Regional Scale Bio-, Hydro-, Atmosphere Modeling

From Numerical Process Simulation to Regional Climate Impact Analysis

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Our Goals

Society

- Scientific based decision support systems

- Vermeidungs- und Adaption strategies to Climate Change

Scientific

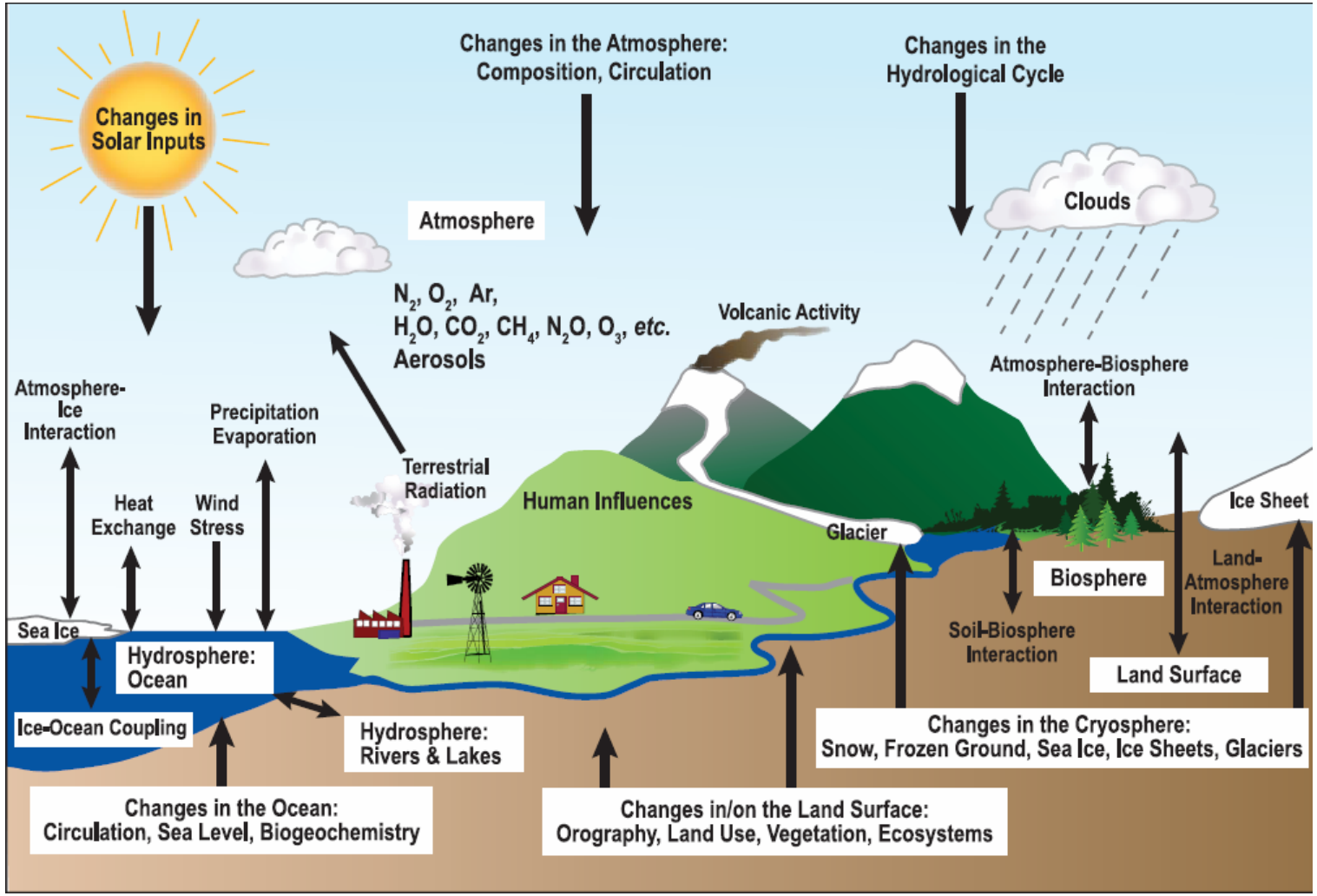
- Development and application of prognostic process based models

- Influence of global climate change on regional climate
  - a) water availability and flood risc
  - b) bio-geochemical greenhouse gas emissions
  - c) urban air quality

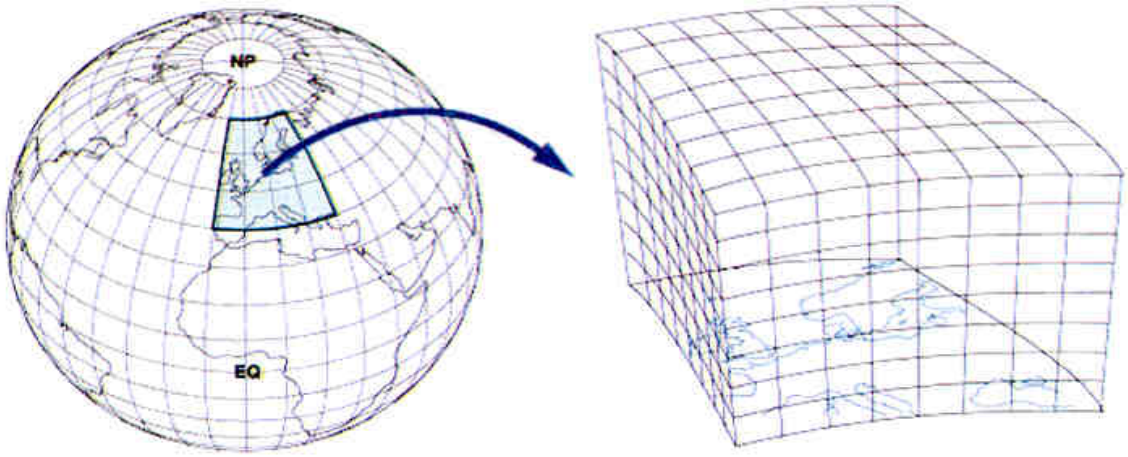
- Dynamic feedback mechanisms
  Climate ⇔ water balance ⇔ vegetation ⇔ bio-geochemistry ⇔ air chemistry

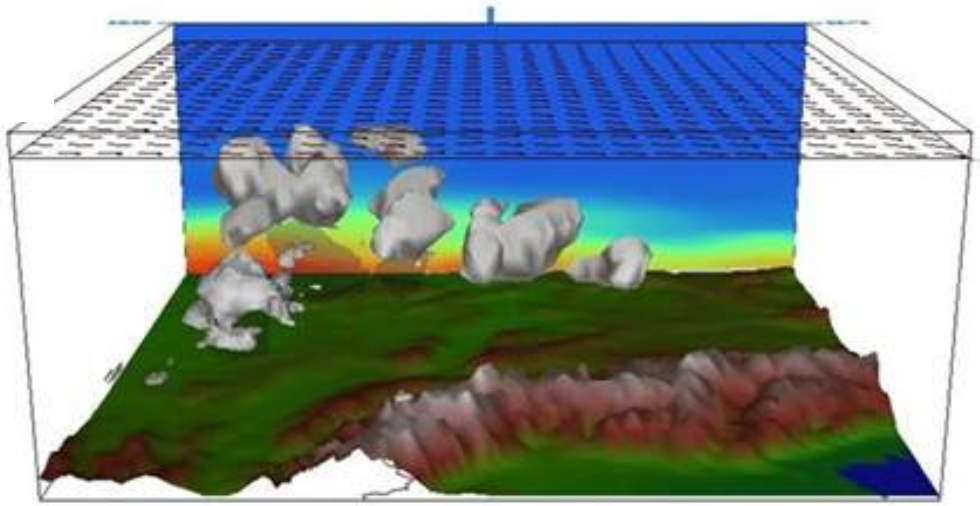
The Challenge

Modeling of the interaction between the bio-, hydro- and atmosphere via a BHA-Model



