Improving Accuracy and Redundancy with GPS and GLONASS PPP

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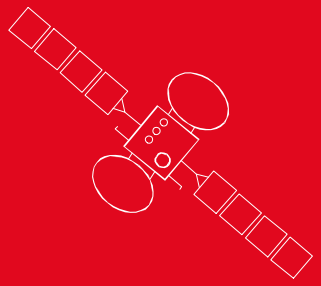
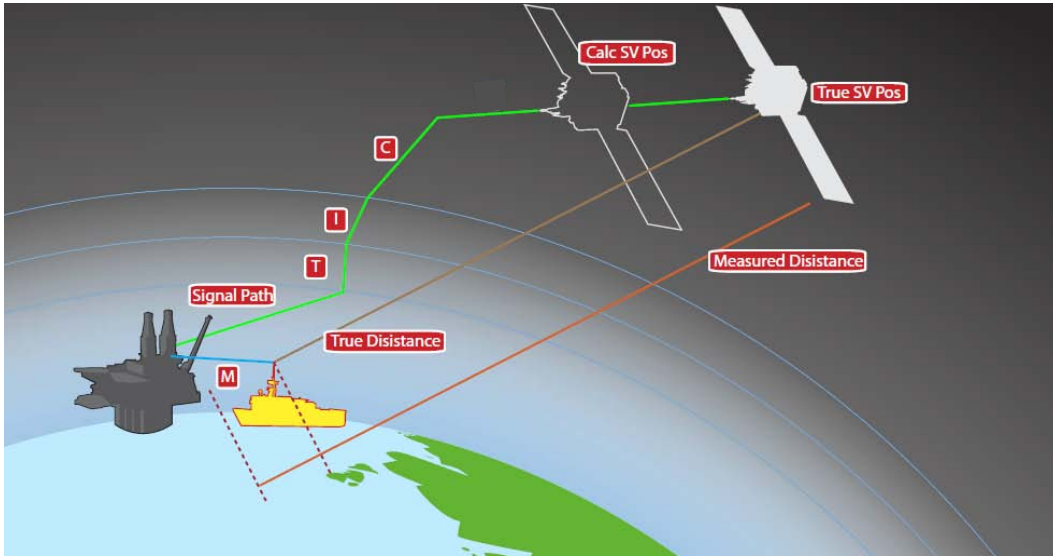


Presentation Overview

- Precise Point Positioning
- GLONASS
- Orbit & Clock Determination
- User Algorithms
- Performance of GPS & GLONASS
- Benefits for the DP User
- Integration into DP Systems

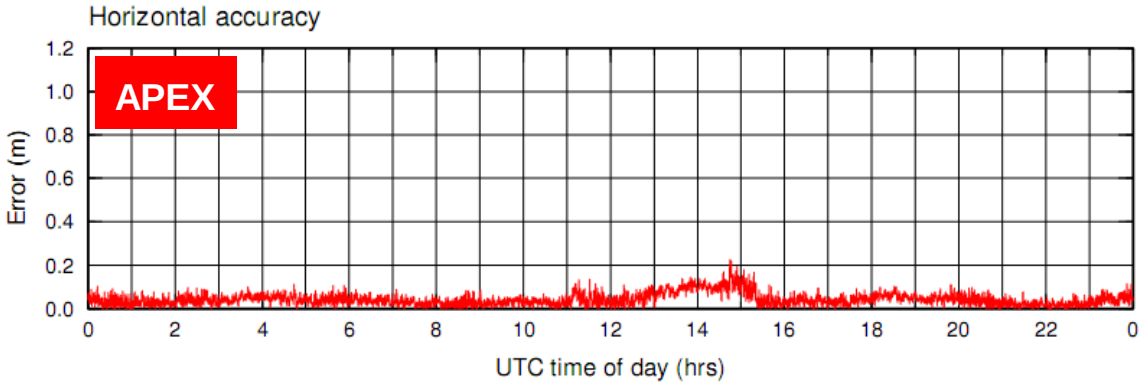
Precise Point Positioning

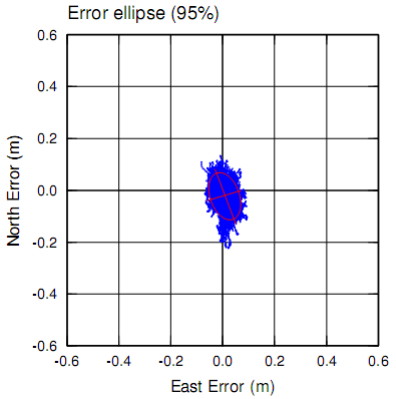
- Absolute positioning technique
  - Used as a real-time system delivering decimetre results
  - Used in offshore positioning for over 10 years
- Correct or model all GNSS error sources
- Single set of orbit and clock corrections for the satellite constellation
  - Valid globally, so position accuracy is maintained regardless of user location
  - Recently seen the addition of GLONASS due to rejuvenation of constellation

