THE IGS MISSION

To provide a service to -support geodetic and geophysical research activities, through GPS data and data products.

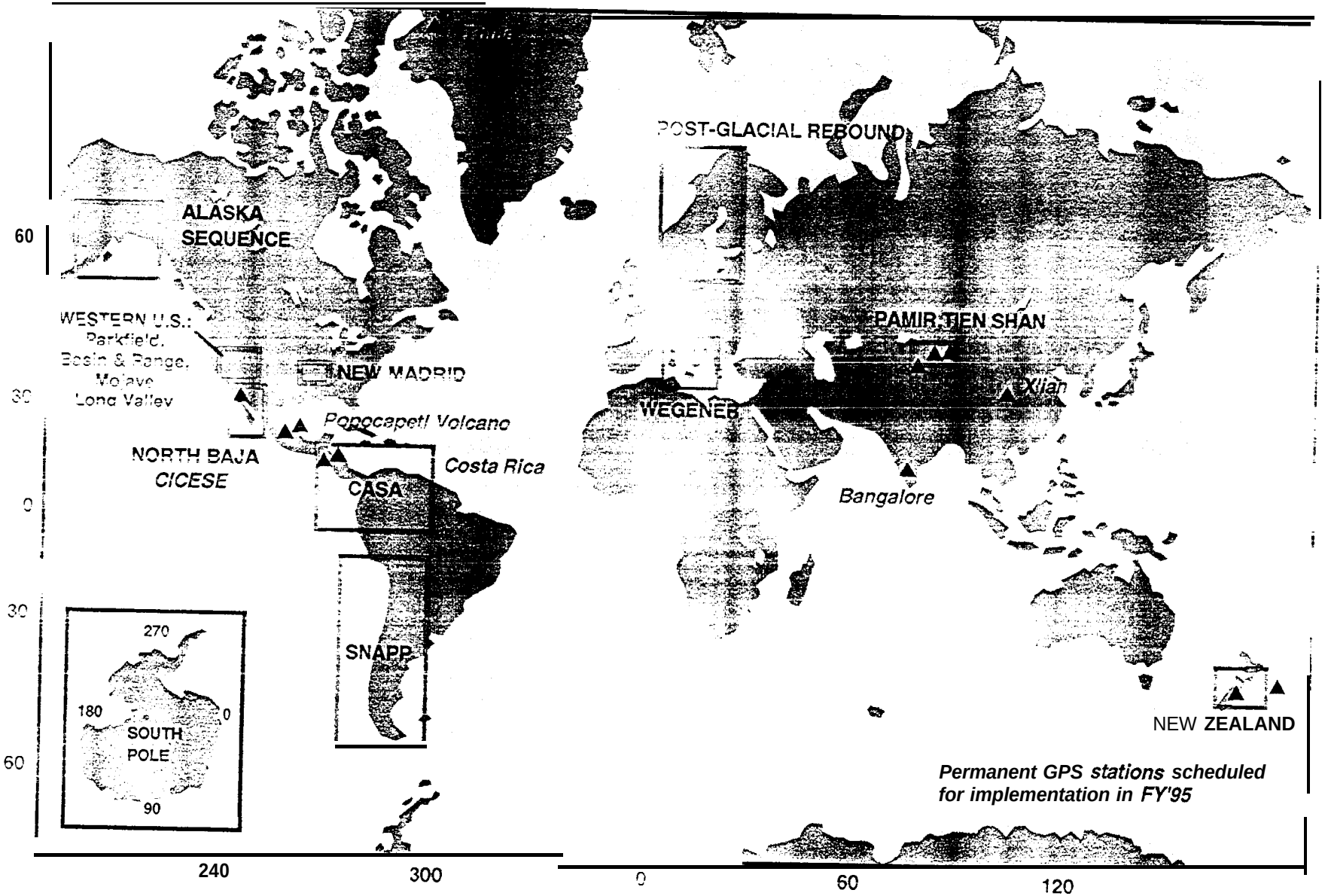
- A network of about 100 permanent precision P-code receivers produce GPS data on a daily basis
- The GPS data sets are used by the IGS to generate:
  - High accuracy GPS satellite ephemerides (≈10cm, <10 day delay)
  - Earth rotation parameters
  - Coordinates and velocities of the IGS tracking stations
  - GPS satellite and tracking station clock information
  - Ionospheric information

*Approved activity of the International Association of Geodesy (IAG), with official start of service January 1, 1994

IGS Objective

- **The accuracies of the IGS data and products are to be sufficient to support scientific requirements including:**
  - Realization of accessibility to and improvement of the ITRF (International Terrestrial Reference Frame)
  - Monitoring the deformation of the solid Earth
  - Monitoring Earth rotation parameters
  - Monitoring deformation of the liquid Earth (sea-level, ice-sheets, etc.)
  - Scientific satellite orbit determination
  - Ionospheric monitoring

