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Temperature influences in receiver clock modelling

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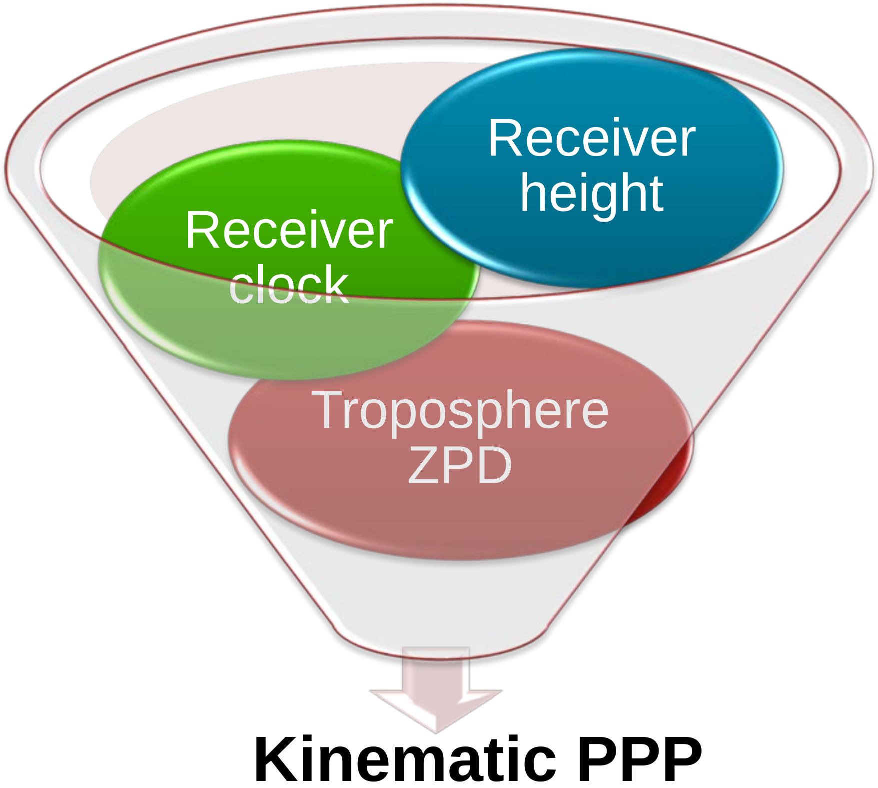
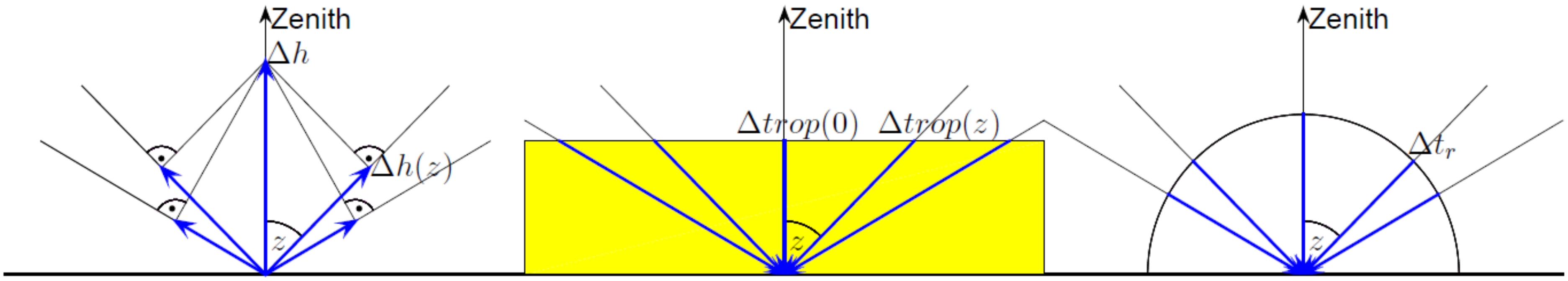
Contents

- Motivation
- True clock, apparent clock
- Correlation between the temperature and the clock estimates
- Conclusion

High correlation

- Decorrelation between the clocks, the receiver height and the ZPDs
- Clock modelling
  - Influences of the environmental effects





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True clocks and apparent clocks

- **True clocks**

  Behaviors of the receiver / satellite clocks under different measurement conditions. The true clock stability can be influenced by the clock type, the clock quality and the environment.

