Diurnal and semidiurnal cycles of the ITCZ

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Shang-Ping Xie
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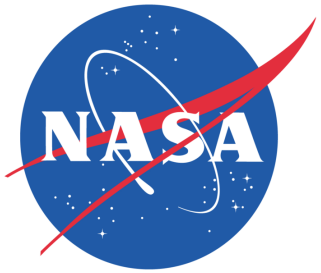


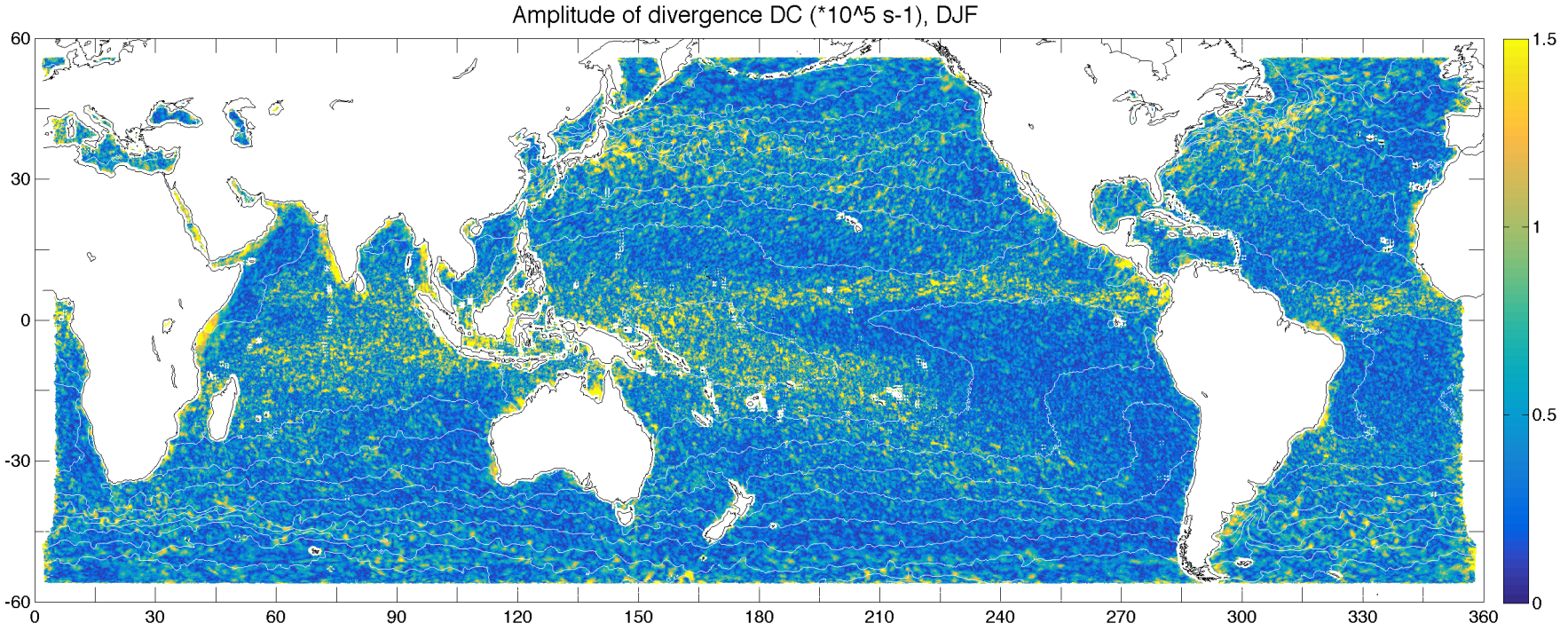
Motivation

The interaction between convection and circulation is a bottleneck in atmospheric science.

Atmospheric convection has a strong diurnal cycle,
due to solar heating over land, sea breeze circulations in coastal areas, and radiative effects (?) in open-ocean regions.

RapidSCAT is well-suited for study of diurnal winds
due to its non-sun-synchronous orbit, opening a window on convection-circulation interaction.

The diurnal cycle of divergence is enhanced in regions of strong air-sea interaction

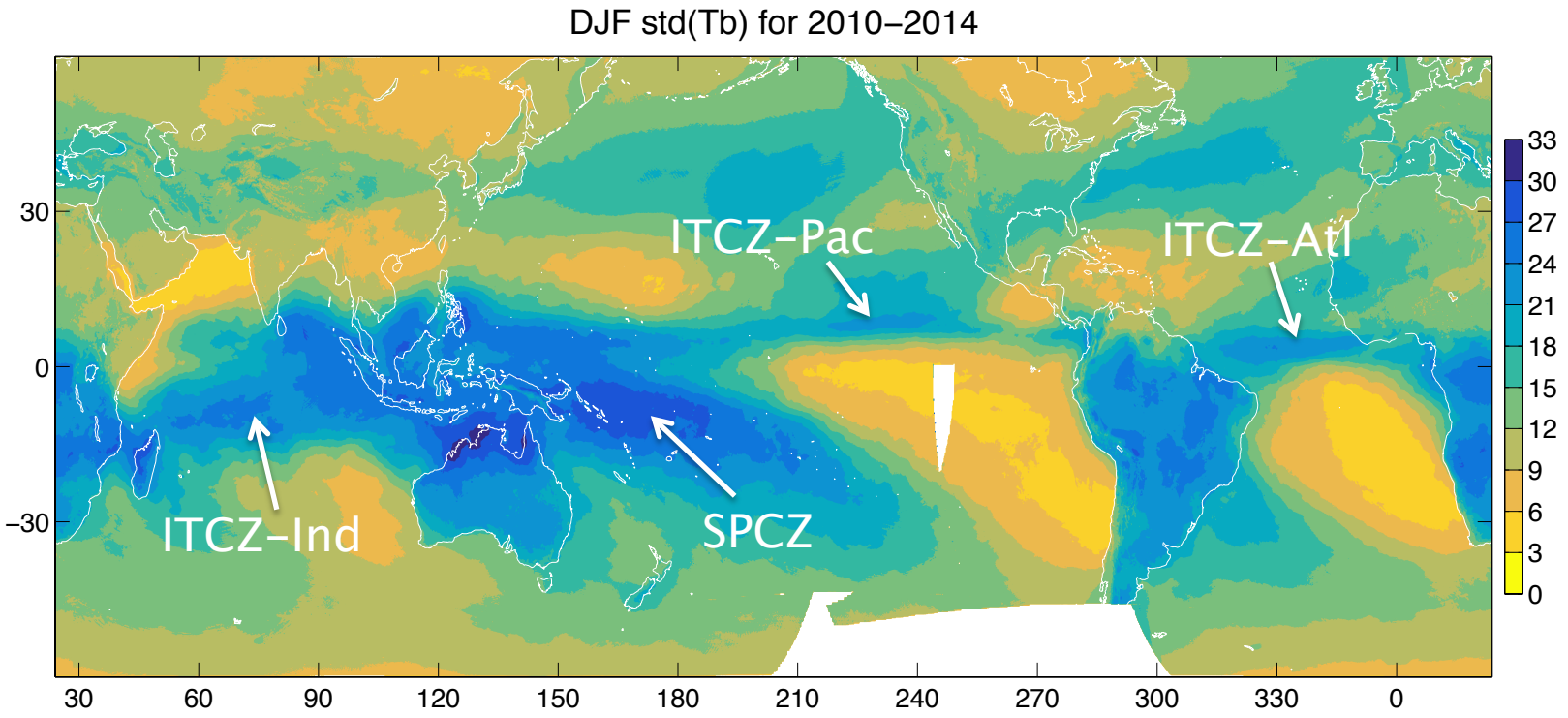


Color = RapidSCAT div. DC amplitude (DJF)
Contours = AMSR SST (DJF)

The RapidSCAT diurnal cycle of divergence picks out regions of strong air-sea interaction:

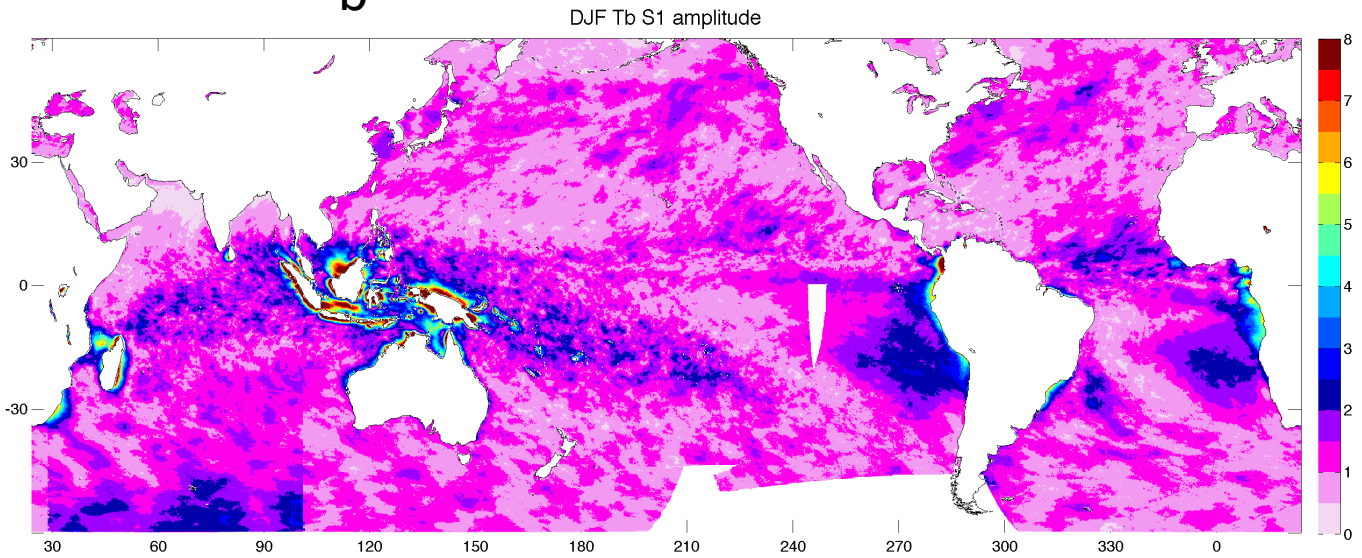
- ITCZ/SPCZ
- Coastal regions with strong sea breezes
- Western boundary current regions

T_b variance shows the strongest convection is in the ITCZ/SPCZ regions

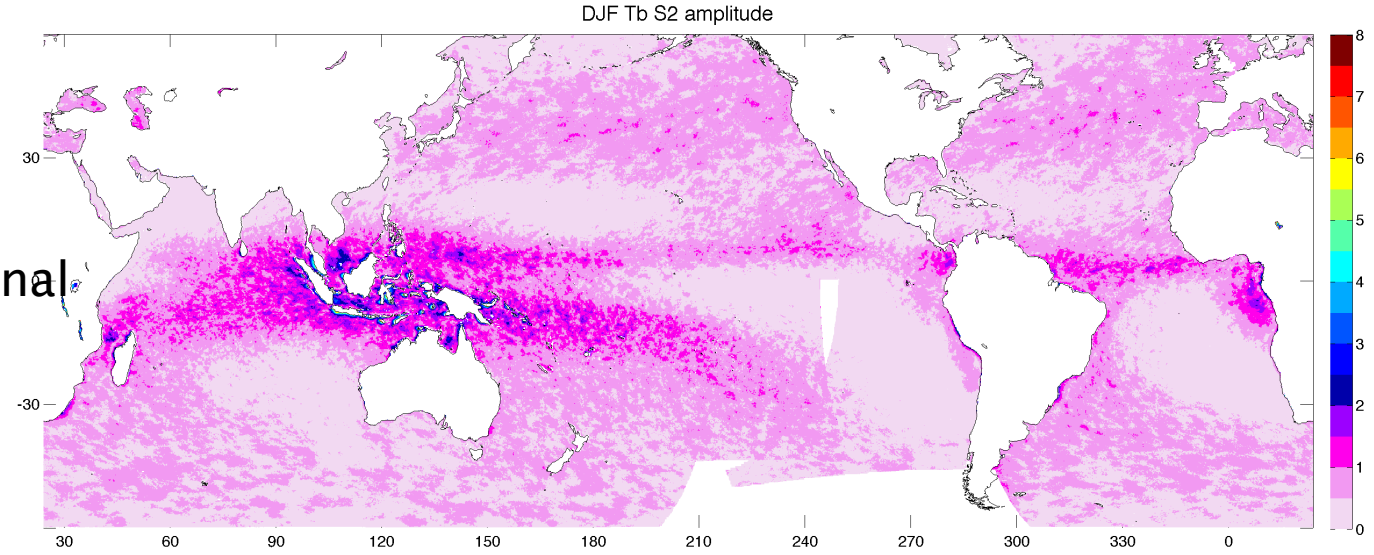


The semidiurnal T_b harmonic is nearly as strong as the diurnal T_b harmonic

Diurnal



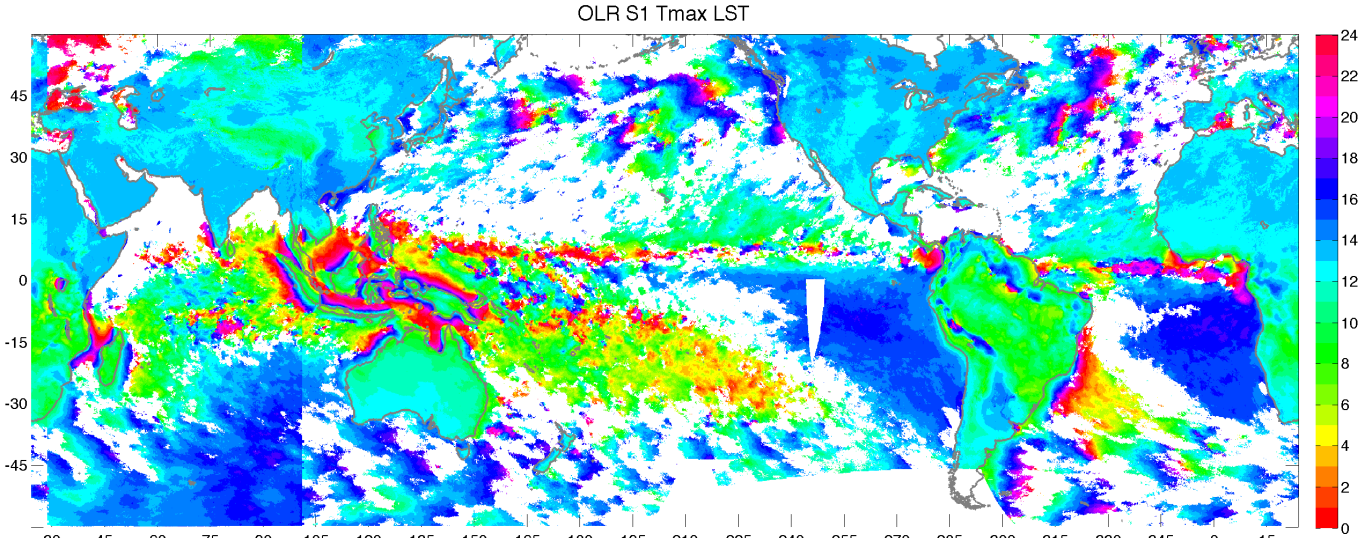
Semidiurnal



Color = amplitude (°C) of T_b harmonic

The semidiurnal T_b harmonic consistently shows coldest clouds tops from 2-5 local time

