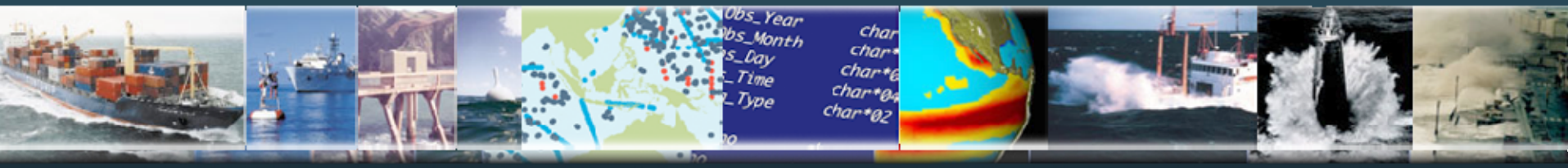
Wave measurements using GPS

David Meldrum
Chair, Data Buoy Co-operation Panel
(dtm@sams.ac.uk)

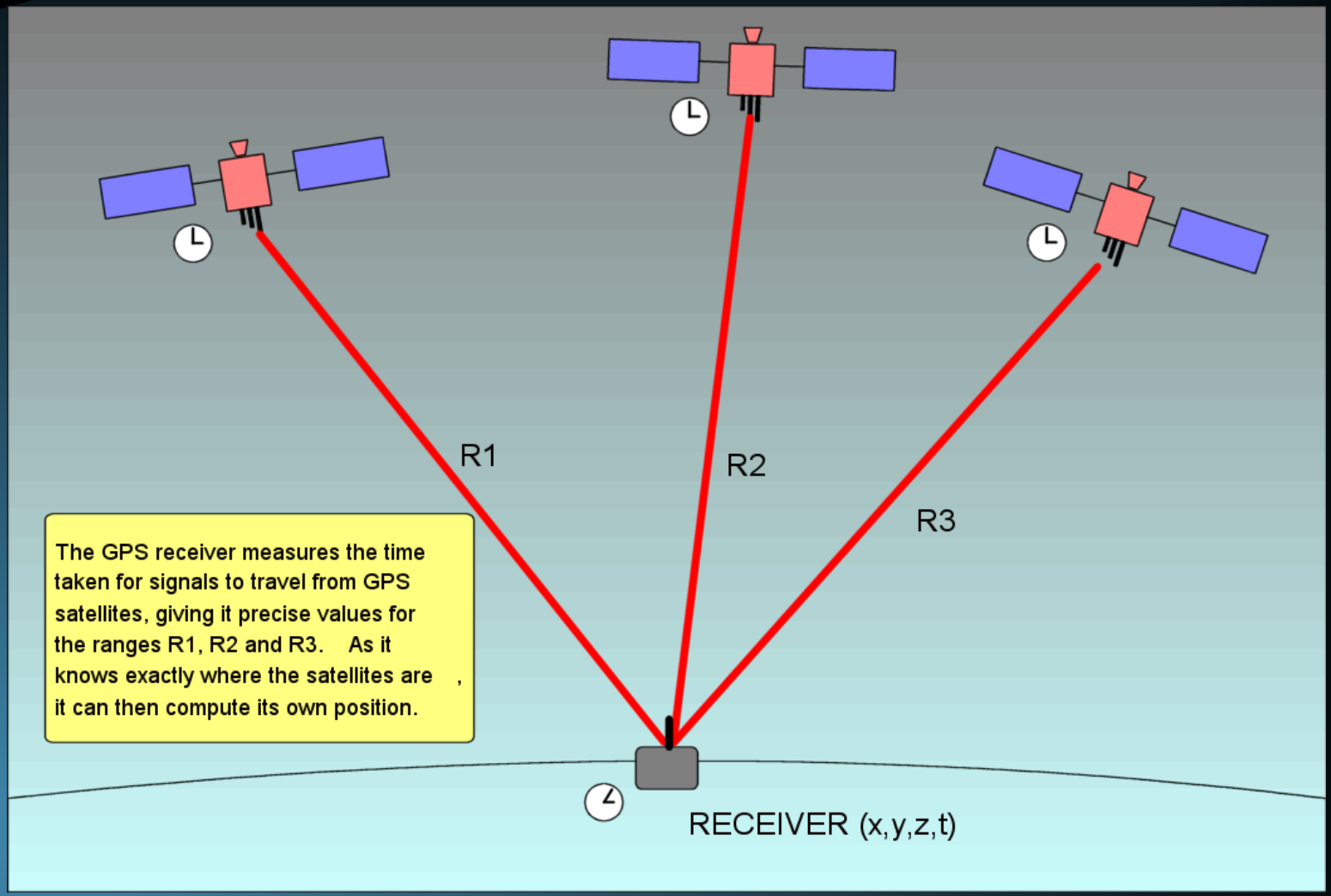


WMO

IOC/UNESCO

- GPS basics
- Error budgets
- Application to wave measurements
- Next steps

GPS basics


R1
R2
R3
The GPS receiver measures the time taken for signals to travel from GPS satellites, giving it precise values for the ranges R1, R2 and R3. As it knows exactly where the satellites are , it can then compute its own position.
RECEIVER (x,y,z,t)

