The El Niño-Southern Oscillation signal in geopotential height and wind derived from GPS RO

Barbara Scherllin-Pirscher, Andrea K. Steiner, and Gottfried Kirchengast

Wegener Center for Climate and Global Change (WegCenter) and Institute for Geophysics, Astrophysics and Meteorology, Inst. of Physics, University of Graz, Austria

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Geopotential height and geostrophic wind

Geopotential height

- based on accurate knowledge of the position and velocity vectors of LEO and GPS satellites

\[ Z(h) = \frac{1}{g_0} \int_0^h g(\varphi, h') dh' \]

- relate geopotential height to pressure in order to obtain \( Z(p) \)
- use data CHAMP, GRACE-A, SAC-C, and COSMIC (WEGC OPSv5.6) for the period January 2007 to December 2012
- compute monthly mean climatologies for \( 5^\circ \times 5^\circ \) equal-area bins
- estimate sampling error using ECMWF analyses
- subtract sampling error from monthly mean RO climatologies
Geostrophic wind

- balances the **pressure gradient force** and the **Coriolis force**
- obtained from monthly mean sampling error-corrected $5^\circ \times 5^\circ$ geopotential height fields:

\[
\begin{align*}
    u_{\text{geo}} &= -\frac{1}{f(\varphi)} \frac{1}{R_e} \frac{\partial \Phi}{\partial \varphi} \\
    v_{\text{geo}} &= \frac{1}{f(\varphi)} \frac{1}{R_e \cos \varphi} \frac{\partial \Phi}{\partial \lambda},
\end{align*}
\]

- $u_{\text{geo}}$ ... zonal component
- $v_{\text{geo}}$ ... meridional component
- $f(\varphi) = 2\Omega \sin \varphi$ ... Coriolis parameter
- $R_e$ ... Earth’s radius
- $\Phi = Zg_0$ ... geopotential
- $\varphi$ ... latitude
- $\lambda$ ... longitude
Geopotential height and geostrophic wind

2009-01: Geopotential height and geostrophic wind at 200.0 hPa

2009-07: Geopotential height and geostrophic wind at 200.0 hPa

2009-01: Geostrophic wind speed, 200.0 hPa

2009-07: Geostrophic wind speed, 200.0 hPa

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Errors in geopotential height fields

- residual sampling error (<10 m)
- systematic error (<7 m)
- statistical error (<2 m)

see Scherllin-Pirscher et al. 2011 (AMT)
# Geopotential height and geostrophic wind

## Errors in geopotential height fields
- residual sampling error ($<10$ m)
- systematic error ($<7$ m)
- statistical error ($<2$ m)

see Scherllin-Pirscher et al. 2011 (AMT)

## Errors in geostrophic wind fields
- ageostrophy (in general $<2$ m/s, larger differences close to the subtropical jet)
- residual sampling error and retrieval error ($<2$ m/s)

see Scherllin-Pirscher et al. 2014 (accepted for publ. in GRL) and Verkhoglyadova et al. 2014 (accepted for publ. in JTECH)

see also poster of Verkhoglyadova et al.
Timeseries of inter-annual anomalies

200 hPa, 120° W to 170° W (Niño 3.4 sector): time × latitude

Geopotential height

Geostrophic wind
Timeseries of inter-annual anomalies

200 hPa, 120° W to 170° W (Niño 3.4 sector): time × latitude

Geopotential height

Geostrophic wind

200 hPa, 17.5° N to 22.5° N: time × longitude

Geopotential height

Geostrophic wind
La Niña: 01/2008

El Niño: 01/2010

- Changes in the atmospheric circulation
- Jet stream is considerably different during La Niña than during El Niño
  - La Niña: strong longitudinal variability
  - El Niño: elongated jet stream
Geopotential height

Geopotential height, El Niño:
- increase at low latitudes, decrease at mid-latitudes
- strongest signal in the central Pacific

Geostrophic wind

Geostrophic wind, El Niño:
- acceleration of winds between about 20° S/N and 40° S/N
- weakening of winds between about 40° S/N and 60° S/N
Regression maps at 200 hPa

Geopotential height: 200.0 hPa

Geostrophic wind speed: 200.0 hPa

Geopotential height:
- Increase at low latitudes, decrease at mid-latitudes
- Strongest signal in the central Pacific

Geostrophic wind:
- Acceleration of winds between about 20°S/N and 40°S/N
- Weakening of winds between about 40°S/N and 60°S/N
Geopotential height, El Niño:
- strong positive tropical signal between 100 hPa and 200 hPa
- strong negative signal at mid-latitudes

Geostrophic wind, El Niño:
- strongest positive signal between about 20° S/N and 30° S/N, 300 hPa to 100 hPa
- negative signal again at mid-latitudes
Geopotential height

- Strong positive tropical signal between 100 hPa and 200 hPa
- Strong negative signal at mid-latitudes

Geostrophic wind

- Strongest positive signal between about 20°S/N and 30°S/N, 300 hPa to 100 hPa
- Negative signal again at mid-latitudes
Geopotential height and geostrophic wind retrieved from RO measurements can be used to study atmospheric dynamics.

RO data clearly capture the ENSO signal in geopotential height and in geostrophic wind in the upper troposphere equatorward of $\approx 60^\circ$ S/N.

Geopotential height ENSO signal in the troposphere shows a distinctive zonal-mean component at low- and mid-latitudes (during El Niño geopotential height increases at low latitudes and decreases at mid latitudes).

The strongest positive signal is found above the central Pacific between 200 hPa and 100 hPa.

Geostrophic wind (jet stream) shows more ENSO-related longitudinal variability;

Elongated jet stream during El Niño;

Strongest signal between 300 hPa and 100 hPa.