  - **True clocks in laboratory**

    Stable environment
    (Temperature, magnetic field, accelerations, …)

  - **True clocks outside laboratory**

    Influence of temperature, magnetic field, accelerations, etc. on the clock stability
    E.g. Galileo Passive Hydrogen Maser (PHM) in ground test:
    $< 2 \cdot 10^{-14}$/°C (6 ps/°C at 300 s)

True clocks and apparent clocks

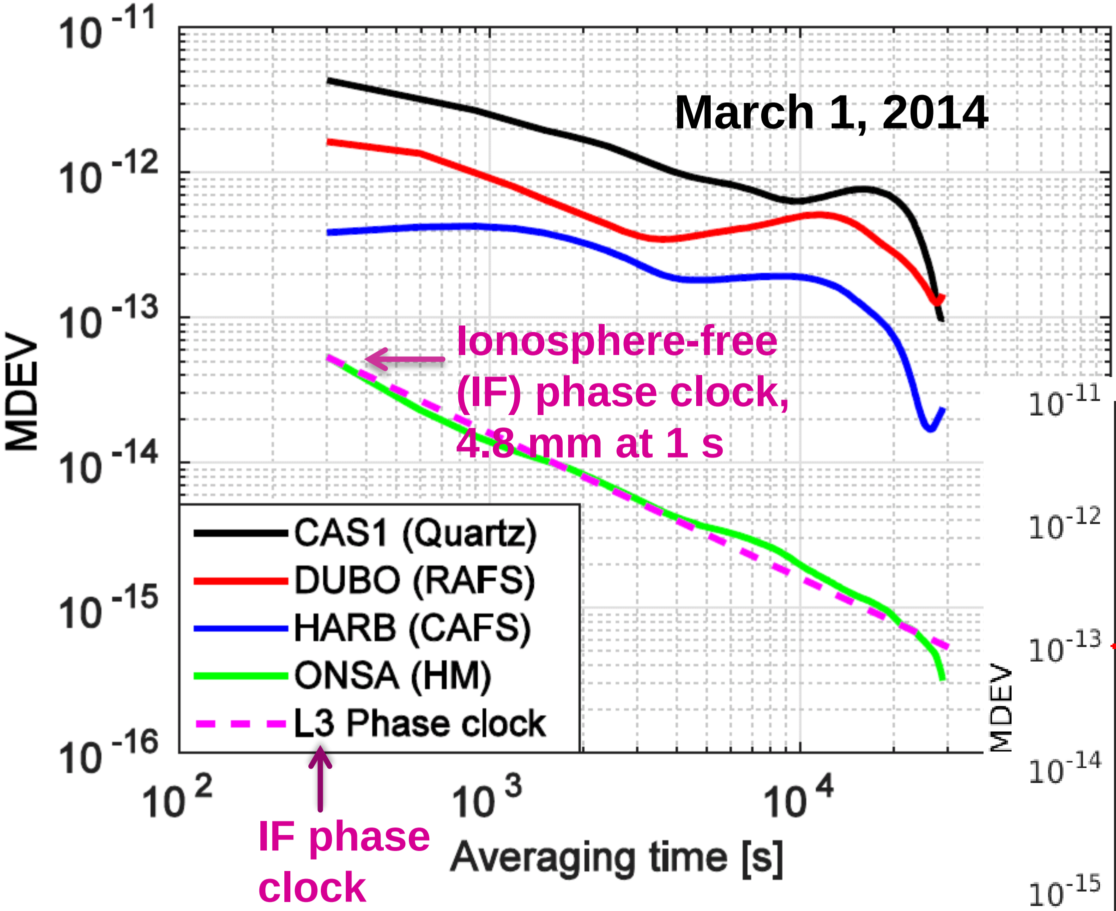
- **Apparent clocks**

  Behavior of the estimated receiver / satellite clock parameters in GNSS processing. The apparent clock behavior can be influenced by the true clocks themselves, by the receiver (tracking algorithms and settings: correlator, error mitigation, smoothing, etc.), by correlated parameters in the GNSS processing and by the environment (hardware delays, multipath, etc.).

