No decrease of tropical convection in deep convective systems with global warming

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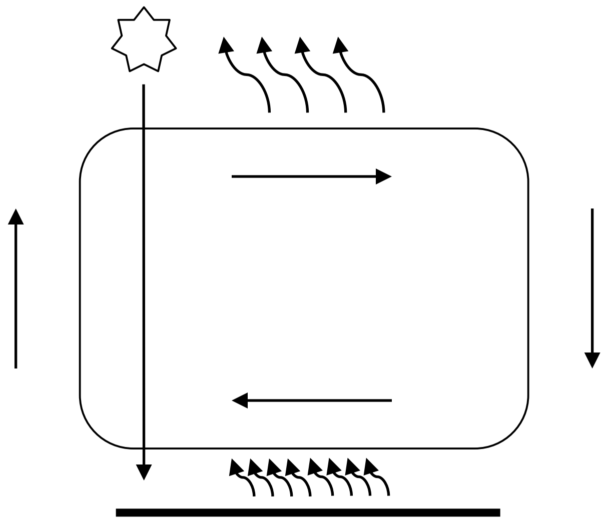
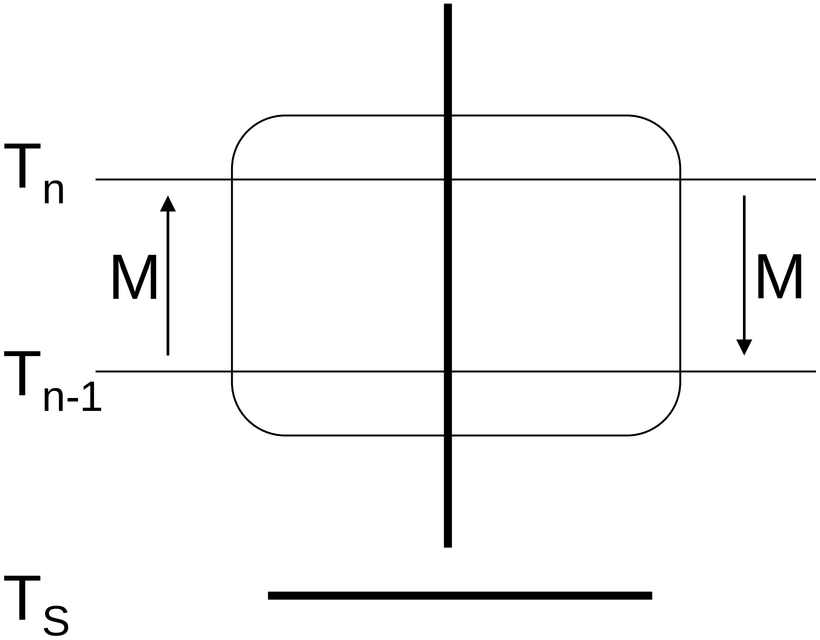
Thermally direct circulation in the tropics



- **Heated from below** by surface absorption of **solar** radiation
- **Cooled from above** by **infrared** emission to space
- Thermally direct circulation
- **Ascending:** deep convection converts PE into KE
- **Descending:** radiative cooling

Decrease with warming of the circulation

(simplified: no moisture effects)



- **Mass flux ascending = descending** (= M)
- **Radiative cooling** balances **downward advection of energy** in descending branch:

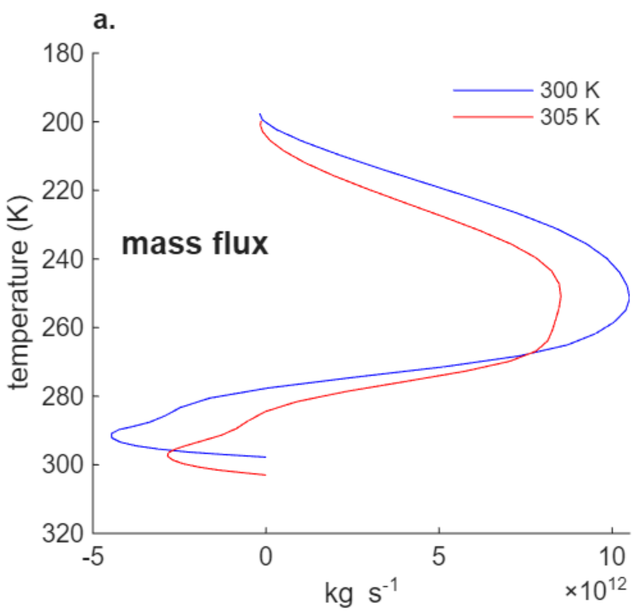
$$M \frac{\partial s}{\partial T} = \frac{\partial F_{rad}}{\partial T}$$

