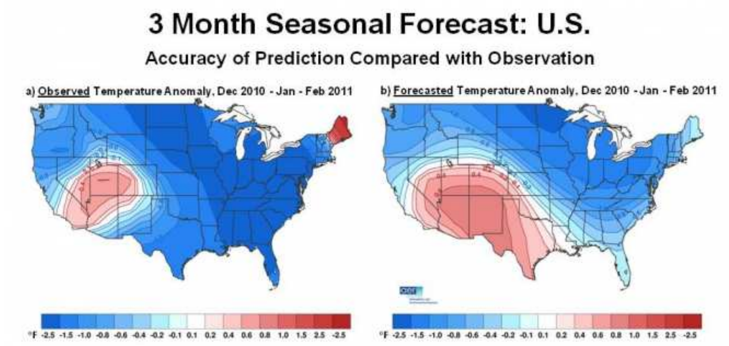
Verification of seasonal forecasts for sectoral variables

E. Rodríguez-Camino, AEMET

With contributions of:

Laurent Pouget, Simon Mason, Eroteida Sanchez, José Voces, Beatriz Navascués, Inmaculada Abia, Nieves Garrido, Irene Mestre, etc.

Forecast quality versus forecast value



- Forecast quality → Good correspondance with observations

  World of modelers → ROC, BSS, Reliability diagr., etc

- Forecast value → Enable beneficial (economical) decisions

  World of users → C/L ratio, value, exotic variables, etc

Hagedorn, R., and L. A. Smith, 2008: Communicating the value of probabilistic forecasts with weather roulette. *Meteor. Appl.*, DOI: 10.1002/met.92.

Mason, S., 2013. Guidance on Verification of Operational Seasonal Climate Forecasts. Prepared under the auspices of WMO CCl XIV.

Guiding principles

- Forecasts possess no intrinsic value. They acquire value through their ability to **influence the decisions** made by users of the forecasts.

(Murphy 1993)

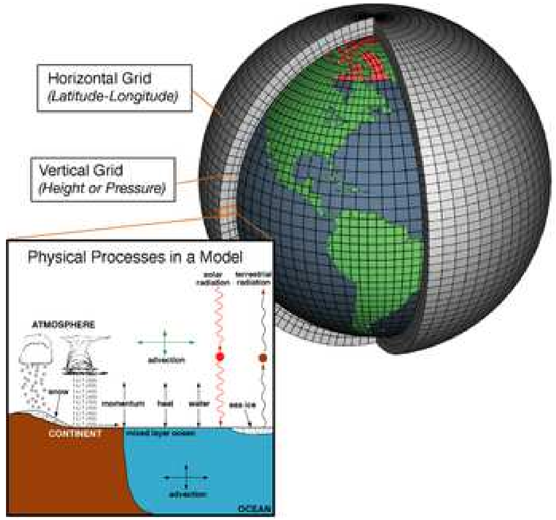
- Nature is pleased with **simplicity**. And nature is not dummy.

(I. Newton)

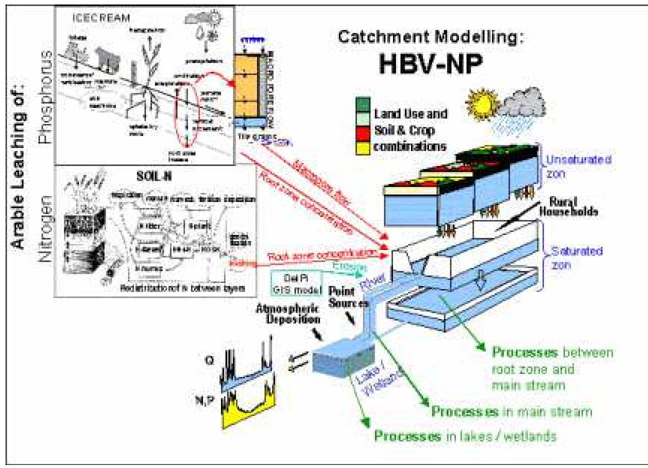
- Do not kill flies using cannons! → **Avoid complexity.**

Forecast of Temp & Prec. versus Forecast of climate sensitive variables

- Seasonal forecasts of T and P has a relatively low skill (except windows of opportunity) in midlatitudes.



- However some climate sensitive variables (e.g., inflow to water dams, river discharge, etc) may have higher skill



Limited skill of seasonal forecasting systems over midlatitudes

Windows of opportunity

Area: BALKANS   Lead-Time: 1   Period: 1988-2008

FORECAST SYSTEM

	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ	DJF
JMA	0.53	0.58	0.65*	0.65*	0.65*	0.61*	0.6#	0.44	0.51	0.39	0.36	0.52
Can	0.51	0.61#	0.79*	0.54	0.52	0.58	0.62	0.54	0.64*	0.46	0.47	0.42
CFSv2	0.56	0.55	0.61#	0.63#	0.43	0.65*	0.62	0.51	0.59	0.28	0.56	0.47
UKMO3	0.59	0.62#	0.52	0.55	0.46	0.7*	0.6#	0.55	0.54	0.44	0.46	0.43
MF3	0.64*	0.53	0.71*	0.54	0.6#	0.68*	0.73*	0.64*	0.48	0.49	0.58	0.57
S4	0.6	0.61	0.7*	0.69*	0.56	0.69*	0.66*	0.59	0.52	0.5	0.49	0.54

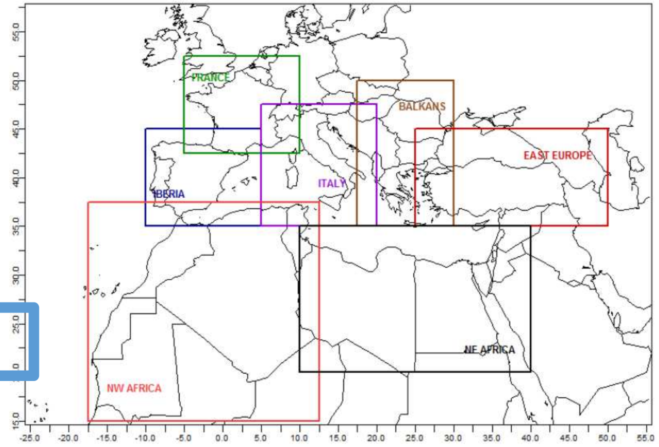
TRIMESTER

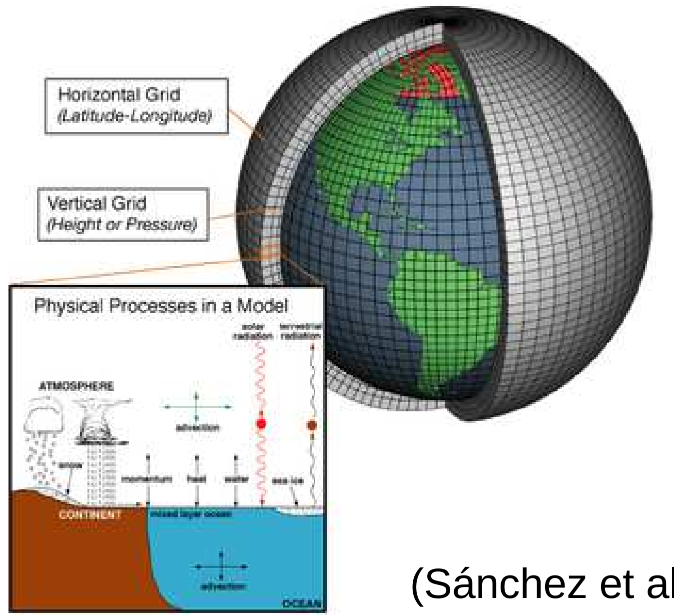
Observations: ERA-Interim

0   0.4   0.5   0.6   0.7   1

Regional Lower ROC Area - TEMPERATURE

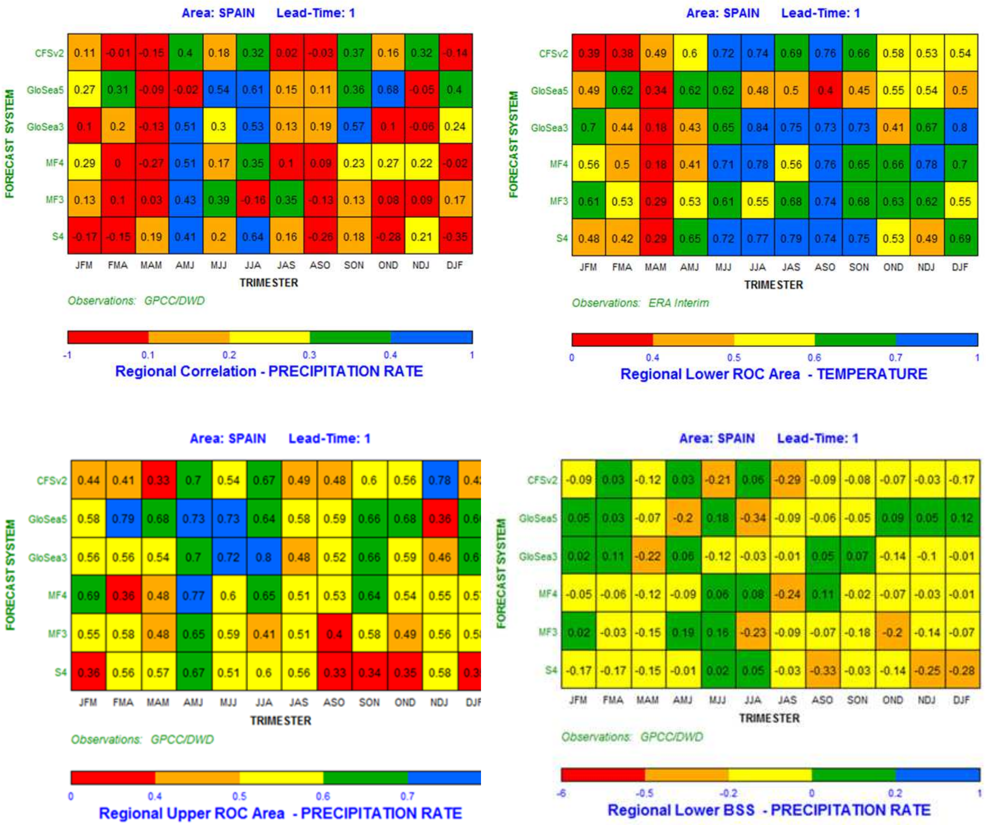
** p-val <= 0.05   # 0.05 < p-val <= 0.10 (nBootstrapping = 1000)*





(Sánchez et al 2014)

Evaluation of (EUROSIP) dynamical models



S4	*ECMWF S4*	*1991-2010*
MF3	*Meteo-France S3*	*1992-2010*
MF4	*Meteo-France S4*	*1992-2010*
GloSea3	*Met Office S3*	*1991-2008*
GloSea5	*Met Office S9*	*1997-2008*
CFSv2	*NCEP S2*	*1991-2010*

Regional correlation coefficient, lower tercile ROC area, upper tercile ROC area and lower BSS between observations and seasonal forecasts computed for the anomaly values of total precipitation, for 12 different 3-month periods and for lead-time 1 over the spatial domain.
Temperature and precipitation were verified against ERA-Interim and GPCC/DWD data, respectively.

Evaluation of potential predictors

PRECIPITATION

SPAIN

	Predictor	MAM								JJA								SON								DJF							
		1ml		4ml		7ml		10ml		1ml		4ml		7ml		10ml		1ml		4ml		7ml		10ml		1ml		4ml		7ml		10ml	
		E	G	E	G	E	G	E	G	E	G	E	G	E	G	E	G	E	G	E	G	E	G	E	G	E	G	E	G	E	G	E	G
Pacific	WP	29	24	54		61	24													11						54	52						
	PNA			11	33					29										18												11	
	NINO3.4		38		24		14			39	57	32	33	18		39				36	14	32	33	32	38								
	NINO1+2		19							21										11			14										
	NINO3		29		19					11	19	18		14		14				25		25	29	32	38								
	NINO4		14		14						38	32	33	39	48	32				14		32	38	29	33								
	EMI			43	29	36	14					32	81		29		24						14										
	SOI				33							18	33	11		14				29	24	36	33	29	48								
	PDO																										19			11		21	
	NPGO				38		19		24																								
	IOD							32	38					11		32												14	14				
Atlantic	NAO				14																									11			
	EA												19									21											
	EA-WR												19									21											
	AMO			14																						18							
	AT*	32				57	29	32		32								25		50	19												
	SCAND		19			32								18		21	33	14															
	TNA	39		11						36								14		36	19	14											
	AO																																
	WEMO		24											25	19	21												11				14	14
	QBO									21	24																			11			19
Snow Indexes	SAI-d**																									79				86			
	SAI-w**																									61				81			
	SAI-w-ext																									57				76			
	SVI**																									79				86			

MOROCCO

	Predictor	MAM								JJA								SON								DJF							
		1ml		4ml		7ml		10ml		1ml		4ml		7ml		10ml		1ml		4ml		7ml		10ml		1ml		4ml		7ml		10ml	
		E	G	E	G	E	G	E	G	E	G	E	G	E	G	E	G	E	G	E	G	E	G	E	G	E	G	E	G	E	G	E	G
Pacific	WP	67	42			56	67			22		11	42																				
	PNA	33	50																														
	NINO3.4									44	17	22		22		11																	
	NINO1+2	22								22	17	22		22																			
	NINO3	33		33						44		22		22		11																	
	NINO4									22		22		33																			
	EMI									11		22		11																			
	SOI						25			33		33		22																			
	PDO										17			11																			
	NPGO																	22															
	IOD											22																					
Atlantic	NAO	56										11	25	11												11		78	58				
	EA							56	33			11						22															
	EA-WR							56	33			11						22															
	AMO									33	42		17		42									44									
	AT*		50				17			22																	33	33	67				
	SCAND		17								17	22		33					17				42										
	TNA	67	83							11																	42		17				
	AO					22	33											11										67	58				
	WEMO	11	33					33						56	25	11				11	33						17						
	QBO									22						22	17																
Snow Indexes	SAI-d**																									78				67			
	SAI-w**																									78				83			
	SAI-w-ext																									89				75			
	SVI**																																

TEMPERATURE

SPAIN

	Predictor	MAM				JJA				SON				DJF			
		1ml	4ml	7ml	10ml	1ml	4ml	7ml	10ml	1ml	4ml	7ml	10ml	1ml	4ml	7ml	10ml
Pacific	WP		18														
	PNA																
	NINO3.4																
	NINO1+2																
	NINO3																
	NINO4																
	EMI																
	SOI																
	PDO																
	NPGO						14	29	50								
	IOD				46												
Atlantic	NAO									39							
	EA			32													
	EA-WR			32													
	AMO																
	AT*					18				71							
	SCAND			21					18								
	TNA					43											
	AO																
	WEMO																
	QBO																
Snow Indexes	SAI-d**																
	SAI-w**																
	SAI-w-ext																
	SVI**													14			

MOROCCO

	Predictor	MAM				JJA				SON				DJF			
		1ml	4ml	7ml	10ml	1ml	4ml	7ml	10ml	1ml	4ml	7ml	10ml	1ml	4ml	7ml	10ml
Pacific	WP														11		
	PNA											33					
	NINO3.4												22				
	NINO1+2					11											
	NINO3								11							33	
	NINO4					11											
	EMI								11								
	SOI															11	11
	PDO																
	NPGO																
	IOD				67												
Atlantic	NAO	22								22							
	EA																
	EA-WR																
	AMO		11								44	22					
	AT*			11		11				100							
	SCAND								22						11		
	TNA		33							56							
	AO																
	WEMO								11						22		
	QBO								56								
Snow Indexes	SAI-d**																
	SAI-w**																
	SAI-w-ext													33			
	SVI**																

- Exploration of 25 global and regional indices over MOSES pilot areas following Eden et al (2015) method.
- Pearson correlation and p-value, between temperature and precipitation and each of the predictors has been computed for MAM, JJA, SON and NDJ, exploring different time lags between predictand and predictor.
- The tables show the percentage of grid points with significant correlation for each predictor, season and month lead for Spain and Morocco pilot areas.

	Predictor	MAM								JJA								SON								DJF							
		1ml		4ml		7ml		10ml		1ml		4ml		7ml		10ml		1ml		4ml		7ml		10ml		1ml		4ml		7ml		10ml	
		E	G	E	G	E	G	E	G	E	G	E	G	E	G	E	G	E	G	E	G	E	G	E	G	E	G	E	G	E	G	E	G
Pacific	WP	29	24	54		61	24													11						54	52						
	PNA			11	33					29										18												11	
	NINO3.4		38		24		14			39	57	32	33	18		39				36	14	32	33	32	38								
	NINO1+2		19							21										11			14										
	NINO3		29		19					11	19	18		14		14				25		25	29	32	38								
	NINO4		14		14						38	32	33	39	48	32				14		32	38	29	33								
	EMI			43	29	36	14					32	81		29		24						14										
	SOI				33							18	33	11		14				29	24	36	33	29	48								
	PDO																										19			11		21	
	NPGO				38		19		24																								
	IOD							32	38					11		32												14	14				
Atlantic	NAO				14																									11			
	EA												19									21											
	EA-WR												19									21											
	AMO			14																						18							
	AT *	32				57	29	32		32								25		50	19												
	SCAND		19			32								18		21	33	14															
	TNA	39		11						36								14		36	19	14											
	AO																																
	WEMO		24											25	19	21												11				14	14
	QBO									21	24																			11			19
Snow Indexes	SAI-d **																									79				86			
	SAI-w **																									61				81			
	SAI-w-ext																									57				76			
	SVI ***																									79				86			

Windows of opportunity

Users are not interested in general solutions. They want solutions adapted to their particular problems and circumstances

- Linked to certain SFS
- Linked to certain regions (e.g., only West Med)
- Linked to certain seasons (e.g., only summer)
- Linked to certain variables (e.g., T)
- Linked to certain states (e.g., ENSO)

Models

- Linked to certain predictors (e.g., SAI)
- Linked to certain predictands (e.g., P)
- Linked to certain regions (e.g., Western Europe)
- Linked to certain seasons (e.g., winter)

Empirical systems

Seasonal Climate Predictions in support of Water Reservoirs Management in Spain

The irregularity of the hydrological cycle in Spain has led to an extended network of reservoirs in the whole country, making these infrastructures key in water management. In addition to the current use of weather forecasts and climate projections delivered by AEMET for water management, a **pilot climate service for application of seasonal climate predictions in water reservoirs management (S-ClimWare)** has been developed. This work is being carried out by a multidisciplinary group, coordinated by AEMET and DG Water of Spain, within the framework of the Global Framework for Climate Services (GFCS) national implementation and the FP7 EUPORIAS project .

