

**Intermittency in precipitation:
duration, frequency, intensity
and amounts
using hourly data**

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How should rainfall change as climate changes?

Usually only total **amount** is considered

- But most of the time it does not rain

Need to consider:

- The **frequency and duration** (how often)
- The **intensity** (the rate when it does rain)
- The **sequence**

The intensity affects how much rainfall runs off (river and stream flow) versus how much soaks into the soils.

Need at least hourly data.

Most analysis is of monthly means or at best daily means.



Observational Data

We use:

CMORPH v1 CRT hourly at 1° resolution.

NOAA's Climate Prediction Center Morphing ("CMORPH")

- new bias corrected estimates of precipitation
- about 8 km resolution from 60°N to 60S at
- 30 minute temporal resolution since 1998
- (CMORPH v1.0 CRT) (Xie et al. 2016).

TRMM 3B42 v7 3 hourly 1998-2012

- 49N-49S 0.25°.
- Microwave calibrated IR matched to GPCP.
- We use 1° resolution

Evaluations show CMORPH much better at representing daily and 3-hourly precipitation than TRMM 3B42 over many regions of the globe. Assessed by Xie et al 2016; Gehne et al. 2016 J Climate



Model Data

CESM LENS: Large Ensemble: 40 members 1920-2005
+RCP8.5

We used 1998-2013 (as for TRMM)

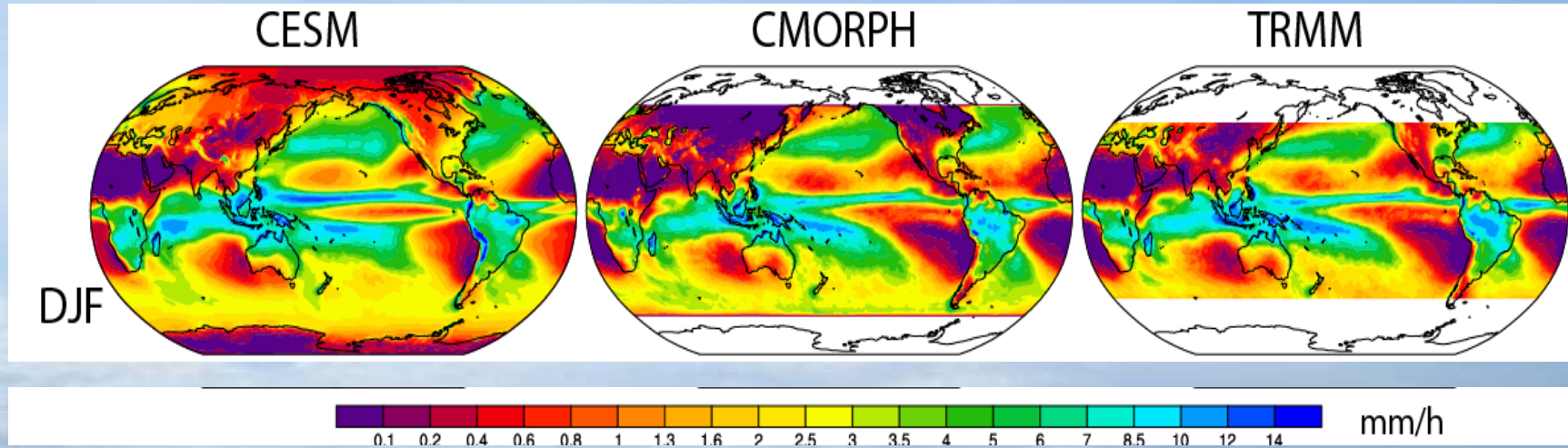
CESM1 (CAM5) (0.9x1.25_gx1v6).

Hourly data (2 special runs)

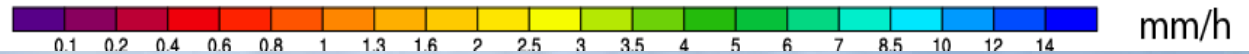
CESM LENS runs 34 and **35**



Means 1998-2013



DJF



Annual means

50N-50S
mm/day

3.38

2.78

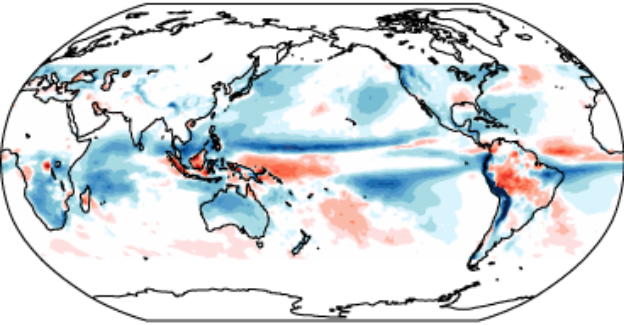
2.90

21.6% higher
than CMORPH

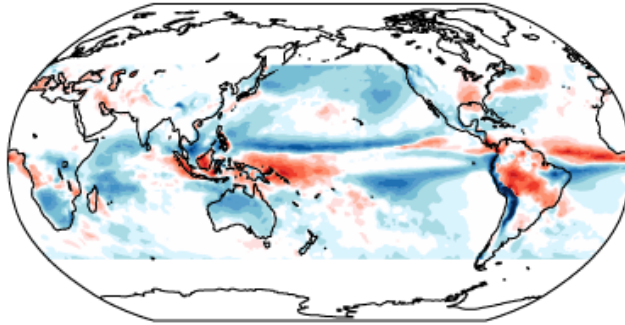


Differences in means: DJF

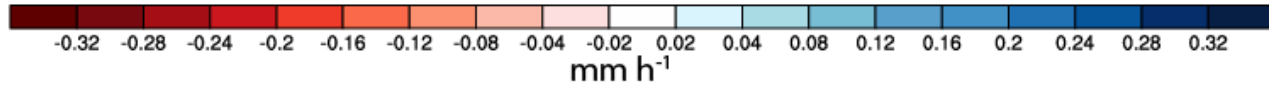
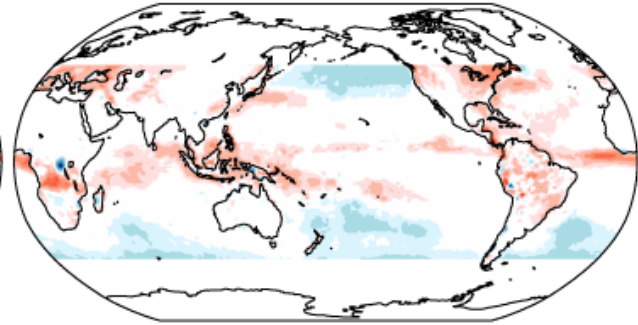
CESM - CMORPH



