Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology

C2SM Center for Climate Systems Modeling

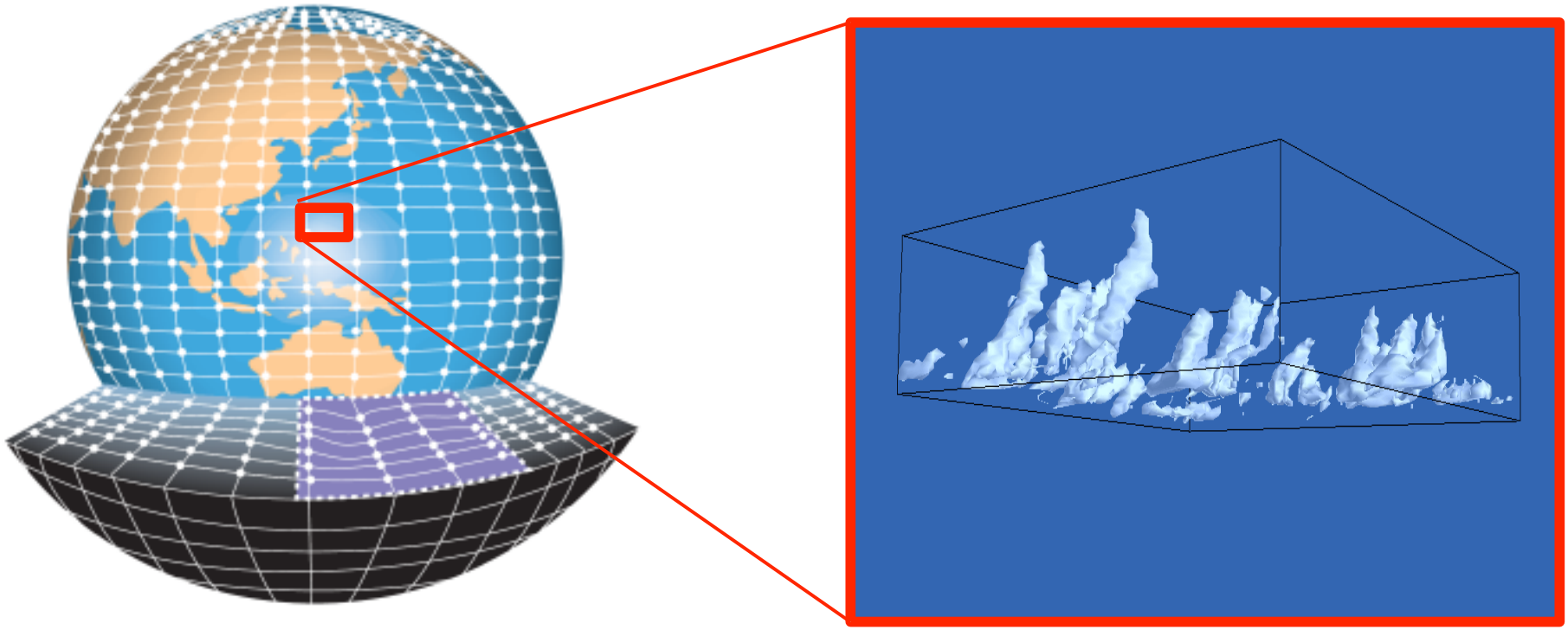
Towards high-resolution climate simulations

Christoph Schär, Tapio Schneider
Nikolina Ban, Michael Keller, Jürg Schmidli

Atmospheric and Climate Science, ETH Zürich
http://www.iac.ethz.ch/people/schaer

C2SM Community Day, June 12, 2013

Global model Parameterized



Convective clouds are subgrid-scale.
Require resolution of 10 m to 1 km.
Usually parameterized.

(Images: http://www.bom.gov.au; DALES model, Pier Siebesma)

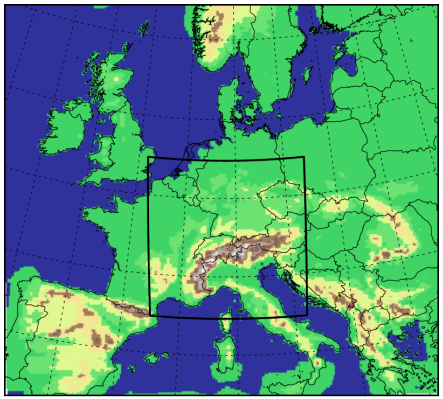
Model hierarchy

GCM
Global Climate Model

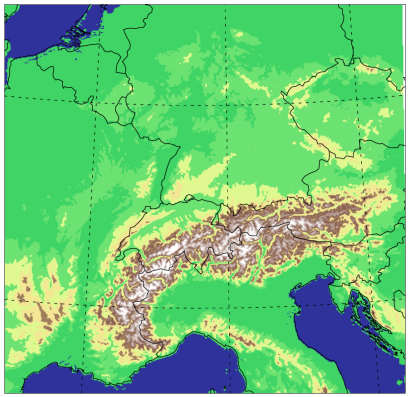
$\Delta \approx 100$ km

RCM
Regional Climate Model (RCM)

