In a extremely deterministic world ....
we would have very accurate site wind conditions forecasts for the next 20 years or so ...

Future

In a slow-down world ...
we would wait 20 years to obtain the data
for each site and then do the analysis ...

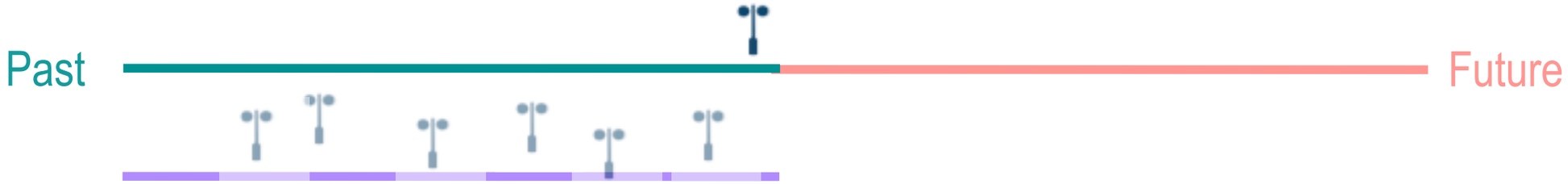
In a symmetric world ....
we can assume that last 20 years wind conditions are about the same as the next 20 years ones...

In a super monitored world,
we would have wind data for the last 20 years
everywhere ...

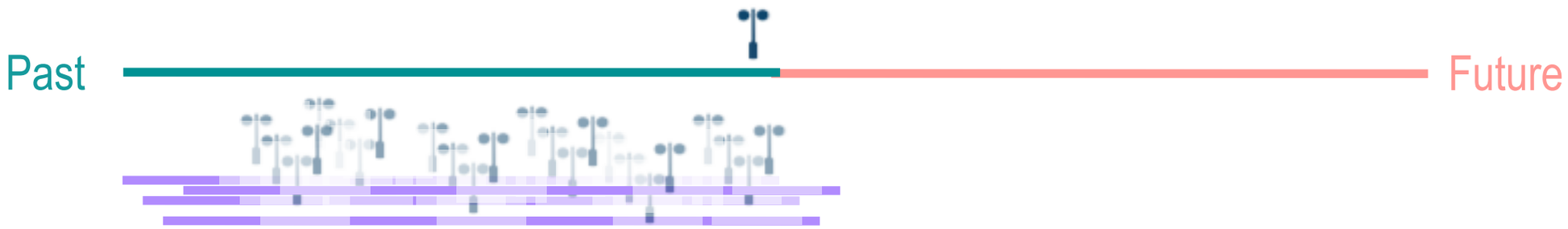
In this real world ...
we seldom have site data covering
more than two full annual cycles

In this real world, we now have modeled times series to *extend representativity back-in-time** of our short-term reference observations

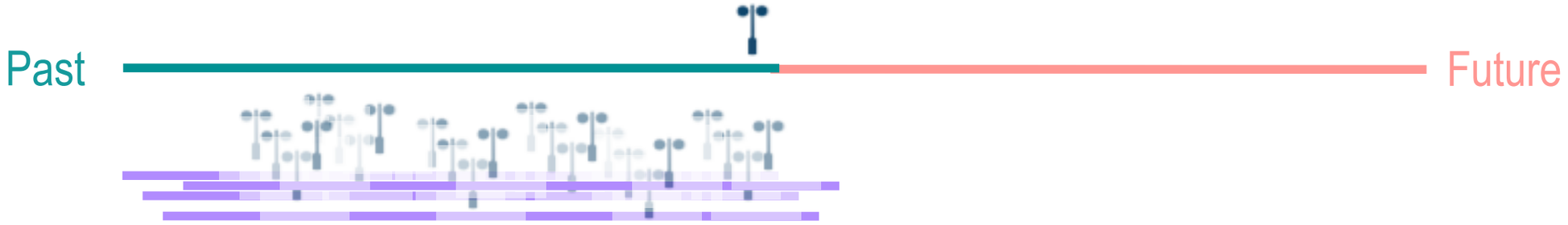
* whatever it means



But in this real world, modeled times series
are not perfect



The objective of this talk is to think over these imperfect time series but tremendously useful in this non-deterministic, asymmetric, poorly monitored* and fast-moving world



* long-term wind conditions data

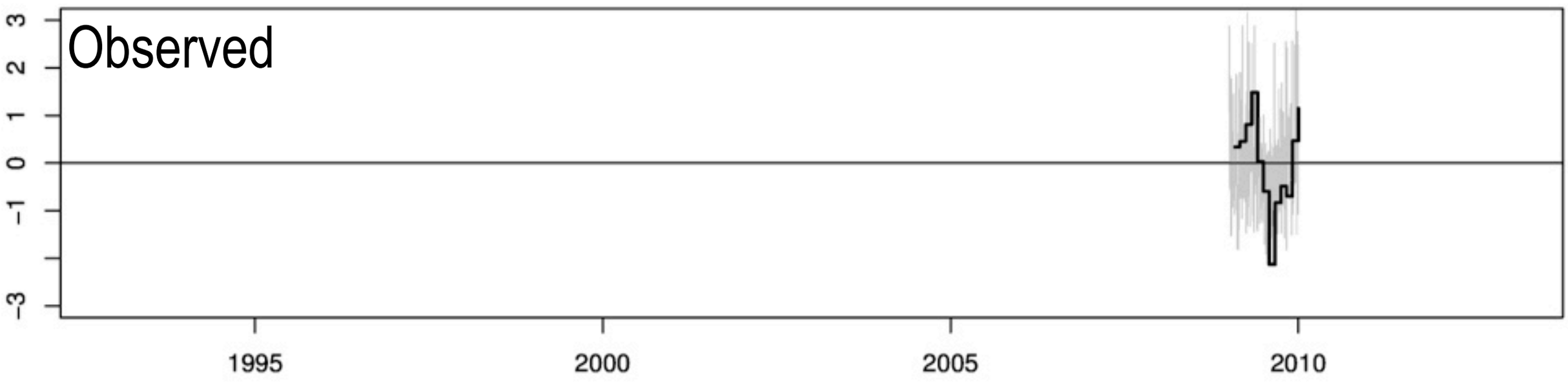
VORTEX

Guidelines to infer and assess wind climate variability uncertainty from modelled time series

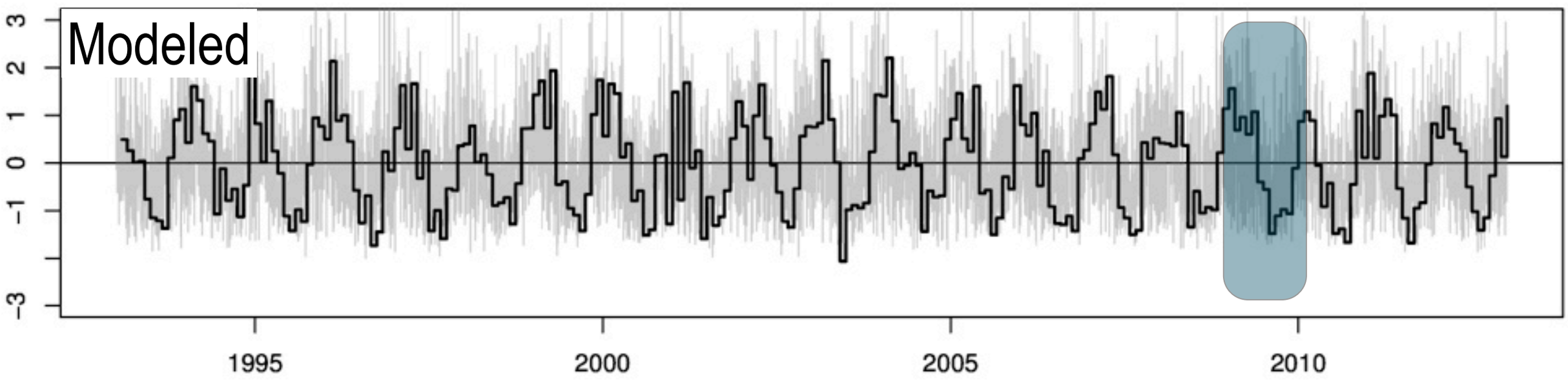
Gil Lizcano, Pau Casso,
Elies Campmany, Patricia Puig

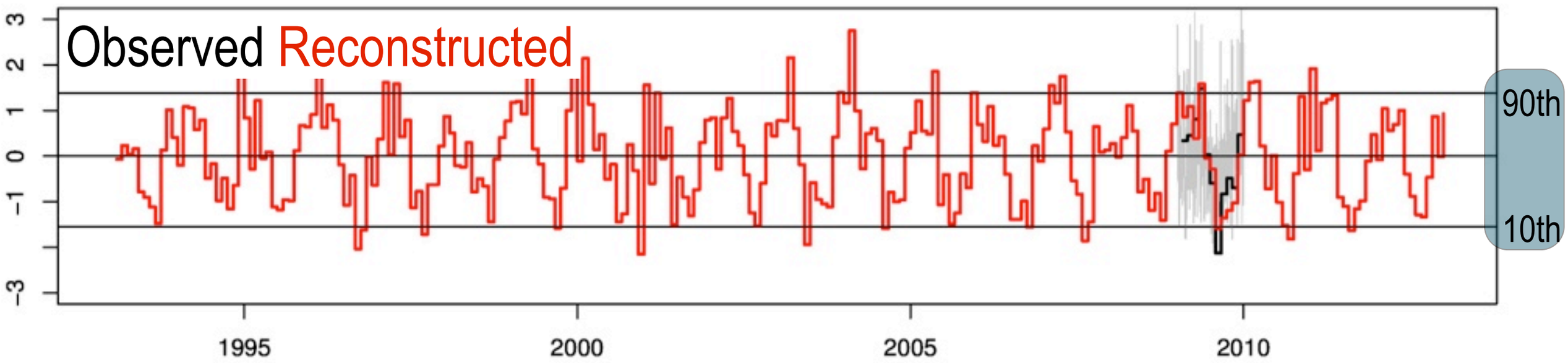
Outline

- Main issues
- Climate representativity
- Time Consistence
- Usage
- Recommendations

