European Geophysical Union 2020
Sharing Geoscience Online

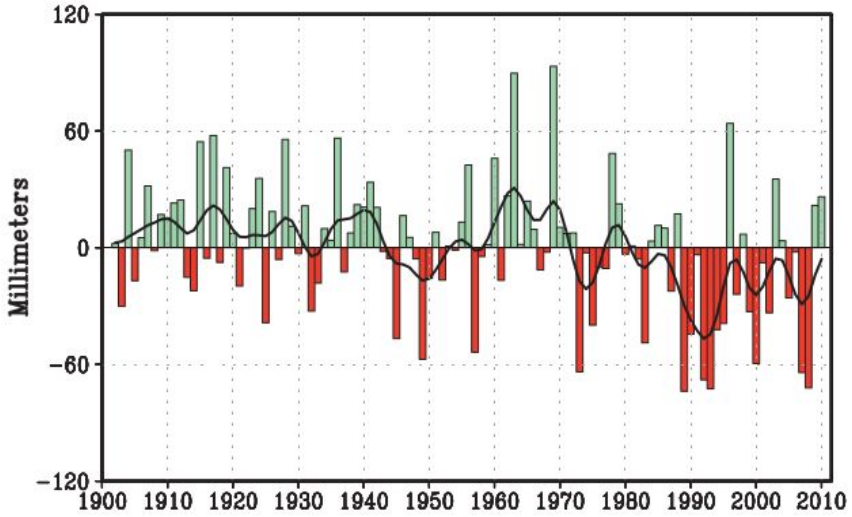
Identification of droughts and heatwaves in the Western Mediterranean: variability and impacts on vegetation and wildfires using the coupled WRF-ORCHIDEE regional model (RegIPSL)

Antoine Guion[1], Solène Turquety[1], Jan Polcher[2], Romain Pennel[3] & Luis Fita[4]

1. Sorbonne Université, Faculté des sciences, Laboratoire de Météorologie Dynamique (LMD), IPSL, France
2. CNRS, Ecole Polytechnique, Laboratoire de Météorologie Dynamique (LMD), IPSL , France
3. Université Paris-Saclay, Ecole Polytechnique, Laboratoire de Météorologie Dynamique (LMD), IPSL , France
4. Universidad de Buenos Aires, CONICET, Centro de Investigaciones del Mar y la Atmosfera (CIMA), UMI, Argentine

Important topic

Precipitation anomalies over the ***Mediterranean*** *(wet season)*



Hoerling et al., 2012 (J. of Climate)

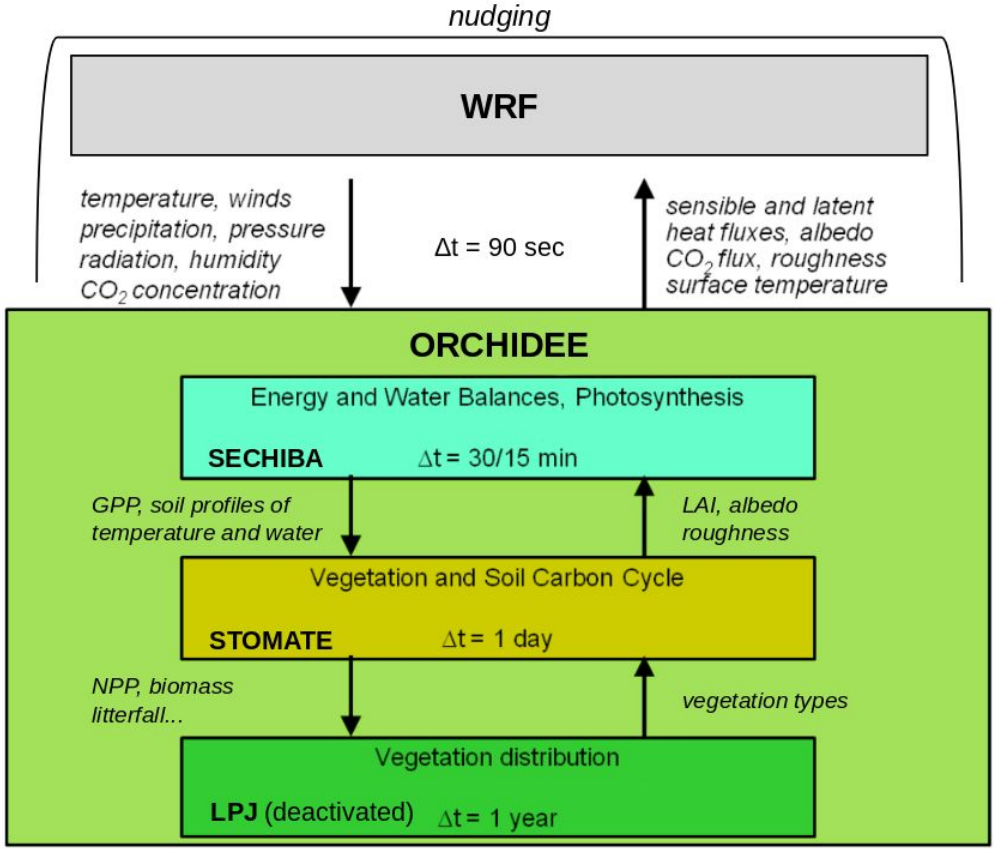
- Increasing frequency and severity of droughts and heatwaves over the Mediterranean

