Strateole 2: Investigating processes in the tropical tropopause layer with long-duration superpressure balloons

Martina Bramberger, Albert Hertzog, M. Joan Alexander, Sean M. Davis, Terry Deshler, Doug Goetz, Jennifer Haase, Lars Kalnajs, Riwal Plougonven, Aurélien Podglajen, François Ravetta, Stephanie Venel, and the Strateole-2 Team

Strateole 2 – Balloon Setup

Super Pressure Balloon
11m or 13m diameter - depending on configuration
- Float at constant density levels

Gondola “Euros”:
- Flight Monitoring/Control
- Scientific instrument: TSEN

Gondola “Zephyr”:
- Various combinations of up tp 3 scientific instruments

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Strateole 2 – Balloon Configurations

STR flight level ~20km

TTL flight level ~18km

STR1
- TSEN
- BeCOOL: Backscattering lidar
- ROC: GPS RO
- BOLDAIR: radiometer

STR2
- TSEN

TTL1
- TSEN
- LOAC: particle counter
- SAWfPHY: water vapor
- B-BOP: Ozone

TTL3
- TSEN
- LPC: particle counter
- RACHuTS: nighttime profiles of water vapor, temperature and particles down to 2km below balloon

TTL4
- TSEN
- B-BOP: Ozone
- Pico –SDLA: Water vapor and CO2

TTL5
- TSEN
- LOAC: particle counter
- SAWFPHY: water vapor
- FLOATS: continuos temperature profiles down to 2km below balloon

Strateole 2 – Balloon Launch

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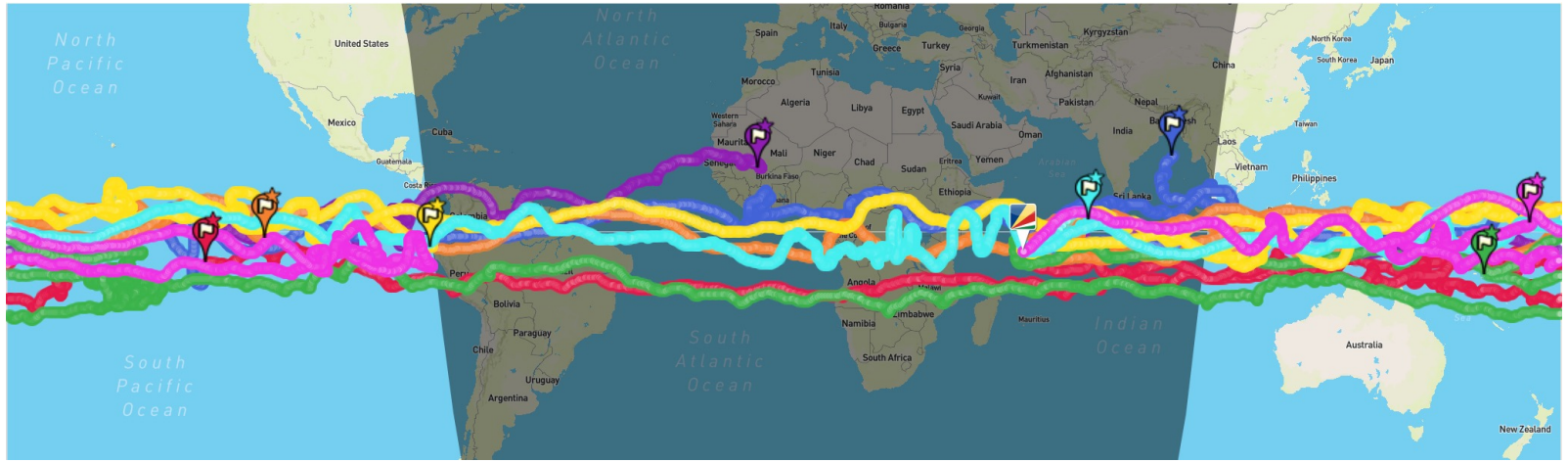
Strateole 2 – Previous Campaigns

