ETH zürich

Runoff and Streamflow Indices for Climate Extremes

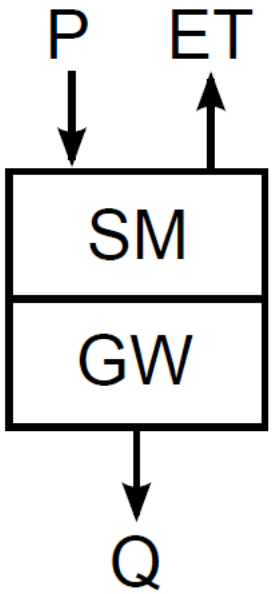
Lukas Gudmundsson & Sonia I. Seneviratne

IAC*ETH*, Land-Climate Dynamics

Why care about ~~runoff/streamflow~~ water on land?

Impacts:

- Agriculture
- Public Water Supply
- Energy
- Flooding
- …



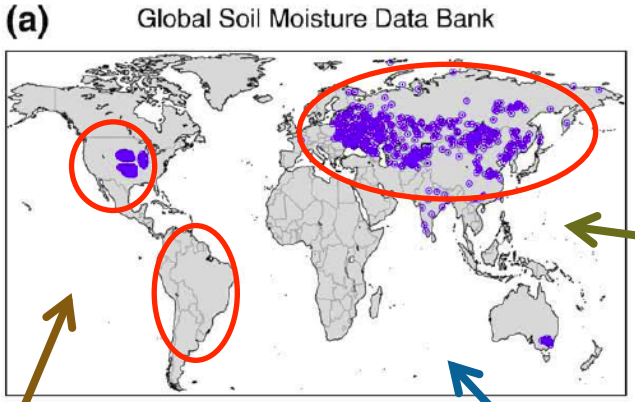
Processes:

- Land-atmosphere feedbacks
- Ecosystem processes
- Carbon Cycling
- …

Note:

*Most Processes and Impacts are controlled by **storage variables***

Availability of in-situ observations:
Issues with storage variables, e.g: Soil Moisture