Regional Limited Area / Site Scale Models





Regional Climate Models

MM5, WRF, CLM

Regional Air Quality Models

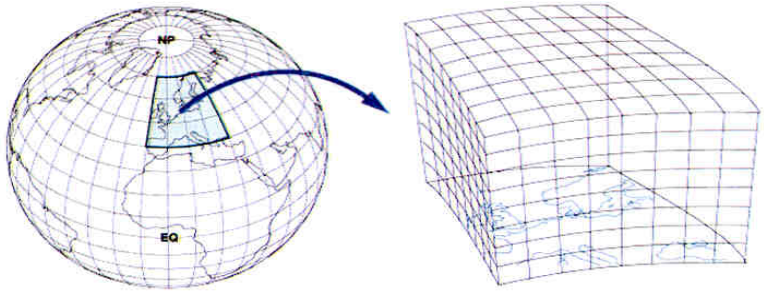
MCCM, WRF-CHEM

Biosphere Simulation Framework

MOBILE, PNET-N-DNDC

Regional atmospheric modeling

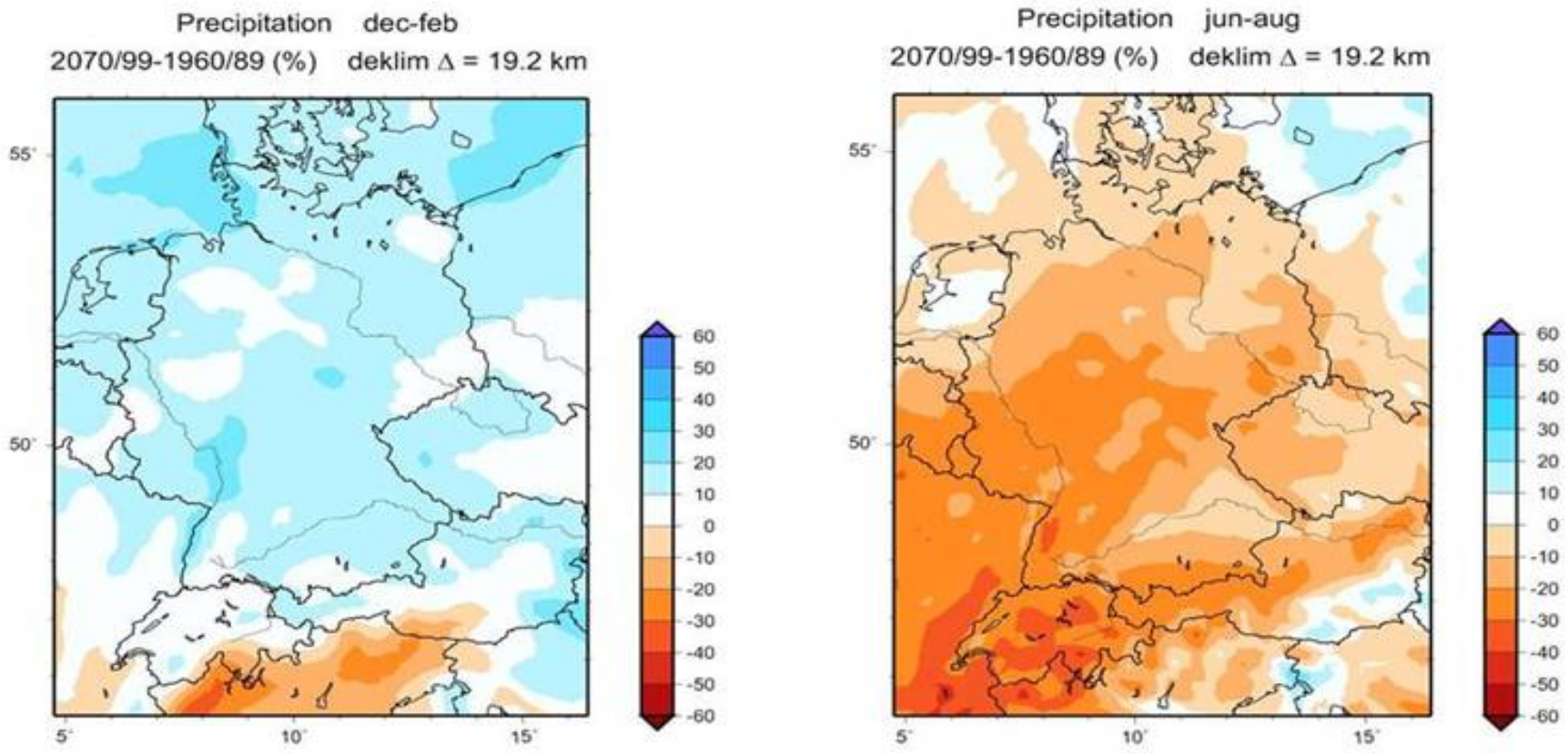
Basic facts



- Scales: 1 km (non-hydrostatic) < Δx < 50 km
  10-60 vertical layers for troposphere
  3 sec < Δt < 150 sec
- Boundary & initial cond. by global atmospheric model
- Nesting approach (successive refinement)
- Grid scale: general physical laws (conservation of energy, momentum, mass)
- Subgrid scale: parameterisations
  (turbulence, convection, cloud & precipitation physics)

