Organización de las Naciones Unidas para la Educación, la Ciencia y la Cultura

Oficina Regional de Ciencia para América Latina y el Caribe

Programa Hidrológico Internacional

CAZALAC

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Overview of the SimGen Package

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Introduction

Objective

The goal of this activity is to contribute to the development of strategies that can increase water productivity – in view of near-term climate change scenarios for different areas of the South Cone, and will focus on three likely areas for action: water shortage (drought), excess rainfall and/or increase in the frequency of extreme events (floods).

Specific outcomes

1. A new tool to decompose climatic variability and project it to near term climate conditions available for download

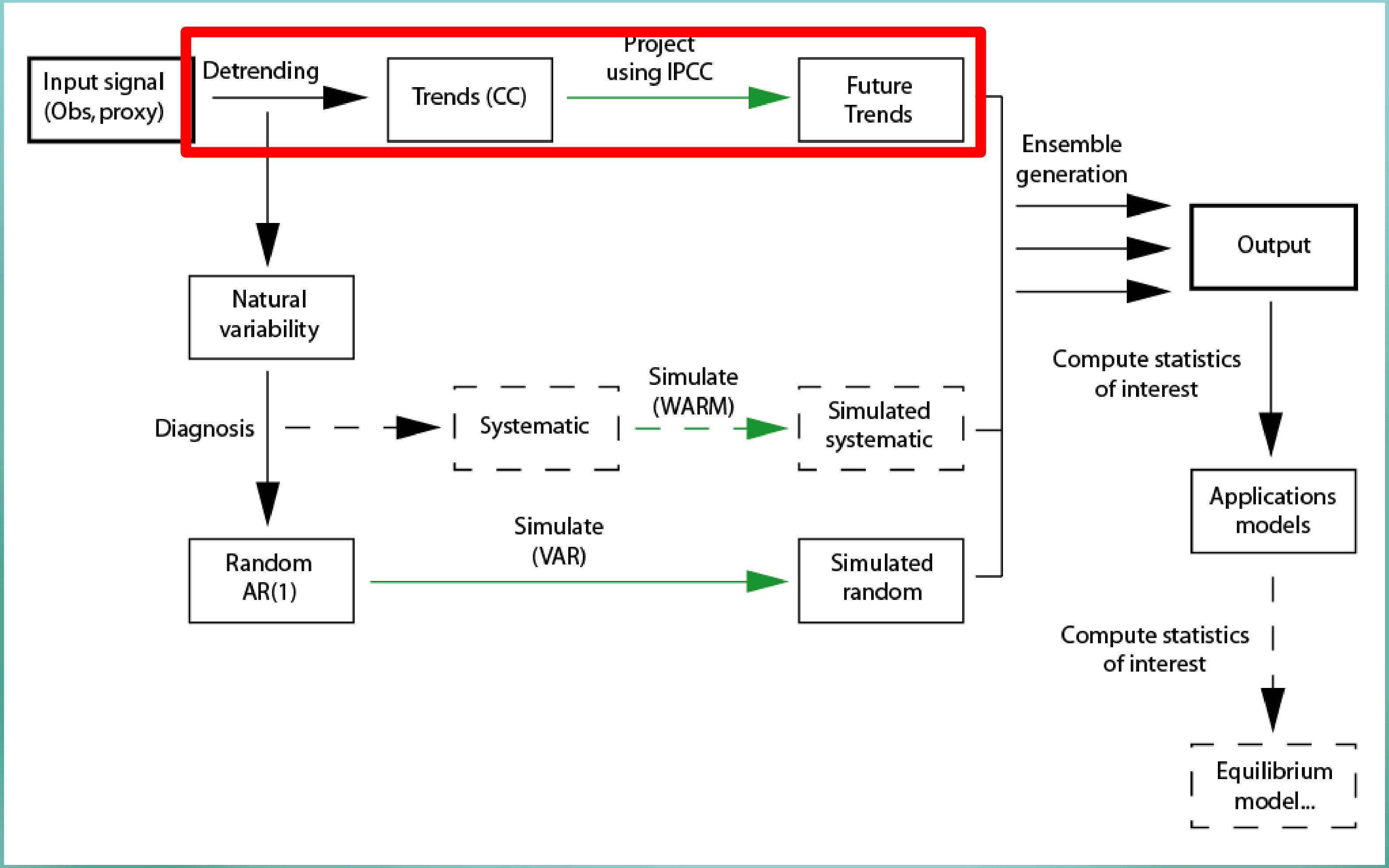
2. Water management models for three different water basins in place and well calibrated

3. Future climate data series downscaled to the measurement stations in the pilot areas available for download

4. Future water resources at the station level visualized by online interactive maps

Inside the SIMGEN Modeling Framework

Step 1: Treatment of trend



Inside the SIMGEN Modeling Framework

Step 1: Treatment of trend

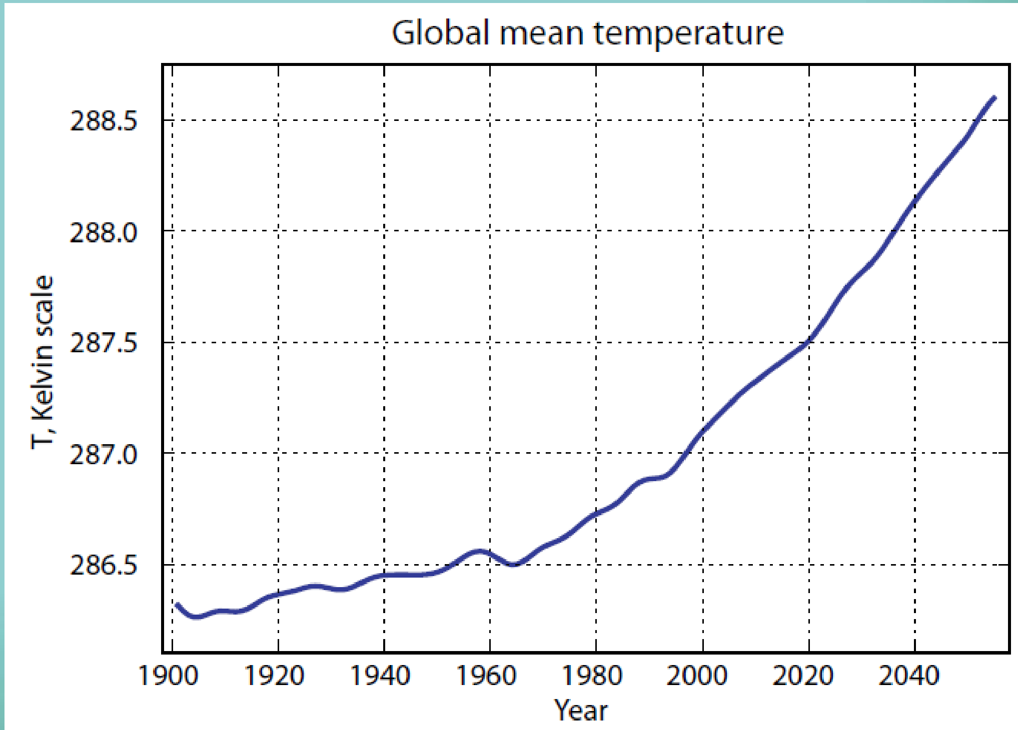
First, we require a *detrending* procedure, to remove the (deterministic) forced response from the observational data on which the decadal component of the simulation model is to be trained. In other words, we expect to fit the simulation model to a detrended series.