$\Delta \approx 12$ km

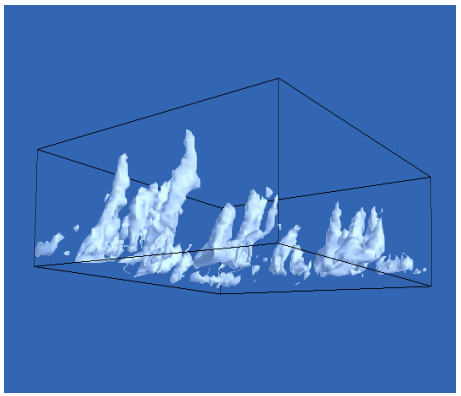


$\Delta \approx 2$ km



LES
Large-Eddy Simulation

$\Delta \approx 10$ m



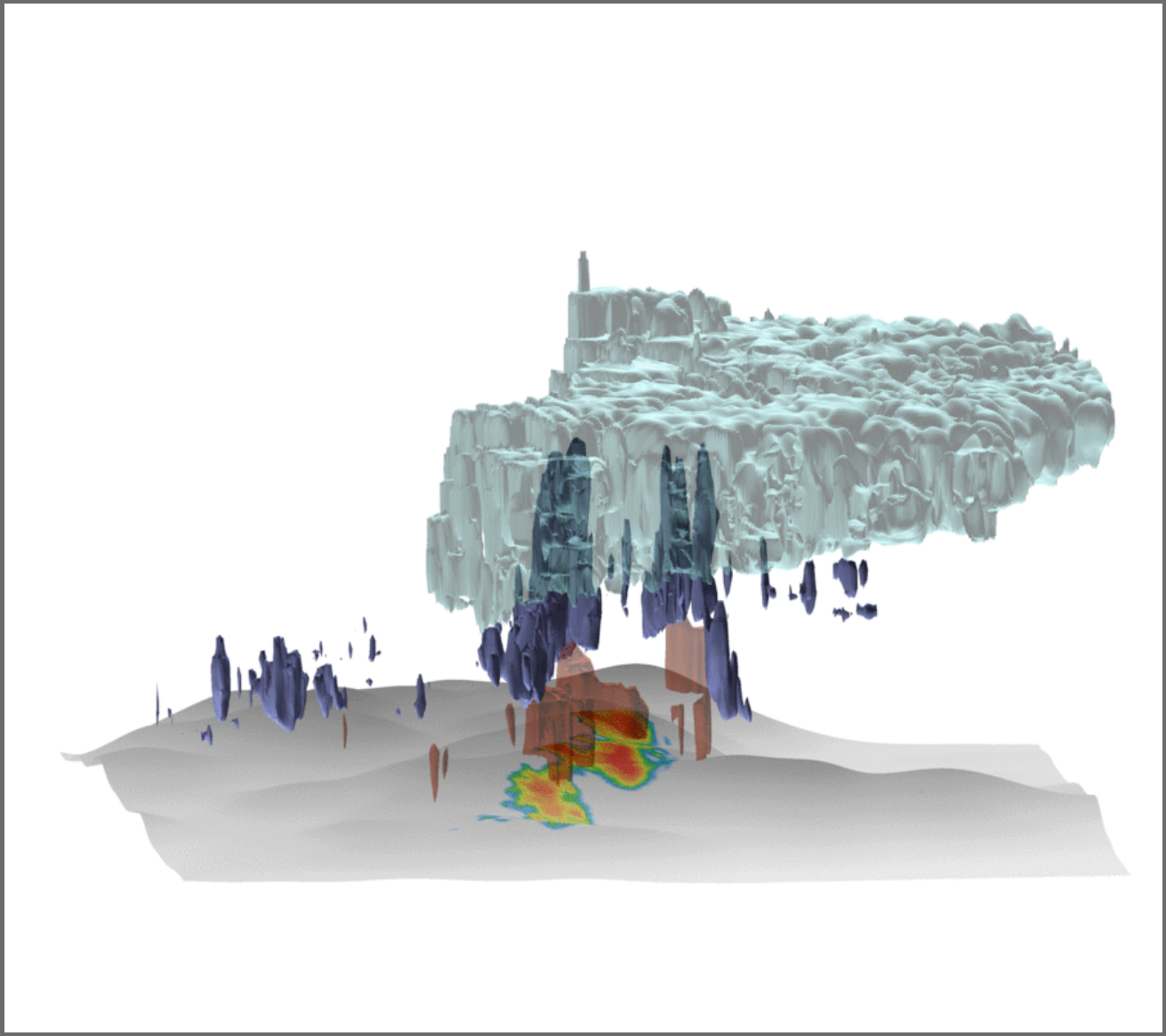
hydrostatic ← → **non-hydrostatic**

horizontal turbulent fluxes neglected ← → **full turbulence model**

explicit deep convection ← → **convection parameterized**

explicit shallow convection