Participants in the group are experts in climate and/or hydrology coming from AEMET, CETAqua, Universidad Politécnica de Valencia, DG Water, and four River Basin Authorities: Ebro, Douro, Tagus, and Miño-Sil.

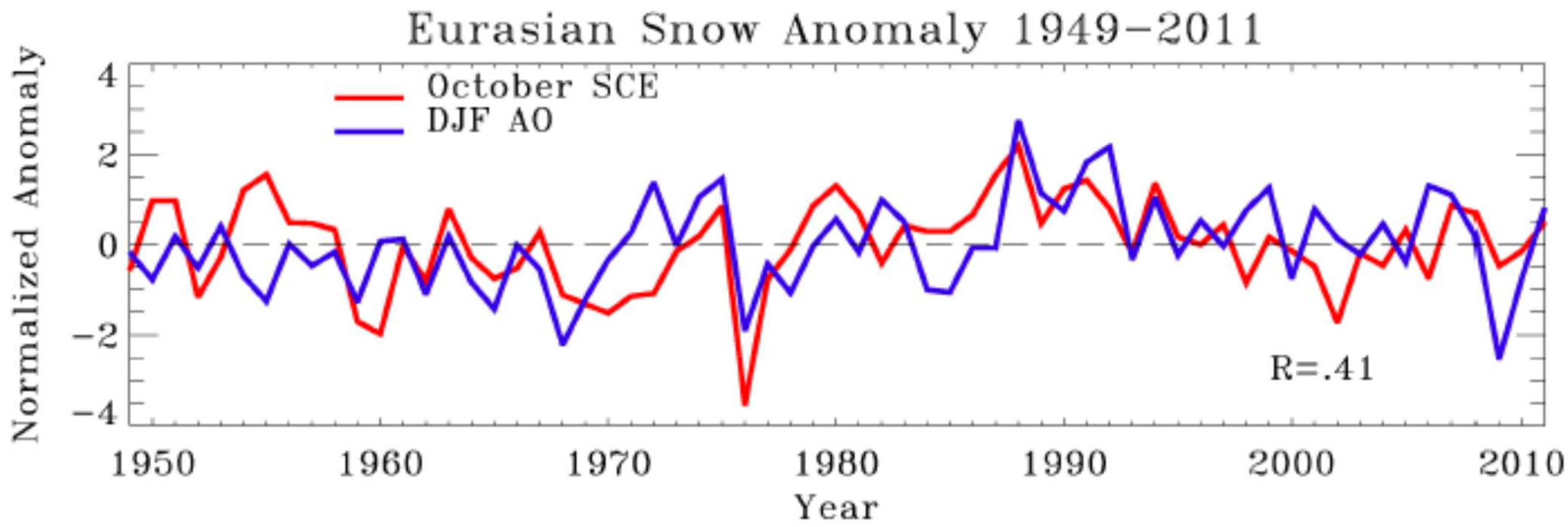
The adopted methodology follows similar experiences carried out by the IRI (International Research Institute for Climate and Society) and tested in some places of Asia and America (Brown et al., 2010). The main components of the pilot climate service S-ClimWaRe are:

1. **A tool for hydroclimatic risk evaluation**
2. **A seasonal forecasting system of dam inflows**
3. **A decision support tool for water reservoirs: SIMRISK**

Seasonal Climate Predictions in support of Water Reservoirs Management in Spain

- Model outputs were disregarded due to their low skill for precipitation over the Iberian Peninsula
- Different predictors for seasonal precipitation were explored
- A tool for hydroclimatic risk evaluation was developed
- SAI and variations thereof were applied for winter (DJF) and extended Winter (NDJFM)
- An empirical seasonal forecasting system for the variable **dam inflow** was developed
- A decision support tool for water reservoirs (SIMRISK) was added to suite
- Extensive verification of the sectoral variable (**dam inflow**)

Simple Correlation Suggests Snow – Arctic Oscillation (AO) Relationship



Cohen and Entekhabi (1999)

Snow advance & N/AO

- When snow cover advances rapidly/slowly across Eurasia in October, this is an indication that the upcoming winter will be more severe/milder for the Eastern US, Europe and East Asia.

- When the N/AO is high/[**low**], **high latitude blocking** is much less/[**more frequent**]. The Jet Stream flows quickly from west to east carrying weather systems along quickly and acts as a divide between cold air to the north and warm air to the south. [The flow of air in the atmosphere is impeded or becomes blocked and the Jet Stream is diverted from its normal trajectory and **meanders north and south** around the high latitude blocking. Mixing of air masses occurs with warm air flowing north into the Arctic and cold air flowing south into the midlatitudes]

(Cohen & Jones GRL 2011)

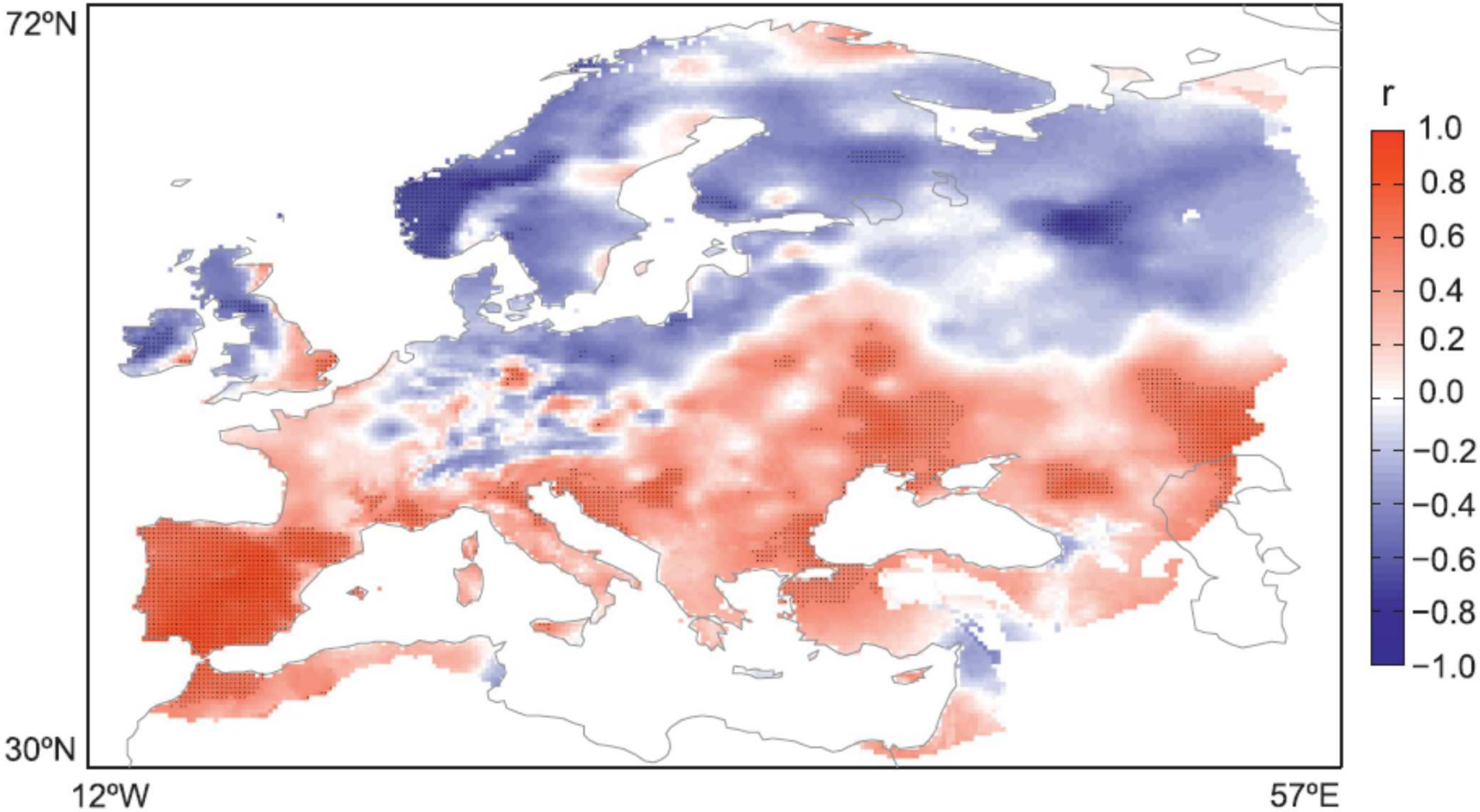


FIG. 1. Pearson correlation coefficients between the October daily SAI and the precipitation sums of the following DJF (n = 14; critical value = ±0.53). Locally significant correlations (α_{local} = 0.05) are shaded in black. Global significance was obtained (α_{global} = 0.05); all calculations are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

(Brands et al., JC, 2012)

TABLE 1. Pearson correlation between hindcast and observed DJF precipitation totals, aggregated to catchment, country, and subcontinental scale; one or two asterisks are assigned in case correlation is significant at a test level of 5% or 1%, respectively.

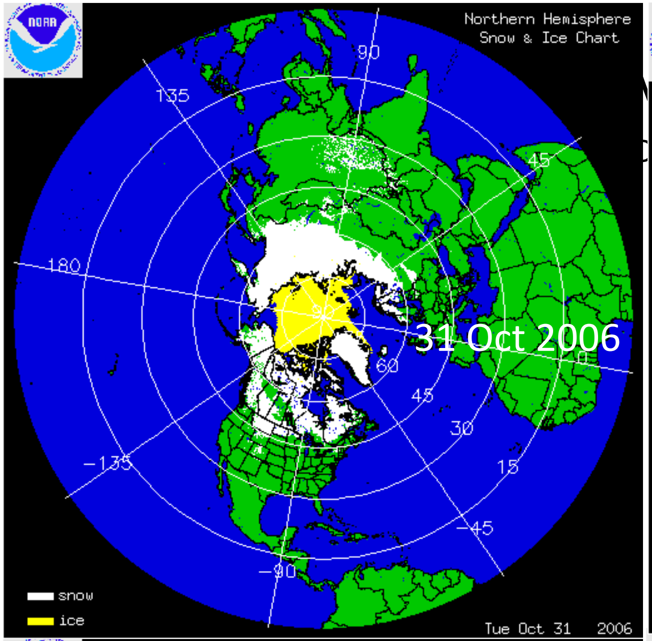
Catchment	Area of aggregation	Daily SAI (n = 14)	Weekly SAI (n = 39)
1	Norte	0.51	0.37*
2	Duero	0.64*	0.42**
3	Tajo	0.71**	0.51**
4	Guadiana	0.73**	0.50**
5	Guadalquivir	0.67**	0.49**
6	Sur	0.49	0.44**
7	Segura	0.34	0.16
8	Levante	0.63*	0.28
9	Ebro	0.68**	0.31
10	Catalana	0.39	0.16
11	Baleares	0.40	0.03
	Portugal	0.61*	0.49**
	Spain	0.78**	0.47**
	Iberian Peninsula	0.75**	0.48**
	Southern Norway	0.58*	0.43**

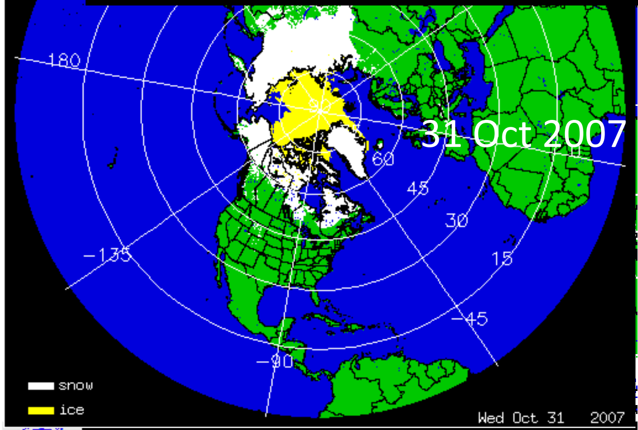
(Brands et al., JC, 2012)

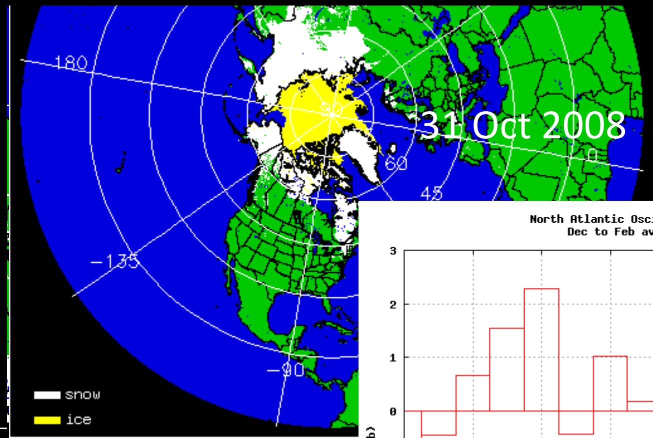
Snow cover extend 31st Oct

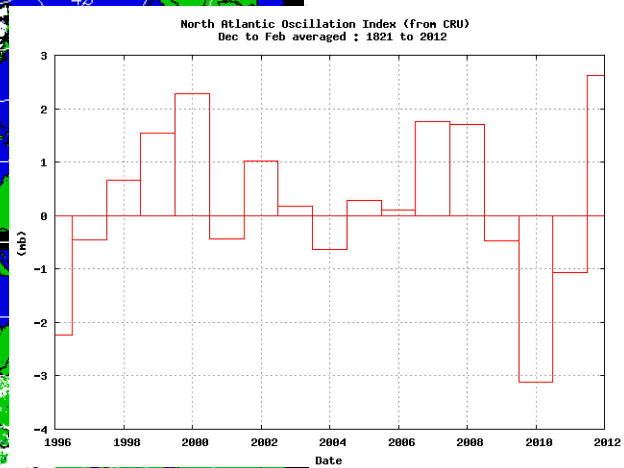
ftp://sidads.colorado.edu/pub/DATASETS/NOAA/G02156/images

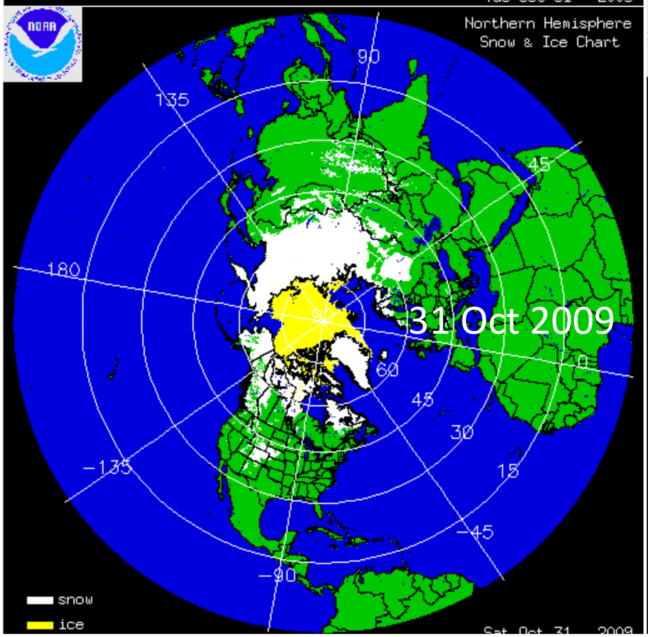
ftp://sidads.colorado.edu/pub/DATASETS/NOAA/G02156/24km/

