The Radiative Effects of Tropical Tropopause Layer (TTL) Water Vapor on Tropical Cyclone Potential Intensity

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Some figures reproduced from Gilford et al. (2015, *in revision, JOC)*

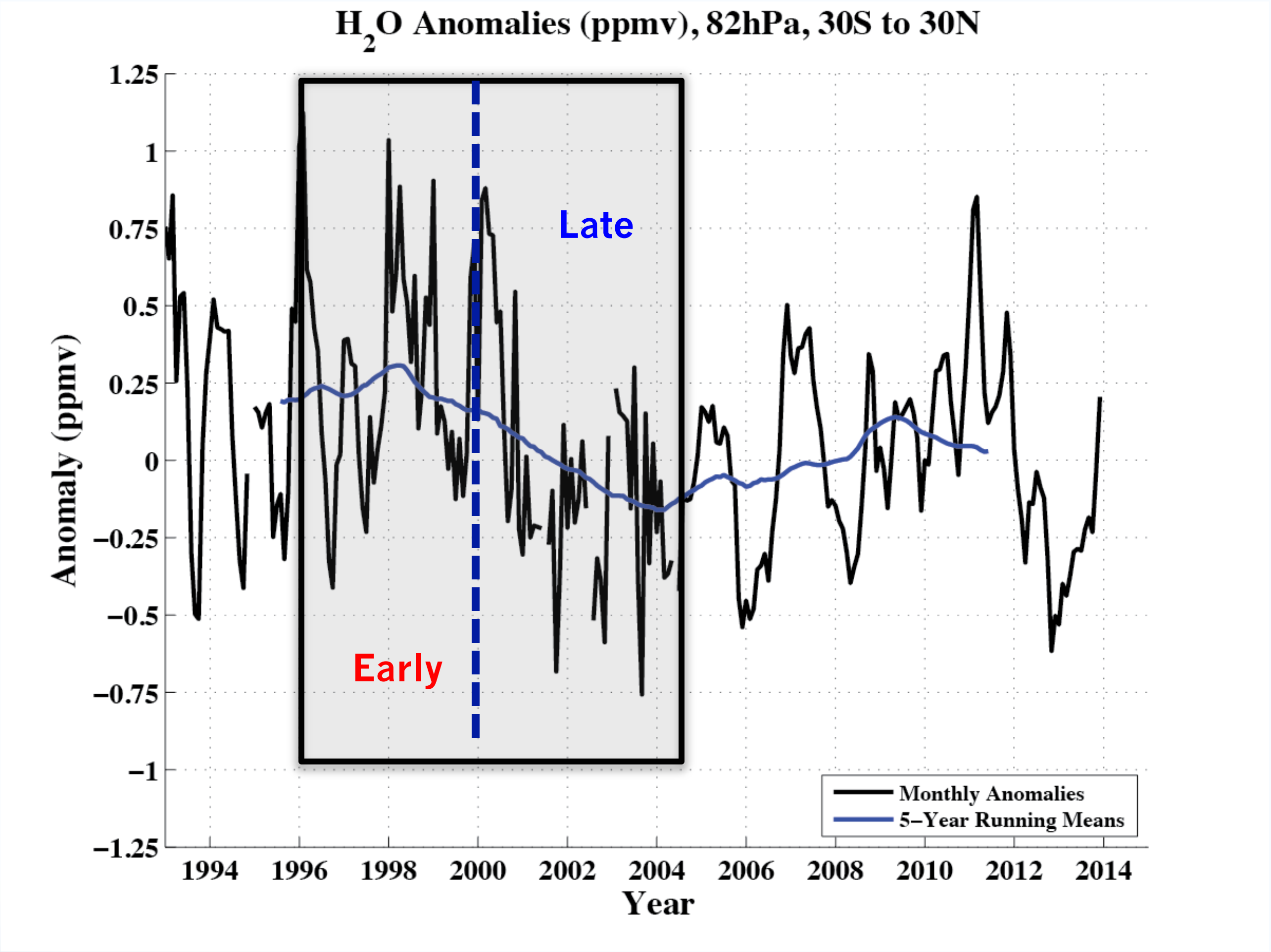
[1]: MIT, [2]: NOAA ESRL CSD

Outline

- "Abrupt Drop" events in the TTL
  - The radiative effects associated with the 2000 abrupt drop
  - The 2011 abrupt drop definition and spatial structure
  - The radiative effects associated with the 2011 abrupt drop in water vapor

- Abrupt drop relationships with tropical cyclones (TCs) and potential intensity (PI)
  - Introduction to PI calculations
  - Application in the Western North Pacific

There are large variability events in the observed H_2O record



Late and Early periods as defined by Solomon et al. (2010) and Maycock et al. (2014)

Randel et al. (2006) highlighted associations with:

→ ozone reductions
→ anomalous upwelling

From SWOOSH = Stratospheric Water and OzOne Satellite Homogenized data set (Davis and Rosenlof 2013)