Real-case cloud-resolving simulation

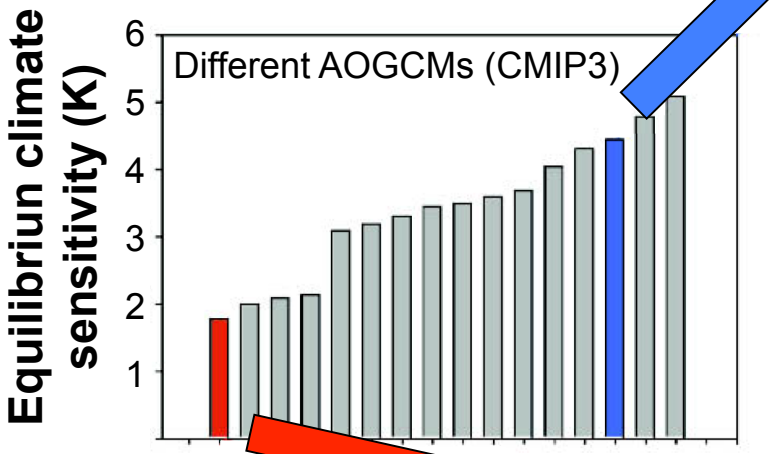


(Wolfgang Langhans, ETH)

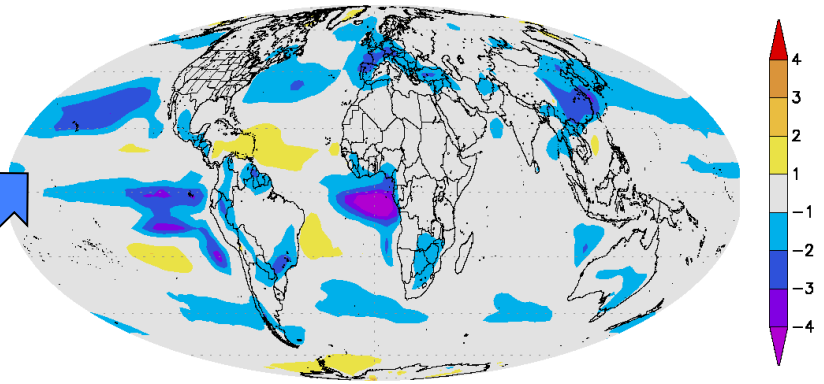
Contents

- Scientific drivers and motivation
- Downscaling framework
- Process study framework
- Outlook

Role of maritime stratocumulus clouds



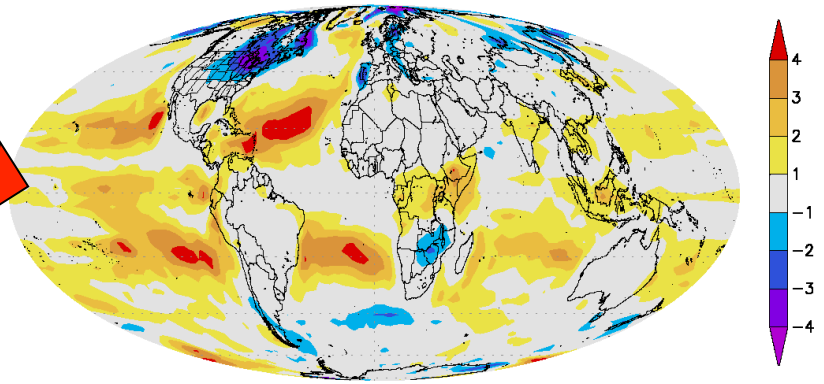
Change in low cloud cover [%]



