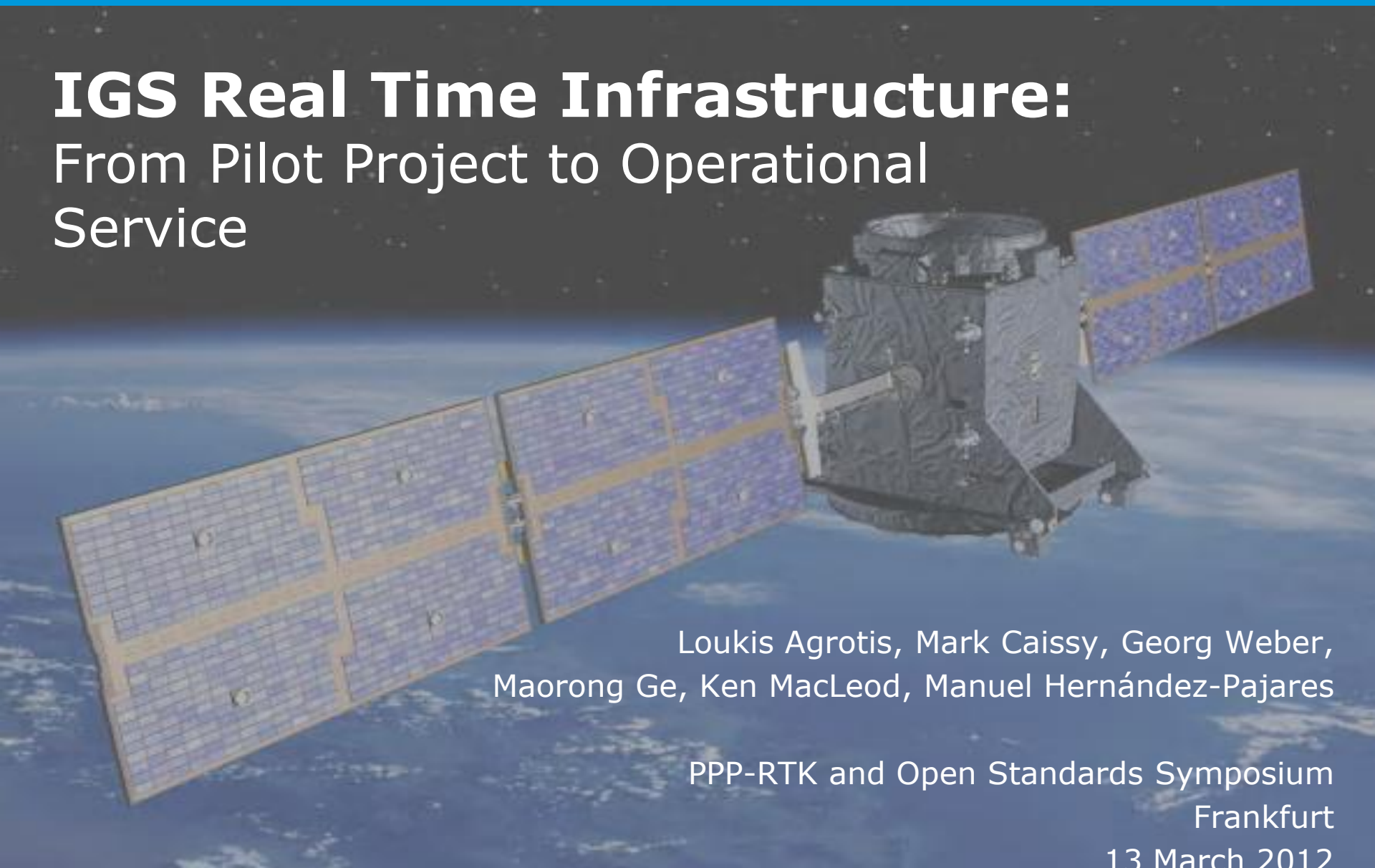
IGS Real Time Infrastructure:
From Pilot Project to Operational Service



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Maorong Ge, Ken MacLeod, Manuel Hernández-Pajares

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Frankfurt
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Introduction

IGS RT Infrastructure

- **Participation from 34 organisations**
  - 10 participating Analysis Centres
  - ESOC is the AC Coordinator, responsible for the combination
- **Data and Product Dissemination Infrastructure**
  - Station operators > 100 RT observation streams
  - NTRIP infrastructure from BKG
  - RTIGS infrastructure from NRCan – now moving to NTRIP/RTCM

Introduction

Contents

- RTPP Objectives and Achievements
- Transition to IGS Operational Service
- Operational Service Redundancy Concepts

Historical Background

- IGS RTWG Charter 2001
  - Design and implement real-time infrastructure and processes → network → data → products (iono, clock and orbits) → users
- IGS RTPP 2007 – 2010
  - 2009 extended until end of 2011
- 2010 RTWG and RTPP charter combined
  - 2011-2012 plan ➔ projects IGS rt-services starting
- RT-Services are a part of the IGS strategic plan
  - IGS → IAG Service → GGOS Natural Hazards theme

RTPP Key Objectives

- Investigate standards and formats for real-time data collection and data and product dissemination
- Manage and maintain a global GNSS real-time tracking network
- Generate real-time products
  - Clock accuracies of 0.3 ns (originally 0.5 ns)
  - Orbit accuracies of 5-6 cm
  - Latency of better than 10 sec
- Monitor the integrity of IGU predicted orbits and GNSS status

