Evaporation and **soil moisture** from **satellites**:

climate-oriented applications

Diego Miralles

Contributions from:

Ryan Teuling , John Gash, Han Dolman, Richard de Jeu, Jordi Vila-Gereau,

Hylke Beck, Thomas Holmes, Martinus van den Berg,

Carlos Jiménez, Niko Verhoest, Wouter Dorigo,

Chiel van Heerwarden, Robert Parinussa (and others)

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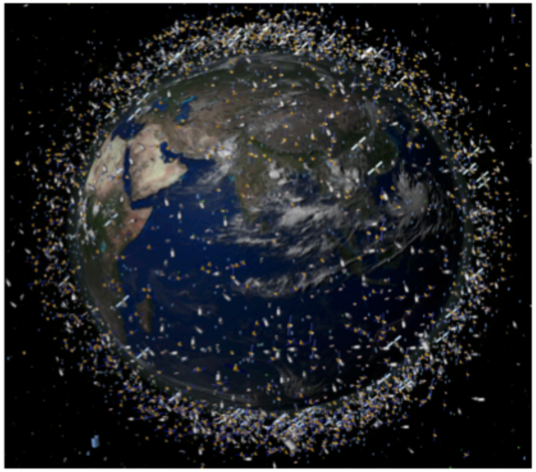
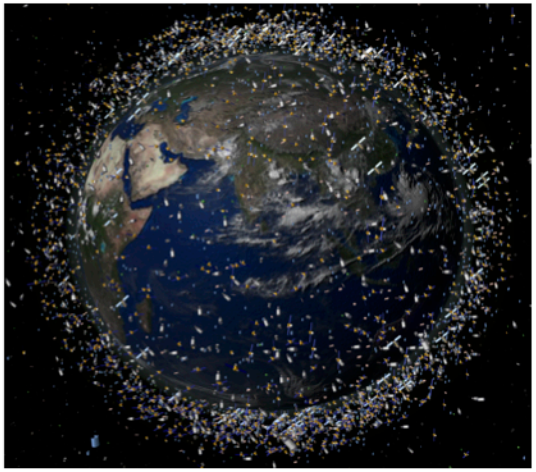


Satellites complement to *in situ* to obtain global multi-decadal *ET*?

***ET*, not directly observable**

Efforts limited to **combining observable drivers** within statistical or process-based methodologies

DRIVERS	(SUB-) DAILY	SEASON	MULTI-YEAR	MULTI-DECADE
Radiation				**Dimming / Brightening + GHGs + clouds**
Soil moisture				**Widening tropics / Dry drier, wet wetter?**
Precipitation				**Volume changes and redistribution**
Temperature				**Global warming**
Vegetation state				**Phenological changes, land use change**
Specific humidity				**Specific humidity trends**
Wind speed				**Stilling (land-use change) / redistribution**
[CO_2]				**Fertilization: WUE rise (more stomata?)**
Land properties				**Landscape and soil property changes**
Soil nutrients				**Leaching, mineralization, weathering**



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Specific humidity				**Specific humidity trends**

Like for soil moisture, satellite-based *ET*, potential for...

1. Benchmarking climate models
2. Hydro/agricultural studies
3. Insight into global water cycle
4. Land-atmospheric interactions

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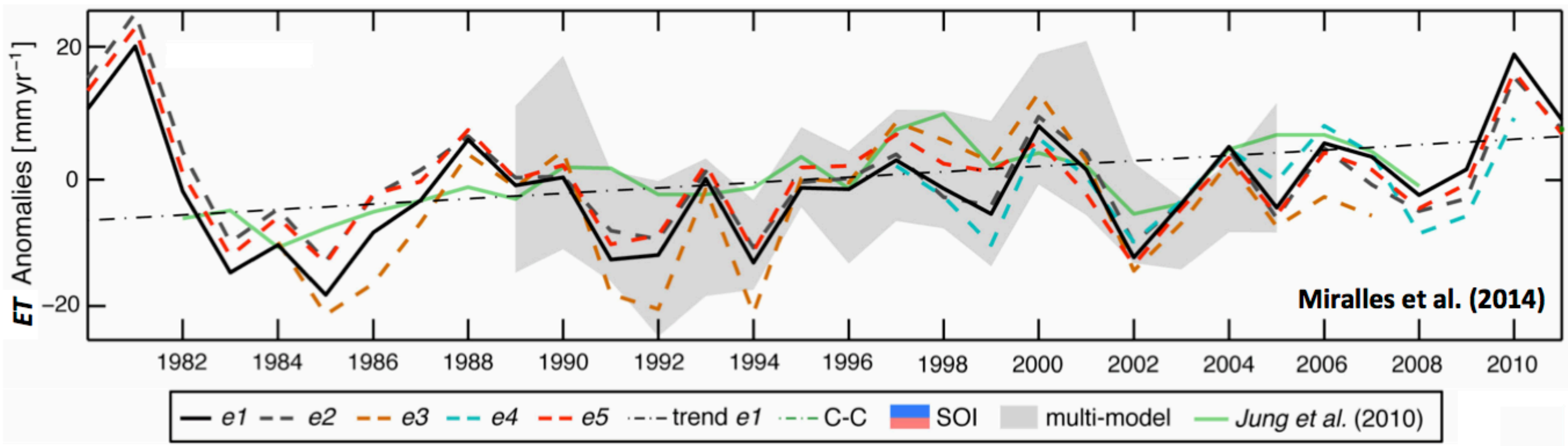
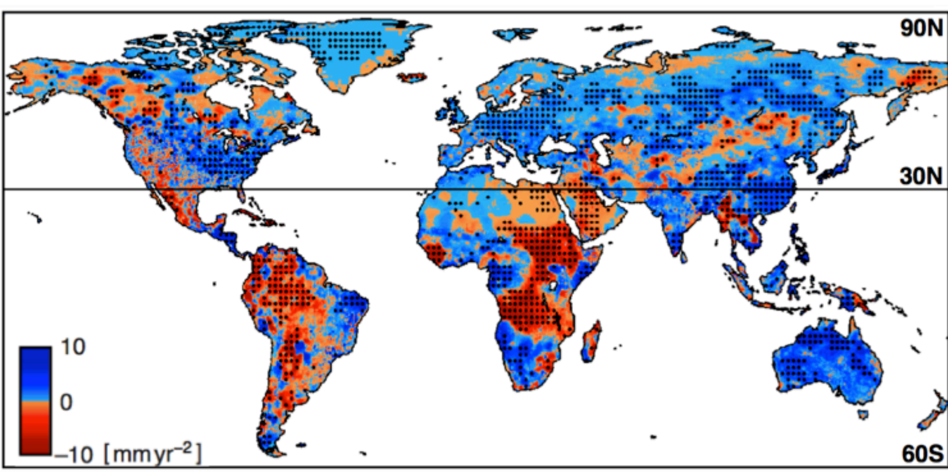
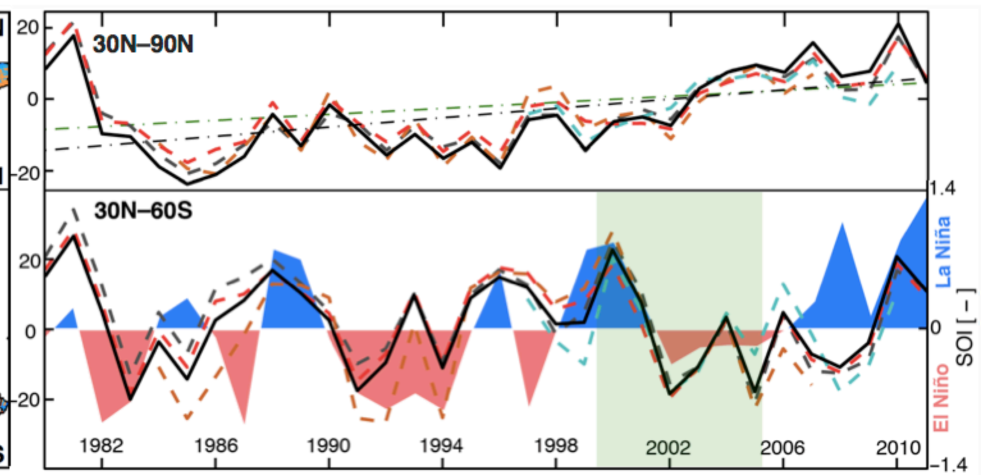
LETTERS
PUBLISHED ONLINE: 8 DECEMBER 2013 | DOI: 10.1038/NCLIMATE2068
nature climate change

