# 3D SAR Positioning Results — Experiences with Electronic Corner Reflectors

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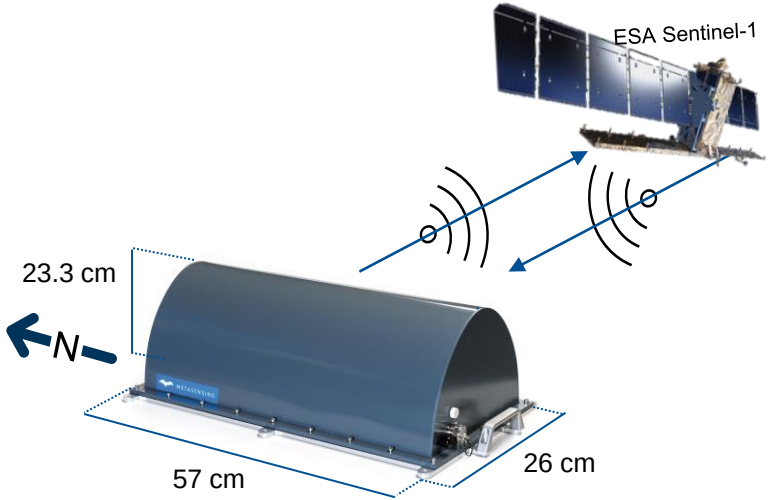
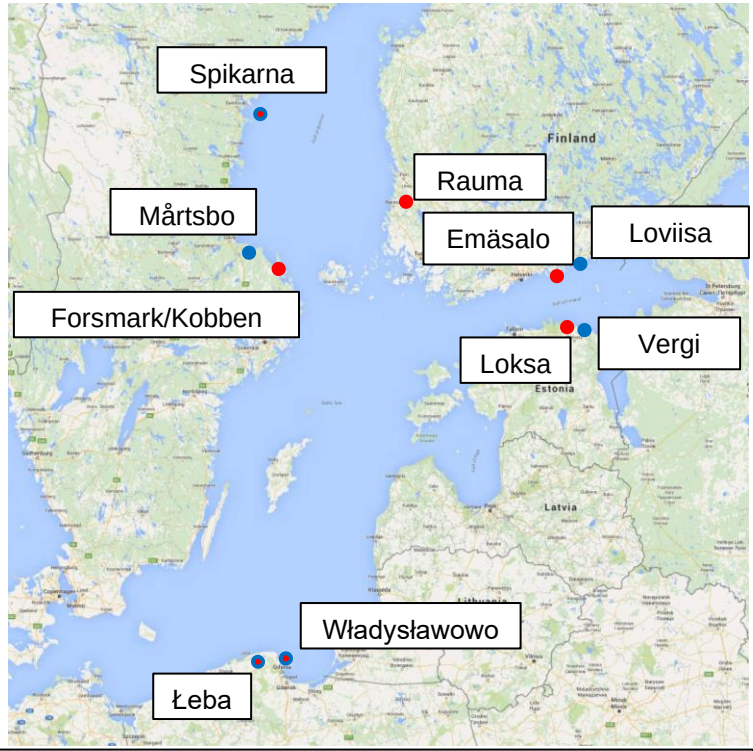
# Active SAR Transponders — Motivation

- Compact active transponders are available
- Compatibility with C-band SAR (e.g., Sentinel 1)
- Operational in remote areas (only power dependent)

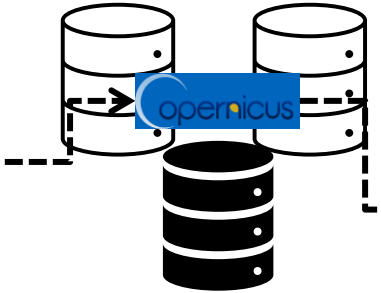
- Independent measurement technique that can densify measurement networks of other techniques such as GNSS

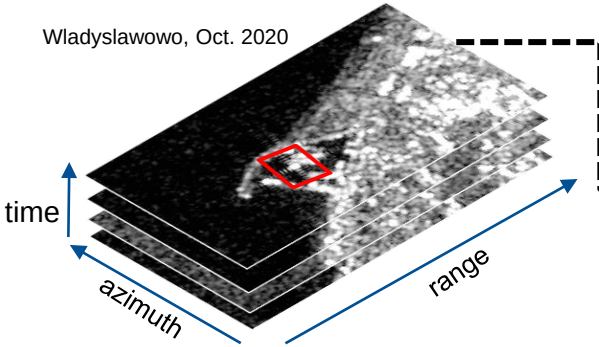


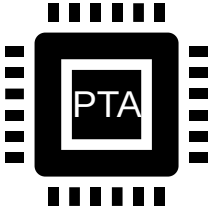

MetaSensing Electronic Corner reflector (ECR-C)

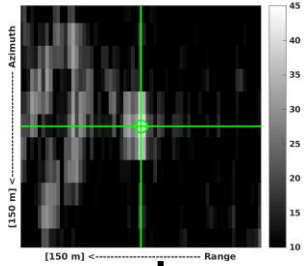


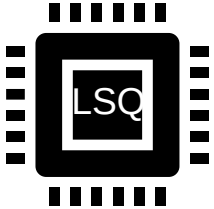
# Active SAR Transponders — 3D Positioning

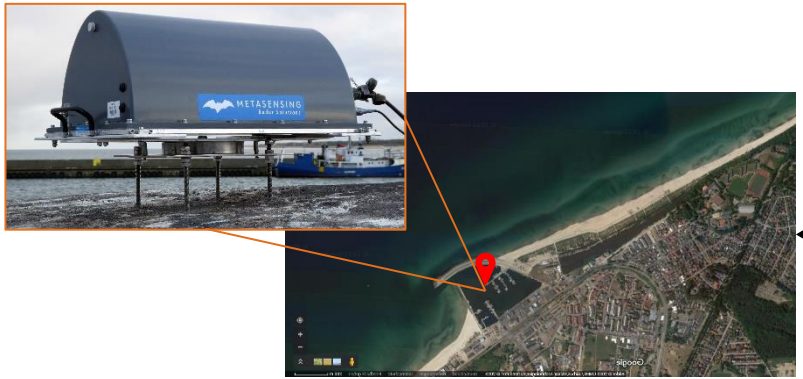



# ECR Stations

- Location: **Oberpfaffenhofen (DLR)**
- Time period: 10.01.20 – 31.12.20
- Position (WGS-84):
  lat= 48.087913°, lon= 11.279133°, height= 623.812m
- Number of passes:
  ASC = 2 , DSC = 2 → ~14 obs./month
- Total acquired Observations: 177

