Geodetic Cloud
Computing Service

Direct access to the ITR
anywhere on Earth

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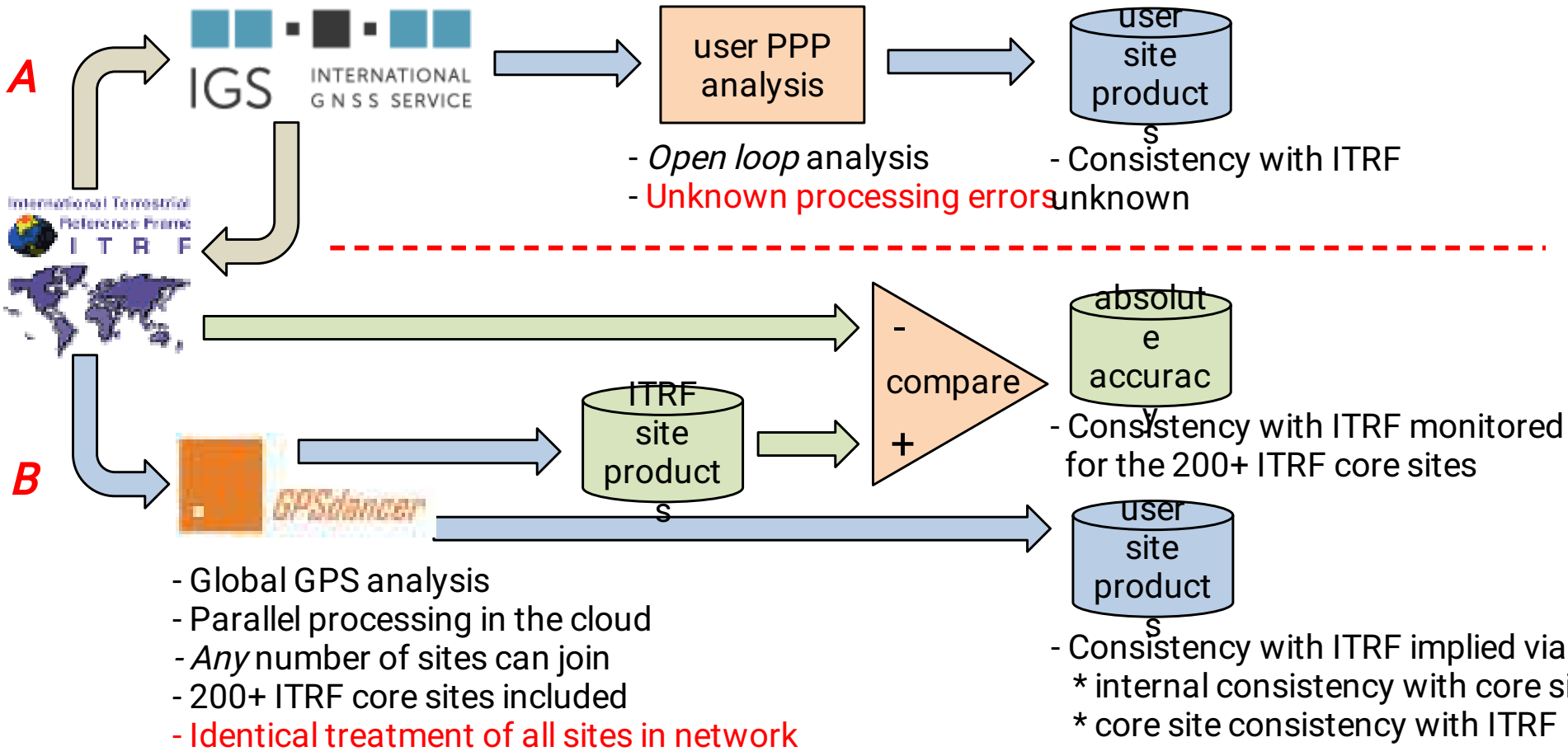
esa business incubation centre Darmstadt

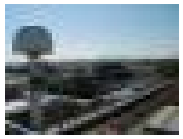
IGS Workshop 2017 Paris

Introduction



Basics of GPSdancer (→GPSdancer.org)

1



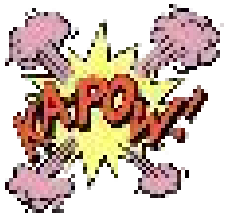
24 hr

$$\begin{pmatrix} A & B \\ B^t & C \end{pmatrix} \begin{pmatrix} x_g \\ x_l \end{pmatrix} = \begin{pmatrix} y_g \\ y_l \end{pmatrix}$$

- A GPSdancer instance accumulates the normal equations from the most recent 24 hours of data from a single receiver
- Pre-elimination of local parameters leaves a singular normal equation for the global parameters (orbits, sat clocks, pole)

$$\begin{cases} x_l = C^{-1}(y_l - B^t x_g) \\ (A - BC^{-1}B^t)x_g = y_g - BC^{-1}y_l \end{cases}$$

2



square dance algorithm

- Distributed P2P accumulation of N contributions
- All N computers end up with total network sum
- Bandwidth per computer only grows by log(N)

