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PHYSICAL STORYLINES OF FUTURE EUROPEAN DROUGHT EVENTS LIKE 2018

BASED ON ENSEMBLE CLIMATE MODELLING

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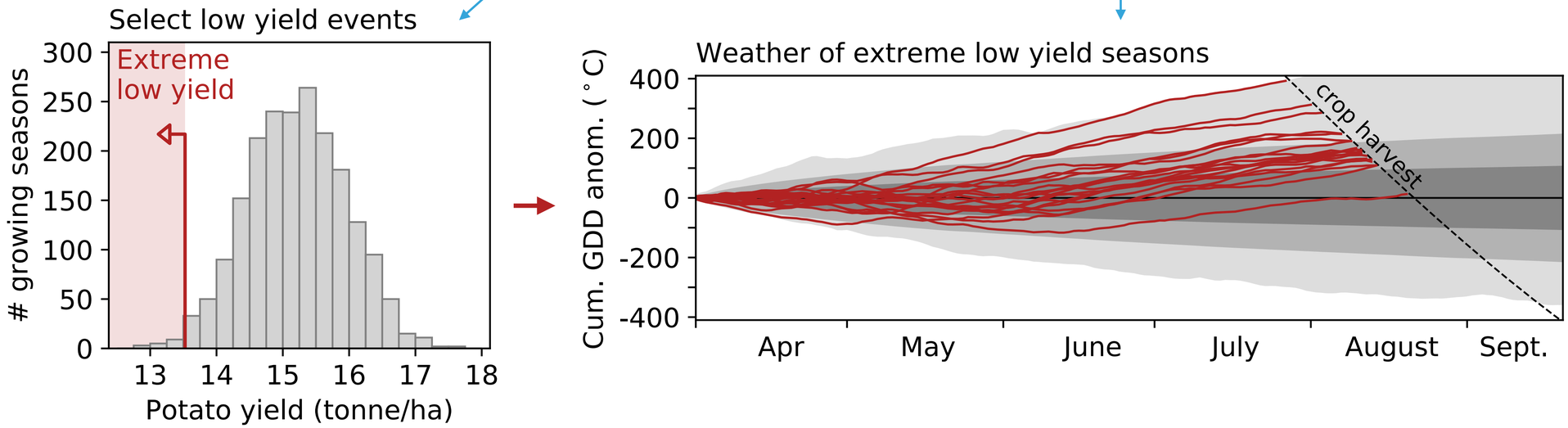
(SOME) ADVANTAGES OF LARGE ENSEMBLE SIMULATIONS

- Large ensembles = many realisations of the same climate model experiment
- The many realisations capture internal variability within the climate system

- Large ensembles thus contain a large diversity of weather events
- We can use this to select events and investigate drivers or changes



Example: ensemble climate-impact modelling to identify (diverse) drivers of extreme events (Van der Wiel et al., 2020, ERL)

(SOME) ADVANTAGES OF STORYLINES

- Storylines improve risk awareness and decision making processes
- This is due to their connection with observed events and user-focus

(Hazeleger et al., 2015, NCC; Shepherd et al., 2018, CC)

- Can we combine the positives of large ensembles and storylines to answer societally relevant questions?

- Aim of this work:

Develop a method to construct storylines of plausible future events that are comparable to an observed event of interest, by selecting events from large ensemble climate model simulations.

(Van der Wiel et al., under review)

PROPOSED METHODOLOGY

1. Select simulated events like the observed event: 'analogues'
2. Compare the analogues in present and future climates

But:

- How to define the observed event, how to select analogues? Slides 5-8
- Are there analogues that resemble the observed event? Slides 9-10
- Does this provide robust and reliable climate change information? Slides 11-15

- This presentation ⟶ proof-of-concept:
  storylines of future European drought events like 2018

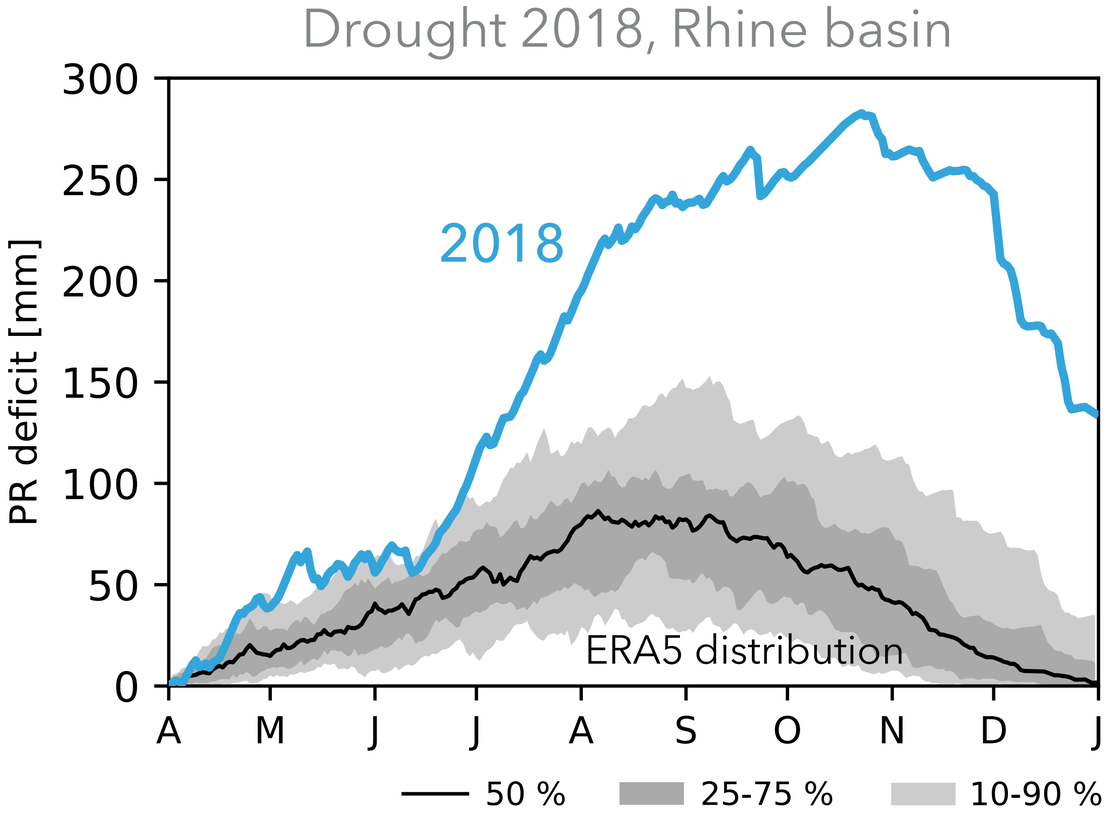
(Van der Wiel et al., under review)

