Analysis and application of 1-way laser ranging data to LRO

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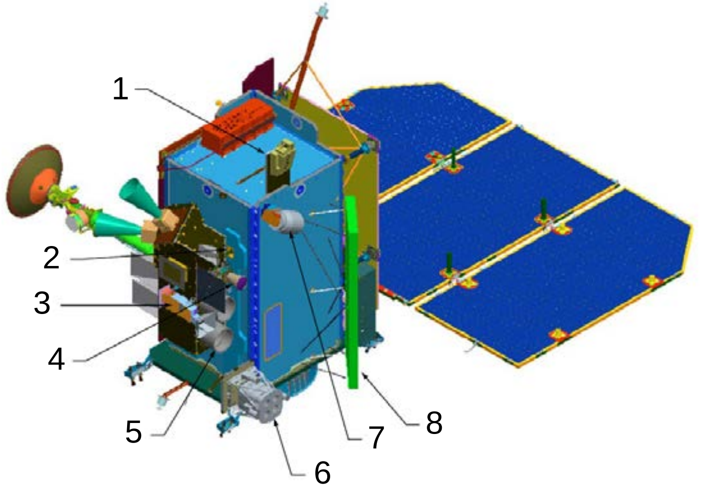
Knowledge for Tomorrow

Facts
LRO & LOLA

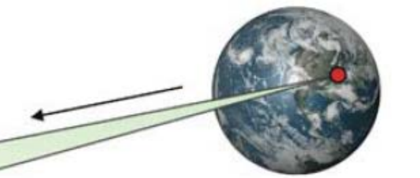
- In a ≈50km near circular & polar orbit around Moon since June 2009
- 30x216km orbit since December 2011
- LOLA (Lunar Orbiter Laser Altimeter) is used for the LR (Laser Ranging) experiment from a ground station to LRO (Lunar Reconnaissance Orbiter)
- LOLA mission goals:
  - Characterize polar illumination and search for water ice
  - Global topographic model and geodetic framework
- LR supports these & overall mission goals
  - Provides very accurate positioning & clock correlation
  - Improves geodetic accuracy of instruments and derived data products