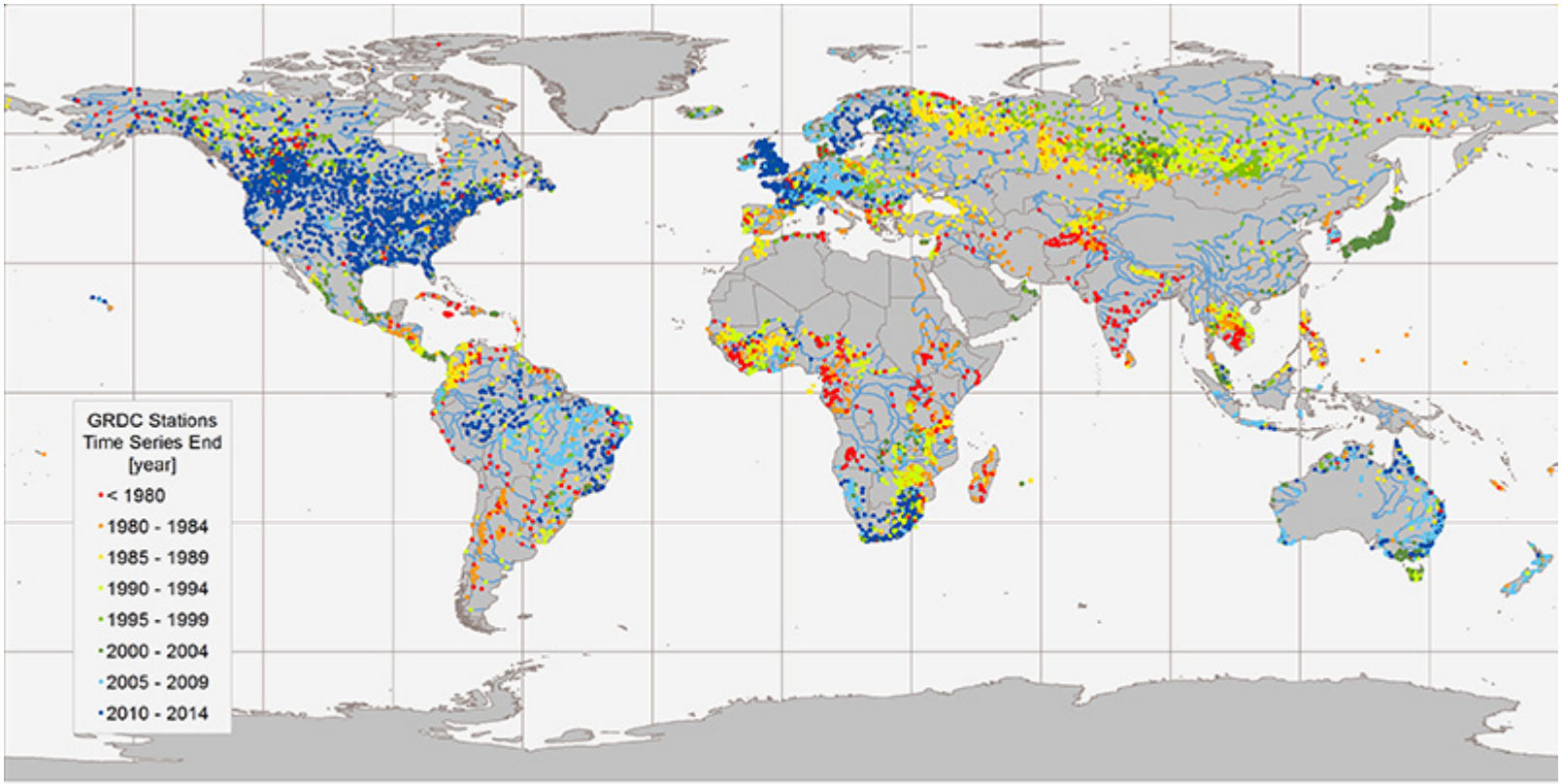
Seneviratne et al (2010)

Instrumentation
- Different principles
- Heterogeneous technology

Spatial coverage
- Irregular station density
- Sparse observation networks

Temporal coverage
- Large regional differences
- Short time series

Availability of in-situ observations:
Runoff & Streamflow: most complete coverage



9011 GRDC stations with monthly data, incl. data derived from daily data (Status: 18 Dec 2014)
Koblenz: Global Runoff Data Centre, 2014.

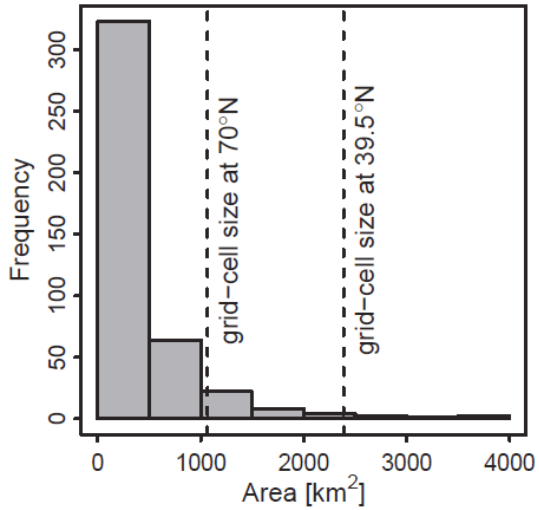
Typical Data Providers

- **The Global Runoff Data Center (GRDC)**
  - Large number of series
  - No regular updates
  - No «full» data base access (copy right restrictions)
- **Regional and national collections**
  - e.g. the USGS, European Water Archive (EWA)
  - Heterogeneous updating policies
  - Large differences in data-access (open access vs. restricted)

Question 1:
How to best integrate observations from different data providers. To which degree interact with other initiatives?

