How to deal with non-linear station motions?

Ralf Schmid, Mathis Bloßfeld, Detlef Angermann

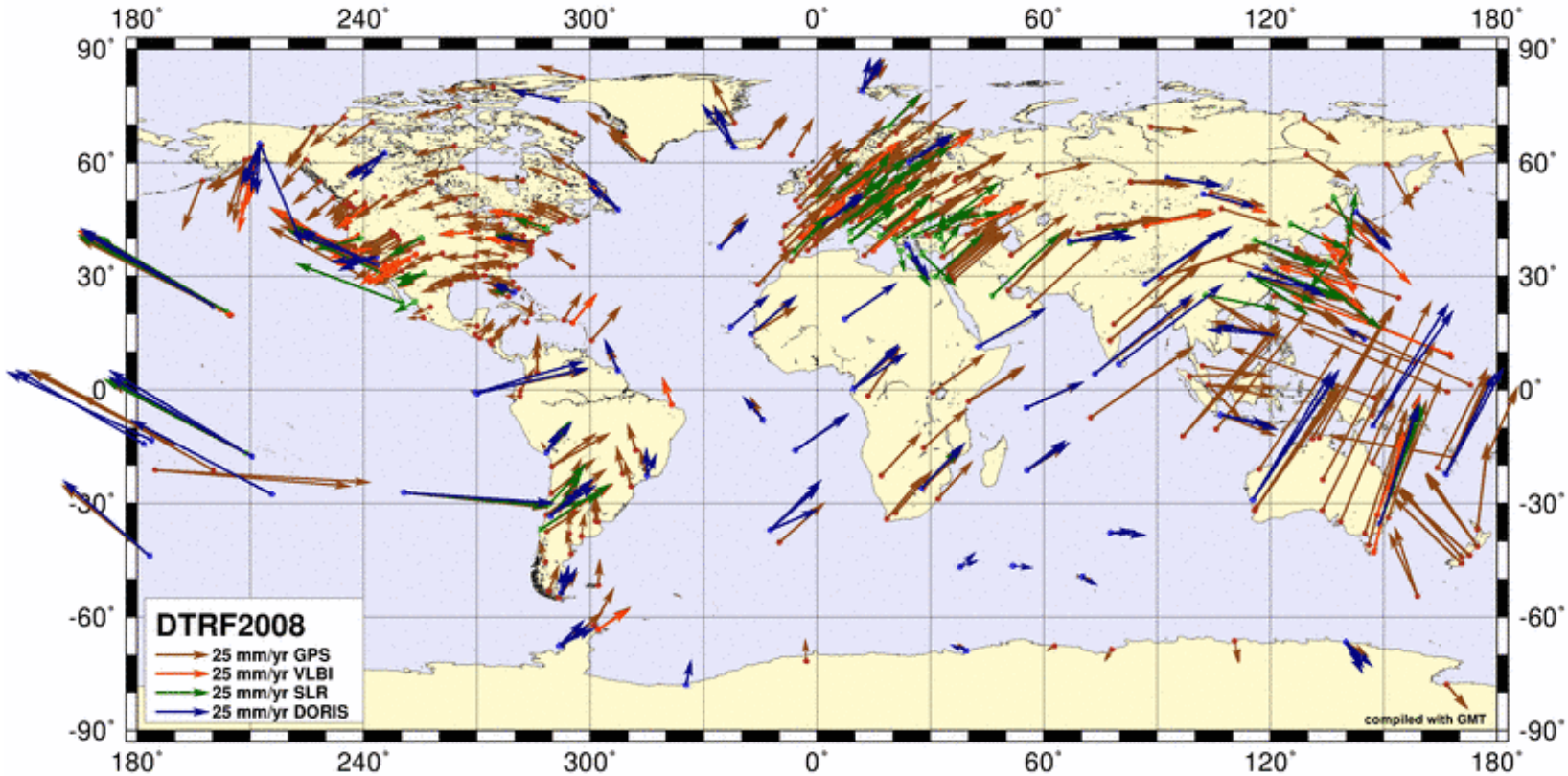
Deutsches Geodätisches Forschungsinstitut (DGFI)
München
e-mail: *schmid@dgfi.badw.de*

DFG Forschergruppe Referenzsysteme

DGFI

CGE Centre of Geodetic Earth System Research

Motivation (1)

