GNSS Vulnerabilities to Space Weather

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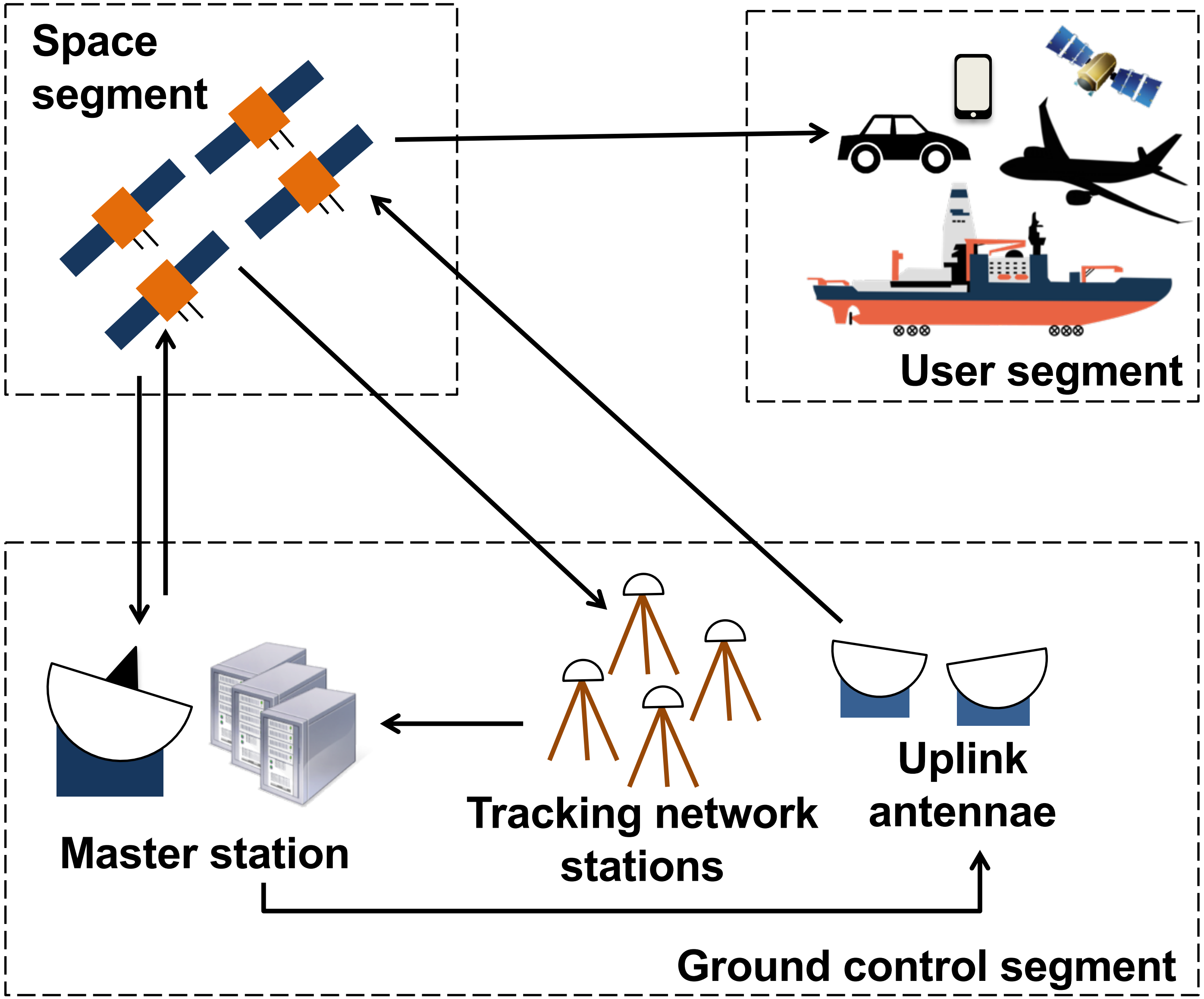
Global Navigation Satellite Systems