RTPP Achievements

Development of standards and formats for RT

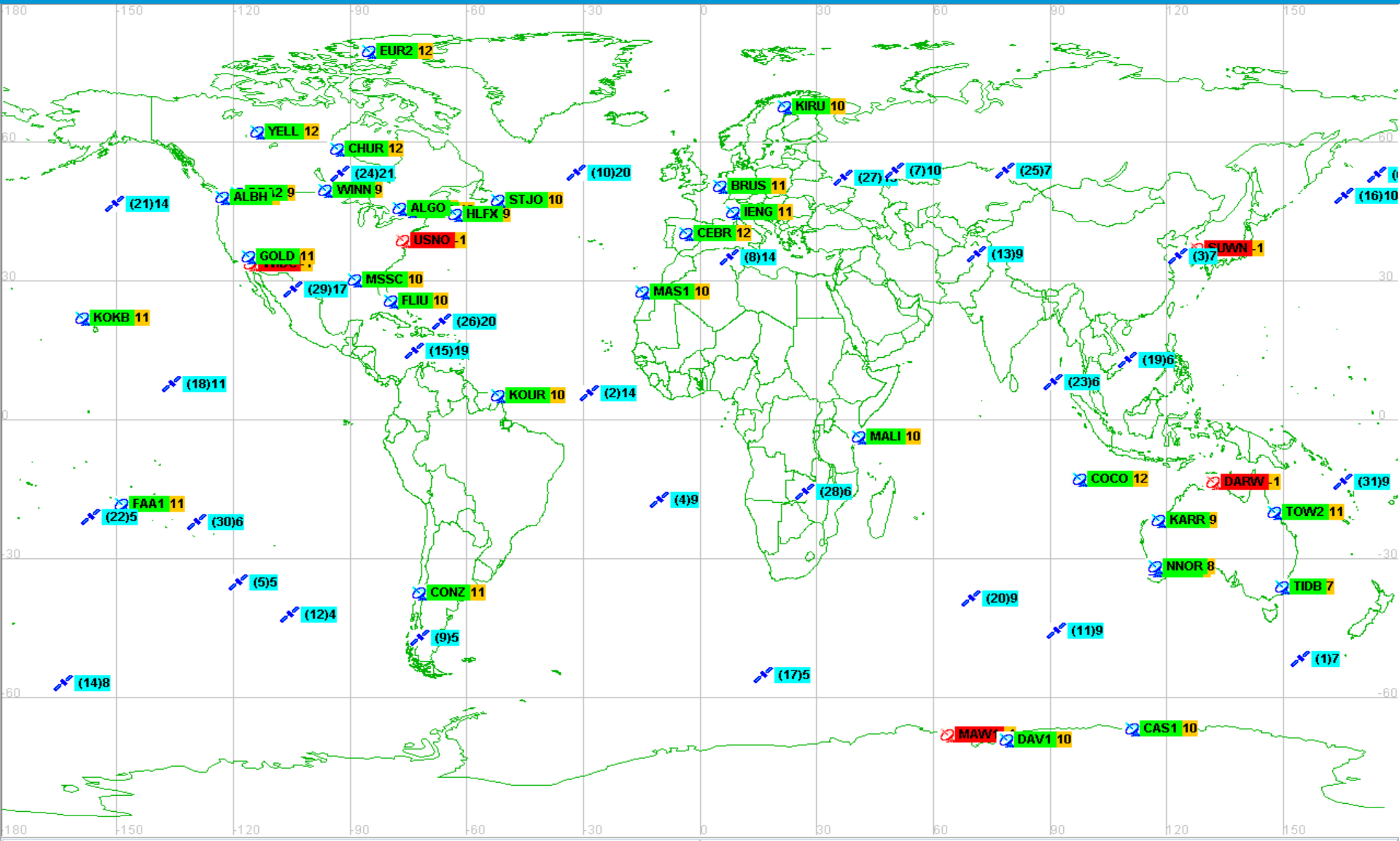
- IGS has joined the Radio Technical Commission for Maritime Services (RTCM) - Mainly represented by NRCan, ESOC, BKG and IGSCB
  - MSM HP formats to satisfy RINEX 3 and multi-constellation requirements
  - Product dissemination via new SSR formats (GPS and GLONASS formats in place)
  - Latest development: Joint IGS-RTCM Working Group on RINEX evolution, chaired by K. MacLeod
    - RINEX 3.02 draft released among WG members
- BKG, NRCan and others developing software to support these standards

GNSS Tracking Network
Current RT Tracking Network

http://www.rtigs.net/nrcan_monitor.php

2011 Oct 14 17:42:15

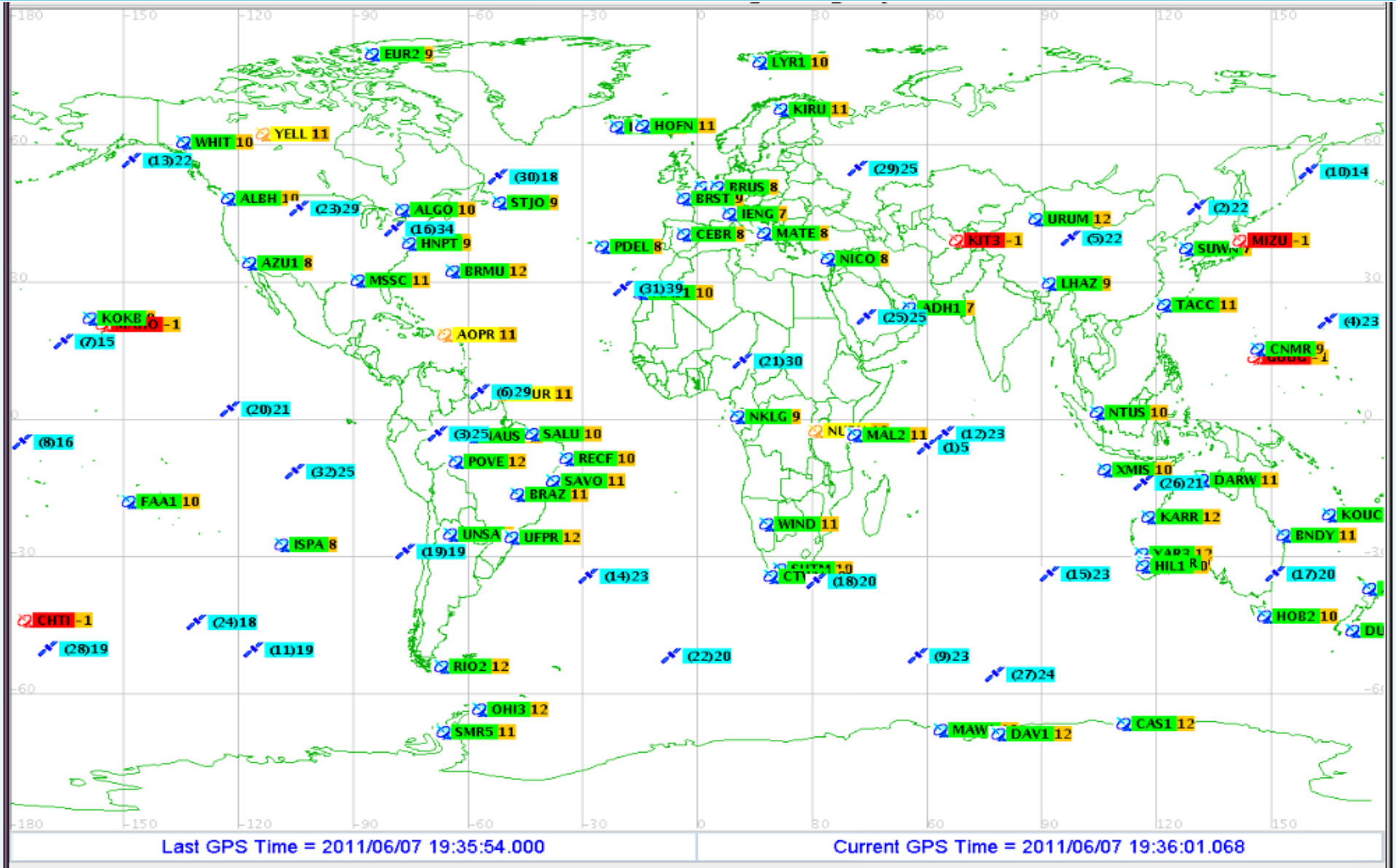
GNSS Tracking Network
Stations in ESOC RT Solution (2008)



Last GPS Time = 2008/04/22 15:20:18.000

Current GPS Time = 2008/05/28 18:15:51.376

GNSS Tracking Network
Stations in ESOC RT Solution (2011)