Diurnal



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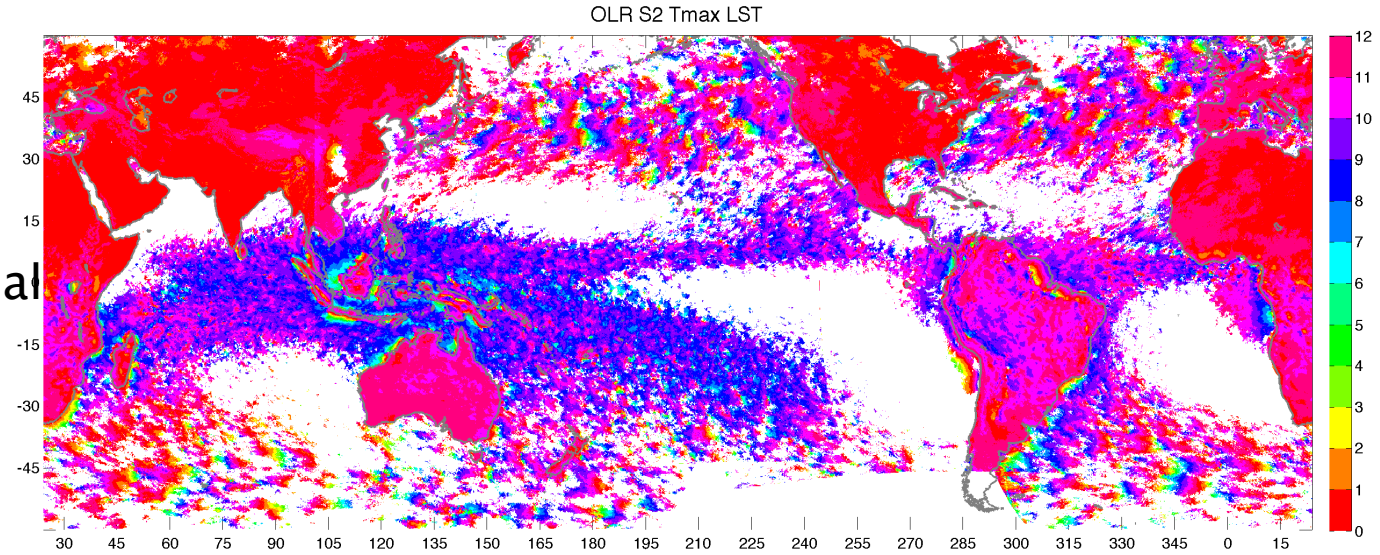


Color = local time of day of max(T_b)

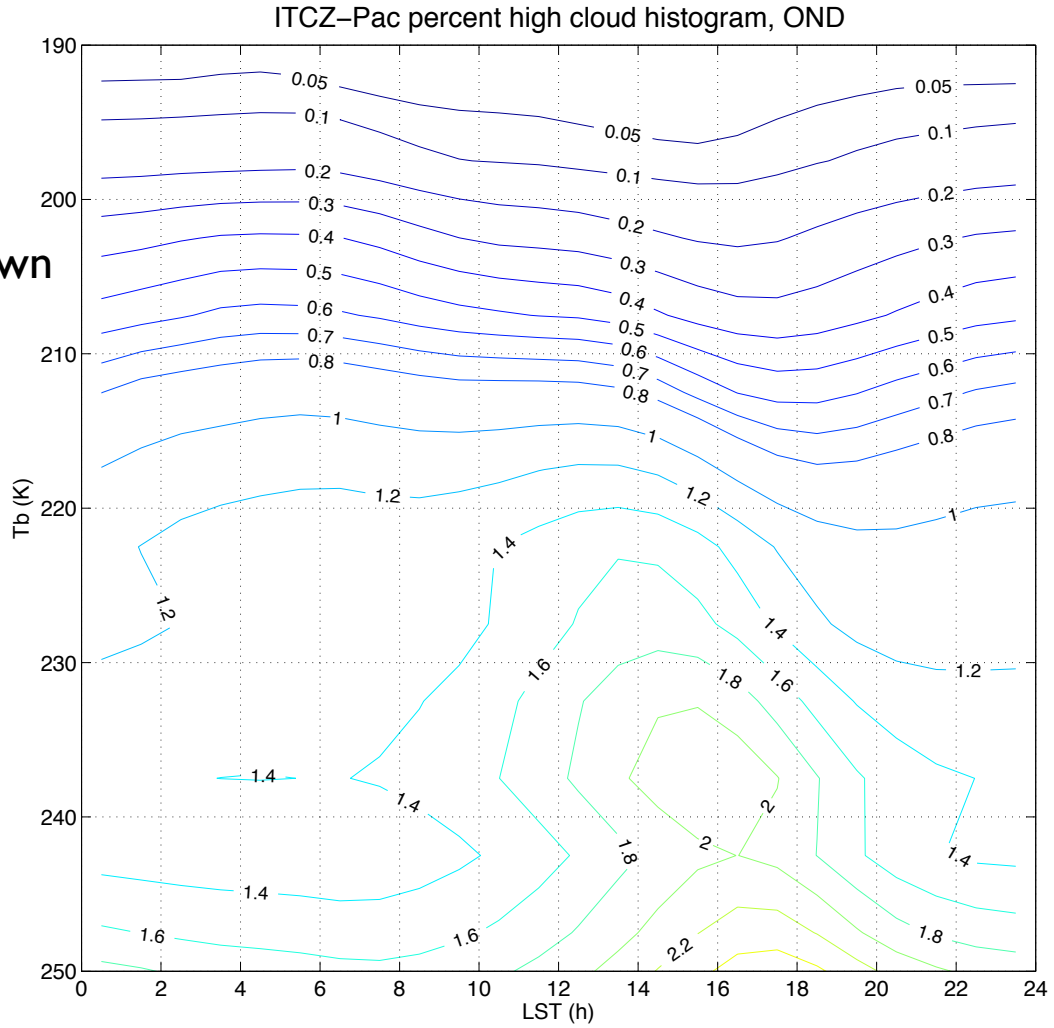
Only the pre-dawn T_b minimum is associated with deep convection

2D histogram of percent high cloud in Pacific ITCZ.

Cloud tops with T_b<208 have a pre-dawn peak.

At lower levels, peak is in afternoon (1400-1600).

See:
Albright et al. 1985
Mapes and Houze 1993
Nitta and Sekine 1994
Chen and Houze 1997
Bain et al. 2010



Summary of OLR harmonic analysis

The semidiurnal T_b variability strongly suggests a dynamical link to the S_2 atmospheric pressure oscillations (atmospheric tides),

e.g. Brier and Simpson 1969.

$S_2 >> S_1$ for tropical SLP.

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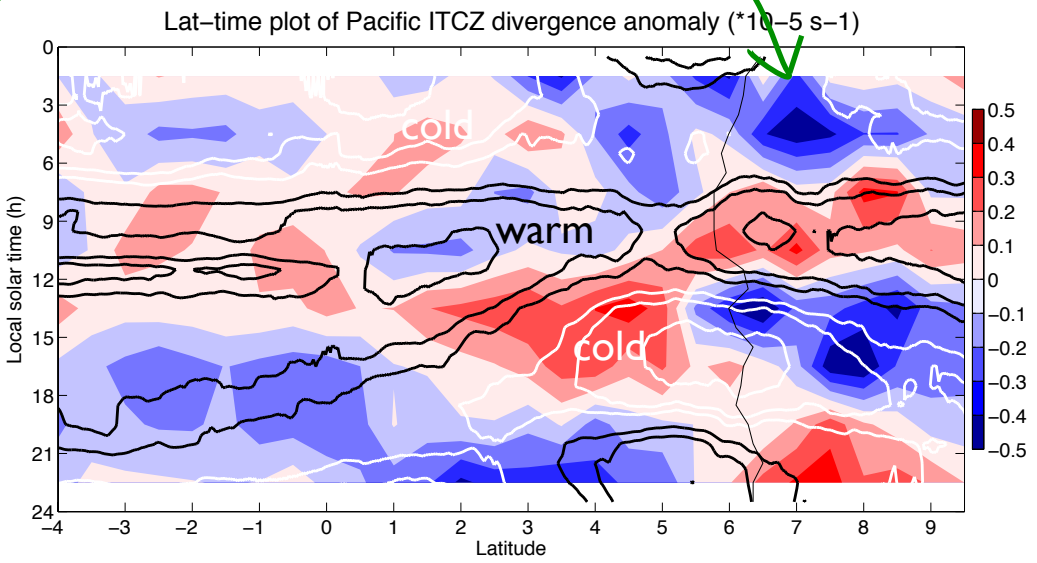
Hypothesis: large-scale moisture convergence by the semidiurnal winds is an important term in the area-averaged *q* budget.

