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Developing a 1.1 km model setup at MeteoSwiss: Impact of changing the boundary conditions

Guy de Morsier

with contributions from:
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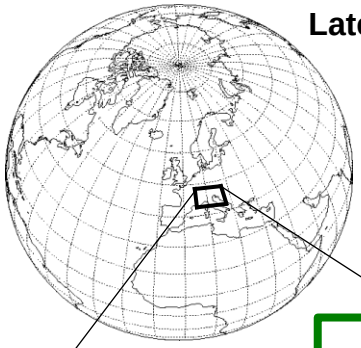
COSMO/CLM/ART **U**ser **S**eminar, 2 March 2015, Offenbach

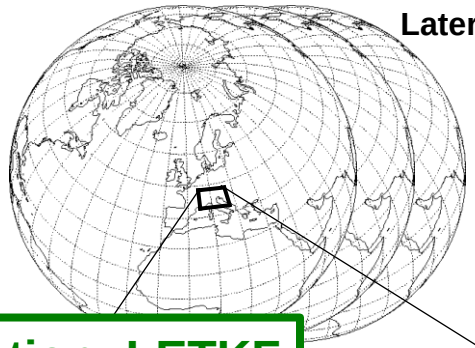
Outline

- COSMO-NExT project
- Deterministic component: **COSMO-1**
- Developments:
  - Changes in the soil model (TERRA)
  - Changes in the driving model (LBC)
- Verification results
- Summary and Outlook

Aim of COSMO-NExT project in 2016



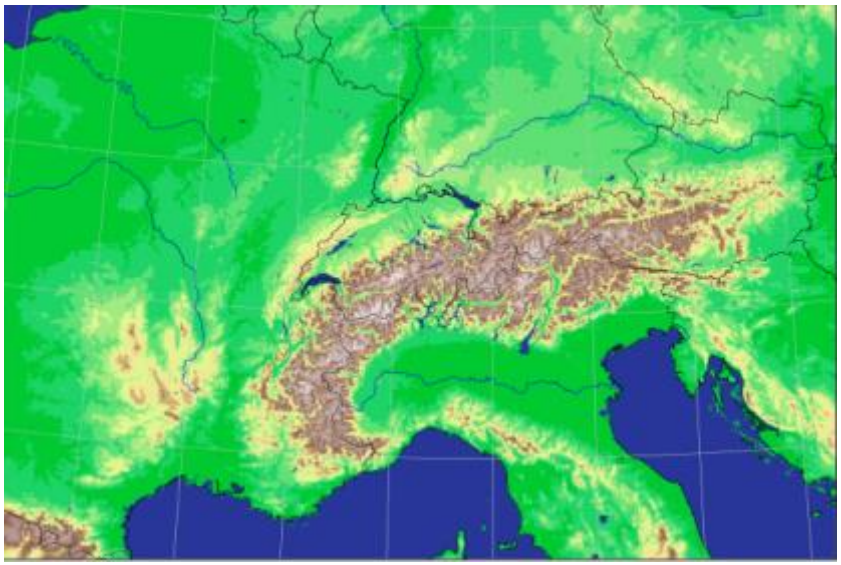
Lateral boundary conditions:
IFS-HRES
8-10km
4x per day



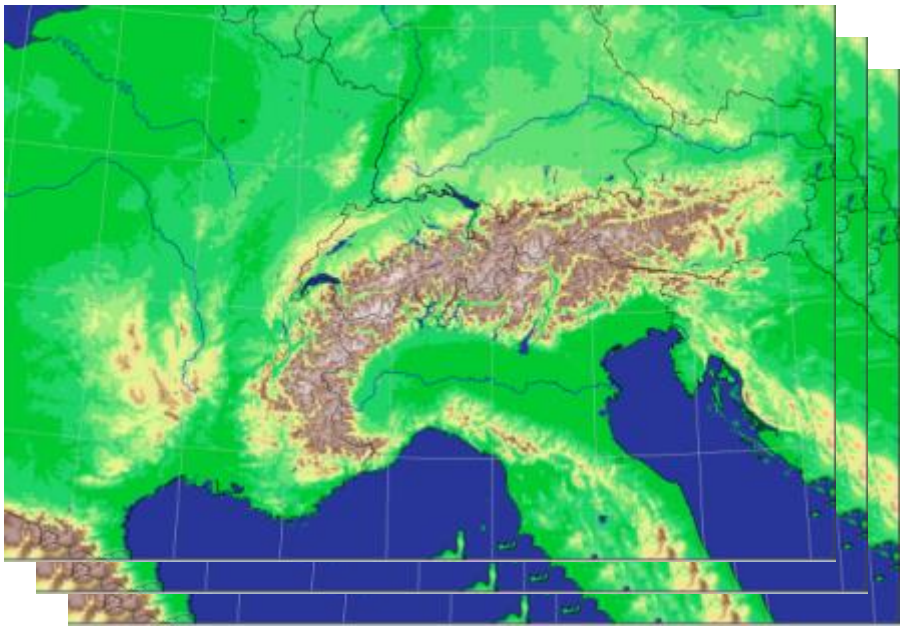
Lateral boundary conditions:
IFS-ENS
~18km
4x per day

ensemble data assimilation: LETKF

COSMO-1: O(24 hour) forecasts, 8x per day
1.1km grid size (convection permitting)



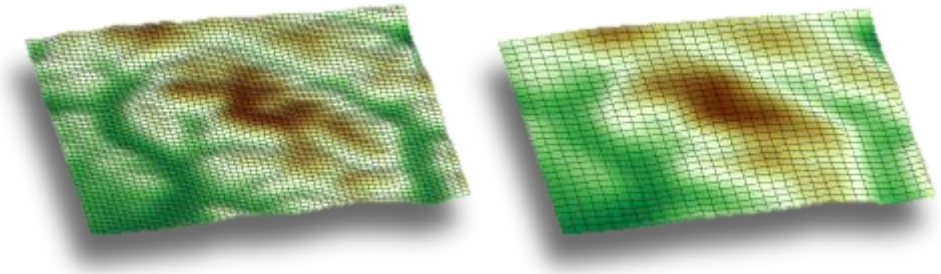
COSMO-E: 5 day forecasts, 2x per day
2.2km grid size (convection permitting)
O(21) ensemble members



Project COSMO-NExT: Structure and timeline

- **4 sub-projects**
  - **KENDA** (leader: Daniel Leuenberger)
  - **COSMO-1** (leader: Guy de Morsier)
  - **COSMO-E** (leader: André Walser)
  - **Infrastructure** (leader: André Walser)
- project leader: Marco Arpagaus
- **4 year** project (2012 – 2015) → **operational in 2016**
- Project-phases and milestones **strongly coupled to development and extension of HPC platform at CSCS** (→ 2 new computers in Mai)

COSMO-1: Keywords



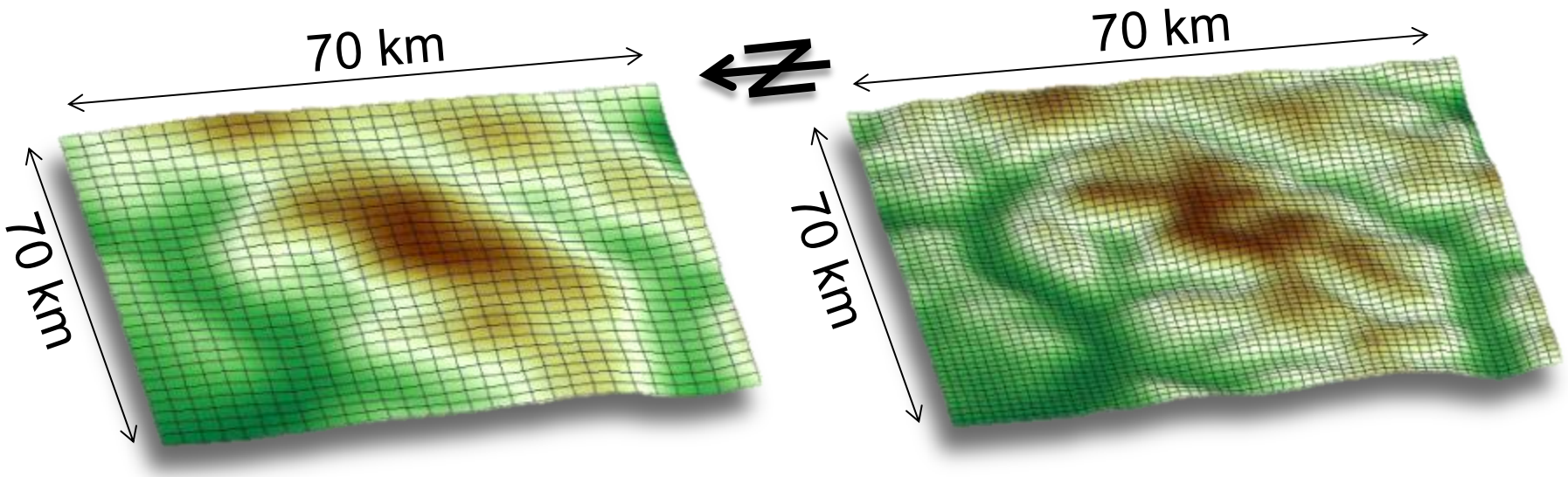
- Deterministic forecasts with **convection-permitting resolution** (1.1 km mesh-size)
- Targeted for the **very short-range** (+24h)
- **Rapid update cycle** with new forecast every 3 hours
- **On demand mode** for key clients
- ICs from LETKF, LBCs from IFS-HRES
- COSMO-1 has the best representation of the …
  - ➢ complex Alpine topography
  - ➢ physical processes of extreme weather events

