Precise Point Positioning: *Is the Era of Differential GNSS Positioning Drawing to an End?*

UNSW — THE UNIVERSITY OF NEW SOUTH WALES

Never Stand Still — **School of Surveying & Spatial Information Systems, UNSW, Sydney, Australia**

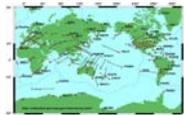Chris Rizos[1], Volker Janssen[2], Craig Roberts[1], Thomas Grinter[2]

[1] School of Surveying & Spatial Information Systems, UNSW, Australia

[2] Land & Property Information, Dept. of Finance & Services, NSW, Australia

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Precise Positioning GNSS Applications

Building Construction

Geodesy

Monitoring

Rapid Mobile Mapping

Port Operations

Land Surveying

Machine Guidance

Precision Agriculture

- Surveying & mapping

- Precise kinematic apps, such as machine guidance/control

- Define/monitor datum, geodesy apps, etc.

- Precise georeferencing of airborne or terrestrial scanning/imaging sensors
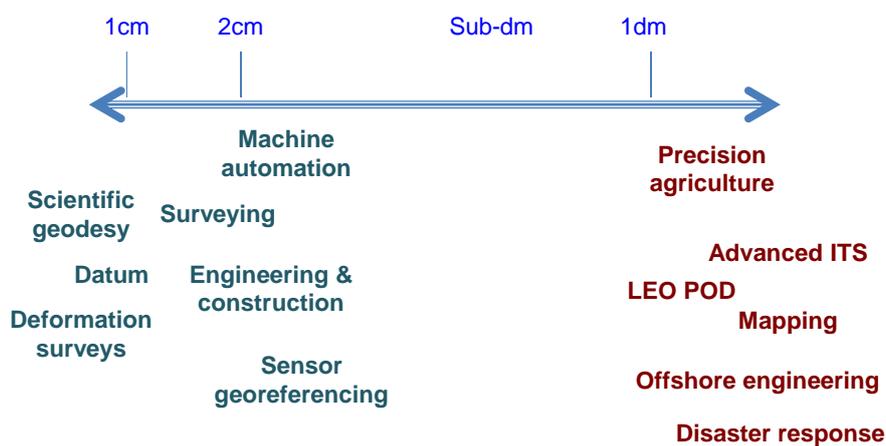
How "precise"?

| 1cm | 2cm | Sub-dm | 1dm |

Machine automation

Scientific geodesy **Surveying**

Datum **Engineering & construction**

Deformation surveys

Sensor georeferencing

Precision agriculture

Advanced ITS

LEO POD

Mapping

Offshore engineering

Disaster response

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For almost all Precise Positioning GNSS applications the differential GNSS technique has been the *only* means of satisfying accuracy requirements...
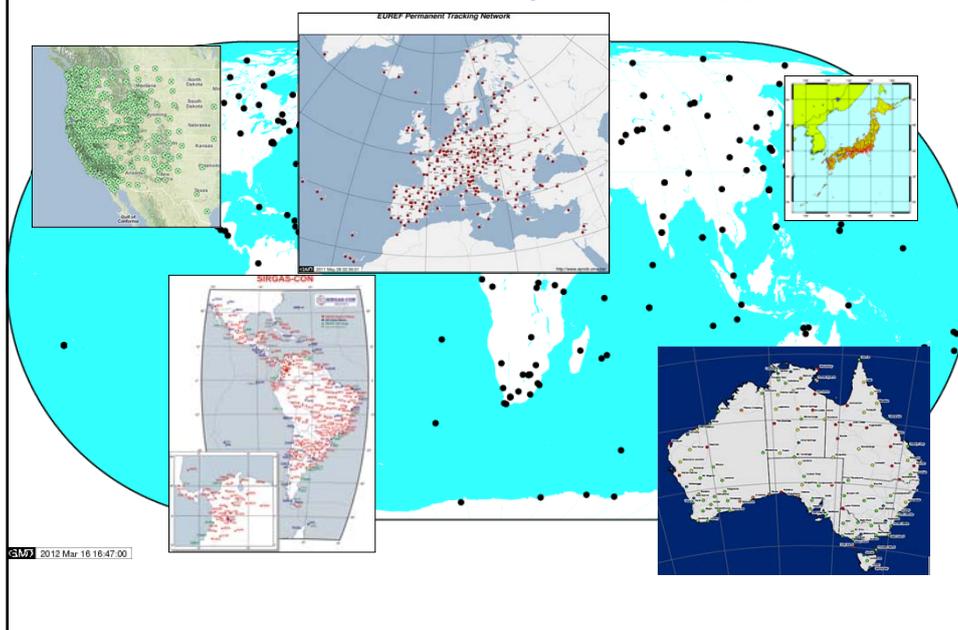
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Over many years a wide range of DGNSS techniques have evolved... *balancing constraints of accuracy, complexity, timeliness, cost & performance*... specialised HW, SW & operations

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Global CORS to support geodetic apps...