s = dry static energy
F_{rad} = radiative flux

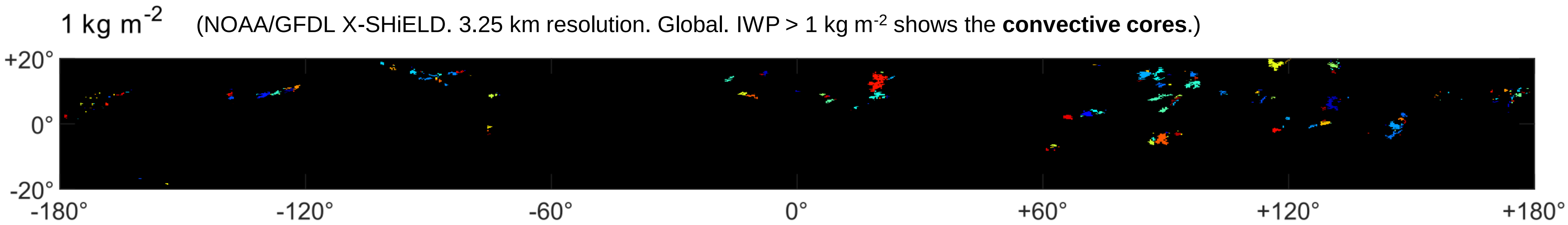
- When $\mathbf{T_S}$ **increases…**
- **Radiative cooling stays constant** between isotherms ($\frac{\partial F_{rad}}{\partial T}$)
- **Static stability increases** ($\frac{\partial s}{\partial T}$)
- **M decreases**