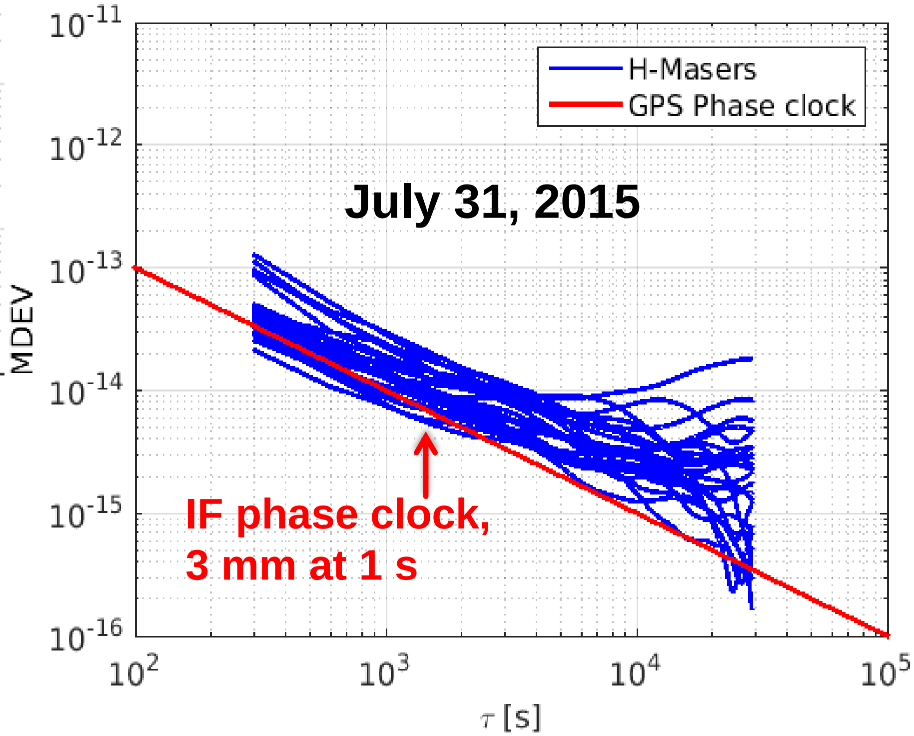
  - Why are the clock estimates influenced by other parameters in GNSS processing?
    - High correlation, e.g.
      - Receiver clock – troposphere ZPD – receiver height
      - Satellite clock – satellite orbit
      - → Reason for clock modelling (parameterization)

    - Environmental effects partially or totally absorbed by clock est.:
      - Hardware delays in receiver-antenna-chain
      - Multipath effects
      - → Modeling of the delays or estimation of add. parameters

Apparent clocks



- **"Apparent" clocks have lower stability than the "laboratory" clocks.**



- **Only HMs are considered for the station clock modeling.**

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Temperature-induced hardware delays

