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EMEP/MSC-W model:

Structure and Technical aspects

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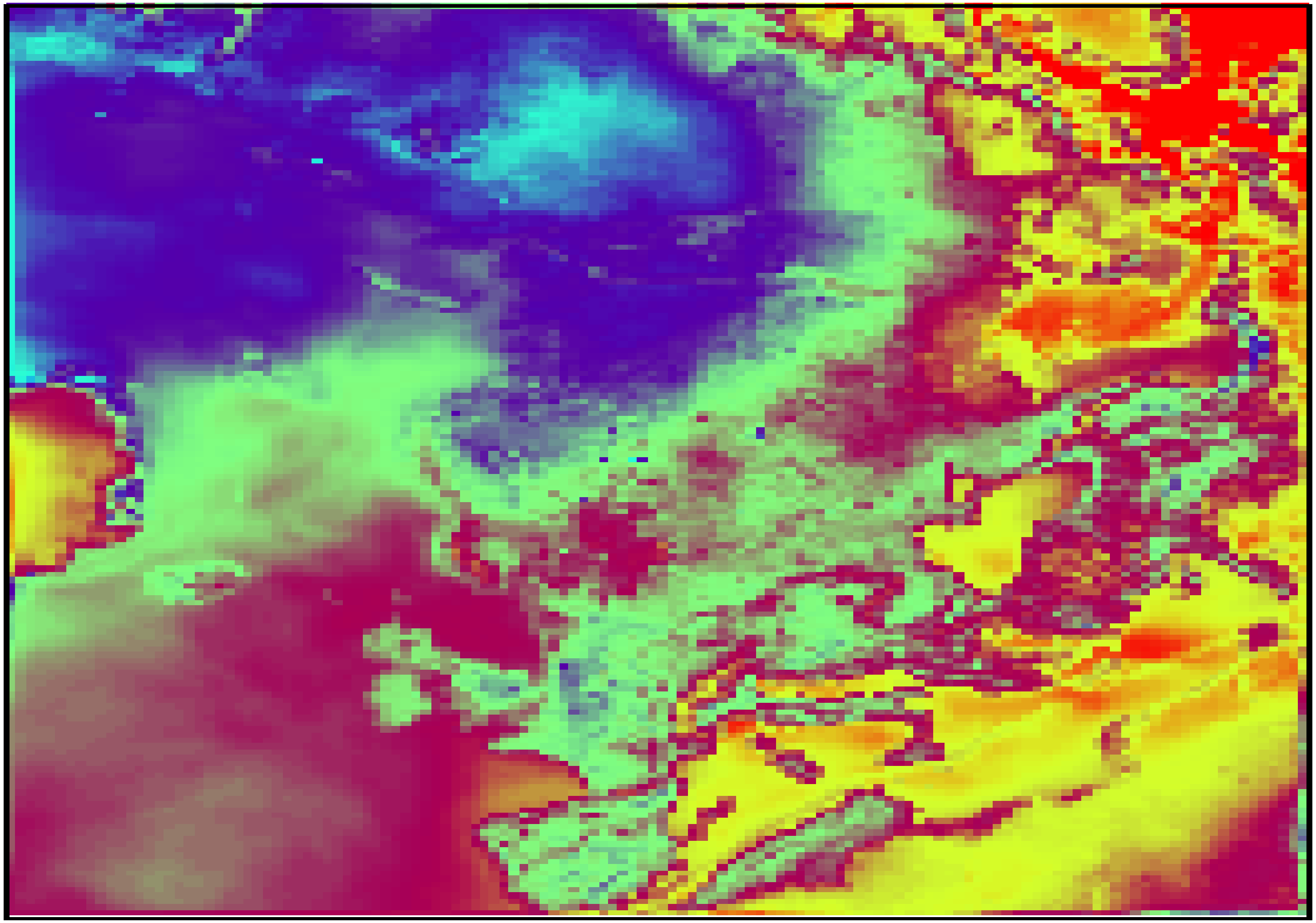
Basic usage:
Pollutants in Europe

SURF_ppb_O3 (ppb)



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Individual customization

- Default values are provided
- Most common usage are relatively easy to control
  - simulation dates
  - emissions reduction by countries
  - 3D output of pollutants
- Less common applications require more efforts
  - New emission sources
  - Other grid/resolution/projection
  - Other meteorological input
  - Different chemical compounds and chemical processes
  - ...

Steer the model with `config_emep.nml`

- Start and end dates of the simulation
  - Startdate = 2013,01,01,000000,
- Restricted domain
  - RUNDOMAIN = 20, 70, 40, 90,
- Emissions to be included
  - USES%FOREST_FIRES = T ...
- Fields to be outputted
  - OutputConcs = 'SO2' ,'ug' ,'2d','AIR_CONCS','SPEC' ,4,
- Nesting (boundary concentrations)
  - MODE=2
  - template_read_BC = 'EMEP_IN.nc'
- Detailed output for individual modules (DEBUG)
  - DEBUG%FORESTFIRE = T
- More details during exercises!

