

The Use of GPS for Earth Science

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With the completion of the Global Positioning System and the appearance of affordable ground and spaceborne receivers, GPS is moving rapidly into the world of Earth science. Basic positioning receivers are coming to be seen as indispensable to navigation on Earth, in the air, and in space. More surprising has been the emergence of direct Earth science uses and particularly the growth of science applications for GPS receivers in space. Science applications of spaceborne GPS include centimeter-level precise orbit determination to support ocean altimetry; Earth gravity model improvement and other enhancements to GPS global geodesy; high resolution 2D and 3D ionospheric imaging; atmospheric limb sounding (radio occultation) to recover precise profiles of atmospheric density, pressure, temperature, and water vapor distribution; and the detection of GPS ocean reflections for direct GPS altimetry and scatterometry. Figure 1 offers a simplified summary of the Earth science now emerging from spaceborne GPS.

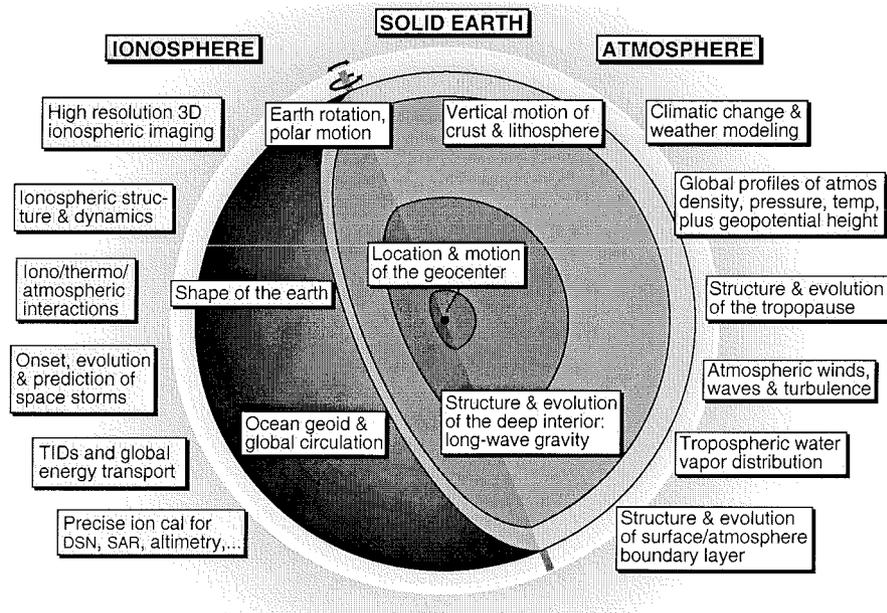
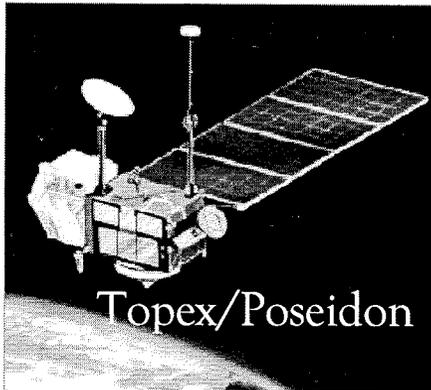
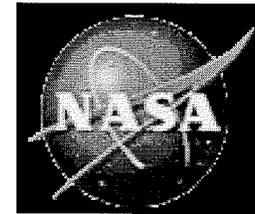
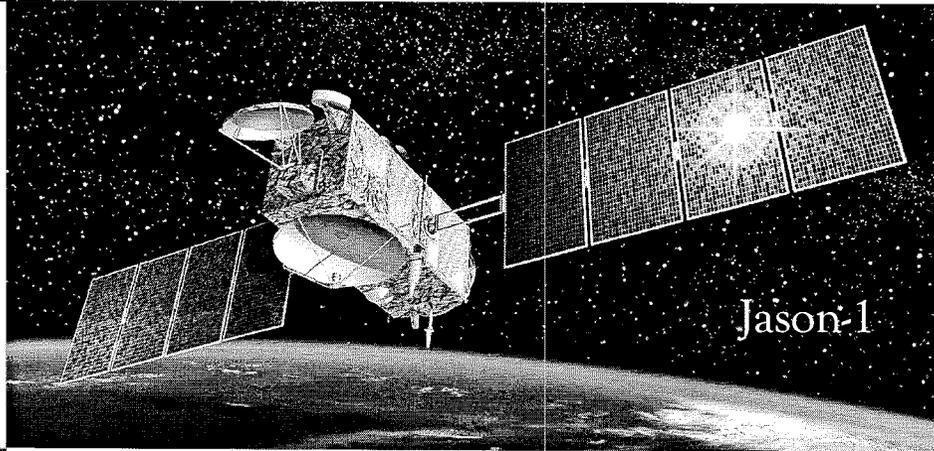
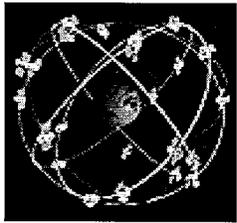
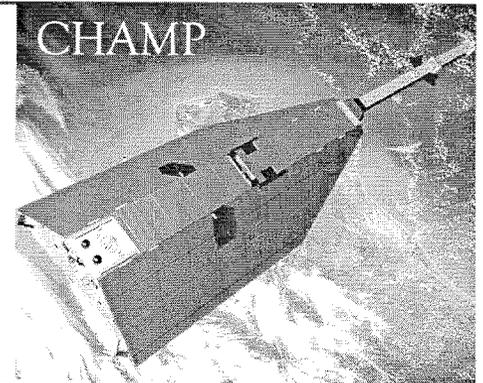


Fig. 1. Some key science applications for a spaceborne array of GPS receivers.

Recently, atmospheric applications have generated considerable excitement. A constellation of six orbiting occultation receivers can measure atmospheric refractivity with a precision equivalent to 0.1 K in temperature within a climate region corresponding to 1/30 the earth's surface, with just a few weeks of data. Vertical resolution can be better than 1 km. This offers perhaps the most promising approach yet to detecting and discriminating among subtle forced climatic signals, which may amount to only a few tenths of a Kelvin average temperature change per decade. This presentation will survey the Earth science applications of spaceborne GPS and describe promising developments for the future.



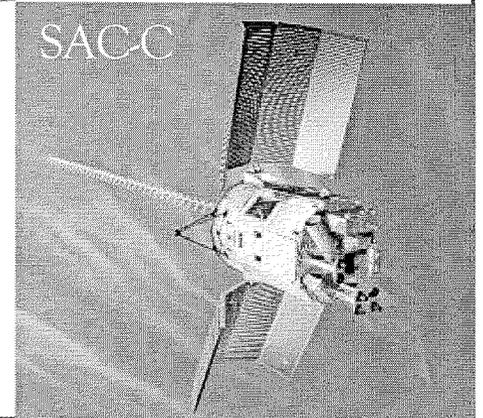
The Use of GPS for Earth Science

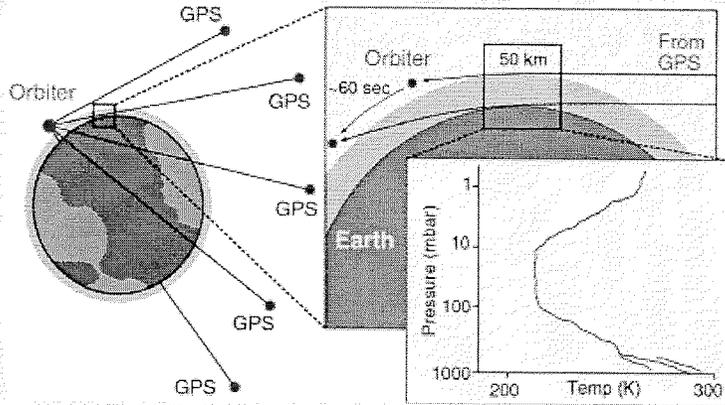


T. P. Yunck

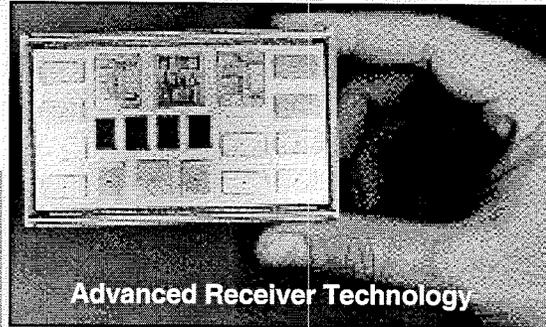
JPL

4 April 2002

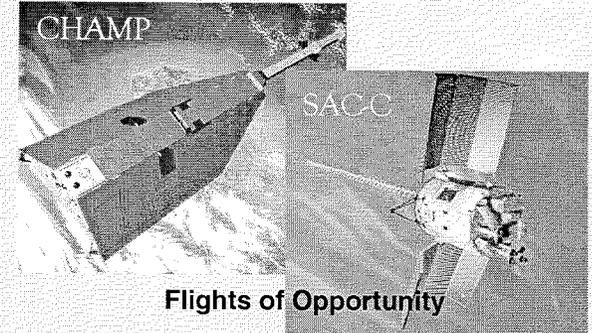




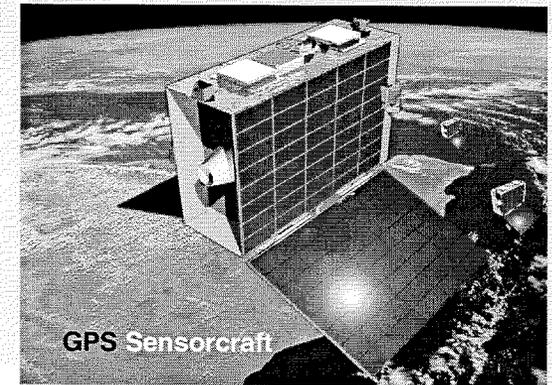
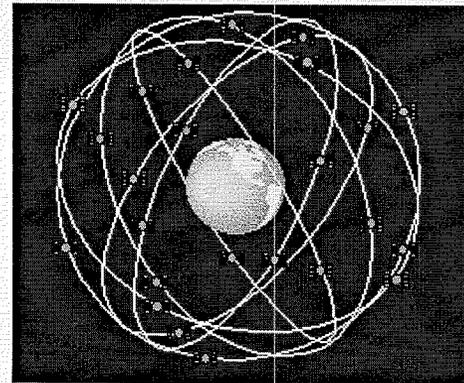
GPS Occultation for atmospheric and ionospheric sounding