$$\sum (A - BC^{-1}B^t)\, x_g = \sum (y_g - BC^{-1}y_l)$$

$$\downarrow$$

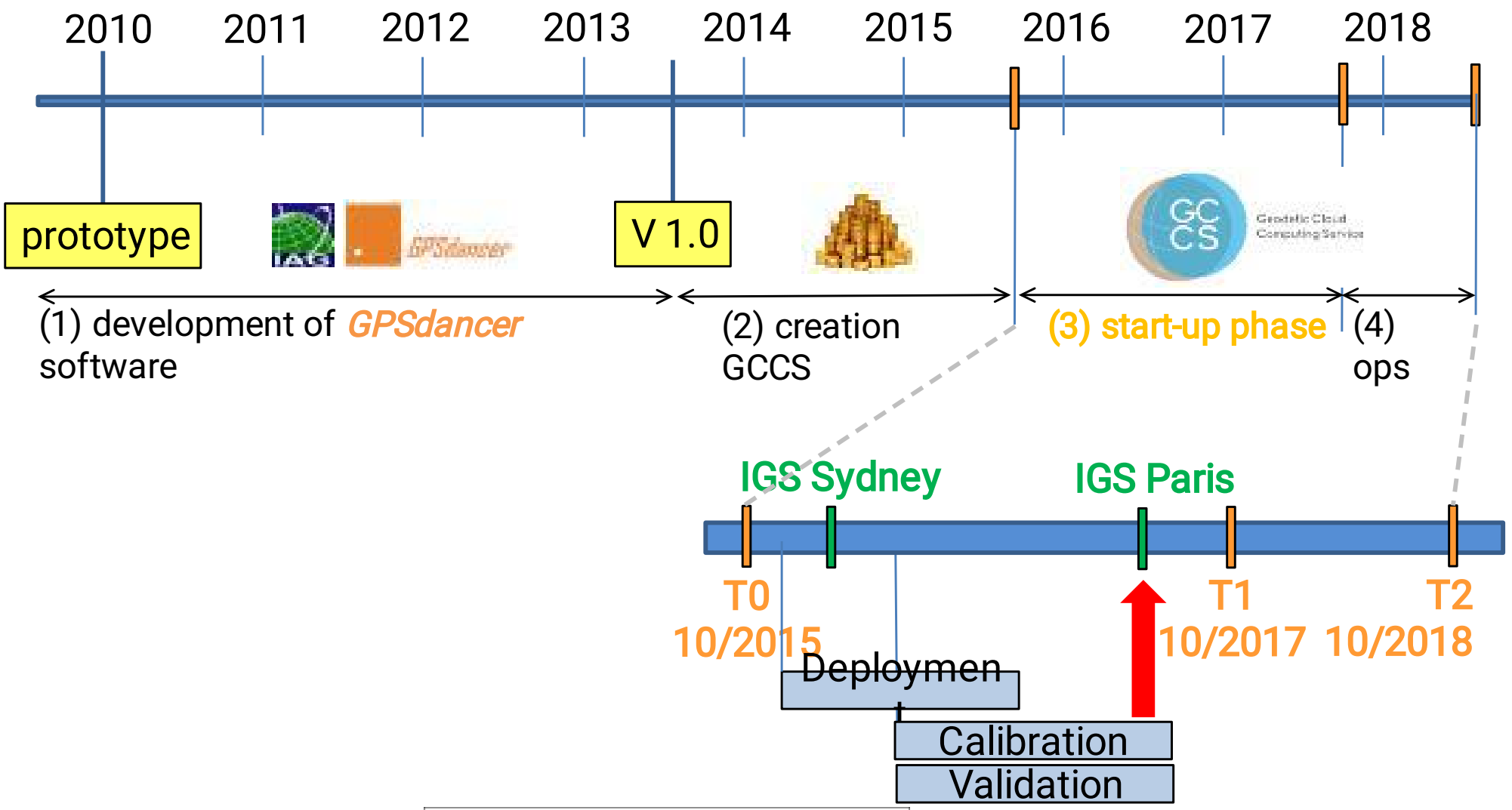
$$x_g$$

$$\downarrow$$

$$x_l$$

- All global normal matrix contributions are accumulated among N GPSdancer processes that can run anywhere in the world
- All N computers then solve the same non-singular global normal equation
- All N computer find their own local solution after back-substitution
- Data and local products remain private to each GPSdancer instance

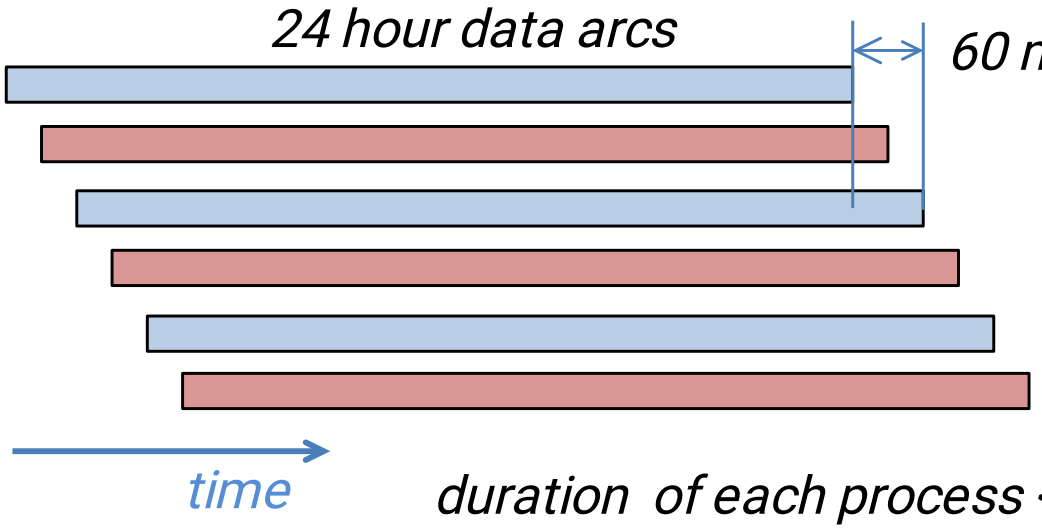
GPSdancer and GCCS timeline



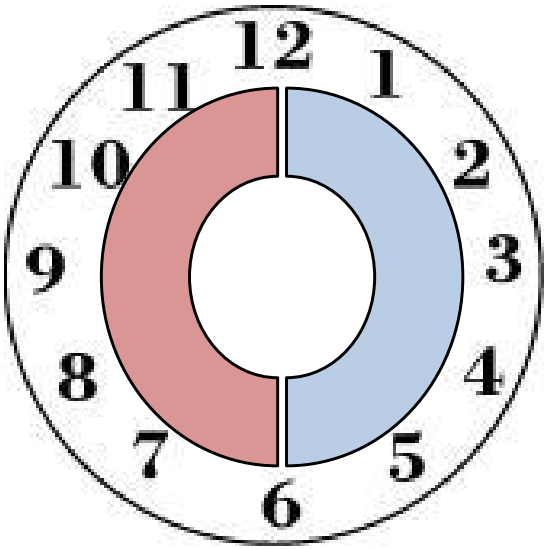
Time sharing of server capacity

Objectives of Calibration / Validation campaign:

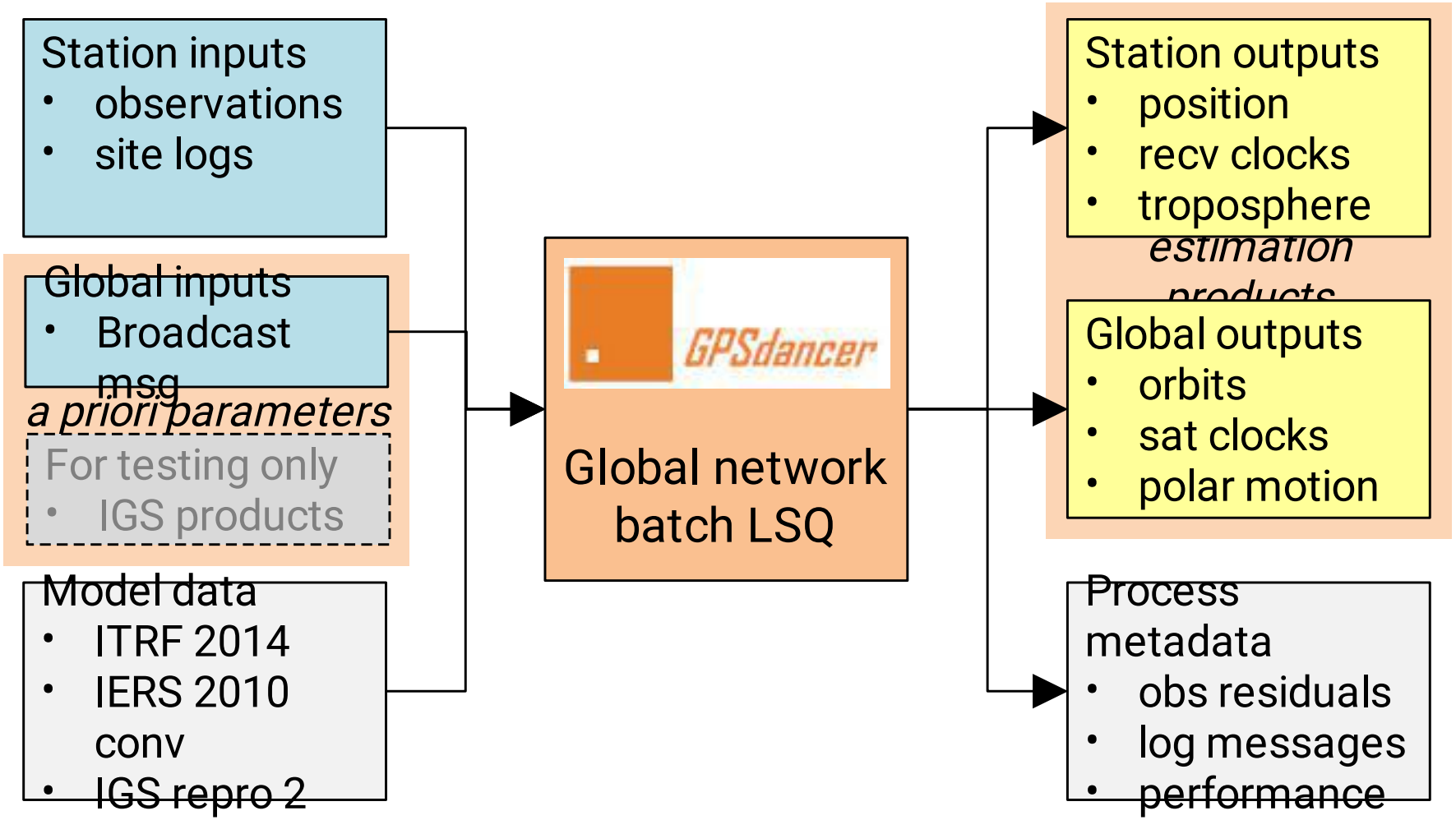
1. Evolve towards stable, routine analysis @ 30 minutes
2. Test and tune the process to reach IGS quality