Particularities of runoff & streamflow data: *(1) Spatial Localization*

Many Small Catchments

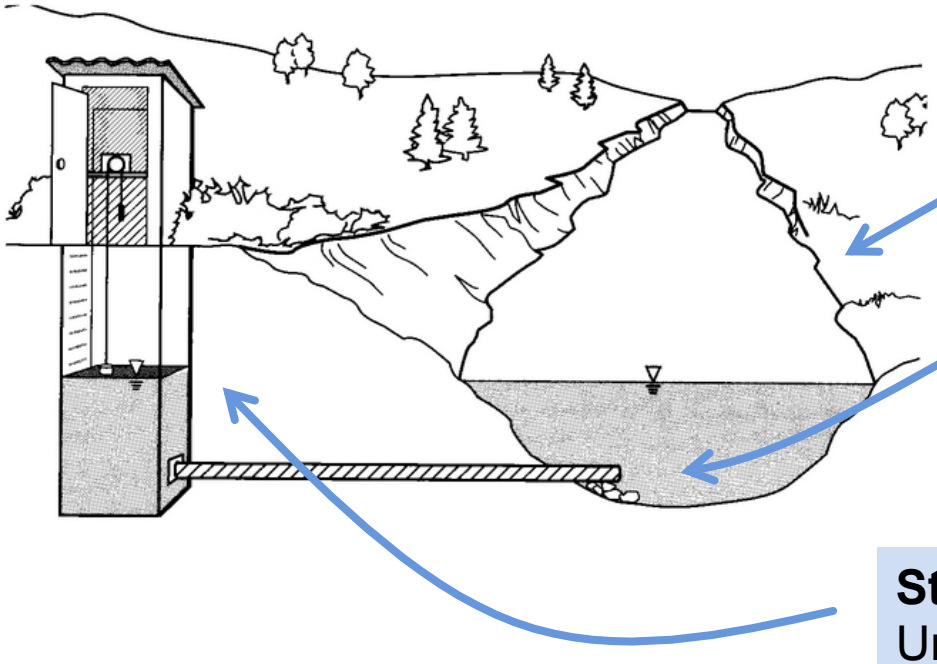


Few Continental River Basins

Question 2:
What does the differences between small head water catchments and continental scale river basins imply?

Particularities of runoff & streamflow data: *(2) Observing Systems*

https://www.utdallas.edu/~brikowi/Teaching/Field_Methods/sanders-1998_fig3-15.jpg



Floods:
«over-flow» issues

Low-flows:
Often decreased resolution

Stage-height Discharge relation:
Uncertainties in rating-curves

Question 3:
Can quality control procedures be developed that help to classify the credibility of observations from heterogeneous observing systems

Particularities of runoff & streamflow data: *(3) Changes in the catchment*

Engineering

Wikimedia Commons / 663highland / CC BY 2.5

Land Use Change

NASA / Wikimedia Commons

Question 4:
How to treat inhomogeneities caused by catchment-engineering and land use change; can we detect the and differentiate between them automatically?

Runoff & streamflow based indices for extremes
(1) Extreme Events

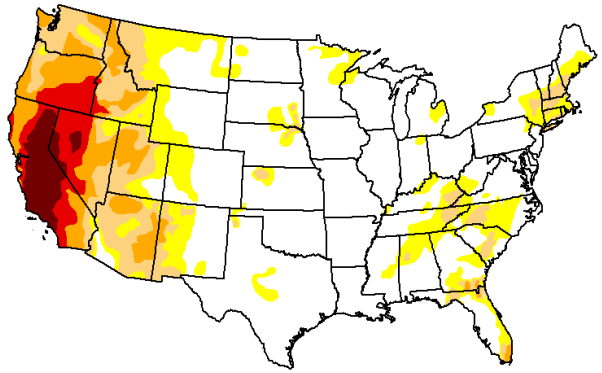
Characterizing *events* with un-usual amounts of water

- Block Statistics (e.g. annual, monthly)
  - maxima / minima
  - Percentiles
- Counts above / below a threshold
- Excess / deficit **volumes**
  - Volume of water that exceeds or is below a threshold
- Complex indices for specific applications
  - E.g. minimum series smoothed with an moving average.