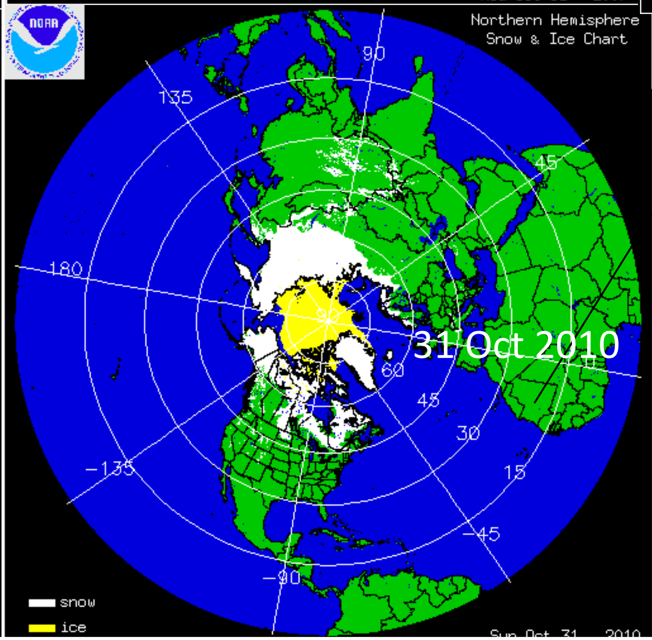


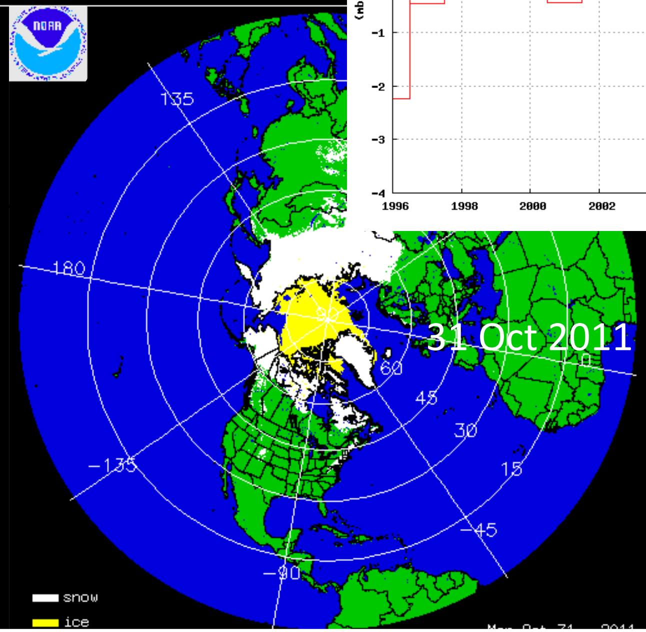




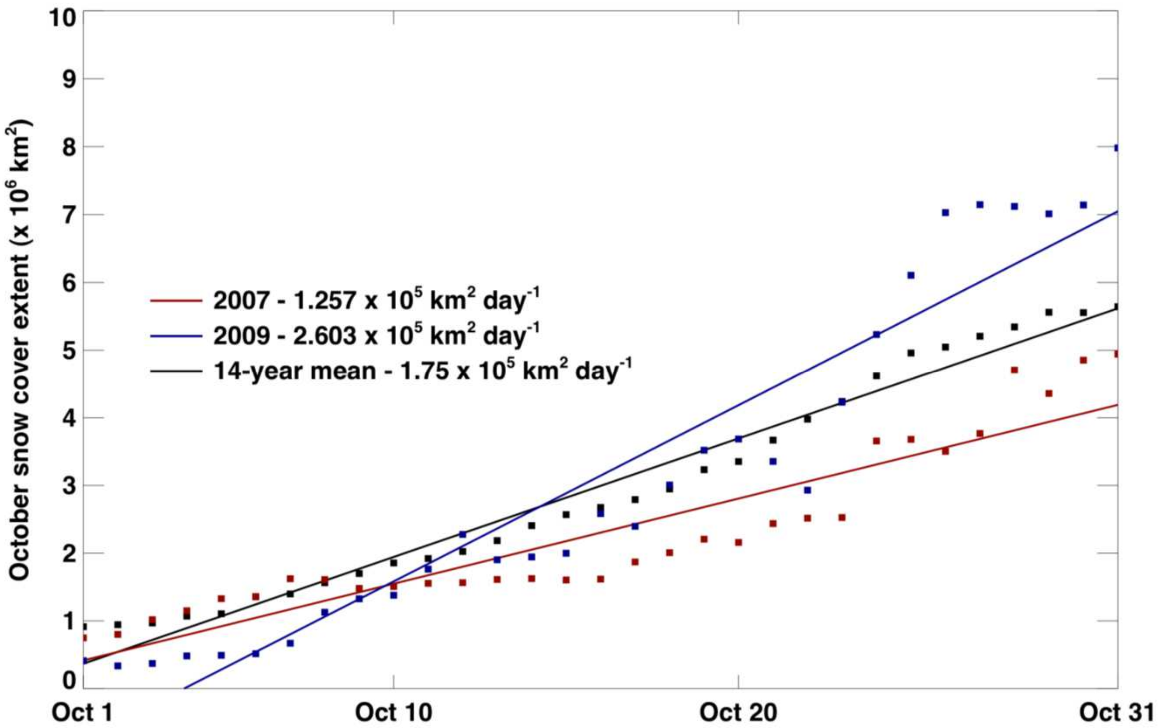








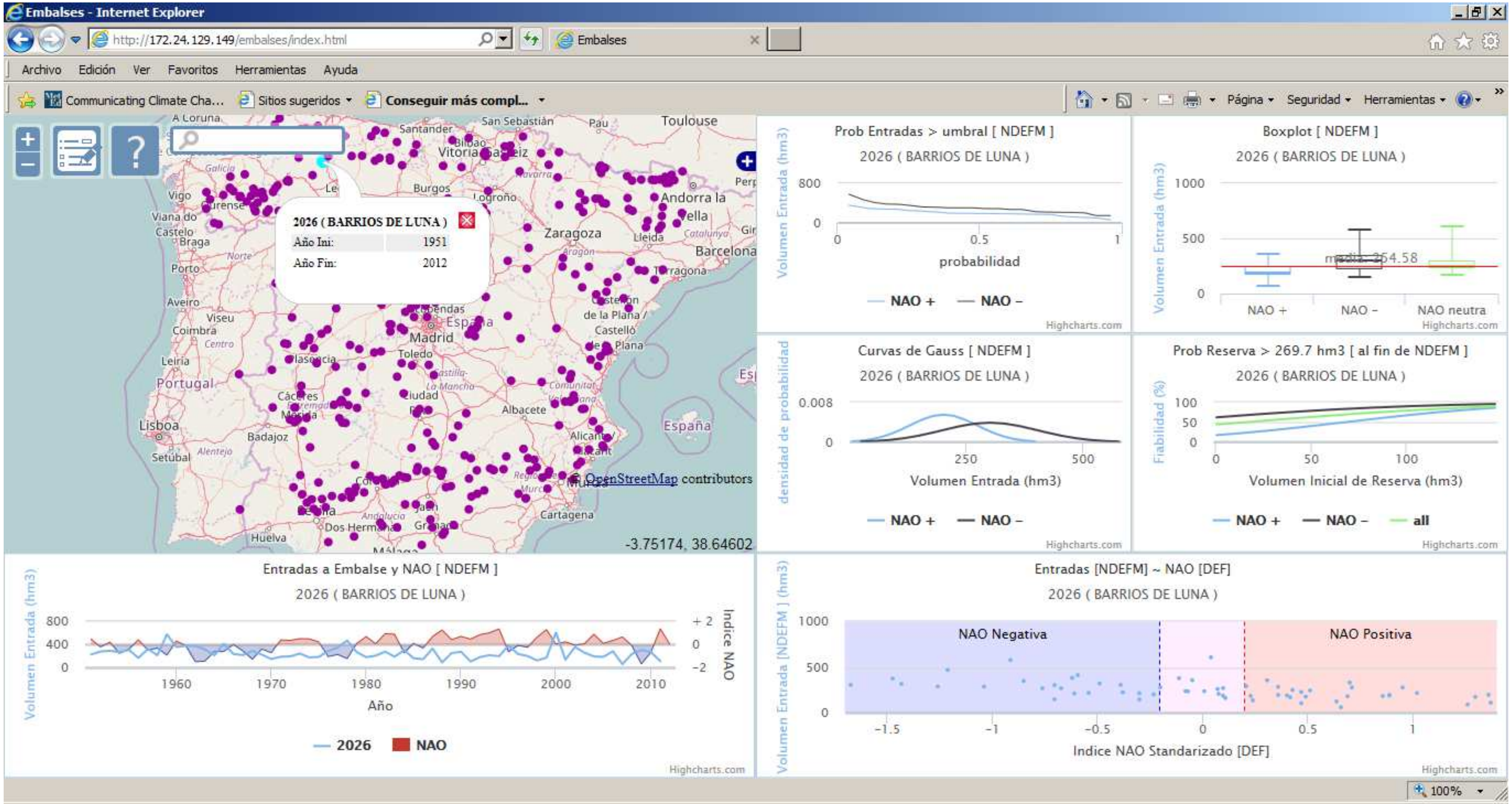
SAI (Cohen_Jones_2011) and SVI (AEMET)



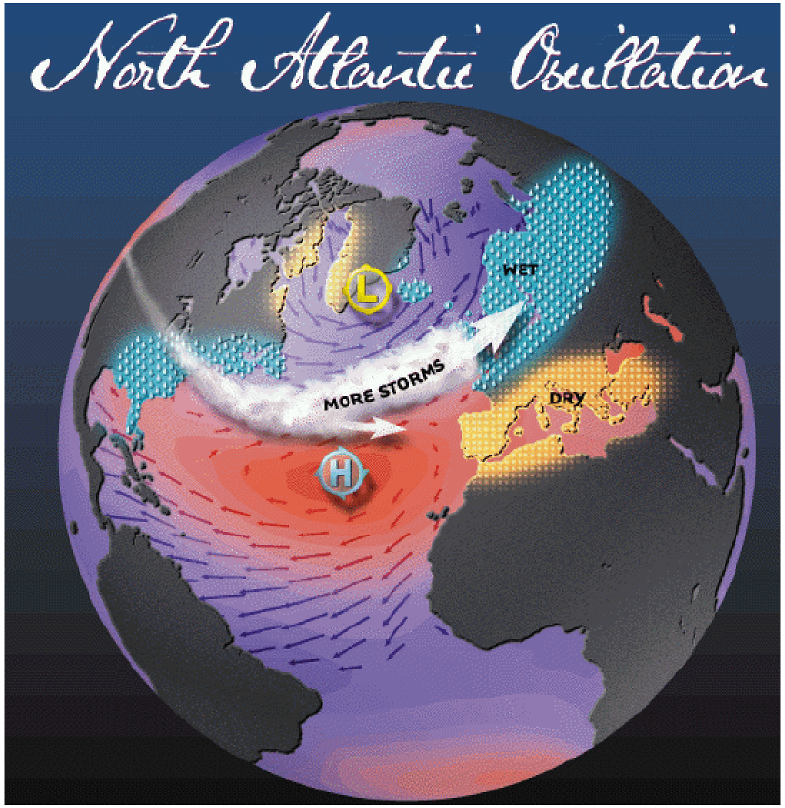
SAI_25._60._0._180._275_305.dat: correlacion NAO_DEF SAI: -0.11105383
SAI_25._60._70._180._275_305.dat: correlacion NAO_DEF SAI: -0.13130572
SAI_25._60._90._270._275_305.dat: correlacion NAO_DEF SAI: -0.29080501
SAI_25._85._0._180._275_305.dat: correlacion NAO_DEF SAI: -0.35093570
SAI_25._85._0._270._275_305.dat: correlacion NAO_DEF SAI: -0.39018694
SAI_25._85._115._270._275_305.dat: correlacion NAO_DEF SAI: -0.38550690
SAI_25._85._70._140._275_305.dat: correlacion NAO_DEF SAI: -0.35642990
SAI_25._85._70._180._275_305.dat: correlacion NAO_DEF SAI: -0.37588337
SAI_25._85._70._225._275_305.dat: correlacion NAO_DEF SAI: -0.38658595
SAI_25._85._70._270._275_305.dat: correlacion NAO_DEF SAI: -0.45894158
SAI_25._85._75._270._275_305.dat: correlacion NAO_DEF SAI: -0.49255186
SAI_25._85._75._270._290_305.dat: correlacion NAO_DEF SAI: -0.46770433
SAI_25._85._80._270._275_305.dat: correlacion NAO_DEF SAI: -0.49401096
SAI_25._85._85._270._275_305.dat: correlacion NAO_DEF SAI: -0.48845035
SAI_25._85._90._270._275_305.dat: correlacion NAO_DEF SAI: -0.48089454
SAI_25._85._90._315._275_305.dat: correlacion NAO_DEF SAI: -0.43759629
SAI_45._60._0._180._275_305.dat: correlacion NAO_DEF SAI: -0.13155539
SAI_45._60._70._180._275_305.dat: correlacion NAO_DEF SAI: -0.14891988
SAI_45._85._70._180._275_305.dat: correlacion NAO_DEF SAI: -0.36846149

SNV_25._60._180._360._266_314.dat: correlacion NAO_DEF SNV: -0.48853528
SNV_25._60._180._360._275_305.dat: correlacion NAO_DEF SNV: -0.54207975
SNV_25._85._180._270._266_314.dat: correlacion NAO_DEF SNV: -0.44202179
SNV_25._85._180._270._275_305.dat: correlacion NAO_DEF SNV: -0.62833428
SNV_25._85._180._295._275_305.dat: correlacion NAO_DEF SNV: -0.61083549
SNV_25._85._180._360._266_314.dat: correlacion NAO_DEF SNV: -0.55996817
SNV_25._85._180._360._275_305.dat: correlacion NAO_DEF SNV: -0.61086786
SNV_25._85._225._270._275_305.dat: correlacion NAO_DEF SNV: -0.56808710
SNV_25._85._75._270._275_305.dat: correlacion NAO_DEF SNV: -0.54766065
SNV_45._60._180._360._275_305.dat: correlacion NAO_DEF SNV: -0.49875915

