Principle of GNSS （GPS） Positioning

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December 4, 2006

Training Class

Contents

1Introduction

What is GNSS（GPS），the main segments and development

Global Navigation Satellite System

GPS(USA) Global Positioni System

GLONASS(Russia) GLObal NAvigation Satellite System

Galileo（Europe,China and India）

Compass Navigation Satellite System (China)

Great benefit for industry and trade

Revolution in Earth Science

Most valuable space technology

Main segments：GNSS

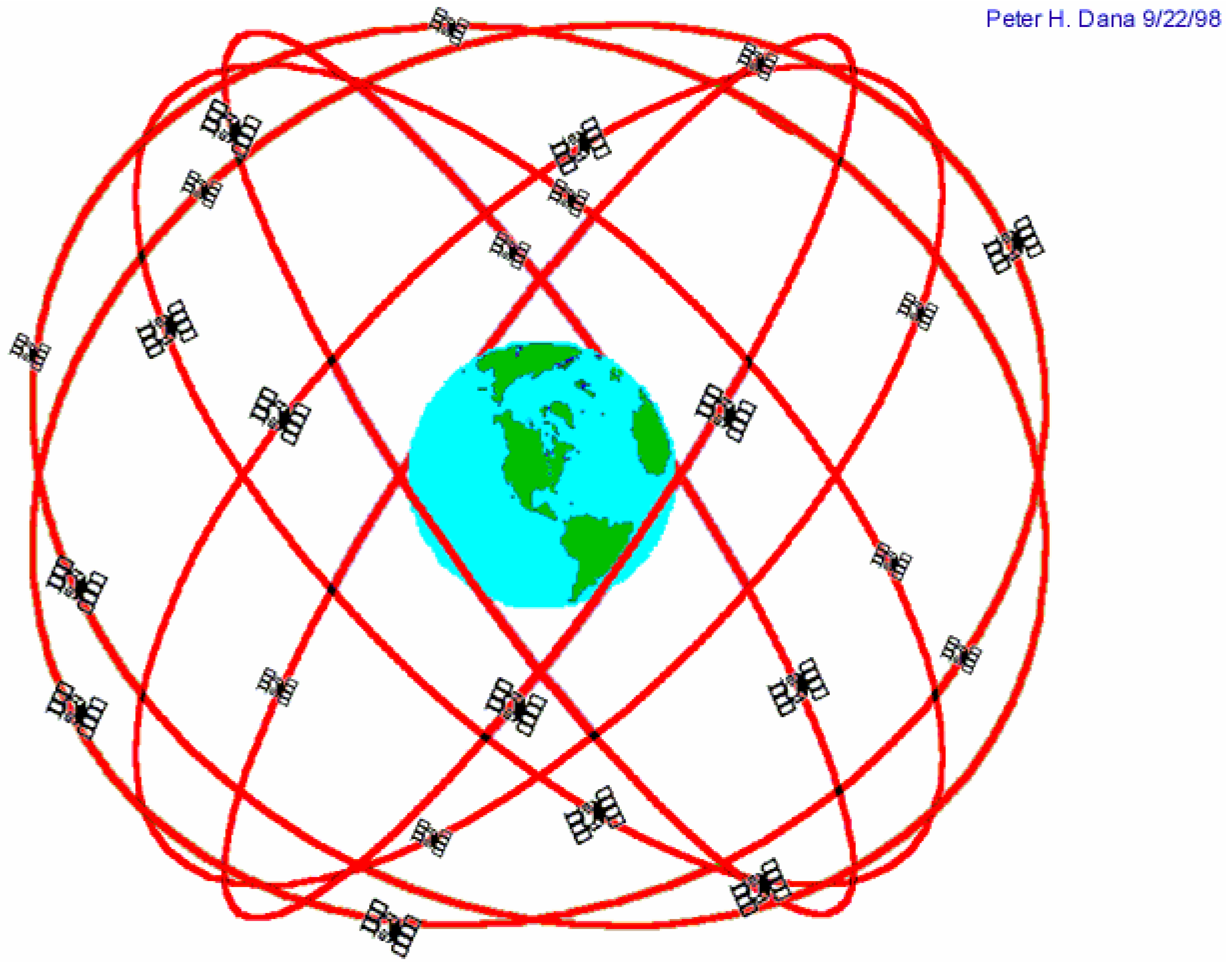
Space segments ：GNSS satellites

Ground segments ：control stations

User segments ：GNSS receivers

GNSS **satellites**

GPS constellation

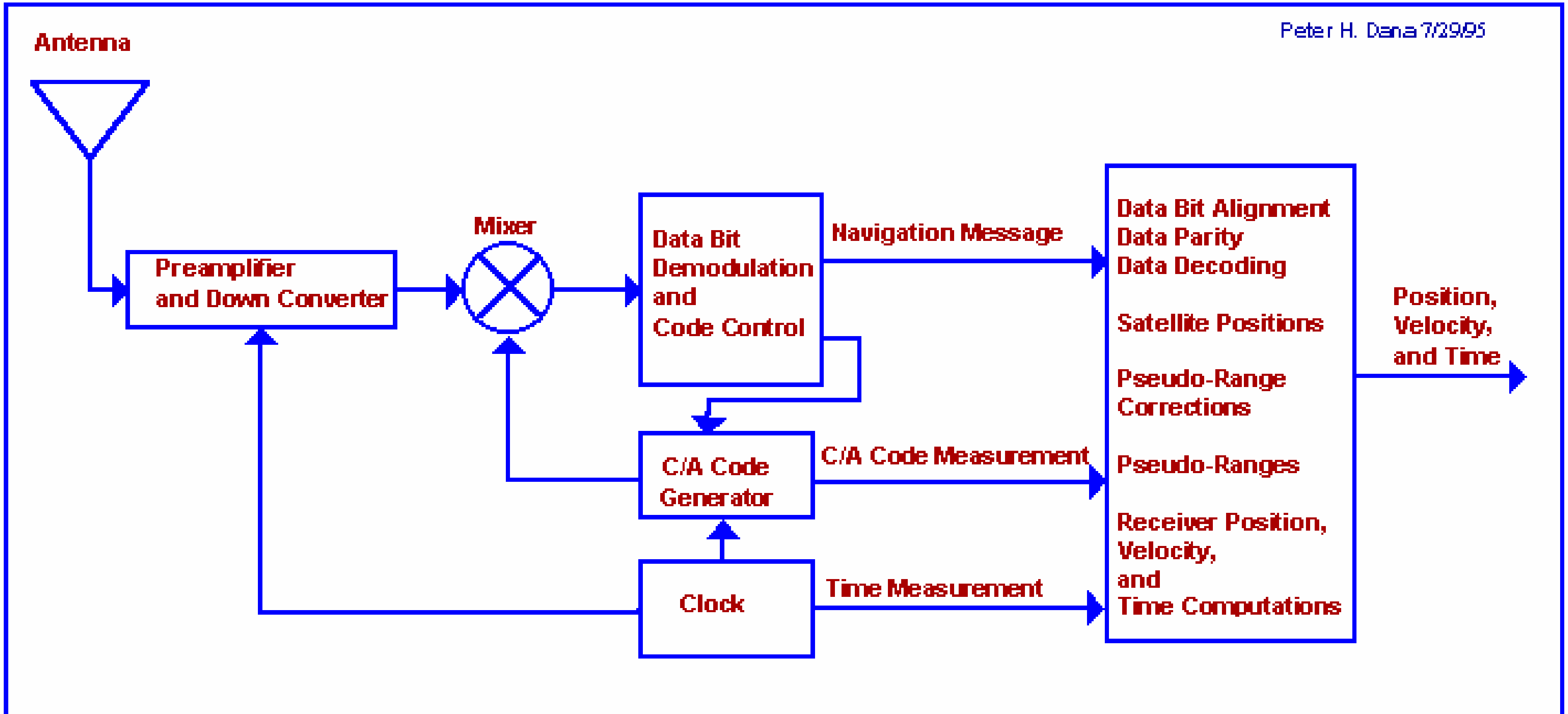


GPS Nominal Constellation
24 Satellites in 6 Orbital Planes
4 Satellites in each Plane
20,200 km Altitudes, 55 Degree Inclination

