Seminario

La gestione delle risorse idriche nel bacino del Mediterraneo: il sapere dei docenti e l'esperienza dell'ICU in Giordania, Libano e Tunisia

Aula Magna "Orabona", Politecnico di Bari, 29 maggio 2014

Le risorse idriche nei bacini a clima Mediterraneo

V. Iacobellis

Acknowledgement

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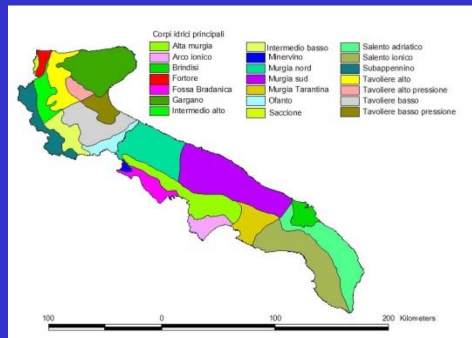
- *Giuseppe Satalino*, ISSIA - CNR, Bari;
- *Pamela Milella, AdBP*
- *Murugesu Sivapalan , Univ WA*

Bilancio Idrico - Hydraulic water balance

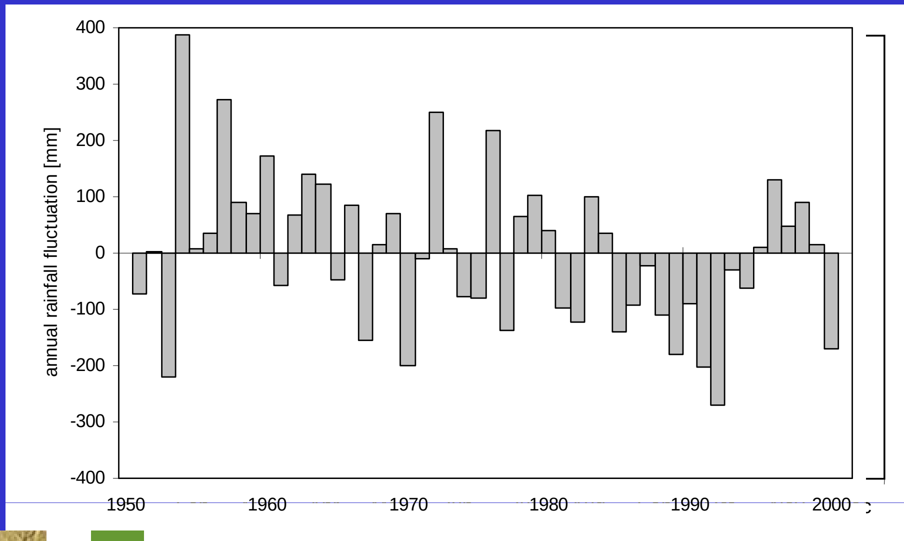
- **Confronto tra Fabbisogni e Disponibilità**

  - Acque superficiali
  - Acque sotterranee
  - Sorgenti
  - Grandi invasi
  - Traverse



Bilancio Idrologico
incertezza e meccanismi di controllo

- **Caratteristiche climatiche**
- **Criticità dell'approvvigio-namento idrico**
- **Tutela dell'ambiente dalle pressioni antropiche**



BioR del bosco sclerofilo o tipico

BioR del bosco ceduo

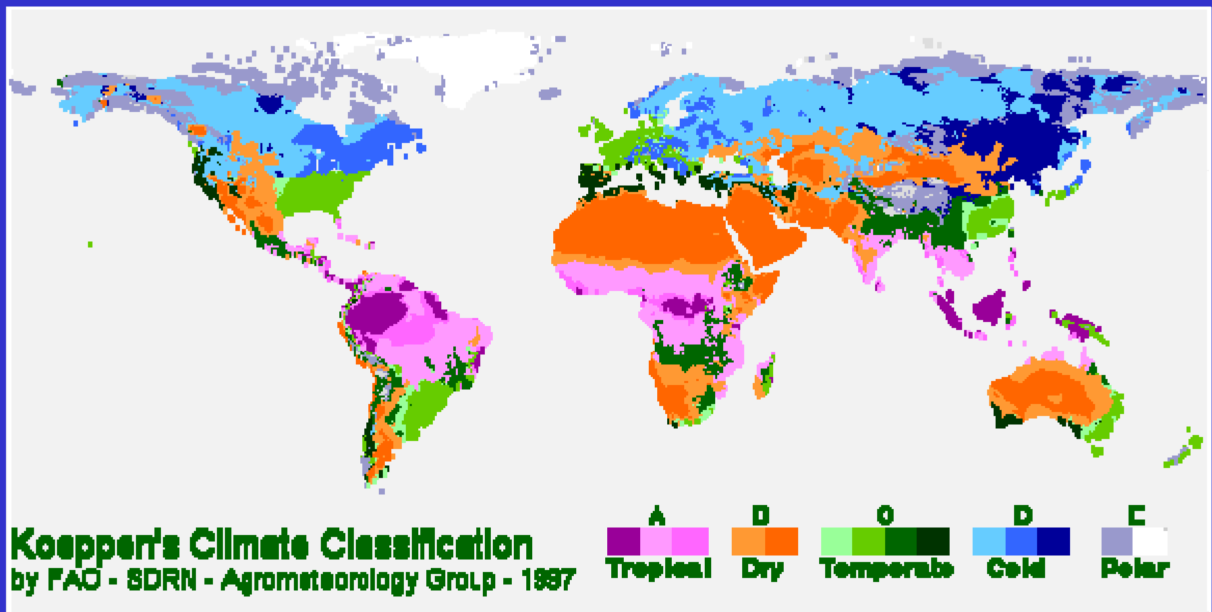
BioR della steppa fredda

BioR Sahariana

BioR del sub-deserto freddo

Mediterranean Climate

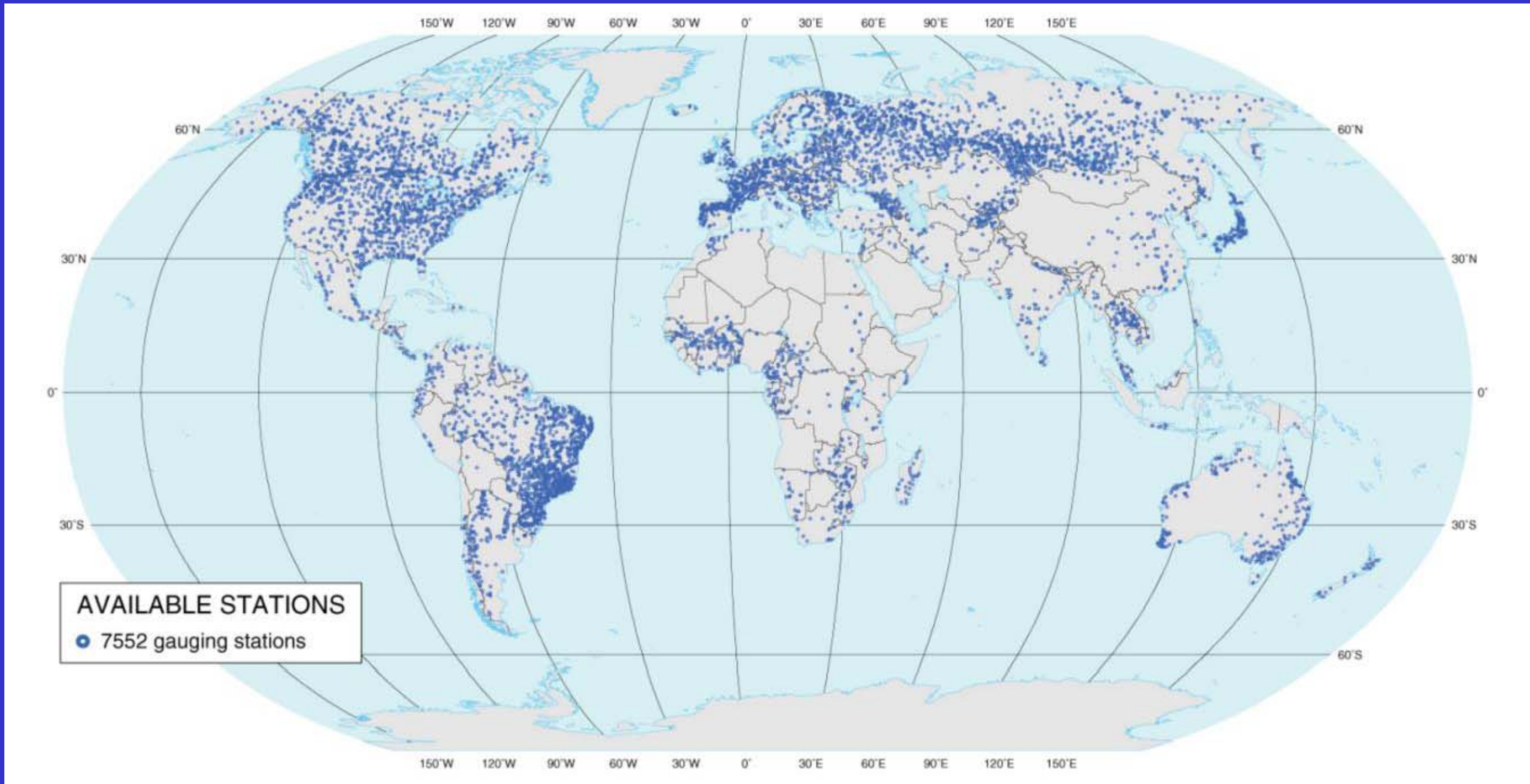
As "Mediterranean" we may identify a large hydroclimatic area rather than only a geographical zone.



Mediterranean Climate

As "Mediterranean" we may identify a large hydroclimatic area rather than only a geographical zone.
Looking at climatic signatures we can count in the world up to five areas, Mediterranean basins, California, western South Africa, central Chile, and South - Western Australia.

Flood monitoring



relatively poor density of gauging stations

Herold and Mouton (HESSD, 2011)

Flood monitoring

relatively poor density of gauging stations

Herold and Mouton (HESSD, 2011)

What is an Ungauged Basin?

- An ungauged basin is one with inadequate records (in terms of both data quantity and quality) of hydrological observations to enable computation of hydrological variables of interest (both water quantity or quality) at the appropriate spatial and temporal scales, and to the accuracy acceptable for practical applications.

- For example, if the variable of interest has not been measured at the required resolution or for the length of period required for predictions or for model calibration, the basin would be classified as ungauged with respect to this variable. Variables of interest can be, for example, precipitation, runoff, erosion rates, sediment concentrations in streamflow, etc., so every basin is “ungauged” in some respect.

IAHS Decade on PUB

INTERNATIONAL ASSOCIATION OF HYDROLOGICAL SCIENCES

IAHS Decade on Predictions in Ungauged Basins (PUB): 2003-2012

PUB Science and Implementation Plan

OBJECTIVES of the IAHS Decade on PUB

1. Advance the ability of hydrologists worldwide to predict the fluxes of water and associated constituents from ungauged basins, along with estimates of the uncertainty of predictions;

2. Advance the knowledge and understanding of climatic and landscape controls on hydrologic processes occurring at all scales, in order to constrain the uncertainty in hydrologic predictions;

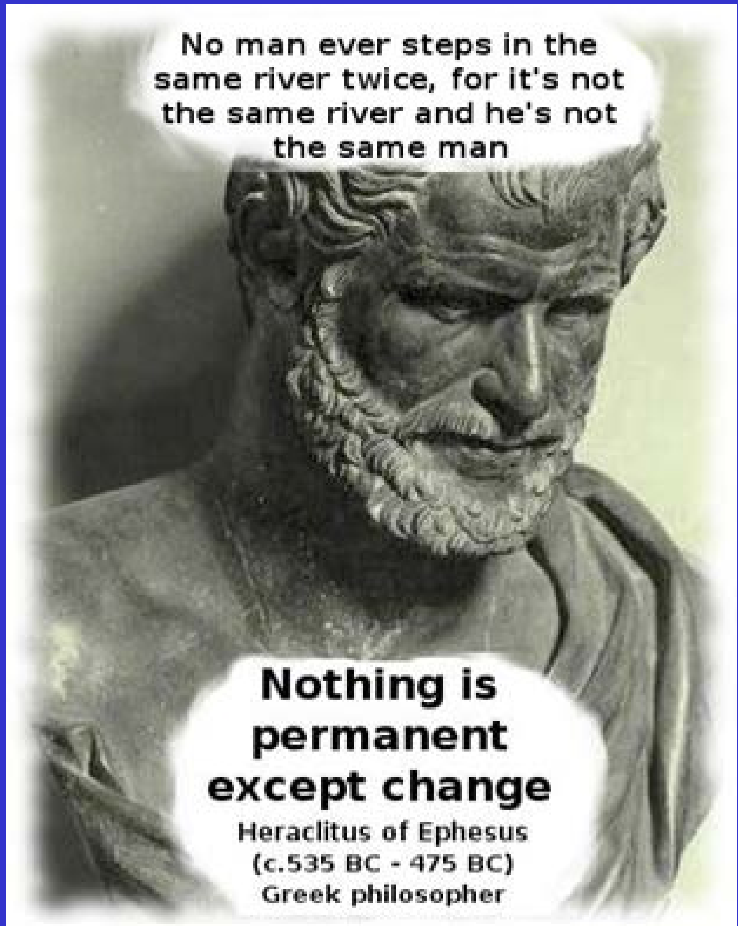
3. Demonstrate the value of data for hydrologic predictions, and provide a rational basis for future data acquisitions, including alternative data sources, by quantifying the links between data and predictive uncertainty;

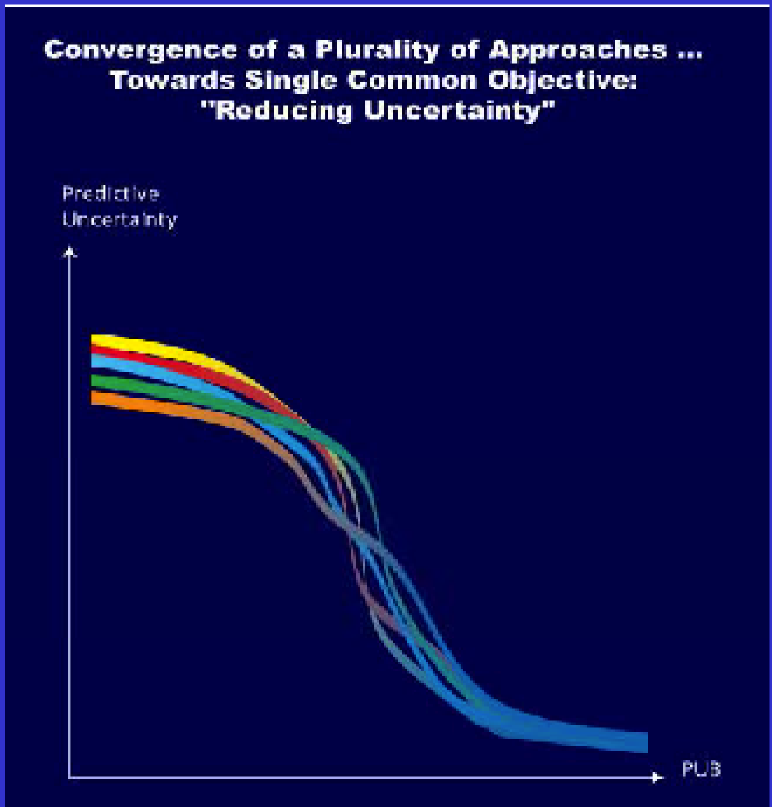
4. Advance the scientific foundations of hydrology, and provide a scientific basis for sustainable river basin management.