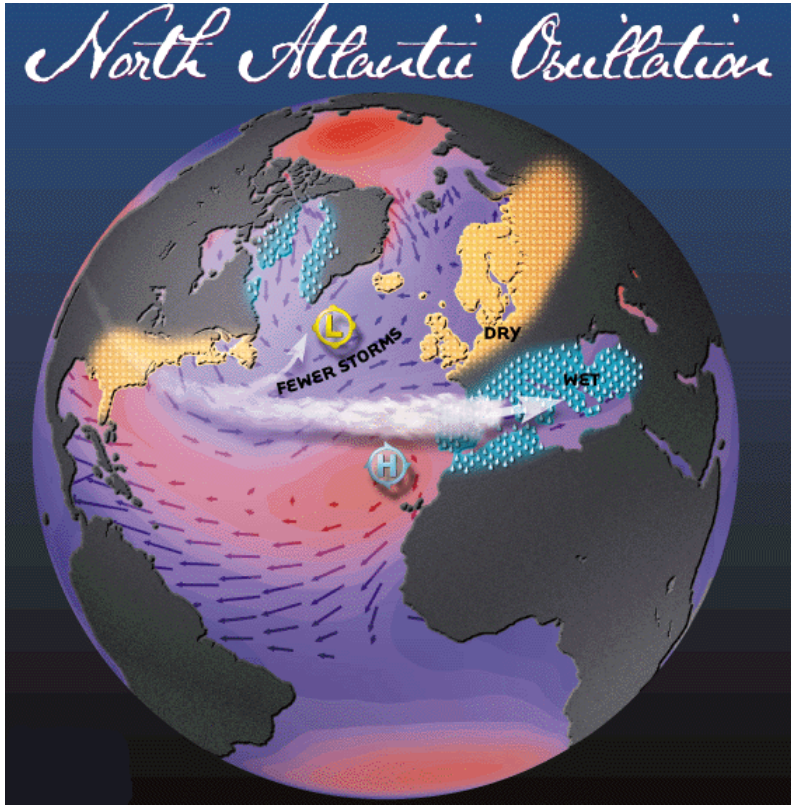
Tool for hydroclimatic risk evaluation



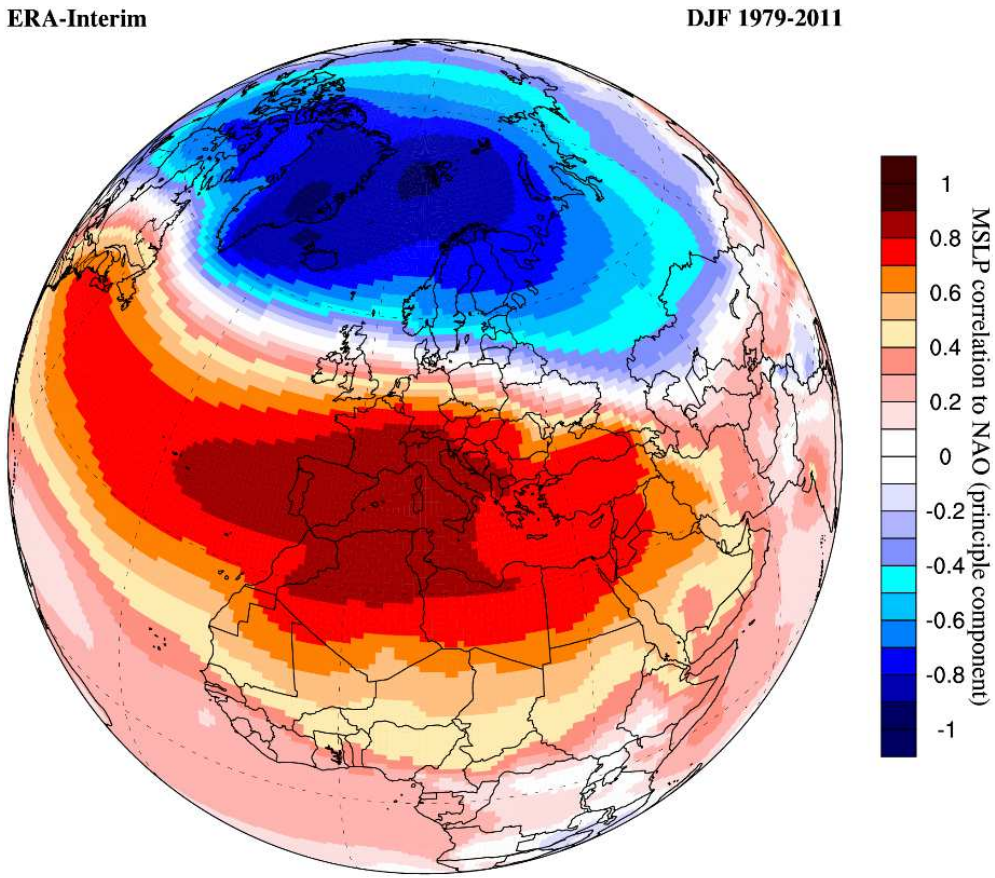
NAO +

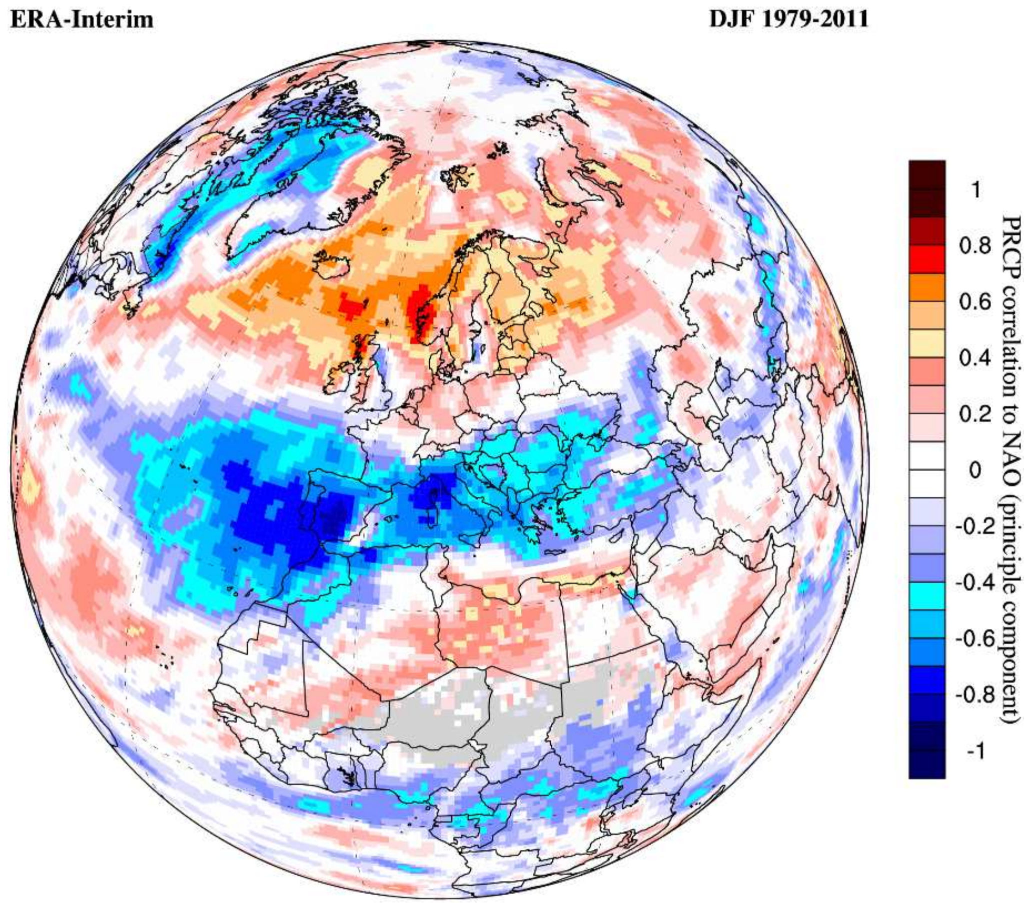

North Atlantic Oscillation
L
WET
MORE STORMS
DRY
H

NAO -

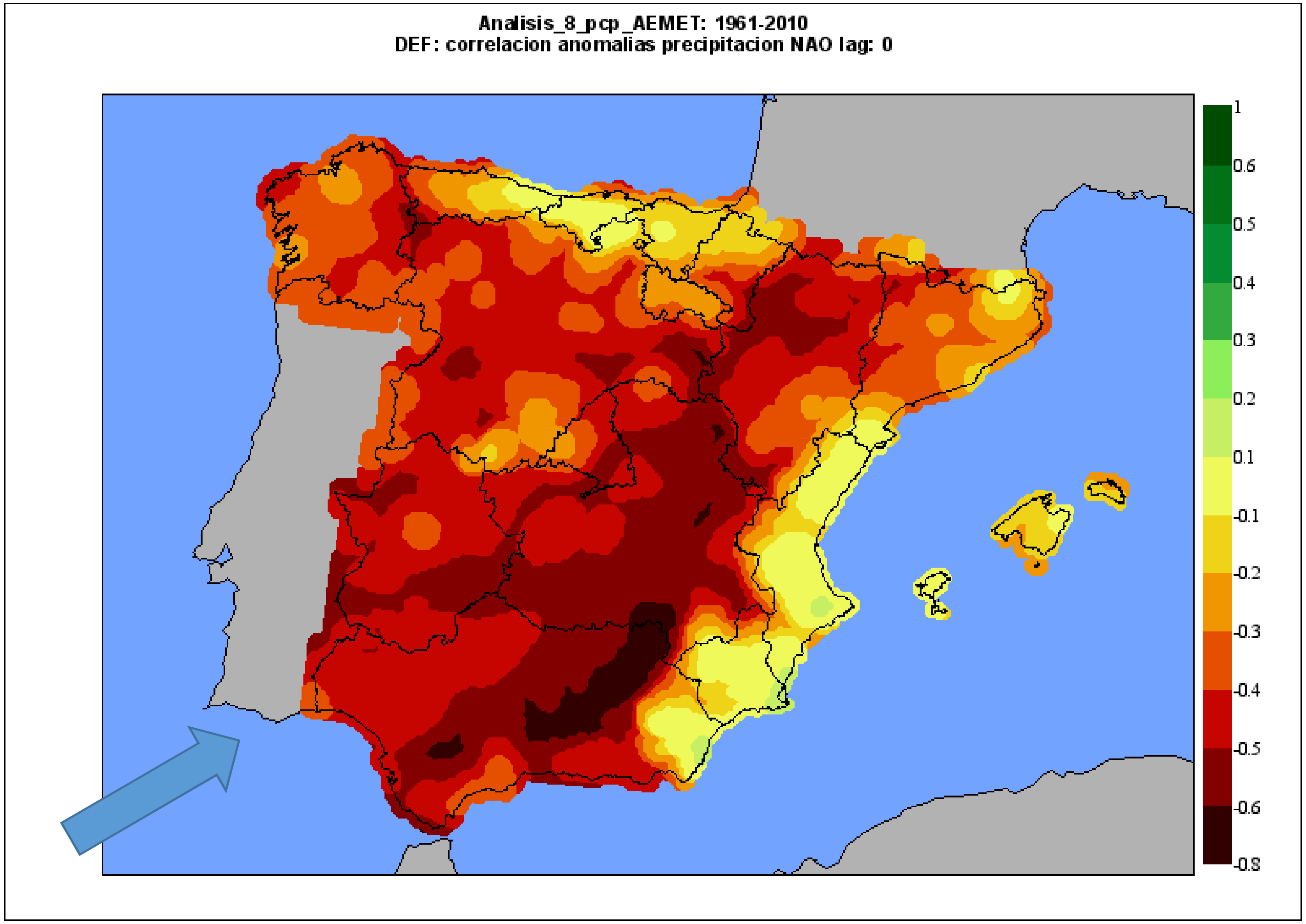

North Atlantic Oscillation
L
FEWER STORMS
DRY
WET
H

Correlating NAO with mslp and precipitation

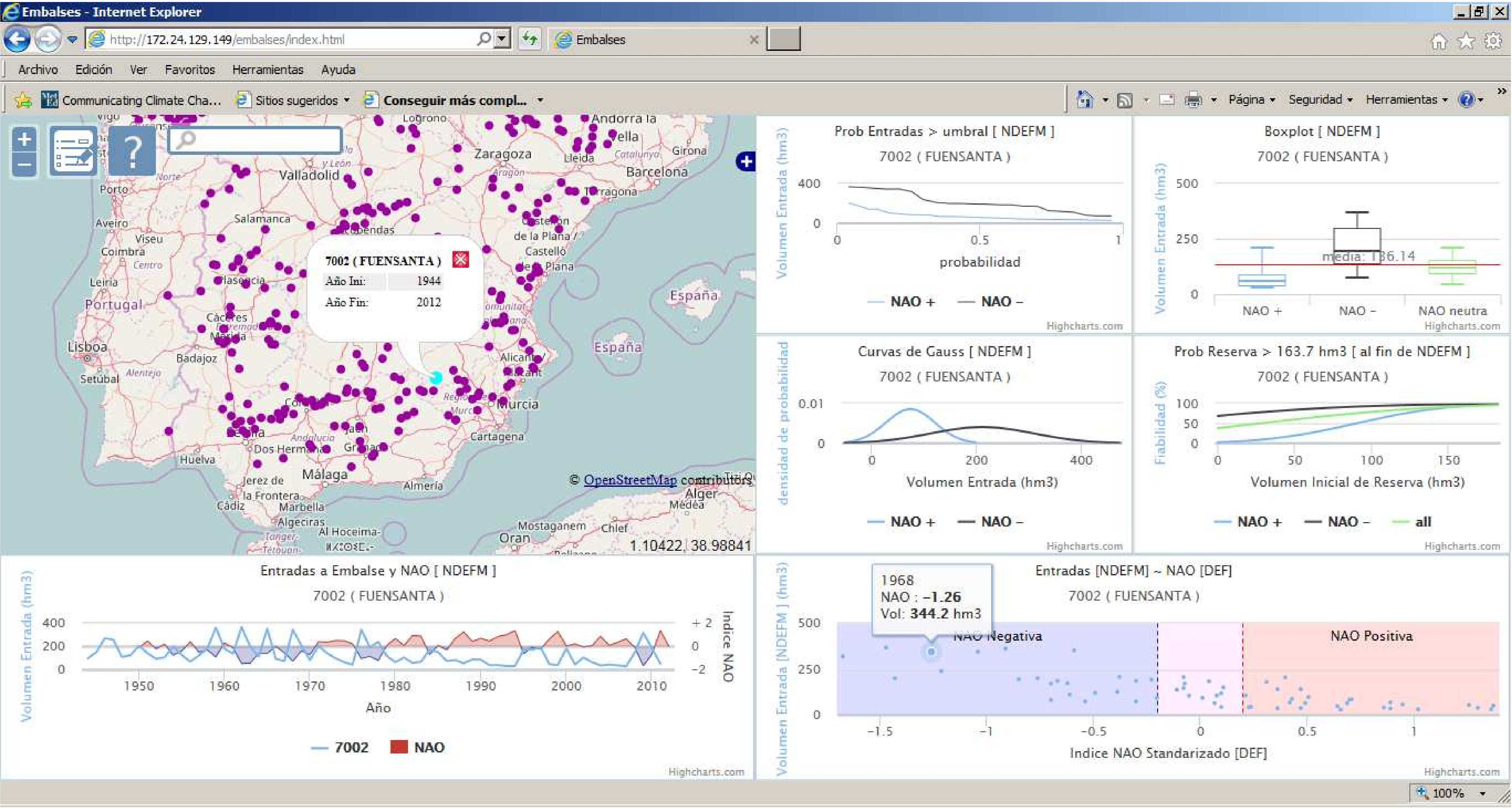


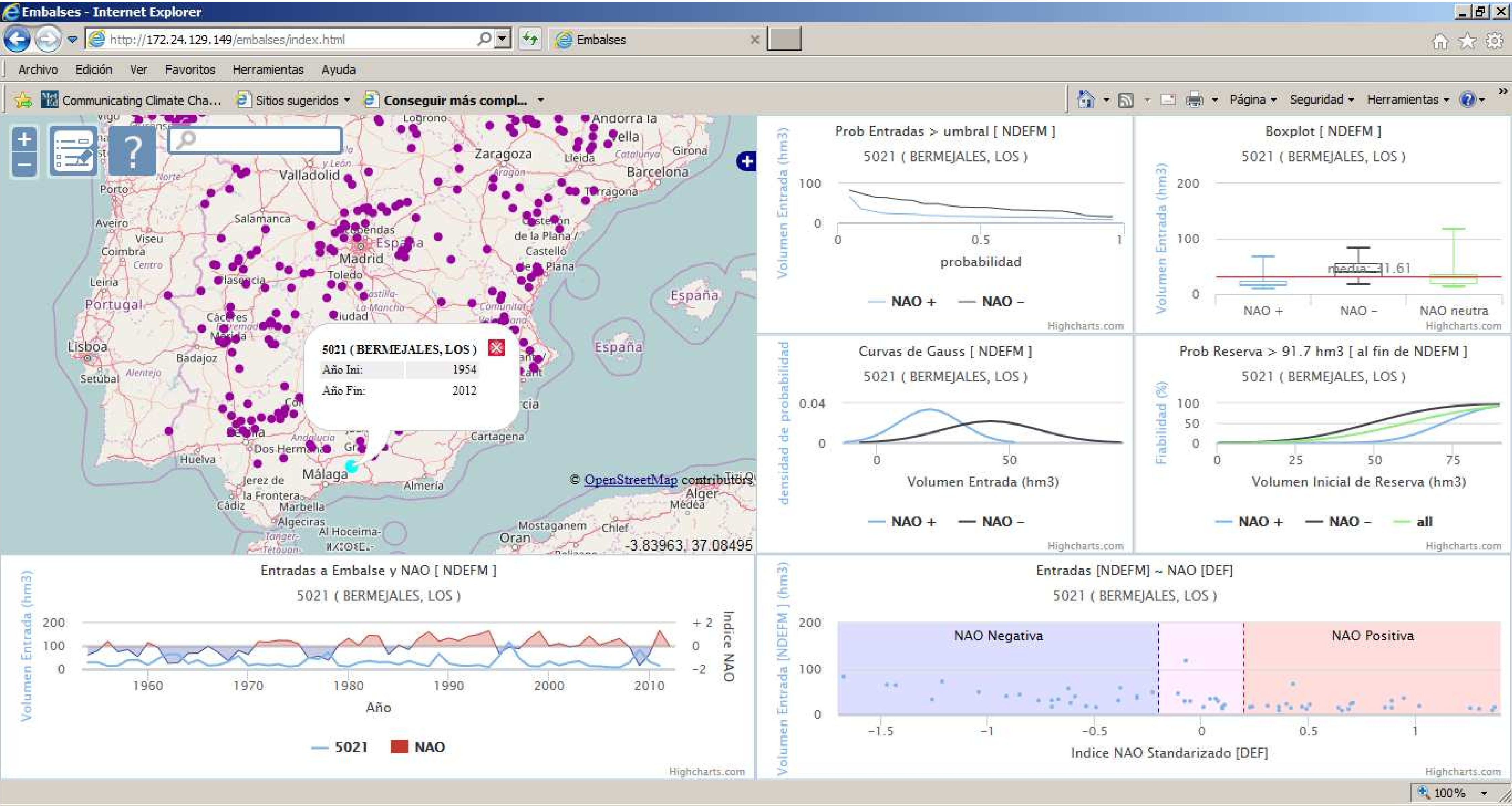


Precip – NAO correlation (DJF, 1961-2010)

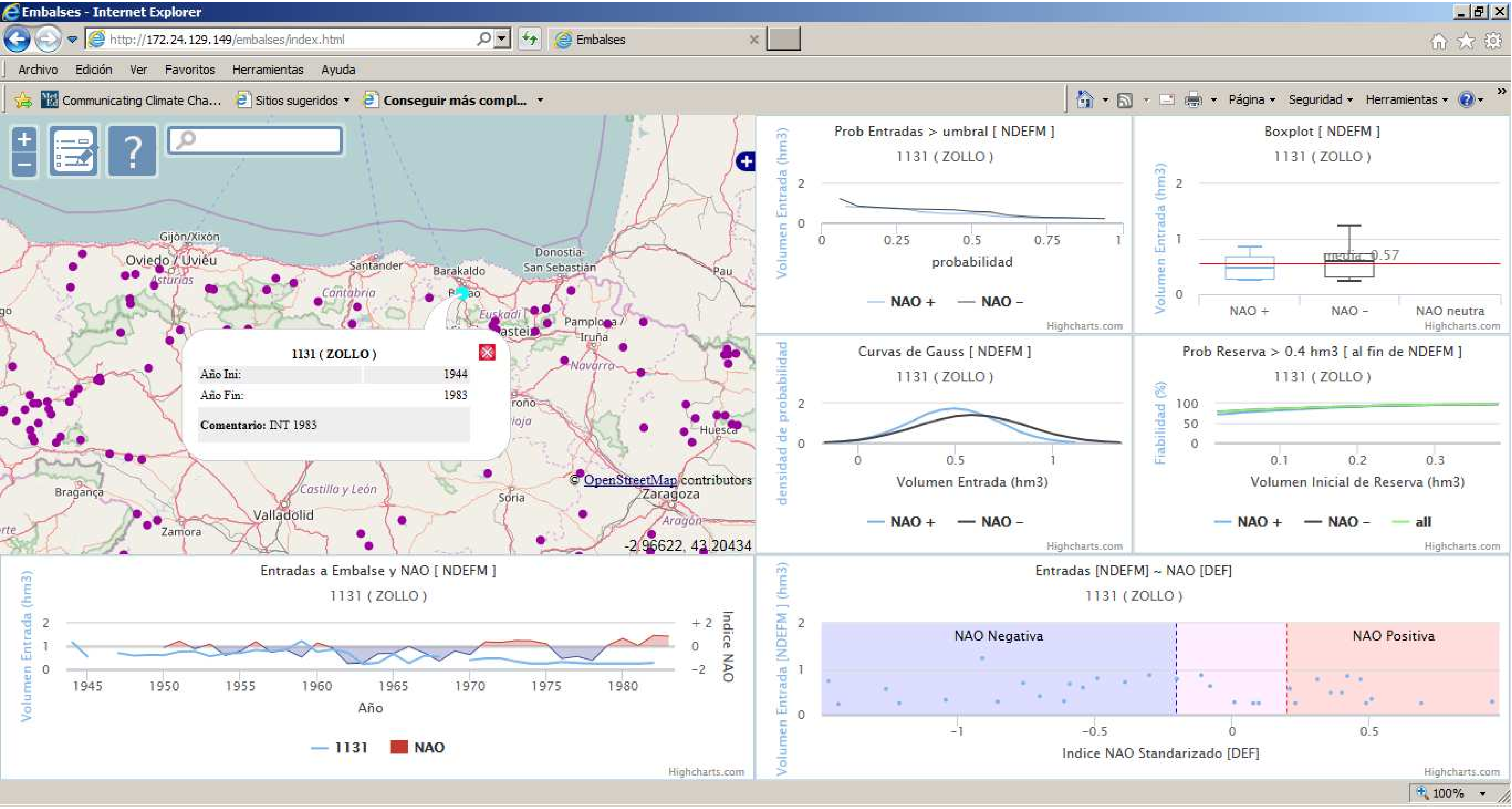


Extended Winter (NDJFM)!!



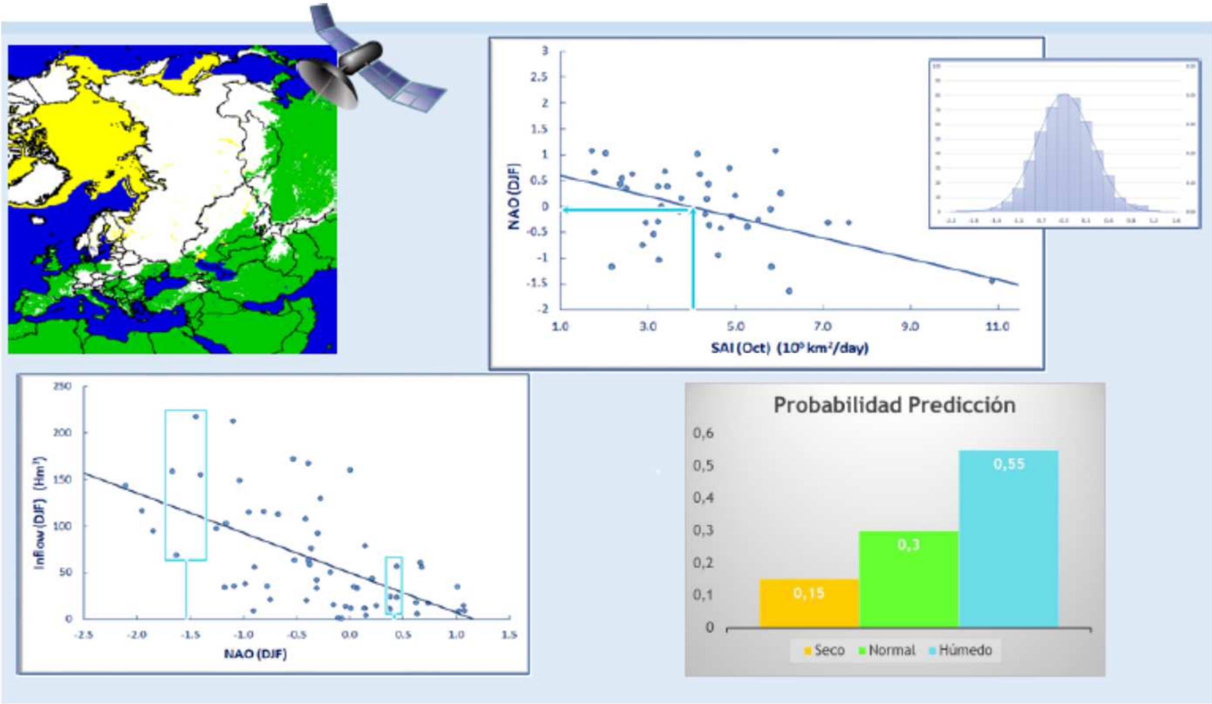


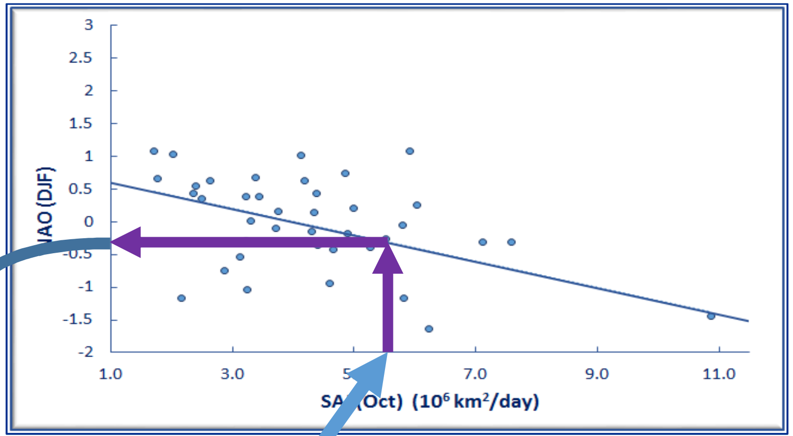
Embalses - Internet Explorer
http://172.24.129.149/embalses/index.html
Embalses
Archivo Edición Ver Favoritos Herramientas Ayuda
Communicating Climate Cha...
Sitios sugeridos
Conseguir más compl...
Página
Seguridad
Herramientas
5021 (BERMEJALES, LOS)
Año Ini: 1954
Año Fin: 2012
© OpenStreetMap contributors
-3.83963, 37.08495
Prob Entradas > umbral [NDEFM]
5021 (BERMEJALES, LOS)
Volumen Entrada (hm3)
probabilidad
NAO +
NAO –
Highcharts.com
Boxplot [NDEFM]
5021 (BERMEJALES, LOS)
Volumen Entrada (hm3)
media: 31.61
NAO +
NAO –
NAO neutra
Highcharts.com
Curvas de Gauss [NDEFM]
5021 (BERMEJALES, LOS)
densidad de probabilidad
Volumen Entrada (hm3)
NAO +
NAO –
Highcharts.com
Prob Reserva > 91.7 hm3 [al fin de NDEFM]
5021 (BERMEJALES, LOS)
Fiabilidad (%)
Volumen Inicial de Reserva (hm3)
NAO +
NAO –
all
Highcharts.com
Entradas a Embalse y NAO [NDEFM]
5021 (BERMEJALES, LOS)
Volumen Entrada (hm3)
Indice NAO
Año
5021
NAO
Highcharts.com
Entradas [NDEFM] ~ NAO [DEF]
5021 (BERMEJALES, LOS)
Volumen Entrada [NDEFM] (hm3)
NAO Negativa
NAO Positiva
Indice NAO Standarizado [DEF]
Highcharts.com
100%