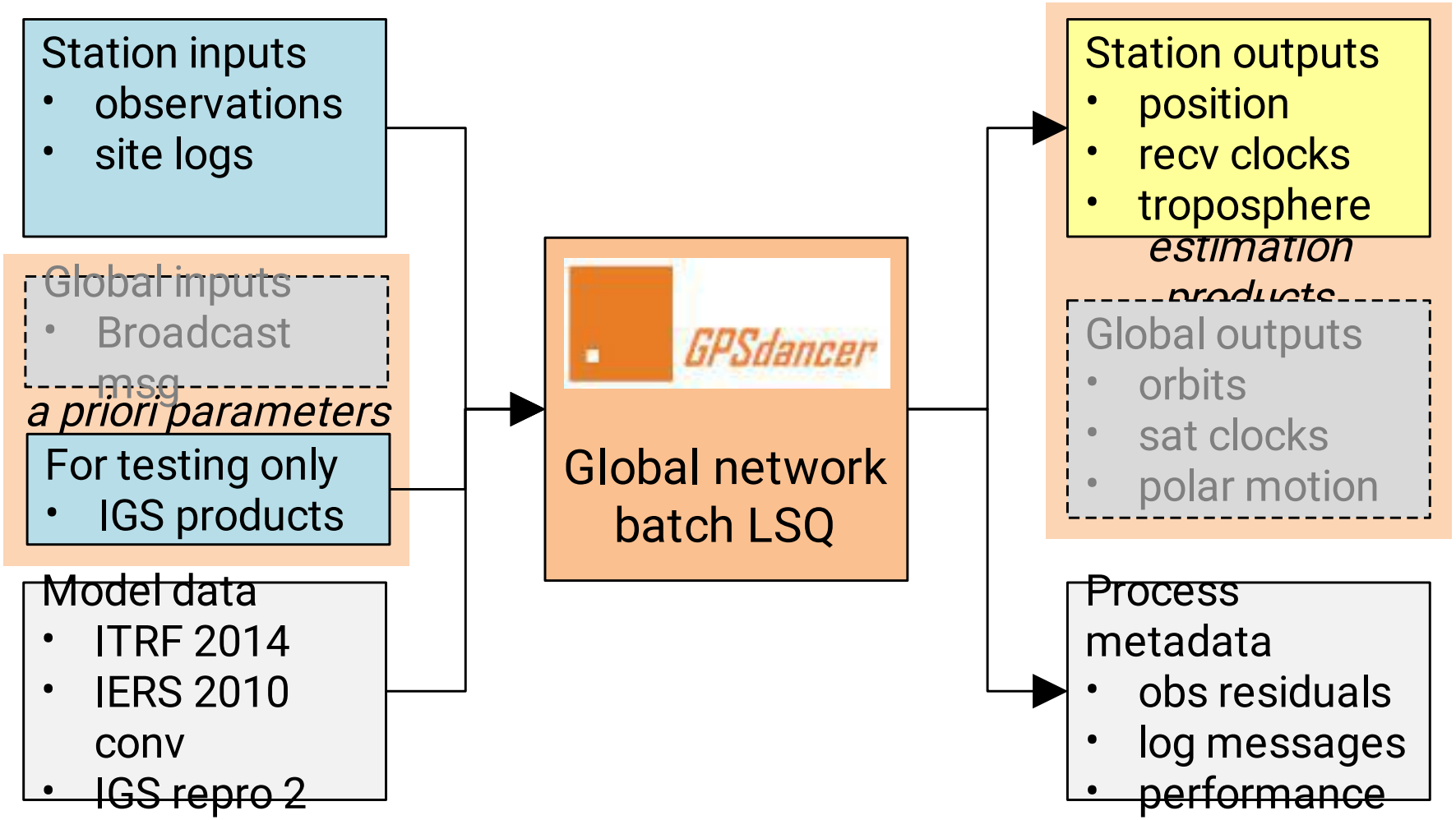
duration of each process < 30 minutes



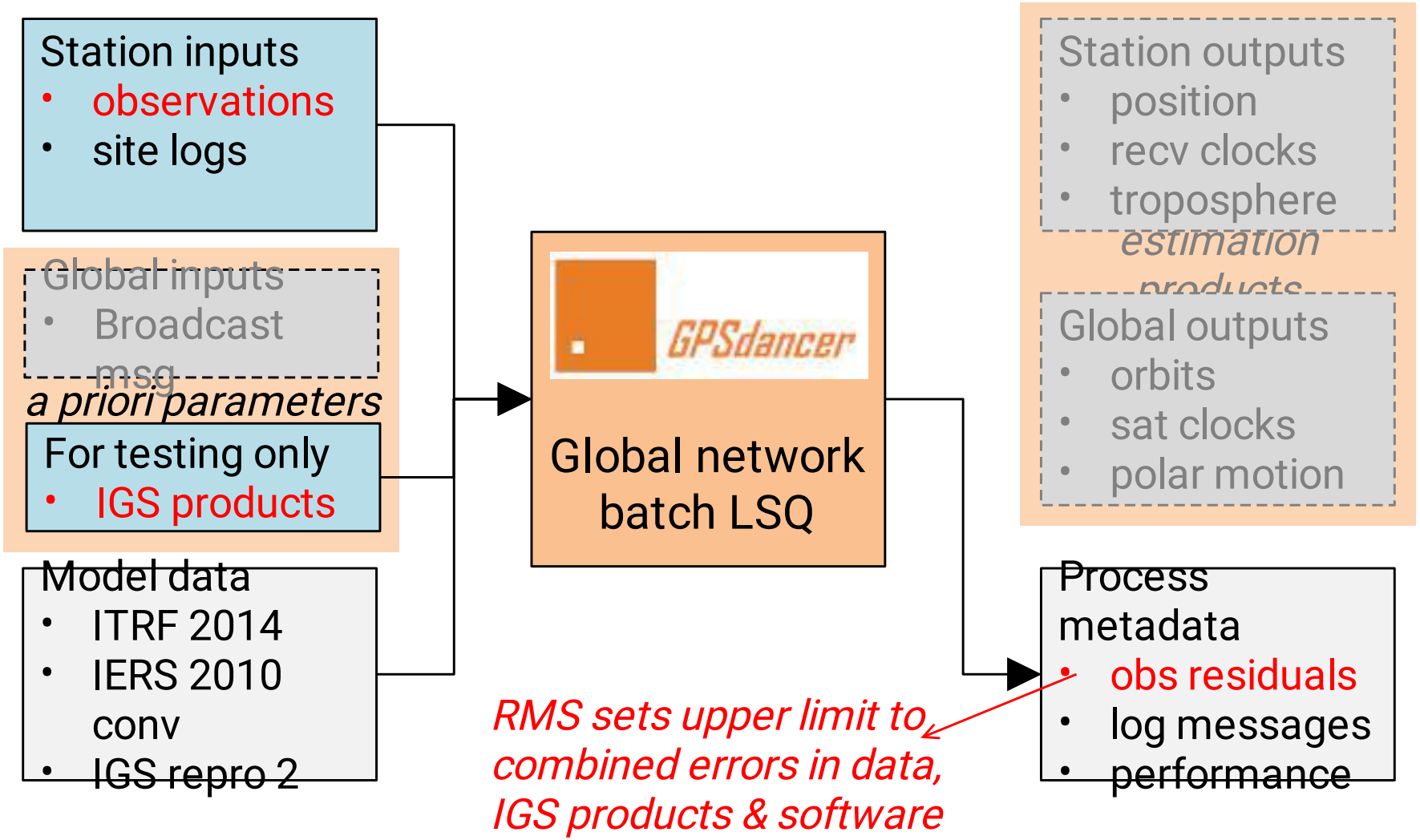
Nominal process



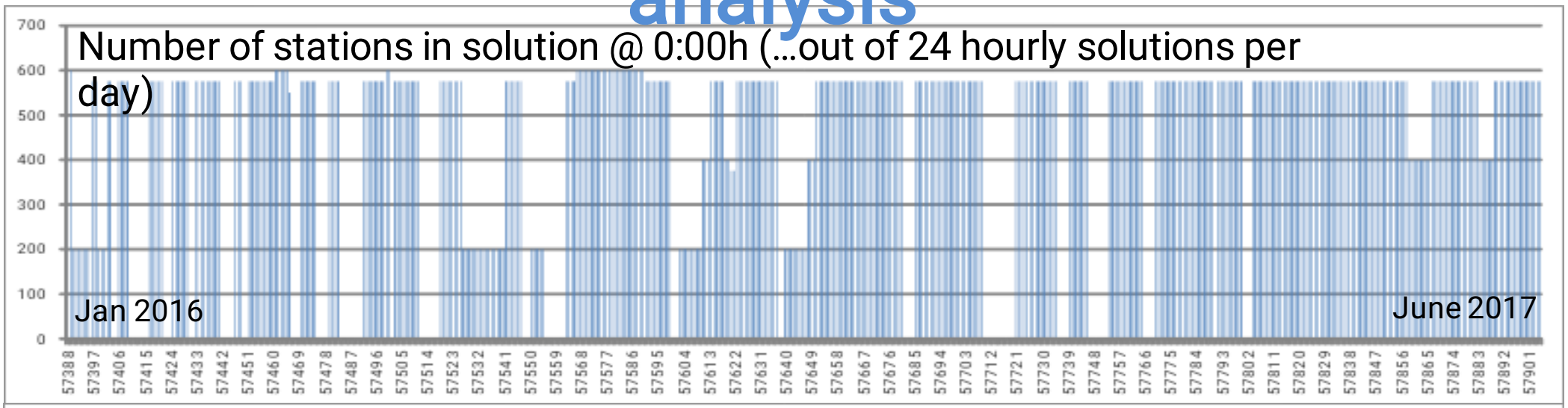
Precise Point Positioning

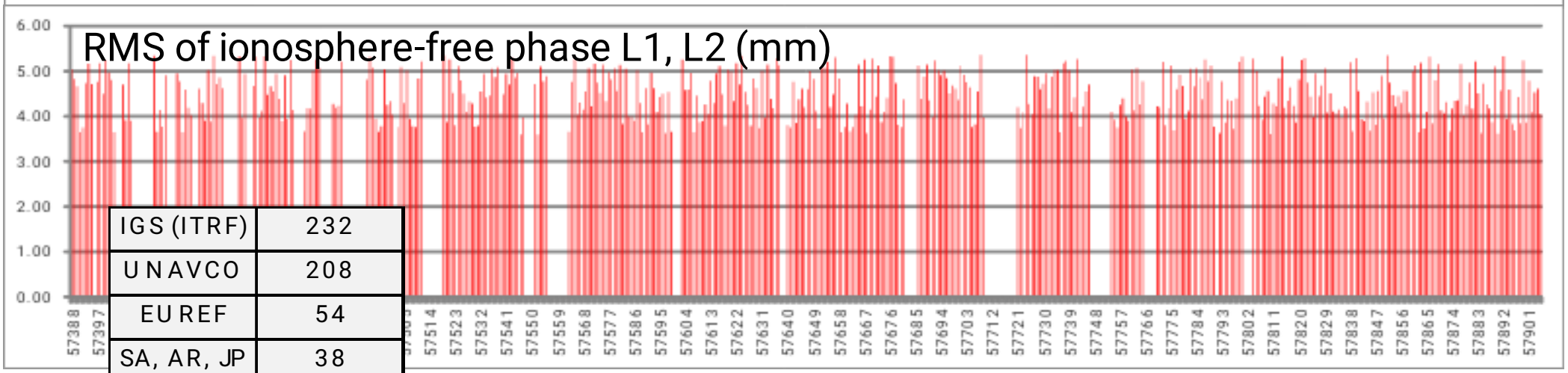


Null test


Station inputs
• observations
• site logs
Global inputs
• Broadcast msg
a priori parameters
For testing only
• IGS products
Model data
• ITRF 2014
• IERS 2010 conv
• IGS repro 2
GPSdancer
Global network batch LSQ
Station outputs
• position
• recv clocks
• troposphere
estimation products
Global outputs
• orbits
• sat clocks
• polar motion
Process metadata
• obs residuals
• log messages
• performance
RMS sets upper limit to combined errors in data, IGS products & software

