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

Anne K. Fleig (1), Paul James (2), Stefan Hagemann (3) & Lena Tallaksen (1)

(1) Department of Geosciences, University of Oslo, Norway; (2) Deutscher Wetterdienst, Offenbach, Germany; (3) Max Planck Institute for Meteorology, Hamburg, Germany.

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.

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).
Motivation

Hydrological drought

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

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).

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.
Objective

I. Can choice of \textbf{input variables} for CT-assignment improve \textbf{CT-frequencies in GCMs}?

II. Investigate \textbf{future hydrological drought characteristics} in north-western Europe based on CT-frequencies.

\textbf{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,

**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

Data source: Centre for Ecology and Hydrology, UK
Data source: National Environmental Research Institute, Denmark
Fleig et al. (EGU 2010) CT-frequencies in ECHAM5 applied to hydrological drought.

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

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,

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.
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
CT-frequencies in ECHAM5: Use of input variables
CT-frequencies in ECHAM5: Use of input variables

Fleig et al. (EGU 2010) CT-frequencies in ECHAM5 applied to hydrological drought.
Drought-related CT-frequencies in GCM: Summer

Fleig et al. (EGU 2010) CT-frequencies in ECHAM5 applied to hydrological drought.
Drought-related CT-frequencies in GCM: Year

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

GB1 North-East Great Britain

GB2 Western Great Britain

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

• **Choice of input variables** for CT-assignment **didn’t improve** CT simulations in **GCMs**;
Summary & Conclusions

• **Choice of input variables** for CT-assignment **didn’t improve** CT simulations in **GCMs**;
  - using less input variables is possible!
Summary & Conclusions

• **Choice of input variables** for CT-assignment **didn’t improve** CT simulations in **GCMs**;
  - using less input variables is possible!

• **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,
    larger bias over whole year, especially for smaller frequencies;
Summary & Conclusions

- **Choice of input variables** for CT-assignment didn’t improve CT simulations in GCMs; using less input variables is possible!

- **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, larger bias over whole year, especially for smaller frequencies;

- **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,
  - ...

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