Lines of work in the analysis of drought events, and impacts on agriculture from remote sensing

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  - Methodological aspects
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- Present and future lines of research
- Acknowledgments

Introduction: UPCT and R&D Group of Water Resources Management

- The Technical University of Cartagena (UPCT) is a medium size University (7000 students), composed by six Schools (4 Higher Technical Schools) and 24 Scientific Departments. The UPCT offers advanced academic programmes in about 20 major fields of study.
- The R&D Group of Water Resources Management corresponds to Hydraulic Engineering Area (Dept. of Thermal Engineering and Fluids). http://www.upct.es/~agua
- The Group is involved in several National Projects (EVISA, DYUNUT) and European Projects (AMMA, TELERIEG, SIRRIMED) related to climate change, water and agricultural resources and land management.

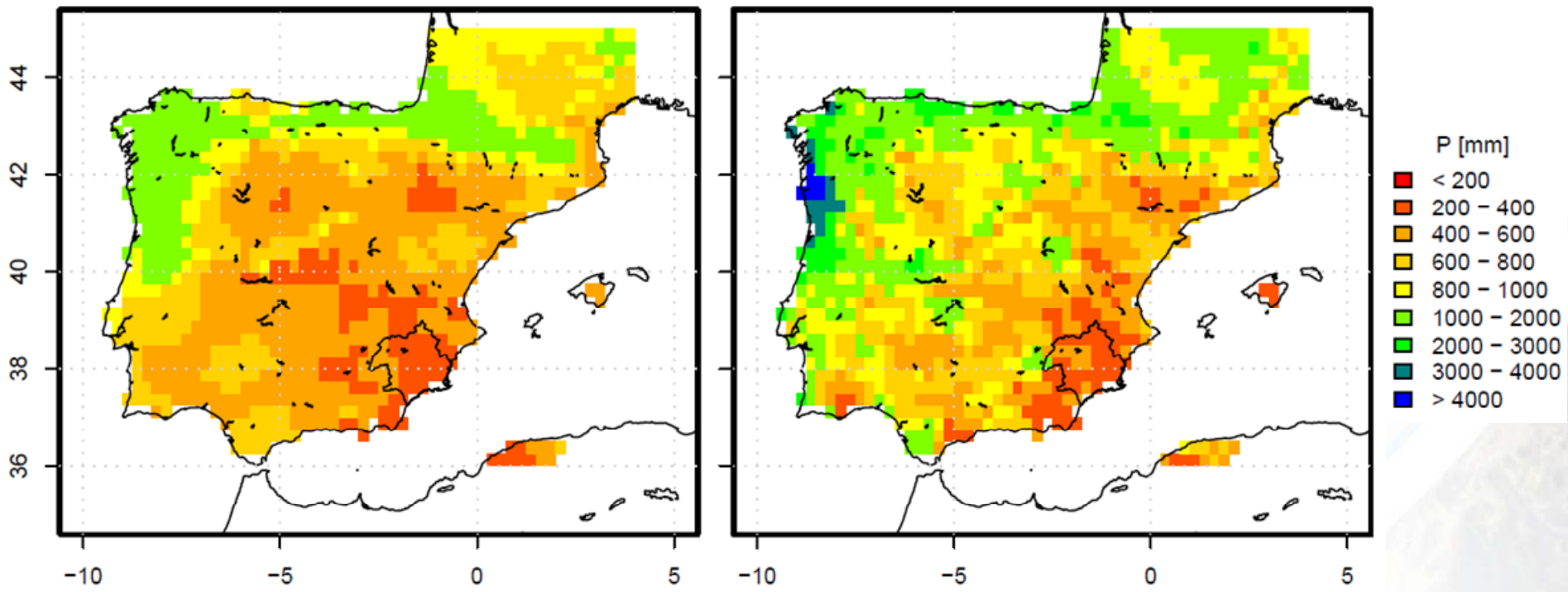
Analysis of Dry Spells from Climate Data

- Dry spell events spread through the hydrological processes of the water cycle. Therefore, they reduce the aquifer recharge and subsequently have a negative impact on the agriculture activities.
- We must build adaptive capacity for climate risks management. Adaptive capacity is considered a necessary condition for designing and implementing effective adaptation strategies, and could be achieved by increasing the knowledge of potential climate risks in individual river basins (EC, 2009).
- Therefore, studies focused on the analysis of future trends in drought events at basin scale are encouraged.
- In this context,
  - Which is the future for Segura River basin ?
  - Which are the impacts on agriculture ?

Which is the future for Segura River Basin ?

- Simulated rainfall of REMO RCM (Jacob, 2001; Paeth et al. 2005) from ENSEMBLE Project (Christensen et al., 2009), with a horizontal resolution of 25 km, and interpolated observed rainfall for a regular grid (Haylock et al., 2008), were used for the analysis.

Mean Annual Rainfall (R) 1961-1990



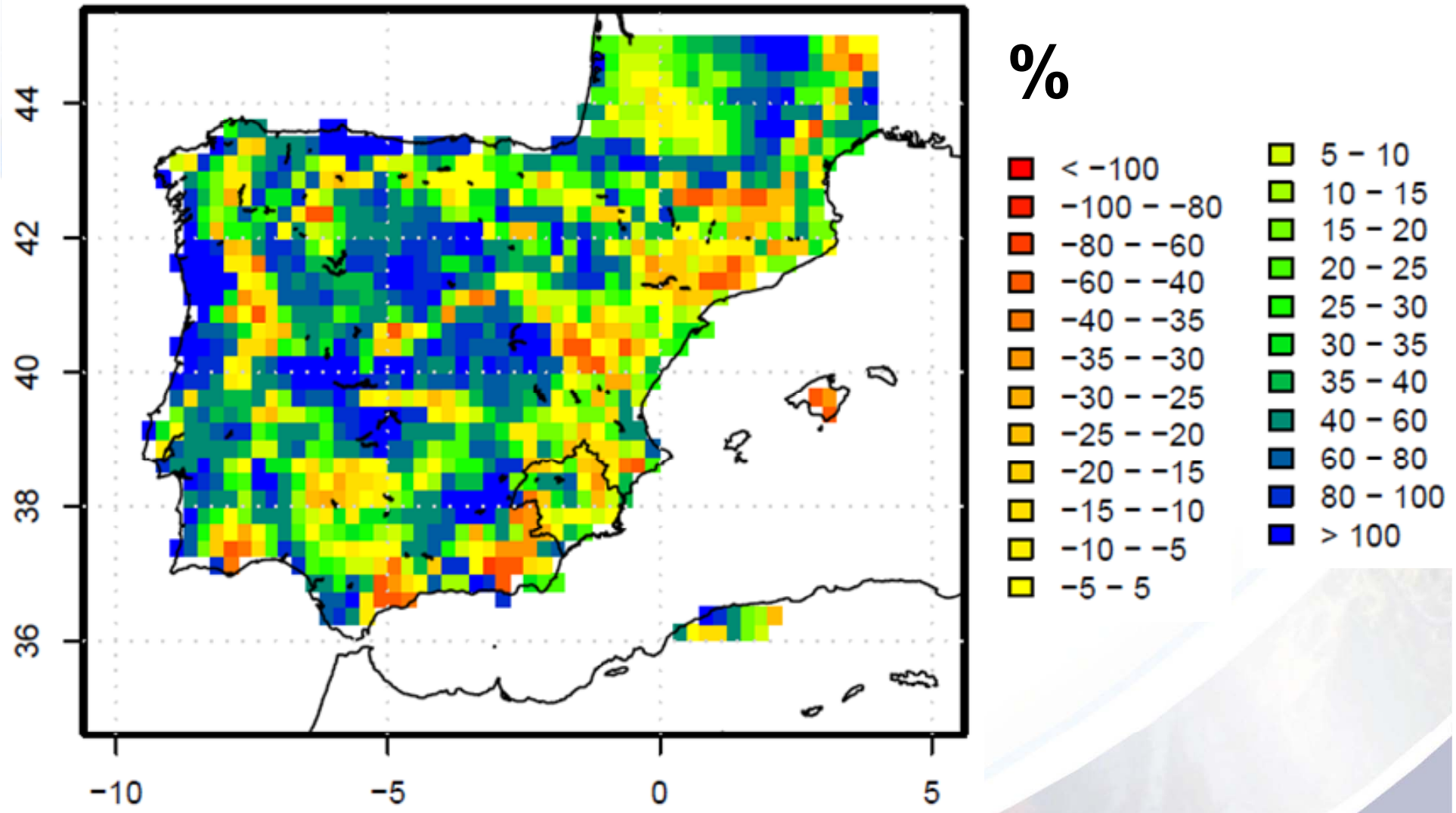
Interpolated from raingauges for Europe (Haylock *et al*., 2008*)

From RCM REMO-ECHAM5-r3.

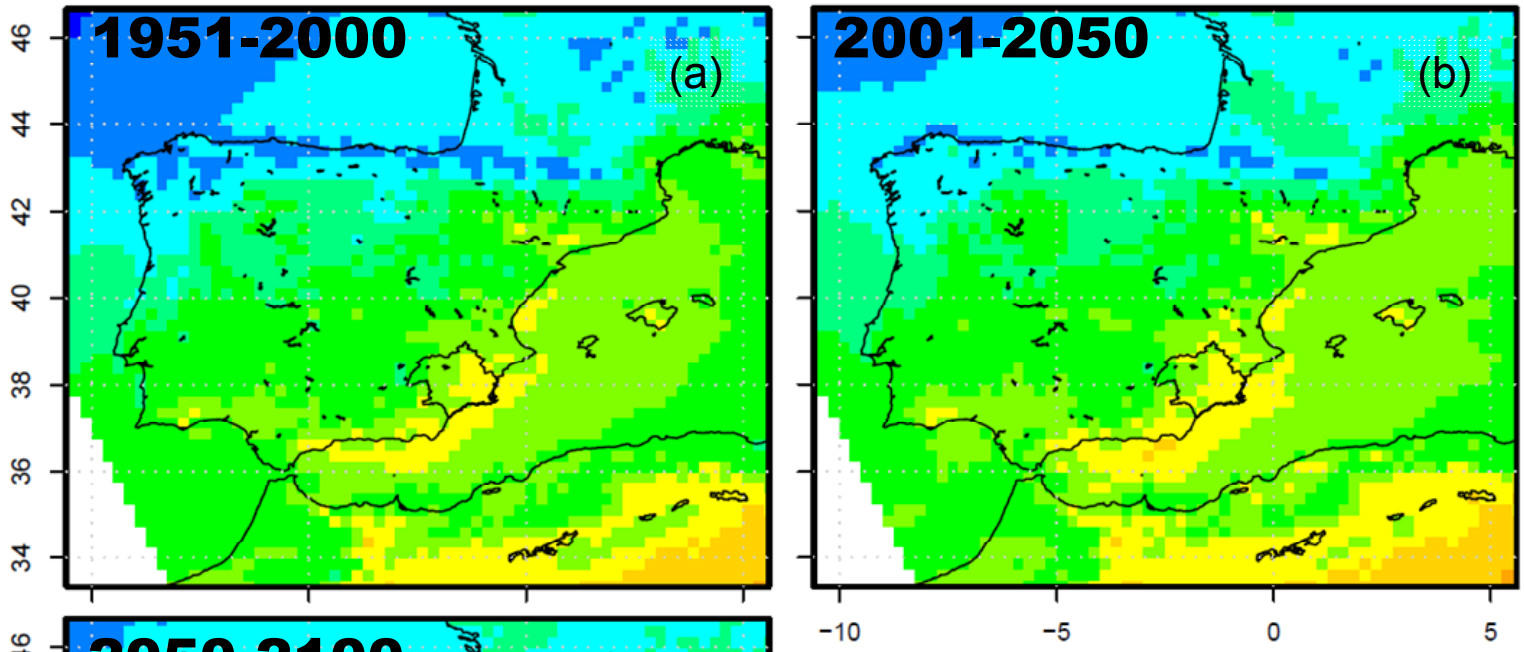
*Haylock, M. R. N. Hofstra, A. M. G. Klein Tank, E. J. Klok, P. D. Jones, and M. New, 2008. A European daily high-resolution gridded data set of surface temperature and precipitation for 1950–2006. *Journal of Geophysical Research, Vol 113, D20119, doi:10.1029/2008JD010201.*

