Land surface predictability in Europe: Extremes & trends

Eric B. Jaeger and S. I. Seneviratne
ECMWF workshop, 9-12 November 2009
Motivation

Several major extreme events over Europe in recent years (e.g. 2003 heat wave: Schär et al. 2004, Nature; Ciais et al. 2005, Nature)
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Land-atmosphere interactions are a substantial contributor to European heat waves in present and future climate (Seneviratne et al. 2006, *Nature*)
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Land surface and its memory cause some predictability (Fischer et al. 2007, J. Climate)
Outline

1. part: land-atmosphere interactions and impact on European summer climate

*Impact on:* …the mean climate
…temperature extremes
…precipitation extremes
…trends
1. BACKGROUND

2. RESULTS

3. IMPLICATIONS FOR PREDICTABILITY

4. CONCLUSIONS

Outline

1. part: land-atmosphere interactions and impact on European summer climate

Impact on: ...the mean climate
...temperature extremes
...precipitation extremes
...trends

2. part: Implications for predictability & ongoing projects at ETH
Model experiments

Regional climate model CLM, 50km, driven by ECMWF re-analysis and operational analysis (1958-2006)
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Regional climate model **CLM**, 50km, driven by ECMWF re-analysis and operational analysis (1958-2006)

*Interactive SM:*
- CTL: control simulation

*Prescribed SM:*
- SSV: lowpass filtered SM from CTL (cutoff ~10d)
- ISV: lowpass filtered SM from CTL (cutoff ~100d)
- IAV: SM climatology from CTL
- PWP: SM const. at plant wilting point
- FCAP: SM const. at field capacity
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Jaeger and Seneviratne., *Clim. Dynam.*
Validation of CTL

Jaeger et al., JGR (2009)
Validation of CTL

Land atmosphere coupling is reasonably represented in CLM

Jaeger et al., JGR (2009)
Mean climate: JJA

1. BACKGROUND
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Mean climate: JJA

SSV-CTL   ISV-CTL   IAV-CTL   PWP-CTL   FCAP-CTL

strong impact on $T_{2m}$, precipitation (but also on clouds, radiation, circulation etc.)
PDFs of $T_{\text{max}}$
PDFs of $T_{\text{max}}$

Soil moisture effects high $T_{\text{max}}$ values stronger than low ones
PDFs of $T_{\text{max}}$

Soil moisture has a dampening effect on temperature.
Extremes: HWDI

HWDI = heat wave duration index:

‘(max, mean) number of consecutive days (at least two) with values above the long-term 90th-percentile’
Extremes: HWDI
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1. BACKGROUND

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Extremes: HWDI
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2. RESULTS

\[ \Delta T = 0 \]

\[ \Delta \text{persistence} \]
Extremes: HWDI

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Due to changes in the PDF of $T_{\text{max}}$ or due to changes in persistence?
Extremes: HWDI
Extremes: HWDI

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Lorenz et al., GRL (submitted)
Continuous reduction in HWDI, likely due to reduction in persistence associated with a loss of SM memory

Lorenz et al., *GRL (submitted)*
Precipitation extremes

1. BACKGROUND
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Precipitation extremes

SM impacts the prec. frequency, but on wet days prec. remains unchanged.
Trends in $T_{\text{max}}$ (mean)
Trends in $T_{\text{max}}$ (mean)
Trends in $T_{\text{max}}$ (mean)

global-dimming
global-brightening
Trends in $T_{\text{max}}$: mechanisms?

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Trends in $T_{\text{max}}$: link to SM

1981-2006: CTL

1981-2006: IAV

no trend
Aerosols are kept constant in CLM, hence (mostly) only cloud trends are the cause for $T_{\text{max}}$ trends, whereas SM act as an amplifier.
Trends in $T_{\text{max}}$ (extremes)
Trends in $T_{\text{max}}$ (extremes)

Stronger than those in mean

1981-2006: IAV

1981-2006: CTL
Trends in $T_{\text{max}}$ (extremes)

Stronger influence of SM

1981-2006: IAV
1981-2006: CTL
Implications for predictability

Soil moisture is found to play a major role for heat waves in Europe: asymmetric effect affecting mostly “hot” extremes; also effect on persistence

Identified effects on precipitation occurrence

➤ Major implications for:
  - short-term predictability
  - seasonal forecasting
  - decadal forecasting
  - climate-change projections
Implications for predictability

Despite low land-atmosphere coupling, diagnostic estimate of soil moisture predictability ($\rho_{SM}^*\Omega$) based on GLACE-1 data suggests significant potential in Europe (Seneviratne et al. 2006, JHM)

(near-monthly) soil moisture autocorrelation
On-going projects at ETH

- SwissSMEX (Swiss Soil Moisture Experiment), 2008-2011

- NRP 61 project DROUGHT-CH: Drought early warning and forecasting in Switzerland and Central Europe (2010-2012)

- EU-FP7 Carbo-EXTREME: Impacts of extreme events on land carbon balance (modeling studies using CLM from NCAR)
Conclusions

- Soil moisture significantly impacts:
  - Extreme (hot) temperatures
  - Heat wave persistence
  - Precipitation frequency
  - Decadal trends in cloud cover and mean/extreme climate

- Important implications for predictability: Need also to be combined with analysis of soil moisture persistence!

- Potential of soil moisture initialization for weather, seasonal, and decadal forecasting needs to be better investigated! However, lack of observations remains an issue