The 2000 “abrupt drop” was associated with radiative forcing impacts

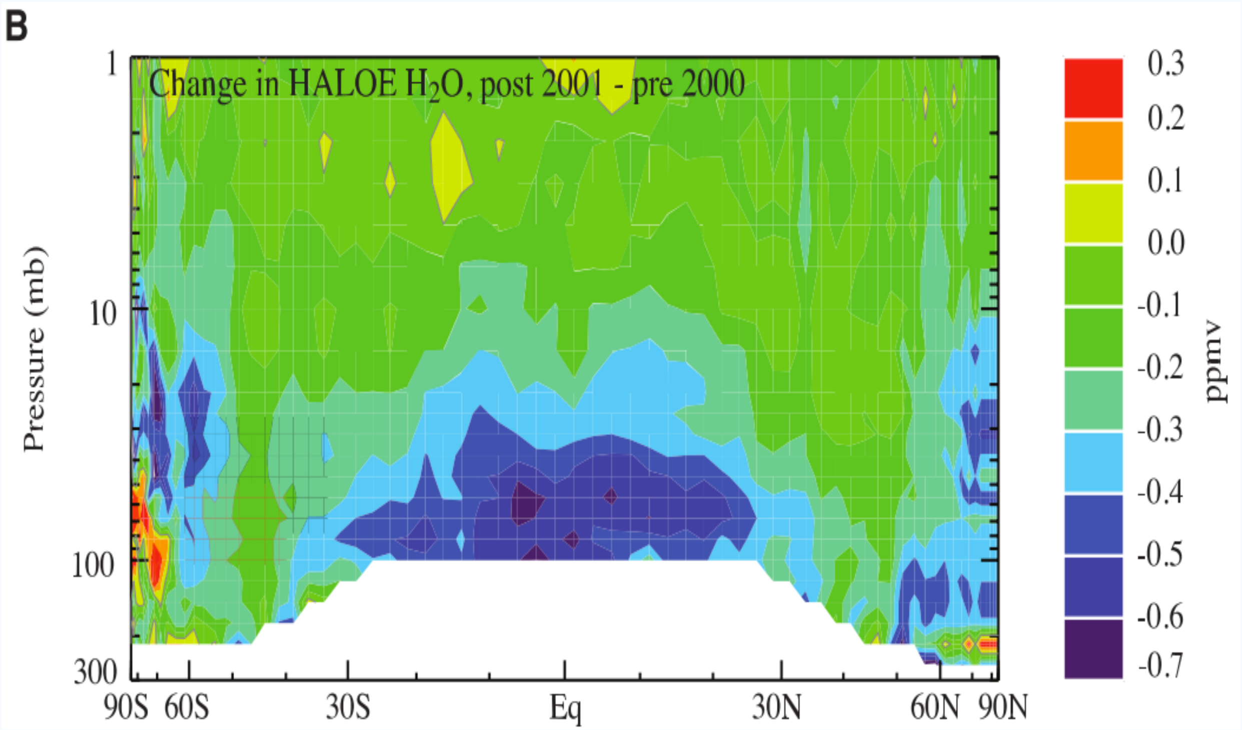


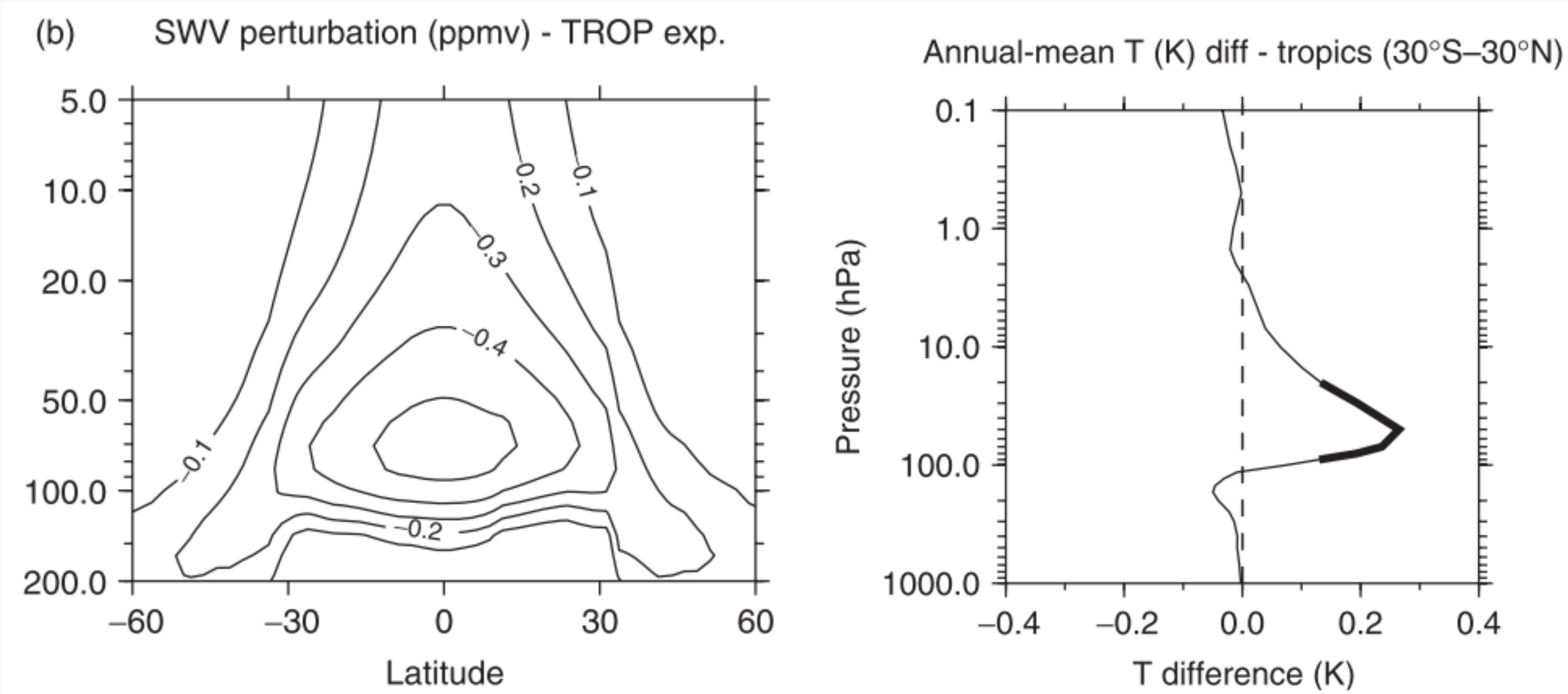
Fig. 2, Solomon et al. (2010)

Global Radiative Forcing (RF) → –**0.098 W/m²**

Local temperatures should also be affected...

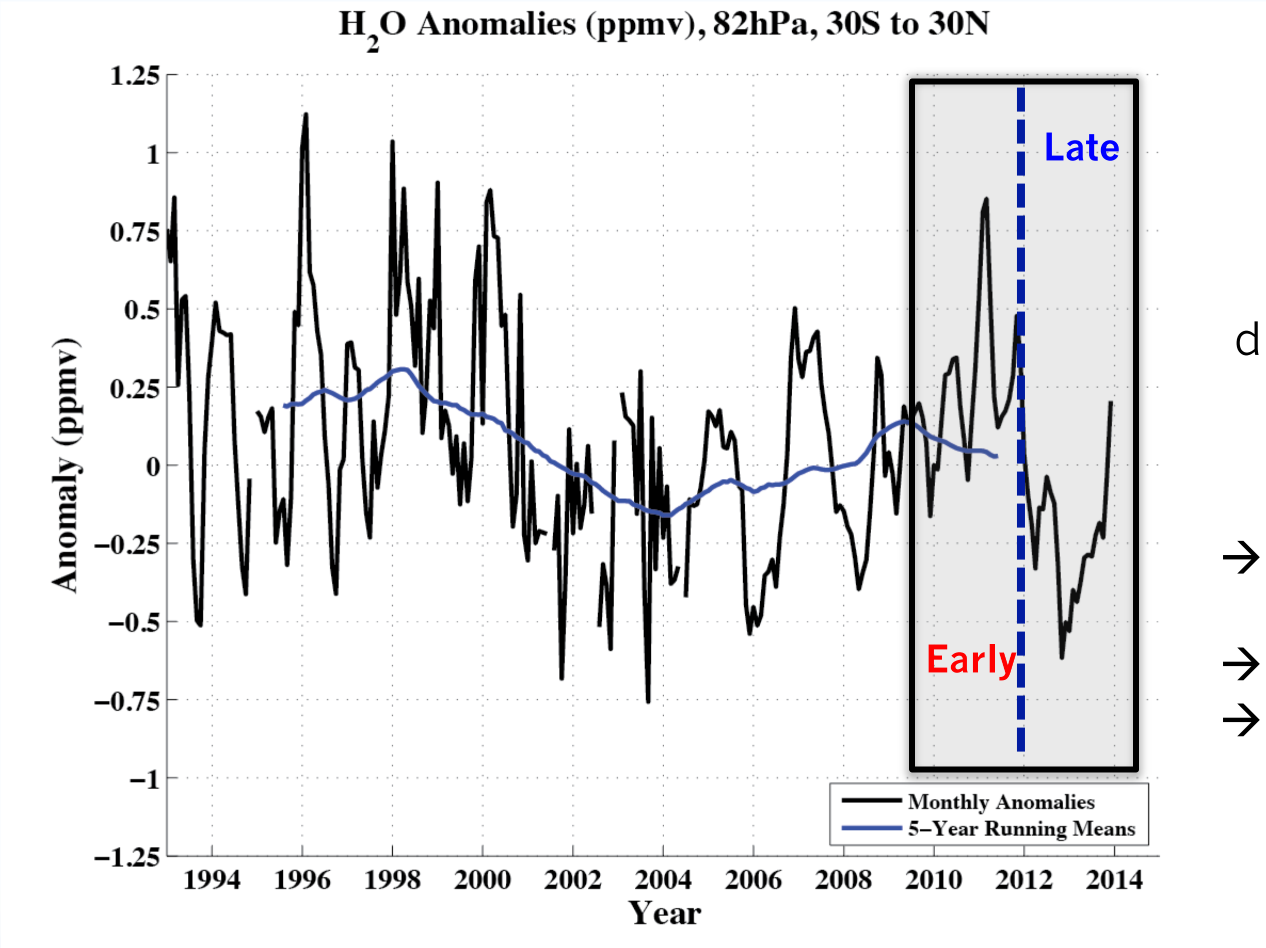
e.g. Randel et al. (2006) Rosenlof and Reid (2008), Joshi et al. (2010), Dessler et al. (2013) Urban et al. (2014), Dessler et al. (2014)

The 2000 abrupt drop also had associated local radiative impacts on temperature



Figs. 5b and 7, Maycock et al. (2014)

Are there radiative impacts associated with the 2011 event?



