# Seasonal prediction over the Euro-Mediterranean region

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SEVENTH FRAMEWORK PROGRAMME

SPECS Seasonal-to-decadal climate Prediction for the improvement of European Climate Services

GOBIERNO DE ESPAÑA MINISTERIO DE ECONOMÍA Y COMPETITIVIDAD

Generalitat de Catalunya Departament d'Economia i Coneixement

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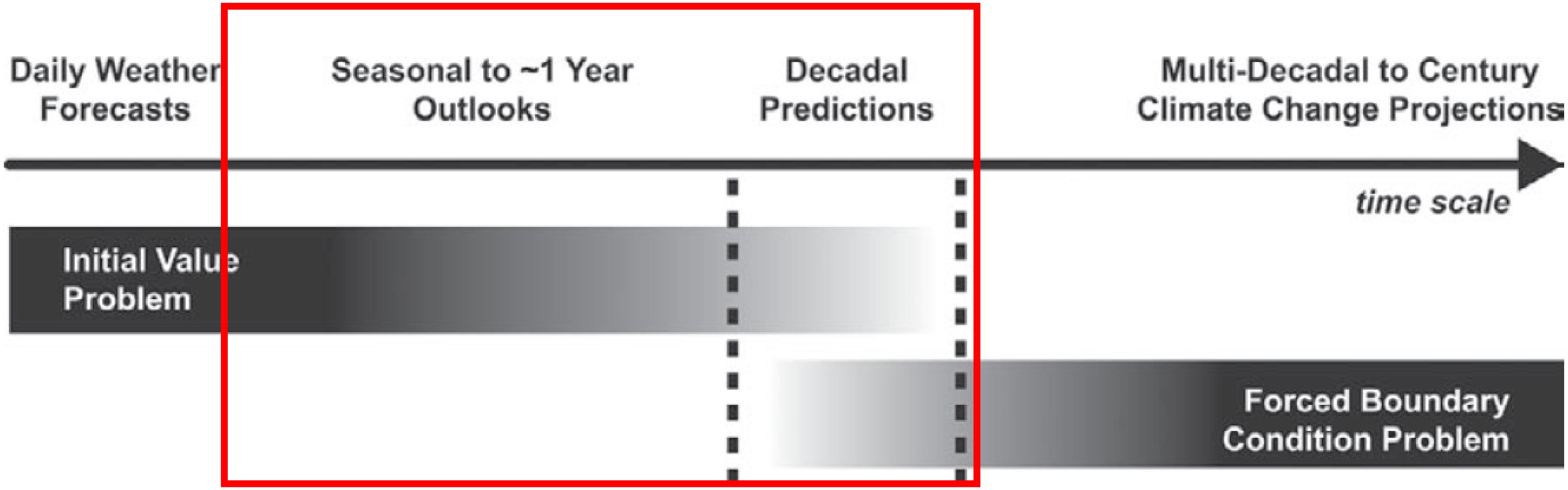
# Climate time scales

Progression from initial-value problems with weather forecasting at one end and multi-decadal to century projections as a forced boundary condition problem at the other, with climate prediction (sub-seasonal, seasonal and decadal) in the middle. Prediction involves initialization and systematic comparison with a simultaneous reference.




Meehl et al. (2009)

# Sources of predictability and error

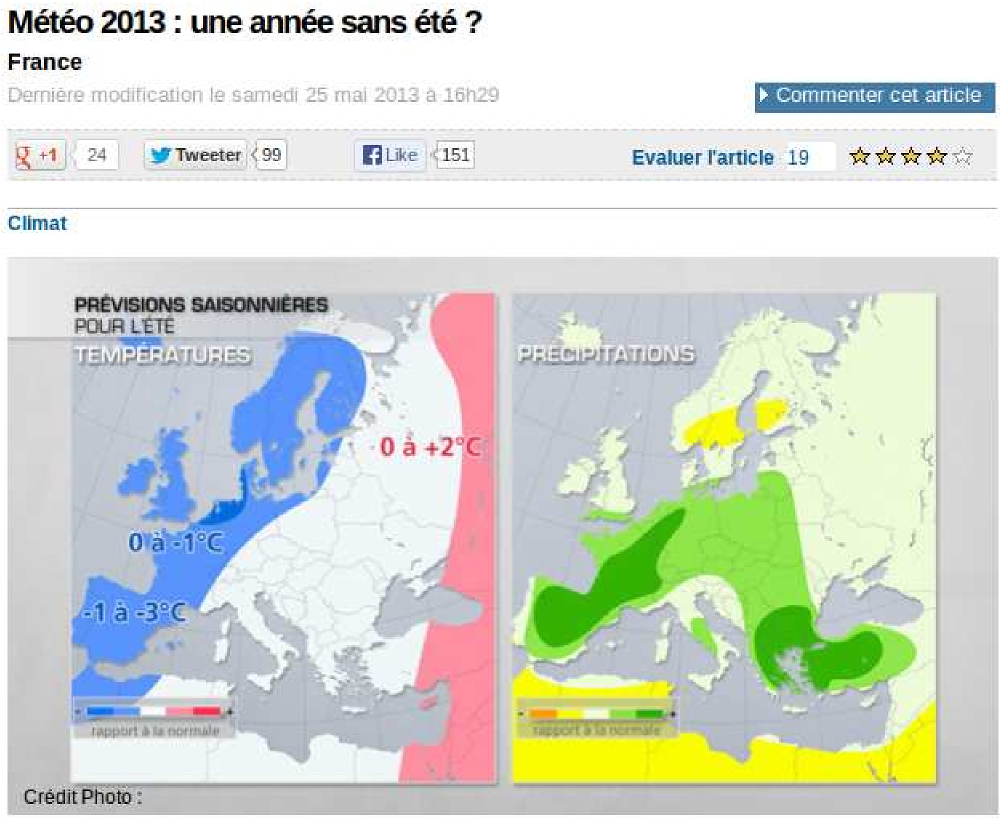
- ENSO and tropical Atlantic
- Extratropical SSTs
- Trends and anthropogenic warming
- Model inadequacy
- Model improvement
- Soil moisture
- Snow
- Stratospheric processes
- Volcanic aerosol

# Methods of seasonal forecasting

- Empirical forecasting
  - Use past observational record and statistical methods
  - Works with reality instead of error-prone numerical models ➨
  - Limited number of past cases ➾
  - A non-stationary climate is problematic ➾
  - Can be used as a benchmark ➨
- Single-tier GCM forecasts
  - Include comprehensive range of sources of predictability ➨
  - Predict joint evolution of ocean and atmosphere flow ➨
  - Includes a large range of physical processes ➨
  - Includes uncertainty sources, important for prob. Forecasts ➨
  - Systematic model error is an issue! ➾

# And verification is fundamental

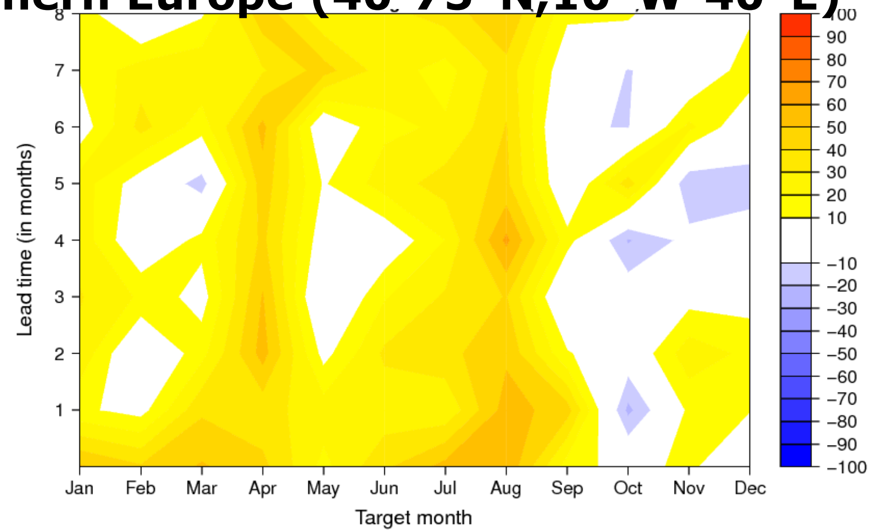
A good example of what should not be happening.