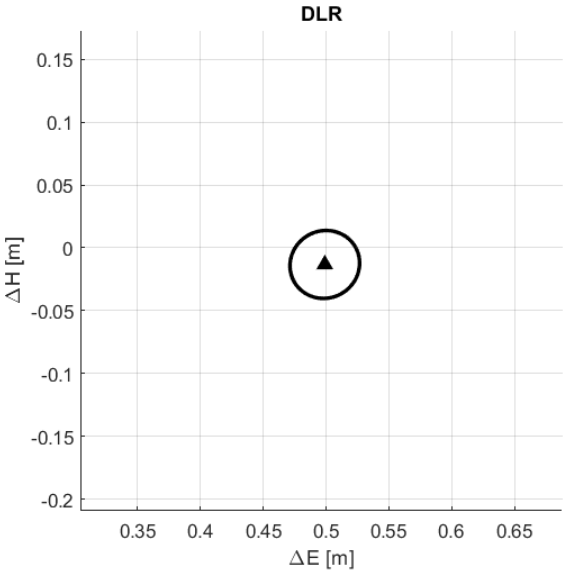
- Location: **Mårtsbo (MART)**
- Time period: 07.01.20 – 31.12.20
- Position (WGS-84):
  lat= 60.595130°, lon= 17.258532°, height= 75.696m
- Number of passes:
  ASC = 3 , DSC = 3→ ~17 obs./month
- Total acquired Observations: 218

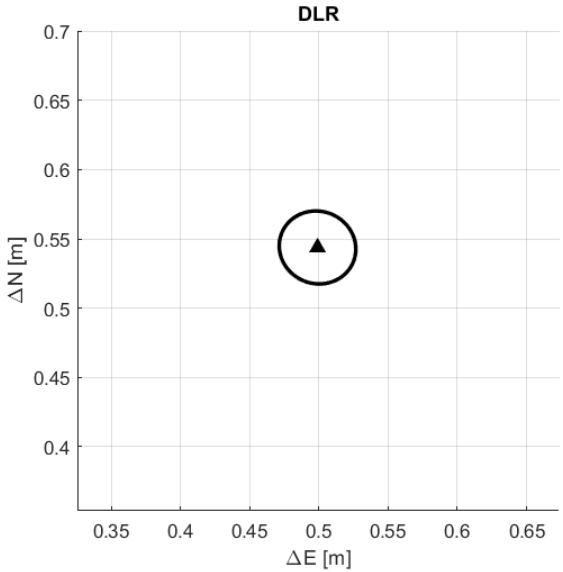
# ECR Stations


- Location: **Władysławowo (WLAD)**
- Time period: 10.01.20 – 31.12.20
- Position (WGS-84):
  lat= 54.796782°, lon= 18.418763°, height= 32.757m
- Number of passes:
  ASC = 2 , DSC = 2 → ~15 - 20 obs./month
- Total acquired Observations: 142

- Location: **Emäsalo (EMAE)**
- Time period: 23.01.20 – 31.12.20
- Position (WGS-84):
  lat= 60.203672°, lon= 25.625669°, height= 34.605m
- Number of passes:
  ASC = 3/6 , DSC = 2/4→ ~12/20 obs./month
- Total acquired Observations: 222

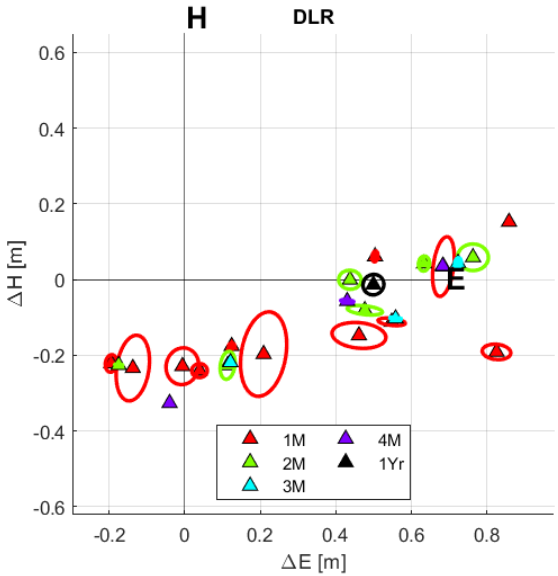
# Positioning Results — Oberpfaffenhofen

