20th International Workshop on Laser Ranging
10-14 October 2016, GFZ Potsdam, Germany

Satellite laser ranging network: Where should a new station be placed?

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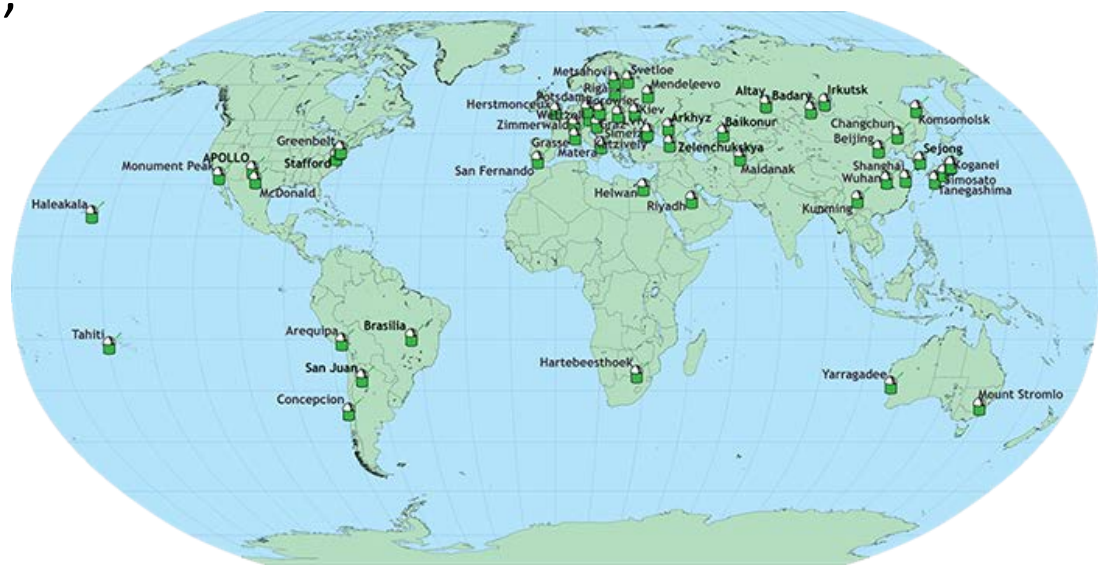
Scope of this study: SLR Network good enough?

- **Current SLR (Satellite Laser Ranging) Network**
  - About 40 stations operational.
  - Filling gaps: S. hemisphere, Russia.
  - Still far from uniform distribution.



ilrs.gsfc.nasa.gov

- **Question: Where should we place a new station?**

2-Step Simulation

[1] Generating Simulation Data Sets

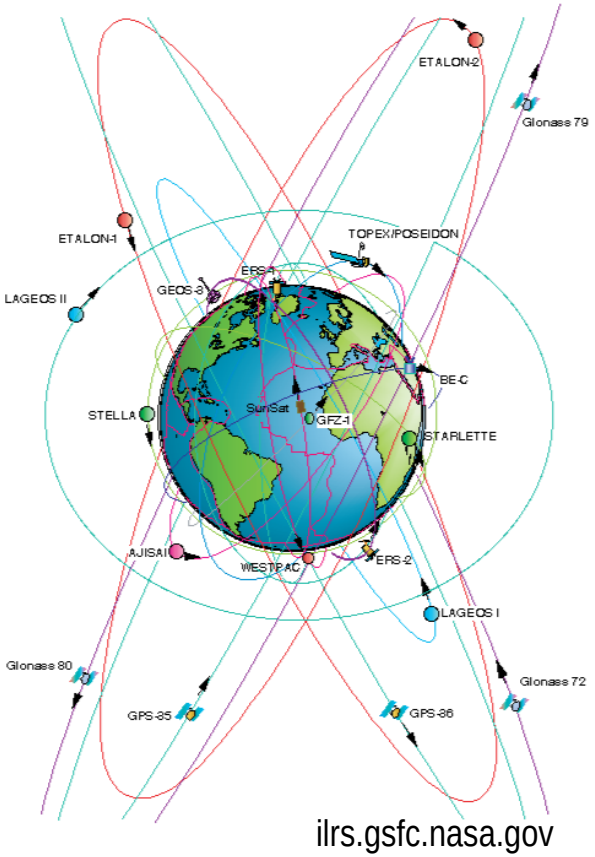
Fly-over chances as a function of a satellite orbit and a station position.