Second, in the simulation step we require some estimate of how the mean process level will evolve in the future, i.e., we need a plausible trend to project forward in time. These two trends, past and future, need not be the same.

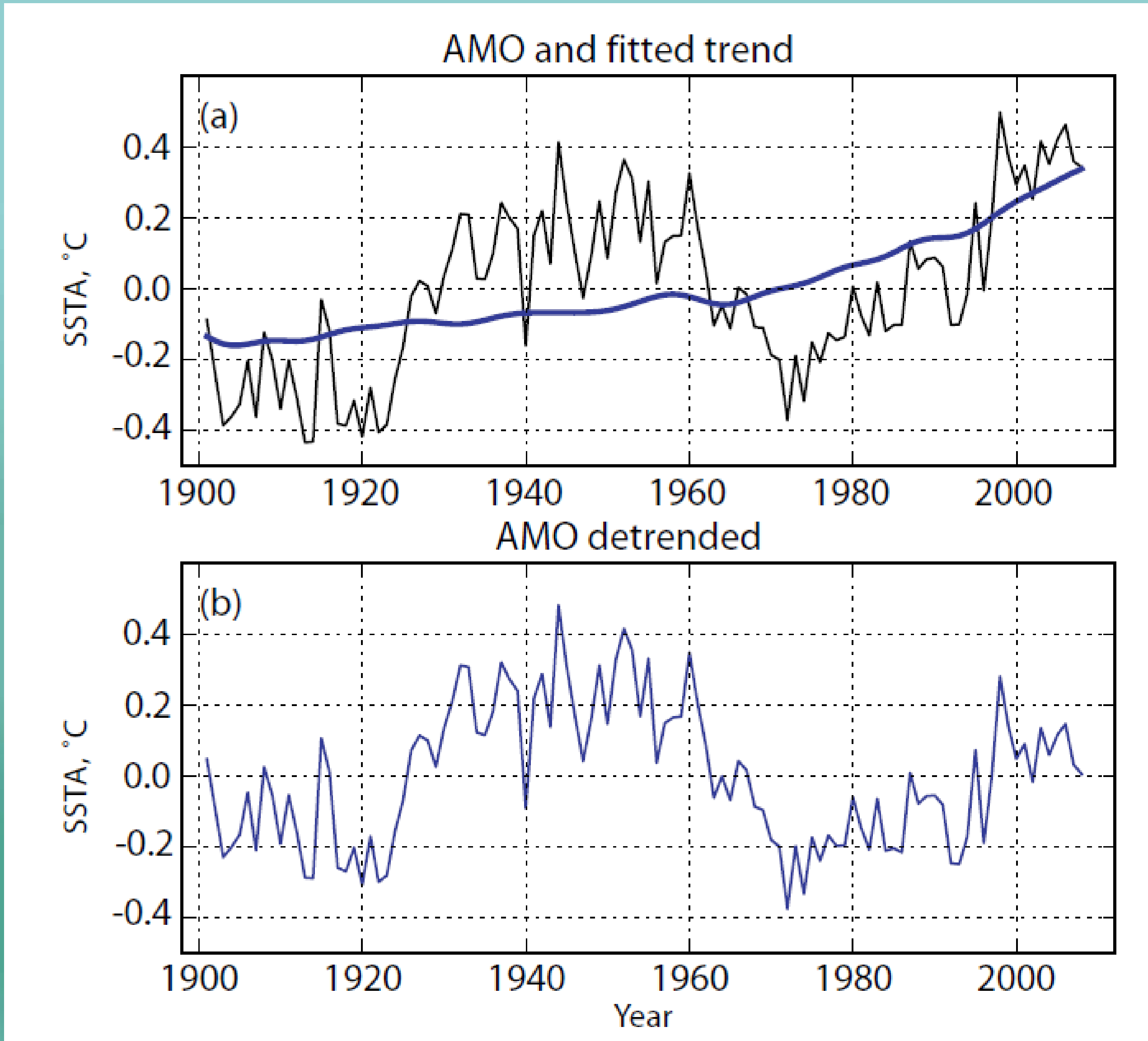
Detrending

Parameterize trend in terms of *climate sensitivity*. Why?

- No anthropogenic forcing = No global warming = Future trends are null.
- The globe is not expected to warm uniformly
  - some regions will warm more rapidly, others less so, than the global mean.
  - Fitting local trends based on global climate sensitivity takes this variation into account.



