INTERNATIONAL GPS SERVICE

INTERNATIONAL COOPERATION AND ACHIEVEMENTS IN GPS/GNSS

IGS Central Bureau
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http://igscb.jpl.nasa.gov

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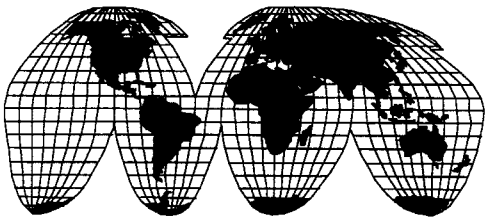
Outline of Presentation

- Mission / Description of IGS
- New Strategic Plan
- Organization
- Projects
- Summary

WHY IGS?

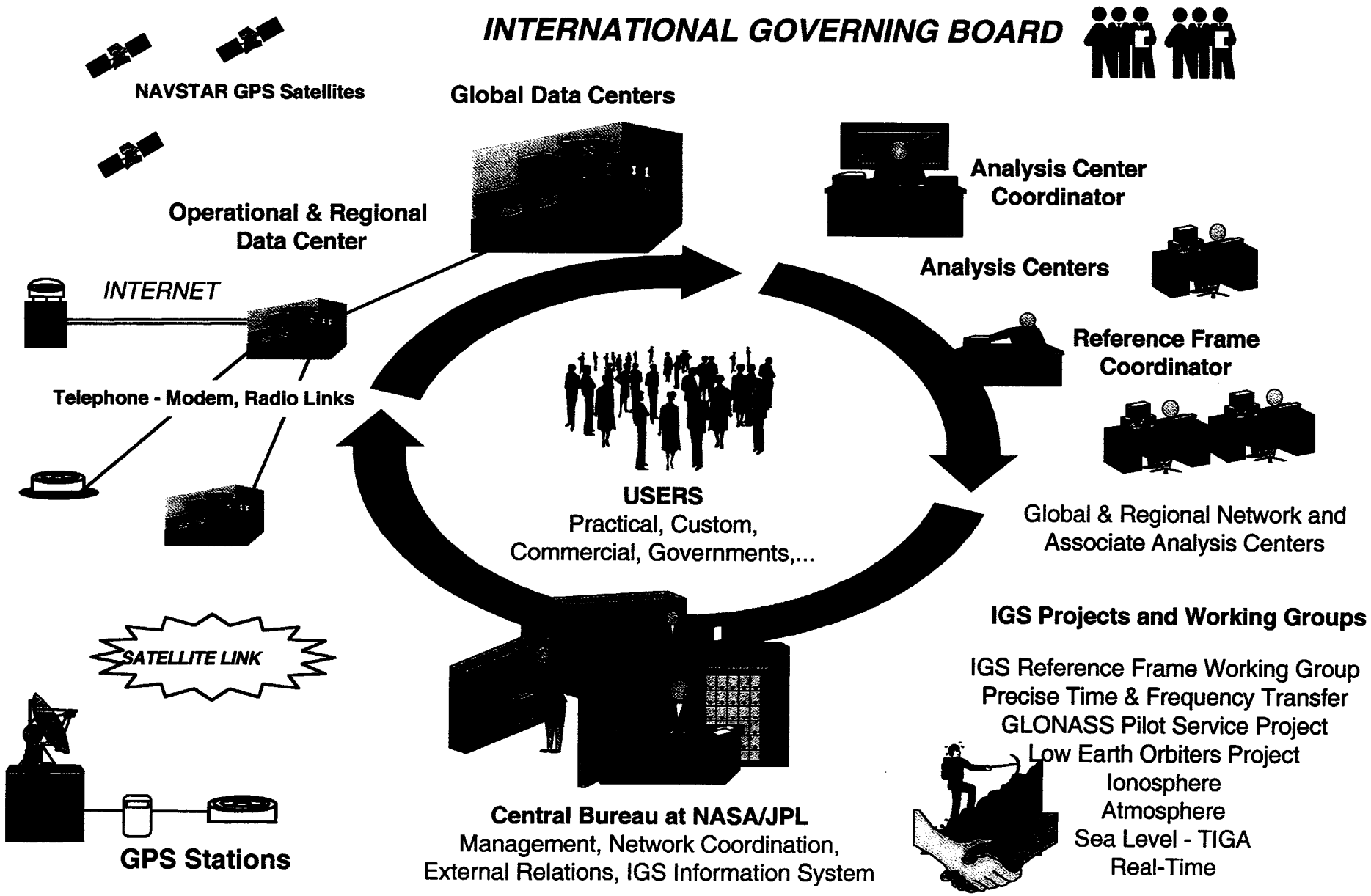


- Key factors in formation of IGS
  - > All geodynamics and geodetic organizations realized the potential of GPS by late 1980's
  - > Motivating goal: millimeter positioning in support of science & engineering anywhere in the world
  - > Not one agency can or should assume the capital investment & recurring operations costs for the entire infrastructure
  - > Join with key international partners to form federation, define cooperation, set standards, science quality driven
  - > Implement a global civilian GPS tracking system for science and research
  - > Global framework for virtually all regional network applications (SCIGN, EUREF, SIRGAS, etc.)

IGS Mission & Objectives

'... committed to providing the highest quality data and products as the standard for global navigation satellite systems (GNSS) in support of Earth science research, multidisciplinary applications, and education. ... as well as to facilitate other applications benefiting society....'

