# Impacts of anthropogenic activities on different hydrological drought characteristics



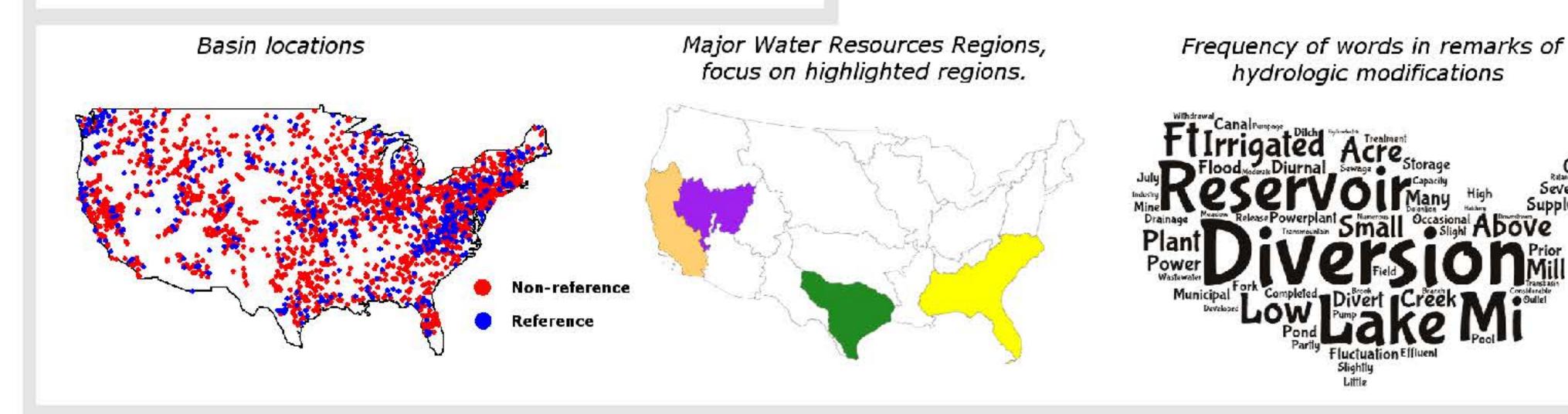
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#### Introduction

Drought research in catchments with near natural flow conditions is crucial to gain process understanding about hydrological droughts. However, the locations of catchments with natural flow often do not coincide with regions with a socioeconomic sector that is highly vulnerable to droughts.

- How different are drought characteristics in anthropogenically influenced basins?
- Have regulations changed the occurrence of drought
- Is it useful to include information from these anthropogenically influenced basins in drought monitoring and early warning systems like the US Drought Monitor?

Non-reference



Examples of anthropogenic influences on droughts

#### Data

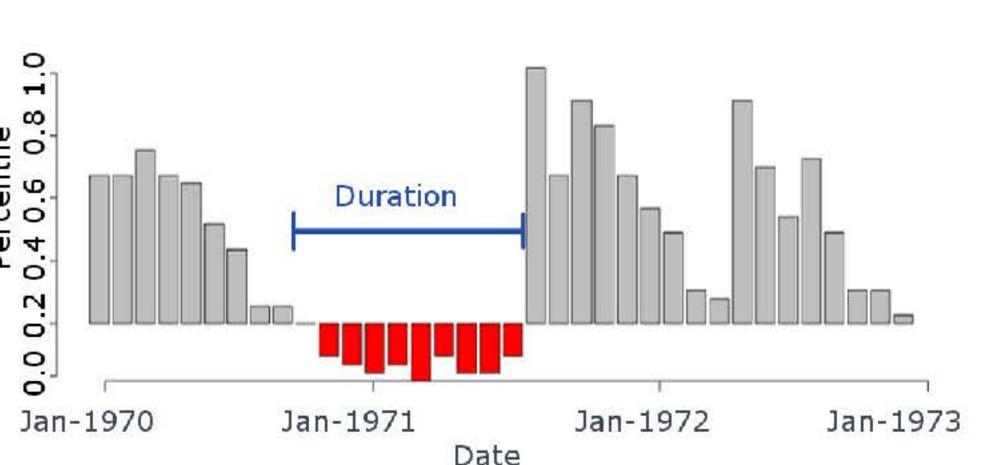
- Daily streamflow data from basins belonging to the GAGES-II dataset was obtained from the USGS website.
- Data selection criteria: at least 40 years of continuous daily data (1970-2010) and daily 20th percentile > 0. Basins are divided into two groups: Near natural (reference,
- Data is further grouped for each of the 18 major Water

HCDN-2009) and other likely influenced (non-reference)

Reference

Resources Regions in the contiguous US (middle map). Water report remarks from the GAGES-II dataset about hydrological modifications are used to indicate different anthropogenic influences (right map).

