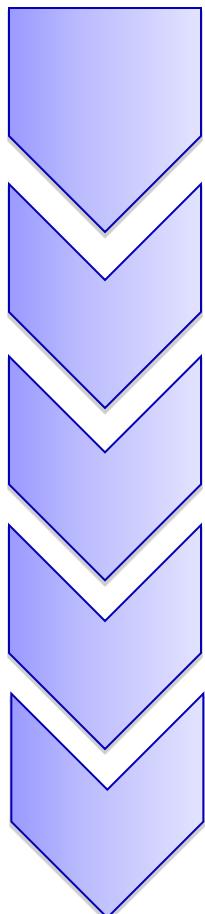




Evaluation of the COSMO-CLM model simulations for the Alpine Region



What you can expect from the next 45 minutes....



Climate models, climate modelling and our contribution at ZAMG
(Ivonne Anders)

Model evaluation – quality and uncertainties of the model results
(Klaus Haslinger)

Added value of increased spatial resolutions
(Maja Zuvela Aloise)

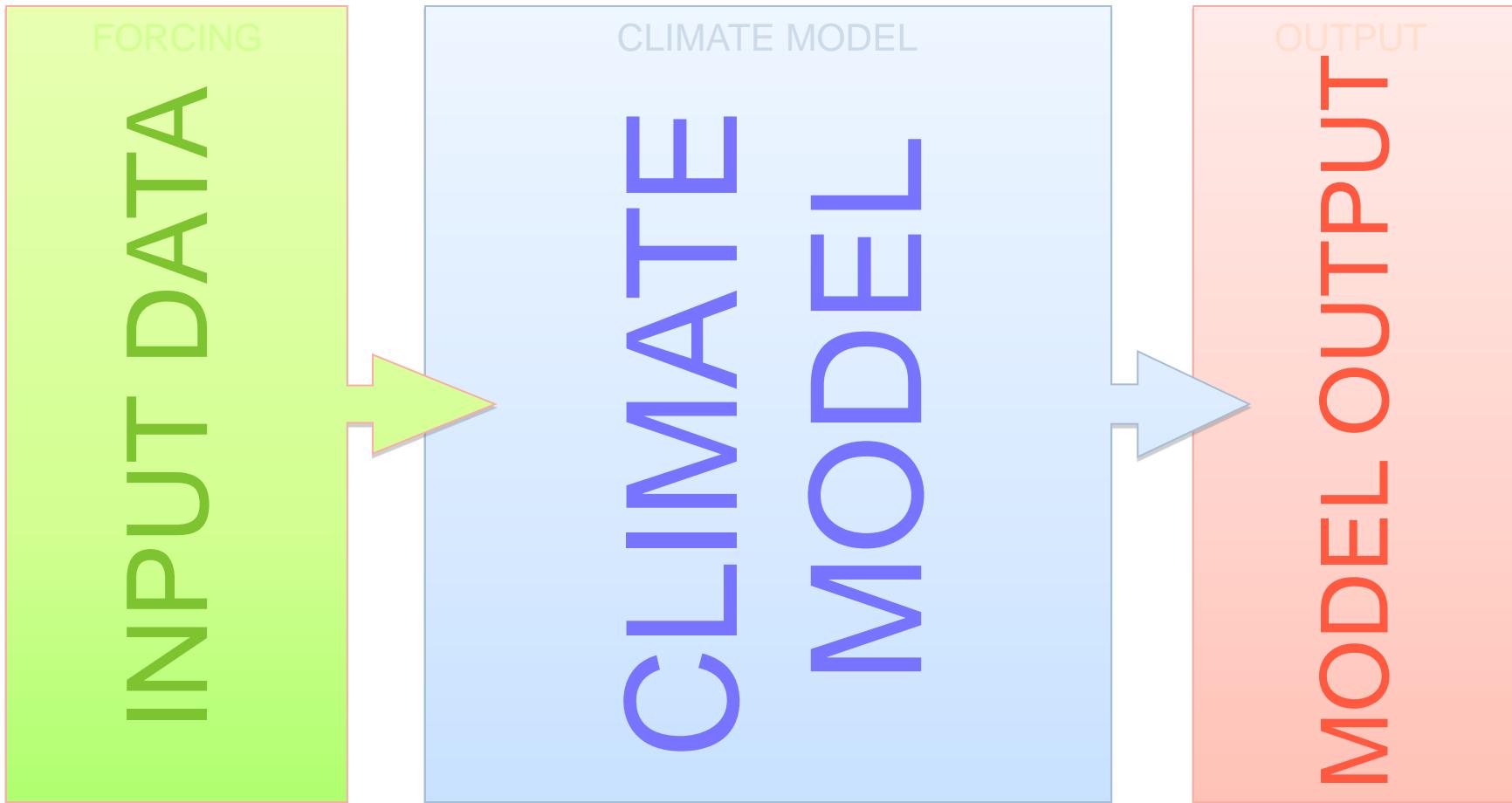
Trends in observations and model data
(Michael Hofstätter)

Summary and “message2go”
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Climate models:

What is it? And how does it work?





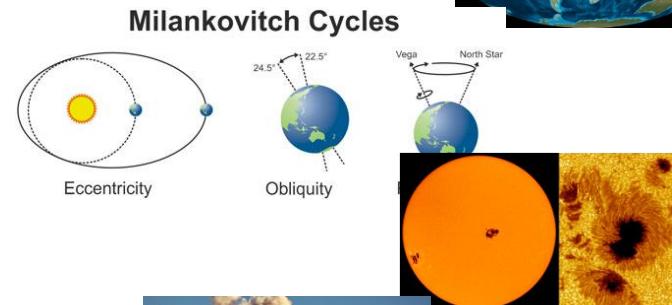
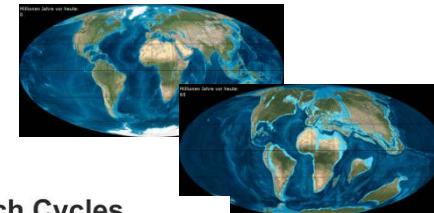
Climate models:

What is it? And how does it work?

INPUT DATA

NATURAL FORCING

- earth covered by plants → reduce the green house gas – Concentration
- moving continents
- orbital forcings (Milanković cycles)
- sunspots
- volcanic eruptions



ANTHROPOGENIC FORCING

- longlived greenhouse gases
- tropospheric sulphate





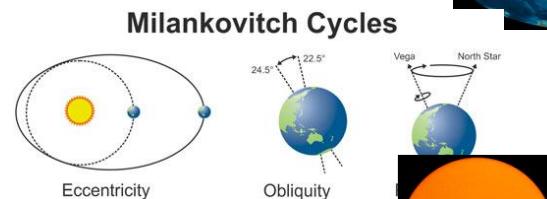
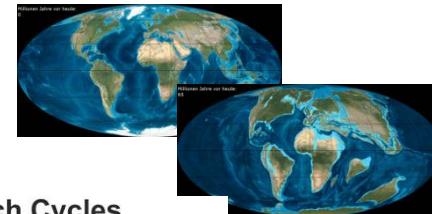
Climate models:

What is it? And how does it work?

INPUT DATA

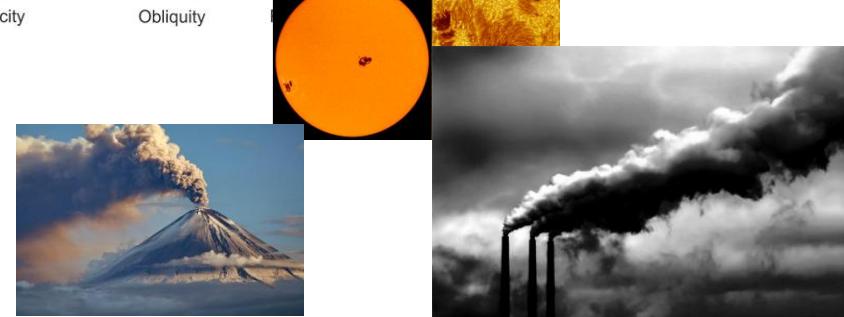
NATURAL FORCING

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ANTHROPOGENIC FORCING

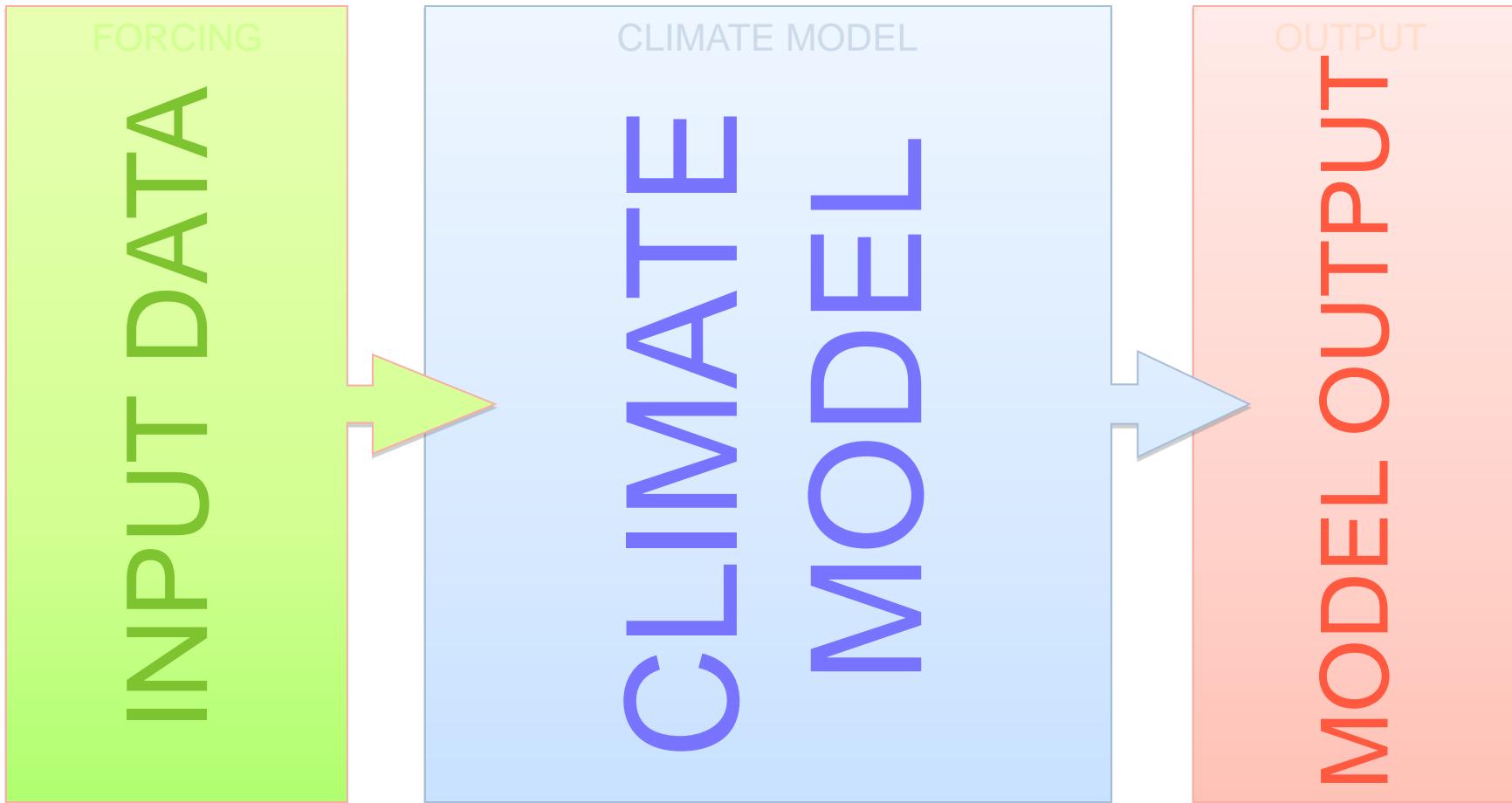
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Climate models:

What is it? And how does it work?

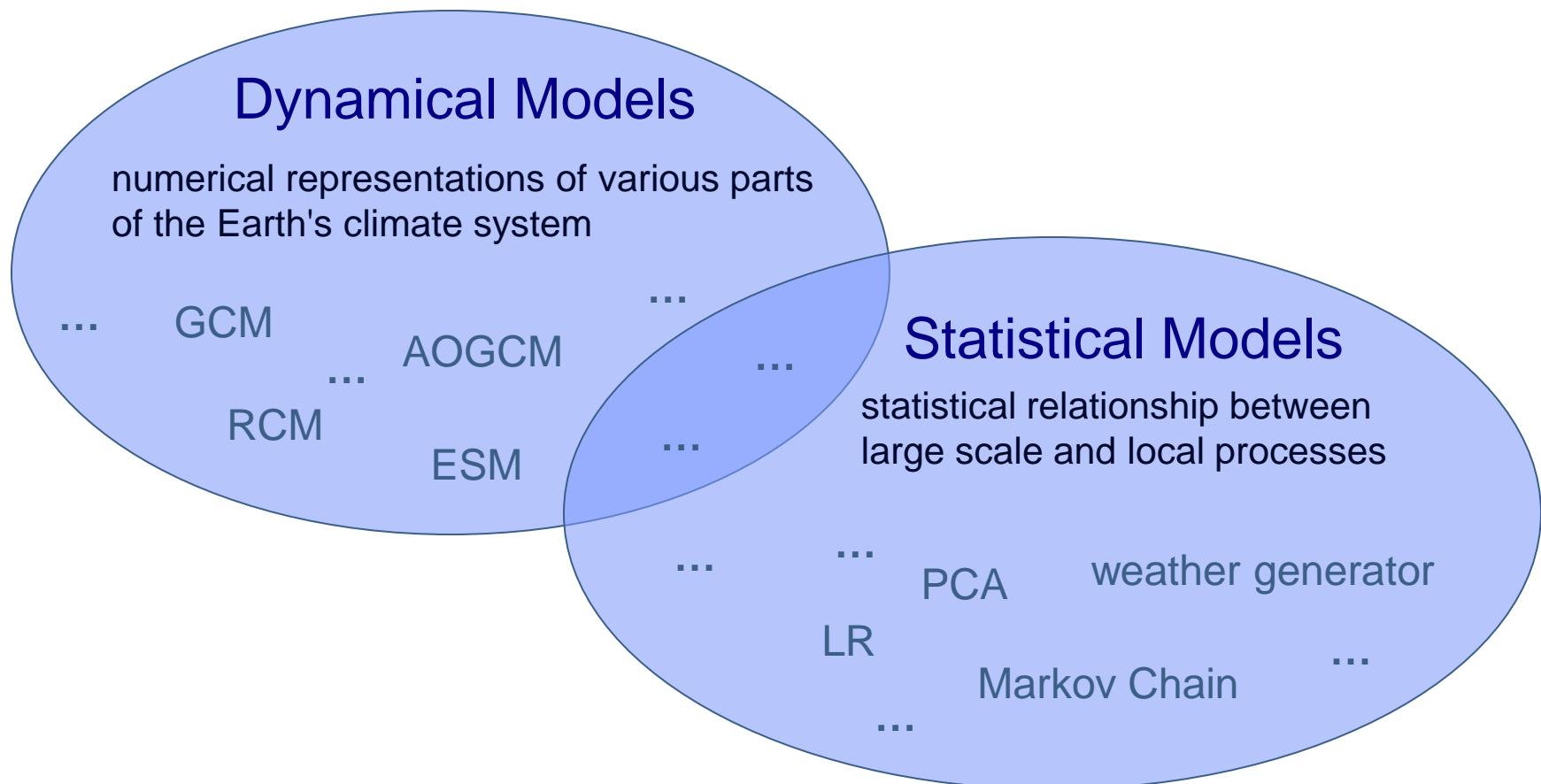




Climate models:

What is it? And how does it work?

CLIMATE MODEL





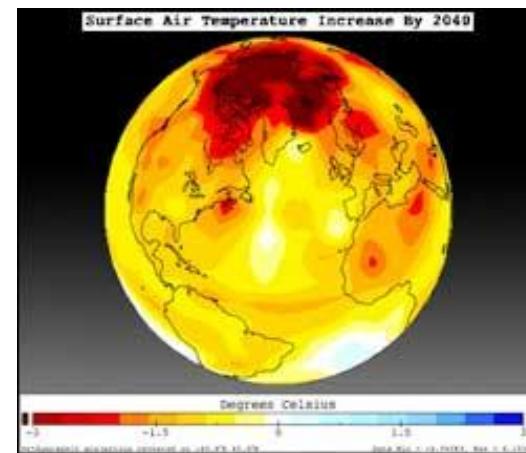
Climate models:

What is it? And how does it work?

CLIMATE MODEL

Global Climate Models (GCM)

- limitations of the GCMs on representation of large scale effects on the global climate due to changes in GHG-concentration, volcanos etc.
- strongly simplified, but containing the most important processes
- horizontal resolutions 3° - 1.5°





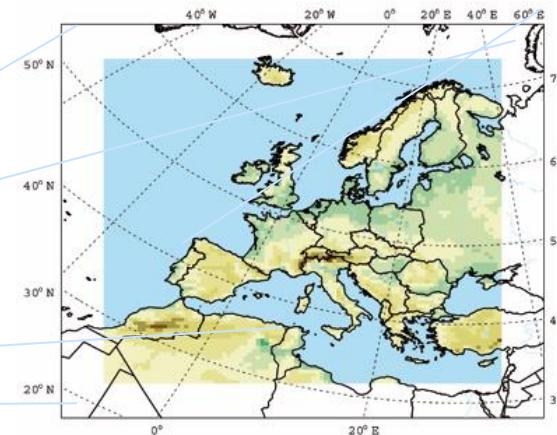
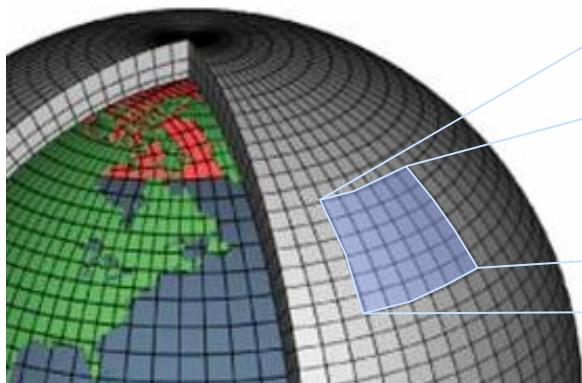
Climate models:

What is it? And how does it work?

