UCAR, Unidata and GPS Observations

Rick Anthes, UCAR President

Unidata Users Workshop

Using Operational and Experimental Observations in Geoscience Education

8 June 2009




UCAR


Happy
25th
Birthday
Unidata!

UCAR at a Glance

- **A consortium of 75 North American universities and a national laboratory (NCAR)**
- **~1450 Staff – 200 Scientists**
- **50th Anniversary in 2010!**
- **Science, computational and observational facilities, huge data sets, high-end numerical models of the sun, atmosphere, oceans, coupled climate system**

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UCAR's 75 Member Institutions (2009/1960)

University of Alabama in Huntsville
University of Alaska
University at Albany, State U of NY
University of Arizona
Arizona State University
Brown University
California Institute of Technology
University of California, Berkeley
University of California, Davis
University of California, Irvine
University of California, Los Angeles
University of Chicago
Colorado State University
University of Colorado at Boulder
Columbia University
University of Connecticut
Cornell University
University of Delaware
University of Denver
Drexel University
Florida State University
Georgia Institute of Technology
George Mason University (2009)
Harvard University
University of Hawaii
University of Houston
Howard University
University of Illinois at Urbana-Champaign
Iowa State University
University of Iowa
The Johns Hopkins University
University of Maryland
Massachusetts Institute of Technology
McGill University
University of Maine (2009)
University of Miami
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University of Minnesota
University of Missouri
Naval Postgraduate School
University of Nebraska Lincoln
Nevada System of Higher Education
University of New Hampshire
New Mexico Institute of Mining and Technology
New York University
North Carolina State University
The Ohio State University
University of Oklahoma
Old Dominion University
Oregon State University
Pennsylvania State University
Princeton University
Purdue University
University of Rhode Island
Rice University
Rutgers University
Saint Louis University
Scripps Institution of Oceanography at UCSD
Stanford University
Texas A & M University
University of Texas at Austin
Texas Tech University
University of Toronto
Utah State University
University of Utah
University of Virginia
University of Washington
Washington State University
University of Wisconsin- Madison
University of Wisconsin-Milwaukee
Woods Hole Oceanographic Institution
University of Wyoming
Yale University
York University

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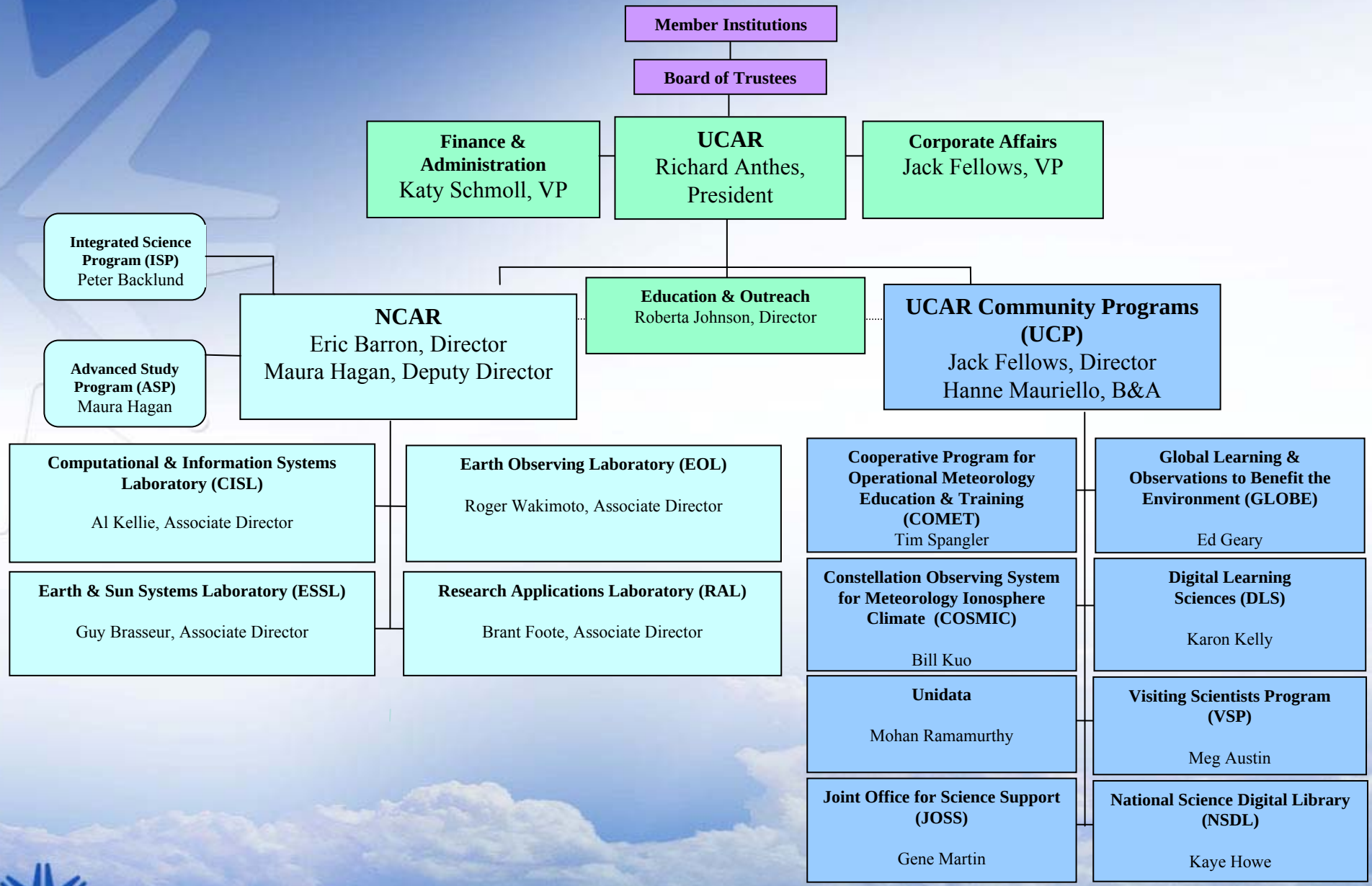
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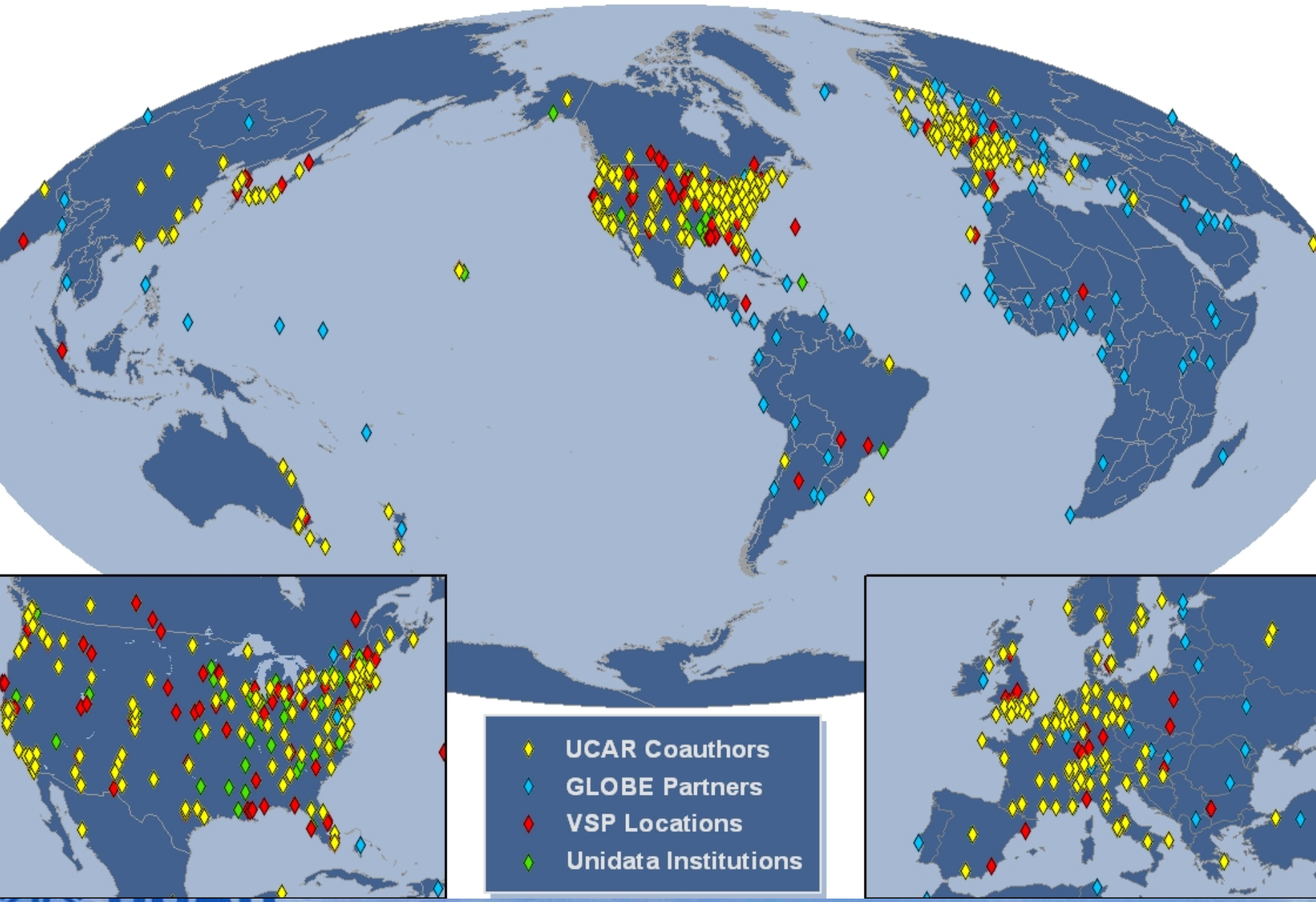
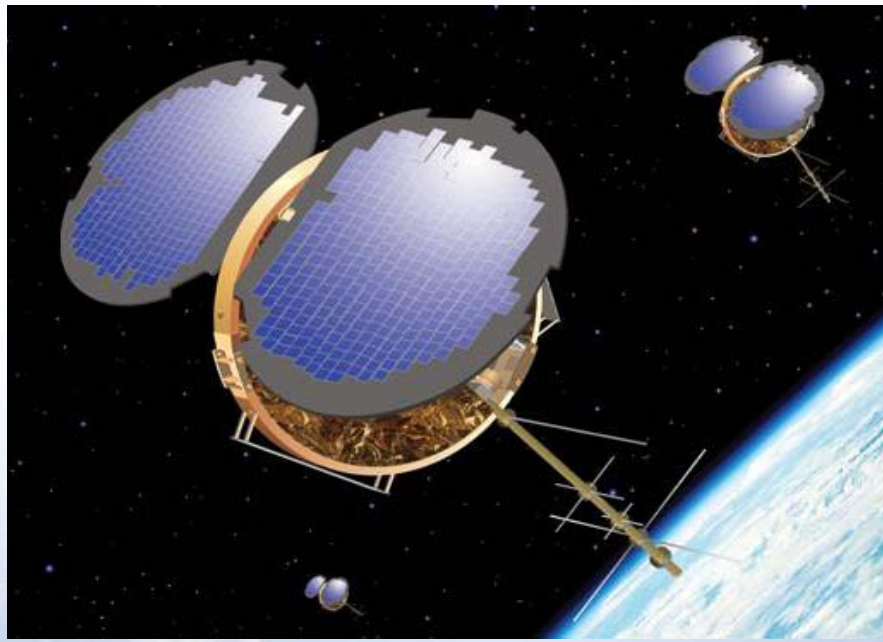
2006 UCAR Interactions and Service



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

- Joint Taiwan and US project
- NSF is U.S. lead agency
  - NOAA, NASA, Air Force, Navy
- 6 Satellites launched April 14, 2006
- Three instruments:
  - GPS receiver, TIP, Tri-band beacon
- Global observations of:
  - Refractivity
  - Pressure, Temperature, Water vapor
  - Ionospheric Electron Density
- Demonstrate quasi-operational GPS limb sounding with global coverage in near-real time



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First results from COSMIC/ FORMOSAT-3 Published in Bulletin of American Meteorological Society, March 2008