Global Navigation Satellite Systems

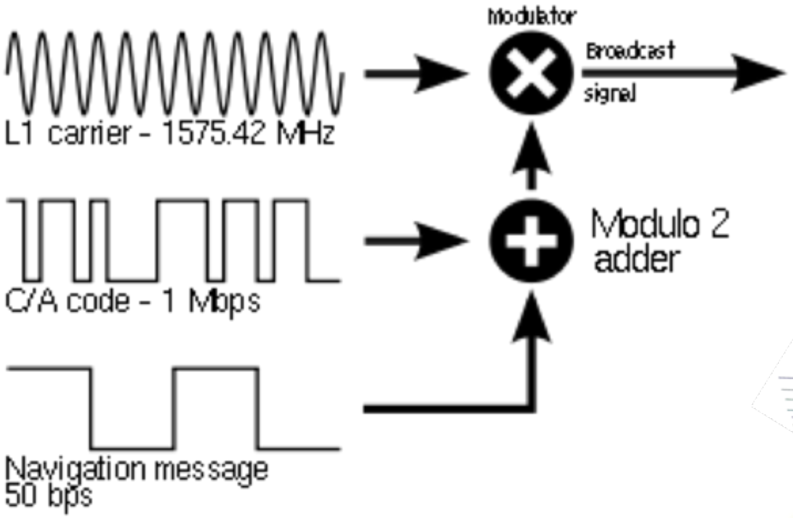
NAVSTAR GPS

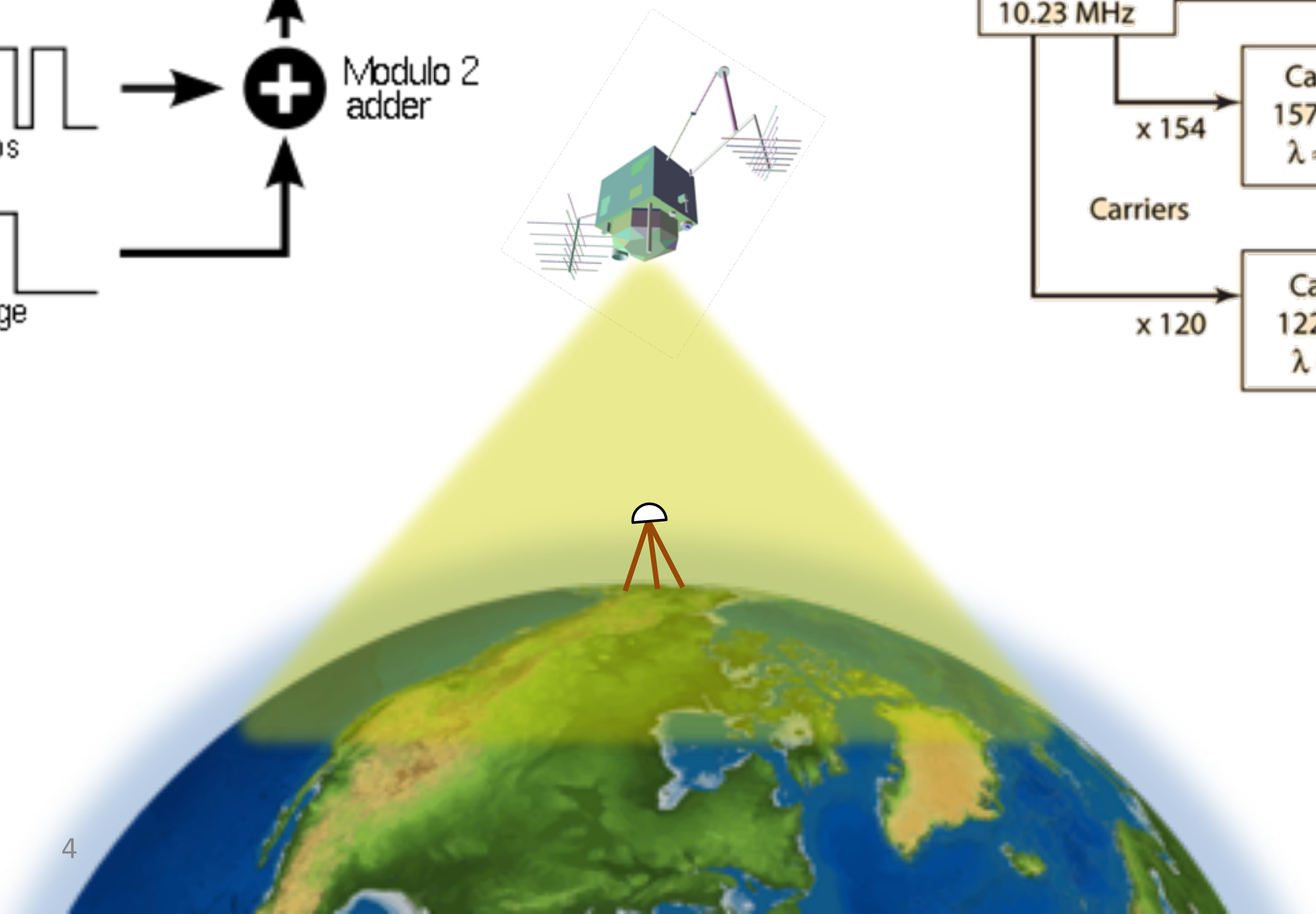
GLONASS