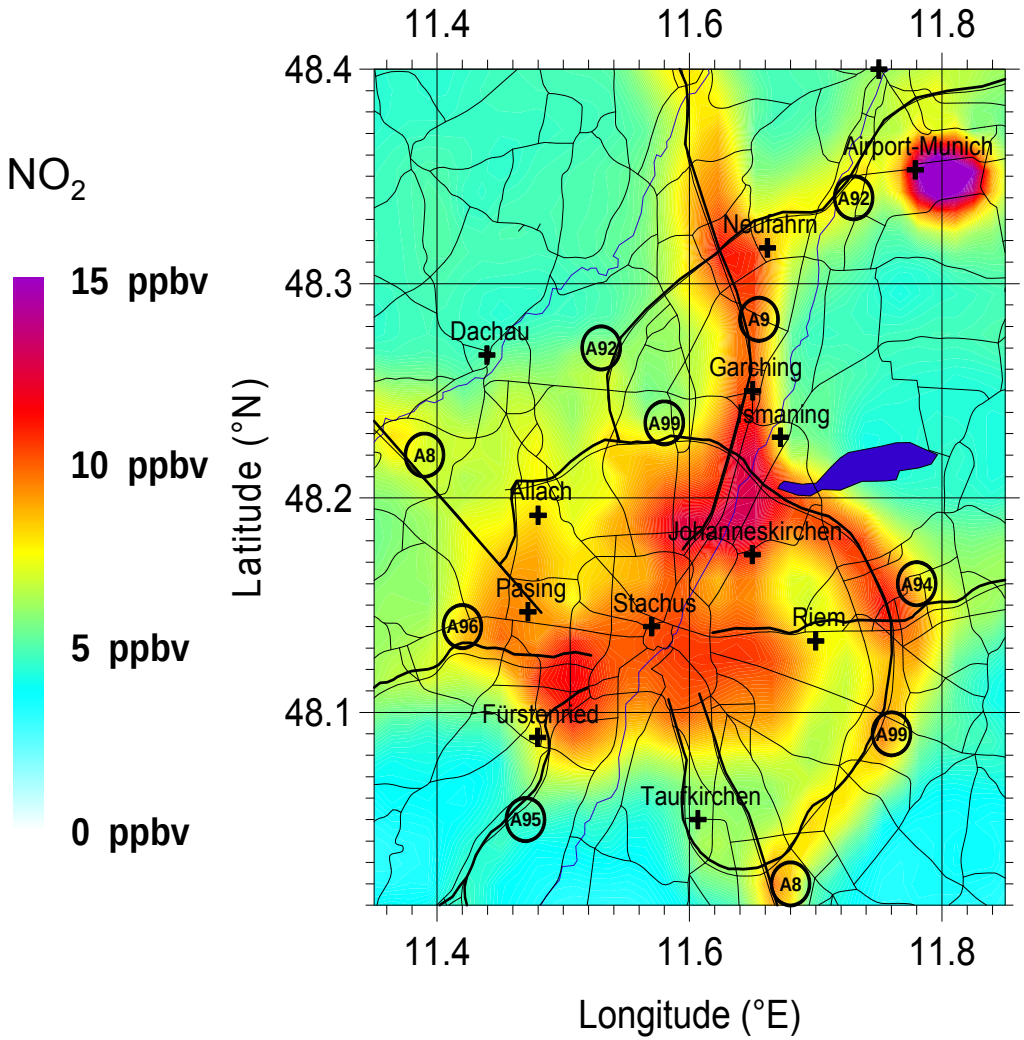
Applications: Regional Climate Modeling

Example: Regional Climate Modeling
Impact of Climate Change on Precipitation

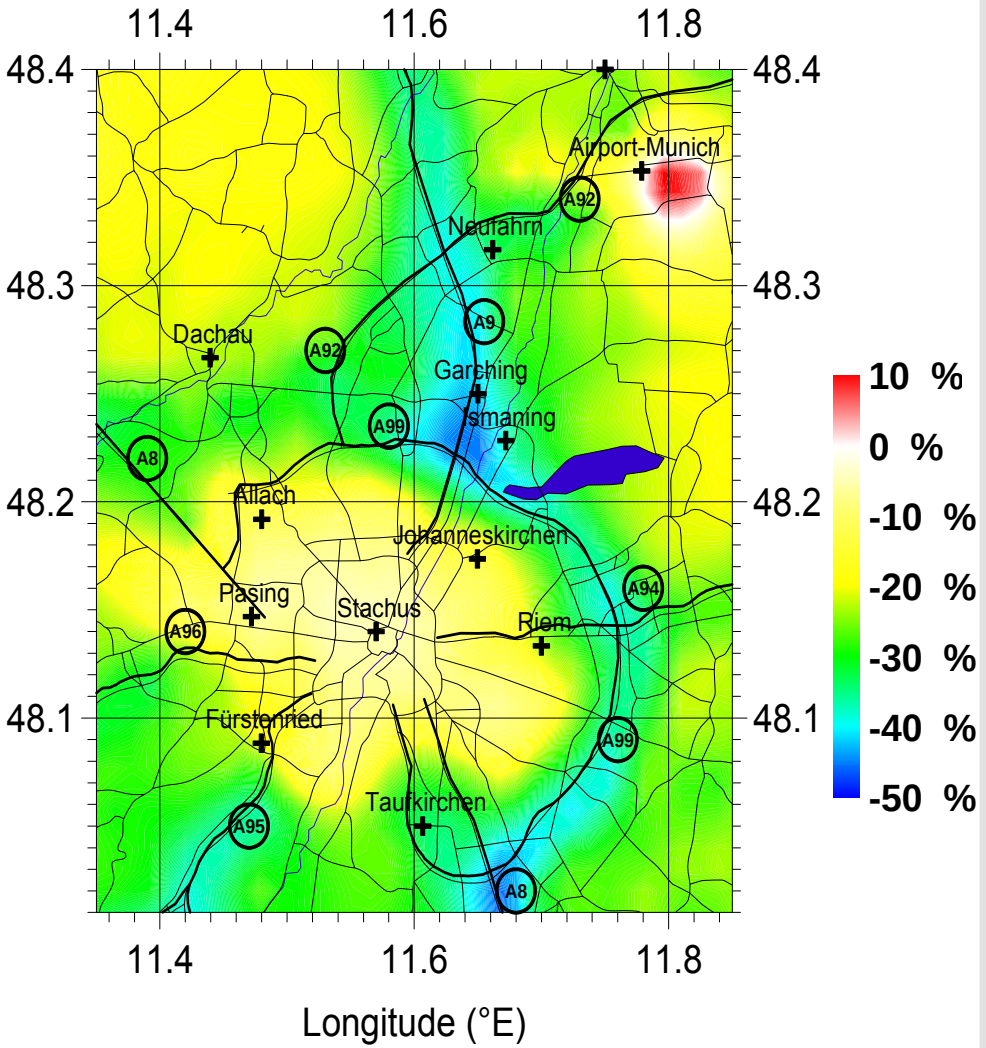


Expected precipitation change MM5-ECHAM4, A2
(Kotlarsky et al. 2005)

Example: Regional Meteorology-Chemistry Simulation
Air Pollution in Metropolitan Areas

