Seasonal climate forecasting for the energy and water industries in SECLI-FIRM

Andrea Alessandri (KNMI) and WP2 Team

Stakeholder Workshop, 17 January 2019 Milan (Italy)

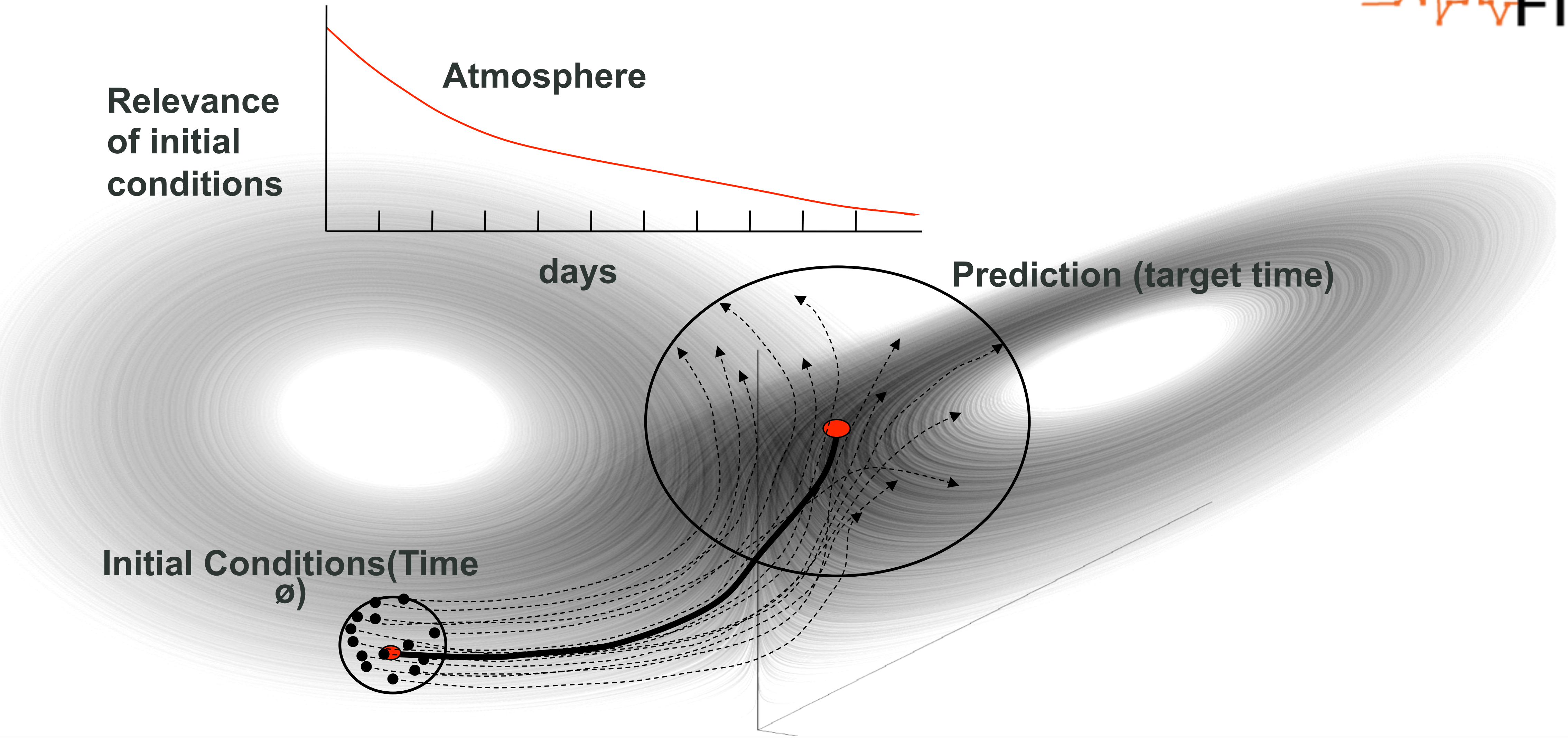
Grant Agreement n. 776868

Outline

- ✓ On the probabilistic nature of Seasonal Predictions
- ✓ Use of Grand-MME seasonal forecasts in SECLI-FIRM
- ✓ Optimization of Seasonal Climate prediction in SECLI-FIRM (WP2)
- ✓ Discussion: Q&A

On the probabilistic nature of Seasonal Predictions

On the probabilistic nature of Seasonal Predictions



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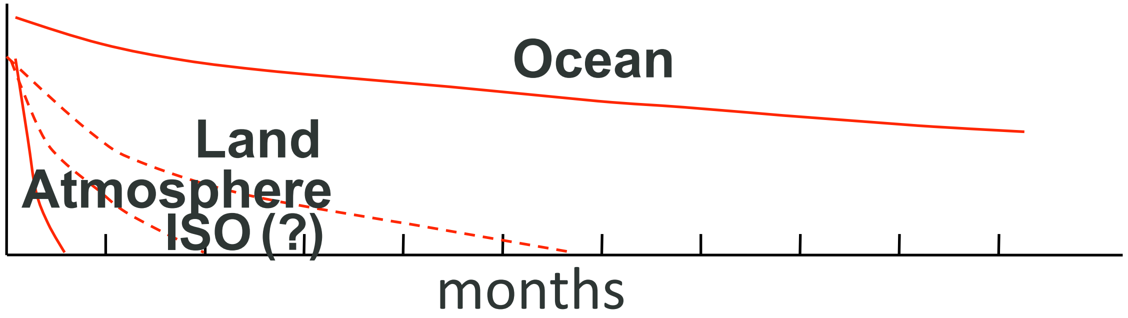
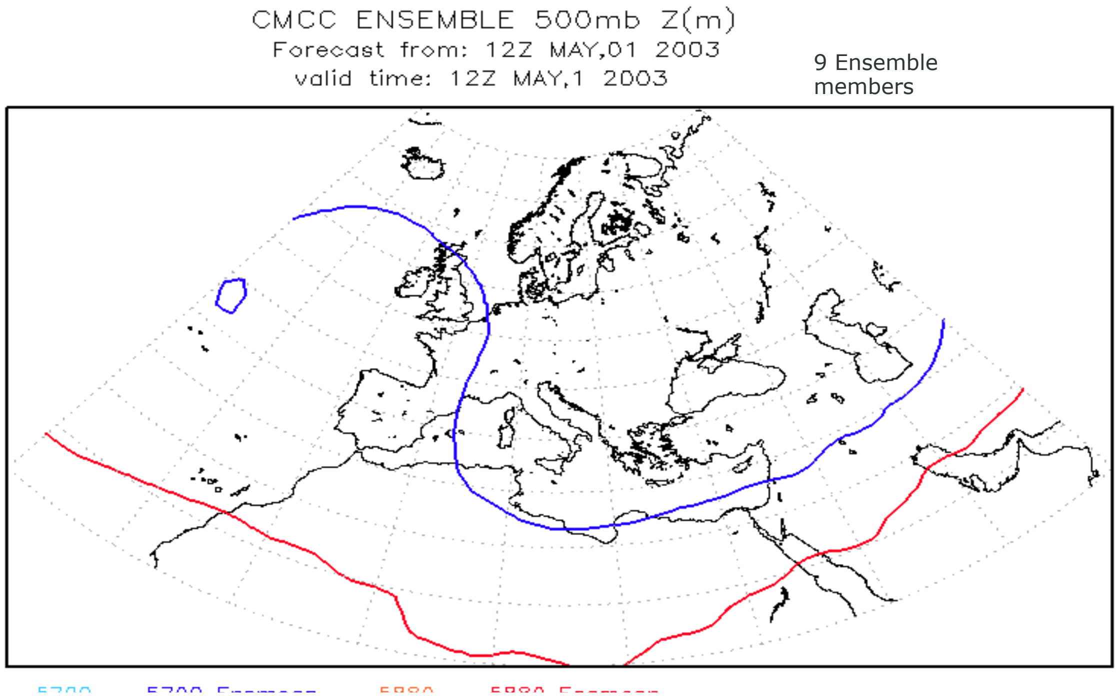
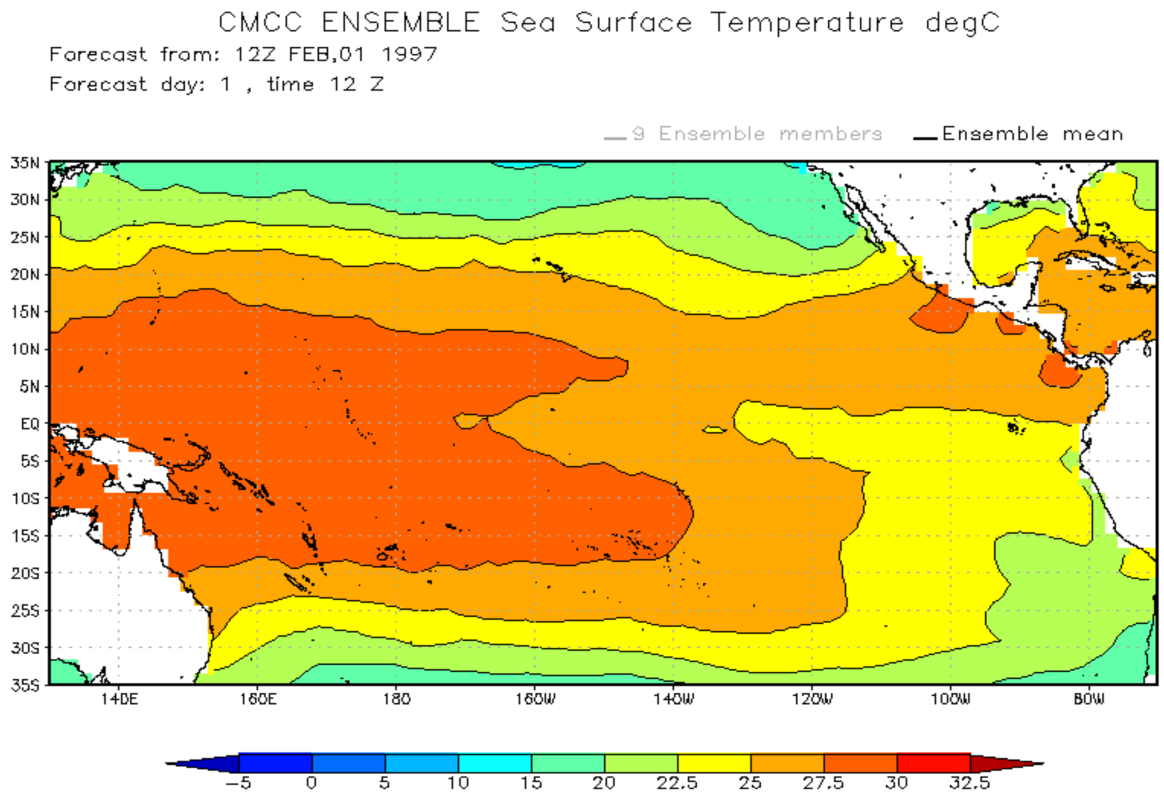
On the probabilistic nature of Seasonal Predictions



