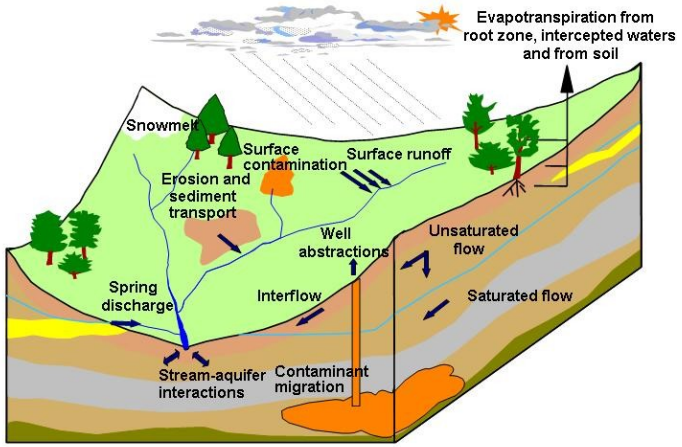
High resolution land surface processes to better understand human intervention

Jan Polcher, Martin Best and Pere Quintana

- How hydrology can help us understand the impact of human intervention on the water cycle.
- Using km-scale RCMs to estimate precipitation.
- Running a land surface model at km-scale resolution.
- Proposed model inter-comparison experiment : reconciling models and observations !

The water cycle of large scale catchments



$$\frac{\partial W}{\partial t} = \int_{catchment} (P - E)\,dc - D$$

- Discharge (D) is arguably the best observed variable of the catchment's water cycle.
- Evaporation (E) is our unknown. Especially given human intervention !
- Catchment storage (W) changes at intra-annual scales are essential but also affected by human intervention.
- High resolution is of essence as we are dealing with small mountain catchments.
- Longer periods are needed to cover hydrological time scales.
- One of the main challenges is our knowledge of precipitation (P).

Modelling high resolution water cycle

- Hydrological and land system models are able to solve this system but in general with the following hypothesis :
  - *No human intervention,*
  - *No riparian processes,*
  - *Simplified groundwater processes.*
- These are all processes which combine the vertical and lateral movements of water. For the moment our view is very much 1D.

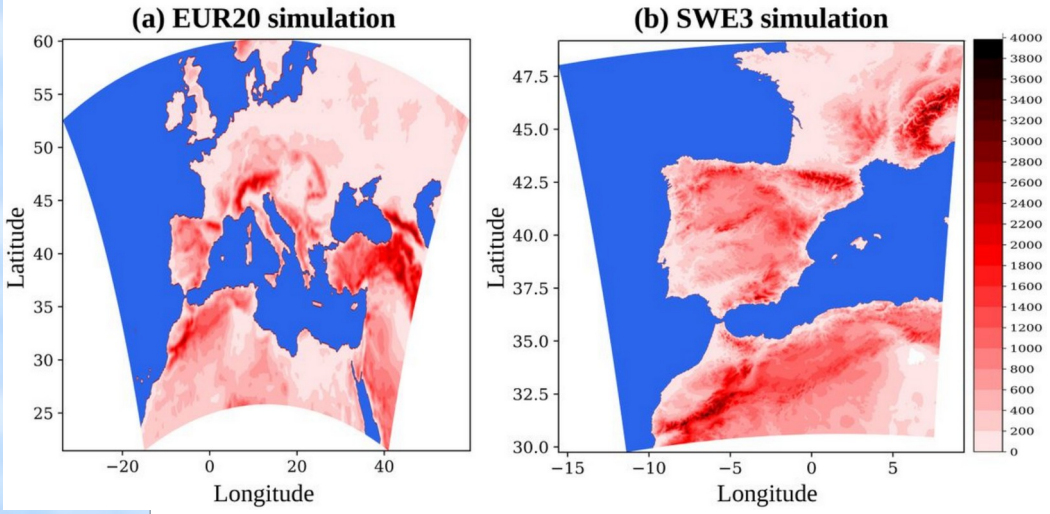
Advancing high resolution surface modelling is key for a number of water resource issues :

- Human intervention and climate change impacts will become more critical.
- Water management for a future climate needs this capacity (evaporation sensitivity, water storage changes, snow melt period).
- Atmospheric model require refined surface conditions at these resolutions.

Which atmospheric information is available km-scale LSM simulations ?