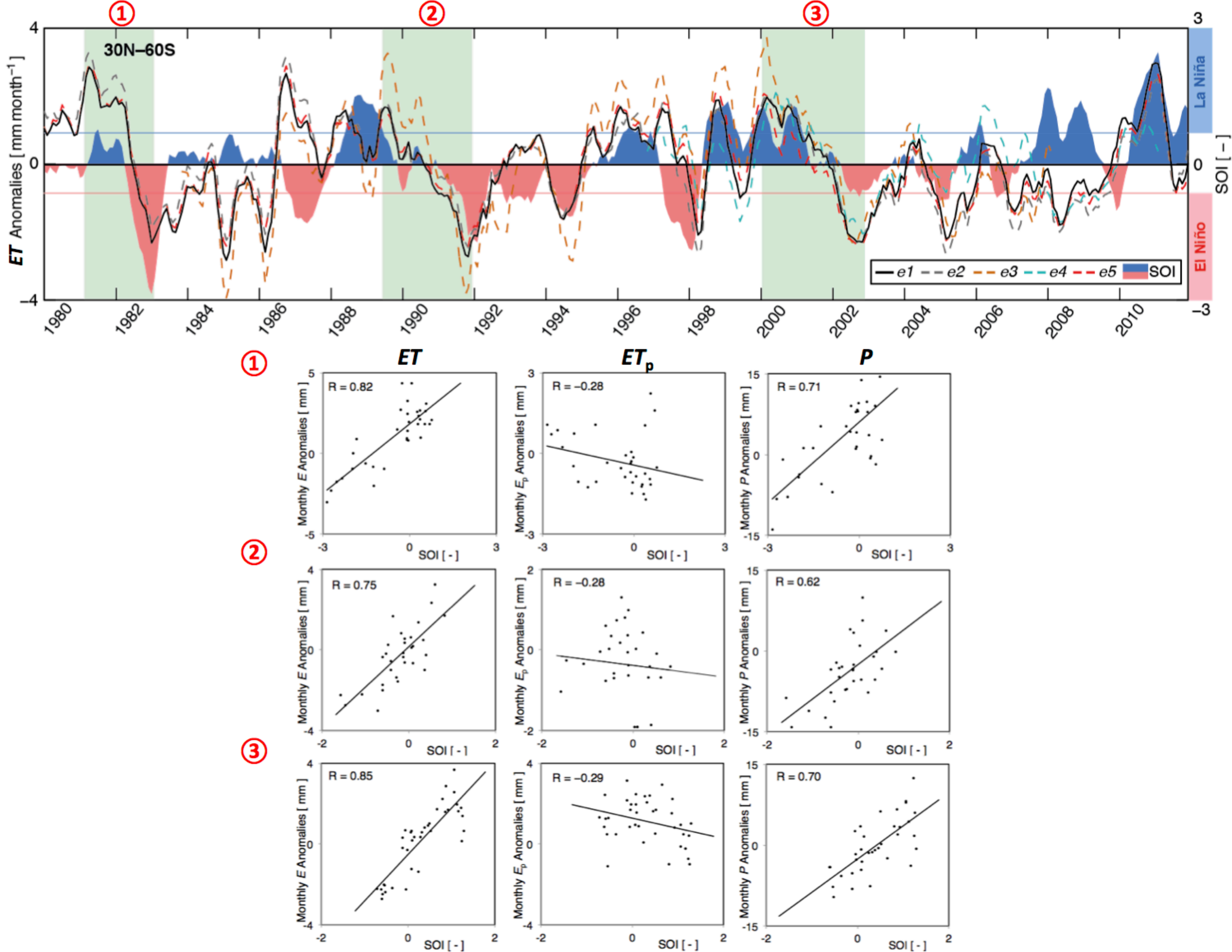
El Niño–La Niña cycle and recent trends in continental evaporation

Diego G. Miralles[1]*, Martinus J. van den Berg[2], John H. Gash[3,4], Robert M. Parinussa[3], Richard A. M. de Jeu[3], Hylke E. Beck[3], Thomas R. H. Holmes[5], Carlos Jiménez[6], Niko E. C. Verhoest[2], Wouter A. Dorigo[7], Adriaan J. Teuling[8] and A. Johannes Dolman[3]