DYNAMICS OF THE SOLID EARTH
GPS SCIENTIFIC INVESTIGATIONS 1992–1 996



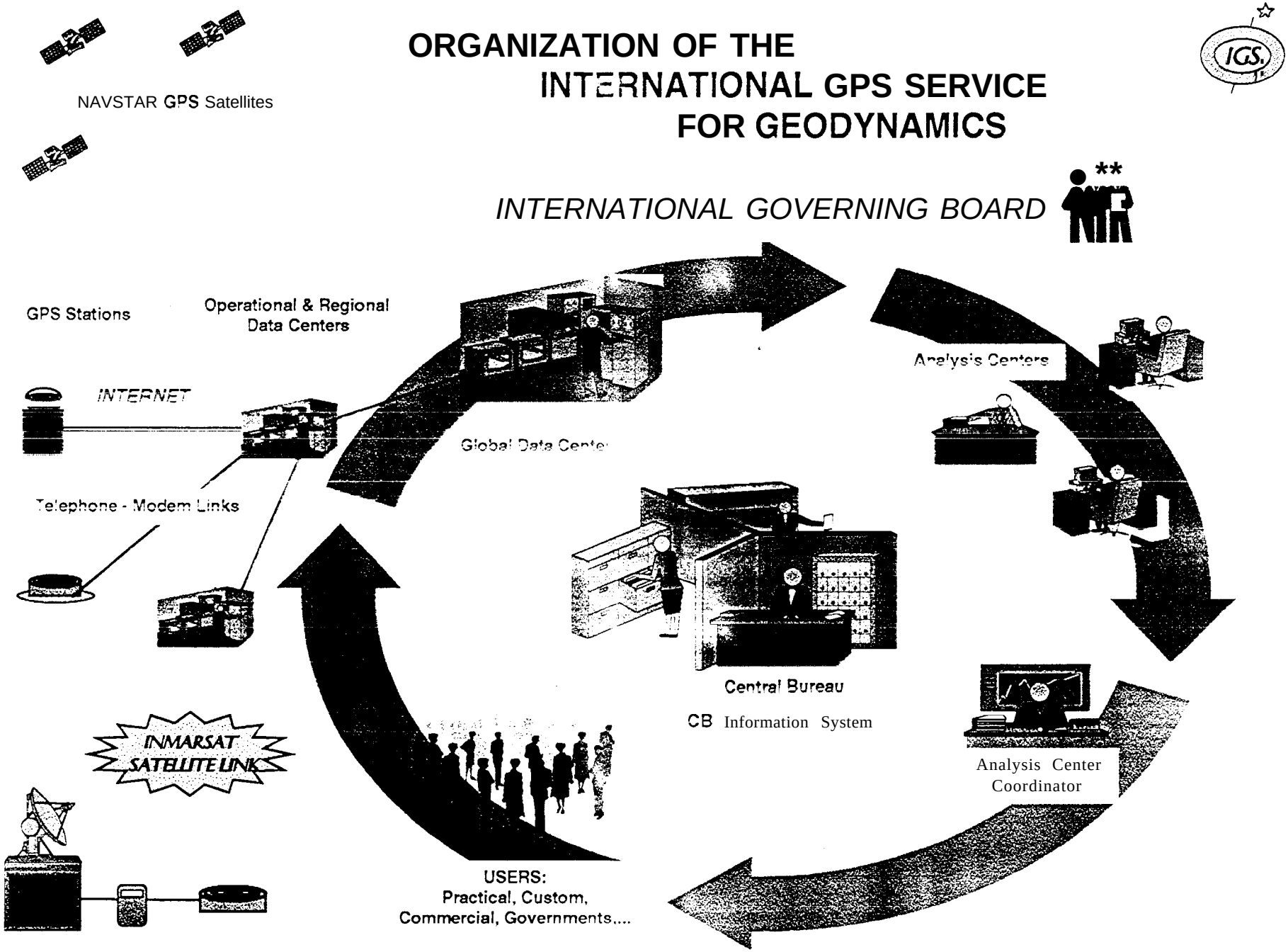
The Organization of the IGS

- The IGS accomplishes its mission through the following components:
  - Network of tracking stations
  - Data Centers
  - Analysis Centers and Associate Analysis Centers
  - Analysis Center Coordinator
  - Central Bureau
  - Governing Board