CLIMATE MODEL

Regional Climate Models (RCM)

- containing complex model physics and due to higher spatial resolution they are able to reproduce local effects due to orography or land use
- using Model output from GCMs as forcing
- horizontal resolution 50 – 3km (0.5° - 0.025°)



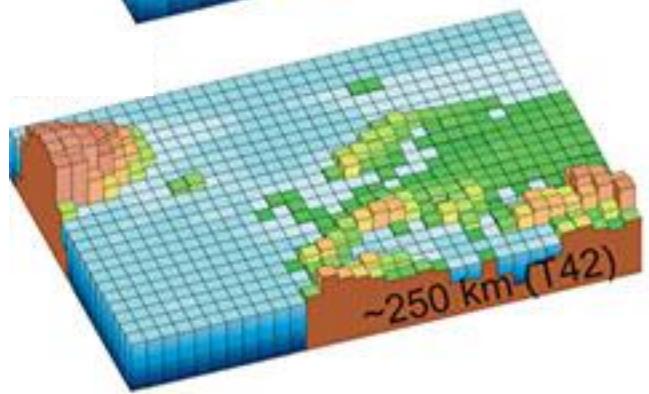
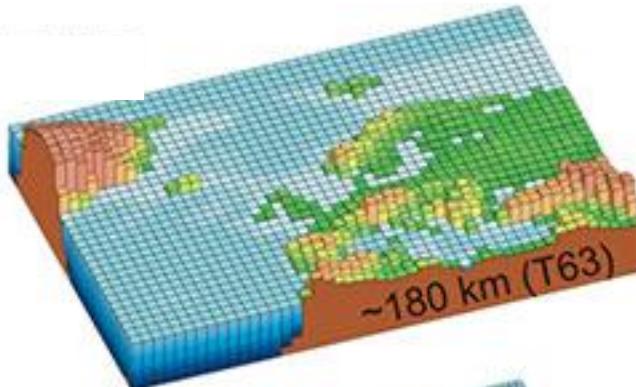
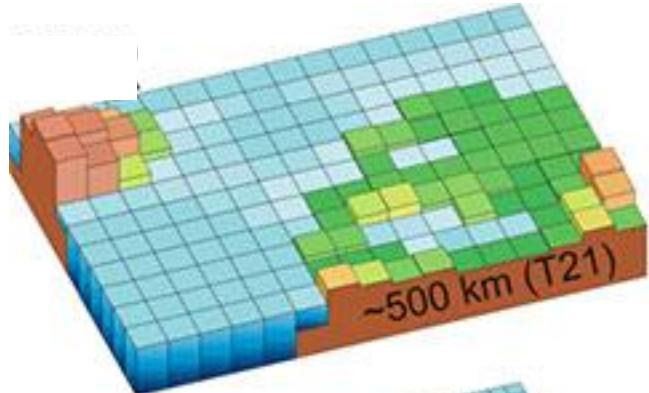


Climate models:

What is it? And how does it work?

CLIMATE MODEL

Horizontal Resolutions - Grids



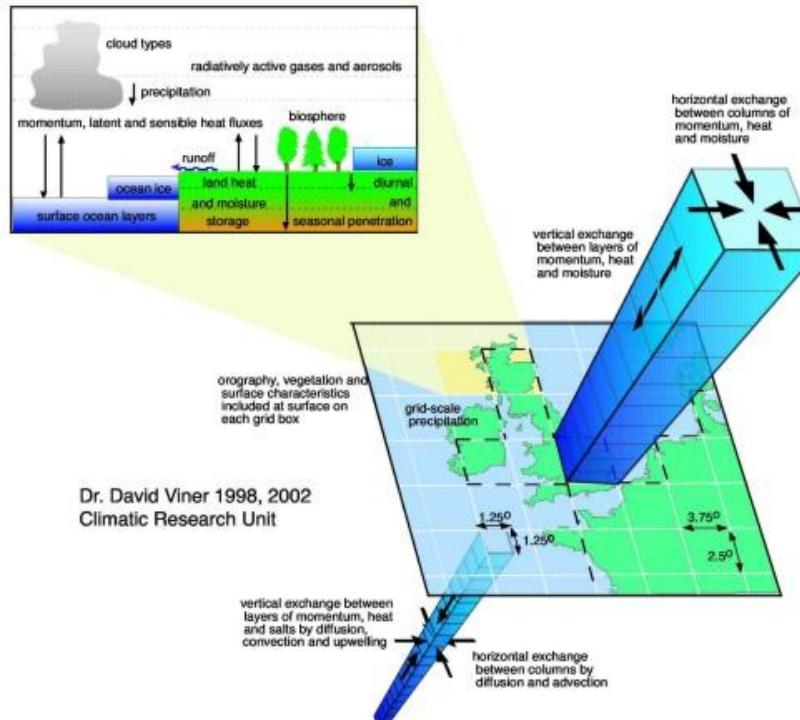
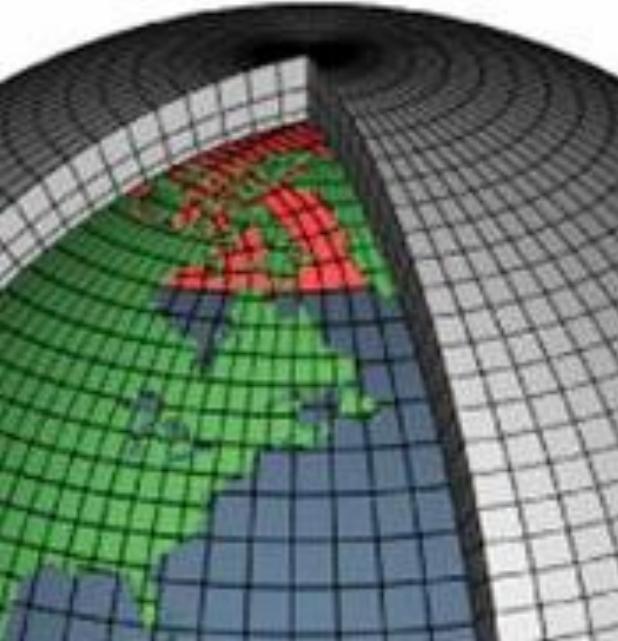


Climate models:

What is it? And how does it work?

CLIMATE MODEL

Vertical Resolutions - Levels





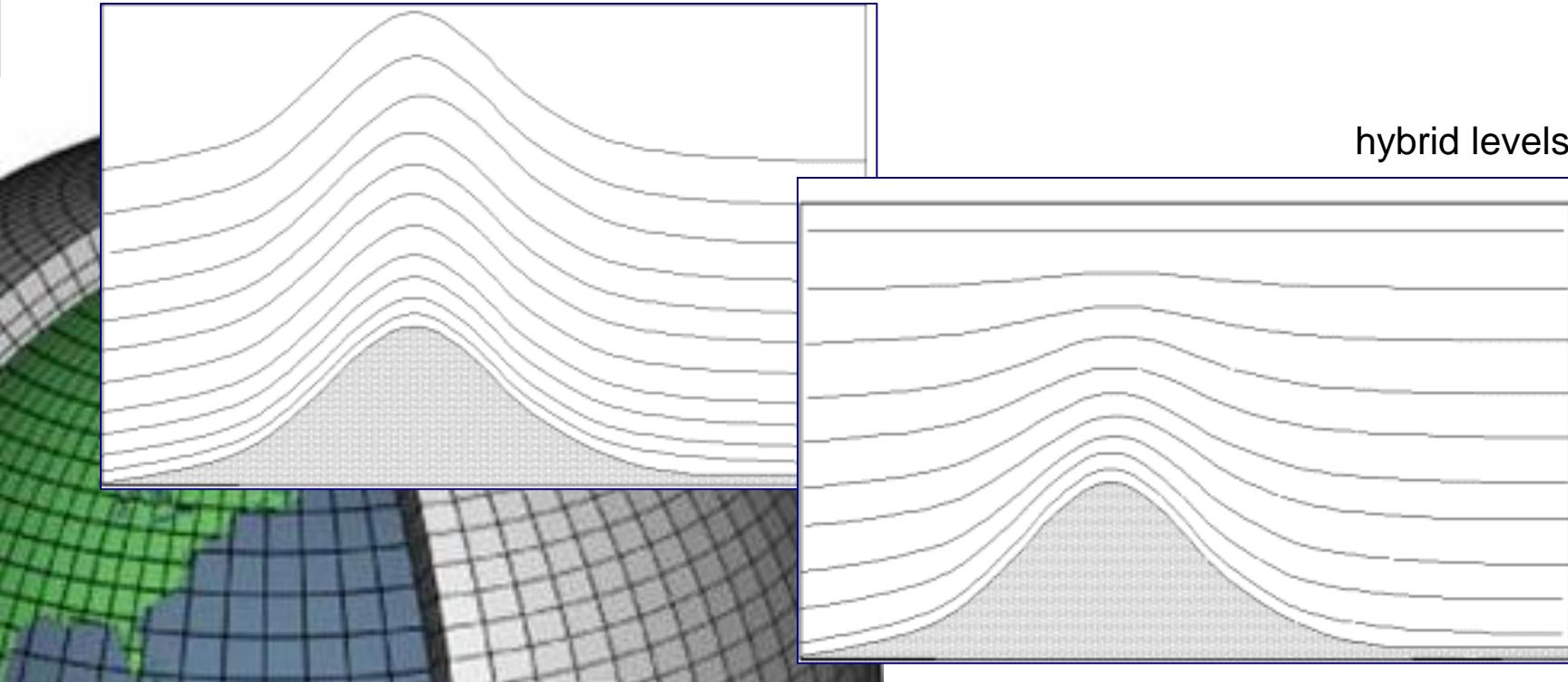
Climate models:

What is it? And how does it work?

CLIMATE MODEL

Vertical Resolutions - Levels

terrain following sigma-coordinates





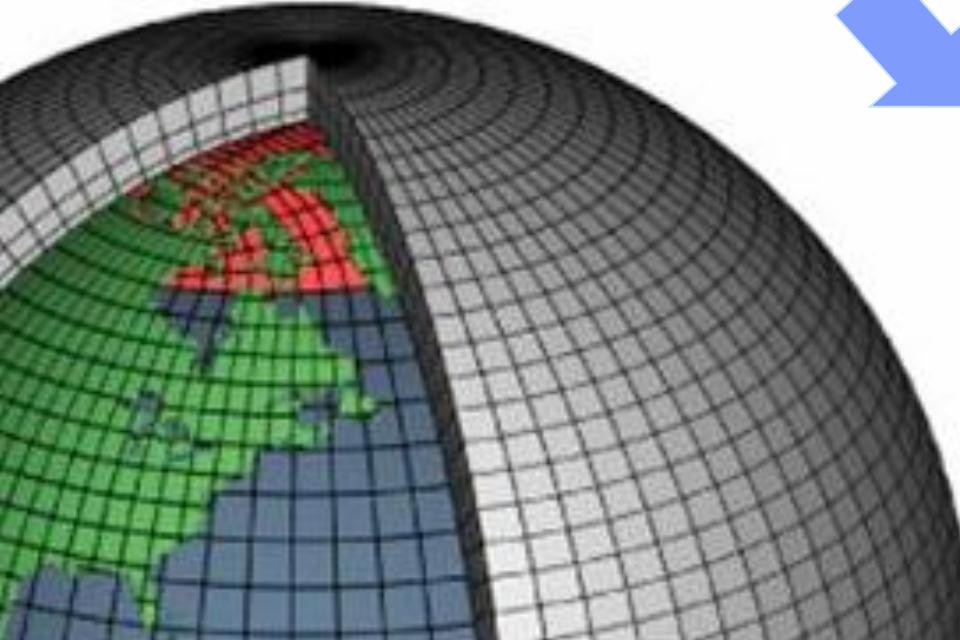
Climate models:

What is it? And how does it work?

CLIMATE MODEL

Subscale Processes - Parameterizations

The problem with dividing the atmosphere into lots of little cubes is that there are many processes that are smaller than the cubes!



Models include lots of parameterizations to describe the processes

e.g. how much cloud is there..

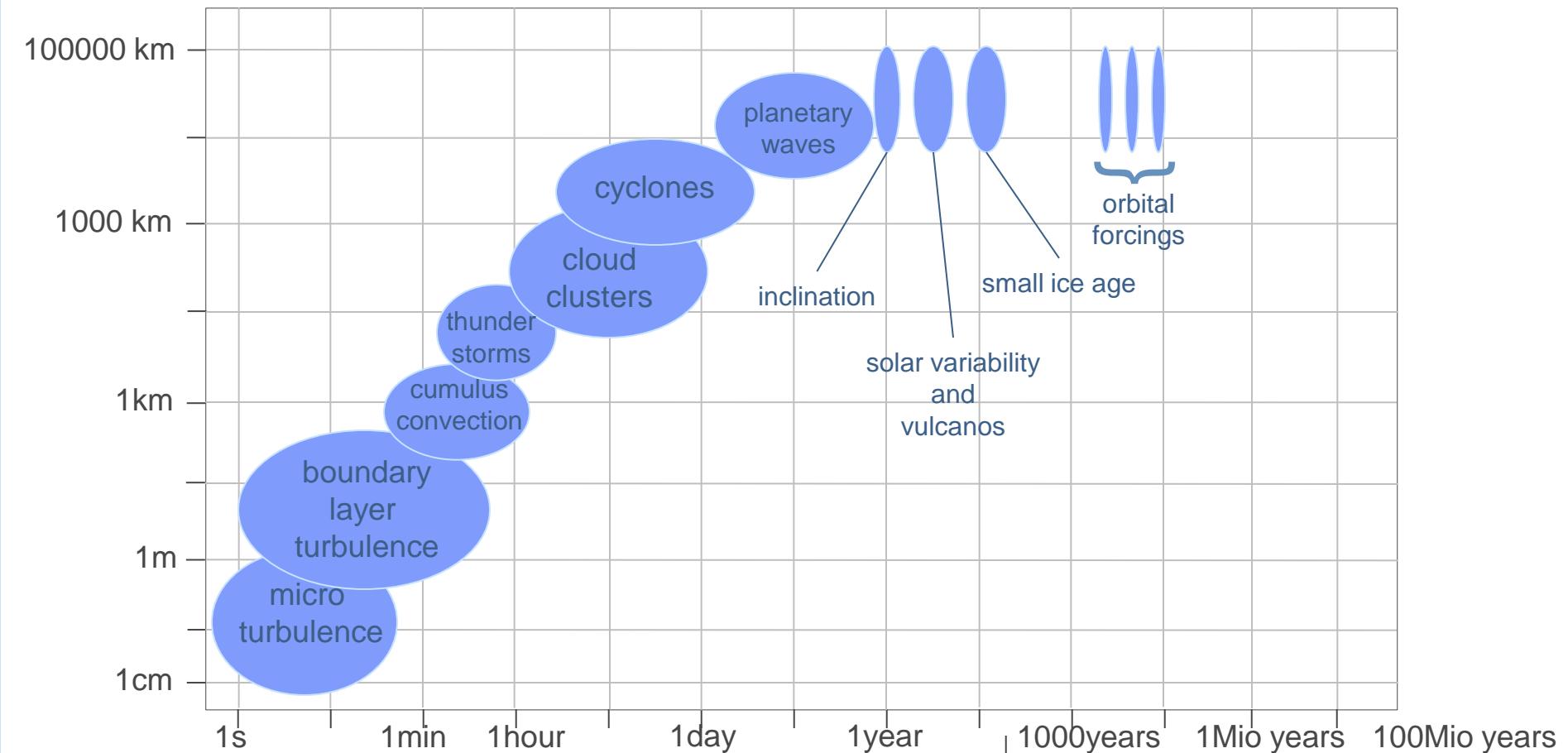




Climate models:

From large to small spatial scales are

CLIMATE MODEL

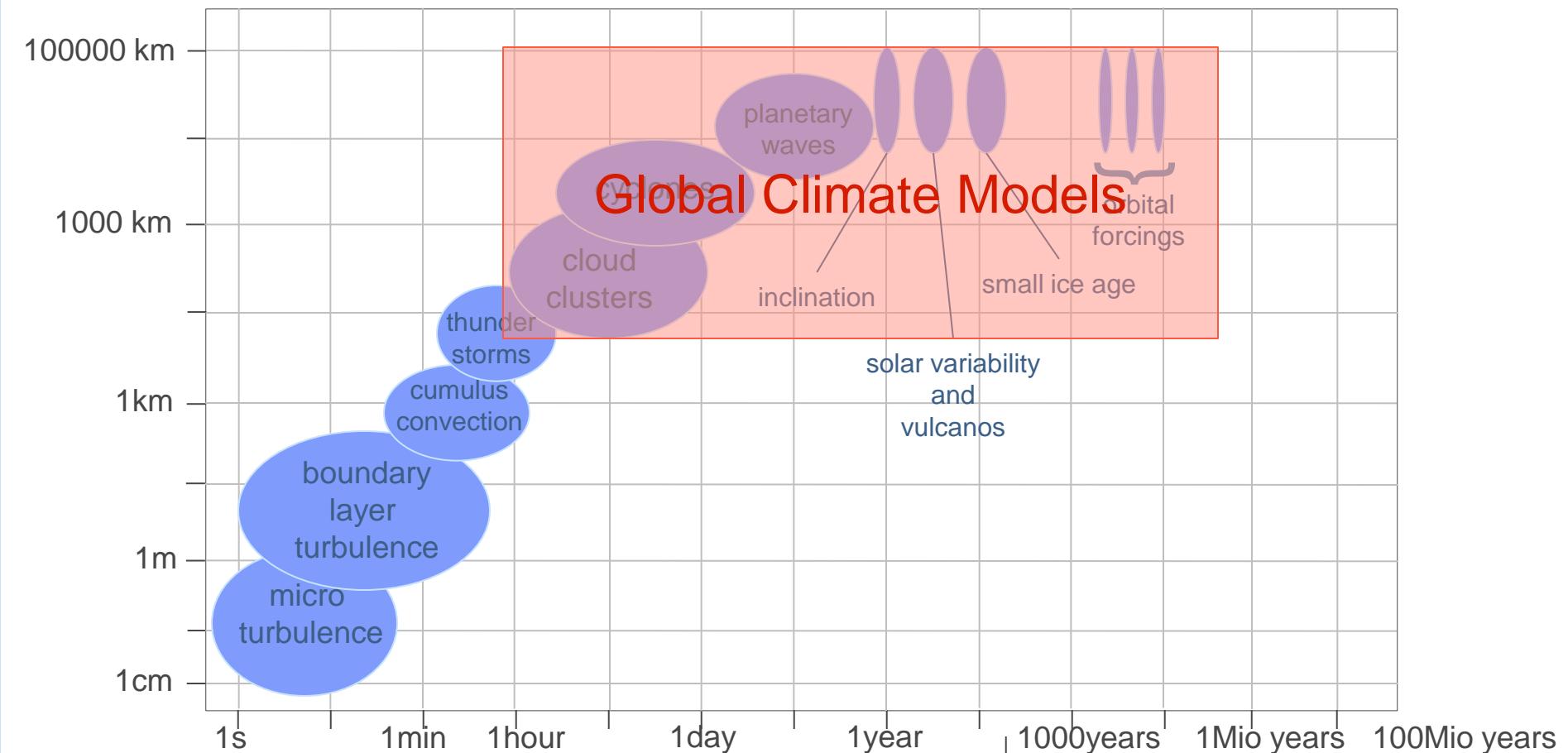




Climate models:

From large to small spatial scales are

CLIMATE MODEL

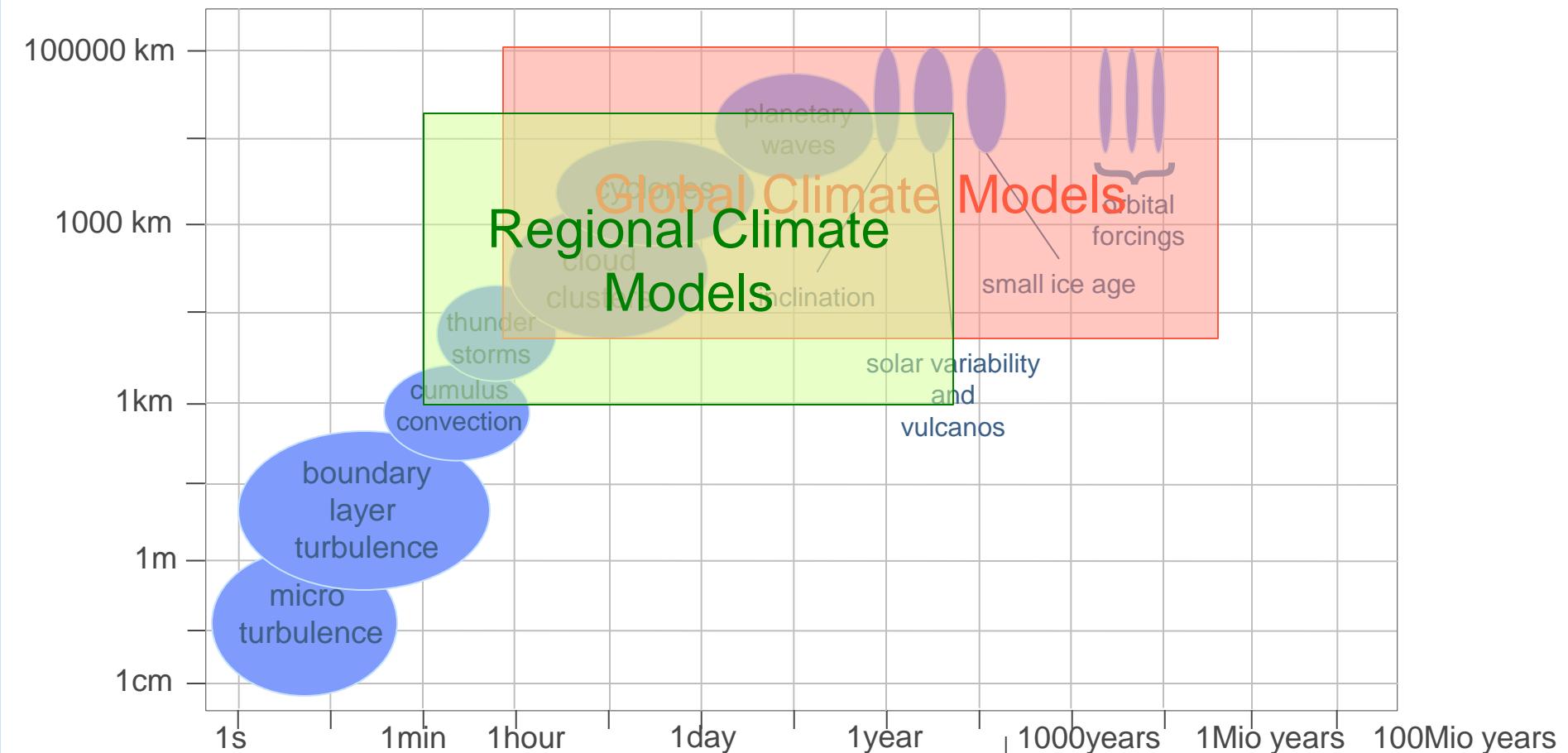




Climate models:

From large to small spatial scales are

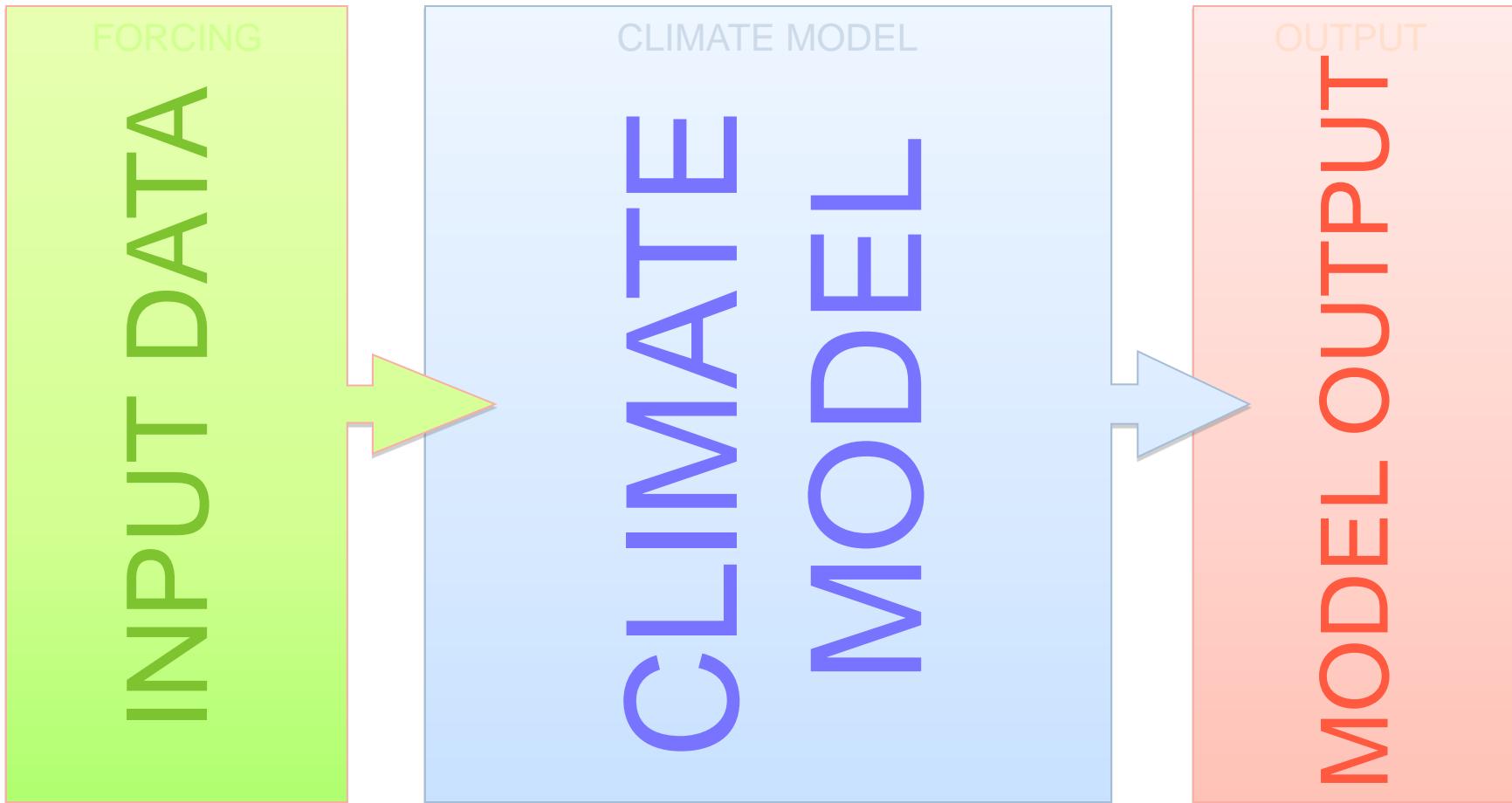
CLIMATE MODEL





Climate models:

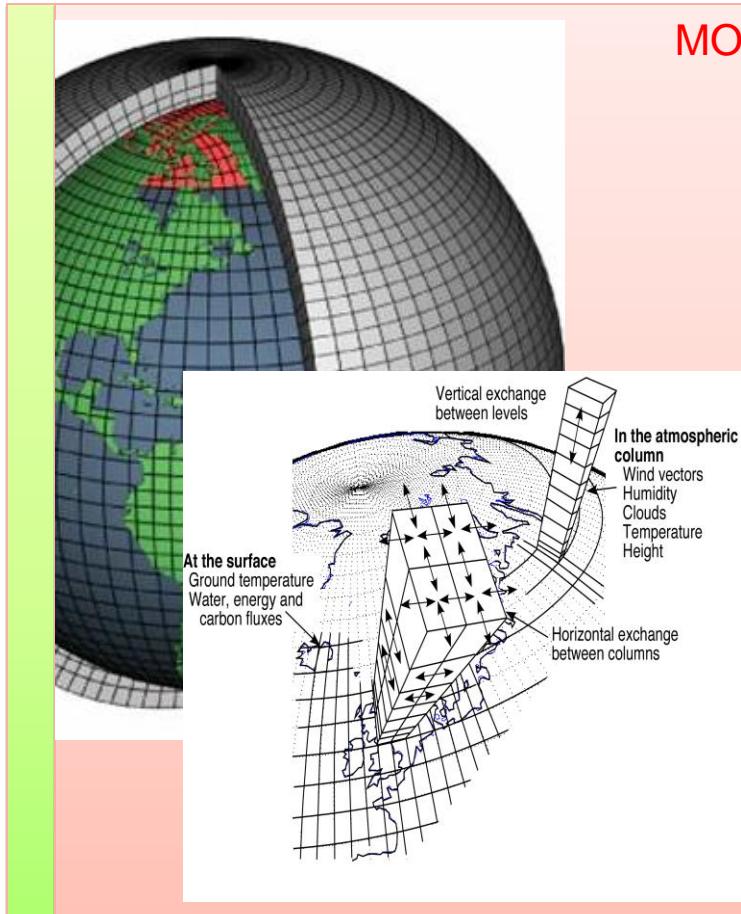
What is it? And how does it work?





Climate models:

What is it? And how does it work?



MODEL OUTPUT

Results for every grid box,
at different pressure levels or at surface



2D- und 3D- arrays, up to hourly



Climate models:

The Regional Climate Model COSMO-CLM

- non-hydrostatic limited-area Modell
- based on the forecast model of DWD (German Weather Service)
- incl. soil model „Terra-ML“ and lake model „FLake“
- Community Model

COSMO- CLM Community
www.clm-community.eu

Meteorologische Zeitschrift
Special Issue, Vol. 17, 2008

COSMO – Dynamics and Physics
[http://www.cosmo-model.org/content/model/
documentation/core/default.htm](http://www.cosmo-model.org/content/model/documentation/core/default.htm)



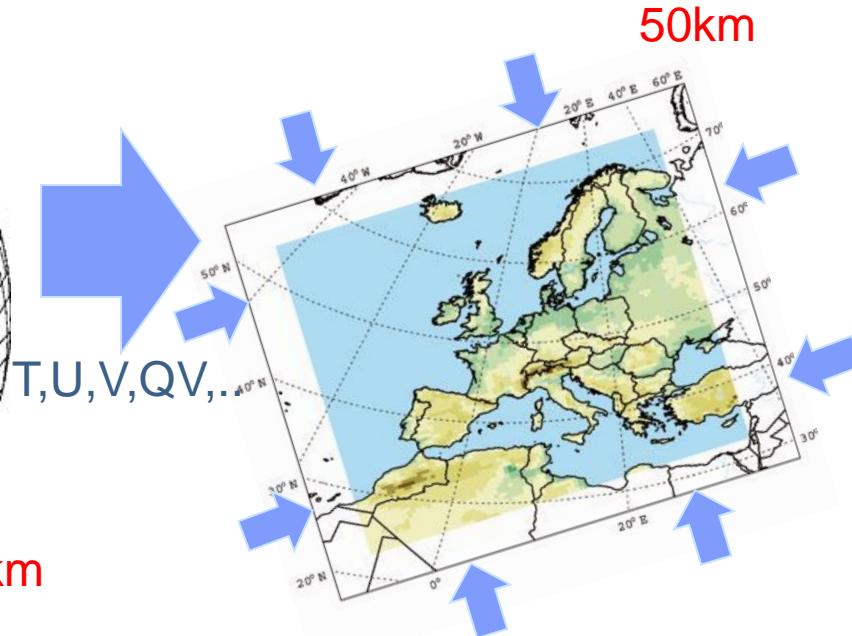
Climate Limited-area
Modelling Community





Climate models:

The simulations we carried out at ZAMG and the validation is about ...



1st nesting step



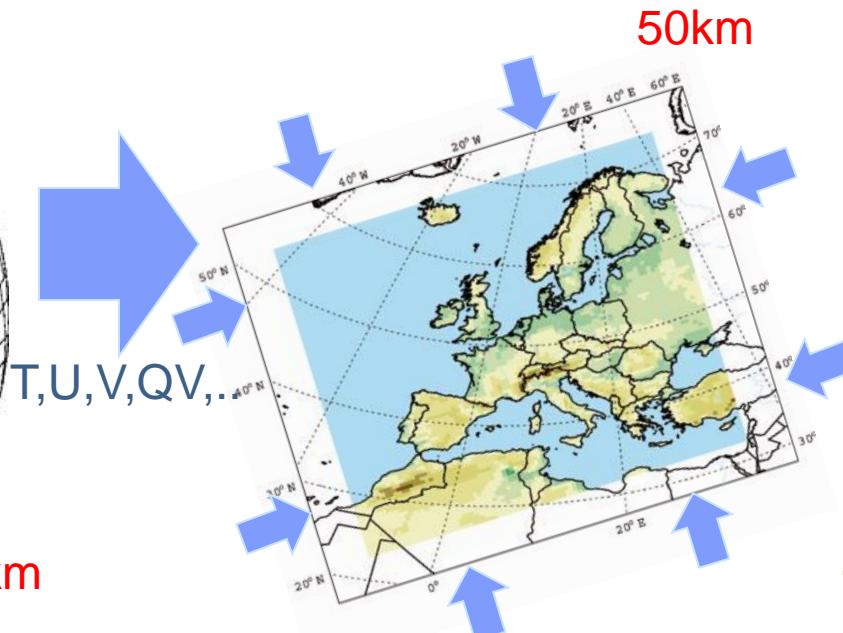


Climate models:

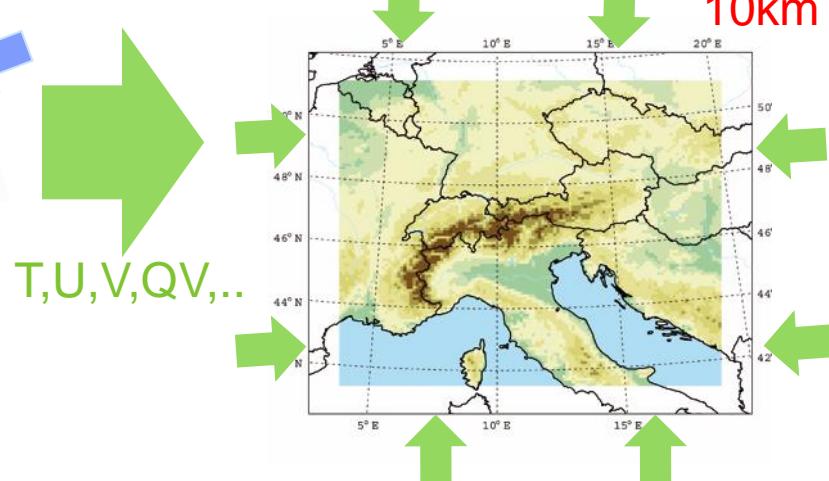
The simulations we carried out at ZAMG and the validation is about ...