COSMO-1:
Setup (as compared to COSMO-2)

- **Newest code version** (25% larger domain)
- **New dynamical core** (required for steep orography)
- **More vertical levels** (80 instead of 60, SLEVE, with dense distribution in boundary layer, i.e. lowest 3 km)
- **No artificial horizontal diffusion** (except for flow dependent Smagorinsky type diffusion)
- **High frequency update of radiation** (every 6 minutes)
- **New upper boundary condition** (only vertical winds are being damped)
- **No sub-grid scale orographic drag** (assumed to be resolved by model)

External parameters

Better topographic dataset (ASTER (30m) instead of GLOBE (1km))

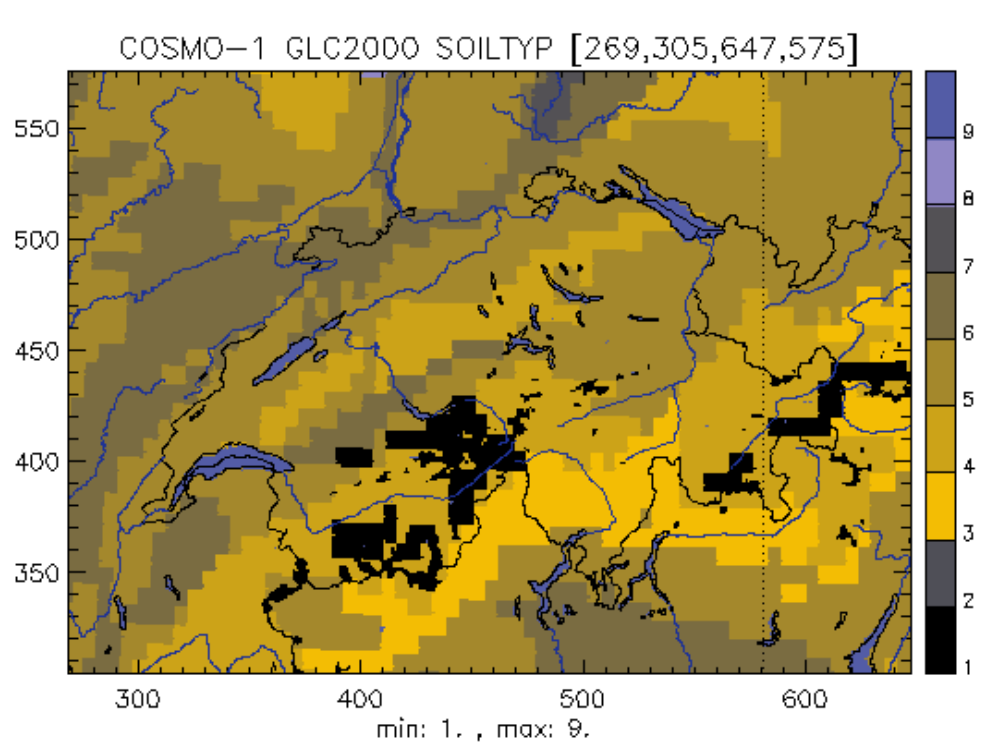


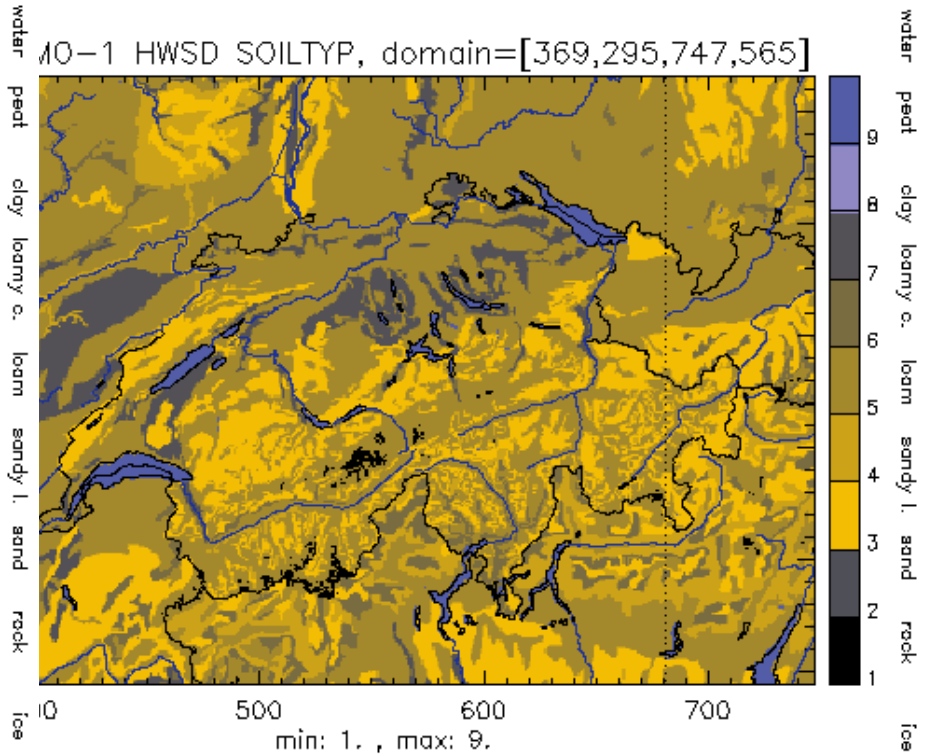
COSMO-2 **COSMO-1**

- Better near surface wind field (valley winds, Föhn, …)
- Better representation of surface heterogeneity (triggering)

External parameters

Better soil dataset: HWSD @1km





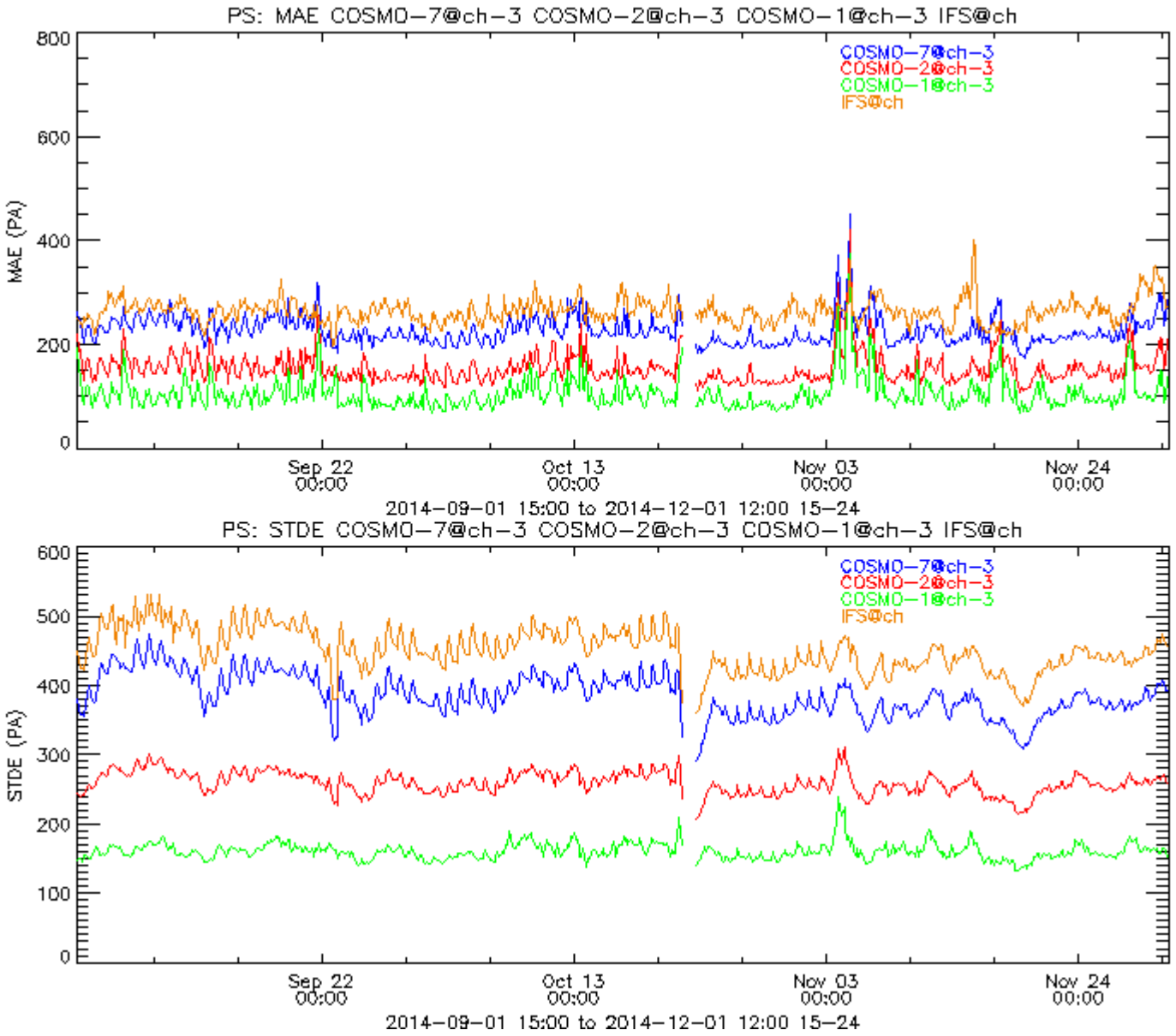
- Structure is much finer
- Regions with ice represent reality much better

