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### ► To cite this version:

Vincent Chabot, Ludovic Bouilloud, Julie Capo, Gaëlle Collin, Viviane Gouget, et al.. Intermittent energy sources availability in case of cold peaks in future climate . 4th International Conferences Energy & Meteorology, Jun 2017, Bari, Italy. hal-01691066

**HAL Id: hal-01691066**

**<https://hal.science/hal-01691066v1>**

Submitted on 23 Jan 2018

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# Intermittent energy source availability during cold peaks in future climate

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## Context

CLIM4ENERGY project, as part of Copernicus Climate Change Service (C3S), aims to provide climate products tailored for the energy sector. The European electric power system is very sensitive to temperatures. The increase of intermittent renewable energies in the energy mix introduces an additional vulnerability to weather conditions. The contribution of intermittent renewable energies is analysed through wind and solar capacity factors built using meteorological fields (wind speed, radiation and temperature). Analysis at different time scales is necessary to help energy practitioners to take short and long term decisions.

## Objectives

**Design indicators tailored to the energy sector** based on meteorological fields to anticipate the risk of imbalance.  
**Provide coherent data** as well as analysis to energy practitioners at different time scales.

## Climate Change Analysis

Source : Eurocordex Climate projection datasets (>10 models)

**Consistency:** change is robust if 80 % of the models find the same tendency of change.

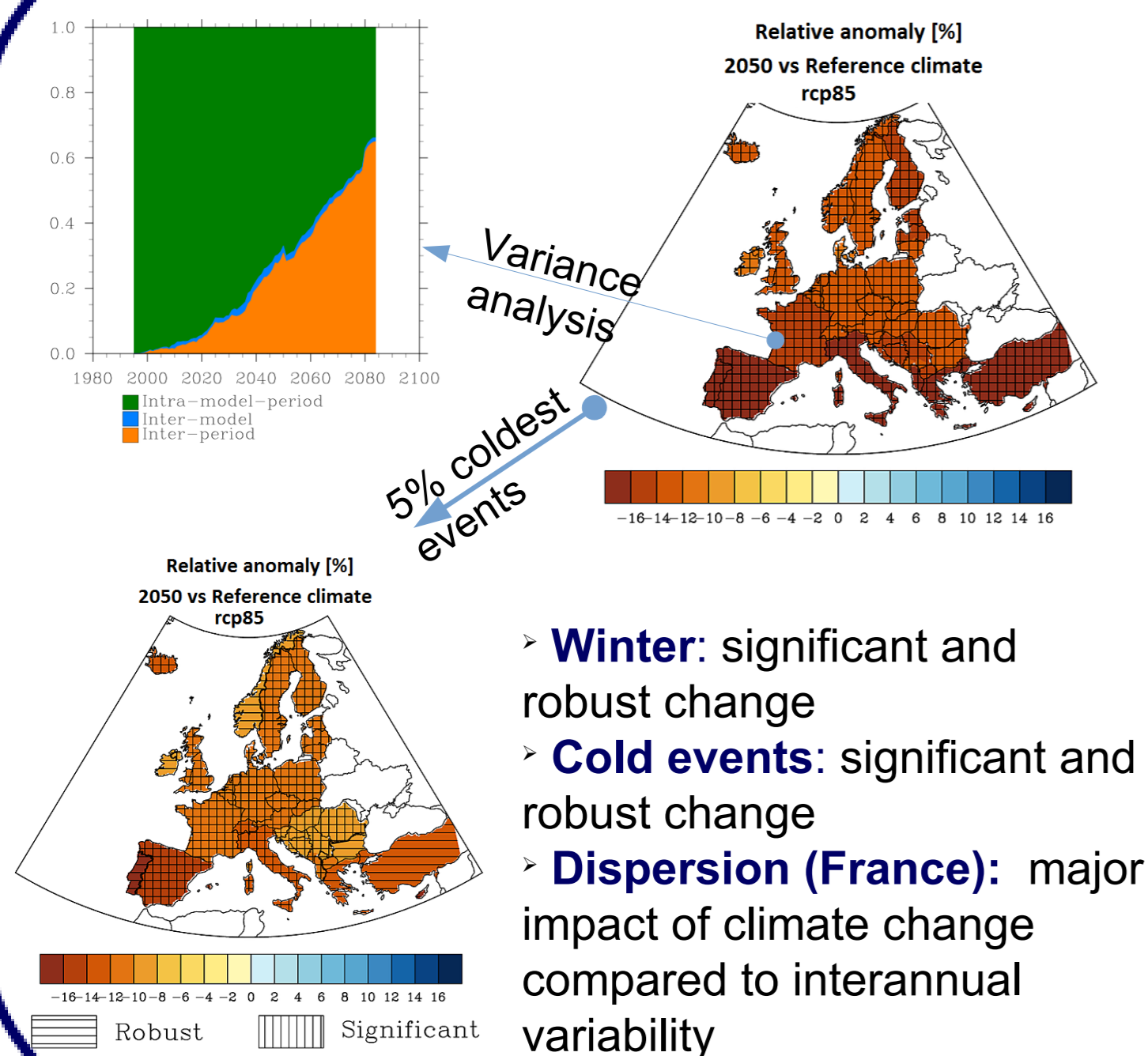
**Significativity:** A statistical test is performed for each model. Change is significant if 80 % of the models find a significant change.