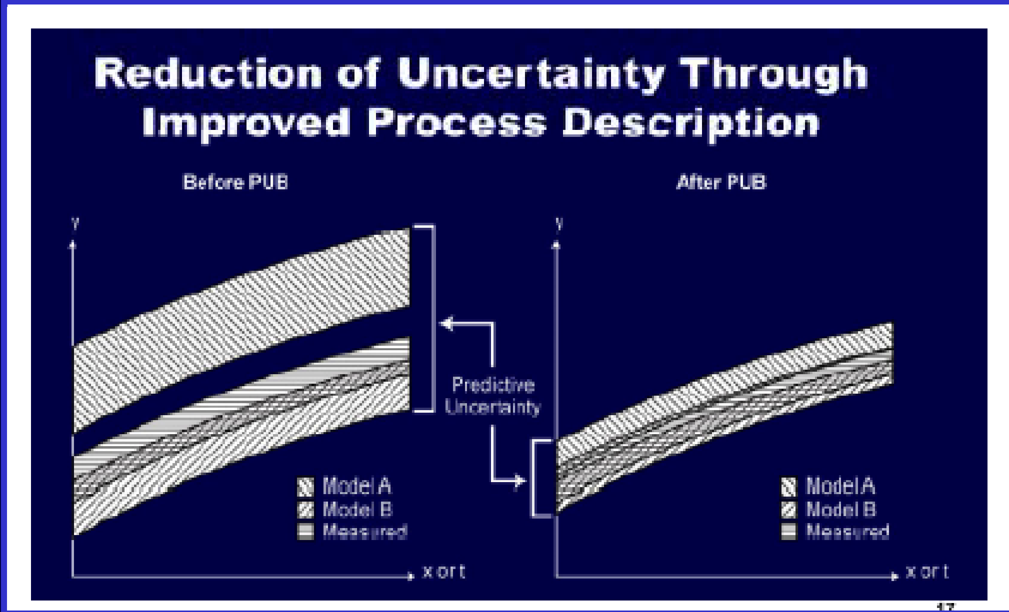
5. Actively promote capacity building activities in the development of appropriate scientific knowledge and technology to areas and communities where it is needed.

IAHS Science Plan for the decade 2013-2022

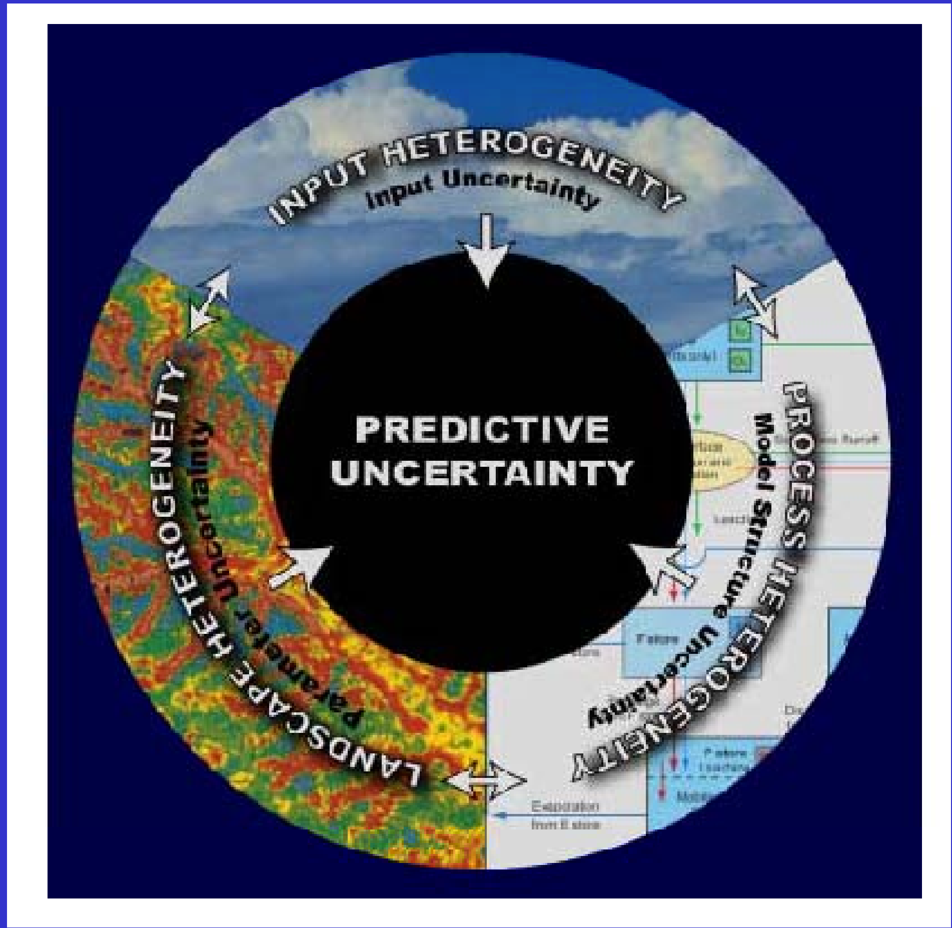
Panta Rhei



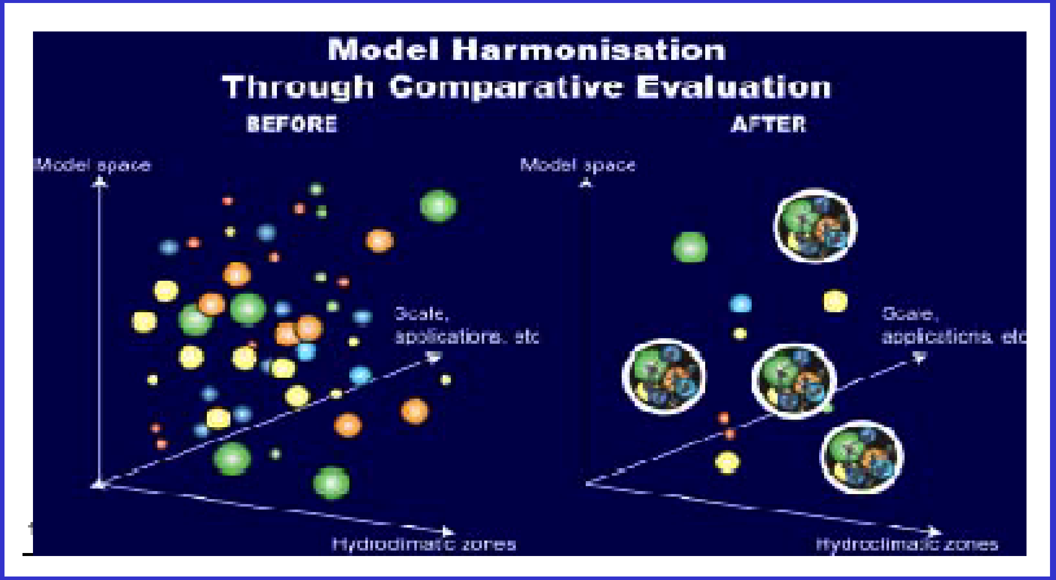

Convergence of a Plurality of Approaches ...
Towards Single Common Objective:
"Reducing Uncertainty"
Predictive
Uncertainty
PUB


Reduction of Uncertainty Through
Improved Process Description
Before PUB
After PUB
y
Predictive
Uncertainty
Model A
Model B
Measured
x or t

About heterogeneity and uncertainty



PUB recognize the need of investigating the plurality of hydroclimatic zones existing around the world.



The role of the "geographical" working groups is to accomplish the PUB core research targets cutting across all the enabling research programmes with the general intent of constraining the predictive uncertainties making the best use of the available information and learning from a comparative evaluation of a variety of models applied to selected basins.

MEDCLUB

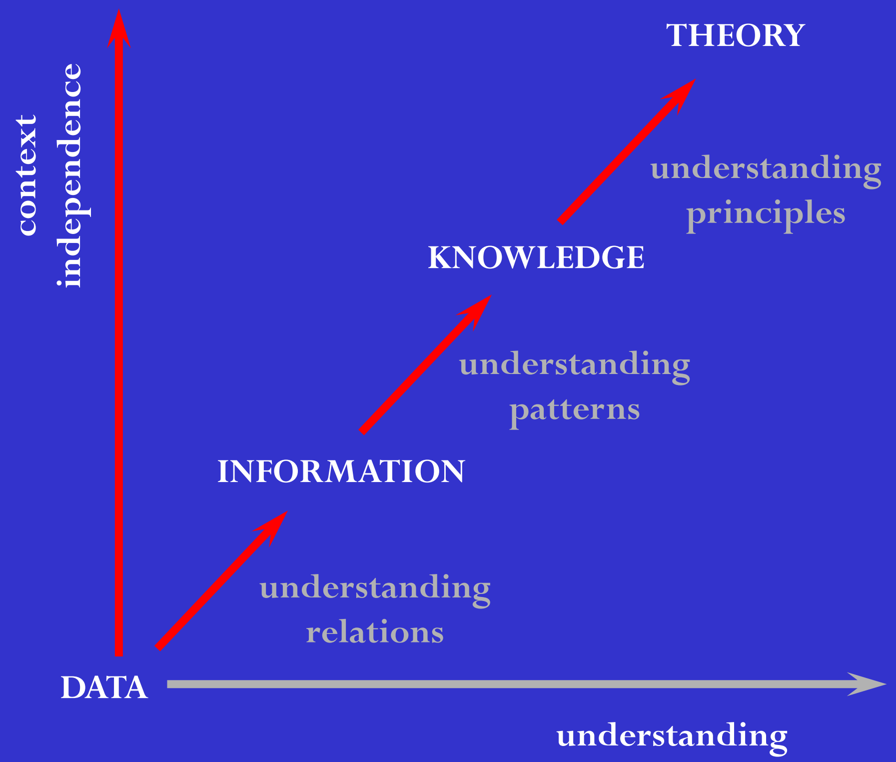
MEDiterranean CLimate Ungauged Basins

MEDCLUB mainly focus on field experiments at basin scale for the analysis of the Climate-Soil-Vegetation dynamics and their impact on hydrological processes and extremes and will work with the aim of

recognizing, within a Mediterranean context:

1) dominant or controlling processes at different scales,
2) the role of ecological functioning and human impact on hydrological basins and associated ecosystems,
3) classification of model performance in terms of time and space scales, local climate, data requirements and type of application.

Continuous learning process



Scientific questions…

1 **"What are the gaps in our knowledge limiting reliable predictions in ungauged catchments?"**

-Regional analysis as a MEDCLUB starting line-

2 **"What are the information requirements to reduce predictive uncertainty?"**

-The role of climate-soil-vegetation dynamics-

3 **"What experimentation is needed to ubderpin the new knowledge required?"**

-candidate basins for field experiments-

4 **"How can we employ new observational technologies in improved predictive methods?"**

-Link between CSV dynamics and field experiments-

5 **"How can we improve the hydrological process descriptions in order to reduce uncertainty?"**

-Advancing process description through comparative evaluation of models-

6 **"How can we maximise the scientific value of available data in generating improved prediction?"**

-Connecting new information to patterns that we already understand-

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1) What are the gaps in our knowledge limiting reliable predictions in ungauged catchments?
Regional analysis as a MEDCLUB starting line.

- Current best performing methods in terms of accuracy of prediction of extremes are still those based on statistic, regional analyses (e.g. Rossi and Villani, 1998). These methods are also generally based on the hypotheses of process stationarity and statistical homogeneity of climatic and physiographic variables.

- The problem of the not-uniqueness solution in the estimation of parameters and in the identification of models imply the need of methodological alternatives to model calibration like objective estimation procedures (Beven and Feyen, 2002);

- Observed processes in Mediterranean areas are characterized by interannual and multidecadal fluctuations that are not easily detectable and the importance of understanding base processes for the extremes evaluation results fundamental in order to account for the dependences and non-linearities that affect the extremes frequency.

Derivation of flood peak statistics

The flood research obtained a remarkable advance with the introduction of theoretically derived probability distributions (Eagleson, 1972), which moved hydrologists from a pure statistical to a more physically based approach. Eagleson showed that the probability distribution of the peak streamflow may be computed by integrating the joint density function $g(i_e,t_e,A_r)$ of the rainfall intensity i_e, rainfall duration t_e and contributing area to the peak flow A_r in the domain $R(q)$ where Q is less than q:

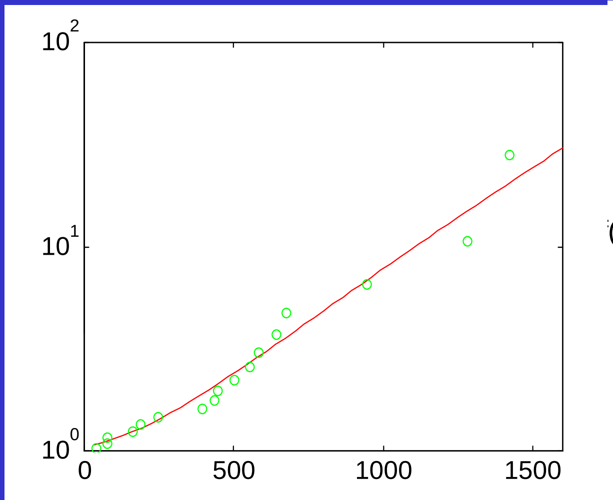
$$G_Q(q) = prob[Q < q] = \iiint_{R(q)} \mathrm{g}(\mathrm{i}_\mathrm{e}, t_e, A_r) d\mathrm{i}_\mathrm{e} dt_\mathrm{e} dA_r$$

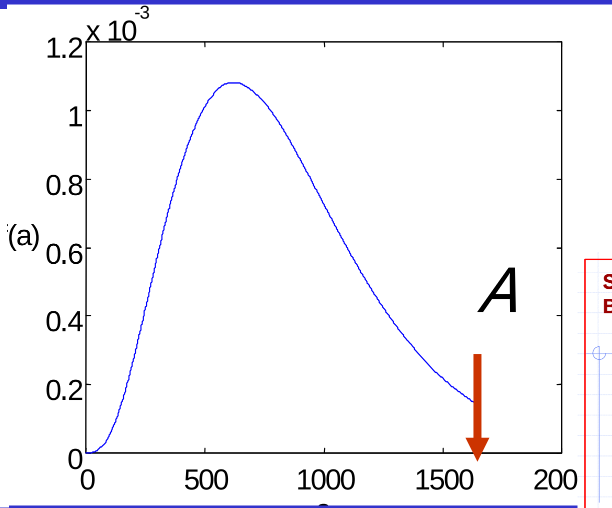
- The model requires assumption on the rainfall stochastic variability;
- Assumption on the infiltration process to define the net precipitation;
- Propagation model to account for network effects.