CESM - TRMM

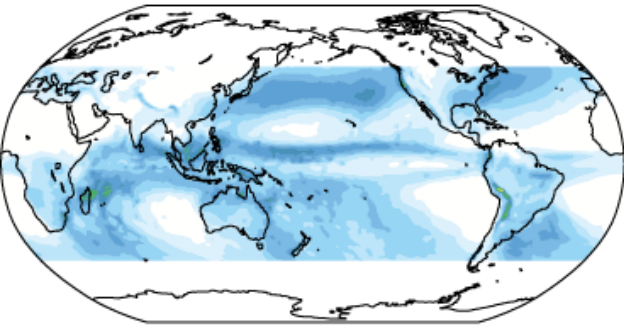


CMORPH - TRMM

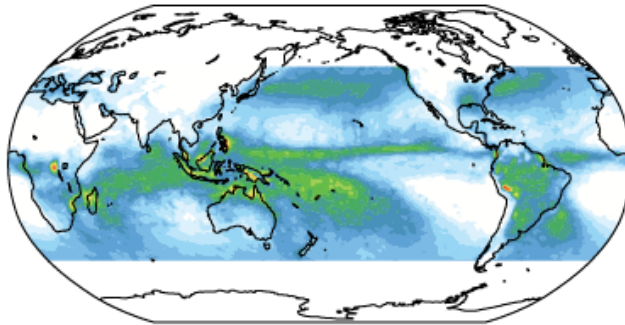


Standard deviations: 3-hourly DJF

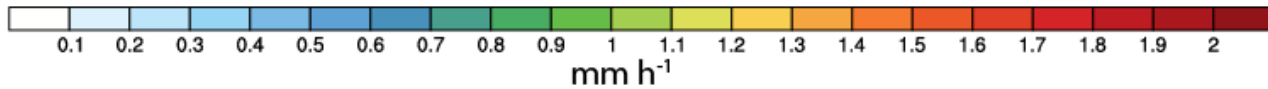
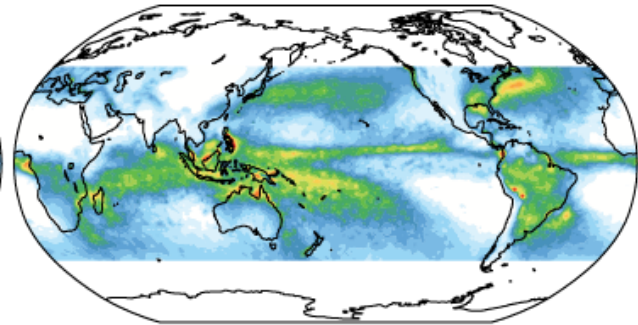
CESM



CMORPH



TRMM



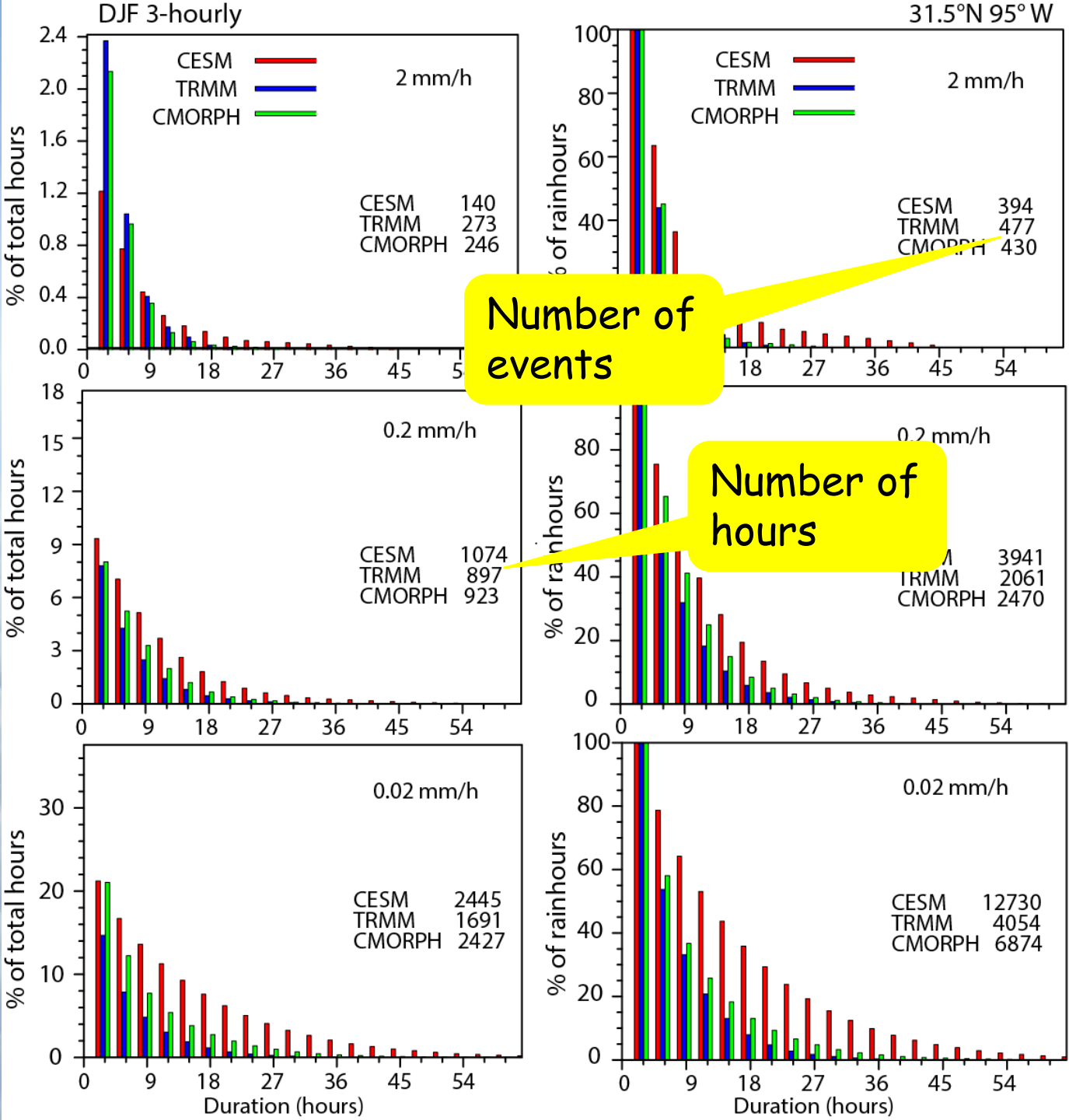
Land point:



Duration conditional on precipitation at previous time

CESM
TRMM
CMORPH

(Plots are made for hourly, 3-hourly and daily data for 0.01, 0.02, 0.05, 0.1, 0.2, 0.5, 1.0, 2.0, 5.0 mm/h)



Number of events

Number of hours

Fraction of time for precipitation for various durations (hours) in DJF @ 0.02 mm/h

CESM

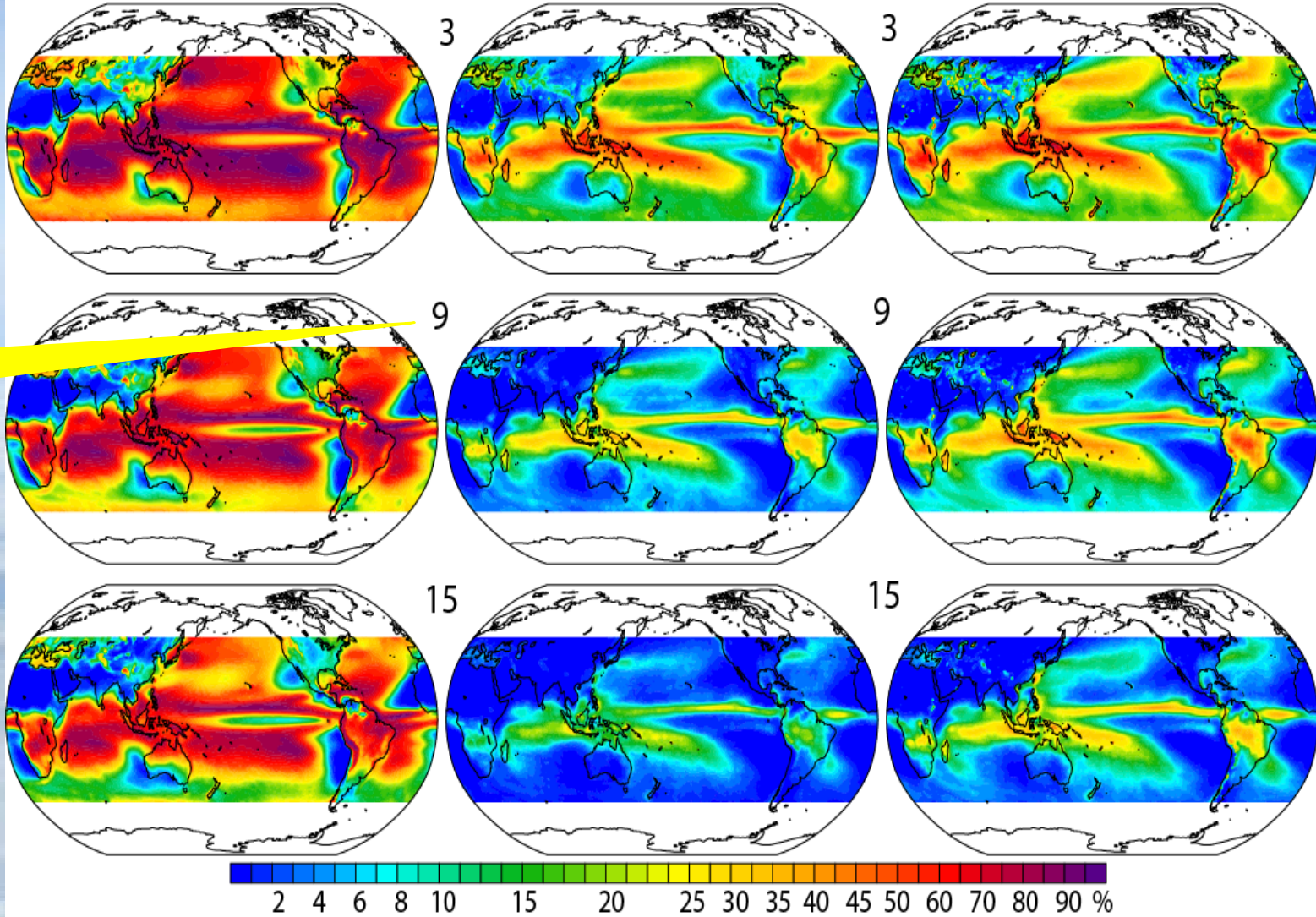
TRMM

CMORPH

Light rain

Duration

0 to 9
hours



Note nonlinear scale



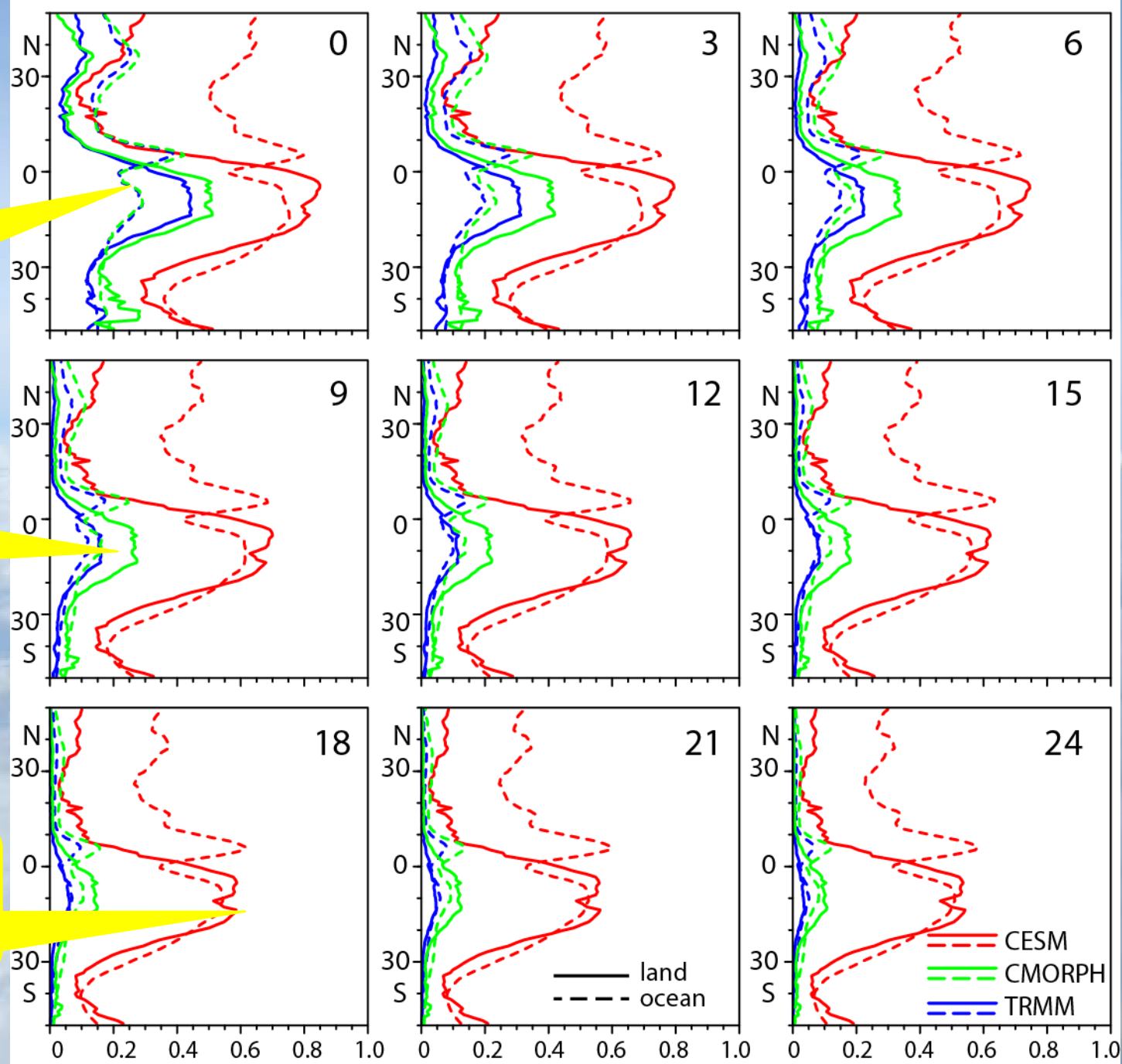
Zonally Averaged DJF Total Fraction of Duration (0.02 mm h^{-1})

