A13M-08: Global assimilation of X Project Loon stratospheric balloon observations

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Question: Is the current conventional and satellite observation network sufficient to characterize the winds in the lower stratosphere?

In this presentation, we add independent wind observations derived from constant pressure balloons to a state-of-the-art data assimilation system and evaluate improvements (if any) to forecasts and analyses.

Project Loon

Project Loon is a network of stratospheric balloons, designed to extend Internet connectivity to people in rural and remote areas worldwide.

Goal: launch and maintain a fleet of balloons to provide Internet coverage to users on the ground.
Autolaunchers: capable of safely and consistently launching a new balloon every 30 minutes.
Status: over 25 million km of test flights since the project began.
Duration: up to 190 days in the stratosphere.

Connection

High speed internet: transmitted up to the nearest balloon from a telecommunications partner on the ground, relayed across the balloon network, and then back down to users on the ground.
Status: demonstrated data transmission between balloons over 100 km apart in the stratosphere and back to the ground with connection speeds of up to 10 Mbps, directly to LTE phones.

Project Loon

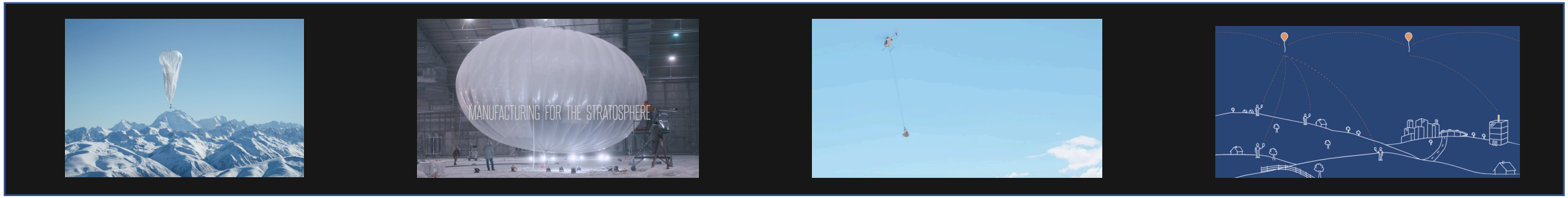
Navigating

Power: Solar panels for day with re-chargeable battery for night.
Tracking: GPS
Altitude: approximately 20 km (60-50 hPa)
Altitude Adjustment: capability to move each balloon up or down into different winds enabling the balloons to provide coverage where it's needed.

Recovery

Coordination: with the local air traffic control to bring balloons to ground in sparsely populated areas.
Descent: parachute
Cleanup: equipment collected for reuse and recycling.

https://x.company/loon/



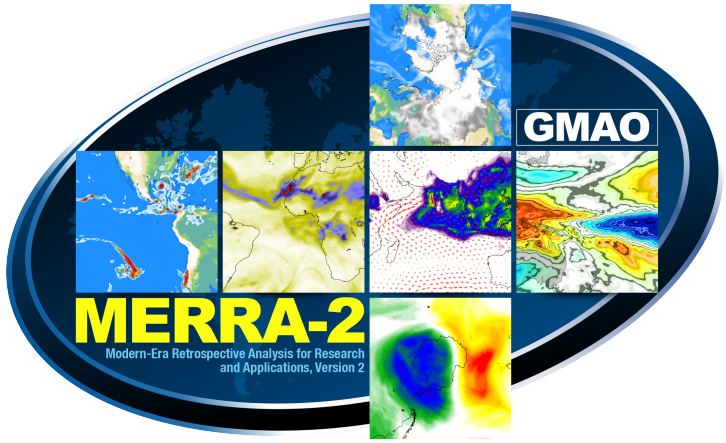
Data Assimilation

NASA MERRA-2 Data Assimilation System (DAS)

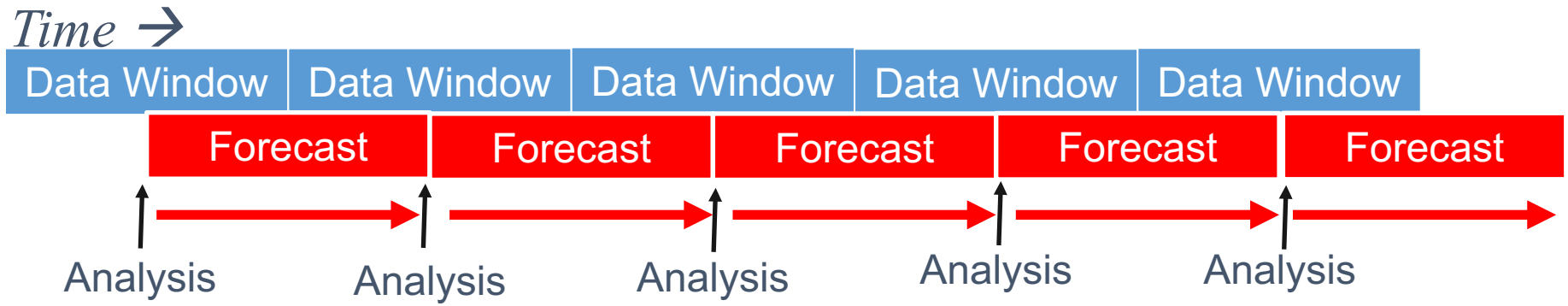
Data Assimilation Combines:

1) a **global forecast model** with
2) **observations**

to produce the analysis, a complete representation of the global atmosphere at a given time.



MERRA-2 DAS cycles with a **six-hour data window**, collecting all the observations (~ 5 million, including satellite based radiances and cloud tracked winds, rawindsondes, aircraft, etc.) within six hours of the analysis time.



Methodology

We ran **two data assimilation system (DAS) experiments**, identical, except that one includes the Loon observations and the other does not. Having these two runs, "**without Loon**" and "**with Loon**", and differencing output, we can assess the changes.

Time Period: June, July, August 2014
This test assimilation period was chosen because there were a large number of Southern Hemisphere Loon launches during this time.

