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The potential of increased station performances for scientific SLR products

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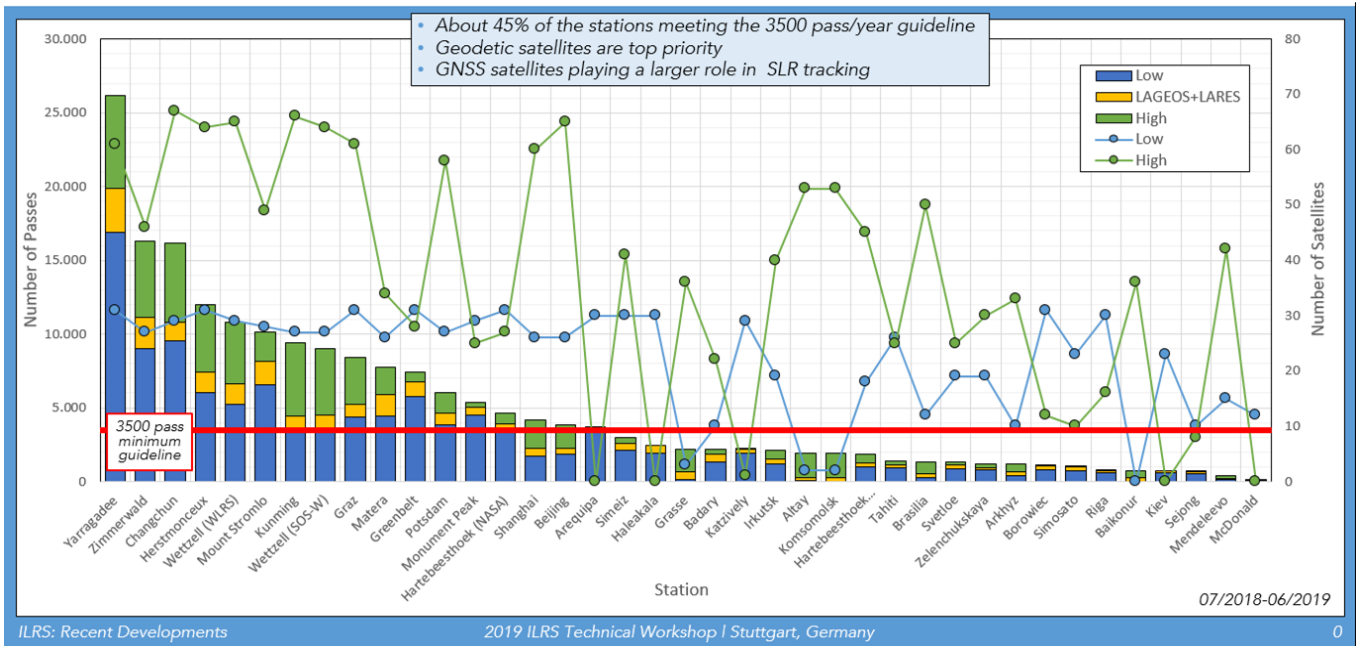
Motivation

- Geodetic products like the ITRF, the EOP or Earth's gravity field coefficients rely on **frequent and homogeneously distributed observations**
- In the last days, I learned a lot about new technologies, system upgrades and other ways to improve the precision and efficiency of SLR stations
- This talk should …
  - … **encourage stations to further improve their systems**
  - … **tries to give an outlook what might happen at product level**
- Simulations what happens if new stations are built in addition to the existing network are given in **Kehm et al., 2017**, **Männel et al., 2019** and **Kehm et al., 2019**

