Report on the SPARC Gravity Wave Activity

October 2009

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Outline:
1. Brief Introduction to new focus since 2007
2. Outcomes of meeting in March 2008
3. New activities

Focus of the project:

Gravity Wave Momentum Budget for Global Circulation Studies

A new phase of the activity was initiated after the 2007 SSG to take advantage of a number of recent developments in observations, modelling, and data assimilation to quantify the role of gravity waves in the forcing of the global circulation for climate studies.

The overarching goal is to bring experts in the field together to develop constraints for improved treatment and parameterization of small-scale waves in global models.

Activity Timeline:

November 2007: Initiation of new phase at SPARC SSG in Bremen

March 2008: First workshop in Toronto, joint with DynVar

July 2008: SPARC Newsletter report on the workshop

July 2008: Bologna planning meeting for preparation of review paper

February 2009: Proposal to ISSI for International Team on merging satellite observational constraints

June 2009: Notification of award to our ISSI International Team

July 2009: Montreal meeting for final coordination on review paper

September 2009: Review submitted to QJRMS

Outcomes of March 2008 Workshop in Toronto

1. The meeting was described in a SPARC Newsletter report July 2008.

2. The participants have jointly prepared and submitted a review paper to the Quarterly Journal:

Alexander, M.J., M. Geller, C. McLandress, S. Polavarapu, P. Preusse, F. Sassi, K. Sato, S. Eckermann, M. Ern, A. Hertzog, Y. Kawatani, M. Pulido, T. Shaw, M. Sigmond, R. Vincent, S. Watanabe, A Review of Recent Developments on Gravity Wave Effects in Climate Models and the Global Distribution of Gravity Wave Momentum Flux, *Q. J. Roy. Meteorol. Soc.*, (submitted), 2009.

Outcomes of March 2008 Workshop in Toronto

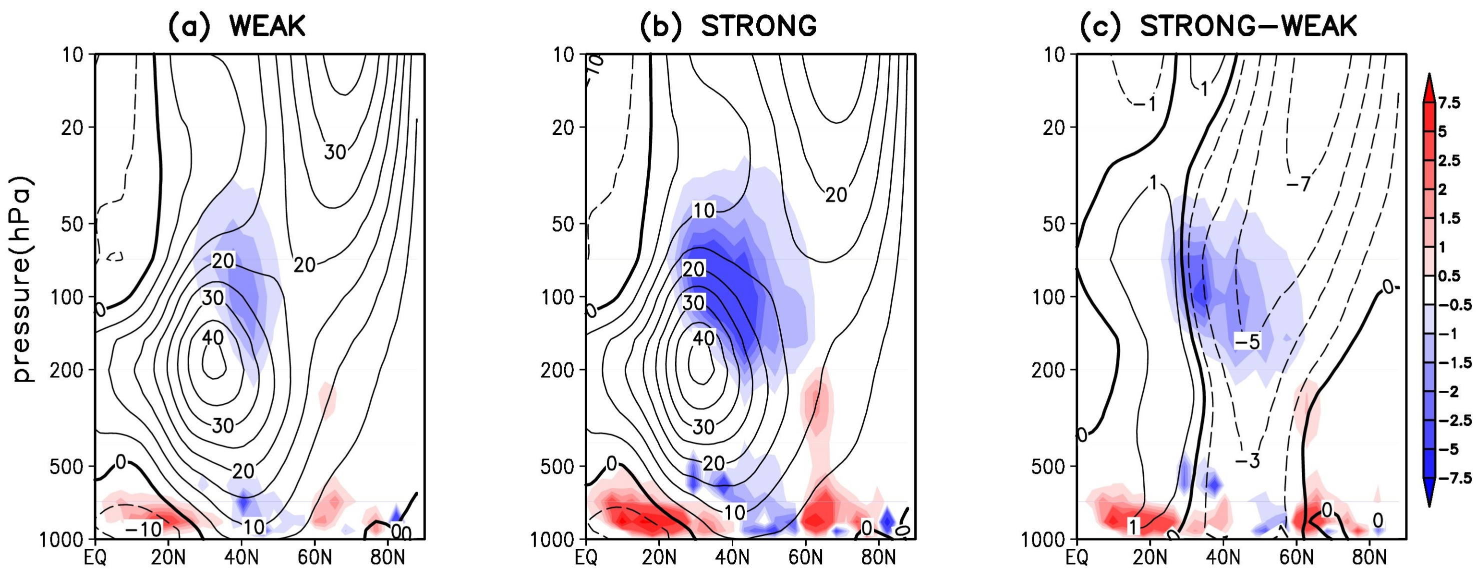
A Review of Recent Developments on Gravity Wave Effects in Climate Models and the Global Distribution of Gravity Wave Momentum Flux