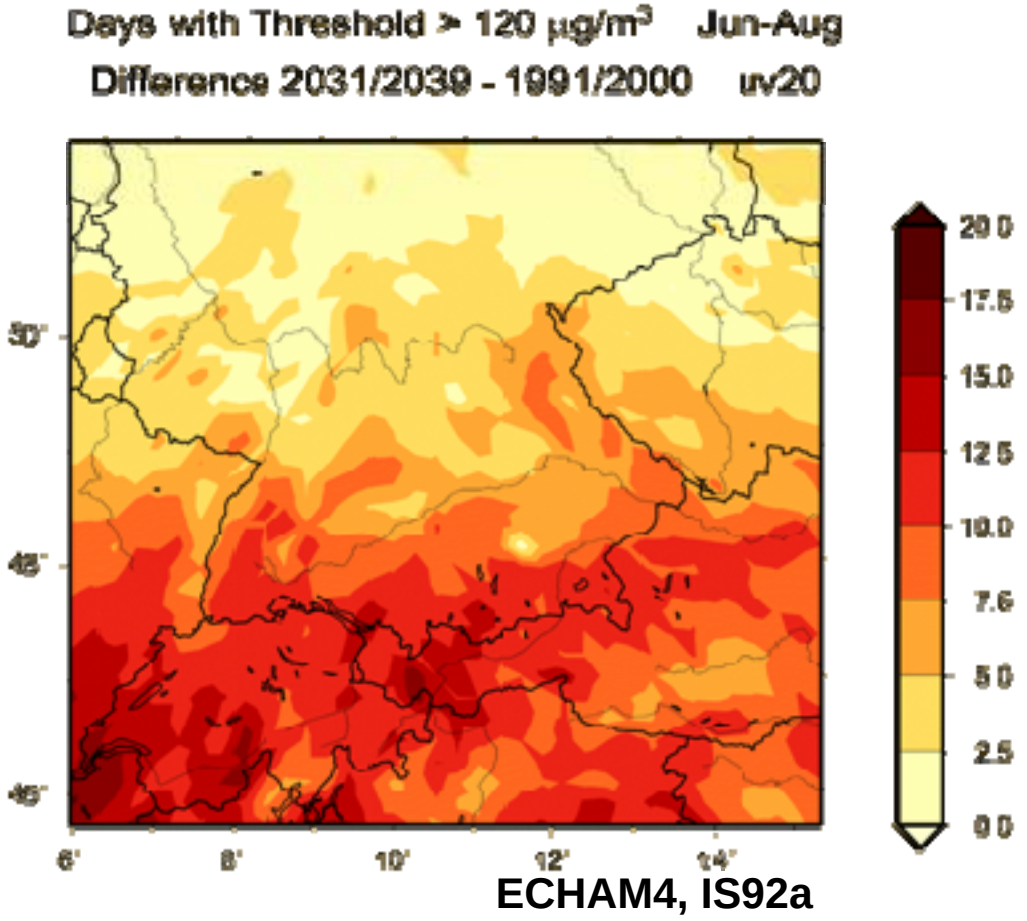


Air pollution distribution for the Munich area in summer 2000

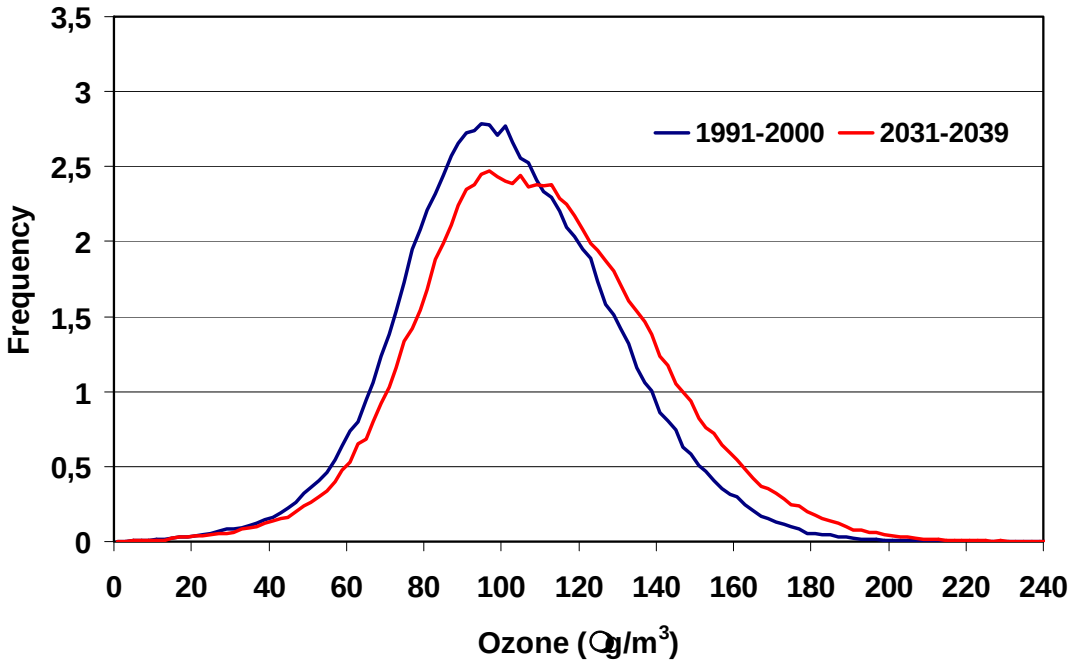


Air pollution difference due to emission projection in 2010

Example: Regional Climate-Chemistry Simulation
Impact of Climate Change on Air Chemistry



ECHAM4, IS92a



Increased occurrence of ozone extreme value conditions (Forkel et al. 2006)

Regional Climate Change in the europ. Alps

Change mean anual temperature 2070-99 vs. 1960-89 [°C]

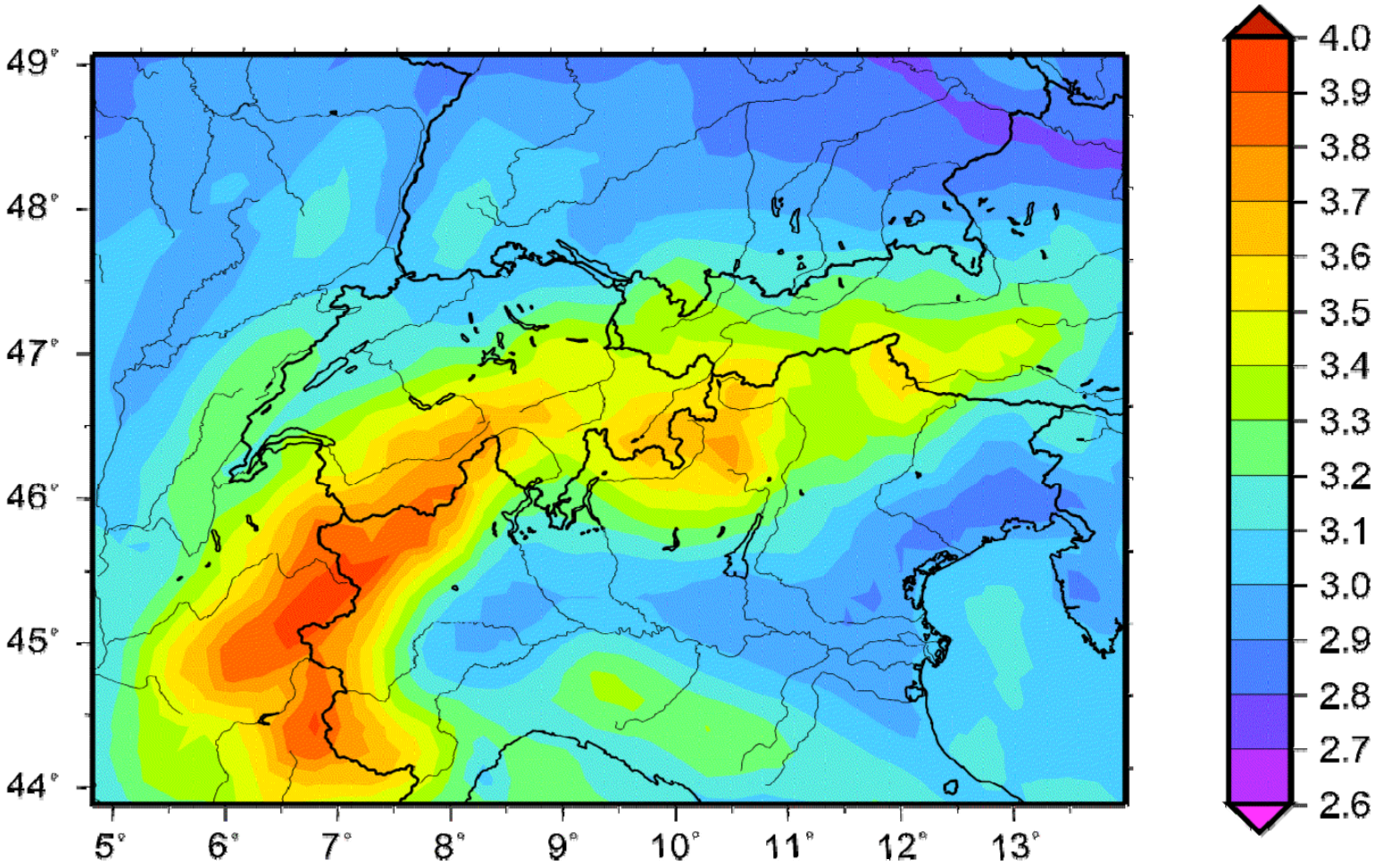
ECHAM4, B2

↓

REMO

↓

MM5 (19.2 km)