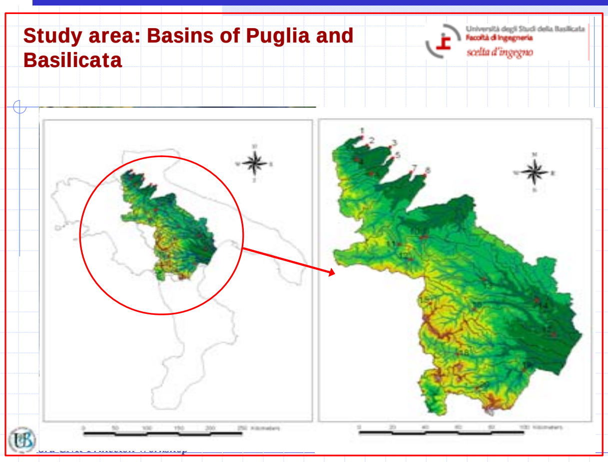
Model consistency: estimated parameters are in the expected range, pdf's of contributing areas are consistent with prevailing runoff generation mechanisms

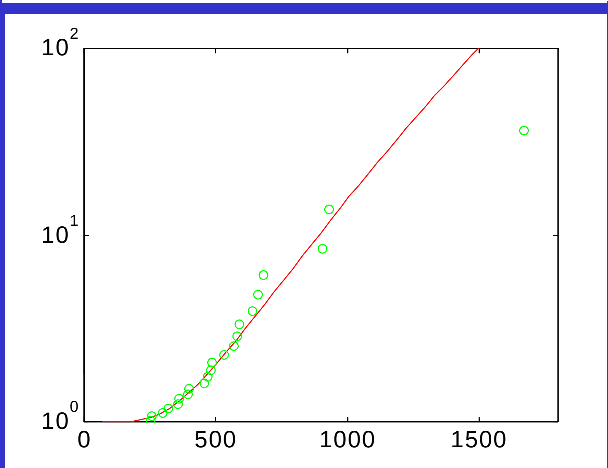
Flood peaks CDFs

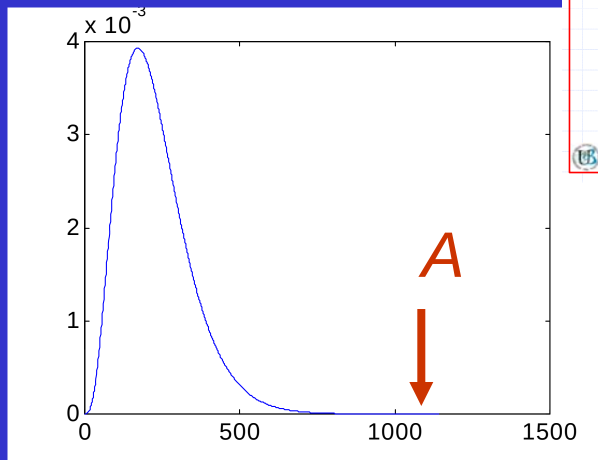
Contributing areas PDFs











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2) "What are the information requirements to reduce predictive uncertainty?"

The role of climate-soil-vegetation dynamics.

The instruments and objects through which MEDCLUB proposes to overwhelm such gaps are:

1) The field experimentation for the analysis of the base processes supported with the use of new observation technologies;

2) The development of models representing controlling processes and the analysis of the impact of such dynamics on base processes and frequency of the extreme events.

Considered process…

1) Soil - Atmosphere Interaction:
Energy budget models for soil and low atmosphere interaction, and the interface with the hydrological models;

2) Analysis of the vegetation dynamics:
Models for the description of growing state or stress of different species of plants, based on the analysis of the biomass variation and species competitiveness;

3) Assessment of the hydrological properties of soils and their representation for distributed models applications.

Storage factor – interazione CSV – processi idrologici

- Clima MEDITERRANEO

→ variabilità, *storminess*,

→ *P* e E_0 in opposizione di fase

- Substrati CARBONATICI → suoli sottili

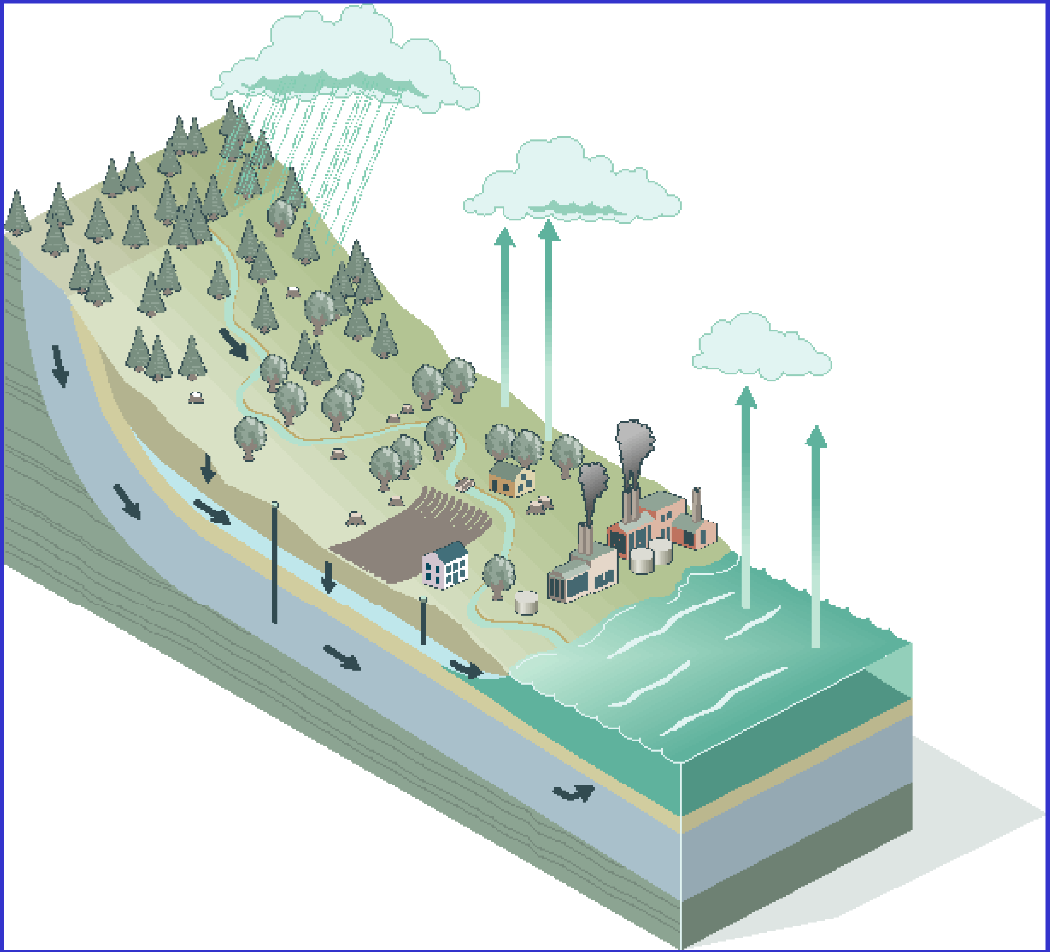
- REGIMI IDROLOGICI

→ regime episodico dei deflussi,

→ perdite idrologiche,

→ deflusso hortoniano

Incertezza e meccanismi di controllo del bilancio idrologico in ambienti semi-aridi mediterranei



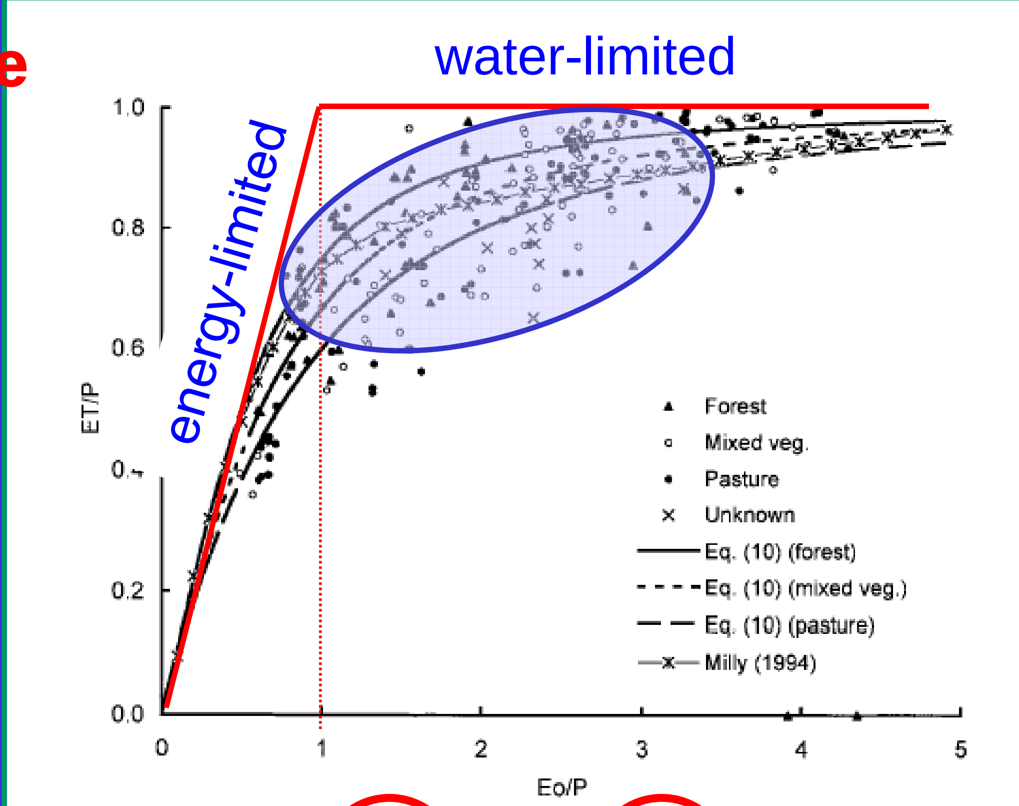
$$Et = P - R - D$$

$$D + R = Y$$

- **Equilibrio tra disponibilità e fabbisogni idrici**
- **Componenti del ciclo idrologico: studio della variabilità spazio-temporale**

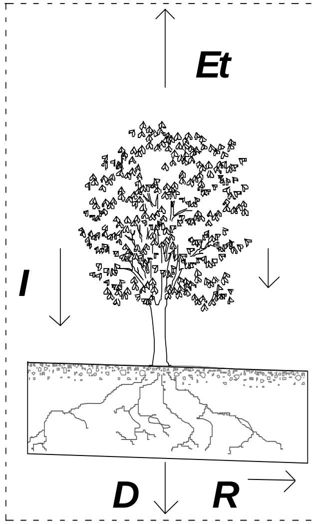
Incertezza e meccanismi di controllo del bilancio idrologico in ambienti semi-aridi mediterranei

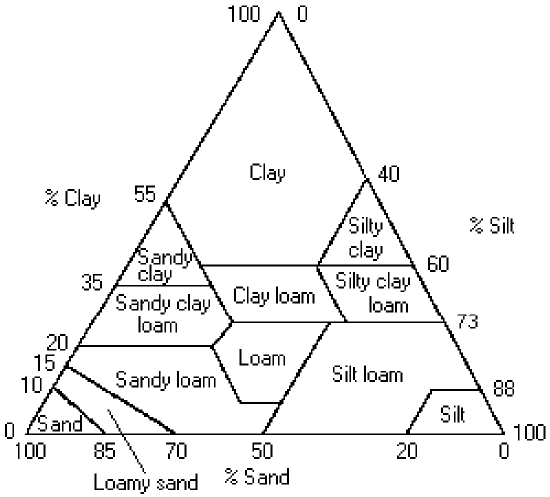
- **Oggetto delle previsioni e modelli previsionali**
- **Variabilità spazio-temporale**
- **Limiti dei metodi statistici**
- **Limiti dei modelli fenomenologici**
- **Limiti di scala degli approcci sperimentali**

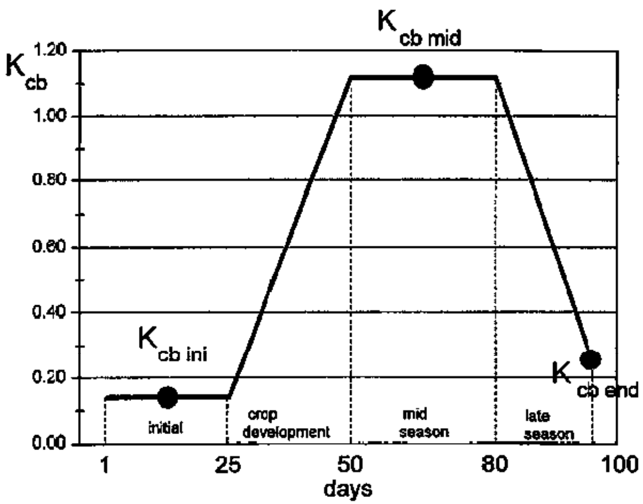


$E_0 > P \rightarrow Et >> Y, Y >> R$

Approccio capacitivo per il bilancio idrico del suolo *(ad es. Rodriguez-Iturbe, Proc. Ryl Soc. Lnd 1999; Milly, WRR 1994; Farmer et al., WRR 2003)*