Detrending

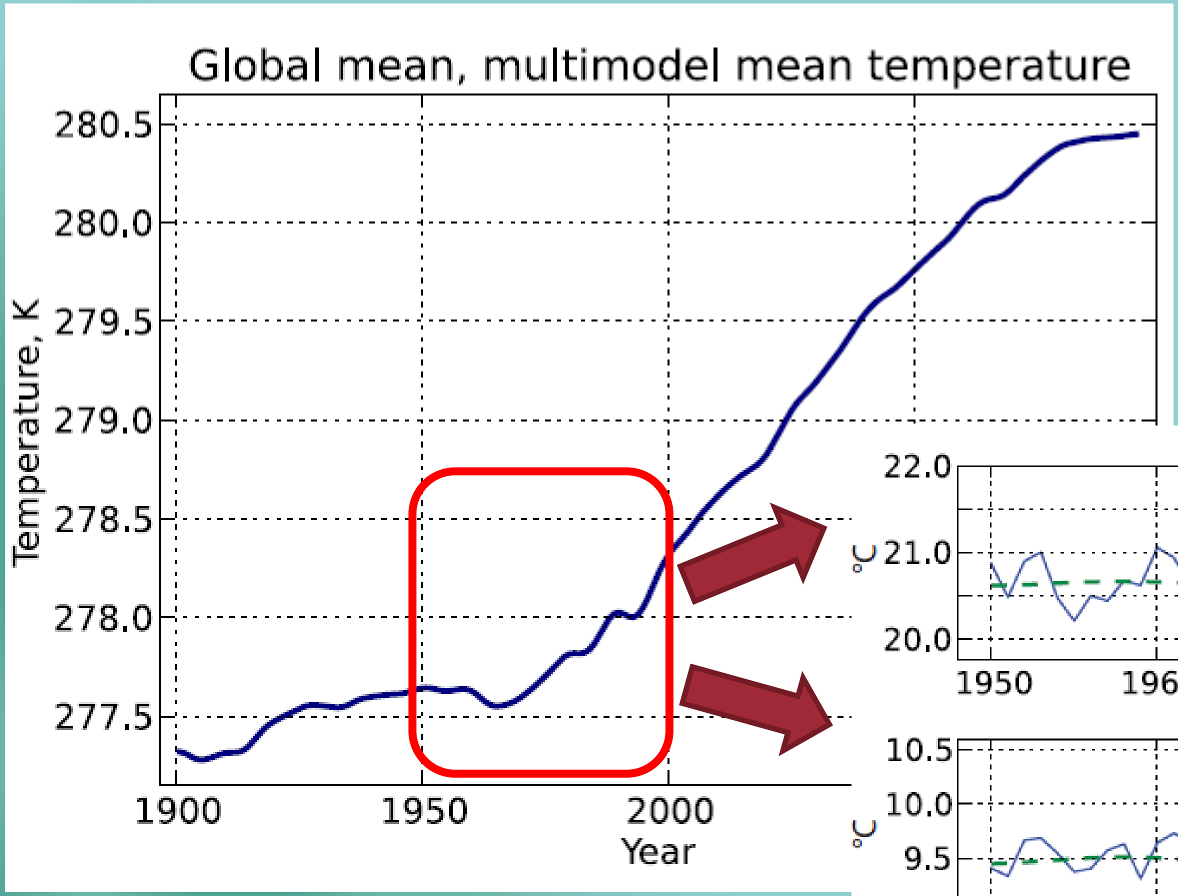


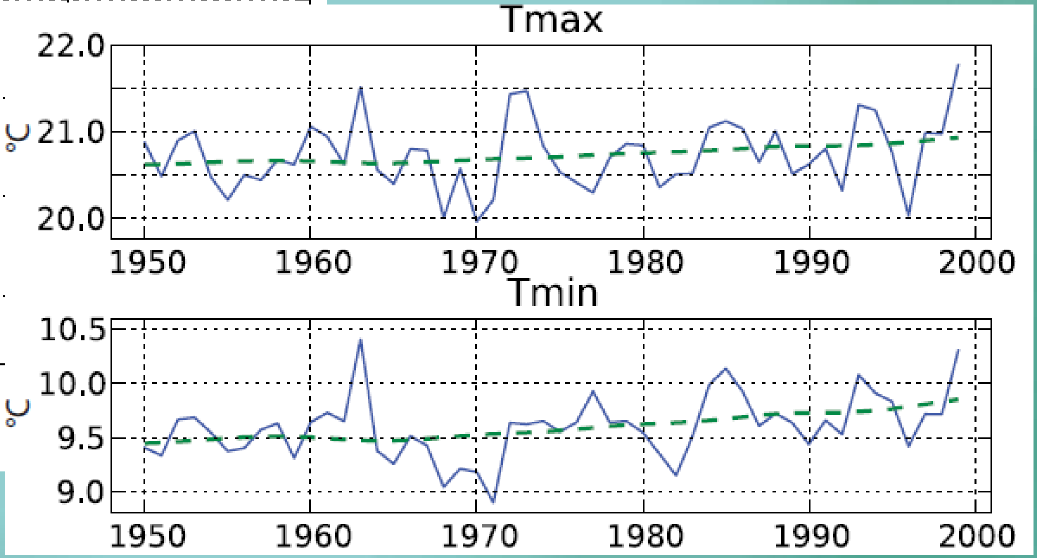
AMO and fitted trend
(a)
0.4
0.2
0.0
-0.2
-0.4
SSTA, °C
1900
1920
1940
1960
1980
2000
AMO detrended
(b)
0.4
0.2
0.0
-0.2
-0.4
SSTA, °C
1900
1920
1940
1960
1980
2000
Year

Forward projection of the trend: Temperature

'Downscaling' of temperature sensitivity to global warming <u>for each station</u>