- Koster et al., 2004; 2010
- Vitart et al., 2006; Wang et al., 2009

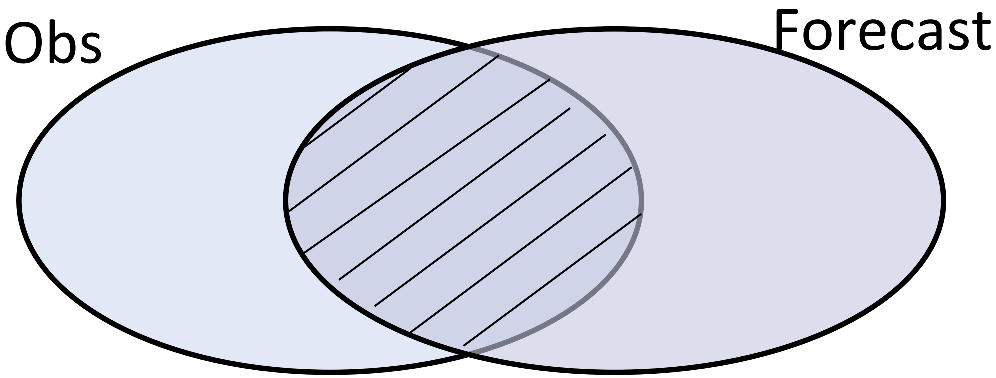




On the probabilistic nature of Seasonal Predictions

On a fundamental level, probabilistic verification/calibration involves investigation of the joint distribution of forecasts and observations (Murphy and Winkler 1987). That is, verification data-set consists of a collection of forecast/observation pairs whose joint behavior can be exploited to assess forecasts performance.

Joint distribution of observed and forecast outcomes



For Joint distribution to be tractable: dichotomous (Yes, No) events need to be identified as well as suitable discretization of the model probabilities performed.

After discretizing probability forecasts to finite set of values (y_1, y_2,...y_i; I = 1,...,I), the joint distribution of forecasts and dichotomous observations (oj; yes j = 1; no j = 0) can be denoted by:

$$\Pr\left(y_i \cap o_j\right) = p(y_i, o_j)$$
$$i = 1, 2, \ldots, I$$
$$j = 0,\ 1$$

y_i model probability forecasts

o_j observed events :

above normal (i.e : > upper tercile)

below normal (i.e : < lower tercile)

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Prediction of adverse event [E+] – **Probabilistic case**

Potential Economic Value

(**Cost-Loss** decision model; Richardson, 2003)

*[E+] implies financial **Loss** if no preventive action is taken at a financial **Cost***

	Event observed (O_1)	No event observed (O_0)
Forecast Probability (Yi) > Cost/Loss Action taken	Hit **COST +** **REDUCED LOSS**	False alarm **COST**
Forecast Probability (Yi) < Cost/Loss No action taken	Miss **LOSS**	Correct rejection

But we are assuming Yi is Reliable (Calibrated)

COST

<

LOSS x Yi

Steele et al. (2017), OTC, pp. 1-8; Steele et al. (2018), OTC, pp. 1-8; Alessandri et al., 2018

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On the reliability of probabilistic information from ensemble forecasts: shall we trust ensemble forecast raw outcomes or do we need any calibration?

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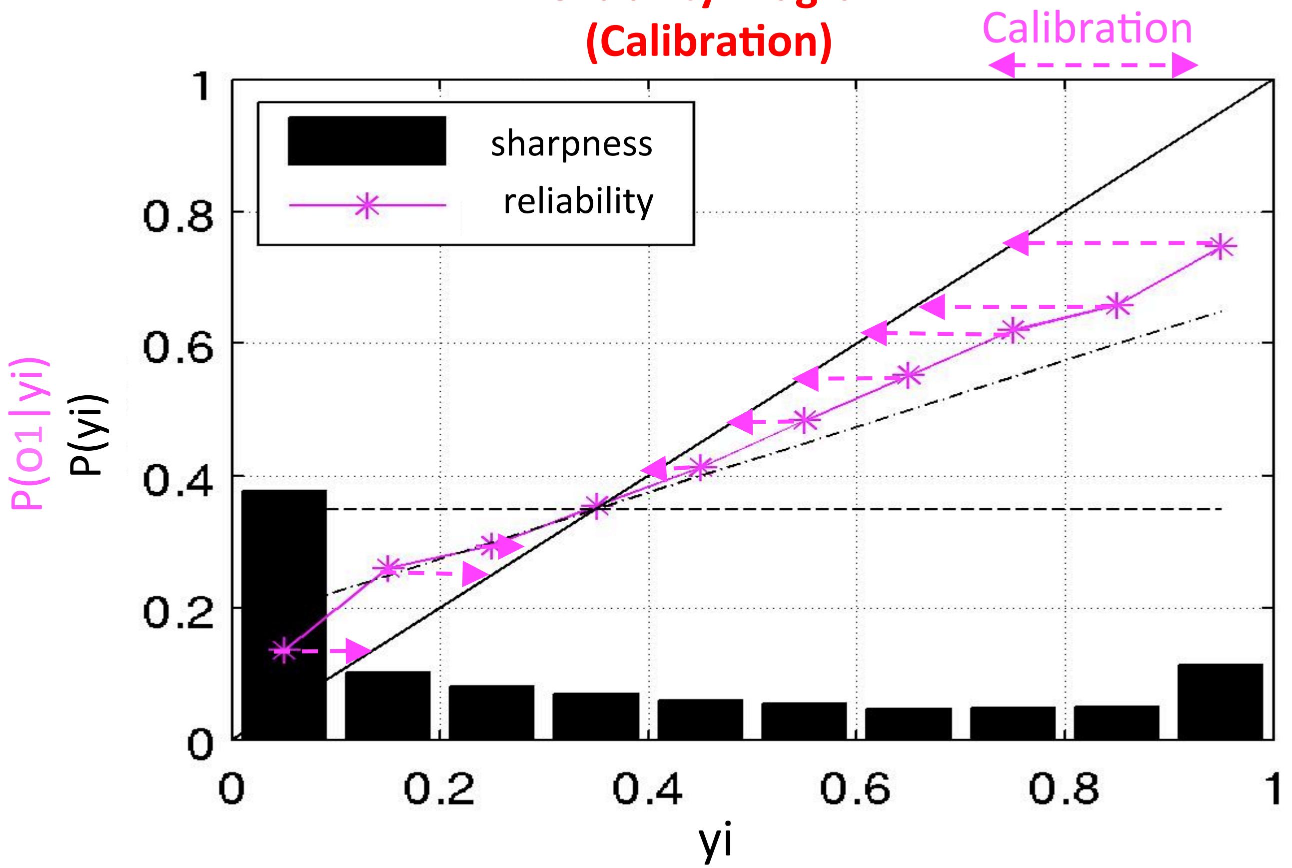
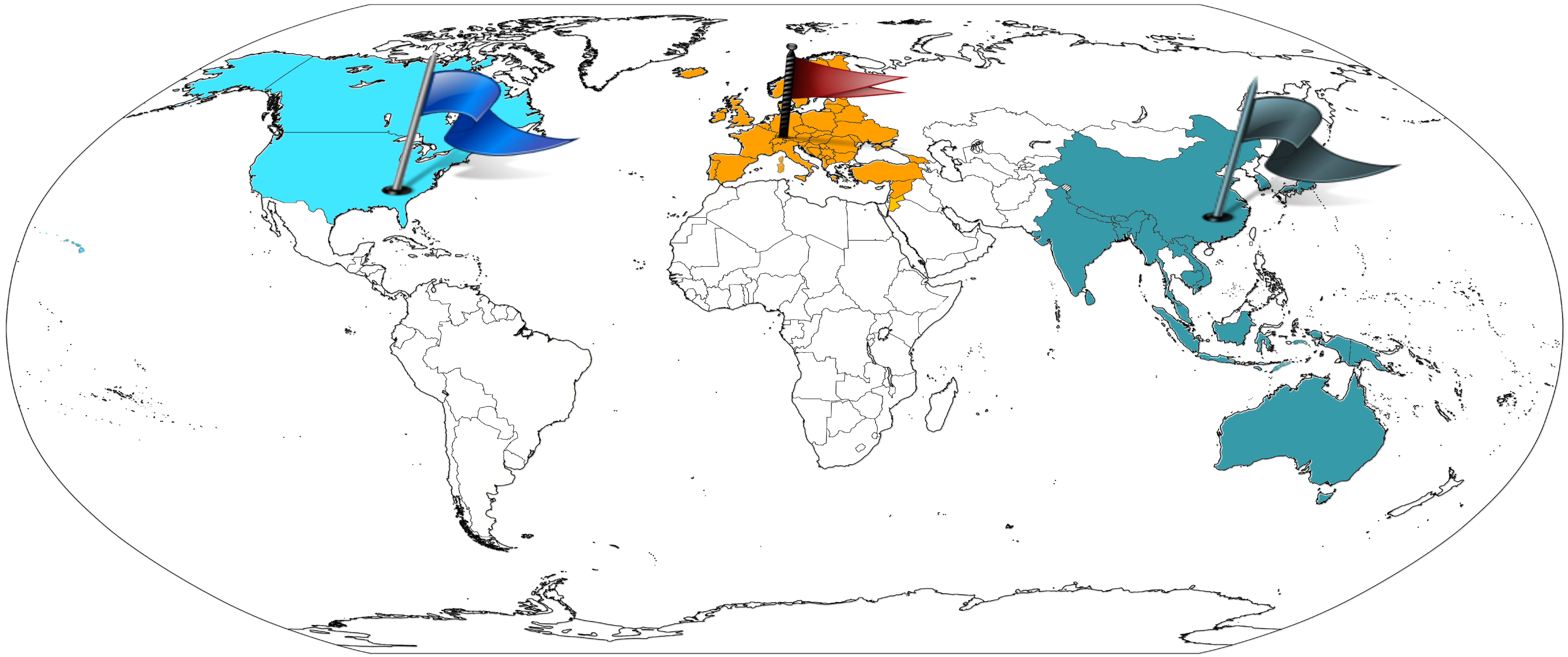
Reliability Diagram (Calibration)