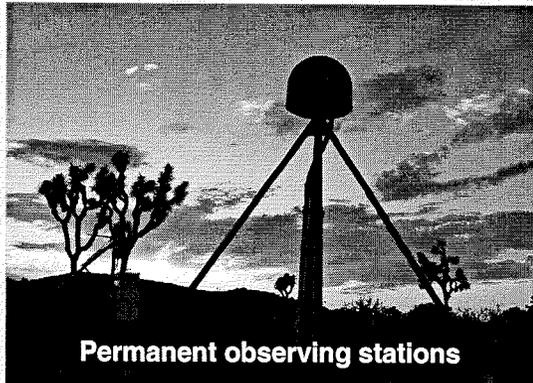
Advanced Receiver Technology



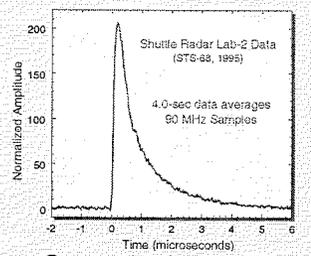
Flights of Opportunity



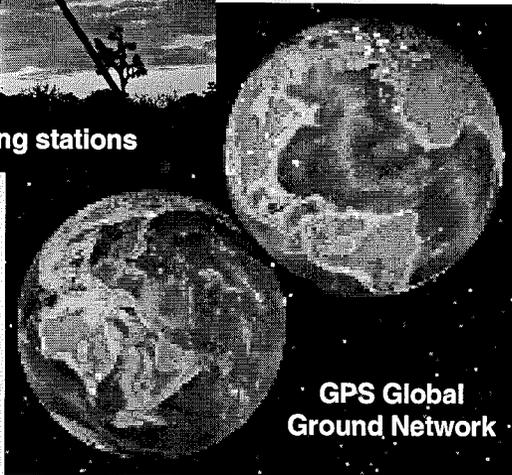
GPS Sensorcraft



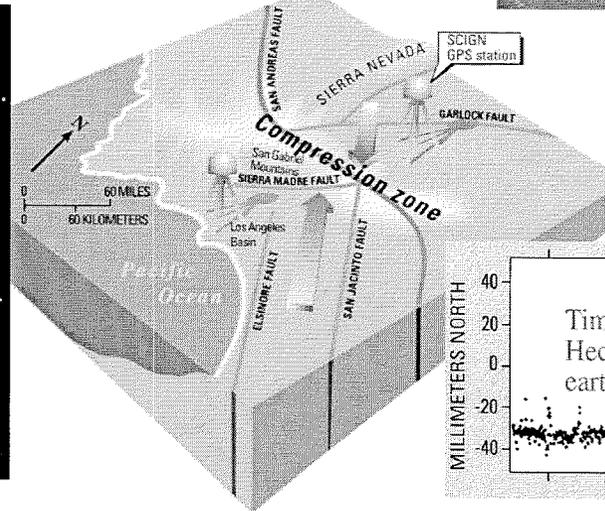
Permanent observing stations



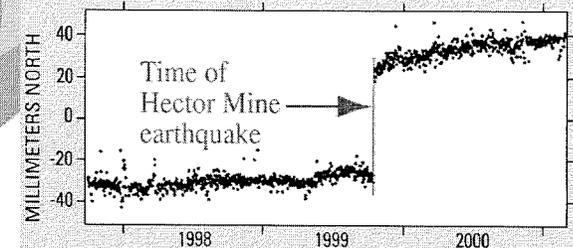
Ocean Reflections



GPS Global Ground Network

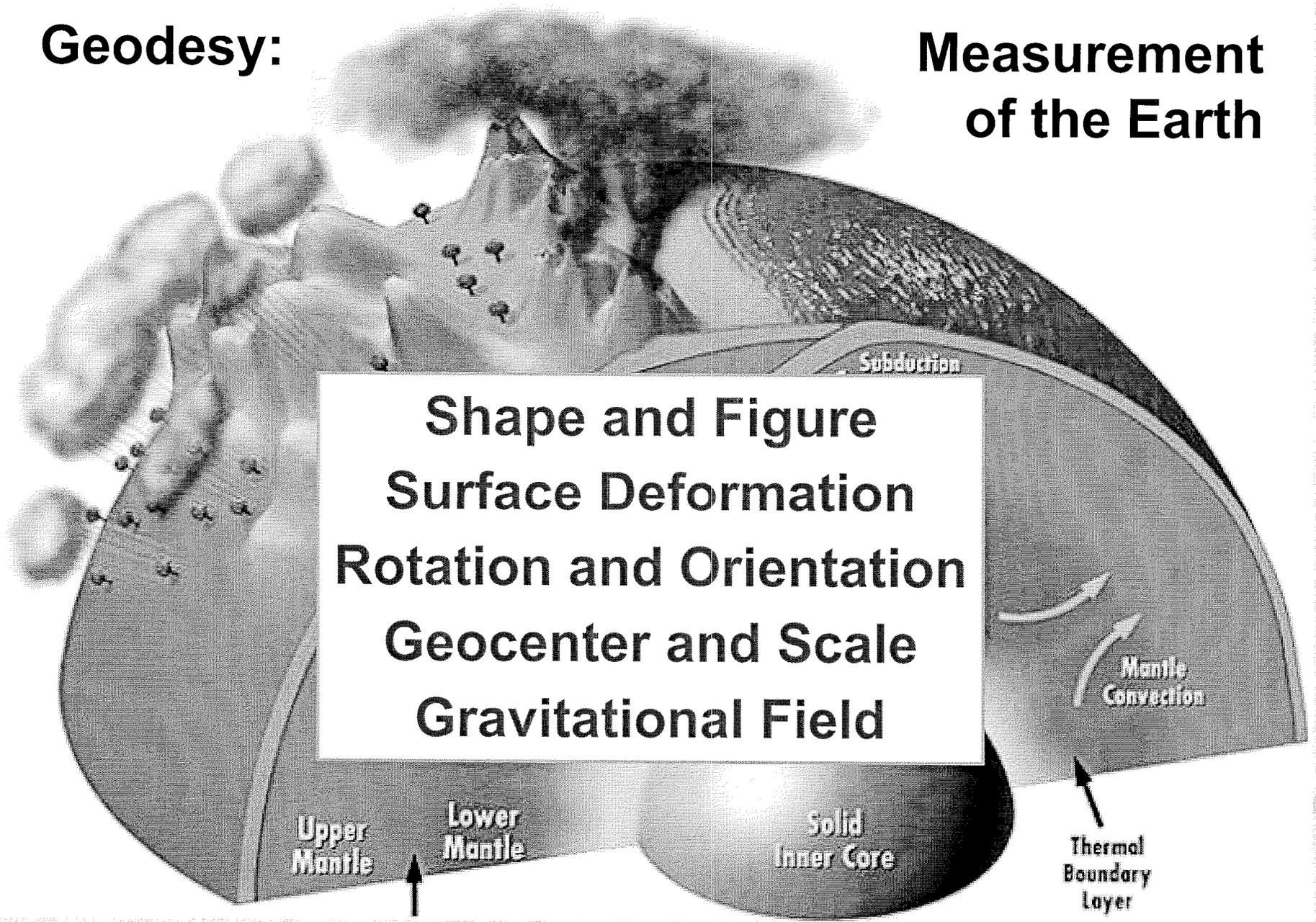


SCIGN
SOUTHERN CALIFORNIA
INTEGRATED GPS NETWORK

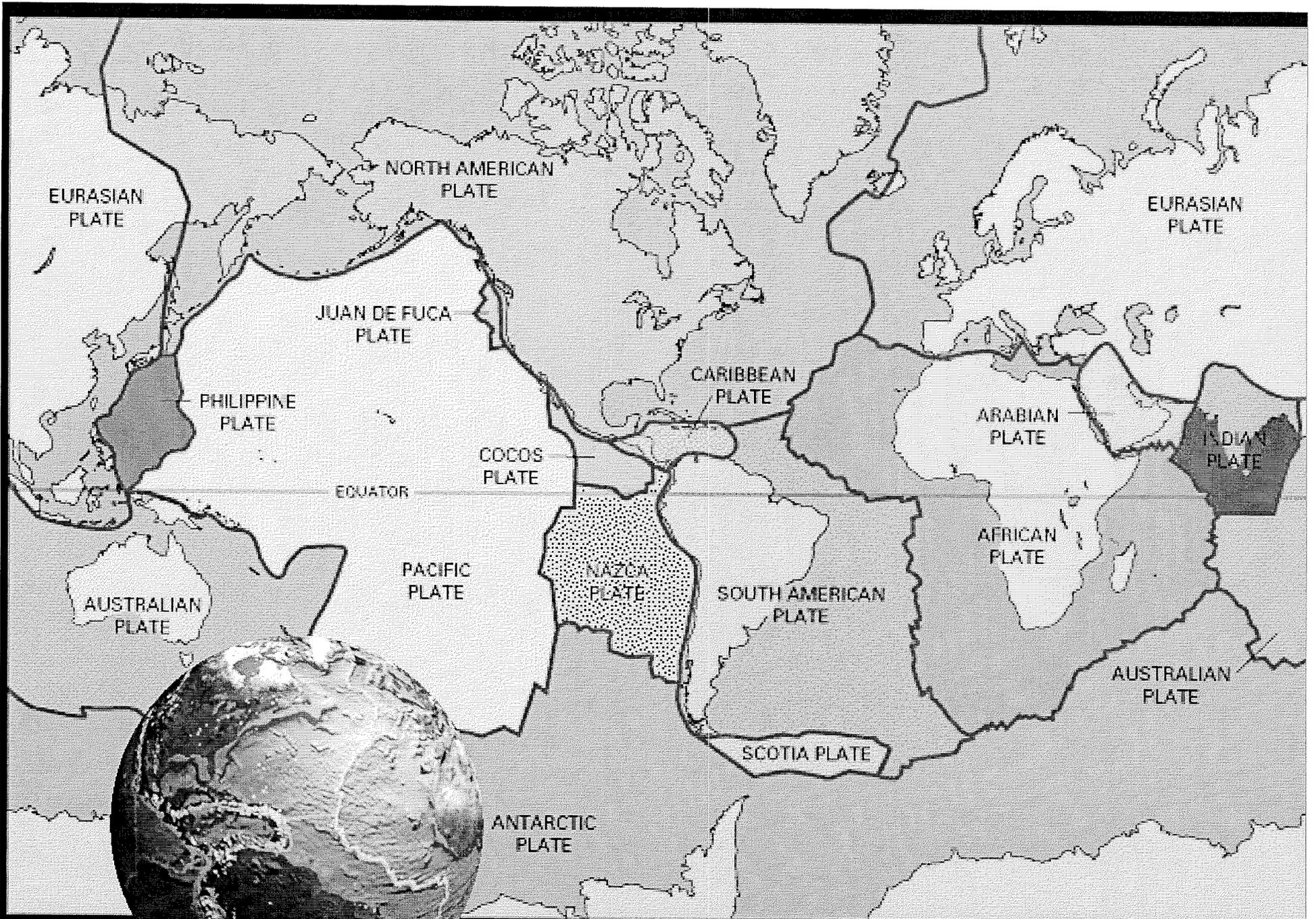


Geodesy:

