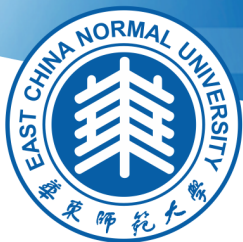


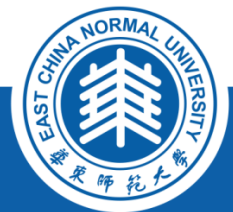
天籁之音——走进千家万户的GPS (全球定位系统 Global Positioning System)



报告人：董大南

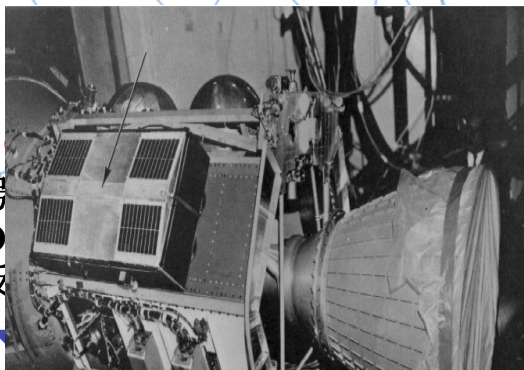
大纲

- GPS历史
- GPS基本原理
- GPS应用
- GPS发展



GPS前期历史

1号D反



全面：验证了用卫星定位的可行性
全面：覆盖面局部，受天气条件影响，2维定位



1967, 第一颗定时卫星 (Timation) 海军军发射, 原子钟引入

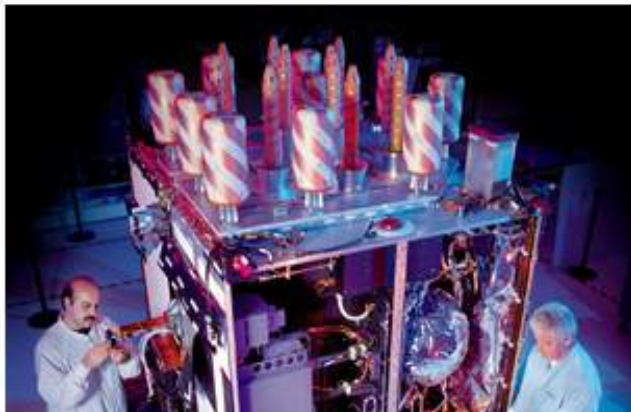
1963-1972, 空军同时在研发类似定位系统 (System 621B), 3维定位,

PRN引入



PRN极大地提高了通讯和抗干扰功能,
1960-, 陆军也在研发定位系统 (SECOR)

GPS历史



8-1985, (洛
尔公司) **Block**
星 (11, 1 失
Phase II 经历
ending cut

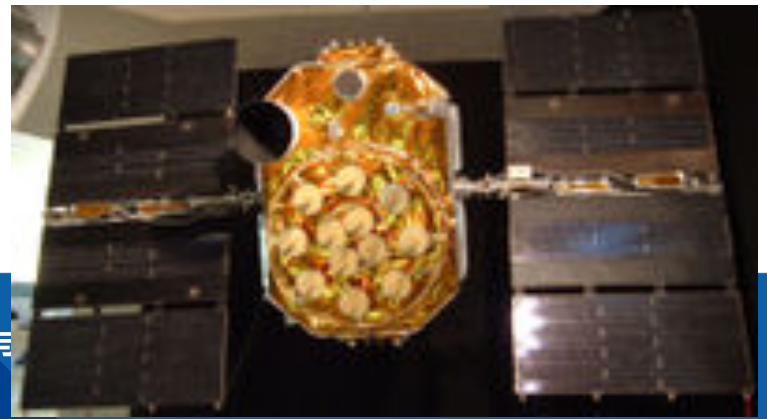
1995-, **Block IIA/**
IIR 卫星 (21)



1989-1994, **Block**
II 卫星 (24, 4 备用),
I公司

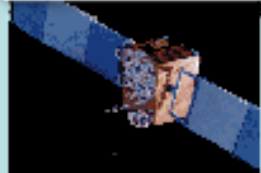


Block IIF 卫星
(33) 在 **Block IIR**
卫星退休后启用,





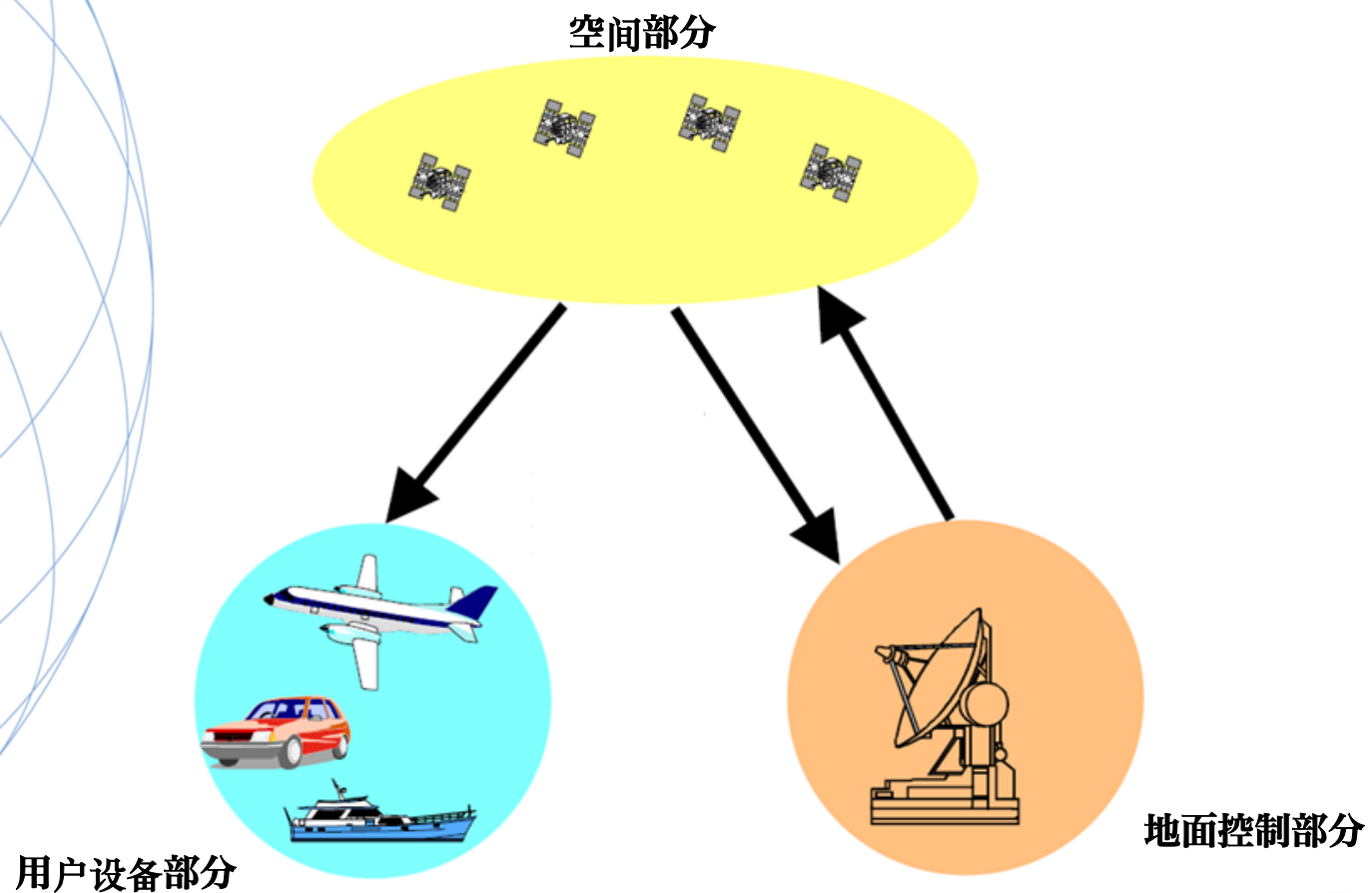
GPS Modernization Program

1978 - 1985	1989 - 1997	1997 - 2004	2005 - 2009	2010 - Present	2014 - 2024
					
Block I	Block II/IIA	Block IIR	Block IIR-M	Block IIF	Block III
11 (10) Satellites	28 Satellites	13 (12) Satellites	8 Satellites	12 Satellites	32 Satellites
Demonstration system	Basic GPS Provides Initial Navigation Capabilities		IIA/IIR Capabilities "Plus"		IIF Capabilities "Plus"
• L1 (CA) Navigation signal • L1 & L2 (P Code) Navigation signal • 5 Year Design Life	• Standard Service • Single Frequency (L1) • C/A code navigation • Precise Service • Two frequencies (L1 & L2) • P (Y) -Code navigation • 7.5 Year Design Life		• 2nd Civil Signal L2 (L2C) • Earth Coverage M-Code on L1/L2 • L5 Demo • Anti-Jam Flex Power • 7.5 Year Design Life		• 3rd Civil Signal L5 • Reprogrammable Nav Processor • Increased Accuracy requirement • 12 Year Design Life
					IIIA • Increased accuracy • Increased Earth Coverage power • 15 Year Design Life • 4th Civil Signal (L1C) IIIB • Real-time Communications IIIC • Navigation Integrity • Spot Beam for AJ

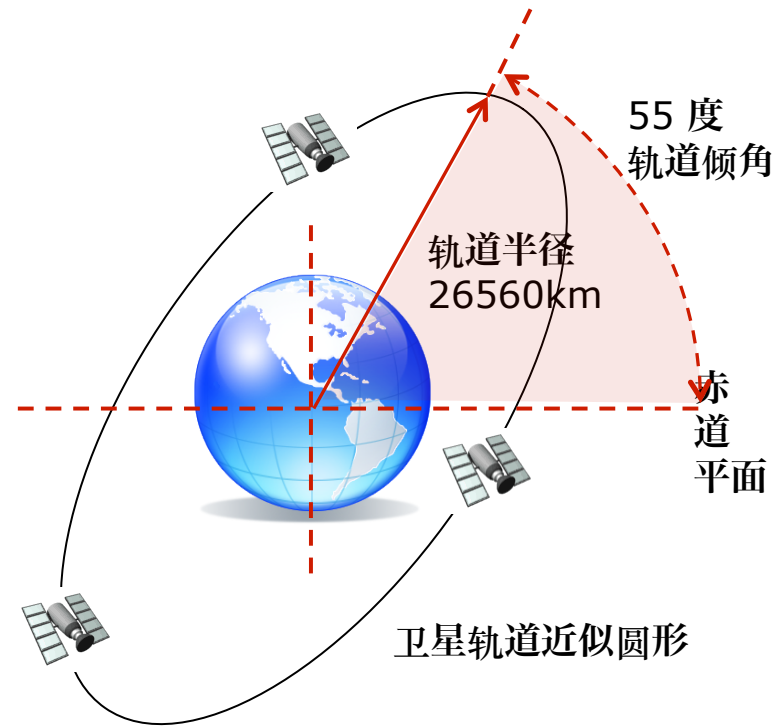
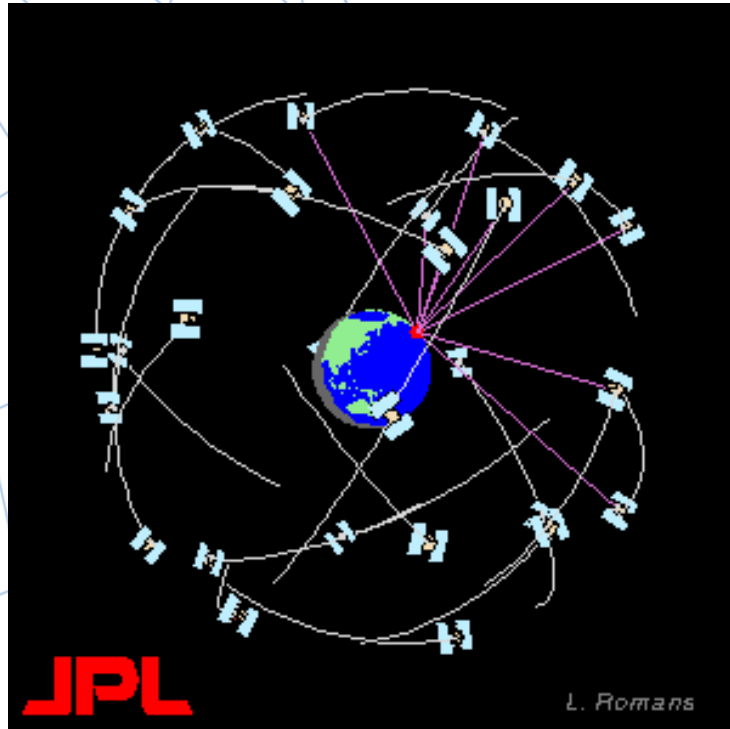
取自D. A. Turner

Increasing Space System Capabilities - Increasing Military/Civil User Benefits

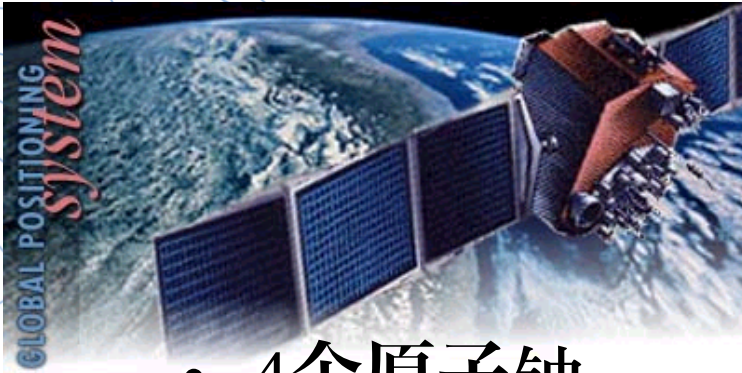
GPS基本组成



空间部分



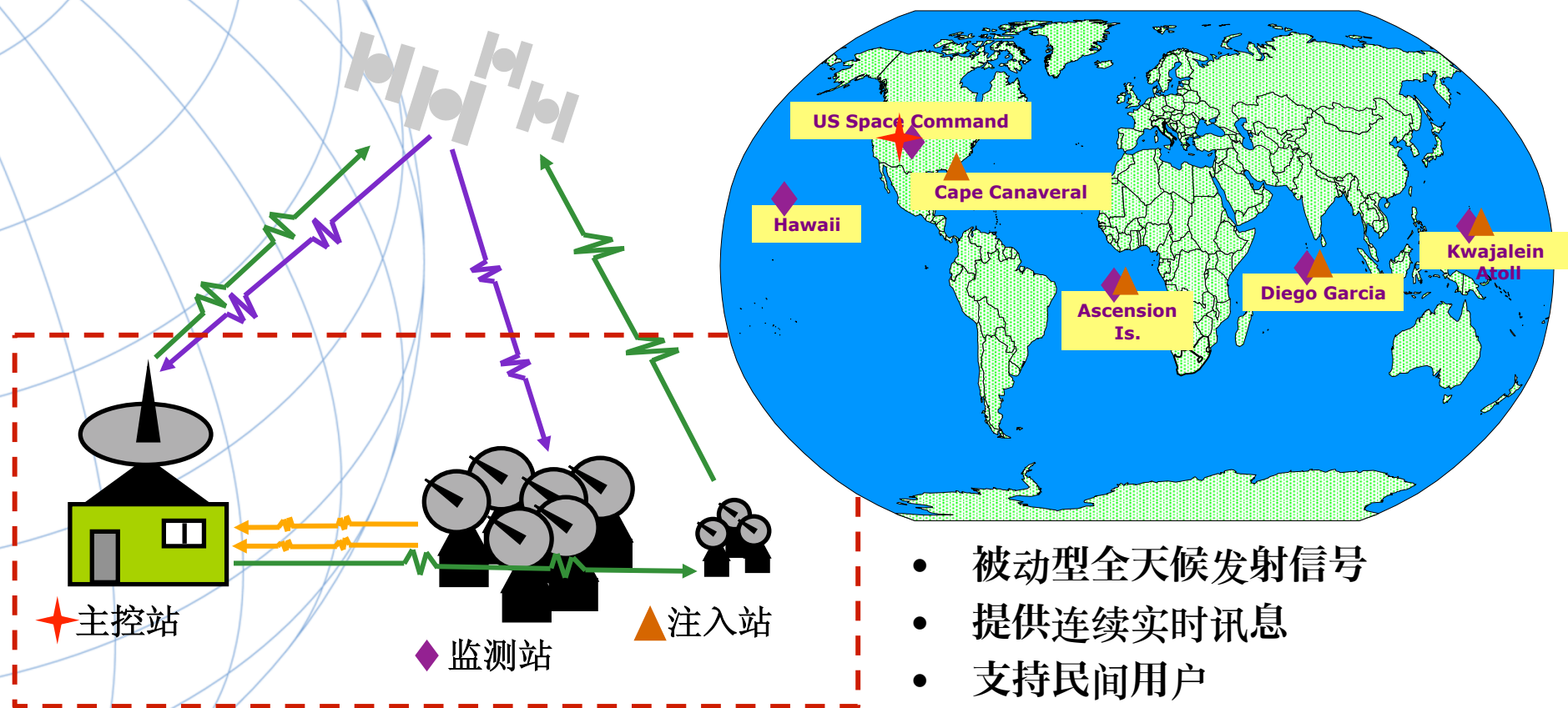
- 24 颗卫星, 3颗备用
- 12 小时周期
- 6 个轨道面, 30 度交角
- 空间位置重复周期23小时56分
- 地球上任何位置任何时刻至少可同时收到至少4颗GPS卫星信号