1. Introduction
2. Gravity wave issues in stratosphere-resolving global climate models
   I*ssues regarding angular momentum conservation, orographic gravity wave drag, and the ozone hole*
3. Global observations of gravity wave momentum fluxes
   Calculation of gravity wave momentum fluxes. Results from global data sets including radiosondes, long-duration balloons, nadir scanning satellites, and limb scanning satellites. Quantifying wave intermittency. Mapping of observations into wavenumber-frequency space.
4. High resolution global models
   Gravity wave momentum fluxes, wave sources, seasonal variations, and three-dimensional wave propagation. Scales of waves drive of the QBO.
5. Data assimilation techniques for estimating the gravity wave momentum budget
   Constraining the mesosphere with measurements from the troposphere and Stratosphere, estimates of gravity wave drag and momentum fluxes.
6. Summary

Outcomes of March 2008 Workshop in Toronto

Principal Results in the Review

Gravity wave effects on climate



Sigmond & Scinnoca (2009)

Parameterized orographic wave drag (shading) has been used to correct upper troposphere/lower stratosphere wind biases in global models for decades, but reports on effects on surface climate are relatively new. Here wind differences (contours in (c)) using two wave drag tunings extend to the surface, but also alter planetary wave propagation and can affect the surface climate response pattern.

Outcomes of March 2008 Workshop in Toronto

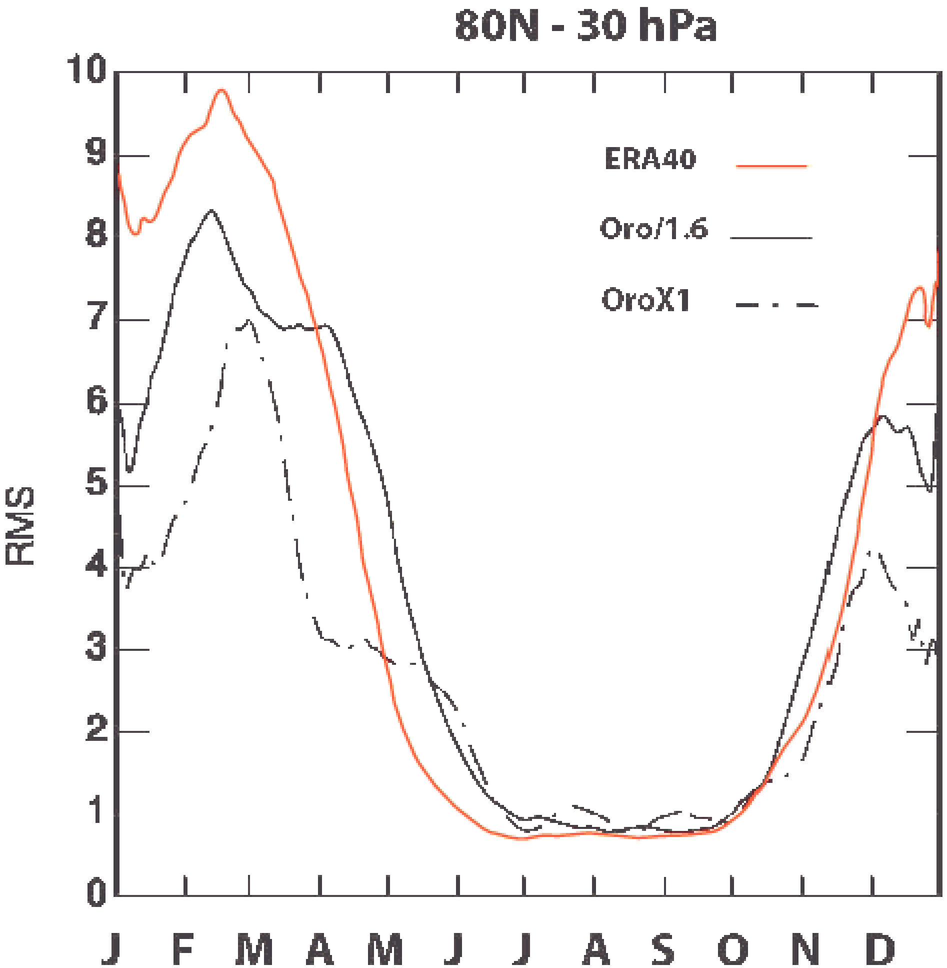
Principal Results in the Review

Gravity wave effects on climate

Other effects include:

- Frequency of occurrence of sudden stratospheric warmings

- Annual cycle of stratospheric temperatures and ozone loss



Effect of different gravity wave intermittency parameter settings on stratospheric variability in WACCM.

Outcomes of March 2008 Workshop in Toronto

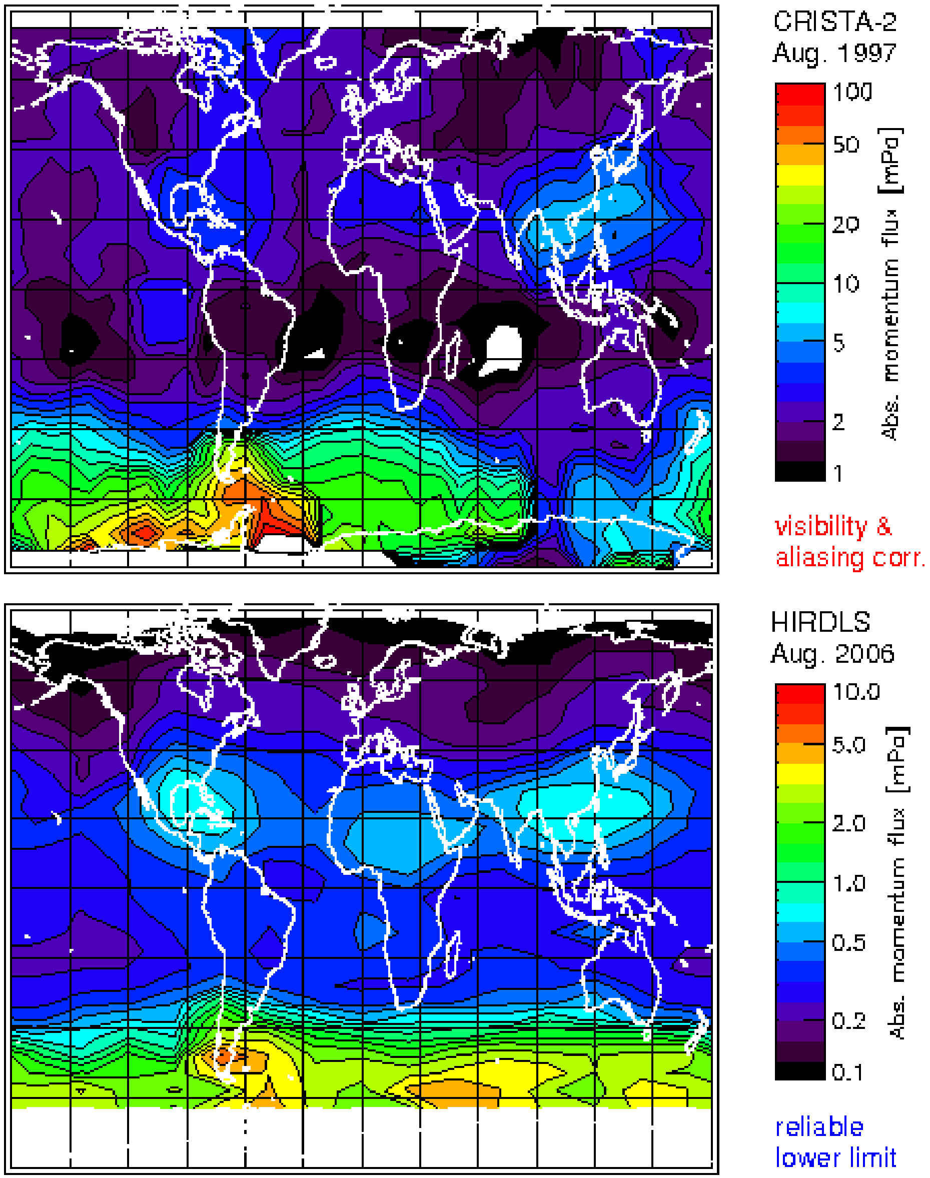
Principal Results in the Review

Global observations of gravity wave momentum fluxes

Results of satellite analyses from CRISTA (top) and HIRDLS (bottom). CRISTA is one week of observations in August 1997. HIRDLS comparison is one month August 2006.