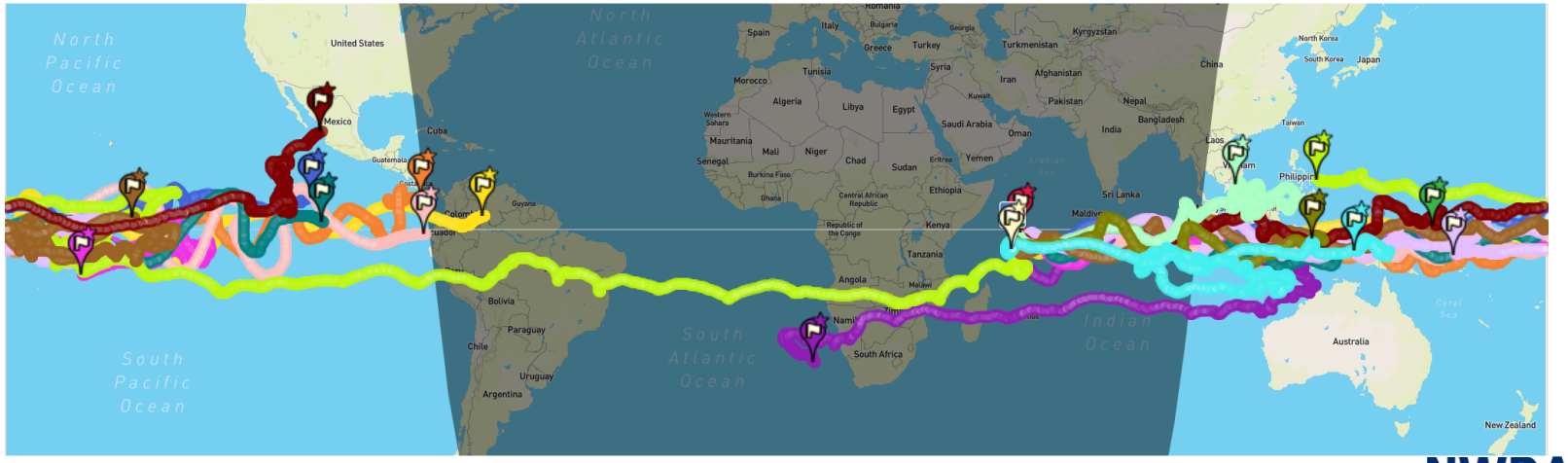
Test campaign in 2019 (8 flights)

- Nov 2019 – Feb 2020
- Quasi-Biennial Oscillation (QBO) westerly phase at 20km



Science campaign in 2021 (17 flights)

- Oct 2021 – Jan 2022
- QBO transition westerly to easterly



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Strateole 2 – Scientific Goals

To address dynamics, transport, microphysics, and dehydration processes as well as their interactions in the deep tropics

- Dynamics of the Tropical Tropopause Layer (TTL) and tropical lowermost stratosphere
  - Quasi-Biennial Oscillation
  - Planetary scale and gravity waves

- Climate effects of water vapor, thin cirrus and temperature variability in the TTL
  - Deep convection and tropical waves
  - Aerosols / cirrus ice particles
  - Profiles of water vapor, particles and temperature

- Satellite cal/val for ESA Aeolus 3D wind lidar

- Tropical forecast improvements

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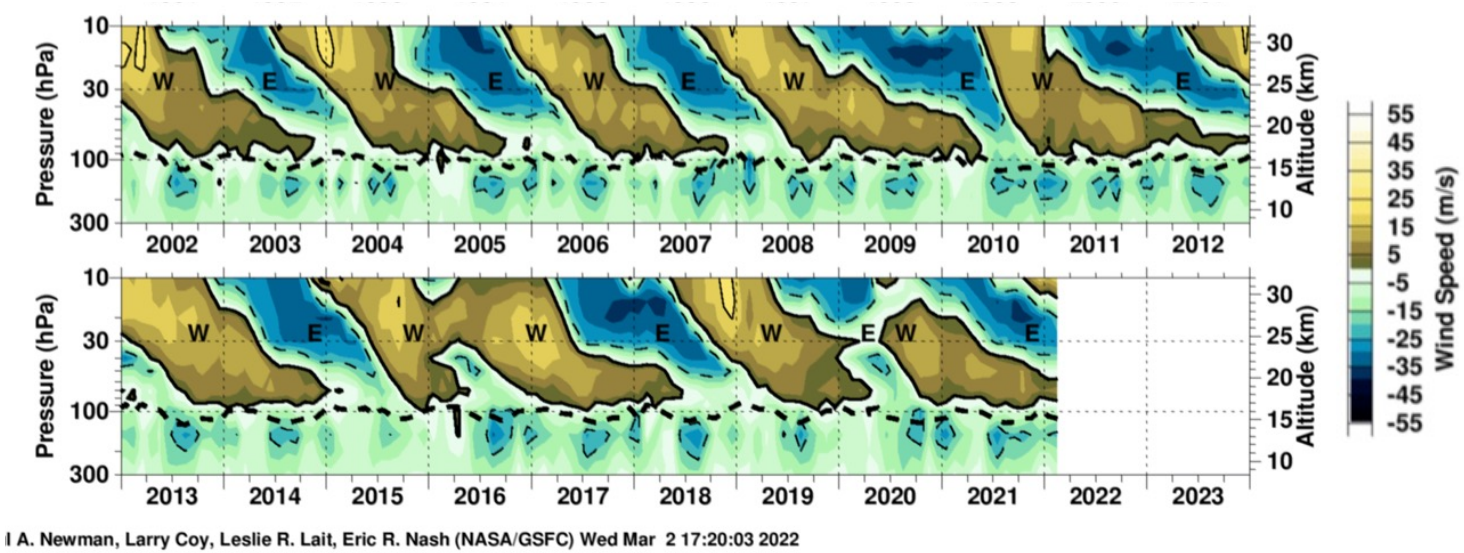
Strateole 2 – Climatological Context