- **International network of over 300 GPS stations are used to produce:**
  - > **Highest accuracy GPS satellite orbits available anywhere**
    - » **(-3-5 cm 3-d wrms)**
  - > **Coordinates and velocities of the IGS tracking stations**
  - > **GPS satellite and tracking station clock information**
  - > **Earth rotation parameters, ionospheric, tropospheric information**
  - > **Derived products in support of science applications and novel projects**


INTERNATIONAL GOVERNING BOARD
NAVSTAR GPS Satellites
Global Data Centers
Analysis Center Coordinator
Operational & Regional Data Center
Analysis Centers
INTERNET
Reference Frame Coordinator
Telephone - Modem, Radio Links
USERS
Practical, Custom, Commercial, Governments,...
Global & Regional Network and Associate Analysis Centers
IGS Projects and Working Groups
SATELLITE LINK
IGS Reference Frame Working Group
Precise Time & Frequency Transfer
GLONASS Pilot Service Project
Low Earth Orbiters Project
Ionosphere
Atmosphere
Sea Level - TIGA
Real-Time
GPS Stations
Central Bureau at NASA/JPL
Management, Network Coordination, External Relations, IGS Information System

IGS Organization

- Over 200 contributing organizations in 75 countries, many more users
- Recognized as an international scientific service
- Advocates an *open data* policy
- Network of over 300 permanent precision geodetic receivers produce GPS data on a continuous basis,
  - ~100 report hourly, subset for a real-time network demonstration
- Approved activity of the International Association of Geodesy (IAG), January 1, 1994.
  - Member of Federation of Astronomical and Geophysical Data Analysis Services, 1996 (FAGS)
- IUGG and ICSU recognition
  - International Union of Geodesy and Geophysics
  - International Council of Scientific Unions

Long Term Goals and Objectives

- Provide the highest quality, reliable GNSS data and products, openly and readily available to all user communities.
- Promote universal acceptance of IGS products and conventions as the world standard.
- Continuously innovate by attracting leading-edge expertise and pursuing challenging projects and ideas.
- Seek and implement new growth opportunities while responding to changing user needs.
- Sustain and nurture the IGS culture of collegiality, openness, inclusiveness, and cooperation.
- Maintain a voluntary organization with effective leadership, governance, and management.

Strategies of the IGS 2002-2007

To achieve the long-term goals and objectives of the IGS, three key strategies are identified:

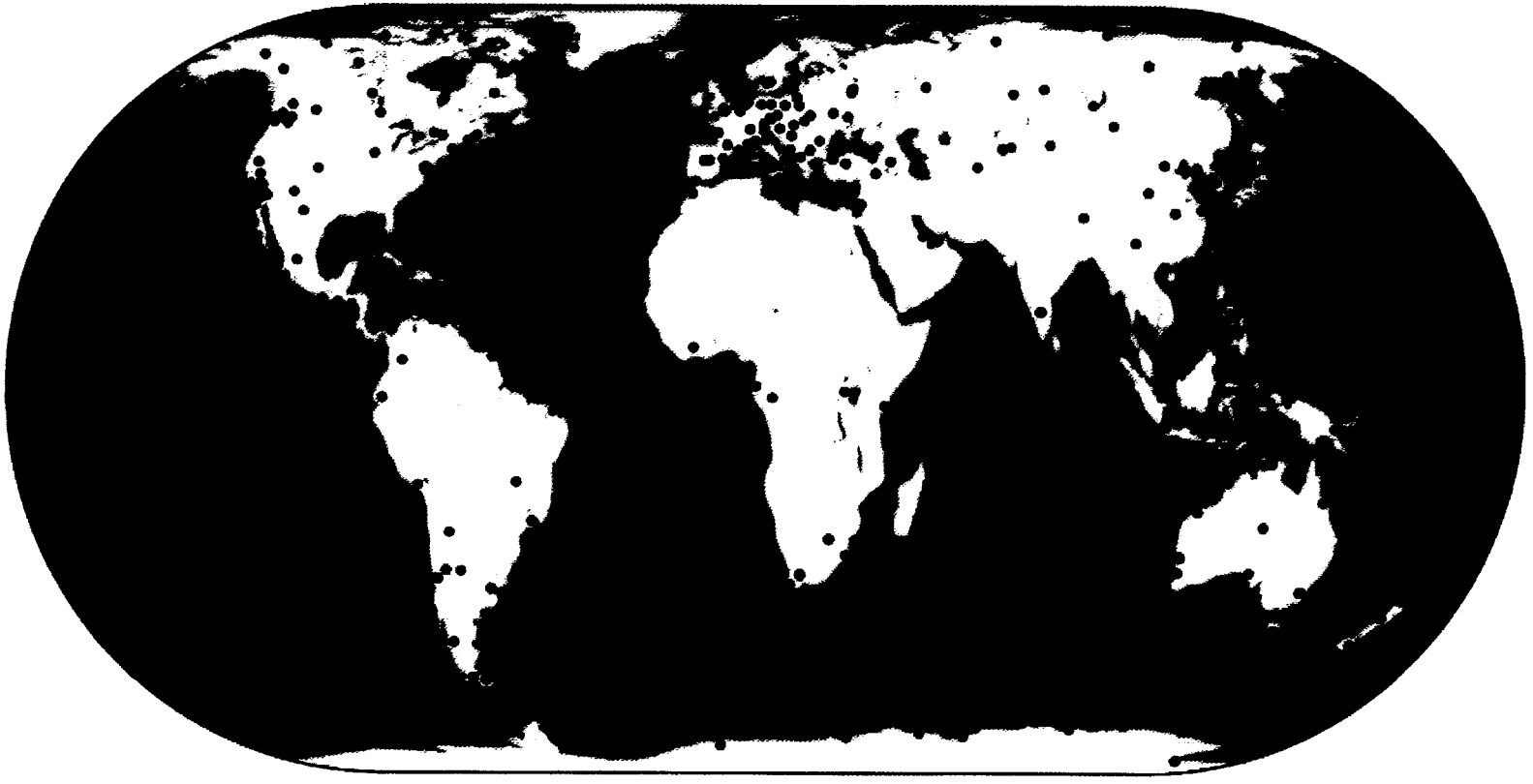
- **Ensure delivery of *"world-standard"* GPS (and other GNSS) data and products, providing the standards and specifications globally.**
- **Pursue new opportunities for growth to improve the services and serve a broader range of users.**
- **Continuously improve the effectiveness of the IGS organization.**

IGS Supports the UN GNSS AT Charter

"Using space applications for human security, development and welfare, action should be taken ... to improve the efficiency and security of transport, search and rescue, geodesy, and other activities by promoting the enhancement of universal access to and compatibility of space-based navigation and positioning systems."