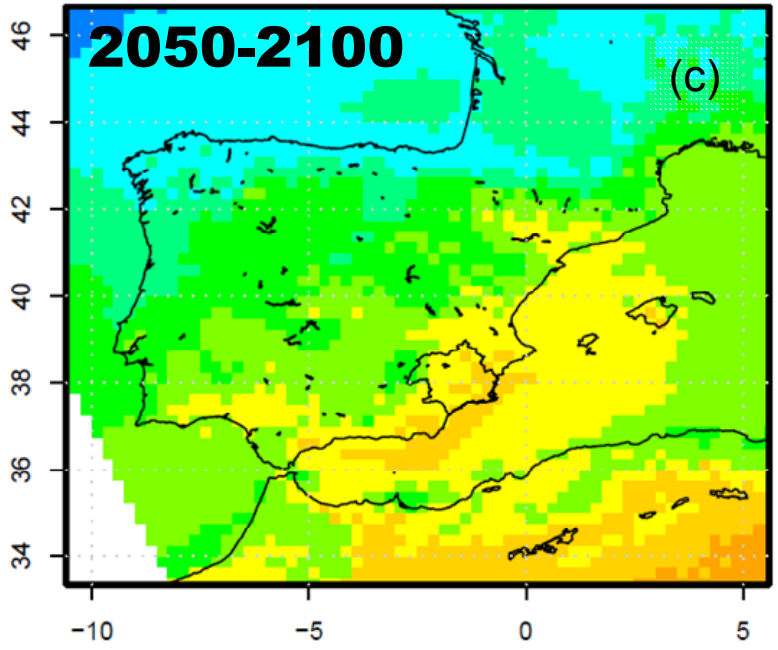
Systematic spatial error = (Rmodel – Robserved)*100/Robserved

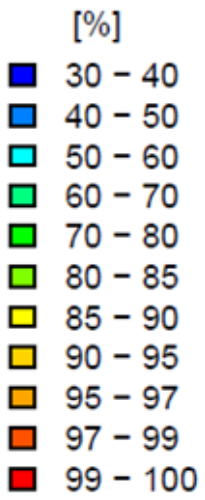
The REMO model is a hydrostatic Regional Climate Model (RCM) that has been developed at the Max-Planck Institute for Meteorology (JACOB, 2001; PAETH et al., 2005).



Percentage of days with R< 1mm/day from REMO RCM

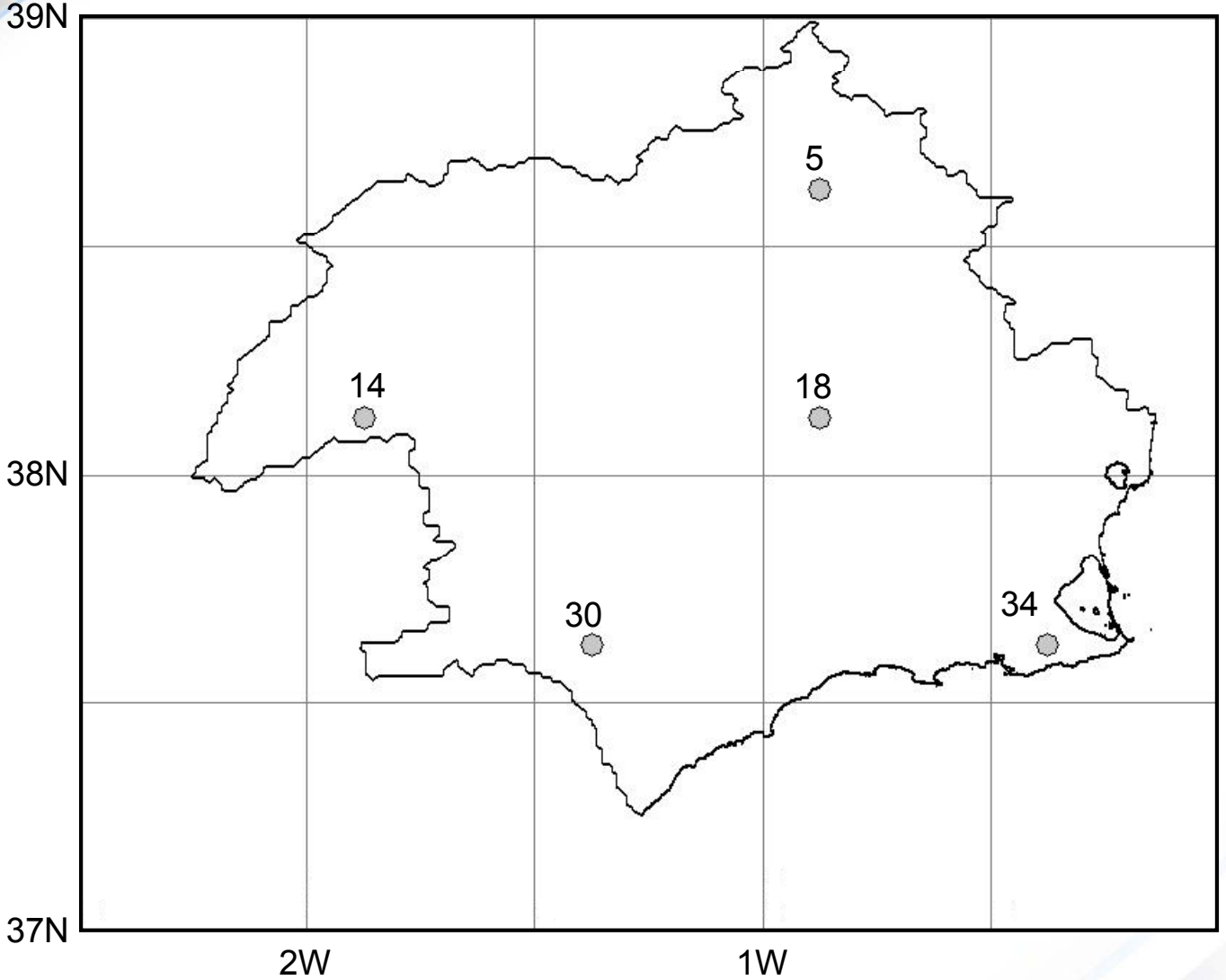






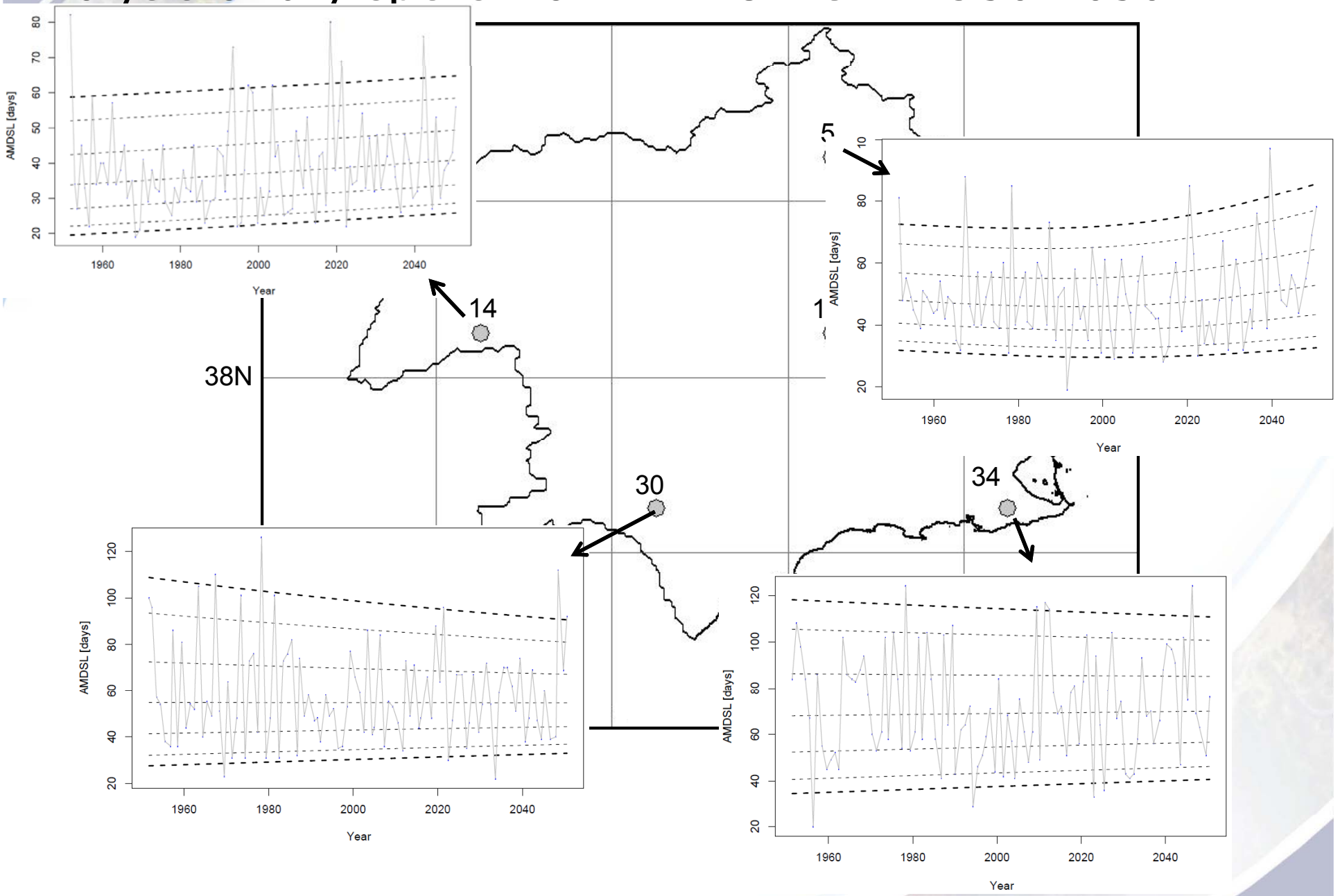
A clear increase of % of days with R<1mm/day – increase of number of dry days - , is projected.

Analysis of dry spells from REMO RCM: 1950-2050



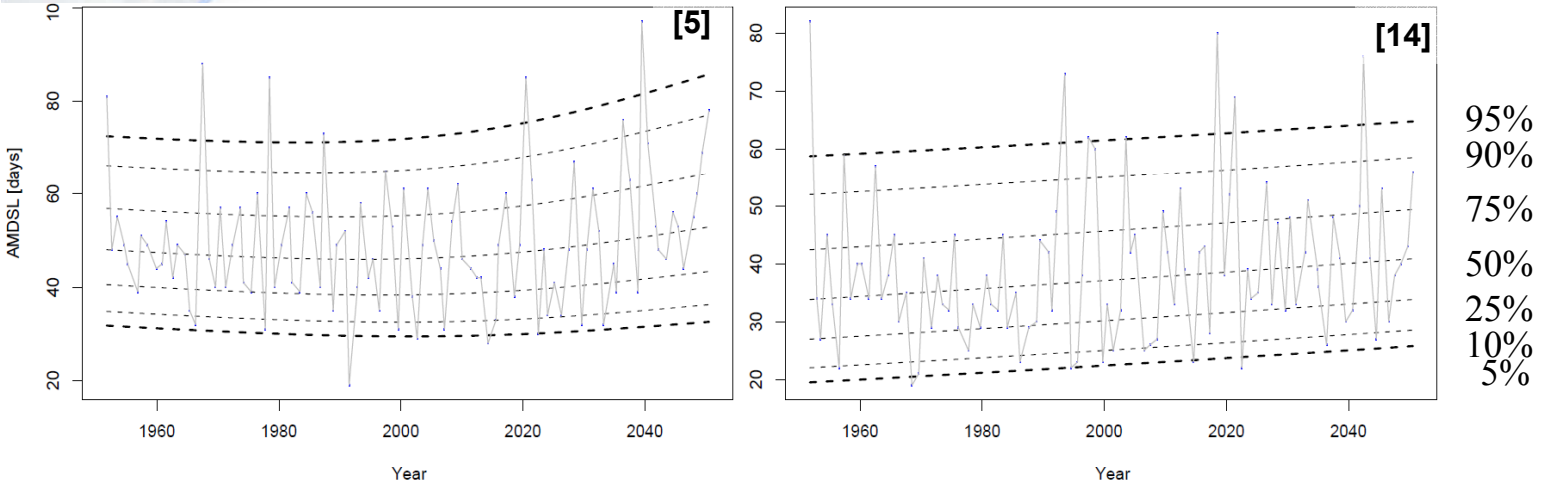
- For selected locations, the time series of Annual Maximum Dry Spell Length (AMDSL) are obtained from REMO RCM.
- We applied GAMLSS (Generalized Additive Models for Location, Scale and Shape, Stasinopoulos and Rigby, 2007) to AMDSL.