⇒ severe impacts on vegetation and wildfires with considerable economic, social and environmental damages

- Too few impact studies integrate complete spatio-temporal dynamics of droughts and heatwaves (with their synergic effects)

- Impact studies on vegetation and wildfires do not use the most appropriate indicator for agricultural droughts

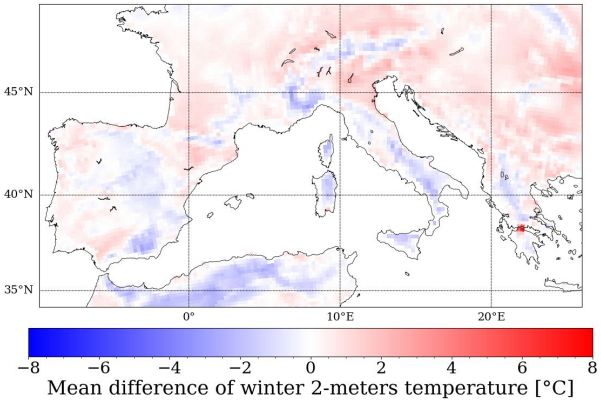
RegIPSL - Coupled land surface atmosphere regional model

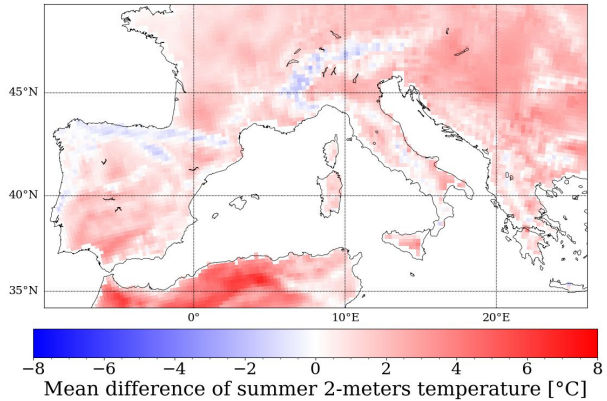


- LPJ module not used
- STOMATE module allows seasonal dynamics and phenology
- Synoptic-scale atmosphere constraint (ERA-Interim reanalysis)
- 13 Plant Functional Types
- Domain : euro mediterranean
- Study area : western mediterranean
- Spatial resolution : 20km
- Temporal coverage : 1979 - 2016

⇒ Med-CORDEX simulation performed

Validation of Med-CORDEX simulation





- Constant overestimation of temperature in comparison to E-OBS data

⇒ atmosphere too clear (too few aerosols and cloud fraction)