Grand MME in SECLI-FIRM

Task 2.1 – Development of multi-model seasonal prediction dataset from independent sources: European, North American and Asian Pacific (Lead UEA) [M1-M12]

Grand MME in SECLI-FIRM



"We'll collect (i) the Copernicus C3S seasonal forecasts product (C3S dataset; https://climate.copernicus.eu/seasonal-forecasts) for the European community, (ii) the APEC Climate Center MME (APCC dataset;http://www.apcc21.org/abt/model.do?lang=en) for the Asian-Pacific community and (iii) the North American Multi-Model Ensemble (NMME dataset; http://www.cpc.ncep.noaa.gov/products/NMME)"

D2.1: Report on the development of the homogenized and calibrated Multi-Model seasonal predictions database. [Lead UEA; M12]
MS2.1: Multi-Model seasonal predictions database made available [M12]

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The Added Value of Seasonal Climate Forecasting for Integrated Risk Management

Q4 2018	Q1 2019	Q2 2019
ECMWF S5	ECMWF S5	ECMWF S5
	NMME Model 1	NMME Model 1
	C3S Model 2	C3S Model 2
	⋮	⋮
	C3S Model **n1**	C3S Model **n1**
	NMME Model 2	NMME Model 2
	⋮	⋮
	NMME Model **n2**	NMME Model **n2**
	Others Model 1	Others Model 1
	⋮	⋮
	Others Model **n3**	Others Model **n3**

Legend

- Monthly (yellow)
- Daily v1 (green)
- Daily revised v2 (orange)

Q4 2018	Q1 2019	Q2 2019
Decision on Monthly variables (it may need revision at later stage)	Decision on Daily variables (comprehensive set of variables and members) Decision on initial set of models to include in MME Decision on the calibration to apply to Monthly and Daily fields	Revise variables, ensemble members needed (after preliminary analysis) Revise set of models to include in MME (daily fields) Revise calibration to apply to Monthly and Daily
UEA HPC Access provided to partners	UEA HPC: 1 TB (fast) +3 TB (slow) (can be upgraded to 1+10 TB storage)	AWS: 10 TB (fast) + ~50 TB (slow) (can be upgraded also looking to partner with MED-GOLD)

The rationale in using multi-models

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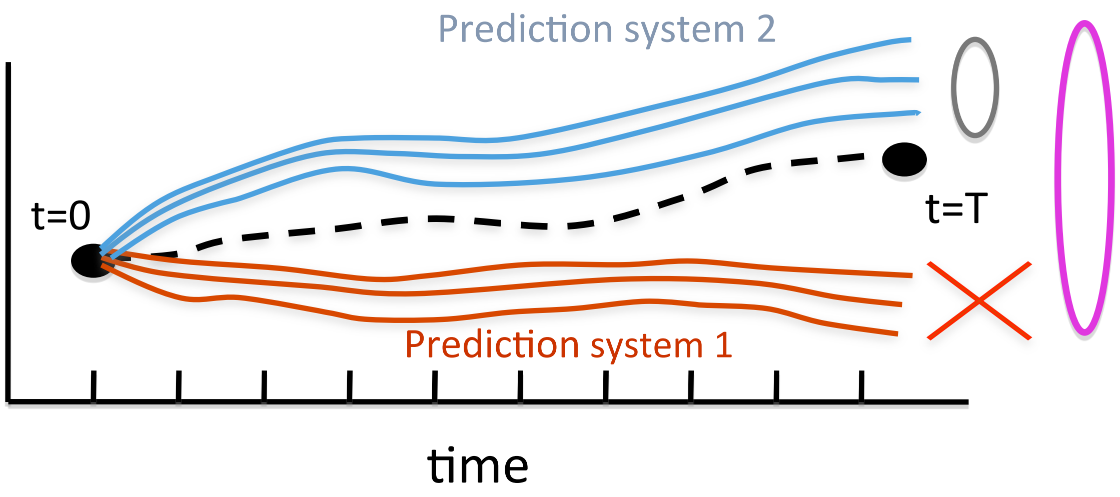
The rationale behind use of Multi-Models



MME can improve by:

- *Combining the skill from the single models*
- *Improve ensembles dispersion and uncertainty consideration*

➢ *Independence of the Single models systems*

➢ *Degree of over-confidence*

(Hagedorn et al., 2005 ; Weigel et al., 2009; Alessandri et al., 2011)

Grand ENSEMBLES-CliPAS/APCC Multi-Model by combining Asian-Pacific (CliPAS/APCC) and European (ENSEMBLES) MMEs

Performance and usefulness of CLImate predictions: Beyond current liMITationS (http://tinyurl.com/fp7-iof-climits)

Supported by European Union (FP7 programme) Marie Curie IOF

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The Grand ENSEMBLES-CliPAS/APCC MME

Two independent MME:
11 Prediction Systems from **CliPAS/APCC** and **5** from EU **ENSEMBLES**

CliPAS/APCC (Wang et al., 2009)
APCC Asia-Pacific Economic Cooperation Climate Center, S. Korea.
NCEP, National Center for Environmental Prediction, USA
BMRC, Bureau of Meteorology Research Center, Australia
PNU, Pusan National University, S. Korea.
MSC, Meteorological Service of Canada, Canada (CANCM3, CANCM4)
NASA, National Aeronautics and Space Administration, USA
SNU, Seoul National University, S. Korea
UH, University of Hawaii, USA
GFDL, The Geophysical Fluid Dynamics Laboratory , USA
FRCGC, Frontier Research Center for Global Change, Japan

ENSEMBLES (Weisheimer et al, 2010; Alessandri et al, 2011)
ECMWF, European Centre for Medium-Range Weather Forecasts, United Kingdom
UKMO, UK-Met Office Met Office, United Kingdom
MF, Meteo France. France
INGV-CMCC, Centro Euro-Mediterraneo per i Cambiamenti Climatici, Italy
IFM-GEOMAR, Leibnitz Institute of Marine Sciences at Kiel University, Germany

ENSEMBLE-based predictions of climate changes and their impacts (**ENSEMBLES**) supported by **EU** FP6 programme

Climate Prediction and its Application to Society project (**CliPAS**; Wang et al., 2009) sponsored by **APCC**

common hindcast period 1983-2005
1 May and 1 Nov start dates

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Maximization of probabilistic seasonal forecasts performance at each grid point by combining ENSEMBLES and CliPAS/APCC models

Performance and usefulness of CLImate predictions: Beyond current liMITationS (http://tinyurl.com/fp7-iof-climits)

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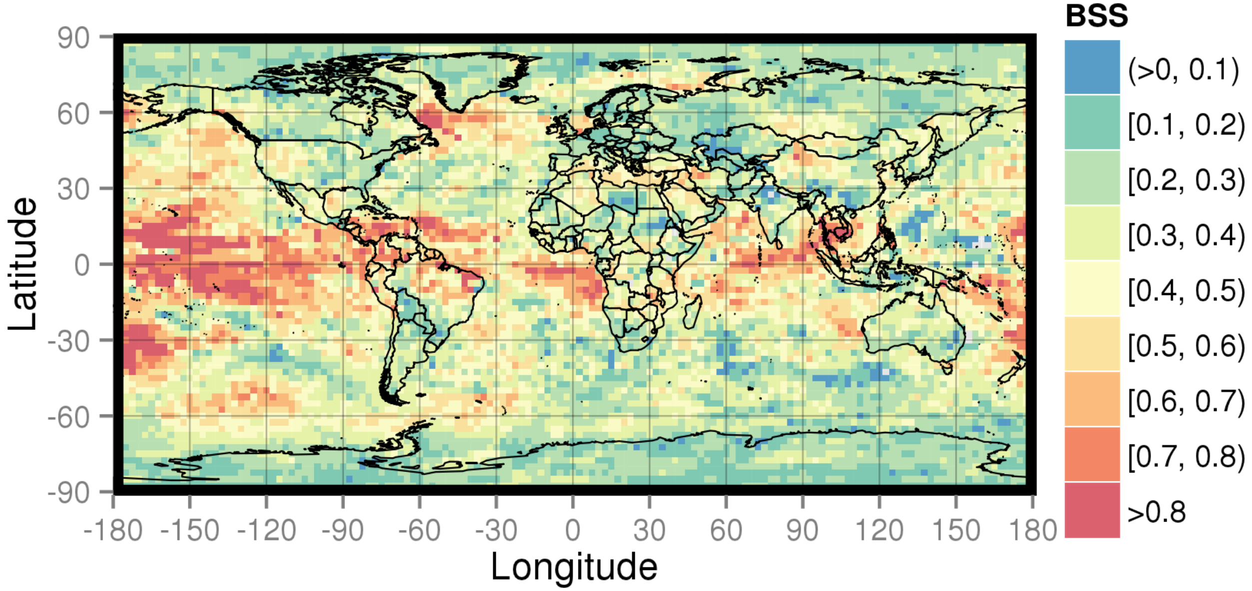
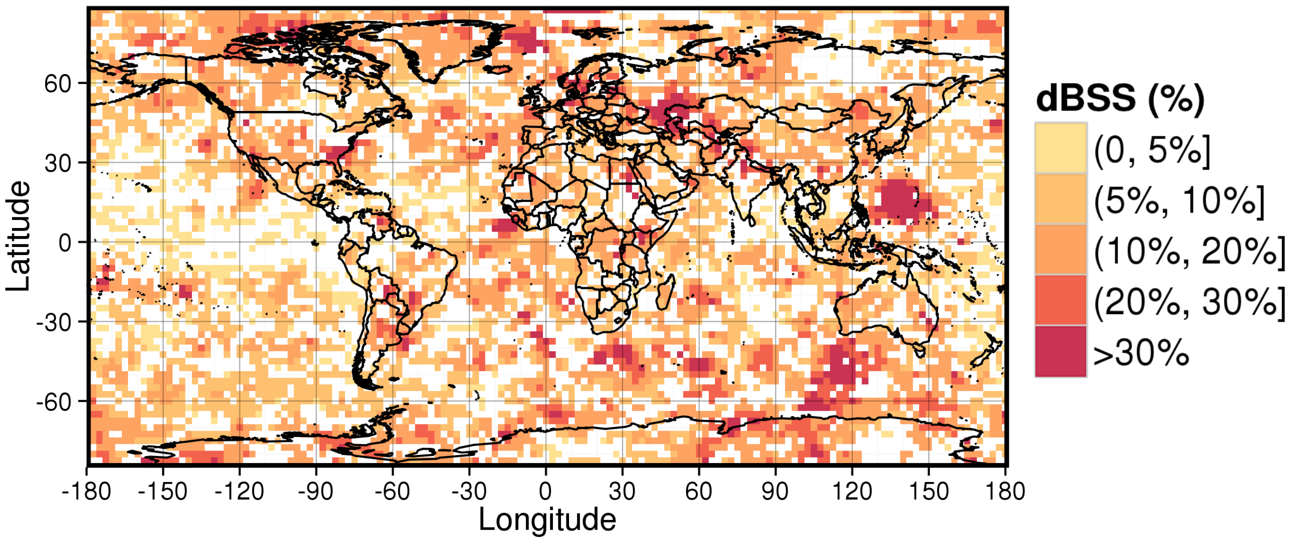
Max [Grand MME] vs Max [ENSEMBLES or CliPAS/APCC]
Brier Skill score - above upper tercile T2m JJA