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Main structure of the code

- Read grid properties, emissions, landuse and all other input data
- Initiate the different modules for these data
- Time loop over the requested period
  - Read new metdata
  - Transport: Advection and diffusion
  - Emissions
  - Chemistry
  - Deposition (wet and dry)
  - Output the requested concentrations

Main structure of the code: Unimod.f90

```
call GridRead

call SetLandUse

call Emissions

call Init_XXX

do while (.not. End_of_Run)

    if (newmonth) call BoundaryConditions

    call Meteoread

    call advecdiff

    call runchem

    call WrtChem

enddo
```

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Structure of the code: details

- Grid projection and resolution are taken from meteorological input data.

  Vertical levels are given separately in a file (Vertical_levels.txt)

- Many different emission sources (see User guide)
- Time loop: dt_advec = 20 minutes (50 km resolution)
  - Metdata every 3 hours + interpolation
  - 15 Chemistry loops every dt_advec
- Emissions and depositions (wet and dry) are performed under «runchem»

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Modules' overview - I

Main: Unimod.f90

Grid: Par_ml.f90, GridValues_ml.f90, InterpolationRoutines_ml.f90

Constants/parameters:

ModelConstants_ml.f90 (config defaults)

PhysicalConstants_ml.f90

Meteorology

Met_ml.f90 (read-in, PBL, kz)

MetFields_ml.f90 (defs)

BLPhysics_ml.f90

CellMet_f90 (sets for grid cells + L, U*)

SubGrid_ml.f90 (stability, L, U*)

Micromet_ml.f90 (Ra for landuses)

SoilWater_ml.f90 (Sets deep soil water)

Emissions Anthropogenic

Emissions_ml.f90

EmisDef_ml.f90

Timefactors_ml.f90

Country_ml.f90

Emissions Natural

SeaSalt_ml.f90

DustProd_ml.f90

ForestFire_ml.f90

ColumnSource_ml.f90

AirEmis_ml.f90

Modules' overview - II

Atm. Transport

Advection_ml.f90

Convection_ml.f90

Landuse

Landuse_ml.f90

LandDefs_ml.f90

Dry Deposition

CM_DryDep.inc

DryDep_ml.f90 (Micromet_ml)

Rsurface_ml.f90

Aero_Vds_ml.f90

Wesely_ml.f90

MosaicOutputs_ml.f90

EcoSystems_ml.f90

Wet Deposition

Aqueous_n_WetDep_ml.f90

CM_WetDep.inc

Chemistry

CM_Chem*.f90

Solver.f90 (2-step chem. solver)

CM_Reactions*.inc (gas/aqueous irrever.)

MARS_ml.f90 (EQSAM_ml)

My_SOA_ml.f90

ChemFunctions_ml.f90

Modules' overview - III

Boundary/Initial Conditions

BoundaryConditions_ml.f90

Nest_ml.f90

ExternalBICs_ml.f90

Input/Output

OutputChem_ml.f90

Output_hourly_ml.f90

NetCDF_ml.f90

EmisGet_ml.f90

Derived_ml.f90

MosaicOutputs_ml.f90

Io_Progs_ml.f90

Sites_ml.f90

Other

MassBudget_ml.f90

TimeDate_ml.f90

Units_ml.f90

Timings_ml.f90

Input data, an essential part of the model:

- Meteorology
- Emissions (many types+time factors)
- Landuse
- Boundary Conditions

Except for meteorology, all other input data can be set to a default value. The data will be interpolated to the required grid.

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Emissions overview

- Gridded input (gridsox, gridnox, gridnh3...)
  - global NetCDF set with 0.5° resolution available
- Forestfire (2002-2014)
- Biogenic VOC
- Soil NOx
- Wind blown dust
- Lightning NOx
- Aircraft NOx
- Volcanoes
- DMS: Not flexible yet
- Roaddust: Europe only

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Computational requirements:

- Linux computer (Fedora, Ubuntu, ...)
- Fortran compiler (ifort (Intel), gfortran (Gnu)...)
- MPI library (OpenMPI,...)
- NetCDF library (version 4 or later)
- 2-4 GB memory
- 30 GB disk space (mainly for metdata)

⇨ In practice any linux PC will do!

Requirement details:

Compilation: use 8 bytes reals

- ifort -r8
- gfortran -fdefault-real-8

- Netcdf: by default uses compressed output (i.e. Netcdf4/hdf5). This can be switched off (in emep_config.nml put NETCDF_DEFLATE_LEVEL=-1)

Parallelization:

- One processor does the computation for one geographical rectangle.
- The processors are exchanging information using MPI
- Communication is only required for Input/Output and advection
- For large grids, the model scales to over 1000 processors

