Around the World in 84 Days

In the Stratéole 2 program, set to launch in November 2018, instruments will ride balloons into the stratosphere and circle the world, observing properties of the air and winds in fine detail.

In preparation for the Stratéole 2 project, a collaboration between France and the United States, scientists launch a helium balloon near Mahé in the Seychelles islands in the Indian Ocean near the horn of Africa. Stratéole 2 balloons will circle Earth, near the equator, drifting with the wind as their instruments collect atmospheric measurements. Credit: Philippe Cocquerez, CNES

By Jennifer S. Haase, M. Joan Alexander, Albert Hertzog, Lars Kalnajs, Terry Deshler, Sean M. Davis, Riwal Plougonven, Philippe Cocquerez, and Stephanie Venel 1 March 2018

Jules Verne's adventure novels *Five Weeks in a Balloon* and *Around the World in 80 Days* highlighted some of the great technological advances of the late 19th century that revolutionized travel and captured the imagination of the public [*Verne,* 1863, 1873]. Among those inspired by the novels was Nellie Bly, an American journalist for the *New York World*, who set off in November 1889 to complete a journey by rail and steamship, following Verne's imagined path around the world in a record 72 days [*Bly,* 1890] (Figure 1).

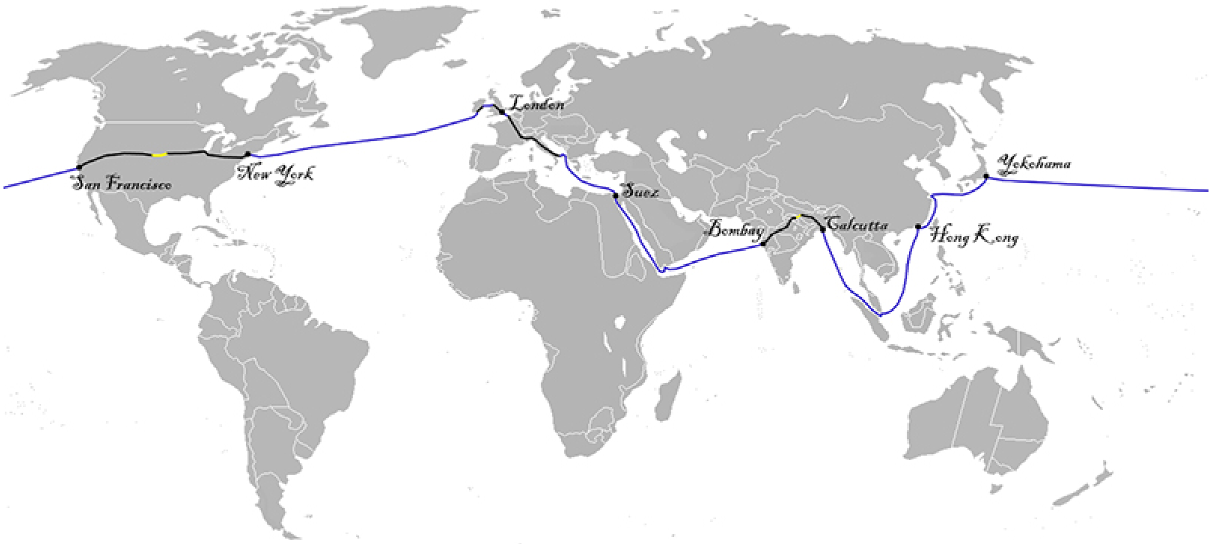


Fig. 1. In 1889–1890, real-life *New York World* reporter Nellie Bly completed Jules Verne's imagined path (shown here) around the world in slightly less than Verne's "80 days." Neither Bly's journey nor Verne's *Around the World in 80 Days* actually involved balloon travel, but Verne's book drew on his previous novel *Five Weeks in a Balloon*. The earlier novel inspired the idea of incorporating balloon travel for one leg of the trip in the 1956 movie *Around the World in 80 Days* that has become a beloved misconception about Verne's later book. Credit: Roke/Wikimedia Commons (https://commons.wikimedia.org/wiki/File:Around_the_World_in_Eighty_Days_map.png) CC BY-SA 3.0 (https://creativecommons.org/licenses/by-sa/3.0/legalcode)

Bly's accounts demonstrated how new technology, such as the transcountry railroads in the United States and India and the Suez Canal, brought exotic destinations within reach. The revolutionary development of submarine cables and the electric telegraph allowed Bly to keep her editors, and the larger connected world, aware of her progress in near-real time.

