STARDEX

STAtistical and Regional dynamical Downscaling of EXtremes for European regions

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Recommendations on the best predictor variables for extreme events

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1. Introduction.

The selection of predictors has to be done under theoretical considerations, and taking into account the final use of the methodologies to be developed. Two basic ideas should be always kept in mind:

1. The stationarity problem: in a climate change scenario, the relationships between predictors and predictands could change. Predictors should be physically linked to the predictands, because those linkages will not change.
2. The characteristics and limitations of the GCMs: the methodologies to be developed will be finally applied to GCM outputs. Therefore, the predictors selected should be well simulated by the GCMs. And the temporal and spatial resolution of the GCM should be also considered.

A third idea should be also considered:

3. No seasonal stratification should be done in the selection of predictors: in a climate change scenario, the climatological characteristics of the calendar seasons may change. Therefore, predictors / predictands relationships detected in a population of "present" days belonging to a certain season, with certain climatological characteristics, could not be applicable for future days of that season, which climatological characteristics may have changed.

According to these ideas, some general considerations regarding the selection of predictors could be done:

A) According to idea 1: The selection of predictors should be done under theoretical considerations, rather than using empirical analyses. These analyses could detect relationships non-physically based that could be not applicable, due to the stationarity problem. The predictors should be physical forcings of the predictands, or at least, should be physically linked to the predictands. And the relationships between predictors and predictands to be identified should be those that better reflect the physical links between them, in order to assure as much as possible the stationarity of those relationships.
B) According to idea 2: The predictors should be field variables, better than point values, because they are more reliably simulated by the GCMs.
C) According to idea 2: The predictors should be free-atmosphere variables, better than boundary layer variables, because they are more reliably simulated by the GCMs.
D) According to idea 2: The predictors should be variables that are well simulated by the GCMs. The downscaling method developed by FIC has been adapted and is used daily to produce operative meteorological forecasts. Many predictors are being used, because it has been shown that they all improve the forecasting skill. But some of them could not be used in climate simulations, because, although those predictors are probed to be well simulated for the next days by the operative Numerical Models, and therefore are useful in meteorological forecasting, they are too dependant on the initial conditions to rely on the ability of the GCMs to simulate them for the next decades.
E) According to idea 2: Working with coarser temporal and / or spatial detail than those offered by the GCMs, means that some information is not used. And many of the physical forcings of the predictands can only be captured working at temporal and spatial scales as smaller as possible. This could be specially relevant for the simulation of some

precipitation extreme events. For these reasons, in our opinion, we should work at daily and synoptic scales, because those are the scales the GCMs are offering information at. Nevertheless, we need to keep in mind that we will have to check whether this "detailed" information is useful information instead of noise.

F) According to idea 3: In the definition of the predictors / predictands relationships, no seasonal stratification should be done. If those relationships reflect correctly the physical links between them, that seasonal stratification is not necessary.

2. Predictors for precipitation.

Precipitation is forced by upwards movements of air. The most important forcings of upward movements are:

  - Dynamic forcing
  - Topographic lift
  - Convection

- Dynamic forcing at the synoptic scale is determined by geopotential configurations at 1000 and 500 hPa (see "_" equation, Holton, 1975).

- Topographic lift could be considered attending at surface winds, which are strongly related to geostrophic flux at 1000 hPa.

- Convection occurs due to triggering factors (differential surface heating, topographic or frontal lifts) on a more or less unstable atmospheric profile.

Beside this, low troposphere humidity is related with the amount of precipitation due to upwards movements.

According to these ideas:

- Dynamic and topographic forcings are implicitly included in circulation-based downscaling approaches. That is the reason of their success.

- Convective precipitation downscaling can be improved attending also to instability predictors (instability indexes, low level thermal advection…). This could be very important for extremes simulation, since some of the extreme precipitation events in certain regions are related to convective precipitation.

Some of the predictor / predictand relationships are strongly non linear. A previous stratification attending to circulation configurations makes these relationships much more linear, an then, much more easily and robustly captured.

The predictors used in the current version of FIC's downscaling method are geostrophic wind speed and direction, at 1000 and 500 hPa. Low troposphere humidity is currently successfully used in the meteorological forecasting system we operate daily, and we will analyse the inclusion of this predictor in the climate change downscaling method. And some instability predictors will also be analysed, in order to better simulate extreme precipitation events related to convective precipitation.

3. Predictors for temperature.

Two meter air temperature is influenced both by low troposphere temperature and by soil surface temperature:

- Low troposphere temperature is well resembled by low troposphere thickness (for example 1000/850, 1000/700 or 1000/500 thickness) that are good predictors for surface temperature. 1000/850 hPa can be also sensitive to land-sea mask in coastal regions.

- Regarding soil temperature:
    - Soil surface temperature is driven by heat fluxes at the surface layer.
    - The insolation angle affects soil temperature, and it can be considered using sine functions of the day of the year. This influence depends on cloudiness.
    - Soil temperature is strongly influenced by cloudiness, because it modifies radiation cooling/heating of the surface. Cloudiness is forced by upwards movements of air, like precipitation, and the precipitation predictors are perfectly suitable for cloudiness.
    - The thermal inertia of the soil could be considered using previous days temperature as predictors.
    - Snow cover strongly modifies radiative cooling / heating of the surface so it should be also used.

- The influence of both low troposphere temperature and soil temperature, on two meter temperature, depends on atmospheric stability: under unstable conditions, there are more vertical heat fluxes, and two meter temperature is more dependant on low troposphere temperature.

Most of the predictor / predictand relationships are strongly non linear. For example, the relationship between the maximum two meter temperature and low troposphere thickness is very non linear, depending on the cloudiness conditions: under covered skies, low troposphere thickness almost determines the maximum two meter temperature; but if the sky is clear, the maximum temperature is driven by solar radiation, and the influence of low troposphere thickness is much lower. A previous stratification attending to cloudiness conditions makes these relationships much more linear, an then, much more easily and robustly captured.

The current version of FIC's downscaling method makes a first stratification, attending to cloudiness (precipitation), using geostrophic wind speed and direction, at 1000 and 500 hPa. After that stratification, a multiple linear regression is performed, using as potential predictors 1000/500hPa thickness, sine of the day of the year, and temperature of the previous days.

We will also try some more predictors, like 1000/850 or 1000/700 hPa thickness, snow cover (it was not used because it is not relevant in Spain, but it is needed for Europe), and some instability indexes.

4. References

Holton, J.R, 1979. 'An introduction to Dynamic Meteorology', Academic Press.