COSMO-1:
Experimental real-time runs

- **Two** forecasts per day (00/12 UTC)
  since end of August 2012
  00 UTC to **+24h**
  12 UTC to **+48h** (exp. to find cross-over from COSMO-E)
- **Initial conditions:**
  continuous **1 km assimilation cycle**
  (including latent heat nudging and snow analysis)
- **Driven by the operational COSMO-7 forecasts** (LBCs)

Examples of verification results

Surface pressure; autumn 2014; CH



mean absolute error

IFS-HRES
COSMO-7
COSMO-2
COSMO-1

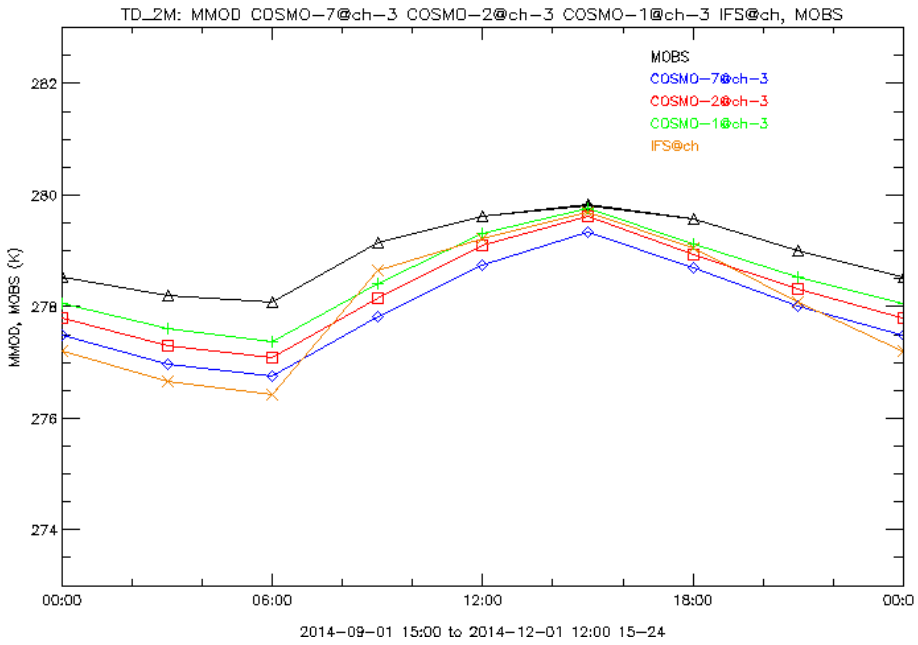
std dev

Dewpoint @ 2m ; autumn 2014; CH

forecasts from +15 to +24h

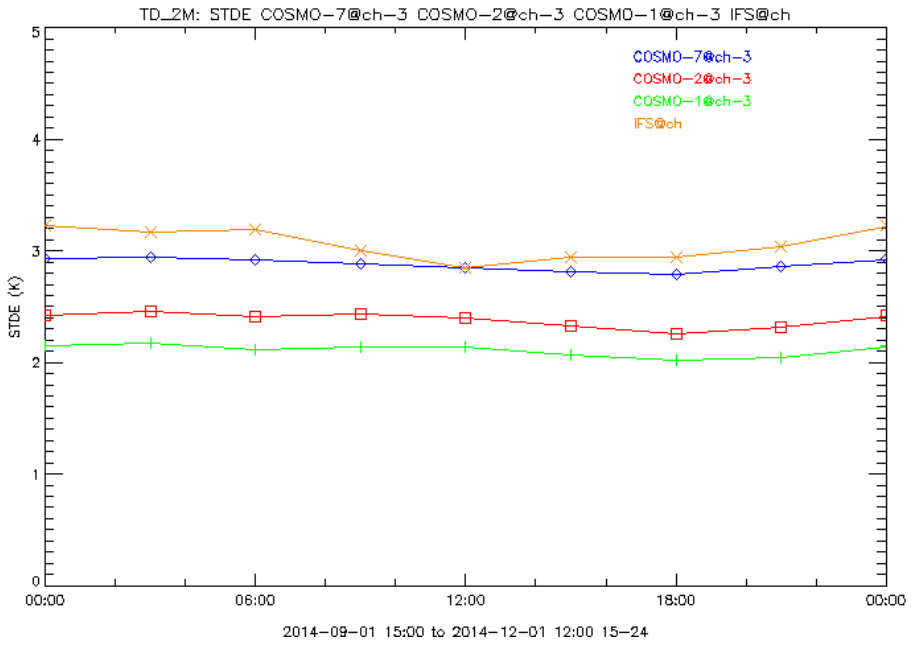
IFS-HRES **COSMO-7** **COSMO-2** **COSMO-1**