Patterns are very similar. Magnitudes differ by a factor of 6. Reasons are uncertain. Partly due to a correction factor that is applied to the CRISTA result to account for horizontal wavelength errors, which was not applied to HIRDLS.

May be partly due to wave intermittency.



Outcomes of March 2008 Workshop in Toronto

Principal Results in the Review

Wave Intermittency

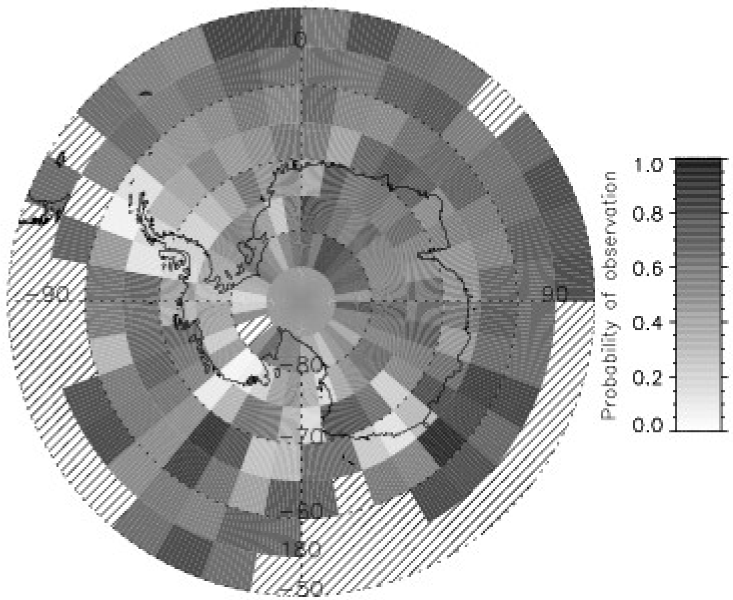
This is a tuning parameter in most gravity wave drag parameterizations that either varies the strength of the source flux and/or the strength of the drag force.

Top panel shows an estimate derived from long-duration balloon flights, and bottom panel the corresponding momentum flux.

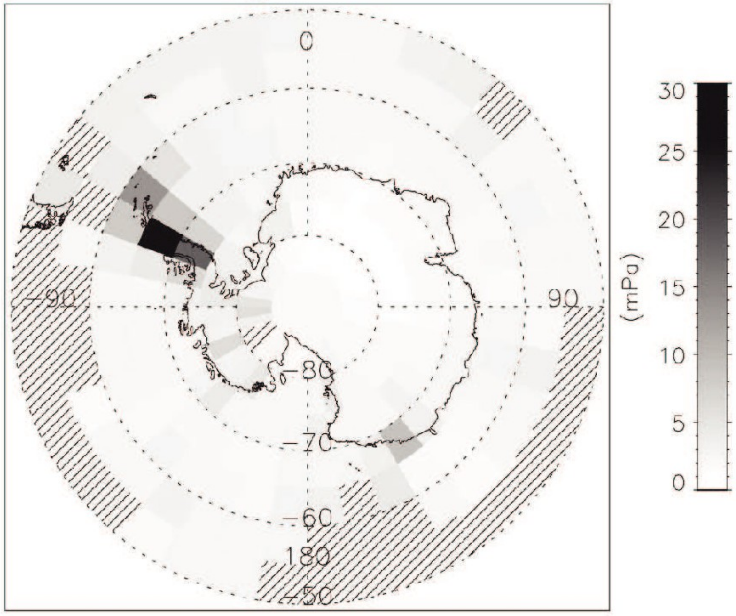
The result shows that strong mountain wave events are the most variable! Intuitively, we might expect that steady mountain waves with fixed sources would be the least variable.

But intermittency due to sources and wind variations that affect propagation are mixed in the observations, whereas models need them separated.