Decrease with warming of the circulation

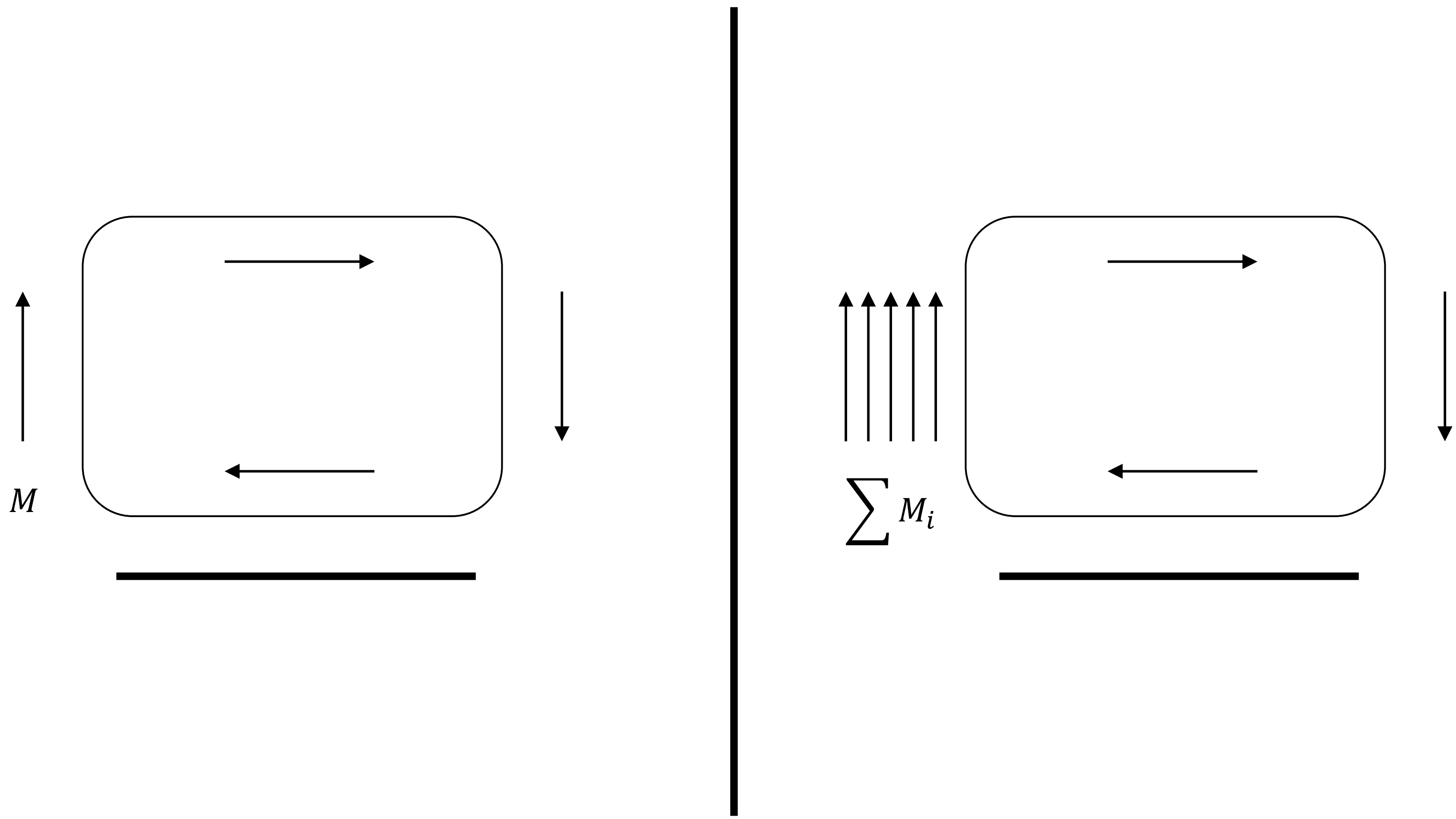
(SAM version 6.11.12. 3 km resolution. RCEMIP long channel.)