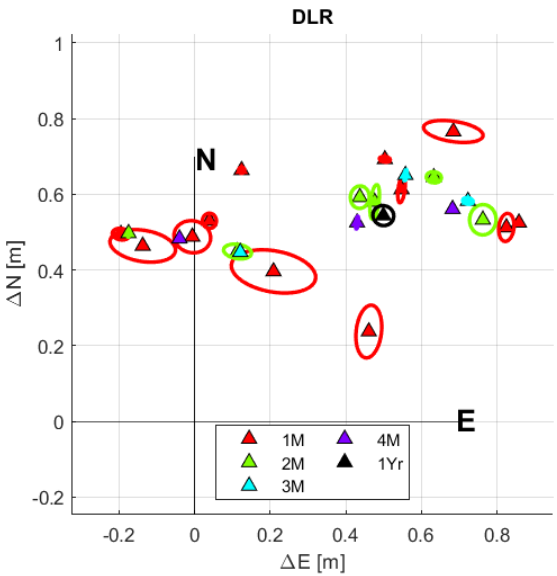


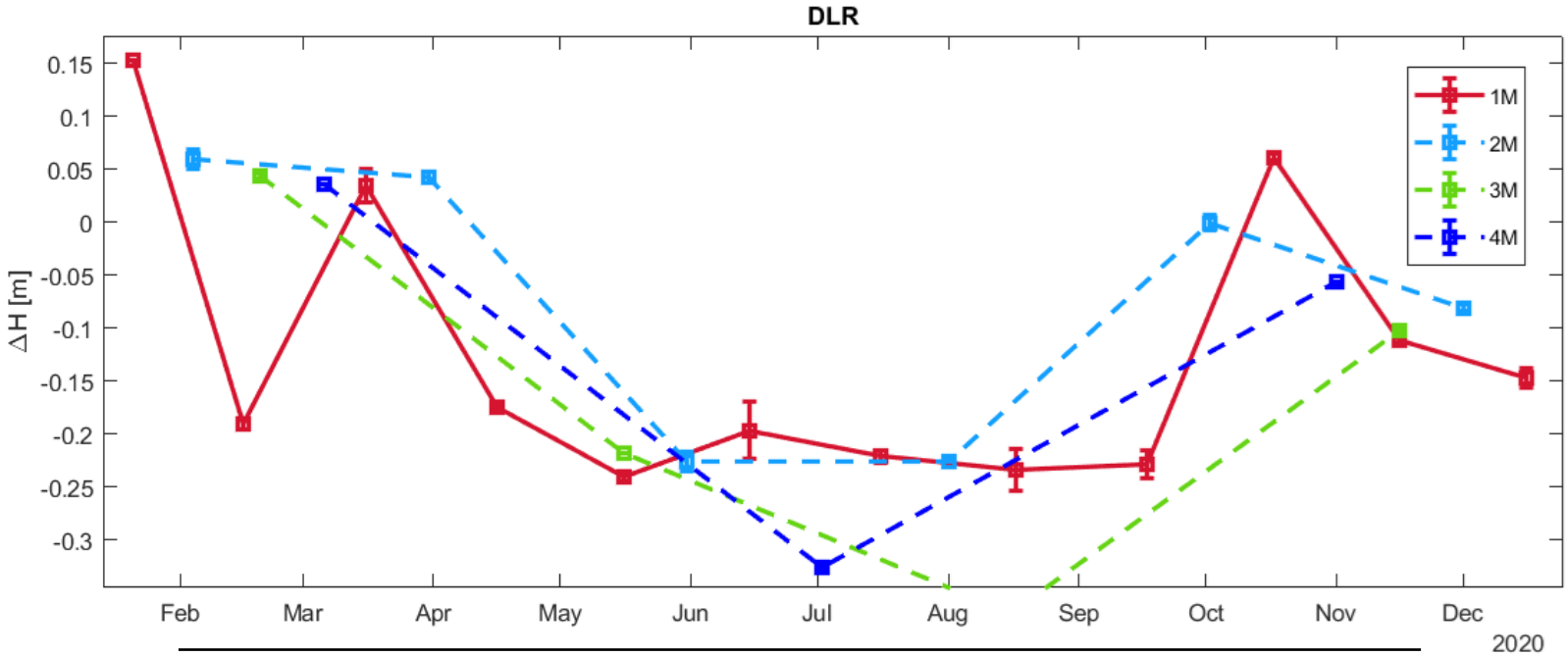

| $\Delta N[m]$ | $\Delta E[m]$ | $\Delta H[m]$ | $\sigma_N[\pm m]$ | $\sigma_E[\pm m]$ | $\sigma_H[\pm m]$ |
|---|---|---|---|---|---|
| 0.5438 | 0.4990 | -0.0132 | 0.0116 | 0.0095 | 0.0072 |

# Positioning over Time — Oberpfaffenhofen



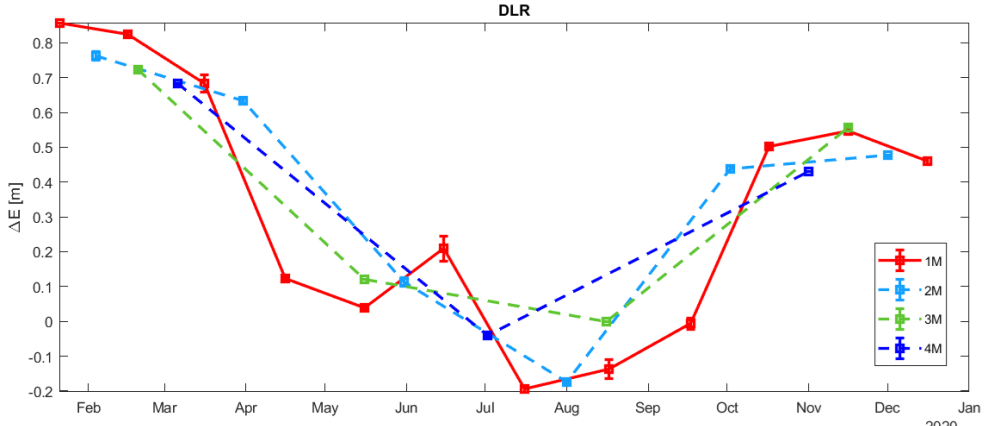



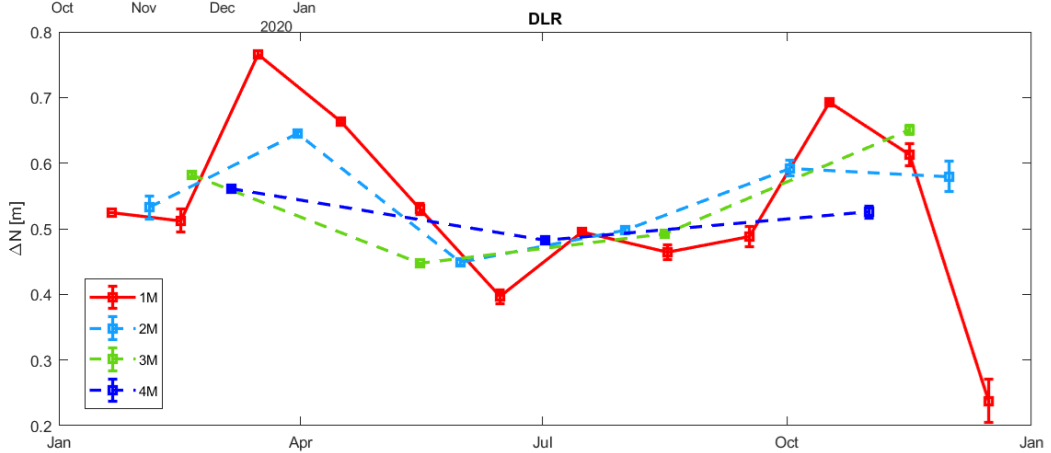
# Positioning over Time — Oberpfaffenhofen