CORS Infrastructure…*commercial*

10,000s of CORS...
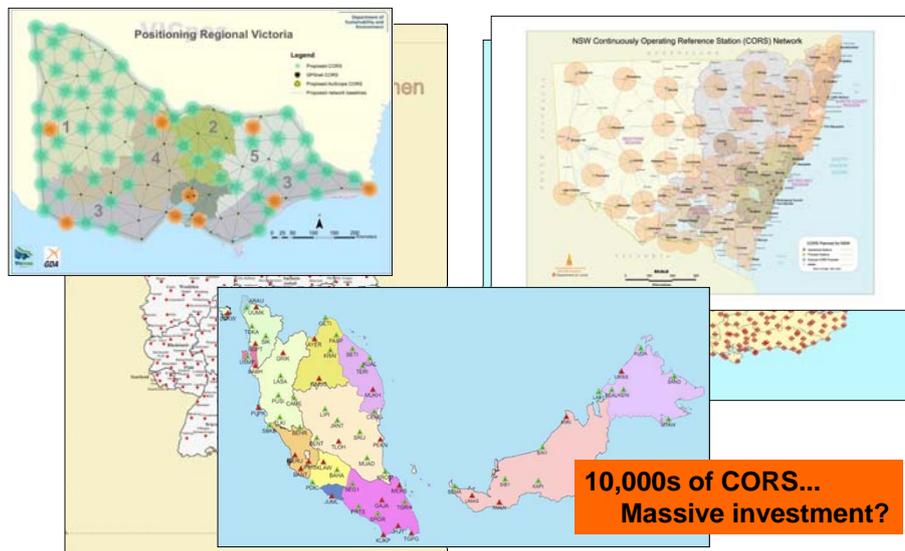Massive investment?

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Precise Point Positioning (PPP) has evolved and some claim it will address weakness of DGNSS, *the need for reference receiver infrastructure*...

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Will PPP displace DGNSS?
... Are they complementary? Do they address different markets? Can they be used interchangeably?

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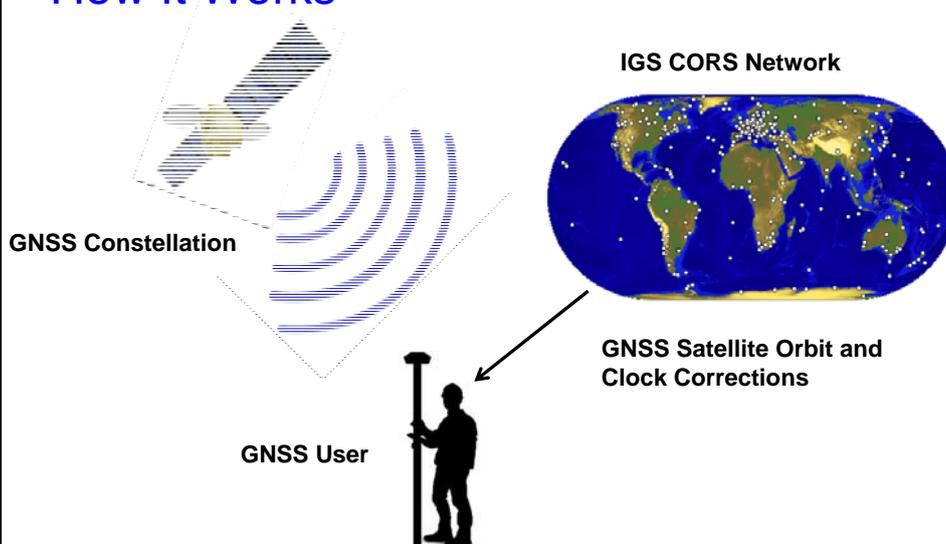
How It Works

IGS CORS Network

GNSS Constellation

GNSS Satellite Orbit and Clock Corrections

GNSS User

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Comparing PPP & DGNSS...