Current situation

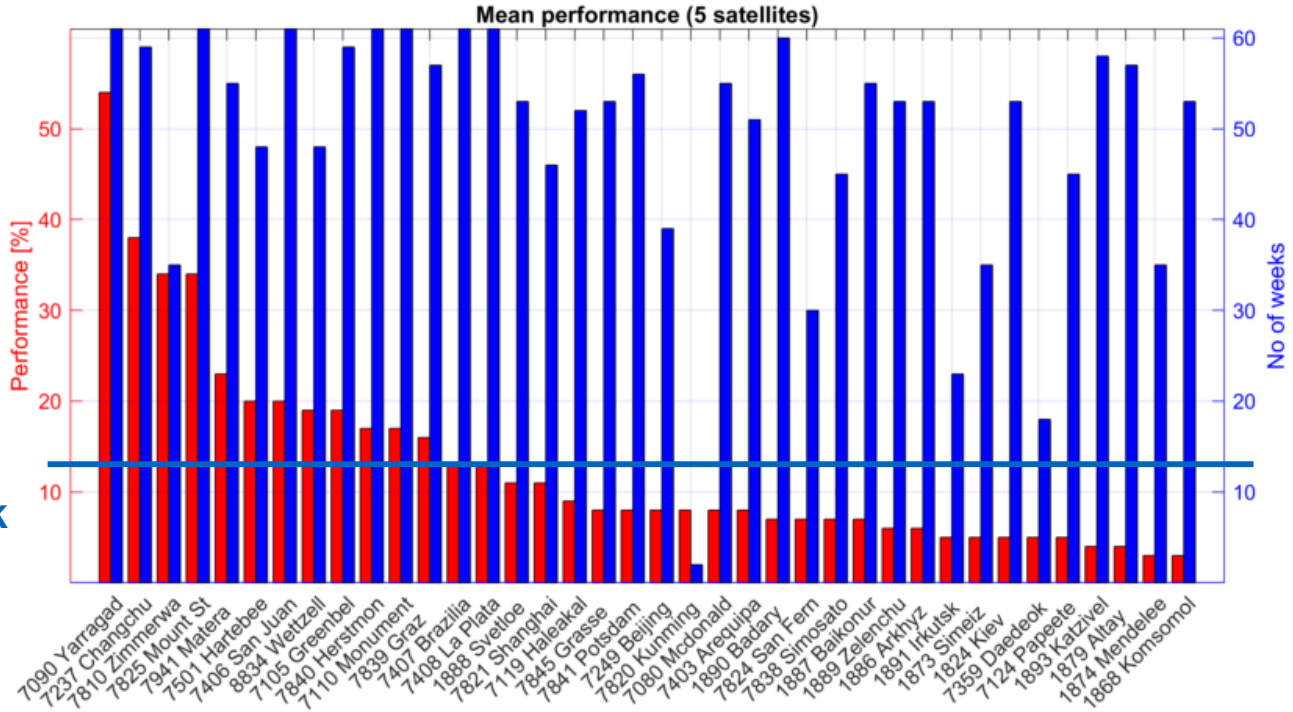
- In 2014/2015, only **12 stations met the required ILRS pass performance** and **contributed significantly to ITRF2014**



[courtesy: C. Noll]

Current situation

- Mean real station performances based on LA-1/-2, Et-1/-2 and LRS in 2014/2015



~ 13%: mean ILRS network performance in 2014/2015

Current situation

- Station performances depend on many things which **can only partly be influenced**
  - weather conditions
  - funding
  - etc.
- Beside such constraints, **technical reasons** such as
  - laser repetition rate
  - grade of automation
  - etc.

  limit the efficiency (performance) of a station
- **What would happen if stations have time/money/people to upgrade their station?**

Simulation scenarios

- To **quantify effect of upgraded stations** (network parts), we defined **5 different scenarios**

Scenario	description
real	2014/2015 ILRS network with real performances
Asian network	5 stations <13% → 13%
Russian network	11 stations <13% → 13%
South-American network	1 station < 13% → 13%
Hartebeesthoek	20% → 30%

Simulation scenarios

- **Performance assumptions (reference case)**
  - Reference network: pass performances determined empirically for a time span of approx. 1.5 years, ranging from 3% … 54 %. The performance values exclude longer periods of inactivity (> 1 week)
  - Stations within the global reference network have been simulated only when actually operational (not in periods of inactivity > 1 week)
  - AGGO (La Plata) and Brazilia have been assumed to be operational throughout the whole time span with a performance of 13 % (the average of the existing network)

