Ice age and Holocene hurricanes

Robert Korty, Texas A&M
Suzana Camargo, Lamont-Doherty
Joseph Galewsky, University of New Mexico

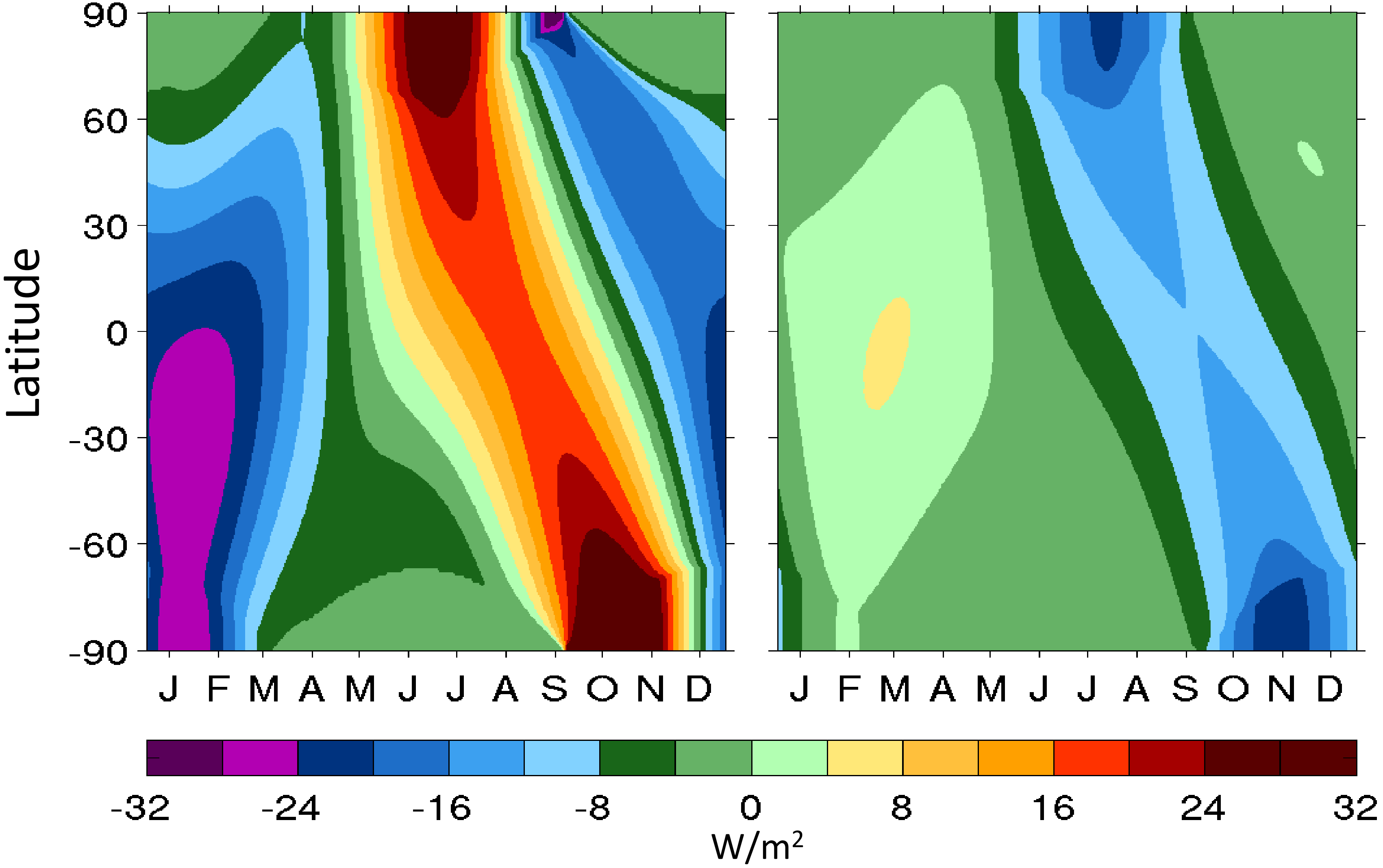
PMIP 2: changes in climate forcings

Mid-Holocene (6ka)

- CO_2, CH_4: 280 ppm, 650 ppb
- Substantial ΔTOA radiation

Last Glacial Maximum (21ka)

- CO_2, CH_4: 185 ppm, 350 ppb; ice
- Smaller ΔTOA radiation



Tropical cyclone genesis studies

Observations culled and analyzed (Gray 1968, 1979)
Renewed attention recently (e.g., Emanuel and Nolan 2004; Camargo et al. 2007; Tippet et al. 2011)

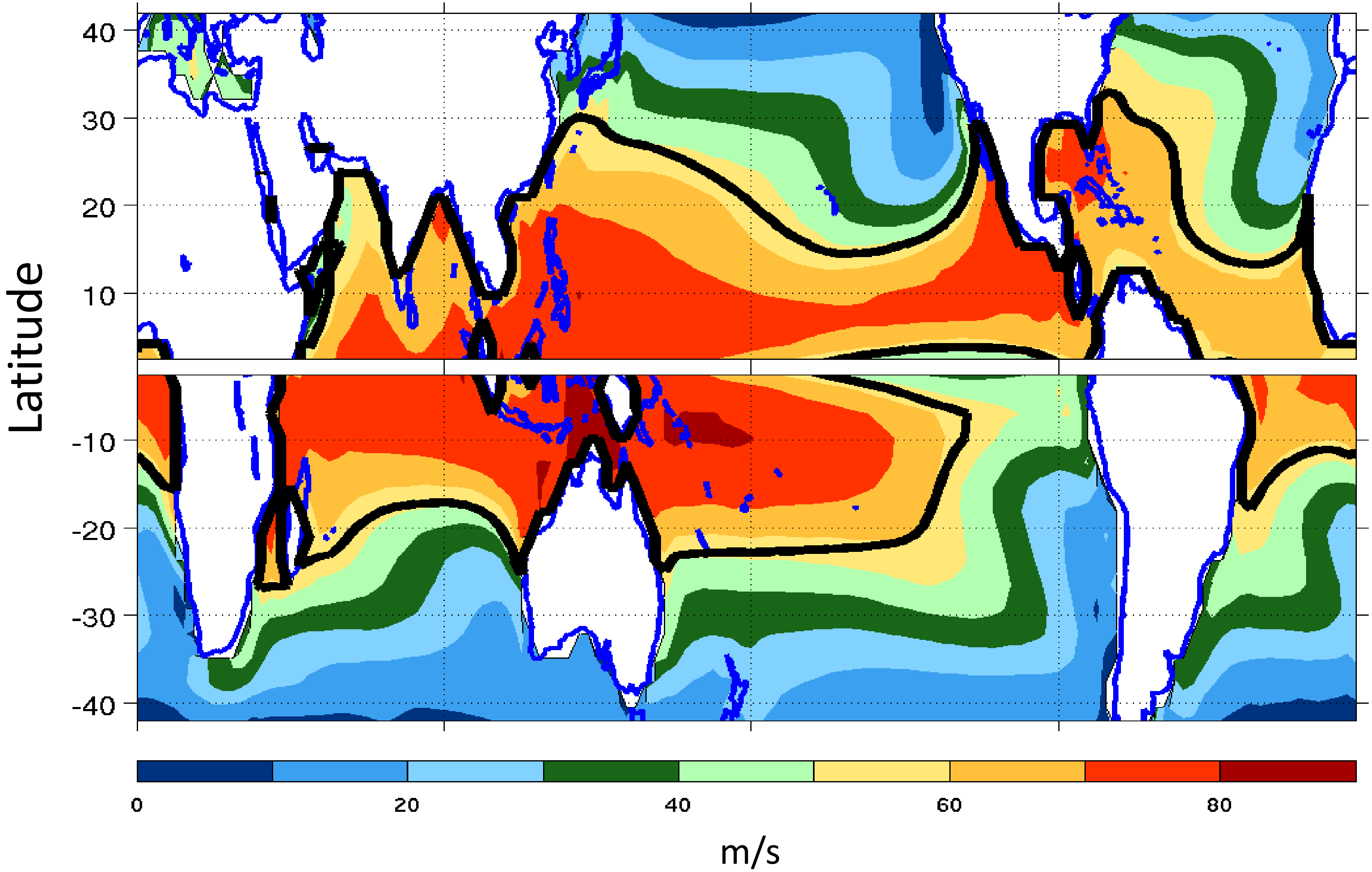
What environmental conditions appear to be crucial for genesis?