150km
Data
002



1st nesting step



2nd nesting step

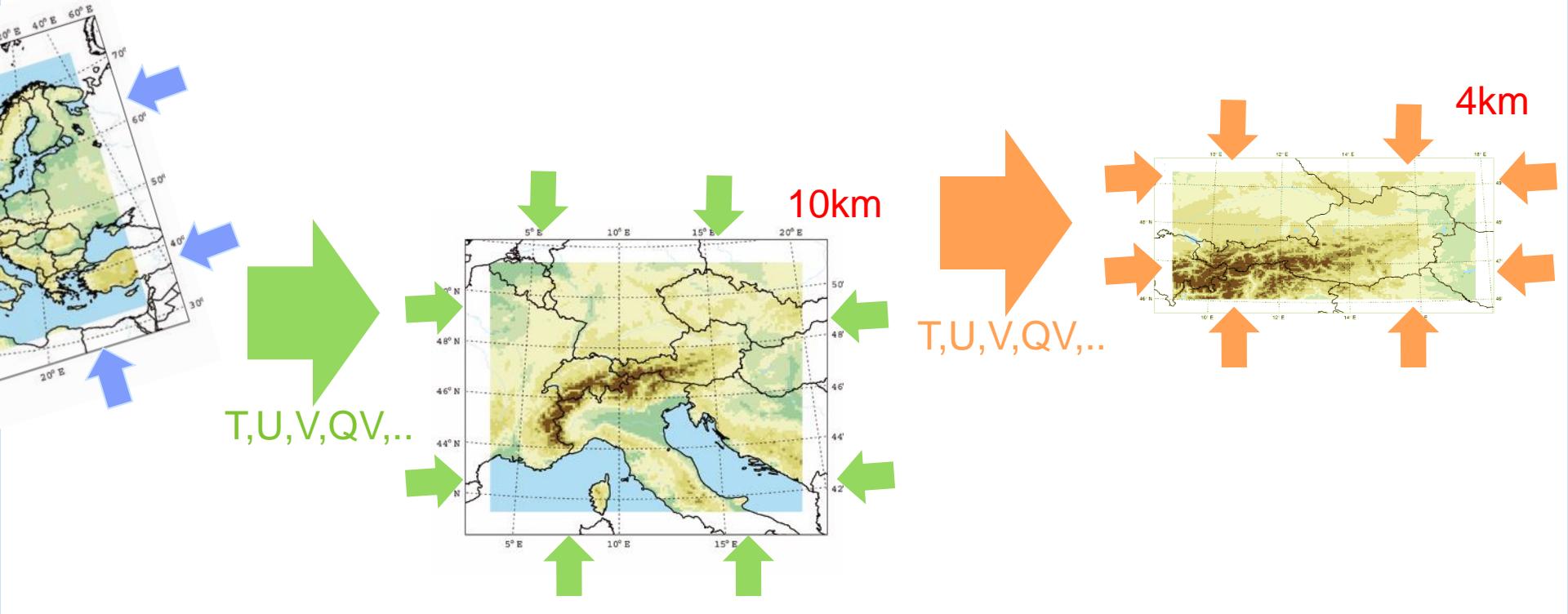




Climate models:

The simulations we carried out at ZAMG and the validation is about ...

50km



2nd nesting step

3rd nesting step



Climate models:

Can I use my home computer for carrying out simulations? (the technical side of the topic)





Climate models:

Can I use my home computer for carrying out simulations? (the technical side of the topic)



Example of a high performance computer for climate modelling at the DKRZ in Hamburg.

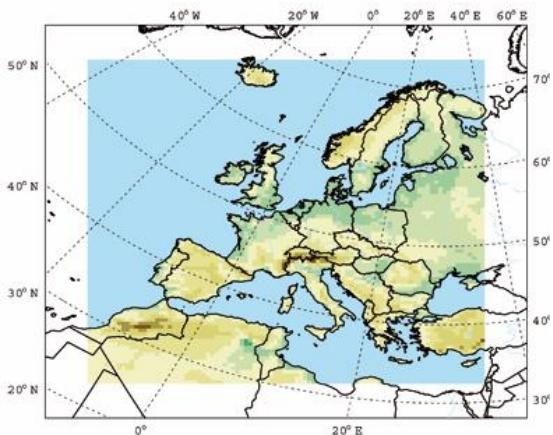
<http://www.dkrz.de>





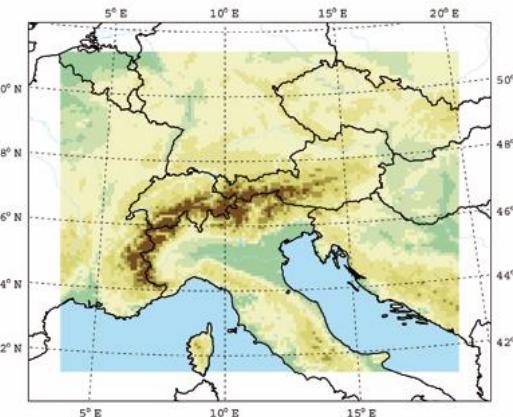
Climate models:

Can I use my home computer for carrying out simulations? (the technical side of the topic)



Europe in 50km x 50km

1 simulated month
runs 17 minutes at 8CPU



Alps in 10km x 10km

1 simulated month
runs 60 minutes minutes
at 8CPU

NEC SX-8R

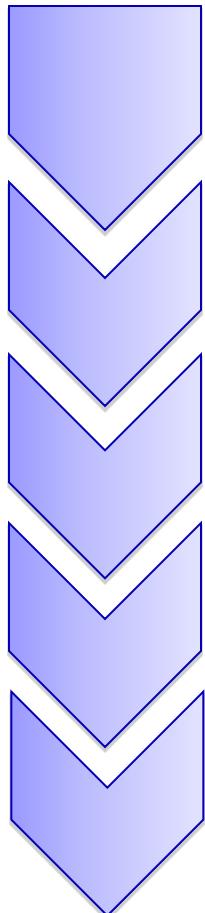


- Cluster of 2 vektor nodes
- 16 CPUs (8 CPU per node)
- 128 Gbyte RAM
- 2 x 310 GB/s Memory band width
- 512 Gigaflops
(cp. Earth Simulator: 80x)





What you can expect from the next 15 minutes....



Climate models, climate modelling and our contribution at ZAMG
(Ivonne Anders)

Model evaluation – quality and uncertainties of the model results
(Klaus Haslinger)

Added value of increased spatial resolutions
(Maja Zuvela Aloise)

Trends in observations and model data
(Michael Hofstätter)

Summary and “message2go”
(Michael Hofstätter)



Evaluation of the 10km CCLM hindcast

Evaluation – what does that mean?

Evaluation is systematic determination of merit, worth, and significance of something (**the Regional Climate Model COSMO-CLM**) or someone using criteria against a set of standards (**different observation datasets**).

Observation data:

Datenset	Period	Parameter	Temporal Res.	Spatial Res.	Domain	Reference
CRU TS 1.2	1901-2000	T, Tx, Tn, P	Monthly	10'	Europe	Mitchell et al., 2003
E-OBS	1950-2006	T, Tx, Tn, P	Daily	0.22°	Europe	Haylock et.al., 2008
GPCC4	1901-2007	P	Daily	18km	Europe	Schneider et al., 2008
HISTALP	1780-2007	T	Monthly	5'	GAR	Chimani et al., 2010 (subm.)
HISTALP	1800-2000	P	Monthly	5'	GAR	Chimani et al., 2010 (subm.)
STARTCLIM	1950-2005	T, P, S	Daily	1km	Austria	Schöner et.al., 2003

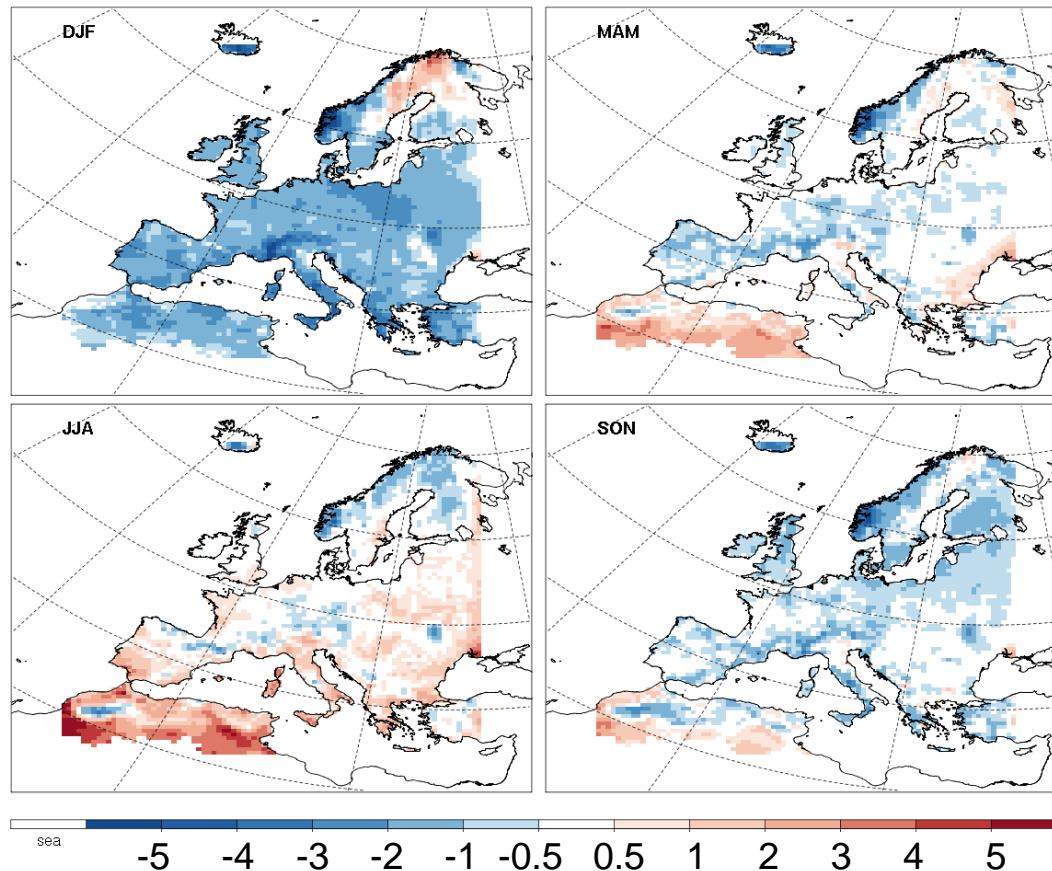




Evaluation of the 10km CCLM hindcast

Mean Bias (50km European Domain)

Mean seasonal bias in 2m temperature [K], CCLM-CRU, 1961-2000

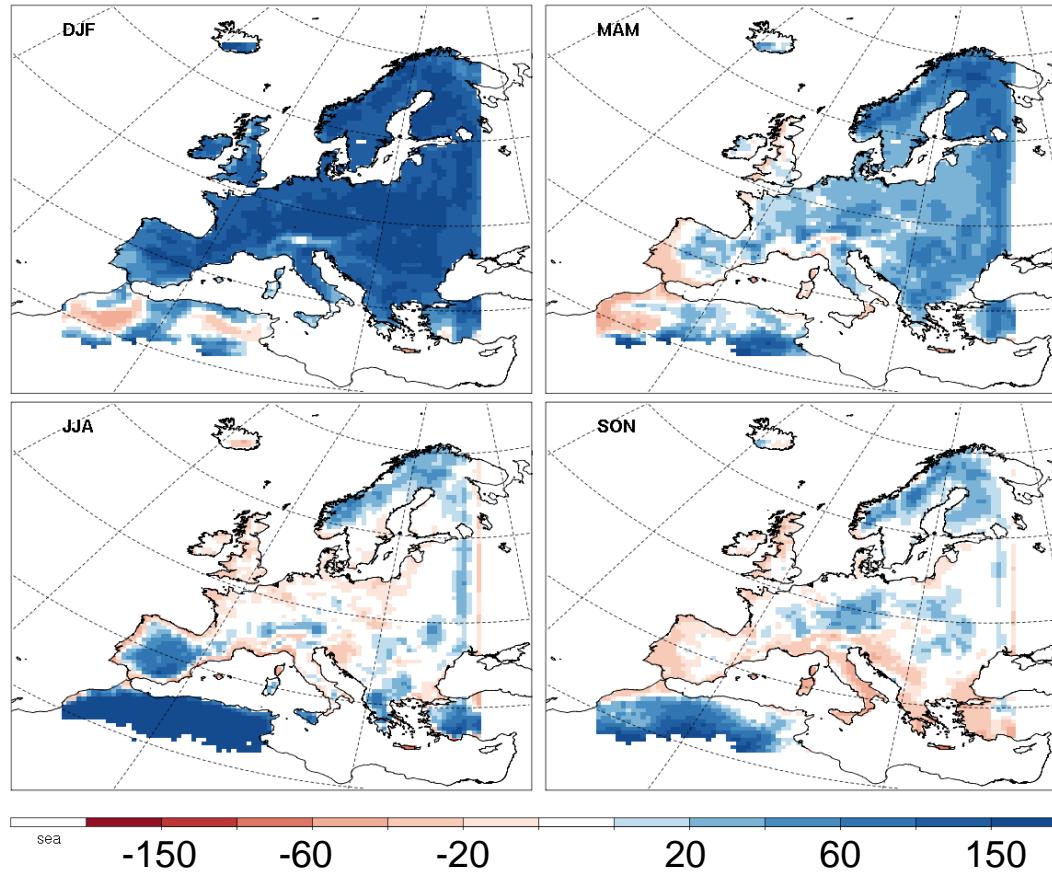




Evaluation of the 10km CCLM hindcast

Mean Bias (50km European Domain)

Mean seasonal bias in precipitation sum [%], CCLM-CRU, 1961-2000

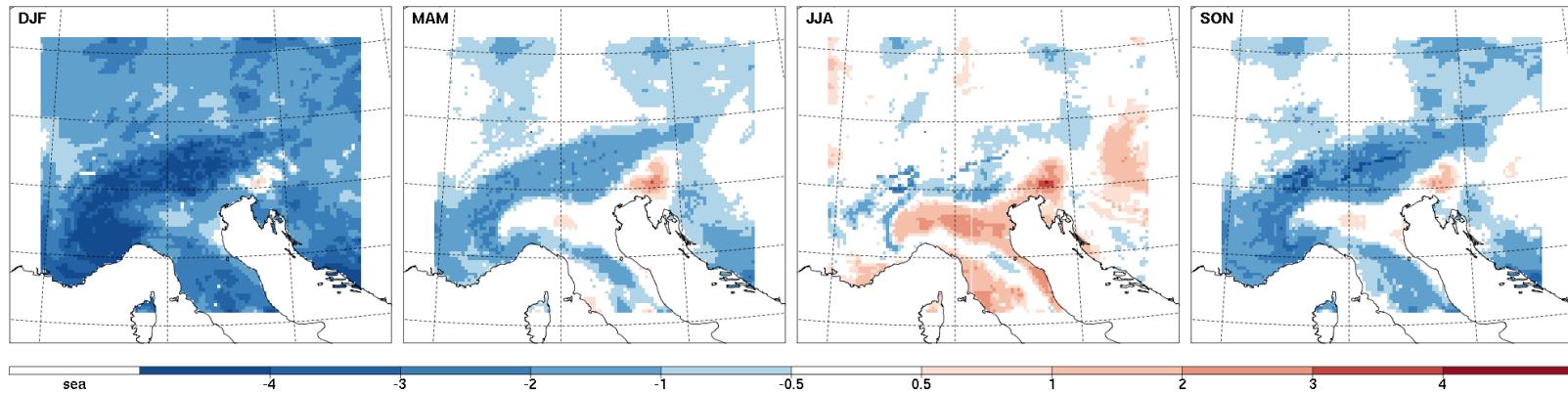




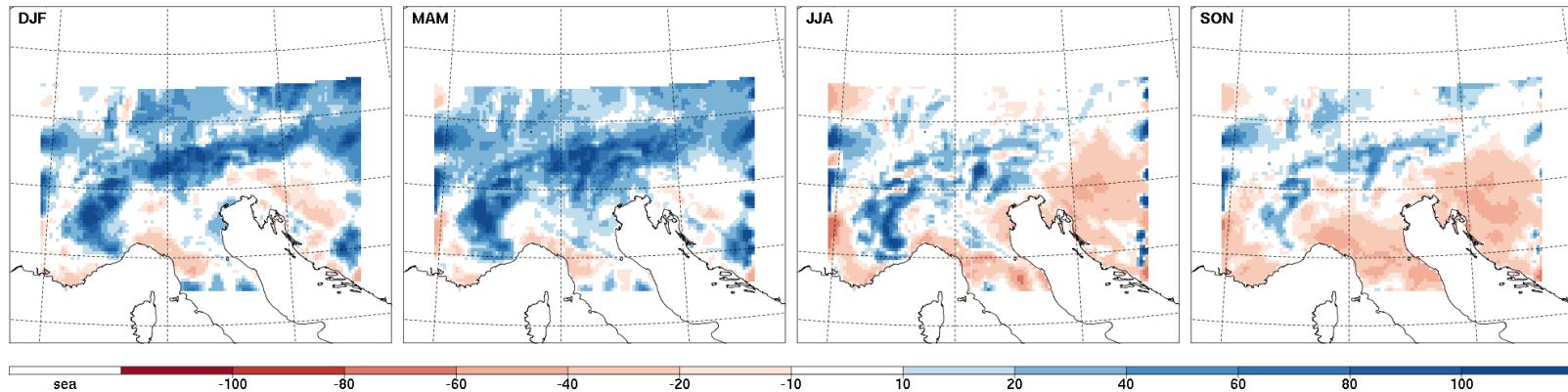
Evaluation of the 10km CCLM hindcast

Mean Bias (GAR)