Stations processed in routine analysis



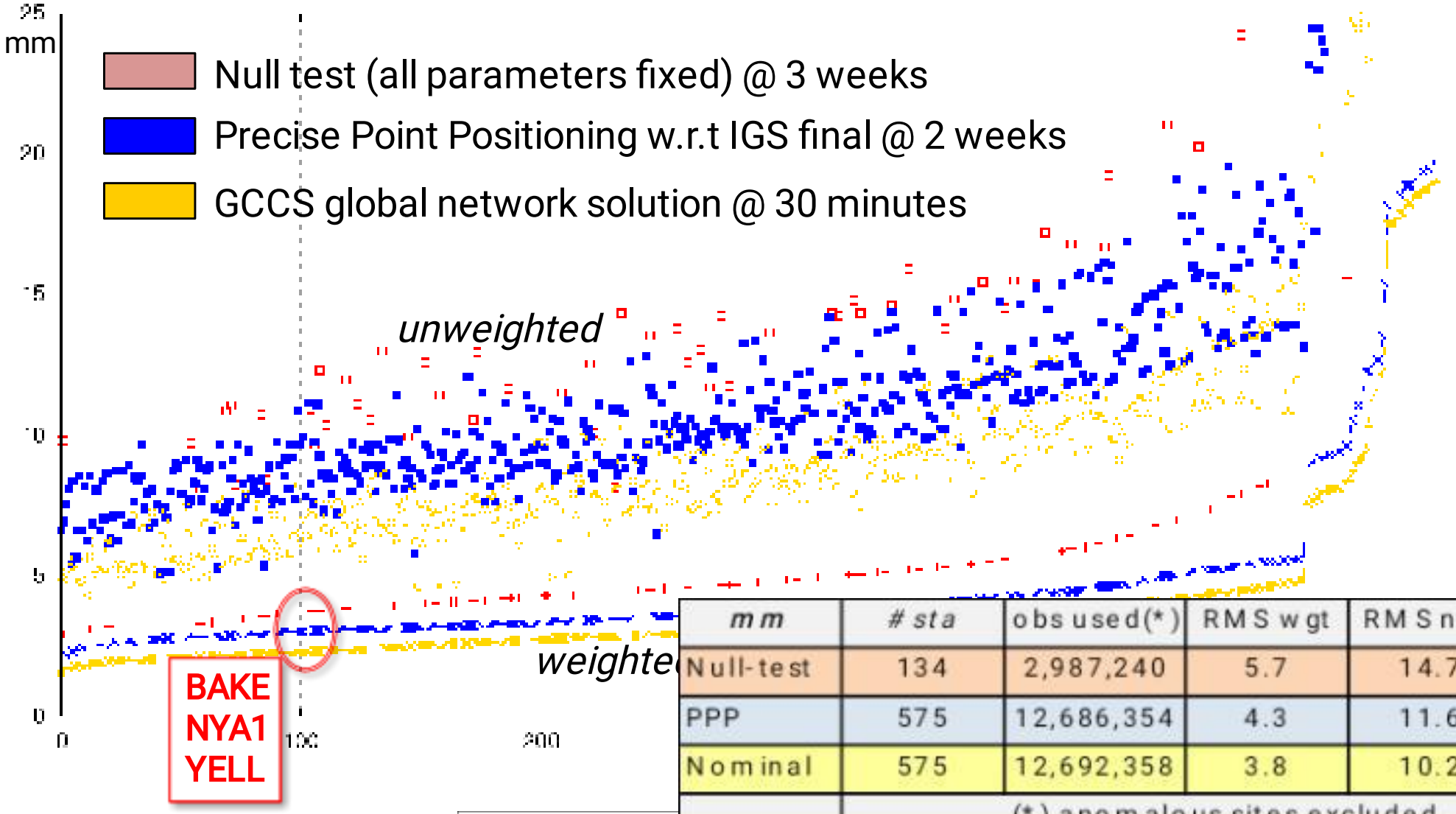


IGS (ITRF)	232
UNAVCO	208
EUREF	54
SA, AR, JP	38
other	68
total	600

- 15 minute RINEX files preferred as input (30 hr buffers)
- 1 CPU reserved for BNC client to handle RTCM streams

Observations residuals for ionosphere-free phase (L1, L2)

RMS per station for GPS week 1947



mm	# sta	obs used(*)	RMS wgt	RMS nrm
Null-test	134	2,987,240	5.7	14.7
PPP	575	12,686,354	4.3	11.6
Nominal	575	12,692,358	3.8	10.2
	(*) anomalous sites excluded			

GCCS Geodetic Cloud Computing Service

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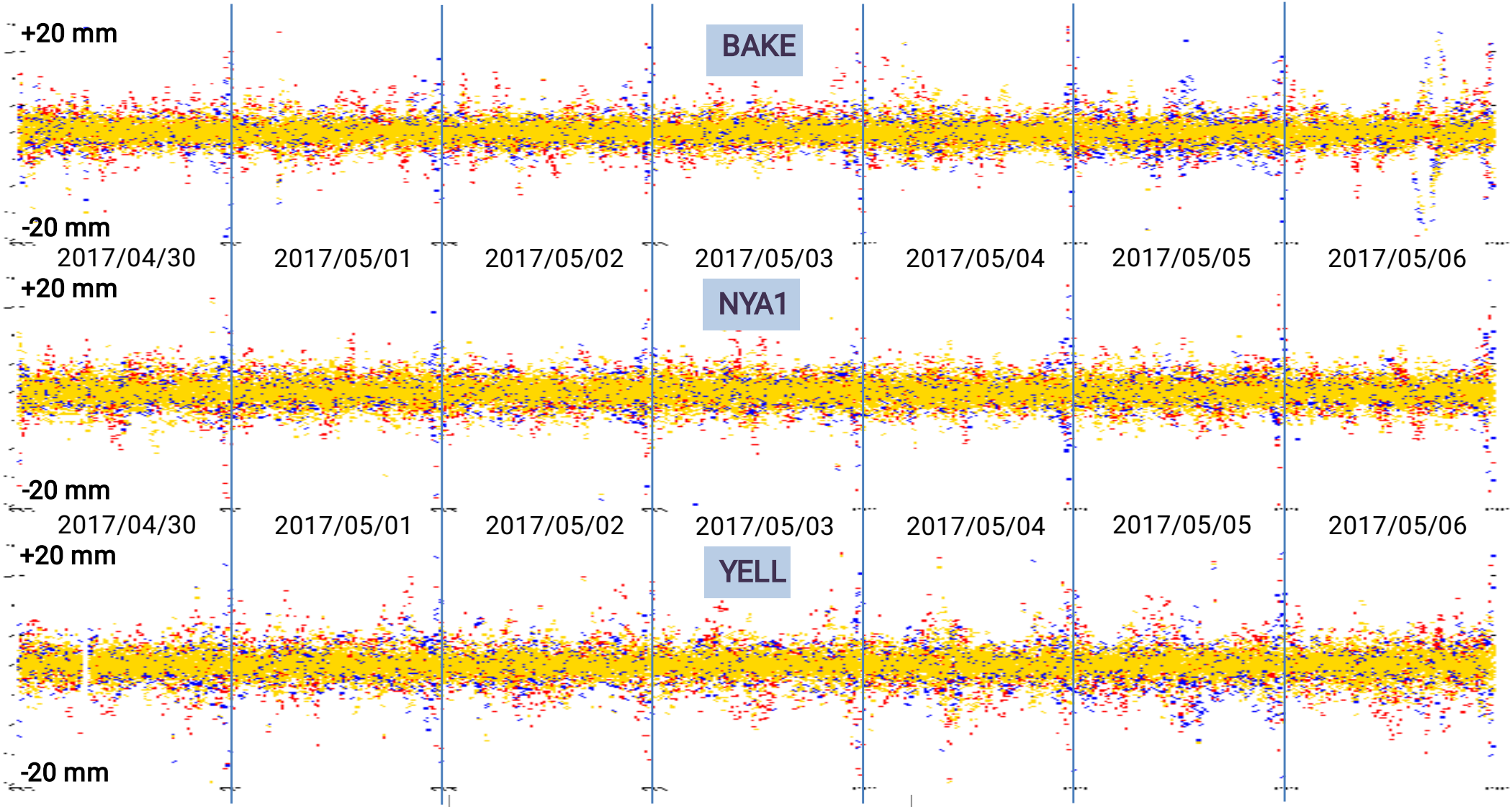
esa business incubation centre Darmstadt