Max [Grand MME]



Max [Grand MME] minus Max [ENSEMBLES or CliPAS/APCC]



Alessandri et al., 2018

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Usefulness of the contributing models

Brier Skill score - above upper tercile T2m JJA

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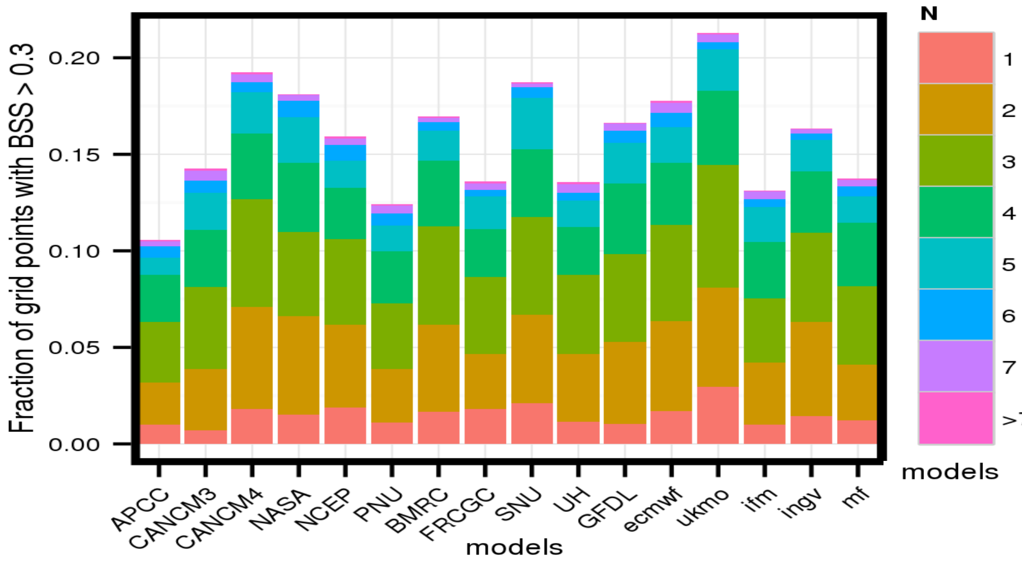
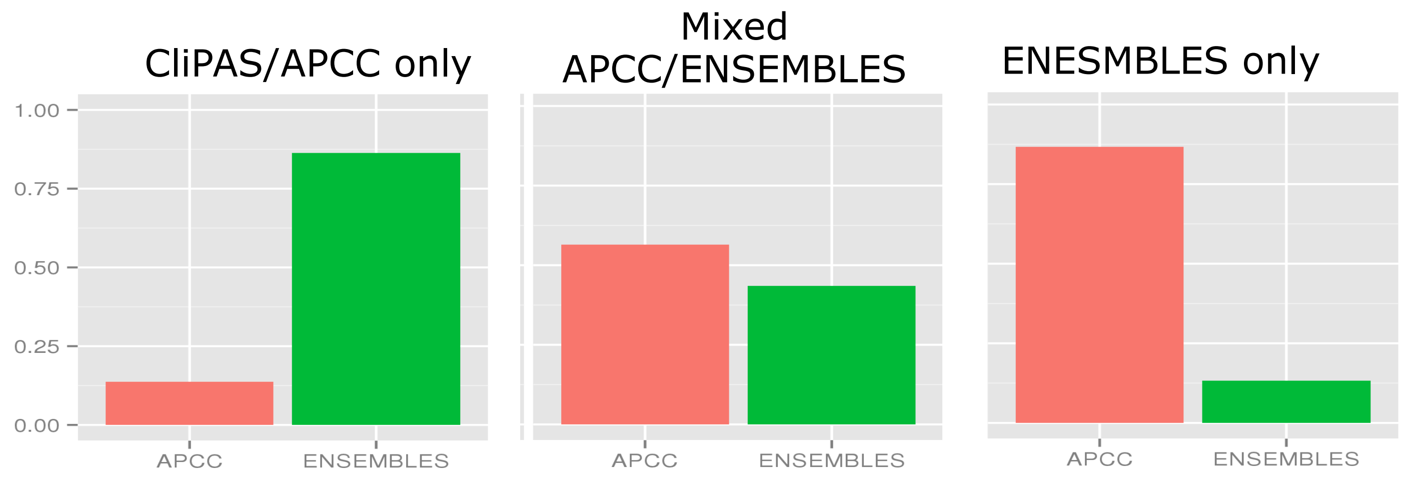
All models contribute to the improved performance of the Grand MME



Fraction of grid-points each model is needed to maximize performance

The improvements are larger when adding independent models to the MMEs



Normalized marginal contribution of adding APCC or ENSEMBLES models to combinations of APCC only, ENSEMBLES only and mixed MMEs

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Alessandri et al., 2016 Under Revision

Prediction of Electricity demand over Italy using seasonal climate forecasts

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•Forecasting of anomalous summer Temperature at the seasonal time-scale over “hot-spot” land areas such as Euro-Mediterranean has been recently shown to have the potential to drive predictions of electricity demand anomalies due to increased summer refrigeration and air conditioning.

De Felice, Alessandri and Catalano, 2015 (Appl. Energy)

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Seasonal forecast skill for Temperature prediction over Italy

Brier Skill score - above upper tercile T2m JJA

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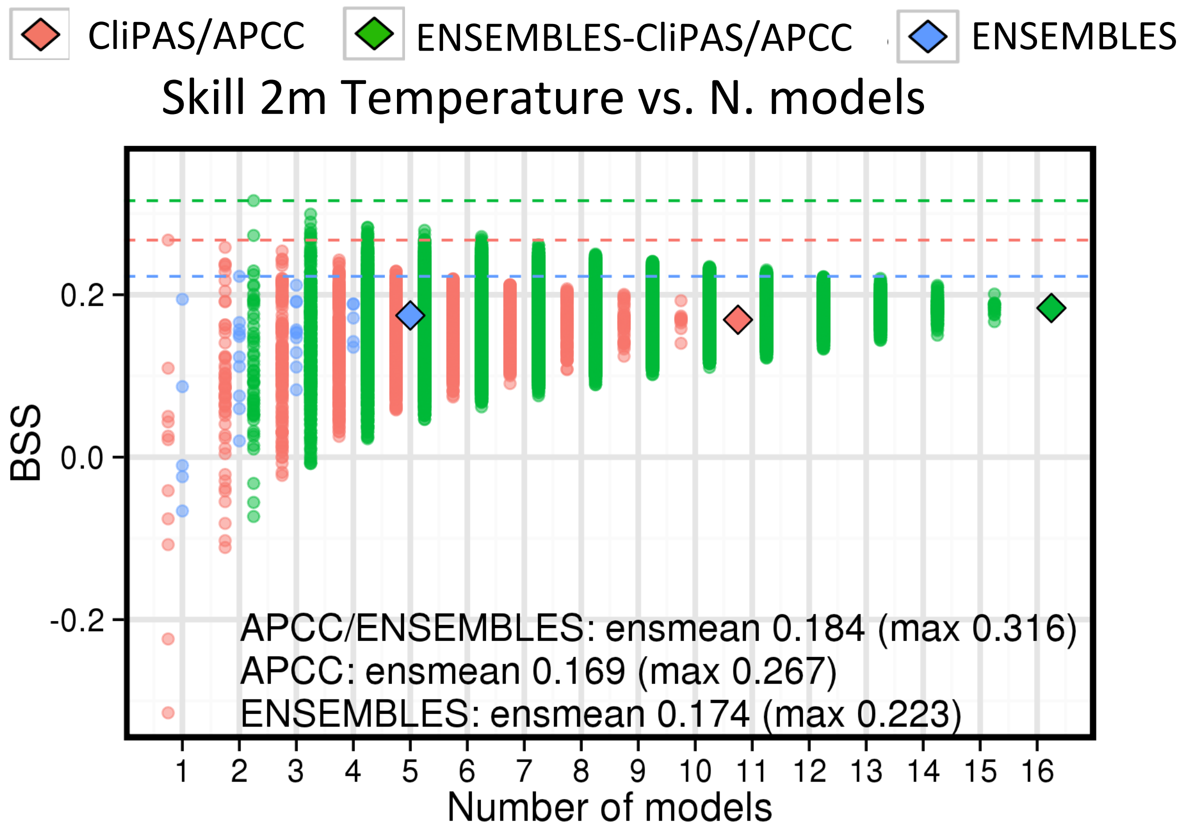