Correction Type	PPP	Differential GNSS
Satellite Specific errors		
Precise satellite clock corrections	✓	✗
Satellite antenna phase centre offset	✓	✓
Satellite antenna phase centre variation		
Precise satellite orbits		
		✗
	✓	✗
	✓	✗
Plate tectonic motion	✓	✗
Atmospheric Modelling		
Troposphere	✓	✓
Ionosphere	✓ (L1 only)	✗

PPP observation model (& SW) is more complex than DGNSS! PPP requires "global" corrections, not local CORS data...
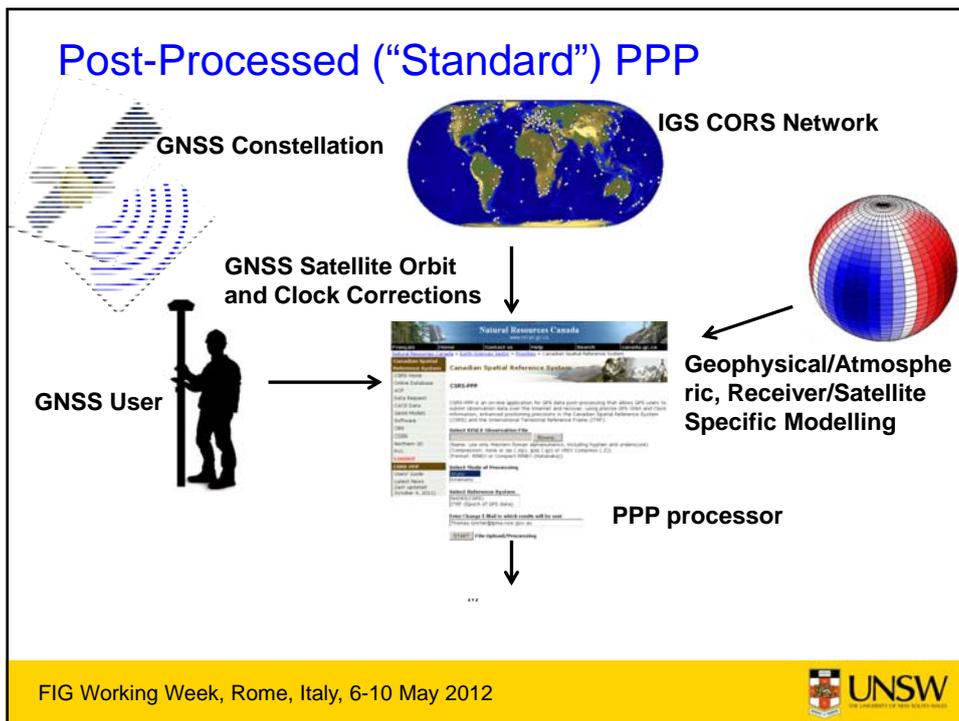
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How It Works

International GNSS Service
Provides Precise Satellite Orbits & Clock Corrections
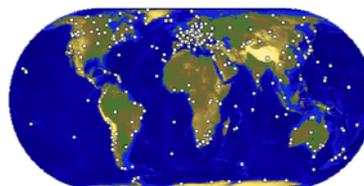
Product	Parameter	Accuracy	Latency
Broadcast	Orbit	~ 100m	Real Time
	Clock	~ 5 ns	
Ultra Rapid (predicted)	Orbit	5 cm	Real Time
	Clock	~ 3 ns	
Ultra Rapid (estimated)	Orbit	< 5 cm	3 hrs
	Clock	~ 0.2 ns	
Rapid (estimated)	Orbit	< 5 cm	17 hrs
	Clock	0.1 ns	
Final (estimated)	Orbit	< 5 cm	~ 14 days
	Clock	< 0.1 ns	
Real-time IGS	**Orbit**	**<10 cm**	**10-20 secs**
	Clock	**0.15 ns**	

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Post-Processed ("Standard") PPP

GNSS Constellation

IGS CORS Network

GNSS Satellite Orbit
and Clock Corrections

Geophysical/Atmospheric, Receiver/Satellite
Specific Modelling

GNSS User

PPP processor

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Comparing "apples" & "oranges"
... By removing CORS/data requirement,
*users have lower accuracy (kinematic),
non-RT positioning on non-local datum...*

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Markets

Network RTK

- Survey
- Engineering
- Construction
- Utilities
- Machine control
- Deformation monitoring
- ...

