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Australian Government
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How well do land models handle extremes?

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ARC Centre of Excellence for Climate System Science

Australian National University · MONASH University · THE UNIVERSITY OF MELBOURNE · UNSW THE UNIVERSITY OF NEW SOUTH WALES · UNIVERSITY OF TASMANIA

Background

- ACCESS1.3 is outstanding in simulating many metrics [Flato et al., 2013]
- ACCESS1.3 is not outstanding in simulating T_{MAX}, T_{MIN} and a range of other extremes indices [Lorenz et al., 2014]

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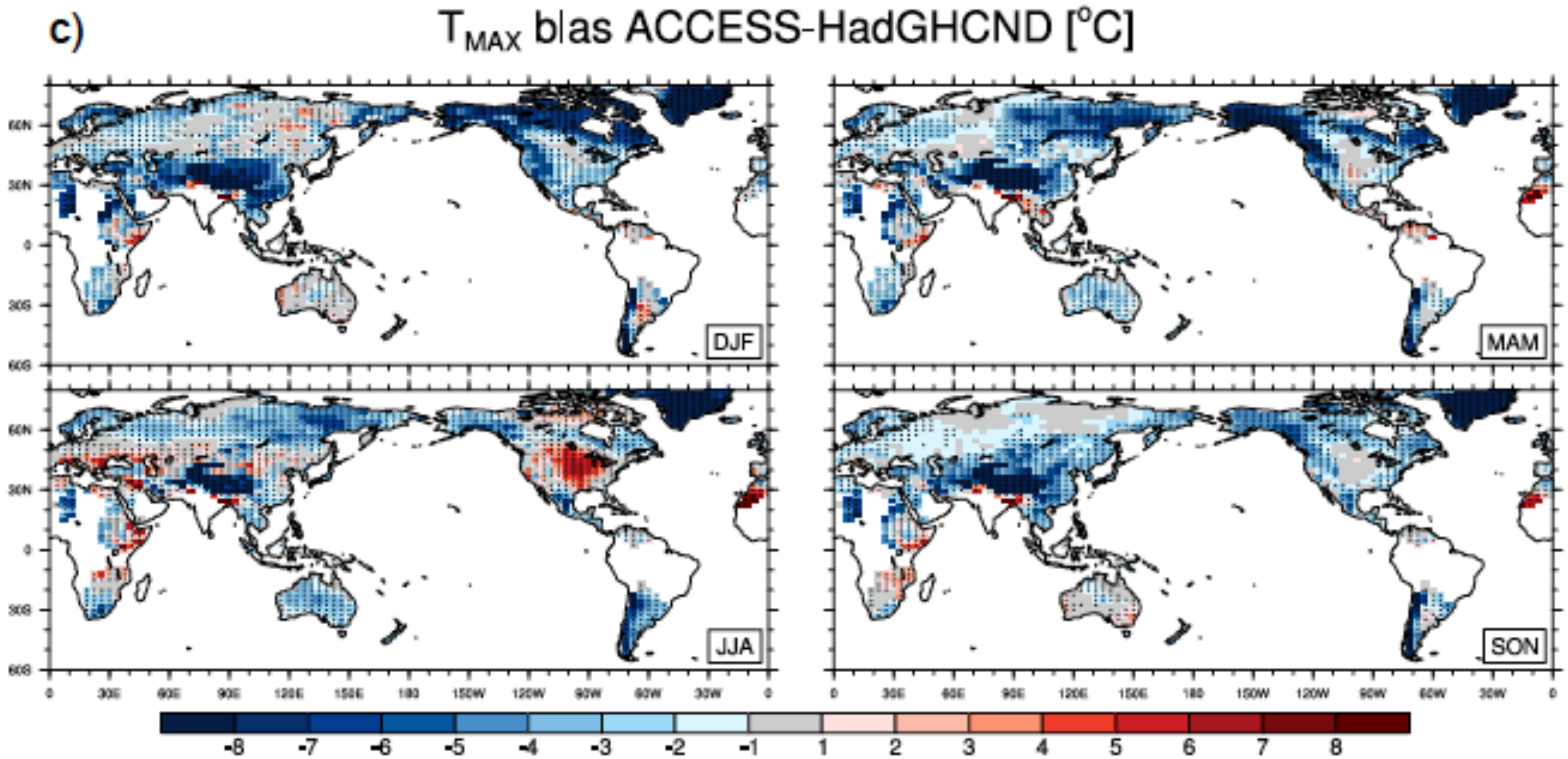
Background



Lorenz et al., 2014, GMD.

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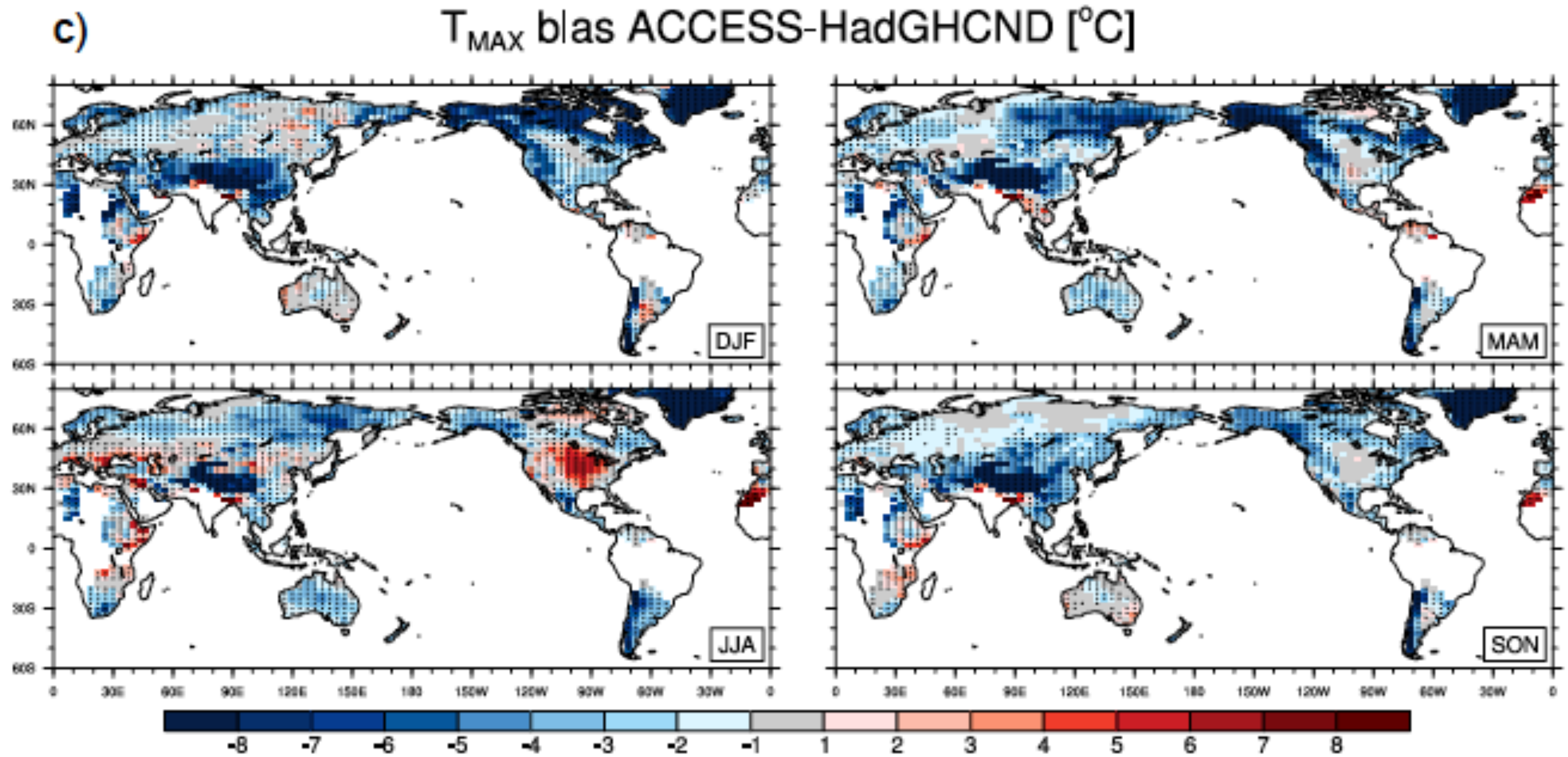

Why ?

Lorenz et al., 2014, GMD.

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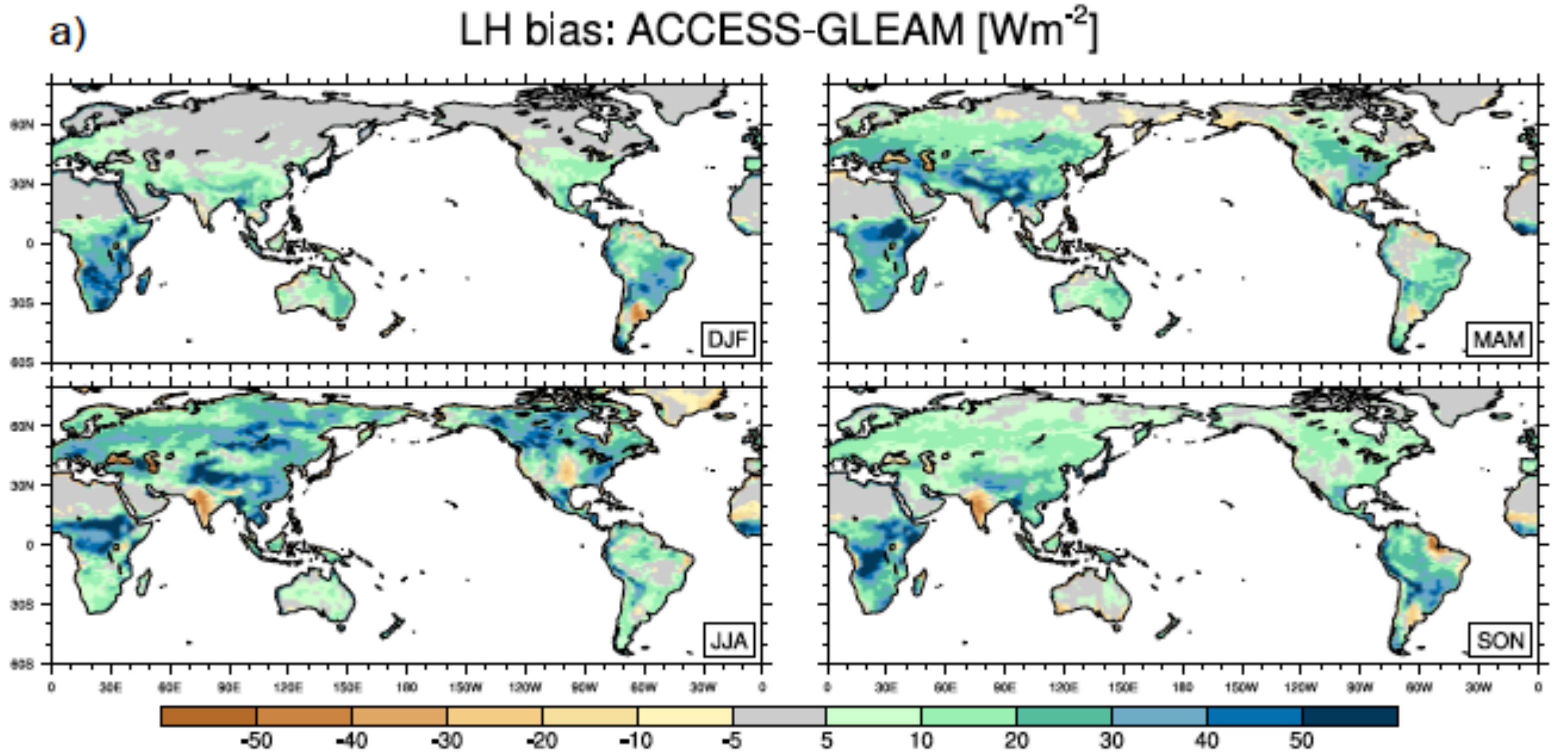