- IGS demonstrates the capability of incorporating other satellite systems into the observation and analysis process - GLONASS and GPS precise and accurate products generated according to accepted world standards
- Future Galileo and other GNSS *must* be interoperable and compatible with with each other.
  - > Seamless to users, interoperable guarantee, but by what definition?
  - > Importance of common Earth reference system (ITRF) and timing/time transfer applications are critical
  - > Continue decade of robust observations for applications requiring long-term monitoring (e.g.,climate, sea-level, crustal deformation, earthquake studies, volcanoes, Low Earth Orbiting satellite and altimeter missions, etc.)
  - > Real-time measurements demand higher degree of system interoperability to achieve consistent and precise results

IGS Tracking Network 2002



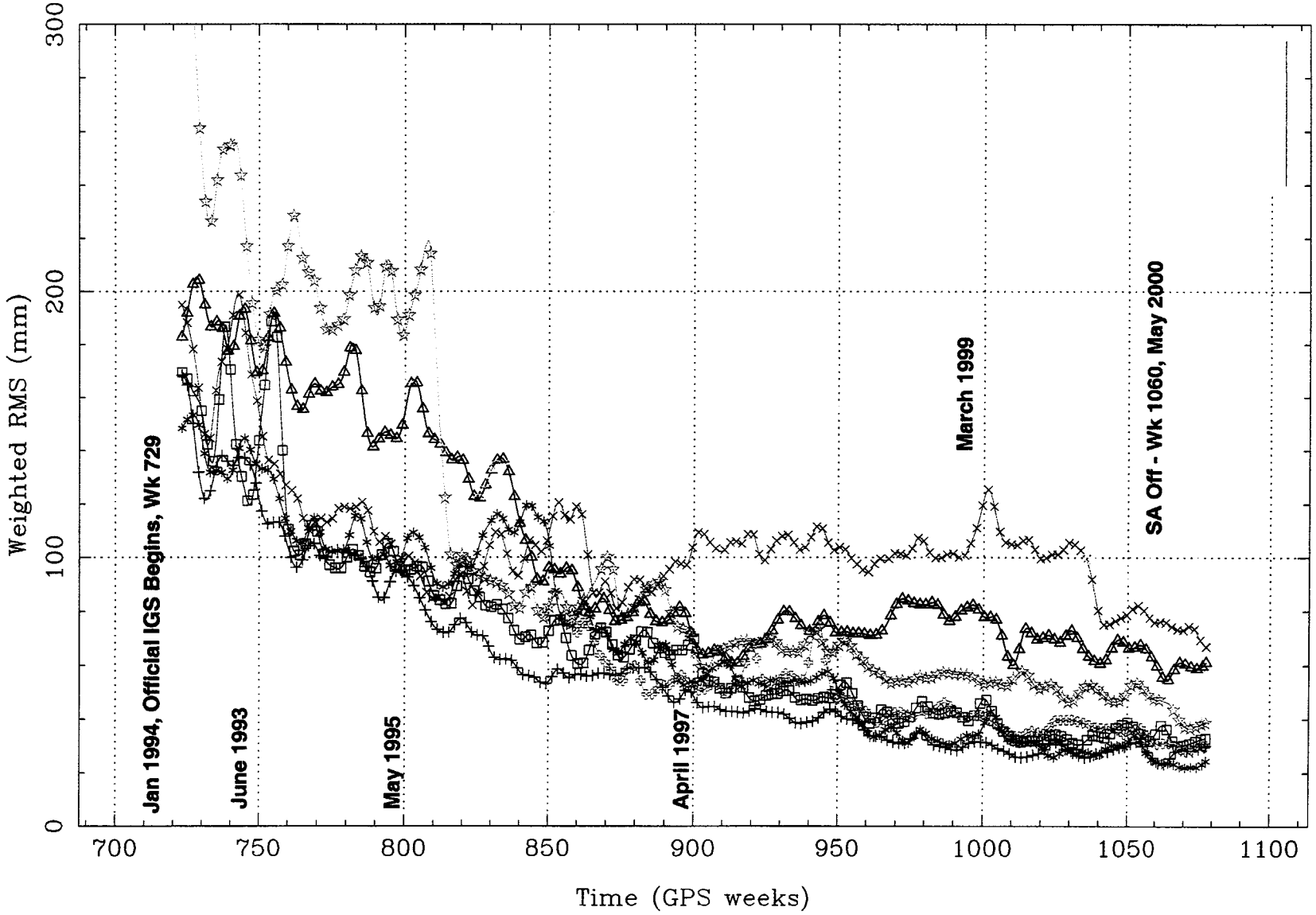
GMT Apr 15 14:54:48 2002

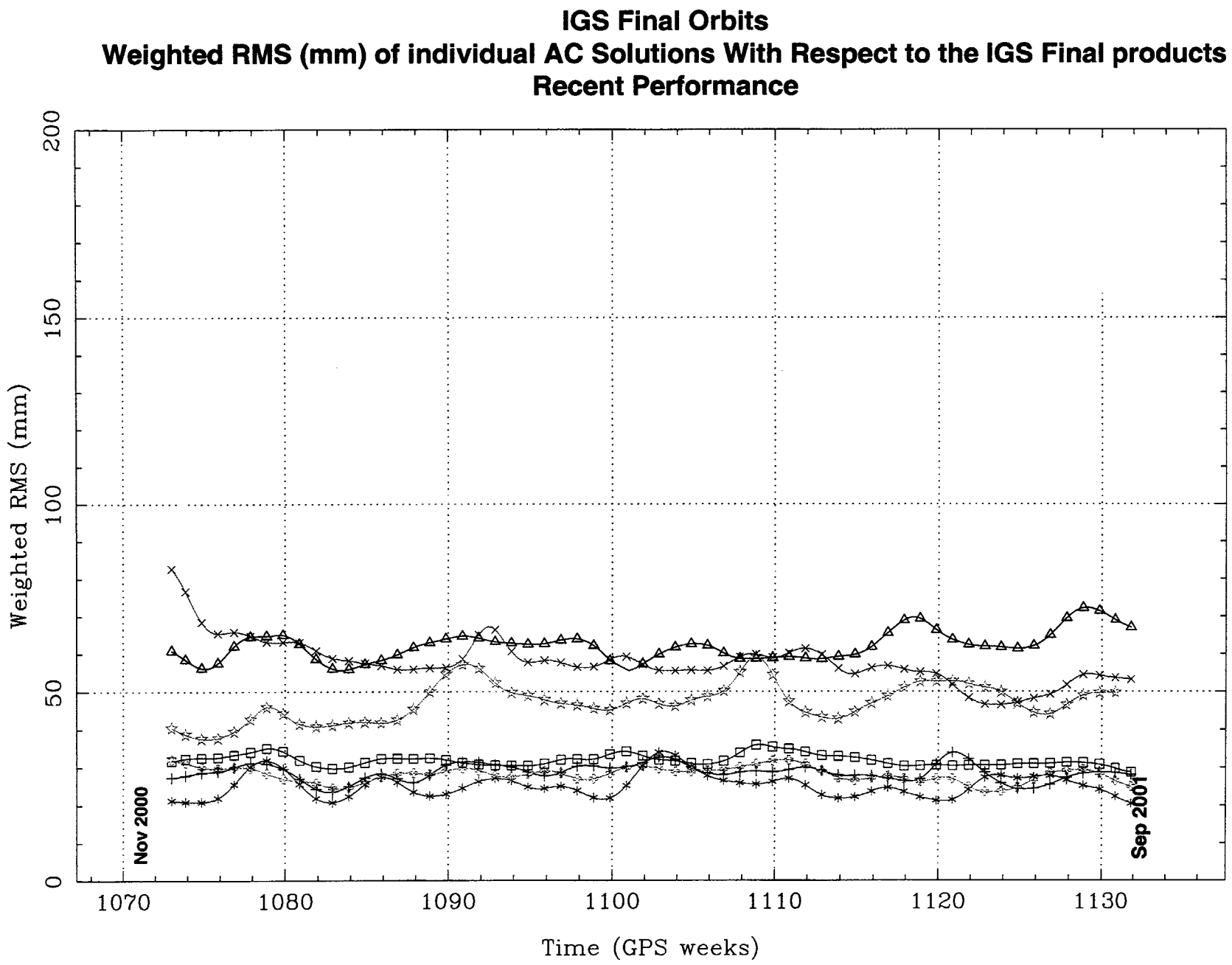
http://igscb.jpl.nasa.gov/network/netindex.html

Operations of the IGS

- Operational Data Centers
  - > Retrieve data from receivers
  - > Validate data and monitor station status
  - > Translate raw GPS data into RINEX (Receiver Independent Exchange)
  - > Forwards appropriate files to Global Data Centers or Regional Data Centers
- Global Data Centers organize the files on the basis of site and time, and provide Internet data access to users and analysts
- IGS Analysis Centers pick up the data from the Global Data Centers, and estimate precise orbits, Earth Rotation parameters (ERP), clocks, etc.
- Analysis Center results are collected by the Analysis Coordinator and combined into the official IGS products

Weighted RMS (mm) of individual Analysis Center Solutions With Respect to the IGS Final products
Performance Improvement Since Beginning of IGS




IGS Final Orbits
Weighted RMS (mm) of individual AC Solutions With Respect to the IGS Final products
Recent Performance
Weighted RMS (mm)
0
50
100
150
200
1070
1080
1090
1100
1110
1120
1130
Time (GPS weeks)
Nov 2000
Sep 2001

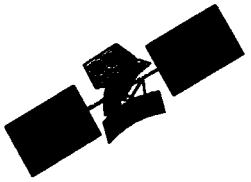
IGS Projects & Working Groups

- Reference Frame Densification
  - > Generate a robust and homogeneous reference system, relating scientific results anywhere in the world
  - > Plot network time series, position and velocities support plate motion and crustal deformation studies
