2nd GOES Users' Conference

October 1-3, 2002
Boulder, Colorado

Conference Report

U.S. Department of Commerce (DOC)
National Oceanic and Atmospheric Administration (NOAA)
National Environmental Satellite, Data, and Information Service (NESDIS)

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Foreword

The NOAA Geostationary Environmental Operational Satellite (GOES) R-series is in the planning stage, with first launch scheduled for the 2012 timeframe. Continuation and improvement of this important system capability is critical to meeting NOAA mission goals of serving society's needs for weather, water, climate and other environmental information. NOAA is conducting a number of outreach efforts to exchange information with the user community to ensure optimal capability is acquired with the future series. NOAA held the 2nd GOES Users' Conference in Boulder, Colorado, in October 2002 to further this user coordination.

The goals of the conference were to:

- Inform users of future capabilities and potential applications of the GOES-R Series
- Determine user needs for:
  - new products
  - distribution of GOES data and products
  - instruments of opportunity
  - access to sample data prior to launch of next series
  - education, training and outreach
- Assess user and societal benefits of future systems
- Develop methods to improve communication between NOAA's National Environmental Satellite, Data, and Information Service (NESDIS) and the GOES user community
  - develop, present, and refine a process for determining and updating requirements

These goals were well realized because many useful recommendations were made that NOAA will consider as we develop the future series. This report documents many of these recommendations. This input is also especially timely since we are in the process of developing requirements for the future series and will be documenting and validating these requirements during this year and next. These requirements form the basis for various technical studies and cost/benefit analyses.

NOAA organized this conference in cooperation with the National Aeronautics and Space Administration (NASA), the American Meteorological Society (AMS), the National Weather Association (NWA), and the World Meteorological Organization (WMO). The National Institute of Standards and Technology (NIST) again assisted by providing the meeting facilities in Boulder. We would like to thank all conference participants, especially the invited speakers, all those who provided valuable suggestions for improving the future GOES program, NIST personnel who provided logistic support, and the program committee that ensured that a highly successful conference resulted. The conference committee members are listed in Appendix 7.

Gary K. Davis
Director
Office of Systems Development

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1 Conference Overview

Extensive activities are involved in planning for a future GOES series. One of the most important of these is outreach to the user community — to share information on NOAA plans for future system capabilities — and to get input from users on future evolving needs. NOAA is in the planning stage for the GOES-R Series, now scheduled for the first launch in 2012. While that may seem to be far in the future, it is not long in terms of acquisition planning. NOAA is conducting technical planning for key sensors and setting mission requirements. So continuing the dialog is essential.

To further NOAA and user information exchange, the 2nd GOES Users' Conference was held October 1-3, 2002 in Boulder, Colorado, with nearly 200 participants from the private sector, academia, government, and the international community.[1] The goals of the conference were to:

- Inform GOES users of plans for the next generation (GOES-R Series) capabilities
- Determine user needs for new products, data distribution, and data archiving
- Assess potential user and societal benefits of GOES capabilities
- Develop methods to improve communication between NOAA's National Environmental Satellite, Data, and Information Service (NESDIS) and the GOES user community

The conference was organized into sessions on:

- User Requirements, Applications, and Potential Benefits from Future GOES
- International Update on Future Geostationary Satellite Systems
- Oceanography, Marine Transportation, and Fisheries
- Climate Monitoring

The last day of the conference consisted of breakout sessions on selected topics. Attendees addressed their future needs for products, services, data distribution, archiving, training — and the potential benefits from the next generation GOES capabilities to their future operations and to society at large.

This report summarizes the conference recommendations, with special emphasis on climate and oceans issues. The report also provides the NOAA approach for continuing communication between NOAA and GOES users to ensure that the needs of the user community are fully considered in the design of future systems, products, and services.

The conference focused on the third generation of the GOES series (the R Series) with the first satellite planned for launch in 2012. Topics covered were:

- User requirements and the requirements process
- Interagency coordination
- A visionary look at future environmental satellites
- Potential new instruments

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[1] The first GOES Users' Conference was held in 2001 and its conference report is available at http://www.osd.noaa.gov/goes_R/goesrconf.htm.

- User applications and benefits
- User training
- Role of GOES in the global observing system
- Requirements for oceanographic, fisheries, and marine observations
- Requirements for climate observations

The third day of the conference consisted of a number of breakout sessions, including climate and oceans monitoring. The breakout session was organized around the following user interests:

- Weather forecasting
- Climate monitoring
- Oceanography
- Natural hazards
- Numerical modeling
- Hydrology and land surface

A number of the recommendations listed in Section 4 were made in these breakout sessions. The central issue of the conference was that of potential benefits to users and society as a whole. Throughout the various panels and breakout sessions, the following question was addressed:

> *Considering the information presented during this conference regarding the potential benefits and service improvements of GOES, can you foresee additional savings in terms of life, injury avoidance or protection of property? Please indicate the three most important benefits to your program or to society.*

Respondents clearly indicated that planned GOES capabilities would lead to significant improvements in detection of atmospheric moisture and improved quality of satellite derived winds — leading to improved numerical model performance. Together with subjective use of the improved satellite data and products by forecasters, this should result in more timely and accurate weather forecasts, including improvements in:

- Forecasts of hurricane landfall
- Forecasts of flooding
- Forecast detail
- Tornado warnings

The improved forecasts should directly lead to preservation of life and property, including:

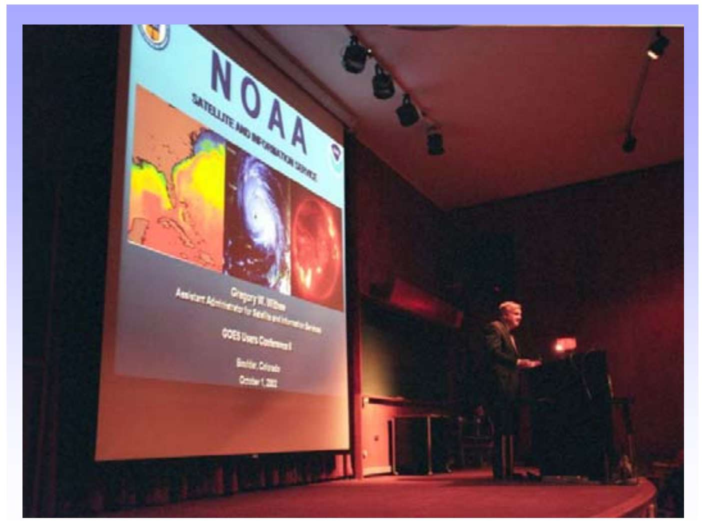
- Safety and economic benefits to commercial, military and general aviation
- Better management of energy resources
- Improved planning and management of ground and marine based transportation
- Better fisheries management
- Improved guidance for State Emergency Managers
- Cost savings for agricultural applications from better planning of watering, and application of pesticides, herbicides and fertilizers
- Improved management of water resources and flood control

- Improved military operations due to improved forecasts for trafficability, weapons trajectories, ship and plane sorties for storm avoidance, and aircraft carrier operations
- Improved quality of life due to better recreational planning

Appendix 1 provides the Conference Agenda listing the overall conference topics, panels, and breakout sessions.

