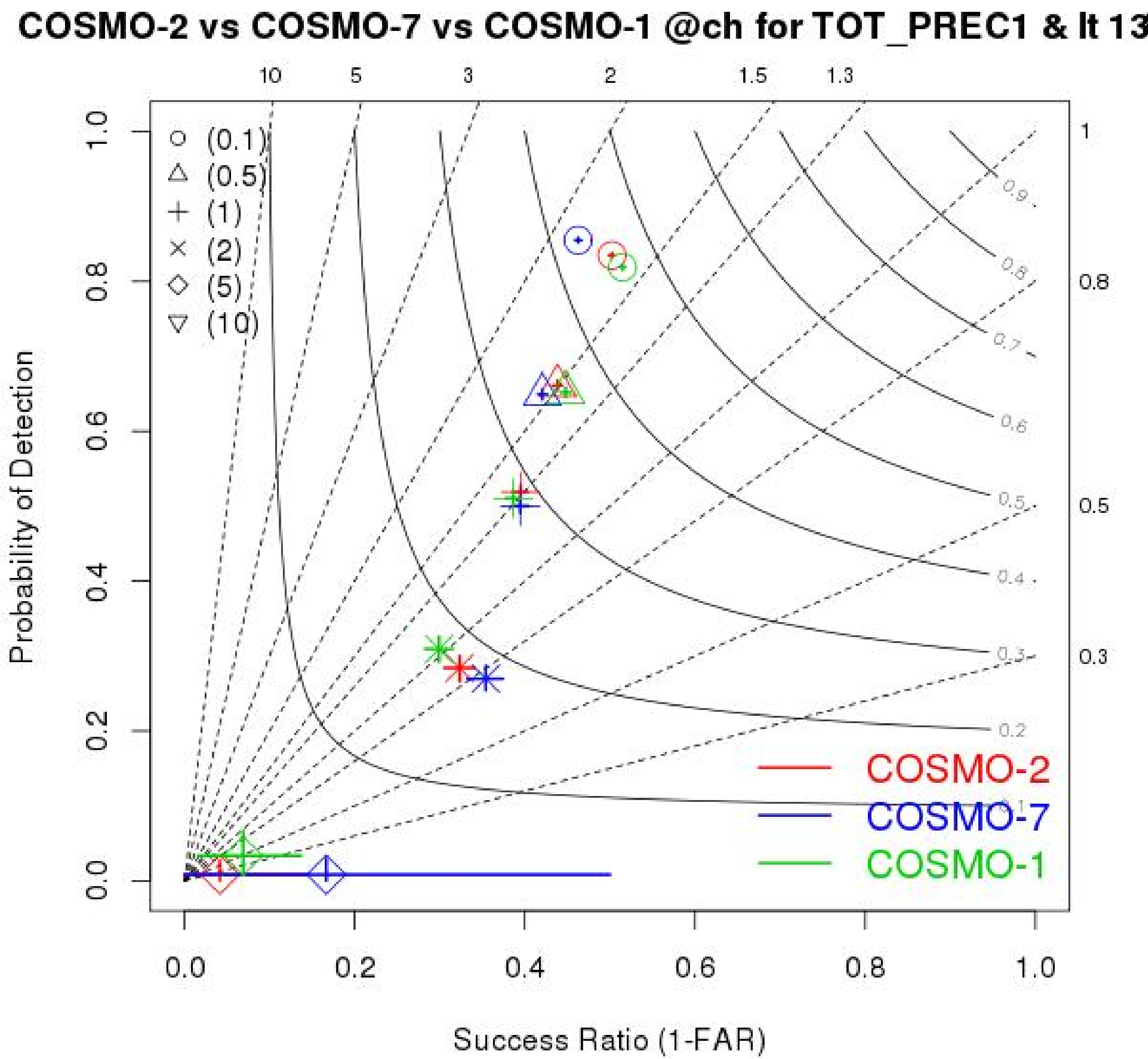




Higher wind speed due to lack of low level friction

COSMO-7
COSMO-2
COSMO-1

Precipitation of **COSMO-1** DJF13



Freq. Bias

Crit. Suc. Ind.