CONTRIBUTING AGENCIES OF THE INTERNATIONAL GPS SERVICE FOR GEODYNAMICS

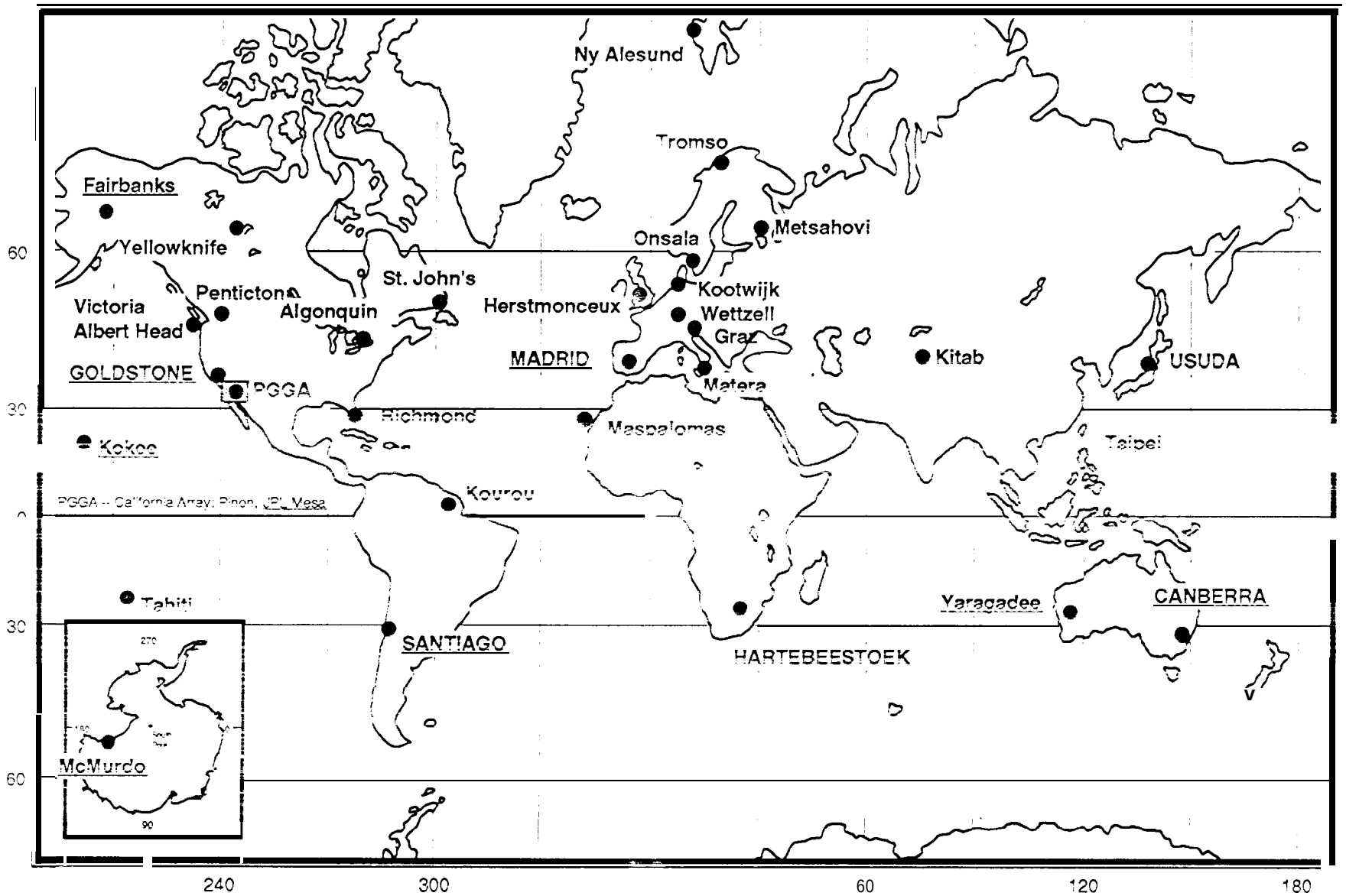
ACRONYM	AGENCY
AIUB	Astronomical Institute, University of Bern, Switzerland
ALO	Astronomical Latitude Observatory Poland
ASI	Italian Space. Agency, Matera, Italy
AUSLIG	Australian Survey and Land Information Group, Australia
BfL	Bundesamt für Landestopographie (Federal Topography), Switzerland
CAS	Chinese Academy of Sciences, China
CDDIS	Crustal Dynamics Data Information System, USA
CEE	Centro de Estudios Espaciales, Chile
CMMACS	CSIR Centre for Mathematical Modelling and Computer Simulation, Bangalore, India
CNES	Centre National de Etudes, Toulouse France
CSR	Center for Space Research, University of Texas at Austin, USA
CU	University of Colorado at Boulder, Boulder, CO, USA
DMA	Defense Mapping, Agency, USA
DOSLI	Department of Survey and Land Information, Wellington, New Zealand
DUT	Delft University of Technology Netherlands
ERI	Earthquake Research Institute, University of Tokyo, Japan
ESA	EuroWan Space Agency, Germany
ESOC	European Space Operations Center Germany
FGI	Finnish Geodetic Institute, Finland
GOPE	Geodetic Observatory Pecny, Ondrejov, Czech Republic
GFZ	GeoforschungsZentrum Institute Potsdam, Germany
GRDL	Geosciences Research and Development Laboratory, NOAA, Silver Spring, MD, USA
GSC	Geological Survey of Canada NRCan, Canada
GSD	Geodetic Survey Division, NRCan, Canada
GSFC	Goddard Space Flight Center, USA
GSI	Geographical Survey Institute, Tsukuba, Japan
IAA	Institute of Applied Astronomy, St Petersburg, Russia
IBGE	Instituto Brasileiro de Geografia de Estatistica, Brazil
ICC	Institut Cartografic de Catalunya Barcelona Spain
IDA	International Deployment of Accelerometers, USA
IESAS	Academia Sinica, Institute of Earth Sciences, Taiwan
IfAG	Institut für Angewandte Geodasie, Frankfurt, Germany
IGN	Institut Geographique National Paris France
IMVP	The Institute of Metrology for Time and Space GPVNIIFTRI, Mendeleevo, Russia
INASAN	Institute of Astronomy, Russian Academy of Sciences, Moscow, Russia
INPE	Instituto Nacional de Pesquisas Espaciais Brazil
IRIS	Incorporated Research Institution for Seismology, USA
ISAS	Institute for Space and Astronautical Science Sagamihara, Japan
ISRO	Institute for Space Research Observatory Graz, Austria
JPL	Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA
NASA	National Aeronautics and Space Administration, USA
NBSM	National Bureau of Surveying and Mapping, China
NOAA	National Oceanic and Atmospheric Administration, USA
NRCan	Natural Resources of Canada (formerly EMR), Ottawa, Canada
OSO	Onsala Space Observatory, Sweden
OUAT	Olsztyn University of Agriculture and Technology, Poland
PGGA	Permanent GPS Geodetic Array of Southern California. USA
POL	Proudman Oceanographic Laboratory, UK
RGO	Royal Greenwich Observatory, UK
ROB	Observatoire Royal de Belgium, Brussels, Belgium
SAO	Shanghai Astronomical Observatory, China
SIO	Scripps Institution of Oceanography, San Diego, CA, USA
SK	Statens Kartverk, Norwegian Mapping Authority, Norway
UB	University of Bonn, Germany
UFPR	University Federal de Parana, Brazil
UNAVCO	University Navstar Consortium, Boulder, CO, USA
UNT	University of Newcastle on Tyne, United Kingdom
UPAD	University of Padova, Italy
USNO	United States Naval Observatory, USA
WING	Western Pacific Integrated Network of GPS, Japan
WTU	Wuhan Technical University, China
WUT	Warsaw University of Technology Poland

