Exploiting the synergy between optical two-way and microwave one-way ranging in a GNSS constellation

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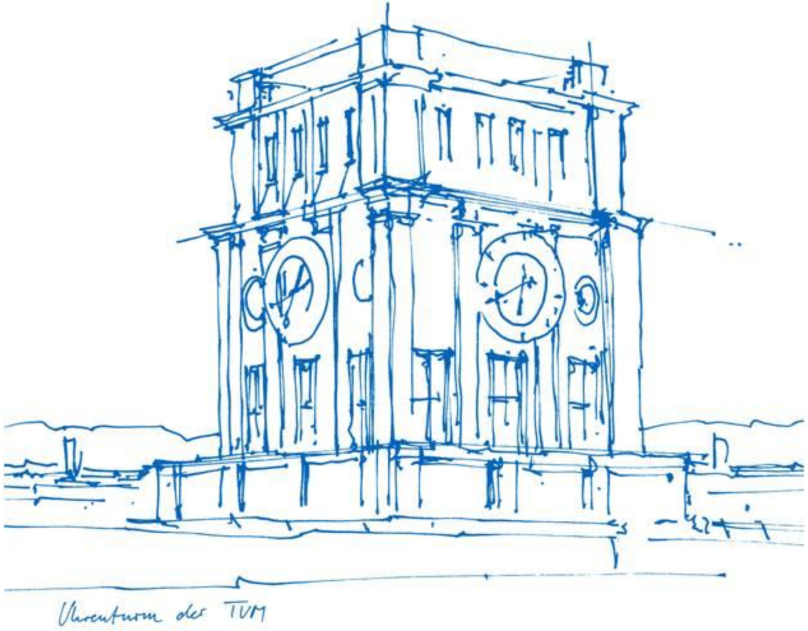


