Autonomous, Persistent Meteorological Observation Networks using Fleets of High Altitude Platforms

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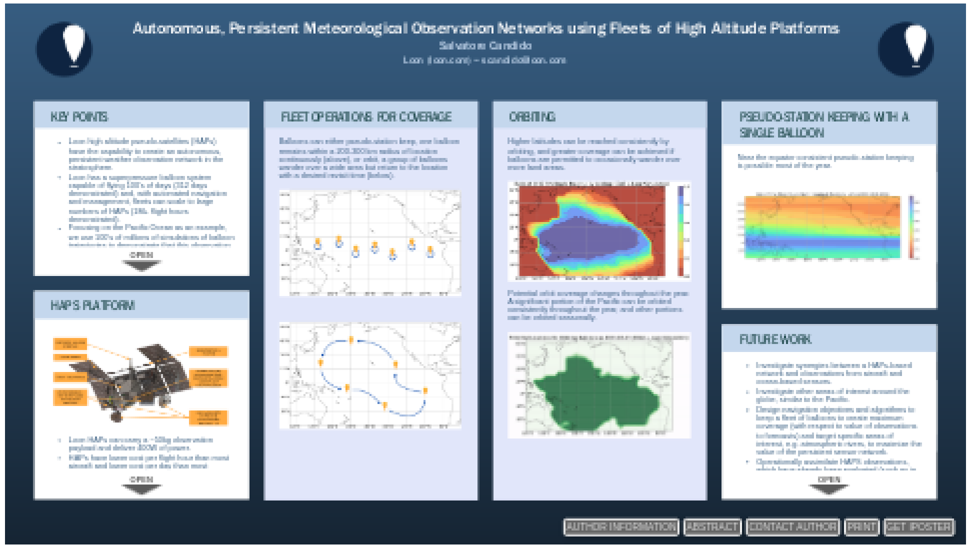
Abstract

High altitude platforms (HAPs) such as stratospheric balloons and eventually other high altitude, long endurance unmanned vehicles have reached a stage where it is possible to deploy a persistent fleet of aircraft acting as a meteorological observation network for a reasonable cost. Whether directly collecting in situ measurements like winds aloft or via dropsondes or performing remote sensing using, for example, radar or GPS radio occultation, these observation networks can collect measurements which are hard to obtain from other observation platforms and are complementary to other systems. They are also highly autonomous and can be deployed worldwide (and thus can add redundancy to the global forecast system). Because they are mobile, the observation network can be adjusted to collect in situ measurements in the places that are most important to forecasters and scientists. We use simulation of fleets of stratospheric balloons that are navigated by machine learning algorithms that actuate an altitude control system to demonstrate some of the potential constellations that are achievable with HAPs and motivate the greater consideration of an autonomous, persistent HAPs-based meteorological observing network.

Autonomous, Persistent Meteorological Observation Networks using Fleets of High Altitude Platforms



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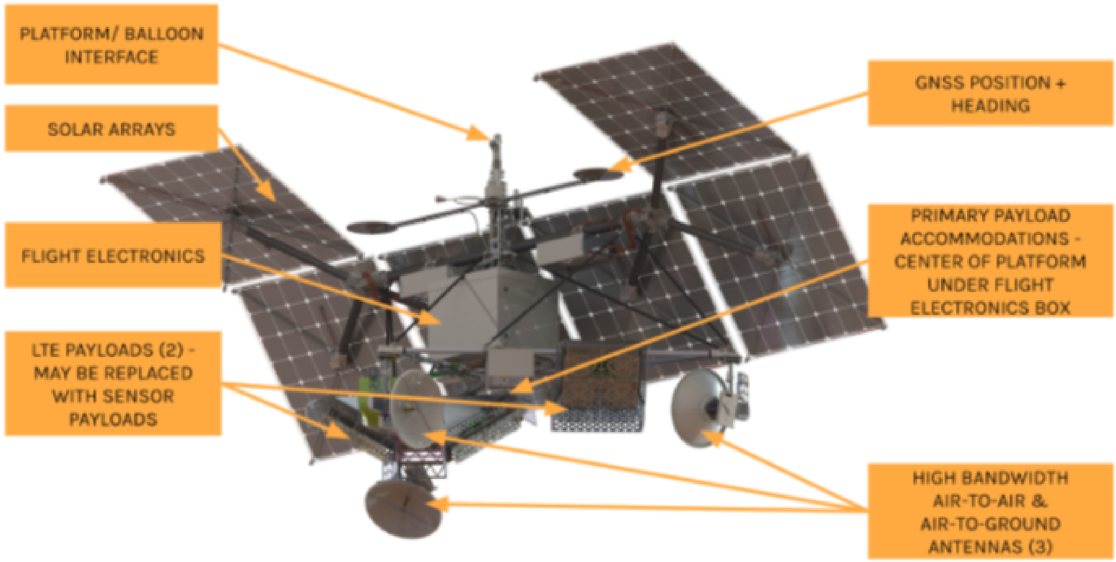
PRESENTED AT:

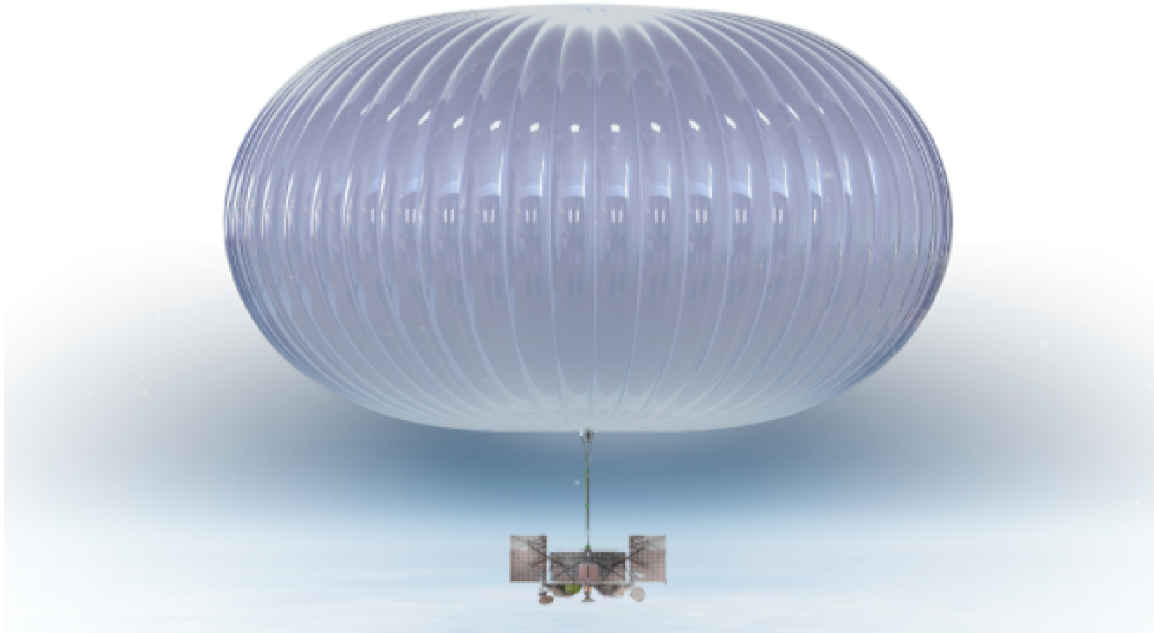
KEY POINTS

- Loon high altitude pseudo-satellites (HAPs) have the capability to create an autonomous, persistent weather observation network in the stratosphere.
- Loon has a superpressure balloon system capable of flying 100’s of days (312 days demonstrated) and, with automated navigation and management, fleets can scale to large numbers of HAPs (1M+ flight hours demonstrated).
- Focusing on the Pacific Ocean as an example, we use 100's of millions of simulations of balloon trajectories to demonstrate that this observation network can persist across a significant portion of the Pacific Ocean and keep the fleet confined to those areas.
- This indicates a practical and sustainable concept of operations is available to use HAPs to augment existing satellite, airborne, and ocean observations.

