Circulation type frequencies in GCM simulations and an application to hydrological drought

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Bewl Reservoir in southeast England, February 2006. (Photo: Reuters)

Motivation

Hydrological drought

- a sustained period with streamflow below a predefined threshold,
- slowly developing,
- becomes severe when it covers a **large region**.

Elbe in Dresden, April 2007 (spiegel.de)

Why circulation types?

- simple characterization of atmospheric conditions over a **large region**,
- may be based on air pressure data only, which is generally **better represented** by GCMs than precipitation and temperature,

➔ found helpful for study of hydroclimatology of droughts (Fleig et al., 2010).

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But…

- Biases in MSLP in GCMs!

Objective

I. Can choice of **input variables** for CT-assignment improve **CT-frequencies in GCMs**?

II. Investigate **future hydrological drought characteristics** in north-western Europe **based on CT-frequencies**.

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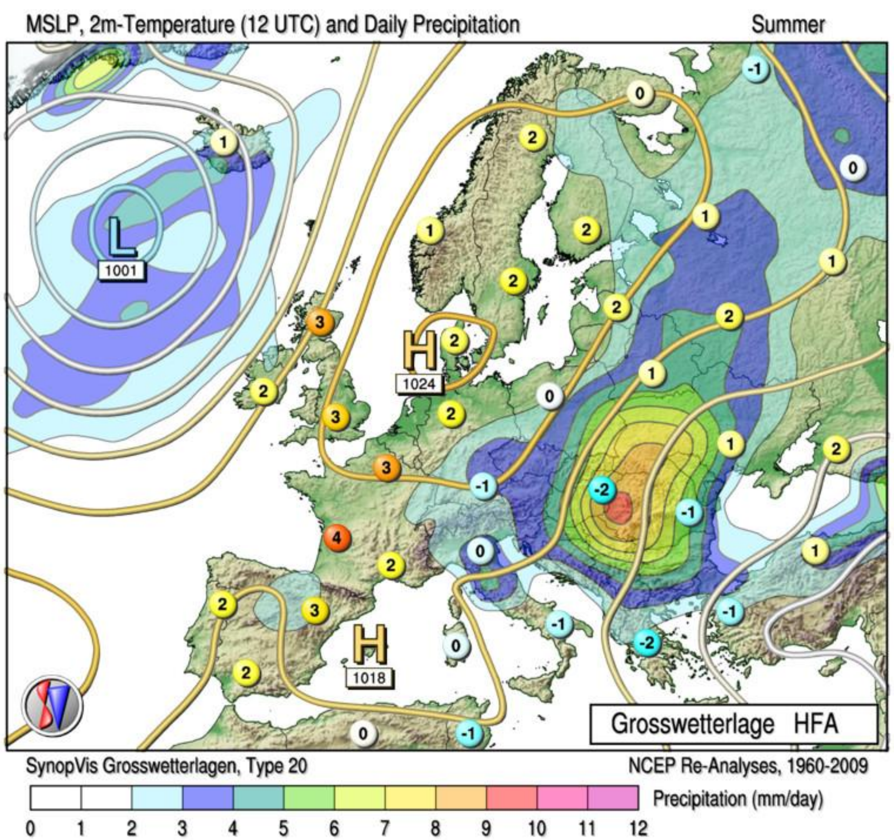
← **Prerequisite**: hydrothermal properties CTs are stationary during changing climatological conditions.

Data: SVG – SynopVis Grosswetterlagen

Similar to OGWL:

- **Objective** CTC based on Hess-Brezowsky Grosswetterlagen,
- 29 CTs,
- CTs are characterised by **flow direction** (W, NW, N, NE,...) and **cyclonicity** (anticyclonic, cyclonic),
- domain: 36 – 69 N, 32 W – 45 E



Improvements:

- input data: **MSLP**, **Z500** and **T850**,
- flexible number of input variables.

Data: Climate observations & simulations

"Observations"

- **NCEP/NCAR reanalysis** data: MSLP, Z500 and T850,
- 1951 – 2000.

GCM

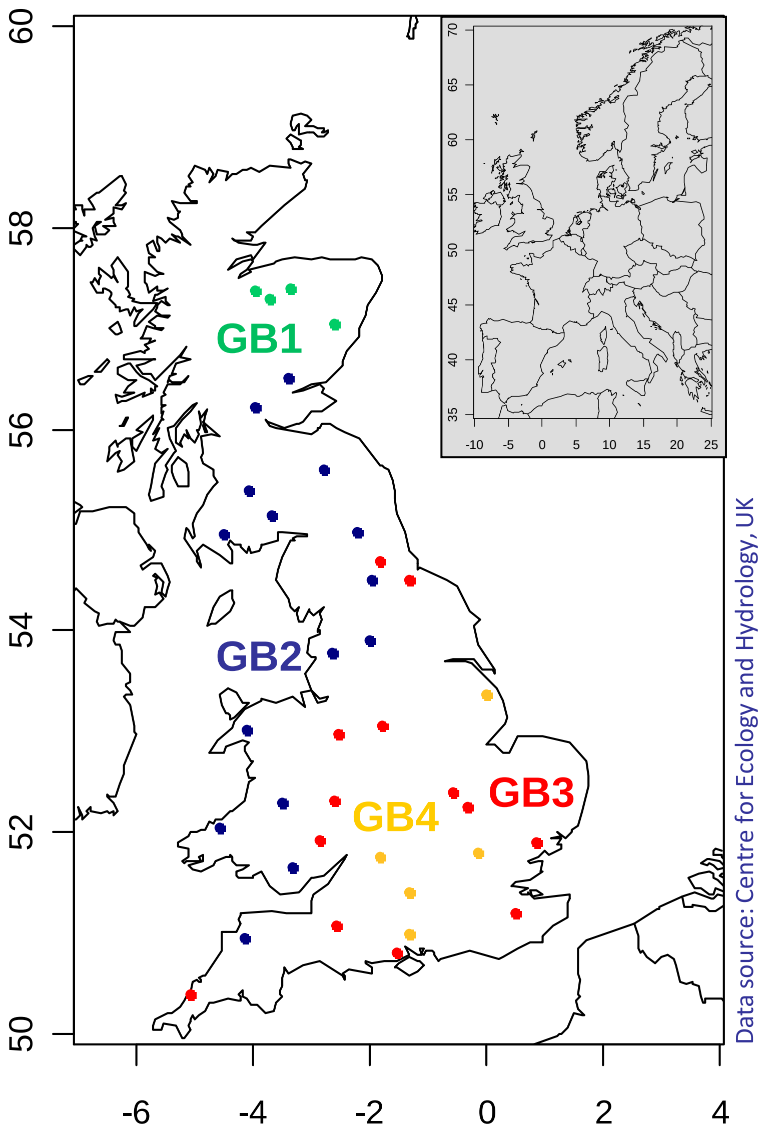
- **ECHAM5/MPI-OM** Control: 1951 – 2000
  Scenarios: 2000 – 2100,

