2a Reunion Red Iberica MM5
Grupo 12: interacciones, modelo mm5 y proyectos actuales

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Interacciones en la Red Iberica

- Grupos 3 (Institut d'Estudis Espacials de Catalunya) y 24 (Servei Meteorologic de Catalunya)
  - Articulo: "*3DVAR assimilation of ground-based GPS ZTD and meteorological observations during the December 14th 2001 storm event over the western Mediterranean sea*" **(MWR, Marzo 2004)**
- Grupo 24:
  - Asesoramiento en la operatividad del modelo MM5
- Grupo 3:
 - Asimilacion de datos GPS (ground-based) en el modelo MM5 3dvar durante campanyas de interes.

Proyectos con el MM5

- Miembro del equipo de desarrollo del modelo MM5/WRF 3dvar (NCAR/MMM)
  - Assimilacion de datos GPS ZTD: "Forward", Tangente Lineal y Adjunto (2002)
  - Asimilacion de radio-ocultaciones GPS: "Forward", Tangente Lineal y Adjunto. (2003)
- Articulo "*Assessing the impact of COSMIC GPS Radio Occultation Data on Weather Analysis and Short-term Forecast over the Antarctic"* (enviado a MWR, Marzo 2004).
- Asimilacion de radio ocultaciones (RO) GPS en el modelo global de NCEP (grid point system). (Actualidad)
  - Disponibilidad (sin coste) de datos RO GPS a los grupos de la Red Iberica (no de software).

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GPS Radio Occultation

- The 24 GPS satellites are distributed roughly in six circular orbital planes at ~55° inclination, 20,200 km altitude and ~12 hour periods.
- Each GPS satellite continuously transmits signals at two L-band frequencies, L1 at 1.57542 GHz (~19 cm) and L2 at 1.227 GHz (~24.4 cm).
- A ray passing through the atmosphere is refracted due to the vertical gradient of density.

GPS satellite

Low Earth Orbiting (LEO) satellite

COSMIC
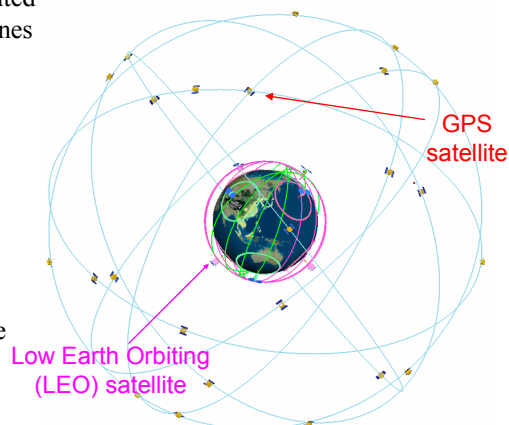
GPS Occultation

Basic measurement principle:

Deduce atmospheric properties based on precise measurement of phase delay and amplitude.

Occulting GPS

20 msec data (LINK 1)

Ionosphere

Neutral atmosphere

Occulting LEO

Earth
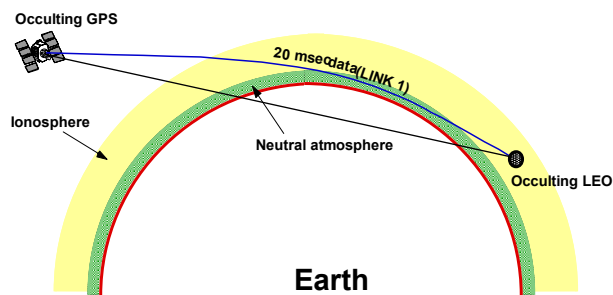
Atmospheric Refractivity N

$$N = 77.6\frac{P}{T} + 3.73\times10^{-5}\frac{P_w}{T^2} - 4.03\times10^{7}\frac{n_e}{f^2}$$

Above 90 km, pressure and water vapor terms are negligible. *N* is directly proportional to the electron density.

In the stratosphere and upper troposphere, water vapor is negligible, *N* can be used to deduce accurate temperatures (with the use of hydrostatic equation.).

In the lower troposphere, water vapor can contribute to as much as 30% of *N*. *N* can be used to deduce accurate vertical profiles of water vapor given independent estimates of temperature (e.g. from global analysis or short-term forecast).