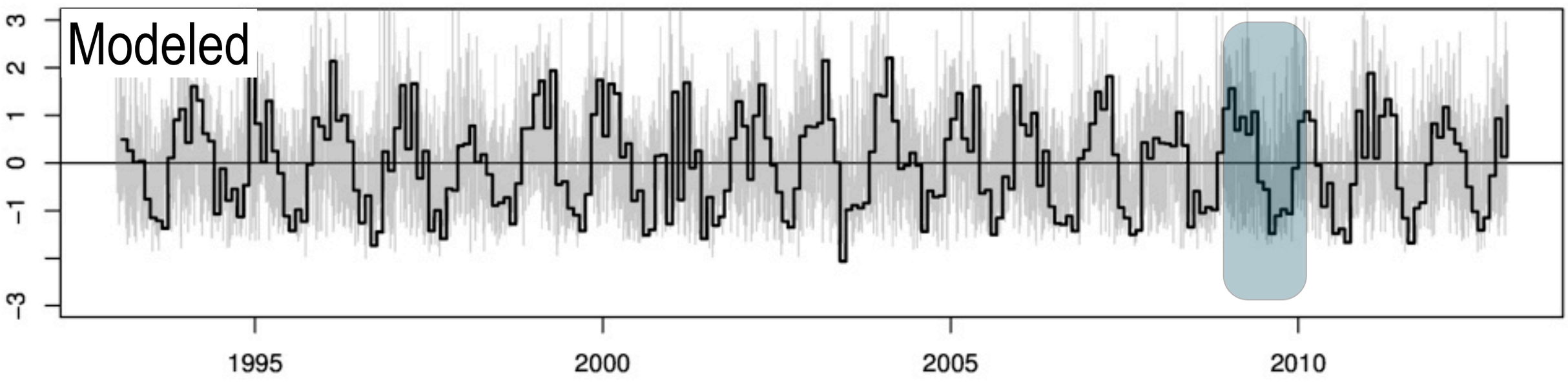


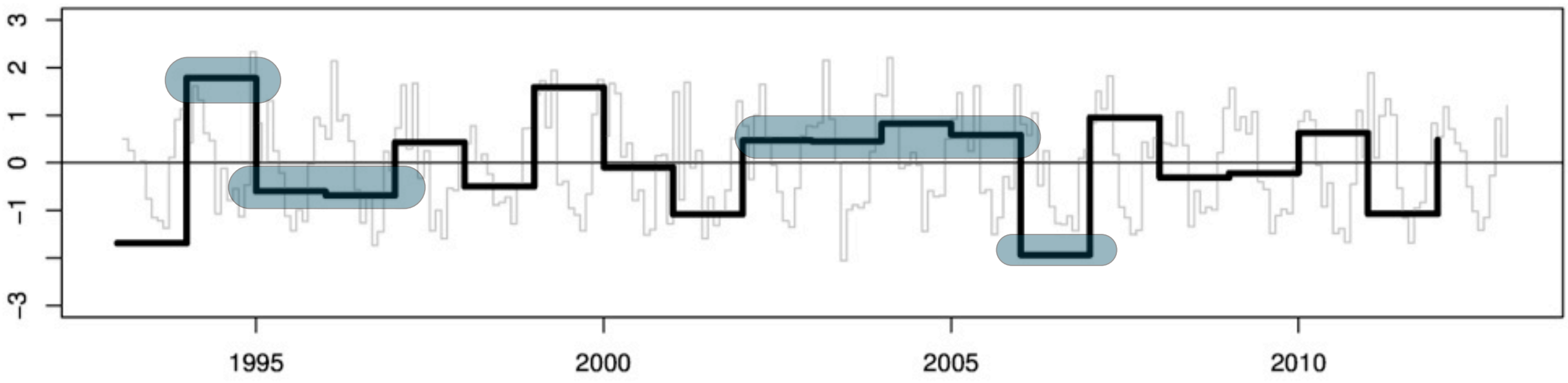
Standardized **Daily** and **Monthly** Wind Speeds





Standardized **Daily** and **Monthly** Wind Speeds





Standardized **Monthly** and **Annual** Wind Speeds

How likely is to have an extreme year?

How likely is to have a sequence of years above/below the average years?