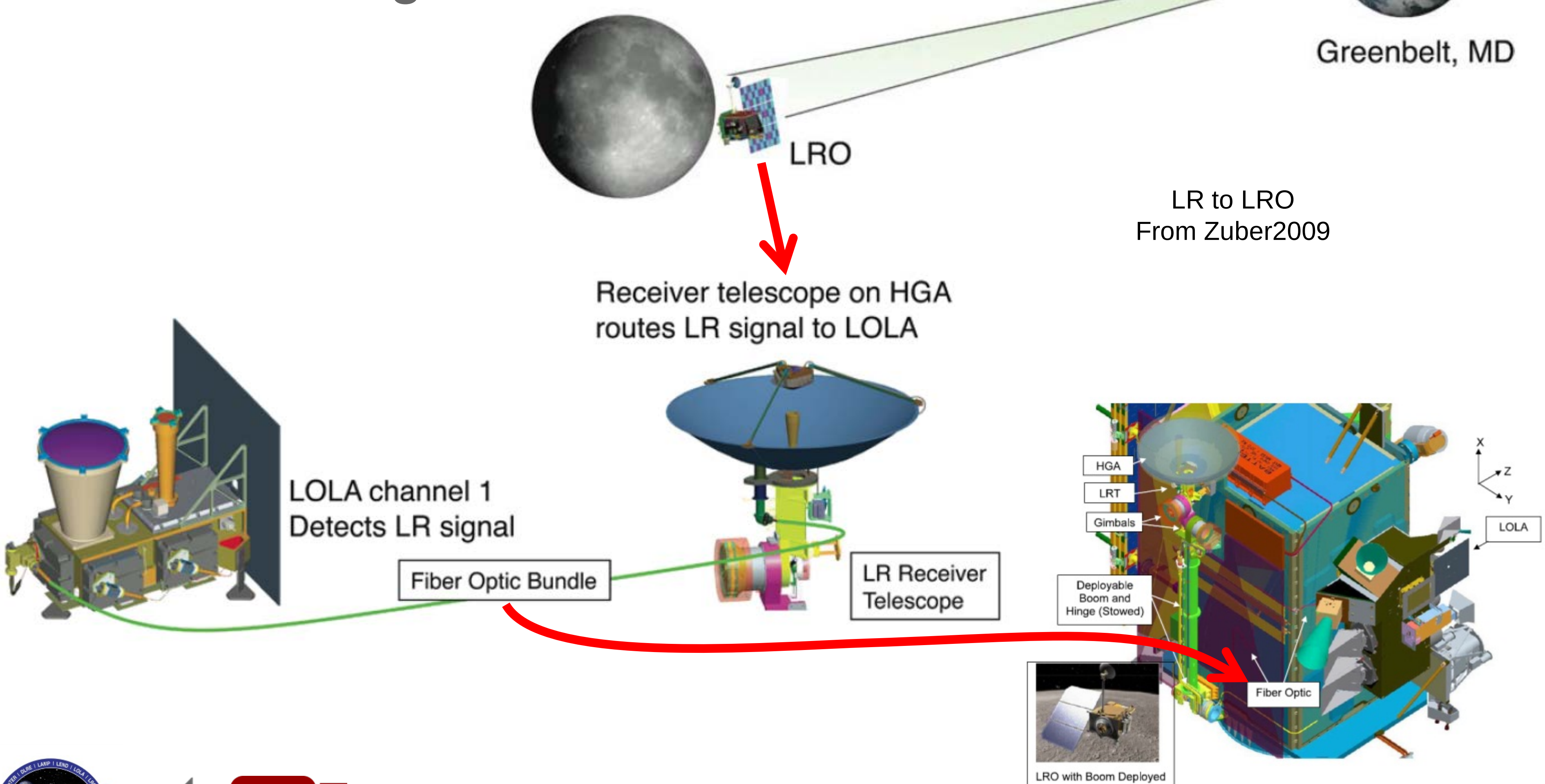


Instruments onboard LRO from LROPresskit2009

1	CRaTER	5	LRO NAC
2	LROC WAC	6	LEND
3	LAMP	7	DLRE
4	LOLA	8	Mini-RF

Facts
LR from ground station to LRO

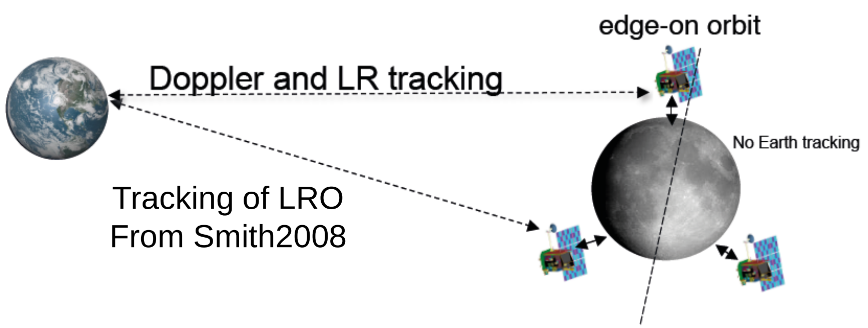




LR to LRO
From Zuber2009

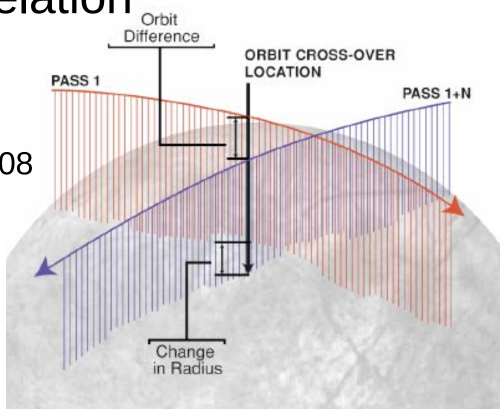
Facts
Benefit from adding LR to the LRO mission

- Originally defined accuracy of radio tracking was not sufficient for the required data product accuracy
- Accuracies:
  - S-Band: Doppler 0.4 – 1.4mm/s, Range 1 – 4m (Mazarico2012)
  - LR: Range 11 – 21cm (Mao2011)
  - Altimetry/Crossovers: Range 10cm (Mazarico2012)
- More accurate range measurements improve orbit determination and gravity field estimation
- LRO clock characterization and more accurate correlation



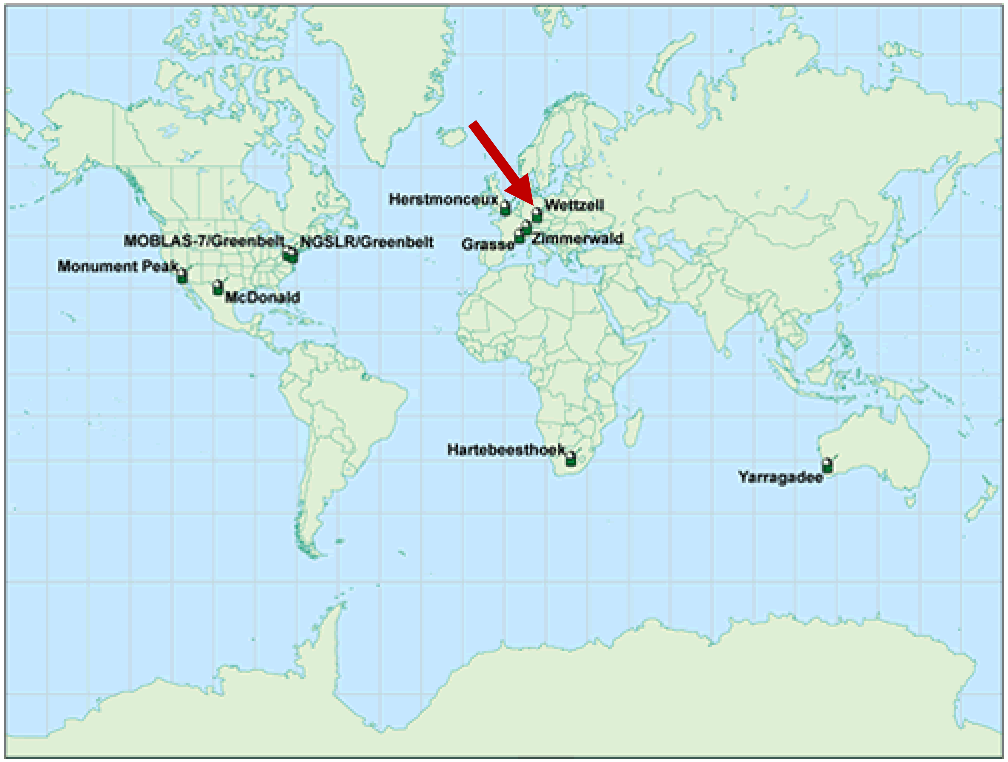
Tracking of LRO
From Smith2008

Crossovers
From Smith2008



Ranging campaign Wettzell station

- ILRS (International Laser Ranging Service) stations that perform LR to LRO
- We joined Wettzell in Germany for a LR campaign to LRO in November 2011