Control (without Loon winds)

Full DAS but does not include the Loon observations in the analysis. Winds are interpolated to Loon balloon locations for comparison.

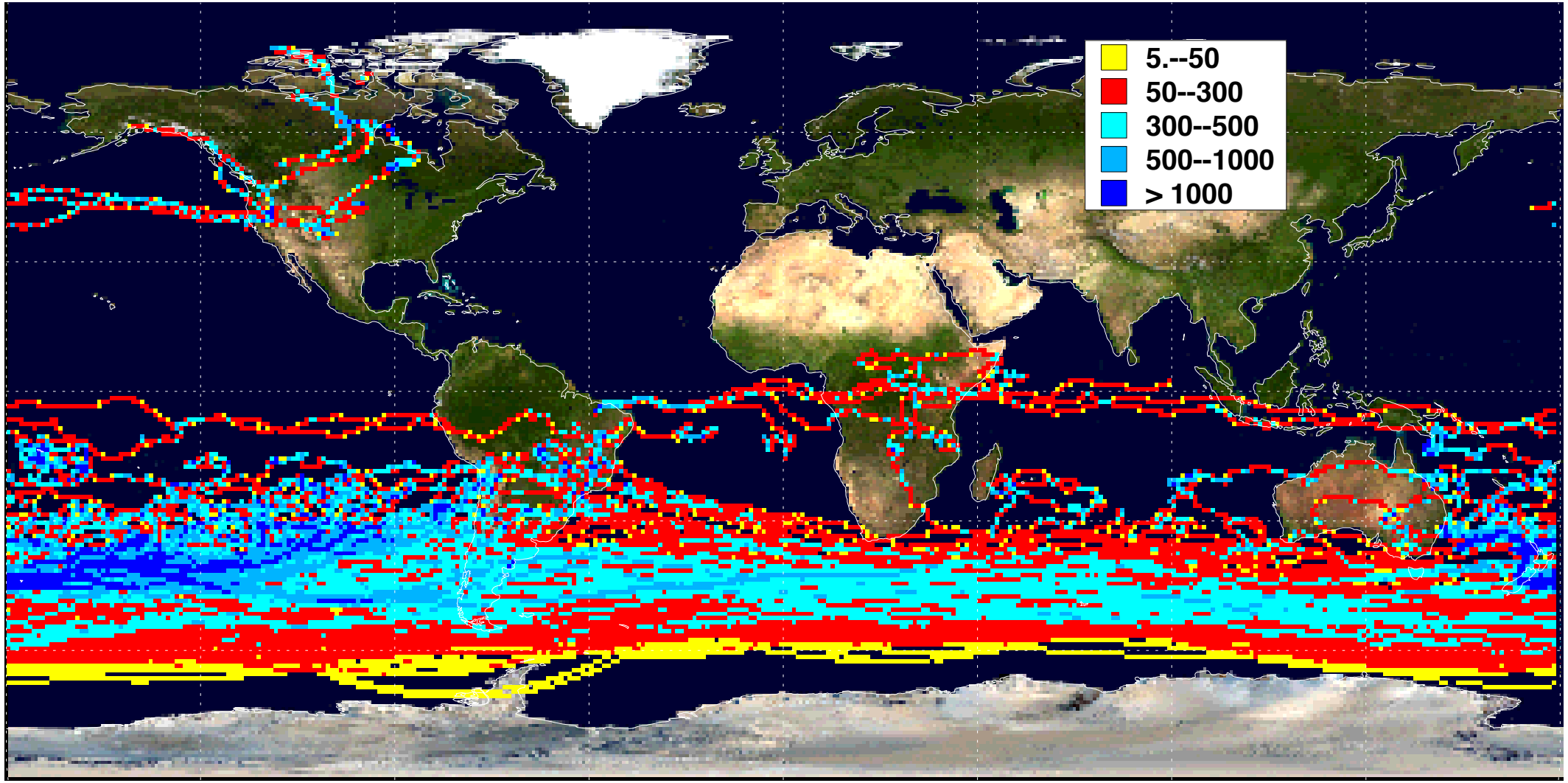
Loon Experiment (with Loon winds)

Full DAS incorporating the Loon observations in the analysis. Loon winds are treated as conventional rawinsonde winds. Winds are interpolated to Loon balloon locations for comparison.

Using the DAS Interpolation enables a consistent comparison of the Control assimilation winds with the balloon observations.