1: THE EVENT OF INTEREST

- Western European summer drought of 2018
- In the Netherlands:
  - Second driest summer on record
  - Economic loss estimated between 450 and 2,080 million Euros

(Sluijter et al. 2018, Ecorys 2018)

Photo: Jannes Wiersema

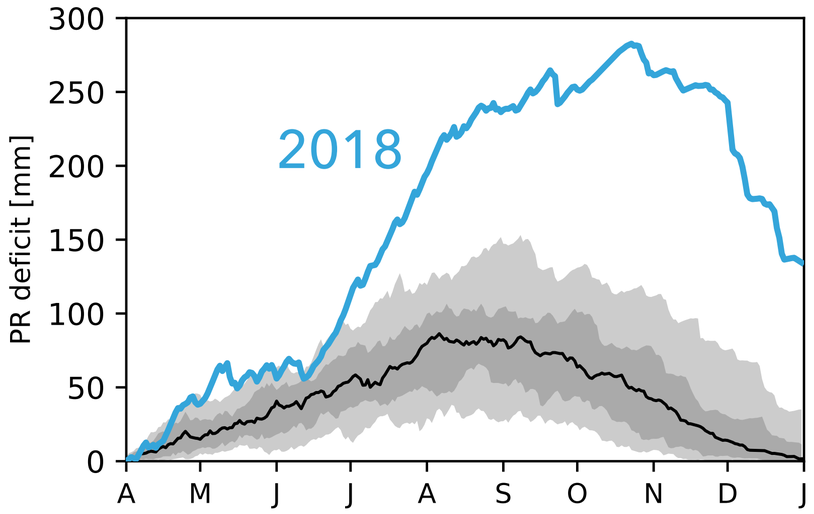


(Van der Wiel et al., under review)

2: SELECTION OF SIMULATED ANALOGUES

- Large ensemble climate model simulations
  - EC-Earth, 3 x 2000 years (present-day, 2C- and 3C-warming) *(Van der Wiel et al., 2019, GRL)*
- **Select similar events** from large ensemble simulations
- Analogue = composite mean over 20 selected events

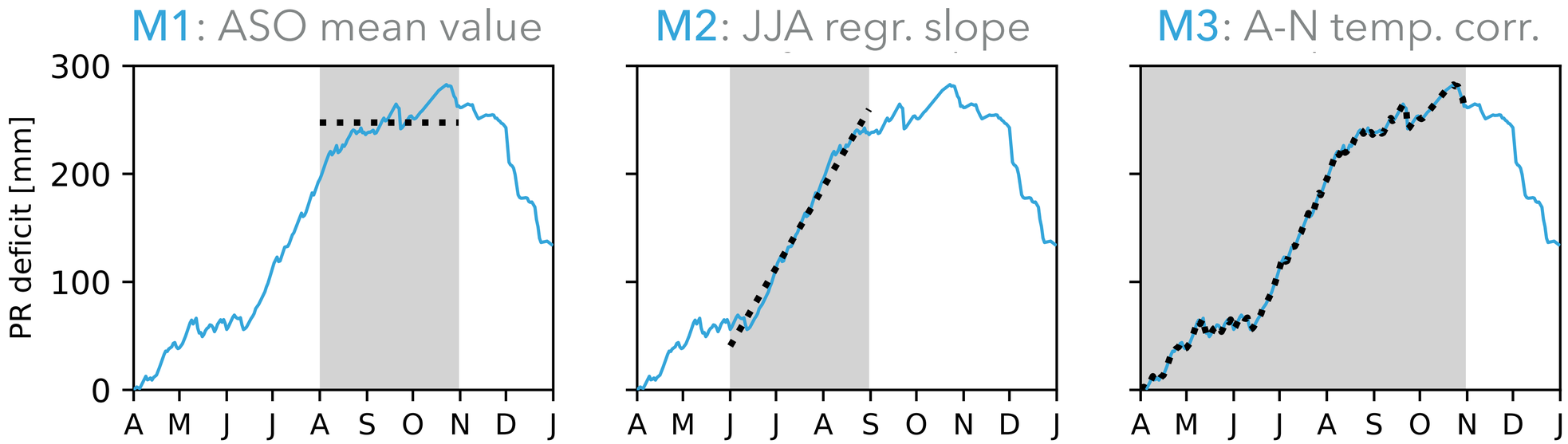
- Event selection using time series of **Precipitation deficit**: potential evapotranspiration minus precipitation, cumulative from 1 April



(Van der Wiel et al., under review)