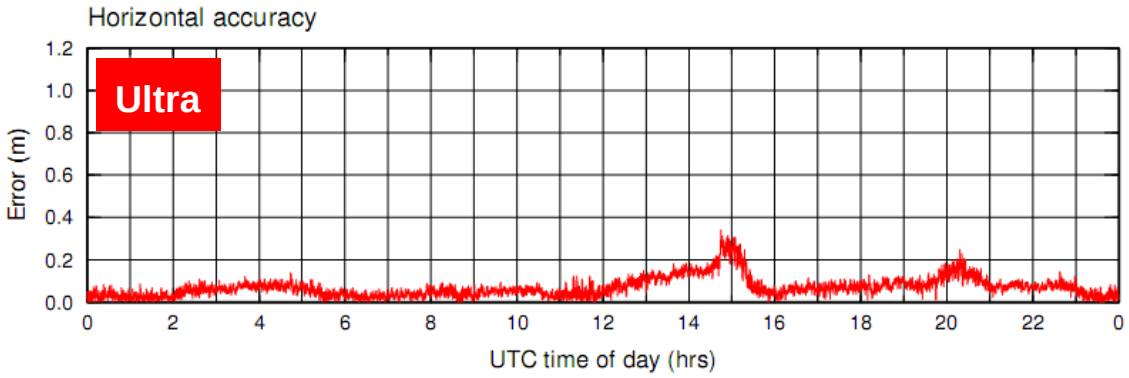


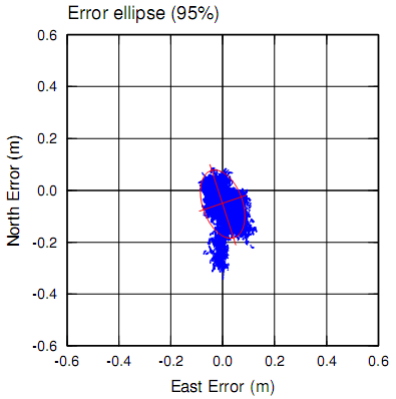
Typical PPP Accuracy

- Typical accuracy of PPP using GPS



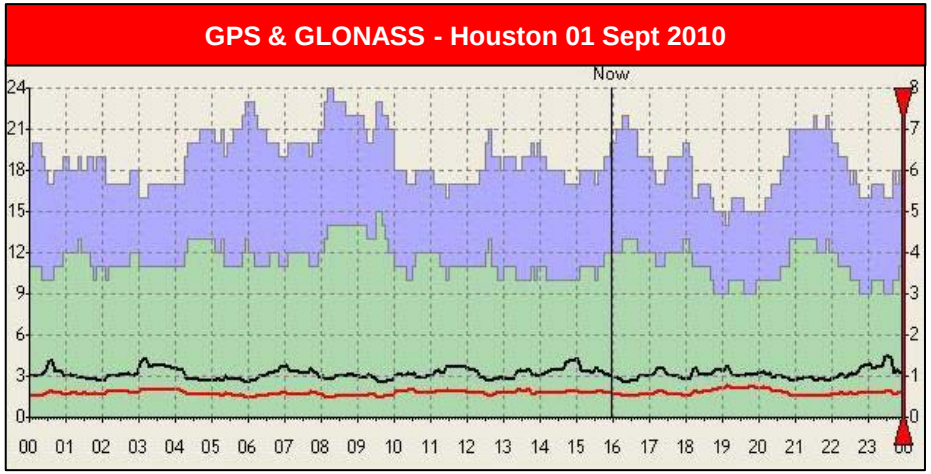






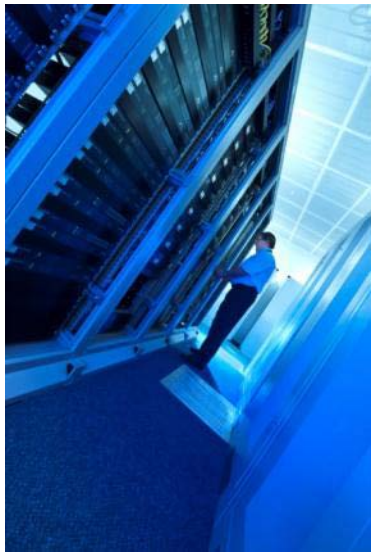
GLONASS – Why?

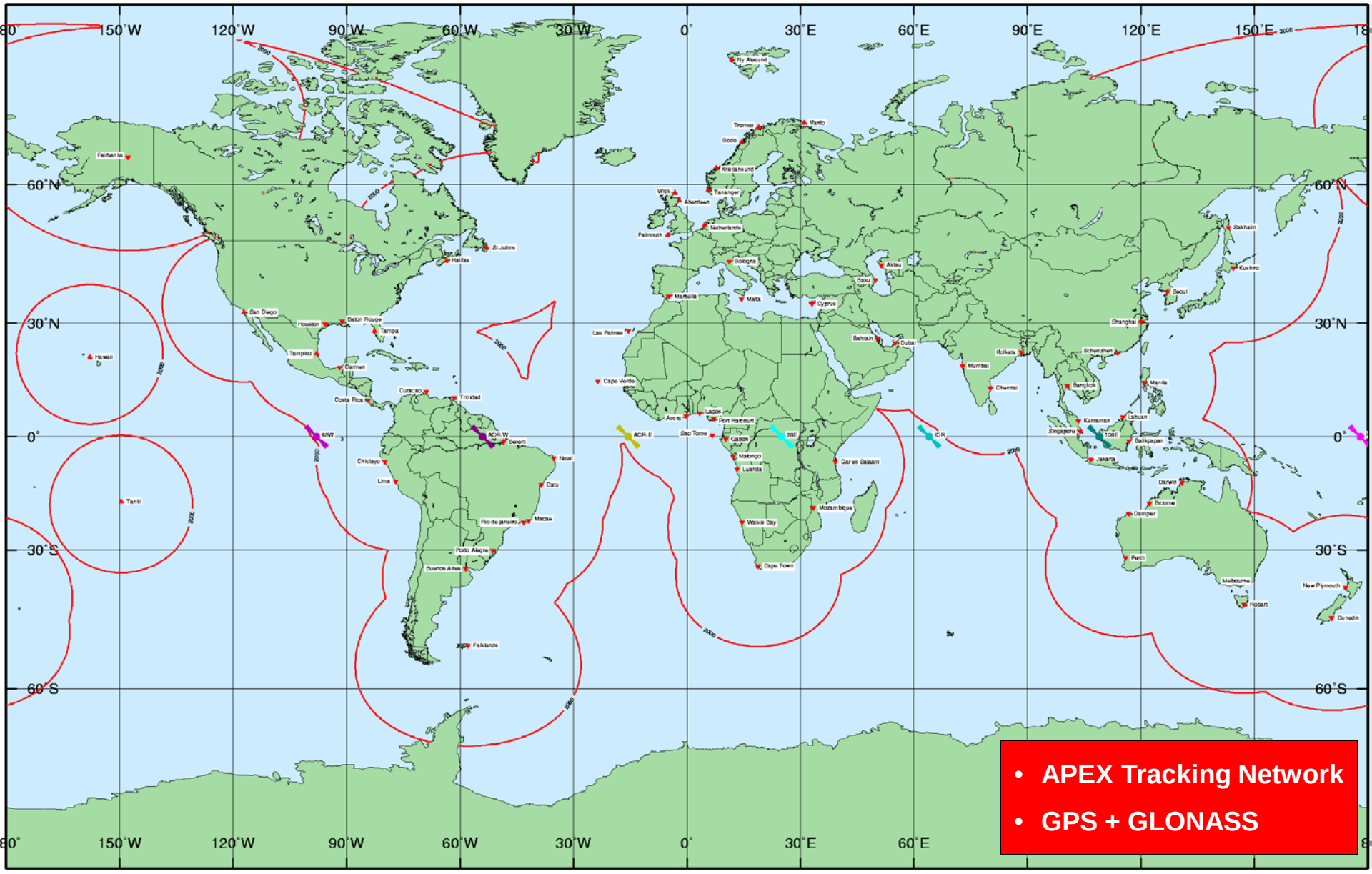
- GLONASS is a viable constellation (again!)
  - Significant investment in system
  - Operational system (unlike Galileo & COMPASS)
  - Current constellation is 24 satellites (last launch 09/02/10)
  - Receiver technology much improved
  - Modernization plan (signals, geodesy etc.)
  - Independent positioning system to GPS