The France-U.S. collaborative Stratéole 2 project (http://www-das.uwyo.edu/~deshler/research/Strateole2/) is planning its own series of balloon trips, which will circle the world near the equator for 80 days (more or less), as did these fictional and factual 19th century adventurers, demonstrating new technology and sending new observations from the voyage back via satellite.

Drifting with the Winds

Scientists with the Stratéole 2 project will release superpressure balloons, designed to drift in the lower stratosphere, from the Seychelles islands in the Indian Ocean (Figure 2). Superpressure balloons contain a fixed amount of helium sealed inside an envelope that does not stretch. This type of balloon is not fully inflated when it is launched, but it expands to its full volume as it rises to an altitude where the gas density inside the balloon matches the density of the surrounding air and where it drifts with the wind.

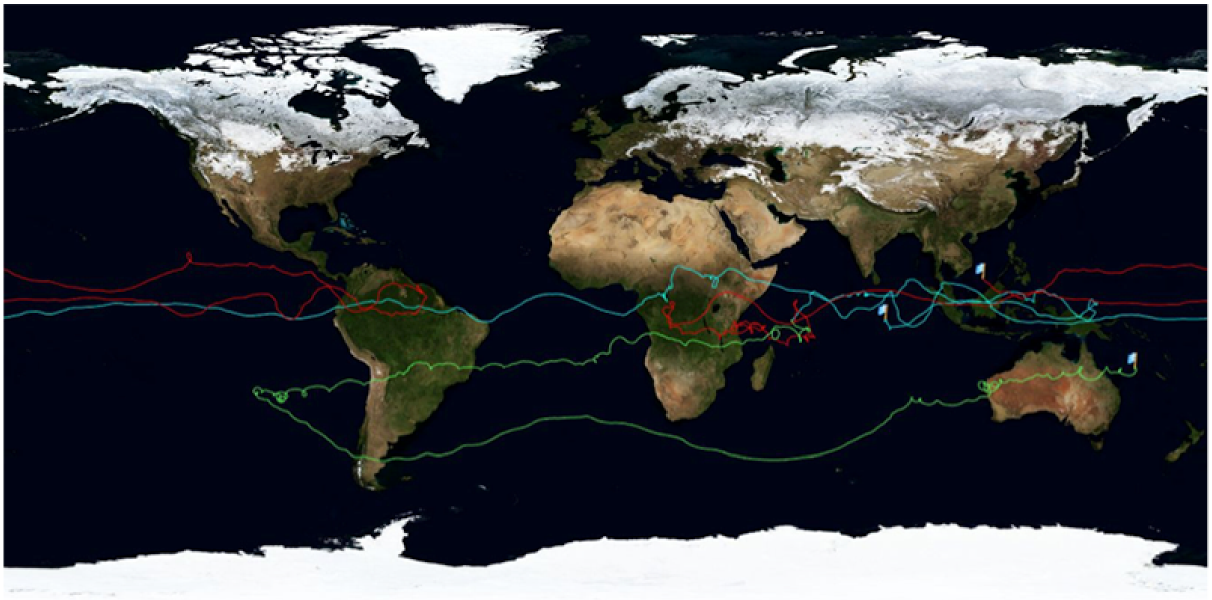
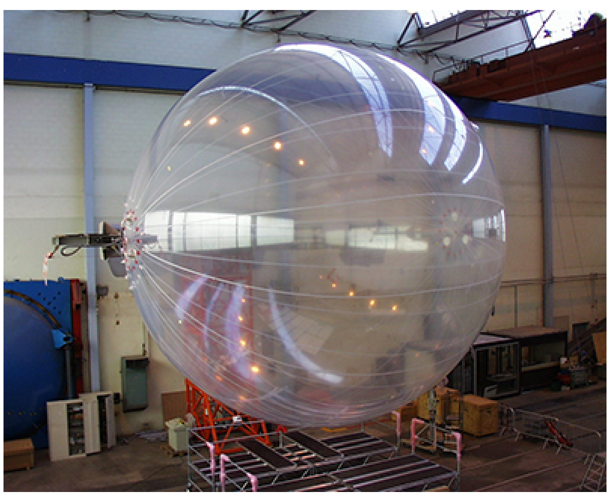