Mean seasonal bias in 2m temperature [K], CCLM-EOBS, 1961-2000



Mean seasonal bias in precipitation sum [%], CCLM-HISTALP, 1961-2000

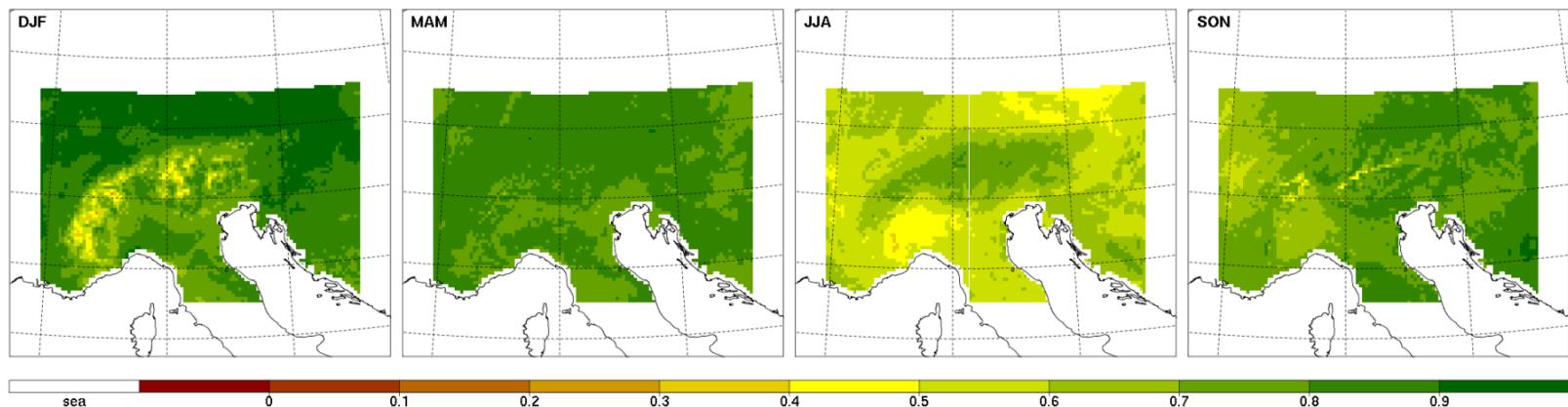




Evaluation of the 10km CCLM hindcast

Correlation (GAR)

Correlation of seasonal 2m temperature mean, CCLM-HISTALP, 1961-2000

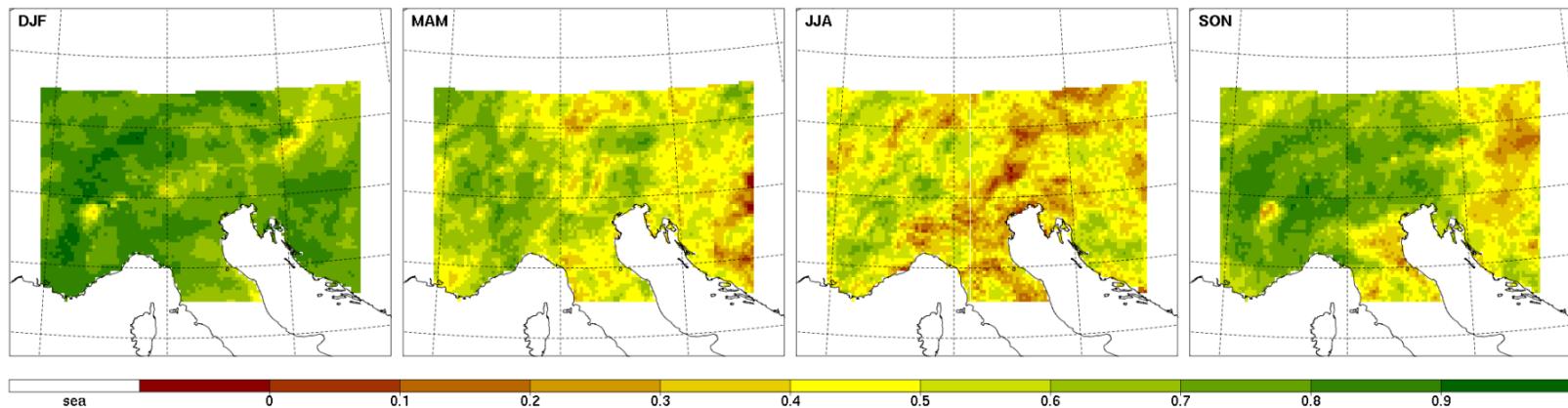




Evaluation of the 10km CCLM hindcast

Correlation (GAR)

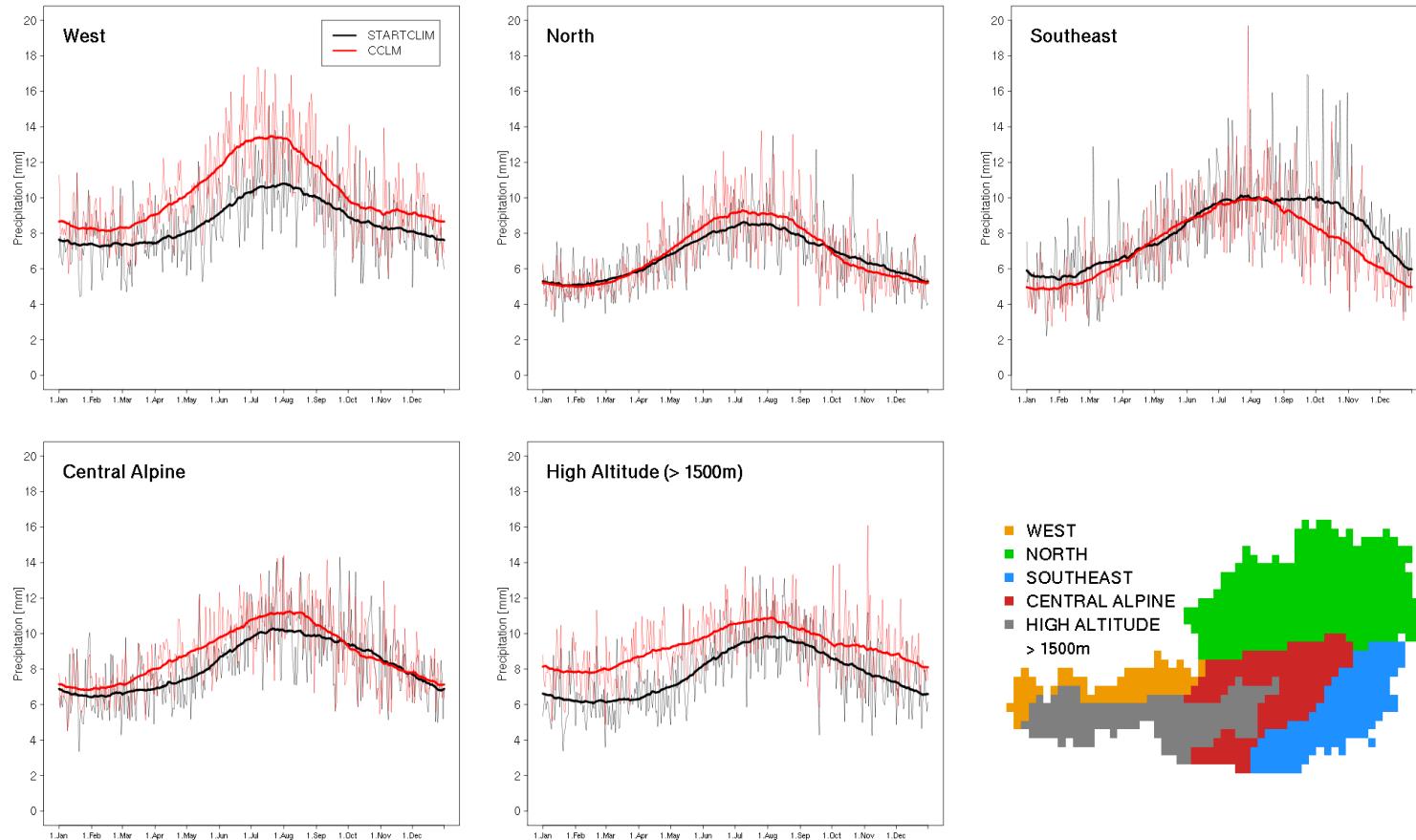
Correlation of seasonal precipitation sum, CCLM-HISTALP, 1961-2000





Evaluation of the 10km CCLM hindcast *Annual Cycles (Austria)*

Mean annual cycle of **precipitation** for five climatic regions in Austria, CCLM-STARTCLIM, 1961-2000

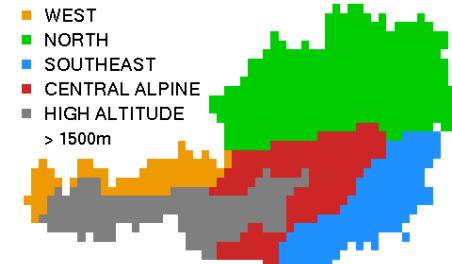
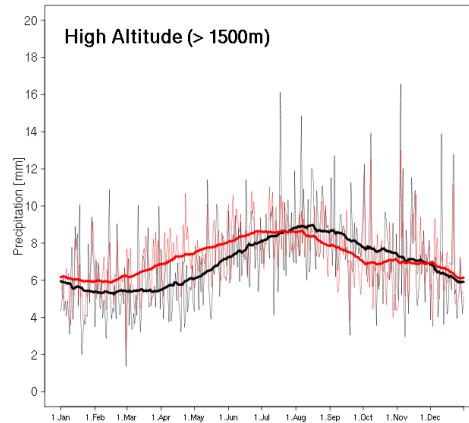
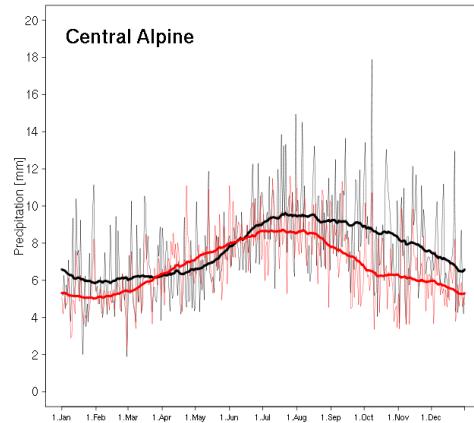
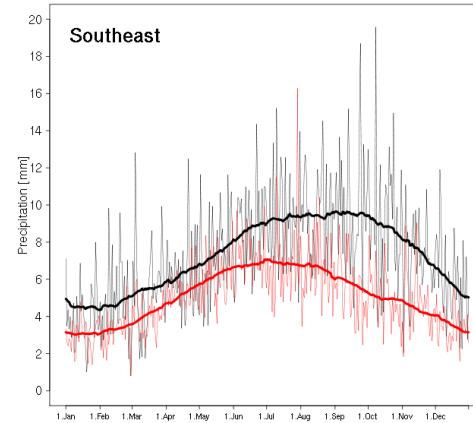
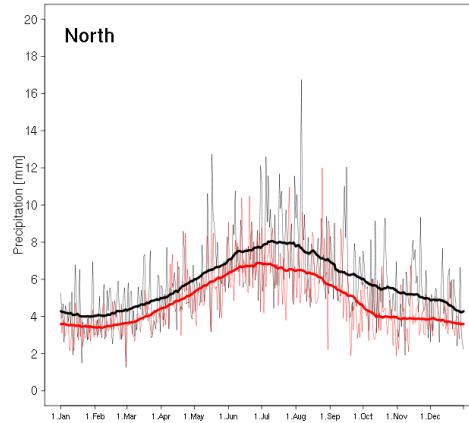
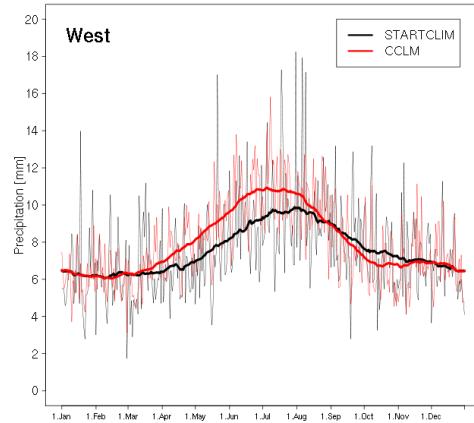




Evaluation of the 10km CCLM hindcast

Annual Cycles (Austria)

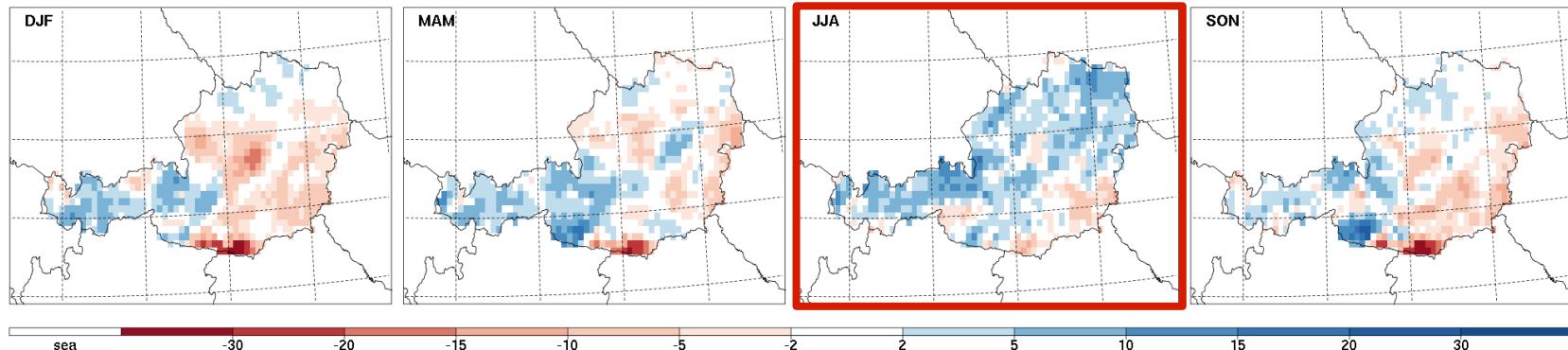
Mean annual cycle of **standard deviation of precipitation** for five climatic regions in Austria,
CCLM-STARTCLIM, 1961-2000



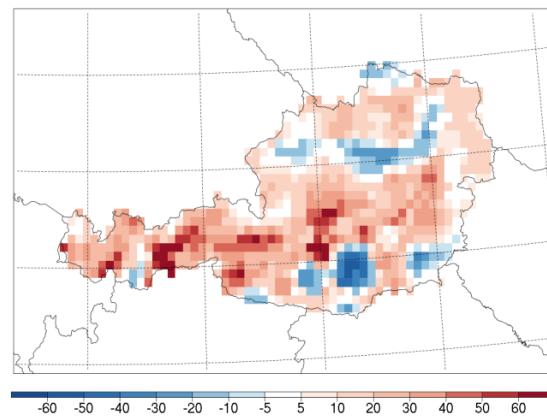
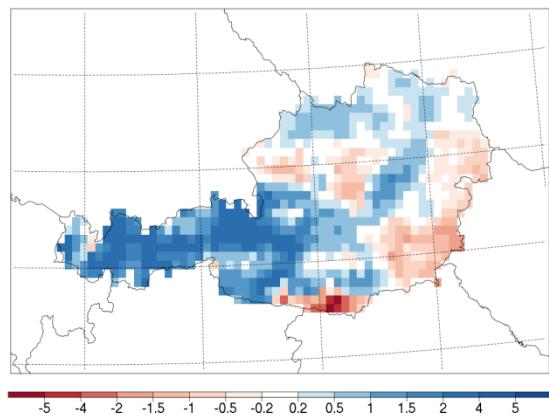


Evaluation of the 10km CCLM hindcast *Bias in Extremes and Derived Indices (Austria)*

Mean seasonal bias of the **precipitation sum above the 98th percentile [mm]**, CCLM-STARTCLIM, 1961-2000

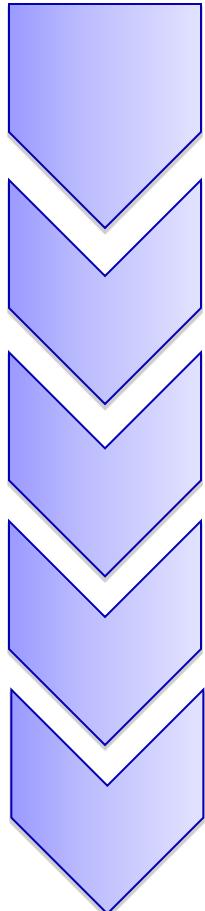


Mean bias of the **simple daily intensity index [mm/d]**, CCLM-STARTCLIM, 1961-2000 Mean bias of **number of days with RR > 1mm [d]**, CCLM-STARTCLIM, 1961-2000





What you can expect from the next 12 minutes....



