The Role of Tropical Cyclones in Cross-Equatorial Total Energy Transport

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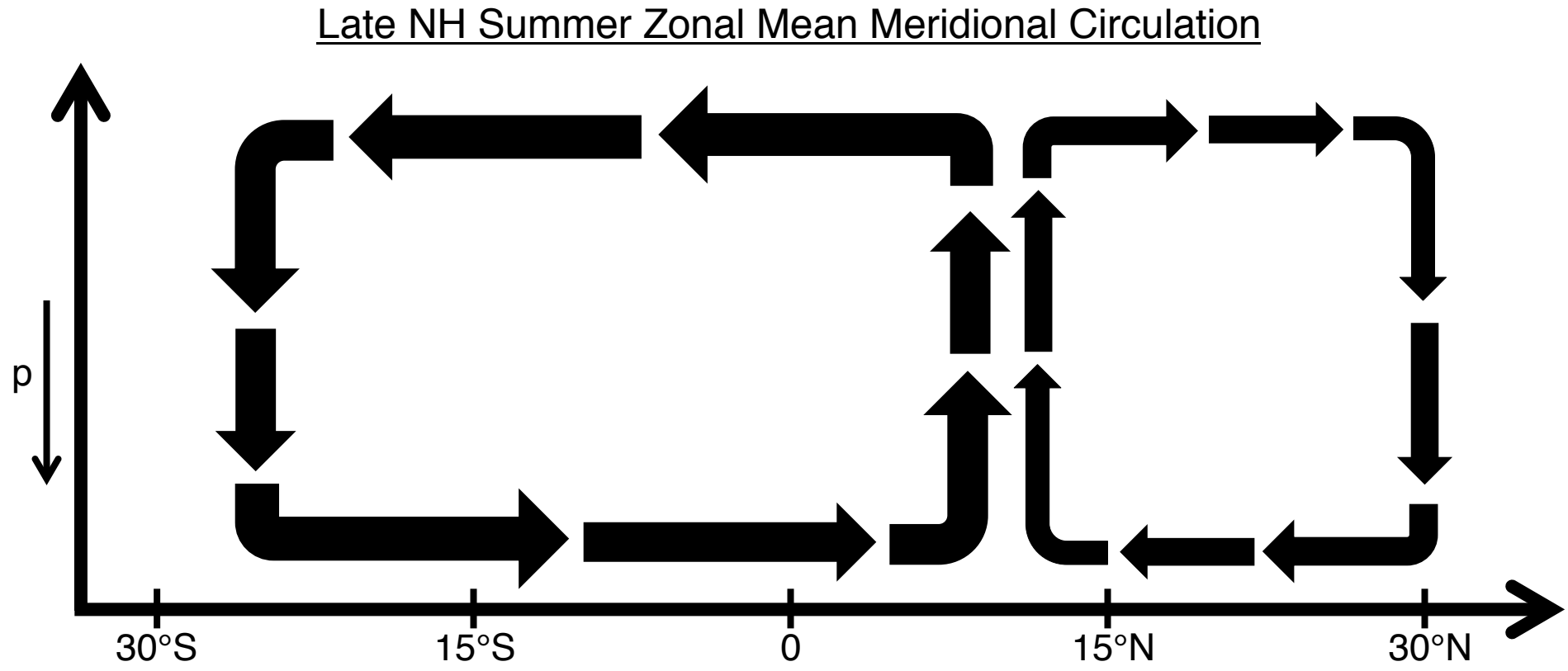
How do TCs Transport Total Energy Meridionally?



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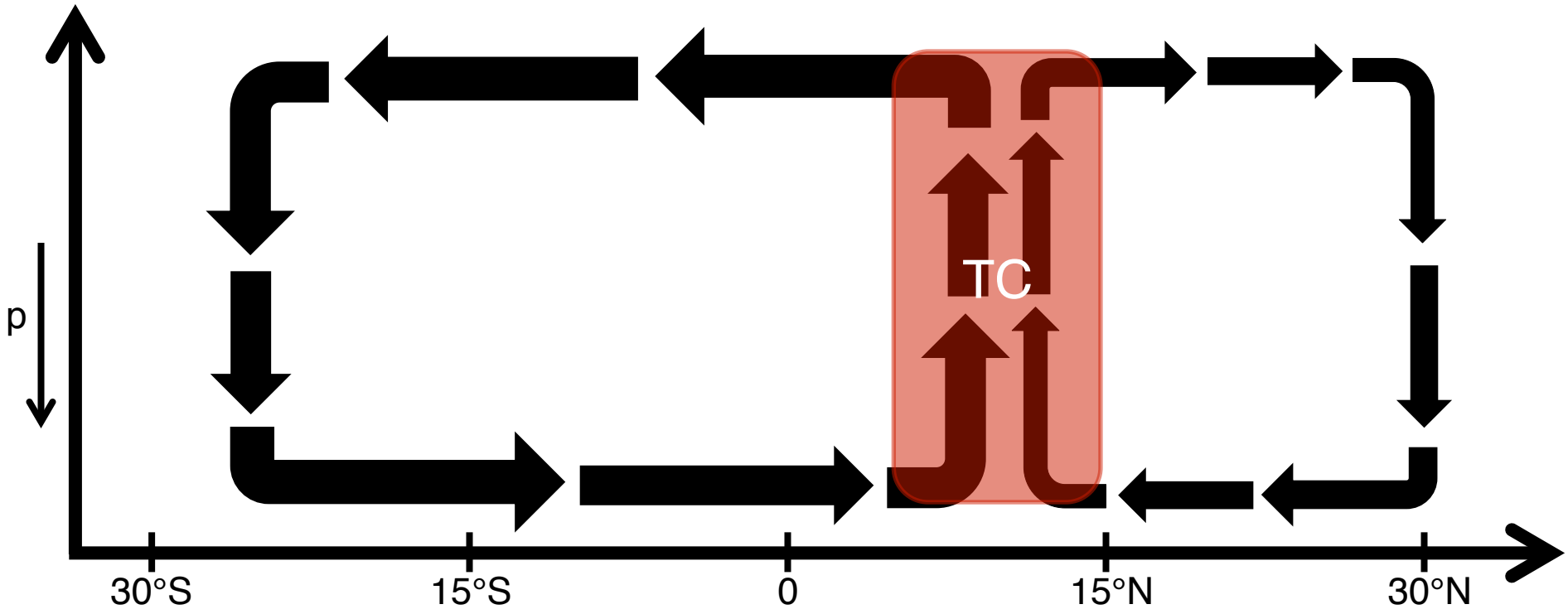
Late NH Summer Zonal Mean Meridional Circulation with TC



- There are three mechanisms whereby TCs can transport total energy meridionally:
  1. Movement of TC from tropics into midlatitudes (e.g., Cordeira 2011)

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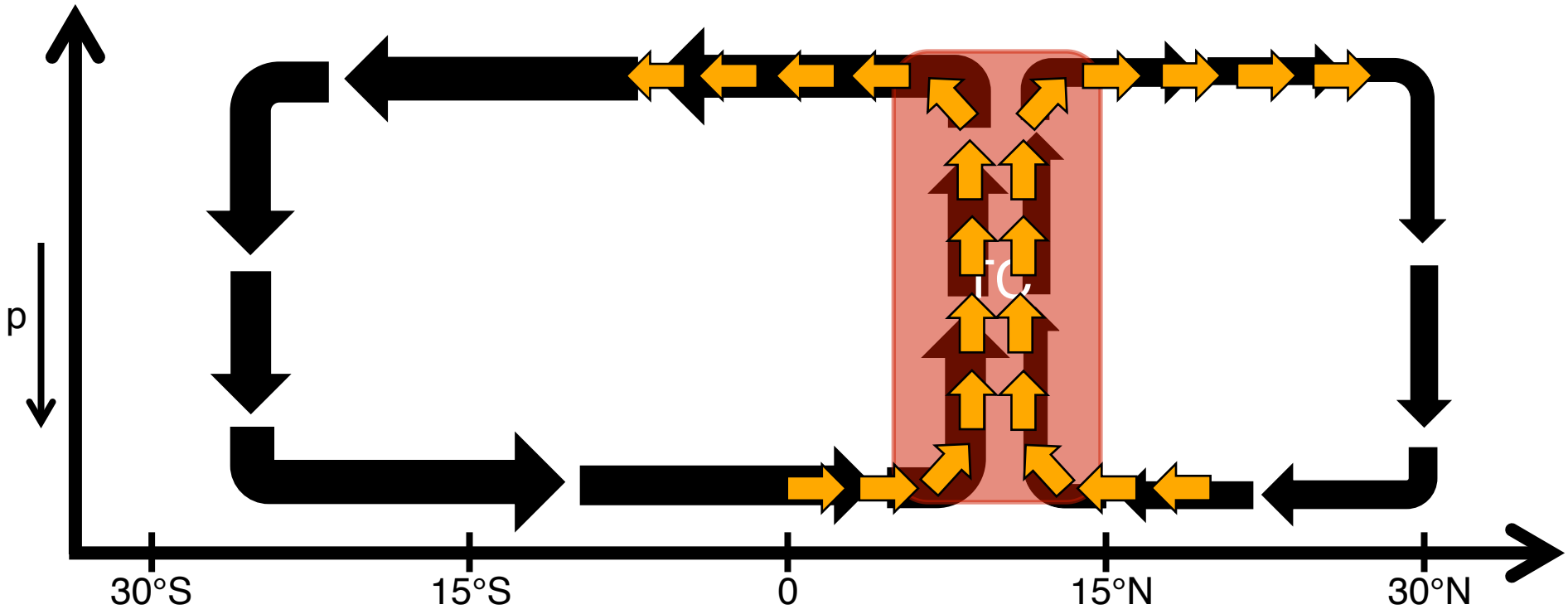