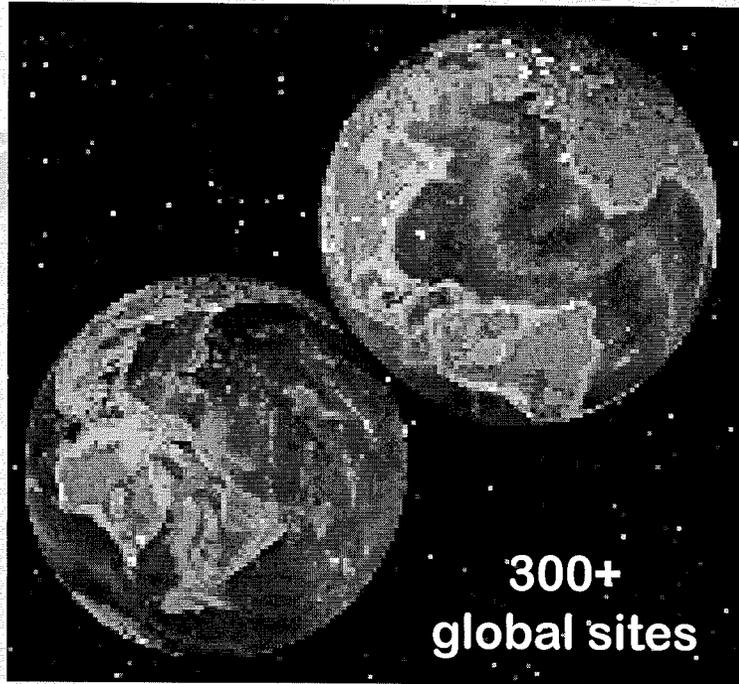
Measurement of the Earth



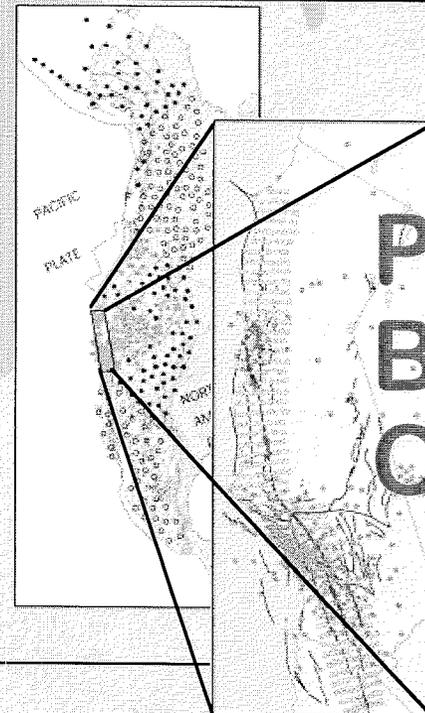
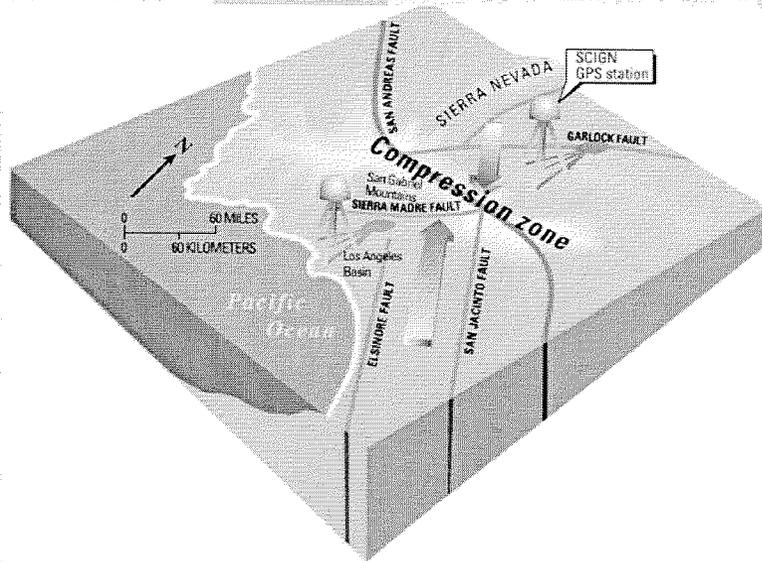
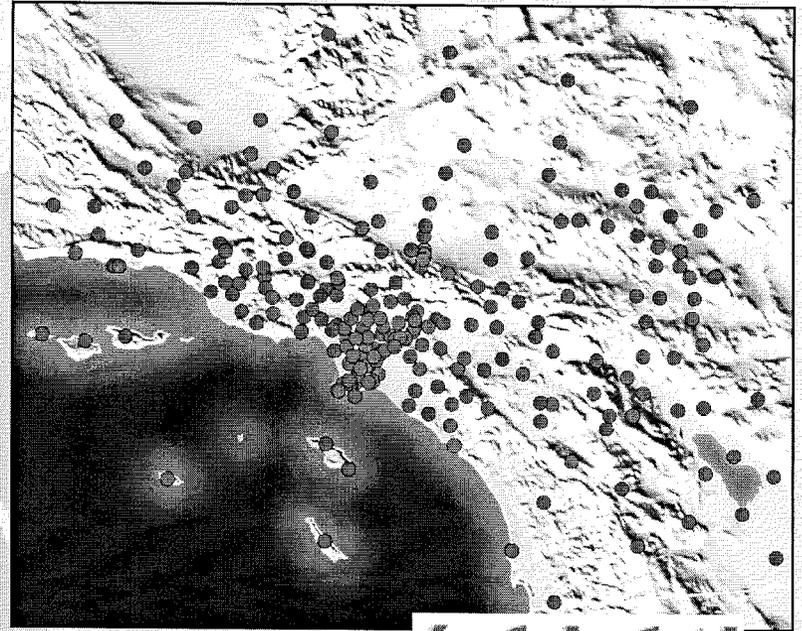
**Shape and Figure
Surface Deformation
Rotation and Orientation
Geocenter and Scale
Gravitational Field**



The Tectonic Plates



2002

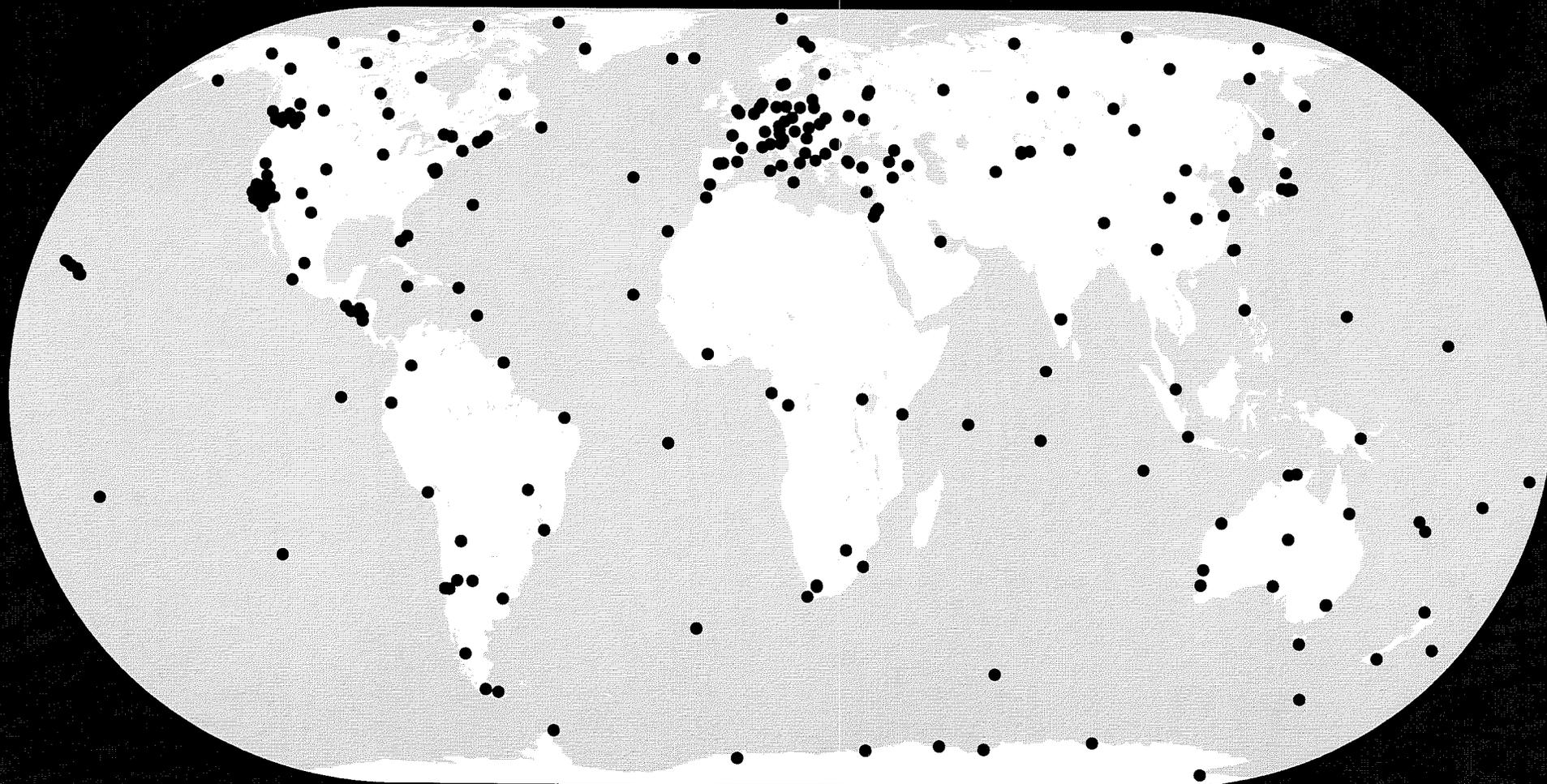


SCIGN
SOUTHERN CALIFORNIA
INTEGRATED GPS NETWORK

Plate
Boundary
Observatory

The IGS Global Network

of more than 200 sites

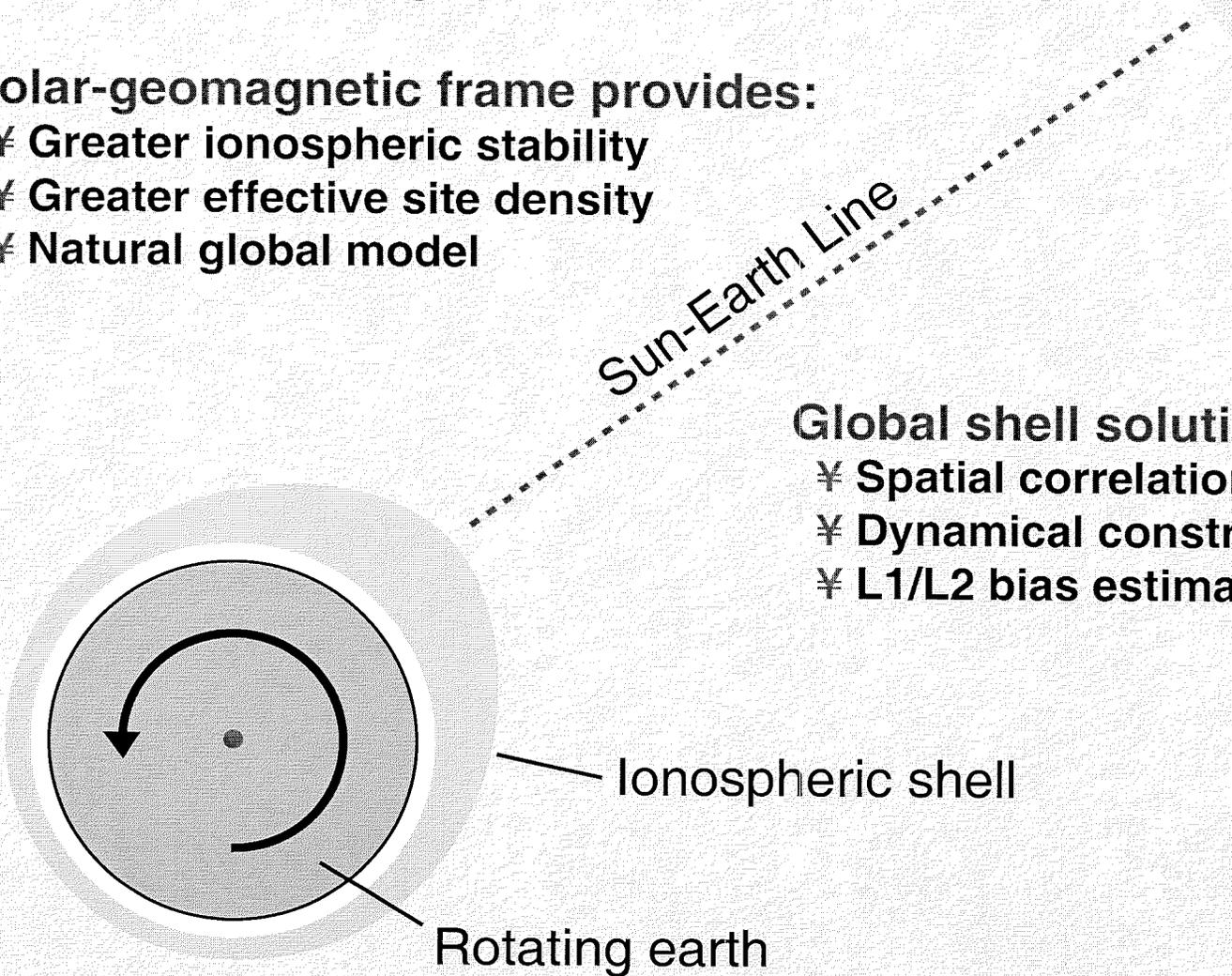


GLOBAL IONOSPHERIC MAPPING with the GPS ground network

Solar-geomagnetic frame provides:

- ¥ Greater ionospheric stability
- ¥ Greater effective site density
- ¥ Natural global model

Sun-Earth Line



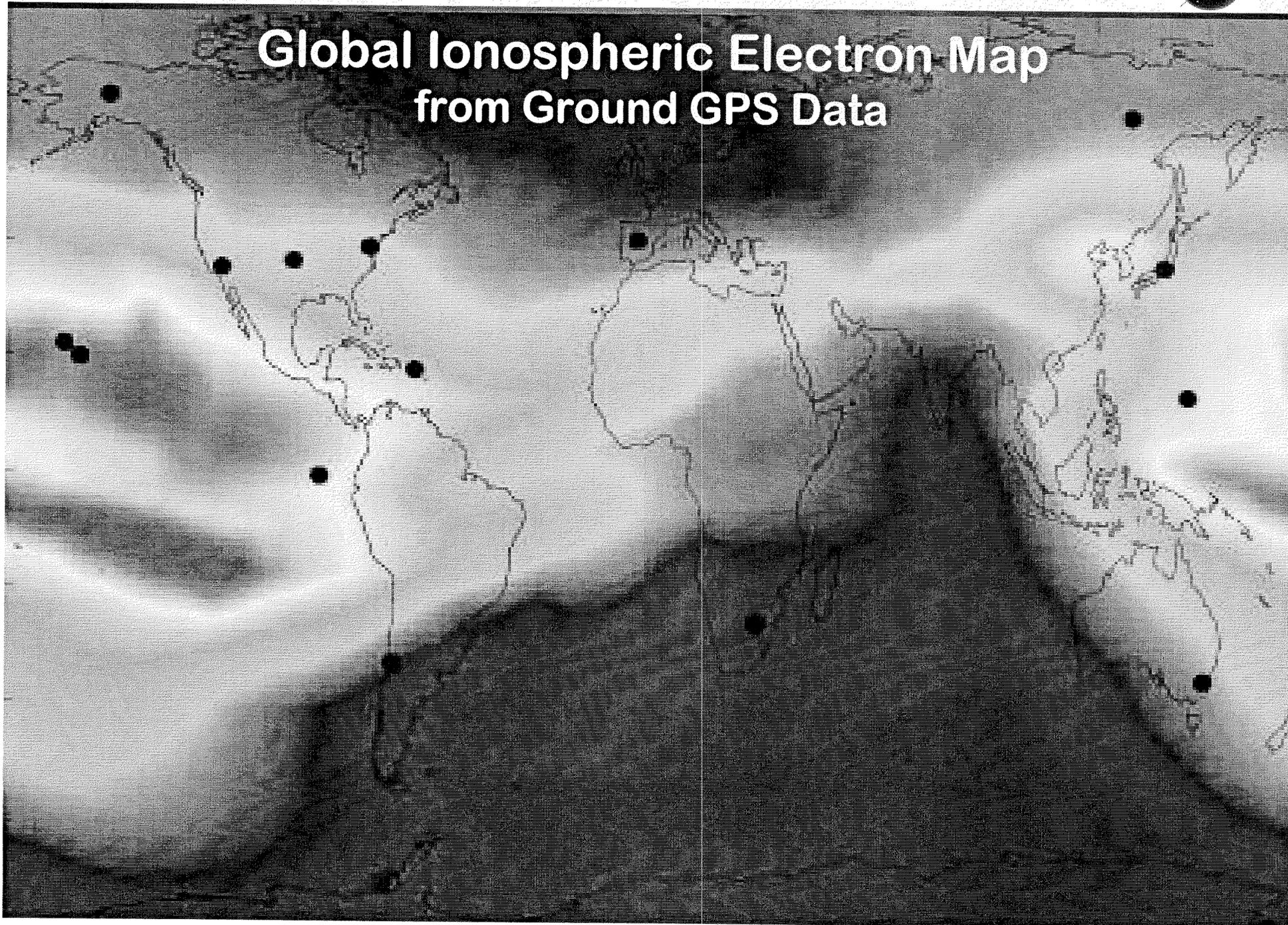
Global shell solution allows:

- ¥ Spatial correlations
- ¥ Dynamical constraints
- ¥ L1/L2 bias estimation

Ionospheric shell

Rotating earth

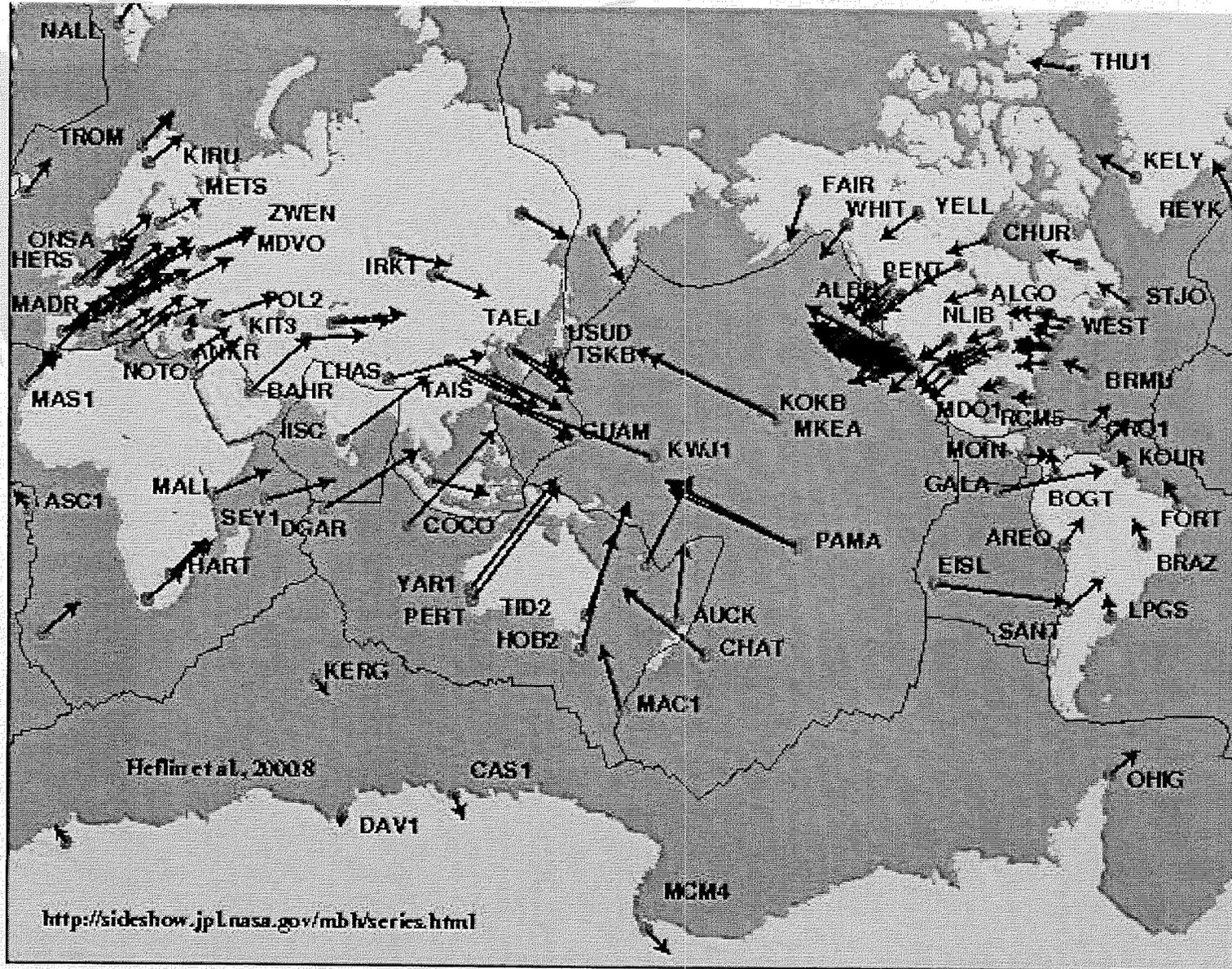
Global Ionospheric Electron Map from Ground GPS Data



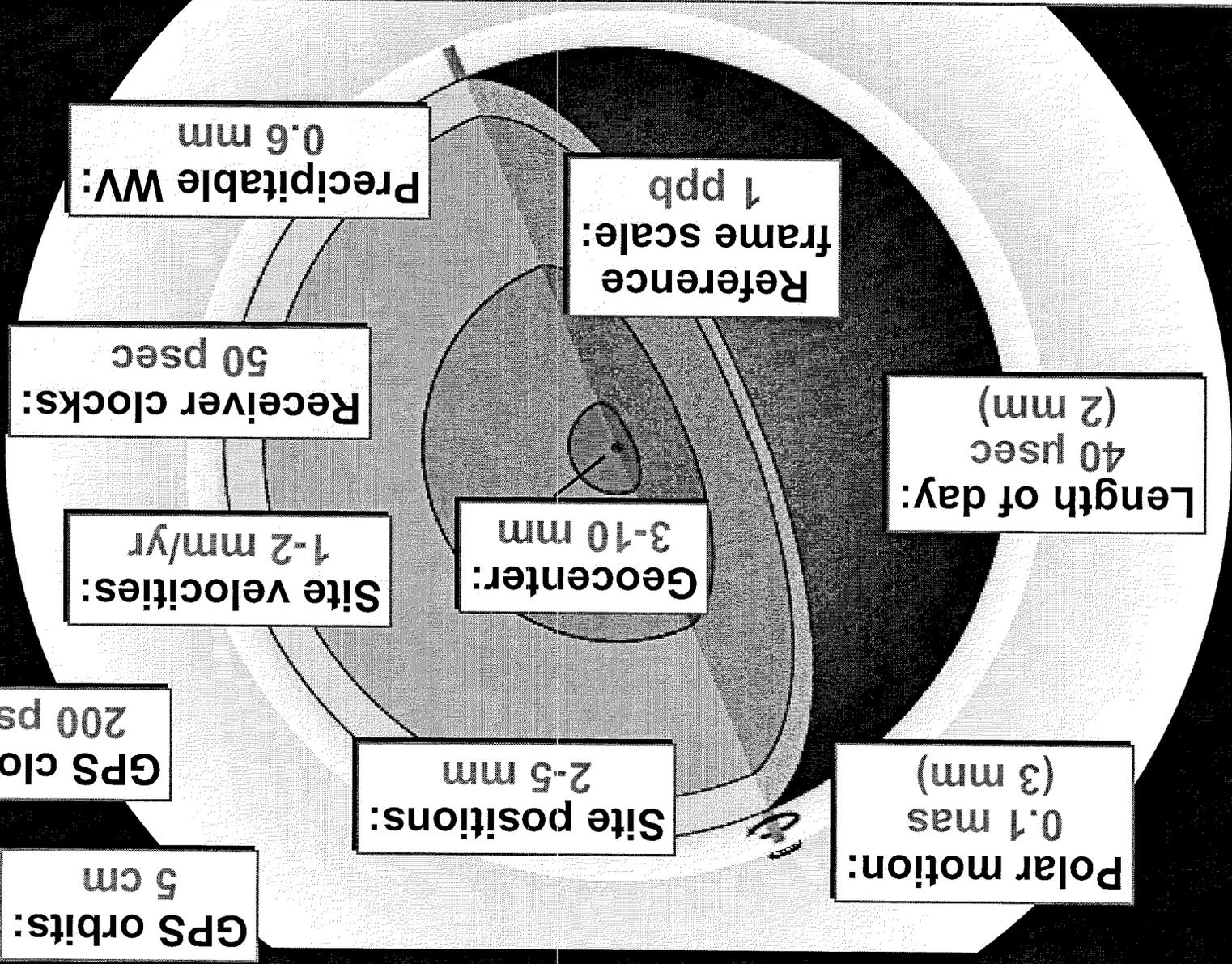
NASA Geodetic Data Products and Services

