Limited-area ensemble activities at ARPA-SIMC: present status and future plans for the COSMO-LEPS system.

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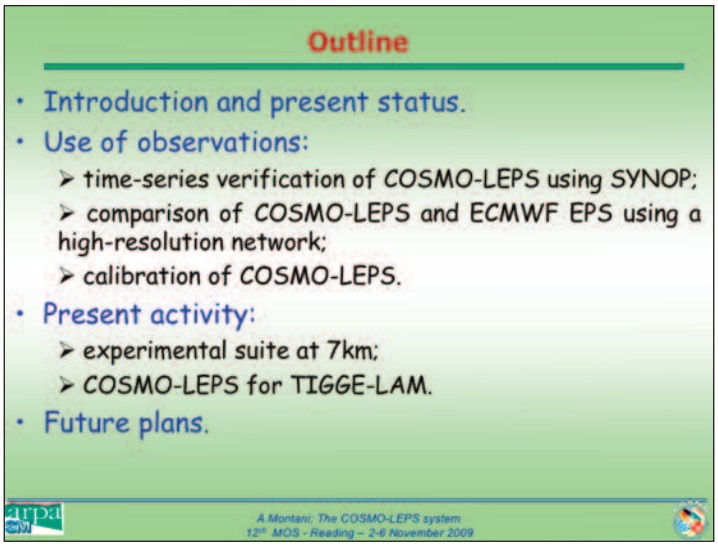
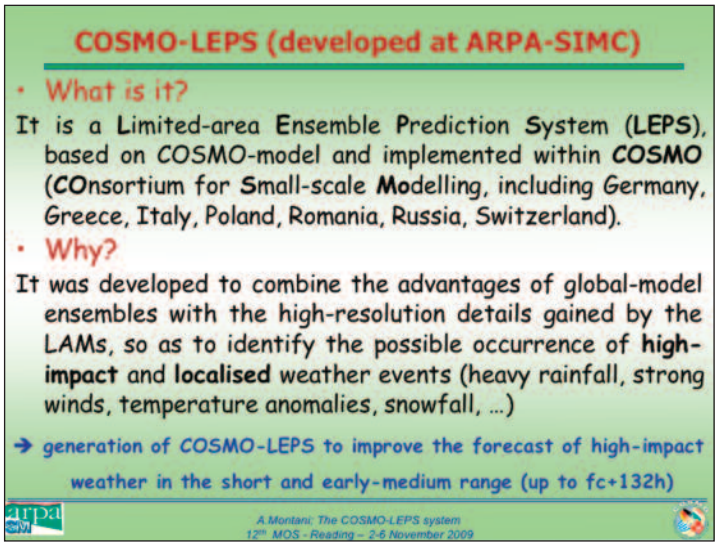
In this contribution, we present the main features of COSMO-LEPS, the limited-area ensemble prediction system based on the non-hydrostatic ``COSMO-model'' and developed by ARPA-SIMC within the COSMO consortium.

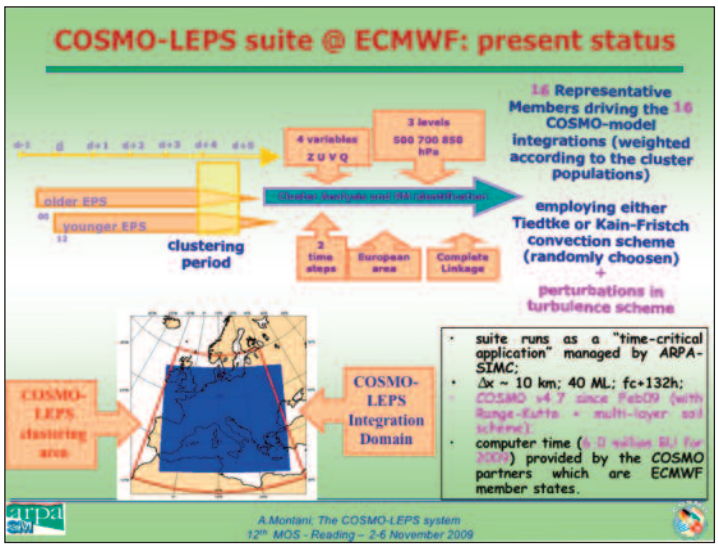
The present status of COSMO-LEPS, based on 16 integrations of the COSMO-model (10 km of horizontal resolution, 40 vertical levels, 132 hours of forecast range) and running as a ``time-critical application'' at ECMWF, is illustrated with the different system upgrades which took place in the last years.