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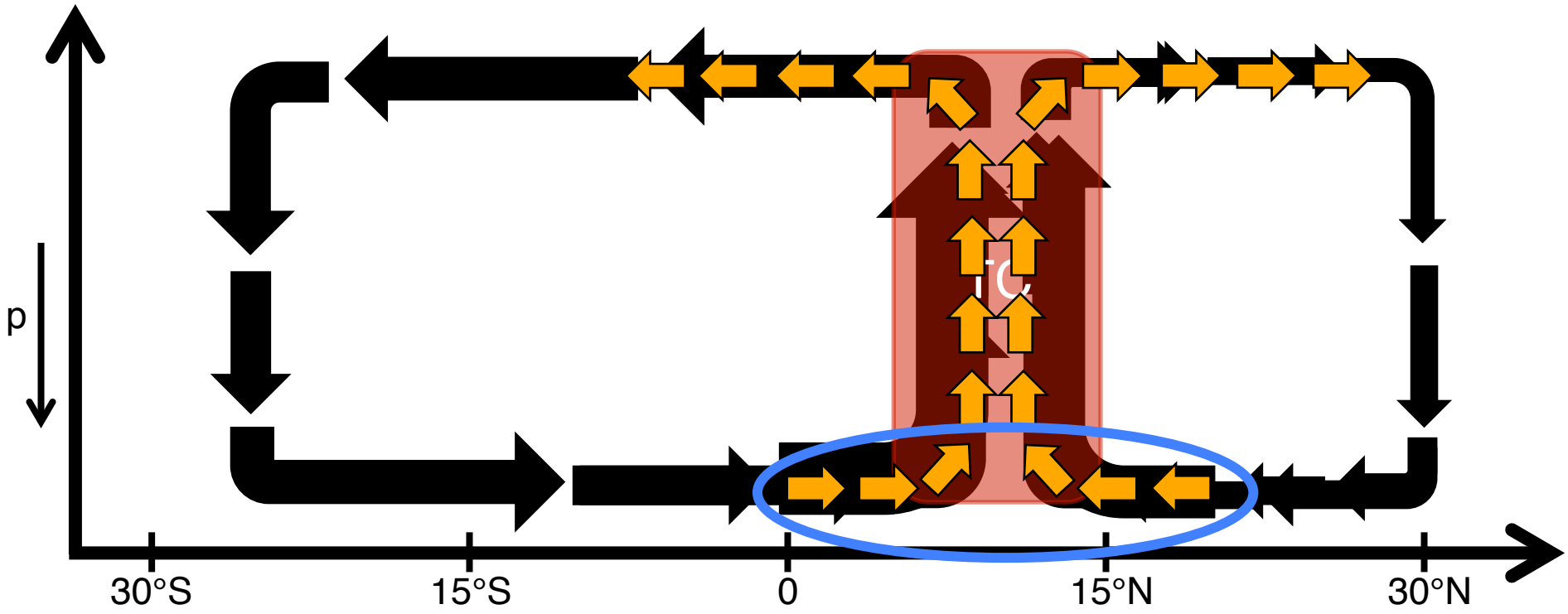

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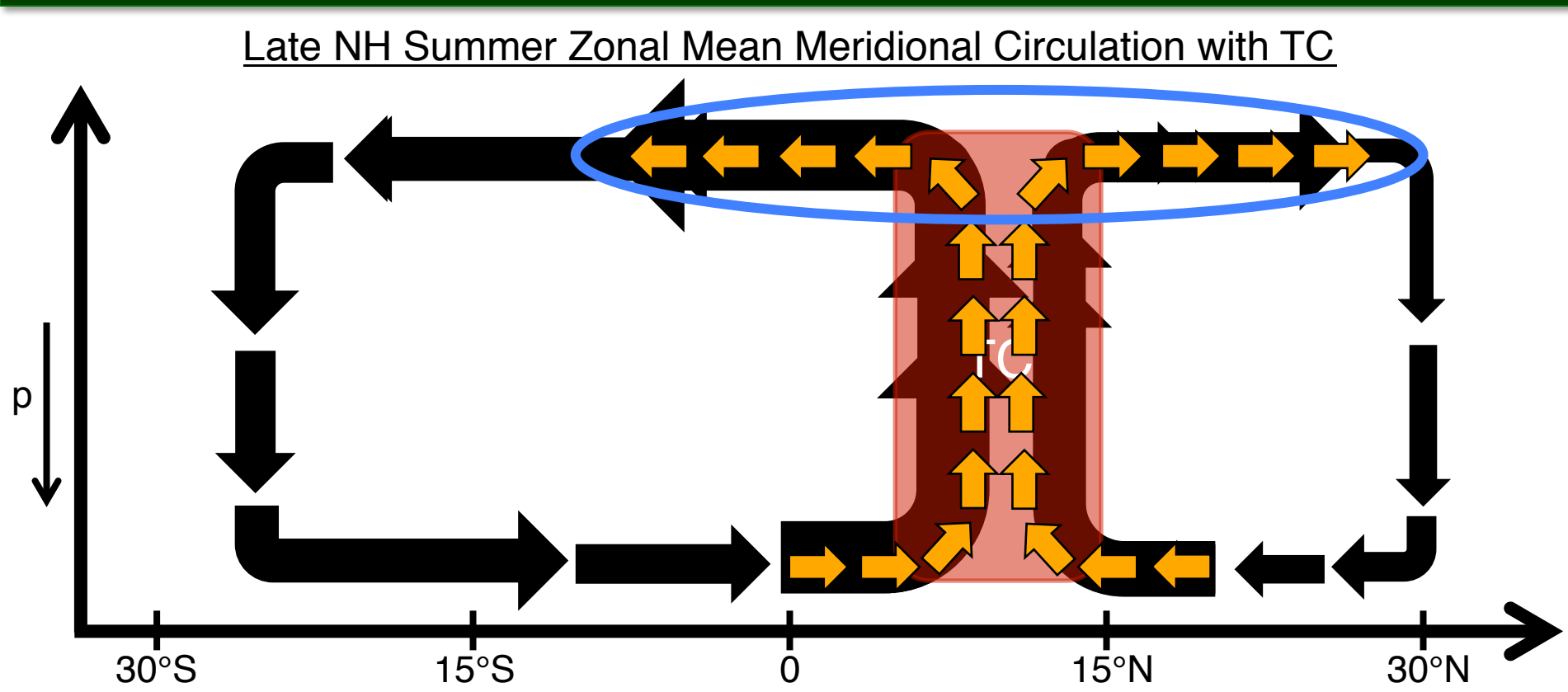

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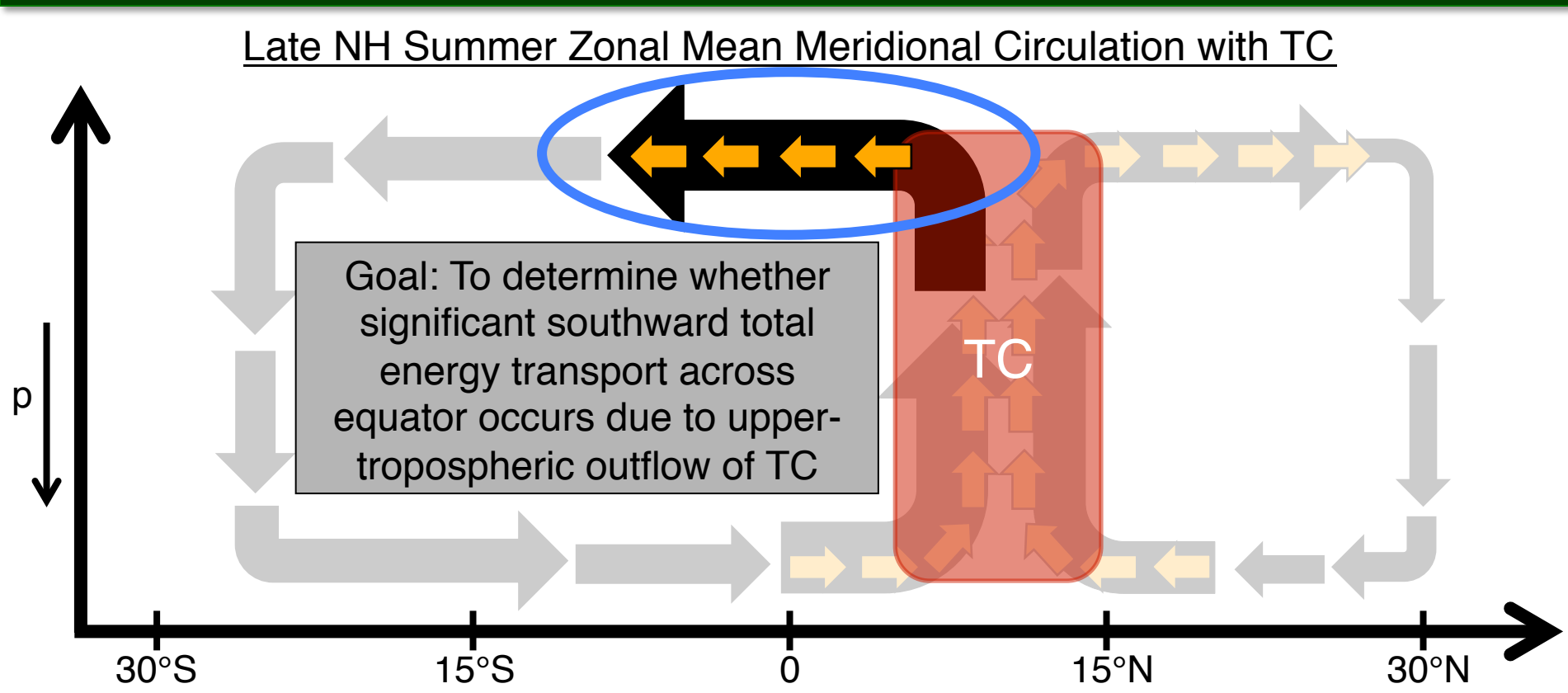

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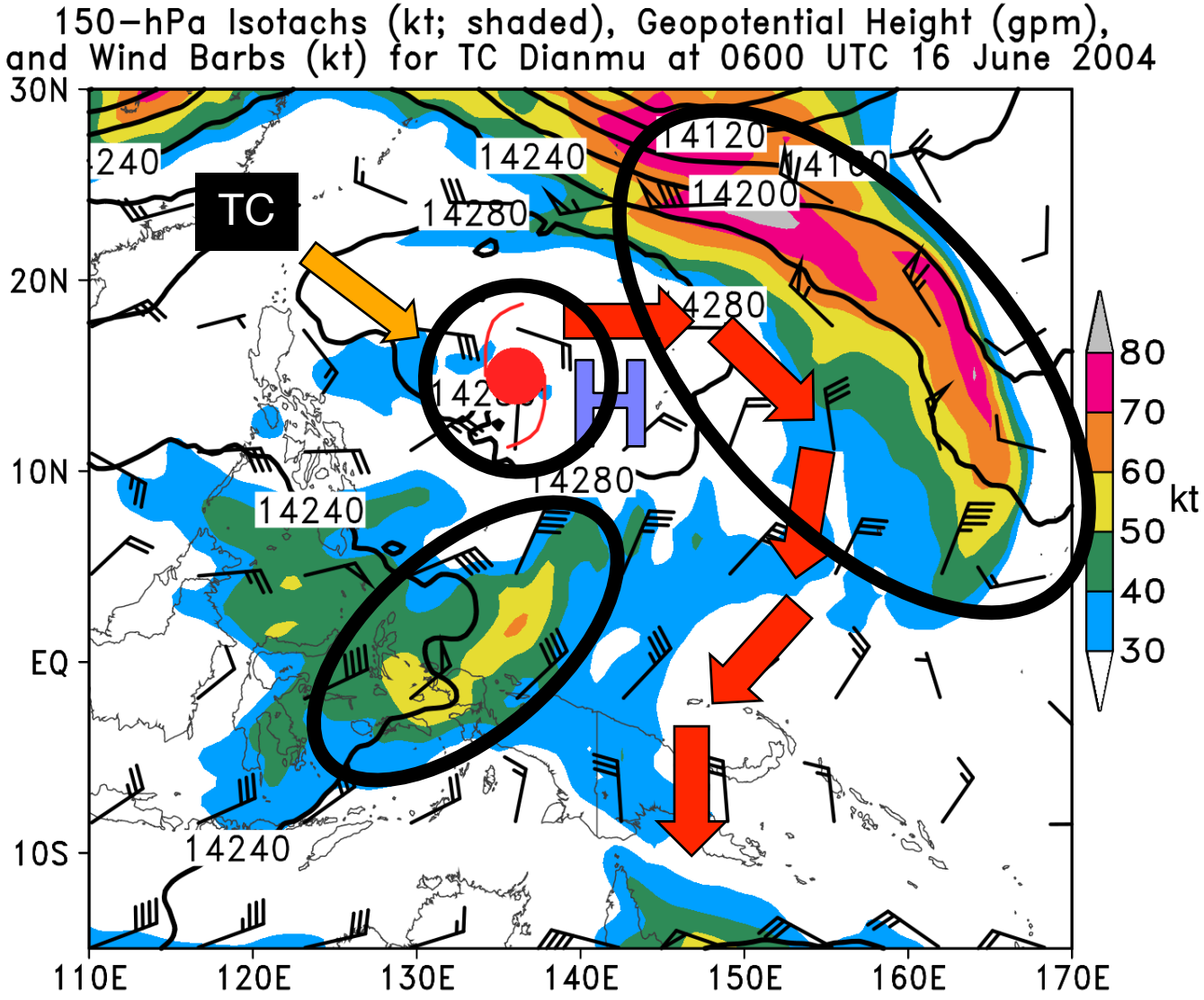
Review of Upper-Tropospheric TC Structure