What is Needed to Deliver a PPP Solution

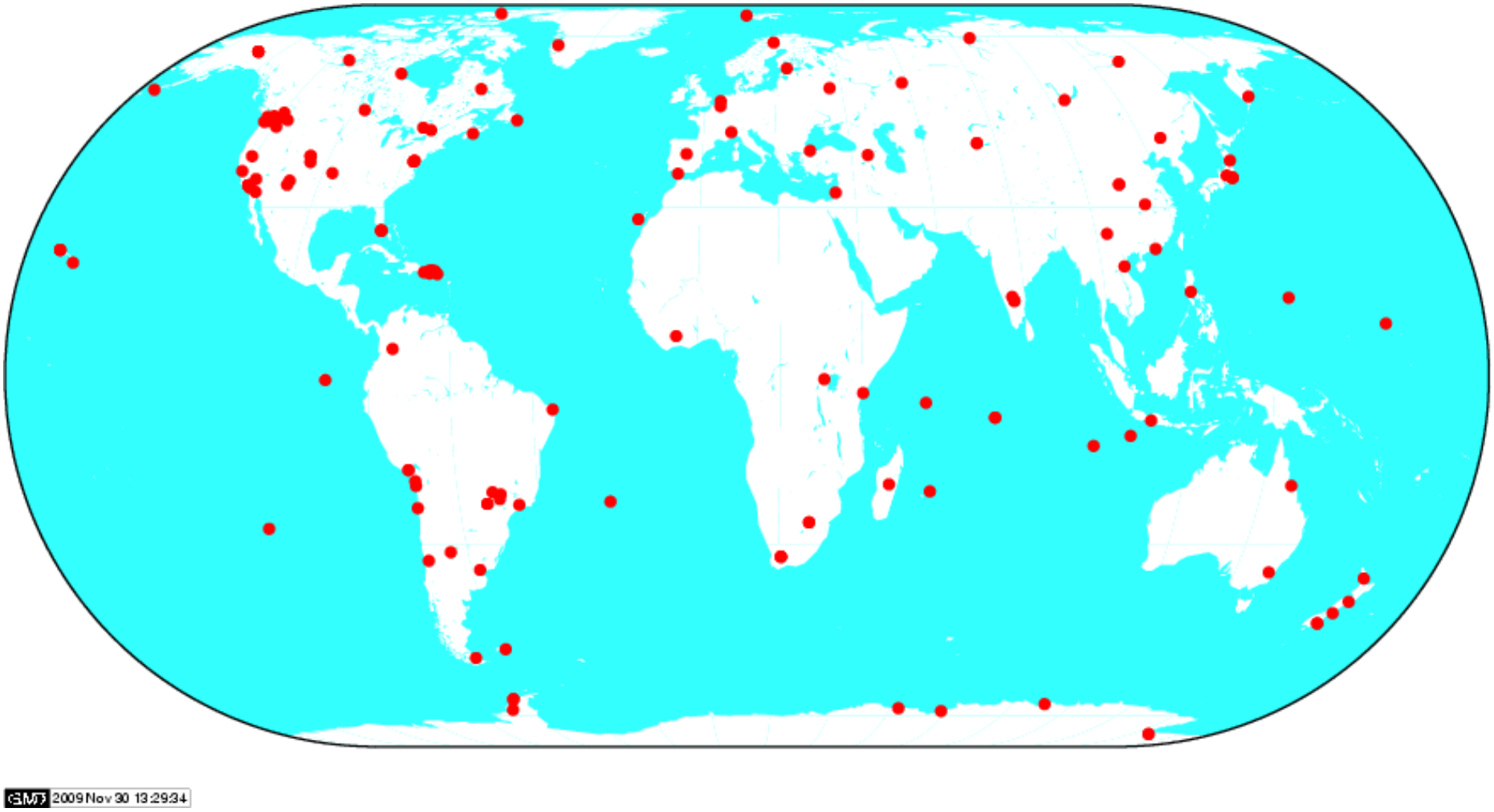
- Global Network of Stations
  - Raw GNSS data required for OCDS to calculate orbit and clock corrections to the satellites
  - Upgrade network to track GLONASS
- Orbit and Clock Determination System (OCDS)
  - Processing to calculate orbit and clock corrections
- Formatting and Scheduling of Augmentation Data
  - More data means addition messages
- Data Delivery to User
  - Same techniques but more data being transmitted
  - RTCM NTRIP delivery via Internet
- User/Mobile
  - Upgrade algorithms to handle GLONASS





