Optical Inter-Satellite Links for Global Navigation Satellite Systems

Monika Stetter, Urs Hugentobler, Anja Schlicht

Institute of Astronomical and Physical Geodesy, Forschungseinrichtung Satellitengeodäsie, TU München

1.1 Outline

Most of the present GNSS constellations are equipped with inter-satellite link (ISL) technology. The key tasks of ISL are the increase of the constellation's autonomy, the achievement of shorter update intervals for the ephemerids in the navigation message and the reduction of operational costs. The common technique for implementing ISL links between GNSS satellites is the use of microwave signals e.g. in the Ka-Band. Another considered technique, which e.g. features a favorable interference resistance, would be optical ISL (OISL).
An evaluation of OISL for the use in a GNSS constellation will be presented. On the basis of simulated OISL observations the benefit of OISL for precise orbit determination is discussed.

1.2 Benefits of optical ISL

In Figure 1 the advantages of ISL and OISL are listed. The major benefits of ISL are the rise of the autonomy from the ground segment, the ability to synchronize the satellite clocks and the potential to reduce the number of stations in the ground segment. The main advantages of OISL compared to microwave ISL are its interference resistance and the higher possible modulation rate.

ISL general

- Potential reduction of ground stations
- Shorter time to Integrity Alert (SOL)
- Robustness against ground station unavailability
- Improved constellation geometry measurements
- Higher data update rates
- Higher Ephemeris/Clock update rates
- Ability for swarm intelligence (S/C cluster)
- Immediate TC/TM for al S/C
- Data relay for all S/C (add, drop and transmit capability)
- Longer communication window for S/C operators

Optical ISL

- No ITU regulations required
- No Interference
- No Jamming
- Robust against eavesdropping
- Key distribution (quantum keys)
- Highly accurate orbit determination
- High bandwidth commercial service
- Ability of hardware savings (clock redundancy)
- Immediate clock dissemination and synchronization of all S/C

Figure 1: Advantages of ISL (left) and in particular of optical ISL (right)

2.1 Simulation flow

The simulation has been aiming at assessing the potential improvement of precise GNSS orbits by introducing OISL observations into the estimation process. Therefore conventional GNSS as well as GNSS-OISL solutions have been computed and compared. The OISL and GNSS observations used have been simulated as ranges and have been attached with realistically systematic and formal orbit errors (see Figure 2). Furthermore errors in the orbit model have been simulated in terms of solar radiation pressure modeling errors. To evaluate the results the estimated orbits have been compared to the "true" orbits (orbits used to simulate the observations).

