Drought and water scarcity indicators in Spain

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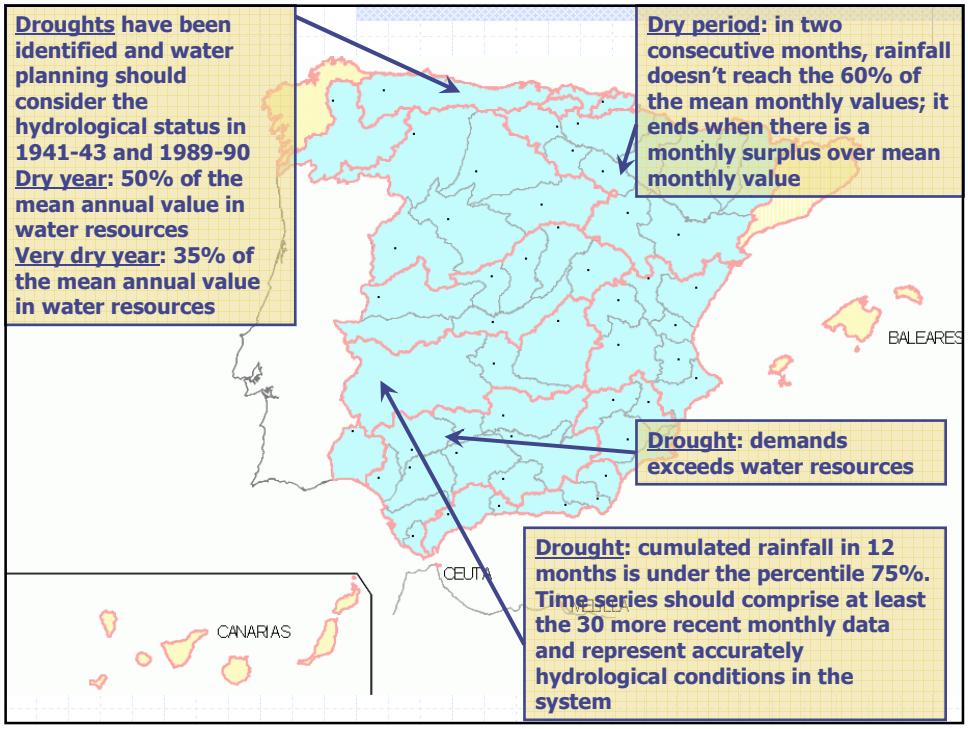
Presentation index

- Spanish National Water Plan and the Global Drought Monitoring System
  - White Paper Book of Waters in Spain and recent experiences in planning process
  - Spanish National Water Plan Act: 10/2001, 5/July. Article 27
  - Emergency Plans
- A definition of a drought monitoring system
  - Requirements and objectives
  - Main variables used
  - Indices selected

Water Planning in Spain

- Process:
  - 1985: New Water Act
  - 1985-1995. River Basin Authorities Planning Process and first attempt for a National Water Plan
  - 1995-2000. White Paper Book of Waters in Spain
  - 10/2001, 5/July, National Water Plan Act and emergency plans
- Statements in White Paper Book of Waters in Spain
  - Need: harmonize differences in drought management, drought event definition, models and variables
    - Deviations from monthly data, rainfall percentiles, deficit based on supply and demands ...
    - No consideration of groundwater
  - Lack in historical compilation of droughts
  - Difficulties found in impact assessment



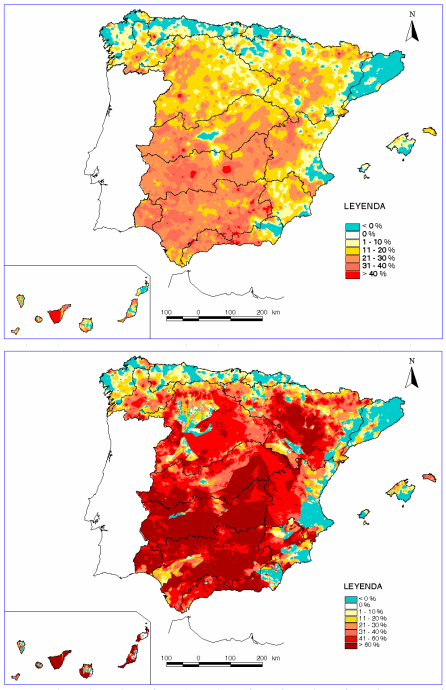
Recent drought impacts

- ...
  - Economic impacts on agriculture, fisheries, transportation, tourism and recreational activities, wood management and energy production, environmental and social impacts
- Recent experiences: 1990-1994 in planning process:
  - Researchers refer to an impact of 4.5 billion US$ in lost crops
  - Irrigation was prohibited in Guadalquivir river basin
  - Water supply restrictions
  - Hydroelectric energy: compensation and out of labor

Drought during 1990-1994

Plan	1990-94
Norte I	24
Norte II	10
Norte III	9
Duero	36
Tajo	49
Guadiana I	74
Guadiana II	74
Guadalquivir	72
Sur	59
Segura	32
Júcar	9
Ebro	22
C.I. Cataluña	-15
Galicia Costa	4
Baleares	17
Canarias	25
Total	28

Percentage of diminution respect of the mean annual value from 1940/41 to 1995/96



National Water Plan Act
Drought monitor+emergency actions

- Article:
  - 10/2001, 5/July, National Water Plan Act (BOE 6 of July 2001). Chapter II "Water planning complementary rules", 27 Article about "drought management"
- Three action levels
  - A system for hydrologic and drought monitoring
  - River basin authorities are requested to develop special emergency plans to react against an alert situation and possible drought
  - Other civil administrations for water supply are also requested to elaborate on the same task

...then

- Emergency plans. National compilation of "operational drought" definition
  - Formal drought or scarcity declarations: Ministry of Environment
- Their own spatial and temporal coordinates considering water management and the balance between resources and demands
- Mitigation strategies:
  - On resources: management according to availabilities, increments on water availability by means of strategic storages (groundwater…), conjunctive use of water, water transfers, desalinization,...
  - On demands: restrictions of use, …

Definition of SIEH... (hydrological monitoring system, HMS)

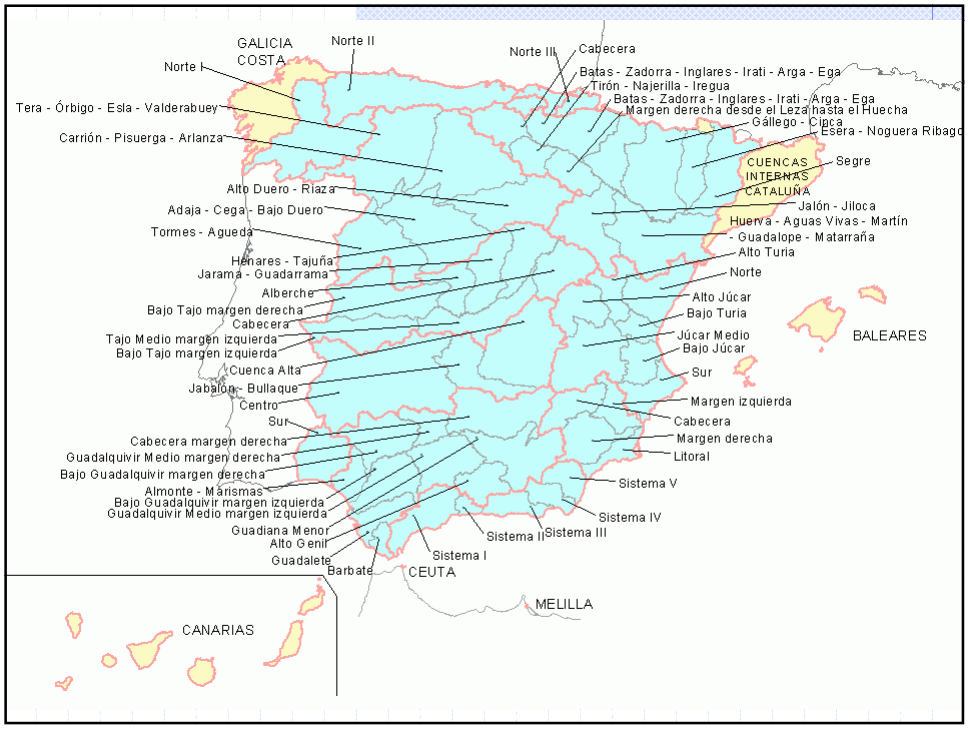
- On development: deal with drought events as natural risks
  - Monitor the hydrological status by means of compiling real-time hydrometeorological data
  - Identify and characterize droughts (natural system): Onset, end, severity, duration and extent
  - Monitor hydrological impacts (quantity and quality)
  - Contribution to seasonal reports of hydrological status
  - Spanish territory
  - Studying propagation across soils and aquifer under natural regime hypothesis
- Uses:
  - Clarify information about drought occurrence as a natural risk
  - Give information to reduce vulnerability and droughts impacts by means of mitigation management

Needs for a monitoring system

- Open communication with organizations responsible for measuring and compiling data
  - Commercial or institutional relationships
- Transmission / database management of real time data
  - Measure and manage data properly, i.e., processes depending on the hydrological variables
    - Ex: flow from levels, rainfall estimation …
  - Remote upgrading
    - Different organizations involved
    - Synoptic network for rainfall data
    - SAIH network for real time reservoir and flow data. Afterwards some hydrometric revisions are included
- Publish and disseminate processed information and results: web site and seasonal reports

Spanish HMS

- Regions for drought monitoring: suggested by planning offices pertaining to River Basin Authorities
  - Try to be adjusted to hydraulic infrastructure and basins where their water resources are used
- Data selection
  - Rainfall (100 approx. from the National Meteorological Office Synoptic network)
  - River flows (65 approx.)
  - Reservoir storage (57 approx.)
  - Groundwater evolution (75 approx.)
  - Flooded area in wetlands (PN Tablas de Daimiel)
  - Snow pack estimation
  - Territorial information (NDVI remote sensing, not available)
- Monthly time step for most of the variables.
  - Availability of 10-day rainfall data



Characterization of regions in terms of vulnerability

NAME: ADAJA – CEGA – BAJO DUERO (24)

River basin in Bajo Duero, Adaja, Cega and afluent. Total area of more than 15.400 km^2, mainly located in Zamora, Segovia, Salamanca, Ávila and Valladolid. Management systems:

Pisuerga-Carrión-Arlanza-Duero Inferior (Part); Alto Duero-Riaza-Adaja-Cega (Part)

HYDRAULIC INFRAESTRUCTURE:

Dams: More than 15 dams. Most important are Castro de las Cogotas, Riolobos, Pontón Alto, Serones, San José, Revenga-Riofrío and Los Ángeles.