- **Model introduced by Weinbach (2013)**

$$clk(t_i) = k_T \cdot T(t_i) + a_0 + a_1 \cdot t_i + \cdots + a_n \cdot t_i^n$$

IGS clock estimates

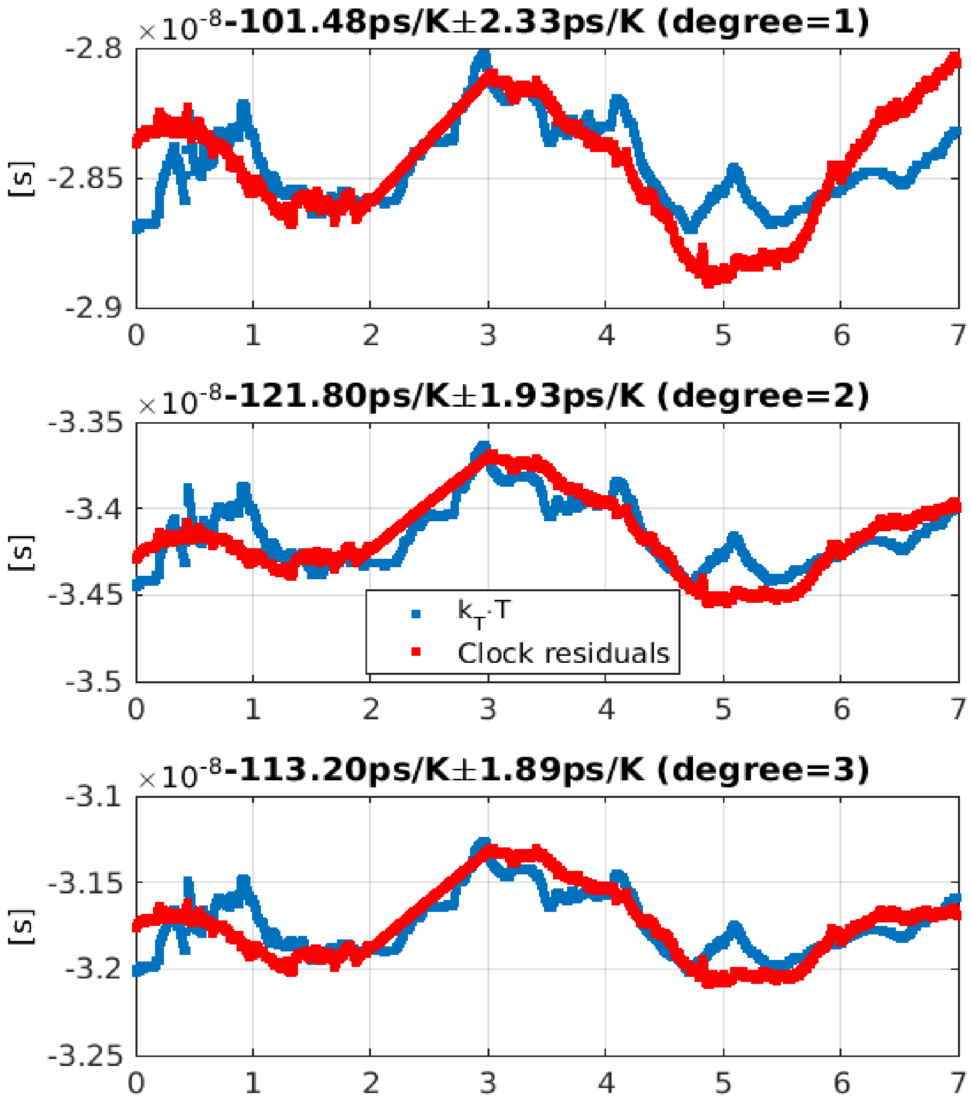
Assumption 2: Long-term clock behavior of HM w.r.t. IGS time (IGST) can be modeled by a low-order polynomial.

Assumption 1: T from the IGS MET files

- **3 years of data in IGST: August 5, 2012 – July 25, 2015**
- **Day boundary jumps are corrected; Days with large clock jumps (> 30 ns) and results with large σ_{k_T} (> 5 ps/K) are removed**
- **Modeling on a weekly basis**

Station	Country	Antenna type	
PTBB	Germany	ASH700936E	SNOW
GODE	US	AOAD/M_T	JPLA
HERS	UK	LEIAR25.R3	NONE
SVTL	Russia	TPSCR.G3	TPSH

Correlation between temperature and clocks



PTBB, 30 December 2012 – 5 January 2013

Clock residuals:

$$r(t_i) = clk(t_i) - a_0 - a_1 \cdot t_i - \cdots - a_p \cdot t_i^p$$

- Large k_T
- Clear correlations even for $p = 1$ (linear fit)

