# A global scale evaluation of extreme events in the *earth2Observe* project


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A coupled land-atmosphere-hydrology system (flooded land surface in Malawi, 2015)

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CEH Centre for Ecology & Hydrology NATURAL ENVIRONMENT RESEARCH COUNCIL

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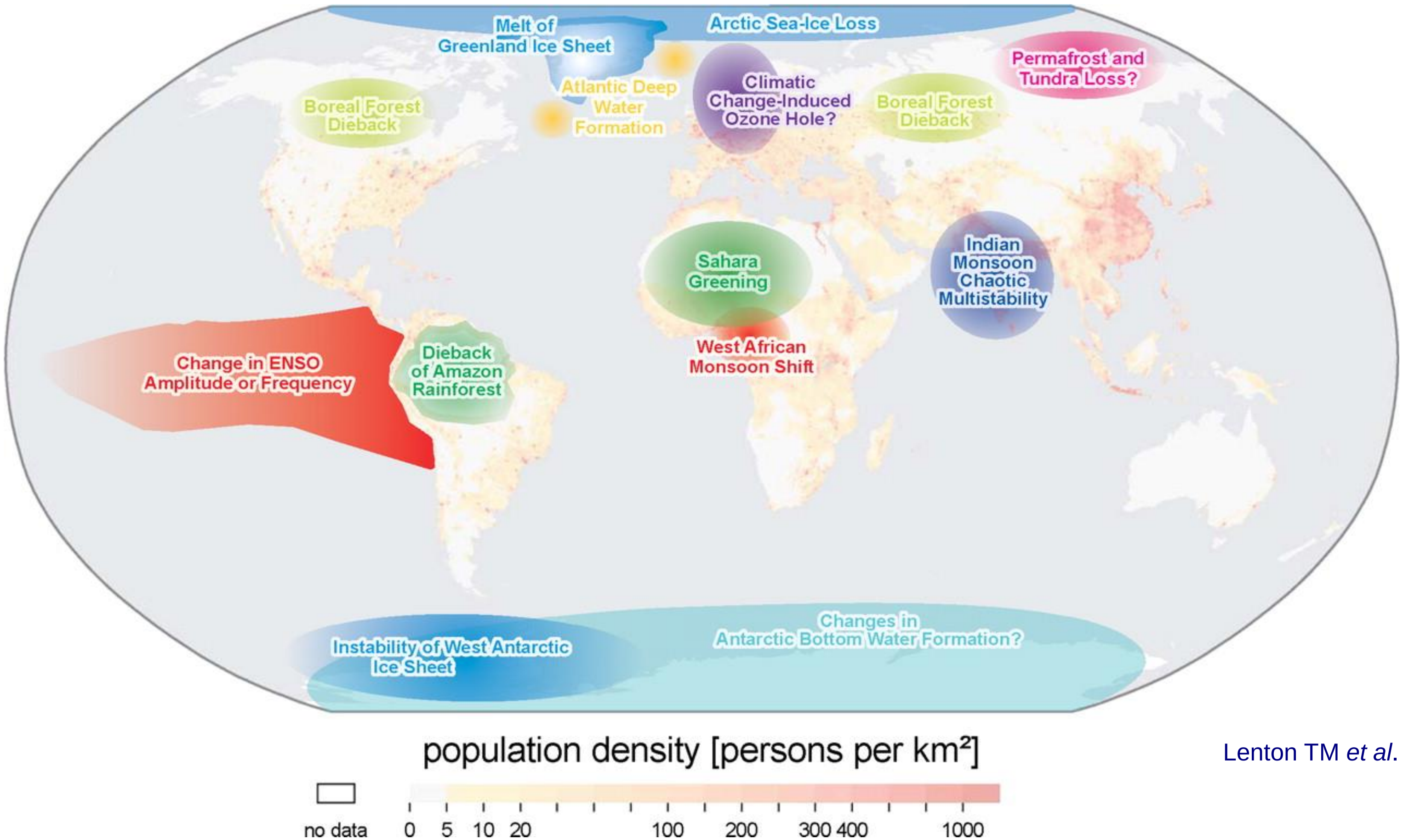
eartH2Observe