RTPP Achievements

Generation of Real-Time Products

- 10 ACs provide a multitude of product streams
  - GPS-only solutions from each AC, with 3 (soon to be 4) GPS+GLONASS
- ESOC provides the RT combination product (GPS-only)
  - Each epoch independently combined (no convergence needed)
  - Outlier detection for clocks and orbits
  - Will transition to the IGS operational product
- BKG generates clock combination products based on Kalman filter combination
- Ambiguity-fixing WG studying techniques and formats for PPP ambiguity fixing
- UPC and DLR are generating RT ionospheric products

Real-Time Products
RT Product Streams

Centre	Description	NTRIP Mountpoint
BKG with TU Prague	GPS and GPS + GLONASS RT orbits and clocks using IGU orbits (CoM/APC)	CLK00/10 CLK01/11
CNES	GPS RT orbits and clocks based on IGU orbits (CoM/APC) GPS+GLONASS orbits and clocks (CoM/APC)	CLK92/93 CLK90/91
DLR	GPS RT orbits and clocks based on IGU orbits GPS+GLONASS orbits and clocks (DLR caster)	CLKC1/A1 CLK21
ESOC	RT orbits and clocks using NRT batch orbits every 2 hours (ESOC) and using IGU (ESOC2) (CoM /APC)	CLK50/51 CLK52/53
GFZ	RT orbits and clocks and IGU orbits (CoM/APC)	CLK70/71
GMV	RT orbits and clocks based on NRT orbit solution (CoM/APC)	CLK81/80
Geo++	RT orbits and clocks (APC) (Geo++ caster)	RTCMSSR
NRCan	RT orbits and clocks using NRT batch orbits every hour (APC)	CLK22
TUW	RT clocks based on IGU orbits (CoM/APC) (out of service)	CLK80/81
WUHAN	RT clocks based on IGU orbits (CoM/APC)	CLK15/16

Real-Time Products
RT Combination Streams

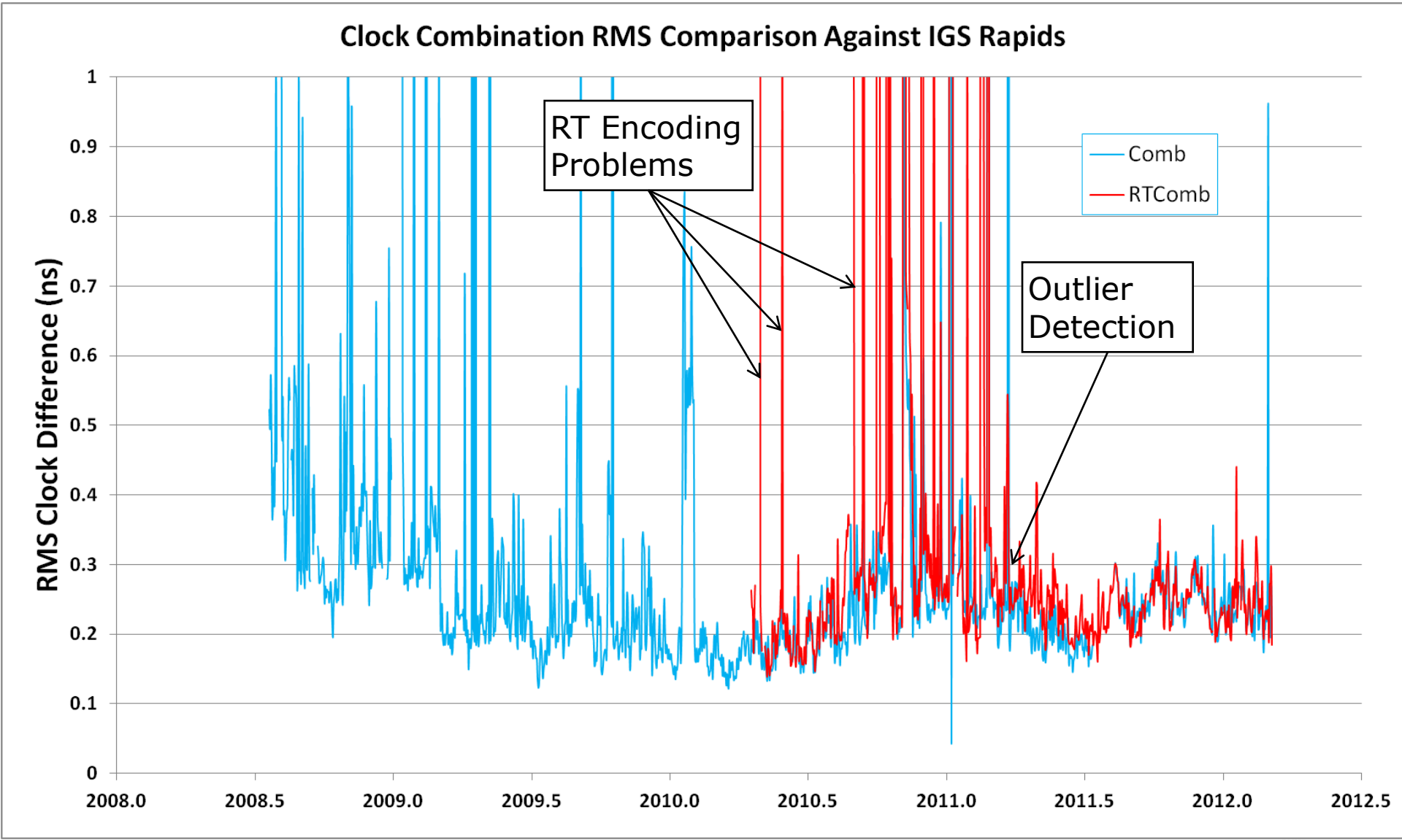
Centre	Description	NTRIP Mountpoint
ESOC	RT GPS-only combination from BKG, CNES, DLR, ESOC, GMV and GFZ streams (CoM /APC)	IGS01/ IGC01
BKG with TU Prague	RT GPS-only Kalman-generated combination from BKG, CNES, DLR, ESOC, GMV and GFZ streams (CoM /APC) RT GPS+GLONASS Kalman-generated combination from BKG, CNES, DLR, ESOC, GMV and GFZ streams (APC)	IGS02/ CLK32 IGS03

AC Performance

Snapshots of AC Satellite Clock Results

AC	Feb 6 2009		June 8 2010		June 15 2011	
	Clock RMS (ns)	Clock Sigma (ns)	Clock RMS (ns)	Clock Sigma (ns)	Clock RMS (ns)	Clock Sigma (ns)
Comb	0.29	0.22	0.16	0.10	0.14	0.07
RTComb	-	-	0.15	0.11	0.18	0.08
BKG	6.72	2.97	0.20	0.12	0.30	0.07
CNES	-	-	-	-	0.30	0.03
DLR	0.38	0.10	0.20	0.12	0.25	0.12
ESOC	0.42	0.38	0.21	0.12	0.17	0.12
ESOC2	0.36	0.30	0.19	0.11	0.16	0.08
GFZ	-	-	-	-	0.33	0.06
NRC	0.67	0.62	0.24	0.10	0.23	0.07
GMV	1.67	1.66	0.28	0.14	0.34	0.10
TUW			0.70	0.53	0.73	0.53

