The Strateole-2 long-duration balloon project in the deep tropics: benefiting from and improving weather forecasts?

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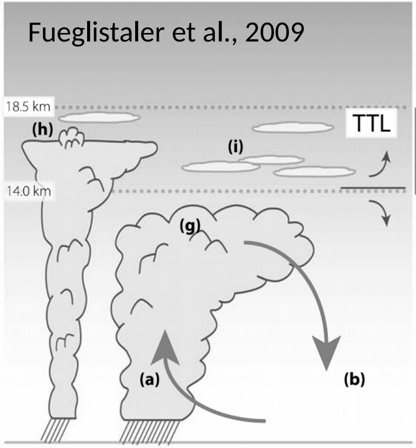
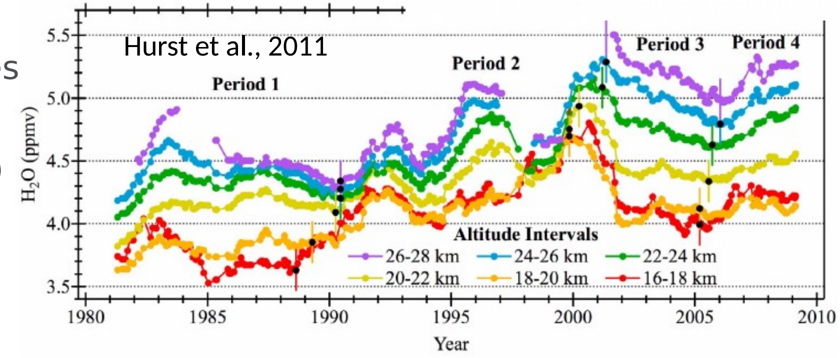
and many others!

The Tropical Tropopause Layer (TTL)

- The TTL is the gateway to the middle atmosphere
    - Transport through the tropical tropopause sets the chemical composition of the stratosphere
    - The stratospheric water vapor content results from the intense dehydration of air parcels that ascend through the cold tropical tropopause…
      …and exhibits large decadal variations that modulate surface warming

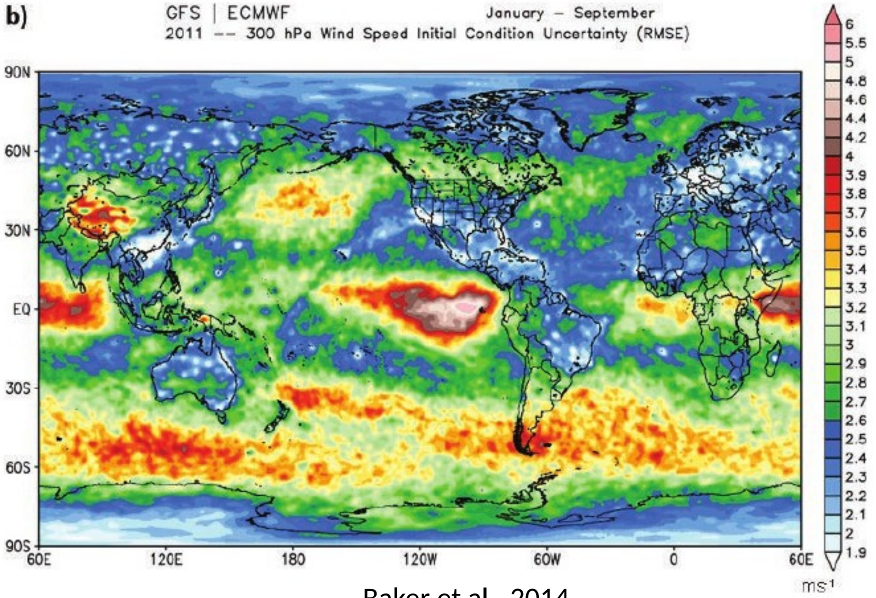


- From a dynamical point of view, the TTL is a very rich and complex region
    - Numerous processes covering a wide range of scales
        - Deep convection and cirrus
        - Planetary-scale (Kelvin, Rossby, Rossby-gravity) and meso-scale gravity waves
        - Quasi-Biennial Oscillation



The Tropical Tropopause Layer (TTL)