Fig. 2. Early test flights of the French National Center for Space Studies superpressure balloon system during February–May 2010 followed a tropical route. The flight durations of the three balloons were 92, 78, and (yes!) 80 days. The traces of the balloon paths show some wave structure, and the balloon paths reversed direction when the quasi-biennial oscillation, a periodic east–west oscillating feature in tropical lower stratospheric winds, changed phase. Credit: A. Hertzog

Each balloon will carry as many as four instruments. As they collect their high-accuracy measurements of meteorological variables, chemical tracers, clouds, and aerosols (https://eos.org/editors-vox/blowin-in-the-wind-observing-stratospheric-aerosols), their horizontal motions (http://journals.ametsoc.org/doi/full/10.1175/BAMS-D-14-00182.1) are nearly identical to those of the surrounding air mass. These measurements will advance our knowledge and understanding of cirrus clouds, aerosols, and equatorial waves in the tropical tropopause layer (TTL; the transition region between the troposphere and the stratosphere) and in the lower stratosphere.



Shown here is a fully inflated superpressure balloon in the lab at the French National Center for Space Studies (CNES). Credit: Philippe Cocquerez, CNES

The Stratéole 2 research program will begin with a five-balloon technology validation campaign in Northern Hemisphere (boreal) fall–winter 2018–2019, followed by 20 balloon flights in boreal fall–winter 2020–2021. In the second campaign, 10 balloons will fly at an altitude near 20 kilometers, just above the TTL, and another 10 will fly near 18 kilometers, within the TTL.

From past experience, we expect each balloon to fly for more than 2 months. Typically, a balloon will fly for about 84 days before chaotic atmospheric motions or interactions with Rossby waves (https://oceanservice.noaa.gov/facts/rossby-wave.html) push it outside of the deep tropics. A final 20-balloon campaign in 2023–2024 will drift in the opposite direction because of the shifting phase of the quasi-biennial oscillation (QBO (https://eos.org/meeting-reports/modeling-the-stratospheres-heartbeat)), a dominant, periodic east–west oscillating feature in tropical lower stratospheric winds.

Challenges Aloft

The Stratéole 2 campaign targets the TTL, the primary entry point for tropospheric air into the stratosphere. As air slowly ascends across the TTL, the coldest temperatures encountered at the cold point tropopause (CPT) freeze water vapor into ice crystals. The formation of ice crystals dehydrates the air and regulates the amount of humidity reaching the global stratosphere, giving the TTL an outsized importance considering its geographic extent.

The ice crystals form thin cirrus clouds, which have a global impact on the balance between incoming solar radiation and radiation reflected back into space at tropical latitudes. Water vapor and cirrus feedbacks are extremely important in climate system models.

The underlying processes that control the formation and sublimation (direct conversion of ice crystals to water vapor) of these clouds remain strongly debated. These processes involve the interplay of deep convection, microphysics, aerosols, wave-induced temperature variations (https://eos.org/research-spotlights/atmospheric-waves-help-cool-our-planet) with timescales ranging from minutes to weeks, and the balance of forces driving large-scale slow ascent of air in the tropics.

The superposition of wave-induced fluctuations on the average upwelling motion forces the temperatures in the TTL to extreme values at the CPT—less than −94°C at times and well below those expected from radiative equilibrium. These same waves also drive the QBO, which has an important long-range indirect influence on high-latitude seasonal forecasts. The waves, generated by convection below, transport momentum vertically across the TTL and drive QBO wind variations as the momentum dissipates in the stratosphere.

Satellite and in situ observations can track the wind reversals of the QBO, but most general circulation models cannot replicate the QBO using current methods. This shortcoming is due to a combination of inadequate spatial resolution and a lack of small-scale wave drag applied at the subgrid scale.