$$g^{-1}\frac{\partial}{\partial t}\int_{p_T}^{p_s} q\,dp = -\nabla\cdot\left(g^{-1}\int_{p_T}^{p_s}\mathbf{u}q\,dp\right) + E - P.$$

RapidSCAT indicates ITCZ divergence is semidiurnal, consistent with OLR

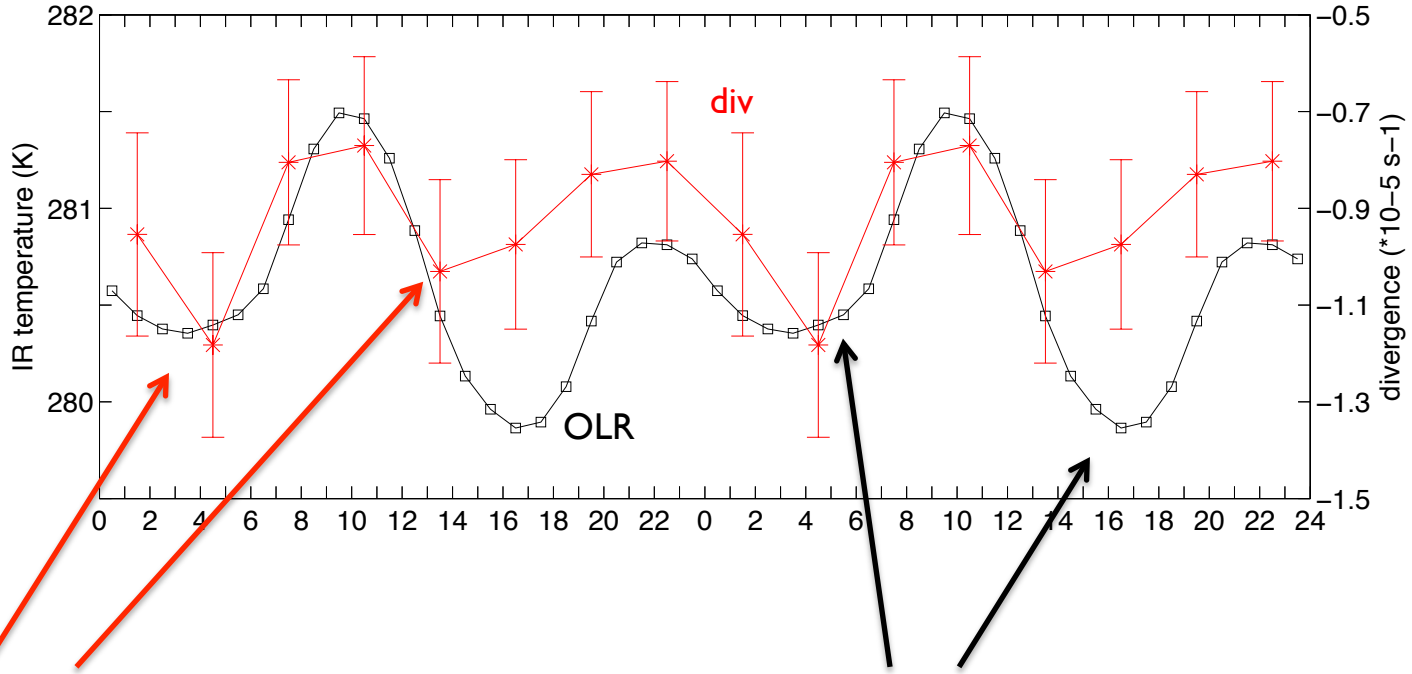
Divergence and T_b are roughly in phase over the ITCZ.

Divergence looks more diurnal south of the ITCZ, consistent with Deser and Smith 1998.



Color = RapidSCAT div ($\times 10^{-5}$ s^{-1})
Contours = T_b anomaly
Black = positive T_b (.25,.5,1,1.5)
White = negative T_b (−.25,−.5,−1,−1.5)

Pacific ITCZ area-averaged divergence dominated by semidiurnal component

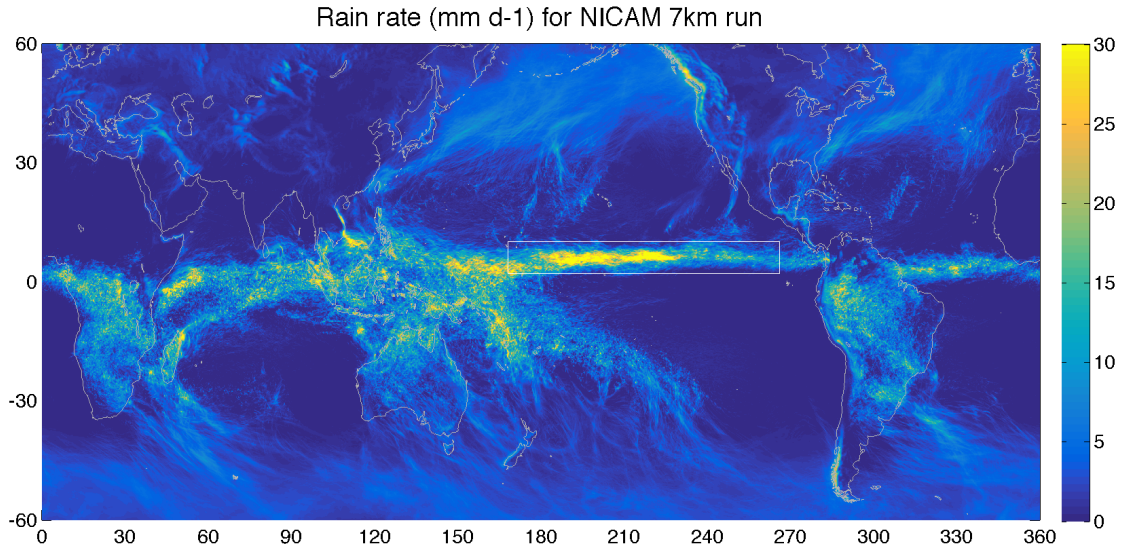


Pacific ITCZ

Convergence peaks pre-dawn and in the early afternoon

T_b minima at roughly the same times

The NICAM model fails to reproduce the ITCZ's semidiurnal divergence signal



NICAM rainfall distribution is pretty good…

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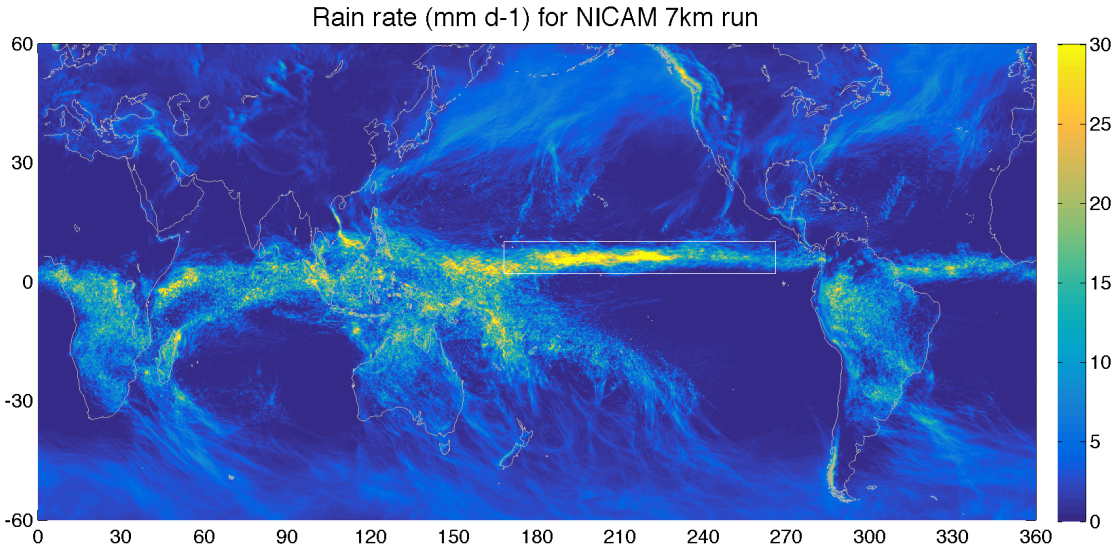