- Precise Final Products: 1-2 week delay
- Rapid Service Products: ~12 hour delay
- Real Time Products: By Internet or INMARSAT
- GIPSY/OASIS Analysis Software:
 - Available for license worldwide
 - No charge for research use
- Auto-GIPSY
 - E-mail GPS data to JPL
 - JPL returns position solutions in minutes
 - Absolute global accuracy of about 1 cm
 - No charge to user

Global Site Velocities

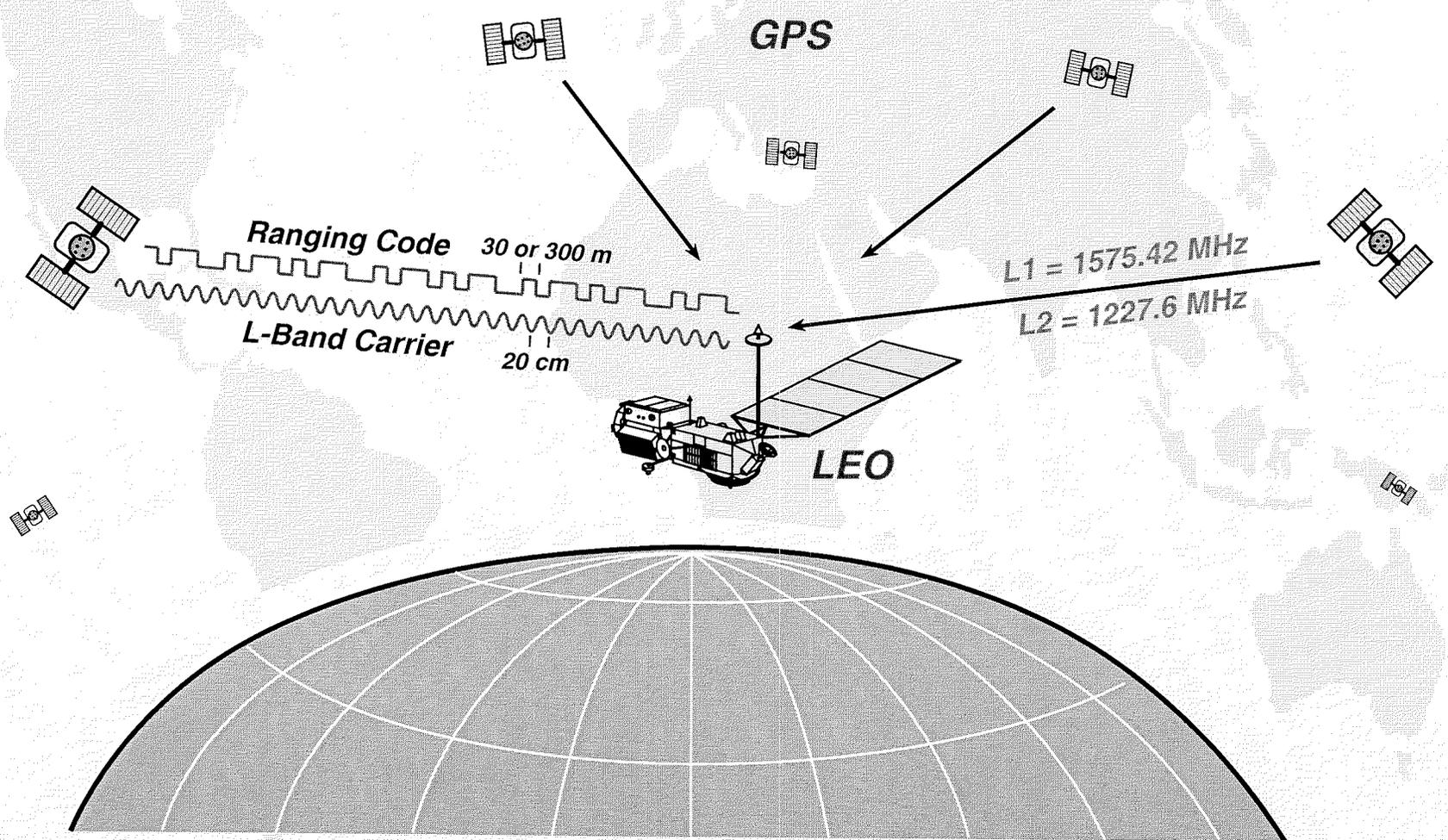


Principal GPS Geodetic Products

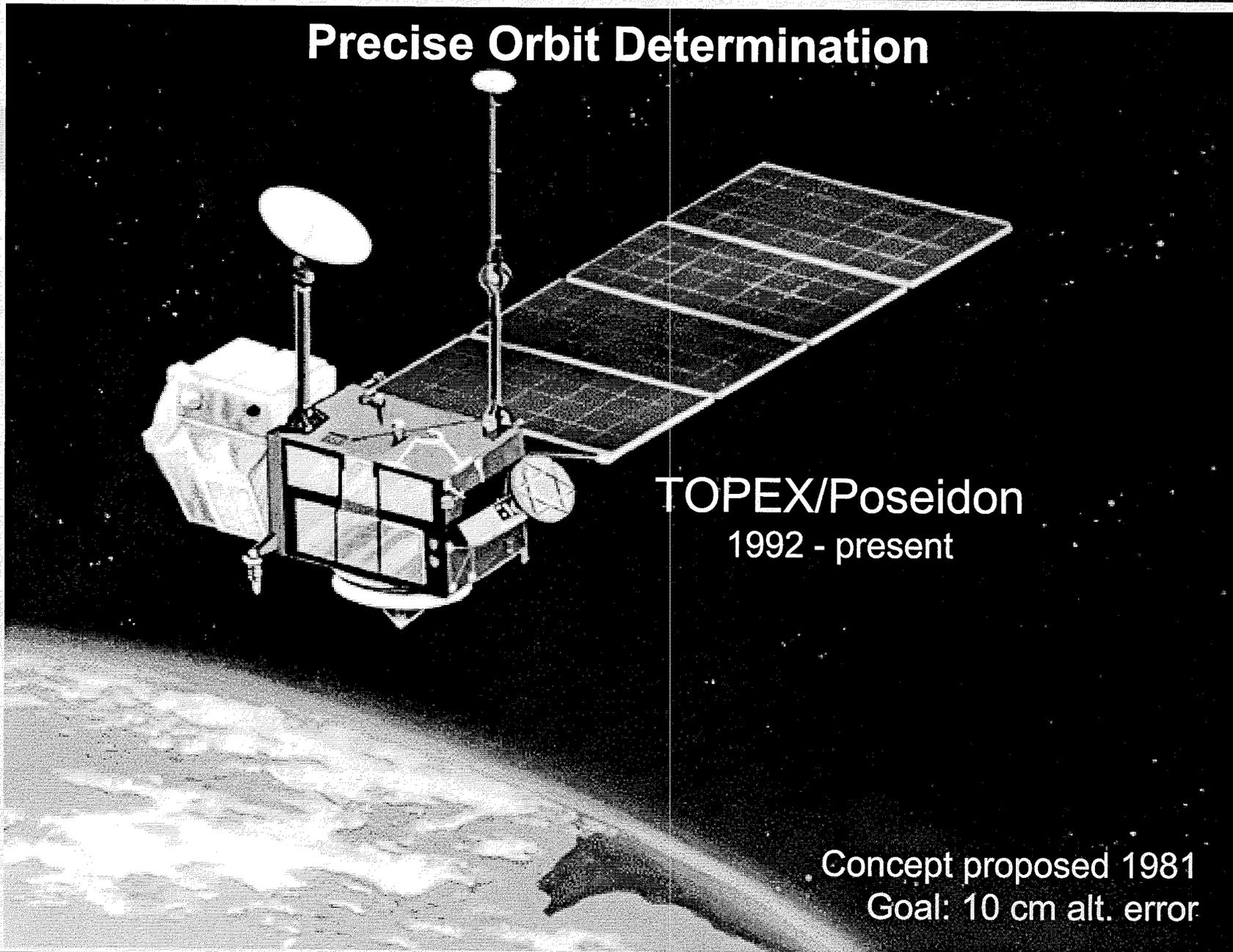


GPS is a principal contributor to the global reference frame (ITRF)