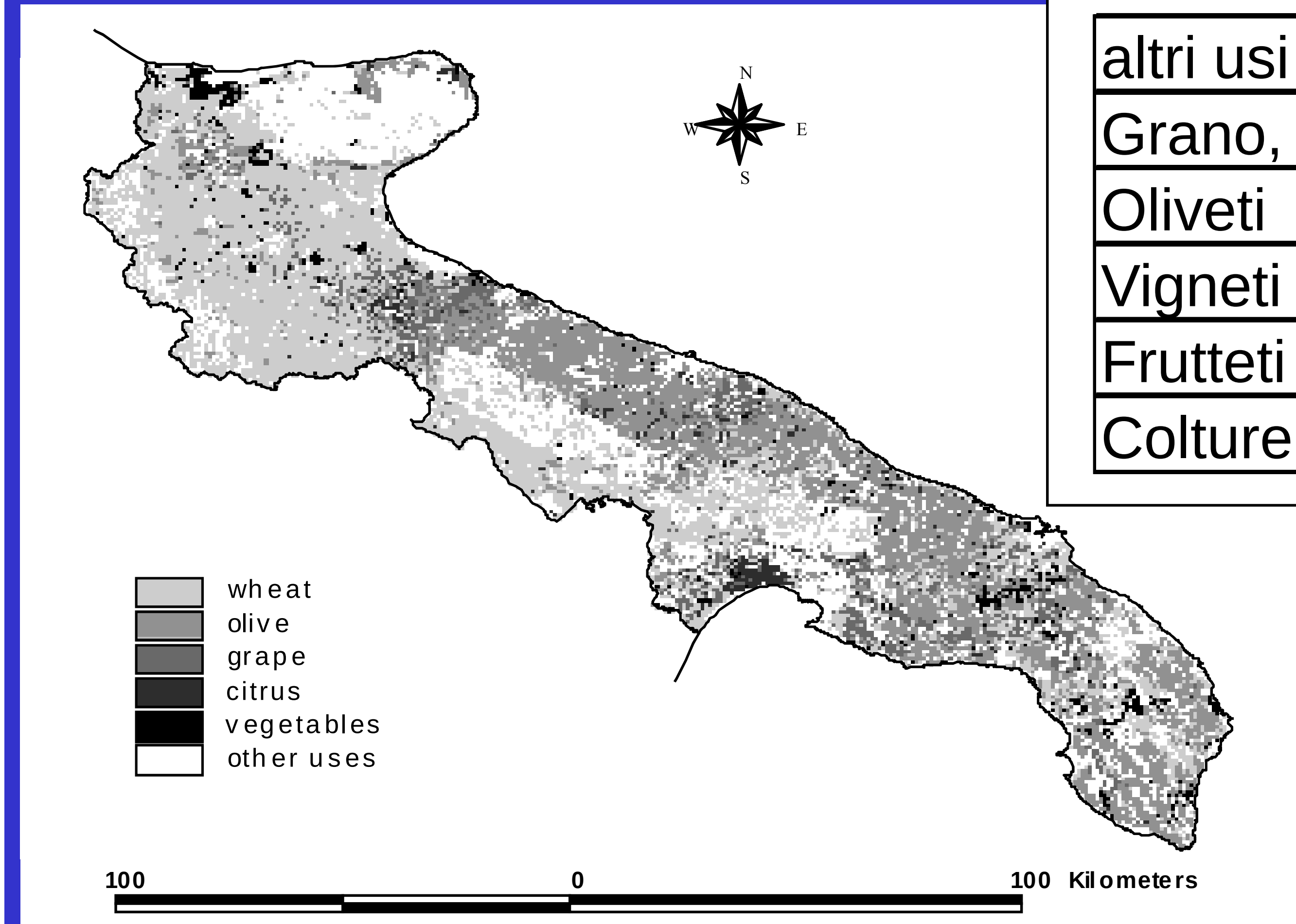




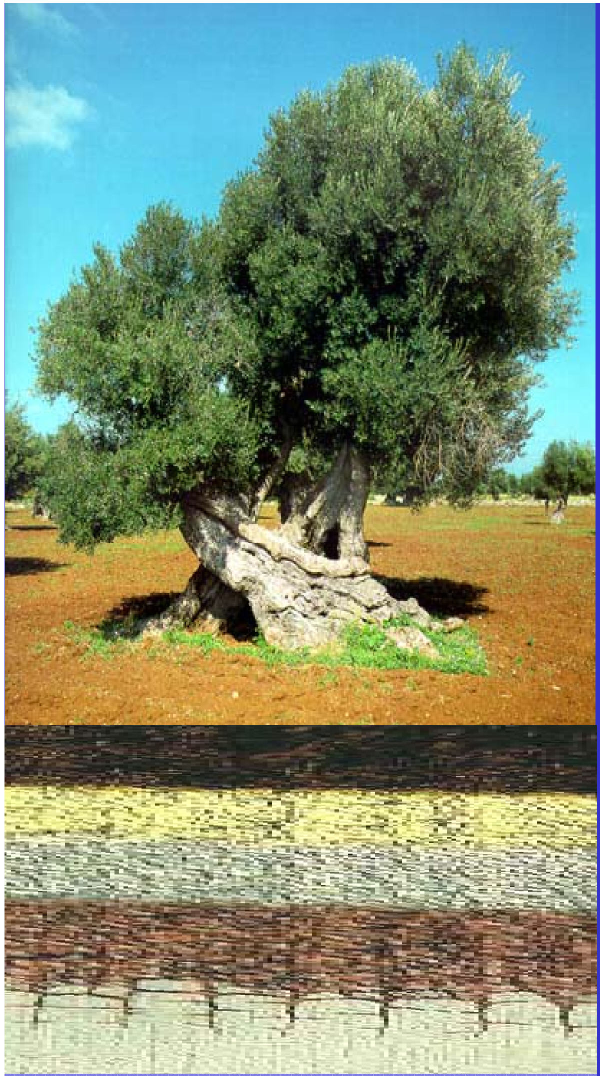


- Stima dei flussi attraverso il suolo e del contenuto idrico medio
- Descrizione concettuale dell'interazione CSV

- 72% colture agrarie, 5 categorie
- Elevato grado di selezione



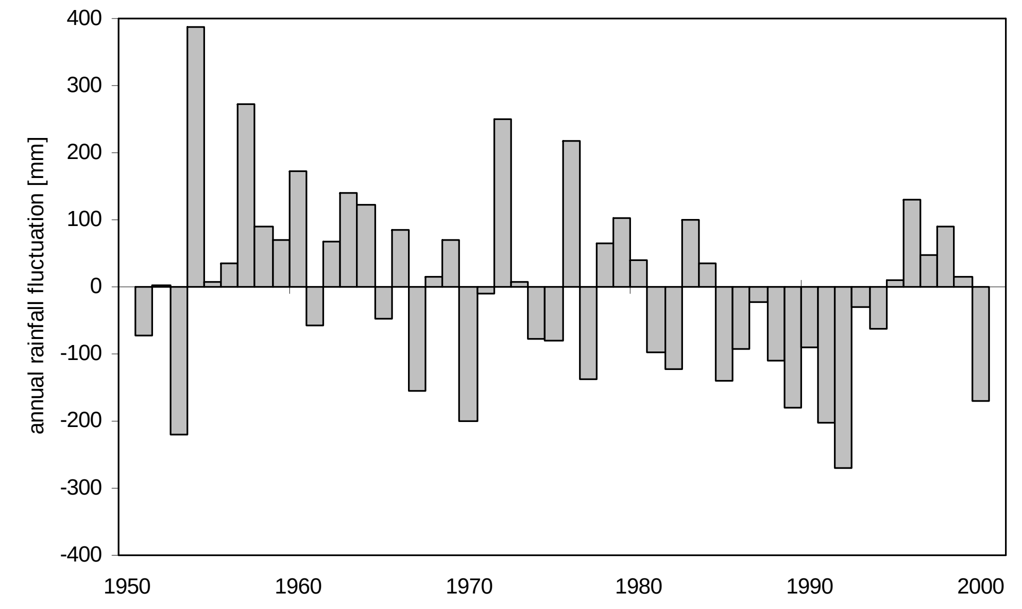
	% area totale
altri usi	28%
Grano, S.n.i.	35%
Oliveti	25%
Vigneti	7%
Frutteti	2%
Colture orticole	3%

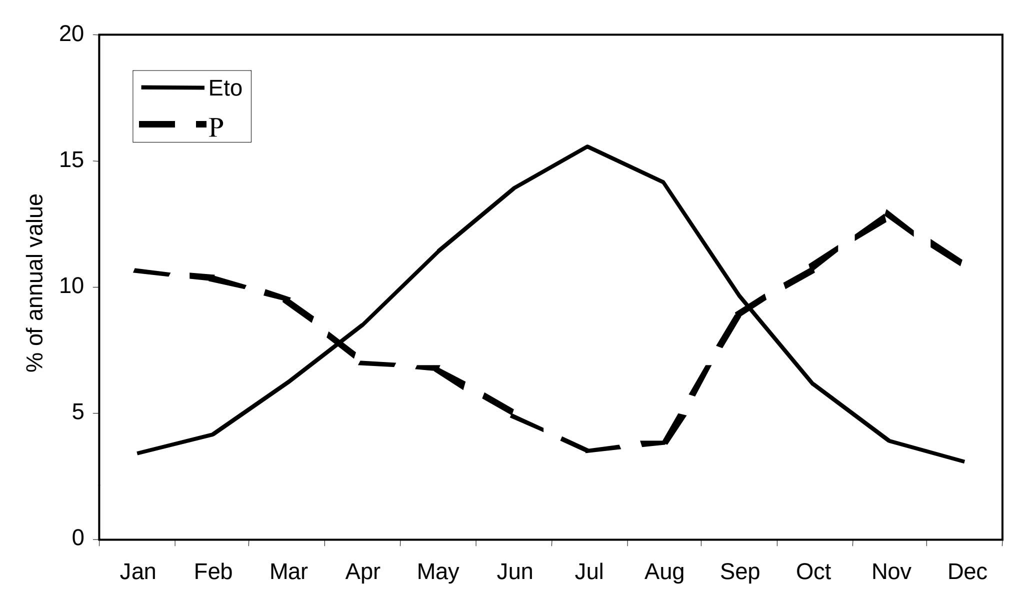


Capacità utilizzabile

$AWC = Dr\ (\theta_{fc} - \theta_{wp}) = S_{fc} - S_{wp}$

- **Vegetazione** → *Dr*, altezza radicale. ~<u>incognita</u>. Dipendenza dal clima e dalle caratteristiche del suolo.
- **Suolo** → spessore totale, tessitura e proprietà idrauliche. <u>Incertezza</u>. Variabilità nello spazio.





Simulazione del bilancio idrico del suolo per una serie di 50 anni di dati climatici, con passo temporale mensile

4 categorie di uso del suolo tipicamente N-I (72% del territorio)

Variazione dei valori dei parametri del suolo adottati nel modello, contenuto idrico unitario e altezzaradicale

Eagleson, Adv.WR 1994, definisce:

Max productivity

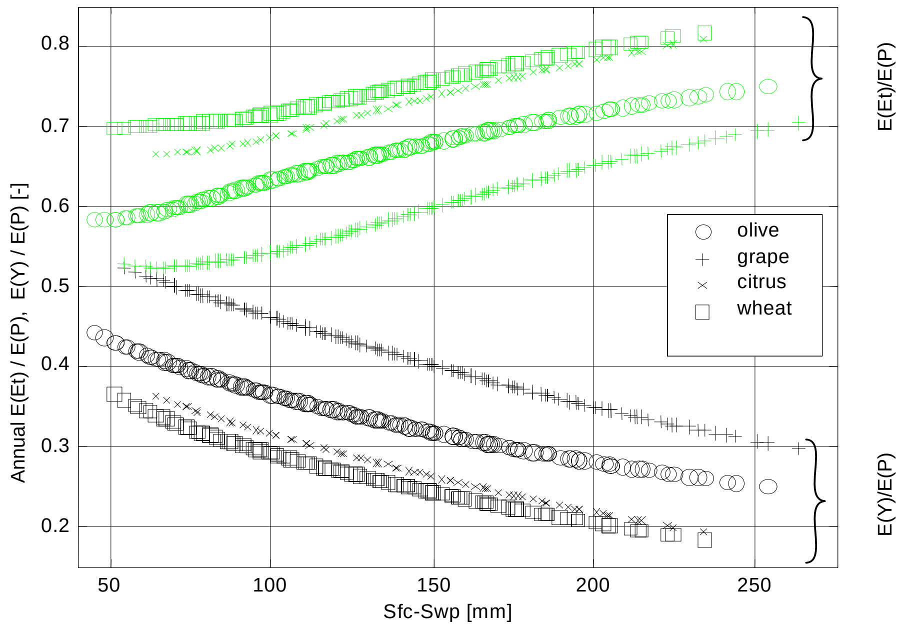
⇔ Max evapotraspirazione

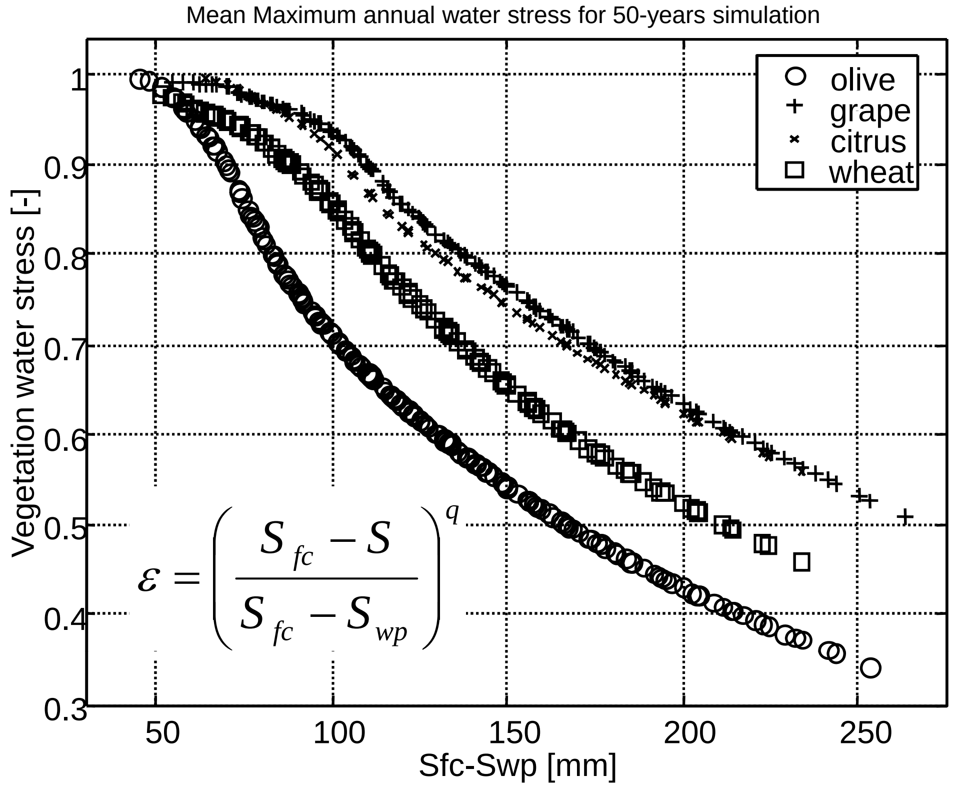
Max security ⇔

Max soil moisture

≅ Min water stress (*Rodriguez-Iturbe*, WRR 1999)

"*Eagleson*, 1994, advances the hypothesis that the canopy density will adjust to a value in the range where the community is between maximum soil moisture and maximum evapotranspiration."