- Precise Time & Frequency Project
  - > Exploit GPS measurements for improved accurate time and frequency comparisons worldwide, sub nanosecond
  - > Joint with the BIPM in France
- Low Earth Orbiter (LEO) Project
  - > Generate precise orbits for LEO satellites, Gravity (CHAMP, SAC-C, GRACE, JASON, etc.)
  - > Support occultation measurements for atmospheric profiling
- GLONASS Service Pilot Project IGLOS-PP
  - > Extensibility of IGS, 'classic' products for Russian GLONASS system
- Tropospheric Working Group
  - > Derive total zenith path delay or precipitable water vapor for GPS observations
  - > Ground-based meteorology, weather forecasting (severe storms), climate

IGS Projects (con't.)

- **Ionospheric Working Group**
  - > **Use dual frequency GPS data to determine Total Electron Content (TEC) including its temporal and spatial variations**
  - > **Daily measurements and maps of the Ionosphere**
- **Sea Level Project - TIGA**
  - > **Measuring long-term motion of Tide-gauge Benchmarks**
    - » decouple crustal deformation or subsidence signatures at coastal areas from long-term sea-level changes, ocean loading effects
  - > **Support altimeter calibration at specific sites and inter-mission calibrations, TOPEX, JASON, etc.**
- **Real-time Working Group**
  - > **Develop international standards for cooperation of real-time data exchanges**
  - > **Evaluate IGS involvement in real-time applications**
- **AFREF Initiative - African Reference System**
  - > **Develop a continental reference system based on sustainable technology for the African continent**
  - > **Establish the geodetic base for all development within Africa**

GLONASS Pilot Service



- International GLONASS experiment IGEX, Investigated uses of GLONASS for geodetic and geophysical applications
  - > October'98 - April'99, 61 GLONASS sites, 30 SLR stations
  - > Interoperability of GPS/GLONASS
  - > Precise Orbit determination and reference frame: PZ90 - ITRF96/97
  - > Time offsets between GPS and GLONASS systems and GLONASS systems to UTC
  - > Orbits average throughout ~ 20- 30 cm between ACs
  - > 30 - 40 cm level comparisons GPS-SLR solutions
- Demonstrates the extensibility of IGS to accommodate other microwave systems, e.g. GALILEO, GNSS
- Pilot Service Project led by Jim Slater, NIMA USA