GPS卫星介绍

- 4个原子钟
- 3个可充电电池
- 2个太阳能发电翼 (1136 watts)
- S band天线 (卫星控制用)
- 12 element L band天线 (发射供用户信号)
- 2370磅 (Block IIF) 重 (主要燃料)
- 16.25英尺高, 38.025英尺宽 (包括太阳能翼)
- 设计寿命10年

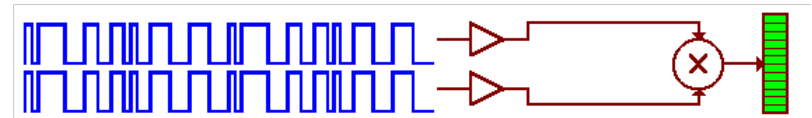
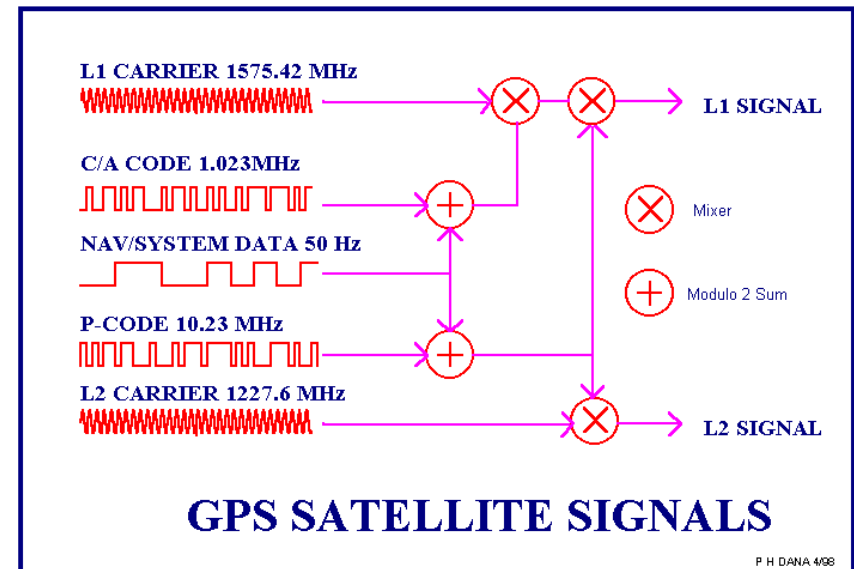
地面控制部分



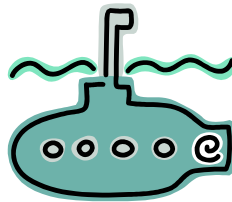
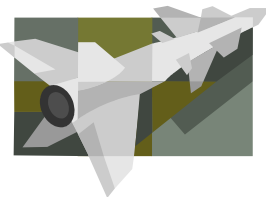
- 被动型全天候发射信号
- 提供连续实时讯息
- 支持民间用户
- 导航服务包括提供卫星的位置，速度和精密时间

GPS信号

- L1 (1575.42 MHz), L2 (1227.60 MHz) 载波
- CA (coarse acquisition) 码 (1.028 MHz) 调制 L1 载波, 每颗卫星用不同的 PRN (100米精度)
- P (precise) 码 (10.23 MHz) 调制 L1 和 L2, 在 AS 模式时 P 码加密成 Y 码 (10米精度)
- 导航信息(50 Hz) 调制 L1-CA 码 (轨道, 时钟改正, 和其它系统参数)



用户设备部分



- GPS 接收机, 天线, 电池
- 单频或双频
- 连续观测或间断观测
- 实时解或后处理精密解
- 导航, 授时, 定位或其它
- 军事, 民用, 工农业, 交通运输, 科学研究

GPS应用

- 定位
- 导航
- 追踪
- 制图
- 定时



GPS载波相位定位



上世纪**70**年代，**MIT**教授**Counselman**提出用**GPS**载波拍频相位定位的革命性想法



从此**GPS**的应用进入了各行各业，并且进入了相关的科学研究



1980年，他们在**Haystack**天文台停车场上用**Macrometer V1000**接收机实现了载波相位定位，精度达到厘米级

GPS 接收机



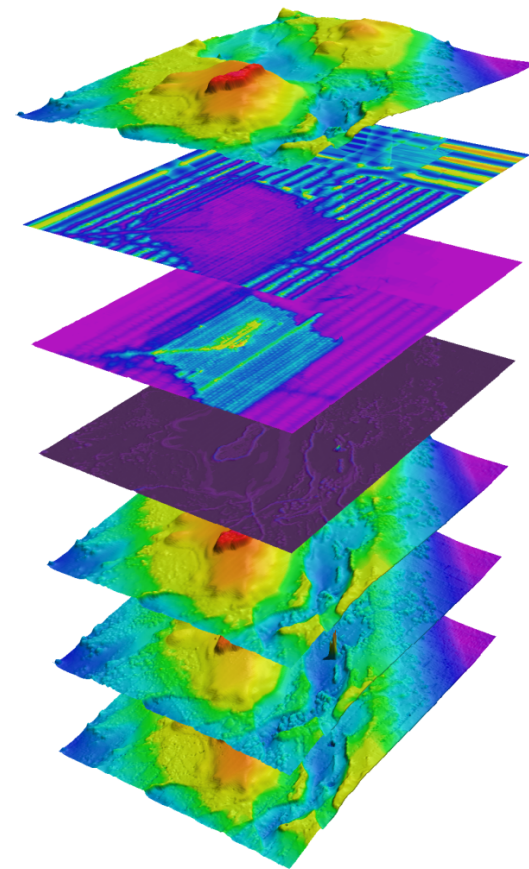
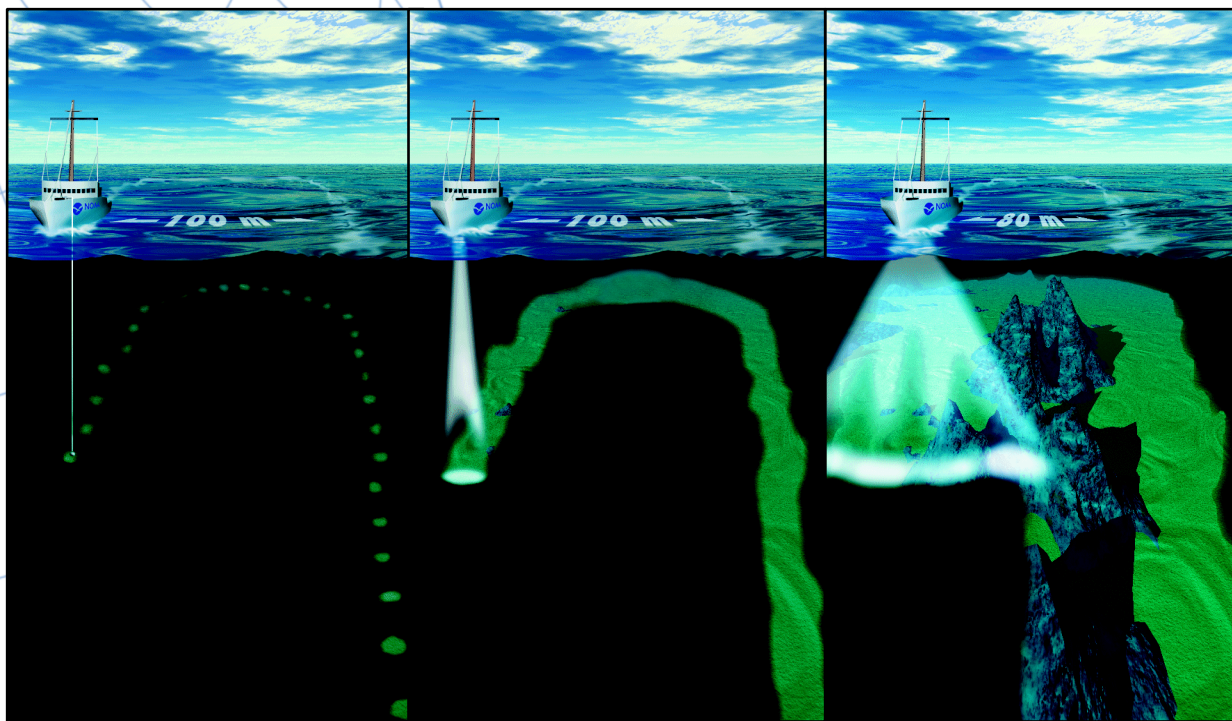
GPS应用：军用



