How can Land Surface Modelers learn from FLUXNET

A case study from the NCAR Community Land Model development

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In Collaboration with Keith Oleson, David Lawrence, Guo-Yue Niu, Zong-Liang Yang, Peter Thornton, Gordon Bonan, Scott Denning and Steve Running

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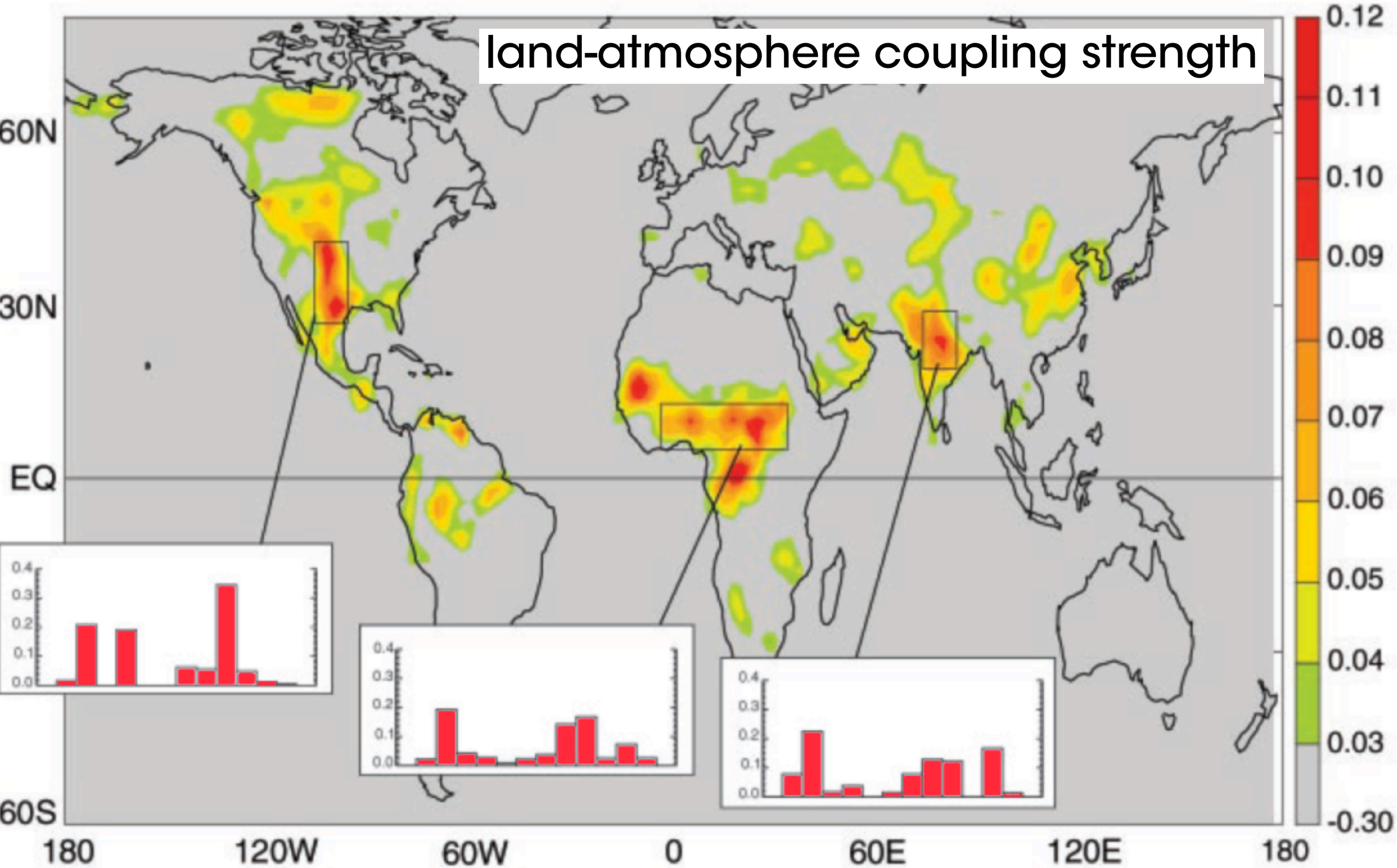
Modeling land - climate interactions



Koster et al. (2004, 2006)

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Land Surface Models: state of science

GLACE (Koster et al. 2006)

- models differ in land-atmos coupling strength

C4MIP (Friedlingstein et al. 2006)

- +CC feedback, but different magnitudes and location (tropics vs. high latitudes)

AMIP II (Henderson-Sellers et al. 2003)

- mechanistic LSMs → better energy partitioning

Use of FLUXNET in LSM development:

- reality-check for range of climate zones
- covers hourly - decadal time scales
- data comparable to model prognostics

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AmeriFlux + LBA

- Morgan Monroe State Forest (1999-2005)
- Fort Peck (2000-2005) grassland
- Harvard Forest (1994-2003)
- Niwot Ridge (1999-2004)
- Boreas Old Black Spruce (1994-2005)
- Lethbridge (1998-2004) grassland
- Santarem KM83 (2001-2003)
- Tapajos KM67 (2002-2005)

CarboEurope

- Castelporziano (2000-2005)
- Collelongo (1999-2003)
- El Saler (1999-2005)
- Kaamanen (2000-2005) tundra
- Hyytiälä (1997-2005)
- Tharandt (1998-2003)
- Vielsalm (1997-2005)

Color Legend:

temperate
tropical
boreal
sub-alpine
north-boreal
mediterranean

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Community Land Model: Development

- **CLM3.0:** original code (Oleson et al. 2004)

Proposed model changes by CLM community

- **CLMgw:** prognostic ground water scheme, more infiltration, sun-shade canopy etc.
- **CLMgw+rsoil:** new bare soil evaporation resistance
- **CLM3.5:** diagnostic nitrogen control on V_{max}, photosynthesis and stomatal conductance