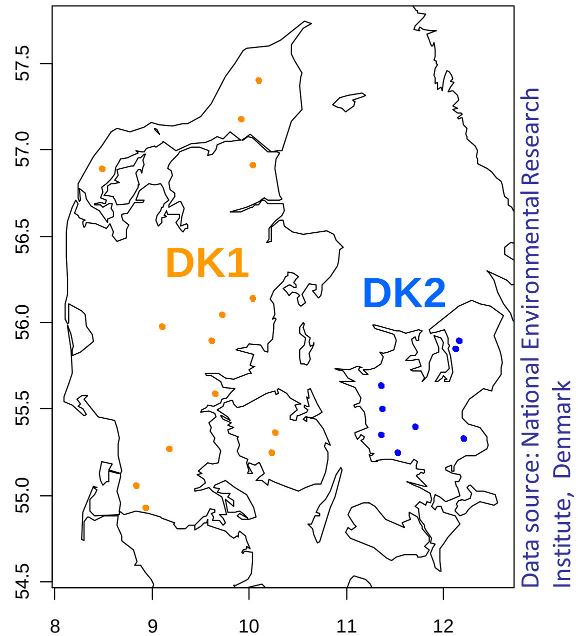
Scenarios

- **A2:** - more **differentiated** world;
  - **little** environmental and social consciousness;
  - continuous **increase** in global population **until 2100**.
- **B1:** - more **integrated** world;
  - **higher** environmental and social consciousness;
  - **increase** in global population **until 2050** to nine billion and **then decreases**.

Hydrological drought

Hydrological drought: Data





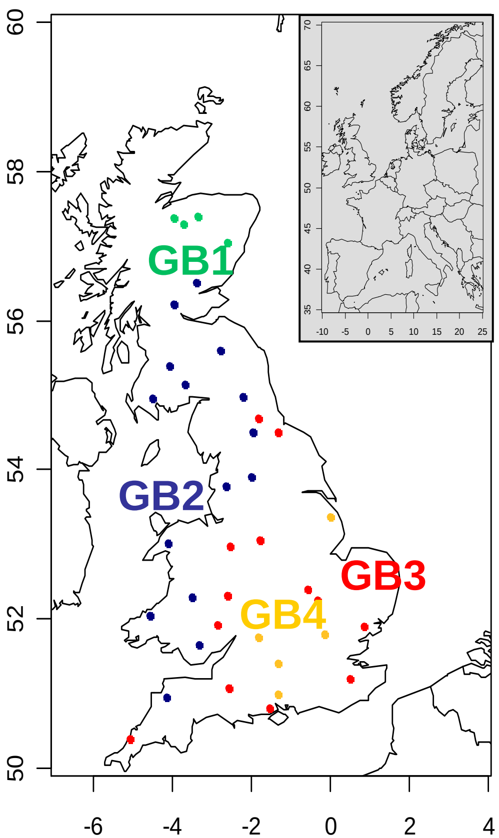
Regional Drought Area Index (RDAI)

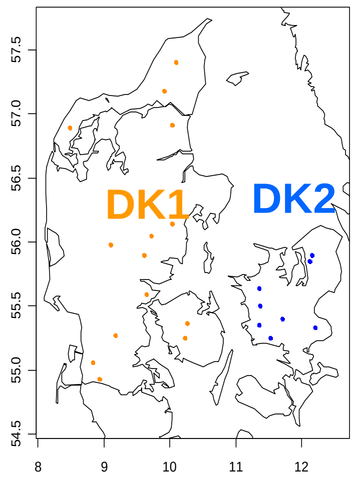
- based on daily streamflow deficits (1964–2001)
- fraction of drought-affected area within a region
- total area = sum of basin areas in the region

→RDAI: 0 – 1.

Regional drought: RDAI > 0.7

Hydrological drought: Region characteristics



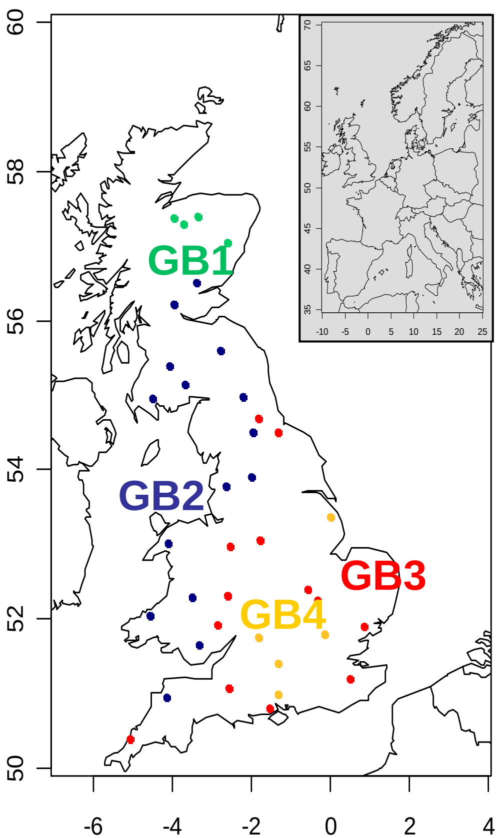


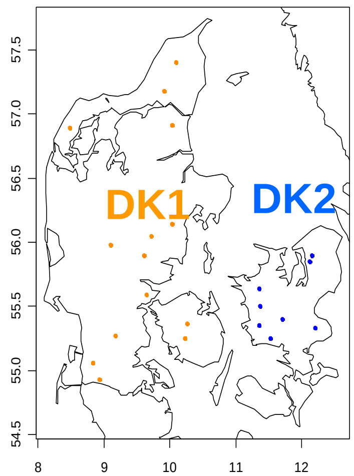
Drought characteristics

- GB1 & GB2 frequent but short droughts,
- GB4 few but long droughts,
- GB3, DK1 & DK2 in between.