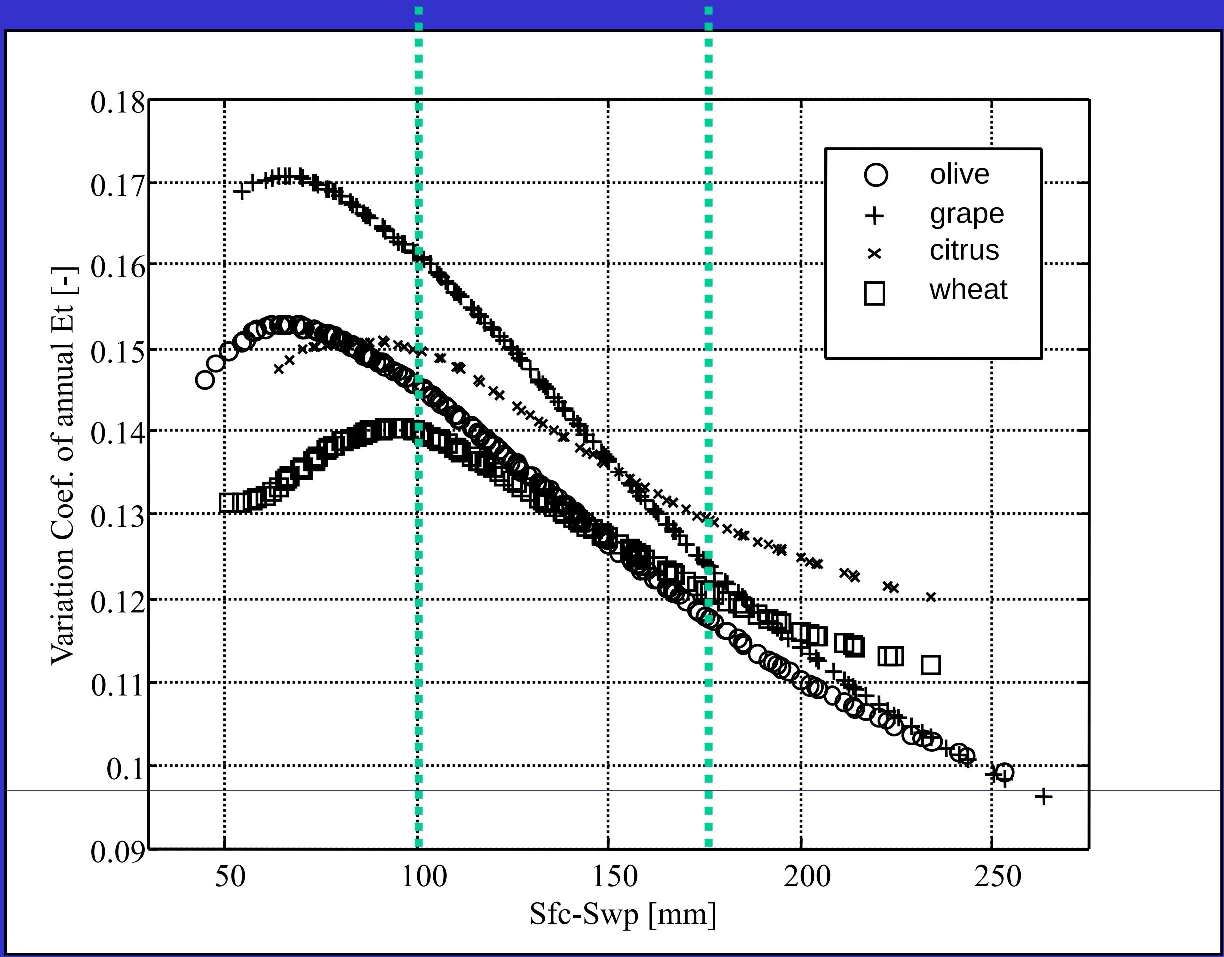


$$\varepsilon = \left(\frac{S_{fc} - S}{S_{fc} - S_{wp}} \right)^q$$

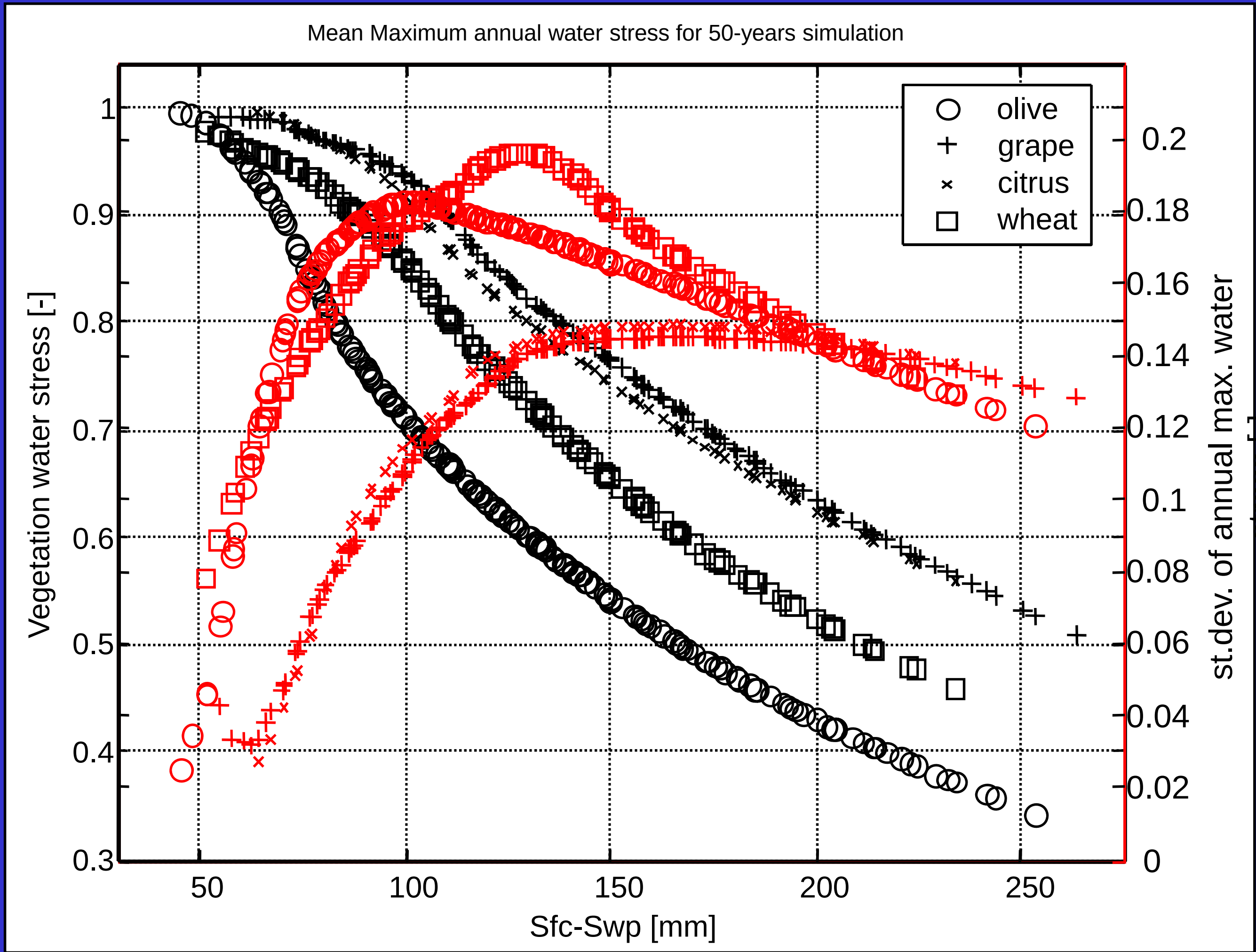
Var. inter-annuale di ***Et*** vs ***AWC***

Produttività α E_t

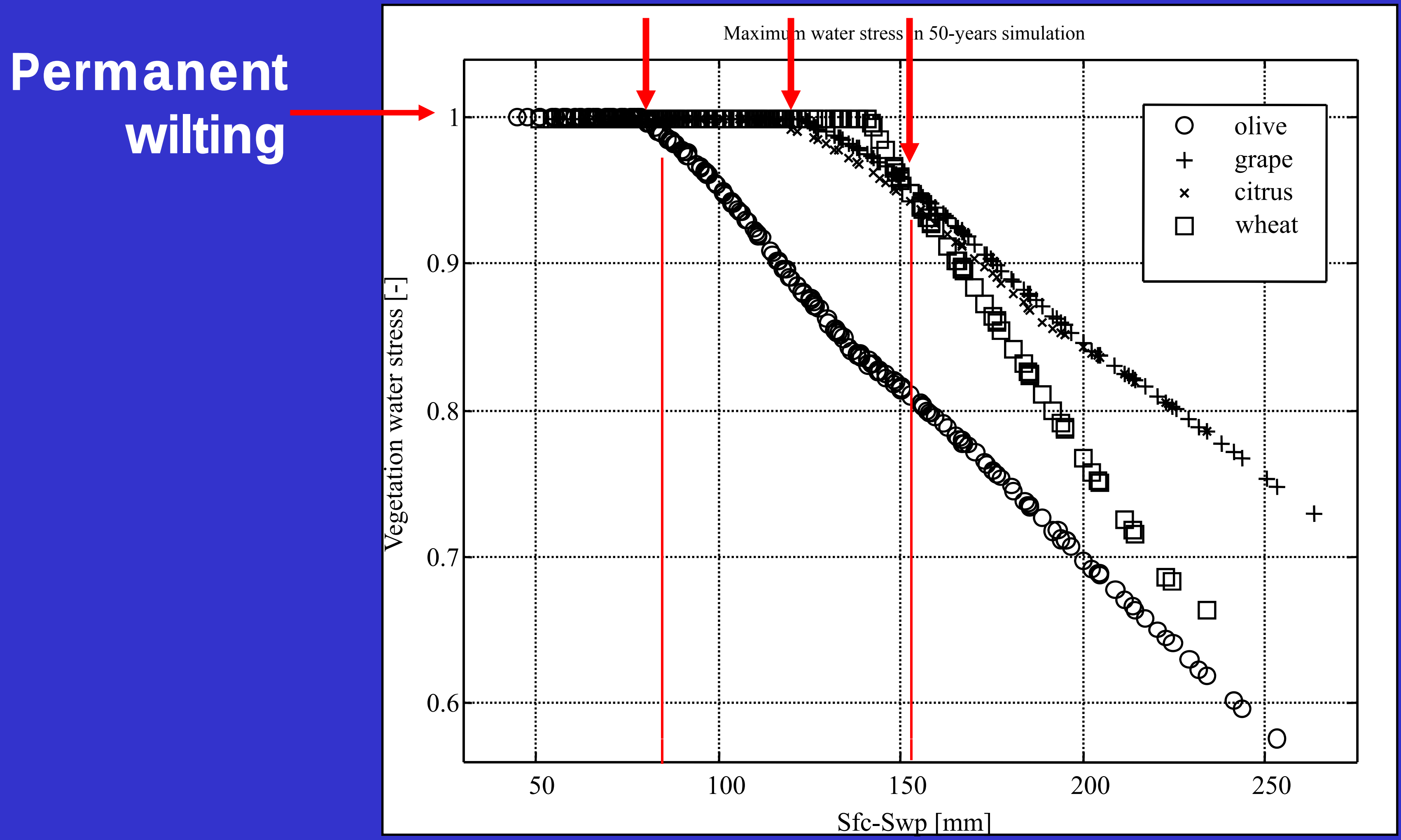
Sensitività e stabilizzazione delle fluttuazioni climatiche



WS, adattabilità e selettività



Massimi del WS nella serie temporale



Considerazioni

- I principi di eco-idrologia (max. produttività, max. sicurezza, fattore limitante), riconosciuti validi per gli ecosistemi naturali, spiegano gli assetti di uso del suolo negli ambienti a clima semi-arido.
- L'analisi delle occorrenze spaziali di una data specie per assegnata classe del contenuto idrico unitario sono spiegabili alla luce dei risultati del modello idrologico adottato.
- In prospettiva, attraverso tali principi è possibile condizionare i valori dei parametri di capacità idrologica dei suoli prescindendo dall'informazione pedologica.

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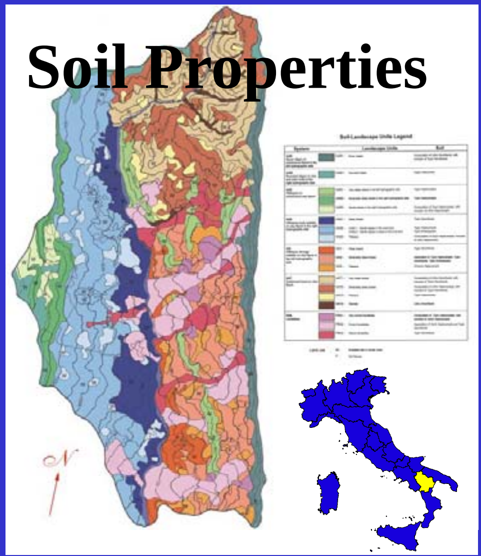
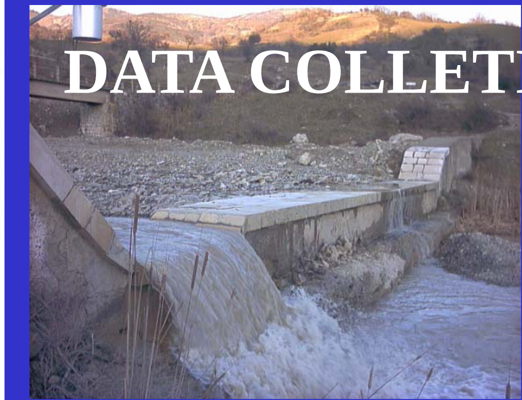
3) MEDCLUB basins for field experiments.