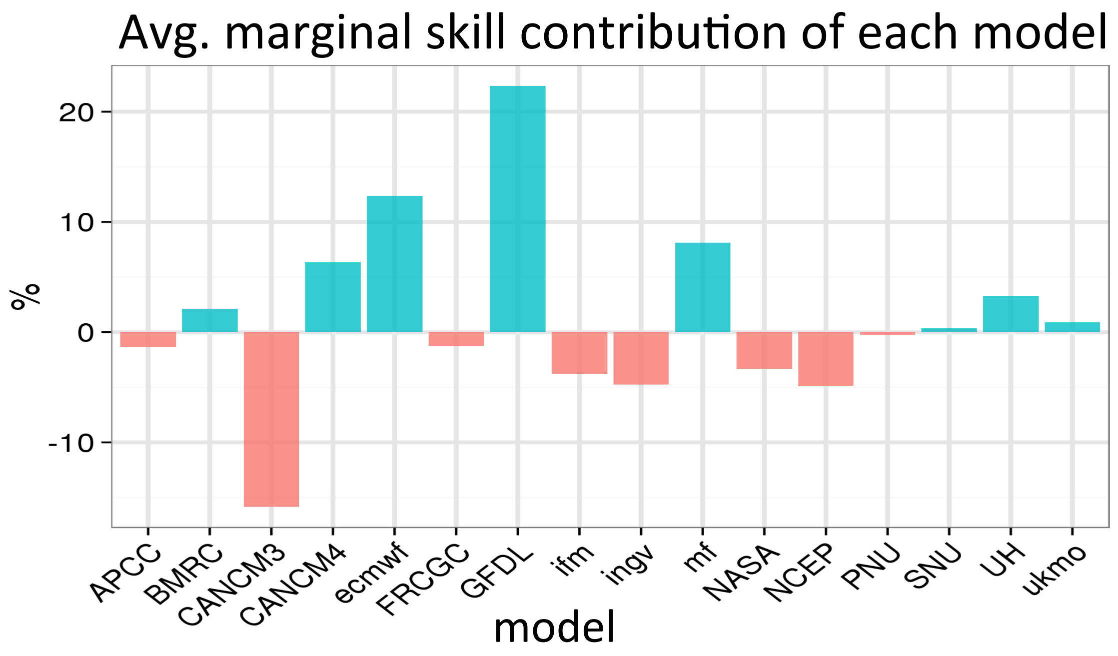

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Prediction of above upper tercile Electricity demand over Italy [E+]

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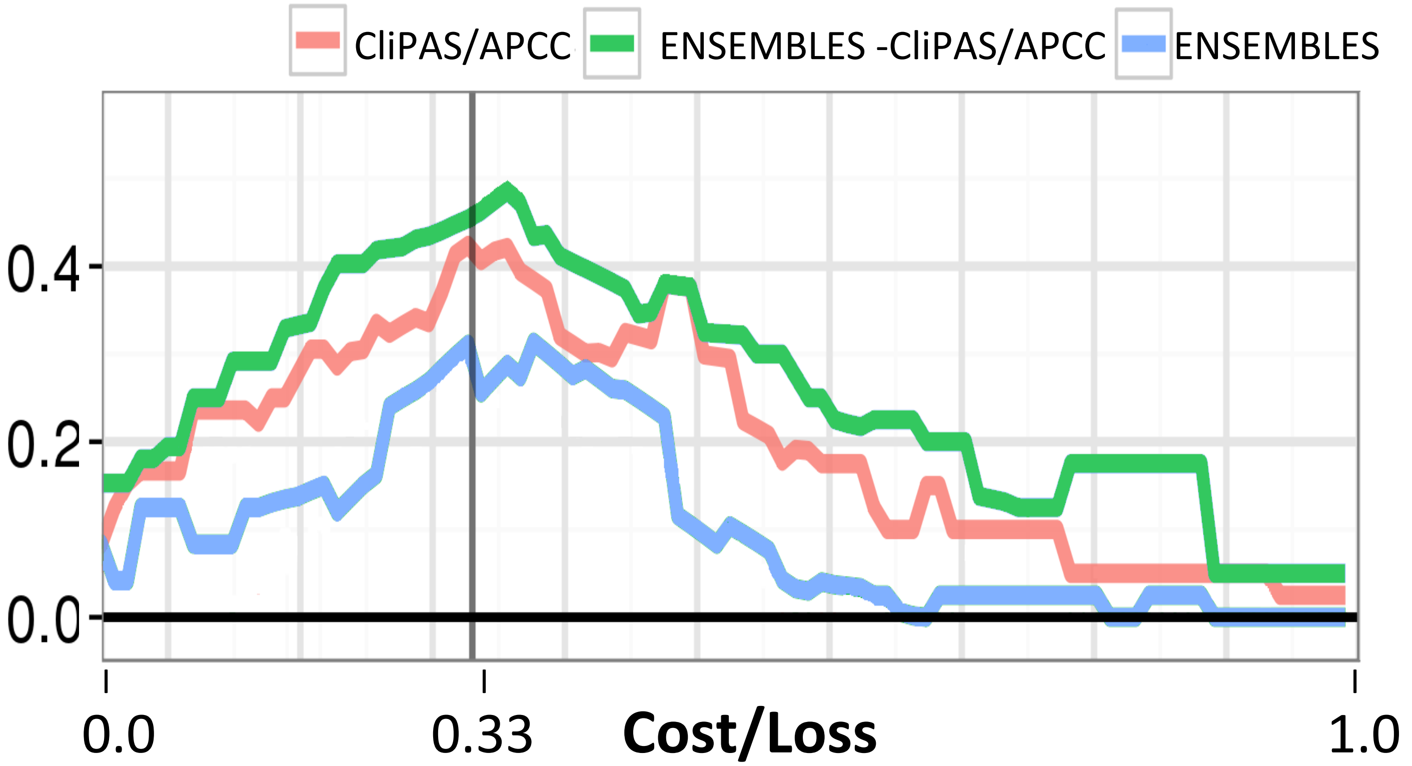
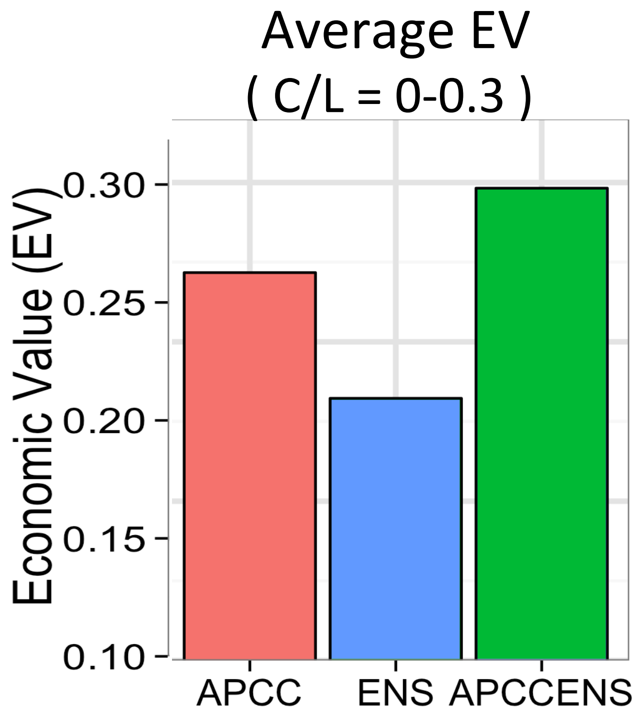
Potential Economic Value

(**Cost-Loss** decision model; Richardson, 2003)

*[E+] implies financial **Loss** if no preventive action is taken at a financial **Cost***





(Electricity demand data for 1990-2007 from Italian TSO TERNA SpA)

Alessandri et al., 2018 Climate Dynamics

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Optimization of Seasonal Climate prediction in SECLI-FIRM (WP2)