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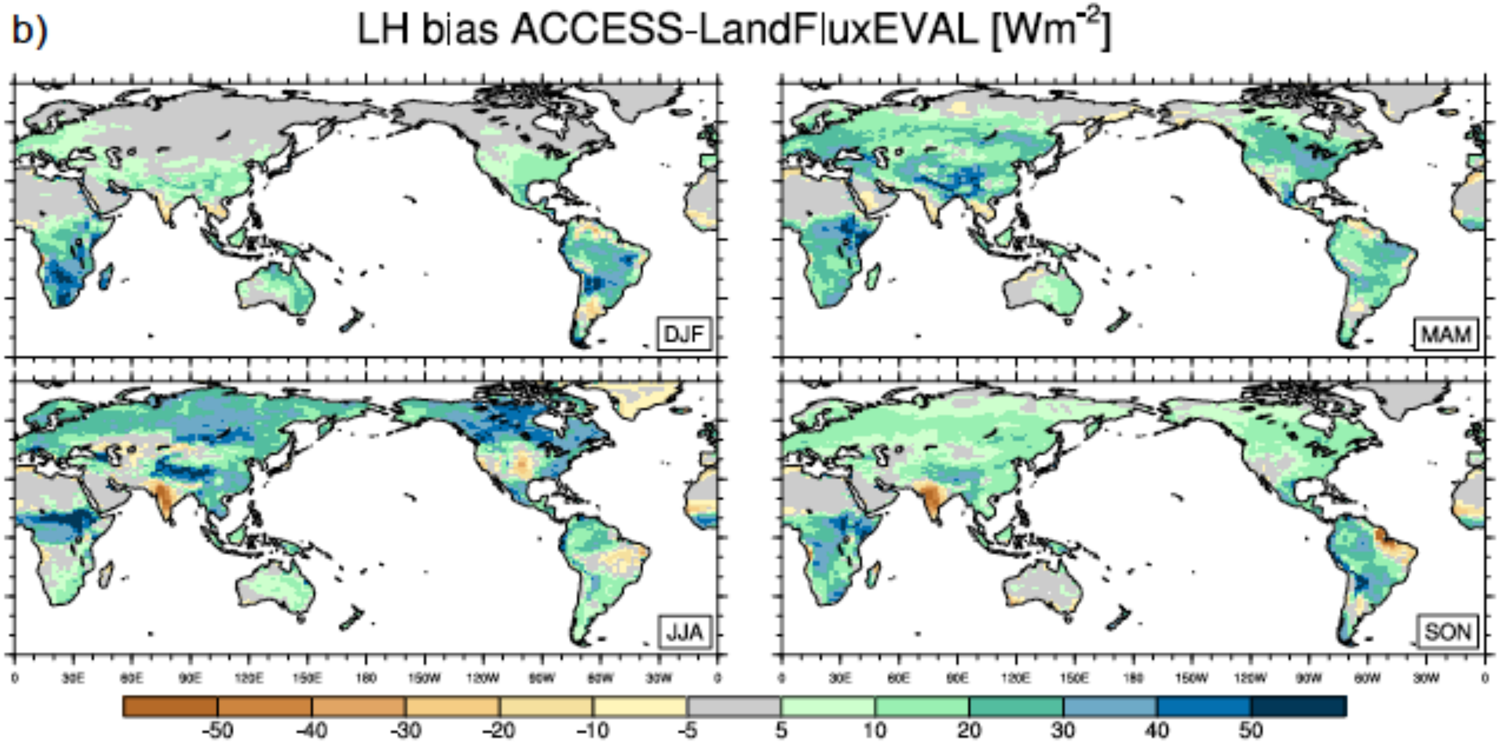

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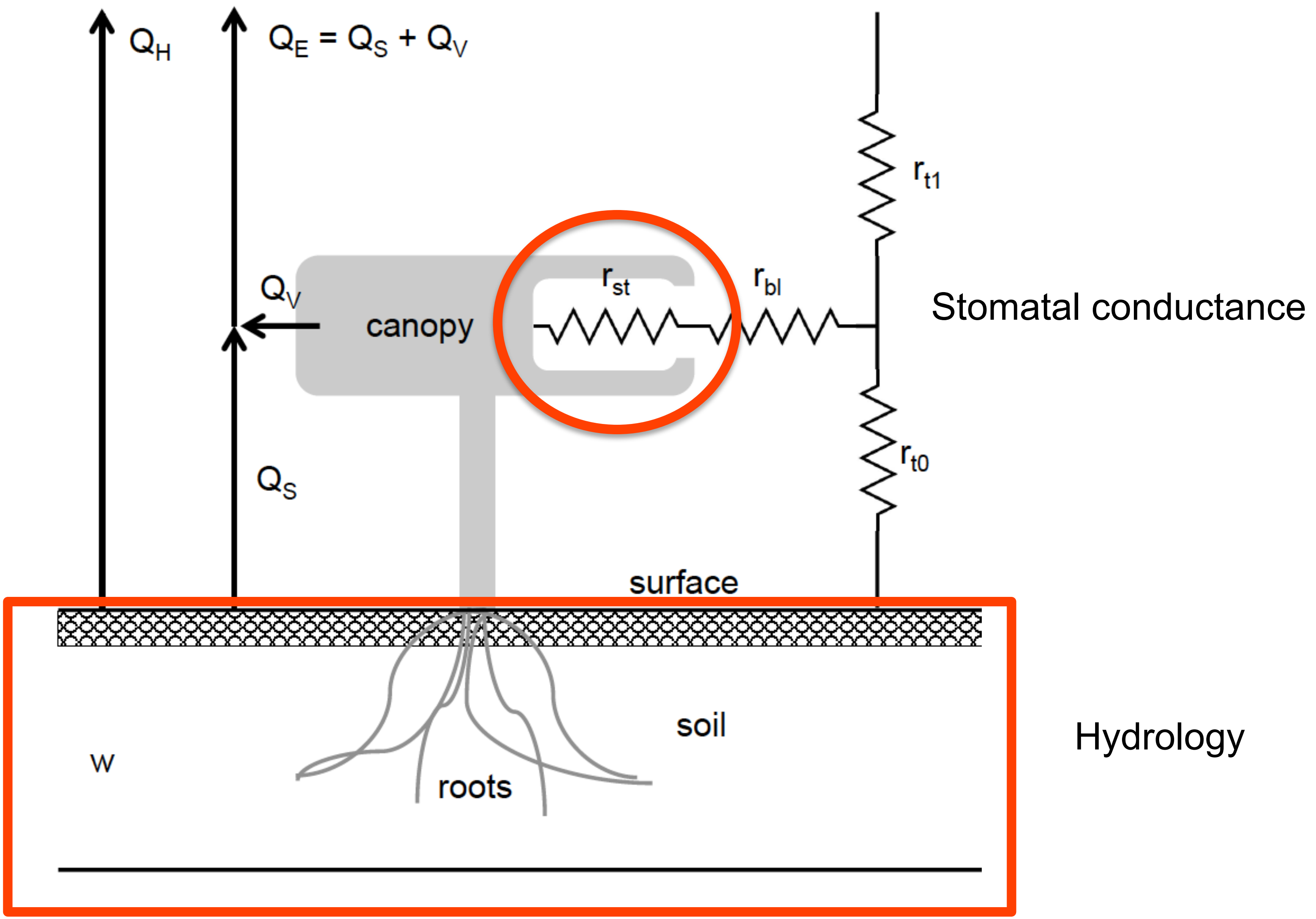
Q_H
$Q_E = Q_S + Q_V$
Q_V
canopy
r_{st}
r_{bl}
r_{t1}
r_{t0}
Q_S
surface
soil
w
roots
Stomatal conductance
Hydrology

Method

- Old g_s scheme [LEU, Leuning et al., 1995]
  - varies by photosynthetic pathway [C3, C4]
  - does not vary by plant functional type

- New g_s scheme [MED, Medlyn et al., 2005]
  - varies photosynthetic pathway
  - varies by plant functional type
  - is linked with plant's water use strategy because we know different PFTs have different water use strategies

  - Based on extensive, global ecophysiological observations

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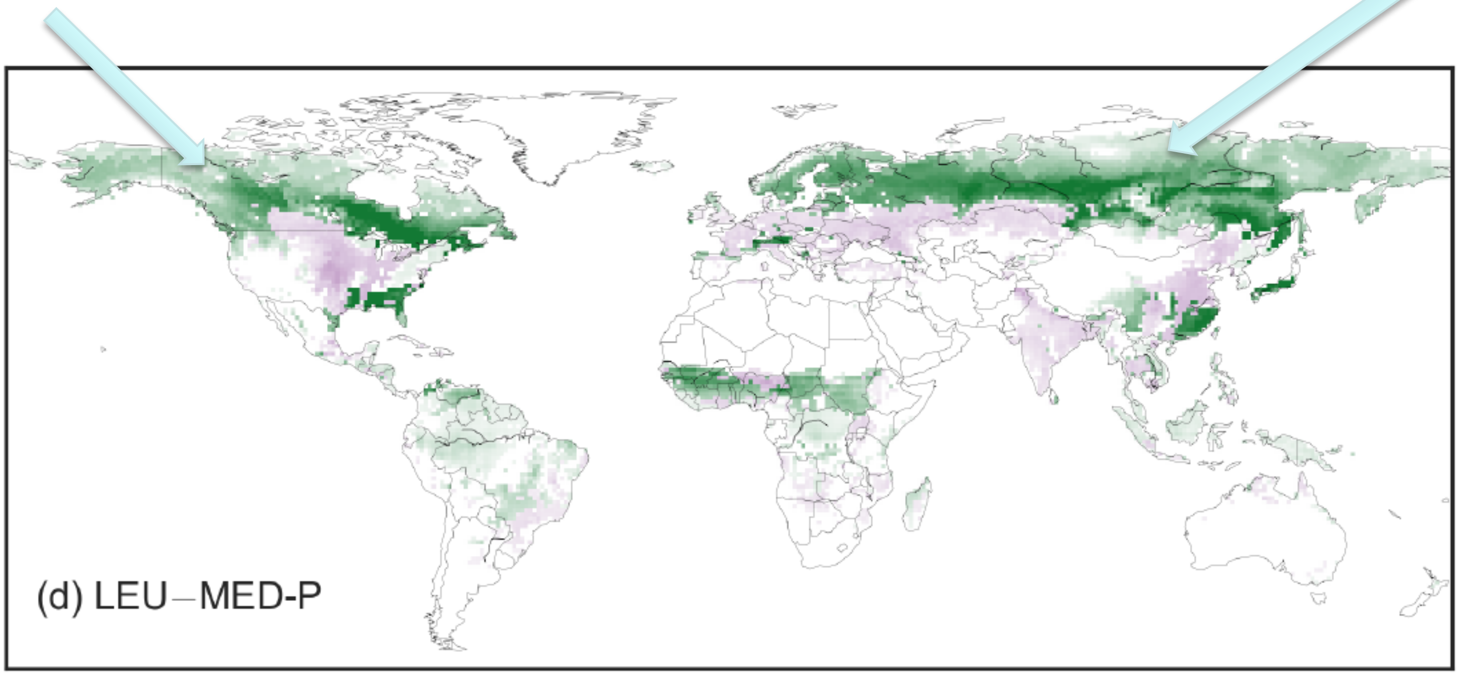
Offline performance - Prescribed Meteorological forcing