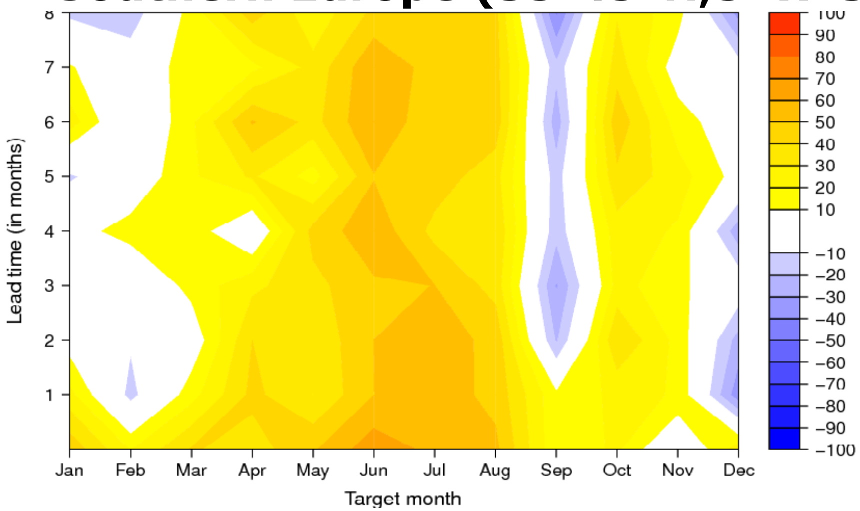
# Simple empirical model: persistence

Correlation of a persistence model based on linear regression with GHCN temperature over 1981-2005, with the first regression model using data for 1952-1980.

**Northern Europe (40-75°N,10°W-40°E)**




**Southern Europe (35-45°N,5°W-30°E)**



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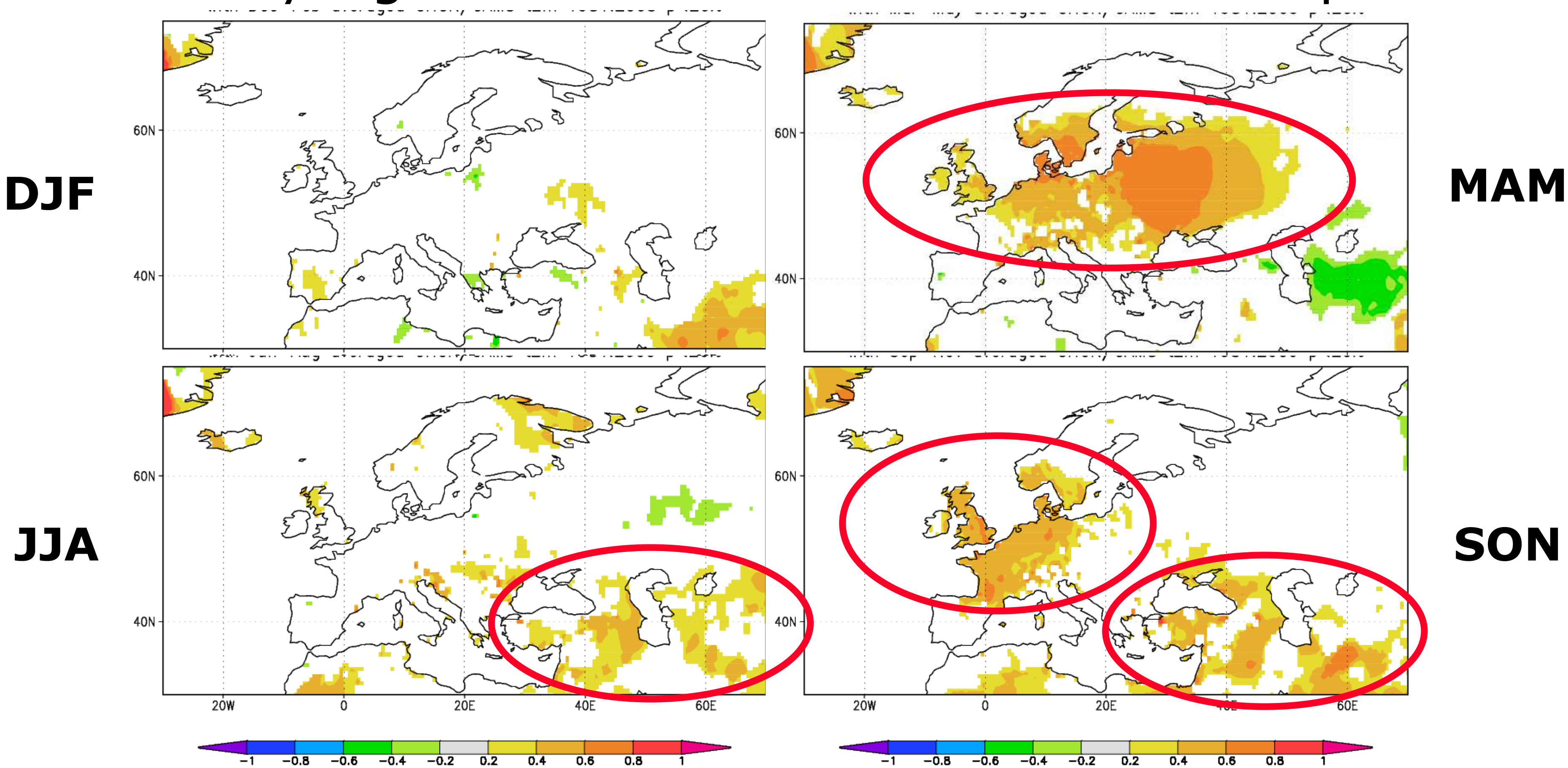
# Temperature skill: persistence

Correlation of GHCN temperature of one-month lead anomaly persistence over 1981-2005. Only values statistically significant with 80% confidence are plotted.



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# Temperature skill: System 3

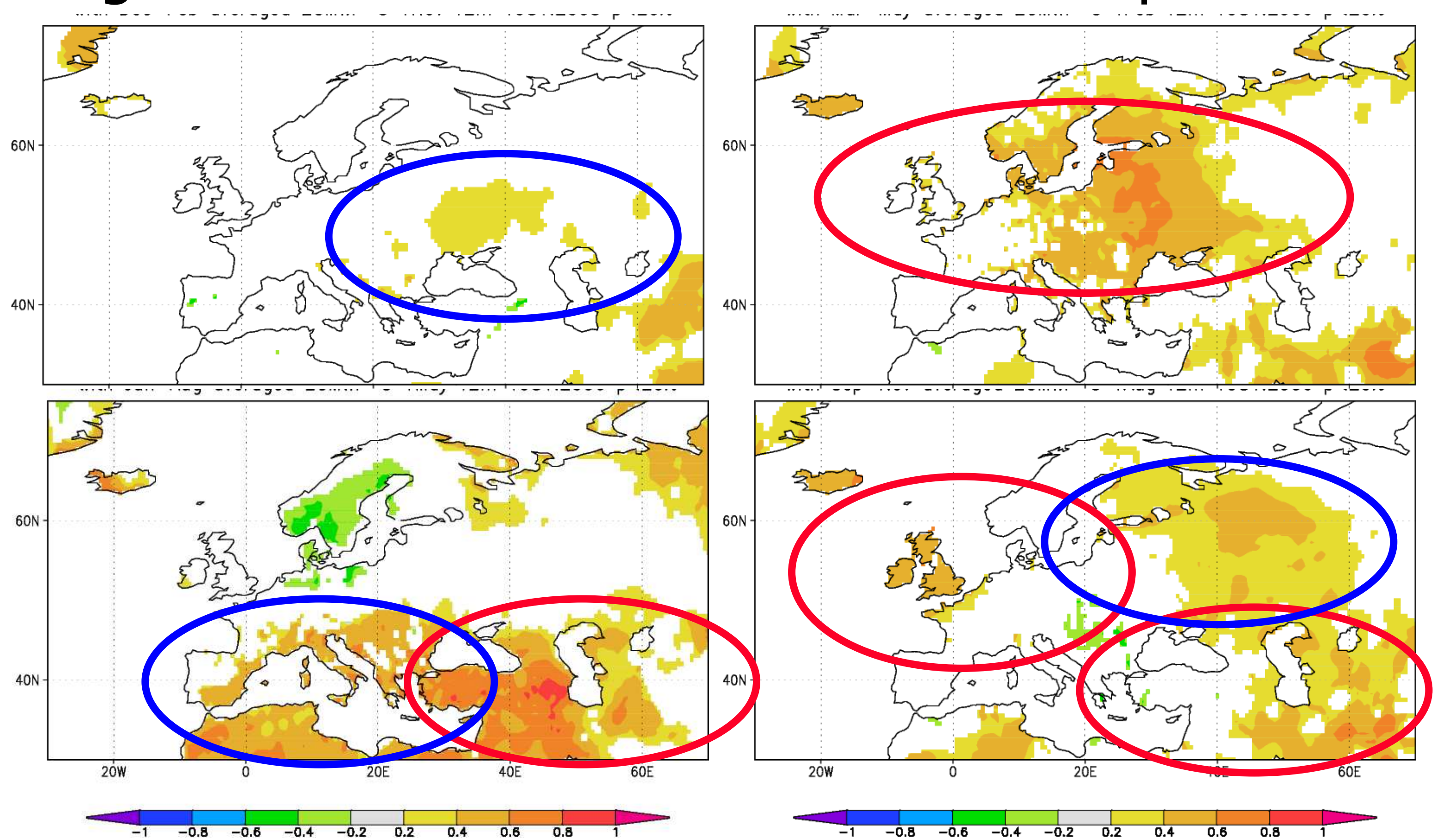
Correlation of System 3 seasonal forecasts of temperature wrt GHCN over 1981-2005. Only values statistically significant with 80% confidence are plotted.

