CL10
The Copernicus Climate Change
Service implemented by ECMWF

How to incorporate expert and empirical knowledge to C3S?

E. Rodríguez-Camino,

AEMET, Spain

Outline

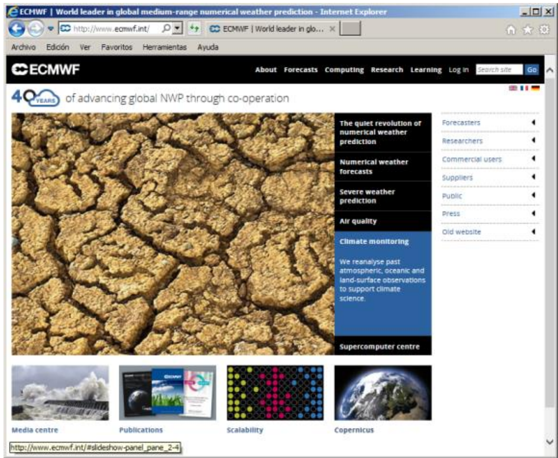
- Motivation
- Distinctive features of C3S
- Role of Met services.
- Empirical knowledge: two examples of seasonal forecasts implementations:
    - Seasonal forecasts for water management in Spain (EUPORIAS Project)
    - Consensus seasonal forecast produced by MedCOF (WMO GFCS)
- Conclusions and lessons learnt (so far)

Motivation

- The usage of **empirical knowledge has traditionally been a valuable source of information** for climate prediction at those scales where models skill was lacking.
- The case of seasonal prediction over Europe -where only recently some model has been able to show some skill for winter NAO- is an example of these limitations.
- Example of successful application of empirical relationships for the specific case of **water resources management over Spain** developed in the context of the Euporias project.
- How the **mechanisms created by WMO for the deployment of GFCS** such as RCCs and RCOFs may help to incorporate expert knowledge where models fail to provide adequate climate services. At the same time RCOFs serve as a platform for interaction with users and for targeted capacity building purposes.

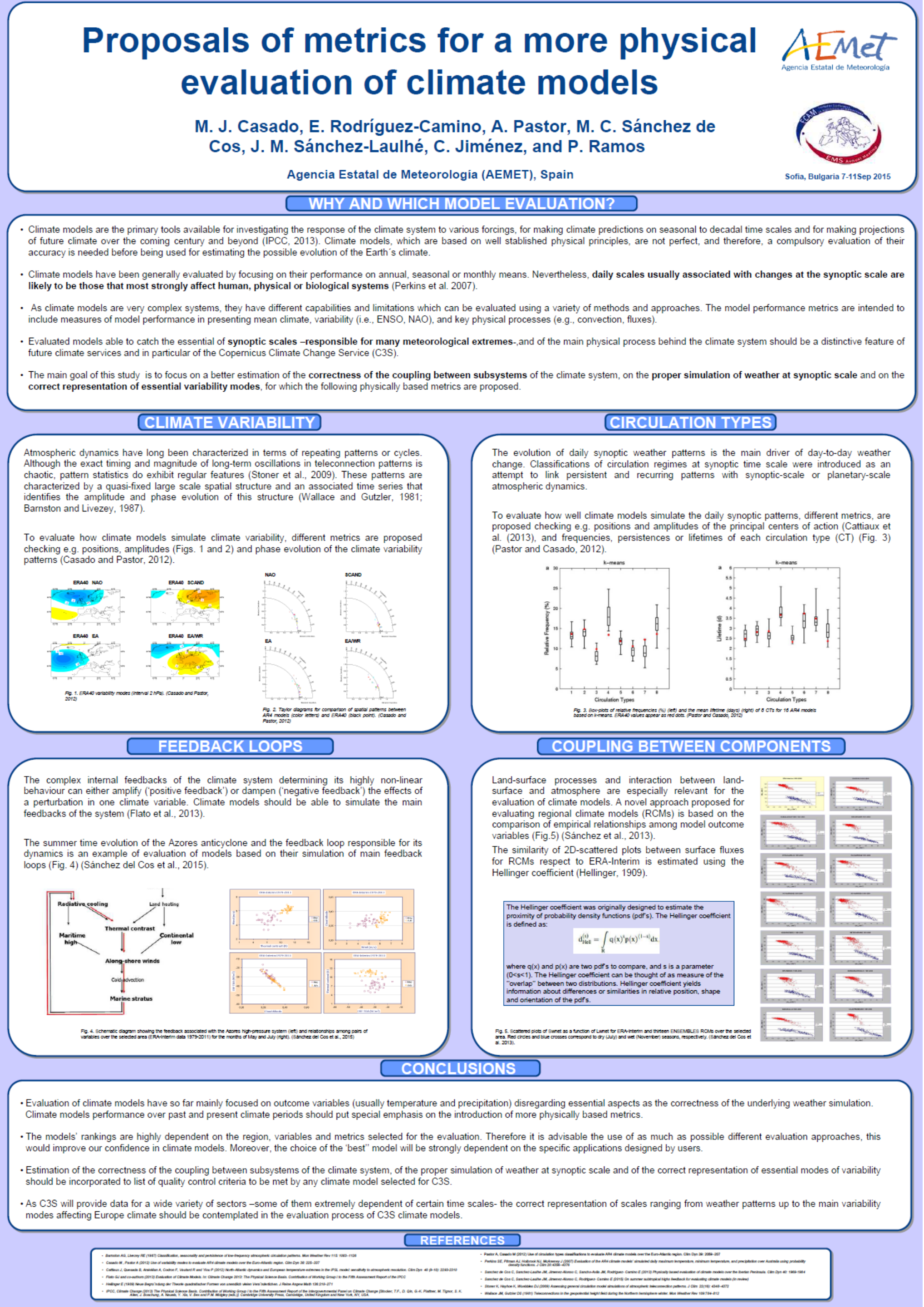
Introduction

- WMO and its partners convened WCC-3 to provide nations with the opportunity to jointly consider an appropriate **global framework for climate services** (**GFCS**)(Geneva, 4 September 2009).
- Copernicus is a European system for **monitoring the Earth** (previously Global Monitoring for Environment and Security (GMES). 3 components: space, in-situ, services. Cost: 8400 M€ (1998-2020)
- The Copernicus Climate Change service (**C3S**) responds to environmental and societal challenges associated with human-induced climate changes.
- In November 2014, the EC signed a Delegation Agreement with **ECMWF** for the implementation of the service. The first stage of implementation will be dedicated to the so called "**proof of concept**", meaning capacity building and testing of the overall architecture. The operational capacity will be reached during the third year of operations and it will be preceded by a pre-operational stage.
- The evolution of the Copernicus Climate Change service will be supported at best by the outcomes of a series of projects launched under the 2013 FP7 Space call related to **climate modelling and observation analyses**.



Distintive features of C3S

- What information will C3S provide?
  - Consistent estimates of multiple **ECVs**
  - Global and regional **reanalyses**
  - Products based on **observations** alone
  - A near-real-time climate **monitoring** facility
  - Multi-model **seasonal forecasts** ⇦
  - **Climate projections** at global and regional scales
- How will the information be produced?
  - C3S will build upon and **complement** existing capabilities
  - Major **contribution from the EU to the WMO GFCS** and its Climate Architecture.
- Defined through:
  - Series of **thematic workshops** (Climate Observation Requirements (29 June-2 July 2015); Climate Projections (20-21 April 2015); Climate Data Store (3-6 March 2015))
  - Procurements including “**proof of concept**” (demonstration of feasibility)
- Emphasis on:
  - **QC**, **evaluation** → The best possible products
  - **Communication** → Climate products understandable to users, general public, policy makers, …


Proposals of metrics for a more physical evaluation of climate models

M. J. Casado, E. Rodríguez-Camino, A. Pastor, M. C. Sánchez de Cos, J. M. Sánchez-Laulhé, C. Jiménez, and P. Ramos

Agencia Estatal de Meteorología (AEMET), Spain

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WHY AND WHICH MODEL EVALUATION?