Moving to Space



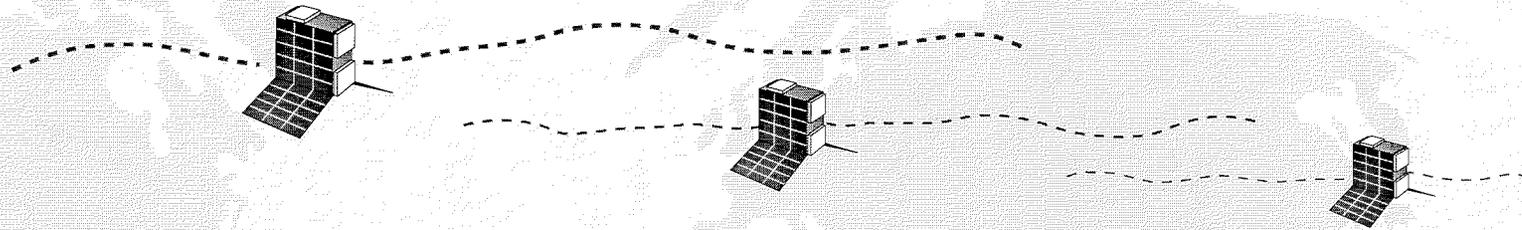
Precise Orbit Determination



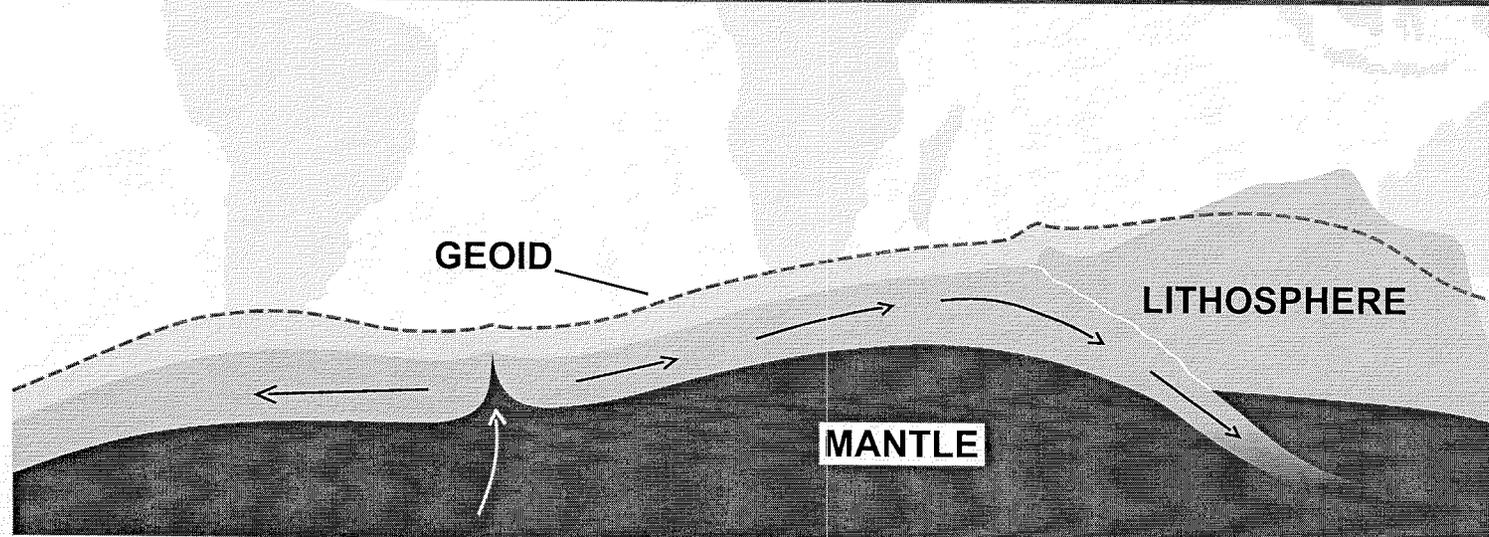
TOPEX/Poseidon
1992 - present

Concept proposed 1981
Goal: 10 cm alt. error

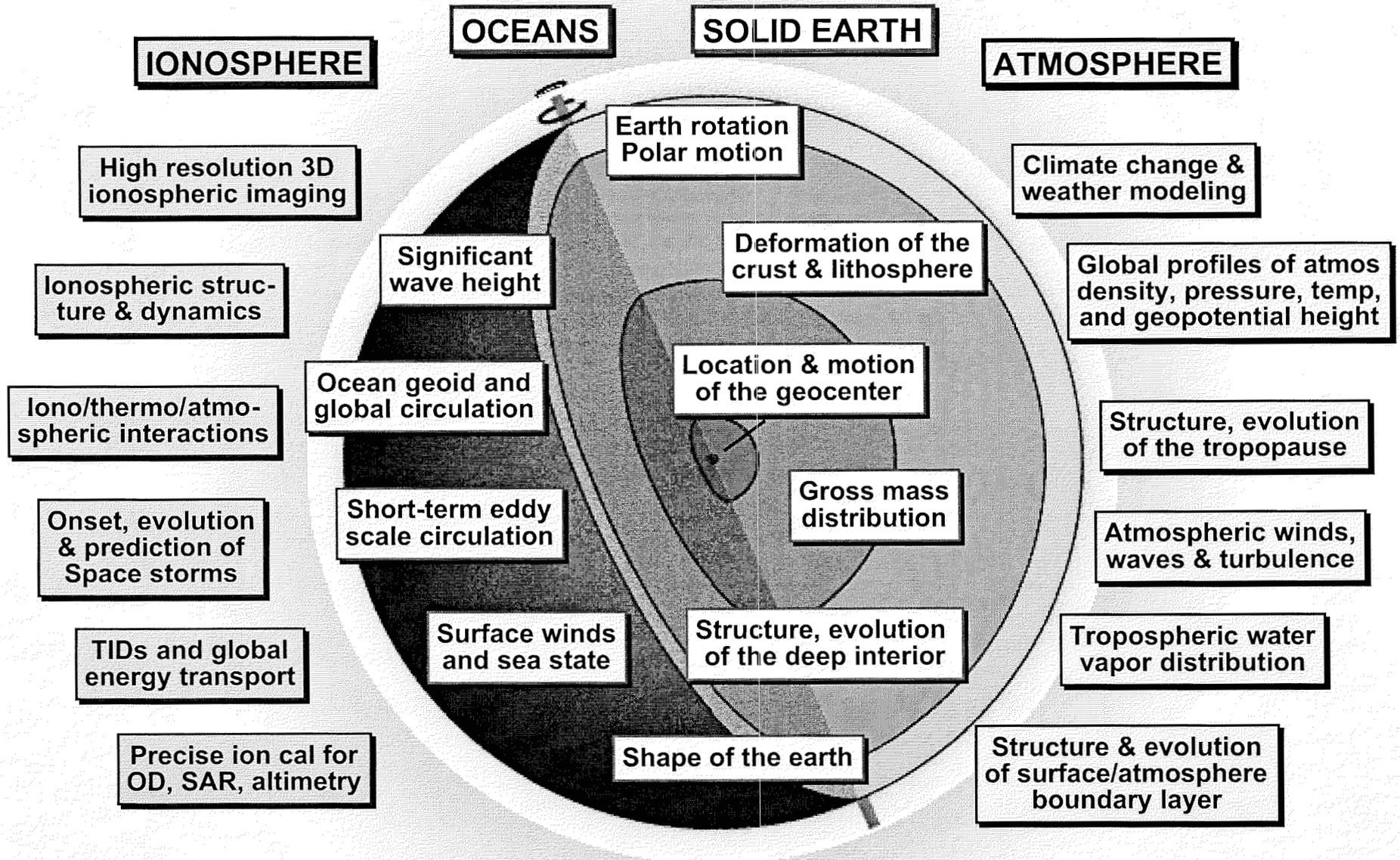
Gravity Recovery with Spaceborne GPS



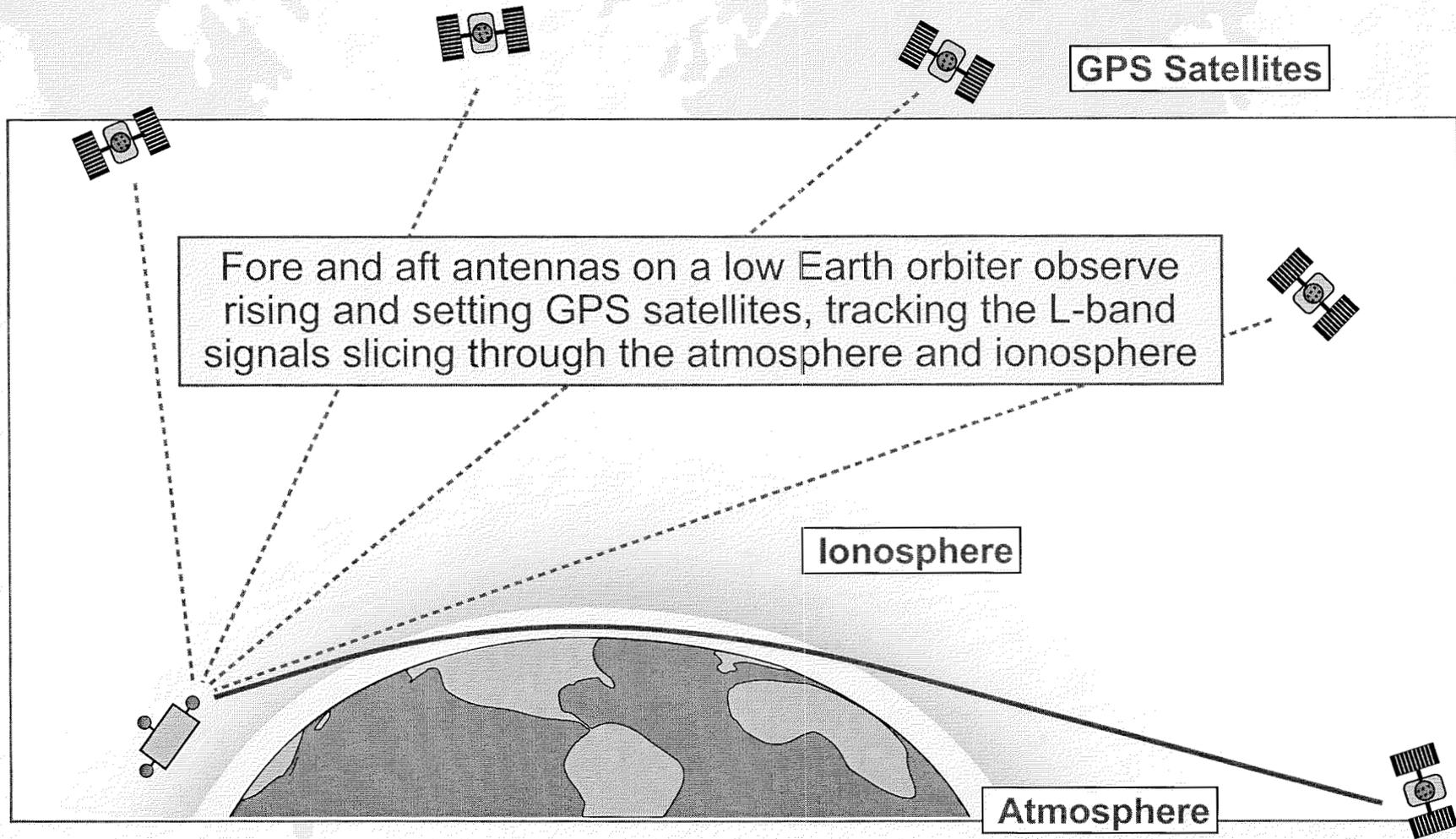
- Continuous refinement of gravity model up to 50 x 50
- Ocean geoid recovery to ~5 cm at 1000 km resolution
- Monthly redetermination to observe temporal change



