The 2010 balloon experiment in the equatorial stratosphere and validation of the dynamics in ECMWF operational analyses

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RESEARCH ARTICLE 10.1002/2014JD021849 Assessment of the accuracy of (re)analyses in the equatorial lower stratosphere

Key Points: Aurélien Podglajen¹, Albert Hertzog¹, Riwal Plougonven¹, and Nedjelja Žagar²
Motivations

- Study of the equatorial UTLS or Tropical Tropopause Layer (TTL)
  - Mesoscale processes: convection, waves, cirrus and dehydration
- Analyses are widely used to study transport in the TTL...
  - … but (upper-air) wind observations are actually very scarce in the tropics
  - And tropical winds are not as simply tied to the mass field as in the extra-tropics

(Fueglistaler et al., 2009)
Void areas over the Oceans and Africa =>
NWP winds poorly constrained by the current observation system in the tropics
Motivations

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Pre-Concordiasi (2010)

- Long-duration balloons
  - Fly on constant density surfaces at ~ 60 hPa (19-20 km)
  - 3 flights, 3-month long
  - GPS, P, T, hor. wind velocities (balloon displacements)
    - Accuracy: 1.5 m, 0.1 hPa, 0.2 K, 0.1 m/s
    - Measurements every 30 s
- Observations were not assimilated by NWPs
- Comparisons w/ ECMWF operational analyses and MERRA reanalyses

Flight duration: 92 days

Launched on Feb 8, 2010
End on May 11, 2010
Dynamical context

Hovmöller diagram of ECMWF winds @ 57 hPa during the campaign: QBO shift, Kelvin and Rossby-gravity (Yanai) waves
Part of this difference is associated with unresolved small-/meso-scale motions... Yet the standard deviation numbers are larger than above Antarctica!
Difference statistics

**Zonal wind**

- $U_{mer} - U_{obs}$, $\langle \Delta U \rangle$ = -0.2 m/s, $\sigma$ = 5.9 m/s
- $U_{cc} - U_{obs}$, $\langle \Delta U \rangle$ = -2.4 m/s, $\sigma$ = 4.8 m/s

**Meridional wind**

- $V_{mer} - V_{obs}$, $\langle \Delta V \rangle$ = -0.3 m/s, $\sigma$ = 4.4 m/s
- $V_{cc} - V_{obs}$, $\langle \Delta V \rangle$ = 0 m/s, $\sigma$ = 3.6 m/s
Difference statistics

Zonal wind
- $U_{\text{mer}} - U_{\text{obs}}$, $<\Delta U> = -0.2 \text{ m/s}$, $\sigma = 5.9 \text{ m/s}$
- $U_{\text{cc}} - U_{\text{obs}}$, $<\Delta U> = -2.4 \text{ m/s}$, $\sigma = 4.8 \text{ m/s}$

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Wind timeseries

Zonal velocities

(m/s)

Date

10/2 15/2 20/2 25/2 5/3 10/3 15/3 20/3 25/3 30/3 5/4 10/4 15/4 25/4 30/4 5/5 10/5
Wind timeseries

Month-long period with differences up to 15 m/s in both NWP products
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Month-long period with differences up to 15 m/s in both NWP products
Cause of discrepancies: model vertical resolution

Meridional velocity in Singapore radiosounding and ECMWF operational analyses during the passage of a Yanai wave packets

Equatorial waves can have small (2-3 km) vertical wavelength, and still large amplitudes => in spite of assimilation, they may only be marginally resolved in NWPs
Cause of discrepancies: observation distribution

- RMS of u-differences
- Errors twice as large over regions void of conventional observations
Constraints on ECMWF analyses

5S-5N wind increments in ECMWF operational analyses

Significant increments over South America and Indonesia...
Model dynamics is almost free-running over the rest of the equatorial belt
Conclusions

- Large, long-lasting errors in the equatorial dynamics in current NWP products
- Those errors are mostly due to poorly simulated equatorial waves that account for most of the wind variability in the UTLS
- Causes of errors include model vertical resolution and lack of wind observations over large areas in the tropics
Strateole 2: A long-duration balloon campaign at the Equator (2017-2019)

http://tinyurl.com/strateole

- 3 campaigns from late 2017 to late 2019
  - Up to 22-24 flights per campaign
  - Flights in the upper TTL (around 18 km) and in the lower stratosphere (around 20 km)
  - Launch from an equatorial site
    => balloons will stay in the ‘tropical pipe’ and provide observations representative of the whole equatorial belt

- Observations available in near-real time
  - Flight level meteorology (P, T, winds)
  - Up to 600 dropsondes/campaign (met profile)
  - Backscatter lidar on some flights
  - In-situ water vapor, ozone, aerosol

- Happy to contribute to ADM/Aeolus related activities!