A 50 Year GSFC Retrospect of IS&T Contributions to NASA Science Driven Missions

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GSFC, Code 610 Emeritus

Presented at IS&T Colloquium
May 13. 2009

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Overview: Focus on groundbreaking IS&T

- 1960-1969: Energy Balance/Clouds/Mflops
- 1970-1979:Earthy looking Sat's/GARP
- 1980-1989: Pilot Data Systems/FGGE/Gflops
-
- 1990-1999:Mission Data Systems/HPCC
- 2000- 2009: EOS op's, EOSDIS/SIPS/Tflops
- 2010-2019:JWST,Climate,Lunar/Pflops

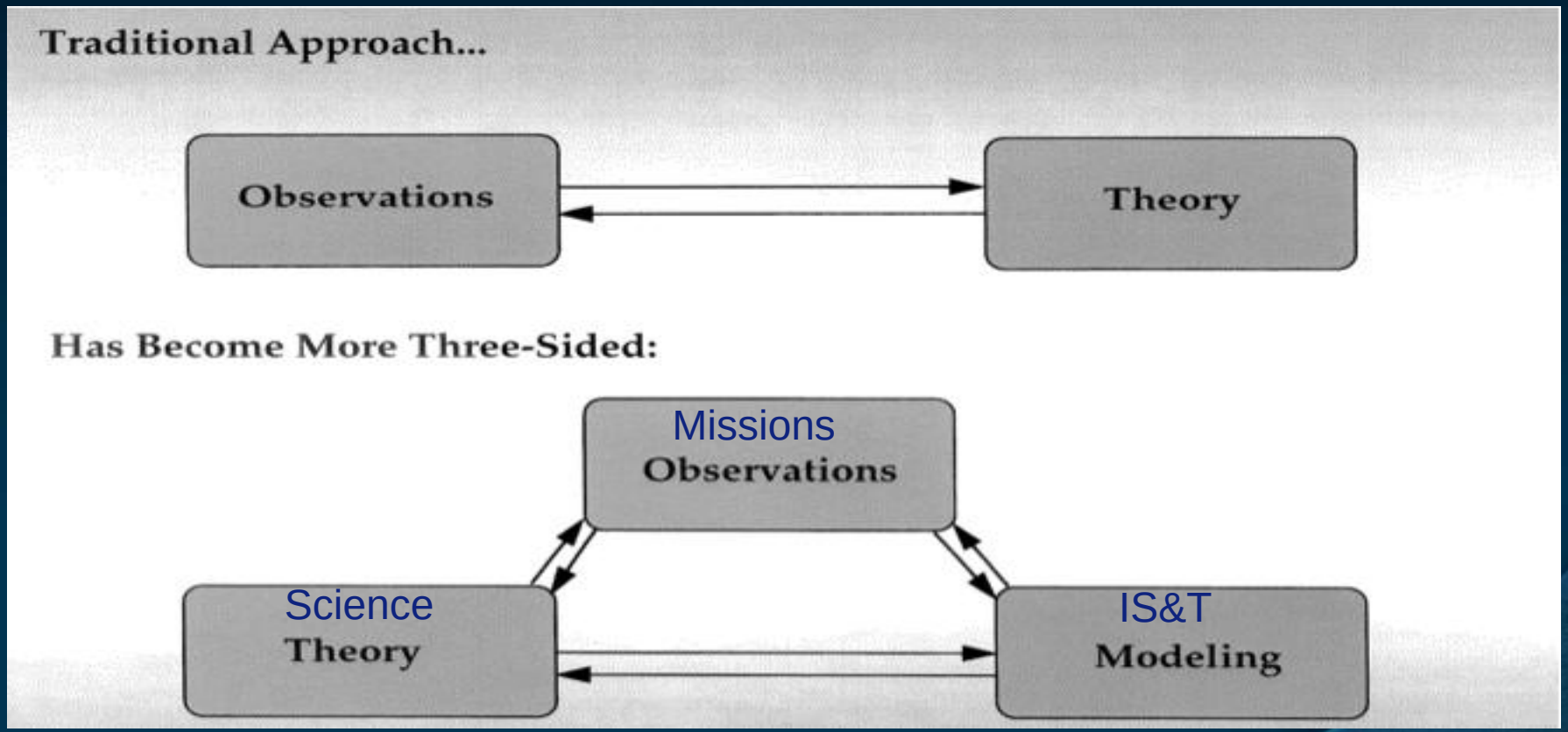
Information Science and Technology

- ‘Information Science’ is an interdisciplinary science primarily concerned with the collection, classification, manipulation, storage, retrieval and dissemination of information from the stakeholders perspective and then applying information and other technologies as needed.

- ‘Informatics’ a synonym for IS and defined as a discipline related to the study of scientific information.

- Information Technology is the study, design, development, implementation, support or management of computer-based information systems, particularly software applications and computer hardware.

Role of IS&T in Earth and Space Science



- Paraphrase of J. Charney: “When the information from a science driven mission answers the science questions, its like a childs DNA legitimizing the father” mh

The 60's:

- TIROS 1,2,3,…7, Nimbus 2,3, Explorers14-41, ATS 1-5
- President Eisenhower views 1st successful weather satellite images from TIROS 1 in April, 1960
- GISS moved to NY in 1961 adjacent to Columbia Univ. in the Interchurch Center with Robert Jastrow as Director
- President Kennedy proposes to UN an international weather program, Sept 1961
- First map of global net radiation from TIROS 2/3 by I. Rasool and Cloud distributions by A. Arking , both 1964
- GSFC/GISS procures their 1st supercomputer; IBM 360/95s
- First IR sounding profile from Nimbus 3, April14, 1969 leading to 1st GCM model study to assimilate global sounding profiles. Charney, et. al.,1969

TIROS 1 April, 1, 1960 showing clouds over the N.E. of US and the curvature of the Earth

New York Times.

CITY EDITION

NEW YORK, SATURDAY, APRIL 2, 1960. M FIVE CENTS

U.S. ORBITS WEATHER SATELLITE; IT TELEVISES EARTH AND CLOUDS; NEW ERA IN METEOROLOGY SEEN

SENT BY SATELLITE: One of TV pictures from Tiros I

CLOUDS: White mass is cloud cover on U. S. and Canada

2 CAMERAS USED

270-Pound Vehicle to Transmit Pictures for 3 Months

By RICHARD WITKIN

CAPE CANAVERAL, Fla., April 1—The first artificial satellite able to provide detailed photographs of the earth's weather was fired into orbit here today by the United States.

Two television cameras looking down from an altitude of about 450 miles made initial pictures of the earth's cloud patterns during the satellite's second orbital trip.

Four pictures, taken by the wider-viewing and therefore less-precise camera of the two, were proudly distributed this evening by the National Aeronautics and Space Administration. The space agency has over-all responsibility for the project.

The pictures showed the cloud cover that lay over the Northeast United States and the adjacent area of Canada this morning. They also showed an identifiable outline of the gulf of the St. Lawrence River. The curvature of the earth was clearly recognizable.

President Sees Photos

Before being made public, the pictures had been taken to the White House by Dr. T. Keith Glennan, the head of the

1,014 BILLS LEFT FOR ROCKEFELLER

Albany Weighs Effects of Legislative Session on Prestige of Leaders

Summary of the 1960 session is printed on Page 10.

By WARREN WEAVER Jr.

ALBANY, April 1—The adjournment of the Legislature early today left conflicting and overdrawn opinions as to who had

AREA: Same places as in TV photos, depicted on a globe

SENATE REJECTS A REFEREE CURB

Quarreling Marks Debate as Kefauver Plan Fails—Courts to Set Hearings

By RUSSELL BAKER

WASHINGTON, April 1—In an afternoon of angry personal quarreling, the Senate killed the Kefauver amendment to the civil-rights bill today. The vote was 68 to 22.

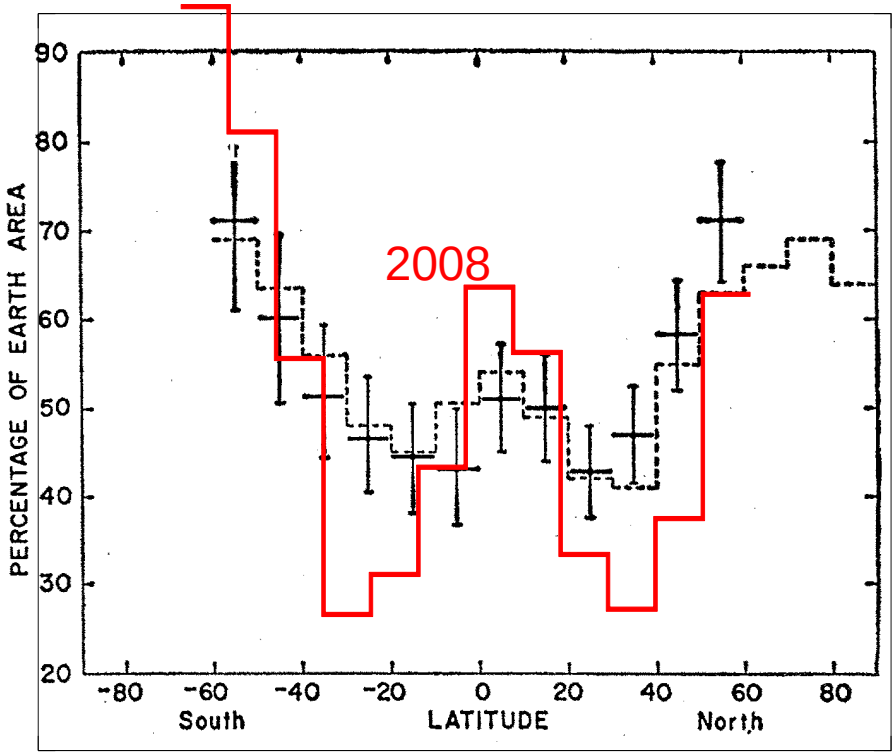
The amendment, sponsored

Goddard Institute of Space Studies

- Dr. Robert Jastrow: A Goddard icon

The first satellite images of Earth processed on a computer to determine the cloud cover distribution (Arking, 1964)

Cloud Cover, Jul 12 – Sep 30



Arking (1964)

Left fig. A typical image from the TIROS III satellite after it was digitized so that it can be quantitatively analyzed on a computer. *Right fig.* shows latitudinal distribution of cloud cover for the summer of 1961, based on computer processing of satellite images made with a video camera on TIROS III. Red reveals the cloud cover distribution based on MODIS for the same season in 2008.

Regional Net Energy Balance at TOA

- **The first observations of the net radiation energy balance at the top-of-the-atmosphere based on satellite measurements (Rasool, 1964).**
- Distribution of net energy balance for the months December 1960 through March 1961, based on TIROS II satellite infrared radiation measurements, and July and August 1961, based on TIROS III. The satellite IR measurements are 5.8-6.5u, 7-13u, and 1-30u regions and were combined with climatological values of the solar radiation component (derived from surface-based observations and numerical calculations of the solar flux) to determine the net energy balance. Extreme dark shade > +175 W m^{-2}, and extreme light shade < -165 W m^{-2}.

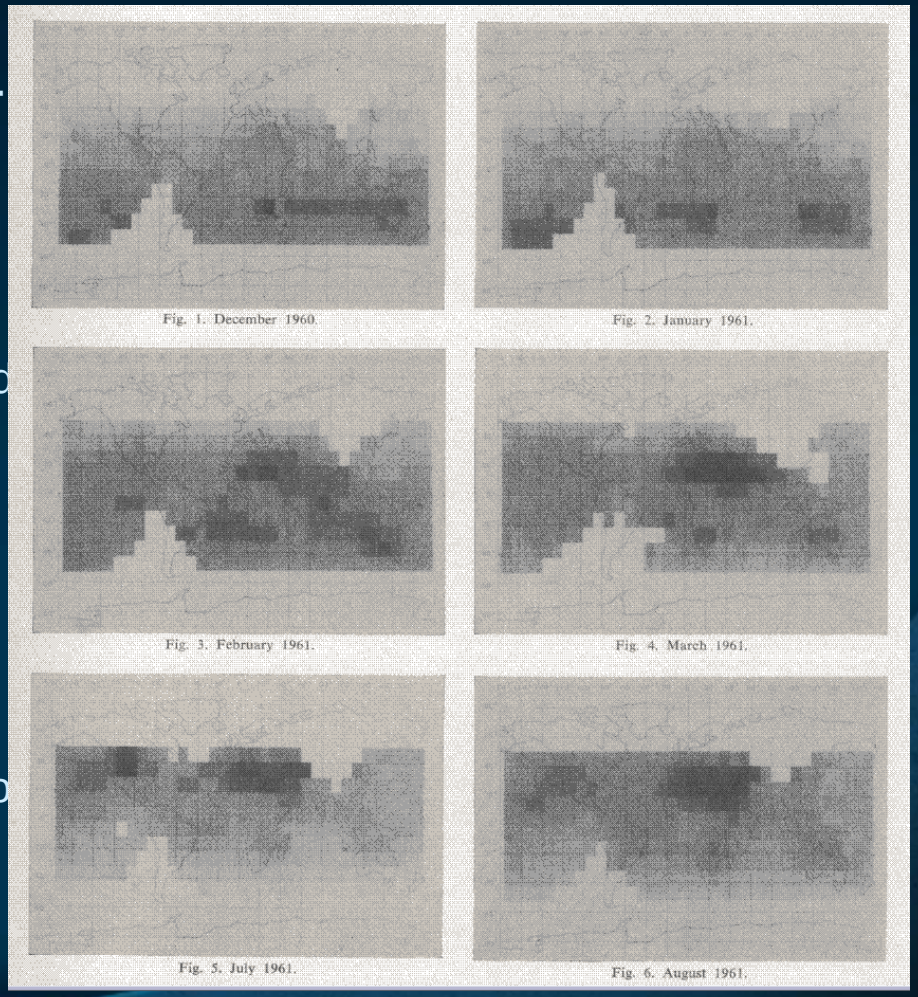


Fig. 1. December 1960.

Fig. 2. January 1961.

Fig. 3. February 1961.

Fig. 4. March 1961.

Fig. 5. July 1961.

Fig. 6. August 1961.