2: SELECTION OF SIMULATED ANALOGUES

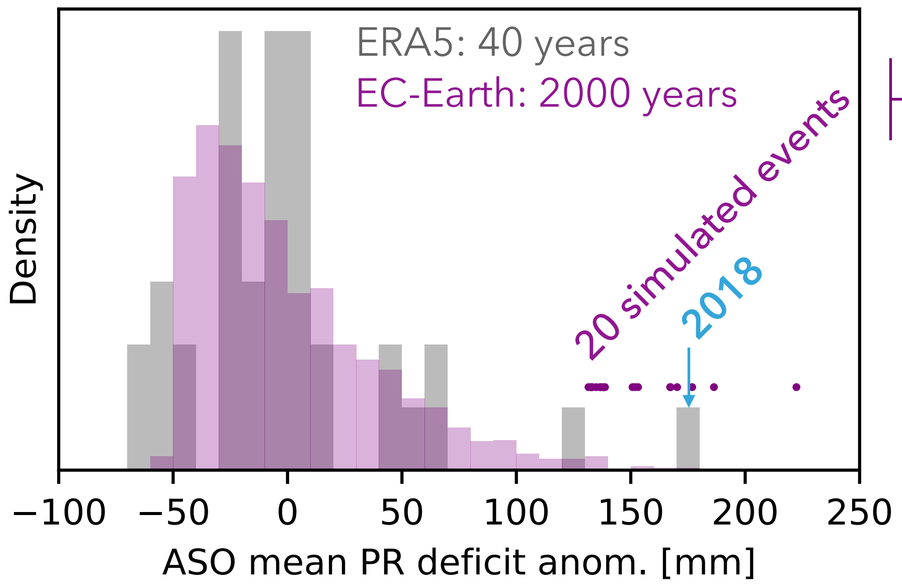
- Quantitative event selection procedure:
  - Time series of precipitation deficit in the Rhine basin
  - Three selection metrics:



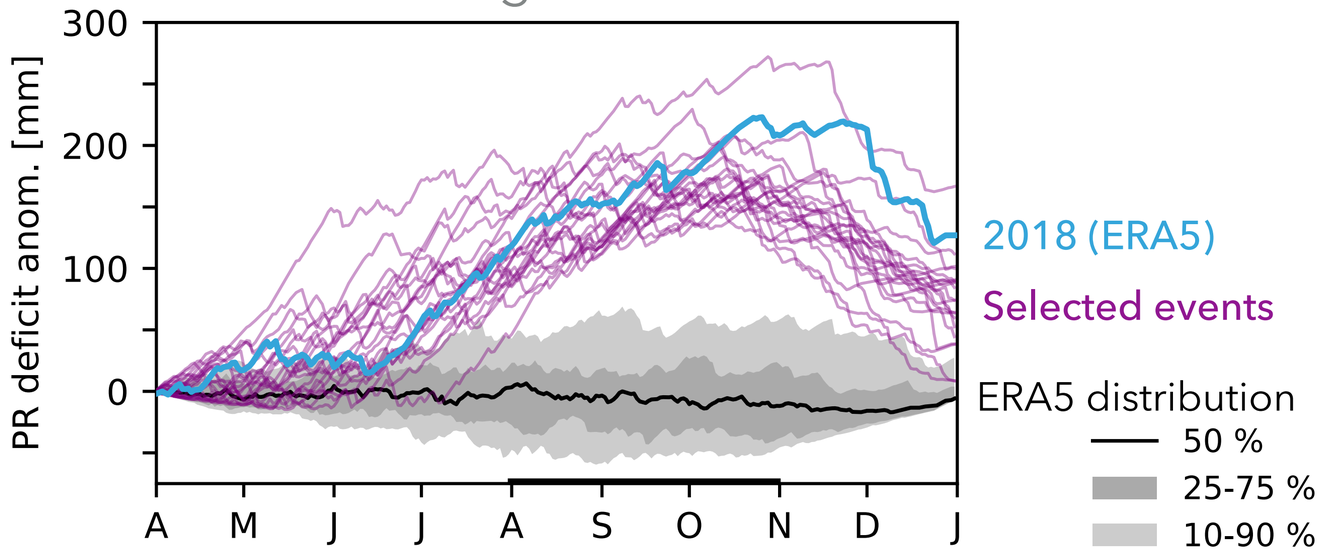
2: SELECTION OF SIMULATED ANALOGUES

- Example M1: Select the 20 simulated events with the highest **August to October mean** precipitation deficit anomaly