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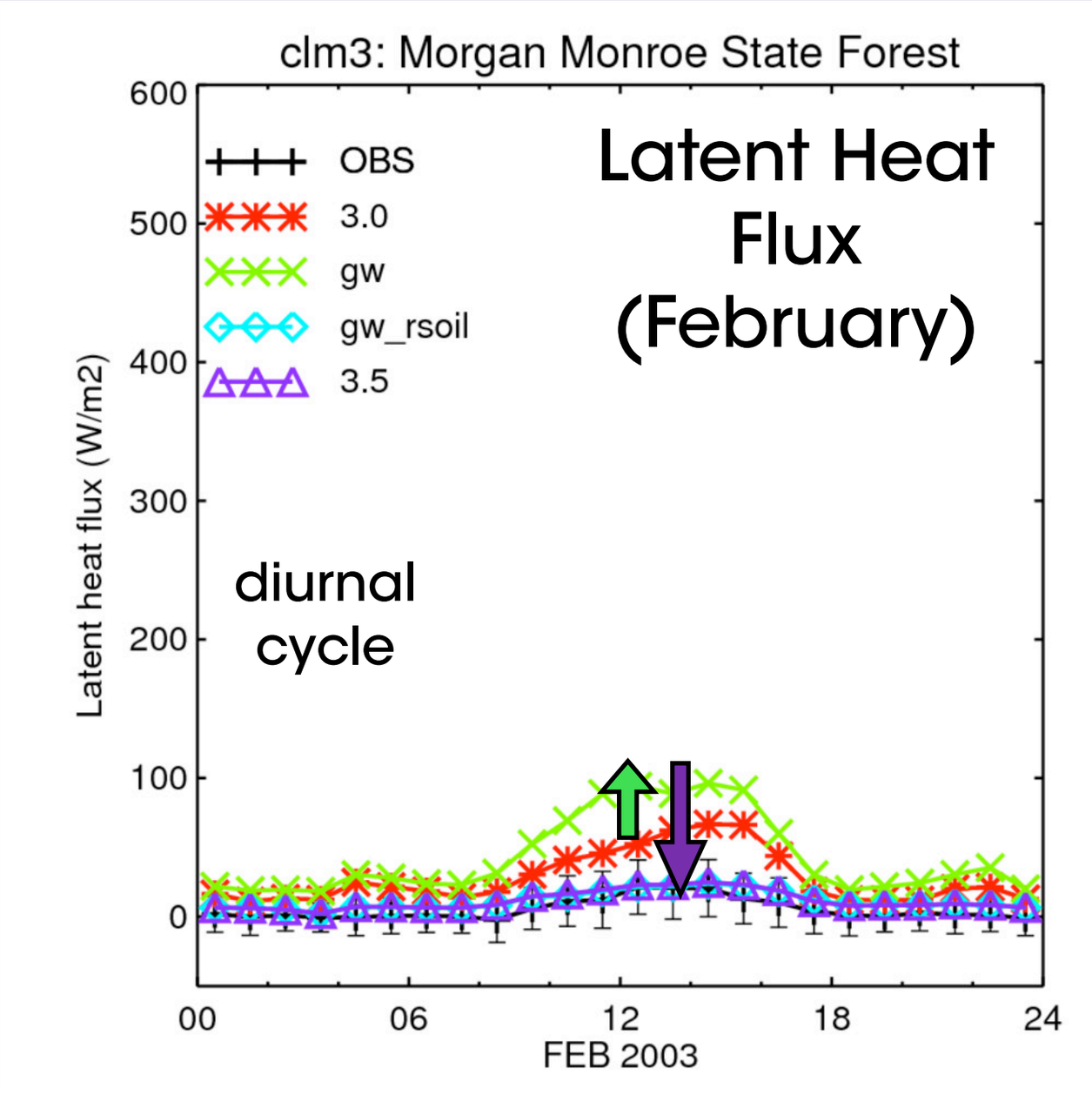
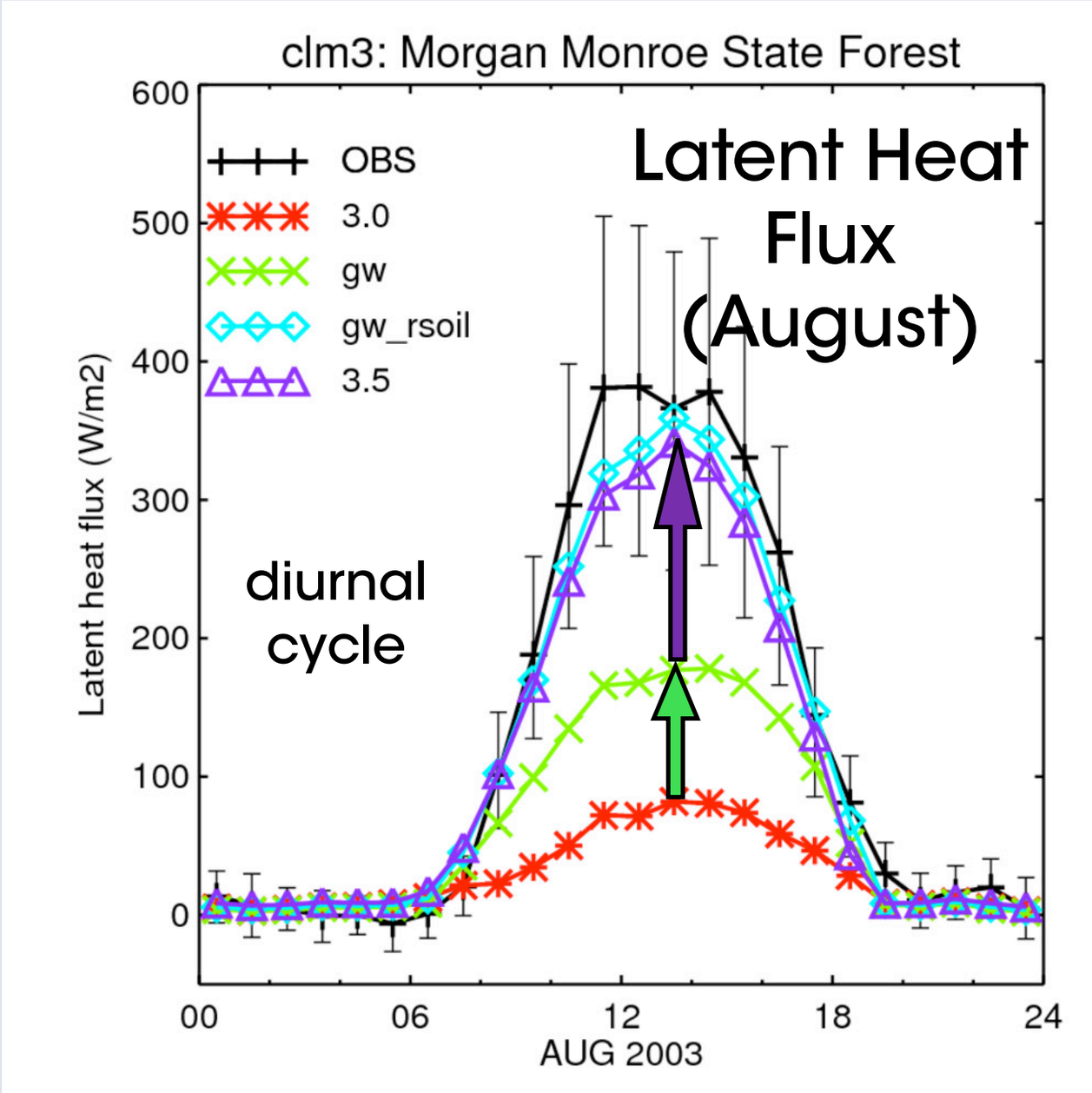
Morgan Monroe State Forest (temperate)





- **CLMgw**: increased off-season LE flux due to increased bare soil evaporation
- **CLMgw+rsoil**: constrain off-season LE flux → water available in summer for transpiration!

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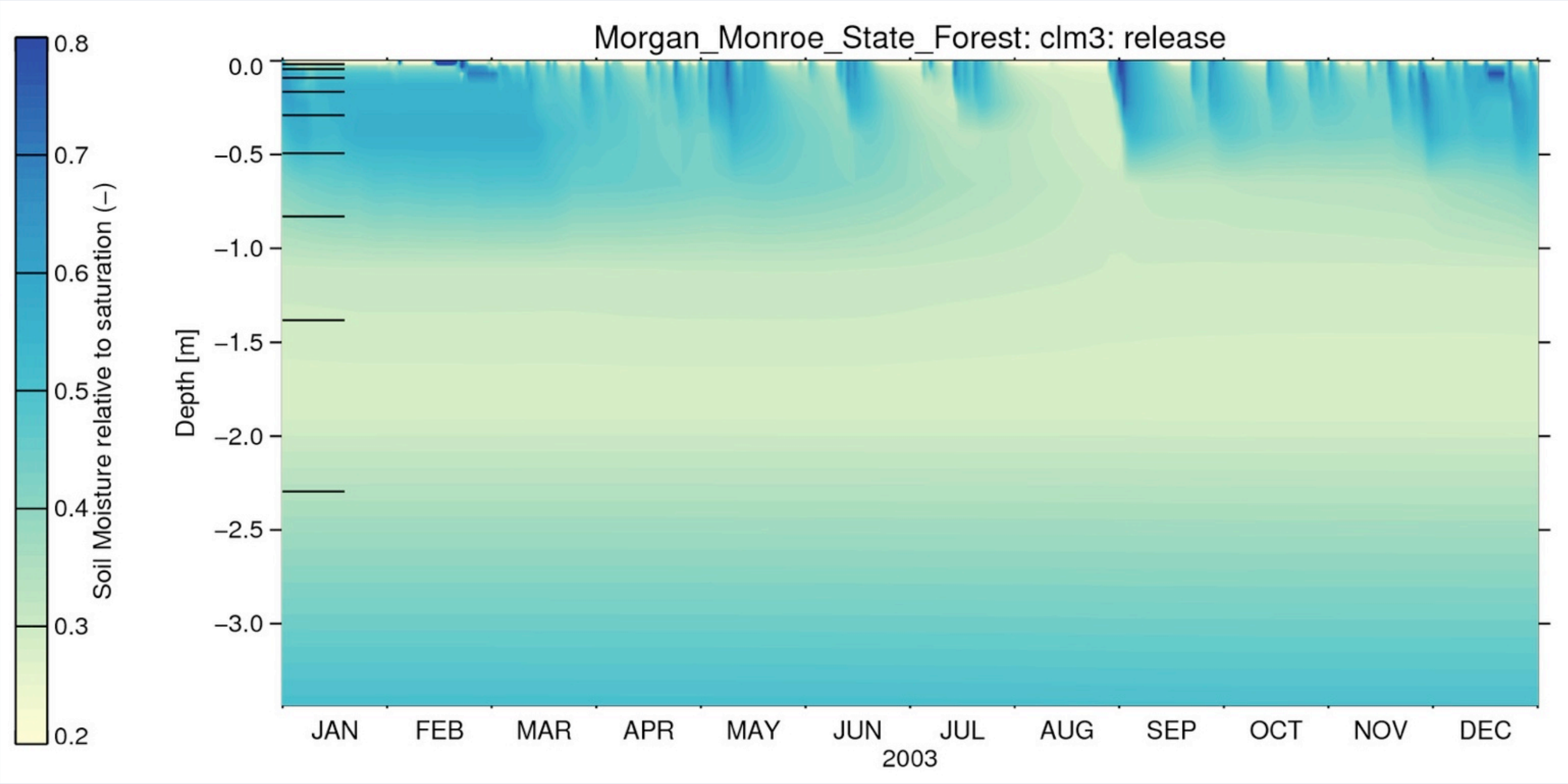

- **CLM3.0**: dry soil layers inhibit infiltration
- **CLMgw**: more infiltration (+numerical stability)
- **CLMgw+rsoil**: gw storage becomes effective