### Methods: drought identification



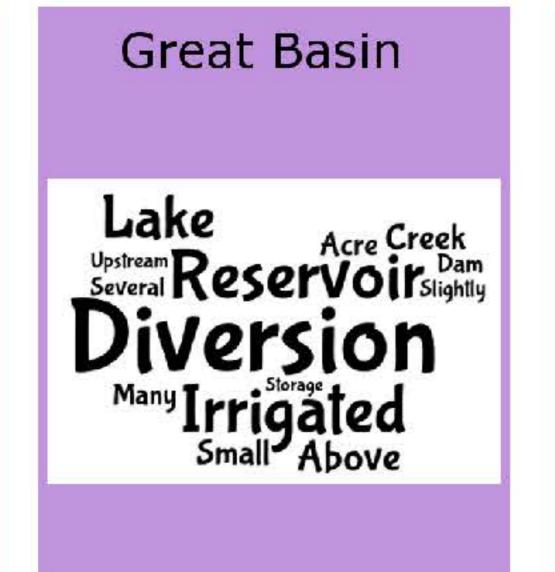
- A monthly percentile based approach is used to rank streamflow values.
- The principals of the threshold approach (threshold level = 20%) are applied to define hydrological drought events
- The following drought characteristics are used: **Duration**: number of consecutive months streamflow percentiles are at or below 20%.

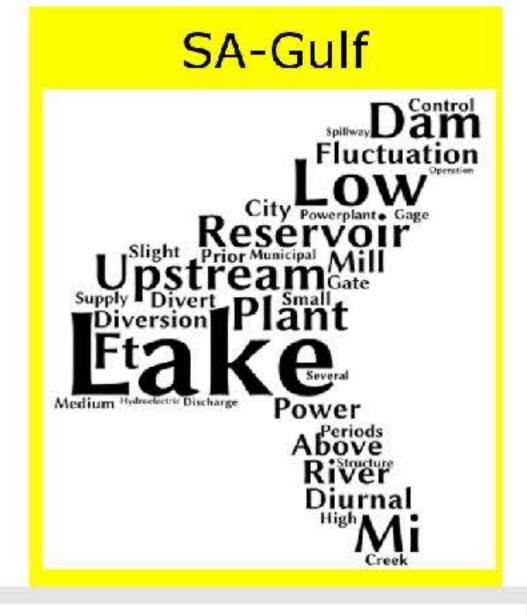
Texas-Gulf

Severity: difference between monthly streamflow and threshold. Severity is standardized by dividing it by the 20th percentile streamflow value of the corresponding month. Monthly severity is summed over the duration of the drought event.

### Results: differences in drought characteristics







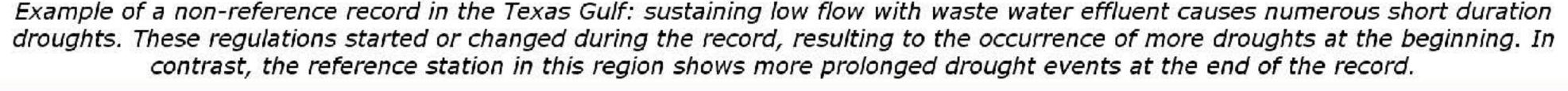
- Word clouds above show the quantity of words used in water report remarks for different water resource regions.
- Diversions are an important anthropogenic influence in all these regions as well as storage/regulation through reservoirs and
- "Irrigated" is an important remark in the three western basins; dams and power plants are noted in California and the South Atlantic-Gulf (SA-Gulf); the remark wastewater effluent is mentioned for Texas, indicating that in this region low flow is sustained by wastewater effluent.
- Graphs below show the cumulative distributions of duration and severity of the most severe drought events (duration of at least one year) within each Water Resource Region. These characteristics are most similar between reference and non-reference basins in the SA-Gulf.
- In the Great-basin, most extreme droughts (especially with regard to severity) are found in the anthropogenically influenced
- basins. This implies that anthropogenic influences in this region intensify hydrological droughts (see example section). In Texas, this is the other way around. Regulations like sustaining low flow with wastewater effluent are likely to moderate hydrological drought characteristics (see example section).
- In California, drought durations are longer in non-reference basins. However, severities are both lower and higher which suggests different types of anthropogenic influences.