Nimbus 2/3 provides first annual net radiation budget: Raschke , Bandeen and Van Der Haar

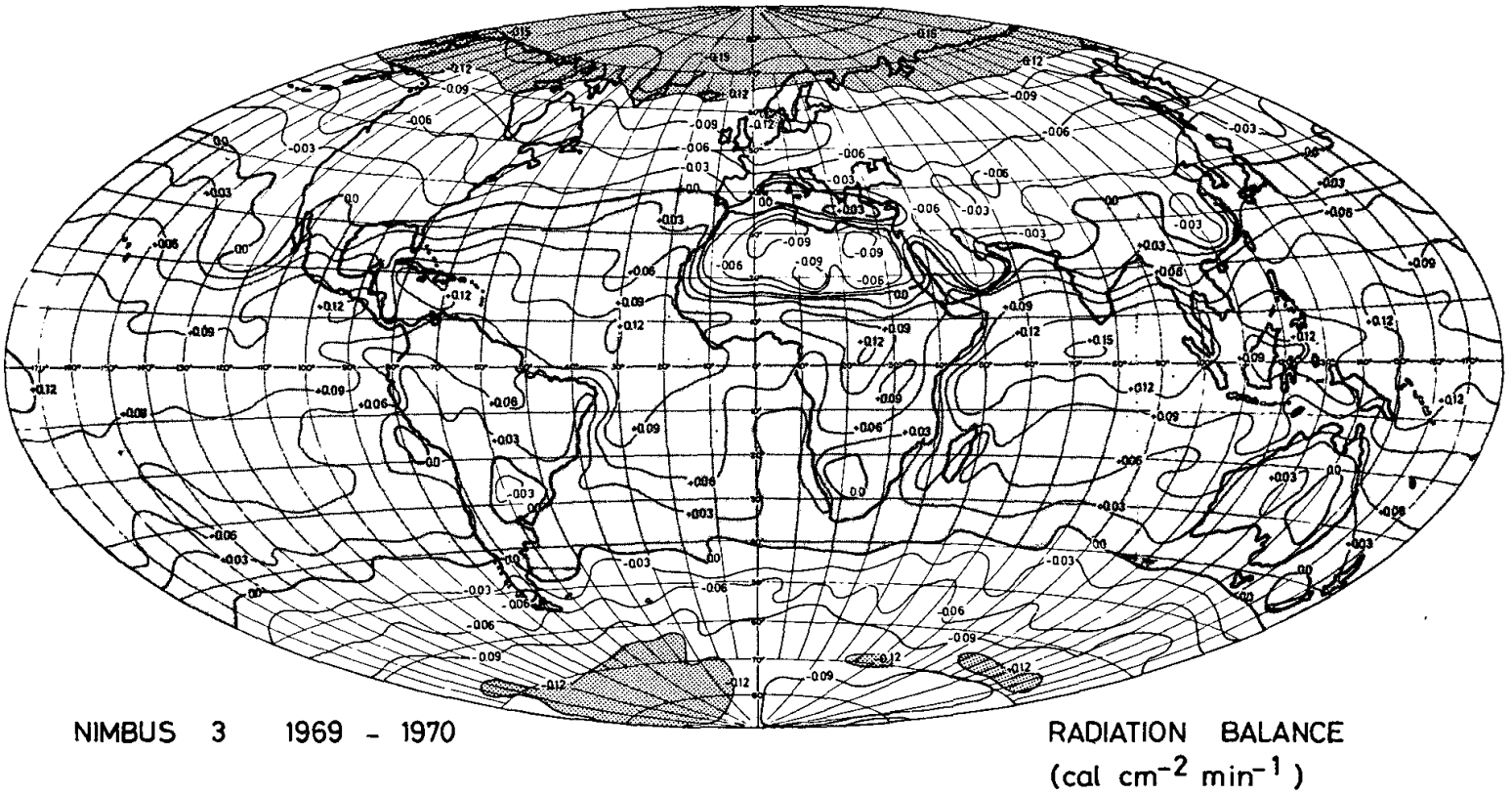
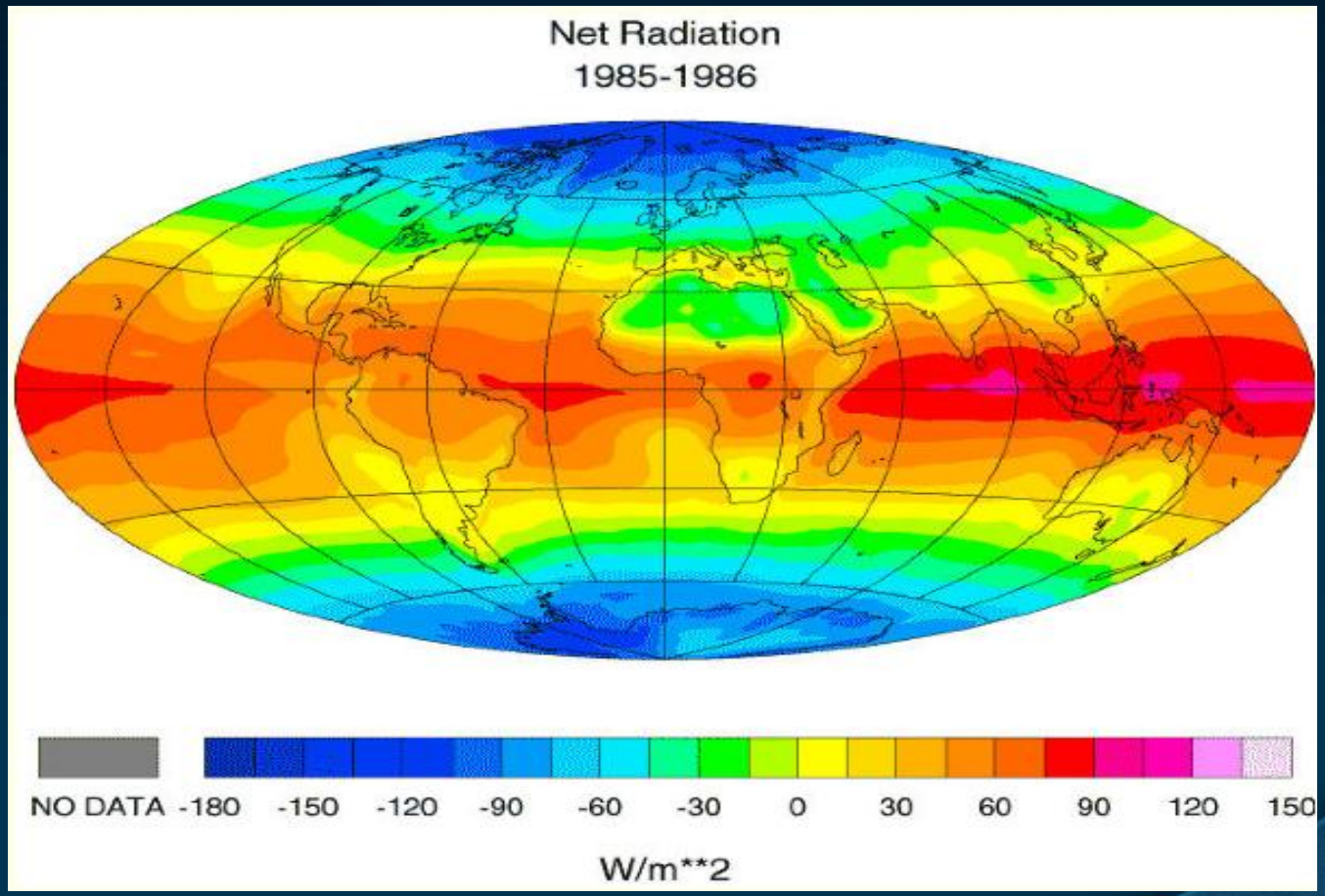


FIG. 17. Annual radiation balance of the earth-atmosphere system.

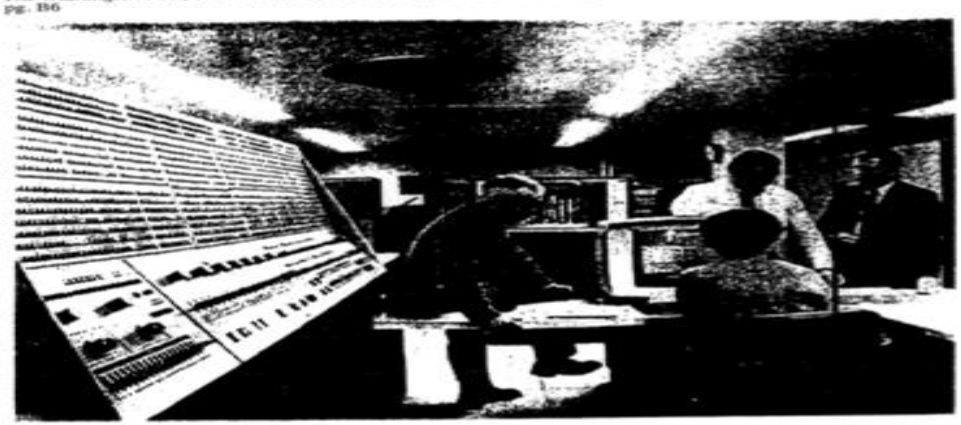
Energy Balance at Top of Atmosphere



- Net annual imbalance between incoming solar radiation and outgoing long wave radiation (ERBE data). Positive values indicate downward flux.

Goddard IBM 360/91 1965

NASA Installs 'Fastest' Computer
By Claude Koprowski Washington Post Staff Writer
The Washington Post, Times Herald (1959-1973); Jan 16, 1968; ProQuest Historical Newspapers The Washington I
pg. B6



GIANT BRAIN—Workers at NASA's Goddard Space Flight Center monitor the "thoughts" of a new computer—reportedly the world's largest and fastest. The leviathan can perform 16.6 million additions a second.

To Study Earth, Solar System

NASA Installs 'Fastest' Computer

By Claude Koprowski
Washington Post Staff Writer

A new $7 million computer capable of performing 16.8 million additions a second has begun operating at the Goddard Space Flight Center.

According to its manufacturer, the new IBM 360-91 is the largest and fastest computer ever built. It can perform in one minute a series of ten digit multiplications which would take a mathematician working 24 hours a day, 365 days a year, 4000 years to calculate.

The National Aeronautics and Space Administration will use the machine to examine the precise structure and environment of the earth, and the evolution of our solar system, stars and galaxies.

"Math-models of star clusters, for example, will be formed inside the computer," said NASA's chief of Mathematics and Computing, William F. Cahill. The computer also will be able to telescope the expansion and collapse of stars over the centuries into a few hours.

The new machine was developed for NASA on contract by IBM. Although IBM would not release production cost figures, they reported that cost to the government included development as well as manufacture. NASA revealed that the government-owned share of the machine was $4.7 million and the remainder was being leased for $2.3 million.

IBM said a number of other model 91s were now in production and scheduled for delivery within 17 months.

Key to the operation of the logical behemoth are ultra-high speed circuits capable of carrying signals at almost the speed of light. Although the computer operates within the system 360's 1.5 million instructions package, it has five automomous execution units capable of storage, instruction, and data processing.

The 91s memory is the largest ever built, according to IBM. It can store two million characters or four million digits.

Intellectual grist for the computer can be programmed through a number of languages including, Fortran and PL/I.

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NASA Goddard IBM 360/95 in 1967

The 60's Inspiration for GARP

- From address before the General Assembly of the U N President John F. Kennedy, September 25, 1961

  " As we extend the rule of law on earth, so must we also extend it to man's new domain--outer space.

  To this end,…. We shall propose further cooperative efforts between all nations in weather prediction and eventually in weather control. We shall propose, finally, a global system of communications satellites linking the whole world in telegraph and telephone and radio and television."

- WMO formally establishes GARP in 1967. B. Bolin Dir.
- NAS Report: Plan for US participation in GARP,1969
- NASA establishes Garp project. H. Press Project Mgr, R. Jastrow, Proj. Sci, L. Durocher, Program Manager

Use of Incomplete Historical Data to Infer the Present State of the Atmosphere J.Charney et. al., JAS Sept. 1969

"shown possibility of trade off of temp's for winds, propose experiments with more levels"

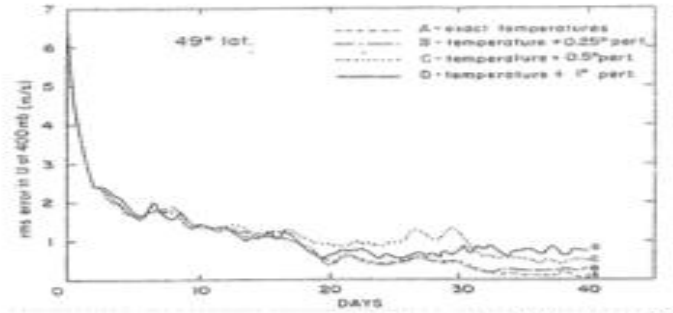


FIG. 1. The rms error in zonal wind (m sec^{-1}) at 400 mb at 49° latitude, in cases where temperatures with random error perturbations of 0, 0.25, 0.5 and 1C are inserted every 12 hr at all grid points.

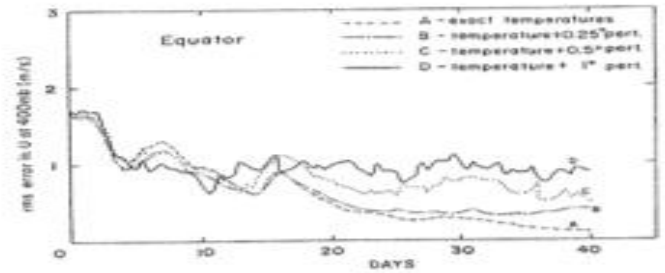


FIG. 2. Same as Fig. 1 for the equator.

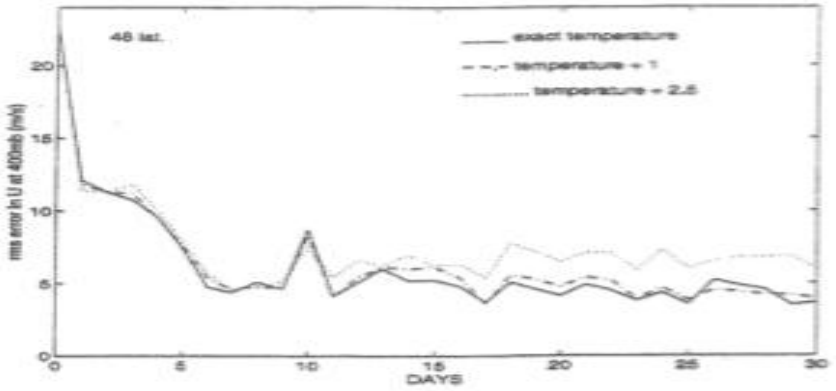


Figure 9 The rms error in 400-mb zonal wind (m s^{-1}) at 48°N, in cases for which temperatures with random error perturbations of 0, 1, and 2.5 K are inserted every 6 hr at all grid points.

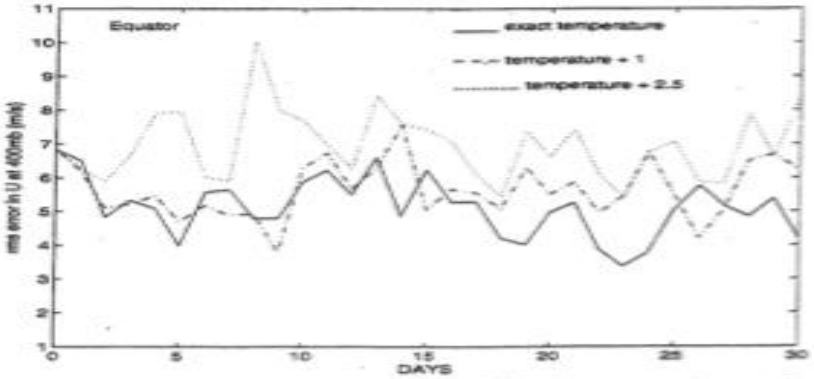


Figure 10 The rms error in 400-mb zonal wind (m s^{-1}) at the equator, in cases for which temperatures with random error perturbations of 0, 1, and 2.5 K are inserted every 6 hr at all grid points.