Distribution of selection metric



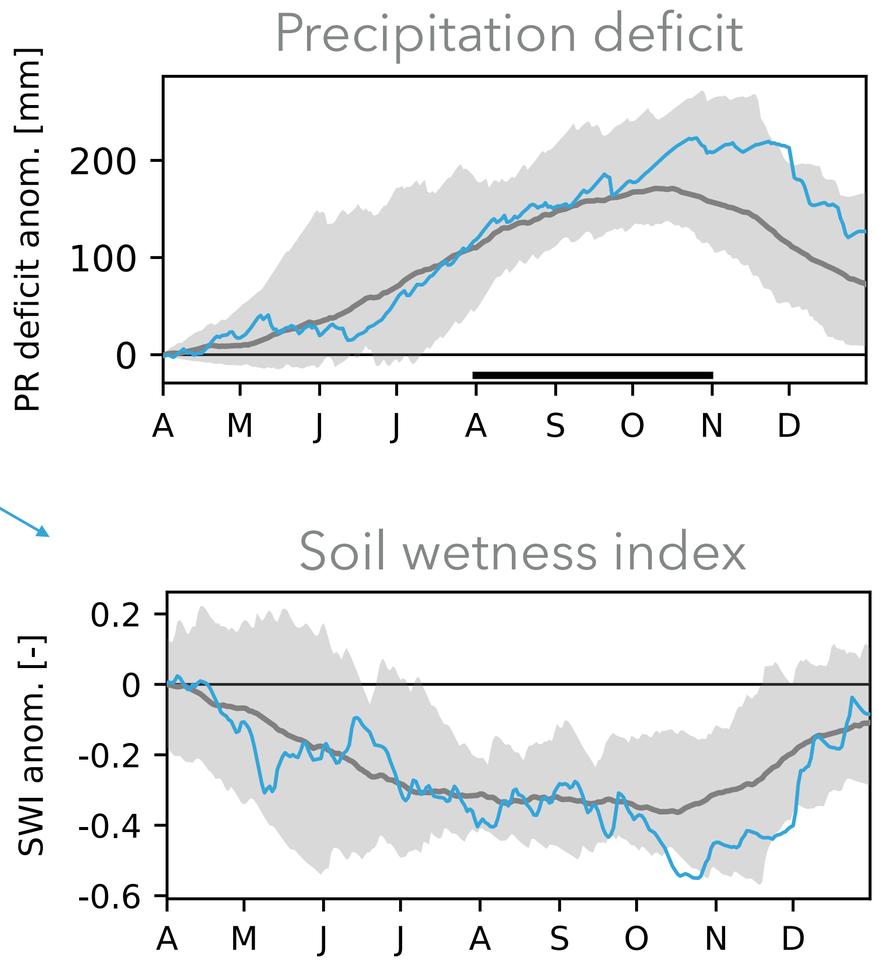
Resulting time series



(Van der Wiel et al., under review)

3: COMPARISON SIMULATED ANALOGUE AND OBSERVED EVENT

- Example M1:
  - The **analogue** time series of precipitation deficit **resembles the observed event**
  - Also for related variables the analogue is comparable to the observed event, e.g. soil moisture (and others, next slide)
- So far, this works. Next we investigate the impact of climate change.



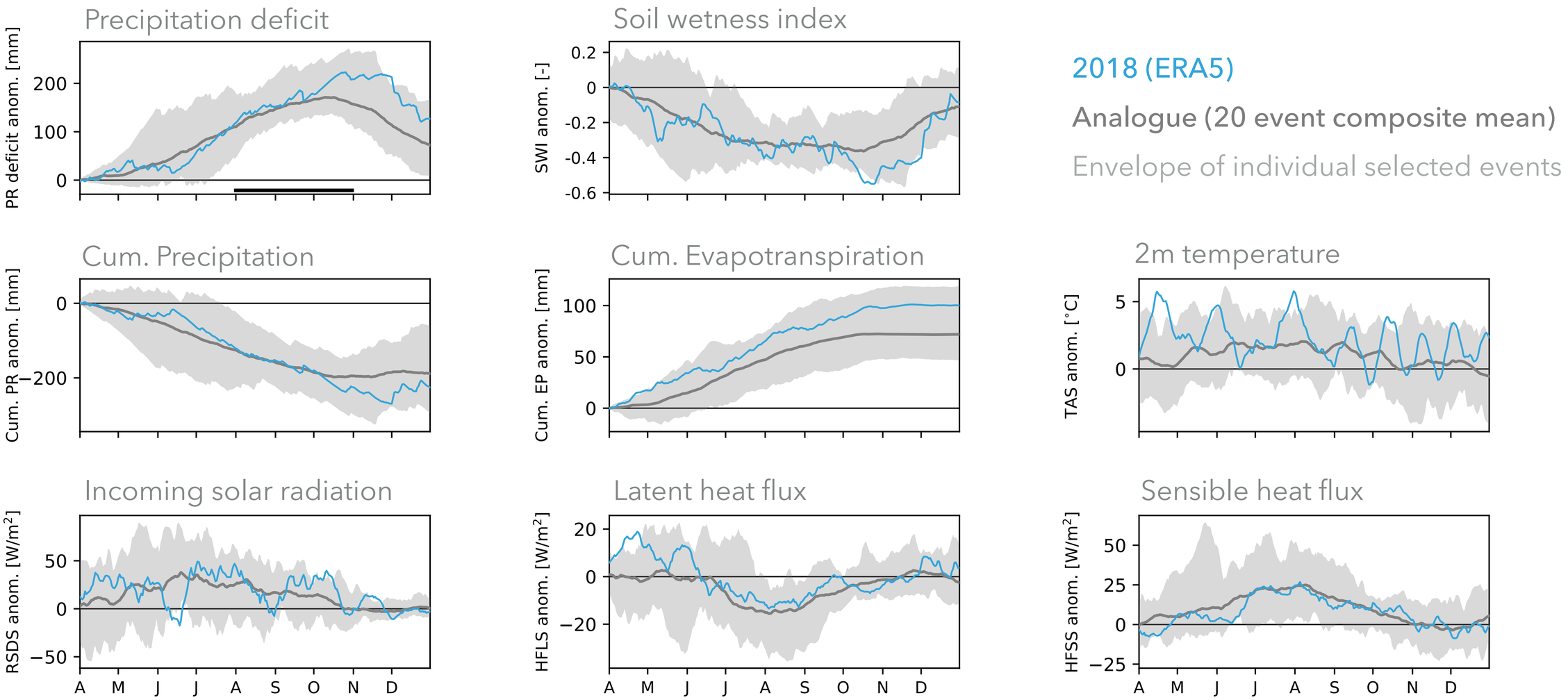
2018 (ERA5)

Analogue (20 event composite mean)

Envelope of individual selected events

(Van der Wiel et al., under review)