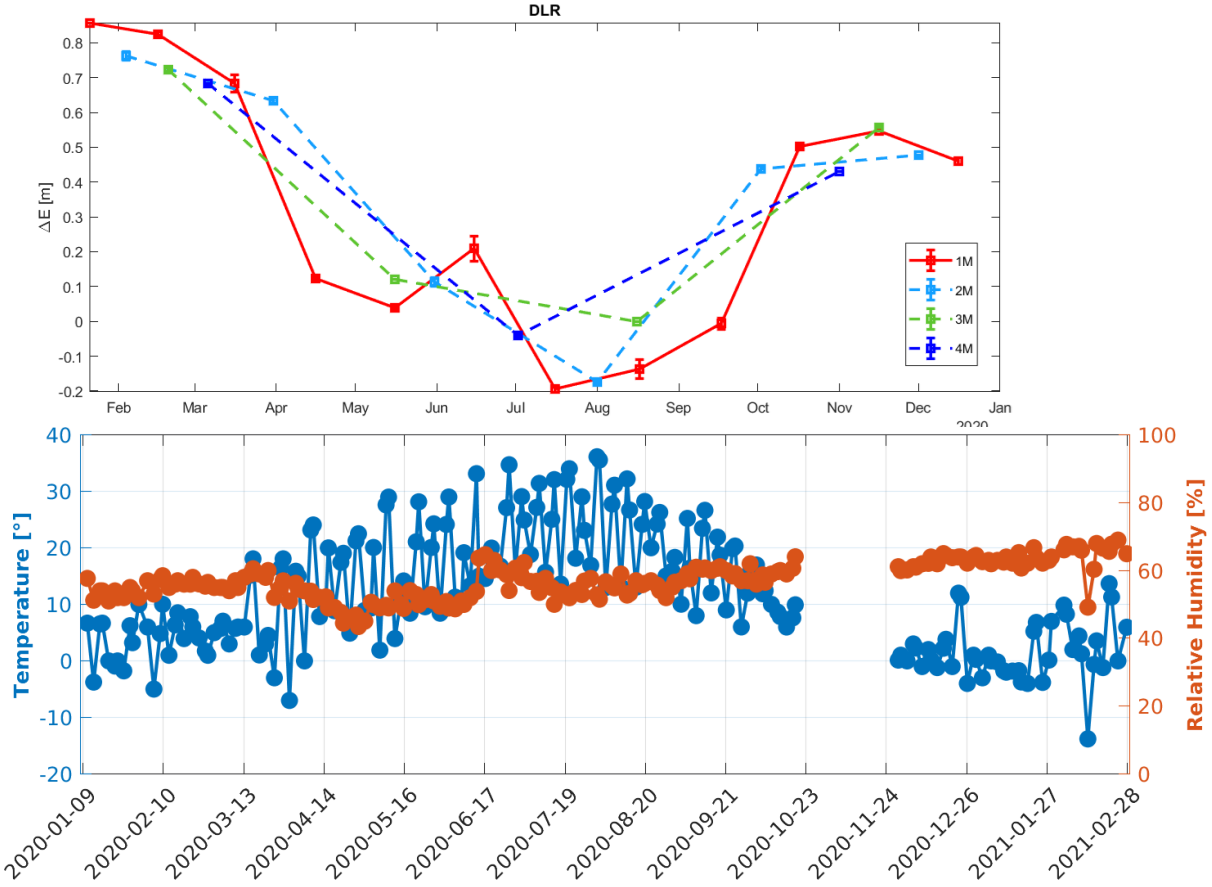

| Temporal Res. | $1M$ | $2M$ | $3M$ | $4M$ |
|---|---|---|---|---|
| # of Observation | ~13.6 | ~26.2 | ~39.8 | ~53.8 |