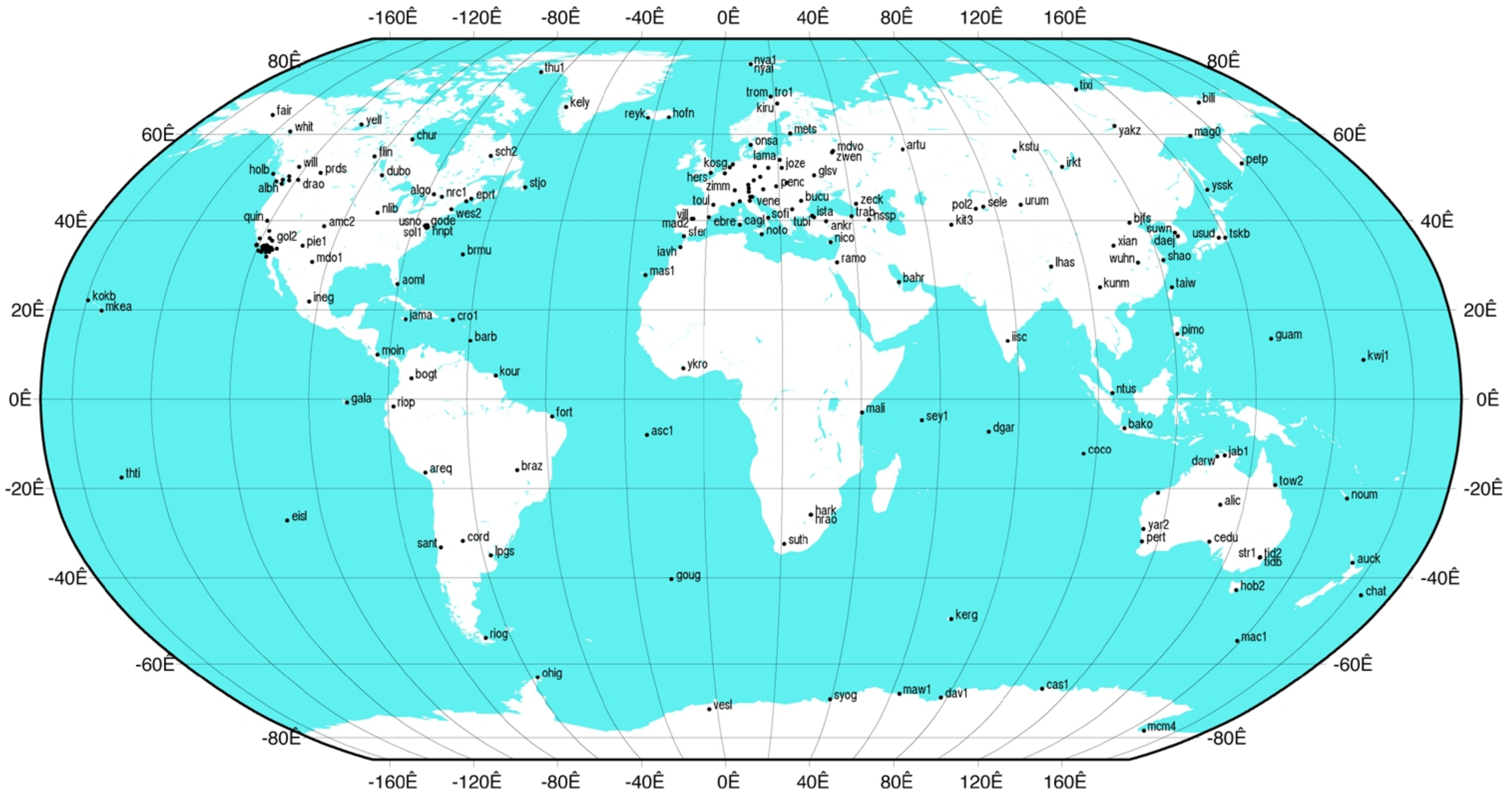
Ground control and monitor stations

Global Positioning System (GPS) Master Control and Monitor Station Network

GNSS receivers

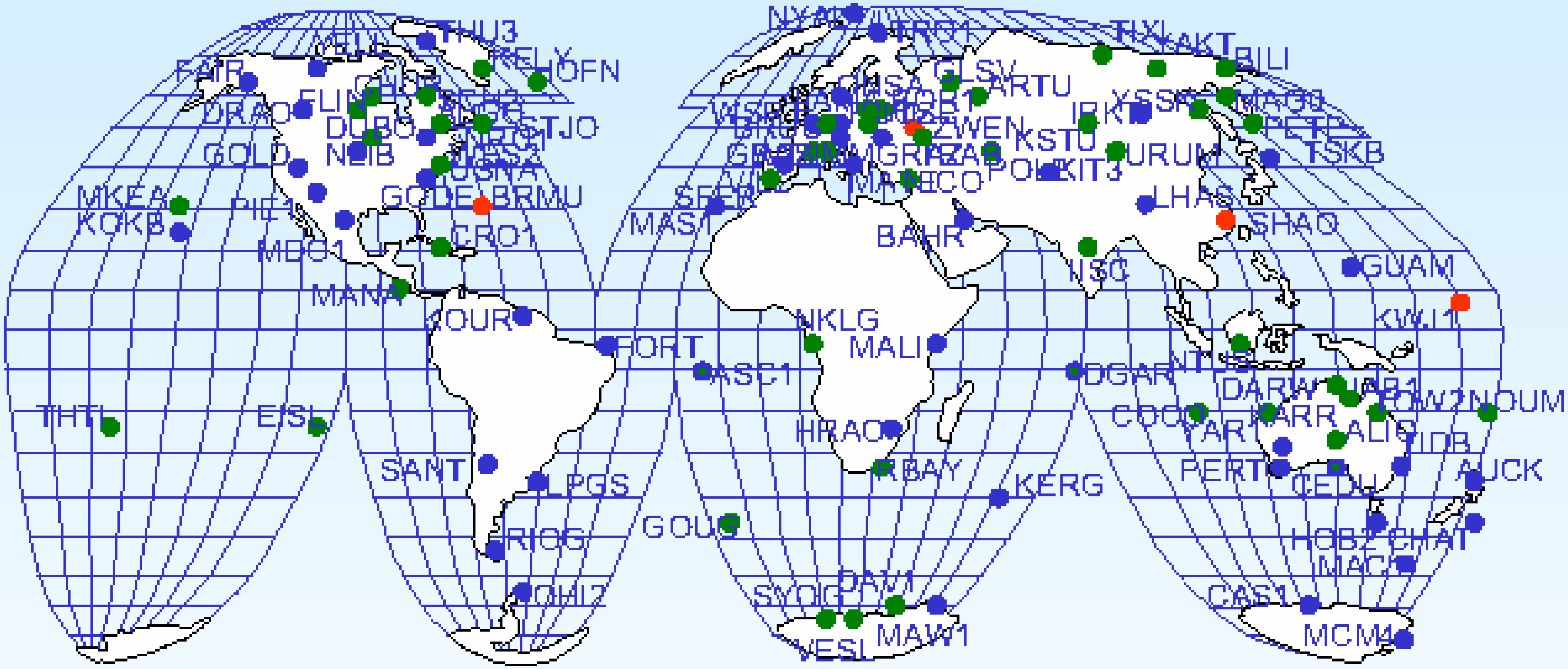


Simplified GPS Receiver Block Diagram



Global GNSS network

IGb00 Realization of ITRS



- ● Tracking Sites used for IGS00 but Removed for IGb00 (4)
- ● Tracking Sites Added to IGS00 (49)
- ● Tracking Sites used for IGS00 and IGb00 (47)

OHIG → OHI2
THU1 → THU3
TROM → TRO1

Natural Resources Canada Ressources naturelles Canada

G F Z POTSDAM

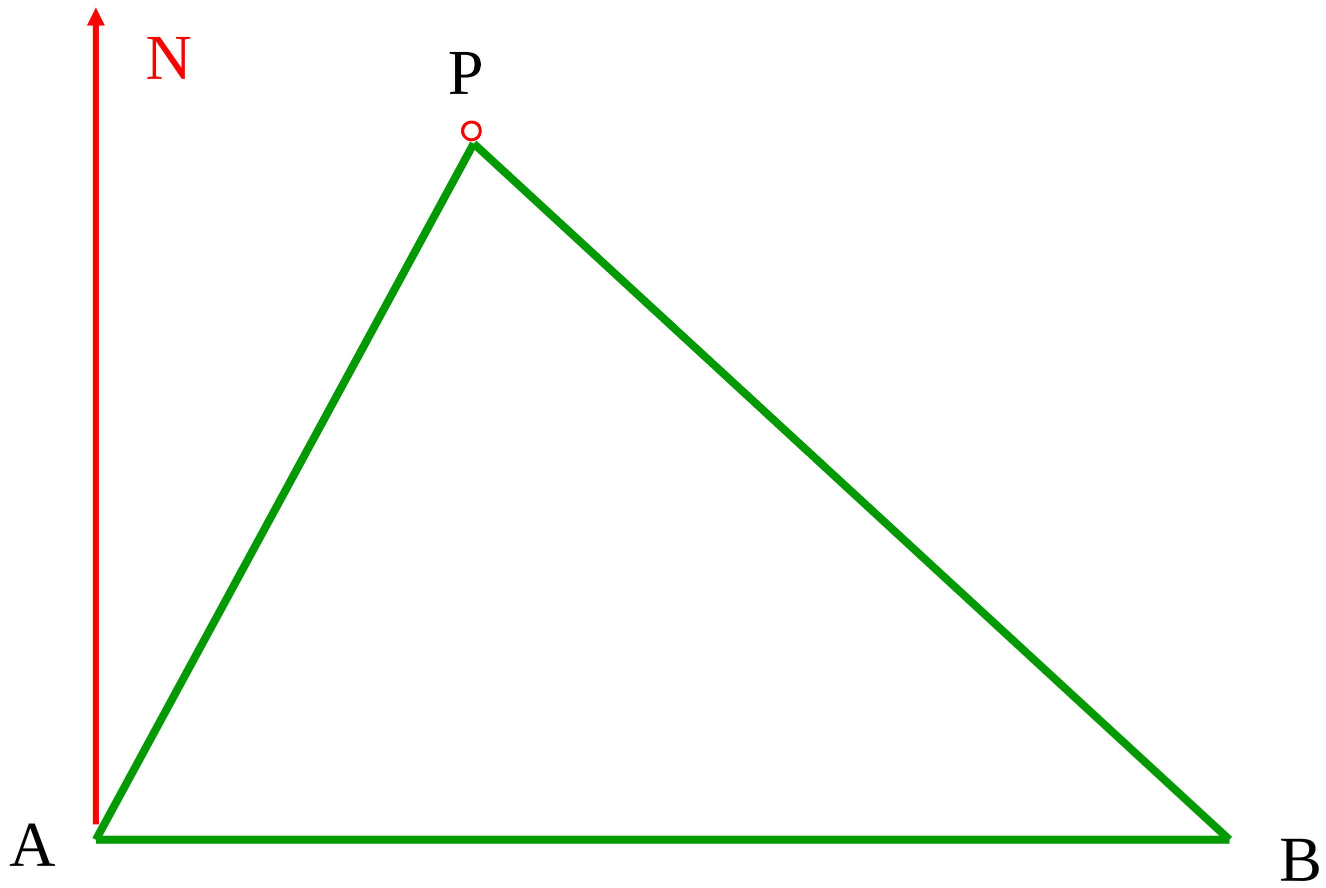
2Principle of positioning and data processing