values



All models **too low** dewpoint especially during night

std dev

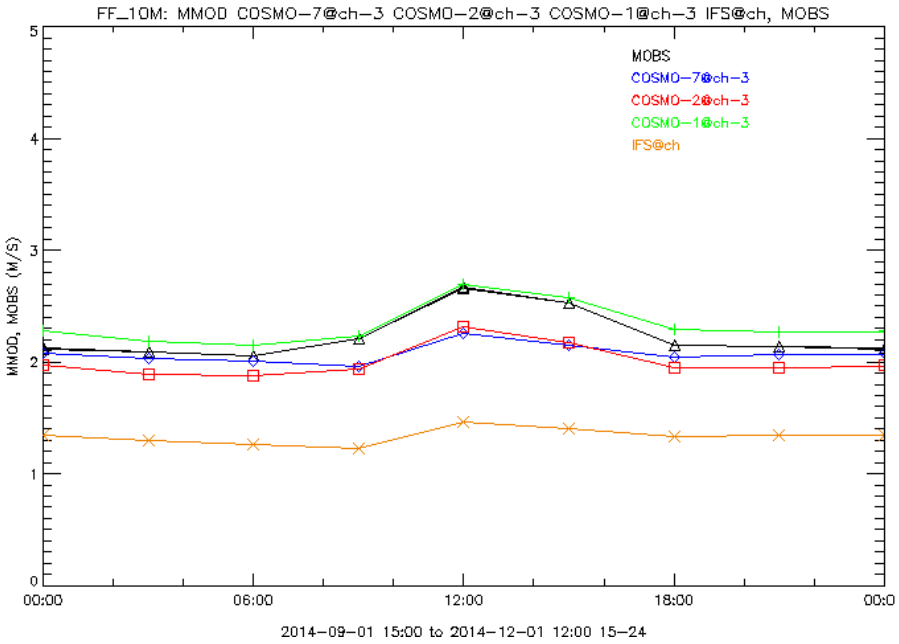


COSMO-1 lowest std dev errors

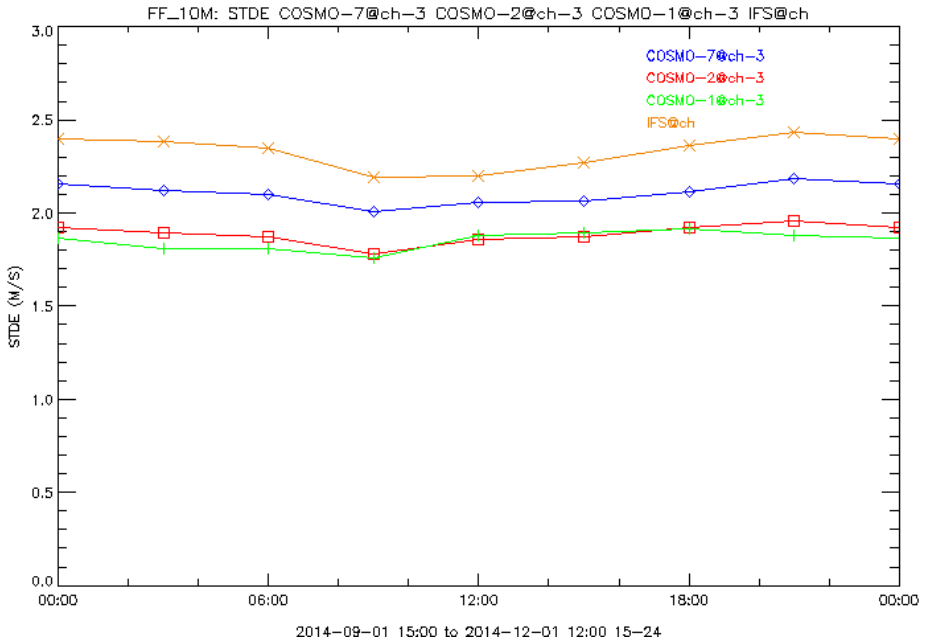
10m-wind speed; autumn 2014; CH

forecasts from +15 to +24h

values



std dev

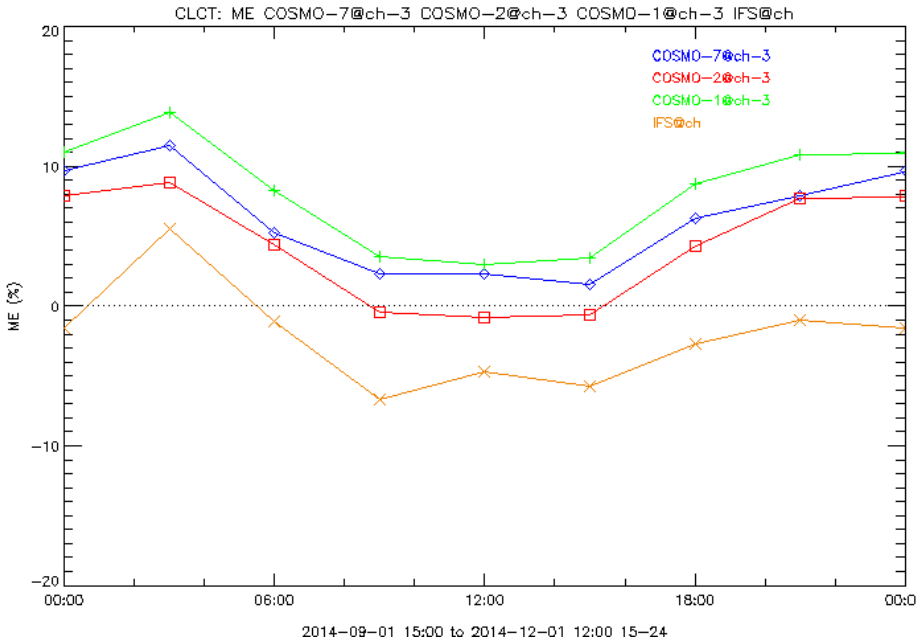


IFS-HRES **COSMO-7** **COSMO-2** **COSMO-1**

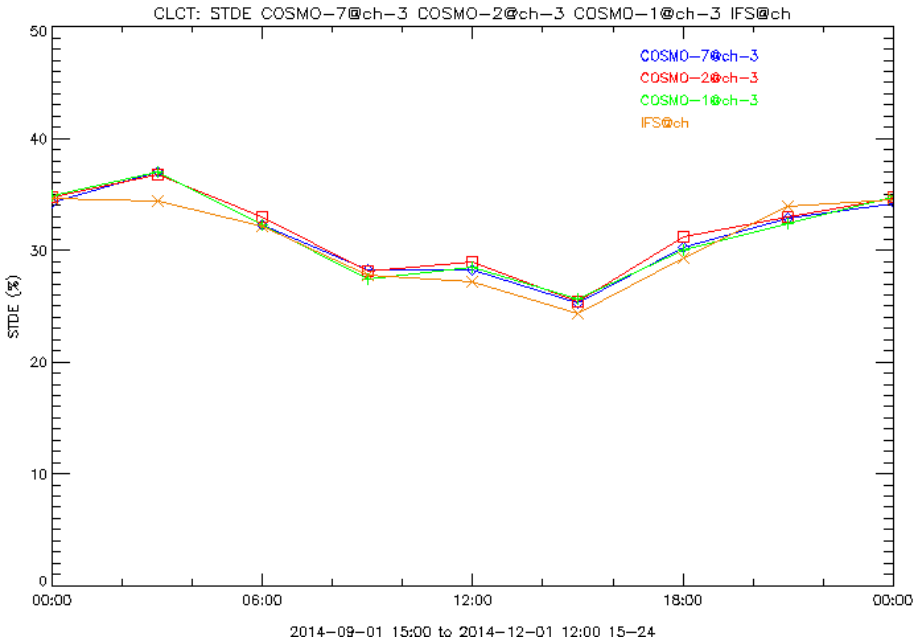
Total cloudiness ; autumn 2014; CH

forecasts from +15 to +24h

bias



std dev



IFS-HRES **COSMO-7** **COSMO-2** **COSMO-1**

First boundary condition experiment: Changes in TERRA

1) Johansen soil thermal conductivity, dependent on actual soil water content

- *itype_heatcond=2 switch in COSMO, no additional fields*

2) Modis albedo

- *itype_albedo=3 switch in INT2LM and in COSMO, additional field ALB_DIF12 required in external parameters and ALB_DIF in analysis*

3) NDVI climatology

- *itype_ndvi=1 switch in INT2LM, additional field NDVI_MRAT required in external parameters*

4) New hydraulic conductivity after Decharme et al. (2006), depth dependent

- ***code modification in COSMO*** *(itype_hydcond=1), no additional fields*

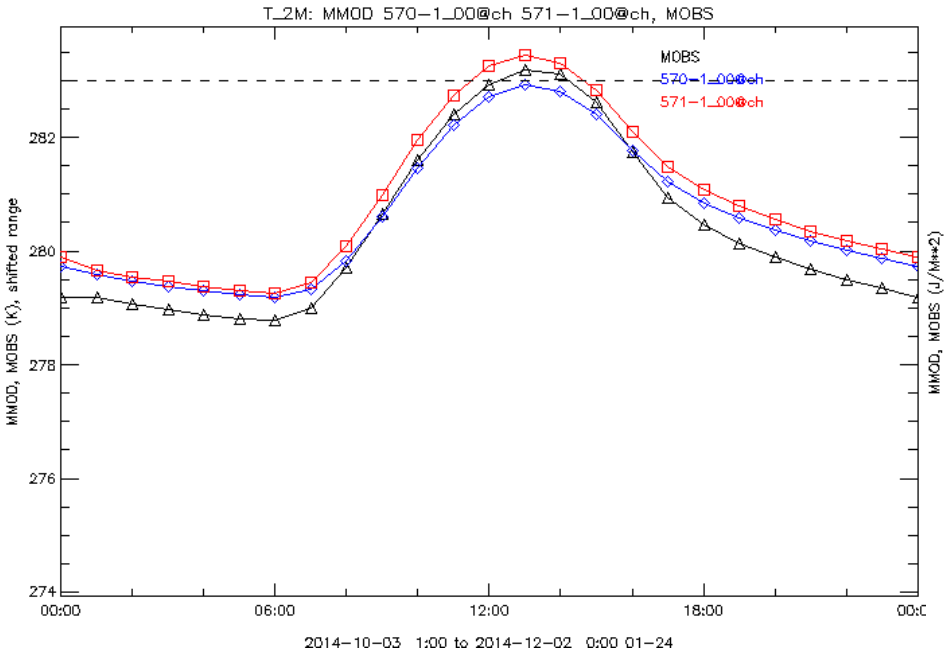
5) Tegen aerosol climatology

- *itype_aerosol=2 switch in INT2LM and in COSMO, new fields AER_SO412, AER_DUST12, AER_ORG12, AER_BC12, AER_SS12 in analysis*

