SENSORS

Integrating Other GNSS with GPS and Its Implication for DP Positioning

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Presentation Overview

Introduction

Global Navigation Satellite Systems

- GPS
- GLONASS
- Galileo
- COMPASS

Integration of GPS and GLONASS

Implications for DP

Conclusions

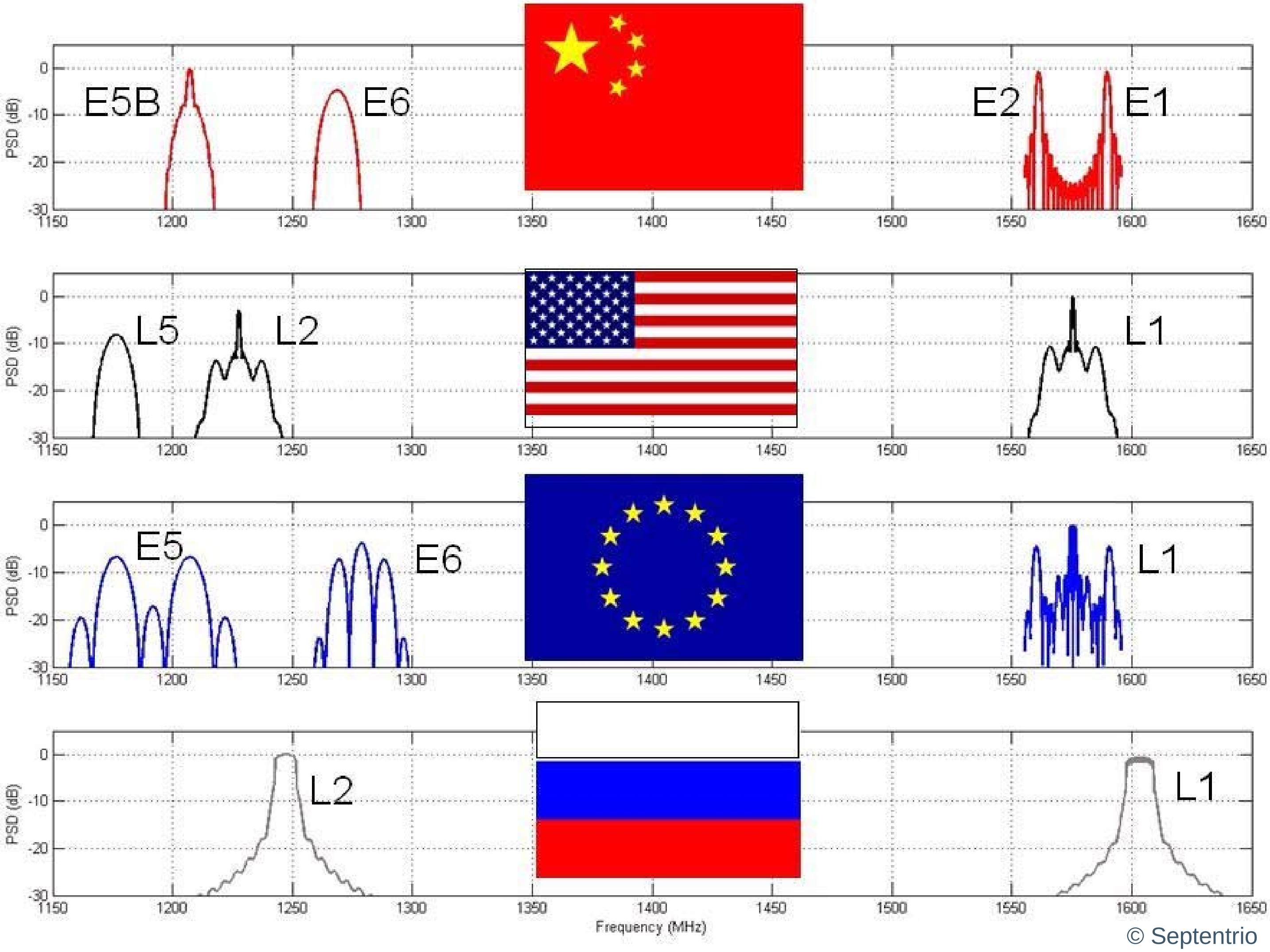
Introduction

- Satellite Navigation is a key technology within the offshore oil and gas sector
  - Utilised since early 1990's
  - Has made positioning and navigation more accessible
  - Used extensively within DP systems
  - To date the Global Positioning System (GPS) has been used exclusively
- Moving to a new era in satellite navigation with the availability of more satellites and signals
- This presentation will look at the advantages that this will bring to the offshore positioning market
- It will also look at the challenges that will be faced when integrating different satellite constellations