The performance of the system for probabilistic prediction of heavy precipitation is assessed in terms of both monthly and seasonal scores from December 2002 up to August 2009.

The future developments of COSMO-LEPS, including the forthcoming increase of horizontal resolution to 7 km and other system upgrades, will be also presented.






COSMO-LEPS suite @ ECMWF: present status
16 Representative Members driving the 16 COSMO-model integrations (weighted according to the cluster populations)
4 variables Z U V Q
3 levels 500 700 850 hPa
older EPS
younger EPS
clustering period
2 time steps
European area
Complete Linkage
employing either Tiedtke or Kain-Fristch convection scheme (randomly choosen)
+
perturbations in turbulence scheme
COSMO-LEPS clustering area
COSMO-LEPS Integration Domain
suite runs as a "time-critical application" managed by ARPA-SIMC;
Δx ~ 10 km; 40 ML; fc+132h;
computer time (6 M value BU for 2009) provided by the COSMO partners which are ECMWF member states.
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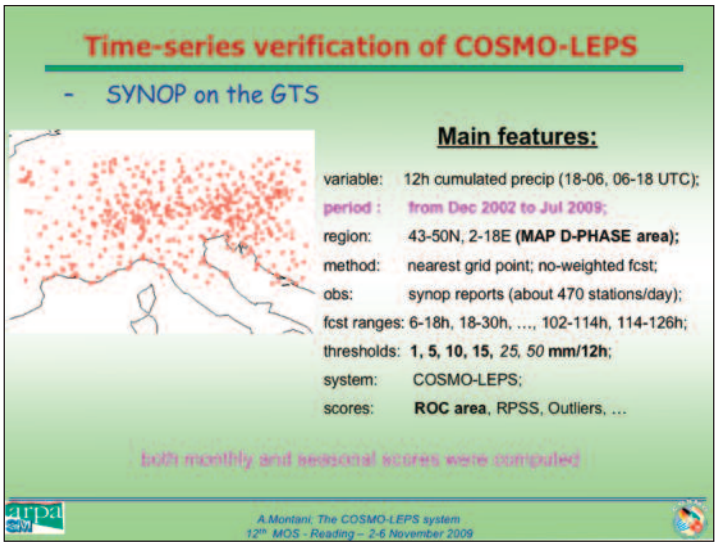
Time-series verification of COSMO-LEPS
- SYNOP on the GTS
Main features:
variable: 12h cumulated precip (18-06, 06-18 UTC);
period : from Dec 2002 to Jul 2009;
region: 43-50N, 2-18E (MAP D-PHASE area);
method: nearest grid point; no-weighted fcst;
obs: synop reports (about 470 stations/day);
fcst ranges: 6-18h, 18-30h, ..., 102-114h, 114-126h;
thresholds: 1, 5, 10, 15, 25, 50 mm/12h;
system: COSMO-LEPS;
scores: ROC area, RPSS, Outliers, ...
both monthly and seasonal scores were computed
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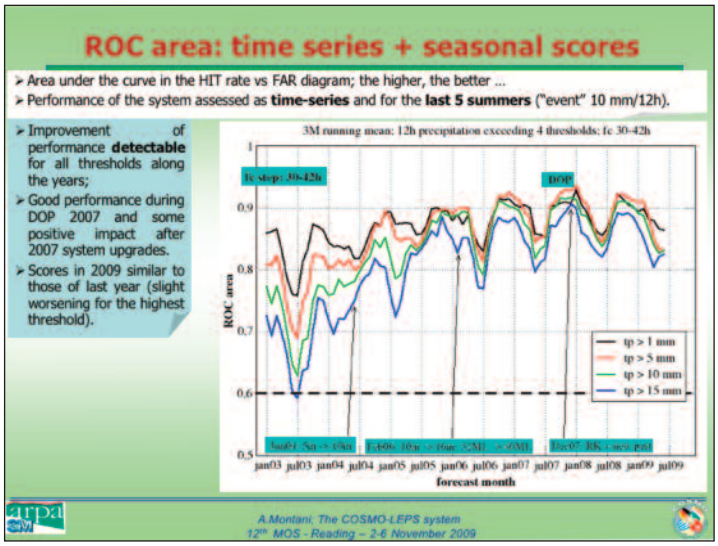
ROC area: time series + seasonal scores
Area under the curve in the HIT rate vs FAR diagram; the higher, the better ...
Performance of the system assessed as time-series and for the last 5 summers ("event" 10 mm/12h).
Improvement of performance detectable for all thresholds along the years;
Good performance during DOP 2007 and some positive impact after 2007 system upgrades.
Scores in 2009 similar to those of last year (slight worsening for the highest threshold).
3M running mean: 12h precipitation exceeding 4 thresholds: fc 30-42h
DOP
ROC area
forecast month
tp > 1 mm
tp > 5 mm
tp > 10 mm
tp > 15 mm
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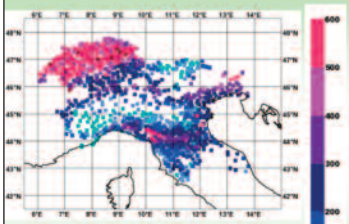
Comparison of COSMO-LEPS and ECMWF EPS