**Dispersion analysis:** enables evaluation of the weight of the **inter-period dispersion** (representative of climate change effect) compared to the **inter-annual dispersion** and to the **model dispersion**

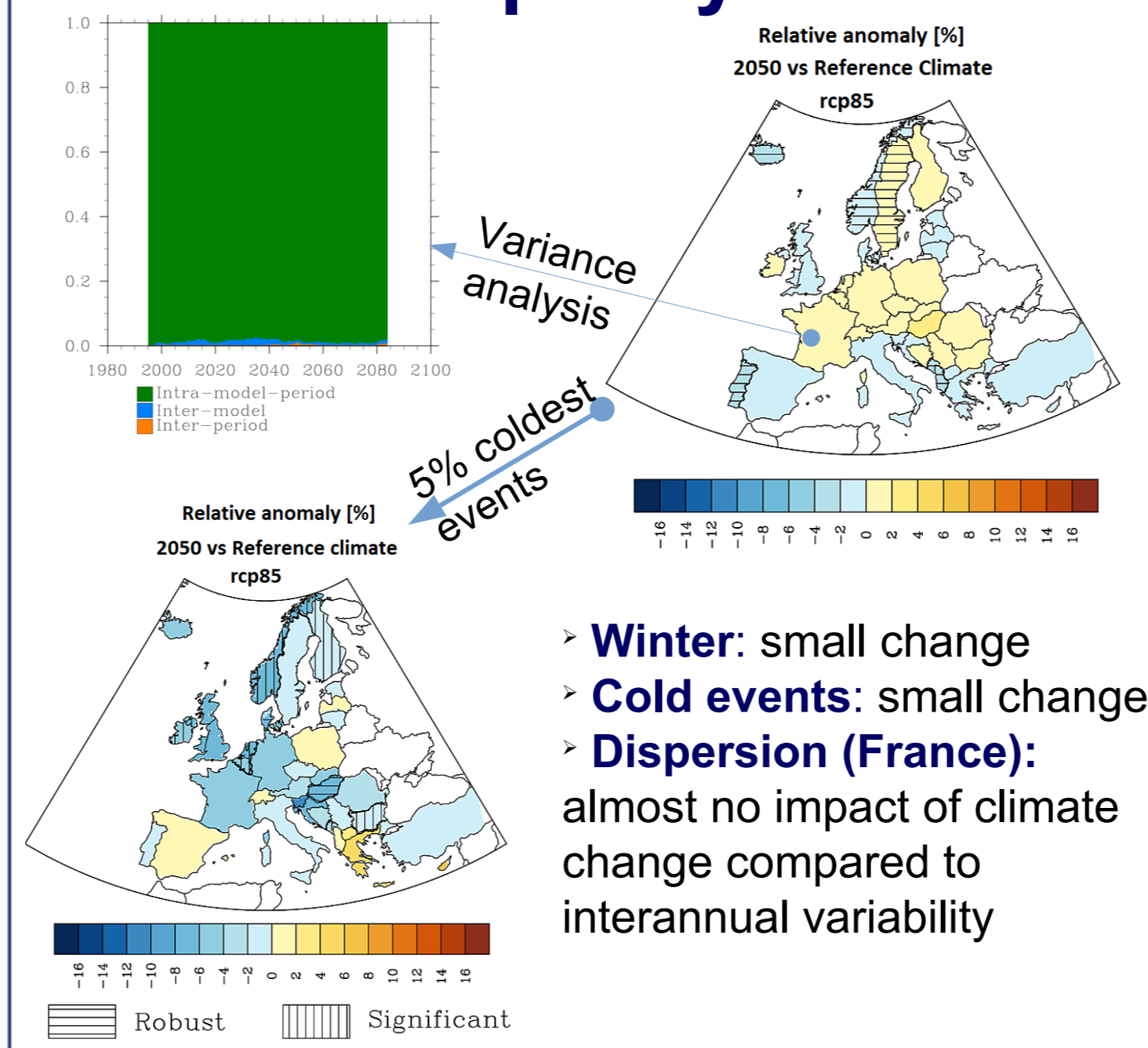
$$X_{m,p,t} = \overbrace{\bar{X}_{m,ref}}^{\text{mean of the reference period for model } m} + \overbrace{a_{m,p,t}}^{\text{anomaly of model } m \text{ at time } t \text{ for period } p}$$