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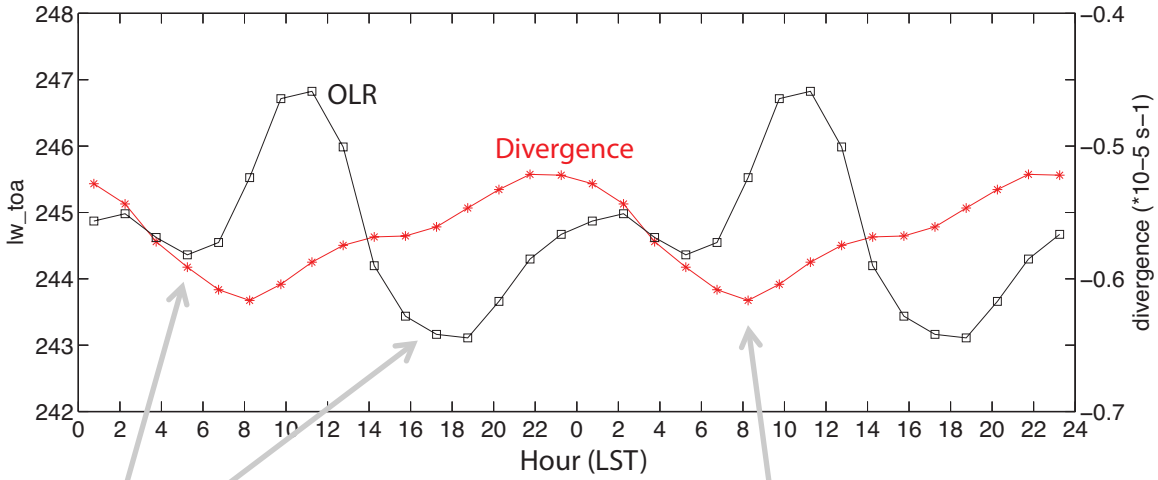

…but ITCZ winds do not show semidiurnal character

Morning/afternoon T_b minima

Peak convergence in morning only

Summary

ITCZ wind divergence looks strongly semidiurnal, suggesting links to the strong semidiurnal signal in OLR.

The pre-dawn T_b minimum is much colder than the afternoon T_b minimum, possibly due to diurnal radiative effects (Randall et al. 1991).

Summary

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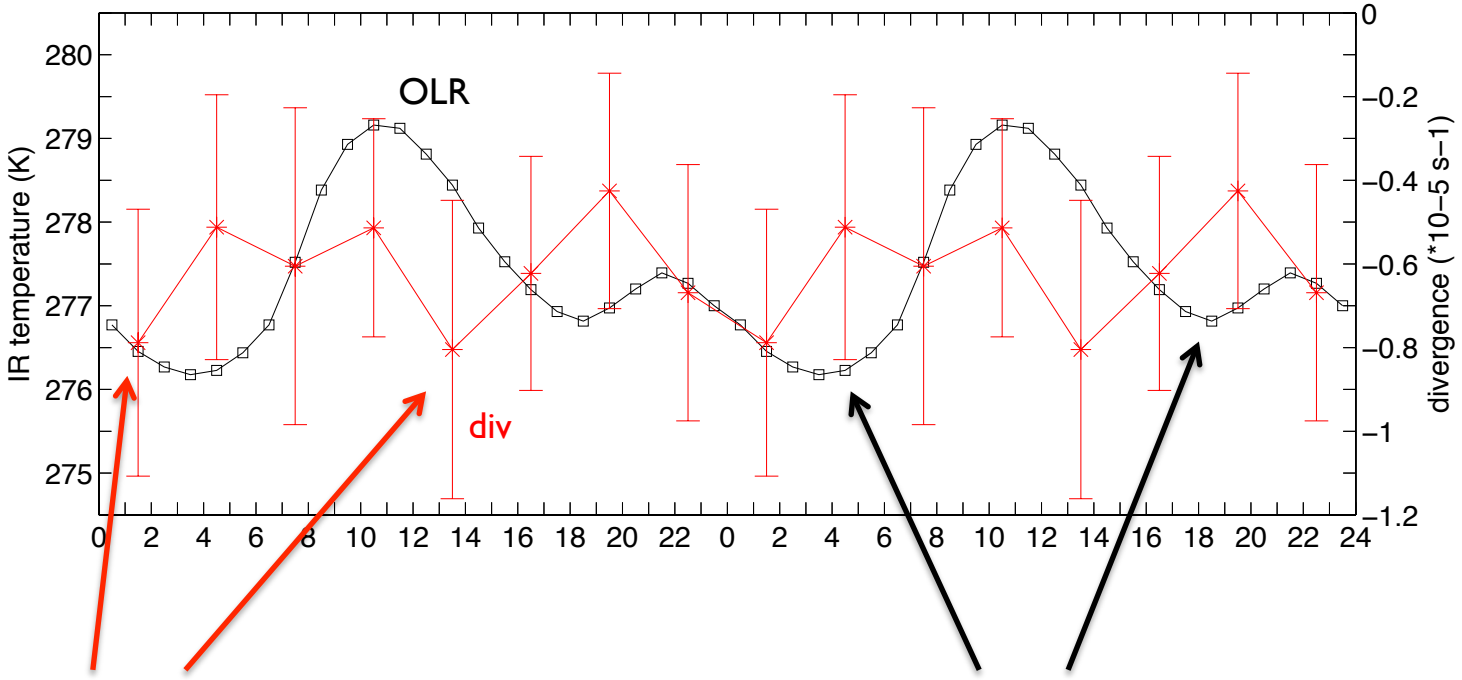
Why does the ITCZ select the semidiurnal frequency?

Lindzen 1978 and Hamilton 1981 suggest that the S_2 atmospheric tide is intimately linked to convection.