Analysis of dry spells from REMO RCM: 1950-2050



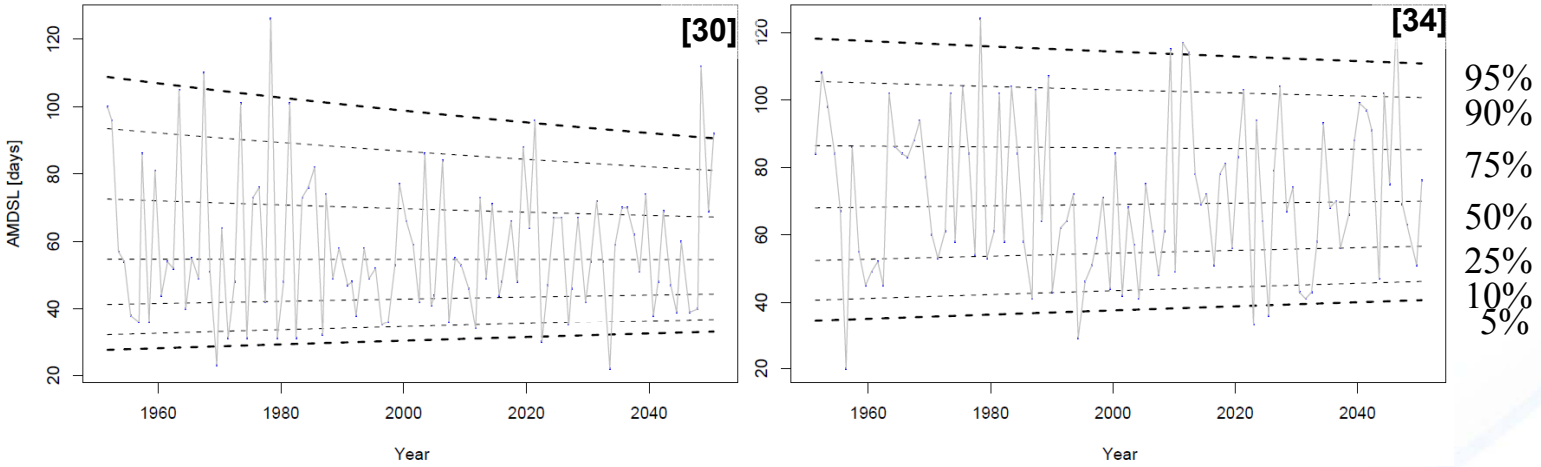
Analysis of dry spells from REMO RCM: 1950-2050

Locations in upbasin (headwater basins)



An increase of length of AMDSL is projected for headwater basins.

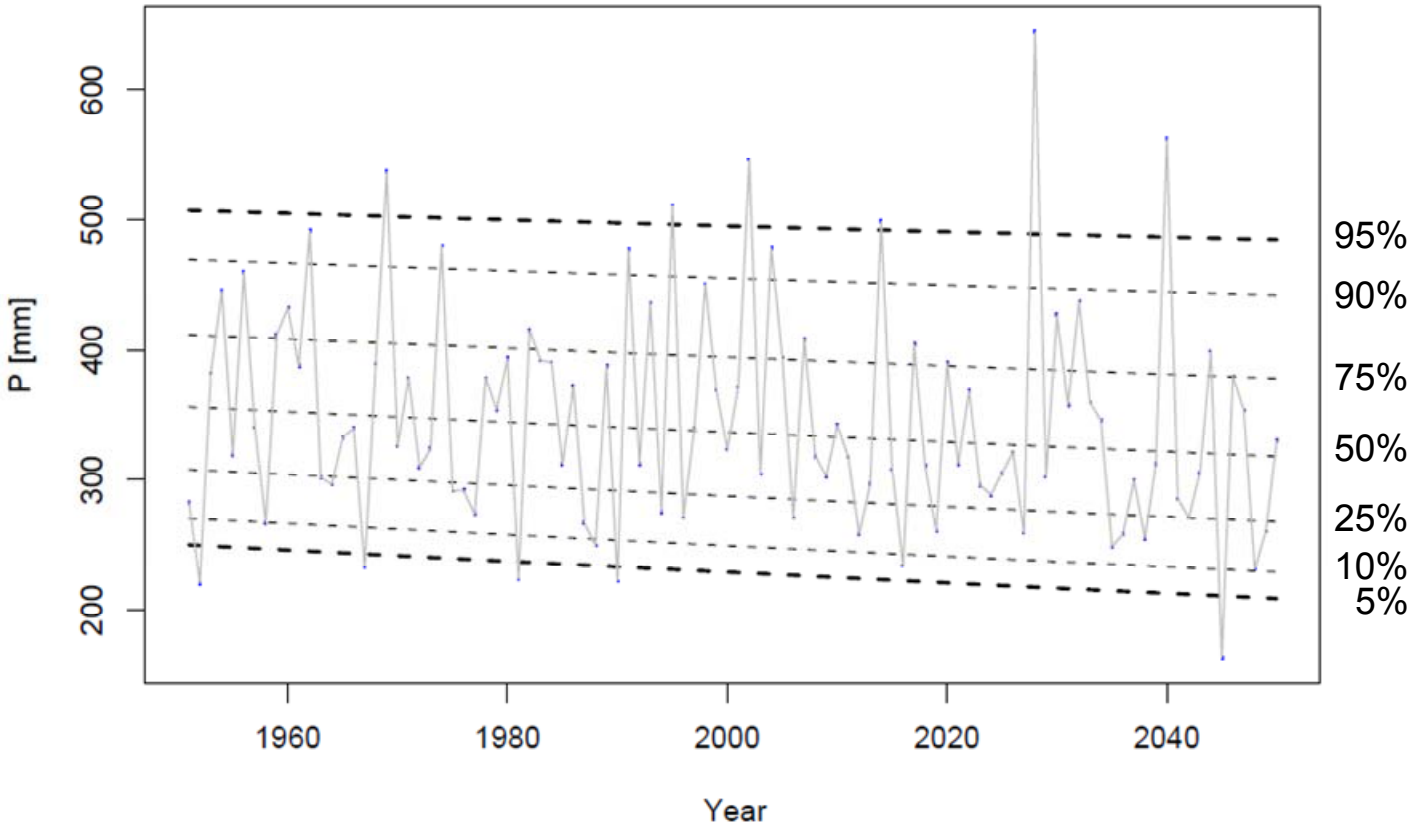
Locations near to the coast



Decrease of length of AMDSL is projected for locations near to the coast.

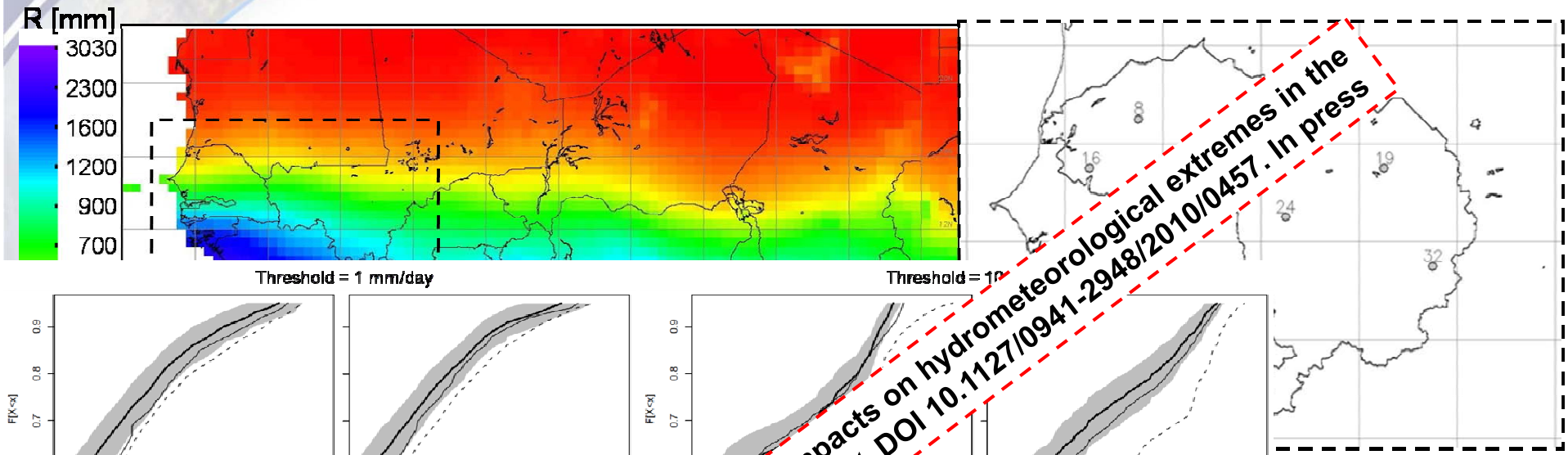
The discontinuos lines represent the cuantiles of probability distribution (between 5% and 95 %).