- New Scheme results in a $\downarrow$ in evapotranspiration over Boreal forests in NH summer by up to 0.8 $\mathrm{mm\ day}^{-1}$



De Kauwe et al., 2015

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Coupled Land-Atmosphere ACCESS simulations

- AMIP style simulations (prescribed SSTs)
  - Historical simulations, 1950 - 2012 with observed SST
    - Compare with observations
  - RCP8.5 simulations, 2012 - 2100 with CMIP5 SST
    - Influence on future climate projections
- Two simulations, 5 ensembles each, initialized a year apart
  - Control with default Leuning (1995) g_s (LEU)
  - Experiment with new Medlyn et al. (2011) g_s (MED)

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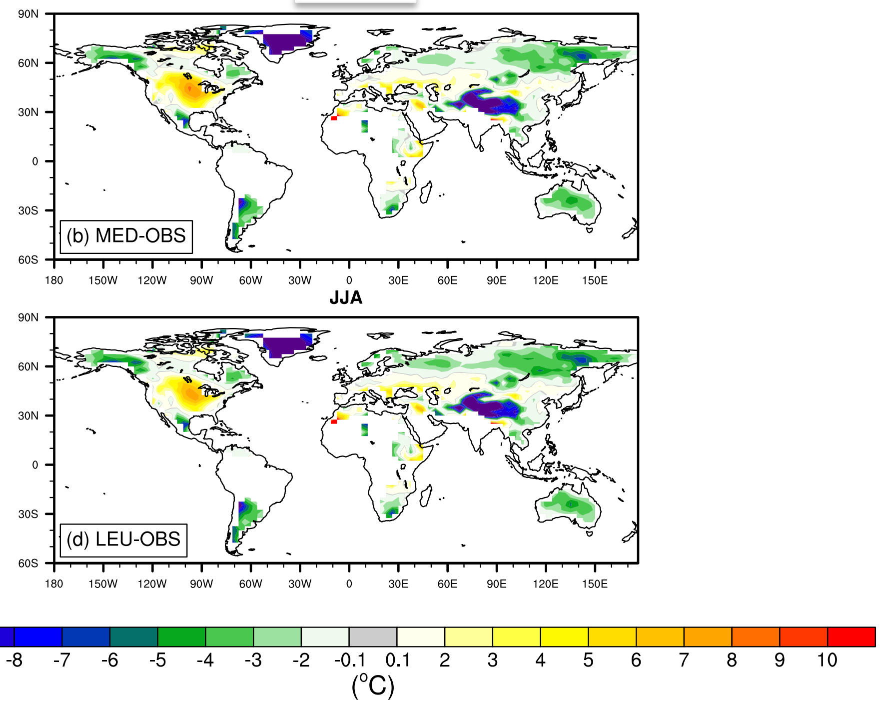
Evaluation under current climate conditions … TMAX

JJA



Kala et al., in review

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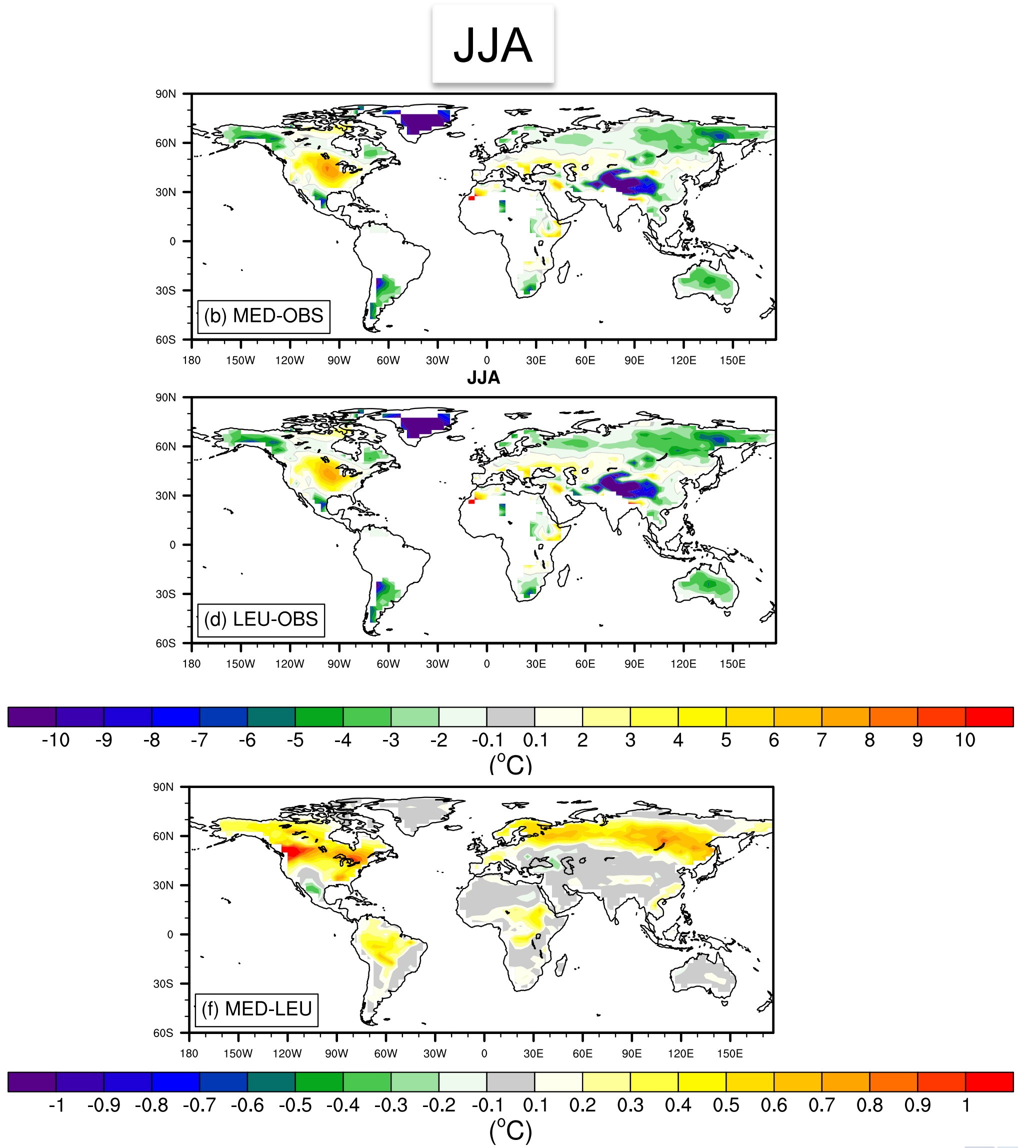

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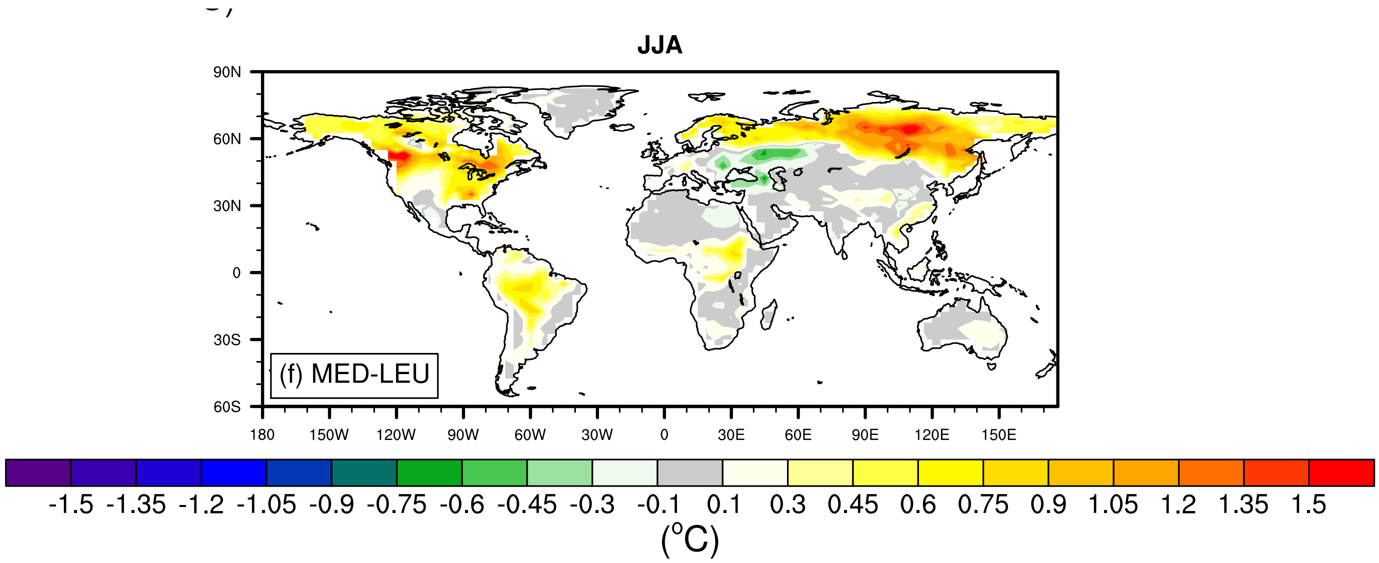
Evaluation under current climate conditions … TXx



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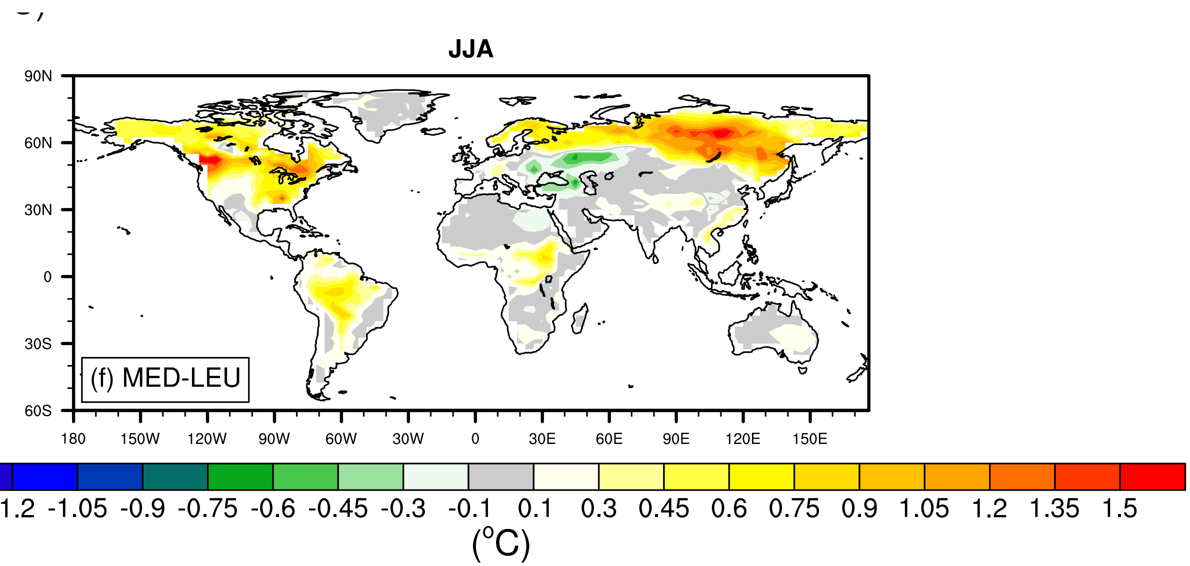
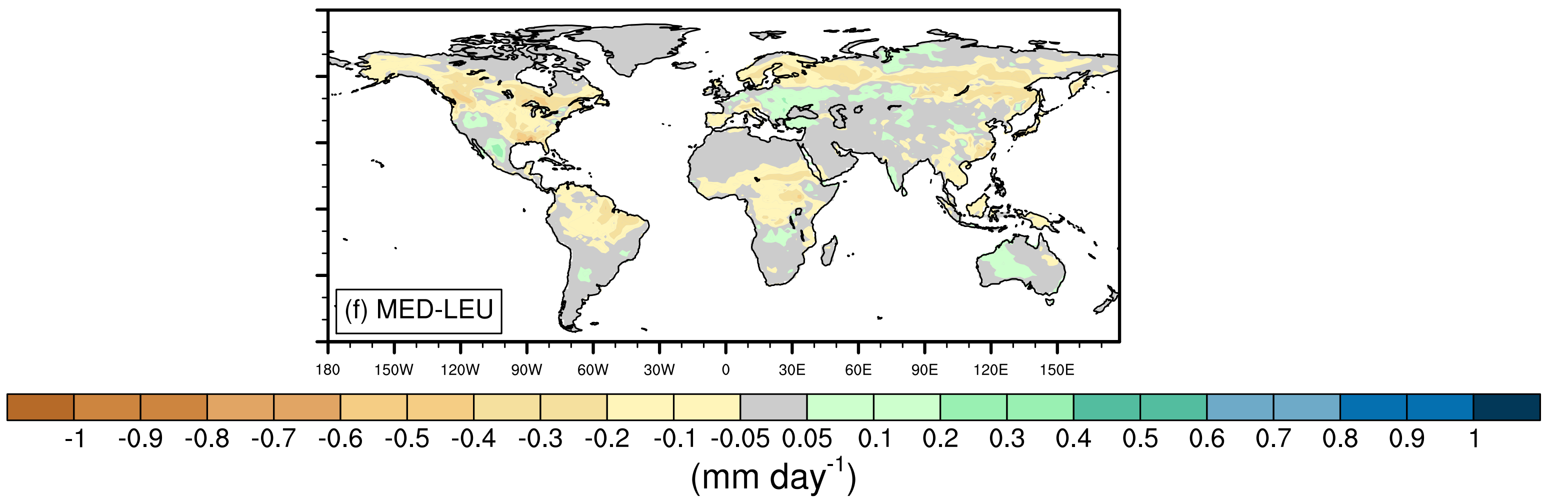
Evaluation under current climate conditions … TXx