- Generation of anticyclone aloft due to latent heat release from convection
- Flow is divergent and asymmetric with strongest wind speeds found in equatorward outflow jets

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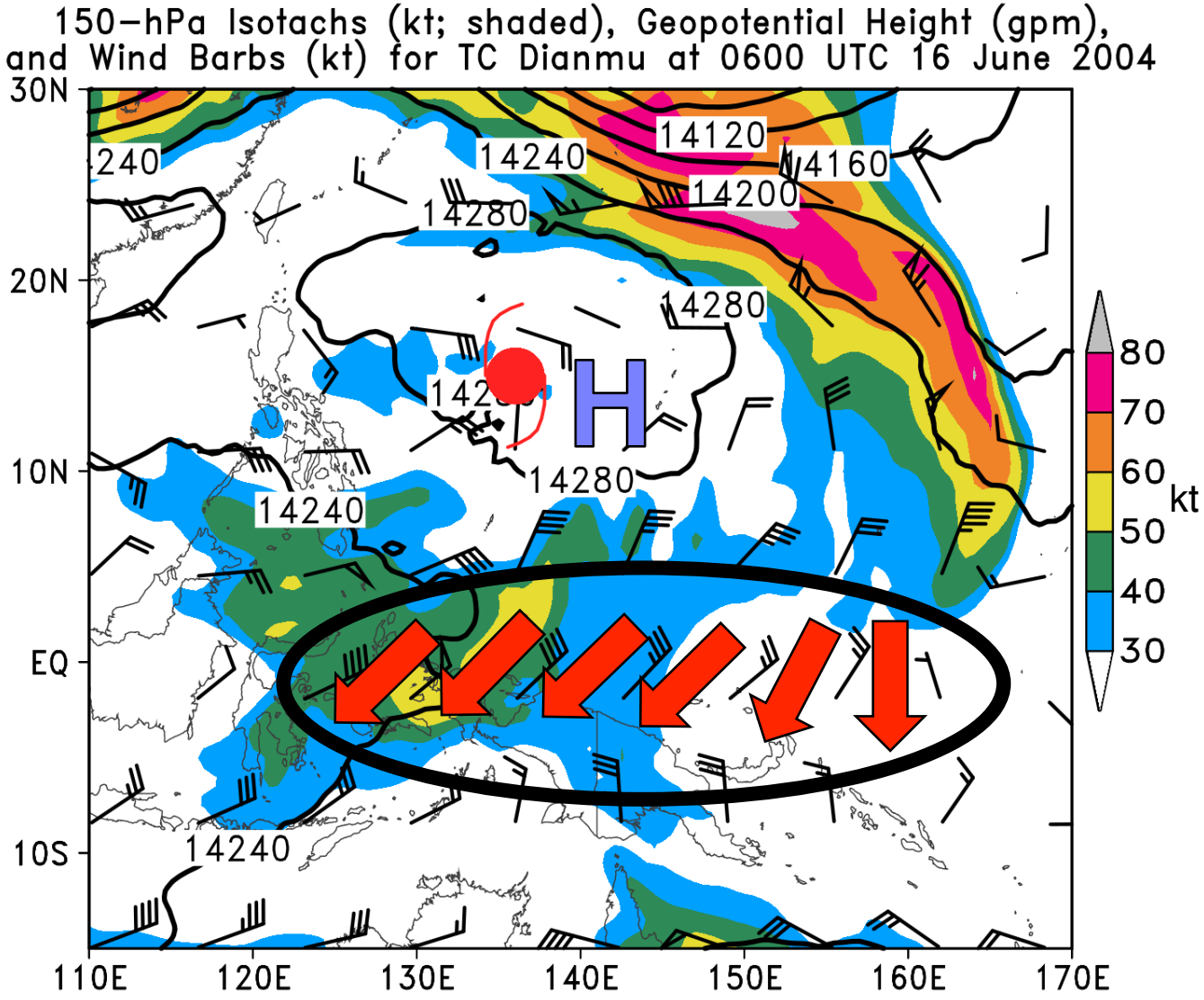


- Generation of anticyclone aloft due to latent heat release from convection
- Flow is divergent and asymmetric with strongest wind speeds found in equatorward outflow jets
- TCs can transport heat and potential energy across equator in upper-tropospheric outflow

Methodology: Quantifying Southward Total Energy Transport Across Equator by TCs

- Evaluation of mean meridional total energy transport by TCs utilizes three-dimensional composites centered on TC longitude

- Composites are constructed using NCEP Climate Forecast System Reanalysis (Saha et al. 2010) for TCs (maximum 10-m wind speed ≥ 34 kt) in western North Pacific at or equatorward of 20°N during 1979–2010 (N = 696 TCs)

- Composites of raw anomalies and normalized anomalies are used to isolate role of TCs in meridional total energy transport

Methodology: Quantifying Southward Total Energy Transport Across Equator by TCs

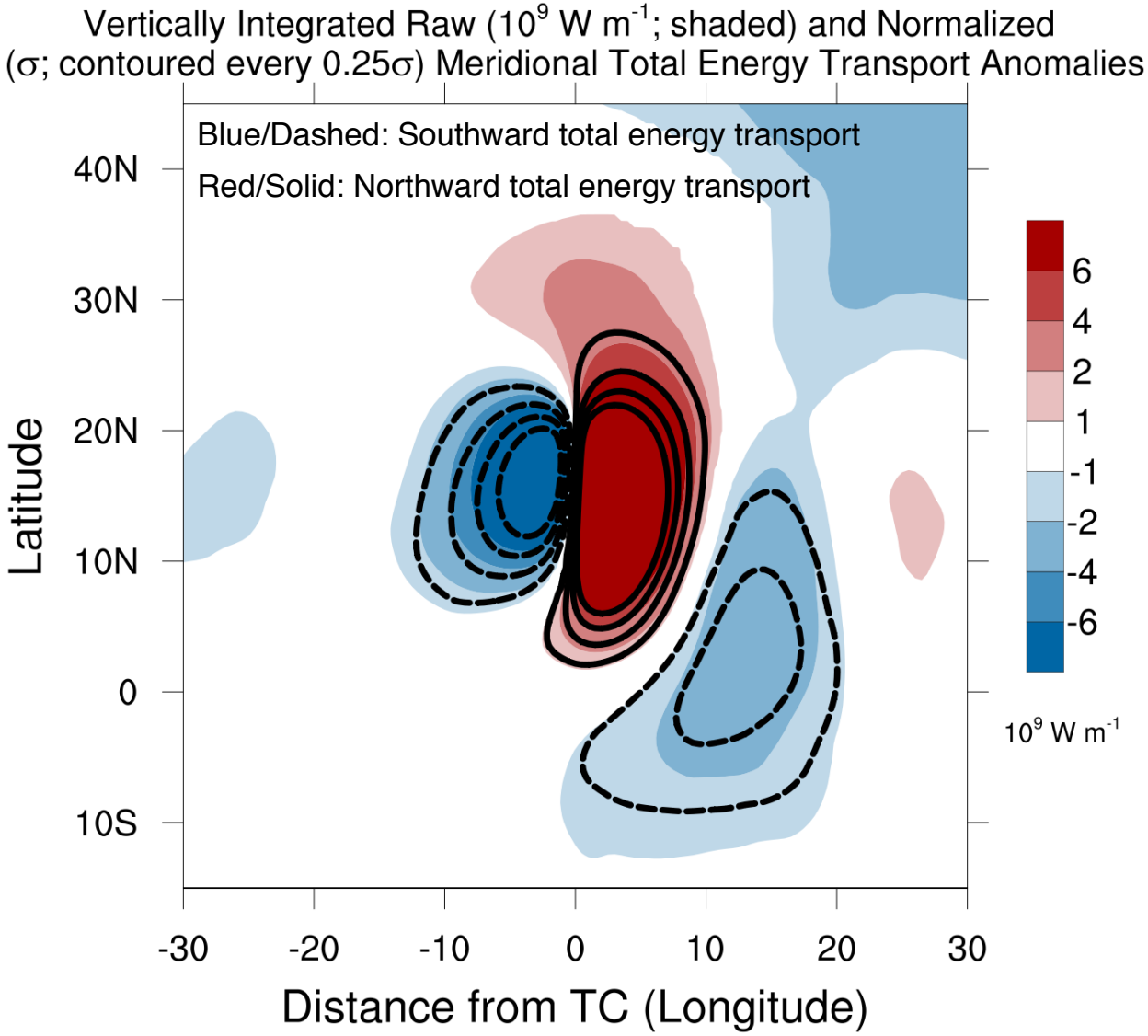
- Composited meridional total energy transport (Trenberth et al. 1997) used to assess role of TCs in southward total energy transport across equator:

$$\text{Total} = \underbrace{\frac{1}{g}\int_{p_t}^{p_s} v\left[\frac{1}{2}(u^2+v^2)\right]dp}_{(2)} + \underbrace{\frac{1}{g}\int_{p_t}^{p_s} v(L_v q)dp}_{(3)} + \underbrace{\frac{1}{g}\int_{p_t}^{p_s} v(c_p T)dp}_{(4)} + \underbrace{\frac{1}{g}\int_{p_t}^{p_s} v(gz)dp}_{(5)}$$

(1)

- **Term 1:** Vertically integrated meridional total energy transport
- **Term 2:** Vertically integrated meridional kinetic energy transport
- **Term 3:** Vertically integrated meridional latent energy transport
- **Term 4:** Vertically integrated meridional sensible heat transport
- **Term 5:** Vertically integrated meridional potential energy transport

Vertically Integrated Meridional Total Energy Transport by TCs



- Meridional total energy transport anomalies in deep tropics due to two factors:

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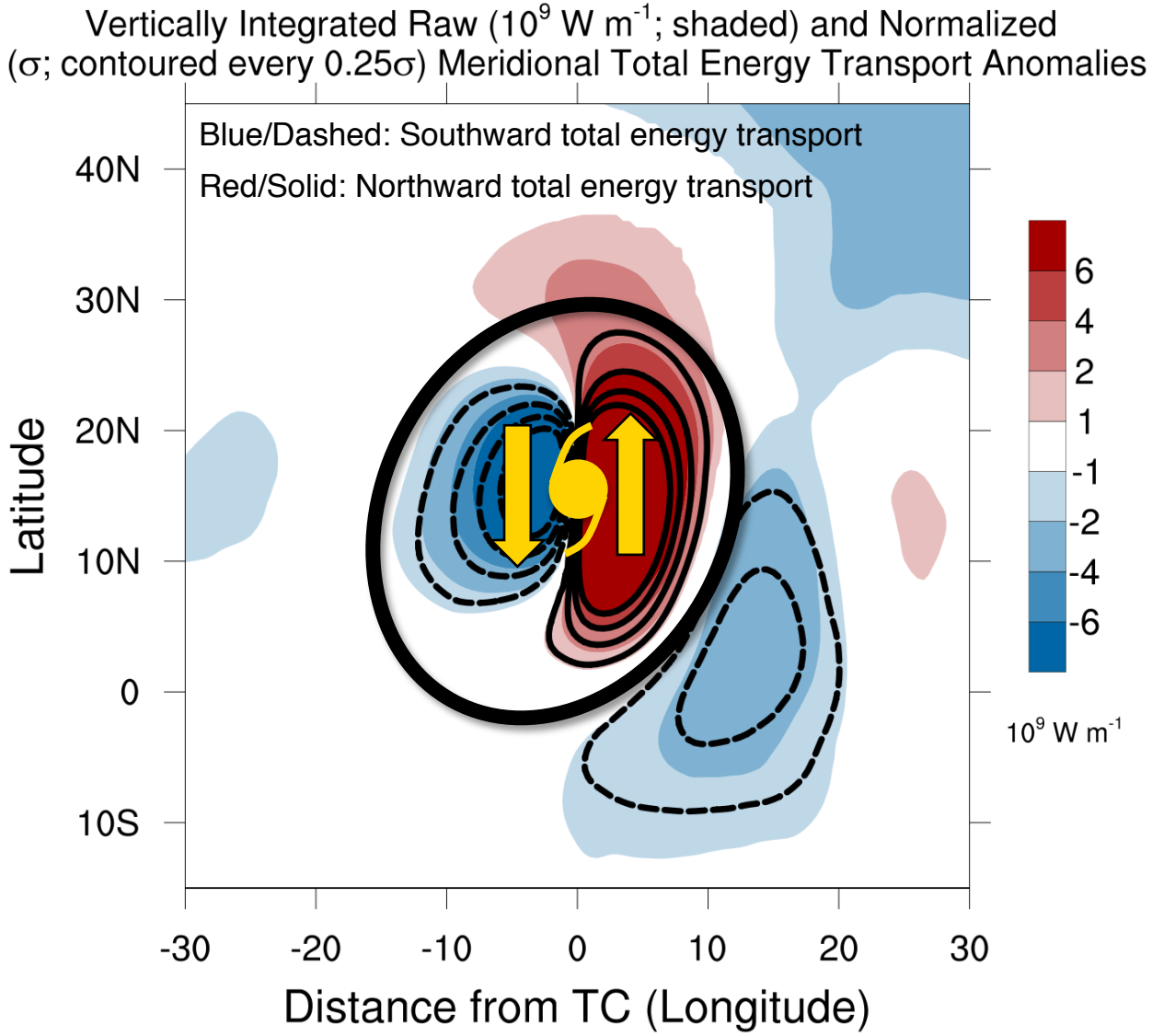

- Meridional total energy transport anomalies in deep tropics due to two factors:
  1. Cyclonic circulation of TC

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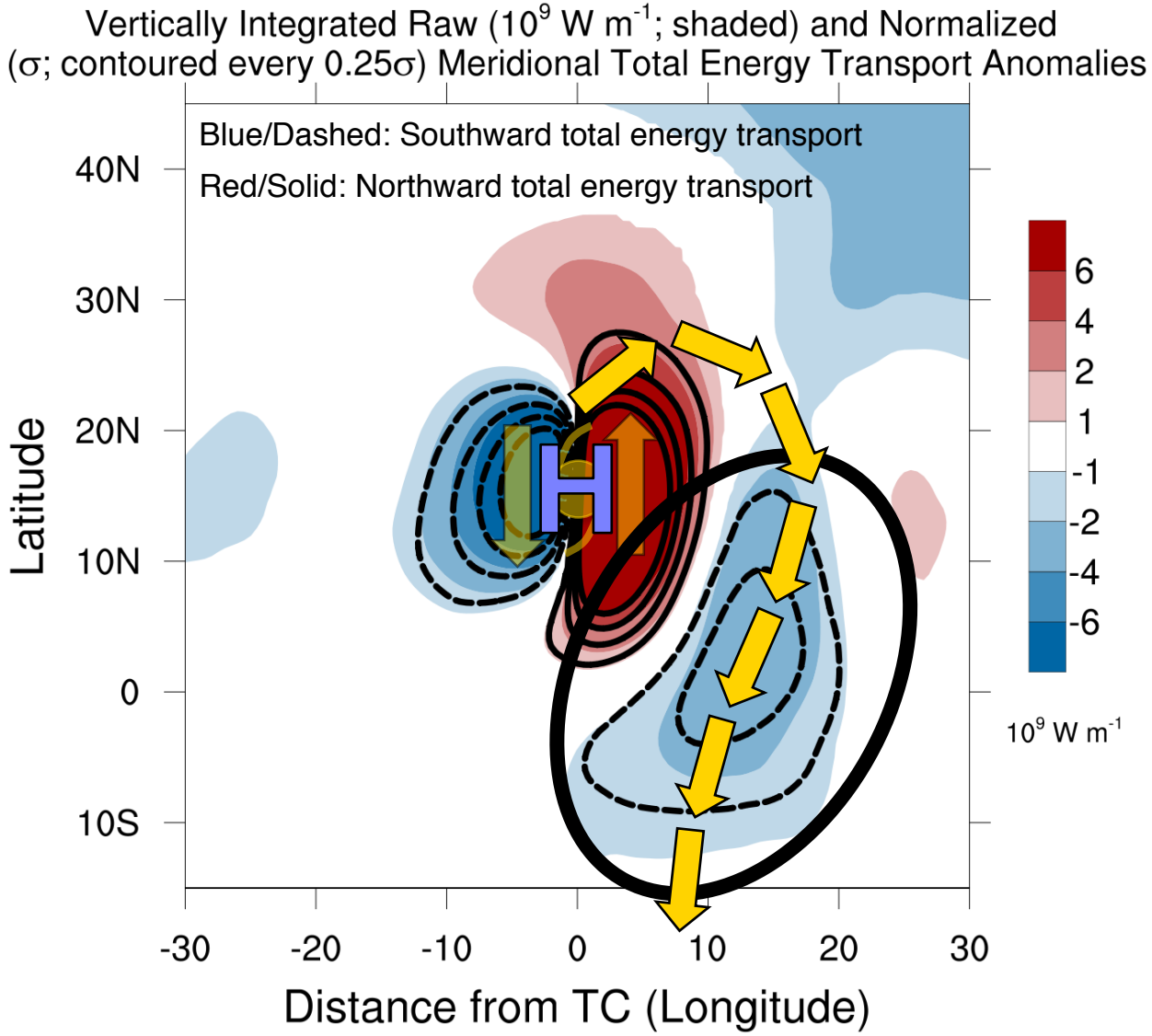

- Meridional total energy transport anomalies in deep tropics due to two factors:
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  2. Upper-tropospheric equatorward outflow jet on southeastern flank of anticyclonic circulation of TC

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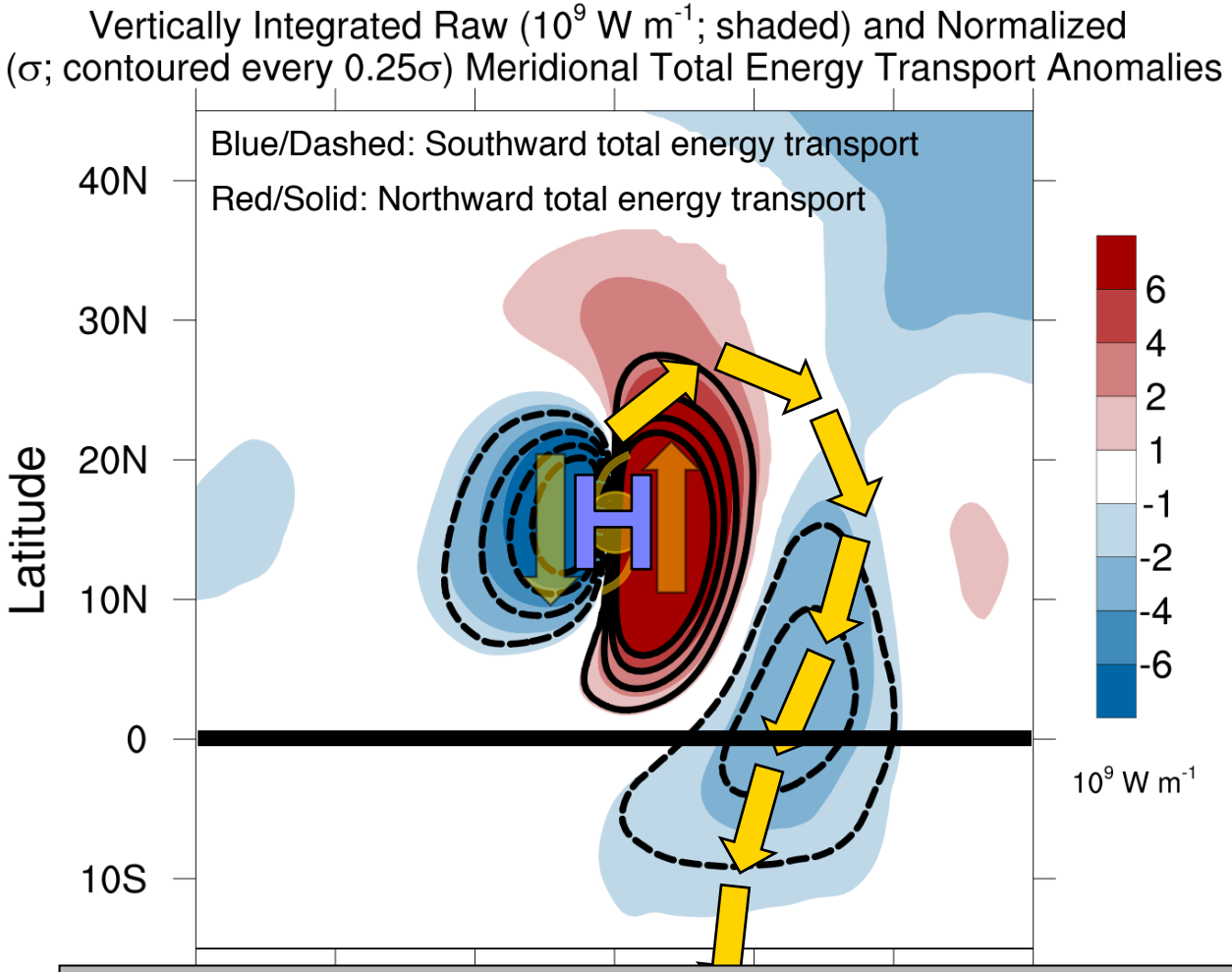
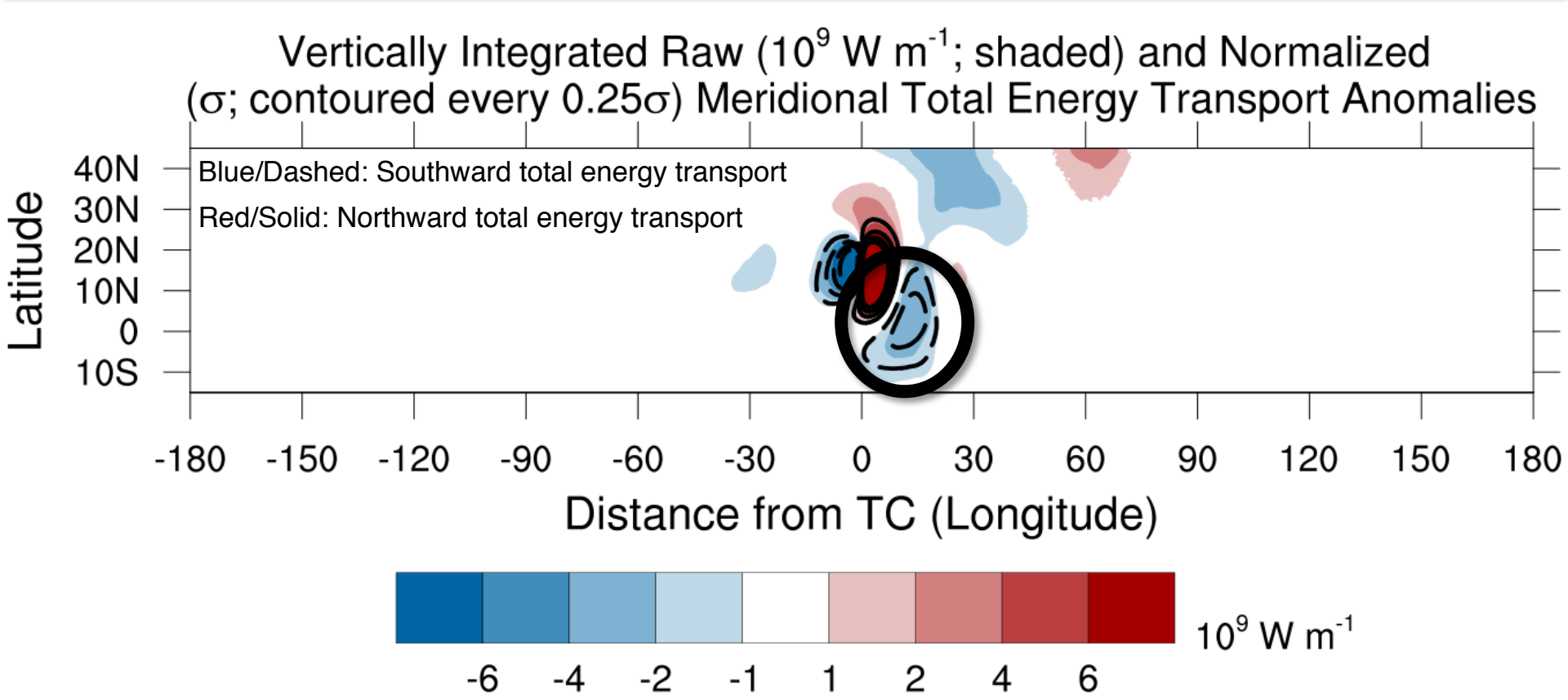