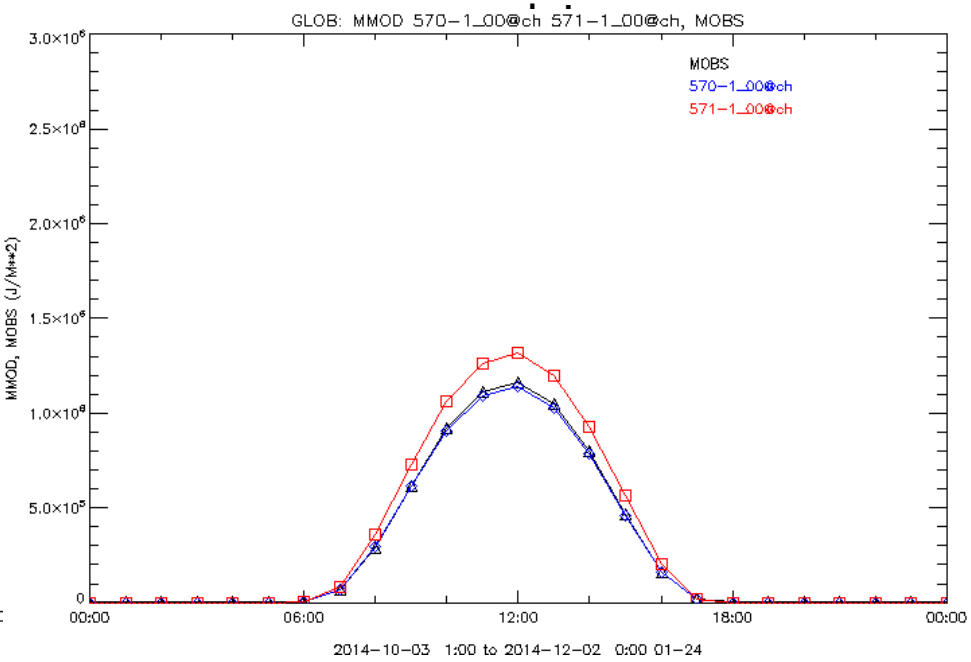
Experiment with its own assimilation cycle from Oct. to Nov. 2014

Result of TERRA with new conductivity incl. albedo/ndvi/aerosol climatology

Values of 2m temp. @ Swiss SYNOP



+18% global rad. due to Tegen aerosols !



- Main impact from aerosols, because a COSMO-E test without TEGEN (rest identical) during 1. April - 30. Juni 2014 shows neutral results (=> use the new TERRA set-up without Tegen)

2nd boundary condition experiment: Change in Lateral Boundary Conditions

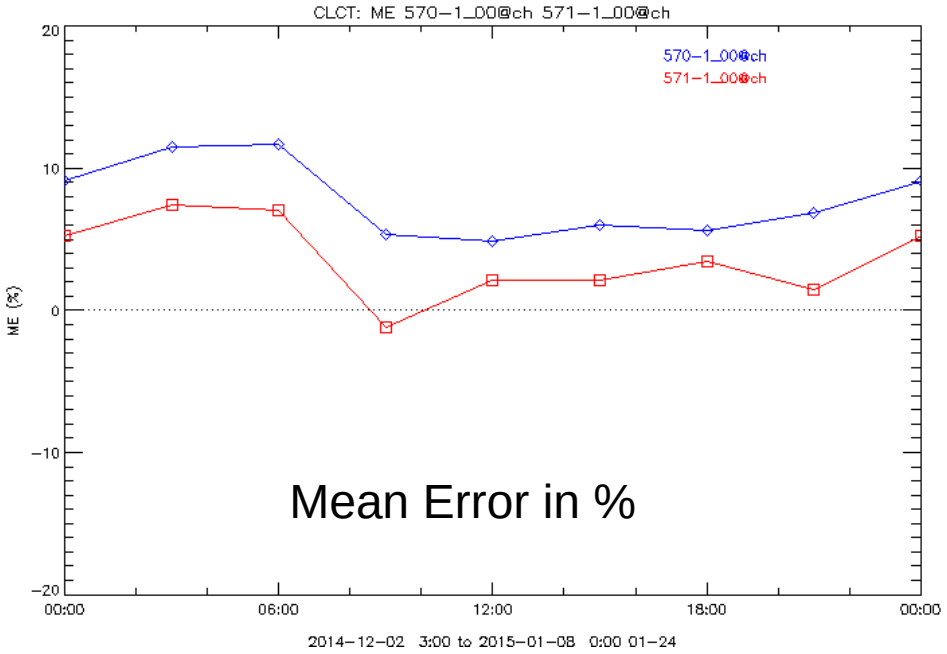
- Use **ECMWF IFS-HRES** as lateral boundary conditions with **hourly update** instead of the COSMO-7 (6.6km)
- **Beginning of 2016: IFS-HRES** with probably an octahedral **resolution** of about **9 km** (8-10km); jump from **16 km to 1.1 km should be less critical !**

Summary of results

- **PS & PMSL** slightly lower surface pressure (from -0.1 to -0.4 hPa) and a smaller positive PMSL bias ; STDE of both slightly **better**
- **T_2M** slightly colder (i.e. increased negative bias) in the first 10h
- **TD_2M** slightly colder ~0.1 K

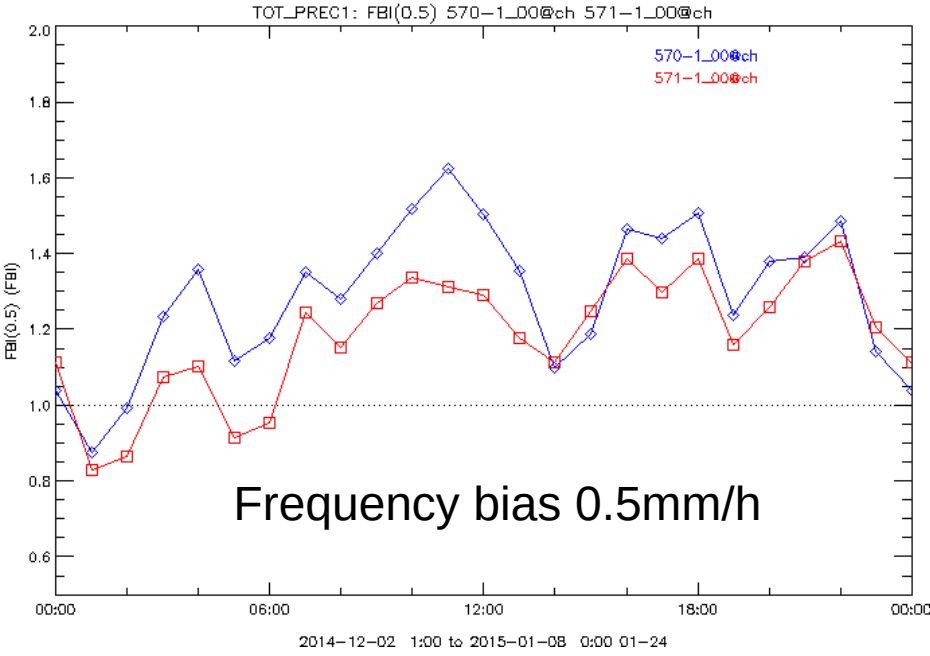
Result with IFS-HRES LBC (571) instead of COSMO-7 (570)

