Increased Southern Hemisphere contribution to SSA (Space Situational Awareness)

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Why?

Up-to-date information about the properties, position and trajectory of each object in Earth's orbit is critical to the safety of space infrastructure and exploration. An approximated 8,000 tonnes of debris orbits Earth, in over half a million individual pieces [1]—from droplets of coolant all the way up to spent but intact rocket bodies.

With each being acted upon by interacting forces of gravity, motion, atmospheric drag and radiation pressure [2], tracking and path prediction for such a mass of high-speed objects is computationally expensive. Along with the need for high-performance radio or optical systems resources, this has historically limited global involvement in SSA [3].

Knowing this, surveys have been conducted into SSA capabilities worldwide to assess current challenges and opportunities. These have often concluded that a clear concentration of sites in the Northern Hemisphere has great impact or is of high priority to address [3, 4, 5]. A key example of this is the spread of sensors in the US Space Surveillance Network (SSN), shown in Figure 1, that is only now nearing operation of a significant Southern site [6].

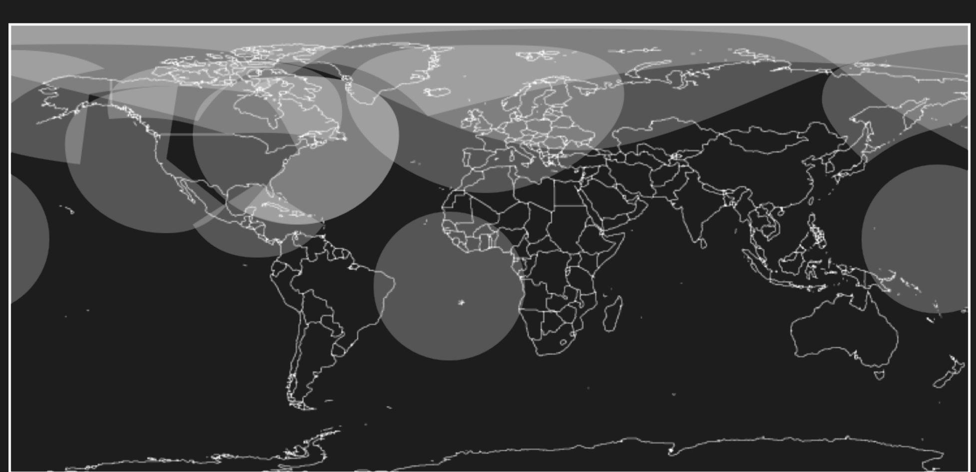


Figure 1. *Approximate global coverage of the ground-based SSN network sensors at an altitude of 800km [8]*

However, the distribution of objects in orbit is neither uniform nor random [7]. This means that bias in the geographical distribution of suitable tracking sites does not necessarily mean significant variance in performance can be asserted globally. Nor can the potential benefits of increased SSA capabilities in the South be assumed to match that which was seen in the North.

In this study, the effects of this location bias are investigated through interrogation of historical detection data from objects favouring each hemisphere, with a focus on key regions where tracking expansion has been recently added or proposed. This aims to realistically project the benefit to be gained from increased SSA presence and contribution in the Southern Hemisphere, and identify geographical or orbital regions that have the most to gain.

What?