ORGANIZATION OF THE INTERNATIONAL GPS SERVICE FOR GEODYNAMICS



Status of the IGS

- Permanent tracking network of about 100 precision P-code receivers
- Three Global Data Centers :
  - Crustal Dynamics Data Information System,
  - Institut Geographique National,
  - Scripps Institution of Oceanography.
  - plus Regional and Operational Data Centers
- Seven Analysis Centers :
  - Astronomical Institut-University of Bern, Switzerland
  - European Space Operations Center/ European Space Agency, Germany
  - FLINN Analysis Center. Jet Propulsion Laboratory. USA
  - GeoForschungsZentrum, Germany
  - Geosciences Lab, National Oceanic and Atmospheric Administration, USA
  - Natural Resources Canada. Canada
  - Scripps Institution of Oceanography, USA
- Analysis Center Coordinator: Jan Kouba, Natural Resources Canada

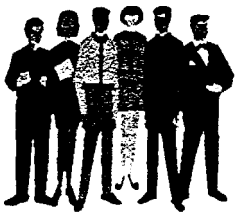


IGS Network, June 1992

The Operational GPS Tracking Network of the International GPS Service for Geodynamics

NASA Station

IGS Central Bureau



The CB is responsible for general management of the IGS

- The primary functions of the CB are to:
  - Coordinate and manage IGS activities
  - Operate the communication center for the IGS, the *CBIS*
  - Establish and promote compliance to IGS network standards
  - Monitor network operations and quality assurance of data
  - Act as GPS coordinator for the IERS
  - Act as day-to-day liaison with external agencies

The Network of the IGS

- **The Network consists of two types of stations based on function:**
  - Global Analysis Stations used by Analysis Centers for Orbit Determination,
    - (~ 40 - 50 stations, **need** better geographic distribution)
  - Regional Stations used by the IGS for reference frame access, extension. of the ITRF, and by scientists for local deformation studies
    - (~ 200-250 stations globally distributed)

Data Centers of the IGS

- **Data Centers have three categories:**
  - operational Centers have direct contact with the stations
  - Regional Centers store all data from a geographic region
  - Global Data Centers are the main interface with Analysis Centers and Users. store all data used by Analysis Centers and all IGS products

Analysis Centers of the IGS

- **Analysis Centers have two categories:**
  - Analysis Centers produce daily products on a continuous basis
  - Associate Analysis Centers produce unique products such as station coordinates and velocities, ionosphere information: they may facilitate distributed processing, analyze dense regional networks, combine network solutions, etc.

IGS Governing Board

Name	Country	Functions	Term*
G. Beutler	Switzerland	Chair & AC Representative	4 years
Y. Bock	USA	Analysis Center Representative	2 years
C. Boucher	France	Appointed (IGS)	2 years
J. Dow	Germany	Network Representative	2 years
B. Engen	Norway	Network Representative	4 years
M. Feissel	France	IERS Representative	---
T. Kato	Japan	Appointed (IGS)	2 years
J. Kouba	Canada	Analysis Center Coordinator	2 years
G. Mader	USA	Appointed (IGS)	2 years
B. Melbourne	USA	IGS Representative to IERS	---
I. Mueller	USA	IAG Representative	---
R. Neilan	USA	Director of Central Bureau	---
C. Noll	USA	Data Center Representative	4 years
Ch.Reigber	Germany	Appointed (IGS)	2 years
B. Schutz	USA	Appointed (IAG)	4 years

*Terms beginning January 1, 1994

Operations of the IGS

- Regional and Operational Data Centers retrieve data from receivers, validate data, monitor station status and form RINEX files that are forwarded to Global Data Centers
- Global Data Centers organize the files on the basis of site and time, and provide Internet access
- Analysis Centers pick up the data from the Global Data Centers, and estimate precise orbits and earth orientation
- Analysis Center results are collected by the Analysis Coordinator and combined into the IGS orbit (including GPS clocks at 15-min intervals)
- The combined orbit is archived in the Global Data Centers and the CBIS
- Results on Earth Orientation and Station Coordinates are coordinated. with the International Earth Rotation Service (IERS)
- IGS combined orbit is currently 10 -14 days behind real time

IGS Orbit Products

- Rapid Service Product:
  - Combined ephemerides based on the IERS Bulletin A EOP adjusted to account for ITRF misalignment are available on a weekly basis within 10 to 15 days after last observation.
- Final Product:
  - Combined ephemerides based on the IERS Bulletin B EOP adjusted to account for ITRF misalignment are produced about 2 months after last observation.

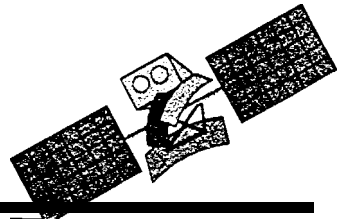
Orbit Combination Strategy

- **Each Centers' ephemerides are evaluated by long arc orbit approximations**
  - Provides independent day-to-day consistency
- Transformation of ephemerides and clock corrections to **common.** reference
  - Required for ephemerides due to solved for EOP
  - Required for clocks because of different references
- **Combination of ephemerides and clock corrections**
  - Weights computed from magnitude of deviation from unweighed average
- **Combined ephemerides evaluation by long arc orbit approximations**

IGS Analysis Timeline

- Current data files contain 24-hours data. Files closed at the end of the UT day.
- Within a few hours to a few days, the data files are available at one of the data centers.
- RINEX files are generated and available for analysis within 30 hours to 3 or 4 days.
- A JPL analysis for that day is started not sooner than 4 days after the day to be analyzed.
- JPL precise orbit is available at end of day 5
- Orbits are not published until 2 weeks worth of daily solutions are ready.
- Weekly fits are submitted to the AC Coordinator usually within 3 to 5 days, but no later than 10 days, of the end of the GPS week.
- The IGS official orbit and report is available within 1 day after the last analysis center submits solutions.