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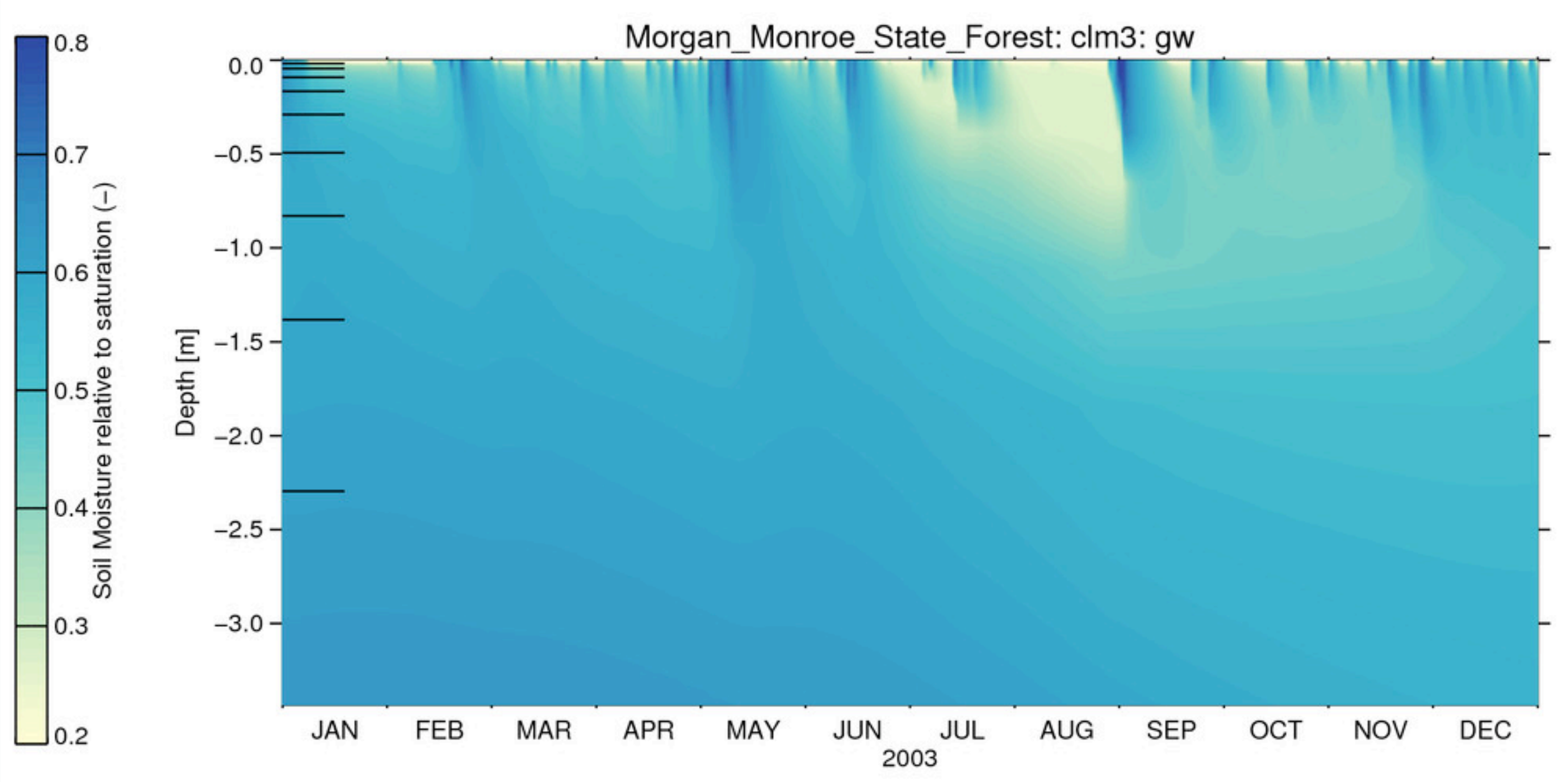

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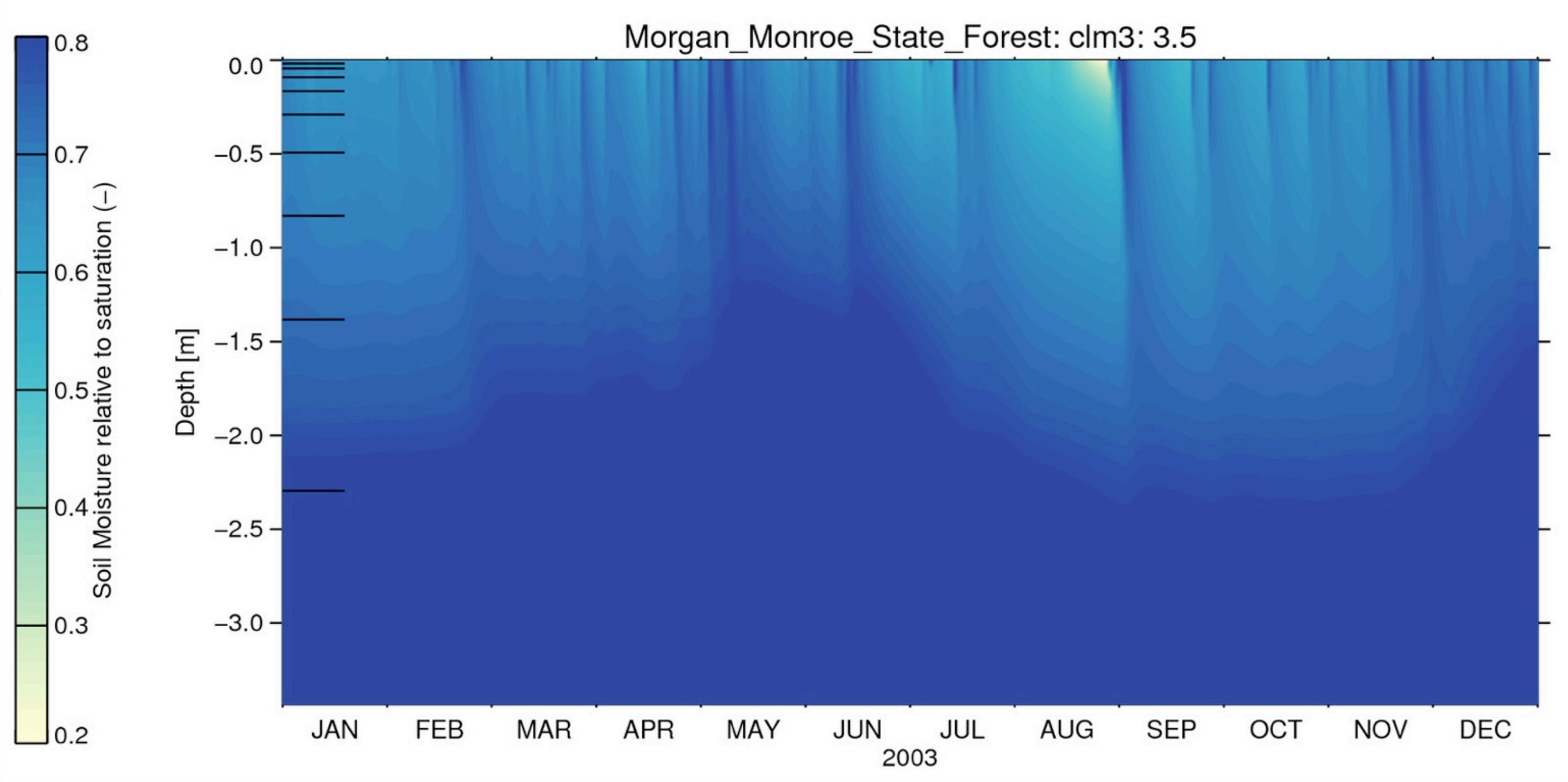