Climate models, climate modelling and our contribution at ZAMG
(Ivonne Anders)

Model evaluation – quality and uncertainties of the model results
(Klaus Haslinger)

Added value of increased spatial resolutions
(Maja Zuvela Aloise)

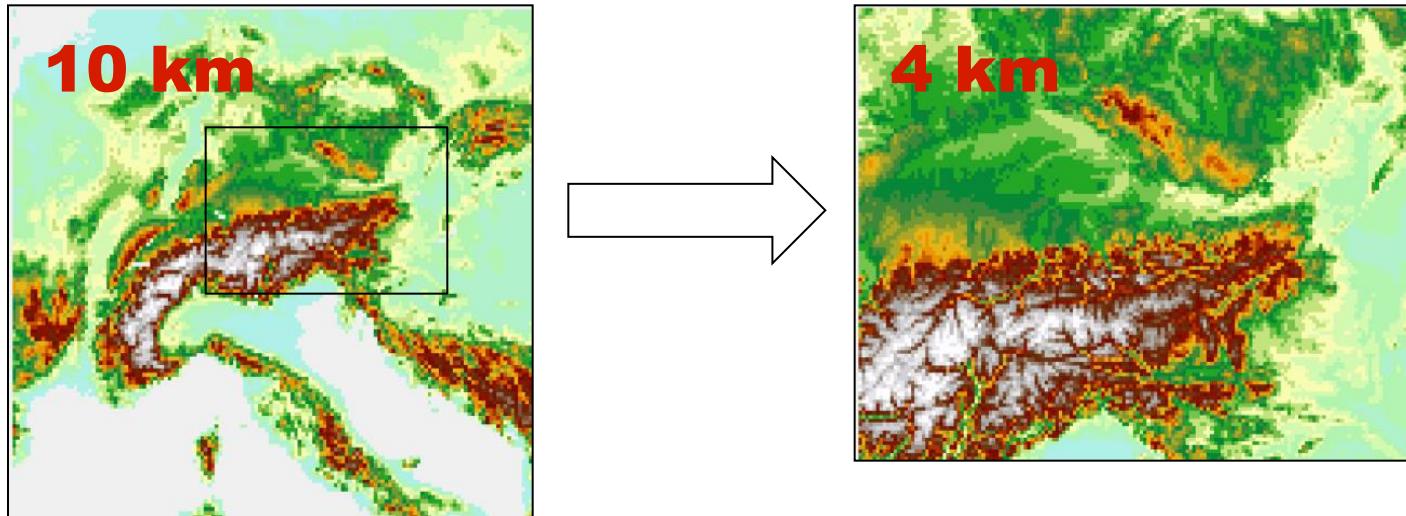
Trends in observations and model data
(Michael Hofstätter)

Summary and “message2go”
(Michael Hofstätter)



CCLM Simulation for Austria: **4 km resolution**

- (1) *Is there a value added by the dynamical downscaling to finer resolution?*
- (2) *How good are the climate model simulations compared to the observational analysis model?*
- (3) *Can we compare the climate model results directly with the observations at the stations?*



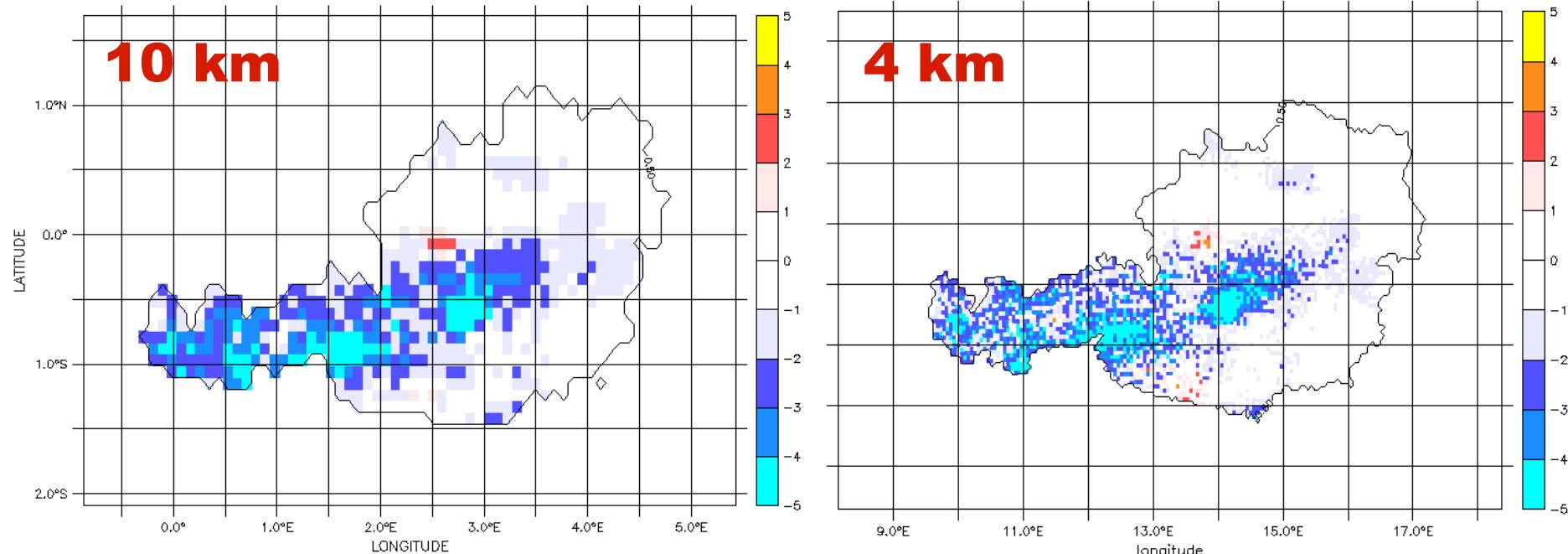


Comparison CCLM 10 km vs. 4 km: *Temperature bias*

Observational dataset: STARTCLIM 1 km gridded daily mean temperature
<http://www.zamg.ac.at/forschung/klimatologie/klimawandel/StartClim2007.A/>

Period: 1961-2000

- (1) similar spatial patterns: cold bias in the mountain region
- (2) mean bias is not reduced

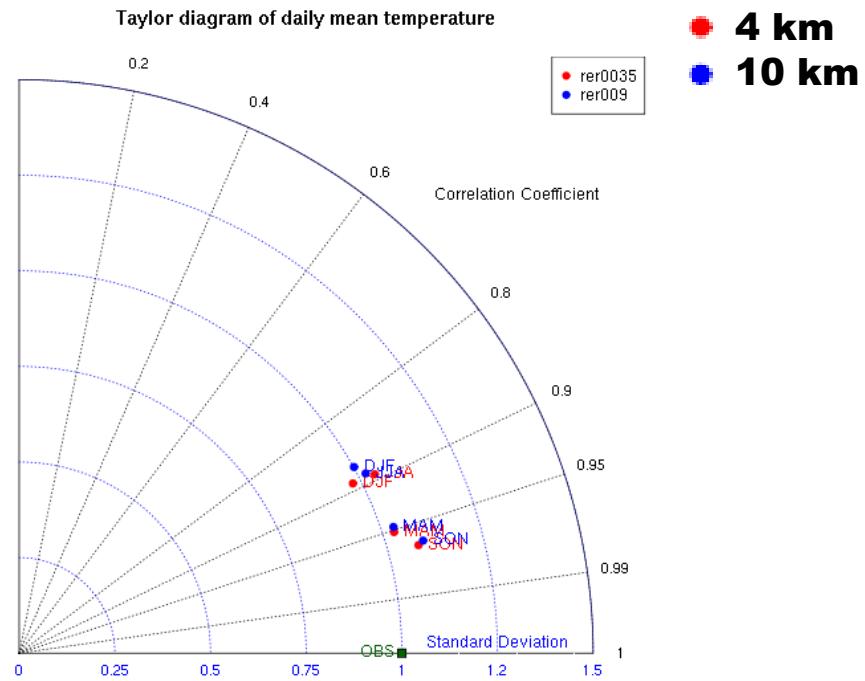
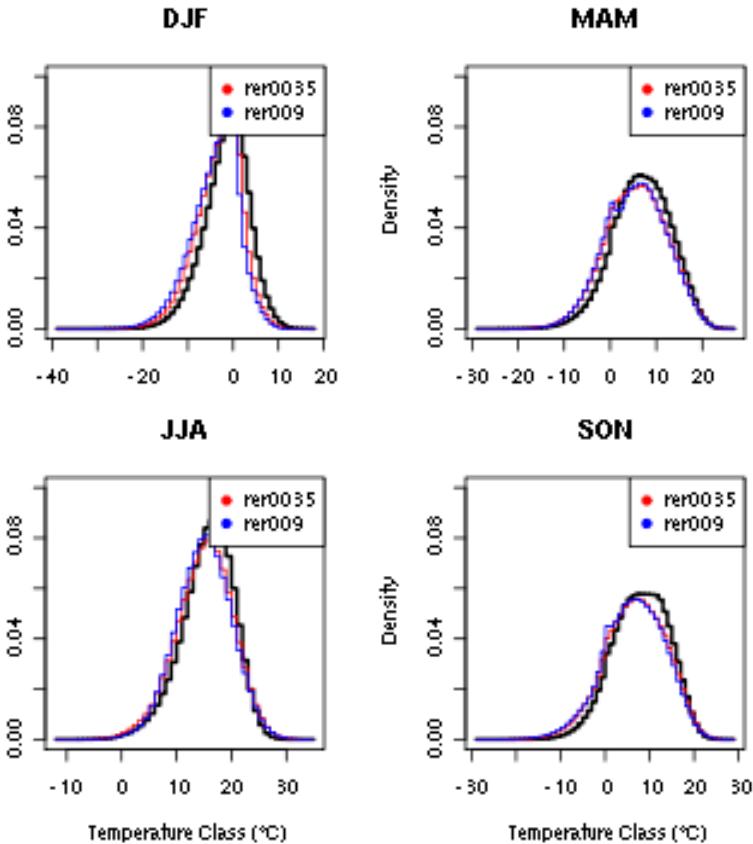




Comparison CCLM 10 km vs. 4 km: *Temperature*

- (1) no significant differences in temperature distributions on seasonal basis
- (2) small improvement in temperature correlation in winter period

Temperature frequency distribution





Comparison CCLM 10 km vs. 4 km: *Precipitation bias*

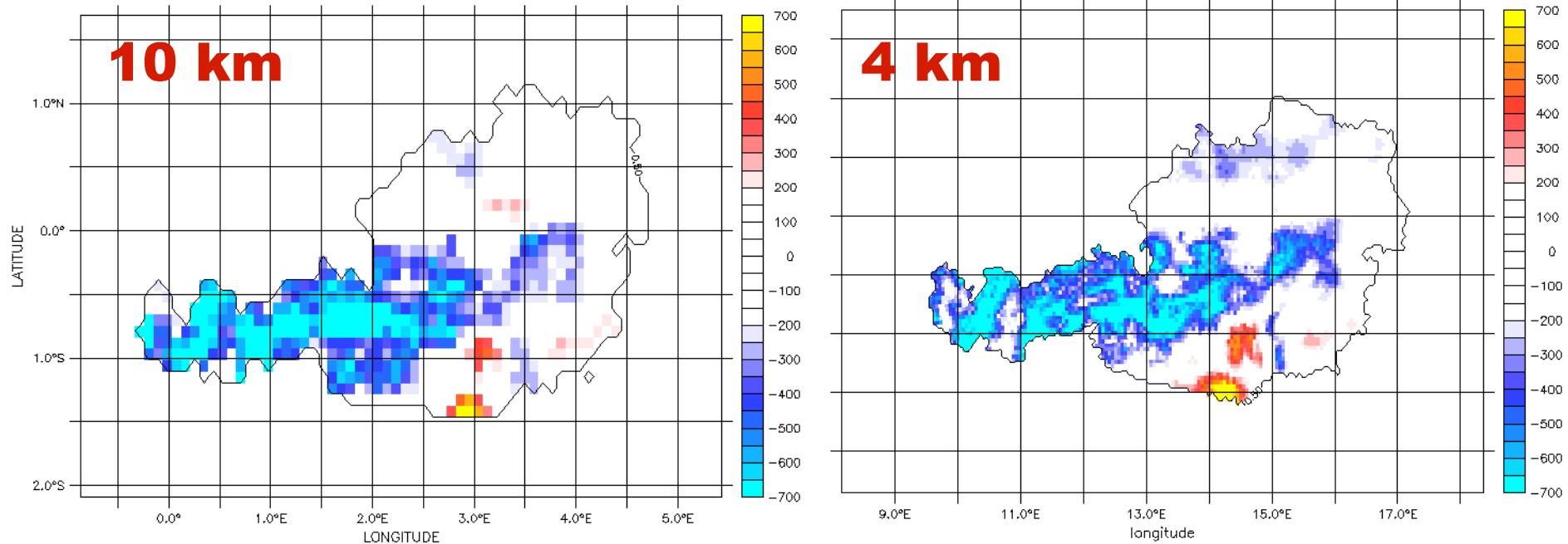
Observational dataset: STARTCLIM 1 km gridded daily precipitation sum

<http://www.zamg.ac.at/forschung/klimatologie/klimawandel/StartClim2007.A/>

Period: 1961-2000

(1) similar spatial patterns: overestimation of precipitation in the mountain region

(2) mean bias is not reduced

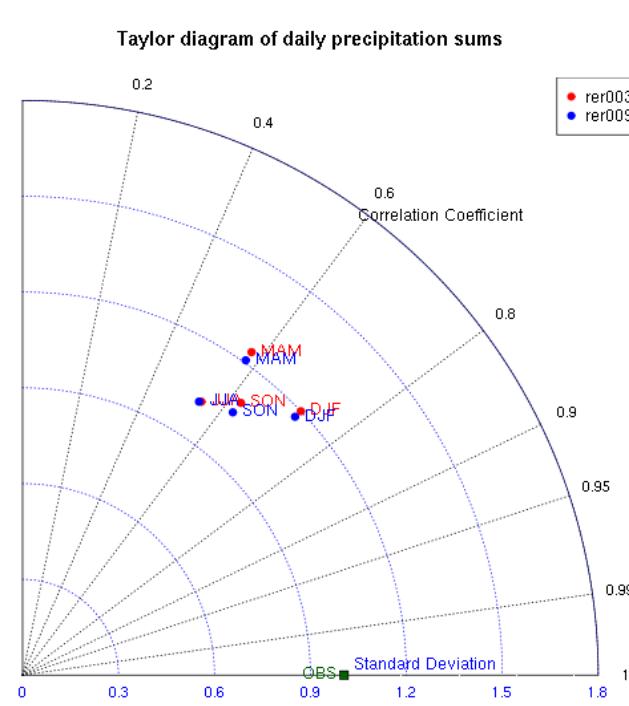
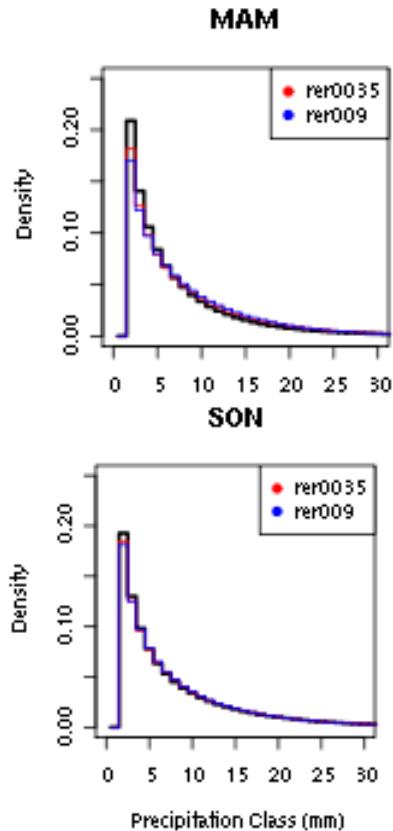
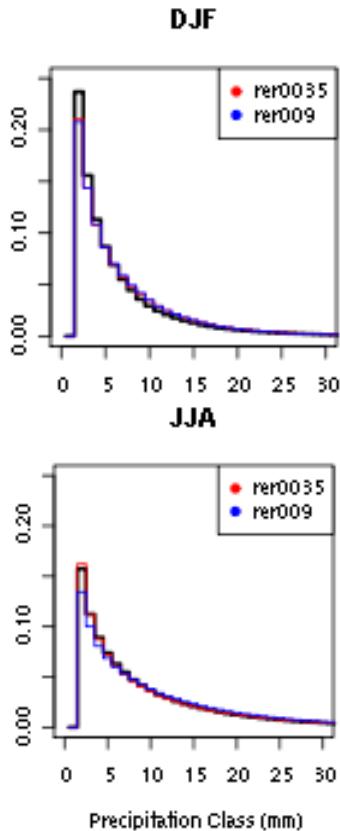




Comparison CCLM 10 km vs. 4 km: *Precipitation*

- (1) small differences in precipitation distributions on seasonal basis
- (2) no significant reduction of bias

Precipitation frequency distribution



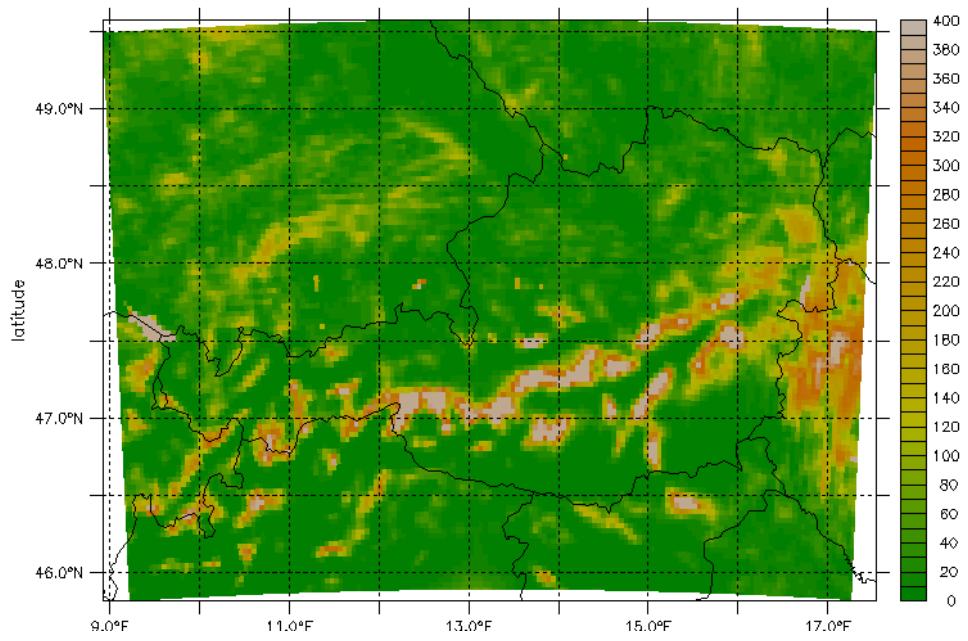
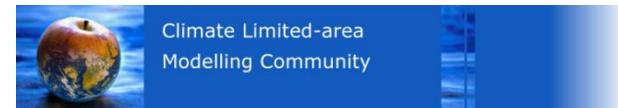