2.1 Opening Speakers

Greg Withee, NOAA Assistant Administrator for Satellite and Information Services



The focus of Mr. Withee's presentation was that NOAA's systems must be user-driven. Users represent a wide range of interests and needs, and NOAA is keenly open to hearing new ways of doing business. Working in partnership with stakeholders, users can make systems innovative and exciting, while NOAA can make those systems efficient and exacting. To fuel the user-driven approach, Mr. Withee encouraged interactivity between users and NOAA managers during the conference. With the input and assistance of all, users and NOAA can work to make the GOES-R series the best system it can be. Major NOAA planning considerations address:

- Complex users and complex integration needs
- User community benefits of satellite systems
- Key ingredients requirements process, and the architecture itself
- Polar (POES) series important complement to the geostationary (GOES) systems
- Importance of partnership between NOAA and NASA to the acquisition
- Integration of weather and space systems with the award of the NPOESS to TRW
- Drive to make GOES as influential and important to research and data gathering as NPOESS
- Importance of clearly demonstrating the value of GOES-R to the NOAA Administrator, the President and Congress to garner support at all levels
- Improved capabilities of satellites, in particular GOES to further the operational monitoring opportunities for
  - CO_2 and other greenhouse gases
  - Precipitation
  - Clouds
  - Winds
  - Aerosols
  - Surface
  - Space weather

Geostationary and Polar satellites will work together to give the complete global environmental picture, including factors such as weather, climate, and surface temperatures.

Gary Davis, NOAA/NESDIS, Director, Office of Systems Development

Mr. Davis pointed out that NOAA used information from the last Users' Conference to make changes to and improvements in requirements, in part by forming a "GOES Users' Working Group." NOAA is listening to the user community, and is conducting trade studies to get a better idea of what can be accommodated in the future NOAA systems. This conference builds on feedback from its predecessor, maintaining a sharp focus on the benefits of GOES use, as well as a focus on requirements, which undergo a constant process of updating and refinement. No ideas should be left out — users must continue to provide feedback so that NOAA can shape GOES systems to meet user needs.

Steve Kirkner, NOAA/NESDIS, GOES Program Manager

Mr. Kirkner gave a GOES Program overview and described GOES' mission and status. He described the acquisition process, the current system being acquired, and how and when the future system will be phased in.

Jim Gurka, NOAA/NESDIS, GOES-R Requirements Team Leader and User Conference Leader

Mr. Gurka reported on recommendations from the last Users' Conference and the progress made to evaluate and incorporate recommendations into the future system. He also reported on means to improve overall communications, including:

- Regular conferences
- Working groups
- Bulletin boards
- Informative special sessions at end user conferences
- Information via e-mail
- Expert teams available to engineers and instrument developers

Michael Crison, NOAA/NESDIS, Chief, Planning, Requirements, and Systems Integration Division

Mr. Crison spoke on transferring science requirements to system implementation, and requirements gathering, validation, and concept studies. GOES is part of a larger system, and is breaking away from any "stovepipe" GOES – serving broad weather, climate and oceanic observing needs. Consequently, the future GOES is serving a broad user base along with its traditional weather mission. We are gathering input on GOES along with other environmental monitoring needs so that those needs can be mapped into and become part of "the system of systems."

We will document user needs such as observation requirements, temporal resolution, spectral coverage, spatial resolution, and radiometric performance. We will translate these needs into architecture solutions and instruments, considering end-to-end architectures. Cost and Benefit Analysis strategy and methodology will also be considered. This helped sell NPOESS, and can be used to aid in supporting GOES.

Mr. Crison also spoke on the subject of response time, capability, and cost/benefit analyses. He placed emphasis on the need to maintain visionary outlook to meet future needs that will evolve as system evolves over the next 10 to 15 years. A visionary approach to future GOES acquisition helps prevent locking out of future improvements and incorporation of advancing technology

2.2 Keynote Address, NOAA Administrator Vice Admiral Conrad Lautenbacher

The Administrator spoke about NOAA's role in future global environmental observing efforts, stating that NOAA could play the critical role of remote sensing in global environmental observation. As part of a "system of systems," NOAA could position itself as its leader, as the nexus where information and systems are gathered and organized. The Administrator pointed out five "T's" that NOAA needs to achieve this important role:

- Transformation, which entails organizational transformation to better meet the mission
- Total systems perspective
- Technology infusion
- Transitioning research to operation
- Teaming with government, academia, corporations, users groups, and international community

These five points are used to describe how to build a better piece of a global sensing system for earth science, oceans, and atmosphere.

NOAA Transformation

- Efficient corporate organization
  - alignment with current and future missions, resolve imbalances between resources and requirements
  - define requirements process, essential for efficiency of budgeting
- Capture user requirements beyond NOAA and in teaming with others
- Fill gaps in architecture by establishing NOAA-wide observing architecture for a "system of systems"

Total Systems Perspective

- Development
- Acquisition
- Launch
- User requirements

- Bringing in data
- Operation
- Part of the global observing system

Technology Infusion

- Advanced Baseline Imager (ABI) and Hyperspectral Environmental Suite (HES)
- Advanced sounder data feeds in directly to commercial benefits, i.e. airline routing and flight patterns
- Weather and climate data use for utilities/power allocation and planning
- Storm warning systems and precision forecasts for increased needs in coastal community evacuation
- Data flow management, data compression, other enabling technologies

Transitioning research to operations

- GIFTS-IOMI Program
- NPOESS NPP
- Joint Center for Satellite Data Assimilation (includes NASA and the military)
- Joint NASA/NOAA planning cycles

Teaming

- Global observing system
- NPOESS — NASA Goddard Space Flight Center, NOAA, TRW, Raytheon
- GOES-R — NOAA, NASA Goddard, User Community
- NOAA and National Space Security Team
- International issues and collaborations
- Integrated Global Observing Community
- International Oceanographic Observing Systems

By engaging these five concepts, NOAA can build a better GOES-R in the most efficient way by establishing integrated systems. The Administrator described how the military's method of establishing systems might answer civilian needs.