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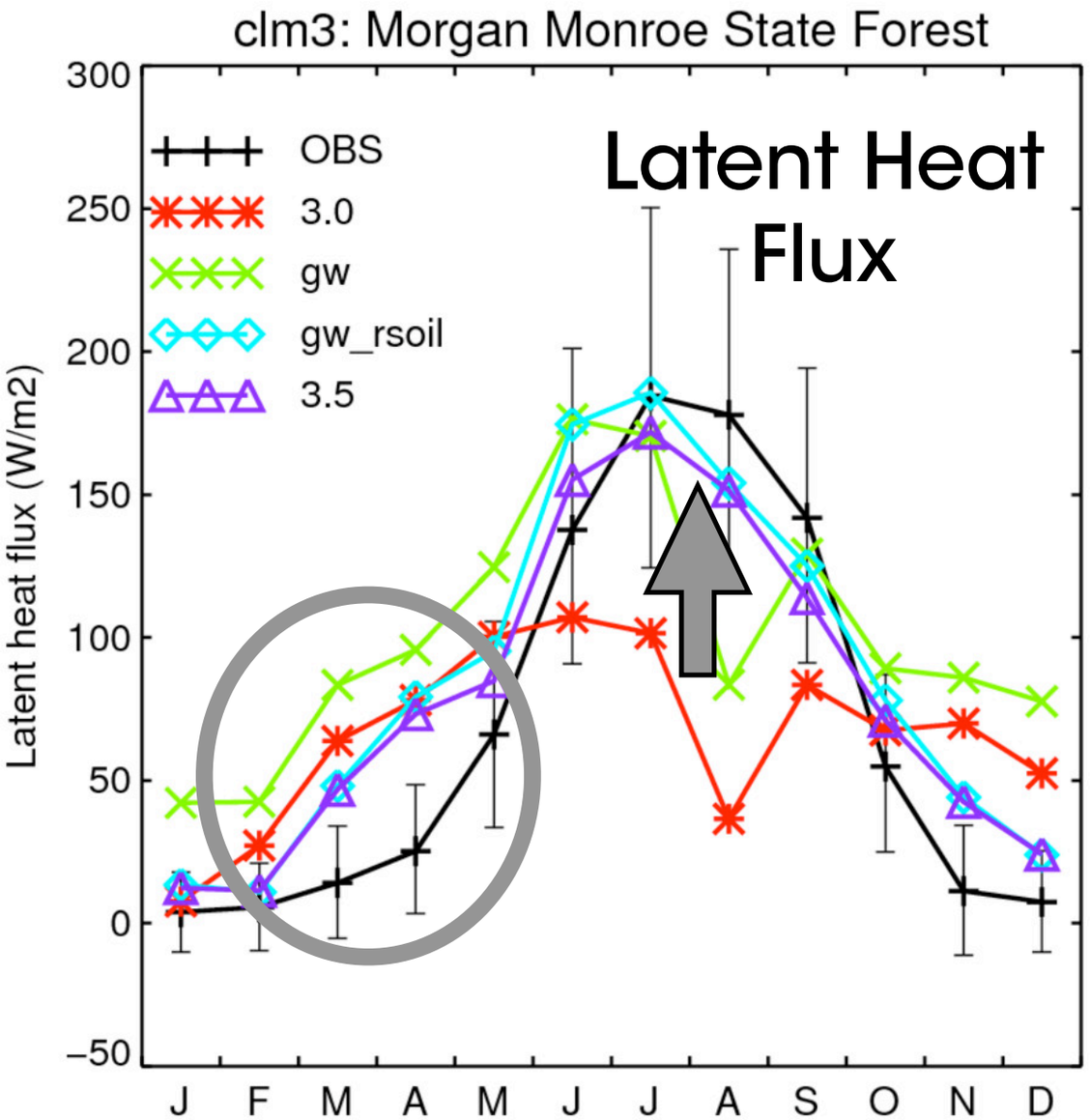
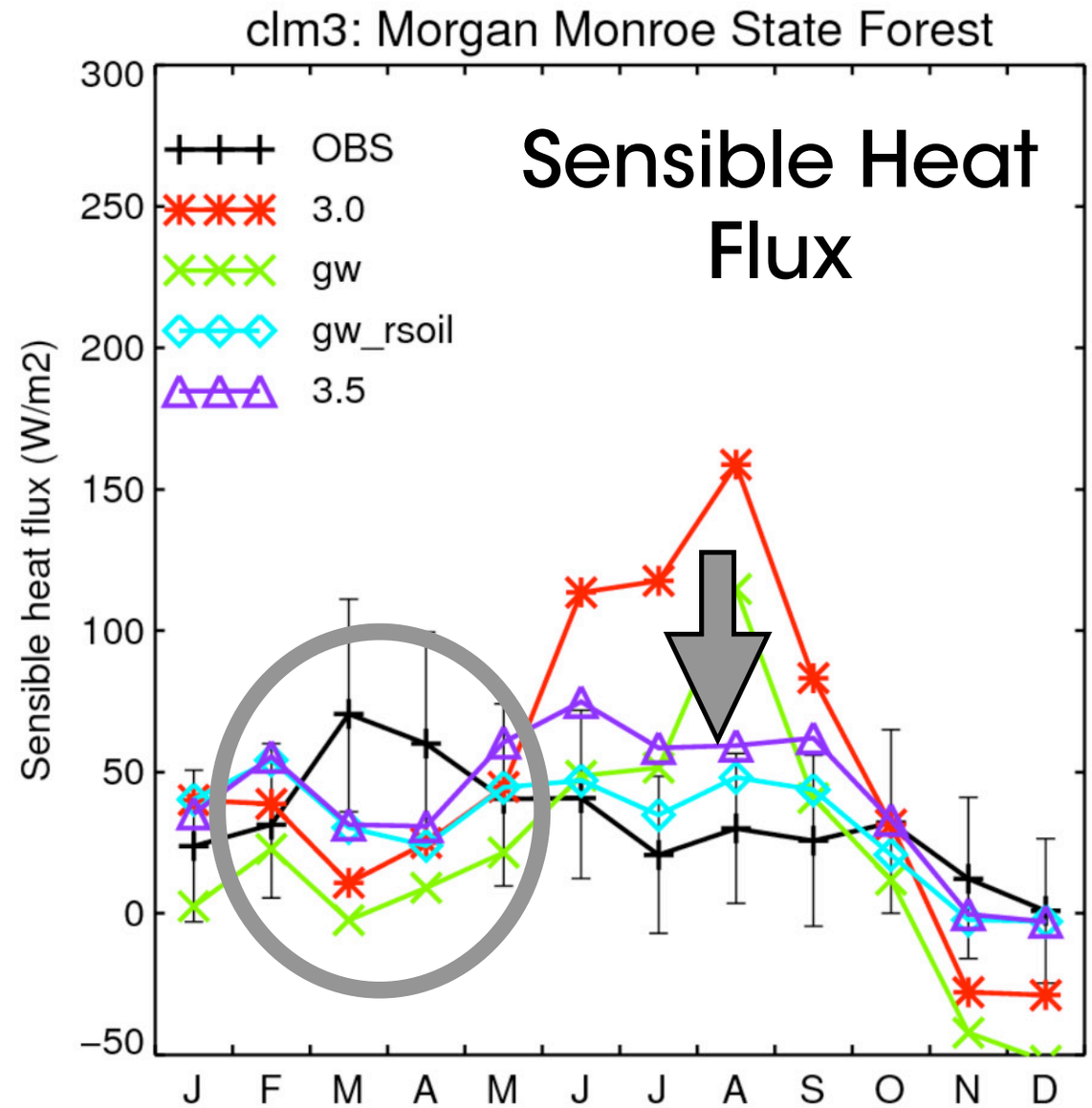
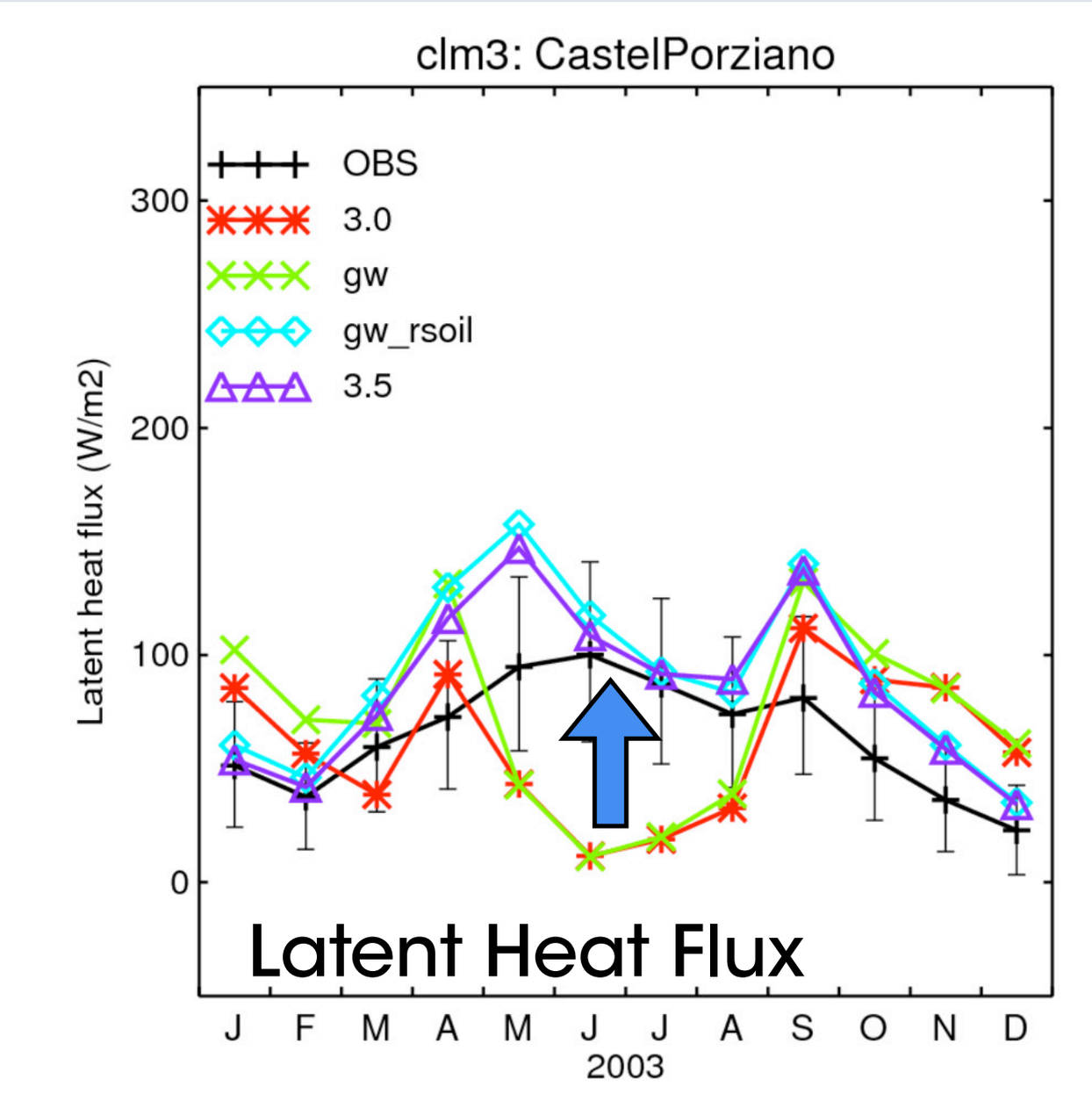
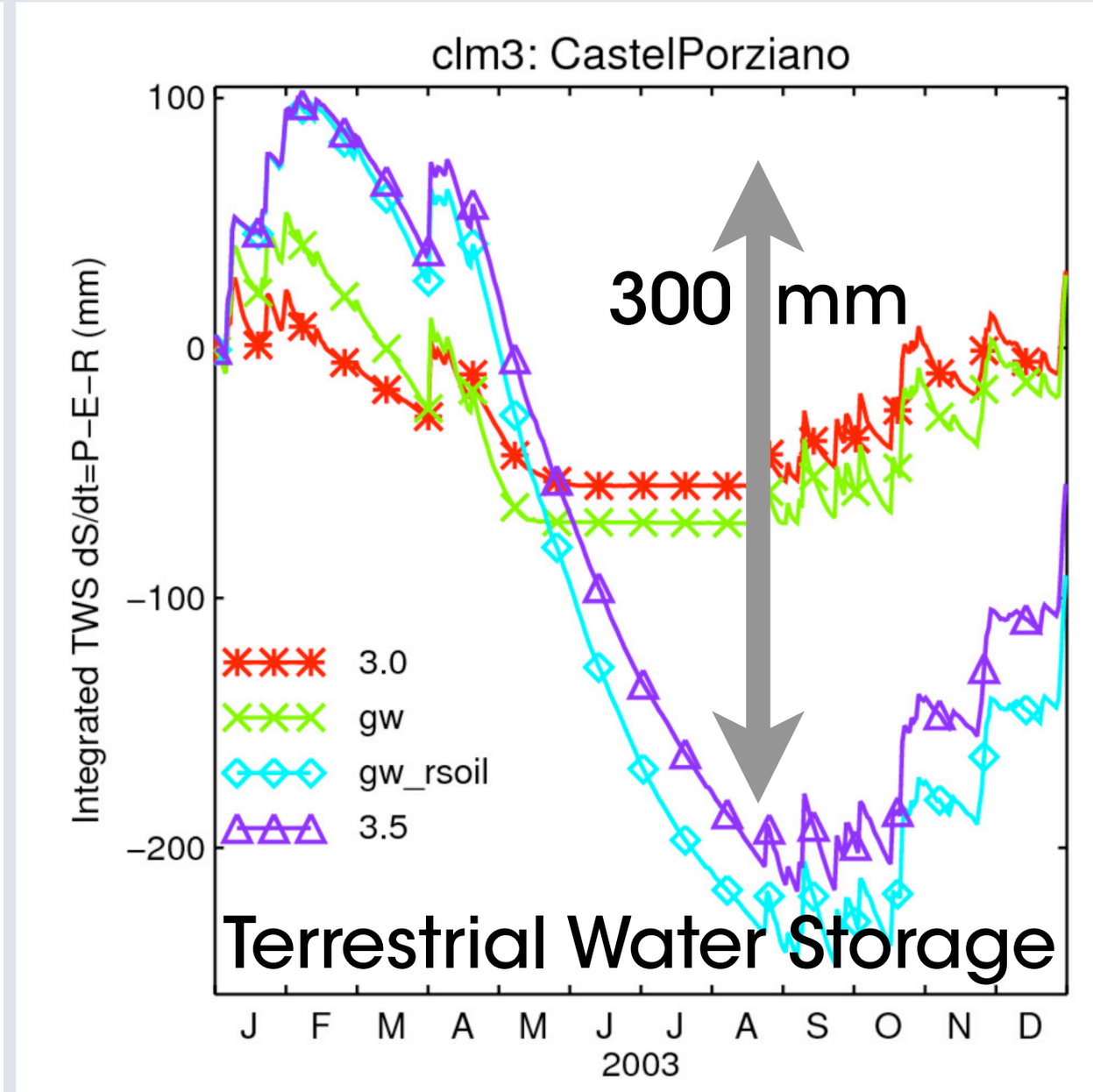