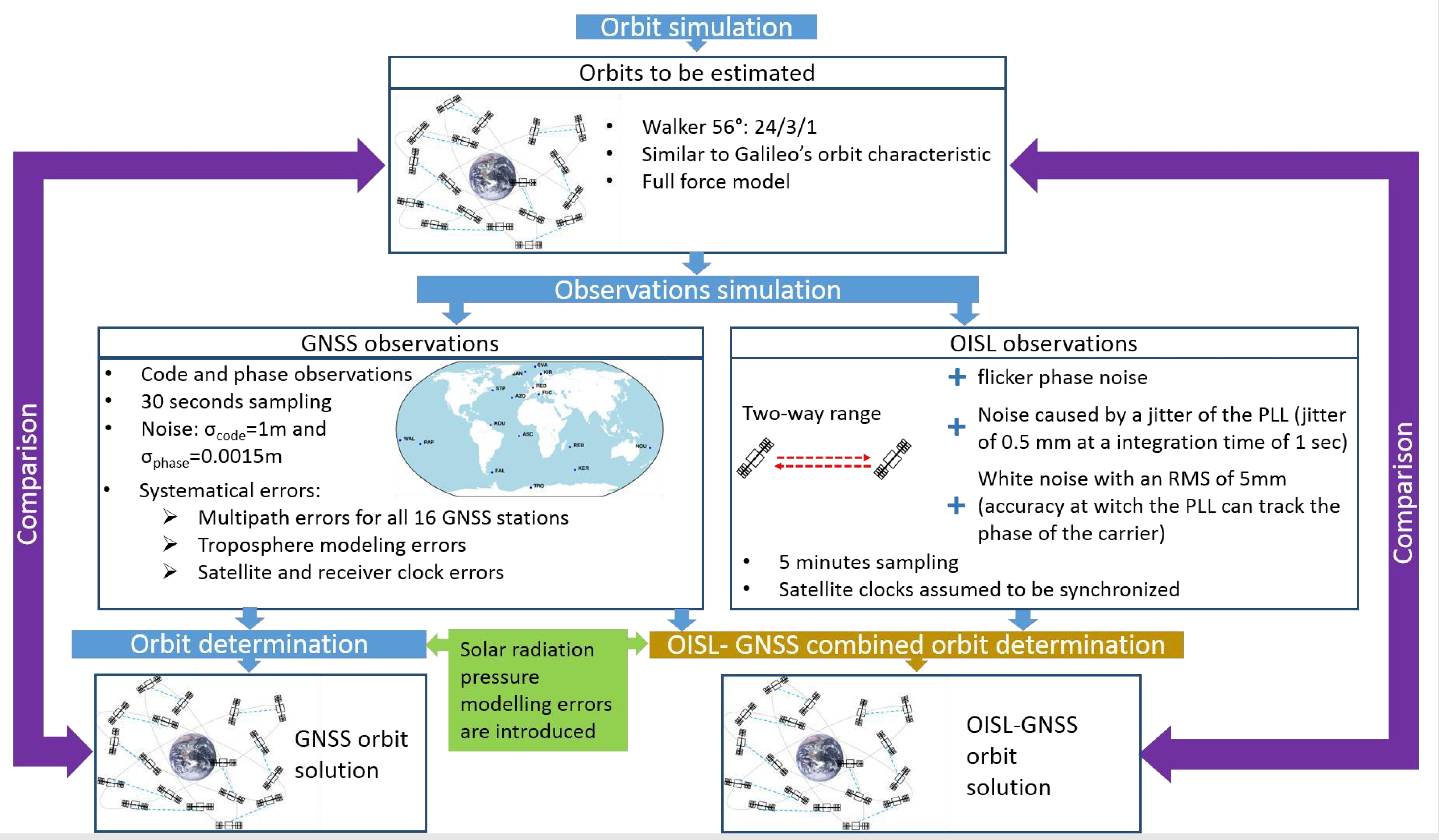

Figure 2: Flow chart of the performed simulation

3.1 Results

Shown are orbit solutions computed only with GNSS observations compared to GNSS-OISL combined solutions. Represented are absolute orbit errors (differences between the estimate and the "true" orbits) as well as formal orbit errors.

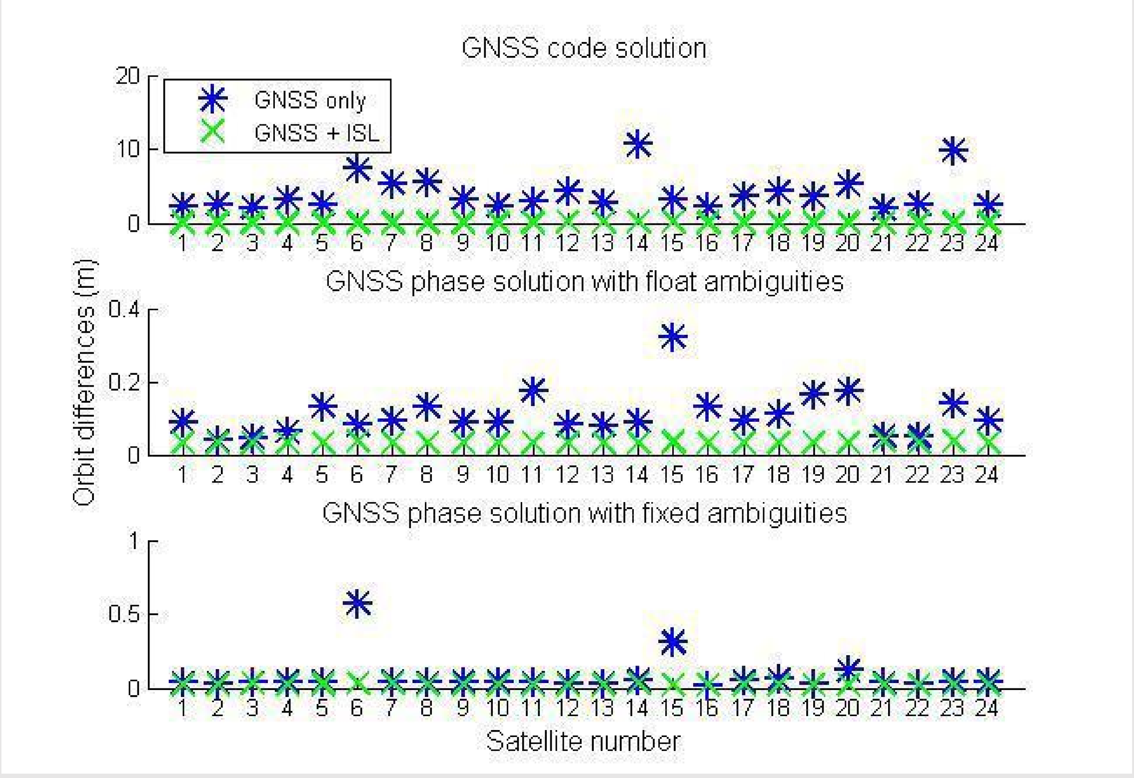

Figure 3: Orbit differences per satellite for the solution of a 7 station GNSS network (blue) and the same solution with additional OISL observations used (green).