Simulation scenarios

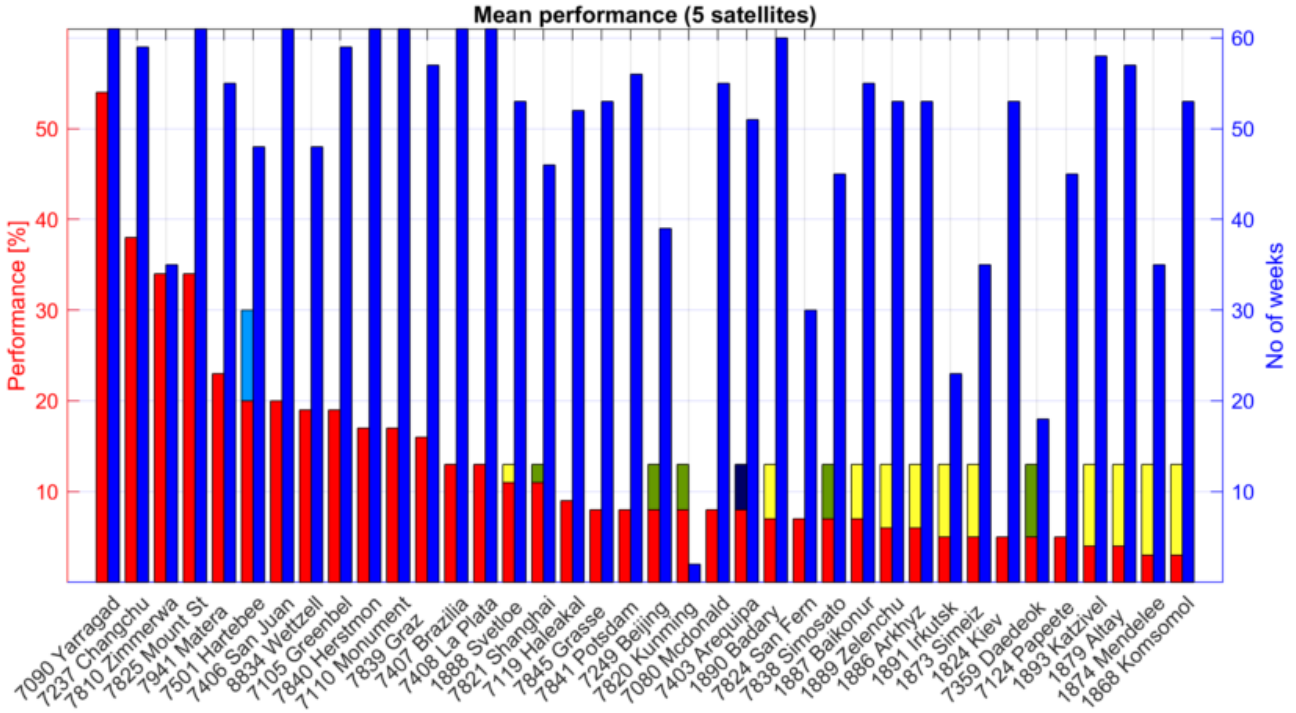
- **Assumed scenario**
  - Weekly SLR-only TRF (origin, scale realized by SLR, orientation via NNR condition) and daily SLR-only EOP
  - 5-satellite setup (LAGEOS-1/-2, Etalon-1/-2, LARES → future ILRS setup)
  - 61 weekly solutions (GPS weeks 1792 … 1852)

- **Error modelling**
  - Observation white noise 1 cm (close to the RMS of real orbit processing)
  - Model errors accounted for by switching the gravity field (EIGEN-6S → GGM05S) and the Ocean tide/loading models (EOT11a → FES2004)