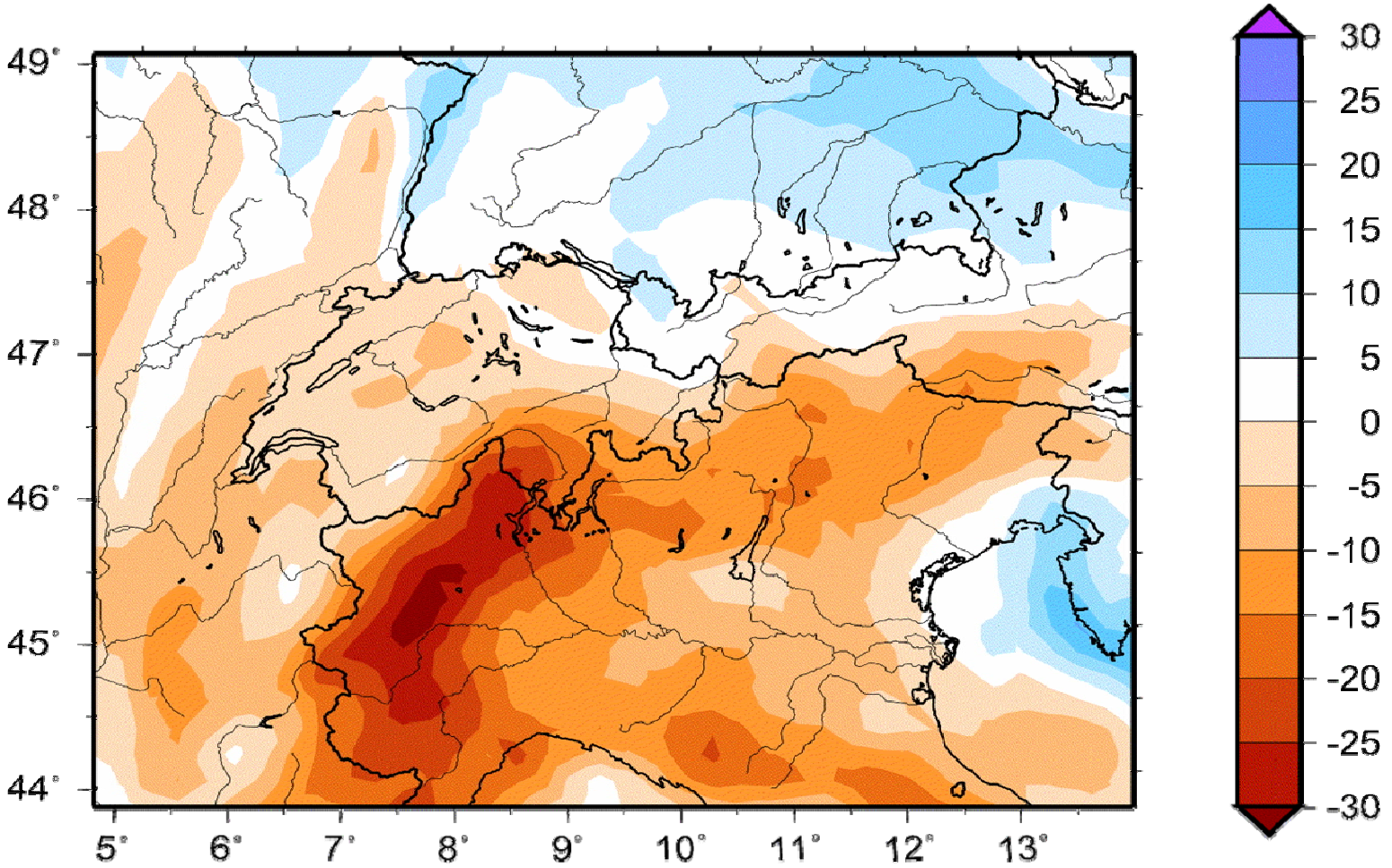


⇒ Regional increase up to 4°C (2-m temperature)!

Regional Climate Change in the europ. Alps

Change in anual precipitation 2070-99 vs. 1960-89 [%]

ECHAM4, B2
↓
REMO
↓
MM5 (19.2 km)



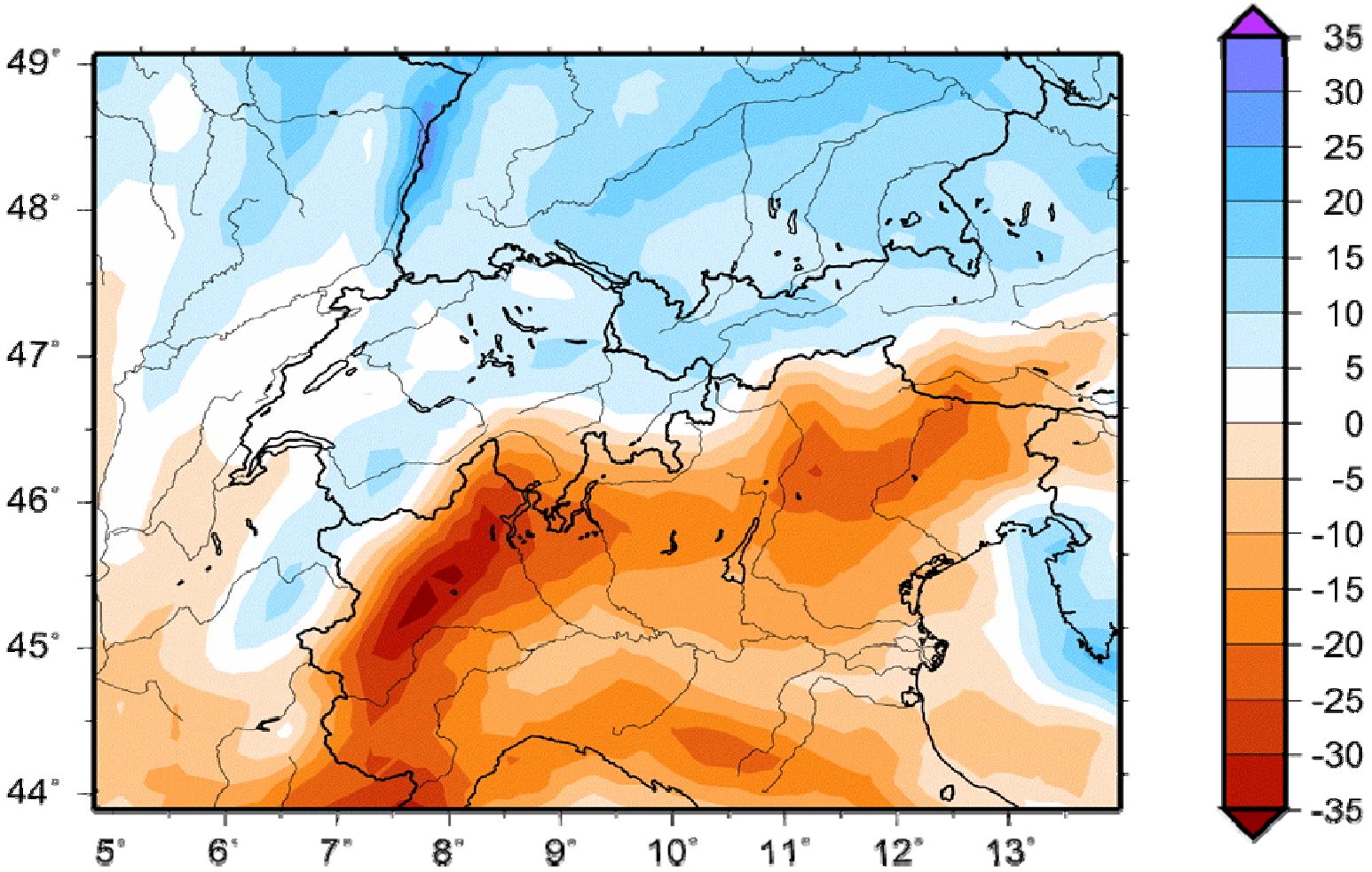
⇒ **Regional up to 30% less total anual precipitation**

⇒ **Increase up to 20% in Southern-Germany!**

Regional Climate Change in the europ. Alps

Change in winter time precipitation DJF 2070-99 vs. 1960-89 [%]

ECHAM4, B2
↓
REMO
↓
MM5 (19.2 km)