Channels: Mainly for irrigation: canal Castronuño, Geria-Villamarciel, Morales, Pollos, S. Frontis, San José, Tordesillas, Toro-Zamora, Villaralbo.

WATER DEMANDS:

Urban: Total demand is 39 hm^3/year for urban supplies of Ávila, Segovia, Medina del Campo, Zamora, ... (37 hm^3/year) and sugar industry in Toro (2 hm^3/year).

Irrigation: Total demand is 990 hm^3/year to Adaja-Cega (467 hm^3/año) and Bajo Duero (523 hm^3/año)

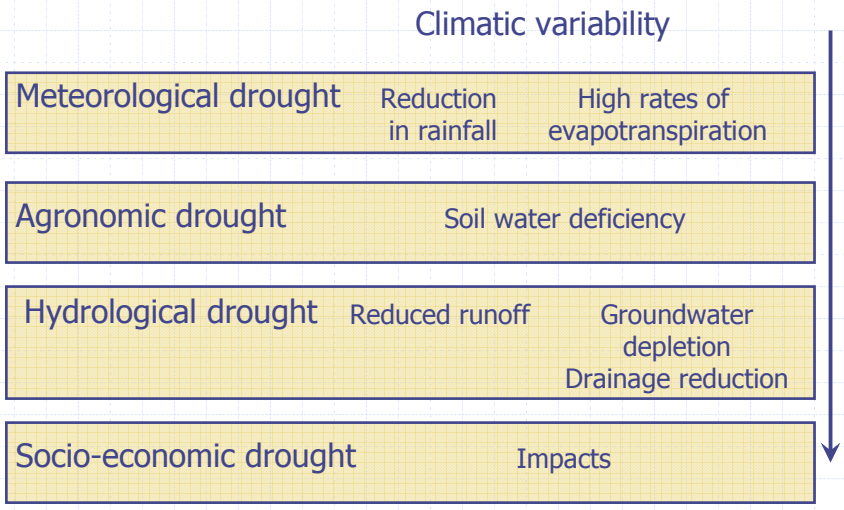
Characterizing the hydrological state

- Precipitation:
  - Monthly, seasonal, annual and cumulated from the onset of the hyd year
  - Percentiles/different time scales:
    - Occurrence probability: Gringorten criteria
    - Monthly, seasonal, annual and cumulated from the beginning of the hyd year
- Spatial view of these frequencies: Percentiles are interpolated and averaged in regions and averaged frequency values per region
- Flow data
- Access to temporal evolution graphs
- Reservoir:
  - Total water stored per region or hydraulic system
  - Evolution in stored water from the onset of the hyd year
- Piezometric levels: temporal trends and volume balance

Monitoring the hydrological evolution and droughts

- Other indices implemented:
  - SPI, standardized precipitation index
  - Threshold level approach to identify and characterized meteorological droughts
- Other indices to be implemented:
  - Low flows. Annual minima frequency studies
  - Simulations of natural regime: aquifer and soil state
  - Water stress through satellite data: NDVI

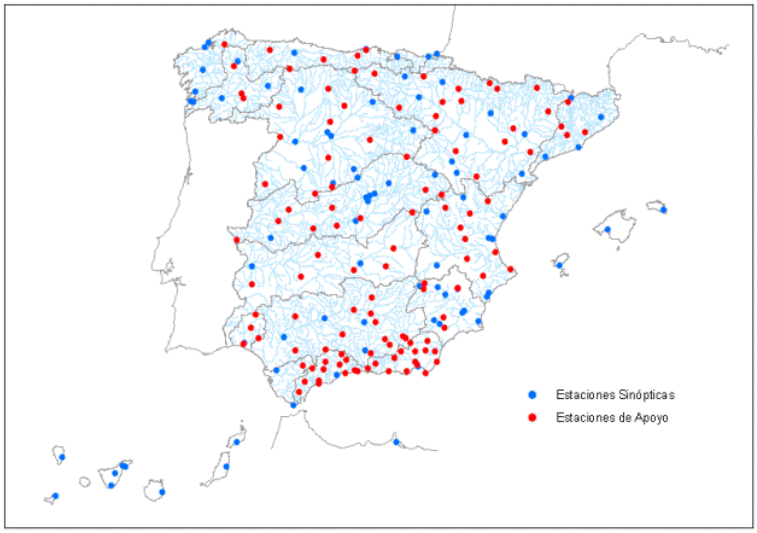
Drought definitions (Hisdal et al and NDMC)



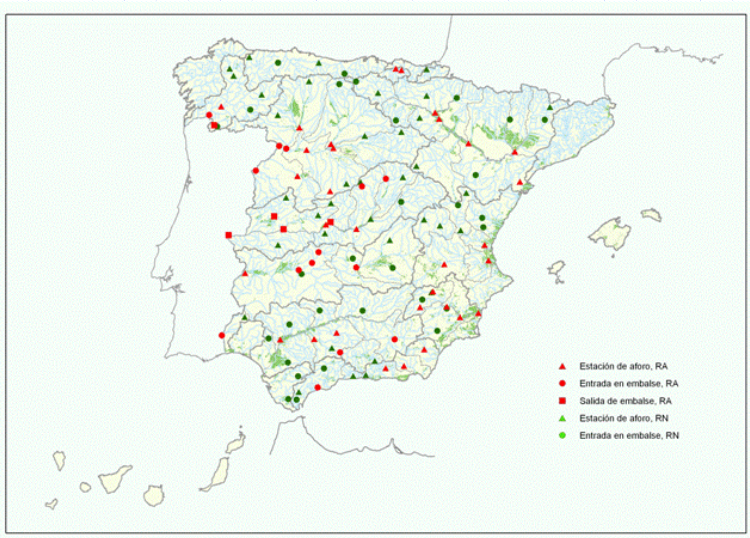
Rainfall and drought

- Principal variable in drought occurrence
- Other phases propagate diminutions through the hydrological cycle
  - Drought effects depend on their characteristics to soften the intensity
- Droughts are identified:
  - Percentile estimation for different time lags
  - Threshold level approach
  - SPI
- Need: historical catalog to check model results

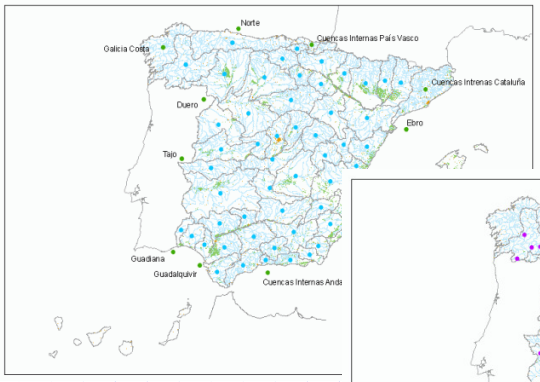
Rainfall data



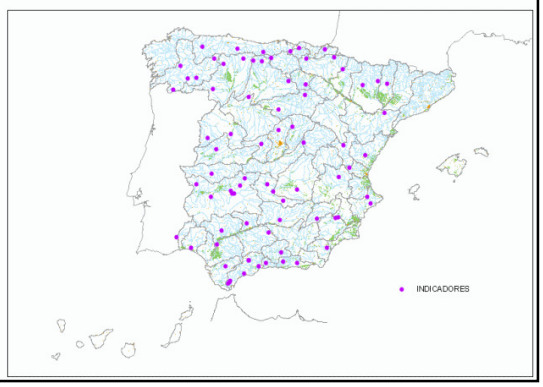
Flow data: natural and altered flow regimes