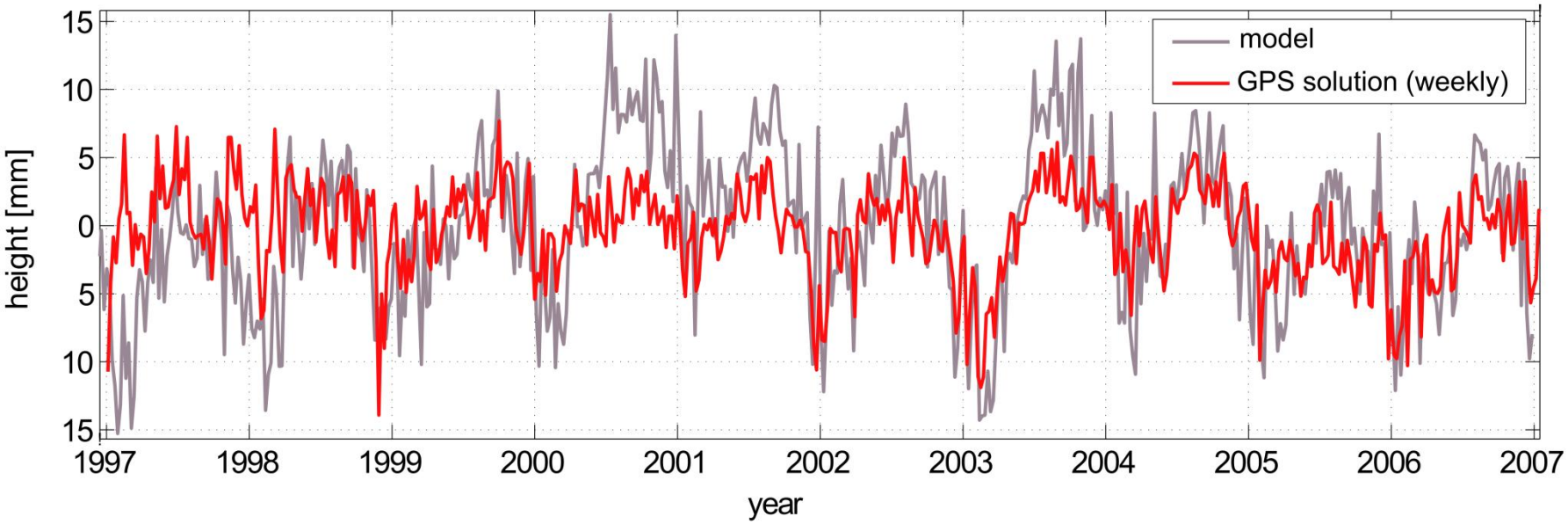


Seitz et al. (2012)

Current station parameterization (coordinates and **velocities**) to realize long-term reference frames can only cover **secular station motions** (caused, e.g., by plate tectonics, post-glacial rebound, etc.)