- Principles of looking at front end mission needs and defining those needs
- Build mission statement and assess requirements that need to be met to meet mission needs
- Begin with mission needs to develop plan to satisfy requirements
- Use model of defining requirements and solid definition of resource needs
- Put programs together and keep the logic of systems in mind

The Administrator then described how NOAA might address international outreach and training:

- Geographic information data on continents for use in resource management decisions
- Use remote sensing data to support sustainable development in other countries
- Capacity building will take time
- Understanding of resources needed to capture and convert data

In thanking NOAA for its contribution to global community needs and technology infusion, the Administrator committed NOAA to continue its path of outreach. The information it provides is essential now and over the U.S., and currently supports training programs and capacity building. NOAA must continue to build a literate public community through outreach, education and training. NOAA also needs the user community to continue to make that important to legislative entities as part of its mission. For user information, the NOAA mission goals to serve society's needs for weather, water, climate and other environmental information are documented in the NOAA Strategic Plan available at *http://www.osp.noaa.gov/docs/publicdraft.pdf*.

2.3 The Role of OFCM in Interagency Coordination

Mr. Sam Williamson, Director of the Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM), reviewed the history of the OFCM requirements coordination activities. His perspective traced OFCM history from the establishment of the Federal Committee for Meteorological Services and Supporting Research (FCMSSR), that sets policy and priorities, and the Interdepartmental Committee and Program Councils that implement the policy decisions, make policy recommendations to FCMSSR, and assess adequacy of Federal programs and guides implementation of new interagency programs.

2.4 Conference Summary

The conference consisted of a number of introductory NOAA speakers, a series of panel sessions, breakout sessions, and recommendation reports. The sessions were structured into the following:

- User Requirements, Applications and Potential Benefits from GOES-R Series
- International Update on Future Geostationary Satellite Systems
- Oceanography, Marine Transportation, and Fisheries
- Climate Monitoring
- Poster Session

There were many very interesting presentations in the sessions and they are all available at *ftp://ftp.osd.noaa.gov/goesuser/* for the Power Point presentations, and the presentation abstracts are available at *http://www.osd.noaa.gov/goes_R/goesrconf.htm*. The breakout sessions were organized into the following:

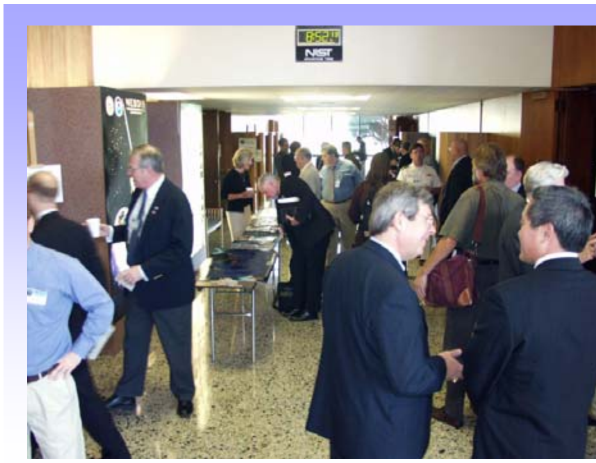
- Weather Forecasting
- Climate Monitoring
- Oceanography
- Natural Hazards
- Numerical Modeling
- Hydrology and Land Surface

The major recommendations of these breakout sessions are found in Section 4.

3 Session Reports and Panel Discussions

The session and panel discussions covered a wide range of important issues. The following selected topics are summarized here:

- Requirements and Applications
- International Update
- Oceans Monitoring
- Climate Issues



3.1 Requirements and Applications

There are three keys to progress:

- Increased computer power
- Improved observations
- Improved understanding of atmosphere and oceans.

Remote sensing from space is the key to improved observations. The Conference provided insight into the Advanced Baseline Imager (ABI) that will provide exciting new products from geostationary orbit, and, the Hyperspectral Environmental Suite (HES), which is the next logical step to acquiring operational high temporal and high spectral data. At the time of the conference, 18 bands were being considered; 16 bands now make up the ABI. The potential benefits of microwave data from geostationary orbits were discussed, including better precipitation measurements and radiances for input to numerical models. Also, space weather and ionspheric disturbances detection and measurements are important for a number of uses (e.g., more people in space, and aircraft over the polar regions).

3.1.1 A Visionary Look at Using Weather Satellites in 2020s

There is a world constellation of geostationary and polar satellites. The key to future improvements is remote sensing from space.

There is a high-resolution global database via GPS, both from ground based and space based sensors. These data, in concert with the GOES will be used for high-resolution water vapor tracking. There will be more of an emphasis on a combination of systems. There is a need for 1 km and higher resolution models. In the future, there will be weather information for "everything, all the time, everywhere."

3.1.2 Imager

The current sensors offer a wide range of GOES imager applications, yet they possess a number of limitations that the ABI can remedy. The ABI will:

- Improve spatial resolution by a factor of four
- Scan faster for improved spatial coverage
- Increase the number of spectral bands

Data from the ABI will improve each product of the current GOES imager. Additionally, the 16-band ABI will allow exciting new products from geostationary orbit.

3.1.3 IR Sounder

There are several key areas in remote sensing: spatial resolution, spectral resolution, temporal resolution and radiometric accuracy. NASA's GIFTS is the first instrument that offers the appropriate balance between these parameters. Impact testing with current GOES sounder data collected in Autumn 2000 has shown significant impact on weather forecast accuracy. The challenge is to more fully utilize the unique temporal aspects of GOES.

The ABS/HES is the next logical step to acquire operational high temporal and high spectral data. The AIRS, IASI, GIFTS datasets will accomplish risk reduction for the ABS/HES.