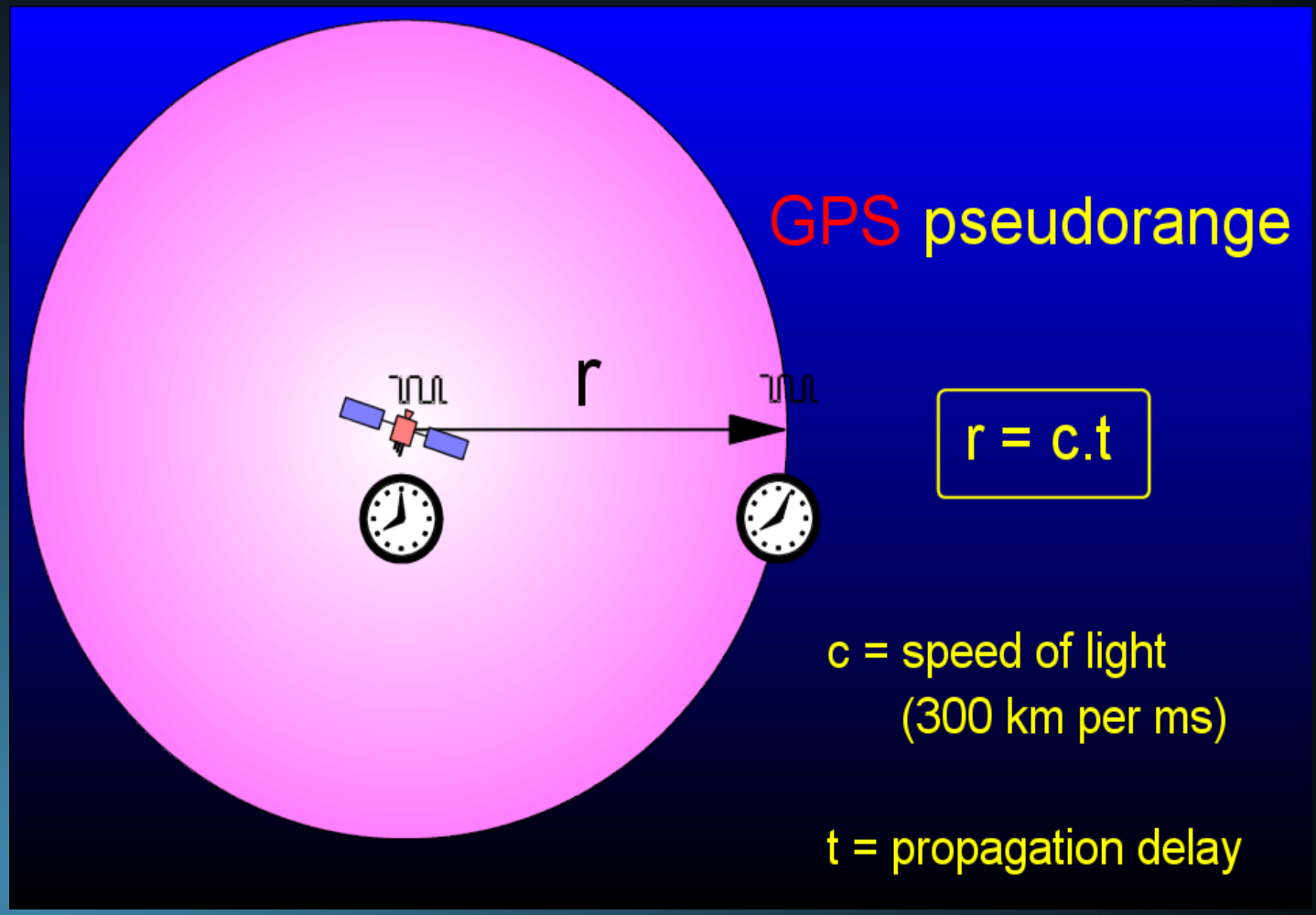
GPS basics

- Up to 32 satellites in high orbit (12 h period)
- Almost identical Russian system (GLONASS)
- New European system (GALILEO)
- Navigation by trilateration
  - Range to satellite measured by propagation delay
  - Receiver knows position of satellites