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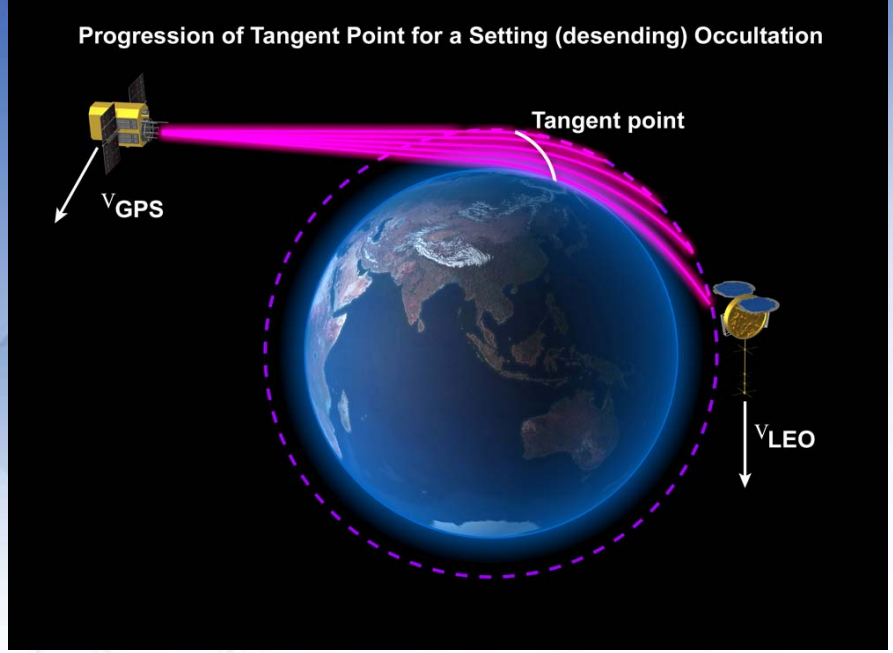
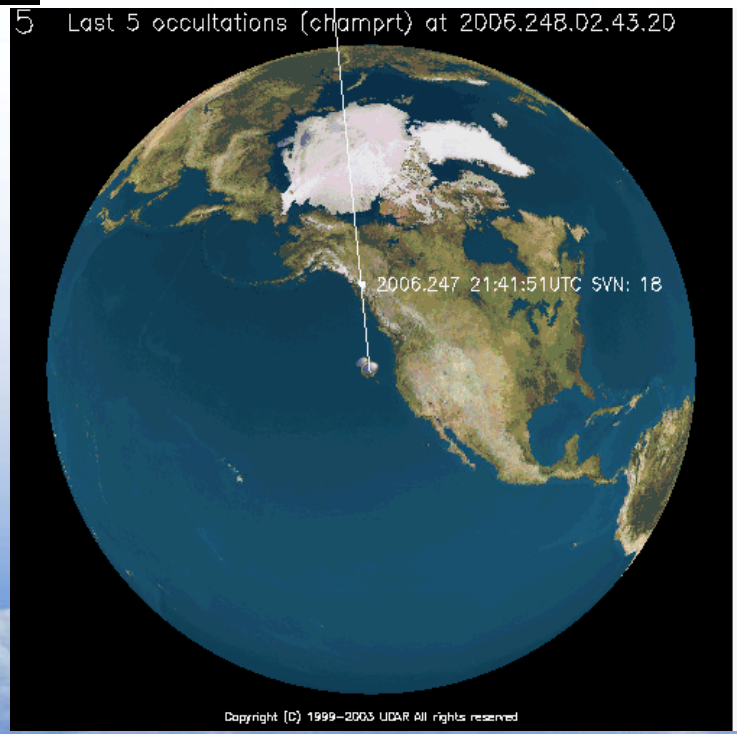
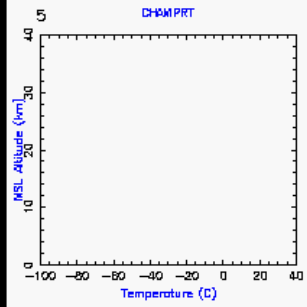


Limb sounding of atmosphere as LEO rises or sets with respect to GPS satellites

Global observations of:

- Pressure, Temperature, Humidity
- Refractivity
- Ionospheric Electron Density





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GPS Radio Occultation (RO) Data

- **Climate**
  - Monitor climate change and variability with unprecedented accuracy- **world's most accurate, precise, and stable thermometer from space!**
  - Evaluate global climate models and analyses
  - Calibrate infrared and microwave sensors and retrieval algorithms
- **Weather**
  - 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, mid-latitude and polar weather systems and their interactions—research case studies
- **Ionosphere and Space Weather**
  - Characterize global electronic density distribution
  - Monitor ionospheric scintillation
  - Observe the interactions among the upper stratosphere, mesosphere and ionosphere
  - Improve the analysis and prediction of space weather.

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Characteristics of GPS RO Data

- **Limb sounding geometry complementary to ground and space nadir viewing instruments**
- **Global 3-D coverage 40 km to surface**
- **High accuracy (equivalent to <1 K; average accuracy <0.1 K)**
- **High precision (0.02-0.05 K)**
- **High vertical resolution (0.1 km surface – 1 km tropopause)**
- **Only system from space to resolve atmospheric boundary layer**
- **All weather-minimally affected by aerosols, clouds or precipitation**
- **Independent height and pressure**
- **Requires no first guess sounding**
- **Independent of radiosonde calibration**
- **Independent of processing center**
- **No instrument drift**
- **No satellite-to-satellite bias**
- **Compact sensor, low power, low cost**

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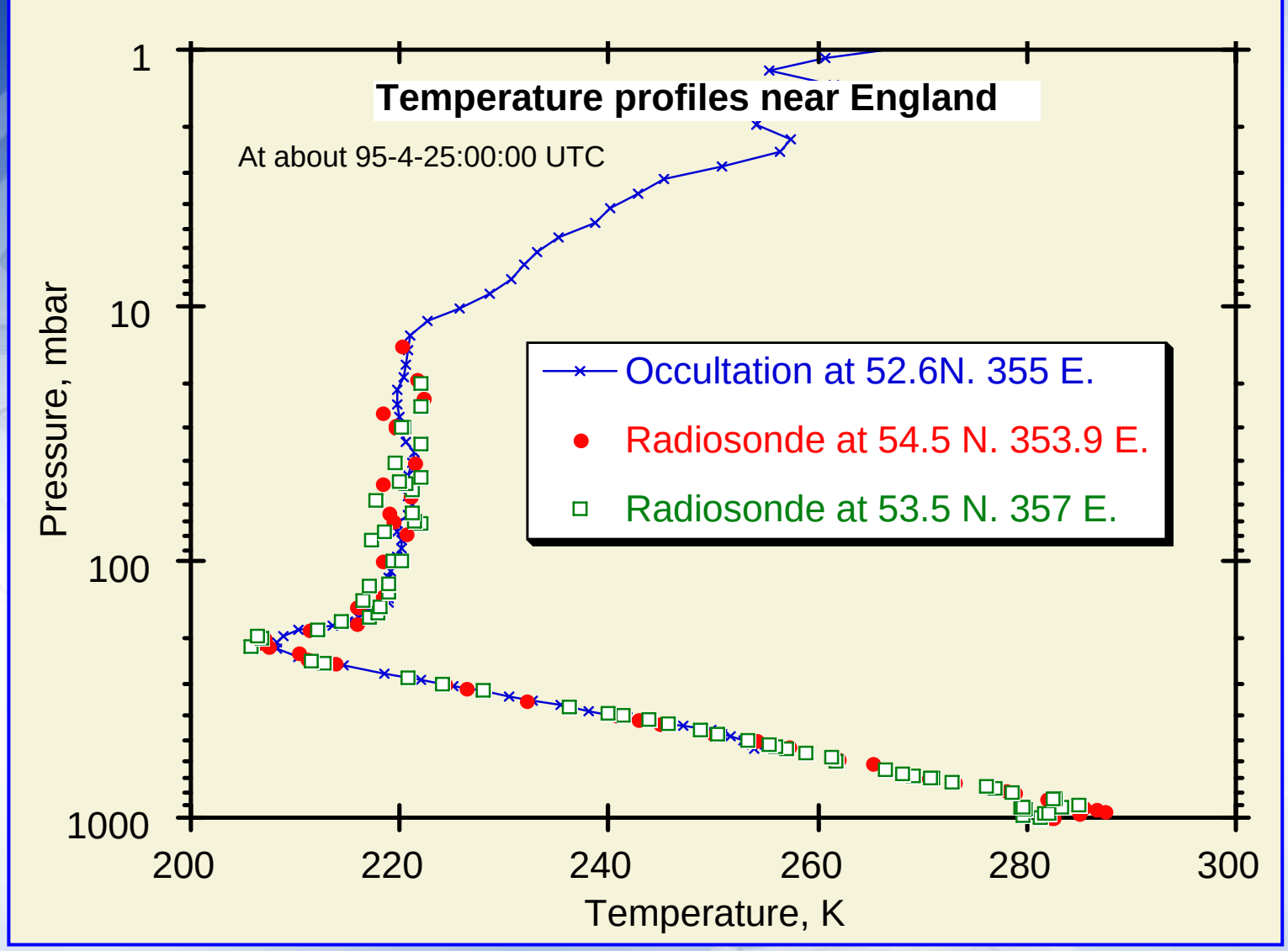

A typical RO sounding showing very sharp tropopause. No other instrument from space provides such high vertical resolution.

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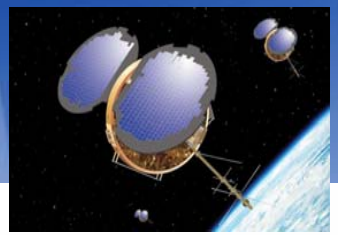
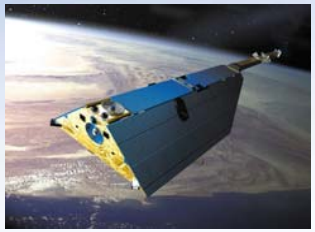
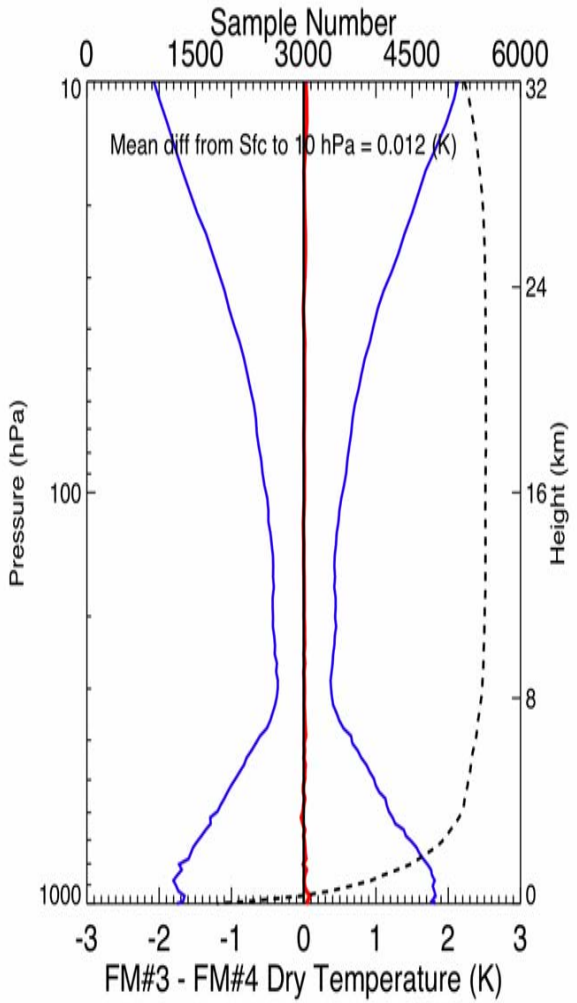
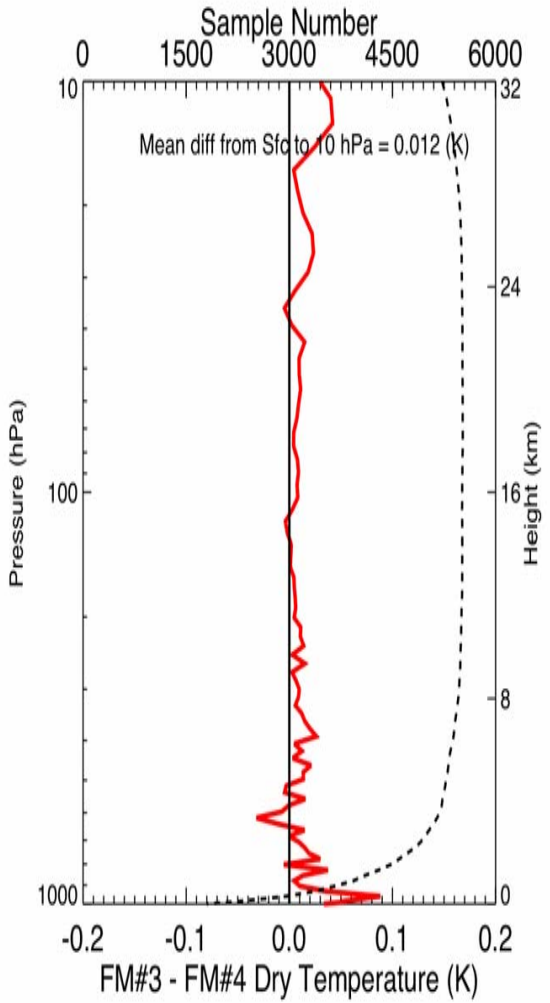