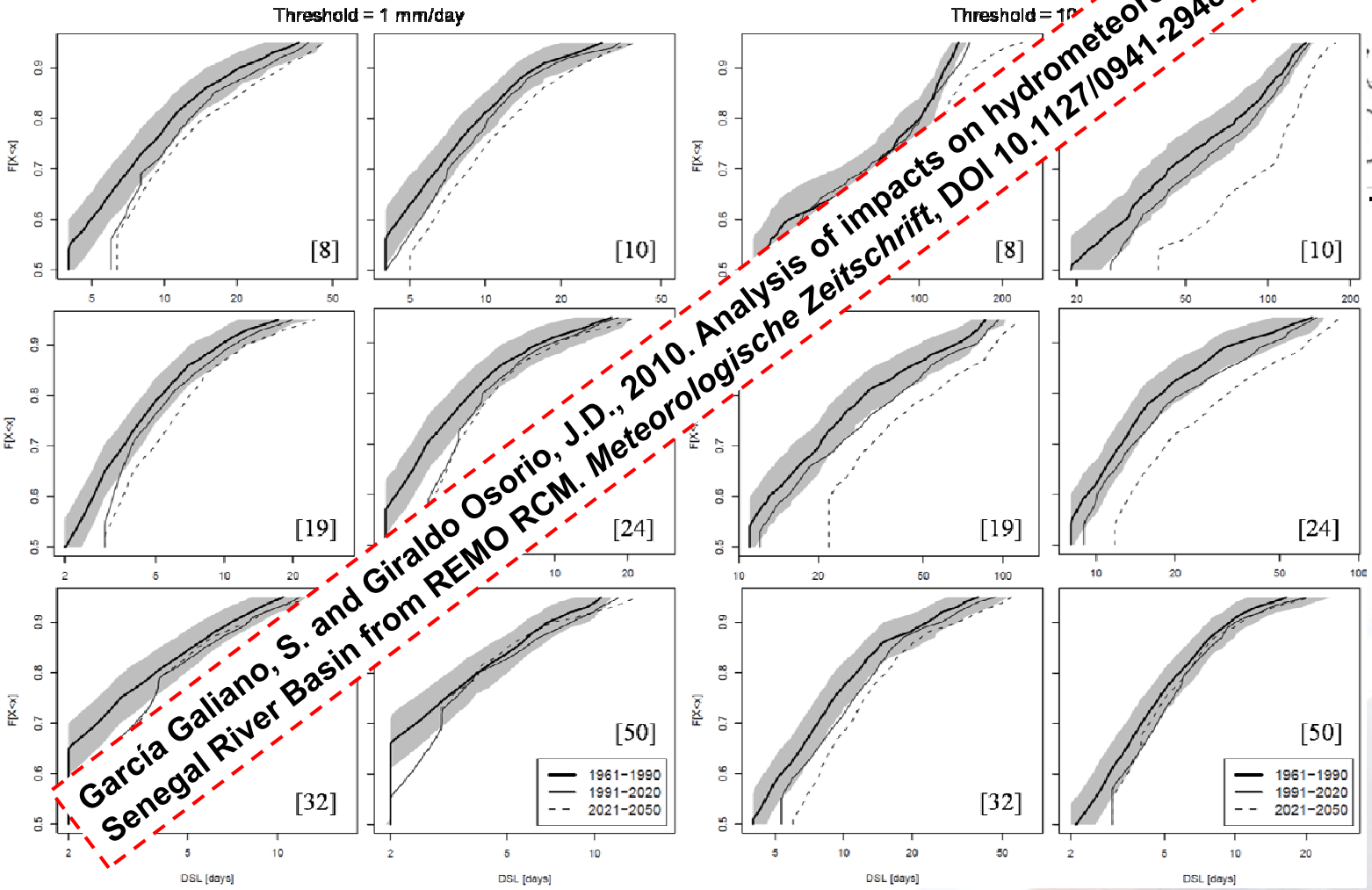
Analysis of mean areal annual Rainfall (1951-2050) from REMO RCM



Slow decrease is projected (applying GAMLSS from REMO RCM data)

Results in other basins - From REMO in Senegal River basin

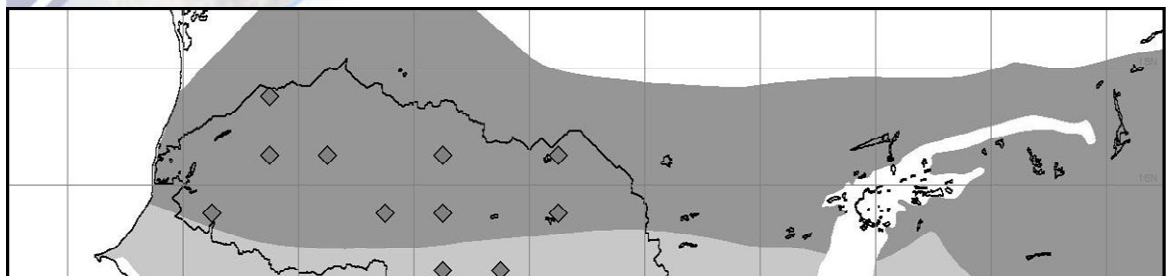




García Galiano, S. and Giraldo Osorio, J.D., 2010. Analysis of impacts on hydrometeorological extremes in the Senegal River Basin from REMO RCM. *Meteorologische Zeitschrift*, DOI 10.1127/0941-2948/2010/0457. In press

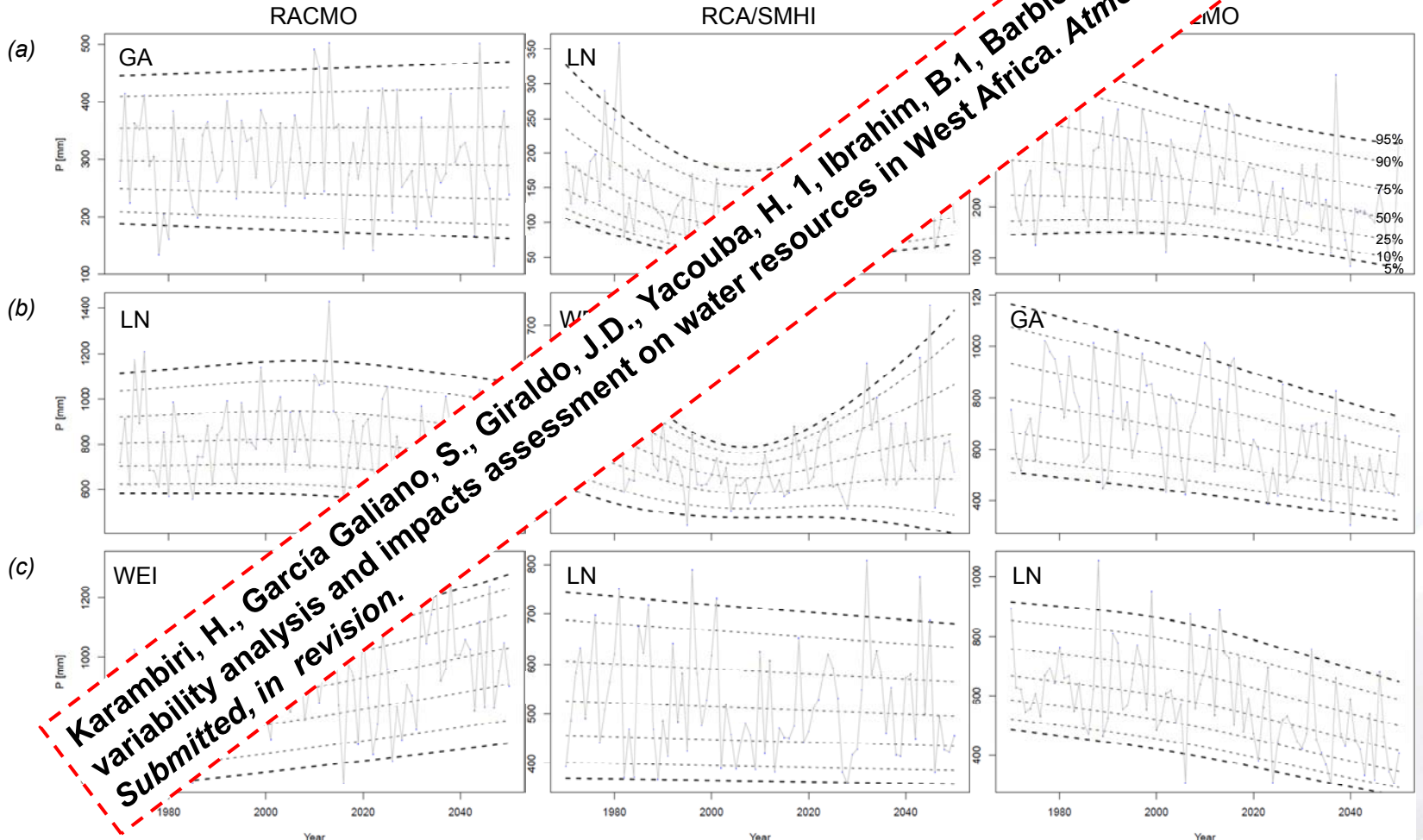
The analyses show an increase in the dry spells lengths, by empirical cdf, being greater in the Sahelian region.

Results in other basins – Nakambé and Senegal River basins



Senegal River basin – Nakambé River basin (Burkina Faso dark gray area represents Sudan Acacia Savanna (SAS) light gray area the West Sudan Savanna (WSS) (according to regions definition in [illegible])

GAMLSS analysis of annual rainfall using RCMs



Senegal basin SAS

Senegal basin WSS

Nakambé basin

Karambiri, H., García Galiano, S., Giraldo, J.D., Yacouba, H. 1, Ibrahim, B.1, Barbier, B.1, Polcher, J., 2010. Climate variability analysis and impacts assessment on water resources in West Africa. *Atmospheric Science Letters.* *Submitted, in revision.*

Which are the impacts on agriculture ?

IMIDA-UPCT Agreement below TELERIEG-SUDOE Project

We are working (Mar-Sept/2010) in the "*Development of TELERIEG-SUDOE EU Project: Analysis of Evolution of vegetation indexes from remote sensing, contrast with irrigation areas*"

Objectives: Evaluation below a GIS of methodologies based on remote sensing, that allow the monitoring of irrigation areas (ATS UDAS) in the Segura River basin.

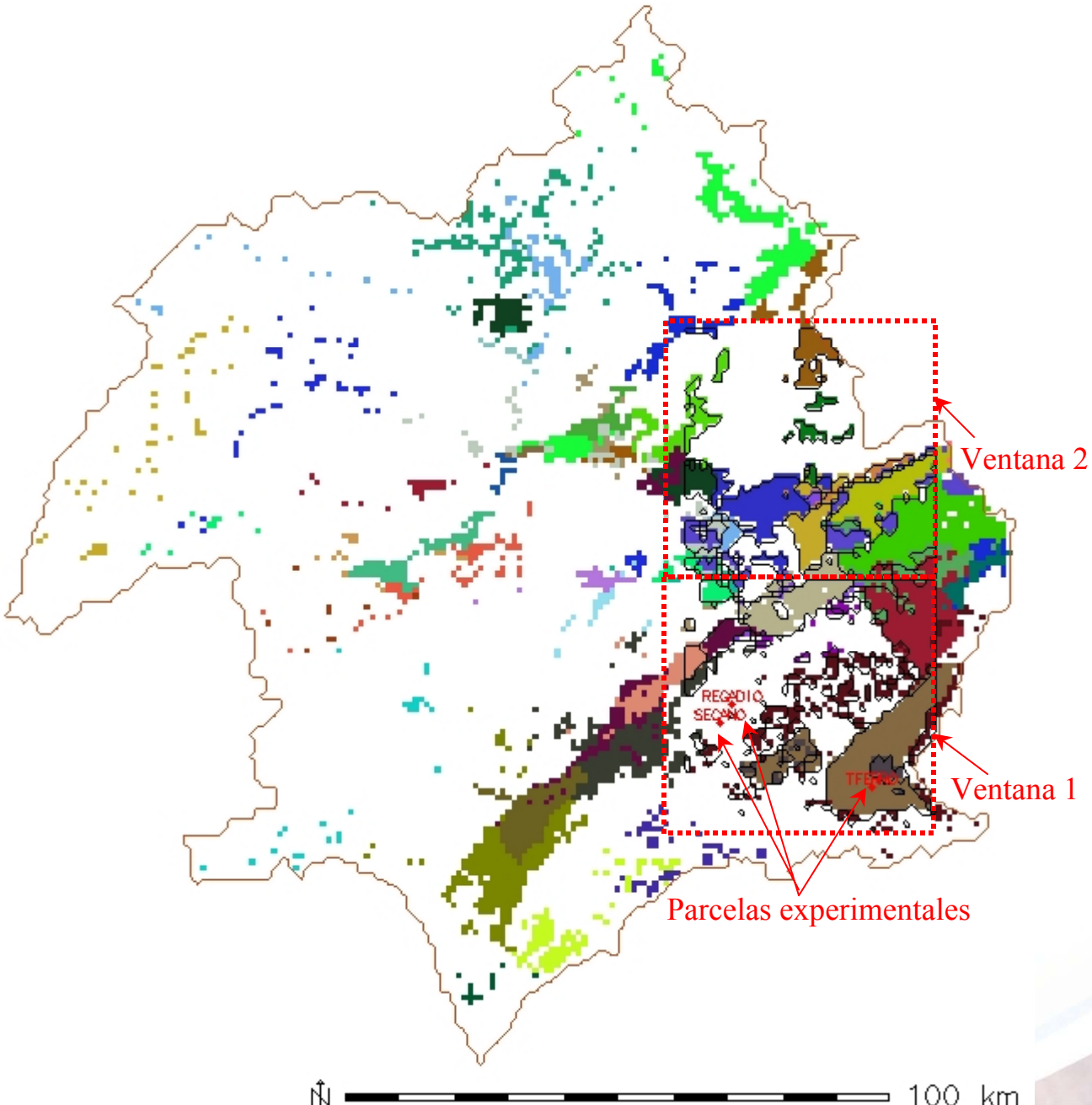
Information to process:

- Satellite images of:

-**Landsat 5 TM** and **SPOT 5** (National Plan of Remote Sensing PNT, Spain) for 2009.