DJF

MAM

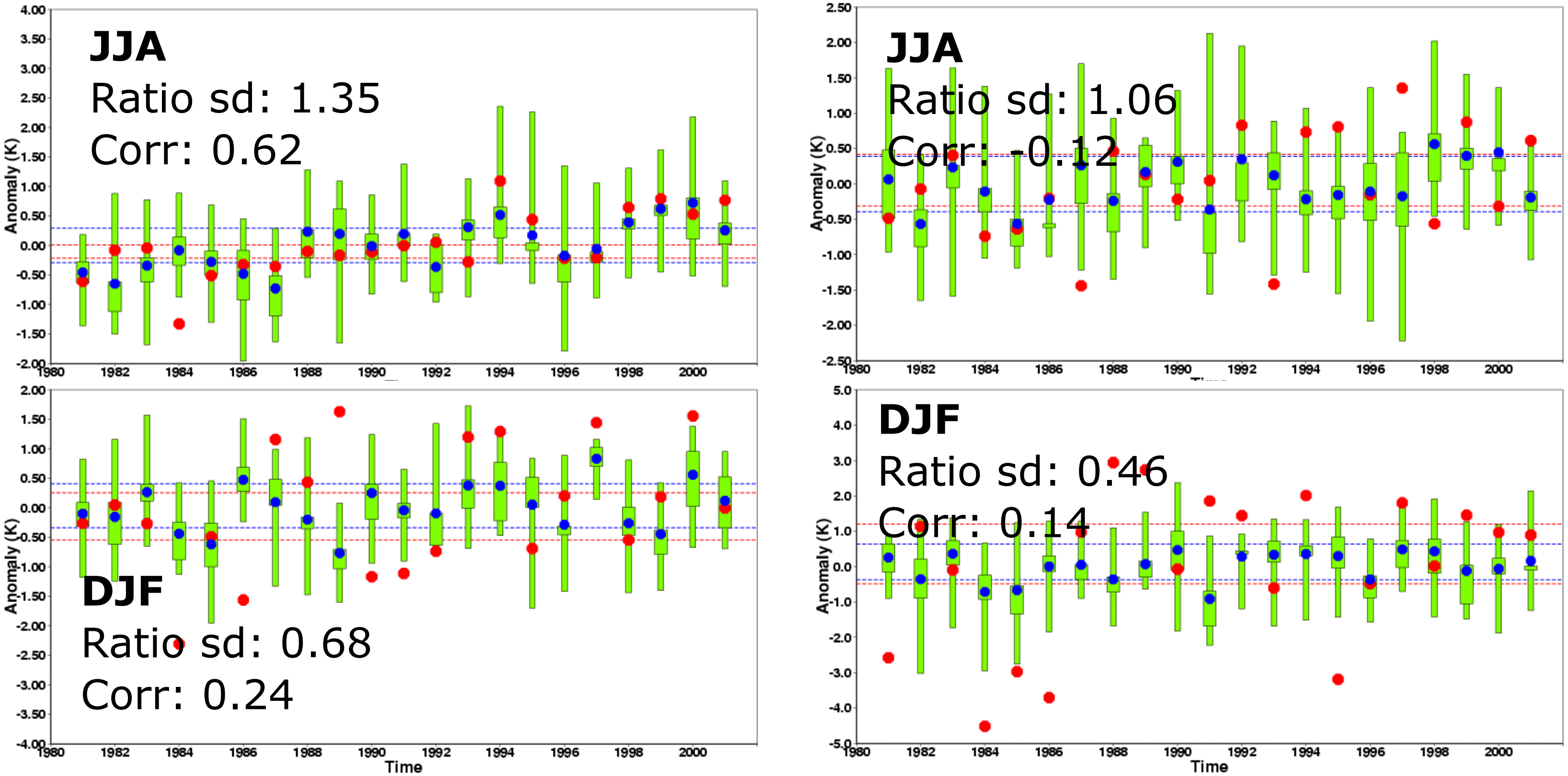
JJA

SON



# Seasonal re-forecasts for Europe

System 3 temperature re-forecasts for Southern (left) and Northern Europe (right) over 1981-2005. The green box-and-whisker show the ensemble range, the blue dot the ensemble mean and the red dot the ERA40/ERAInt value.