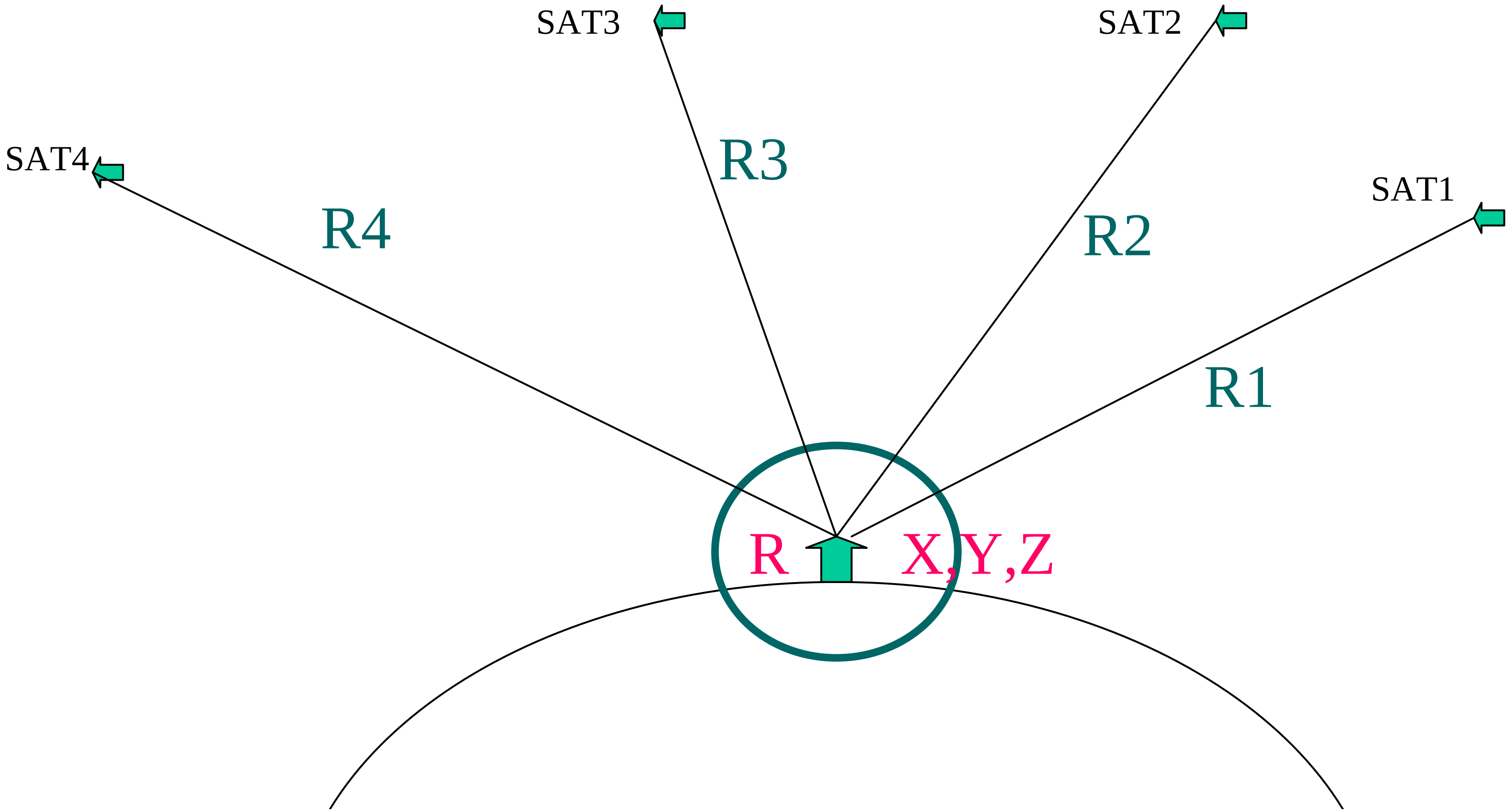
Principle of positioning

Kinematic and static positioning

2 Principle of positioning

Principle of positioning： positioning in one dimensional space and two dimensional space





$$R=((xr-xs)^2+(yr-ys)^2+(zr-zs)^2)^{1/2}+\ \Delta\ \ \tau$$

Principle of GNSS positioning

Coordinate Conversion
Geodetic Latitude, Longitude, and Height to ECEF, X, Y, Z

$$X = (N + h)\cos\phi\cos\lambda$$

$$Y = (N + h)\cos\phi\sin\lambda$$

$$Z = [N(1 - e^2) + h]\sin\phi$$

where:

ϕ, λ, h = geodetic latitude, longitude, and height above ellipsoid

X, Y, Z = Earth Centered Earth Fixed Cartesian Coordinates

and:

$N(\phi) = a / \sqrt{1 - e^2 \sin^2 \phi}$ = radius of curvature in prime vertical

a = semi-major earth axis (ellipsoid equatorial radius)

b = semi-minor earth axis (ellipsoid polar radius)

$f = \dfrac{a - b}{a}$ = flattening

$e^2 = 2f - f^2$ = eccentricity squared

Peter H. Dana 8/3/96

Coordinate Conversion: Cartesian (ECEF X, Y, Z) and Geodetic (Latitude, Longitude, and Height)

Direct Solution for Latitude, Longitude, and Height from X, Y, Z

This conversion is not exact and provides centimeter accuracy for heights < 1,000 km
(See Bowring, B. 1976. Transformation from spatial to geographical coordinates.
Survey Review, XXIII: pg. 323-327)

$$\phi = \operatorname{atan}\left(\frac{Z + e'^2 b \sin^3\theta}{p - e^2 a \cos^3\theta}\right)$$

$$\lambda = \operatorname{atan2}(Y, X)$$

$$h = \frac{p}{\cos(\phi)} - N(\phi)$$

where:

ϕ, λ, h = geodetic latitude, longitude, and height above ellipsoid

X, Y, Z = Earth Centered Earth Fixed Cartesian coordinates

and:

$$p = \sqrt{X^2 + Y^2} \qquad \theta = \operatorname{atan}\left(\frac{Za}{pb}\right) \qquad e'^2 = \frac{a^2 - b^2}{b^2}$$

$N(\phi) = a / \sqrt{1 - e^2 \sin^2\phi}$ = radius of curvature in prime vertical

a = semi - major earth axis (ellipsoid equatorial radius)

b = semi - minor earth axis (ellipsoid polar radius)

$f = \frac{a - b}{a}$ = flattening

$e^2 = 2f - f^2$ = eccentricity squared

3 Measurements and measurement equations
Ambiguity, cycle slip

4 Error source

Orbit

Ionosphere delay

Troposphere delay

Phase centers of satellite antenna and receiver antenna

Multipath

Clock error(Sat. and RCV)