- Meridional total energy transport anomalies in deep tropics due to two factors:
  1. Cyclonic circulation of TC
  2. Upper-tropospheric equatorward outflow jet on southeastern flank of anticyclonic circulation of TC
- Southward transport by outflow jet of TC

Next, meridional total energy transport anomalies in environment outside of TC are examined using domain extending zonally across globe

Global Structure of Meridional Total Energy Transport Anomalies



- Equatorward outflow jet of TC is primary source of anomalous meridional total energy transport at equator

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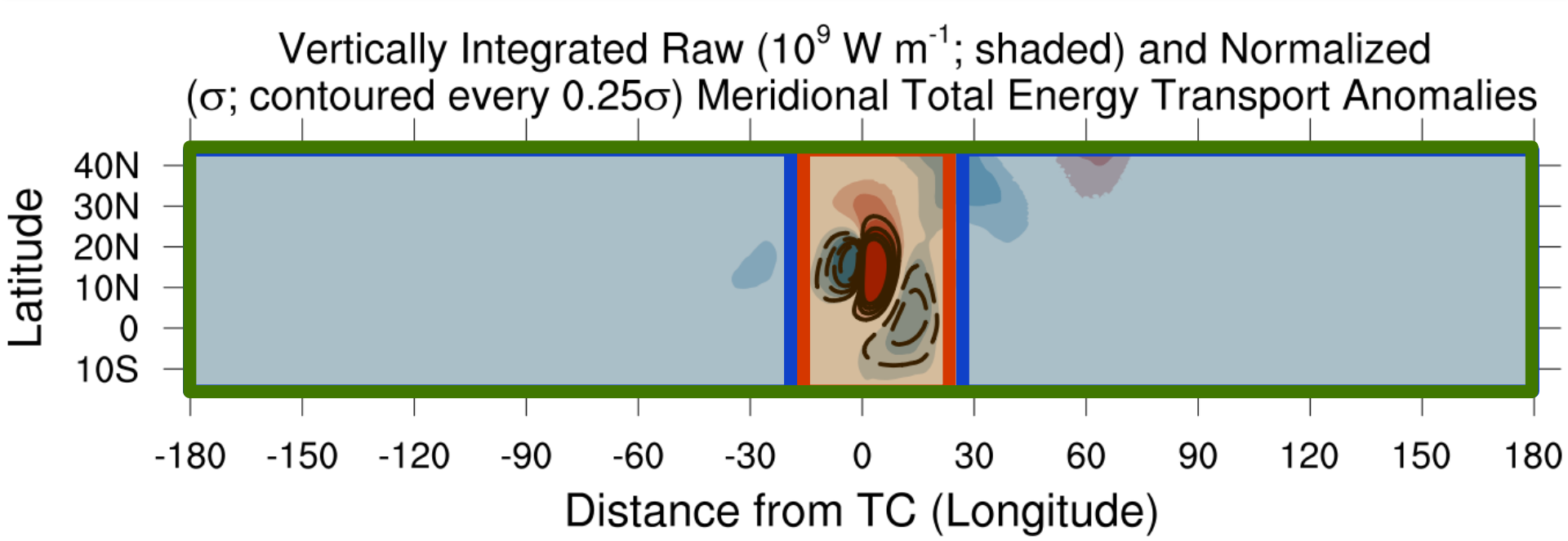

To quantify meridional total energy transport anomalies across equator by TC, composites are zonally integrated over three regions:

1. **TC and its immediate environment (Near TC)**
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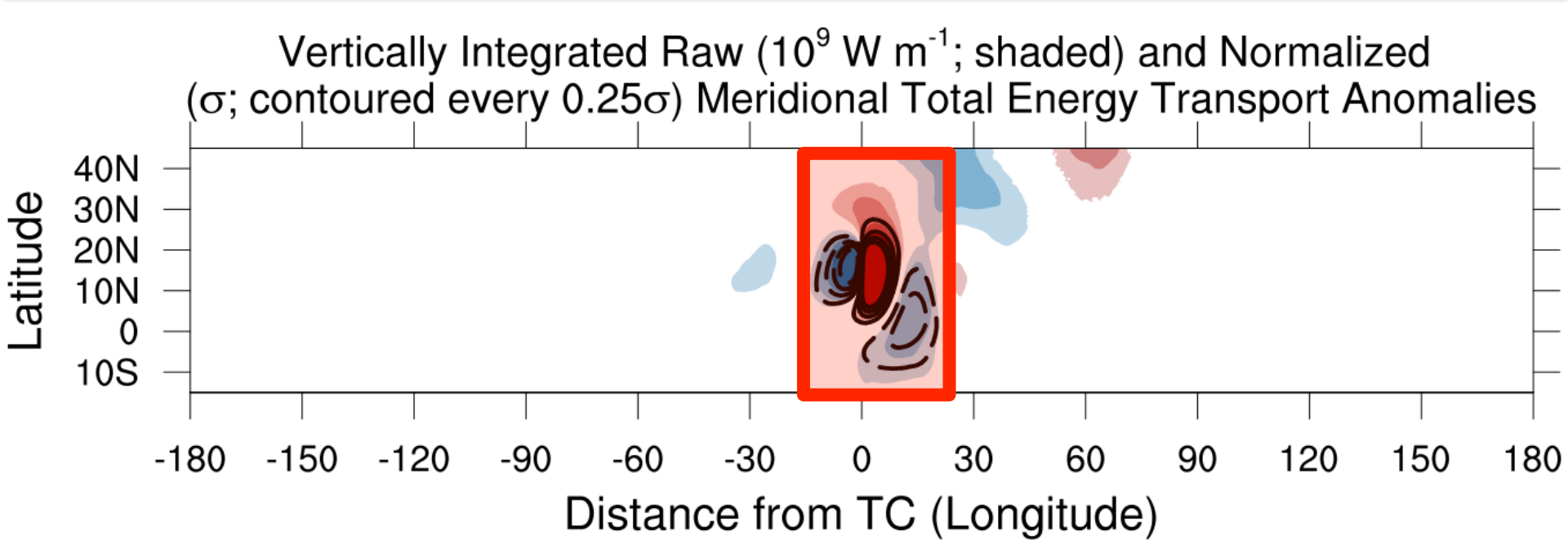