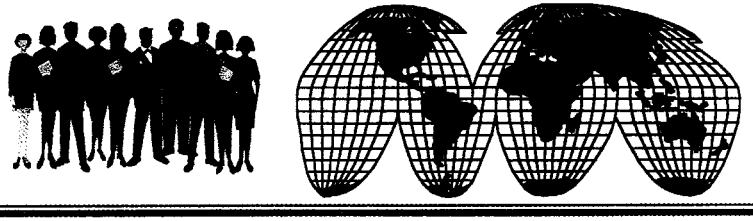
Incorporation of Other GNSS Systems - IGS & Galileo

- Flexible Infrastructure of the IGS allows incorporation of other data types into processing streams
  - > Successful IGEX-98 campaign utilized GLONASS data; upcoming IGLOS Pilot Project will further integrate with existing GPS activities
  - > Well-positioned to incorporate other GNSS such as Galileo; formation of a GNSS working group is expected at the end of this calendar year
- IGS global infrastructure and knowledge of a large group of experts may provide the Galileo system support for:
  - > Design phase,
  - > Demonstration phase
  - > Early operation periods
- Demonstration phase: campaign by IGS on the basis of GPS and (if Galileo receivers are available) Galileo signals
  - > Operational phase: calibration of the Galileo system (reference frame, time system, clock calibration, systematic effects) and evaluation of the system (quality phase data, etc.)

New Initiative - AFREF

- AFREF - African Reference System
  - > Develop a continental reference system based on sustainable technology for the African continent
  - > Establish the geodetic base for all development within Africa
  - > IGS methodology enables robust reference system at global and regional scales (EUREF, SIRGAS)
- IAG Commission X and IGS support and foster the development of African led projects and initiatives
  - > Need for such a geodetic basis recognized by UNESCO Food and Agricultural Organization (FAO), and the UN Economic Commission of Africa (ECA)
  - > The 50+ nations within Africa will achieve a homogeneous reference system consistent with ITRF
  - > See IGS AFREF mail archive for more details

Conclusion



- The economics of GPS make the measurement technology readily available and globally accessible to *all* users
- The organization and outreach of the IGS enables users to take advantage of data, systems, and products developed cooperatively with the top international GPS/GNSS experts
- Standards are developed and adopted worldwide through the IGS activities
  - > contributing to robust, homogenous reference system
  - > implementing common processes
- IGS is a supporting global foundation for nearly all regional and national GPS geodetic networks, projects and numerous applications worldwide
- Must ensure appropriate evolution, coordination, and interoperation of mutliple GNSS systems for societal and scientific benefit

IGS Web Site

http://igscb.jpl.nasa.gov

- The Central Bureau Information System is a key resource for all users
- One of the first websites in 1993
- Repository of IGSMail, IGS Reports, LEO Mail, AFREF Mail, IGLOS Mail, etc.
- IGS Directory, Calendar
- On-line access to all IGS publications
- Links to IGS sites and other locations of interest
- Rich FTP archives
- Tracking station information, site logs, network information
- FAQ