Allows spatial variability in CC response

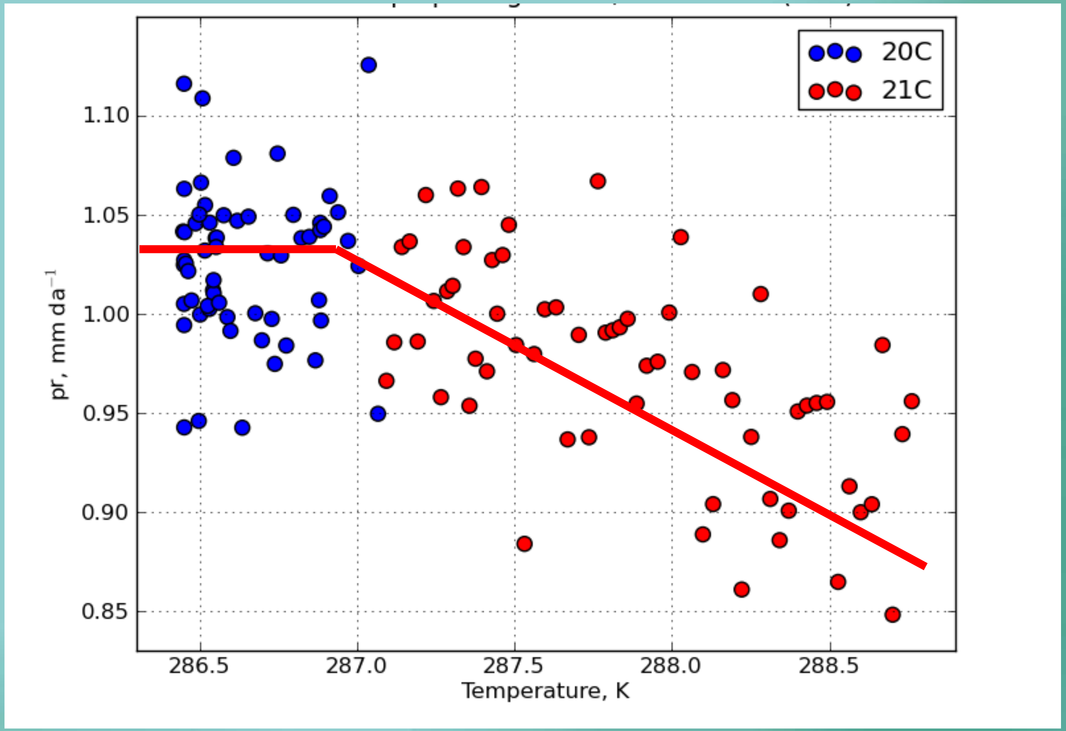




Forward projection of the trend: Precipitation

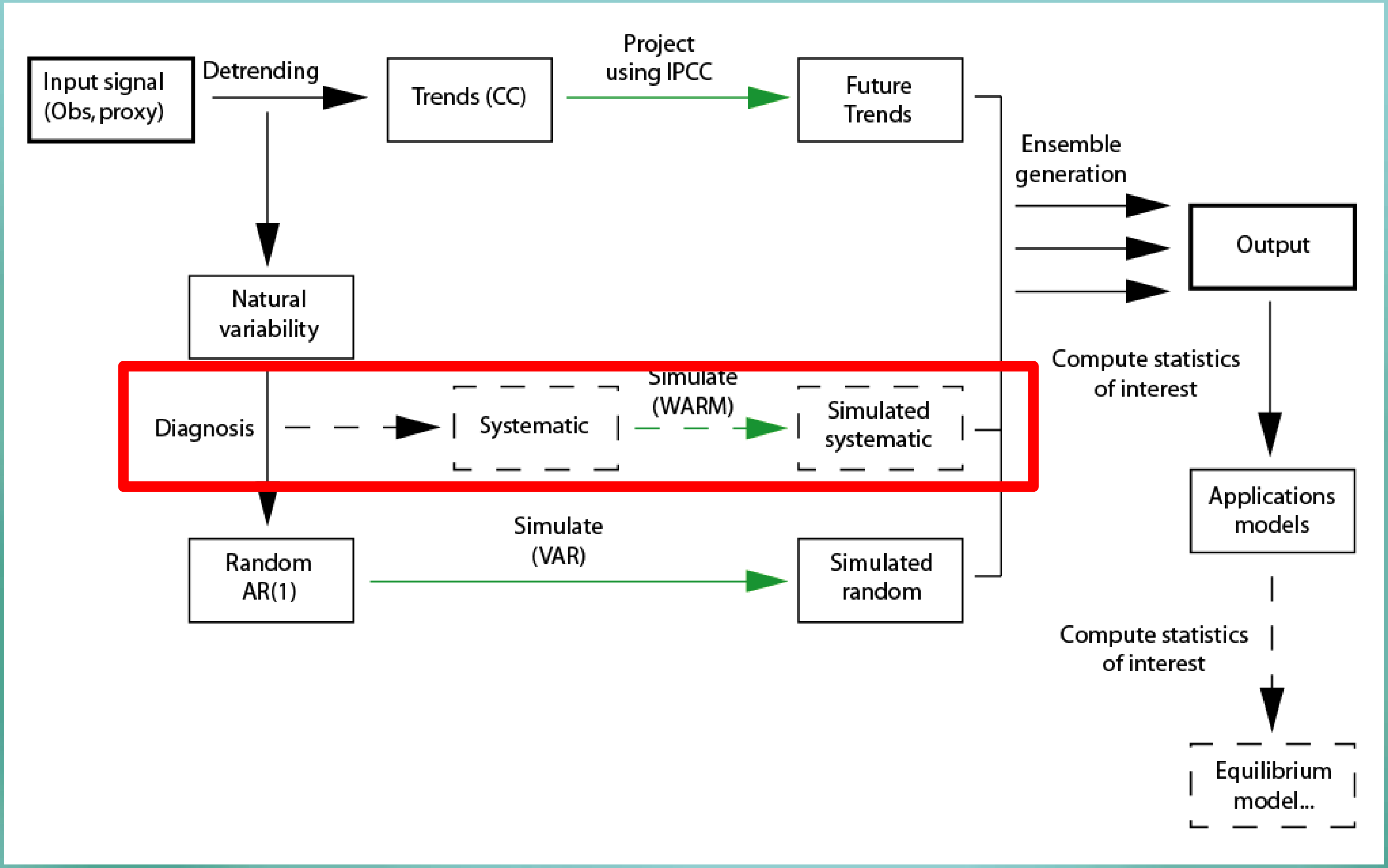
Precipitation trends are best parameterized in terms of <u>% change per degree of global temperature increase</u>, rather than absolute change. Why?

- Precipitation amounts cannot fall <u>below zero</u>
- <u>Regional sensitivity</u> to be "propagated" to a network of stations having differing precipitation means



