Potential Benefits of CubeSat Constellation

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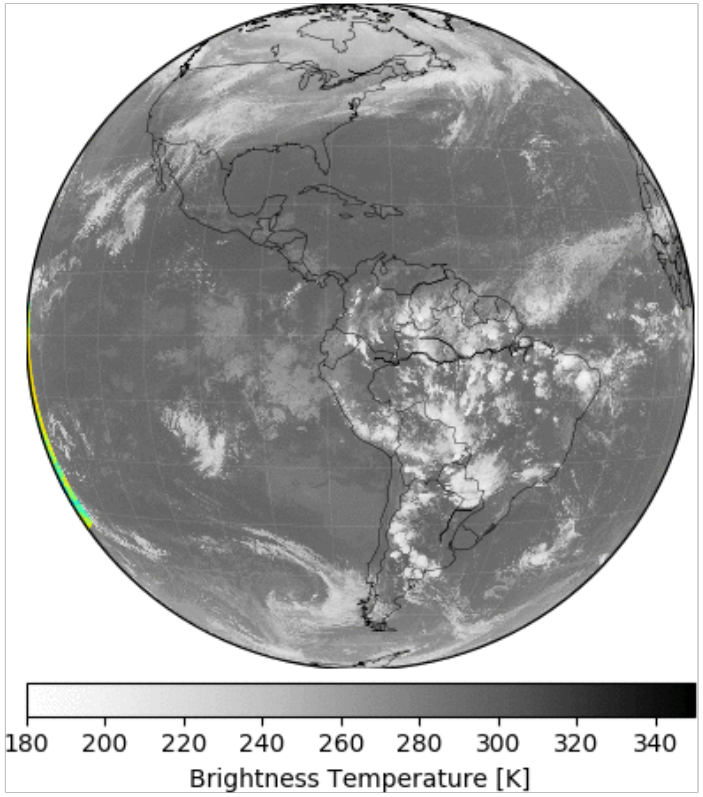
NOAA Satellite Observation System



- NOAA maintains GOES and POES satellite systems for decades.
- The need for global high spatial and temporal resolution satellite observations
  - global winds, real-time fire or smoke monitoring, high temporal rain rate estimate
- The need for global high temporal microwave observations
  - MW observations are important for NWP and weather monitoring
  - Challenges for geostationary MW instruments

Space-X StarLink Constellation

- **Starlink** is a satellite constellation development project underway by Space-X, to develop a low-cost, high-performance satellite bus and requisite customer ground transceivers to implement a new space-based Internet communication system

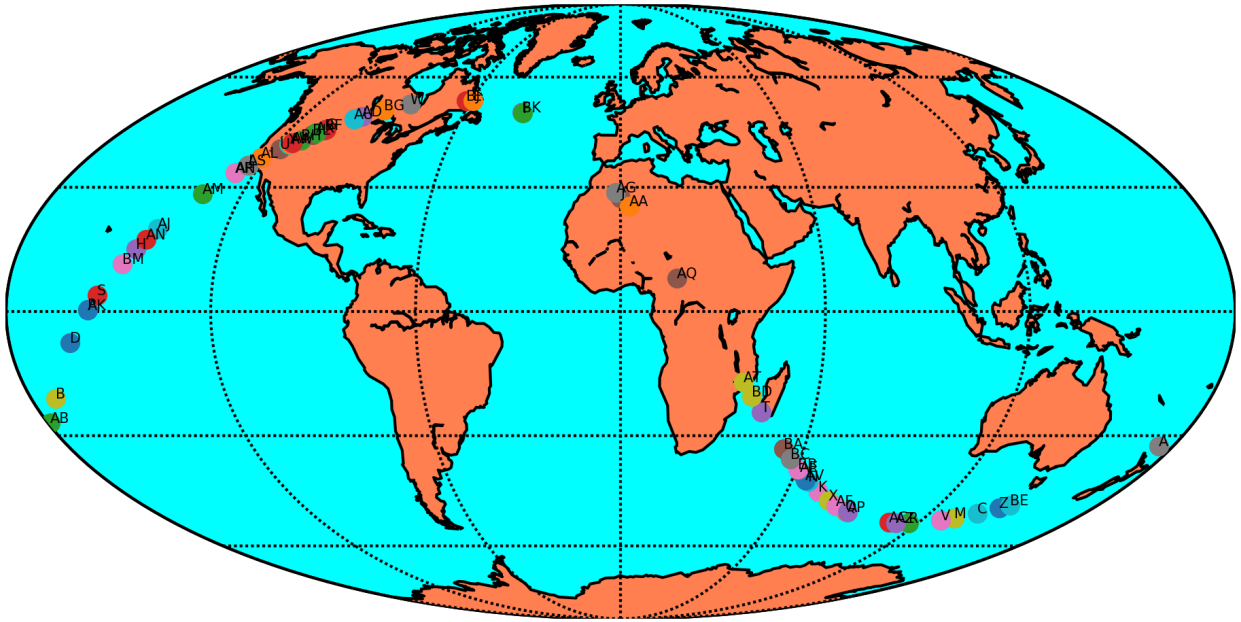
- SpaceX also plans to sell satellites that may be used for military, scientific or exploratory purposes.