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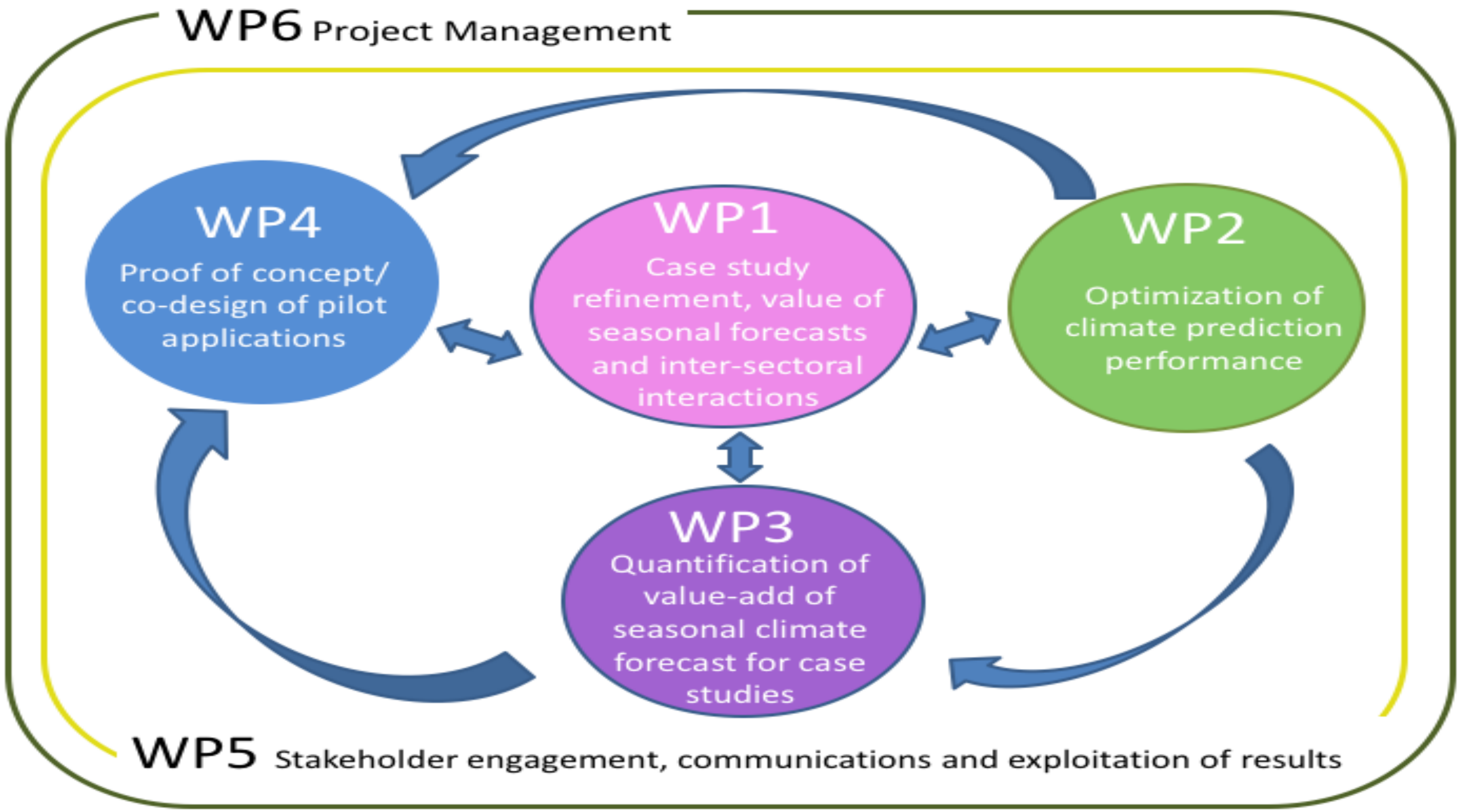
SECLI-FIRM WP2



Objective to optimize and exploit maximum seasonal climate prediction performance for the key climate variables considered in the case studies identified in WP1 by the industrial co-designers

Optimization of Seasonal Climate prediction in SECLI-FIRM (WP2)

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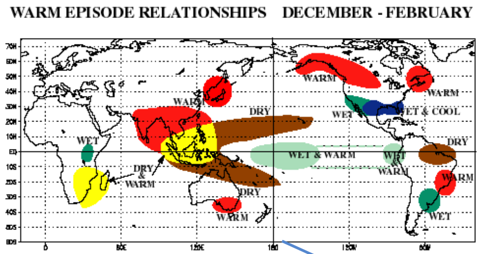
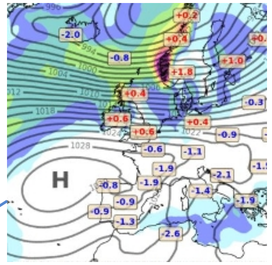
MME FORECASTS

Task 2.1

Exploit teleconnected vs. locally-forced signal (Task 2.2)



Predictability of weather regimes (Task 2.3)

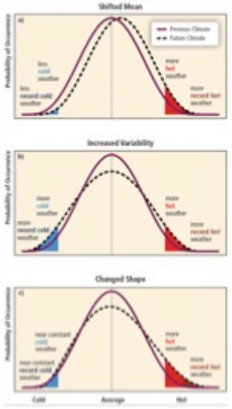


WP2

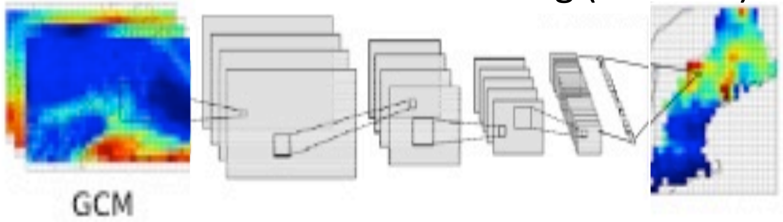
Optimization of climate prediction performance

Engage International prediction community (Task 2.6)

Prediction of high-risk events (Task 2.5)



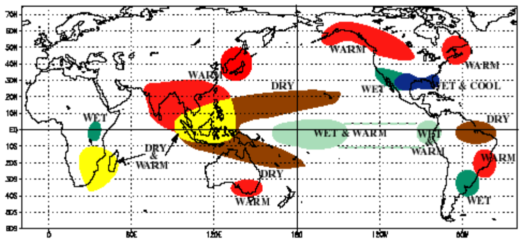
Statistical downscaling (Task 2.4)



Optimization of Seasonal Climate prediction in SECLI-FIRM (WP2)

Task 2.2: Exploit teleconnected vs. locally-forced signal

WARM EPISODE RELATIONSHIPS   DECEMBER - FEBRUARY



Monsoon-desert mechanism (Rodwell and Hoskins, 1996; 2001)

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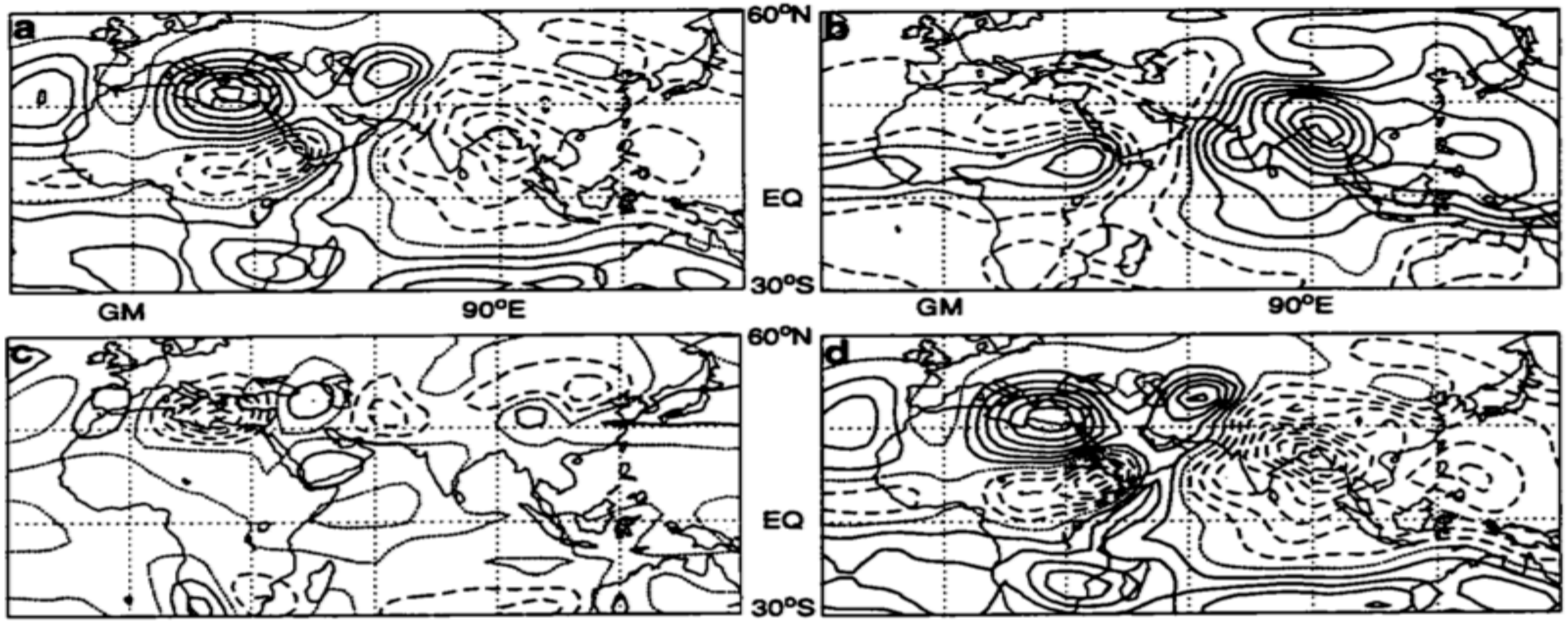
descent over the Mediterranean region is a consequence of the interaction between westward propagating Rossby waves (generated by diabatic heating over the Asian monsoon sector) and mean westerly flow north of it

ω at 477 hPa

diabatic heating at 477 hPa

horizontal advection at 477 hPa

vertical advection at 477 hPa



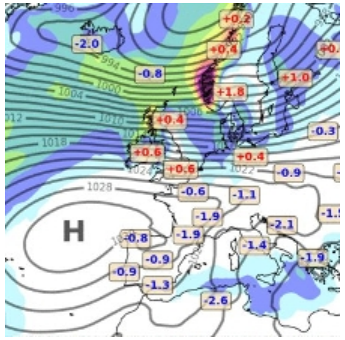
Thermodynamic energy equation:

$$\frac{Q}{c_p} = v \cdot \nabla_p T + \left(\frac{p}{p_0}\right)^k \omega \frac{\partial \theta}{\partial p}$$

horizontal temperature advection to balance temperature equation in mid-latitudes

Optimization of Seasonal Climate prediction in SECLI-FIRM (WP2)