Pre-construction

Assess average and percentiles of the production

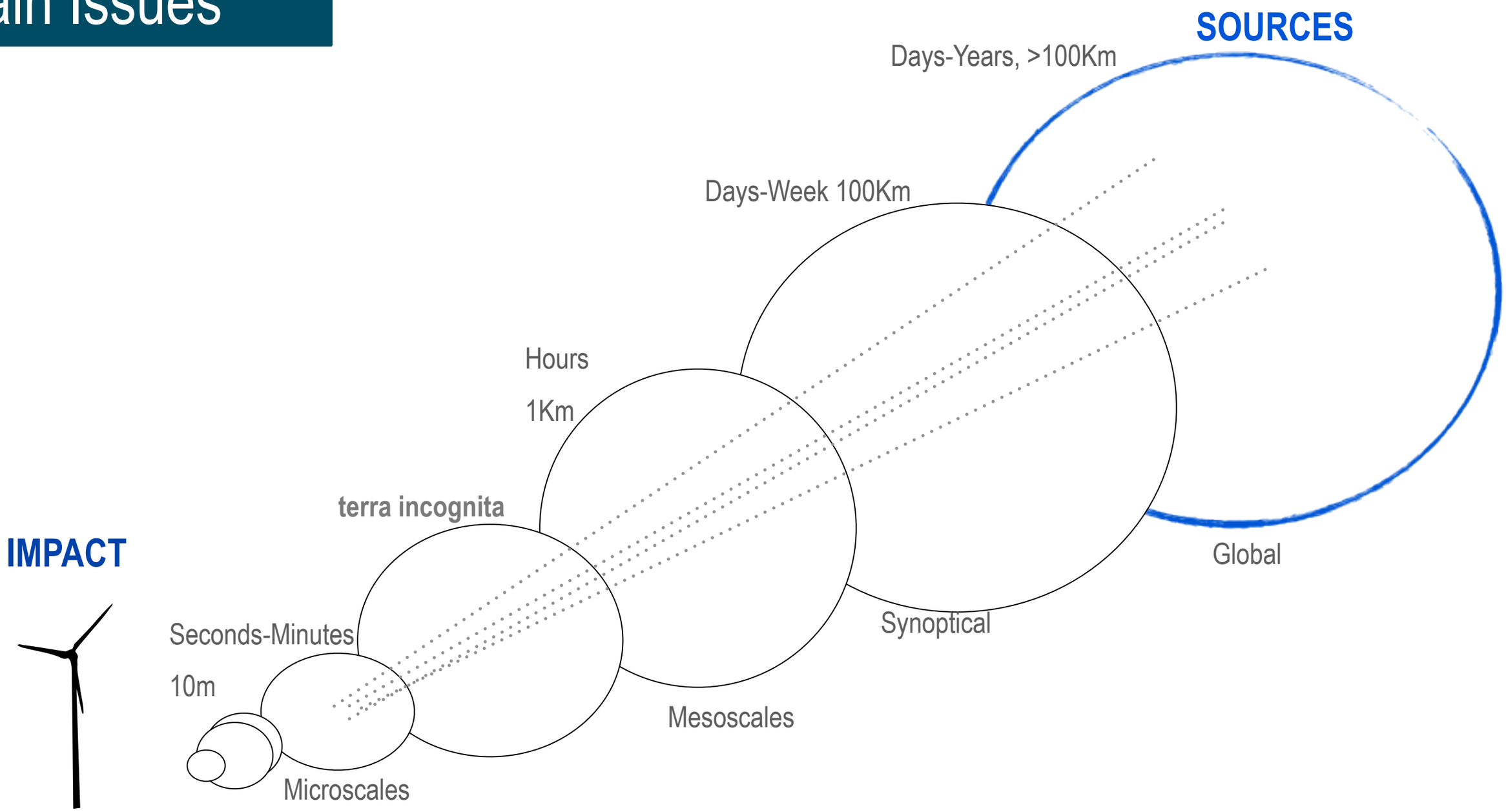
Feasibility

Post-construction

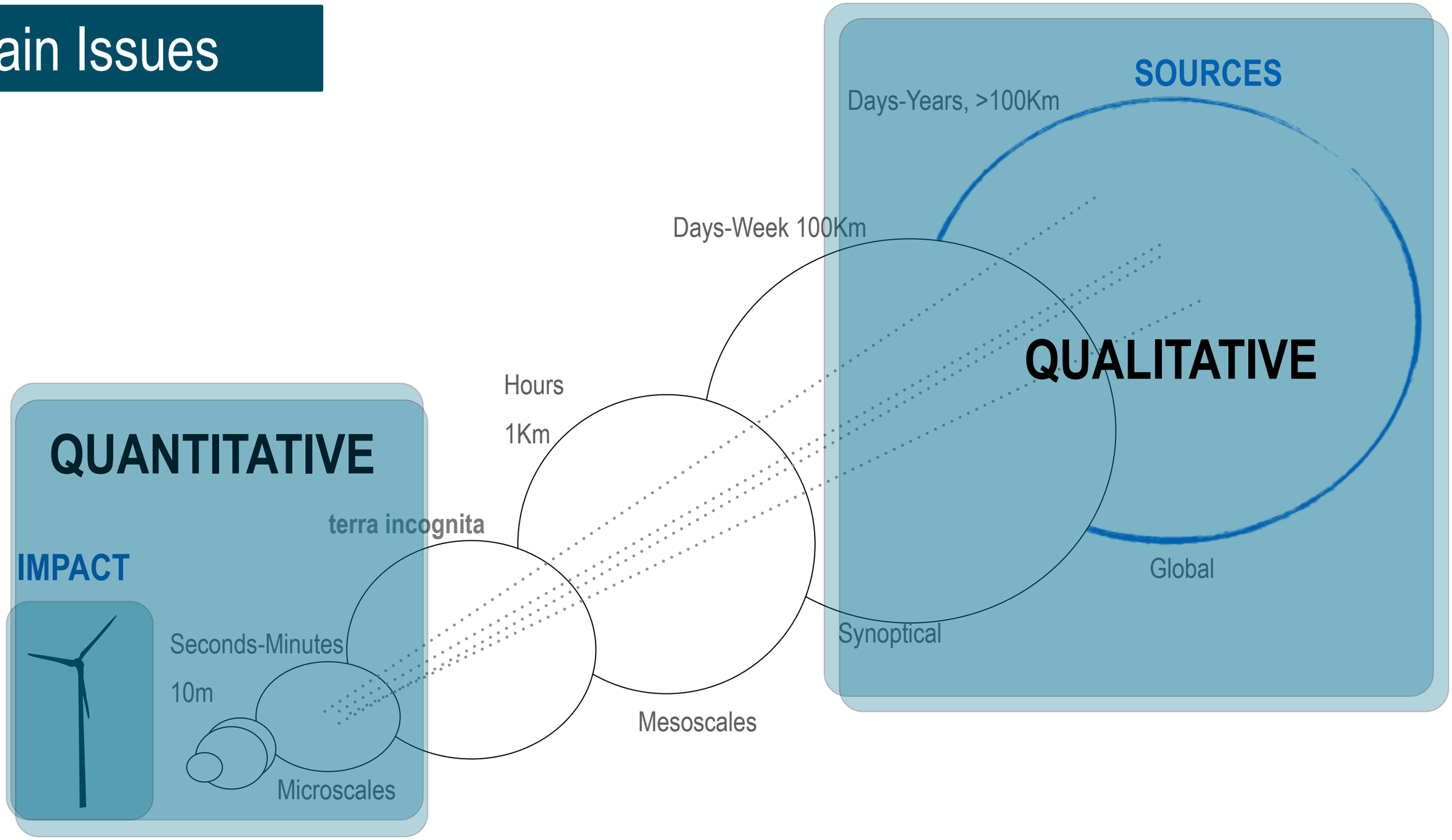
Maximize the benefits of the productions according to the market demands

Speculate (RISK)

Main Issues


SOURCES
Days-Years, >100Km
Days-Week 100Km
Hours
1Km
terra incognita
IMPACT
Seconds-Minutes
10m
Microscales
Mesoscales
Synoptical
Global

Main Issues


SOURCES
Days-Years, >100Km
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Hours
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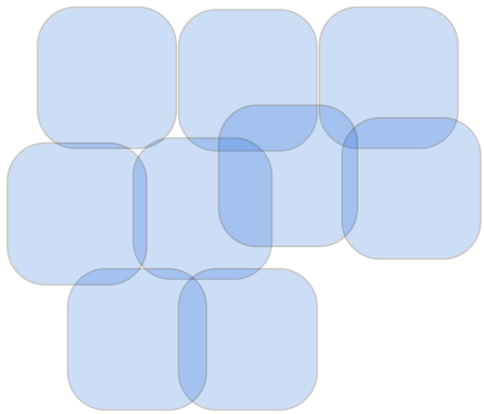
QUALITATIVE
QUANTITATIVE
terra incognita
IMPACT
Seconds-Minutes
10m
Microscales
Mesoscales
Synoptical
Global

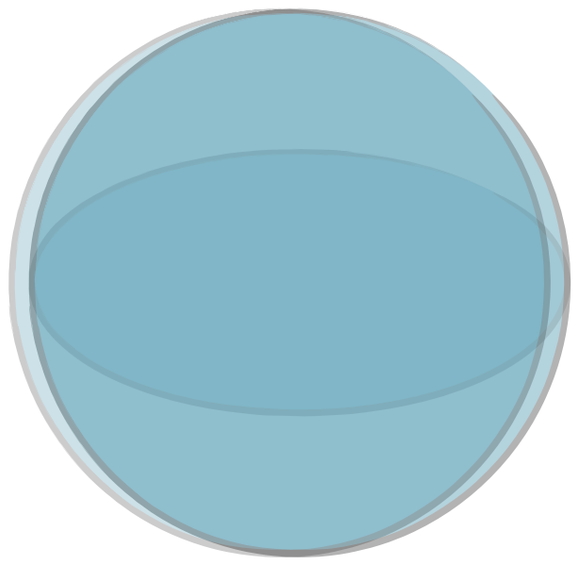
Main Issues

Re-Analysis

Multisource
Input Data



Data Mining/Assimilation
System

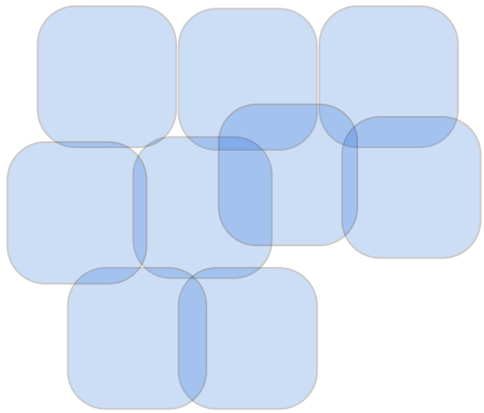


Global Forecast Model
(+ bias correction)

Main Issues

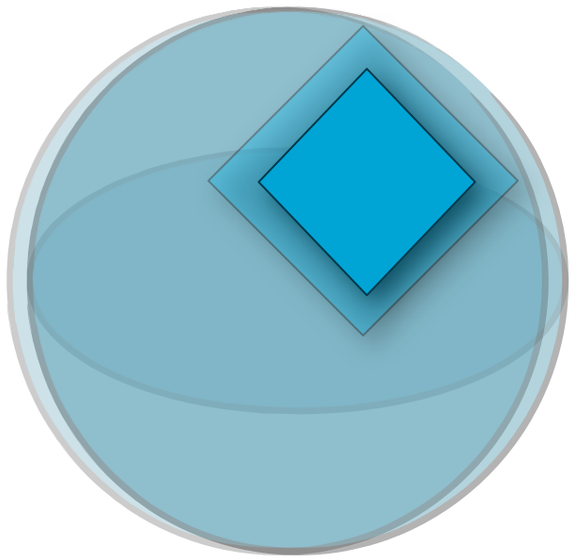
Re-Analysis

Multisource
Input Data



Data Mining/Assimilation
System

Mesoscale Model



Global Forecast Model
(+ bias correction)

Main Issues

Re-Analysis users perspective

Lack of resolution to resolve wind conditions

- Daily cycle
- Near-shore conditions
- Extremes
- Directional bias
- Atmospheric stability
- Jets, gravity waves
- ...

Main Issues

Re-Analysis users perspective

Lack of resolution to resolve wind conditions

- Daily cycle
- Near-shore conditions
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- Atmospheric stability
- Jets, gravity waves
- ...

Is this an problem when we are interesting in seasonal to annual scales of variability ?

Main Issues

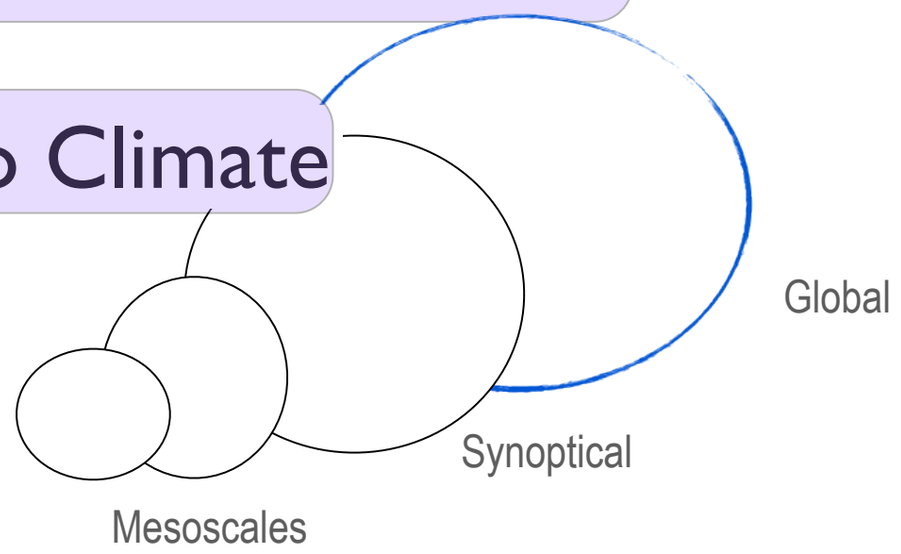
Re-Analysis users perspective

Lack of resolution to resolve wind conditions

- Daily cycle
- Near-shore conditions
- Extremes
- Directional bias
- Atmospheric stability
- Jets, gravity waves
- ...

Is this an problem when we are interesting in seasonal to annual scales of variability ?