# Global tipping points

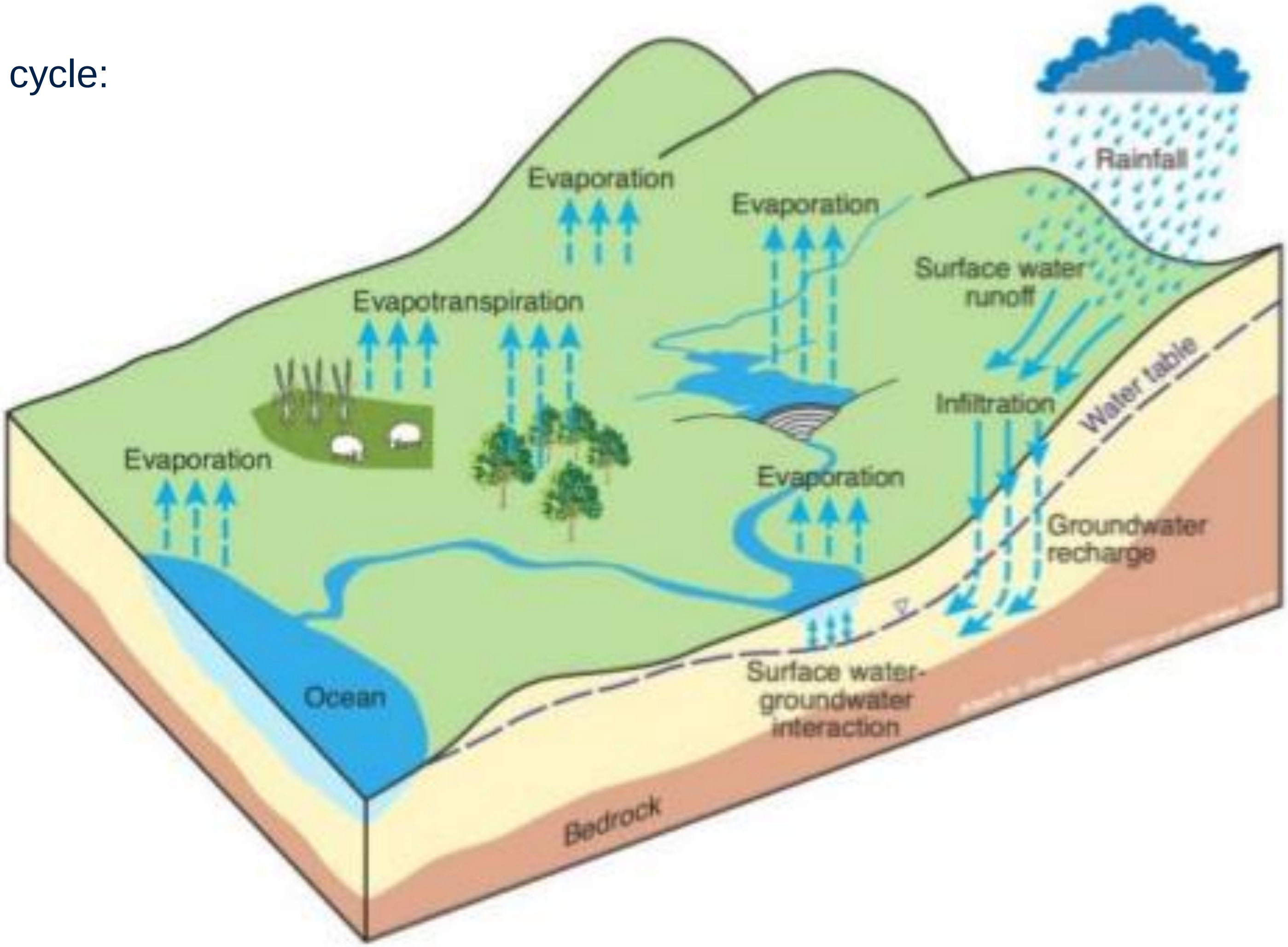
The importance of hydrology: many of these potential tipping points in the climate system are related to too much or too little water being available.




Lenton TM *et al*. (2008). *PNAS*

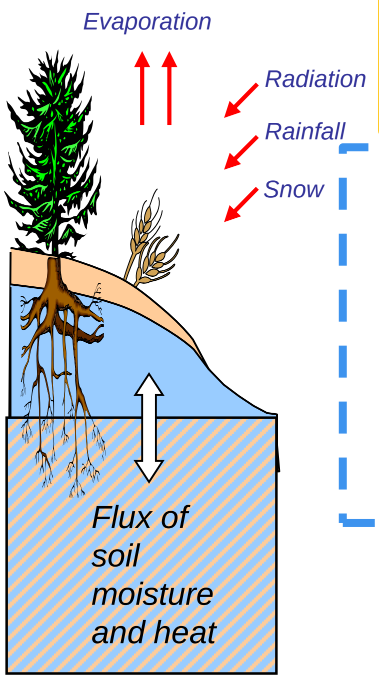
# Hydrological modelling

The water cycle:




Many (though not all) of these processes feature in JULES in some way.

# Water cycle processes in JULES




Dadson *et al.* (2010, *JGR*)

**Precipitation**

Within-gridcell processes

Precipitation is intercepted by vegetation first, with some evaporating (**evaporation** options) and the rest reaching the soil.

The **soil water characteristic** controls vertical fluxes (options are Brooks & Corey or van Genuchten in *JULES*; Marthews *et al.* 2014, *GMD*)

**Rainfall-runoff production** in *JULES* is either handled by *TOPMODEL* (=*LSH*) or *PDM* (Marthews *et al.* 2015, *HESS*)

**Evapotrans-piration**

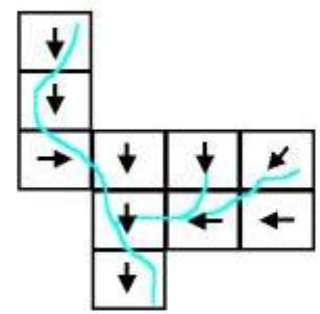
**Runoff**

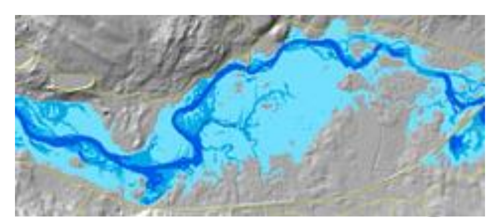
River routing between gridcells

**Runoff routing** follows a 1D kinematic wave equation either using *TRIP* or *RFM* (see Lewis *et al*. 2018, *GMD*)

**Overbank inundation** is a necessary process whereby rivers can expand into their floodplains (see my ticket #724 on the *JULES TRAC*)

**(Evaporation here not yet implemented in JULES)**





# The earthH2Observe project

*Earth$H_2$Observe* http://www.earth2observe.eu/ is a collaborative project (27 partners) funded under the EU FP7 programme 2014-17. EarthH2Observe is bringing together the modelling (LSMs and global hydrological models) and EO communities.