- Both meteorology and internet satellites require global coverage with high temporal resolution

Phase	No. of Orbit planes	Satellites Per Plane	Total satellites	Orbit Altitude (km)	Orbit Inclination angle (Degree)
1	**24**	**66**	**1584**	**550**	**53**
2	32	50	1600	1100	53.8
3	6	75	450	1325	70
3	8	50	400	1130	74
3	5	75	375	1275	81

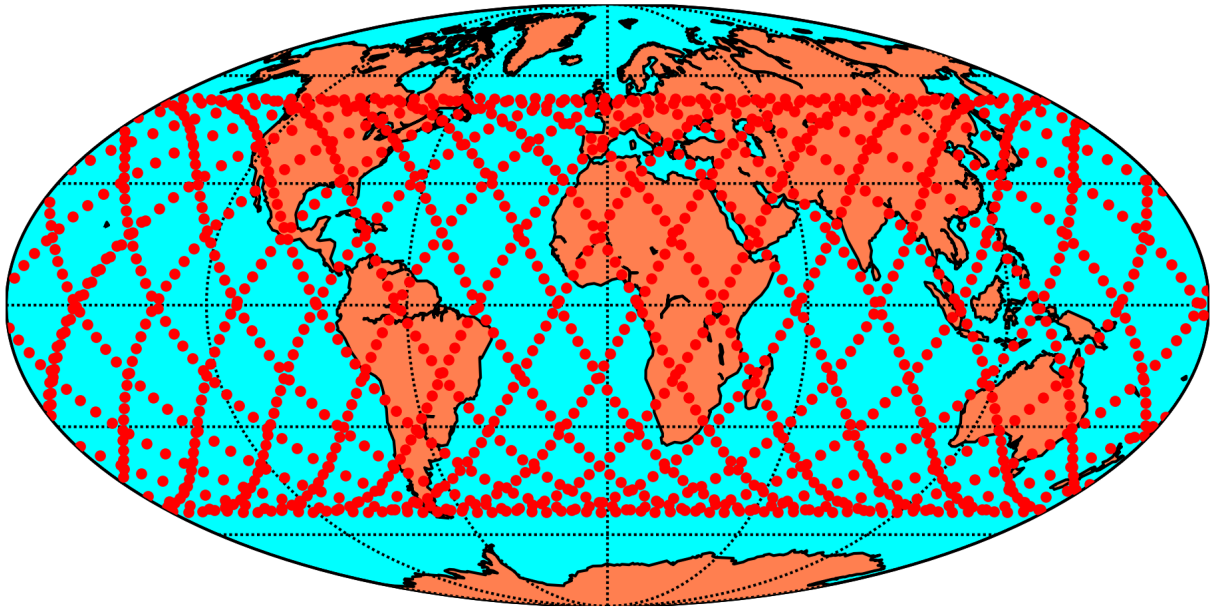
Launch on 24 May 2019