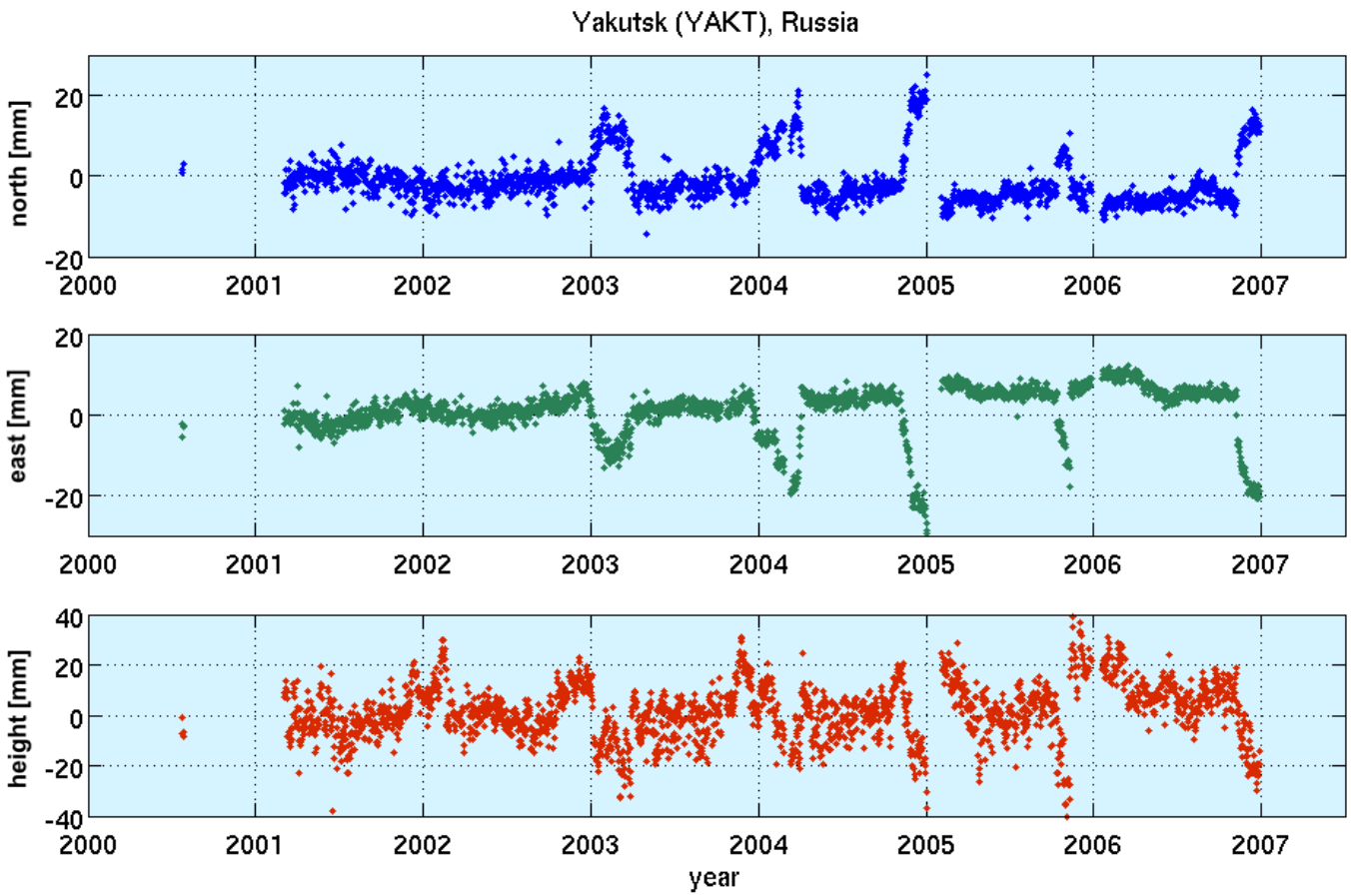
Motivation (2)

Observed (GPS) vs. modeled (atmospheric loading derived from NCEP data, hydrological loading from GLDAS) weekly height variations for Wettzell:



Unmodeled effects like atmospheric or hydrological loading cause **periodic signals** in coordinate time series. Available models are still not accurate enough.

Motivation (3)



Episodic effects (e.g., local hydrological effects or post-seismic deformation) can neither be covered by linear station velocities nor by periodic signals

Strategies to deal with non-linear station motions

- **Modeling**
  - improved modeling of global geophysical fluids (atmosphere, oceans, hydrology, etc.) that are mainly responsible for periodic station motions
  - ideal solution, long-term objective
- **Parameterization**
  - set up parameters like annual and semi-annual sine functions for the station coordinates (besides linear station velocities)
  - interim solution
- **Sampling**
  - estimation of epoch reference frames in addition to multi-year reference frames
  - only possibility to approach episodic effects