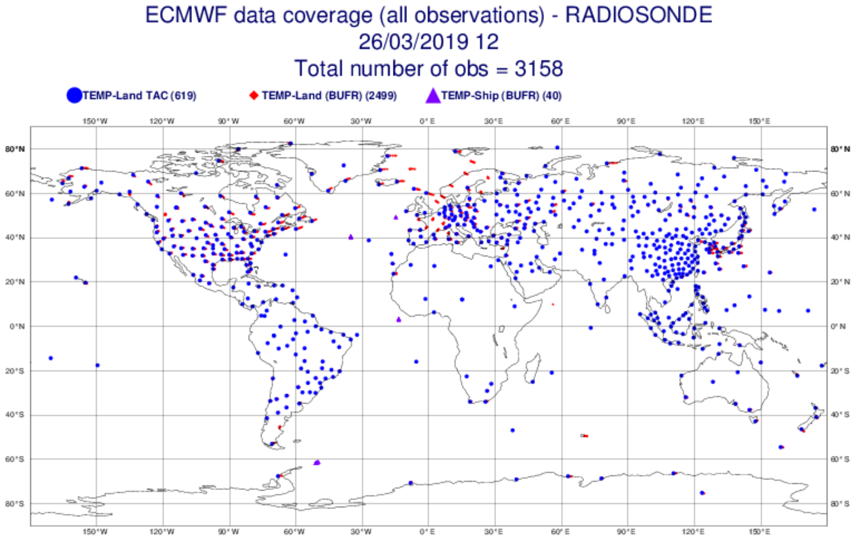
- A significant part of our knowledge of transport in the TTL relies on the use of meteorological analyses
  - But wind observations are very sparse in the tropics
  - And tropical winds are not as simply tied to the mass field as in the extra-tropics (although GPS RO have a positive impact on tropical wind analyses)



Baker et al., 2014

Wind observations in the TTL

- With the exception of Aeolus products, current direct wind observations in the TTL are associated with radiosoundings
  - Most stations in the Maritime continent and South America
  - Large data-void areas: Indian Ocean and the Eastern Pacific Ocean



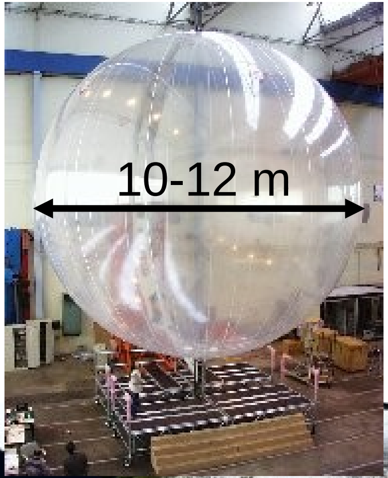
Stratéole-2: Science objectives and schedule

- French-US initiative focused on equatorial UTLS
- Science objectives
  - Dynamics of TTL and tropical lower stratosphere (planetary-scale and gravity waves, driving of the QBO)
  - Transport and dehydration (CPT, wave-microphysics interactions)
  - Satellite cal/val: Aeolus
  - Improve operational forecasts
  - High temporal resolution/global coverage
- Stratéole-2 campaign schedule
  - Nov. 2019 – Feb. 2020 : rehearsal, 6 balloons
  - Fall 2021: 1st main campaign, 20 balloons
  - Fall 2024: 2nd main campaign, 20 balloons
- Balloons launched from Seychelles Islands (5°S)

A superpressure balloon launch in Seychelles Islands in 2010

Stratéole-2 : balloon flights and observations

- Long-duration balloons
  - Flight duration: ~ 3 months
  - Drift on constant density surfaces at 18-20 km
    Flight over convection/clear sky, ocean/continents
- Met observation (TSEN):
  - GPS, P, T, 3D wind velocities (balloon displacements)
  - Accuracy: 1.5 m, 0.1 hPa, 0.2 K, 0.1 m/s
  - Measurements every 30 s
  - Transmitted on the GTS (Iridium connection to the balloons)
- Past campaigns
  - Pre-Concordiasi (2010), 3 flights
    - Tropics
    - Observations not assimilated by NWPs
  - Concordiasi (2010), 19 flights
    - Antarctica
    - Observations assimilated by some NWPs (including ECMWF)
  - Vorcore (2005), 27 flights
    - Antarctica



Flight duration : 90 days

Stratéole-2: payload and flight configurations

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

10 flights
Lowermost stratosphere
Remote sensing

STRAT1

- *TSEN*
- *BeCOOL:*
- *Backscattering lidar*
- *ROC: GPS RO*
- *BOLDAIR: radiometer*