Methodology

Step 2: Selection of the Decadal deterministic component



Treatment of “deterministic” components

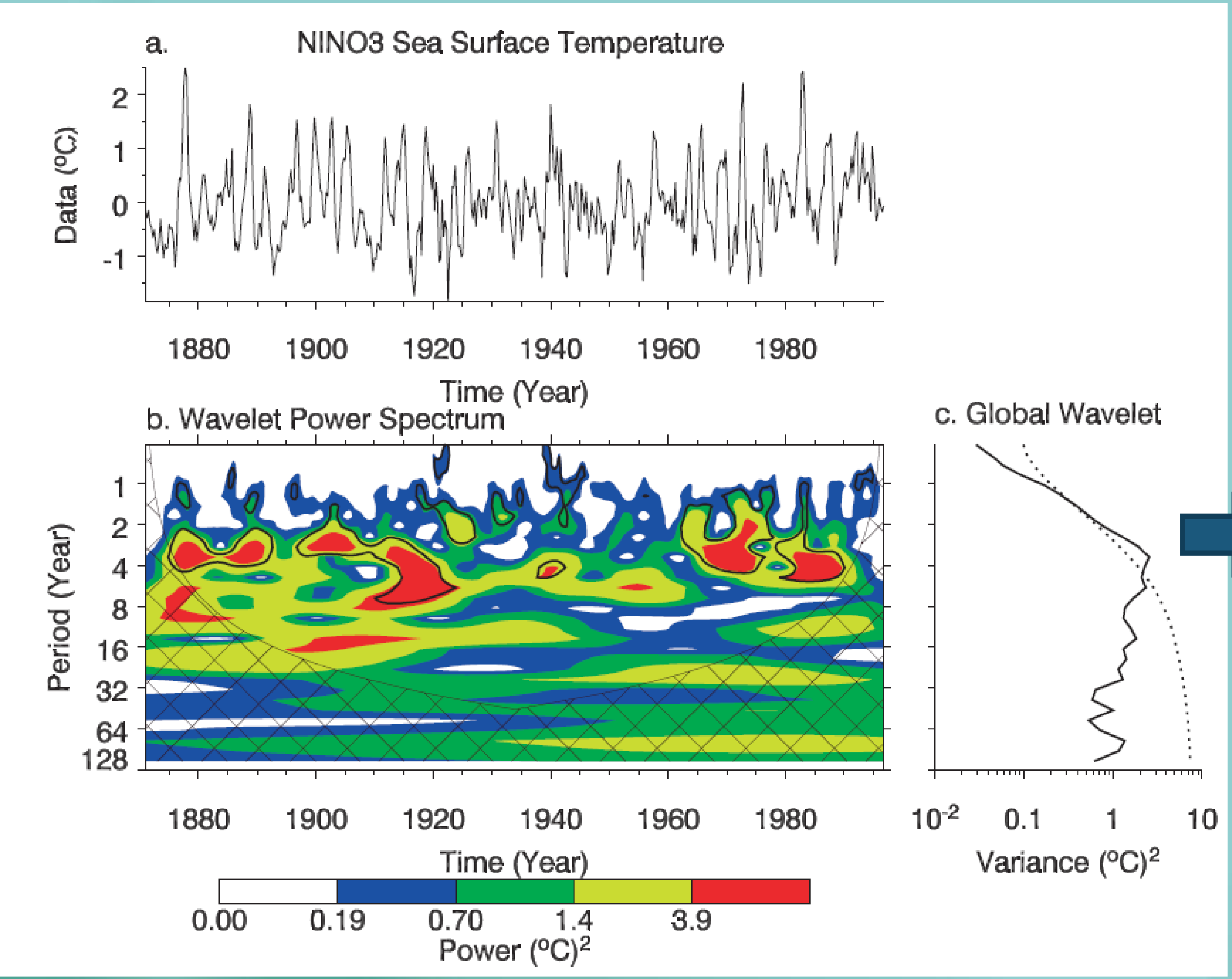
Working method

- Fit a statistical model to the <u>detrended</u> time series sequence comprising a wide spectrum of variability on periods of one year and longer.
- Generate the “low-frequency” (i.e., annual-to-superannual) component of the simulated sequences.
- Determine the extent to which this “natural” component of variability represents the expression of <u>deterministic</u>, as opposed to <u>random</u> processes.

➡ More than just ‘redness’ in our timeseries?

Treatment of “deterministic” components

Wavelets

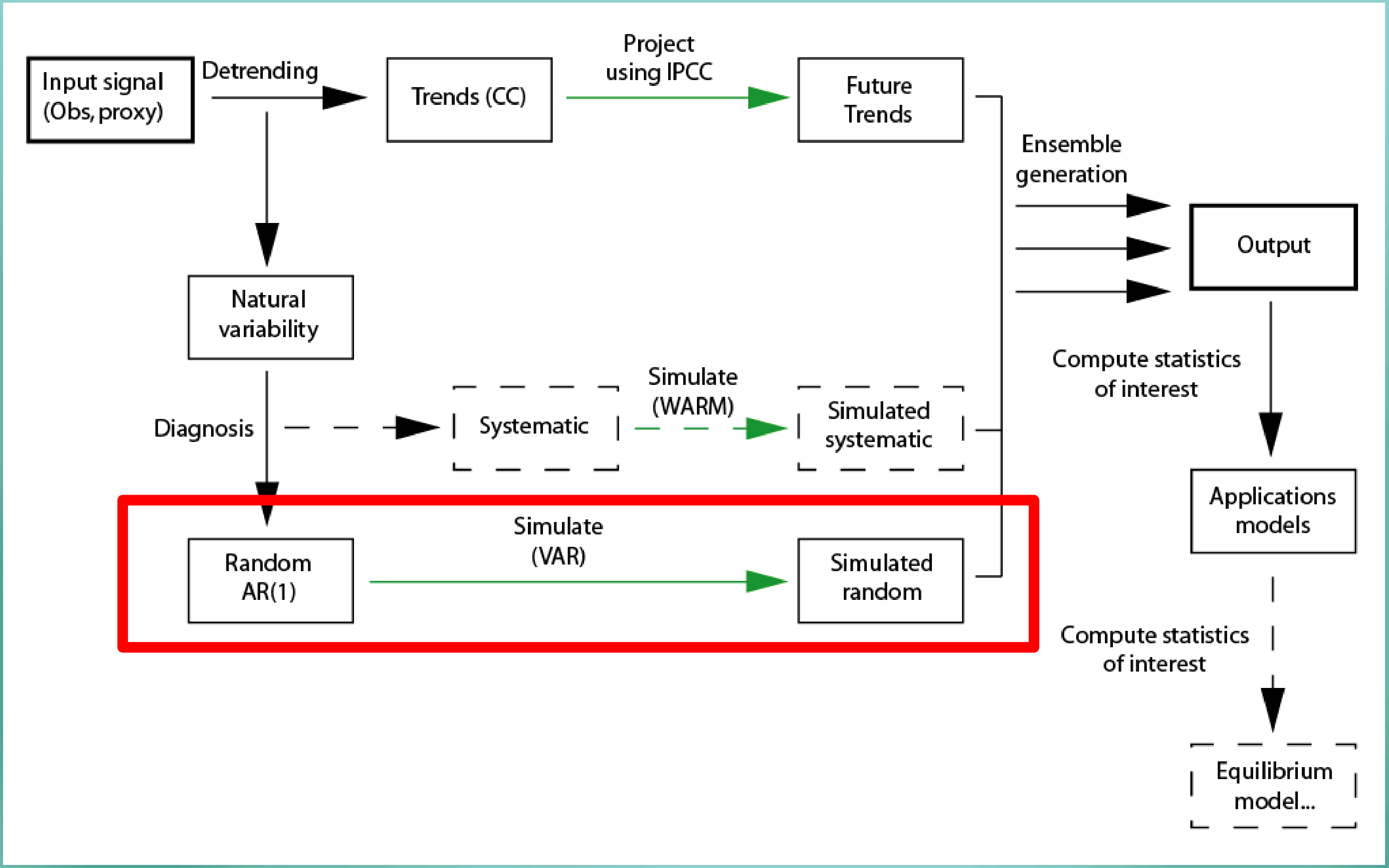


Deterministic part
(2-8 years oscilation)

- A red-noise model alone would not suffice
- ARMA(3,1) model needed
- Not active continuously

Methodology

Step 3: Selection of the Decadal stochastic component



Treatment of random components

Working method

- Random components are treated via a purely stochastic model.
- Most terrestrial decadal variability falls into this category, since the recognized modes are principally oceanic, or ocean-atmosphere coupled.
- A first-order autoregressive model is taken as the basic building block for the random simulation component.
- For water management: Multivariate Input needed (Precipitation + Temperature)