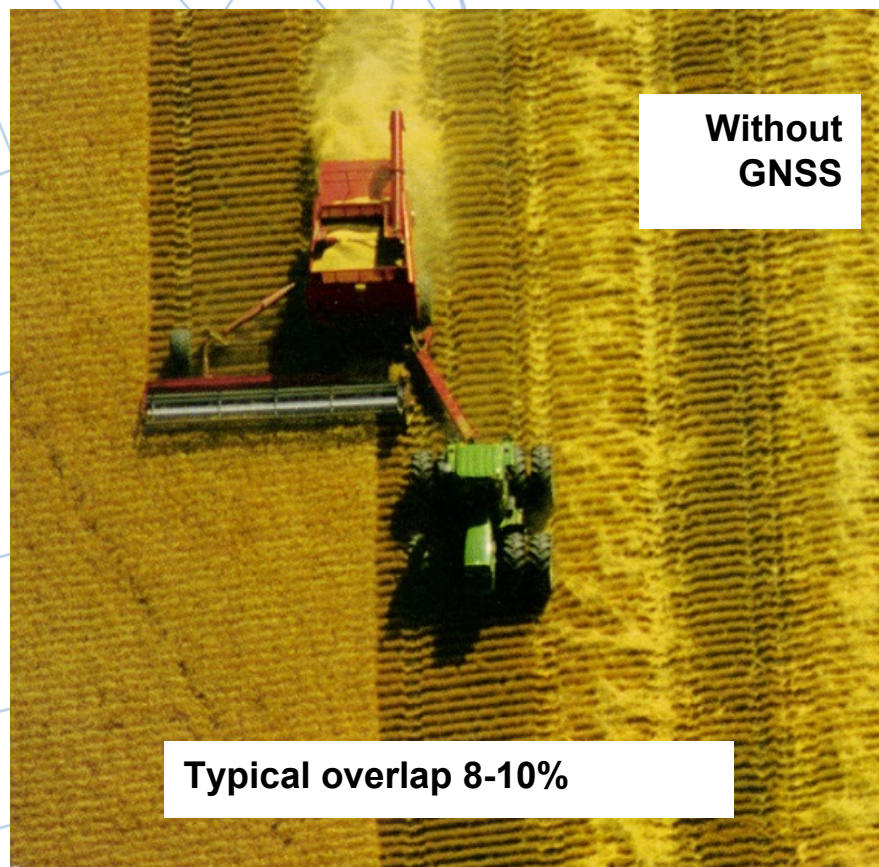
GPS应用：民用



GPS在海洋上的应用

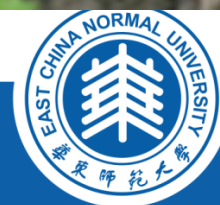


GPS应用：精准农业



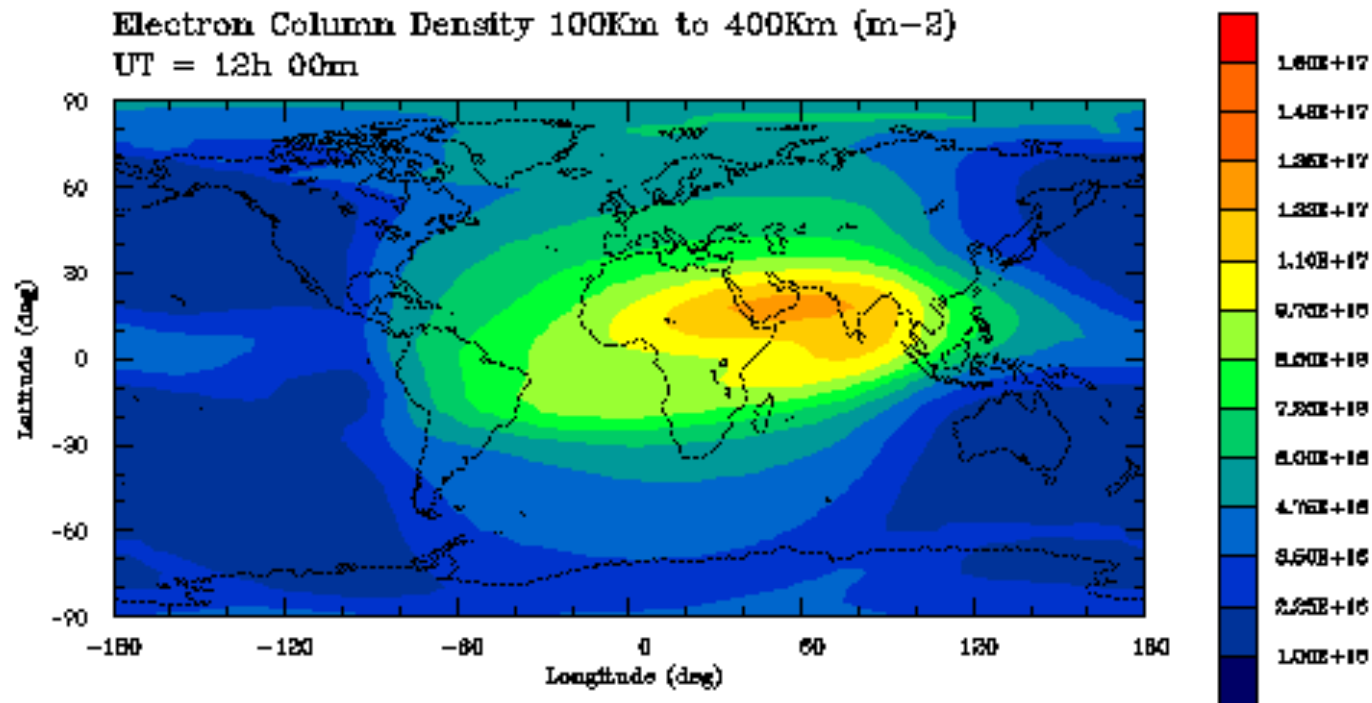
取自M. O'Connor

空间信息与定位导航上海高校工程研究中心

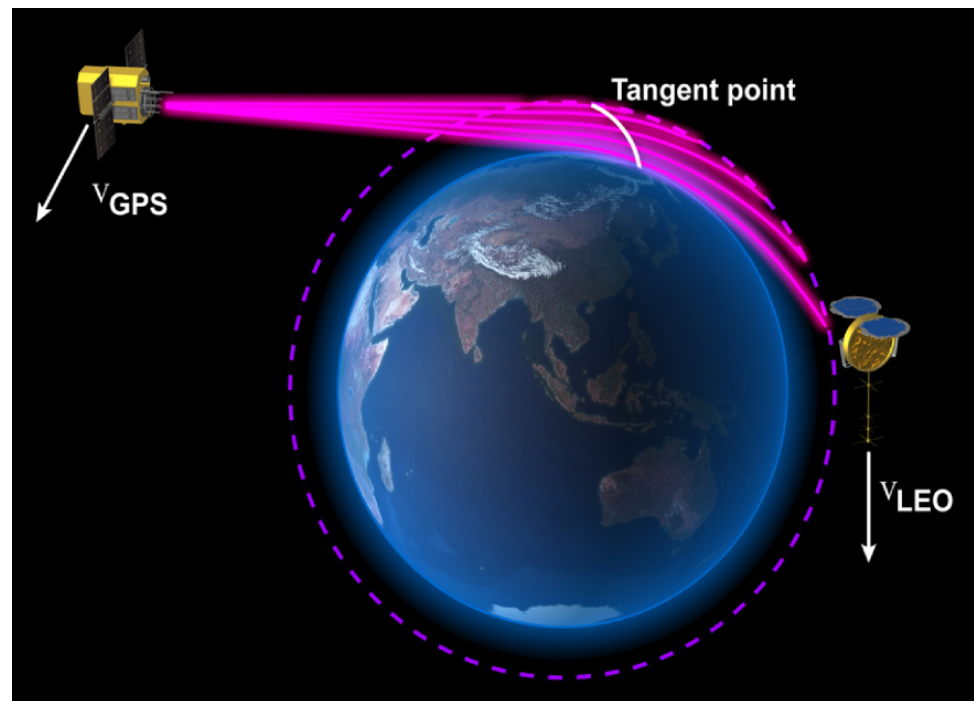
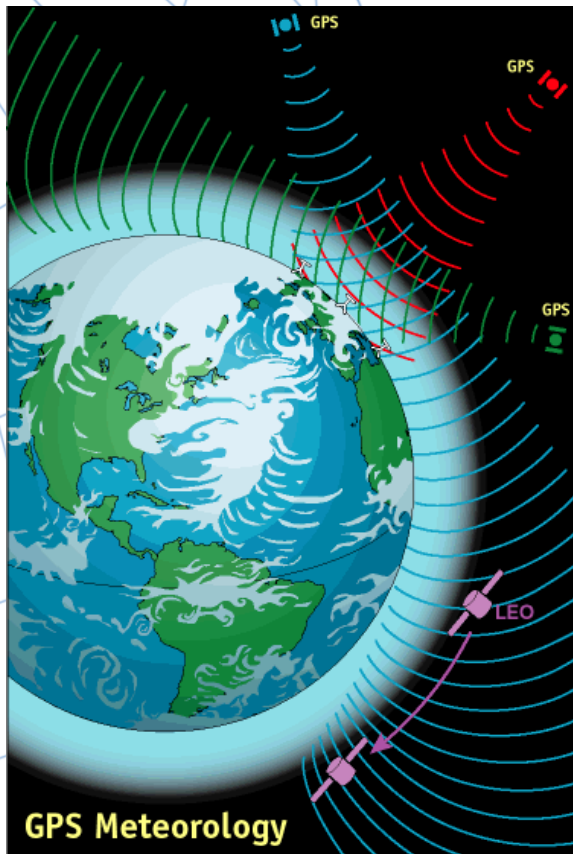


GPS科研：电离层

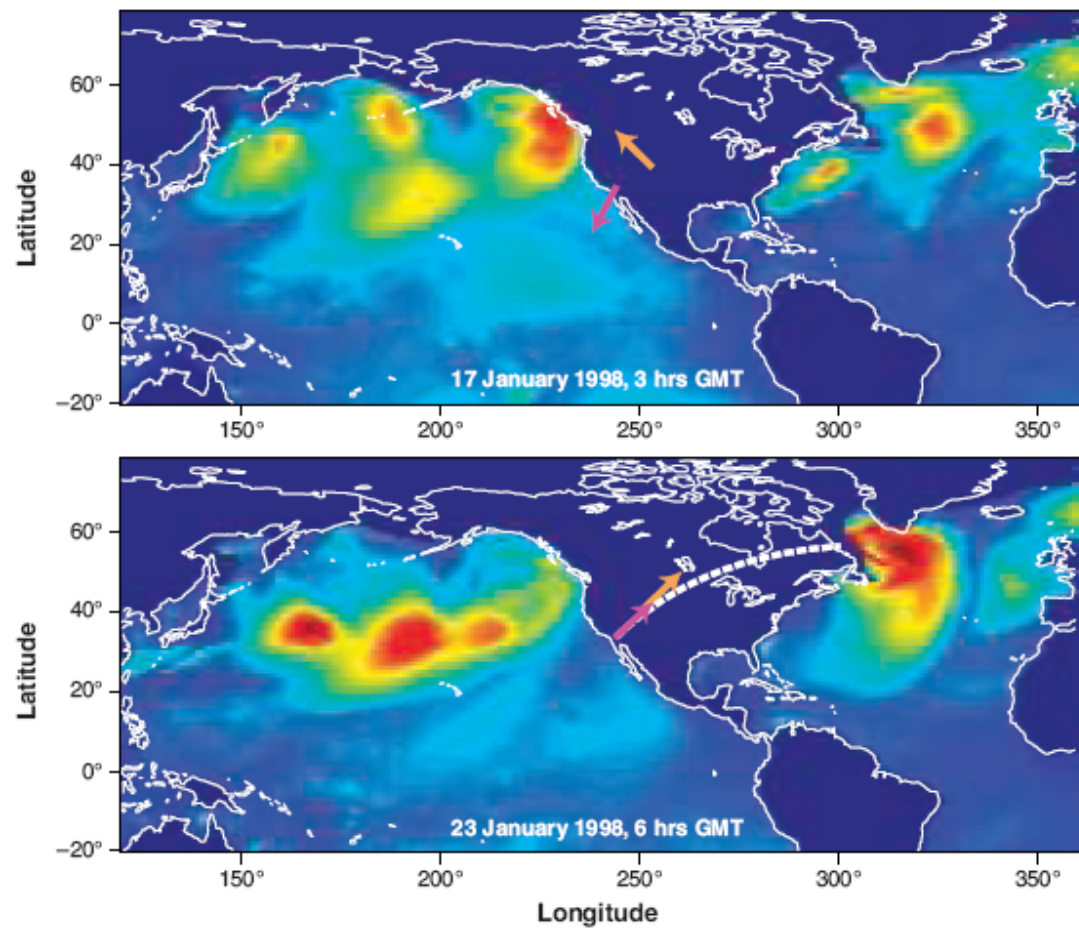
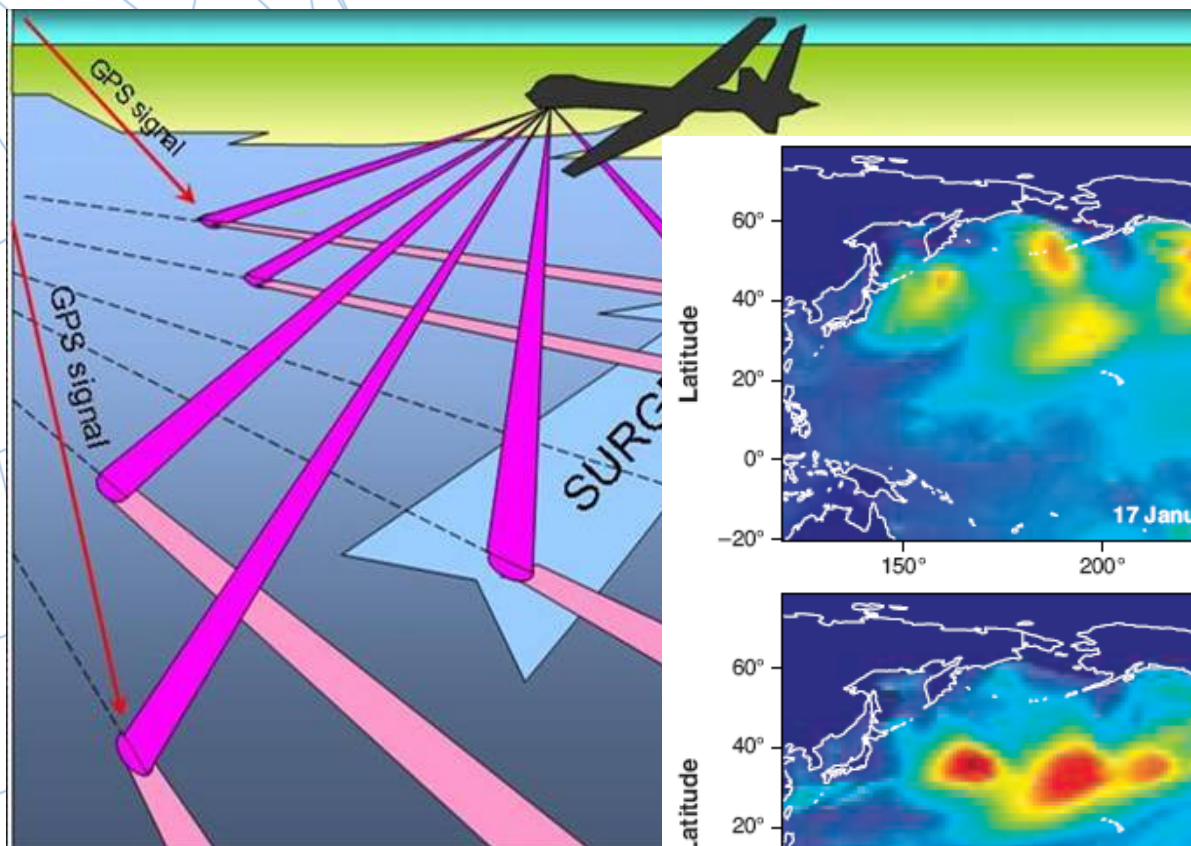
Quiet Ionosphere UT = 12h 00m