Question 5:
A plethora of extreme-indices are in use in hydrology; Which ones to use and why?

Runoff & streamflow based indices for extremes
(2) Extreme Episodes

US Drought Monitor July 2, 2015



Droughts: *prolonged episodes* of limited water availability

Often quantified through:

- Standardized anomalies of water-balance variables
- «Drought Indicators» (SPI) can easily be applied to streamflow data.

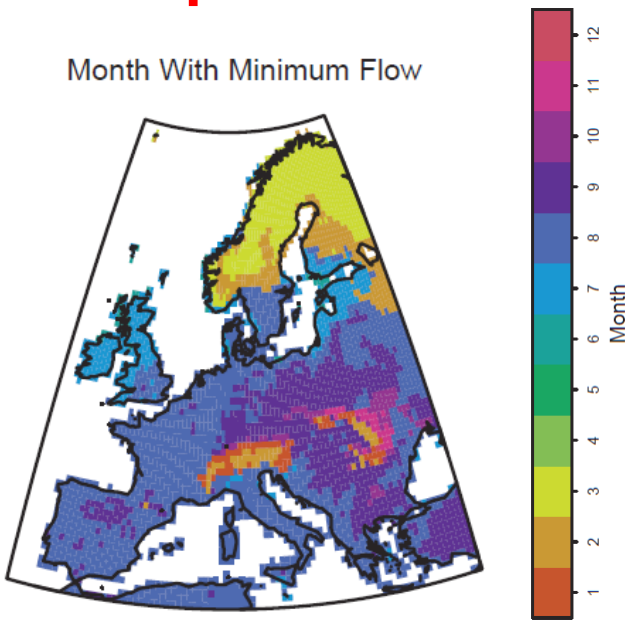
Question 6:
Should extreme episodes in runoff & streamflow be quantified through standardized indices or is it important to keep physical units intact

```
SCI: Standardized Climate Indices such as SPI, SRI or SPEI
```

Runoff & streamflow based indices for extremes
(3) Supporting Indices & Climatologies

Background information to facilitate interpretation

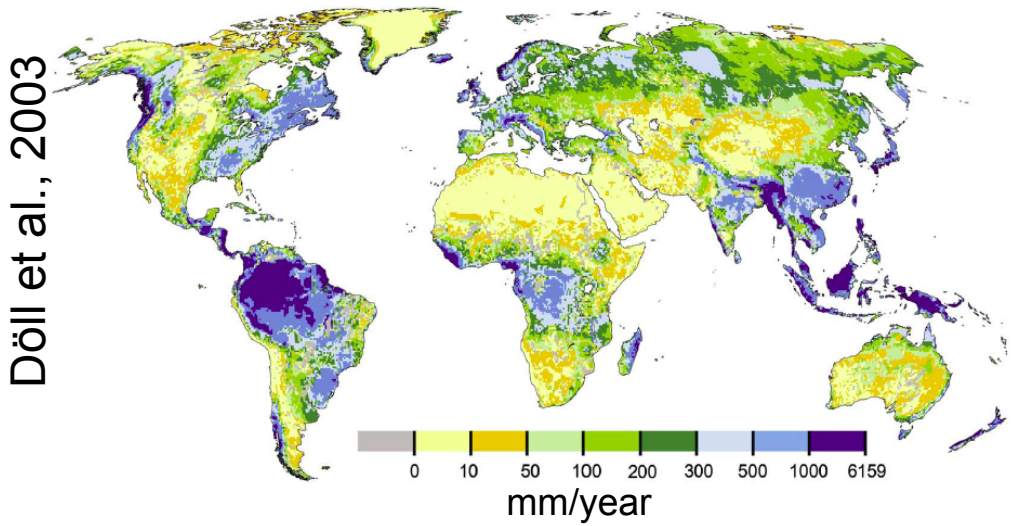
- Climatologies
  - Long-term means
  - Average date of occurrence
- Water-availability indicators
  - Annual and monthly statistics
- Indicators for timing
  - Date of occurrence
  - center of mass



Gudmundsson & Seneviratne (2015)

Question 7:
Should supporting indices and climatologies also be collected?