Weather to Climate



Main Issues

Re-Analysis + Mesoscale layer

- Transfer climate variability impact to local scale (equalizer)
- Facilitate calibration with site specific data
  - Improve daily cycle phenomena
  - Enhance sector-wise representation
  - ...
- Mesoscale layer DNA is marked by Re-Analysis
- Mesoscale role is to add the local IMPACT component

Main Issues

- Time evolving vs Average Statistics
- Modeled time series are not observed time series *
- Criteria to accept or reject
- Facilitate usage as part of the AEP analysis (manual)

- Passport
  - Climate representativity
  - Time consistency

* even if we manage to forget it

Climate Representativity

Metric: Pearson Correlation Coefficient

- Measure of linearly shared variance among both series
- But: Penalizes non-linear relationship
- But: Weak robustness for small samples, ...
- With all the ‘but’, it remains a good first guess

Climate Representativity

Source: Vortex internal validation
Over 200 certified windmasts (**155** employed)
One full annual cycle cross-validations Observed against Modeled
Re-analysis and 3Km WRF downscaling

R^2 Monthly	10th pctl	25th pctl	Median	75th pctl	90th pctl
CFS + WRF	0.73	0.82	0.89	0.94	0.96
CFS	0.43	0.66	0.82	0.90	0.95
MERRA +WRF	0.74	0.80	0.88	0.94	0.96
MERRA	0.54	0.71	0.86	0.93	0.97
ERAI + WRF	0.75	0.82	0.89	0.94	0.97
ERAI	0.58	0.72	0.83	0.91	0.95

Climate Representativity

Source: Vortex internal validation
Over 200 certified windmasts (**155** employed)
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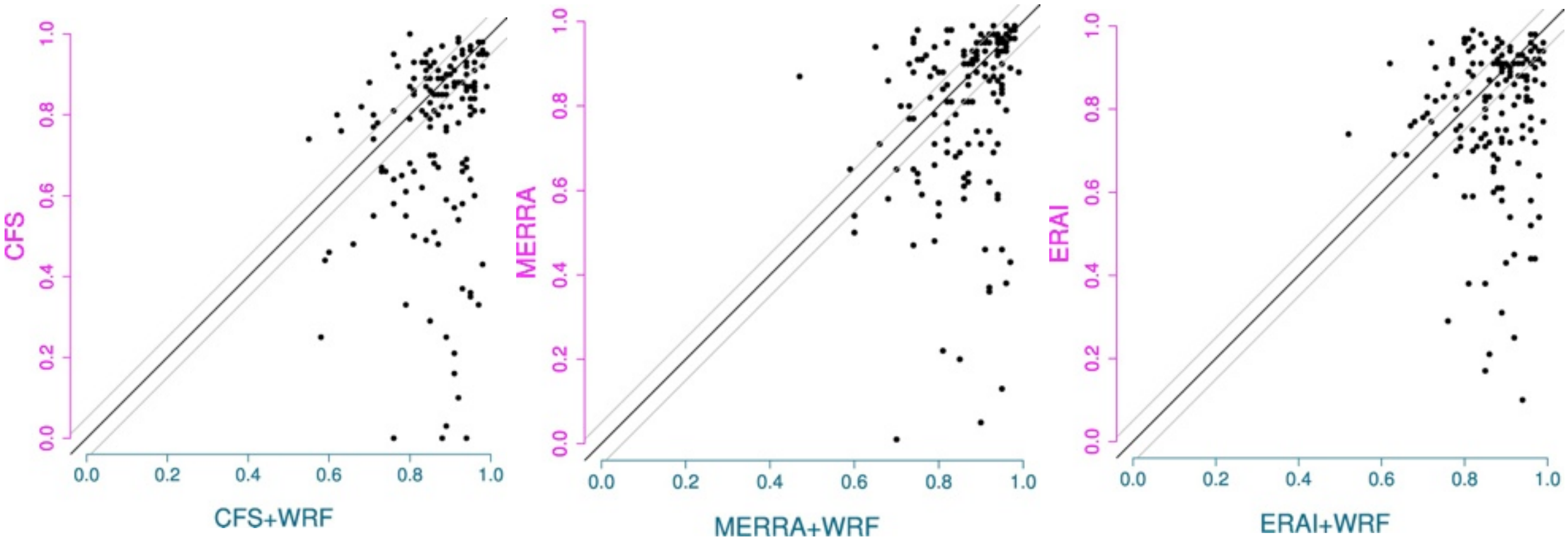
ERAI	0.58	0.72	0.83	0.91	0.95

Climate Representativity

Source: Vortex internal validation
Over 200 certified windmasts (**155** employed)
One full annual cycle cross-validations Observed against Modeled
Re-analysis and 3Km WRF downscaling

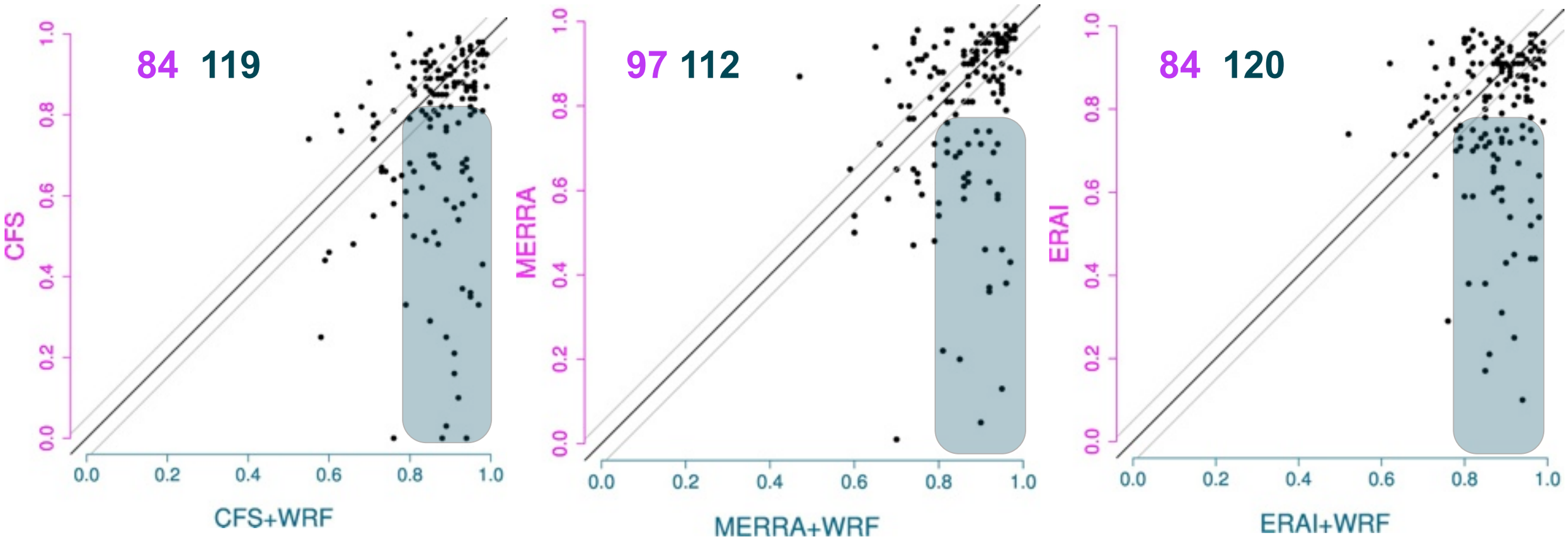
R^2 Daily	10th pctl	25th pctl	Median	75th pctl	90th pctl
CFS + WRF	0.70	0.77	0.82	0.87	0.91
CFS	0.53	0.65	0.78	0.84	0.88
MERRA +WRF	0.69	0.76	0.82	0.87	0.91
MERRA	0.54	0.64	0.76	0.84	0.90
ERAI + WRF	0.69	0.76	0.82	0.87	0.91
ERAI	0.43	0.62	0.75	0.82	0.87

Climate Representativity



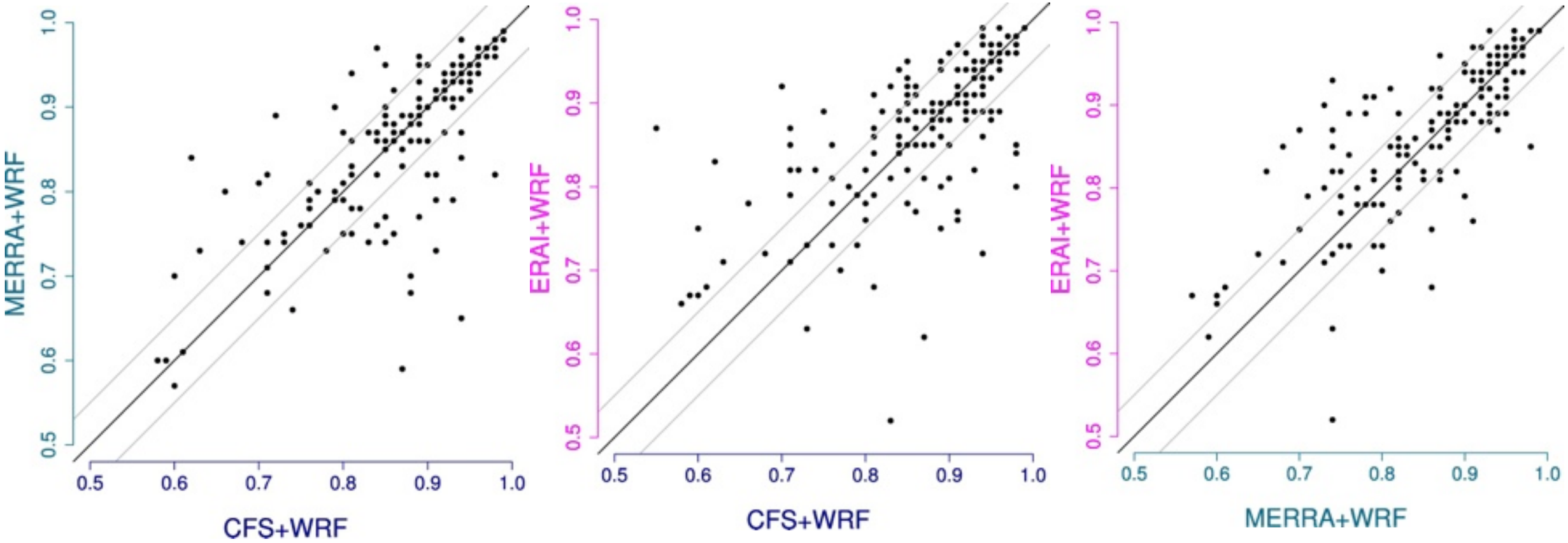
Scatter plot, Monthly R^2 Drivers vs Meso (WRF 3KM), 12 months period