The 70's

- NIMBUS 5, 6, 7 SMS/GOES,TIROS N, Landsat 2, 3 Explorers IMP 10, Seasat -A

- Simulation studies related to GARP show feasibility of observing system to improve weather forecasts. (BAMS 1970)
- GISS develops MOU with ARC for use of ILLIAC
- GISS acquires first Amdahl V6 computer in June 1975
- Pre-FGGE Data Systems Test 1976
- GISS GARP Project relocated to Goddard 1977
- FGGE: First GARP Global Experiment launched Jan. 1979

US Global Atmospheric Research Program Plan (NAS) Chairperson, Prof. Jules Charney MIT

- Program for Global Observing System

  The system will be an international undertaking. US is and will continue to contribute many of the components of the system. In addition, we propose the US undertake two programs to assist the WMO in adopting a precise date for the First Global Experiment and the configuration of sensors.

First , conduct a series of Observing Systems Simulation Experiments consisting of computer evaluations of various alternative system components for the purpose of ascertaining forecast performance of alternative systems taking into account continuous assimilation of data inhomogeneous in space and time.

Second, conduct a Global Observing System Pacific Test, suggested for about 1973 to observe and analyze simultaneous operation of a number of key elements of the global system over a limited portion of the Earth.

Colloquium in Bld'g 3 1978

- Prof. Jules Charney: Dynamic meteorology icon

OSSE Experiments related to GARP

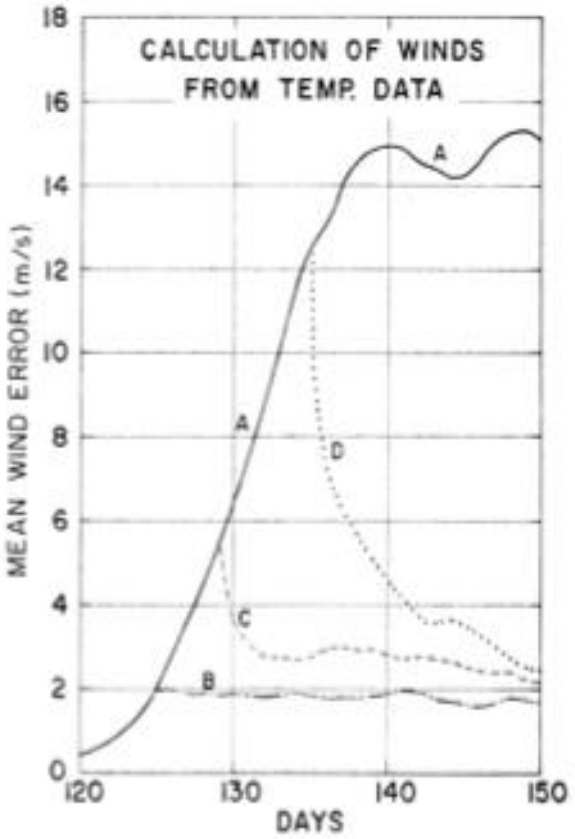


FIG. 1. Effect of inserting temperature data from two polar orbiting satellites, rms error of ± 1C). Curve A shows the typical growth of wind error, defined as global rms difference between an unperturbed and a perturbed solution. Curve B shows the controlling influence of temperature data inserted under conditions imitating the satellite coverage. Curves C and D show the effect of the temperature data when the initial wind perturbation or "error" is 5 m sec^{-1} and 12 m sec^{-1}, respectively. The final value of the wind error is seen to be roughly independent of the initial conditions.

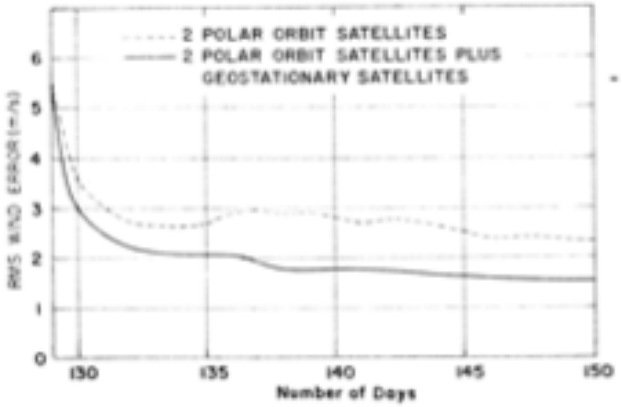


FIG. 7. Effect of adding IR vertical sounders to geostationary satellites. The dotted curve indicates the wind error when data are inserted from two polar orbiting satellites and is identical with Curve C of Fig. 1. The solid curve shows the improvement gained when temperature data from geostationary satellites are added at hourly intervals.

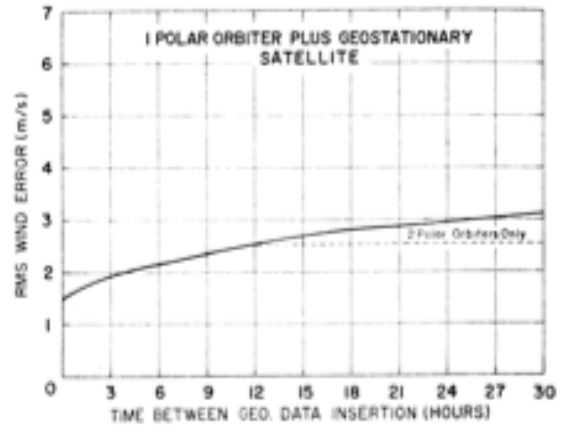


FIG. 8. Effect of variations in the frequency of insertion of geostationary satellite data. One polar orbiter plus geostationary satellites, with data inserted at intervals of 12 hours or less, yield better results than two polar orbiters.

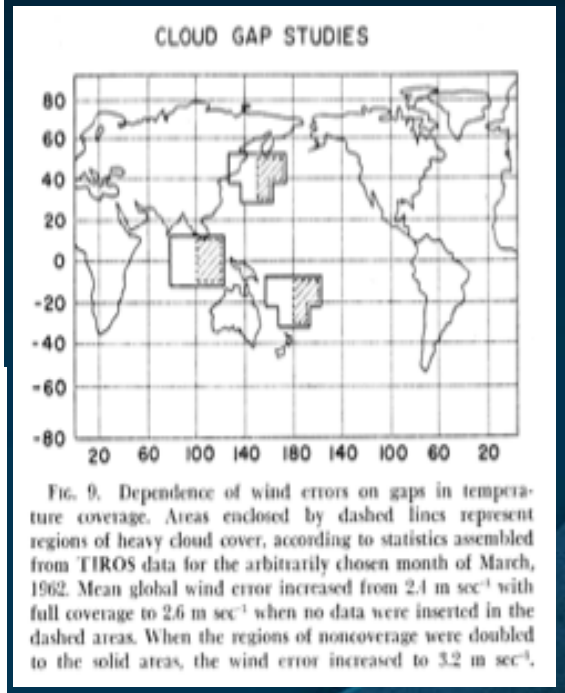
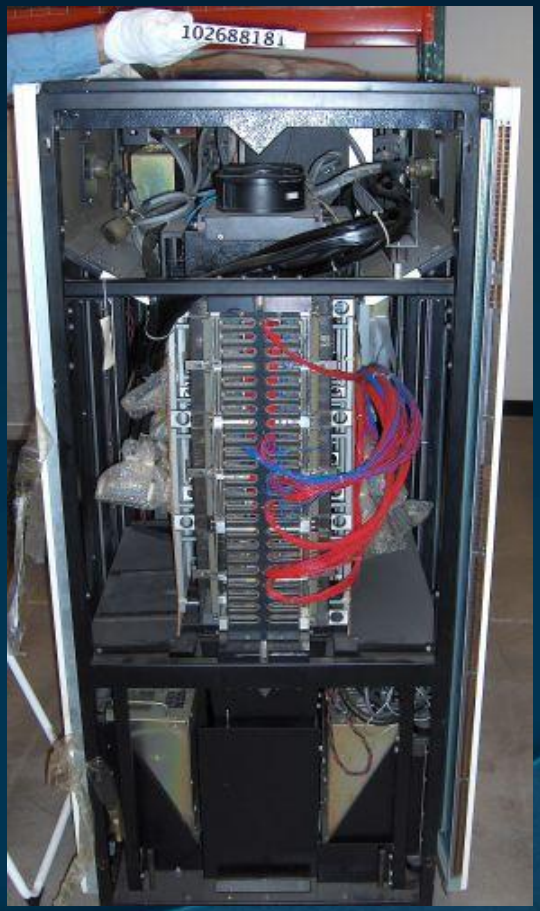


FIG. 9. Dependence of wind errors on gaps in temperature coverage. Areas enclosed by dashed lines represent regions of heavy cloud cover, according to statistics assembled from TIROS data for the arbitrarily chosen month of March, 1962. Mean global wind error increased from 2.1 m sec^{-1} with full coverage to 2.6 m sec^{-1} when no data were inserted in the dashed areas. When the regions of noncoverage were doubled to the solid areas, the wind error increased to 3.2 m sec^{-1}.

First Amdahl V6 delivered June 1975

- Amdahl 470/V6 CPU chassis
- Manufacturer
- Amdahl Corporation
- Dimensions
- overall: 64 in x 30 1/4 in x 75 1/2 in



Chassis

Real time Data Systems Test 1976

Nimbus 6 Instruments Payload: June 1975

- ERBS (Earth Radiation Budget Sensor)
- ESMR (Electrically Scanning Microwave Radiometer) GSFC
- HIRS (High-Resolution Infrared Radiation Sounder)NESDIS
- LRIR (Limb Radiance Inversion Radiometer) NCAR
- PMR (Pressure Modulated Radiometer)
- SCAMS (Scanning Microwave Spectrometer)MIT
- T+DRE (Tracking and Data Relay Experiment)
- THIR (Temperature-Humidity Infrared Radiometer)
- TWERLE (Tropical Wind Energy Conversion and Reference Level Experiment) NCAR

NOAA/NMC provides data assimilation and global forecast

U/WISC provides McIDAS cloud tracked winds LeRC transmits A/C winds

GISS processes sounding temperatures transmitted from GSFC in real time

FGGE: First GARP Global Experiment

- DST. NASA/Goddard/GISS conducts a US pre FGGE end-to end Data Systems Test, 1976 in collaboration with GSFC,GISS,NOAA NCEP, NESDIS ,U/WISC, LeRC, NCAR, UCLA
- FGGE. A WMO/ICSU international coordinated one year global atmospheric and oceans data collection effort conducted in 1979 consisting of ground, air, space, balloon, buoy systems to improve numerical weather prediction

TIROS N

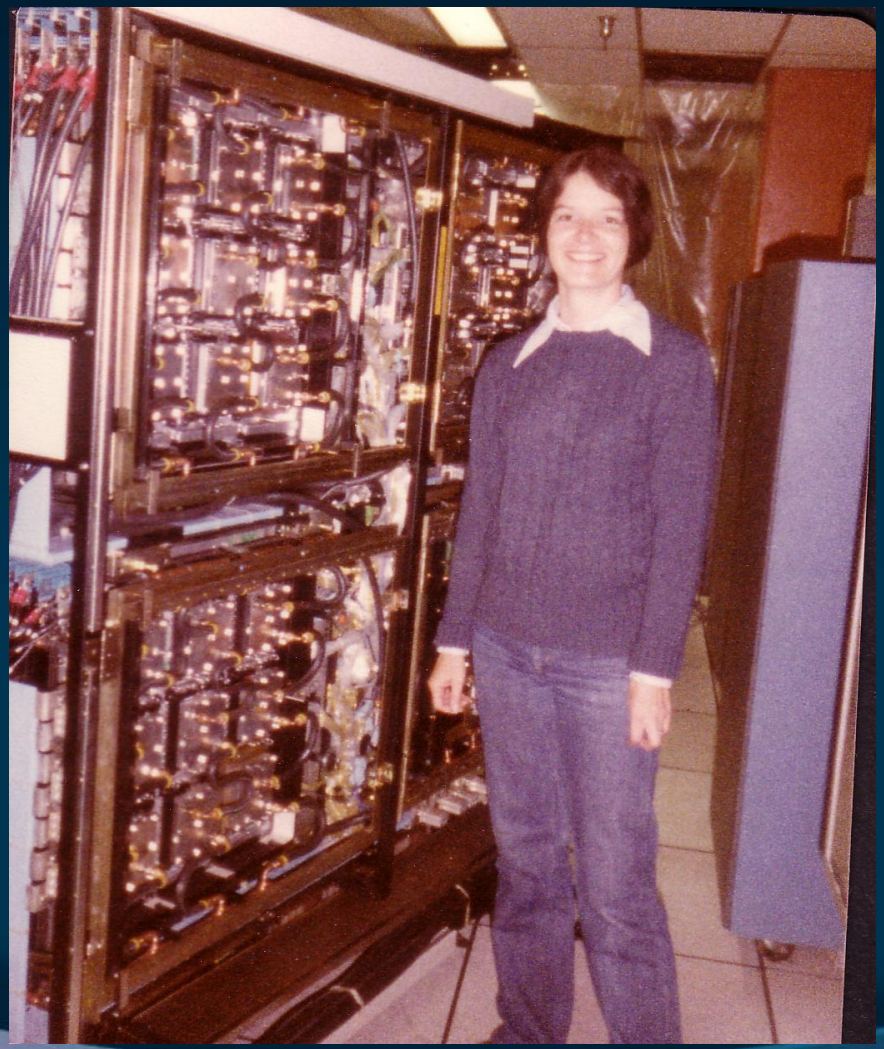
Instrument Payload List:

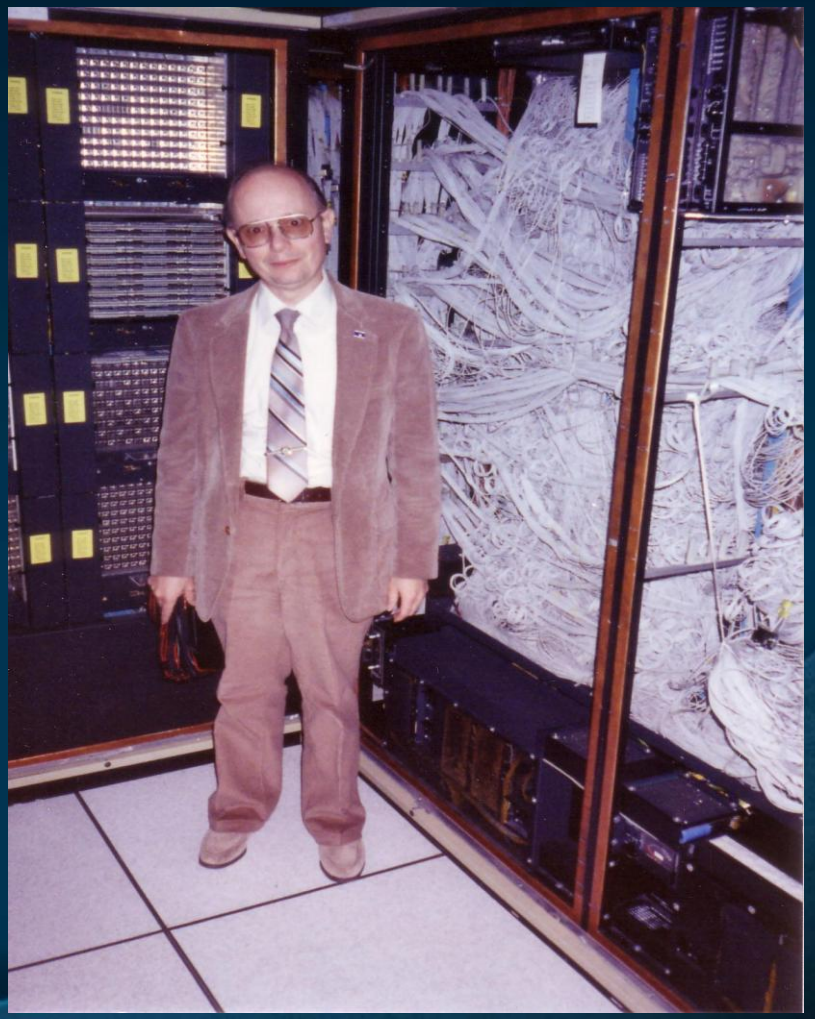
- *AVCS (Advanced Vidicon Camera System)*
- *APT (Automatic Picture Transmission system)*
- *FPR (Flat Plate Radiometer)*
- *SPM (Solar Proton Monitor)*
- *VTPR (Vertical Temperature Profile Radiometer)*
- *VHRR (Very High Resolution Radiometer)*
- *AVHRR (Advanced Very High Resolution Radiometer)*
- *ASS (Atmospheric Sounding System)*
- *SEM (Space Environment Monitor)*
- *TOVS (TIROS Operational Vertical Sounder)*
- *TIP (TIROS Information Processor)*
- *MIR (Manipulated Information Rate processor)*
- *CSU (Cross-Strap Unit).*