22nd International Workshop on Laser Ranging

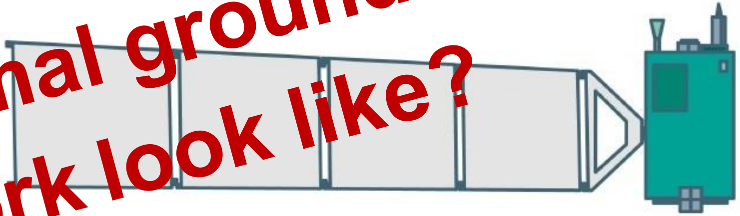
Jebes Spain

Motivation: GGOS

Co-location on ground

Co-location in space

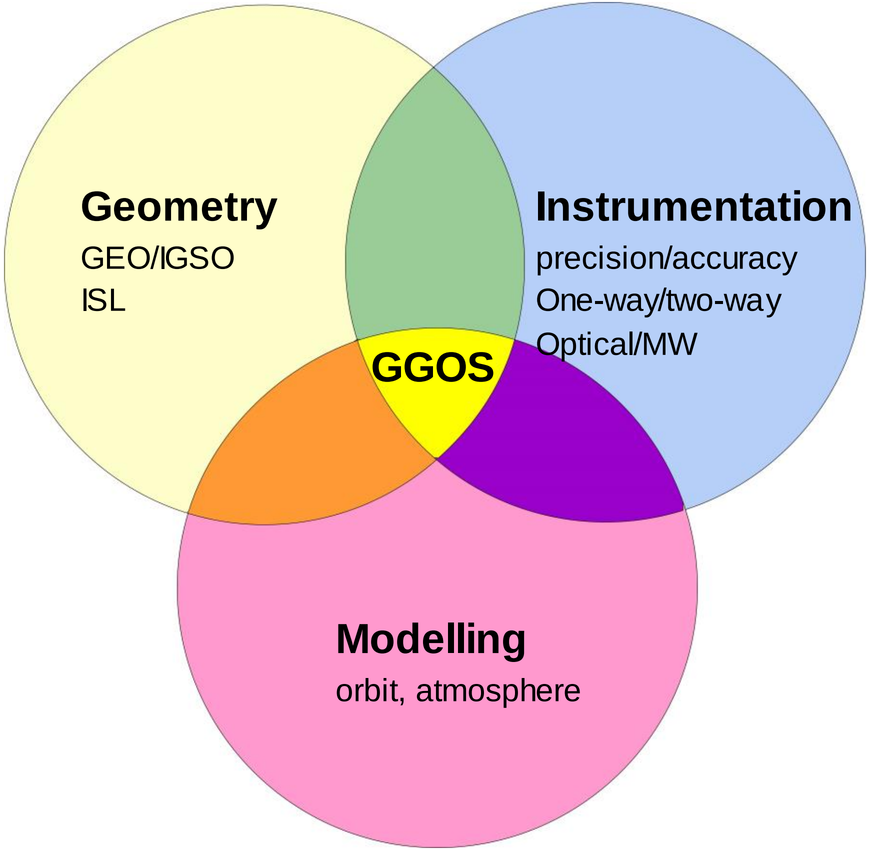
e.g. GENESIS



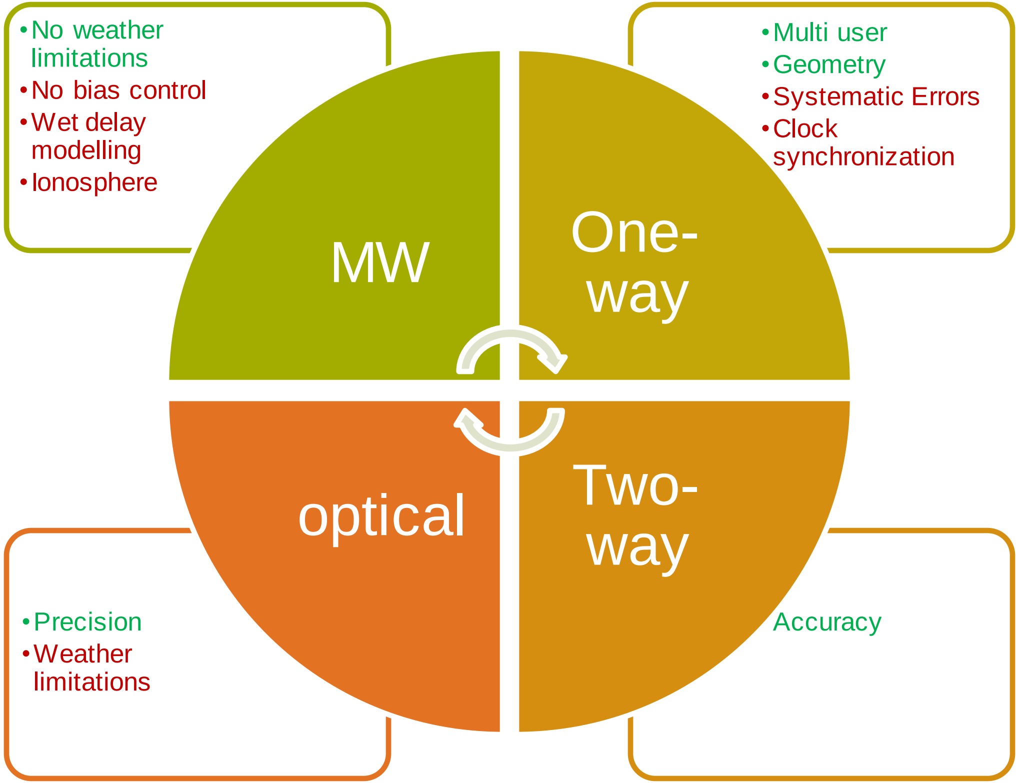
How to combine?

How would an optimal ground and satellite network look like?

Dependencies



Ranging and Time Transfer Methods



Inter-Satellite Links in GNSS:

- optical two-way 1mm precision @ 30s,
- any-to-any scenario
- biases estimated

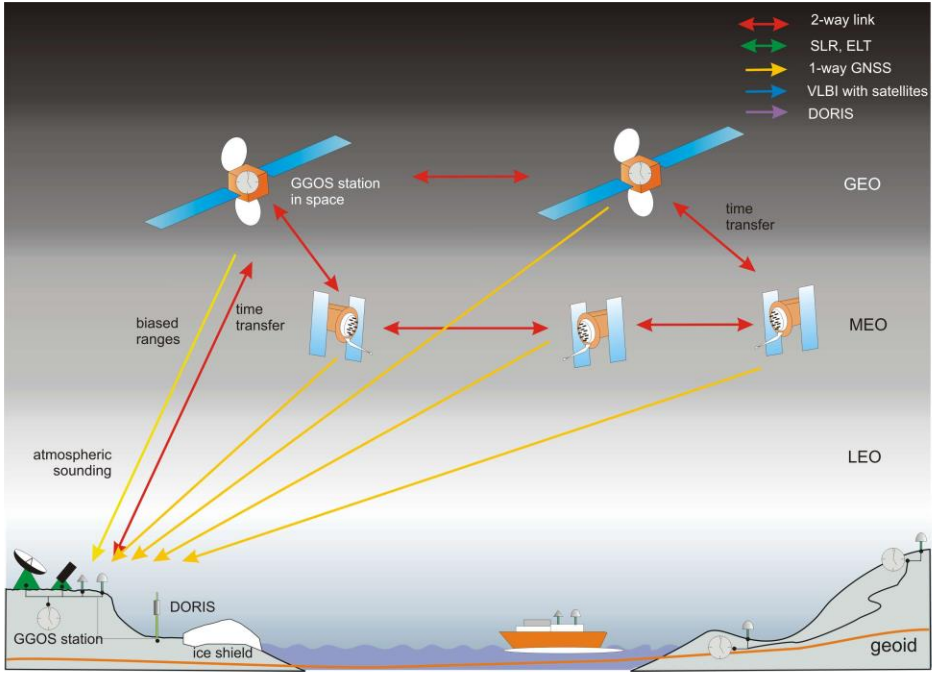
Ground Links:

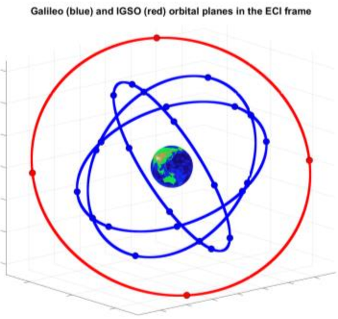
- co-located MW one-way and optical two-way 1mm precision @ 30s
- time and range
- biases estimated
- Common Troposphere Parameter estimation

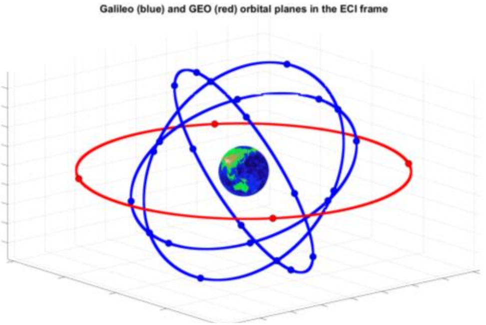
Problem in combination:

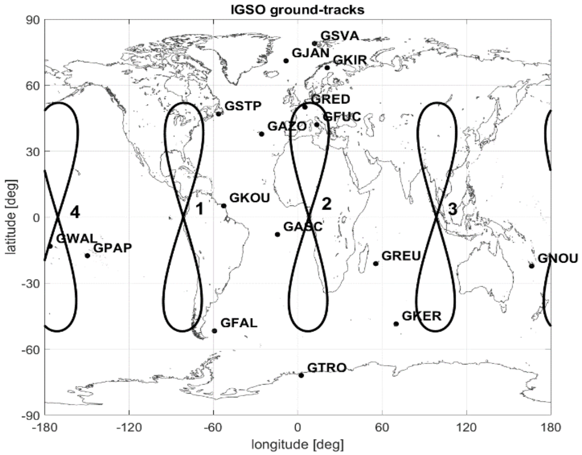
- Weighting of measurements with great difference in number of observations, accuracy, and modelling parameters

Ranging methods, satellite constellations and ground station network









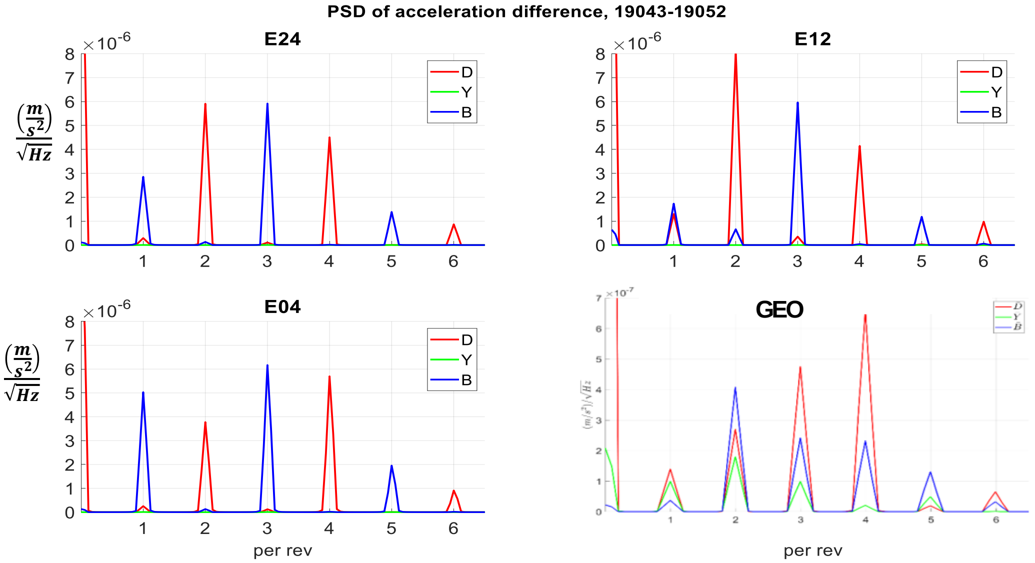
Measurement Errors and Estimated Parameters