- low vertical wind shear
- incipient vortex (supply of vorticity)
- enthalpy flux from ocean to atmosphere
- sounding supportive of deep convection
- high mid-tropospheric humidity

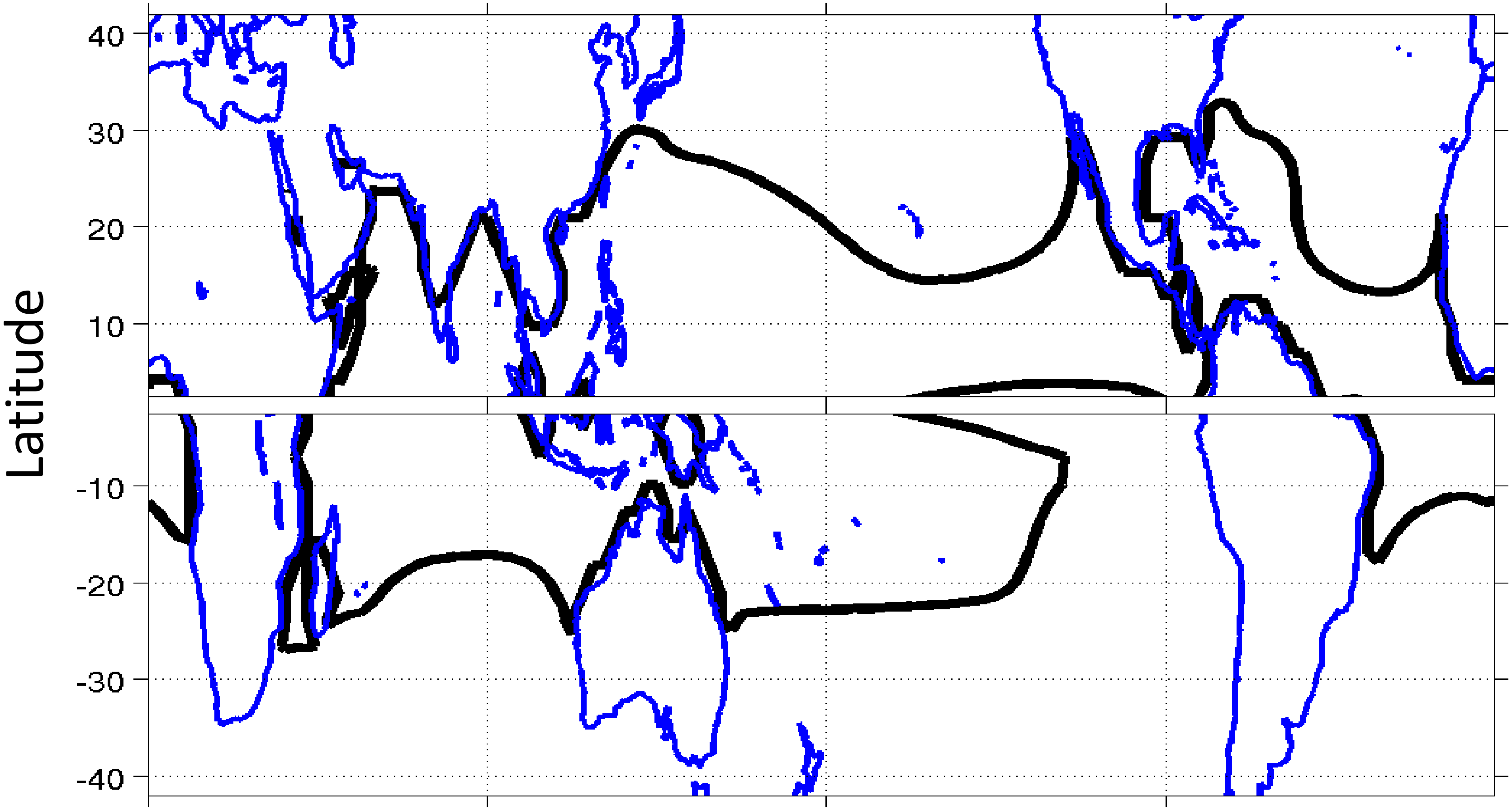
What conditions appear coincidental rather than controlling?

- 26°C water (nothing magic happens)
- a specific location (aside from being off the equator)

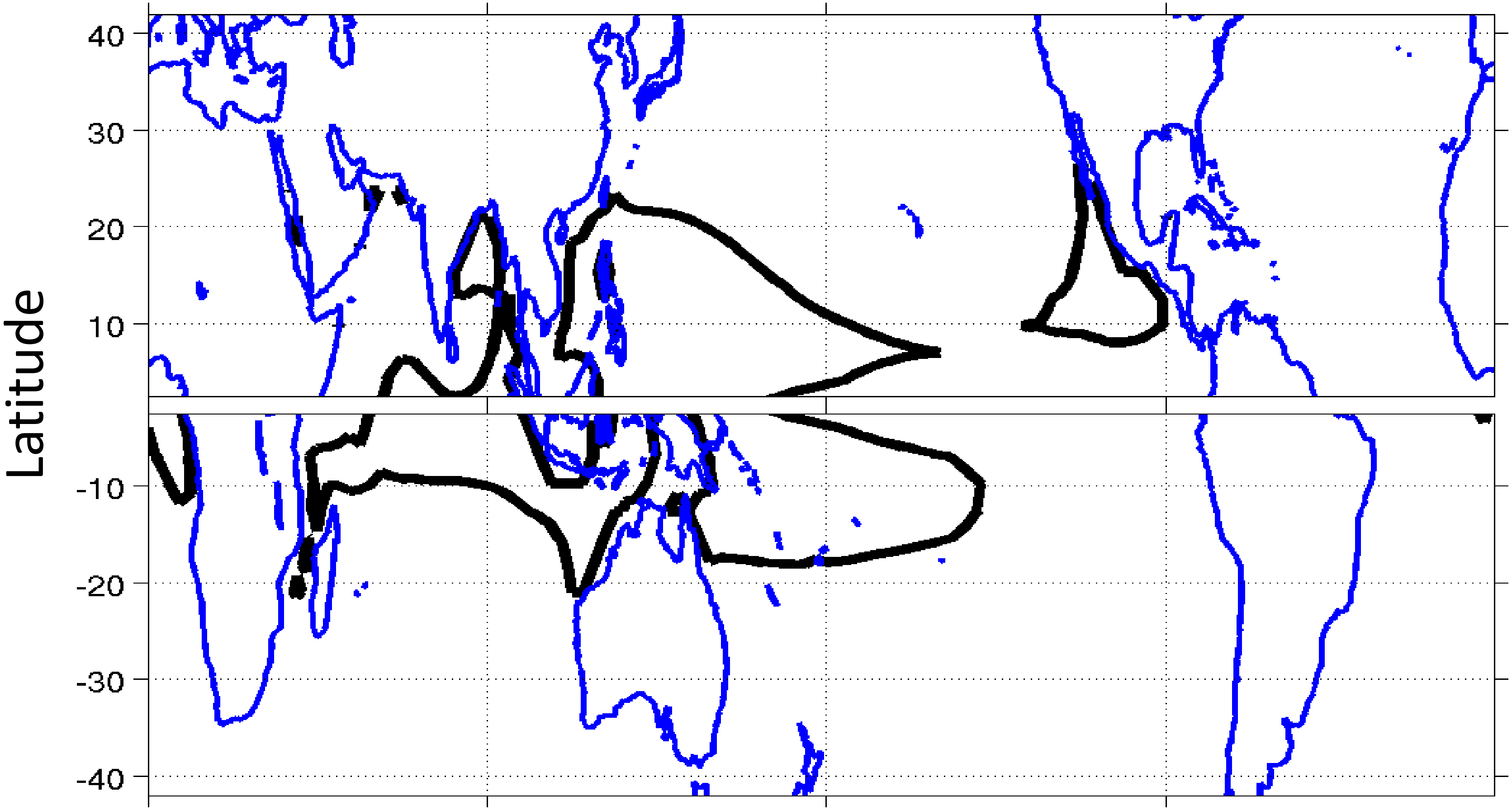
Storm season potential intensity (0k)