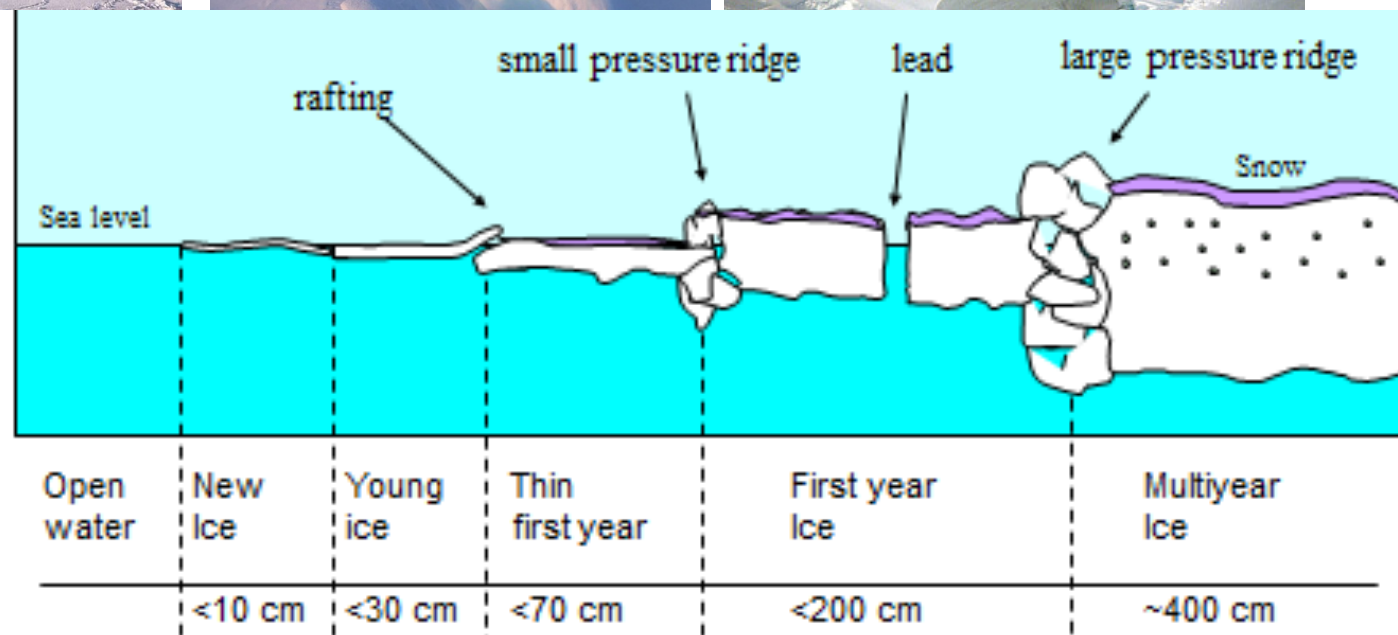
GPS科研：大气层



GPS科研：海洋

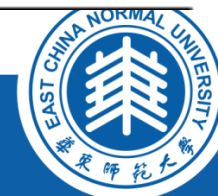


GPS科研：极地，冰山



取自Colorado大学

空间信息与定位导航上海高校工程研究中心



GPS科研：地表物质迁移

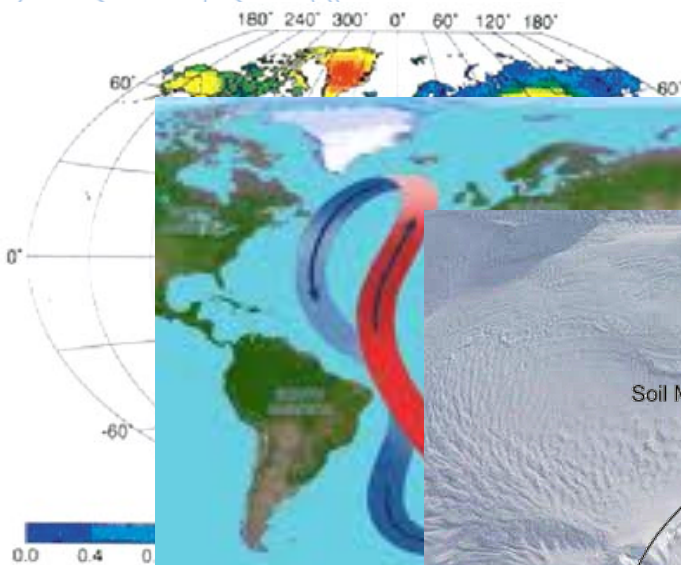
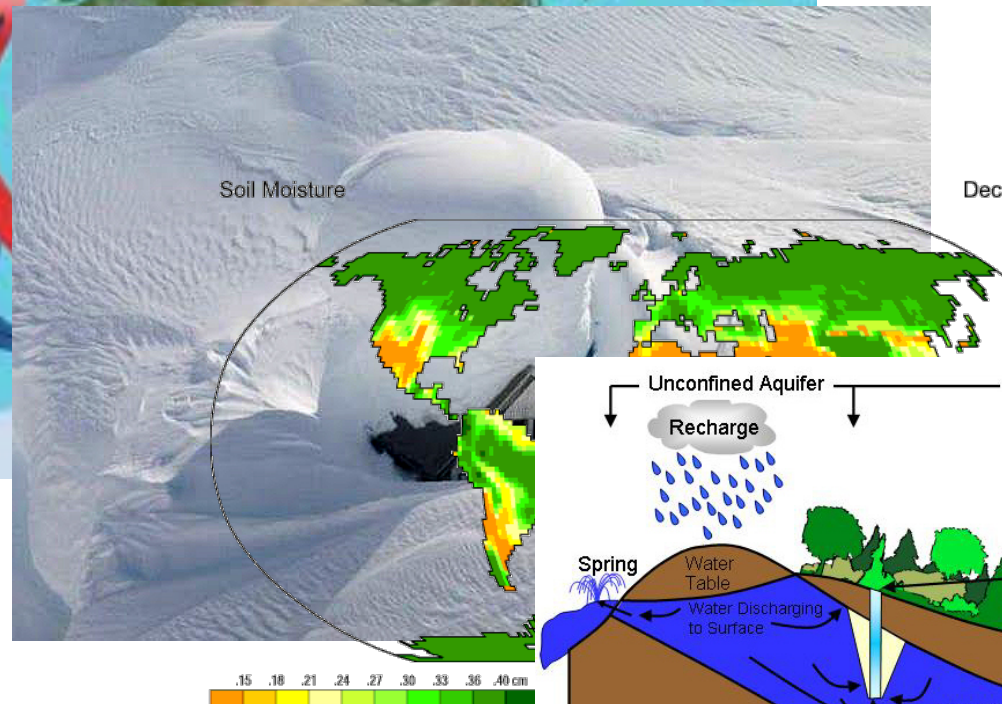
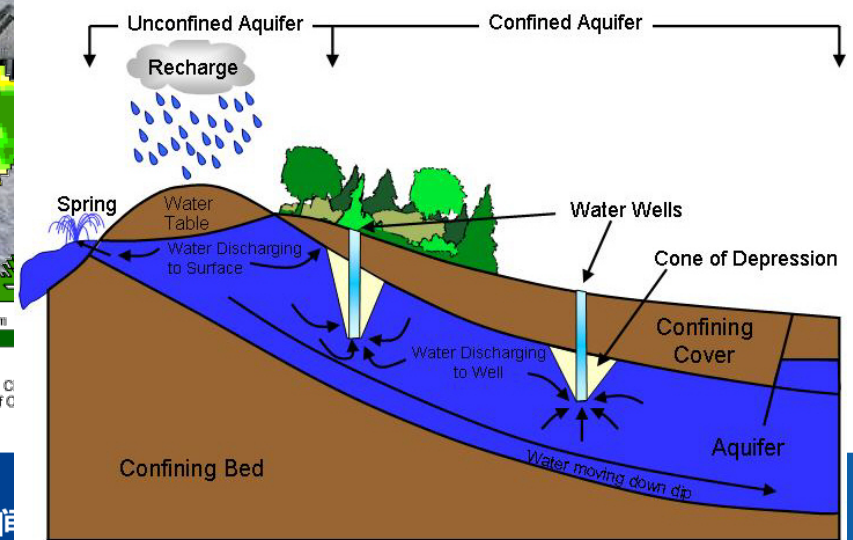


Figure 2 – Annual
from National Center

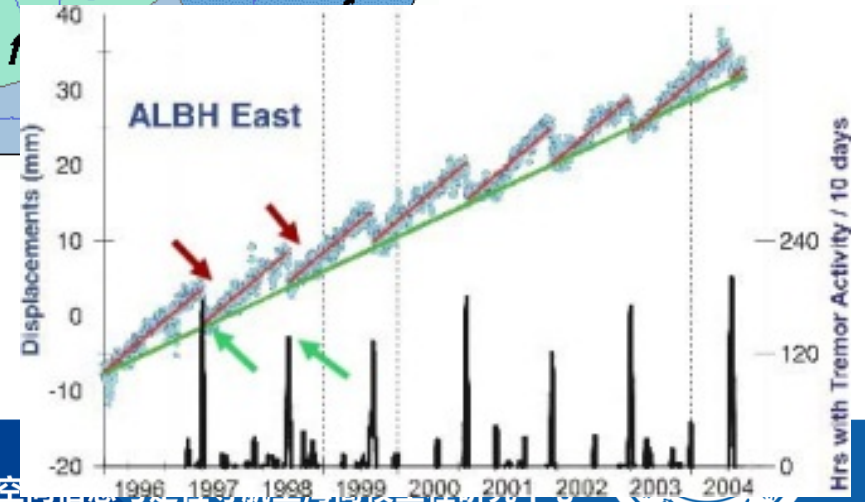
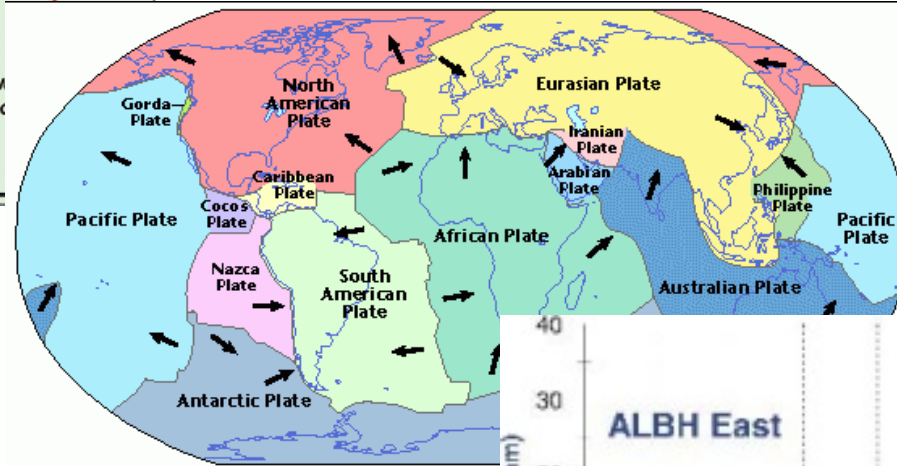
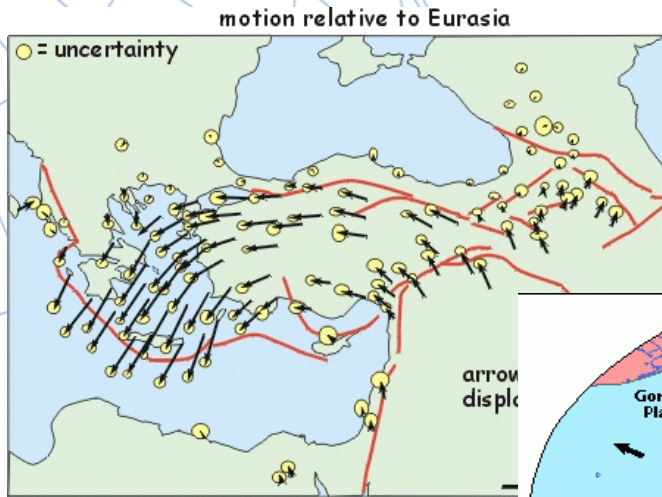


Data: NCEP/NCAR Reanalysis Project, 1959-1997 C
Animation: Department of Geography, University of C

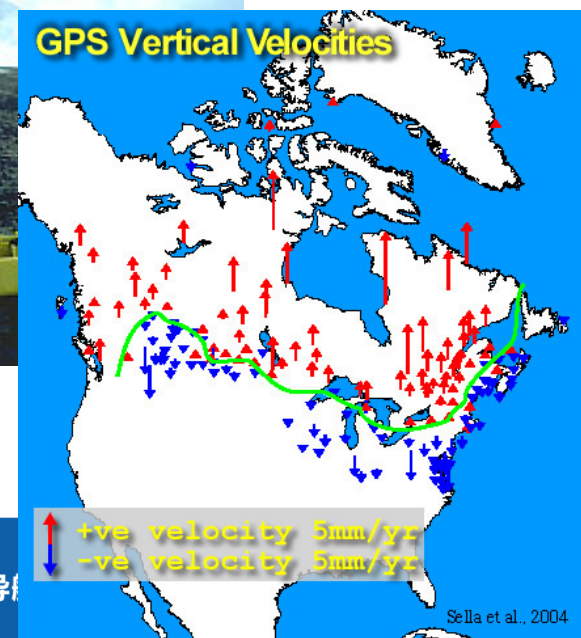
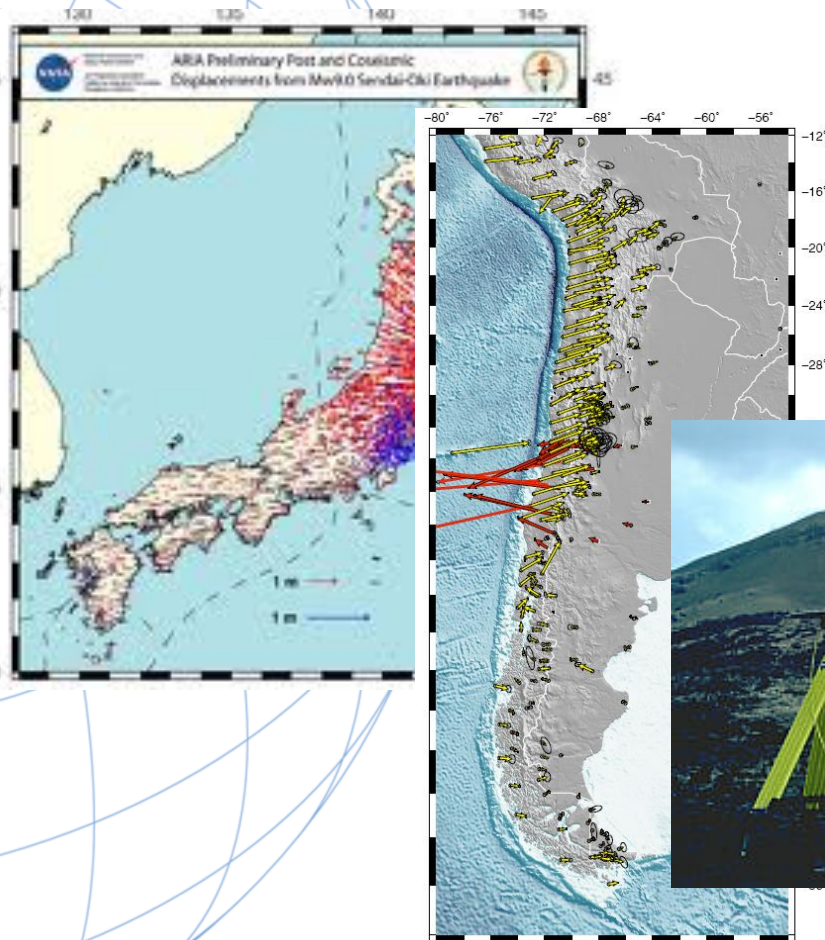


空间

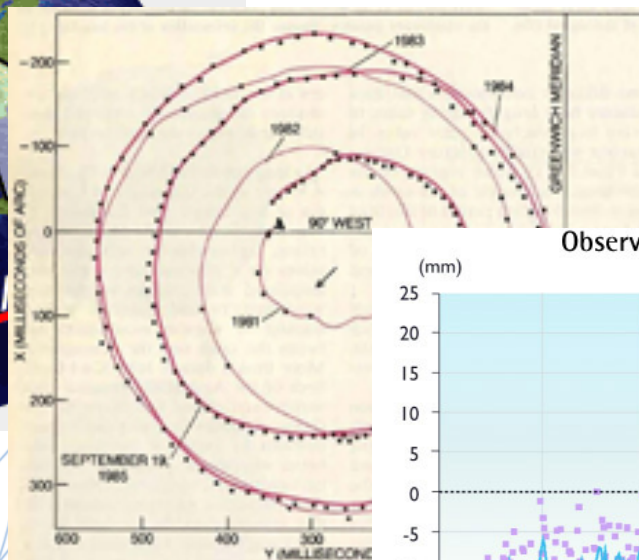
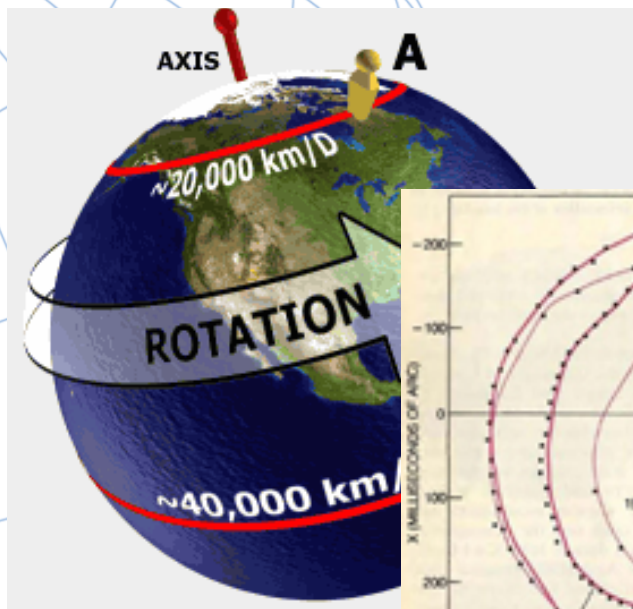
GPS科研：构造运动



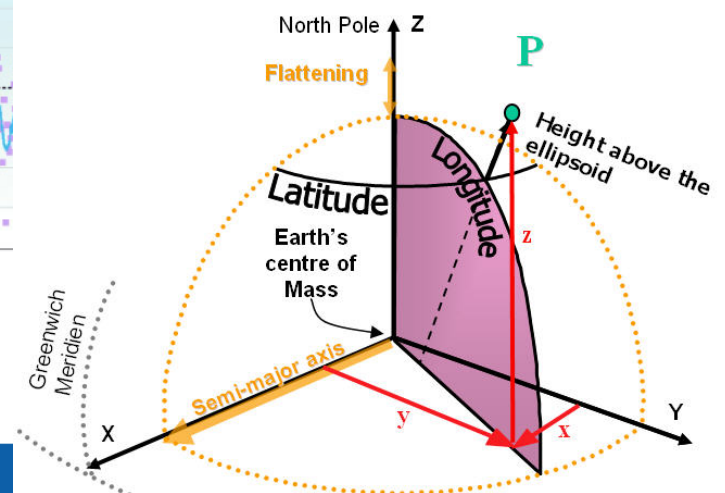
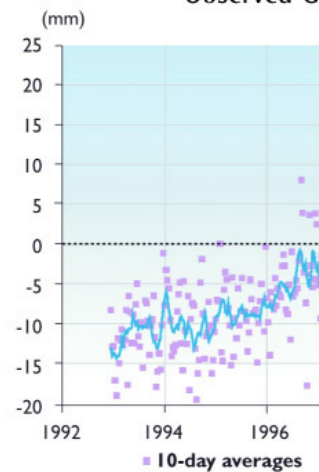
GPS科研：构造运动（续）