Open Challenge:
How to derive observational runoff grids



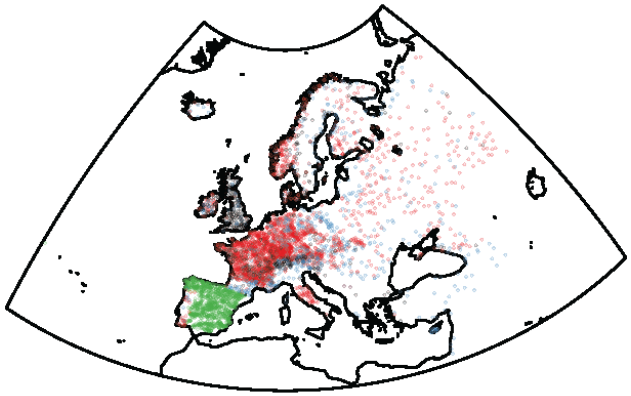
Most common approach:

- Re-analysis driven LSM
- Under-utilize observations
- No data-assimilation (state updating)

Question 8:
What approaches should be used to produce continental/global observation-based estimates? Which alternatives do exist?

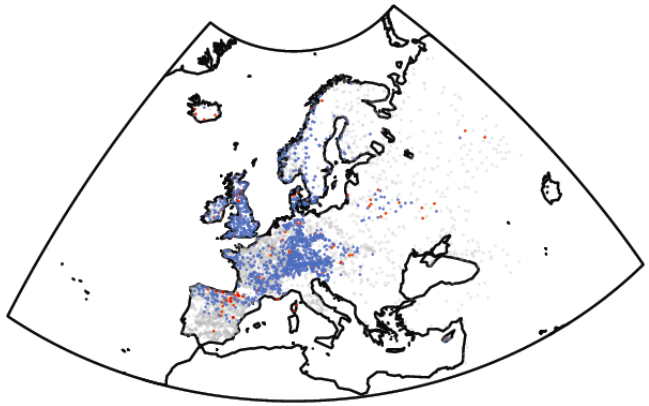
European Case-study:
(1) Data Collection & Quality Control

Data Sources



Source Data Base
- EWA
- GRDB
- Spain
- EWA and GRDB

Homogeneous stations



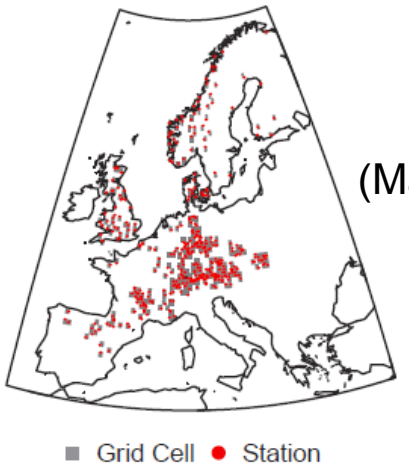
- Usefull
- Suspect
- Not sufficent data in 1971– 2005 or catchment ara > 5000 km2

data-base merging:
using statistical record-linkage

Quality control & homogeneity testing:
Following EAC&D recommendations

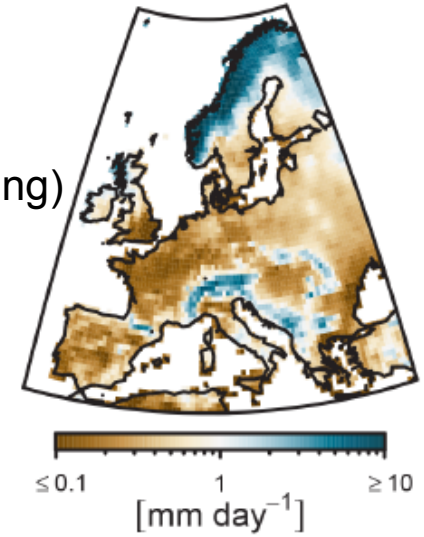
European Case-study:
(2) Statistical Upscaling / Reconstruction