2019-06-09T00:00:00



One satellite orbit track

STARLINK A

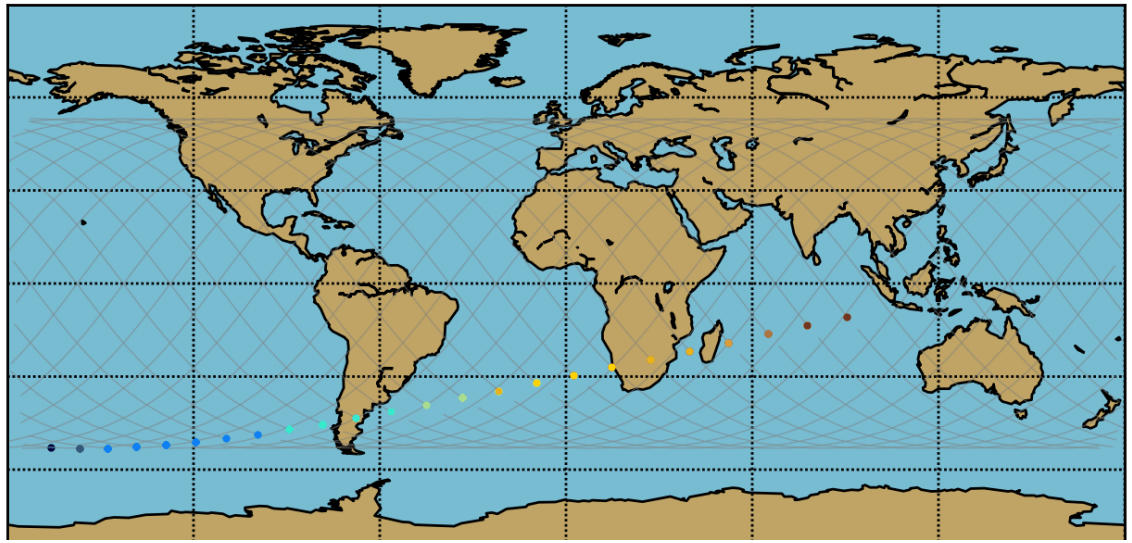


The 60 operational satellites were launched on 24 May 2019

Orbit altitude: 436-454 km Inclination: 53.5 Degree
Orbit period: 93.3415736139 minutes

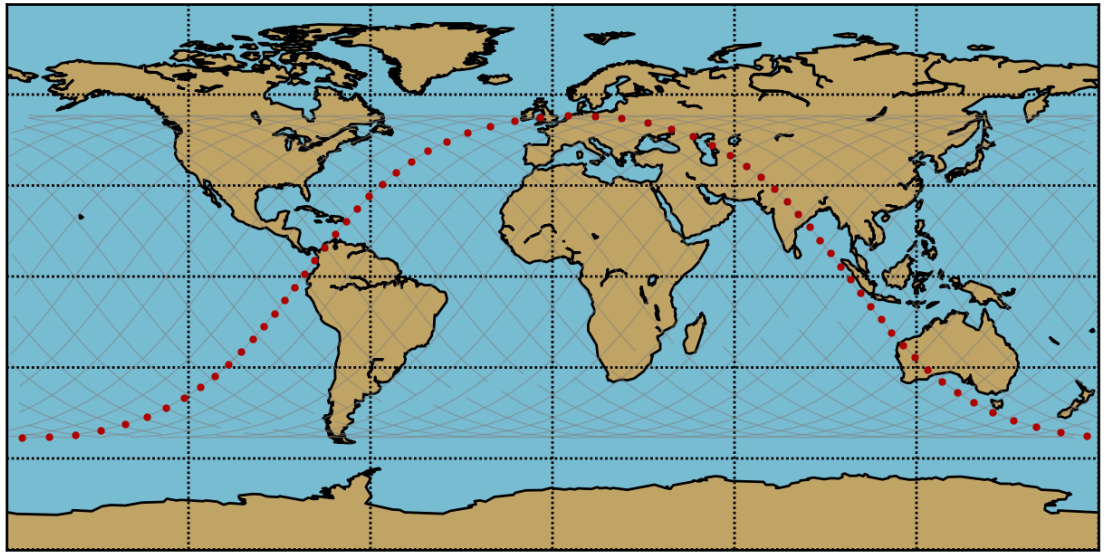
Phase 1 Simulations : 1584 Satellites

2019-05-27T00:00:00



24 orbit planes and each orbit plane shifts 15 degree.