BeiDou

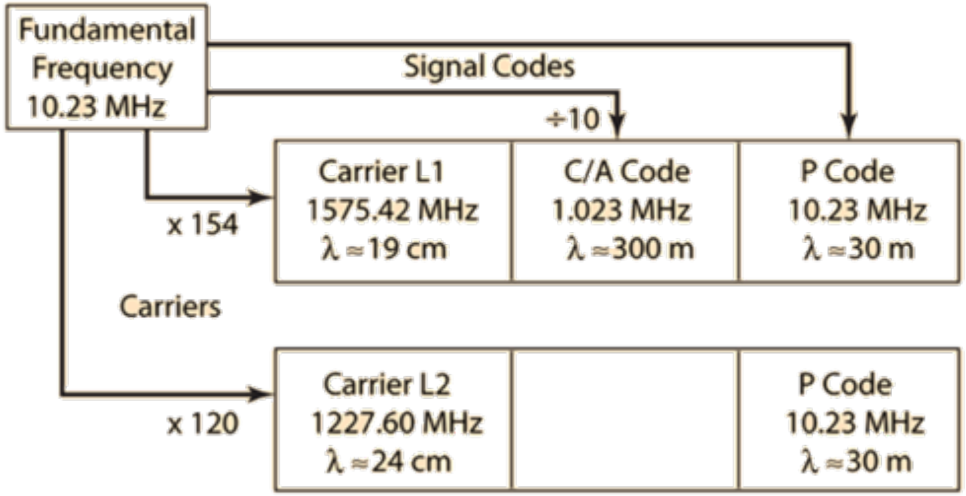
Galileo

GNSS Signals: Low power, susceptible to interference



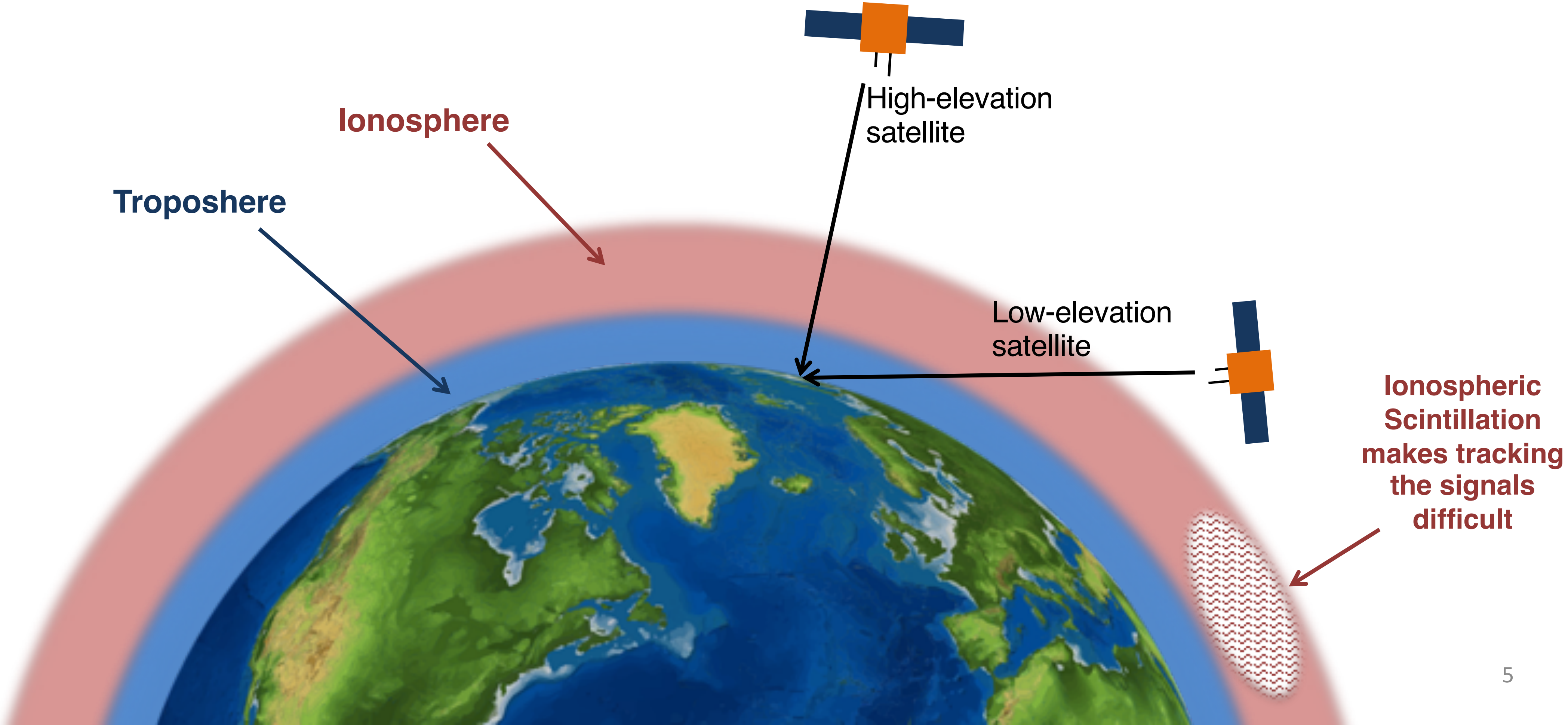