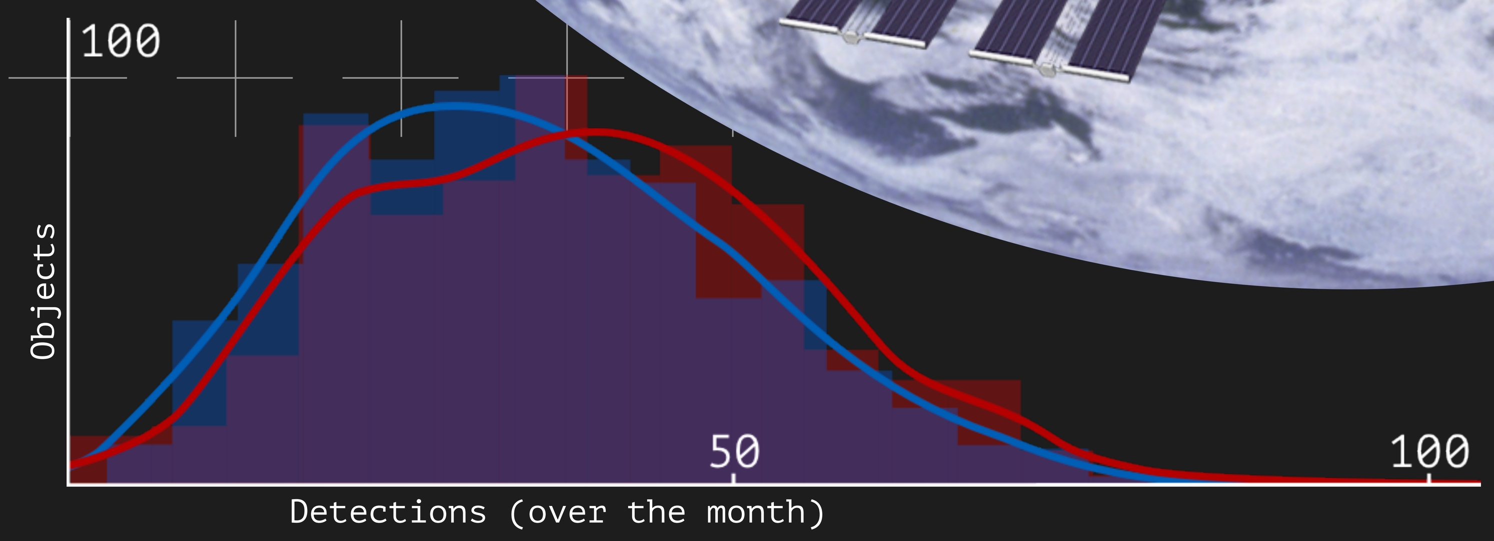
Projection of the benefits to be gained from increased capabilities in targeted locations can be estimated through measurement of the opposite: the current differences seen in the tracking of objects in the Southern Hemisphere.

This is based on an assumption that the accuracy and frequency of detections over a particular region can be broadly attributed to the sensors in that region. New developments can then be recommended for regions where tracking history of the most objects is of the poorest quality against these criteria, on the basis that coverage in areas associated with the highest cumulative re-acquisition times would offer the greatest benefits to performance.

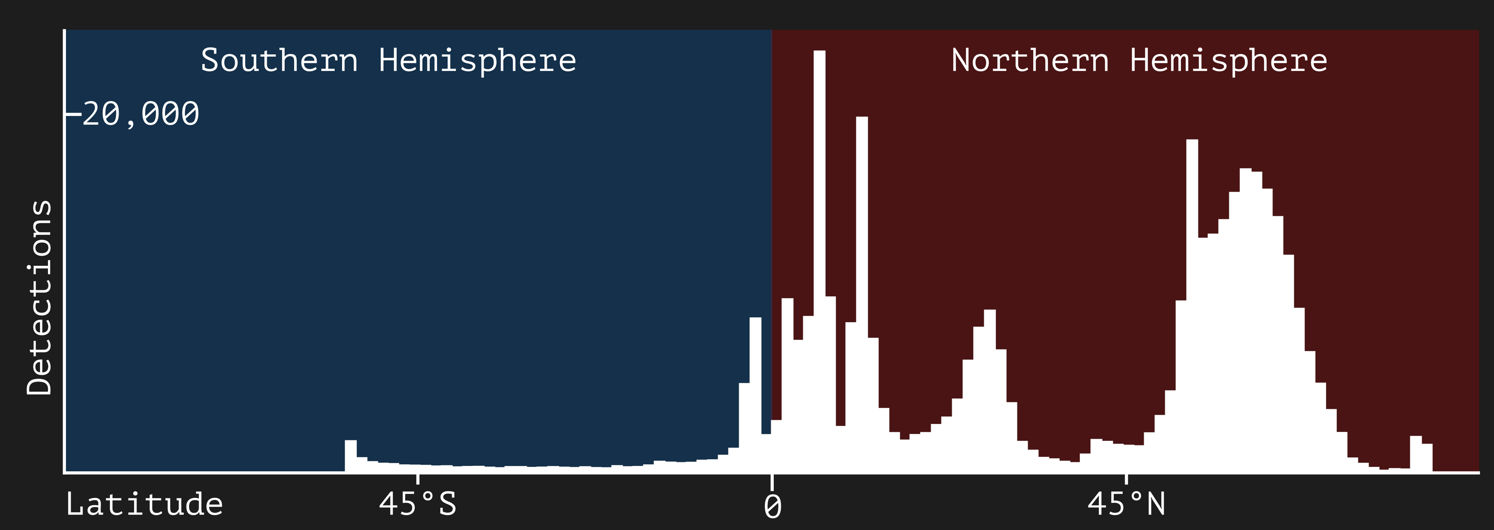
How?