Even when models do simulate the QBO, doubts remain on the contribution from various families of waves with different scales and frequencies. As a result, even models that internally generate a QBO were unable to forecast the anomalous disruption of the oscillation that occurred in February 2016 [*Osprey et al.,* 2016].

Science Objectives

This superpressure balloon, shown here at launch, is not fully inflated. As it rises, the volume of helium sealed inside increases until the spherical balloon is fully inflated, giving the balloon a fixed density. Once the balloon has reached the atmospheric level where the air has the same density, it drifts with the wind, providing accurate wind measurements. Credit: Philippe Cocquerez, CNES

The overarching objectives of Stratéole 2 are to explore processes that control the transfer of trace gases and momentum between the equatorial upper troposphere and lower stratosphere. The instruments will provide fine-scale measurements of water vapor, temperature, and aerosol/ice at the balloon gondola and also within several kilometers below flight level, documenting air composition and investigating the formation of cirrus in the upper TTL.

The balloons also provide unique measurements of equatorial waves over the full spectrum from high-frequency buoyancy waves to planetary-scale equatorial waves, providing information needed to improve representation of these waves in climate models. Stratéole 2 balloons will sample the whole equatorial band from 20°S to 15°N, thus complementing the widespread (but limited-resolution) spaceborne observations and the high-resolution (but geographically restricted) airborne and ground-based measurements from previous field missions.

Past balloon campaign measurements sampling the Antarctic stratospheric vortex [see *Podglajen et al.,* 2016] have been used to make accurate estimates of wave momentum fluxes as well as to explain springtime stratospheric ozone loss rates; we expect similar successes with our current campaigns.

Stratéole 2 balloon flights will collect measurements over oceanic areas that are otherwise devoid of any stratospheric wind measurements. Other Stratéole 2 science objectives include contributions to operational meteorology and satellite validation. Wind analyses and forecasts have notably large errors in the tropics because sparse tropical wind measurements cannot be modeled in a straightforward way through their dynamical relation to temperature, as they are at higher latitudes. Thus, reducing these errors requires a higher density of measurements. Stratéole 2 balloon flights will address this data shortage by providing unprecedented, accurate wind observations in the equatorial regions of the upper troposphere and lower stratosphere. In particular, the project will collect measurements over oceanic areas that are otherwise devoid of any stratospheric wind measurements.

The data will also contribute to the validation of Atmospheric Dynamics Mission Aeolus (ADM-Aeolus) wind products. An innovative European Space Agency mission, ADM-Aeolus, due to be launched in September 2018, is designed to perform the first spaceborne wind lidar measurements, providing unprecedented global coverage.

The ensemble of Stratéole 2 instrumentation (http://www.lmd.polytechnique.fr/VORCORE/st2_instruments.htm) includes in situ measurements of pressure, temperature, and winds every 30 seconds and less frequently sampled observations of ozone, aerosols, water vapor, and carbon dioxide, plus remotely sensed cloud structure from microlidar and directional radiative fluxes. Instruments providing profiles will include GPS radio occultation (http://www.cosmic.ucar.edu/ro.html) receivers that measure (https://news.agu.org/press-release/new-airborne-gps-technology-for-weather-conditions-takes-flight/) temperature profiles to the side of the balloons. Novel reel-down devices suspended as far as 2 kilometers directly below the balloons will also provide profiles to explore the fine-scale distribution of temperature, aerosol/ice, and humidity.

Capturing temperature variations in high-resolution profiles, in particular, from the unique balloon platform, is an approach that will provide new insight into equatorial wave processes. Measuring ozone in combination with water vapor and carbon dioxide enables us to discover correlations among these tracers that describe transport processes at the top of the TTL, including convective overshoots that rapidly transport air from the surface into the TTL.