- **APEX Tracking Network**
- **GPS + GLONASS**

JPL Reference Station Network

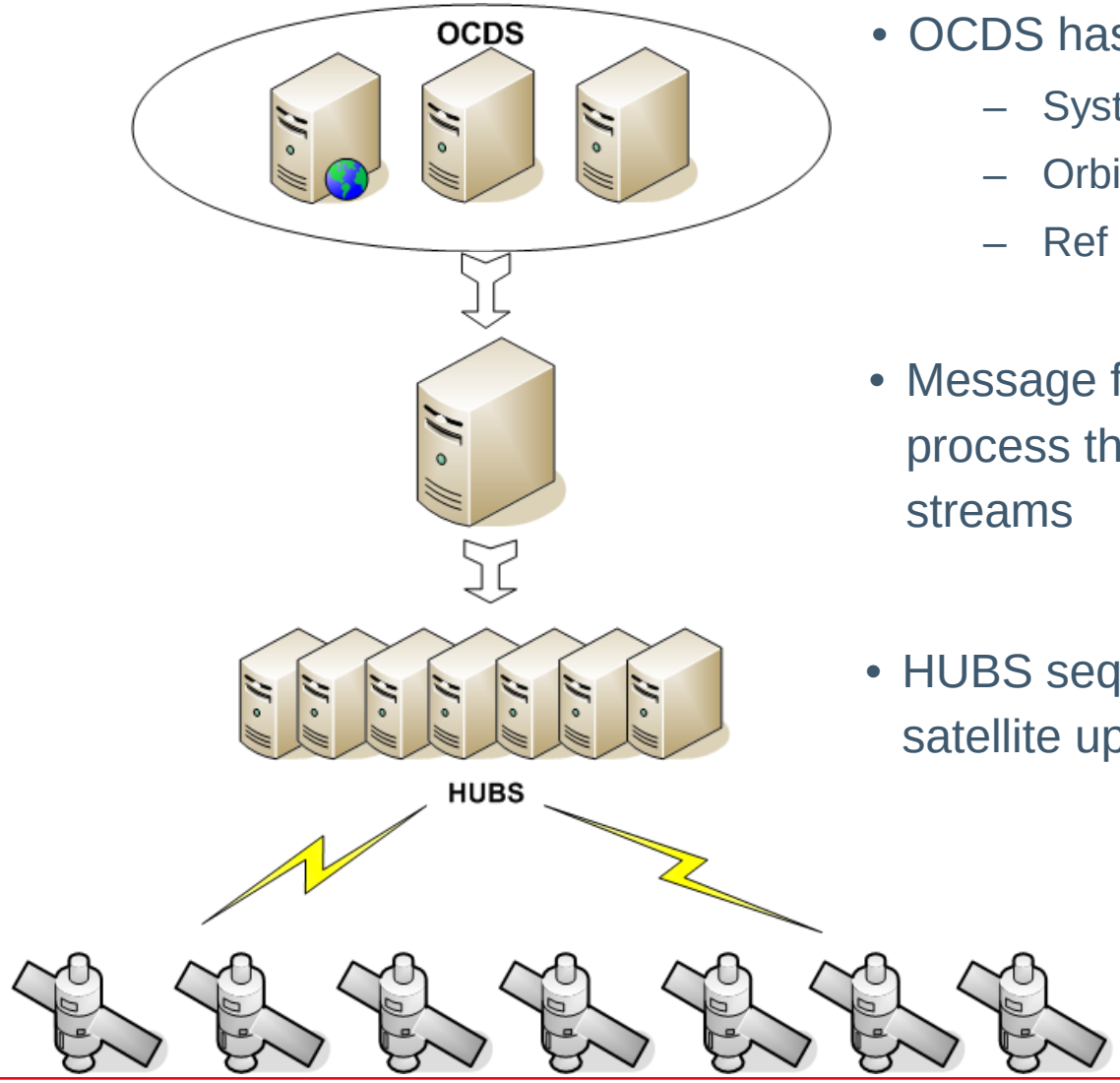


From JPL website (http://www.gdgps.net/system-desc/images/world.png)

Orbit and Clock Determination

- This is the core requirement for providing a PPP solution
- System takes in the raw GNSS measurement data from all VERIPOS reference stations
  - From primary and secondary receivers at the site
- Data is managed & fed into process which calculates orbit and clock corrections
  - Additional data needed includes satellite info (health etc.) and station info (coordinates, ocean loading etc.)
- Data input and output is monitored to check performance and ensure that enough redundancy is in the system
- Why develop your own OCDS??
  - Independence and flexibility (e.g. addition of other satellite systems)
  - Ability to control development - improvements to orbit and clock determination to derive higher accuracy orbits and clocks
  - Derive additional monitoring capability particularly of the GNSS networks

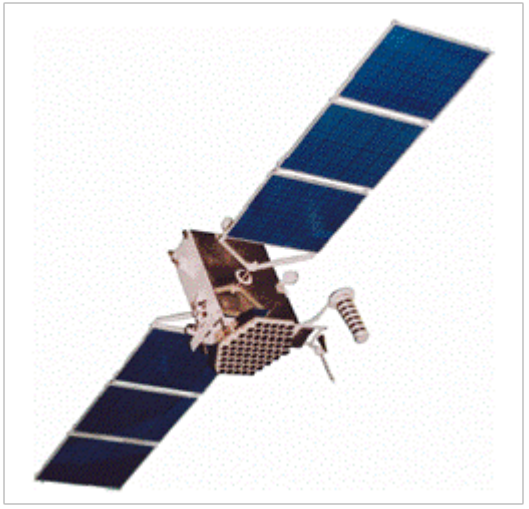
OCDS System Architecture



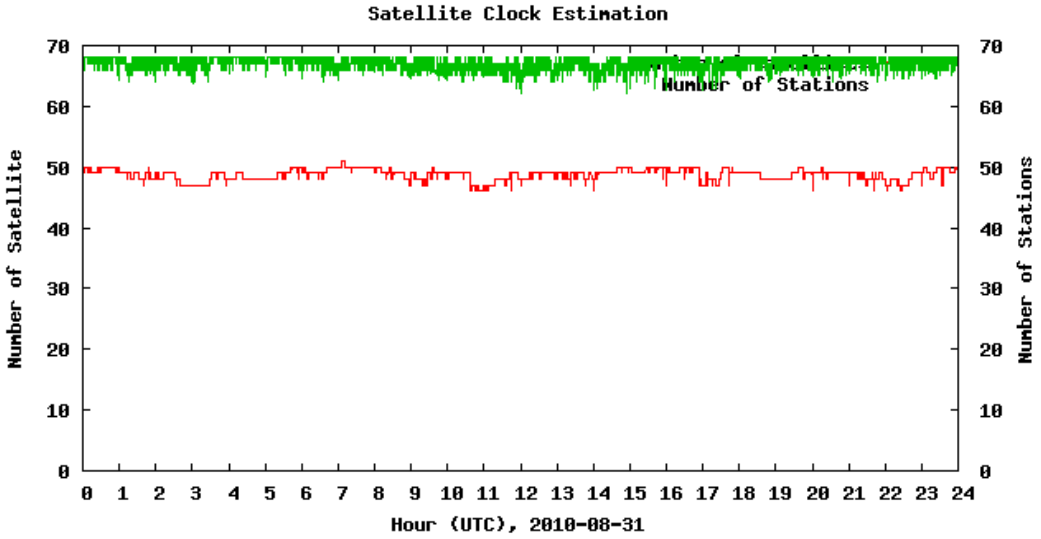
- OCDS has 3 components
  - System Control & Monitoring
  - Orbit and Clock generation
  - Ref station raw data management
- Message formatter required to process the multiple formats and streams
- HUBS sequence the data and send to satellite uplink sites