*Earth$H_2$Observe* overall objective: to contribute to the assessment of global water resources through the use of new Earth Observation datasets and techniques.

# The earthH2Observe project

- There is generally high uncertainty in model predictions of water cycle variables (meaning uncertainty between comparable land surface models like *JULES*, *H-TESSEL*, *ORCHIDEE*). This is ‘model uncertainty’.

- However, remember there is also variation between the driving precipitation numbers (which generally come from products like *MSWEP*, *TRMM*, *CMORPH*). This is ‘product uncertainty’.

# The earthH2Observe project

## Does model output uncertainty come from differences between models or differences between model driving data?

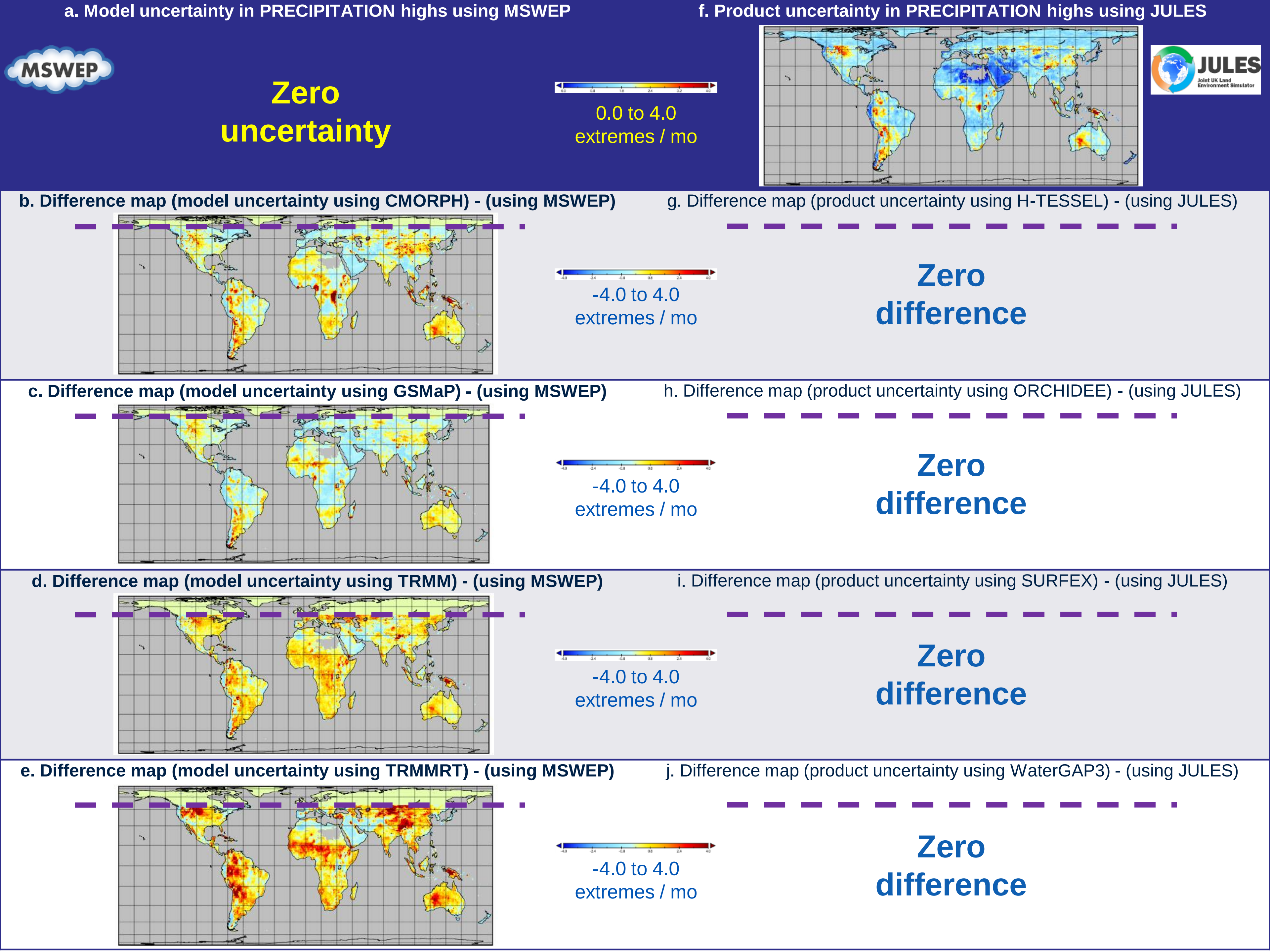
- I'm focusing on extreme events, defined as extreme high/low occurrences of large/small values of precipitation (i.e. high/low rainfall), runoff (e.g. flood), evapotranspiration (e.g. drought).