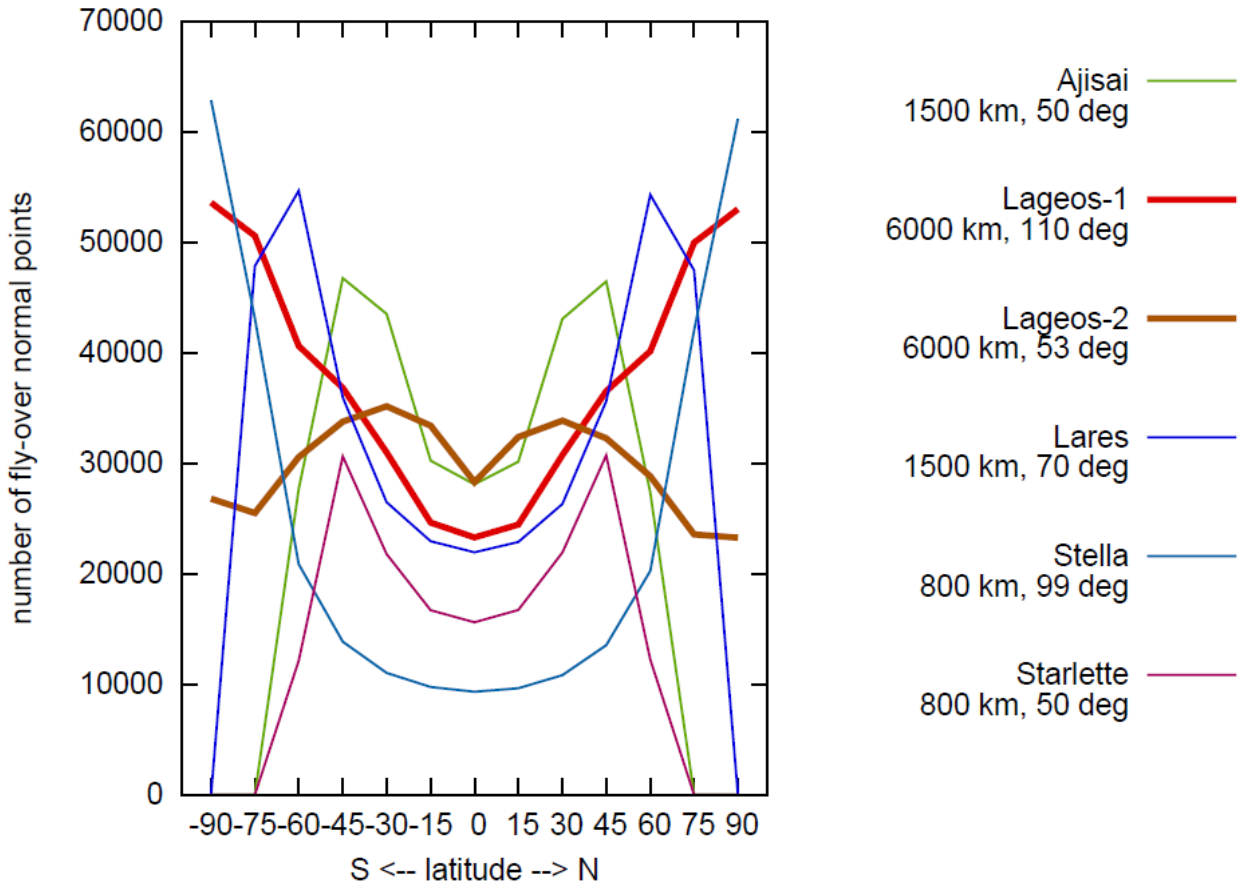
SLR: not a 100%-time observable technique (weather, operator,..).