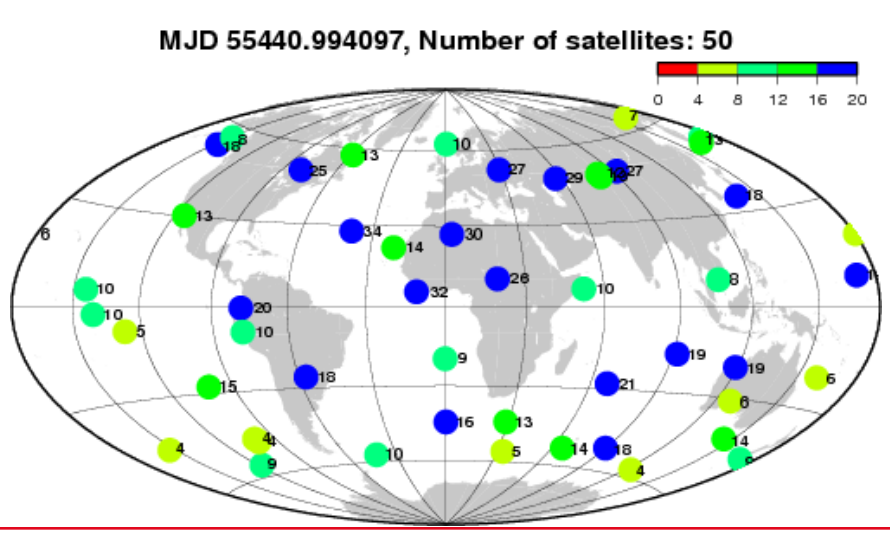
Issues with GLONASS

- Navigation messages
  - Satellites missing and/or excluded
  - Bad/wrong messages
  - Channel changes without prior warning!
- Time systems
  - GLONASS and GPS used different time systems
- Data cleaning issues
  - More problematic for GLONASS than GPS
- GLONASS orbit model
  - Important for the orbits predictions
  - Area for improvement
- GLONASS phase centre variations
  - Area for improvement