OBS: u* > 0.2 m/s (Schmid 2003), ebr + random uncertainty (Richardson 2006)

Castelporziano (mediterranean)





- obs: LE sustained during dry summer
- CLMgw: ground water only effective with new bare soil evaporation in CLMgw+rsoil

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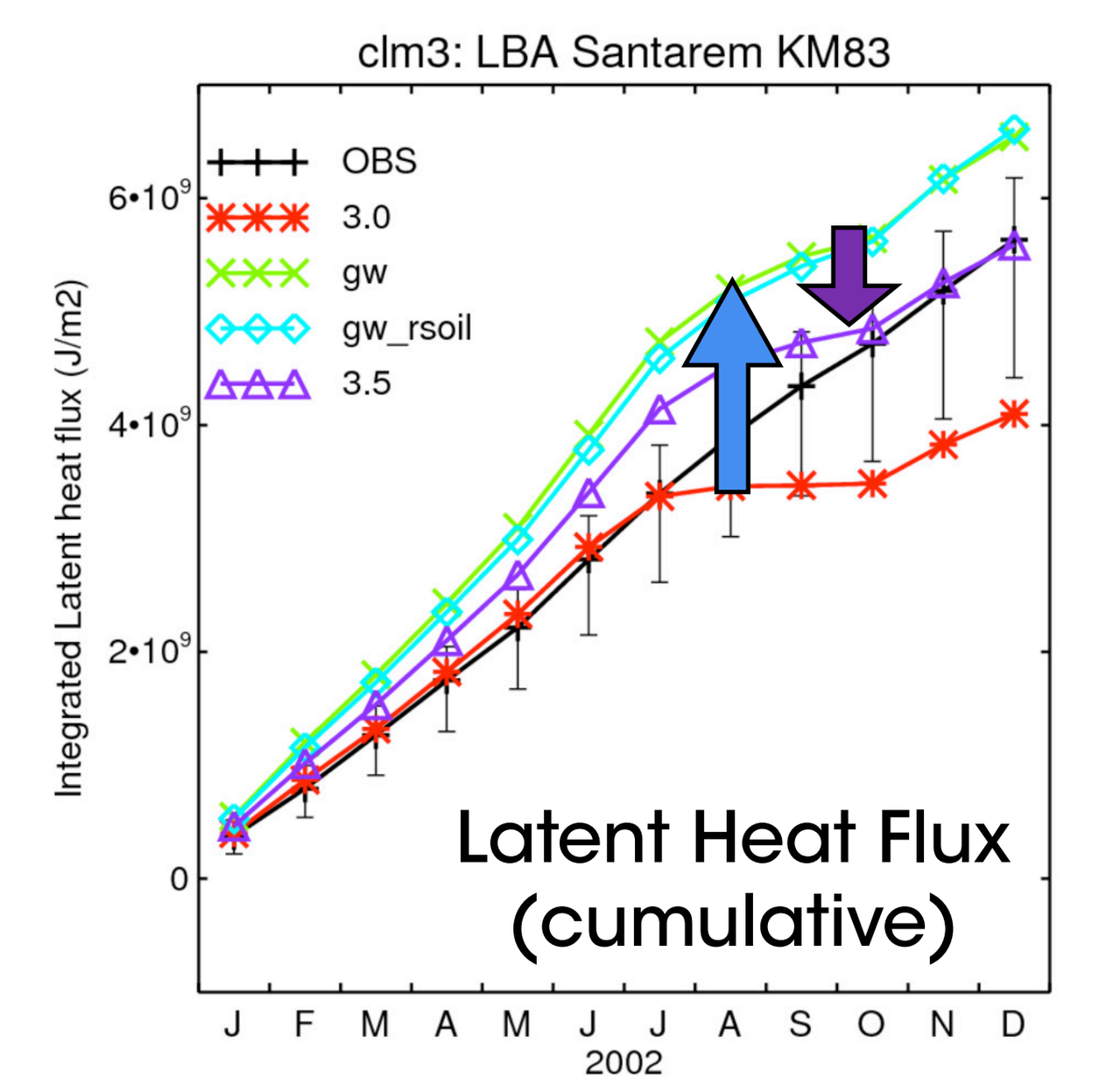
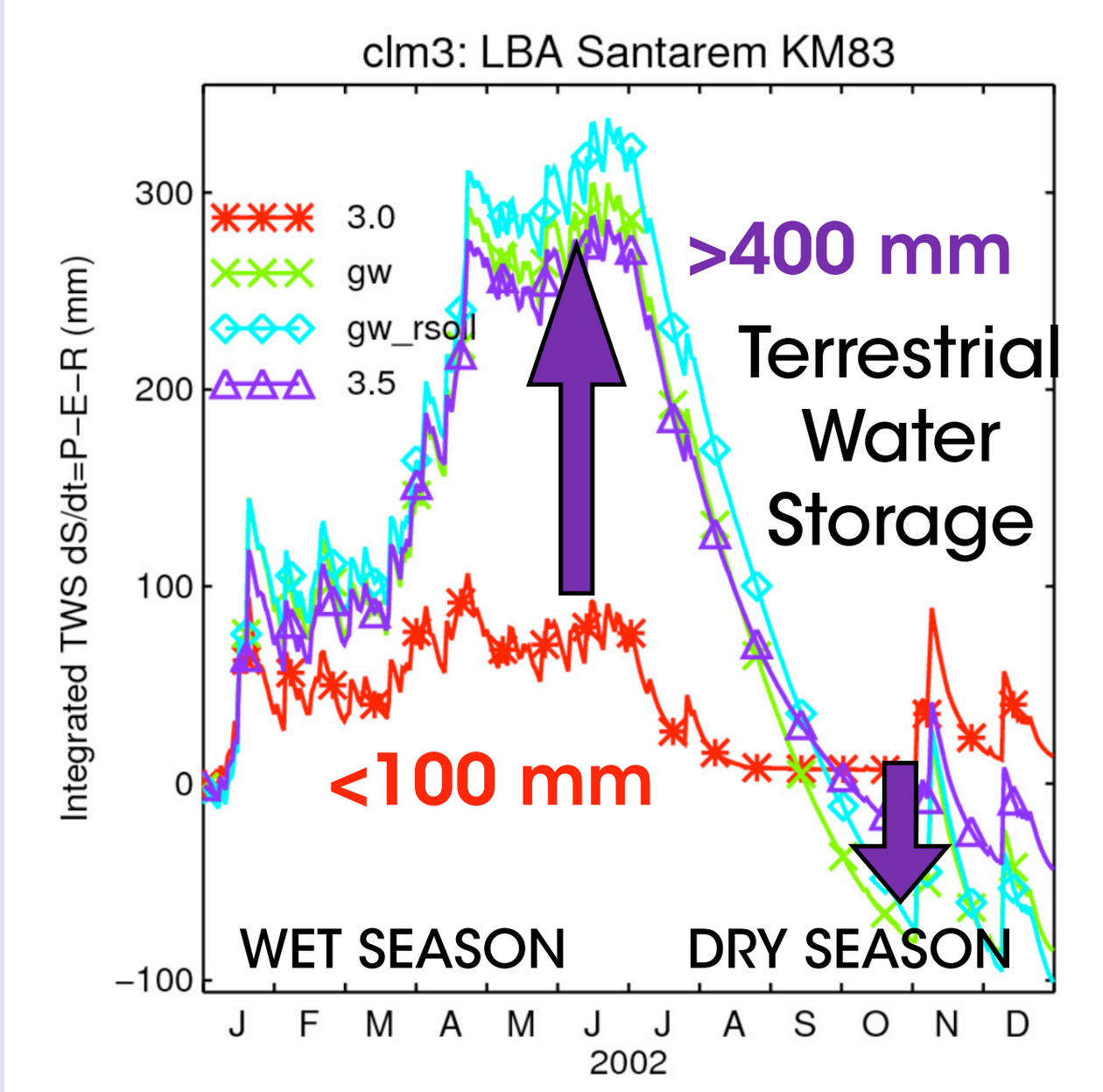
Santarem KM83 (tropical, broadleaf)