Global Navigation Satellite Systems

- The SatNav landscape is changing
  - Modernisation of GPS
  - Replenishment & Modernisation of the Russian GLONASS system
  - Addition of new European and Chinese systems
- Benefits include
  - Availability – more satellites and signals giving better geometry
  - Accuracy – newer signals permitting better signal tracking and will be able to selectively reject questionable data
  - Reliability – better signal tracking under challenging conditions
  - Independence – will be possible to have different position solutions for each constellation in addition to a combined solution

GNSS Frequency Spectrum



Global Positioning System (GPS)

- Present GPS constellation has 31 satellites on orbit
- New signals – L2C, L5 and in the future L1C
- First signal that will be available to civilian users is the L2C
  - Tracking coded signal (as opposed to semi-codeless) = high SNR
  - Better chipping rate provides better signal tracking
  - More robust and accurate signal tracking when multipath present
  - Pilot signal which carries no data meaning that receivers can acquire the signal under weak condition (e.g. RF interference or ionosphere scintillation)

- The future for GPS
  - Affirmed to IMO that system will remain free and will provide at least 6 years notice prior to any termination of service

GLONASS

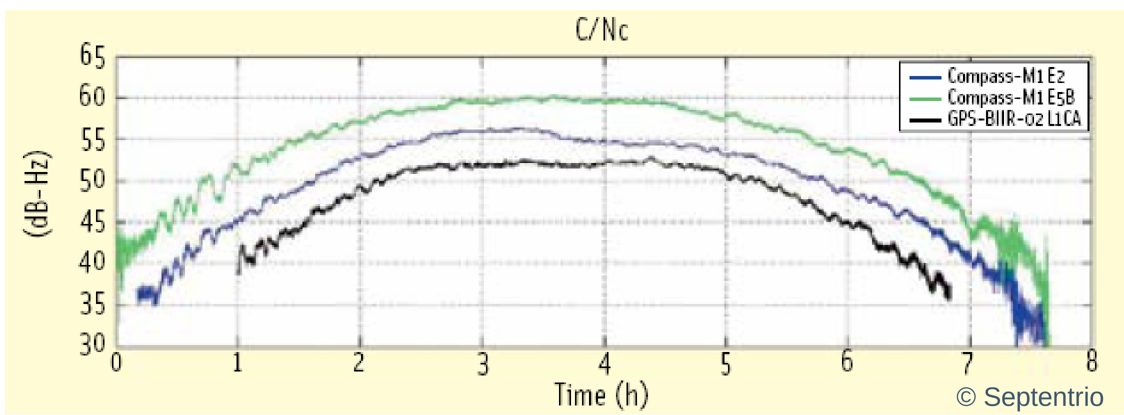
- The Russian equivalent of GPS has been undergoing a revival with the launch of new satellites which has made the system a viable alternative to GPS
  - Presently the system has 17 operational (healthy) satellites
  - 3 added on 26th Sept 08 with 3 more scheduled for launch in December 08
  - Improvements to geodetic reference frame and ground control segment = better accuracy
  - Recently, the Russian government announced extra funding for GLONASS program (67 billion roubles)
- Looking to modernise the constellation
  - New generation of satellites
  - New civil signal at L3 and the possible change to code division multiple access for the L1 signal

Galileo

- At present the Galileo program is looking to place contracts with companies to implement the system (ground and space segment)
- At present 2 satellites are in orbit – Giove-A and Giove-B
- Advantages of the Galileo signals compared against the current GPS satellites:
  - Power of signals will be greater by a factor of 2 = reduction in tracking noise
  - Pilot signal (data-less)
  - Signal modulation schemes will result in reduction of tracking and multipath noise
  - Robust coding scheme for nav bits to increase reliability of decoding (useful in presence of interference or with low signal power)
- Recent glitch with the Giove-B satellite when affected by solar radiation and satellite was put into safe mode – still under investigation by ESA

COMPASS

- The Chinese have launched a satellite with SatNav capability named COMPASS (or Beidou 2)
- There is very little information in the public domain about the signal and data structures and no ICD has been published
  - No timeline or launch schedule available for the system
- Various organisations have managed to decode the signals and successfully track the satellite
- The current plan calls for a system to provide global positioning and navigation
  - Constellation of 35 satellite (5 geostationary)
  - Three frequency structures that operate at similar frequencies to GPS & Galileo