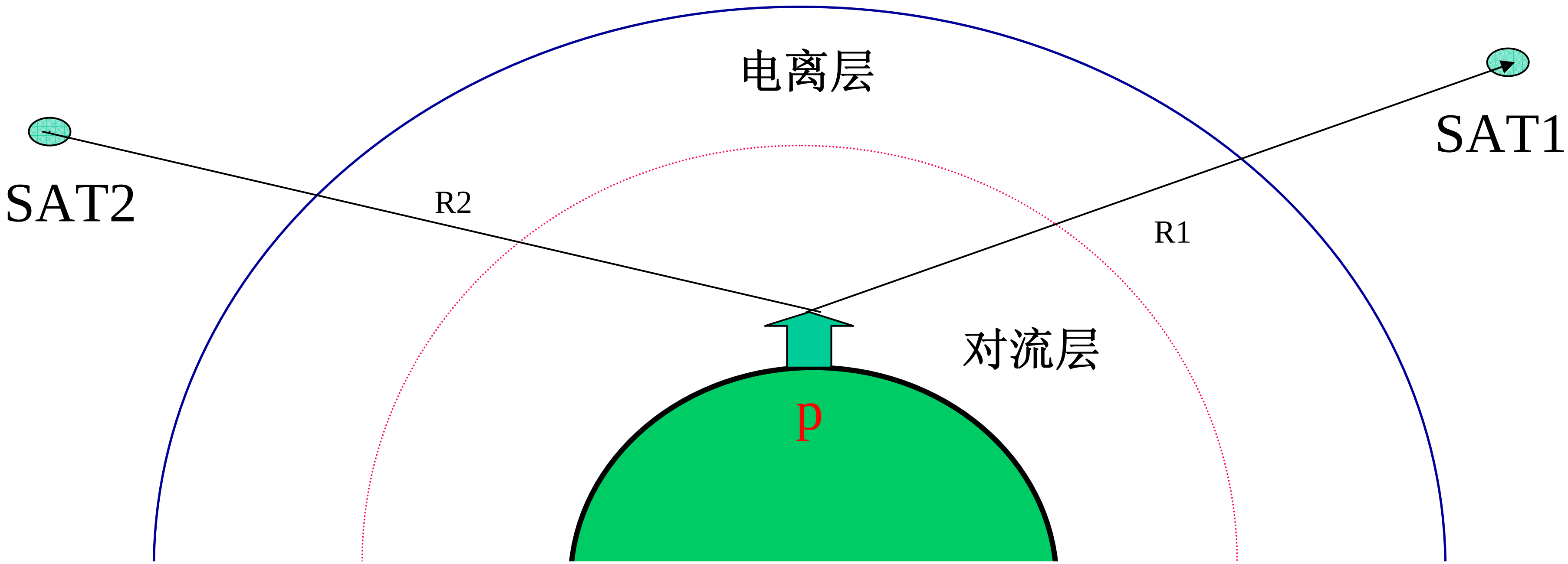
Displacement tides (Earth tide, pole tide, ocean loading, atmosphere loading

