Soulivanh THAO (LSCE), Yoann ROBIN (IPSL),
Mathieu Vrac (LSCE)

Introduction au **downscaling statistique** et à la **correction de biais** des simulations climatiques

Ecole de Printemps
« *Impacts hydrologiques des changements climatiques* »
Banyuls-sur-mer, 09-13 mai 2022

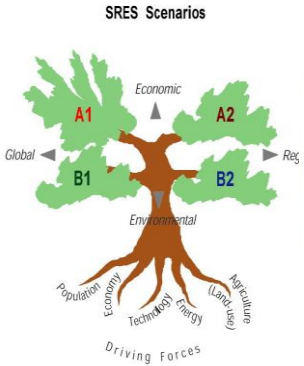
From scenarios to adaptations/mitigations

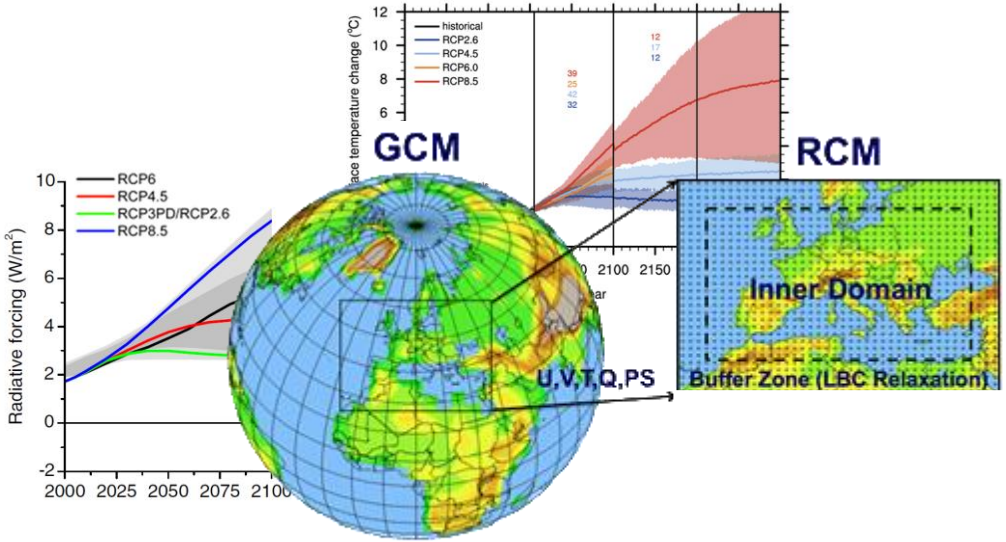
Future society

GHG emissions