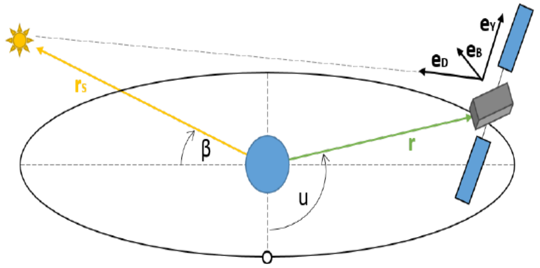
Simulated measurement errors	L-band	OTWL	OISL
White noise	Yes 15 cm for code, 1.5 mm for phase	Yes up to 0.5 mm	Yes up to 0.5 mm
Flicker noise (distance dependent)	No	Yes 1.2-1.4 mm (MEO), 1.7-1.9 mm (GSO)	Yes 0.1-1.5 mm (MEO and GSO)
Troposphere	Yes	Yes	-
PCV/Multipath	Yes	No	No
Constant bias	Yes up to 5 mm	Yes between ±0.5 mm	Yes between ±0.5 mm
Variable bias	Yes up to 5 mm	Yes between ±0.5 mm	Yes between ±0.5 mm

Estimated parameters per day	L-band	OTWL	OISL
Station specific tropospheric zenith delays	Yes	No	-
Ground station coordinates	No	No	-
Satellite initial state vectors and Solar Radiation Pressure (SRP) parameters	Yes	Yes	Yes
Epoch-wise satellite and ground station clock parameters	Yes	Yes	Yes
Phase ambiguities	Yes	-	-
Const. range and clock biases	No	Yes	Yes

Solar Radiation Pressure Modelling

Acceleration error: wrong box-wing parameters





$D = D_0 + D_{2c}\cos(2\Delta u) + D_{2s}\sin(2\Delta u) + D_{4c}\cos(4\Delta u) + D_{4s}\sin(4\Delta u)$

$Y = Y_0$

$B = B_0 + B_{1c}\cos(\Delta u) + B_{1s}\sin(\Delta u)$ (1)

$B = B_0 + B_{1c}\cos(\Delta u) + B_{1s}\sin(\Delta u) + B_{3c}\cos(3\Delta u) + B_{3s}\sin(3\Delta u)$ (2)

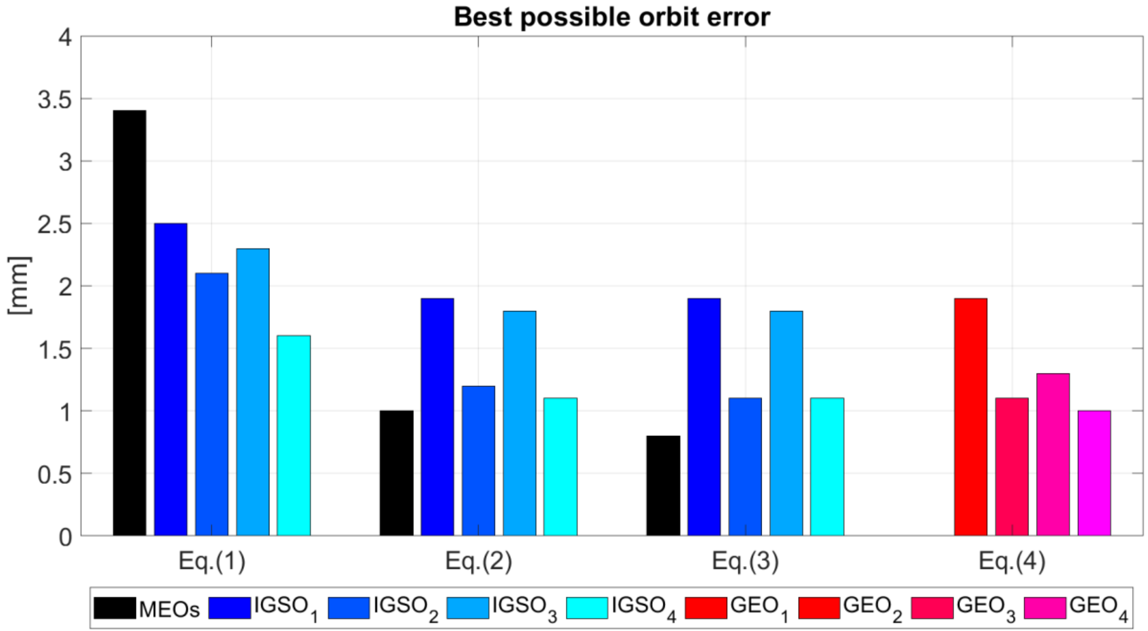
$B = B_0 + B_{1c}\cos(\Delta u) + B_{1s}\sin(\Delta u) + B_{3c}\cos(3\Delta u) + B_{3s}\sin(3\Delta u) + B_{5c}\cos(5\Delta u) + B_{5s}\sin(5\Delta u)$ (3)