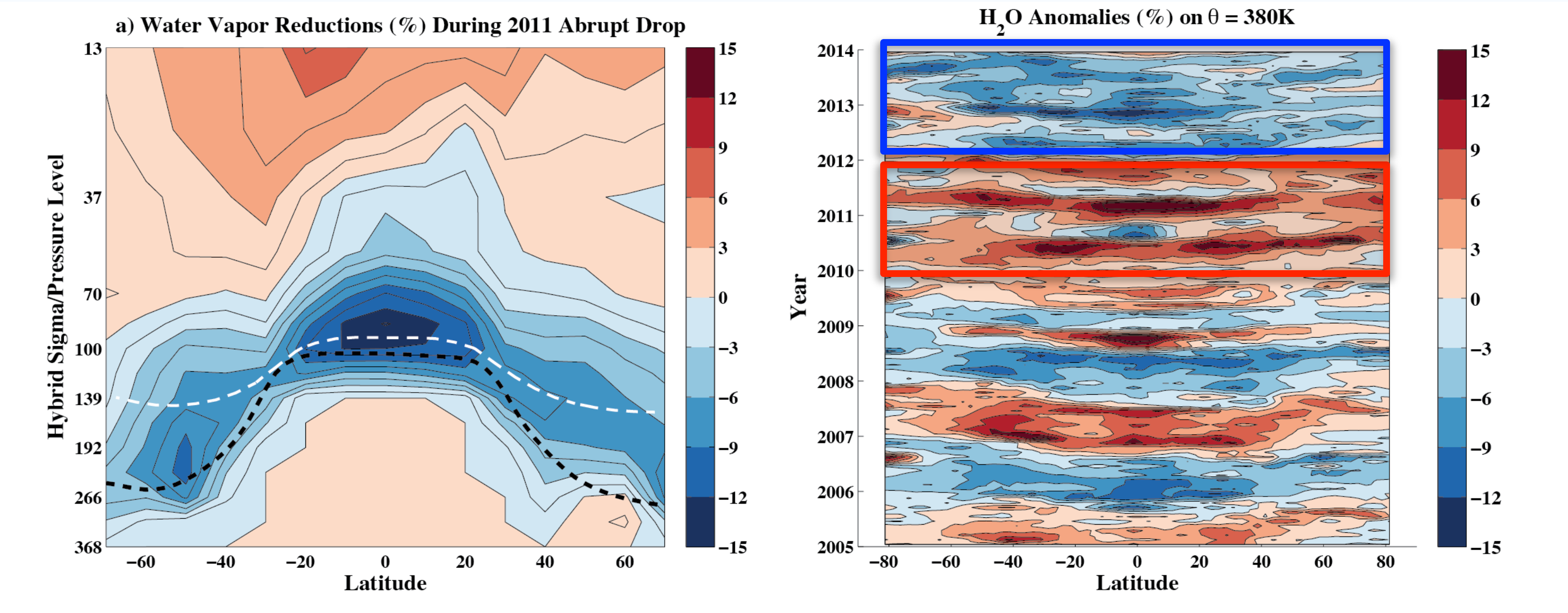
2011 Abrupt Drop = Late − Early

Using the mean differences from MLS v3 data at each three-dimensional location.

→ Examine the event structure
→ Apply to an RTM
→ Explore impacts on tropical cyclones

From SWOOSH = Stratospheric Water and OzOne Satellite Homogenized data set (Davis and Rosenlof 2013)

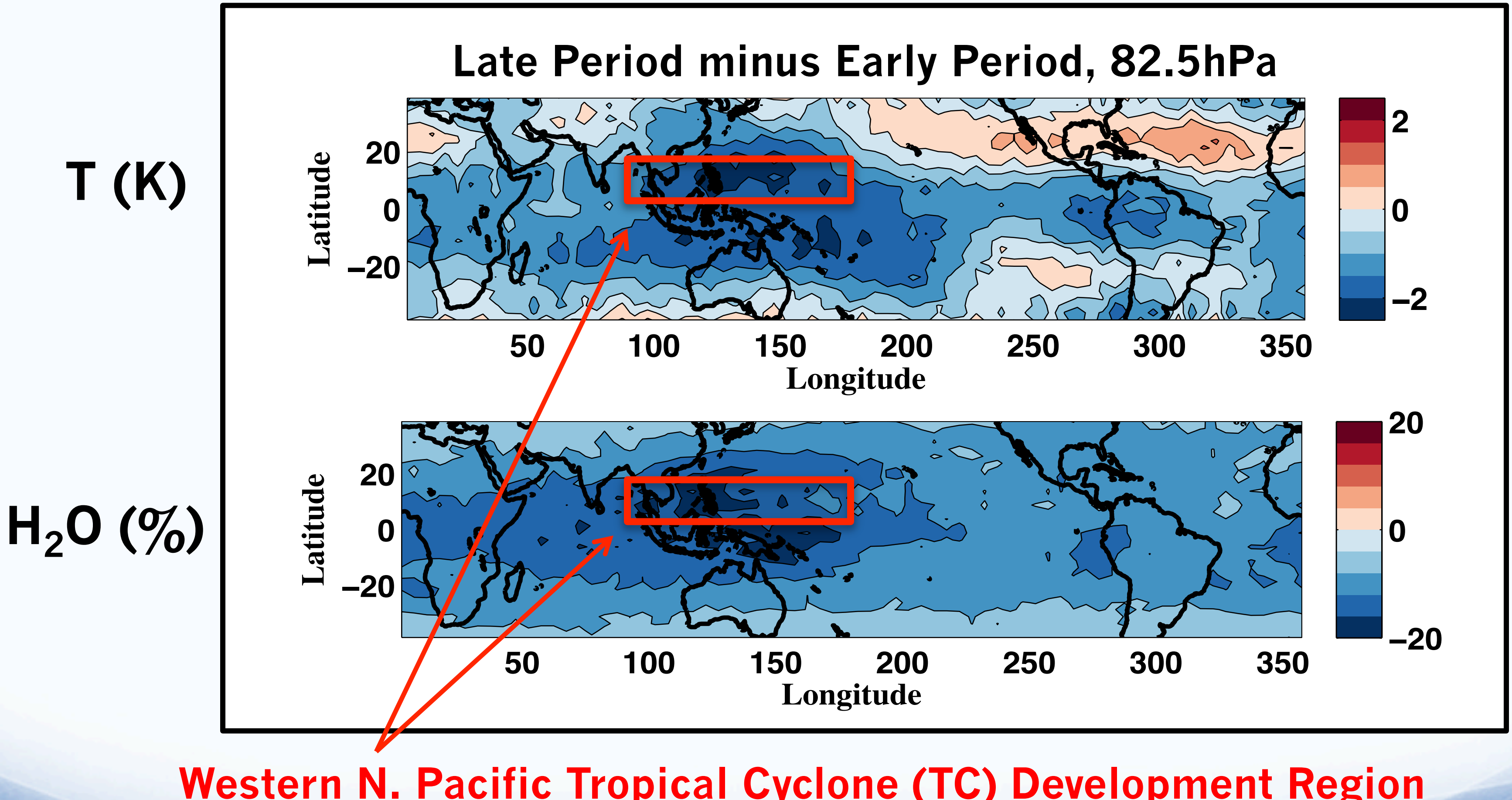
Zonal-mean abrupt drop structure reveals large differences in the tropics *and* the midlatitudes