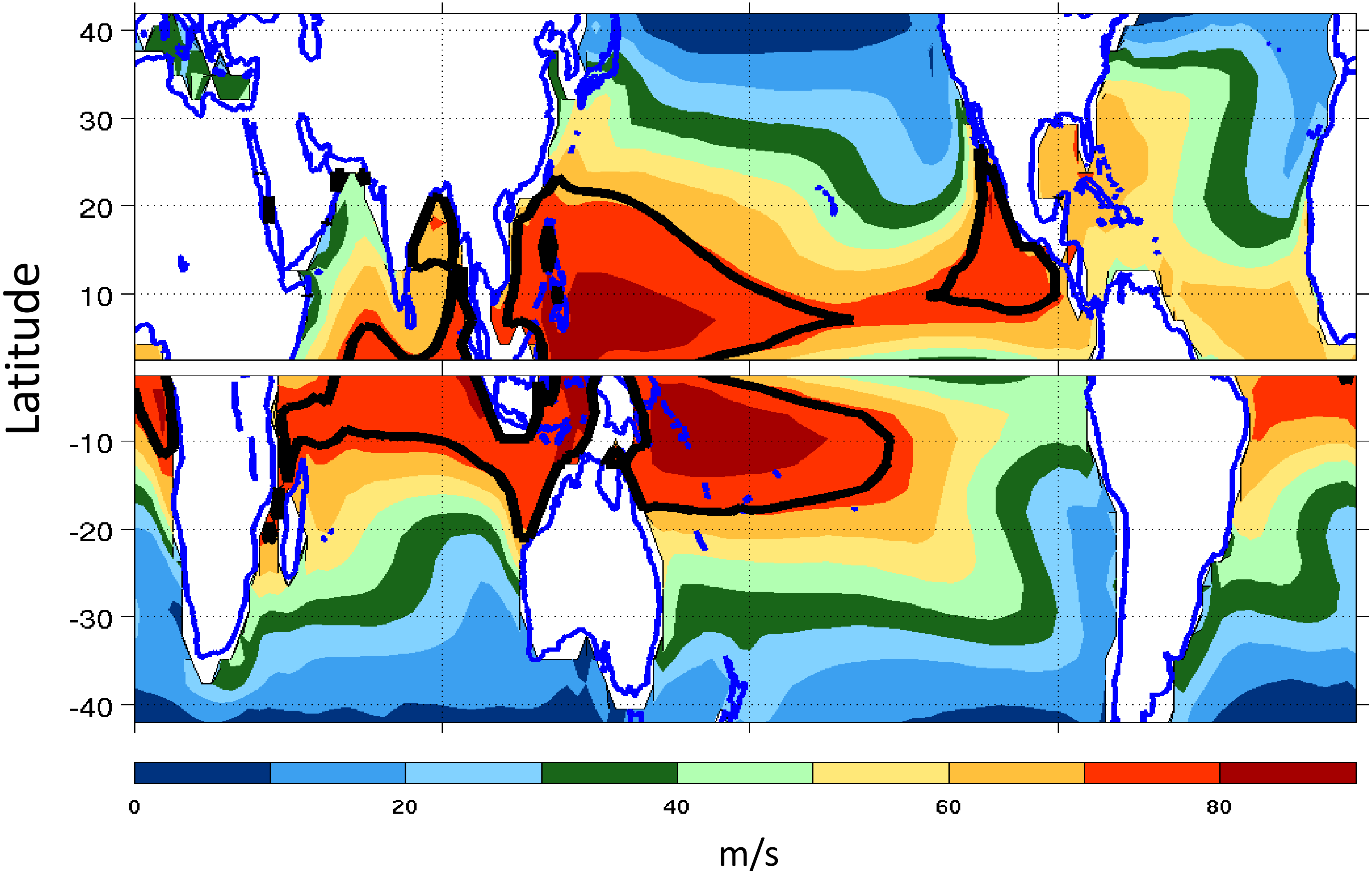
Storm season 26^{o}C isotherm (0k)



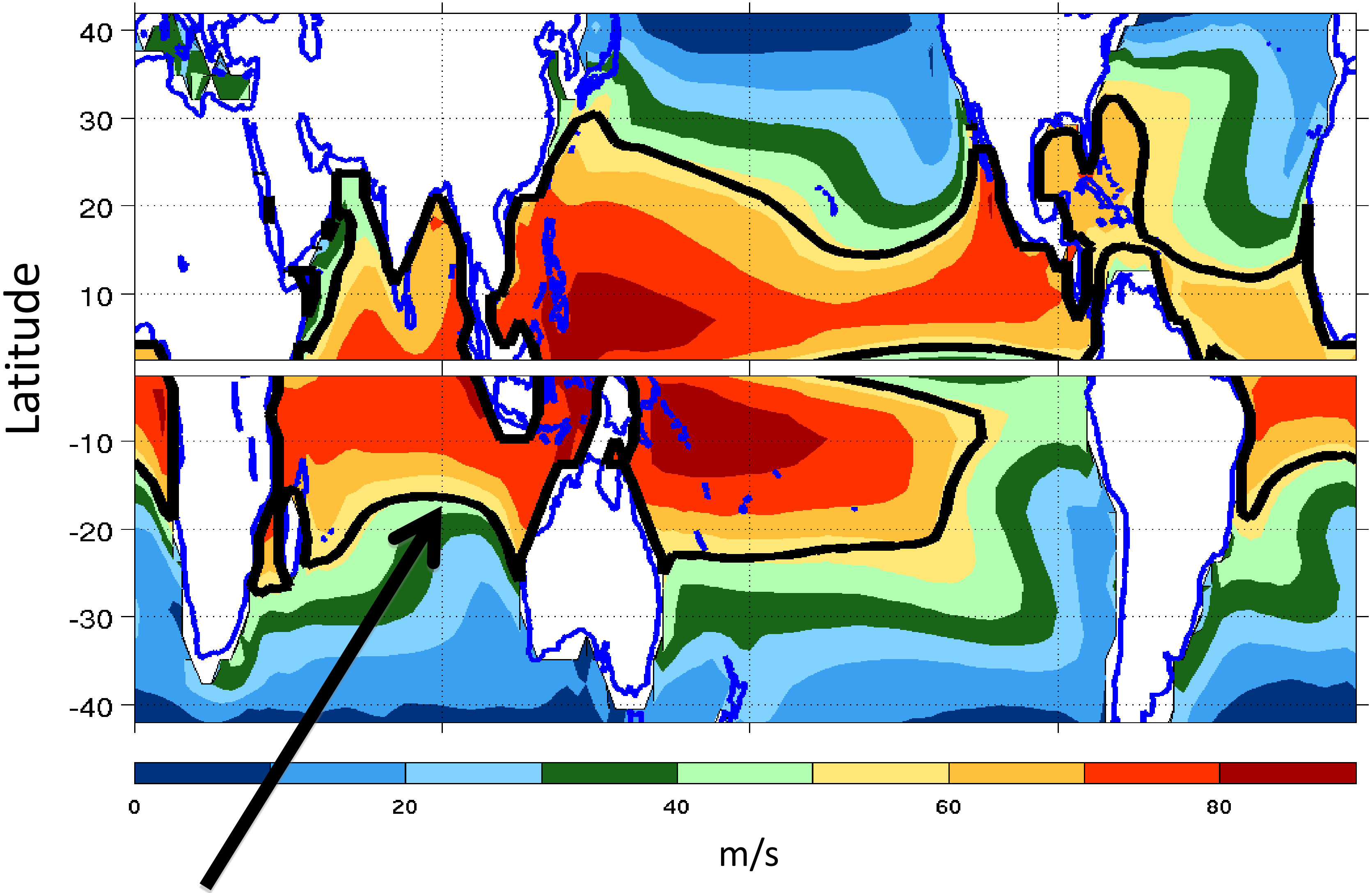
Storm season 26^{o}C isotherm (LGM)