ILRS stations that range to LRO
From http://lrolr.gsfc.nasa.gov

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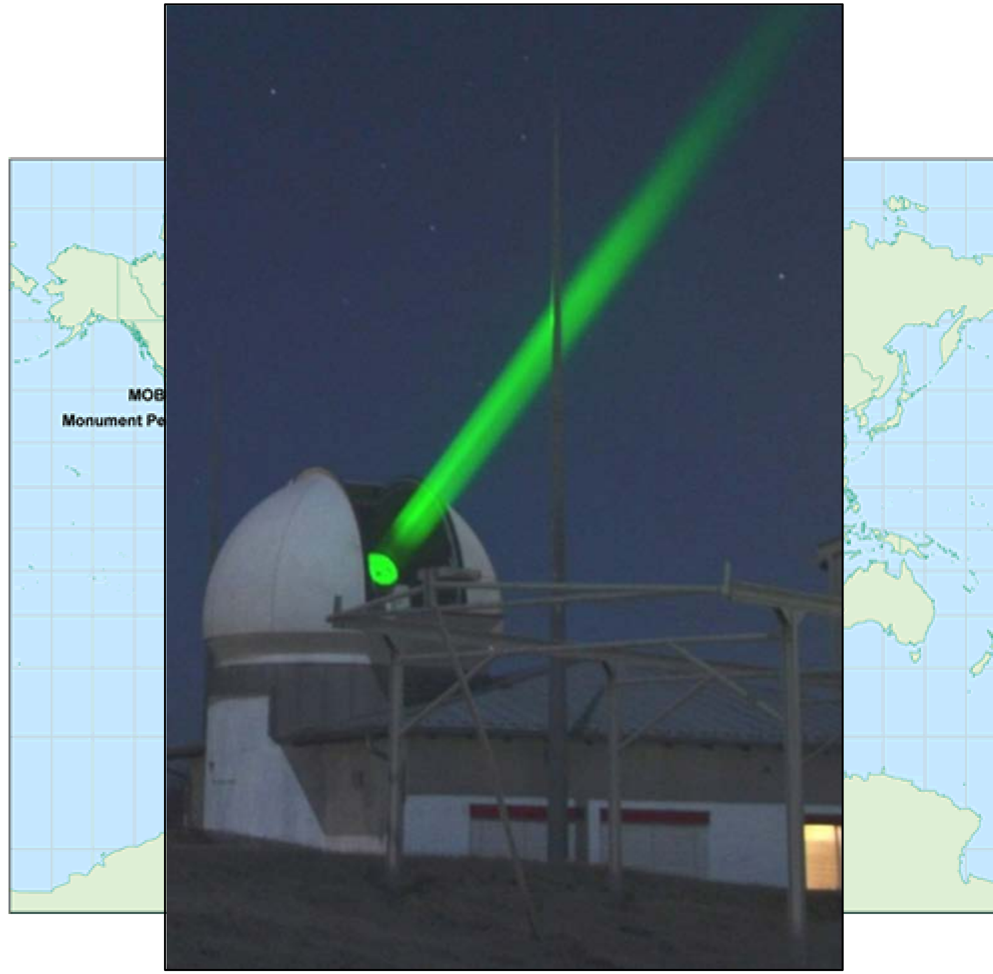
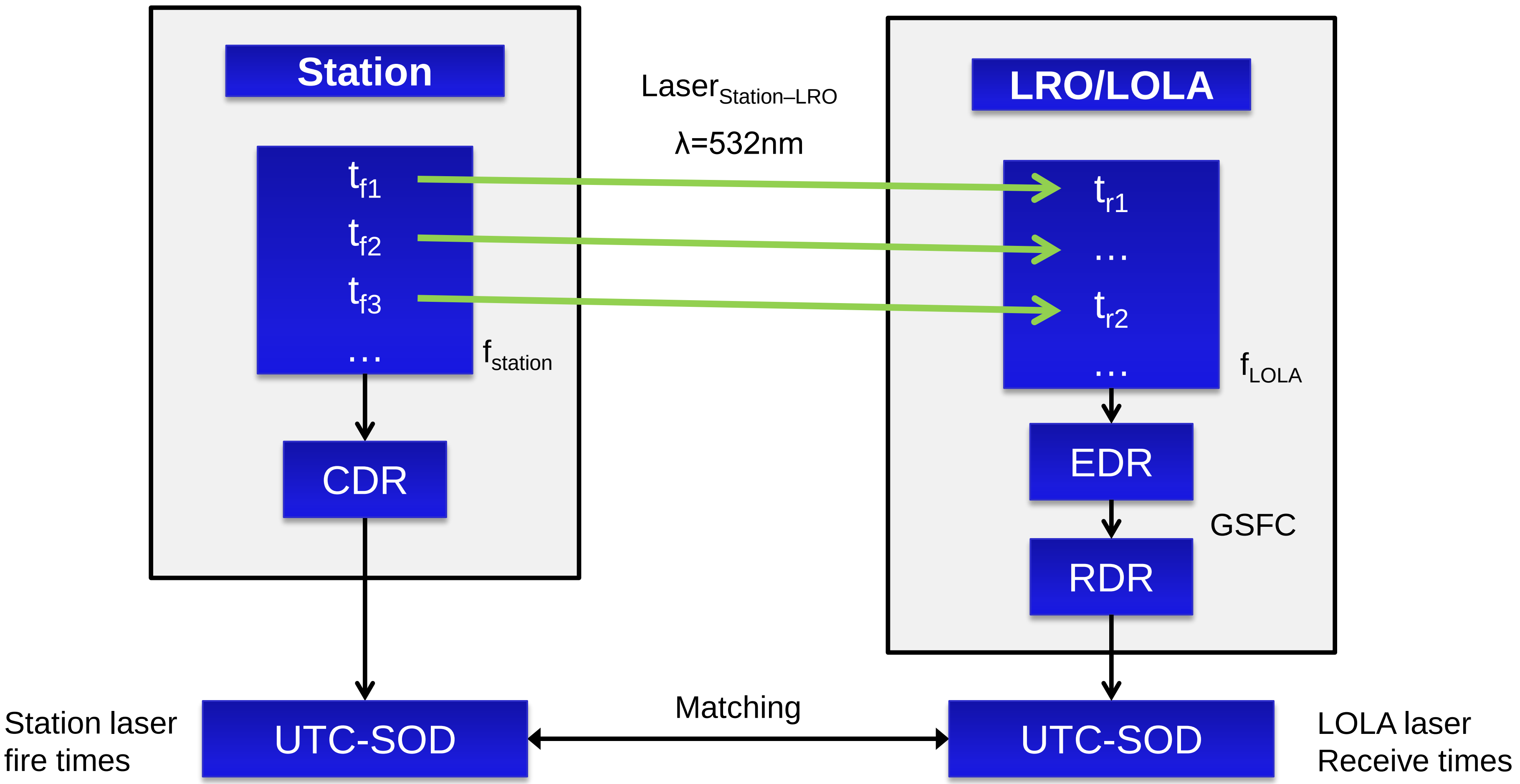
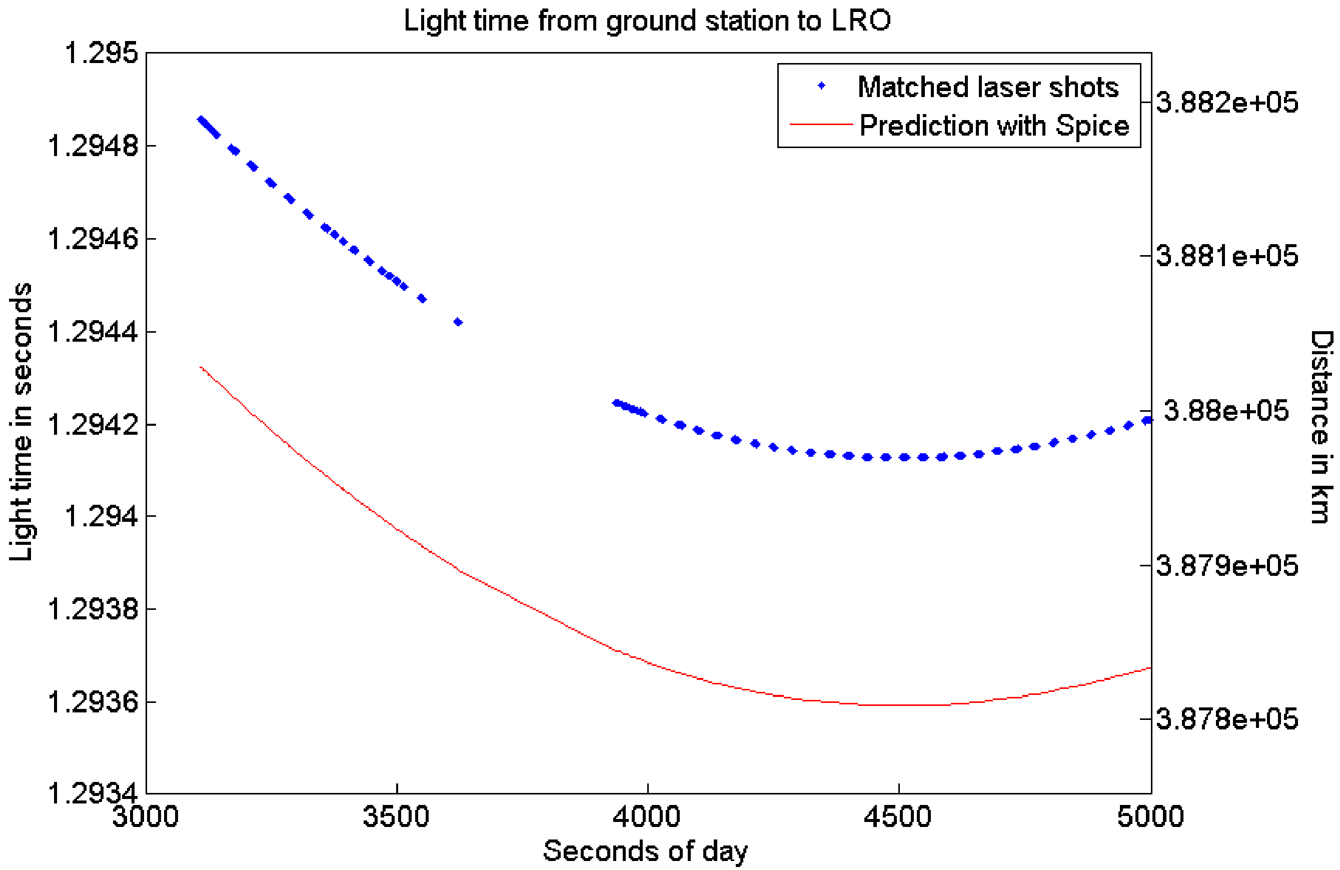