⇒ downward solar radiation overestimated by 20W/m² over most of the domain in comparison to satellite products (SARAH-2 & CLARA-A2)

- Seasonal variability of the bias (lower in winter)

- Spatial and temporal correlation of 0.95 (peaks are well simulated)

⇒ RegIPSL is adapted and appropriate for research about droughts and heatwaves

Identification of droughts and heatwaves

Two complementary methods (PLA & SPEI)

Percentile Limit Anomalies (from Lhotka and Kysely, 2015)

- Daily deviation *(dX)* between the variable $X_{i,j,t}$ and the percentile $X^{p}_{i,j}$ of the day *t* computed cell by cell (*i,j*) of the grid, after normalization
- Use of percentile 75 (and 85 but not shown here)
- Detect heatwaves and agricultural droughts

$$dX_{i,j,t} = X_{i,j,t} - X^{p}_{i,j}$$

X ≡ surface temperature (heatwave)
X ≡ soil dryness (drought)

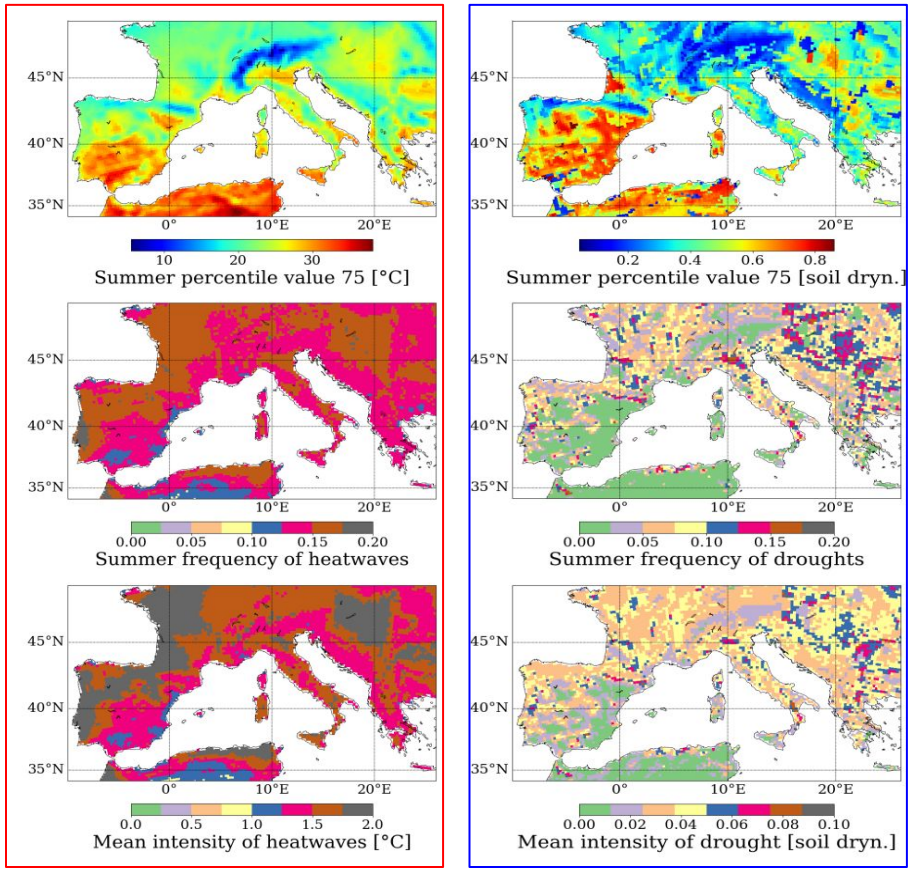
Standardized Precipitation Evapotranspiration Index (from Vicente-Serrano et al., 2010)

- Water deficit (D_m) accumulated over several months (3, 6 and 12)
- Range of values:
  - SPEI > 1.5 ⇒ very wet
  - SPEI = 0 ⇒ normal conditions
  - SPEI < -1.5 ⇒ very dry
- Detect meteorological droughts

$$D_m = P_m - PET_m$$

P_m = monthly precipitation
PET_m = monthly potential evapotranspiration

Spatial distribution of droughts and heatwaves — **PLA (75) method**



Heatwaves:

- Two explaining factors of the spatio-temporal patterns

⇒ occurrence of weather regimes at synoptic scale as the Blocking & Atlantic Low (e.g. eastern part)

⇒ 75th percentile value distribution (e.g. southern part)

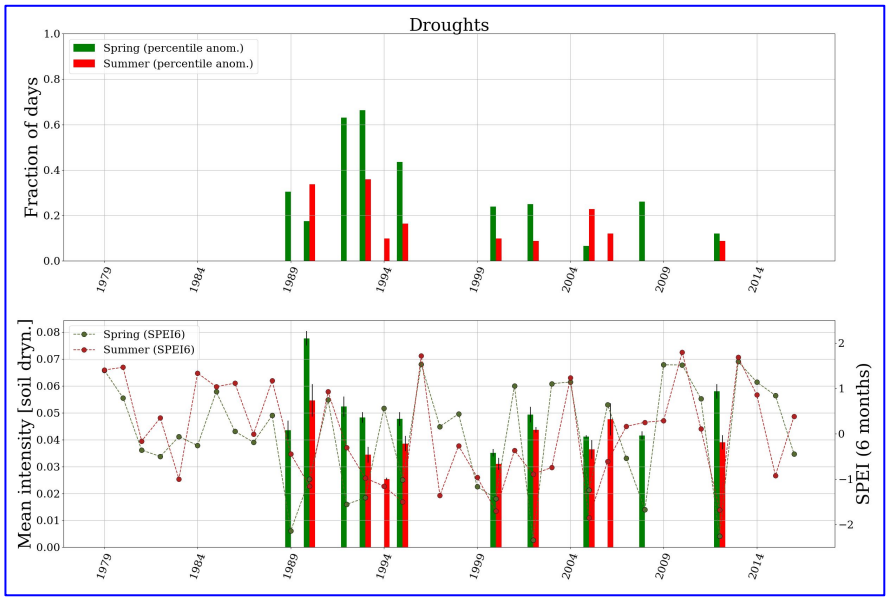
Droughts:

- Greater spatial heterogeneity than heatwaves

⇒ influence of vegetation and soil type at sub-regional scale

- PLA [soil dryness] method is focused on agricultural droughts

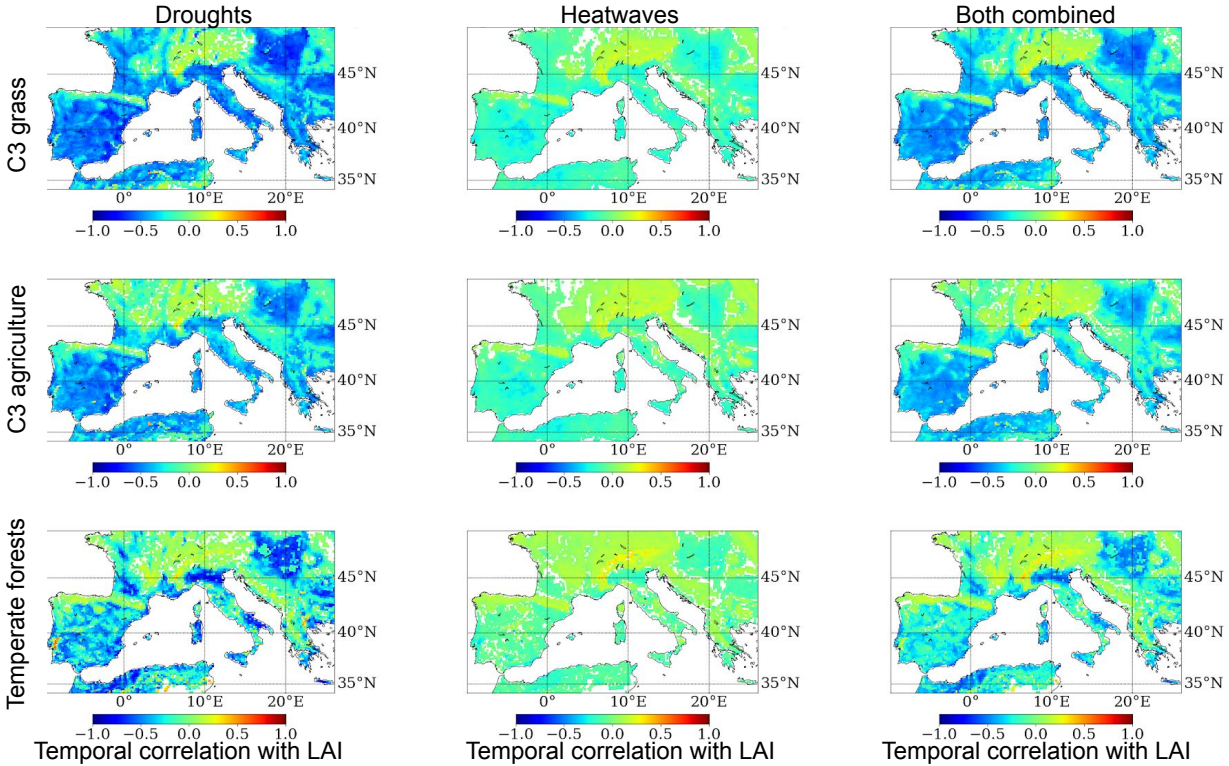
Temporal variability of droughts and heatwaves **PLA (75) & SPEI method**