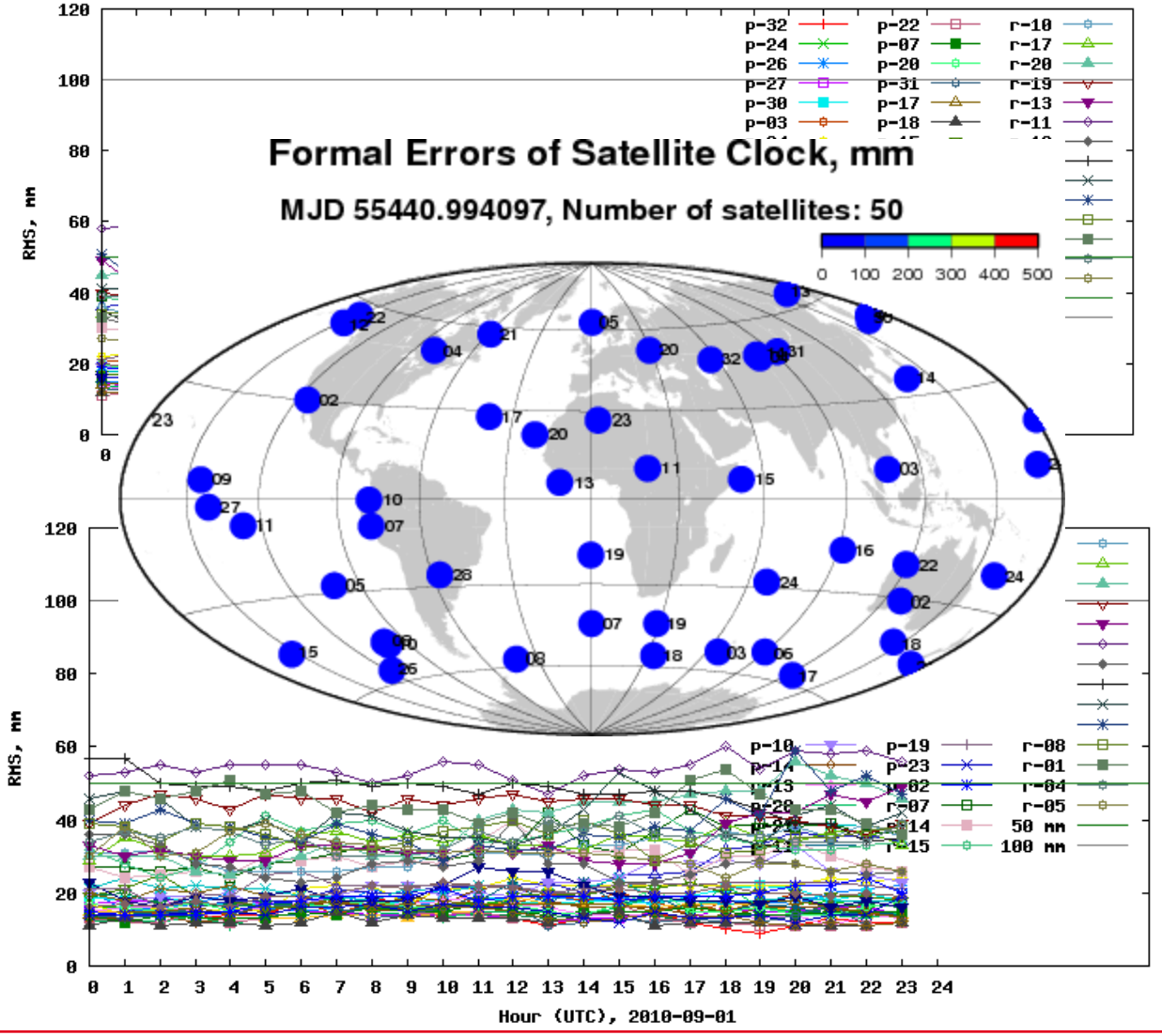


System Monitoring Plots

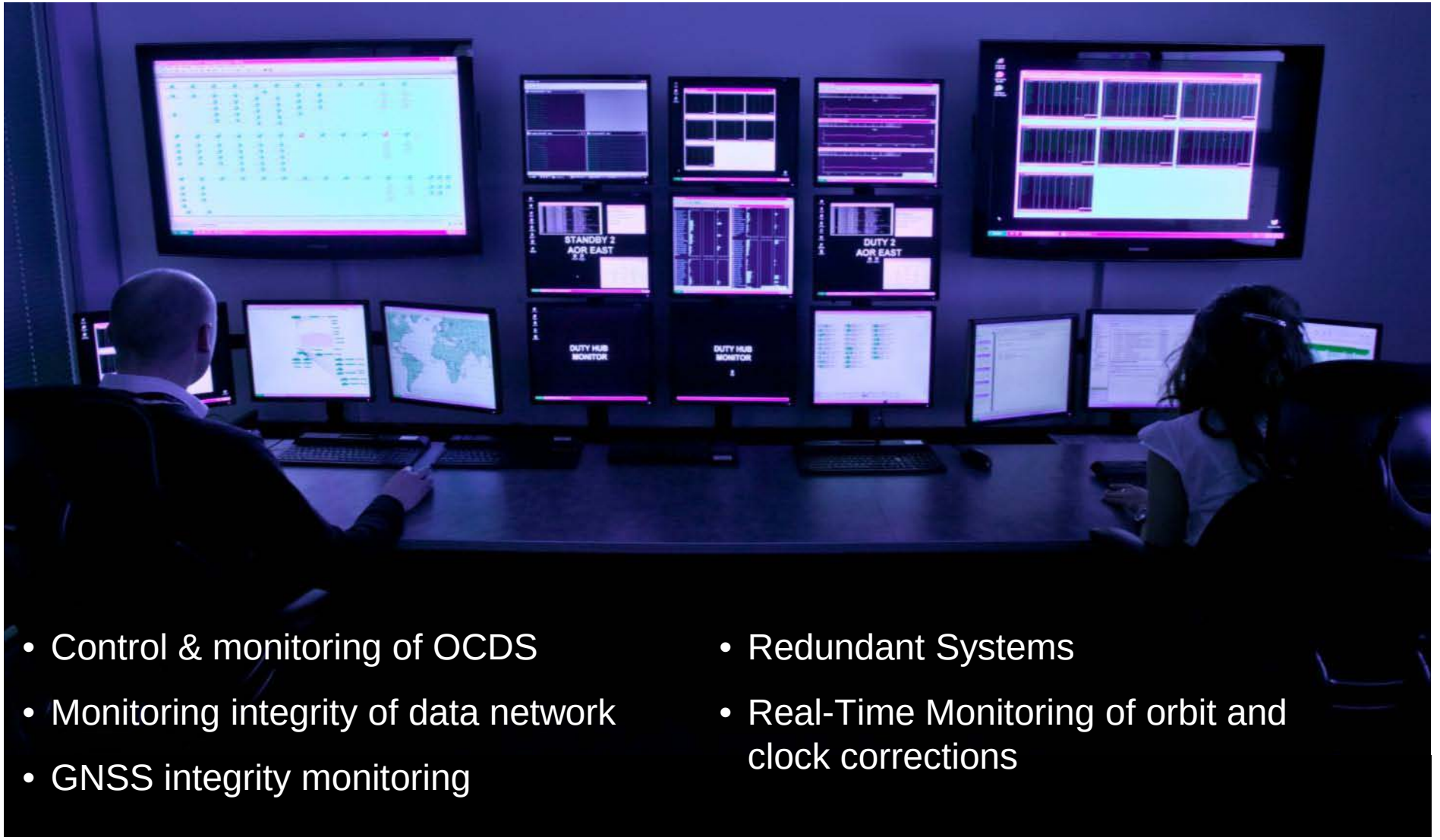




Orbit and Clock Accuracy

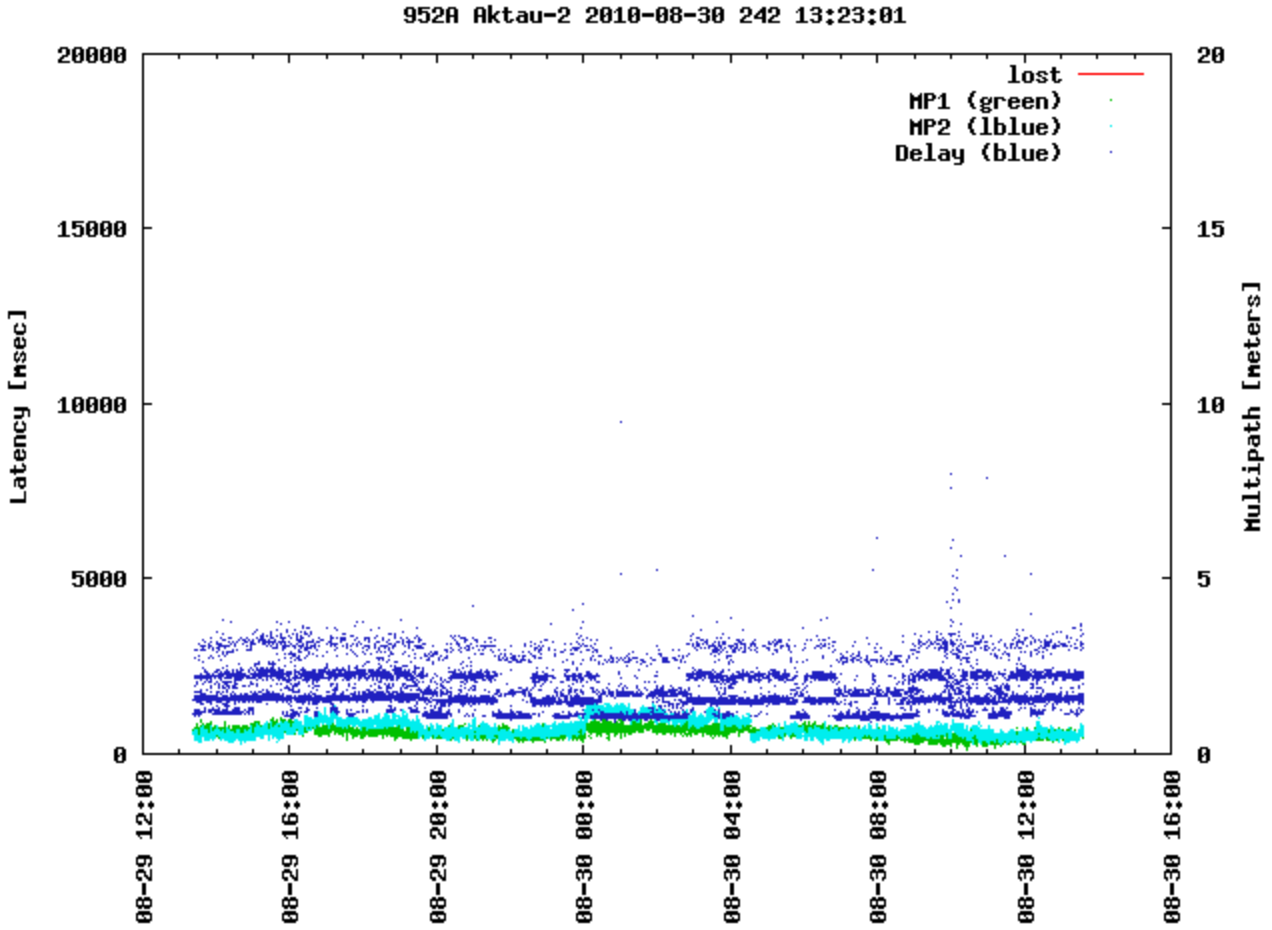


Network Control Centre



- Control & monitoring of OCDS
- Monitoring integrity of data network
- GNSS integrity monitoring
- Redundant Systems
- Real-Time Monitoring of orbit and clock corrections

Additional Benefits



Delivery of Data to Users

- Typical delivery is via redundant geostationary satellites
  - Provide global coverage
- How do you deliver the data
  - Orbit corrections change slowly over time compared to satellite clocks
- To increase accuracy and minimise impact on bandwidth
  - Transmit orbits and clocks separately
  - Clocks transmitted at a higher rate than orbits
  - Also aids convergence of position solution