-Additionaly, **MODIS TERRA** images will be included.

- **Irrigation areas**: Polygons of ATS **UDAS** (unit of agricultural demands of Tajo-Segura water transfer) and from SIOSE (uses of soils at national level) dataset
- **Meteorological data**



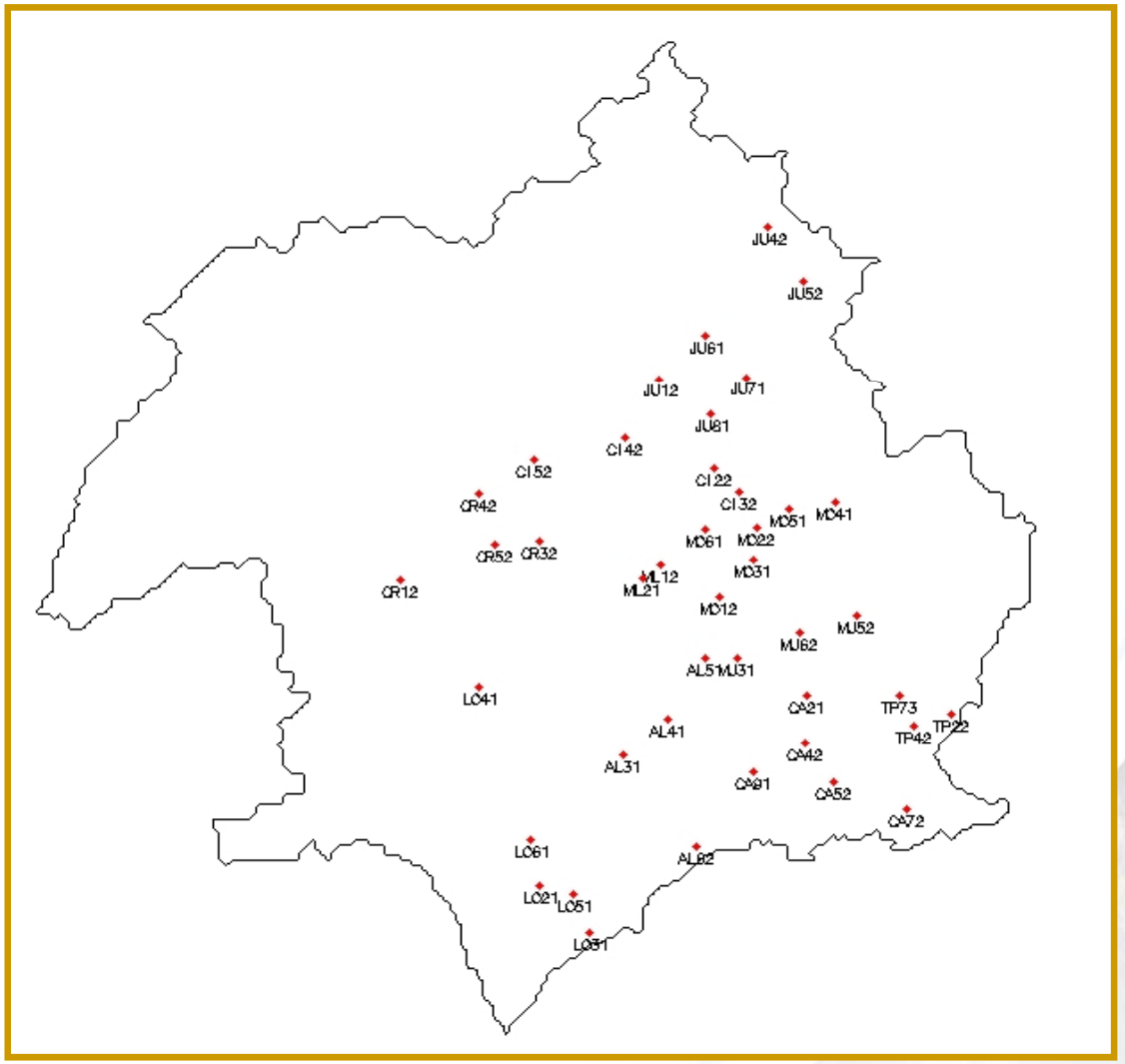
UDAS Areas of agricultural demands (Source: CHS – MIMAM)

-The work will be focus on ATS UDAS-

-However, we will include another sources of information. For example, from SIOSE database.

Processing of information

• 42 **Daily thermometric stations from SIAM (**Servicio Murciano de Información Agraria) of IMIDA, and stations from **AEMET** and **CHS**.



SIAM daily thermometric stations

Methodological aspects

Approaches in the estimation of indexes related with water deficit and water stress in the soil and vegetation:

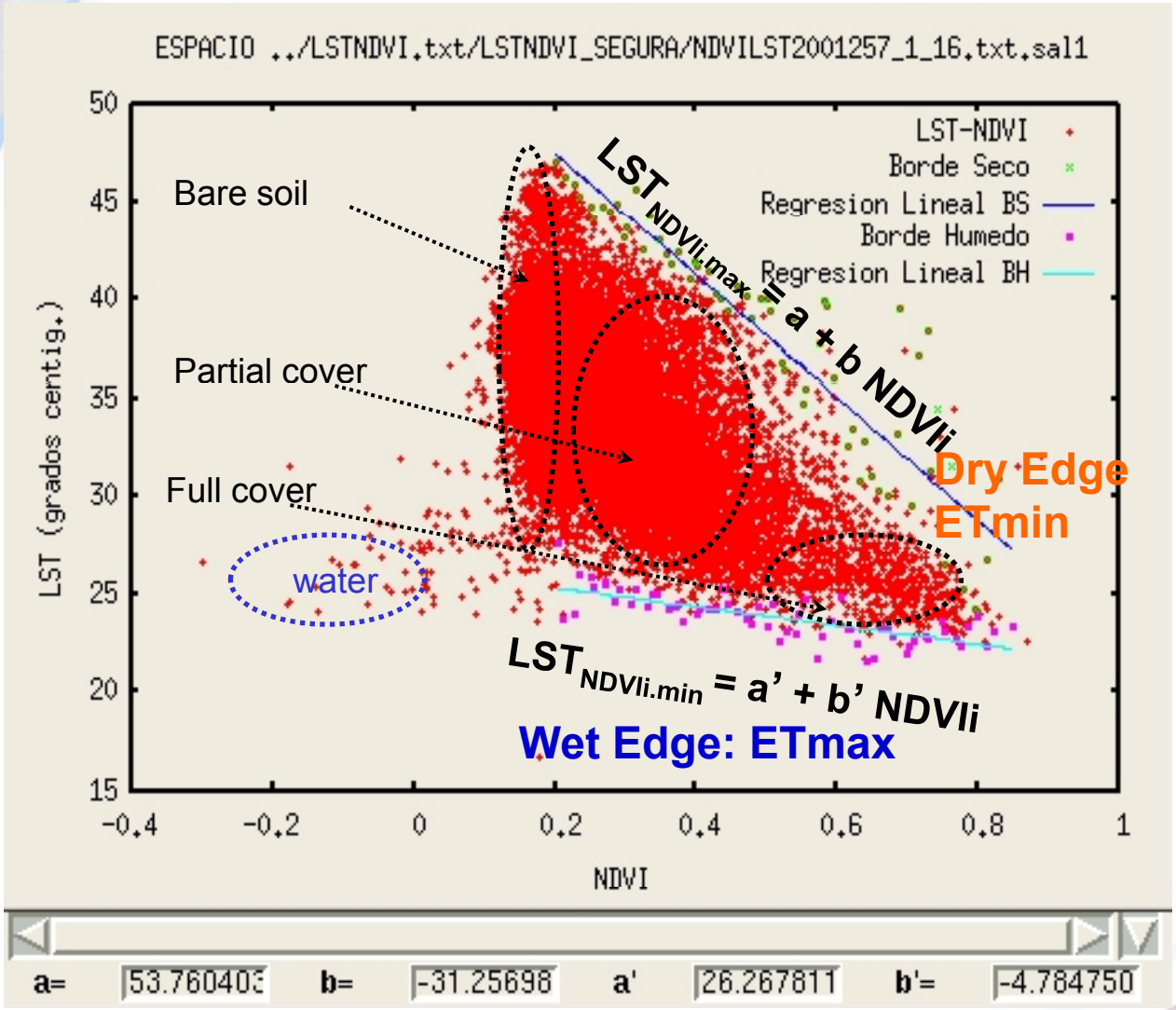
- **Based on remote sensing and meteorological data**
  - Interpretation of land surface temperature (LST) vs NDVI space
  - Interpretation of (LS-Ta) vs NDVI space

- **Based of processes**
  - Modellling of actual evapotranspiration → We will advance in the development of algorithms based on graphic methods, such as the proposed by Jiang e Islam (1999).

  Another, indicators will be integrated.

Methodological aspects

Interpretation of Land Surface Temperature (LST) vs NDVI space



Triangle
- TVDI
- VTCI

Trapezoid
- WDI

14/09/01-29/09/01 (2001257) time period. Segura River Basin

TVDI Temperature Vegetation Dryness Index

TVDI, inversely correlated to soil moisture, is expressed based on Sandholt *et al.* (2002), as:

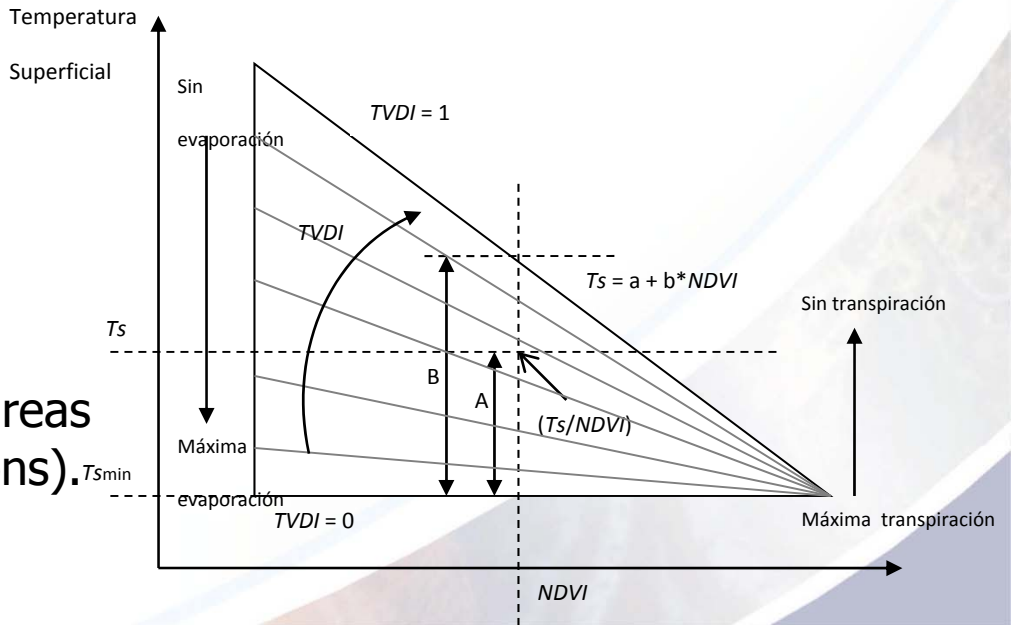
$$TVDI = \frac{LST_{NDVIi} - LST_{NDVIi.\min}}{LST_{NDVIi.\max} - LST_{NDVIi.\min}}$$

Modified equation

where:

$LST_{NDVIi.\max}$ = "dry edge" EVTmin (dry areas)

$LST_{NDVIi.\min}$ = "wet edge", EVTmax (areas without water restrictions).