STRAT2

- *TSEN : wind, temperature, pressure*

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

10 flights
Tropical tropopause
In-situ sensors

TTL1

- *TSEN*
- *SAWfPHY: H_2O*
- *B-Bop: O_3*
- *LOAC: particle counter*

TTL2

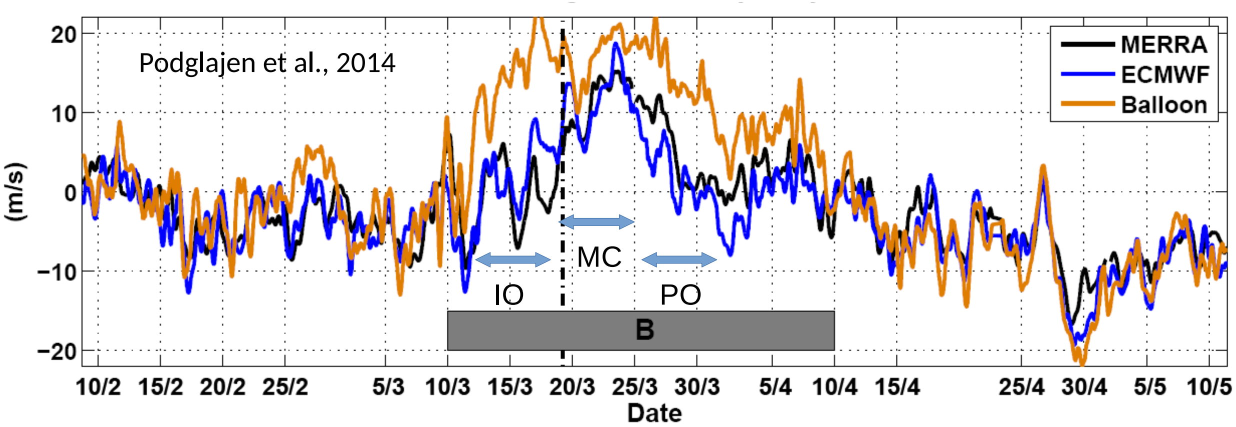
- *TSEN*
- *Pico-SDLA: H_2O & CO_2*
- *FLOATS: continuous temperature profiles down to 2 km below the balloon*

TTL3

- *TSEN*
- *LPC: particle counter*
- *RACHuTS: nighttime profiles of temperature, particles and H_2O down to 2 km below the balloon*