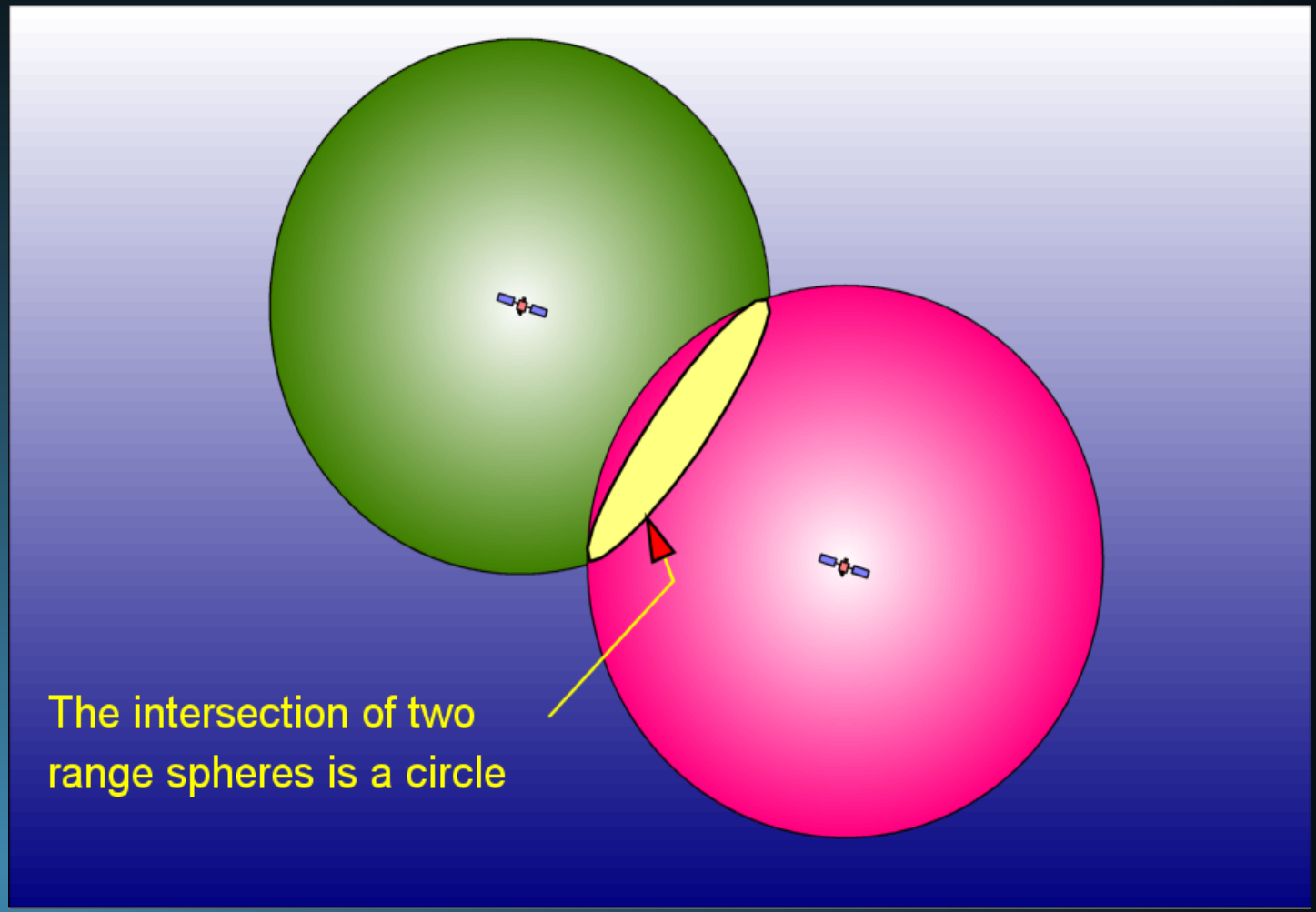
GPS basics

- Time ‘product’ as useful as navigation product
- Errors may be reduced using broadcast corrections (DGPS, SBAS)
- Unforeseen use as precise survey tool
  - Use of carrier phase as reference frame