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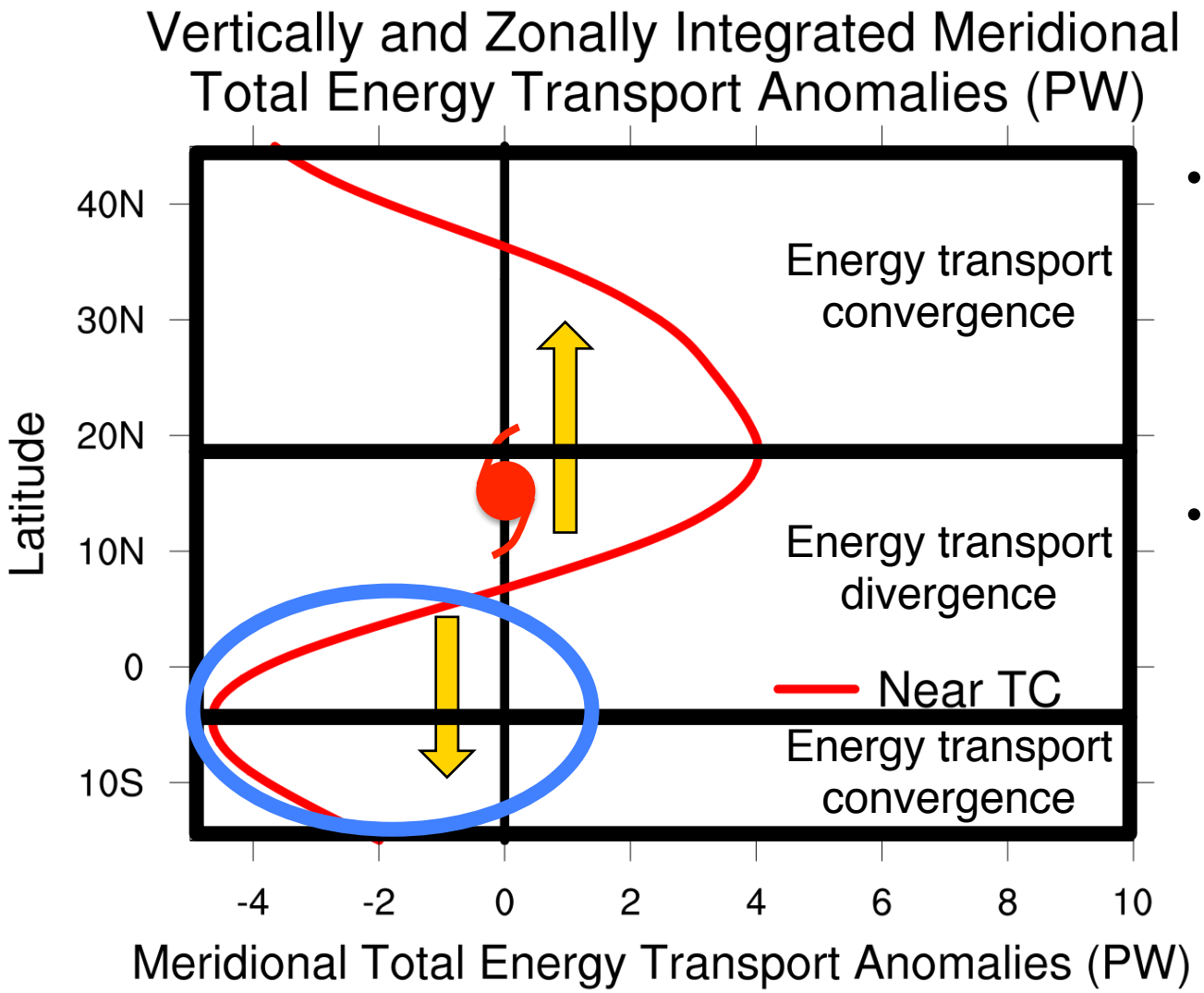
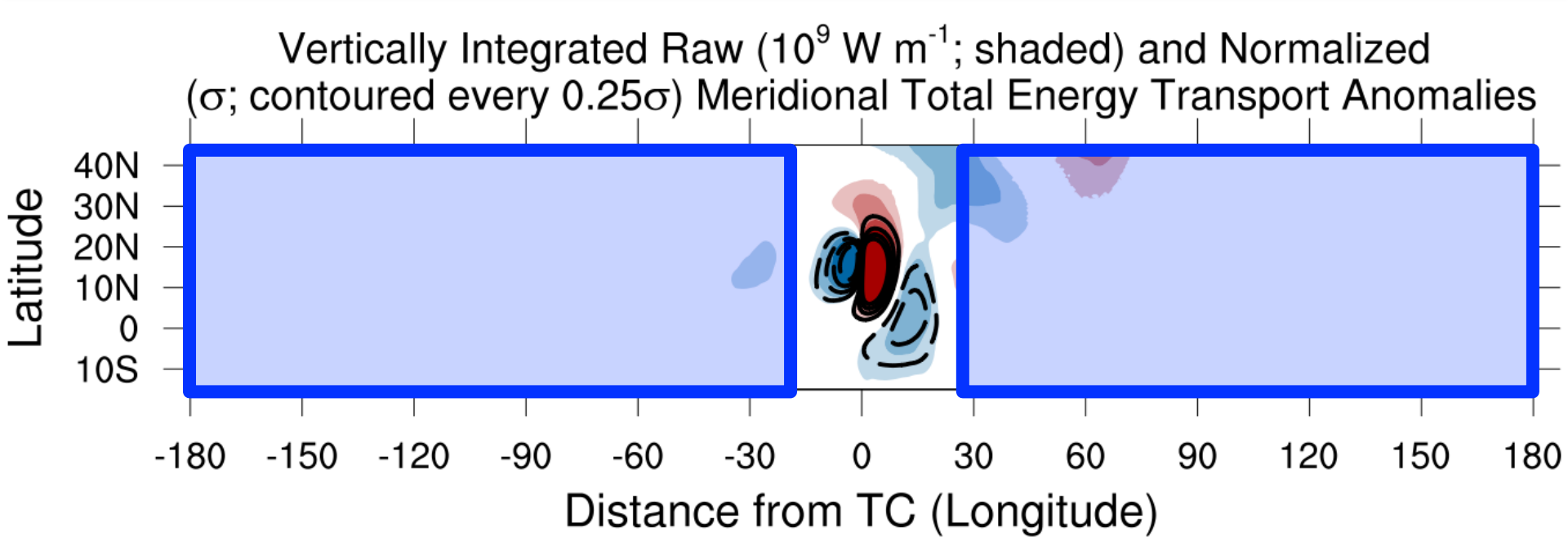
Quantifying Meridional Total Energy Transport by TCs in a Global Context



- Anomalous meridional total energy transport from NH tropics into NH subtropics and SH tropics
- Anomalous southward meridional total energy transport at equator due to equatorward outflow jet of TC

Global Structure of Meridional Total Energy Transport Anomalies



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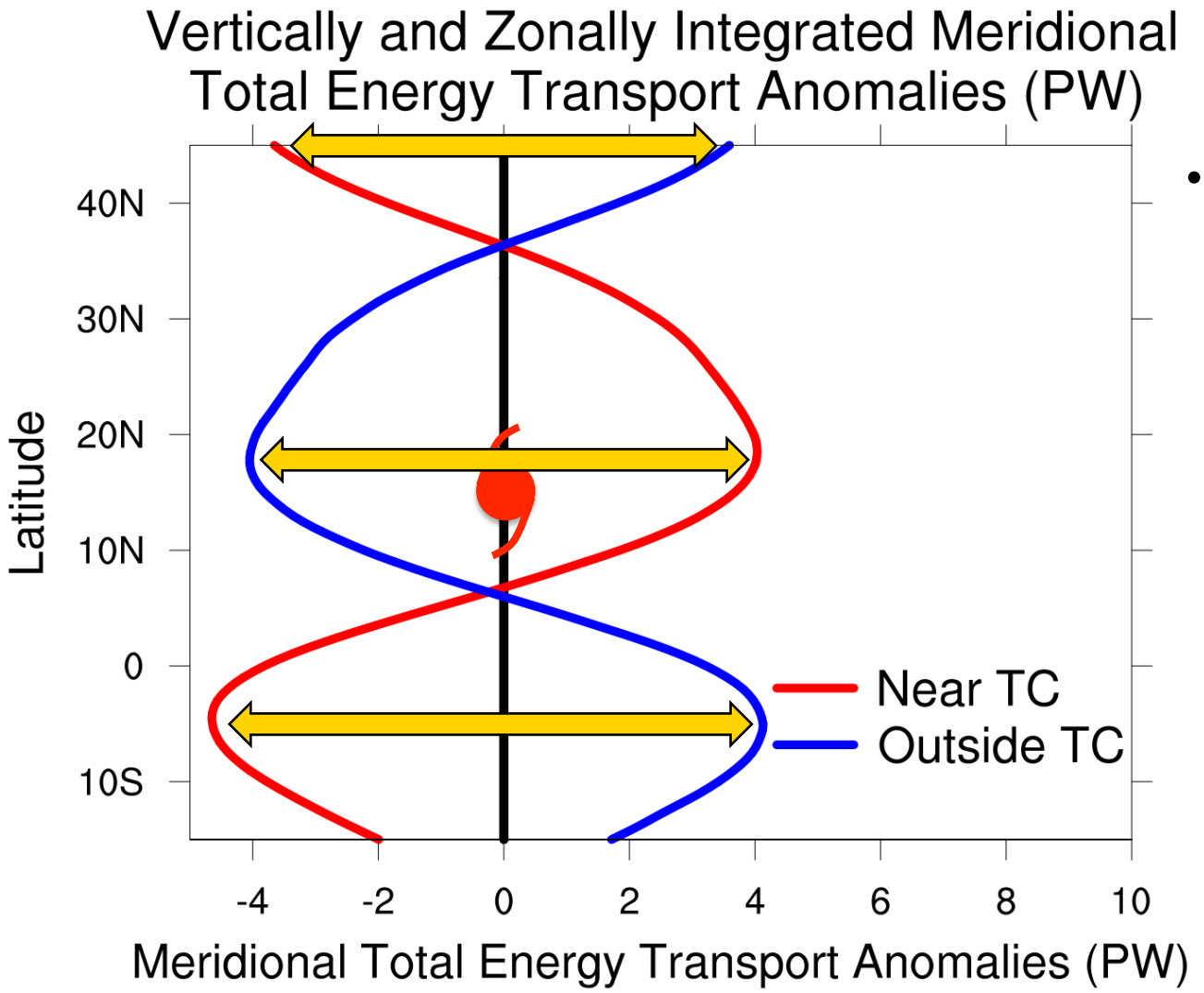

- Meridional total energy transport anomalies outside TC nearly balance meridional total energy transport anomalies by TC

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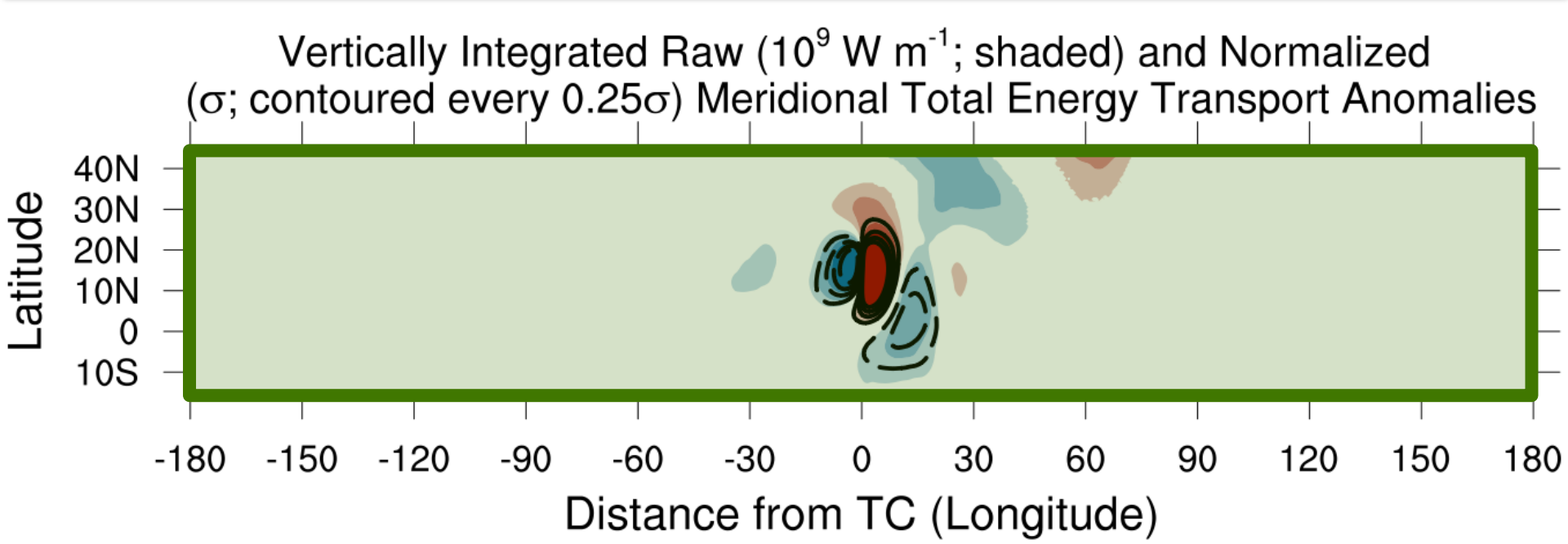