IGS Orbit Accuracy



GPS Satellite orbits estimated by each of the seven Analysis Centers.

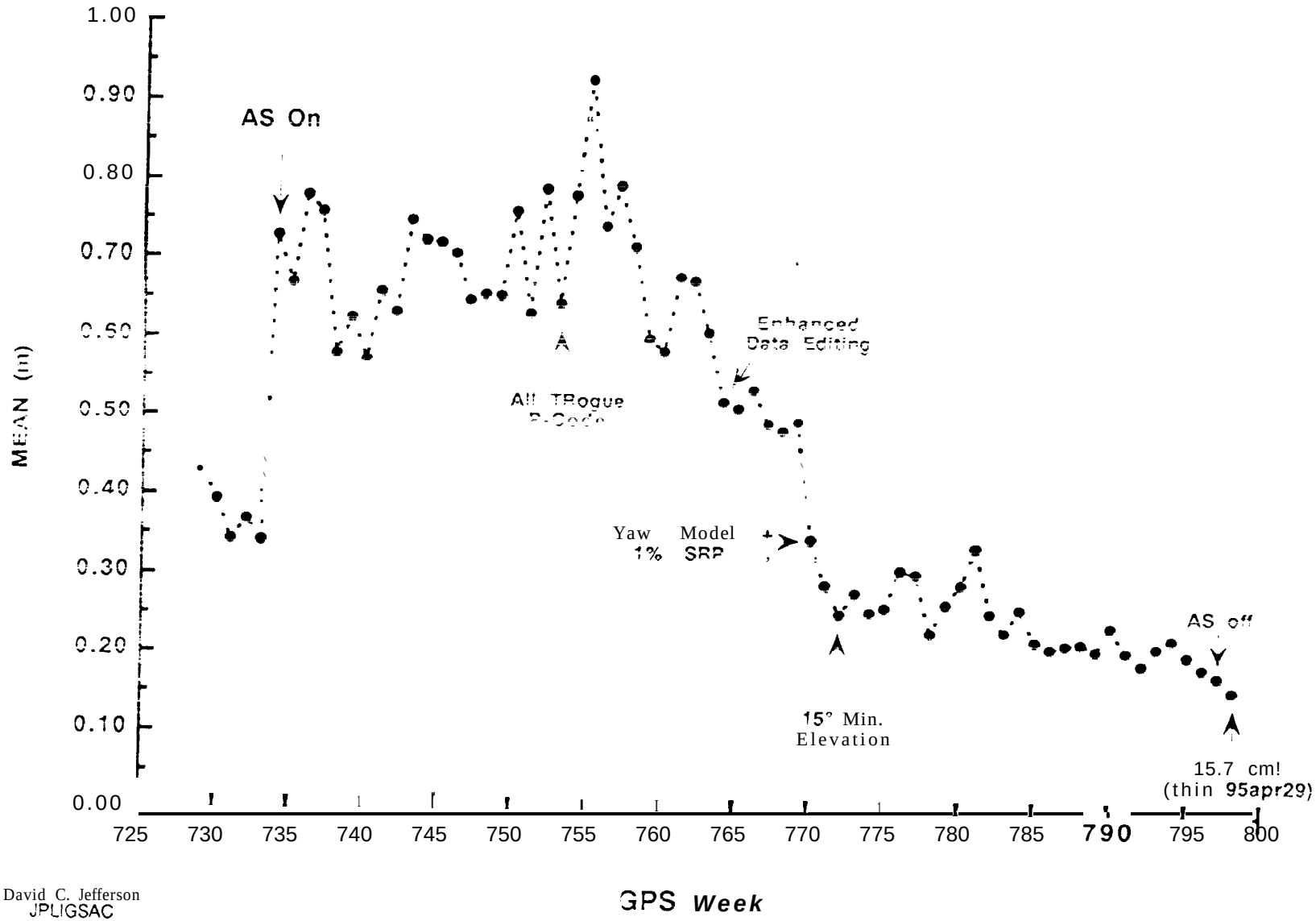
- Accuracy of the individual center Orbit Series:

~ 5 - 20 cm per satellite coordinate

- Estimated accuracy of the IGS Combined Orbits:

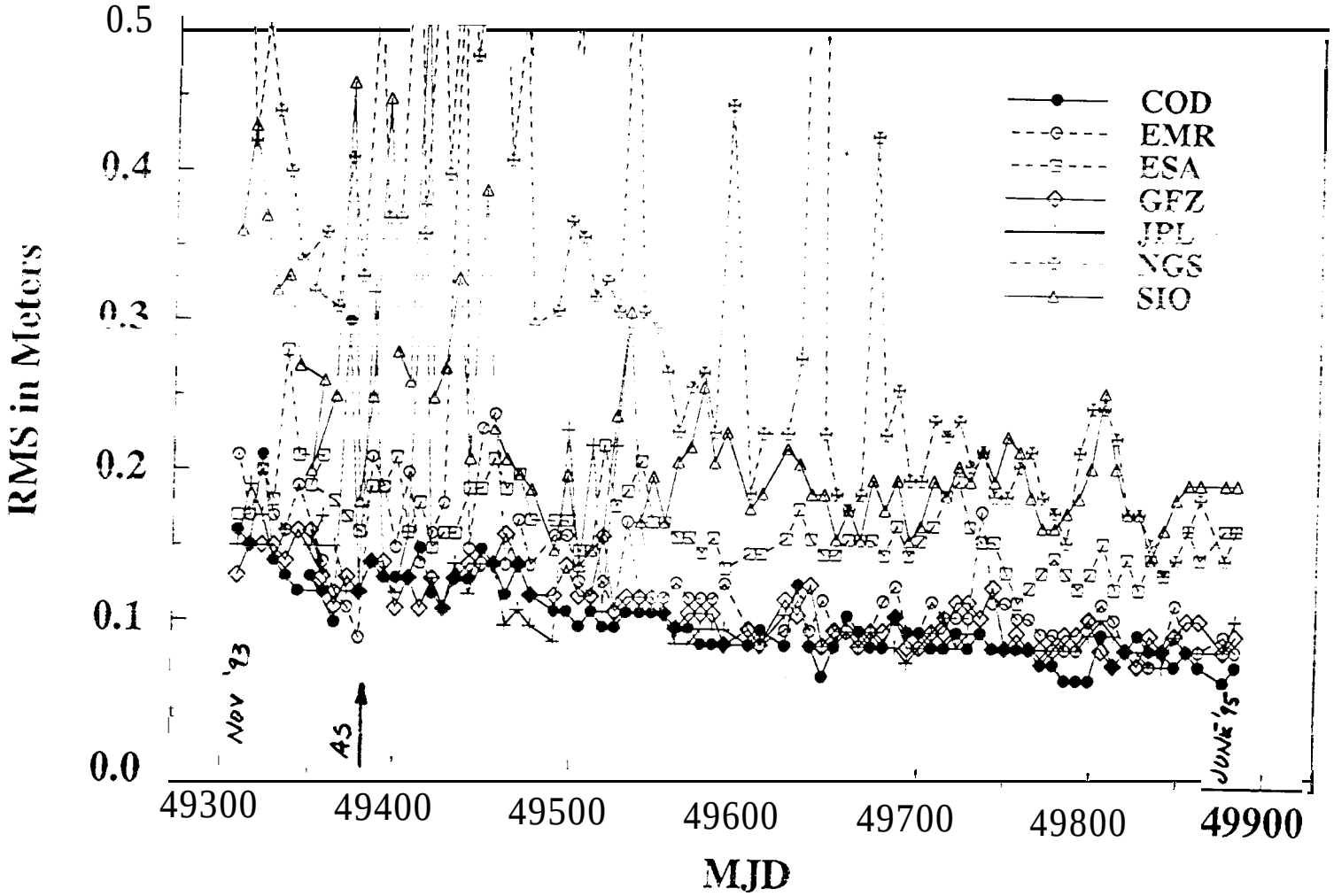
~ 10 cm per satellite coordinate

MEAN ORBIT REPEATABILITY



David C. Jefferson
JPL/GSAC

ORBIT QUALITY (WEEKLY AVERAGES) FROM IGS ORBIT COMBINATION (WEIGHTED RMS)



Earth Rotation Parameters

- Daily ERP-series of the IGS Processing Cetners are submitted to the International Earth Rotation Service (IERS) Rapid Service branch at the US Naval Observatory
- Present Accuracy of Polar Motion:

~ 0.2 - 0.3 mas for x- and y- coordinate

- Present Accuracy of Excess in Length of Day:

~ 0.03 ms

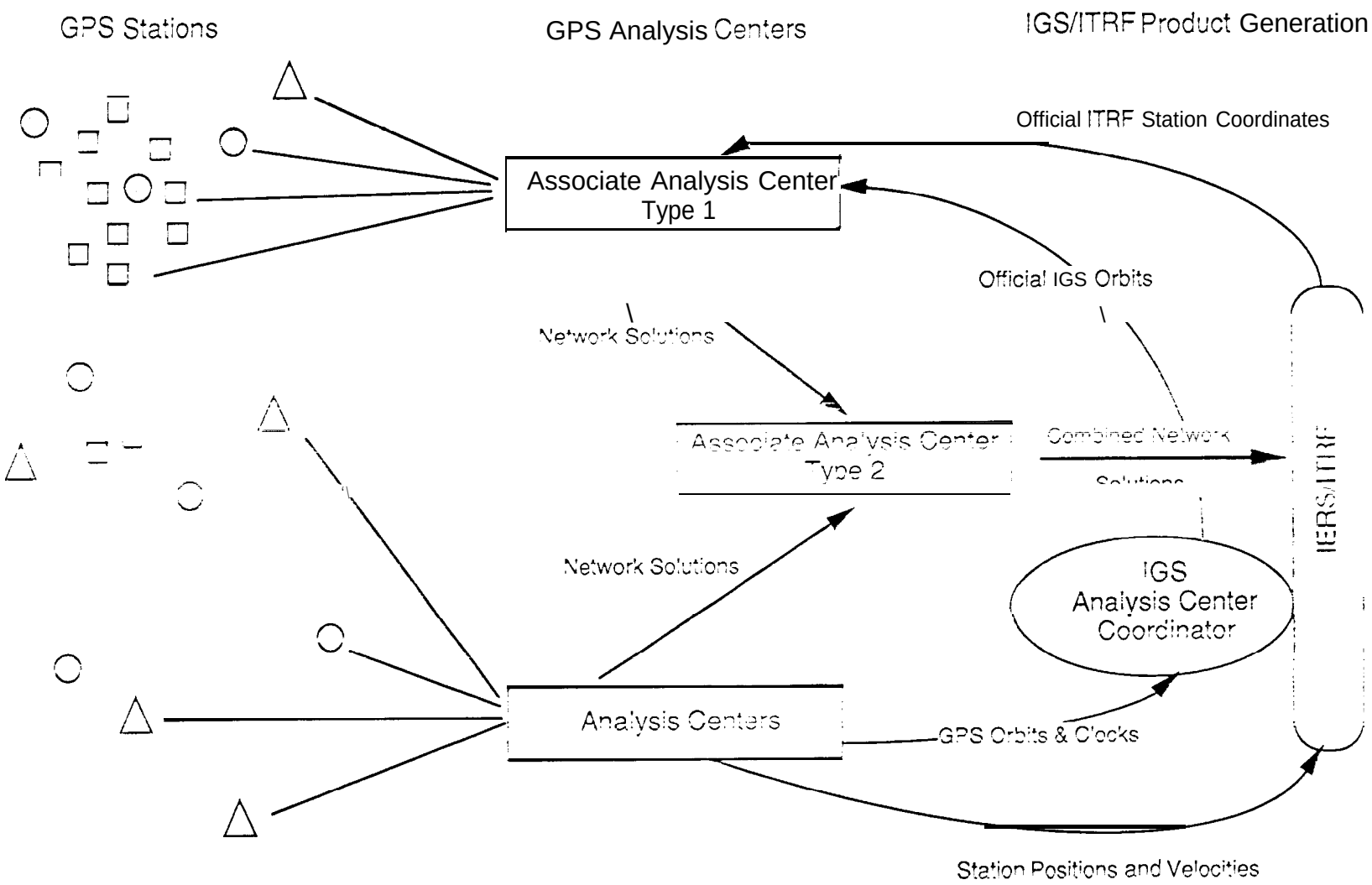
IGS Station Coordinates

- Station coordinates estimated by *'free network solutions'*, combination of the normal equation systems of the daily solutions and removing apriori weights. Station positions and velocities are determined.
- Consistency of the 1994 Annual GPS Solution:

~5 - 10 mm
for horizontal coordinates
~10 - 20 mm
for vertical coordinates

http://sideshow.jpl.nasa.gov/mbh/series.html

Accurate Determination of GPS Station Locations in the ITRF



□ Dense Array or Cluster Station, Special Scientifc Application

○ Regions! GPS Station, ITRF Extension

△ Global GPS Station for Ephemeris Production

Neilan et al., 7995

Accessing the CBIS

- Mosaic (freely available from NCSA) and Netscape gives point-and-click interface (versions for Unix, Mac, PC)
- Lynx runs in vanilla terminal window
- CBIS is a client on the World Wide Web
  - URL is http://igscb.jpl.nasa.gov/
- anonymous ftp to igscb.jpl.nasa.gov; for example:
  - get igscb/mail/igsmail/IGSMESS.INDEX
  - get igscb/mail/igsreport/IGSREPORT.INDEX