Atlantic ITCZ divergence also looks semidiurnal



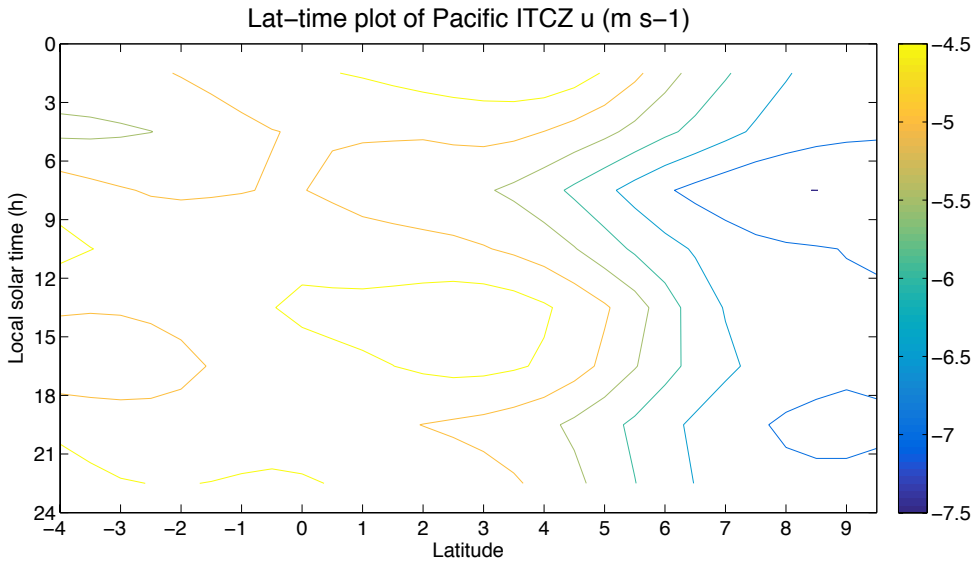
Atlantic ITCZ

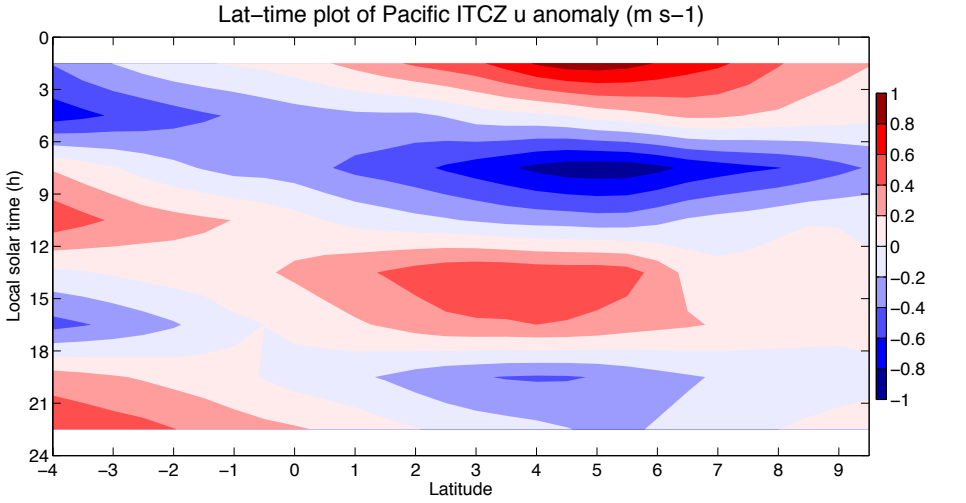
Convergence peaks pre-dawn and in the early afternoon

T_b minima are offset by a few hours

Pacific ITCZ: u

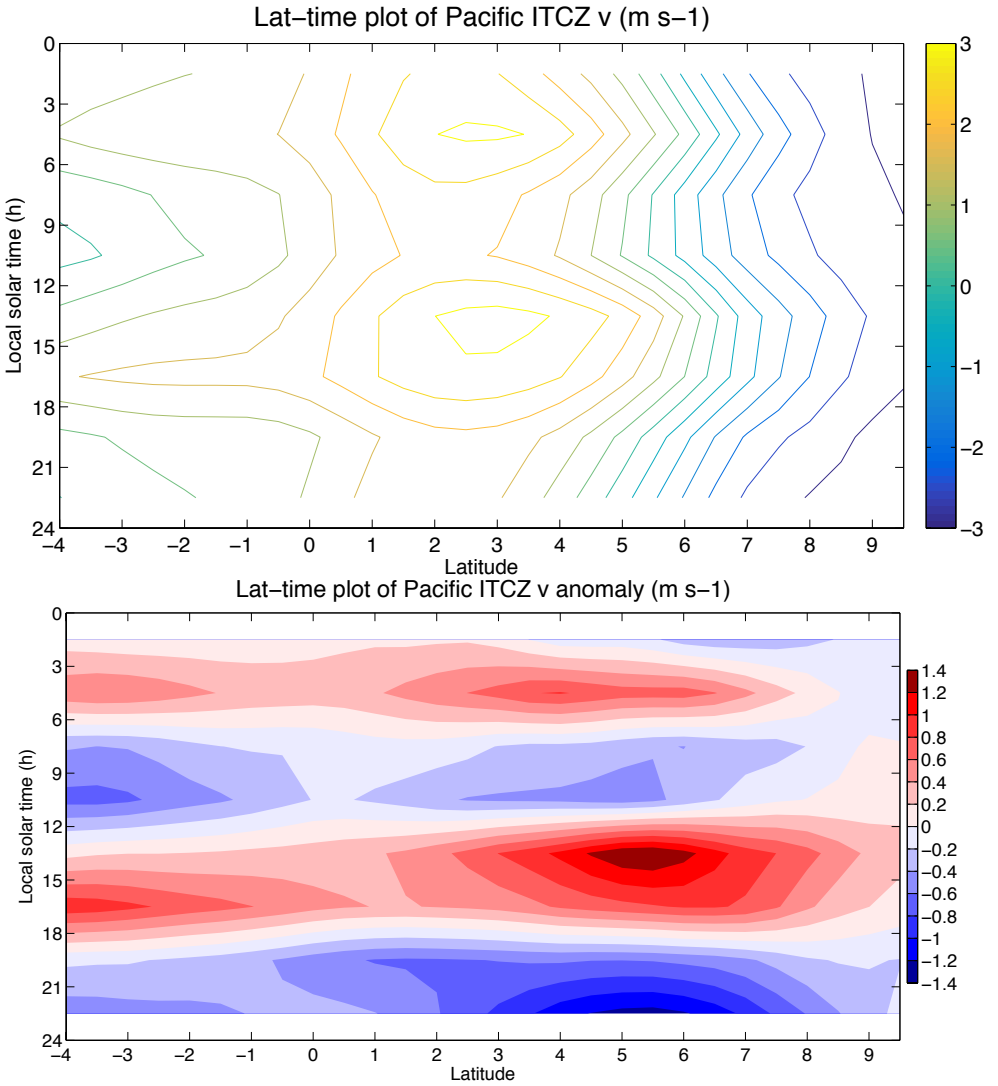
- Easterly trade evident in total *u* (top). 0.5 m/s contours in full *u*.
- Semidiurnal oscillation prominent in departure from time mean (bottom). 0.2 m/s contours in anomaly.
- Note that northern and southern hemispheres appear out of phase. Is this consistent with tidal theory? Should plot for a wider latitude swath.