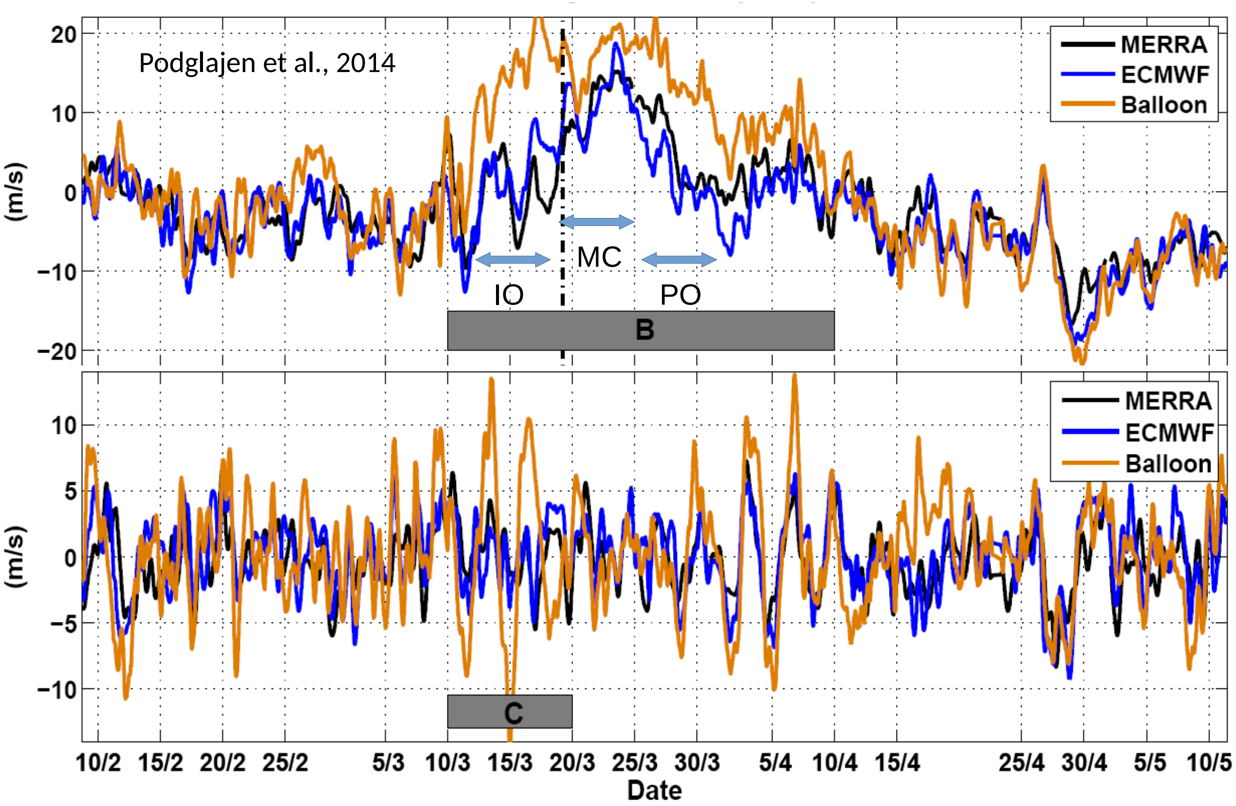
Stratéole-2: NWP improvement

Pre-Concordiasi (2010)
Balloon #1, U



Stratéole-2: NWP improvement

Pre-Concordiasi (2010)
Balloon #1, U

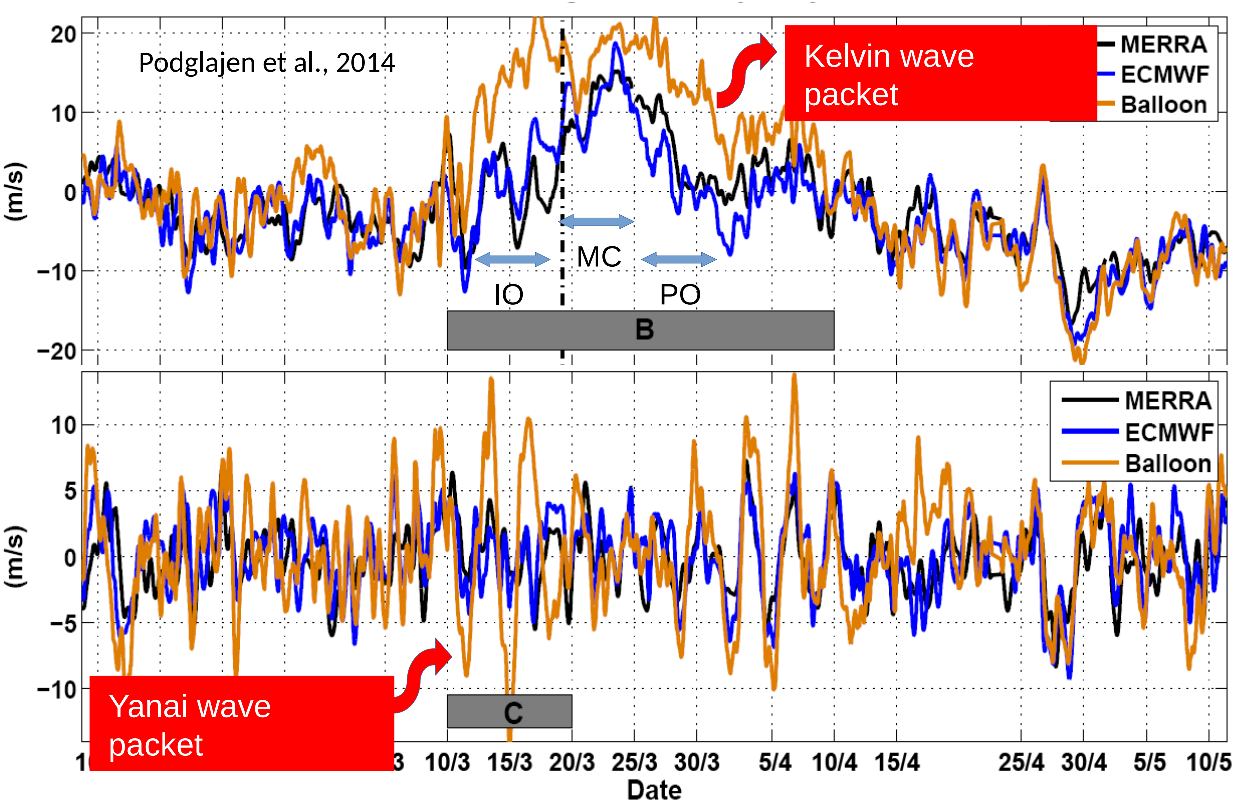


Pre-Concordiasi (2010)
Balloon #1, V

Stratéole-2: NWP improvement

Pre-Concordiasi (2010)
Balloon #1, U

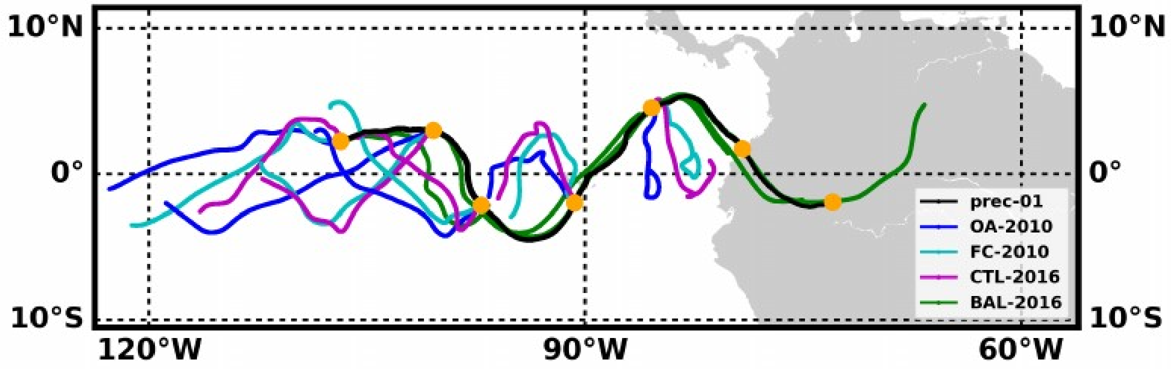
Pre-Concordiasi (2010)
Balloon #1, V