See Randel and Jensen (2013)

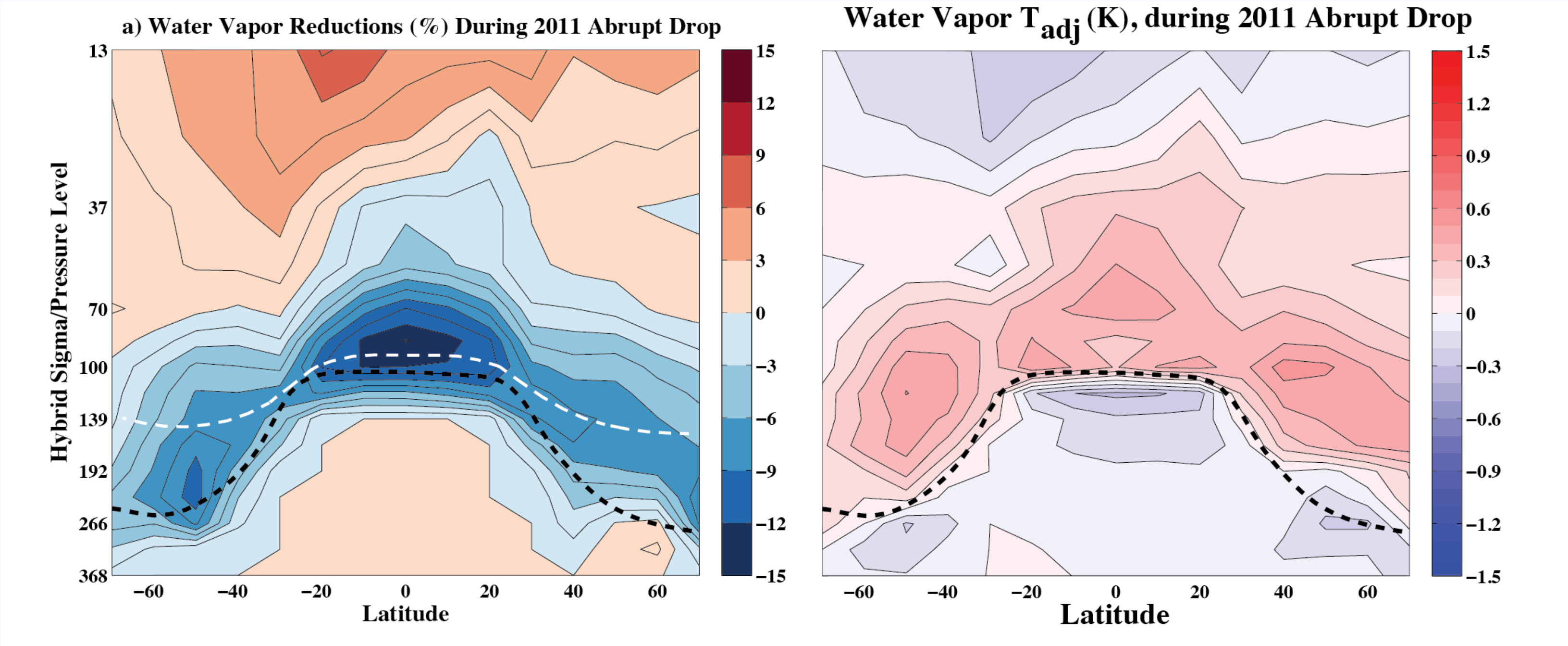
H_2O (%)

Horizontal structure shows variability maximized over the Western Pacific Warm Pool



WNP as defined by Wing et al. (*accepted, GRL*)

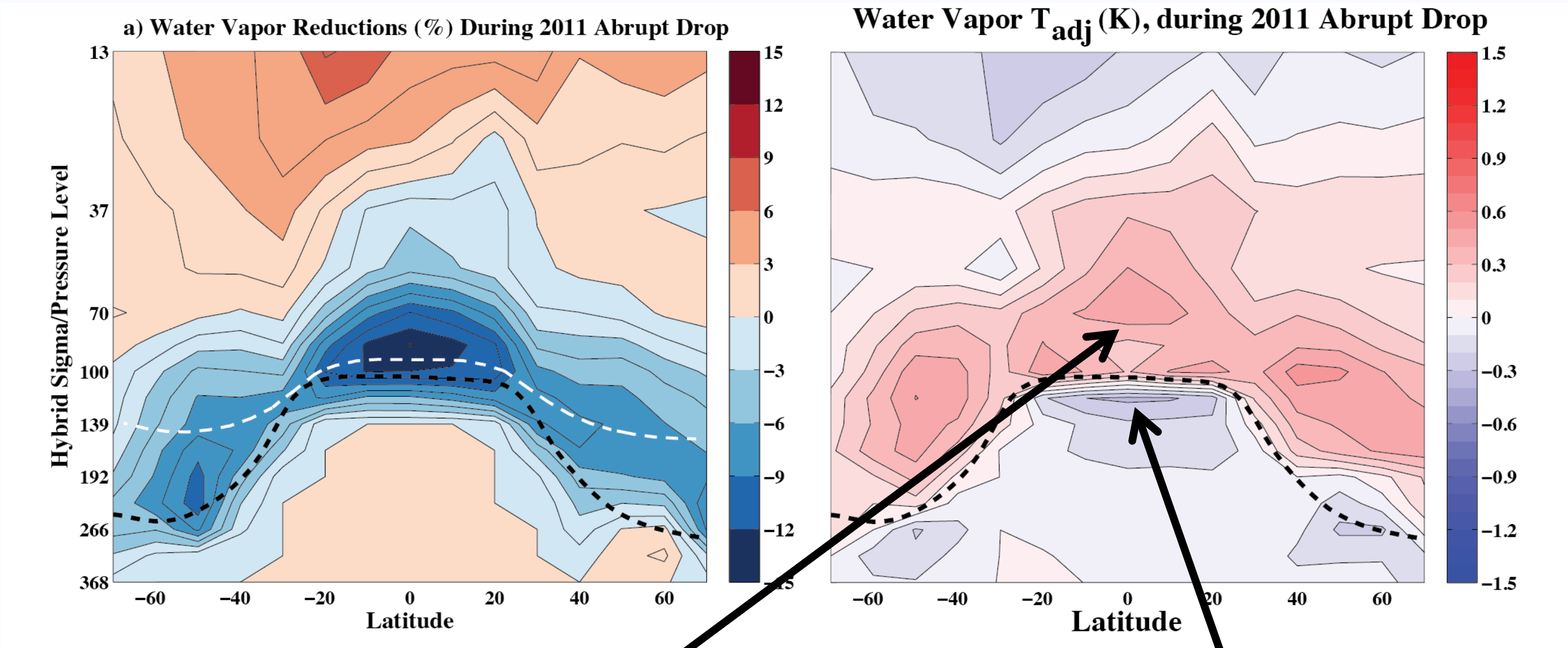
Radiative response associated with the 2011 water vapor drop