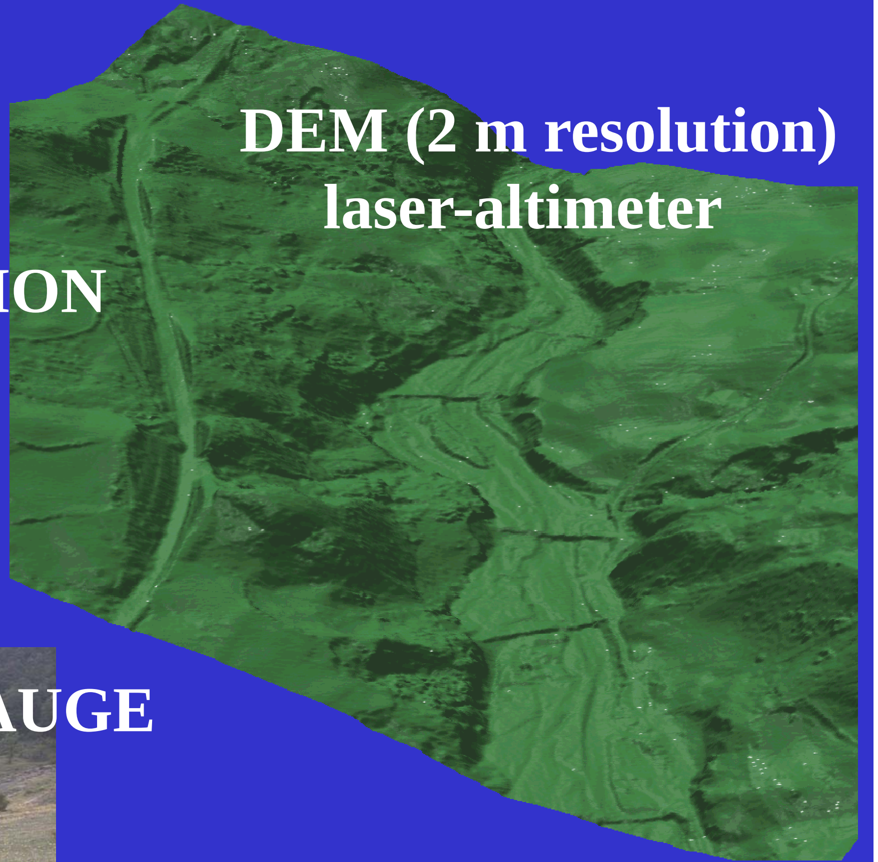
MEDCLUB activities include experimental field campaigns on basins located in different climatic and vegetation conditions:

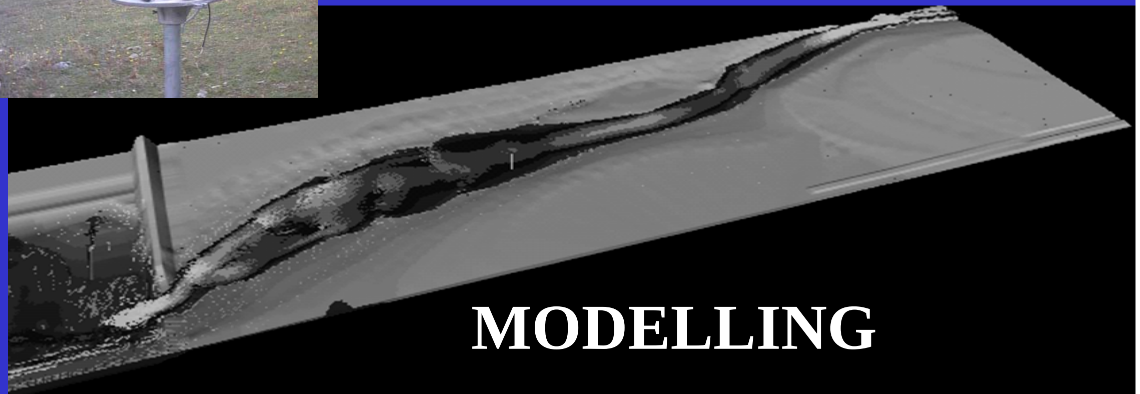
- Fiumarella di Corleto (Agri basin);
- Segezia (Carapelle basin);
- Celone (Candelaro basin).

ACDP, Soil moisture









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4) "How can we employ new observational technologies in improved predictive methods?" – The link with CSV dynamics and field experiments.

ASAR

ASTER

ENVISAT

LANDSAT

NOAA

CSK

SENTINEL

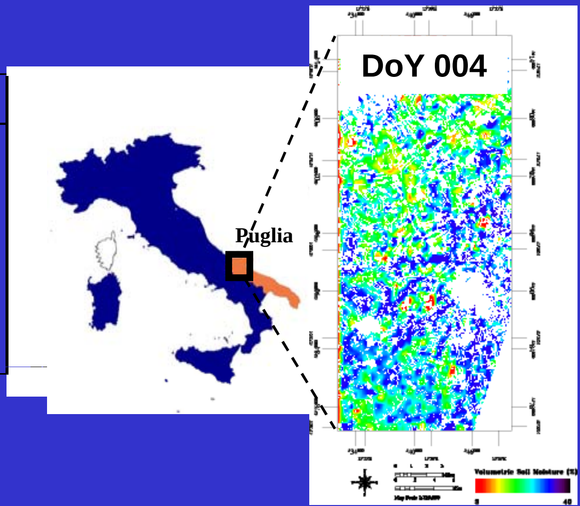
Output: Surface temperature, soil water content, Soil cover, Vegetation and Snow cover.

Soil moisture content (m_v) retrieval

SMOSAR algorithm using backscatter temporal change

Example of application: eight PALSAR ScanSAR WB1 images acquired approximately bi-weekly over Southern Italy from January to May 2007

DoY	Date
004	04/01/2007
050	19/02/2007
072	13/03/2007
084	25/03/2007
101	11/04/2007
113	23/04/2007
118	28/04/2007
130	10/05/2007

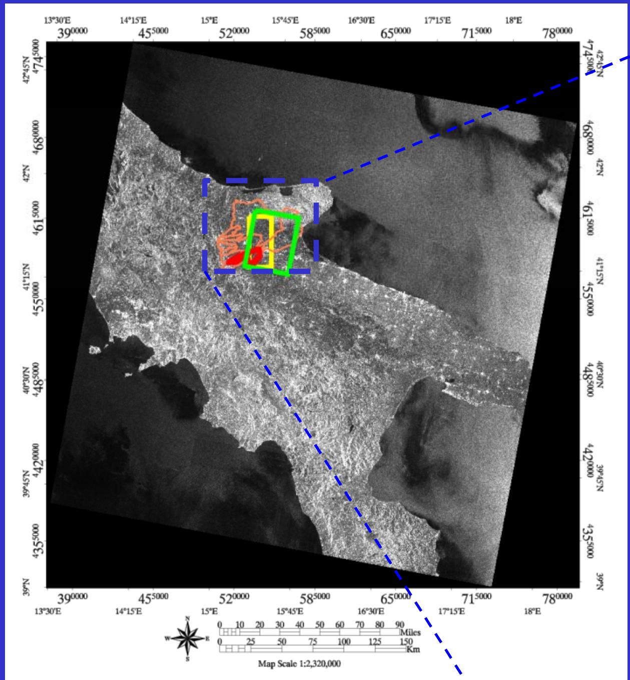


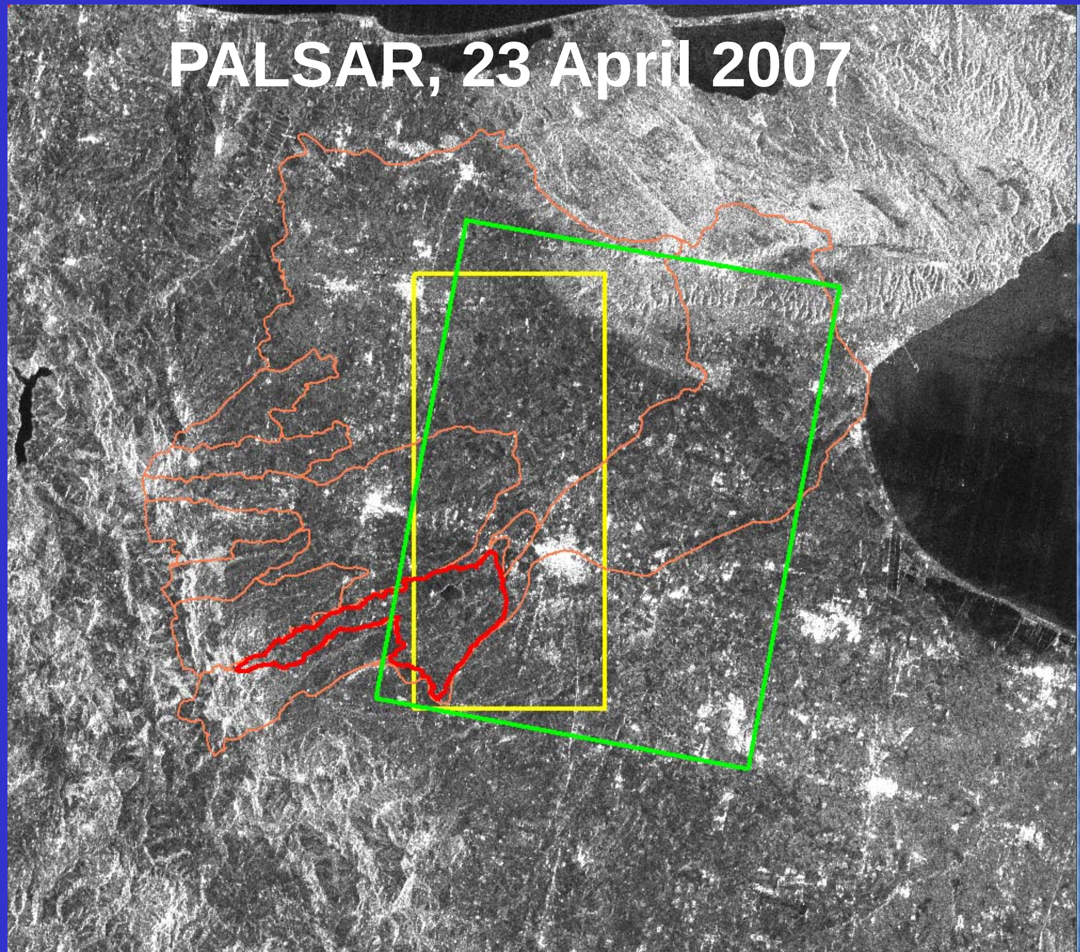
- The SMOSAR retrieval algorithm requires **dense/quasi-dense temporal series of SAR data**.
- Under the hypothesis that the time series of N SAR images is dense the **backscatter change between two subsequent acquisitions is mainly related to the temporal change of soil moisture conten**t, which is characterized by a temporal scale of few days, and poorly related to the temporal changes of vegetation biomass or crop canopy or surface roughness, which are usually characterized by a temporal scale of few weeks.

SMOSAR has been tailored to X band data (**SMOSAR-X**) and L-band data (**SMOSAR-L**)

Balenzano et al.," SMOSAR ALGORITHM FOR SOIL MOISTURE RETRIEVAL USING SENTINEL-1 DATA", IEEE Proceedings IGARSS'12

ALOS/PALSAR and COSMO SkyMed (CSK) over Foggia





- CSK footprint
- Candelaro basin
- Celone basin
- Area of the soil moisture maps from PALSAR and CSK data using SMOSAR software [Balenzano et al., 2012] adapted to the L-band [Satalino et al., 2010] and X-band [Mattia et al., 2012].

