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1 Learn more about the COSMO-Modell

1.1 Model Properties: Dynamics and Numerics, Physics, Data Assimilation, and more ...

The COSMO Model is a limited-area model developed within the framework of the Consortium for Small-Scale Modelling (COSMO).

A general description of the COSMO model is available from the COSMO website. More detailed information on the COSMO Model can be found in the COSMO Newsletters or from the scientific documentation (see box "further reading").

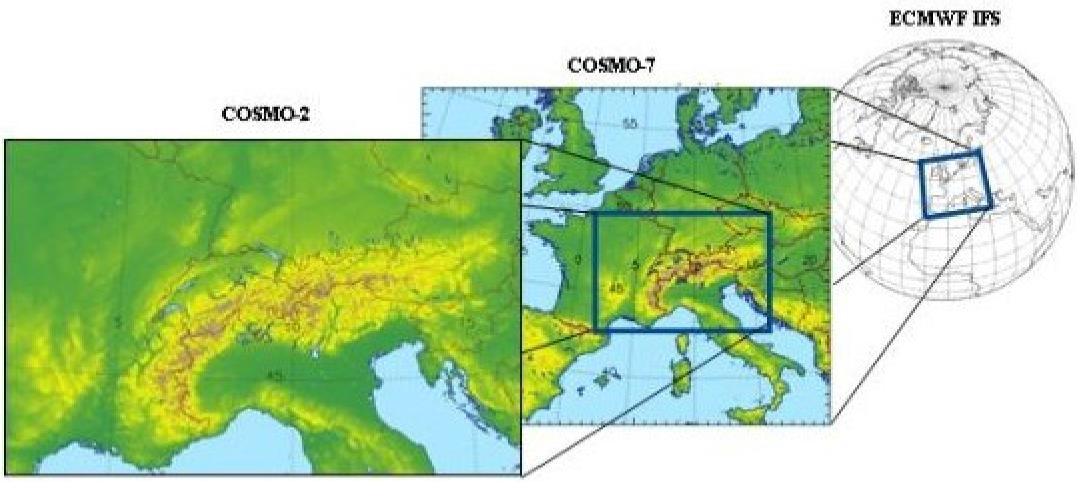

Figure 1: The three nested numerical weather prediction models of the COSMO system. The European Center for Medium Range Weather Forecast operates a global model describing the synoptic scales. MeteoSwiss operates the regional scale COSMO-7 and the local scale COSMO-2 models.

1.2 Operational Aspects

MeteoSwiss uses the COSMO Model in two resolutions: COSMO-7 with a grid spacing of 6.6 km, and COSMO-2 with a grid spacing of 2.2 km.

COSMO-7 is integrated three times a day out to 72 hours (at 00, 06 and 12 UTC), the higher resolution COSMO-2 is updated seven times a day out to 33 hours and once a day out to 45 hours. Both models run on a Cray XE6 parallel computer at the Swiss National Supercomputing Centre (CSCS) in Lugano (TI). During the operational forecasting slots, the Cray Supercomputer works in dedicated mode. About 50 minutes are required for a full COSMO-7 and COSMO-2 forecast cycle.

http://www.cscs.ch/services/for_public_sector/index.html

For more details on the operational COSMO Models, refer to the operational applications page of the COSMO website, which also lists the current configuration options (Fortran namelist) used for the COSMO Models.

1.3 Dynamics and Numerics

The COSMO Model is based on the primitive hydro-thermodynamical equations describing compressible non-hydrostatic flow in a moist atmosphere without any scale approximations. The model equations are solved numerically on a rotated latitude-longitude grid, with terrain-following coordinates in the vertical, using an Eulerian finite difference method.

The dynamical and numerical key features of the COSMO Model are summarized on the dynamics and numerics page.