- SAFRAN Spain … see Pere's presentation.
- EUCP Downscaling simulations :
  - *4 models are available.*
  - *2-4km resolution some variables available at hourly intervals.*
  - *Driven by ERA-I large scale atmospheric conditions over the 2000-2009 period.*
  - *Much better representation of orography.*
  - *Challenging to validate as observations are at lower effective resolution.*
- Evaluation is carried out on winter here as this the season of largest rainfall.

Validation of the RegIPSL simulation

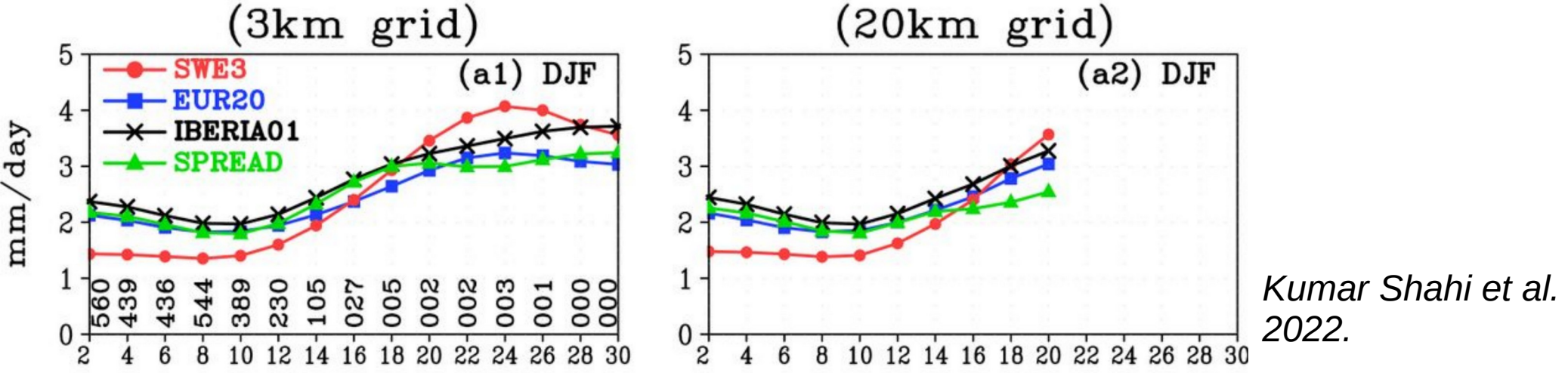


Two precipitation products over Spain :

- IBERIA01 : 0.1°x0.1°, 3761 gauges
- SPREAD : 0.05°x0.05, 12858 gauges

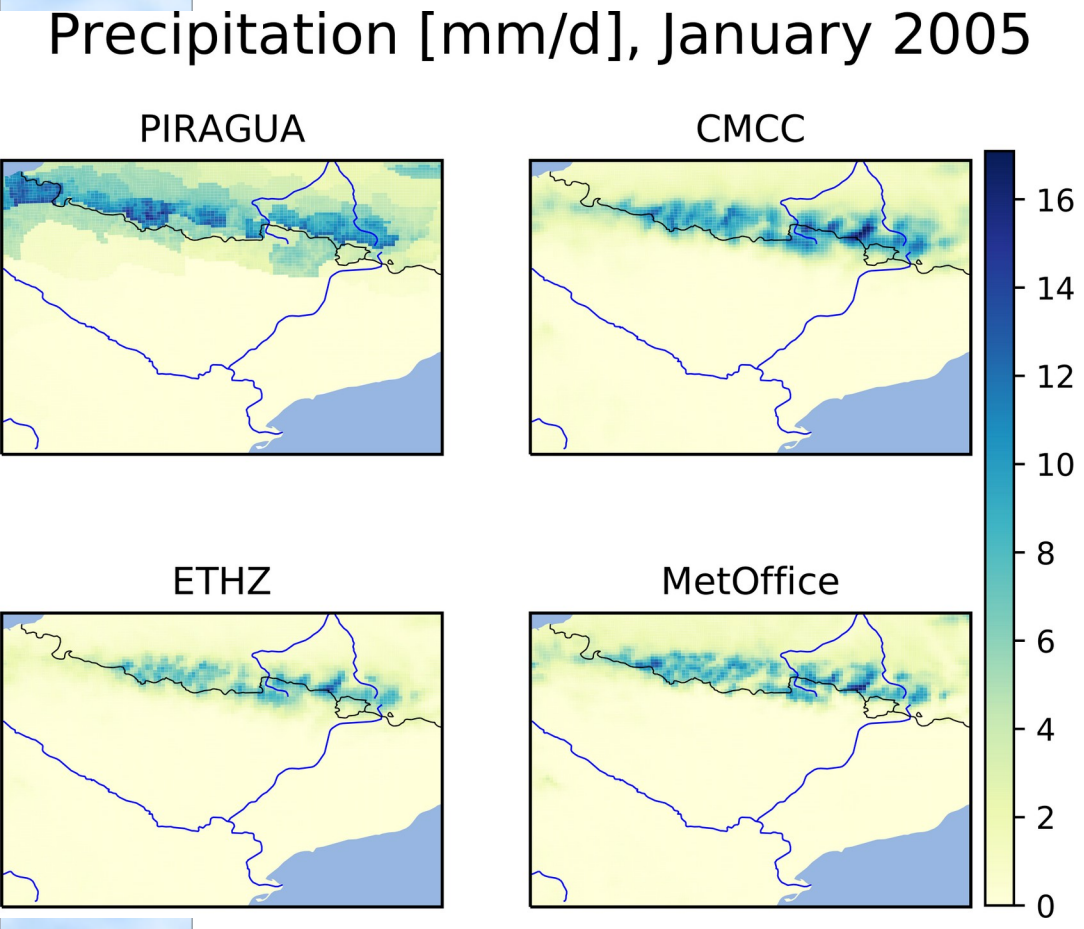
Models have and will always have large biases.
But, over topography observations are missing to invalidate models.
These are the areas where models should be better :