Comparison CCLM (4 km) vs. INCA (1 km): **Wind speed maximum**

Strong wind days: Number of days where daily maximum wind speed > 10.5 m/s

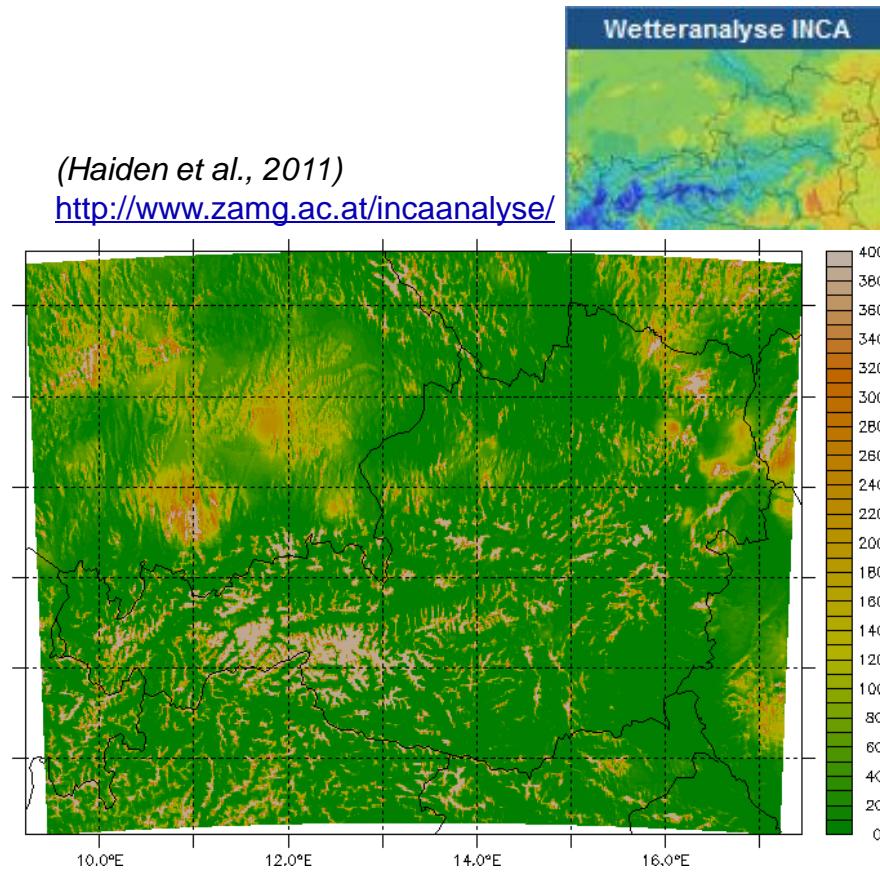
(1) *similar horizontal patterns*

(2) *difference in resolution and time period*



(Haiden et al., 2011)

<http://www.zamg.ac.at/incaanalyse/>

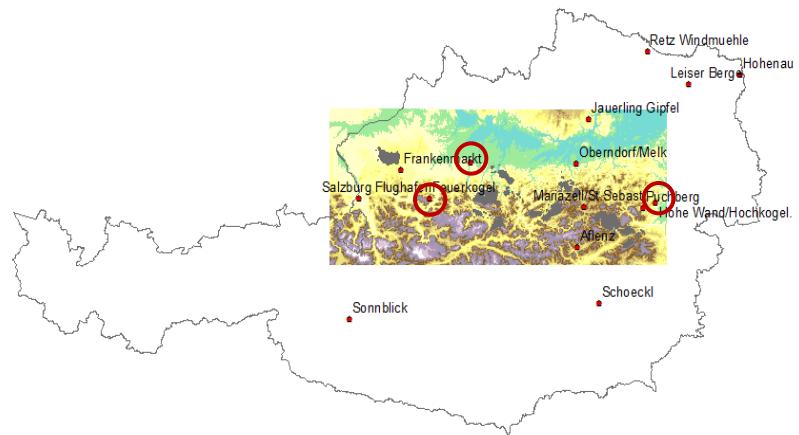




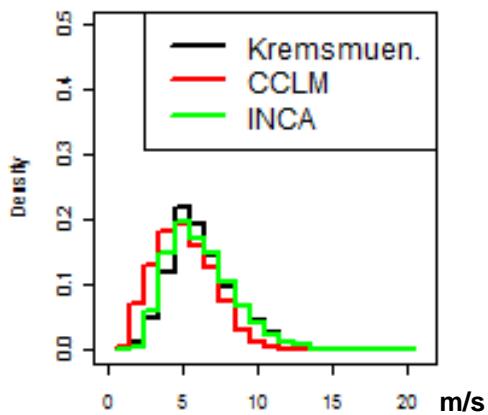
Comparison CCLM (4 km), INCA (1 km), Observations: *Wind speed*

Wind speed distribution at the stations:

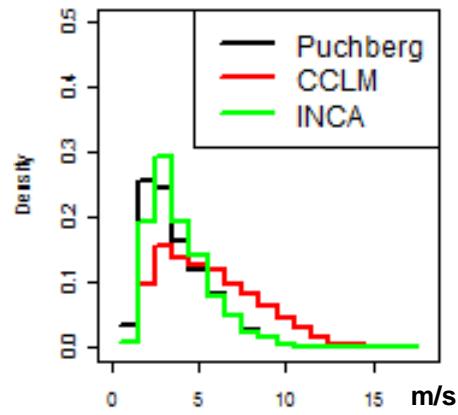
- (1) **Lowland: good agreement**
- (2) **Valley: station dependant**
- (3) **Mountain: underestimation of wind speeds**



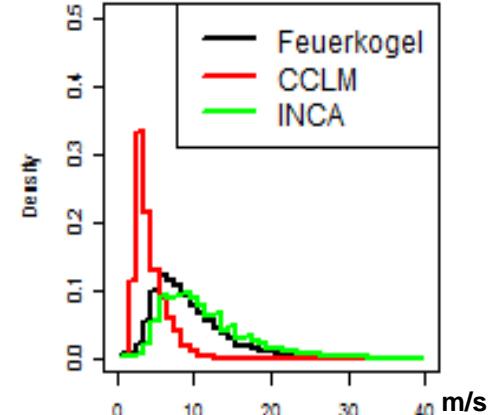
Lowland



Valley



Mountain



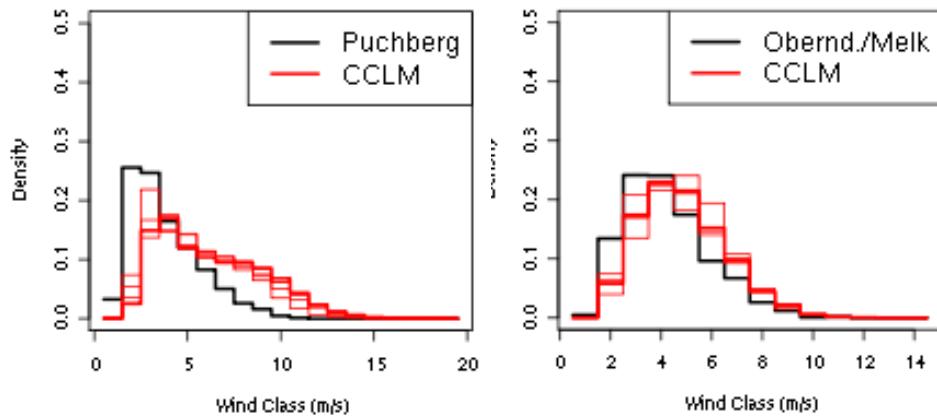


Comparison CCLM (4 km) vs. station data: *Wind speed*

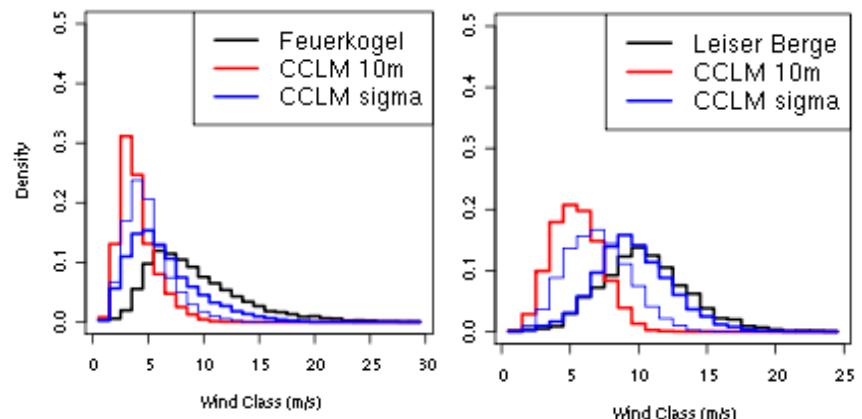
Wind speed distribution at the stations compared to:

- (1) *Neighbouring points in the model: possible improvement*
- (2) *Vertical levels: better agreement for the mountain stations*

Neighbouring points



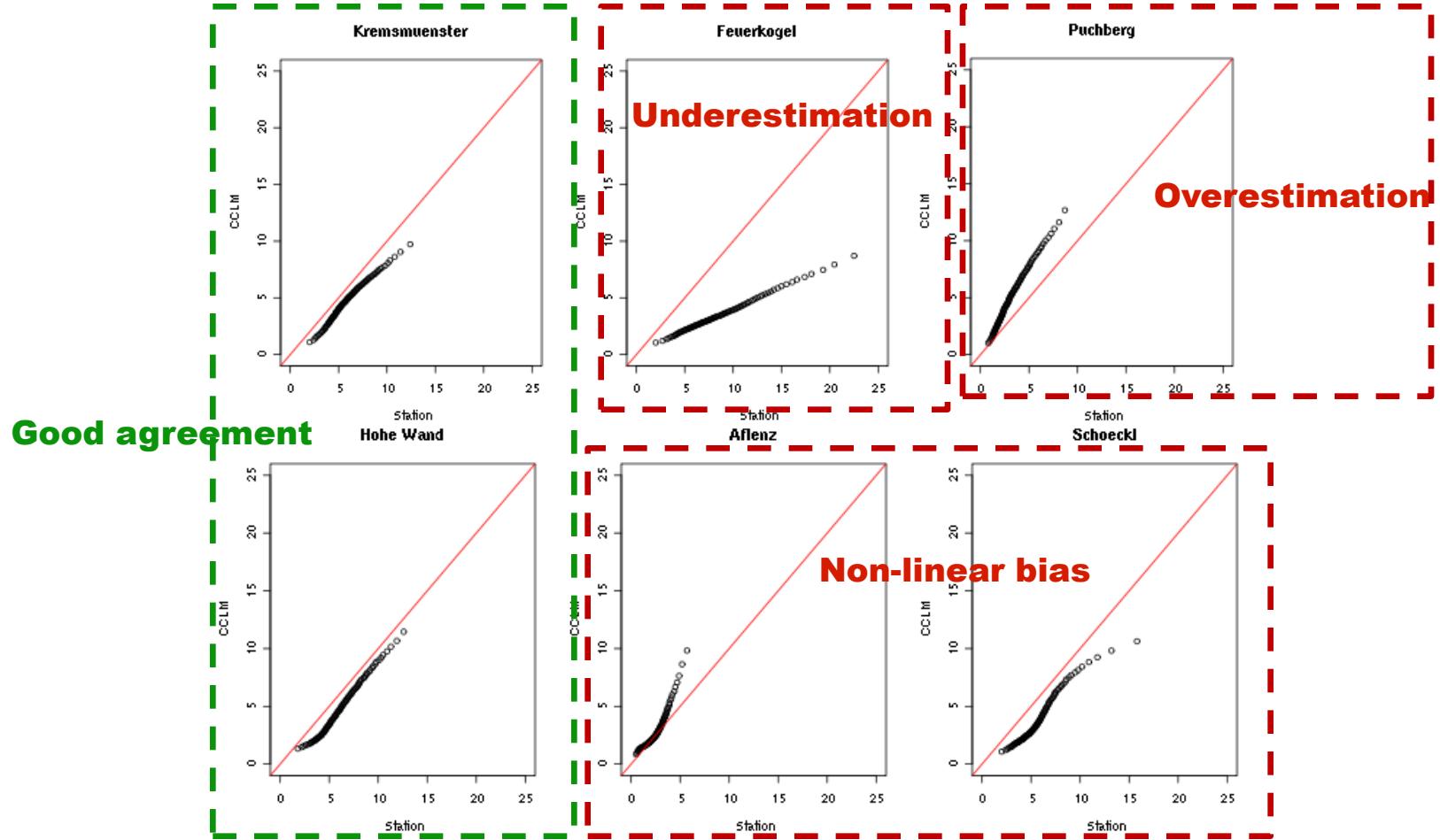
Vertical levels





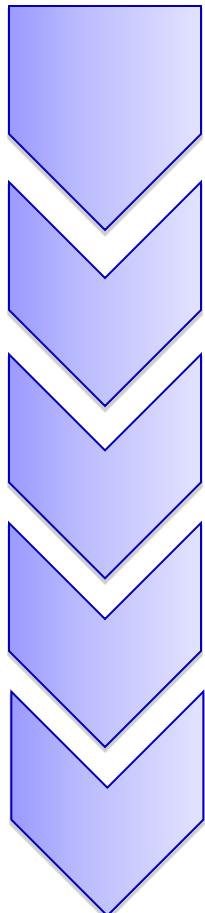
Comparison CCLM (4 km) vs. stations: *Wind speed*

QQ-Plot: Percentiles of wind speed at the stations compared to the model





What you can expect from the next 7 minutes....



Climate models, climate modelling and our contribution at ZAMG
(Ivonne Anders)

Model evaluation – quality and uncertainties of the model results
(Klaus Haslinger)

Added value of increased spatial resolutions
(Maja Zuvela Aloise)

Trends in observations and model data (10km Hindcast GAR)
(Michael Hofstätter)

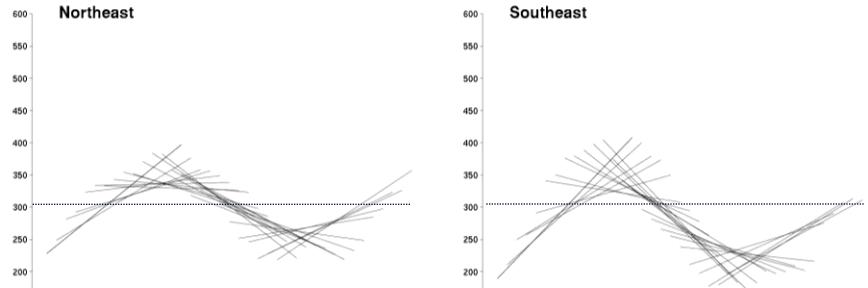
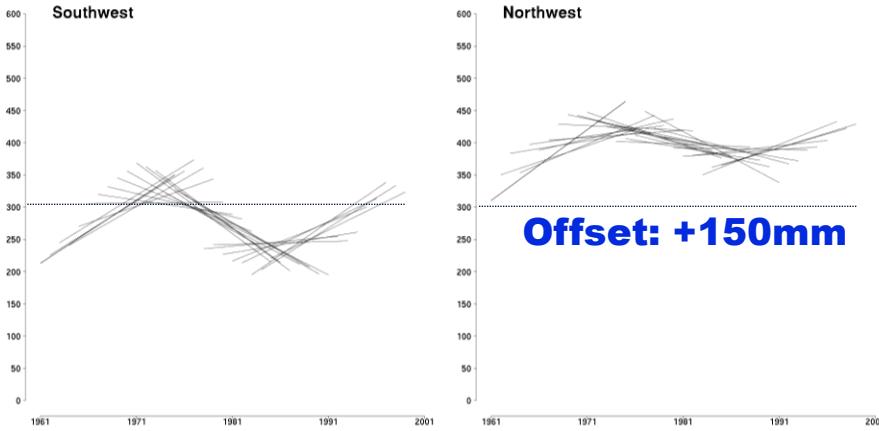
Summary and “message2go”
(Michael Hofstätter)



Evaluation of the 10km CCLM hindcast GAR-Regions

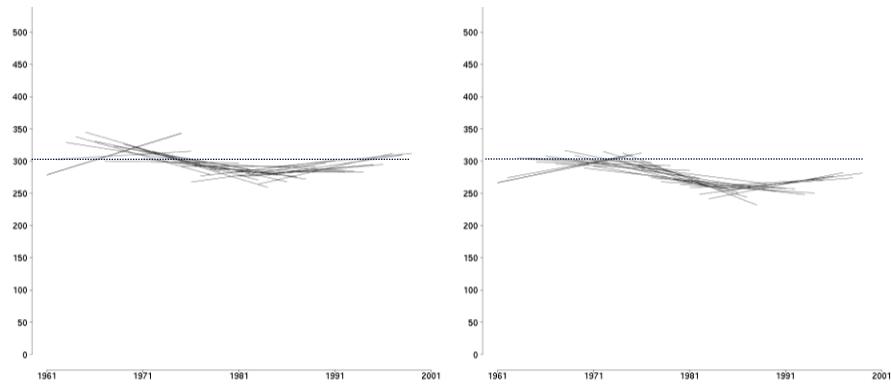
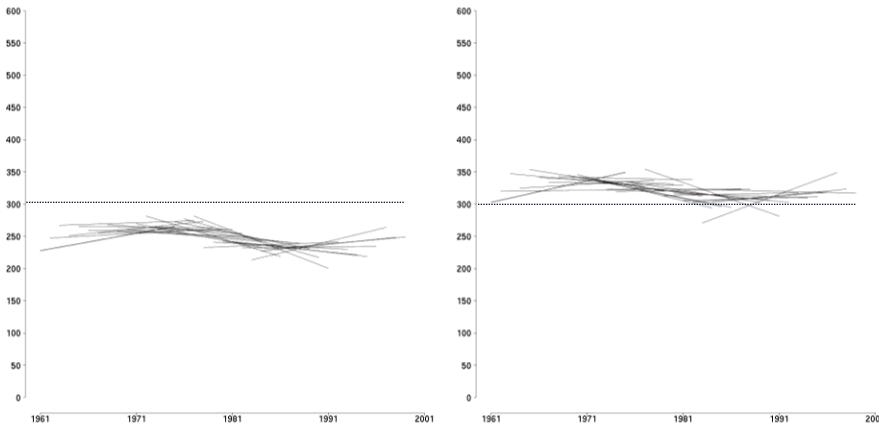
Summer precipitation (JJA): Floating Trend Analysis (15y) 1961-2000