Reservoir data

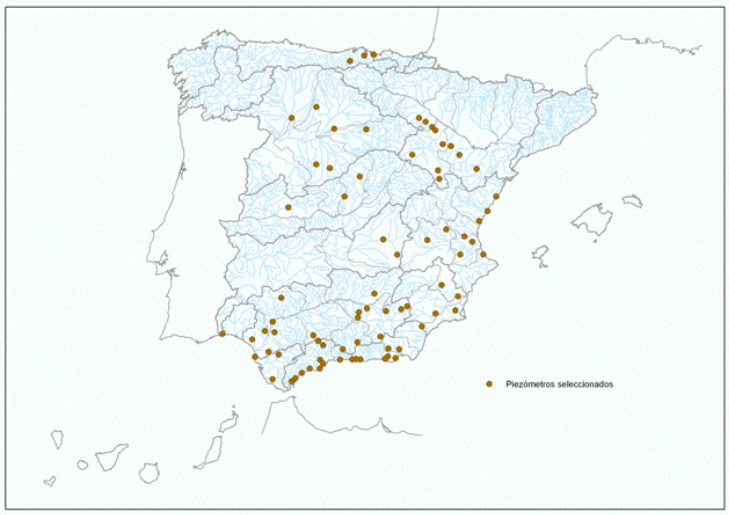


Total water stored per region

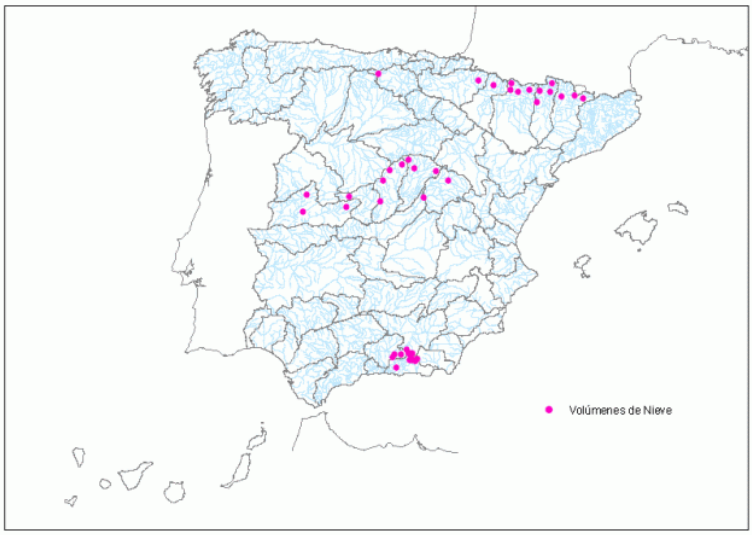


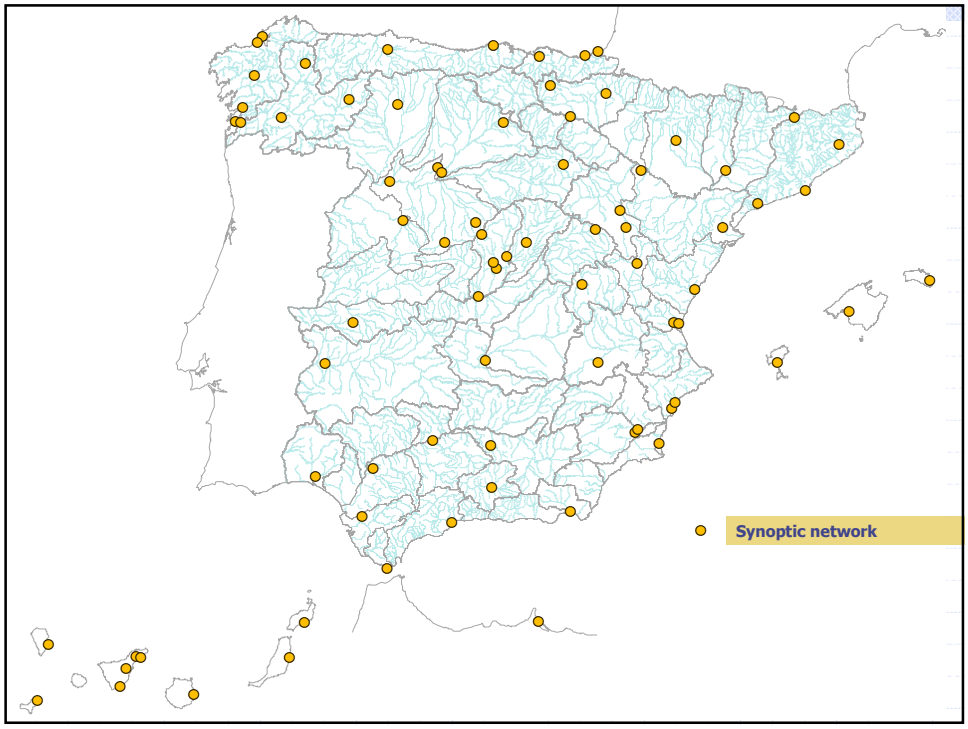
Considering certain demands (ATS, Madrid, ...)

Piezometric data

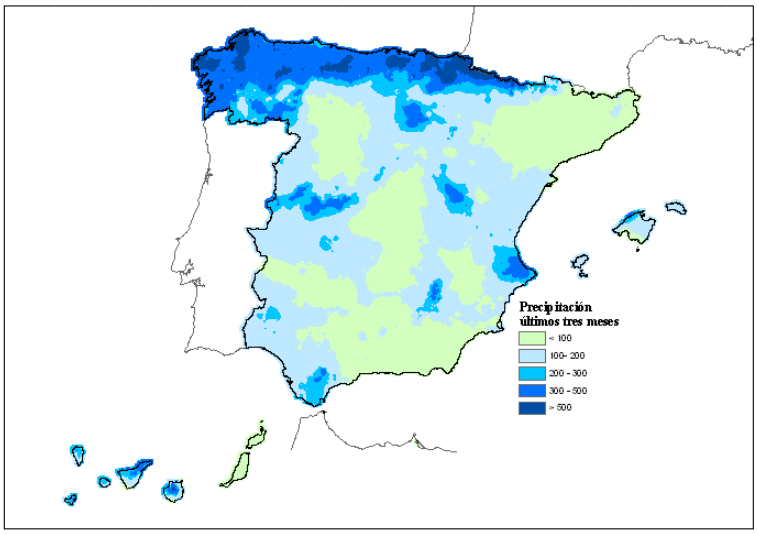


Snow data

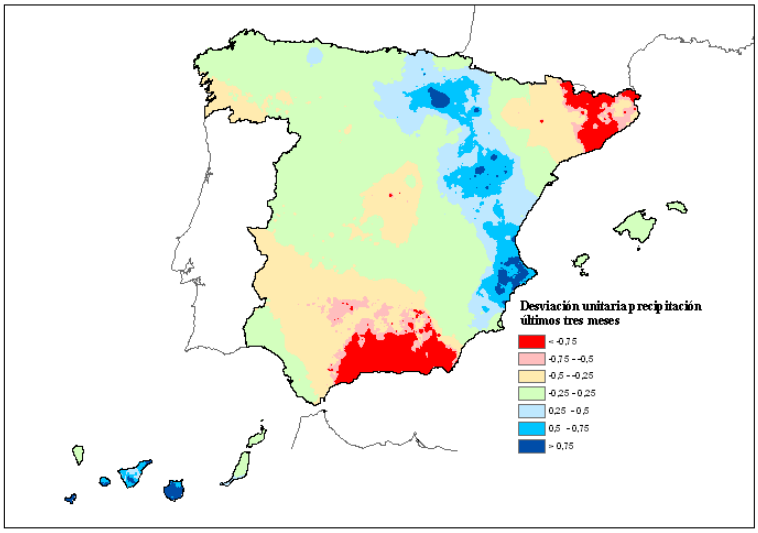


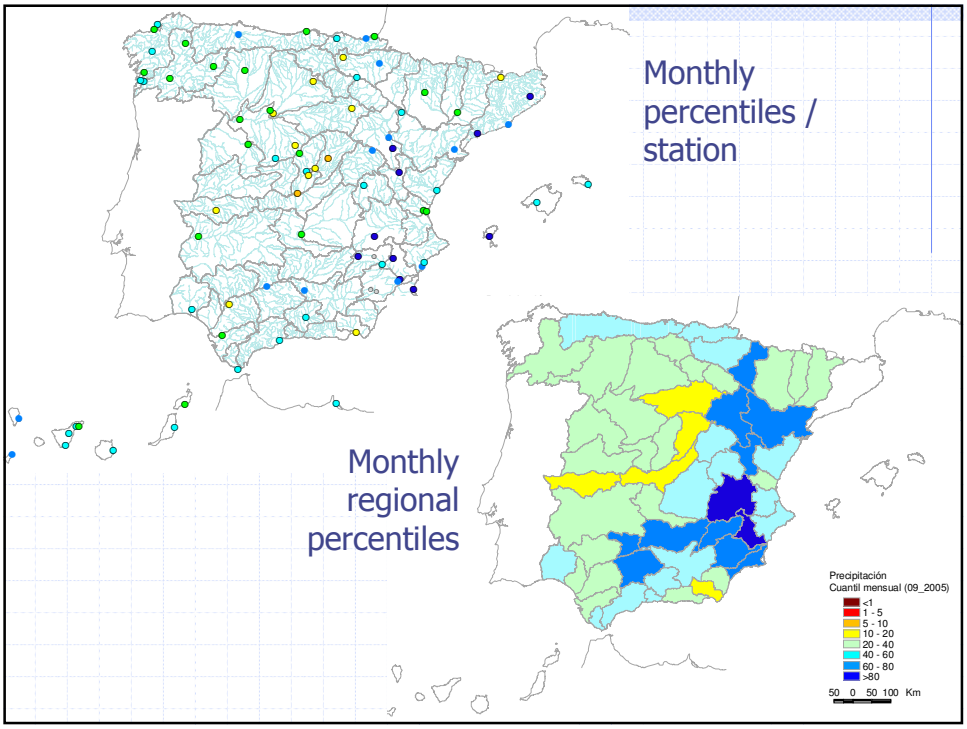


Amounts of rainfall (three months)