➢ high-resolution network



Main features:

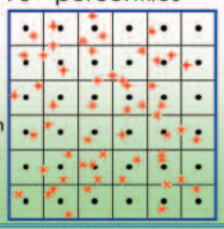
variable: 24h cumulated precip (06-06 UTC);
period: MAM 2009;
region: Switzerland, Northern Italy;
method: BOXES (1.0 x 1.0);
obs: COSMO network (1400 stations x day);
fcst ranges: 18-42h, 42-66h, 66-90h, 90-114h;
thresholds: **1, 10, 20, 30,** 50, 100 **mm/24h;**
systems:
- COSMO-LEPS (16m, 10 km, 40 ML)
- full EPS (51m, 50 km, 62 ML)

Verification of the distributions

The verification has been made in terms of:

- **Average value**
- **Maximum value**
- 50th percentile (Median)
- 75th, 90th, 95th percentiles

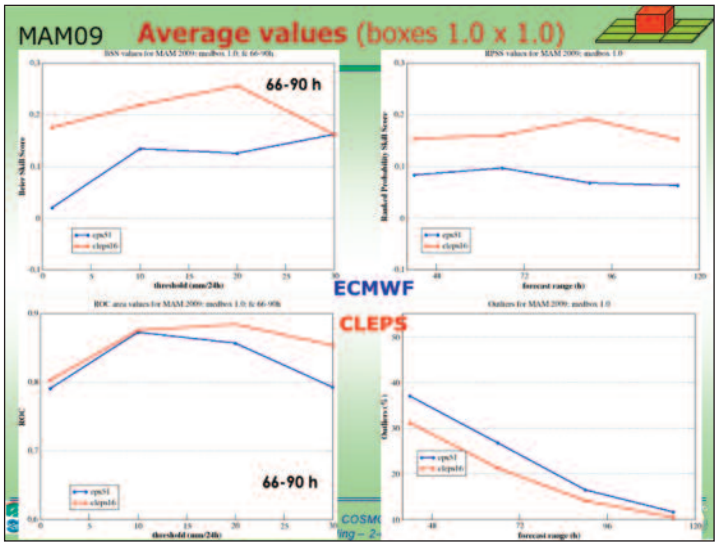
} in a box



Station observation
Grid point forecast

two measures of precipitation:

➢ the cumulative volume of water deployed over a specific region;
➢ the rainfall peaks occurring within the same region.