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Evaluation under current climate - Summary

- MED reduces ET over boreal forests using NH summer by 0.5 to 1.0 mm day^{-1}
- Leads to warmer daily TMAX and TMIN temperatures by up to 1.0^{o}C
- Leads to warmer TXx by up to 1.5^{o}C
- We improve the model's climatology by 10-20%

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Evaluation under current climate - Summary

Reduce evapotranspiration

↓

Less evaporative cooling

↓

More sensible heating

↓

Acts more strongly on tails

↓

$+T_{MAX}$, +TXx

- MED reduces ET over boreal forests using NH summer by 0.5 to 1.0 mm day^{-1}
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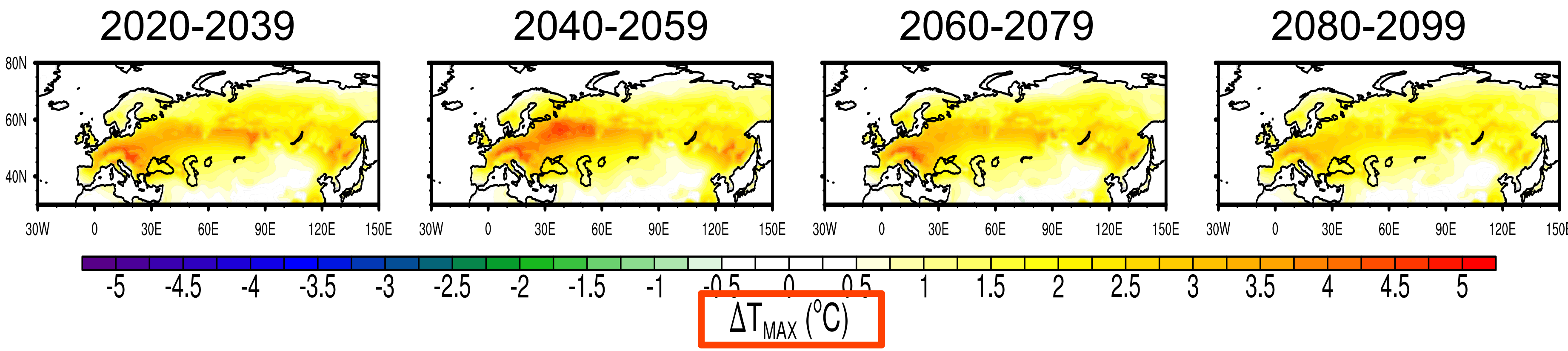
Influence on future climate (RCP8.5) - MED minus LEU



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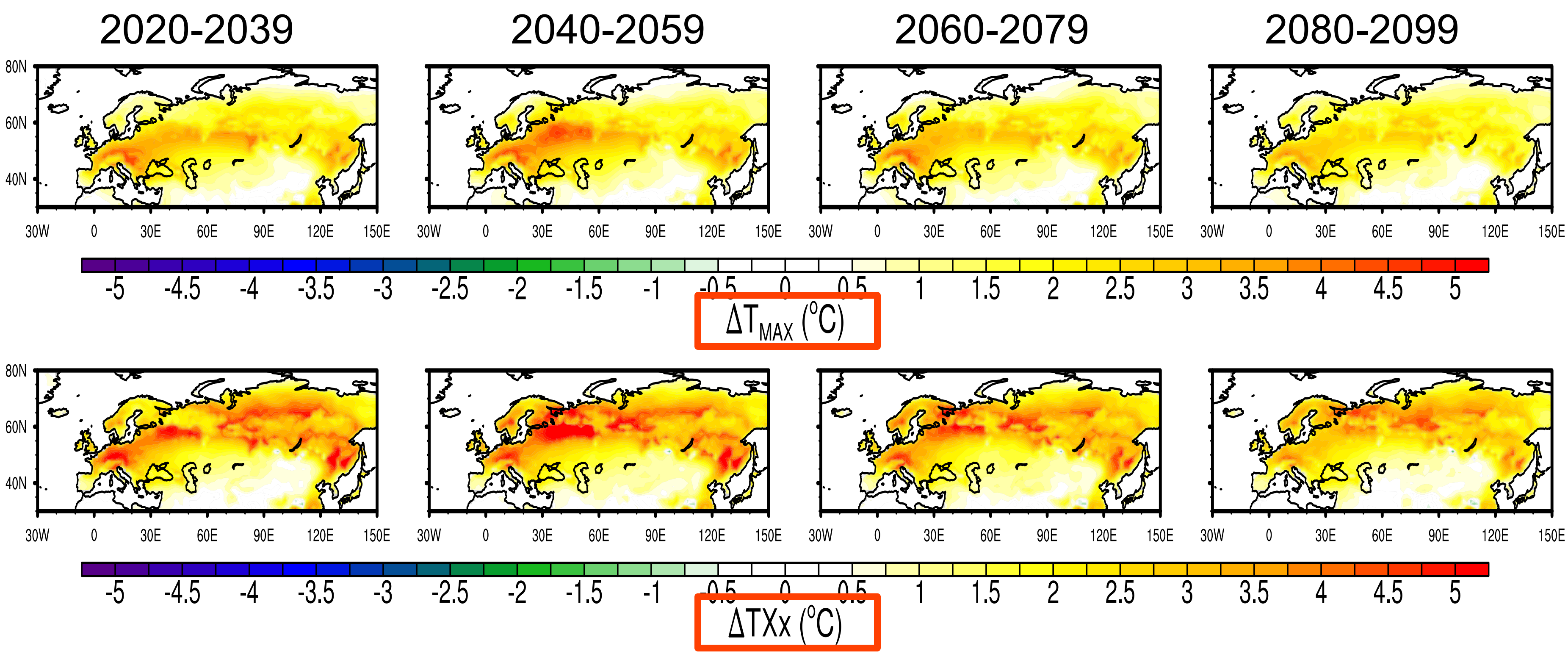

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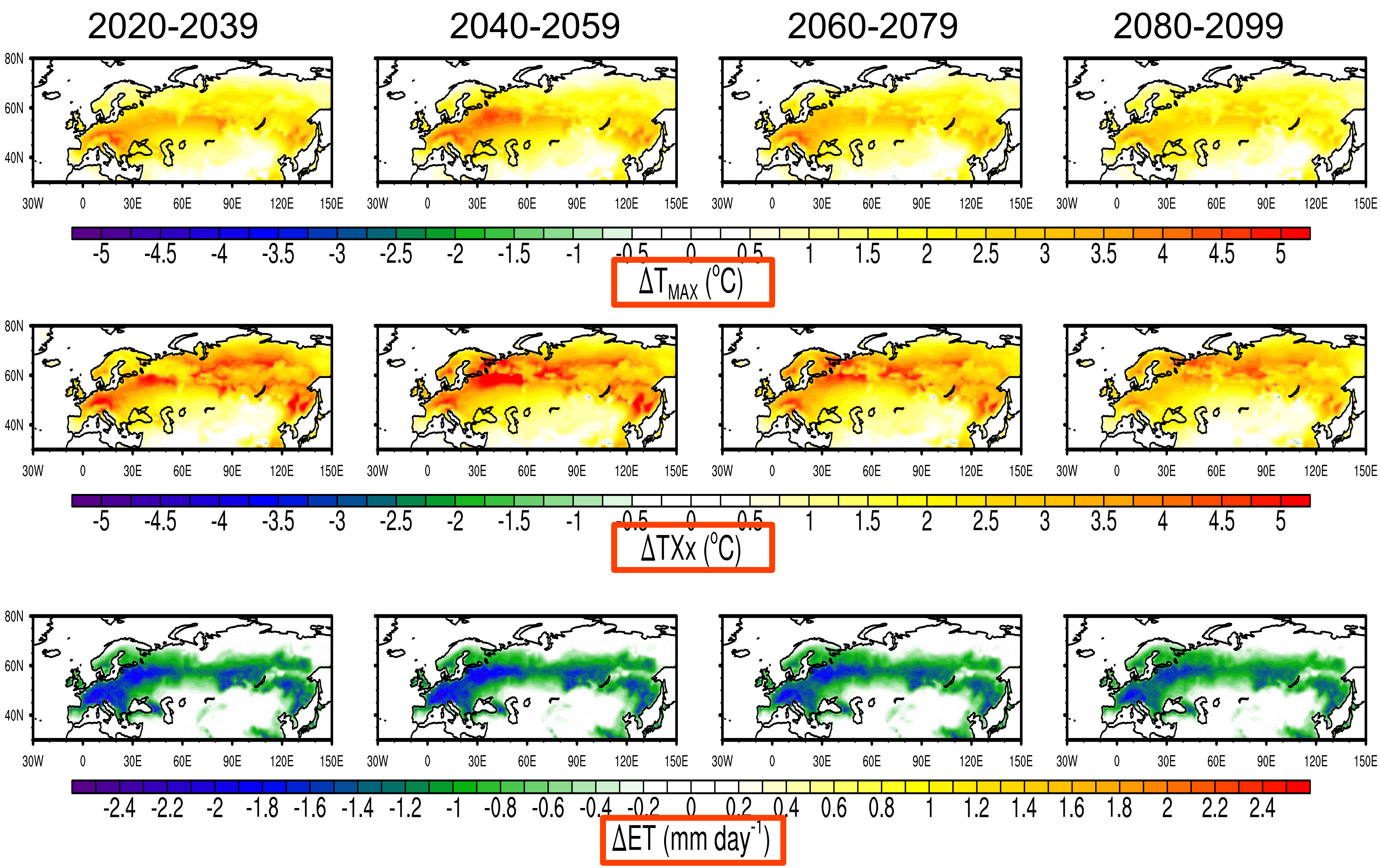