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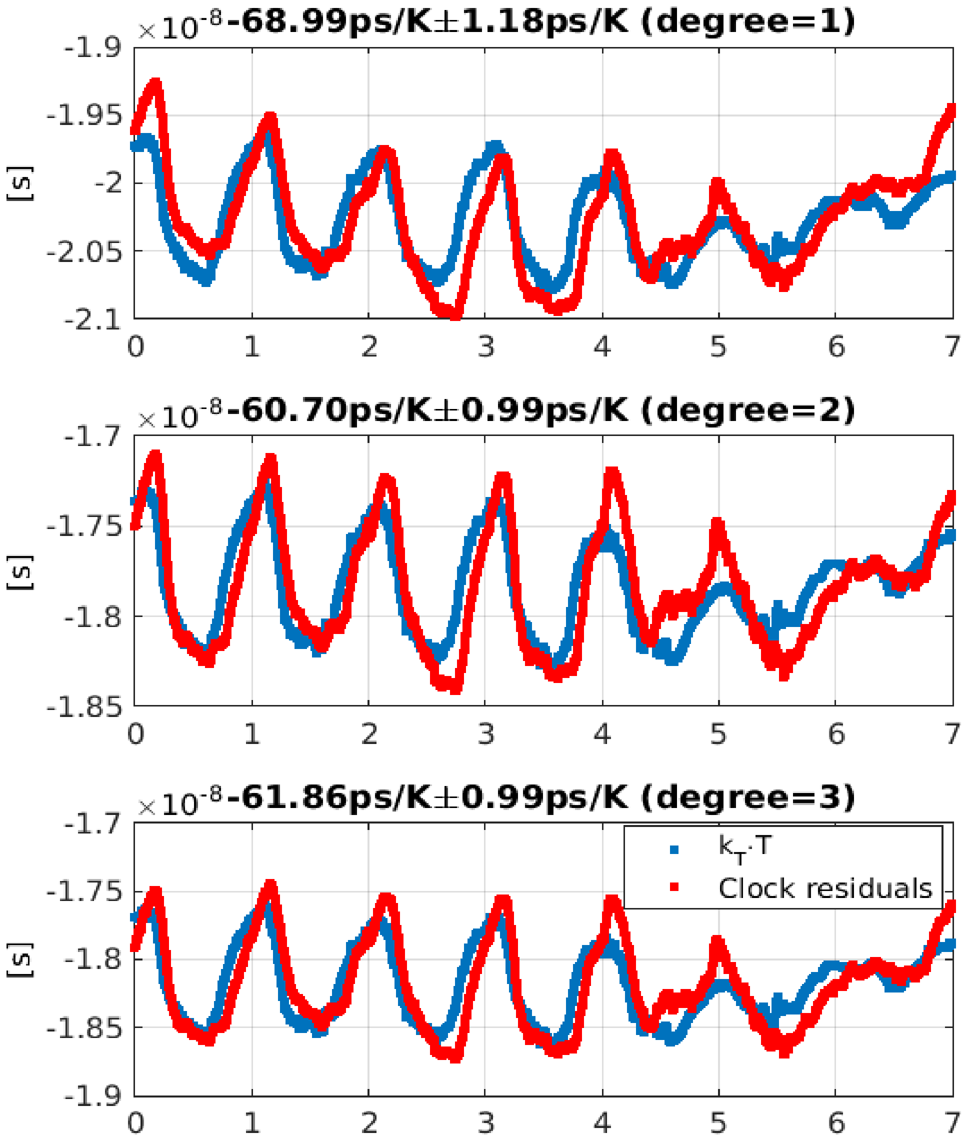
Correlation between temperature and clocks

PTBB 14234M001

- Braunschweig, Germany
- connected to an external active H-Maser
- Antenna on a steel mast on the roof of the PTB-building, 11.1 m above the ground
- Long RG 214 cable running outside
  → cable effects?