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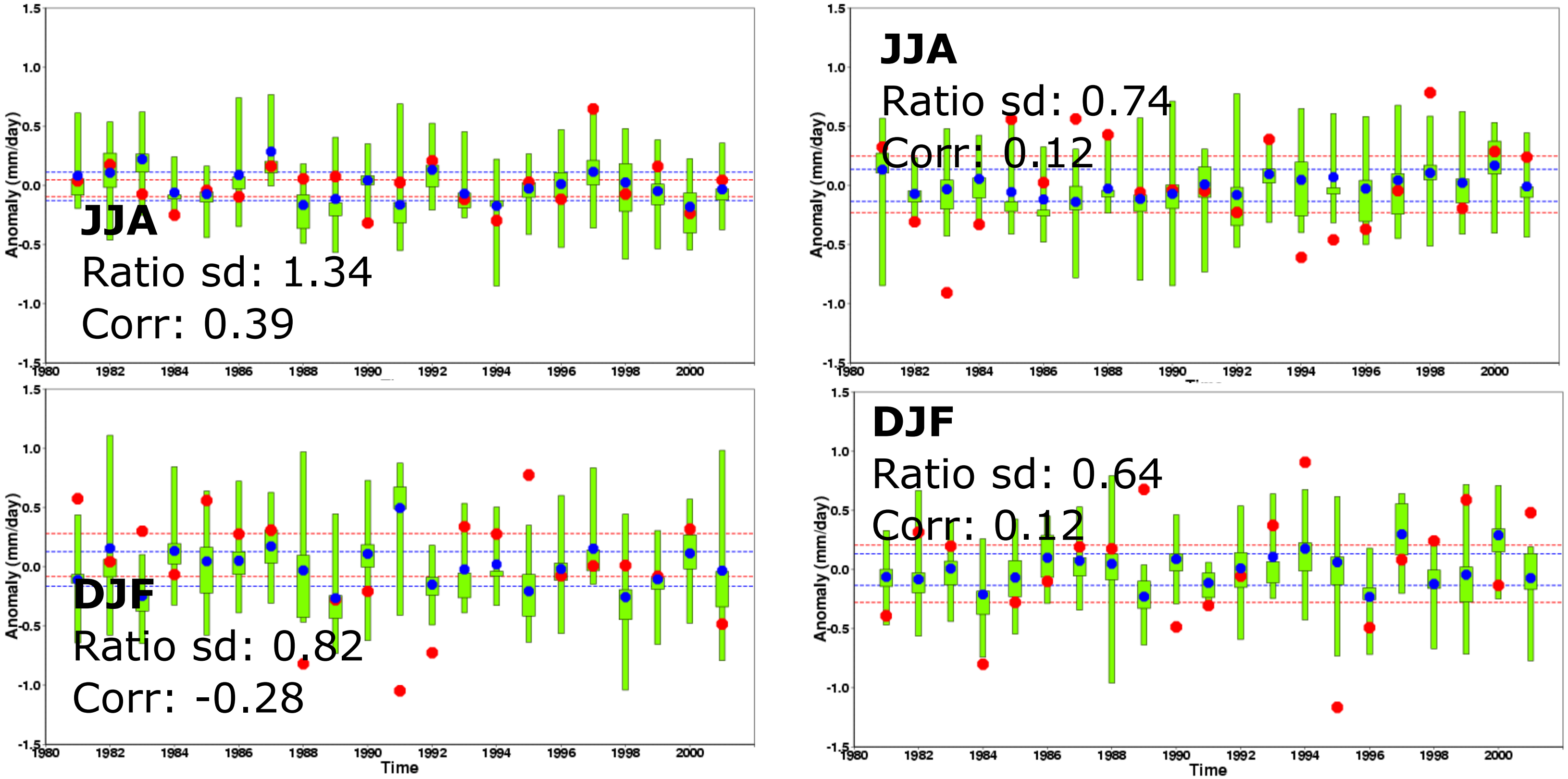
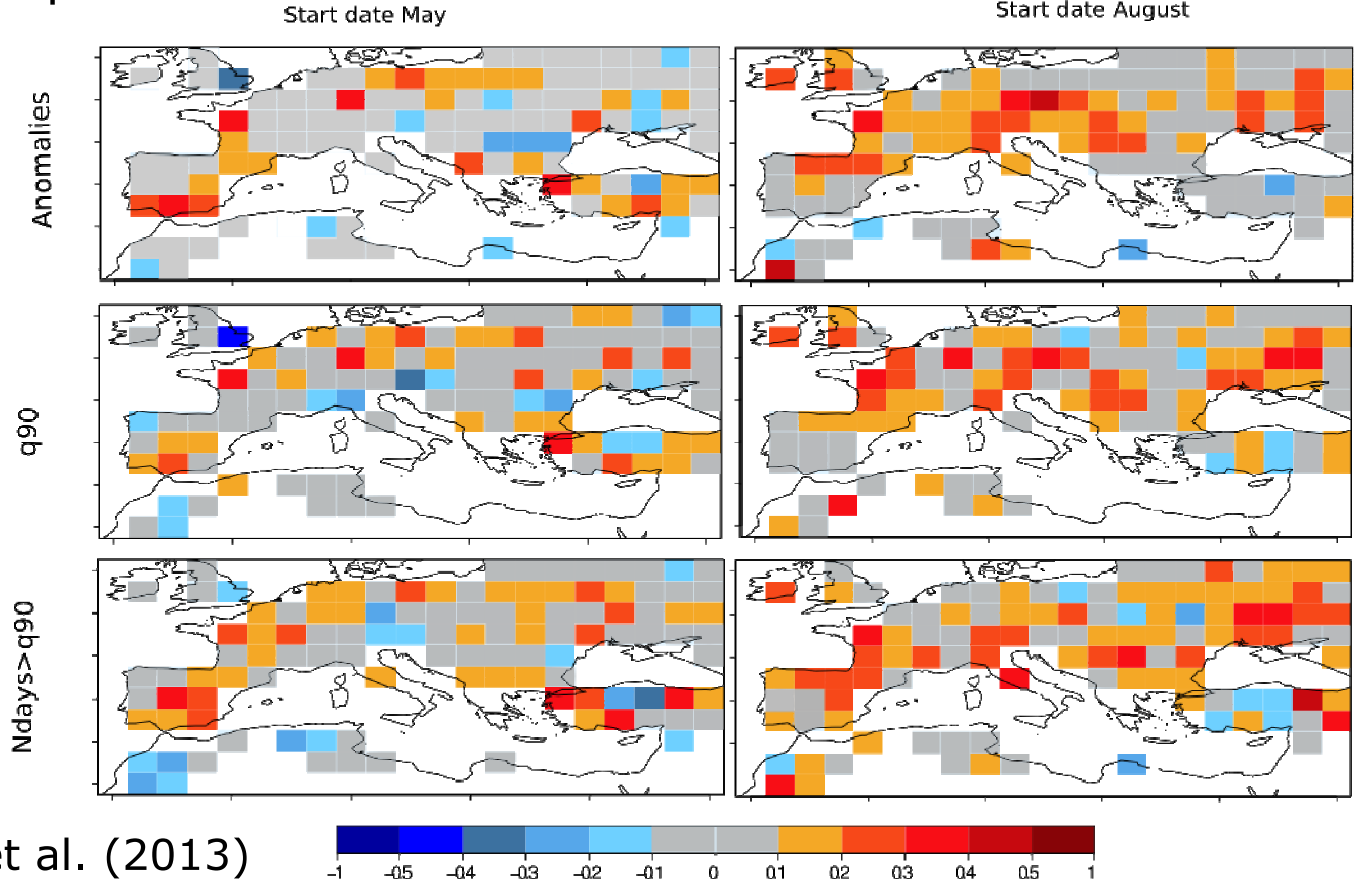
# Seasonal re-forecasts for Europe

System 3 precipitation re-forecasts for Southern (left) and Northern Europe (right) over 1981-2005. The green box-and-whisker show the ensemble range, the blue dot the ensemble mean and the red dot the GPCP value.



# Seasonal prediction: extremes

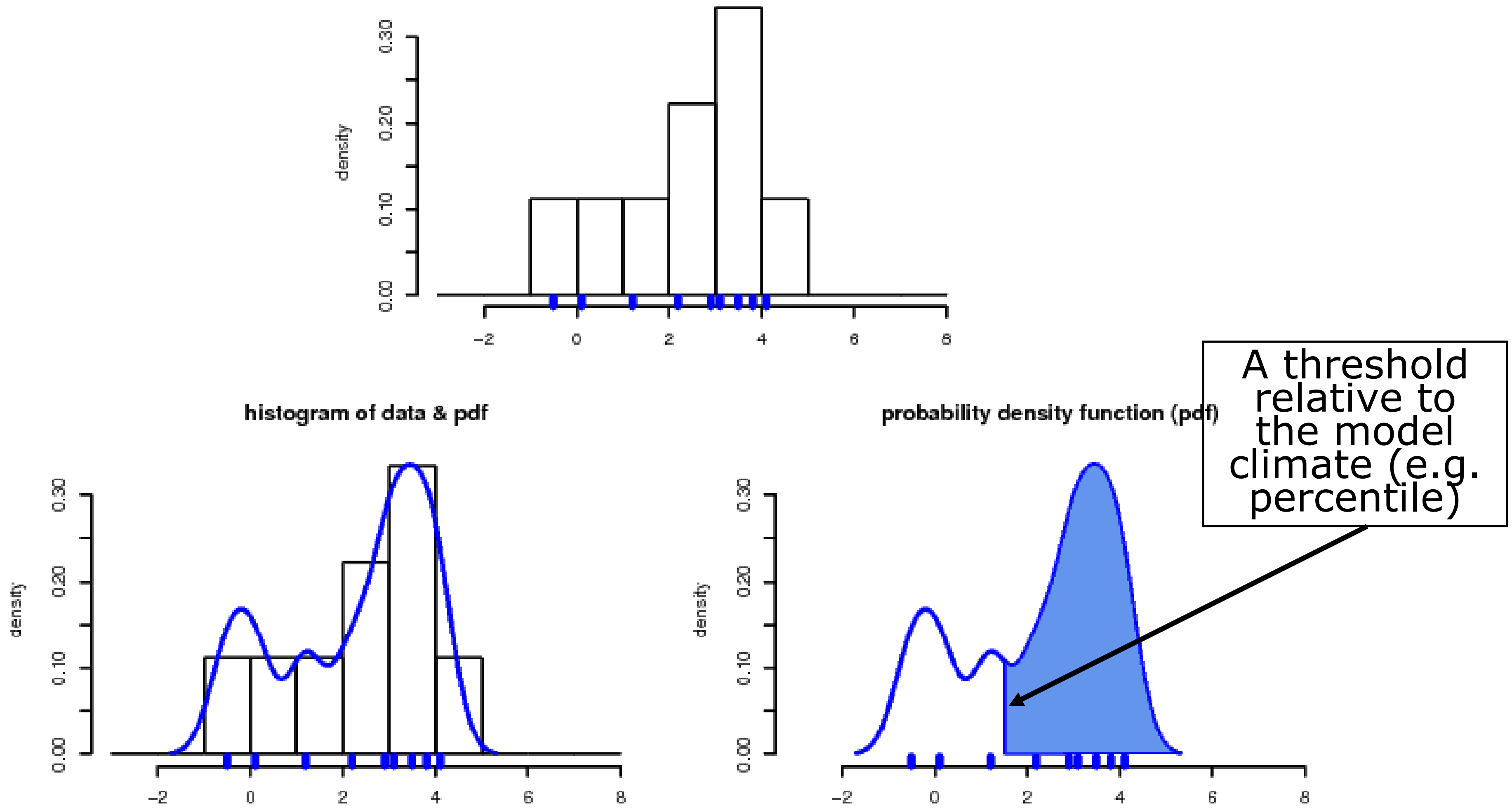
Ensemble-mean correlation of August (top row) monthly-mean precipitation anomalies, (middle row) 90th monthly percentile and (bottom row) number of days with precipitation above the 90th climatological percentile from DePreSys_PP hindcasts initialized in May (left) and August (right). Hindcasts over 1960-2005. Reference precipitation from the EObs dataset.