- Precision agriculture
- Mapping/GIS
- Airborne laser scanning
- GNSS meteorology
- ...

Standard PPP

- Offshore positioning
- Disaster monitoring
- Glacier monitoring
- LEO orbit determination
- ...

T. Horvath, "PPP-RTK: Friend or Foe?", BKG PPP-RTK & Open Standards Symposium, Frankfurt, Germany, 12-13 March 2012

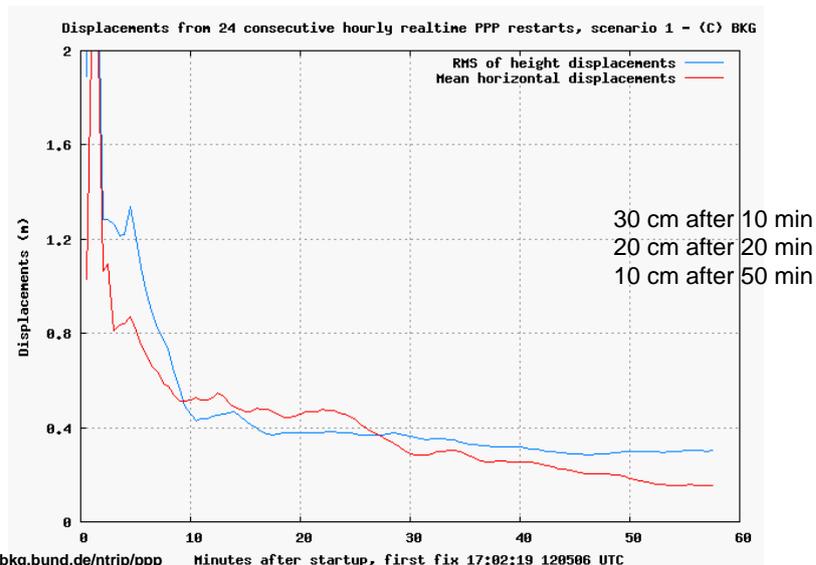PPP has other challenges... to reach RTK performance <u>need</u>:
industry message format stds, higher accuracy orbit/clk products, convenient transmission, commercial Rx (non-proprietary) implementations, AND some local CORS

IGS Real-Time Pilot Project

- Real-time product generation is part of IGS Strategic Plan, started 2002
- Infrastructure:
  - More than 120 active real-time stations
  - Data streaming using NTRIP
  - Close link to RTCM...joint WG established
- Analysis:
  - 8 real-time Analysis Centres (one in China)
  - Real-time orbit & sat clock combination...can support RT-PPP
- Future:
  - Real-time service to be launched mid-2012...GPS-only
  - Satellite clock corrections, orbits, ionosphere corrections
  - Include new systems and signals

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Slow convergence...

Displacements from 24 consecutive hourly realtime PPP restarts, scenario 1 - (C) BKG

RMS of height displacements
Mean horizontal displacements

30 cm after 10 min
20 cm after 20 min
10 cm after 50 min

Displacements (m)