CLM



*Decadal variability
CONCURRENT but OVERESTIMATED
in terms of magnitude!*

Histalp

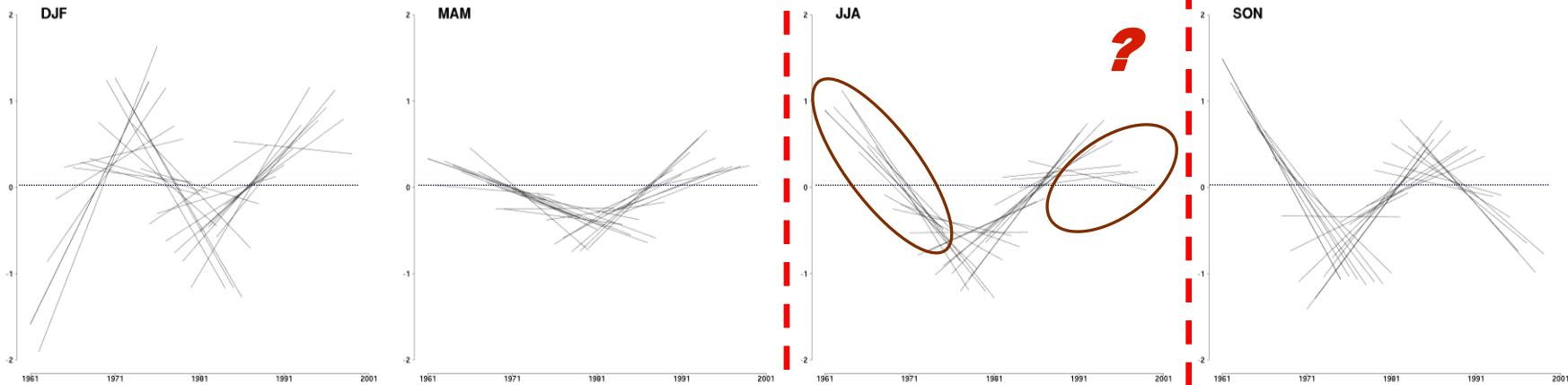




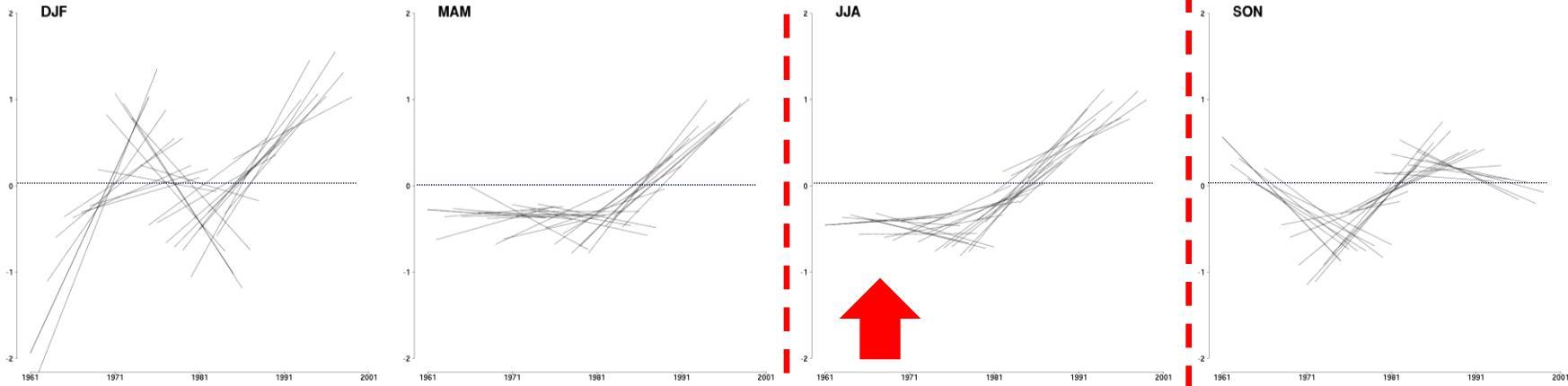
Evaluation of the 10km CCLM hindcast GAR

Temperature 2m: Floating Trend Analysis (15y) 1961-2000

CLM



Histalp

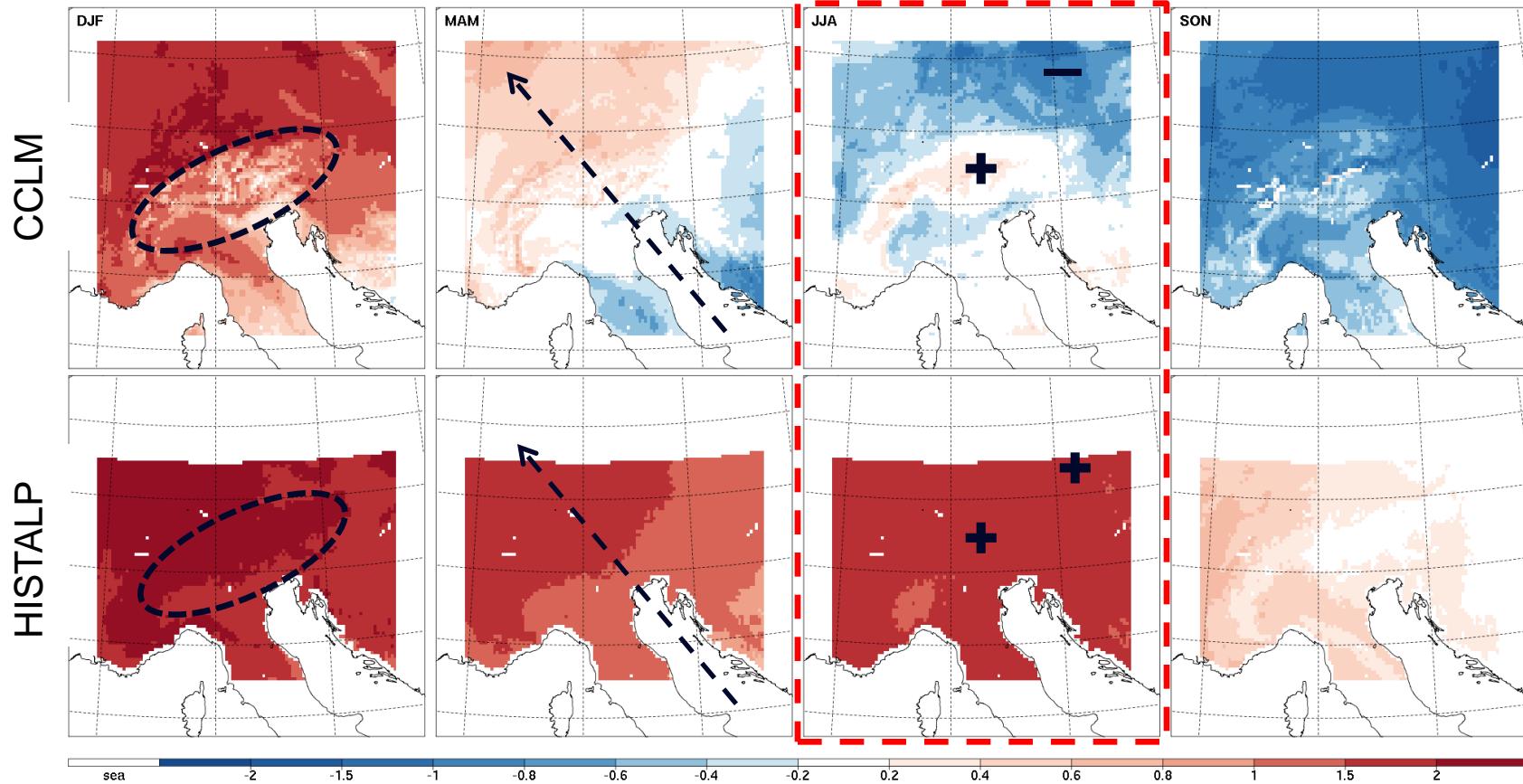




Evaluation of the 10km CCLM hindcast

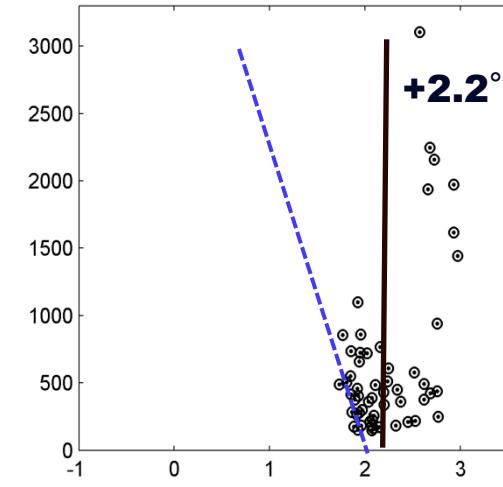
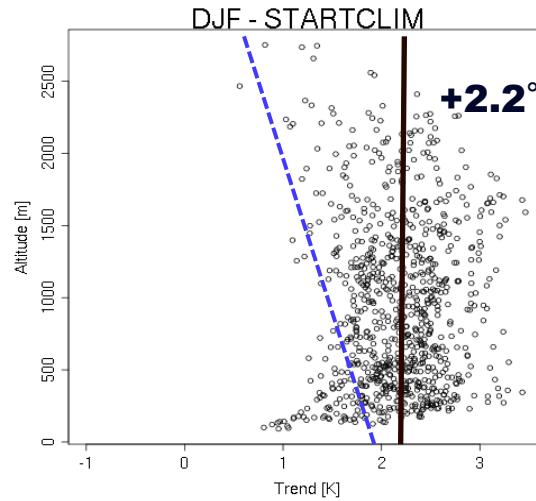
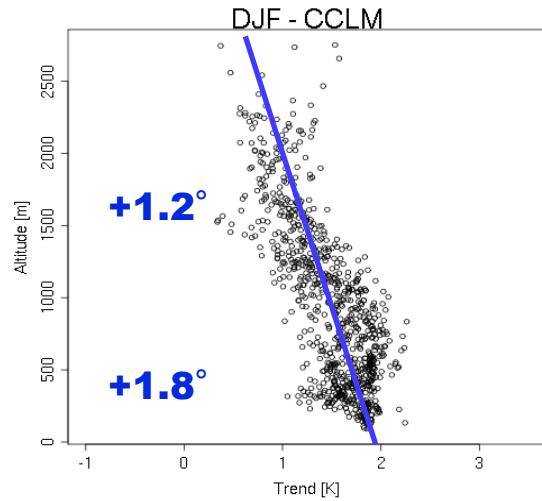
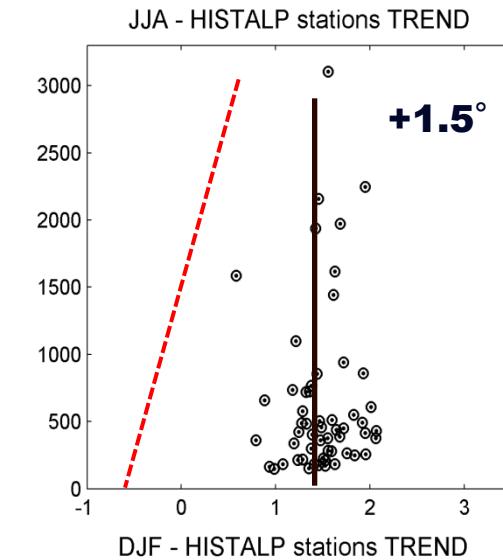
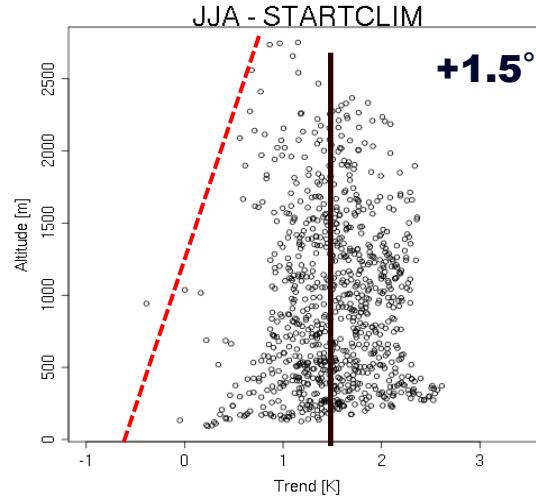
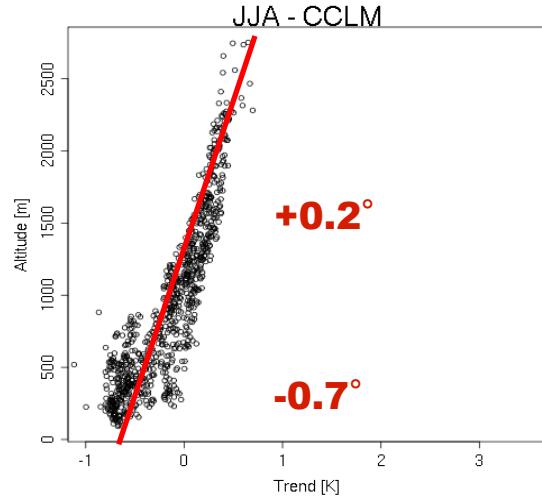
Trends (GAR)

Seasonal trends in 2m temperature [K], 1961-2000



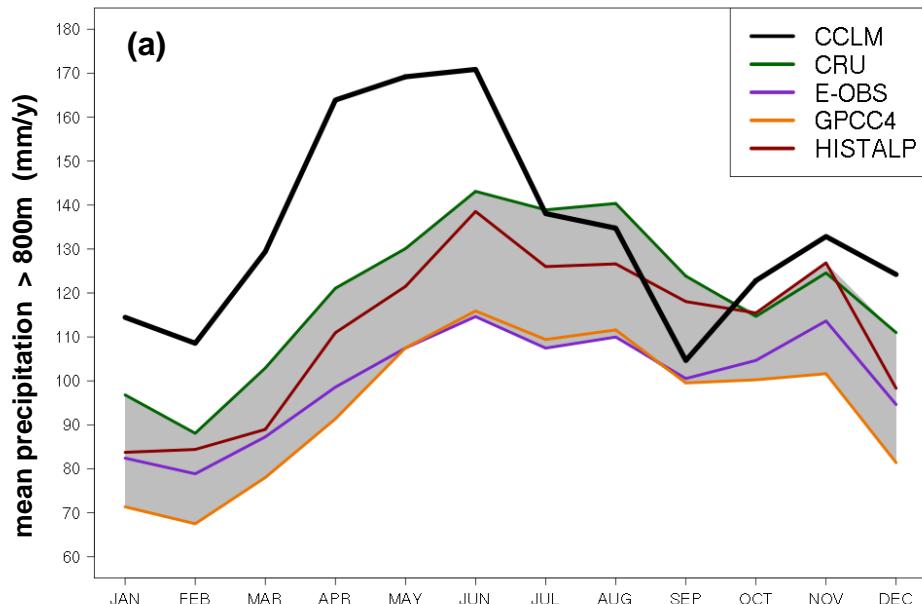


Trend dependency on height – T2m (AT 1961-2000)





Uncertainty of observations GAR:



(a) mean precipitation > 800m (mm/year)

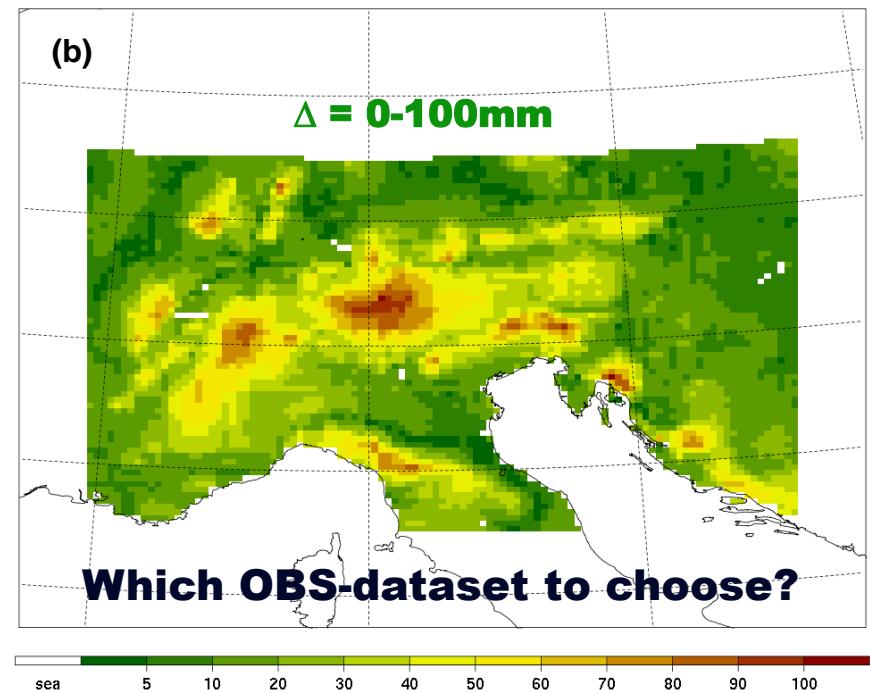
(b) Range of mean monthly precipitation (1961-2000)
between OBS datasets

FREI ET AL.: DAILY PRECIPITATION STATISTICS IN REGIONAL CLIMATE MODELS

Table 1. Estimates of Precipitation Bias (Underestimate) in the Alpine Analysis Due to Measurement Bias and Network Bias

	Measurement Bias ^a			Domain Mean Bias ^b		
	<600 (62%) (%)	600–1500 (34%) (%)	>1500 (4%) (%)	Measurement Bias (%)	Network Bias (%)	Total (%)
Winter	8	12	40	11	5	16
Spring	5	10	25	7	4	11
Summer	4	8	12	6	4	10
Autumn	5	10	25	7	4	11

COSMO-CLM (0.09deg): RANGE OF MONTHLY PRECIPITATION [mm] BETWEEN OBSERVATION-DATASETS (CRU, EOBS, GPCC4, HISTALP); 1961-2000





CCLM Simulation for Austria: some CONCLUSIONS 2 go

(1) CCLM shows reasonable skill in certain processes in the Alpine Region

(2) Is there an added value downscaling from 10km to 4km ?

no significant bias reduction can be detected, similar bias with finer spatial structures

(3) We see RCM simulations are currently at their limits at 10km in the Alpine Region
furthermore gridded OBS with effective resolution .lt. 10km are missing.

(4) Future aspects: boundary layer processes, surface/soil parametrization, coupled Mediterranean Sea,..

(5) One model strategy: when focus is on specific processes (selective optimisations)

(6) Multi model strategy: for conventional climate change scenarios (uncertainty estimates!)





**Regional Climate
Change Scenarios**

**Urban Climate
Simulations**

**Variability, Extremes and
Uncertainty Analysis**

**Climate Simulations for
Impact Research**