Light rains

Great agreement

CMORPH higher land

CESM much higher, esp ocean

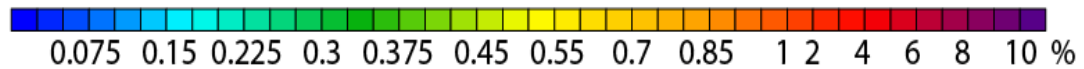
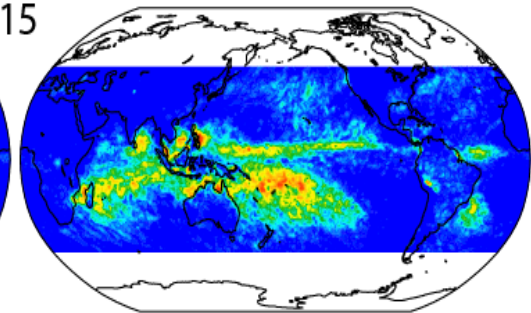
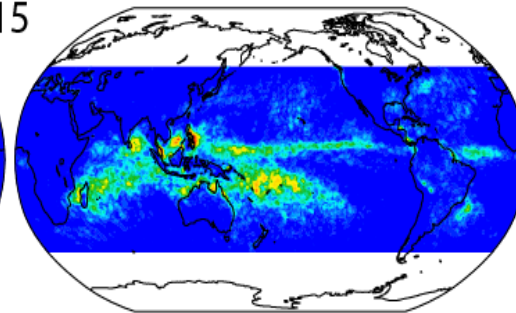
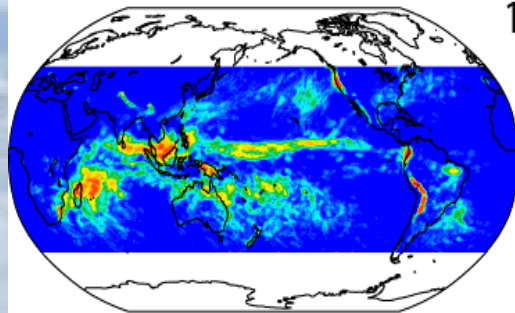
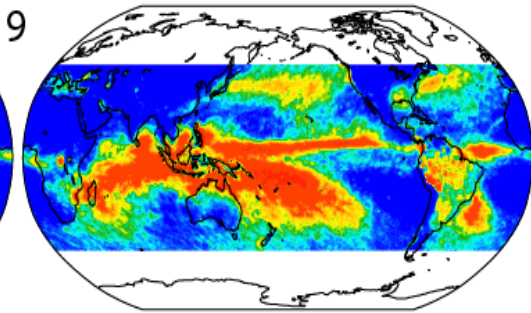
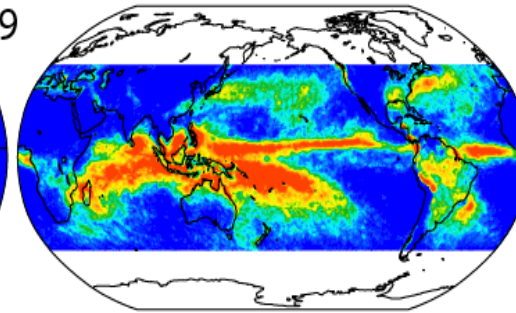
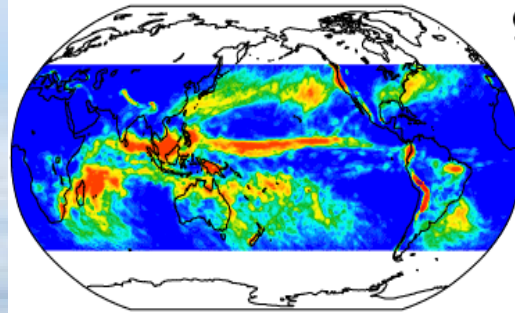
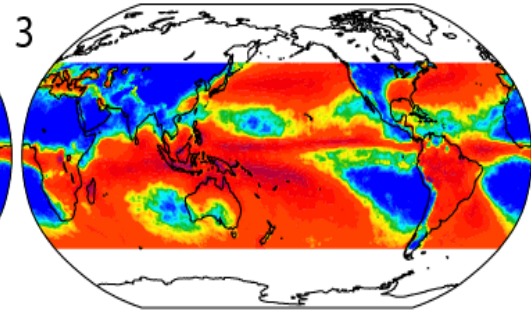
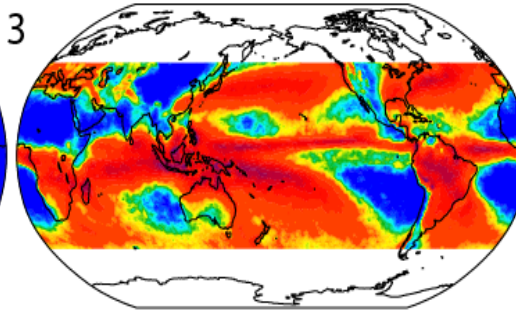
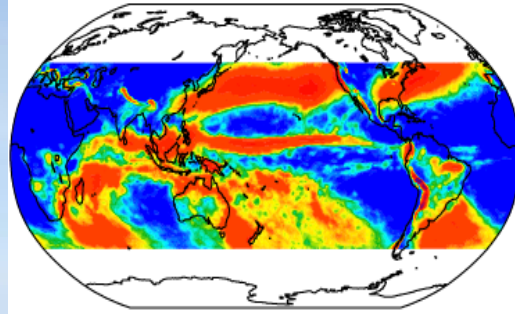