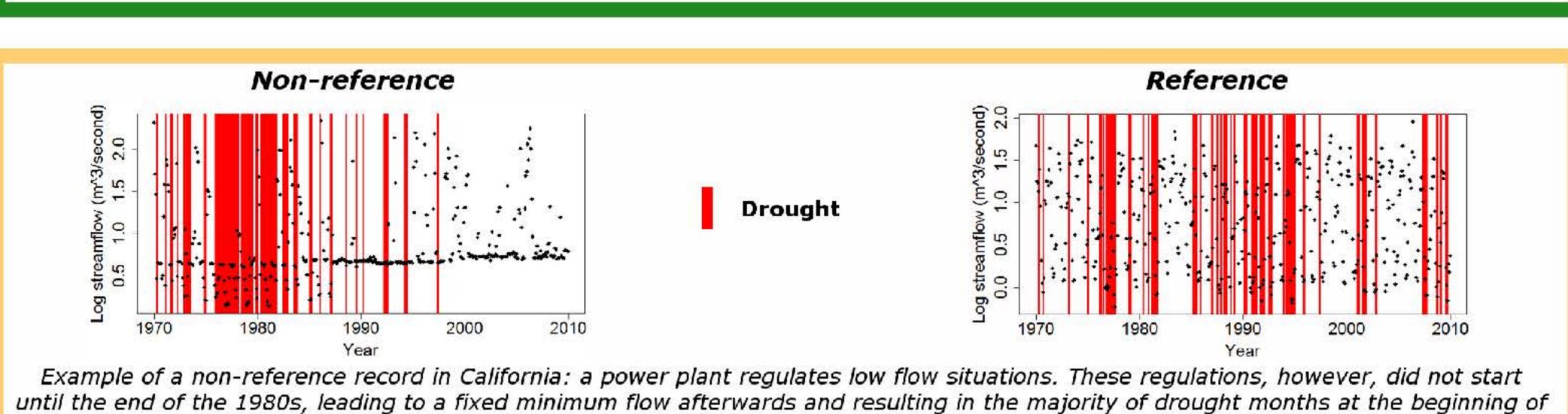
# Non-reference Reference Drought Example of a non-reference record in the Texas Gulf: sustaining low flow with waste water effluent causes numerous short duration

Drought

Example of a non-reference record in the Great Basin: flow regulations by a dam at the outlet of a lake are the cause of one

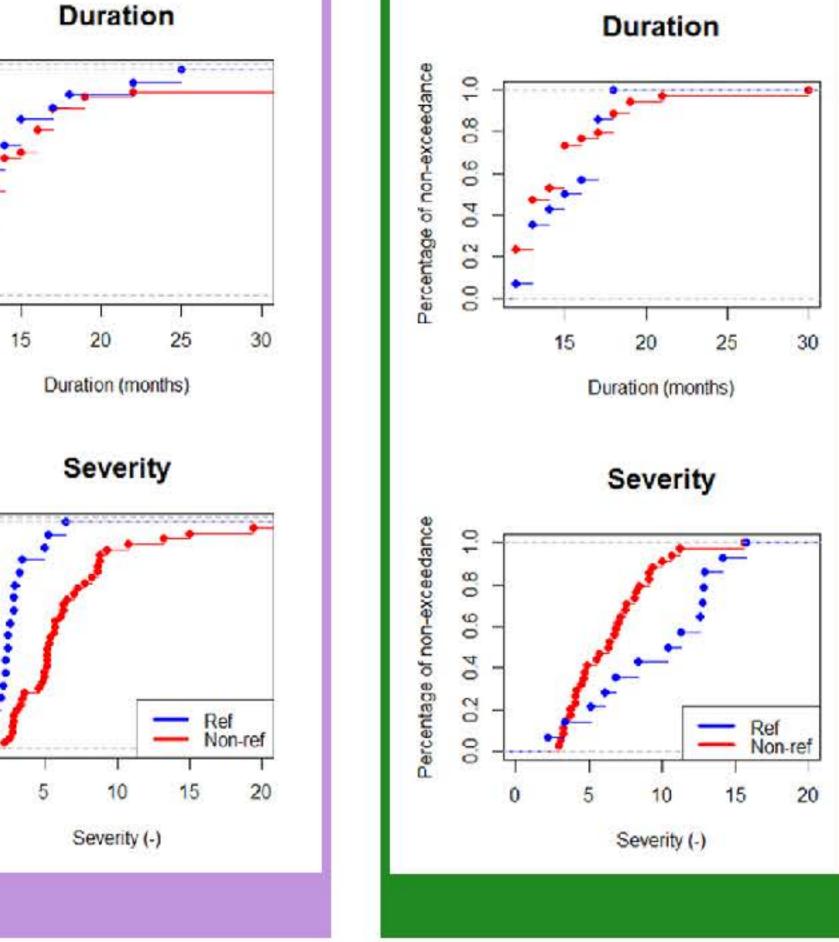
major drought event that lasted for 57 months. This continuous period of low flow is not found in a close-by reference basin.