$\rho_0\langle u'_{//}w'\rangle$ intermittency: Bernoulli



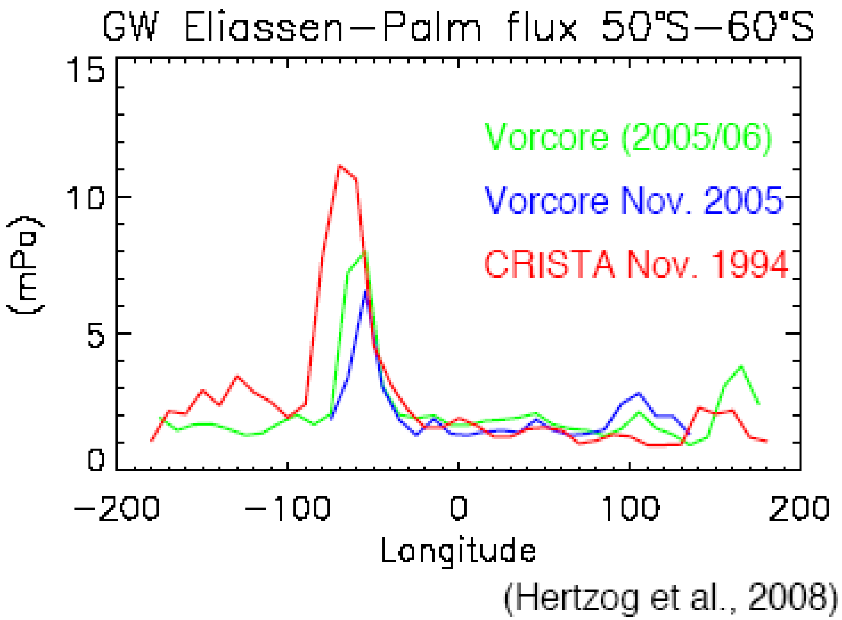
$\rho_0\langle u'_{//}w'\rangle$

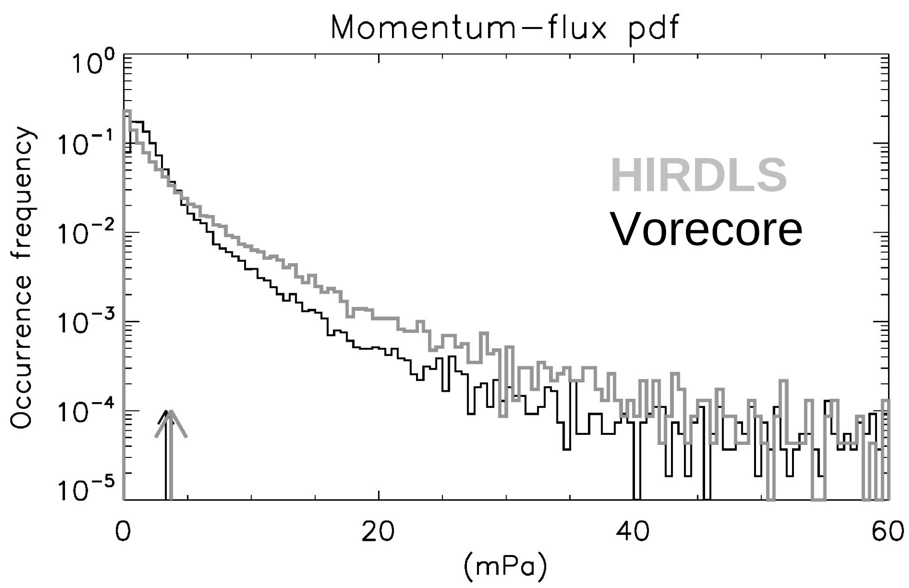


Outcomes of March 2008 Workshop in Toronto

Principal Results in the Review

Wave Intermittency





Previously published comparison of the "corrected" fluxes from CRISTA to the long-duration balloons showed some reasonable agreement.