→Realistic amount/coverage based on the actual observing statistics.

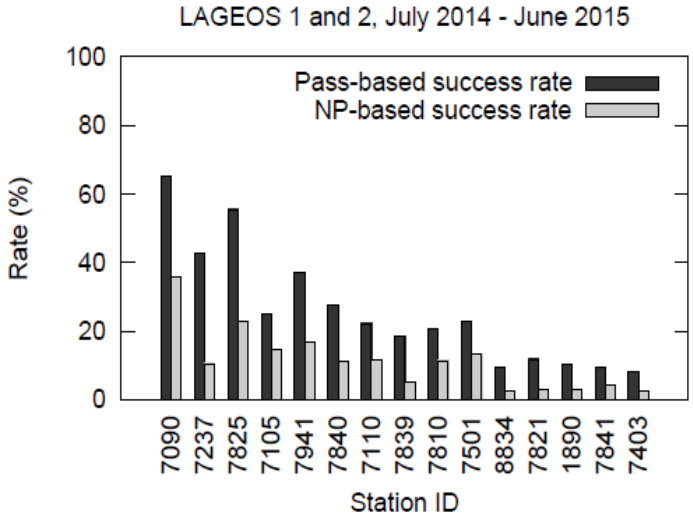
[2] Simulating POD Analysis

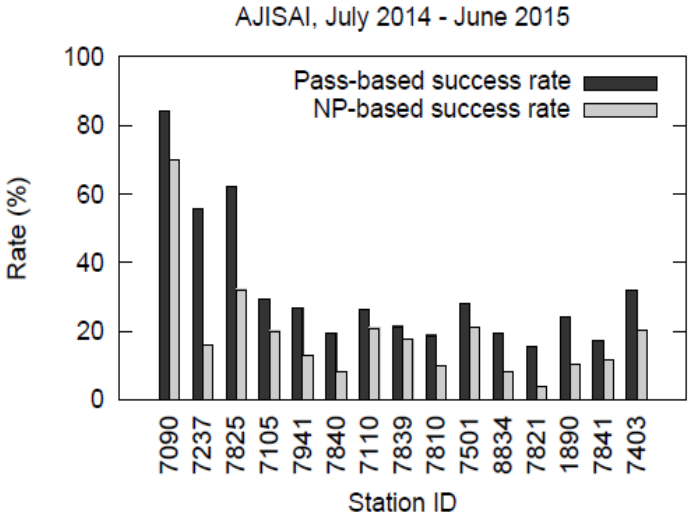
To be explained later.