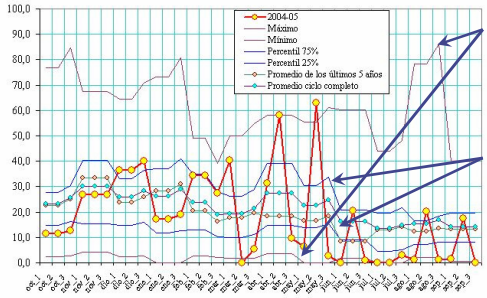


Deviation from normal values



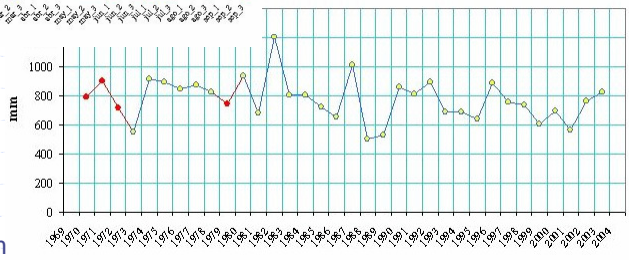


Annual and intrannual evolution



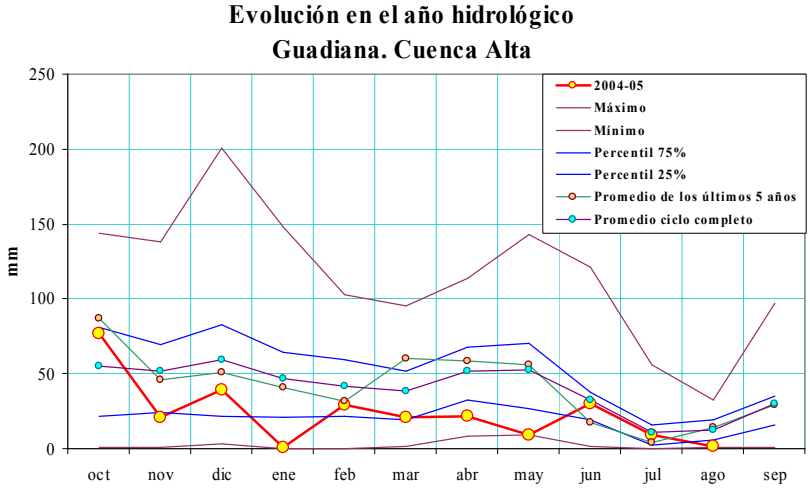
Maximum and minimum monthly data

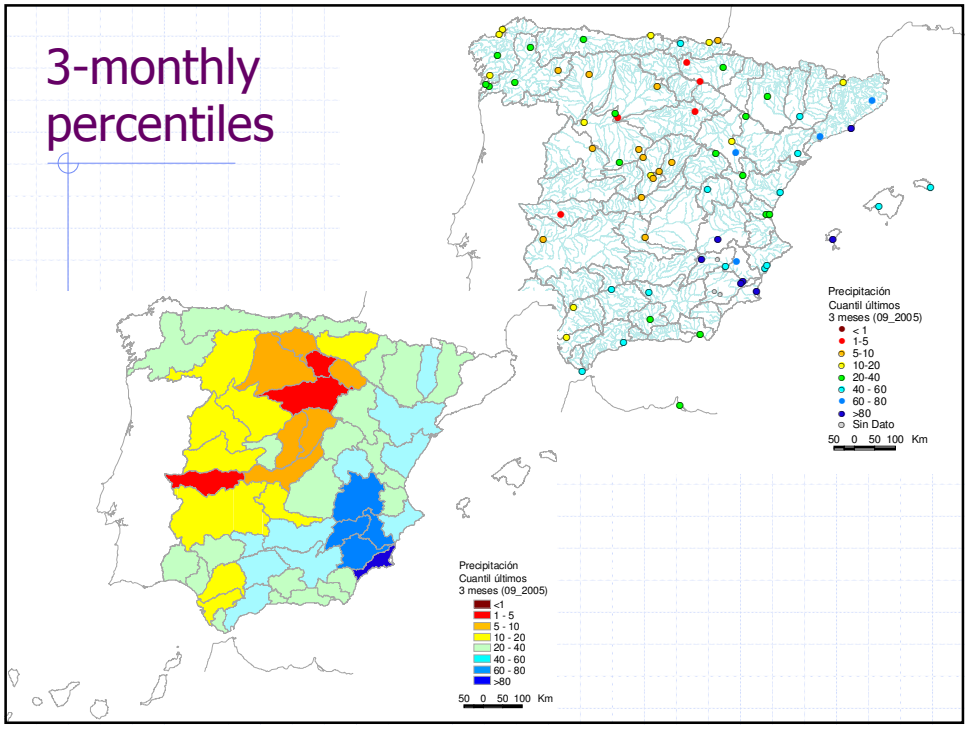
Normal values in-between quartiles

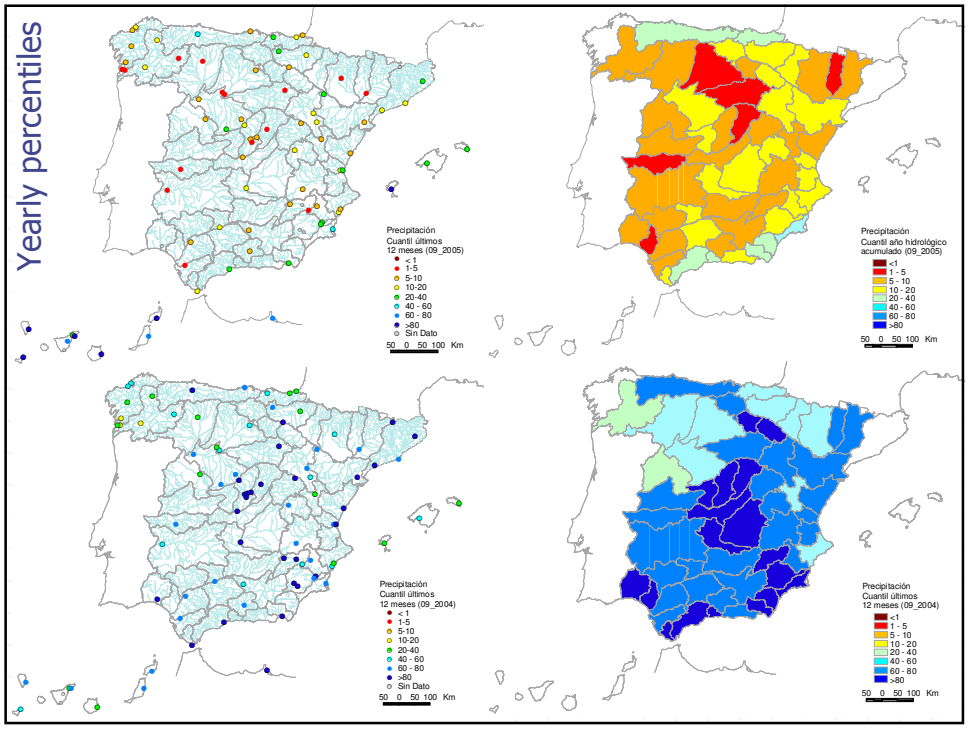


Annual rainfall evolution

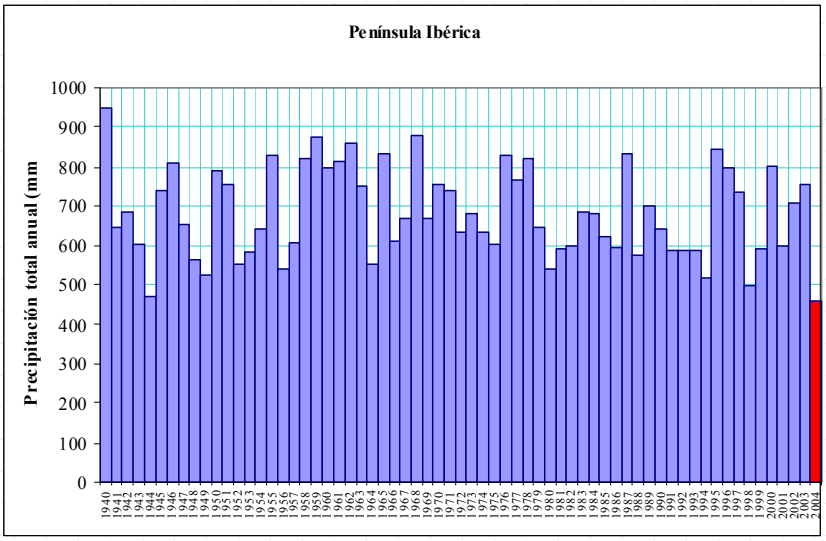
Regional rainfall evolution



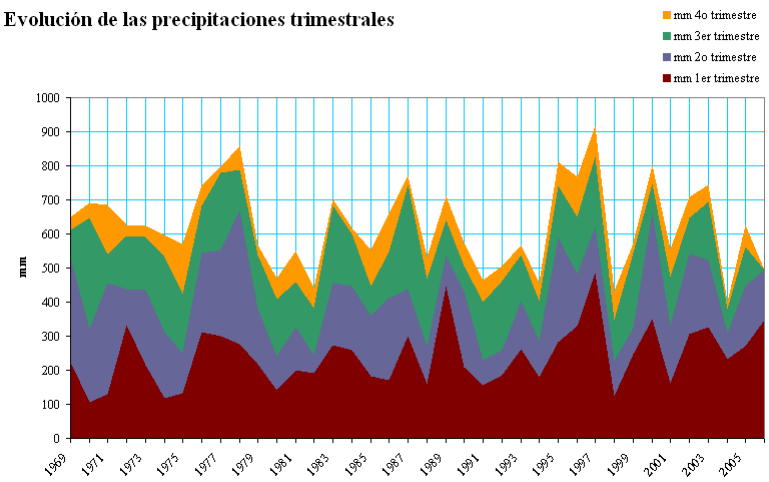

3-monthly
percentiles
Precipitación
Cuantil últimos
3 meses (09_2005)
< 1
1-5
5-10
10-20
20-40
40 - 60
60 - 80
>80
Sin Dato
50 0 50 100 Km
Precipitación
Cuantil últimos
3 meses (09_2005)
<1
1 - 5
5 - 10
10 - 20
20 - 40
40 - 60
60 - 80
>80
50 0 50 100 Km