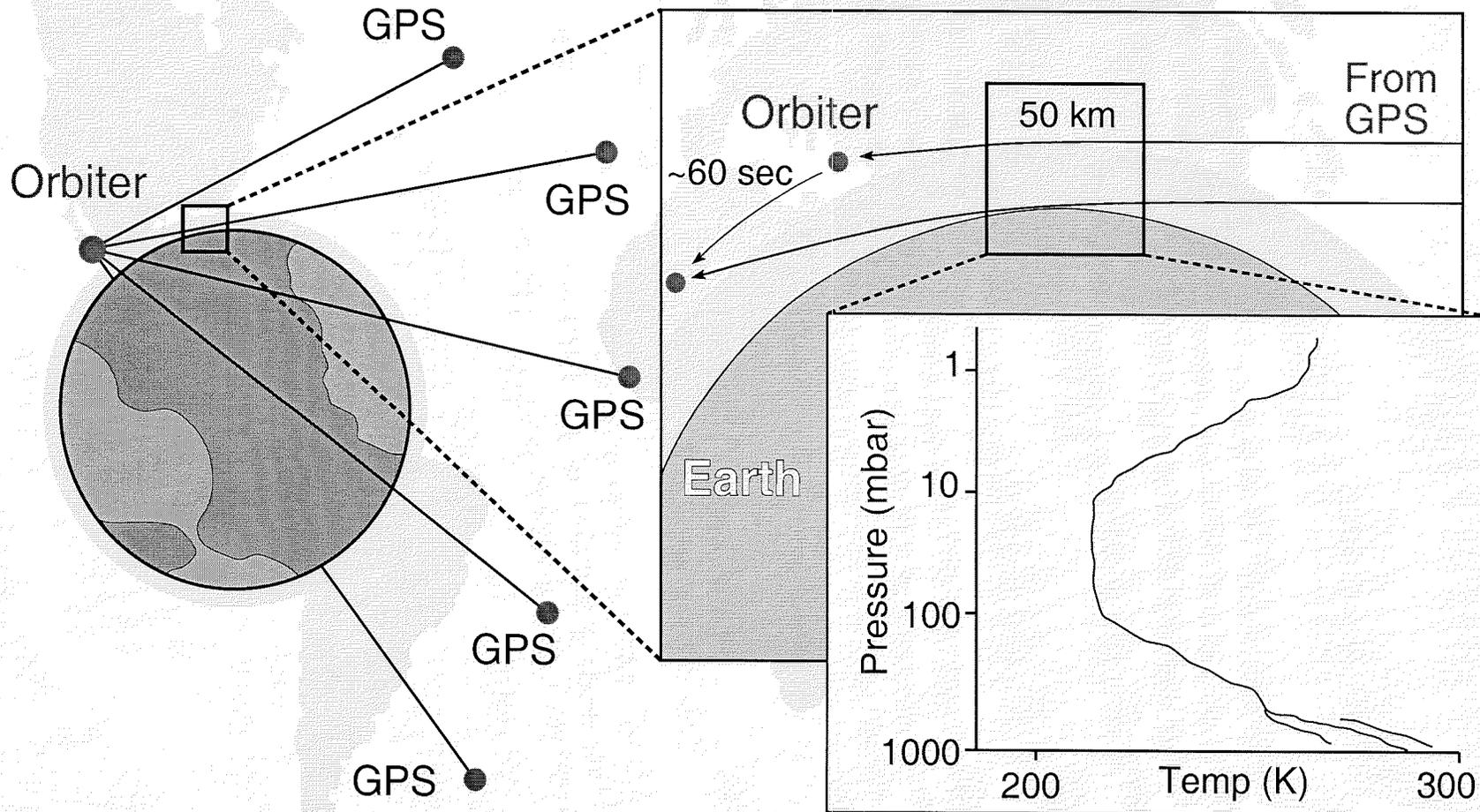
Probing the Earth with GPS

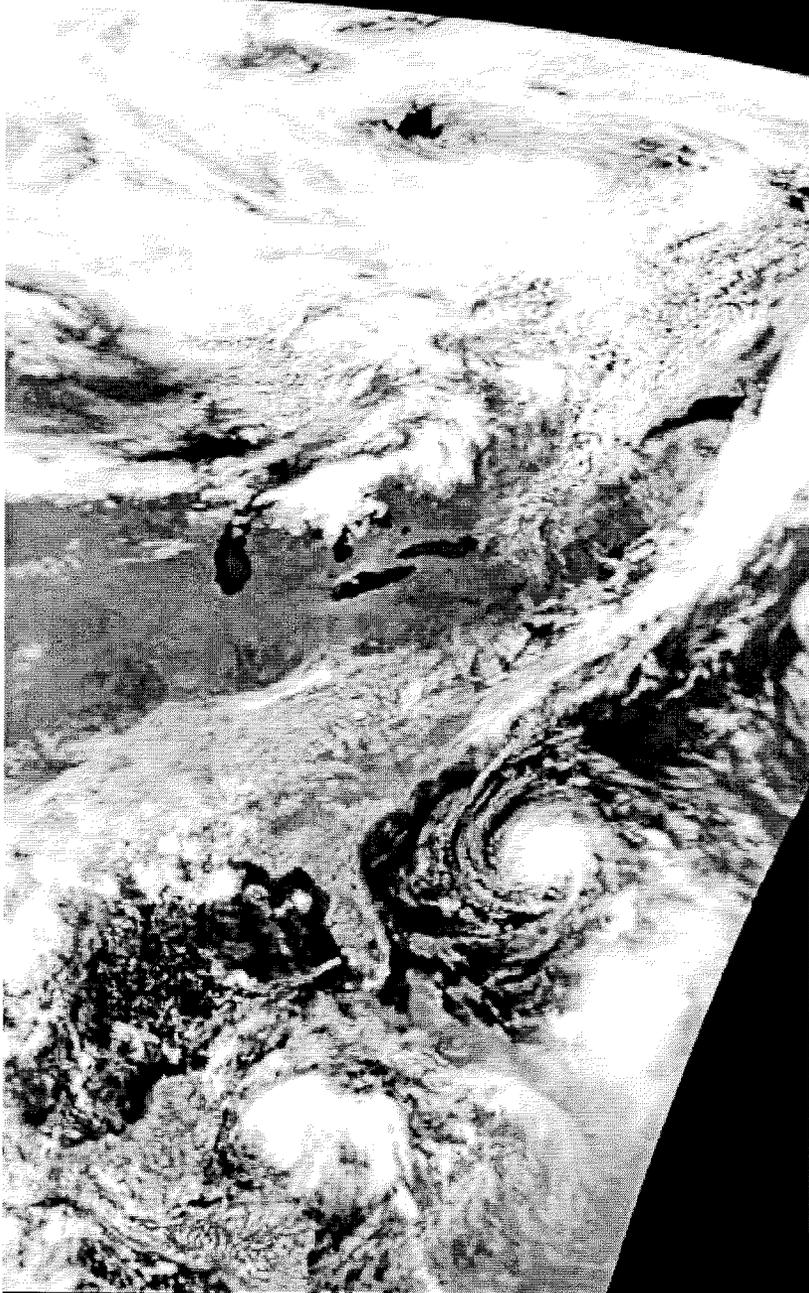


GPS Occultation Geometry



GPS Atmospheric Limb Sounding

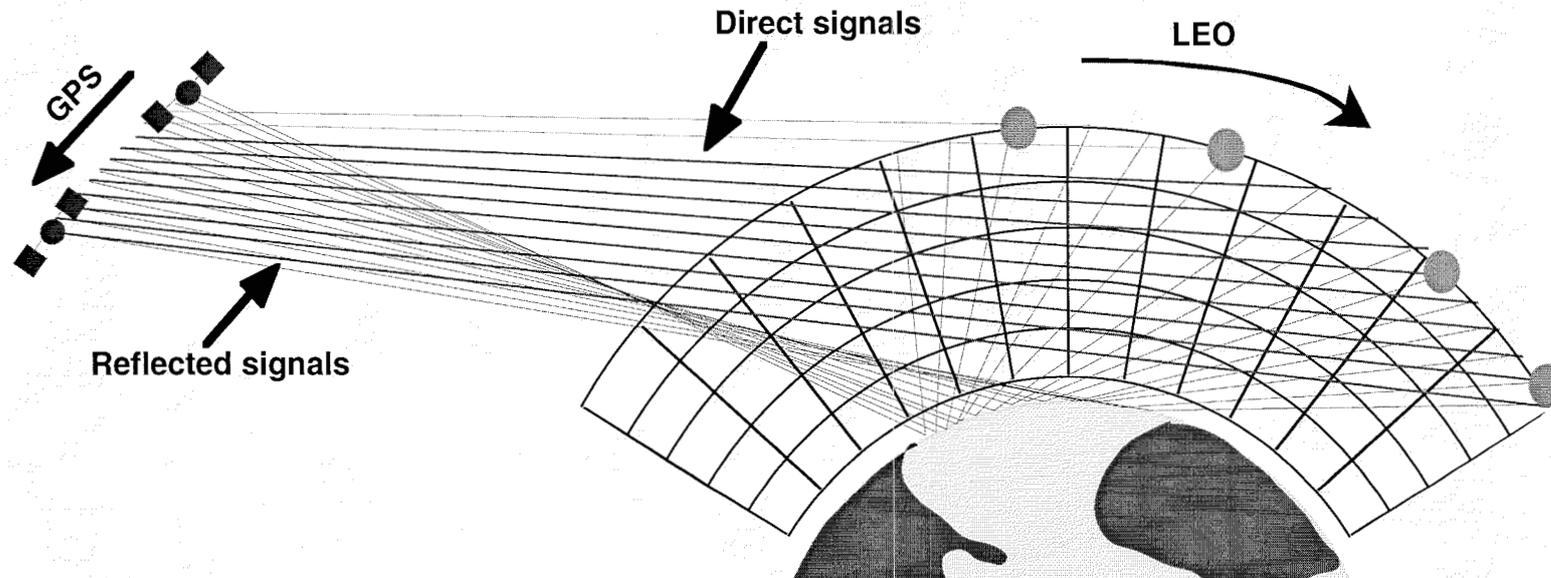




Atmospheric Occultation Products

- - Bending angle
 - Refractivity
 - Density
 - Pressure
 - Temperature
 - Moisture
 - Geopotential height
-
-
-
-

Remote Sensing with Reflected GPS

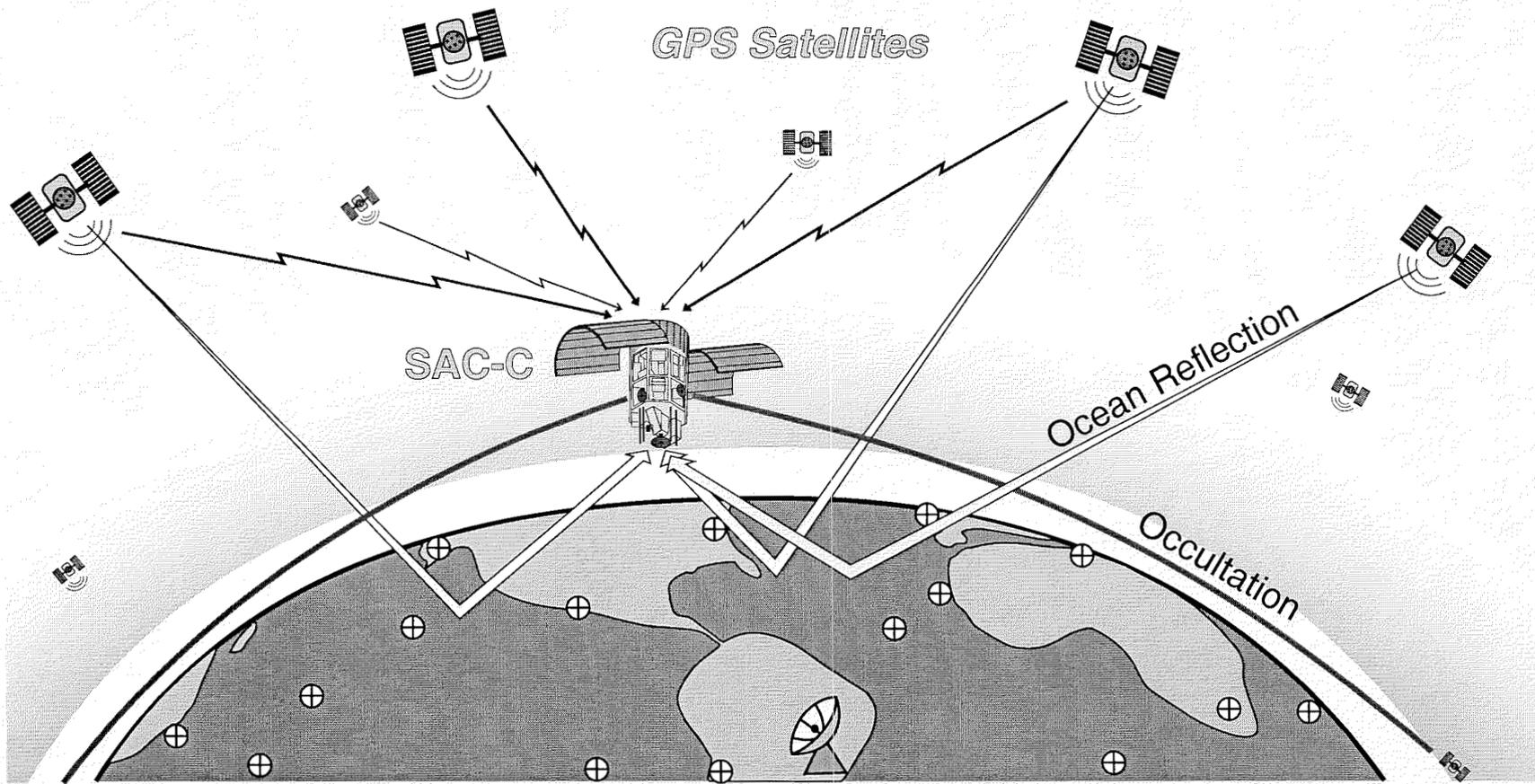


Applications

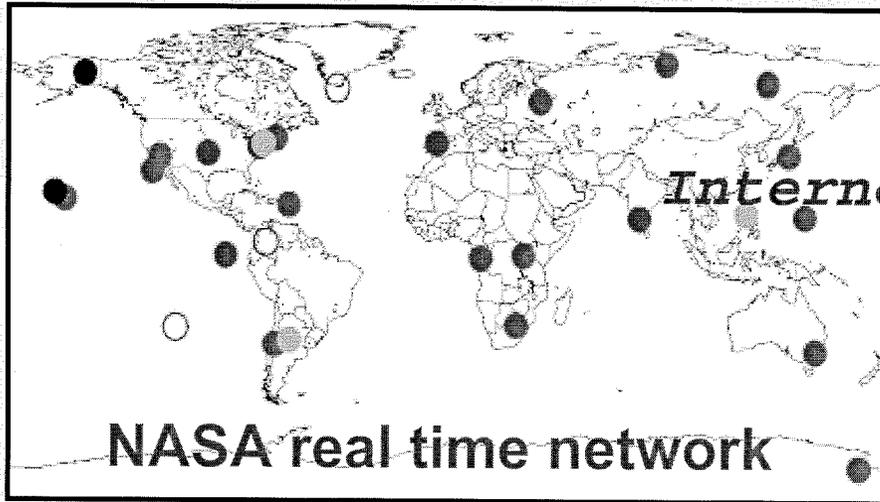
- **Ocean Altimetry** (topography, circulation)
- **Scatterometry** (sea state, surface winds)
- **Atmospheric and Ionospheric Imaging**