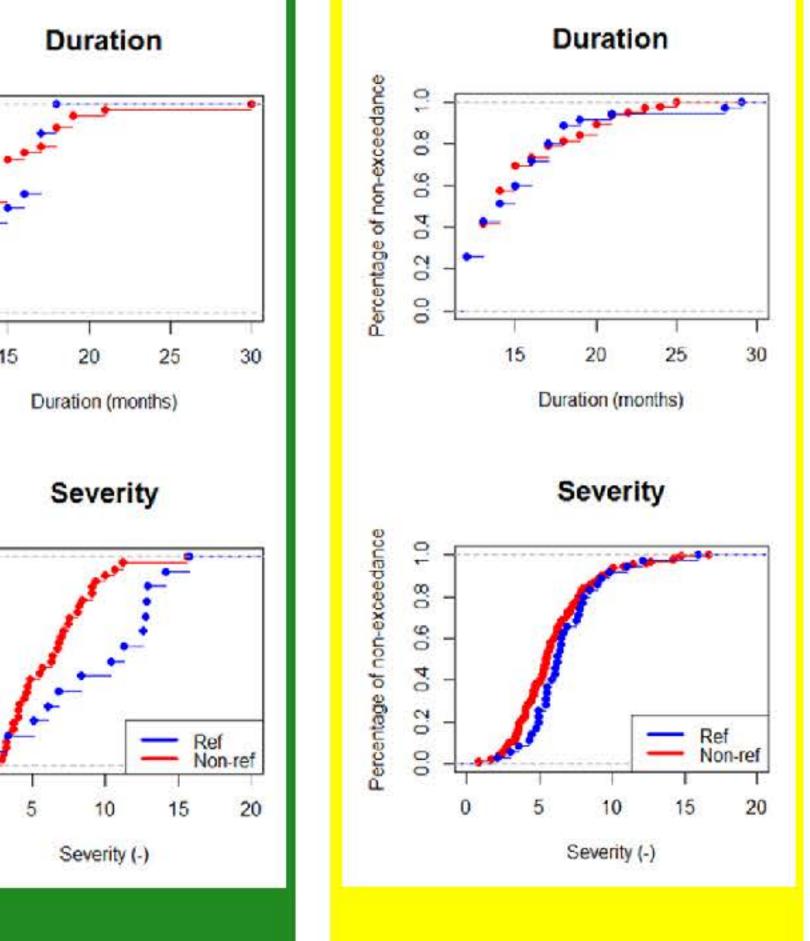




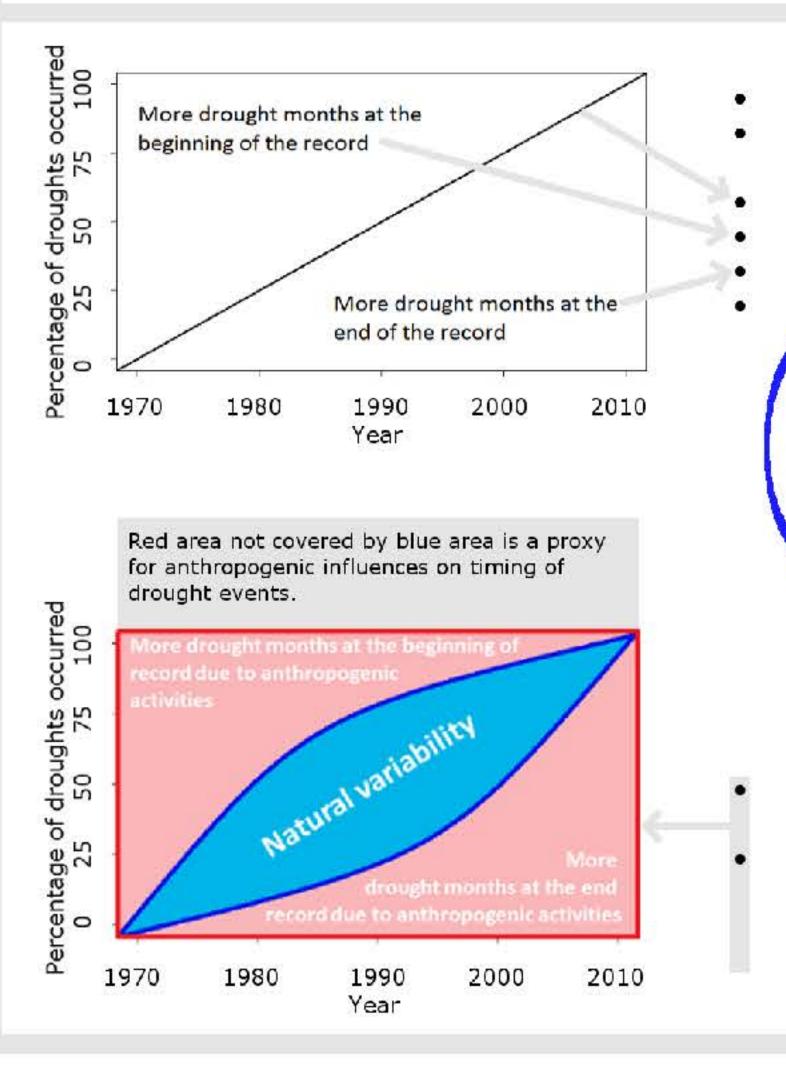
the record. This change in low flow conditions was not observed for the nearby reference station.

