Stratéole 2:
Long-duration balloons providing wind information in the deep tropics

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http://www.tinyurl.com/strateole
Stratéole 2 concept

- Heritage from previous CNES projects that used long-duration (> 1 month) stratospheric balloons

Vorcore (2005) – 27 flights
150 000 obs.
Stratéole 2 concept

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Amma (2006): 8 flights
Stratéole 2 concept

• Heritage from previous CNES projects that used long-duration (> 1 month) stratospheric balloons

Vorcore (2005) – 27 flights
150 000 obs.

Concordiasi (2010) – 19 flights
3 200 000 obs.

Amma (2006): 8 flights
Stratéole 2 concept

• Heritage from previous CNES projects that used long-duration (> 1 month) stratospheric balloons

• Stratéole 2 will use the long-duration balloons
  • To address dynamics, transport, microphysics, and dehydration processes as well as their interactions in the deep tropics
  • To contribute to operational meteorology and satellite cal/val

• Stratéole 2 is an international project leaded by CNES and LMD involving several research groups in France, USA, Italy

Launched on Feb 8, 2010
Pre-Concordiasi flight (2010)

End on May 11, 2010
Transport in the Tropical Tropopause Layer (TTL)

- Located between 14 km and ~ 20 km
  - Rapid convective transport below
  - Slower vertical motion in the TTL as air continues to ascend to the tropical stratosphere
- Transition from troposphere to stratosphere, gateway for the overworld
- Stratospheric water vapor mixing ratio is set in the TTL, and present decadal variations that modulate stratospheric chem., and surface warming
Transport in the Tropical Tropopause Layer (TTL)

- Analyses are widely used to study transport in the TTL...
  - ... but (upper-air, above convection) wind observations are very scarce in the tropics
  - And tropical winds are not as simply tied to the mass field as in the extra-tropics
Transport in the Tropical Tropopause Layer (TTL)

Void areas over the Oceans and Africa =>
NWP winds poorly constrained by the current observation system in the tropics.
Dynamics of the equatorial stratosphere

- QBO is driven by a continuum of waves (gravity waves → planetary-scale waves) that are mainly generated by deep convection in the tropics (Dunkerton 1997; Ern 2008; Kawatani et al., 2010)
  - Lack of global observations of gravity-wave momentum fluxes in the tropics
  - Climate/operational models have still difficulties in generating a realistic QBO (GWD parameterization, explicit/numerical dissipation, resolution)
Example of balloon observations

Measurements of meteorological variables every 30s

Concordiasi balloon #6: winds

Concordiasi balloon #6: temperature

U, V

Day in 2010

Day in 2010

(K)
Example of balloon observations

Long-duration balloons can resolve the whole spectrum of atmospheric waves

- Planetary waves
- Gravity waves
- Polar flight
- Equatorial flight

Kinetic energy spectrum

Inertial frequency

BV frequency
Operational meteorology

Zonal velocities

Pre-Concordiasi flight #1
(Podglajen et al., 2014)
Operational meteorology

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
Geographical distribution of model errors

Errors twice as large over regions void of conventional observations.
Operational meteorology

- Strateole 2 meteorological observations will be
  - Disseminated on the GTS (through satellite Iridium phone system) in near real time during the balloon campaigns (BUFR encoding by Meteo-France)
  - Used to assess the impact of wind assimilation to improve analysis quality in the tropics (Meteo-France, ECMWF)
  - Used to contribute to ADM-Aeolus cal/val activities in the tropics
Strateole-2 planning and schedule

- 3 balloon campaigns
  - During boreal winter (DJF) to address convective processes and most intense dehydration
  - Balloons will be launched from Seychelles Islands (5°S)
  - Technological campaign: late 2018 (5 flights)
  - 1st scientific campaign: late 2020 (20 flights)
  - 2nd scientific campaign: late 2023 (20 flights)

- Basic in-situ meteorological observations
  - 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
Each scientific campaign: 20 flights on 2 different levels

10 flights
Lowermost stratosphere
Remote sensing

STRAT1
(4 flights)
• GPS, P & T
• Backscatter Lidar
• GPS RO
• Radiometers

TTL1
(4 flights)
• GPS, P & T
• Water vapor
• Ozone
• Aerosol counter

TTL2
(3 flights)
• GPS, P & T
• CO2 & CH4
• High-frequency temperature profiles down to 2 km below the balloon

TTL3
(3 flights)
• GPS, P & T
• Aerosol counter
• Nighttime cloud/water vapor/temperature profiles down to 2 km below the balloon

10 flights
Tropical tropopause
In-situ sensors

Upper Level: Air density 125g/m³
Altitude ~ 18 000 m

Lower Level: Air density 95g/m³
Altitude ~ 20 000 m
Conclusions

- Strateole 2 will provide in-situ observations of winds in the TTL and will contribute to assess ADM-Aeolus observations in this very important region
  - Late 2018 and late 2020 campaigns
- Possibility to increase ADM-Aeolus vertical resolution in the deep tropics UTLS during Strateole 2 flights?
  - e.g. 1-km resolution in 17-20 km altitude range
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

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

Meridional wind

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

Frequency of occurrence

m/s

ECMWF MERRA

m/s

ECMWF MERRA
Difference statistics

Zonal wind

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

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RESEARCH ARTICLE

Assessment of the accuracy of (re)analyses in the equatorial lower stratosphere

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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!