Data Dissemination

Within 12 months of the end of each balloon campaign, the Stratéole 2 data set will be freely available to the scientific community.
The Stratéole 2 data policy is in compliance with World Meteorological Organization (WMO) Resolution 40 (WMO Cg-XII (https://public.wmo.int/en/our-mandate/what-we-do/data-exchange-and-technology-transfer)) on the policy and practice for the exchange of meteorological and related data and products. Within 12 months of the end of each balloon campaign, the Stratéole 2 data set will be freely available to the scientific community through the Stratéole 2 Data Archive Center (S2DAC), which is scheduled to launch its website in July 2018. S2DAC will collect and make available the balloon observations and associated ground-based and satellite data, reanalyses, and model outputs. The S2DAC includes a primary, full repository at the Dynamic Meteorology Laboratory (LMD) in France and a secondary mirror site at the Laboratory for Atmospheric and Space Physics (LASP) in Boulder, Colo., in the United States.

In addition, during the balloon campaigns, a subset of the Stratéole 2 data set, specifically flight-level winds, will be disseminated on the Global Telecommunication System (http://www.wmo.int/pages/prog/www/TEM/GTS/index_en.html) for their assimilation in numerical weather prediction systems. We invite and encourage the use of Stratéole 2 data by the broader scientific community, and potential users can watch for future campaign updates on the project website (http://www-das.uwyo.edu/~deshler/research/Strateole2/).

Up, Up, and Away

In the spirit of Verne's imagined use of new technologies and Bly's real-world application of those technologies to explore the world, the Stratéole 2 campaign will scientifically explore the tropical tropopause and lower stratosphere from a long-duration superpressure balloon platform. The use of multiple balloons will permit extensive exploration of the finely layered features and unique processes occurring in this remote part of the atmosphere. With the involvement of the broader scientific community, analyses of the Stratéole 2 measurements hold promise to provide a new and deeper understanding of these processes and the connections of this region to global chemistry, dynamics, and climate variability.

Acknowledgments

Major funding for the Stratéole 2 campaign is provided by France's National Center for Space Studies (CNES) and National Center for Scientific Research (CNRS), as well as the U.S. National Science Foundation (NSF).

References

Bly, N. (1890), ***Nellie Bly's Book: Around the World in Seventy-Two Days***, Pictorial Weeklies, New York.

Osprey, S. M., et al. (2016), An unexpected disruption in the atmospheric quasi-biennial oscillation, ***Science, 353***(6306), 1424–1427, https://doi.org/10.1126/science.aah4156 (https://doi.org/10.1126/science.aah4156).

Podglajen, A., et al. (2016), Lagrangian temperature and vertical velocity fluctuations due to gravity waves in the lower stratosphere, ***Geophys. Res. Lett., 43***(7), 3543–3553, https://doi.org/10.1002/2016GL068148 (https://doi.org/10.1002/2016GL068148).

Verne, J. (1863), ***Cinq Semaines en Ballon,*** Pierre-Jules Hetzel, Paris.

Verne, J. (1873), ***Le Tour du Monde en Quatre-Vingts Jours,*** Pierre-Jules Hetzel, Paris.

Author Information

Jennifer S. Haase (email: jhaase@ucsd.edu (mailto:jhaase@ucsd.edu)), Institute of Geophysics and Planetary Physics, Scripps Institution of Oceanography, University of California, San Diego, La Jolla; M. Joan Alexander, NorthWest Research Associates, Boulder, Colo.; Albert Hertzog, Laboratoire de Météorologie Dynamique (LMD), École Polytechnique, Palaiseau, France; Lars Kalnajs and Terry Deshler, Laboratory for Atmospheric and Space Physics, University of Colorado Boulder; Sean M. Davis, NOAA Earth System Research Laboratory (ESRL), Boulder, Colo.; also at Cooperative Institute for Research in Environmental Sciences, University of Colorado Boulder; Riwal Plougonven, LMD, École Polytechnique, Palaiseau, France; and Philippe Cocquerez and Stephanie Venel, Centre National d'Etudes Spatiales, Toulouse, France

Citation: Haase, J. S., M. J. Alexander, A. Hertzog, L. Kalnajs, T. Deshler, S. M. Davis, R. Plougonven, P. Cocquerez, and S. Venel (2018), Around the world in 84 days, *Eos, 99,* https://doi.org/10.1029/2018EO091907. Published on 01 March 2018.