# Positioning over Time — Oberpfaffenhofen

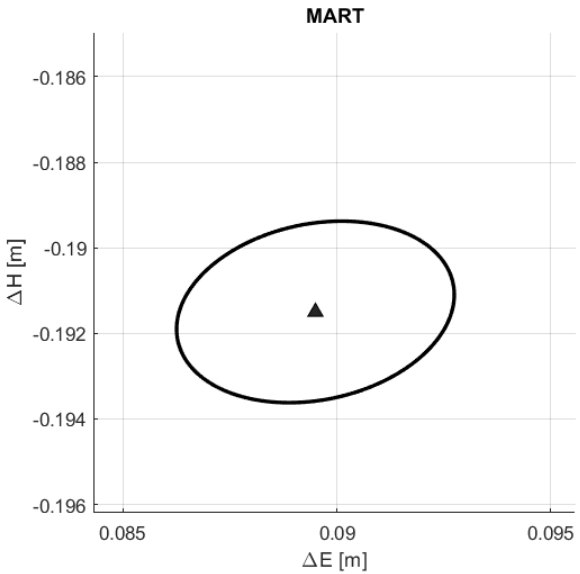


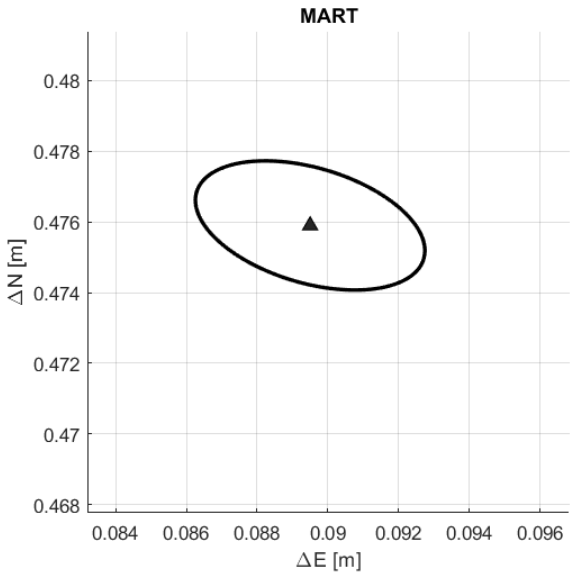



# Stability of ECRs — Oberpfaffenhofen



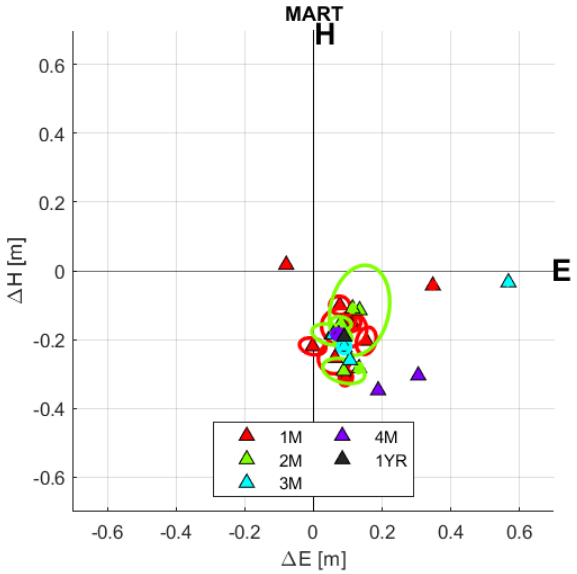
# Positioning Results — Mårtsbo

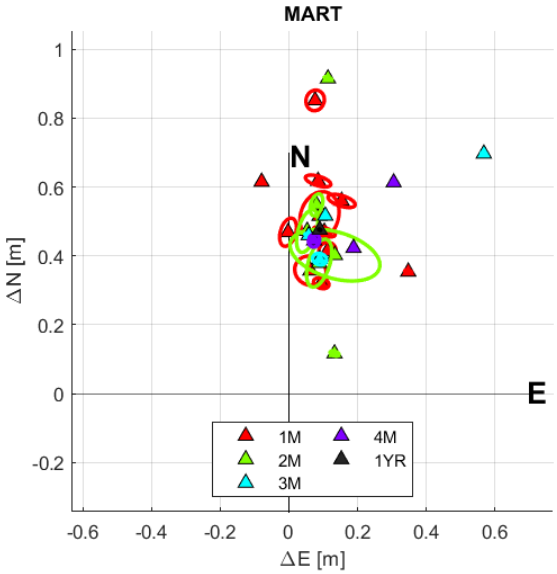


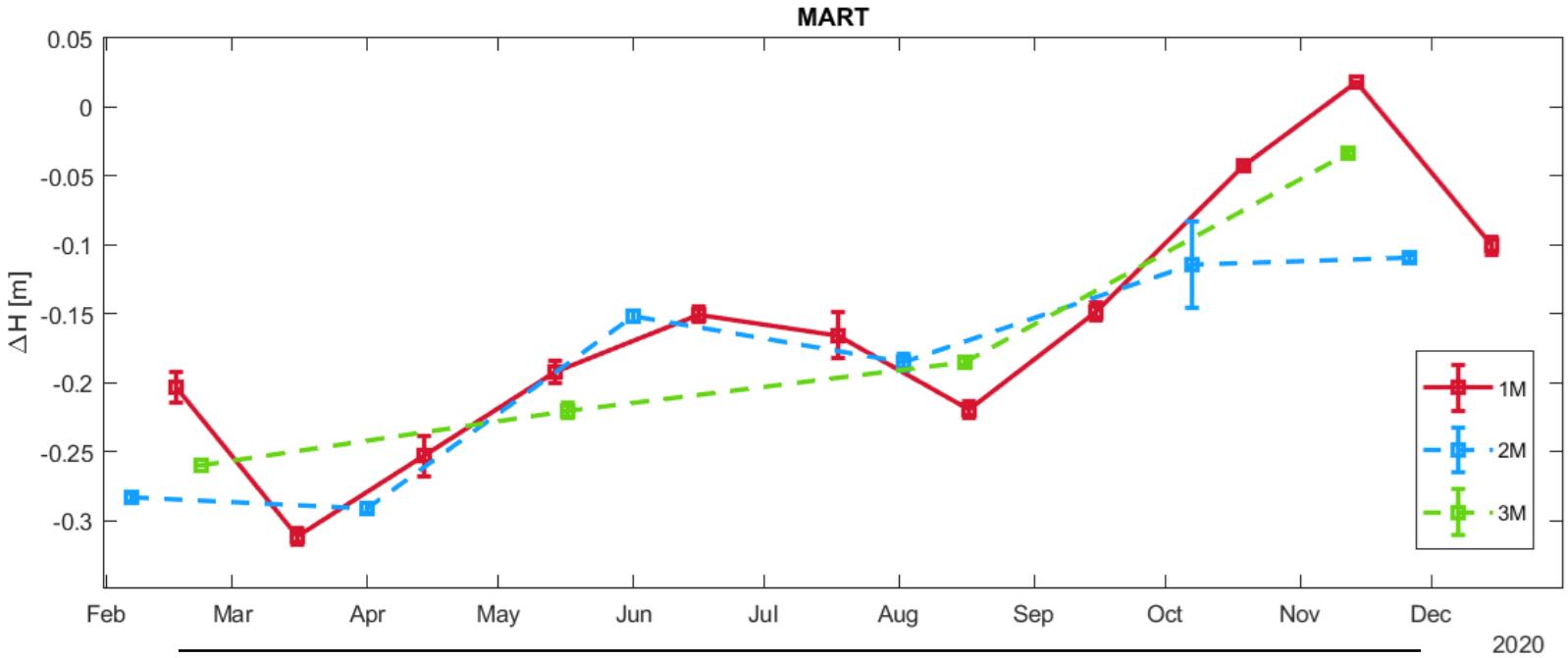

| $\Delta N[m]$ | $\Delta E[m]$ | $\Delta H[m]$ | $\sigma_N[\pm m]$ | $\sigma_E[\pm m]$ | $\sigma_H[\pm m]$ |
|---|---|---|---|---|---|
| 0.4759 | 0.0895 | -0.1915 | 0.0003 | 0.0013 | 0.0008 |