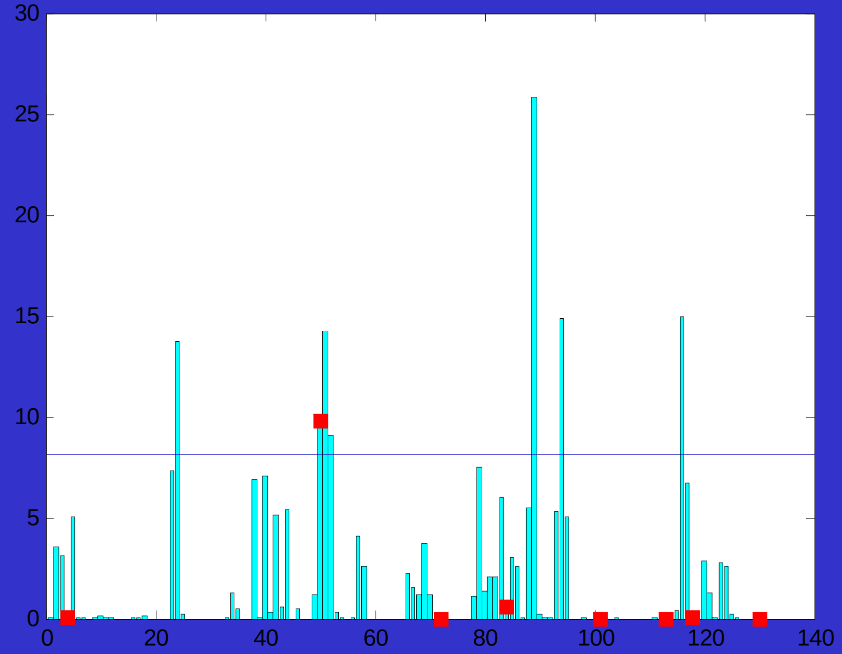
Richard's equation

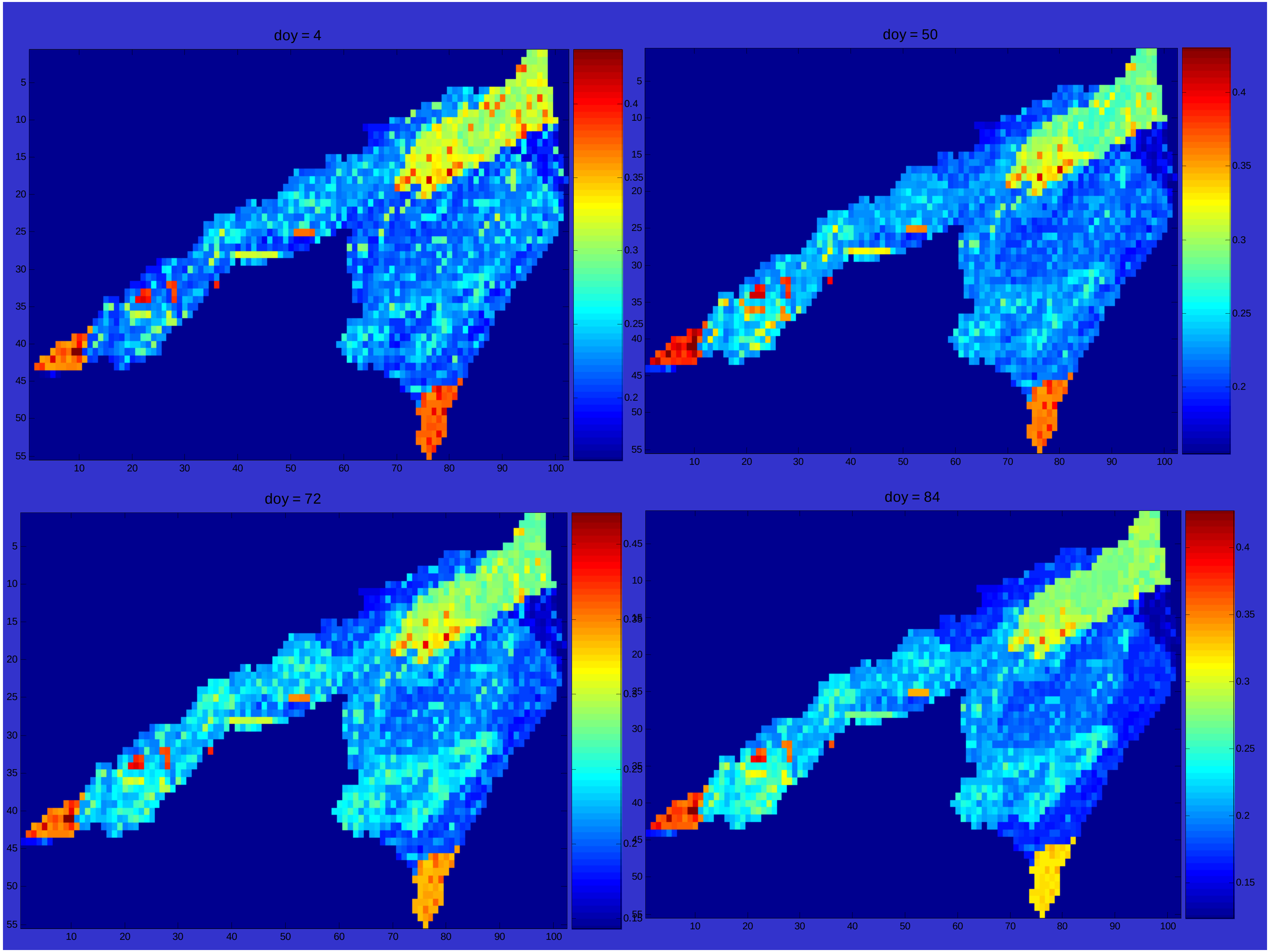
$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial x}\left[K\left(\frac{\partial h}{\partial x} + \cos\omega\right)\right] - S$$

- h is the water pressure head, θ is the volumetric water content, t is time, x is the spatial coordinate, S is the sink term, ω is the angle between flow direction and the vertical axis (ω=0° for vertical flow) and K is the unsaturated hydraulic conductivity function
- The unsaturated water content and the hydraulic conductivity were related to pressure head (h) using the equations of van Genuchten (1980), depending on five parameters: the residual water content (θr), the saturated water content (θs), the inverse of the bubbling pressure (α), the pore-size distribution index (n) and the saturated hydraulic conductivity (Ks)
- A numerical solution of the differential equation was implemented as in Simunek et al. (2009)

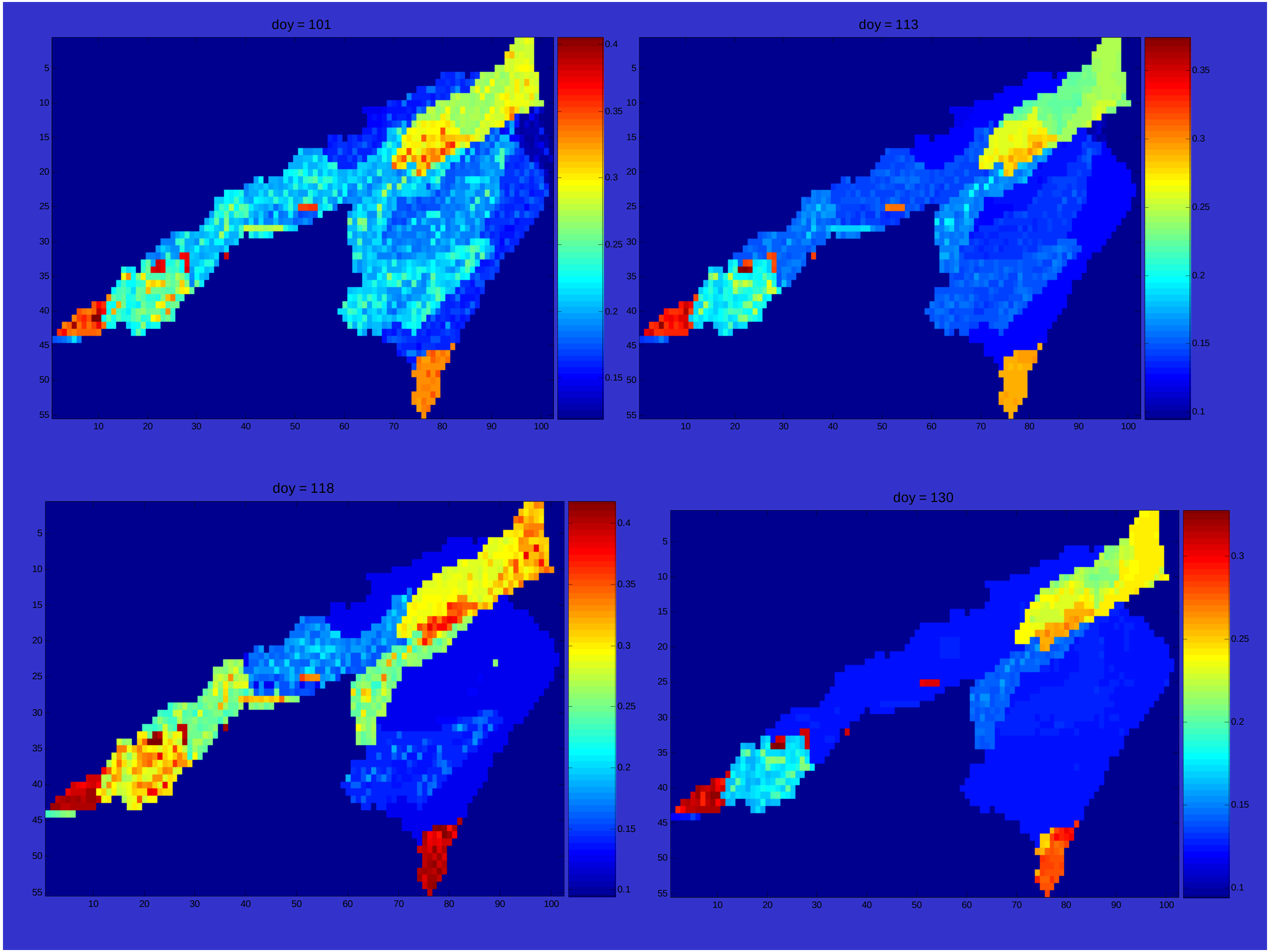
Palsar images 2007

doy	date
4,	04/01/2007
50	19/02/2007
72,	13/03/2007
84,	25/03/2007
101,	11/04/2007
113,	23/04/2007
118,	28/04/2007
130,	10/05/2007