$\bar{D} = \bar{D}_0 + \bar{D}_{1s}\sin(\Delta u) + \bar{D}_{2c}\cos(2\Delta u) + \bar{D}_{3s}\sin(3\Delta u) + \bar{D}_{4c}\cos(4\Delta u)$

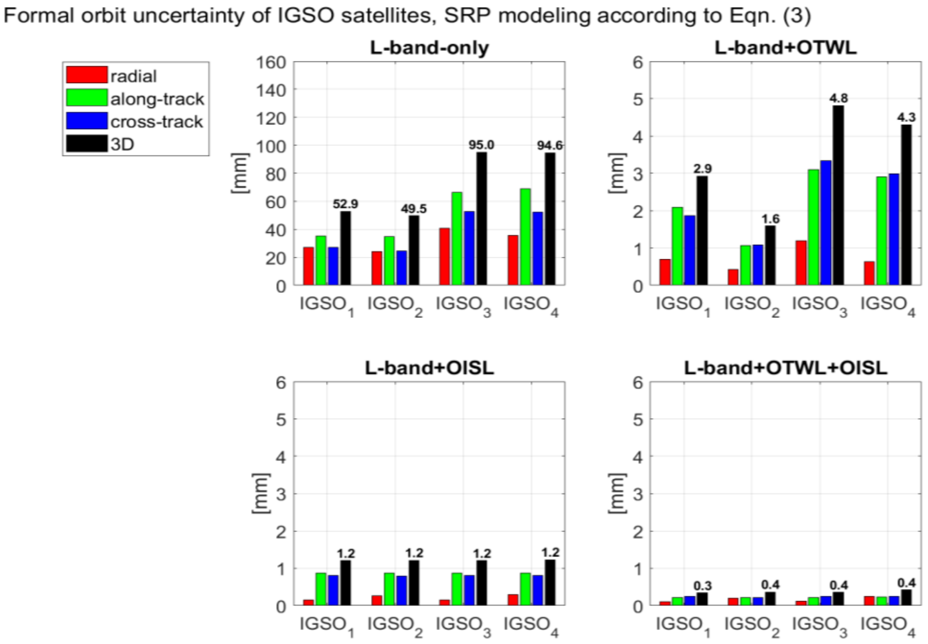
$\bar{Y} = \bar{Y}_0 + \bar{Y}_{1s}\sin(\Delta u) + \bar{Y}_{2c}\cos(2\Delta u)$ (4)

$\bar{B} = \bar{B}_0 + \bar{B}_{1c}\cos(\Delta u) + \bar{B}_{2s}\sin(2\Delta u) + \bar{B}_{3c}\cos(3\Delta u) + \bar{B}_{4s}\sin(4\Delta u)$