Storm season potential intensity (LGM)

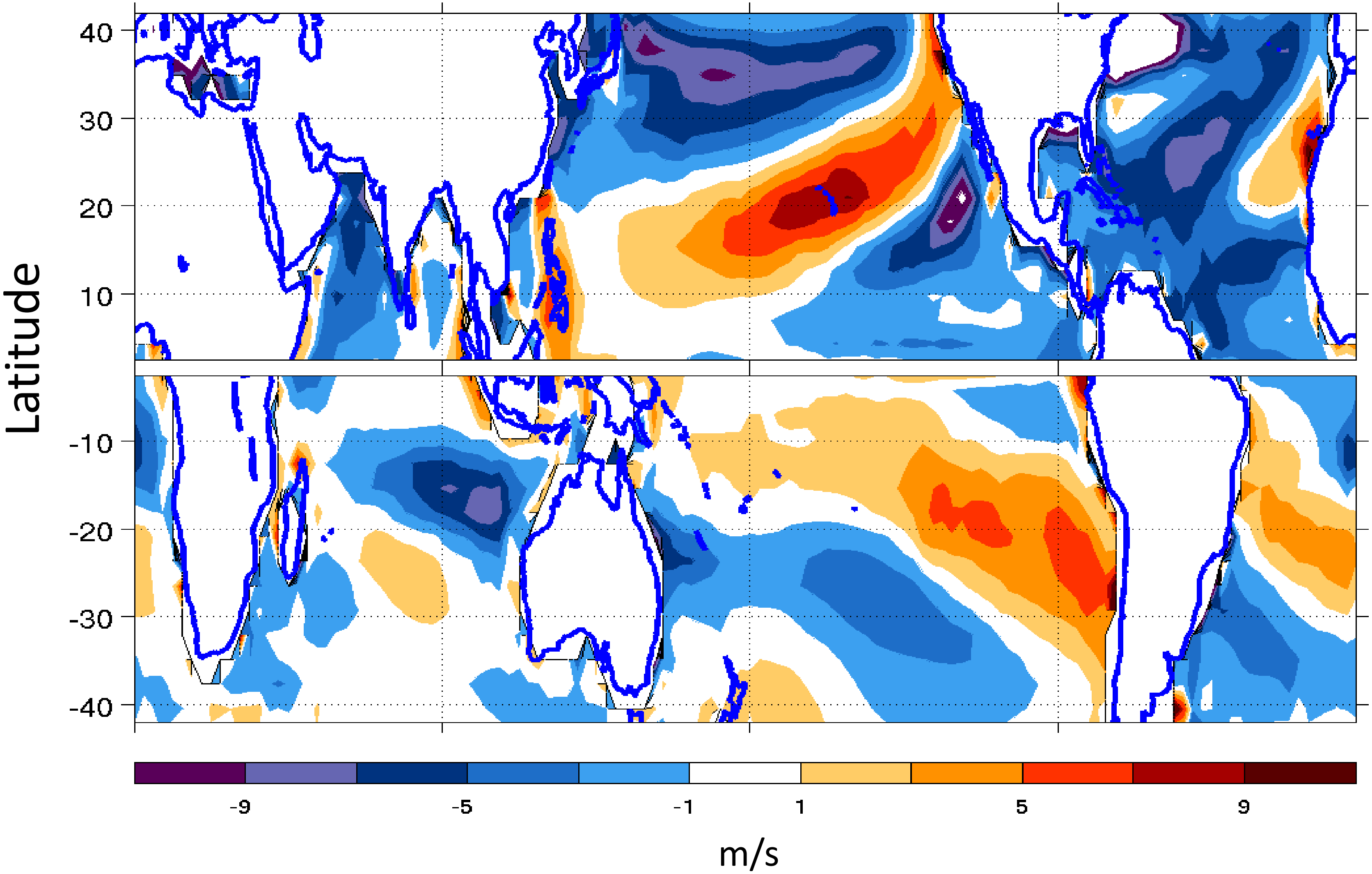


Storm season potential intensity (LGM)