Embalses - Internet Explorer
http://172.24.129.149/embalses/index.html
Embalses
Archivo Edición Ver Favoritos Herramientas Ayuda
Communicating Climate Cha...
Sitios sugeridos
Conseguir más compl...
Página
Seguridad
Herramientas
1131 (ZOLLO)
Año Ini: 1944
Año Fin: 1983
Comentario: INT 1983
© OpenStreetMap contributors
-2.96622, 43.20434
Prob Entradas > umbral [NDEFM]
1131 (ZOLLO)
Volumen Entrada (hm3)
probabilidad
NAO +
NAO –
Boxplot [NDEFM]
1131 (ZOLLO)
Volumen Entrada (hm3)
media: 0.57
NAO +
NAO –
NAO neutra
Curvas de Gauss [NDEFM]
1131 (ZOLLO)
densidad de probabilidad
Volumen Entrada (hm3)
NAO +
NAO –
Prob Reserva > 0.4 hm3 [al fin de NDEFM]
1131 (ZOLLO)
Fiabilidad (%)
Volumen Inicial de Reserva (hm3)
NAO +
NAO –
all
Entradas a Embalse y NAO [NDEFM]
1131 (ZOLLO)
Volumen Entrada (hm3)
Indice NAO
Año
1131
NAO
Entradas [NDEFM] ~ NAO [DEF]
1131 (ZOLLO)
Volumen Entrada [NDEFM] (hm3)
NAO Negativa
NAO Positiva
Indice NAO Standarizado [DEF]
Highcharts.com
100%

Seasonal forecast for dam inflow

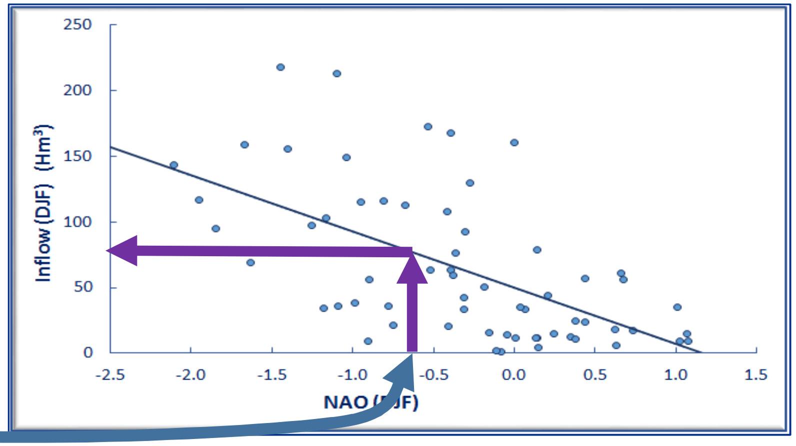
As the forecasted precipitation skill from most dynamical models over this geographical area is generally very low (Sanchez et. 2015), AEMET has developed the S-ClimWaRe empirical system for the probabilistic seasonal prediction of winter dam inflows (Voces et al. 2016). It is based on the fact that wintertime North Atlantic Oscillation (NAO) is statistically associated with Eurasian snow cover advance during the previous October (SAI) (Cohen and Jones 2011). The forecast system output is an ensemble of forecasted inflows, from which probabilities for the different terciles (dry,normal,wet) are calculated.

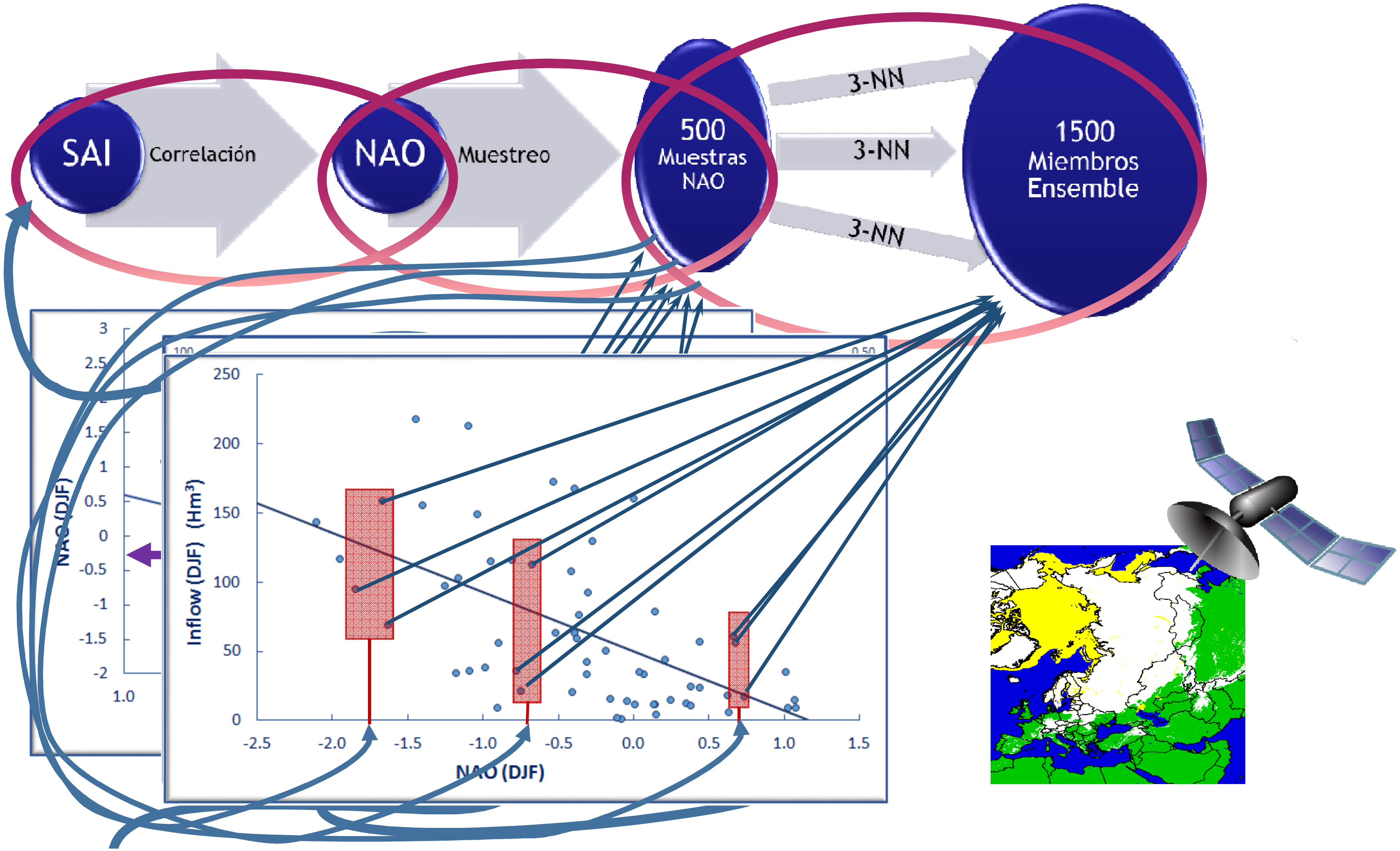


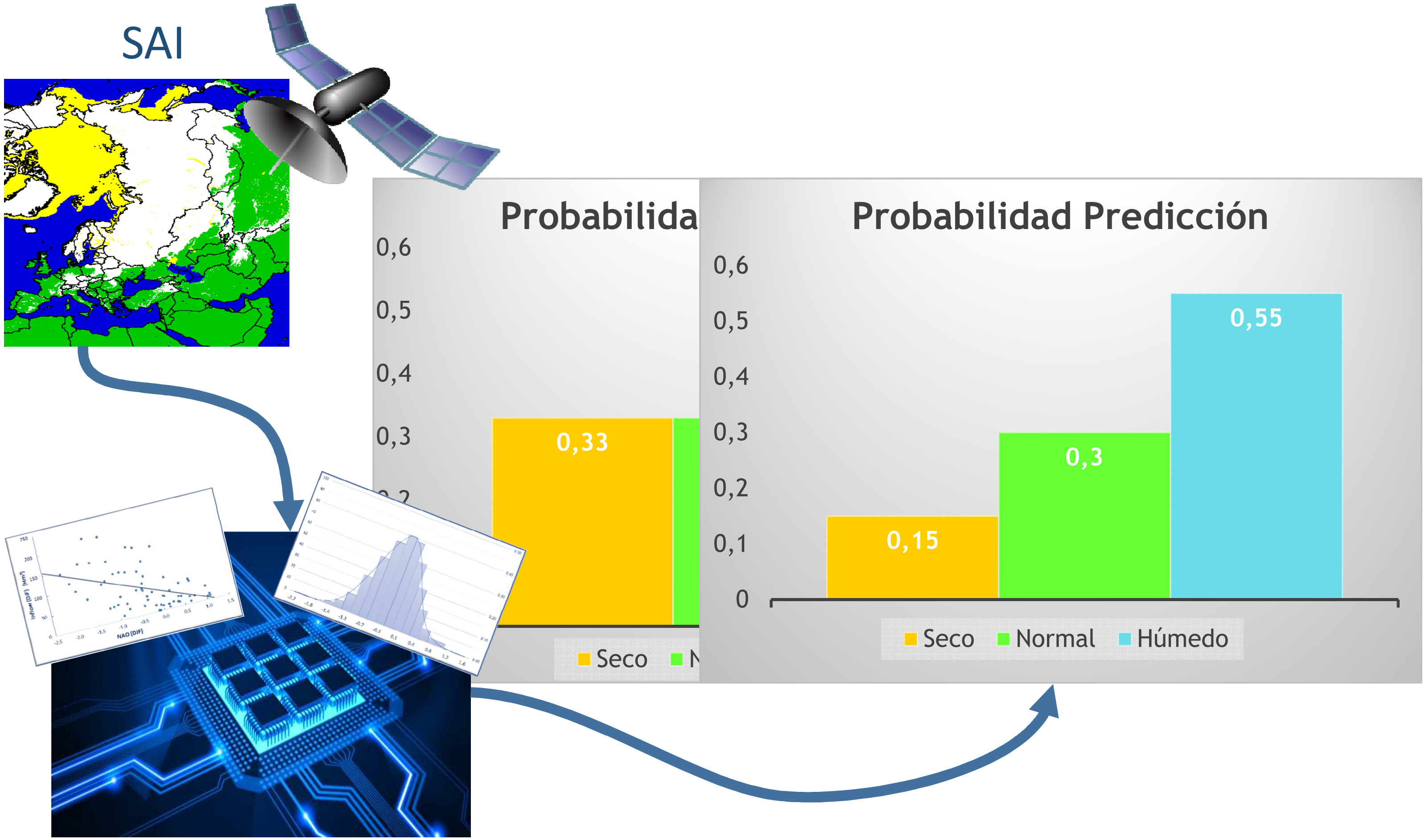


Correlation SAI – NAO

Correlation
NAO – Dam inflow




SAI
Correlación
NAO
Muestreo
500
Muestras
NAO
3-NN
3-NN
3-NN
1500
Miembros
Ensemble
Inflow (DJF) (Hm³)
NAO (DJF)
NAO (DJF)

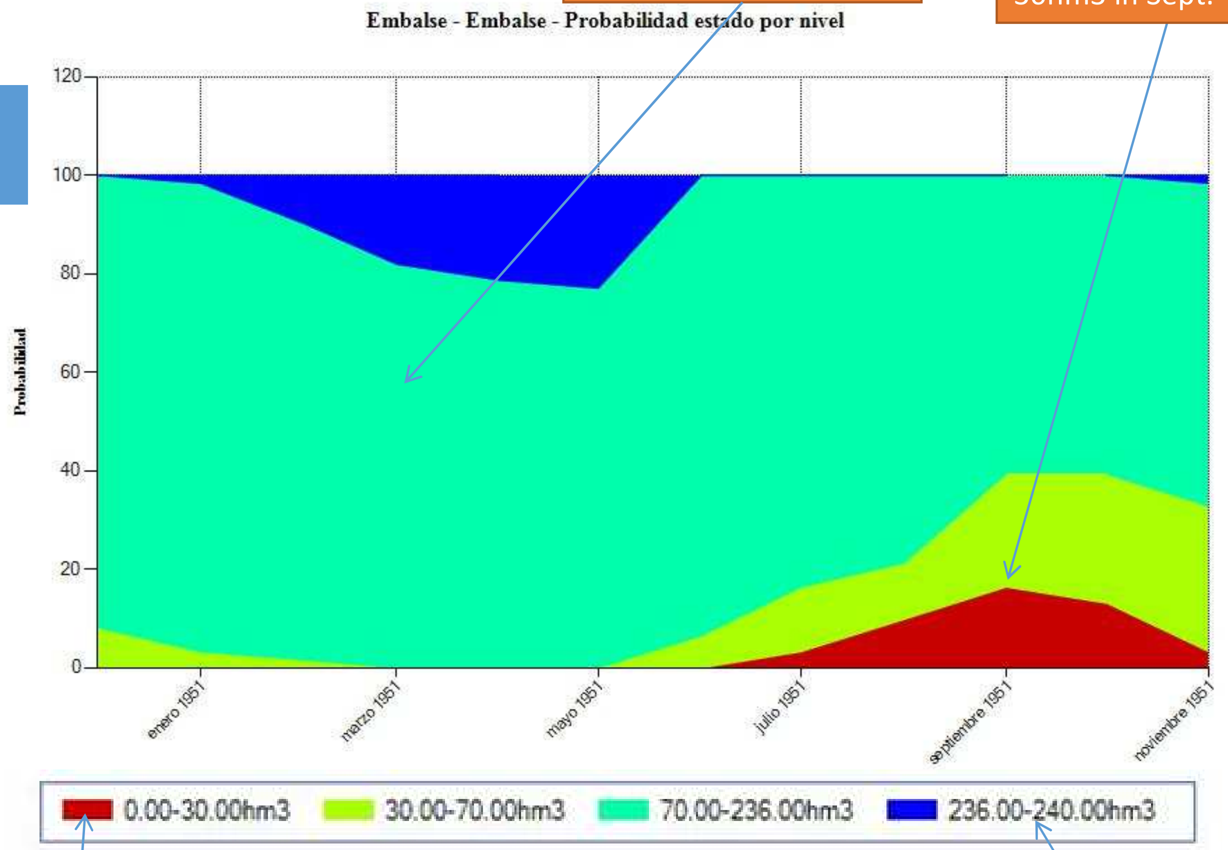

SAI
Probabilidad Predicción
0,6
0,5
0,4
0,3
0,2
0,1
0
0,15
0,3
0,55
Seco
Normal
Húmedo
Probabilida
0,33
Seco

Probability of different dam states

20% prob. full dam in March

15% prob. less than 30hm3 in Sept.

Interphase SIMRISK



Almost empty!

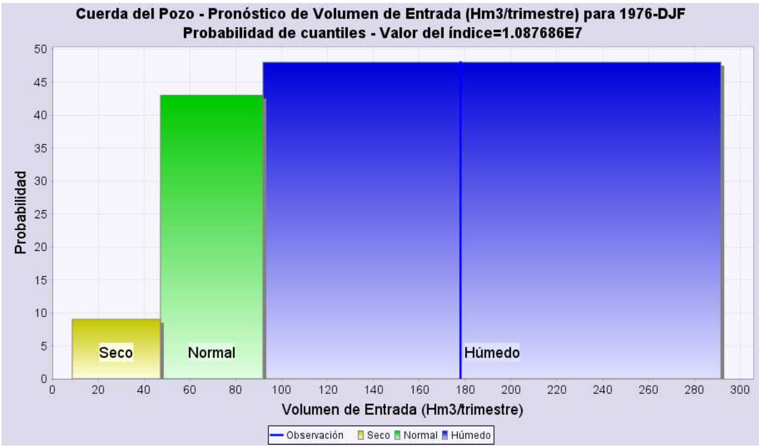
Almost full!