WDI Water Deficit Index

- WDI can be applied to semiarid areas with mix of surfaces.
- Cuantifies the relative rate of latent flux. Correlated with soil moisture (0 value: surfaces completely wetted. 1 value: dry surfaces).
- According to Verstraeten *et al.*, 2001:

$$WDI = \frac{\Delta LST_{NDVIi.\min} - \Delta LST_{NDVIi}}{\Delta LST_{NDVIi.\min} - \Delta LST_{NDVIi.\max}}$$

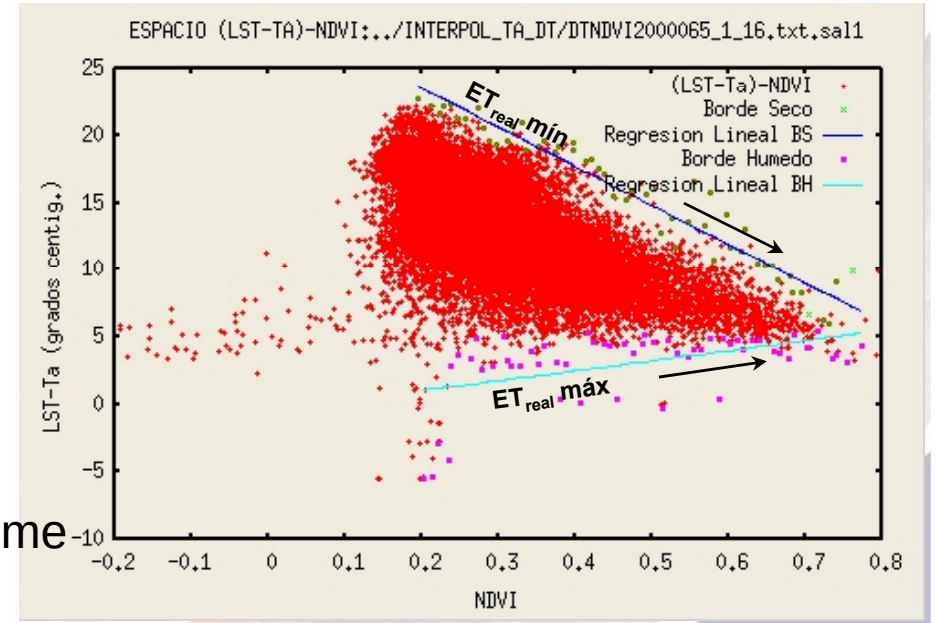
$$\Delta \mathrm{LSTi} = LSTi - T_{\mathrm{ai}}$$

$$\Delta LST_{NDVIi.\max} = a + bNDVIi$$

Dry edge or Minima ET_{real}

$$\Delta LST_{NDVIi.\min} = a' + b'NDVIi$$

Wet edge or Maxima ET_{real}



05/03/00 – 20/03/00 time period. Segura River Basin

VTCI Vegetation-Temperature Condition Index

Proposed by Wang *et al*. (2001), is defined as:

$$VTCI = \frac{LST_{NDVIi.\max} + LST_{NDVIi}}{LST_{NDVIi.\max} - LST_{NDVIi.\min}}$$

Below, IMIDA-UPCT Agreement (March-Sept/2010), another indexes will be analysed. The estimation of actual evapotranspiration will be assessed.

Processing of information

Meteorological data

Remote sensing data

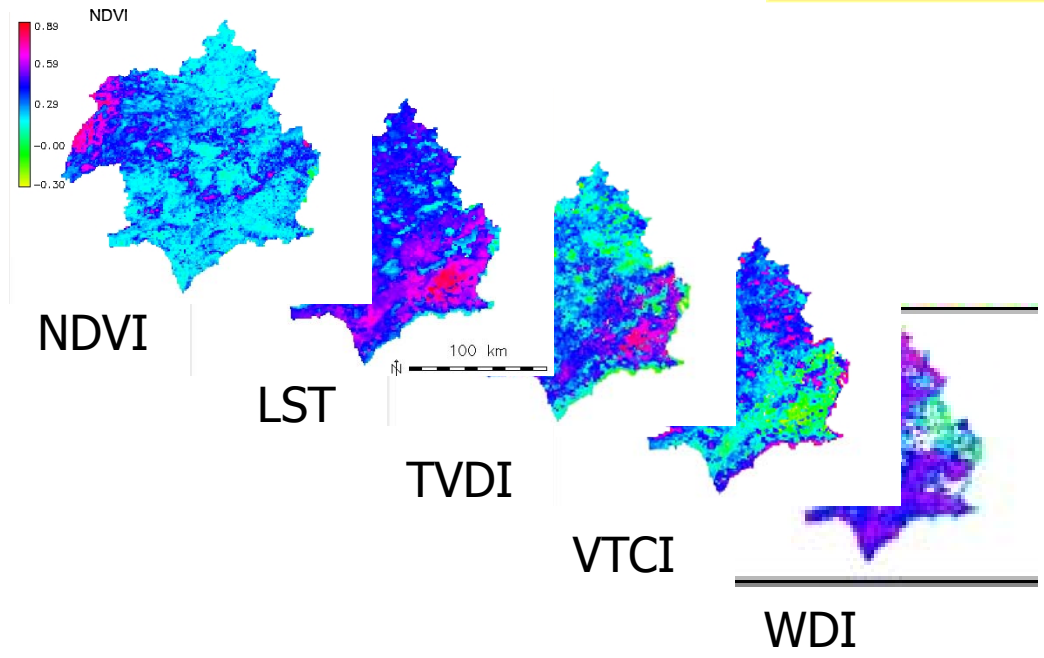
GRASS Geographical Resources Analysis Support System

$$VTCI = \frac{LST_{NDVIi.max} + LST_{NDVIi}}{LST_{NDVIi.max} - LST_{NDVIi.min}}$$

$$WDI = \frac{\Delta LST_{NDVIi.min} - \Delta LST_{NDVIi}}{\Delta LST_{NDVIi.min} - \Delta LST_{NDVIi.max}}$$

$$LST_{NDVIi\min} = a' + b'NDVIi$$

$$TVDI = \frac{LST_{NDVIi} - LST_{NDVIi.min}}{LST_{NDVIi.max} - LST_{NDVIi.min}}$$



NDVI

LST

TVDI

VTCI

WDI

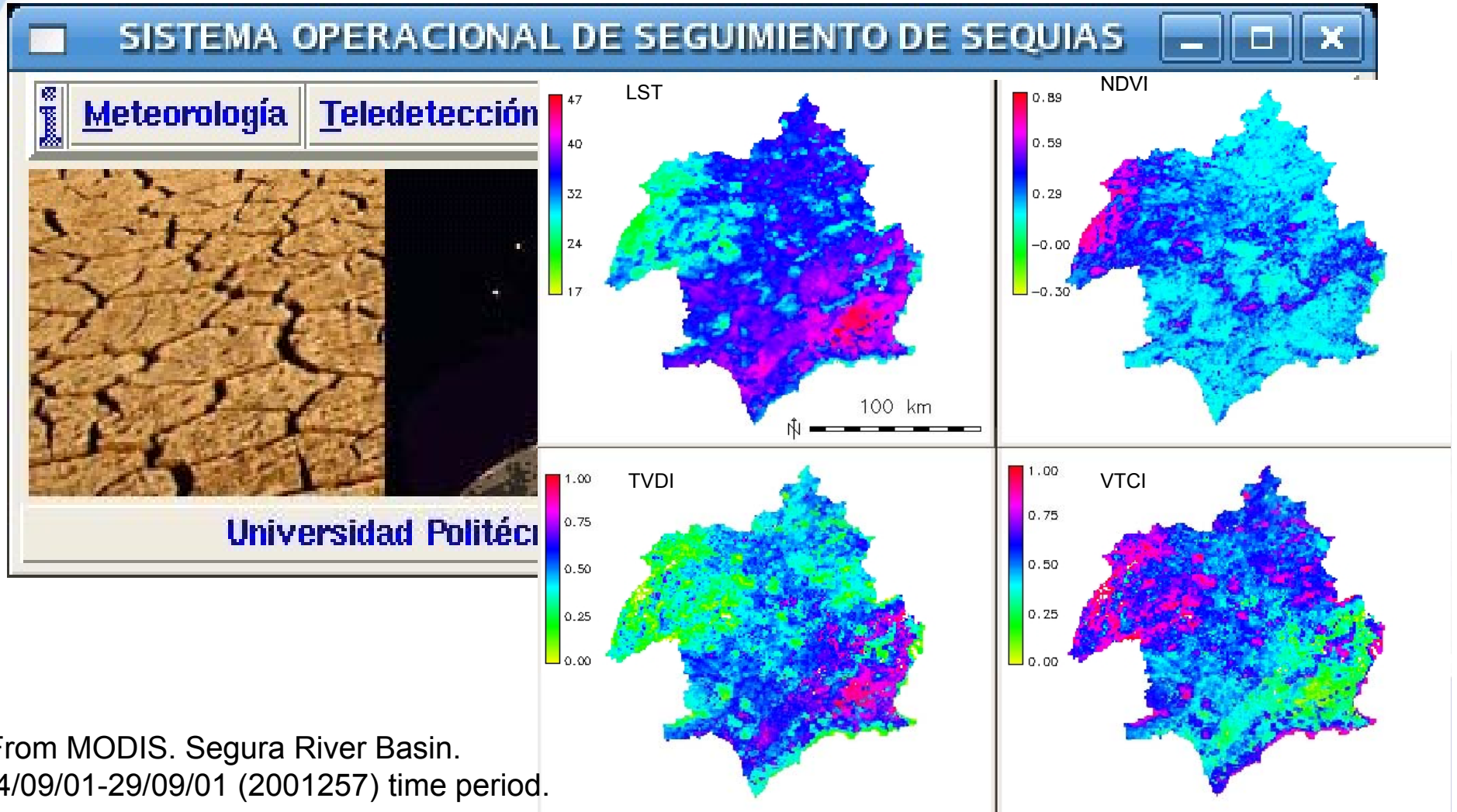
...