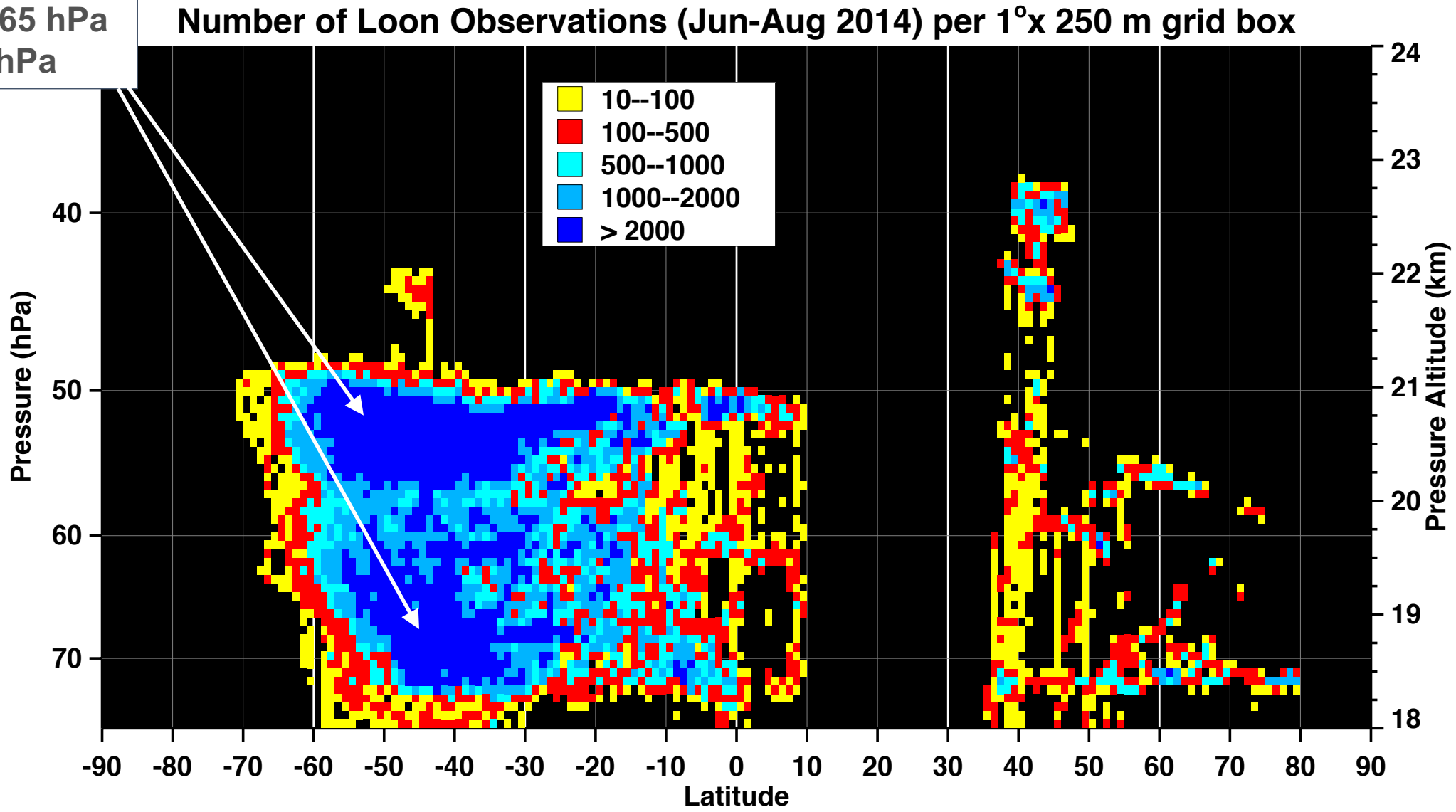
Longitude Latitude Distribution

Number of Loon Observations (Jun-Aug 2014) per 1°x1° grid box



Latitude Altitude Loon Balloon Distribution

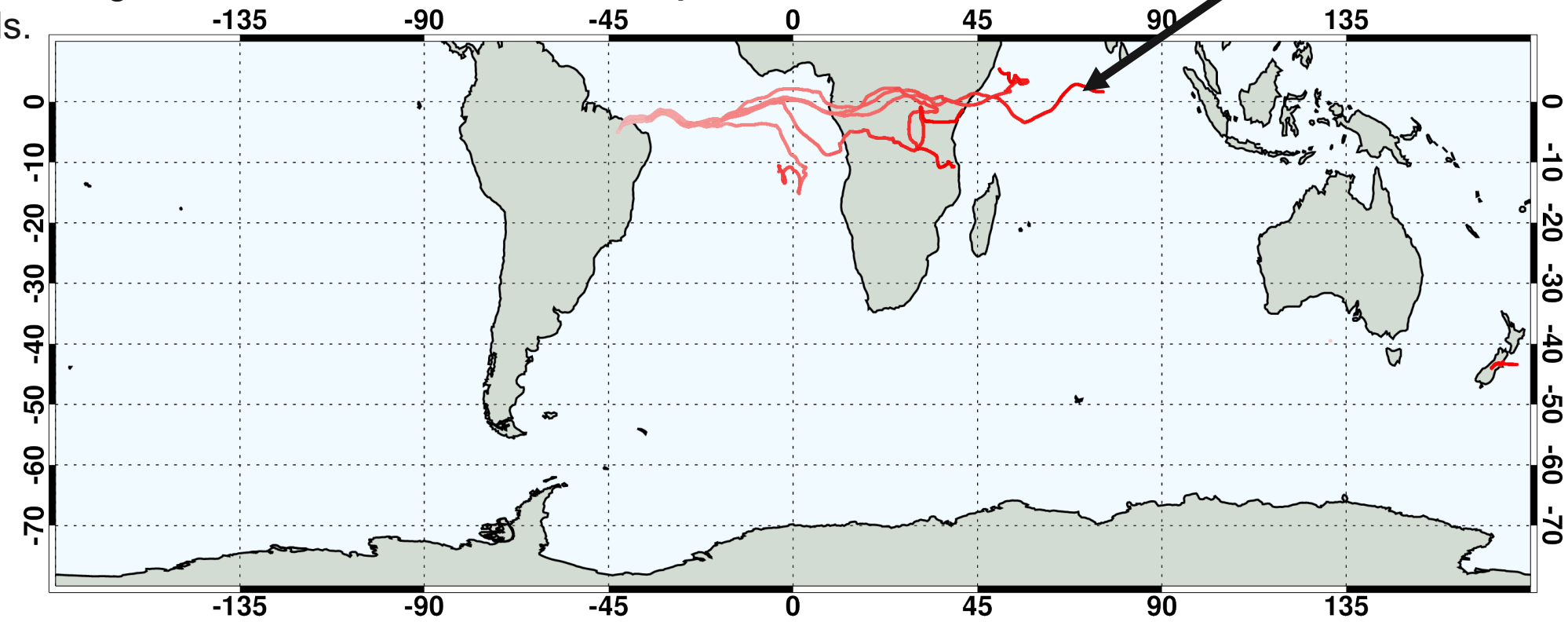
Loon pressures peak at **65 hPa and 55 hPa**



Tropical Loon Trajectories (14 Days)

Tropical observations provided some of the largest DAS adjustments when assimilating the Loon winds.