Year 1976

Water available on 1st December

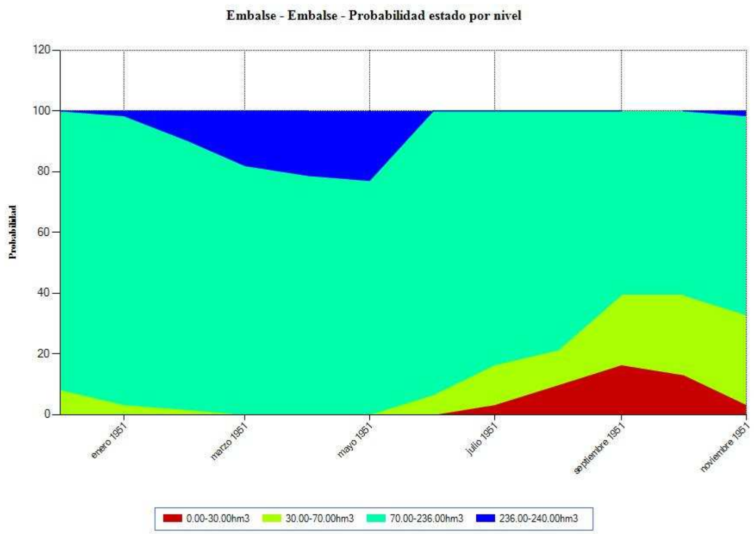
71 hm3

Forecasted inflow

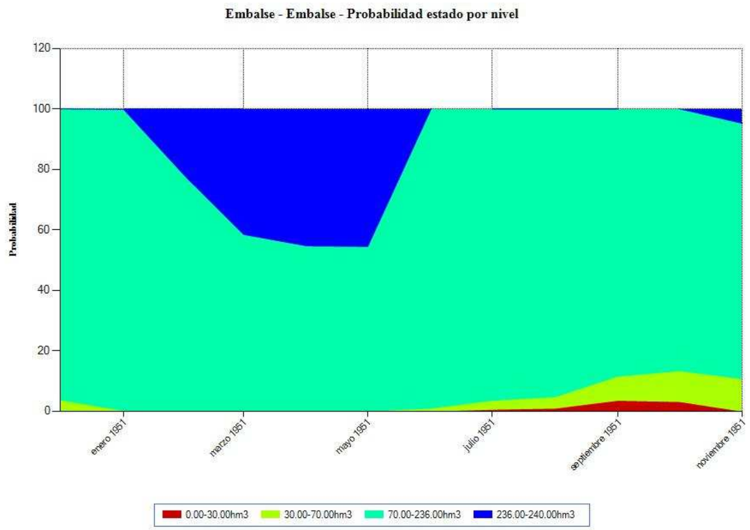


Evolution of available water

Climatology



Forecast (AEMET emp.+ SIMRISK)

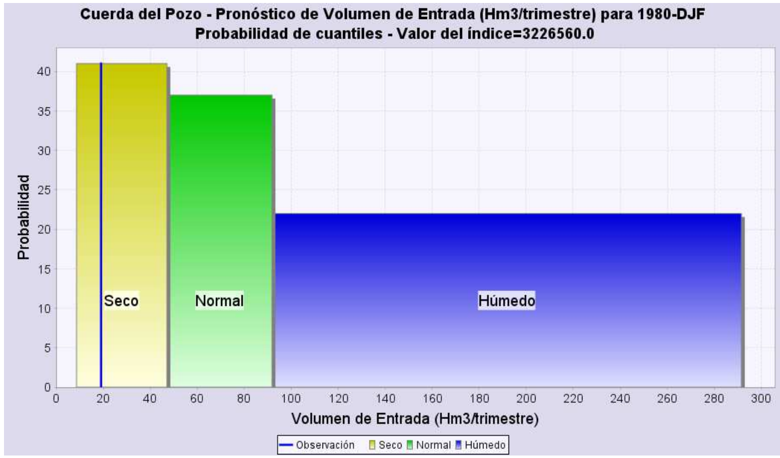


Year 1980

Water available on 1st December

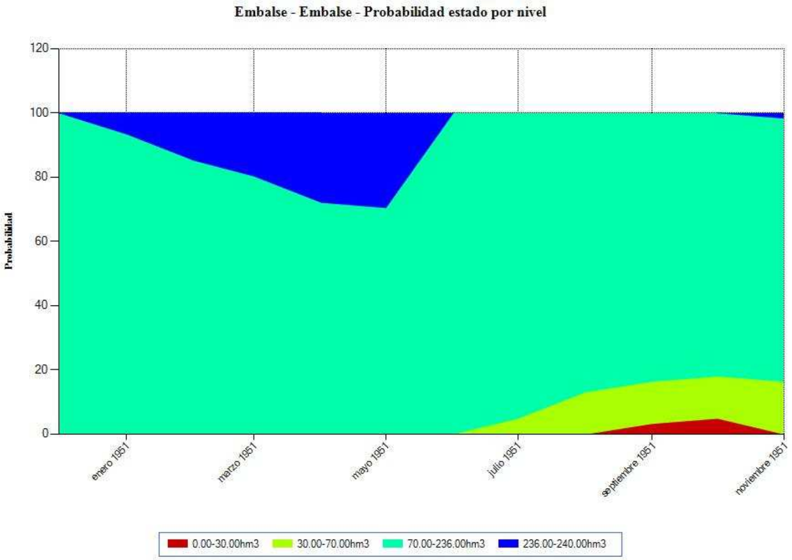
105 hm3

Forecasted inflow

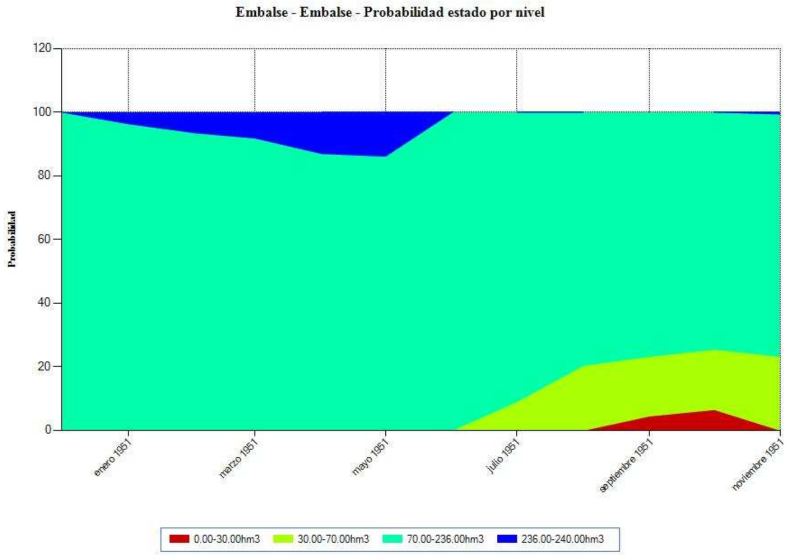


Evolution of available water

Climatology



Forecast (AEMET emp.+ SIMRISK)



Probability of different future dam states: summary

Using SF

Year	Inflow				Dam reserve				Demand deficit
		Seasonal Forecast (Dic-Jan-Feb)		Observed DJF	Observed	Forecasted 1st Octuber		Forecasted. 1st March	Forecasted 1st Octuber
	% BN (Dry)	% NN	% AN (Wet)	Category	1st December	Proba < 30Hm3	Proba < 70 hm3	>98% Vol max	Fallo>5%
1976	9	43	48	AN	71	**5%**	**23%**	**26%**	5%
1980	41	37	22	BN	105	**6%**	**23%**	**13%**	6%
2007	41	39	20	BN	132	**0%**	**10%**	**22%**	0%
2009	20	37	43	AN	147	**0%**	**0%**	**52%**	0%

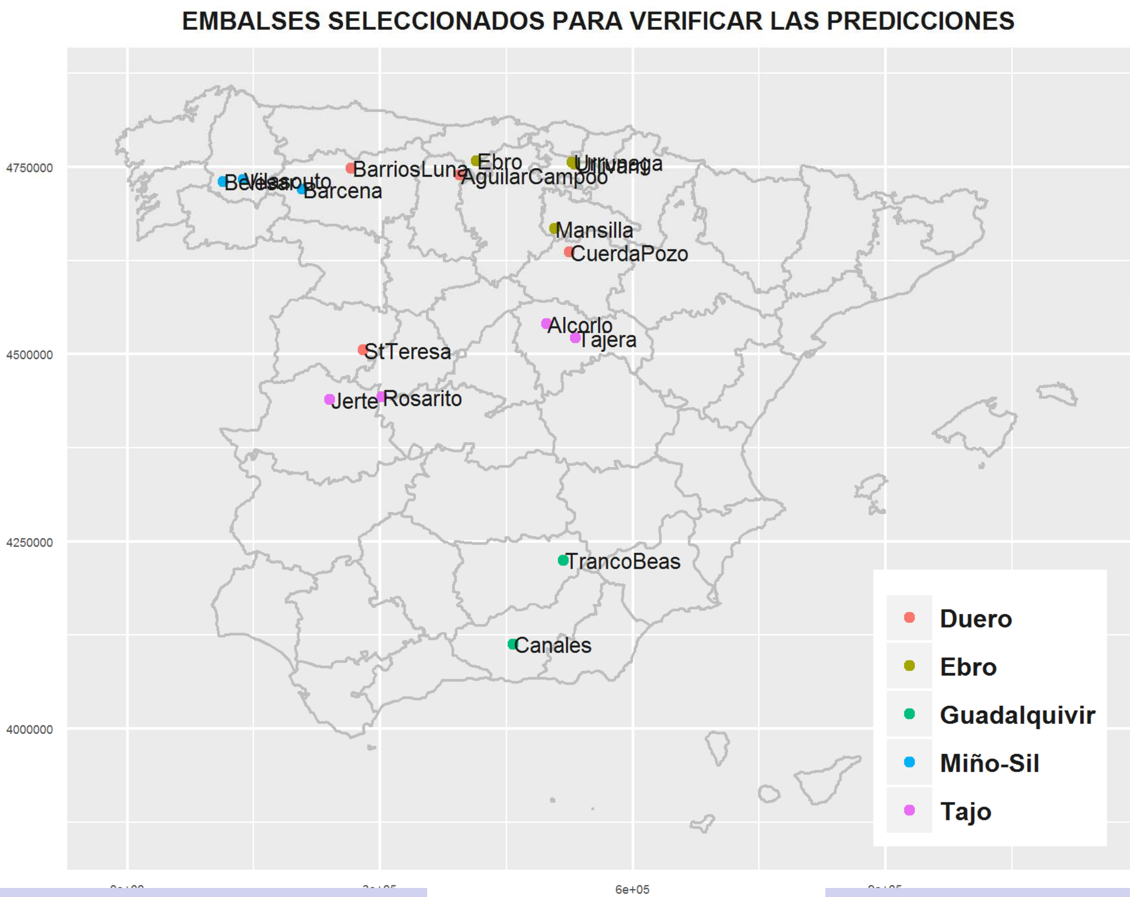
Using climatology

Significant differences

Year	Inflow				Dam reserve				Demand deficit
	Climatology			Observed DJF	Observed	Forecasted 1st Octuber		Forecasted. 1st March	Forecasted 1st Octuber
	% BN (Dry)	% NN	% AN (Wet)	Category	1st Dicember	Proba < 30Hm3	Proba < 70 hm3	>98% Vol max	Fallo>5%
1976	33	33	33	AN	71	**13%**	**39%**	**18%**	**13%**
1980	33	33	33	BN	105	**5%**	**18%**	**20%**	**5%**
2007	33	33	33	BN	132	**0%**	**8%**	**33%**	**0%**
2009	33	33	33	AN	147	**0%**	**0%**	**41%**	**0%**

- Percentiles (terciles) are not symetric in terms of C/L, value, etc
- The systems have memory and the initial conditions are very relevant (it is not the same start from an almost full water reservoir than from an almost empty one).
- Exotic predictands do not behave like temperature and precipitation (if we use money as a variable and we go into bankrupcy …)!!!

Selected water dams for verification



DUERO	
2001	Cuerda del Pozo
2016	Aguilar de Campoó
2026	Barrios de Luna
2038	Santa Teresa
EBRO	
9801	Embalse del Ebro
9809	Mansilla
9827	Ullivarri
9828	Urrunaga
GUADALQUIVIR	
5001	Tranco de Beas
5048	Canales
MIÑO-SIL	
1627	Belesar
1709	Barcena
1796	Vilasouto
TAJO	
3079	La Tajera
3127	Rosarito
3145	Jerte-Plasencia
3287	Alcorlo

VARIABLES:
- Precipitation (mm/months)
- Water inflow (Hm3/months)

VERIFICATION PERIOD:
1997-2013 (NDEFM)

Attributes of “good” probabilistic forecasts (Murphy 1993)

- Resolution

  Does the outcome change when the forecast changes? OUTCOME CONDITIONED BY FORECAST
  Example: does above-normal rainfall become more frequent when its probability increases?

- Discrimination

  Does the forecast differ when the outcome differs? FORECAST CONDITIONED BY OUTCOME

  Example: is the probability on above-normal rainfall higher when above-normal rainfall occurs?

- Reliability

  if observation falls in the category as FREQUENTLY as the forecast implies

- Sharpness

  Probabilities differing MARKEDLY from the climatology

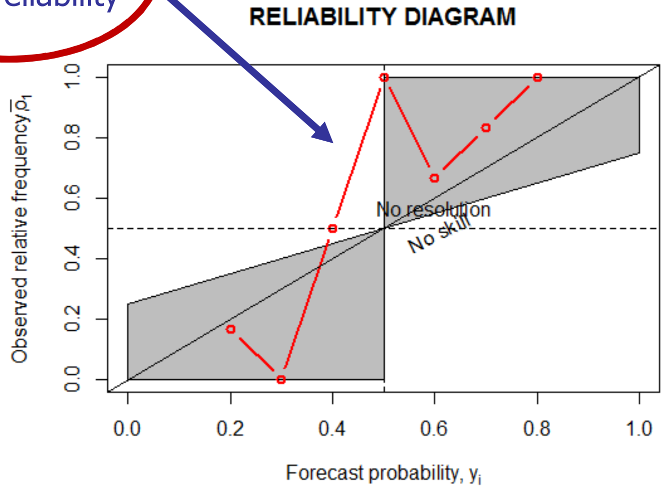
- Skill

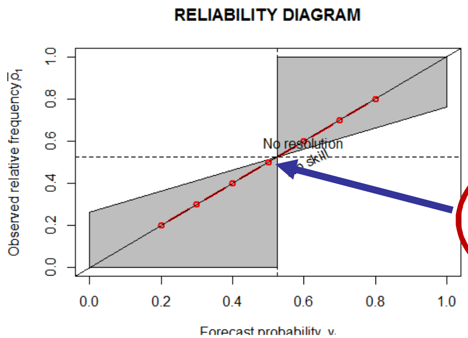
  It COMPARES two forecasts with some metric

Reliability: the event occurs as frequently as implied by the forecast

Prob. For.	Ni	Obs. Freq. f
0.0	-	-
0.1	-	-
0.2	6	1/6
0.3	6	0/6
0.4	4	2/4
0.5	3	3/3
0.6	3	2/3
0.7	6	5/6
0.8	2	2/2
0.9	-	-
1.0	-	-

The closer to diagonal the better reliability





Perfect Reliability

DEF	Oi	Pi
1986	0	0.3
1987	1	0.2
1988	0	0.3
1989	1	0.7
1990	1	0.5
1991	1	0.7
1992	0	0.3
1993	1	0.4
1994	1	0.5
1995	0	0.7
1996	0	0.2
1997	0	0.3
1998	0	0.2
1999	1	0.7
2000	1	0.4

DEF	Oi	Pi
2001	1	0.5
2002	0	0.6
2003	0	0.2
2004	0	0.4
2005	1	0.8
2006	1	0.7
2007	0	0.3
2008	0	0.2
2009	1	0.6
2010	0	0.2
2011	1	0.6
2012	1	0.7
2013	0	0.4
2014	0	0.3
2015	1	0.8

Reliability diagrams:

observed relative freq. vs forecasted relative freq.

Scores to verify the consensus forecasts

and

scores to improve the consensus process

(*a*) perfect reliability,

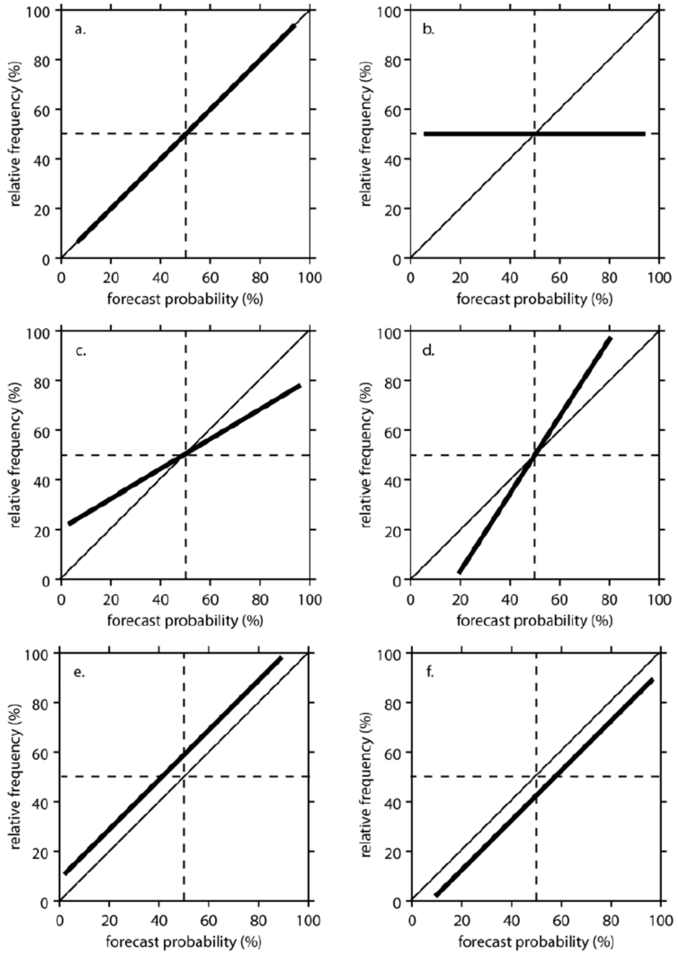
(*b*) no resolution

(*c*) over-confidence

(*d*) under-confidence

(*e*) under-forecasting

(*f*) overforecasting



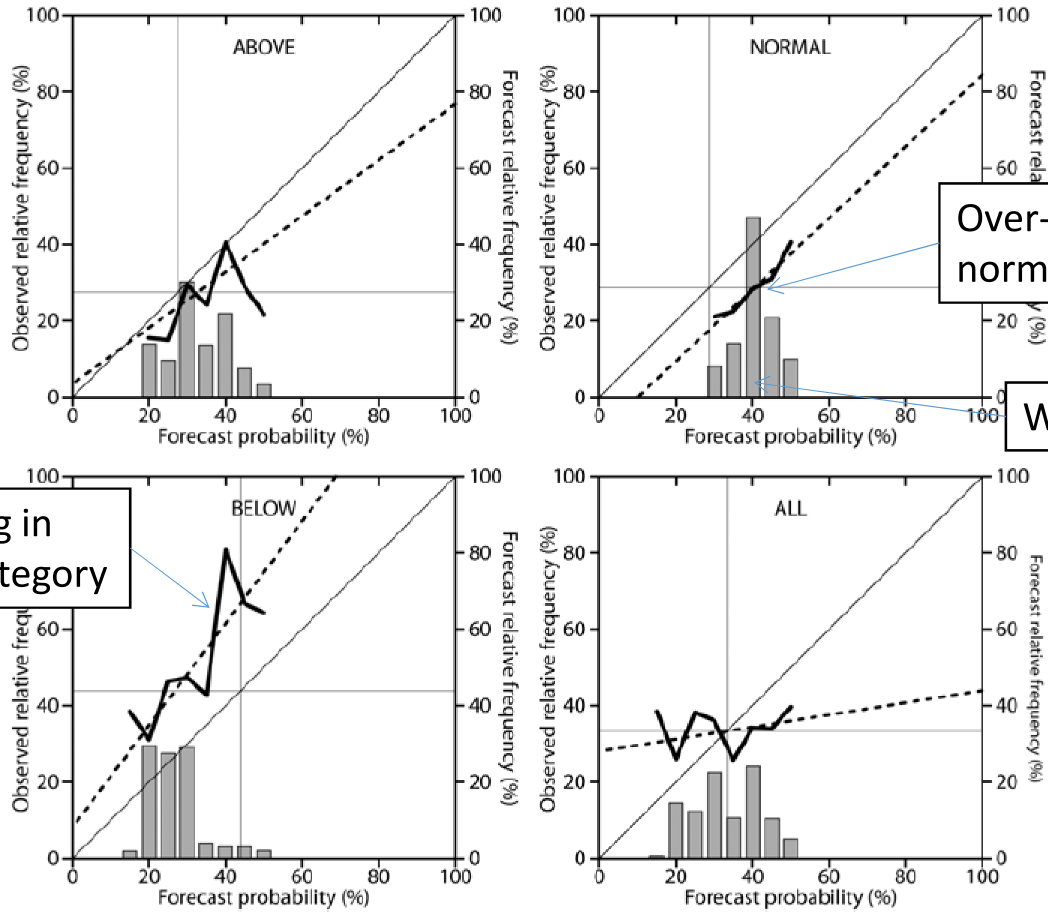
(Mason 2013)