Apply perturbations to PORT background → Run PORT assuming FDH into equilibrium → Examine resulting temperature adjustments

PORT = Parallel Offline Radiative Transfer model, Conley et al. (2013)

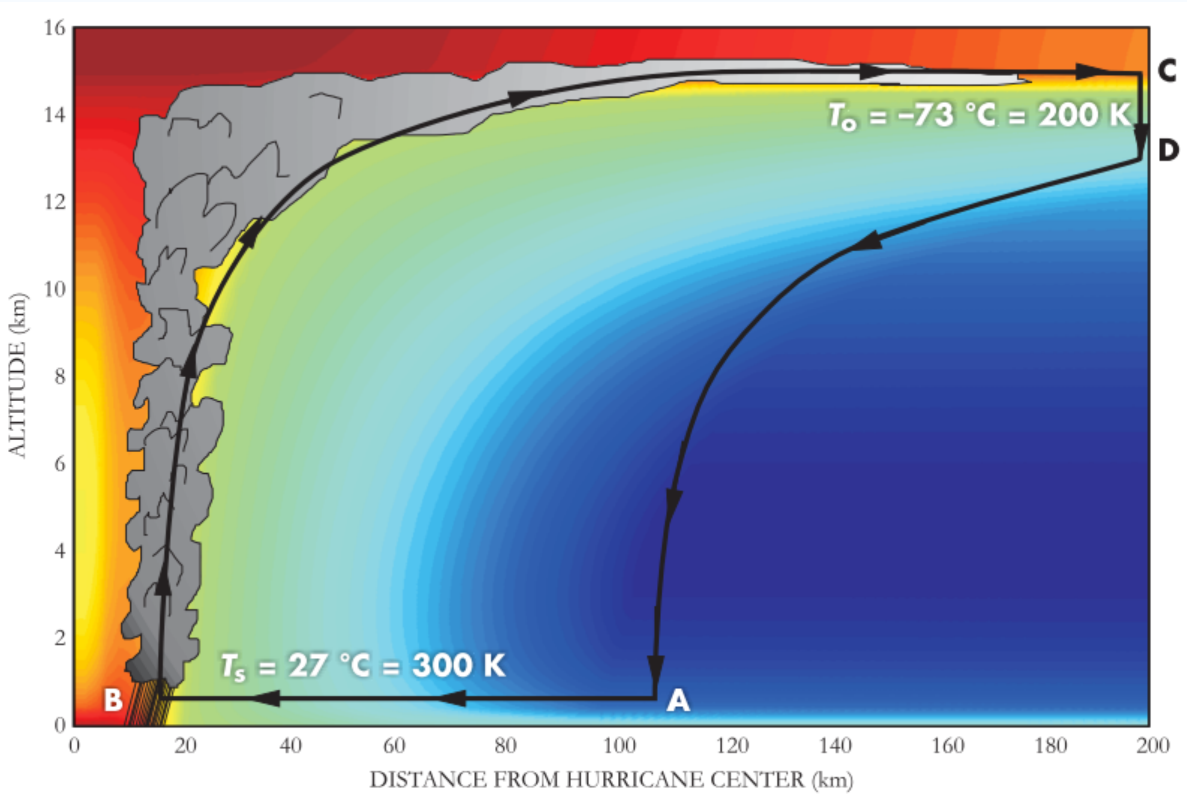
Water vapor has local and nonlocal radiative impacts on temperature



Water vapor reductions *locally* **warm** the TTL

Water vapor reductions *nonlocally* **cool** the tropical upper troposphere

The Potential Intensity (PI) of a Tropical Cyclone (TC) is a function of TC outflow temperatures in the UTLS



Emanuel (2006)

T_s = sea surface temperature
T_0 = outflow temperature
E = thermodynamic disequilibrium

The potential intensity (PI) of a TC is defined inas (e.g. Bister and Emanuel 1998):

$$PI^2 = \frac{T_s - T_0}{T_0} E$$

PI increases with:

→ Warmer SSTs (T_s)
→ Cooler outflow temperatures (T_0) at the level of neutral buoyancy (LNB)

TTL abrupt drops are associated with both of these

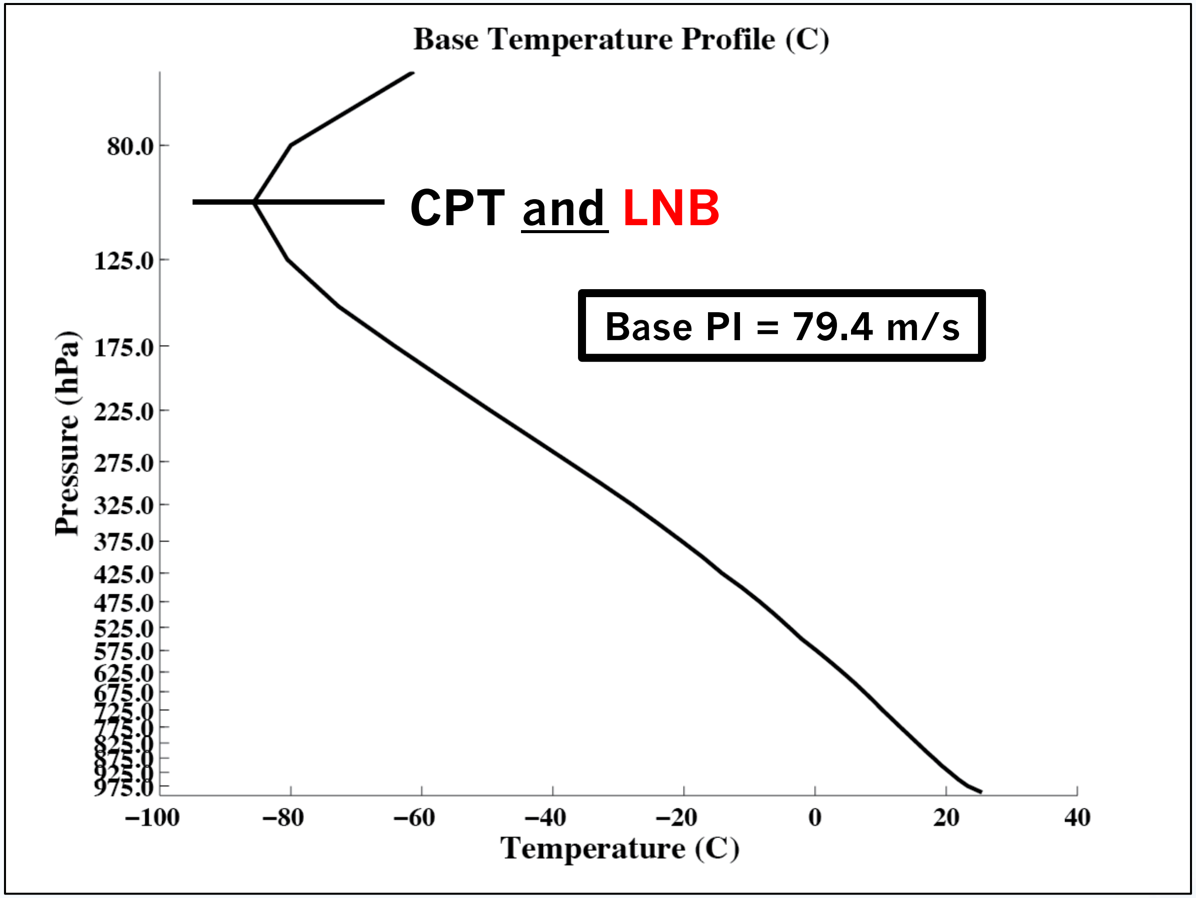
We run the MIT single-column radiative-convective model into equilibrium