# The models and precipitation products

- The **land surface models** used in the Earth2Observe project were:
  - ❑ *H-TESSEL* (Hydrology Tiled ECMWF Scheme for Surface Exchanges over Land model, ECMWF)
  - ❑ *JULES* (of course!, MetO/CEH)
  - ❑ *ORCHIDEE* (ORganizing Carbon and Hydrology In Dynamic EcosystEms model, CNRS/LSCE)
  - ❑ *SURFEX* (SURFace EXternalisée model, Météo-France)
  - ❑ *WaterGAP3* (Water – Global Assessment and Prognosis-3, Univ. Kassel)

- The **precipitation products** used were:
  - ❑ *MSWEP* (Multi-Source Weighted-Ensemble Precipitation) - reanalysis data.
  - ❑ *CMORPH* (Climate prediction center MORPHing technique) - blended MW/IR
  - ❑ *GSMaP* (Global Satellite Mapping of Precipitation) - blended MW/IR
  - ❑ *TRMM* (Tropical Rainfall Measuring Mission) - mainly MW
  - ❑ *TRMM-RT* (Tropical Rainfall Measuring Mission - Real Time) - mainly MW

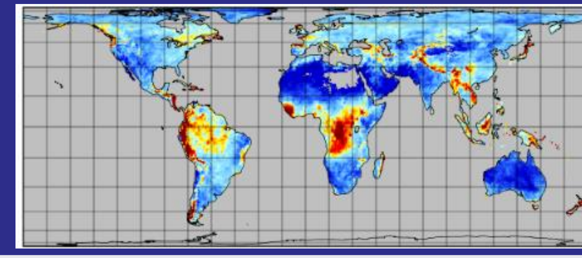
- So, for each variable - and high/low for each variable - my results are averaged over an ensemble of 5x5=25 runs at 0.5° global resolution.


a. Model uncertainty in PRECIPITATION highs using MSWEP
MSWEP
Zero uncertainty
0.0 to 4.0 extremes / mo
f. Product uncertainty in PRECIPITATION highs using JULES
JULES
Joint UK Land Environment Simulator
b. Difference map (model uncertainty using CMORPH) - (using MSWEP)
-4.0 to 4.0 extremes / mo
g. Difference map (product uncertainty using H-TESSEL) - (using JULES)
Zero difference
c. Difference map (model uncertainty using GSMaP) - (using MSWEP)
-4.0 to 4.0 extremes / mo
h. Difference map (product uncertainty using ORCHIDEE) - (using JULES)
Zero difference
d. Difference map (model uncertainty using TRMM) - (using MSWEP)
-4.0 to 4.0 extremes / mo
i. Difference map (product uncertainty using SURFEX) - (using JULES)
Zero difference
e. Difference map (model uncertainty using TRMMRT) - (using MSWEP)
-4.0 to 4.0 extremes / mo
j. Difference map (product uncertainty using WaterGAP3) - (using JULES)
Zero difference

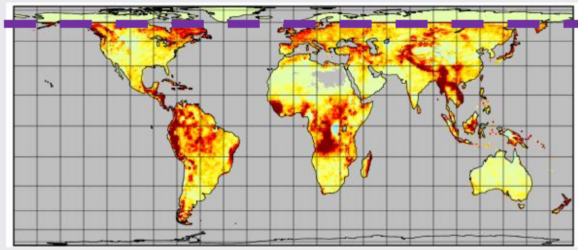
**a. Model uncertainty in PRECIPITATION lows using MSWEP**

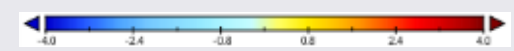
0.0 to 4.0
extremes / mo

**f. Product uncertainty in PRECIPITATION lows using JULES**



**b. Difference map (model uncertainty using CMORPH) - (using MSWEP)**

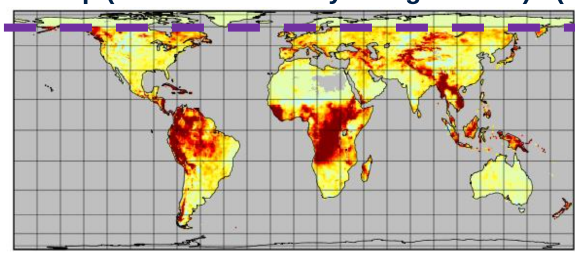




-4.0 to 4.0
extremes / mo

g. Difference map (product uncertainty using H-TESSEL) - (using JULES)

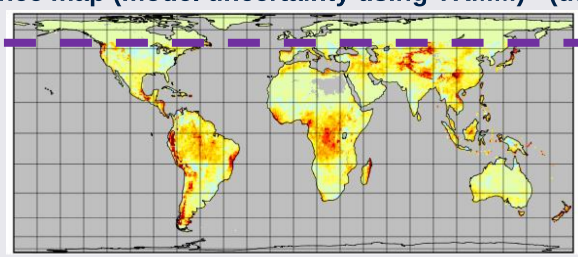
**c. Difference map (model uncertainty using GSMaP) - (using MSWEP)**

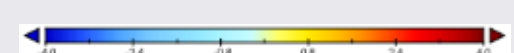


-4.0 to 4.0
extremes / mo

h. Difference map (product uncertainty using ORCHIDEE) - (using JULES)