Combination Solution Performance



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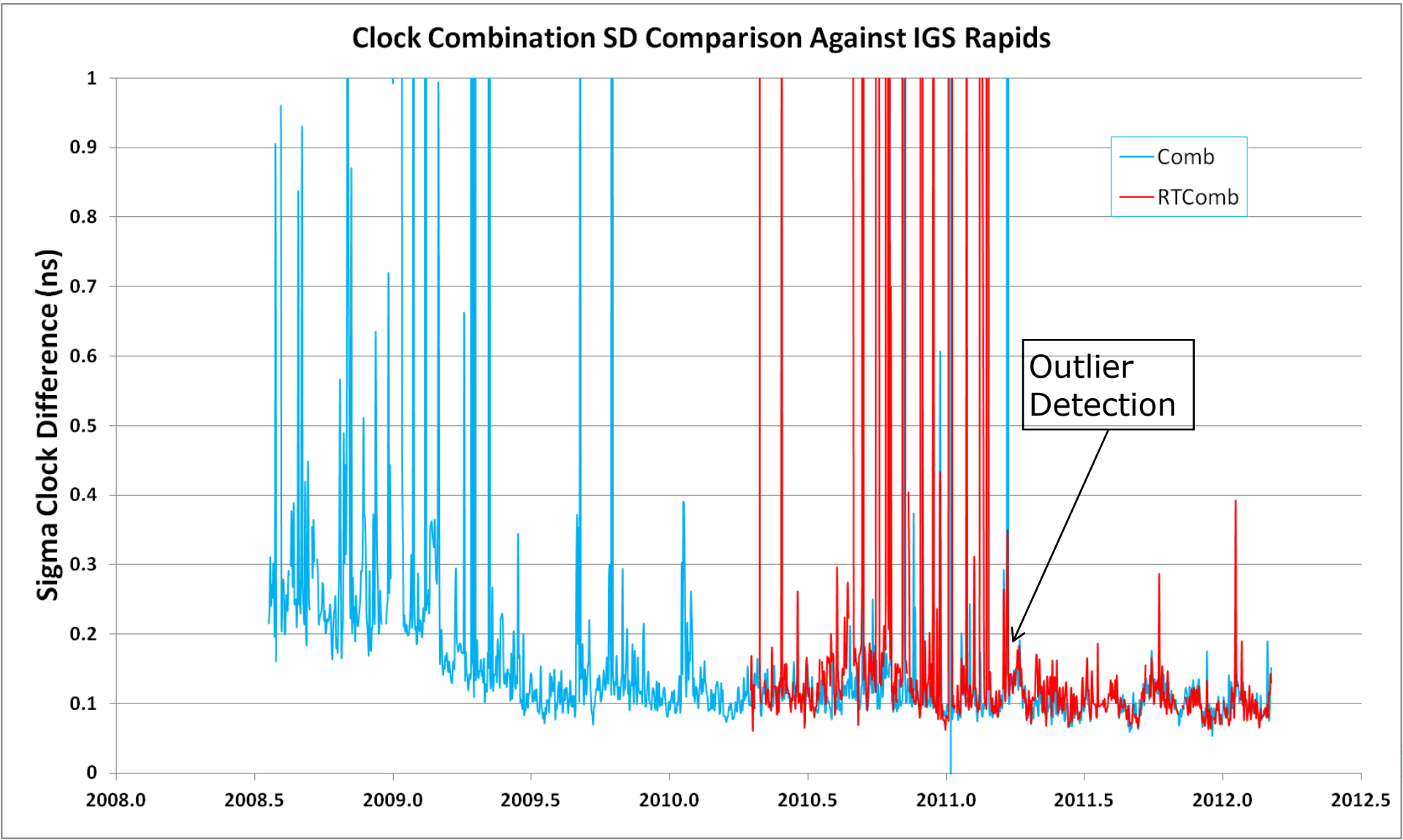
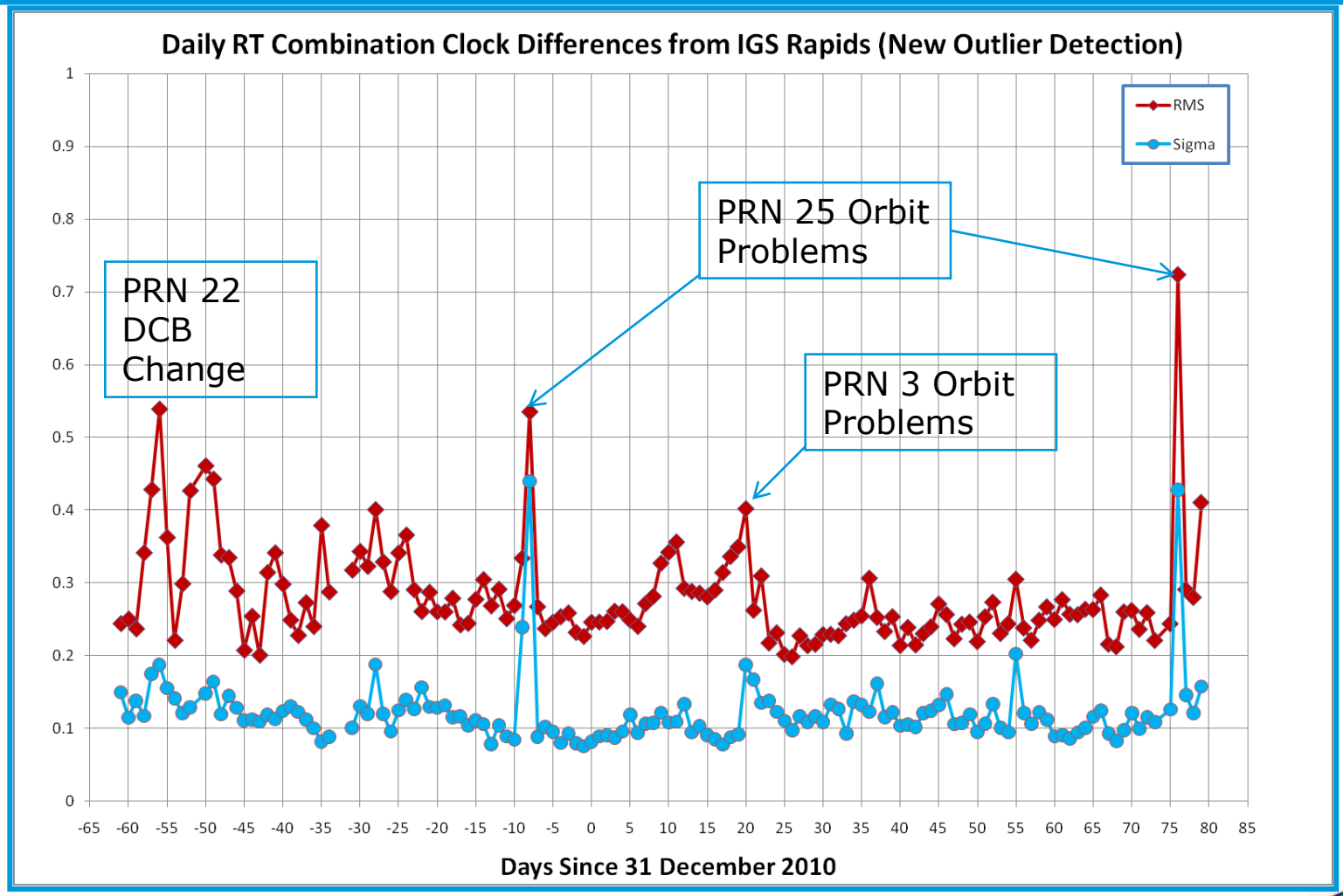
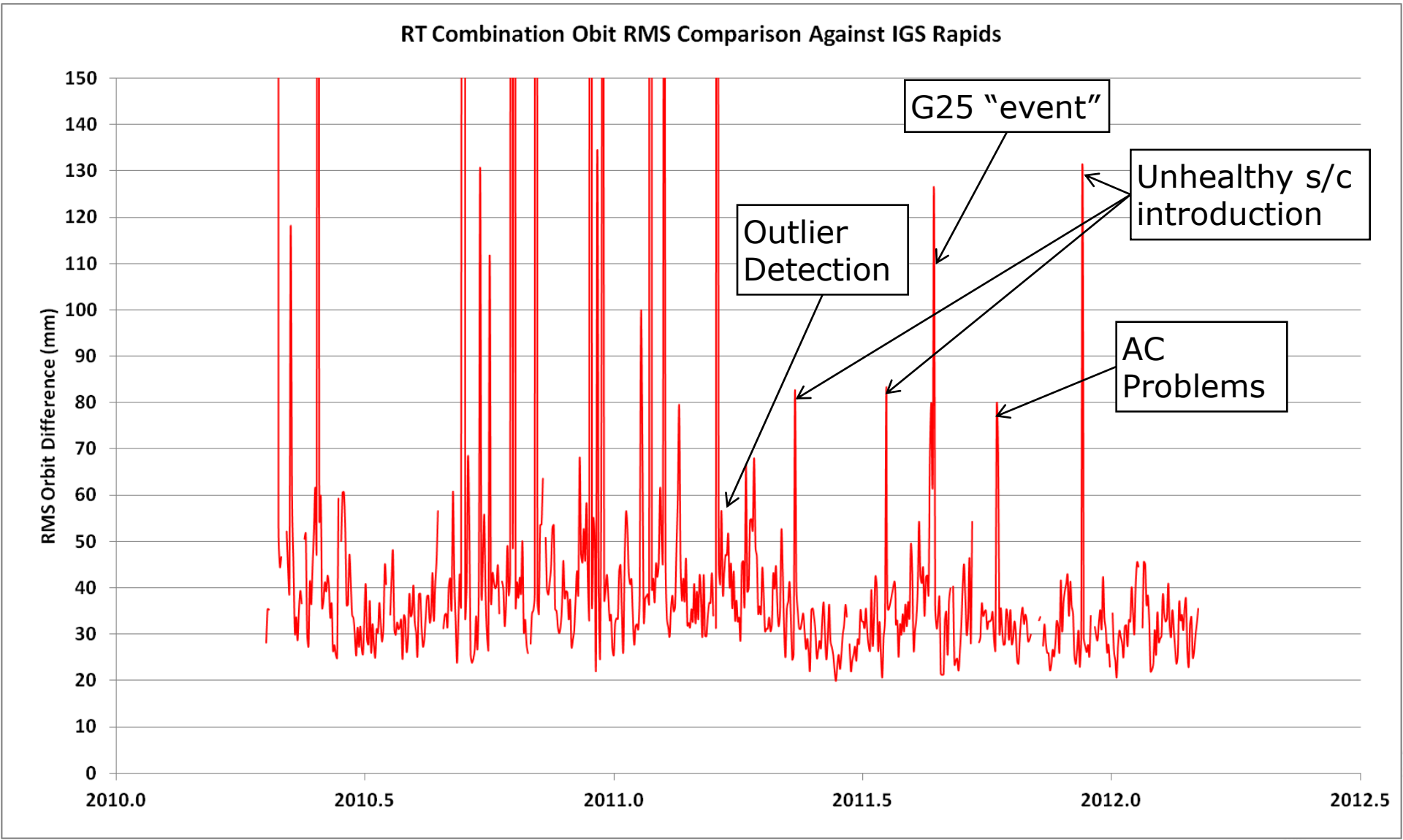