- Heatwaves occur almost every year while droughts appear 1 over 3 years on average
- Droughts last longer (39 days on average) than heatwaves (18 days)
- PLA [soil dryness] method is generally in good agreement with SPEI (6 months)

Isolate and combined impact on vegetation — **Leaf Area Index simulated**

Significant correlation between PLA (75) and LAI summer anomalies for different vegetation type



- Significant and negative correlation with soil dryness anomalies

⇒ lower over the mountainous areas and the temperate forests

- Combined index = sum of both standardized variables

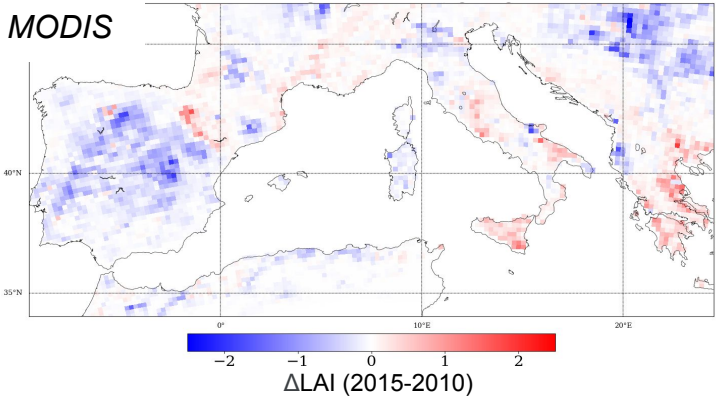
⇒ signal slightly less pronounced regarding surface temperature anomalies

Isolate and combined impact on vegetation

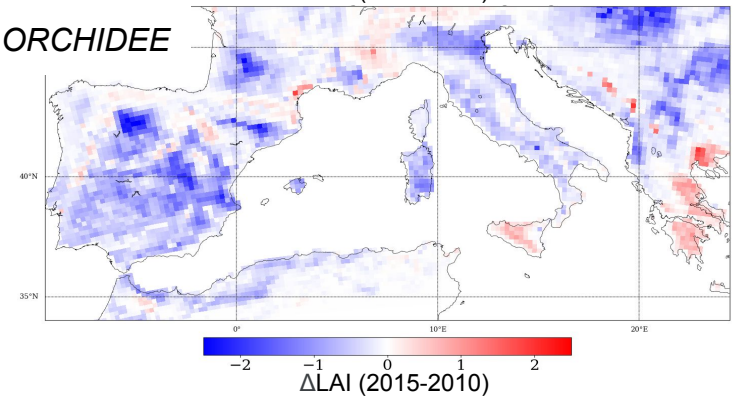
Leaf Area Index reconstructed from observations