GFDL AM2 ⇔ ECS=4.5 K

A large fraction of global uncertainty is due to low strato-cumulus clouds

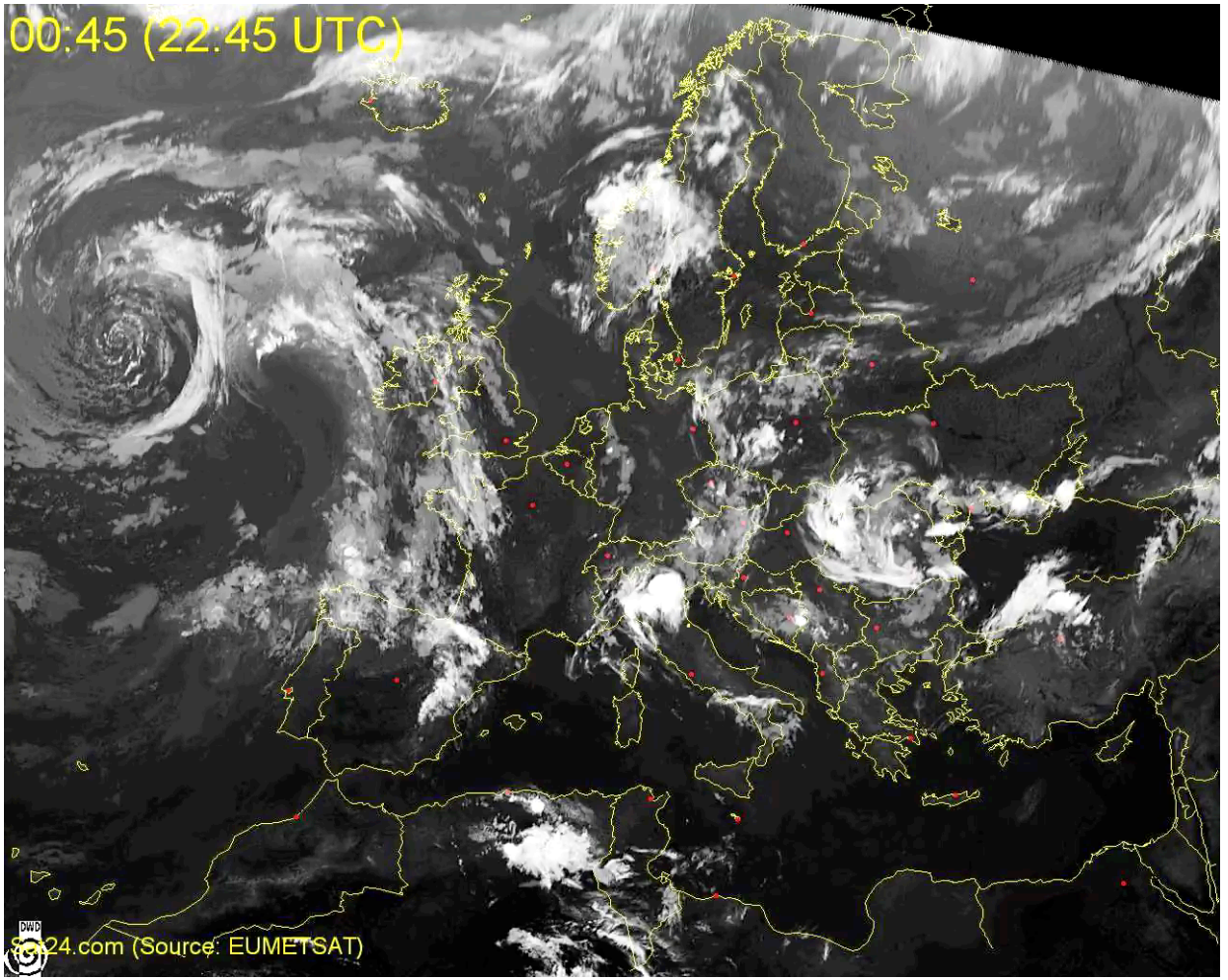
Change in low cloud cover [%]



NCAR CAM2 ⇔ ECS=1.5 K

(Bjorn Stevens; Chris Bretherton; Tapio Schneider; Ulrike Lohmann; others)

Diurnal convection over land



SEVIRI 10.8µm, June 30 till July 2, 2009
Imagery from http://imkhp2.physik.uni-karlsruhe.de/~muehr/satpicsf/DWD/

(Michael Keller, ETH Zürich)

Importance of short-term precipitation

Station "Haldenbach"