- **Winter time precipitation: opposite trend north vs. south**
  +10% nothern vs. -30% southern alps

Regional Climate Change in the europ. Alps

Change in summer time precipitation JJA 2070-99 vs. 1960-89 [%]

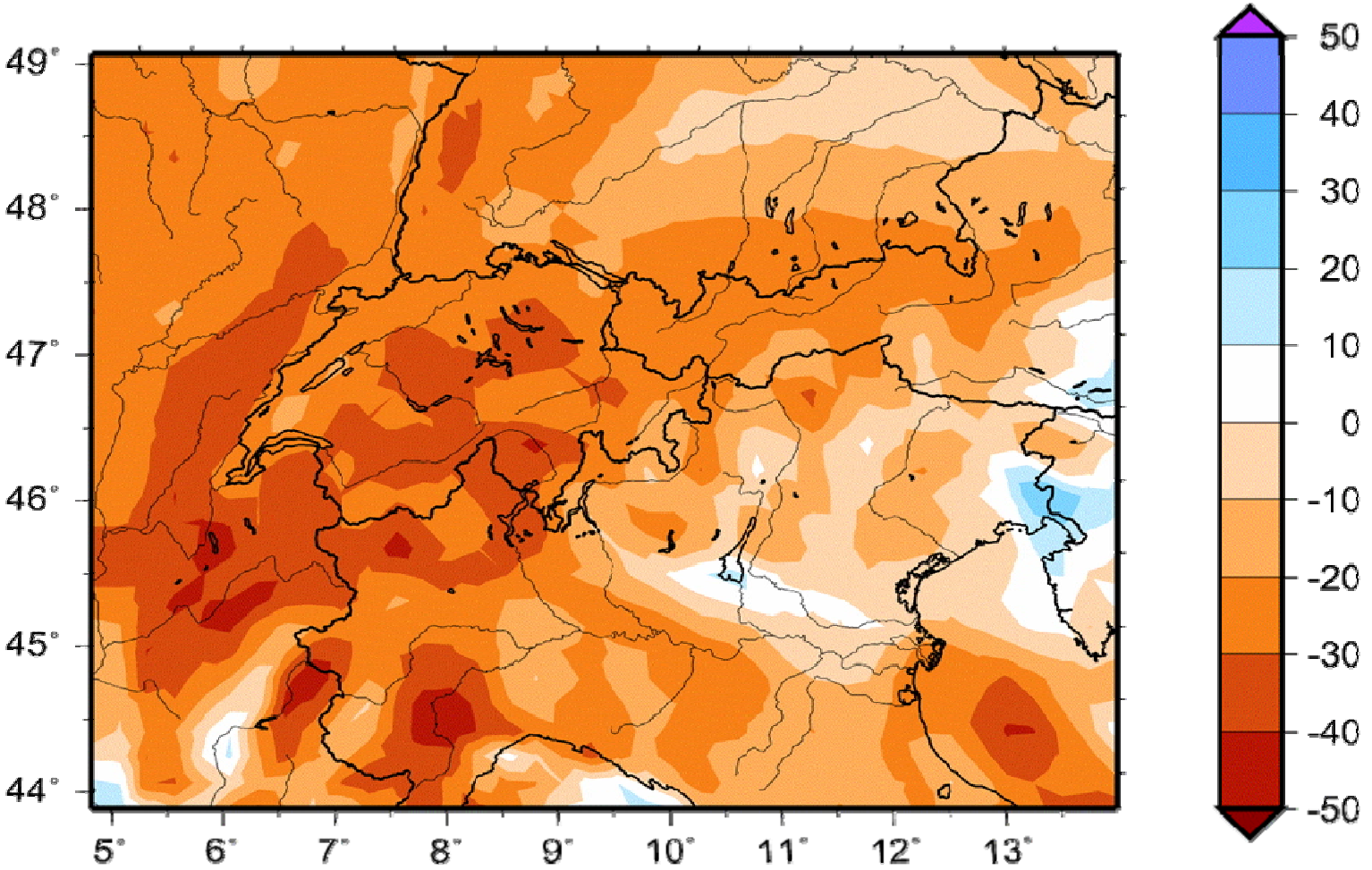
ECHAM4, B2

↓

REMO

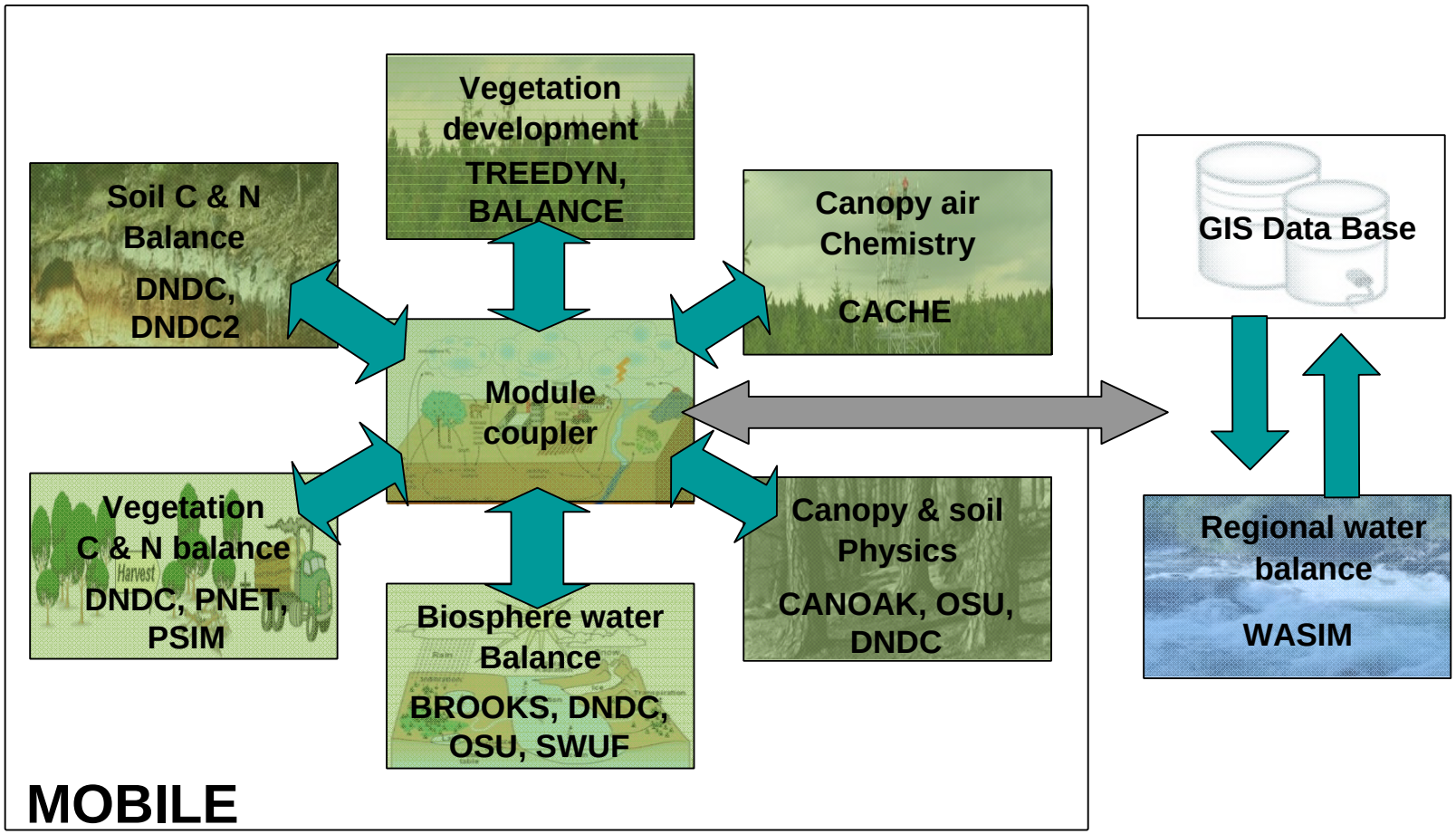
↓

MM5 (19.2 km)