The 80's: The Era of Data Systems

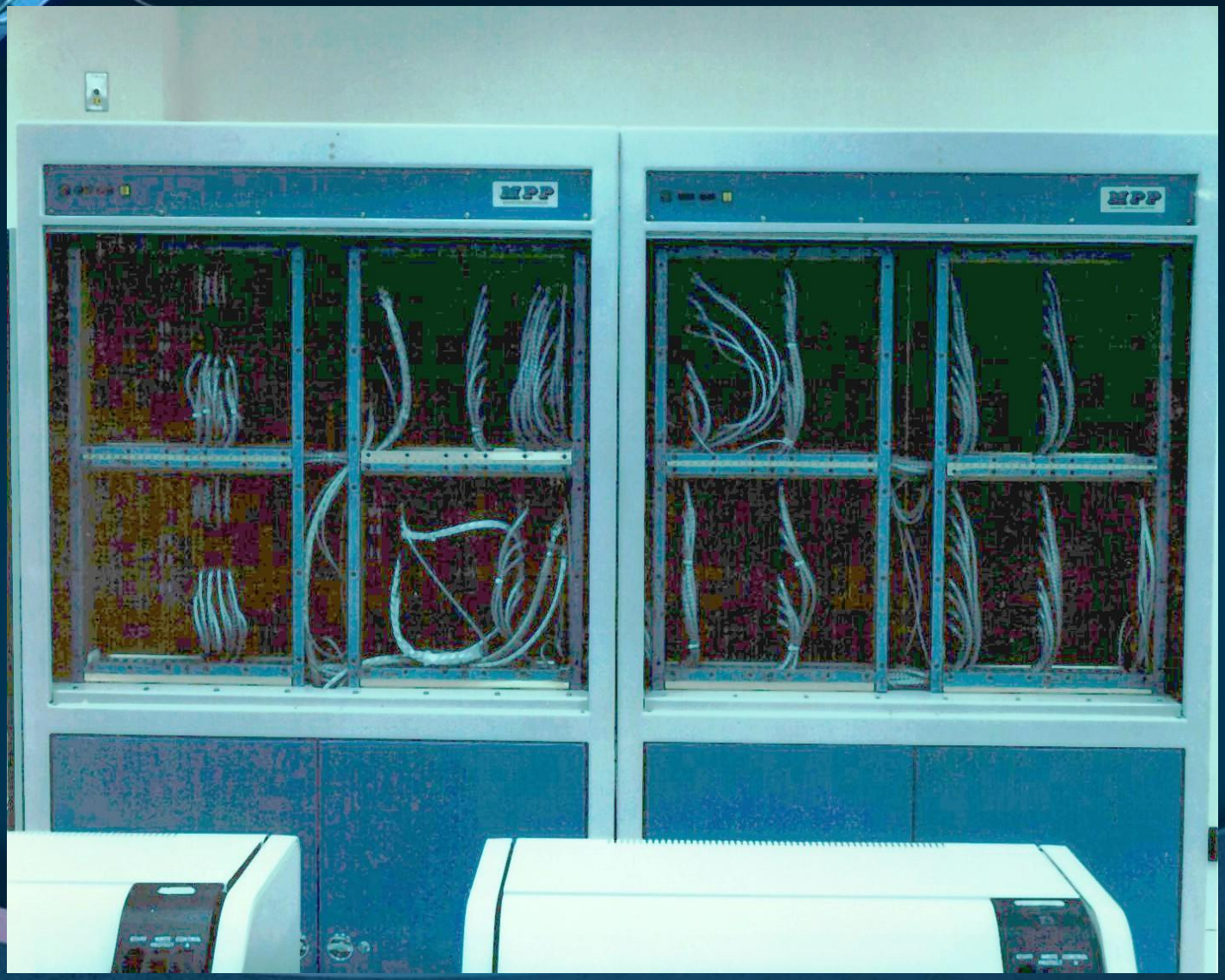
- Landsat 4/5,TDRS A,B,C,D, COBE
- CDC Cyber 205, IBM 3081
- FGGE: First GARP Global Experiment
- Massively Parallel Processor (MPP) by Goodyear Aerospace
- Re-organizing Space and Earth Science Directorates
  IS&T combined (Computing, Data, Mission IS)
- Pilot data systems (PCDS,PLDS, PPDS,LAS, ADS, CDAWs, AOIPS)
- First inter-annual model prediction , El Nino
- SPAN: the harbinger of networks for science (Decnet)
- Master Directory