Orbit Modelling Errors – Best possible Orbit

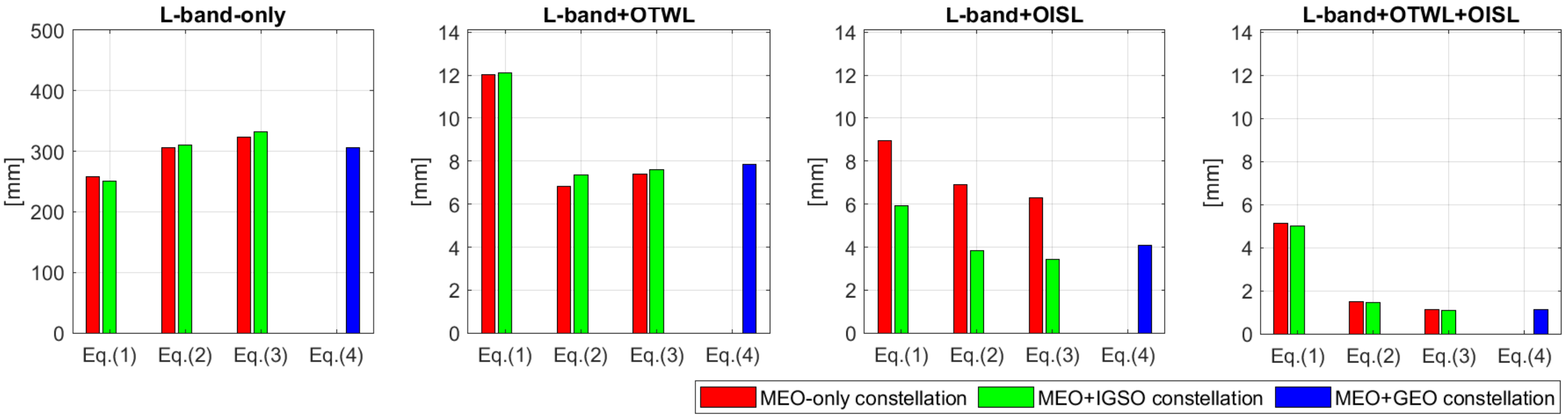


Formal Errors – Influence of geometry and white noise

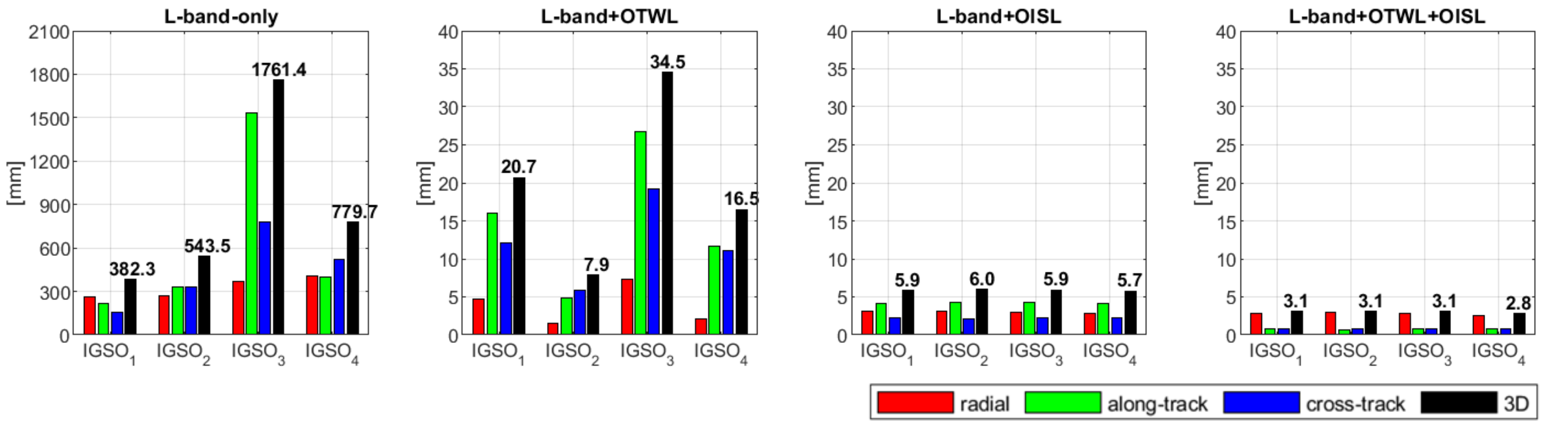


Orbit Errors (no weather limitations in optical)