Characteristics of GPS RO Data

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- **Limb sounding geometry complementary to ground and space nadir viewing instruments**
- **High accuracy (equivalent to < 1 deg K from 5-25 km)**
- **High vertical resolution (0.1 km surface - 1km tropopause)**
- **All weather-minimally affected by aerosols, clouds or precipitation**
- **Independent height and pressure**
- **Requires no first guess sounding**
- **Independent of radiosonde calibration**
- **No instrument drift**
- **No satellite-to-satellite bias**

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GPS Radio Occultation (RO) Data

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- **Climate:**
  - Characterize climate, its variability and change
  - Evaluate global climate models and analyses
  - Monitor climate change and variability with unprecedented accuracy-**world's most accurate thermometer!**
- **Meteorology:**
  - Improve global weather analyses, particularly over data void regions such as the oceans and polar regions
  - Improve skill of global and regional weather prediction models
  - Improve understanding of tropical, midlatitude and polar weather systems and their interactions
- **Ionosphere:**
  - Characterize global electronic density distribution
  - Observe the interactions among the upper stratosphere, mesosphere and ionosphere
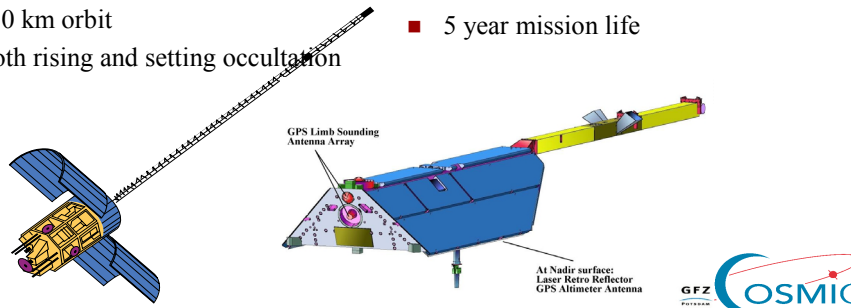 - Improve the analysis and prediction of space weather.

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Two Recent GPS Occultation Missions

SAC-C
- Argentine spacecraft carrying a multispectral imager and magnetometer
- Launched: Nov. 21, 2000
- 98.3° inclination
- 700 km orbit
- Both rising and setting occultation

CHAMP
- a German mission for magnetometry and gravity mapping
- Launched: July 15, 2000
- 87° inclination
- 435 km orbit
- 5 year mission life

GPS Limb Sounding Antenna Array

At Nadir surface:
Laser Retro Reflector
GPS Altimeter Antenna

GFZ Potsdam COSMIC

UCAR

COSMIC (Constellation Observing System for Meteorology, Ionosphere and Climate)

- 6 Satellites launched in late 2005
- Three instruments:
  GPS receiver, TIP, Tri-band beacon
- Weather + Space Weather data
- Global observations of:
  Pressure, Temperature, Humidity
  Refractivity
  Ionospheric Electron Density
  Ionospheric Scintillation
- Demonstrate quasi-operational GPS limb sounding with global coverage in near-real time
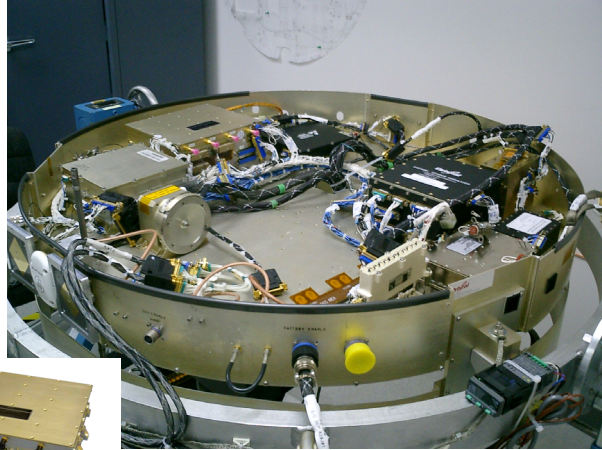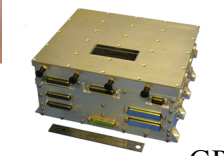- Climate Monitoring
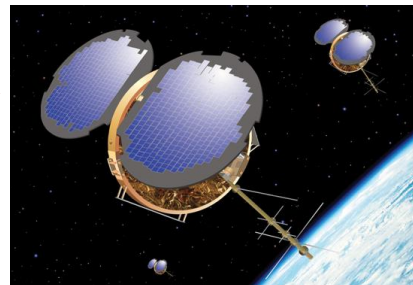
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COSMIC Spacecraft Status