1.4 Physics

Physical processes not resolved by the 3-dimensional numerical grid need to be parameterized. In numerical weather prediction, "parameterization" is the technical term for the art of estimating the properties of sub-grid scale processes (e.g. condensation: is sub-grid scale condensation taking place?) and their feedback on the resolved model variables (e.g. temperature and humidity: does condensation heat the air in the grid box under consideration and hence alter its temperature?) . The COSMO Model uses parameterization schemes for the following sub-grid scale physical processes: vertical diffusion (turbulence), cloud and precipitation formation (condensation), convection (not needed for resolutions better than few kilometers), radiation, and finally soil processes in a soil model.

The COSMO physical parameterizations page provides more details about the parameterization schemes of the COSMO Model.

1.5 Data Assimilation, Initial Conditions

To provide initial conditions for the COSMO Model forecasts, a four-dimensional data assimilation system based on the observation nudging technique is used. This nudging or Newtonian relaxation relaxes the model's prognostic variables (i.e., pressure, temperature, wind, and mass fractions of different water species) towards observations within a predetermined space- and time-window. The output of this procedure is called analysis and - besides providing initial conditions for COSMO Model forecasts

- is the best estimate of the state of the atmosphere, a 3-dimensional hydro-thermo-dynamically consistent snapshot for any given time.

More information is available on the COSMO data assimilation page.

1.6 Lateral Boundary Conditions

Besides initial conditions, the limited-area COSMO Model forecasts also need lateral boundary conditions for the entire forecasting period. For COSMO-7, these are provided by the coarser global model (IFS) of the ECMWF, whose fields drive COSMO-7 using a 1-way nesting technique. For COSMO-2, the 1-way nesting is used to run it with lateral boundary conditions from COSMO-7.

1.7 Developments specifically targeted at improving COSMO Model analyses and forecasts in the Alpine region

Most numerical weather prediction models, including the COSMO Model, are written in terrain-following coordinates. The height of the model levels thus depend on the underlying topographic structure. Over complex mountainous areas the inhomogeneities in the levels may cause truncation errors in the numerical schemes.

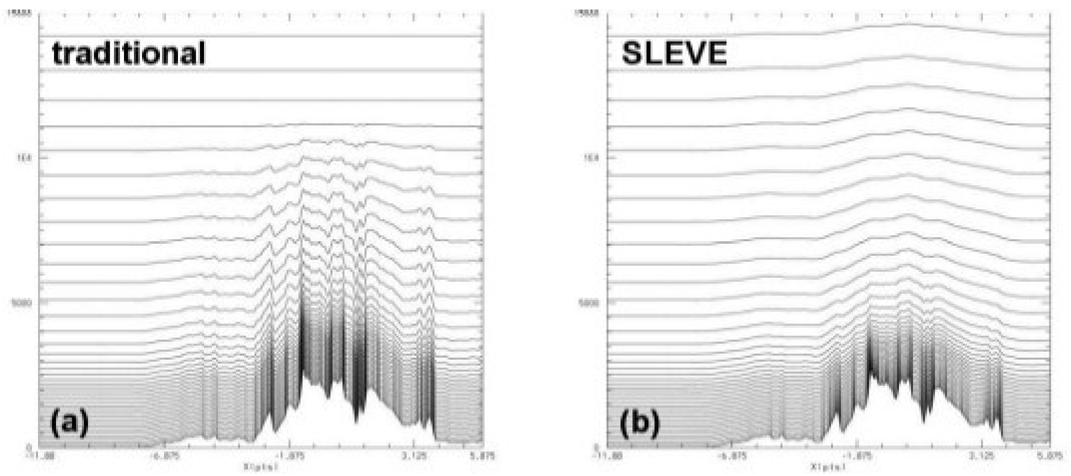

Figure 2: Vertical West-East cross-sections across the Alps showing the height of the computational surfaces for a) the traditional coordinate and b) the SLEVE coordinate.

Schär et al. (2002) have suggested a new SLEVE (Smooth Level VErtical) coordinate which produces a smooth computational mesh at mid and upper levels. Unlike traditional formulations, the new SLEVE coordinate transformation is characterized by a scale dependent, exponential vertical decay of the terrain structure. This allows for a fast decay of small-scale topography components with height, leading to a fast transition from terrain-following to smooth levels (Fig. 1).