Yearly percentiles
Precipitación
Cuantil últimos
12 meses (09_2005)
Precipitación
Cuantil año hidrológico
acumulado (09_2005)
Precipitación
Cuantil últimos
12 meses (09_2004)
Precipitación
Cuantil últimos
12 meses (09_2004)

Mean annual rainfall in Spain

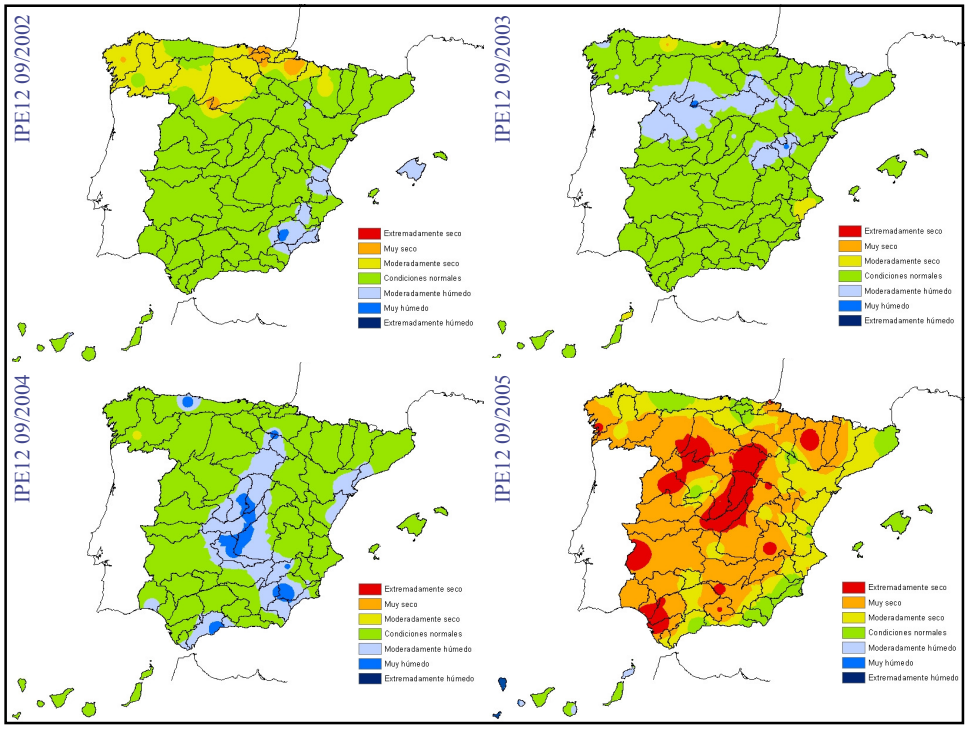


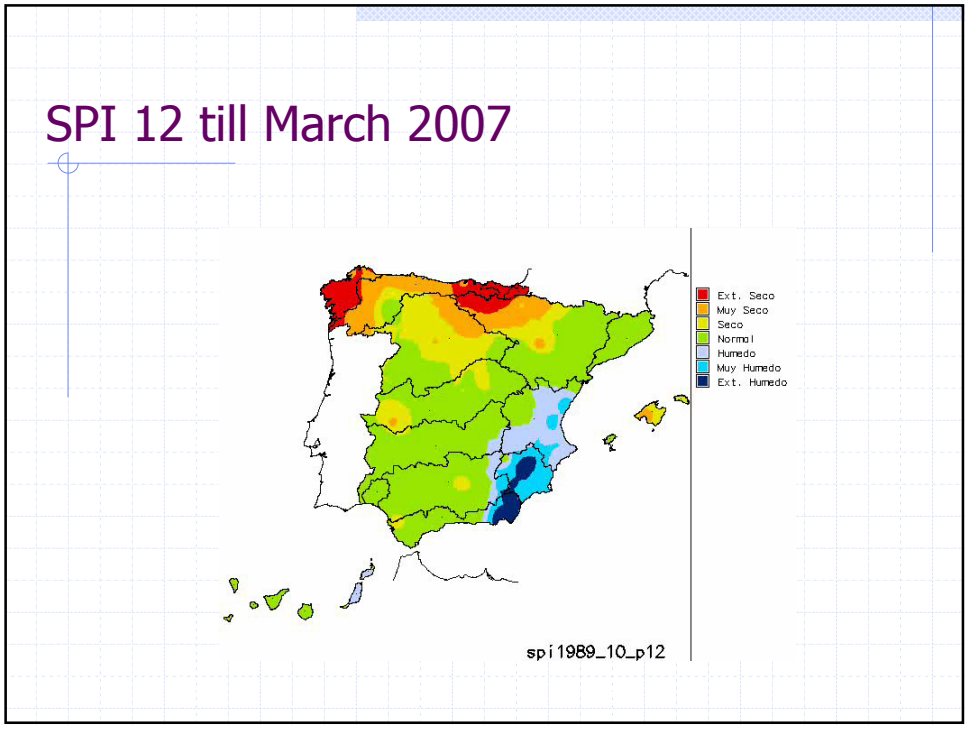
Seasonal rainfall values in Tajo river basin

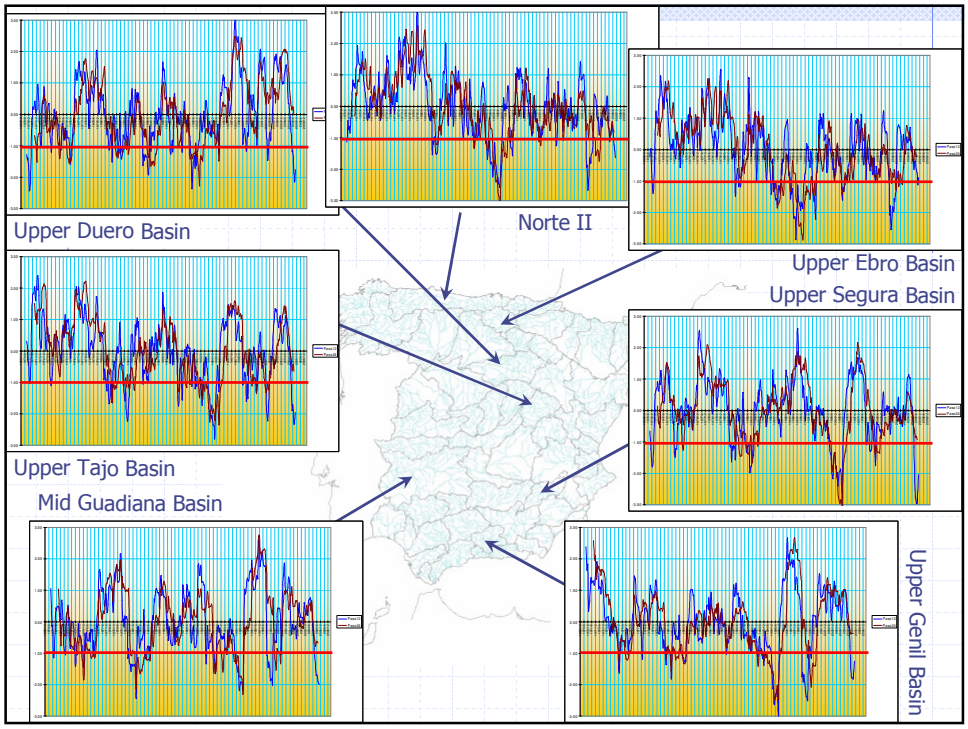


Standardized Precipitation Index

- Widely used
  - Information and free software available
  - Drought studies simplified in rainfall studies
  - With different time lags to consider impacts on other hydrological phases (seasonal, 3 months; half a year, 6 months; annual, 12 months; 24 months …)
- SPI is obtained in each rainfall station and interpolated without any consideration about physiographic influence
  - View of the drought extension
  - Problems: synoptic network representativeness