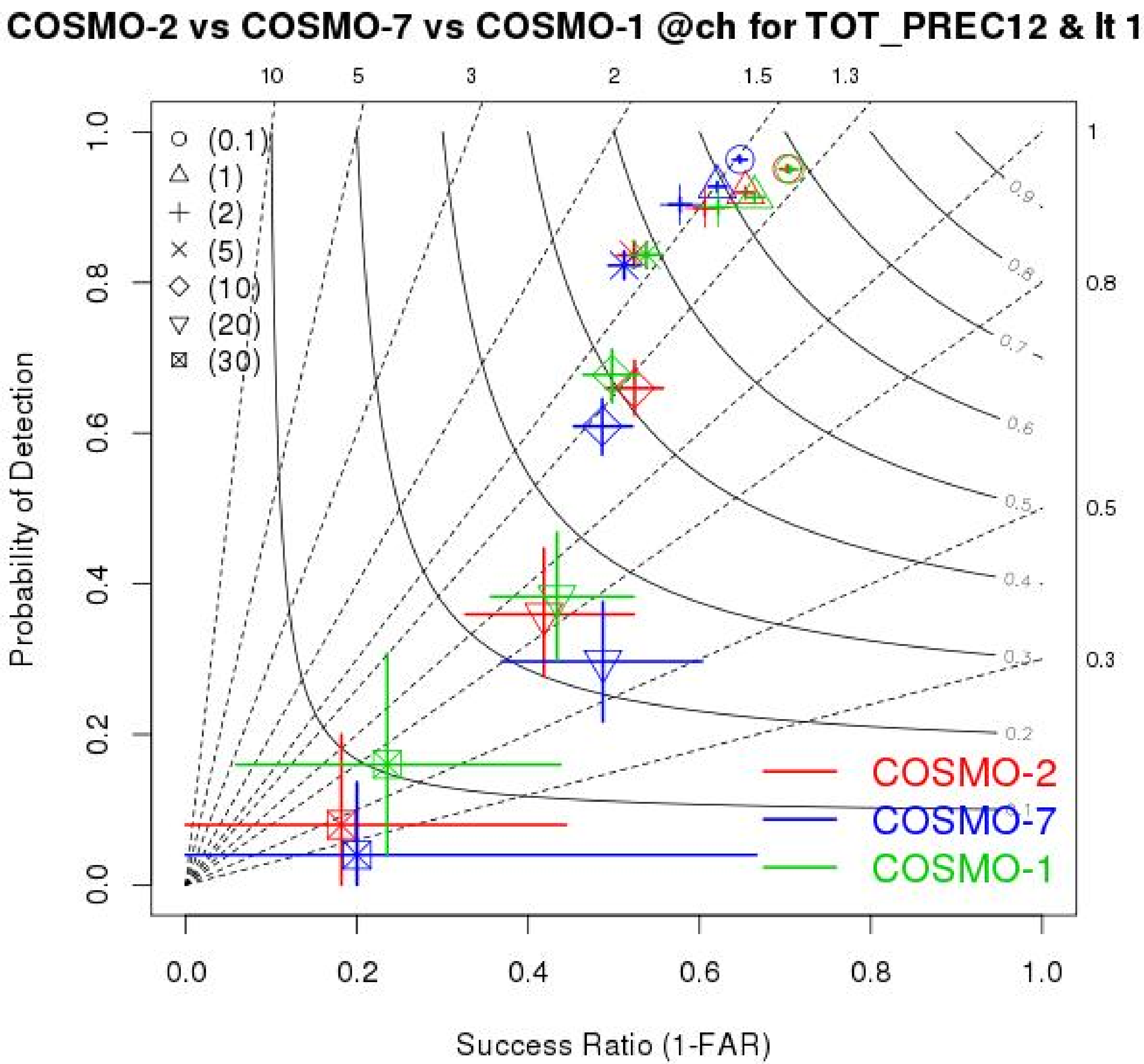
——————

+13h-24h

1h accumulation

(9 grid point averaging)

Precipitation of **COSMO-1** DJF13



Freq. Bias

Crit. Suc. Ind.