- Climate models are the primary tools available for investigating the response of the climate system to various forcings, for making climate predictions on seasonal to decadal time scales and for making projections of future climate over the coming century and beyond (IPCC, 2013). Climate models, which are based on well stablished physical principles, are not perfect, and therefore, a compulsory evaluation of their accuracy is needed before being used for estimating the possible evolution of the Earth´s climate.
- Climate models have been generally evaluated by focusing on their performance on annual, seasonal or monthly means. Nevertheless, **daily scales usually associated with changes at the synoptic scale are likely to be those that most strongly affect human, physical or biological systems** (Perkins et al. 2007).
- As climate models are very complex systems, they have different capabilities and limitations which can be evaluated using a variety of methods and approaches. The model performance metrics are intended to include measures of model performance in presenting mean climate, variability (i.e., ENSO, NAO), and key physical processes (e.g., convection, fluxes).
- Evaluated models able to catch the essential of **synoptic scales –responsible for many meteorological extremes-**,and of the main physical process behind the climate system should be a distinctive feature of future climate services and in particular of the Copernicus Climate Change Service (C3S).
- The main goal of this study is to focus on a better estimation of the **correctness of the coupling between subsystems** of the climate system, on the **proper simulation of weather at synoptic scale** and on the **correct representation of essential variability modes**, for which the following physically based metrics are proposed.

CLIMATE VARIABILITY

Atmospheric dynamics have long been characterized in terms of repeating patterns or cycles. Although the exact timing and magnitude of long-term oscillations in teleconnection patterns is chaotic, pattern statistics do exhibit regular features (Stoner et al., 2009). These patterns are characterized by a quasi-fixed large scale spatial structure and an associated time series that identifies the amplitude and phase evolution of this structure (Wallace and Gutzler, 1981; Barnston and Livezey, 1987).

To evaluate how climate models simulate climate variability, different metrics are proposed checking e.g. positions, amplitudes (Figs. 1 and 2) and phase evolution of the climate variability patterns (Casado and Pastor, 2012).

CIRCULATION TYPES

The evolution of daily synoptic weather patterns is the main driver of day-to-day weather change. Classifications of circulation regimes at synoptic time scale were introduced as an attempt to link persistent and recurring patterns with synoptic-scale or planetary-scale atmospheric dynamics.

To evaluate how well climate models simulate the daily synoptic patterns, different metrics, are proposed checking e.g. positions and amplitudes of the principal centers of action (Cattiaux et al. (2013), and frequencies, persistences or lifetimes of each circulation type (CT) (Fig. 3) (Pastor and Casado, 2012).

FEEDBACK LOOPS

The complex internal feedbacks of the climate system determining its highly non-linear behaviour can either amplify ('positive feedback') or dampen ('negative feedback') the effects of a perturbation in one climate variable. Climate models should be able to simulate the main feedbacks of the system (Flato et al., 2013).

The summer time evolution of the Azores anticyclone and the feedback loop responsible for its dynamics is an example of evaluation of models based on their simulation of main feedback loops (Fig. 4) (Sánchez del Cos et al., 2015).

COUPLING BETWEEN COMPONENTS

Land-surface processes and interaction between land-surface and atmosphere are especially relevant for the evaluation of climate models. A novel approach proposed for evaluating regional climate models (RCMs) is based on the comparison of empirical relationships among model outcome variables (Fig.5) (Sánchez et al., 2013).

The similarity of 2D-scattered plots between surface fluxes for RCMs respect to ERA-Interim is estimated using the Hellinger coefficient (Hellinger, 1909).

CONCLUSIONS

- Evaluation of climate models have so far mainly focused on outcome variables (usually temperature and precipitation) disregarding essential aspects as the correctness of the underlying weather simulation. Climate models performance over past and present climate periods should put special emphasis on the introduction of more physically based metrics.
- The models' rankings are highly dependent on the region, variables and metrics selected for the evaluation. Therefore it is advisable the use of as much as possible different evaluation approaches, this would improve our confidence in climate models. Moreover, the choice of the 'best' model will be strongly dependent on the specific applications designed by users.
- Estimation of the correctness of the coupling between subsystems of the climate system, of the proper simulation of weather at synoptic scale and of the correct representation of essential modes of variability should be incorporated to list of quality control criteria to be met by any climate model selected for C3S.
- As C3S will provide data for a wide variety of sectors –some of them extremely dependent of certain time scales- the correct representation of scales ranging from weather patterns up to the main variability modes affecting Europe climate should be contemplated in the evaluation process of C3S climate models.

REFERENCES

- Climate models have been generally evaluated by focusing on their performance on annual, seasonal or monthly means. Nevertheless, daily scales usually associated with changes at the **synoptic scale are likely to be those that most strongly affect human**, physical or biological systems.
- The model performance metrics are intended to include measures of model performance in presenting mean climate**, variability (i.e., ENSO, NAO), and key physical processe**s (e.g., convection, fluxes).
- Evaluated models able to catch the essential of **synoptic scales –responsible for many meteorological extremes-**,and of the main physical process behind the climate system should be a distinctive feature of future climate services and in particular of the Copernicus Climate Change Service (C3S).
- The main goal of this study is to focus on a better estimation of the correctness of the **coupling between subsystems of the climate system, on the proper simulation of weather at synoptic scale** and on the correct representation of essential variability modes, for which the following physically based metrics are proposed.

Role of Met services

- From **climate applications** (mainly based on observations) to **climate services** (additionally based on model outputs).
- Taking-off:
    - Official: Creation of GFCS (WCC-3, Geneva 2009)
    - Unofficial: Climate projections (1990's) for CC Adaptation
- CC Adaptation → involves multitude of sectors with specific needs
    - Need of permanent dialogue with users to define climate info
    - Need of incorporating users to co-design climate info (e.g., as in EUPORIAS Project)
    - Big expectancy for climate community

Empirical knowledge: Example 1

Seasonal climate predictions (SCP) for management of Spanish water dams (case study within the EUPORIAS Project)

- Water dams were so far managed in Spain using climatological (historical) information and short/medium range weather forecasts.
- Use of SCF in Spain is rather limited. Some sectors (water, insurance, energy) are taking the lead for its use.
  - Reasons:
    - Lack of precipitation **skill** over Spain
    - Accessibility, **usability** of information by end-users
    - Format of information (**probabilistic** versus deterministic)
    - Lack of **tools** to exploit information
    - **Complexity** of products
    - Lack/limitated **support**

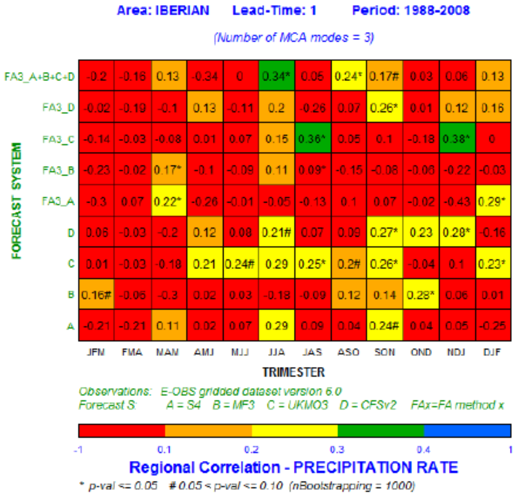
EUPORIAS Project study case

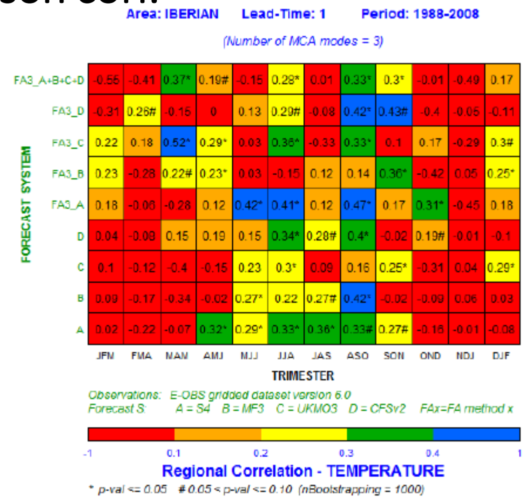
- WG encompassing AEMET, CETaqua, DG Water (Spanish Ministry for Agric/Envir), Douro, Tagus, Ebro Basin Water Authorities, AQUALOGY
- Start from a very single algorithm for seasonal prediction of user’s relevant variables
- Add complexity in further steps
- Co-design and co-production with users (Basin Water Authorities)
- Emphasis on decision making based on probabilistic information
- Proto-type for a few representative dams
- Final product for all water dams over Spain

Skill of seasonal models

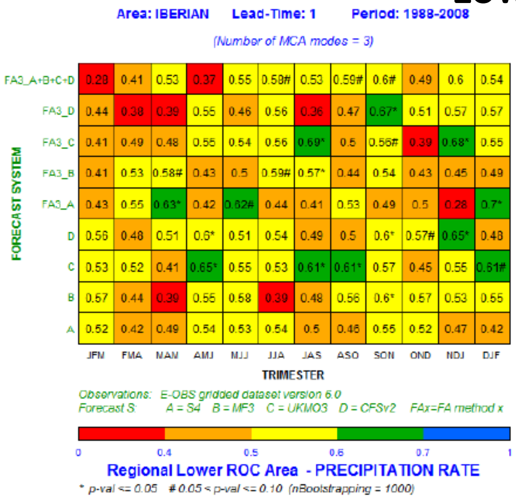
- Precip. Temp. Prec. Temp.