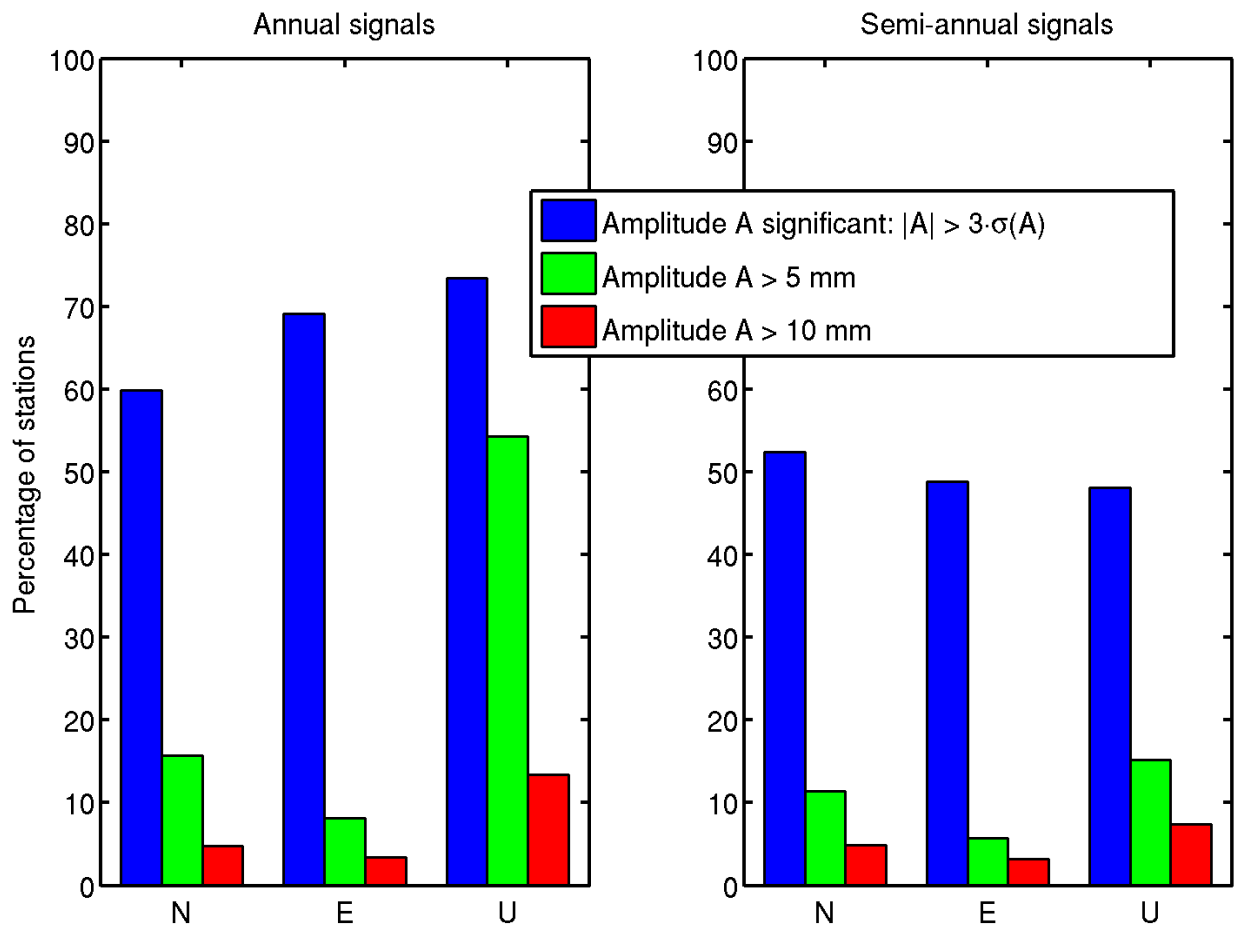
Parameterization

Only necessary, as long as (loading) models have deficiencies and, therefore, an interim solution, but...

- calls attention to the general problem
- gives feedback to the modeling approach
- helps to categorize stations with respect to sub-annual stability
- interesting as regards the necessary datum constraints

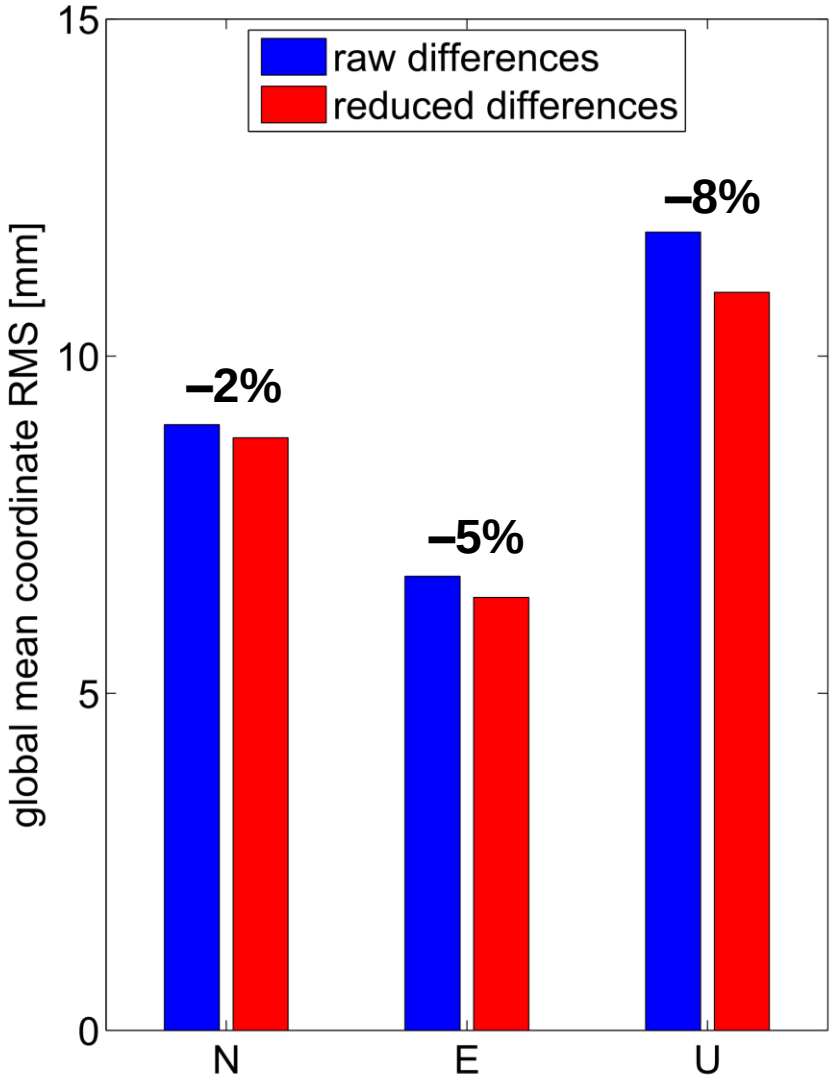
So far, only **indirect estimates** from final coordinate time series for the periodic signals available. Direct estimation important, as other parameters could absorb parts of the signal.