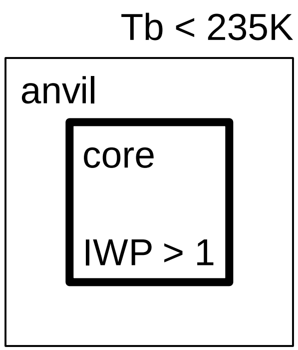
Convective mass flux = multiple storms

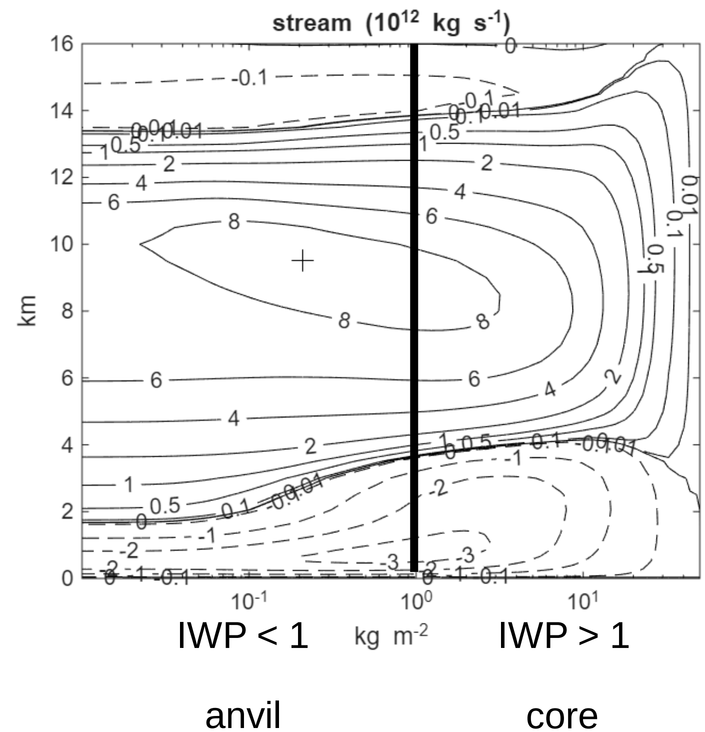


Convective mass flux = multiple storms



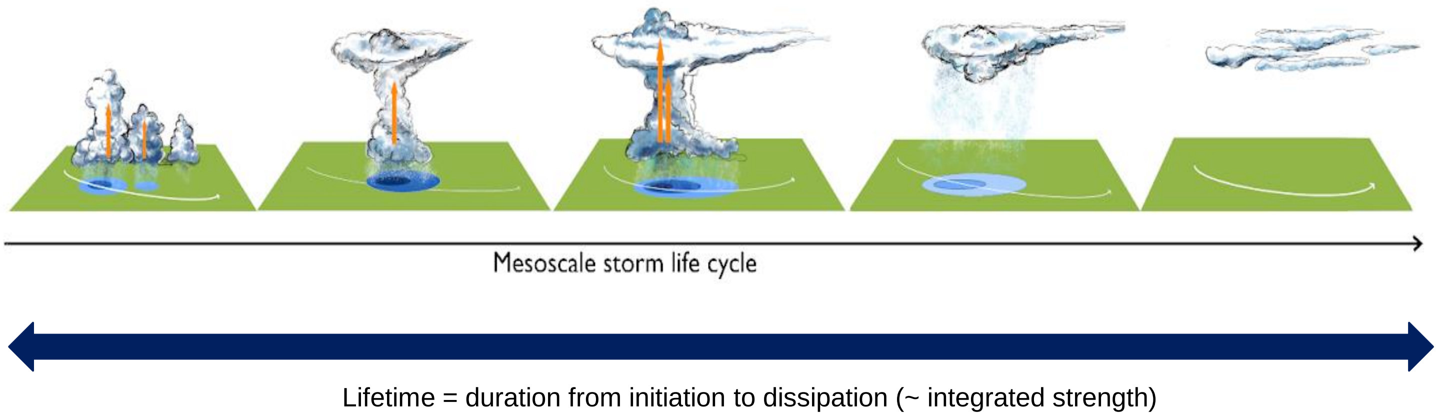
The cores inside the storms do the transport





- **Convective core** is where transport is **mostly vertical**

Storms undergo a lifecycle

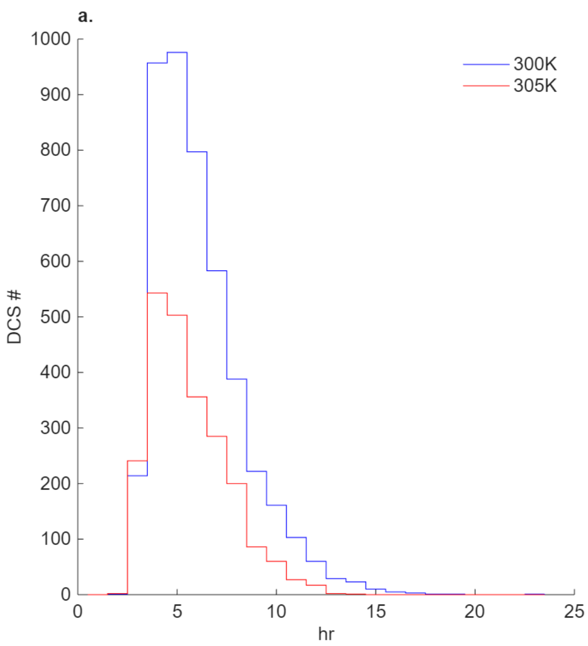


- Initiation, growth, decay, dissipation
- **Storms propagate** as they undergo their lifecycle

Experiment

- SAM version 6.11.12. 3 km resolution. RCEMIP long channel
- 300K, 305K
- Storms tracked in time with the Tracking Of Organized Convection Algorithm through a 3-D segmentation (TOOCAN)