Comparability of COSMIC data from different receivers







Dry temperature difference between FM3-FM4 receivers

Within 25 km

Using FM3-FM4 pairs in early mission

Need to quantify all COSMIC-COSMIC pairs

Precision < 0.05 K

Shu-peng Ben Ho, UCAR/COSMIC

Main Results So Far from COSMIC

- General
  - High accuracy, precision and vertical resolution demonstrated
  - Inexpensive, all weather soundings
  - 1000 registered users from 45 countries
  - Free and open data policy
  - Only space system to give information on ionosphere, stratosphere and troposphere
- Weather analysis and prediction:
  - 80% observations available within 3 hr
  - Significant positive impact on skill scores of operational NWP
  - Large impact in individual forecasts (e.g. Hurricane Ernesto 2006)
  - Unbiased, good "anchor" for radiance assimilation
  - Observations of tropical boundary layer from space for 1st time

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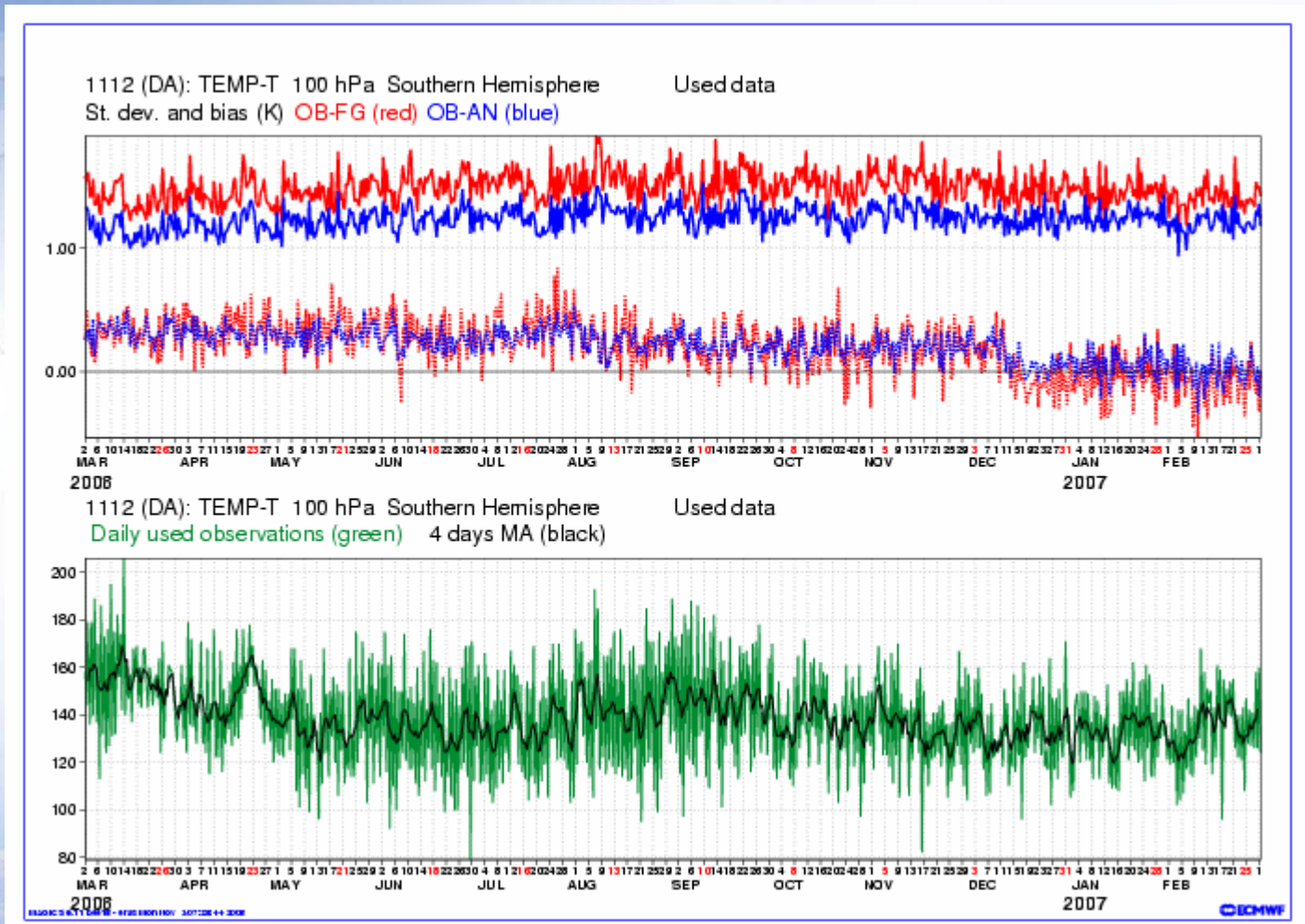
Main Results So Far from COSMIC

- Climate:
  - Calibrate longer-term MSU/AMSU data
  - Calibrate SSM/I water vapor retrievals
  - Compare well with CHAMP-no satellite to satellite bias
  - No difference in processed results from four independent centers
- Ionosphere and space weather:
  - Vertical structure of ionosphere
  - Verify ionospheric models
  - Discovery of new ionospheric features (e.g. plasma caves)
  - Observations of scintillation

Introduction of COSMIC measurements into ERA-Interim (Dec 12, 2006)



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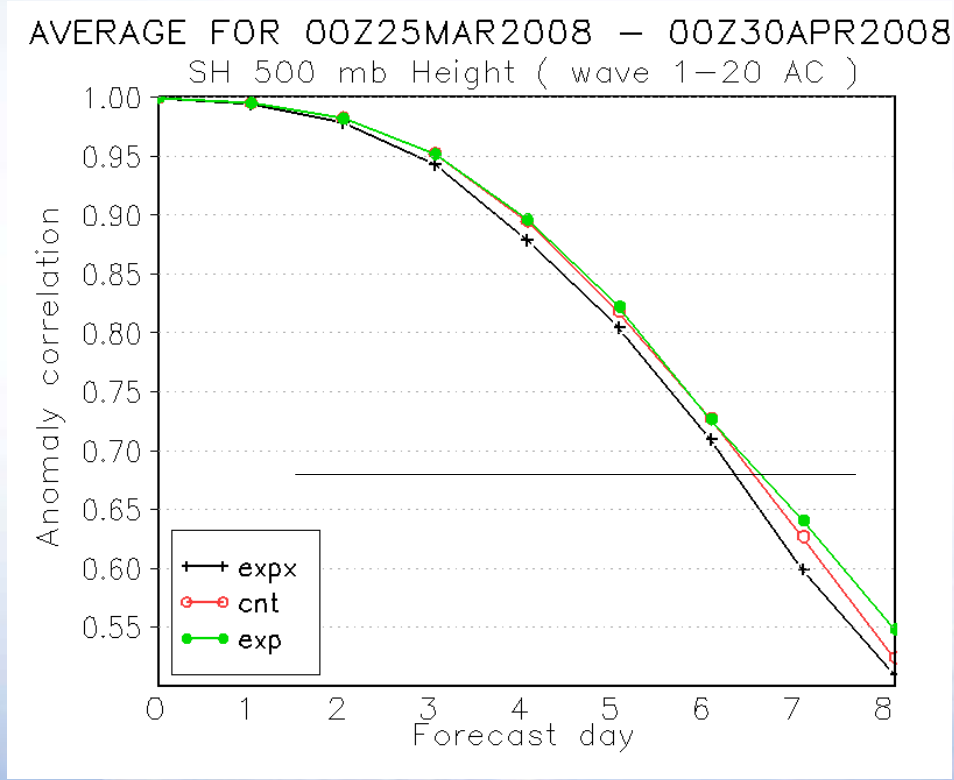
ECMWF

NCEP recent impact

- AC scores (the higher the better) as a function of the forecast day for the 500 mb gph in Southern Hemisphere
- 40-day experiments:
  - **expx (NO COSMIC)**
  - **cnt (operations - with COSMIC)**
  - **exp (updated RO assimilation code - with COSMIC)**
    - Many more observations
    - Reduction of high and low level tropical winds error



COSMIC provides 8 hours of gain in model forecast skill at day 4!!!!

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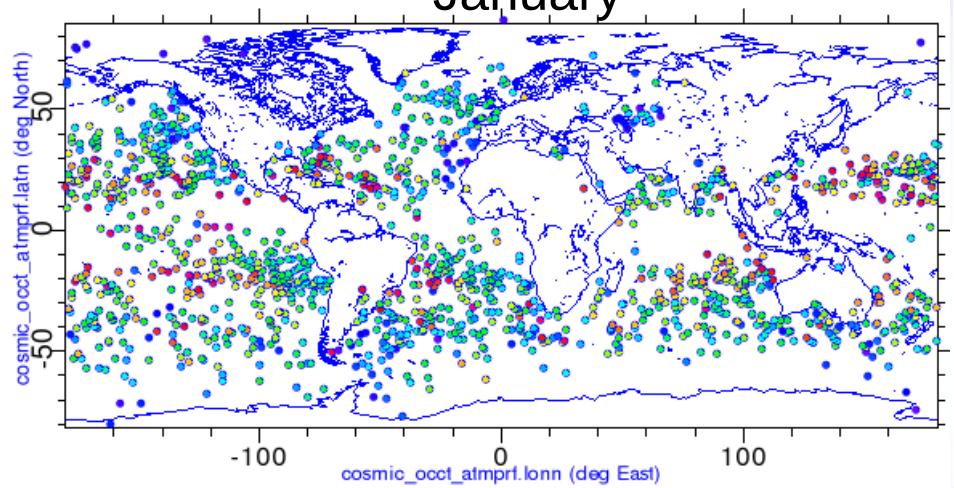
Global distribution of ABL depth over the oceans from COSMIC RO

- most sharp ABL top in sub-tropics - no pronounced ABL top in ITCZ
- decrease of ABL depth toward west coasts of continents

January



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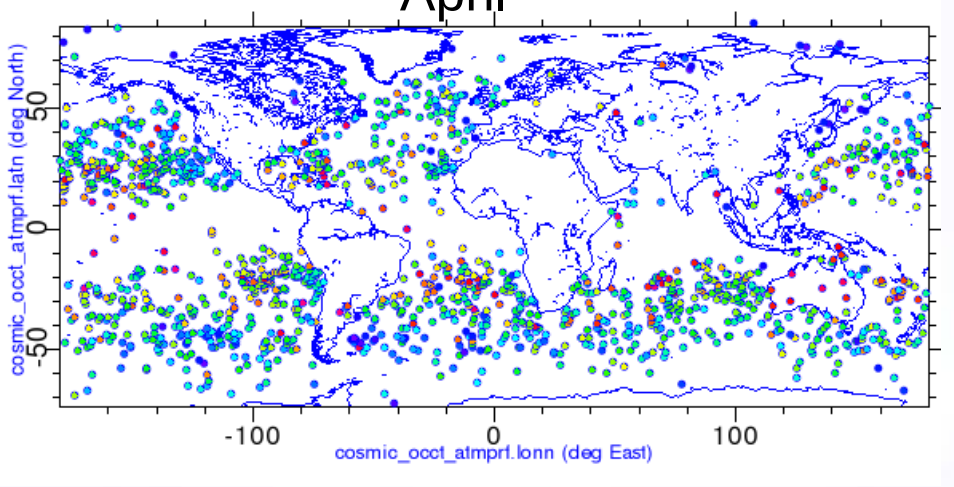
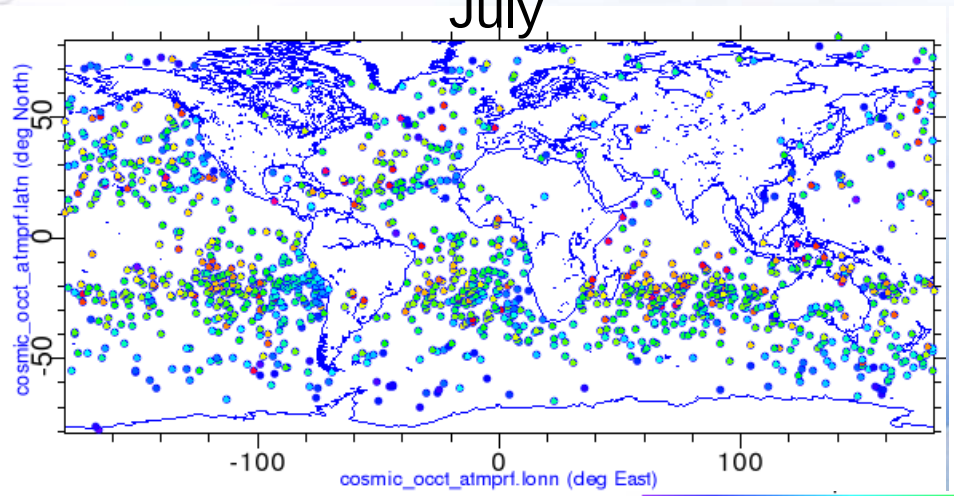
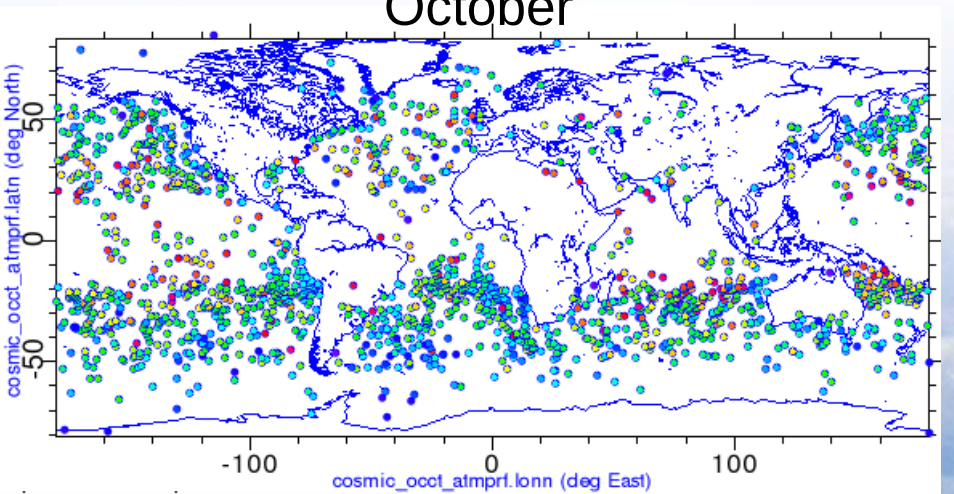