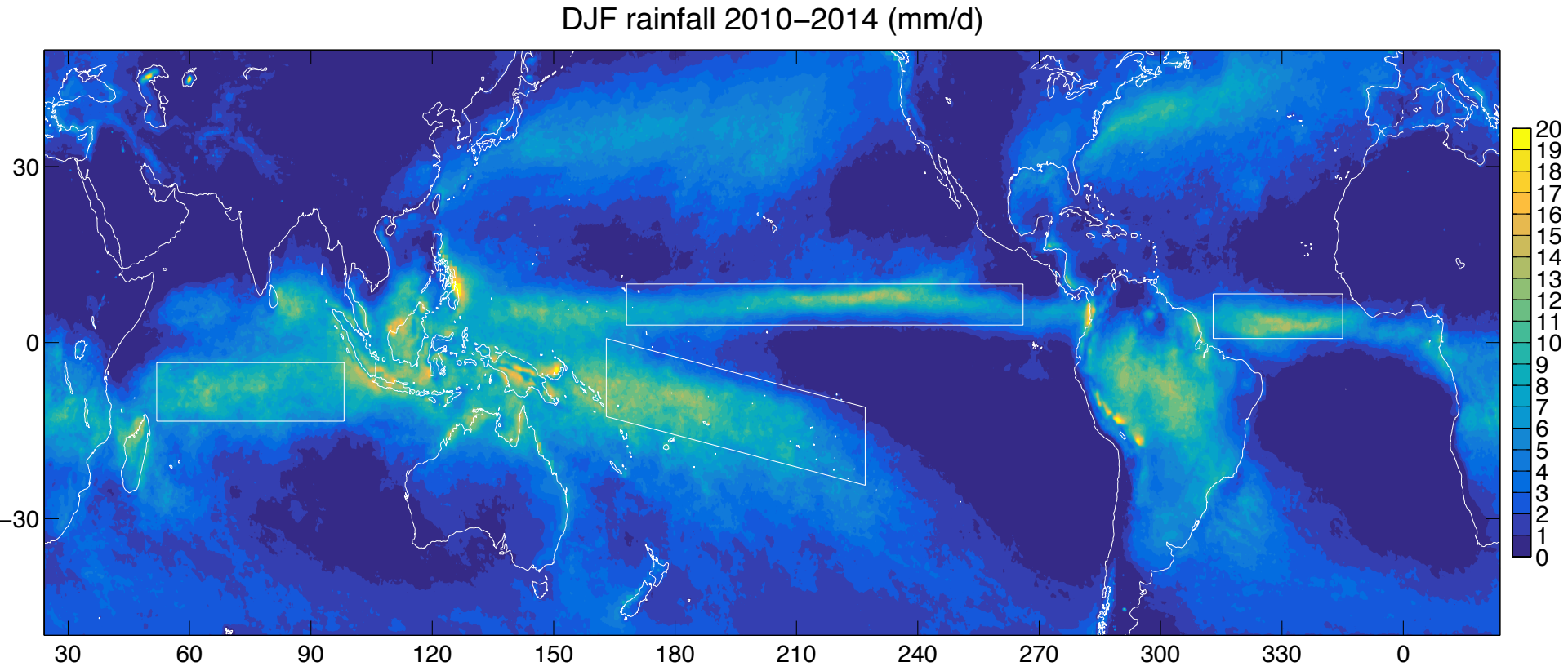


Pacific ITCZ: v

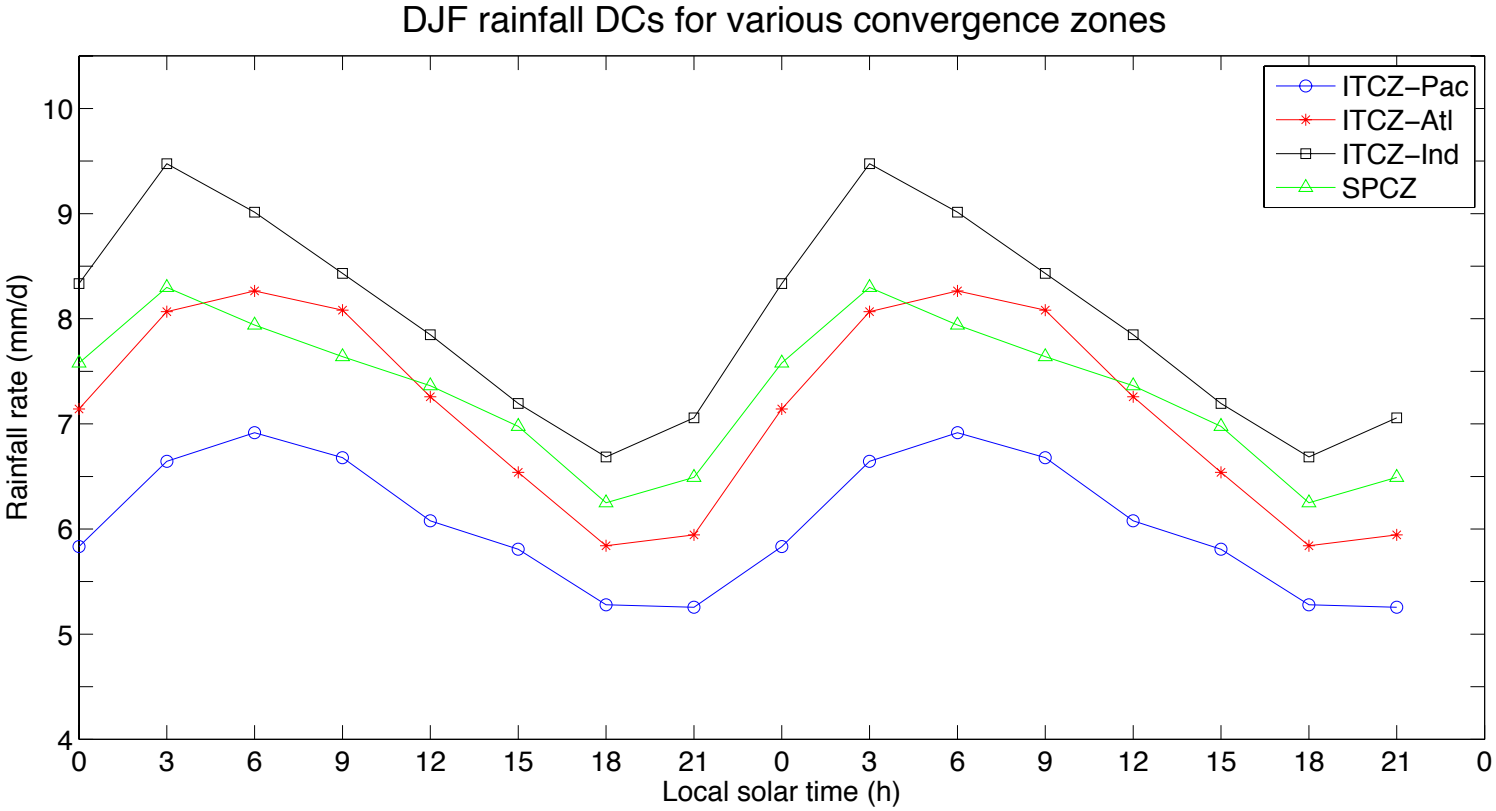
- Semidiurnal oscillation visible even in full field. This contributes a lot of the divergence.
- Again, 0.5 m/s contours on top and 0.2 m/s contours below.
- Northern and southern hemispheres appear more symmetric than for *u*.
- Ueyama and Deser found *v* to be more diurnal, so there is some disagreement here.



We examine TRMM 3B42 rainfall in the same boxes as winds…



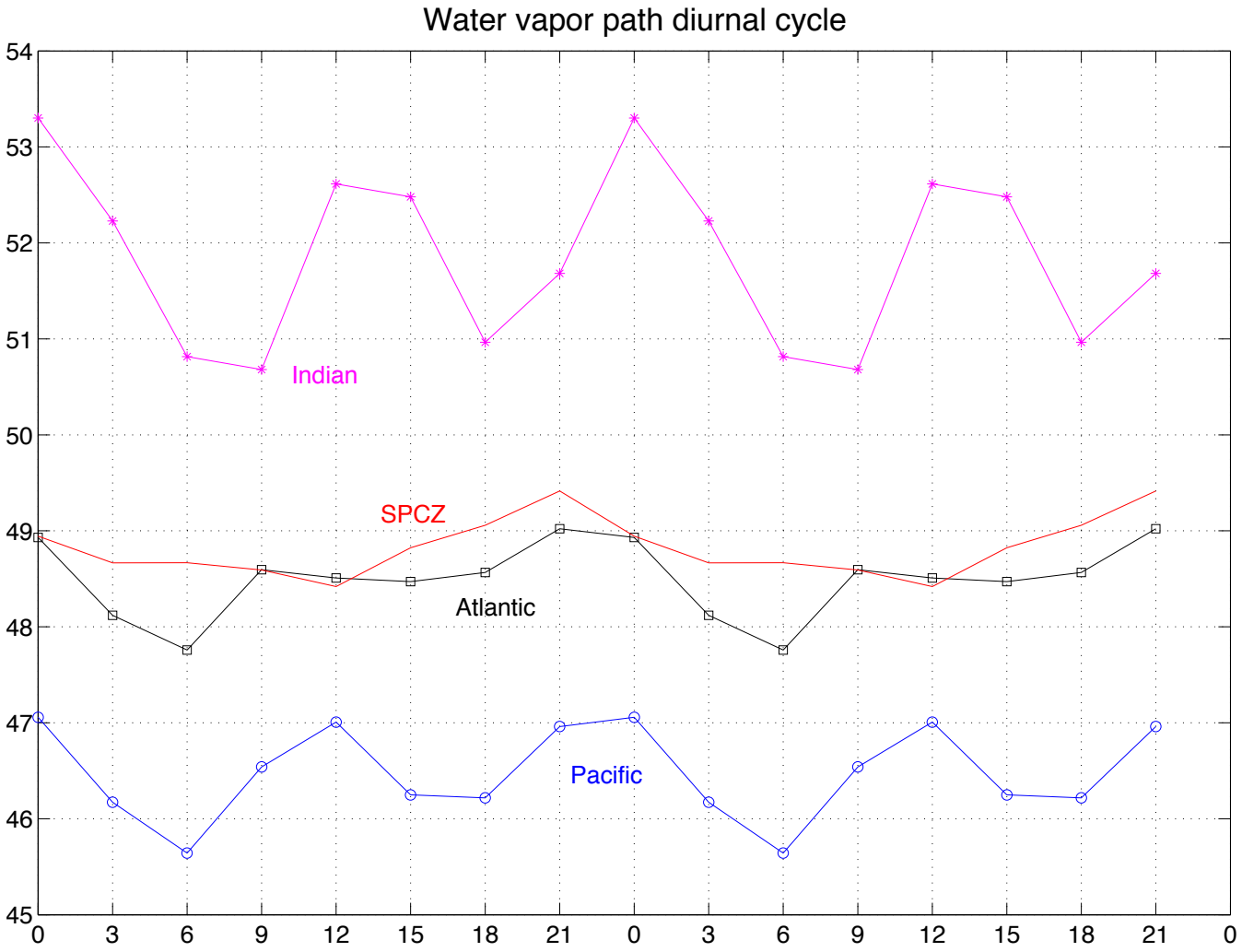
…and find that diurnal rainfall variability dominates in all 4 regions