HAPS PLATFORM

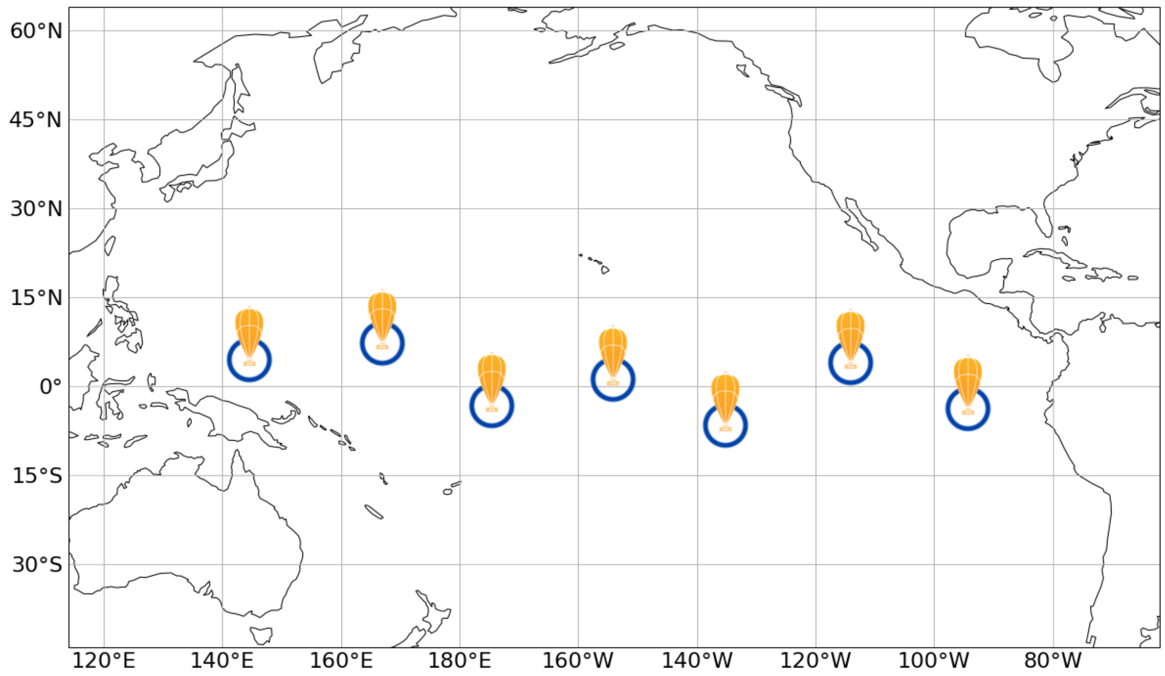


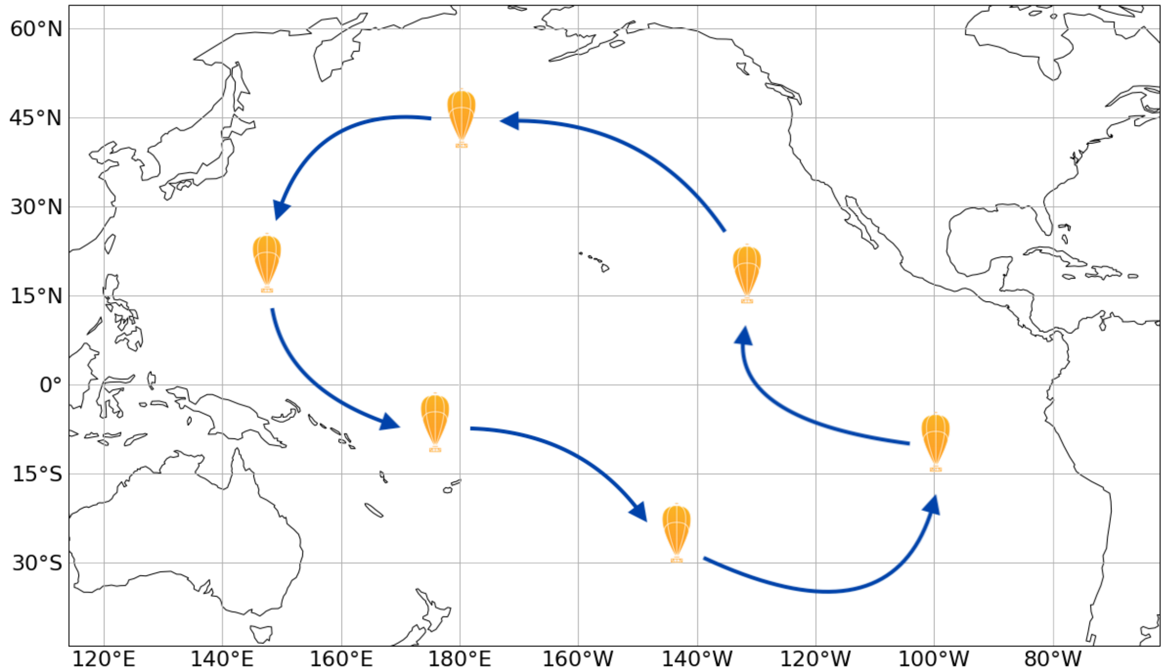
- Loon HAPs can carry a ~50kg observation payload and deliver 400W of power.
- HAPs have lower cost per flight hour than most aircraft and lower cost per day than most satellites.
- HAPs can persist for 100's of days in locations that are conventionally difficult to observe.
- HAPS can be deployed in a scalable fashion to cover seasonal and/or regional phenomena (e.g. hurricane season).
- HAPS can be maintained within a specified geographic region to provide increased temporal and spatial density of observations.
- Observations include in situ winds (demonstrated), temperature and pressure (demonstrated), GNSS-RO (demonstrated), downward facing remote sensor, e.g., radar, or dropsondes. (Non-exhaustive.)