Task 2.3: Predictability of weather regimes



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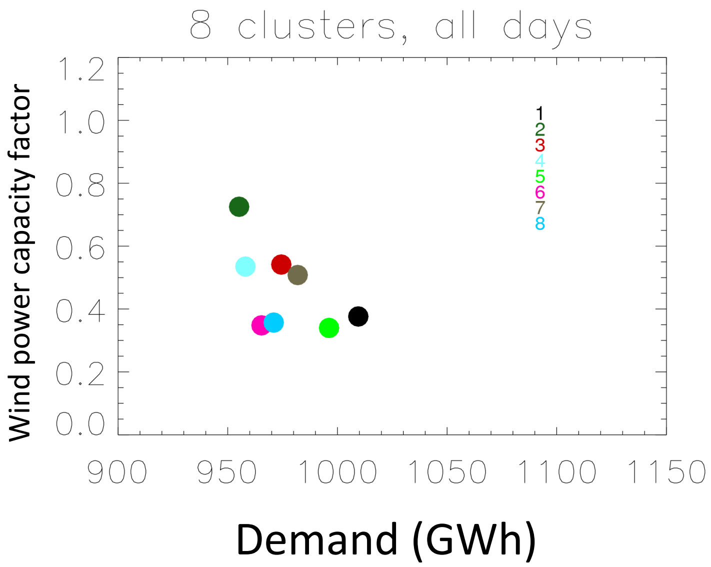
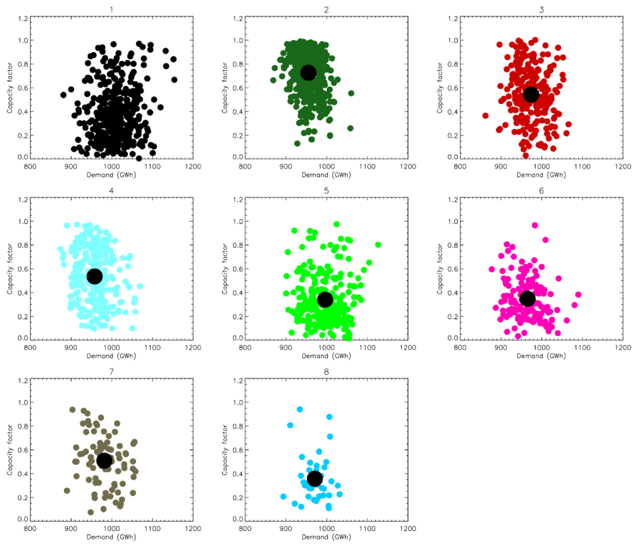
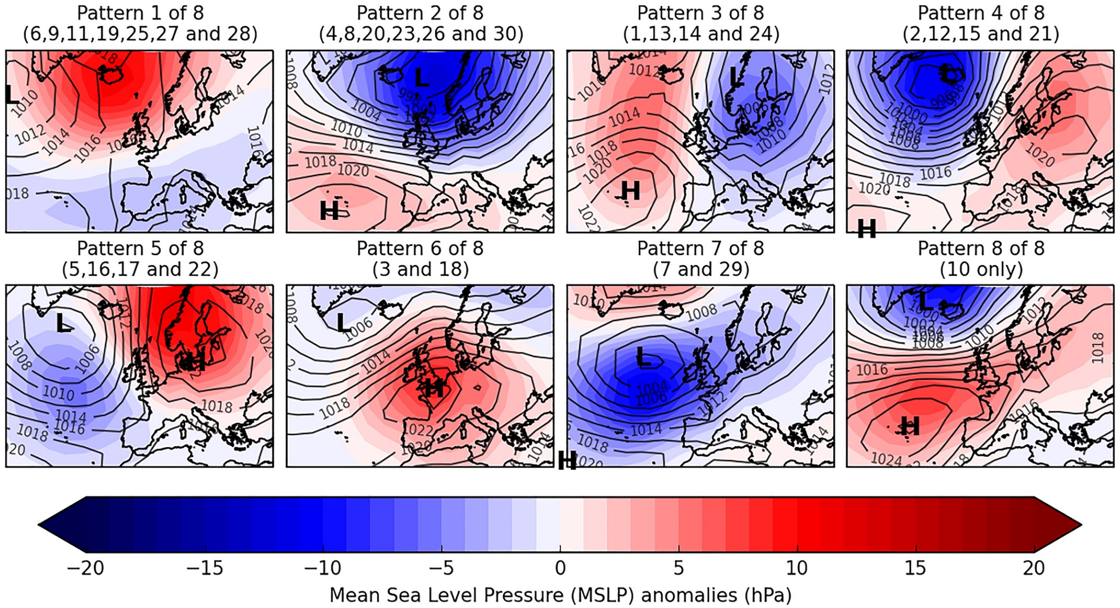
Predictability of weather regimes

The Neal et al. (2016) Weather Types

Early exploration from Hazel Thornton, relating wind power, demand, and WTs:

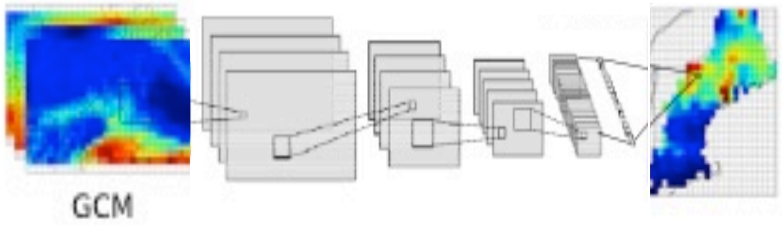






Optimization of Seasonal Climate prediction in SECLI-FIRM (WP2)

Task 2.4: Statistical downscaling



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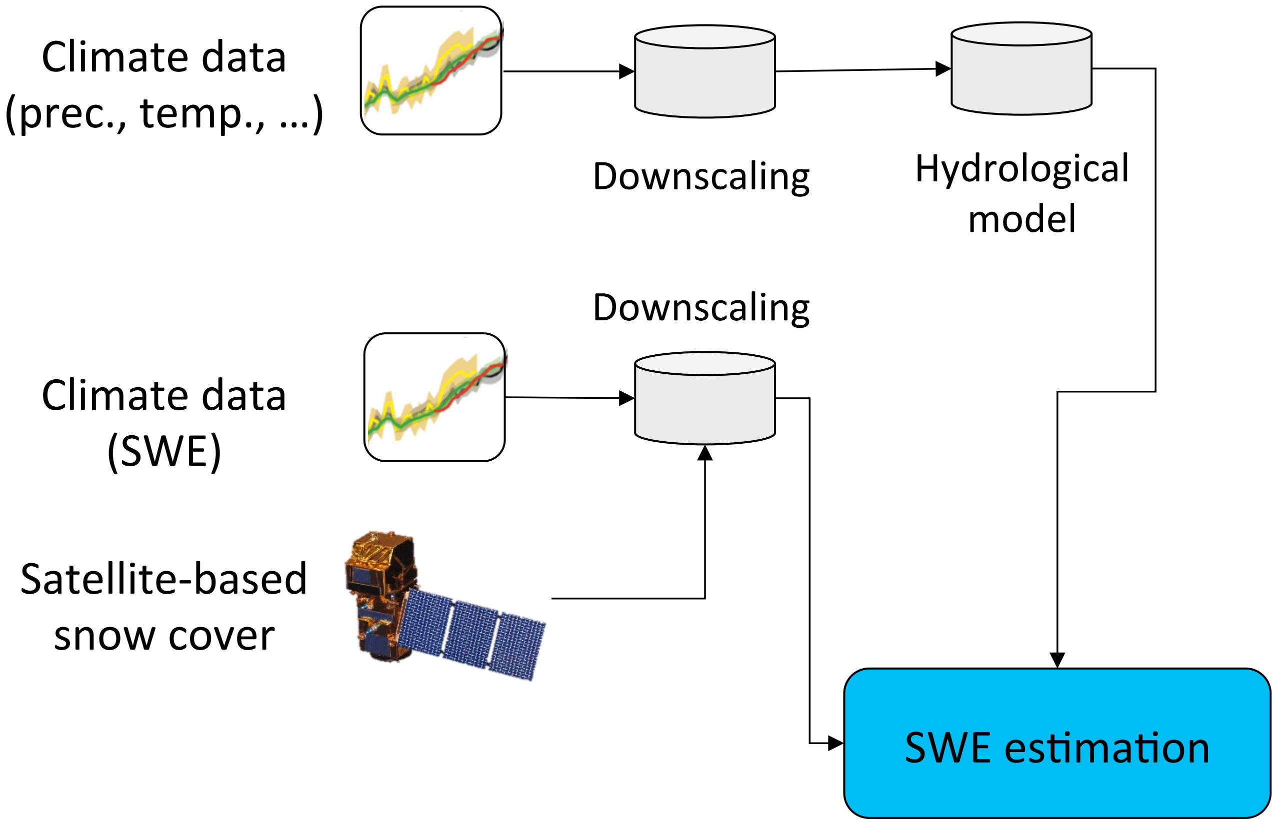
Downscaling of snow depth (sdp) / snow water equivalent

We are working on two approaches

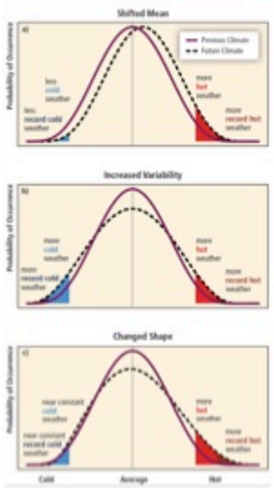
1. Combination of downscaled climate forecasts and hydrological modelling to derive snow
2. Exploiting remotely sensed snow cover fraction for the downscaling of the snow variables of the seasonal climate forecast

3. Combination of approach 1 and 2



Optimization of Seasonal Climate prediction in SECLI-FIRM (WP2)