# Positioning over Time — Mårtsbo



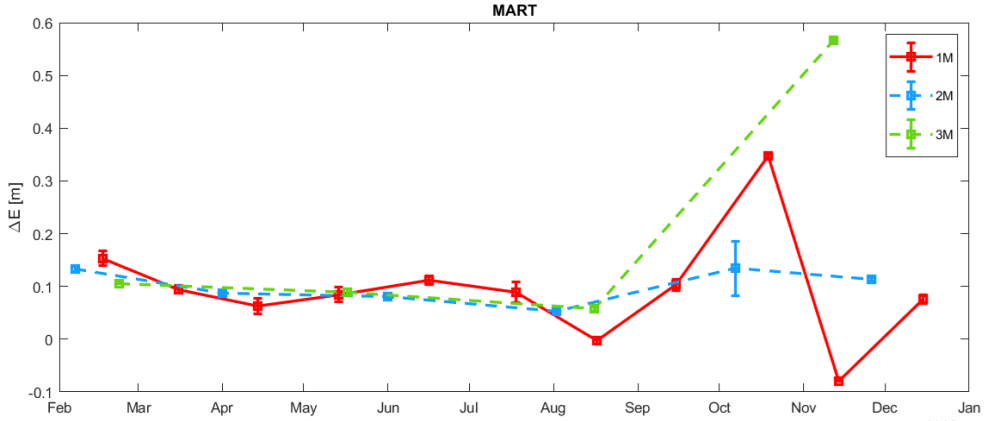



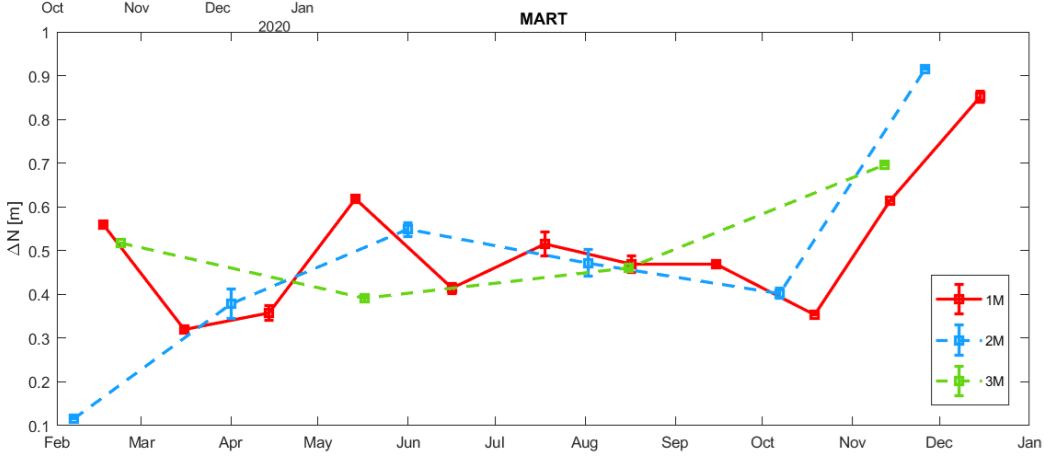
# Positioning over Time — Mårtsbo



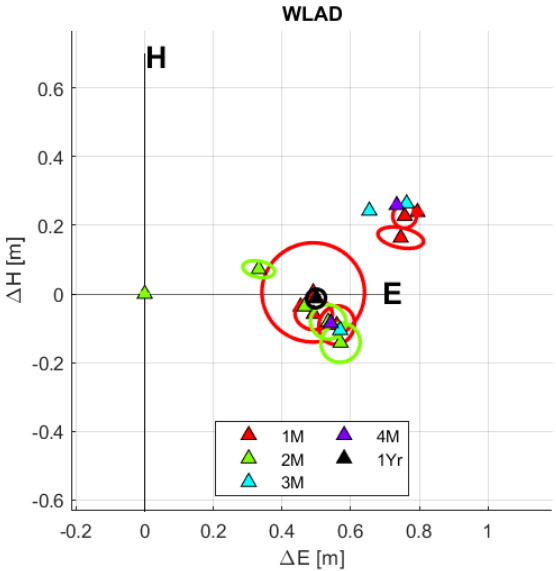

| Temporal Res. | $1M$ | $2M$ | $3M$ | $4M$ |
|---|---|---|---|---|
| # of Observation | ~17.7 | ~31.8 | ~46.8 | ~62.5 |