# Duration 20 25 30 Duration (months) Severity

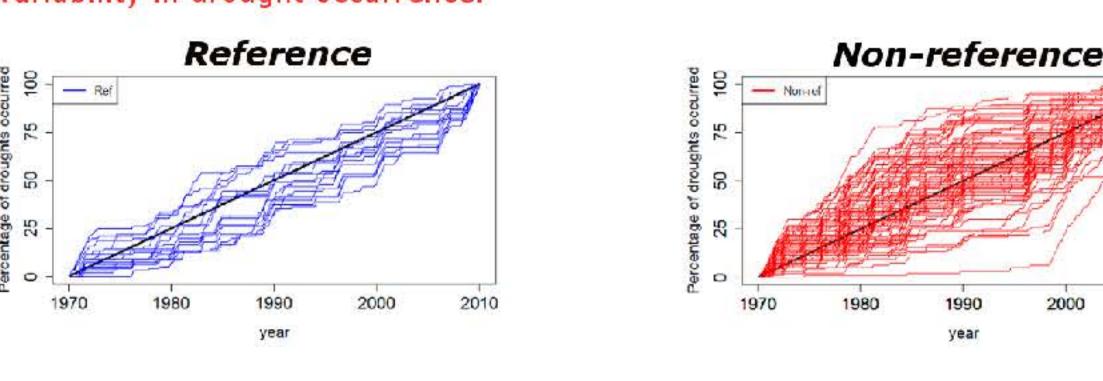


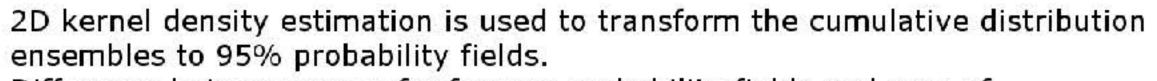


### Methods: occurrence of drought events (1970-2010)



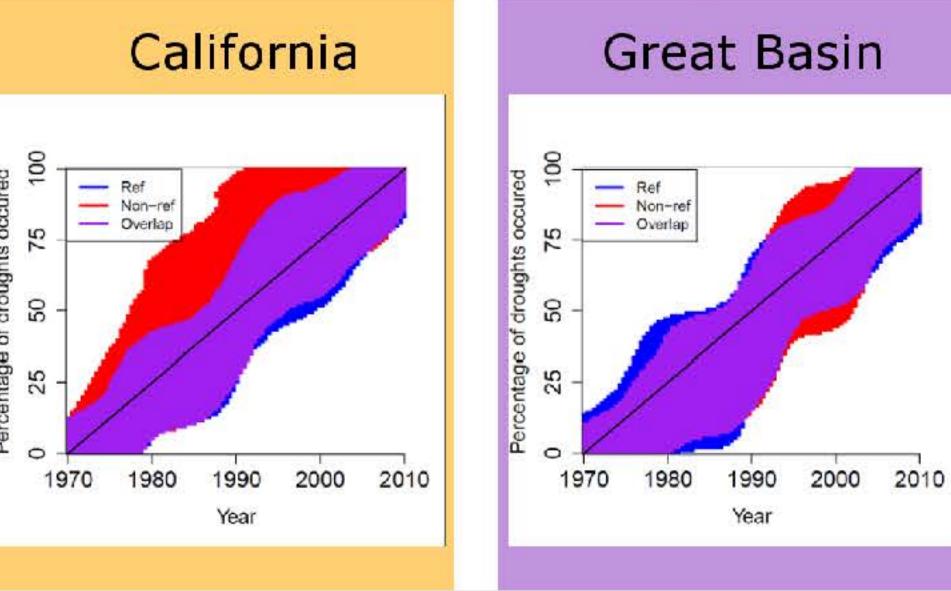
- By definition, 20% of the months are drought months. Percentage of drought occurred is plotted over time (i.e. a cumulative distribution of drought months) to quantify the occurrence of drought events. Uniform distribution means one drought every 5 months (black line) Cumulative distribution above this line.