Simulation scenarios

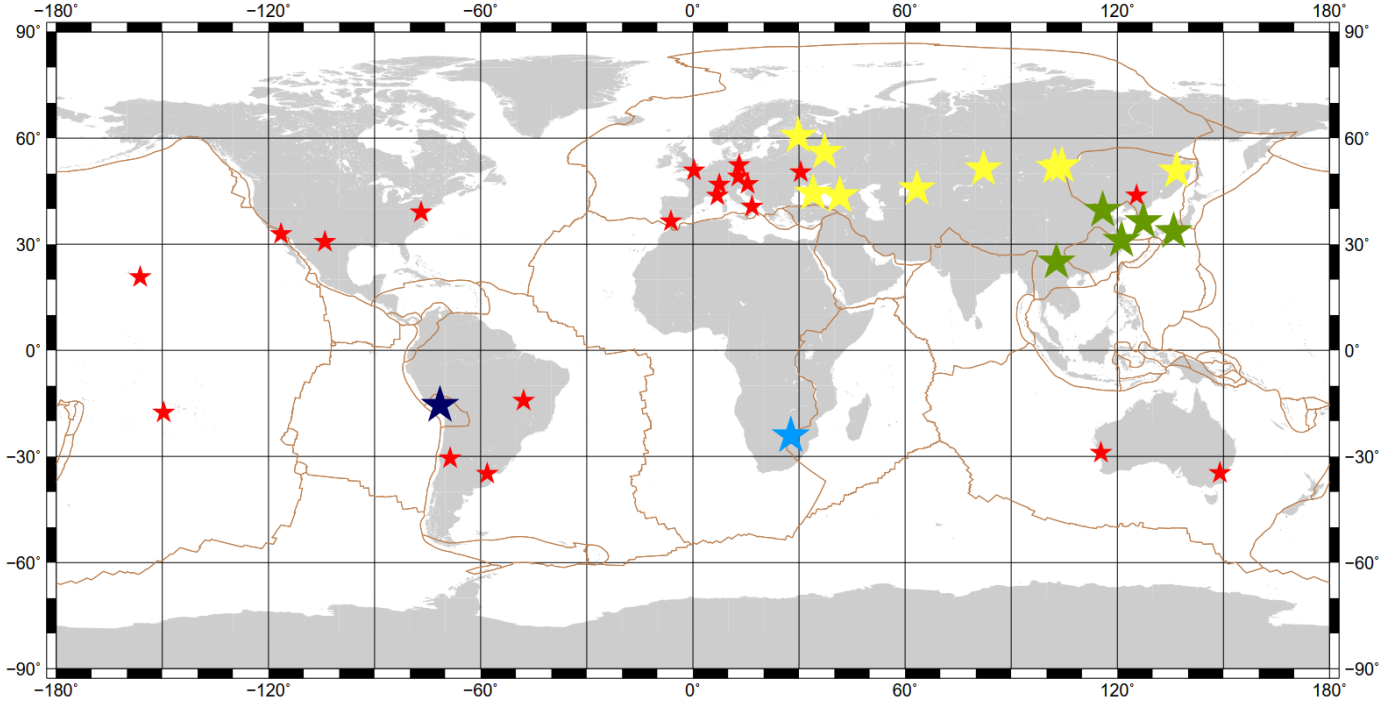
➢ **Increased performances** for the simulated scenarios

- Real ILRS network in 2014/2015
- South American network
- Hartebeesthoek
- Asian network
- Russian network



