Multiscale Variability of the Tropical Tropopause Layer during AMIE

Erin L. Dagg, Thomas Birner, Richard H. Johnson
Department of Atmospheric Science, Colorado State University, Fort Collins, CO

Introduction

The interface between the troposphere and the stratosphere is best described as a transition layer with characteristics of both the troposphere and the stratosphere. In the tropics, this region is known as the Tropical Tropopause Layer (TTL). The TTL extends from the level of main convective outflow ~200 hPa to the lower stratosphere ~ 70 hPa. It sets the boundary conditions for atmospheric tracers entering the stratosphere. Specifically, TTL temperatures control stratospheric water vapor concentrations, which play a key role in the radiative budget of the stratosphere.

AMIE, along with companion field campaigns DYNAMO and CINDY, offers a broad suite of data sets in the location of the origin of the MJO to investigate tropical convective systems over wide-ranging time scales and their impact on the tropopause and TTL. Here we present initial analysis of the response of TTL temperatures and winds to the MJO passages based on the intense high-resolution sounding observations on Gan from October-December 2011. In particular we analyze the characteristics of the observed wave structures and their impact on TTL structure, and relate these to the observed deep convective and cirrus clouds.

Background Wave Structure

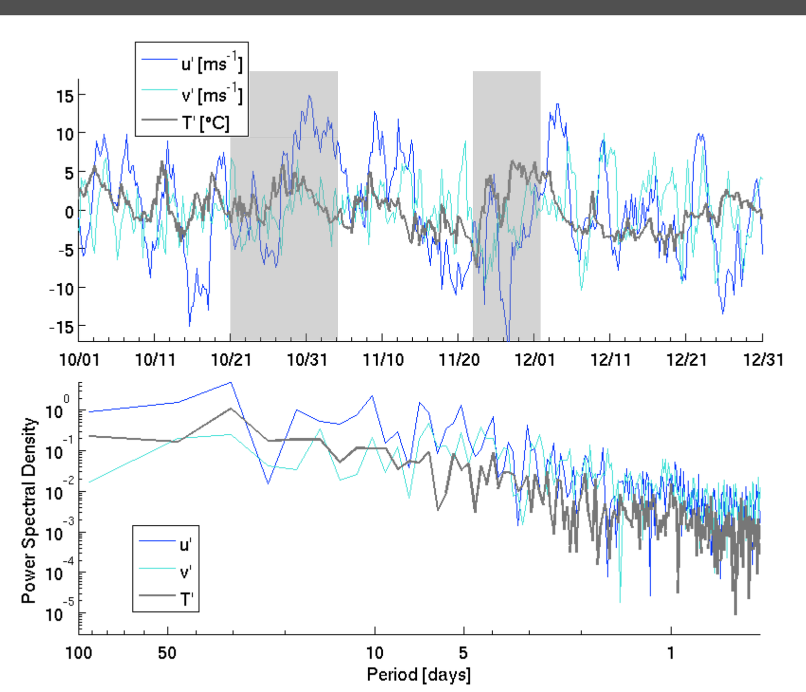

Figure 1: [Top] Time series comparison of temperature, zonal wind and meridional wind anomalies at 100 hPa, using ECMWF operational analysis data interpolated at Gan. Periods during RMM phases 2 & 3 are shaded in grey. [Bottom] Periodicity of temperature, zonal wind and meridional wind anomalies during the October-December time period, using discrete Fourier transform analysis.

- Multiscale variability, including a 30-day cycle associated with the MJO
- Equatorial Kelvin waves are predominant in the background flow
- Higher frequency gravity waves excited by convection