Stratéole-2: Assimilation study

ECMWF model setup

Name	Configuration
OA-2010	2010 model: Operational Analyses
FC-2010	2010 model: Operational Forecasts
CTL-2016	2016 model: Control Run (balloon winds are not assimilated)
BAL-2016	2016 model: balloon winds are assimilated



Selvaraj et al., 2019

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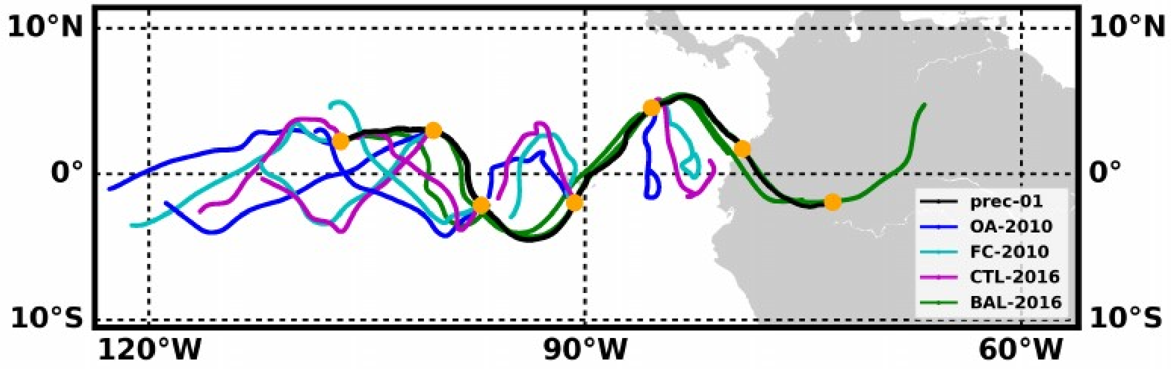
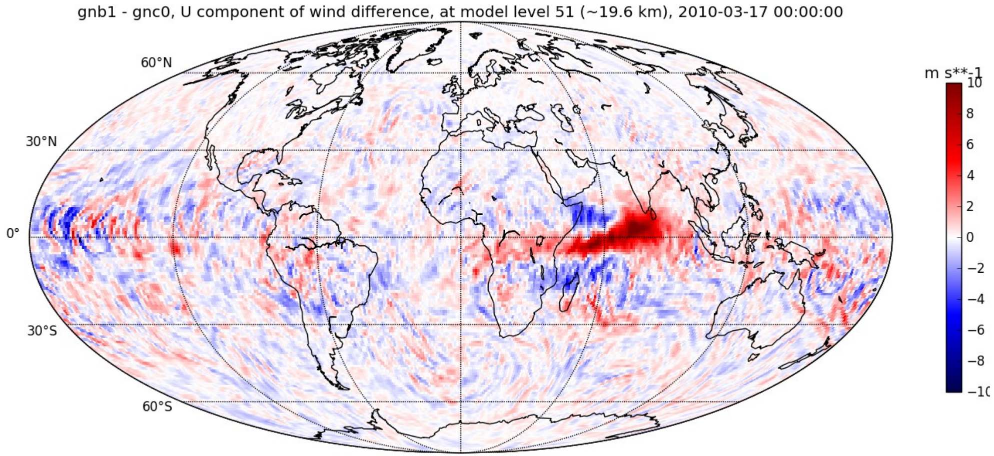