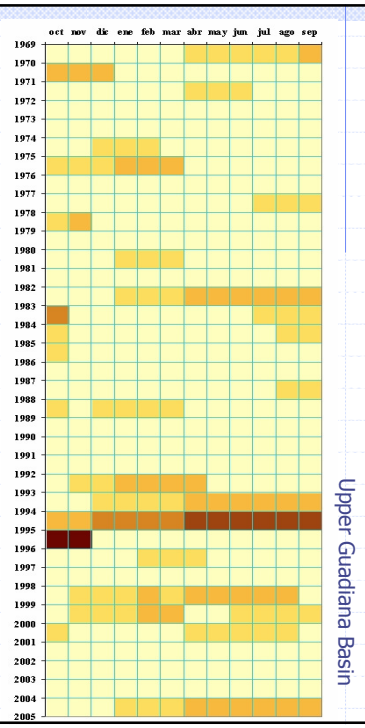

SPI 12 till March 2007
Ext. Seco
Muy Seco
Seco
Normal
Humedo
Muy Humedo
Ext. Humedo
spi1989_10_p12

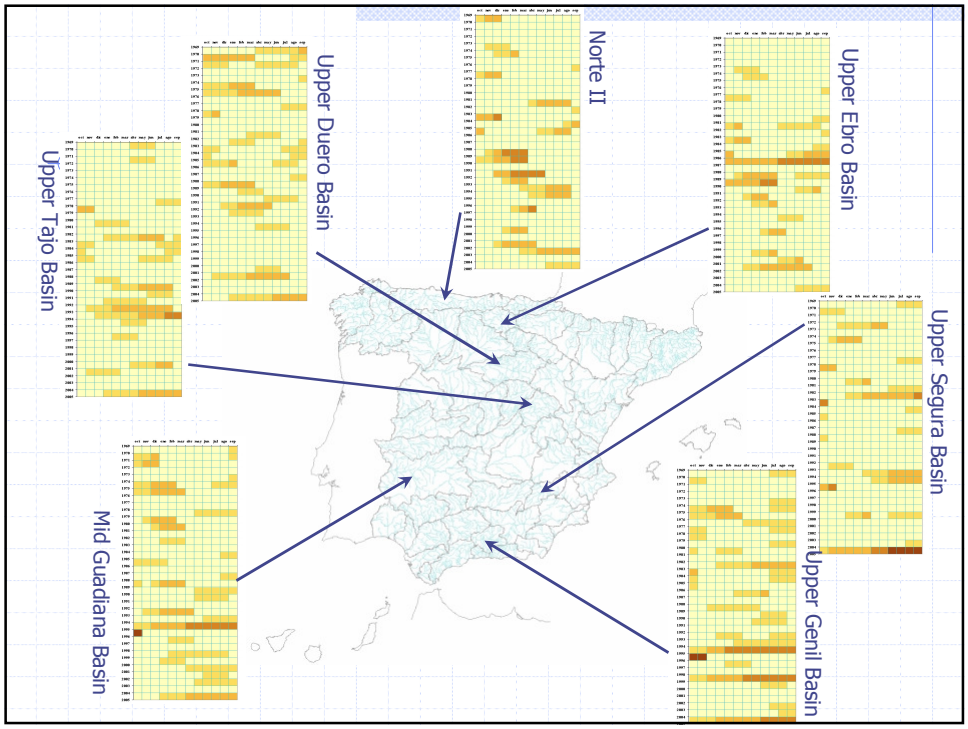

Upper Duero Basin
Norte II
Upper Ebro Basin
Upper Segura Basin
Upper Tajo Basin
Mid Guadiana Basin
Upper Genil Basin

Regional deficit chronograms

Drought are defined with a threshold level approach:

- Drought onset: reach 90% monthly percentile
- Recover: surplus of 10% over mean value concerning cumulated deficit
- Duration: at least one season (3 months)



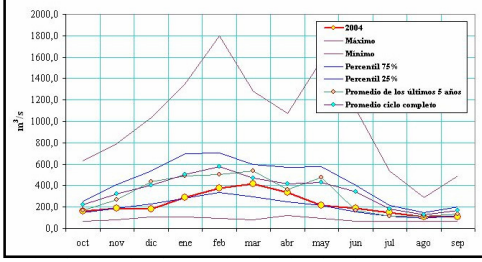


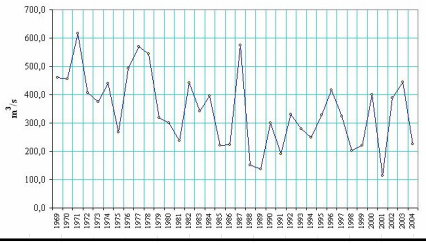
River flow data: gauging stations and volumes entering in reservoirs

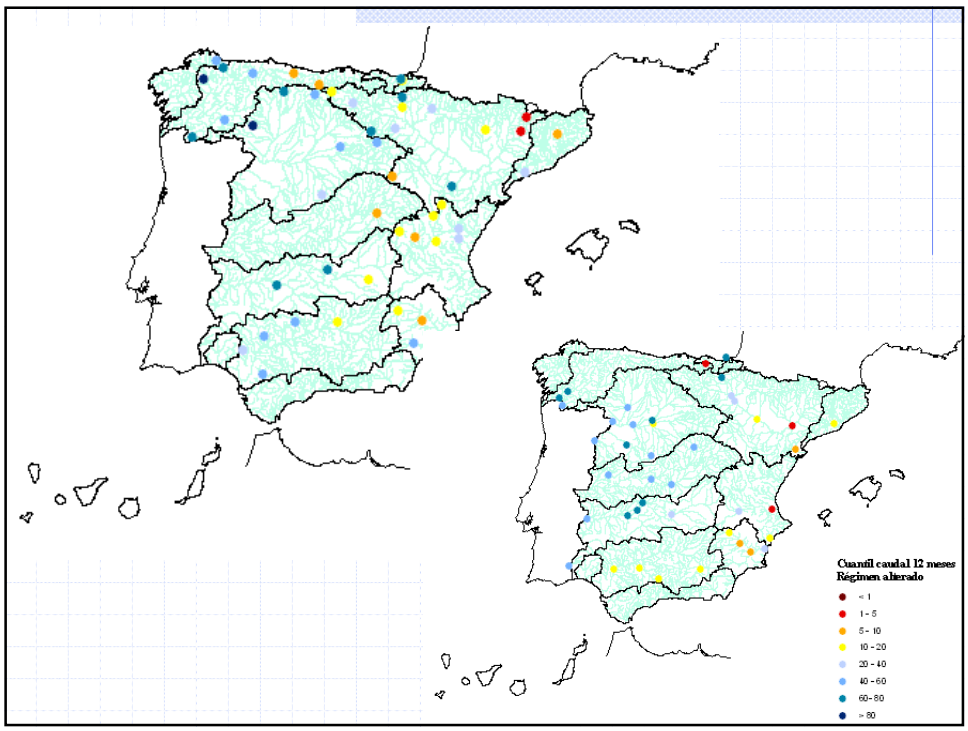
River flow stations
Inflow in reservoirs

Zona	Descripción	Código	Código del tipo de dato	Evaluación en régimen natural
91	Río Oca en Oña	09093	2	SÍ
91	Entrada Embalse Ebro	09801E	3	SÍ
92	Entrada Embalse Mansilla	09809E	3	SÍ
93	Río Ega I en Andosilla	09003	2	SÍ
93	Río Arga en Funes	09004	2	SÍ
93	Río Ulzama en Olave	09067	2	SÍ
93	Río Ega en Estella	09071	2	SÍ
94	Río Odacos en Arnedillo	09253	2	SÍ
95	Río Veral en Ezaez	09062	2	SÍ
95	Entrada Embalse Yesa	09829E	3	
96	Río Jalón en Jubera	09058	2	SÍ
96	Entrada Embalse Tranquera	09812E	3	SÍ
910	Entrada Embalse Cueva Foradada	09817E	3	SÍ

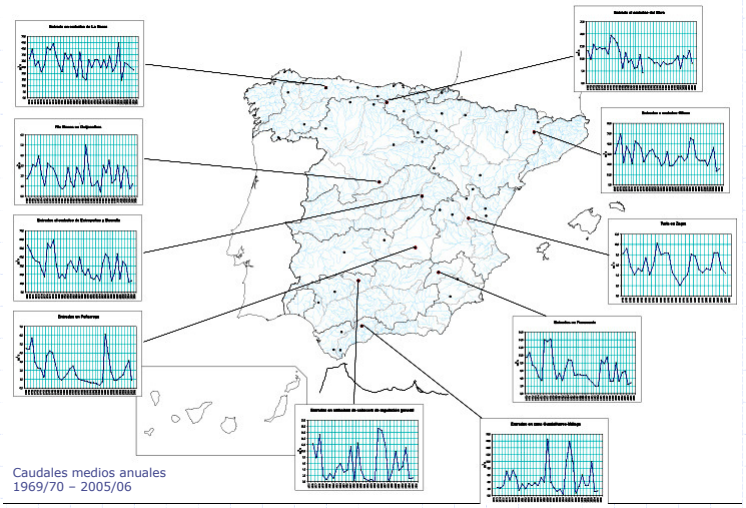
Name, code, altered or natural flow regimes.
Access to time evolution