Reliability diagrams for the first 10 years of PRESAO (seasonal rainfall forecasts Jul-Sept)

Scores to verify the consensus forecasts

and

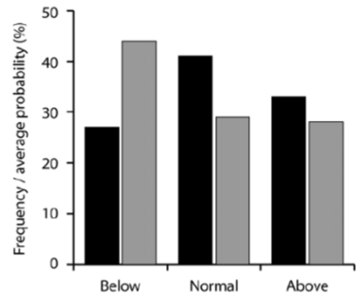
scores to improve the consensus process



Over-forecasting in normal category

Weak sharpness

Under-forecasting in below normal category

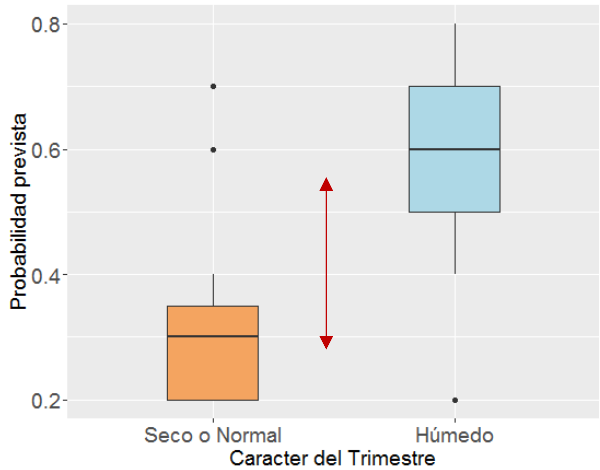


(Chidzambwa and Mason 2008)

Resolution: the outcome differs when the forecast differs

Dry or normal years

DEF	Oi	Pi
1986	0	0.3
1988	0	0.3
1992	0	0.3
1995	0	0.7
1996	0	0.2
1997	0	0.3
1998	0	0.2
2002	0	0.6
2003	0	0.2
2004	0	0.4
2007	0	0.3
2008	0	0.2
2010	0	0.2
2013	0	0.4
2014	0	0.3

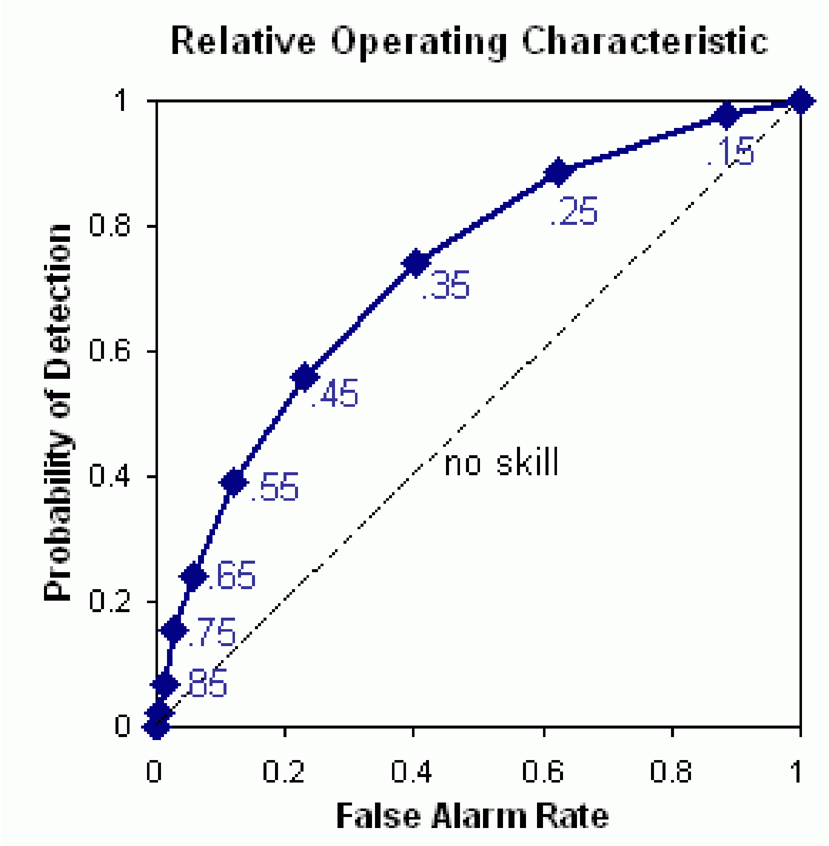


The higher separation between box.plots, the bigger resolution

Wet years

DEF	Oi	Pi
1987	1	0.2
1989	1	0.7
1990	1	0.5
1991	1	0.7
1993	1	0.4
1994	1	0.5
1999	1	0.7
2000	1	0.4
2001	1	0.5
2005	1	0.8
2006	1	0.7
2009	1	0.6
2011	1	0.6
2012	1	0.7
2015	1	0.8

ROC curve

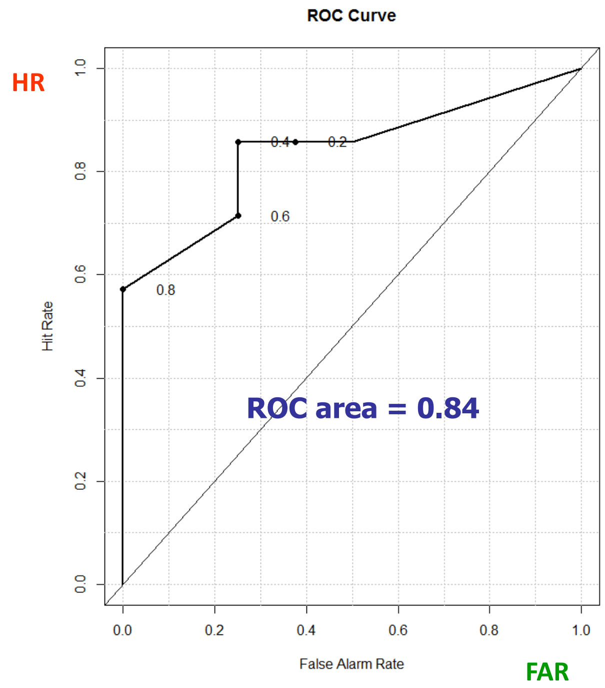


Relative Operating Characteristic
Probability of Detection
False Alarm Rate
0
0.2
0.4
0.6
0.8
1
.15
.25
.35
.45
.55
.65
.75
.85
no skill

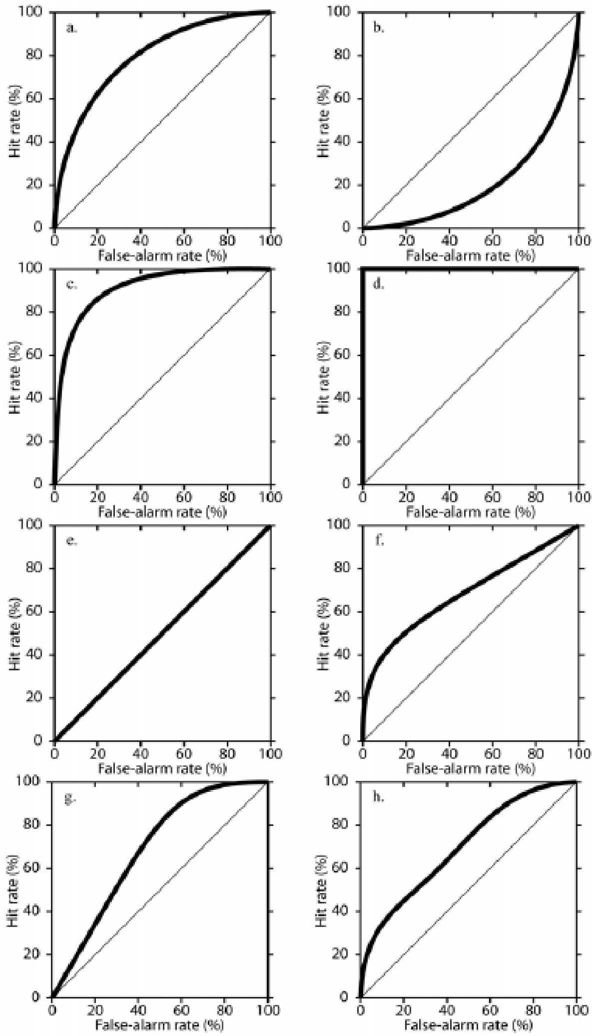
ROC curves

	Oi	Pi
1	0	0.8
2	0	0.8
3	0	0
4	1	0.9
5	1	0.9
6	1	0.6
7	0	0.4
8	1	0.8
9	1	0
10	0	0
11	0	0.2
12	0	0
13	0	0
14	1	0.9
15	1	0.9

	HR	FAR
p>-1	7/7=1	8/8=1
p>0	6/7=0.86	4/8=0.5
p>0.2	6/7=0.86	3/8=0.37
p>0.4	6/7=0.86	2/8=0.25
p>0.6	5/7=0.71	2/8=0.25
p>0.8	4/7=0.57	0
p>1	0	0



ROC curves: idealized examples



(a) good discrimination and good skill

(b) good discrimination but bad skill

(*c*) excellent discrimination

(*d*) good discrimination

(*e*) no discrimination

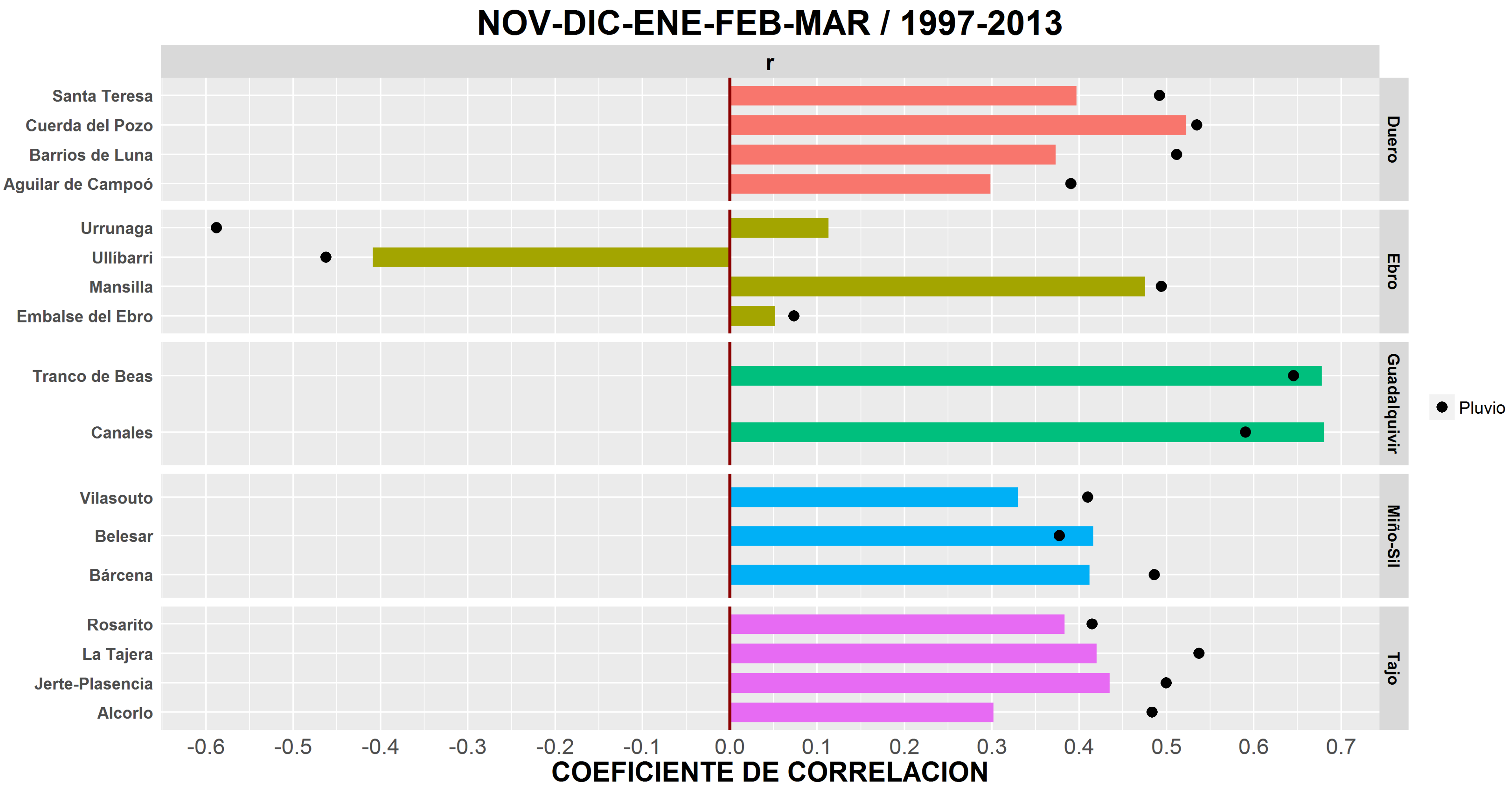
(*f*) good discrimination for high probability forecasts

(*g*) good discrimination for low probability forecasts

(*h*) good discrimination for confident (high and low probability) forecasts.

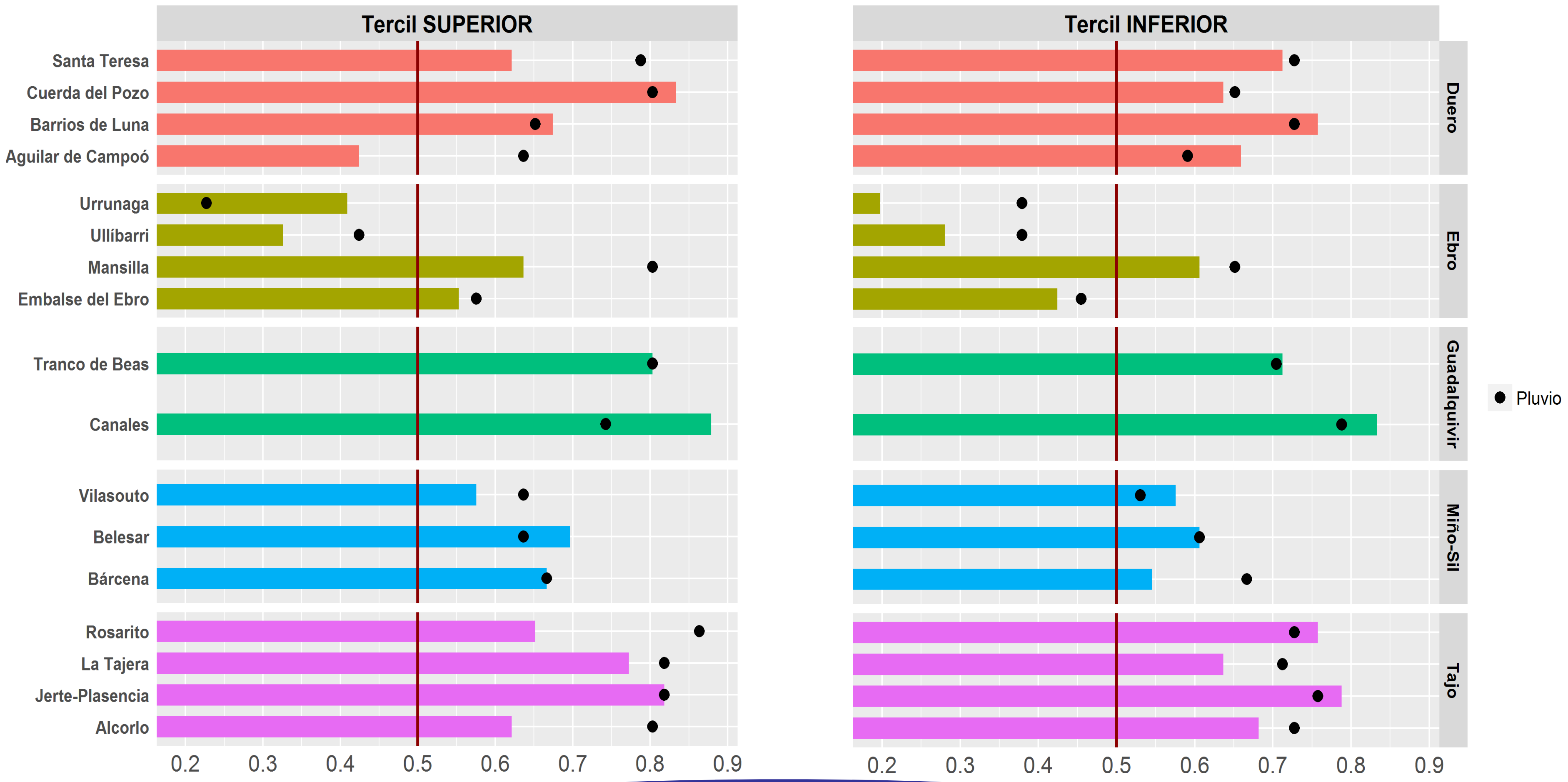
(Mason 2013)