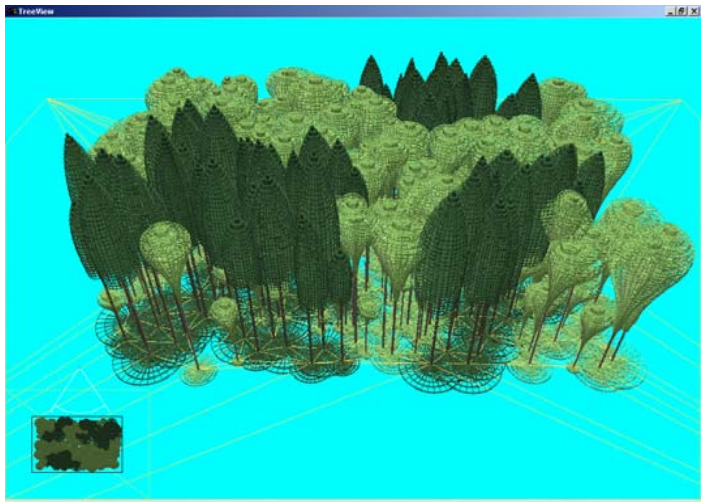


- **Summer time precipitation: up to 40% less (western alps)**
- **South-Germany: ~ 20 % less**

MOBILE Simulation Framework



Biosphere Modeling



Macro-scale ecosystem

Micro-scale ecosystem

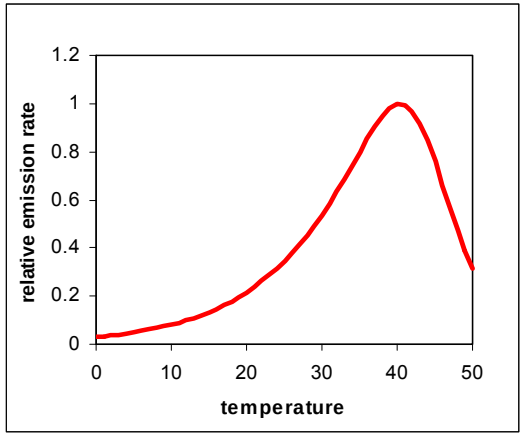
Basic facts (DNDC; MOBILE)

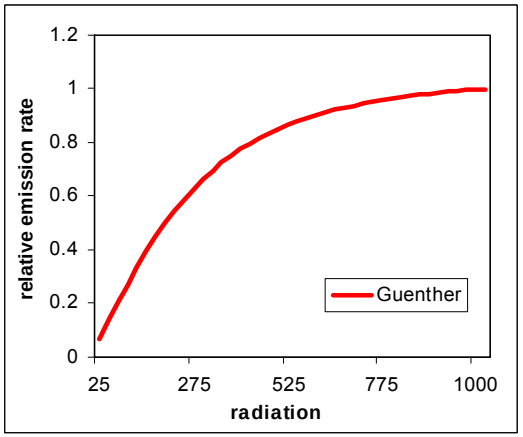
- 1-d column approach (soil & vegetation layers)
- 10 sec. < Δt < 1 day
- Driven by met./climate & air chemistry data
- **Macroscale ecosystem**
  1) Vegetation dynamics: stand level, foliage, LAI
  2) Soil-hydrology approaches: a) bucket b) SVAT
- **Microscale ecosystem**
  1) Physiological (vegetation) & biogeochemical (soil) processes (C & N- fluxes & balances): mass fluxes, dissolution, decomposition, oxidation, adsorption, complexation, assimilation & reverse processes
  2) optionally (celluar level): biochemical processes C-metabolism (e.g. VOC emission)