GPS科研：全球变化



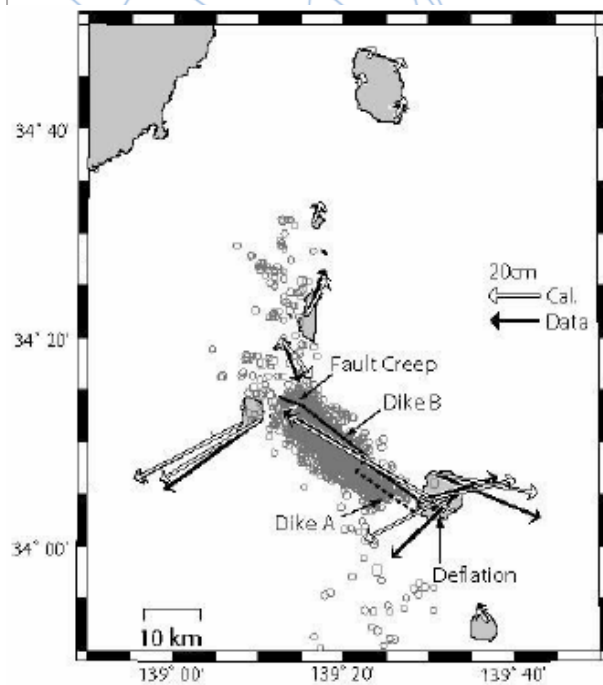
Observed Global Sea Level Rise



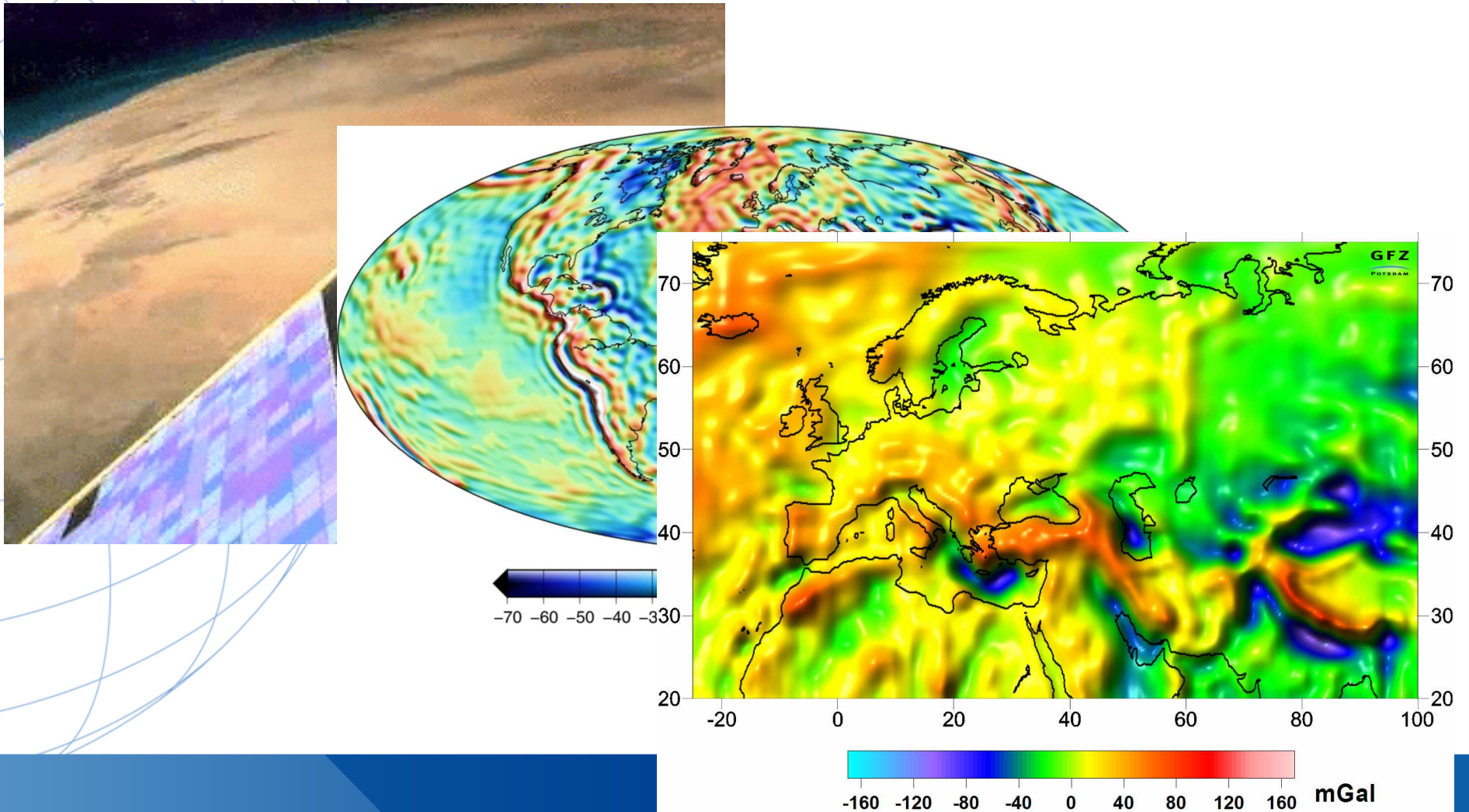
GPS: 环境, 自然灾害监测



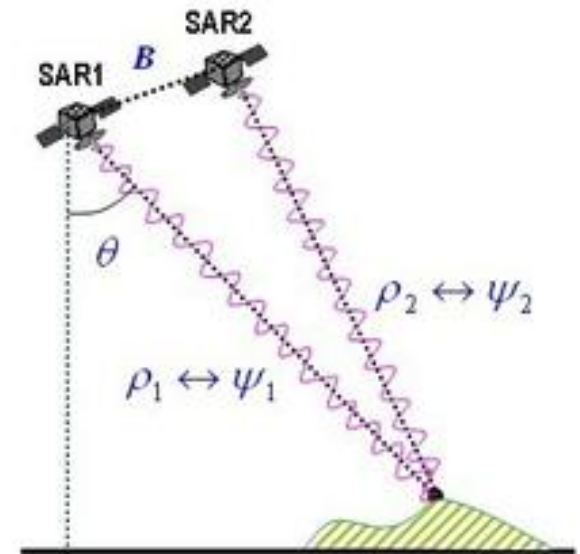
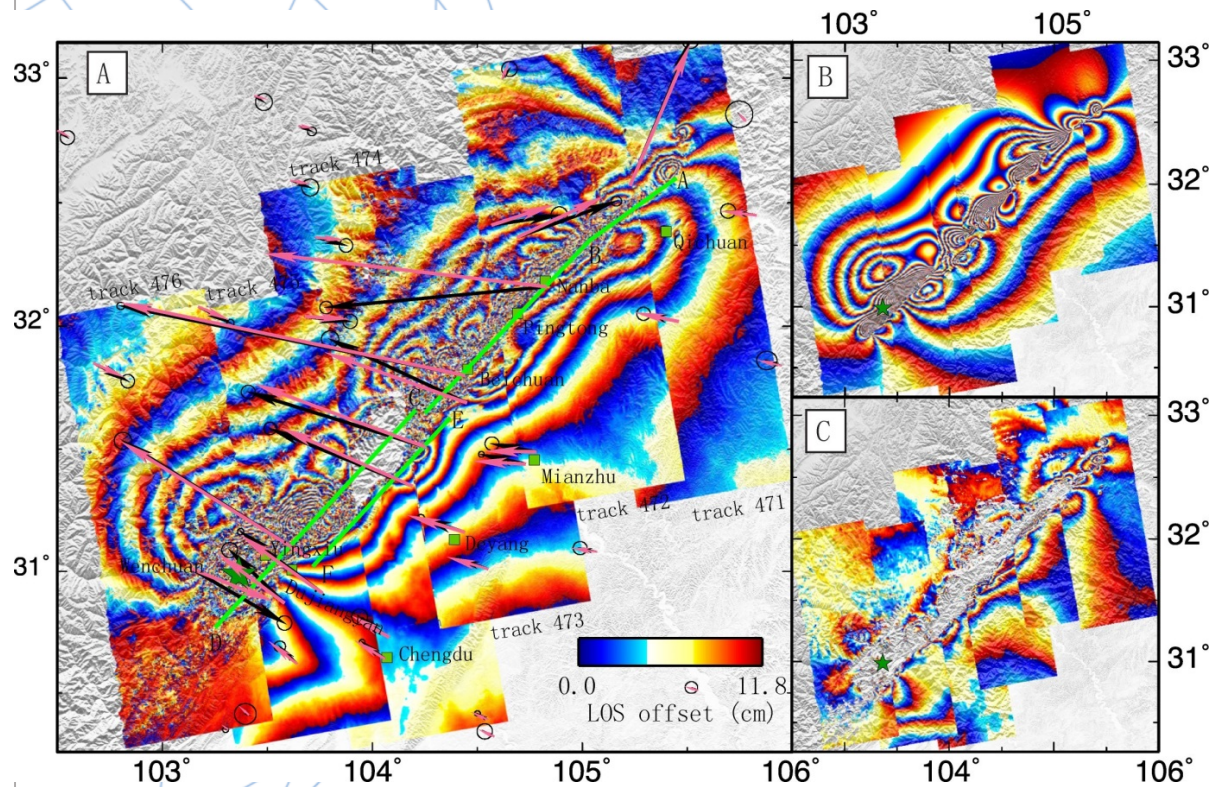
Miyakejima 火山爆发