- GB1 & GB2 droughts typically start earlier in the summer compared to other regions,

Hydrological drought: Region characteristics





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Drought response time

i.e. period during which daily weather types influence drought development

GB1, GB2:	45 days
DK1, DK2:	60 days
GB3:	90 days
GB4:	210 days

➔ drought characteristics vary according to regional hydrogeological properties.

Fleig et al. (EGU 2010) CT-frequencies in ECHAM5 applied to hydrological drought.

Drought-related CTs

Identification

- **Data**: NCEP/NCAR reanalysis data: MSLP, Z500 and T850,
- **Method**: CT-frequency anomalies **preceding** and **concurrent** to drought,
  - **five** most severe **drought events** per region,
  - preceding period = **regional hydrological response time**.

Quality in ECHAM5

- **total frequencies of drought-related CTs**
  - annual cycle in monthly means,
  - during summer (16 Apr – 15 Oct),
  - over the whole year (16 Oct – 15 Apr).

CT-frequencies in ECHAM5: Use of input variables

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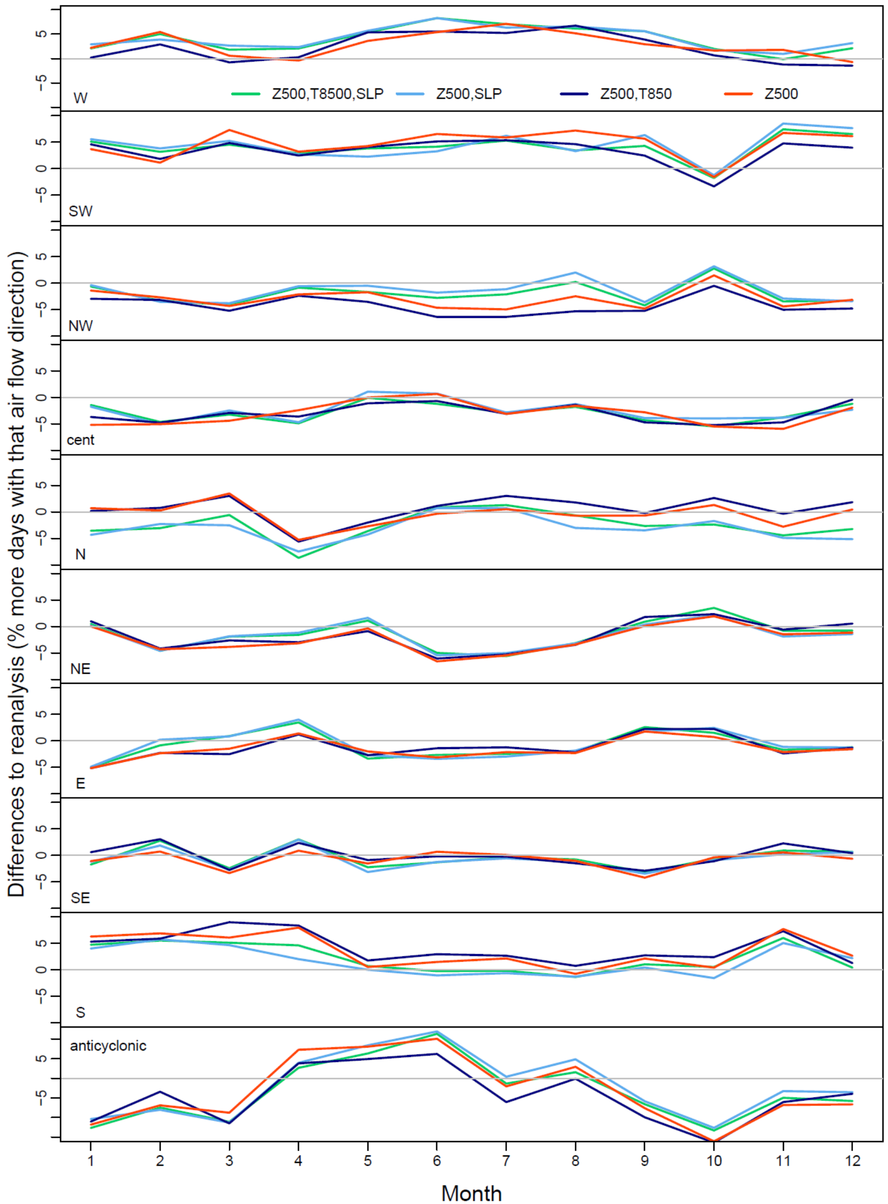