QBO

-> modulates MJO intensity /duration
-> modulates polar stratospheric vortex
-> teleconnections to NH winter season weather
-> **important for S2S forecasts and interannual climate**



https://acd-ext.gsfc.nasa.gov/Data_services/met/qbo/qbo.html

Challenges in representation of QBO in current GCMs:

- QBO is far too weak between 50hPa and 100hPa in most climate models (Bushell et al. 2020)
- Two disruptions in the cycle in the last 6 years suggest QBO may already be changing
- No consistency among GCMs on how QBO period will evolve in a warming climate

-> Representation of tropical waves and parameterization of gravity wave drag are large sources of uncertainty in modelling QBO (Holt et al. 2020, Richter et al. 2020)

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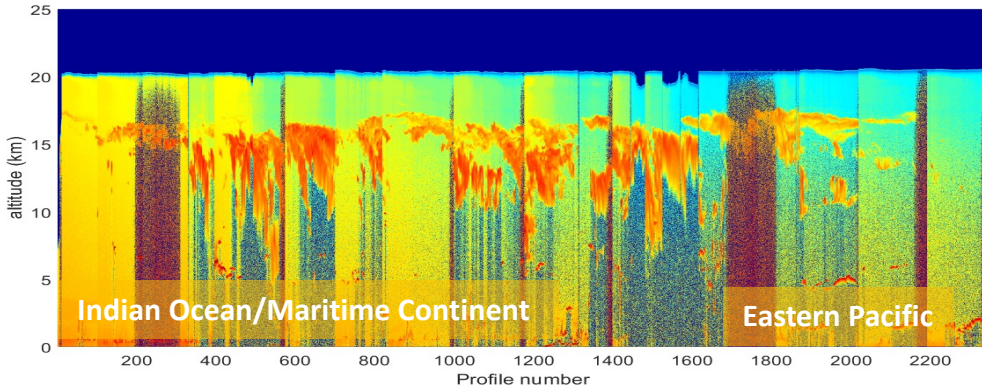
Strateole 2 – Climatological Context

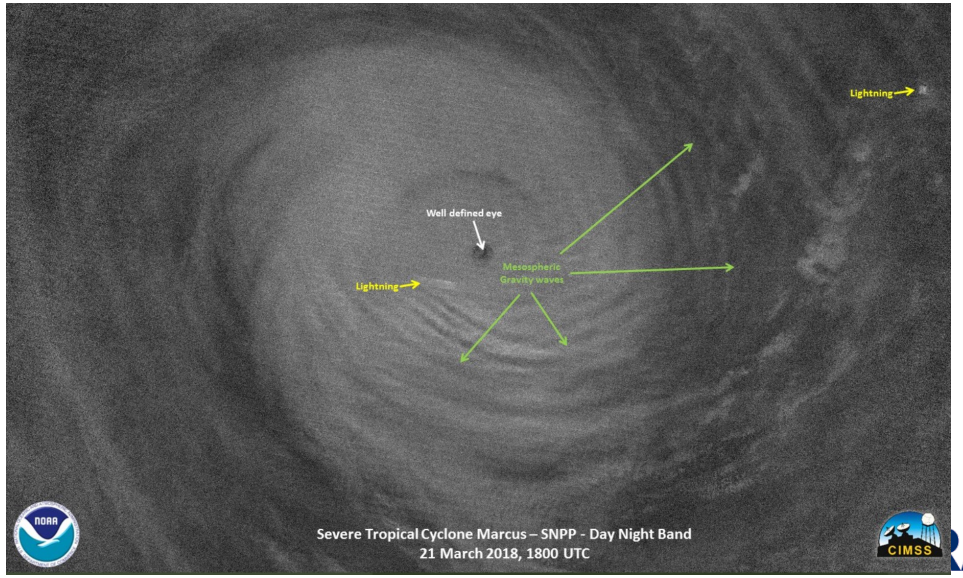
Stratospheric Water Vapor:

- Important greenhouse effect impacting surface temperatures
  - radiative impacts comparable to other greenhouse gases
- Global stratospheric concentrations are controlled by processes in the TTL
  - observed decadal variations in the water vapor are not understood



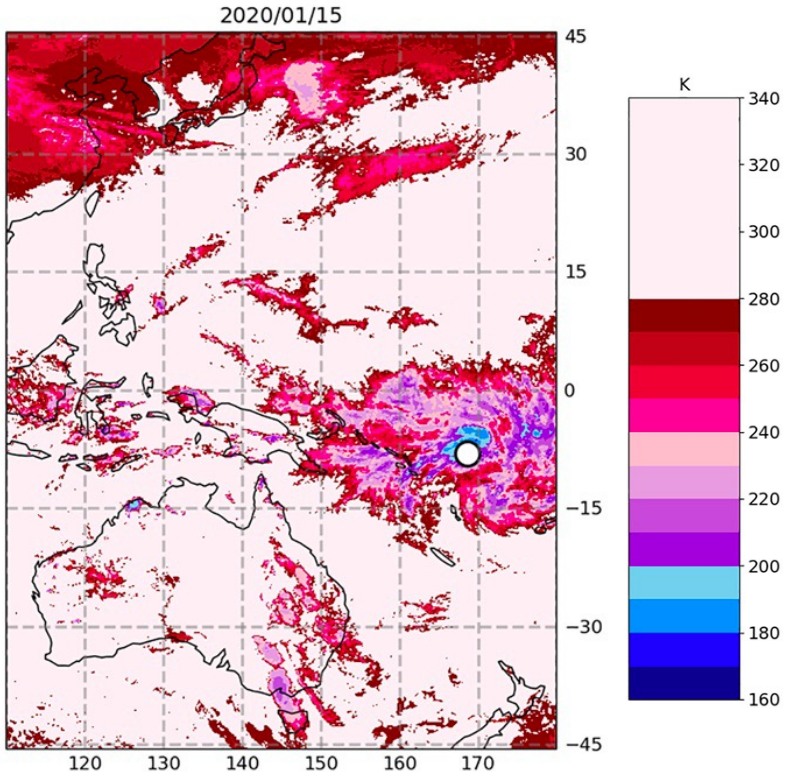
Tropical Waves:

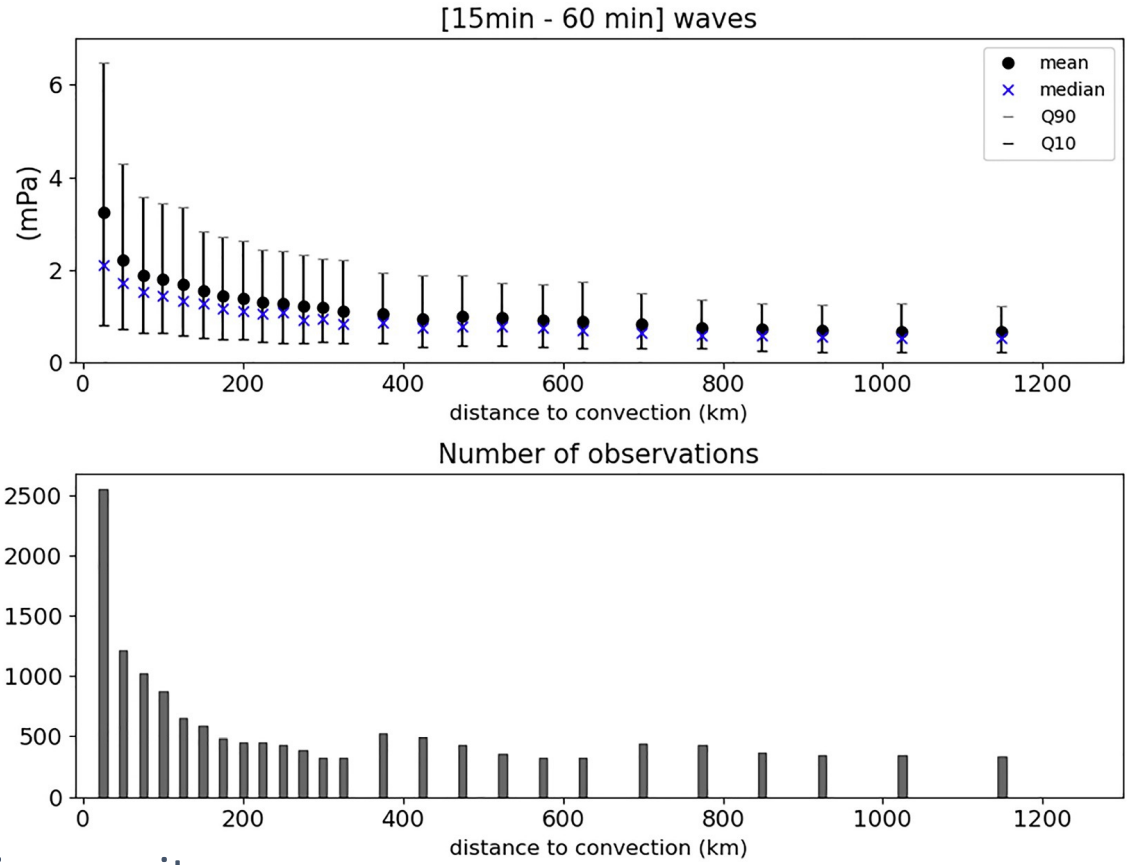
- Drive Quasi-Biennial Oscillation (QBO)
- Influence transport of water vapor to the stratosphere across TTL
- Generate and modulate life-cycle of cirrus clouds