Climate Representativity



Scatter plot, Monthly R^2 Drivers vs Meso (WRF 3KM), 12 months period

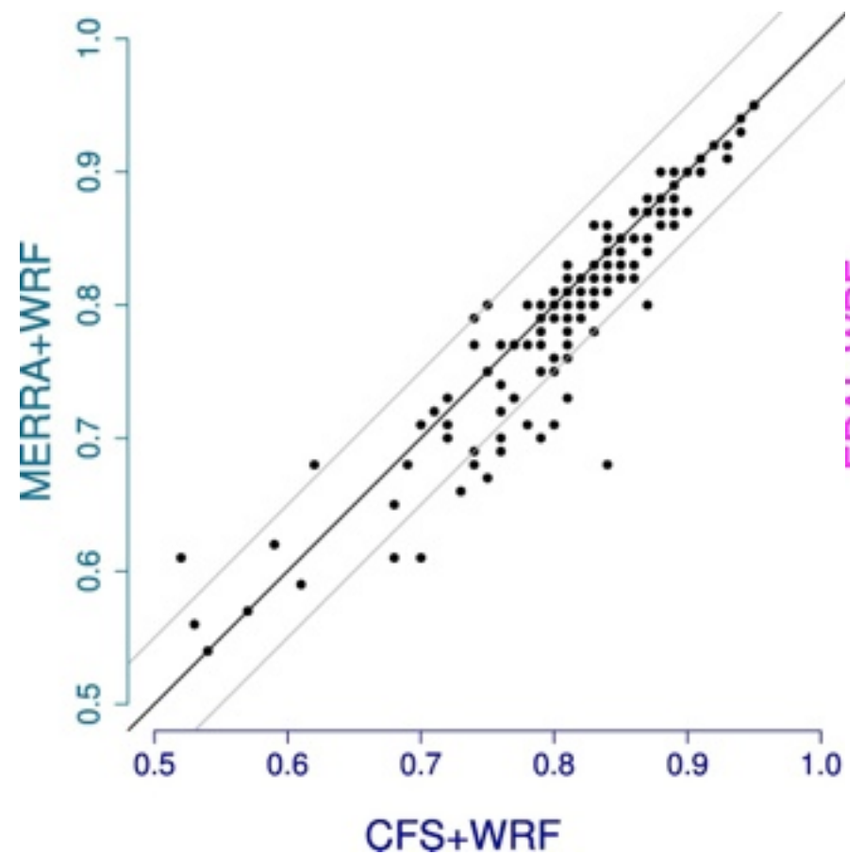
Climate Representativity

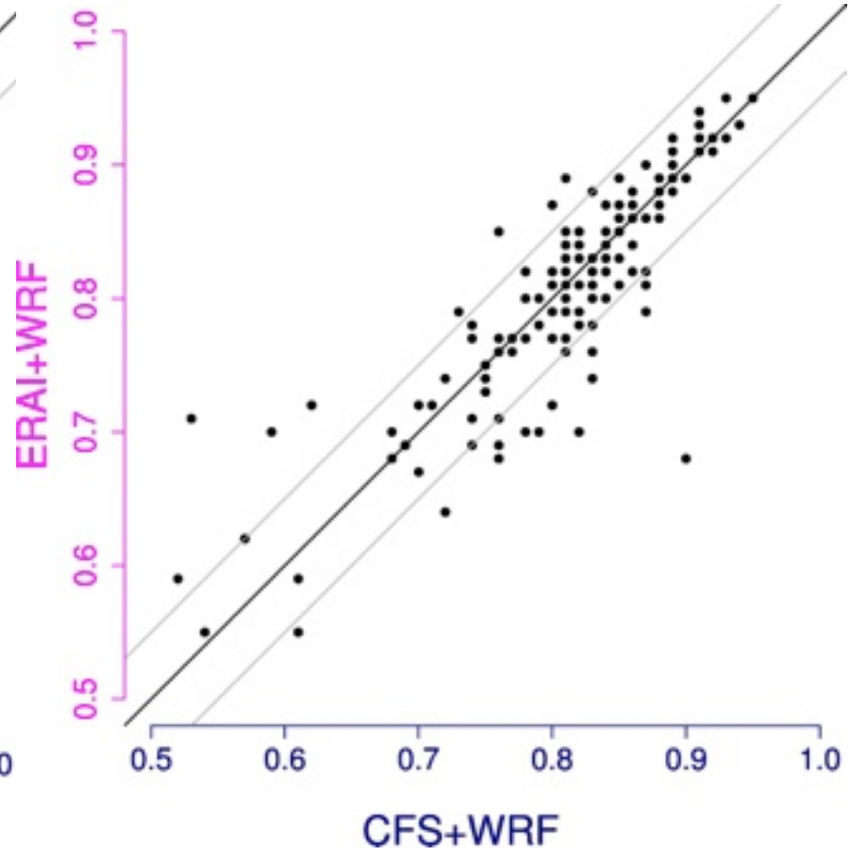


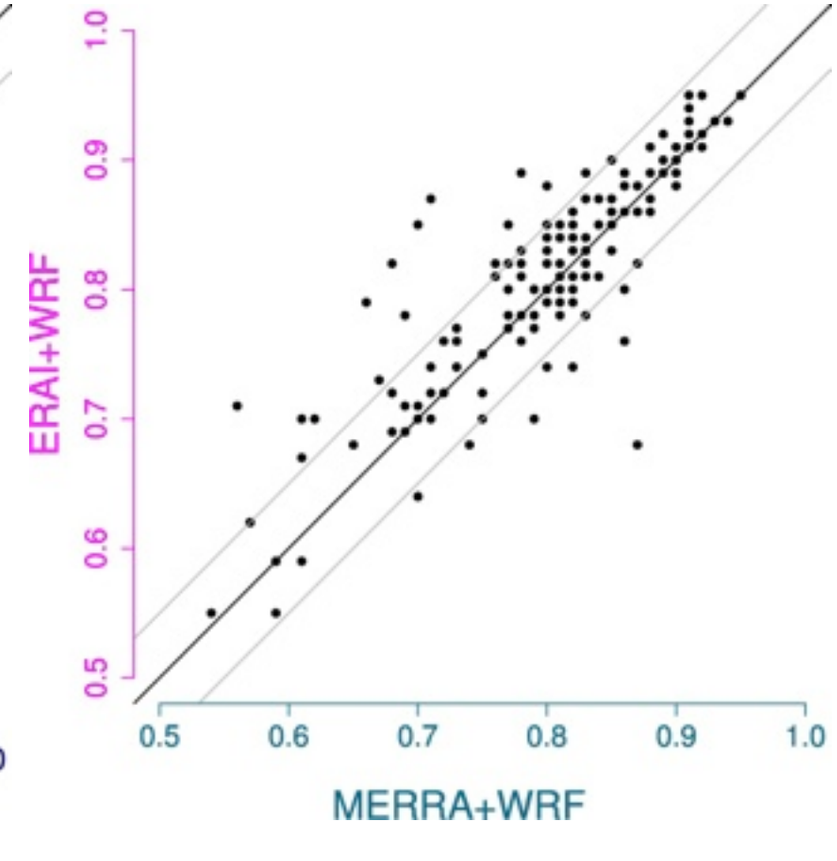
Scatter plot, **Monthly** R^2 Meso vs Meso (WRF 3KM), 12 months period