Doblas-Reyes et al. (2013)

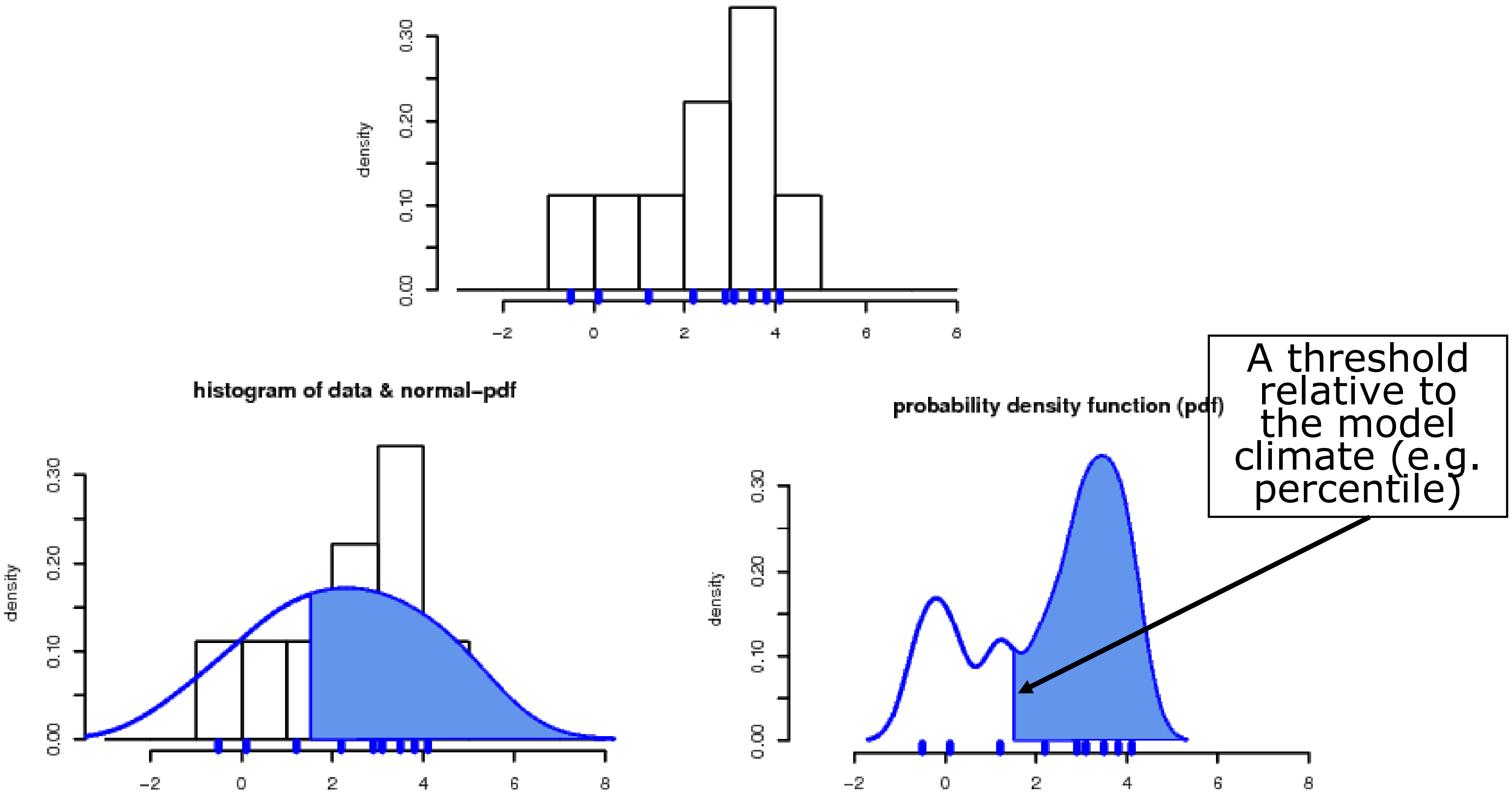
# From ensembles to probability forecasts

## Constructing a probability forecast from a nine-member ensemble



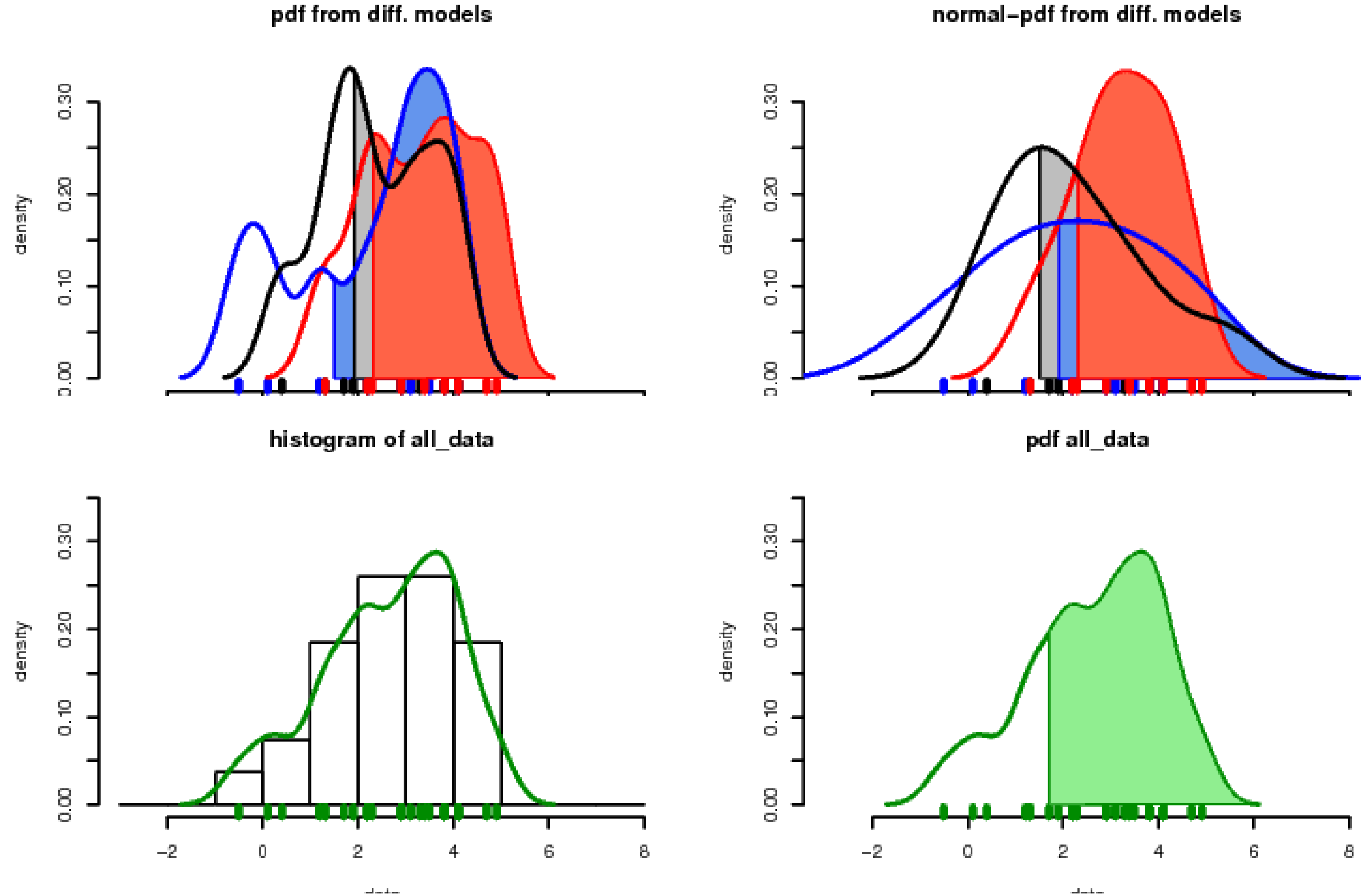
# From ensembles to probability forecasts