https://twitter.com/i/status/1173952942379917312

Strateole 2 - First results (Corcos et al. 2021)





- Statistical analysis of momentum flux of convective gravity waves
- Dependence of momentum fluxes to distance to the nearest convective cell
- Wave amplitudes are highly intermittent and poorly represented in parameterizations (Alexander et al. 2021)

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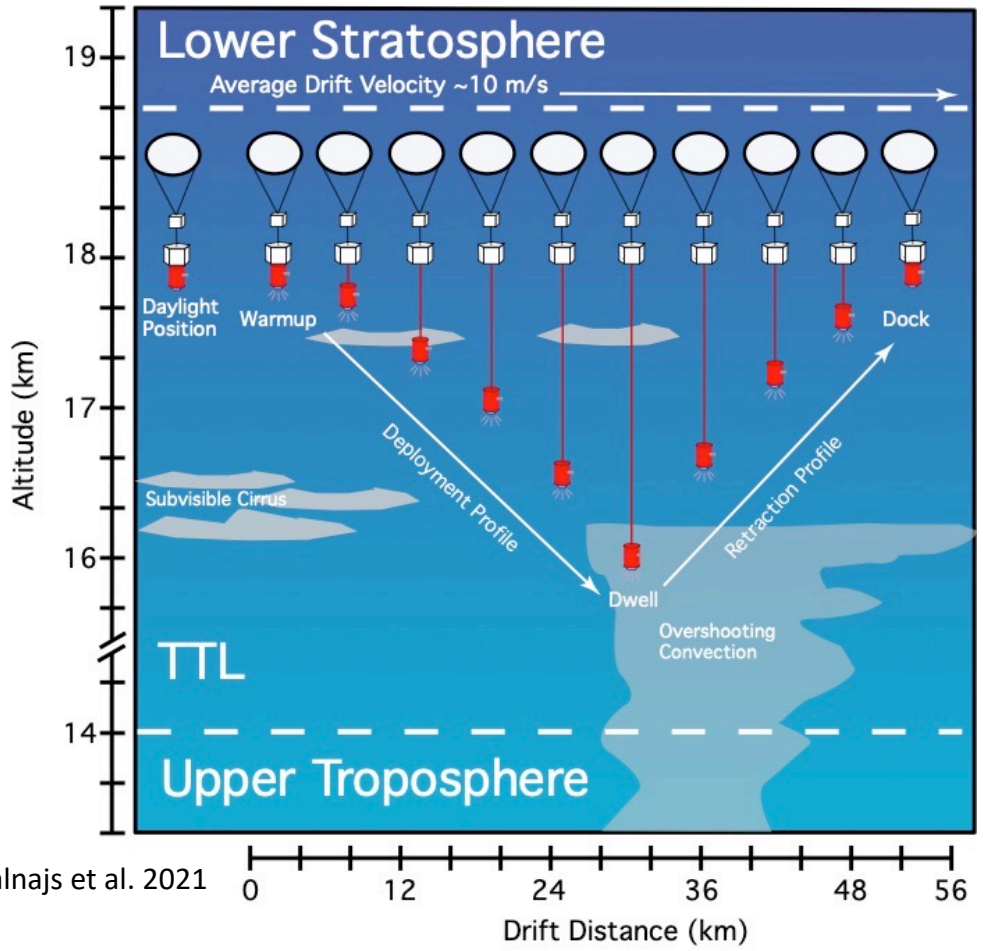
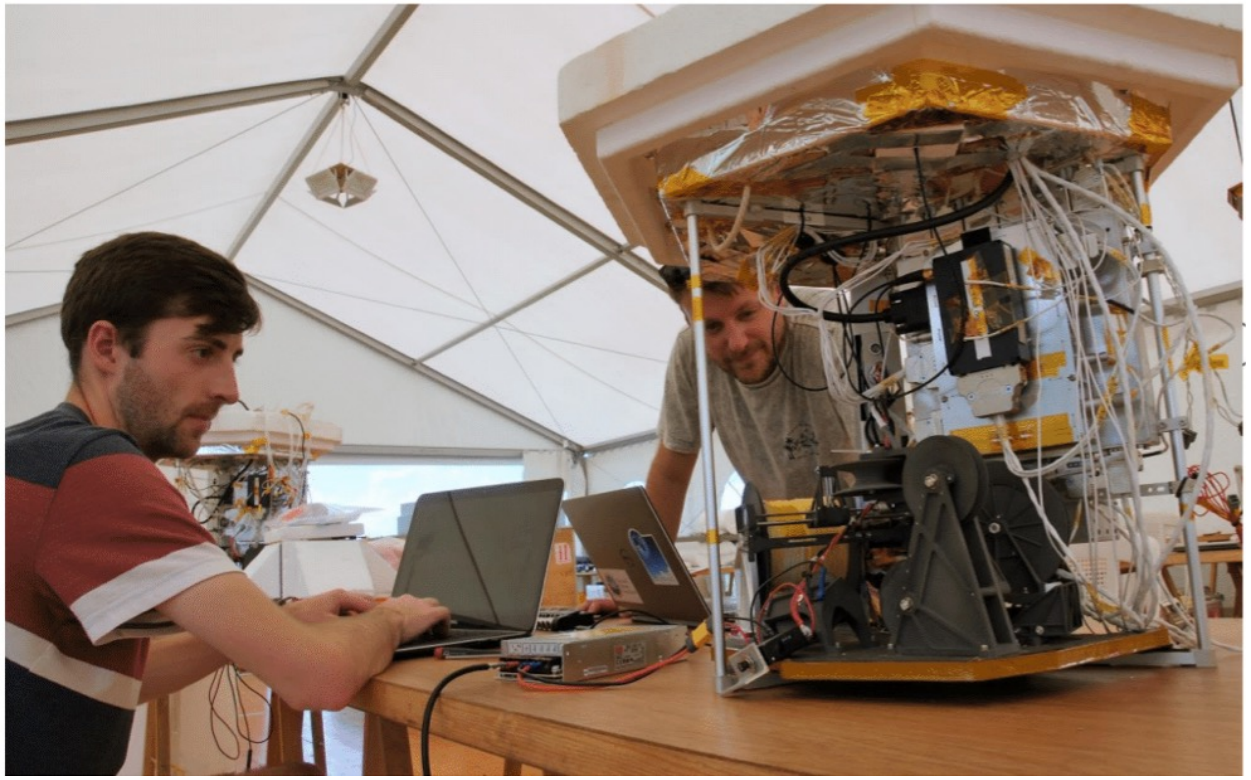
Strateole 2 - Complementary Observations



Kalnajs et al. 2021



Can combine for the first time balloon-borne profiling measurements with horizontal balloon wind and temperature observations.