The GPS L1/L2 signal structure:



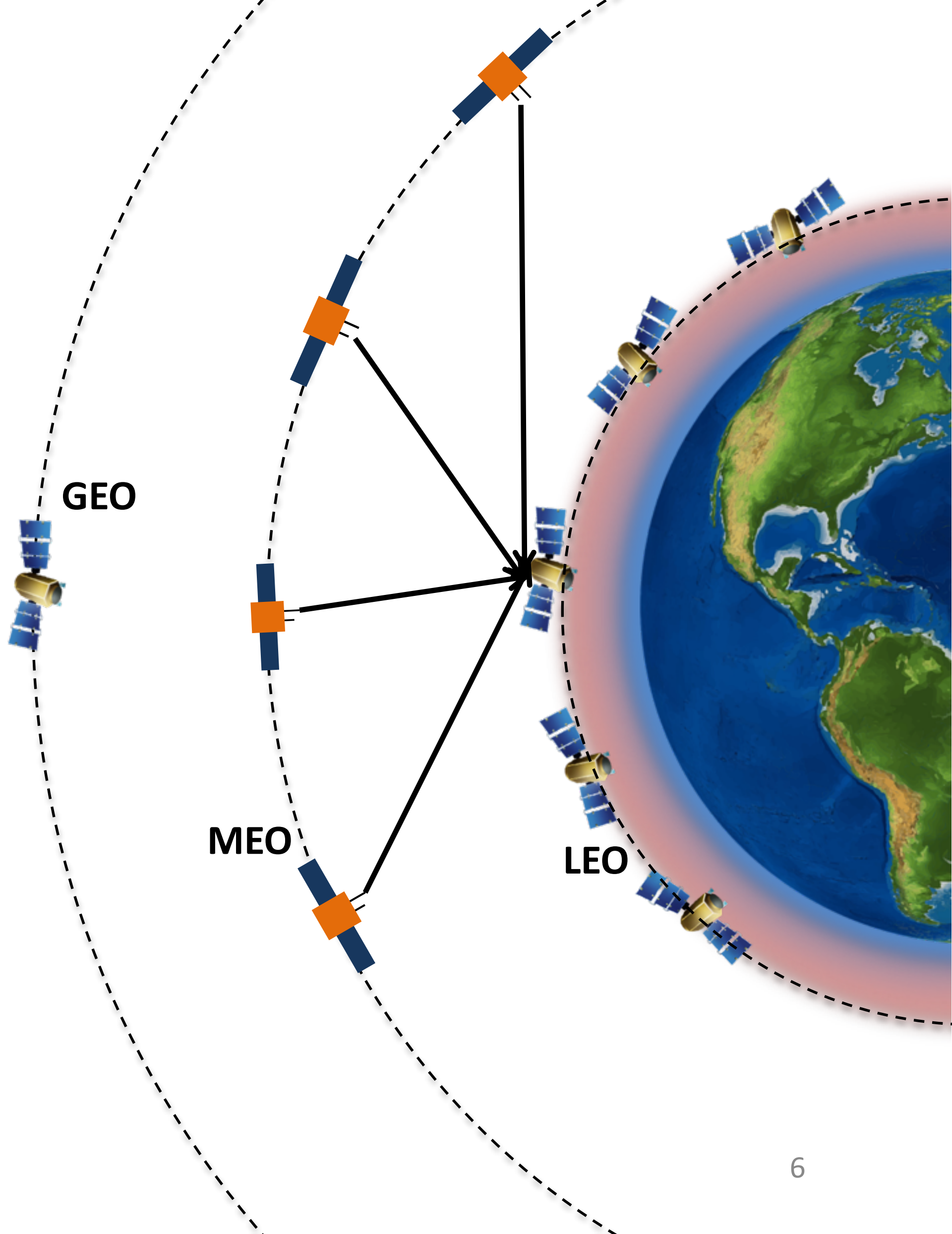
Space Weather and GNSS: Atmospheric Propagation Delays