Combination Solution Performance



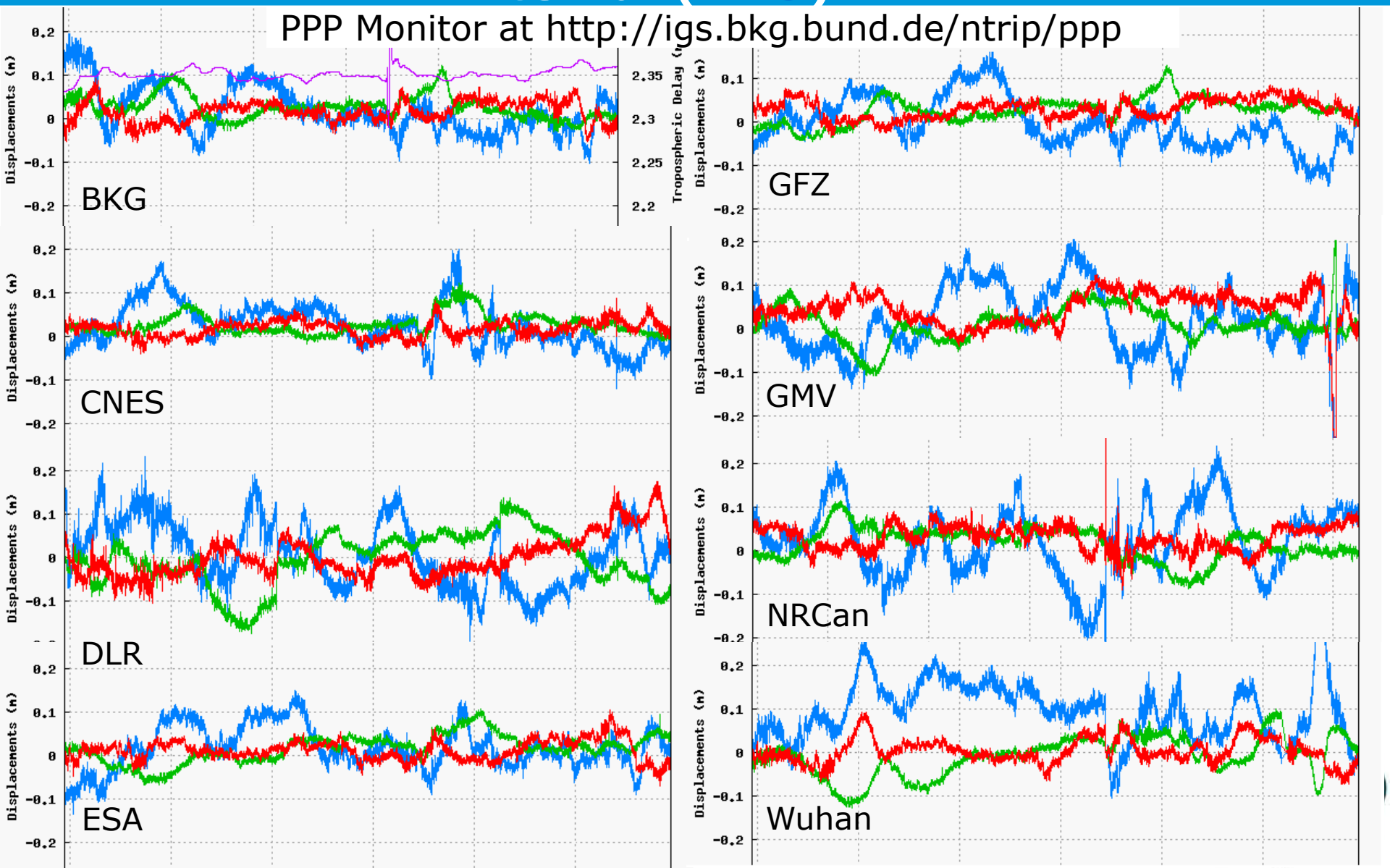
Combination Solution Performance



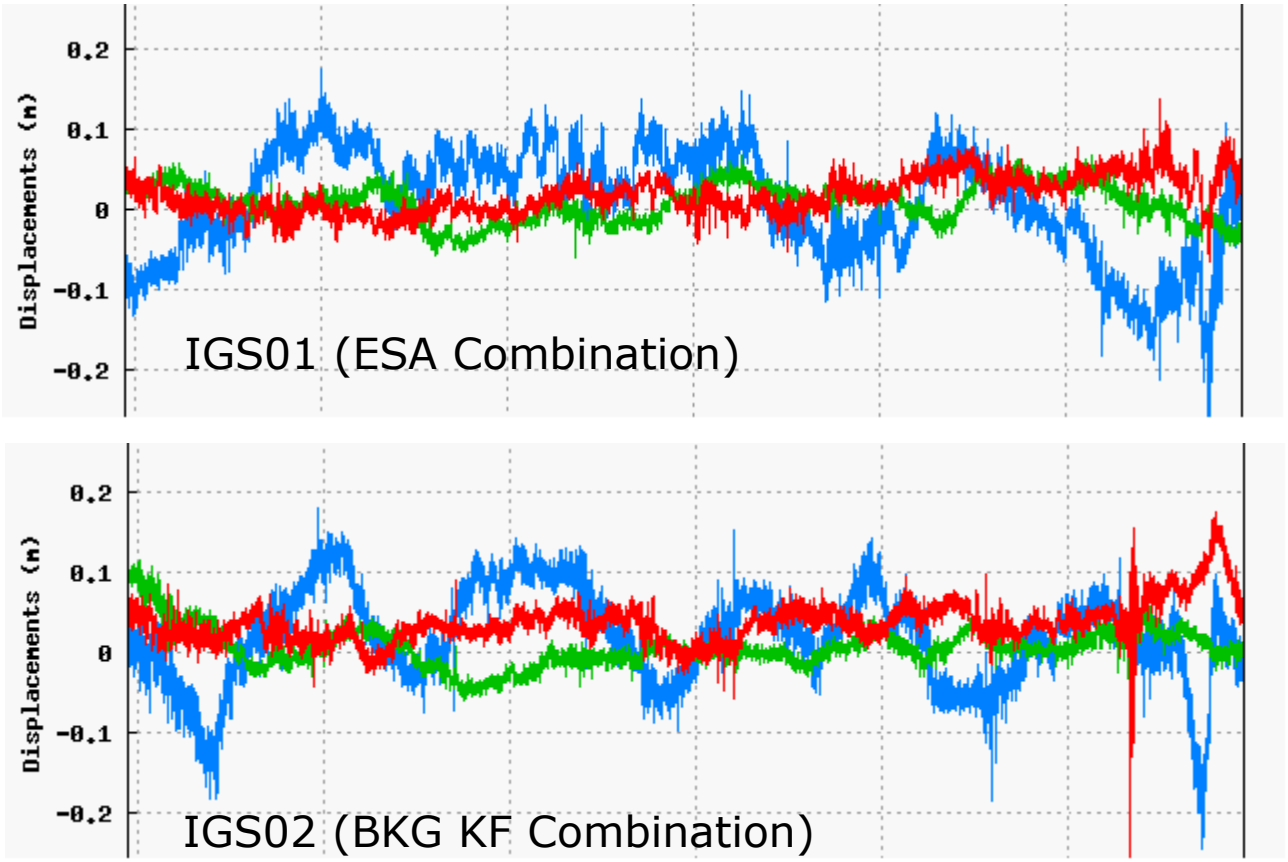
PPP Performance

Kinematic PPP Displacements in 24 h Interval (ENU)

PPP Monitor at http://igs.bkg.bund.de/ntrip/ppp



PPP Performance
Kinematic PPP Displacements in 24 h Interval (ENU)