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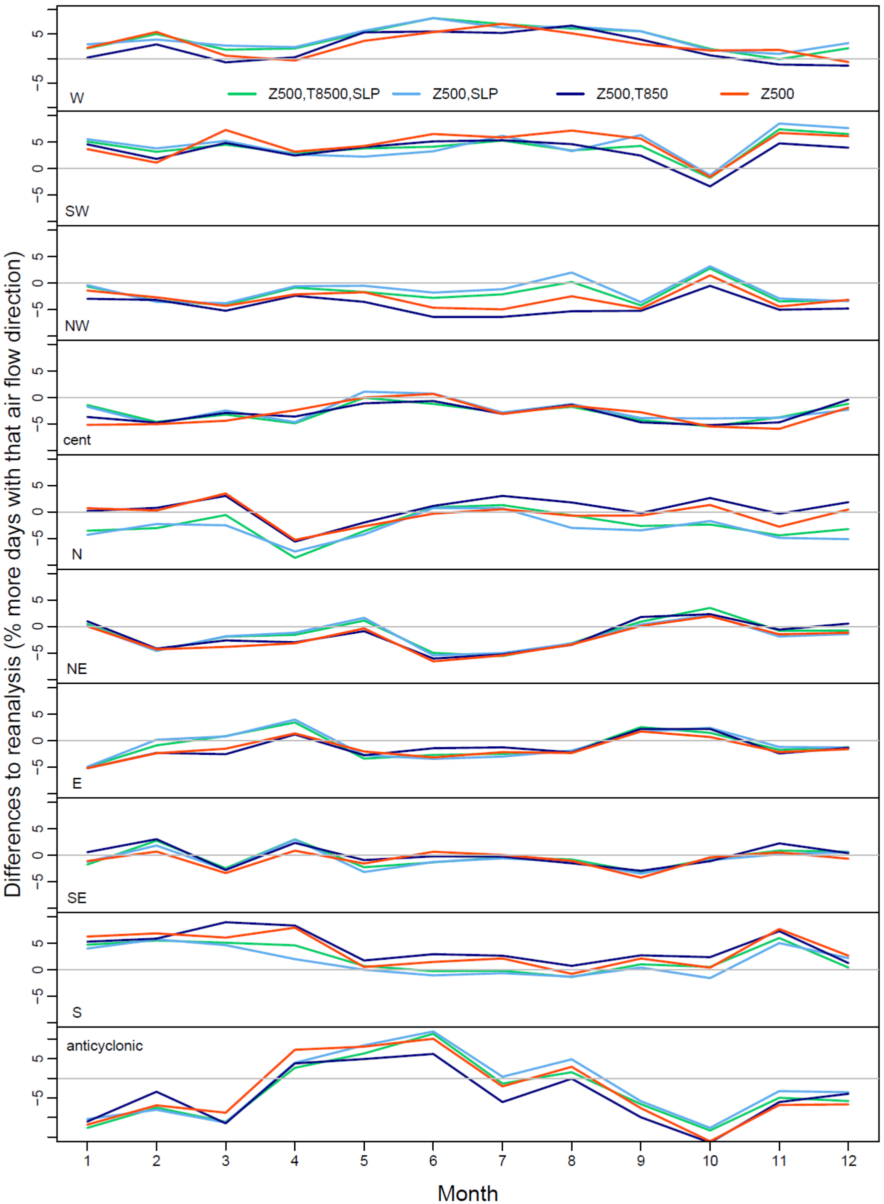