July



October



height of the strongest (BAL>1E-2rad) inversion layer (km)

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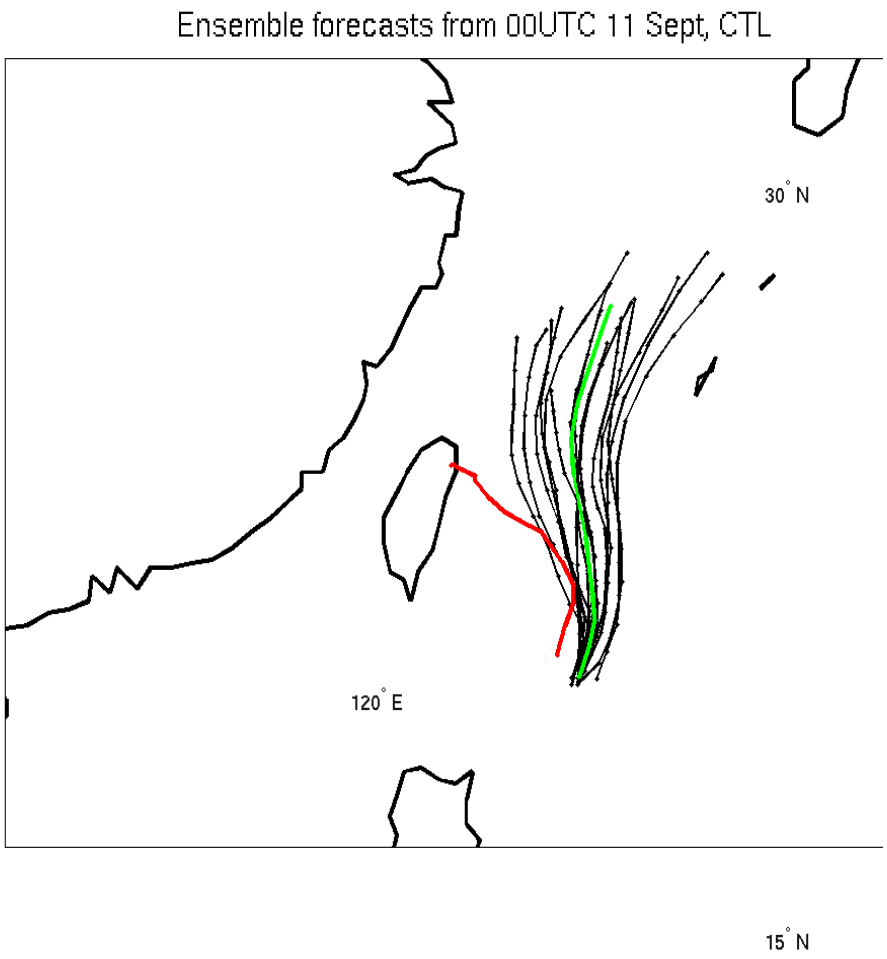
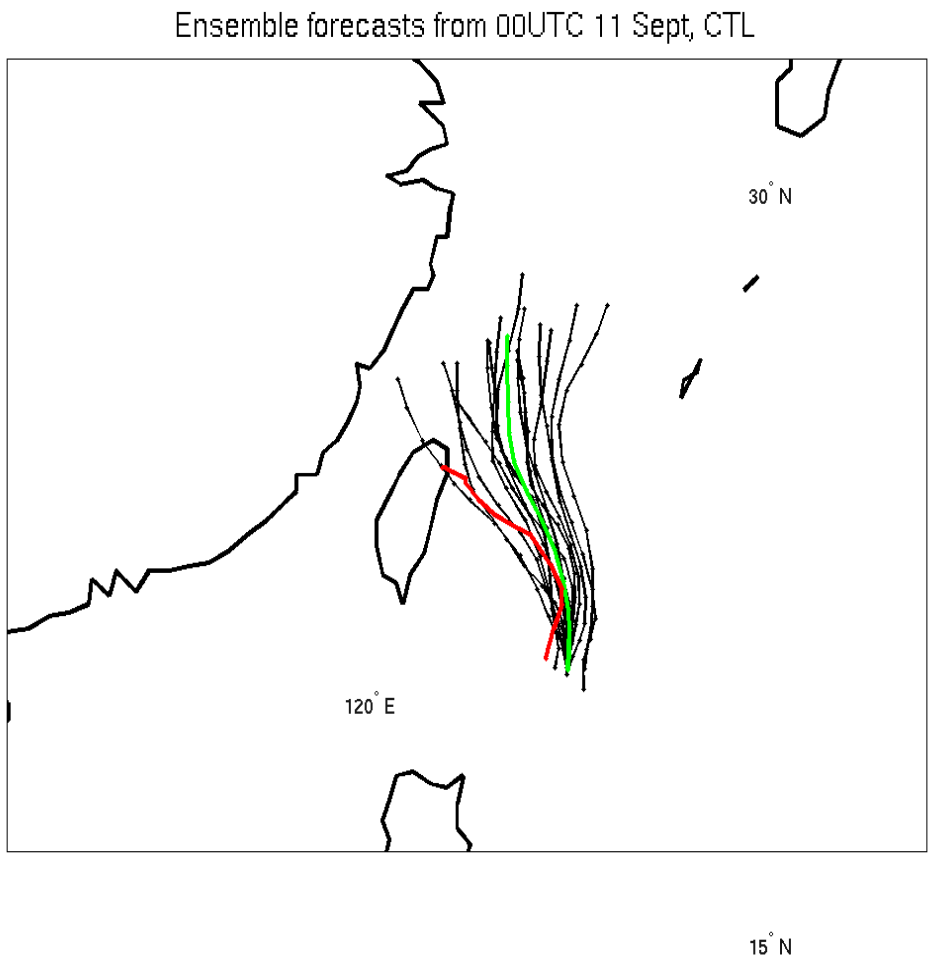
Ensemble Forecasts of Typhoon Sinlaku (2008) Track with WRF/DAT system (from Hui Liu, CISL/iMage)

NoGPS



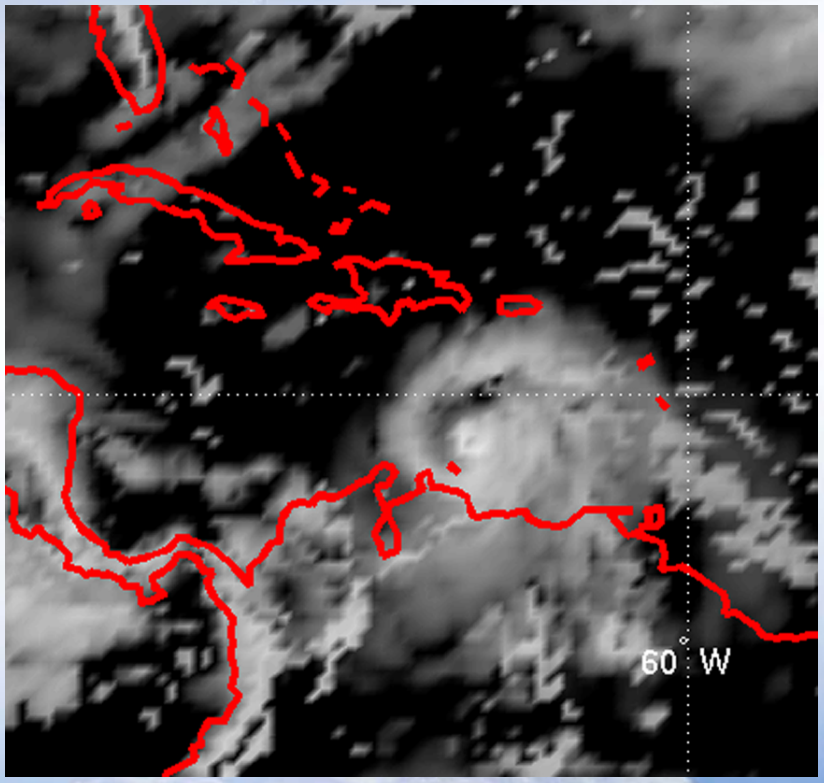
GPS



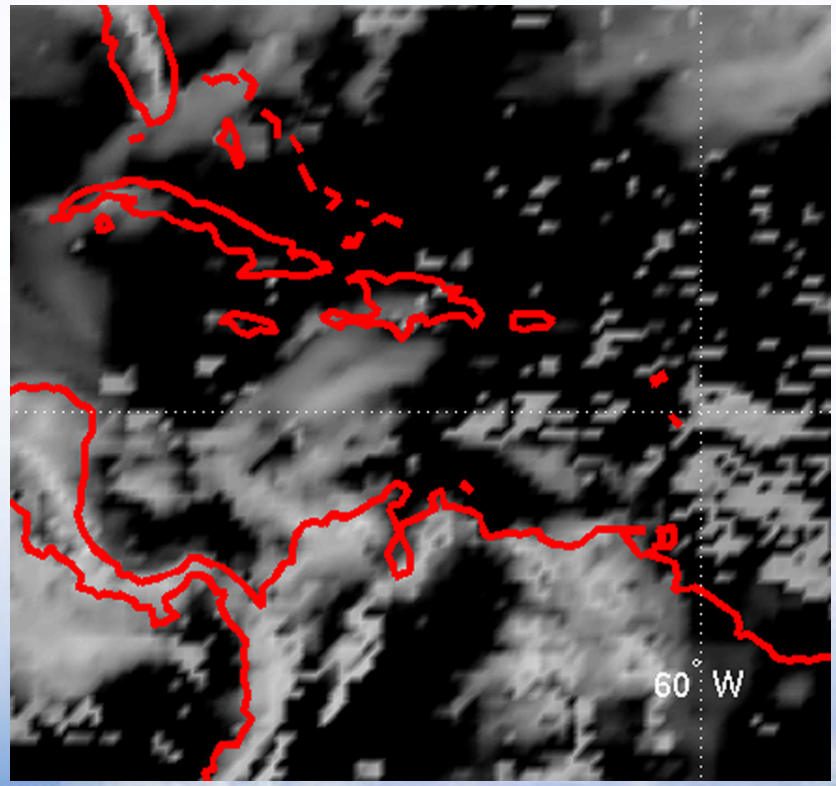
Red: Observed track, Black: Ensemble members, Green: Ensemble mean. Leftward turning of typhoon track is better predicted with the assimilation of COSMIC data.

