1. Introduction

Frierson, Held, and Zurita-Gotor (2006) investigate the impact of moisture on the circulation of an idealized GCM by magnifying the saturation pressure of moisture in the Clausius-Clapeyron Equation by a factor \( \text{es}_{00} \).

- Moisture has a large impact on the dry static stability and tropopause height, as shown in Fig. 1, but the energy containing length scale in all simulations remained the same, approximately 4000 km.

- How can this be connected to the dry Rossby radius of deformation, Lt/NH? (N is the Brunt-Vaisala frequency). (If it is taken to be the height of tropopause) and if \( L_t \) is taken to be the value of the Coriolis parameter in the jet core) change significantly; is this evidence of an upscale cascade?

2. Methodology

- We study the background by computing the most unstable wavenumber in the system. We need a technique that will allow us to study life cycles in both the dry and moist context.

- Life cycle experiments are conducted in a unforced, primitive equation AGCM. When moisture is included, precipitation is governed by large scale and moist context.

- The mean wavenumber as a function of time, normalized by the growth rate. The mean wavenumber as a function of pressure for 5 simulations of the moist model of Frierson et al. (2006) with varying moisture content. The N profiles are constructed from the time and zonal average T. The profile must be made stably stratified and smoothed in the tropics, so that a zonal wavenumber profile in geostrophic balance can be constructed. The time mean wind at the surface is used as the integral condition for the zonal wind. Lastly, the surface pressure is computed to balance the surface wind. The meridional wind is set to zero.

- The tropospheric static stability (\( N^2 \)) is varied by a factor of 9. By \( L_t-NH/F \) scaling, the length scale should vary by a factor of 3.

- The tropopause height is varied by a factor of 3 from 6 to 18 km. If \( H \) should be calculated the depth of the troposphere (as implied by the early problem), the simple scaling above indicates that length scale should vary by a factor of 3.

- We consider the two endpoints: dry integrations with no moisture, and moist integrations, where the troposphere is initially saturated at all points.

- The most unstable wavenumber decreases with moisture content, as one would expect based on dry Rossby radius scaling.

- Moisture appears to increase the most unstable wavenumber; though not enough to compensate for changes in the stratification.

- There is room for an upscale cascade in the drier simulations.

3. Life Cycles Based on Model Climatologies

- Life cycles are initialized with the zonal mean climatology of the GCM. Profiles are constructed from the time and zonal average T. The profile must be made stably stratified and smoothed in the tropics, so that a zonal wavenumber profile in geostrophic balance can be constructed. The time mean wind at the surface is used as the integral condition for the zonal wind. Lastly, the surface pressure is computed to balance the surface wind. The meridional wind is set to zero.

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4. Idealized Life Cycles

- The most unstable wavenumber, \( k \), as a function of time, normalized by the growth rate. The most unstable wavenumber, \( k \), as a function of time, normalized by the growth rate. We specify \( N^2 \) to be constant in the troposphere (at the latitude of maximum baroclinicity) as in the model profiles used in the idealized life cycle integrations.

- We begin with an analytic jet (Polvani and Esler, 2007) and compute the temperature profile that preserves geostrophic balance. We can specify the background stability (T independent of latitude) as an integral condition. We choose profiles so that the static stability in the jet core is given by a hyperbolic tangent profile, transitioning from constant \( N^2 \) in the tropopause to constant \( N^2 \) in the stratosphere, as shown in Fig. 4. As with the model based life cycles, the meridional wind is set to zero.

- The tropospheric static stability (\( N^2 \)) is varied by a factor of 9. By \( L_t-NH/F \) scaling, the length scale should vary by a factor of 3.

- The tropopause height is varied by a factor of 3 from 6 to 18 km. If \( H \) should be calculated the depth of the troposphere (as implied by the early problem), the simple scaling above indicates that length scale should vary by a factor of 3.

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Key Observations from Model-Based Life Cycles

- The most unstable wavenumber decreases with moisture content, as one would expect based on dry Rossby radius scaling.

- Moisture appears to increase the most unstable wavenumber, though not enough to compensate for changes in the stratification.

- There is room for an upscale cascade in the drier simulations.

Key Observations from Idealized Life Cycles

- We find qualitative, but not quantitative, agreement with \( L_t-NH/F \) scaling of the deformation radius.

- Moisture increases the most unstable wavenumber and growth rates.

- Impact of moisture is inversely proportional to the stratification. With strong stratification, moisture has almost no effect.

5. Conclusions and Questions

- The dry Rossby radius has relevance in a moist context: the most unstable mode increases by a factor of two as moisture in the model is increased, qualitatively consistent with changes in the stratification and inverse baroclinic height.

- The most unstable wavenumber is larger than the wavenumber with most energy. Is this evidence of an upscale cascade, or is the linear problem not relevant to the nonlinear system?

- Moisture increases the most unstable wavenumber and growth rates, consistent with earlier studies.

- Impact of moisture is inversely proportional to the stratification. With strong stratification, moisture has almost no effect.

- The NHF scaling for the Rossby radius provides only qualitative guidance in predicting the most unstable modes. Can a stronger definition be developed, especially one that accounts for moisture?

References


Key Observations from Idealized Life Cycles