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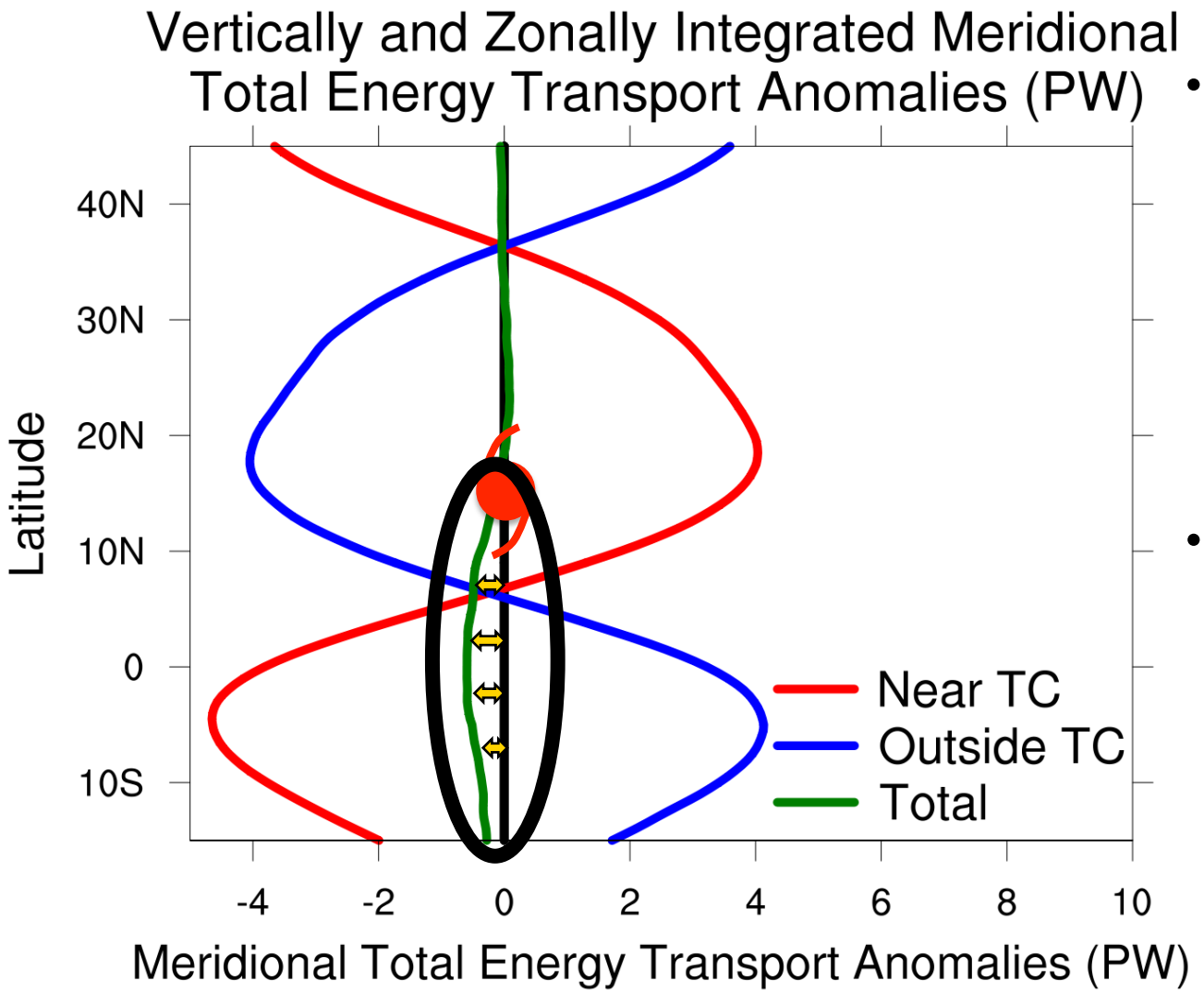
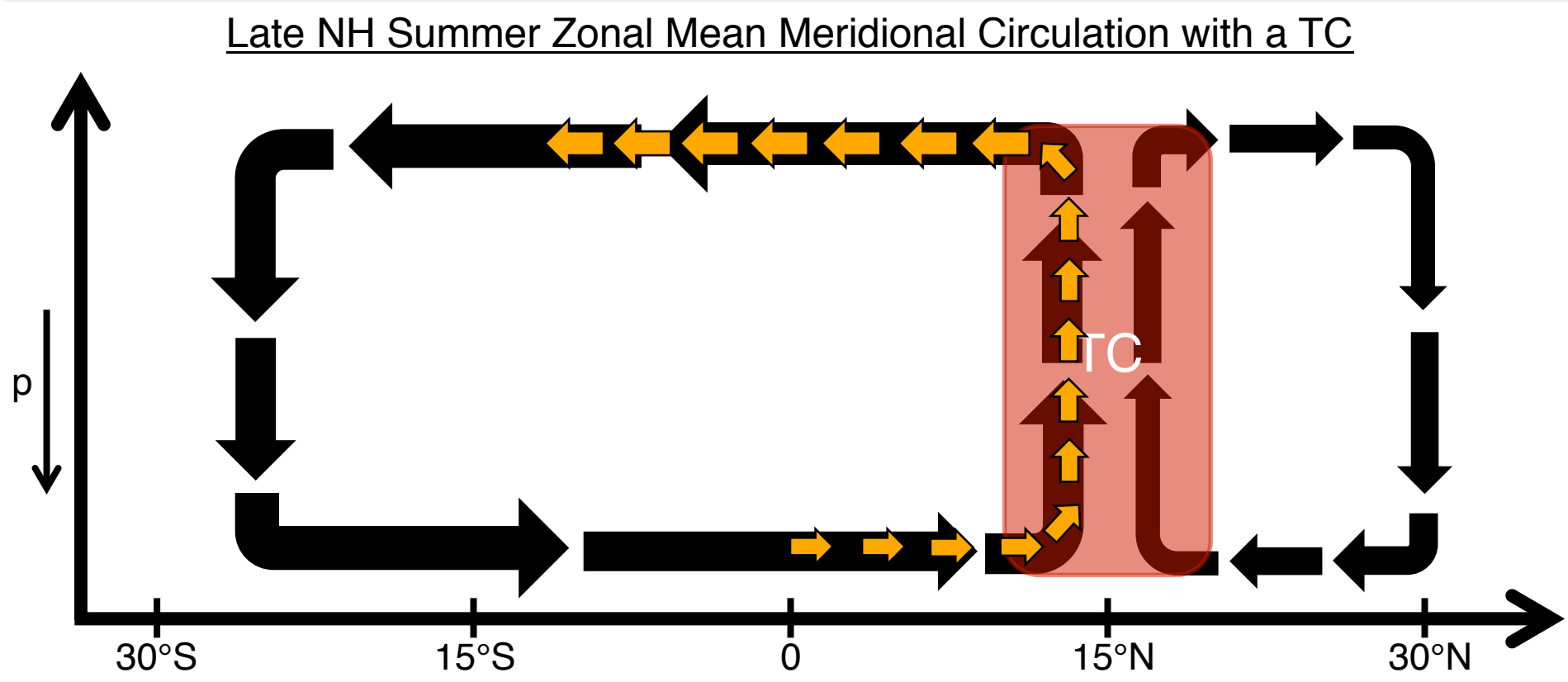


- Zonal integration over all longitudes yields –0.5 PW southward energy transport near equator suggesting transport by TCs is dominant
- –0.5 PW southward energy transport anomalies by TC are large relative to –1.0 to –2.0 PW climatological southward energy transport near equator during NH summer and fall

Summary: TC Impacts on Meridional Total Energy Transport



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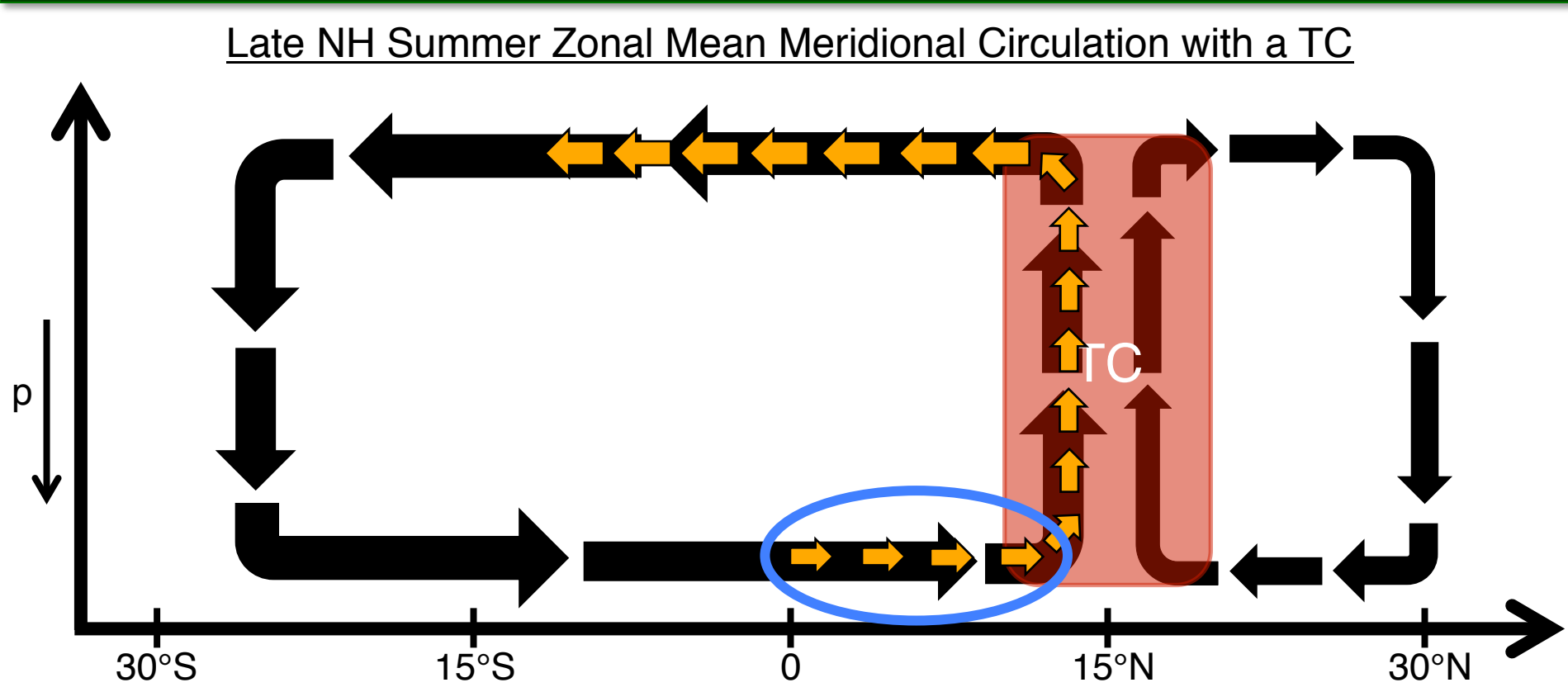