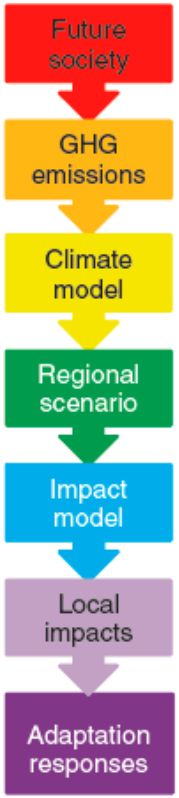
Climate model

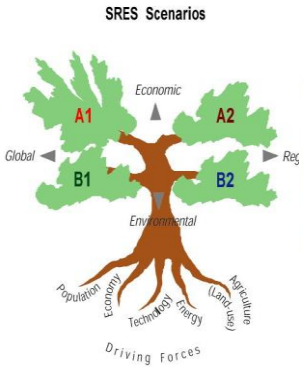
Regional scenario

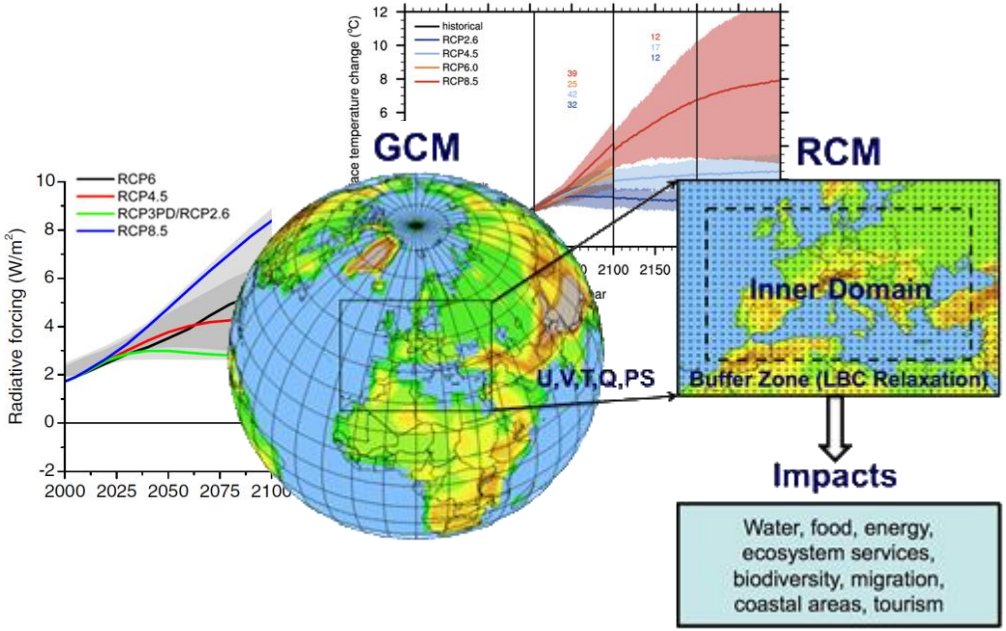




From scenarios to adaptations/mitigations



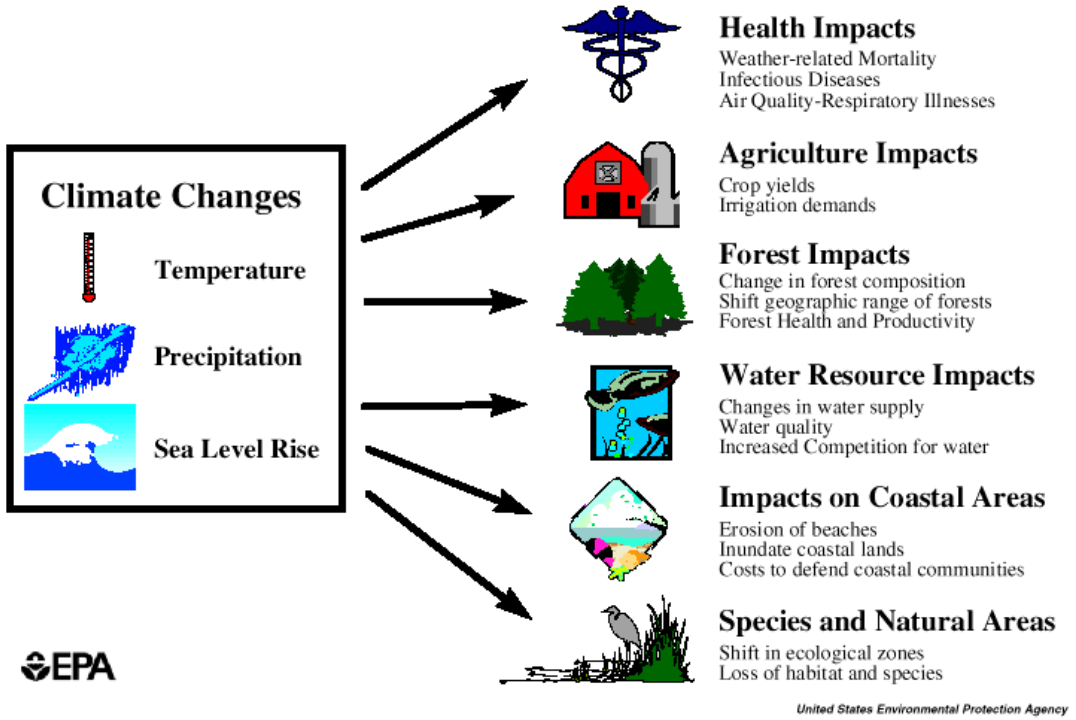




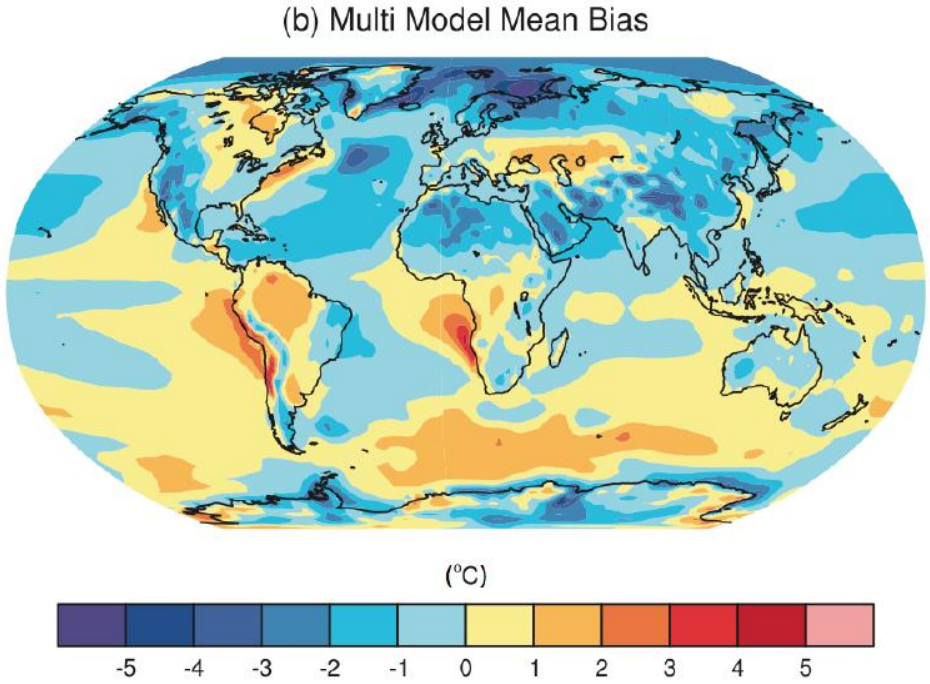
From climate simulations to impact models

Future society
GHG emissions
Climate model
Regional scenario
Impact model
Local impacts
Adaptation responses