SORPRESA System

Spatiotemporal distributions

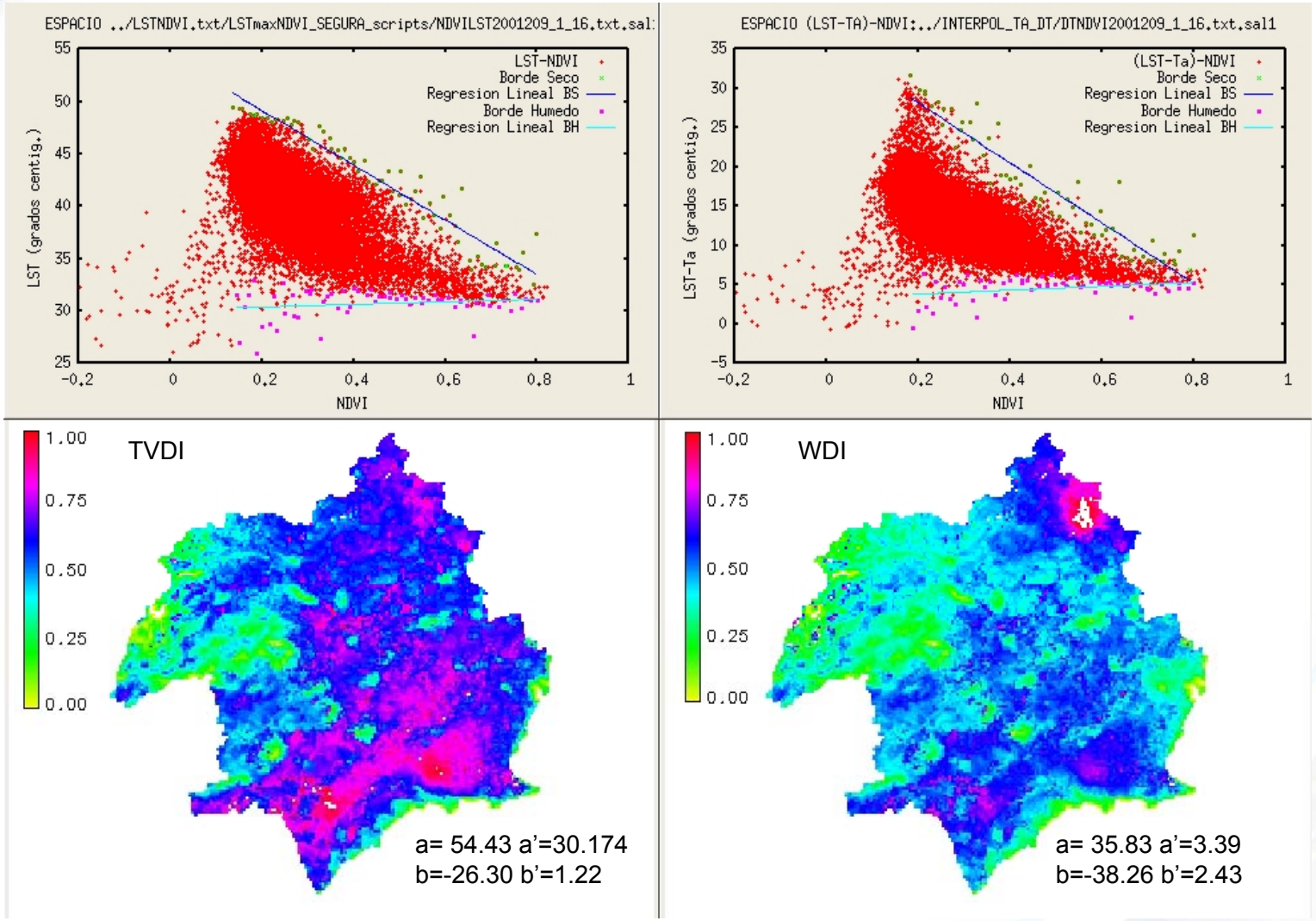
SORPRESA System (García et al., 2006)

GRASS GIS **TCL/TK** **C language**



From MODIS. Segura River Basin.
14/09/01-29/09/01 (2001257) time period.

Some examples of results from MODIS



LST-NDVI and ΔLST-NDVI spaces. Spatial distributions of TVDI and WDI. 28/07/01-12/08/01 (2001209), time period. Segura River Basin. SORPRESA system.

Some examples of results from MODIS

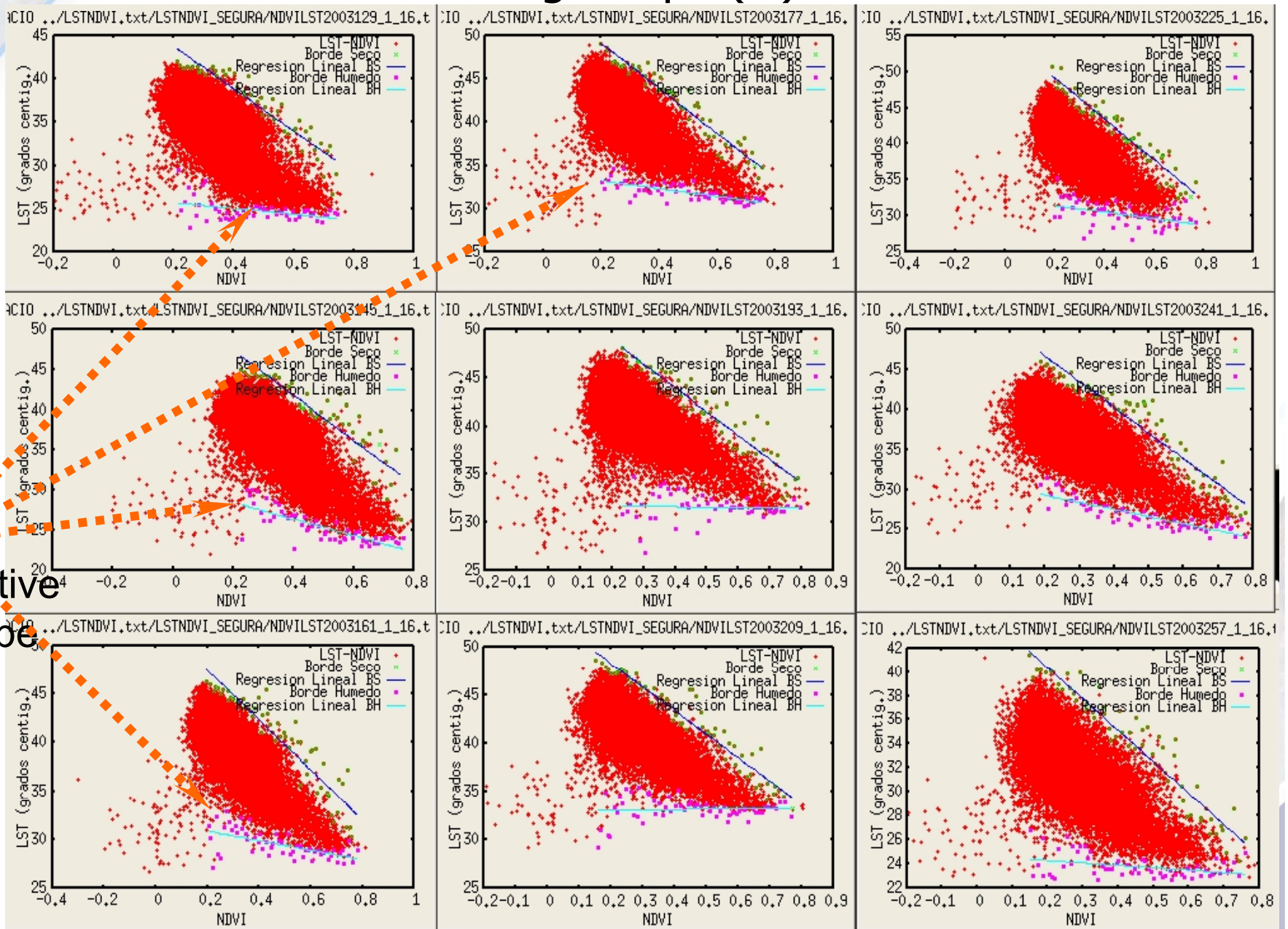
LST-NDVI spaces

From the LST-NDVI spaces, generated for **2000-2006** time period, we can observe:

- The dry edge (b) always presents negative correlation with NDVI
- But the wet edge (b') presents negative or positive correlation with NDVI related with wet or dry conditions, respectively. This behaviour of slope of wet edge (b'), will be evaluated in the framework of TELERIEG from Landsat images.

Year 2003: Time period 129 to 257 (09/05/2003 to 28/09/2003)

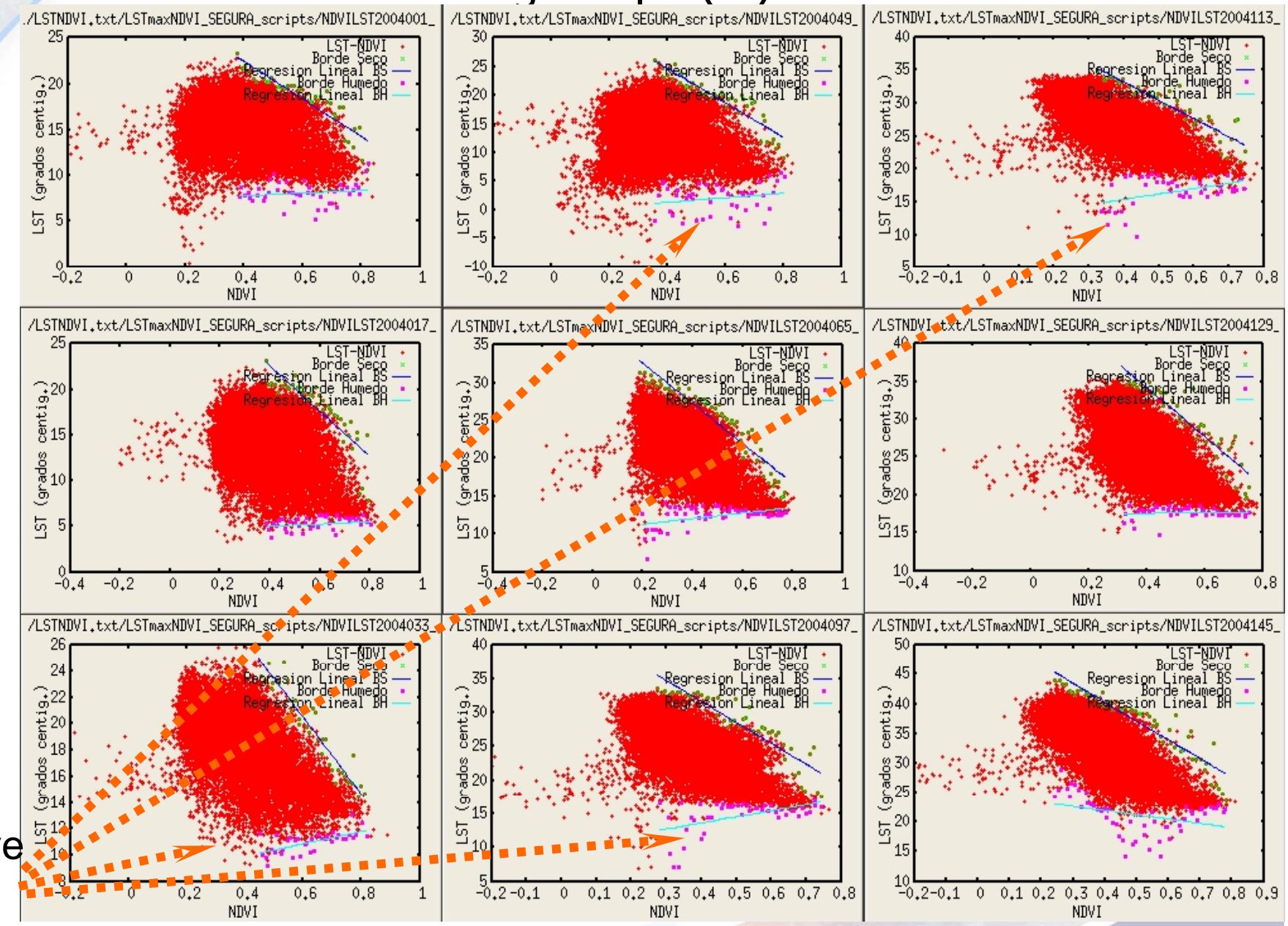
Negative correlations of wet edge slope (b') with NDVI



Negative b' slope

2004 year: Period 001 to 145 (01/01/2004 to 08/06/2004)

Positive correlations of wet edge slope (b') with NDVI

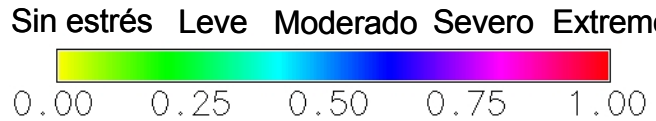


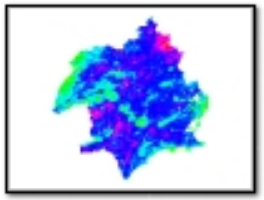
Positive b'

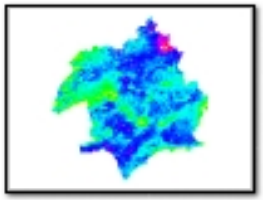
Some examples of spatial results from MODIS

WDI, TVDI and VTCI indexes: between 0 and 1

WDI (2003-04)