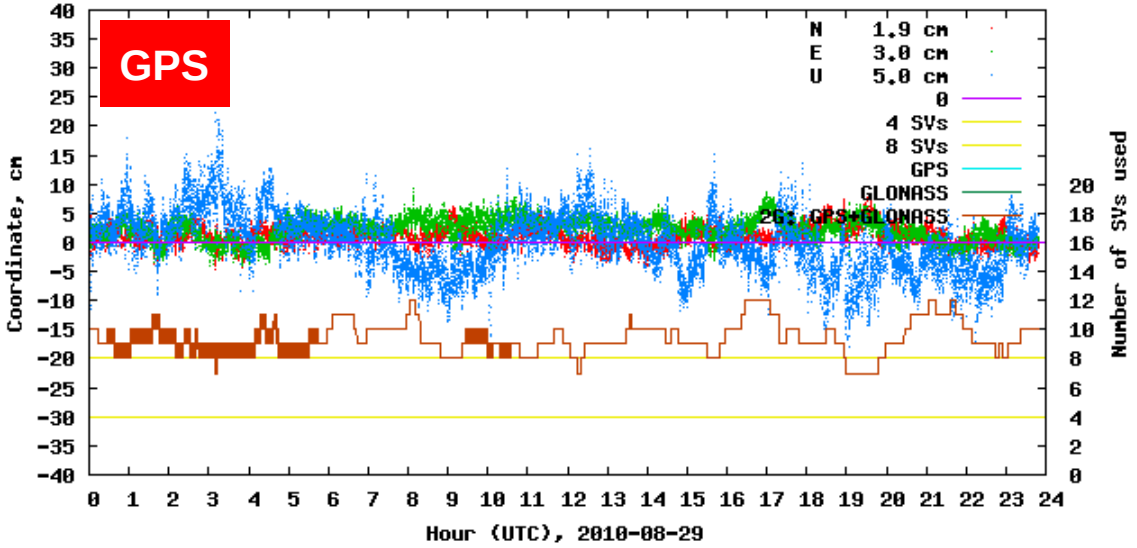
NTRIP Delivery of Data to Users

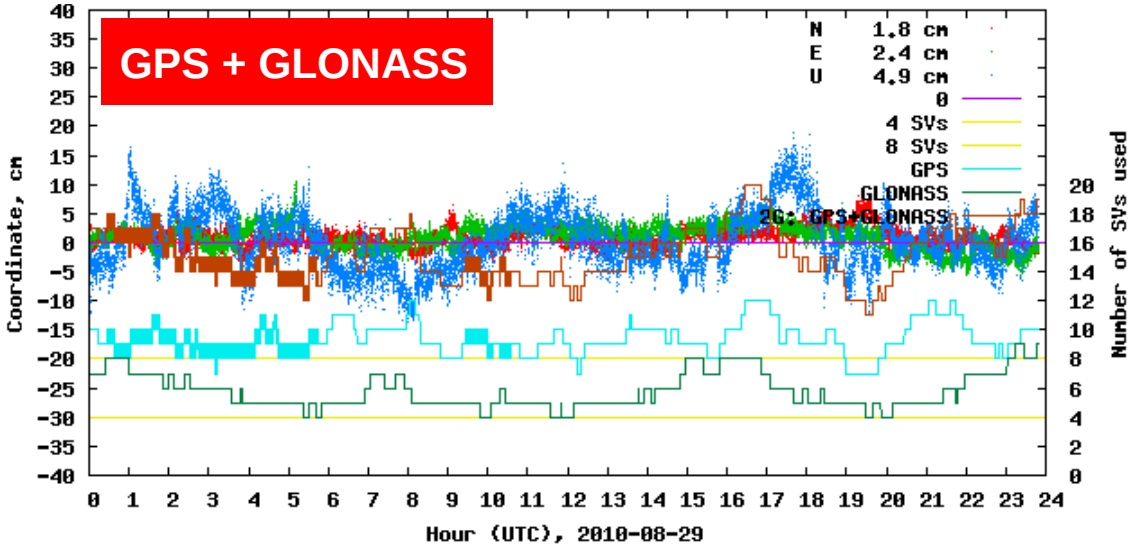
- More clients requesting delivery of corrections via the internet
  - Particularly new builds where no Inmarsat terminals installed
- NTRIP - Network Transport of RTCM via Internet Protocol
  - RTCM Standard
- RTCM data supplied by this service is identical to that broadcast via geostationary satellites
- Supports mass usage as hundreds of data streams can be transmitted to thousand's users
- Main issue is control of delivery as service providers have no control of data once it leaves their network
  - Delivery to vessel depends on vessel's internet delivery system (e.g. KU band)
  - Implementation of monitoring software to confirm that the data has left network