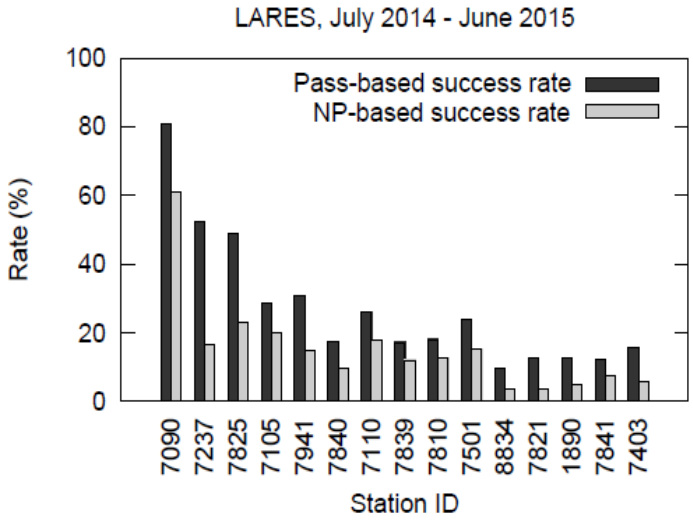


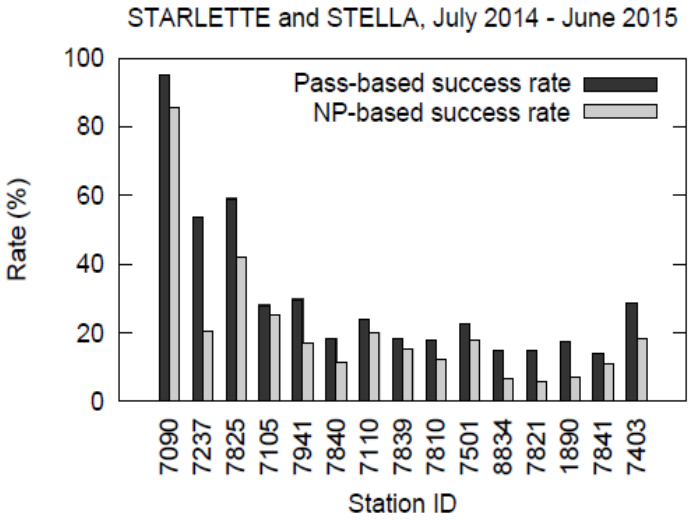


The number of fly-over normal points with respect to the latitude (in degrees) of a ground station, for six geodetic satellites during a one-year period from