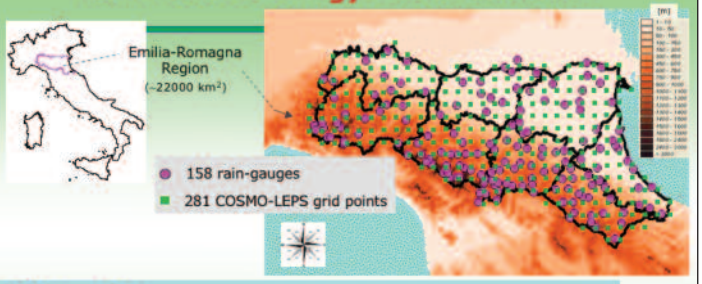


Calibration of COSMO-LEPS

Why? To improve COSMO-LEPS quantitative precipitation forecasts (QPFs), so as to provide calibrated QPFs **to be** mainly **used as an input to hydrologic models.**

➔ need to develop and apply a calibration strategy to the ensemble output

Calibration strategy – data collection



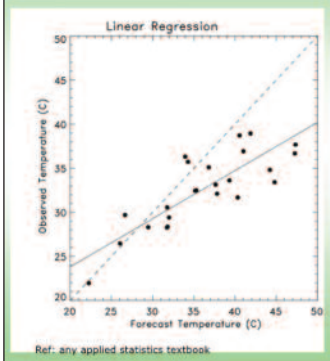
- **Observations**
  - Emilia-Romagna Region
  - 24-h precipitation (08-08 UTC), 1970-2007
- **COSMO-LEPS reforecasts (performed by MeteoSwiss)**
  - 30 years: 1971-2000
  - 1 member, nested on 6-hourly ERA40 analyses, COSMO v4.0
  - 1 run every third day (+90h)
- **COSMO-LEPS operational QPFs**
  - 5 years: 2003-2007

Calibration strategy – methodologies

- Choice of methodologies which enable a calibration of 24-h QPFs, not only of the probabilities of exceeding a threshold.
- Tested methods:
  - Cumulative Distribution Function (CDF) based corrections
  - **Linear Regression**
  - Analogues (based on the similarity of forecast precipitation fields)

Calibration strategy – methodologies

Linear Regression



Ref: any applied statistics textbook

For each model grid point:

x-axis: COSMO-LEPS reforecasts

y-axis: historical observations

$$y_i = \beta_0 + \beta_1 x_i$$

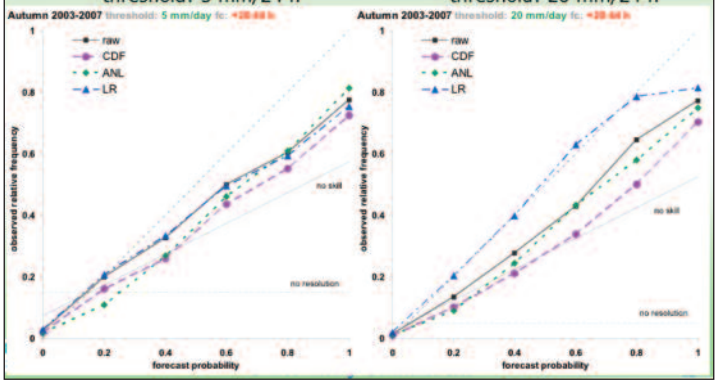
Calibration strategy – first results

Attributes Diagram
method comparison
season: autumns 2003-2007
(lead time: +20-44 h)

total area

threshold: 5 mm/24 h

threshold: 20 mm/24 h



Present activity

1) Implementation of COSMO-LEPS at 7 km

2) COSMO-LEPS for TIGGE-LAM

Implementation of COSMO-LEPS at 7 km

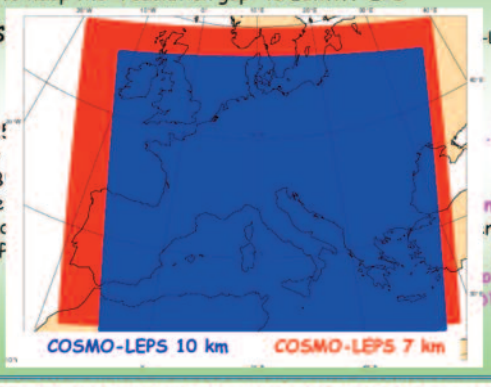
Why? - to improve the forecast of near-surface parameters
- to keep the "resolution gap" vs ECMWF EPS