## Constructing a probability forecast from a nine-member ensemble



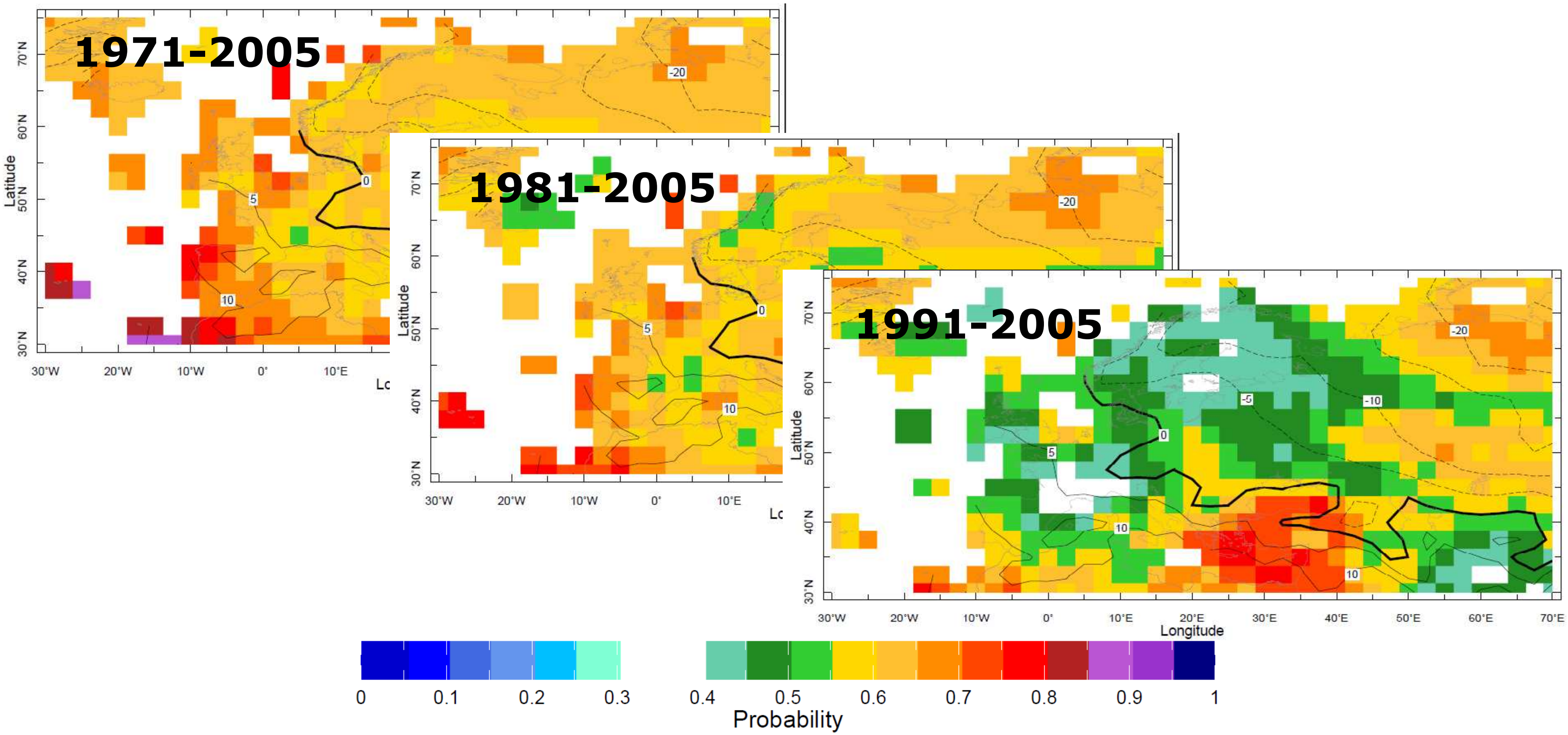
# From ensembles to probability forecasts

## Constructing a probability forecast from a multi-model ensemble



# Probabilistic prediction

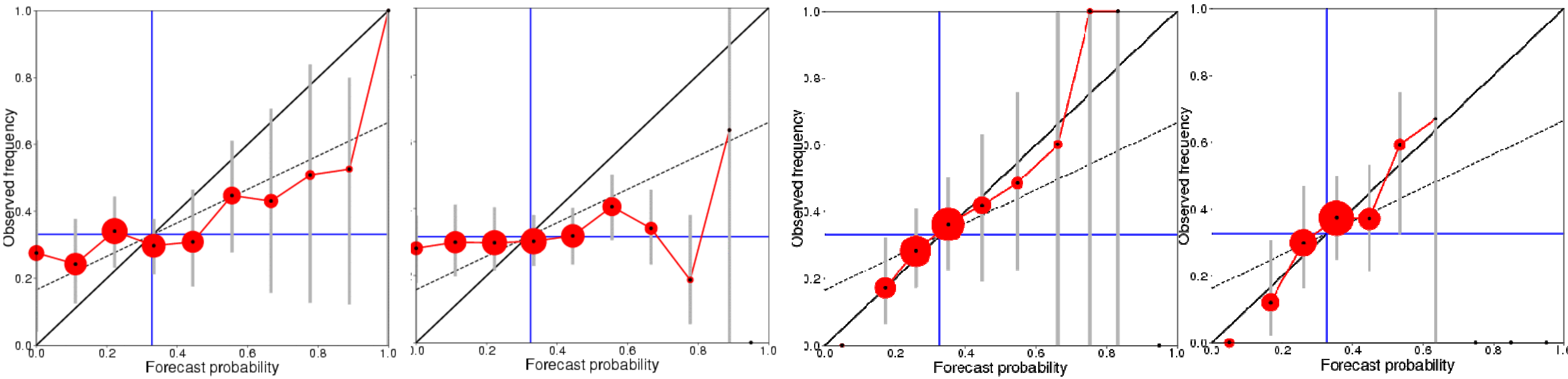
## One-month lead DJF 2009-10 IRI (flexible format) temperature forecasts for anom. above the upper tercile



# Multi-model improvement

Attribute diagrams for one-month lead seasonal (DJF) temperature over Southern Europe for System 3 (left, 9 members) and the ENSEMBLES Stream 2 multi-model (right, 45 members) over the period 1981-2005 verified against ERA40. Brier and ROC skill scores and 95% confidence intervals (in brackets) computed using a bootstrap method, are shown on top of each panel.