**d. Difference map (model uncertainty using TRMM) - (using MSWEP)**

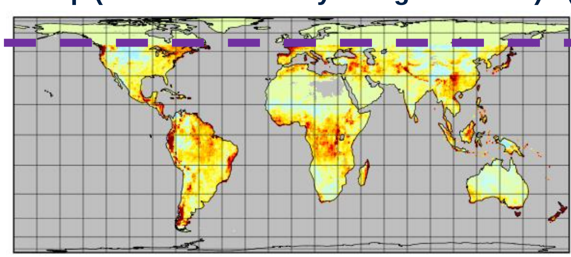




-4.0 to 4.0
extremes / mo

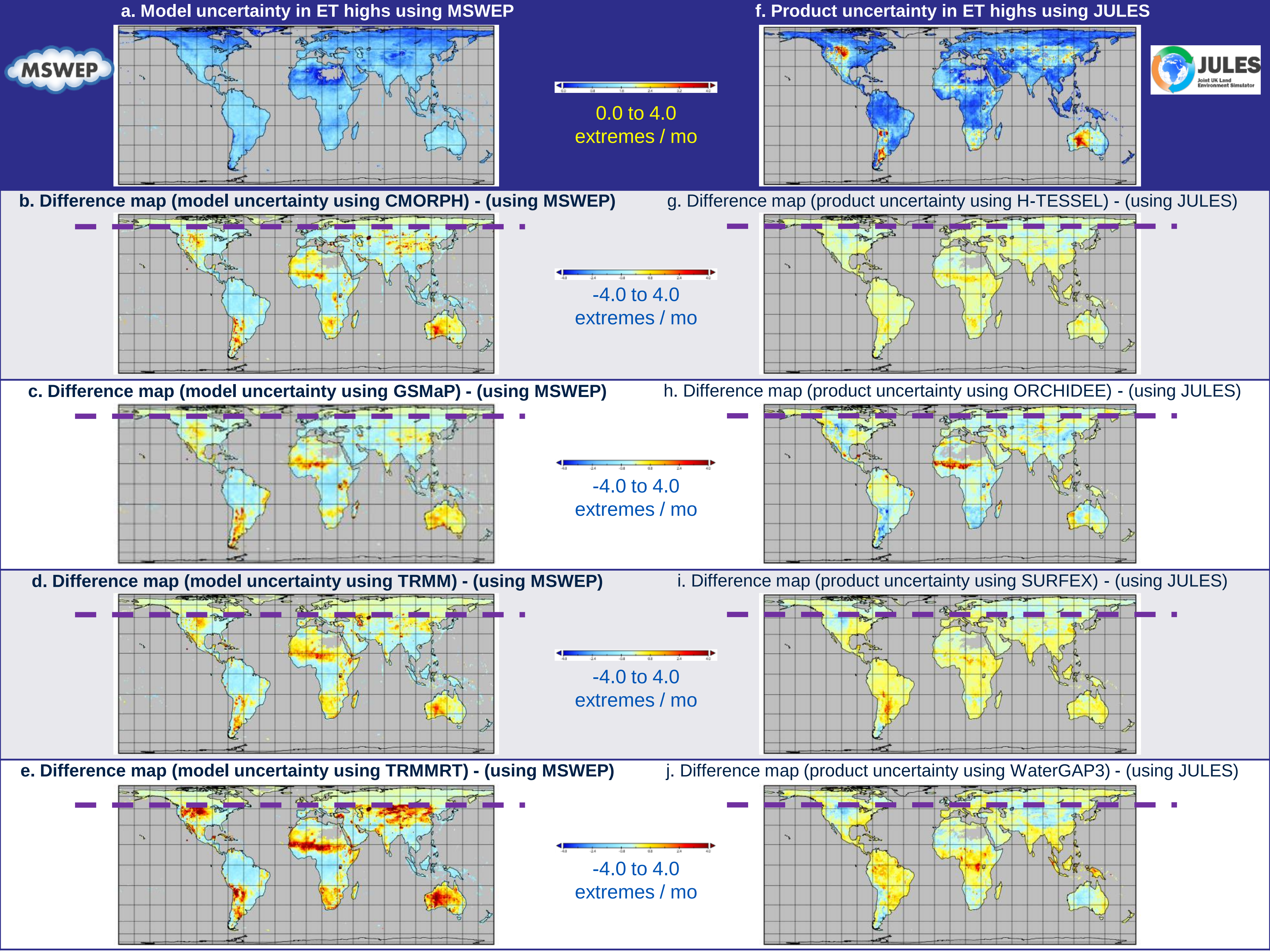
i. Difference map (product uncertainty using SURFEX) - (using JULES)

**e. Difference map (model uncertainty using TRMMRT) - (using MSWEP)**



-4.0 to 4.0
extremes / mo

j. Difference map (product uncertainty using WaterGAP3) - (using JULES)