Task 2.5: Prediction of high-risk events



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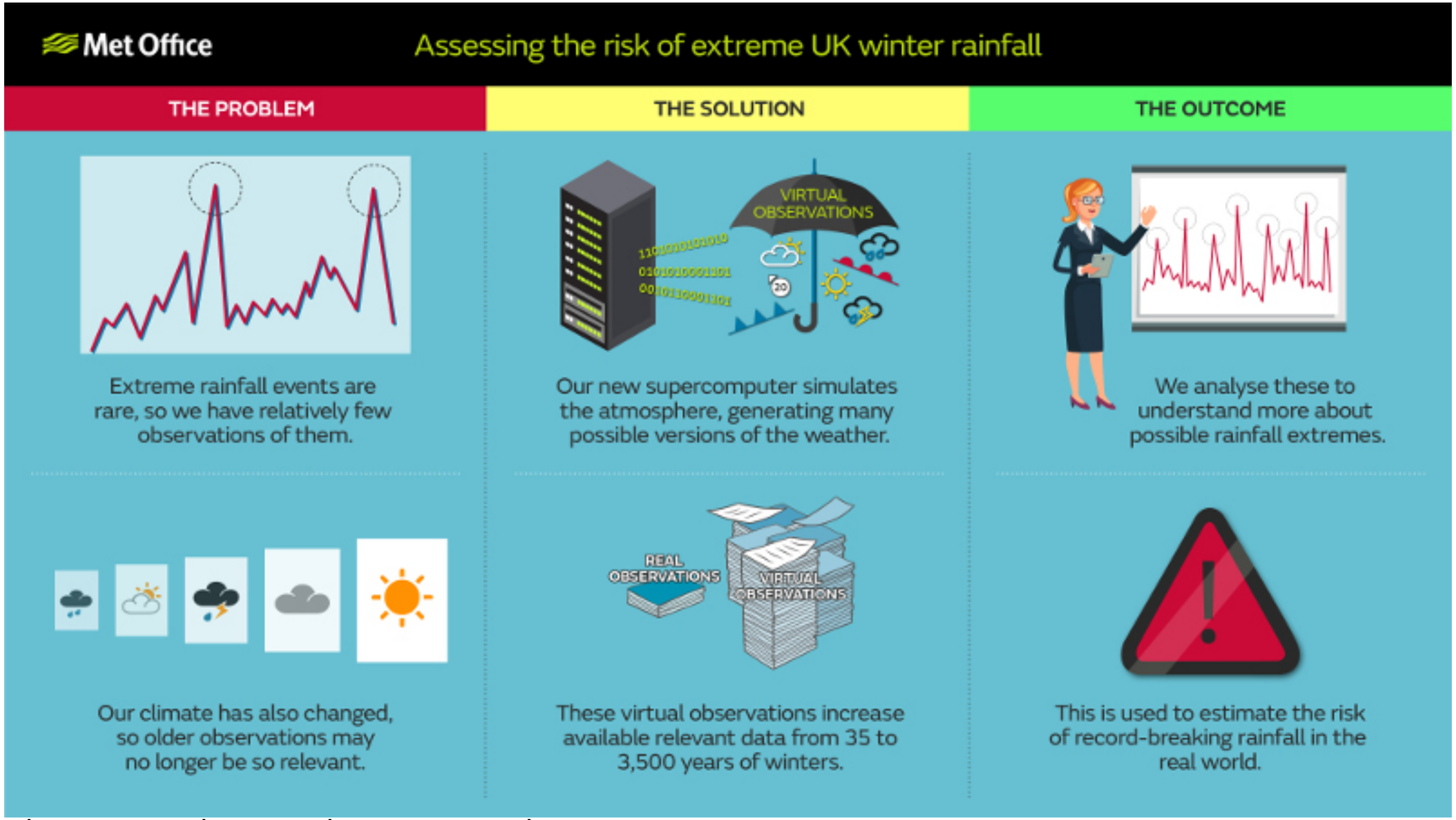
Following the methodology of Thompson et al., 2017*

Using an ensemble of hindcasts from the Met Office's DePreSys3 prediction system
(based on GloSea5)



* High risk of unprecedented UK rainfall in the current climate. Thompson et al., 2017. *Nature Communications.*

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Optimization of Seasonal Climate prediction in SECLI-FIRM (WP2) –

Task 2.6: Engage International prediction community

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Task 2.6 – Engagement and feedback with international prediction community (Lead KNMI)

SECLI FIRM

Organized Sessions in 2018 at EGU and AOGS:

-EGU2018, Earth System Prediction and Applications

-AOGS 2018, Earth System Prediction Predictability and Applications

-Participation at the WMO/WCRP "Sub-seasonal to decadal (S2D)" conference (17-21 September 2018, Boulder, CO, USA)

Proposed session for 2019

-EGU2019, "Challenges in climate prediction: multiple time-scales and the Earth system dimensions".

D2.6: Report on the capability of the very latest advancements in the prediction systems from the ongoing international efforts to overcome limitations in forecasting the key predictands [Lead KNMI; Month 36]

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Performance and limitations of ECMWF prediction system over land
Preliminary analysis of SYS5 vs. SYS4

Potential for improvement over Land
-> link to other EU H2020 projects (e.g. PROCEED)

Alessandri et al., 2017, Clim Dyn.
Catalano et al., 2017, In Preparation

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Seasonal hindcasts - 1st Nov start date - 2m Temperature
Correlations vs. ERA-Interim

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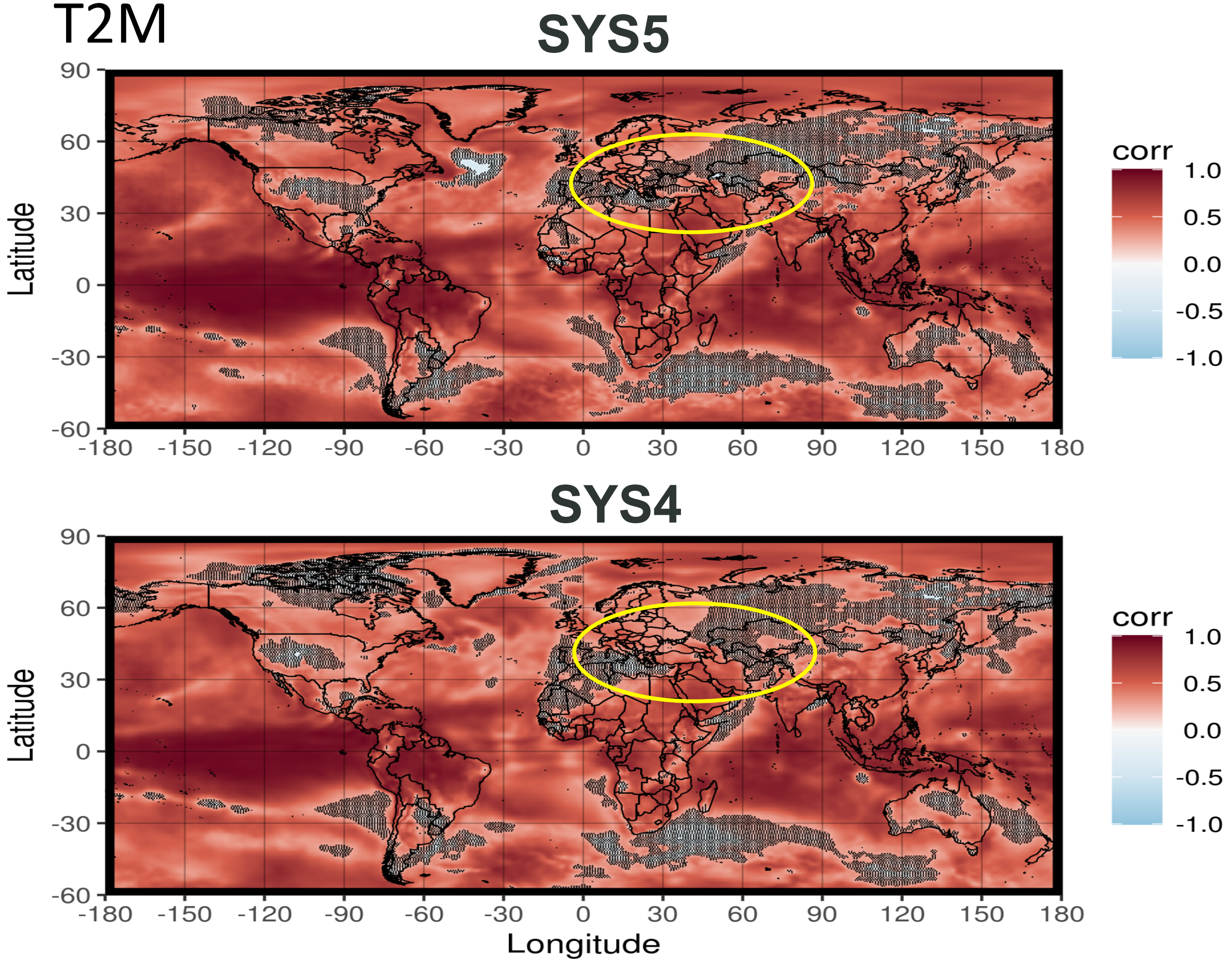
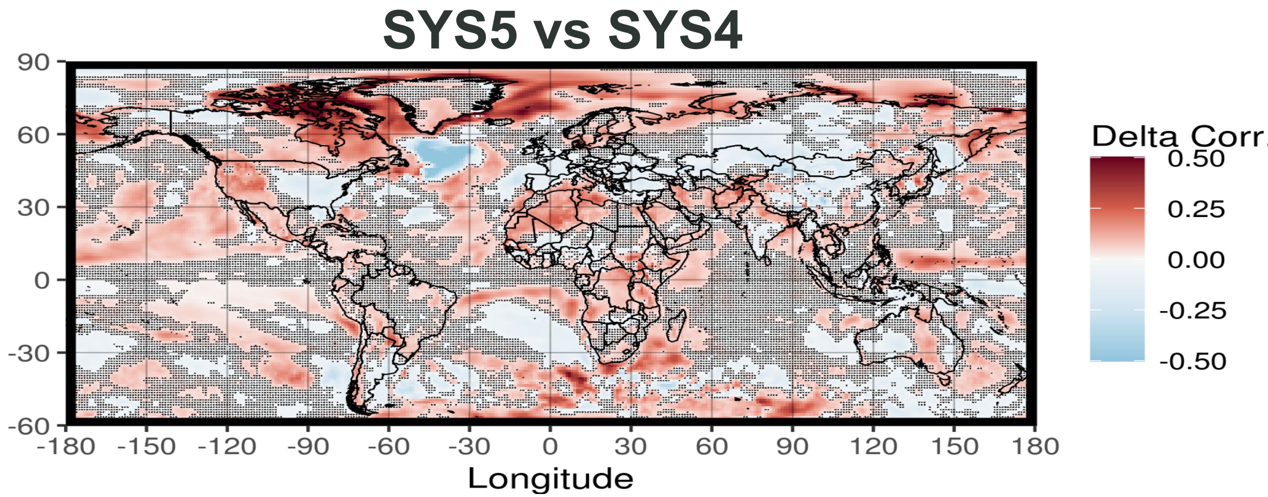
T2M

WINTER DJF

1-month lead

(dotted non significant 10% level)





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Discussion: Q & A

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