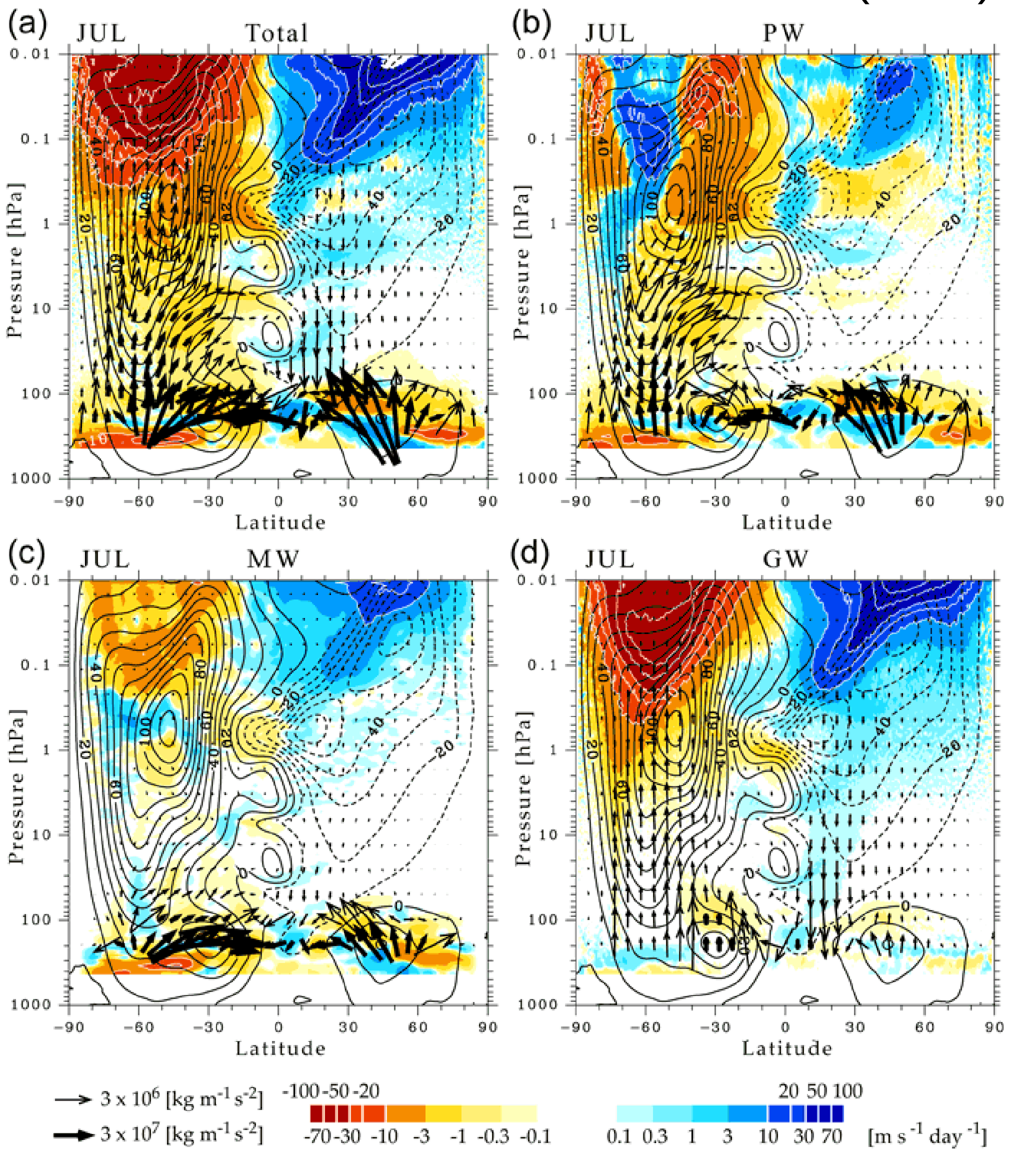
Distribution of fluxes are compared here between "uncorrected" HIRDLS & long-duration balloons. They are very similar with similar means.

More work is required. The very intermittent nature of small scale gravity waves may mean that the mean values decrease as more data is averaged.

Outcomes of March 2008 Workshop in Toronto

Principal Results in the Review

Watanabe et al. (2008)



Global Gravity Wave Resolving Models

These are not yet resolving the full spectrum of gravity waves, but they are showing some very realistic properties compared to observations Including:

- Wind reversals near the mesopause.
- A QBO-like oscillation.
- Good comparison of wave fluxes to radar observations.
- Realistic gravity wave sources.