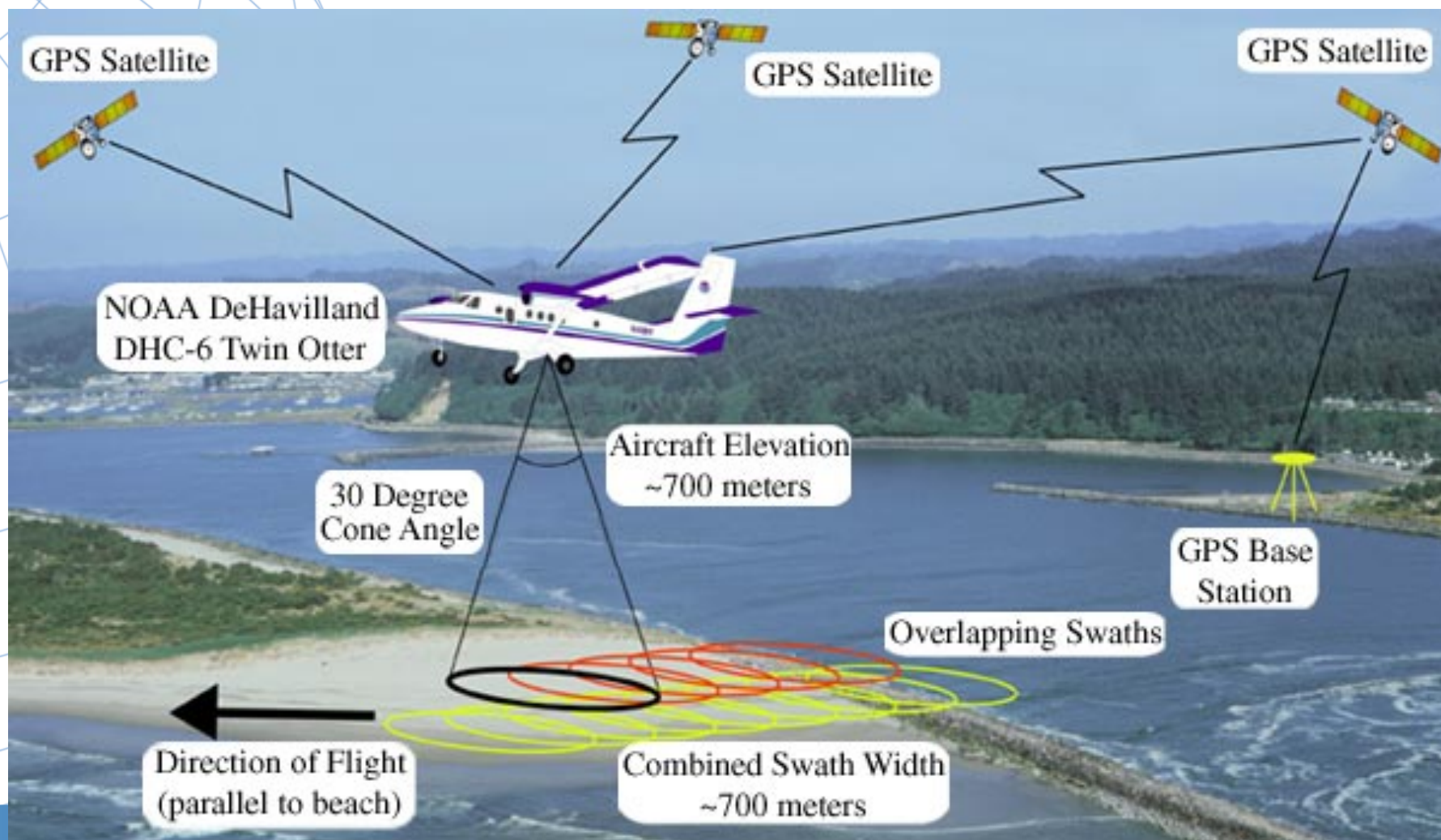
GPS：支持重力卫星

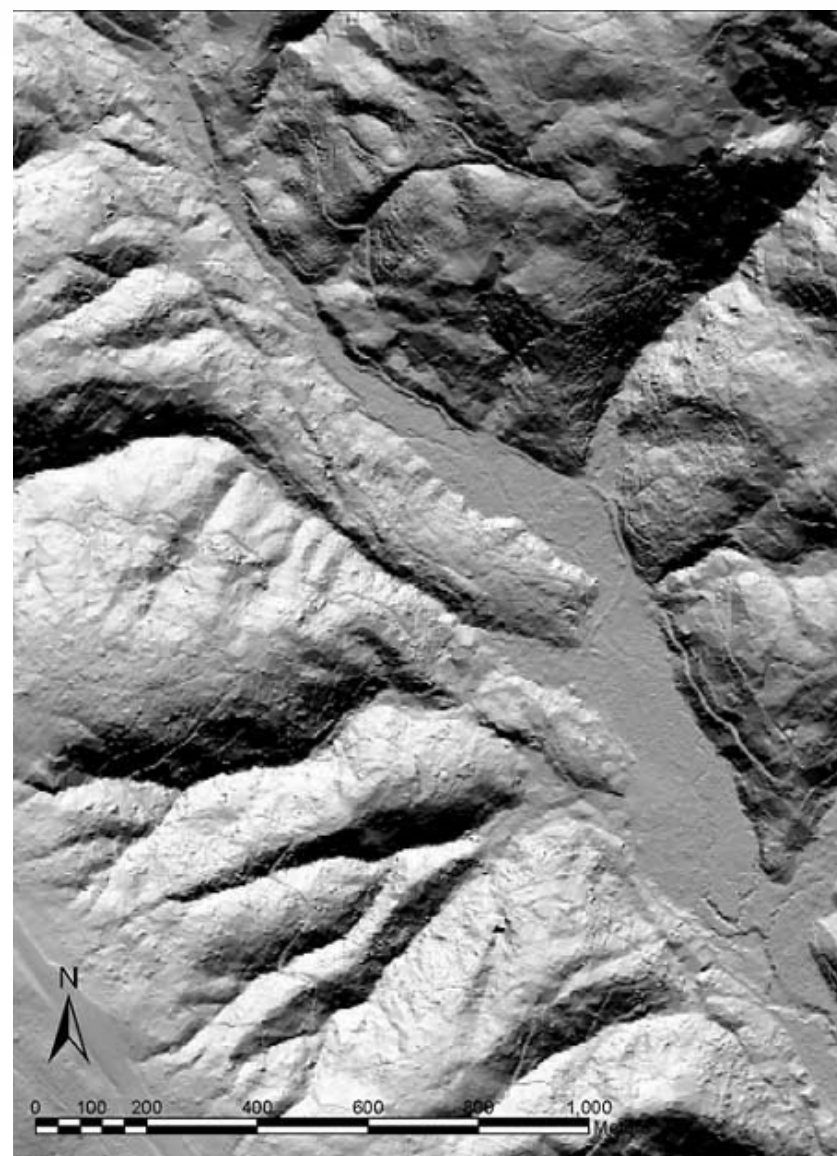


GPS : 支持InSAR

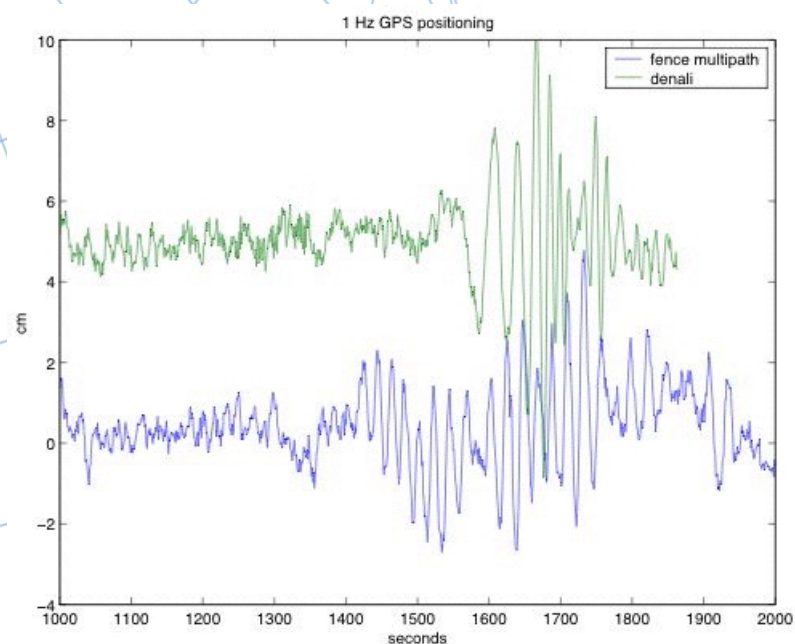


GPS : 支持激光雷达

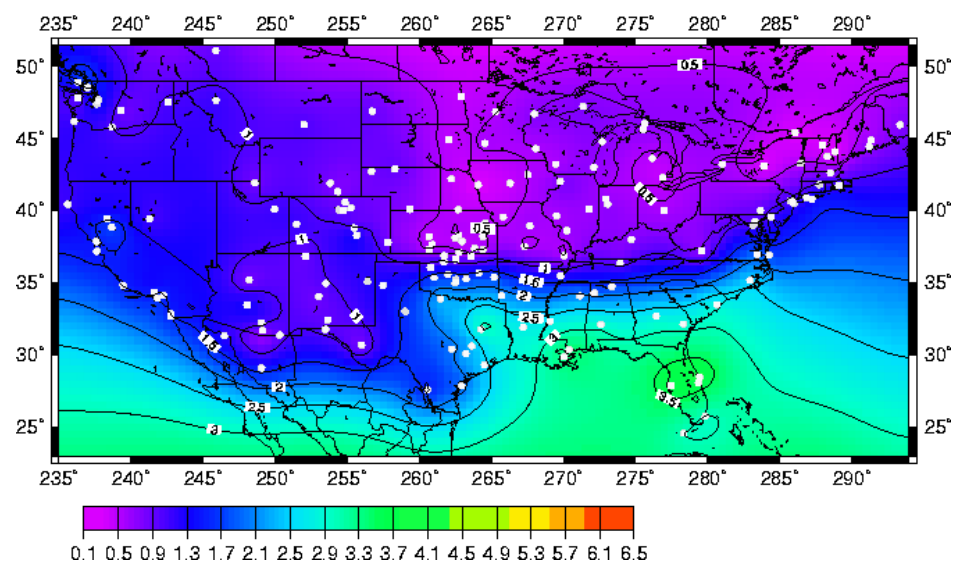




GPS发展：实时监测



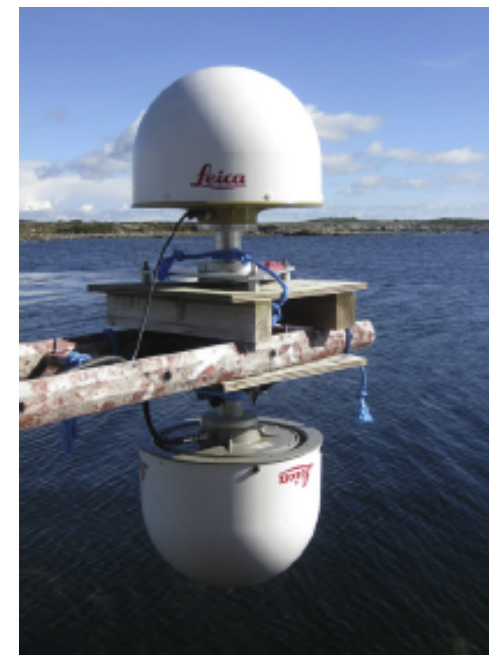
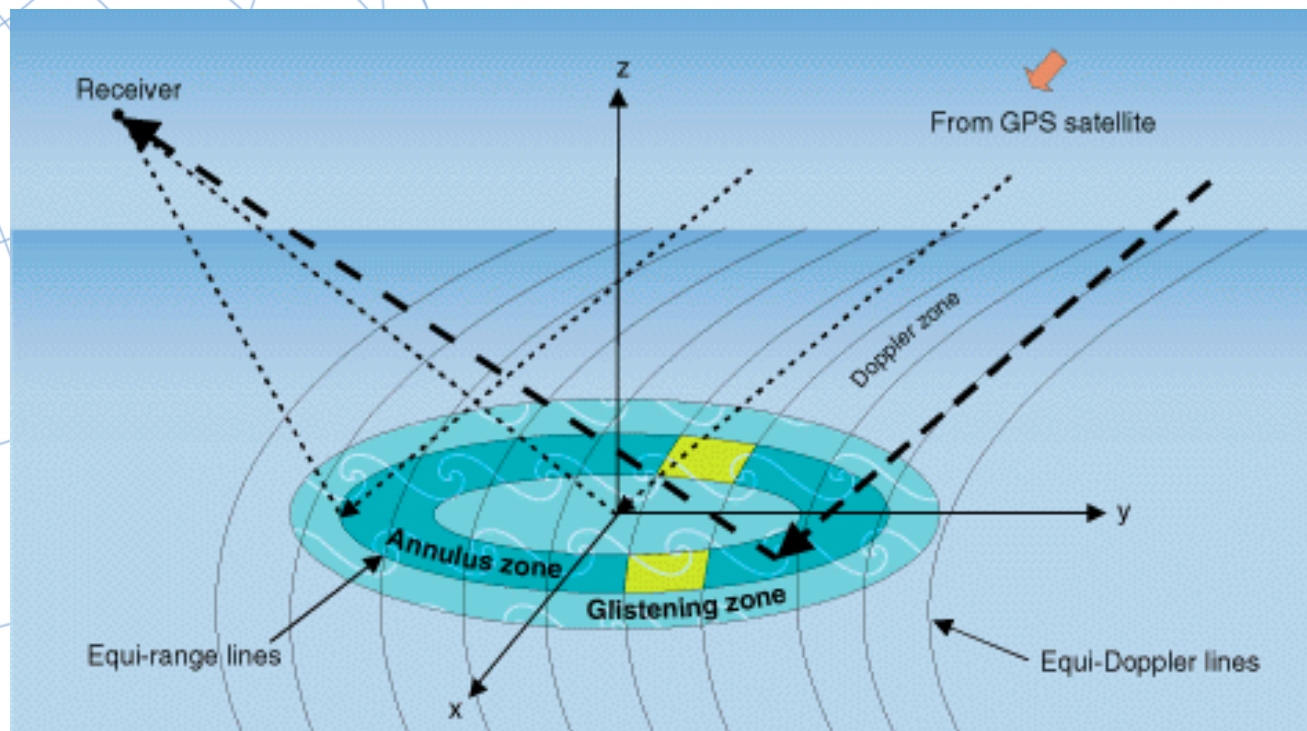
PWV 00h-1h 02/25/04



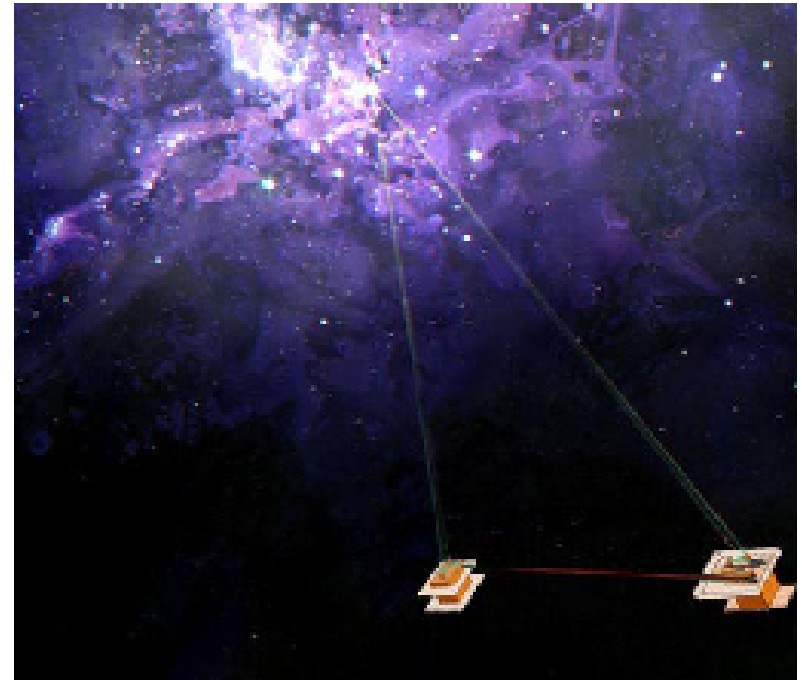
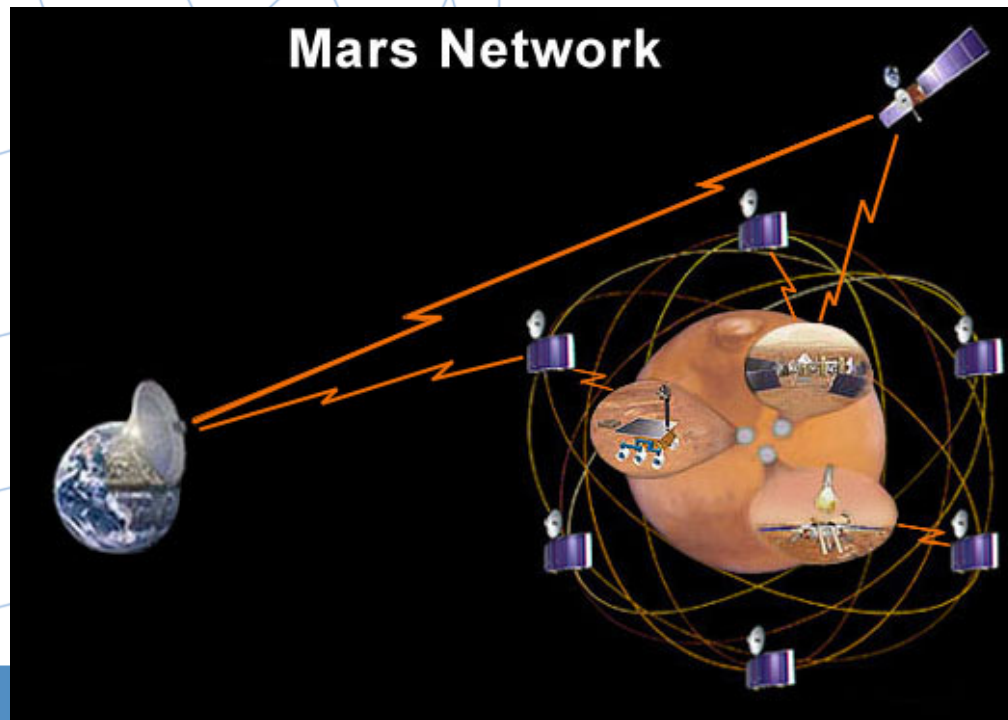
延伸：室内定位