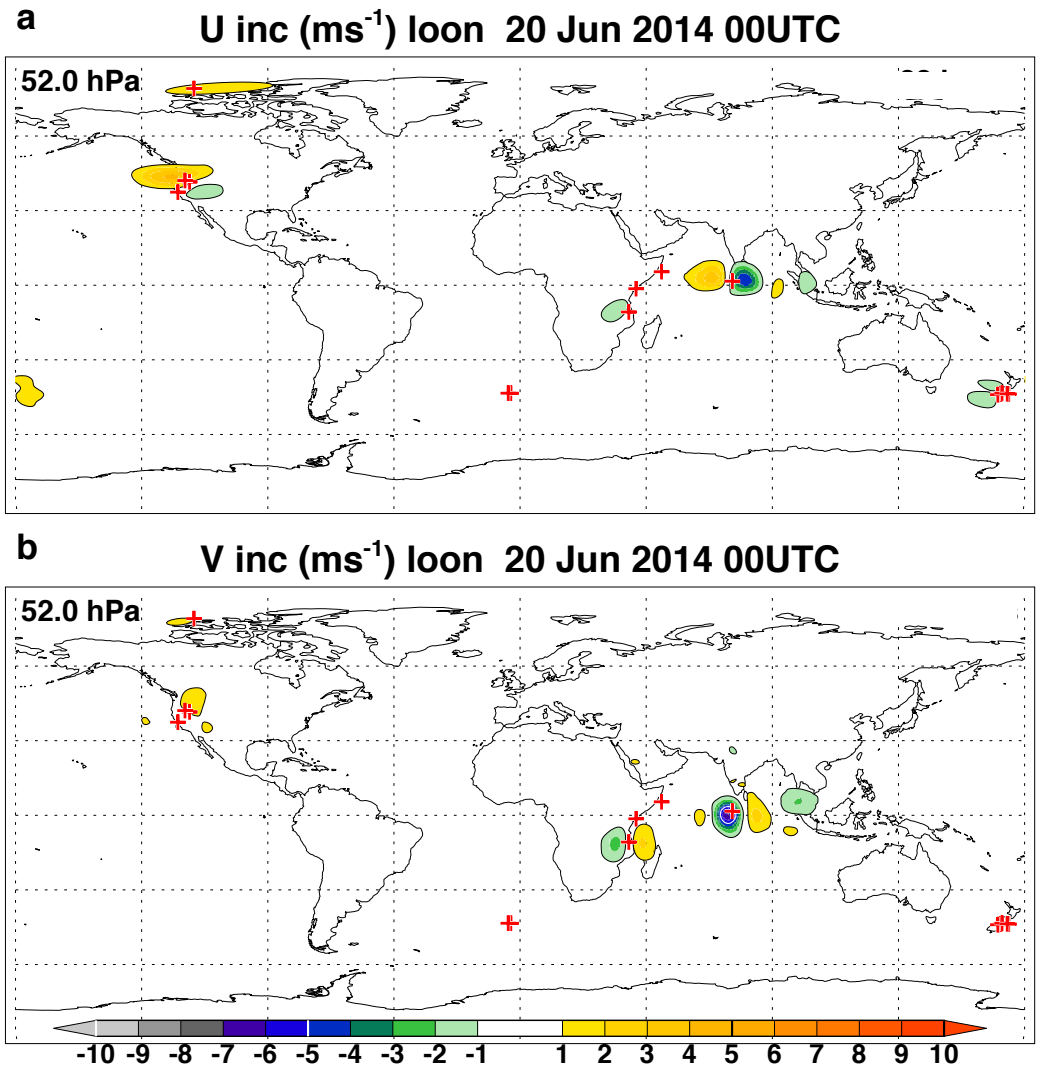
This Loon trajectory will be examined in more detail later.