Significance of (semi-)annual station motions



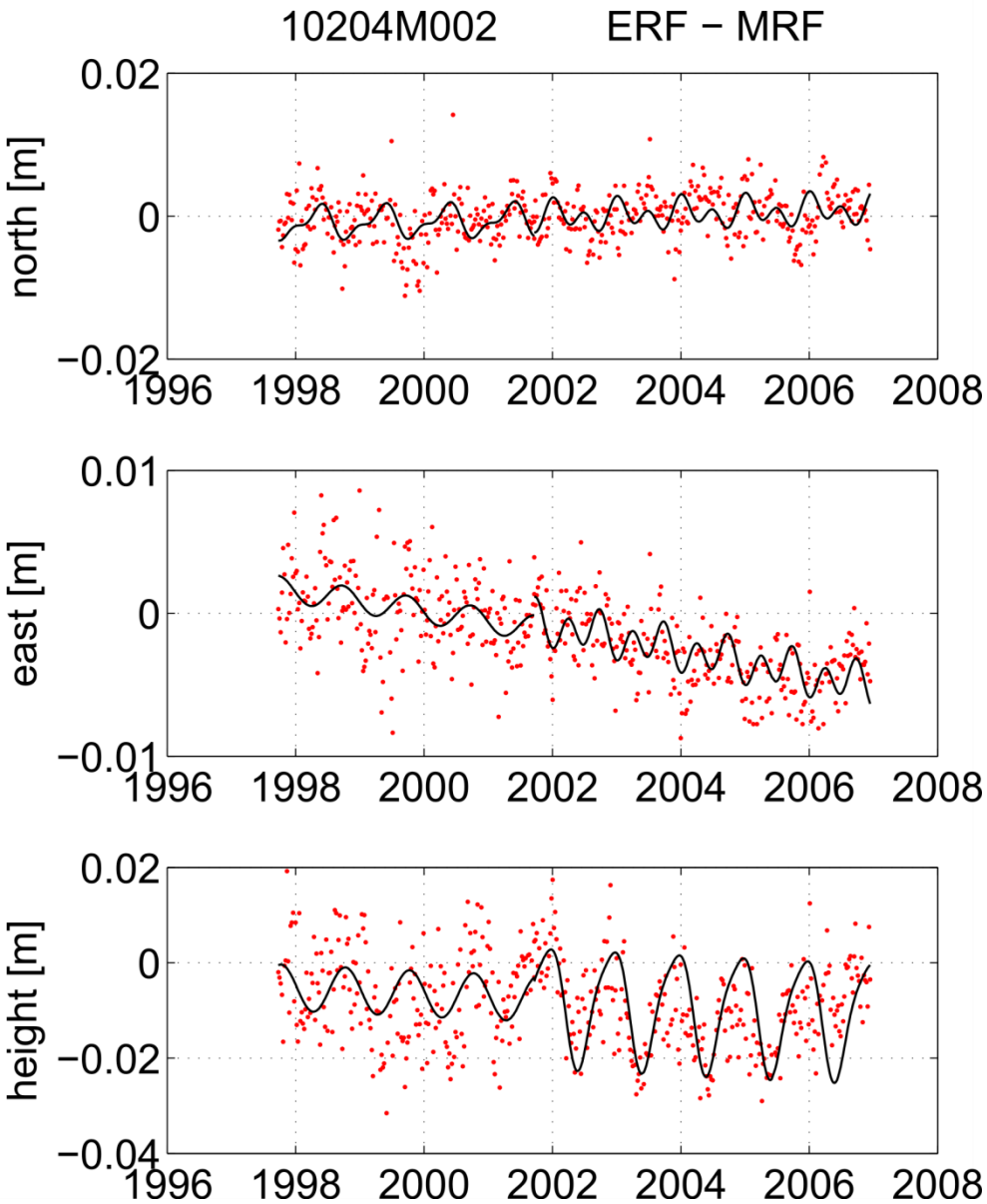
Derived from **differences between epoch and multi-year reference frames** (combined GPS, SLR and VLBI solutions; 1994-2006; 335 stations with 528 sets of positions)