WLRS – Wettzell Laser Ranging System

Analysis
Data products used



Analysis
Results of Wettzell pass from 15th November 2011



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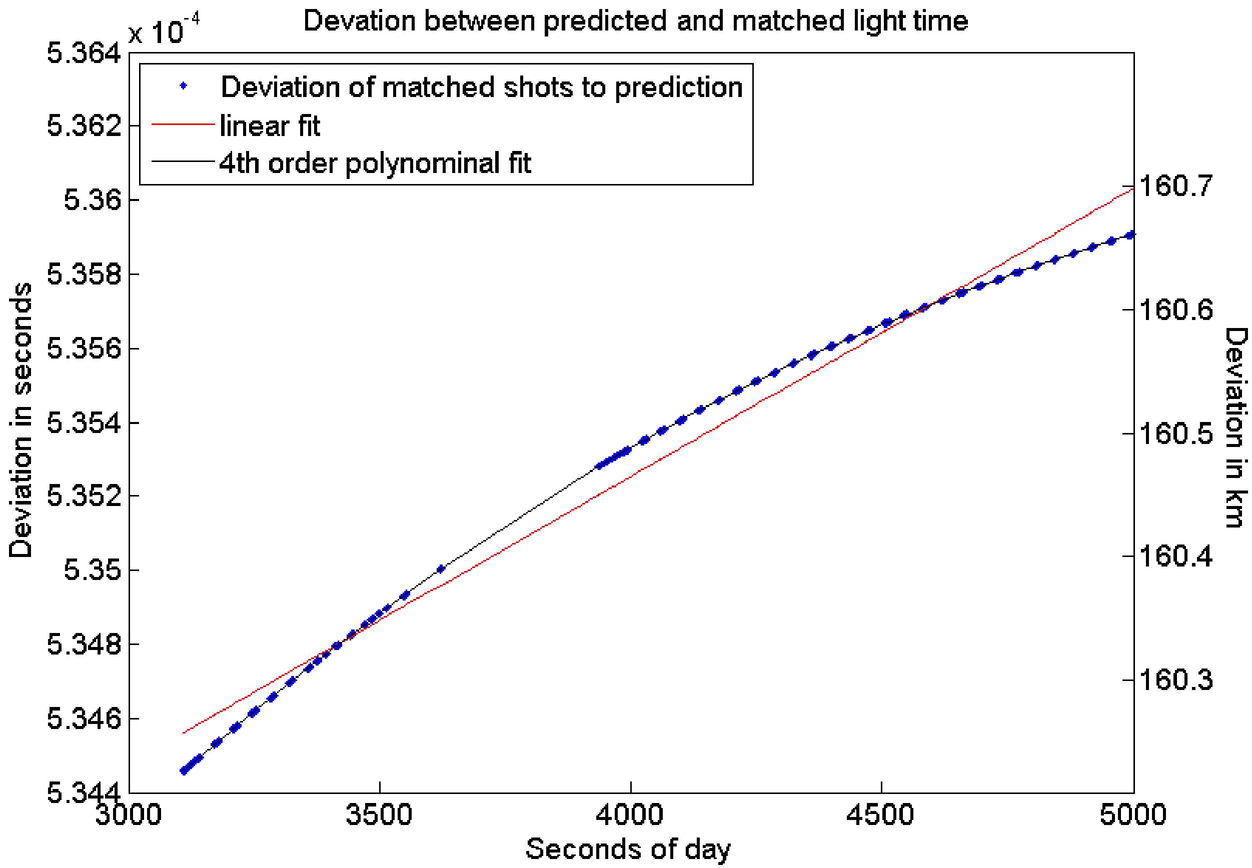