3.1.4 NWS Forecast Operations 2012 and Beyond

The National Weather Service has embraced the use of experimental as well as operational satellites. The GIFTS instrument will be a risk reduction exercise for GOES-R. There are several challenges for users:

- Fire hose of information
- Managing data, integrating data, feeding necessary information to users in the right amount to the right people at the right time
- Integrating data from multiple sources

3.1.5 Future Role of Satellite Data in NCEP's Numerical Models

The main challenge for numerical weather prediction is how to optimize resources of the total system by improving model performance with improved satellite data assimilation. The new Joint Center for Satellite Data Assimilation will accelerate the use of research and operational satellite data in operational numerical prediction models.

Key factors include:

- Data and instruments
- The science of data assimilation
- Computer and communications capacity.

Motivation for the NASA/NOAA/DoD partnership is to address future challenges through:

- Improved exploitation of existing satellite data in operational models
- Preparation for future data
- Leveraging of multi-agency resources

3.1.6 Microwave Sensing from GEO orbit

As prominent activities in Europe have shown, microwave data from geostationary orbit provides a plausible solution for precipitation detection and all-weather temperature and moisture soundings. The potential benefits of microwave data include better precipitation measurements and radiances for inclusion in numerical models.

3.1.7 Future Aviation Applications from GOES

The impact of adverse weather on the aviation industry is in the range of $100 million per year. This consists of better observing of: icing, volcanic ash, turbulence, lightning (via a lightning mapper), head/tail winds, clouds and restrictions to visibility. Both high spectral and spatial resolution data are critical to observations of middle-level turbulence so the fine-scale features are not blurred.

3.1.8 Space Environment Monitor and Solar Imaging

Monitoring the sun and near-Earth space environment is very important. The GOES is important for observing solar radiation storms, geomagnetic storms and radio blackouts. The Solar X-ray Imager (on GOES-12) will give advance warning for changes in space weather changes near the Earth.

3.1.9 Ionospheric Imaging from Geosynchronous Orbit

The Navy and Air Force have interest in space weather. The ionosphere is highly variable, and is affected by tidal, wind and seasonal changes. The Solar Imager would allow for the first time understanding between the troposphere and ionosphere. Current ionospheric models have limited accuracy because ionospheric bubbles and disturbances can interrupt GPS or create communications interference and noise.

3.2 International Panel Summary

WMO Deputy Secretary General Michel Jarraud reported that there are now three constellations in the space-based component of the Global Observing System (GOS): Polar-Orbiting, Geostationary and the recently added Research & Development. NASA confirmed its commitment to WMO and to the world community to make observations from relevant missions available without restriction. Since data from NASA's EOS missions are readily available, its satellites can be considered a *de facto* constituent of the GOS' space-based component. In particular, NASA's Aqua launched on May 4, 2002, into a sun-synchronous afternoon orbit provides a direct broadcast service for its data. NASA's Terra, launched December 18, 1999, continues to provide data from its direct broadcast service. All data from NASA instruments and NASDA's AMSR-E onboard Aqua are available to WMO Members.

ESA is developing information for WMO Members on the availability of specific data and products from ESA's EO satellite missions, including the ENVISAT mission launched in March 2002. ESA plans to propose an Announcement of Opportunity (AO) to foster the use of ESA Earth Observation data by the WMO community. ESA's ENVISAT was launched on October 1, 2001, and its valuable data are available through the ESA web site in Frascati, Italy. Japan's NASDA indicated that its future satellite missions including ADEOS II and the GCOM series are candidate contributors to the GOS. Finally, the Russian Aviation and Space Agency (Rosaviakosmos) confirmed that experimental and R&D instruments on board its operational METEOR 3M N1 satellite as well as on its future Okean series and other missions could be considered part of the GOS.

Dr. Bizzarro Bizzarri spoke about the possibilities for geo-microwave capabilities. He noted that recently two developments gave the idea of MW sounding from GEO new impetus:

- On the technological front, it has become possible to extend radiometry to the sub-millimeter range, which allows antenna size reduction or, alternatively, improved resolution.
- On the applications front, strong requirements have appeared to frequently observe precipitation, due to growing capability of NWP models to assimilate precipitation data at the appropriate scale.

The objective of a geo-microwave demonstration program would be to explore the capabilities of very-high-frequency microwaves and sub-millimeter waves to provide frequent sounding, as allowed from the geostationary orbit, of:

- nearly-all-weather atmospheric temperature and humidity profiles
- cloud liquid and ice water (total column and gross profile)
- precipitation rate from convective clouds (and non-convective clouds to a limited extent).

Future possible operational undertakings should be explored, since frequent observations of temperature/humidity, cloud liquid/ice water and precipitation rate are of primary importance for Nowcasting and Regional/Global NWP, as well as for climate characteriztion (hydrological regimes) and improved description of the water cycle in General Circulation Models. Direct use in hydro-agro-meteorology also would be important. A geo-microwave with limited antenna size (3 m) could provide synoptic scale 30 km sounding resolution with hourly duty cycle, 20 km cloud resolution every hour, and 10 km precipitation resolution every 15 minutes.

Rolf Stuhlmann from EUMETSAT was congratulated on the successful launch of Meteosat Second Generation (MSG) in September 2002. This 12 channel vis (1 km) and IR (3 km) sensor will significantly boost geostationary observing capabilities. He then reported on the Post MSG User Consultation process. The EUMETSAT goals were to:

- Establish agreed upon user/service needs and priorities that serve as a reference for deriving performance, functional, and other high level specifications for a post-MSG system (time frame 2015 - 2025)
- Use high level specifications to issue (with ESA as partner) an open invitation to tender to industry for pre-phase A activities to assess mission/system architecture concepts
- Evaluate/consolidate documented mission concepts and preliminary system architecture and derive/propose detailed plans for phase A and related R&D activities.

EUMETSAT desires that operational applications (NWC, NWP, climate monitoring), and not technology drive formulation of user/service needs, related observational requirements and priorities in the first phase of the User Consultation Process. Feasibility, technology, and technical realization should only be addressed in the second phase (propose mission concepts and system architecture).