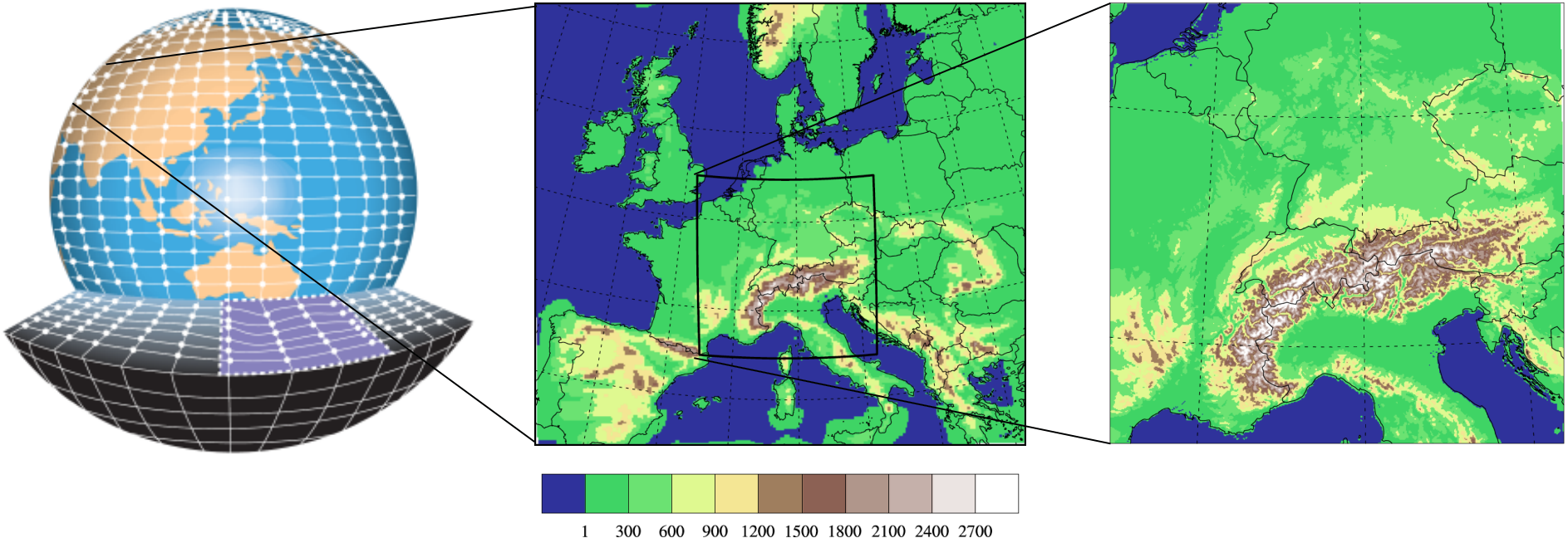
Many floods in urban environments are due to short-term events!