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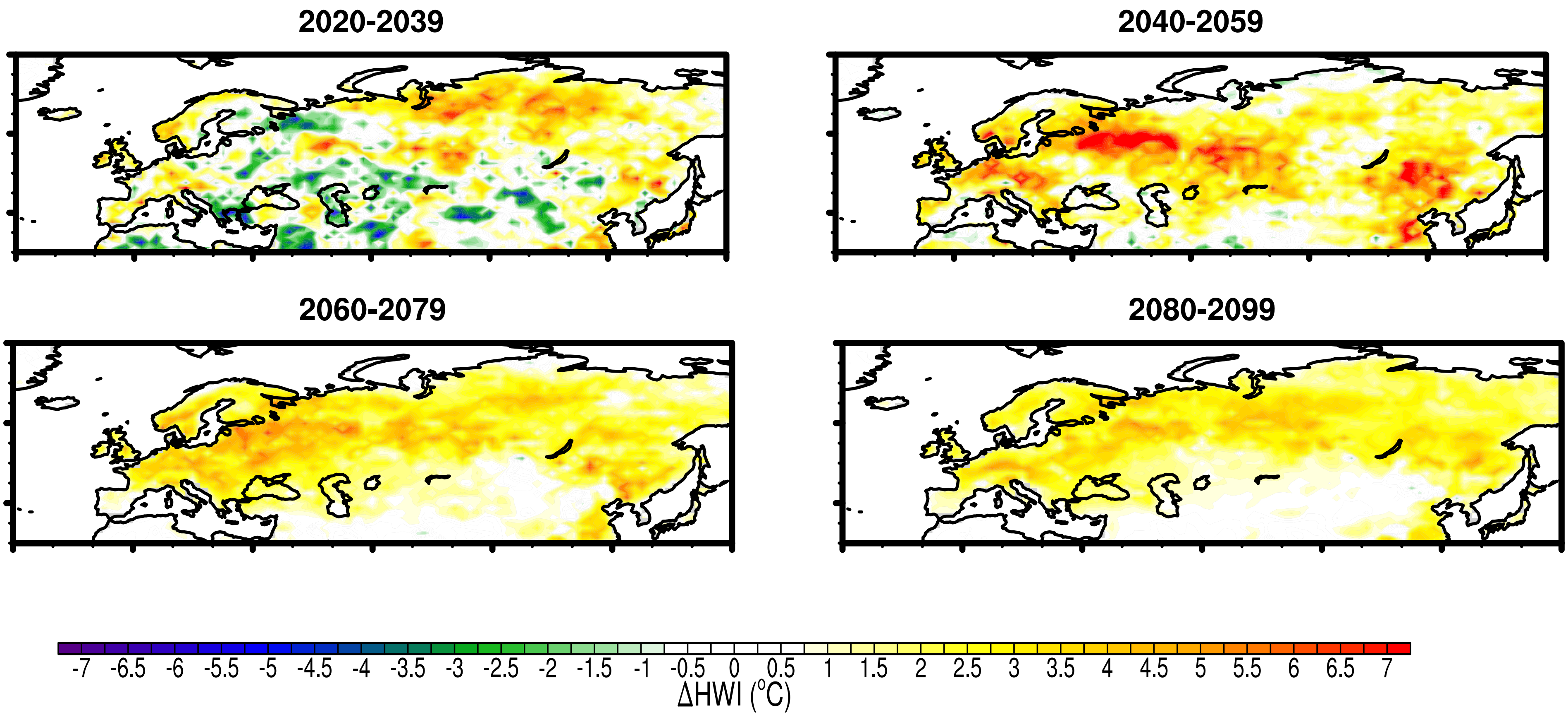

Heat wave intensity

Kala et al., submitted

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Influence on future climate (RCP8.5) - Summary

- Large increases in warm extremes under RCP8.5 during summer with new scheme over NH up to 4-5^{o}C!
  - Driven by reduced latent heat flux and increase in sensible heat

- Magnitude of increase, decreases towards 2070-2099
  - At high leaf temperatures, photosynthesis and stomatal conductance (and thus ET) are reduced due to photosynthetic inhibition
  - This minimizes the differences in ET between the two models

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Improving CABLE

- Fix stomatal conductance – improves T_{MAX} by ~20% but still major systematic errors …

- Replace the hydrology with a new model developed from CLM

- Add ground water

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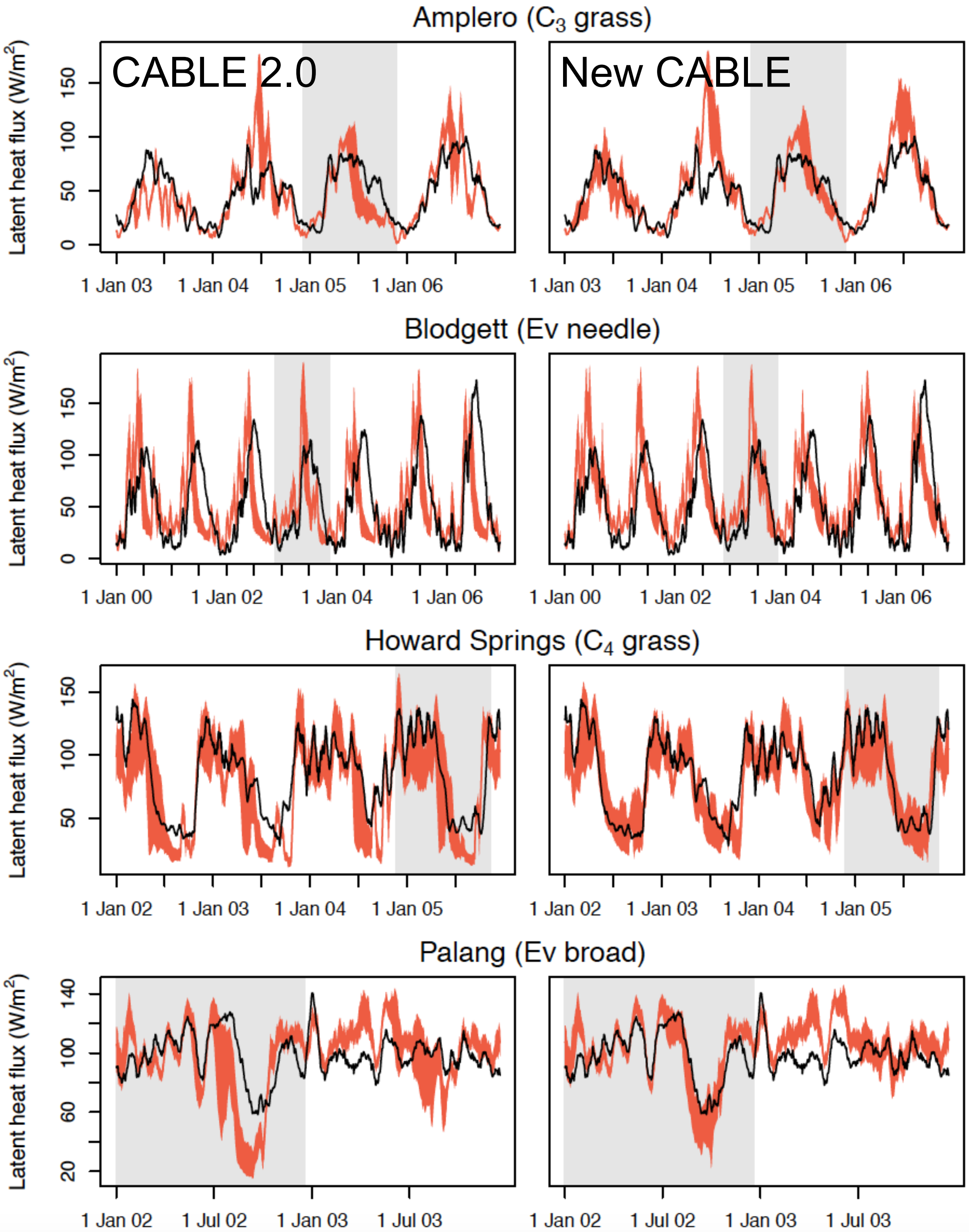

Red range is f(LAI, soil parameters)

Four example sites

Full length of observed latent heat flux

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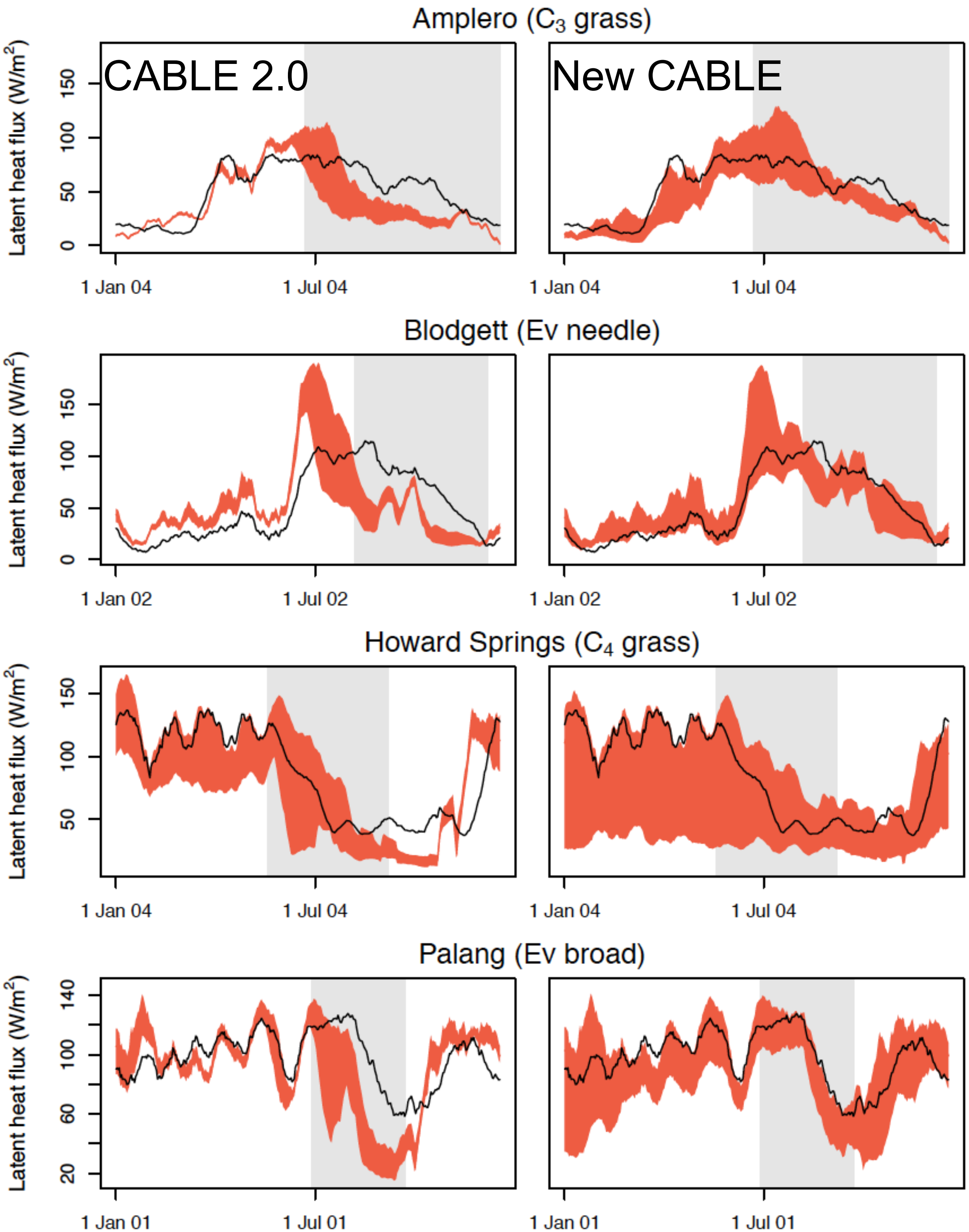