Below the level of neutral buoyancy (LNB):

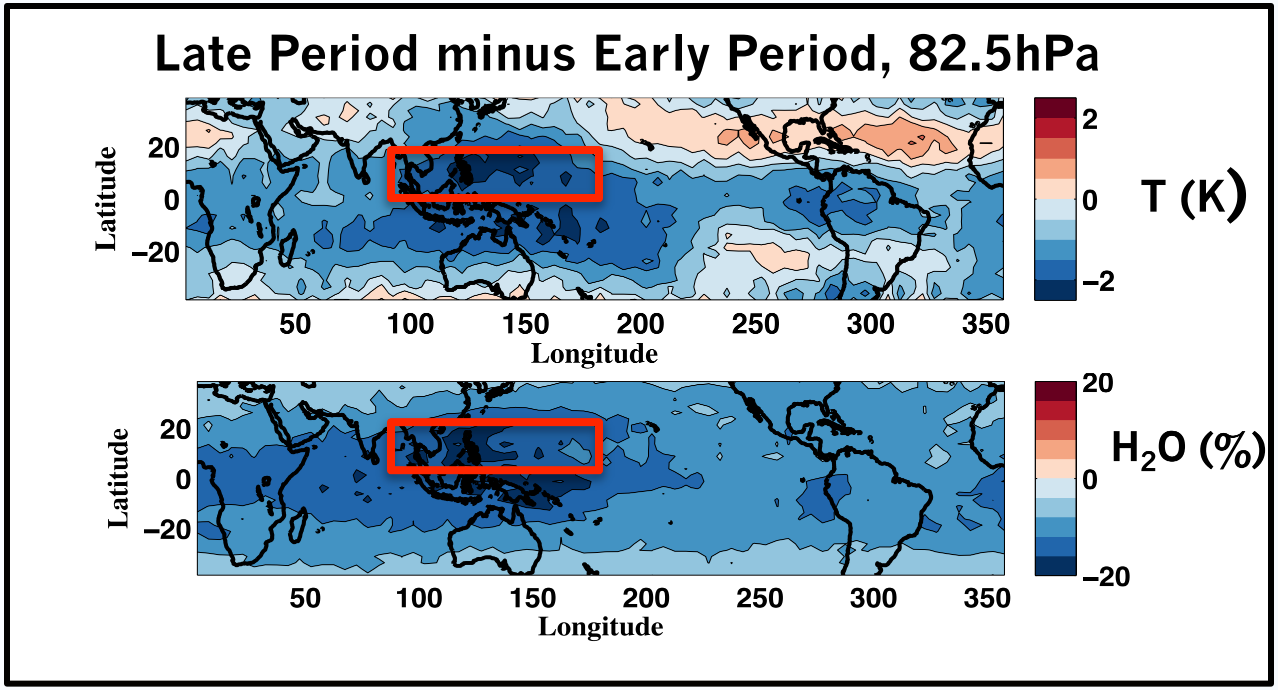
→ profile in radiative-convective equilibrium (RCE)

At and above the LNB:

→ profile in radiative-dynamical equilibrium (there is imposed dynamical upwelling in the UTLS)



Apply the observed abrupt drop changes in temperature along with the calculated radiative temperature adjustments



WNP as defined by Wing et al. (*accepted, GRL*)