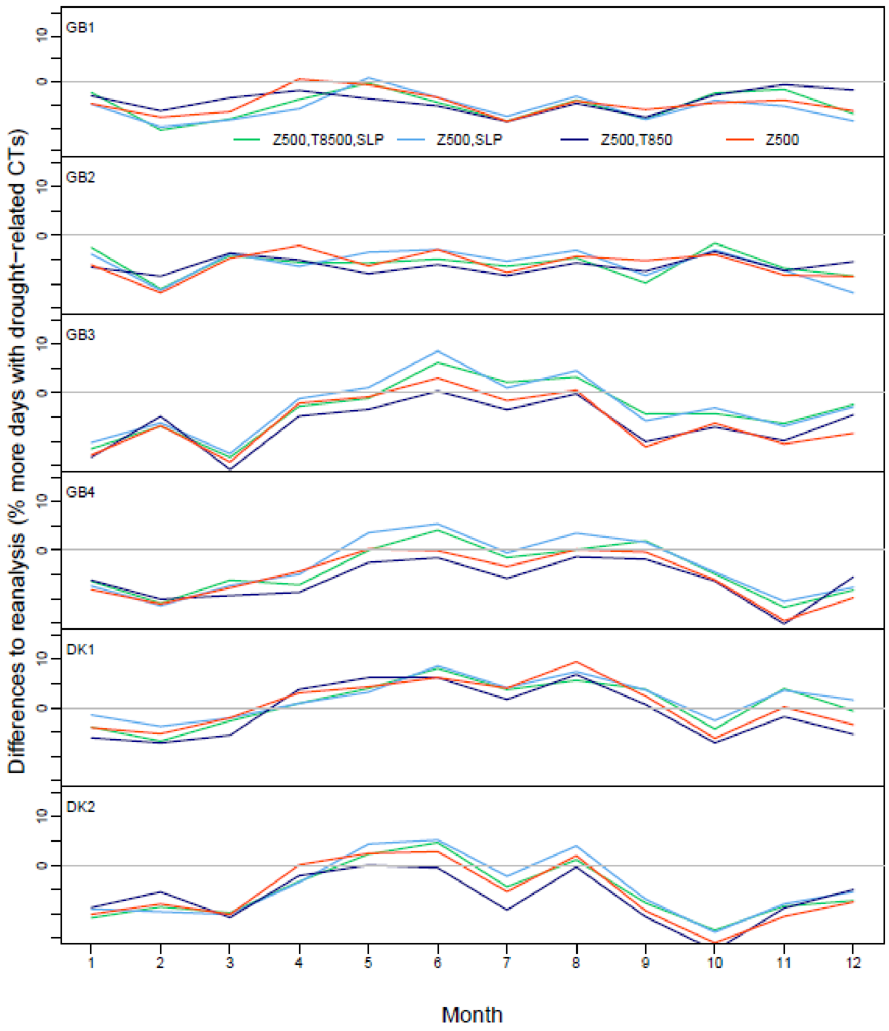

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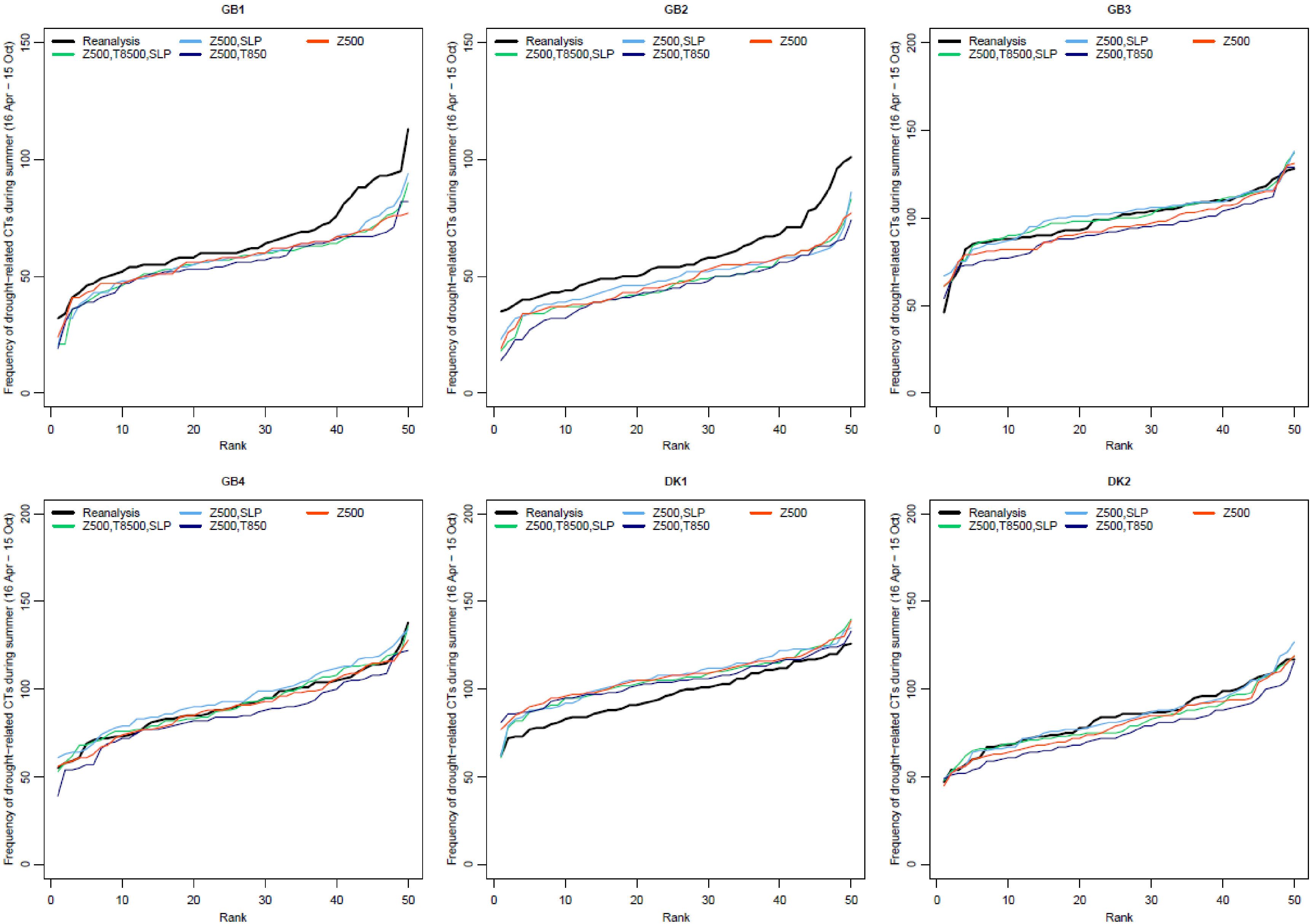
Drought-related CT-frequencies in GCM: Summer



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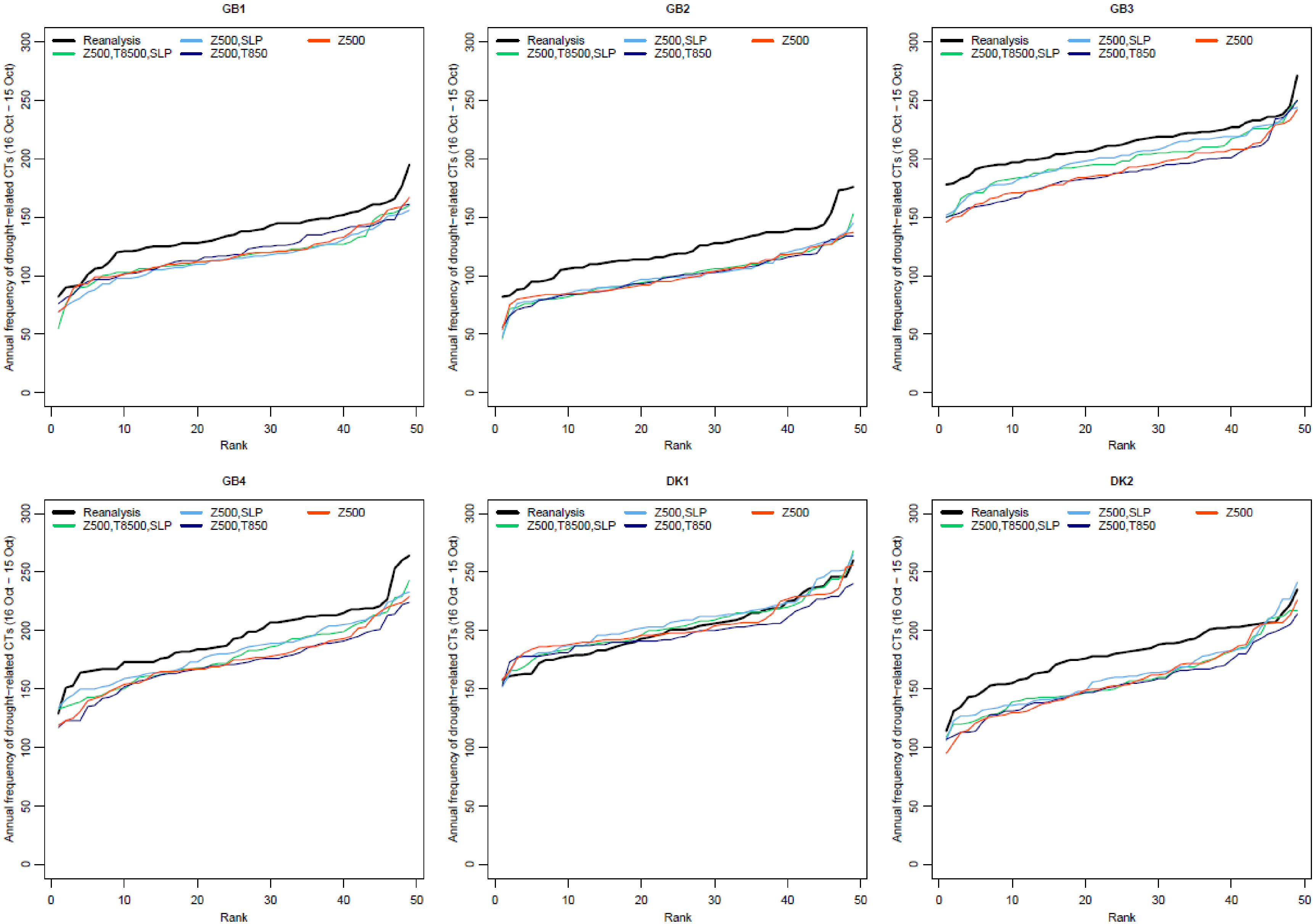