Cloud Cover @ Swiss SYNOP



Mean Error in %

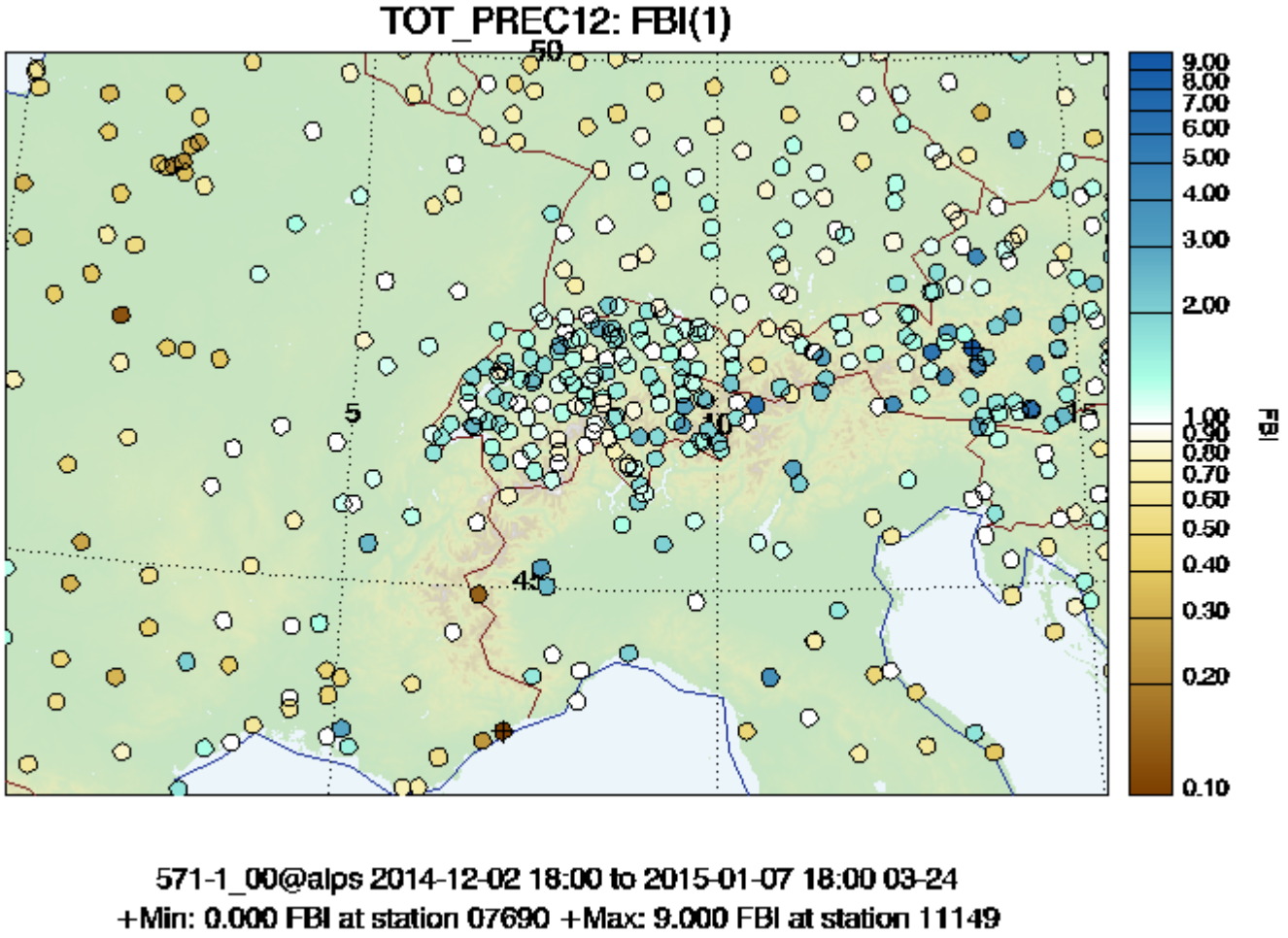
Total Precipitation @ Swiss SYNOP



Frequency bias 0.5mm/h

Result: IFS-HRES LBC (571)

Frequency Bias for 1mm/12h



2nd boundary condition experiment: Change in Lateral Boundary Conditions

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  - **PS/PMSL** slightly lower surface pressure (from -0.1 to -0.4 hPa) and a smaller positive PMSL bias ; STDE of both slightly **better**
  - **T_2M** slightly colder (i.e. increased negative bias) in the first 10h
  - **TD_2M** slightly colder ~0.1 K
  - **CLCT** **less overestimation by ~4%**
  - **TOT_PREC** **reduced positive bias** (valid for all thresholds), 18% less precipitation and strong reduced positive bias
    - But strong underestimation with IFS-HRES **near** lateral borders: -20% overestimation for 1 mm/12h threshold over the full domain.
- Same effect with operational COSMO-7 that has LBC from IFS-HRES.

Summary SYNOP and TEMP verification for the last seasons till Autumn 2014

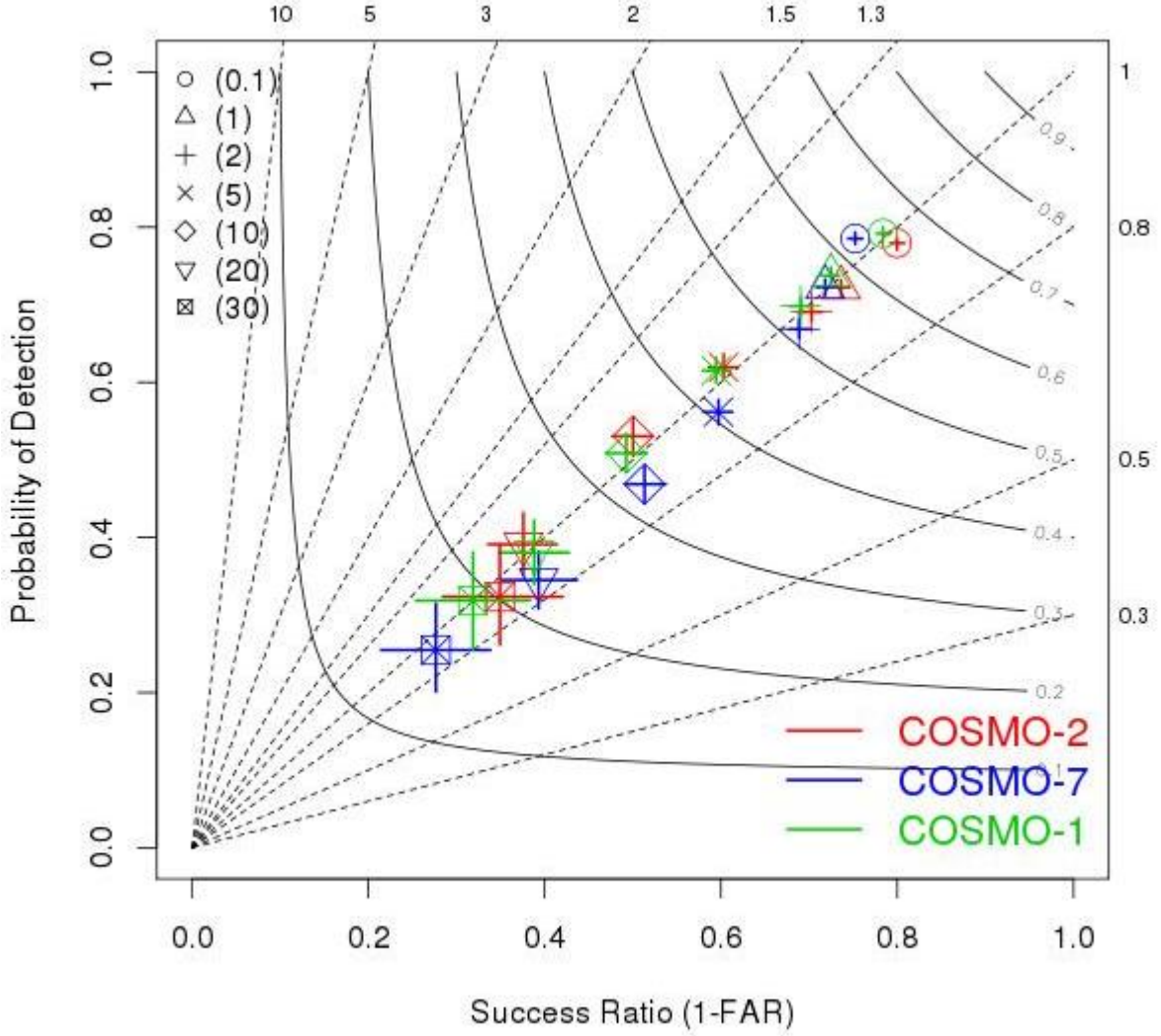
- **Good results of COSMO-1 as compared to COSMO-2:**
  - ✓ **Surface Pressure: higher values** (reduced negative bias) and reduced standard deviation of errors
  - ✓ **Temperature**: since Spring 2014 **similar** positive bias over CH; lower values outside CH; in Winter colder <850hPa (increased negative bias) but **reduced** standard deviation of errors
  - ✓ **Dewpoint**: same bias (except Autumn 2014, **reduced** negative bias) and ~10% **reduced** standard deviation of errors at 2m
  - ✓ **10m-wind**: higher wind speed (mainly on valley and mountain stations [i.e. reduced negative bias on mountains])
  - ❑ **Gusts**: higher positive bias (much stronger positive bias > 20 m/s, especially in the afternoon)

Summary SYNOP and TEMP verification for the last seasons till Autumn 2014

- **Good results of COSMO-1 as compared to COSMO-2:**
  - **Cloud Cover**: higher positive bias;
    IFS-HRES smaller bias as compared to COSMO-2 and COSMO-1
  - ➢ Positive impact by using IFS-HRES @ LBC
  - ✓ **Precipitation**: slightly better results (despite the smaller radius), reduced errors in bias, better false alarm ratio
    → see performance diagrams
    → see neighbourhood verification
  - Large boundary impact with IFS-HRES @ LBC
    Can be detrimental for certain meteorological situations!