- **CLMgw**: sustain LE in dry season
- **CLMgw+rsoil**: LAI limits bare soil evaporation
- **CLM3.5**: V_{max}: GPP → transpiration?

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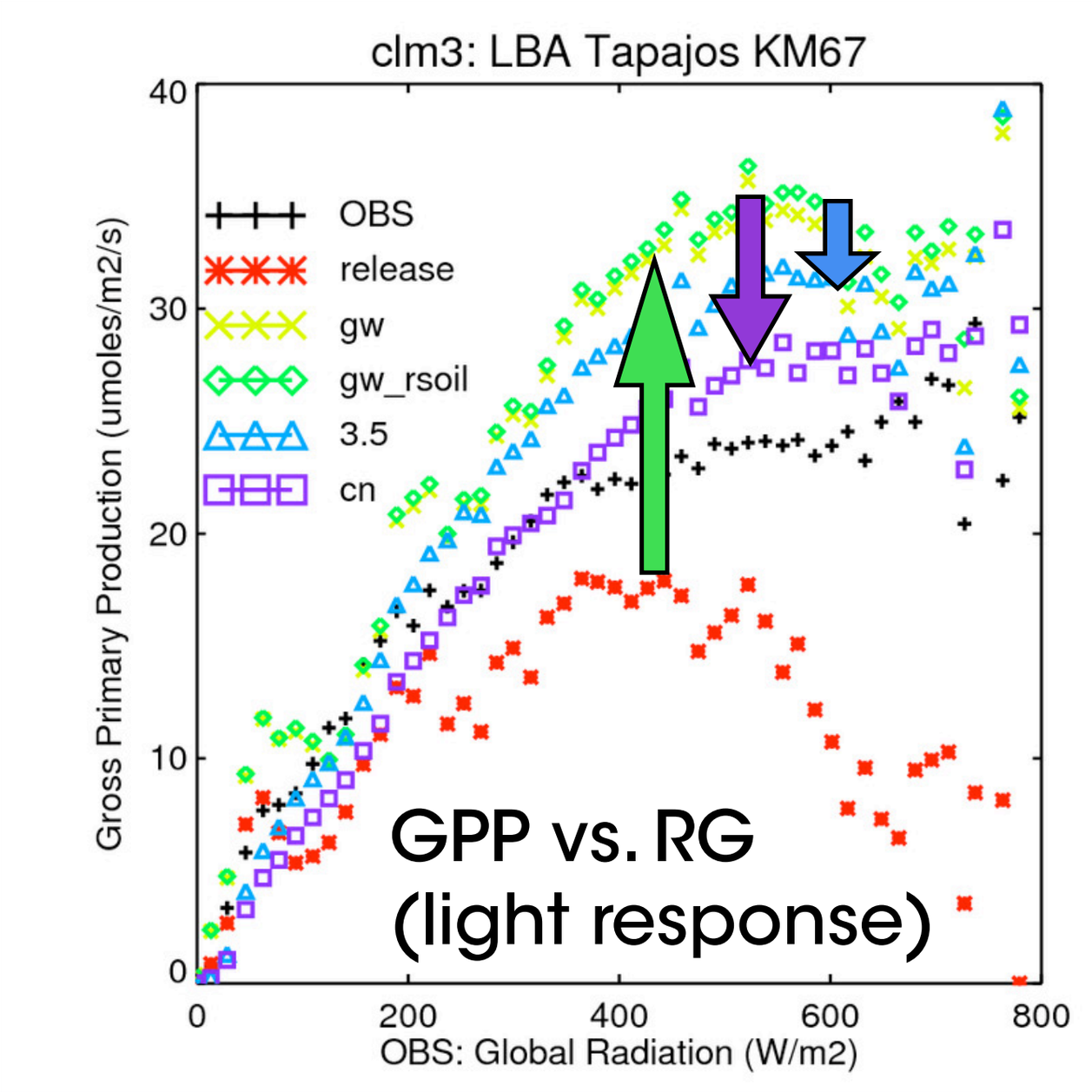
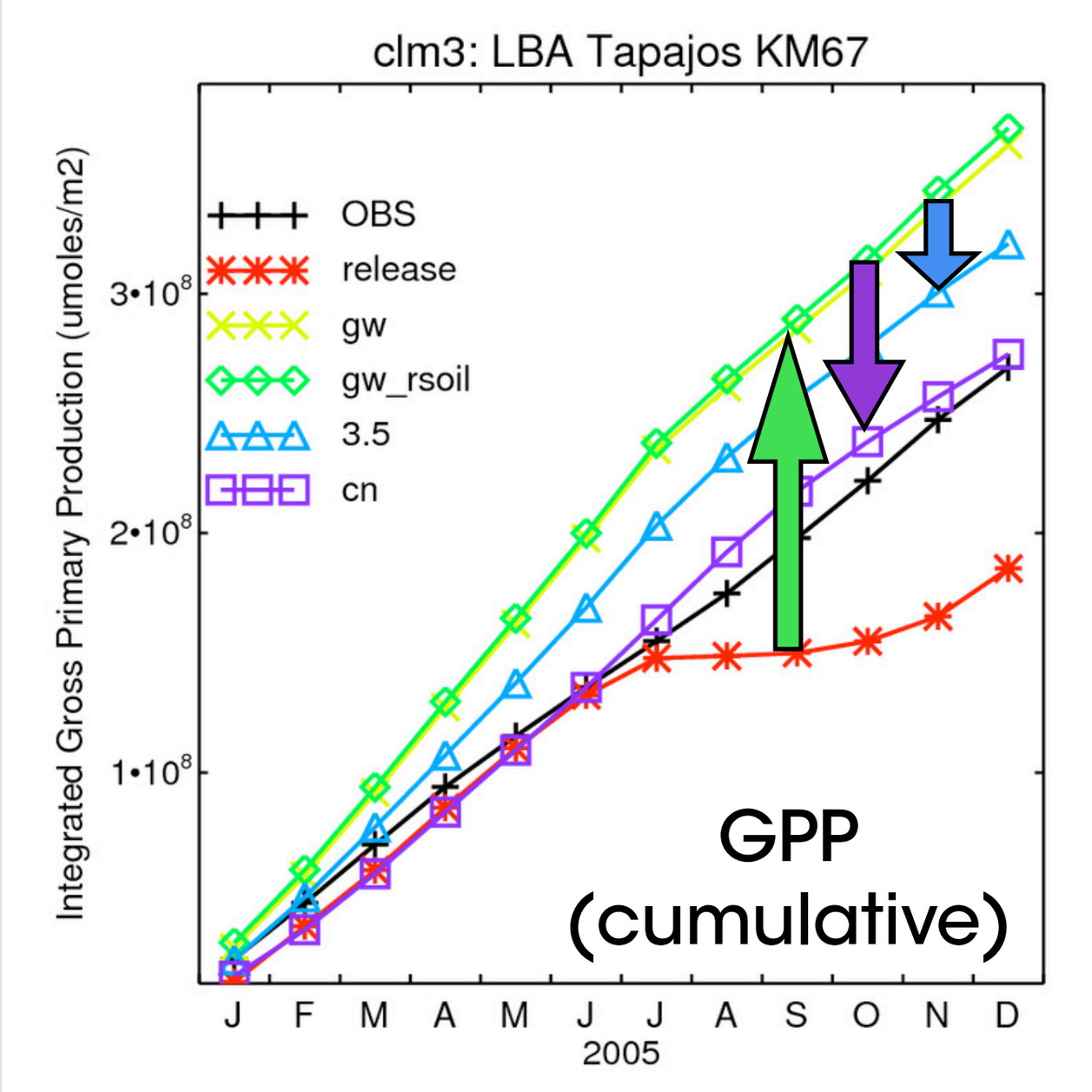
carbon + water: light response, nitrogen





Exaggerated light Response with new hydrology: missing nitrogen control on V_{max}?