Downscaling framework

$\Delta \approx 100$ km

$\Delta \approx 12$ km

$\Delta \approx 2$ km



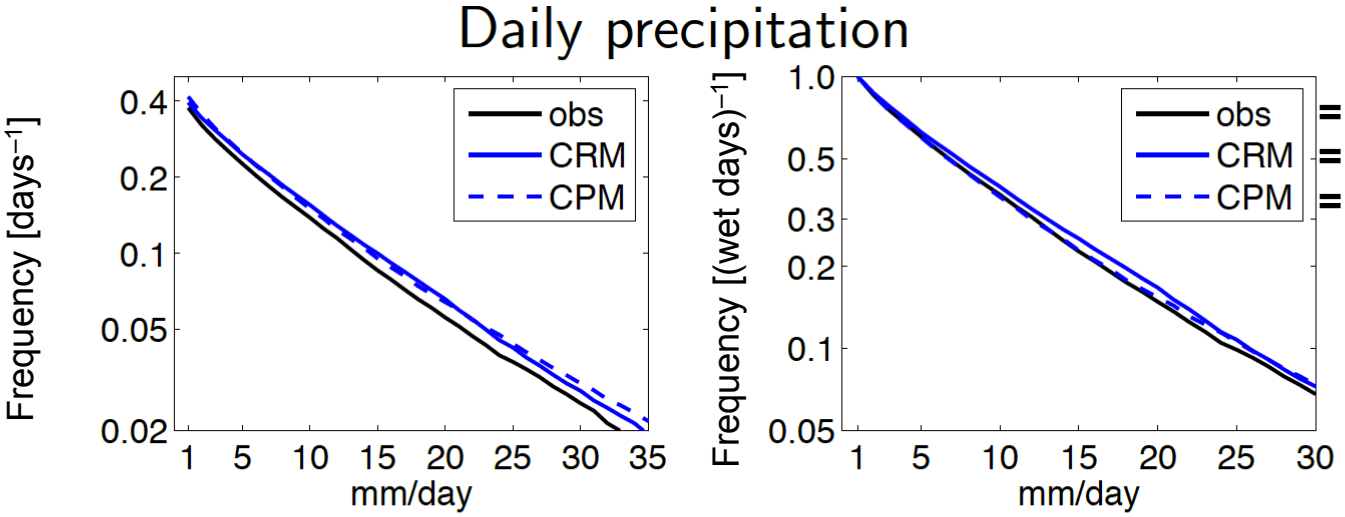
CPM
Cloud-Parameterizing Model

CRM
Cloud-Resolving Model

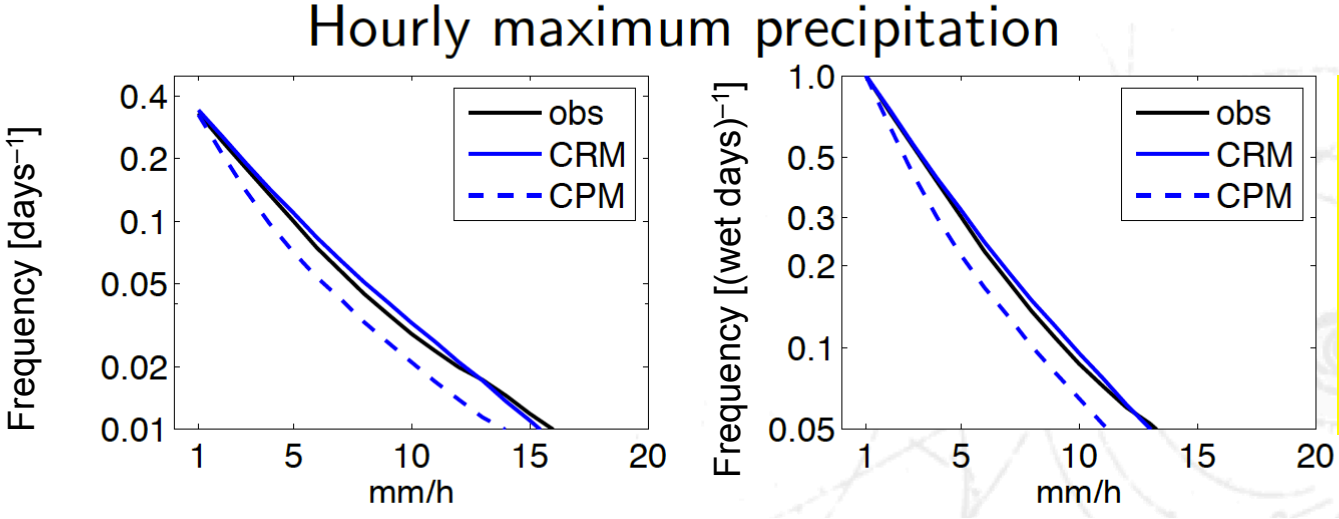
(Nikolina Ban and Jürg Schmidli)

Precipitation intensity over Switzerland

10-year long simulation driven by Reanalysis data



= Observations for 24 CH stations
= Cloud-Resolving Model
= Cloud-Parameterizing Model



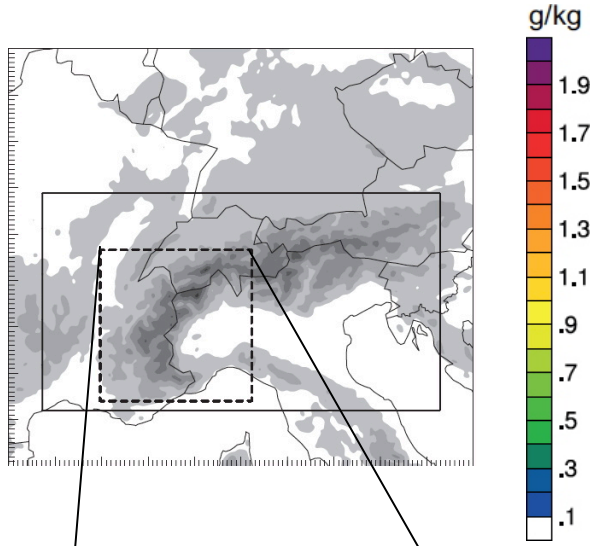
CPM and CRM agree for daily, but disagree for hourly precipitation