- Cumulative distribution below this line.
- Cumulative distributions of reference stations: natural variability in drought occurrence. Distributions of non-reference stations: anthropogenically influenced variability in drought occurrence.

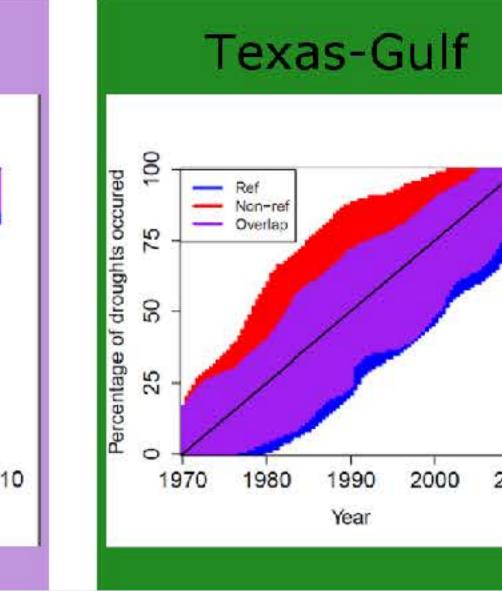


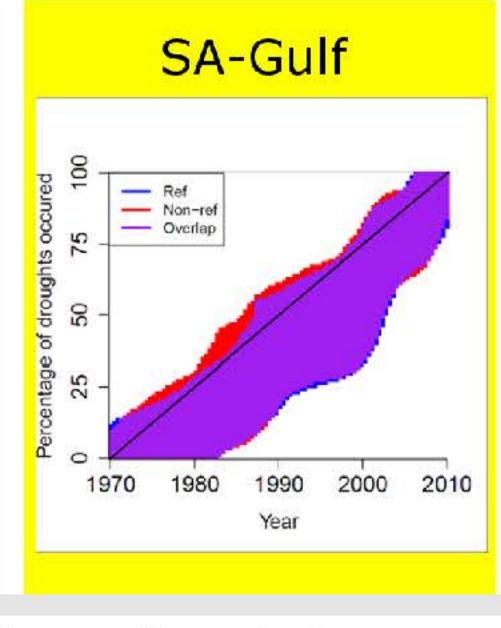


Difference between area of reference probability fields and area of non-reference probability fields (total, below and above the natural variability) is used to indicate how anthropogenic activities influence the occurrence of drought