Integrating Earth and Space Sciences Computing
IBM 3081 and Cyber 205





Goodyear/NASA MPP

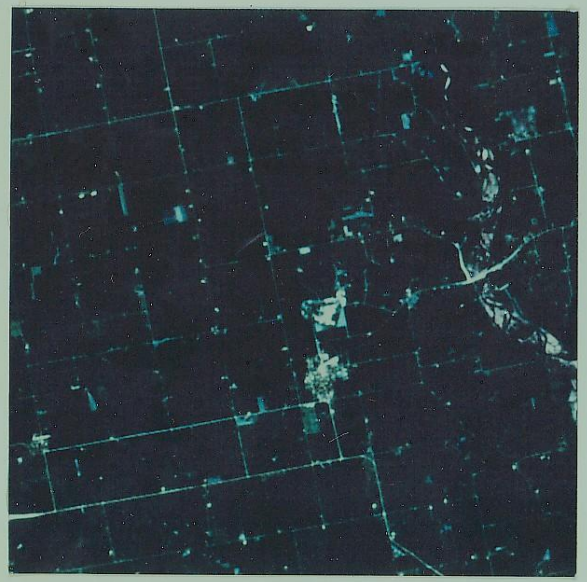


16,384 proc

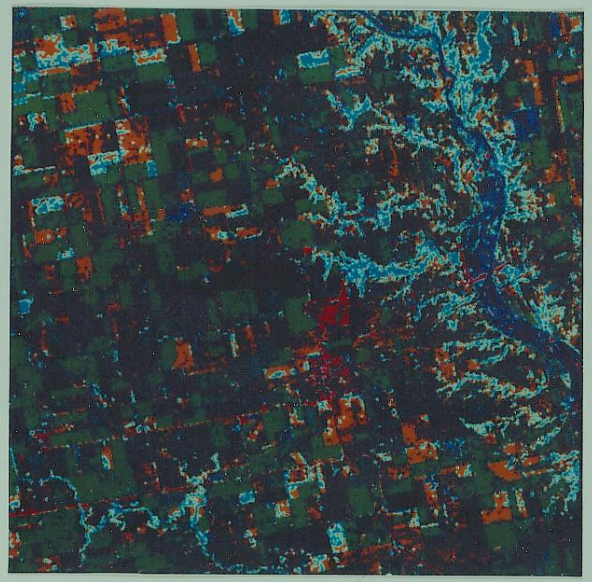
1024 bits/proc

ISODATA Classification

APPLICATION OF MPP PROCESSING TO THEMATIC MAPPER DATA



PORTION OF LANDSAT THEMATIC MAPPER IMAGE BEFORE MPP PROCESSING



SAME PORTION AFTER APPLYING ISODATA CLASSIFICATION ALGORITHM TO IMAGE ON MPP

Computed on Goodyear MPP

Shallow Water Model on MPP

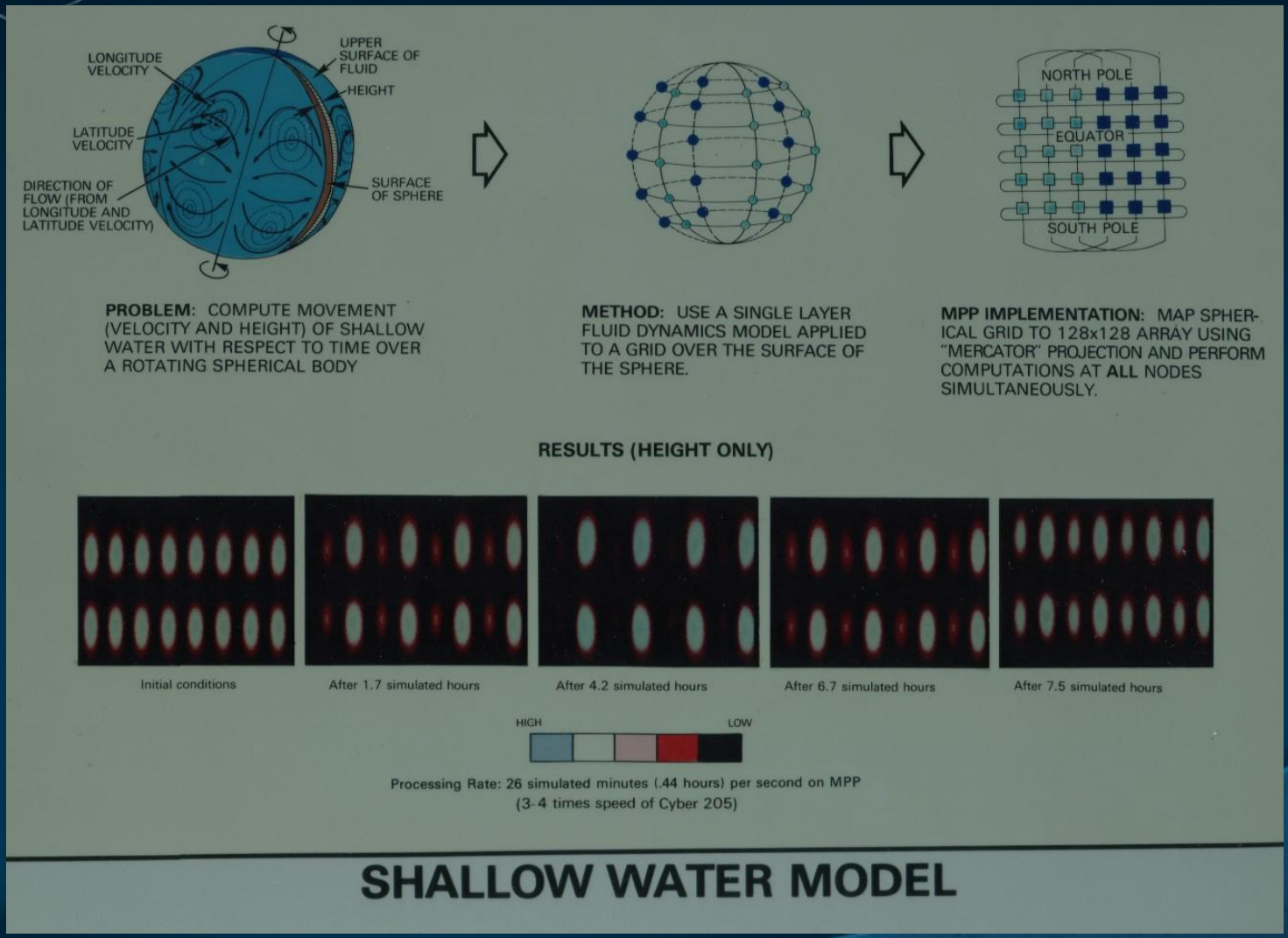


Image Rotation by Sort Computation

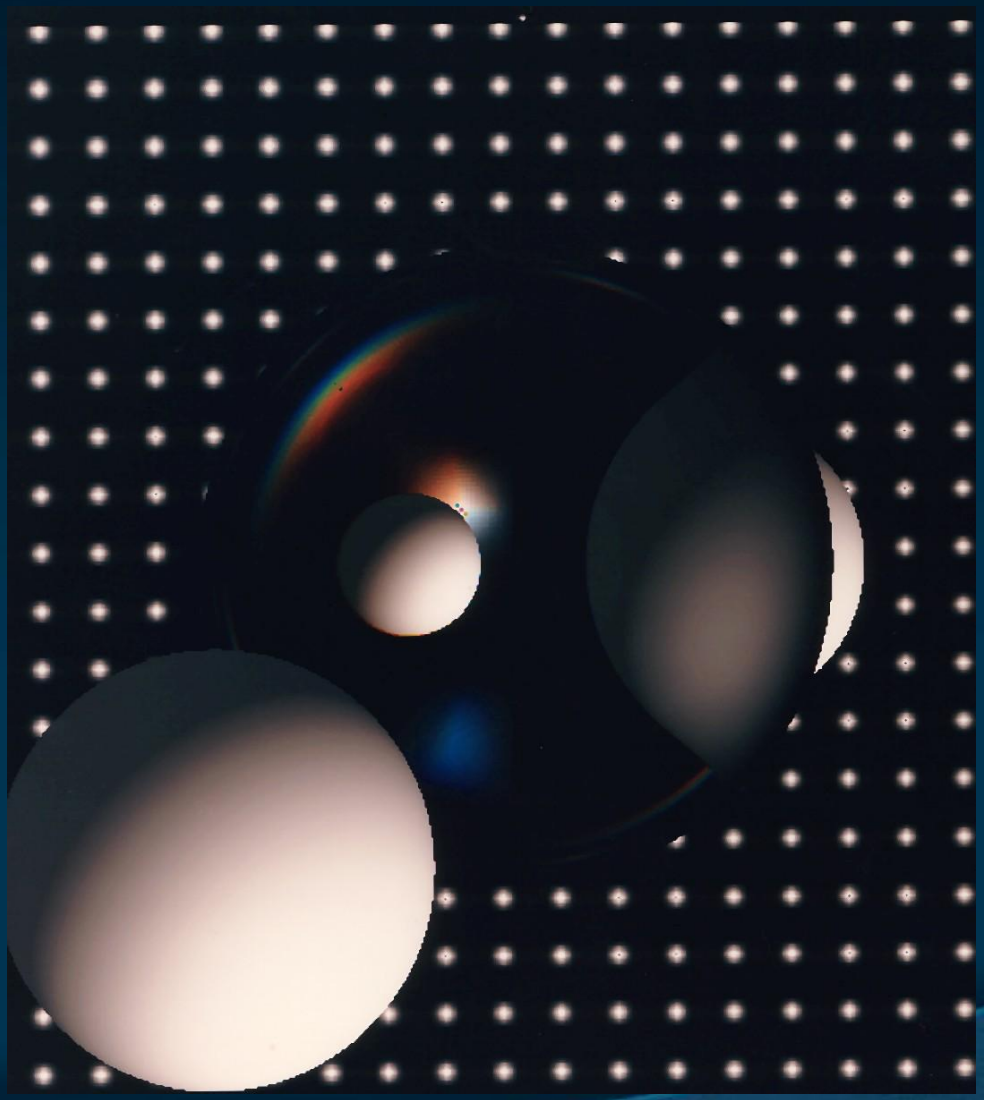
By Dr. J. Dorband

Computed on Goodyear MPP

SAR processing on MPP

By Dr. James Strong

Ray-tracing on the MPP



Block Jacobi Method

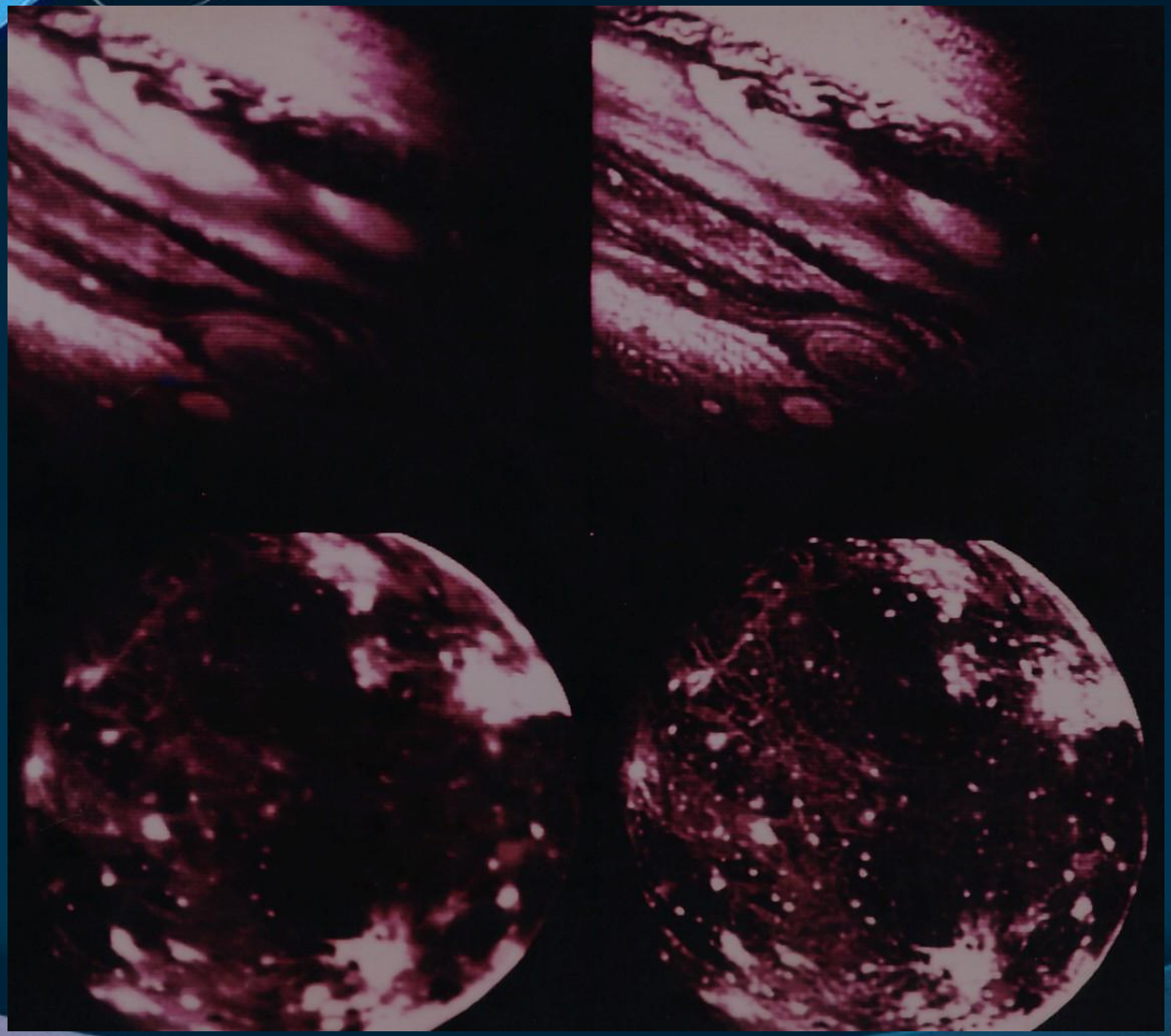


Image Deblurring
on the MPP
using the
Block Jacobi Method

The 90's

- HST,ROSAT, UARS,TOMS, TRMM, Seawiffs
- HPCC Grand Challenge Teams and Earth Science Modeling Framework (ESMF)
- Beowulf Clusters 1994 Open S/W linux
- EOSDIS v0 and Seawifs processing systems, RACs
- COBE Processing (Lifting the veil of god)
- Scientific Visualization Studio
- A. Diaz recognizes IS&T by establishing Ass't Director of Information Science and CIO at Center level and approves IS&T colloquium and Excellence in IS&T award in Nov. 1999.

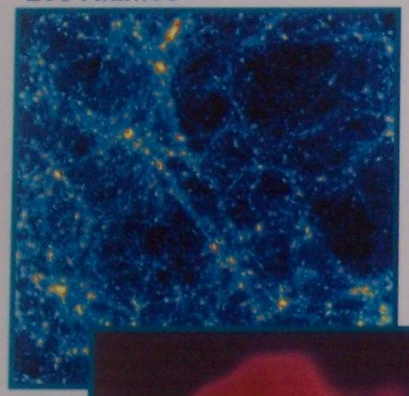
Space and Earth Science Directorate

- Retreat: ~1992

1992-1996

ESS Grand Challenge PI Investigations

Cosmology and Accretion Astrophysics
Wojciech Zurek
Los Alamos



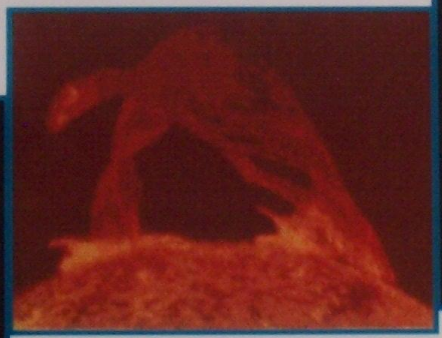
Selected through the NASA Research Announcement Process

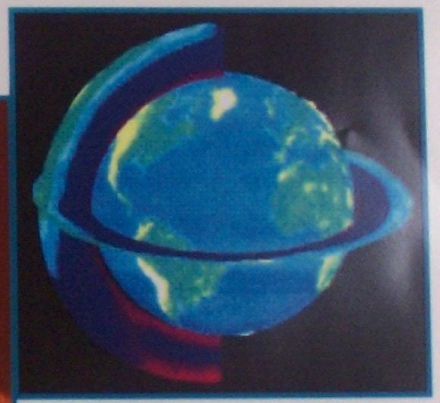
Four-Dimensional Data Assimilation
Richard Rood
NASA Goddard

Climate Models
Max Suarez
NASA Goddard

Knowledge Discovery in Geophysical Databases
Richard Muntz
UCLA

Convective Turbulence and Mixing in Astrophysics
Robert Rosner
University of Chicago





Large Scale Structure and Galaxy Formation
George Lake
University of Washington

Solar Activity and Heliospheric Dynamics
John Gardner
NRL

Atmosphere/Ocean Dynamics and Tracers Chemistry
Roberto Mechoso
UCLA

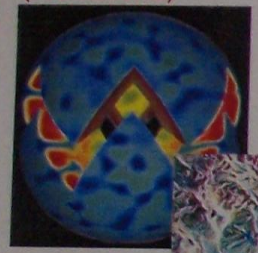
1996-2000

HPCC/Earth and Space Sciences (ESS) Project

http://sdcd.gsfc.nasa.gov/ESS/

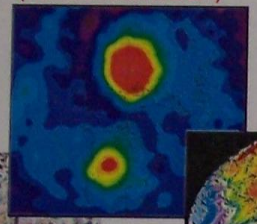
Round-2 ESS Grand Challenge Investigators

Simulations of the Earth's Core and Mantle Dynamics (P.Olson/JHU)

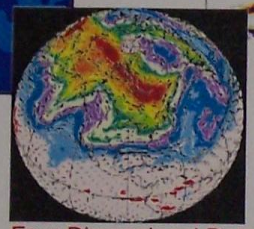


SAR Interferometry and Imaging Science (D.Curkendall/JPL)

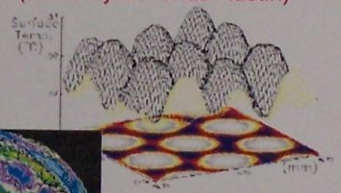
Atmosphere/Ocean Dynamics and Tracers Chemistry (R.Mechoso/UCLA)



Four Dimensional Data Assimilation (P.Lyster/U.Maryland)



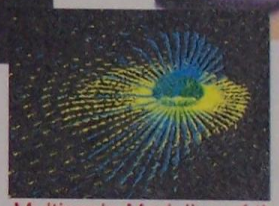
Rayleigh-Benard-Marangoni Problems in a Microgravity Environment (G.Carey/U.Texas Austin)



Solar Activity and Heliospheric Dynamics (J.Gardner/NRL)

Turbulent Convection and Dynamos in Stars (A.Malagoli/U.Chicago)

Multiscale Modeling of the Heliosphere (T.Gombosi/U.Michigan)



Relativistic Astrophysics and Gravitational Wave Astronomy (P.Saylor/U.Illinois UC)

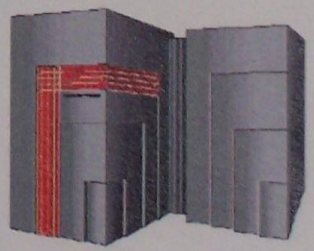
Collaborations to port specified Investigator codes to achieve milestone performance

All performance codes will rapidly be made available to the scientific community via the National HPCC Software Exchange.

T3D
Cray Research, Inc.

10/50/100 Gigaflop/s End-to-End Sustained Testbeds

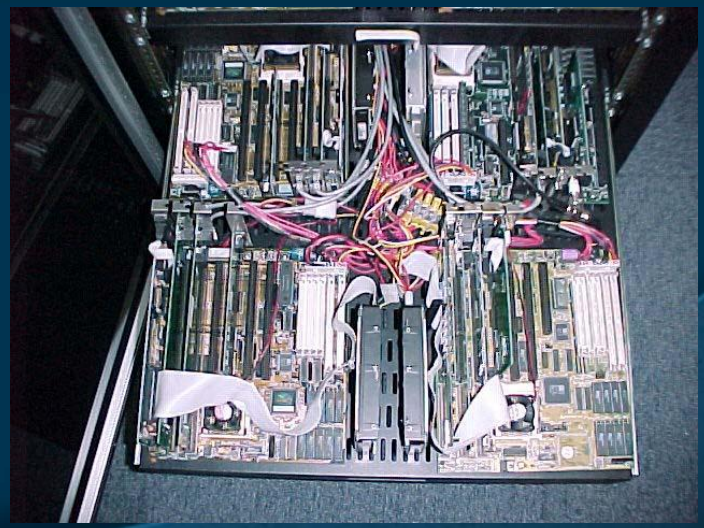
T3E
Cray Research, Inc.



J.Fischer/GSFC 970423

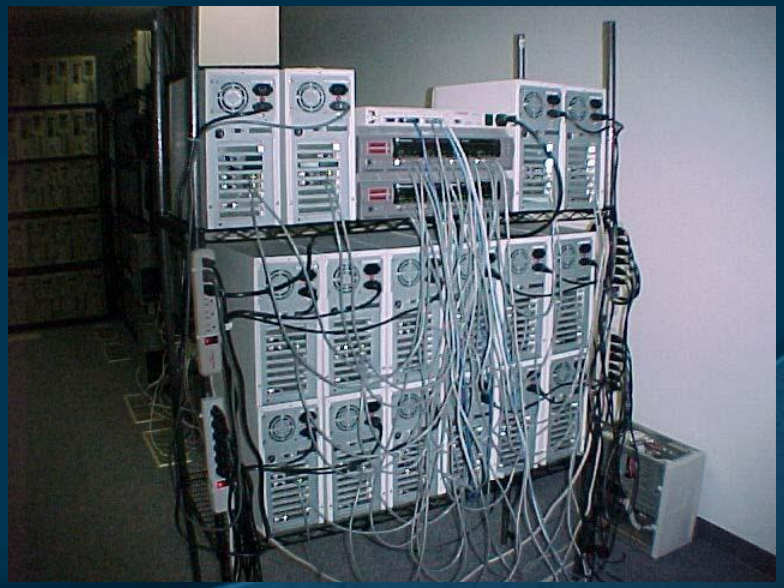
Beowulf developed by D. Becker, T. Sterling, J. Dorband

Beowulf I : Wiglaf 1994
16 - 100Mhz 486DX4
$40,000
50 MFlops sustained (PPM)
Dual 10Mhz ethernet

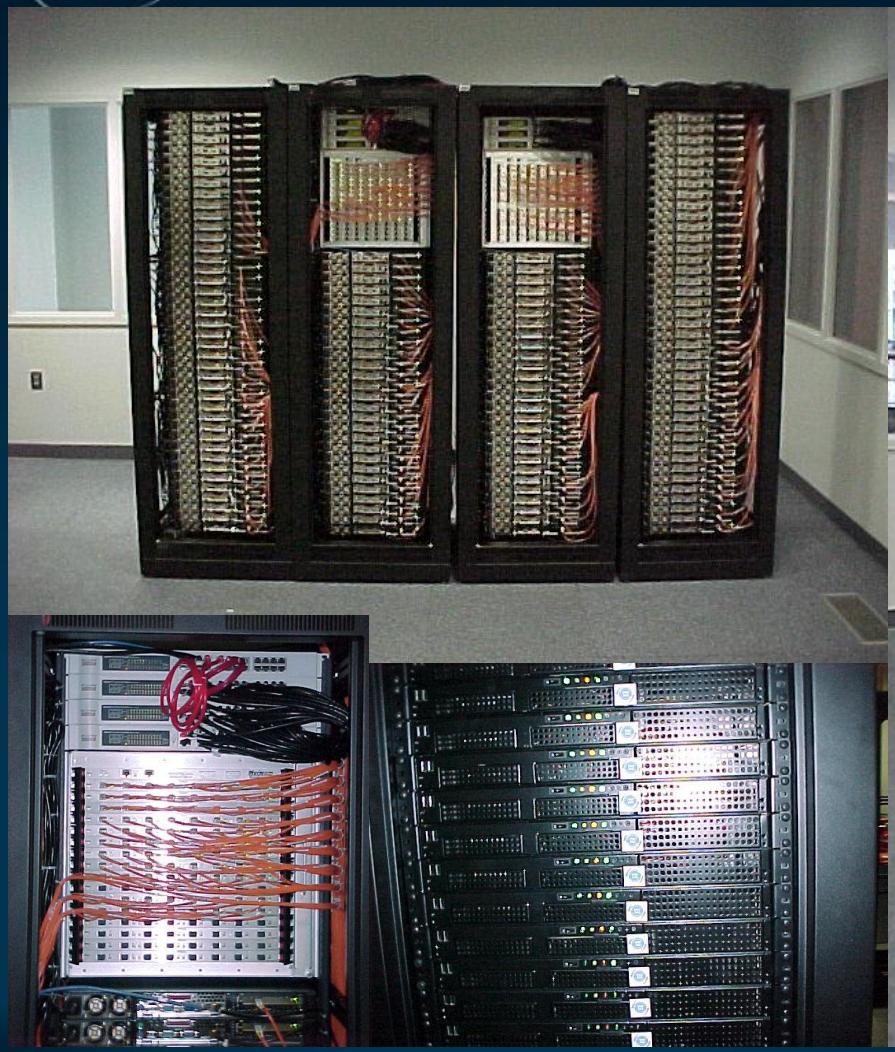


Beowulf II: Hrothgar

1995
16 - 100Mhz Pentium
$40,000
150 Mflops sustained (PPM)
Dual 100Mhz hub-based ethernet
1999: Dual 100Mhz switched ethernet



Thunderhead (HIVE III)520 Pentium 4 Xeons



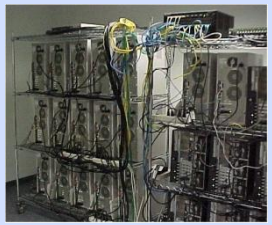
Ensemble Calculations for Seasonal Forecasting

Max Suarez/GSFC, NASA Seasonal to Interannual Prediction Project (NSIPP)
http://nsipp.gsfc.nasa.gov/

Goal: *Establish the degree to which clusters of PC's may reduce the cost of ensemble forecasting.*

For the NSIPP atmospheric model, a cluster of commodity PC's provides performance similar to commercial products, but at significantly lower cost.