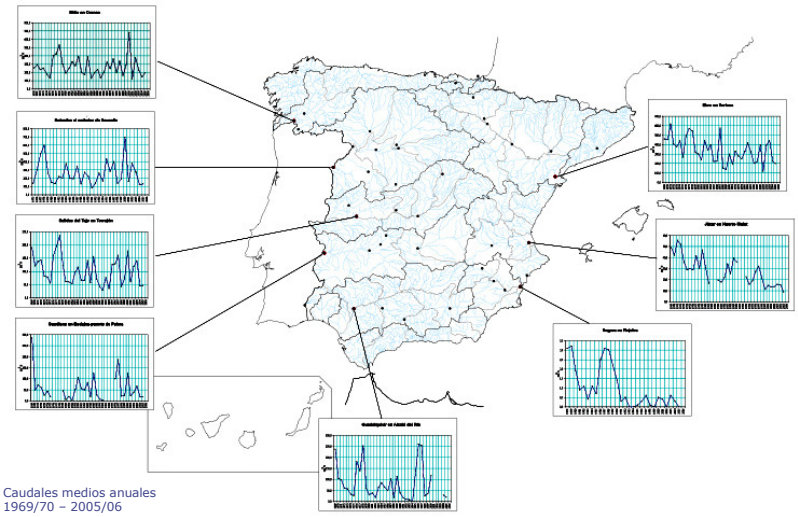


Flow data. Natural regime



Caudales medios anuales
1969/70 – 2005/06

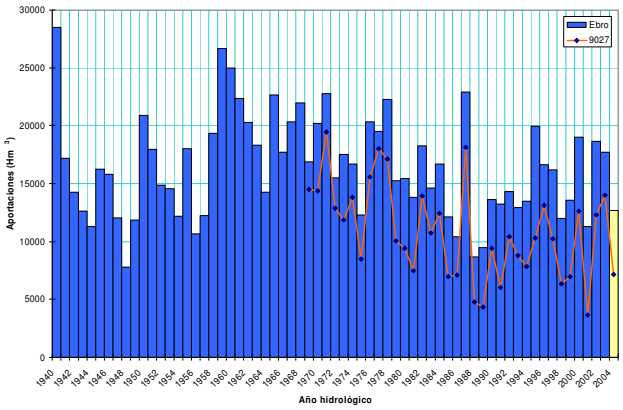
Altered flow regimes



Caudales medios anuales
1969/70 – 2005/06

Using gauging stations in natural flow regime and regression techniques some evaluations about the hydrological behavior are inferred

River flow stations and inflow reservoirs
- **Natural flow regimes**
- **Human-altered flow regimes**

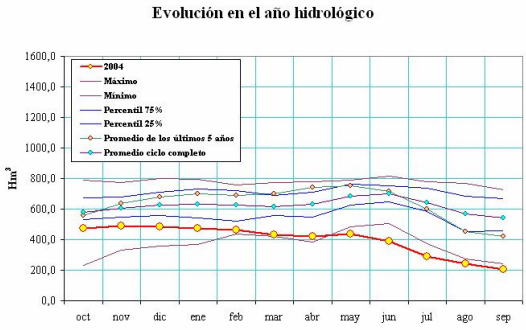


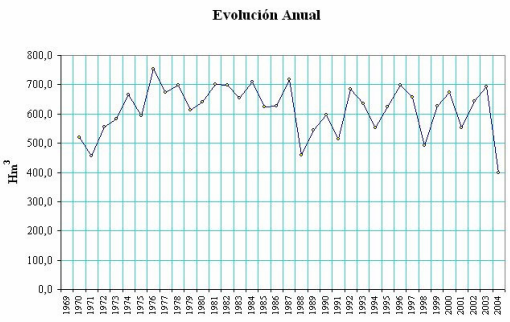
Ebro river basin

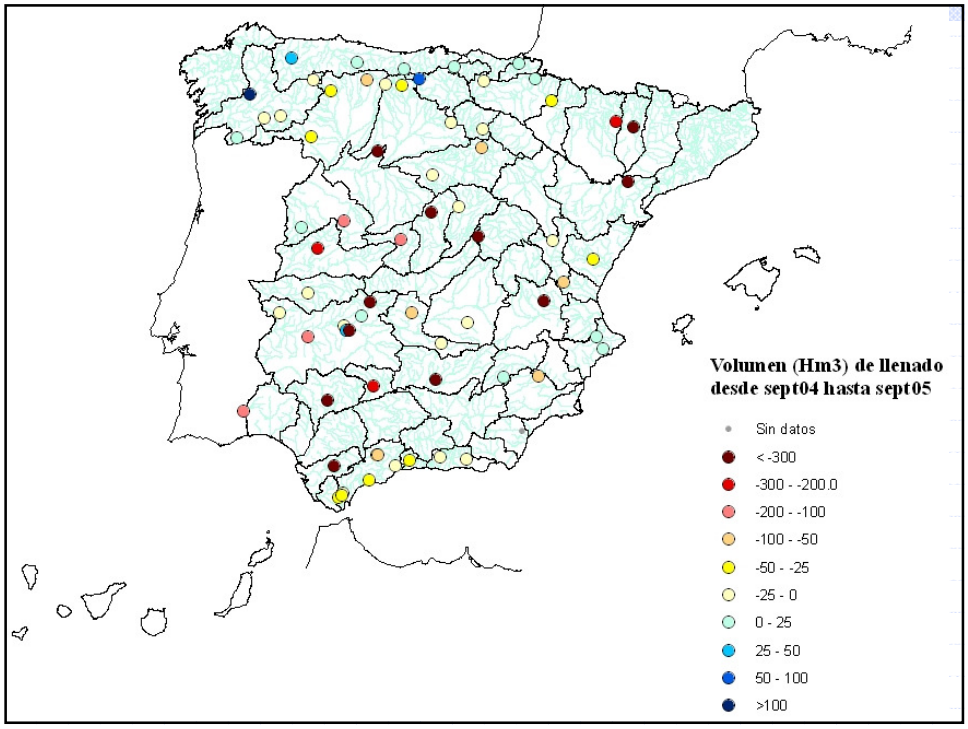
Reservoirs

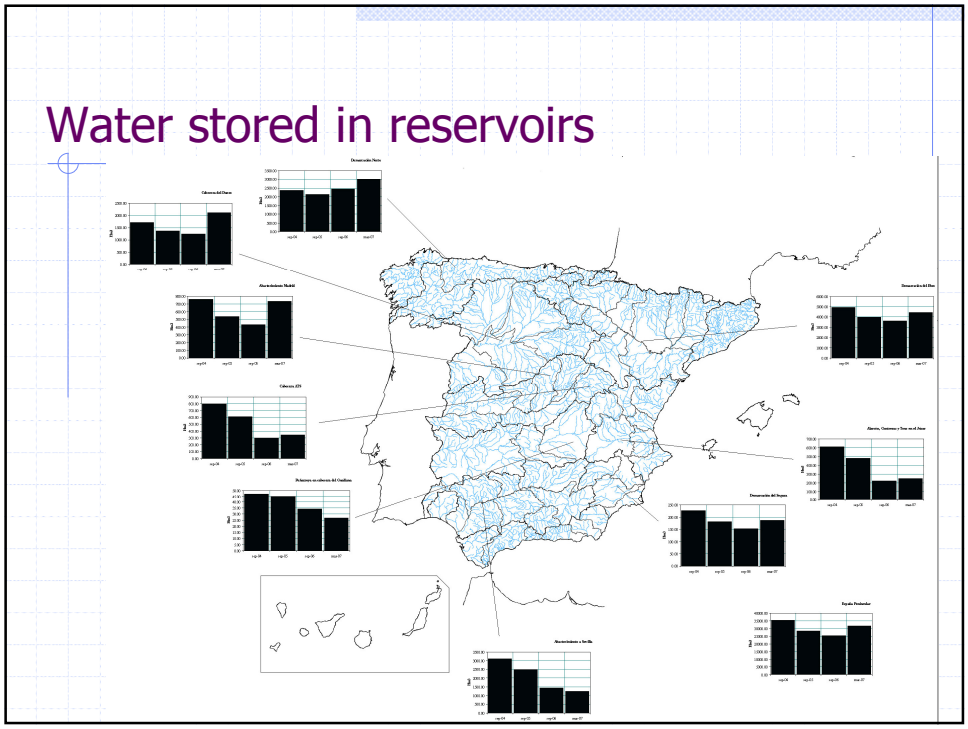
Monthly and annual evolution

Indices:
- % stored
- Evolution
- Storage percentile (short time series)






Volumen (Hm3) de llenado
desde sept04 hasta sept05
Sin datos
< -300
-300 - -200.0
-200 - -100
-100 - -50
-50 - -25
-25 - 0
0 - 25
25 - 50
50 - 100
>100