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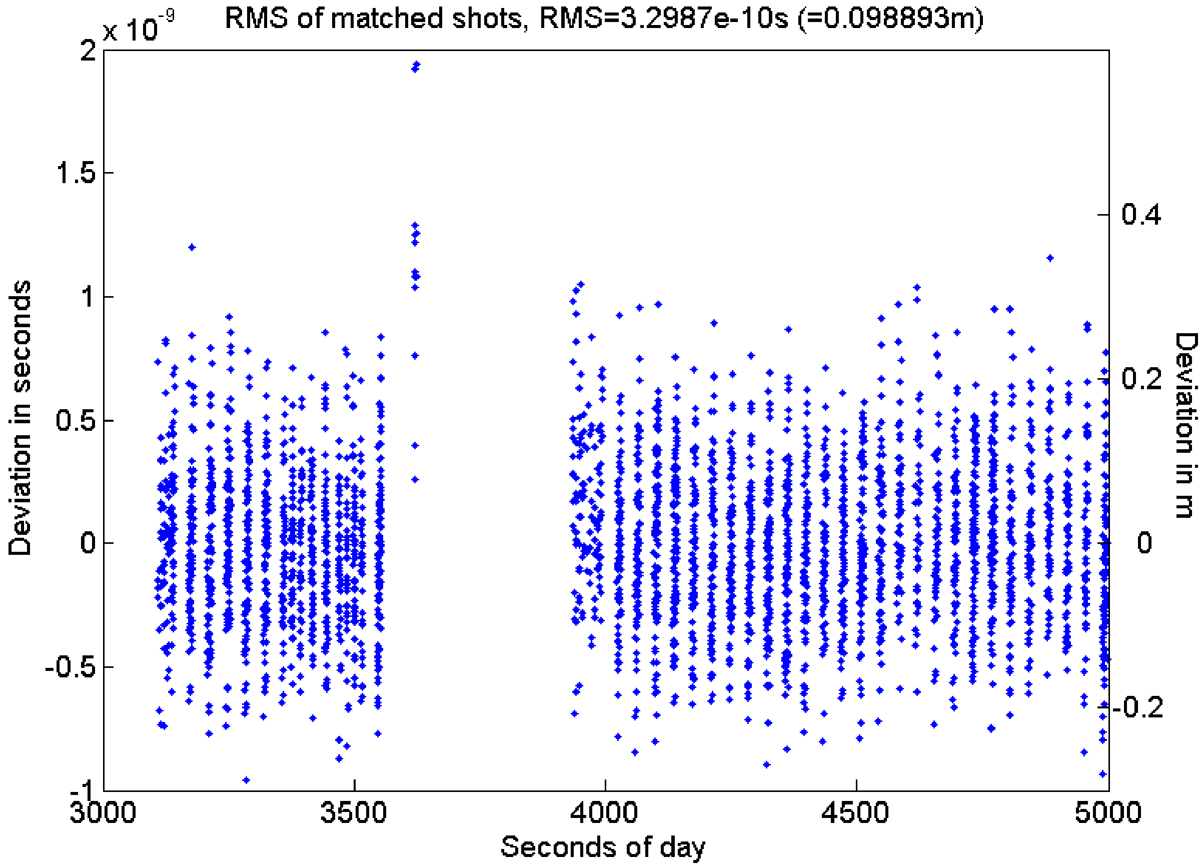
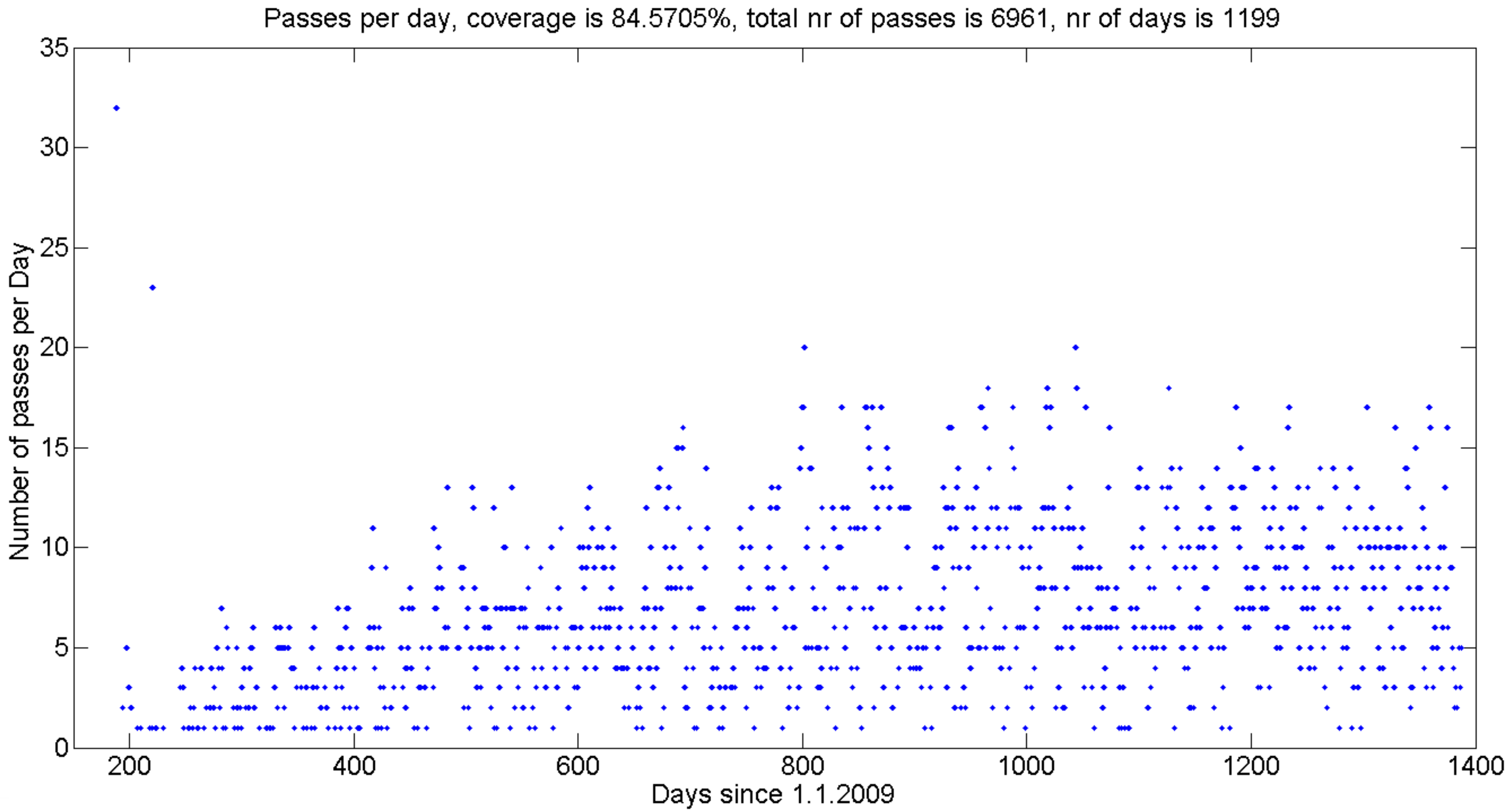