Correlation coefficient for the ensemble mean



ROC areas

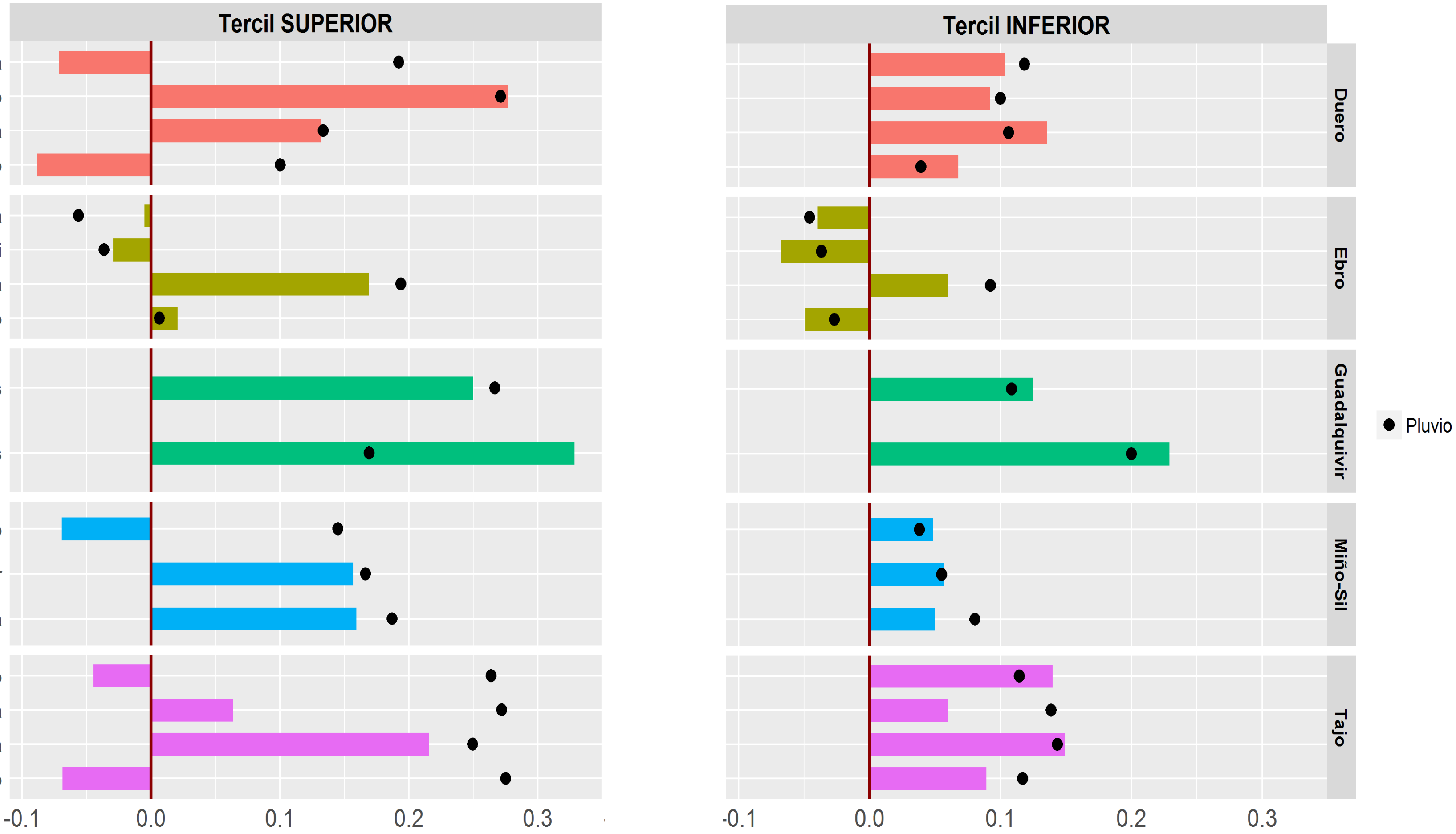
NOV-DIC-ENE-FEB-MAR / 1997-2013



ROC area > 0.5 Better than climatology

Brier Skill Score (BSS) (reliability)

NOV-DIC-ENE-FEB-MAR / 1997-2013



BSS > 0 Better than climatology

Verification from the user’s perspective

Matrix C/L

	Adverse **OBS**	Adverse **NOT OBS**
Precautionary action **FORECASTED**	C €	C €
Precautionary action **NOT FORECASTED**	L €	0 €

Probability of adverse event: p

Cost precautionary action: C

Cost NOT precautionary action: pL.

Prec. action passes cost-benefit analysis if $C/L < p$

C/L should be provided by the user

C/L framework requires detailed information on:

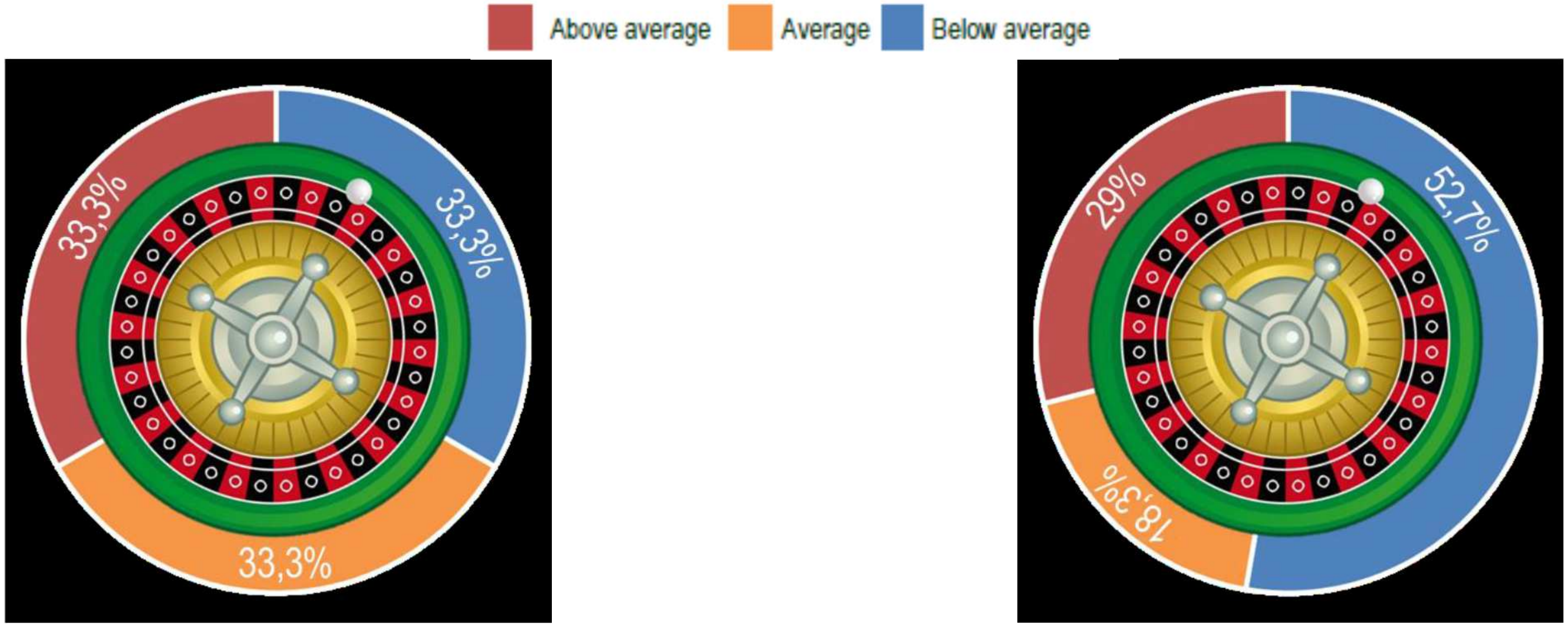
- which weather/climate events will impact on the activity
- what effect those weather/climate events have on the activity
- cost of weather/climate impacts on the activity
- actions that can be taken to mitigate the impacts
- cost of undertaking these actions
- residual cost of the weather/climate impacts after the mitigating actions.

Analysis of the benefits of improved seasonal climate forecasting. Managing Climate Variability Program (2014).

Rate of return

- The rate of return tells us **how much money would be made if one invested on the forecast with odds corresponding to the probabilities given in the forecast**. The amount of money made refers to the average proportion of the initial money gained per individual forecast.
- The score reflects discrimination, reliability and resolution.
- A more concrete understanding of the meaning of the rate of return can be gained by considering the proportion of money that a better would gain when starting with some initial amount of money, and betting on each of a set of forecasts with odds that correspond to the forecast probabilities assigned to each of the possible categorical outcomes, and reinvesting all of the resulting balance in this same way for each successive forecast.

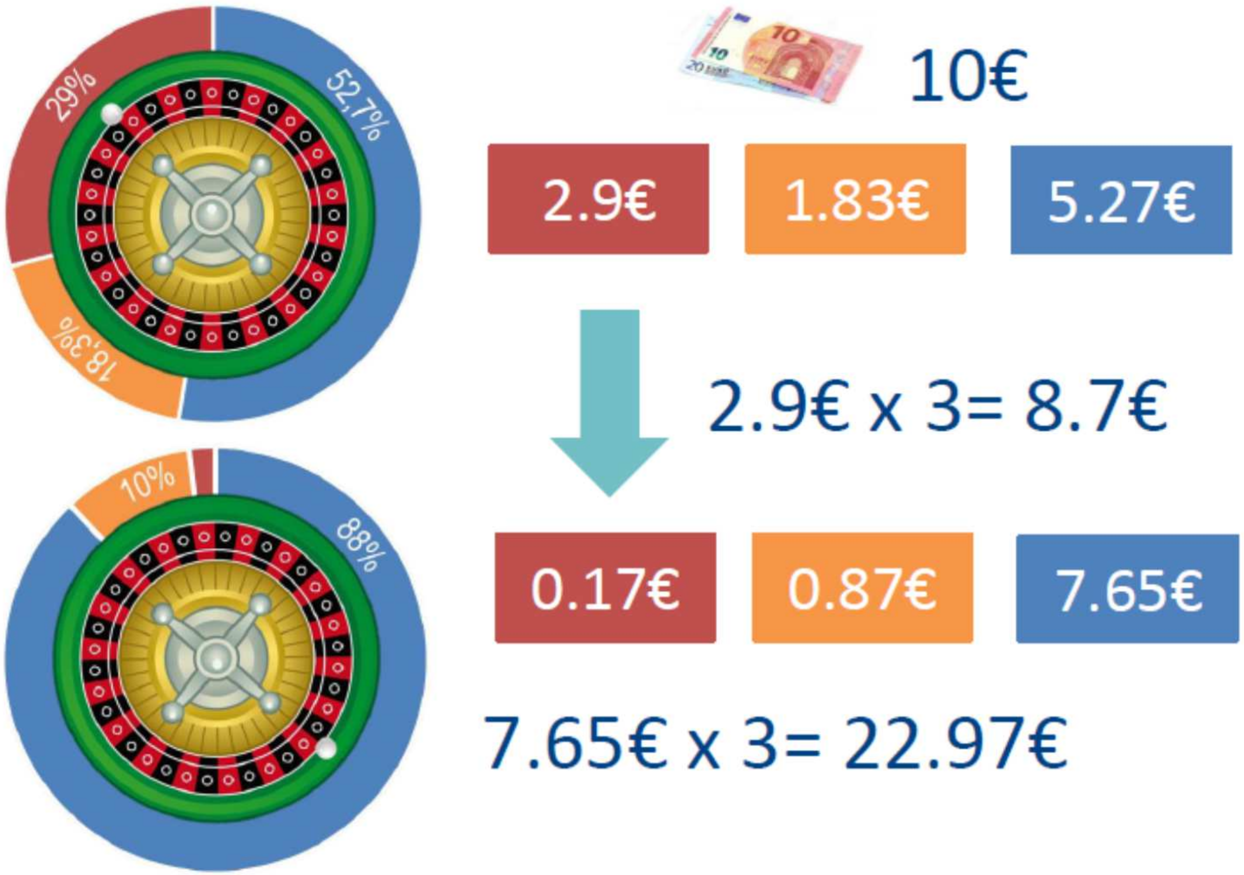
The Weather Roulette: Methodology



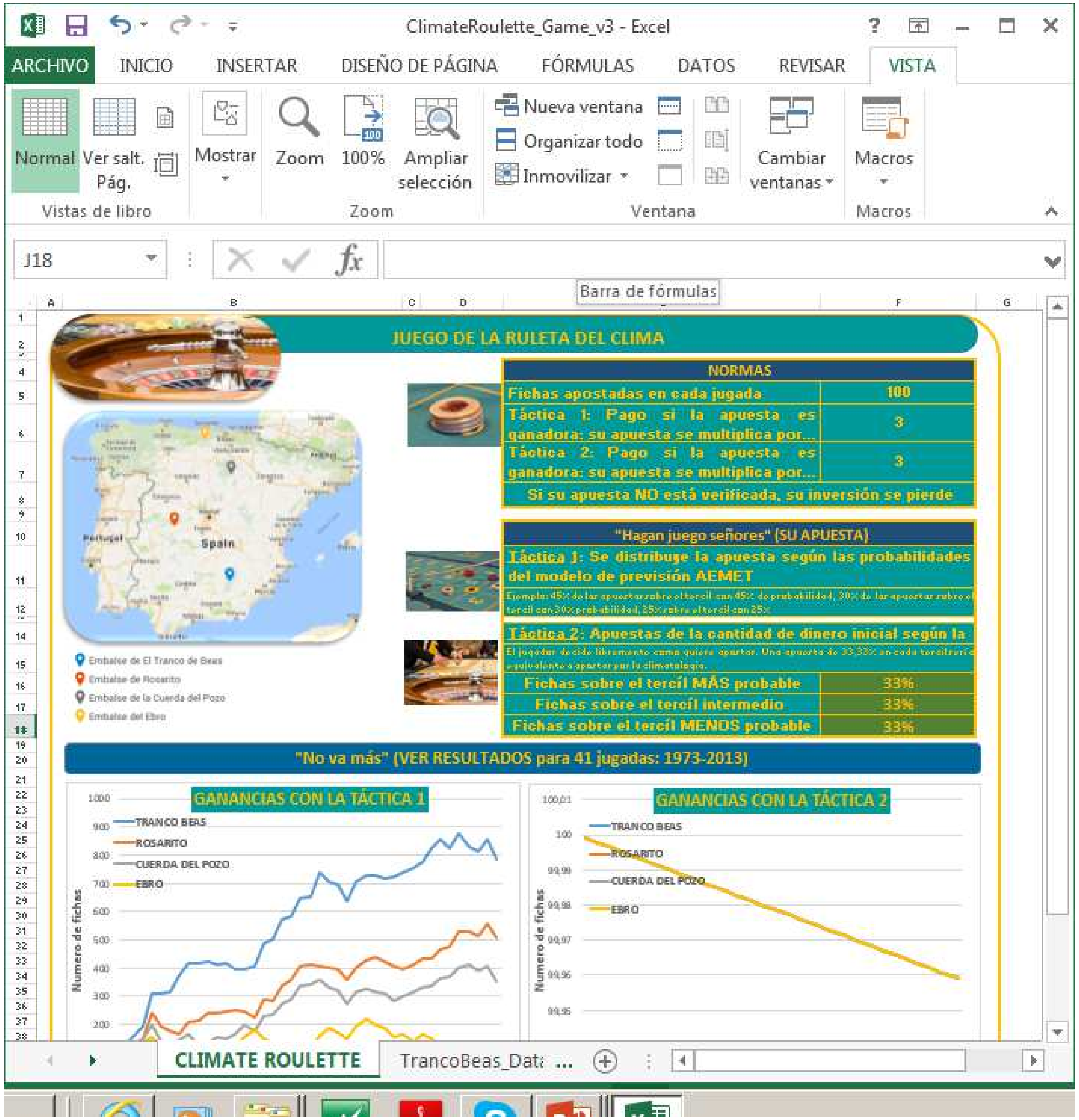
Climatology   Seasonal predictions

Climatology assumes a fixed probability to each category while climate predictions adjust the category probabilities of the ‘climatology’ forecast. There is an initial investment of 10€ and everything earned is reinvested in the next run.

The Weather Roulette: Methodology



In the game, the user bets proportionally to the probabilities estimated in the seasonal forecast and the amount invested in the observed category is multiplied by 3 (i.e. the inverse of the climatology probability)



Developed by L. Pouget for S-ClimWaRe Users Workshop (10th Nov 2016)

Best Practices in Seasonal Forecasting

(First WCRP Workshop on Seasonal Prediction)

- Forecast error must be addressed by appropriately quantifying dynamical model **uncertainty**;
- Model output should be **recalibrated** based on historical model performance;
- **Probabilistic** forecast information should be issued;
- A description of the forecast process should be made available;
- In retrospective forecast mode, no information about the future should be used;
- Forecast quality information should be provided, including several **metrics of quality**;
- Regional climate service providers need to work with both the forecasting and application communities to develop **tailored** downscaled products;
- Users must be encouraged to use **all the ensemble** members to quantify forecast uncertainty;
- Web-based tools need to be developed to allow users to tailor forecast information;
- Regional mechanisms like Regional Climate Outlook Forums (**RCOFs**) should be used to develop regional climate outlooks based on the consensus and objective scientific assessment of multiple-prediction outcomes;
- Liaison with users should be promoted to understand their **climate information needs in decision making** and also to raise their awareness of the uncertainty aspects of seasonal forecasting;
- Regional/national ownership of seasonal forecasts should be promoted through **effective and sustained capacity building** and infrastructural support.

Conclusions

- Work closely with users to understand their specific needs, variables, critical situations and decision making process.
- Keep simplicity when possible! Do not kill flies using cannons!
- Develop tools jointly with users (algorithms, webpages, toolboxes, videos, …)
- Develop mutual trust and confidence.
- The long road aiming to incorporate probabilistic seasonal information into climate sensitive sectors has to be covered hand by hand with users