Reduction of station RMS



Reduction of height RMS	Percentage of stations
> 1 mm	38%
> 2 mm	14%
> 3 mm	4%

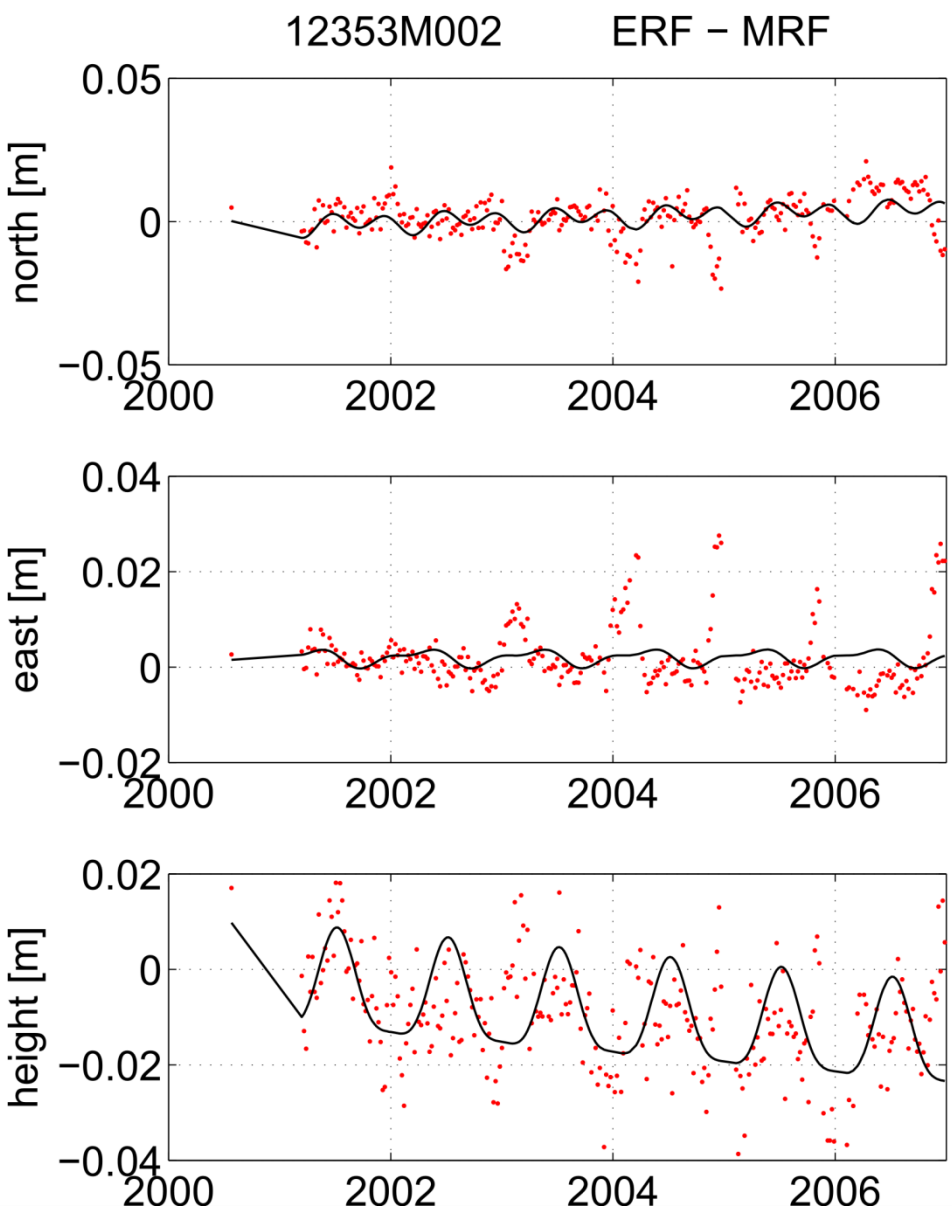
(Semi-)annual station motions (1)