Analysis
Automated processing and matching



Analysis
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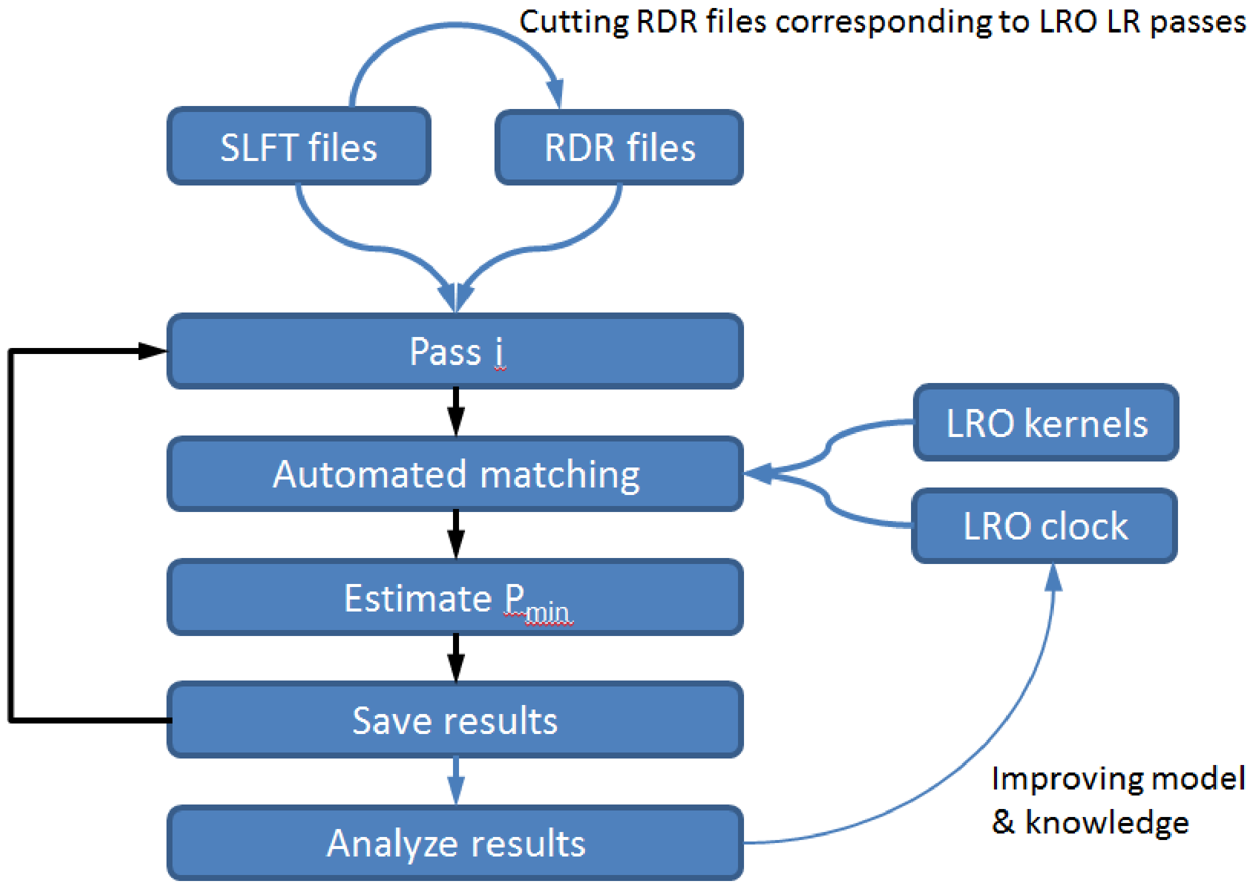
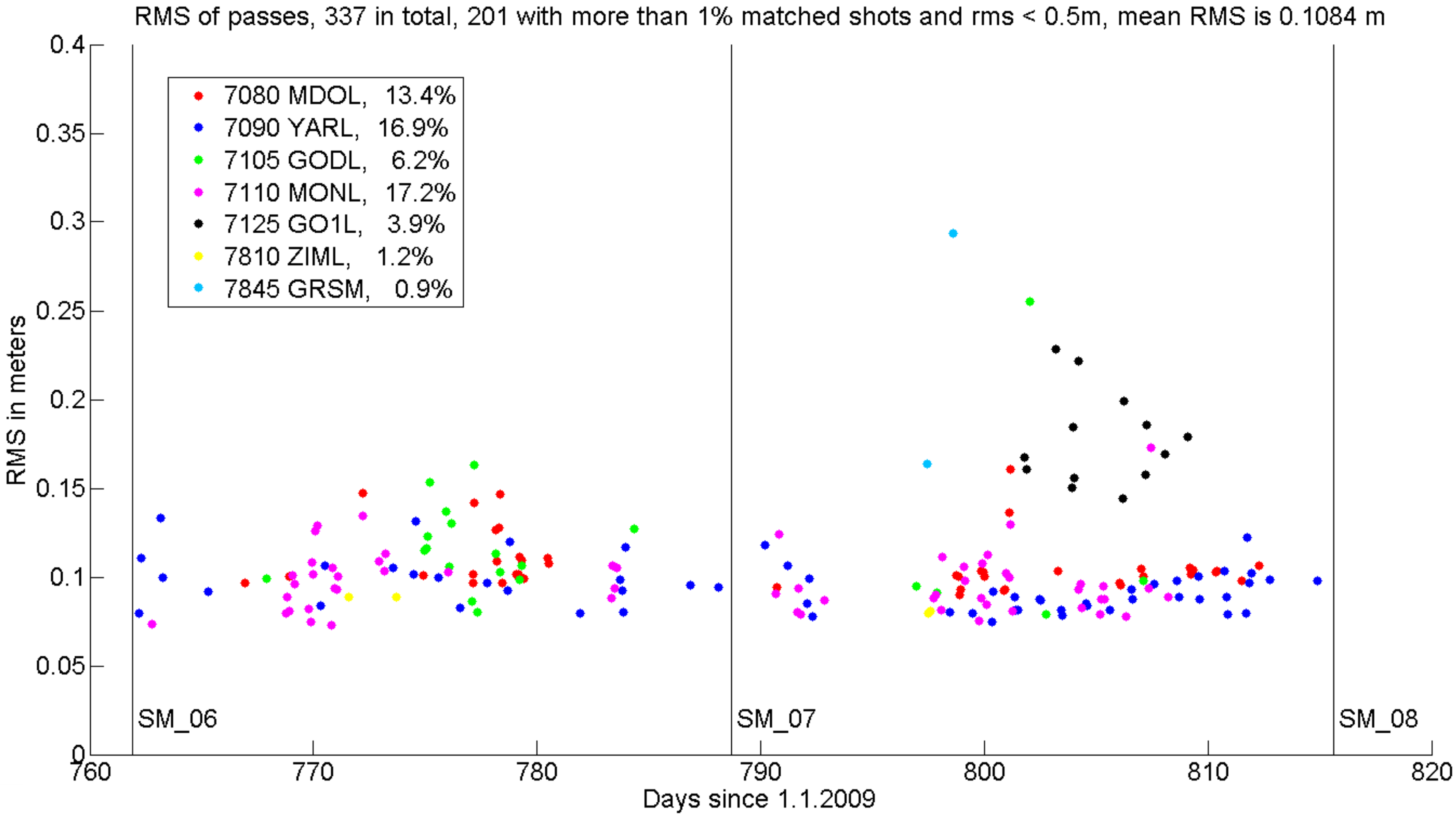