July 2014 to June 2015. The distance (km) and the angle (degrees) in the legend are the altitude and the inclination of satellite orbits.









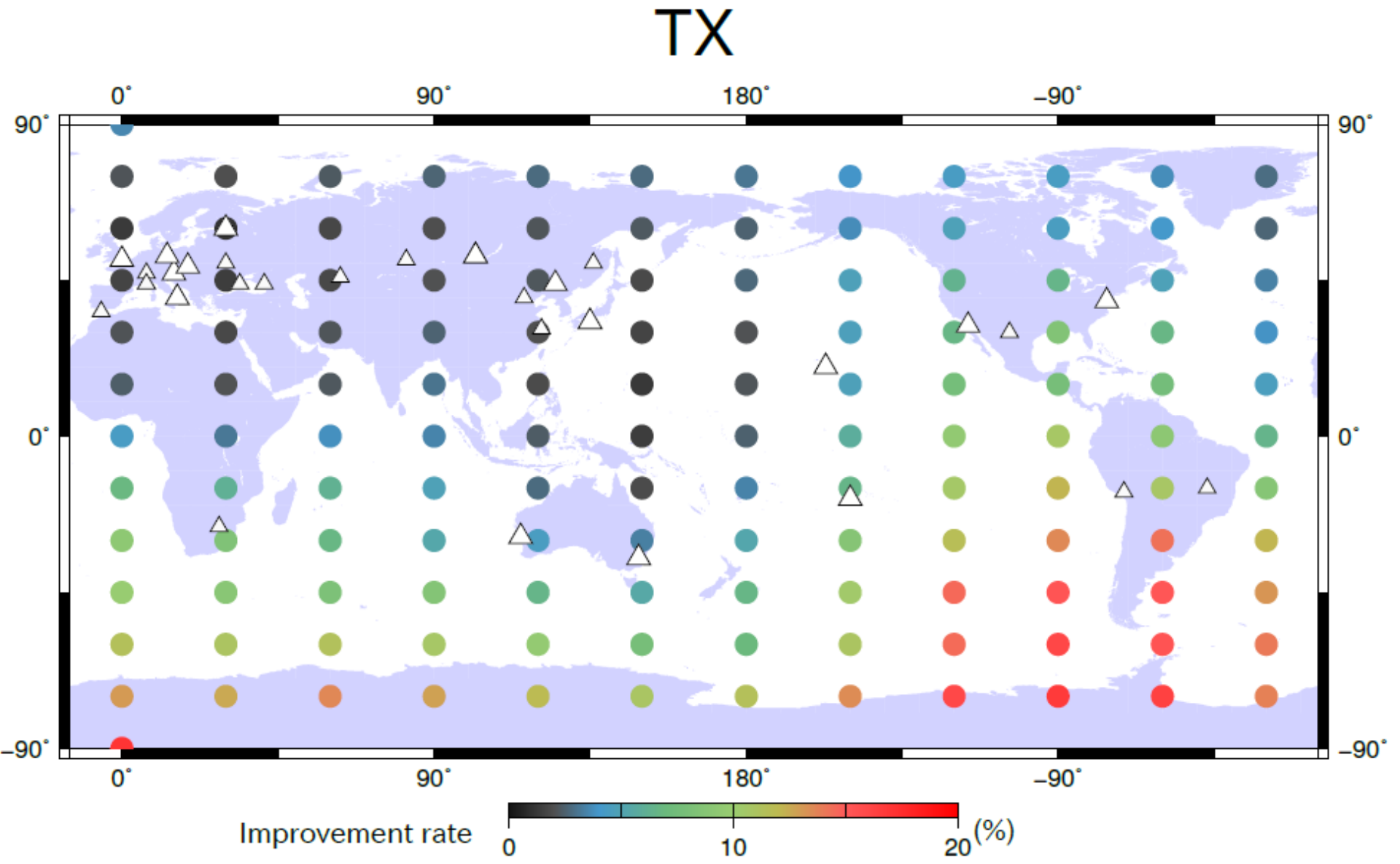
→
Assume
Pass rate 25%
NP rate 15%
（equiv. 5th-10th ）