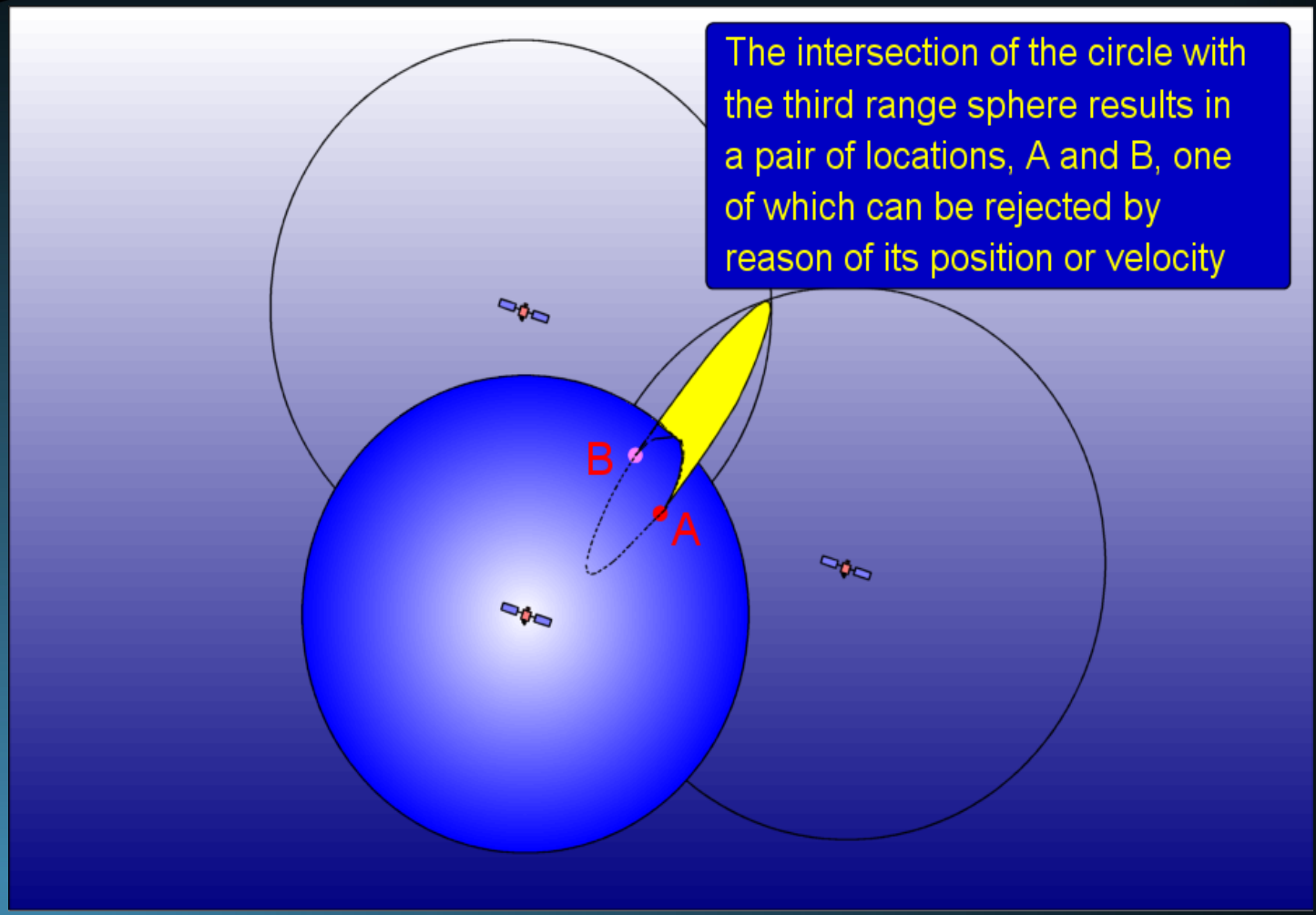
GPS basics


GPS pseudorange
r
r = c.t
c = speed of light
(300 km per ms)
t = propagation delay

GPS basics

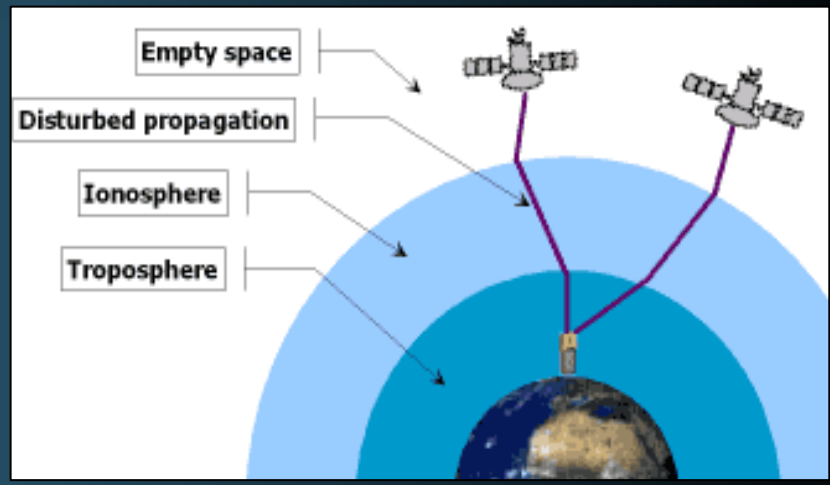


GPS basics


The intersection of the circle with the third range sphere results in a pair of locations, A and B, one of which can be rejected by reason of its position or velocity
B
A

GPS basics – error terms

Sources of User Equivalent Range Errors (UERE)	
Source	**Effect**
Ionospheric effects	± 5 m
Ephemeris errors	± 2.5 m
Satellite clock errors	± 2 m
Multipath distortion	± 1 m
Tropospheric effects	± 0.5 m
Numerical errors	± 1 m