Stations

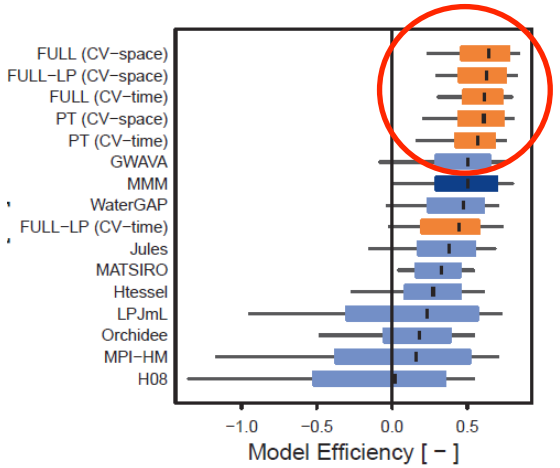


Upscaling
(Machine Learning)

Gridded runoff



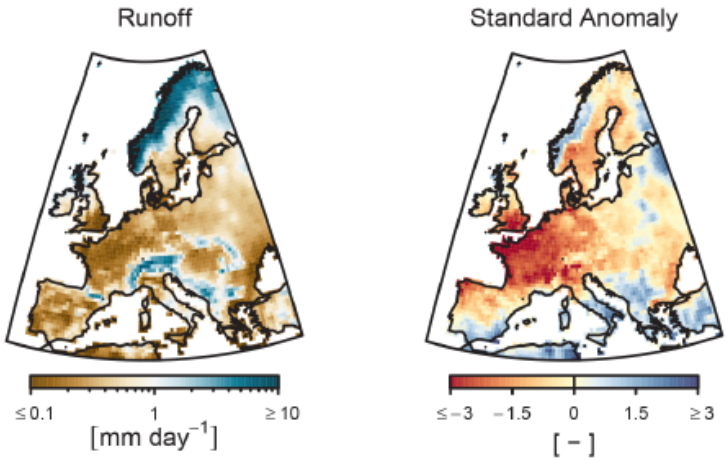
Performance

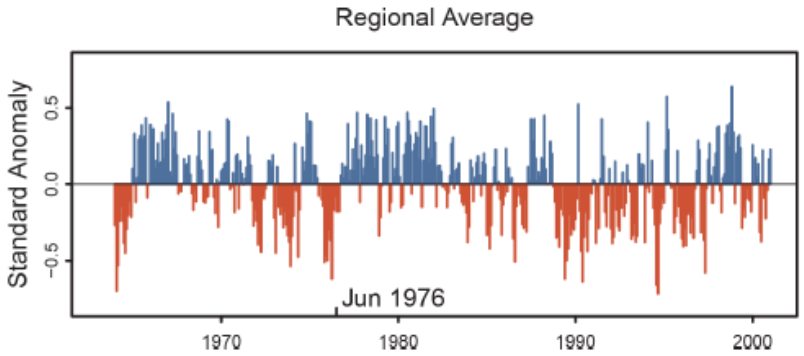


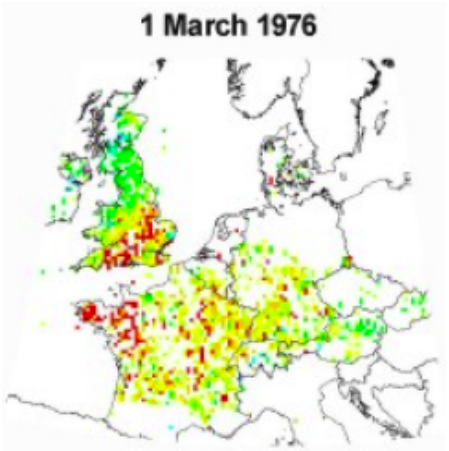
Gudmundsson & Seneviratne (2015)