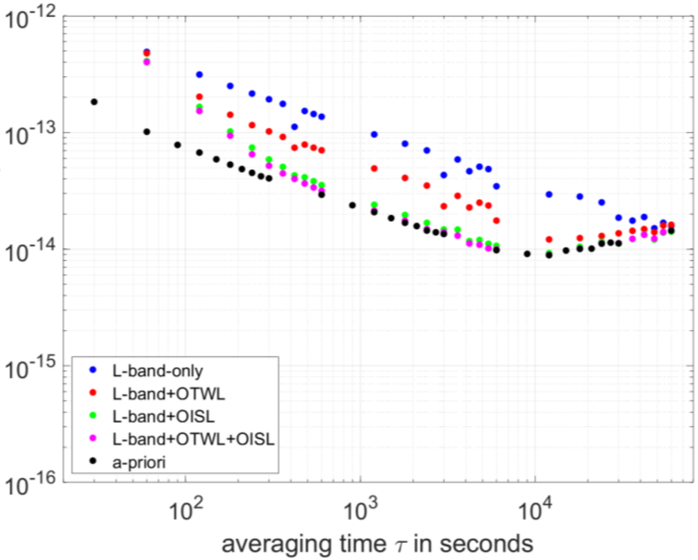
MEO

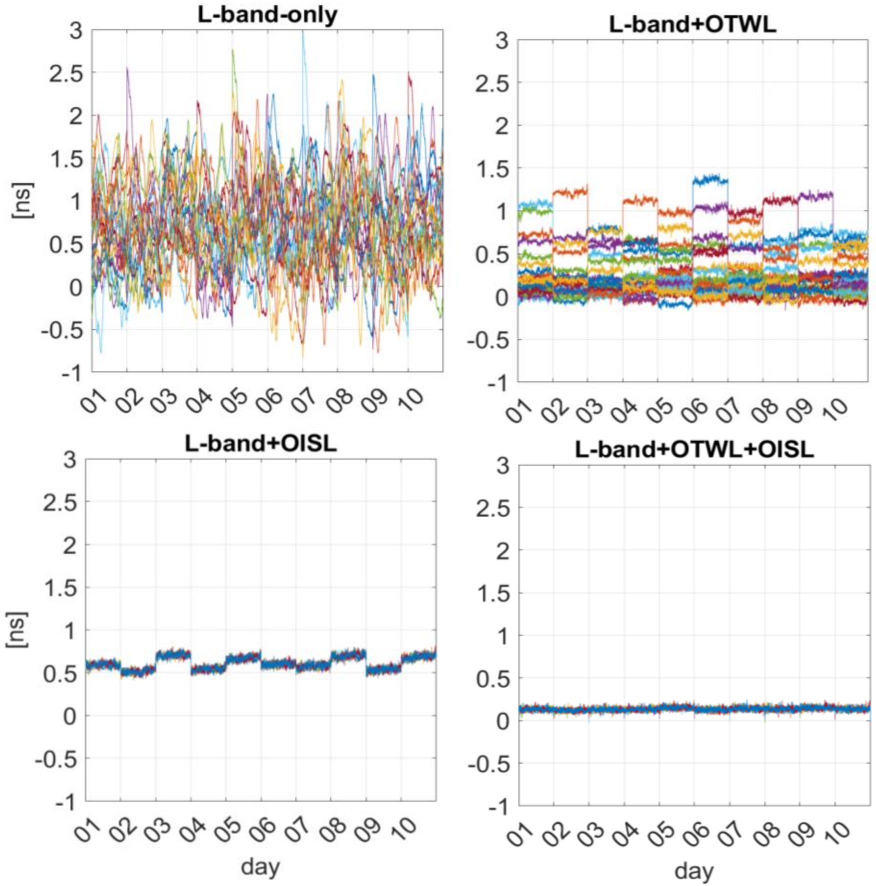


IGSO



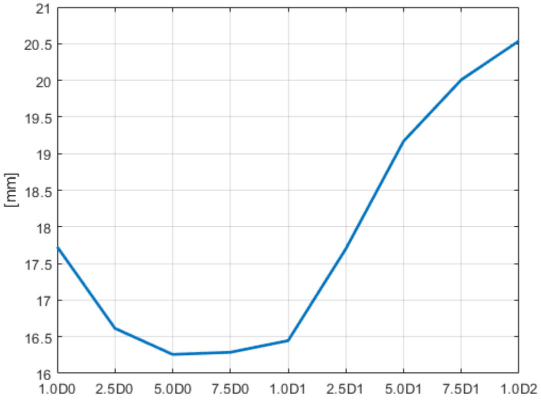
Clock Errors



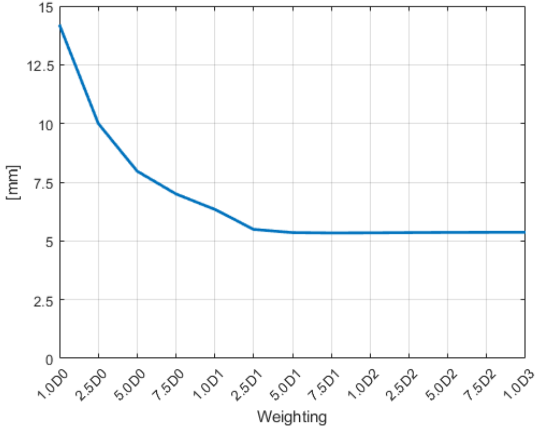


Weighting

OISL ECOM2
Without GSO

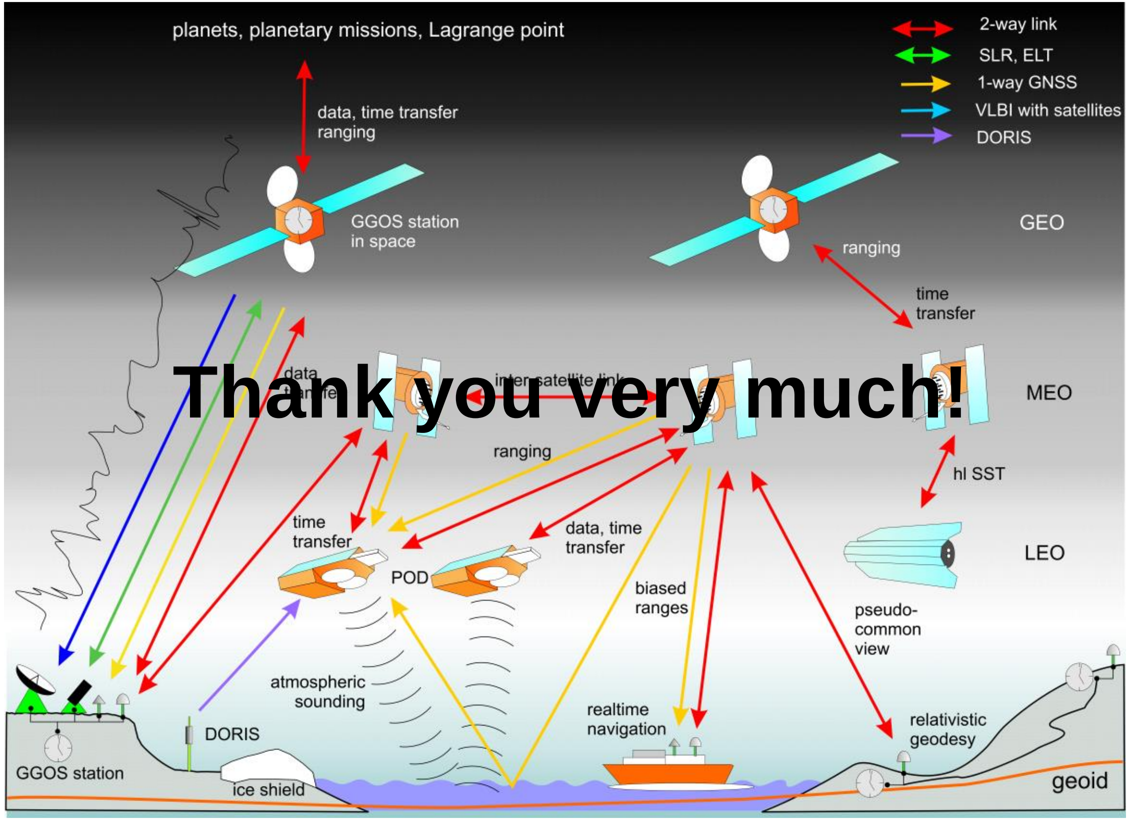


OTWL ECOM2+B3
Without GSO



	with IGSO satellites			with GEO satellites		
SRP modeling according to	L-band + OTWL [mm]	L-band + OISL [mm]	L-band + OTWL + OISL [mm]	L-band + OTWL [mm]	L-band + OISL [mm]	L-band + OTWL + OISL [mm]
Eqn. (1)	25	2.5	2.5			
Eqn. (2)	25	25	25			
Eqn. (3)	25	25	25			
Eqn. (4)	-	-	-	100	100	10

Future in navigation und time synchronization



Thank you very much!