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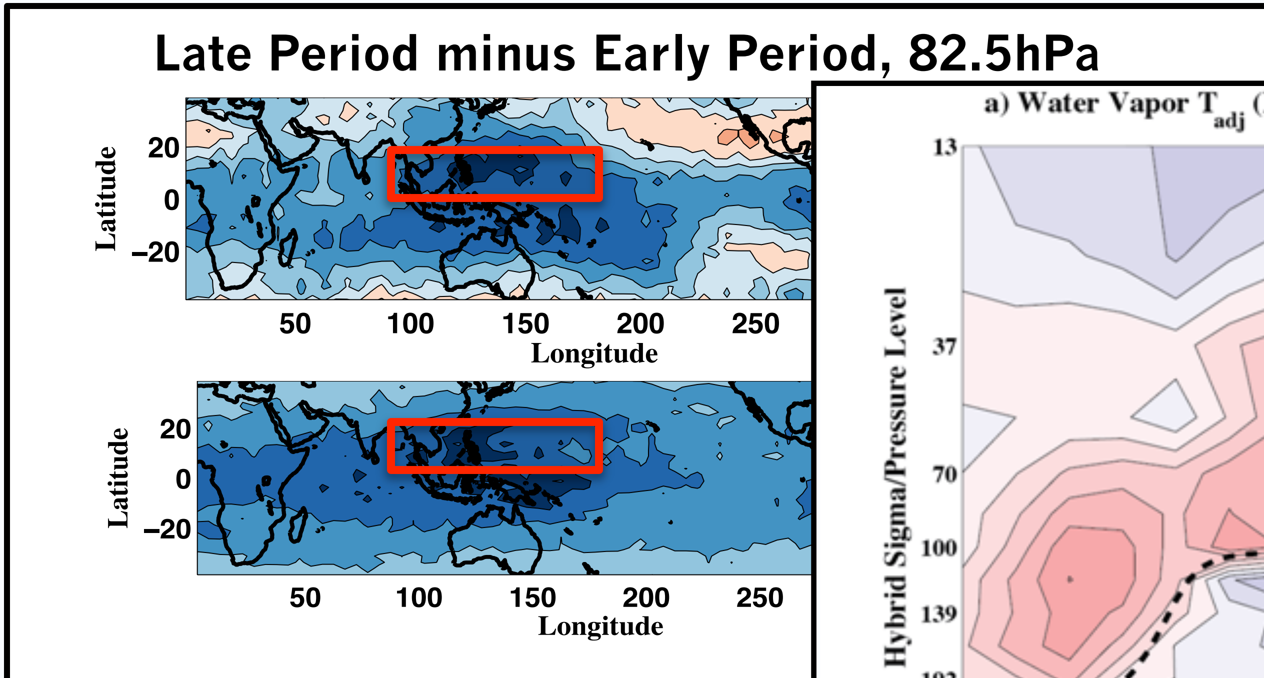
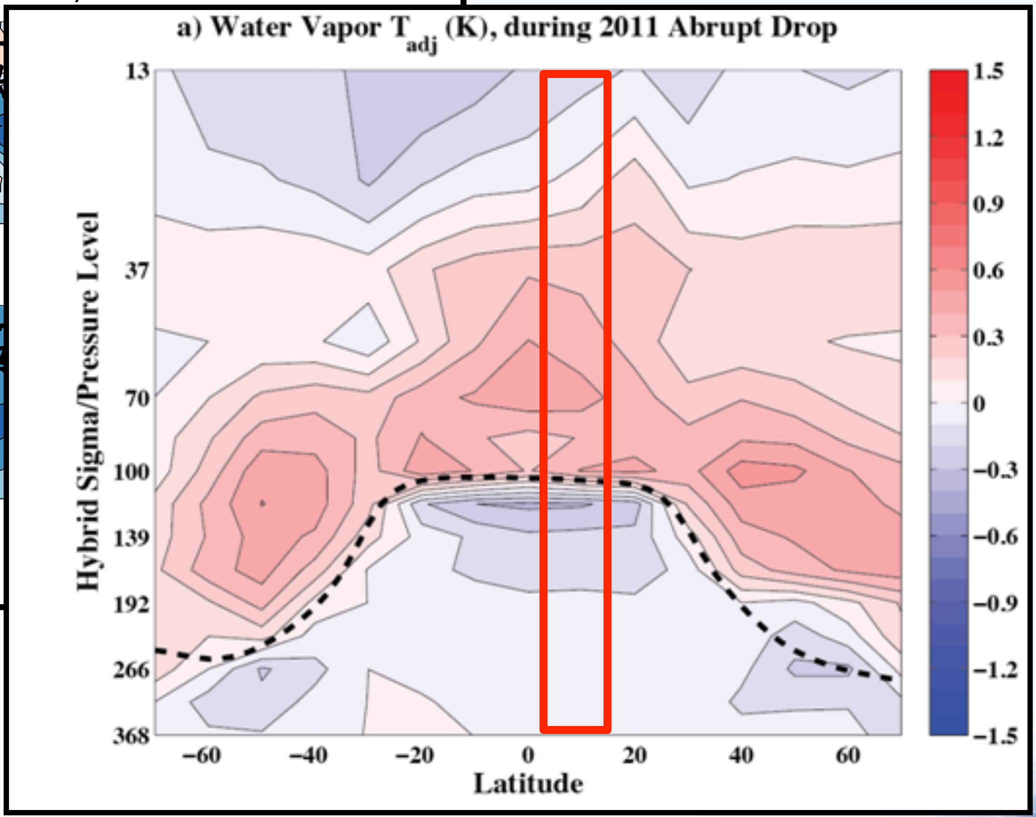
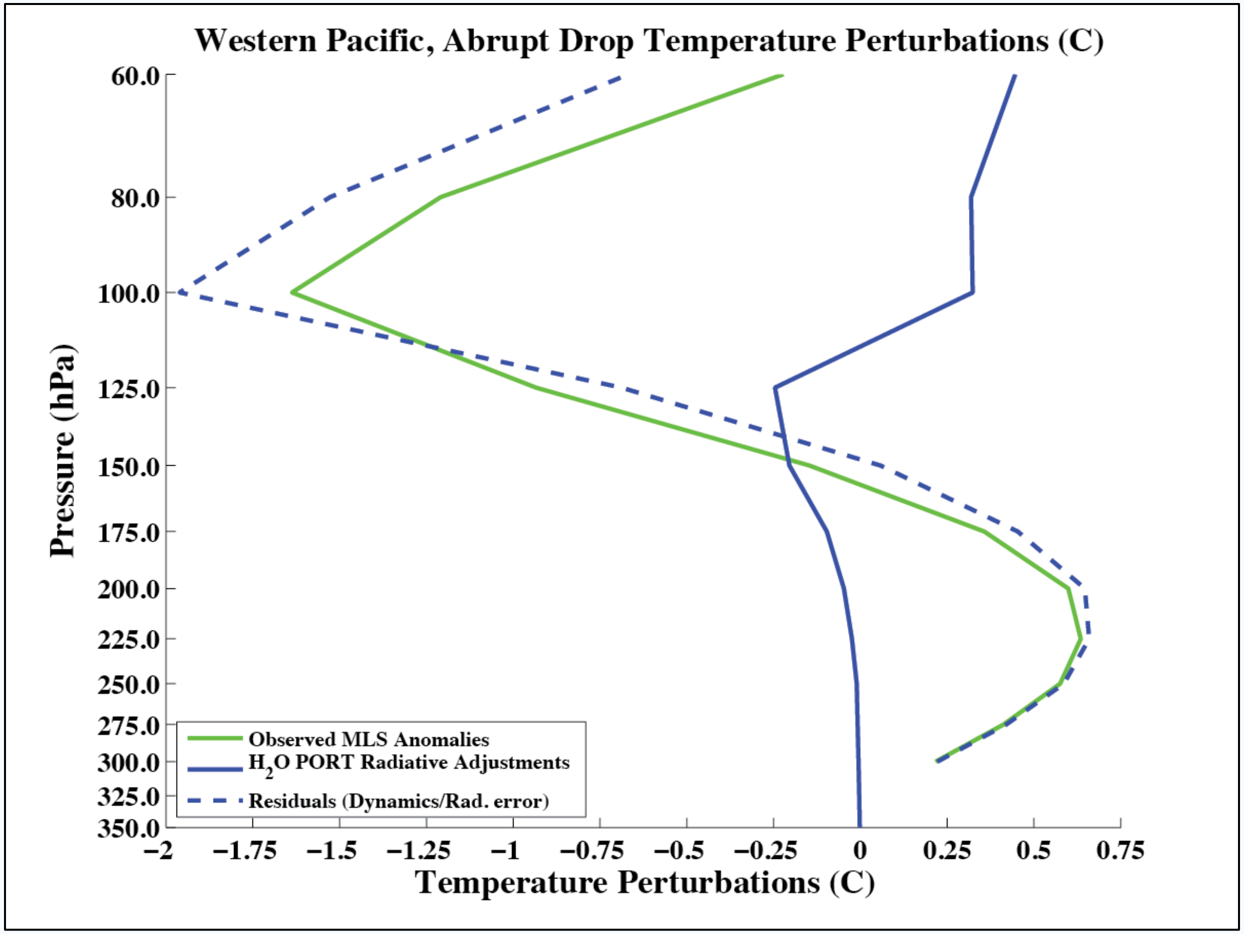




WNP as defined by Wing et al. (*accepted, GRL*)

After applying perturbations, we calculate PI changes



Emanuel and Bister (1998)
Wing et al. (*accepted, GRL*)
PI code freely available at: ftp://texmex.mit.edu/pub/emanuel/TCMAX/