24°C isotherm

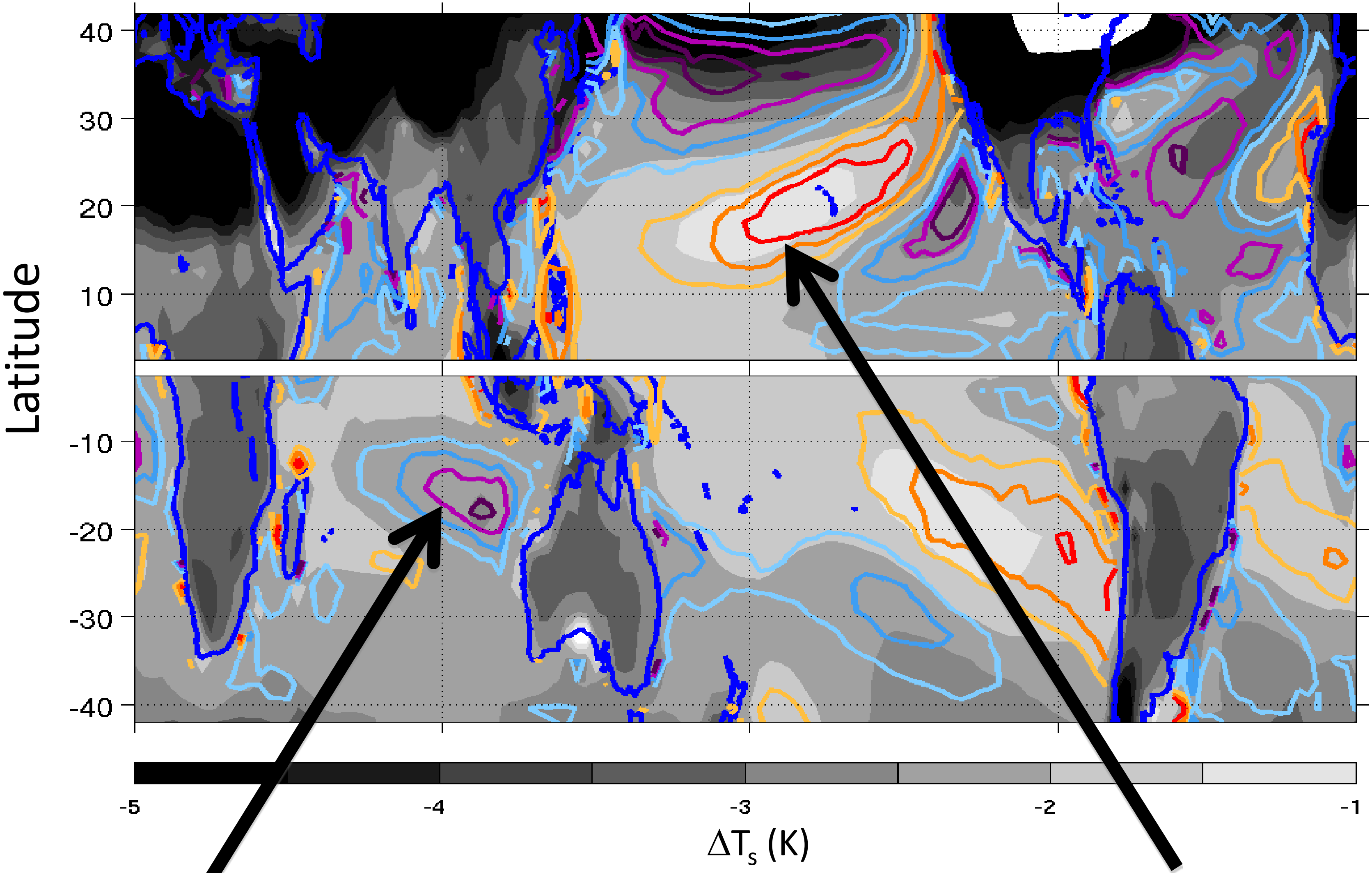
Change in potential intensity: LGM-0k



weaker at LGM than Preindustrial

stronger at LGM than Preindustrial

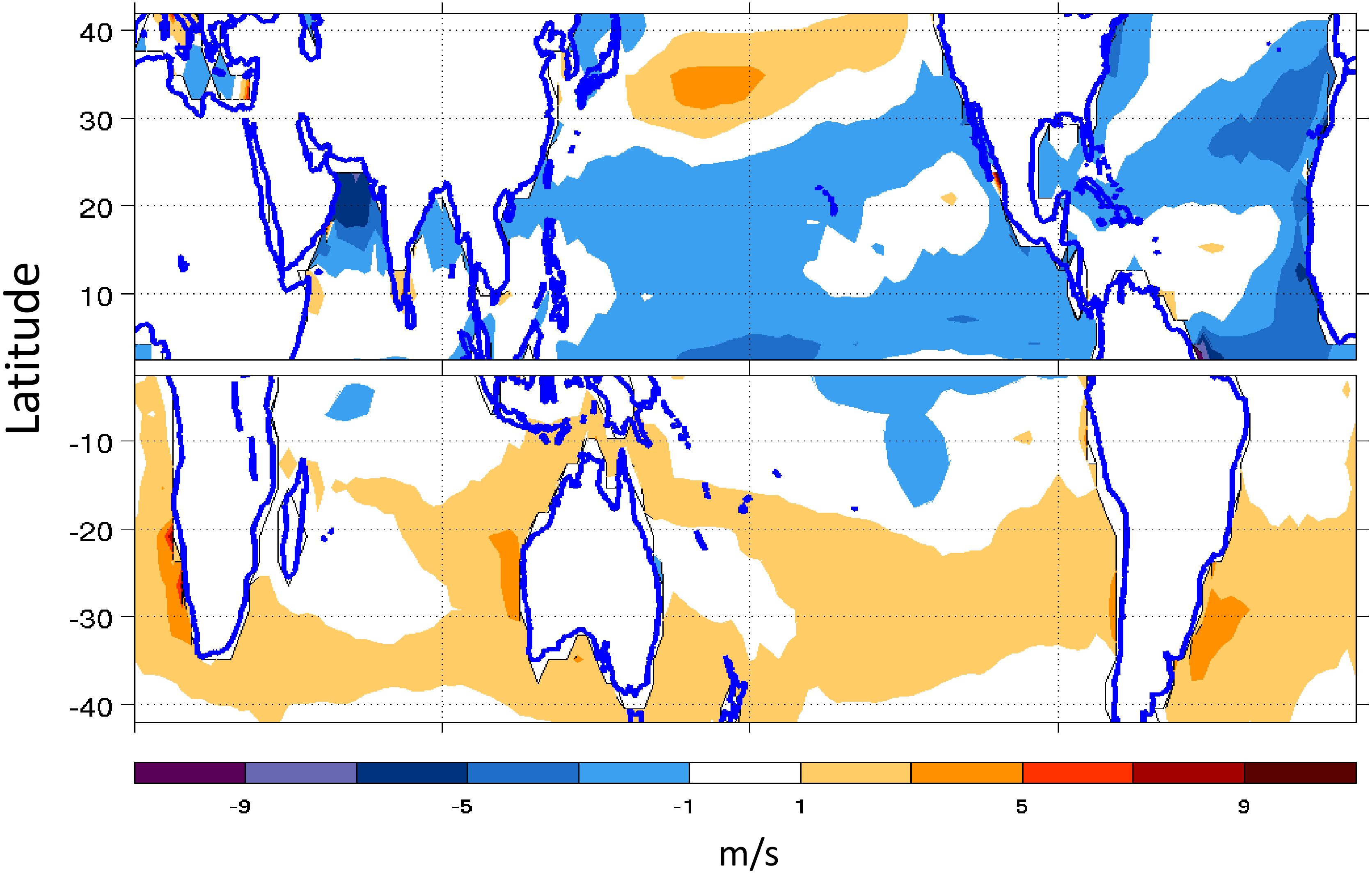
Change in T_s and potential intensity: LGM-0k



weaker intensity at LGM than Preindustrial

stronger intensity at LGM than Preindustrial

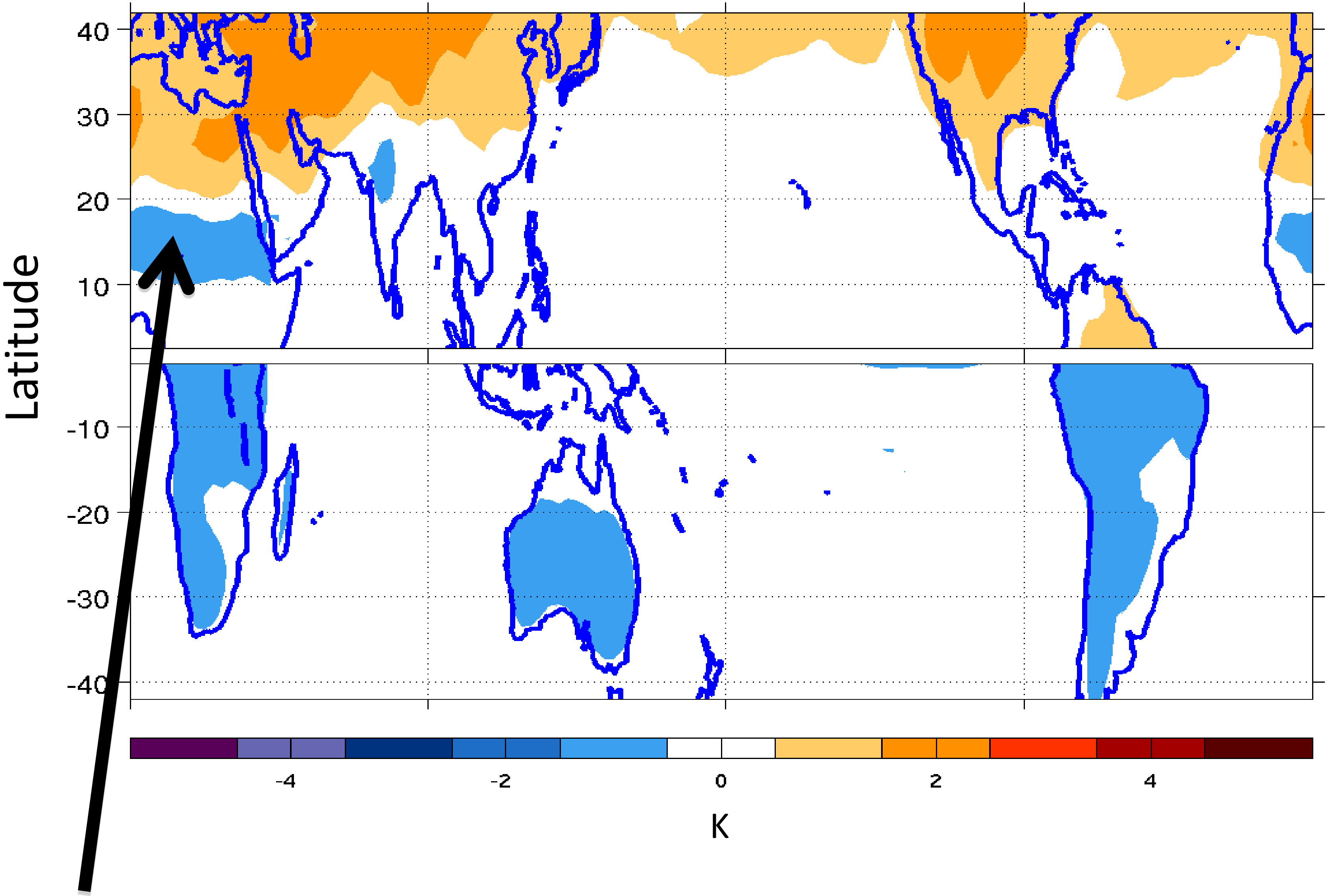
Change in potential intensity 6000 years ago