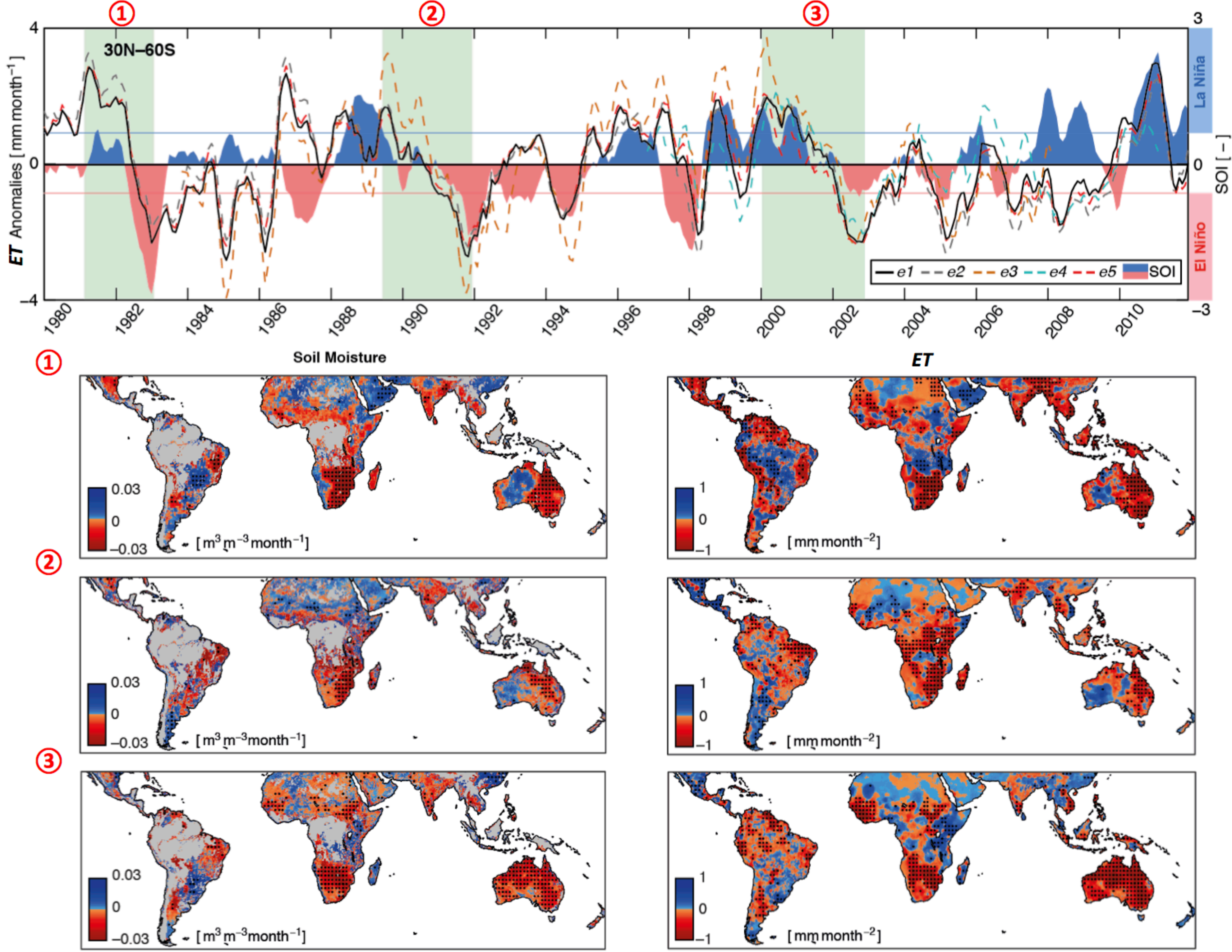








①
②
③
30N–60S
ET Anomalies [mm month−1]
SOI [–]
La Niña
El Niño
e1
e2
e3
e4
e5
SOI
ET
ETp
P
R = 0.82
R = −0.28
R = 0.71
R = 0.75
R = −0.28
R = 0.62
R = 0.85
R = −0.29
R = 0.70
Monthly E Anomalies [mm]
Monthly Ep Anomalies [mm]
Monthly P Anomalies [mm]
SOI [-]



①
②
③
30N–60S
ET Anomalies [mm month−1]
SOI [–]
La Niña
El Niño
e1
e2
e3
e4
e5
SOI
4
0
−4
3
0
−3
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
Soil Moisture
ET
0.03
0
−0.03
[m3 m−3 month−1]
1
0
−1
[mm month−2]

1. Benchmarking climate models
2. Hydro/agricultural studies
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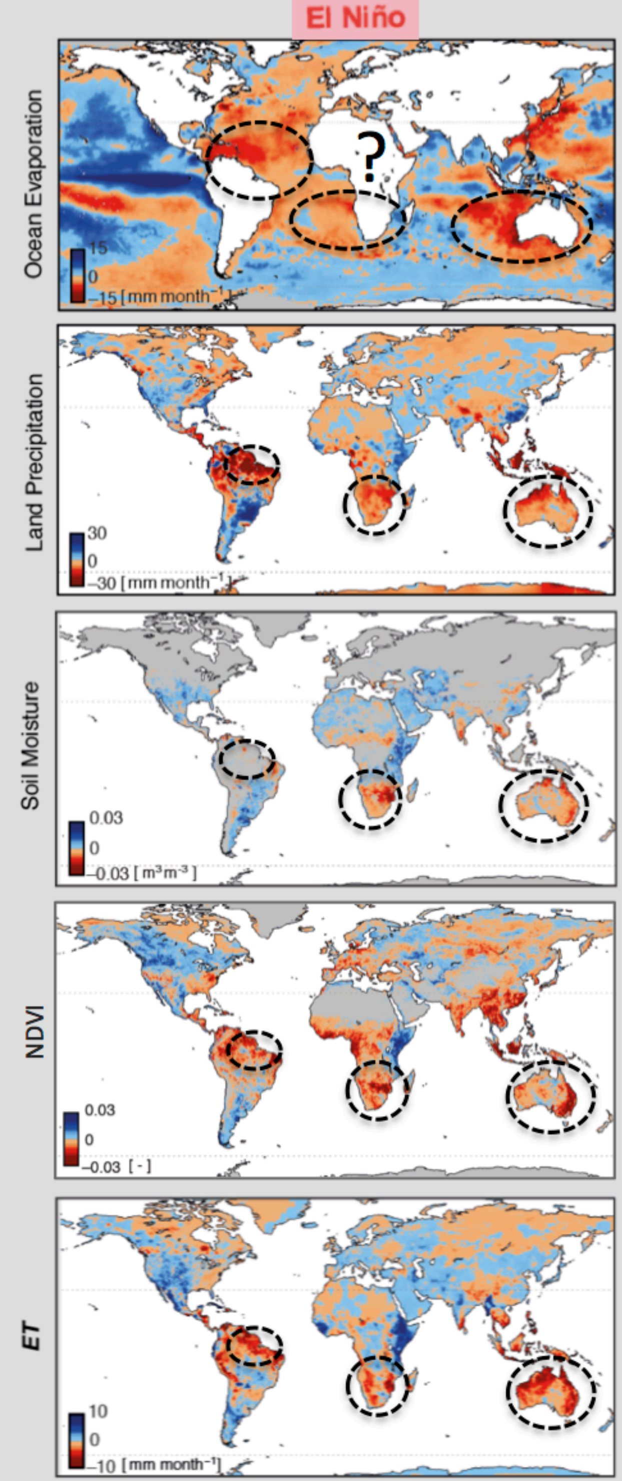
4. **Land-atmospheric interactions**

