Soil drying in Europe and its impact on atmospheric circulations

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How does the land change the hydroclimate?

- It is part of the hydrological cycle
  - It may buffer precipitation anomalies

d’Andrea et al (2006): in regions of weak advection positive feedback may lead to ‘locking in’ on dry or wet regimes
How does the land change the hydroclimate?

- It is part of the hydrological cycle
  - It may buffer precipitation anomalies
  - It may change the atmospheric ability to form precipitation

Findell and Eltahir (2003): this feedback can be **positive** (wet soils favouring convection when MSE build up is required) or **negative** (dry soils leading to PBL reaching LCL)
How does the land change the hydroclimate?

- It is part of the hydrological cycle
  - It may buffer precipitation anomalies
  - It may change the atmospheric ability to form precipitation

- It may change the atmospheric circulation

- e.g. Kanamitsu et al (2003) looked at SW US
- Cook et al (2006) looked at Southern Africa
A famous plot on land-atmosphere interaction

- Areas where changing soil moisture variability affects local daily precipitation variability

Probably dominated by local feedback

No strong feedback in Europe

Koster et al., Science 2004
How to ‘measure’ land-atmosphere coupling?

- Compare two multi-year simulations:
  - One normal (‘coupled’) simulation
  - One ‘uncoupled’ simulation with fixed land cond’s

- See what is the effect on variability of $T$, $P$
Change in interannual variability for future conditions

- Land-atmosphere interaction influences this variability!
- Northward shift of areas with strong variability

Seneviratne et al, 2006

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Change of circulation and precipitation in summer

Van Ulden and Van Oldenborgh, 2006
Feedback hypothesis

Soil water stress

Relatively high land temperature

Van Ulden and Van Oldenborgh, 2006
Feedback hypothesis

Soil water stress

Relatively high land temperature

High land-sea temperature contrast

Thermal low above land, high above sea

Van Ulden and Van Oldenborgh, 2006
Summary so far

- Land-atmosphere interaction has impact on regional hydroclimate
  - local feedback and/or change in circulation?
- Over Europe signal within a season is not strong
  - local or remote?
- In Europe year-to-year variability is a function of land-atmosphere interaction
  - and changes with climate change
- Can we find a circulation response over Europe?
2 studies concerning Europe

- Do we see effect of land-atmosphere interaction on summertime blocking?
- Can we explain changes in atmospheric circulation from land drying?

- 2 sets of model runs (1950 – 2100)
  - ESSENCE
    - ensemble of ECHAM/OM1
    - plus one member with daily climatological soil
  - IFS
    - ECMWF atmosphere-only model with prescribes SSTs
    - plus one simulation with altered regional surface condition
Analysis of JJA ESSENCE and ECMWF time slice runs

ECMWF IFS

ESSENCE

MSLP

T2m


Haarsma et al, submitted

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A first diagnostic exploration in ESSENCE

- Basic question: is it true that soil-atm interaction has impact on blocking circulation?
  - Persistence of blockings
  - Frequency of blocked conditions

- Start with summer blockings
  - blocked if $\frac{\partial Z}{\partial y_{40-50}} > 0$ and $\frac{\partial Z}{\partial y_{50-67}} < -10 \text{ m/°}$

Equation: $40$ $50$ $67$ $\text{N-pole}$

Equator

Tibaldi & Monteni, 1990

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The ESSENCE experiments

- Baseline experiment (17 members; 5 analysed)
  - # 1-16: only monthly soil fields stored
  - fixed daily soil moisture (and snow): stored from #17
  - climatological surface fields: monthly soil moisture/snow from #1 – 16 averaged and interpolated to daily fields

- CLIM experiment (1 member)
  - using climatological surface fields

- ‘GLACE’ experiment (5 members)
  - each using fixed soil moisture
  - failed 😞
The CLIMSOIL run

one member of control ensemble

climsoil
Impact of prescribing soil moisture

CTL

evaporation

more evap (and precip) in dry areas

CLIMSOIL minus CTL

precipitation

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Although soil moisture variability is removed, more variability in atmospheric flow (more depression activity?)
The blocking index in JJA

(Interannual) variability is large. CLIMSOIL signal seems higher in Western sector, lower in Eastern sector.

European sector is blocked when at least 3 consecutive longitudes pass the criterion.
Persistence of blockings

Duration of JJA blocking sequences CTL climate (1950-2000)

No clear impact of cutting land-atm interaction
Composite of Z500-anomaly

High pressure pattern shows preference for more westward position

CTL 01–04 days (n=614)

CTL 05–09 days (n=678)

ΔW/σ_W,daily

CLIMSOIL 05–09 days (n=678)

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Patterns of Z975-anomaly

Not surface heat low
(here it forms more
preferentially over
high lat. sea)
2 studies concerning Europe

- Do we see effect of land-atmosphere interaction on summertime blocking? Not a lot.
  - no change in blocking persistence or frequency
  - with interaction: less Z500 variability over land
  - high pressure anomaly in blocked conditions a bit more off the continent (shift to the West)
- Can we explain changes in atmospheric circulation from land drying?
Matching patterns
soil m. (June) - MSLP (Jul-Aug)

- SVD analysis (patterns giving maximum correlation)

Note: no clear correlation exists in N-Europe
Likewise matching...

Subsequent precipitation response in area with largest MSLP-gradient
Future - control ECMWF run

- Low precipitation/high evaporation in spring in S. Europe

- Dry summer soil in S. and C. Europe
Future - control ECMWF run

- Dry summer soil in S. and C. Europe

- Reduced evaporation and enhanced heating mainly in S. Europe (where evap is moisture limited)
Future - control ECMWF run

- Reduced evaporation and enhanced heating mainly in S.Europe
- S.European heat low

(confirmed with experiment with extra heating in only S.Europe)
Future - control ECMWF run

- S. European heat low
- More subsidence in C. Europe
Future - control ECMWF run

• More subsidence in C.Europe

• Less cloud & precipitation, more heating in C.Europe
What did we learn?

- Blockings do not seem less persistent when land-atm interaction is reduced
- Z500 and surface patterns tend to shift westward
- Mediterranean heat lows and their effect on European circulation play a role