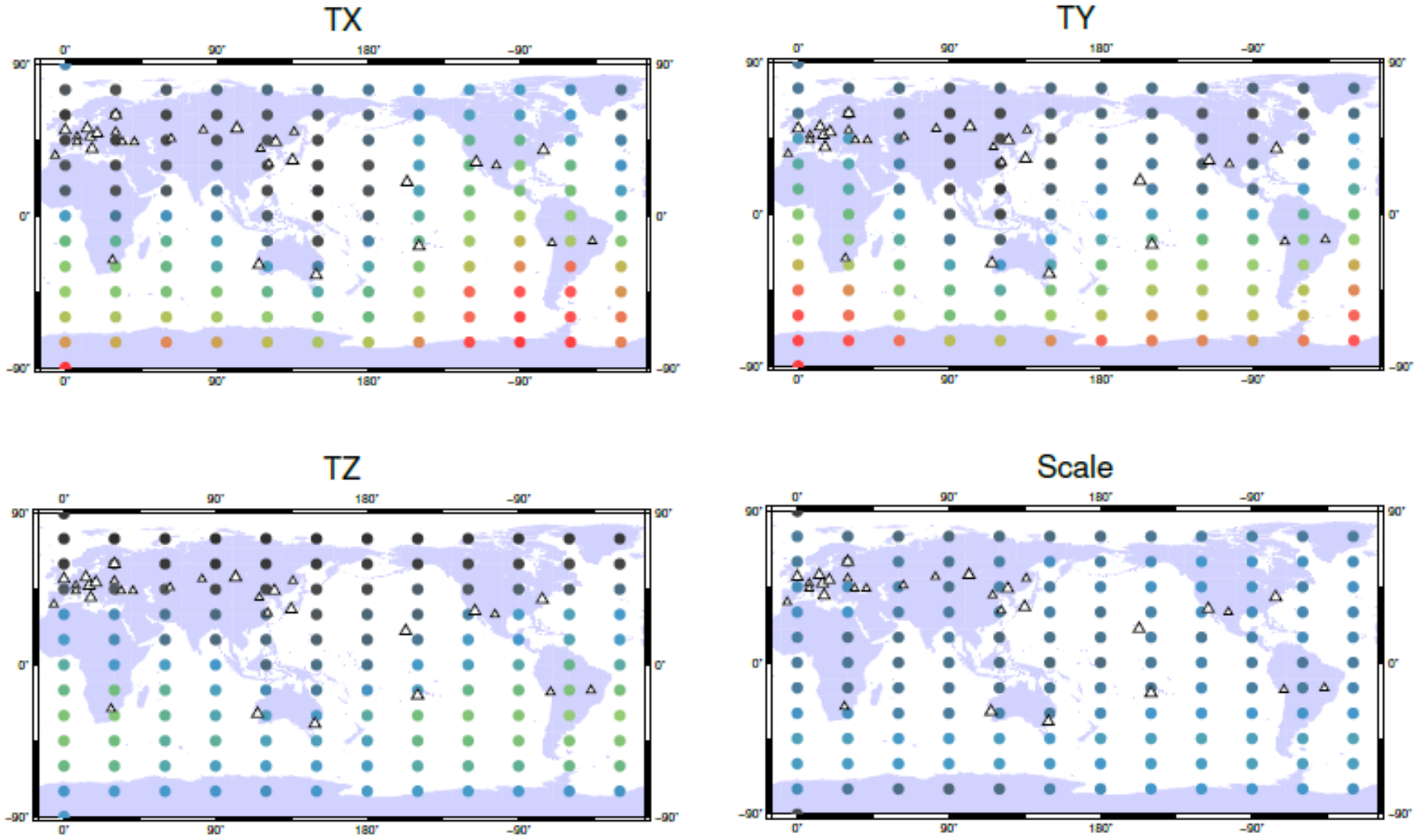
Pass-based success rates and normal-point-based success rates for four types of satellites during a one-year period from July 2014 to June 2015. The horizon for observability is uniformly set at El = 20 deg.