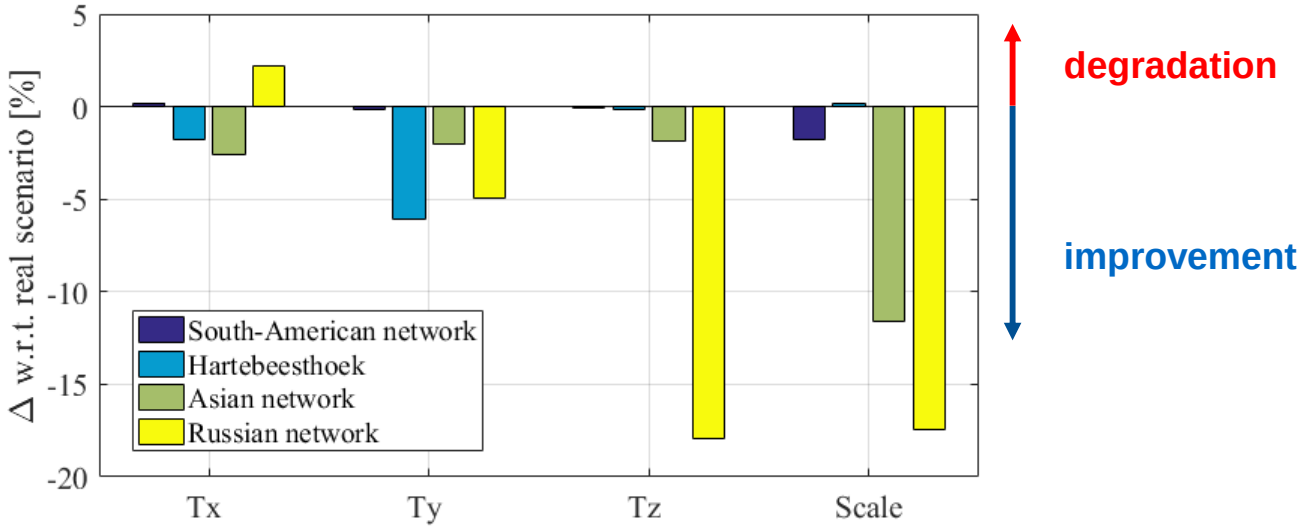
Simulation scenarios

- real network in 2014/2015, South-American network, Hartebeesthoek, Asian network, Russian network



Simulation results

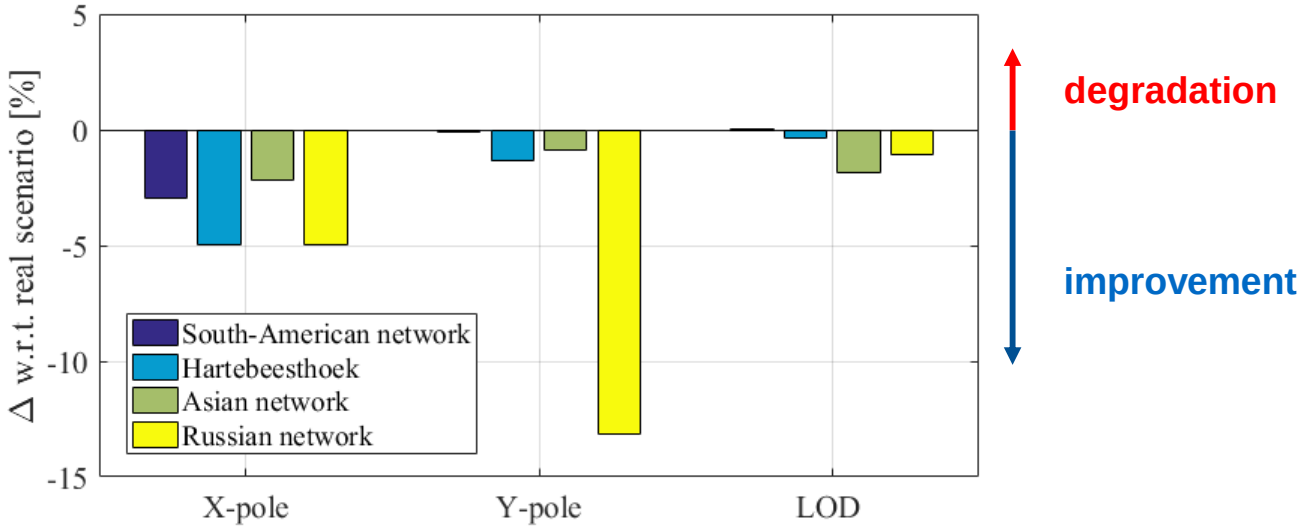
- Effect on **TRF datum parameters** (uniquely) realized by SLR (change of time series scatter w.r.t. SLRF2014 compared to real scenario)