____

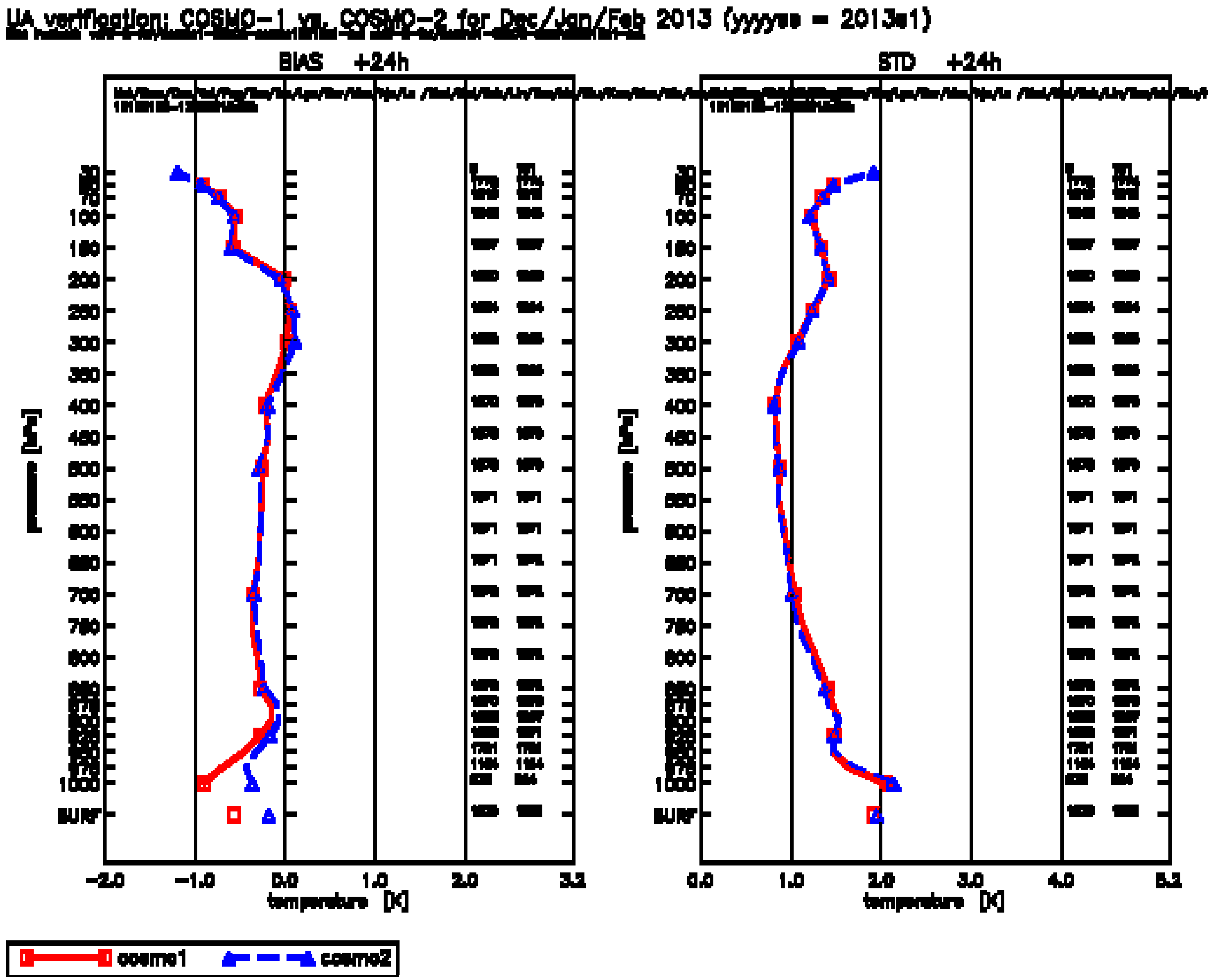
+6h-18h

12h accumulation

(9 grid point averaging)