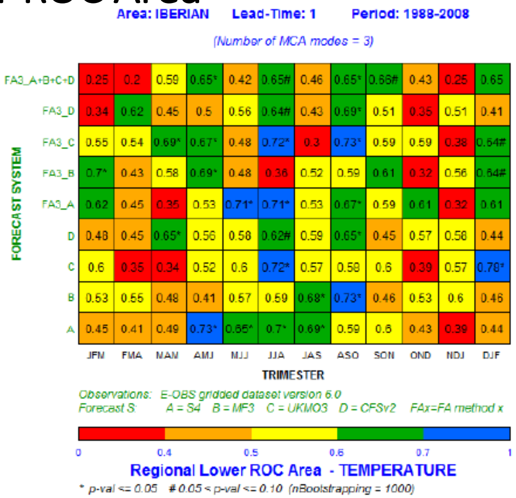
Pearson corr.



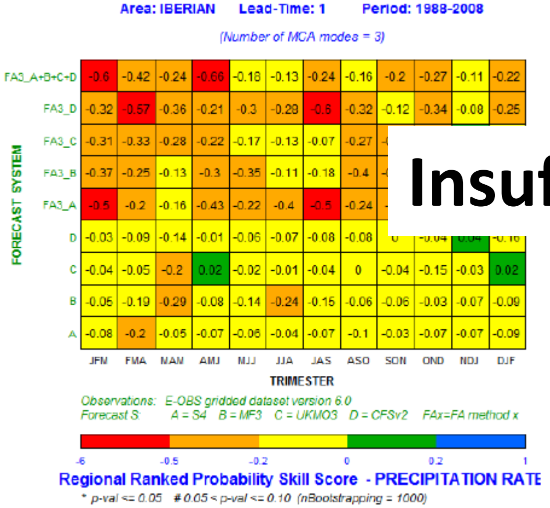


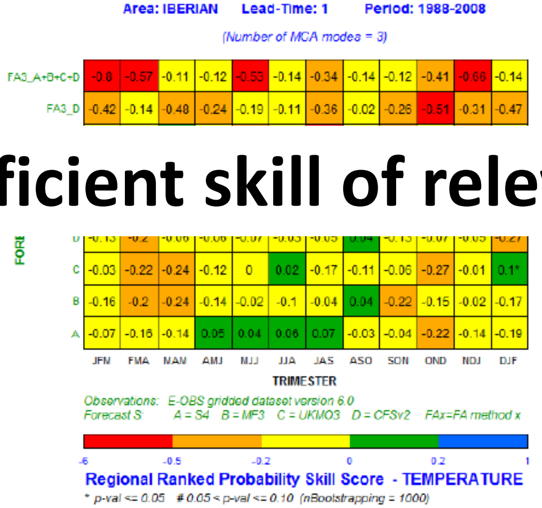
Lower ROC Area



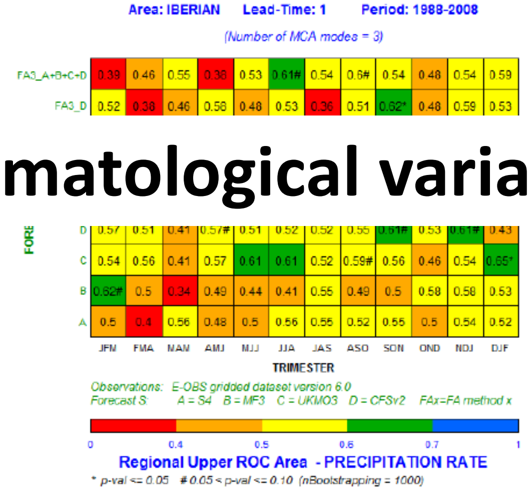


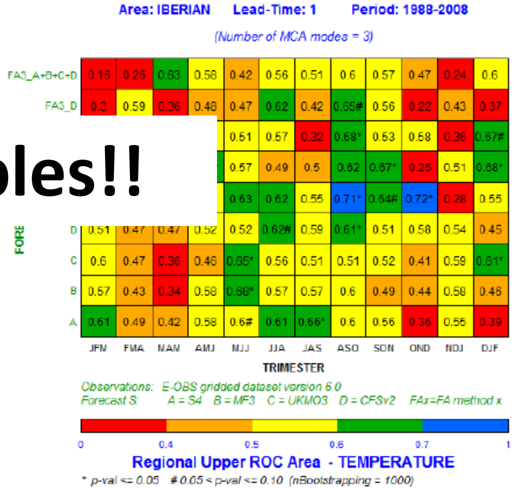
RPSS





Upper ROC Area





Insufficient skill of relevant climatological variables!!

Pearson correlation coefficients btw October daily SAI and following winter precipitation (DJF)