IGS Workshop 2017

Paris

Observations residuals for ionosphere-free phase (L1, L2)

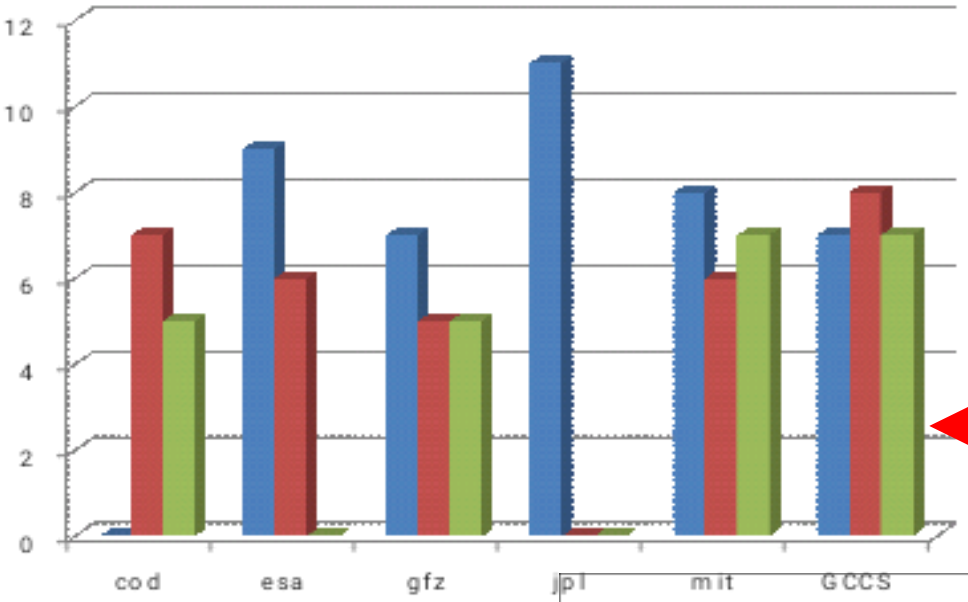
Details for 3 stations in GPS week 1947



Observations residuals for ionosphere-free phase (L1, L2)

Example stations BAKE, NYA1, YELL

GPS week 1947		Null test		PPP		Global solution	
# obs	available	Used	Rejected	Used	Rejected	Used	Rejected
BAKE	22213	21797	416	21808	405	22104	109
NYA1	22362	21956	406	21979	383	22253	109
YELL	21601	21213	388	21229	372	21495	106
RMS (mm)		wghtd	nrmlzd	wghtd	nrmlzd	wghtd	nrmlzd
BAKE		3.51	11.98	3.22	10.81	2.19	7.18
NYA1		3.65	13.53	3.33	12.11	2.14	7.61
YELL		3.53	11.73	3.32	10.88	2.19	7.02



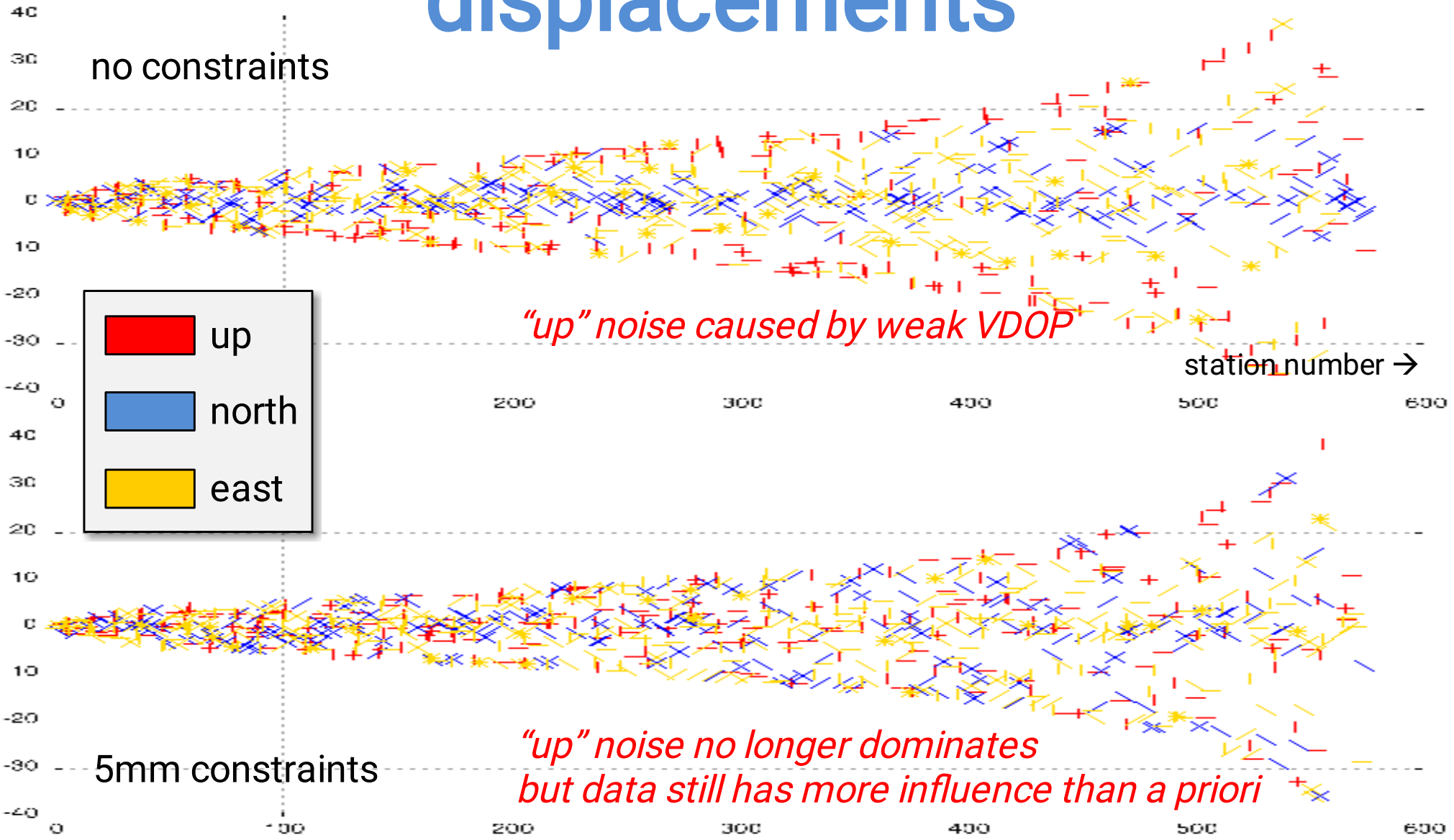
wghtd = elevation weighted residuals
nrmlzd = unweighted residuals