Present system	New system (COSMO-LEPS_7)
Δx = 10 km	Δx = 7 km
Δz = 40 ML	Δz = 40 ML
Δt = 90 s	Δt = 60 s
ngp = 306x258x40 = 3.157.920	ngp = 511x415x40 = 8.482.600
fcst range = 132h	fcst range = 132h
cost = 570 BU x run	cost = **2100** BU x run
elapsed time = 25 min/run	elapsed time = 48 min/run
initial conditions: interpolated from EPS members	initial conditions: interpolated from EPS members merged with surface and soil-layer fields produced at DWD for COSMO-EU

COSMO-LEPS_7 running in e-suite since 24 May 09 (no merging yet)

Implementation of COSMO-LEPS at 7 km

Why? - to improve the forecast of near-surface parameters
- to keep the "resolution gap" vs ECMWF EPS



COSMO-LEPS_7 running in e-suite since 24 May 09 (no merging yet)

COSMO-LEPS_10 (oper) vs COSMO-LEPS_7 (exp)

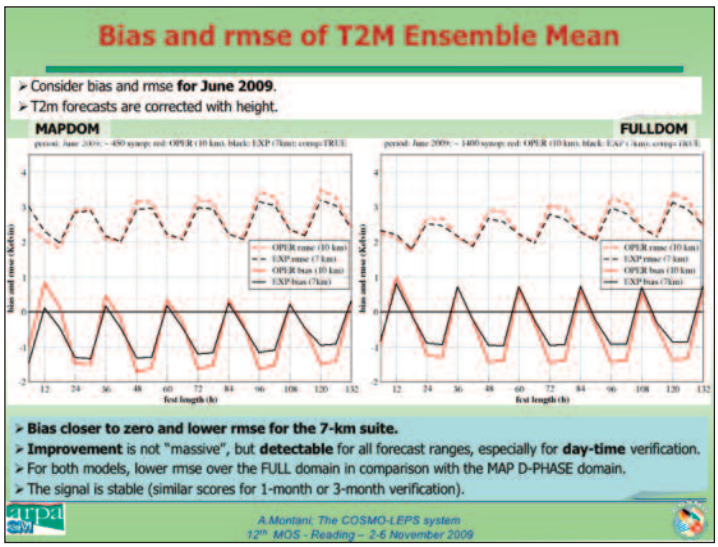
- Observations: SYNOP reports over either MAP D-PHASE region (450 reports/day) or the FULL-DOMAIN (1400 reports/day).
- Method: nearest grid point; no-weighted fcst.

Deterministic verification of T2M ensemble mean

- Variable: 2-metre temperature.
- Period: 3 months, from 24/5 to 24/8/2009.
- Forecast ranges: fc+6h, fc+12h, ..., fc+132h.
- Scores: root-mean-square error, bias.

Probabilistic verification of 12-hour cumulated precipitation

- Variable:12h cumulated precipitation (18-06, 06-18 UTC).
- Period: 2 months, June and July 2009.
- Forecast ranges: fc 6-18h, fc 18-30h, ..., fc 114-126h.
- Scores: ROC area, BSS, RPSS, Outliers.
- Thresholds: 1, 5, 10, 15, 25, 50 mm/12h.