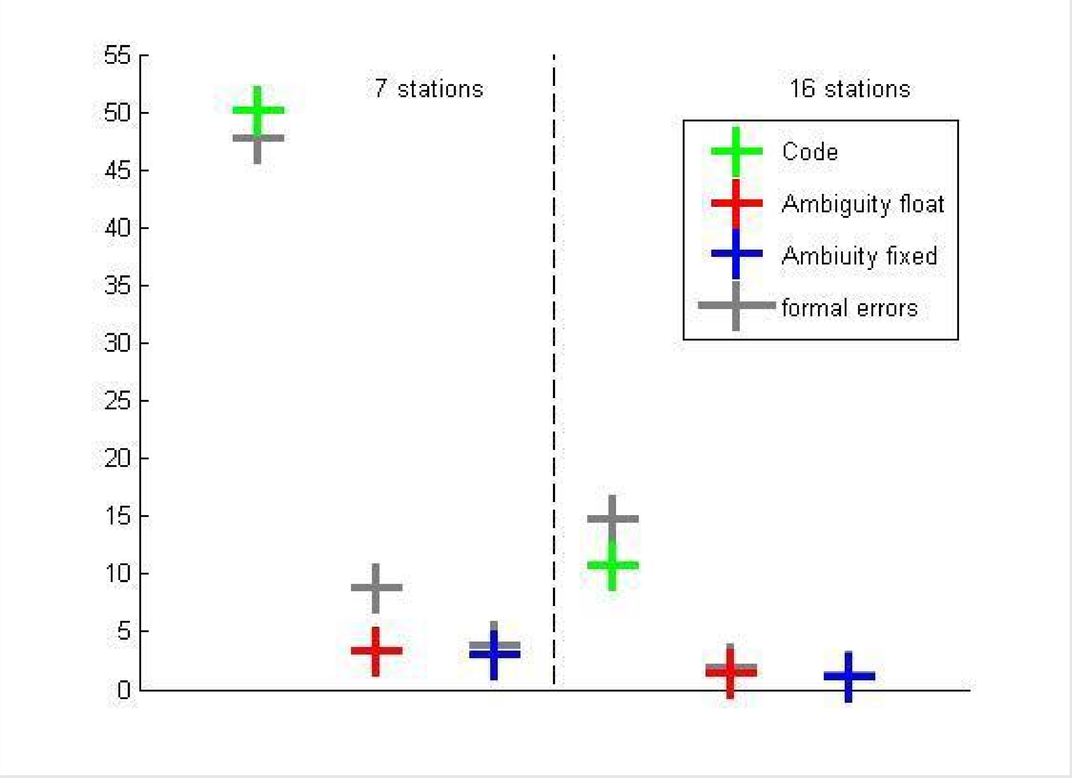

Figure 4: Mean factor by which the orbit differences (colored) and the formal orbit errors (gray) are reduced when OISL observations are introduced.

		7 stations			16 stations		
		Code	Amb. float	Amb. fixed	Code	Amb. float	Amb. fixed
Orbit differences in mm	GNSS only	3973	109	75	758	38	20
	GNSS + OISL	79	33	25	71	27	20
Formal orbit errors in mm	GNSS only	5747	25	9	731	4	1
	GNSS + OISL	120	3	2	50	2	1

Table 1: Mean orbit differences and mean formal orbit errors for GNSS only solutions compared to GNSS+OISL solutions.

3.2 Conclusions and outlook

It has been shown that GNSS small network solutions (7 stations) and GNSS code solutions can be significantly improved by the introduction of OISL observations. Furthermore, OISL observations make it possible to determine orbits very precisely for satellites with a reduced number of GNSS observations.
The here presented results have been generated within the framework of a DLR project called GOISL. For this project OISL observations of low accuracy have been used. Therefore it could be promising to carry out an analysis with more accurate OISL observations, what might lead to higher improvements also for the GNSS phase solutions. Future work will focus on expanding the simulations by bringing more variation into the modeled errors (e.g. into the tropospheric delays) and on introducing EOP parameters as additional unknowns into the estimation process.

IGS WORKSHOP **2017**

PARIS | 3-7 July 2017

email: m.stetter@tum.de