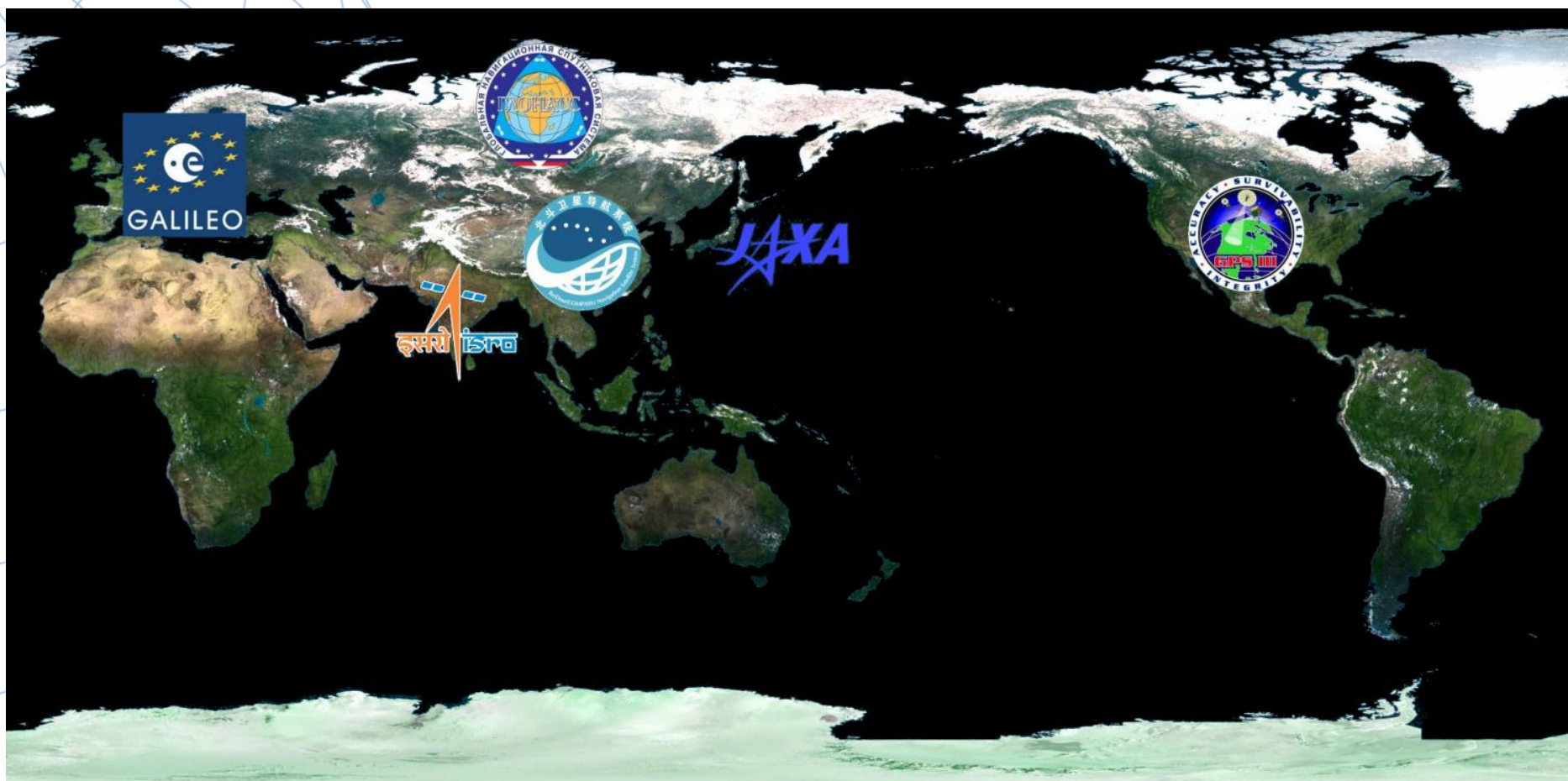
化腐朽为神奇——GNSS-R



GPS走向深空探测



GNSS — 从一枝独秀到四足鼎立



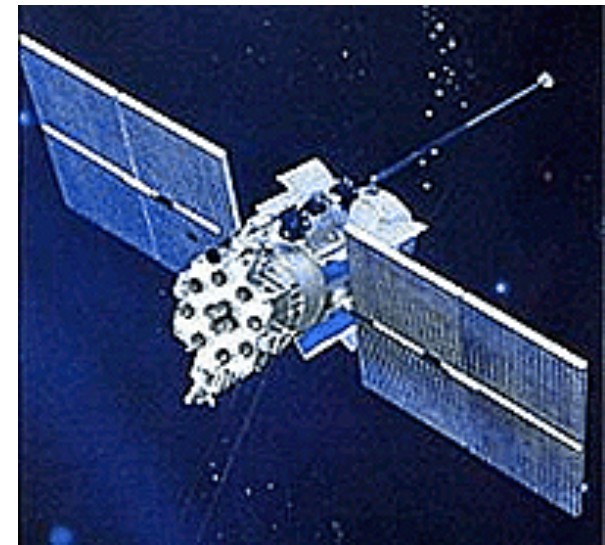
GPS的改进

- 增加第二个民用频道
(L2C) (2016)
- 增加第三个民用频道
(L5) (2020)
- 增加第四个民用频道
(L1C) (2026)



GLONASS

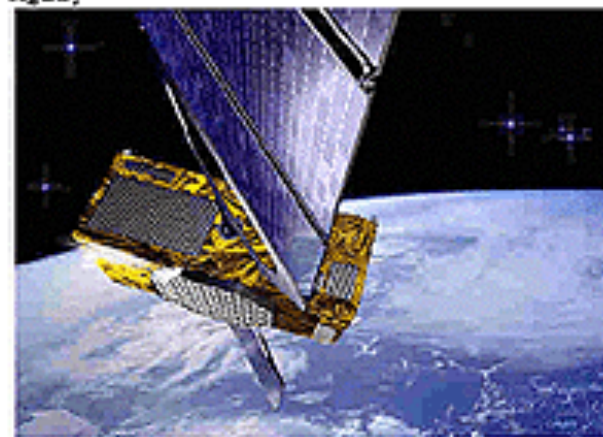
- 前苏联从上世纪80年代起开始发展
- 24颗卫星，3个轨道平面，轨道倾角 64.8°
- 1598.0625 – 1604.25 MHz，每颗卫星有自己不同的频率
- 离地面19130 公里高
- GLONASS-K 将增加第三个民用信号



Galileo

- 欧洲共同体从1994年开始开发
- 30 颗卫星 (3 颗备用), 分布在3 个圆轨道平面, 倾角 56°
- 1164-1214, 1563-1591 MHz
- 离地面23616 公里高
- 设计卫星寿命12年以上
- 系统一旦出现问题, 可在10秒钟内察觉
- 完全为民用

GALILEO GPS Satellite
Country: European Space
Agency



Galileo (2)

First 2 IOV Satellites
launched October 2011
2 more in October 2012



At least 18 out of
a total of 30
satellites will be
in orbit by the
end of 2014.

Galileo System Testbed v2
2 initial test satellites
2005



2003



Initial Operational Capability
Early Services for OS, SAR, PRS

2014 (OS/SAR) – 2016 (PRS)

In-Orbit Validation
IOV satellites plus
ground segment

2011/2012

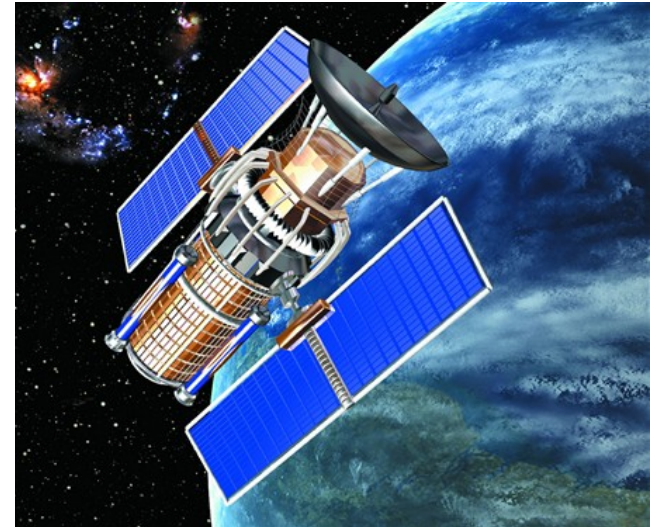


Full Operational Capability
All services, 30 satellites
2019/2020



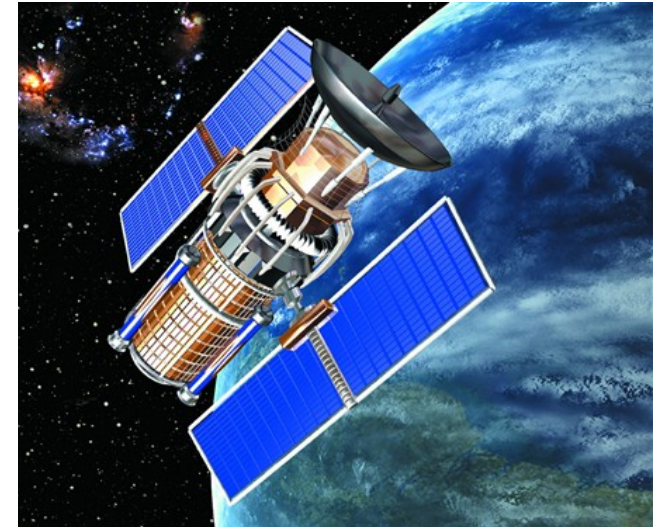
北斗卫星系统 (1)

- 北斗1号系统
- 两颗工作卫星，一颗备用卫星
- 赤道平面上地球同步卫星
- 2000-2007年发射
- 覆盖范围 70°E - 140°E , 5°N - 55°N
- 主动式双向测距二维导航，三维定位
- 授时精度100纳秒，定位精度几十米
- 不足之处

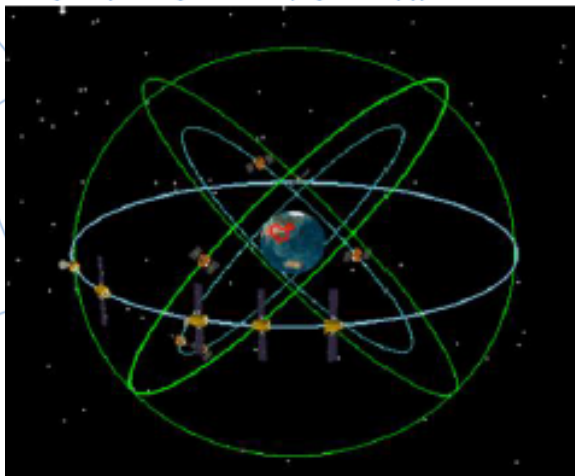


北斗卫星系统 (2)

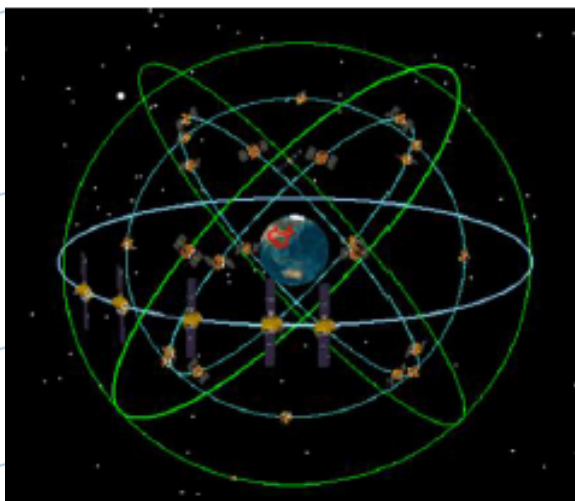
- 北斗2号系统
- 5颗静止轨道卫星，30颗非静止轨道卫星
- 2007-2011.4.10已发射8颗卫星
- 2012年: 5GEO+5ISGO+5MEO 覆盖亚太地区
- 2020年: 5GEO+3ISGO+27MEO 覆盖全球
- 被动式定位
- 保持接受短信功能
- 授时精度10纳秒，定位精度10米
- 更高精度授权服务



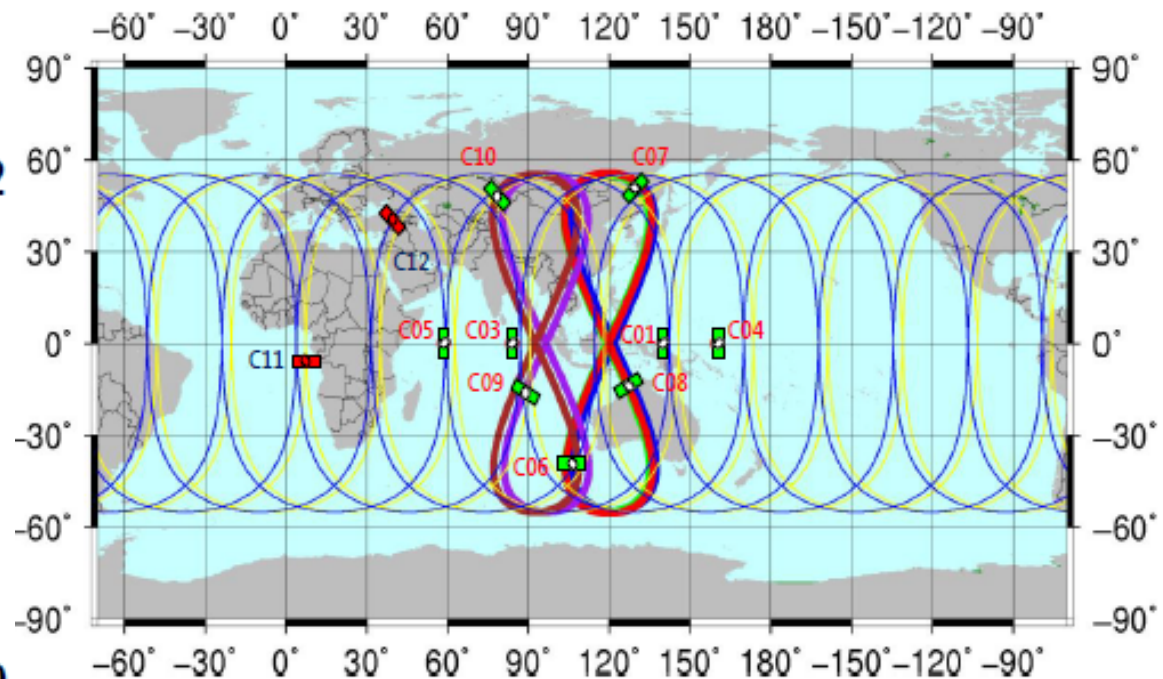
北斗卫星系统 (3)



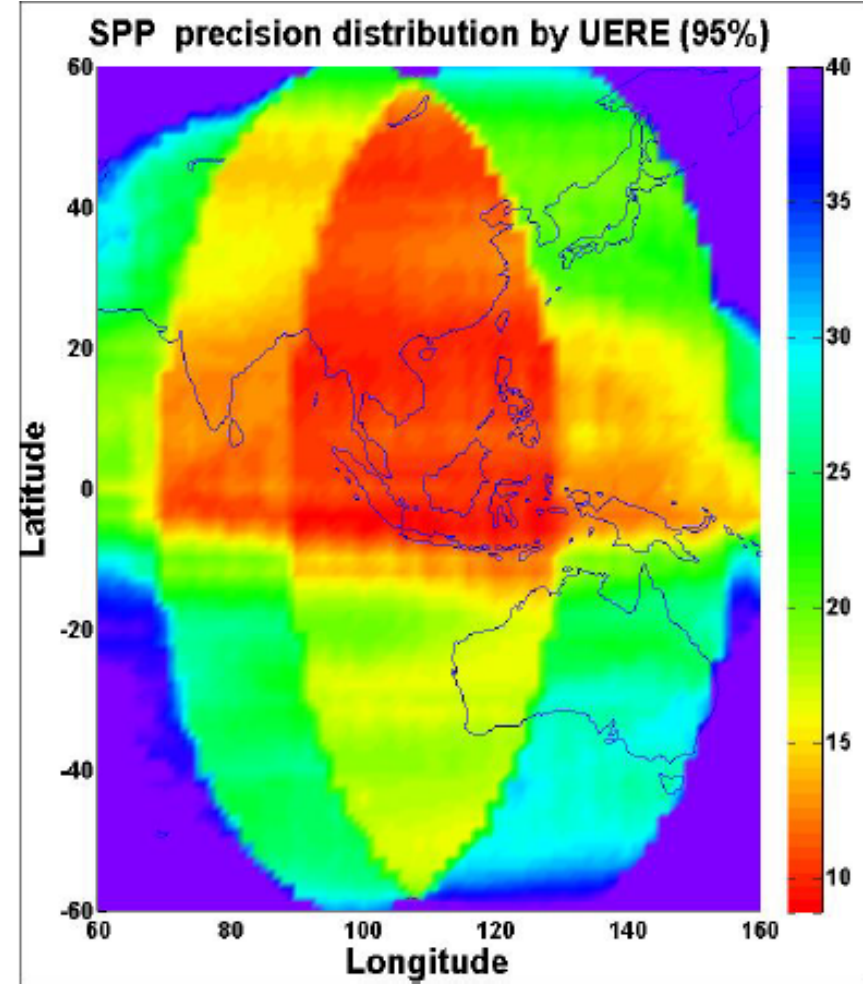
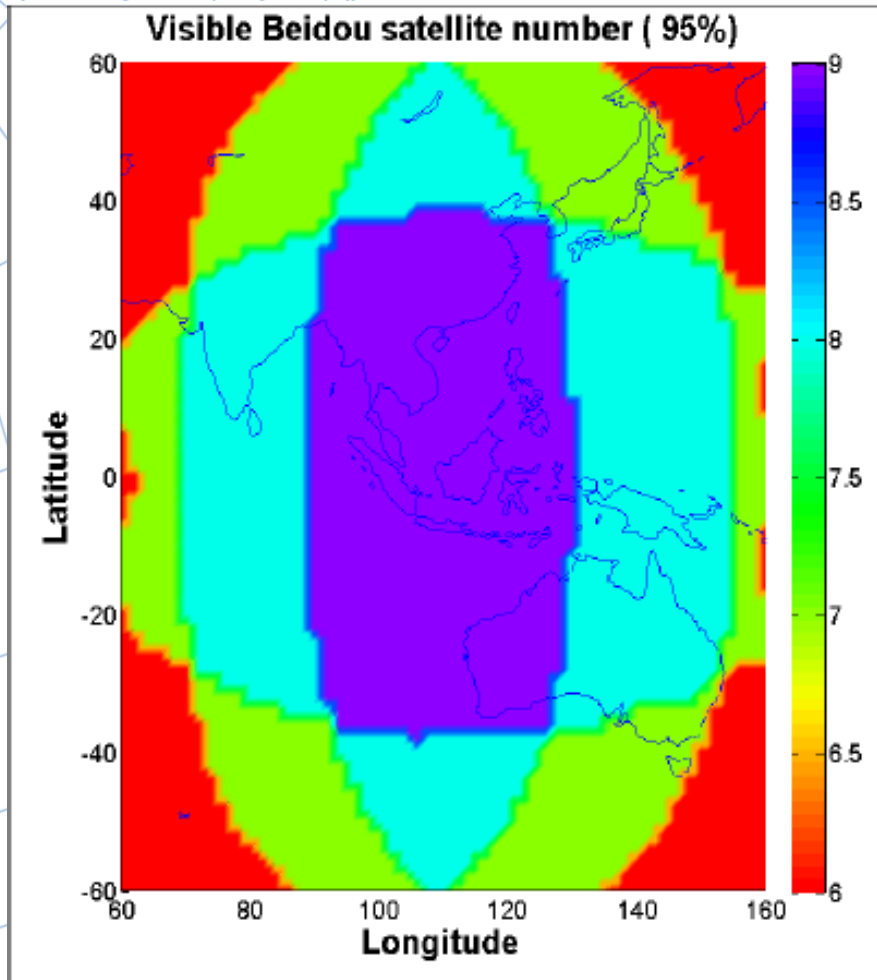
2012