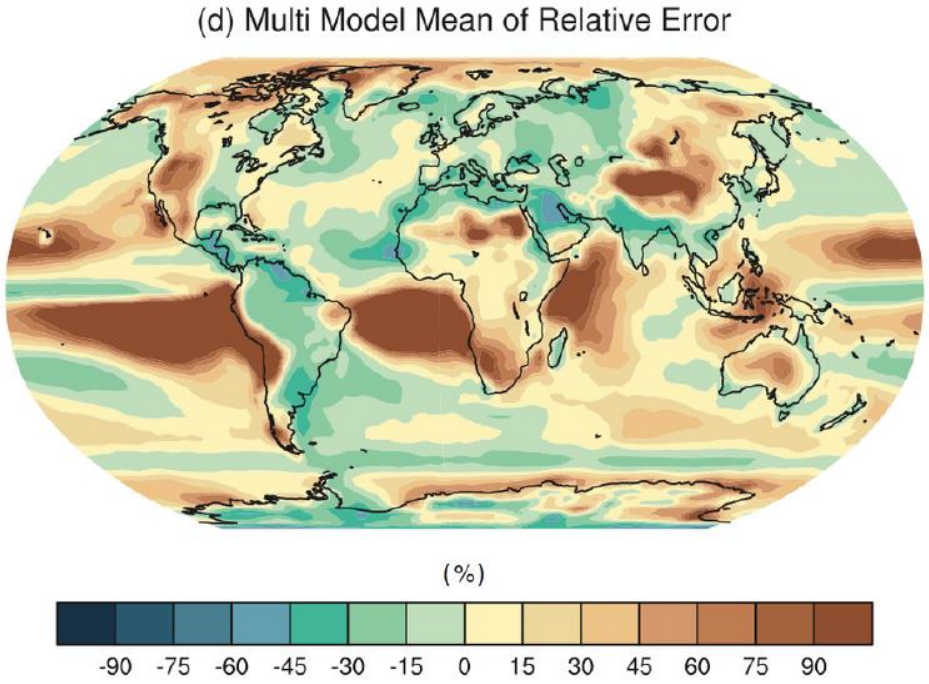
Many impact models



But GCMs have biases…



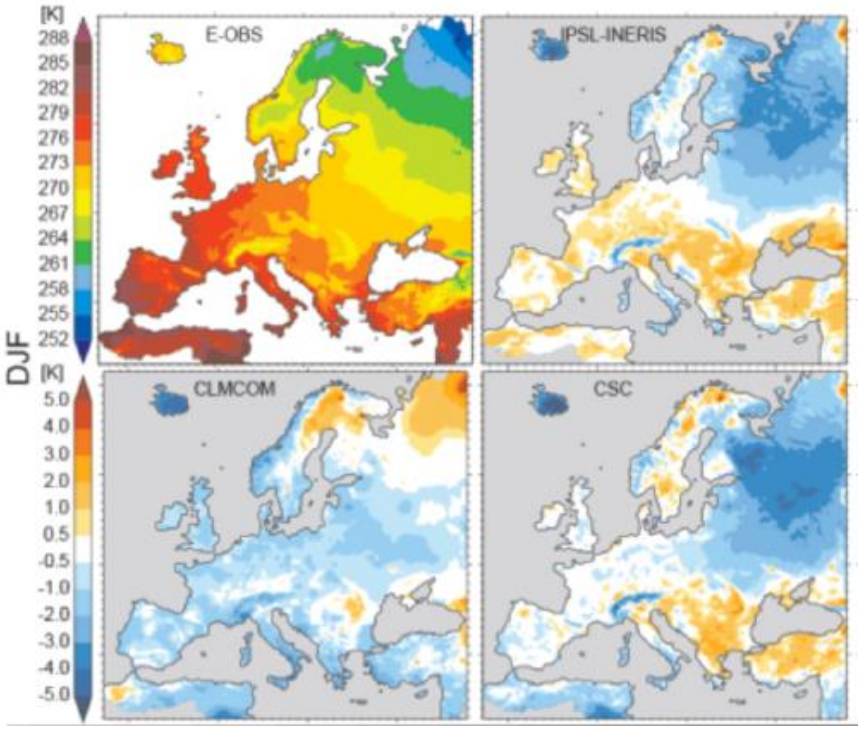
Temperature



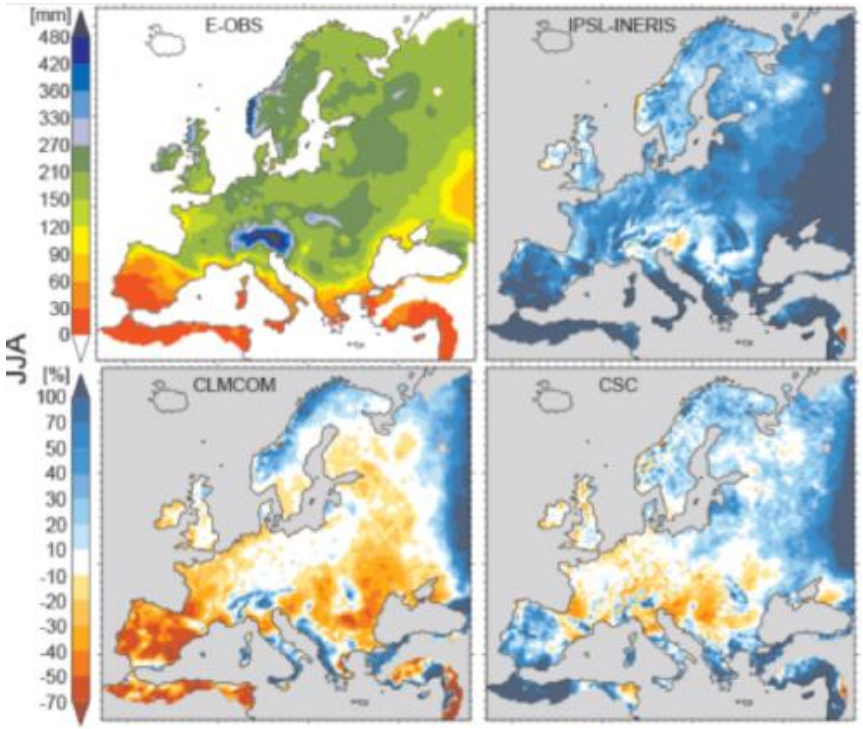
Precipitation

Source: Flato et al., IPCC AR5, 2013