PPP Monitor at http://igs.bkg.bund.de/ntrip/ppp

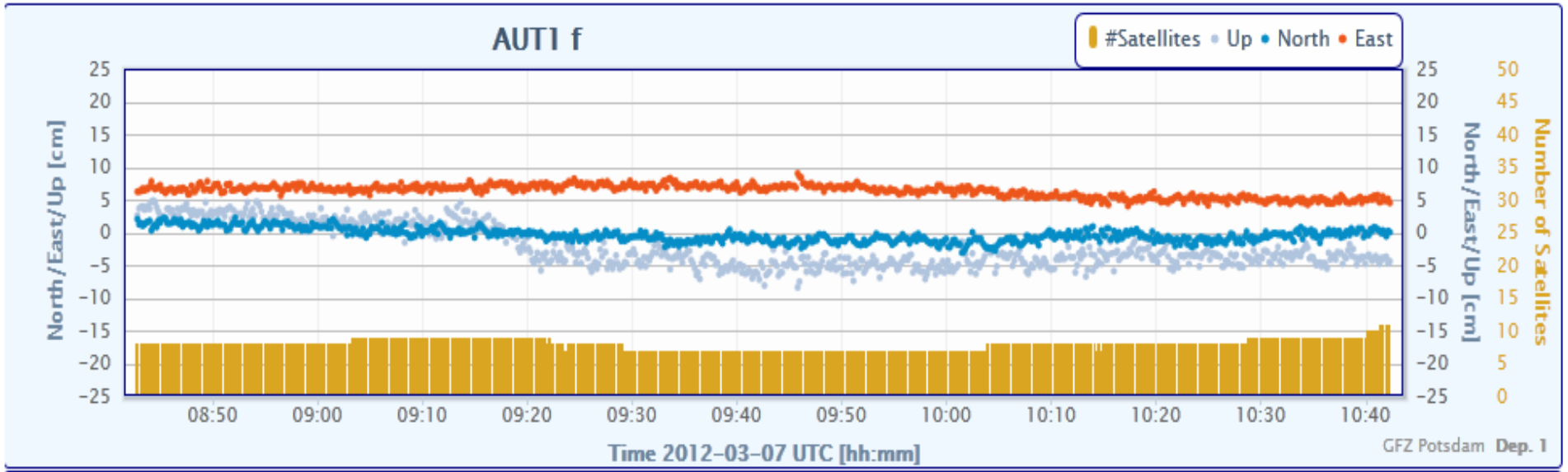
Product Performance Summary

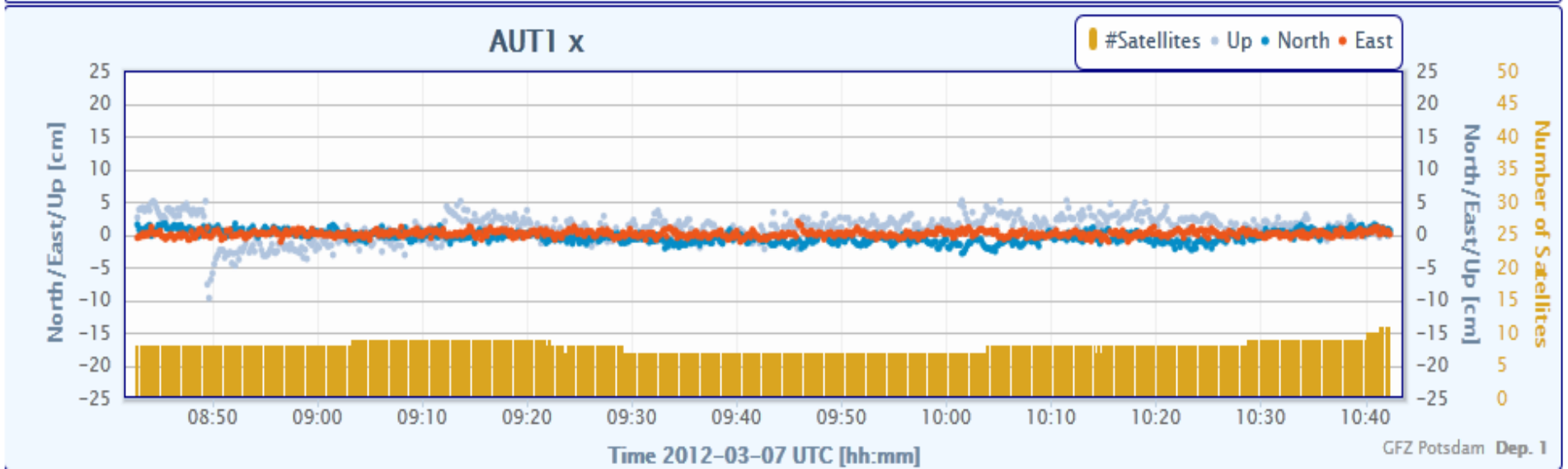
- Accuracy (compared to IGS Rapids)
  - Orbit: 2-5 cm 1-D RMS
  - Clock RMS: 0.2-0.3 ns
  - Clock Sigma: 0.1 ns
- Latency
  - Latency of Individual Solutions: 5-15 sec
  - Latency of Combination: 20 – 25 sec
- PPP Performance
  - 2-D RMS of 4-5 cm after convergence

Ambiguity Fixing WG

- WG established at 2010 IGS Workshop in Newcastle
- CNES and GFZ now compute products for PPP ambiguity fixing
- RTCM UPD format has been proposed by CNES and GFZ/Alberding and discussed with Geo++
- GFZ RT PPP results for about 80 stations are published on kg6-dmz.gfz-potsdam.de/rtgnss and CNES results are on www.ppp-wizard.net

Ambiguity Fixing Results



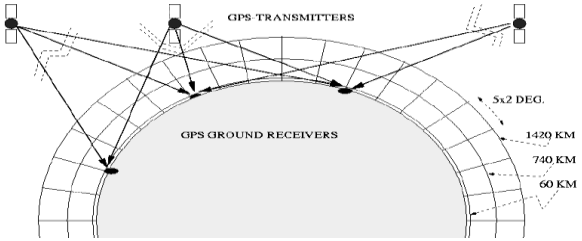


RT-IGS global VTEC: First results

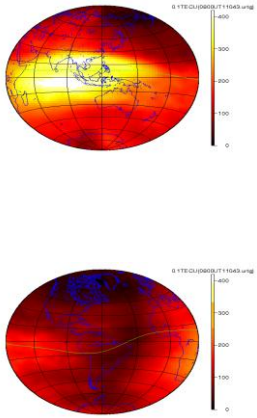
UPC 4D Iono model + Kriging interpolation (RT-TOMION)

