Evaluating the contribution of land-atmosphere feedbacks to heat extremes in CMIP5 models

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Motivation

- Hot extremes increase faster than the mean
- Land surface drying in hotspot regions

Donat et al. GRL (2017)
Motivation

- Hot extremes increase faster than the mean
- Land surface drying in hotspot regions

- How well do models capture these processes?

Donat et al. GRL (2017)
Co-variation of hot and dry extremes

- Land-atmosphere feedbacks can amplify heat extremes
- e.g. Europe 2003

Alexander, 2010
Role of aridity

**Wet regime**

- Positive temperature / radiation anomaly
- Soil moisture deficit
- Evapotranspiration

**Dry & transitional regime**

- Positive temperature / radiation anomaly
- Soil moisture deficit
- Evapotranspiration

Land impacts atmosphere via reduced ET and concurrent increase in sensible heat and temperature.

Sippel et al. ESD (2017)
Methods

- 2.5% hottest days of year
- Evaporative fraction on the day

\[ EF = \frac{\text{latent}}{\text{latent} + \text{sensible}} \]
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- Group by aridity (wet, transitional, dry)
Methods

- 2.5% hottest days of year
- Evaporative fraction on the day
  \[ EF = \frac{\text{latent}}{\text{latent} + \text{sensible}} \]
- Group by aridity (wet, transitional, dry)
- Can models capture the rel. ship between \( T_{\text{max}} \) and EF?
Observed relationship

**Wet**
- Slope = 0.21, n = 703

**Transitional**
- Slope = -9.29*, n = 252

**Dry**
- Slope = -7.12*, n = 246

- Maximum temperature (°C)
- Evaporative fraction (-)
Transitional and dry environments

Observations

Slope = -9.29, n = 252

hotter

drier

Transitional

Slope EF-Tmax (°C)

Dry

Obs range  Model
Wet environments

Observations

Slope = 0.21, n = 703

Wet

Slope EF-Tmax (°C)

Obs range  Model
Biases in land surface models

Latent heat

Sensible heat

Palang (Ev broad)

Evapotranspiration (mm/day)

Sensible heat (W m$^{-2}$)

1 Jan 02 1 Jul 02

Observed  CABLE–SLI  CABLE–GW  CABLE–2.0  CABLE–GW
JULES–3.1  JULES–altP  Mosaic  CHTESSEL  COLASSiB
ISBA–3L  ISBA–dif  NOAH 2.7  NOAH 3.2  NOAH 3.3  ORCHIDEE

Ukkola et al. ERL (2016)
Why some models over-amplify $T_{\text{max}}$?

Strong amplification due to?

1. Low latent heat (on the day / during warm season) $\times$
Why some models over-amplify $T_{\text{max}}$?

Strong amplification due to?

1. Low latent heat (on the day / during warm season) $\times$
2. Different seasonality $\checkmark$
Why some models over-amplify $T_{\text{max}}$?

**Strong amplification due to?**

1. Low latent heat (on the day / during warm season) ✗
2. Different seasonality ✓
3. High spring LAI ✗
Conclusions

- Most models capture obs in dry & transitional zones
- But many overestimate land surface feedbacks in wet regions
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- Consistent with offline LSM biases
Conclusions

- Most models capture obs in dry & transitional zones
- But many overestimate land surface feedbacks in wet regions
- Consistent with offline LSM biases
- What does this mean for projections of heat extremes?
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Observations by site

a) Wet

Slope = 0.51, n = 754

b) Transitional

Slope = -9.29*, n = 252

c) Dry

Slope = -7.12*, n = 246