… RCMs as well …



Temperature

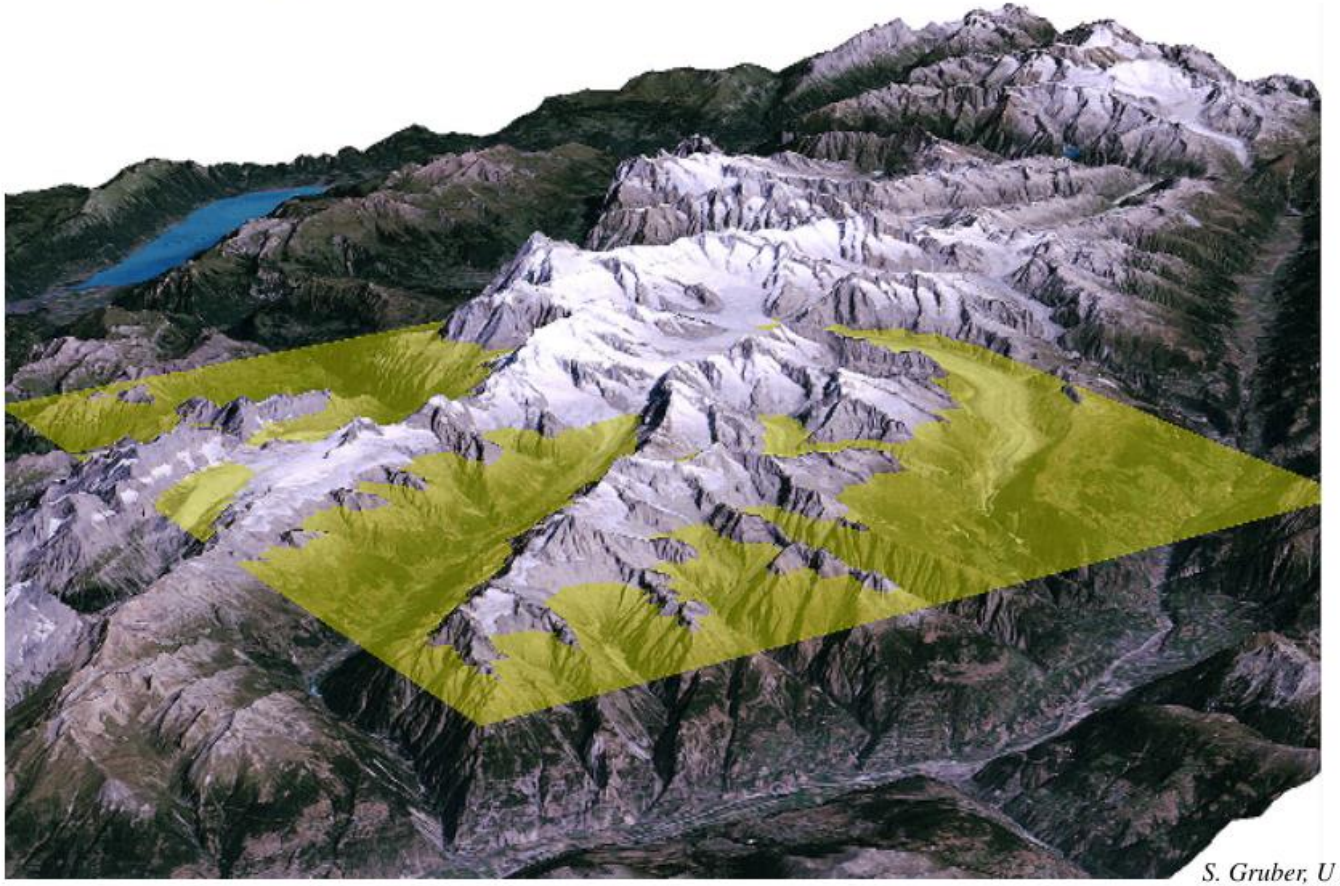


Precipitation

Source: Kotlarski et al., Geosci. Model Dev, 2014

Some are due to differences in resolution

18 km x 18 km RCM grid box



S. Gruber, U Zurich