Estimated parameters

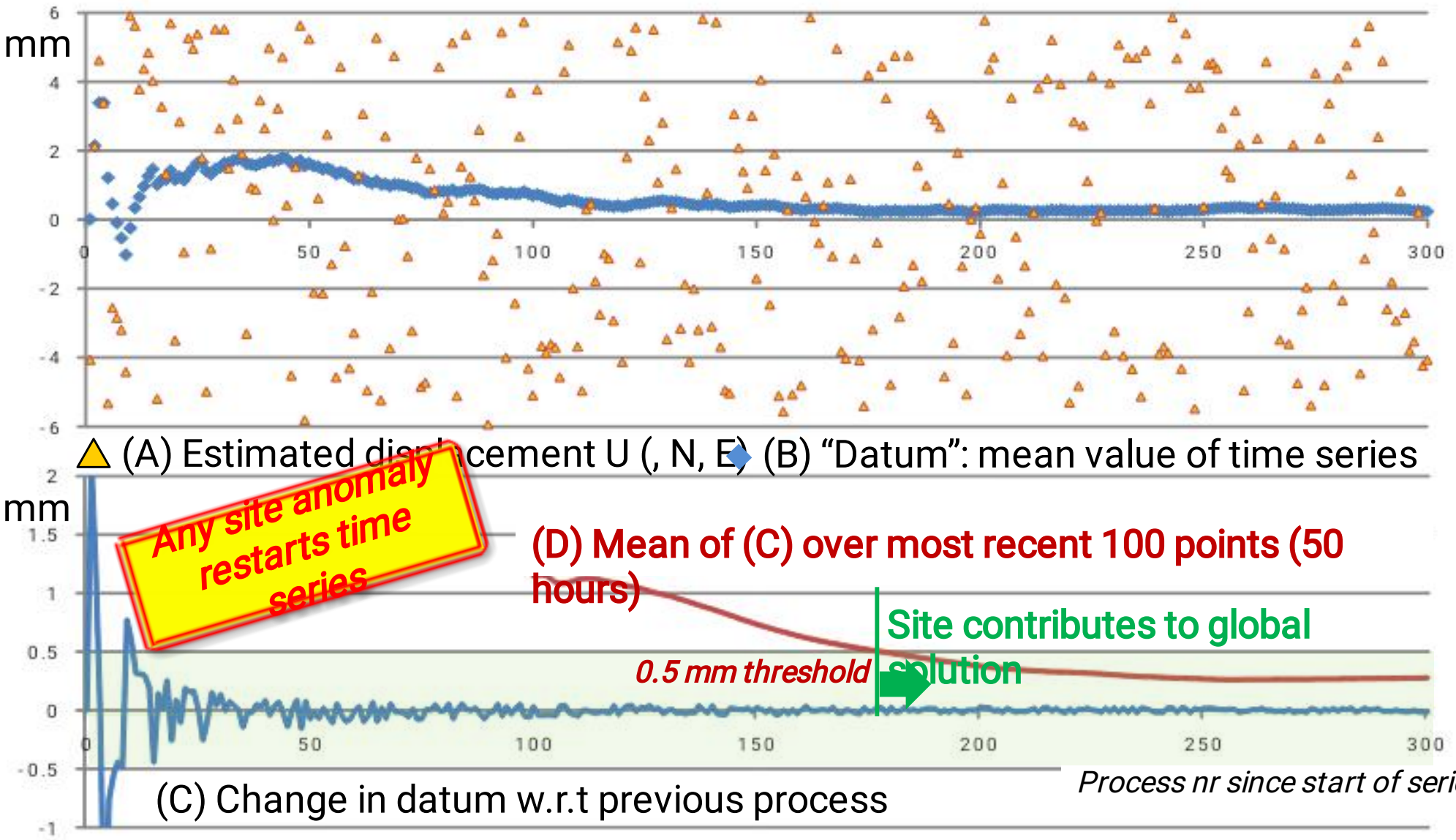
	Parameter		Frequency	per run	initial value	initial sigma	constraint	est sigma	units
Global	Polar motion	Xp, Yp	2 pair per arc	4	mean pole	1.00E-02	no	1.00E-05	masec
		dUT1	1 per arc	1	0	1.00E+00	no	1.00E-06	s
	Orbit	X, Y, Z	per sat per arc	96	broadcast	1.00E+02	no	1.00E-02	m
		vx, vy, vz	per sat per arc	96	broadcast	1.00E-02	no	1.00E-06	m/s
	SRP	5-param Bernese	per sat per arc	160	0	1.00E-08	no	1.00E-10	-
	Clocks	transmitter	per sat per epoch	9216	broadcast	1.00E-06	no	1.00E-11	s
Local	Clocks	receiver	per sta per epoch	288	0	1.00E-06	no	1.00E-11	s
	Displacement	dX, dY, dZ	per sta per arc	3	0	1.00E-03	YES	1.00E-03	m
	Troposphere	zenith delay	per sta per 2 hour	12	0	1.00E-01	no	1.00E-03	m
		gradients N, E	2 pair per sta per a	4	0	1.00E-03	no	1.00E-04	m
	Other	ambiguity	per pass	60	L - P	1.00E+00	no	1.00E-02	m

- Parameter initialization independent from previous run
  - Goal is to maximize decorrelation, in spite of large overlaps
- Unconstrained LSQ except for station displacements
  - No-net rotation condition w.r.t. ITRF core network
  - Absolute constraints → *see next slide*