The EUMETSAT vision on prospective user/service need (2015-2025) has been prioritized and documented in three position papers on "Nowcasting (NWC), regional-, and global-NWP by Application Expert Groups (AEGs)" and endorsed by EUMETSAT Council and have been discussed in detail at the 1st Post-MSG User Consultation Workshop in November 2001. The Council has endorsed these recommendations and tasked EUMETSAT to implement without delay a consolidation of Observational Requirements and Technical and Remote Sensing Expert assessment. Remote Sensing Experts have encouraged EUMETSAT to look at two scales of GEO VIS/IR imagery (I-1 and I-2) and to specify the relevant "channels to be considered for an instrument concept proposal" for both. These are:

- Imagery-1 mission with spatial resolution of 500 m and temporal resolution of 5 min
- Imagery-2 mission with spatial resolution of 1 km and temporal resolution of 15 min.

Imagery-2 channel selection should consider two options: there is no sounding mission and a de-scoped set in case of an additional sounding mission.

Hitomi Miyamoto, from JMA, reported that the Multi-functional Transport Satellite (MTSAT) was to have taken over the meteorological missions of Geostationary Meteorological Satellite-5 (GMS-5) in the spring of 2000. However, due to the failure of launch vehicle of MTSAT, a new plan was formulated to launch MTSAT-1R as a replacement of MTSAT in early 2003 and MTSAT-2 as the next one in mid 2004 to function in stand-by operations for three years and start of service in 2008. Currently preparation has been progressing for operation of both satellites. MTSAT-1R is now planned for launch in early 2004. MTSAT-1R and MTSAT-2 are multi-purpose satellites with both aeronautical and meteorological missions.

Dr. Paul Menzel summarized the geostationary observation plans for China, India, and Russia.

China

The second Chinese geostationary meteorological satellite, FY-2B, was launched on June 25, 2000. The satellite is spin-stabilized and stationed at 105^0E. FY-2C is planned for launch in 2004, and will carry the current GOES Imager spectral bands at 1 km (vis) and 5 km (IR) resolution.

India

India launched INSAT-3B in March 2000 as the first of the INSAT-3 series. INSAT-3C followed on January 24, 2002. A geo dedicated to meteorological applications, METSAT, was launched in September 2002; this carries an imager with vis (2 km), IRW (8 km), and WV (8 km) channels and a CCD array at 0.7, 0.8, and 1.6 microns. Launch of INSAT-3E is in early 2003 and that of INSAT-3D at the end of 2003 or in the first quarter of 2004; the latter payload will also include a 19 channel sounder.

Russia

Russian geostationary observations plans include the GOMS/Electro N2 satellite to be designed for a 3-axis stabilized platform. The key payload will consist of MSU-G, a scanning radiometer-imager with 12 channels in VIS and IR similar to MSG SEVIRI. The spatial resolution in sub-satellite point will be about 1 km (VIS) and 4 km (IR). GOMS/Electro N2 launch to geostationary orbit at 76°E is planned for 2005.

The session confirmed that the Global Observing System is truly an international enterprise and that research contributions will significantly expand the GOS capabilities. Users encouraged all participants to engage in active inter-calibration efforts.

3.3 Oceanography, Marine Transportation, and Fisheries Observations

GOES ocean measurements from platforms now in orbit, the planned GOES-R instruments and from future GOES systems offer many benefits, including:

- Advances in understanding of the role of the oceans in coupled geophysical and ecological processes
- Cost savings and increased safety for marine transportation
- Enhanced fisheries production and conservation through science-based knowledge
- Improved numerical prediction (ocean, atmosphere, and coupled) models.

The Oceanography, Marine Transportation, and Fisheries Session included a panel discussion and a breakout session the following day with 15 active participants. The panel was organized to have two GOES user representatives with different requirements, an ocean-atmosphere panel member with remote sensing expertise, and a panel member reporting on NASA Earth Science 10-25 year vision. Each cited clear benefits provided by present, planned (GOES-R), and envisioned geostationary satellite measurements. Panel member Walter McKeown, Senior Scientist at the Naval Atlantic Meteorology and Oceanography Center, described the benefits to the Navy and commercial maritime transport of having timely geostationary satellite data to avoid losses and achieve maximize efficiency. Examples include unpredicted waves that can impact a military aircraft carrier's elevator with aircraft in transit between the hangar deck to the flight deck, or smaller ships encountering high seas during critical refueling. These examples alone represent losses of at least $100 million a year. In the commercial maritime shipping industry, time is money. Winds, currents, and waves directly impact shipping schedules. A geostationary satellite with advanced microwave and multispectral measurement capabilities would greatly reduce the present estimates of hundreds of million dollars a year in losses. Knowing sea state in near real time will also have benefits in rescue operations.

Another panel member, David Foley, a contractor at the Joint Institute for Marine and Atmospheric Research at the University of Hawaii and NOAA Fisheries Honolulu Laboratory, presented specific applications of data derived from geostationary satellites important to fisheries research and management. As Figure 1 illustrates, his work underscores the need for near real time data distribution, and measurements at high spatial resolutions.