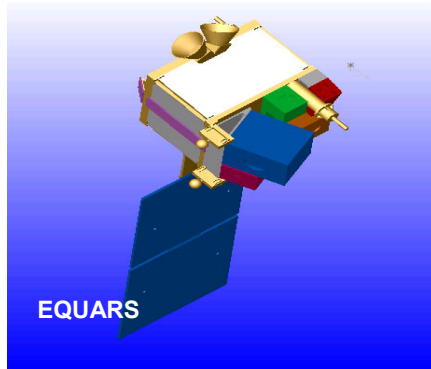Minotaur
launch vehicle

GPS receiver

COSMIC
spacecraft

COSMIC is a partner in two additional missions

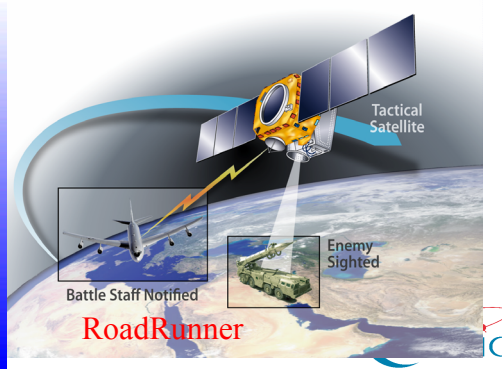EQUARS - real-time RO data from low-latitudes analyzed as CDAAC
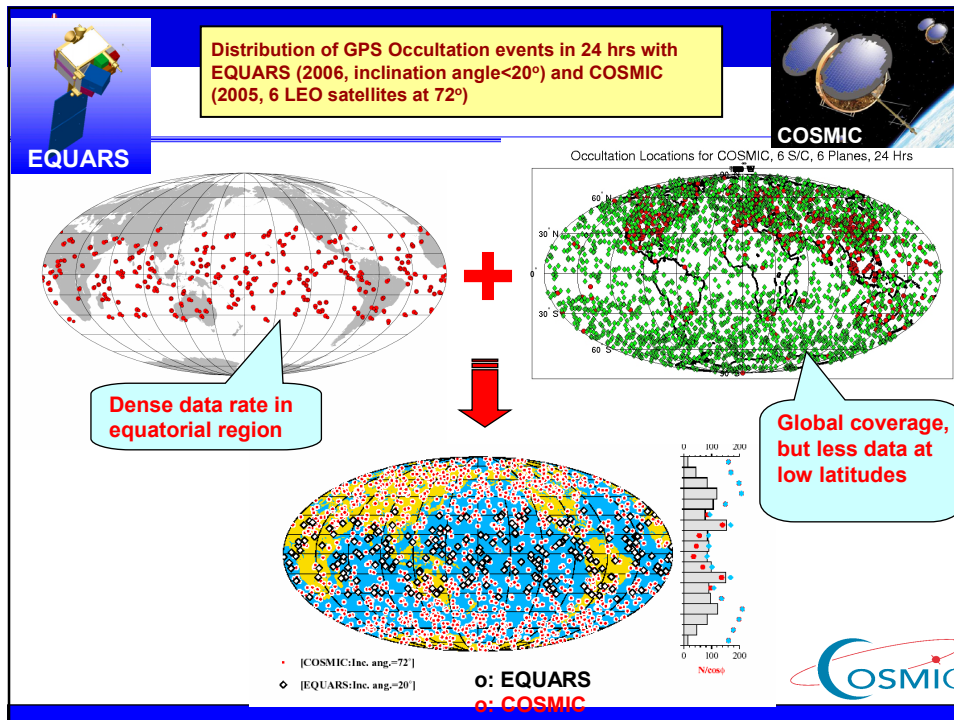RoadRunner - Late 2004 launch with IGOR receiver - Risk Reduction