GPS-Based Earth Science on SAC-C

- POD and Long Wavelength Gravity
- Atmospheric & Ionospheric Imaging
- Ocean Reflection Engineering Test



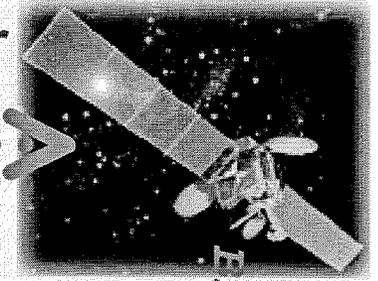
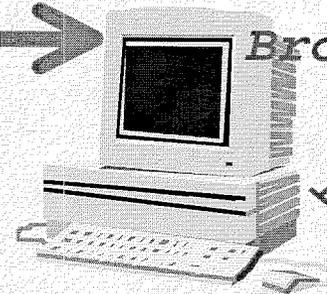
NASA's Global Real Time Differential System



JPL processing center

Internet

Broadcast



Internet
384 bps

256 bps



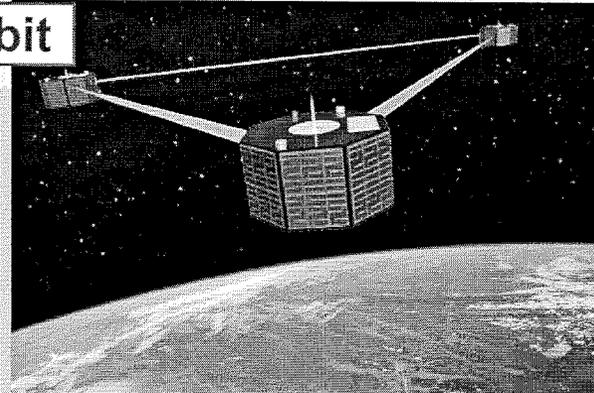
Remote user

Decimeter real time positioning everywhere

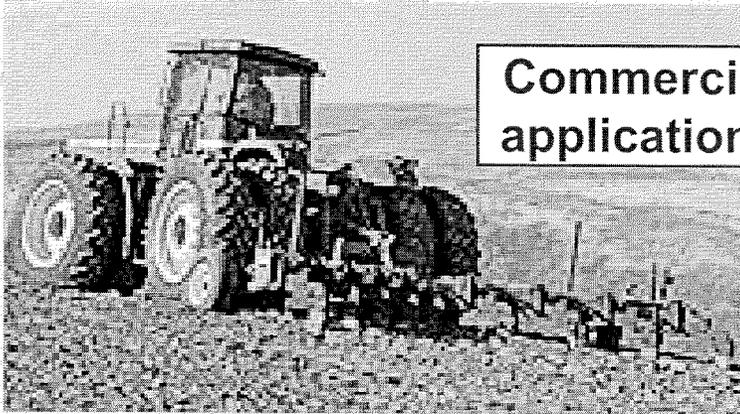
Coverage:	Global	Yes
	Seamless	Yes
	Usable in space	Yes
Accuracy:	Kinematic applications	0.1 m horizontal 0.2 m vertical
	Orbit determination	0.01 – 0.30 m (goal)
Dissemination method		Internet/broadcast

Special Value to NASA and Society

Autonomous operations in Earth orbit



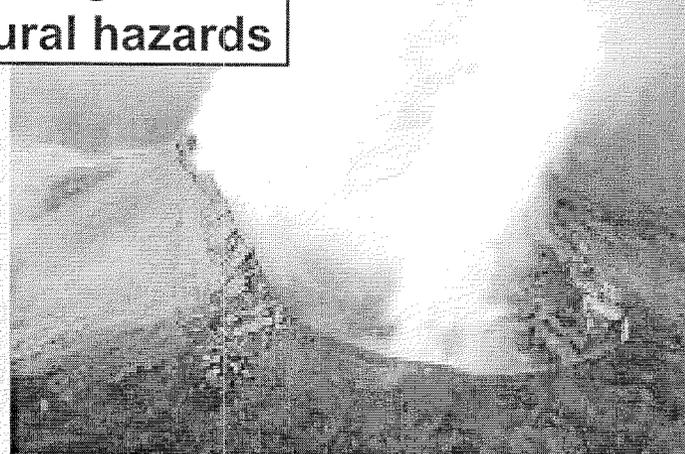
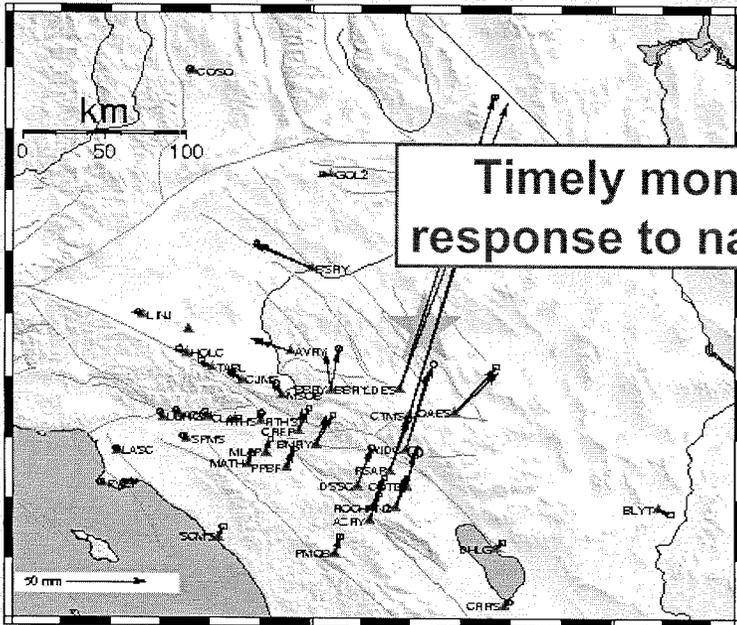
Commercial applications



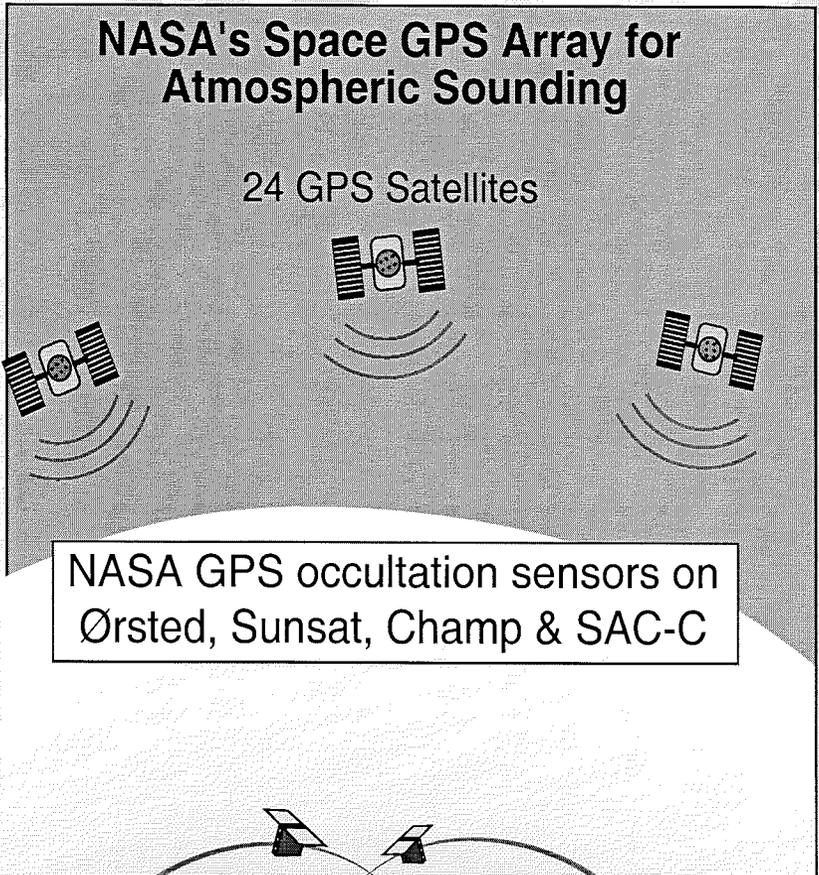
Aviation safety and efficiency



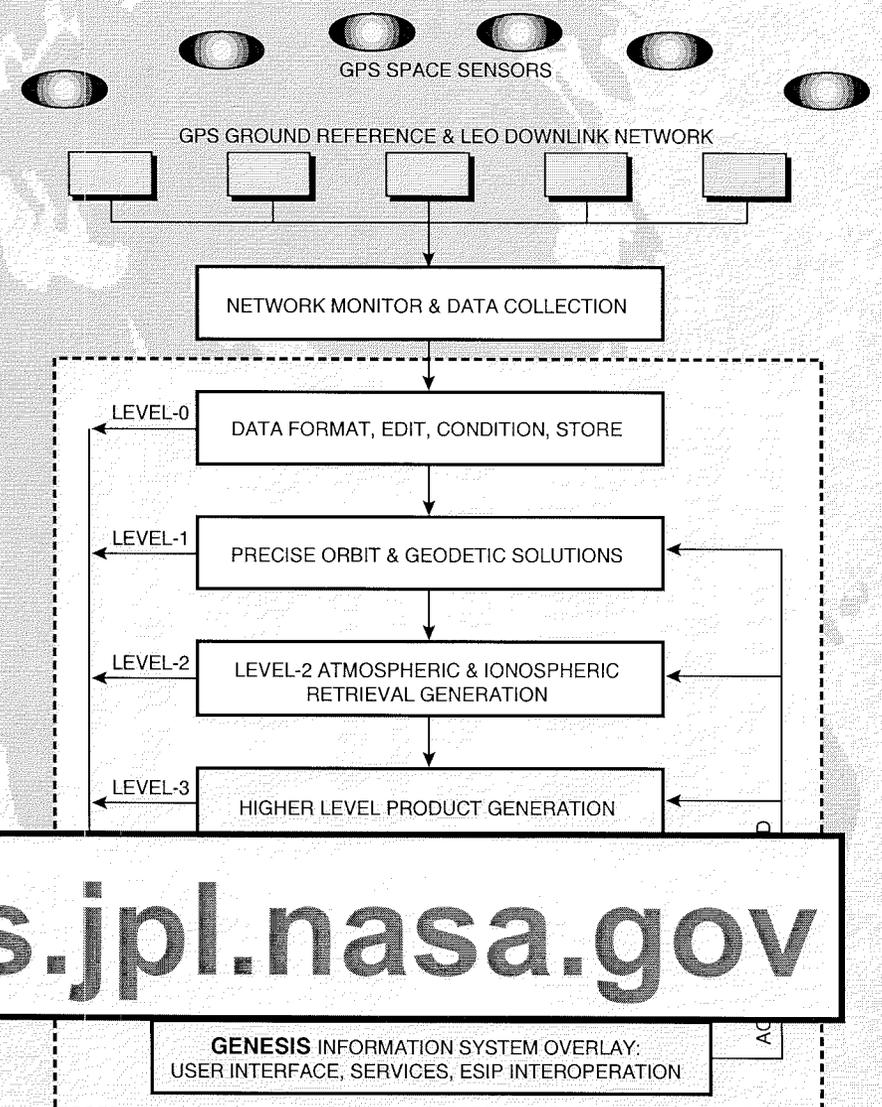
Timely monitoring and response to natural hazards



GPS ENVIRONMENTAL & Earth Science Information System



Complete GPS Data Information System



<http://genesis.jpl.nasa.gov>