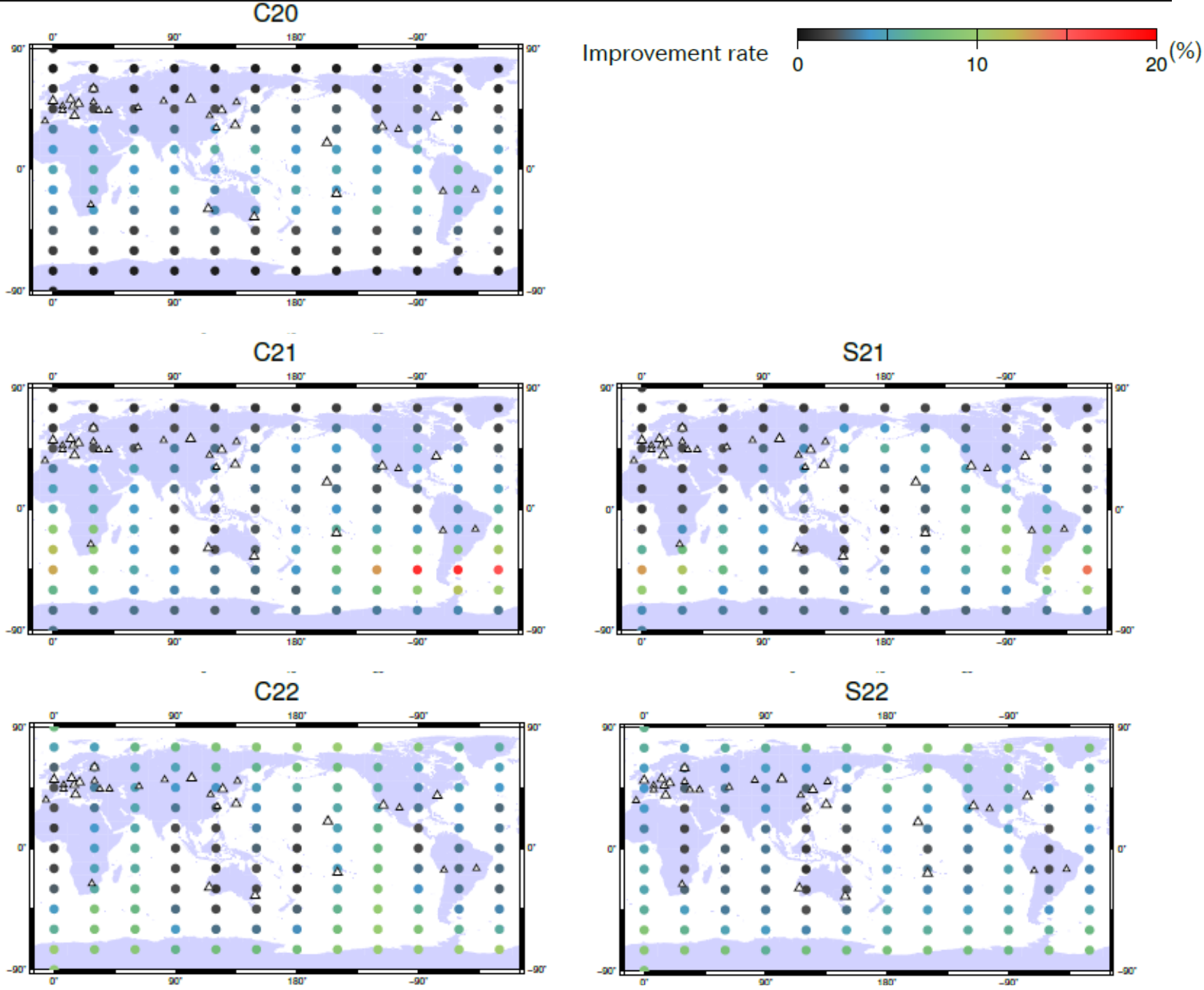
[2] Simulation Analysis

- **Parameters to be investigated**
  - Geocenter (TRF translation)
  - TRF Scale
  - Low-degree Earth gravity terms (up to degree/order 4)
  - (EOP), (Orbit), …

- **POD analysis simulation using software "c5++" R854**
  - 6 satellites (LAGEOS-1, LAGEOS-2, Ajisai, Starlette, Stella & LARES)
  - Baseline setup: Existing ground station network (equal weights for all)
  - Virtual setup: Baseline + one of virtual stations (134 points: latitude 15-deg, longitude 30-deg interval)
  - Span: Mar-Apr 2015
  - **Estimated formal error** = Sqrt(Diagonal element of covariance matrix)
  - Look at the **improvement rate** from baseline to virtual
  - 4-6% increase of total number of observation → 2-3% improvement expected according to the Sqrt(N) rule.


TX
0˚
90˚
180˚
−90˚
90˚
0˚
−90˚
Improvement rate
0
10
20
(%)


TX
TY
TZ
Scale
0°
90°
180°
−90°
90°
0°
−90°
Improvement rate
0
10
20
(%)


C20
Improvement rate
0
10
20
(%)
C21
S21
C22
S22

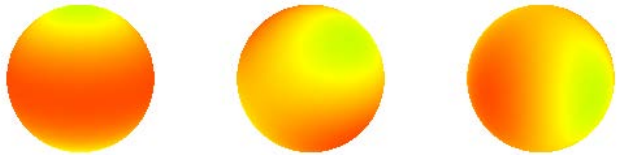
Results

Published in Earth, Planets and Space (Frontier Letter) on 26 Apr 2016

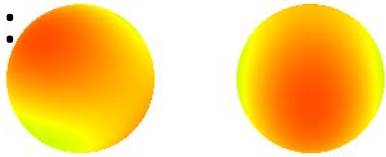
- **Improvement rate: mostly better than 2-3% (predicted by the Sqrt(N) rule).**
  - Building a new station should be encouraged almost anywhere.
- **High latitude stations in S hemisphere effective in general.**

- High-latitude station effective
  - TX, TY, C22, S22 (Sectoral terms)
- Middle-latitude station effective
  - C21, S21 (Tesseral terms)
- Low-latitude station effective
  - TZ, C20 (Zonal terms)
- Similar results for gravity degree-3 & 4 terms
- No significant improvement
  - TRF Scale, Polar motion XY

C_{20} -- C_{22}:



S_{21} -- S_{22}:



Future Studies

- **To relate the outcome with physical phenomena & future projects.**

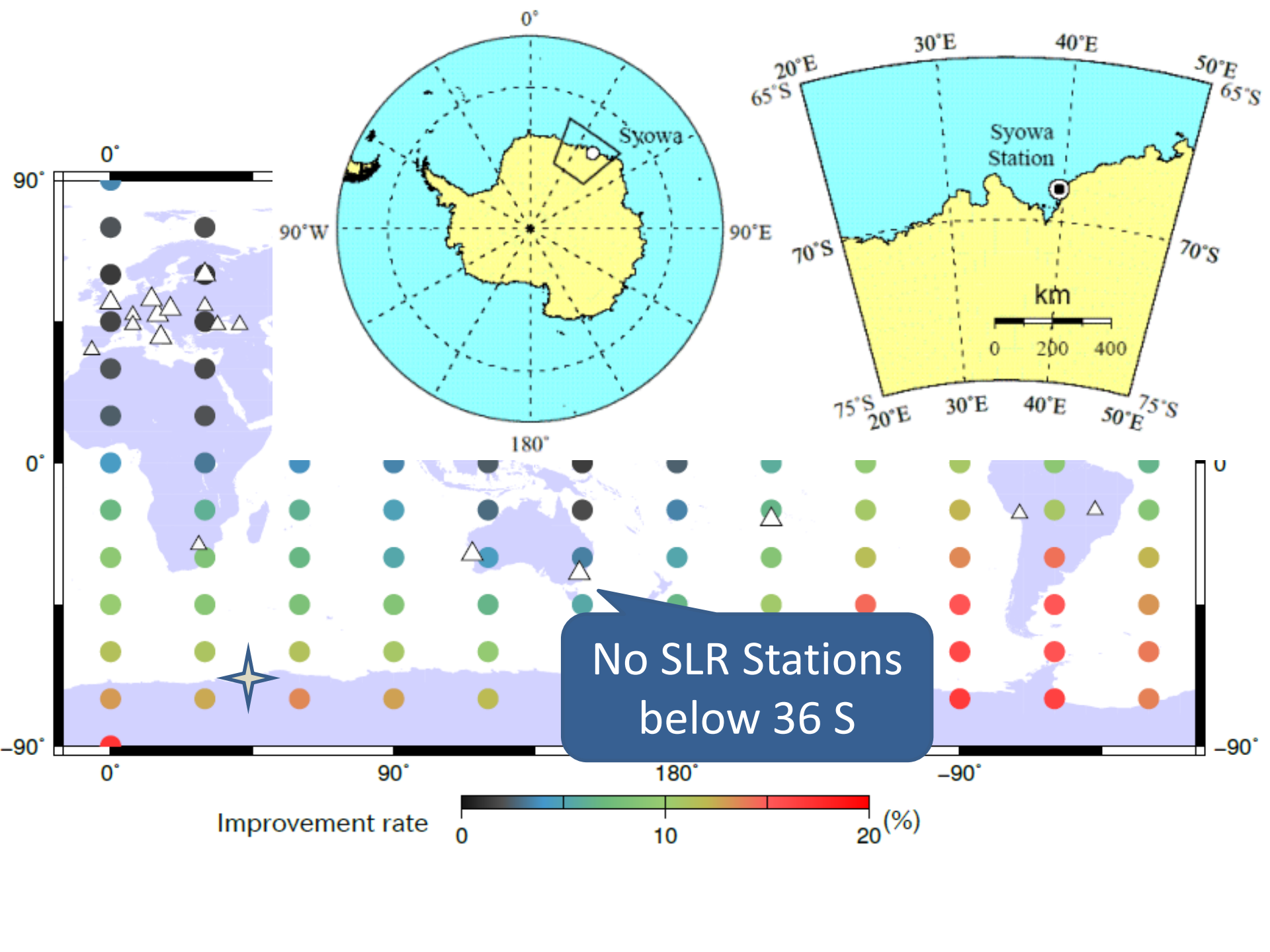
  Proposals welcome.

- **To add “orbits” to the target parameters.**

  For uniform orbit quality all over the world.

- **To compare/combine with VLBI, GNSS, DORIS etc.**

  Analysis software development. GGOS.


0°
90°W
90°E
180°
Syowa
20°E
30°E
40°E
50°E
65°S
70°S
75°S
Syowa
Station
km
0
200
400
90°
0°
−90°
0°
90°
180°
−90°
No SLR Stations
below 36 S
Improvement rate
0
10
20
(%)

Explanatory Research (*not fully funded*) in National Institute of Polar Research, Japan
"Development of Satellite Laser Ranging System for Antarctica" (PI: T Otsubo; 2016.4-2018.3)