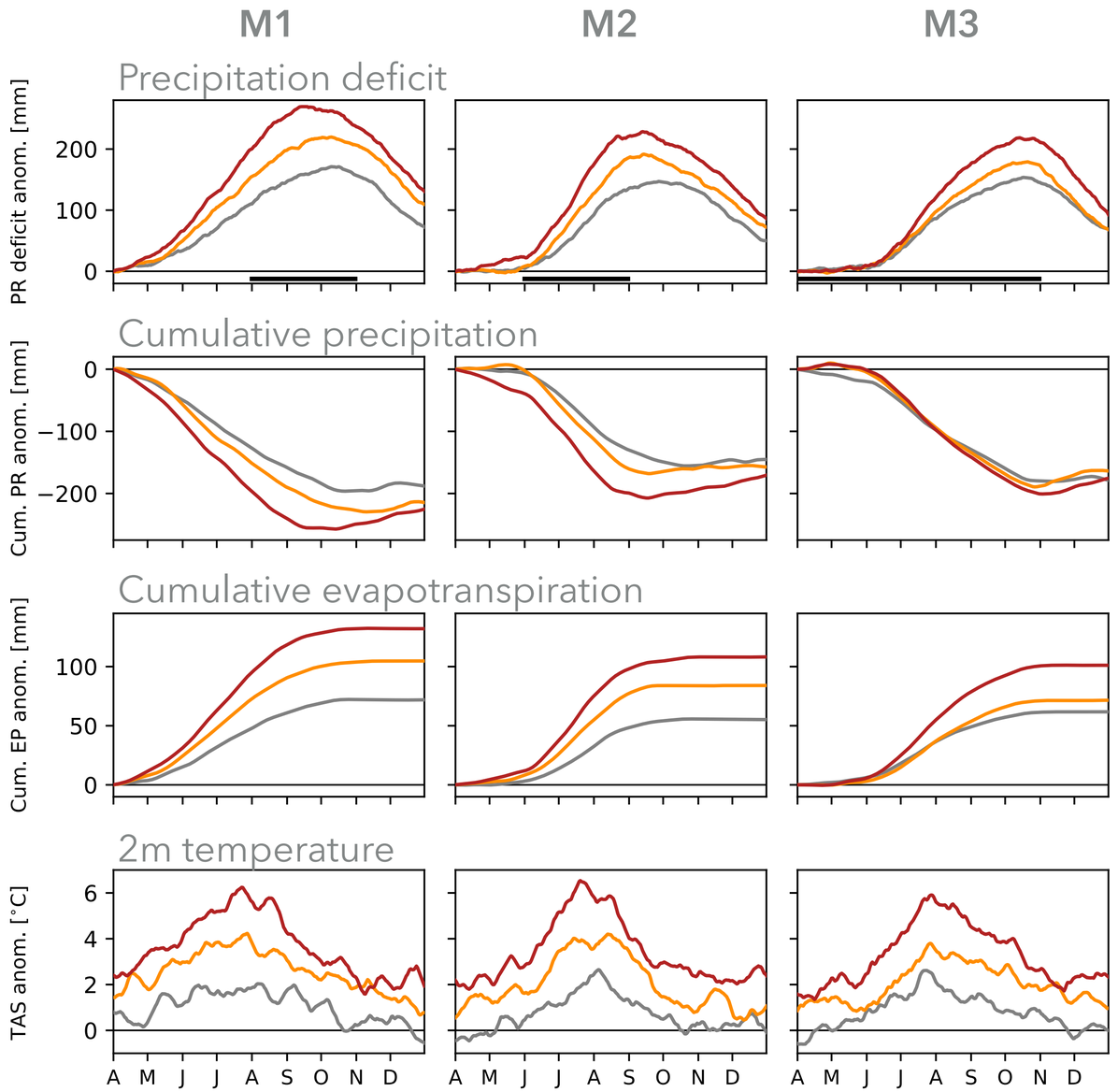
3: COMPARISON SIMULATED ANALOGUE AND OBSERVED EVENT



(Van der Wiel et al., under review)

4: FUTURE DROUGHTS LIKE 2018

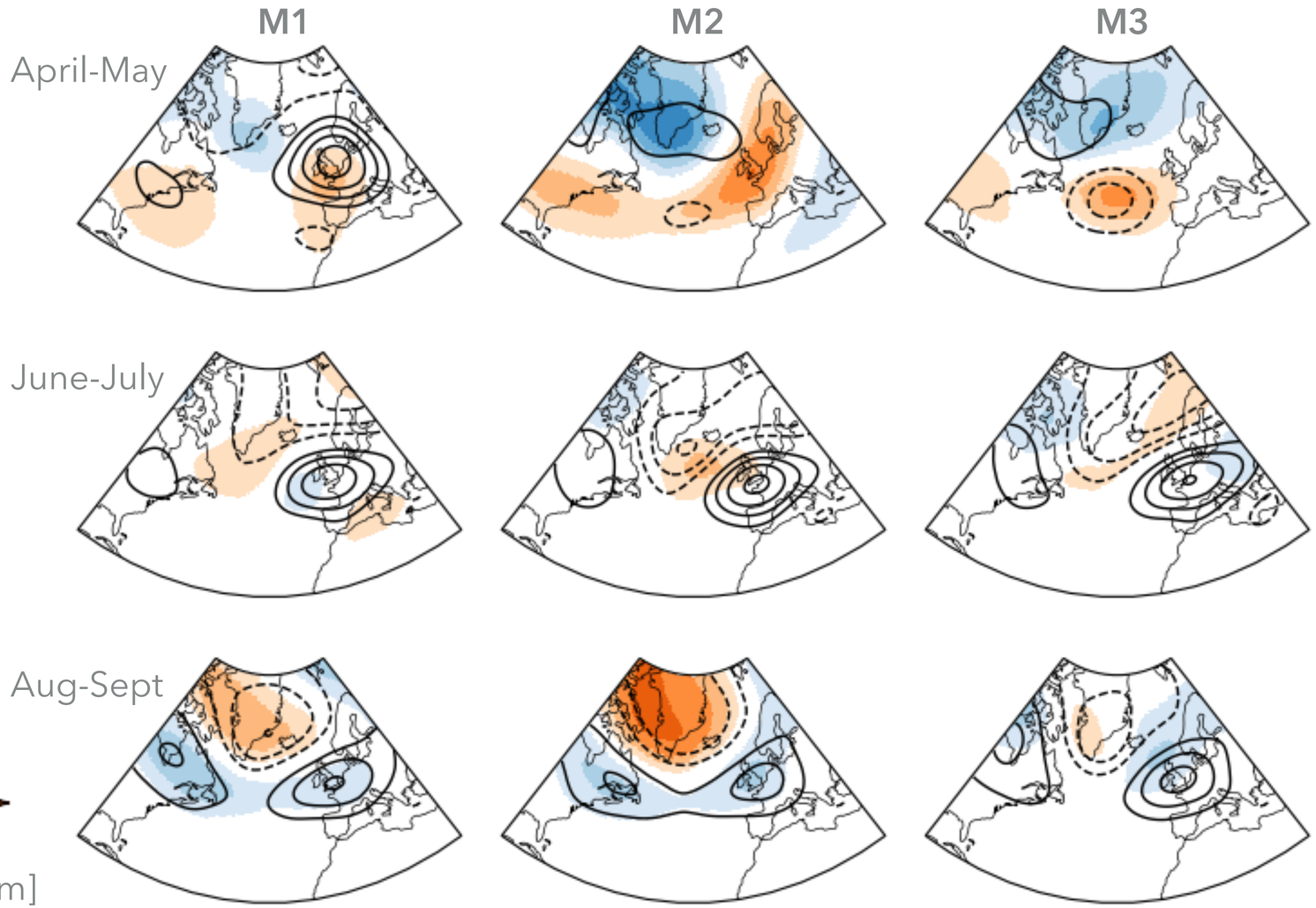
- Drought severity:
  - Higher future peak PR deficits
  - Caused by:
    - Lower precipitation
    - Higher evapotranspiration
  - Timing and magnitude of changes is metric dependent