Preliminary Results

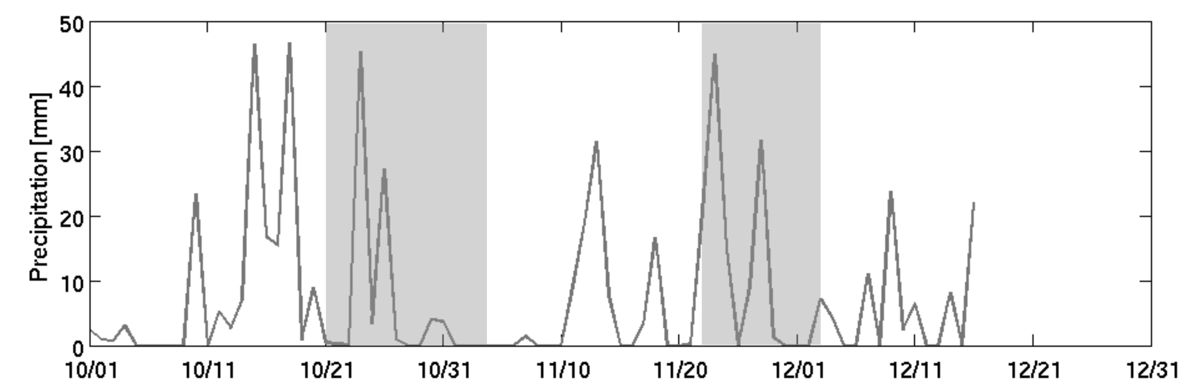

Figure 2: Time series of daily surface precipitation at Gan. Periods during RMM index phases 2 & 3 are shaded in grey.

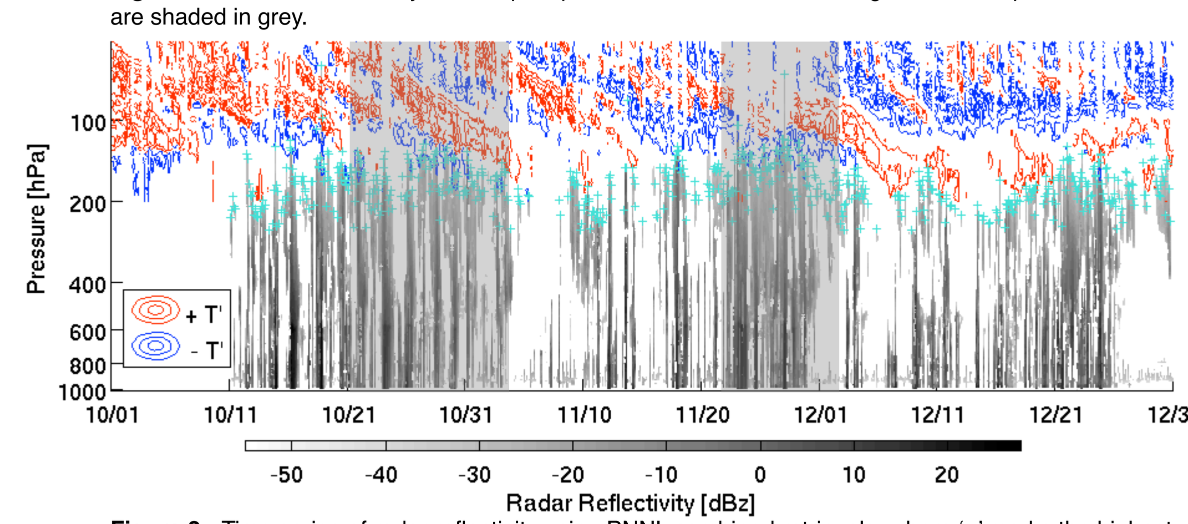

Figure 3: Time series of radar reflectivity using PNNL combined retrievals, where '+' marks the highest cloud height corresponding to -35 dBz. TTL temperature anomalies are contoured every 2 °C, with red indicating warmer temperatures and blue indicating cooler temperatures relative to the October-December mean vertical profile. Periods during RMM index phases 2 & 3 are shaded in grey.