Integration of GNSS

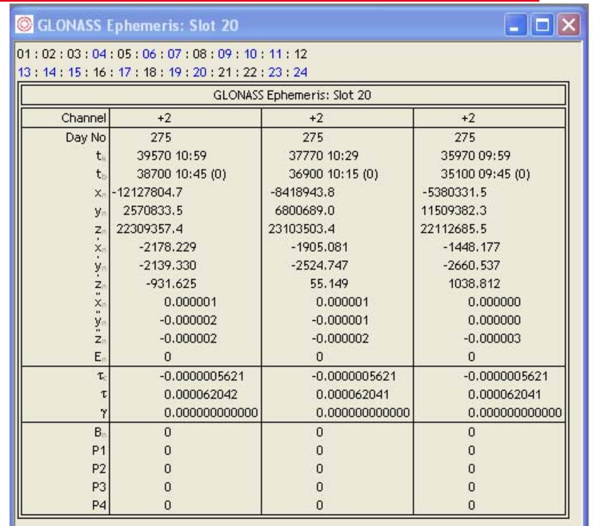
- Why integrate different Global Navigation Satellite Systems?
  - More satellites providing better geometry
  - Additional measurements giving redundancy and also the potential for rejecting questionable data
  - Additional data allowing multiple parameter estimation
  - Better accuracy when new or modernised signals become available
  - More signals at different frequencies aids resilience to potential interference
- GPS – the geriatric system??
  - 19 satellites are past their design life with many only one component away from navigation payload failure
  - US policy is still that GPS is a 21 satellite system with 3 spares
- Integration of different GNSS helps prevent the reliance on just one system and provides more opportunity to provide a more robust position solution

Integration of GPS and GLONASS

- Each GNSS operates in a similar fashion – i.e. they broadcast radio signals with information that allows a user to determine their position
- The differences in each system must be accounted for when developing an integrated solution so that the position solution is not degraded in any way
- Main difference between GPS and GLONASS is the frequency of transmission
  - GPS broadcasts a L1 and L2 frequency using different codes for each satellite
  - GLONASS uses frequency division multiple access to uniquely identify each satellite
- Data snooping/rejection
  - Measurement quality from older GLONASS satellites can be questionable
- Other areas that need to be addressed are:
  - Ephemeris
  - Atmosphere
  - Geodetics

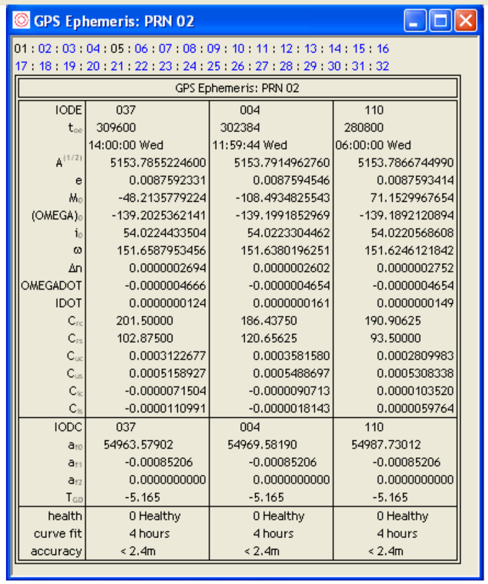
Ephemeris / Almanac

- Each satellite system broadcasts Ephemeris and Almanac data which allows users to determine the position of the satellites
- GPS and GLONASS transmit parameters in a different format and also in a different reference frame and time system
- Typically operate in the GPS system, so must convert the GLONASS satellite positions into the GPS reference frame
- GLONASS ephemerides are typically updated every 30min (GPS is every 2 hours)
- This update contains a value which permits the user to determine the which ephemeride was used to generate the RTCM correction