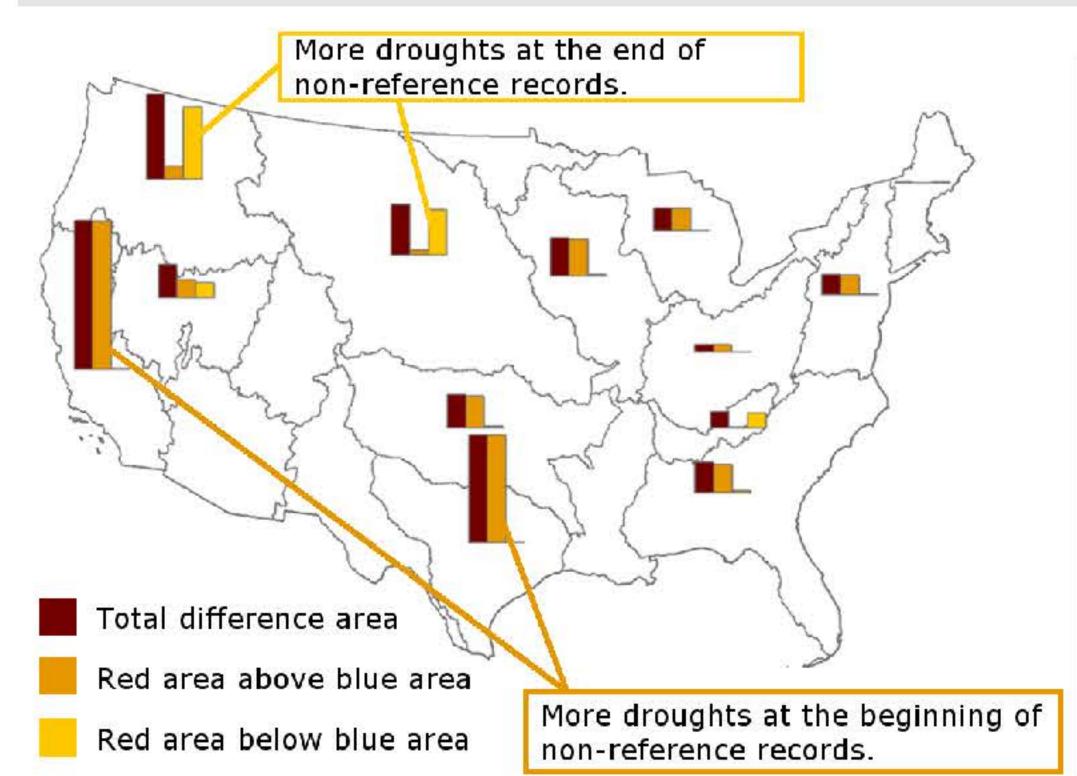
### Results: occurrence of drought events (1970-2010)







- Probability fields of the major Water Resource Regions California and Texas show that for part of the non-reference basins, more droughts occurred at the beginning of the record compared to the natural variability in timing of drought events (see example section). This difference in occurrence is not clearly visible for the Great Basin and the South Atlantic-Gulf.
- The map below shows the difference between blue and red area per region.
- Especially the southern and western regions show differences in occurrence of drought events, whereas the occurrence in droughts in the eastern regions is not very different for the non-reference basins. Map below further indicates if differences in area are above (more droughts in the beginning of the record) or below (more
- droughts at the end of the record) the natural variability field.
- Southwestern regions: more droughts at the beginning of the record. Northwestern regions: more droughts at the end of the



### Conclusions

- Drought duration and severity of extreme drought events are both moderated and intensified due to anthropogenic
- Occurrence of drought events is influenced by these anthropogenic activities as well.
- Anthropogenic influences on both these drought characteristics are strongest in the Southwestern US. In the Eastern US, drought characteristics in non-reference basins are similar to characteristics in reference basins
- Water shortages in anthropogenically influenced basins likely have a strong impact and could possibly feed additional information into drought monitoring and early warning systems. However, further research link with reported drought impacts is needed to prove this.
- Furthermore, (changes in) regulations over time that modify the flow regime limit the applicability of classical drought identification methods for these basins.