1. **No significant global *ET* trend; no decline**
2. **Northern latitudes increase**, partly explained by *T* increase
3. For the rest, **ENSO controls multi-annual *ET* dynamics**: **El Niño-driven drought causes regional declines in *ET* in Australia & Southern Africa** (which dominate the global averages)
4. Findings suggest an **oceanic control over the terrestrial water cycle**: importance of ENSO-related ocean evaporation and circulation anomalies – ***FLEXPART*** **?**
5. Future of terrestrial water cycle depending on fate of ENSO



El Niño–La Niña cycle and recent trends in continental evaporation | nature climate change

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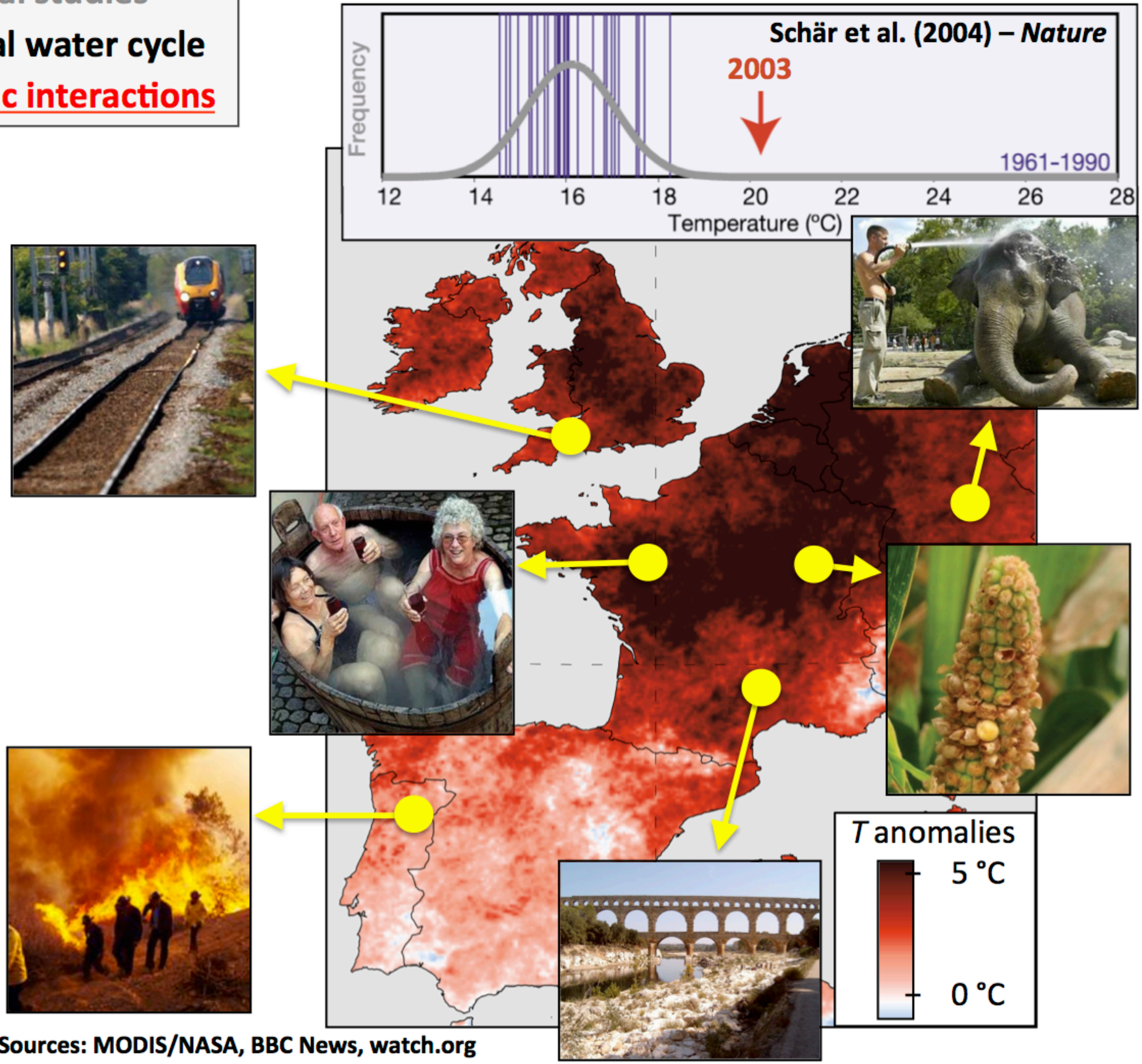
Mega-heatwave of 2003