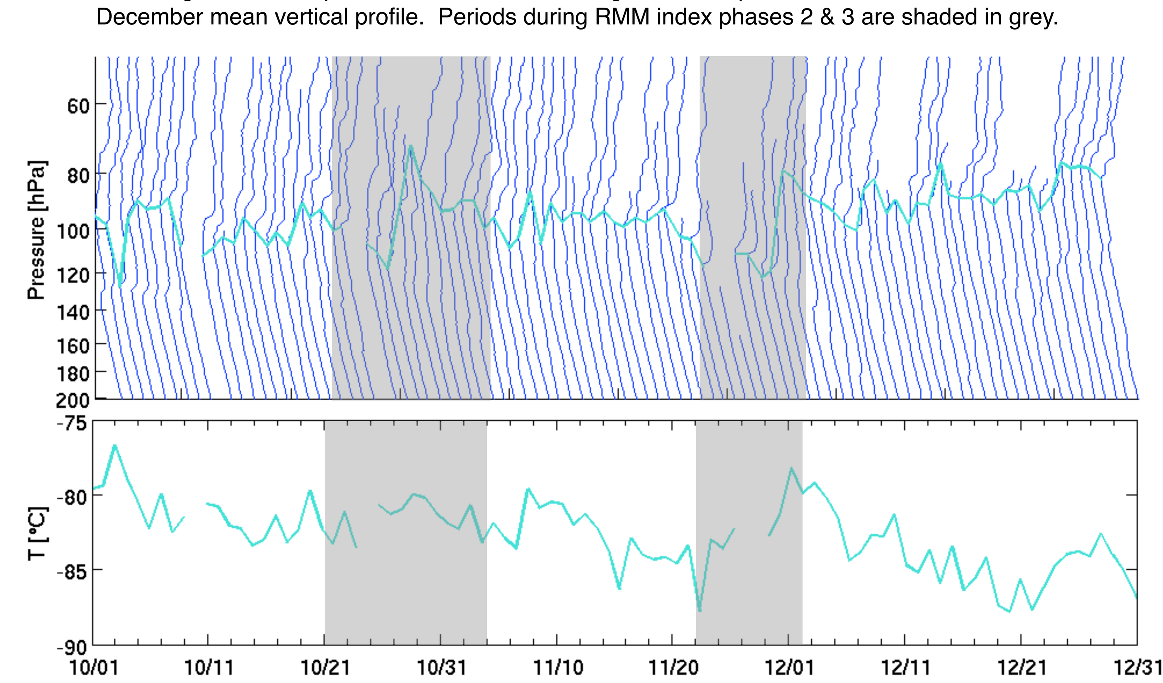

Figure 4: [Top] Time series of daily vertical temperature profiles during October-December, using DYNAMO atmospheric soundings. Profiles are spaced by 10 °C. The trend in cold point tropopause height is shown in light blue. [Bottom] Time series of cold point tropopause temperature. RMM index phases 2 & 3 are shaded in grey.

Impacts of the Madden-Julian Oscillation

- Two prominent **MJO events** in the Indian Ocean during AMIE, based on RMM index phases 2 & 3:
  - 21 October to 4 November
  - 22 November to 2 December
- **Heavier precipitation** is seen preceding and during the MJO events
- Precipitation associated with the October event shows a two-day cycle; in November this changes to a four-day cycle
- Radar reflectivity shows increased convection and **higher cloud tops** during the MJO passages
- Higher cloud top heights due to convection appear to be enhanced by cool anomalies
- Temperature anomalies indicate distinct Kelvin wave structure
- Modulation of the **cold point tropopause** is seen as a gradual lowering of heights followed by a sudden jump to higher levels
- Descending cool anomalies are associated with lower cold point tropopause heights

Wind & Temperature Covariation

- **Temperature and wind anomalies** slope downward with time
- Cooler temperatures **covary** with easterly anomalies, while warmer temperatures covary with westerly anomalies
- At the 120 hPa level, zonal wind anomalies appear westerly prior to the MJO passage and reverse to easterly during the active phase
- Meridional wind anomalies also indicate **descending pattern**