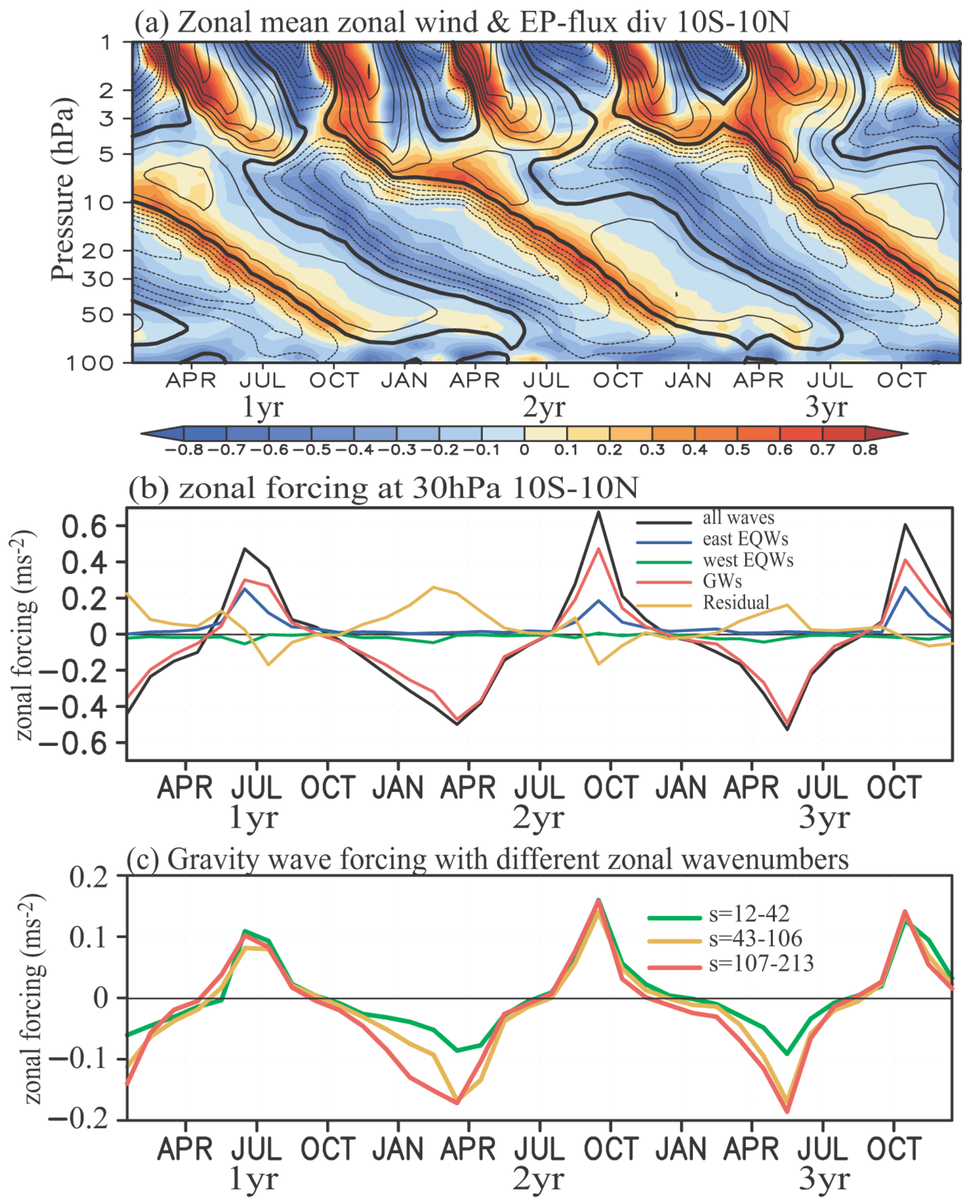
The models are also revealing some interesting effects of winds on wave propagation.

Outcomes of March 2008 Workshop in Toronto

Principal Results in the Review

Kawatani et al. (2009)

Global Gravity Wave Resolving Models



What drives the QBO-like oscillation in the model?

Eastward phase:
- 25-50% Equatorial waves
- 50-75% Gravity waves

Westward phase:
- ~10% Equatorial waves
- 10-20% Extratropical Rossby waves
- Remainder gravity waves

Bottom panel breaks down the gravity waves by horizontal scale. The shortest waves contribute the most.