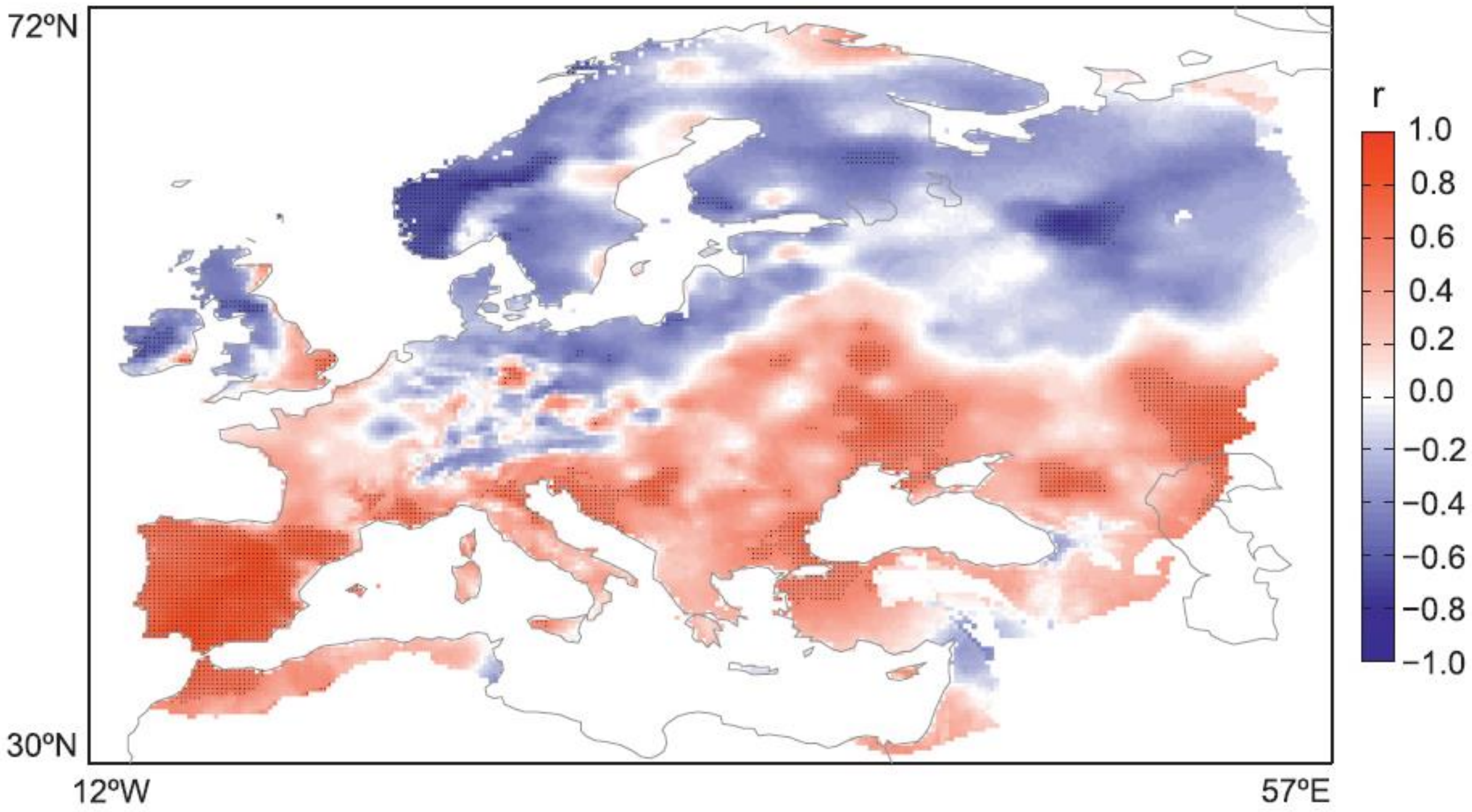


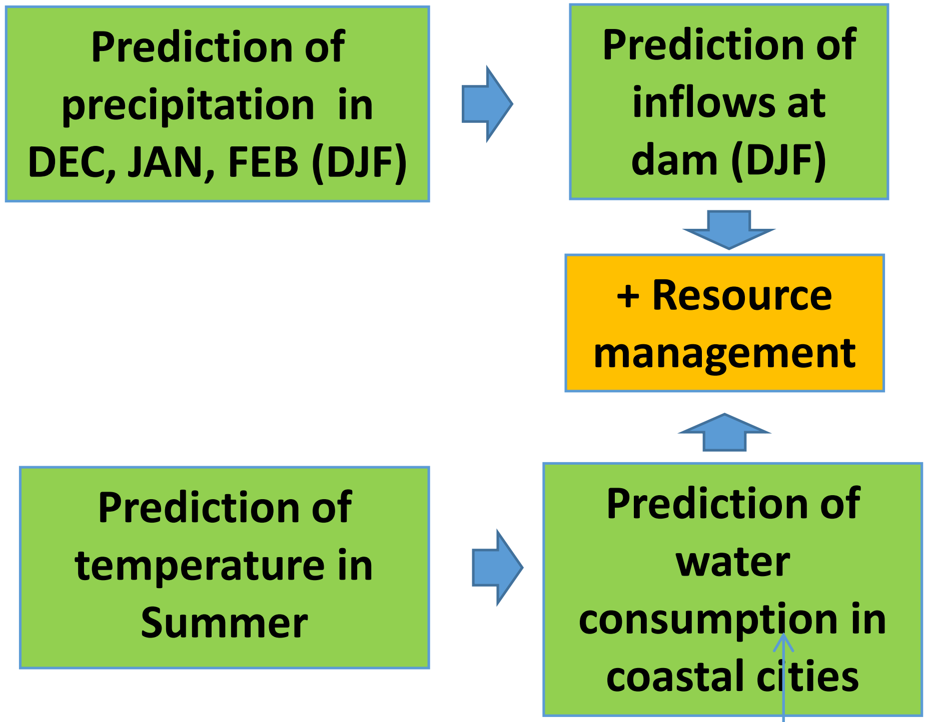
FIG. 1. Pearson correlation coefficients between the October daily SAI and the precipitation sums of the following DJF (n = 14; critical value = ±0.53). Locally significant correlations (α_{local} = 0.05) are shaded in black. Global significance was obtained (α_{global} = 0.05); all calculations are based on E-OBS.

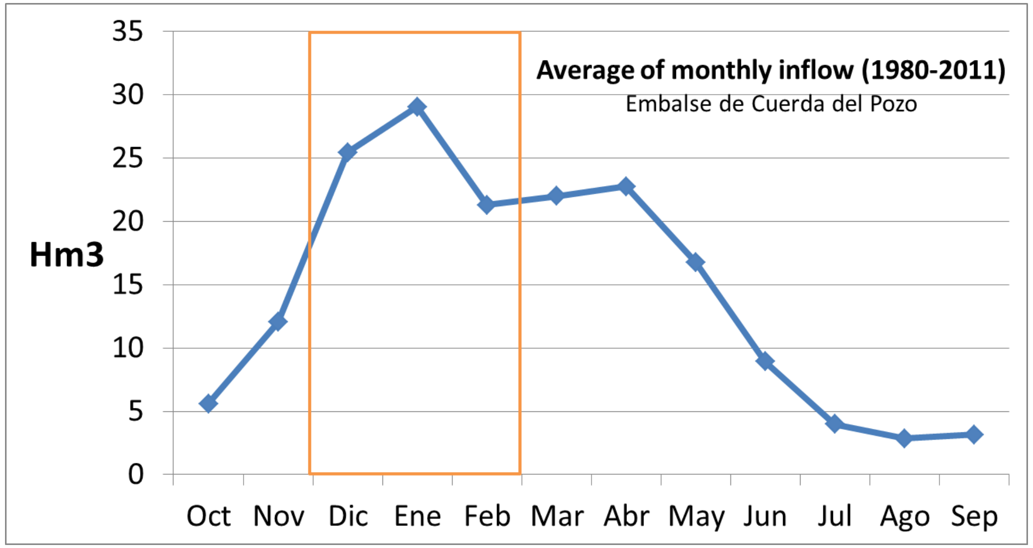
General recommendations

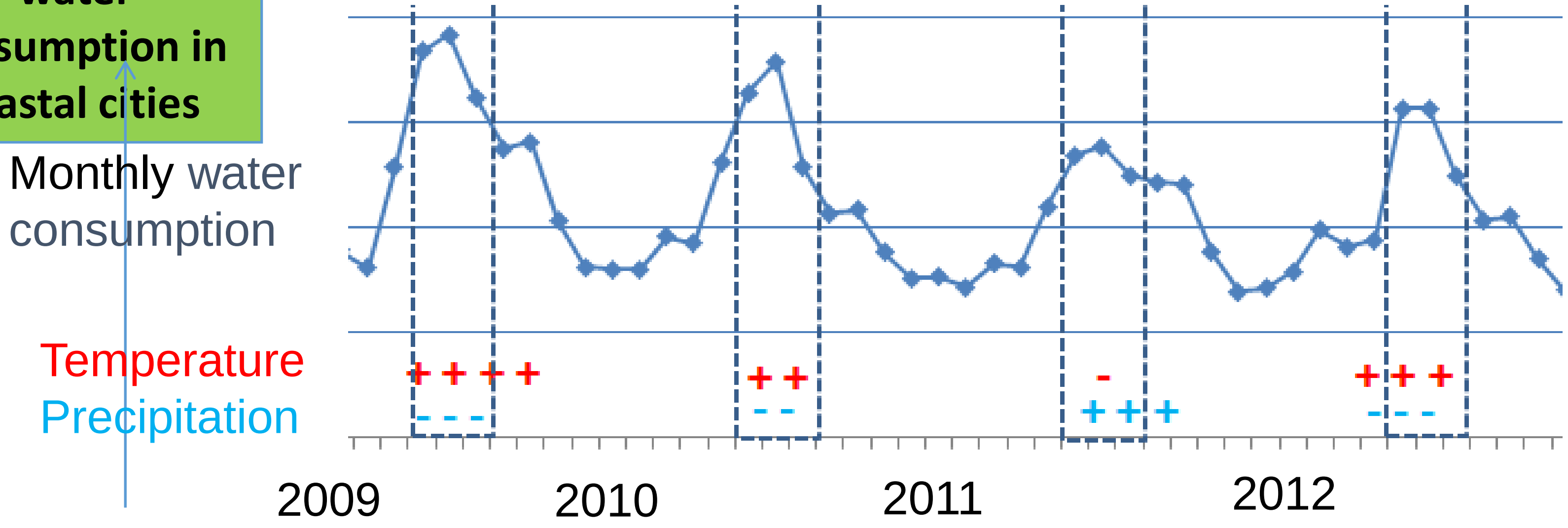
- Windows of opportunity linked to certain seasons, regions, variables, state, patterns, …
- Do not disregard empirical/statistical methods
- Incorporate users to the process of design and production of SCP
- Users are interested in certain specific variables (not always T and/or Prec)
- Explore the skill of such variables
- Effect on decision making process

(Brands et al., JC, 2012)