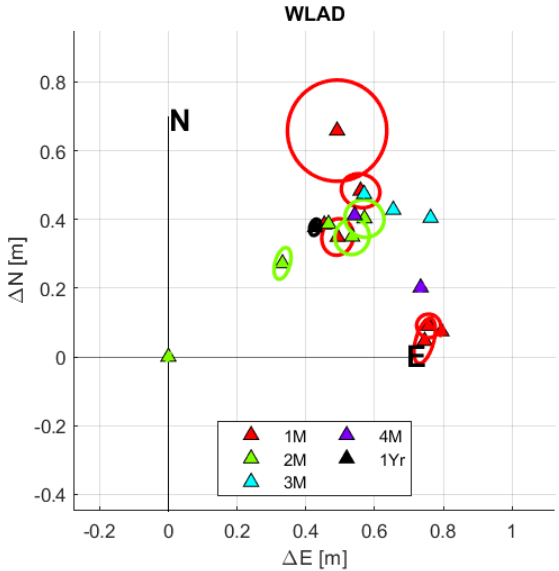
# Positioning over Time — Mårtsbo



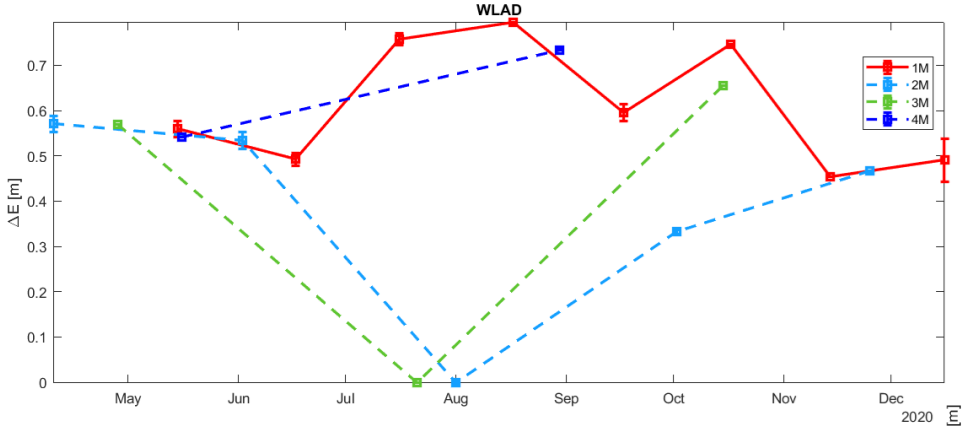
# Positioning over Time — Władysławowo

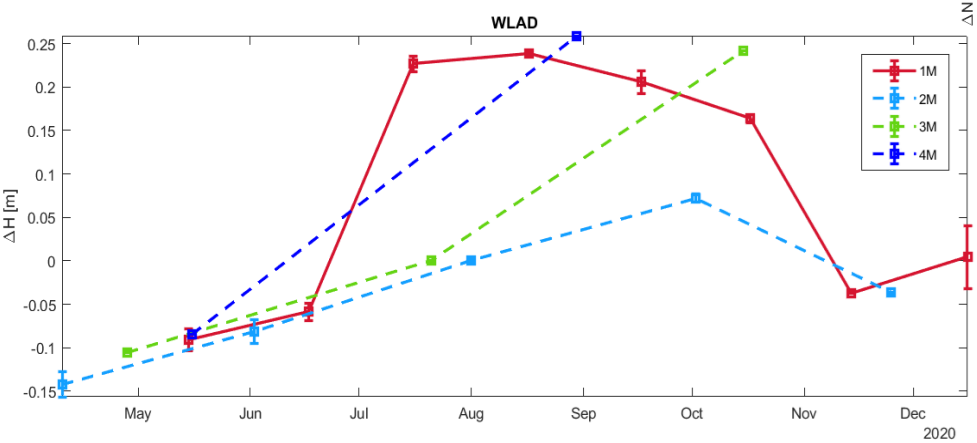


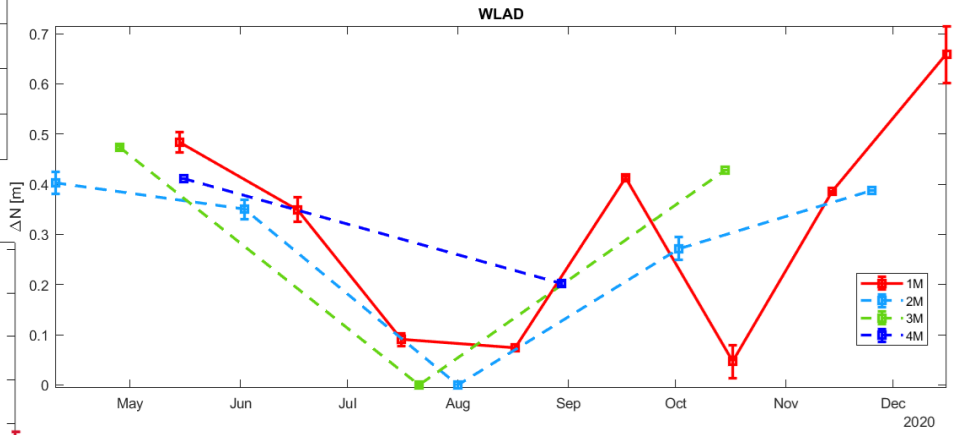




| $\Delta N[m]$ | $\Delta E[m]$ | $\Delta H[m]$ | $\sigma_N[\pm m]$ | $\sigma_E[\pm m]$ | $\sigma_H[\pm m]$ |
|---|---|---|---|---|---|
| 0.3772 | 0.4268 | 0.0190 | 0.0120 | 0.0044 | 0.0036 |

# Positioning over Time — Władysławowo

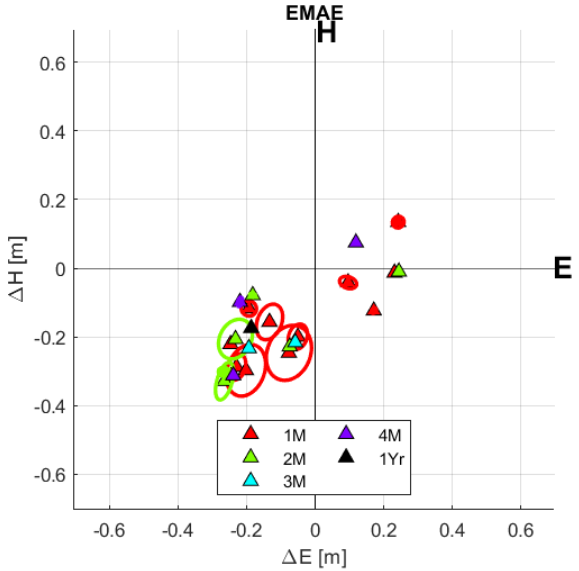


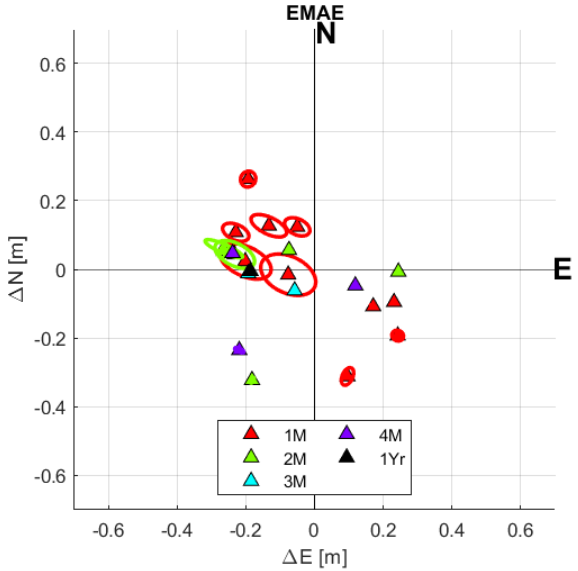




| Temporal Res. | $1M$ | $2M$ | $3M$ | $4M$ |
|---|---|---|---|---|
| # of Observation | ~15.5 | ~26 | ~41 | ~54.3 |