a. Model uncertainty in ET highs using MSWEP
MSWEP
0.0 to 4.0
extremes / mo
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c. Difference map (model uncertainty using GSMaP) - (using MSWEP)
-4.0 to 4.0
extremes / mo
h. Difference map (product uncertainty using ORCHIDEE) - (using JULES)
d. Difference map (model uncertainty using TRMM) - (using MSWEP)
-4.0 to 4.0
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i. Difference map (product uncertainty using SURFEX) - (using JULES)
e. Difference map (model uncertainty using TRMMRT) - (using MSWEP)
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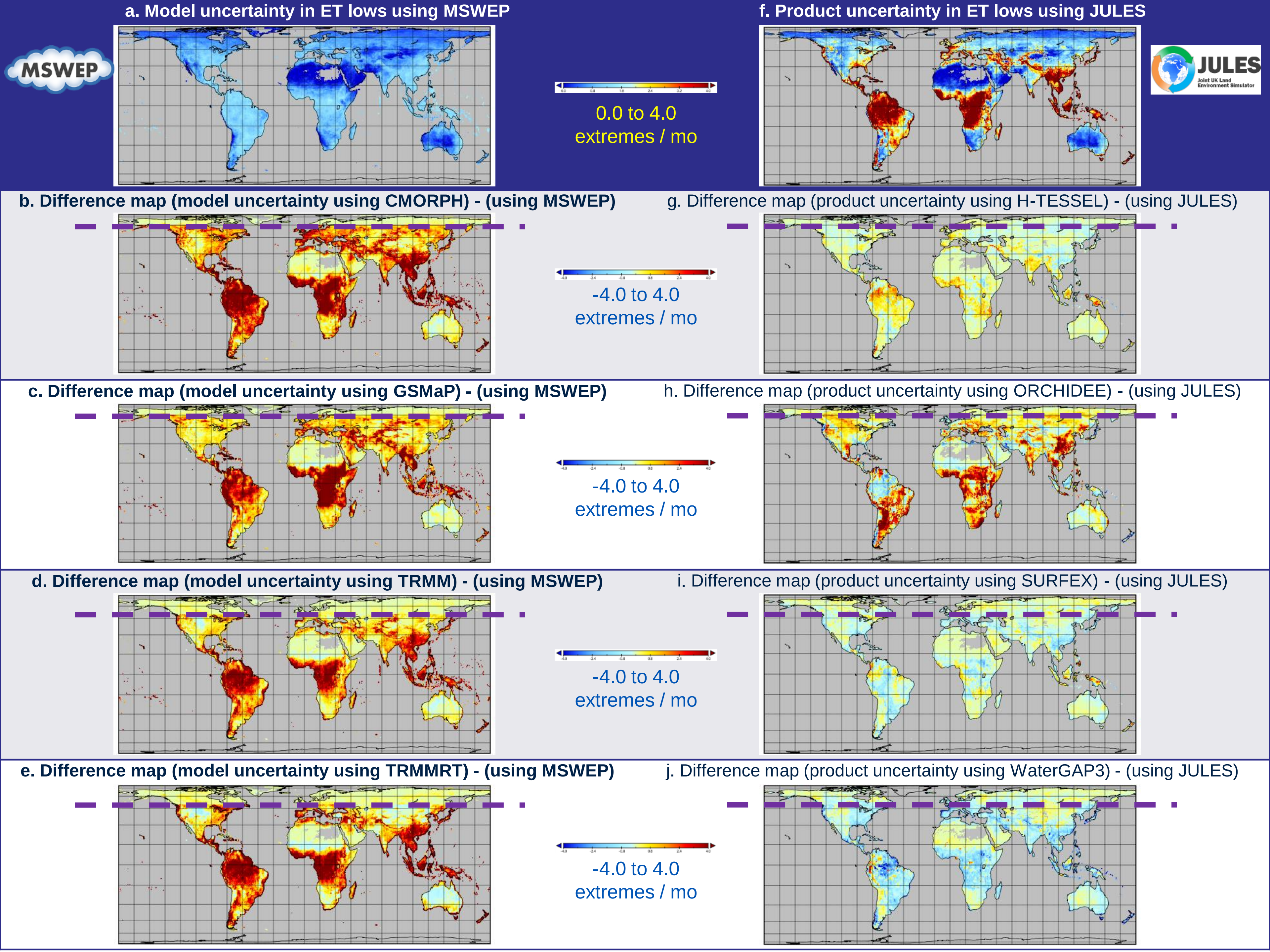
