Improving the estimation of canopy interception in Great Britain

Walter Thompson\textsuperscript{1}, Rafael Rosolem\textsuperscript{1}, Eleanor Blyth\textsuperscript{2}

\textsuperscript{1}University of Bristol, Bristol, UK
\textsuperscript{2}Centre for Ecology and Hydrology, Wallingford, UK

Note: This talk was submitted for undergraduate assessment at the University of Bristol
Canopy interception is an important process in GB’s water cycle

• Approximately up to 50% of precipitation over a forest is intercepted (depends on leaf type)

• Fraction of intercepted water has big influence on water cycle (affects ET + runoff)

• Therefore, important we model accurately!
JULES interception parametrisation was developed in 1992

\[ T = P \left(1 - \frac{C}{S}\right) \exp \left(-\frac{\mu S}{P \Delta t}\right) + P \frac{C}{S} \]

\[ T = \text{Throughfall} \]

\[ P = \text{Precipitation rate} \]

\[ C = \text{Current storage of leaves (i.e. intercepted water)} \]

\[ S = \text{Maximum storage of leaves} \]

\[ \mu = \text{Rainfall intensity factor} \]
It uses two values for rainfall intensity, also chosen in 1992

• By default, $\mu = 0.3$ used for convective rainfall (air temperatures at least 20 °C)

• $\mu = 1$ used for large scale precipitation (air temperatures less than 20 °C)

• These are constant values
Land Surface Models have evolved in the last few decades, and are continuing to do so

- Global (satellite based) hyper-resolution models
- Gap between observations and models is ever decreasing
- 2019 UKV model runs at 1.5km spatial resolution on 3 hourly timestep

Wood et al. (2011)
Research Questions

1. Does the JULES interception model perform well when using modern datasets?

2. At 1x1 km resolution, how does measured rainfall intensity differ from the JULES parametrisation?

3. If there is a difference in measured rainfall intensity compared to the JULES default, how does this affect interception estimates?

4. How is the modelling of interception affected by climate change?
Data and Methods
We tested our approach on six sub-domains within Great Britain

• Processing entire GB out of project scope

• 6 domains chosen to represent regional climates

• CHESS, GEAR & UKCP18 data used

• More towards the south as convective rainfall is more common here

• Test resolutions are 80, 40, 20, 10, 5, 2 km
We used a mesh-type approach to compute $\mu$ for a wide range of spatial resolutions

- GEAR 1x1 km hourly dataset used for precipitation
- CHESS 1x1 km daily dataset used for temperature
- Count rainy cells and compare to total number of cells
- 25 years of data used
A simple ‘bucket’ model was used to describe the canopy water balance

- Interception model used in JULES replicated in MATLAB, allowing control over parameters

- CHESS data used (temperature, daily temp. range, pressure and radiation)

4 experiments:
- JULES Default ($\mu = 0.3$ when temp. > 20 °C)
- Seasonal ($\mu = 0.3$ in summer, $\mu = 1$ in winter)

\[ C = P - T - E \]
Results
Clear dependence of $\mu$ on spatial resolution of input data - $\mu$ tends to 1

- $\mu$ increases exponentially as resolution increases.
- At 2x2 km resolution, $\mu = 1$ across the UK.
- Difference between convective and large-scale rain reduces too.

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The use of incorrect $\mu$ values can result in poor interception estimates in GB

- All analyses hereafter at 1x1 km resolution
- JULES below $\mu = 1$ by approximately 7.5%
- Change occurs in summer due to convective rainfall
- $\mu = 0.3$ completely below expected interception
Interception can be manipulated by changing canopy storage although this is not ideal

- $\mu = 0.3$ clearly too high
- $\mu = 1$ closest to measured storage values
- Similar % difference between JULES and $\mu = 1$ as before
Current discrepancies are exacerbated significantly under future UK climate conditions (UKCP18)

- JULES default falls dramatically, approximately equal to Seasonal
  
- Constant parametrisations remain similar as no convective switch in model
Future climate drastically impacts model performance in all subdomains

- In each region, interception is underestimated by default JULES using UKCP18

- Important to update model sooner rather than later!

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JULES Science Meeting 2020
Conclusions
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1. JULES default parametrisation of rainfall intensity is **outdated**

2. **Hyper resolution models** (2x2 km resolution or higher) need $\mu = 1$, and should never use $\mu = 0.3$

3. In GB **interception** is slightly **underestimated** at the moment, but in the tropics it is expected to be much worse

4. **Climate change will drastically worsen** the performance of the current JULES model, even in areas such as the UK
Thank you very much for listening!