Two types of post-processing methods

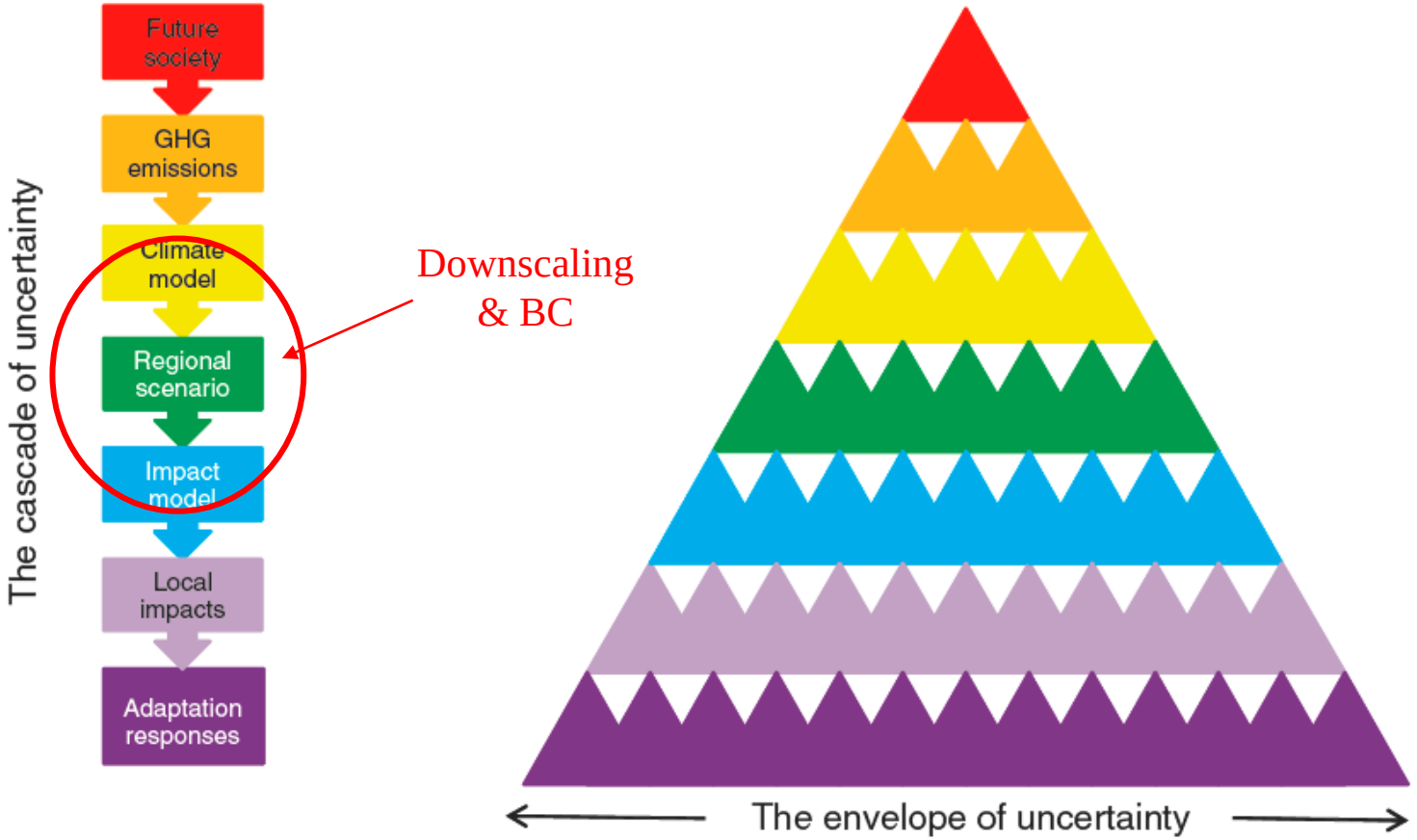
1. Statistical downscaling (Perfect prog)

2. Bias correction (Model Output Statistics)

Philosophy and principles,

not all variants and methods !!