Sources: MODIS/NASA, BBC News, watch.org

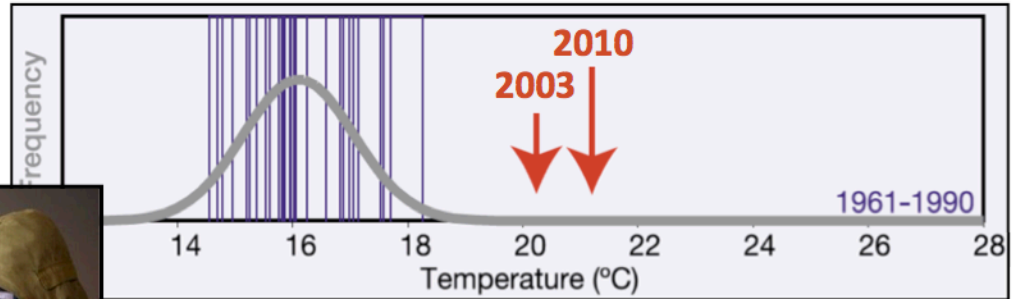
① Benchmarking climate models

② Hydro/agricultural studies

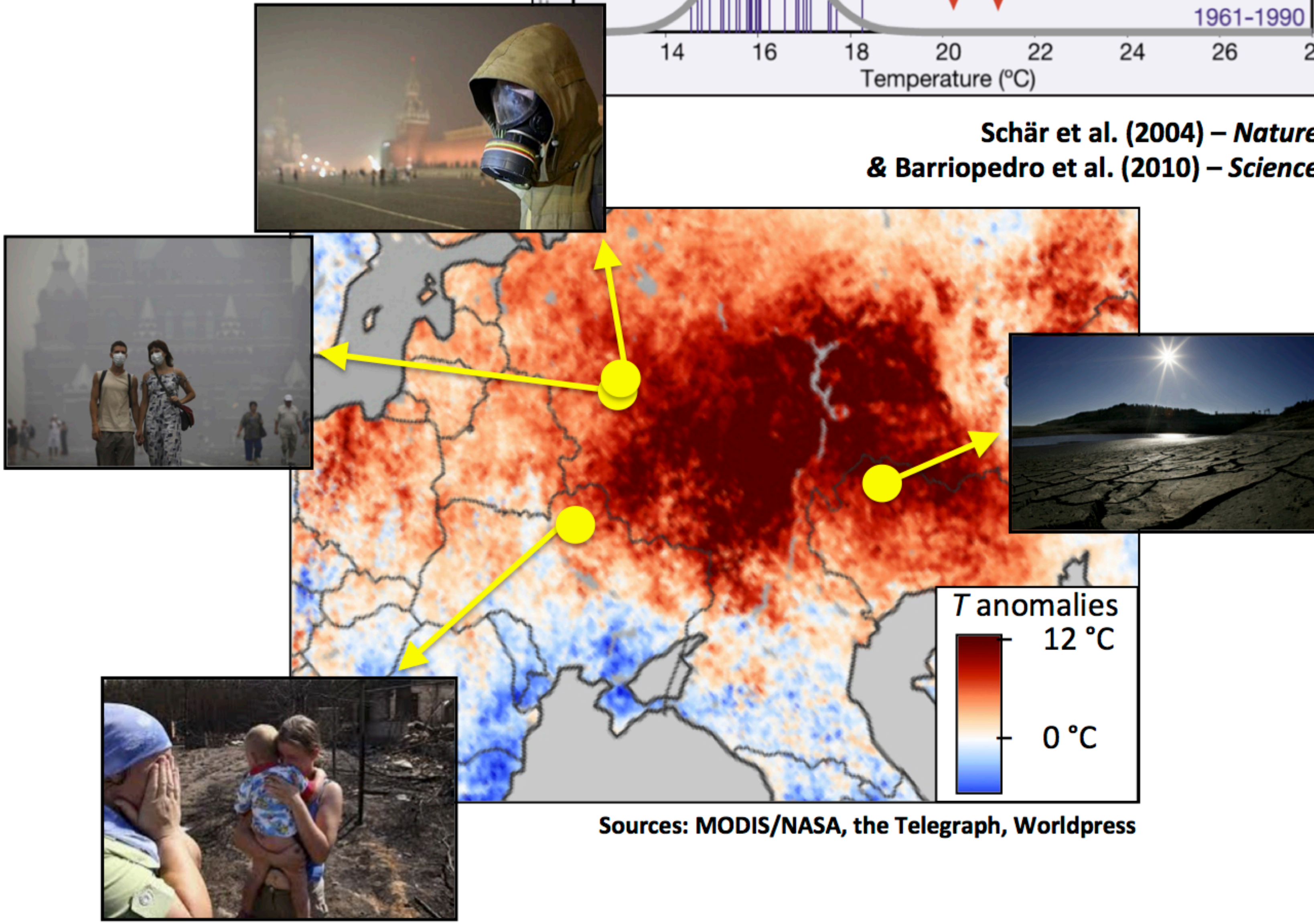
③ **Insight into global water cycle**

④ **Land-atmospheric interactions**

Mega-heatwave of 2010



Schär et al. (2004) – *Nature*
& Barriopedro et al. (2010) – *Science*



Sources: MODIS/NASA, the Telegraph, Worldpress

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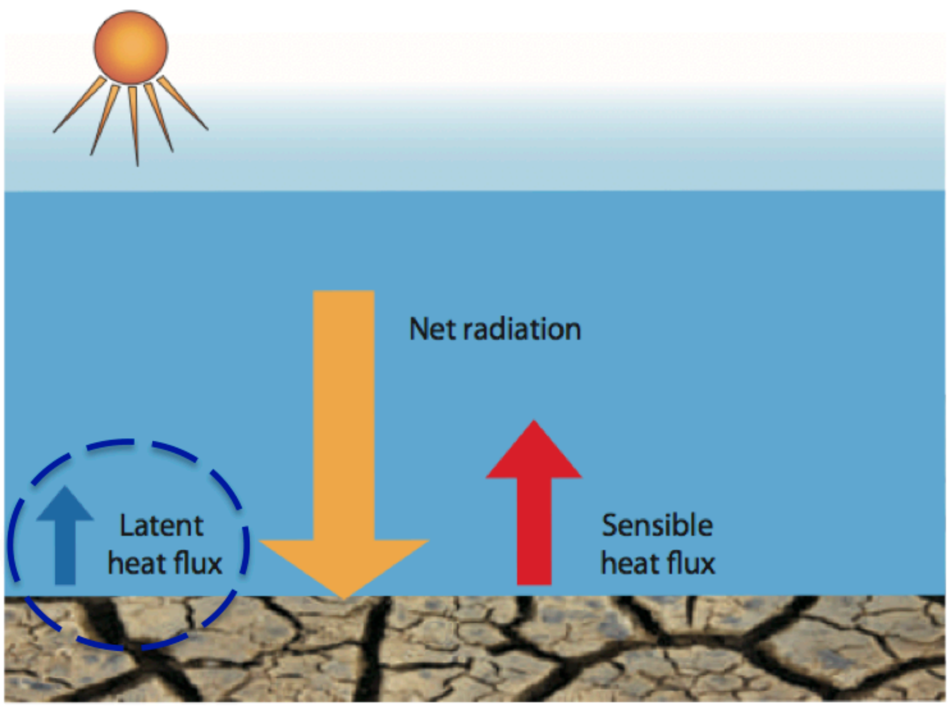
The mechanism

Can a **mega-heatwave** occur without antecedent **drought**?