http://igs.bkg.bund.de/ntrip/ppp   Minutes after startup, first fix 17:02:19 120506 UTC
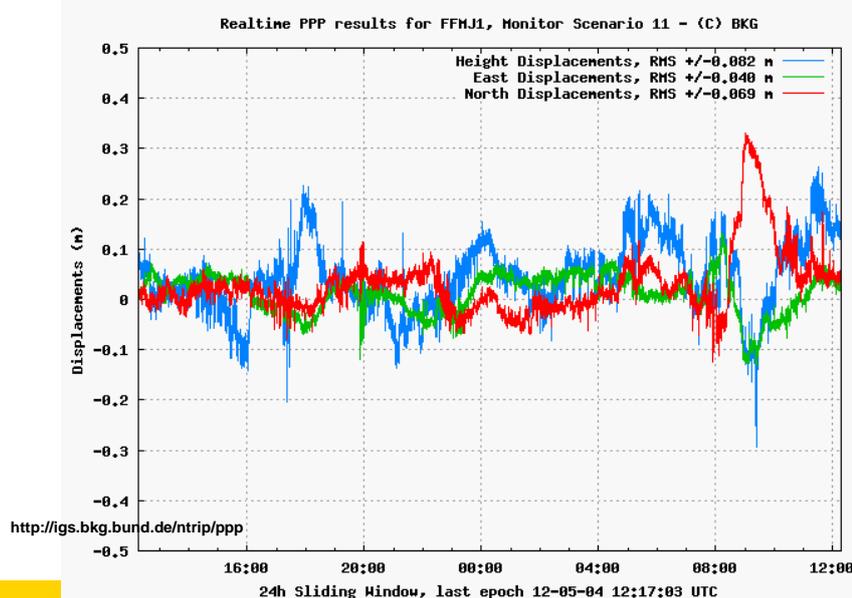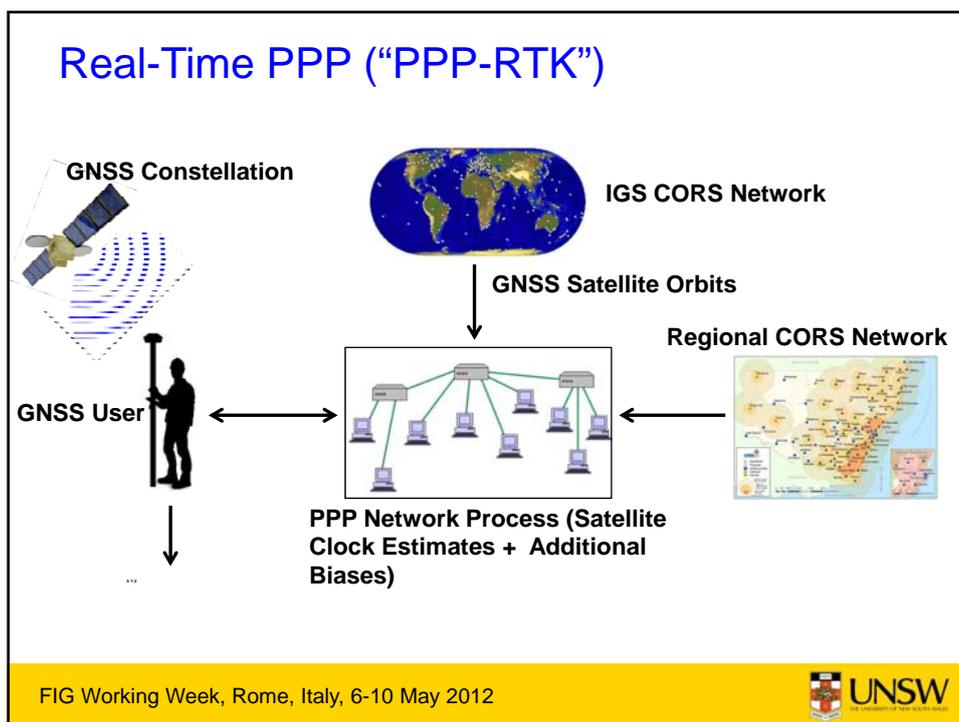
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RT-IGS... *supporting RT-PPP*

Can speed up convergence...
... Rapid OTF ambiguity resolution...with local CORS-generated atmospheric correction messages... Or start from "known point"...
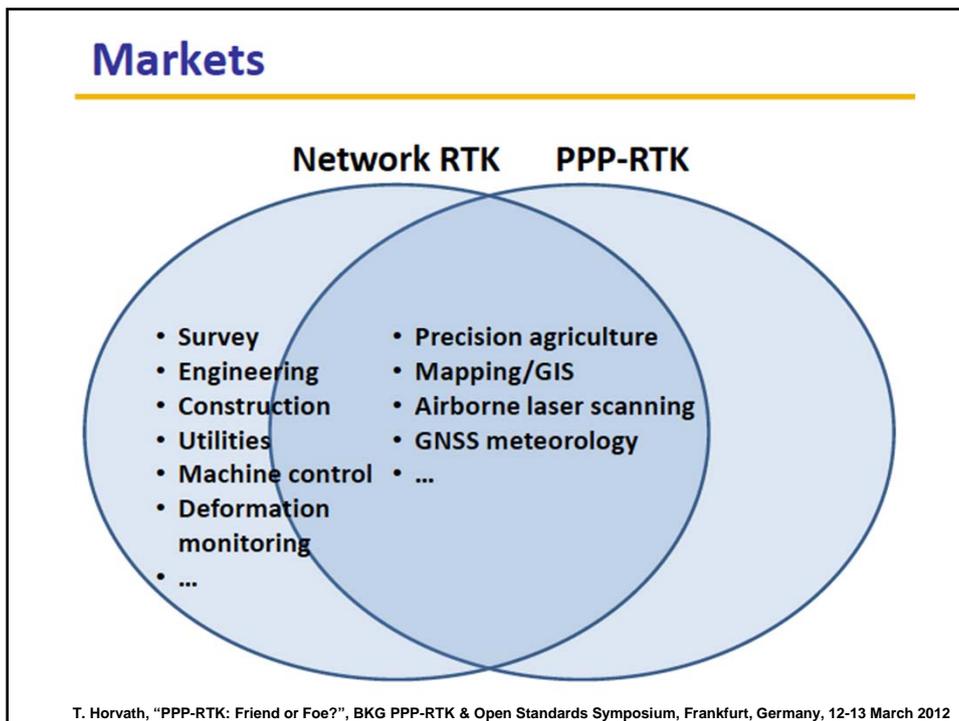
Real-Time PPP ("PPP-RTK")