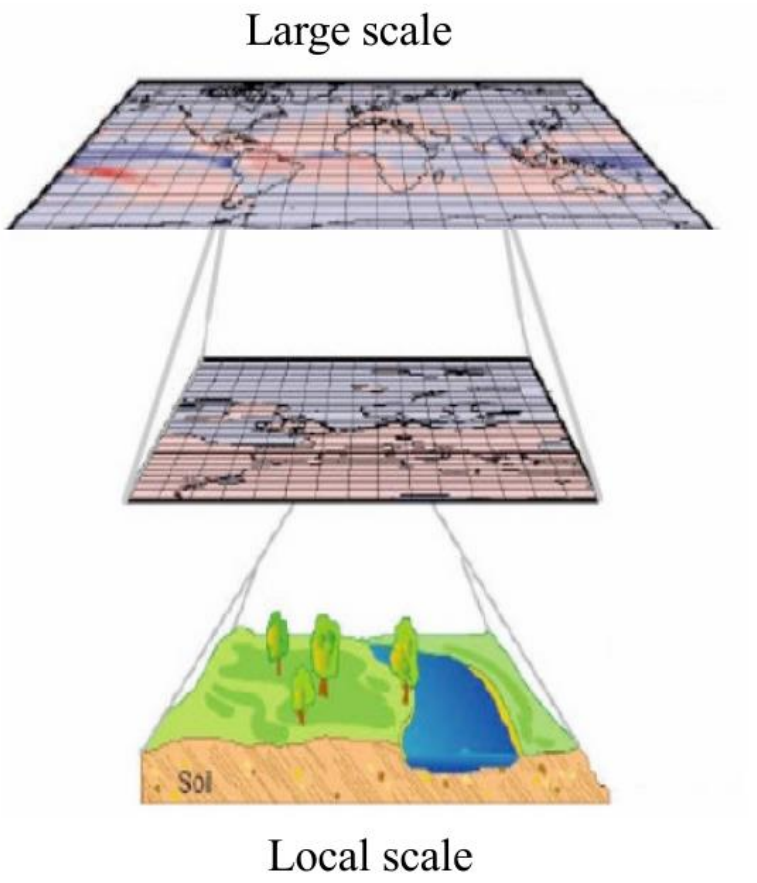
Not that easy: some (!) uncertainties



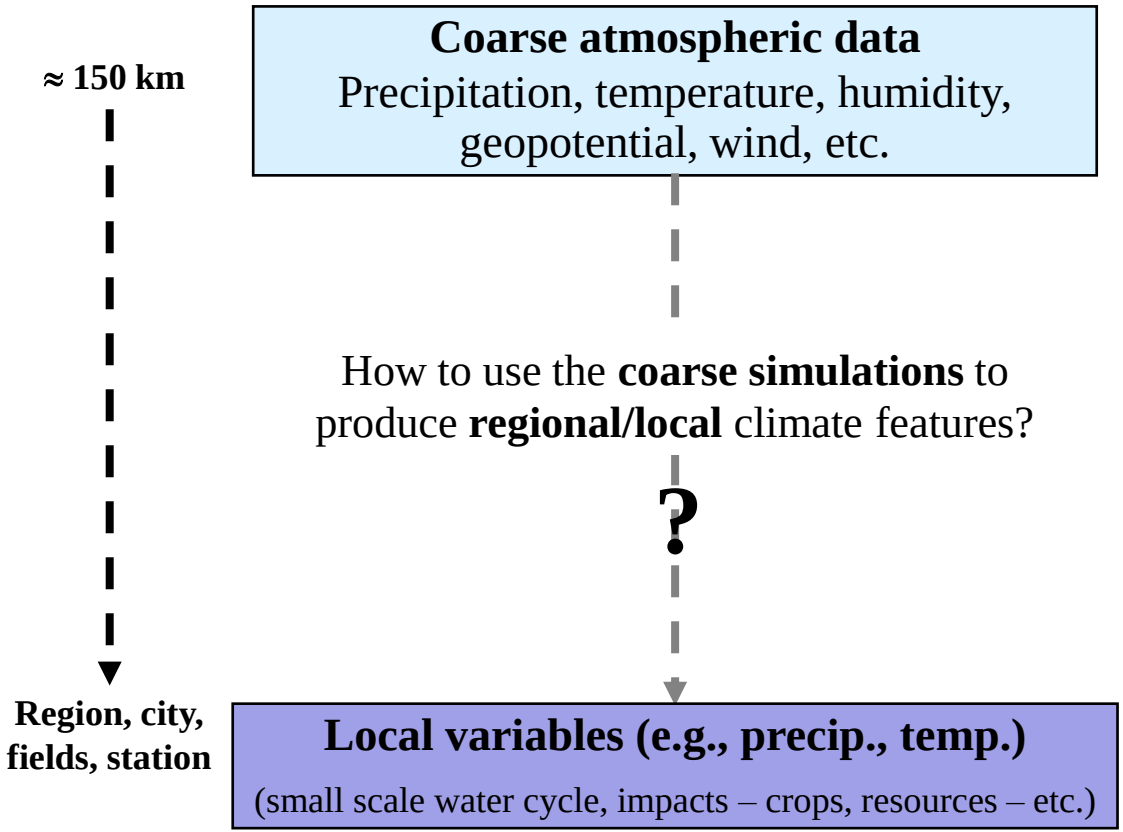
What is downscaling ???

Definition:

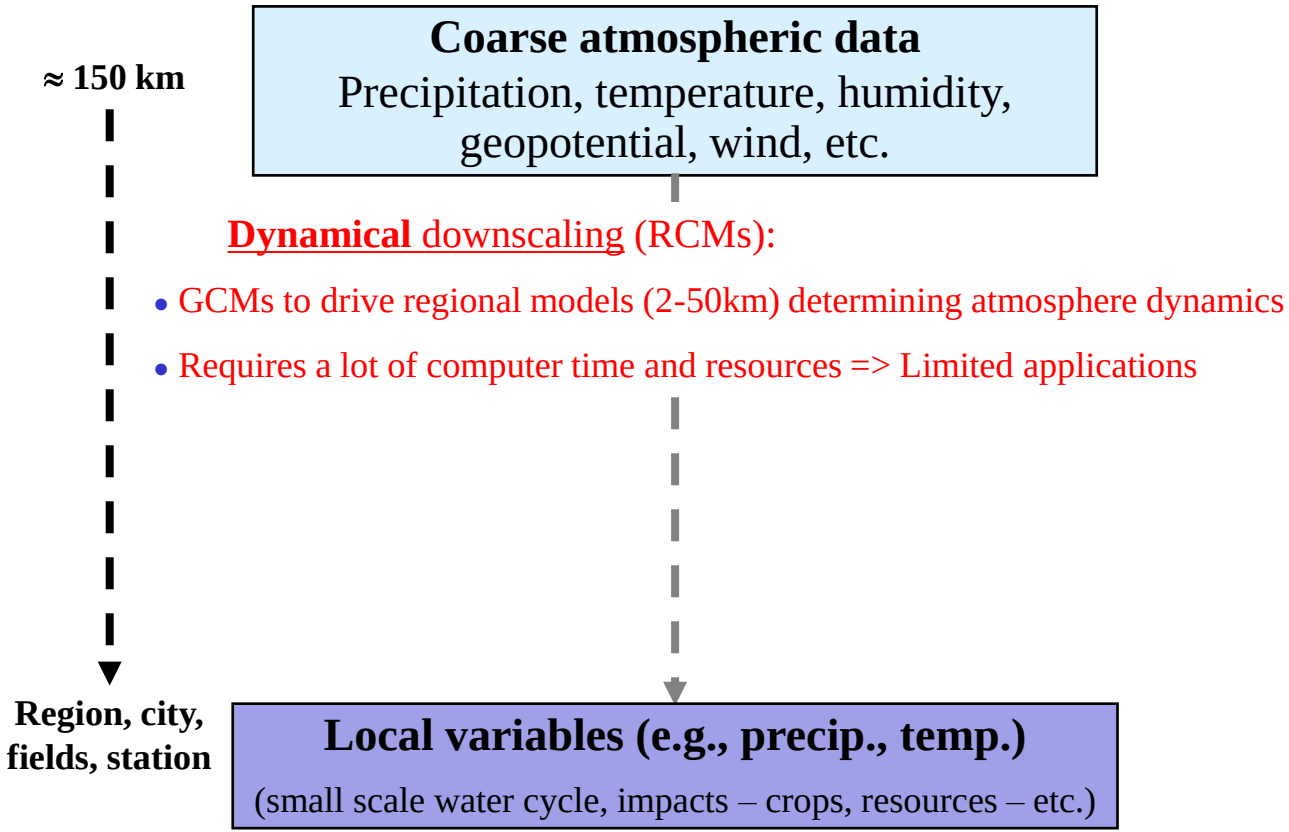
Downscaling is the action of generating climatic or meteorological values and/or characteristics at a local scale, based on information (e.g., from GCM or reanalyses) given at a large scale.



How to downscale?: The basics



How to downscale?: The basics



How to downscale?: The basics

≈ 150 km

Coarse atmospheric data
Precipitation, temperature, humidity, geopotential, wind, etc.

Dynamical downscaling (RCMs):

- GCMs to drive regional models (2-50km) determining atmosphere dynamics
- Requires a lot of computer time and resources => Limited applications

Statistical downscaling:

- Based on statistical relationships between large- and local-scale variables
- Low costs and rapid simulations applicable to any spatial resolution
- Uncertainties (results, propagation, etc)

Region, city, fields, station

Local variables (e.g., precip., temp.)
(small scale water cycle, impacts – crops, resources – etc.)

Perfect Prognosis

Trouver comment transformer une réalisation x_i en une réalisation y_i.

Un exemple de modèle classique

$$Y = f(X) + \epsilon$$

- approche par fonction de transfert / régression, on cherche à modéliser

$$\mathbb{E}[Y|X = x] = f(x)$$

- approche par générateur de temps stochastique, on cherche à modéliser la variable aléatoire

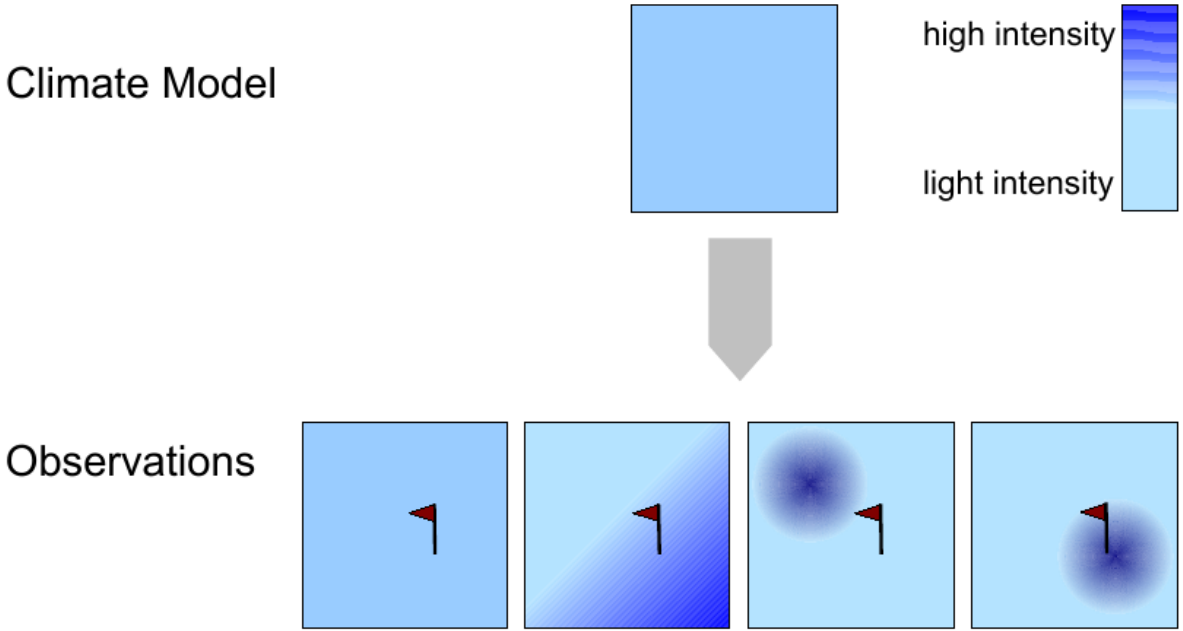
$$(Y|X = x) = f(x) + \epsilon$$

  en essayant d'estimer la fontion f et de modéliser la distribution du bruit ϵ.