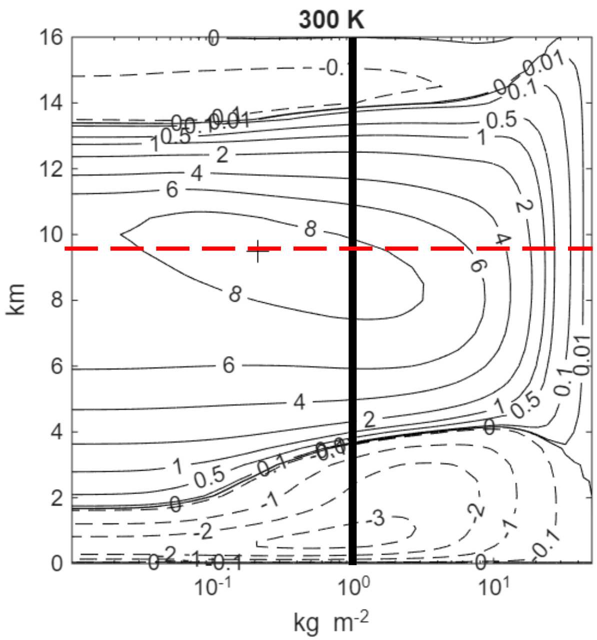
Storm number decreases with warming

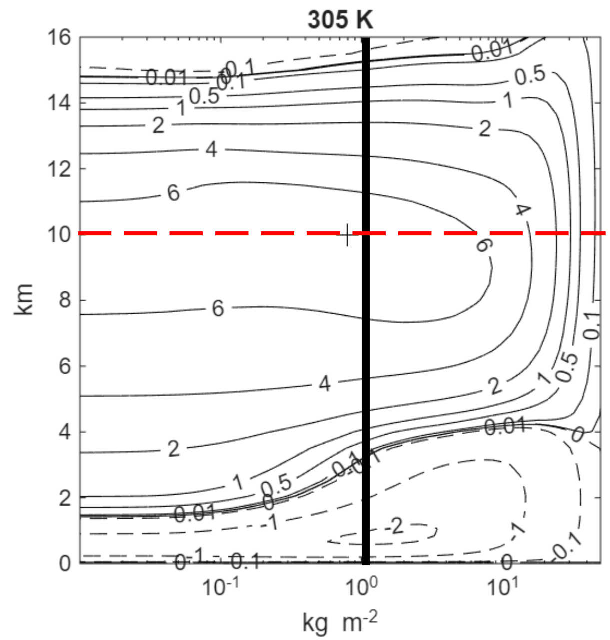


- Broad **decrease at all lifetimes**
- Longer-lived systems disproportionately affected by surface warming
- # from 4535 to 2323

Convective mass flux tracked across systems and climates

Max stream.





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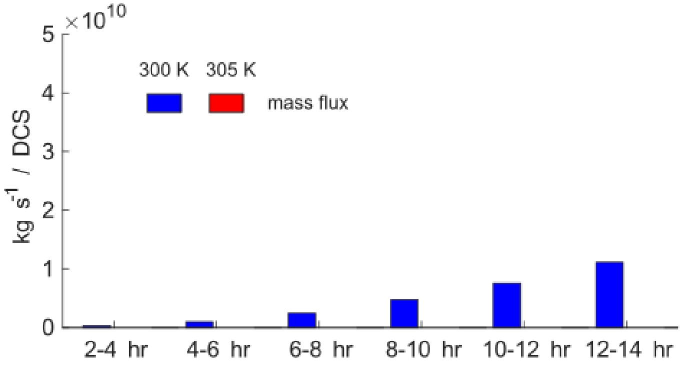
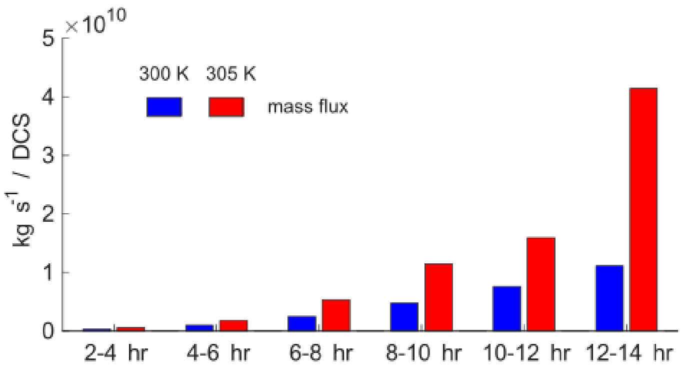
Longer-lived systems carry more mass flux