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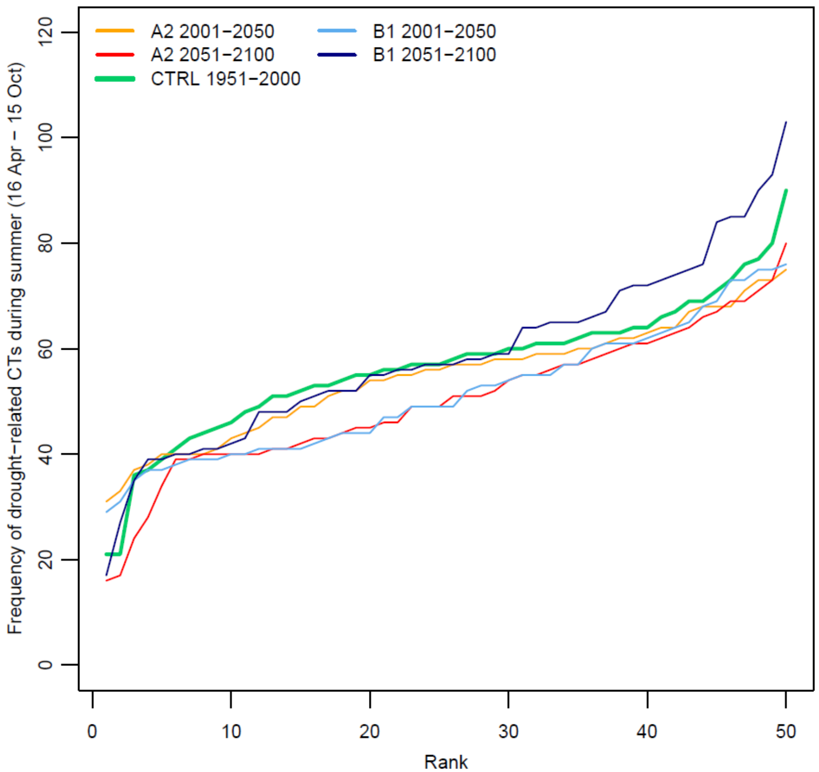
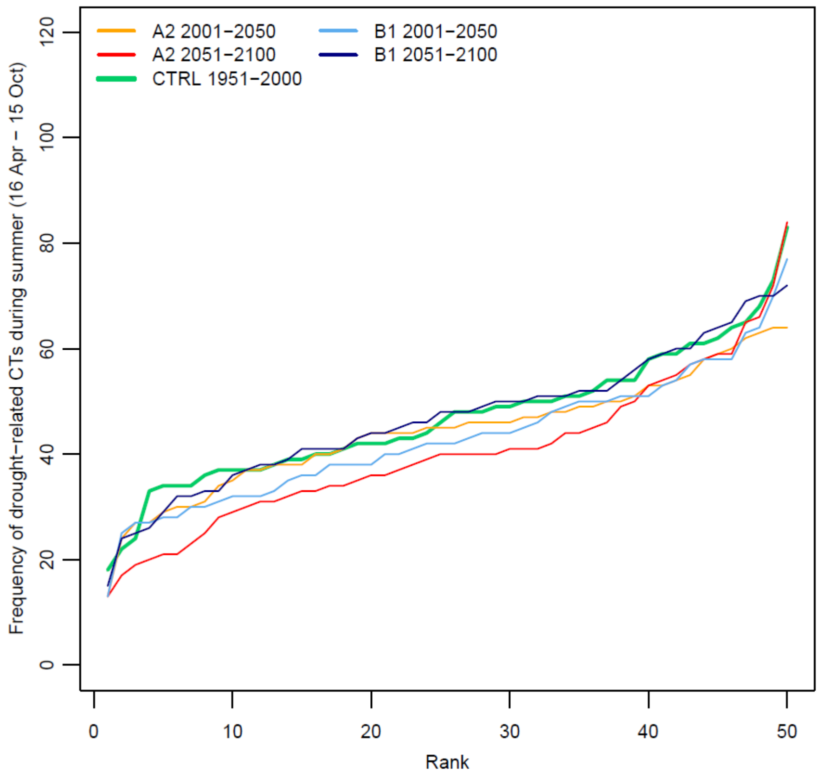
Future drought-related CT-frequencies:

GB1 North-East Great Britain



GB2 Western Great Britain



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Future drought-related CT-frequencies:

GB1 North-East Great Britain

A2: • small decrease both periods

B1: • small decrease

• strong increase after 2050

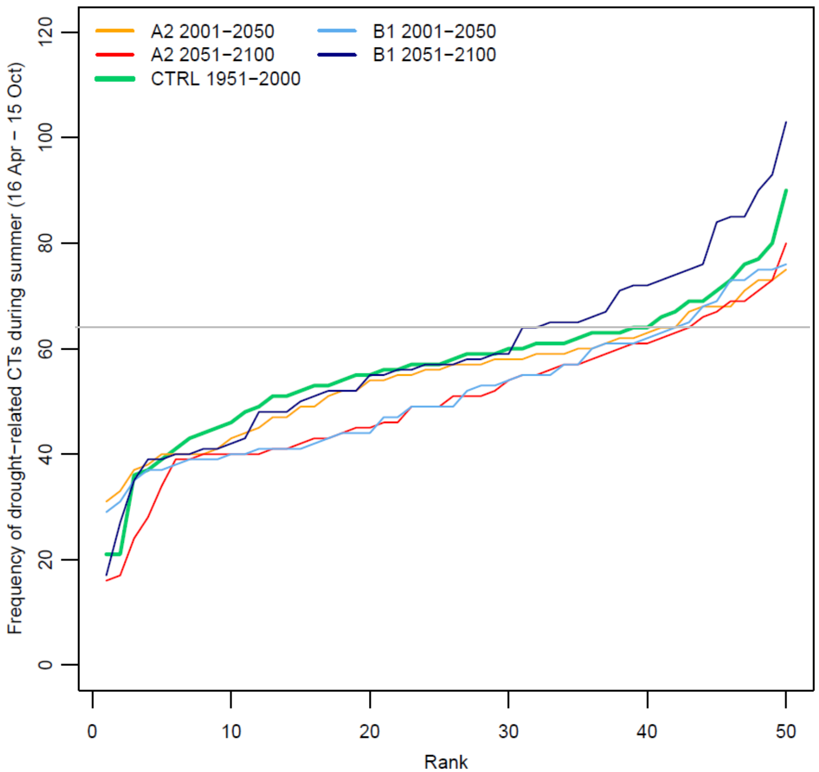
GB2 Western Great Britain

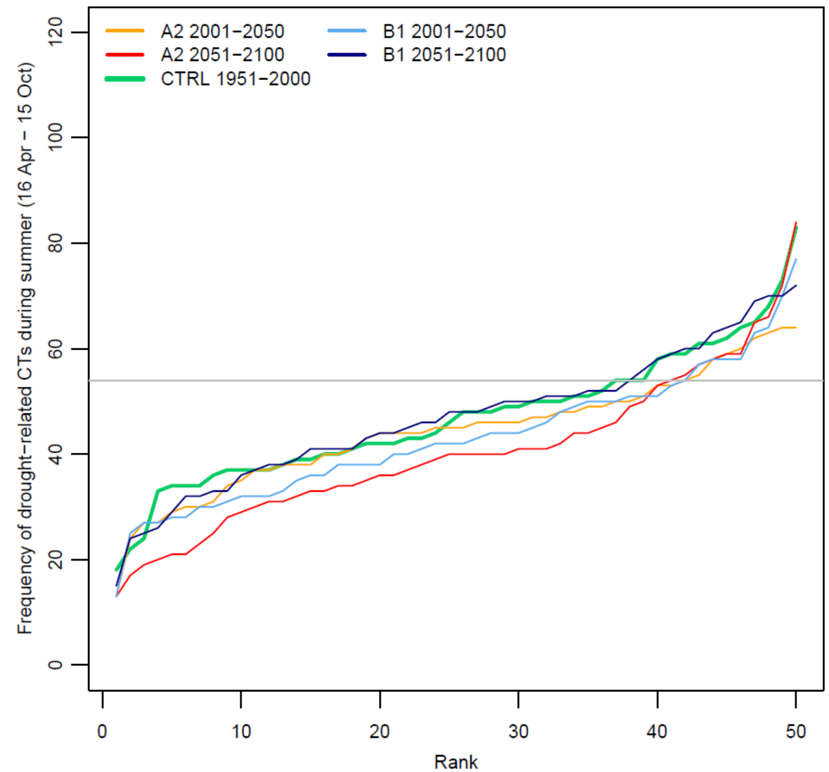
A2: • decrease both periods,

• max frequency unchanged (>2050)

B1: • decrease

• after 2050 similar to today



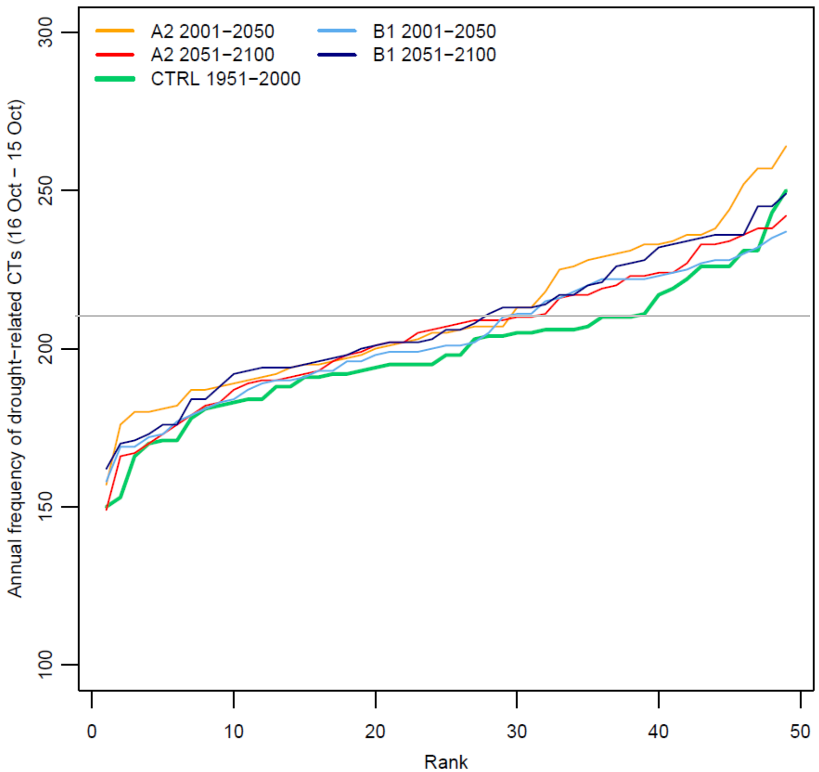


Future drought-related CT-frequencies:

GB3 South-East Great Britain

A2:
- first increase (no. & max)
- then increase in no. only

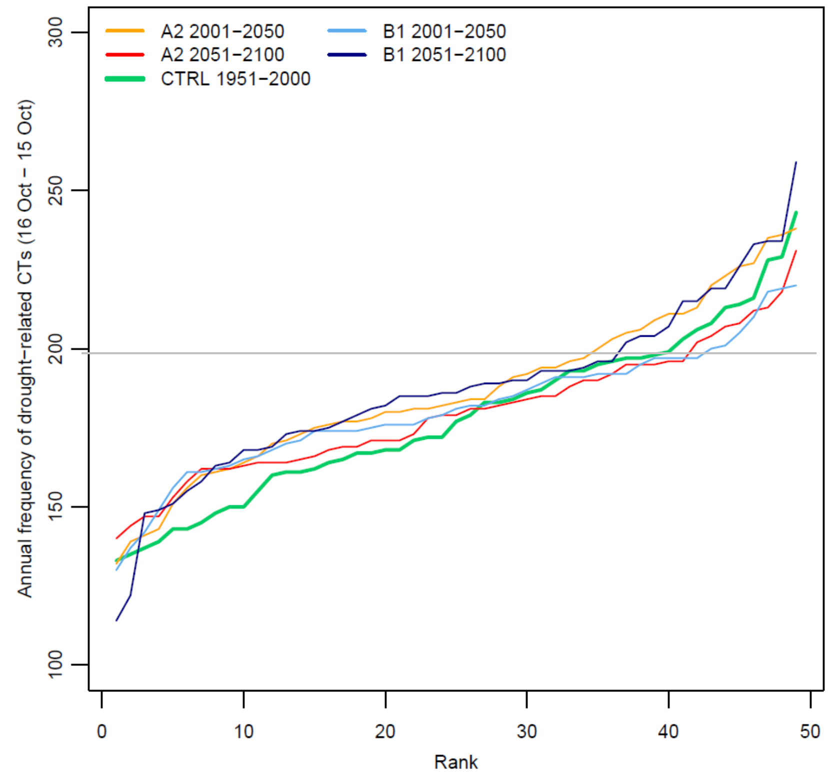
B1:
- increase in no.
- max similar to today



GB4 South-East Great Britain

A2:
- first increase (no. & max)
- then small decrease (no. & max)

B1:
- first decrease (max)
- then increase (no. & max)



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Future drought-related CT-frequencies:

DK1 West Denmark

A2: • strong increase in no.

B1: • increase in no.

• max similar to today

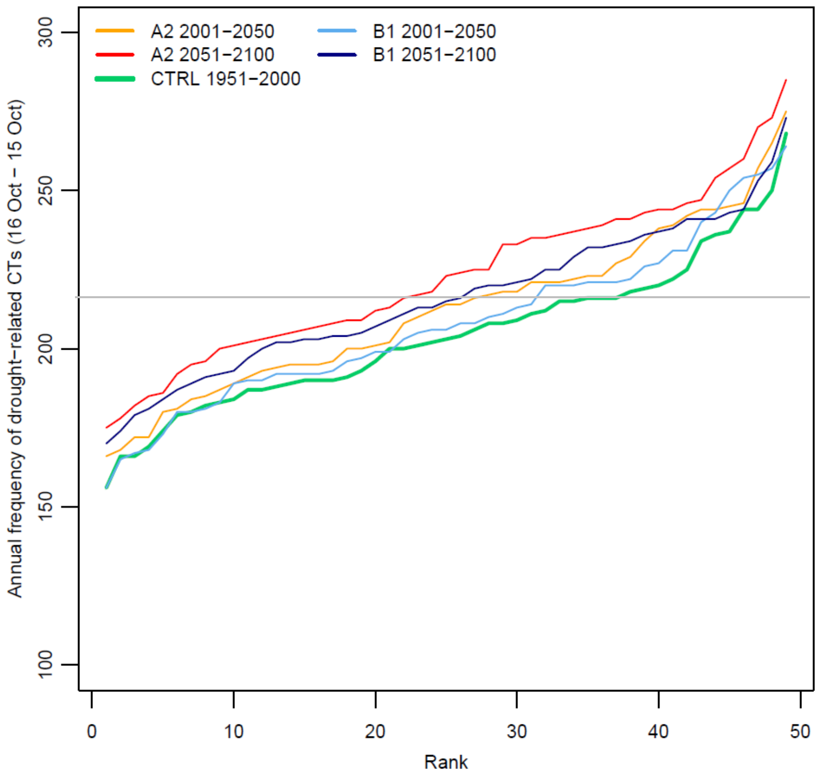
DK2 East Denmark

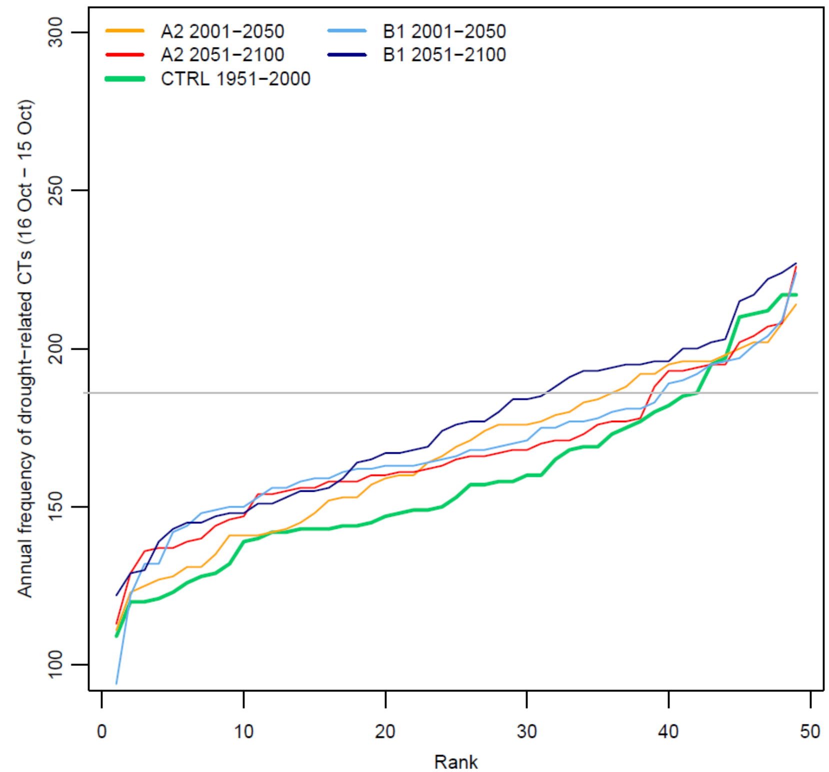
A2: • increase in no.

• decrease in max (both periods)

B1: • first increase no., decrease max

• then increase





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- **bias in drought-related CTs** in ECHAM5:
  - for North & West GB:
    drought-related CTs underestimated, especially max frequency during summer,
  - for other regions:
    little bias during summer,
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    little bias during summer,
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- **climate change estimations:**
  - for North & West GB: mostly decrease in no. of droughts (except B1 after 2050);
  - other regions: mostly increase in no. of droughts.

Further work

- compare more GCMs;
- study future drought characteristics in more detail:
  - time of occurrence,
  - duration,
  - ...

Thank you!