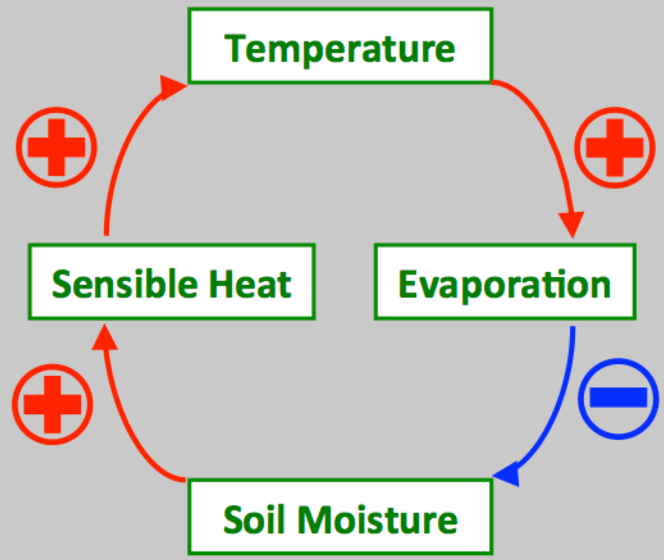
Dry soils

Alexander (2010)

① Steady clear skies and warm advection

+

② Local feedback temperature intensification



Mega-heatwave

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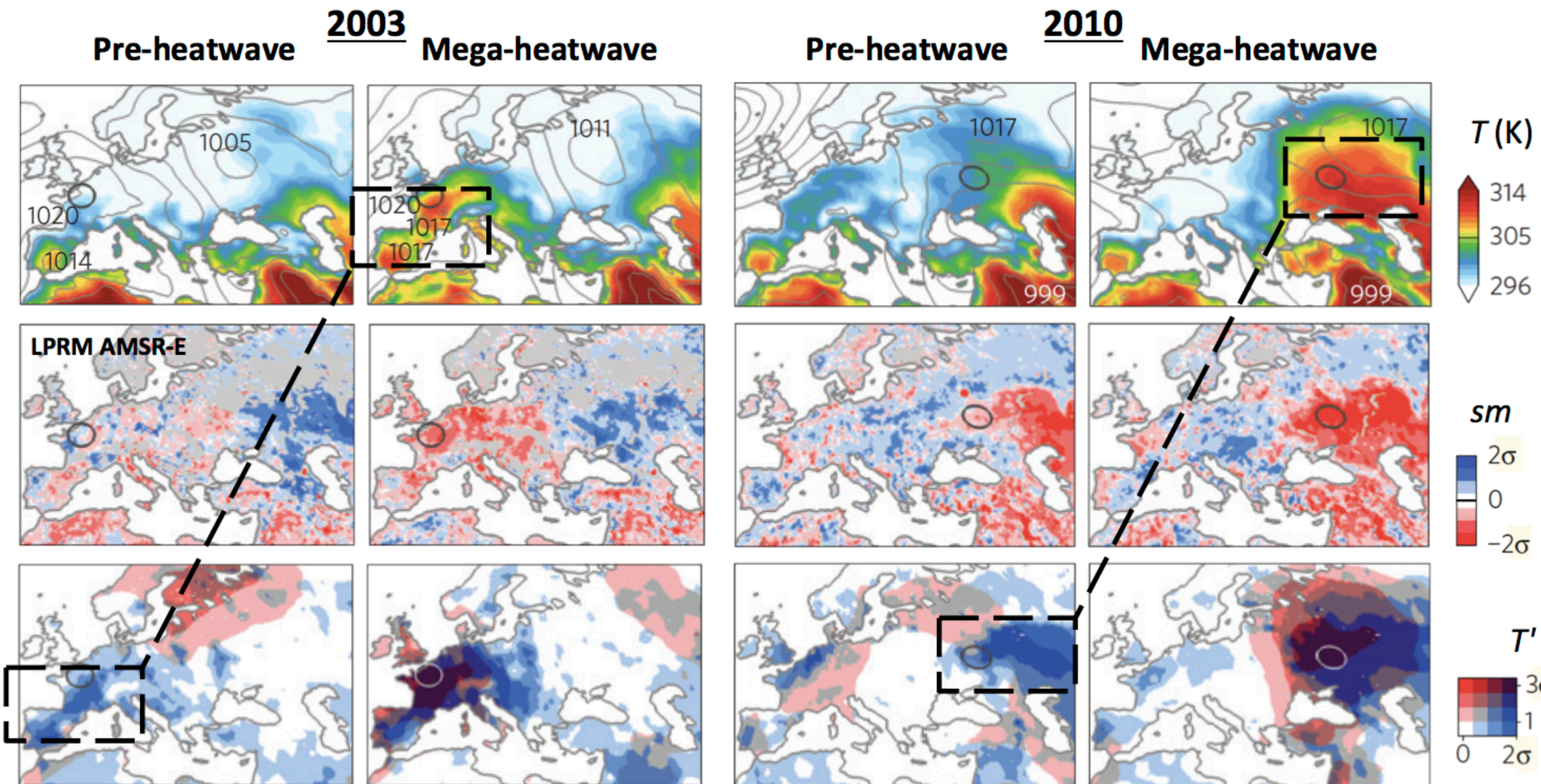
nature geoscience LETTERS
PUBLISHED ONLINE: XX MONTH XXXX | DOI: 10.1038/NGEO2141

Mega-heatwave temperatures due to combined soil desiccation and atmospheric heat accumulation