Tropical Coverage in June 2014

Light Red: trajectory start
Dark Red: trajectory end

Sample Analysis Wind Increments

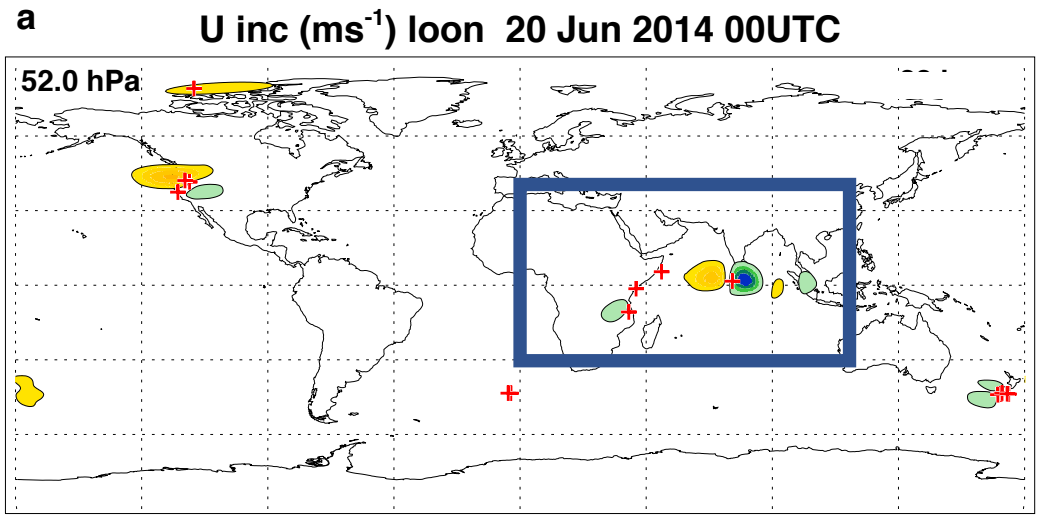


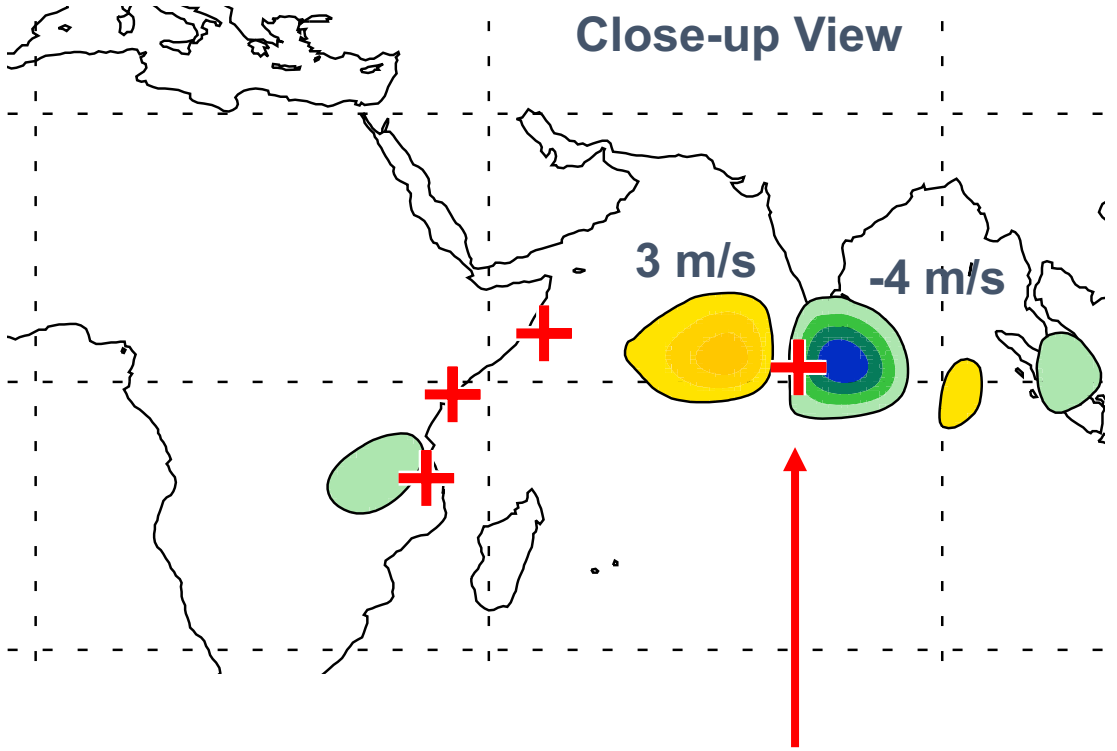
Example of the data assimilation wind increments. The **assimilation increment** fields are the **difference between** the background **forecast** and the current **analysis. Loon locations are indicated as red +.**

The contoured field is the **difference between the Loon Experiment and the Control**, so that only the effects of the Loon data assimilation are seen in the analysis increment differences.

Data assimilation spreads the point observations in the horizontal and vertical domains.

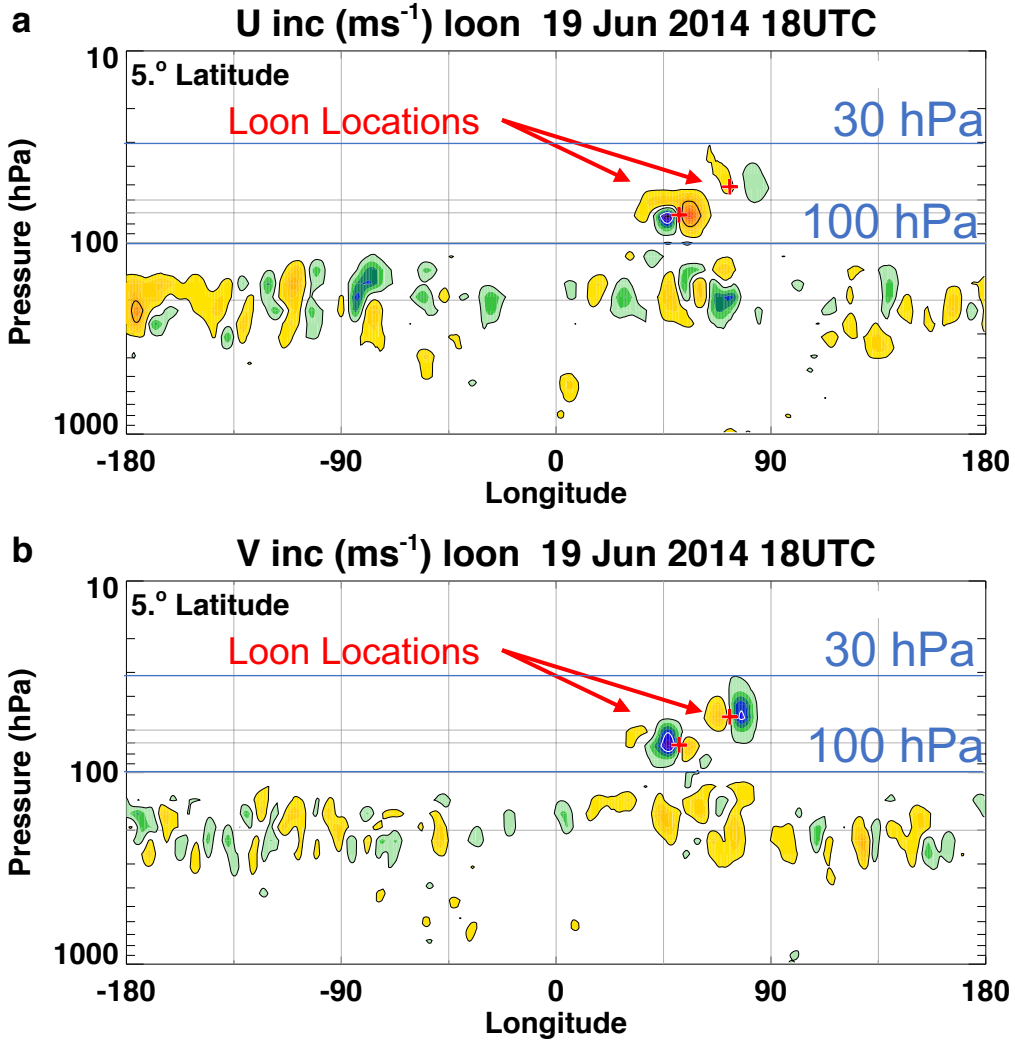
Sample Analysis Wind Increments





This shows how far the zone of influence can extend from the assimilation of the Loon wind observation.