BACK-UP CHARTS

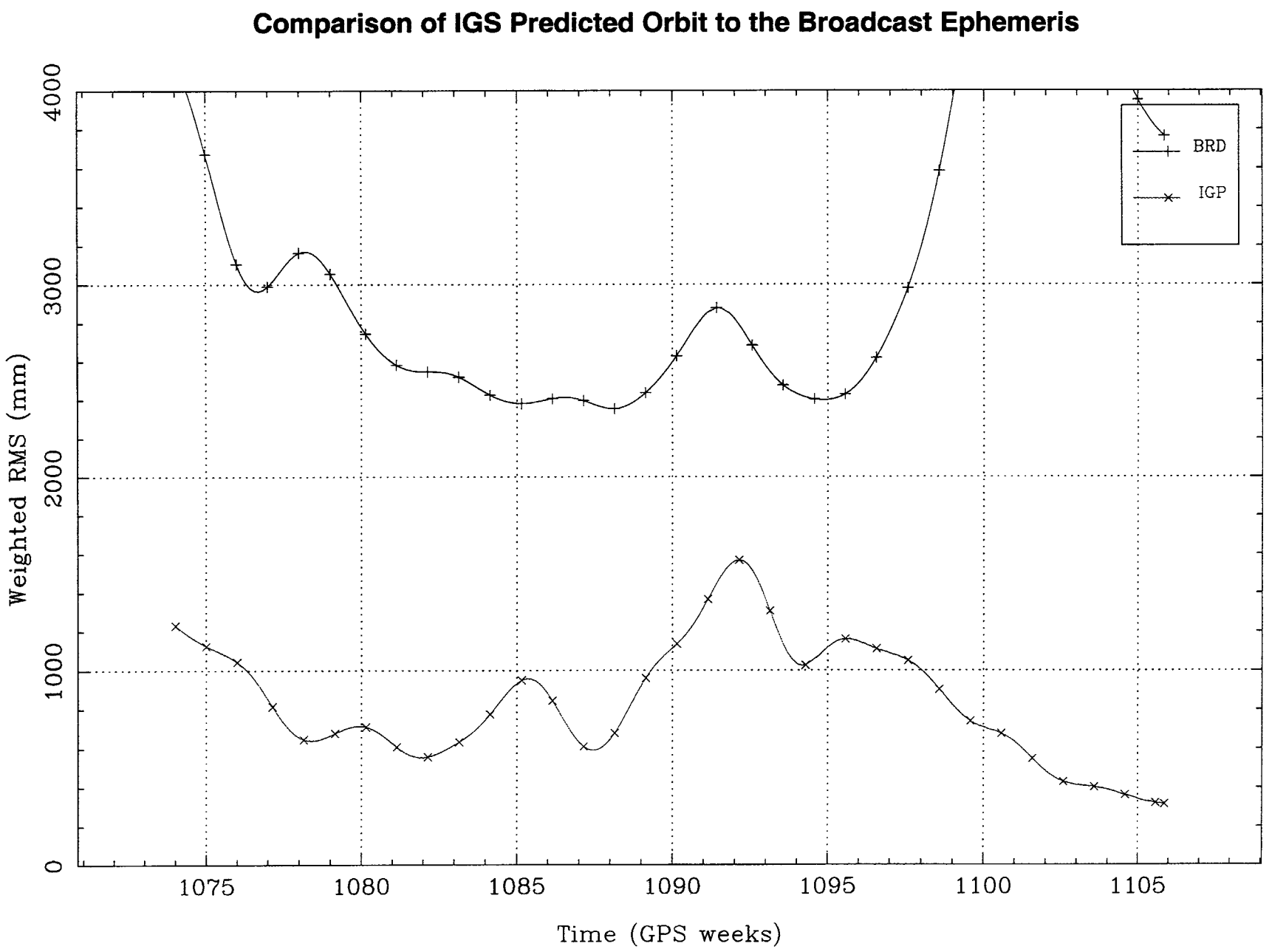
Acknowledgements

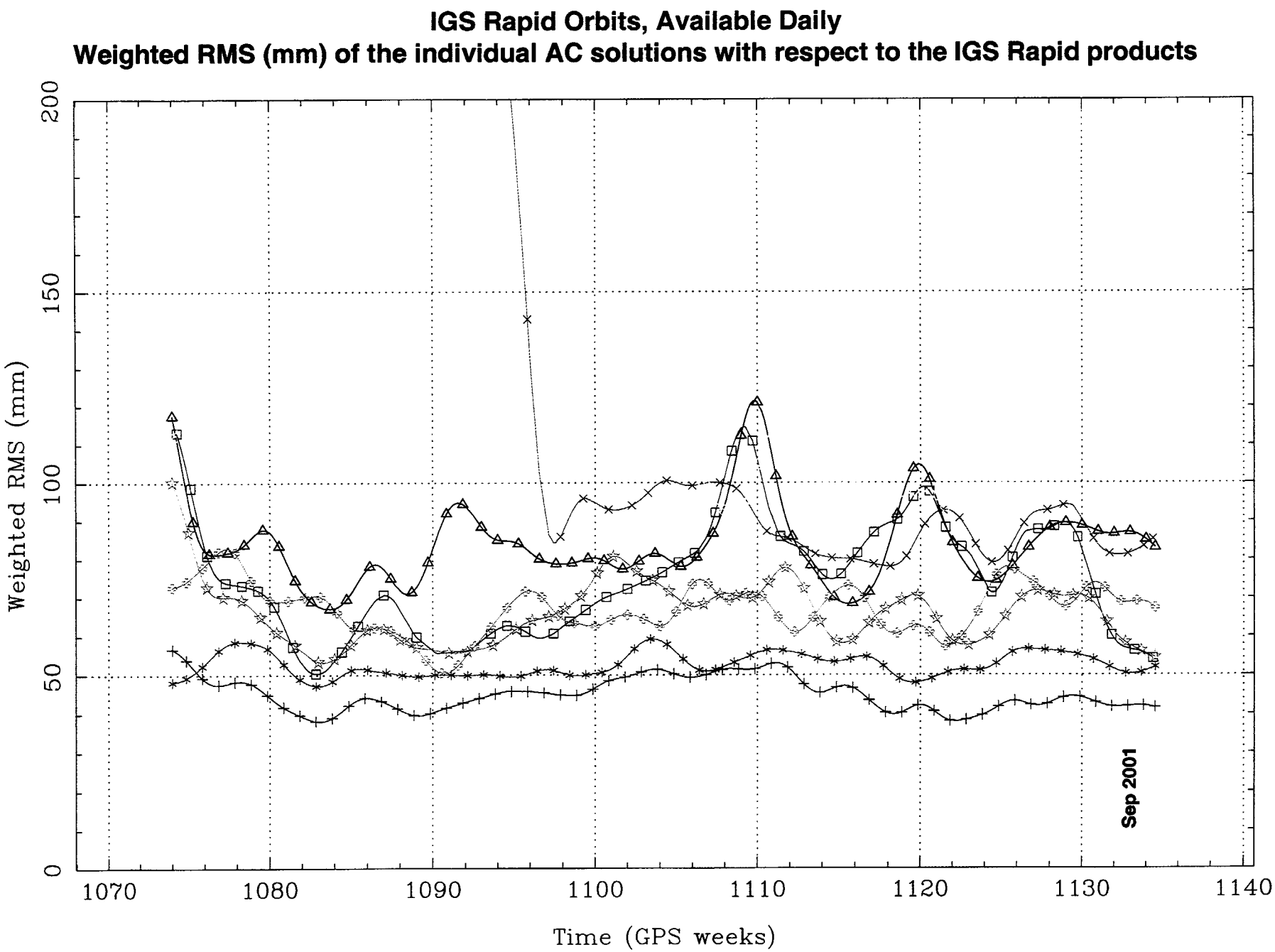
> It is important to recognize the significant contributions of the IGS components: station and network operators, data centers, analysis and associate analysis centers, coordinators, working group and project chairs, governing board members, associate members and all organizations worldwide who support and sponsor IGS activities.