- Orography is well known at high resolution.
- Precipitation generating processes on slopes are well known.



Kumar Shahi et al. 2022.

Snap-shot of precipitation

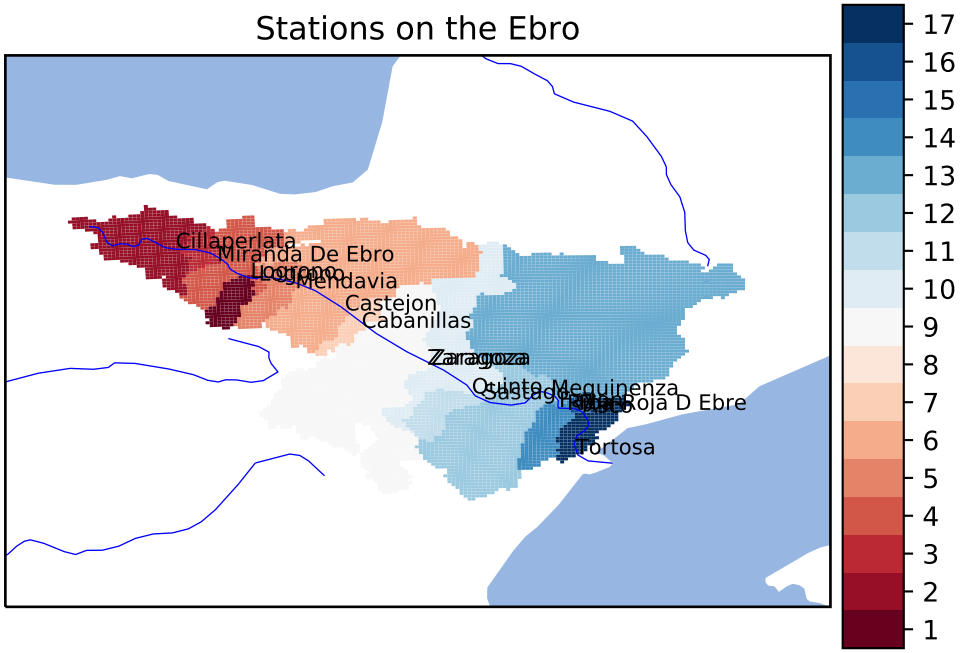


- Spatial structures are critical for any land surface modelling
- Models offer a more realistic distribution than gauge derived products.
- Orographic maximum and rain shadows agree between models.

- Snowfall is also an issue as it is an important storage term. The models can be expected to be better.
- The dynamical disaggregation provides robust spatial information for hydrology.