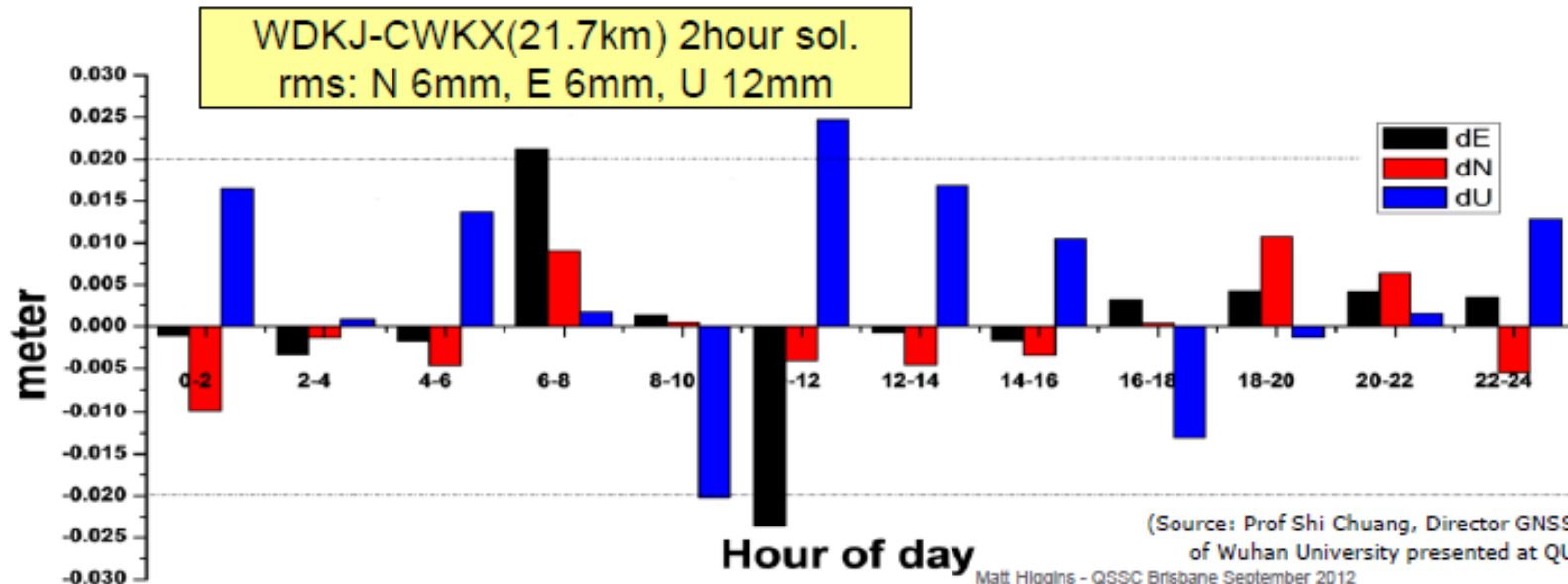
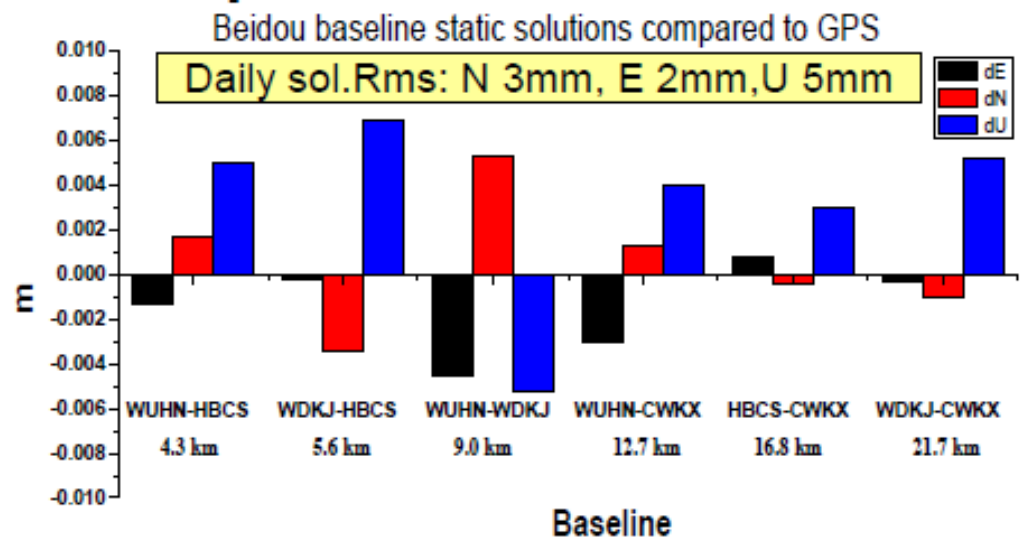
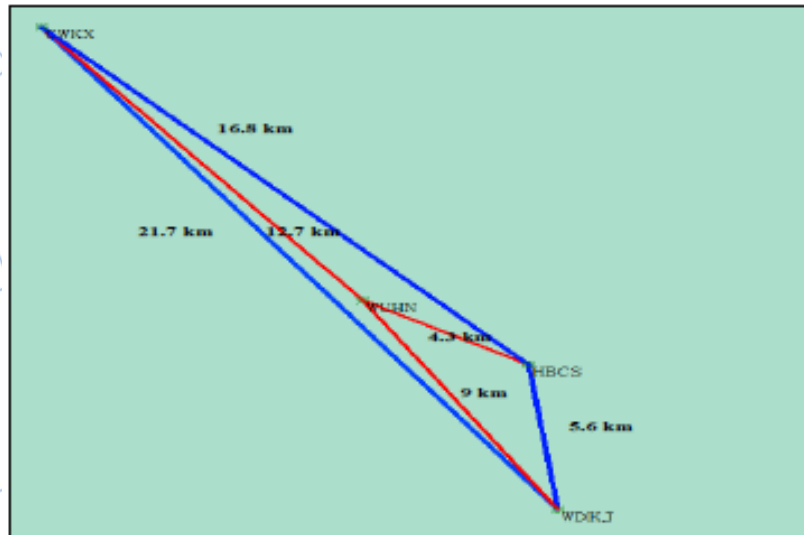
2020



目前北斗卫星系统评估

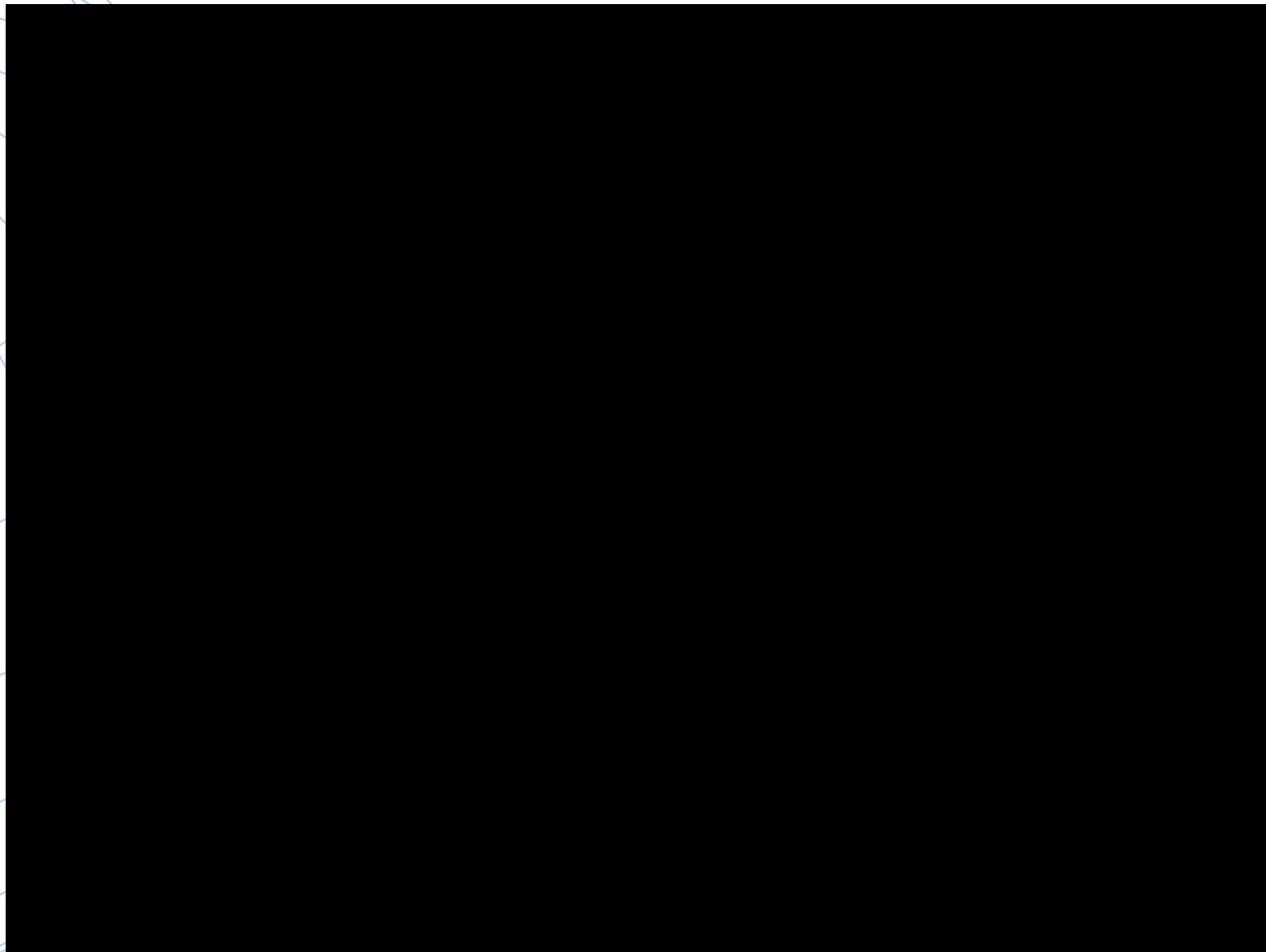


北斗系统和GPS的精度比较

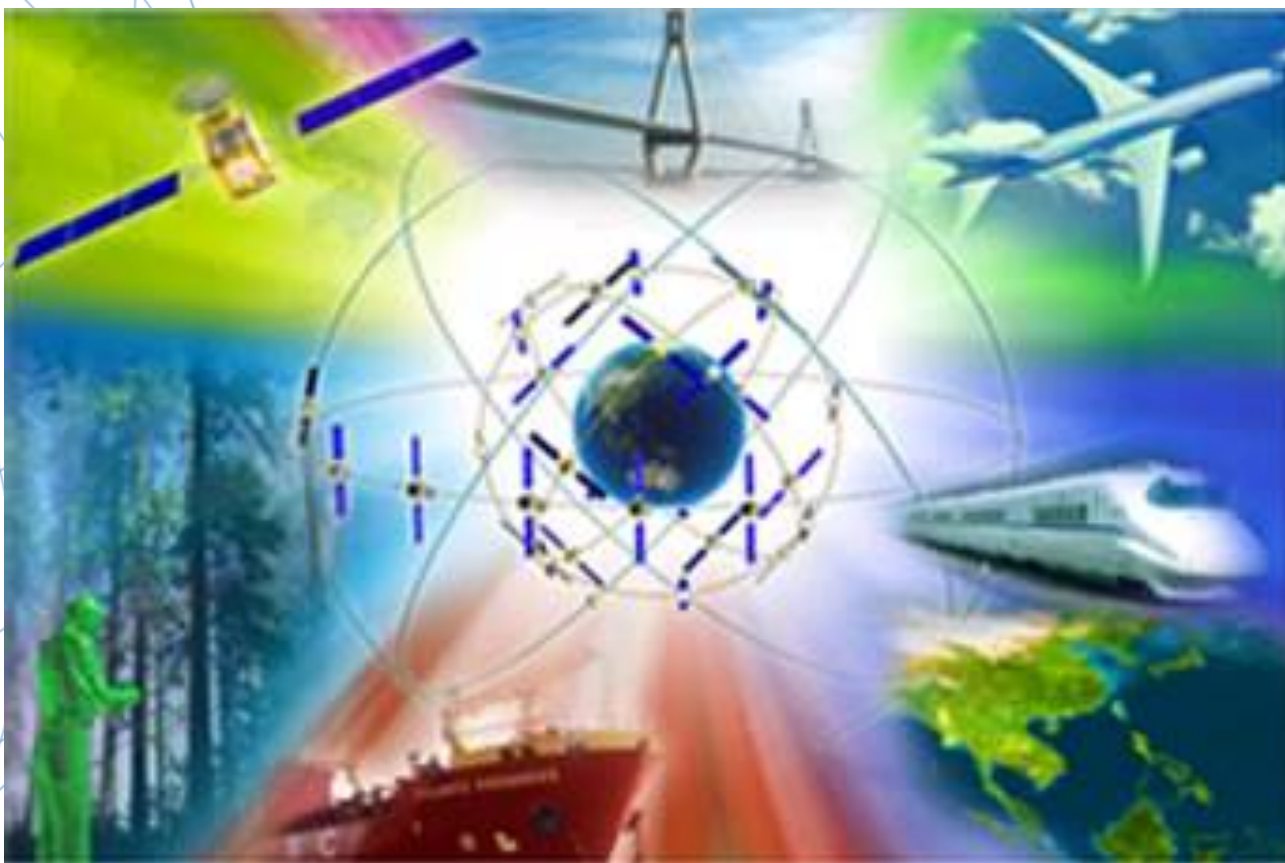


(Source: Prof Shi Chuang, Director GNSS Research Center of Wuhan University presented at QUT, 9/8/2012)

Matt Higgins - QSSC Brisbane September 2012



谢谢各位



空间信息与定位导航上海高校工程研究中心