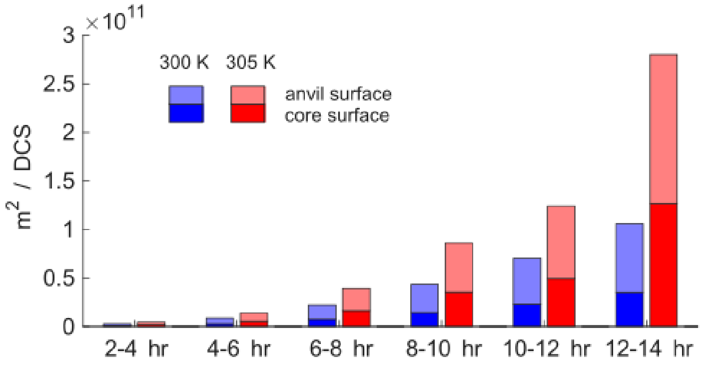
- 12-14 hr storms carry 5x the mass flux of 6-8 hr
- **Additional mass flux per hour of storm duration** necessary to reconcile the observations

Mass flux dramatically increases with warming



- Broad **increase at all lifetimes**
- More pronounced in longer-lived systems
- **Contrast with the constrained decrease in aggregated statistics**

Similar trends are observed in the surface per system



- Suggests that the **convective mass flux passively follows (core) surface changes**
- (whether at constant climate or the change with warming)

Mass flux follows surface changes

(**integrated** over the distribution of lifetimes)

- Mass flux

$$M = ndm$$

aggregated
-3.1% K^{-1}

#
-13.4% K^{-1}

duration
-1.9% K^{-1}

per system
+12.1% K^{-1}

- Core surface

$$C = ndc$$

aggregated
-3.1% K^{-1}

#
-13.4% K^{-1}

duration
-1.9% K^{-1}

per system
+12.1% K^{-1}

Mean pressure velocity in the core is resilient

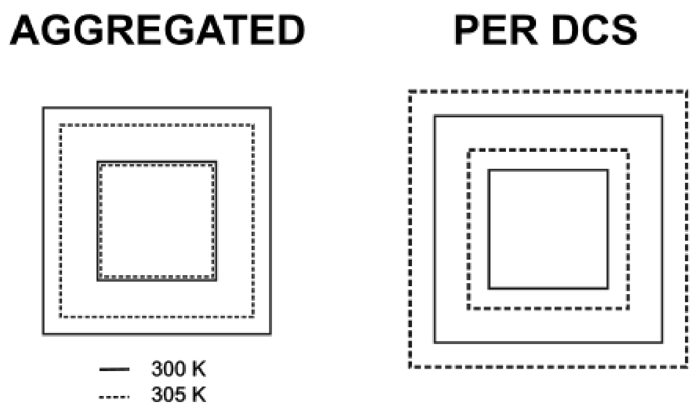
- Mass flux density (= pressure velocity) stays invariant

