In-situ measurements of ozone and gravity waves during the Concordiasi 2010 long-duration balloon campaign in the Antarctic lower stratosphere

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AWI team and sounding stations in Antarctica
Concordiasi Workshop, Boulder, Oct. 2011

19 long-duration, superpressure-balloon flights
Sept. 2010- Jan. 2011
Mean duration : 69 days

Flight-level measurements
- Meteorological obs. every 30 s (> 2.3 Gobs)
  TSEN (LMD) + GPS (ISBA/CNES)
  u, v (0.02 m/s), P (0.1 Pa), T (<0.1/0.3 K)
  → assimilated by operational NWPs
- Ozone obs. every 15 min (6 flights)
  B-Bop (LMD) + UCOz (UCAR)
  lightweight ozone UV photometer
  precision: 20 ppb

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Tsen dataset

- A final version of the Tsen dataset has been produced in May 2011
  - Merge of Isba positions w/ Tsen met. Observations
  - Interpolation in small data gaps (< 15 min)
  - Correction for daytime heating of temperature sensors
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Archived in the Concordiasi database and LMD ftp repository
Some observations

Concordiasi balloon #6: winds

Concordiasi balloon #6: temperature
Some observations

Concordiasi balloon #6: winds

Concordiasi balloon #6: temperature

Rossby waves
Some observations

Concordiasi balloon #6: winds

Inertia-gravity waves

Concordiasi balloon #6: temperature

Rossby waves
Some observations

- Rossby waves
- Inertia-gravity waves
- Mountain waves

Concordiasi balloon #6: winds
Concordiasi balloon #6: temperature
Gravity waves

- Gravity waves play a major role in driving the global Brewer-Dobson circulation in the middle atmosphere, as well as in warming the winter polar stratosphere
  - Parameterized in GCMs → need observations to constrain parameters
  - Observations at global scales are difficult, as well as diagnosing momentum flux
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![Graphs showing zonal/meridional velocity spectra and pressure spectrum.](image)
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![Graphs showing zonal/meridional velocity spectra and pressure spectrum with labels for Rossby waves, Gravity-wave band, and Balloon neutral oscillations.](image)
Orographic gravity waves

T' $\sim$ 15 K, $u'$ $\sim$ 35 m/s
Vertical displ. 1.5 km
Period of 10 min – 1 hr → fully resolved by obs.

Such mountain waves are not only important for dynamics but can also trigger the formation of PSC particles
Antarctica Peninsula and Drake Passage are hotspots of gravity-wave activity in Antarctica. Potential energy (higher frequency waves) increases from the Pole toward mid-latitudes → GW source above the oceans (storm tracks, front, convection)
Directional momentum fluxes

Extend Vorcore 2005 results to higher-frequencies in terms of momentum fluxes
Directional momentum fluxes

Extend Vorcore 2005 results to higher-frequencies in terms of momentum fluxes and wave intermittency
Ozone observations – PSC 14

Super-pressure balloons behave as quasi-Lagrangian tracers → could track ozone evolution in an 'air mass'
Ozone observations - PSC14

Chemical depletion

Transport-dominated variations
Ozone observations - PSC14

Coordinated match campaign

McMurdo
24 Sept.

McMurdo
1st Oct.

Belgrano
23 Oct.

South Pole
28 Nov.
Ozone loss estimates

• Explain the ozone variations due to balloon motions:
  - Project ozone variations on potential temperature (1 day window)
    \[ X_{O_3}(t) = a \theta(t) + \varepsilon(t) \]

• Explain the residual in terms of ozone loss:
  \[ \varepsilon(t) = \text{loss} \cdot t + c(t) \]
  express loss in ppb/sunlit hour
Ozone loss estimates

Ozone loss generally < 10 ppb/sunlit hour but can reach up to 25 ppb/sunlit hour
Conclusions

- Concordiasi dataset shows promising dynamics studies
  - Almost whole gravity-wave range resolved
  - Ability to compute momentum fluxes, study wave intermittency
- Ozone measurement have been successfully performed
  - Diagnose ozone loss on a quasi-Lagrangian vector
  - Compare PSC 14 w/ other flights (including Ucoz)
- ... obviously lot of work to do in the coming years
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- ... obviously lot of work to do in the coming years
- Willing to make a 'similar' campaign at low latitudes: Strateole Phase 2
  - Waves dynamics, transport (dehydration), clouds, NWP accuracy

Thank you for your attention!
Orographic/Non-orographic waves

- Geographical criterion (based on topography gradients) to flag boxes as mountainous or non-mountainous
- Compute zonal-mean absolute fluxes and the contribution of both types of areas
South Pole Ozone Sounding

Value used for the comparison = Same potential temperature

LD Balloon Altitude

Long-duration balloon flew in a strong ozone gradient that may explain part of the difference

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