Computation of one simulated day using a 288x180x22 grid run on 32 processors of.

Cray T3E-600	Origin 2000	theHive (Linux cluster of PCs)
		
Requires: 20 minutes	10 minutes	29 minutes

The 32 processor Linux cluster cost $120K in mid 1999, making it roughly 3 times more cost effective than the Origin.

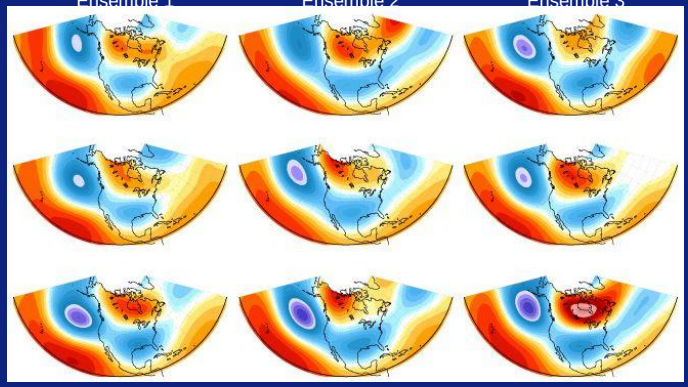
The PC cluster approach is now commercially offered. It allows the latest PC chips to be made available in the computing center for high end applications as soon as they are available to the public.

Creation of the Linux cluster: John Dorband/GSFC
Porting to the Linux cluster: Tom Clune/SGI
Porting to the Origin: Jim Abeles/SGI, Tom Clune/SGI
Timing on the T3E: Max Suarez/GSFC

Since ensemble members are independent they can be run in parallel. 18 runs, using 32 processors each, would efficiently utilize 576 processors. Such work can be done cost effectively on 18 small clusters, reserving large, tightly coupled supercomputers, such as the T3E, for tasks in which independent calculations cannot be so readily organized.

Results produced by NSIPP atmospheric model

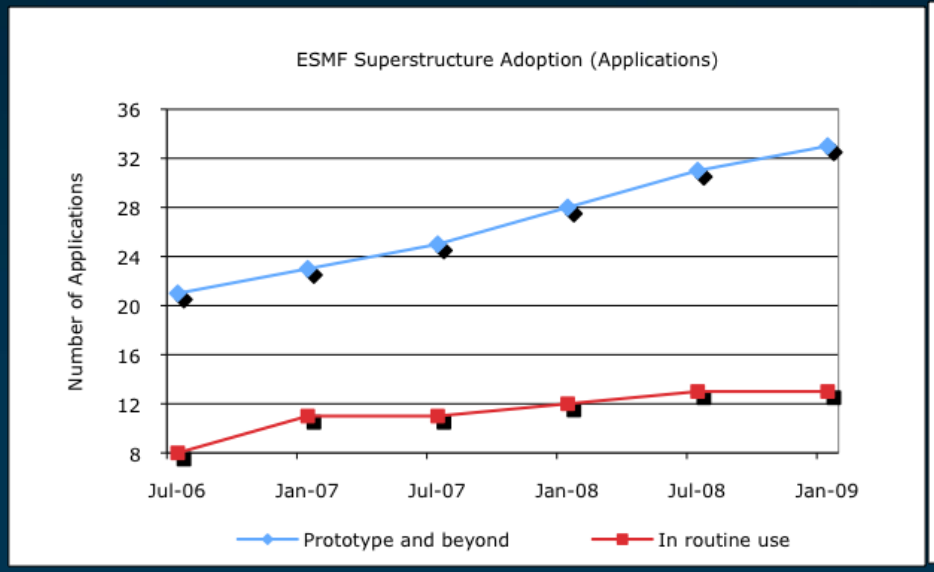
Forecast anomalies of the upper level flow of the 1983 El Nino event.

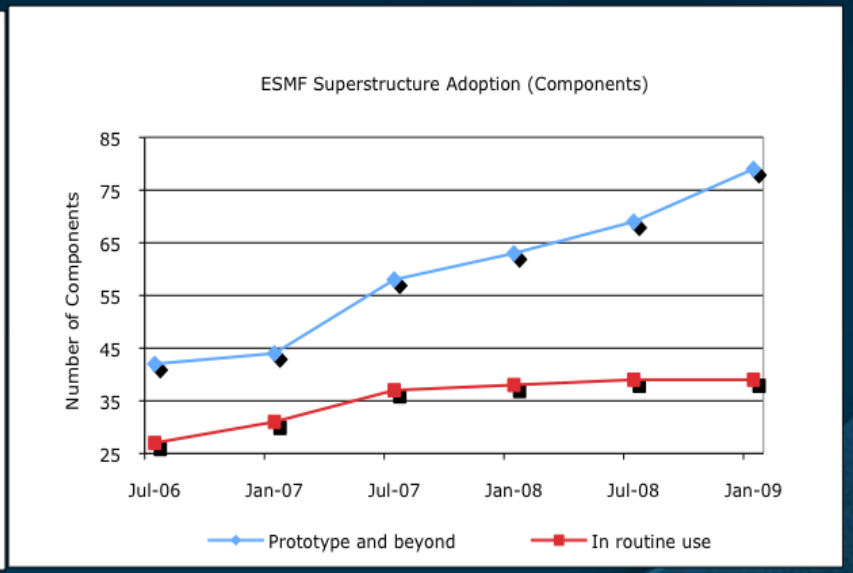


The panels show nine realizations taken at random from an 18-member ensemble forecast. Anomalies over North America are very similar in all members. Over the North Atlantic, however, there is considerable random variability. Ensemble forecasts are required to distinguish between these situations.

Round 3 ESMF sponsors

- Left chart shows number of executable science applications adapting ESMF.
- Right chart shows number of science components adapting use of ESMF.





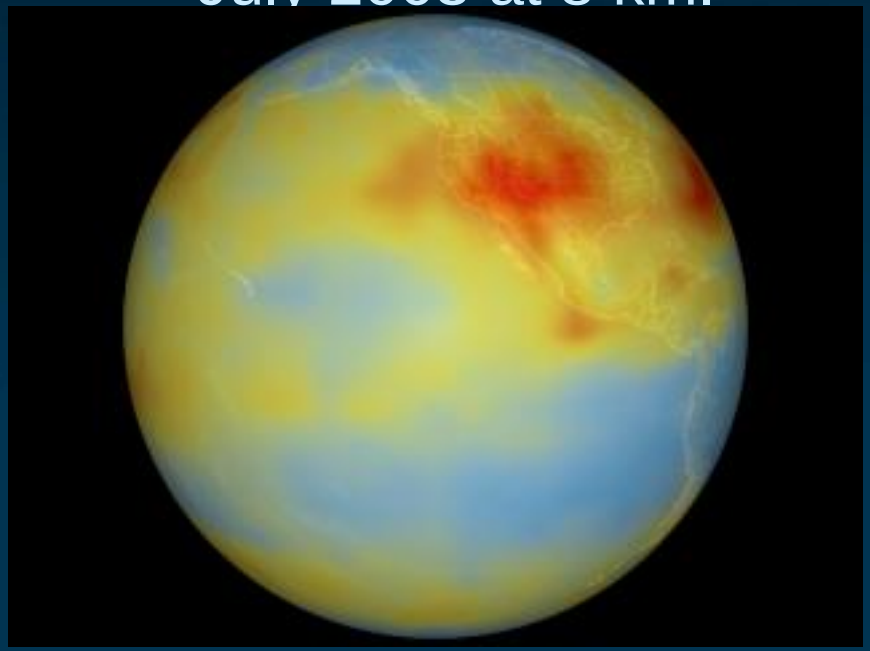
Users: DOD ERDC, DOD NRL, U/Hawaii, NASA/GISS,NASA/GSFC,MIT,NCSU, NSF NCAR,NOAA NCEP, UCLA, ,Harvard Univ,GMU, NOAA GFDL, DOE LANL, NASA GMAO,U/MICH, UMBC

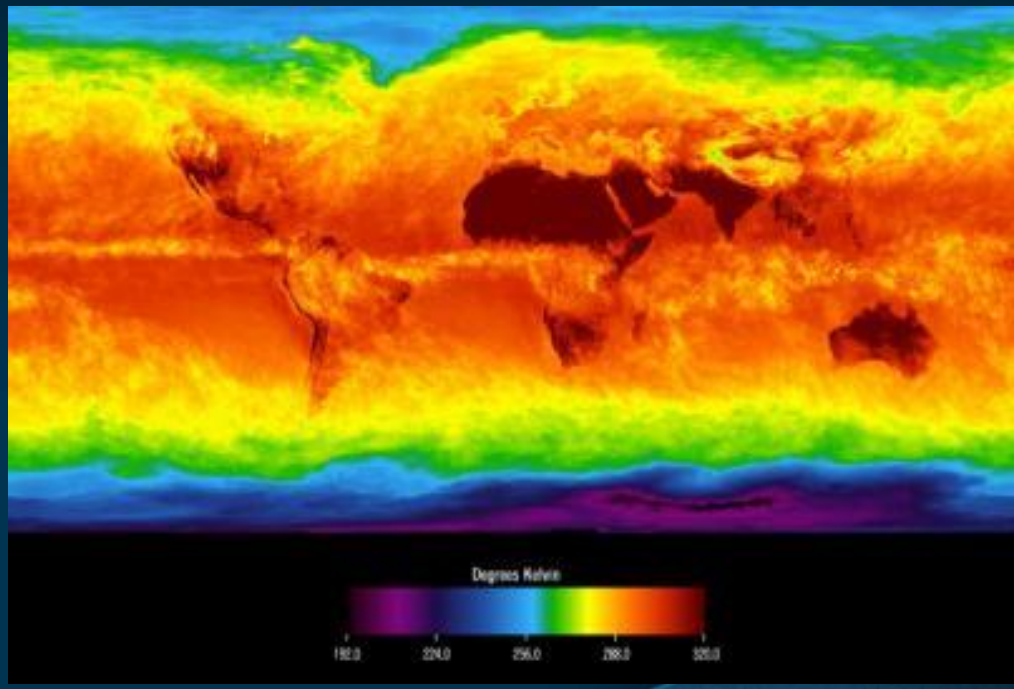
The 00's Delivering Data and Services

- EOS Terra, Aqua, Icesat, Aura launched and successfully producing science data products operationaly on a daily basis,
- AIRS and MODIS revolutionizing remote sensing products
- EOSDIS effectively managing petabytes of data across all DAAC's and serving up millions of files of data globally on an annual basis
- MODAPS delivering more than 2TB's of data products/per month
- Service oriented science enabling users to leverage data and scientific algorithms to create their own products
- Computing, data storage media and network bandwidth evolving at better than Moore's law.

AIRS Products

- Global Carbon Dioxide for July 2003 at 8 km.