⇒ First-order vector autoregressive model needed: VAR

Requirements of Vector Autoregressive Models

Intervariable correlation

Observations

	pr	Tmax	Tmin
pr	1.000		
Tmax	-0.447	1.000	
Tmin	0.068	0.733	1.000

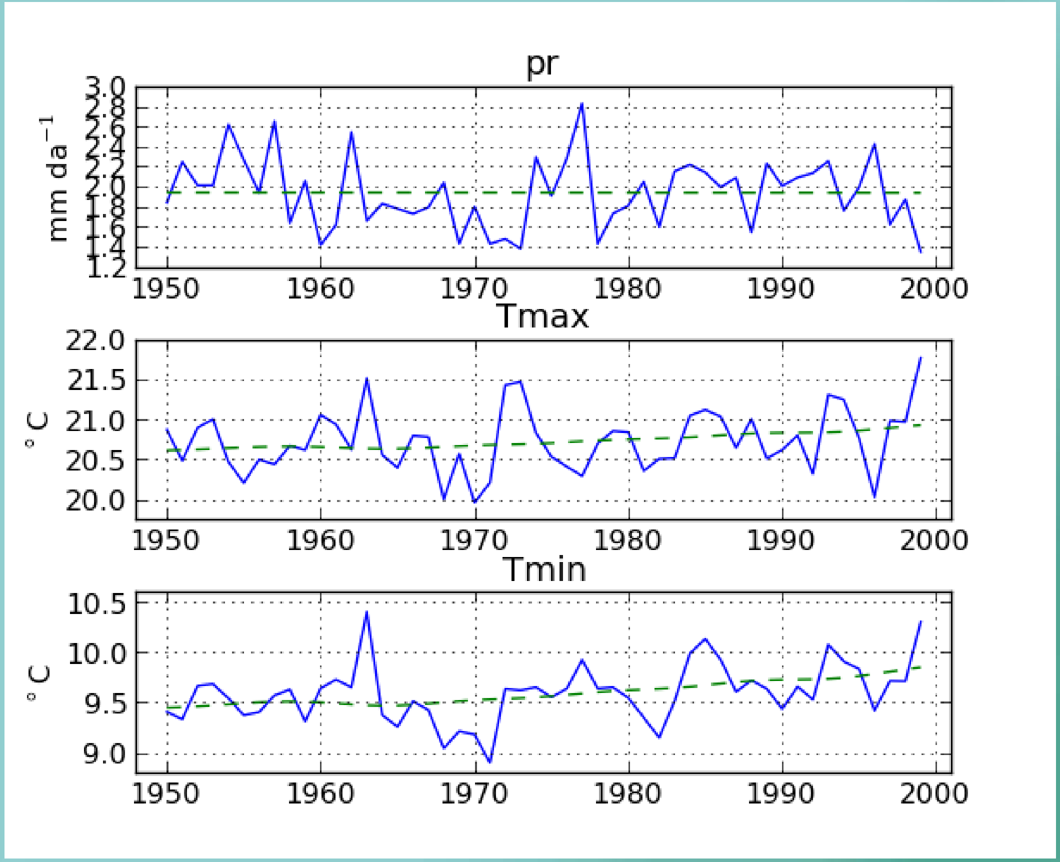
Simulation

	pr	Tmax	Tmin
pr	1.000		
Tmax	-0.445	1.000	
Tmin	0.068	0.733	1.000

Serial autocorrelation

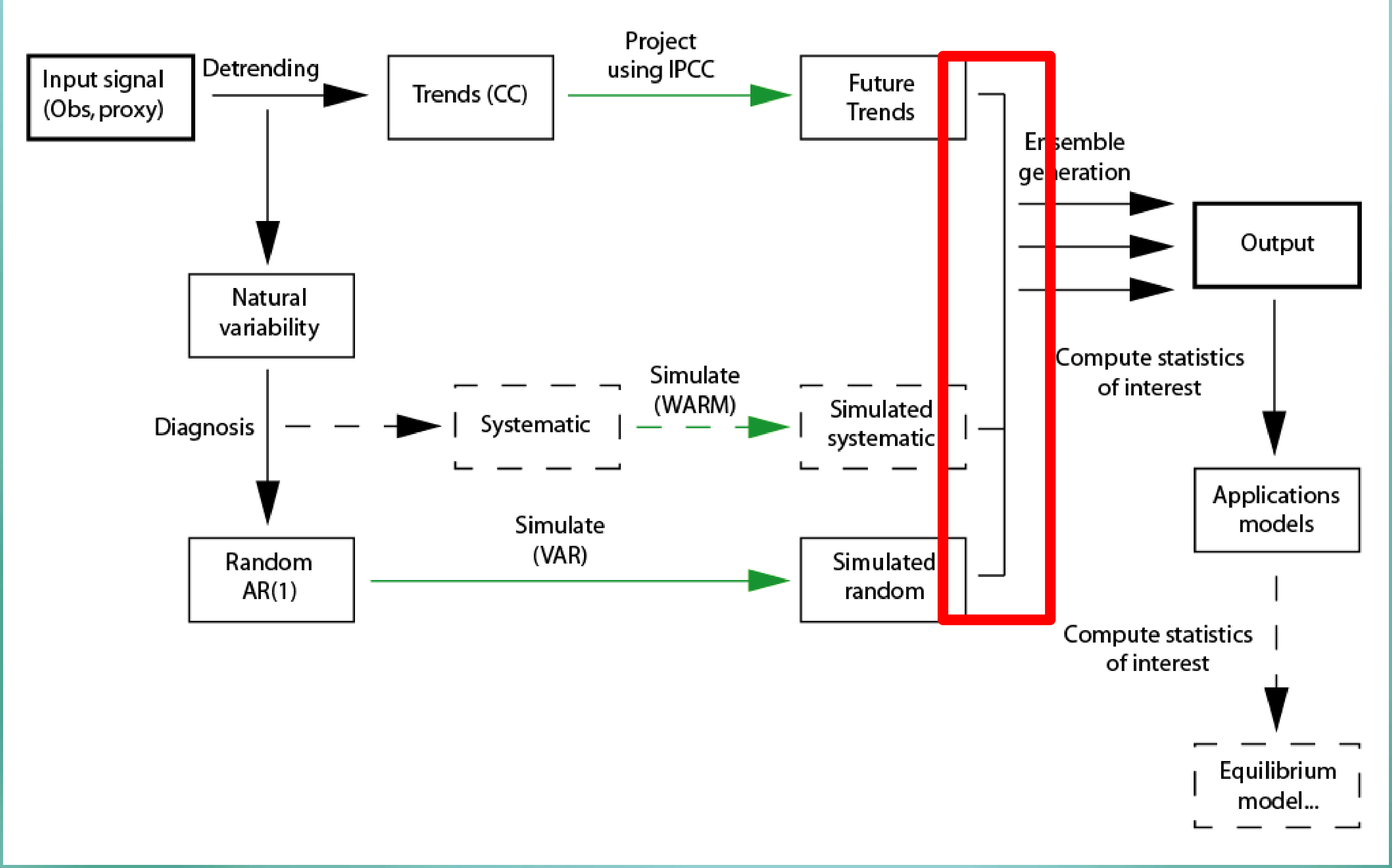
	pr	Tmax	Tmin
Obs	0.004	0.168	0.297
Sim	-0.008	0.176	0.303

Annualized data (171-station means)



Methodology

Step 4: Reassembly



Reassembly / downscaling

Step 4-A: Annual/decadal variability

- Deterministic elements from the low-frequency signal component are simulated first.
- To these a random component, based on the selected stochastic model (VAR) is added

➡ The result of this step is a simulation of regional low-frequency variability, annually resolved and without trend, of a specified length, typically several decades.

Reassembly / downscaling

Step 4-B: Projection of the Trend

- Trend is extended into the future:
  - If the 21st-century sensitivity is expected to be the same as that of the 20thcentury, the trend is projected forward using the coefficients from the 20th-century regression, applied to the 21st-century global temperature signal.
  - If the 21st-century sensitivity is GCM-derived this sensitivity is used instead as the basis for trend projection. For temperature the trends are applied additively; for precipitation, multiplicatively.