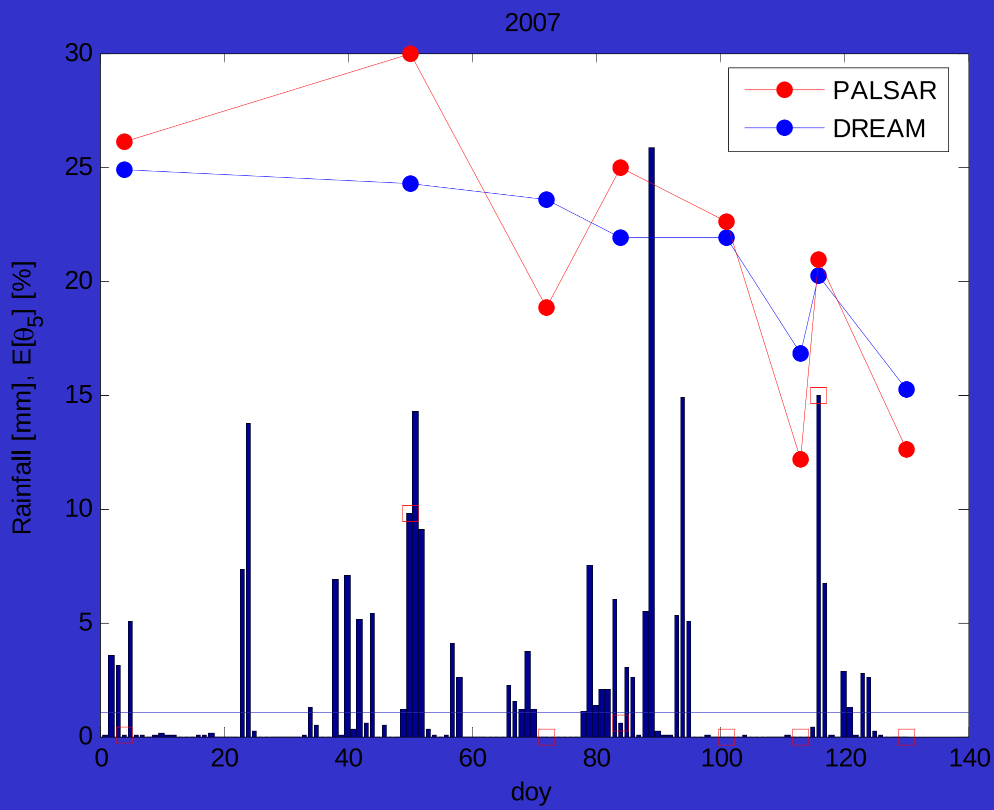




doy = 4
doy = 50
doy = 72
doy = 84

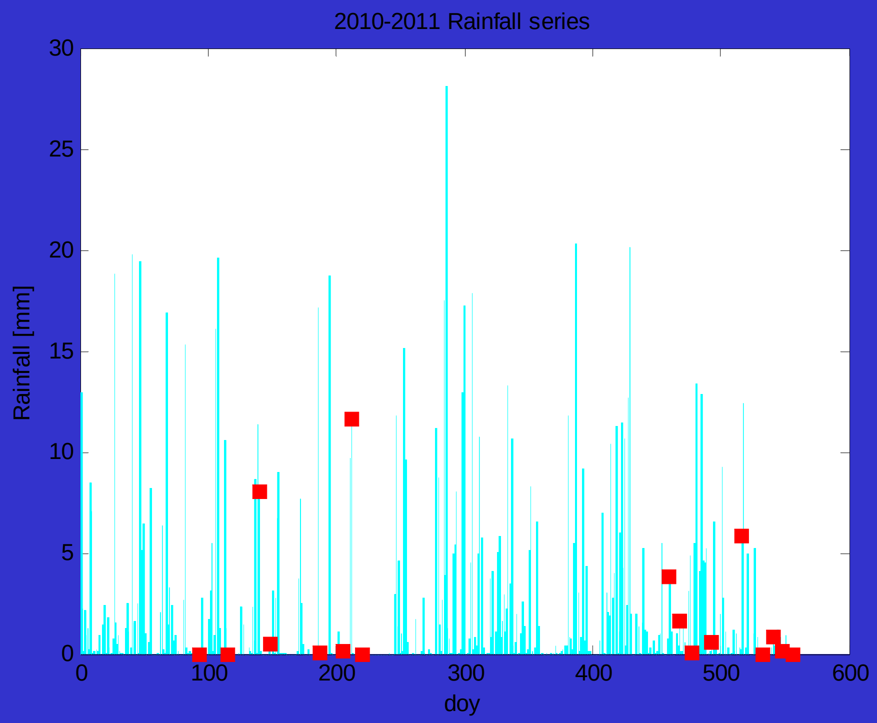


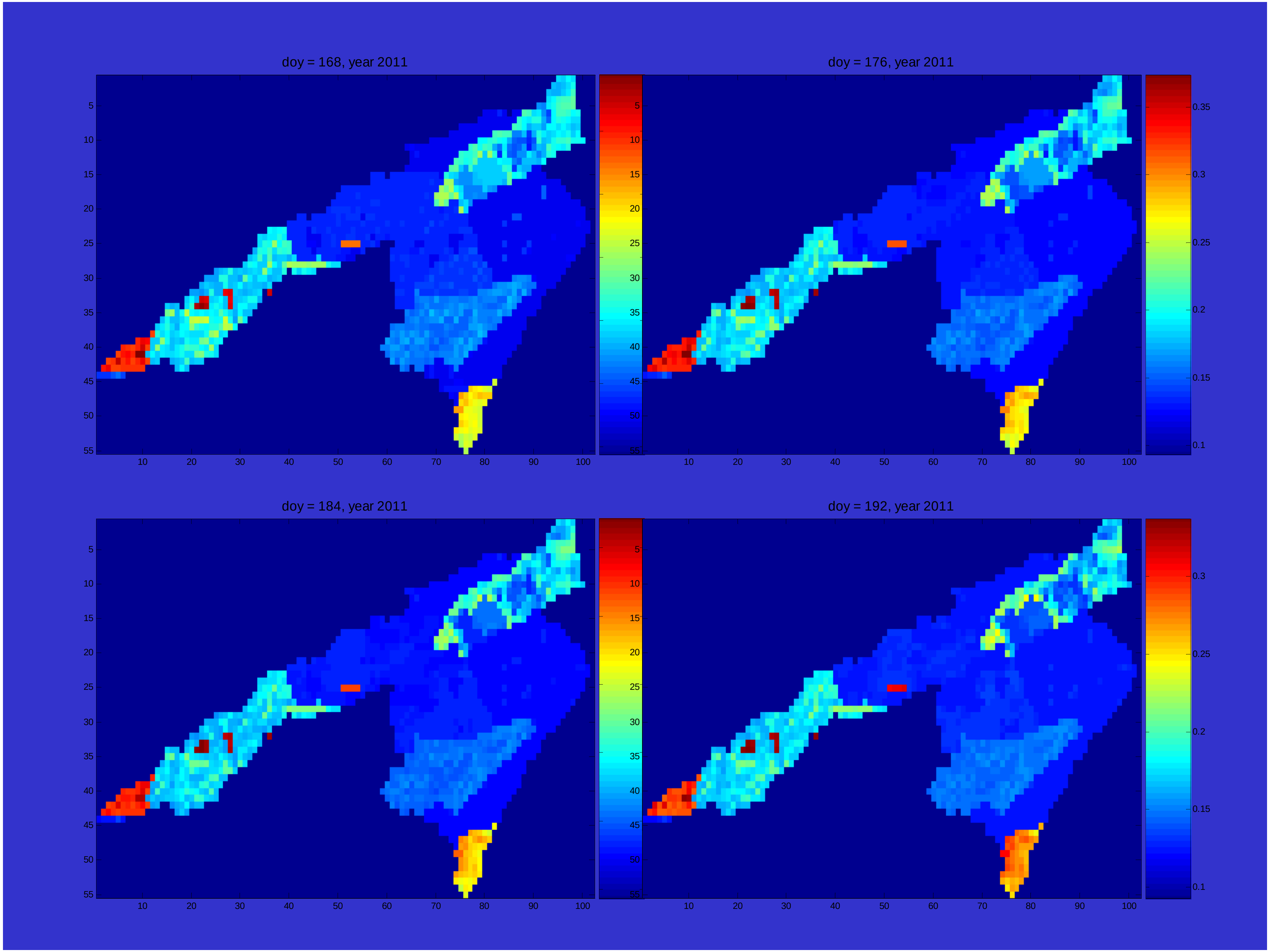
doy = 101
doy = 113
doy = 118
doy = 130

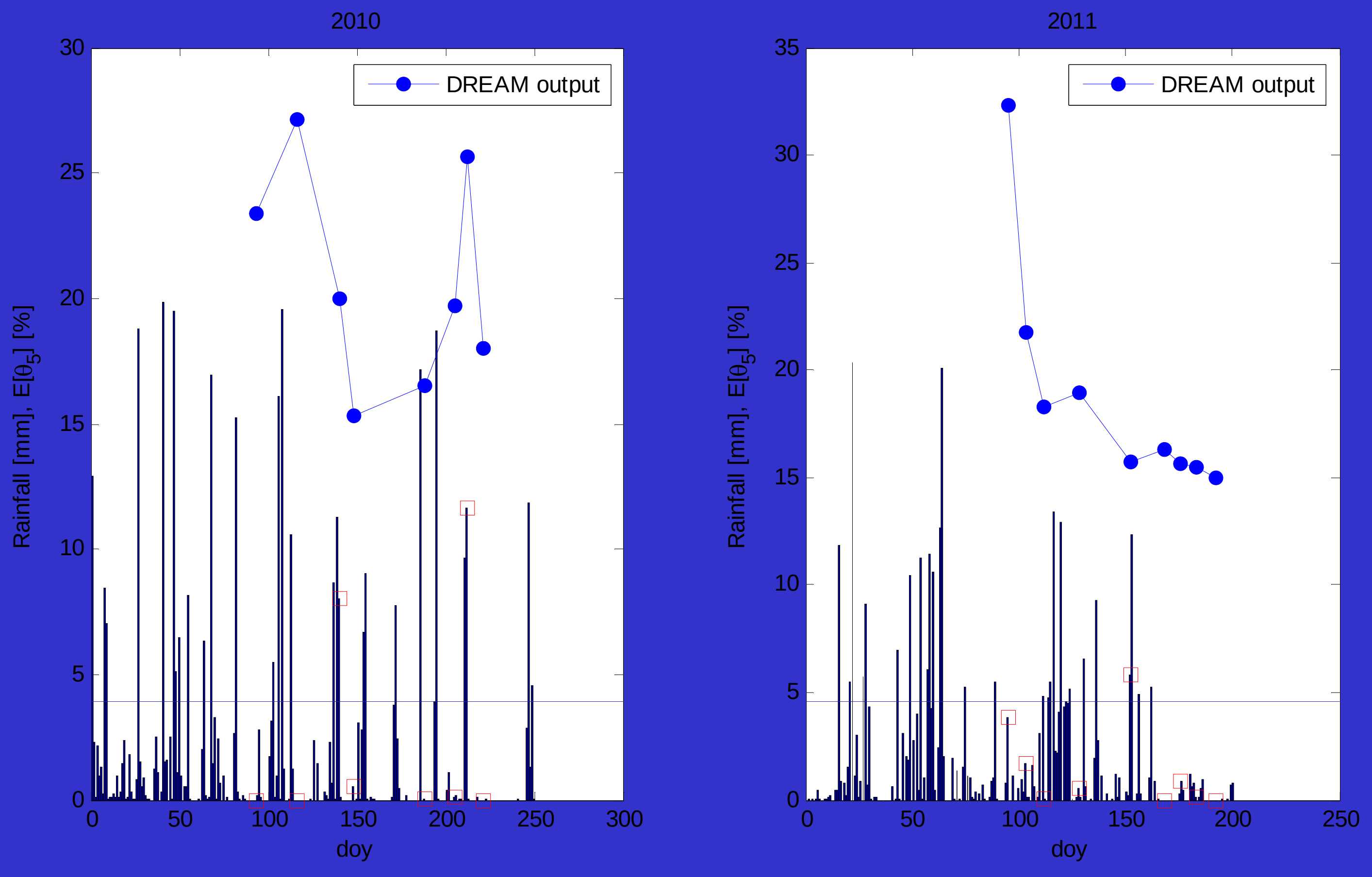

2007
PALSAR
DREAM
Rainfall [mm], E[θ_5] [%]
doy
0
5
10
15
20
25
30
0
20
40
60
80
100
120
140

CSK images 2010/11

doy	date
93	03/04/2010
117	27/04/2010
141	21/05/2010
149	29/05/2010
189	08/07/2010
205	24/07/2010
213	01/08/2010
221	09/08/2010
96	06/04/2011
104	14/04/2011
112	22/04/2011
128	08/05/2011
152	01/06/2011
168	17/06/2011
176	25/06/2011
184	03/07/2011
192	11/07/2011

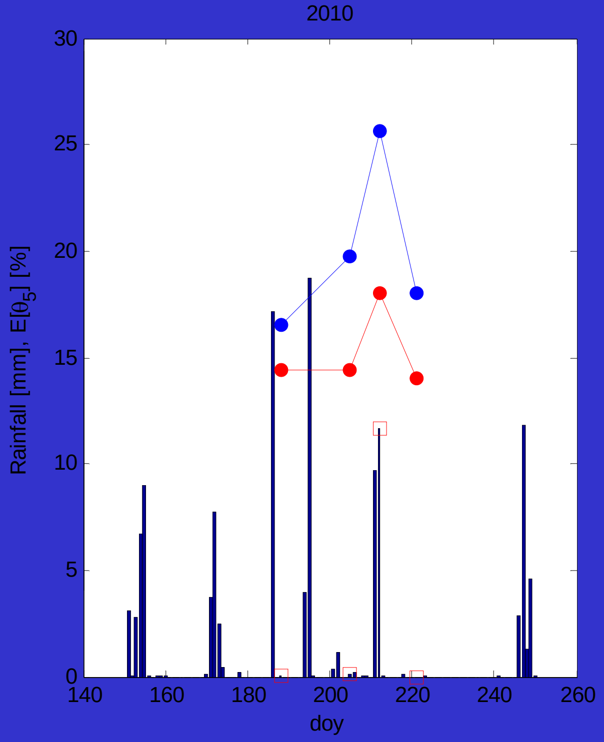


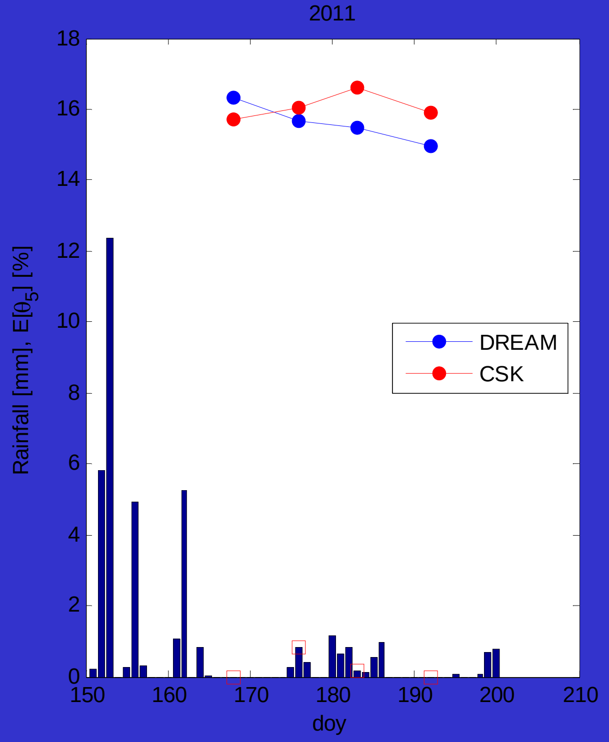

doy = 168, year 2011
doy = 176, year 2011
doy = 184, year 2011
doy = 192, year 2011



2010
DREAM output
Rainfall [mm], E[θ5] [%]
doy
0
50
100
150
200
250
300
0
5
10
15
20
25
30
2011
DREAM output
Rainfall [mm], E[θ5] [%]
doy
0
50
100
150
200
250
0
5
10
15
20
25
30
35

CSK vs DREAM





DOY	189/2010	205/2010	213/2010	221/2010	168/2011	176/2011	184/2011	192/2011
CSK $E[\Theta_5]$ %	14.439	14.448	17.995	14.046	15.727	16.054	16.630	15.889
DREAM $E[\Theta_5]$ %	16.530	19.731	25.623	17.990	16.307	15.666	15.468	14.975

Scientific questions…

1 "What are the gaps in our knowledge limiting reliable predictions in ungauged catchments?"

-Regional analysis as a MEDCLUB starting line-

2 "What are the information requirements to reduce predictive uncertainty?"

-The role of climate-soil-vegetation dynamics-

3 "What experimentation is needed to ubderpin the new knowledge required?"

-MEDCLUB candidate basins for field experiments-

4 "How can we employ new observational technologies in improved predictive methods?"

-Link between CSV dynamics and field experiments-

5 "How can we improve the hydrological process descriptions in order to reduce uncertainty?"

-Advancing process description through comparative evaluation of models-

6 "How can we maximise the scientific value of available data in generating improved prediction?"

-Connecting new information to patterns that we already understand-

5) "How can we improve the hydrological process descriptions in order to reduce uncertainty?"

-Advancing process description through comparative evaluation of models-

- We found extremely instructive the comparative use of distributed physically based model with lumped models (Manfreda et. al., 2005).

- The comparison between theoretical derivation of flood distributions and the continuous numerical simulation:
  1. to verify the reliability of theoretical models.
  2. to facilitate the formulation of hypothesis, sometime arbitrary assumed, on the dependency or less of variables involved in the flood generation or on the distribution of key variables.

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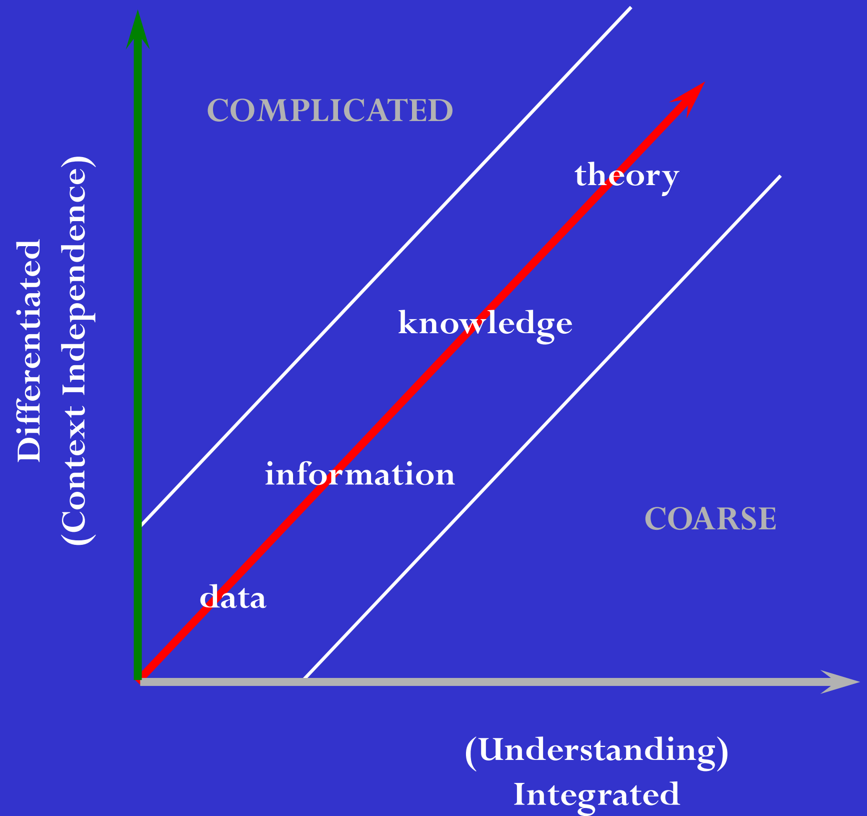
Differentiated vs Integrated in the learning process.

High levels of differentiation without integration promote the complicated status, high integration, without differentiation, produces coarse.

In order to improve modelling and reduce uncertainty we tend to avoid the complicated and we are not interested in the coarse.

From the hydrologist's point of view, one may assimilate "differentiated" to "distributed" and "integrated" to "lumped".



inspired by Bellinger (2004)

“Science is built up with facts, as a house is with stones.

But a collection of facts is no more a science than a heap of stones is a house”

Jules Henri Poincaré (1854-1912)

… e grazie per l’attenzione!