Fraction of time for precipitation for various durations (hours) in DJF @ 2 mm/h

CESM

TRMM

CMORPH



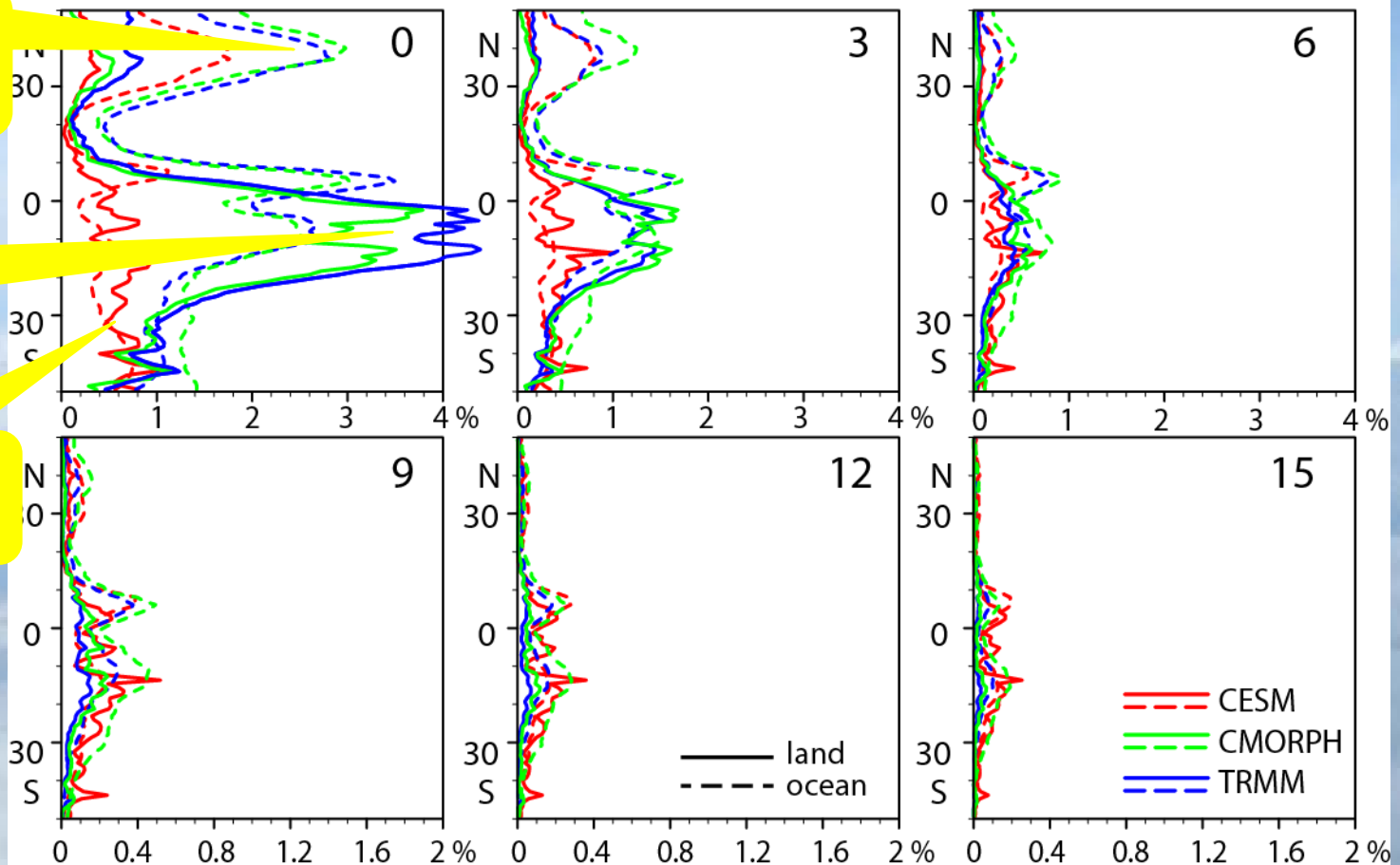
Heavy rain
Duration

Note nonlinear scale



Heavy rains

Zonally Averaged DJF Total Fraction of Duration (2.0 mm h^{-1})



Duration of events

Consider precipitation rates of 1 mm h^{-1} .

For a daily mean:

- This could arise from 1 mm h^{-1} every hour for 24 hours.
- Or it could arise from 24 mm h^{-1} for 1 hour and then all zeros.
- Or it could be from 12 mm h^{-1} for 2 hours and then zeros; etc.

If R is the average precipitation rate for a rainy spell of duration d , then $A^{24} = \sum R \cdot d = R \cdot \bar{D}$, where A^{24} is the 24-hour amount.

D is total duration, R is mean rain rate when raining.