FLEET OPERATIONS FOR COVERAGE

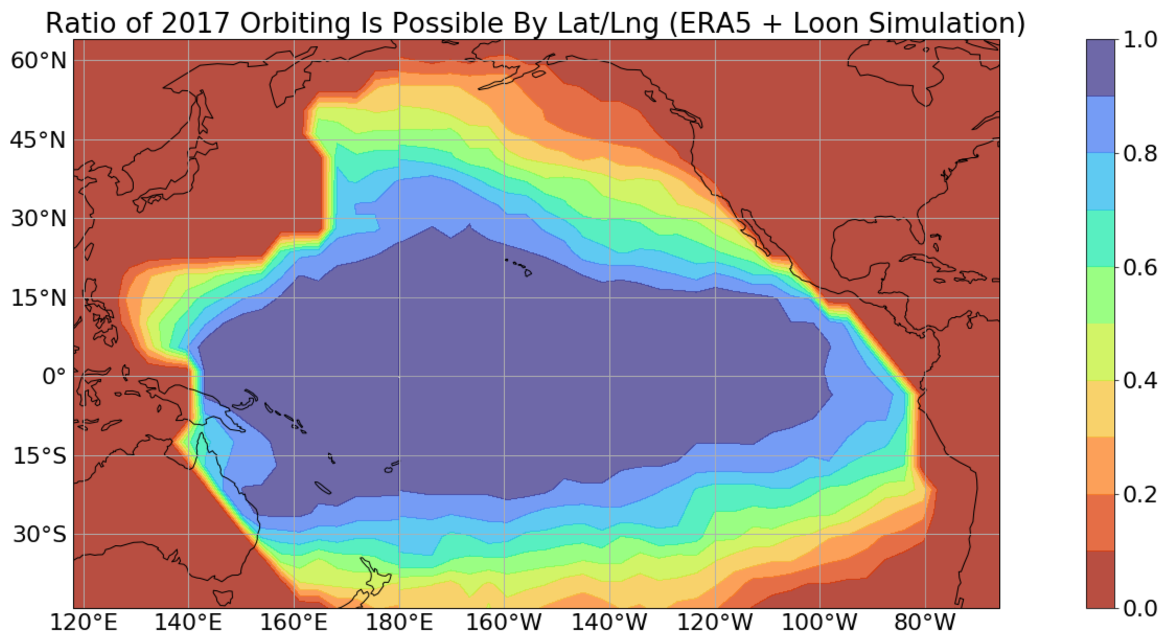
Balloons can either pseudo-station keep, one balloon remains within a 200-300 km radius of location continuously (above), or orbit, a group of balloons wander over a wide area but return to the location with a desired revisit time (below).