source: Vortex internal validation

Climate Representativity





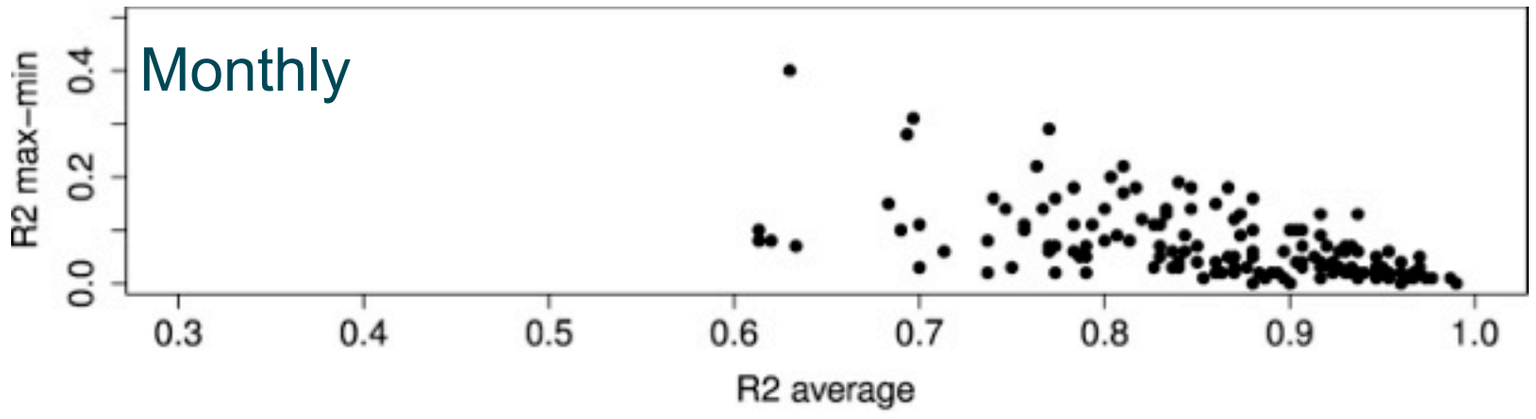


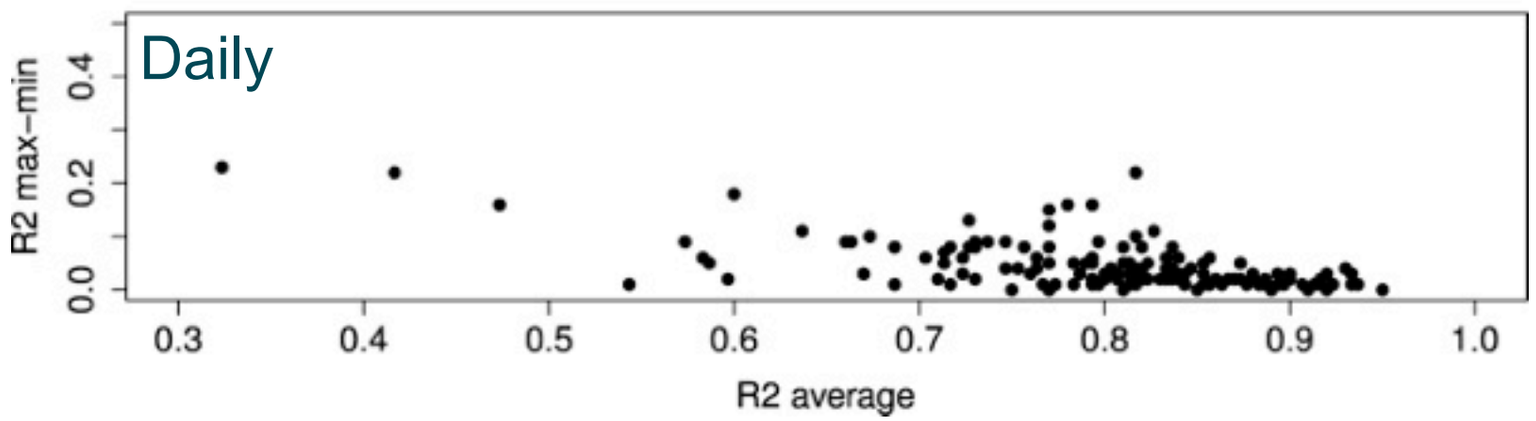
Scatter plot, **DAILY** R^2 Meso vs Meso (WRF 3KM), 12 months period

source: Vortex internal validation

Climate Representativity

R^2 dispersion= max(R^2)-min(R^2) across all the series

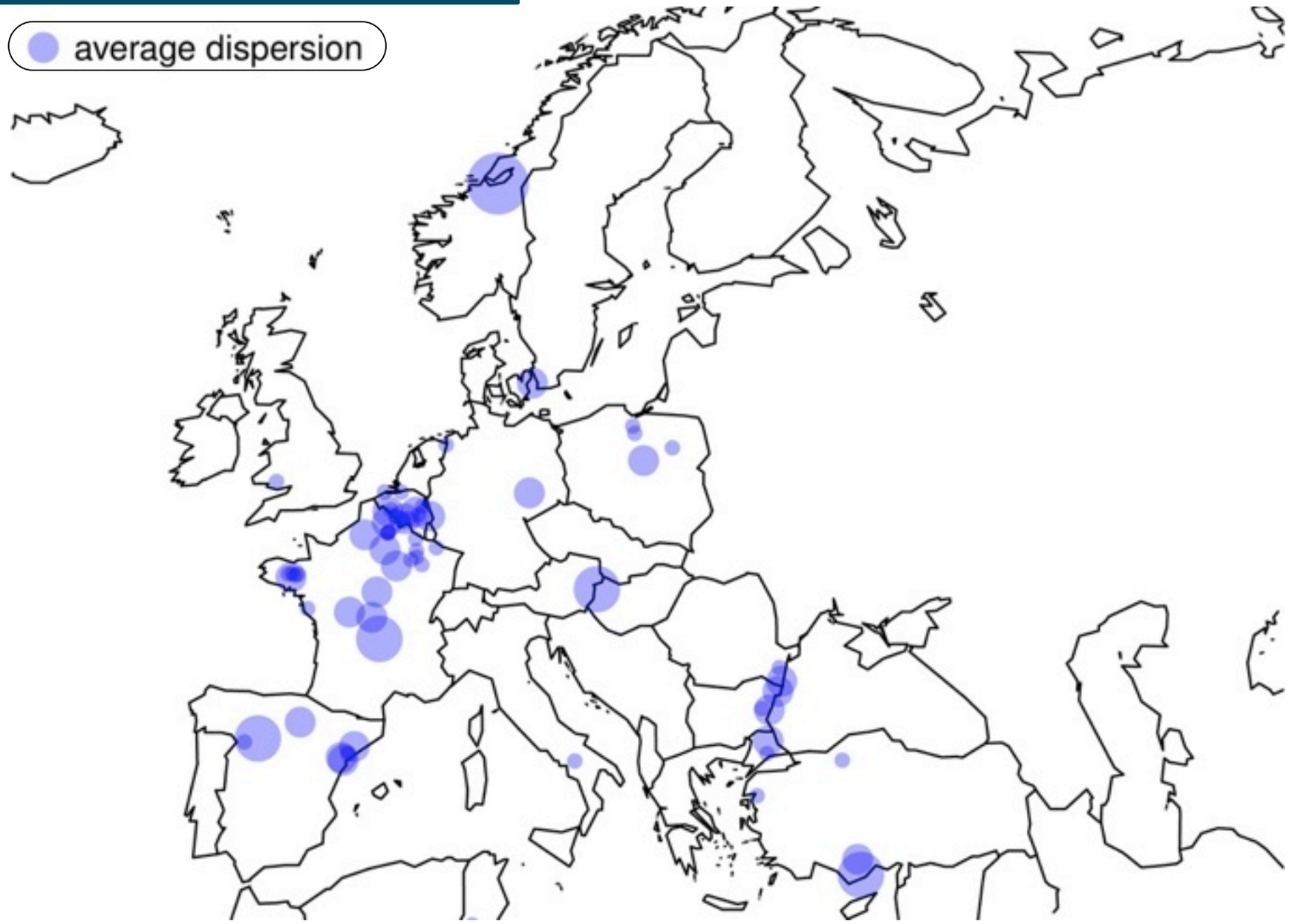




R^2 dispersion against R^2 mean across
Meso Series (WRF 3KM) driving CFS, MERRA and ERAI
12 months period