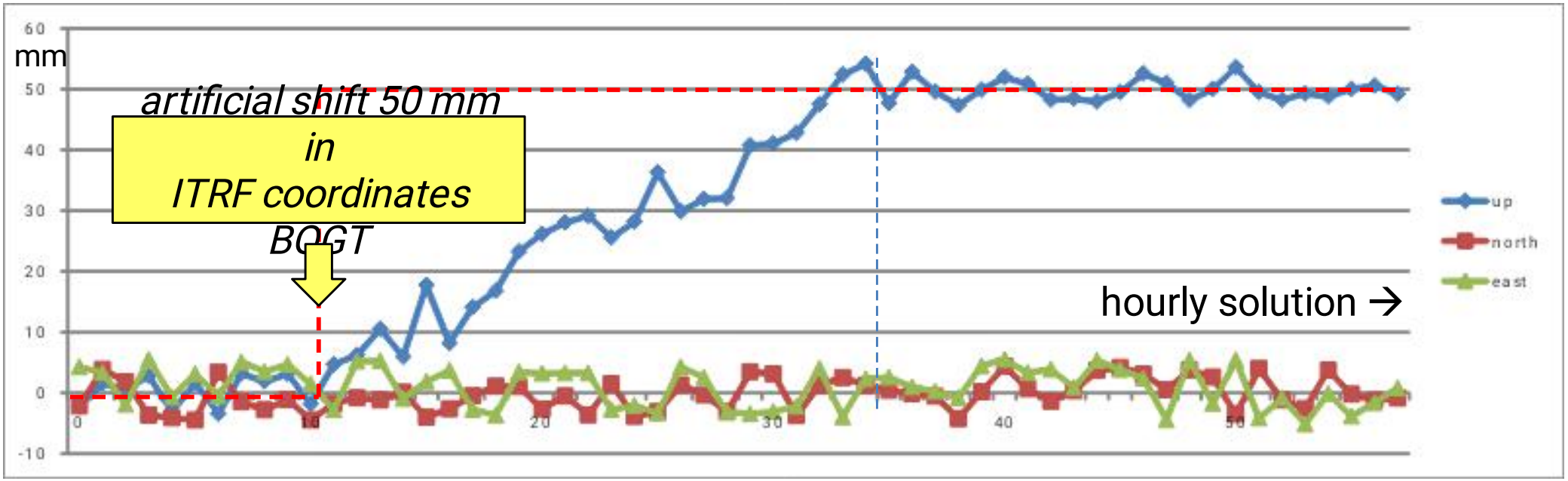
Constraints on station displacements



Introduction of new sites in solution



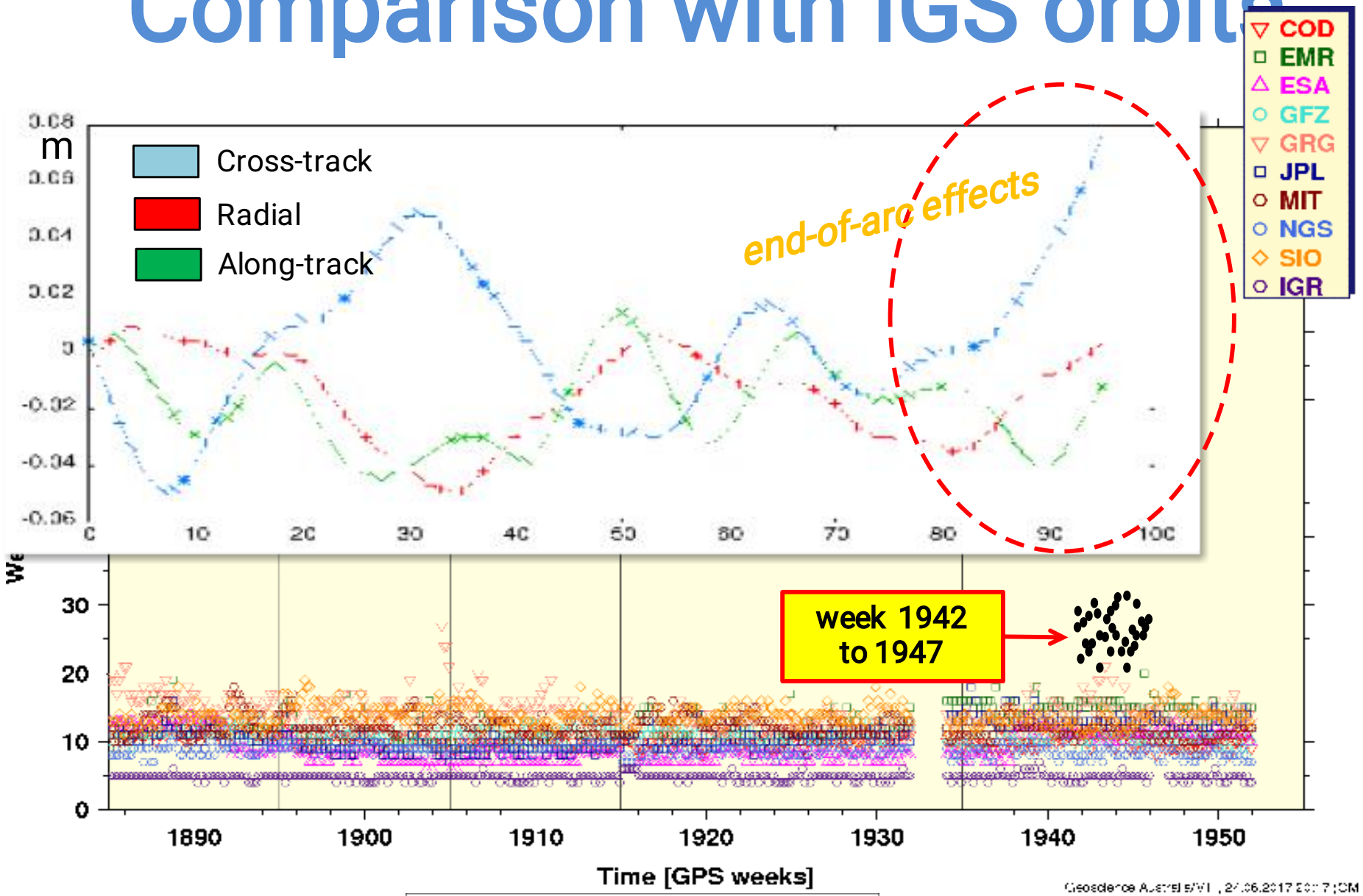
Example: recovery after shift



With 5 mm constraints on site displacements:

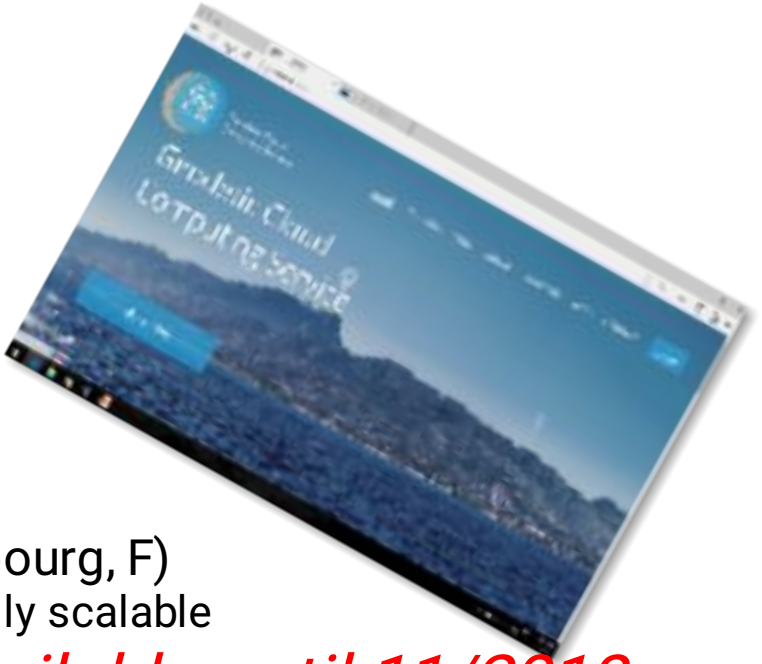
- Solution time series relatively noisy (RMS > 5mm)
- Quick response to real events: impact invisible after 24 hours
  - Data arc no longer contains "old" position data
- Long-term site datum recovered after several days

Comparison with IGS orbits



Remaining steps

- Before 10/2017:
  - **GCCS website on-line** at “itrf.cloud”
    - Detailed Cal-Val report also on this site
  - Routine analysis at **30 minute latency**
    - No more time sharing with test runs
  - **Server capacity** will be extended
    - Currently 3 x 200 stations (@Frankfurt, D)
    - Extended with 4 x 100 stations (@Strassbourg, F)
      - Capacity will be 1000 stations but arbitrarily scalable



Subsidized servers will only remain available until 11/2018

- Gradual incorporation of real users is needed
  - Regional RTK operators, receiver manufacturers, etc.
  - Target: 10,000 stations using **GPSdancer** in the cloud by 2020

Summary and conclusions

- Distributed global analysis based on GPSdancer is approaching its mature operational status
  - Station products are comparable with IGS
    - **Combined noise in data, IGS finals and GPSdancer does not exceed 5 mm RMS**
  - Processing capacity now 600, soon 1000 sites
    - …twice the size of the IGS network

- ITRF datum can be transferred **reliably** to any non-ITRF CORS site
  - ITRF sites and non-ITRF sites are processed in **exactly** the same solution
  - 200+ ITRF sites in network demonstrate the absolute solution accuracy
  - Non-ITRF sites show identical output characteristics (noise, sigmas)
    - Stable mean of the output position time series accurately represent the ITRF
    - Risk of unobservable systematic errors in regional PPP has been mitigated
- …we still need the IGS!
  - IGS defines ITRF as conventional reference frame
  - GCCS can densify the ITRF to include all CORS stations on Earth