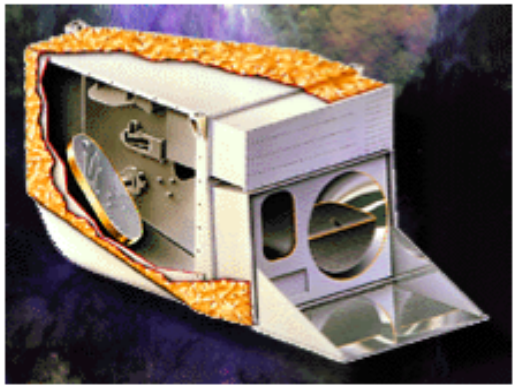
High concentration Red, Low Blue

Global average brightness Temperature

MODAPS

NATIONAL AERONAUTICS
AND SPACE ADMINISTRATION
ESDS Reuse Working Group

Background of MODAPS



- The Moderate Resolution Imaging Spectroradiometer (MODIS) Adaptive Processing System (MODAPS) was developed to produce global products for the MODIS instrument on the Terra and Aqua spacecraft.
- MODAPS has a history of reuse
  - Used to produce atmospherically corrected and Earth-located radiances for various instruments onboard the Land Remote-Sensing satellites (Landsats) and the NOAA 7 through NOAA 14 spacecraft
- Most of the development was spent in refining software to produce improved science products.
  - Only minor effort was expended on modifying the overall processing and distribution framework of MODAPS

MODAPS Land & Storage Servers
Designed and implemented by C. Tilmes

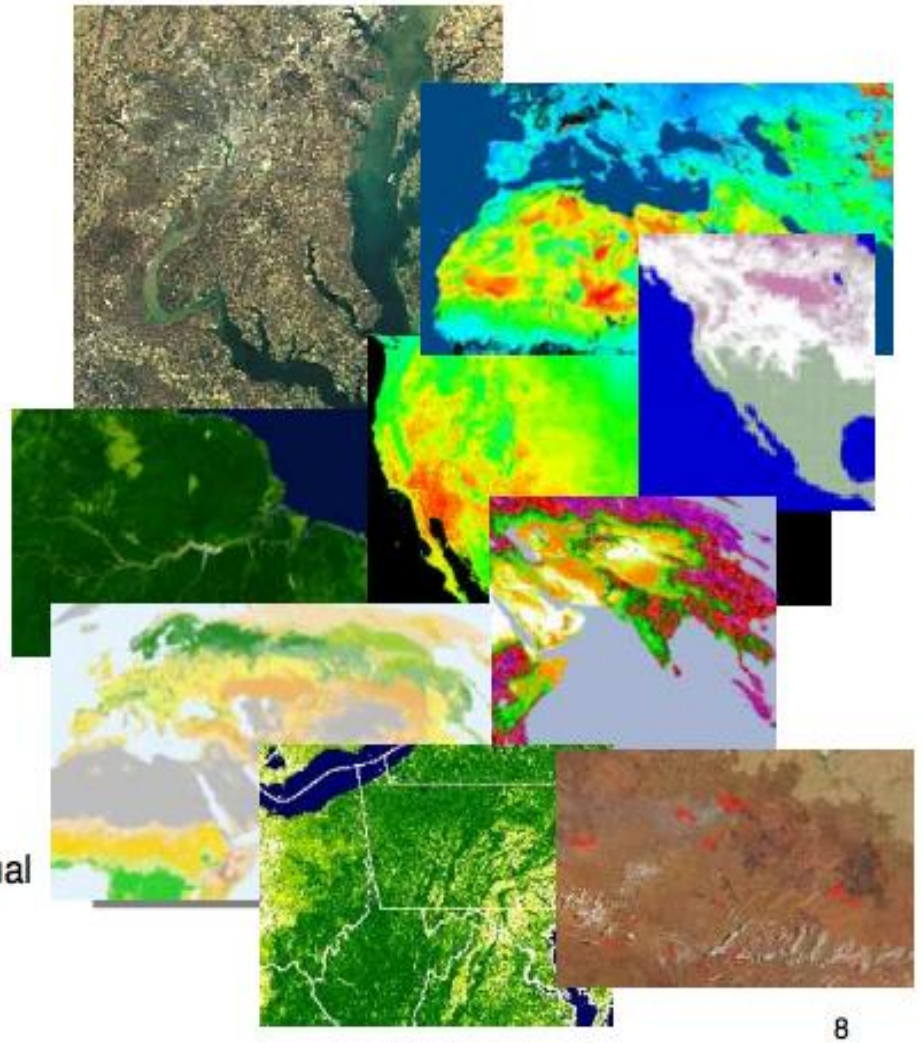
MODIS Land Products

Energy Balance Product Suite
- Surface Reflectance
- Land Surface Temperature, Emmisivity
- BRDF/Albedo
- Snow/Sea-ice Cover

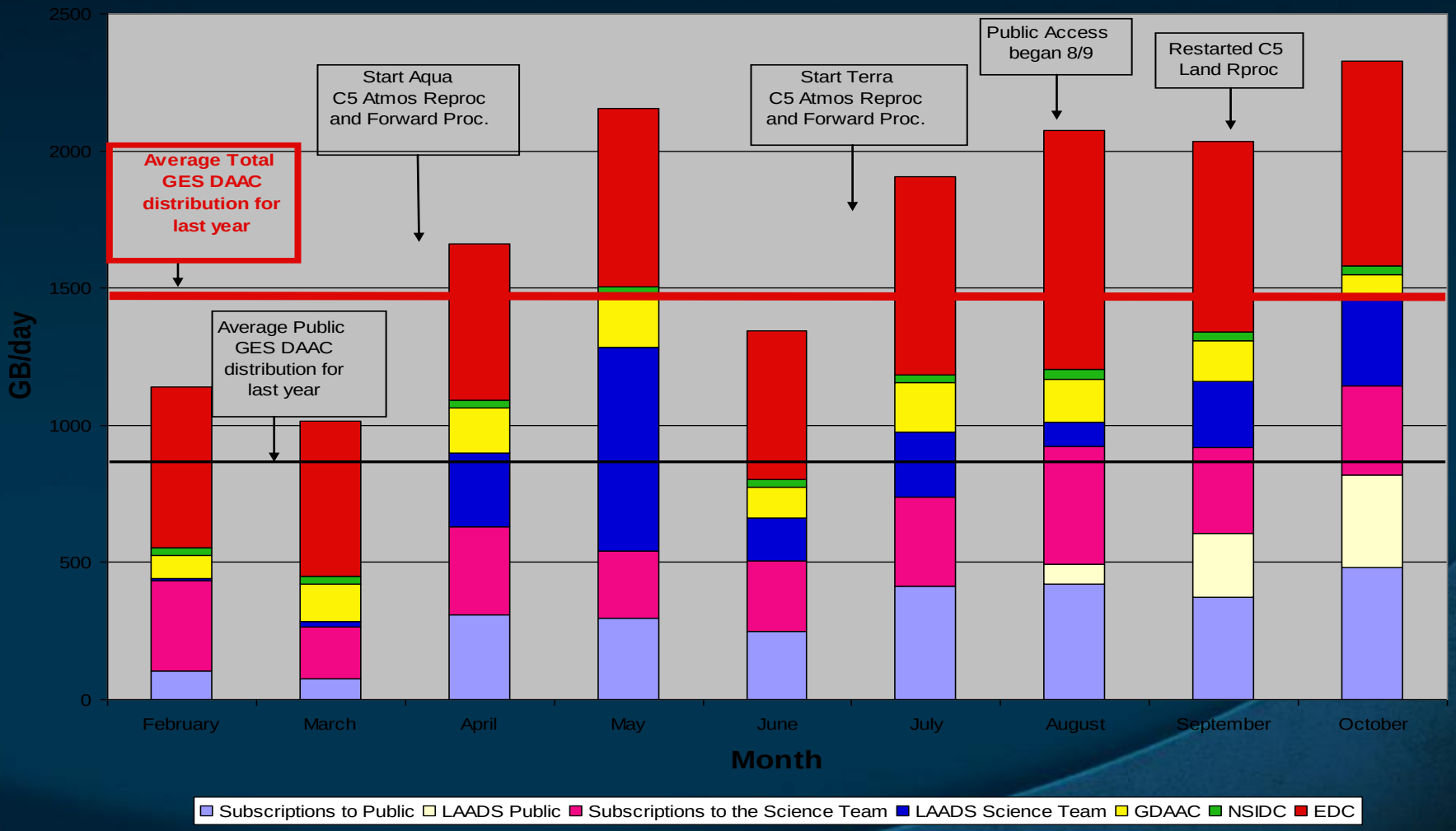
Vegetation Parameters Suite
- Vegetation Indices
- LAI/FPAR
- GPP/NPP

Land Cover/Land Use Suite
- Land Cover/Vegetation Dynamics
- Vegetation Continuous Fields
- Vegetation Cover Change
- Fire and Burned Area

Global Products
- Daily, 8-day, 16-day, monthly, annual
- 250m, 500m, 1km, 0.05 deg.



MODAPS/LAADS Data Distribution



Beyond 2010

Opportunities:

- Petaflop to Exaflop computing
- Global Weather (Replacing model parameterizations with embedded models)
- Fundamental Climate Data Records (NRC report)
- Service oriented science for data and information
- Hybrid Cloud Computing as a Service

Barriers:

Security, Energy and Power, Outsourcing, Data Preservation, and Information Science staffing, Collaborative IS&T Centers and Institutes

10 Most important Goddard IS&T Contributions

1. Beowulf Clusters
2. GARP Data Assimilation and Simulation Studies
3. Pioneering Supercomputers (IBM 360/95, MPP, Cray T3E)
4. HPCC (Grand Computing Challenges/ESMF)
5. Earth Science Data Information Systems (Climate, Land, Oceans, ISCCP, ESDIS)
6. Data Systems (PC/LDS,LAS,COBE, MODAPS, AIRS, Seawifs)
7. Scientific visualization of NASA observing instruments
8. Networking and communication including direct read out
9. Designing and managing mass storage systems
10. Public web access to NASA data to promote science education

Conclusion

- “….When we think of NASA, we think of Space Rockets, Astronauts, Robots, but the real future of NASA lies in Information Technology.

  Administrator Dan Goldin

Thank you

Questions?