Potential uses from the supply and demand sides





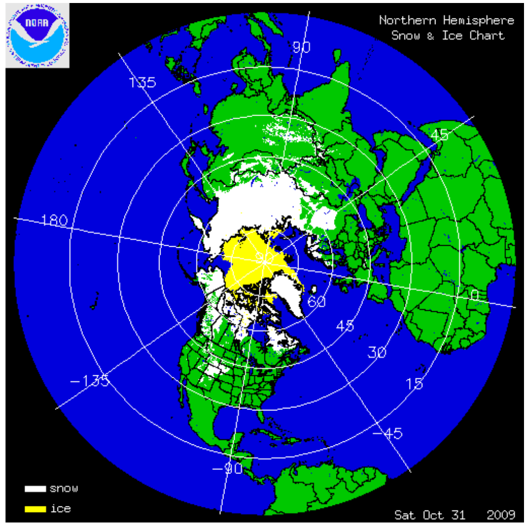


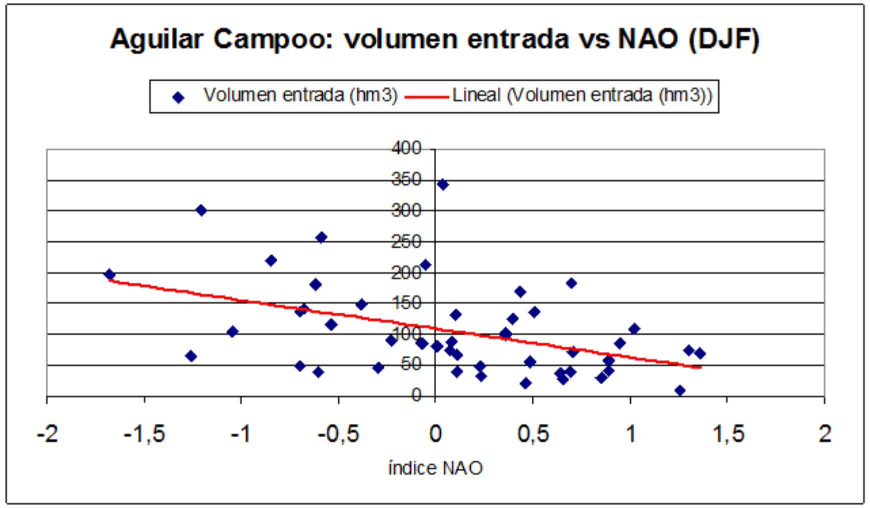
Many different strategies are being tested both for the supply and demand sides!!

SUPPLY SIDE

Predictor (SAI) → NAO → Precipitation → Inflow
Predictor (SAI) → Inflow

Predictor (SAI October) -→ Inflow (DJF)
Predictor (SAI October) → Inflow (NDJFM); N, M clim
Predictor (daily SAI October) → Inflow (DJF)
Predictor (weekly SAI October) → Inflow (DJF)
Combination empirical + model outputs





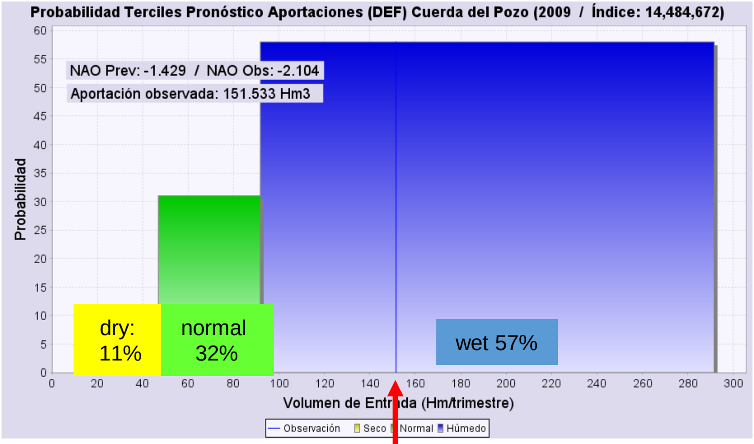
- Big difference in skill for different dams
- From predictors to user variables (inflow, demand)
- Inflow encompasses precipitation over basin, snow melting, etc
- Consumption encompasses temperature, humidity, evapotranspiration, etc

How to present information?

Duero - Cuerda del Pozo

Historical DJF dam inflow
(1950-2013)

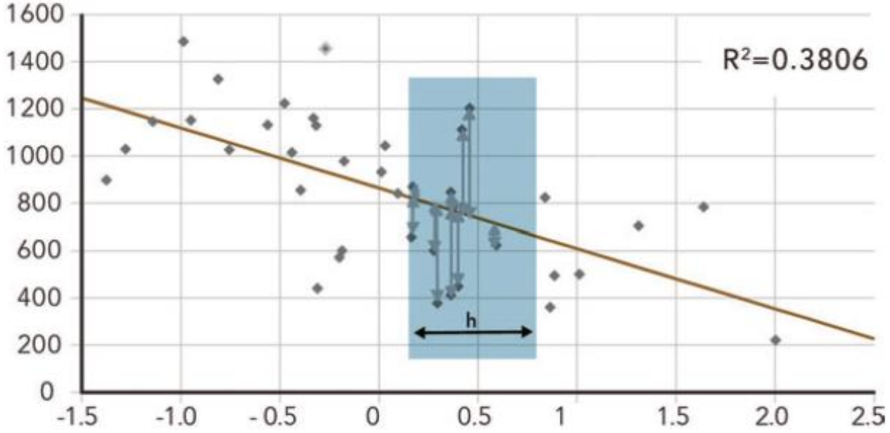
DJF inflow forecasts:
probability for lower/middle/upper terciles of historical distribution



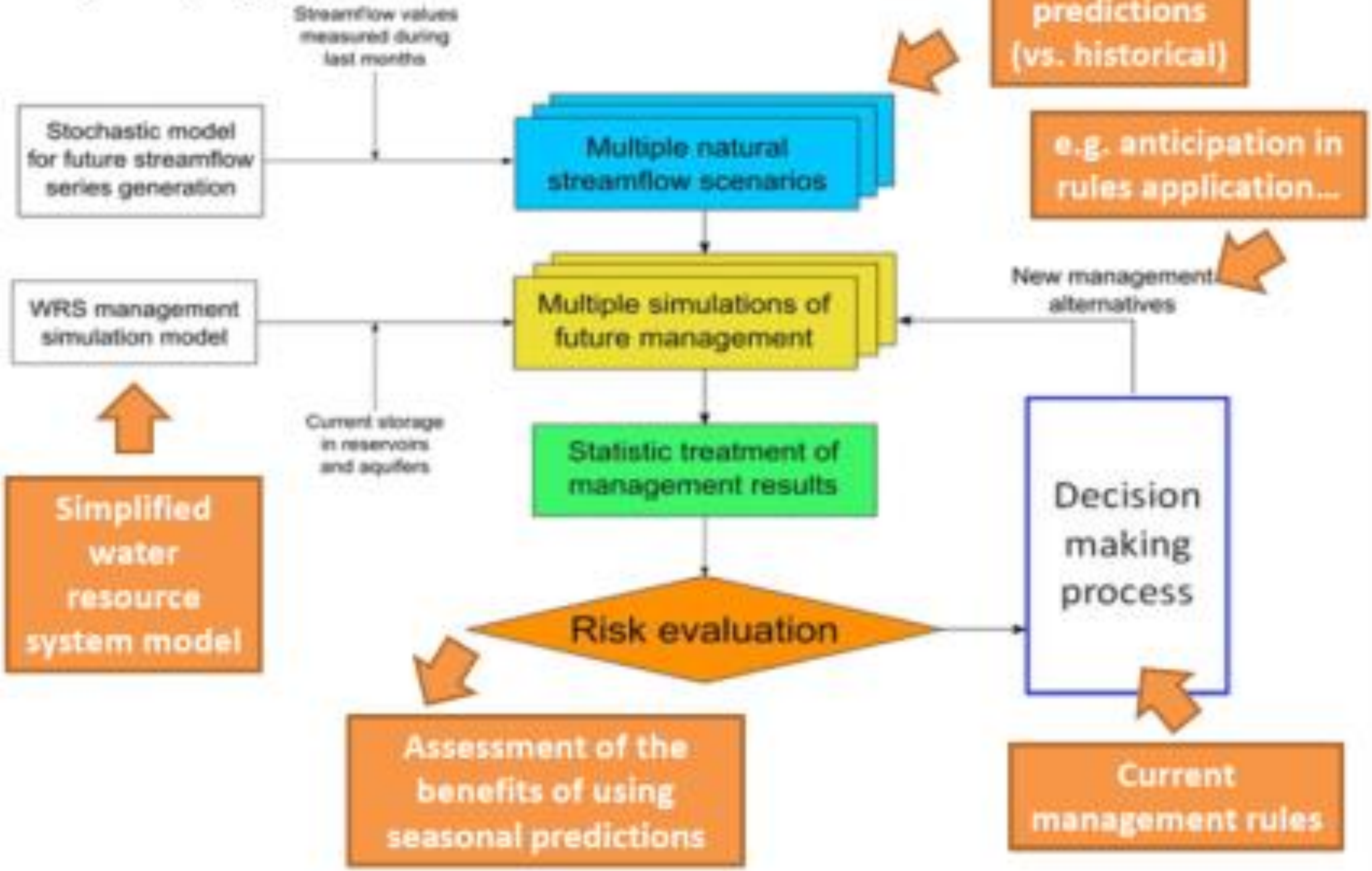
2009

observed inflow

- Different approaches (e.g., nearest neighbor sampling) for generation of an ensemble of forecasts
- Probabilistic forecasts expressed in terciles



