nature geoscience

Article

https://doi.org/10.1038/s41561-023-01215-1

Widespread shallow mesoscale circulations observed in the trades

Pressure perturbations due to moisture heterogeneity

One aspect relevant to the discussion of the study is if moisture-induced buoyancy is sufficiently large to cause/maintain SMOCs?

We estimate how much the observed moisture difference translates to pressure perturbation, because of the virtual buoyancy effect. Similar to Equation-1 of Yang [50], we note the horizontal momentum equation for the sub-cloud layer as:

$$-\frac{1}{\rho_o}\partial_x p - \frac{u}{\tau} = 0 \tag{1}$$

where ρ_o is the reference density in the layer, $\partial_x p$ is the horizontal pressure gradient, u is the perturbation horizontal velocity and τ is a damping term parameterizing friction. From Fig. 3a, the difference between the $\mathcal{D}'$ composites at top of the sub-cloud layer translates to $u = 1.2$ m s^{-1} for a SMOC branch of 100 km width. We assume $\tau = 1$ day. Thus, substituting the above values in Equation-1, for an average density of 1.11 kg m^{-3} at this altitude, the pressure perturbation comes to $\sim$1.54 Pa.

The density perturbations only due to moisture differences is,

$$\delta\rho = \rho_o \cdot \epsilon \cdot \delta q_v \tag{2}$$

where ϵ is the ratio of the molar masses of dry air and water vapor subtracted by one and δq_v is the moisture difference. From Fig. 3c, we find a difference of 0.7 g kg^{-1} almost throughout the sub-cloud layer. This gives a density perturbation of 0.48 g m^{-3}. Estimating the pressure gradient averaged over the sub-cloud layer can be given as,

$$\overline{\delta p} \approx \frac{\overline{\delta\rho} g h}{2} \tag{3}$$

where g is the gravitational acceleration of the Earth near the surface and h is the sub-cloud layer top (600 m). This comes to a pressure perturbation of $\delta p \approx 1.41$ Pa, which is not far from the estimate of 1.54 Pa perturbation from the divergence composites.

However, it must be noted that the assumptions behind these estimates are not validated and hence, we refrain from quantifying these estimates in the manuscript. For example, large day-to-day variability in the frictional component has been estimated by Nuijens et al. [51] from these same field measurements. Also, buoyancy contributions from temperature differences haven't been included here (although discussed later). Modelling will thus be necessary to evaluate what sets the strength and scale of the observed circulation.

For the same perturbation pressure as due to moisture difference δq, the temperature difference would have to be,

$$\delta T = \frac{\epsilon \cdot T \cdot \delta q_v}{1 + \epsilon \cdot q_v} \tag{4}$$

Mean values of T and q_v in the sub-cloud layer are $\sim$297 K and $\sim$15 g kg^{-1}, respectively. Therefore, for a pressure perturbation due to 0.7 g kg^{-1} moisture difference, the equivalent temperature difference would have to be $\sim$0.13 K.

If we assume that q_v and T contribute equally to the buoyancy flux, i.e.

$$w'q_v'\epsilon T = w'T' \tag{5}$$

then the ratio of latent to sensible heat fluxes becomes,

$$\frac{\mathrm{LHF}}{\mathrm{SHF}} = \frac{L_v}{\epsilon \cdot T \cdot c_p} \tag{6}$$

where L_v is the latent heat of vaporization and c_p is the specific heat at constant pressure. For $T = 297$ K, the ratio of latent to sensible heat fluxes comes to 13, which is of the same order of magnitude as found in EUREC^{4}A observations [52].

Therefore, temperature perturbations of an expected magnitude can also suffice to maintain a perturbation pressure for SMOCs. However, as also explained previously, from the observations alone it is difficult to ascertain if the proposed mechanism is active, and modeling efforts need to be undertaken to answer this question.

References

[50] Da Yang. "Boundary Layer Height and Buoyancy Determine the Horizontal Scale of Convective Self-Aggregation". In: *Journal of the Atmospheric Sciences* 75.2 (2018), pp. 469–478.

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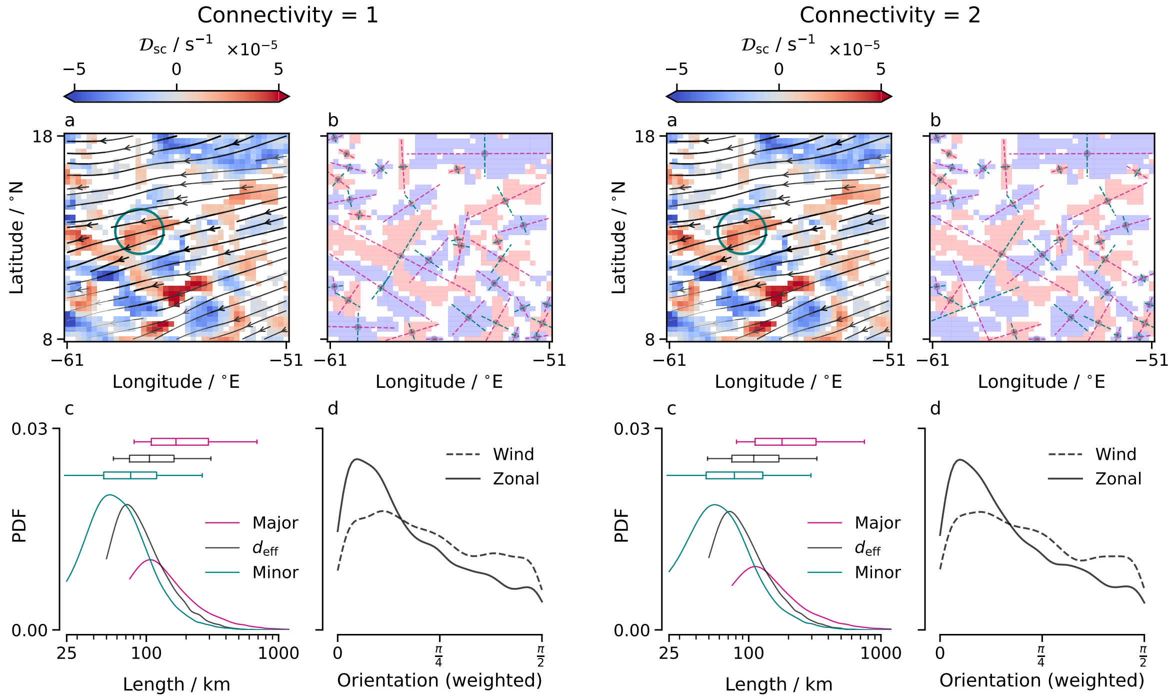

SI-Fig. 1: Same as Fig. 4 in original manuscript, but shown here for the two different connectivity types.