weaker in mid Holocene than Preindustrial

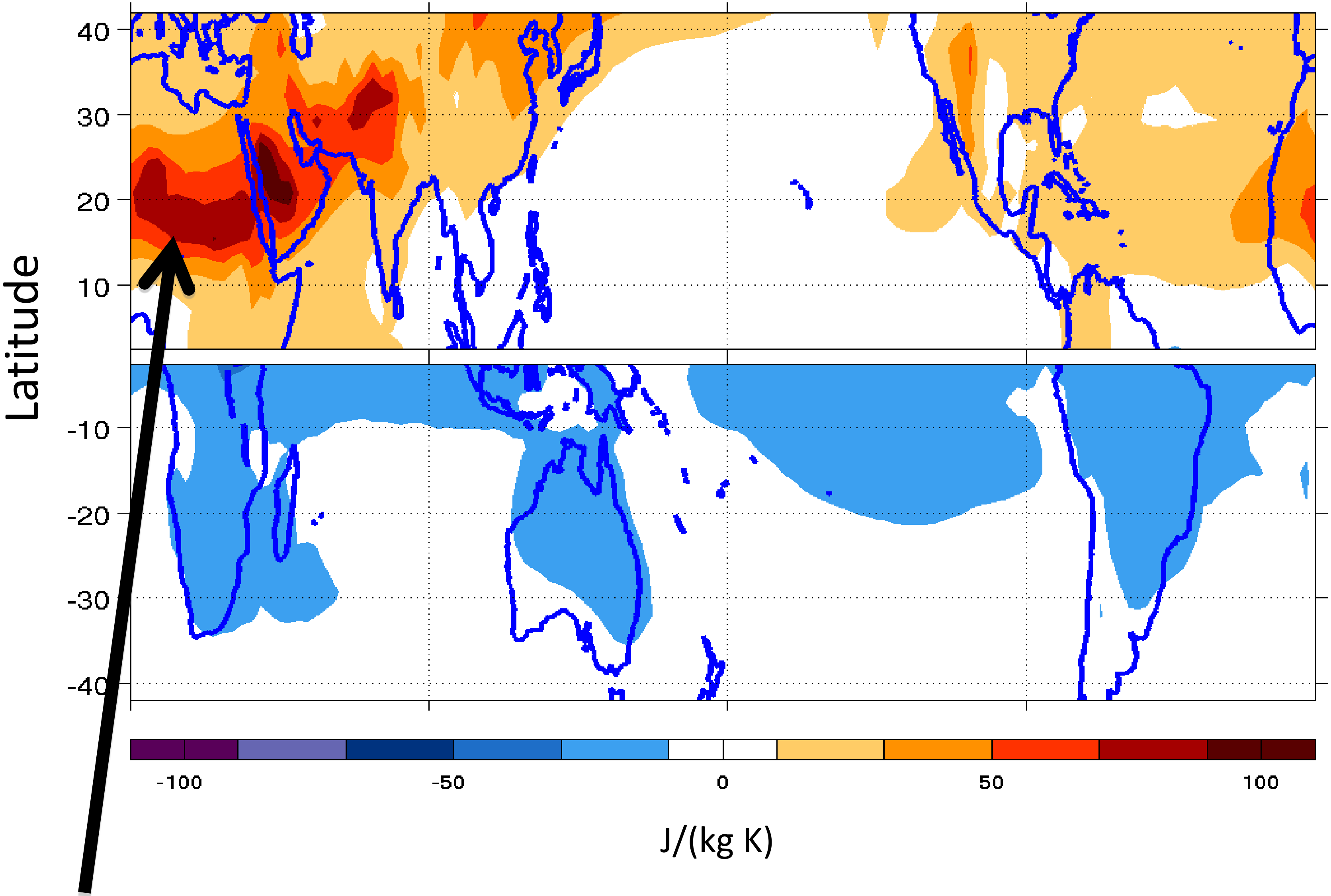
stronger in mid Holocene than Preindustrial

Change in T_s 6000 years ago



Sahel rainfall and cloudiness increase.

Change in surface entropy 6000 years ago



Sahel rainfall and cloudiness increase.