Reassembly / downscaling

Step 4-C: Spatial downscaling

- Trend computations are based either on station-level regressions or GCM-based estimates. Thus, these are already implicitly downscaled, or ready to be downscaled
- For the low-frequency component the procedure differs somewhat: Over a region, local stations will not be perfectly correlated with the regional decadal signal. For this reason the regional simulation is propagated to the local level using linear regression, a residual being supplied in the form of uncorrelated noise to insure that station variance is conserved. The downscaling of simulated regional low-frequency variations, as distinct from trend, is performed in the same manner for both temperature and precipitation variables.

Reassembly / downscaling

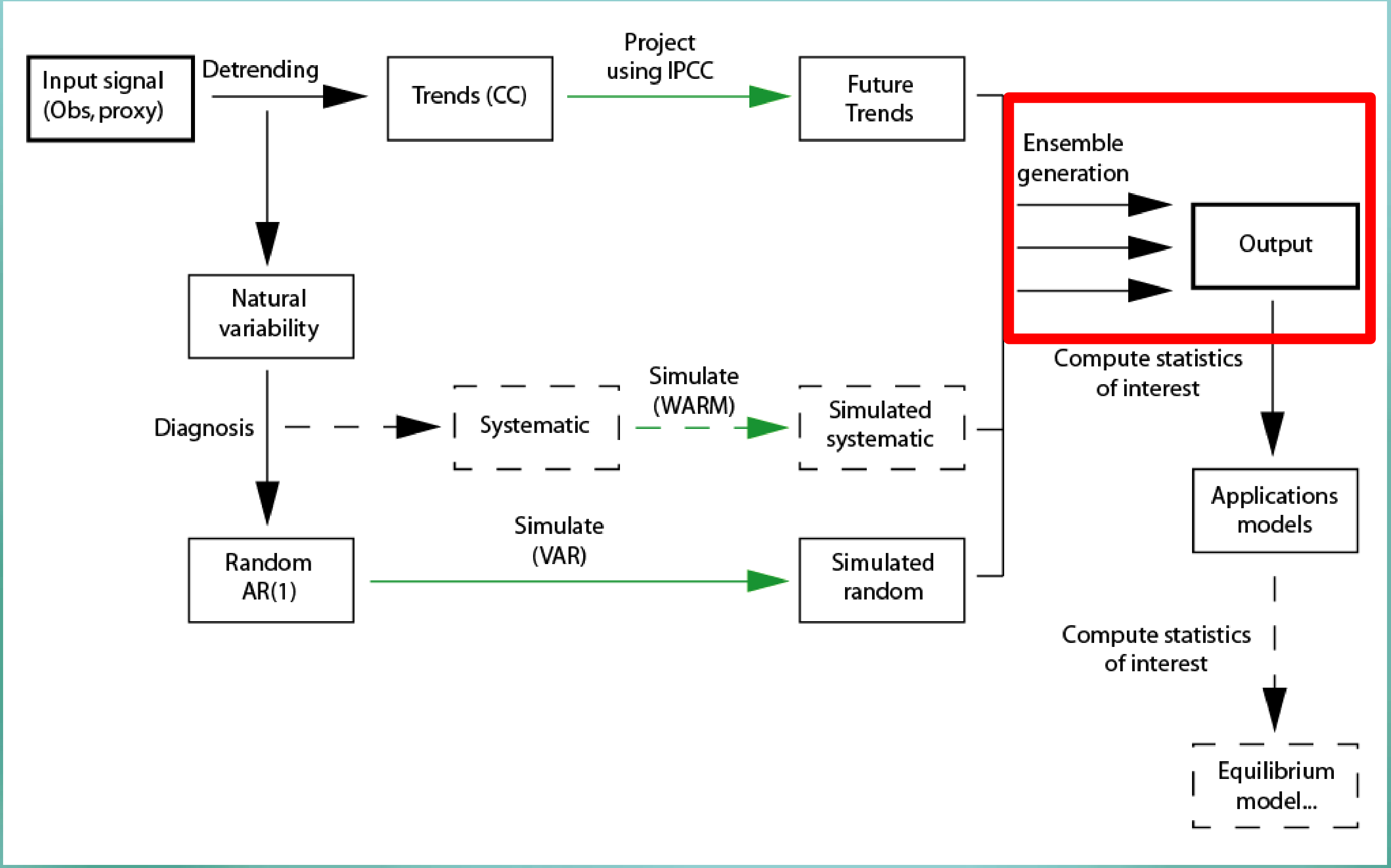
Step 4-D: Temporal downscaling

- Entire years from the observational record are resampled at random, and the daily values rescaled to have the annual mean value of the regional simulation. This method preserves the seasonal cycle, daily variability and covariances, not only across variables but across the entire network being simulated, while stripping out the interannual component and substituting for it the simulation value.

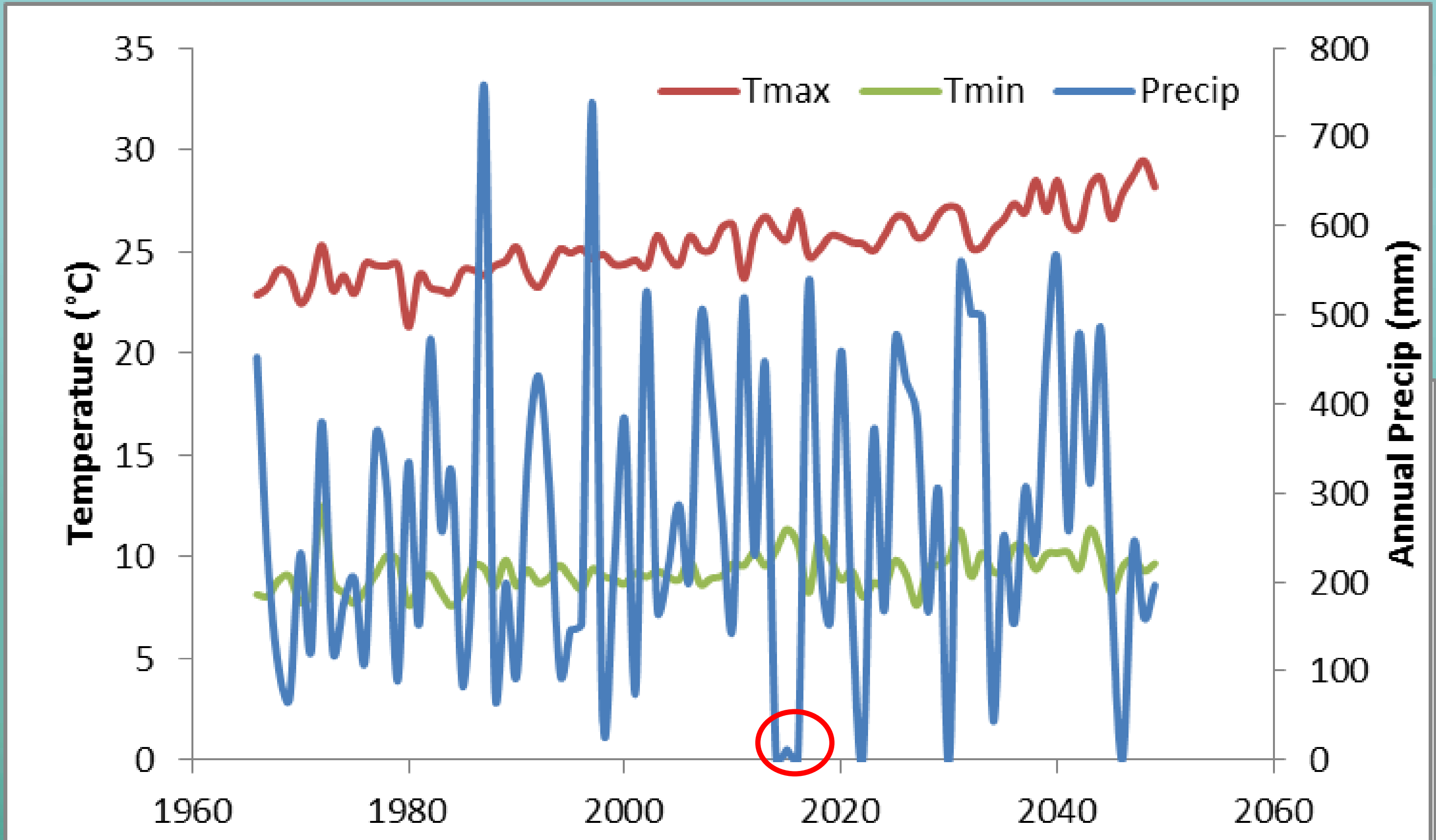
➡ The result is a set of hybrid station-level simulations, each having the subannual characteristics of the station but the annual-superannual properties of the simulation.