GLONASS Ephemeris: Slot 20

Channel	+2	+2	+2
Day No	275	275	275
t_k	39570 10:59	37770 10:29	35970 09:59
t_b	38700 10:45 (0)	36900 10:15 (0)	35100 09:45 (0)
x_n	-12127804.7	-8418943.8	-5380331.5
y_n	2570833.5	6800689.0	11509382.3
z_n	22309357.4	23103503.4	22112685.5
$\dot{x}_n$	-2178.229	-1905.081	-1448.177
$\dot{y}_n$	-2139.330	-2524.747	-2660.537
$\dot{z}_n$	-931.625	55.149	1038.812
$\ddot{x}_n$	0.000001	0.000001	0.000000
$\ddot{y}_n$	-0.000002	-0.000001	0.000000
$\ddot{z}_n$	-0.000002	-0.000002	-0.000003
E_n	0	0	0
τ_c	-0.0000005621	-0.0000005621	-0.0000005621
τ	0.000062042	0.000062041	0.000062041
γ	0.000000000000	0.000000000000	0.000000000000
B_n	0	0	0
P1	0	0	0
P2	0	0	0
P3	0	0	0
P4	0	0	0

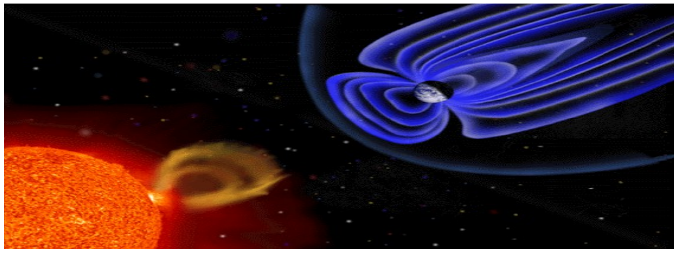


GPS Ephemeris: PRN 02

IODE	037	004	110
t_{oe}	309600	302384	280800
	14:00:00 Wed	11:59:44 Wed	06:00:00 Wed
$A^{(1/2)}$	5153.7855224600	5153.7914962760	5153.7866744990
e	0.0087592331	0.0087594546	0.0087593414
M_0	-48.2135779224	-108.4934825543	71.1529967654
$(OMEGA)_0$	-139.2025362141	-139.1991852969	-139.1892120894
i_0	54.0224433504	54.0223304462	54.0220568608
ω	151.6587953456	151.6380196251	151.6246121842
Δn	0.0000002694	0.0000002602	0.0000002752
OMEGADOT	-0.0000004666	-0.0000004654	-0.0000004654
IDOT	0.0000000124	0.0000000161	0.0000000149
C_{rc}	201.50000	186.43750	190.90625
C_{rs}	102.87500	120.65625	93.50000
C_{uc}	0.0003122677	0.0003581580	0.0002809983
C_{us}	0.0005158927	0.0005488697	0.0005308338
C_{ic}	-0.0000071504	-0.0000090713	0.0000103520
C_{is}	-0.0000110991	-0.0000018143	0.0000059764
IODC	037	004	110
a_{f0}	54963.57902	54969.58190	54987.73012
a_{f1}	-0.00085206	-0.00085206	-0.00085206
a_{f2}	0.0000000000	0.0000000000	0.0000000000
T_{GD}	-5.165	-5.165	-5.165
health	0 Healthy	0 Healthy	0 Healthy
curve fit	4 hours	4 hours	4 hours
accuracy	< 2.4m	< 2.4m	< 2.4m

Atmosphere

- Atmospheric delays (ionosphere and troposphere) also need to be accounted for to improve the accuracy of the position solution
- Troposphere delays occur in the lower part of the atmosphere and the same techniques used for GPS can be applied to GLONASS as the frequency of the signal does not have any impact
- Ionosphere delay is affected by the frequency of the transmitted signal
  - GPS broadcasts a Klobuchar model to compensate for the iono-delay
  - Klobuchar delays are derived with respect to L1 frequency
  - GLONASS broadcasts on multiple frequencies so the equation needs to be modified
- Currently investigating the use of the GLONASS second civil signal to determine the true iono-delay (similar to using L1-L2 GPS)