User/Mobile

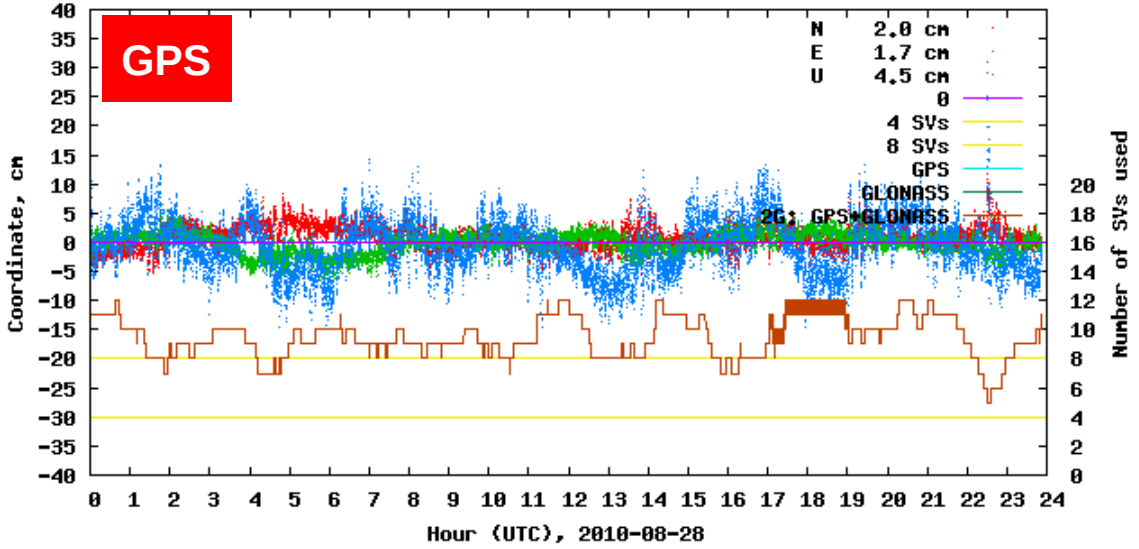
- Algorithms need to handle both GPS & GLONASS
- Ensure models to correct GNSS errors are the same as those used in the OCDS
- Existing industry standards and guidelines need to be updated to reflect multiple constellations
  - RTCM standard and UKOOA guidelines being updated
- No specific provisions for multi-constellation and high accuracy GNSS systems
  - Independence
  - Quality
  - Consistency

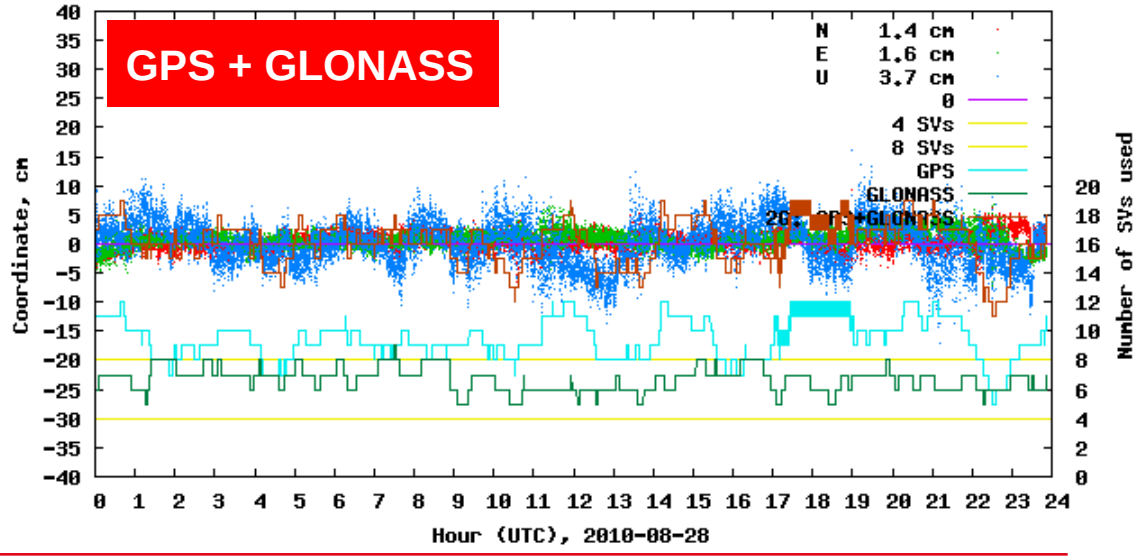
Positioning Performance @ Catu, Brazil





Positioning Performance @ Kristiansund, Norway





Benefits to DP Operators

- Why use multiple Global Navigation Satellite Systems?
  - More satellites providing better availability
  - Remove single points of failure
  - Improved error detection & rejection
  - More signals at different frequencies aids resilience to potential interference
  - Better accuracy when new or modernised signals become available
  - Potential to use each system independently or in a combined solution

- Implications of additional GNSS
  - Increased complexity of different modes of GNSS system operation
  - How to achieve visibility on performance and independence of different GNSS systems?
  - New data interfaces into DP systems

Improved Integration into DP Systems

- Additional information would benefit DP systems
  - Solution independence – *GNSS solution type information*
  - GNSS satellite counter - *number of satellites for each GNSS constellation*
  - Ability to weight independent solutions appropriately – *quality information*
- Such information requires a new data interface with DP systems
  - Upgrade of existing standards?
  - Or, proprietary interfaces?
- Opportunity to visualise additional information in DP systems
  - Calculation type (GPS-only, GLONASS-only, GPS+GLONASS etc)
  - Number of GPS / GLONASS / GALILEO satellites
  - GNSS PosRef quality