Hofn (Iceland):

- time series of differences between epoch (ERF) and multi-year reference frames (MRF)
- **trends** probably due to deficiencies in the velocity estimates of the MRF
- semi-annual signal not always significant
- strong annual signal in the **up component**
- different amplitudes for consecutive intervals, but **good phase agreement**

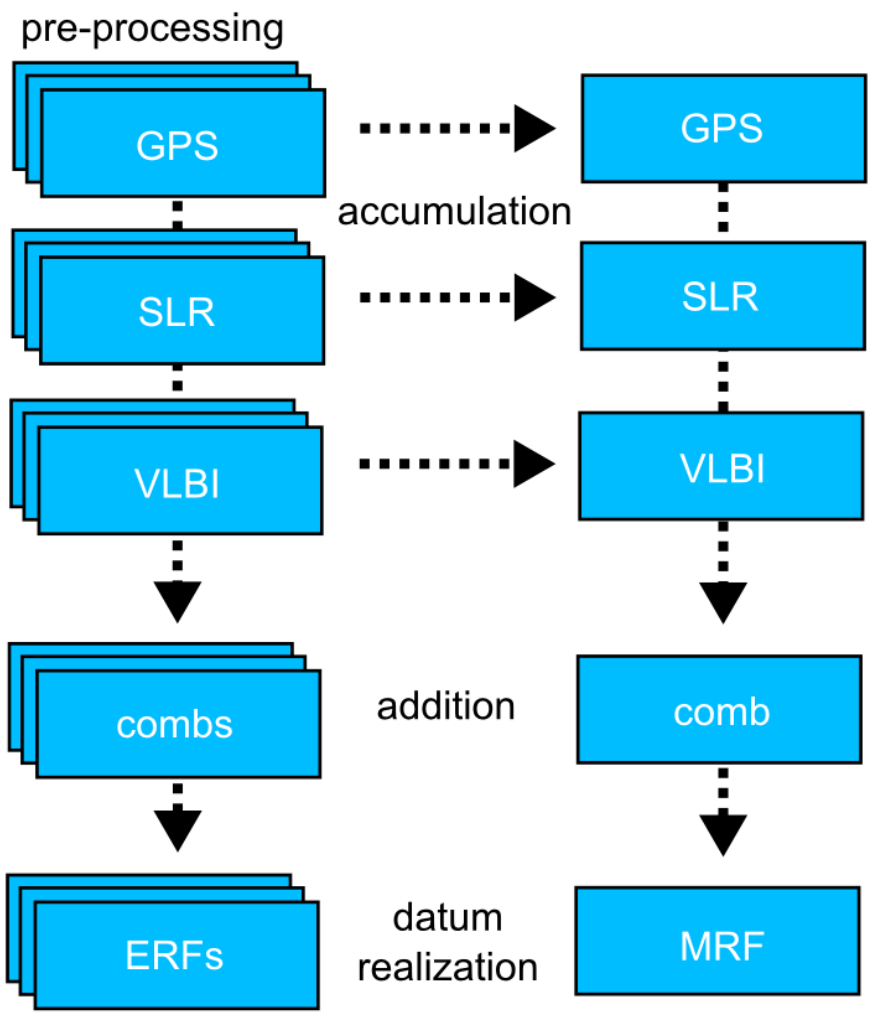
(Semi-)annual station motions (2)



Yakutsk (Russia):

- strong annual signal in the up component
- annual signals not able to cover **episodic effects** contained in the horizontal components