2019-05-27T00:00:00



Each orbit plane contains 66 satellites. Every 1.5 minutes, have satellite

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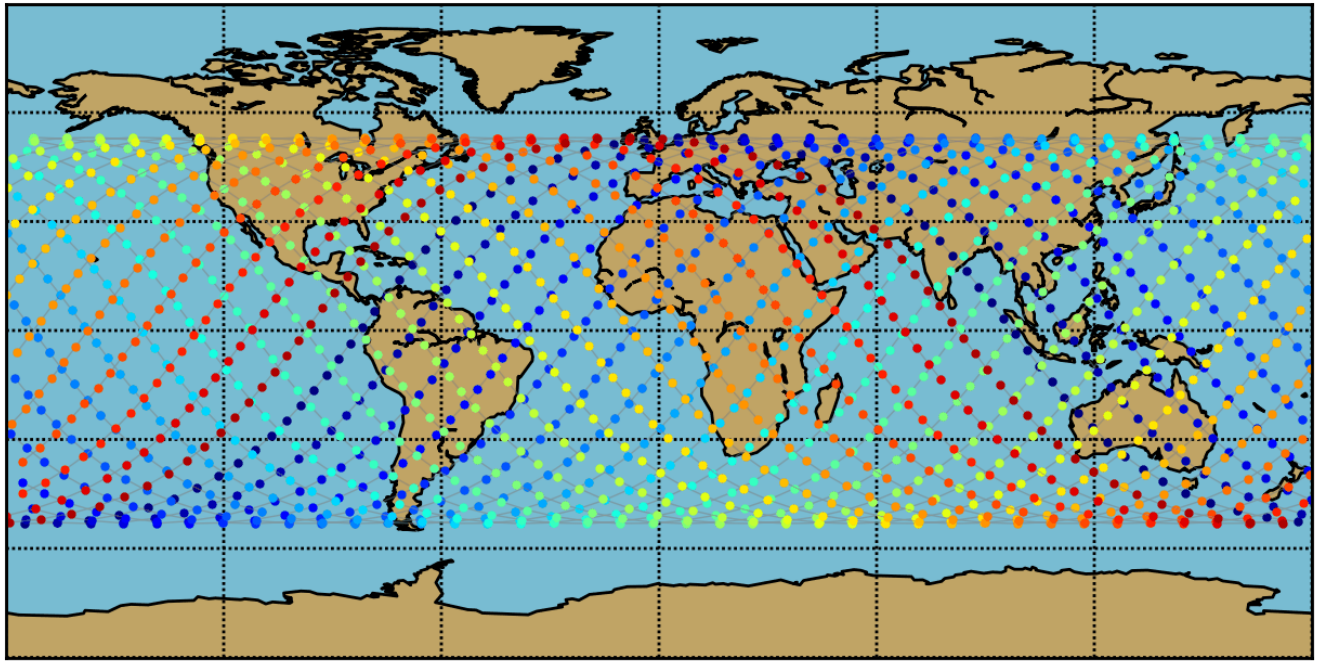


To avoid crushing, each satellite has phase shift:
360°/24/ 66
Using the launch satellite orbit parameter: 53 °
Inclination angle with ~ 440 km orbit altitude

Potential Benefits of CubeSat Constellation

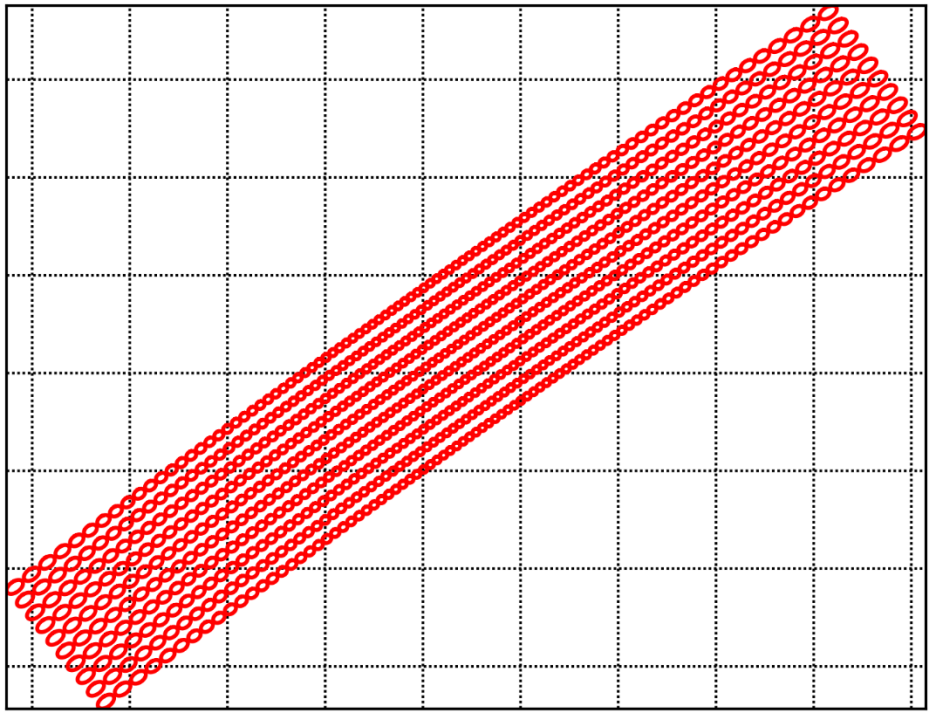
- Global high spatial and temporal observations
  - GOES-like global observations every 15 minutes
  - Winds, Fire, Precipitation

- If we treat the observations within 15 minutes' window from identical instruments independently, how many of this kind of observations we can get in each grid?
  - Assuming a normal distribution, theoretically, doubling the number of sweeps and averaging them should reduce the noise by a factor of the square root of 2