Present-day, 2C-warming, 3C-warming
Anomalies relative to PD climatology

4: FUTURE DROUGHTS LIKE 2018

- Atmospheric dynamics:
  - Droughts forced by high pressure systems
  - Small dynamical changes
    - e.g. M1 stronger spring high

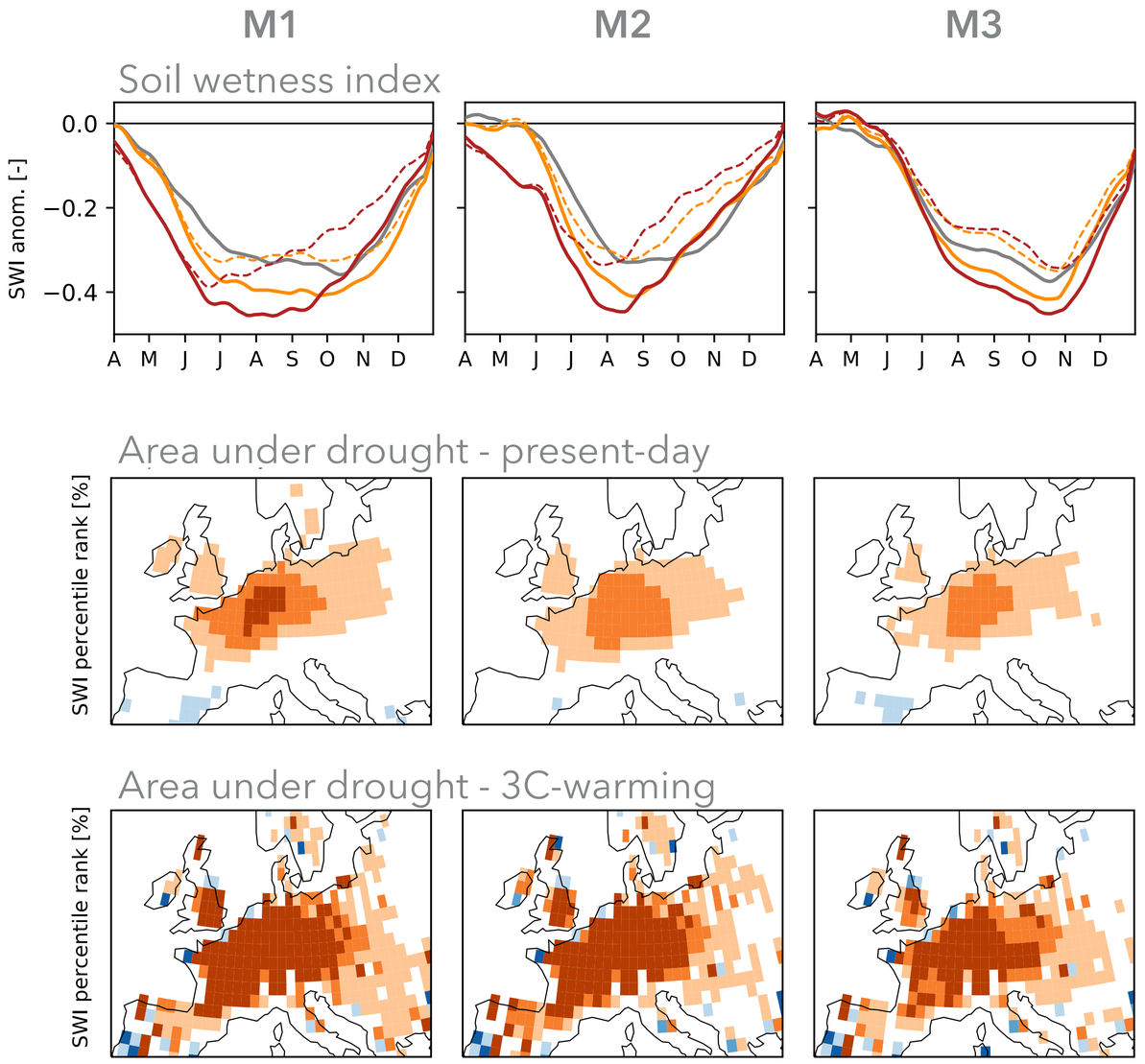


Contour lines: 500 hPa geopotential height anomalies in present-day analogue, interval 10 m.