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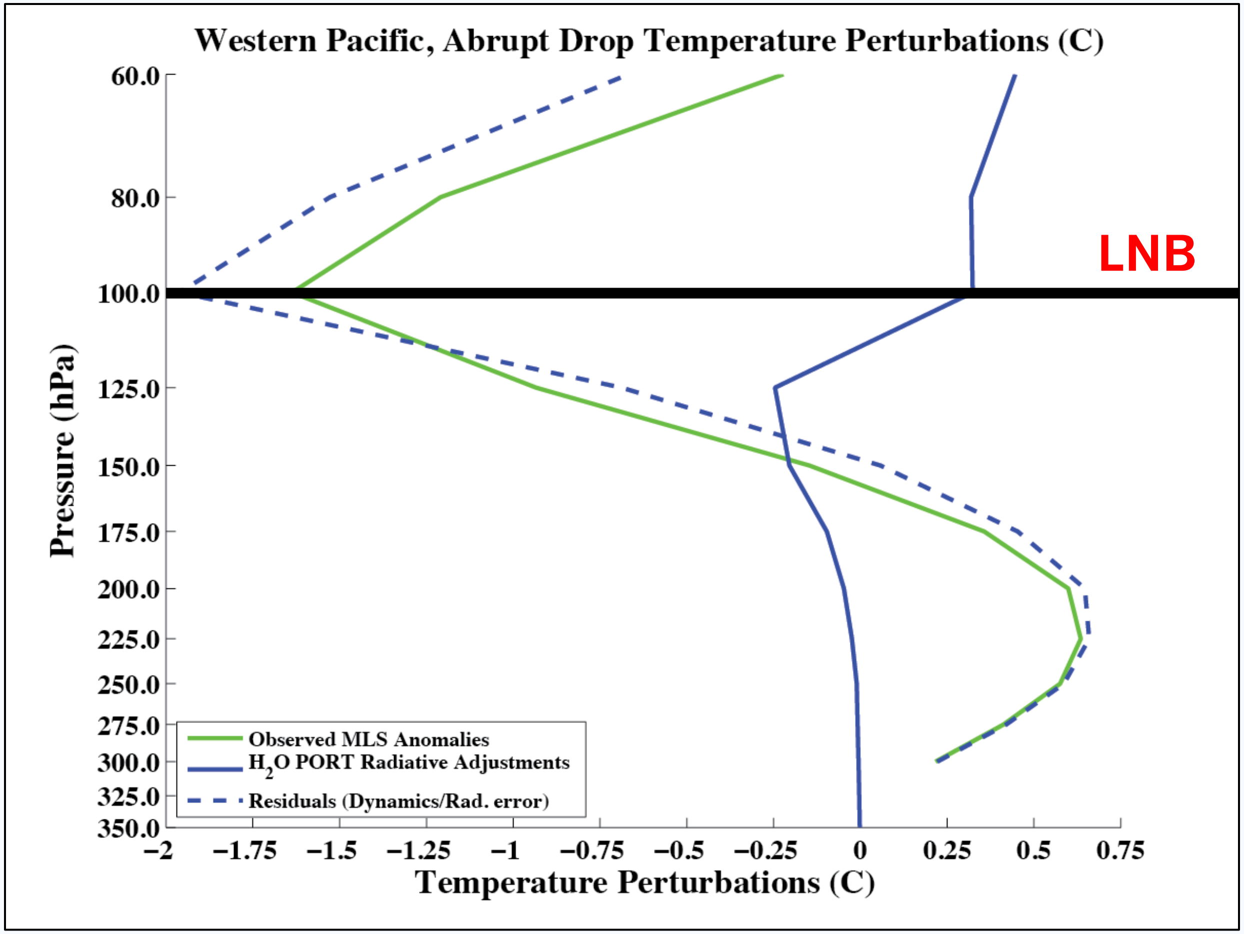

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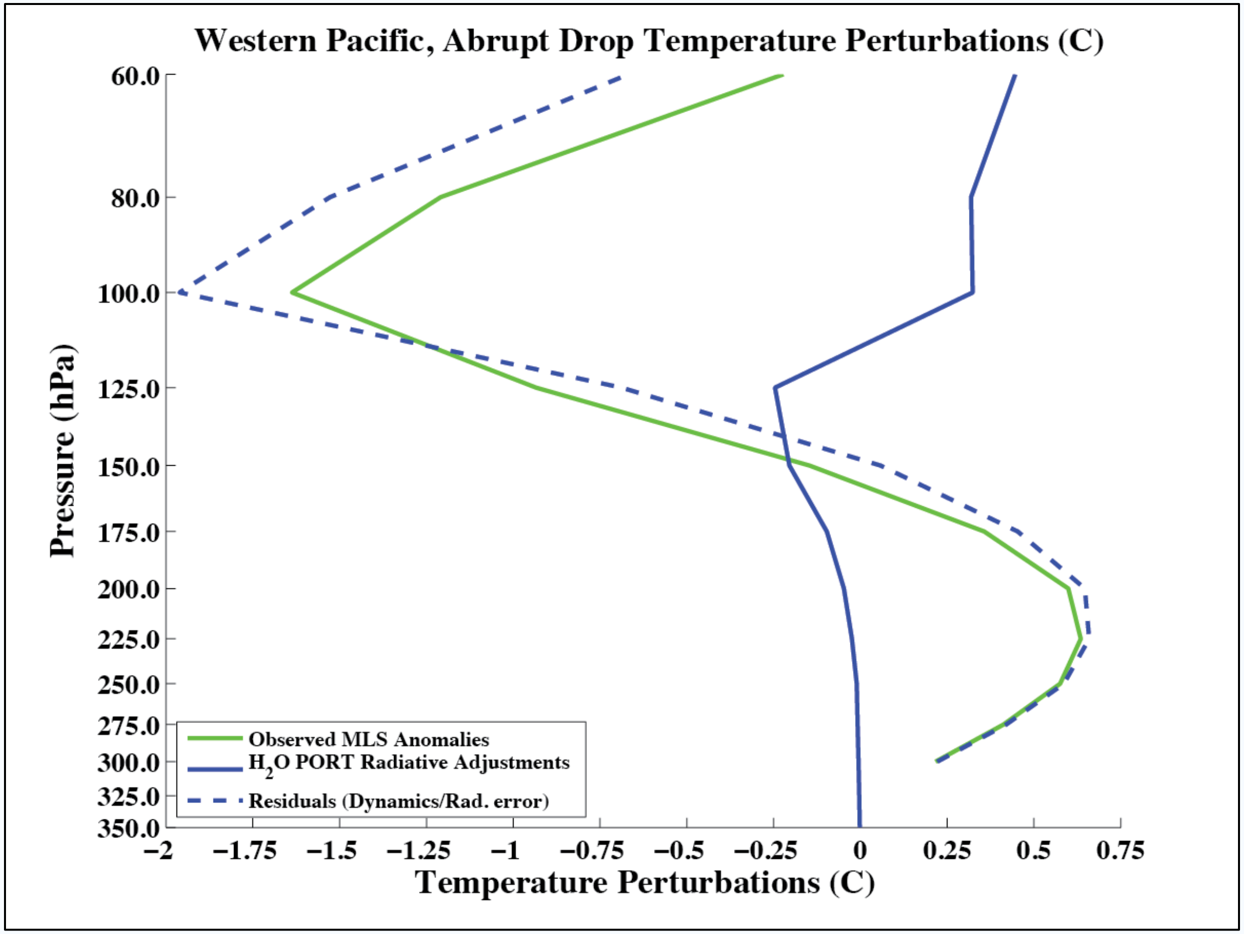
After applying perturbations, we calculate PI changes

Observed Temperatures: ΔPI = +0.68 ± 0.05 m/s

Radiative Adjustments: ΔPI = –0.14 ± 0.02 m/s

Residual Temperatures: ΔPI = +0.82 m/s



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Summary

→ The 2011 abrupt drops in water vapor and temperature maximized over the Western North Pacific:

-- The temperatures dropped by **~ +1.5K** on average

-- Radiative temperature adjustments associated with **~15%** reductions in water vapor were about ~ +0.35K at the CPT and ~ –0.25K below the CPT

→ The CPT and the LNB are found at the same pressure level, resulting in:

-- Observed PI *increases* of ~ 0.68 m/s

-- Radiative adjustments associated with water vapor *reduced* PI by ~ 0.14 m/s

In future work we plan to:

-- Examine other basins to determine radiative/dynamical effects of TTL variability on PI
-- Determine the sensitivity of the PI calculation to background temperature profiles
-- Use the SCM in a fully interactive mode to simulate impacts of abrupt drops on TC PI