During periods of soil dryness

CABLE2.0:

- transitions into "drought" too fast
- generates too intense a drought
- We never checked!
- What about other LSMs ? Is this a CABLE-specific problem?
- New CABLE does not have these biases

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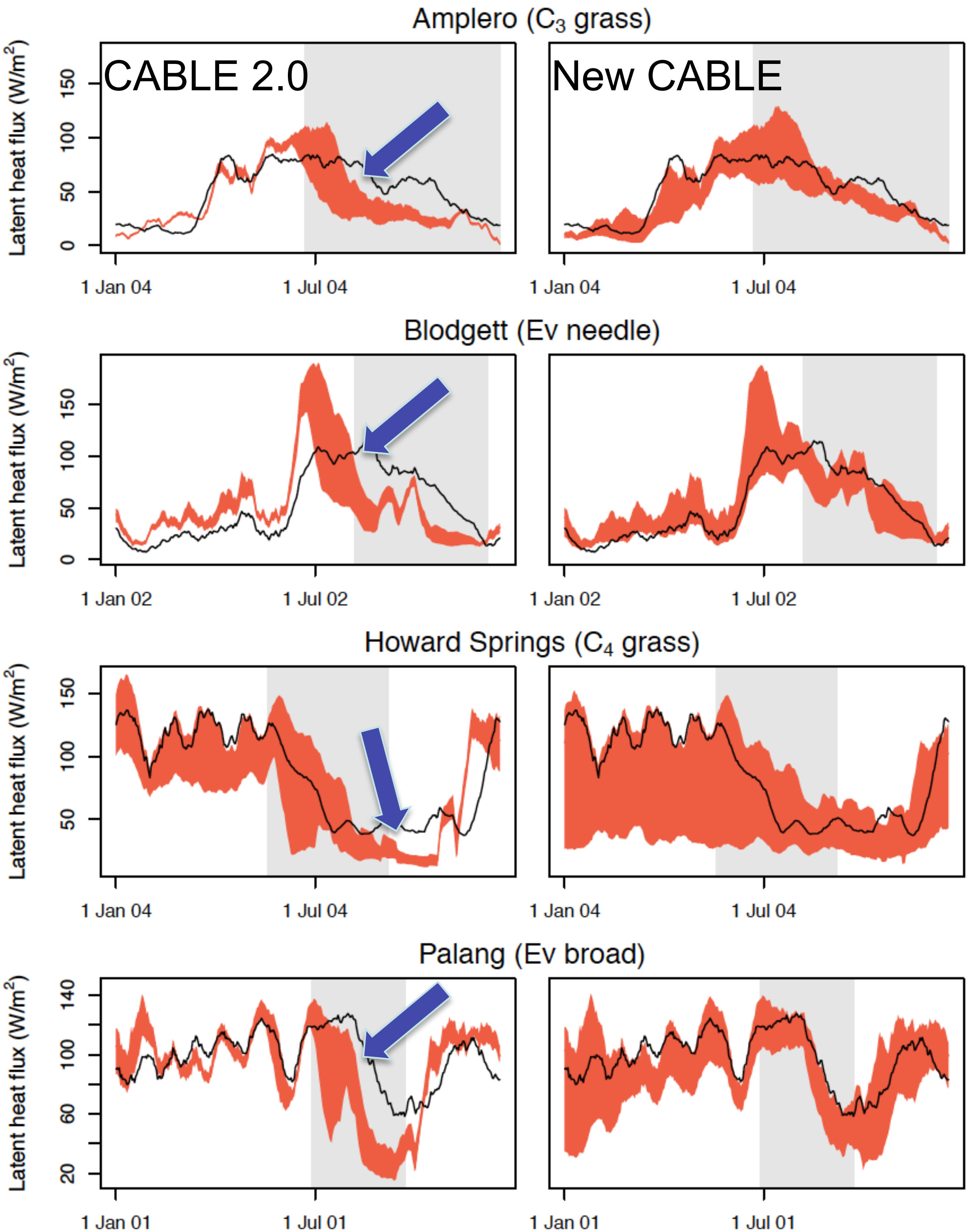

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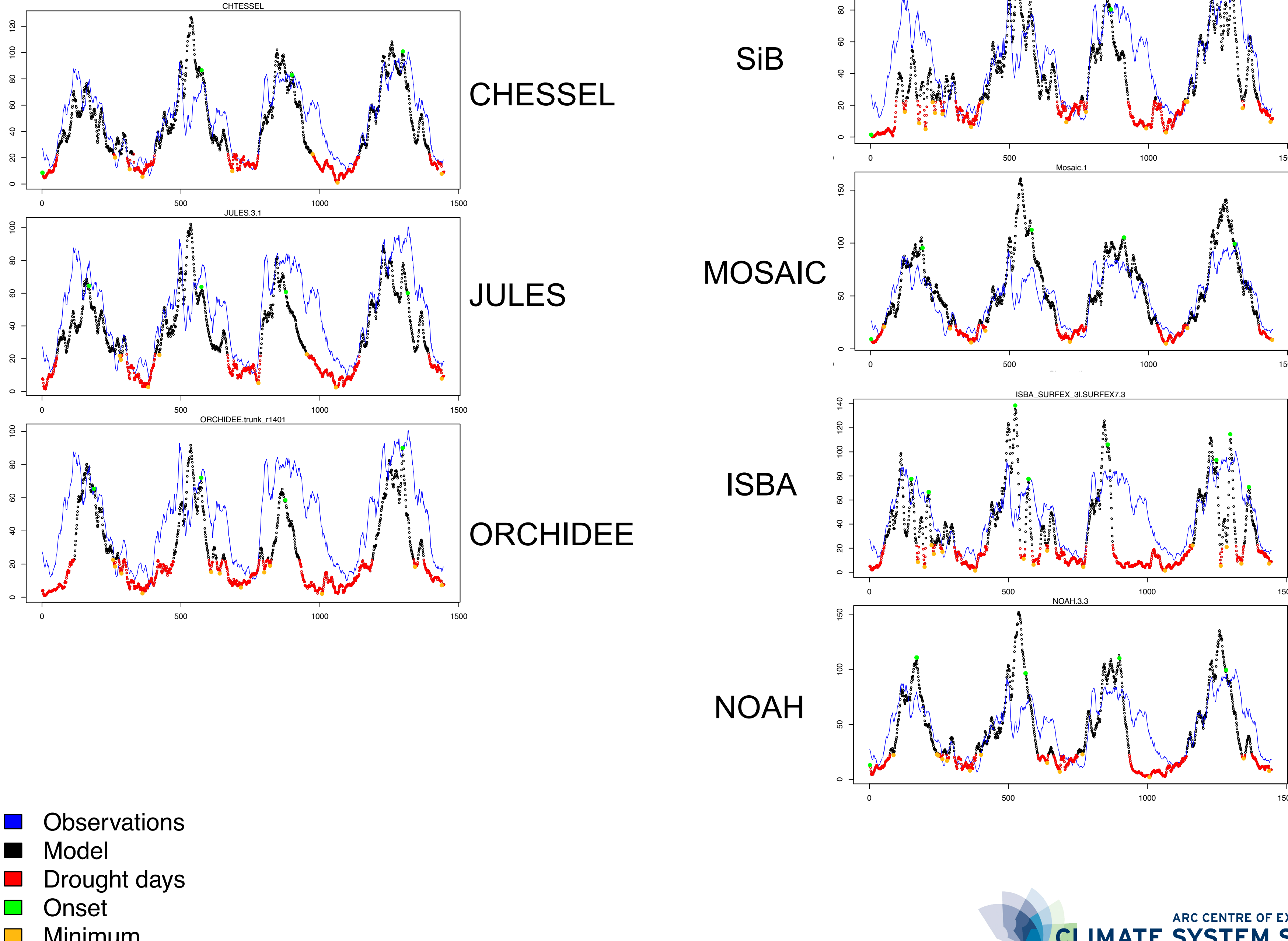
Amplero



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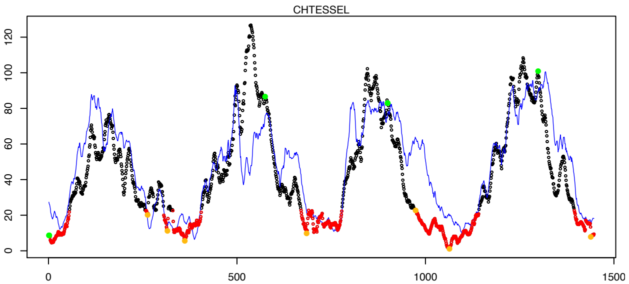
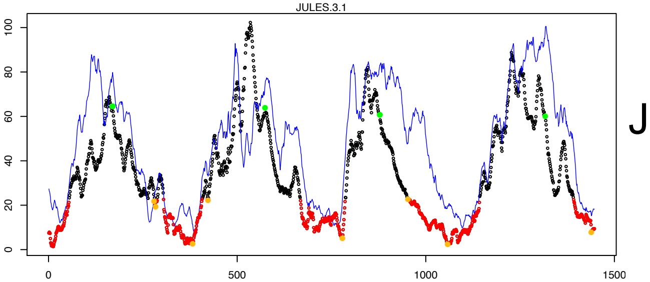
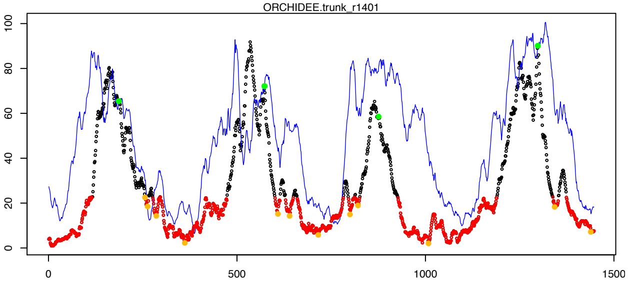
Amplero



CHESSEL



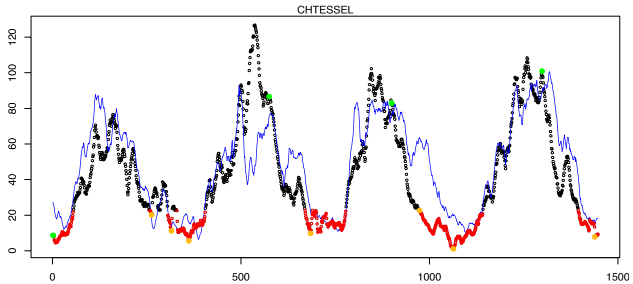
JULES



ORCHIDEE

- Observations
- Model
- Drought days
- Onset
- Minimum

Amplero



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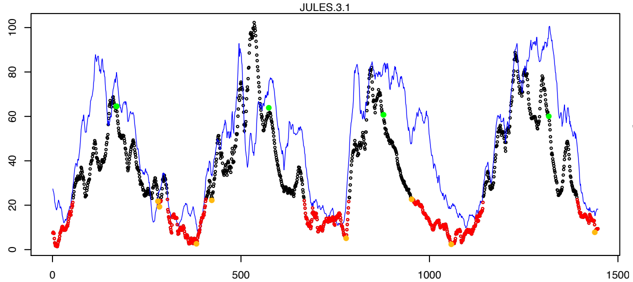