- **Large impact of Russian and Asian network** on scale improvement (up to 18%), **Hartebeesthoek important** for y-component of origin

Simulation results

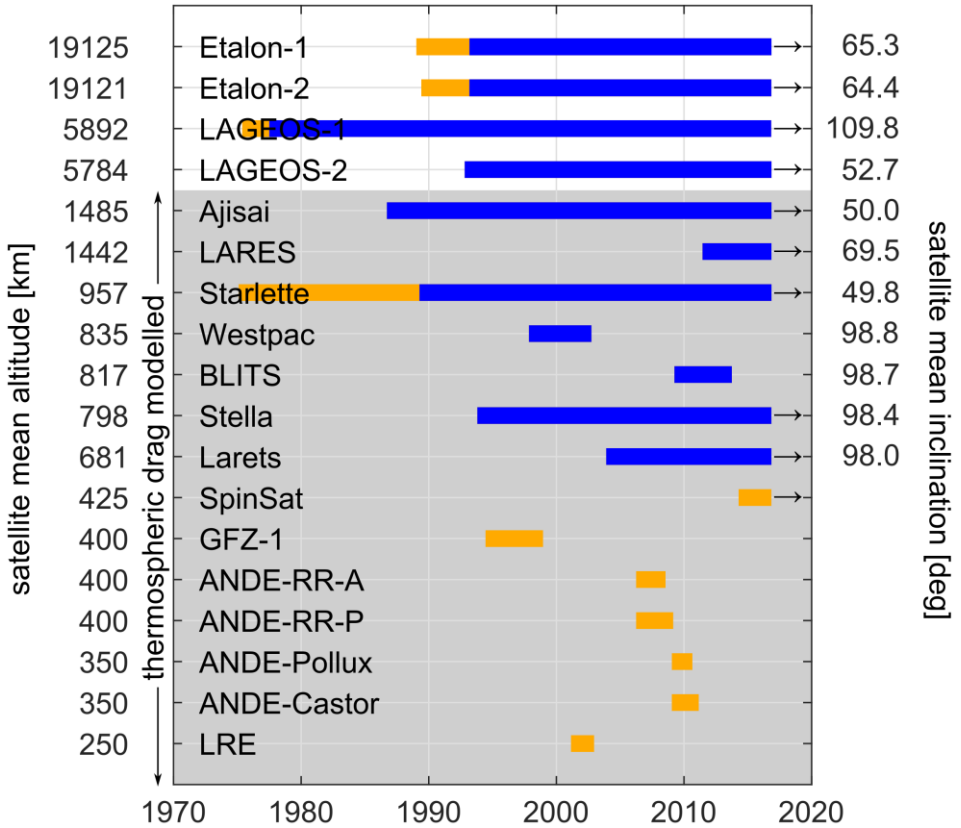
- Effect on Earth Rotation Parameters (ERP; change of time series scatter w.r.t. IERS 14 C14 compared to real scenario)



- **X-pole benefits from any network upgrade** by up to 5%,
  Y-pole significantly improved by Russian network upgrade (up to 14%)

Increased performance → more time for other targets

- SLR observations to up to **11 geodetic spherical satellites**
- Nearly **4 decades of data** (1979 - 2017)
- Various satellite altitudes / satellite inclinations
- Diverse target signatures
- Relative weighting via VCE
- **ILRS includes LARES observations now in routine products**
- This will continue in the future → **what to expect?**



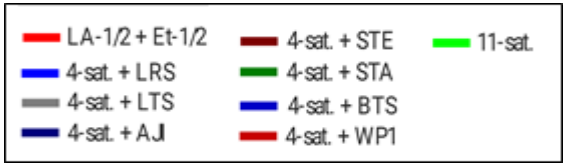
Increased performance → more time for other targets