Diego G. Miralles[1,2*], Adriaan J. Teuling[3], Chiel C. van Heerwaarden[4] and Jordi Vilà-Guerau de Arellano[5]

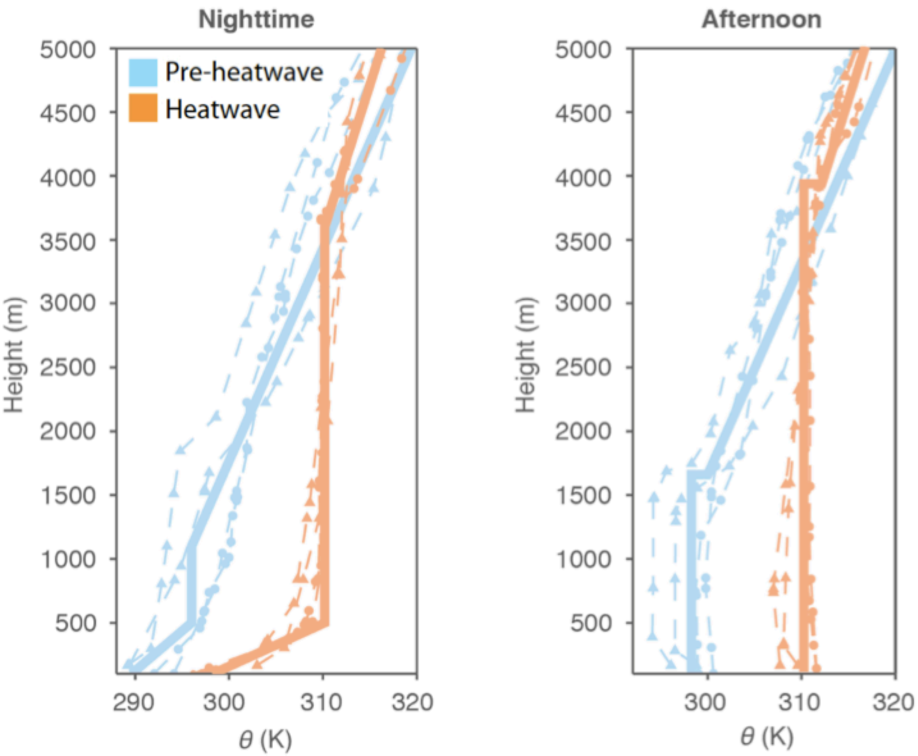


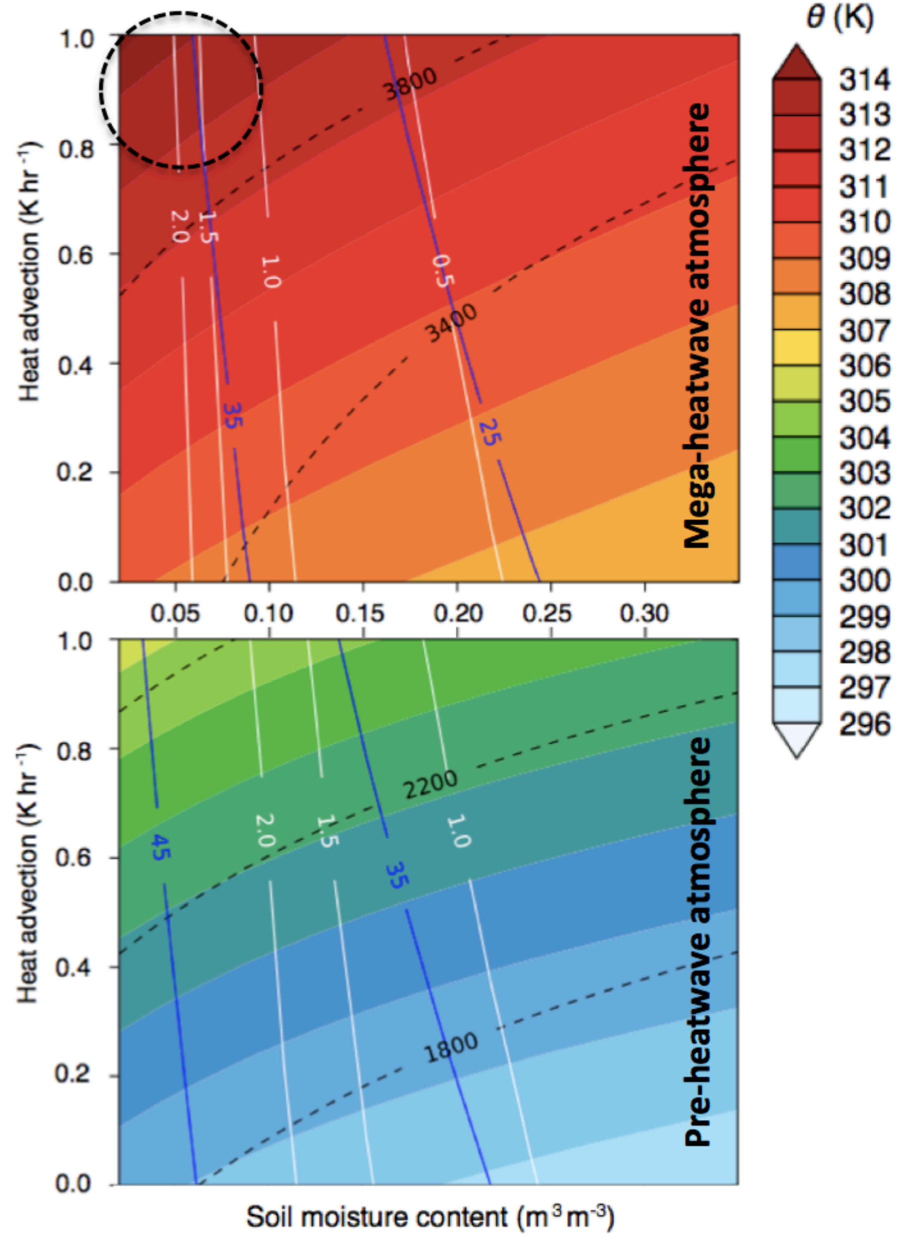
$$e' = (R_n - \lambda E)' - (R_n - \lambda E_p)'$$

Physically interpreting observations using **CLASS model** constrained by

① Bowen ratios from satellite

② Nighttime soundings





① Only **combined conditions of dry soils + high heat advection** yield observed *T*