INPE / Brazil

USAF / US

EQUARS

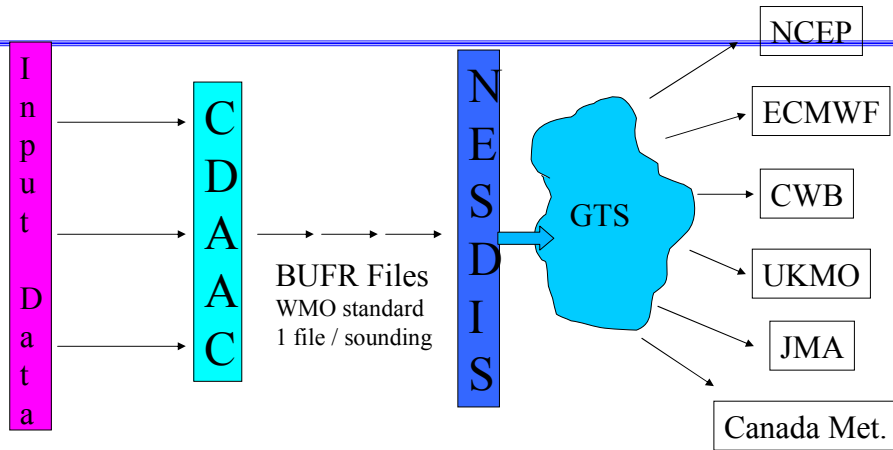Tactical Satellite

Enemy Sighted

Battle Staff Notified

RoadRunner

Distribution of GPS Occultation events in 24 hrs with EQUARS (2006, inclination angle<20º) and COSMIC (2005, 6 LEO satellites at 72º)

EQUARS

COSMIC

Occultation Locations for COSMIC, 6 S/C, 6 Planes, 24 Hrs

Dense data rate in equatorial region

Global coverage, but less data at low latitudes

• [COSMIC:Inc. ang.=72˚]
◇ [EQUARS:Inc. ang.=20˚]

o: EQUARS
o: COSMIC

GPS radio occultation missions

Mission	Launch-Duration		# Soundings/day	Remarks
GPS-MET	4/1995	2+	~125	Proof of Concept
CHAMP	11/2000	~5	~250	Improved receiver, tracking
SAC-C	11/2000	~3	~500	Improved receiver, open loop tracking test
GRACE	5/2002	~5	~500	RO data not yet available
COSMIC	9/2005	~5	2500-3000	Real time-ops
TerraSAR-X	7/2005	~5	~400	COSMIC RX & Antennas
EQUARS	7/2006	~3	~400	COSMIC RX & CHAMP antennas
METOP	5/2007	~5	~500	Real time - ops
NPOESS	3/2011	~10	~500	Real time-ops. Ionosphere

Getting COSMIC Results to Weather Centers

Input Data → CDAAC → BUFR Files (WMO standard, 1 file / sounding) → NESDIS → GTS → NCEP, ECMWF, CWB, UKMO, JMA, Canada Met.

This system is currently under development by UCAR, NESDIS, + UKMO

Inter-relationships of GPS/RO Data Providers, Processors and End-users (with emphasis on USA and NOAA)
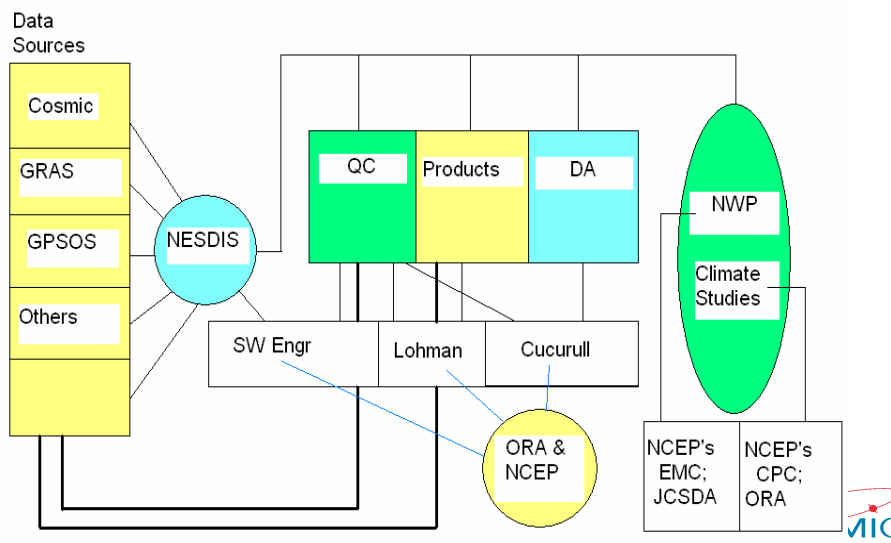
COSMIC and CDAAC Web

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