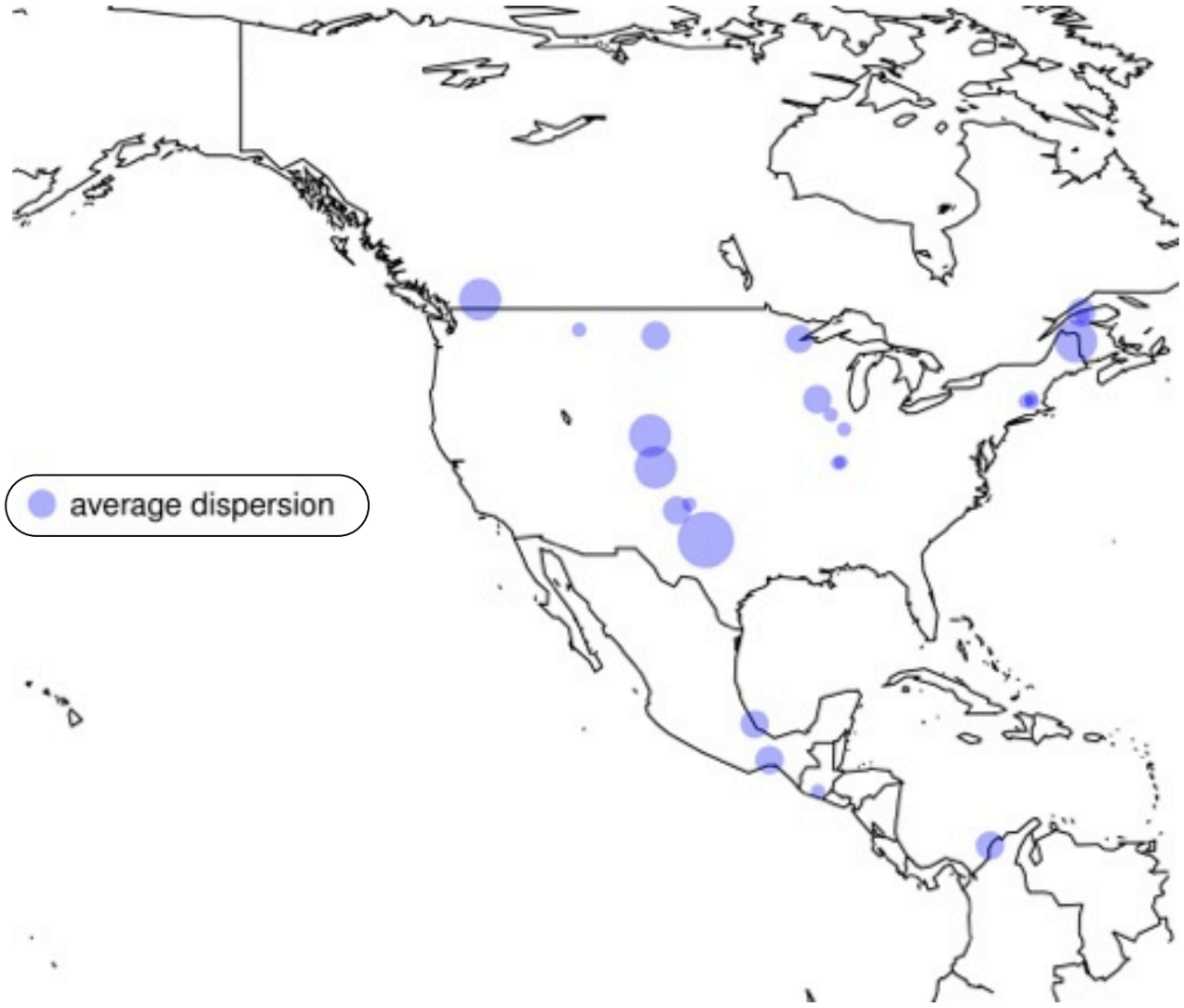
Climate Representativity

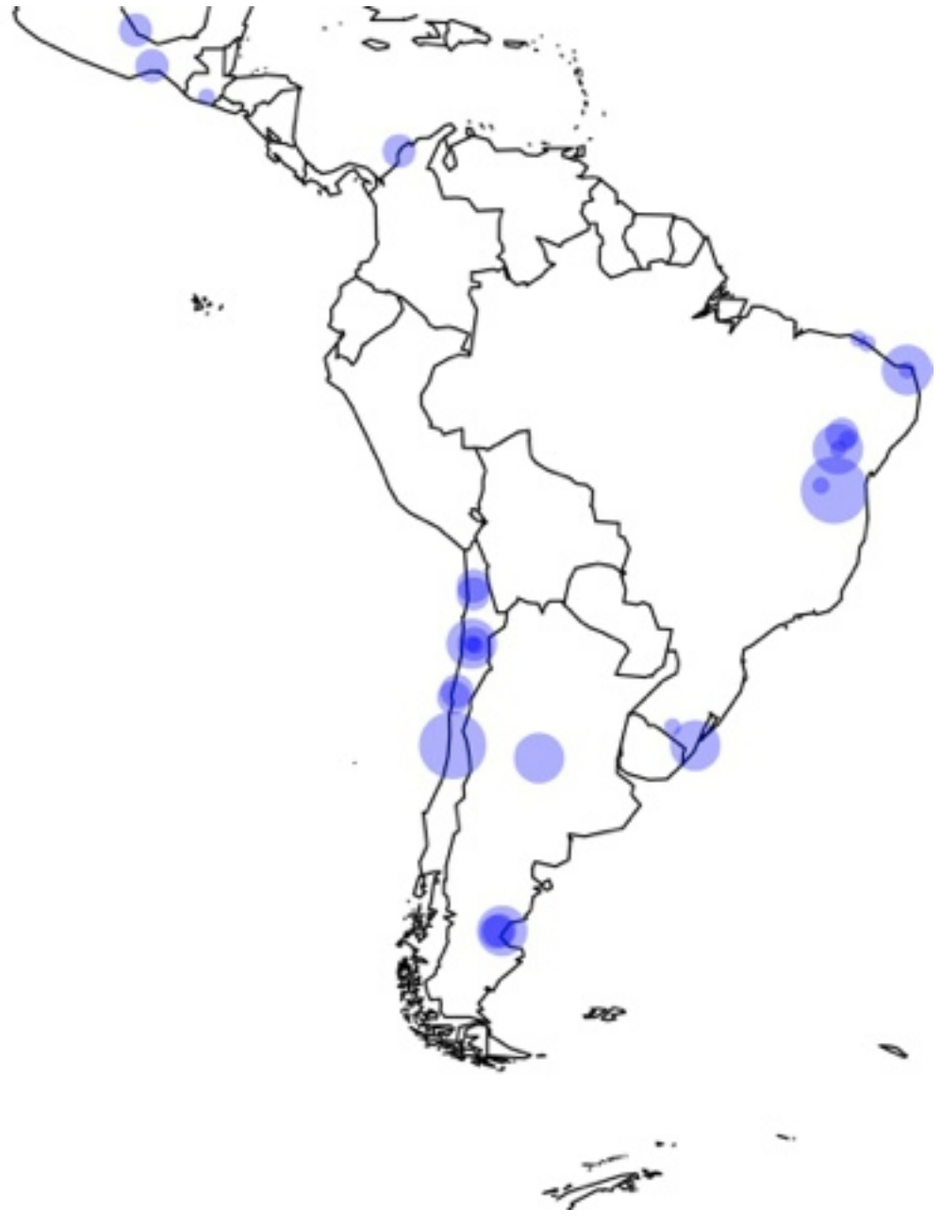
Sites R^2 Monthly higher than 0.8



Climate Representativity

Sites R^2 Monthly higher than 0.8



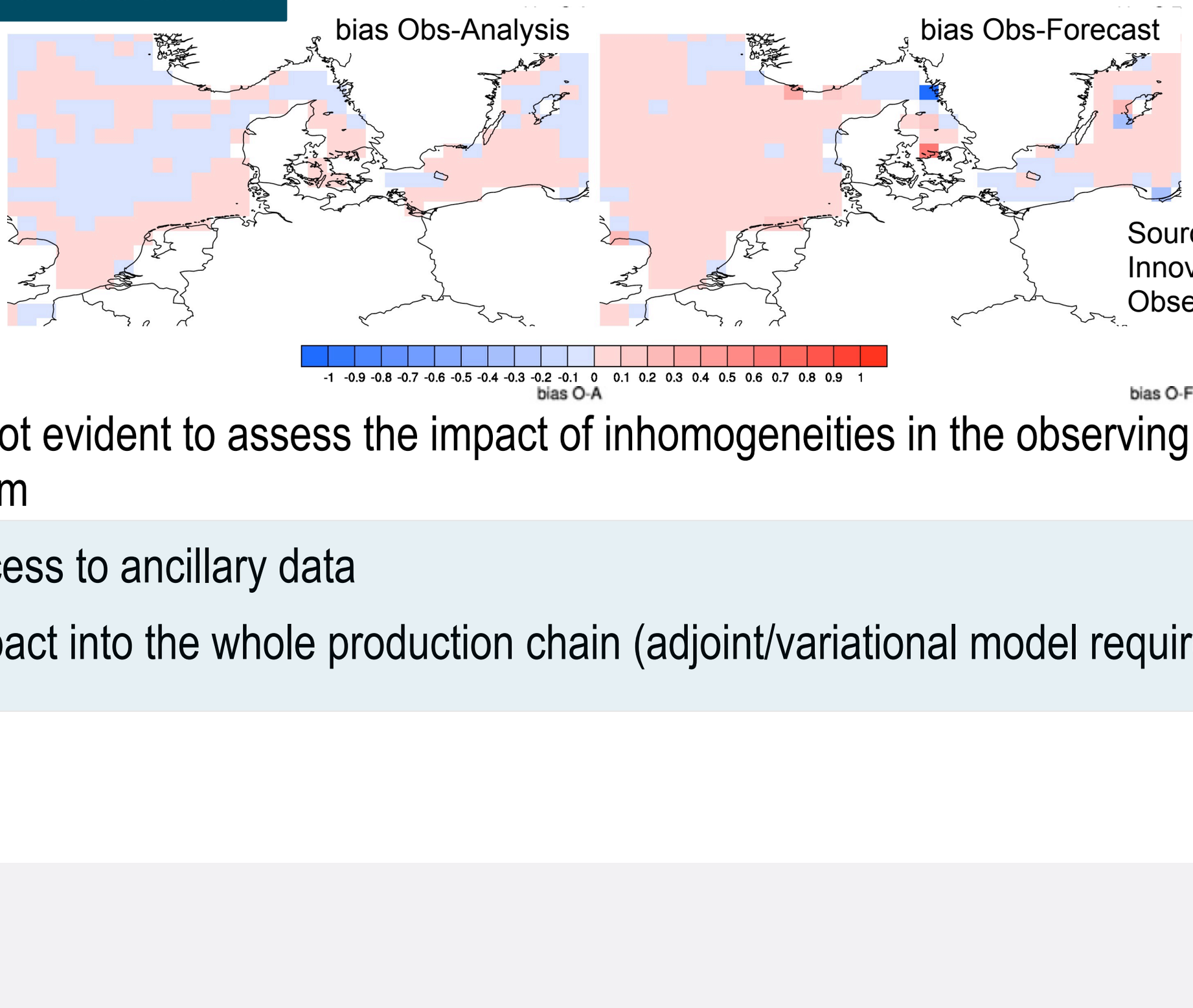


Time Consistence

- **COMBO**: Multi-source observed data, data mining and a global/mesoscale model

How strongly is the variability constrained by observations? Does the observing system drive part of the detected variability and the changes over the years?

Time Consistence



U-wind SCAT regression against time + Kendall test

Source: MERRA Gridded Innovation and Observations Data (GIO)

It is not evident to assess the impact of inhomogeneities in the observing system

- Access to ancillary data
- Impact into the whole production chain (adjoint/variational model required)

Time Consistence

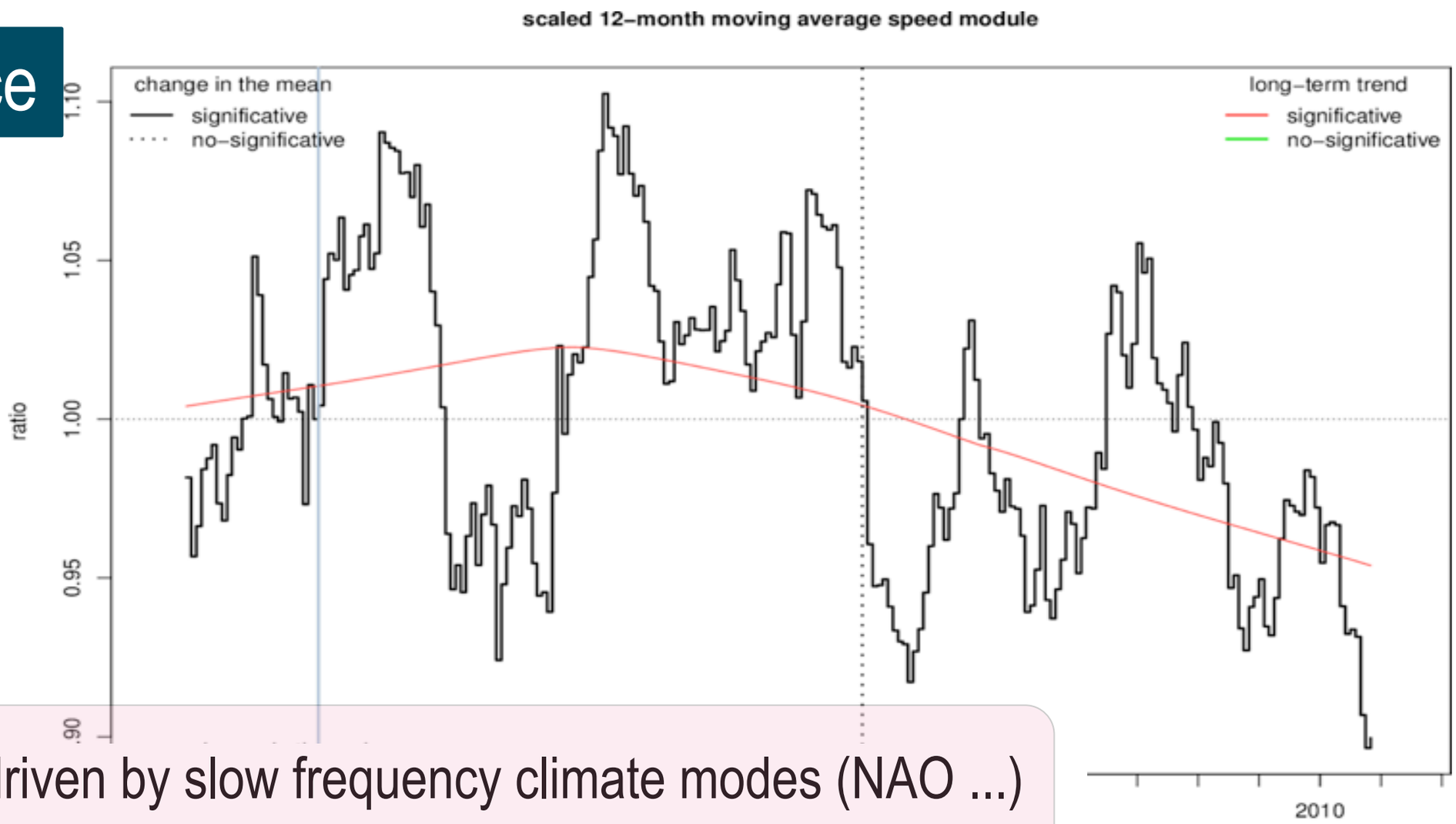
Time consistent?