The SLEVE coordinate reduces computational noise in the mid and upper model domain over complex topography, such as the Alps and is particularly useful in high-resolution simulations.

References

Schär, C., D. Leuenberger, O. Fuhrer, D. Lüthi and C. Girard, 2002: A new Terrain-Following Vertical Coordinate Formulation for Atmospheric Prediction Models. Mon. Wea. Rev., 130, 2459-2480.

Leuenberger, D., 2002: The SLEVE Coordinate in LM. In: COSMO Newsletter, No. 2, 105-110.

1.8 Verification of COSMO forecasts

MeteoSwiss supervises many aspects of its model suites. COSMO Model output, for instance, is operationally verified against:

- surface observations in Switzerland (hourly) and Europe (3-hourly) for 2 m-temperature, dewpoint, pressure (station pressure and reduced to sea level), wind (speed and direction), cloud cover, precipitation, wind gusts, relative humidity, and global radiation.
- upper air data from radiosonde ascents for temperature, wind, geopotential and humidity
- radar data for precipitation
- wind profiler data and flux measurements in Payerne for different near-surface and boundary layer parameters (short and longwave surface radiation, albedo, sensible and latent heat flux).

1.9 Applications based on COSMO Model output

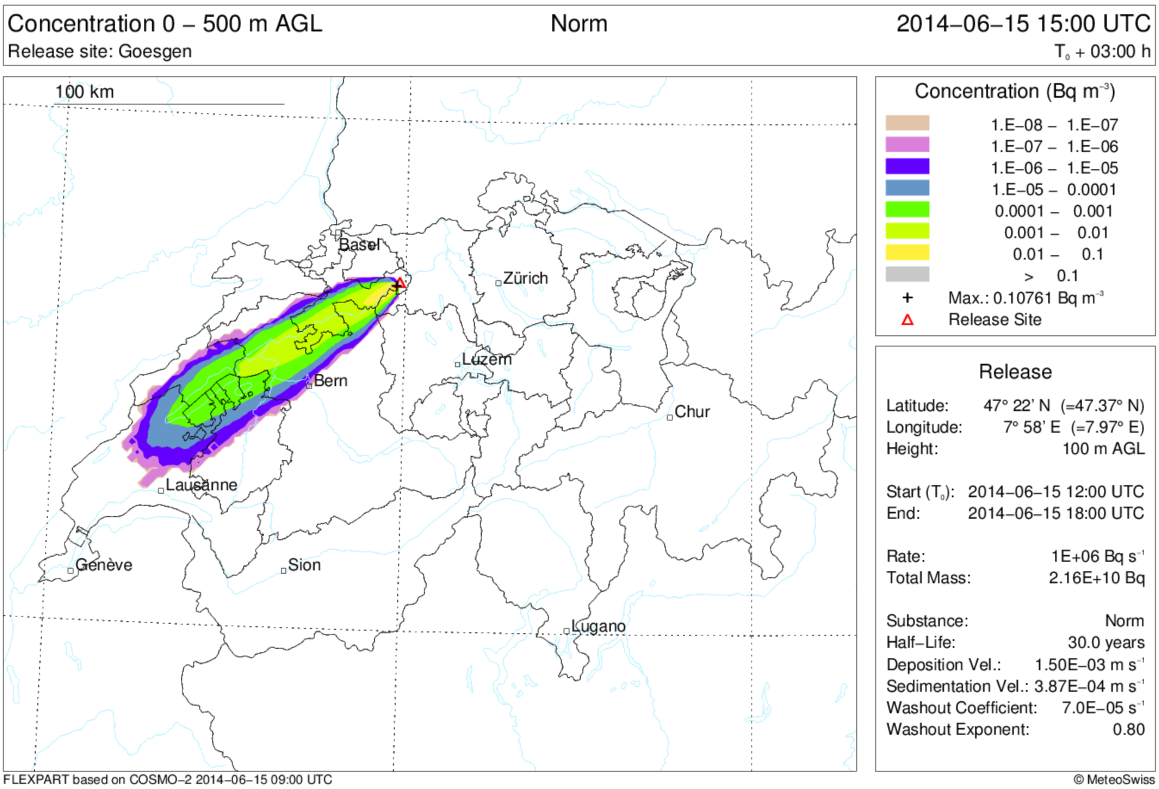

Figure 3: Near-surface concentration field; hypothetical emission at Gösgen

1.10 Dispersion modeling

The Lagrangian Particle Dispersion Model FLEXPART predicts, routinely for emergency preparedness and on demand for emergency response, the long-range transport, dispersion, and wet and dry deposition of airborne radioactive material. The calculation of about 200 000 particle trajectories is based on wind fields from the COSMO Models and the stochastic simulation of turbulent diffusion (so-called Monte Carlo simulation). Radioactive decay and convective mixing are taken into account. The concentration is calculated by summing up the particle masses in a diagnostic grid.

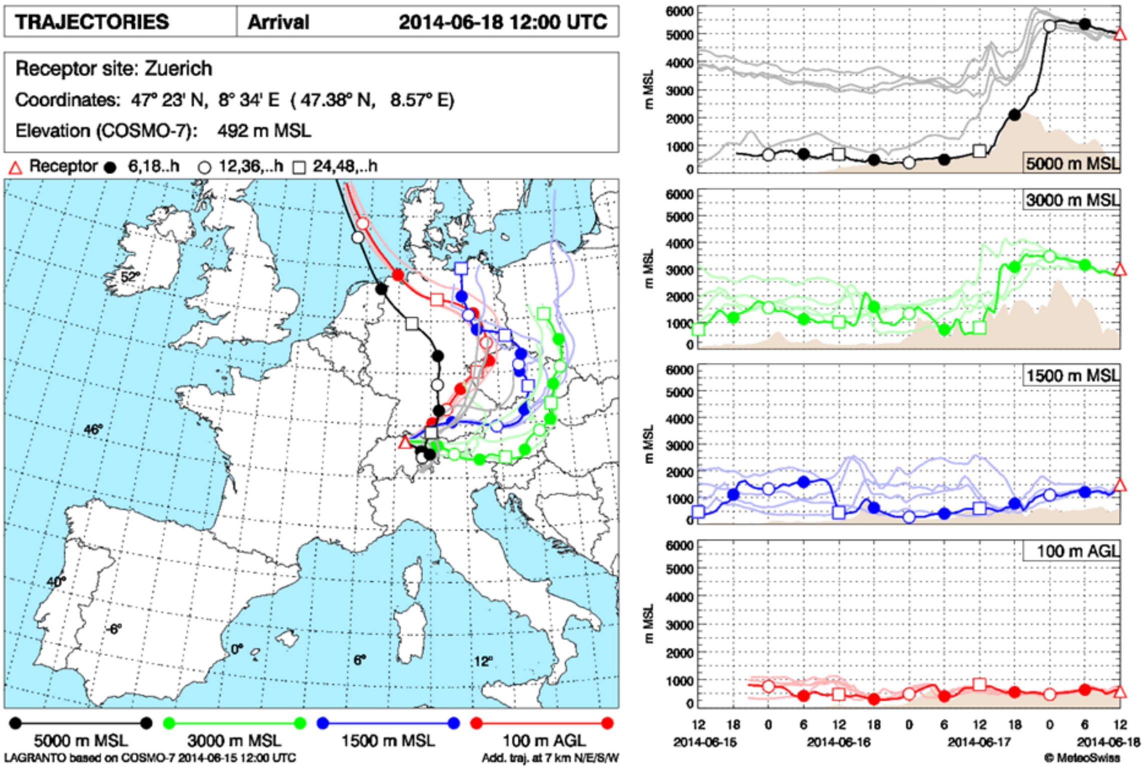

Figure 4: Backward trajectories arriving at Zurich, left: map, right: profile along main trajectory (colors denote different arrival heights,). The additional trajectories in light colors give an impression on the reliability of the main trajectory.