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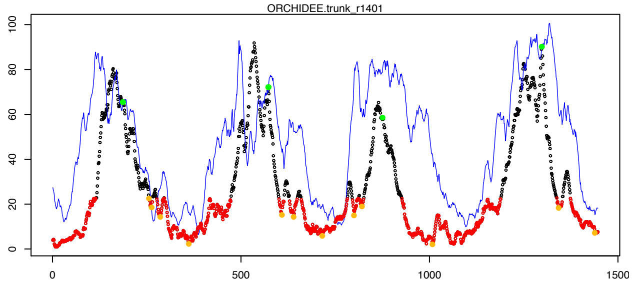

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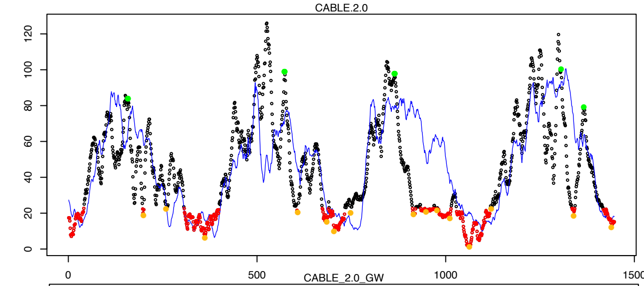
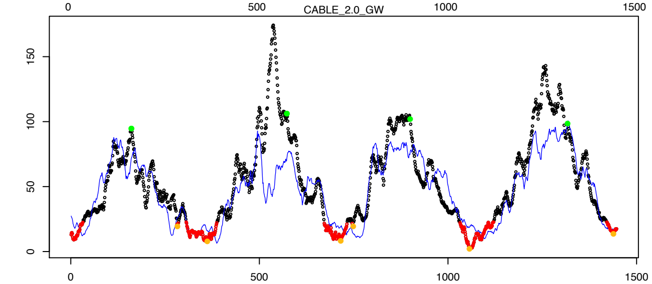
CABLE2.0



CABLE-GW



- Observations
- Model
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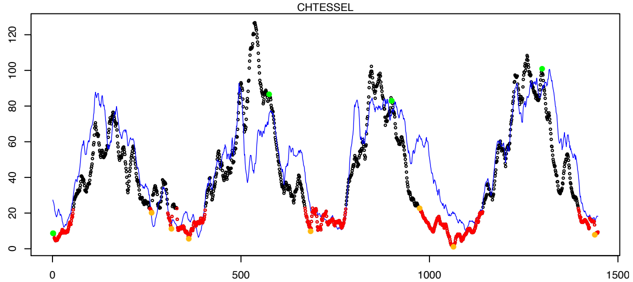

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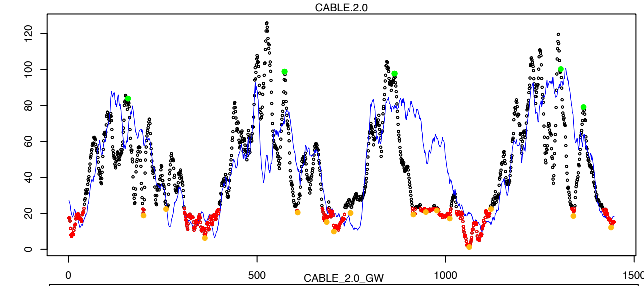
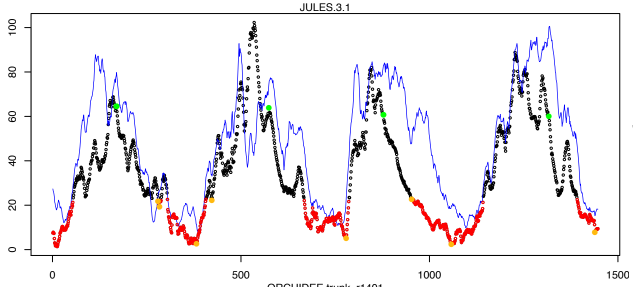


CABLE2.0



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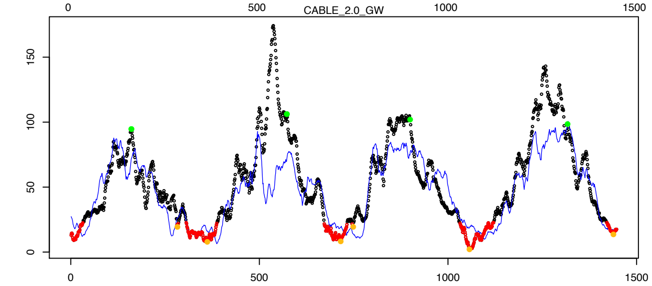
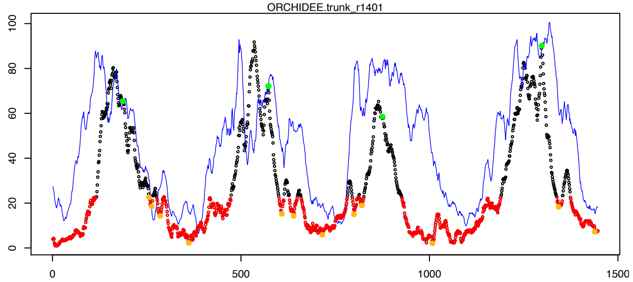


CABLE-GW



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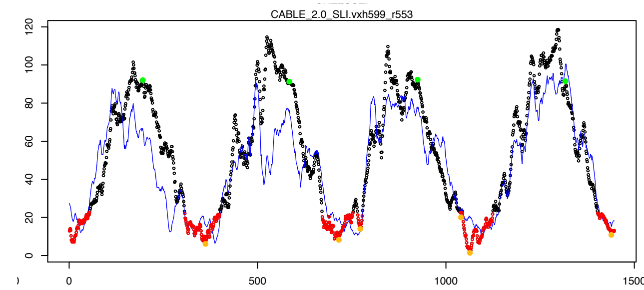
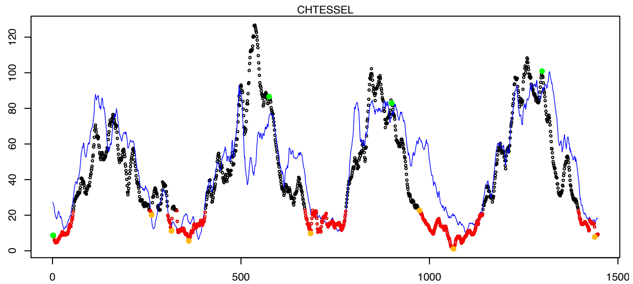


CABLE-SLI

- Observations
- Model
- Drought days
- Onset
- Minimum

Amplero



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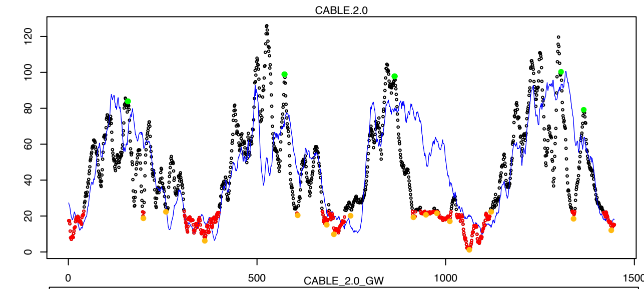
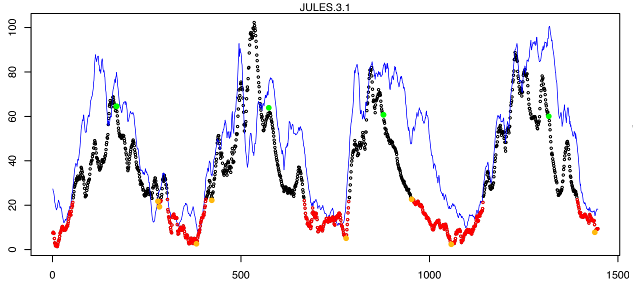


CABLE2.0



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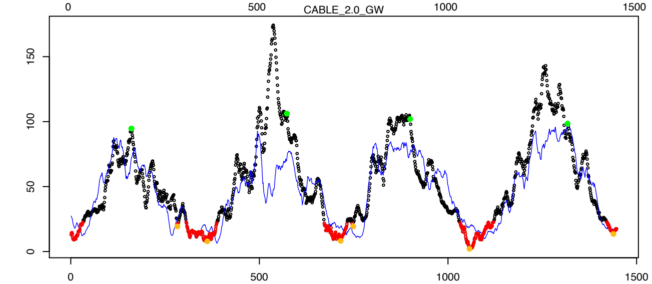
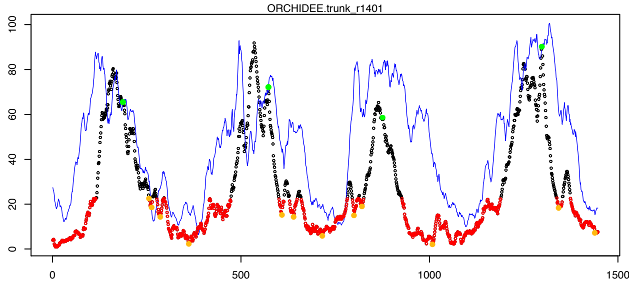


CABLE-GW



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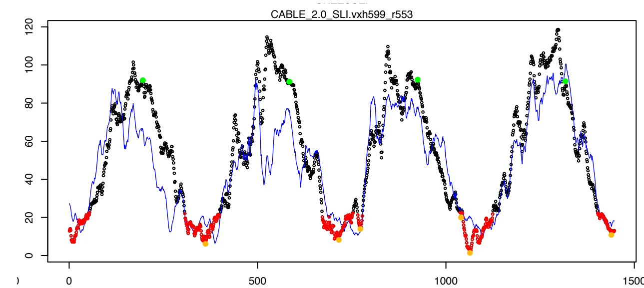
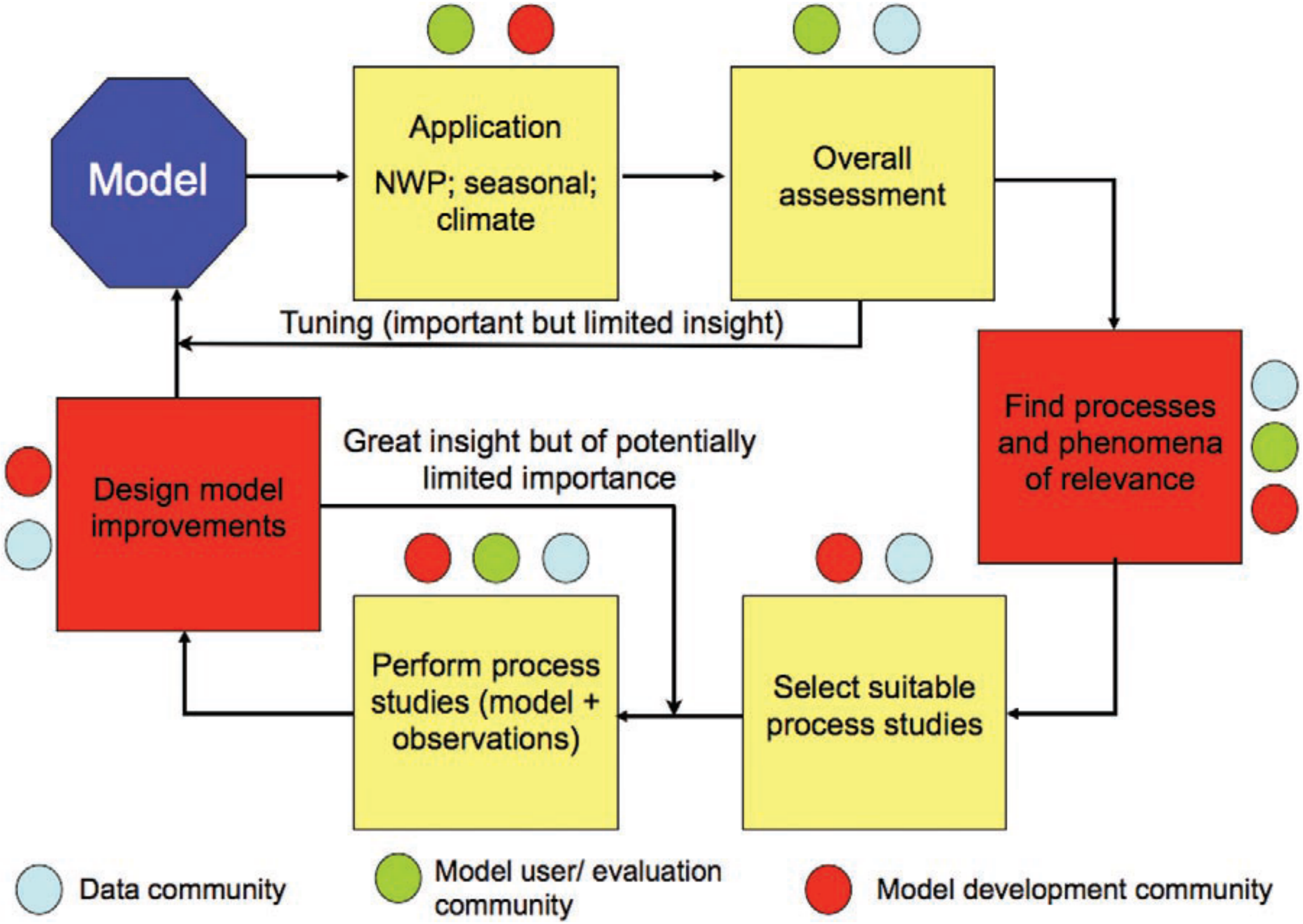