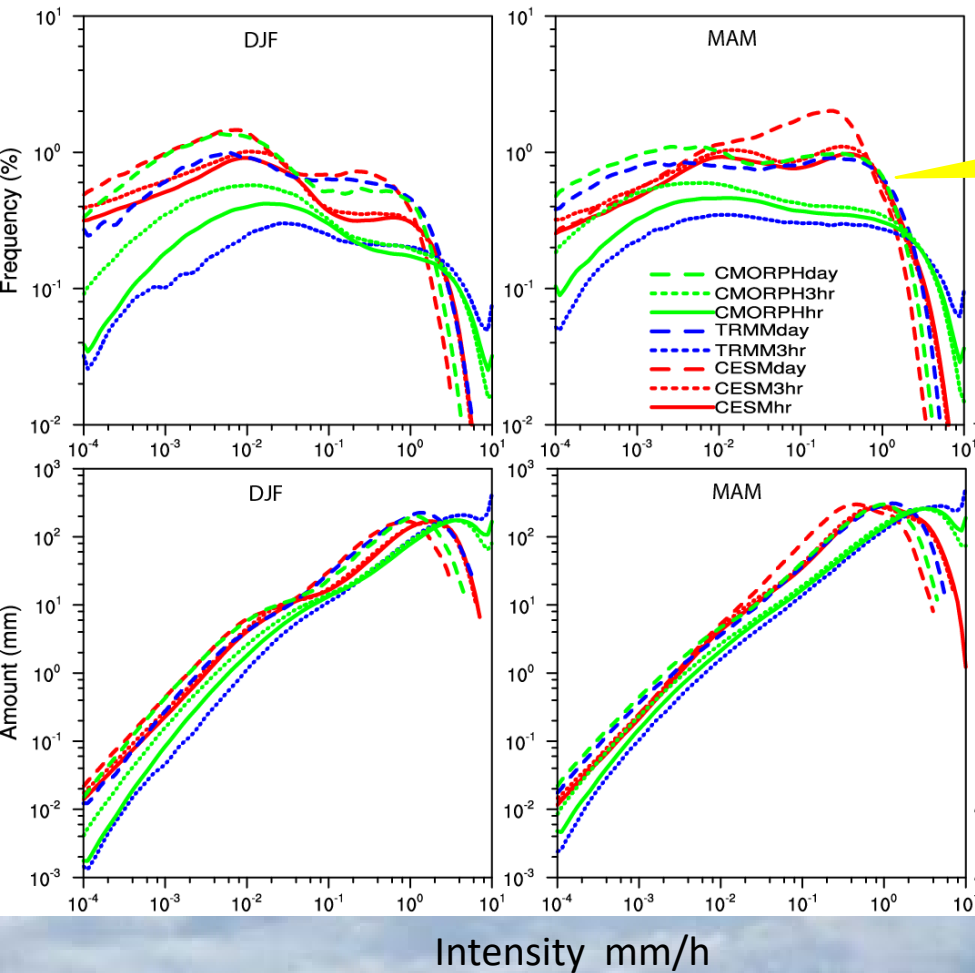
The fraction of time it precipitates F is always longer for a longer average, but the intensity will be less unless continuous.

$$F^{24} > F^3 > F^1$$

e.g. we define $D = 24F^1 / F^{24}$, and it ranges from 1 for 1 hour of precipitation to 24 for continuous precipitation.



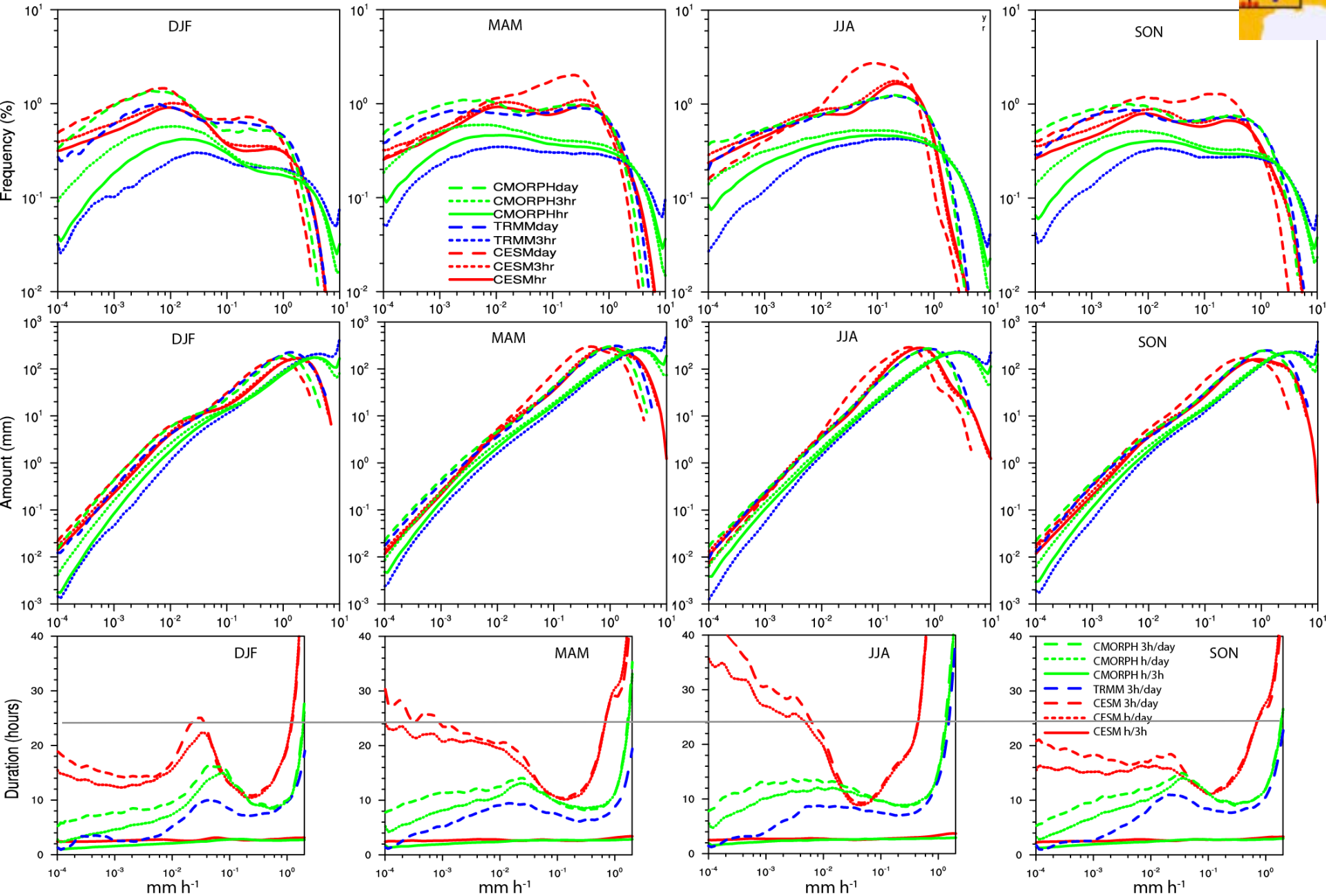
30-40°N 100-90°W SE U.