1.11 Trajectories

A trajectory model is run routinely with COSMO output to provide information on air-borne transport routes (advection of air masses, passive tracers, and pollen) and guidance for ballooning. It is applied both in source-oriented (forward) and receptor-oriented (backward) mode. The meteorological input is provided by the COSMO models at hourly intervals. In the case of accidents with release of toxic material into the air, it is run on demand to provide a quick estimate of the primary dispersion path.

1.12 Other post-processing tools

Various other post-processing tools are used to provide tailored products (data and graphics) for various commercial and non-commercial customers. Two examples worth mentioning are the Kalman filter, used to remove systematic model biases in the forecast of temperature, humidity at 2 m and of wind speed at 10 m above ground, and the Model Output Statistics (MOS) post-processing application.

1.13 COSMO-2: Very High-Resolution Model for the Alpine Region

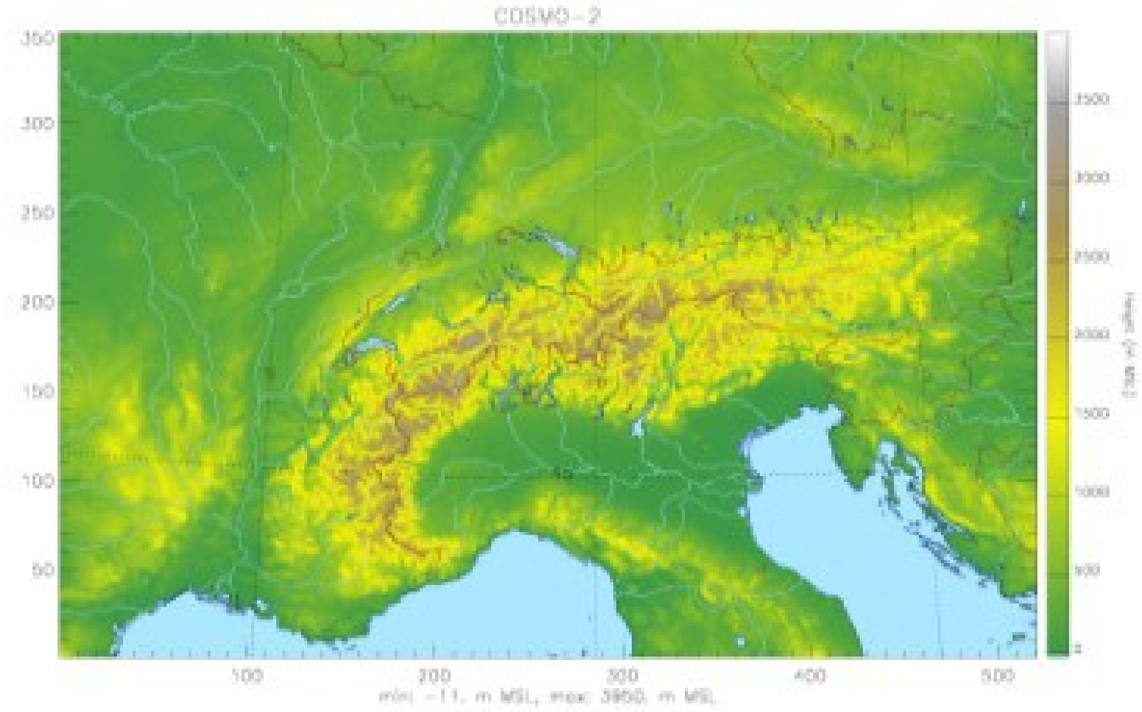

Figure 5: COSMO-2: Computational domain and orography (colour shading)

The very high-resolution numerical weather prediction model COSMO-2 provides, with a grid spacing of 2.2 km, detailed and accurate forecasts for the entire Alpine region out to 33 hours in advance. This model became operational on 27 February 2008.

An important part of the continuing development is the improvement and optimization of the data assimilation system at the kilometer scale. Apart from ingesting new types of data, the appropriate assimilation of high-resolution (spatial and temporal) data in complex topography is a challenge and needs careful attention.

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