Biosphere Modeling

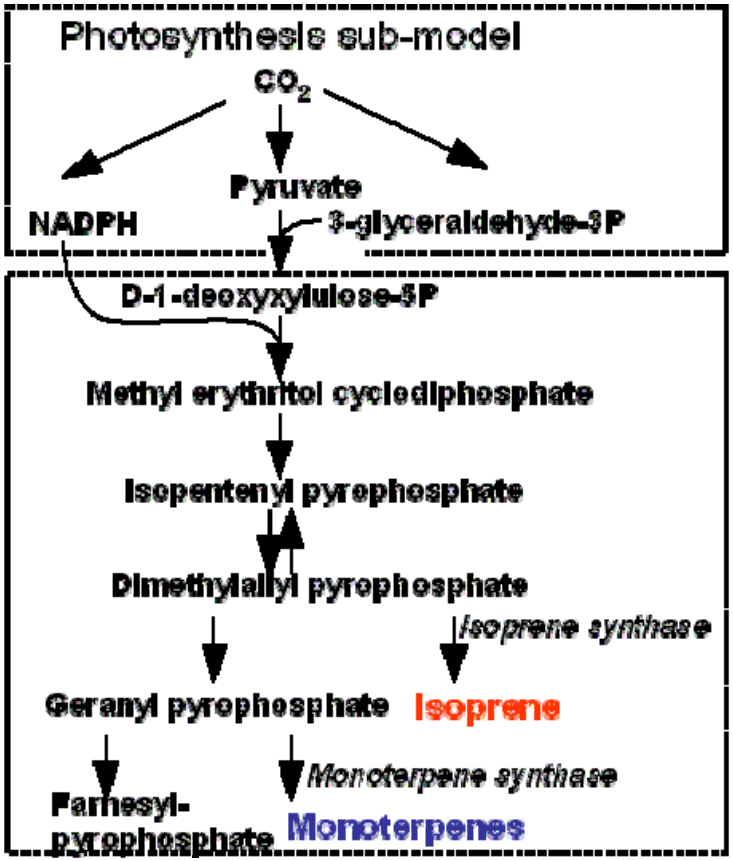
Process based vs. empirical approaches

Example: VOC modeling



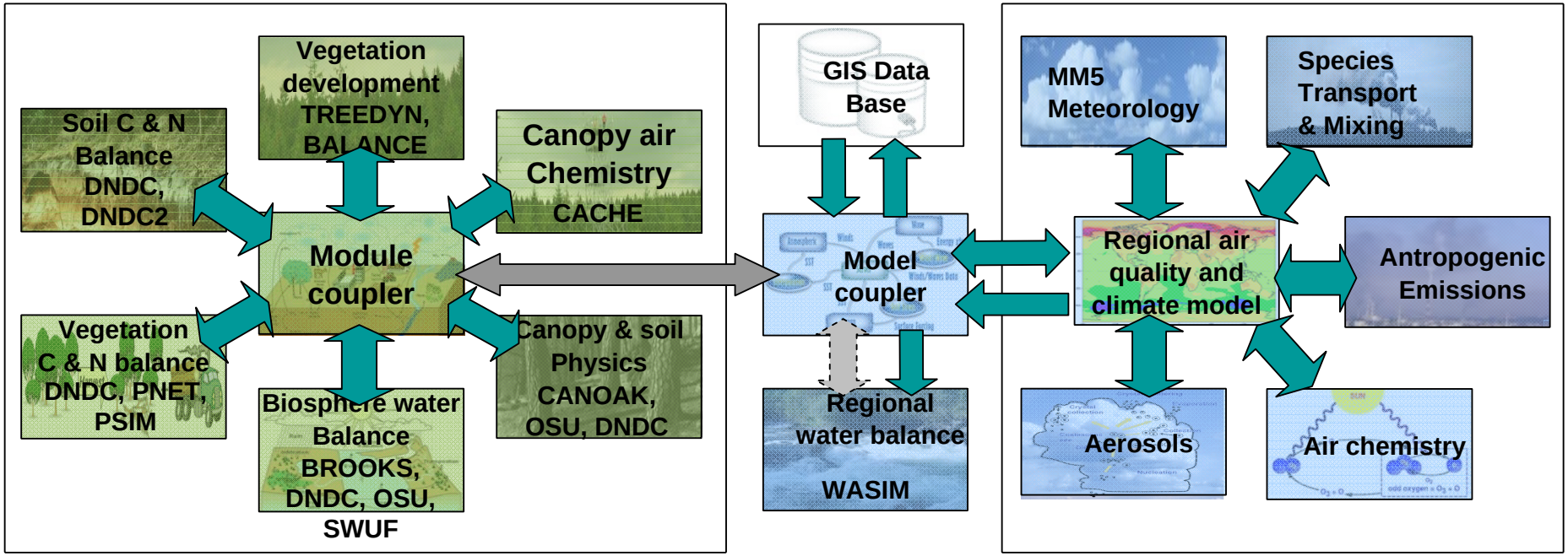


Empirical



Process based

Coupled Model



MOBILE **MCCM**

Model Coupling Approach

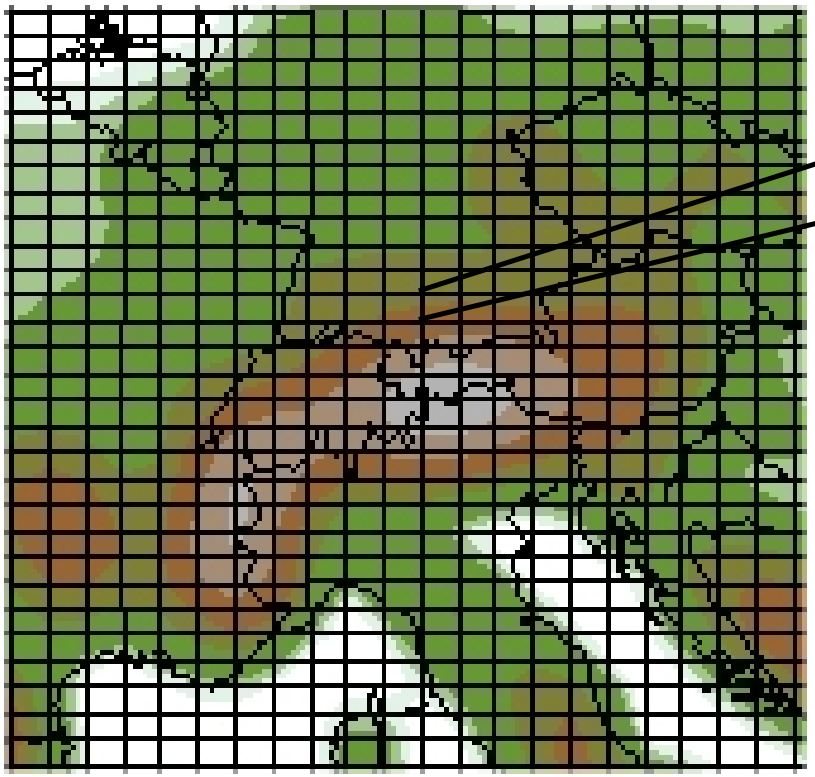
Mixed-Language-Programming

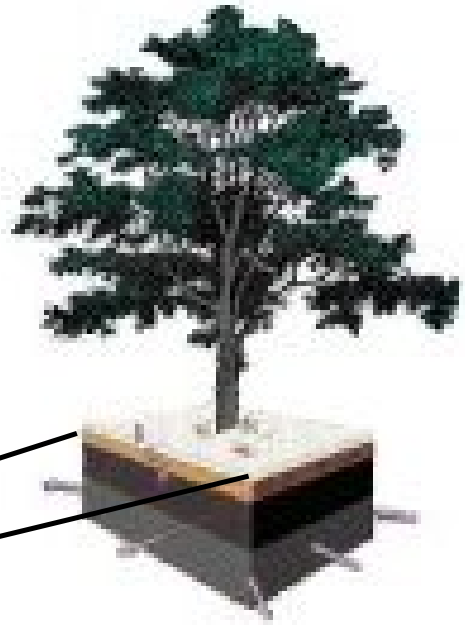
MCCM

Fortran, OpenMP & MPI parallelisation

$\Delta t \approx$ 6 sec - 3 min,

100 x 100 = 10 000 grid cells





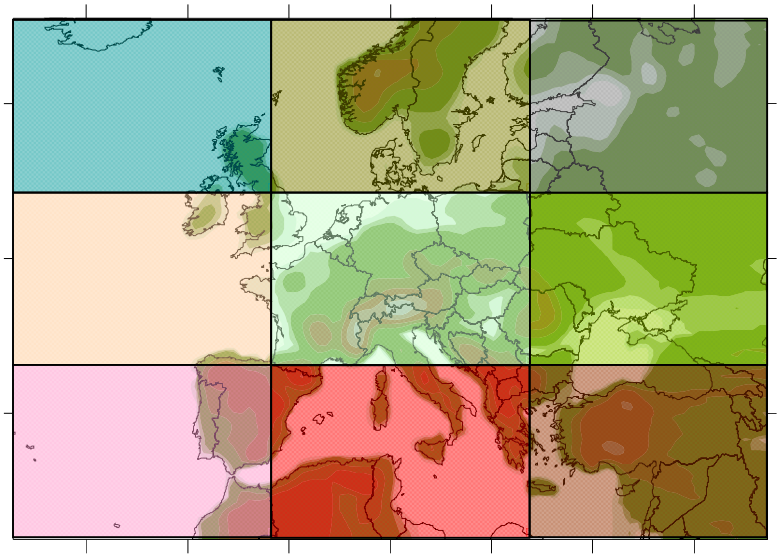
MOBILE

Ansi C++,
Windows, Linux, Apple

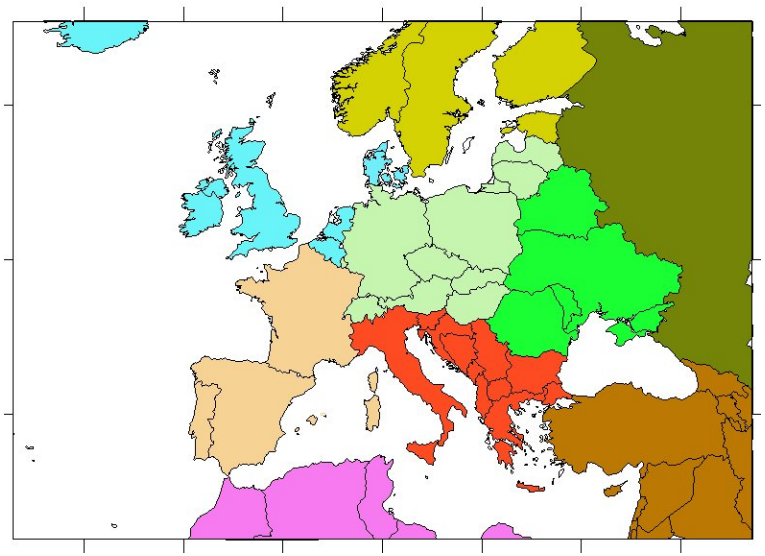
Model Coupling by the OASIS Coupler

Coupling strategy for the regional BHA-Model

OASIS Model-Coupler &
Linux-Cluster Technology



Regional Air Quality Model MCCM



Biosphere Model Framework MOBILE


Thank you for your attention