(Van der Wiel et al., under review)

4: FUTURE DROUGHTS LIKE 2018

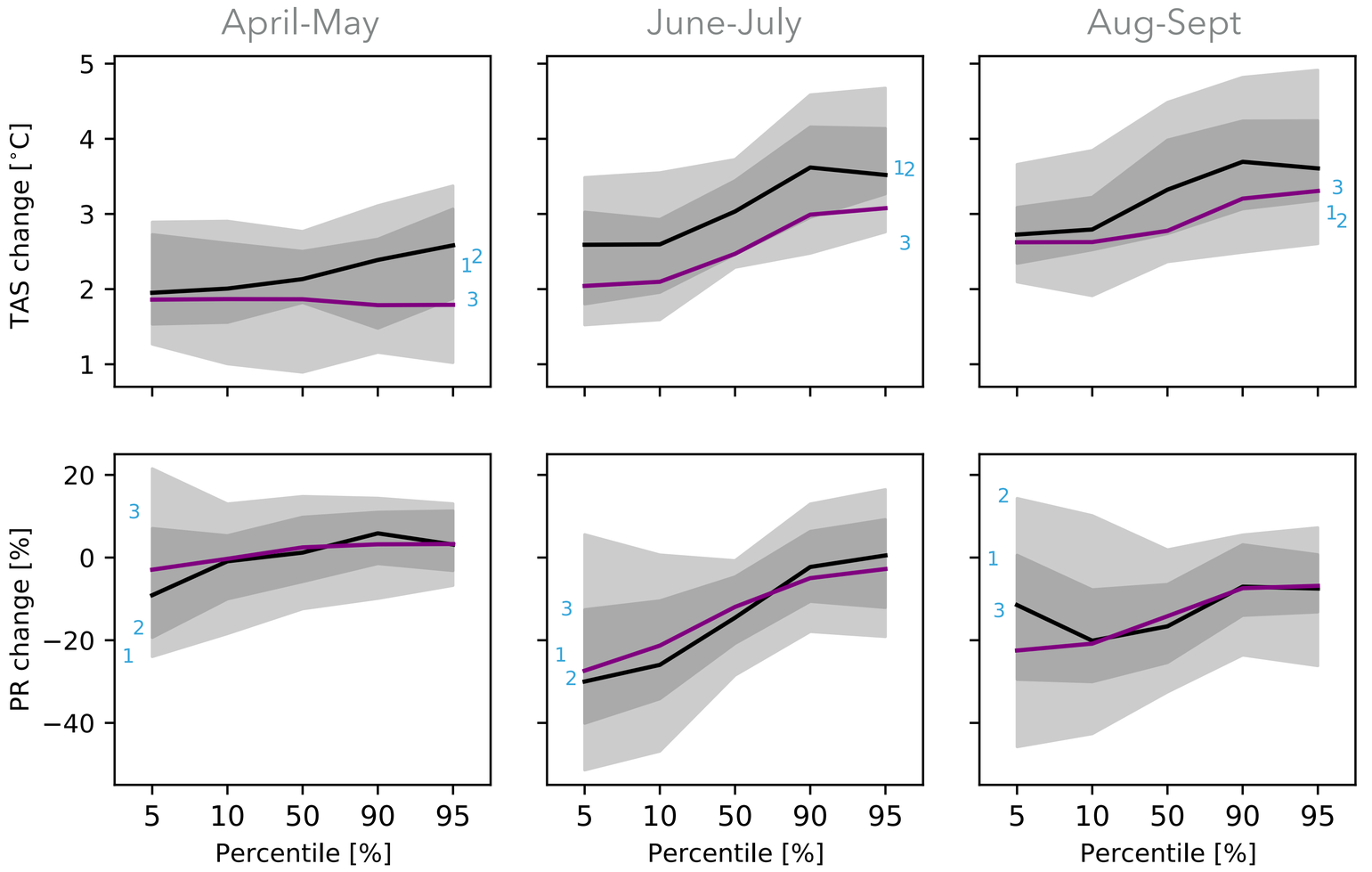
- Drought hydrological impacts:
  - Decreased availability of soil moisture
  - Large increase in area with severe soil moisture drought



(Van der Wiel et al., under review)