Impact of COSMIC on Hurricane Ernesto (2006) Forecast

With COSMIC



Without COSMIC



Results from Hui Liu, NCAR

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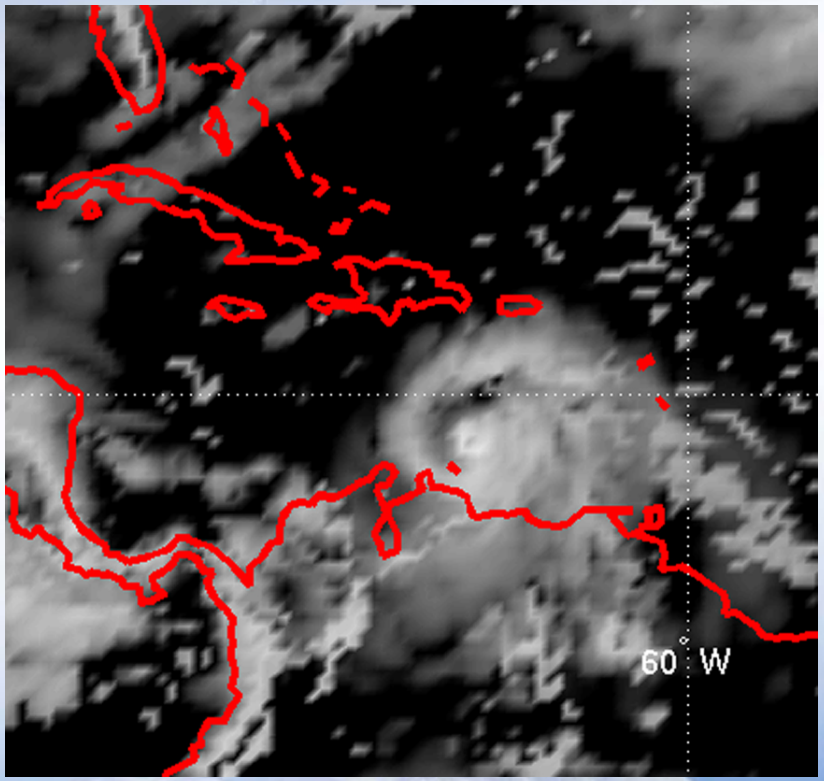
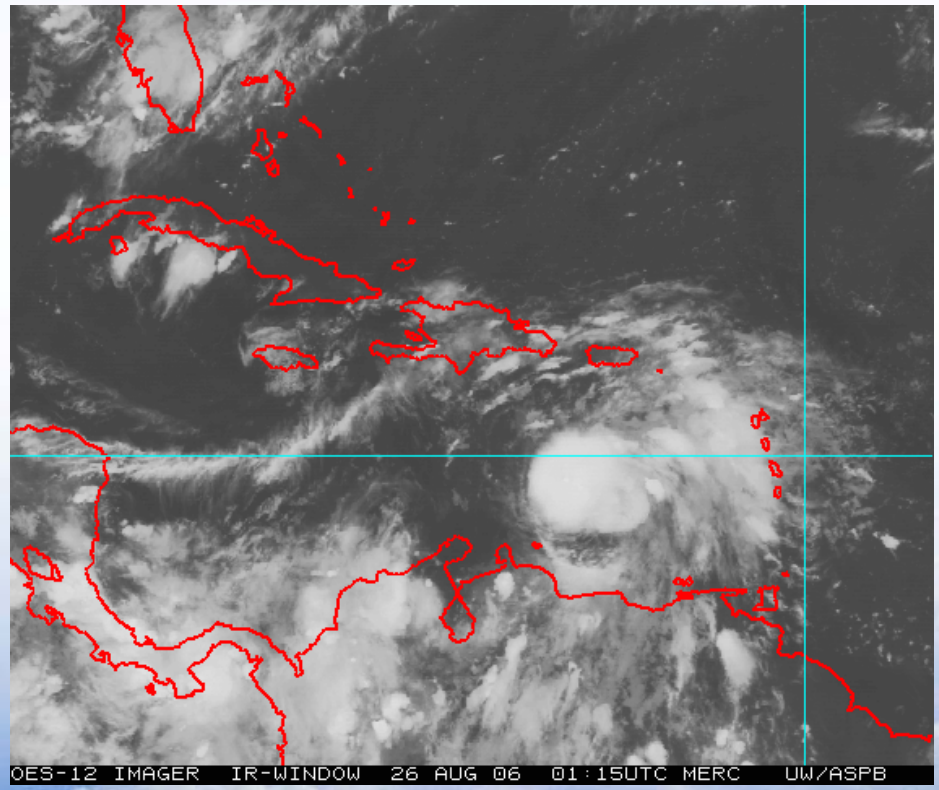
Impact of COSMIC on Hurricane Ernesto (2006) Forecast

With COSMIC



GOES Image



GOES Image from Tim Schmitt, SSEC

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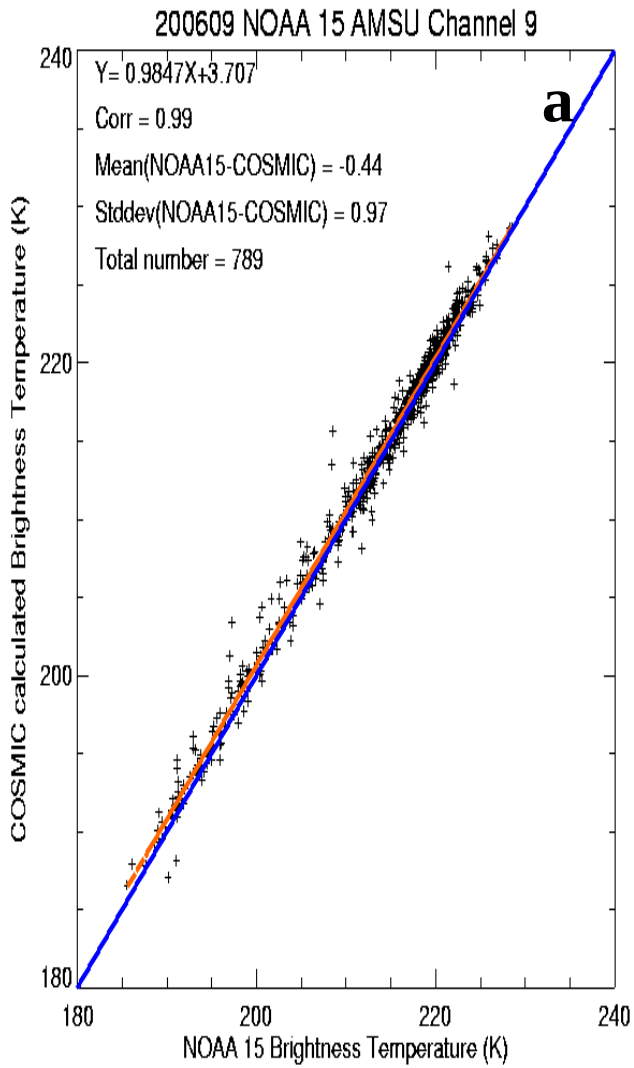
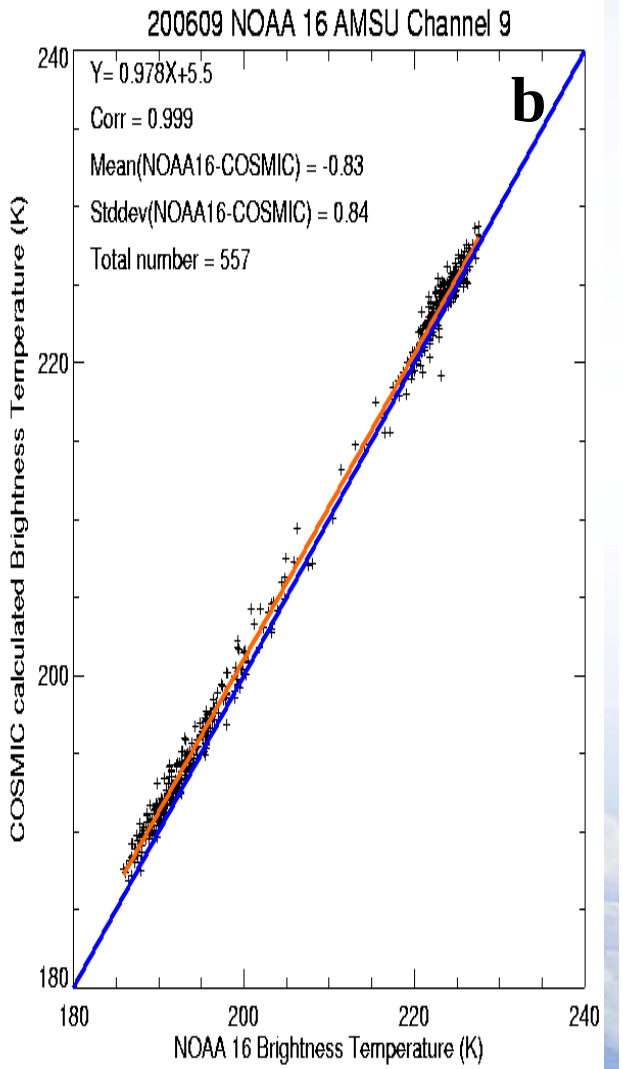
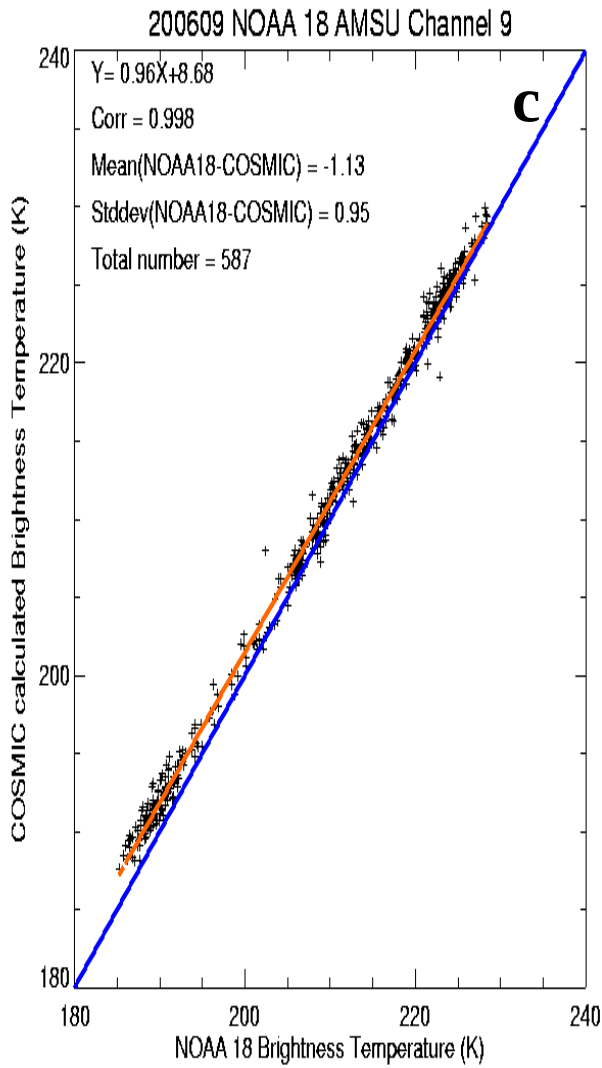
Applications of GPS RO for climate studies

Can we use RO data to calibrate other instruments ?