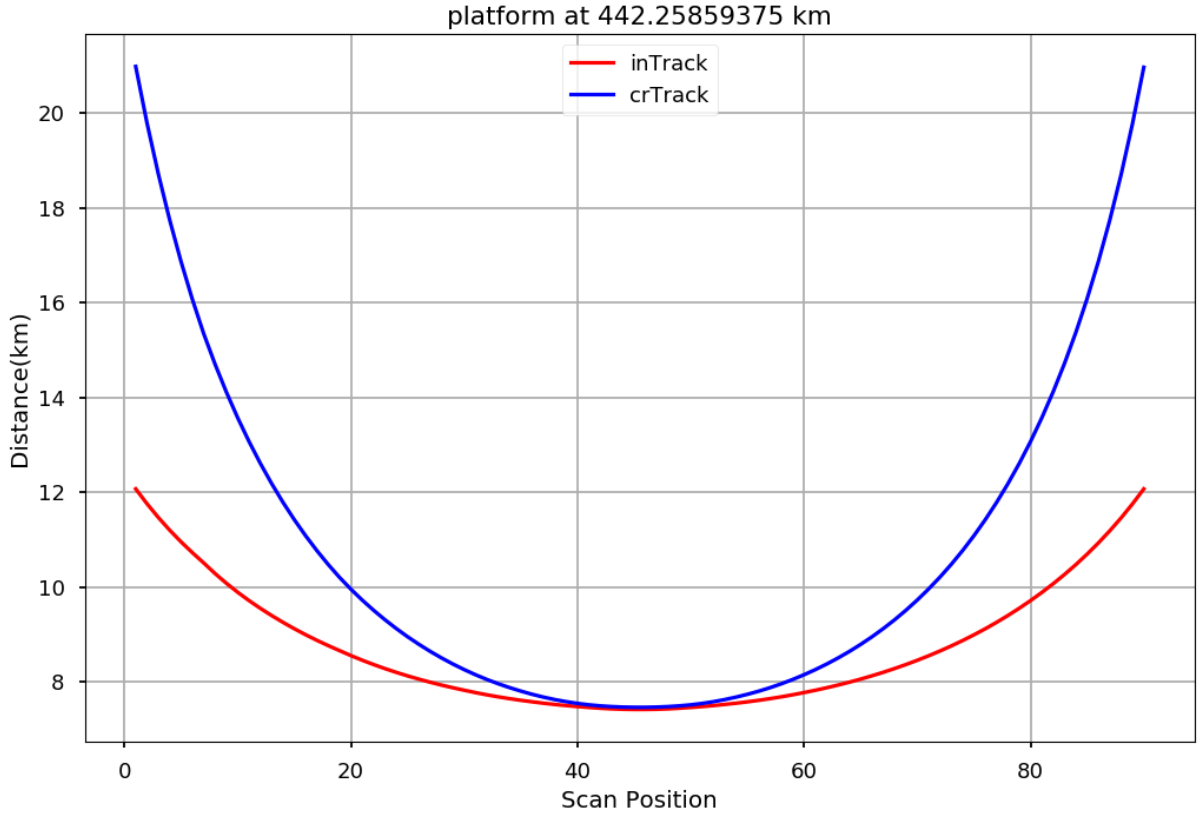
- How to achieve it by orbit deign?

- Method:
  - Simulate Instrument Scan Mechanism on satellite platform
  - Count how many observations in each grid box (mean refresh rate)
  - Orbit plane goes first, and then add satellite in each orbit plane

Adding Scan Mechanism on StarLink Satellite



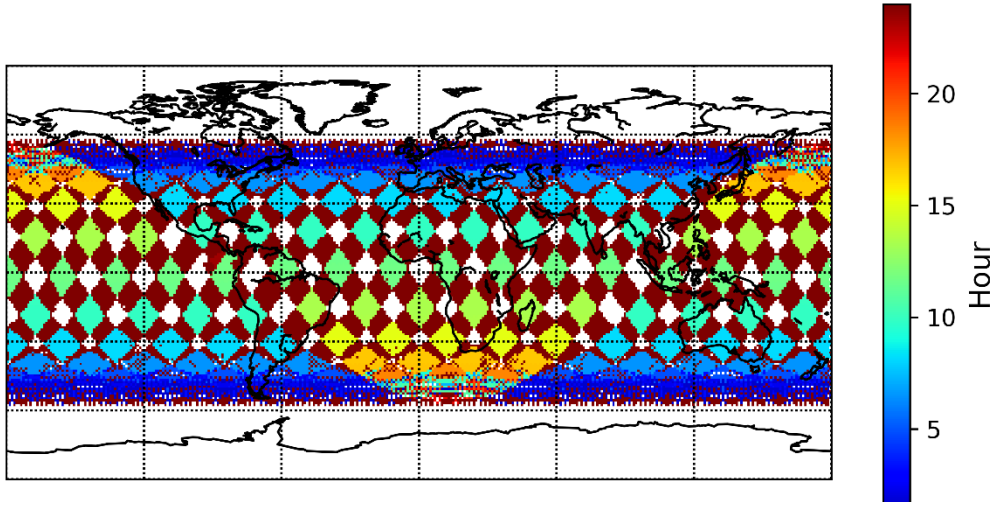
step_angle = 1.1 Degree
90 FOVs in Every Scan
max_scan_angle = 49.5 Degree
fov_angle = 0.963 Degree
Scan Rate: 8/3 seconds per Scan