CABLE-SLI

- Observations
- Model
- Drought days
- Onset
- Minimum

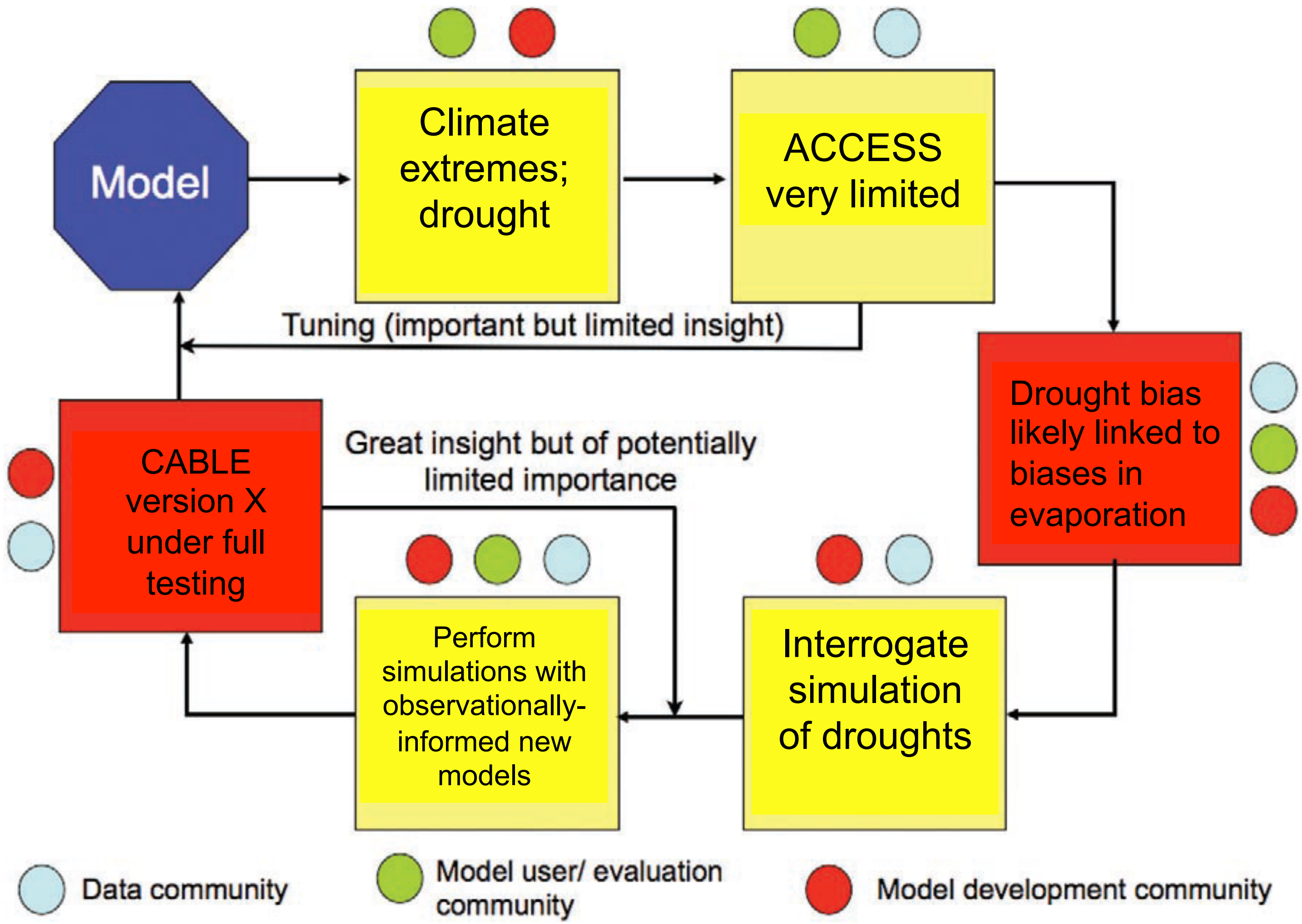
- CABLE2.0 has the same lousy behavior as almost all other LSMs
- CABLE SLI and CABLE-GW do not display this problem
- MOSAIC (Koster's model) looks good too
- Common factor ? Probably really careful treatment of hydrology

Model improvement …



Jakob, 2010

Model improvement …



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Jatin Kala
Annette Hirsch
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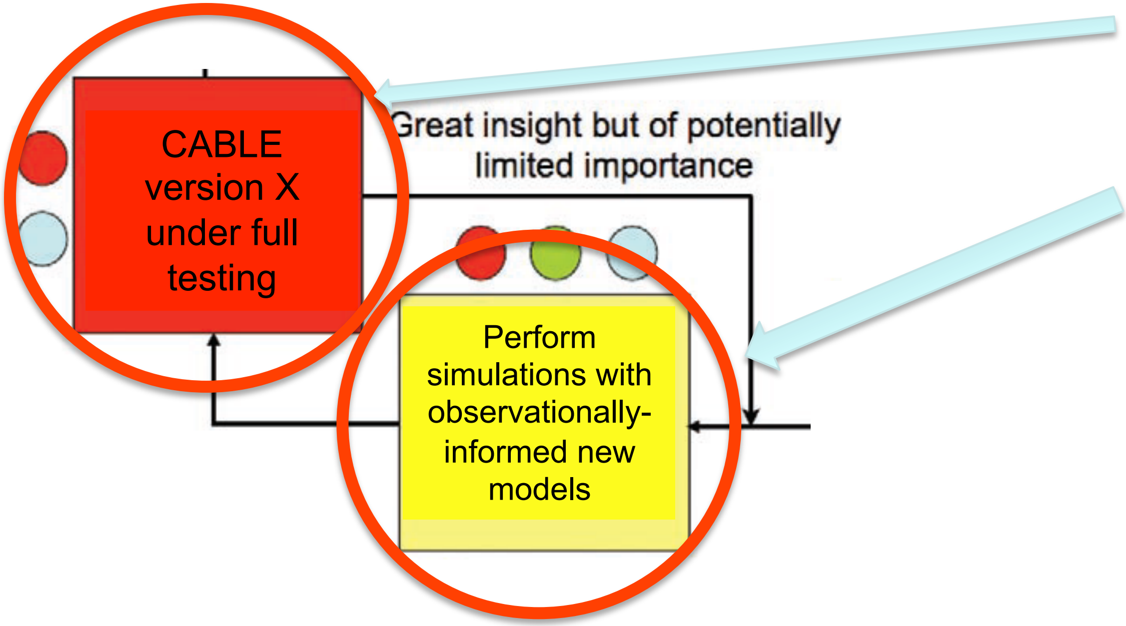
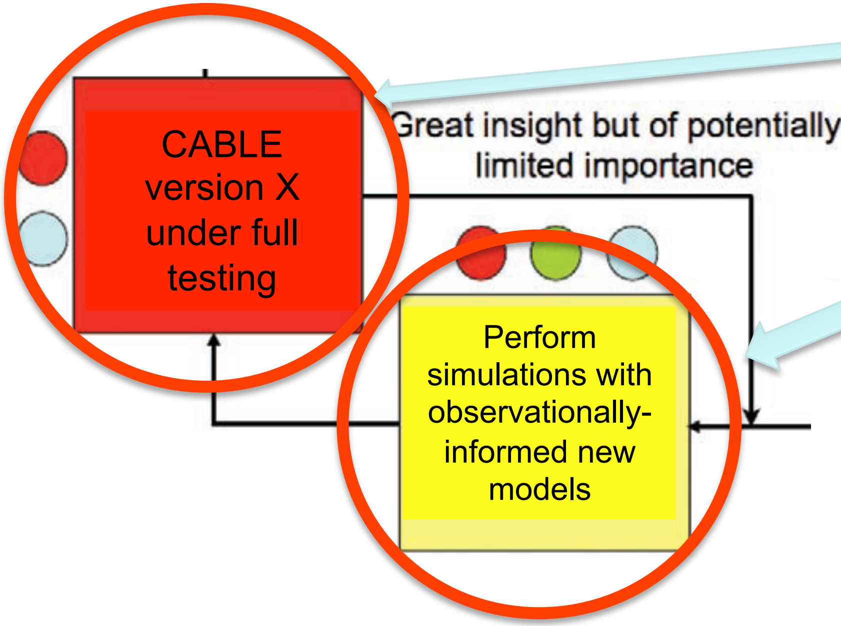
Model improvement …



- Individual points [~20]
- PALS benchmarking
- PLUMBER
- For whole time periods
- For selected “drought” periods
- GSWP3 [global]
- AMIP [global coupled]

- Then …

Model improvement …



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- For whole time periods
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- GSWP3 [global]
- AMIP [global coupled]

- Then …

- Independent testing
- Coupled simulations?
- Documentation
- Code checking
- CABLE committee decision

Lessons learned

- ACCESS1.3 has a poor climatology of land-related extremes
  - Likely linked to excess evaporation

  - We have explored several major aspects of CABLE2.0's land climate

- CABLE2.0 simulates dry-down poorly
  - Its too fast
  - Its too intense
  - Dry periods likely last too long

- CABLE2.0 would get the land contribution to the frequency, magnitude and duration of droughts wrong.

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Lessons learned

- Virtually all LSMs fail to simulate dry-down
  - Three exceptions: CABLE-SLI, CABLE-GW and MOSAIC.
  - All have strong hydrology
- This is only discoverable when one
  - focuses on phenomenon (dry-down)
  - has a hierarchy of evaluation – from AMIP to GSWP-3 to flux net observations across a wide range of environments
- The resulting failures are resolvable when one responds with a process-level investigation, in a version controlled environment with careful and thorough testing
- Acid test is to see how this improves ACCESS1.4's climate of extremes …