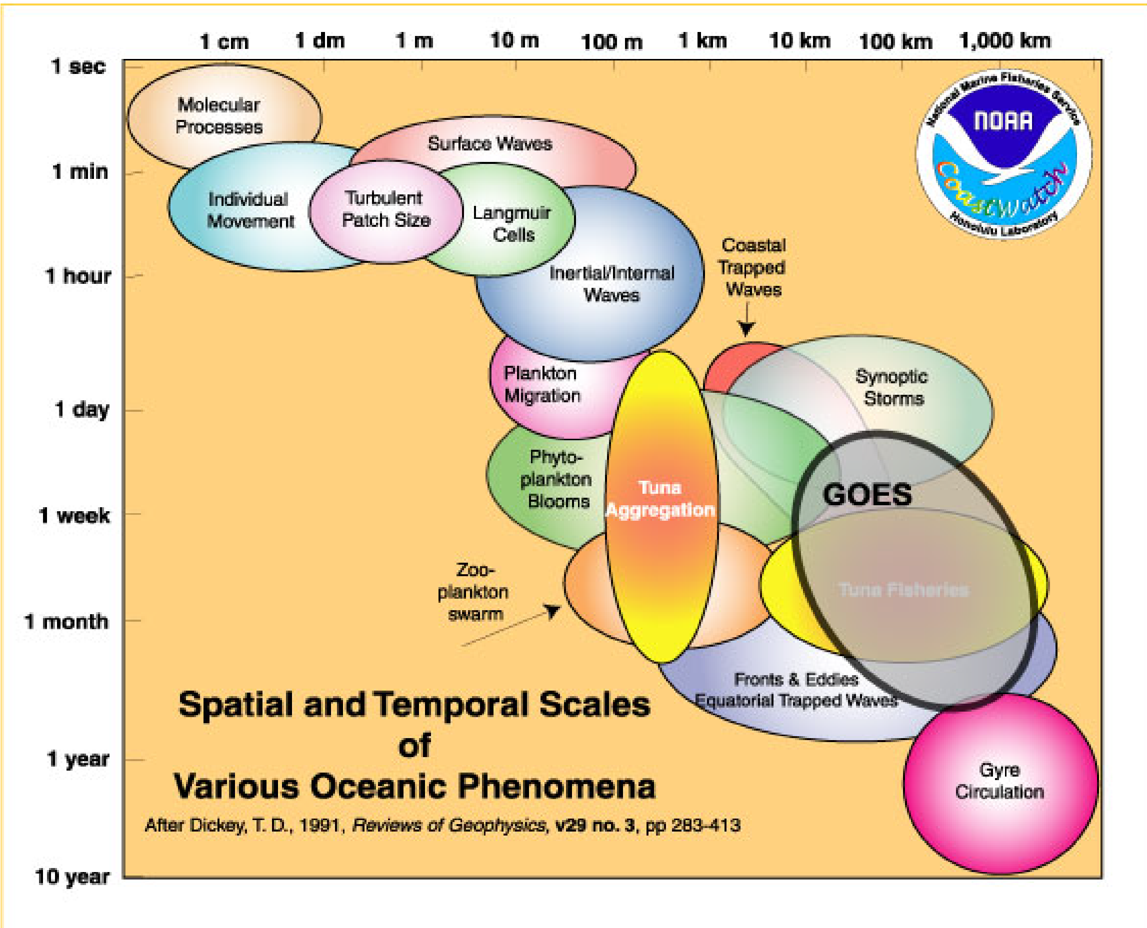


Figure 1: Oceanic phenomena observable from GOES[2]

Examples included the use of geostationary data to provide part of the information needed to mitigate the interaction between marine turtles and long line fisheries. Mr. Foley cited the case of the March 30, 2001, 9th Federal District Court order to close Hawaii-based long line fishing for swordfish in a broad area of the North Pacific Ocean. It is estimated that this has resulted in a loss of up to $100 million per year for Hawaii's swordfish long-line fishery, and has impacted associated infrastructure within the state of Hawaii.

Panel member Dr. Peter Hildebrand, Chief of Hydrospheric Processes at NASA Goddard Space Flight Center, presented a view into the future of geostationary satellite data applications to 2025. His topics included user specific and tailored data delivery, highly facilitated data access and an

[2] Provided by David G. Foley and R. Michael Laurs at the 2nd GOES Users' Conference.

increase in a commercial role and partnering with government agencies both foreign and domestic.

The panel presentation delivered by Director of NOAA's Atlantic Atmospheric and Oceanography Laboratory, Kristina Katsaros noted the importance of sea surface temperature, wind, and wave observations measurements. Satellite measurements should be integrated with an *in situ* observing system for calibration of derived meteorological and oceanographic quantities while the satellite is in orbit. Ms. Katsaros mentioned air sea fluxes and the importance of the characteristics of the atmospheric boundary layer for evaluating turbulent fluxes. Certain boundary layer variables are currently not obtainable remotely such as surface air temperature and the boundary layer height. These may ultimately have to be obtained from good models that assimilate the available direct measurements but which thereby constrain the models. The air sea fluxes themselves can be used for comparison to numerical model estimates and have application to ecosystems in coastal regions at small time and spatial scales and to climate and ocean gyre studies at longer time and space scales.

The panel presentations produced questions from the general audience that shaped in large part the discussions during the breakout session on the following day. For example, there was a discussion on adding radiometric instruments to standard oceanographic buoys. Suitable radiometric instruments for large buoys have been developed at the European Commission Joint Research Centre, Space Applications Institute. These instruments will provide radiometric measurements for validating satellite radiometric measurements of sea surface temperature (SST) with the potential to double the accuracy of GOES SST. The satellite SSTs are radiometric skin temperatures but algorithms are validated with bulk water temperatures. In addition, surface radiometric SST adds a crucial piece of information to air sea flux calculations. The temperature difference of bulk and skin correlates closely with total heat flux. Comparing flux values from this approach with those from bulk formulas refines both methods, a fertile field for research. This flux measurement is also helpful to models, since fluxes measured without bulk formulas are difficult.

To achieve enhancement of present and GOES-R benefits, the measurements of the sea surface were considered to be of fundamental importance. However, for ocean observations to be useful for scientific studies and produce credible information for transportation, fisheries, and policy decision makers the GOES measurements must be consistent and with appropriate spatial resolution. For these reasons the following new ocean related recommendations are to require:

- Validated pre- and post-launch radiometric calibration on all bands
- For coastal zones, spatial resolution on the order of 100 meters is needed for measurements to be useful.[3]

The following needs for spectral bands to observe the coastal zone by remote sensing were submitted by Oscar Huh and Nan Walker from Earth Science Laboratory, Louisiana State University. They are for:

- Suspended sediments (0.64 μm)
- Chlorophyll a, harmful algal blooms (0.49 μm, 0.55μm)
- Land/water boundary, flooding (0.86μm)

[3] The Oceanography breakout group suggested the following definition of "Coastal Zone" to be "Extends from top of watershed to the 'Exclusive Economic Zone' and is dependent on geophysical boundaries."

- Sea surface temperature (3.9, 11, 12 µm).

Coastal zone spatial resolution needs are: < 0.5km visible, 1 km thermal and temporal resolution of 15-30 minutes.

A complete report of the presentations and recommendations of the Oceanography, Marine Transportation, and Fisheries Observations Panel is attached as Appendix 5.

3.4 Value of Geostationary Observations for Climate[4]

The value of geostationary observations is the system's unique capability to observe sub-synoptic atmospheric and surface events, particularly precipitating cloud systems and to characterize the diurnal cycles of the surface and atmospheric boundary layer.

Characterization of the annual cycle and diurnal cycles is crucial to an understanding of climate and a better knowledge of the diurnal cycle improves the characterization of the annual cycle. This can be understood by imagining a situation where observations are taken at nearly the same time each day of the year, such as the case with a sun-synchronous polar orbiter. If the diurnal variation changes throughout the year, the annual cycle derived from the fixed-time observations would be fallacious. Averaging measurements from a number of polar orbiters could reduce the error, but not eliminate it.