Performance diagram: 12h precipitation sums

Summer 2014: all hourly sums from +6h to +18h



Performance diagram: 12h precipitation sums

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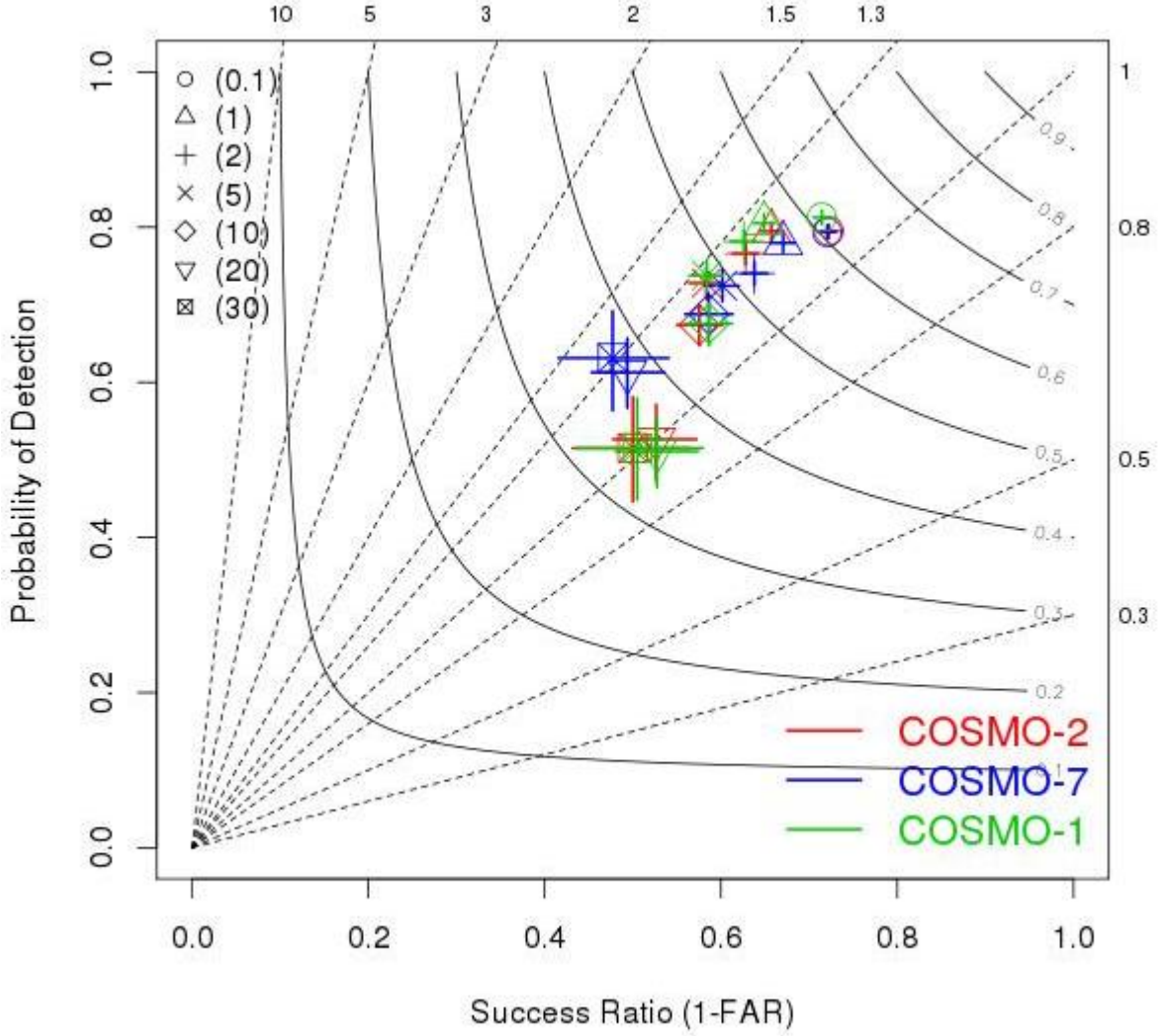


Summary and Outlook

- **COSMO-1** provides locally more **detailed** and more **accurate deterministic forecasts**
- **Do not change the aerosols without retuning the physics!**
- **Possible to use IFS-HRES @ LBC with some drawbacks!**
- Further development of the **COSMO Modell**, e.g.,
  - Improvement of turbulence and precipitation processes
  - Improvement of the forecasts, e.g., by better capturing small-scale local phenomena in the Alps

- **Goal**: pre-operational by summer 2015, **operational in 2016**

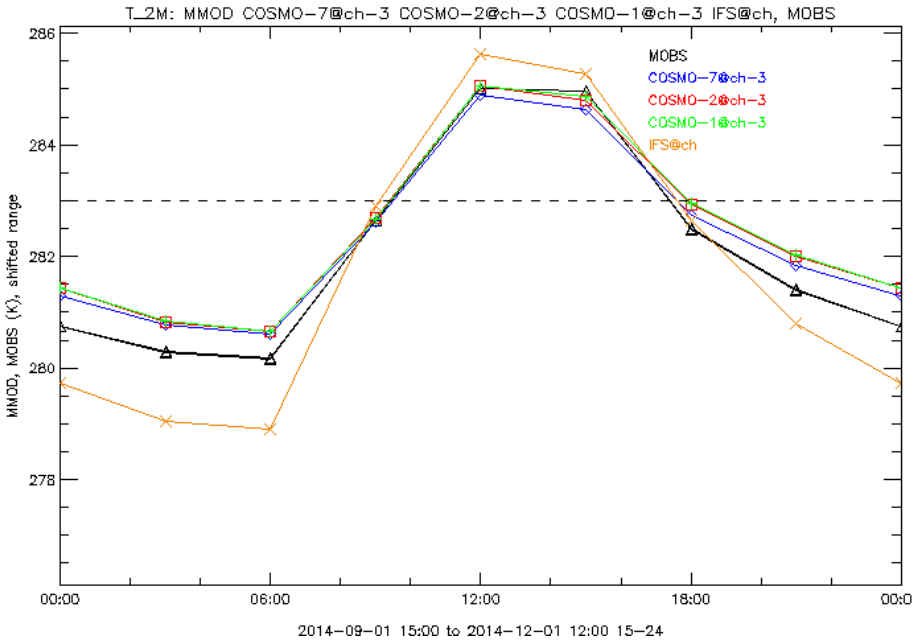
Thank you!

- Questions?