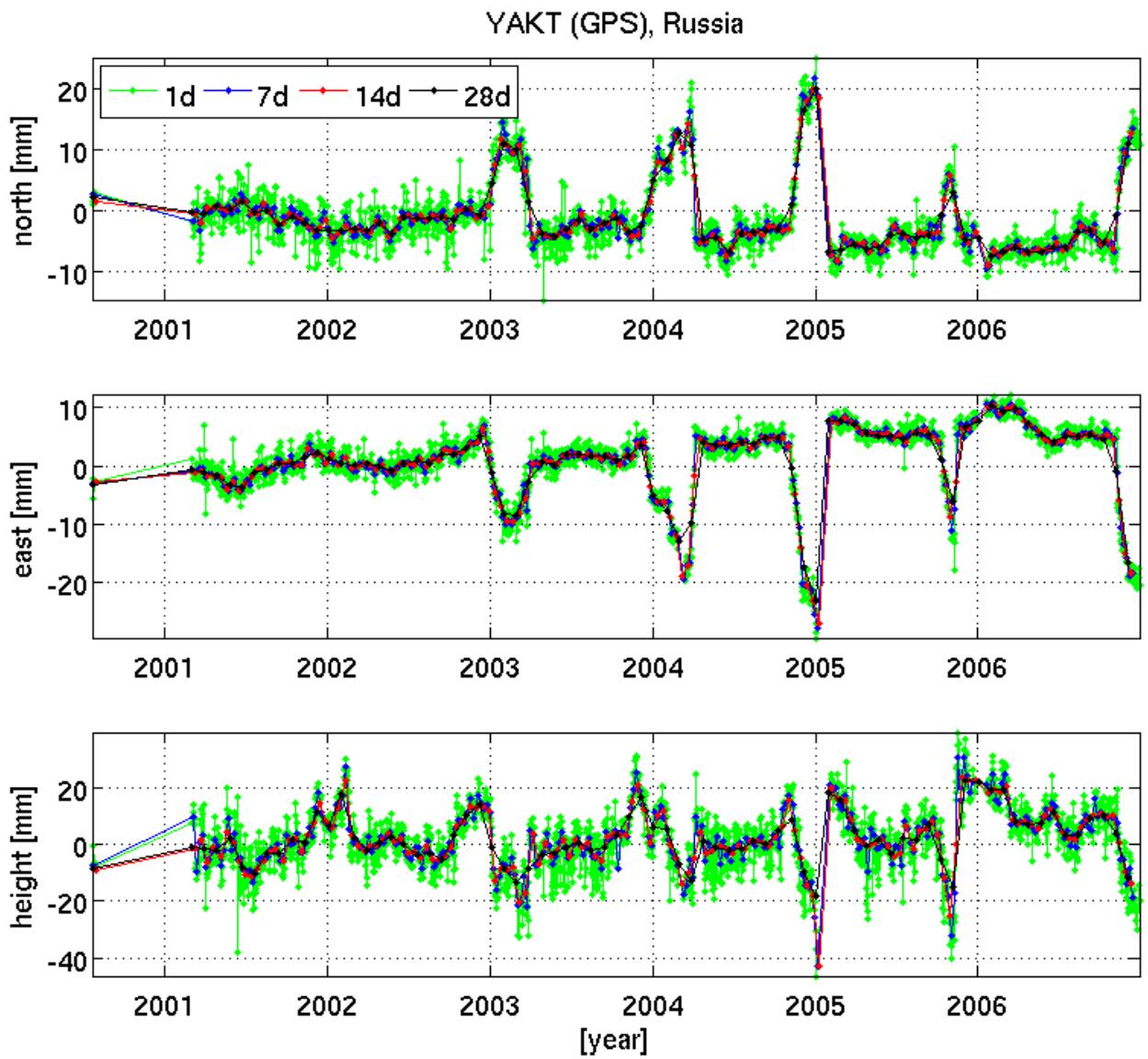
Sampling



- **epoch-wise combination** of different space geodetic techniques (GPS, SLR, VLBI)
- epoch reference frames (ERFs) only contain station positions (no velocities!)
- **datum realization**:
  - origin: SLR
  - orientation: NNR (GPS)
  - scale: SLR/VLBI
- adequate number of **local ties** per epoch necessary

Epoch reference frames

Different sampling rates
(1 d, ..., 28 d): compromise between datum stability and the possibility to sample short-term effects



Epoch vs. multi-year reference frames

	ERF	MRF
Parameterization	$X(t_i)$	$X(t_0)$, dX/dt
Stability	short-term	long-term
Non-linear station motions	frequently sampled	suppressed
Station network	sparse	dense
Number of local ties	low	high
Latency (e.g., after earthquakes)	few epochs	≥ 2.5 years

Summary

- Stations currently parameterized with coordinates and corresponding velocities for TRF computations
- Station velocities cover secular station motions, but neither periodic nor episodic effects
- Parameterization of (semi-)annual station signals can serve as an interim solution, as long as geophysical fluid models are imperfect
- (Semi-)annual signals are significant; the amplitude of the up component exceeds the cm level for about 15% of the stations
- Epoch reference frames (ERFs) can sample both periodic and episodic effects
- Sampling rate is a compromise between datum stability and the temporal resolution of the station motion
- ERFs are available with short latency (e.g., after earthquakes)