Sample Analysis Wind Increments (Vertical Structure)



Example of the data assimilation wind increments. The **assimilation increment** fields are the **difference between** the background **forecast** and the current **analysis. Loon locations are indicated as red +.**

The contoured field is the **difference between the Loon Experiment and the Control**, so that only the effects of the Loon data assimilation are seen in the analysis increment differences.

The **vertical influence** is typically located between **100 and 30 hPa.**

Tropical Launch June 2014

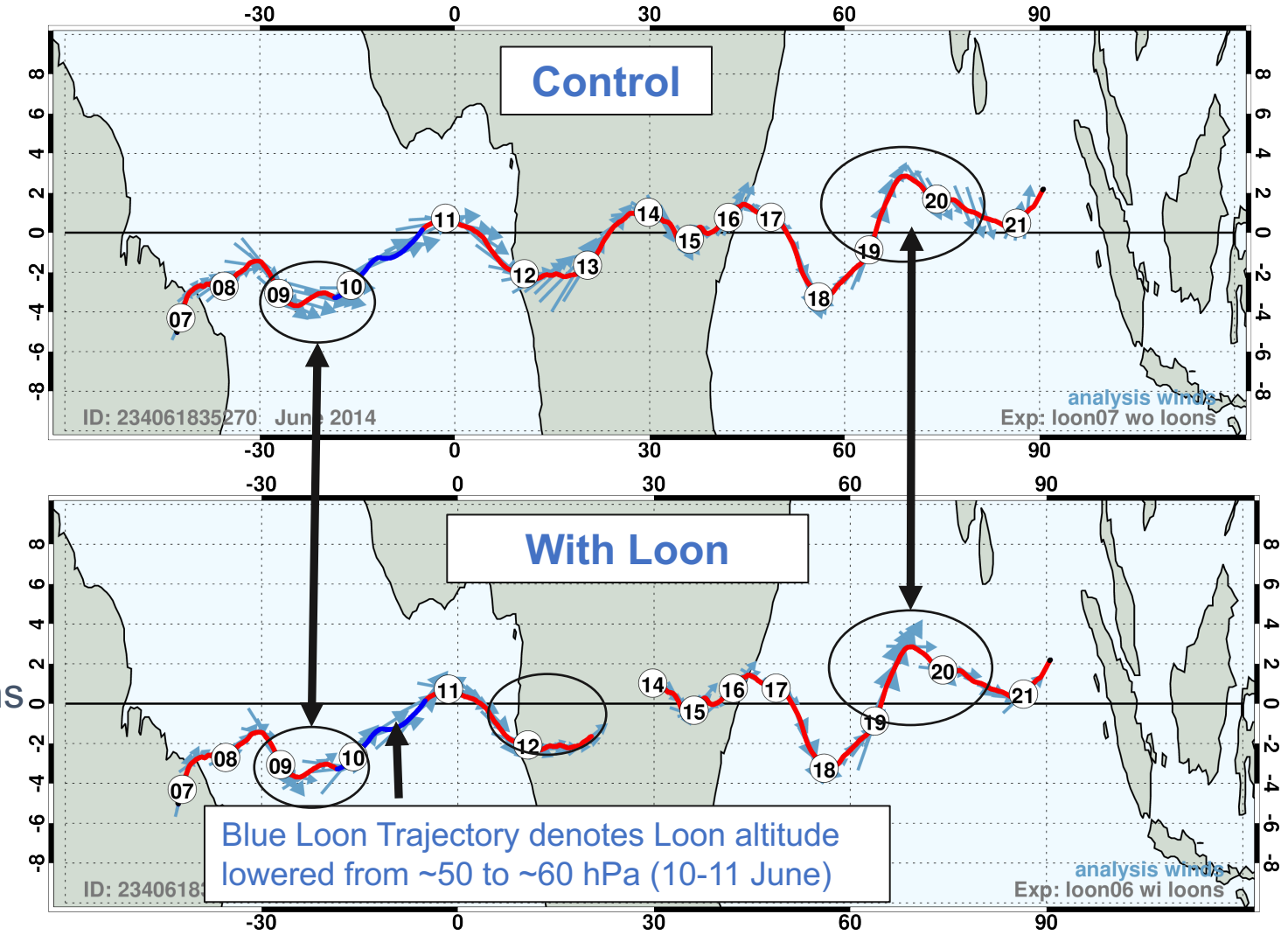
Detail about one balloon launched from Brazil on 6 June 2014