Selvaraj et al., 2019

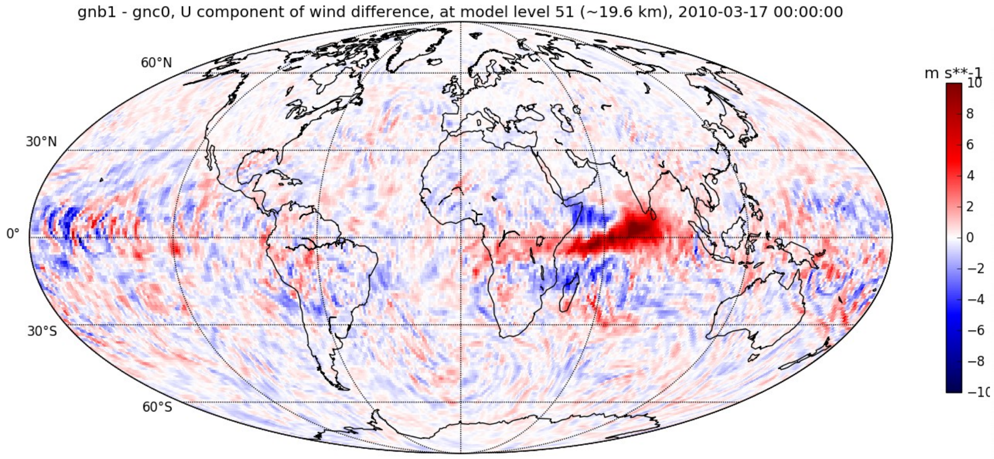
Accurate forecast of balloon trajectories is key for flight management

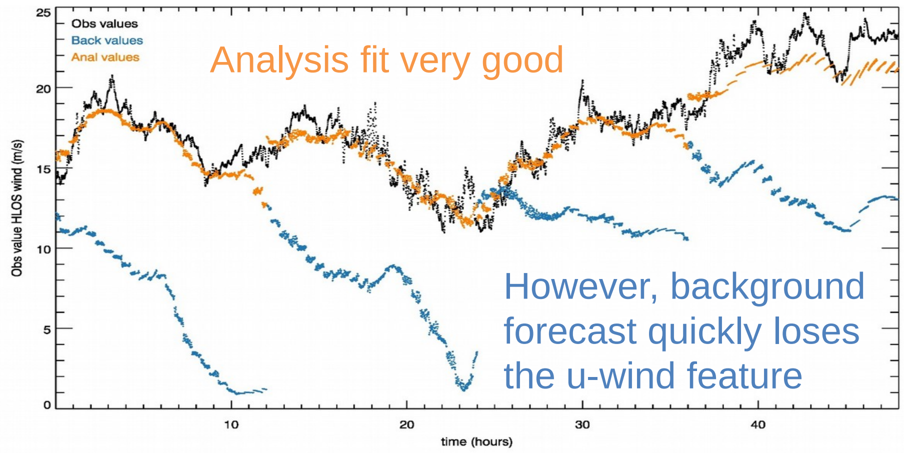
Stratéole-2: Assimilation study (courtesy of M. Rennie)



Integrated effect over cycles
of balloon wind assimilation

Stratéole-2: Assimilation study (courtesy of M. Rennie)





Integrated effect over cycles of balloon wind assimilation

Loss of information points toward deficiencies in the model,
e.g. too large parameterized vertical diffusion in the stratosphere

Conclusions

- Simulating winds in the tropical UTLS is a challenging task for current NWP systems

- Largest wind errors are associated with planetary-scale waves that account for most of the wind variability

- Stratéole-2 (and Aeolus) will contribute to increase the number of clear-sky wind observations, which are key to improve NWP forecasts in the deep tropics.
  Flight management will greatly benefit from those improvements.

- Stratéole-2 will also provide a unique opportunity to assess current convective GWD parameterizations