Tendency to shift to left with averaging, as well as to lower values



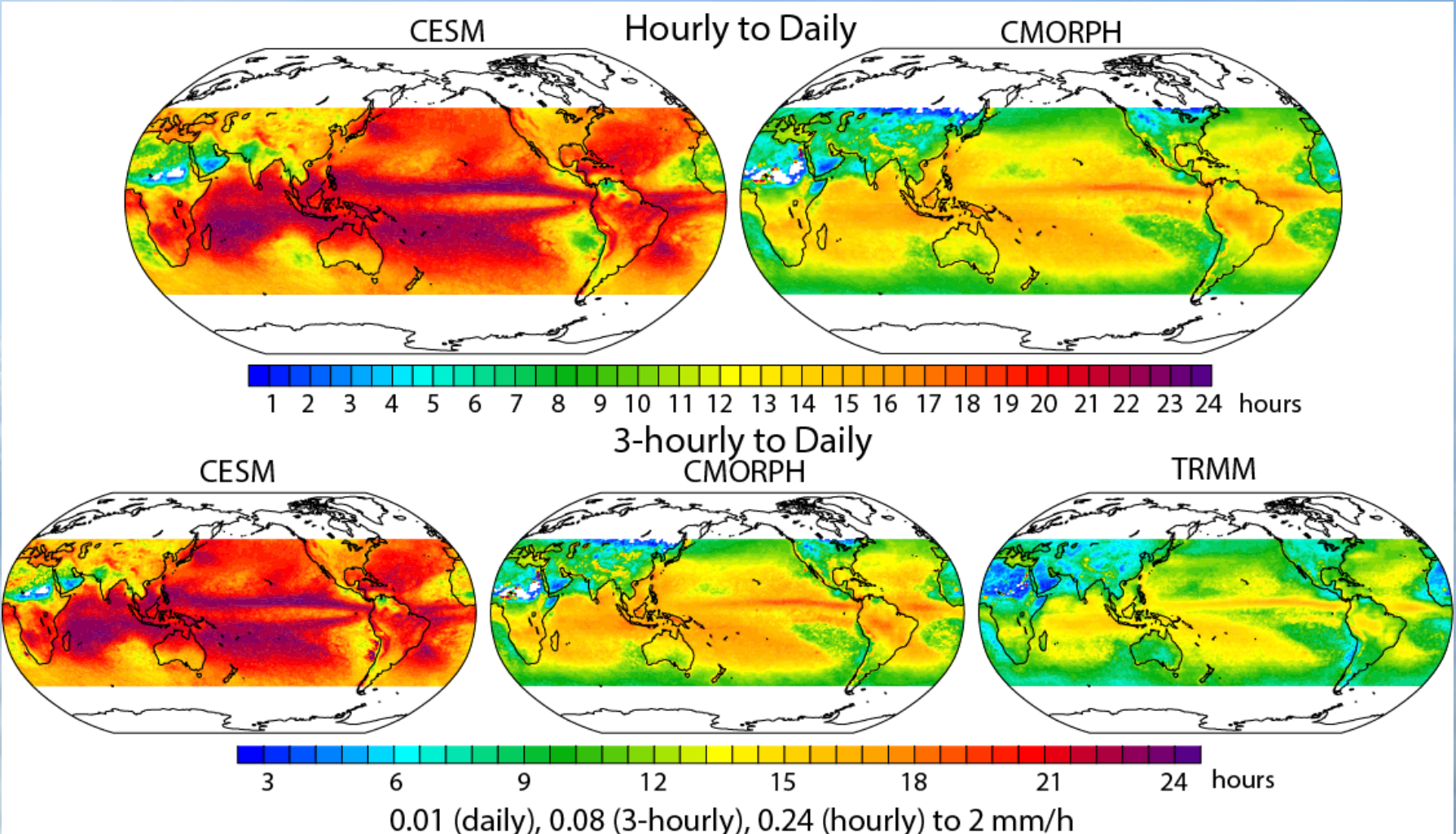
30-40°N 100-90°W SE U.S. Precipitation



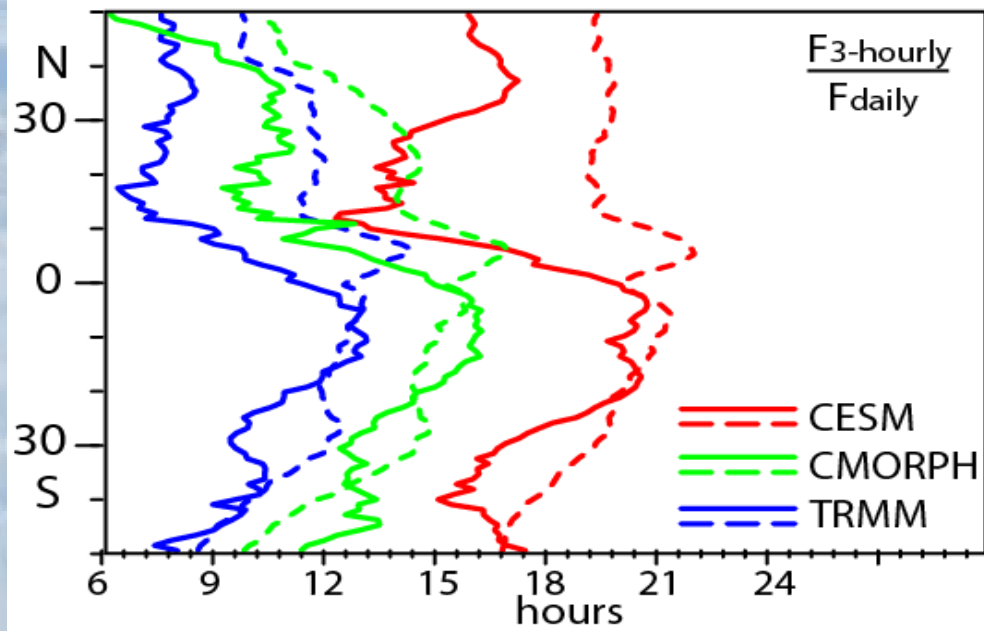
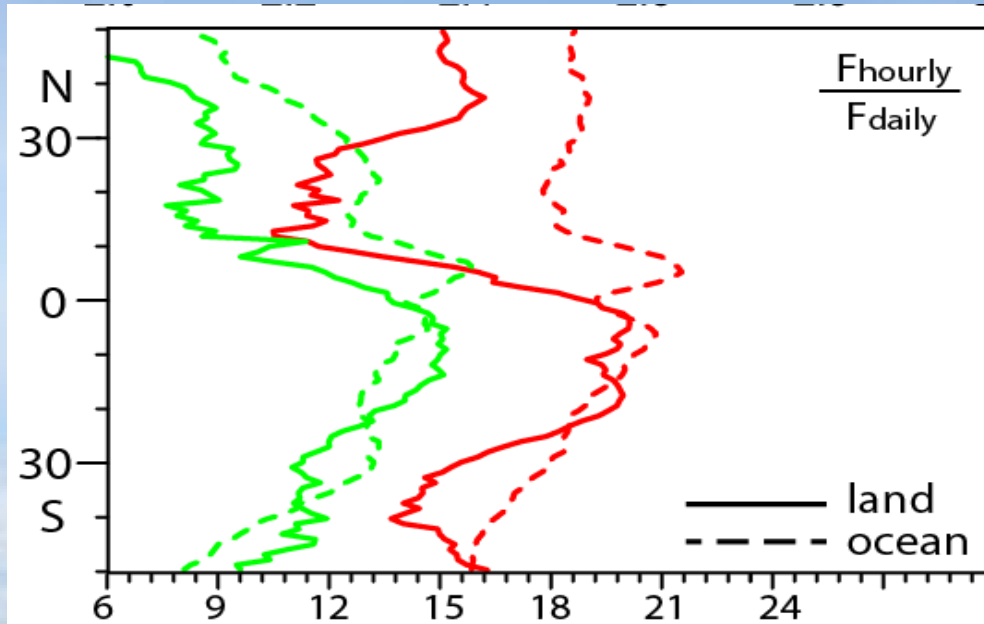
Duration of events