Red Curve: Balloon Trajectory

Blue Arrows: Analyzed Winds

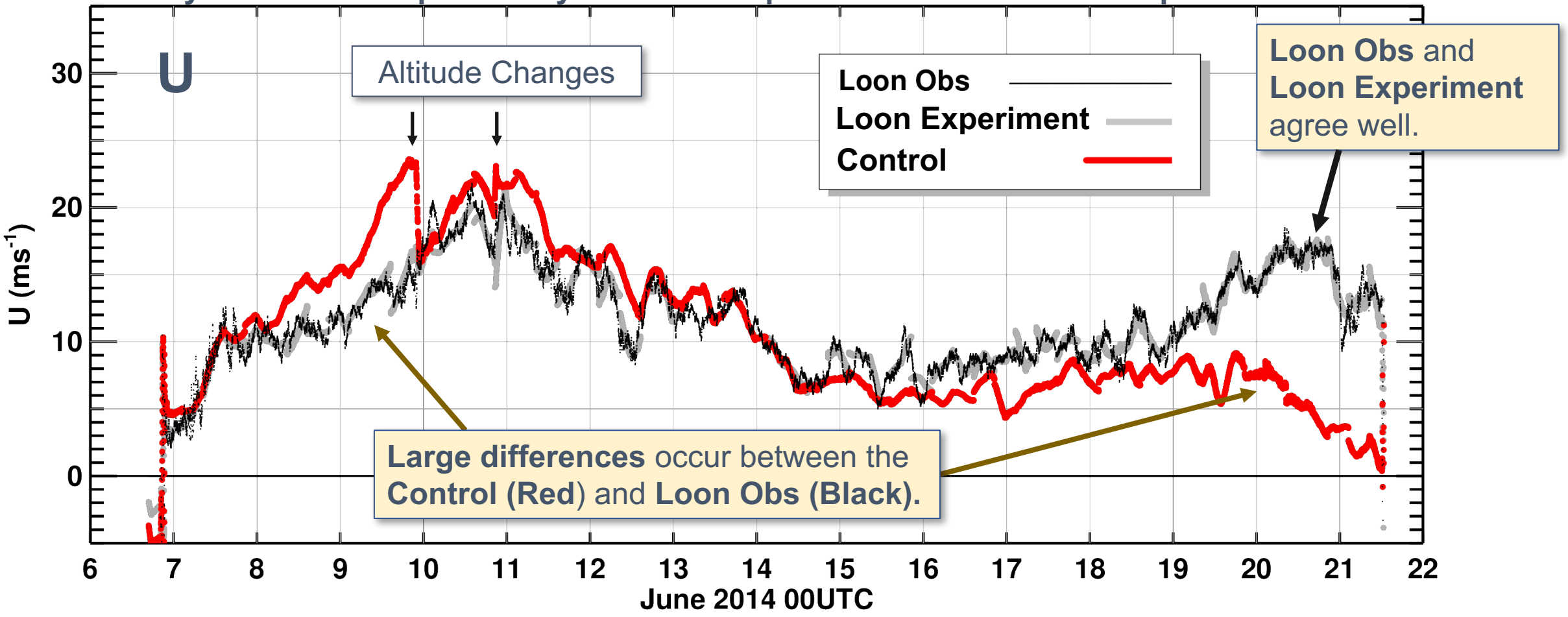
Control Analysis Winds: Wind arrows **do not** line up with the trajectory, indicating a difference from Loon observations.

Loon Experiment Analysis Winds: Arrows line up with balloon trajectory. Significant differences in indicated regions



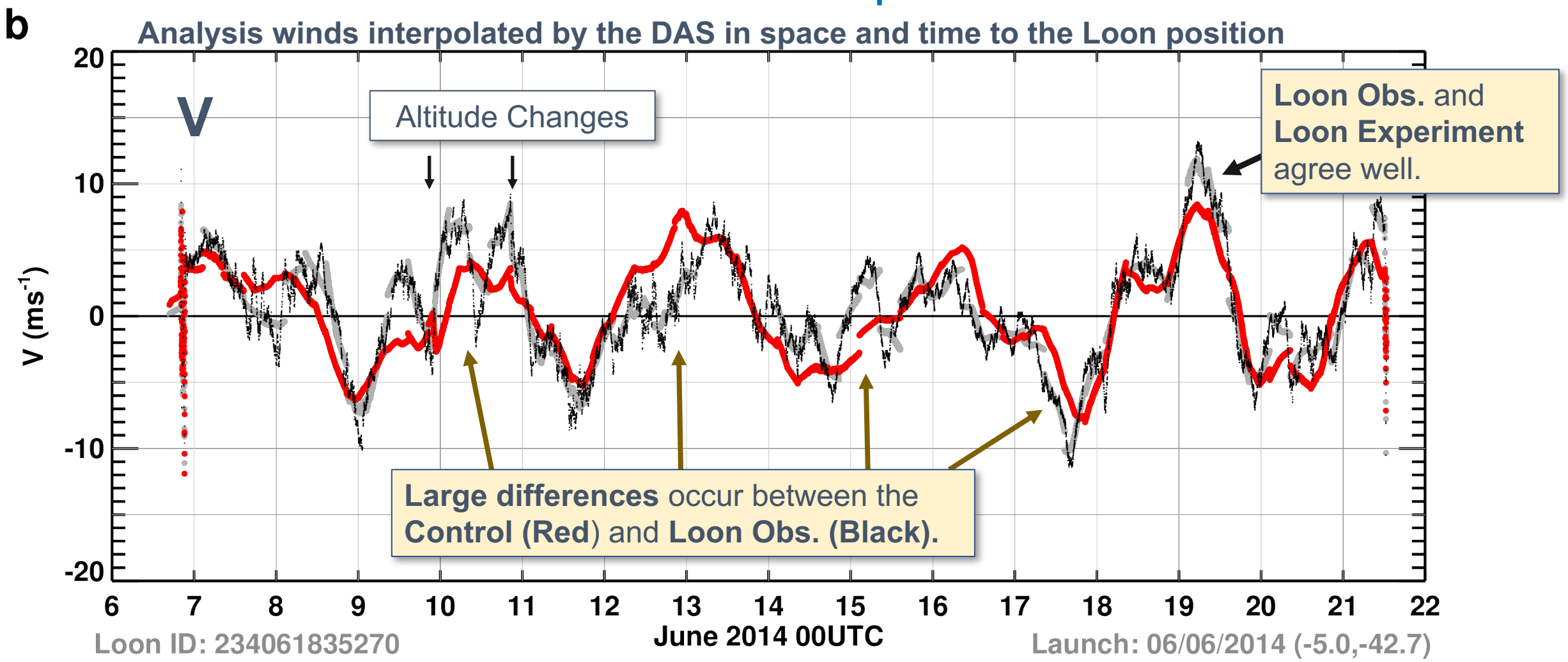
Tropical Launch June 2014
Zonal Wind Comparison