IGS CENTRAL BUREAU INFORMATION SYSTEM
DIRECTORY TREE

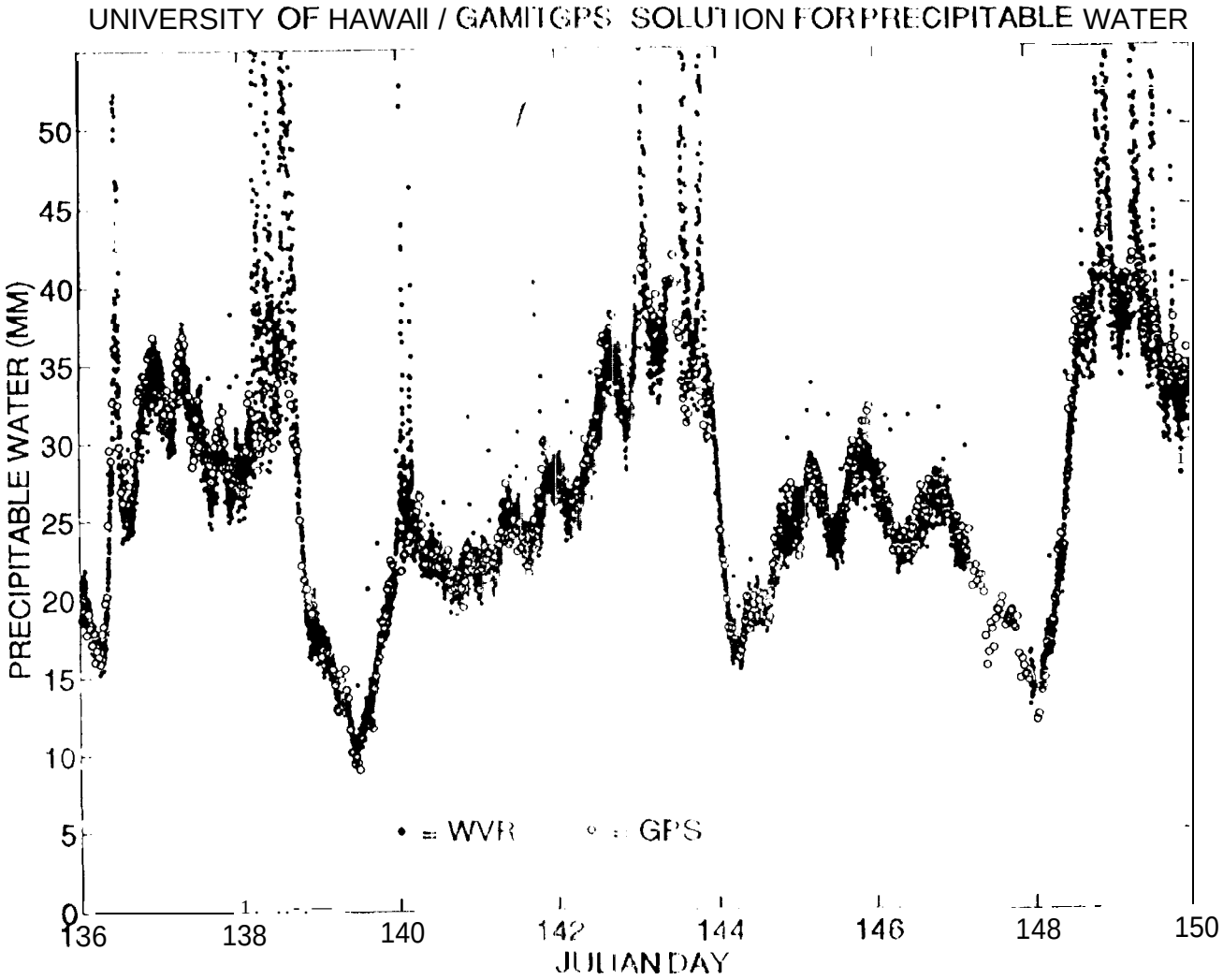
IGSCB.DIR			complete file list
NEWS.TXT			new features/changes
README.TXT			CBIS general info
TREE.TXT			directory structure info
center	README.CEN		center info
	analysis	'center'.acn	Analysis Center descriptions
	data	'center'.dcn	Data Center descriptions
	oper	'center'.ocn	Operational Center descriptions
data	format	rinex2.txt	RINEX format specifications
		sp3.txt	SP3 orbit format specifications
	holding	'center'.syn	data center holdings
		'center'.s'yy'	data center holdings by year
		glob'mmyy'.syn	data availability by month
		glob'yyyy'.syn	data availability by year
	network	igs.net	IGS data network diagram
general	gps	constell.gps	NANU GPS constellation status
		euref.txt	EUREF Information System info
		nanu'yyyy'.mes	NANU messages by year
		nanu'yyyy'.sub	NANU subject index byyear
		sources.txt	catalog of GPS-related info sources
		status.zim	ZIMM current tracking status
	igs	g_board.igs	IGS Governing Board
		resource'mo'.ps	IGS Resource Information (PostScript)
		terms.igs	IGS Terms of Reference
	org	meetings.agu	AGU symposia/meetings
		meetings.iag	IAG symposia/meetings
mail	address	cddis.adr (.Z)	CDDIS SGP address catalog
		directory.txt	IGS Colleague Directory text
		dose.adr	DOSE Mail distribution list
		igsmail.adr	IGS Mail distribution list
		igsreport.adr	IGS Report distribution list
		scign.adr	SCIGN Mail distribution list
	igsmail	IGSMESS.INDEX	IGS Mail message index
		igsmess.'111111	IGS Mail messages
	igsreport	IGSREPORT.INDEX	IGS Report index
		igsreport.'mm'	IGS Reports
	regional	DOSE	DOSE Mail archive
		SCIGN	SCIGN Mail archive
product	'wwww'	igs'wwww'7.erp	IGS earth rotation parameters
		igs'wwww'[0-6].sp3	IGS combined daily orbits
		igs'wwww'7.sum	IGS weekly product summary
	holding	'center'.pcd	analysis center product holdings
	iers	bulletinb.'mm'	IERS earth orientation
		eop90c04.'yy'	IERS earth rotation parameters
software	cbis	dos, unix, vms	CBIS browsing/ftp program
	compress	dos, vms	compression/decompression programs
	qc	aux, dos, unix, vms	quality check program for GPS data
station	moral	igsmap.ps	map of IGS tracking stations (PostScript)
		itrf'yy'.sec	ITRF 92 station coordinates
	general	BLNK FORM.LOG	station log form (blank)
		antenna.gra	antenna diagrams
		rcvr_ant.tab	receiver/antenna table
	log	'site''mmyy'.10	station logs
	oldlog	'site''mmyy'.log	old station logs
	tie	localtie.chg	local tie changes/updates
		localtie.tab	local tie file
workshop.'mmyy'		various	IGS workshop information

Jul 1995

IGS Future Developments

IGS workshop 'Special Sessions and New Directions' at GFZ, Potsdam (May 1995), proposed using IGS Network for:

- Climatology
- Weather forecasting
  - instrumenting stations with high accuracy **meteorological** sensors, **especially** barometers, Total Precipitable Water Content can be **extracted**
- **Ionospheric information**
  - Calibration of Radio Signals (GPS and others)
  - Ionosphere Maps
  - Assessing stochastic behavior of the Ionosphere



Comparison of precipitable water solutions derived from GPS and water vapor radiometer **(WVR)** observations acquired at Purcell, OK during the GPS/STORM field experiment held in May 1993. The WVR estimates scatter wildly during episodes in which the device was wetted either by rainfall or by dew.

Conclusion

- **The International GPS Service for Geodynamics has proven to be a very fruitful and productive endeavor**
- **IGS is the basis for nearly all GPS projects in regional and global geodynamics**
- The IGS can make significant contributions to multi-disciplinary sciences such as:
  - Global Change
  - Meteorology and Atmospherics
  - Ionospheric Physics
  - Time Trans . . . . .
- **The dedicated contributions of nearly 100 government and research institutions are what make the IGS successful!**