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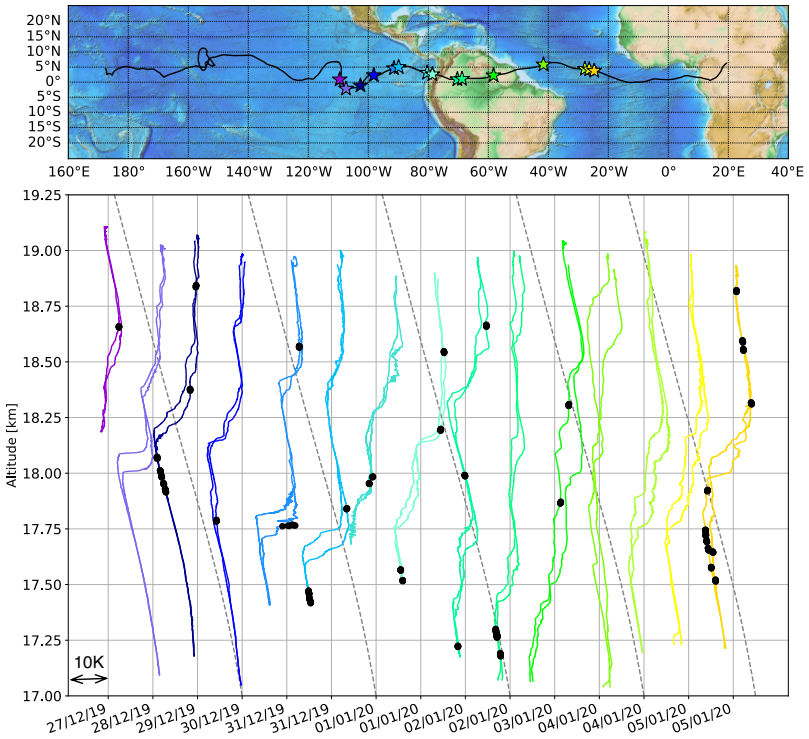
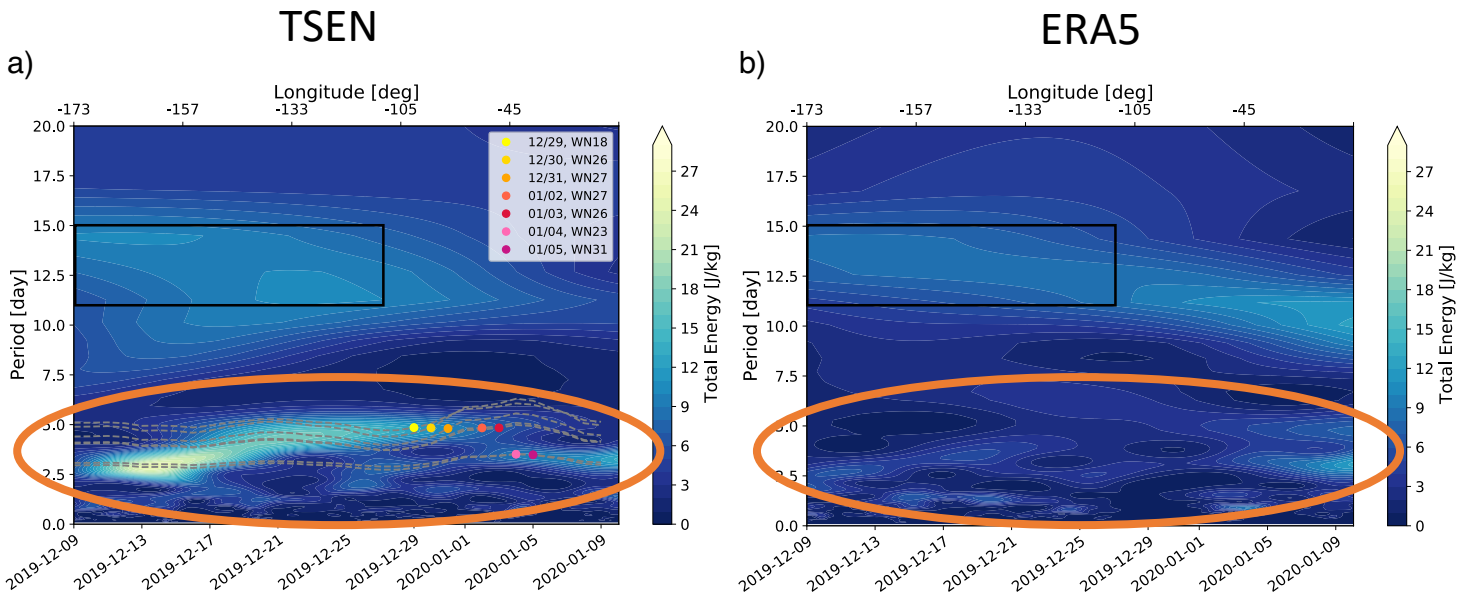
Strateole 2 - First Results (Bramberger et al. 2022)





- Analysis of fine-vertical scale waves that previously eluded observation and simulation in climate models and modern reanalyses
- In the observed period these waves:
  - Provided majority of forcing of QBO in lowermost stratosphere
  - Controlled relative humidity and subvisible cirrus clouds occurrence through their temperature variations