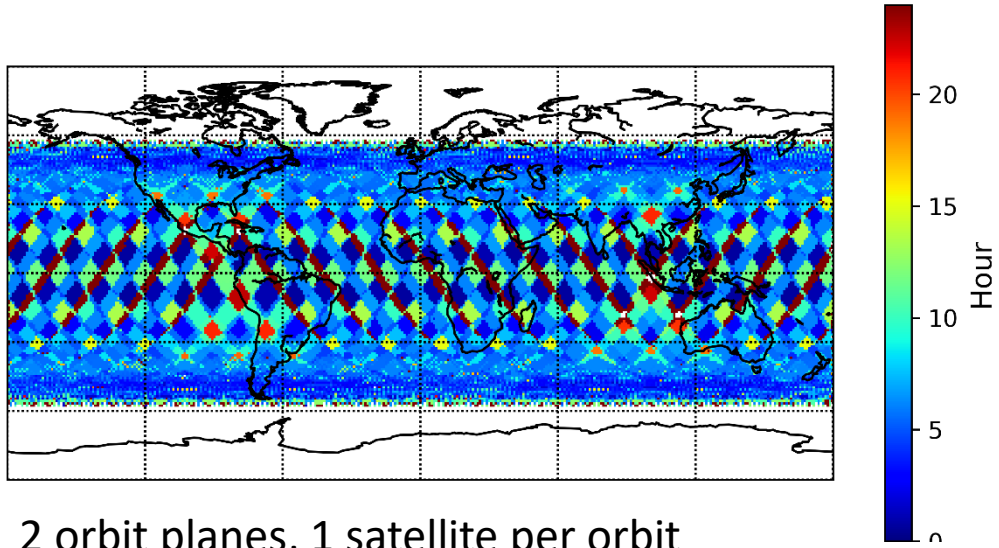
Cross-track and in-Track FOV footprint size on Ground

Local Refresh Rate

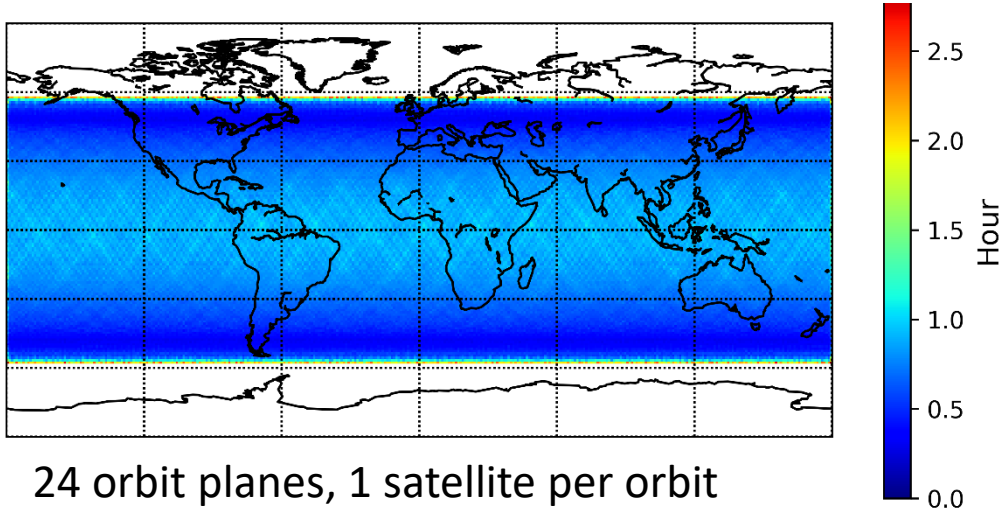
How long the observations will be updated locally?