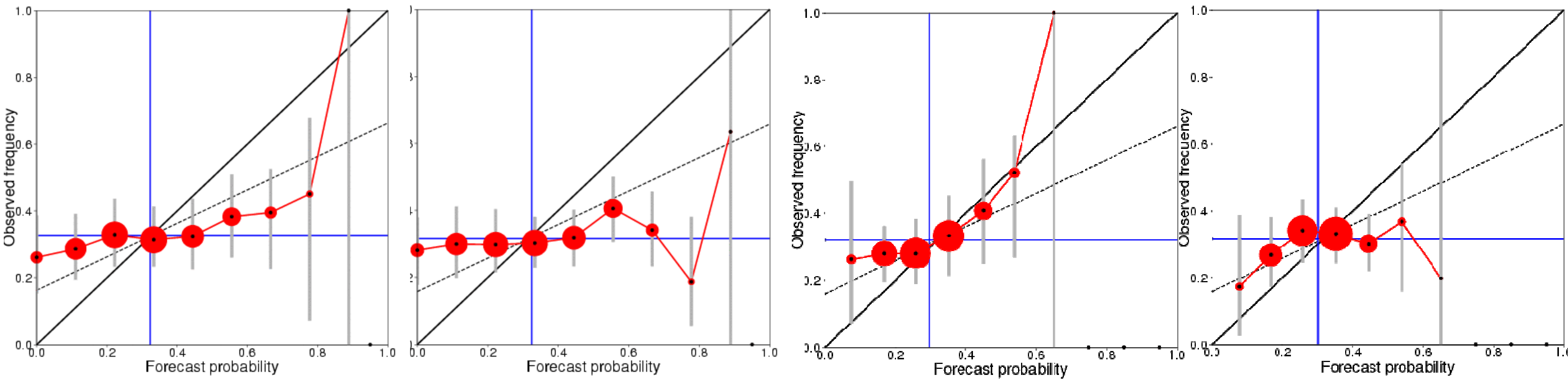
| System 3 | | Multi-model | |
|---|---|---|---|
| Above upper tercile | Below lower tercile | Above upper tercile | Below lower tercile |
| -.078 (-.287,.093) | -.140 (-.348,.022) | .054 (-.063,.140) | .047 (-.050,.106) |
| .148 (-.073,.379) | .109 (-.095,.325) | .256 (-.004,.464) | .253 (.027,.460) |



# Multi-model improvement

Attribute diagrams for one-month lead seasonal (JJA) precipitation over Southern Europe for System 3 (left, 9 members) and the ENSEMBLES Stream 2 multi-model (right, 45 members) over the period 1981-2005 verified against GPCP. Brier and ROC skill scores and 95% confidence intervals (in brackets) computed using a bootstrap method, are shown on top of each panel.

| System 3 | | Multi-model | |
|---|---|---|---|
| Above upper tercile | Below lower tercile | Above upper tercile | Below lower tercile |
| -.088 (-.167,-.038) | -.118 (-.178,-.071) | .001 (-.069,.046) | -.031 (-.082,.002) |
| .075 (-.027,.175) | .081 (-.018,.140) | .133 (-.022,.274) | .051 (-.070,.174) |



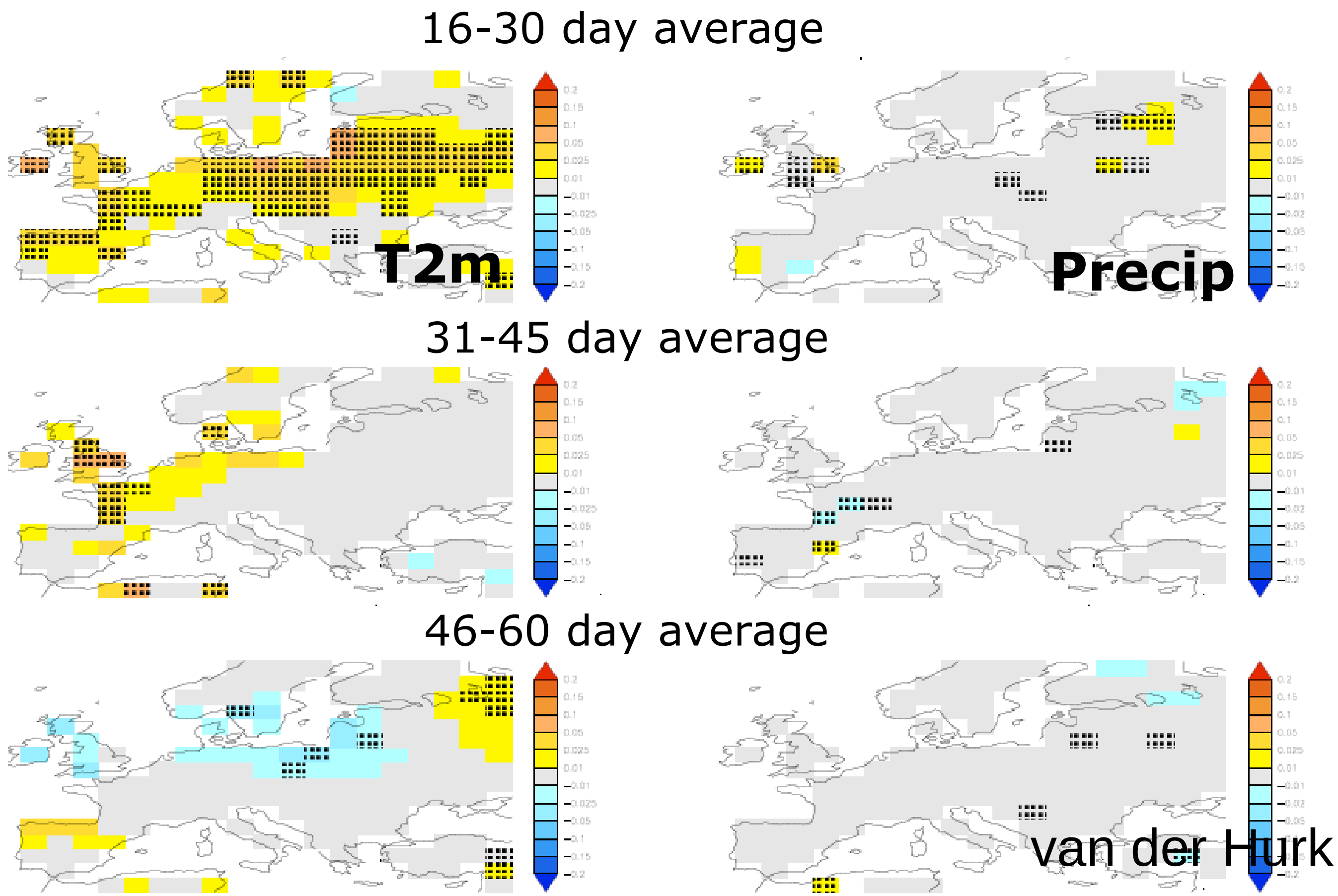
# Dealing with model inadequacy

Debiased Brier skill score of one-month lead predictions of land temperature over the Giorgi regions for Multi-model (45 members, left columns), Perturbed parameters (9 members, central columns) and Stochastic physics (9 members, right columns) over 1991-2005. Significantly positive or negative scores are in bold.