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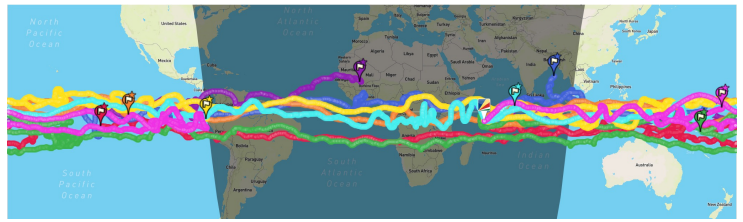
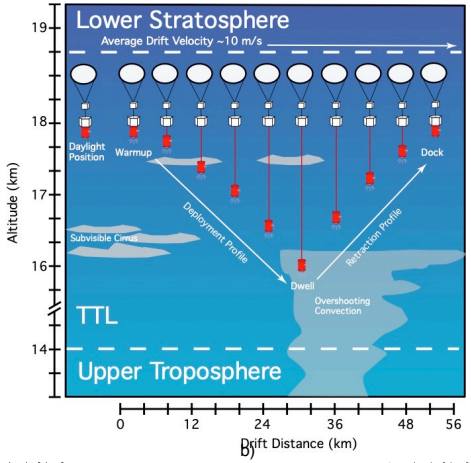
Strateole 2 - Summary

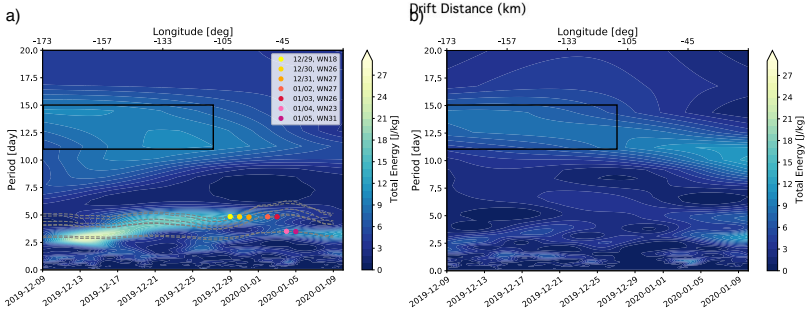
- Data around the Equator



- Combination of high-resolution horizontal in-situ observations with vertical profiling measurements
- Unprecedented number of high-resolution profiles in the lowermost stratosphere, directly above the cold point



- Observation of global scale wave, gravity wave, and water vapor processes that are poorly represented in current GCMs and cannot be observed with current satellite technology



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Strateole 2 - Outlook

New measurements:

- Third campaign with 24 balloons planned in 2024

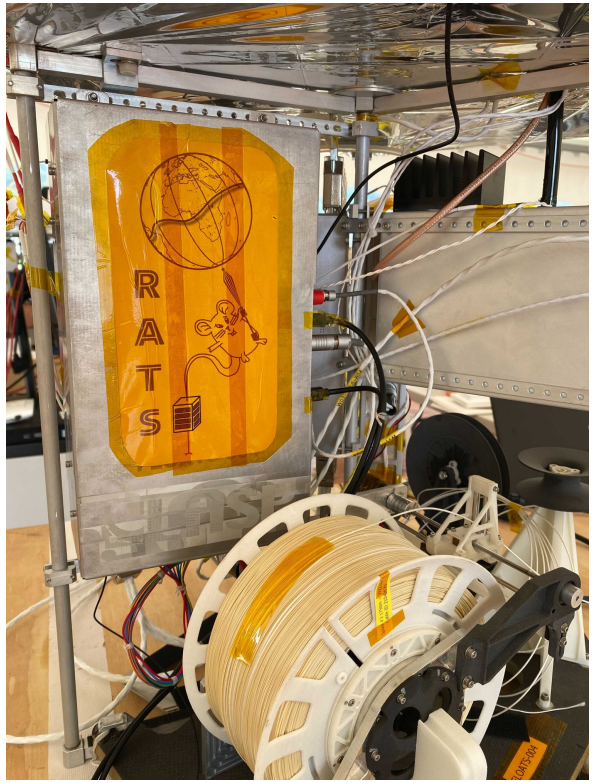
- New instruments:
  - dual-altitude temperature sensor (RATS)
  - Vertical Airspeed and Temperature Anemometer (VATA)

New analysis and applications:

- 3D wave analysis with balloon-borne radio-occultation measurements

- Development of new gravity wave parameterizations

- Improved QBO teleconnections in models



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