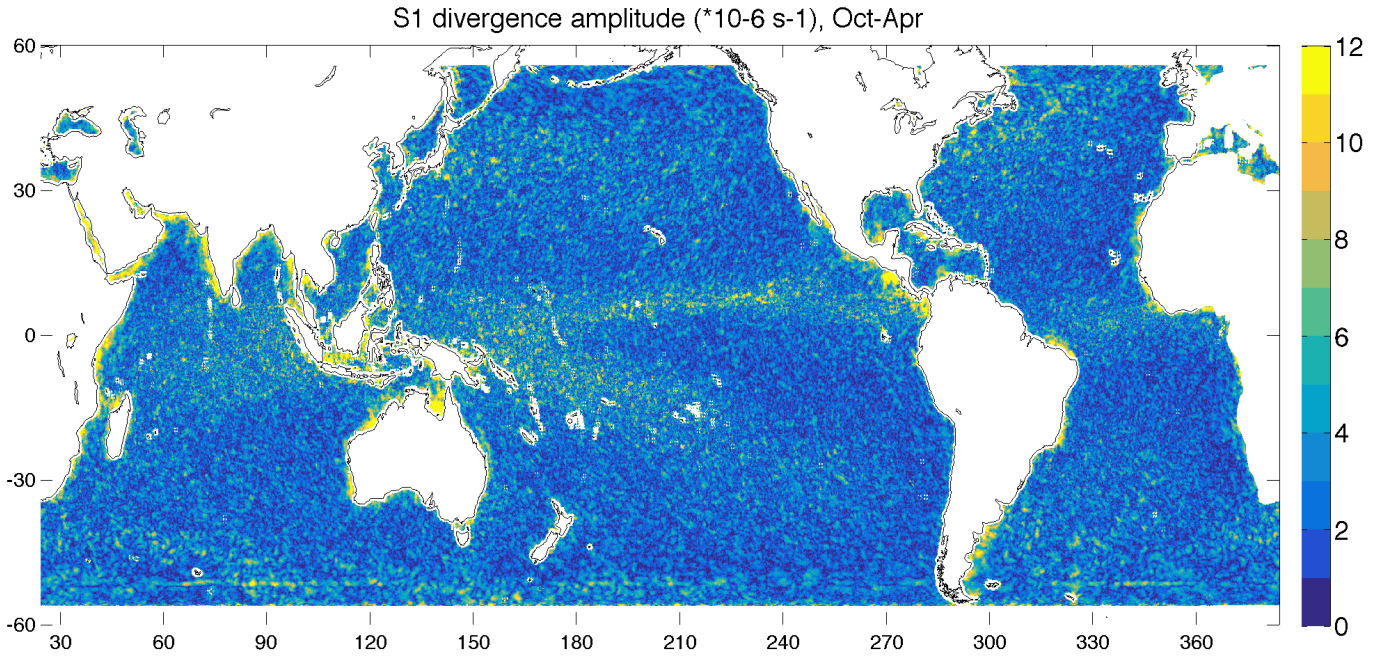


The diurnal rainfall variability is in contrast to OLR,

which has a strong semidiurnal component.

Water vapor also has substantial semidiurnal variability in the ITCZ





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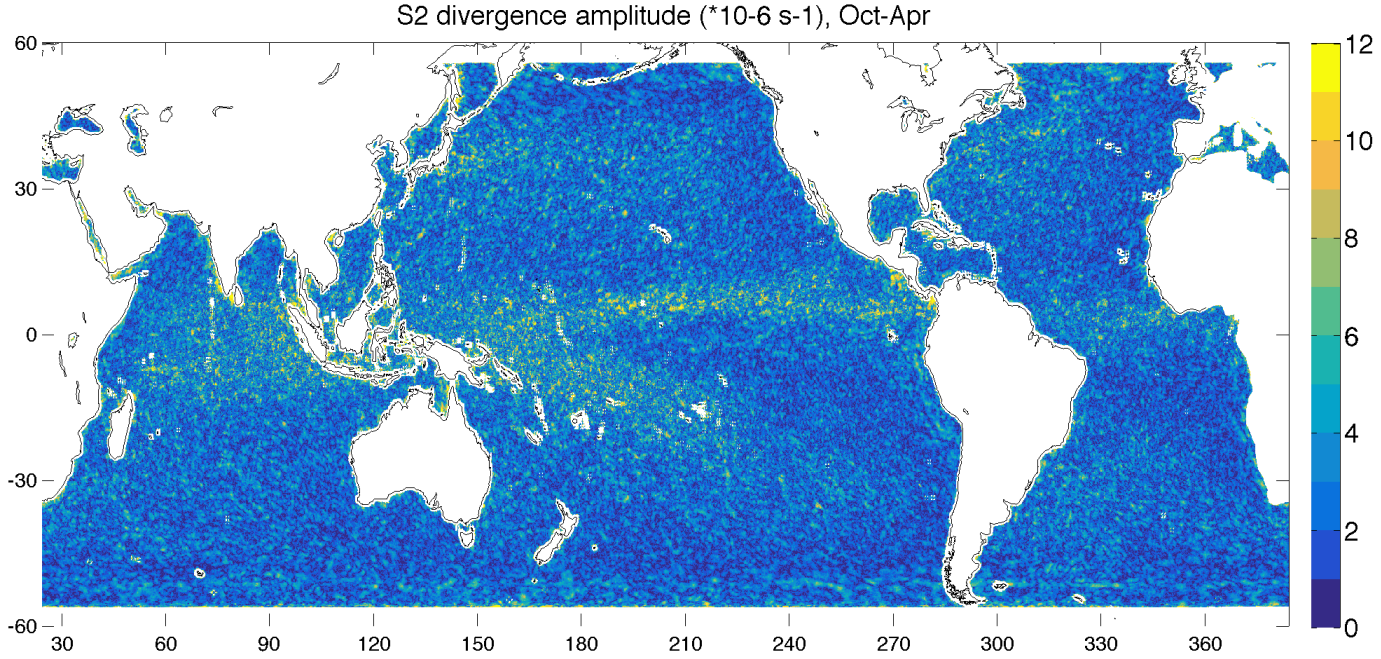

Semidiurnal

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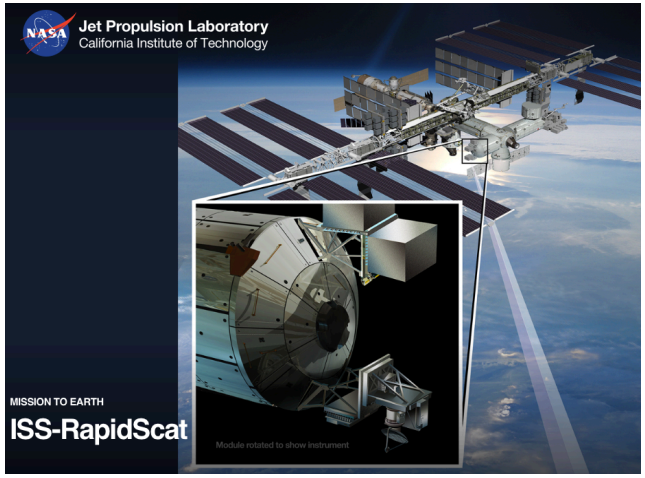

- 2°N