| | PRECIPITATION | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | JJA | | DJF | | JJA | | DJF | | JJA | | DJF | |
| | dry | wet | dry | wet | dry | wet | dry | wet | dry | wet | dry | wet |
| Australia | 7.6 | 7.0 | 0.9 | 3.0 | 5.1 | 8.0 | **12.4** | 5.2 | 2.5 | 5.0 | **10.5** | 6.6 |
| Amazon Basin | **10.3** | **10.3** | **16.0** | 14.3 | **8.8** | 5.4 | 3.4 | 0.5 | **12.2** | **11.4** | **16.1** | 16.8 |
| Southern South America | 6.2 | 7.1 | 4.6 | 6.0 | 1.3 | 1.6 | -4.5 | -1.7 | 3.3 | **9.0** | -4.7 | 0.2 |
| Central America | **9.2** | **7.8** | **23.4** | **18.9** | **12.9** | 5.2 | **23.3** | **25.9** | **10.6** | 7.7 | **24.9** | **23.7** |
| Western North America | 2.4 | **8.1** | **7.2** | **7.8** | 4.5 | **7.5** | 4.5 | 4.9 | **9.1** | **8.4** | 5.7 | 5.3 |
| Central North America | 0.6 | 2.2 | 7.7 | **10.4** | -3.5 | -5.7 | **10.0** | **10.4** | 1.7 | 3.0 | 2.1 | 5.5 |
| Eastern North America | -1.9 | -1.1 | **8.3** | **10.6** | **-9.6** | **-11.1** | 9.7 | **13.2** | **-15.0** | -6.8 | 7.5 | 2.1 |
| Alaska | -1.3 | 0.0 | 4.0 | -2.2 | -2.3 | -1.0 | **11.3** | 3.7 | -4.3 | -0.7 | 0.2 | -2.5 |
| Greenland | 2.6 | **2.8** | **-3.7** | **-3.0** | 1.4 | 0.2 | **7.5** | -1.7 | **-6.8** | -2.6 | -2.2 | -2.1 |
| Mediterranean | -1.2 | 1.2 | -1.0 | -1.3 | -6.1 | -4.4 | -3.0 | 0.1 | -0.9 | 0.1 | **11.5** | 10.7 |
| Northern Europe | 2.3 | 2.1 | -3.1 | **-4.7** | **7.7** | **11.5** | -1.8 | -1.6 | **8.2** | 6.0 | 6.6 | 1.6 |
| Western Africa | -1.5 | -0.1 | -0.5 | 1.3 | **-10.9** | -3.8 | 4.8 | -1.6 | -4.8 | 2.4 | **-13.7** | -0.1 |
| Eastern Africa | -2.8 | 1.8 | 3.9 | 2.5 | -7.0 | **-7.6** | **14.4** | **13.2** | -1.5 | 3.4 | 0.9 | 5.7 |
| Southern Africa | 3.5 | 1.0 | 5.7 | **9.5** | **7.2** | 4.7 | **6.0** | **11.3** | 7.8 | 9.2 | 7.7 | 8.9 |
| Sahel | **-4.6** | **-3.6** | **-3.2** | -1.5 | **-9.2** | **-6.7** | -2.7 | -2.4 | **-10.0** | -1.0 | **-8.2** | -3.6 |
| South East Asia | **14.3** | 9.7 | **8.8** | **8.3** | 5.5 | 4.8 | 5.6 | 8.3 | 10.3 | 1.1 | 9.6 | **12.5** |
| East Asia | 0.5 | -0.5 | 4.7 | **4.6** | **5.6** | 1.4 | 8.9 | 3.6 | 2.8 | 0.6 | 8.9 | **15.7** |
| South Asia | 0.2 | 0.9 | **6.5** | **7.4** | 0.6 | -2.7 | 7.0 | 9.4 | 2.7 | 1.9 | 5.5 | **10.2** |
| Central Asia | -0.8 | 0.2 | 7.4 | 5.7 | 0.8 | -3.1 | **10.3** | **8.4** | -1.5 | 0.2 | 2.9 | 1.6 |
| Tibet | 5.5 | 3.5 | **6.5** | 5.4 | -1.4 | -0.9 | 1.2 | 7.8 | 4.2 | **6.4** | **10.7** | **10.0** |
| North Asia | **2.4** | **2.6** | 3.1 | 0.6 | 3.3 | 2.9 | 2.1 | -1.0 | 1.0 | 0.6 | 2.5 | -1.9 |
| | multi-model | | | | perturbed parameters | | | | stochastic physics | | | |

# Sources of predictability: soil moisture

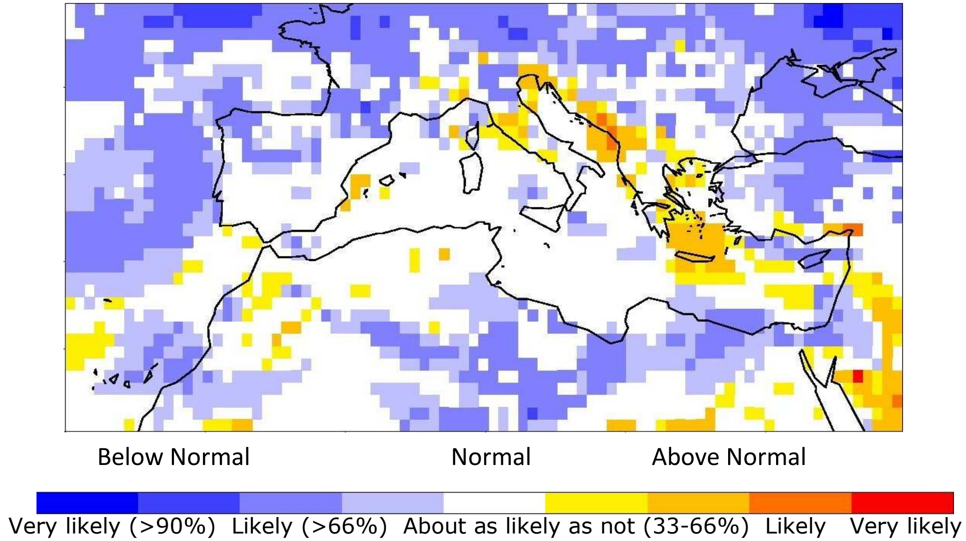
GLACE2 multi-model R2 difference between Series 1 and Series 2. Grid points with statistically significant differences with 98% confidence level are dotted.



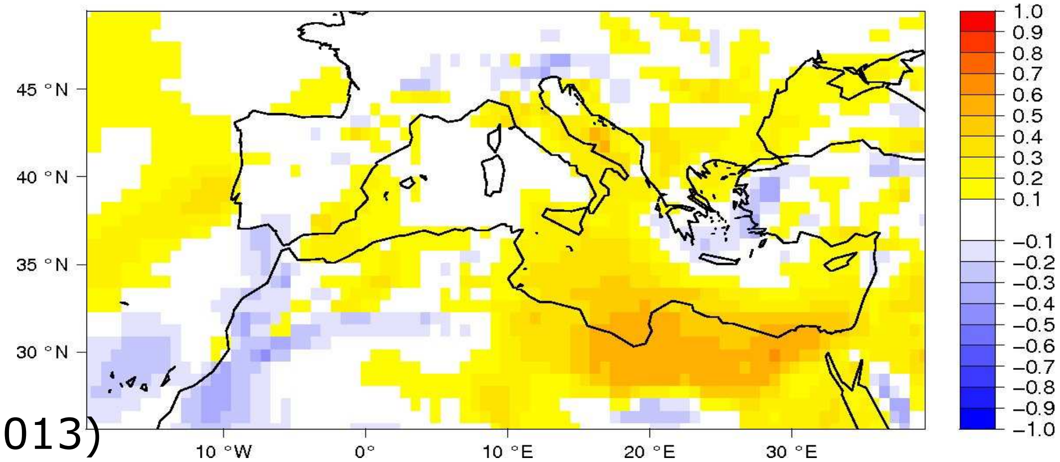

van der Hurk et al. (2010)

# Climate services: renewable energy

Seasonal prediction of 10-metre wind speed from ECMWF System 4, with climatology computed from 1981-2010. Reference from ERA Interim.




Probability most likely tercile (%) DJF 2010




Correlation of DJF wind speed predictions

Doblas-Reyes et al. (2013)

# Seasonal forecast sources

- EUROSIP: Multi-model available at ECMWF:
  - ECMWF System 4
  - Met Office GloSea4 (in the future GloSea5)
  - Météo-France System 4
  - CFSv2
  - MPI/DWD in the near future
  - Real-time since mid-2005, all data in ECMWF operational archive
  - Common operational schedule (products released at 12Z on 15$^{th}$)
- Other European operational systems
  - CMCC
- North American Multi-Model Ensemble
  - Nine systems from the USA and Canada (CFS, GFDL, NCAR, NASA, CCCma, IRI)
  - Available from a repository at IRI
- APCC

# Some final thoughts

- In the end we need trustworthy models, but model development is a slow process.
- Timescale for improvements
  - o Optimist: in 10 years, we'll have much better models, pretty reliable forecasts, confidence in our ability to handle climate variations
  - o Pessimist: in 10 years, modelling will still be a hard problem, and progress will largely be down to improved calibration Users will require calibration and can provide feedback on the presentation of forecast information.
- Seasonal forecasting would benefit from a coordinated effort to improve the forecast systems and to combine climate information from different sources -> SPECS.
- Seamless prediction paradigm: dynamical weather and seasonal-to-interannual forecasts used to infer aspects of the quality of climate-change predictions in a seamless framework -> estimation of the reliability of regional predictions and projections.