Use of SIMRISK for a few dams in Spain (Douro, Ebro, Tagus)



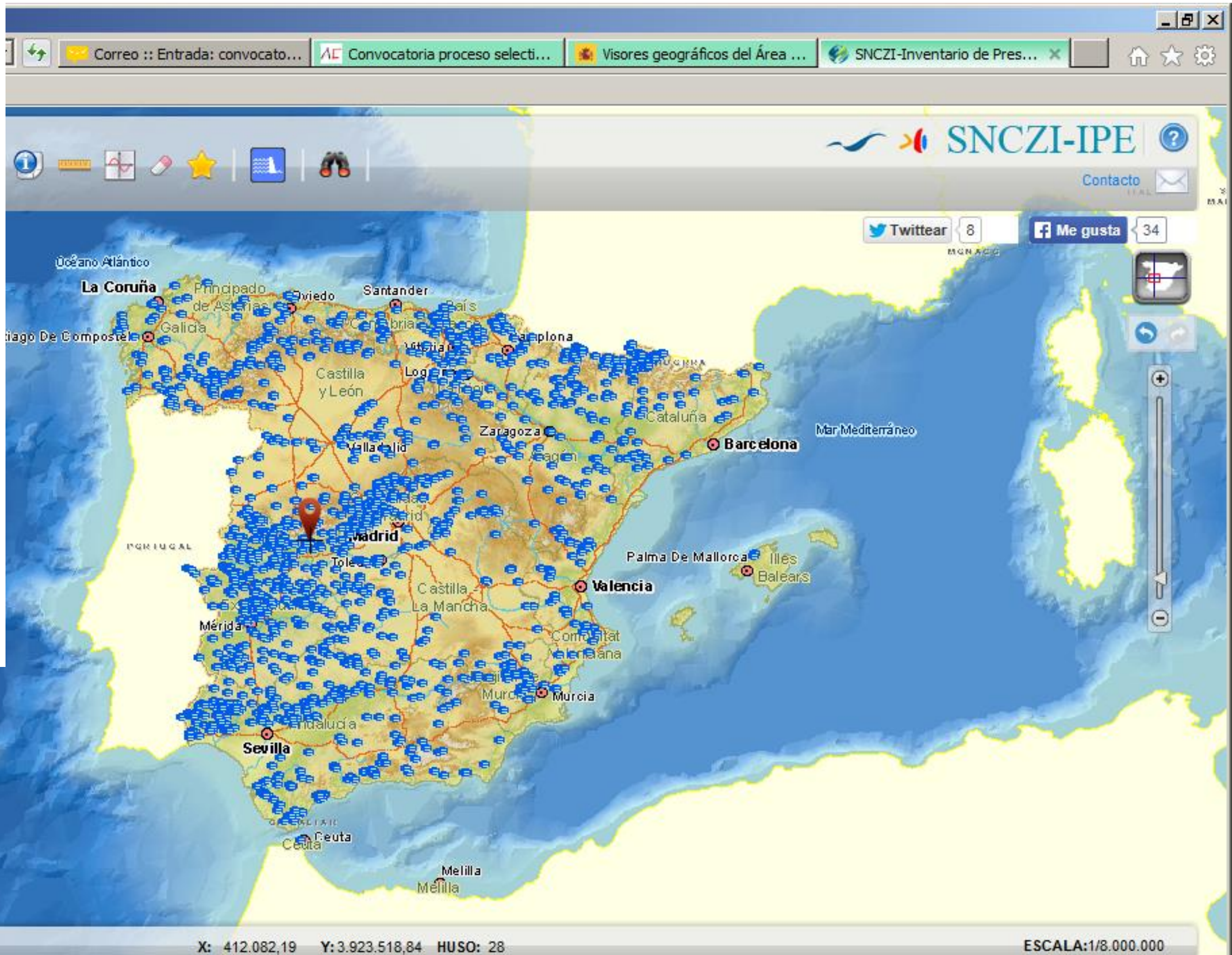
Big difference in skill among river basins!!

Verification scores of inflow probabilistic forecasts
ROC area for lower/upper terciles

Forecast System	Predictor
B	Snow advance index in Eurasia in October (weekly values of snow cover)
C	Snow advance index in Eurasia in October (daily values of snow cover)

Water reservoir	Cuerda del Pozo			Rosarito			Tranco de Beas			Ebro		
Forecast System/ period	B 1999-2011	C 1999-2011	B 1973-2011	B 1999-2011	C 1999-2011	B 1973-2011	B 1999-2011	C 1999-2011	B 1973-2011	B 1999-2011	C 1999-2011	B 1973-2011
ROC_area (lower tercile)	0.48	0.76	0.63	0.55	0.71	0.64	0.71	0.88	0.71	0.42	0.28	0.5
ROC_area (upper tercile)	0.86	1	0.76	0.8	0.97	0.4	0.56	0.78	0.76	0.69	0.82	0.7

< 0.41	0.41 - 0.5	0.51 - 0.6	0.61 - 0.7	0.71 - 1

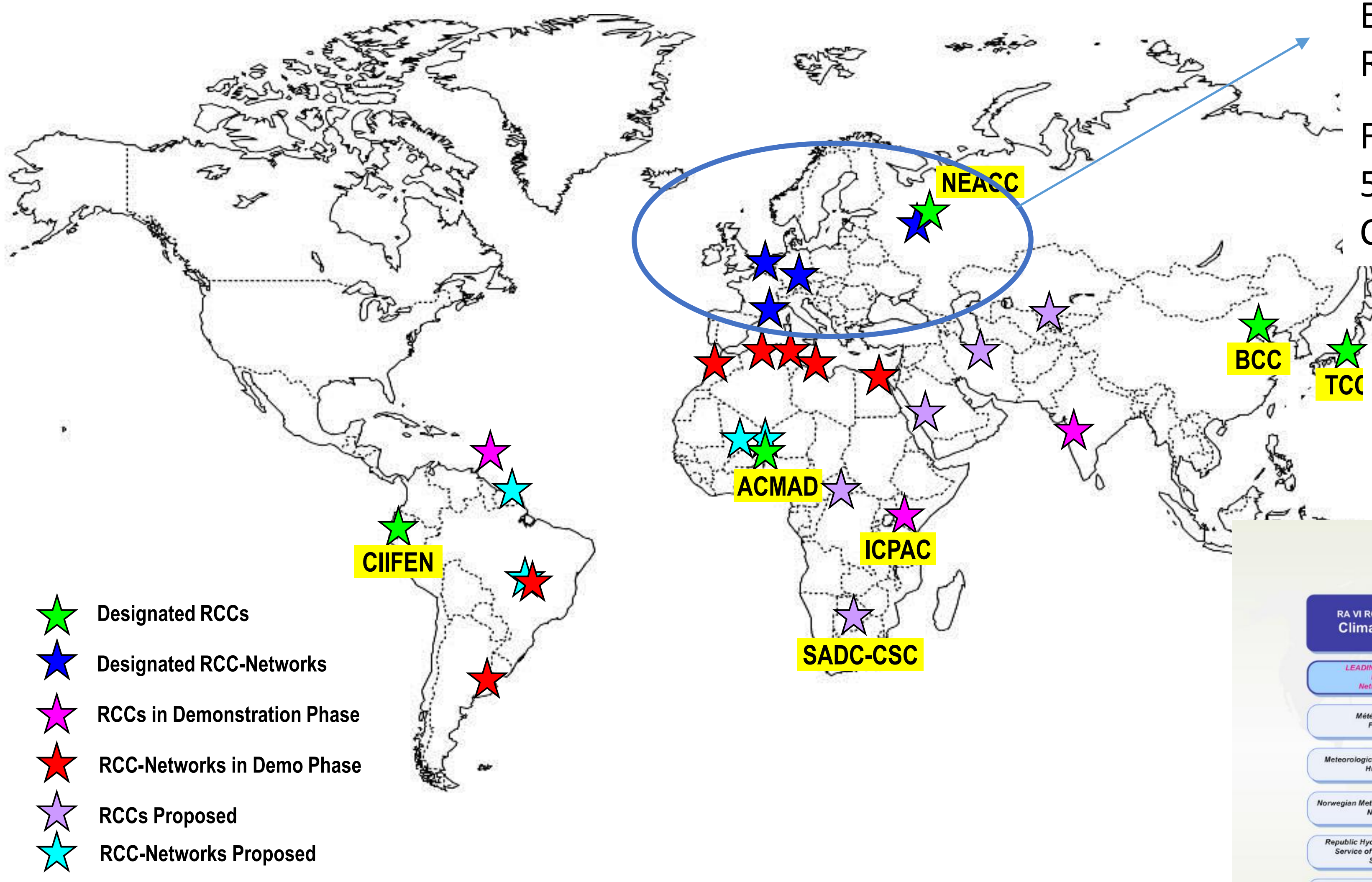


Empirical knowledge: Example 2

Mediterranean Climate Outlook Forum (MedCOF)

- RCCs and RCOFs are mechanisms created by WMO for the deployment of GFCS helping to incorporate expert knowledge where models fail to provide adequate climate services.
- MedCOF → room for discussion and incorporation of expert knowledge.
- At the same time RCOFs serve as a platform for interaction with users and for targeted capacity building purposes.