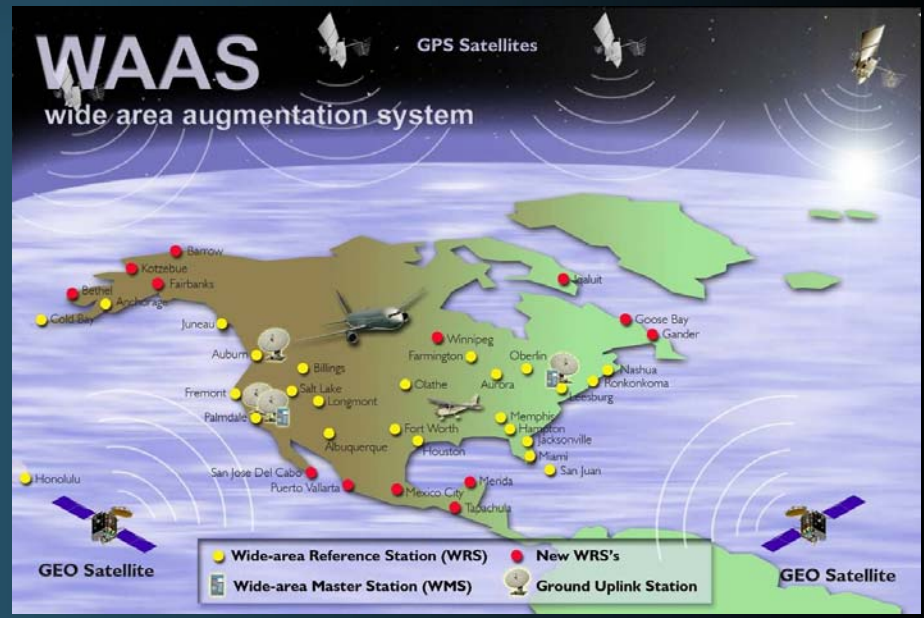


GPS basics - DGPS

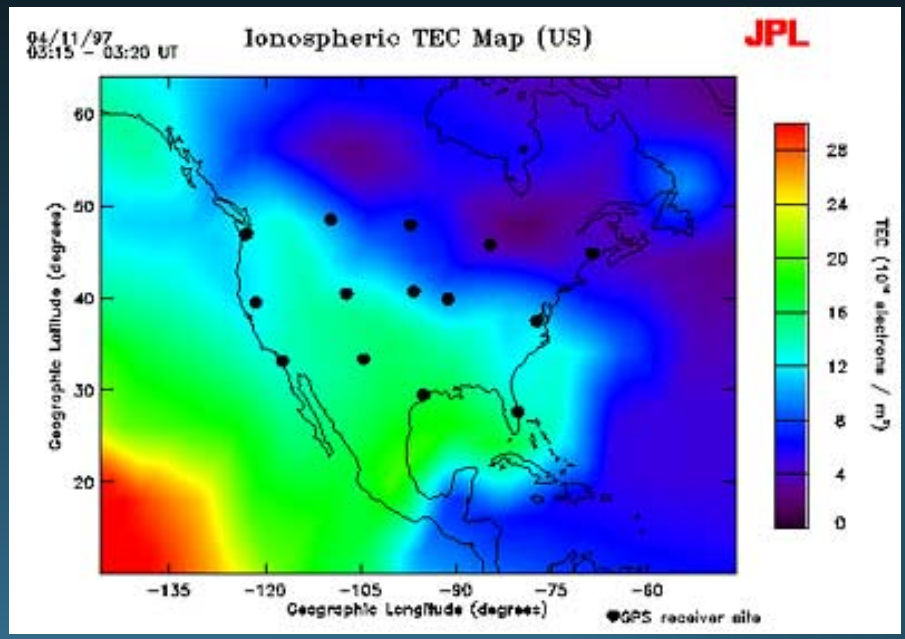
- Need base stations in known locations
- Base station estimates range errors for each satellite received
- Broadcasts these errors as corrections for use by mobile
- Accuracies decrease with distance from base station
  - A metre or so at best