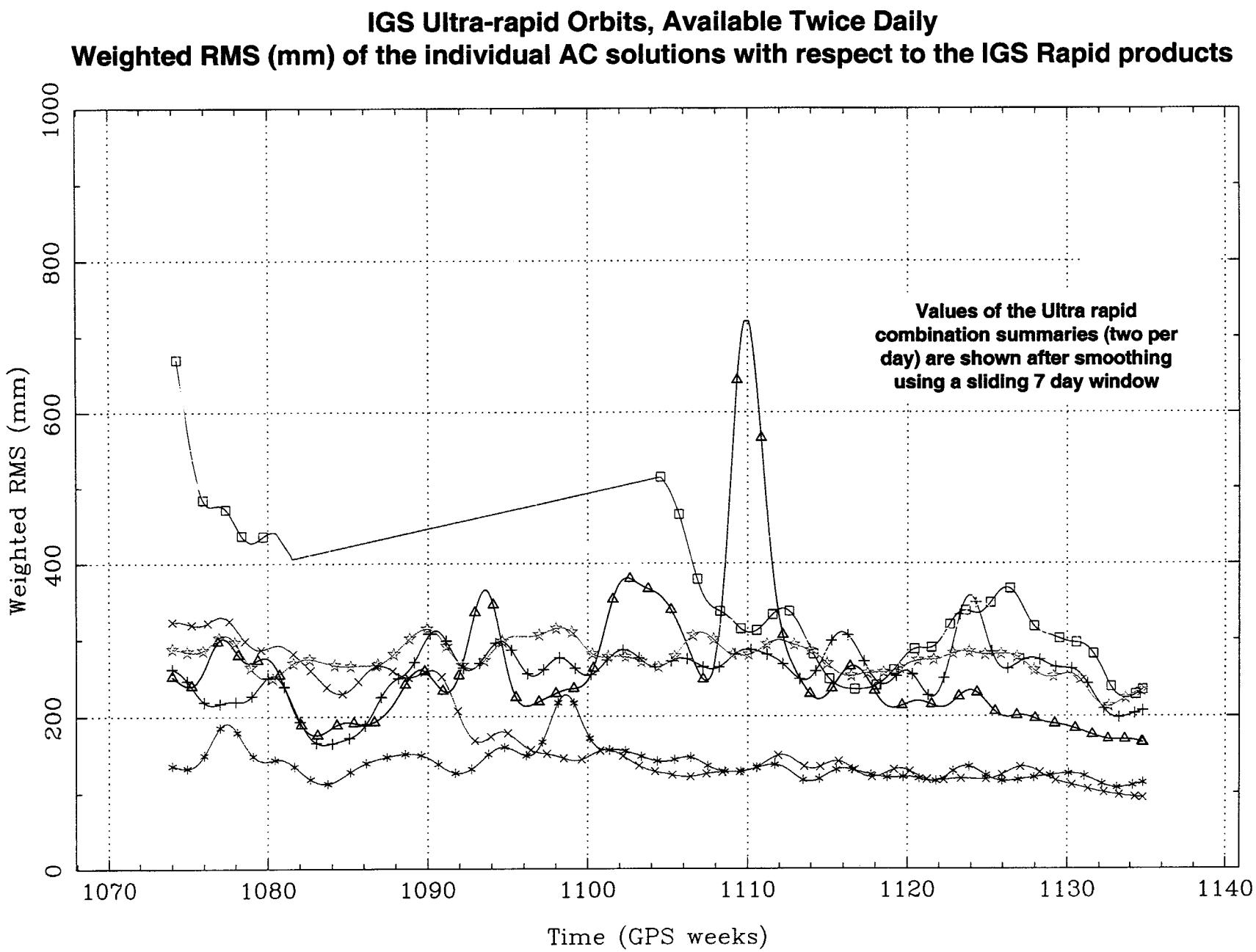
> The IGS counts over 200 contributing organizations in more than 75 countries.

Brief History of IGS

- CIGNET (Coordinated International GPS Network)
  - ~1987, an activity of CSTG, led by Gerry Mader, NGS
- Coordinated, standardized permanent network discussed at IAG meeting in Edinburgh, Scotland, September 1989
- Planning Committee formed in early 1990 led by Prof. Ivan Mueller, then President of IAG
- GIG'91 (GPS for IERS and Geodynamics) Campaign, January '91, organized to support IERS/ITRF
- IGS Call for Participation (CfP) developed, proposals due May 1991
- IGS Oversight Committee formed at Vienna 1991 IUGG meeting, Prof. Gerhard Beutler elected to Chair, oversee demonstration campaign
- IGS Pilot Campaign Demonstration June 21 - Sept 23,1992 was highly successful, proof of concept and validation of CfP Proposals
- IGS approved as a permanent service of IAG in 1993
- Formal organization established in January, 1994
- Progress documented in IGS Annual Reports, available at IGS website