5: EVALUATION – CLIMATE CHANGE RESPONSE OF SINGLE MODEL IN CONTEXT

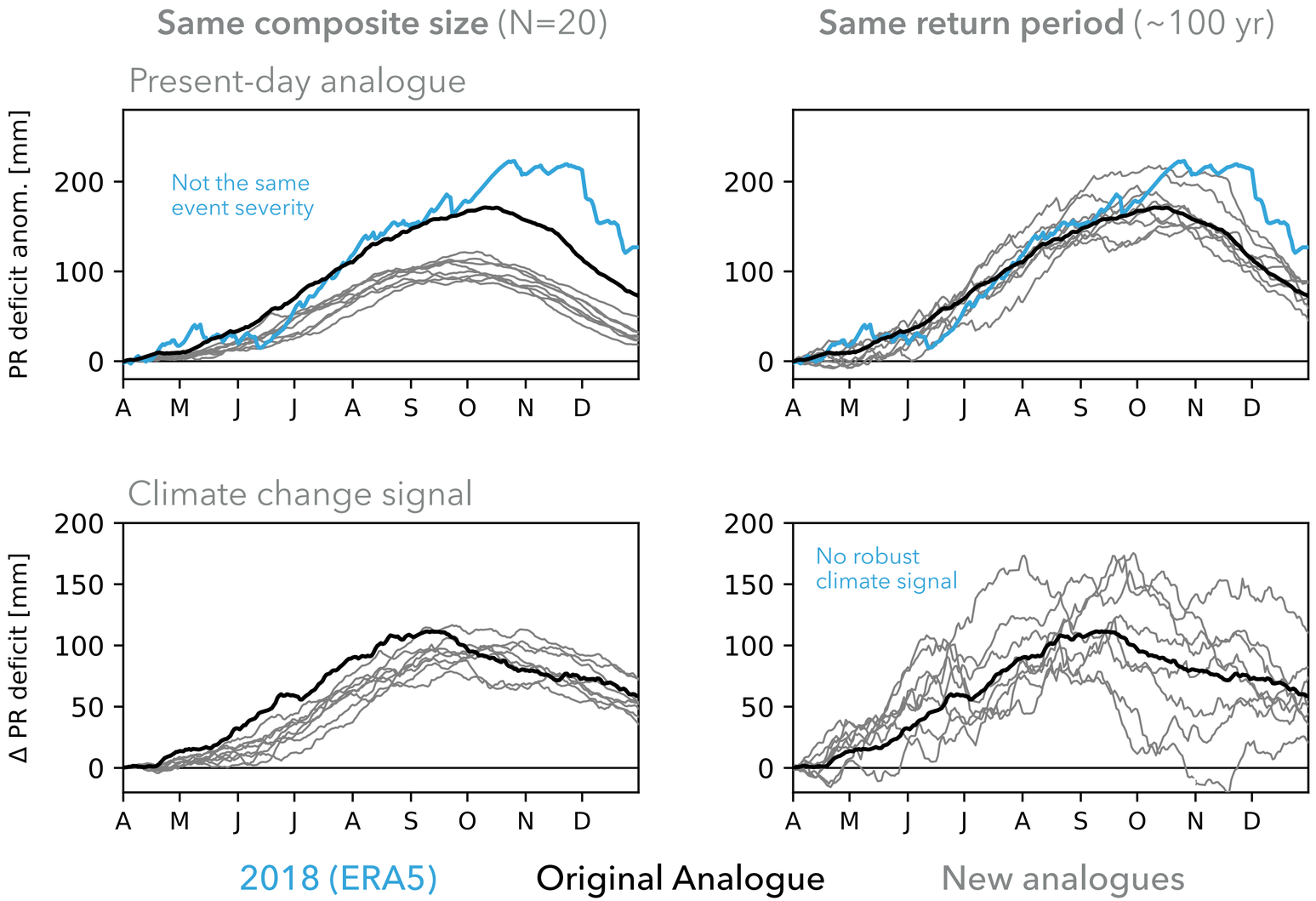
- EC-Earth response of local change in TAS/PR falls within 25-75 % range of CMIP6
- **Specific drought response** (M1-3) is not simply the median/dry response



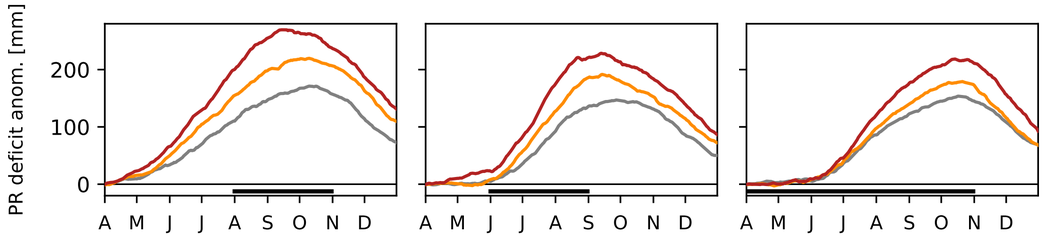
(Van der Wiel et al., under review)

6: EVALUATION – HOW LARGE AN ENSEMBLE DO WE NEED?

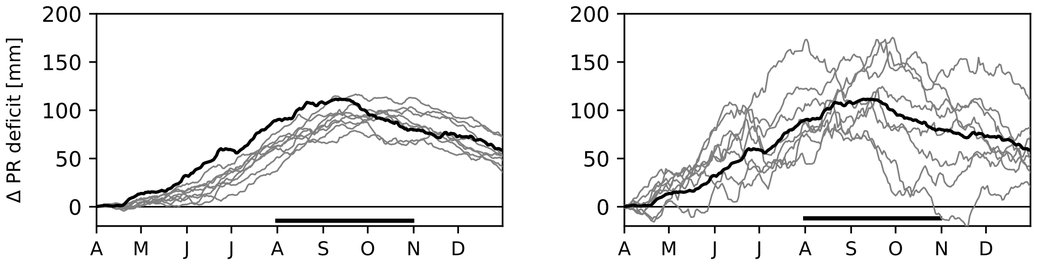
- Analysis repeated with eight smaller ensembles
  (2000 years vs. 8 x 250 years)
- Analogues should resemble event (e.g. event severity)
- Climate change signal has to be robust
- Balance composite size and return period



CONCLUSIONS



- Future drought events like 2018:
  - Meteorology: warmer, drier, sunnier → higher peak PR deficit
  - Hydrology: lower soil moisture availability, larger area under drought



- Large ensemble storyline method
  - **Yes, works!**
    - Analogues resemble observed event
    - Robust climate change information
  - Ensemble has to be quite big
  - Balance between analogue composite size and return period

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A paper describing the presented work is currently undergoing peer-review:

- Van der Wiel, K., G. Lenderink, H. de Vries: **Physical storylines of future European drought events like 2018 based on ensemble climate modelling**, submitted to Weather and Climate Extremes.