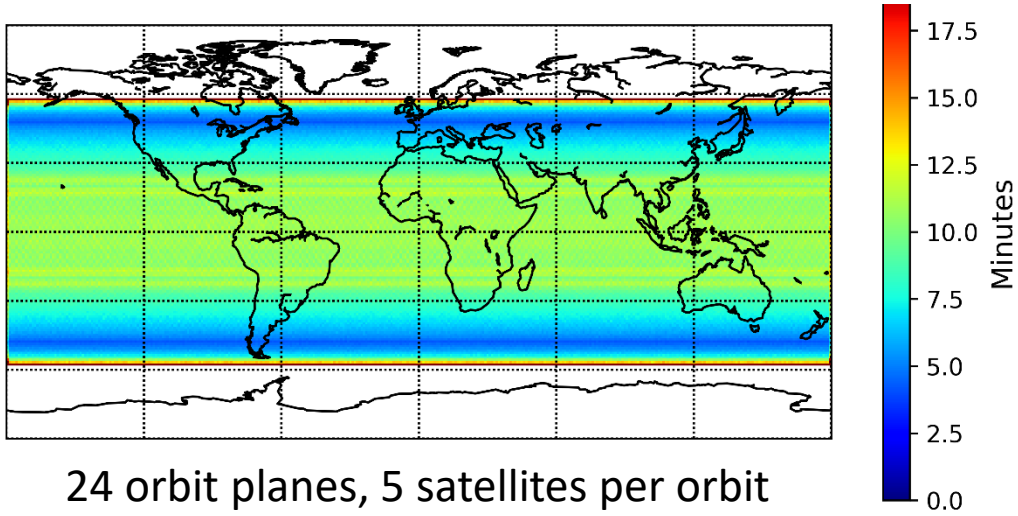
1 orbit Plane, 1 satellite per orbit



2 orbit planes, 1 satellite per orbit



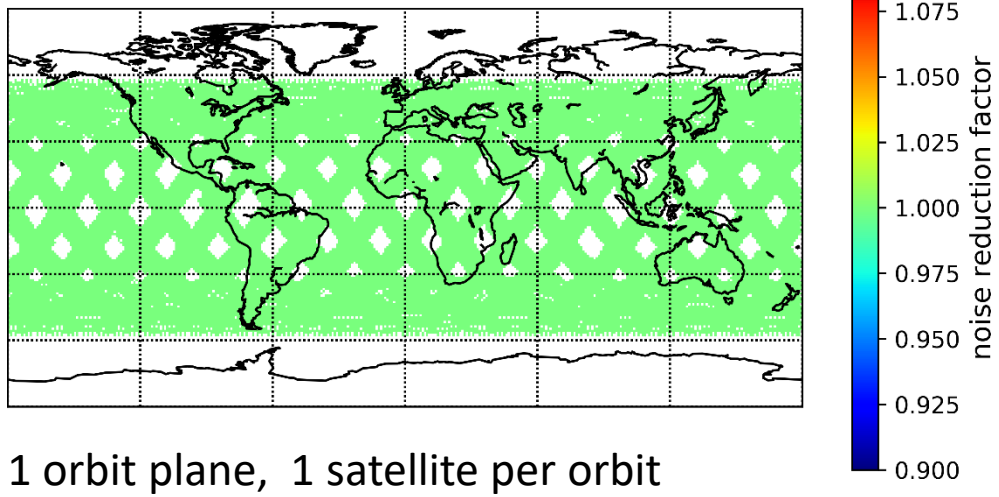
24 orbit planes, 1 satellite per orbit



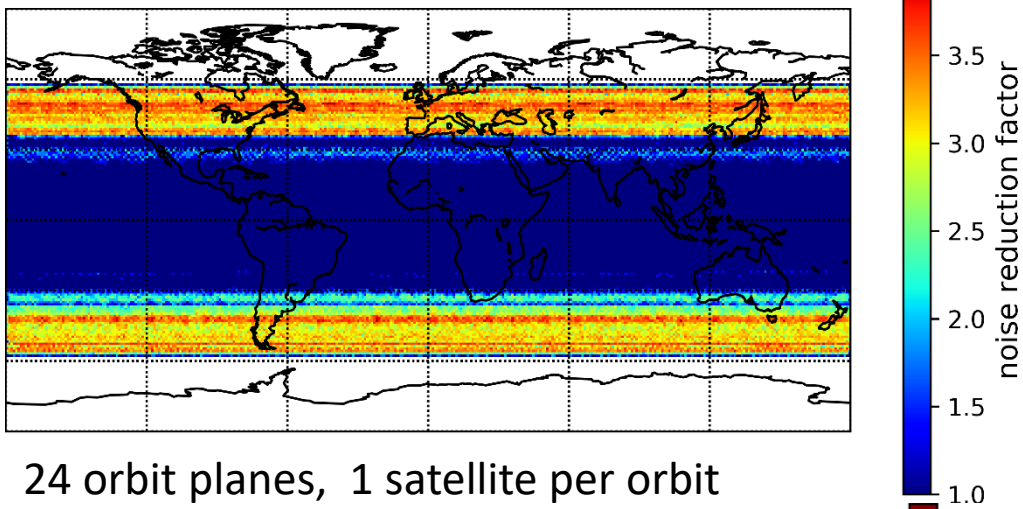
24 orbit planes, 5 satellites per orbit

At least 24 orbits plane and each has 5 satellites

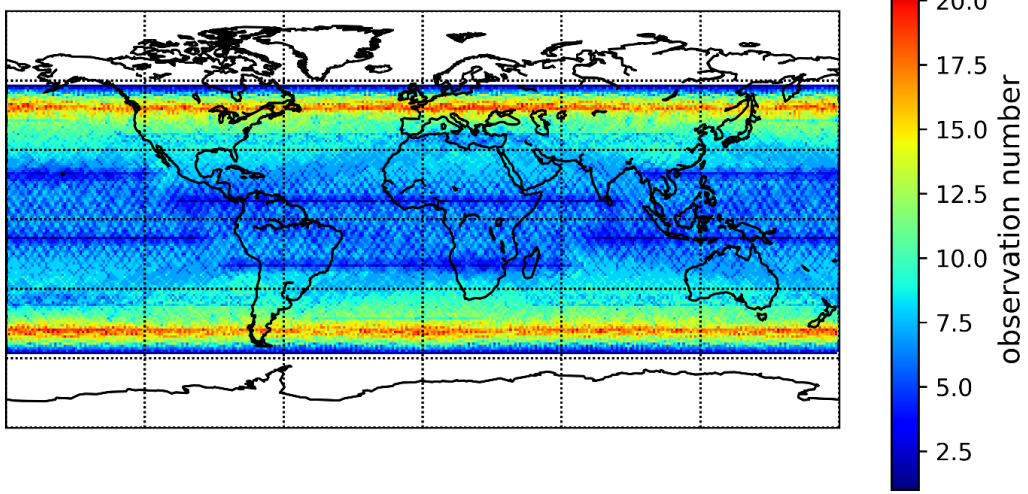
Noise Reeducation



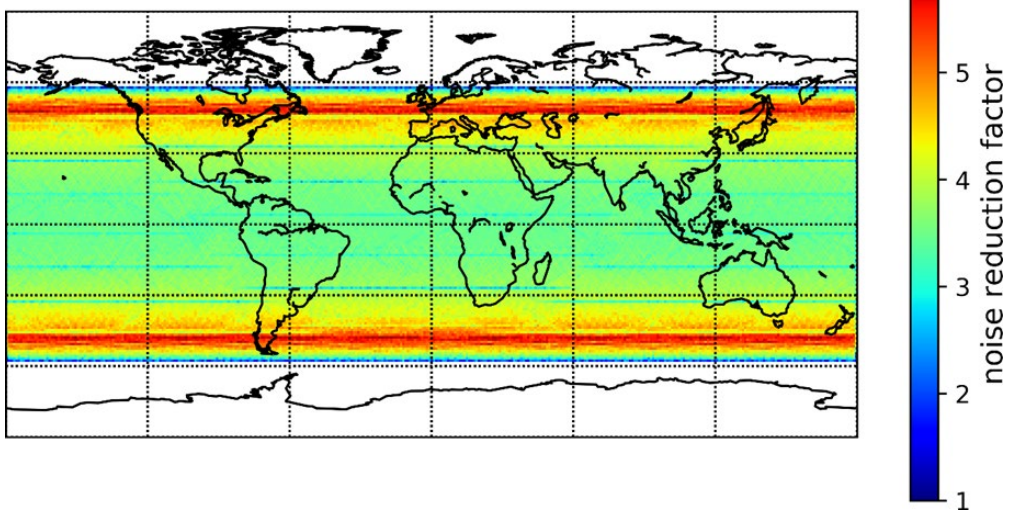
1 orbit plane, 1 satellite per orbit



24 orbit planes, 1 satellite per orbit



24 Orbit Planes, 6 satellites per obit



24 orbit planes, 11 Satellites per orbit

24 orbit planes, more satellites per orbit are better

Concluding Remarks

- CubeSat constellation can provide geostationary-like global observations with appropriate configuration
  - 24 orbit planes, 5 satellite per orbit, local fresh rate is less than 15 minutes
- CubeSat constellation can provide another way to reduce observation noise
  - 24 orbit planes, more satellites are better
- CubeSat constellation can provide new application
  - E.g., global winds