Water stored in reservoirs

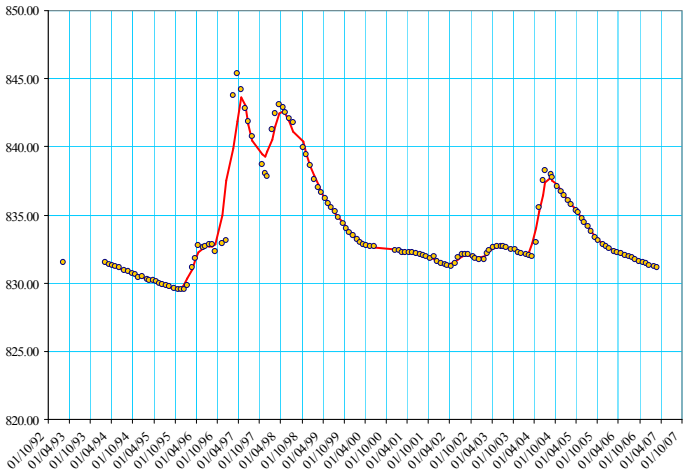
Selected piezometers

Piezometric levels

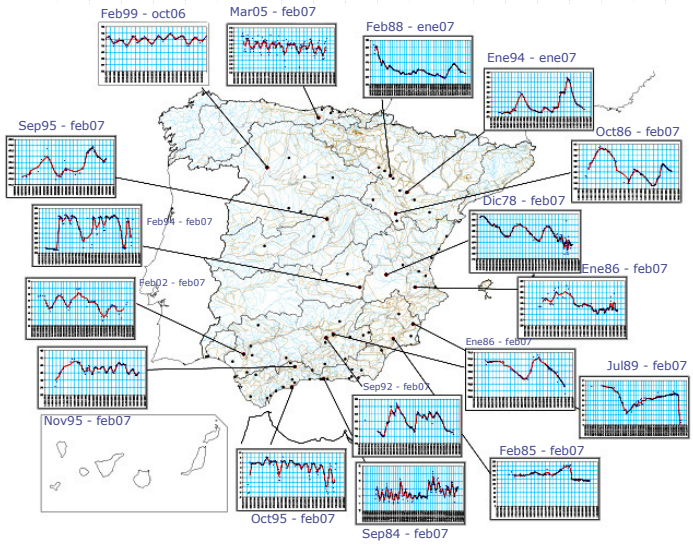
Descripción	Zona	Código	Código tipo de dato
IRYDA AÑAMAZA	94	09601001	5
SONDEO DPZ POLÍGONO INDUSTRIAL	94	09602002	5
Z-51 (2) DGA	96	09702001	5
Z-44 DGA LOS FORCALLOS	96	09602007	5
Z-40 DGA	96	09602014	5
P-17 DGA VIRGEN DE LAGUNAS	96	09603009	5
IRYDA TE-19	96	09704002	5
DGA. TE-42	96	09704006	5
BARRANCO DE LAS POZAS	910	09603013	5
SGOP MUNIESA-1. AGUAS DEL PUERTO	910	09801003	5
CAMINO A "LA FOYA" SG-2 BIS. MAS DE VIRGÓS	910	09802002	5

Name, code, location and access to temporal evolution

Piezometric levels in Upper Guadiana Basin



Piezometric levels



Groundwater

- Piezometric levels are included in HMS
  - Trend and volume oscillation are remarked by means of moving averaged
- Problems:
  - Short term series
  - Need of data and parameterization of aquifer figures:
    - Geometric, storage coefficient, ...
  - is it a consequence of water uses or a reflection of meteorological drought?
- Drought: Propagation of drought through groundwater systems. Elisabeth Peters

Tank model: connection model for surface and groundwater systems

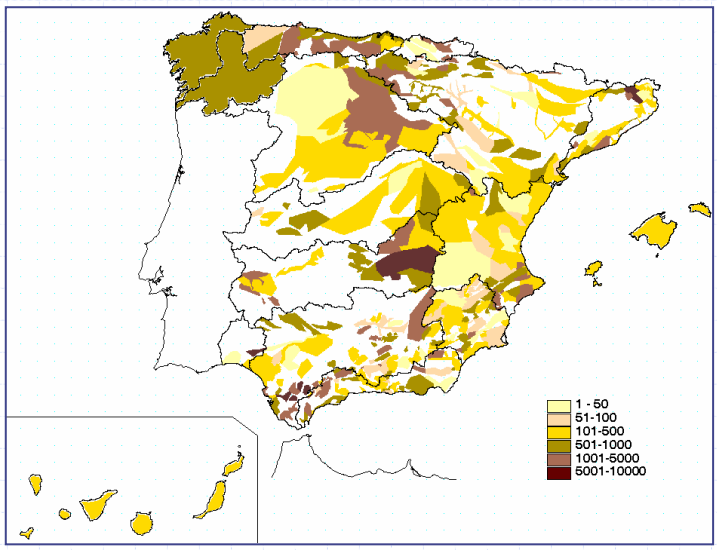
- Solution of the differential equation (1d) for volumes drainage by a free aquifer
  - Unit α, T^{-1}
  - Water balance

$$Q = \alpha \cdot V$$

$$R - Q = \frac{dV}{dt}$$

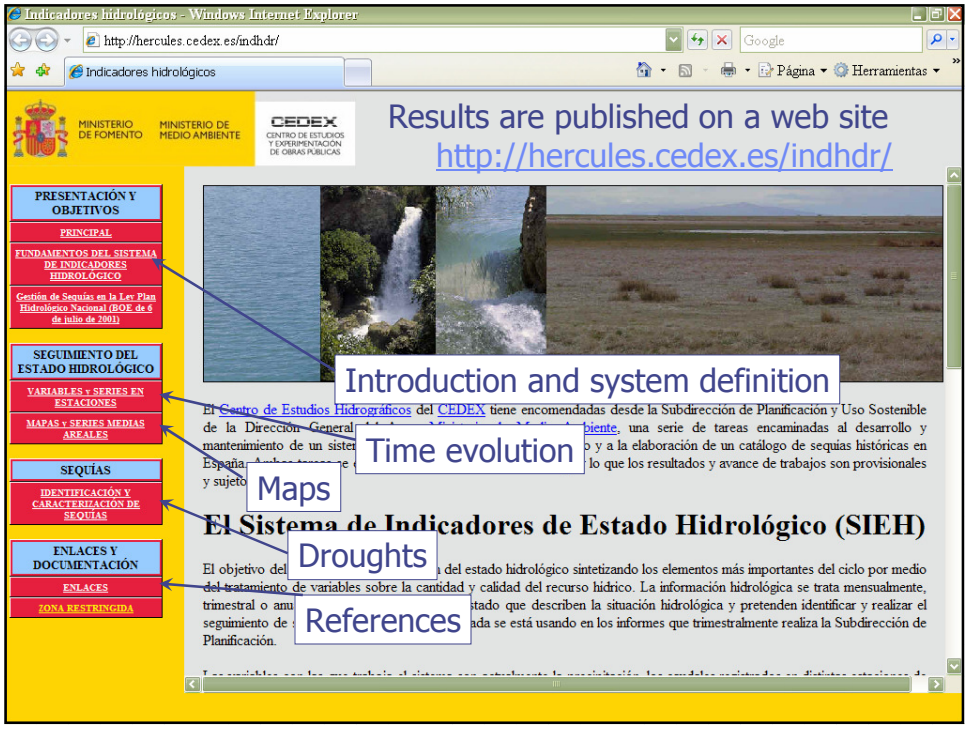
$$\dot{V} + \alpha \cdot V - R = 0 \Rightarrow V = V_o \cdot e^{-\alpha \cdot t} + \frac{R}{\alpha} \cdot \left(1 - e^{-\alpha \cdot t}\right) \Rightarrow Q = Q_o \cdot e^{-\alpha \cdot t} + R \cdot \left(1 - e^{-\alpha \cdot t}\right)$$

Characterization of recession constant



Disseminating information

- Through a web site
- Coordinated by the Ministry of Environment, seasonal reports are made. Main chapters:
  - Rainfall deficiencies
  - Impacts on flow data
  - Flooded areas in Parque Nacional de las Tablas de Daimiel
  - Storage in reservoirs and snow content



Tabular statistics

	Península	Norte	Duero	Tajo	Guadiana	Guadalquivir	Sur	Segura	Júcar	Ebro
Valor alcanzado en año hidrológico 2004/05	461	1131	440	394	316	294	395	190	293	472
Valor alcanzado en año hidrológico 2003/04	755	1362	621	770	699	717	736	554	556	736
Promedio 5 años anteriores	692	1386	640	659	583	603	522	403	490	662
Desviación respecto al promedio de los 5 años anteriores	33%	18%	31%	40%	46%	51%	24%	53%	40%	29%
Promedio ciclo 1940/41-2004/05	685	1399	626	646	543	593	531	382	500	666
Desviación respecto al promedio del ciclo 1940/41-2004/05	33%	19%	30%	39%	42%	50%	26%	50%	41%	29%
Percentil del valor 2004/05	Mínimo	9%	6%	3%	5%	5%	11%	Mínimo	Mínimo	Mínimo

Results 2004/05
Water resources

Unidades en mm/año *Unidades en Hm³/año*	Península	Norte	Duero	Tajo	Guadiana	Guadalquivir	Sur	Segura	Júcar	Ebro
Valor alcanzado en año hidrológico 2004	133 ***65.440***	610 ***32.570***	76 ***6.020***	59 ***3.290***	38 ***2.270***	52 ***3.310***	29 ***520***	31 ***600***	57 ***2.460***	148 ***12.690***
Media 5 años anteriores	201 ***99.060***	716 ***38.230***	172 ***13.520***	155 ***8.620***	91 ***5.480***	138 ***8.710***	100 ***1.790***	36 ***690***	78 ***3.360***	188 ***16.040***
Desviación respecto a la media de los 5 años anteriores	34%	15%	56%	62%	59%	62%	71%	14%	27%	5%
Promedio ciclo 1940/41 – 2003/04	215 ***106.020***	789 ***42.160***	172 ***13.520***	183 ***10.190***	92 ***5.540***	139 ***8.810***	129 ***2.310***	43 ***810***	80 ***3.440***	192 ***16.440***
Desviación respecto a la media del ciclo 1940 - 2004	38%	23%	56%	68%	59%	62%	77%	26%	29%	23%
Percentil del valor 2004	11%	15%	9%	9%	28%	25%	5%	22%	14%	23%

Thanks for your attention

MINISTERIO DE FOMENTO MINISTERIO DE MEDIO AMBIENTE CEDEX CENTRO DE ESTUDIOS Y EXPERIMENTACIÓN DE OBRAS PÚBLICAS