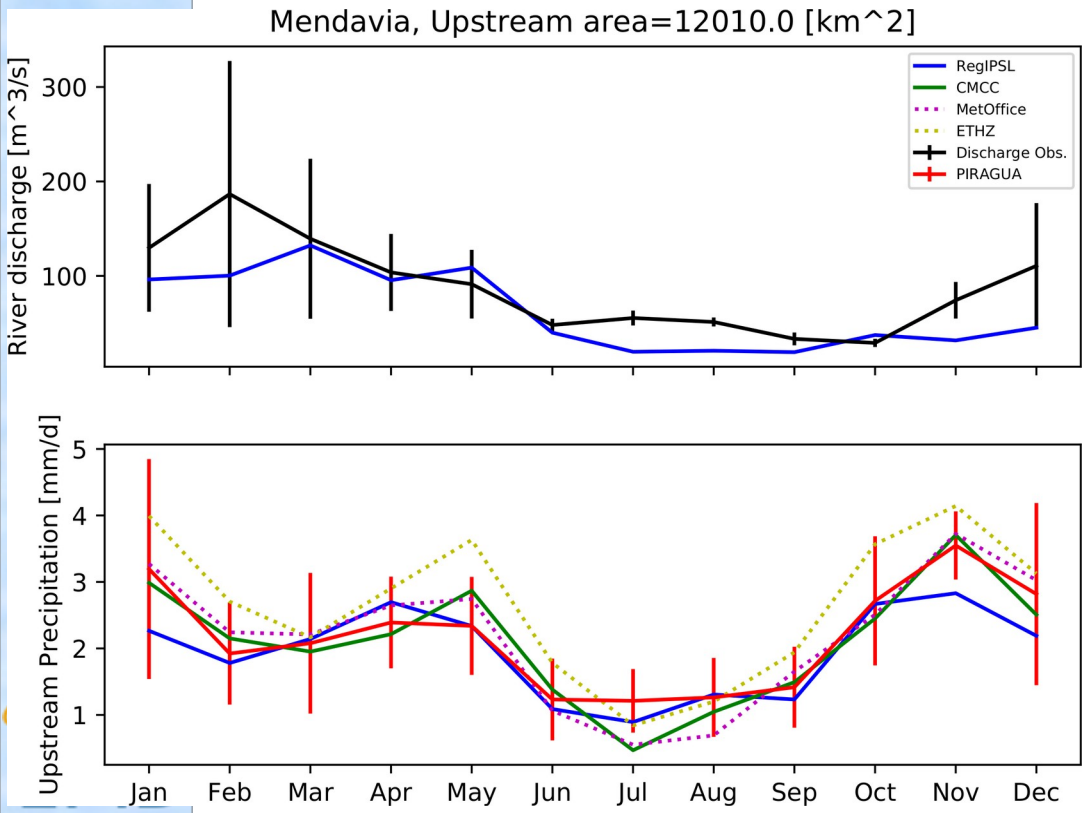
Running ORCHIDEE at 3km resolution

- ORCHIDEE is run to show the value of such off-line simulations.
- Only natural processes are considered here.
- It also allows to compare rainfall products over catchments defined at km-scales.
- Routing is performed on sub-grid aggregation of the 1km HydroSHEDS HDEM.
- Lack of stations on the Segre ! It is possible that they could not be placed on our river graph.
- Natural flows are simulated.