Phase wind-up

Relativity effect

Known coordinates

Antenna centering



卫星轨道误差
卫星钟差
卫星天线相位中心偏差
相对论效应

接收机钟差
多路径效应
接收机天线相位中心偏差
固体潮
极潮
海水负荷
对中误差（对点误差）
已知点点位误差

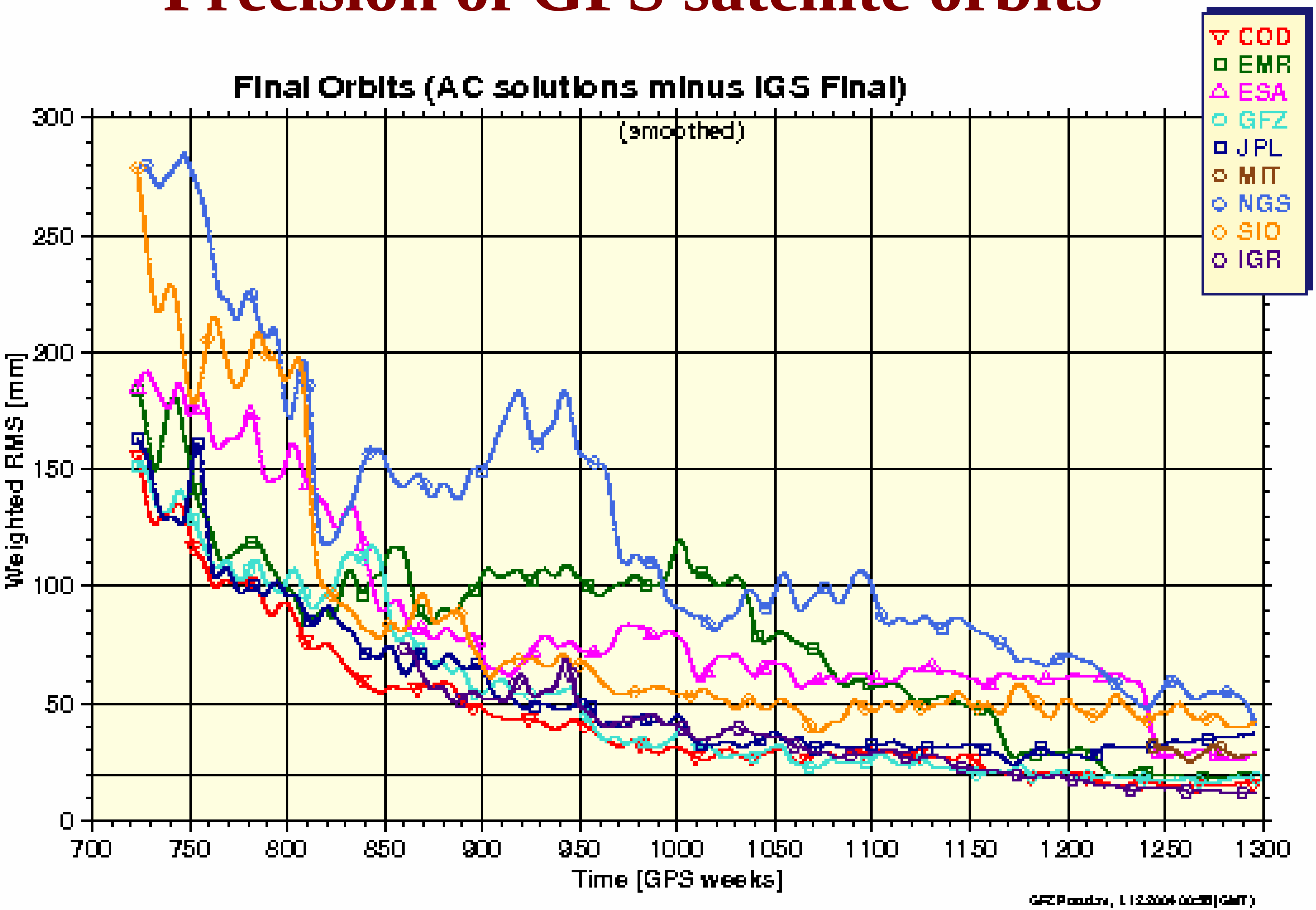
天线相对旋转
相位增加效应

GPS相对定位误差源

GPS 卫星轨道

Precision in GPS results

Precision of GPS satellite orbits



5 Time and coordinate system

GPS time
UTC
GPS week