Change in the structure?

Change in the mean?

Change in the variance?

Artificial trends?



Changes can be driven by slow frequency climate modes (NAO ...)

Composite analysis over extreme years can give some hints

Check covariance with other fields (temperature, pressure, precip)

Time Consistence

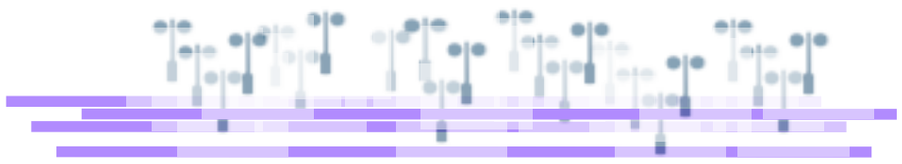
Source: Vortex internal validation
Over **12** certified windmasts
8-10 full annual cycle cross-validations Observed against Modeled
Re-analysis and 3Km WRF downscaling

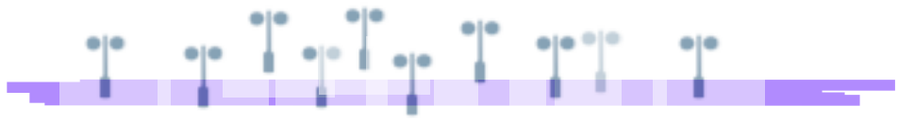
- No traces of trends and jumps in **R^2 and mean bias** (monthly and daily) *
- Consistent values of **R^2** across the years
- **Mean annual** bias shows inter-annual variability (site dependent)
    - **HINT: bias correction**
    - **HINT: use as much as possible information from the model backend**

* Several test applied

Usage

- Modeled time series are not observed time series
- Response (performance) of the model is not linear
- Some years are more gentle to simulate than others (see previous slide)
- Bias correction
  - **Remodeling** via training/learning/predict approach (many methods available)
  - using observed data and model outputs (predictors)

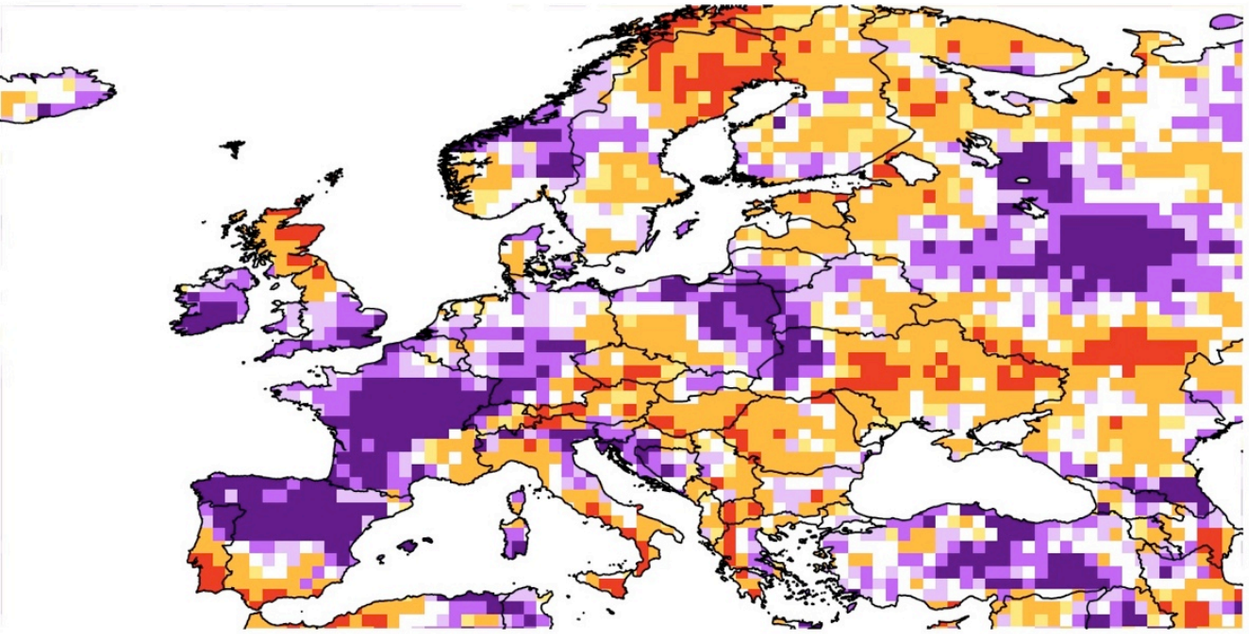




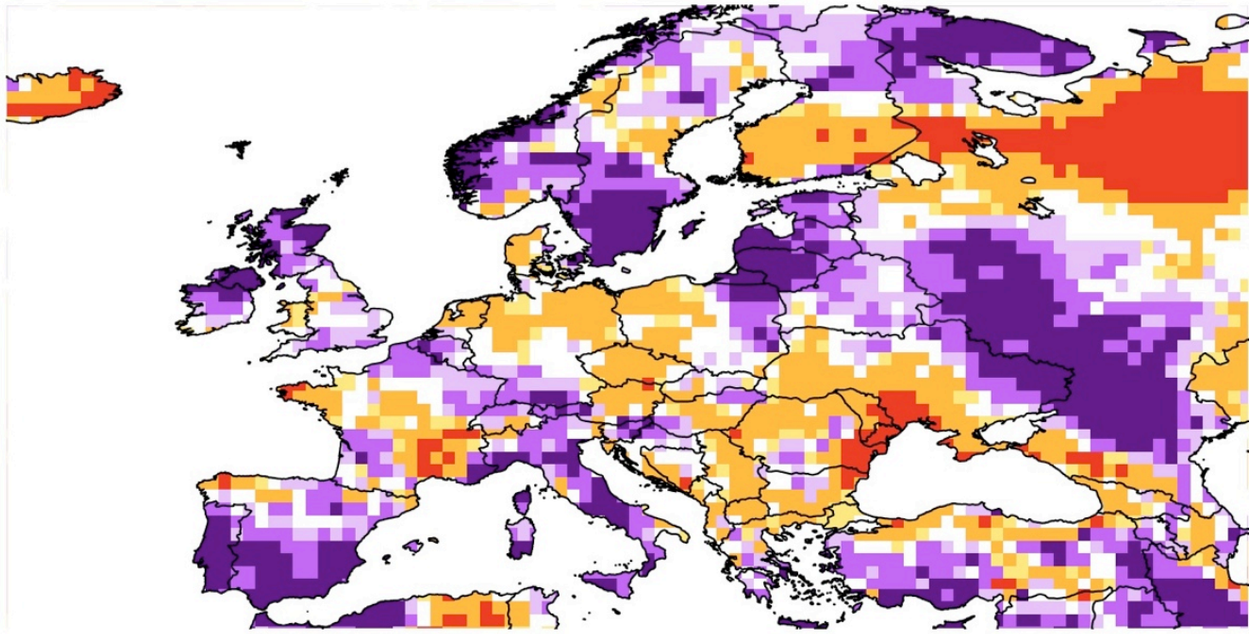
Some conclusions

- Passport
  - Downscaling facilitates the accreditation of the modeled series
- Dispersion
  - Ensemble of SERIES can be employed to gain information
- Consistency
  - Explore bias sensibility to inter-annual variability
- Remodeling
  - remove bias
  - use of model output variables to identify different responses

2000-2009/1990-1999 % change in number of season below 10th



2000-2009/1990-1999 % change in number of season above 90th



Source: ERA-Interim

In a symmetric world ....
we can assume that last 20 years wind conditions are about the same as the next 20 years ones... really?

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SPECS

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Past — Futures climates

Predictability of wind resource

Battery of new S2D predictions made by *la creme de la creme* of the climate modelers in Europe

Stakeholders WANTED

SEVENTH FRAMEWORK PROGRAMME

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SPECS

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Past — Futures climates

Fist Mission:
to prove that S2D skills are not experimental but also profitable by the wind industry

SEVENTH FRAMEWORK PROGRAMME

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Muchas Gracias