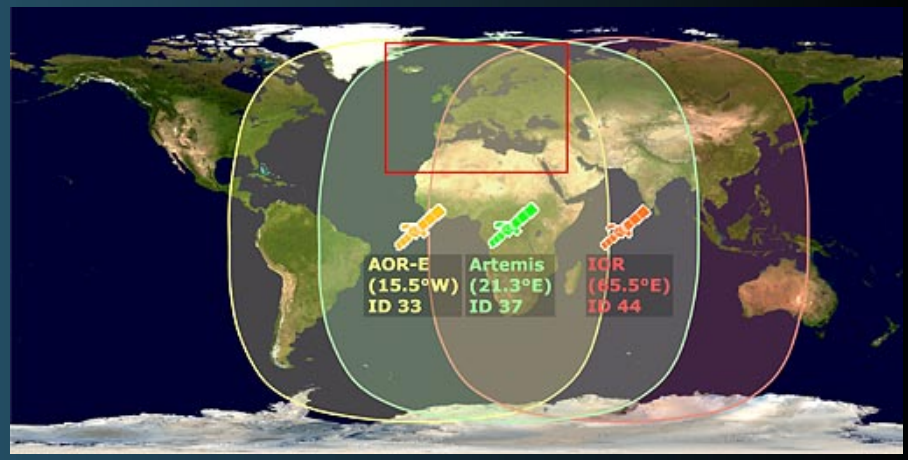
GPS basics - SBAS

- Satellite Based Augmentation System
  - WAAS, EGNOS, MSAS
- Network of base stations computes correction MAP
  - Total Electron Content (TEC) map
  - Broadcast by geostationary satellites on GPS frequency
  - Regional coverage
  - Height error ~1.3m



GPS basics - SBAS





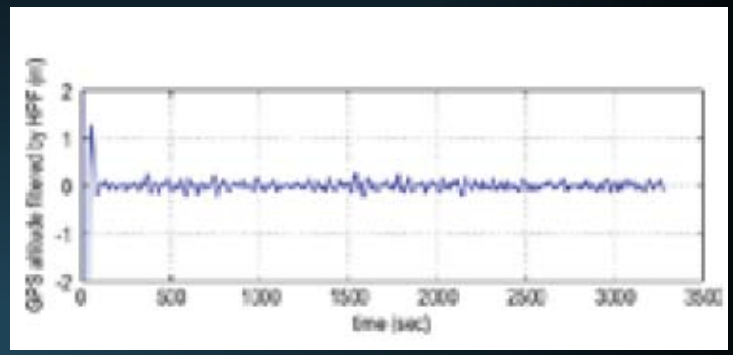
GPS basics - errors

Sources of User Equivalent Range Errors (UERE)		
Source	**Effect**	**Time constant**
Ionospheric effects	± 5 m	10 min
Ephemeris errors	± 2.5 m	1 hour
Satellite clock errors	± 2 m	5 min
Multipath distortion	± 1 m	100 sec
Tropospheric effects	± 0.5 m	10 min
Numerical errors	± 1 m	White noise

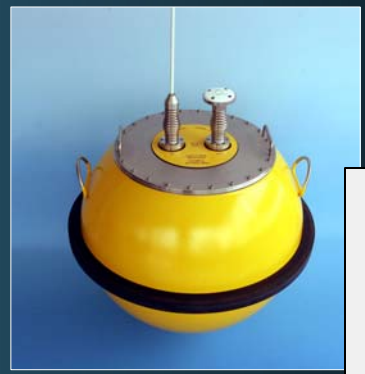
Power spectrum of most errors lies well below ocean wave power spectrum

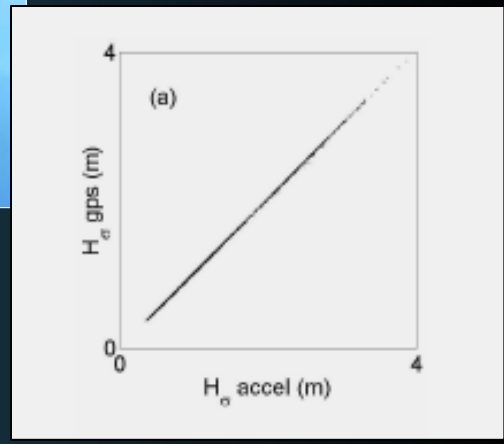
Practical systems

- JMA/JAXA protoype wave buoy
  - GPS World, May 2005
  - HP filter to separate out wave signal
  - Claimed accuracy of a few cm
  - US Patent 6847326



- Datawell wave buoy DWR-G
  - Sea Technology, Dec 2003
  - Probably similar technique





Future directions?

- Carrier phase techniques
  - Low-cost CP-capable receivers are available
  - Can use transmissions other than GPS
- DBCP Pilot project for low-cost technologies
  - Submit proposal to DBC24 10 days from now
  - Can we recover useful wave data from the 30-40cm dia buoys that make up our 1200+ drifter fleet?