These are the largest sources of error in many GNSS-based positioning, navigation and timing algorithms (ranging errors can vary from 0.1 to ~ 100 m), under normal solar conditions. Most problematic in signals from low-elevation satellites – because those signals pass through more atmopshere (iono and tropo) to reach users. Problematic during high solar activity.



Space Weather and GNSS – where are the vulnerabilities?

- **Ionospheric delay models**, used in single-frequency PNT algorithms are not reliable during periods of high solar activity, affecting measurement accuracy
- **Ionospheric gradients and ionospheric scintillation**, primarily driven by space weather, remain problematic effects that receiver manufacturers struggle to mitigate against, especially near geomagnetic equator and polar regions (can cause localised outages)
- **Space segment (GNSS and SBAS) risks:** Solar cell damage, computer failure, memory upsets
- **Solar flares:** May have spectral component at GNSS frequencies resulting in interference with transmitted signal – performance degradation
- **CME's: …**



Space Weather and GNSS – where are the vulnerabilities?

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On the probability of occurrence of extreme space weather events

Pete Riley[1]

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[1] By virtue of their rarity, extreme space weather events, such as the Carrington event of 1859, are difficult to study, their rates of occurrence are difficult to estimate, and prediction of a specific future event is virtually impossible. Additionally, events may be extreme relative to one parameter but normal relative to others. In this study, we analyze several measures of the severity of space weather events (flare intensity, coronal mass ejection speeds, *Dst*, and >30 MeV proton fluences as inferred from nitrate records) to estimate the probability of occurrence of extreme events. By showing that the frequency of occurrence scales as an inverse power of the severity of the event, and assuming that this relationship holds at higher magnitudes, we are able to estimate the probability that an event larger than some criteria will occur within a certain interval of time in the future. For example, the probability of another Carrington event (based on $Dst < -850$ nT) occurring within the next decade is ~12%. We also identify and address several limitations with this approach. In particular, we assume time stationarity, and thus, the effects of long-term space climate change are not considered. While this technique cannot be used to predict specific events, it may ultimately be useful for probabilistic forecasting.

Citation: Riley, P. (2012), On the probability of occurrence of extreme space weather events, *Space Weather*, 10, S02012, doi:10.1029/2011SW000734.

- A study published in 2012 suggested ~12% risk of a extreme, Carrington-like event within the next 10 years
- No such event has occurred in the modern space era
- The effects of such an event to GNSS, and the space population in general, is largely unknown
- With multiple constellations, on-orbit spares, and other redundancies it is possible that modern GNSS would be resilient to such an event
- But in a worst case scenario, we might expect irreversible damage to a significant portion of the space segment (and potentially ground segment)
- At UCL, we are developing long-term simulations of space population (up to 2043)
- One scenario we are developing will consider the impact of a Carrington-style event …

Thanks!

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