Correlation between temperature and clocks



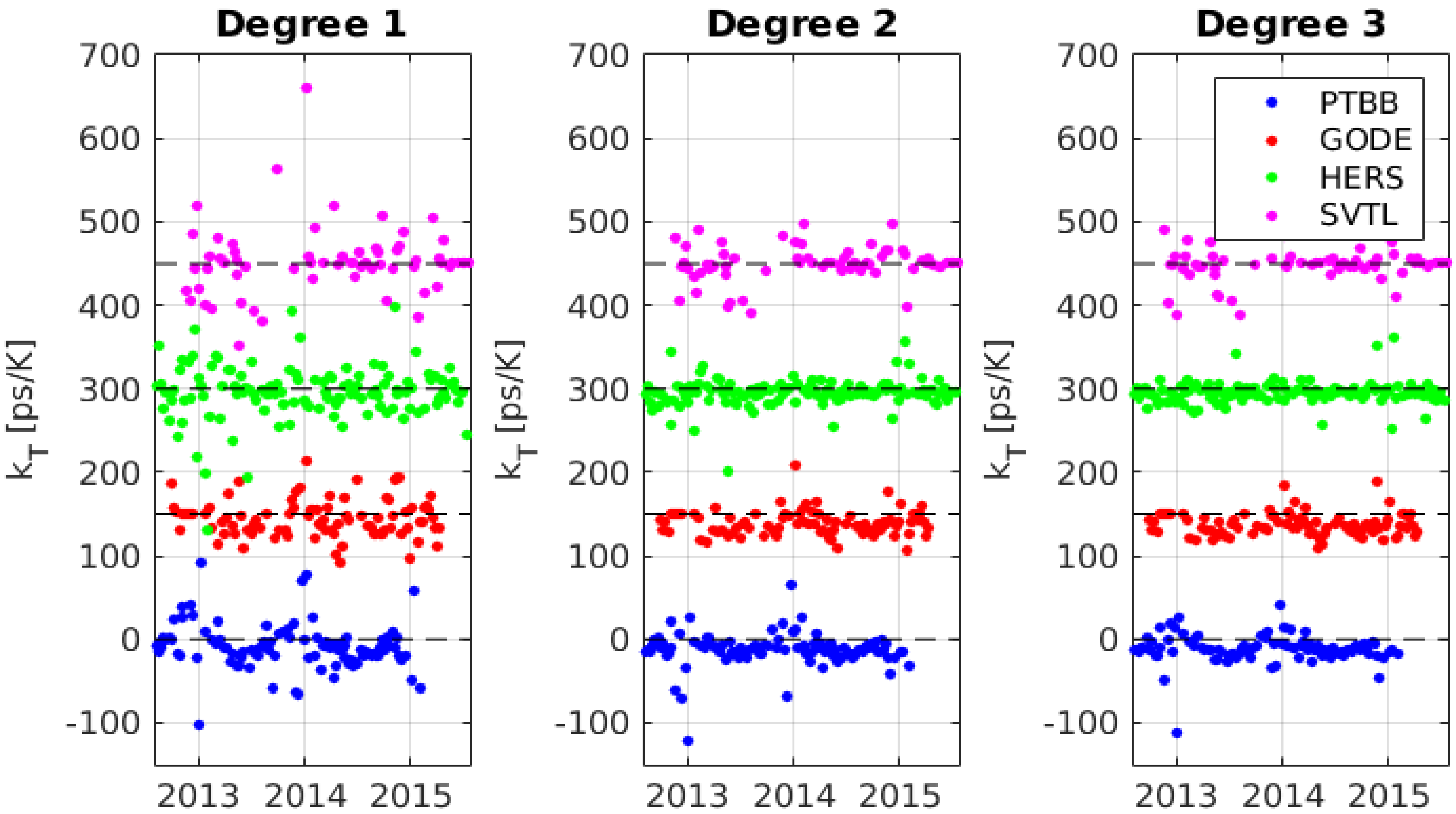
SVTL, 4-10 August 2013

Clock residuals:

$$r(t_i) = clk(t_i) - a_0 - a_1 \cdot t_i - \cdots - a_p \cdot t_i^p$$

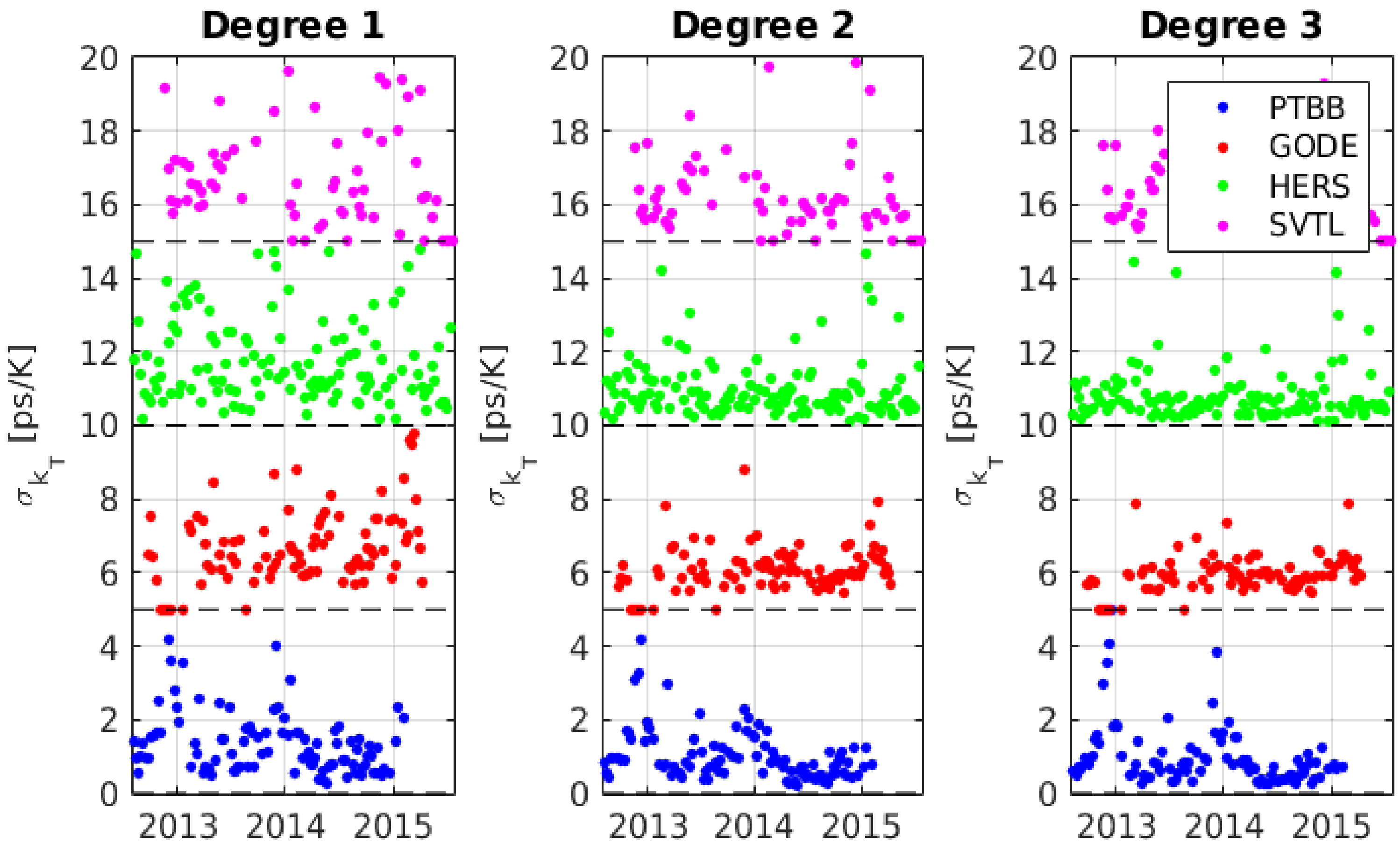
- Large k_T
- Strong correlations even for $p = 1$
- Daily periodical fluctuation

Temperature coefficient k_T



- Values shifted by n ×150 ps/K
- k_T decreases with the increasing polynomial degrees
- Large k_T visible
- Higher values in winter

Formel error of k_T: σ_{k_T}



- Relatively small σ_{k_T} → clear correlation between the temperature and the clock estimates
- Values shifted by $n \times 5$ ps/K

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Correlation between temperature and clocks

- The temperature-induced hardware delays are sometimes large enough to influence the clock estimates (22% of the $|k_T|$ > 30 ps/K applying a linear polynomial with σ_{k_T}< 5 ps/K).
- According to our analysis with 3 year's of IGS data of 4 stations connected to HMs, a clear correlation between temperature and clock estimates can be observed.
- It is unclear which part/parts of the hardware delays (cables, antenna, receiver) has generated the temperature-correlated biases. The modelling is thus with respect to the total temperature-induced hardware delays.
- It could be helpful to add a temperature coefficient k_T in the receiver clock model to model the total temperature-induced hardware delays. The temperature coefficients can either be estimated together with the clock model parameters or be pre-calculated and introduced into the adjustment.
- Effects of the receiver clock models with and without the temperature coefficients on the coordinates and troposphere ZPDs are still to be analyzed.