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Factors to Determine Wave-Propagation Direction of Convective Gravity Waves: Application to a GWD parameterization

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Introduction

- Momentum transport by non-orographic gravity waves (GWs) is one of the most crucial processes in the large-scale circulation of the middle atmosphere.
- Cumulus convection has been regarded as one of the most promising sources.

Parameterization of Convective GWs

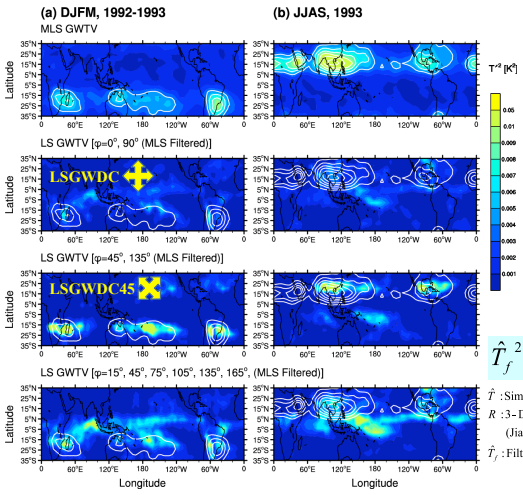
- Column-based parameterizations
  - ✓ Chun and Baik (1998, 2001), Beres (2004), and Song and Chun (2005)
  - ✓ GWs propagate only in the vertical direction
- Lagrangian (ray-based) spectral convective gravity wave drag (LS) Parameterization
  - ✓ Song and Chun (2008)
  - ✓ Explicit calculation of the GW propagation properties
  - ✓ Implementation of this parameterization in the NCAR Whole Atmosphere Community Climate Model (WACCM) version1b
  - ✓ It is important to consider explicitly the actual GW propagation properties in the GWDC parameterizations for reproducing more realistic stratospheric variabilities and zonal-mean climatology

Motivation

- Although the LS parameterization is the most physically consistent approach among GWDC parameterizations to date, there are still many uncertainties associated with unknown parameters (e.g., wave-propagation direction at source-level).
- Wave-propagation direction is one of the most important factors to determine the distribution and magnitude of the GW variances in the parameterization.

Sensitivity to the wave-propagation direction

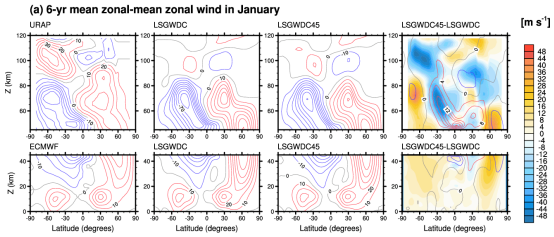
- **Comparison with MLS GW temperature variances (Offline simulations)**



$$\hat{T}_f^{\,2} = R\hat{T}^2$$

$\hat{T}$: Simulated (Unfiltered) GWTV
R : 3-D MLS analytical filter function (Jiang et al., 2004a, JGR)
$\hat{T}_f$: Filtered GWTV

- **6-yr mean zonal-mean zonal wind in January (WACCM simulations)**



✓ **Shading** Difference between LSGWDC and URAP (ECMWF)

✓ **Line** Difference between LSGWDC45 and LSGWDC (Blue: negative, Red: positive)

- The LS parameterization can produce more realistic GW effects when the wave-propagation directions of northeast-southwest and northwest-southeast are chosen.
- However, the GW temperature variances are overestimated in the equatorial regions when nearly isotropic waves (φ=15°, 45°, 105°, 135°, 165°) are considered in the LS parameterization.
- It is required to decide reasonably the wave-propagation direction for realistically reproducing the GW effects in the parameterization.

➡ **What factors determine the wave-propagation direction of convective GWs ?**

"Propagation direction of convective GWs is likely related to moving direction of convective sources"

Experimental Designs

- **Investigation of moving direction of convective sources through spectral analysis for Global Cloud Imagery (GCI) data**
- **Use of dominant moving directions of convective sources in the wave-propagation directions**

GCI data

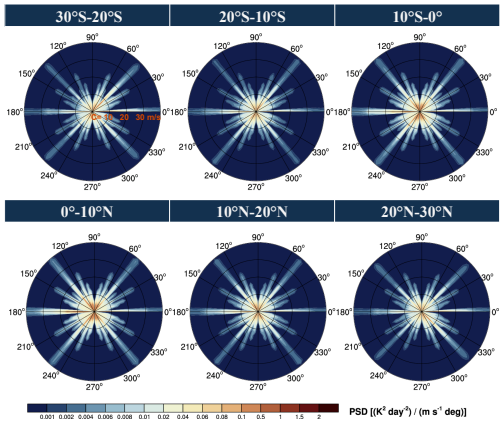
- **Grid spacing :** 0.35° × 0.7° (lat × lon)
- **Domain :** 30° S~30° N
- **Frequency :** 3 hr
- **Period :** 1 yr (April 1985 ~ March 1986)
- **Variable :** TBR (Brightness Temperature) → Deep convective activity (DCA)

$$\mathrm{DCA} = \begin{cases} 240\,\mathrm{K\text{-}TBR} & \text{if} \quad \mathrm{TBR} < 240\,\mathrm{K} \\ 0 & \text{otherwise} \end{cases}$$

✓ Ricciardulli and Garcia (2000)

Spectral Analysis of DCA

Power spectrum density (PSD) of DCA



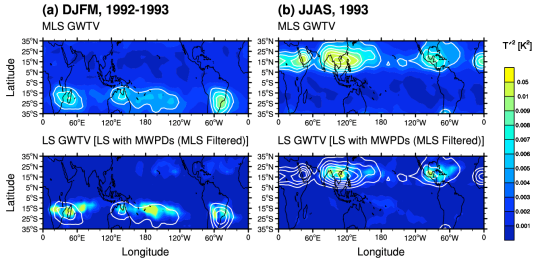
✓ Annual- and zonal-mean of PSDs of DCA calculated for each 10° × 10° (latitude and longitude) bin for each month

- Dominant moving directions of the convective sources (east-west, northeast-southwest, and northwest-southeast) are longitudinally and seasonally robust although the magnitude of the PSD of the DCA is variable (not shown).
- Dominant moving directions of the DCAs are weakly latitudinally variable. The convection sources propagate in a little more zonally shifted direction at high latitudes of more than 20°N or 20°S.

Modified wave-propagation directions (MWPDs)

$$\mathrm{WPD}(\varphi) = \begin{cases} 0°, 45°, 135° & \text{if} \quad Lat = 30°\mathrm{S}\text{-}20°\mathrm{S} \ \text{or} \ 20°\mathrm{N}\text{-}30°\mathrm{N} \\ 0°, 50°, 130° & \text{otherwise} \end{cases}$$

Offline Simulation of LS Parameterization with Modified WPDs



- More realistic MLS GW temperature variances (GWTVs) are reproduced in the LS parameterization when wave-propagation directions are modified into dominant moving directions of convective sources obtained through spectral analysis of GCI data.
- Especially, overestimated GWTVs in the equatorial regions for JJAS are significantly reduced.
- However, there are still uncertainties about factors that determine the wave-propagation direction of convective GWs.