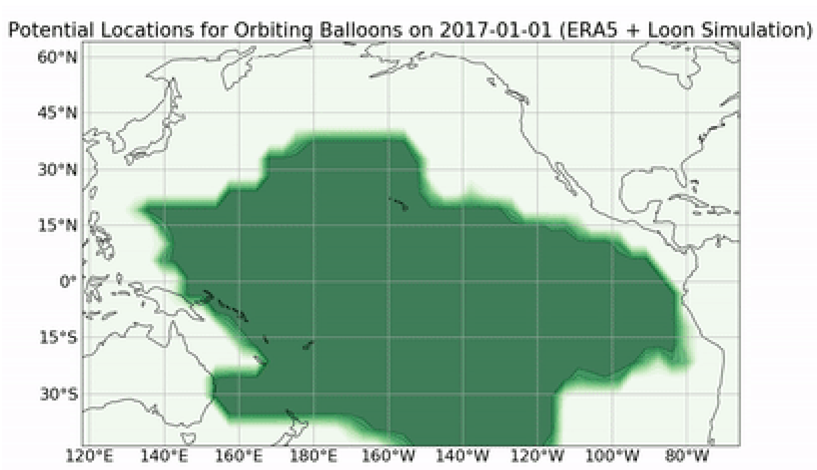

60°N
45°N
30°N
15°N
0°
15°S
30°S
120°E
140°E
160°E
180°E
160°W
140°W
120°W
100°W
80°W

ORBITING

Higher latitudes can be reached consistently by orbiting, and greater coverage can be achieved if balloons are permitted to occasionally wander over more land areas.

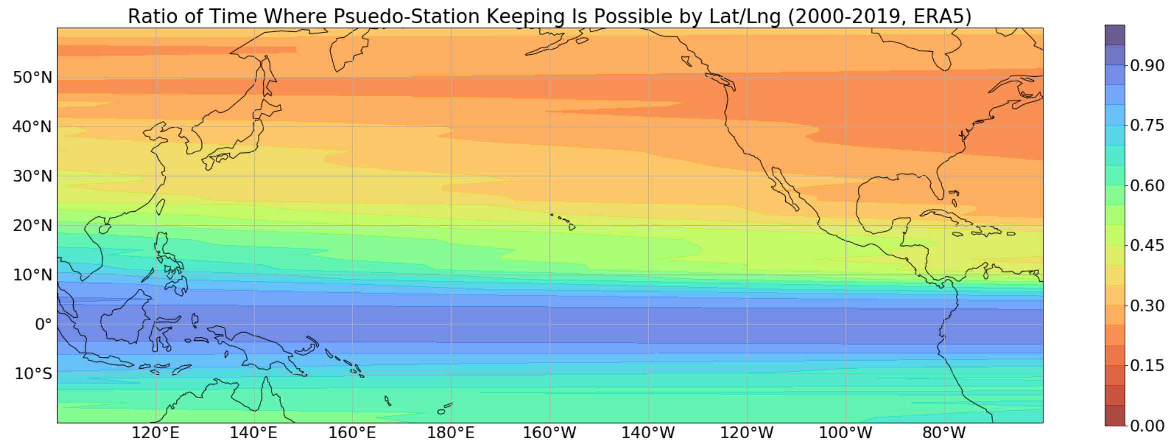


Potential orbit coverage changes throughout the year. A significant portion of the Pacific can be orbited consistently throughout the year, and other portions can be orbited seasonally.



PSEUDO-STATION KEEPING WITH A SINGLE BALLOON

Near the equator consistent pseudo-station keeping is possible most of the year.



FUTURE WORK

- Investigate synergies between a HAPs-based network and observations from aircraft and ocean-based sensors.
- Investigate other areas of interest around the globe, similar to the Pacific.
- Design navigation objectives and algorithms to keep a fleet of balloons to create maximum coverage (with respect to value of observations to forecasts) and target specific areas of interest, e.g. atmospheric rivers, to maximize the value of the persistent sensor network.
- Operationally assimilate HAPS observations, which have already been evaluated (such as in-situ stratospheric winds), into global models.
- Evaluate other HAPS observations (such as GNSS RO) further through pilot programs.

AUTHOR INFORMATION

Salvatore Candido is the Chief Technology Officer for Loon. (www.loon.com)

ABSTRACT

High altitude platforms (HAPs) such as stratospheric balloons and eventually other high altitude, long endurance unmanned vehicles have reached a stage where it is possible to deploy a persistent fleet of aircraft acting as a meteorological observation network for a reasonable cost. Whether directly collecting in situ measurements like winds aloft or via dropsondes or performing remote sensing using, for example, radar or GPS radio occultation, these observation networks can collect measurements which are hard to obtain from other observation platforms and are complementary to other systems. They are also highly autonomous and can be deployed worldwide (and thus can add redundancy to the global forecast system). Because they are mobile, the observation network can be adjusted to collect in situ measurements in the places that are most important to forecasters and scientists. We use simulation of fleets of stratospheric balloons that are navigated by machine learning algorithms that actuate an altitude control system to demonstrate some of the potential constellations that are achievable with HAPs, taking the Pacific Ocean as an example, and motivate the greater consideration of an autonomous, persistent HAPs-based meteorological observing network.