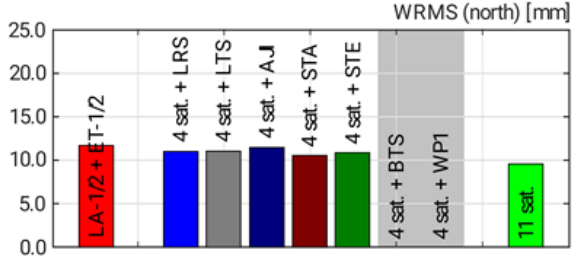
Weekly transformation of estimated TRF w.r.t. SLRF2014

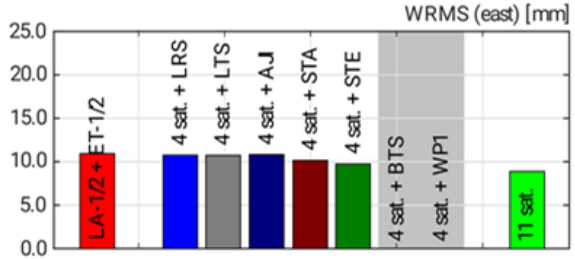
- Max. reduction of scatter of TRF datum: **35 %**
- Station repeatability improvement by up to **22 %**
- **No significant spurious signals** (e.g., draconitic periods) in station coordinate time series

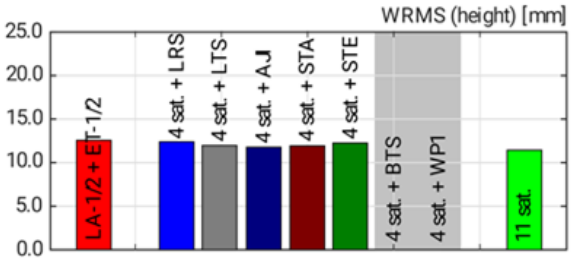
ERP benefit similarly from additional satellites