Upper Air Temperature Verification

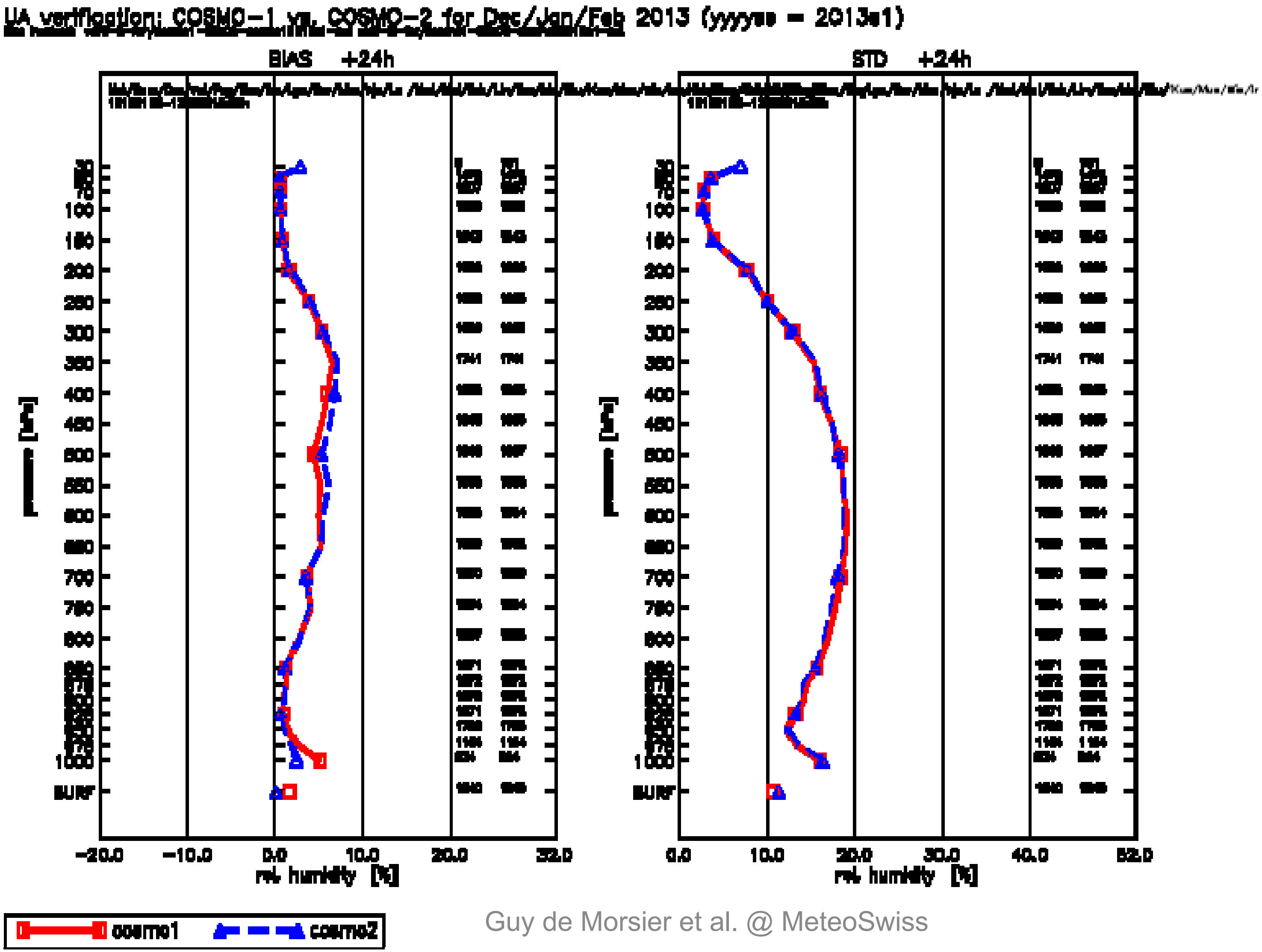
COSMO-1 vs. COSMO-2 DJF13



+24h
all stations

Upper Air Relative Humidity Verification

COSMO-1 vs. COSMO-2 DJF13



Summary Part II

Autumn and winter verifications of COSMO-1 show **good results:**

•**Better humidity** specially in the standard deviation (surface)

•Slight **cold** bias (not for all stations)

•Overestimation of **10m winds** (except around 12 UTC)