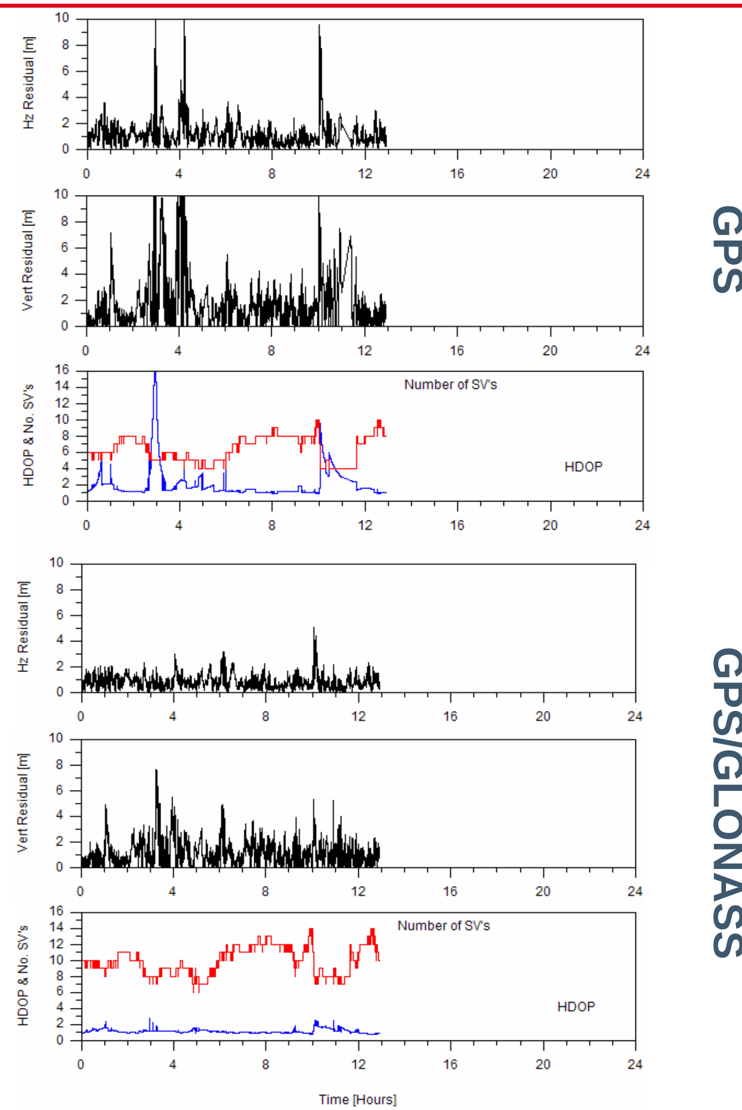


Geodetics

- Perhaps the most important area that needs to be addressed in order to provide high accuracy positioning is the geodetic datums used
- GPS system uses WGS84 and GLONASS PZ90, therefore must transform from one system into the other
- Typically a 7-parameter Helmert transformation is used to convert GLONASS datum into the GPS datum
    - There is no globally accepted set of transformation parameters
    - Receiver manufacturers use different parameters
    - Must be accounted so as not to degrade the position solution
- While it is relatively easy to transform geodetic datums, the other issues that must be accounted for is the actual accuracy of the geodetic datums themselves
    - This could potentially degrade the position solution
    - GLONASS recently updated its datum to PZ90.2 resulting in better orbit accuracy

Performance

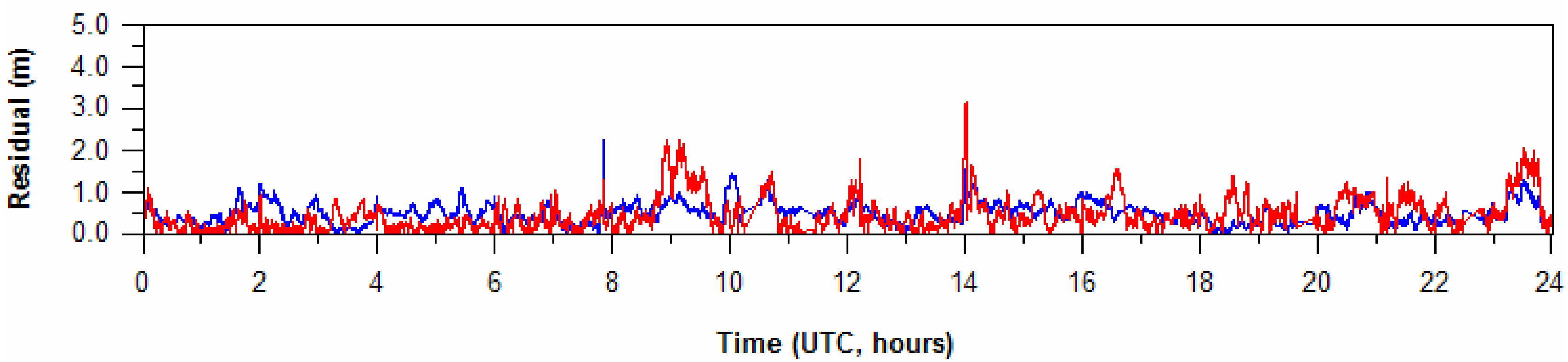
- At present, GLONASS is used as an augmentation to the GPS system to provide better redundancy
- Results show that the utilising the GLONASS system does not degrade the position solution
- With the launch of more GLONASS satellites it should be possible to calculate a GLONASS only solution (can be done today but coverage limited)