IBM System 360

- Courtesy of computer museum history center

360/95 Console

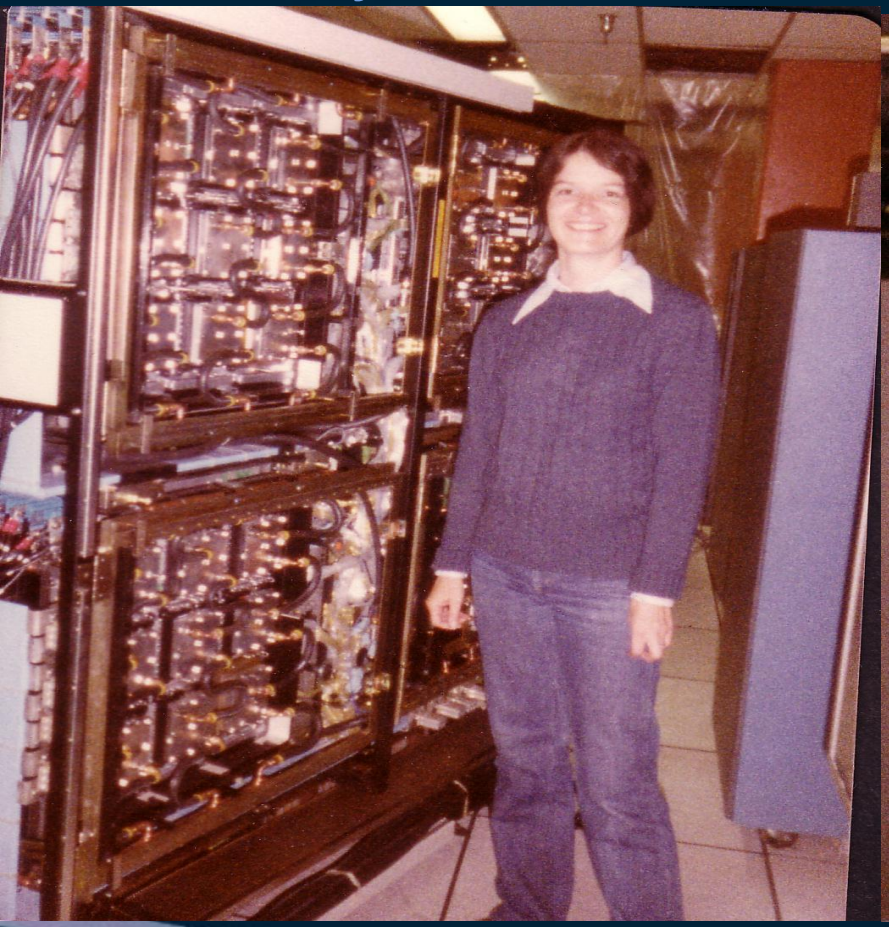
Goddard IS&T Perspective

- Science drives Missions
- Missions drive IS&T
- IS&T drives Science

- A Moore's law driver for space related IS&T

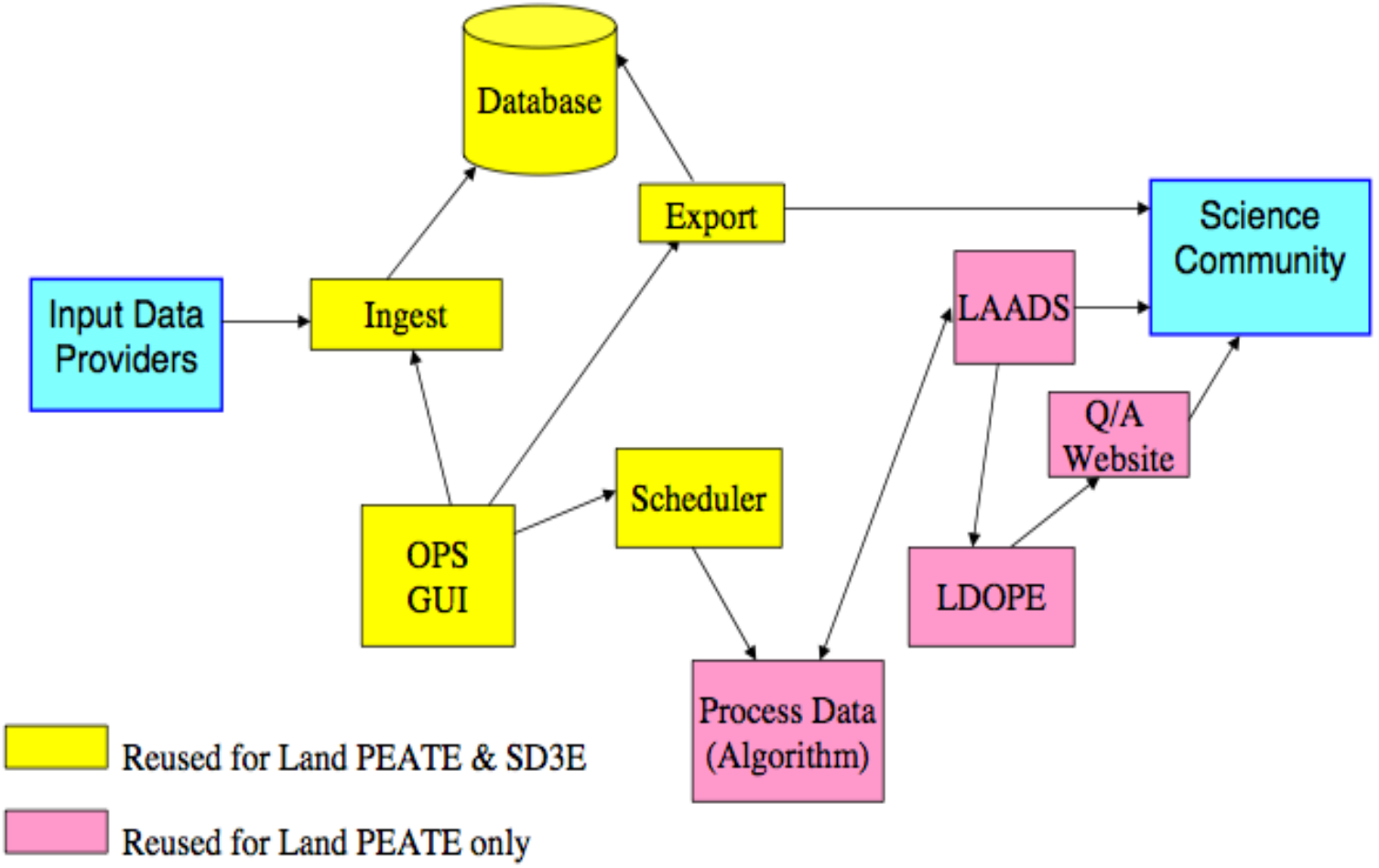
IBM 3081 and CDC ETA 10

- Nancy Palm



Chris Bock & Fred Shaffer

MODAPS Block Diagram



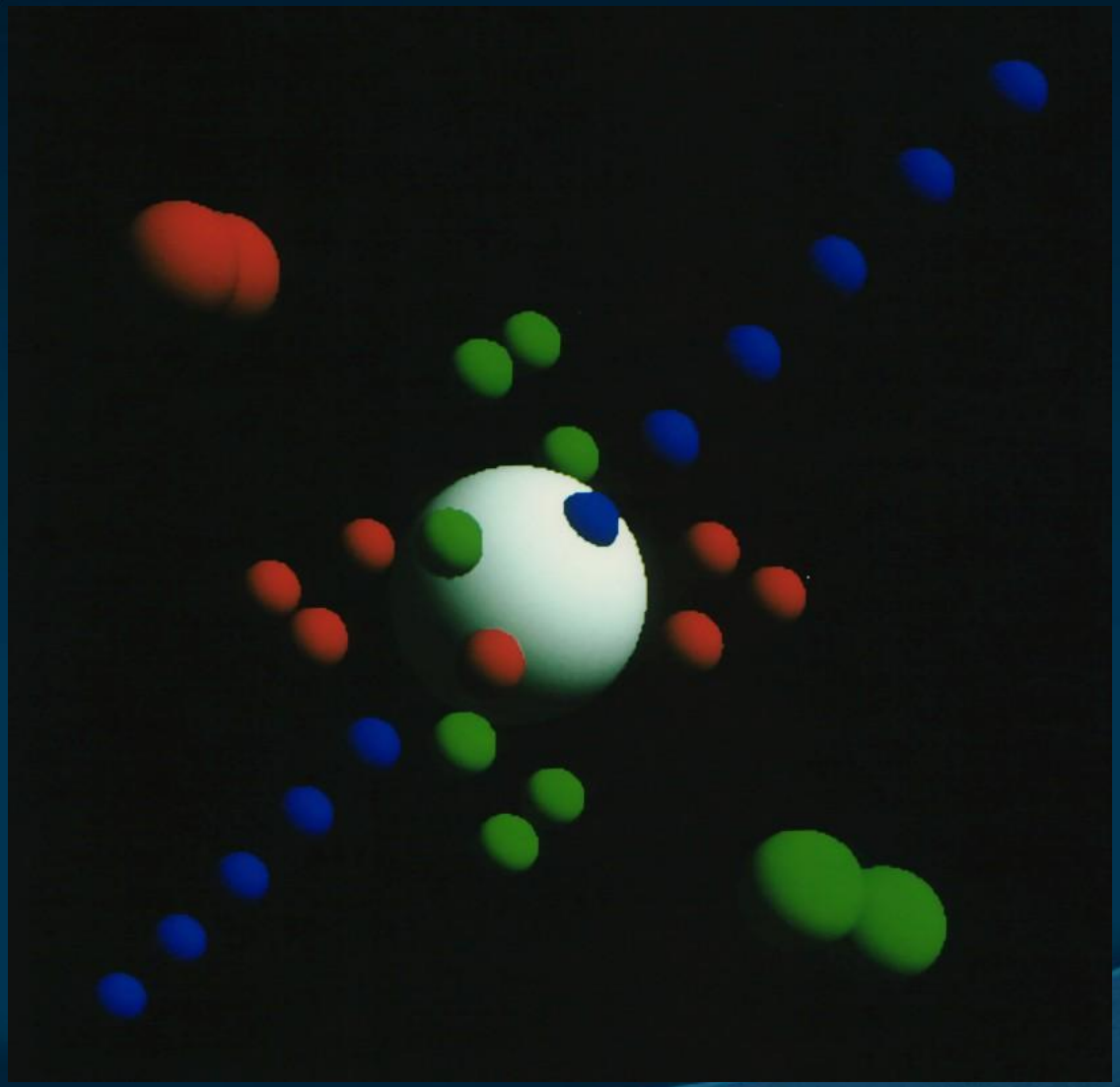
U.S. FGGE special data sets and special effort

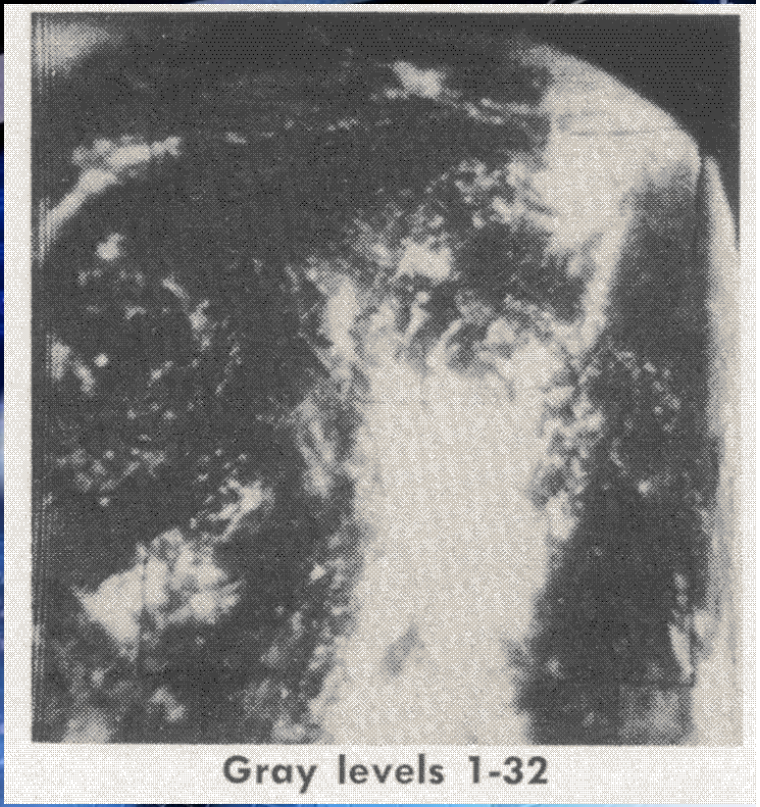
- First, the FGGE Level II-b data set is the most comprehensive set of synoptic-scale meteorological data ever assembled to date. Under development is a program aimed at compacting and restructuring the Level II-b data according to observing systems, so that the data will be more readily usable and more economical for users interested in smaller and/or different portions of the total FGGE Level II-b data set.

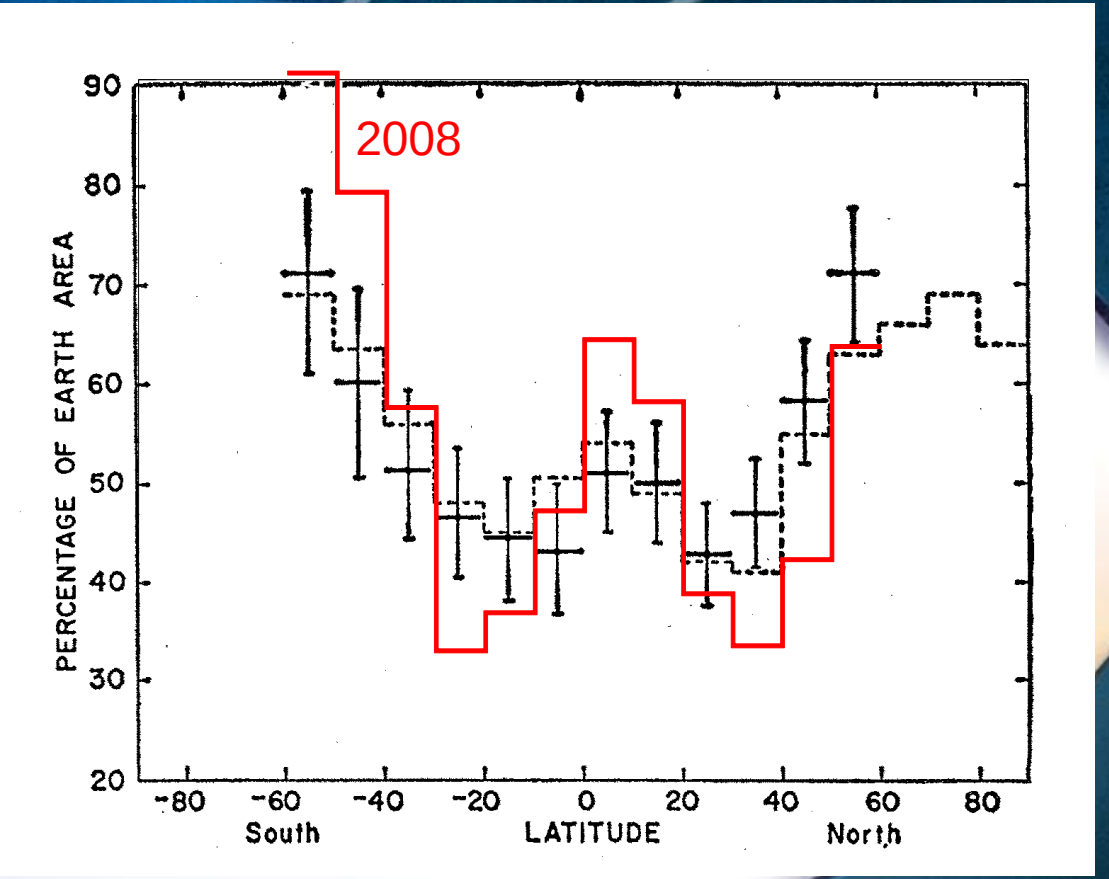
- Next, the production of Level III-b oceanographic and meteorological analyses in the FGGE format has been undertaken by the Fleet Numerical Oceanography Center. The oceanographic data, in particular the sub-surface oceanographic data, is a unique addition to the FGGE data base.

- Lastly, as a result of the United States pre-FGGE Data Systems Tests, a need was indicated for a special effort to edit and enhance satellite soundings and cloud motion wind data during FGGE. A formal program to carry out such an effort has been established jointly by NASA, NOAA, and the University of Wisconsin.

Ray-casting on the MPP




Gray levels 1-32


2008
PERCENTAGE OF EARTH AREA
90
80
70
60
50
40
30
20
-80
-60
-40
-20
0
20
40
60
80
South
LATITUDE
North

Arking (1964)

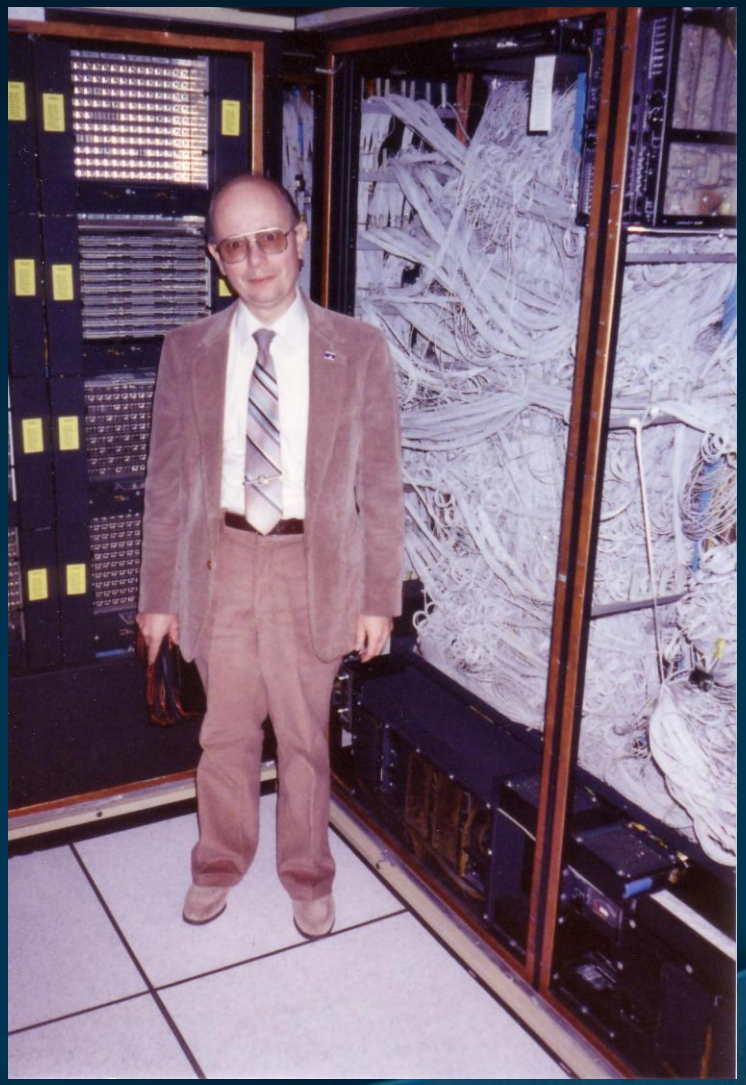
Beowulf Project

MODAPS Hardware Configuration

- Level 0 – storage servers with RAID disk to hold Level 0 (raw) MODIS products
- Datapool – Linux servers and storage used to hold those MODIS Level 1 calibrated radiance products that are not permanently archived, for a period of 30 days.
- AADS storage nodes – Linux servers holding the archive of MODIS Atmosphere products
- LADS storage nodes – Linux servers holding the archive of MODIS Land products
- POD servers – Processing On Demand to produce products not stored in the archive and to transform products in the archive to user specified formats, projects and subsets.

Function	Quantity	Manufacturer & Model	CPU type/#	Operating System	Memory/Disk
Compute Server	77	Dell PowerEdge 1550	Intel PIII 1.1Ghz, 2	Mandrakelinux 10.1	2GB/0.26TB
Compute Server	26	Dell PowerEdge 2650	Intel Xeon 2.4Ghz, 2	Mandrakelinux 10.1	2GB/0.26TB
Compute Server	101	Dell PowerEdge 2850	Intel Xeon 2.8Ghz, 2	Mandrakelinux 10.1	2GB/0.26TB
Compute Server	100	Dell PowerEdge 2950	Intel Xeon 2.3Ghz, 2	Mandrakelinux 10.1	3.2G/0.32TB
Computer Server	100	Dell PowerEdge 2950	Intel Xeon 2.7Ghz, 2	Mandrakelinux 10.1	3.2G/0.8TB
L0 archive Server	16	Dell PowerEdge 2850	Intel Xeon 2.8Ghz, 2	Mandrakelinux 10.1	2GB/21.8TB
Atmosphere storage severs	7 6	Dell PowerEdge 2650 Dell PowerEdge 2850	Intel Xeon 2.4Ghz, 2 Intel Xeon 2.8Ghz, 2	Mandrakelinux 10.1	2GB/13.6-26.7TB
Land storage servers	6	Dell PowerEdge 2850	Intel Xeon 2.8Ghz, 2	Mandriva 2006	2GB/8.7-27.3TB
Datapool disk servers	11	Dell PowerEdge 1550, 2650, 2850, 6650	Intel Xeon	Mandriva 2006	2.0-3.8GB/5.5-28.3TB
Processing On-Demand Server	5	Dell PowerEdge 2850	Intel Xeon 2.8Ghz, 2	Mandriva 2006 Solaris	2GB/9.7-18.4TB
LAADS Database	1	Dell PowerEdge 6850	Intel Xeon 3.2Ghz, 8	Mandriva 2007	32GB
Production Databases	5	Dell PowerEdge 6850 Dell PowerEdge 2850	Intel Xeon 2.7Ghz, 4 Intel Xeon 2.8Ghz, 2	Mandriva 2007	16GB 8GB
Central hosts	3	Dell R900	Intel Xeon 2.1Ghz, 2	Solaris	64GB/.6TB
Additional servers – Q/A, development	7	Dell 2650, Dell 2850, Dell 6850	Intel Xeon	Mandriva	varies

Table 1. Linux computing systems in MODAPS

CDC CYBER 205

- Fred Shaffer