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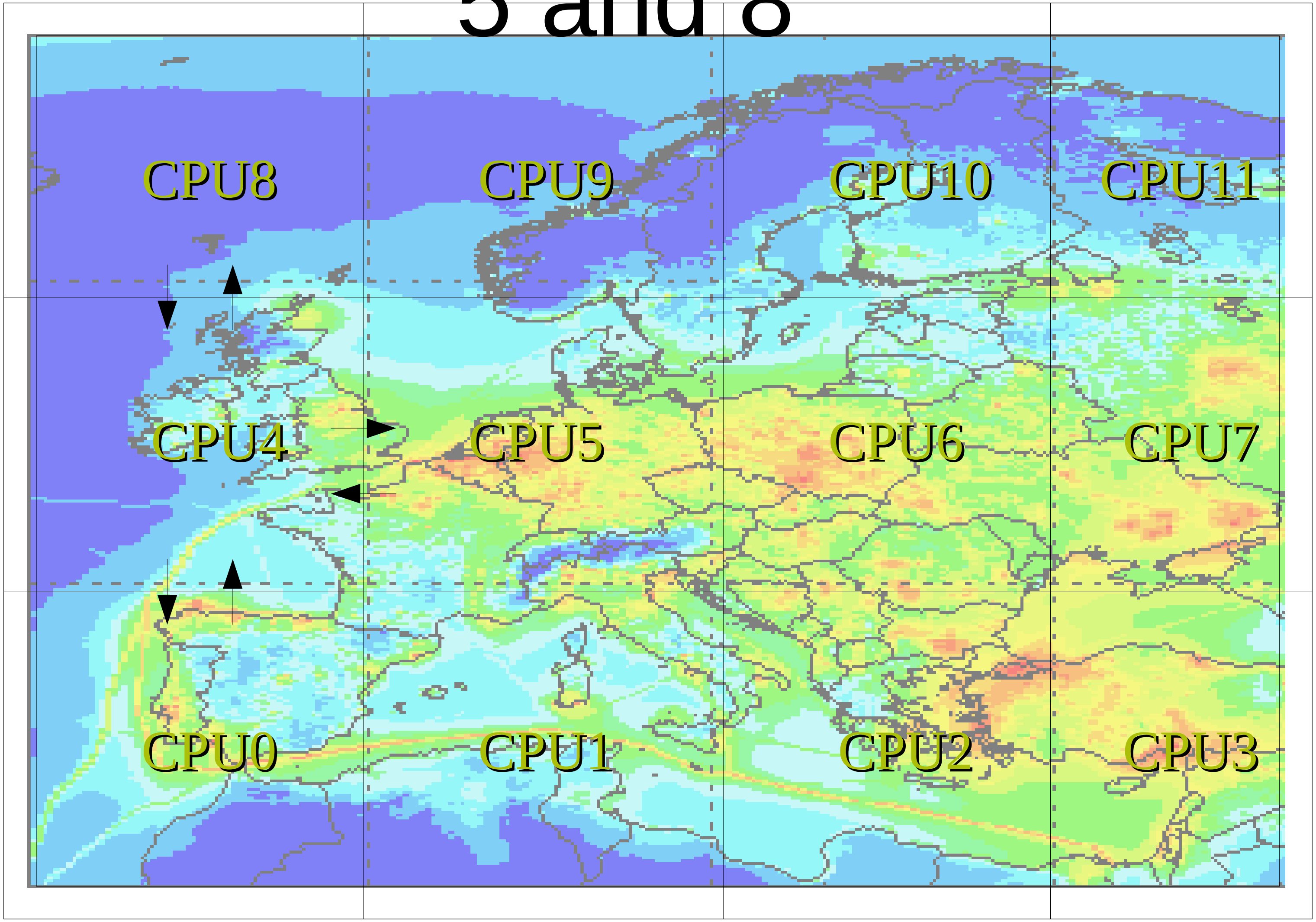
Example 12 processors

CPU4 communicates with CPU 0, 5 and 8



How long time take a run:

- Typically one year simulation for EMEP grid (132x111) on 64 CPU, takes 2.3 hours.
- Time will increase with:
  - Larger grid
  - Fewer processors
  - Finer resolution
  - Large output (3D, hourly...)
- 60% chemistry, 20% advection, 20% I/O + communication

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Grid flexibility:
How does it work?

- The grid properties (projection, resolution, size etc.) are read from the file defining the meteorological data. These must be written as attributes in the NetCDF file.
- The input data which are not in the right grid are automatically interpolated into the proper grid
- The model can read directly WRF output meteorology.
- Making new meteorological input data for other met model from scratch is easy in theory... but not in practice

Resolution

- In principle the projection and resolution of the model are not limited
- Main supported projections:
  - Polar stereographic
  - Spherical (lon-lat)
  - Rotated spherical
- Scales from global (0.5° degree resolution), to regional at fine scales (1 km) have been used
- Gridsize up to 1440x1440 has been tested

Hybrid vertical coordinates

- Defined with a set of constants (A_n and B_n) in
  Vertical_levels.txt
- Pressure at level n defined by
  $$P_n = A_n + B_n P_{surface}$$
- Terrain following lower levels (large B, small A)
- Pressure levels at high altitude (large A, small B)
- Levels can be defined differently from the meteorological levels
- (the “old” sigma levels are a particular case of hybrid levels)

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- The model is evolving constantly, much based on your feedback!

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