RT-IGS GNSS data-streams

First UPC predicted global VTEC maps



First real-time global VTEC maps

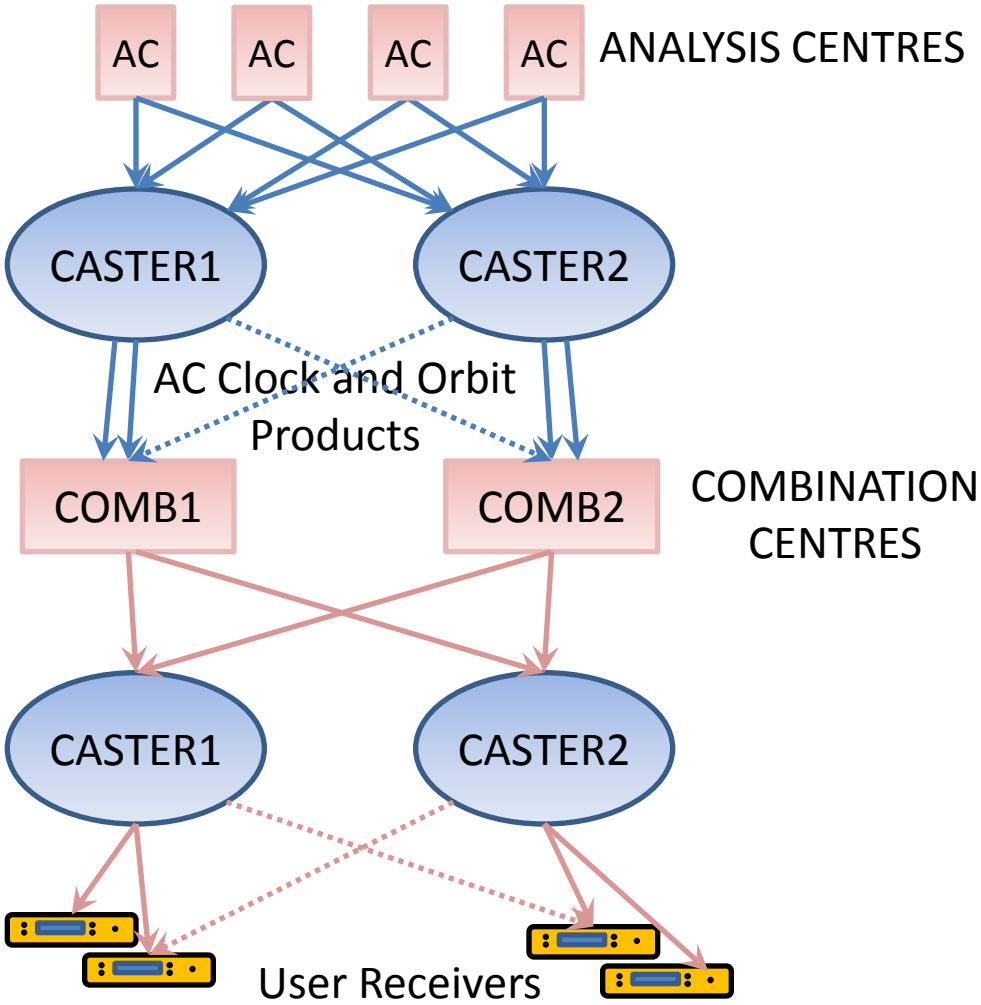


- Participation from DLR and UPC
- RT-VTEC map (2D) in IONEX format, 15 minutes rate and latency (in future it could be provided as 3D grid and data stream)
- Main problem found so far: lack of globally-distributed receivers
- Comparisons suggest that both UPC and DLR results, using a sufficient number of available receivers, could be compatible for a combination solution with hopefully better performance than any one of the individual real-time maps
- New assessments of DLR and UPC RT-VTEC maps against JASON data are being conducted with the objective of generating combined RT-IGS VTEC products

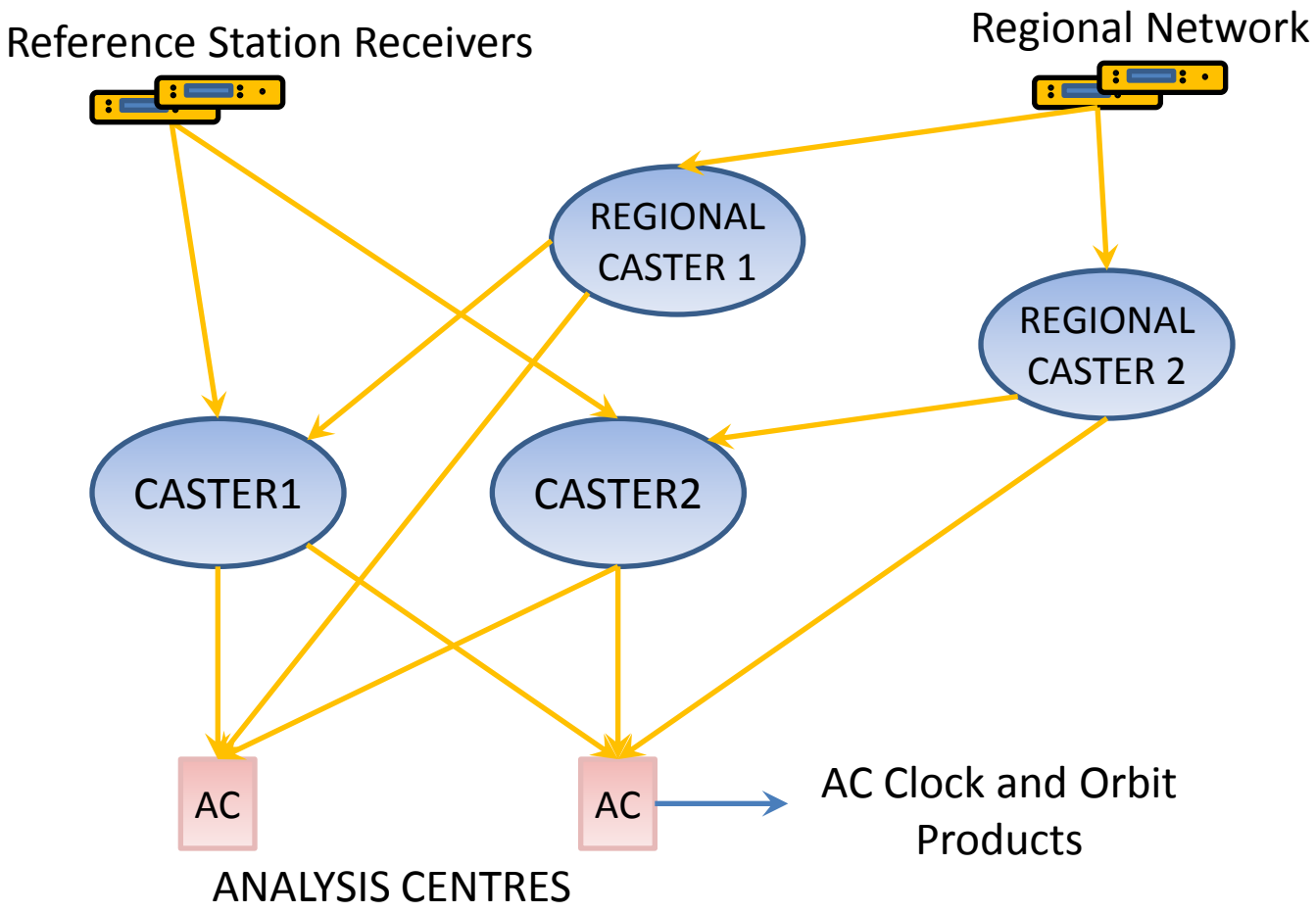
Transition to Operational Service

- RTPP participants are being asked to confirm their commitment to an operational service
- Initial Service in Q3 2012
  - GPS-only combination
  - Stage 1 Redundancy Concept to be implemented
  - Stage 2 Redundancy Concept to be phased in gradually
- Other products to be added later:
  - KF combination
  - Multi-GNSS products

Redundancy Concept Stage 1



Redundancy Concept Stage 2



Conclusions

- RTPP data and products have been available since 2008
- Formats and processes are now ready to allow an initial operational service in Q3 2012
- Interested users who may want to test the combination products earlier can contact the RTWG for access and complete an online registration form:
  - http://register.rtcm-ntrip.org
  - Mark Caissy caissy@nrcan.gc.ca
  - Georg Weber georg.weber@bkg.bund.de
  - Loukis Agrotis loukis.agrotis@esa.int

Acknowledgements

- BKG
  - Data and product dissemination, RTCM and NTRIP software, PPP client, NTRIP web site
- NRCan
  - Data dissemination, udpRelay software, RTCM, RINEX Working Group, PP web site
- ESOC
  - Sponsoring of AC Coordination Activities, RTCM, RINEX Working Group
- ACs and station operators/data providers
- IGSCB (and GB)
  - Support of RTPP, data and product dissemination