reference frame----foundation of geodetic results

WGS84
ITRF from ITRF89 to ITRF2005
IGS IGS05

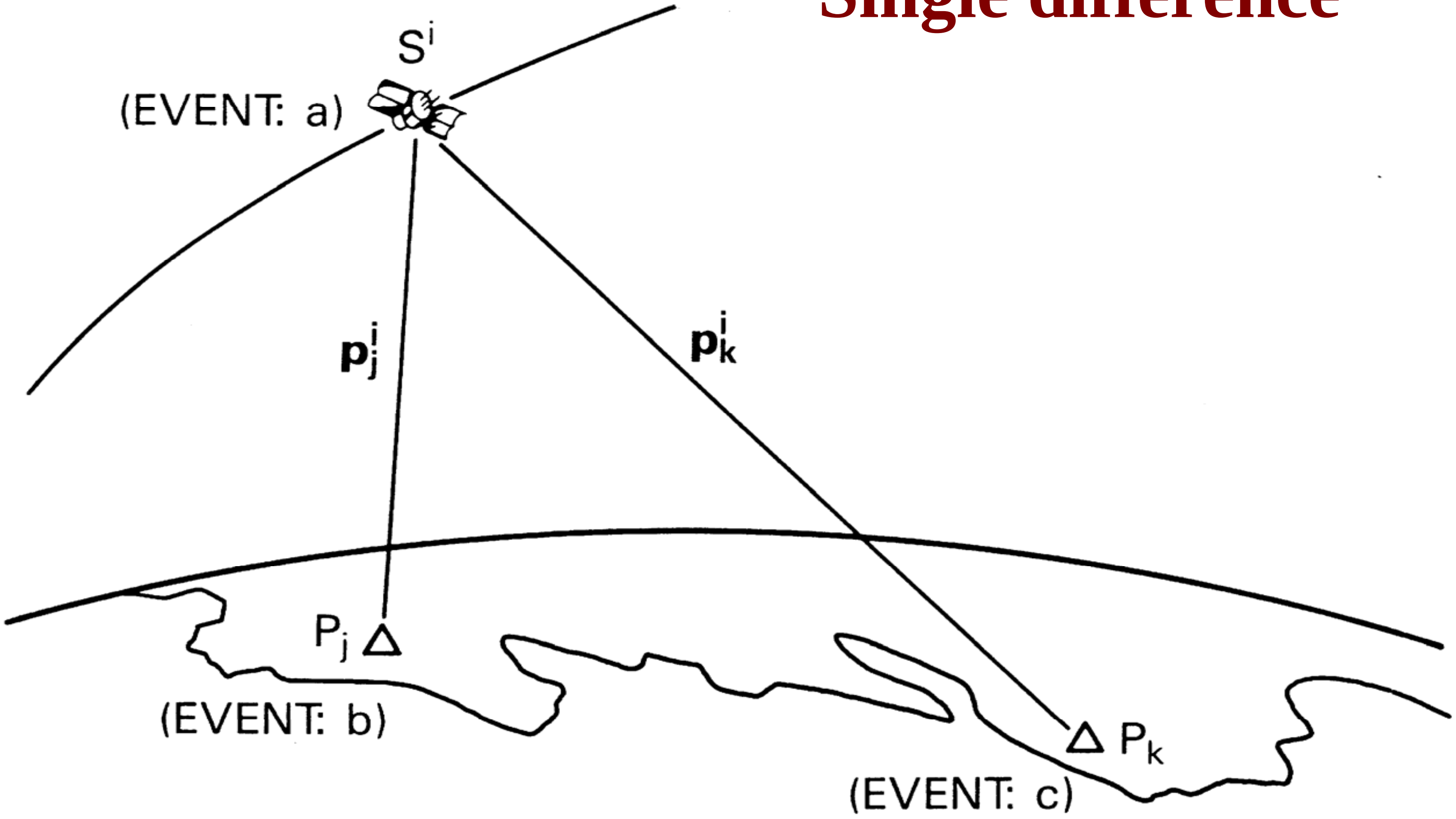
6 Data processing and software
Differencing, linear combinations

Zero difference
Single difference
Double difference
Triple difference

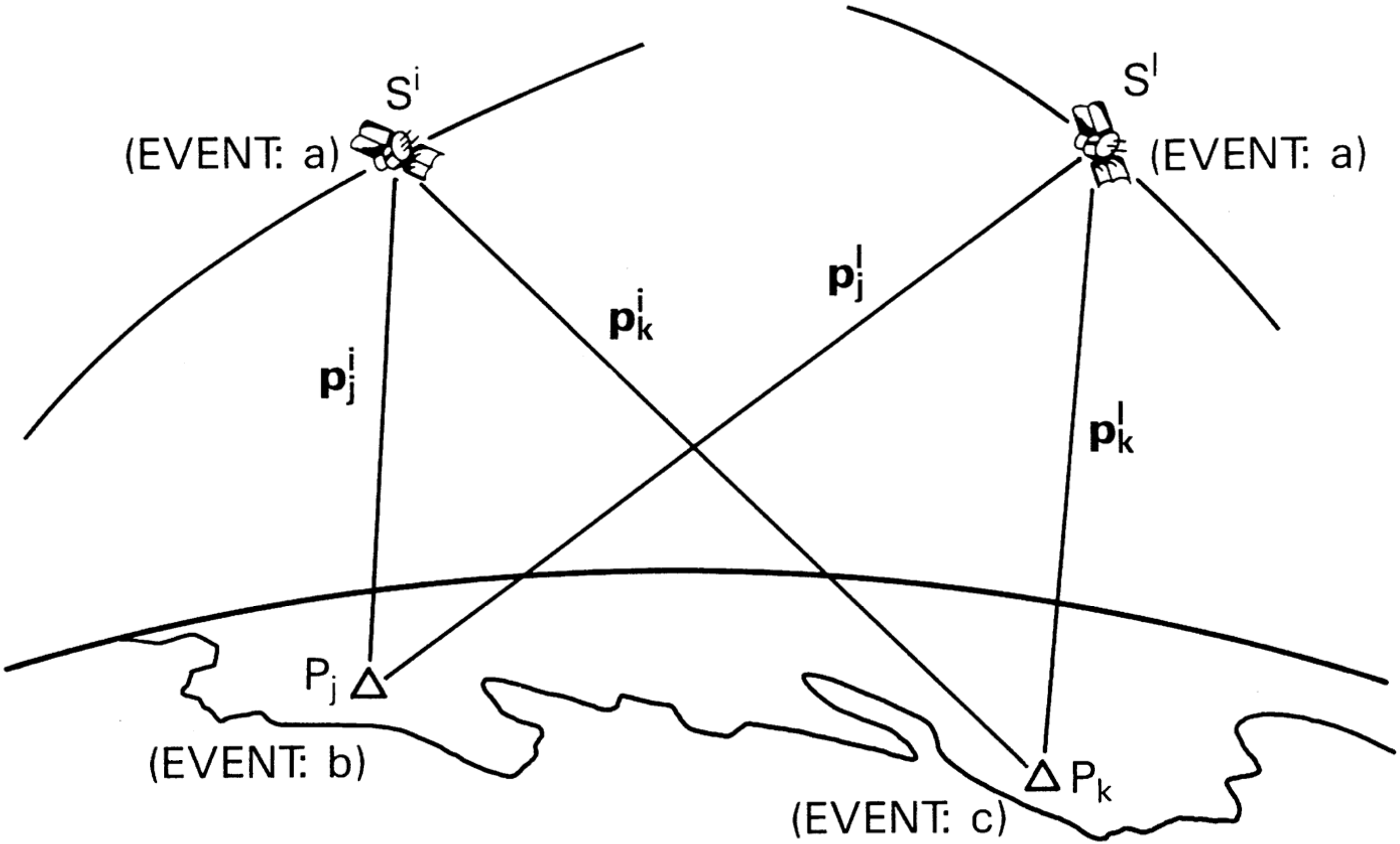
Ionosphere-free observations
Geometry-free observations