Drought effect (ΔLAI between wet summer 2010 and dry summers 2006 & 2015)

MODIS



ORCHIDEE



Compared to 2010 wet summer	ΔLAI simulated	ΔLAI observed	% of dry days simulated
W. Medit. 2006 (spatial mean)	-0.70 (-18.42%)	-0.58 (-12.45%)	19
W. Medit. 2015 (spatial mean)	-0.35 (-6.48%)	-0.15 (-4.25%)	10

- Summer droughts induce a decrease of biomass for simulated and observed LAI

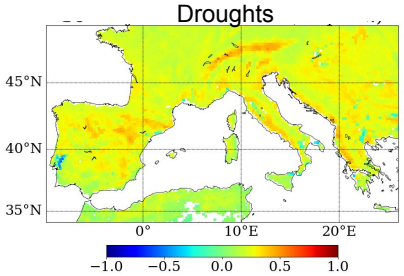
⇒ overestimated with ORCHIDEE both in absolute and relative

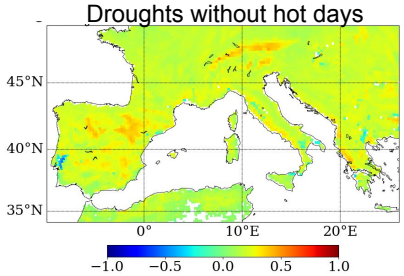
- Some discrepancies (e.g Italy)

⇒ human intervention, burned area...?

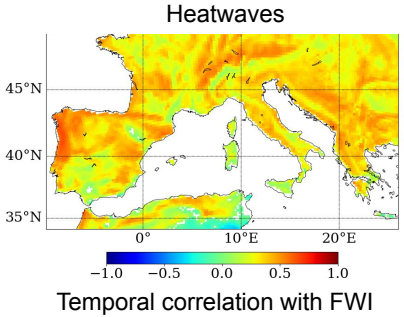
Isolate and combined impact on wildfire behaviour **Fire Weather Index simulated**

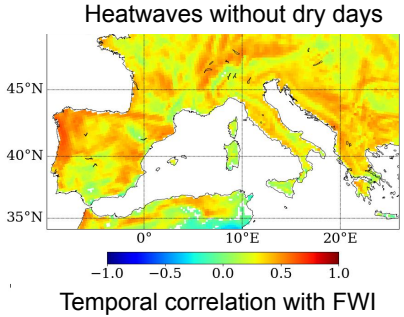
Significant correlation between PLA (75) and FWI summer anomalies

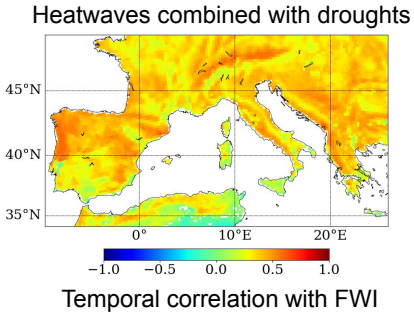




- Fire Weather Index (Turner et al., 1978) computed from meteorological conditions (Med-CORDEX daily outputs)