Analysis winds interpolated by the DAS in space and time to the Loon position



Tropical Launch June 2014

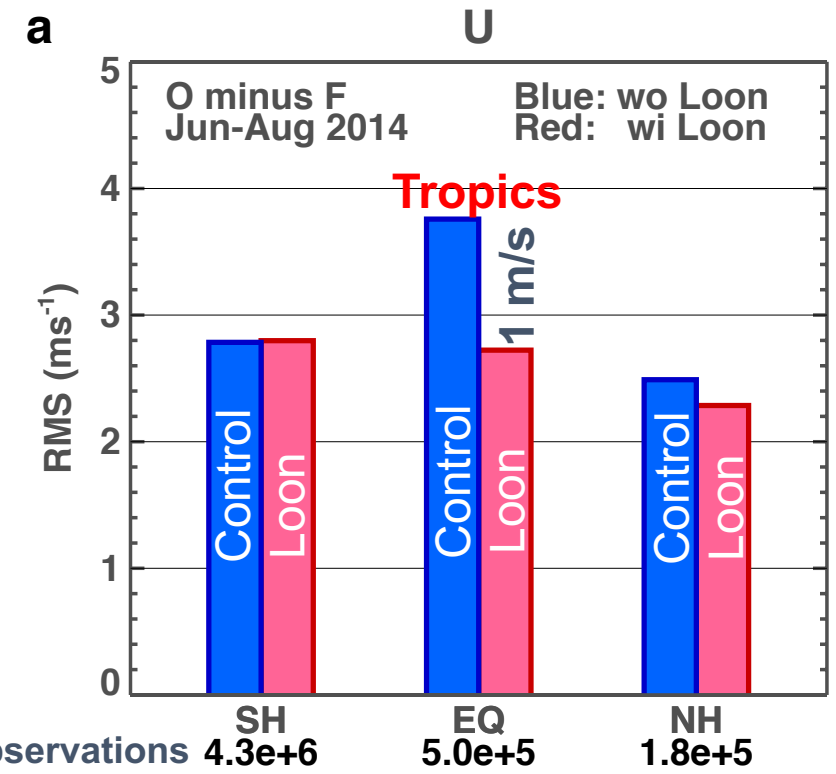
Meridional Wind Comparison



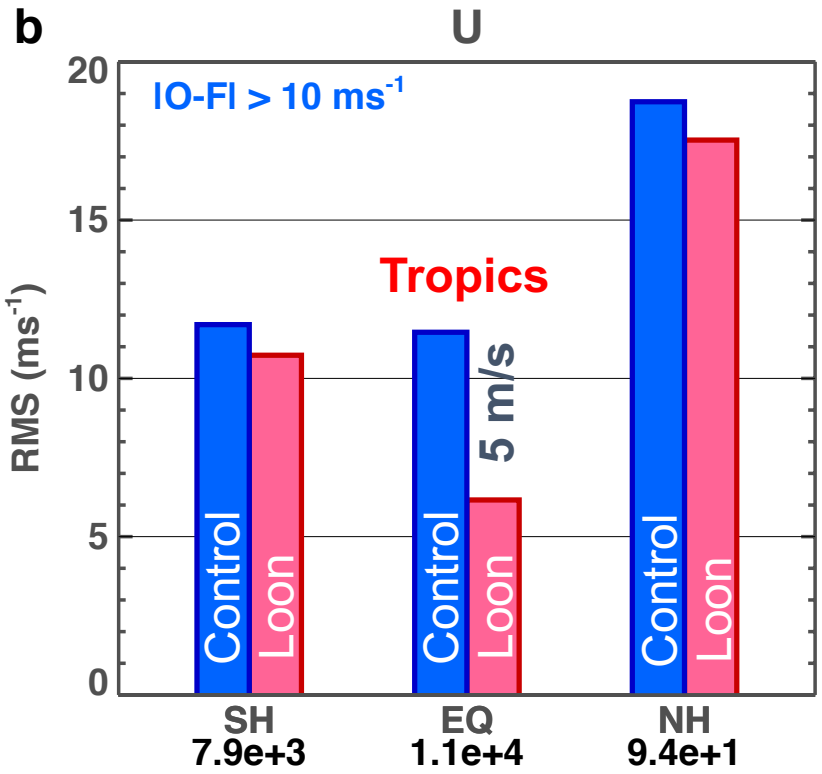
Observation minus Forecast (RMS)

Zonal Wind Jun-Aug 2014

All Loon Observations



Only times when Control and Loon Obs show large (> 10m/s) differences



Assimilating the Loon winds greatly improves tropical wind forecast

Summary and Conclusions

Summary: The Loon balloons were incorporated into a global data assimilation system for three months in order to test their impact. Date range: June-August 2014.

Results: Assimilation of the Loon balloon winds had a significant impact in the tropical lower stratosphere, especially in regions were direct wind measurements are lacking.

Future Work: This preliminary study showed the potential for constant pressure balloon data to aid in real-time data assimilation system analyses and forecasts. We plan to assimilate the entire 3+ year Loon data set into the NASA GMAO data assimilation system for further tests.

Question: Is the current conventional and satellite observation network sufficient to characterize the winds in the lower stratosphere?

Answer: No

We would like to thank X and the Loon Project for providing their data.

References:

Schoeberl, M. R., E. Jensen, A. Podglajen, L. Coy, C. Lodha, S. Candido, and R. Carver (2017), Gravity wave spectra in the lower stratosphere diagnosed from project loon balloon trajectories, J. Geophys. Res. Atmos., 122, 8517–8524, doi:10.1002/2017JD026471.

Podglajen, A., A. Hertzog, R. Plougonven, and B. Legras (2016), Lagrangian temperature and vertical velocity fluctuations due to gravity waves in the lower stratosphere, Geophys. Res. Lett., 43, 3543–3553, doi:10.1002/2016GL068148.

Friedrich, L. S., McDonald, A. J., Bodeker, G. E., Cooper, K. E., Lewis, J., and Paterson, A. J.: A comparison of Loon balloon observations and stratospheric reanalysis products, Atmos. Chem. Phys., 17, 855-866, https://doi.org/10.5194/acp-17-855-2017, 2017.