Methodology

Step 5: Generate stochastic simulations of projected Precip, Tmin, Tmax

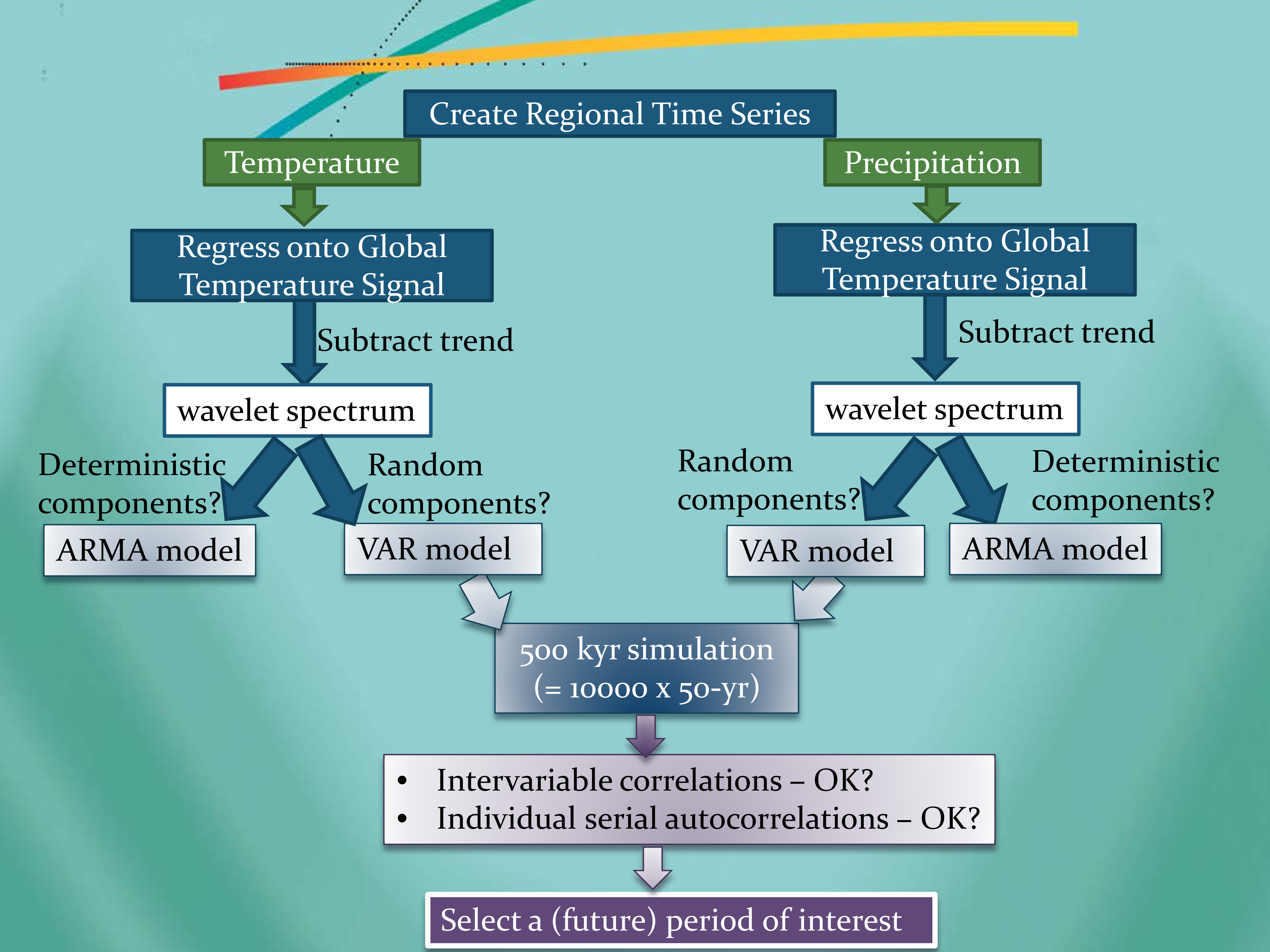


Downscaling of simulations to the local level



- Continuous time series visualize extreme events which differ from past ocurrences
- Allows to evaluate the probability of droughts and extreme events and evaluate the potential impact on water resources

1960 1980 2000 2020 2040 2060



Create Regional Time Series
Temperature
Precipitation
Regress onto Global Temperature Signal
Regress onto Global Temperature Signal
Subtract trend
Subtract trend
wavelet spectrum
wavelet spectrum
Deterministic components?
Random components?
Random components?
Deterministic components?
ARMA model
VAR model
VAR model
ARMA model
500 kyr simulation (= 10000 x 50-yr)
• Intervariable correlations – OK?
• Individual serial autocorrelations – OK?
Select a (future) period of interest

Select a (future) period of interest

Downscale to all stations

Temperature vs. Global Temperature

Project 21stcentury Temperature trends

Regress stations on regional signal

Add natural variability (noise)

random resampling

Downscale to daily resolution

GCM projection vs. Global Tempeature (log)

Project 21st century Precipitation trends

Regress stations on regional signal

Add natural variability (noise)

random resampling

Downscale to daily resolution

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