GIPSY/OASIS GAMIT/GLOBK BERNESE

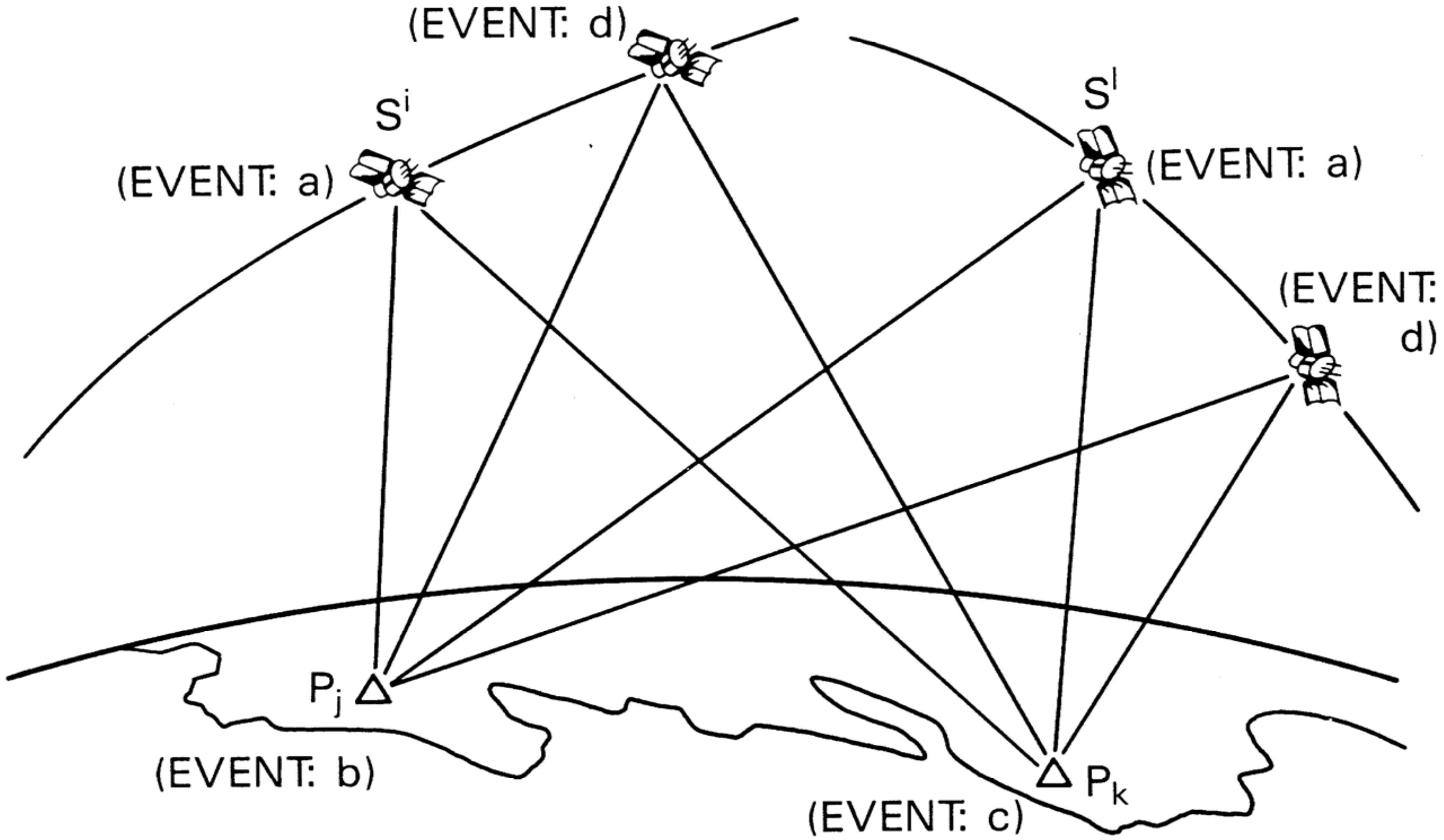
Single difference



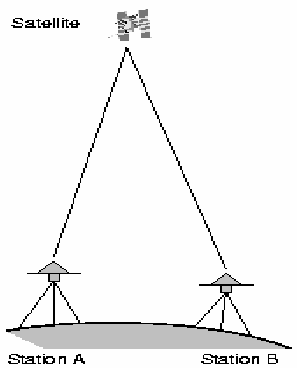
Double difference



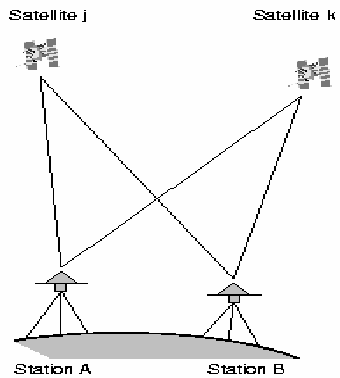
Triple difference



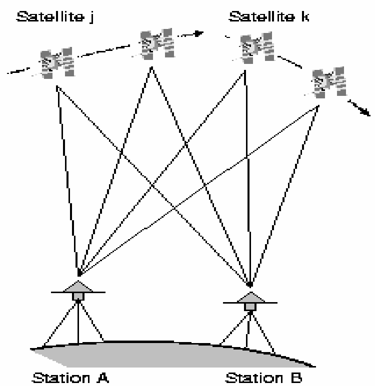
DIFFERENCING: ILLUSTRATIONS



Single Differences



Double Differences



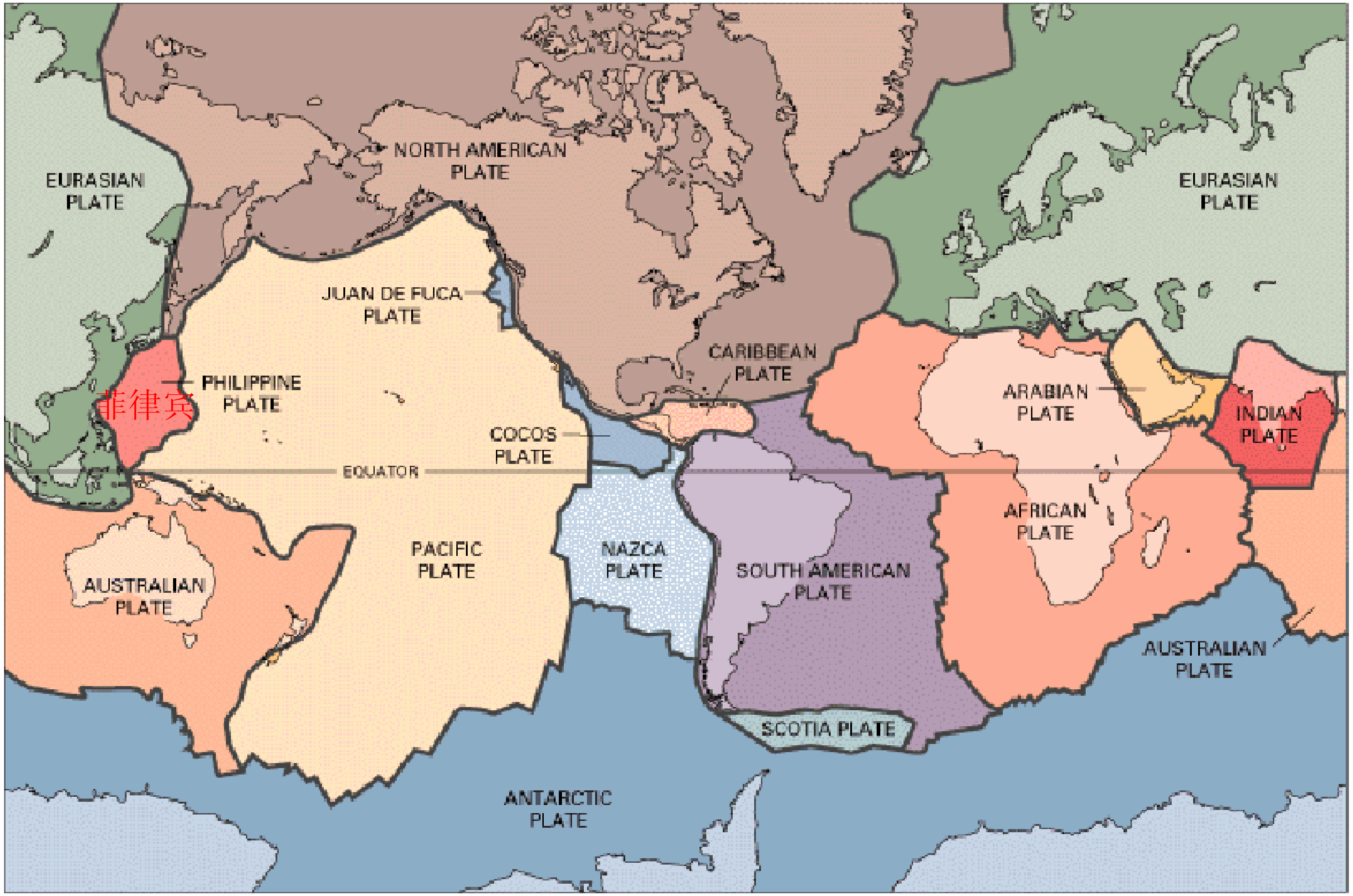
Triple Differences

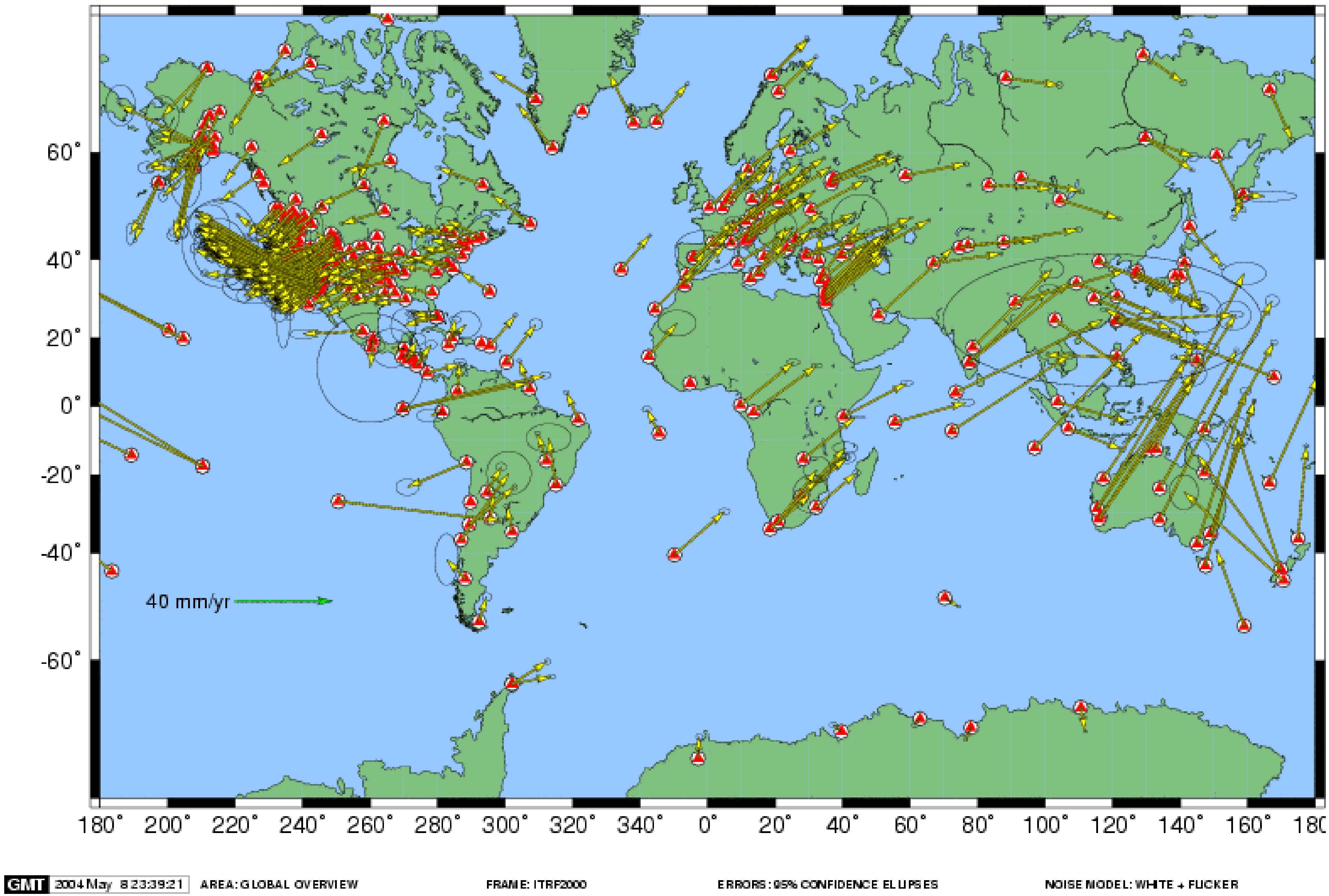
7 Application of GNSS（GPS）in Earth Science

Geodesy
Geodynamics----plate motion
Space physics----ionosphere monitoring
Meteorology----water vapor monitoring
Crustal movement----earthquake prediction, volcanic activity, land subsidence, land slides
Sea level change
Satellite orbit determination for deferent missions for earth science

Seismicity、 plates and plate motion

Tectonic Plates





2004,5,9 SIO

Plate motion

Horizontal Displacement on Chinese Mainland

Crustal movement

8 Conclusion

Thank you !