Upscaling monthly runoff from small catchments
- Based on re-analysis data and machine learning regression
- Good overall performance of the upscaling model (**orange**)

European Case-study:
(3) Drought Assessment







Zaidman et al., 2002

1976:
One of the driest years in the record

- The newly derived grid captures reported anomalies well.

Gudmundsson & Seneviratne (2015)

Tentative Deliverables (2018): *Assessment based on the GRDC collection*

- **Automated quality control for streamflow data**
  - Credibility of individual values (daily & monthly)
  - Detection of inhomogeneity's
  - Classify human influence on catchments
- **Develop Indicators to assess trends in extremes**
  - Floods, low-flows and droughts
  - Changes in their seasonality
- **Produce global gridded runoff time series**
  - Focus on monthly time series to provide background information
  - Extend to extreme indices if feasible

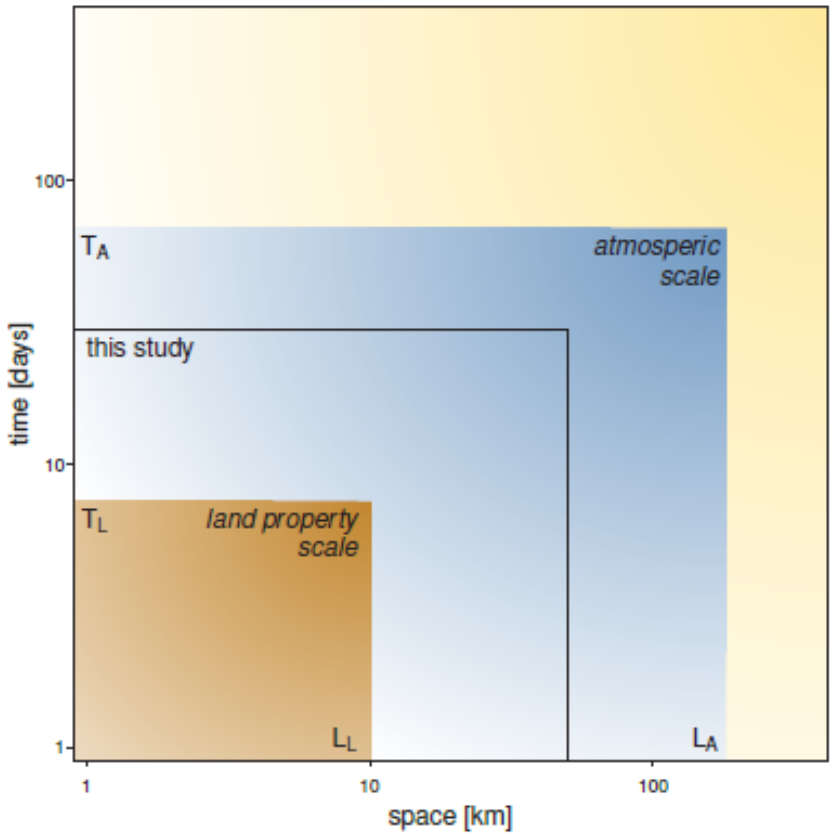
Questions

1) How to best integrate observations from different data providers? To which degree interact with other initiatives?
2) What does the differences between small head water catchments and continental scale river basins imply? ***Scaling issue***
3) Can quality control procedures be developed that help to classify the credibility of observations from heterogeneous observing systems?
4) How to treat inhomogeneities caused by catchment-engineering and land use change; can we detect the and differentiate between them automatically?
5) A plethora of extreme-indices are in use in hydrology; Which ones to use and why?
6) Should extreme episodes in runoff & streamflow be quantified through standardized indices or is it important to keep physical units intact
7) Should supporting indices and climatologies also be collected?
8) What approaches should be used to produce continental/global observation-based estimates? Which alternatives do exist? ***reconstruction***