- **CLM3.5**: empirical adjustment
- **CLM-CN**: process-based adjustment

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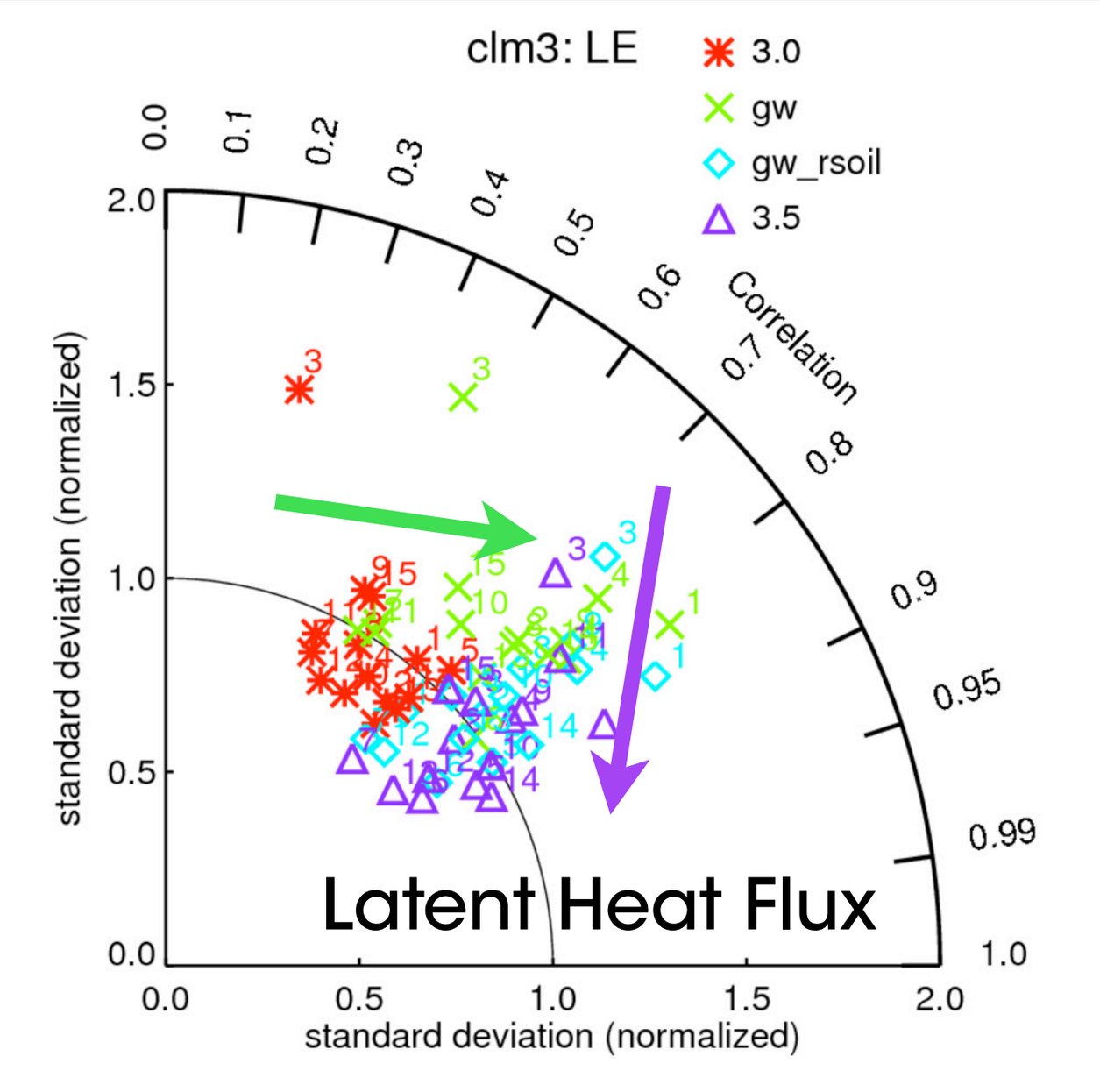
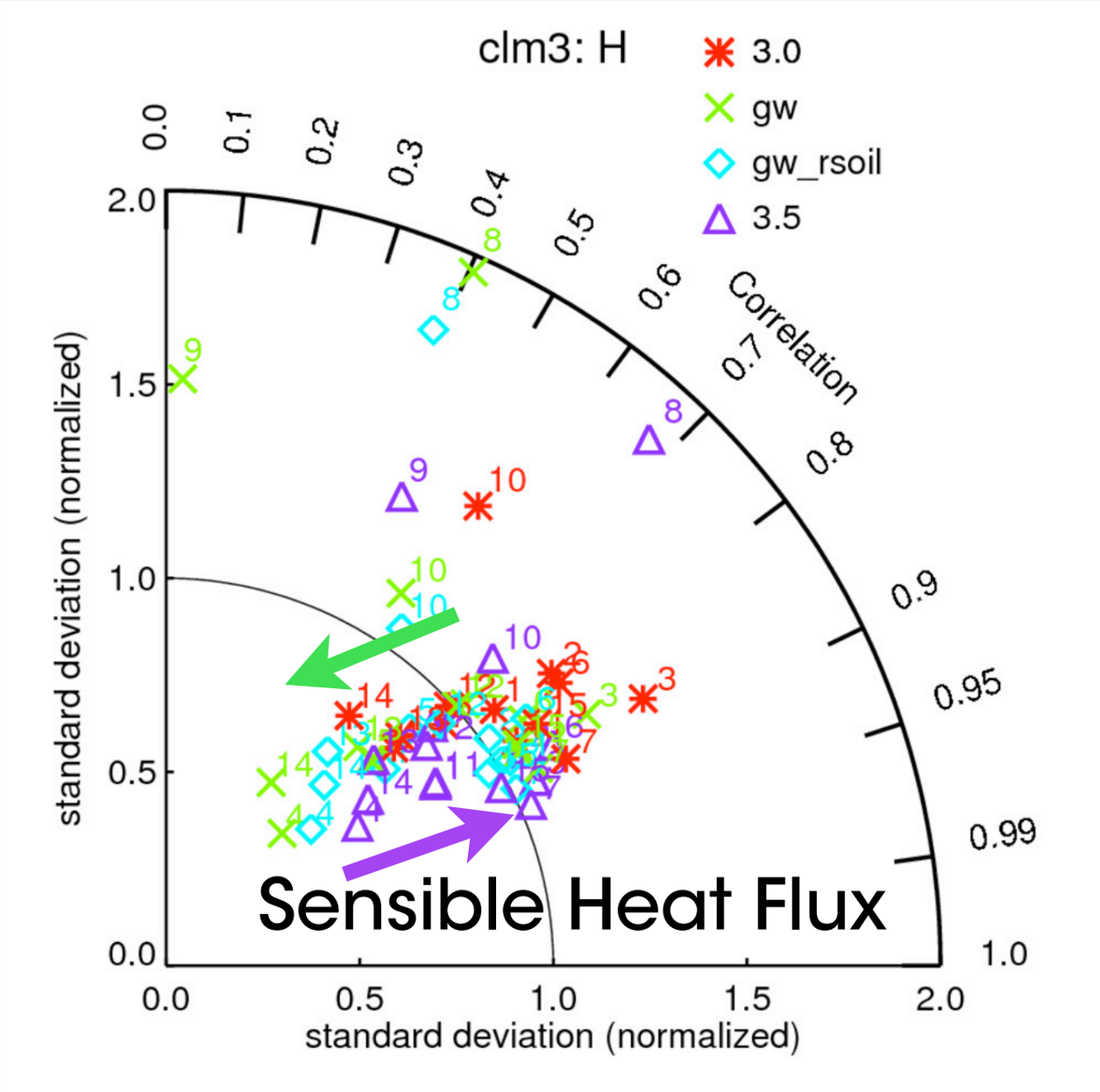
Summary of Results: all sites (Taylor plots)





- **CLM3.0**: dry, high bowen ratio, R2 = 0.4 - 0.7
- **CLMgw**: excess off-season LE flux, R2 = 0.5 - 0.8
- **CLM3.5**: evaporation constrained, R2 = 0.7 - 0.9