Analysis
Automated processing and matching results



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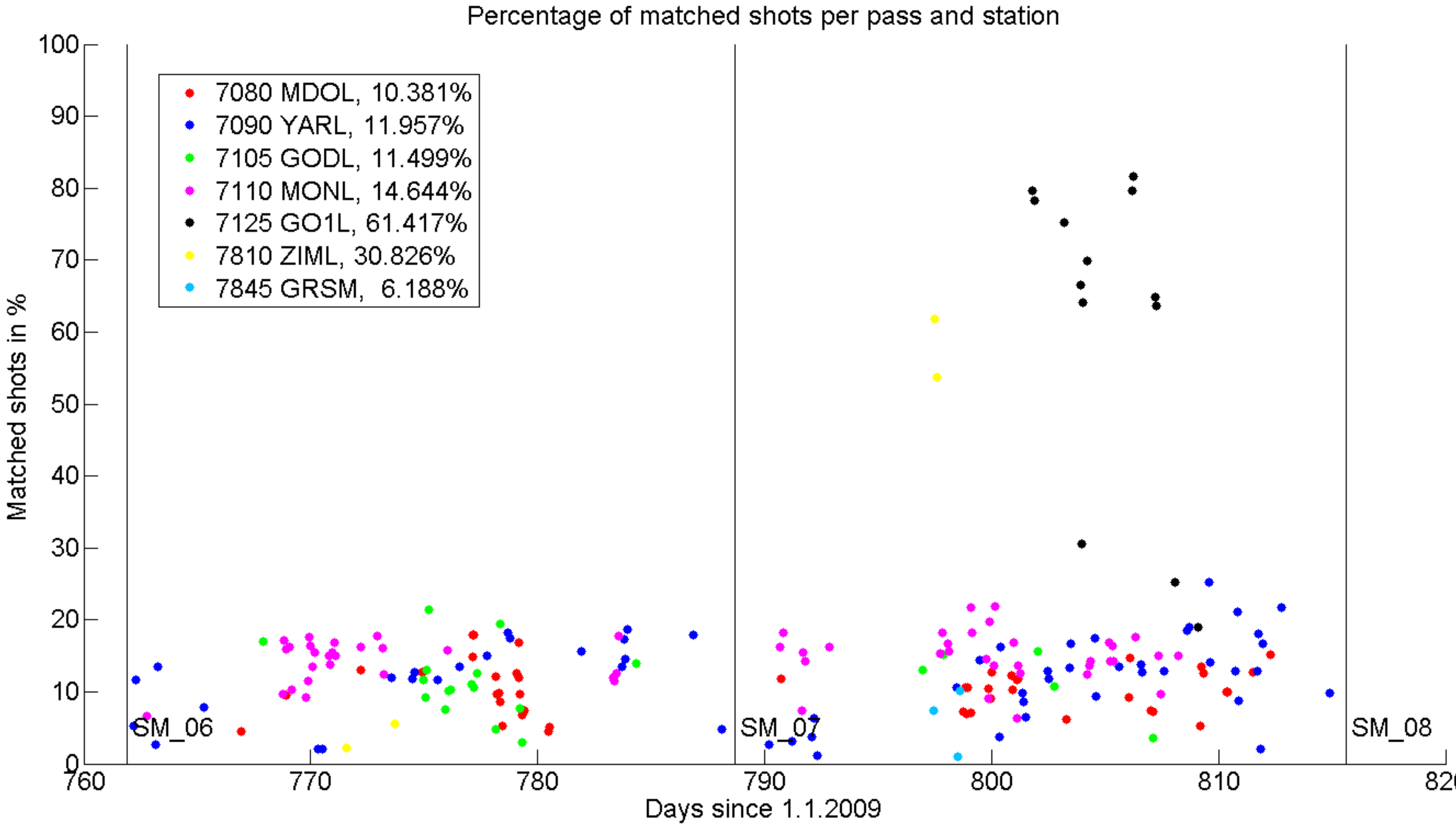

Application of LR data
Current status

- Status at GSFC (Goddard Space Flight Center)
  - Added crossover into orbit determination and updated gravity field
  - Adding LR data currently under research

Gravity field	Radio	Radio + Crossovers	Radio + Crossovers + LR
GLGM-3	70.06m	22.91m	??
LLGM-1	23.39m	13.63m	??

Overlap RMS differences of total LRO position
From Mazarico2012

  - Preliminary Grail gravity fields for position improvement
  - Use LR for communication

Application of LR data
Current status

- Status at DLR
  - Matching almost complete
  - Automated processing and matching is working
  - Process LRO LR data
  - Improvement of LRO clock understanding
  - Collaboration with Dominic Dirkx (TU Delft) on “simulation of interplanetary laser ranging”
  - Application to orbit determination and gravity field estimation as well

Summary & Outlook

- We have carried out a 1-way LR campaign to LRO from Wettzell station
- Devolped an automated processing and matching
- 1-way LR data shows RMS of ≈ 10 cm (achievable accuracy for LRO 1-way LR)
- Characterization and correlation of LRO clock
- Application of LR data to orbit determination and gravity field estimation

Thank you!

LROPresskit2009	„Lunar Reconnaissance Orbiter (LRO): Leading NASA's Way Back to the Moon Lunar Crater Observation and Sensing Satellite (LCROSS): NASA's Mission to Search for Water on the Moon", NASA (2009)
Mao2011	D. Mao et al, „Laser Ranging Experiment on Lunar Reconnaissance Orbiter: Timing Determination and Orbit Constraints", 17th International Workshop on Laser Ranging, Bad Koetzting Germany (2011)
Mazarico2012	E. Mazarico et al, "Orbit determination of the Lunar Reconnaisence Orbiter" 2012
Smith2008	D. Smith et al, „Orbit determination of LRO at the Moon", 16th International Workshop on Laser Ranging, Poznan Poland (2008)
Zuber2009	M. Zuber et al, „The Lunar Reconnaissance Orbiter Laser Ranging Investigation", Space Sci Rev (2010)