3.4.1 The Importance of Calibration for Climate Observations

Radiometric calibration of GOES sensors must have an accuracy and precision that are comparable to equivalent radiometers on other operational and research satellites (geostationary or low-earth orbit). Pre-launch and post-launch calibration procedures must include cross-calibration with these other radiometers. Calibration must include all spectral bands. The solar reflected spectral observations are expected to reveal valuable information about trends in cloud and surface properties.

The accuracy and precision of observations from the GOES radiometers should be sufficient to quantify the variations in the Earth's radiation and physical properties needed to understand climate change. Information on the calibration, including the accuracy, precision, and the procedures used to obtain the calibration must be archived along with the data. This is essential when reprocessing is performed.

A formal, active GOES calibration Working Group was recommended to guide the requirements process and the system planning and development as well as to document the characteristics of the radiometric calibration.

3.4.2 Long-Term Data Consistency for Climate Observations

It is essential that NESDIS ensure the long-term consistency of the GOES environmental data for climate monitoring. This includes formally identifying sensor characteristics and data formats and establishing requirements that ensure their long-term consistency across multiple platforms over many decades. Sensor evolution must take into account these characteristics and formats.

[4] See Appendix 4 for the paper, Value of Geostationary Satellite Observations for Climate Studies, William B. Rossow, NASA Goddard Institute for Space Studies, September 2002.

Cross-calibration across platforms (GOES, NPOESS, other platforms) is a must. Finally, requirements for long-term archiving of algorithms, metadata, and reprocessing history must be established.

3.4.3 Specific Recommendations

GOES-R calibration is REQUIRED for climate use. Calibration is required to make reliable measurements of climate parameters from GOES-R. The GOES observing location is well suited to determine the diurnal component of chaotic processes like clouds and precipitation, which play a large part in the Earth's energy and water budget. Long-term trends and changes in the diurnal cycle can be measured reliably only by a consistently calibrated time-series of daily processes over decades.

GOES-R calibration must be correlated with other satellite radiometers. For climate use, GOES-R instruments require radiometric calibration accuracy and precision that are comparable to the other satellite radiometers on operational and research satellites. The pre-launch and post-launch calibration procedures should facilitate cross-calibration among all the other satellites.

GOES-R calibration must include all spectral bands. Both the thermal emission and solar reflected spectral data must be calibrated. In particular, the solar reflected channels contain important information about cloud and surface properties whose variations and trends must be reliable.

GOES-R calibration must be accurate (±1 K and ±3%) and precise (±0.1 K and ±1%). The calibration accuracy and precision from the GOES-R radiometers should be sufficient to measure variations and change in the Earth's radiation and physical properties with an acuity that is sufficient to answer the important questions about climate change.

GOES-R calibration must be controlled and determined across the spectrum and over the field-of-regard, before and after launch. Instrumental effects that affect calibration as a function of wavelength and viewing angle should be minimized. For example, the sensitivity to polarized light from the Earth should be minimized among the solar reflective bands. Pre-launch calibration should be traceable to standards. Post-launch calibrations should be validated periodically.

There should be a formal GOES calibration working group. An active calibration group is required to guide the requirements process, the system planning and development, and to monitor and document the calibration characteristics of the radiometers. Group expertise is required to estimate the quality of the long-term accuracy of GOES observations. The working group must include users, especially members from the climate-observing programs.

Calibration information must be included in the data archive process. Climate determinations are achieved by reprocessing archived radiometry. Therefore, calibration data and metadata must be part of the archive.

4 Summary of Recommendations

4.1 Technical Recommendations

User recommendations were developed that identified the kinds of improvements and capabilities that are expected over the current system. User recommendations dealt primarily with refinement of current sensing and the introduction of new instrument capabilities. The following are specific recommended requirements:

- Need for 4 km footprint on sounder
  - Allows for partial view through thin cirrus
  - Provides information in some hurricane eyes
  - Provides more information between clouds in convective situations
  - Identify clear air turbulence signature
- Strong recommendations to explore feasibility of passive microwave instrument in Geostationary orbit were made
  - Precipitation estimation (real time and climate applications)
  - All weather temperature and moisture profiles
  - Need a six month program to define pathway to deployment of a Geostationary microwave instrument
    - Identify voids in current and planned Global Observing System (GOS) to be met by Geostationary microwave instrument
    - Determine incremental benefits
    - Define detailed development plan with implementation options
- Strong recommendation for operational lightning mapper
  - With flexible scanning for near full disk coverage
  - Provide locations of convective storms
  - Provide indication of storm intensity
  - Optically more efficient than radio frequency detection
- Data from experimental satellites should be used operationally to prepare for GOES-R
  - Develop ways to deal with the "fire hose of data"
  - GIFTS is critical for HES preparation
    - Will be over CONUS initially, then over the Indian Ocean after 1 year
  - Visible channels must be calibrated
    - Need rigorous on-ground and adequate on-board calibration
    - Need cross calibration with other instruments

- Hyperspectral visible and Infrared (IR) observations preferred over discrete broad channels
  - Benefits include:
    - Algorithm transferability
    - Channel adaptability
    - Application growth
    - Inter satellite calibration
    - Provides stable climate record
  - Ultimate strength of hyperspectral:
    - Simultaneous and adaptive retrievals of atmospheric and surface features

Why GOES is important for climate research:

- Must understand diurnal and annual cycle
- Recent atmospheric warming is associated with change in the diurnal amplitude of near surface temperatures
- GOES-R will provide better understanding of surface/atmospheric processes leading to better climate parameterization
- Geostationary satellites are the only tools capable of resolving the precipitation process at proper space-time scales
- Better climate assessments and forecasts result in large economic benefits
- Additional topics were concerned with the added value from hyperspectral instruments. This would provide the capability of matching channels from instruments decades apart for studying long-term climate records. It was emphasized that it would provide an improved measurement of the radiation budget. The value of microwave in a geostationary orbit was discussed, since it allows one to observe surface effects and precipitation through 2/3 of the earth covered by clouds.
- A series of low-volume products was suggested be made available, such as what currently exists for the International Satellite Cloud Climatology Project (ISCCP).

It was also suggested that the GOES Instrument of Opportunity (IOO) innovation be retained, but in a somewhat different structure. Instrument costs should be borne by the sponsor, but NOAA's NESDIS should provide funds for platform integration and the whole process should be more flexible.