WMO RCC Status Worldwide



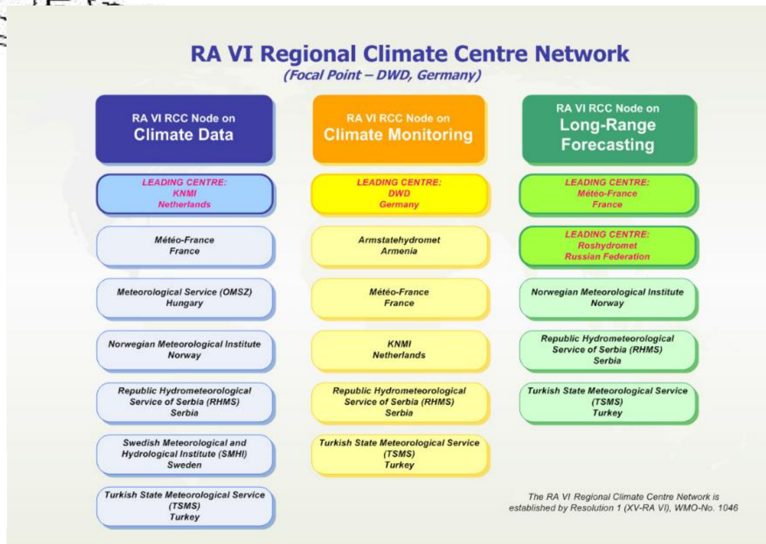
RCCs in RAVI

Established by Res. 1 (XV-RAVI) [Sept 2009]

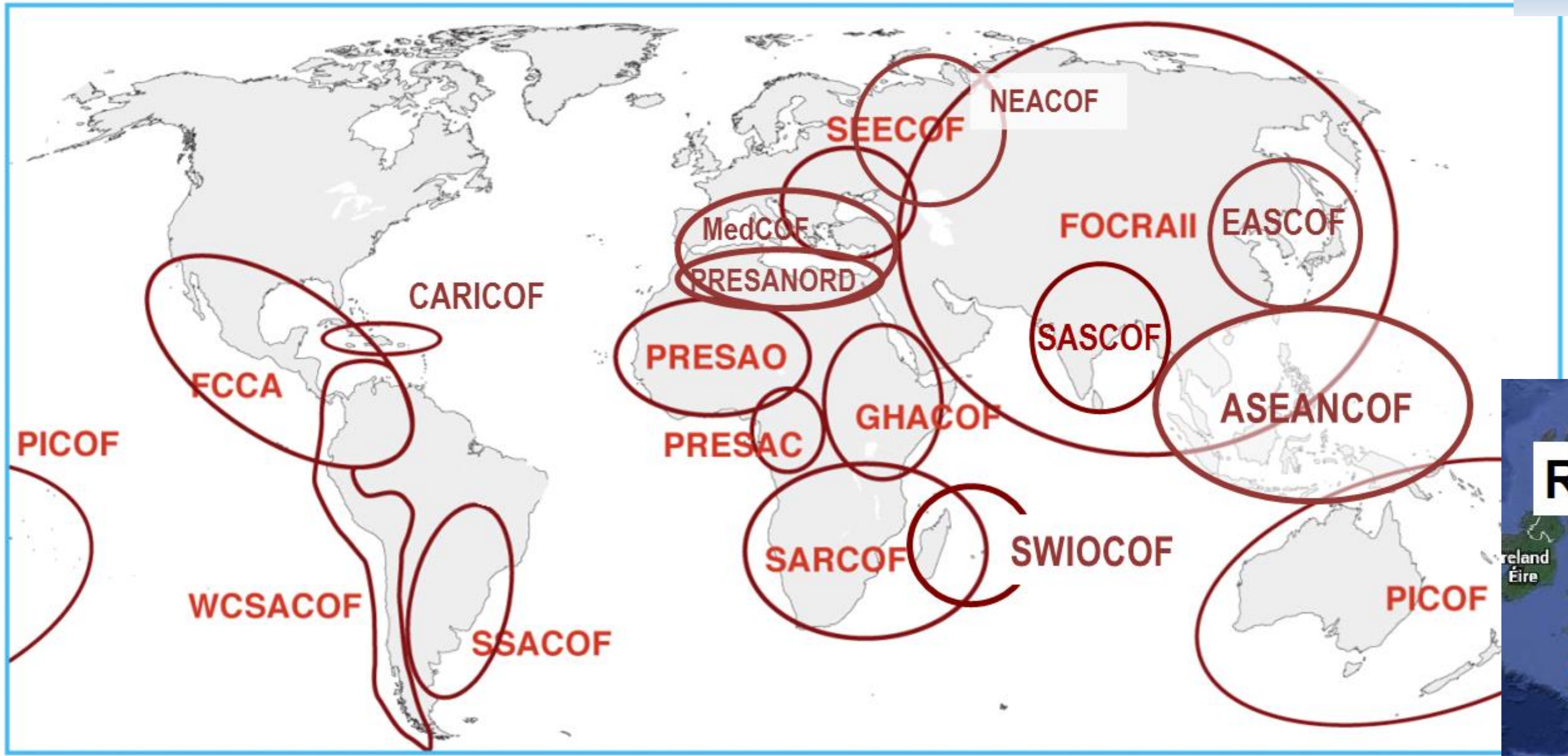
Formal designation by Res. 5 (EC-65) following recom. CBS-15 [May 2013]

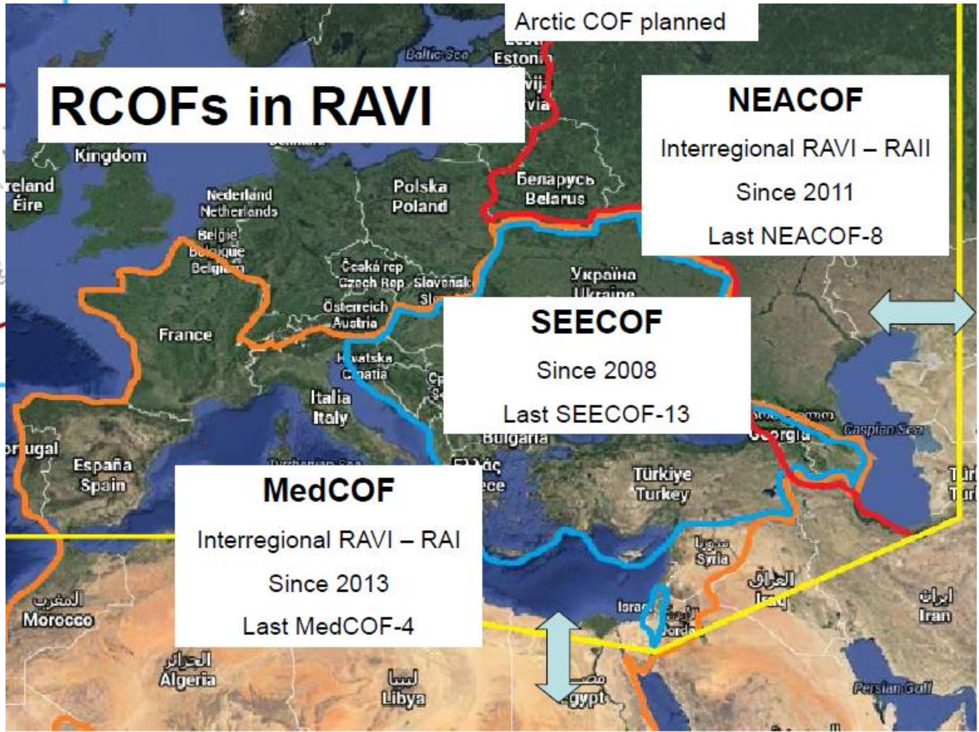
South East European Virtual Climate Change Center (SEEVCCC) [Estab. 2008]