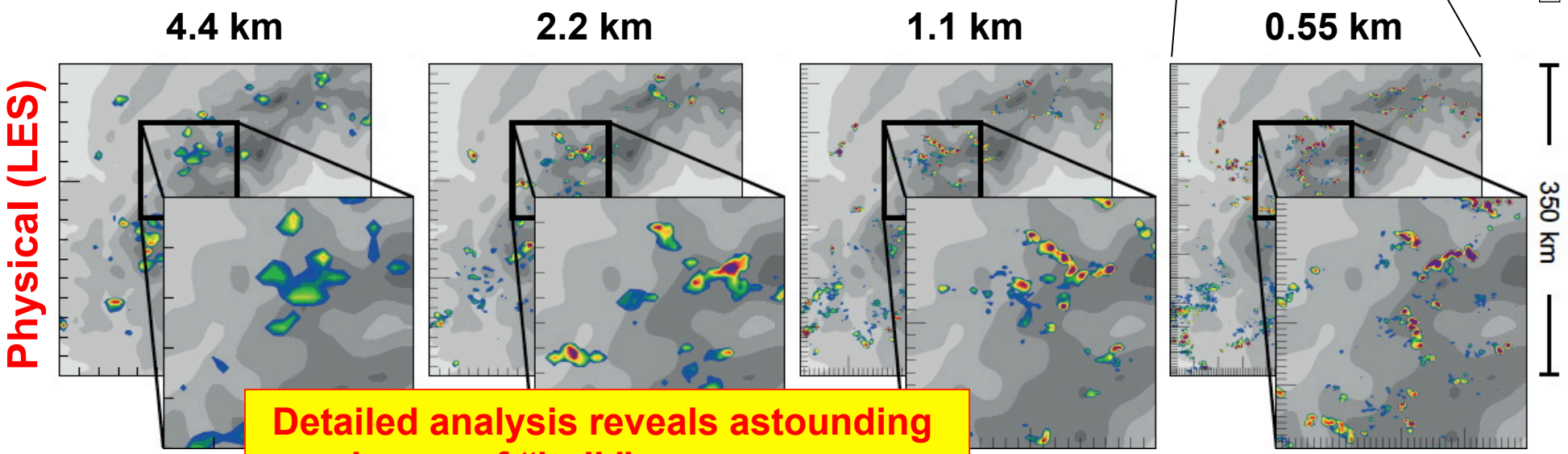
CRM close to Obs

(Nikolina Ban and Jürg Schmidli)

Do CRMs converge?

- Summer convection over Alps (liquid water content)
- Scales of convective cells decrease with $\Delta x \rightarrow 0$
- Convergence is far from obvious, due to scale collapse.
- Simulations conducted for 1D and LES turbulence.





Detailed analysis reveals astounding degree of "bulk" convergence

(Langhans et al., J. Atmos. Sci, 2012)

Process framework

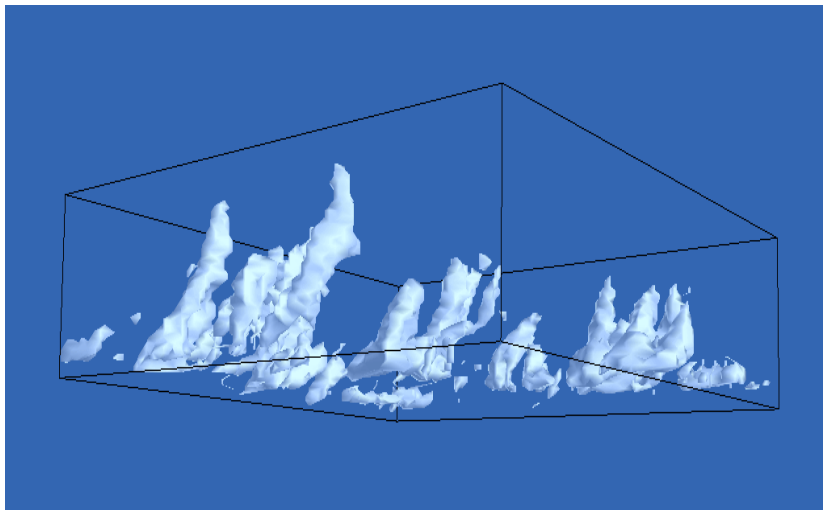
Global model

Large-scale climate

Improved representation of cloud dynamics

Improved scenarios

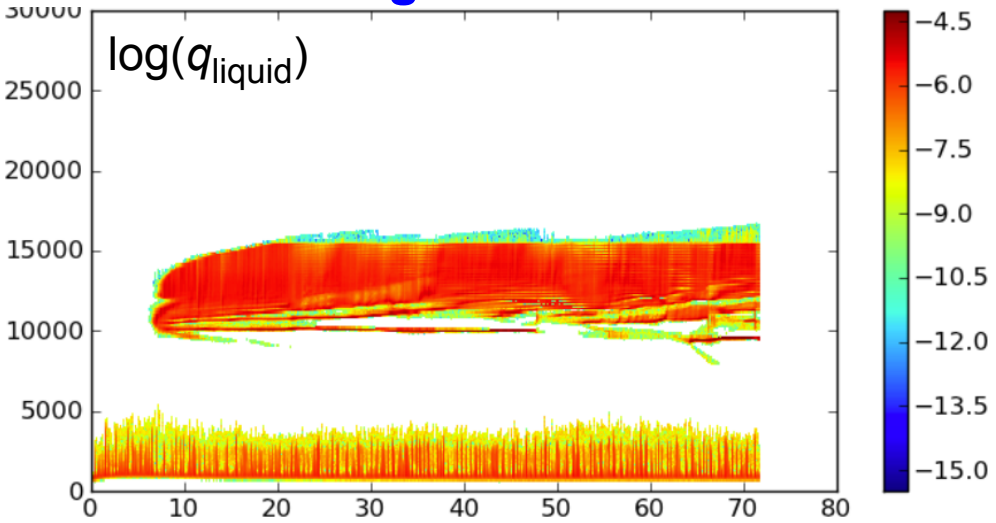
Regional model (LES)