Bias and rmse of T2M Ensemble Mean
Consider bias and rmse for June 2009.
T2m forecasts are corrected with height.
MAPDOM
FULLDOM
Bias closer to zero and lower rmse for the 7-km suite.
Improvement is not "massive", but detectable for all forecast ranges, especially for day-time verification.
For both models, lower rmse over the FULL domain in comparison with the MAP D-PHASE domain.
The signal is stable (similar scores for 1-month or 3-month verification).
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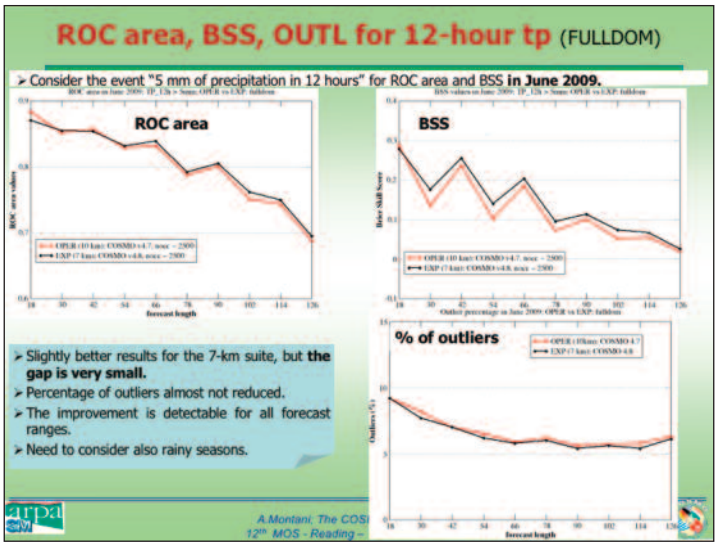
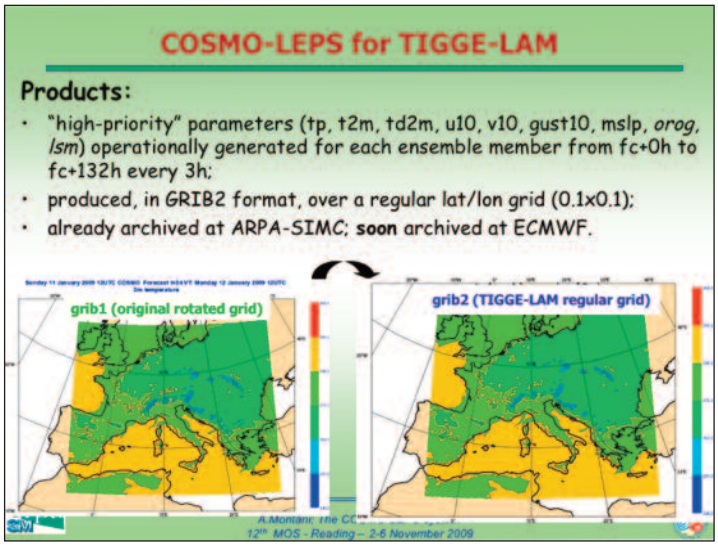

ROC area, BSS, OUTL for 12-hour tp (FULLDOM)
Consider the event "5 mm of precipitation in 12 hours" for ROC area and BSS in June 2009.
ROC area
BSS
% of outliers
Slightly better results for the 7-km suite, but the gap is very small.
Percentage of outliers almost not reduced.
The improvement is detectable for all forecast ranges.
Need to consider also rainy seasons.


COSMO-LEPS for TIGGE-LAM
Products:
"high-priority" parameters (tp, t2m, td2m, u10, v10, gust10, mslp, orog, lsm) operationally generated for each ensemble member from fc+0h to fc+132h every 3h;
produced, in GRIB2 format, over a regular lat/lon grid (0.1x0.1);
already archived at ARPA-SIMC; soon archived at ECMWF.
grib1 (original rotated grid)
grib2 (TIGGE-LAM regular grid)
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Main results

Time-series verification scores cannot disentangle improvements related to COSMO-LEPS upgrades from those due to better EPS boundaries; nevertheless, positive trends can be identified:

- increase in ROC area scores and reduction in outliers percentages;
- positive impact of increasing the population from 5 to 10 members (June 2004);
- some deficiencies in the skill of the system were identified after the system upgrades occurred on February 2006 (from 10 to 16 members; from32 to 40 model levels);
- system upgrades of December 2007 brought small but positive impact.

High-res verification shows better scores of COSMO-LEPS with respect to EPS in forecasting both average and maximum precipitation values within boxes.

As for calibration,

- both ensemble skill and calibration impact are quite variable, depending on the season and the geographical area;
- Linear Regression improves the ensemble reliability especially for higher thresholds;
- smaller (greater) impact of calibration in autumn (spring).

Future plans

- **COSMO-LEPS_7km** (operational on 1 December):
  - use the soil moisture analysis fields provided by DWD;
  - tune old perturbations and introduce new ones;
- **COSMO-LEPS for TIGGE-LAM**:
  - implement coding, post-processing and archiving of COSMO-LEPS output files in GRIB2 format;
  - develop "hybrid" clustering mixing ECMWF EPS and UKMO MOGREPS.
- Support calibration and verification.
- Carry on collaboration within research project (e.g. SAFEWIND).
- Towards the end of 2010, start to think about
  - COSMO-LEPS_2.8km
  - COSMO-LEPS with 20 members