Location information of NORAD catalogue objects for the month of October 2020 was obtained from SpaceTrack's historical record. This data contained a snapshot of over a million individual detections across the 31 days of just under 20 thousand catalogued and reliably trackable objects that were in orbit at that time. These were converted from their initial TLE format to CSV before being analysed using tools from the Python programming language.

For the purpose of this analysis, objects were seen to be "favouring" a certain hemisphere based on the angle of their perigee. In contrast, detection latitudes and geocentric subpoints are based on the location of the object at the time of detection.



Among difficult-to-track objects such as those with high inclination (>25°N/S) objects, the average number of monthly detections between objects with a ***Southern perigee*** *was significantly lower than those with a* ***Northern perigee****.*



Among objects whose detections were not associated with a reference location at their ascending node (omitted from graph for clarity), the proportion of detections in the ***Southern Hemisphere*** *was only 10% to the* ***Northern Hemisphere****'s 90%.*

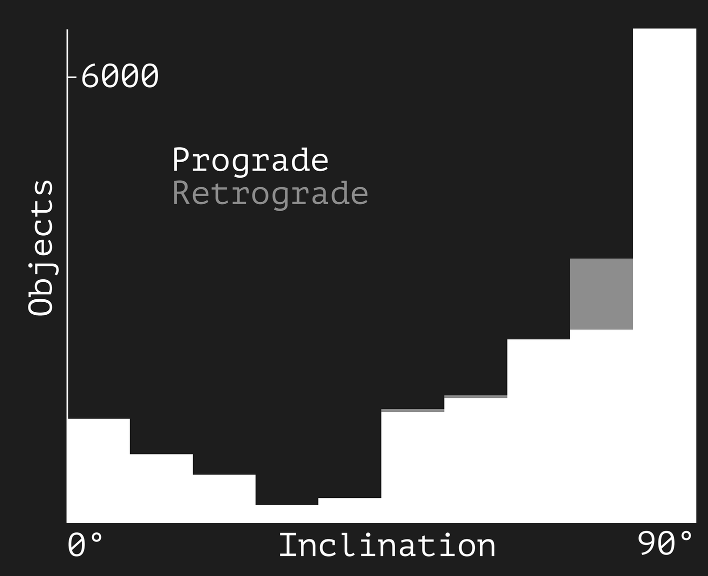


Figure 2. *Distribution of object inclinations, showing near-polar Molniya or highly-inclined orbits are prominent in catalogued objects.*

References

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Results

Objects were examined for their relative reacquisition frequency and regularity by way of distribution testing that compared the detections of Northern and Southern object subgroups across the month of detections. First looking at frequency and variance of detections among objects with a perigee in the Northern versus Southern Hemisphere, Southern-favouring objects uniformly suffered lower average number of detections and higher variance in re-acquisition times. These only *just* met a level of statistical significance, until comparison targeted the difference among problematic subgroups such as objects with high eccentricity (>0.125), high inclination (>25°N/S), low altitude (>11.25 revolutions per day) high variance in orbital parameters across the month, small objects (based on RCS information) or inactive ones. In these, **Northern Hemisphere objects were seen 5 additional times** in the month on average.

Looking to the hemisphere each object was located in at the time of detection, this can be seen in approximately 42% of detections that have not used an equatorial reference for their epoch time. Of detections with position information available only **10% of these detections occured in the Southern Hemisphere**. This meant that the median number of times an object with positional information was seen above the equator during the month was 27 times, compared to only 12 times below.

Of these Southern detections **only 2% occurred at below 45° South**—a region key to monitoring objects in highly eccentric Molniya orbits—despite examination of catalogue objects showing that approximately 83% orbit at high inclinations between 45° and 135°, shown in Figure 2.

These results support that tracking information is subject to bias favouring the Northern Hemisphere.

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