Les predicteurs sont supposés parfaits.

On a besoin de l'appariement temporelles entre les variables X_i et Y_i.

One Grid Box State ↔ Several Local States

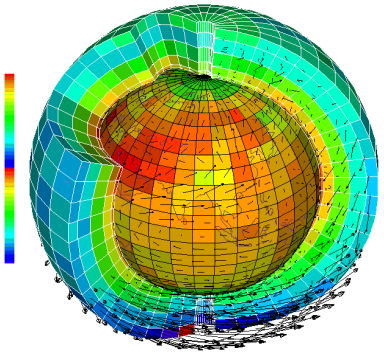


Grid box variability does not explain all local variability

Large-scale & Local-scale data

Large-scale data = Data to downscale or BC

- Global Climate Model = General Circulation Model (GCM)
  - Computer code(s) *simulating* the main characteristics (pressure, temp., prec., etc.) of the Earth system
  - Based on physical equations

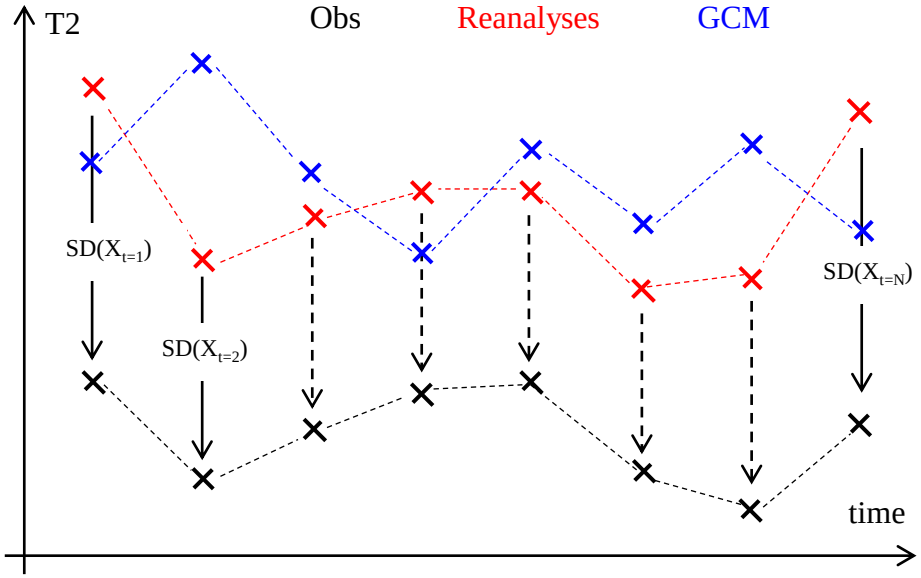


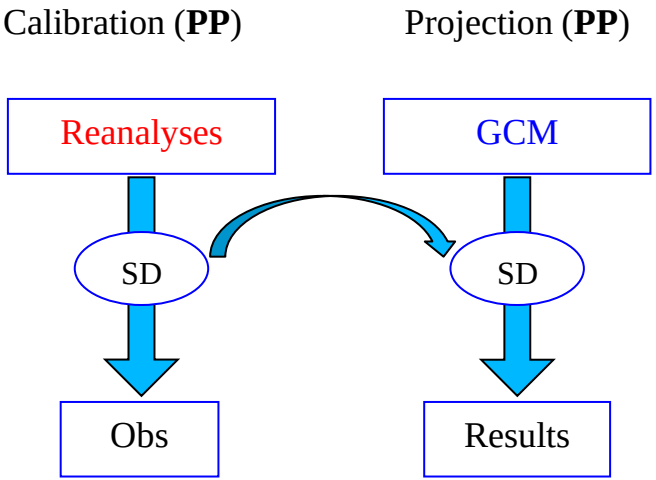
Local-scale data = « **reference** » data to calibrate SD or BC methods

- Reanalyses
  - Based on "data assimilation" approach
- Observations
  - weather stations / satellites / radar

- Note: Climate ≠ Meteo !! (even though, same variables)

Perfect prognosis





Main **PP hypotheses**: GCM predictors have no bias & SD valid in proj. period

Main (implicit) assumptions of SDM

For calibration under (near-) **present** climate:

- A1: $\text{local scale} = f(\text{large scale, regional characteristics})$
- F1: We need local-scale data!!!

Using SDMs under **climate change**:

- A2: Predictors are relevant and realistically modeled by GCM
- A3: The predictors fully represent the climate change signal
- A4: The SDM is valid also under altered climatic conditions

TP
Downscaling with linear regression and analogues

There are more complex methods, e.g.:

Deep learning for downscaling:
https://github.com/paulaharder/deep-downscaling-overview