j. Difference map (product uncertainty using WaterGAP3) - (using JULES)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0.0 to 4.0
extremes / mo
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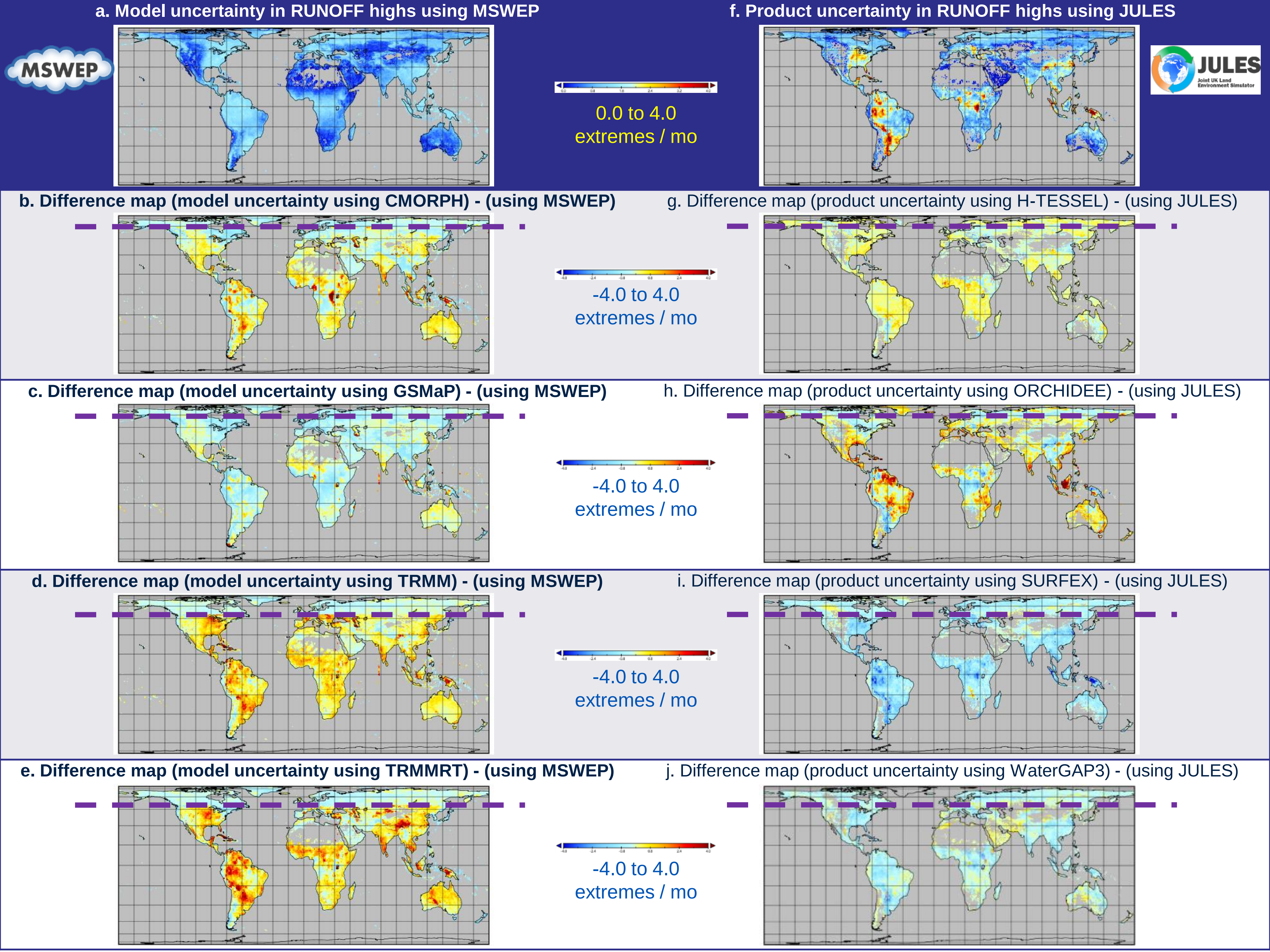
a. Model uncertainty in RUNOFF highs using MSWEP
MSWEP
0.0 to 4.0
extremes / mo
f. Product uncertainty in RUNOFF highs using JULES
JULES
Joint UK Land Environment Simulator
b. Difference map (model uncertainty using CMORPH) - (using MSWEP)
-4.0 to 4.0
extremes / mo
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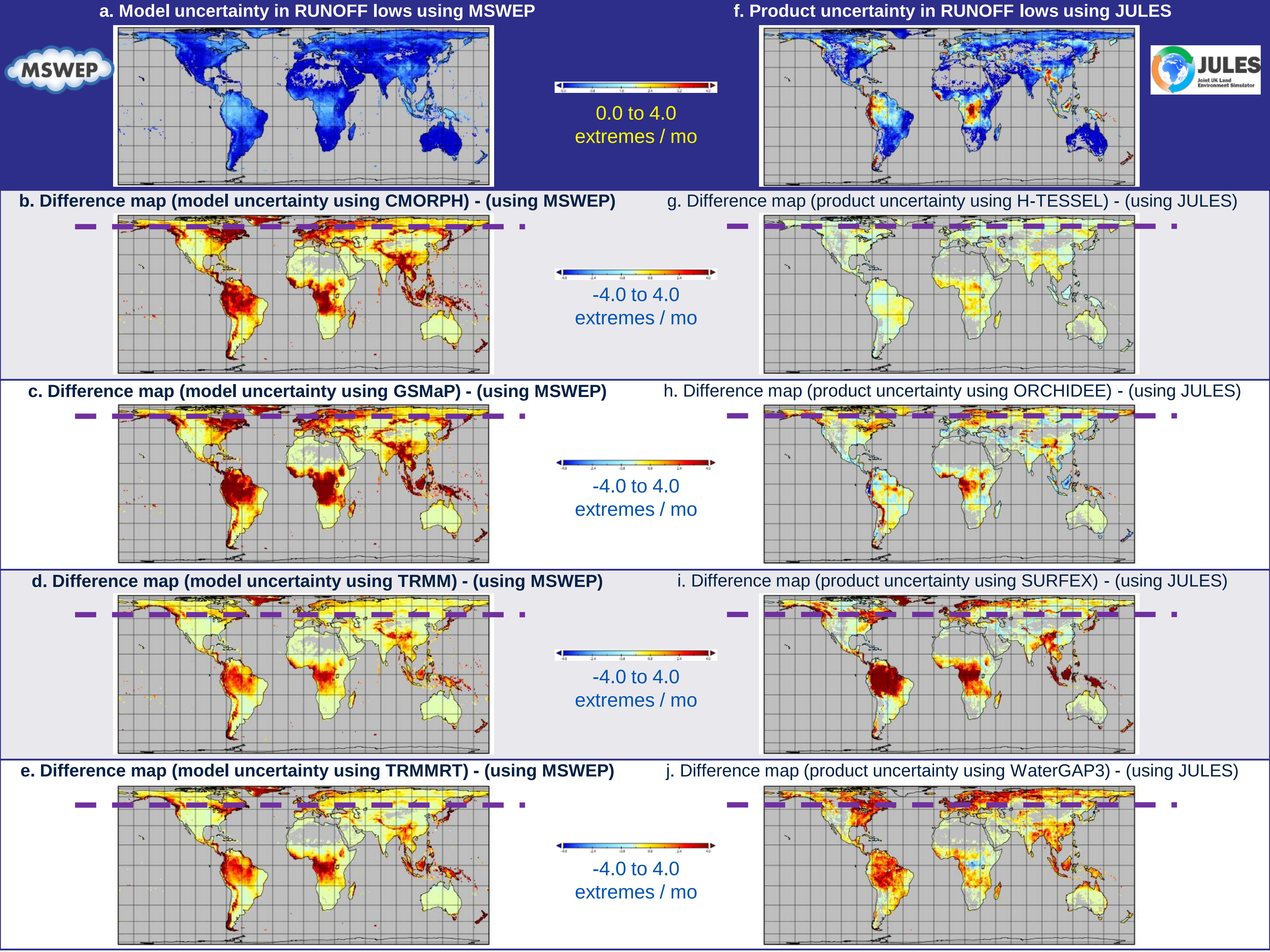
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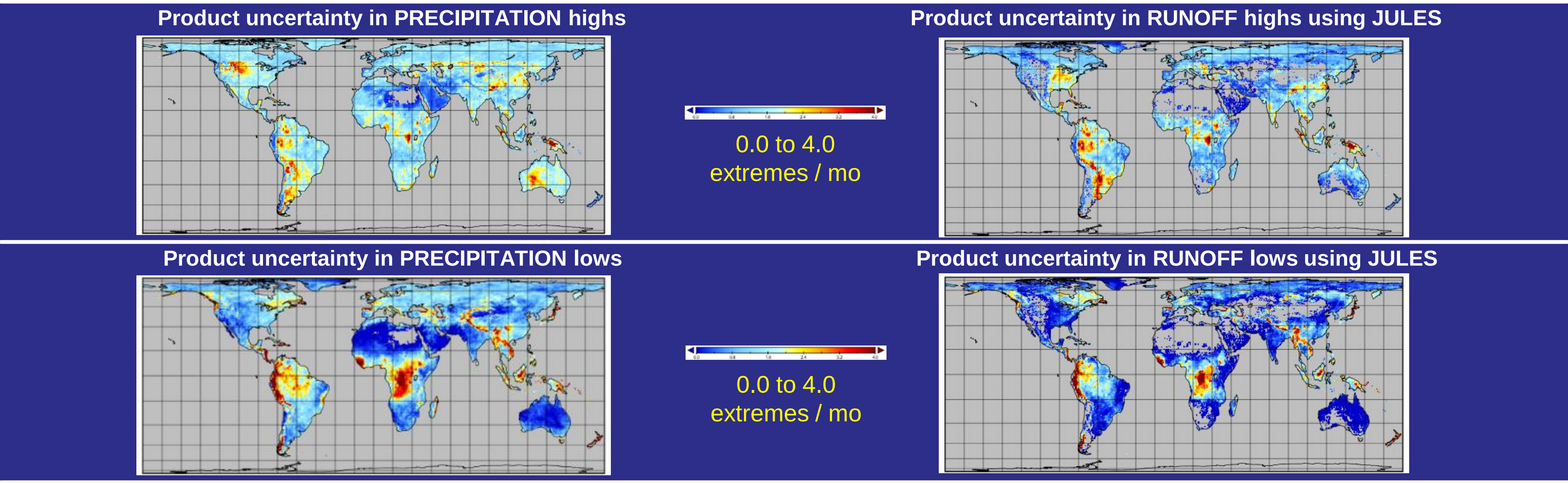