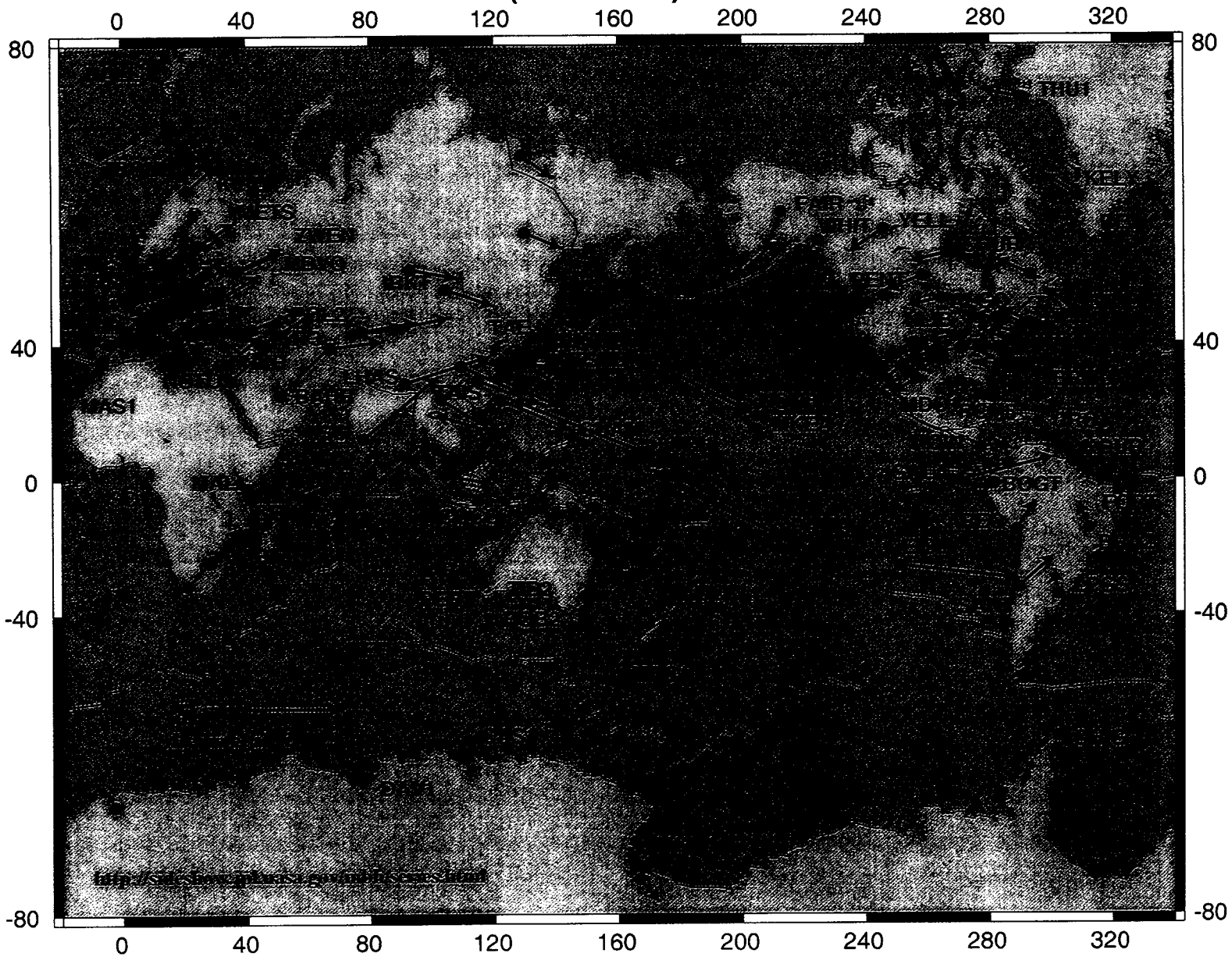

Comparison of IGS Predicted Orbit to the Broadcast Ephemeris
Weighted RMS (mm)
0
1000
2000
3000
4000
1075
1080
1085
1090
1095
1100
1105
Time (GPS weeks)
BRD
IGP

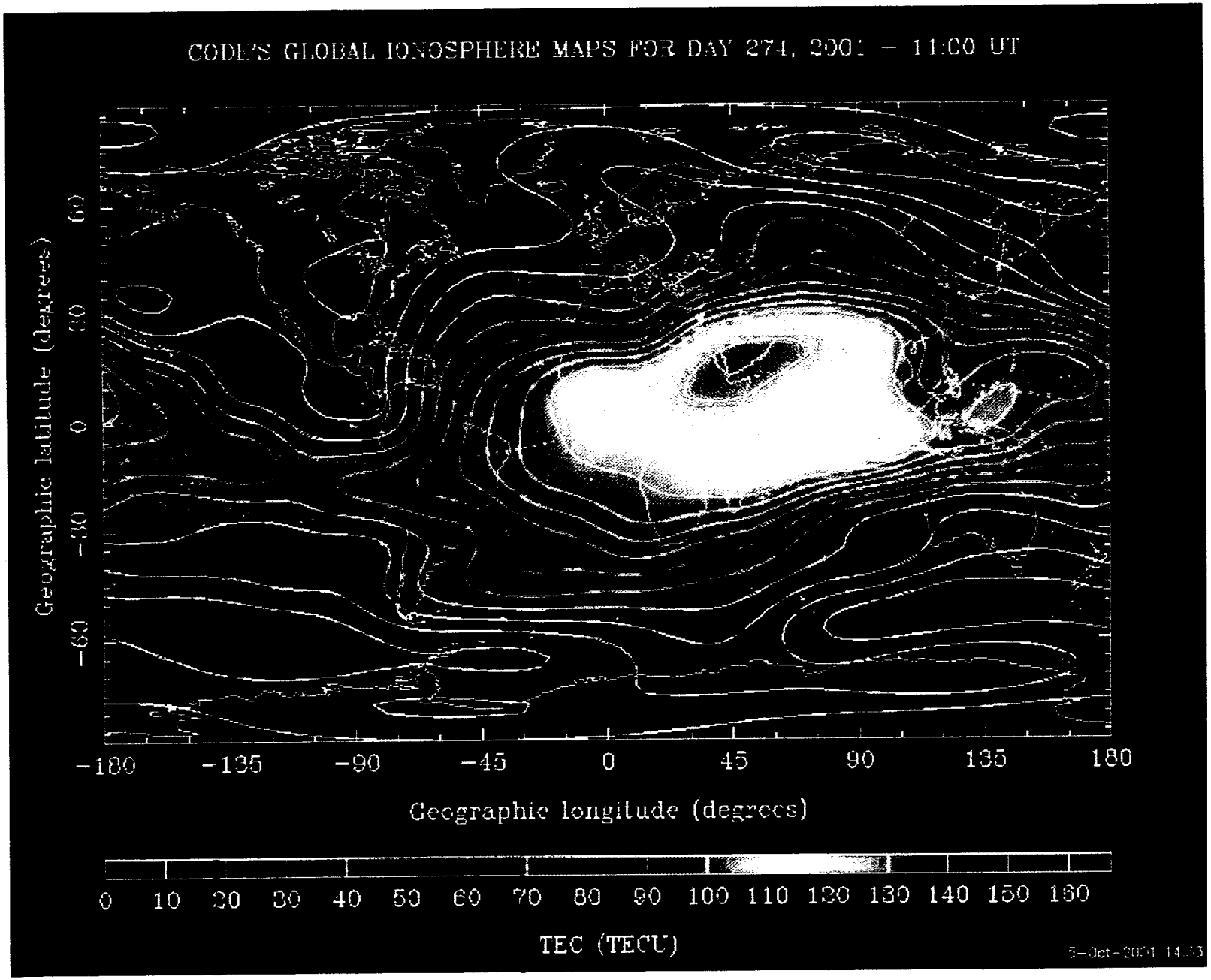

IGS Rapid Orbits, Available Daily
Weighted RMS (mm) of the individual AC solutions with respect to the IGS Rapid products
Weighted RMS (mm)
0
50
100
150
200
1070
1080
1090
1100
1110
1120
1130
1140
Time (GPS weeks)
Sep 2001


IGS Ultra-rapid Orbits, Available Twice Daily
Weighted RMS (mm) of the individual AC solutions with respect to the IGS Rapid products
Values of the Ultra rapid combination summaries (two per day) are shown after smoothing using a sliding 7 day window
Weighted RMS (mm)
0
200
400
600
800
1000
1070
1080
1090
1100
1110
1120
1130
1140
Time (GPS weeks)

Global Site Motion Map

(1992 - 2001)




CODE'S GLOBAL IONOSPHERE MAPS FOR DAY 274, 2001 — 11:00 UT
Geographic latitude (degrees)
60
30
0
-30
-60
-180
-135
-90
-45
0
45
90
135
180
Geographic longitude (degrees)
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160
TEC (TECU)
5-Oct-2001 14:33