200609

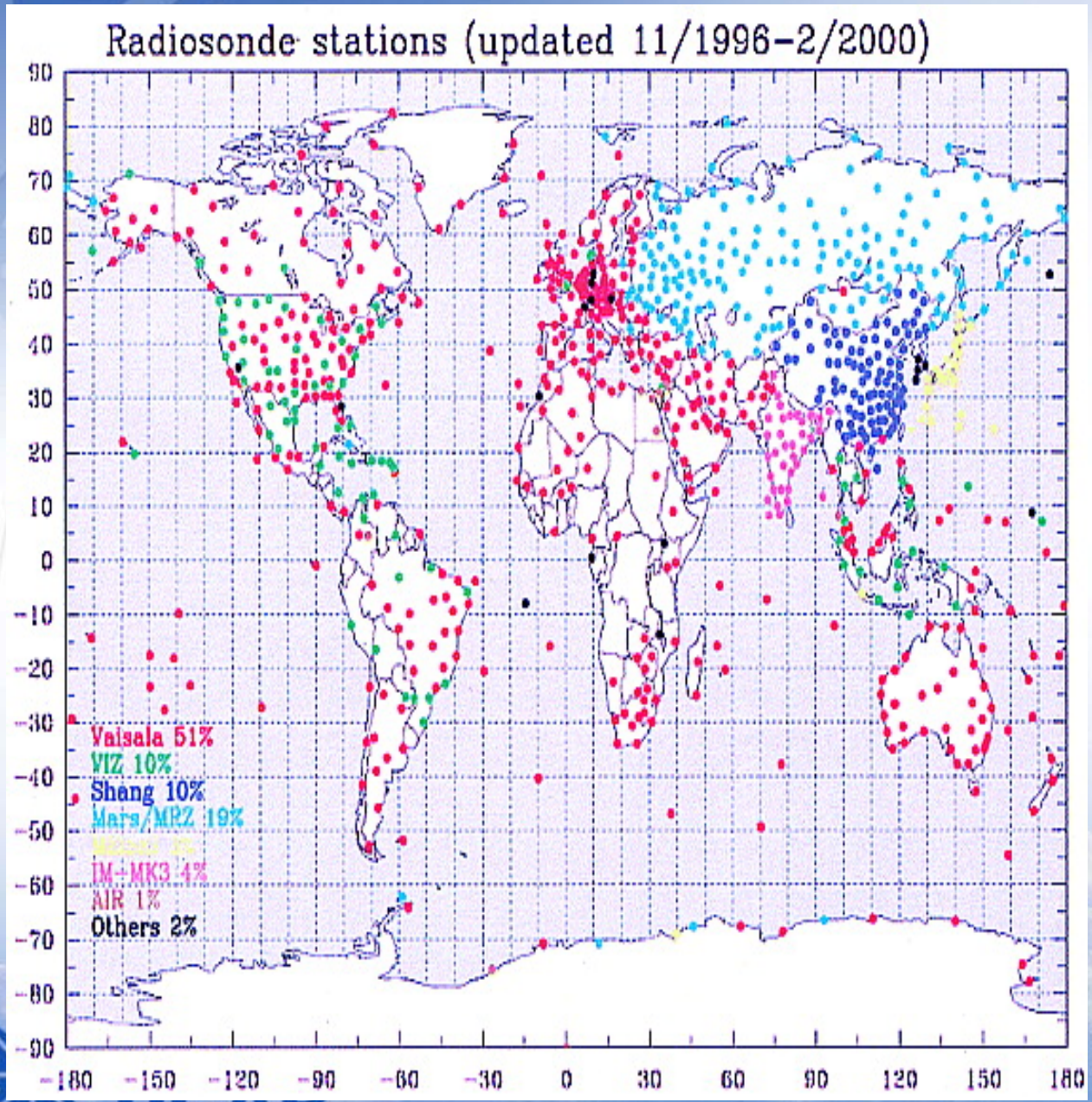




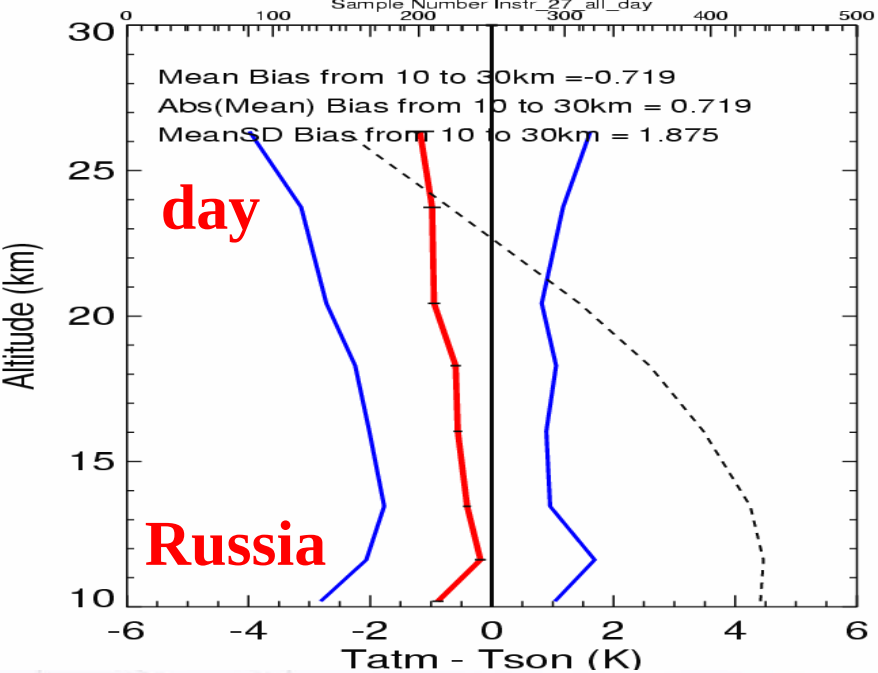


N15, N16 and N18 AMSU calibration against COSMIC

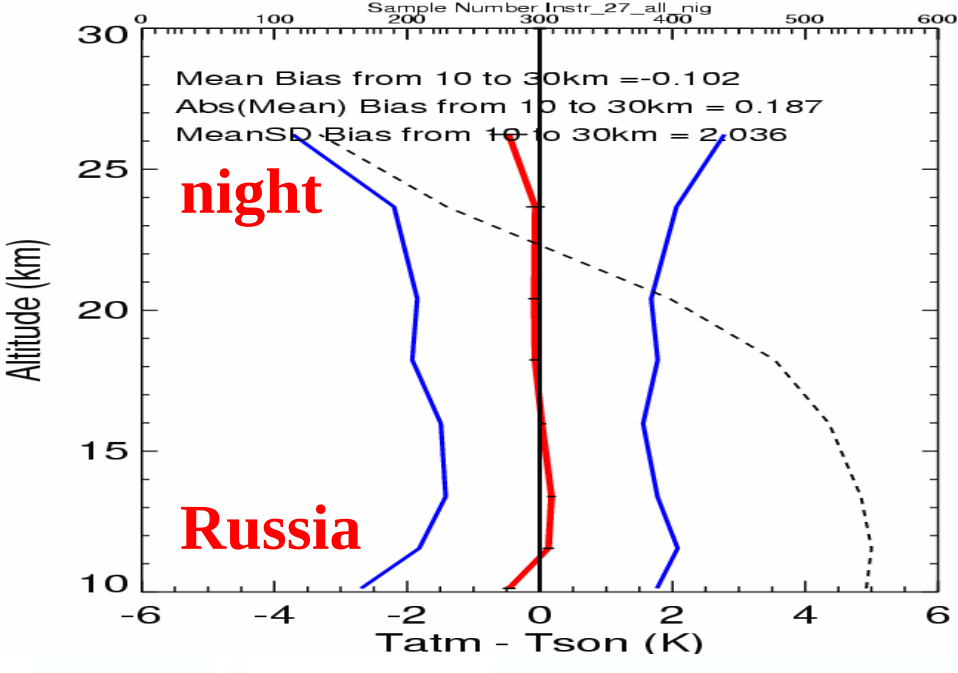
Using RO data to assess the quality of radiosonde data



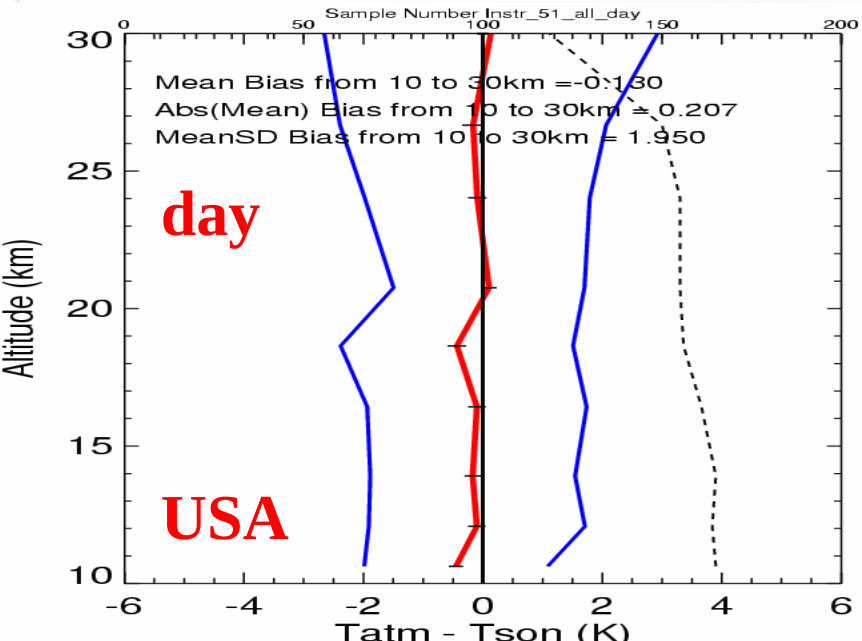
Region	Sonde Type	Matched Sample
Russia	AVK-MRZ	2000 (20%)
China	Shang	650 (6.1%)
USA	VIZ-B2	600 (5.9%)
Others	Vaisala	3140 (30%)