- WRMS of the ERP reduced by up to **26 %**





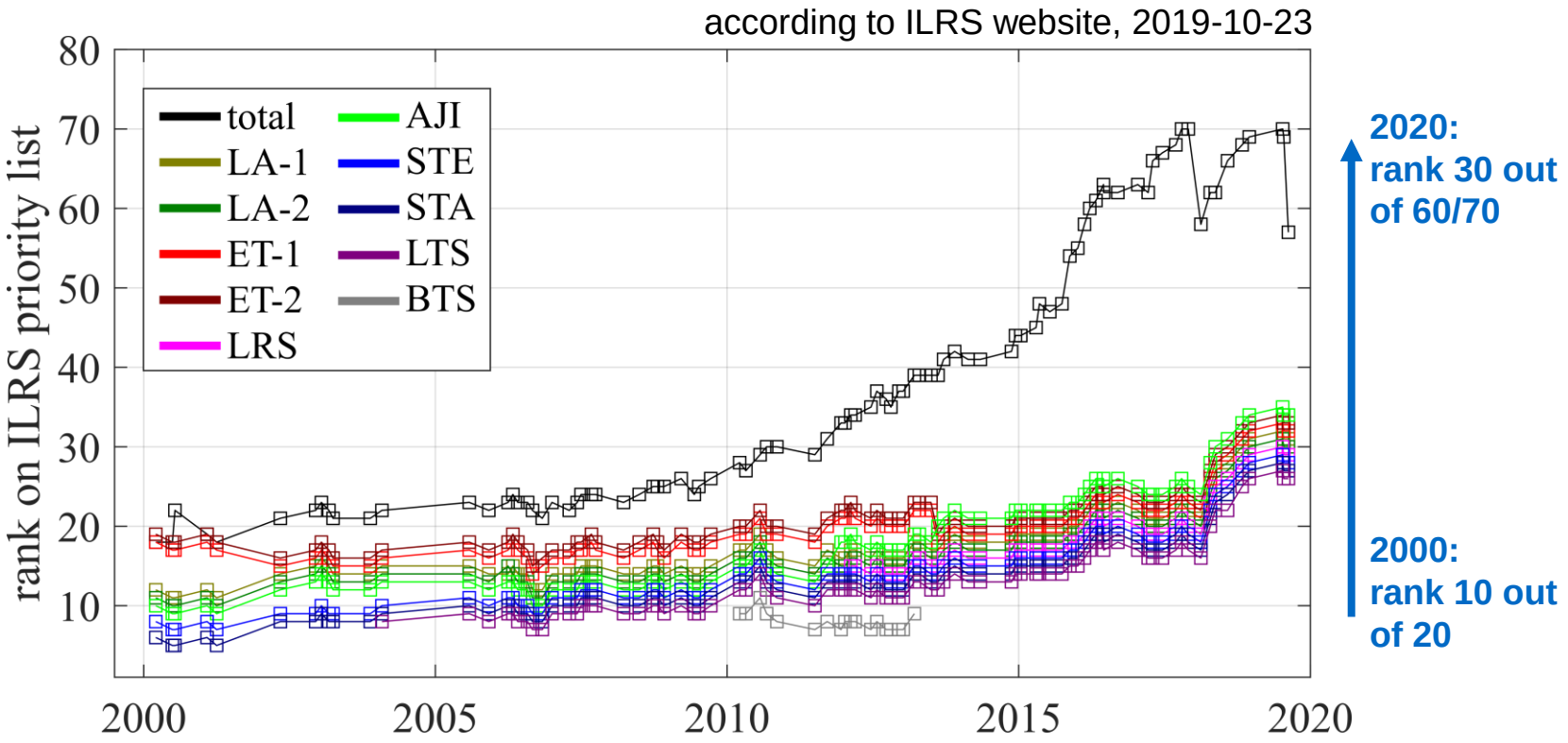




Conclusions

- **System performance improvement**
  - Large impact of Russian and Asian network on scale improvement (up to 18%), Hartebeesthoek important for y-component of origin
  - X-pole benefits from any network upgrade by up to 5%, Y-pole significantly improved by Russian network upgrade (up to 14%)
- **Satellite constellation improvement**
  - Max. reduction of scatter of TRF datum about 35 %, station repeatability improvement by up to 22 %, no significant spurious signals introduced
  - ERP benefit similarly from additional satellites

Current ILRS priority list



Key aspects investigated at DGFI-TUM

- Kehm A., Bloßfeld M., Pavlis E. C., Seitz F.: **Future global SLR network evolution and its impact on the terrestrial reference frame**. J Geodesy, 92(6), 625–635, 10.1007/s00190-017-1083-1, 2017

  Discussion of station upgrade vs. network extension

- Männel B. Thaller D., Rothacher M., Böhm J., Müller J., Glaser S., Dach R., Biancale R., Bloßfeld M., Kehm A., Herrera Pinzon I., Hofmann F., Andritsch F., Coulot D., Pollet A.: **Recent Activities of the GGOS Standing Committee on Performance Simulations and Architectural Trade-Offs (PLATO)**. IAG Symposia, 10.1007/1345_2018_30, 2018

  Summary of the GGOS WG PLATO activities

- Bloßfeld M., Rudenko S., Kehm A., Panafidina N., Müller H., Angermann D., Hugentobler U., Seitz M.: **Consistent estimation of geodetic parameters from SLR satellite constellation measurements**. J Geodesy, 92(9), 1003–1021, 10.1007/s00190-018-1166-7, 2018

  Improvement of geodetic products based on SLR space segment extension

- Kehm A., Bloßfeld M., König P., Seitz F.: **Future TRFs and GGOS – Where to put the next SLR station?**. ADGEO (accepted; EGU open access journal), 2019

  Where to put the next SLR station?

Take home messages

- **Upgrading the station performances is of equal importance than building completely new stations!**

- **Please upgrade your station to increase efficiency!**

  Station upgrades lead to an increased performance which **strengthens the impact of the particular station** in the ILRS network and **improves derived geodetic products**!

  (If you need a special simulation just for your station, feel free to contact us!)

- **Please track as many spherical satellites as possible!**

  Future geodetic products like the **ITRF will most likely be based on those observations** and therefore, a **long observation history is needed**!

  (Also tracking of non-spherical LEOs and GNSS satellites is important since co-location in space will cause a boost of consistency in future geodetic products)