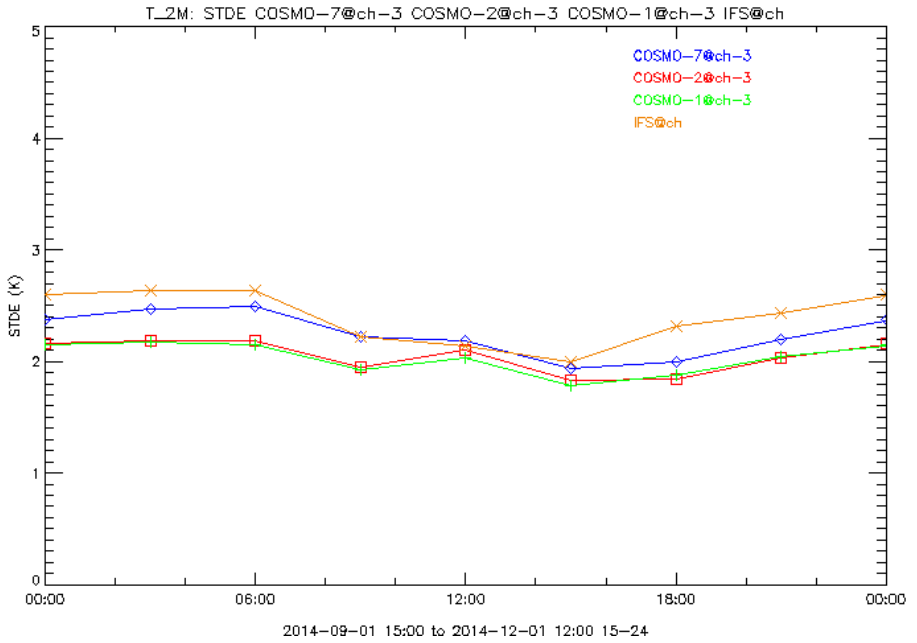
Temperature @ 2m ; autumn 2014; CH

forecasts from +15 to +24h

values



std dev



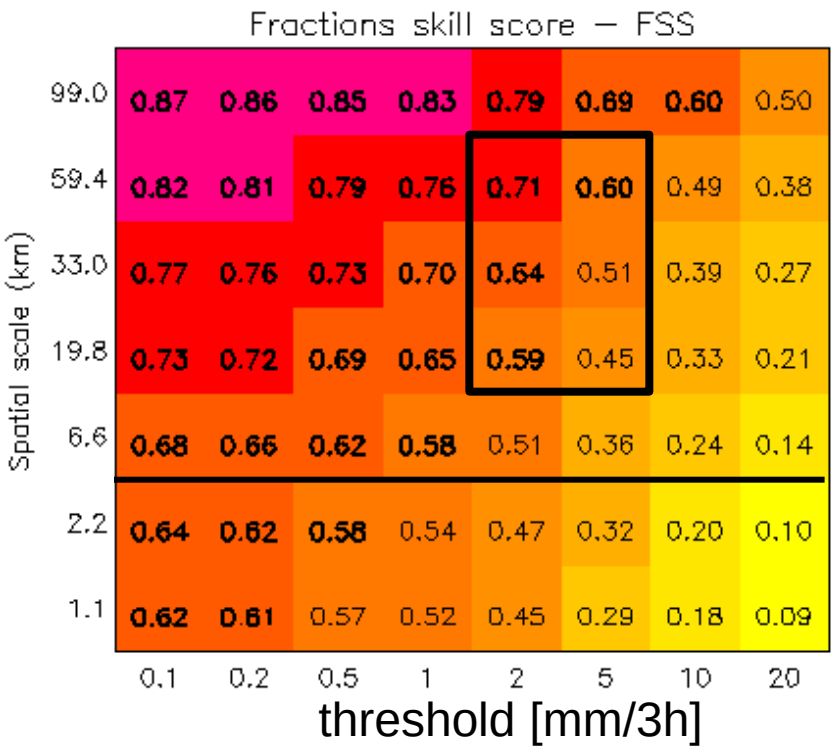
IFS-HRES **COSMO-7** **COSMO-2** **COSMO-1**

Observational data

- Interpolated onto the different model grids
- **CombiPrecip**: **hourly precipitation** estimated over Switzerland from the radar composite of the 4 Swiss radars and about 180 automatic rain-gauges by spatio-temporal co-kriging
  pixel resolution: 1km
- **METEOSAT-8 data: brightness temperature** (BT) from the infrared 10.8 μm channel of MSG SEVIRI, detection of clouds in contrast to warm emission by the earth surface
  pixel resolution: 5 km

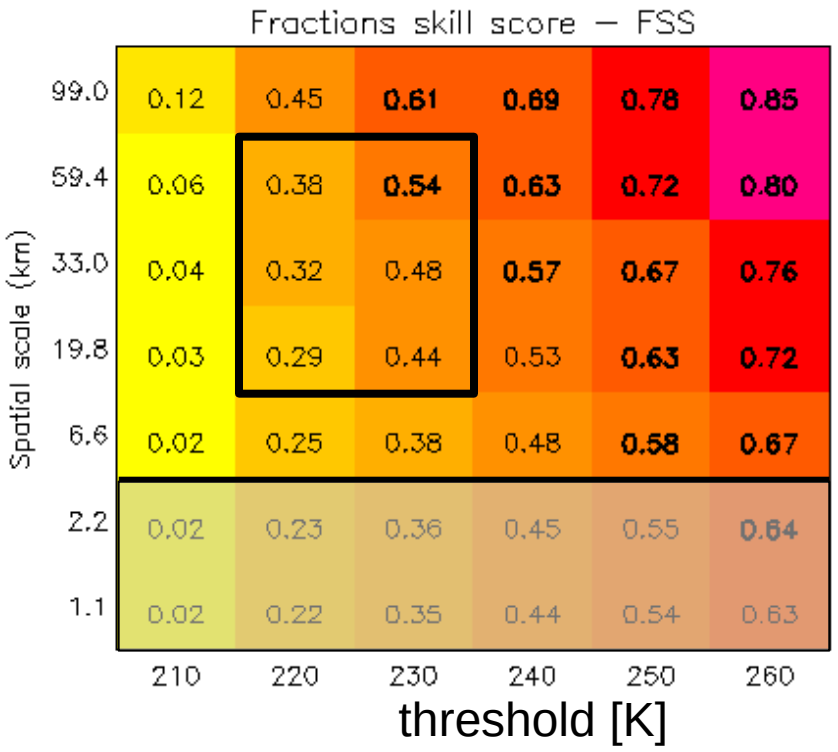
FSS Summer 2014
COSMO-1 (forecasts up to +24h)

precipitation (3h-sums)



high precipitation

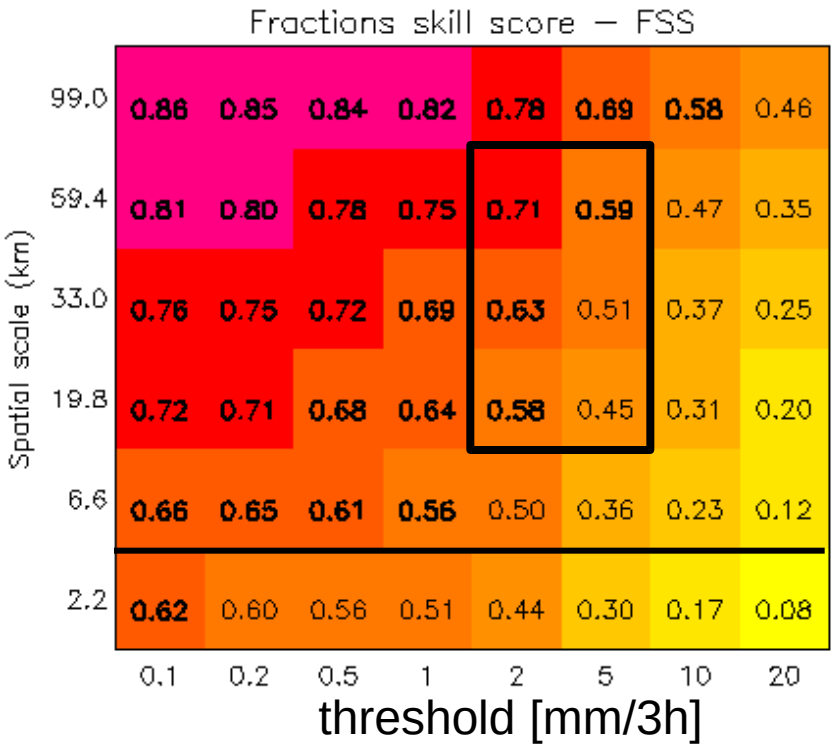
brightness temperature



high clouds

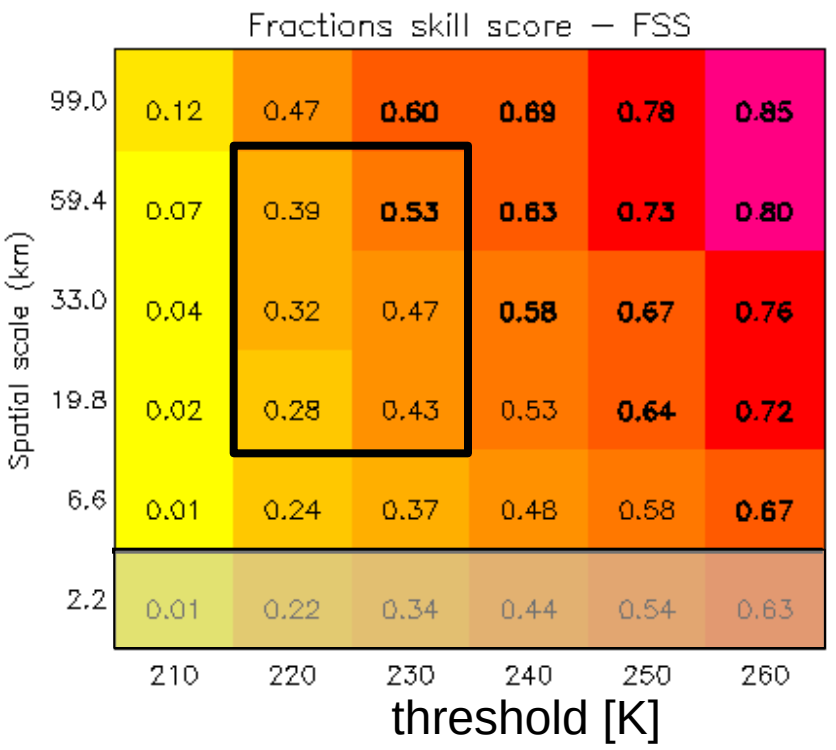
FSS Summer 2014
COSMO-2 (forecasts up to +24h)

precipitation (3h-sums)



high precipitation

brightness temperature



high clouds