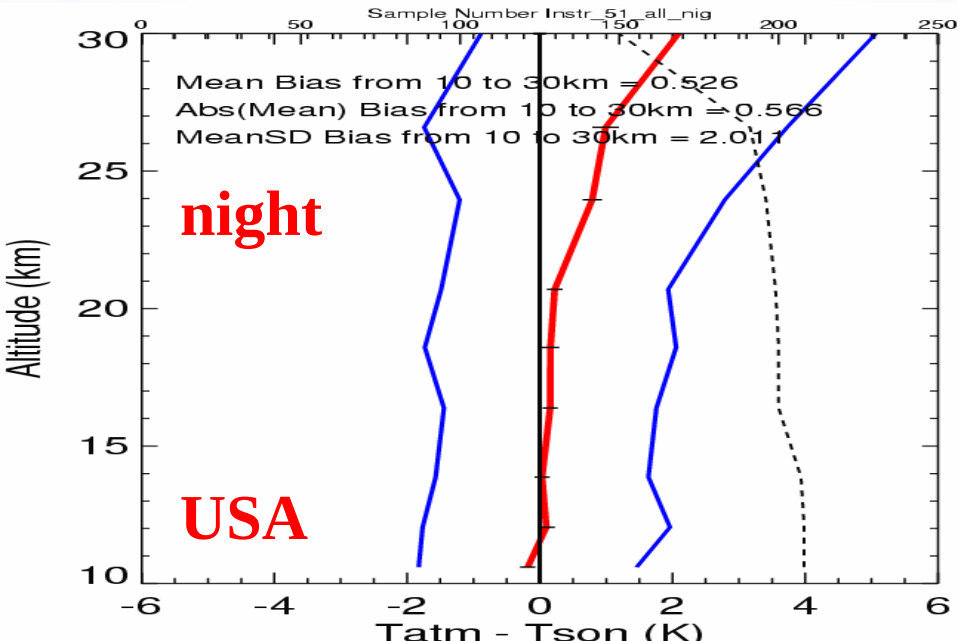


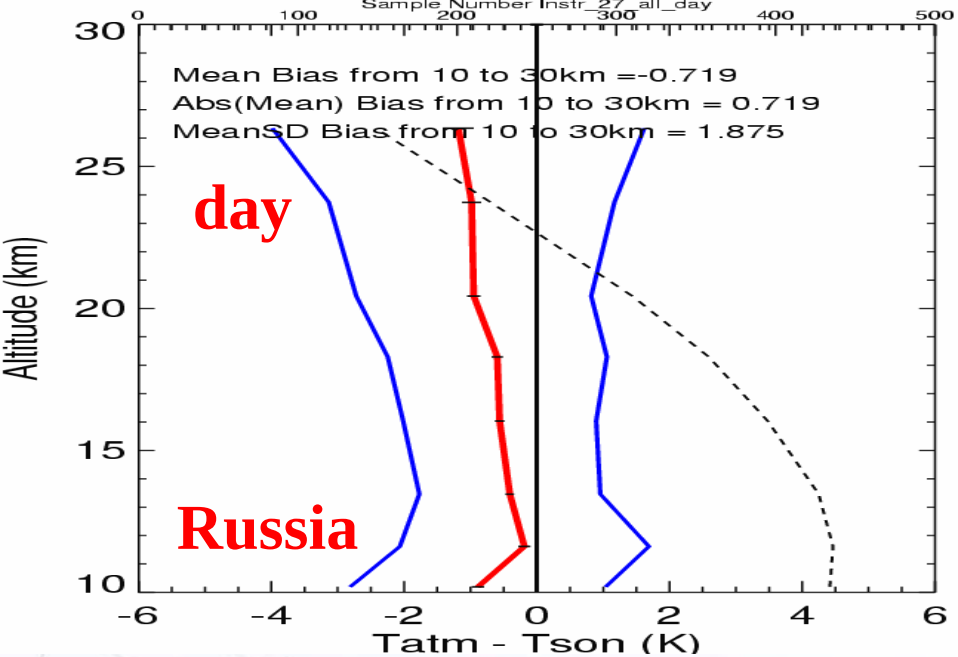
COSMIC-Radiosonde

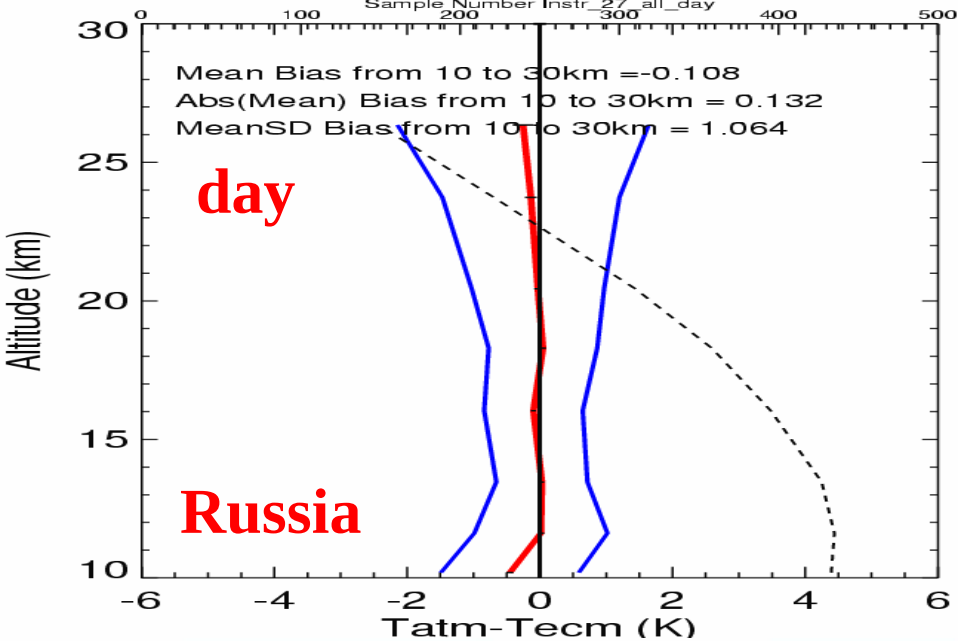


COSMIC-Radiosonde



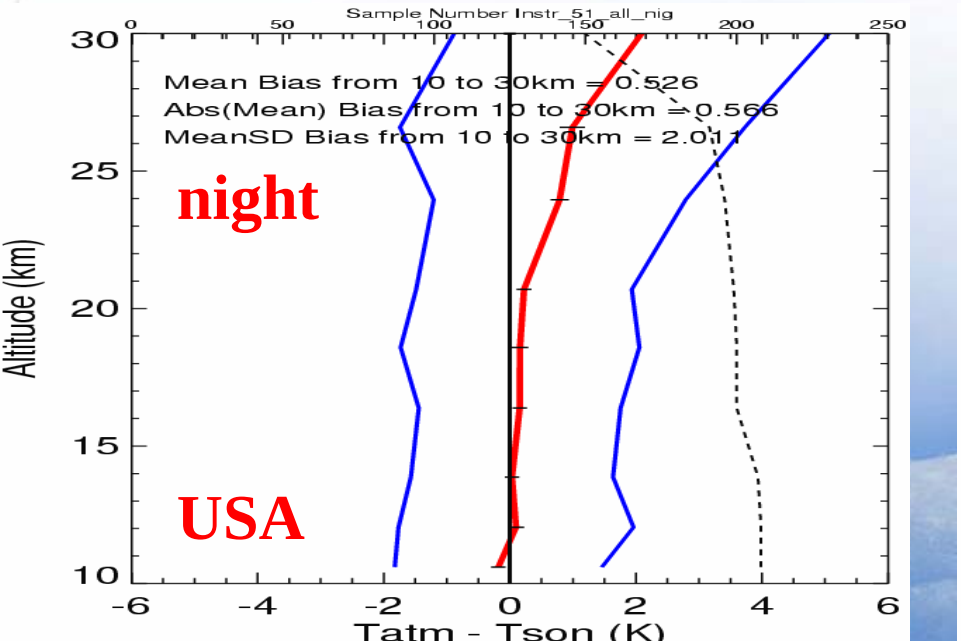


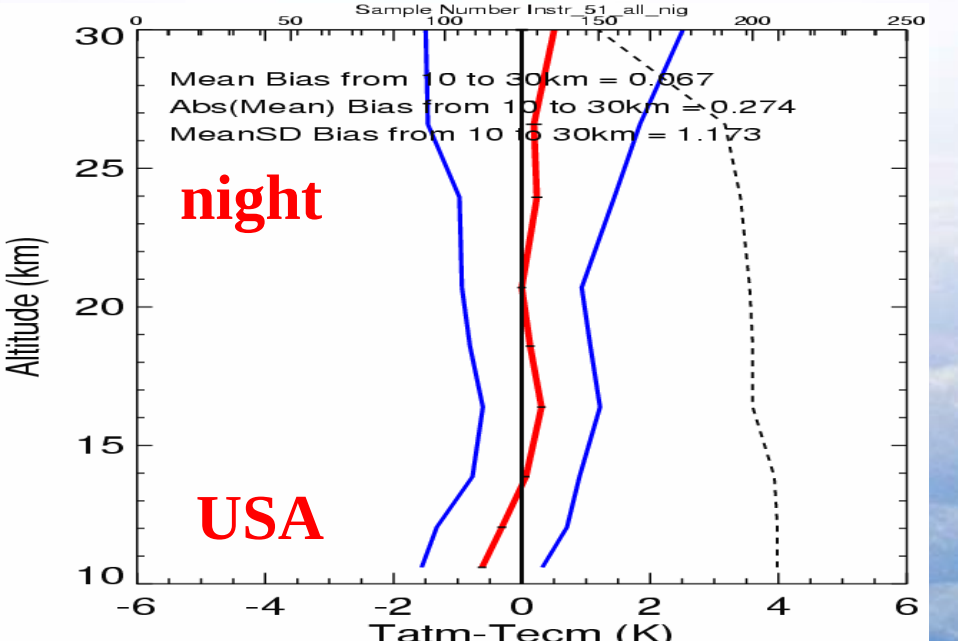




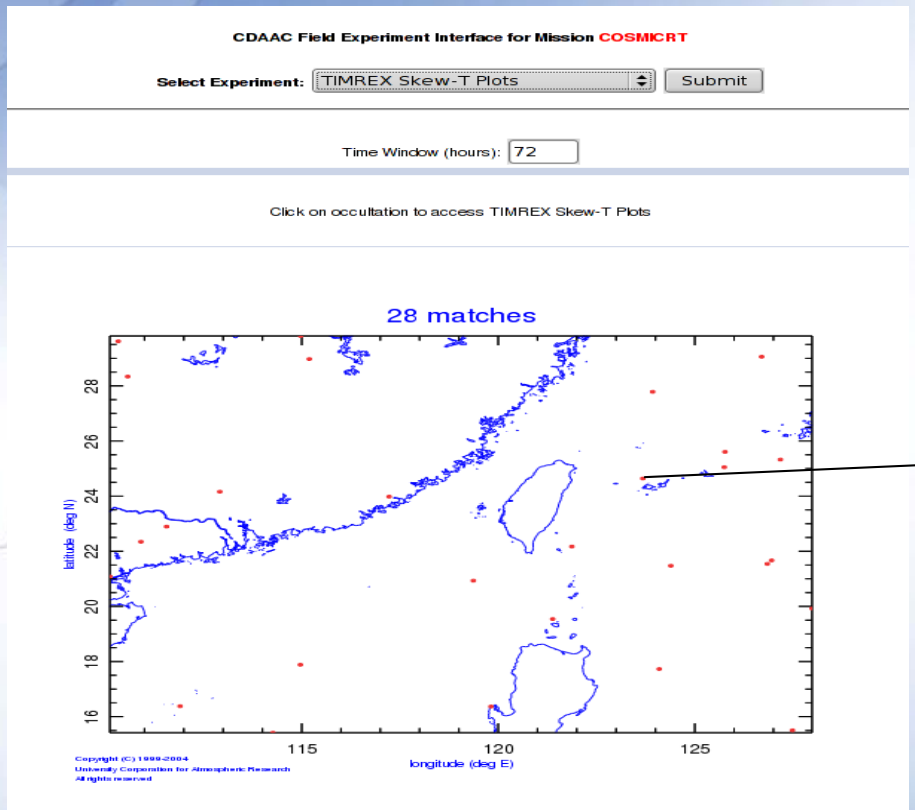
COSMIC-Radiosonde

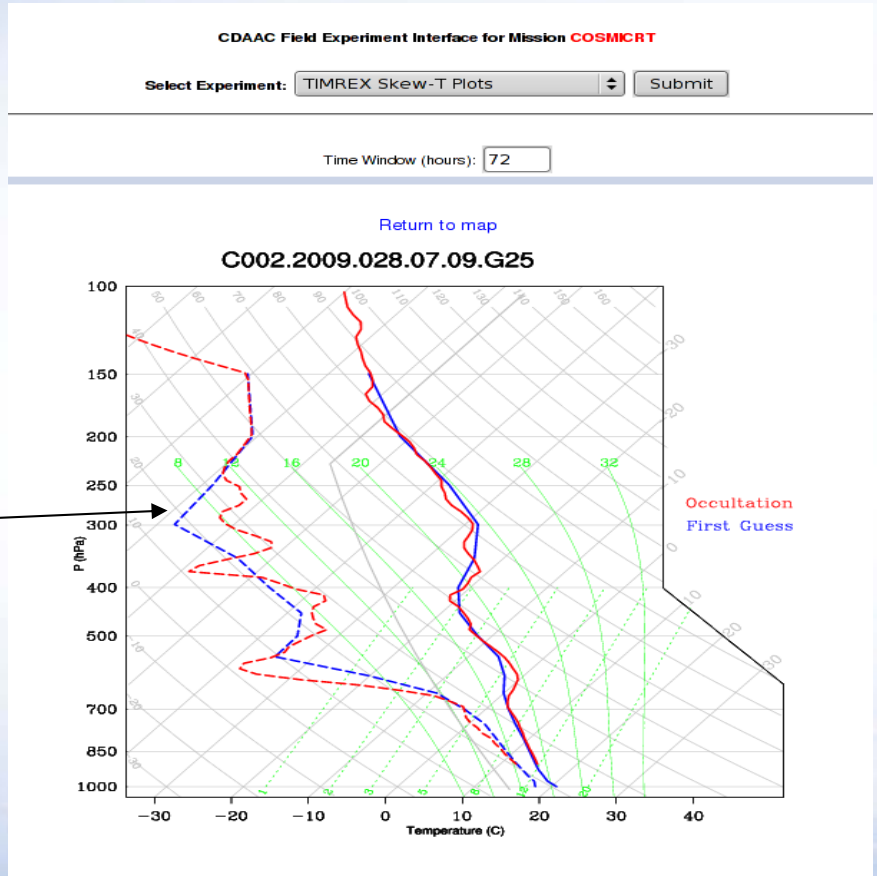
COSMIC-ECMWF





Support for EOL field campaigns in near-real-time





- Select occultation sounding location on map to display skewT plot
- Interface customizable for different field campaign
- Supports TIMREX (Taiwan), T-PARC, VOCALS (Chile), and HIPPO
- Also shows predicted occultation locations

From Doug Hunt

http://catalog.eol.ucar.edu/cgi-bin/hippo/ops/date_browse?dateUTC=20090123

Opportunity for Radio Occultation Data

Last summer, Unidata and COSMIC (UCAR/UOP programs), surveyed the Unidata community regarding COSMIC data. Over 90% of the respondents indicated interest in receiving the data using Unidata LDM data distribution technologies.

The FORMOSAT-3 COSMIC satellite mission provides up to 2,500 radio occultation observations on vertical profiles of atmospheric air density, temperature, and water vapor as well as ionospheric electron density per day. Follow this link for additional information about the data.

Working collaboratively with COSMIC and Taiwan's FORMOSAT-3 project, we now have a path for you to follow to receive the data for education and research purposes.

Steps to take to receive the data using LDM technology.

Unidata has enhanced IDV and GEMPAK visualization and analysis software to use with the data. Unidata Support support@unidata.ucar.edu will field questions from the Unidata community pertaining to their technologies.