Precipitation Frequency Ratio DJF

Based upon ratio of e.g. hourly to daily



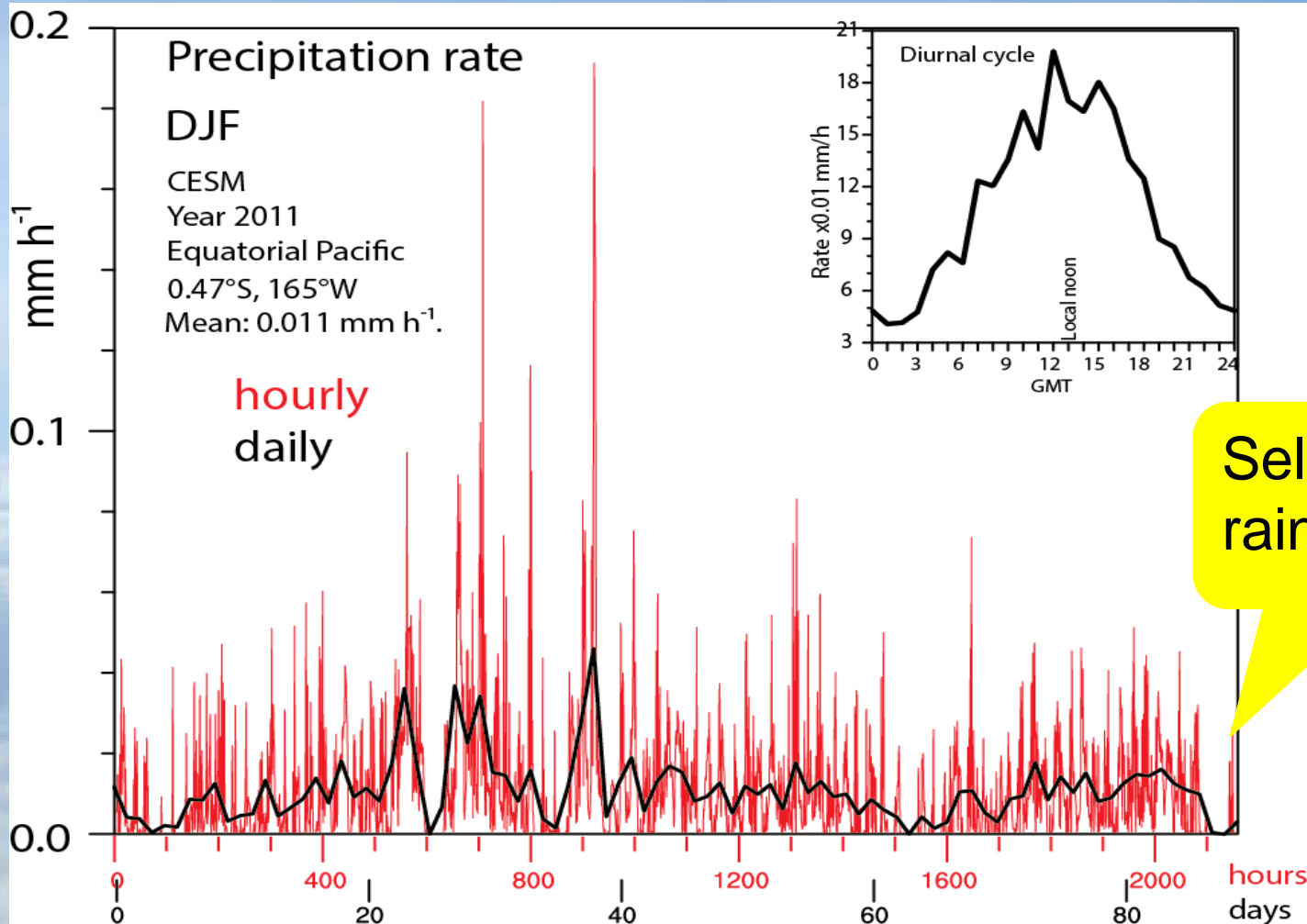
DJF Zonal average duration



TRMM about 15-20% less than CMORPH; CESM much greater.



Problem points



Leakage from or to outside of band considered.

A trace of rain is defined as < 0.01 inches (0.25 mm) in 24 hours.

Here we have almost continuous drizzle at trace amounts every 12 hours.



Some conclusions

- The most frequent rains are in ITCZ, SPCZ and monsoons.

>50% at light rates; >5% at heavy rates.

- TRMM similar in pattern but about 15 to 20% less duration than CMORPH. Especially over land in tropics.

- CESM very different.

- CESM frequency of rain is almost double that

observed. The CESM precipitation also has way too much duration,

but is deficient at high intensity rates > 2 mm/h.

The diurnal cycle likely remains an issue: premature onset.



Outstanding issues

In spite of observational uncertainties:

- CESM has far too much precipitation!
- CESM drizzles and rains lightly far too much at rates less than about 1 mm/h and rains not enough at rates above about 1.5 to 2 mm/hr.

The precipitation has way too much duration.

The diurnal cycle likely remains an issue: premature onset.

The convective parameterization is a major issue.



Some conclusions

*There has often been no attempt to parameterize some phenomena: **tropical storms, hurricanes, MCSs** as if they play no role in the general circulation and climate.*

Yet they do.

The evidence suggests that models like CESM tend to trigger convection prematurely.

The parameterizations are based upon CAPE but may not include CIN. **Convective Available Potential Energy**
Convective INhibition

Having small amounts of rain continually: **perpetual drizzle** does not create the same diabatic heating as having a stronger event only a small fraction of the time, with consequences for teleconnections, Hadley and Walker circulations, and resolved storms like hurricanes.



Some Recommendations

Intermittency is a core characteristic of precipitation, not well described by data and very poorly modeled.

Intermittency deals with the frequency, intensity, duration and amounts: all are fundamental measures of precipitation.

Most studies deal only with **amounts**:

- which matter because they relate to latent heating and the energy budget,
- but this is often distorted in models by cloud radiative forcing (amount, optical thickness, distribution).

But **intensity** and **frequency** matter because they relate to temperature and Clausius-Clapeyron, and where latent heat is deposited affects the stability of the atmosphere.

Need hourly global precipitation datasets and