•**Good** precipitation scores

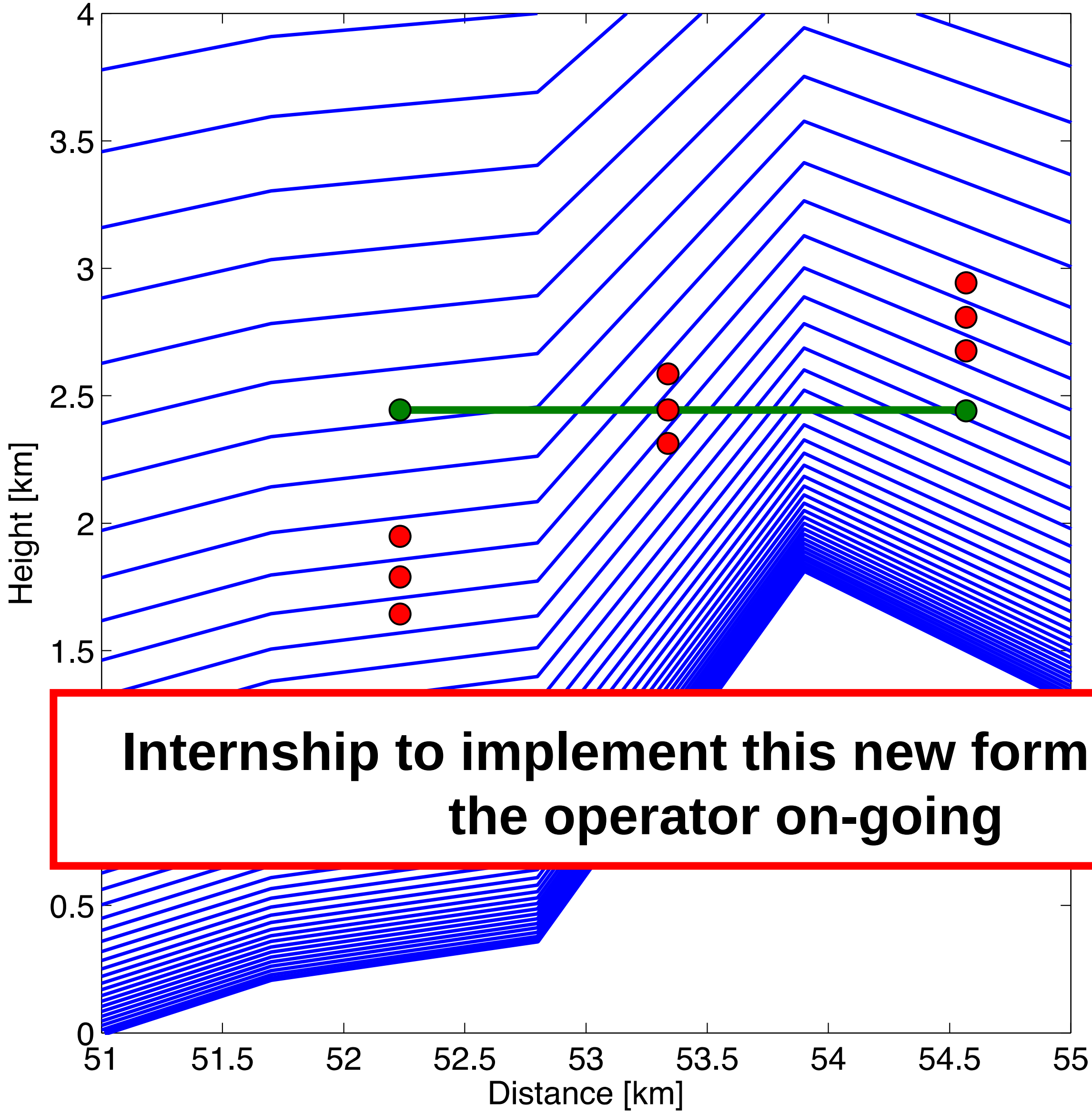
•**Similar** upper air scores as COSMO-2

Outlook

- New external parameters including:
    - a better representation of **orography** and **roughness length** using ASTER with a resolution of 30m (now 900m)
    - more detailed **soil types** using HWSD with a resolution of 1km (now 10km)
- Tests without shallow convection
- Changes to the turbulent scheme

Thank you for your attention!
Questions?

Horizontal turbulent diffusion



Current

Not stable over Alps!

Strong extrapolation

New

Stable over Alps!

Local interpolation

Boundary handling?

Internship to implement this new formulation of the operator on-going