WDI2003113_1_16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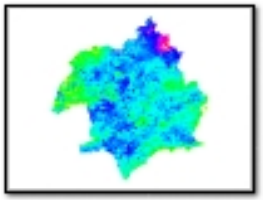
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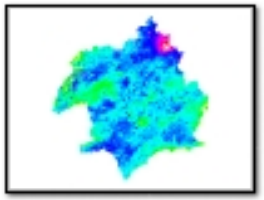
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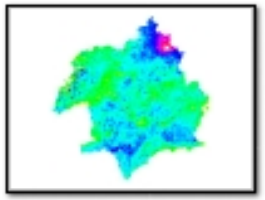
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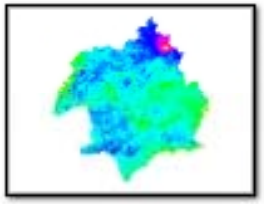
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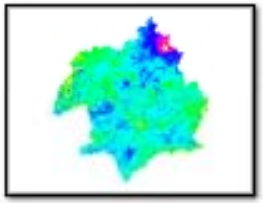
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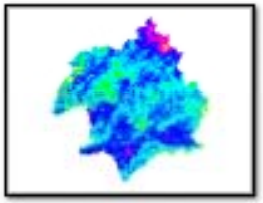
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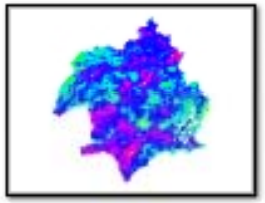
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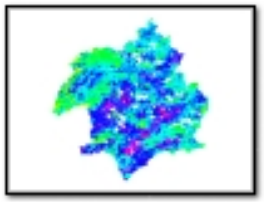
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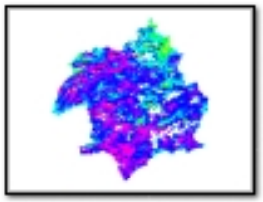
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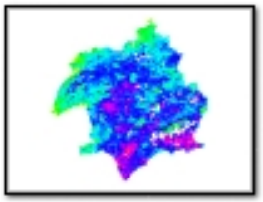
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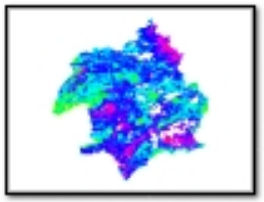
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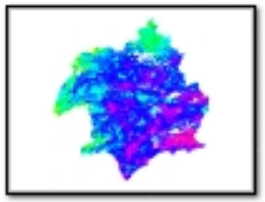
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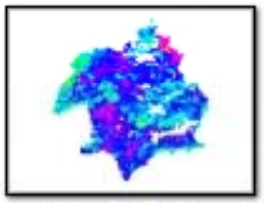
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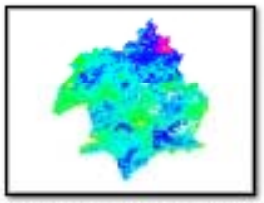
WDI2004081_1_16


WDI2004097_1_16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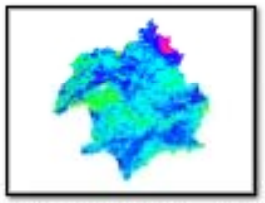
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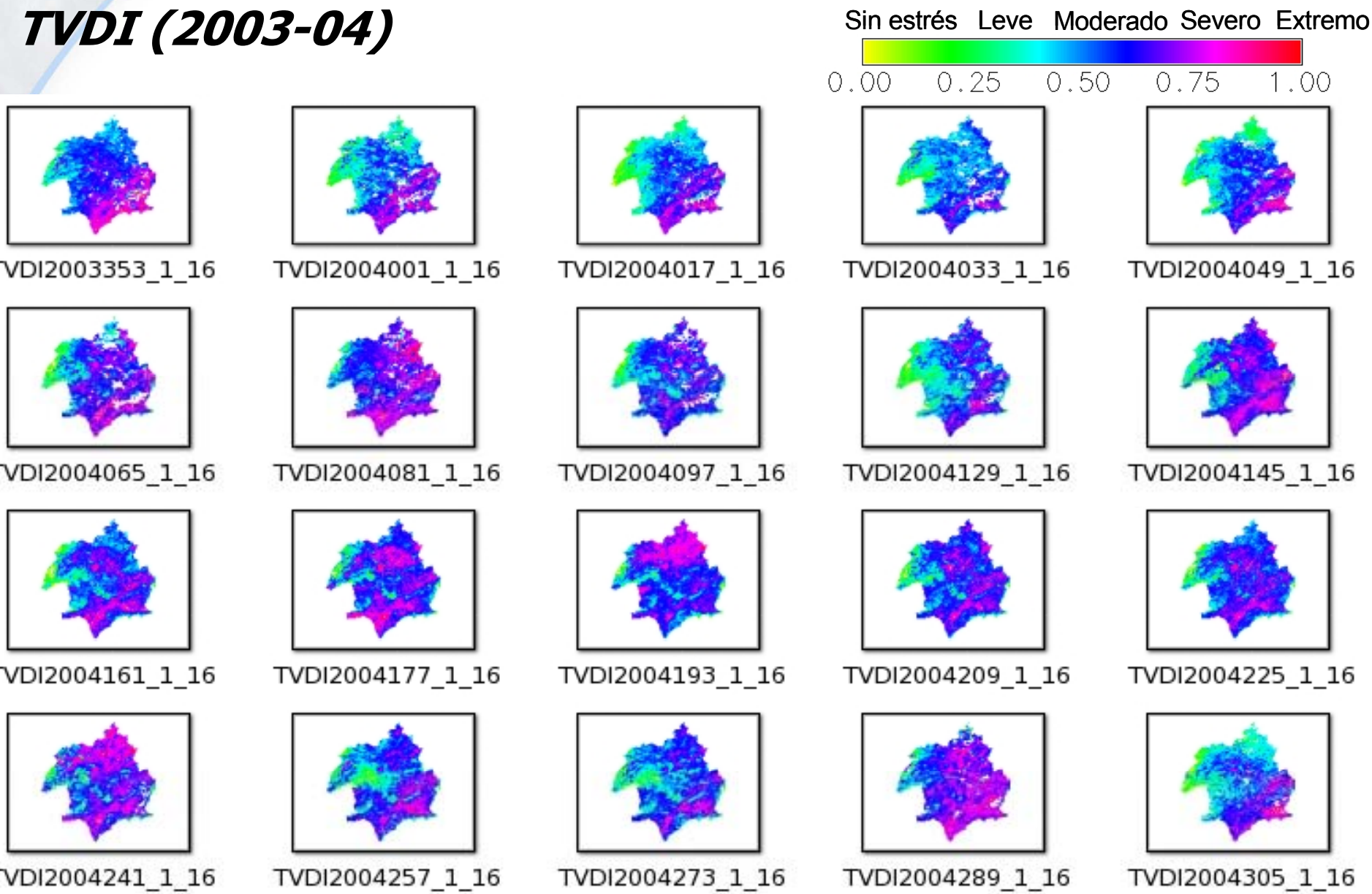
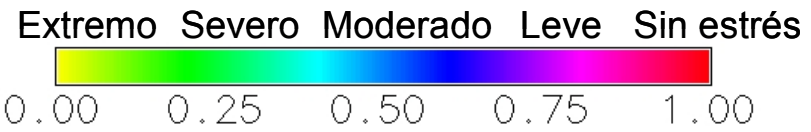
Some examples of results from MODIS

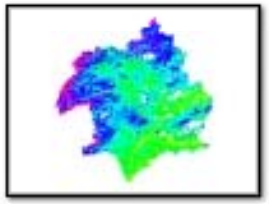
TVDI (2003-04)



Some examples of results from MODIS

VTCI (2003-04)

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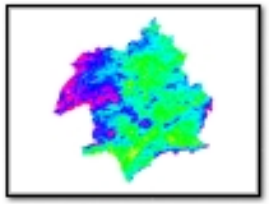
VTCI2003049_1_16


VTCI2003081_1_16


VTCI2003097_1_16


VTCI2003113_1_16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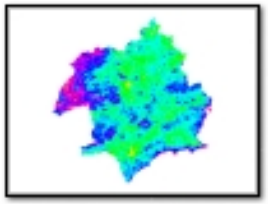
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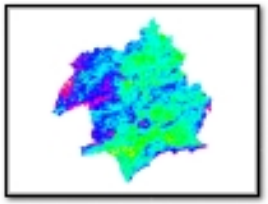
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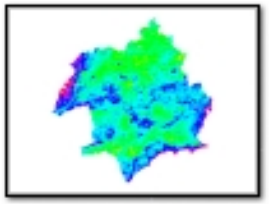
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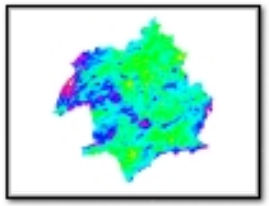
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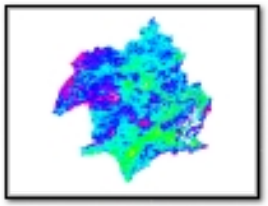
VTCI2003225_1_16


VTCI2003241_1_16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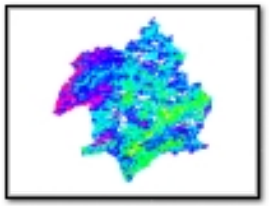
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VTCI2003337_1_16


VTCI2003353_1_16

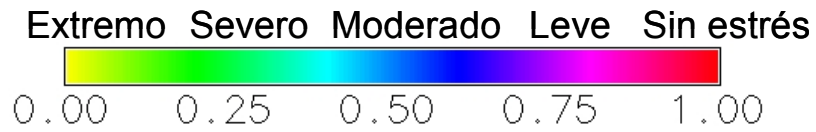

VTCI2004001_1_16


VTCI2004017_1_16


VTCI2004033_1_16

Some examples of results from MODIS

VTCI (2004-2005)




VTCI2004049_1_16


VTCI2004065_1_16


VTCI2004081_1_16


VTCI2004097_1_16


VTCI2004129_1_16

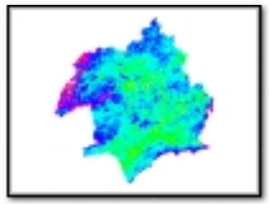

VTCI2004145_1_16


VTCI2004161_1_16


VTCI2004177_1_16


VTCI2004193_1_16


VTCI2004209_1_16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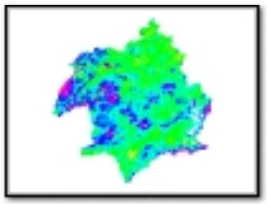
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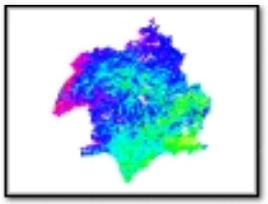
VTCI2004257_1_16


VTCI2004273_1_16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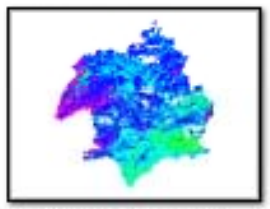
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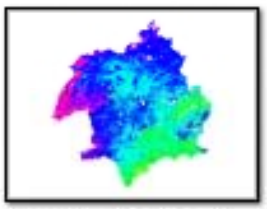
VTCI2004337_1_16


VTCI2004353_1_16


VTCI2005273_1_16


VTCI2005289_1_16

Present and future lines of work

At the present time, we are working with Landsat and SPOT satellite images in contrast with irrigations areas (from UDAS and SIOSE spatial dataset).

The RCMs from ENSEMBLE EU Project and observed rainfall data, will be analysed for the Region in order to assess the projected impacts on hydrometeorological events.

Acknowledgments:

The firsts works in the development of SORPRESA system, were made in the framework of R&D Project between UPCT and General Deputy of Water (Ministry of Environment of Spain): "*Development of a Early warning of droughts for the Jucar and Segura River Basins".* The financial support from TELERIEG-SUDOE EU Project is apreciated.

Thanks for your attention !