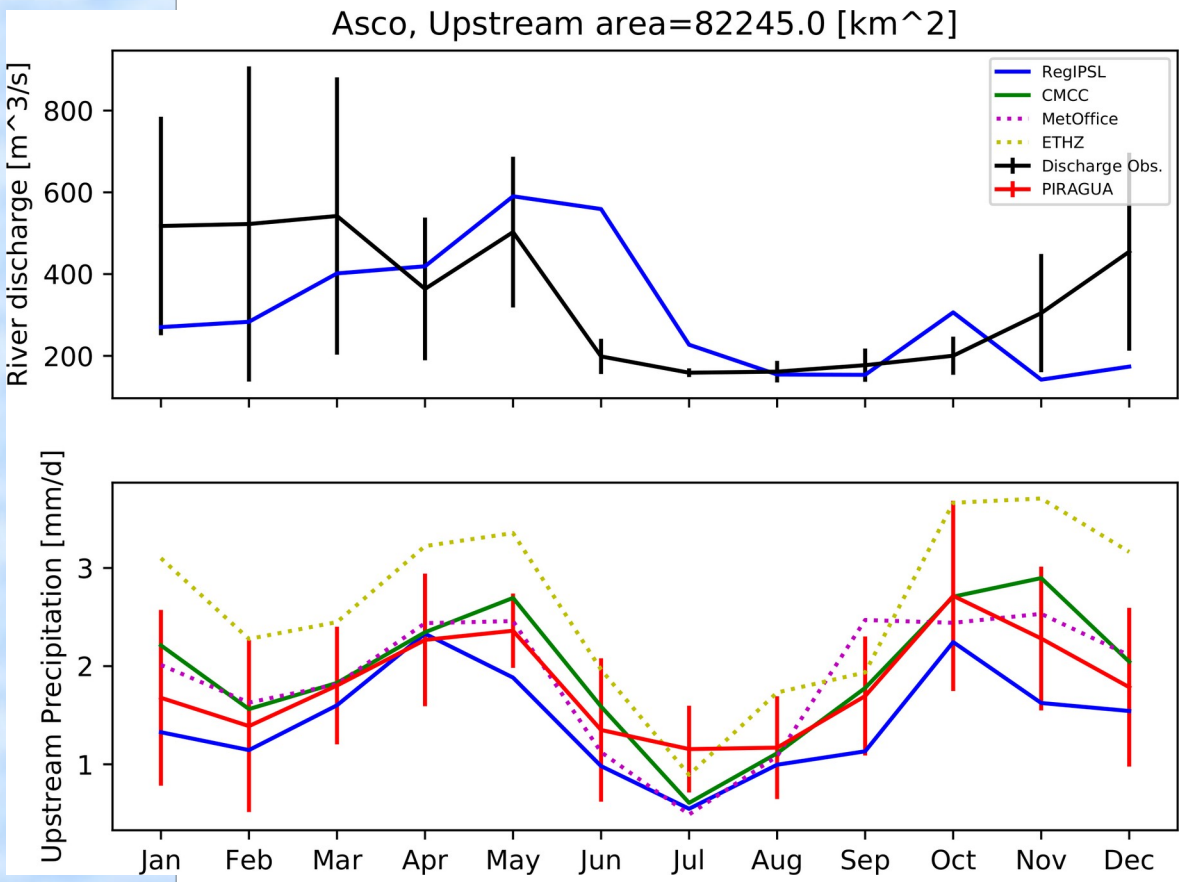
Mendavia a medium sized catchment

- Station downstream of Logroño.
- Smallest stations with discharge observation over the period.



- All models are quite close to the observational product (PIRAGUA).
- The Simulation of discharge shows the same bias as rainfall of RegIPSL in winter.
- The station shows higher low-flows, is this the result of human intervention ?
- Should this be true, then the error in precipitation less relevant !

Larger catchment : Ebro after the confluence with the Segre



- The spread of precipitation estimates is much wider.
- The river discharge is not good and not consistent with the rain bias.
- Many processes intervene in the river discharge.
- The link between discharge and P-E is more complex.

The contrast between the results at the small and large station shows the value of starting with mountain catchments and then working downstream.

The advantage of small mountain catchments

- The atmospheric data situation is difficult in small catchments, but we now have km-scale downscaled re-analysis.
- Discharge and P-E are more closely related there.
- On steep catchments storage variations are small relative to P.
- River processes are simpler and probably more natural.
- At high elevation energy is limited. So discharge is more directly linked to precipitation.
- Validating small mountain catchment gives us access to the water resources of the plains.
- Error characterisations can be propagated downstream.

Proposed Land Surface Modelling experiment

- Build a number (2-3) consensus forcing data at km-scale resolution.
- Run hydrological and land system models over the 2000-2009 period.
- Validate discharge and thus catchment water cycle at different scales.
- Compare spatial patterns of evaporation between models (to LST based estimates) and to point observations.
- Compare to observed contrasts between natural and irrigated in July 2021.
- Validate surface temperature anomalies to check areas of high evaporation.

Conclusion

- Hydrology brings a complementary view of human intervention on the water cycle.
- Data is now available to run land surface models (LSM) at km-scale resolutions.
- Current LSMs can be used to identify missing processes or critical processes in highly management basins such as the Ebro.
- An inter-comparison would allow to explore uncertainties.
- Provide answers to the question : Where and when does water management have a larger impact that our uncertainties in atmospheric data and surface process ?
- It would also be a driver of LSM developments.

Who would be game for a model inter-comparison ?