Mid tropospheric moisture content

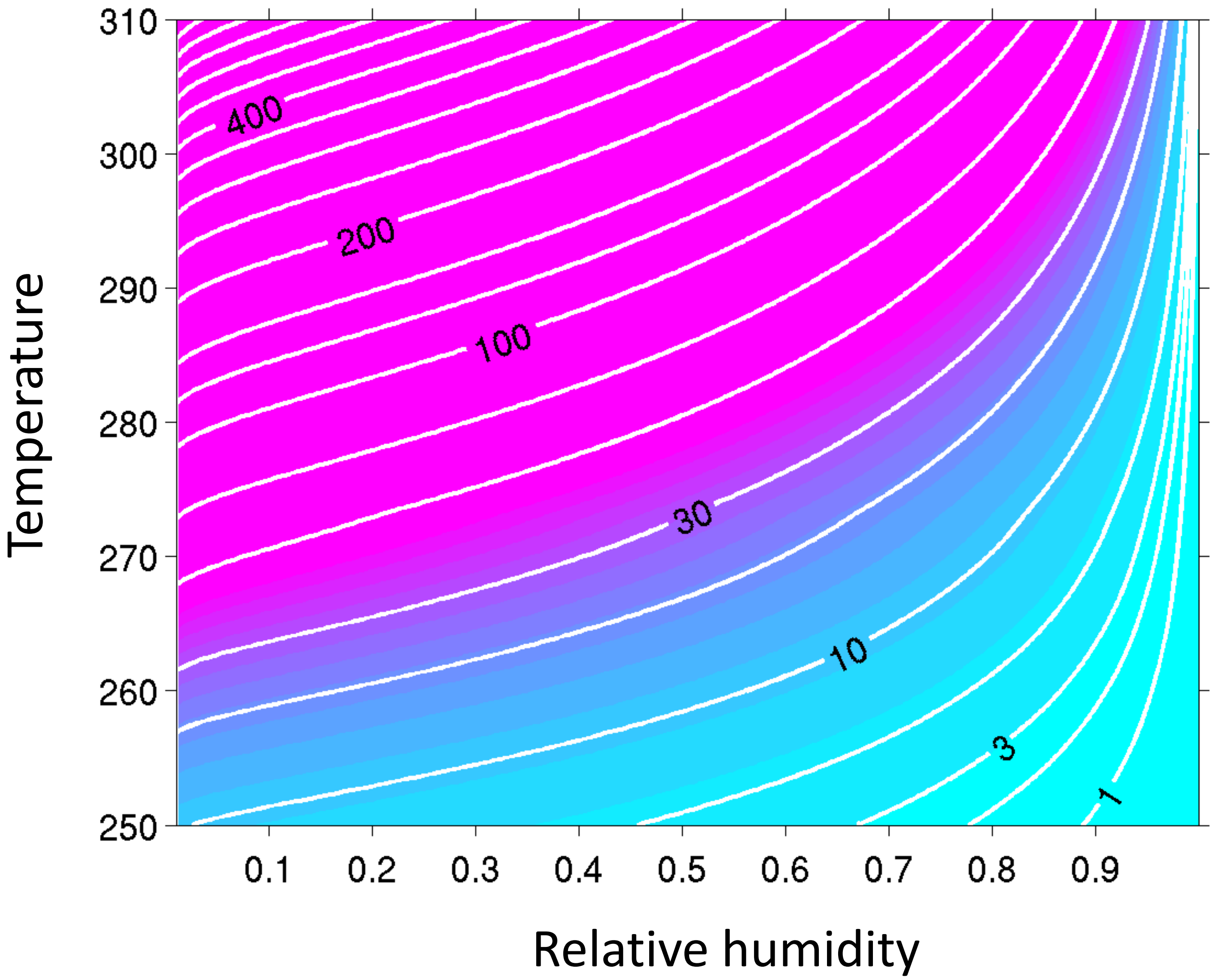
- Nascent storms are impeded by dry air in the mid troposphere
- Downdrafts choke off supply of high entropy boundary layer air
- Time needed for genesis shortens when entropy deficit is small
- Entropy deficit is related to the saturation deficit, *f* (T):

$$s_b - s_m \approx s_m^* - s_m \propto \left(q^* - q\right)/T$$

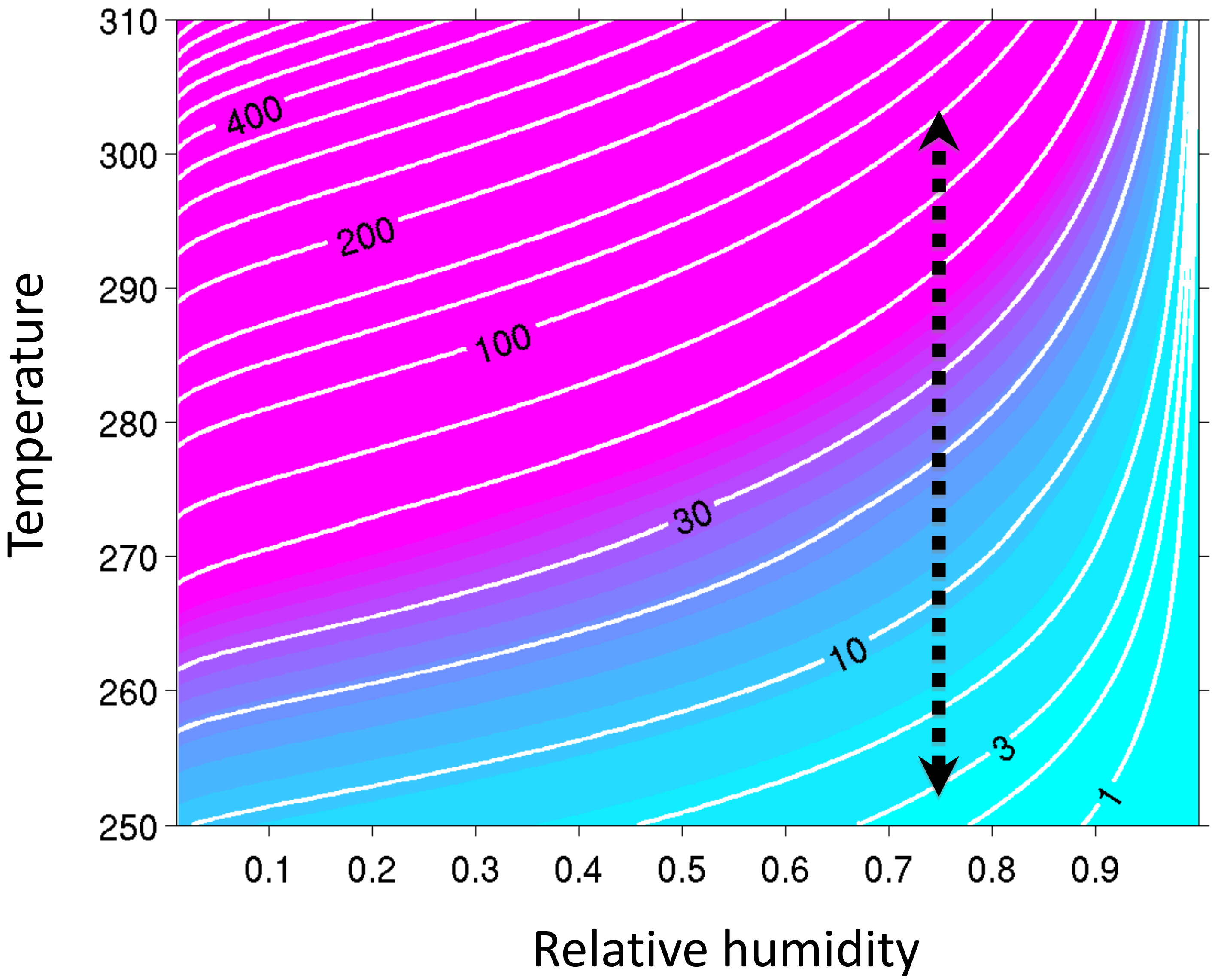
Shear

Shear also reduces thermodynamic efficiency of a storm (Tang and Emanuel, 2010) by advection of outside air (which is dry) into the hurricane and ventilating it.