New Activities

A new International Team funded by the International Space Science Institute (ISSI)

The Gravity Wave Project:
An International Team for Merging Space-Based Observational Constraints for Gravity Wave Parameterizations in Climate Models

- Proposal to ISSI submitted February 2009
- Selected for funding July 2009
- First workshop planned February 22-26, 2010 at ISSI in Bern, Switzerland
- Meeting costs, hotel, and per diem for participants paid by ISSI

The Team:
Joan Alexander (Team Leader, USA), Marv Geller (USA), Julio Bacmeister (USA) Stephen Eckermann (USA), Manfred Ern (Germany), Albert Hertzog (France), Takeshi Horinouch (Japan), Elisa Manzini (Italy),Peter Preusse (Germany), Kaoru Sato (Japan), Adam Scaife (UK), Bob Vincent (Australia), plus two young scientists we nominate for ISSI approval.

The team has expertise in the relevant satellite measurements plus crucial additional measurements needed for calibration, and members of the global modeling community who will help ensure the results of our project will be utilized.

New Activities

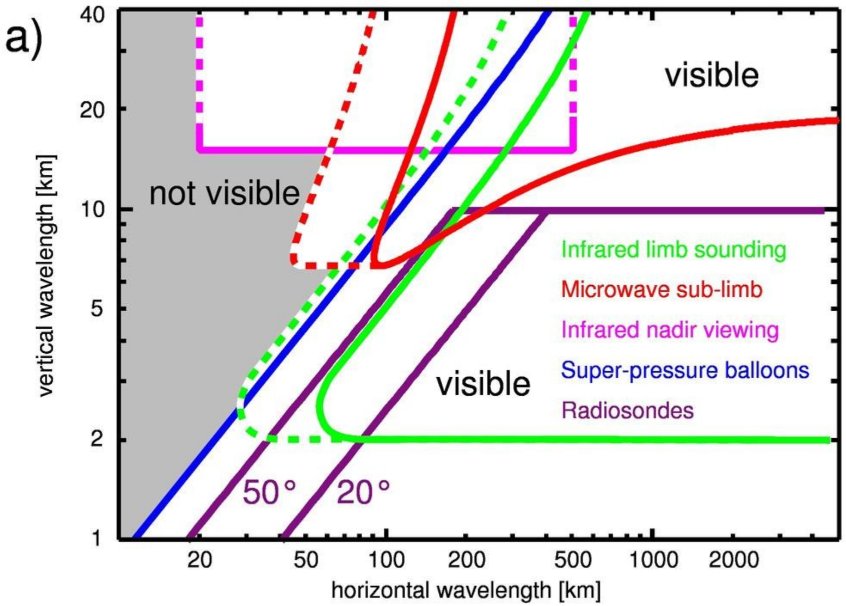
A new International Team funded by the International Space Science Institute (ISSI)

The Gravity Wave Project: An International Team for Merging Space-Based Observational Constraints for Gravity Wave Parameterizations in Climate Models

The goal of the project is to create a self-consistent data set of atmospheric gravity wave momentum fluxes and propagation properties suitable for climate and weather forecasting applications.

The existing data cover much of the spectrum, and data from PREMIER, if selected by ESA, could cover the remaining important portions.

We hope that SPARC will join in supporting this project by providing funding for the airfare costs for the two young scientists and for one of the participants.



After Preusse et al. (2008)

New Activities

A Chapman Conference Proposal to the American Geophysical Union
on
Atmospheric Gravity Waves and their Effects
on the General Circulation & Climate

Convenors: Joan Alexander, Kevin Hamilton (U Hawaii), and Kaoru Sato (U Tokyo)

Proposed location and time: Hawaii, February 2011
Expected participants: 80-100

Previous very successful meetings focused on gravity waves were held in 1996 and 2004 (K. Hamilton lead convenor). There have been recent surges in progress on this topic and the community is growing. The meeting would provide a chance for this community to come together to assess the recent results and forge the interdisciplinary collaborations that are needed to address the current issues.

New Activities

A Chapman Conference Proposal to the American Geophysical Union
on
Atmospheric Gravity Waves and their Effects
on the General Circulation & Climate

Highlighted Session Topics:

1. Ultra-high Resolution Global Model Studies
2. Satellite Observations
3. Gravity Wave Effects on the Extratropical Circulation
4. Gravity Wave Effects on the Tropical Circulation
5. Surface Climate Effects
6. Gravity Wave Sources

We are requesting some additional support from SPARC to facilitate participation of a strong contingent of graduate students and early career scientists and for some scientists from under-represented nations.