# Most of the story is in these 4 plots only:

- **TOP LEFT: Precipitation-high uncertainty** appears to show us the areas where our basic source data is poor, e.g. the Andes, Eastern Congo, S.E. Asia, Mongolia, Great Sandy Desert in Oz.
- **BOTTOM LEFT: Precipitation-low uncertainty** appears to pick out all very wet tropical forest areas.
- **Runoff-high uncertainty** generally follows the precipitation highs (which is kind of what we would expect), but at least in South America it seems to be 'downhill' from where the precipitation extremes are.
- Mapping **runoff and ET low uncertainty** generally seems to just give us a map of areas that are extremely wet.
- HOWEVER, it's the areas where these general patterns don't hold that are the most interesting.
- In terms of model uncertainty, it seems to be the case that WaterGAP3 and SURFEX have the lowest uncertainty, JULES and H-TESSEL medium and ORCHIDEE more extreme (which may be ORCHIDEE responding much more to precip extremes, which may not be wrong).
- In addition, from previous plots my interpretation is that CMORPH exaggerates precipitation extremes (distribution of uncertainty closely follows the precipitation highs), GSMaP is usually like CMORPH but is much more consistent over tropical forest areas, TRMM has high uncertainty everywhere except very dry deserts, TRMMRT is like TRMM but even more extreme.

# Conclusions

- Do we see an augmentation of uncertainty or a telescoping of uncertainty during the model simulations?
  - In many areas, yes: telescoping.

- Do we see spatial displacement, e.g. high precipitation uncertainty in the Ethiopian highlands producing high runoff uncertainty in the lower parts of the Nile River?
  - Yes, especially in South America I think

- It's not new to say that drought indices based on precipitation only are limited and uncertain (e.g. SPI). However, can we tell from these maps where such indices do badly and where they do acceptably well?
  - Perhaps: need a bit more time for that!

# Thank you very much!


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