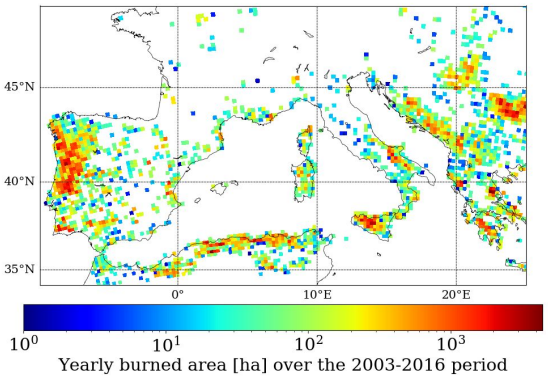




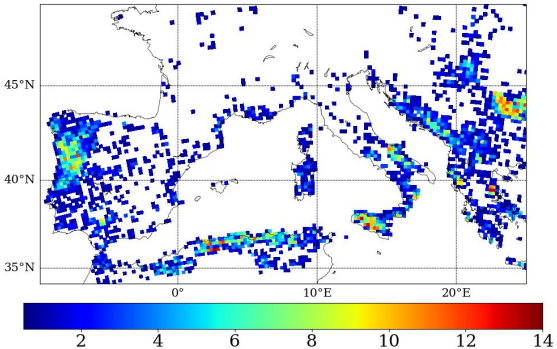
- Strongest sensitivity to heatwaves (surface temperature) but additional effects of droughts (soil dryness)

Isolate and combined impact on wildfire behaviour — **Fire activity observed**

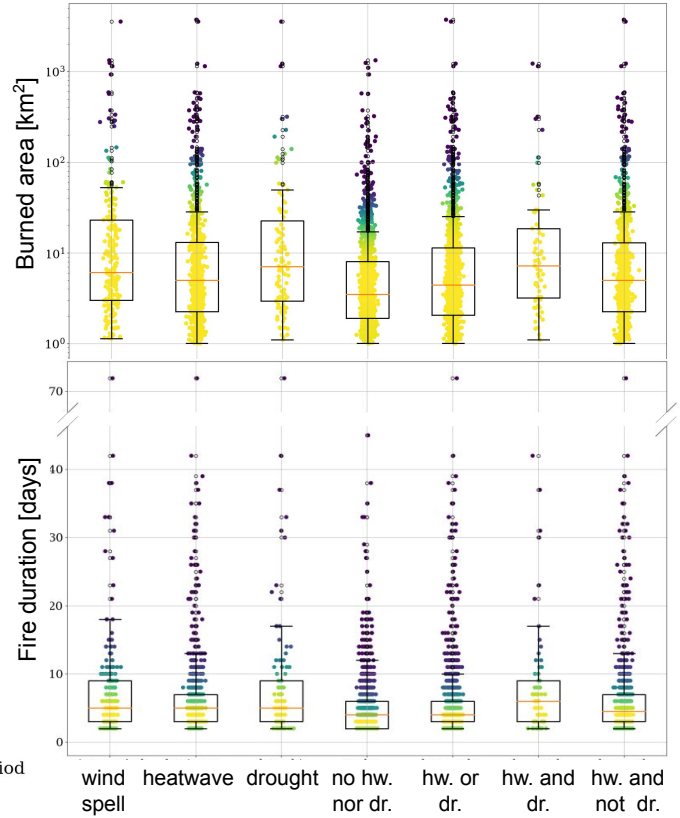
MODIS observations of wildfire activity (left) clustered by simulated extreme events (right)



Yearly burned area [ha] over the 2003-2016 period



Number of summers affected by wildfires over the 2003-2016 period



- Simultaneous heatwaves and droughts are the worst environmental conditions for the burned area and the fire duration
- The fire radiative power is the strongest during windspells (not shown)
- Significant differences with normal conditions (no hw. nor dr.)

Conclusions

Plant depletion:

- Summer droughts can induce 25% decrease of LAI (spatially averaged over the Western Mediterranean) in ORCHIDEE with some critical areas reaching 50%
- Different responses to drought according to the vegetation type (long vs short root system) and biome (temperate vs semi-arid)

Wildfire behaviour:

- Significant impact of combined heatwaves and droughts on wildfire activity in comparison to normal conditions

⇒ Fire duration (days) 1.77 times higher | Burned area (km^2) 4.39 times higher | Fire radiative power (MW) 4.15 times higher

- The fire weather risk (FWI) increases (till 2 times higher) during heatwaves and meteorological droughts
- Based on meteorological conditions, FWI does not catch agricultural drought effects on vegetation moisture and structure at long timescales

Question / answer session

Thanks for your attention !

Contact: antoine.guion@lmd.polytechnique.fr