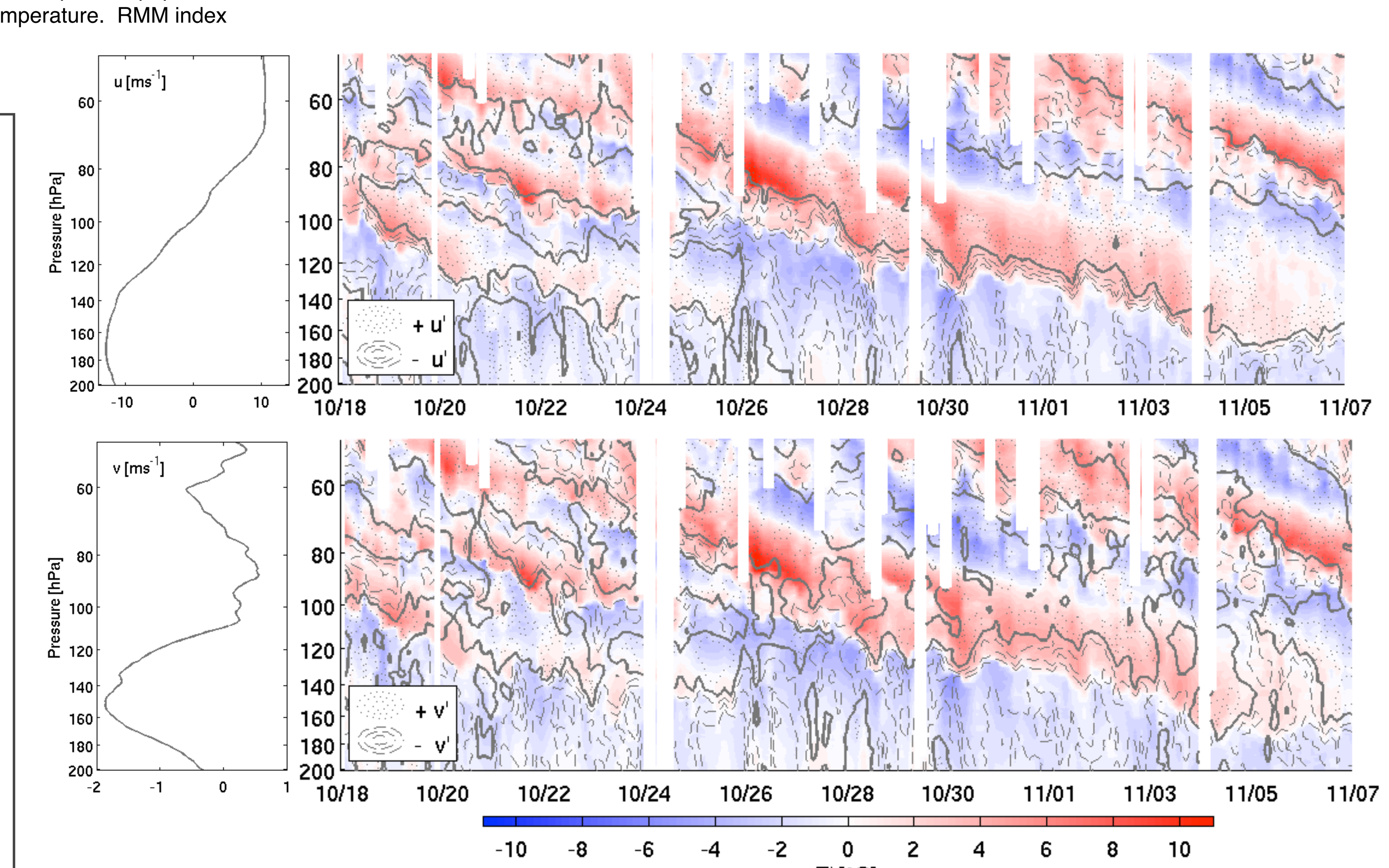

Figure 5: [Left] Mean vertical zonal/meridional wind profile during October-December, using DYNAMO atmospheric soundings. [Right] Time series of TTL temperature and zonal/meridional wind anomalies during the MJO passage in late October. Wind anomalies are contoured every 4 ms^{-1}, with positive values indicating a stronger westerly/southerly component relative to the mean vertical profile.

Data

Gan Island, Maldives [0.69S, 73.15E]

DYNAMO Atmospheric Soundings
50-meter vertical resolution, 3-hour time resolution

ECMWF Operational Analysis
20 vertical levels (provided), 6-hour time resolution

PNNL Combined Retrieval (clouds & precipitation)
224 vertical levels, 30-second time resolution

Future Work

- Dynamical effects of convection on TTL properties and structure
- Cloud radiative effects, including localized warming due to cirrus and cooling effect due to deep convective clouds
- Overshooting convective plumes and their role in dehydration
- Incorporation of satellite data from COSMIC, CALIPSO, CloudSat

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Contact

edagg@atmos.colostate.edu