Performance

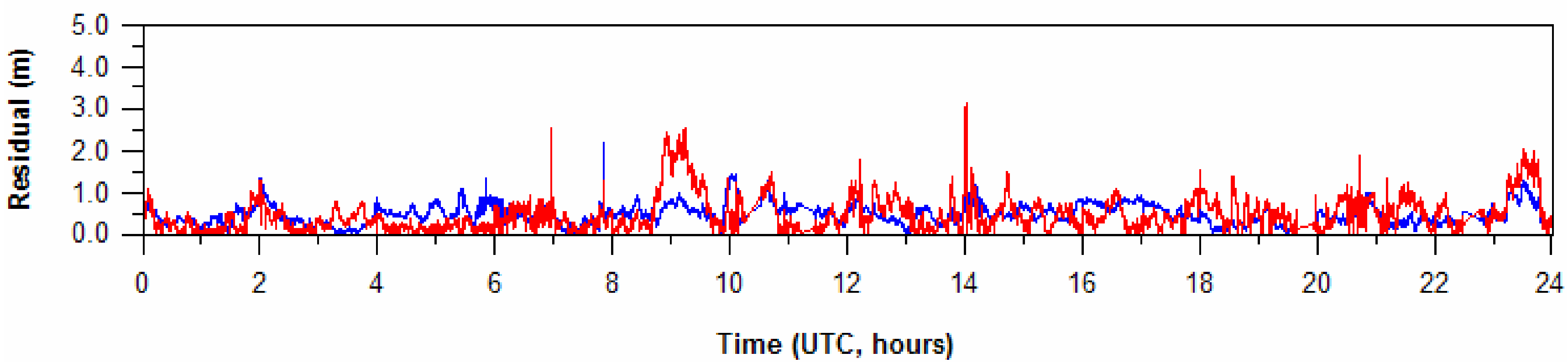
GPS-only

Horizontal (blue) & Vertical (red) Residual



GPS+GLONASS

Horizontal (blue) & Vertical (red) Residual



Implications for DP Positioning

- GNSS will remain as one of the principal references used within a DP system
  - Changes within the SatNav will help meet the future needs of offshore community
- The advantages that the changes in the satellite navigation will bring are:
  - Better availability due to increased number of satellites and signals
  - Multiple signals at different frequencies should help make the solution more resilient to interference
  - Potential to use each system independently or in a combined solution
- The disadvantages of GNSS
  - Perceived to be a consumer technology – cheap, infallible providing positioning anytime and is always correct

Integration into DP Systems

- Selection of the most appropriate positioning system for the vessel to meet operational or class requirements

- What information should be made available to the DP system?
  - Important when there is the potential for different solutions to be made up of different signals and constellation
  - Ability to weight solutions appropriately within DP system which will need additional information about the position solution (e.g. co-variance matrix)
  - Standardised interface to ease integration

- What about future systems such as INS and how will GNSS integrate with that technology?
  - Who will be responsible for the integration
  - There is a requirement for a standard protocol or interface to exchange data

Certification

- In the future the certification of positioning reference systems will become more prominent
  - Will there be a requirement for certifying all position references feeding the DP?
  - Certification process must be able to handle the advances in technology
  - What about the integration of other sensors (e.g. INS)
  - Who will be responsible for attaining certification
- Presently, the principal certification required for positioning systems feeding a DP system is Type Approval for IEC60945
- The other standard that covers positioning systems is the Marine Equipment Directive (MED)
  - Designed to enhance safety at sea
  - Driven by a number of specific resolutions issued by IMO

Certification - MED

- Some Notified Bodies request that the position references feeding into a DP system must meet MED
- If only the vessel approved SOLAS approved GNSS receiver is used to ensure safe passage of the vessel then;
- The service and equipment used as a position reference for the DP system is understood to fall outside the jurisdiction of the IMO regulations and hence outside MED
  - Need further discussion with Notified Bodies

Conclusions

- Whatever the challenges ahead, the landscape of satellite navigation is going to change
  - Will help meet the future requirements of the industry
  - Will improve on what we currently have
  - New possibilities including the integration with other sensors and derivation of new solutions
- Need the industry to work together to develop standard interfaces and protocols to maximise the benefits of all these new developments