② **But with multi-day accumulation in residual layer**

③ Heat contributions: ~50% from sensible heat, ~40% advection, ~10% entrainment

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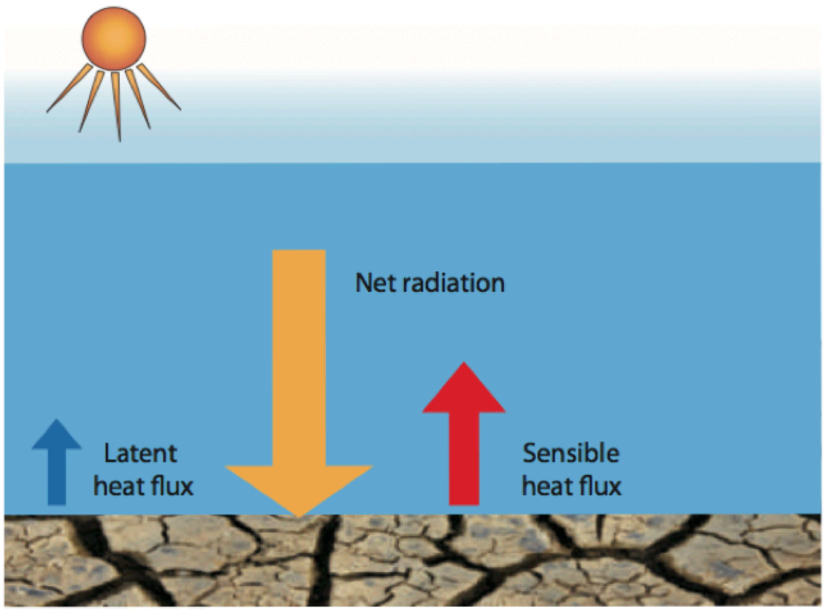
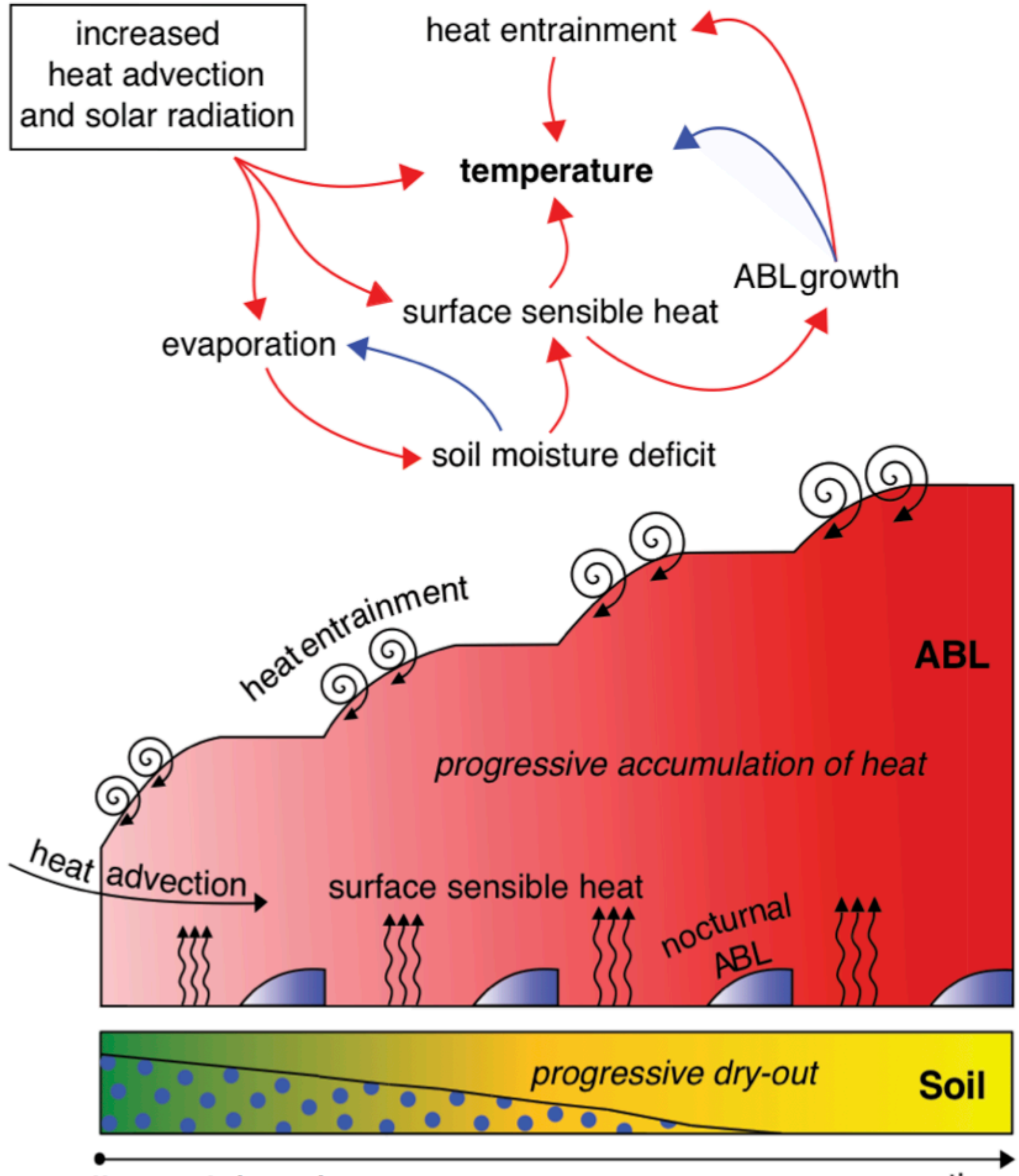


Alexander (2010) Dry soils

1. **Increased sensible heat**
2. Intense convection favors **entrainment of warm air**
3. Deep residual layers that **preserve heat day-by-day**

The soil moisture effect on mega-heatwaves is more complex...



Miralles et al. (2014)

Some conclusions

① Operational **global observation-driven *ET* data** now available for three decades (5–6 methods)

② Use for benchmarking climate models, hydrological/ agricultural studies, **understanding of the global water cycle** and **feedbacks on climate**

③ Subject of several international activities like **WACMOS-ET** (ESA), or **LandFlux** (GEWEX), **SMOS+ET**

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