Further Topics/Questions:

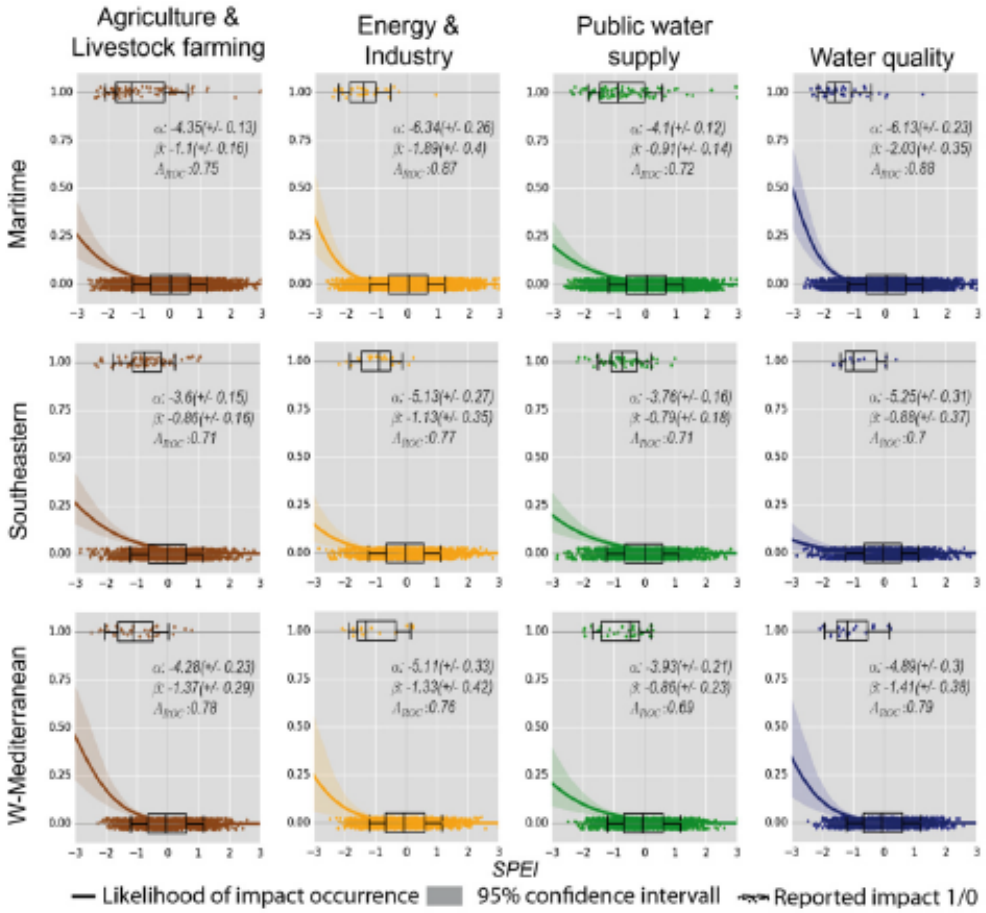
- Is it useful to classify series into “useful” time resolutions? e.g. “daily” vs. “monthly” vs. “annual”?
- How to address issues related to data availability?
  - e.g. no global telecommunication network…
  - Which role should estimates / **reconstructions** play?
- Drought: water-availability-indicators
  - “episode” not “event”
  - SPI etc. (but strongly dependent on model assumptions)

Scaling Issues:
Hypothesis: land & atmospheric scale



Gudmundsson & Seneviratne (2015)

Impact/sector related Indices?
Probability of impact occurrence



Blauhut et al. (2015)