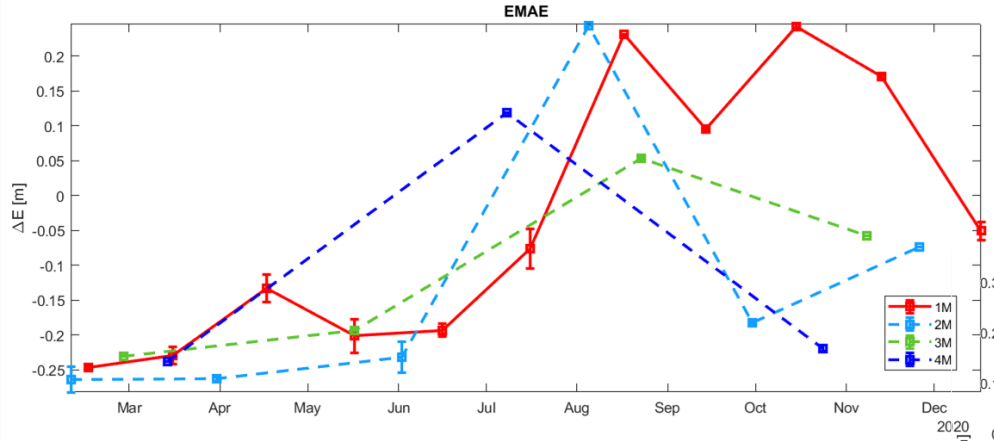
# Positioning over Time — Emäsalo

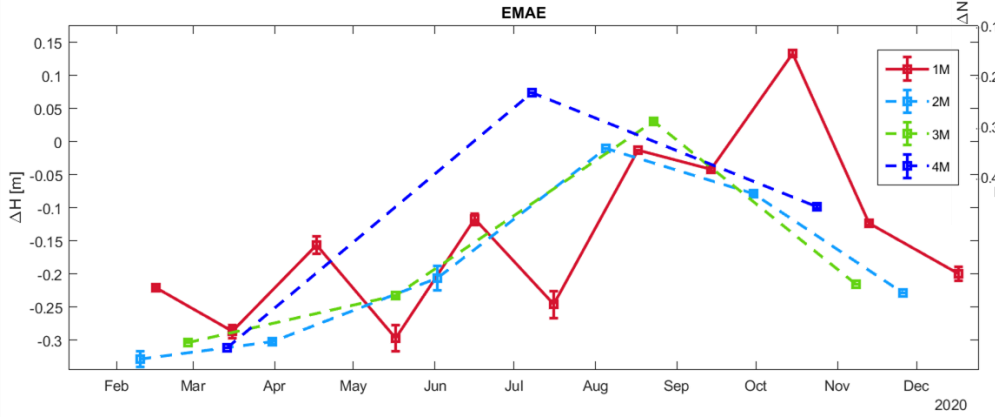


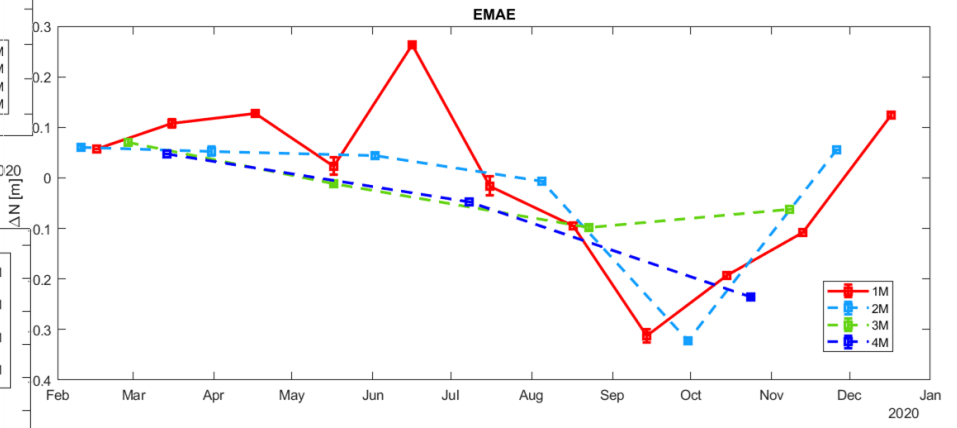




| $\Delta N[m]$ | $\Delta E[m]$ | $\Delta H[m]$ | $\sigma_N[\pm m]$ | $\sigma_E[\pm m]$ | $\sigma_H[\pm m]$ |
|---|---|---|---|---|---|
| -0.0054 | -0.1862 | -0.1744 | 0.0011 | 0.0000 | 0.0002 |

# Positioning over Time — Emäsalo




| Temporal Res. | $1M$ | $2M$ | $3M$ | $4M$ |
|---|---|---|---|---|
| # of Observation | ~15.5 | ~27.3 | ~42.1 | ~56.5 |

# Conclusion

- Amplification creates strong scatterers that are reliable for positioning.
- For an observation period of several months a high precision can be achieved (cm-mm).
- Temporal resolution is limited to a month → more than 10 SAR images needed
- Spatial accuracy is limited as ECRs must be individually calibrated, due to electronic delay and other systematic effects.
  - Władysławowo & Oberpfaffenhofen show annual variations
  - Emäsalo & Mårtsbo show a drift towards the end of the year
- Operability of ECRs shows room for improvement.
  - Robustness of the devices needs to be improved (e.g., weather seals)
  - Constant performance should be ensured (calibration of systematic effects)

# Reference


- Gisinger, Christoph; Balss, Ulrich; Pail, Roland; Zhu, Xiao Xiang; Montazeri, Sina; Gernhardt, Stefan; Eineder, Michael (2015): Precise Three-Dimensional Stereo Localization of Corner Reflectors and Persistent Scatterers With TerraSAR-X. In *IEEE Trans. Geosci. Remote Sensing* 53 (4), pp. 1782–1802. DOI: 10.1109/TGRS.2014.2348859.

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