$$\frac{m}{c} = 0.3\ \mathrm{kg\ m^{-2}s^{-1}}$$

Resilience of pressure velocity is remarkable

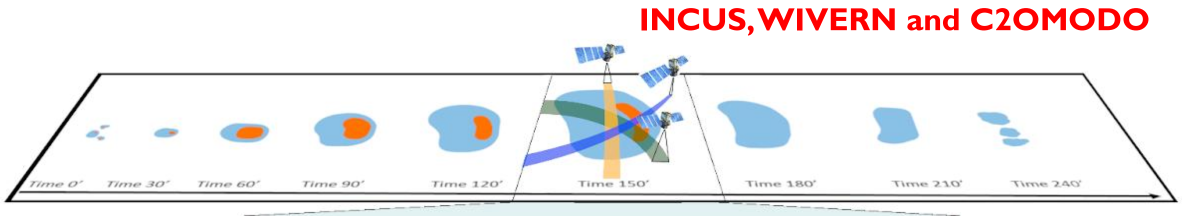
- **Mechanical work** in the cores does +16.4% K^{-1} (66 W m^{-2} to 150 W m^{-2})
- **Vertical velocity increases**
- **Compensating decrease in pressure** as updrafts move with rising isotherms
- Also, **IWP** does +7.3 K^{-1}
- Convection does **more work to lift the water**, impeding KE generation
- Resilience of pressure velocity results from **many compensating factors**

Conclusions



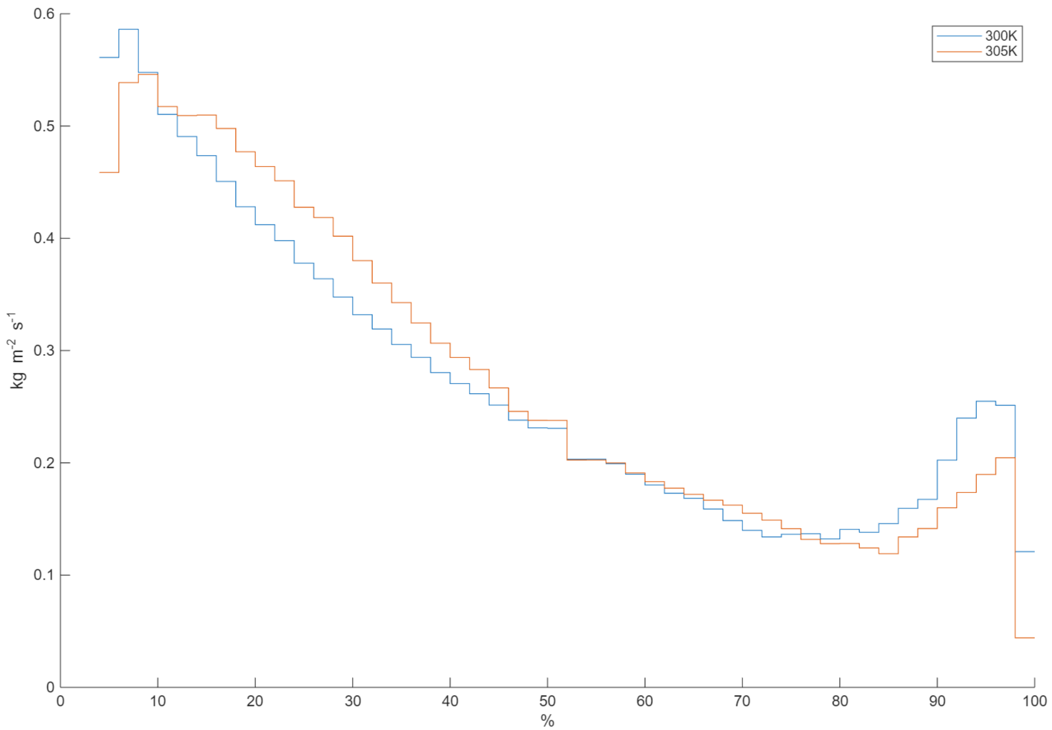
- In our simulations…
- Systems become **larger** and **mass flux** per system **passively follows the variations in surface**
- More broadly…
- **Constrained decrease** in mass flux **need not transfer** to the scale of individual storms
- Because of **unconstrained degree of liberty in storm number**

Perspectives



- Storm response from obs. **INCUS** (NASA), **WIVERN** (ESA), **C2OMODO & AOS** (NASA/JAXA/CSA/CNES)

Reserve slide



- Mean pressure velocity (in core) also resilient when measured against lifecycle time