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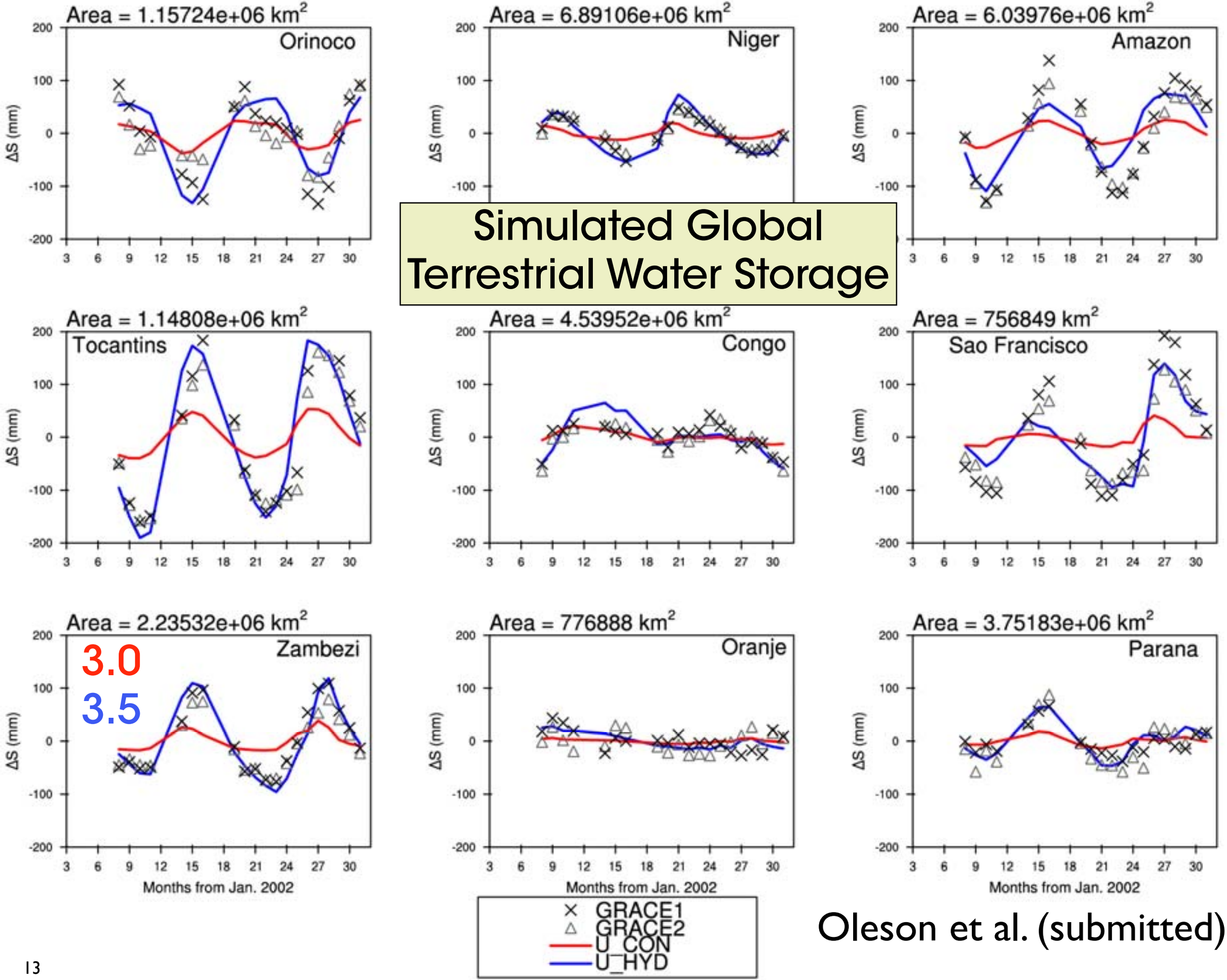
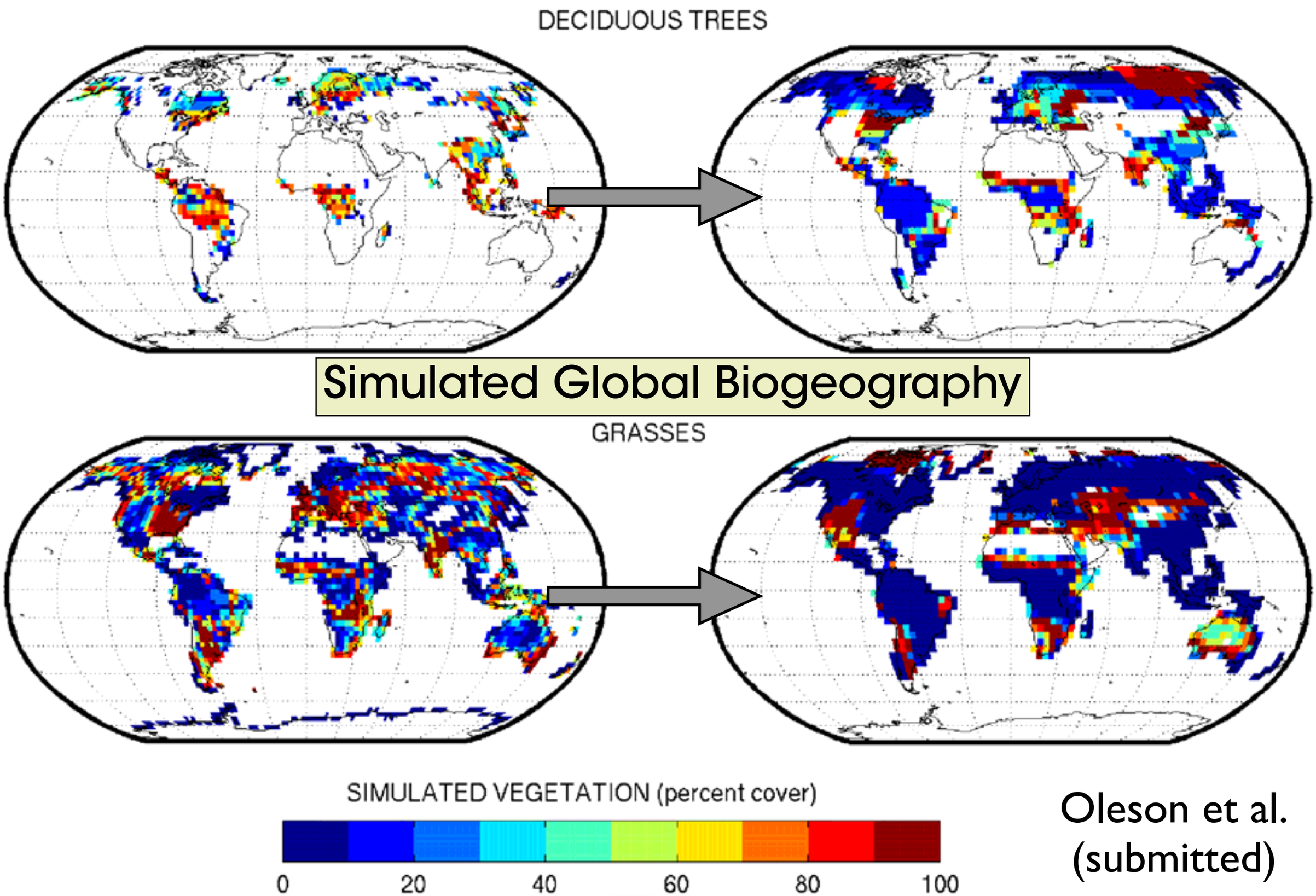
Simulated Global Terrestrial Water Storage



Oleson et al. (submitted)

CLM 3.0 CLM 3.5 (new hydrology)



Simulated Global Biogeography

Oleson et al. (submitted)

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CONCLUSIONS

Science

- TWS capacity increased: 100mm → 400mm
- prognostic aquifer: cope with seasonal drought (long term storage) in tropics
- working hydrology → modeling carbon

Method

- FLUXNET: major climatic-ecosystem regimes
- allows process-based model development
- very efficient (CPU) & few sites needed

Open Questions

- new hydrology → carbon-climate feedback?
- FLUXNET → empirical model parameters?

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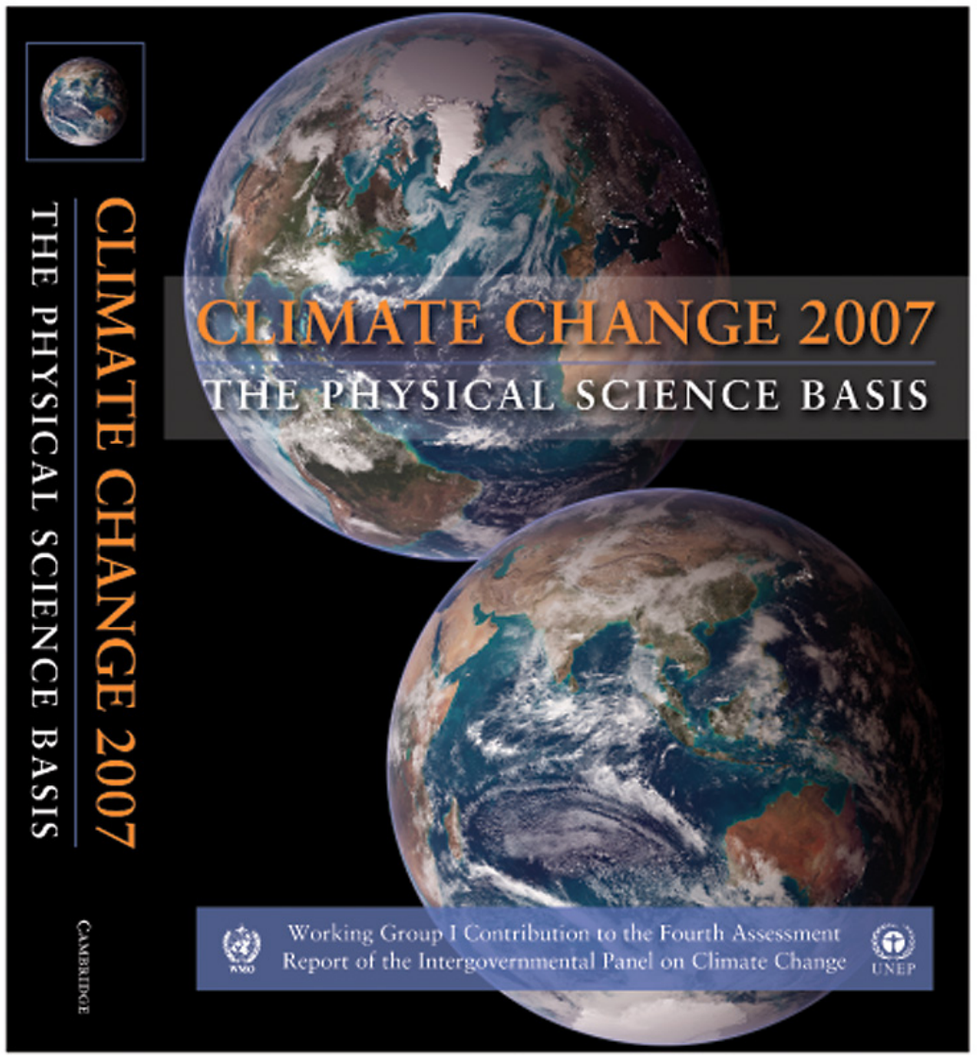
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