GNSS Constellation

IGS CORS Network

GNSS Satellite Orbits

Regional CORS Network

GNSS User

PPP Network Process (Satellite Clock Estimates + Additional Biases)

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Real-Time PPP... *some issues*

- Real-time corrections... *from IGS or commercial entities?*
- Orbit reference point... *CoM or APC?*
- Implementation of industry standards... *RTCM HP-MSM, RTCM SSR*
- Real-time "latency"... *10-20 seconds*
- RT-IGS is GPS-only... *GPS + Glonass in 2013?*
- Transmission of RTCM SSR... *Satcoms or terrestrial?*
- Cm-level accuracy for "RTK-PPP"... *Local datum (like DGNSS)?*
- Cooperation of CORS operators, RTK-PPP message providers, RT-IGS, comms operators, Rx manufacturers...

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Markets

Network RTK

• Survey
• Engineering
• Construction
• Utilities
• Machine control
• Deformation monitoring
• ...

PPP-RTK

• Precision agriculture
• Mapping/GIS
• Airborne laser scanning
• GNSS meteorology
• ...

T. Horvath, "PPP-RTK: Friend or Foe?", BKG PPP-RTK & Open Standards Symposium, Frankfurt, Germany, 12-13 March 2012

GNSS services

Service	Accuracy	Correction source	Navigation satellites	Satellite frequencies	Positioning mode
L1	Meter	Reference station			
					Differential
	Decimeter	Orbit & clock (JPL)	GPS	Dual	PPP
G2	Decimeter	Orbit & clock (Fugro)	GPS & GLONASS	Dual	PPP

Commercial (proprietary) service... Sowing "FUD"... will CORS investment be reduced?

*: actual performance may vary and depends upon propagation of electromagnetic signals (e.g., ionospheric propagation), satellite performance, solar flare activity and other environmental factors

JOHN DEERE

All the disadvantages of PPP &
increased complexity & <u>still</u> some
CORS requirements...!!!!
Less CORS? 100-200km spacing?
Yes less than RTK/NRTK, but what
about future triple-freq DGNSS?

Accuracy "creep" from dm->sub-dm->cm...
... How is the orbit/clk information now at
sub-cm level (remember PDOP effect)?
With "no" latency?"... *Implying higher*
performance than RT-IGS...
Is PPP-RTK being over-sold?

Friend or foe?

Friend, but it's not a pure friendship...

Network RTK service providers be prepared,
- start cooperating early with PPP-RTK service providers,
- provide local augmentation, etc. data,

or else you may have to do something else in 4-5 years time...

T. Horvath, "PPP-RTK: Friend or Foe?", BKG PPP-RTK & Open Standards Symposium, Frankfurt, Germany, 12-13 March 2012

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PPP vs DGNSS...

- Another tool for the GNSS user... *But performance of RTK-DGNSS relies on CORS infrastructure design*.
- Should we be phasing out CORS investment because "PPP-RTK" is improving?...*NO*.
- Still need sparse CORS for "PPP-RTK"... *So care must be taken to not abandon CORS networks*.
- PPP techniques fail on "transparency" grounds...

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