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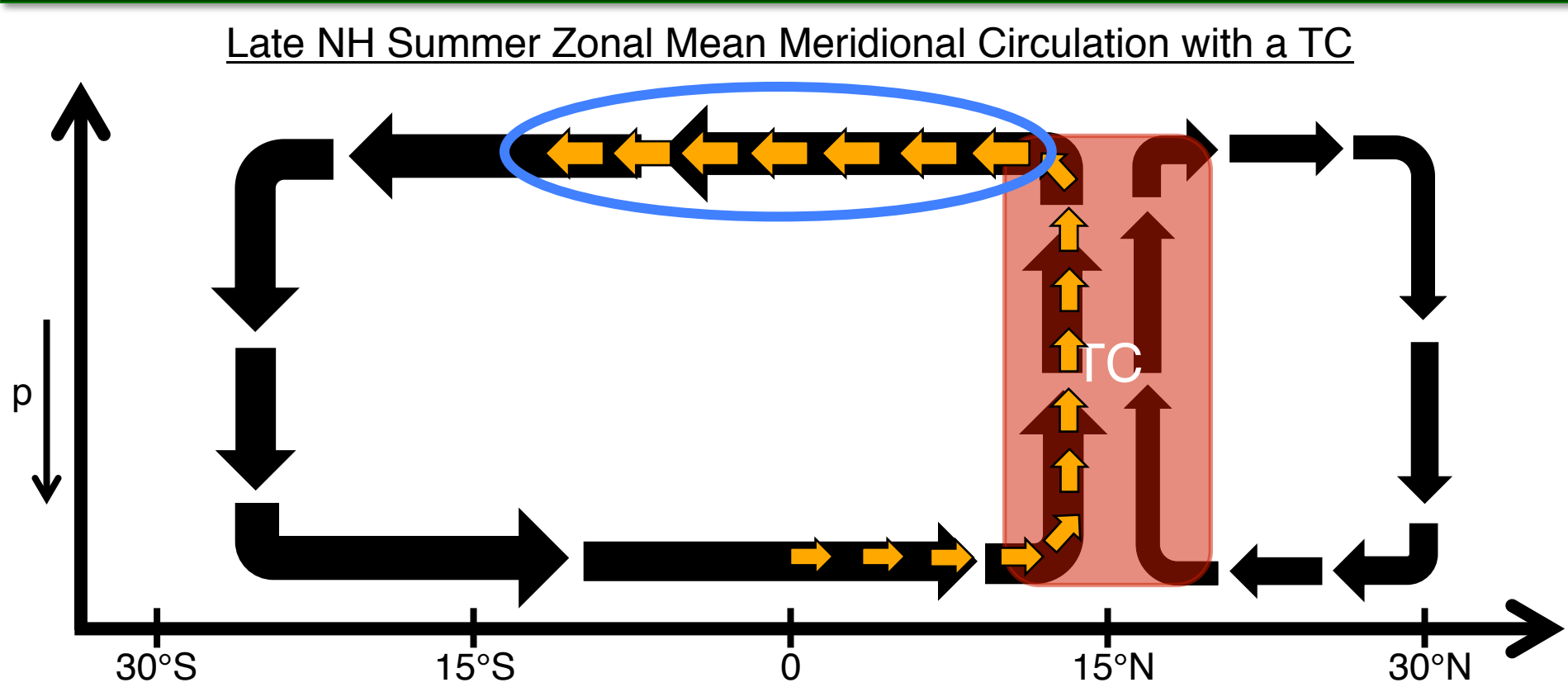

- Northward lower-tropospheric total energy transport by TC inflow
- Southward upper-tropospheric total energy transport by TC outflow

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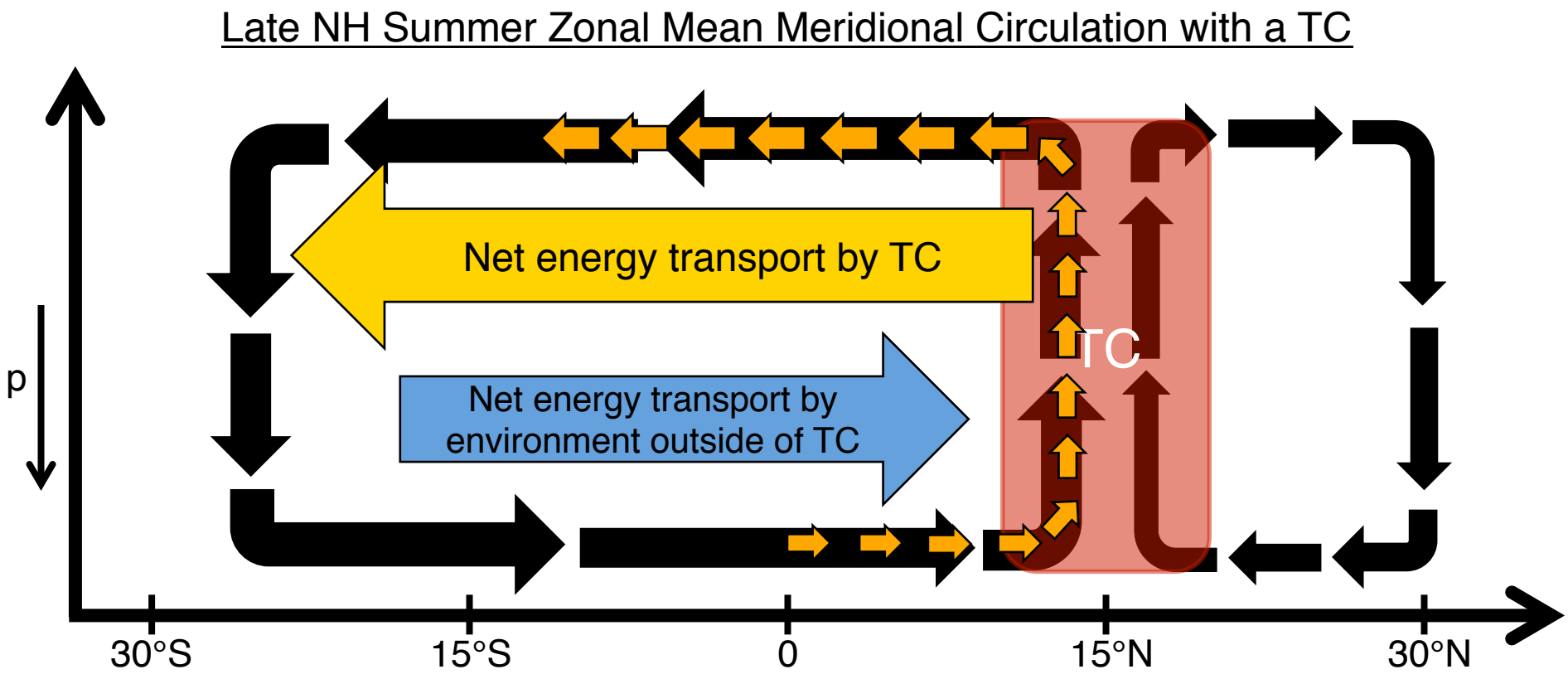

- Net southward vertically integrated total energy transport across equator by TC
- Net northward vertically integrated total energy transport across equator by environment outside of TC

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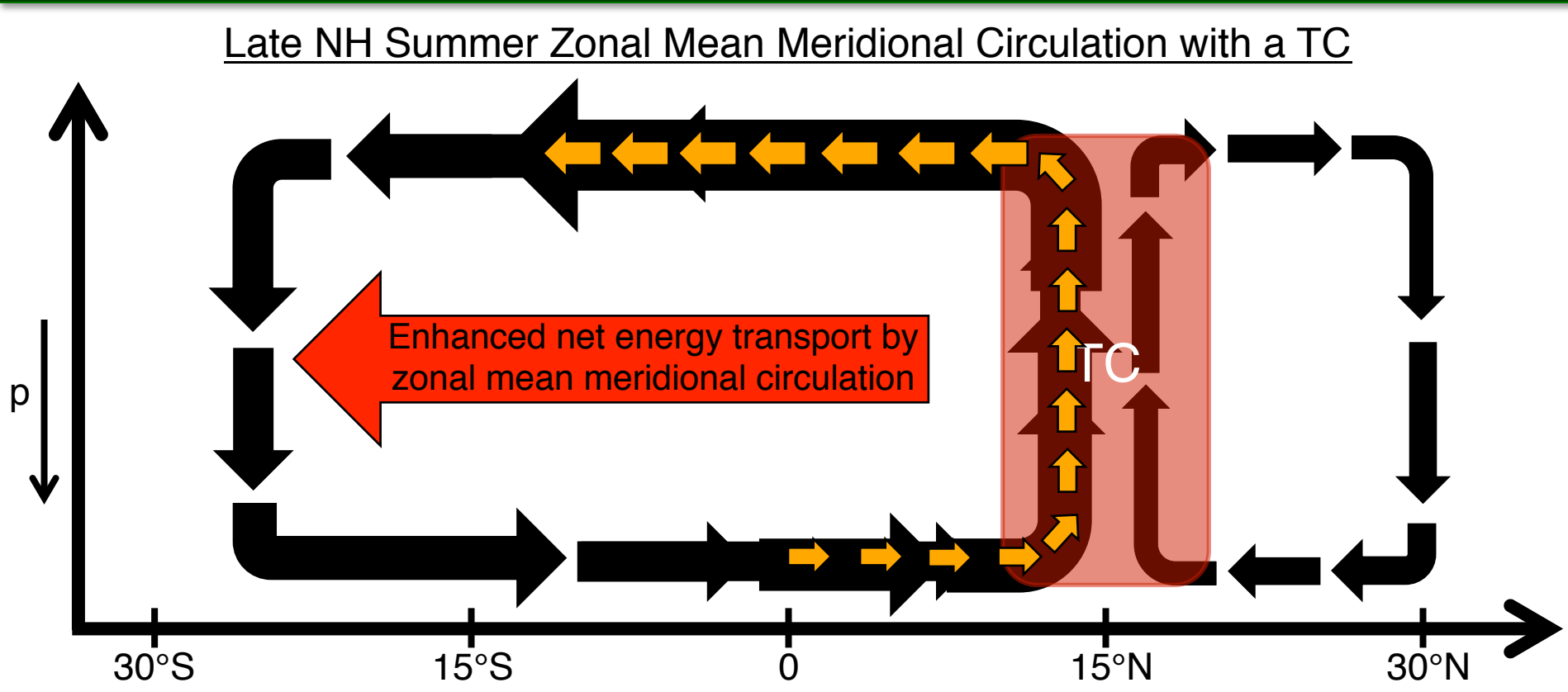

- Enhanced net southward vertically integrated total energy transport across equator by zonal mean meridional circulation due to TC