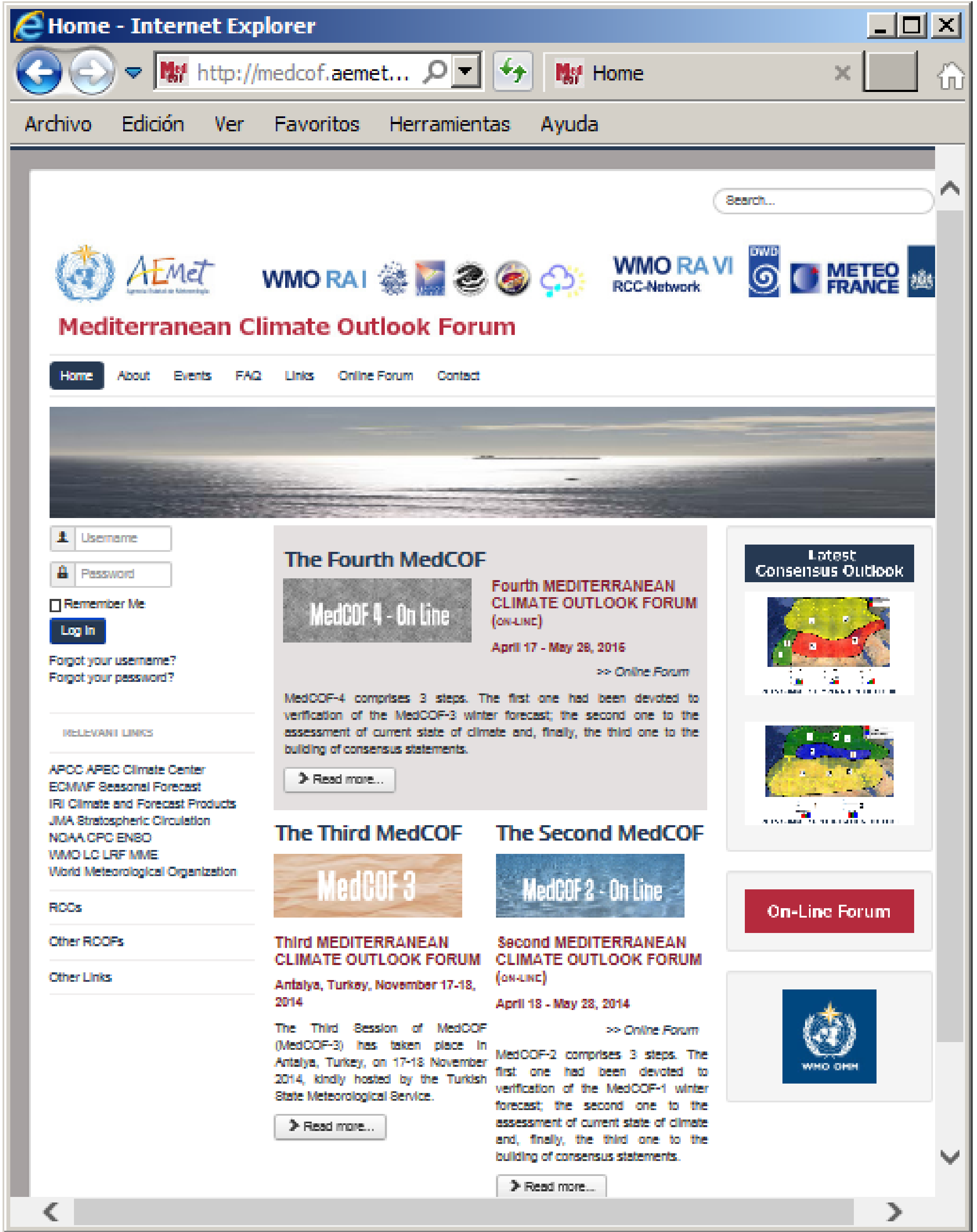
Further information at: http://www.rccra6.org/

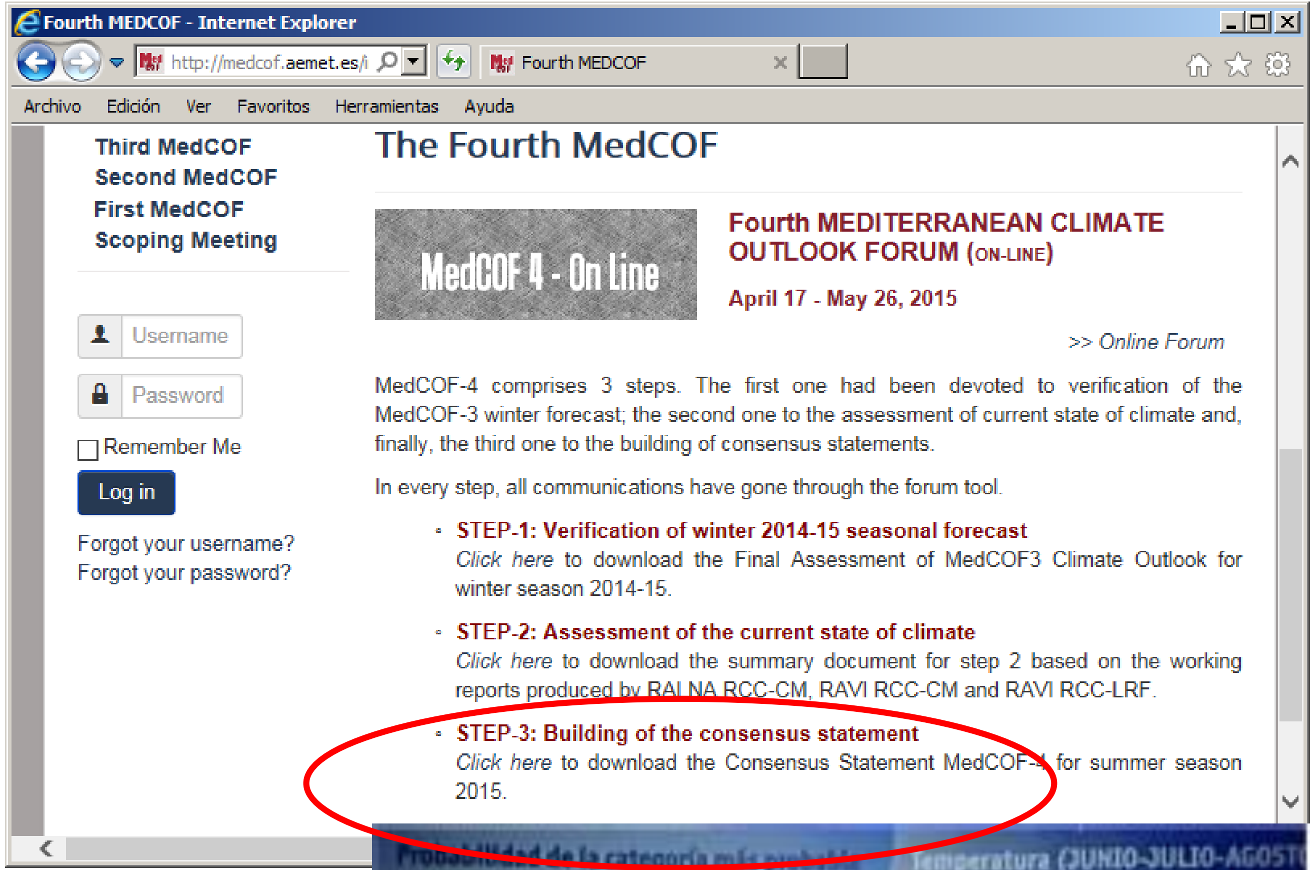


Regional Climate Outlook Forums worldwide









The MedCOF seasonal forecast products shown at the Spanish public TV channel (TVE1)

Building of the consensus statement

- Analysis of drivers: ENSO, QBO, Global/regional SST; Sea Ice; Snow cover; volcanoes; solar, etc.
- Models → verifications, windows of opportunity, consistency, how well do they simulate drivers, etc
- Regional foot print →
- Discussion → several rounds → consensus statement

Conclusions and lessons learnt (so far!)

- Need to use current mechanisms, such as RCCs and RCOFs, to **potentiate the expert and empirical knowledge**
- **RCCs and RCOFs need to be further expanded** and strengthened by introducing more systematic and objective procedures.
- Need of **demonstration projects** for high quality climate services (not only in regions of high skill), using **optimal combinations of empirical and dynamical techniques**
- There is a need to make climate **information valuable for decision-making** by being specific and tailored.
- **Uncertainty** information is needed at all stages
- Need for more **interdisciplinary work** to better address specific user needs in various sectors

Thanks for your attention!