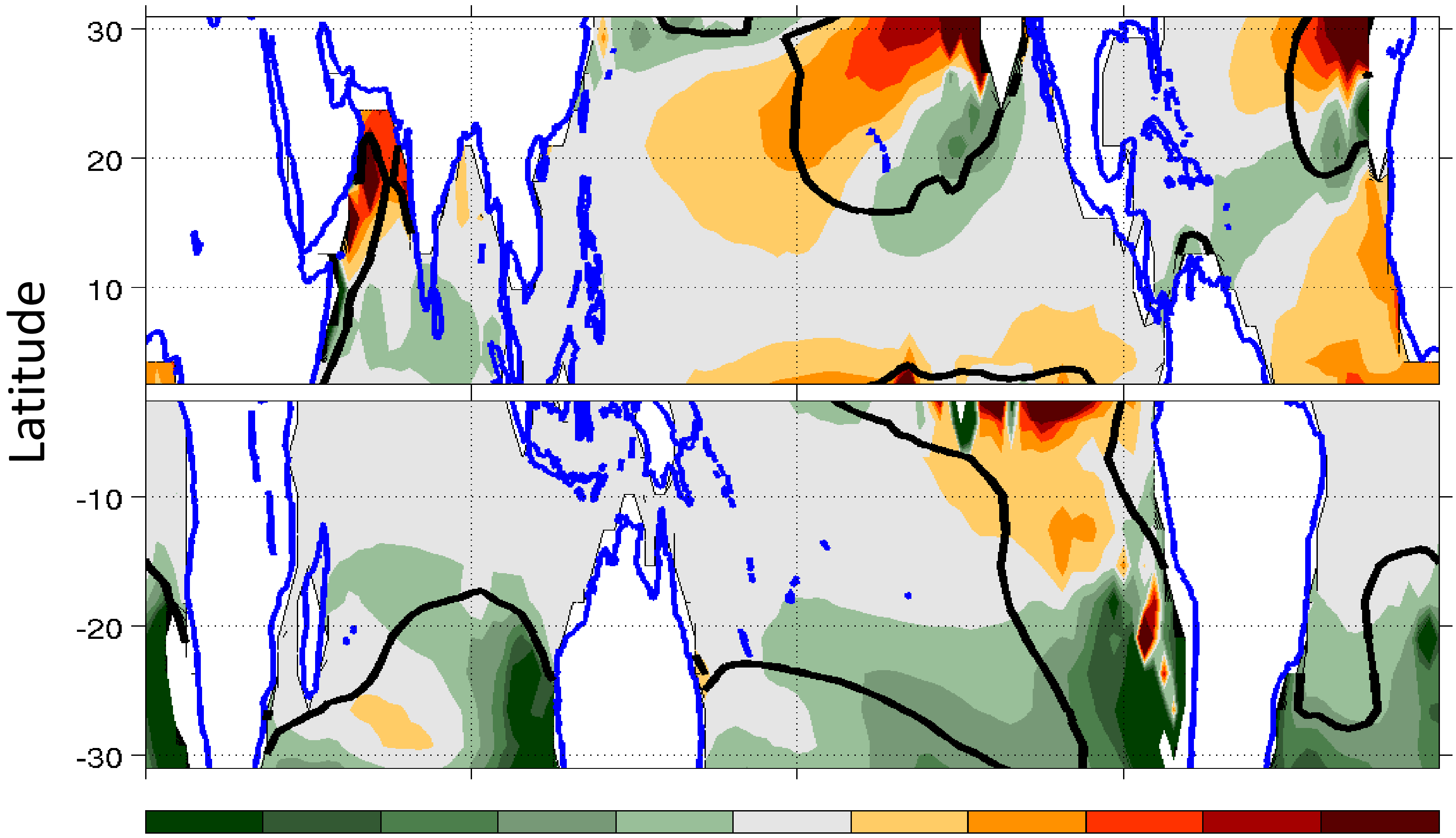
Saturation entropy deficit: s* – s



Saturation entropy deficit: s* – s



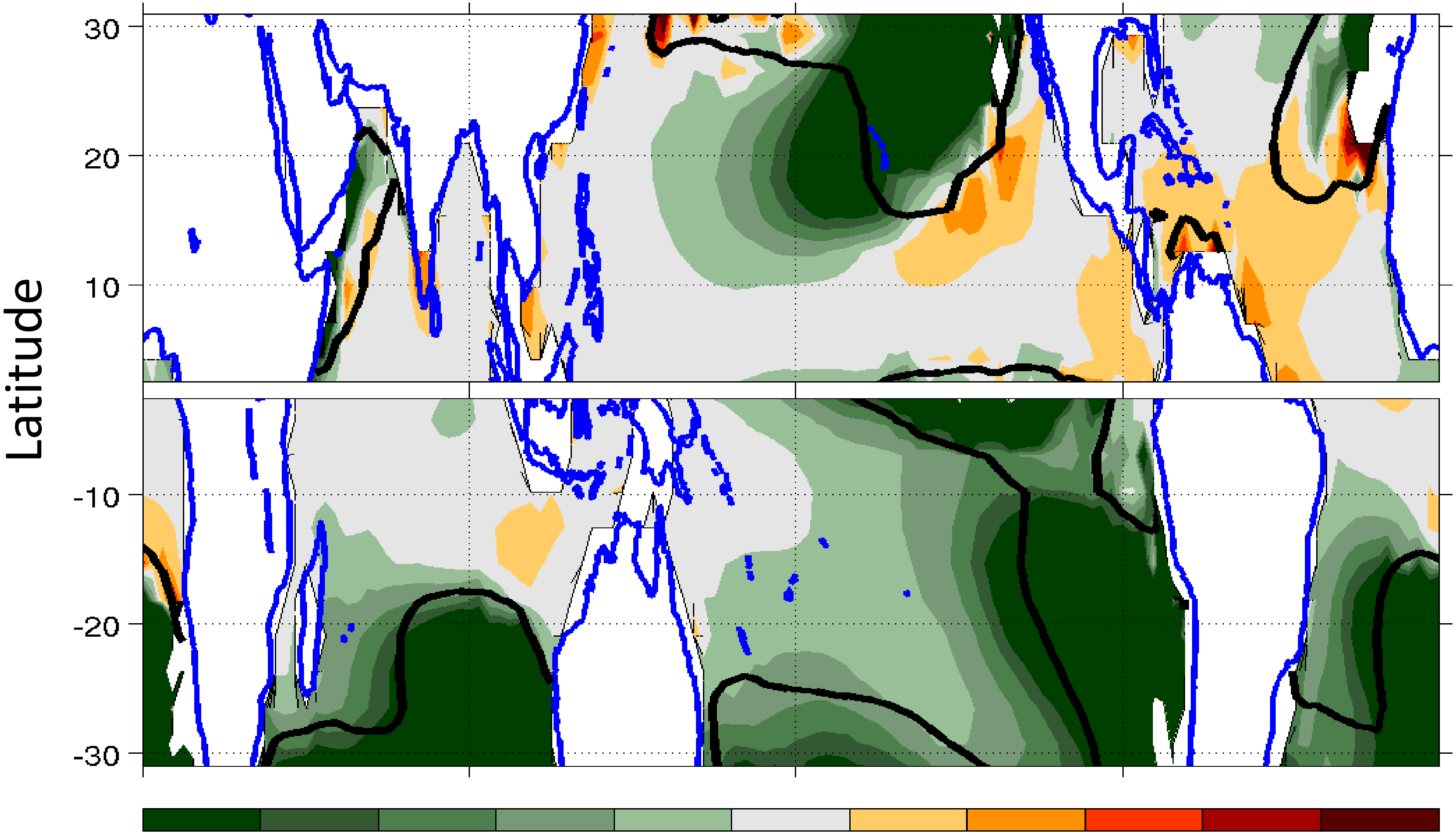
Changes to incubation period at 6k



shorter incubation period
improved environment for genesis

longer incubation period
more hostile environment

Changes to incubation period at LGM



← *shorter incubation period*
improved environment for genesis

→ *longer incubation period*
more hostile environment

Summary (Phase 1)

Mid-Holocene (6ka)

- Potential intensities in both hemispheres change inversely with the top of atmosphere (TOA) solar radiation perturbation
- Tropical SST differed little from today, but summer atmosphere was warmer in N. Hem., which yields larger saturation deficits
- S. Hem. potential intensities rise and incubation time shortens

LGM (21ka)

- Tropical SSTs fall ~2^{o}C, but this does not preclude tropical cyclones
- Potential intensities are higher in western and central North Pacific, where SSTs dropped least
- They are lower in eastern North Pacific and Atlantic
- S. Hem. changes also follow relative SST
- Incubation periods are generally shorter in the colder climate, except in the North Atlantic where they rise

Next steps

Phase 2

- Use higher resolution CCSM4 MOAR from LGM, 6ka, and PI
- Track vorticies (model cyclones) for track density assessment and model genesis
- Apply techniques used on reanalysis and CMIP runs to PMIP simulations and develop a CCSM specific genesis index.

Phase 3

- Downscale to simulate paleo-cyclones in WRF, using MOAR 6ka and LGM as boundary conditions
- Assess storm climatology: basin specific responses, frequency, duration, intensity (?)
- Lessons from our adaptation of WRF may be useful for future paleoclimate applications

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