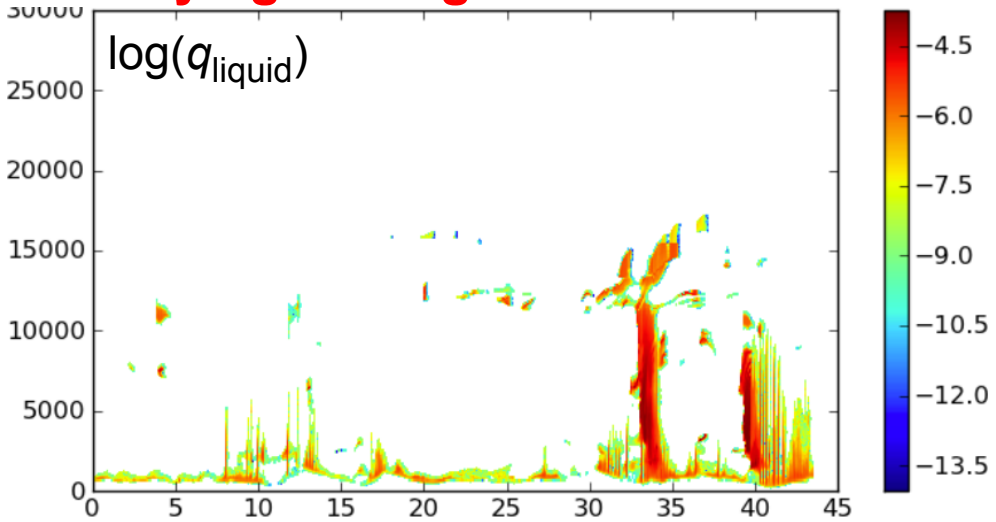
(Group of Tapio Schneider)

LES of tropical clouds

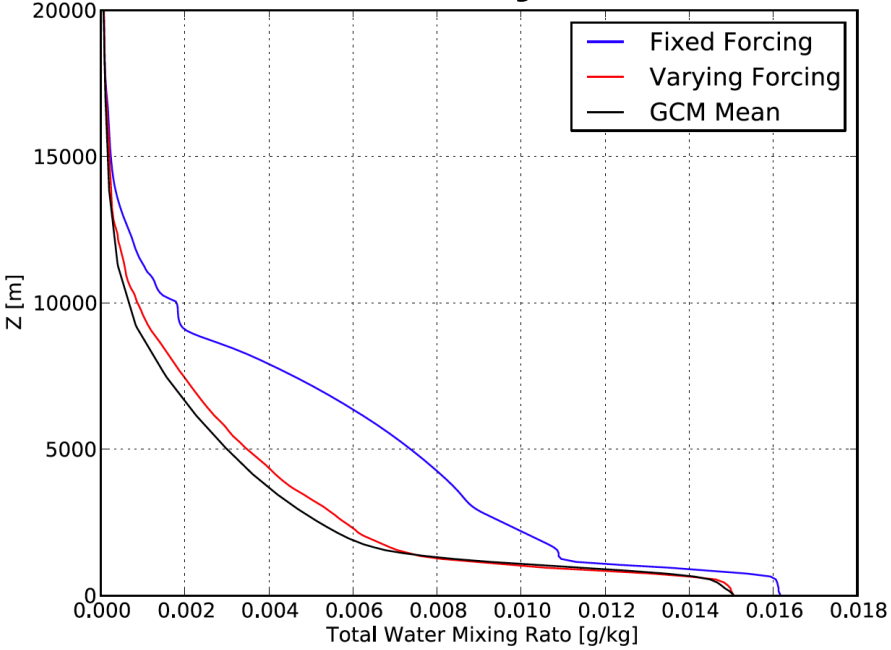
Fixed forcing



Varying forcing



Relative humidity



(Group of Tapio Schneider)

Prospects and implications

Cloud-resolving approach:

- Allows explicit convection, is much closer to first principles (quantum jump)
- Improved representation of processes and underlying topography and land-surface
- Rapidly growing international community (even in GCMs, e.g. ICON @ DWD & MPI-M)

Prospects:

- Still very expensive, but feasible for
  - numerical weather prediction,
  - process studies at resolutions down to O(10m),
  - scenarios at regional scales and O(1 km) resolution.
- Increasingly used in C2SM community (ETH, MeteoSwiss, Empa)
- Attractive for impact studies (e.g. hydrology, topography)

Implications:

- Requires fast codes and re-consideration of data flow issues.
- Evident benefits from community efforts (C2SM, HP2C), c.f. talk of Isabelle Bey