$$\sum_{m,p,t} (a_{m,p,t} - \bar{a})^2 = \underbrace{\sum_{m,p,t} (a_{m,p,t} - \bar{a}_{p,m})^2}_{\text{inter-annual dispersion}} + \underbrace{\sum_{m,p,t} (\bar{a}_{p,m} - \bar{a}_p)^2}_{\text{model dispersion}} + \underbrace{\sum_{m,p,t} (\bar{a}_p - \bar{a})^2}_{\text{climate change effect}}$$

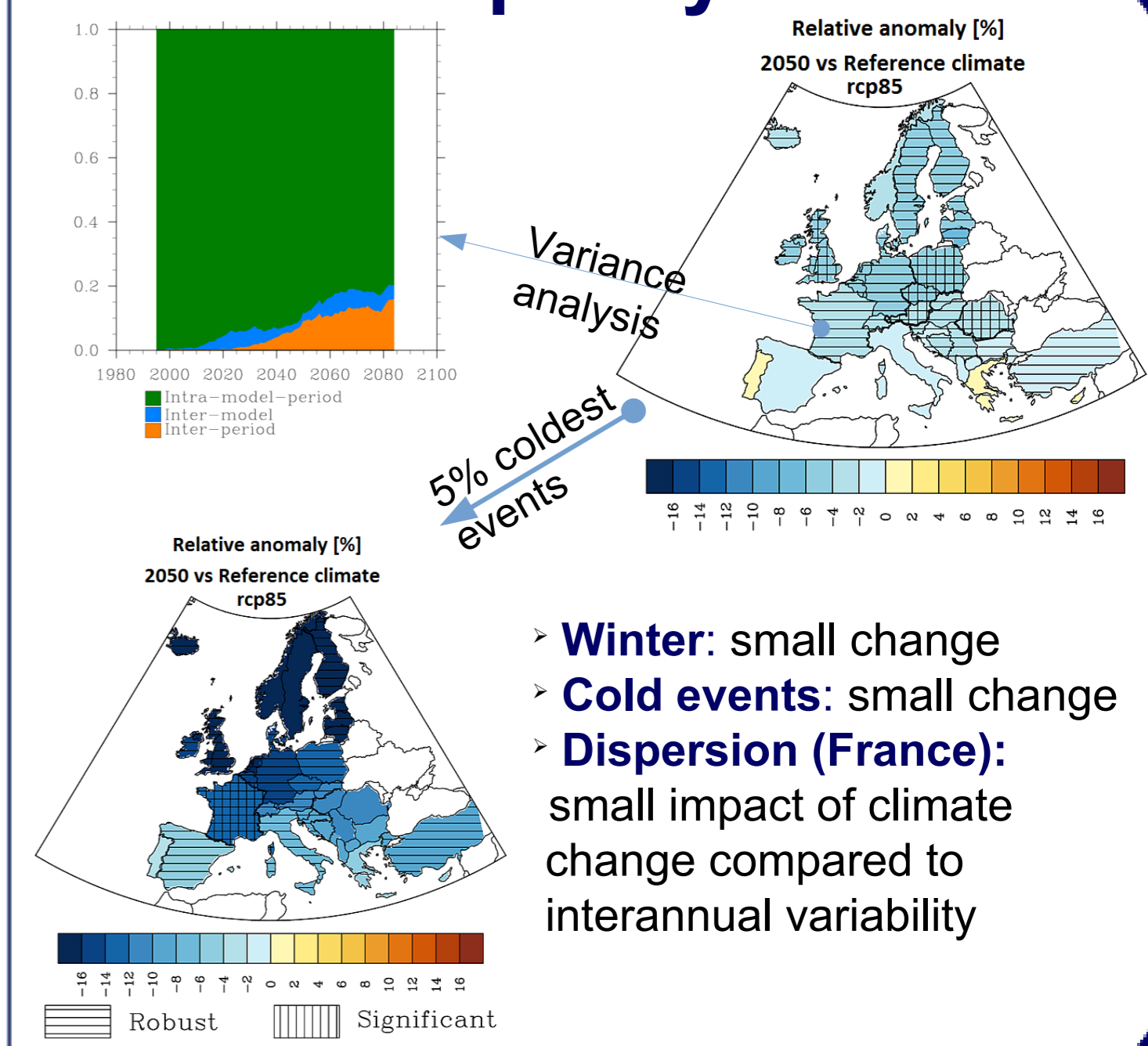
## Demand Indicator



## Wind Capacity factor



## Solar Capacity factor



## Indicators

**Wind capacity factors:** based on three power curves representative of three wind turbine generator classes (IEC classes) and 10m-wind speed. 10m-wind speed is extrapolated at hub height.

**Solar capacity factors:** based on performance ratio (see Jerez et. Al 2015). Solar radiation, as well as other meteorological fields (wind, temperature) can be used to define different indicators.

**Heating Degree Day weighted by population:** based on thresholded 15°C deviation for temperature weighted by population (Eurostat)

$$HDD = \begin{cases} 15 - T & \text{if } T < 15^\circ\text{C} \\ 0 & \text{otherwise} \end{cases}$$

**Electricity consumption:** Based on a linear model using Heating degree day weighted by population adapted for each country.

## Data availability

First data version will soon be available online  
<http://clim4energy.climate.copernicus.eu/>

	Reanalysis 1981-2010	Seasonal Forecast 1991-2014	Climate Projection 1971-2100	Spatial resolution
<b>Demand (2 indicators)</b> Daily	WFDEI	ARPEGE-S5 DJF	11 climate models 2 scenarios, Daily	National or regional
<b>Wind capacity factor (3 ind.)</b> 3 hrs	WFDEI	ARPEGE-S5 DJF	11 climate models 2 scenarios, 3 hrs	National or regional
<b>Solar capacity factor (3 ind.)</b> 3hrs	WFDEI	ARPEGE-S5 DJF	11 climate models 2 scenarios, 3 hrs	National or regional
<b>Weather Regime</b> daily	ERA-Interim	ARPEGE-S5 DJF	11 climate models 2 scenarios, daily	Europe