Unidata: http://www.unidata.ucar.edu/

COSMIC: http://www.cosmic.ucar.edu/

Linda Miller
Community Services, Unidata

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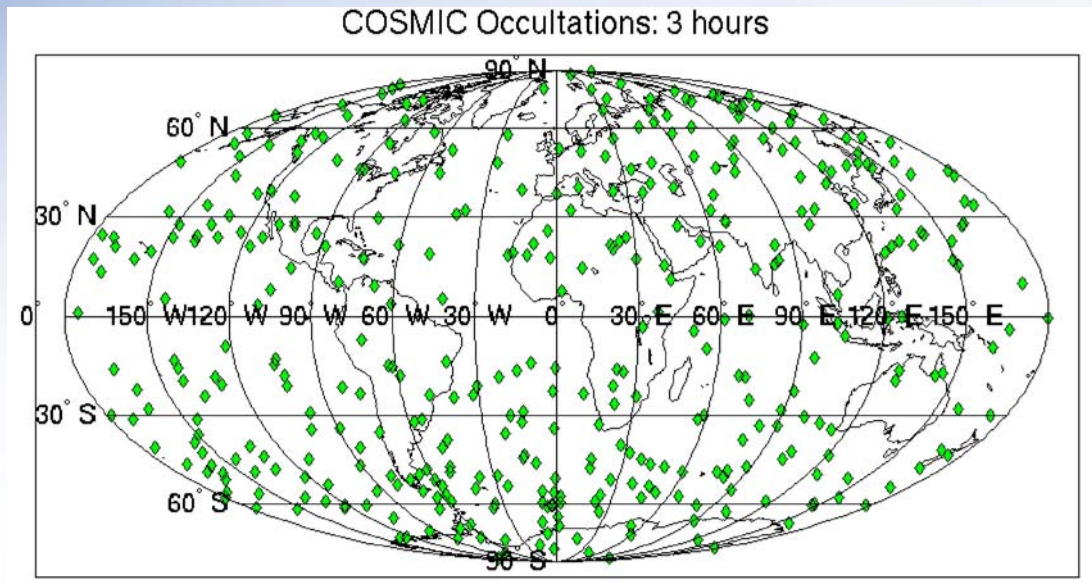
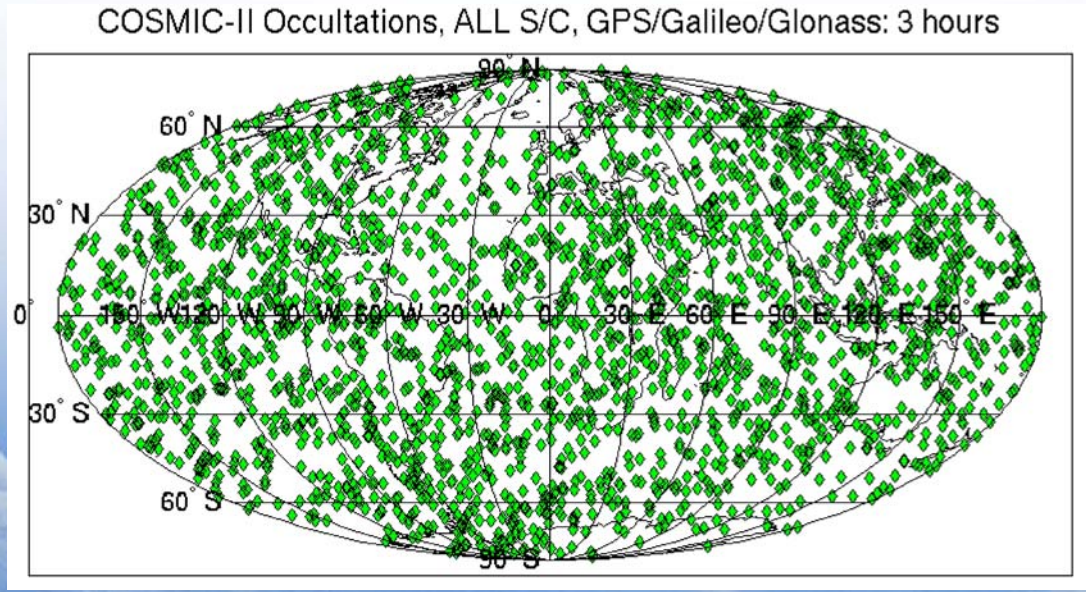
COSMIC-II

- 12 micro-satellites tracking three navigation systems: GPS, GALILEO, and GLONASS.
- 8 satellites on 72^{o} inclination, and 4 satellites on 24^{o} inclination, enhancing tropical observations.
- Will produce 14,000 soundings per day.
- Comparison of sounding distribution over three hour periods between COSMIC and COSMIC-II is shown.





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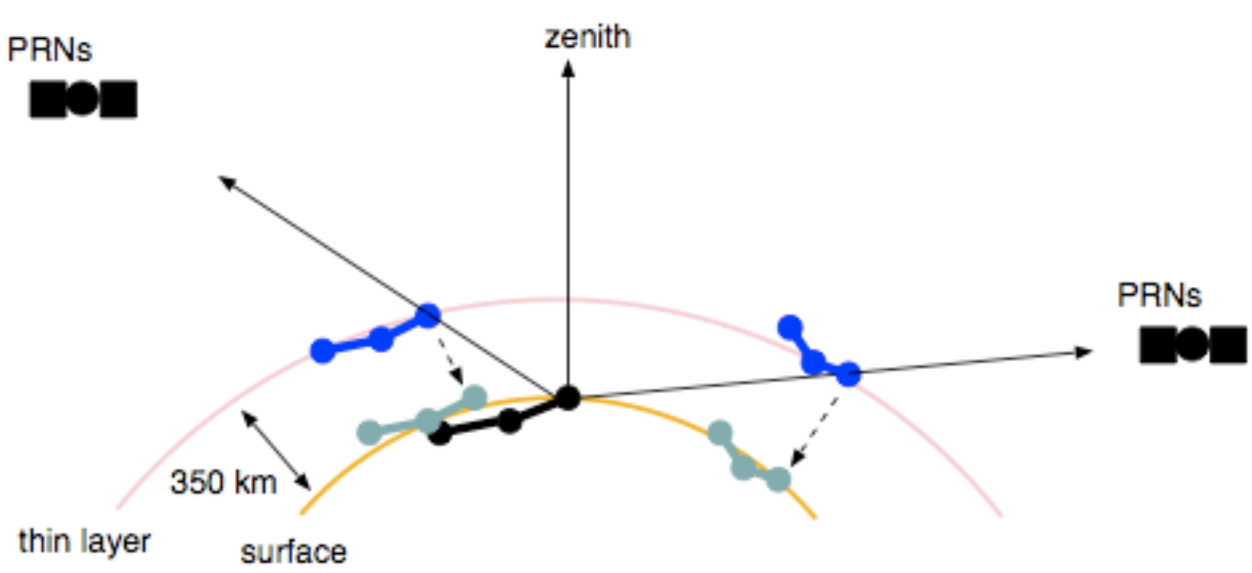
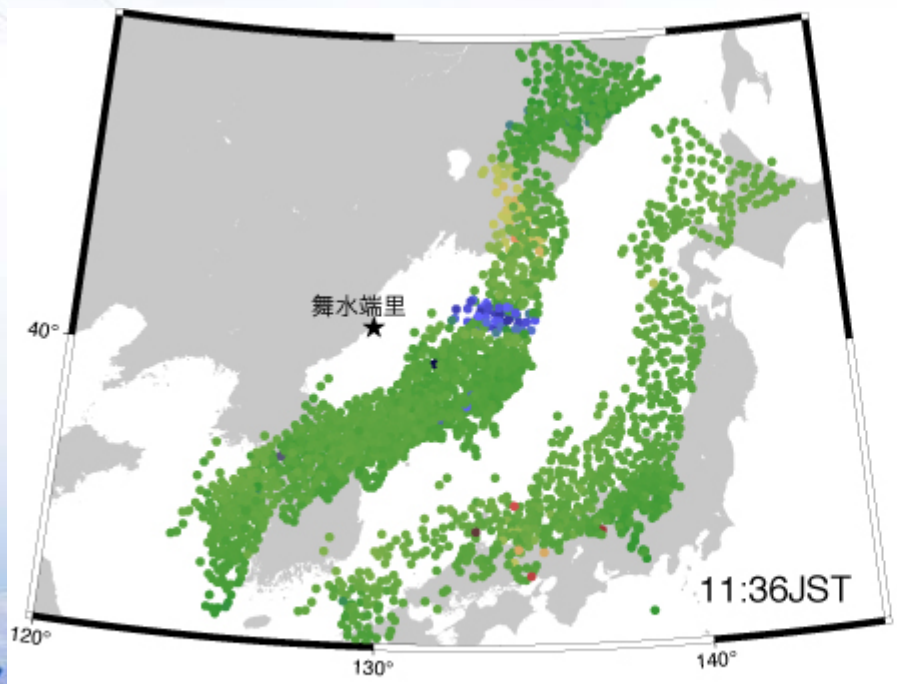
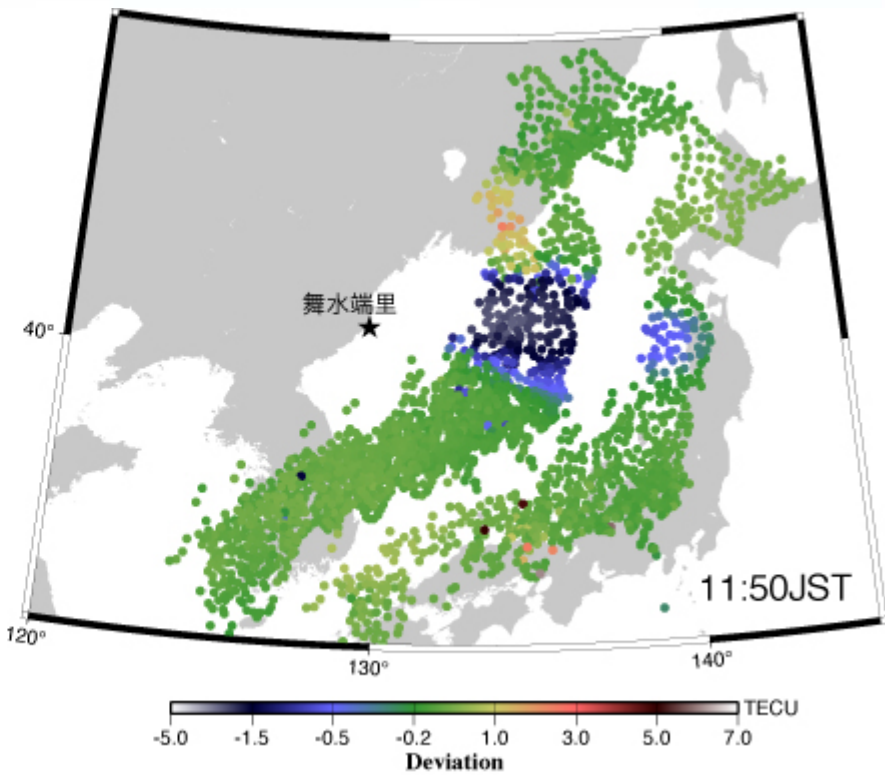
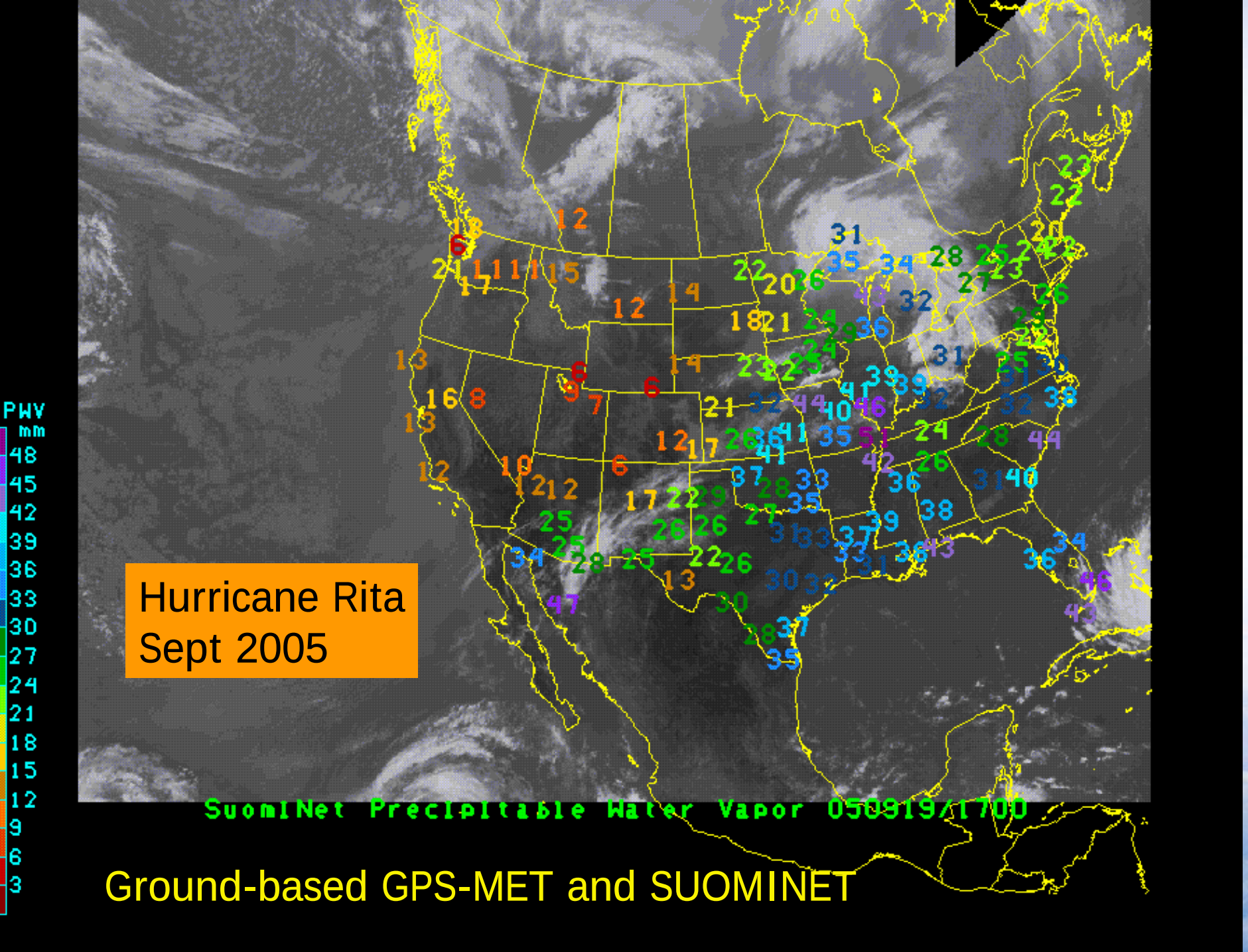
Detection of N. Korea missile launch by ground-based GPS stns in Japan









Ground-based GPS-MET and SUOMINET

Thank you!