4.2 Communication Between NOAA's NESDIS and the GOES User Community

It was expressed that communication between NOAA's NESDIS and the user community has been improved and that continuing outreach will continue to be valuable. One proposed method was to continue the GOES users' conferences. Some other methods suggested are to expand the use of advisory groups such as the Council for Long-term Climate Monitoring at the National Climatic Data Center (NCDC) and the recommended GOES Calibration Working Group. User community training would also enhance communication. Fellowships and post doc opportunities to study the impact that geostationary platforms have on monitoring and understanding weather, oceans and climate was recommended. Also, there should be the development of a web page with links to weather and climate measurements from geostationary satellites. The NASA GOES web page (rsd.gsfc.nasa.gov/goes) was considered an excellent example for the development of such a web page.

GOES Users' Conference II
Oct. 1 - 3, 2002
at the
NIST Auditorium and the Millennium Hotel
Boulder, Colorado

Goals for Conference:

1) Inform users of future capabilities and potential applications of the GOES-R Series
2) Determine user needs for:
   - new products
   - distribution of GOES data and products
   - instruments of opportunity
   - access to sample data prior to launch of next series
   - education, training and outreach
3) Assess user and societal benefits of future systems
4) Develop methods to improve communication between NOAA's NESDIS and the GOES user community
   - develop, present, and refine a process for determining and updating requirements

Day 1 (Tuesday): NIST Auditorium

8:00 am	Registration
9:00 am	Introduction (logistics, conference format etc) (Jim Gurka/ NESDIS)
9:05 pm	Welcome/ Opening Remarks (Greg Withee/ NESDIS)
9:30 am	Conference goals (Gary Davis/ NESDIS)
9:40 am	The GOES Program (overview) (Steve Kirkner/ NESDIS)
10:00 am	BREAK
10:30 am	Keynote Address (Vice Adm. Conrad C. Lautenbacher, Jr./ NOAA)

Session 1A: User Requirements, Applications and Potential Benefits from GOES-R Series
Chairperson: Gary Davis

11:00 am	Recommendations from GOES Users' Conference I (Jim Gurka/ NESDIS)
11:20 am	Requirements gathering, validation, and concept studies (Michael Crison/ NESDIS)
11:40 am	Transferring Science Requirements to System Implementation (Marie Colton/ NESDIS)
12:00 pm	LUNCH (on your own)
1:30 pm	The role of OFCM in interagency coordination (Sam Williamson/ OFCM)

Session 1B: User Requirements, Applications and Potential Benefits from GOES-R Series
Chairperson: Tim Schmit

1:50 pm	A Visionary Look at Using Weather Satellites in 2020 (Rick Anthes/ UCAR)
2:10 pm	Imager (Timothy Schmit/ NESDIS)
2:30 pm	IR Sounder (Paul Menzel/ NESDIS)
2:50 pm	Infusion of Satellite Data: Today and Tomorrow (John (Jack) J. Kelly, Jr./ NWS)
3:15 pm	Future Role of Satellite Data in Numerical Models (Louis Uccellini/ NWS)
3:35 pm	BREAK
3:55 pm	Microwave Sensing from Geo Orbit (Al Gasiewski/ OAR)
4:15 pm	Future Aviation Applications from GOES (Fred Mosher/ NWS)
4:35 pm	Space Environment Monitor and Solar Imaging (Howard Singer/SEC)
4:55 pm	Ionospheric Imaging from Geosynchronous Orbit (Robert McCoy/ONR)
5:10 pm	Questions/ Issues for further discussion
5:30 pm	End of day 1 sessions
6:00 pm	ICEBREAKER (Millennium Harvest House)

Day 2 (Wednesday): NIST Auditorium

Session 1C: User Requirements, Applications and Potential Benefits from GOES-R Series
Chairperson: Jim Purdom

8:15 am Satellite data sets that will lead to user readiness for GOES-R (Jim Purdom/ CIRA)
8:40 am GIFTS update (Bill Smith/ NASA)
9:00 am AIRS update (Mitch Goldberg/NESDIS)
9:15 am Hyperspectral Applications (Hsiao-hua Burke/ MIT/LL)
9:35 am Observations needed for natural hazards monitoring in 2010-2020 (Overview - fires, floods, volcanoes,etc.) (Levin Lauritsen/ NESDIS)
9:50 am Update on Instruments of Opportunity (IOO) (Dennis Chesters/ NASA)
10:00 am BREAK
10:20 am NASA Vision 2020 (Peter Hildebrand/ NASA)
10:35 am Commercial Applications of GOES (Jim Block/ Commercial Weather Services Association (CWSA))
10:50 am 5-min Poster introductions:
The future of rainfall estimates from GOES (Bob Kuligowski/ NESDIS)
Training, Education and Outreach (Tony Mostek/ NWS)
Data Compression (Allen Huang/ CIMSS)
Direct User Services (Marlin Perkins/ NESDIS)
Use of GOES to Force Land Surface Models (Andy Heidinger/ NESDIS)
Tropical Cyclone Application of GOES-R (Mark DeMaria, et al / NESDIS)
Coastal Zone (Oscar Huh, Louisiana State Univ.)
Solar Imaging (Dan Wilkinson/NESDIS/NGDC)
11:30 am LUNCH (posters will be displayed)

Session 2 International Update on Future Geostationary Satellite Systems
Moderator: Paul Menzel

1:10 pm Value of International Cooperation in the GOS and the Geo Contributions (Michel Jarraud/ WMO)
1:25 pm Geo Microwave Consideration in Europe (Bizzarro Bizzarri/ CNR Istituto Scienze dell'Atmosfera e del Clima (ISAC))
1:45 pm Panel Discussion (Zhang, Stuhlmann, Miyamoto)
2:35 pm BREAK plus review posters (with presenters)

Session 3 Oceanography, Marine Transportation, and Fisheries..
Moderator: Paul Twitchell

3:00 pm Panel Discussion (Kristina Katsaros, Walter McKeown, David Foley, and Peter Hildebrand)
4:00 pm BREAK

Session 4 Climate Monitoring
Moderator: Paul Try

4:15 pm Panel Discussion (Tom Karl; Bill Rossow; Stan Kidder)
5:15 pm End of day 2 Sessions
6:15 pm DINNER (Speaker: Bryan Norcross, CBS)

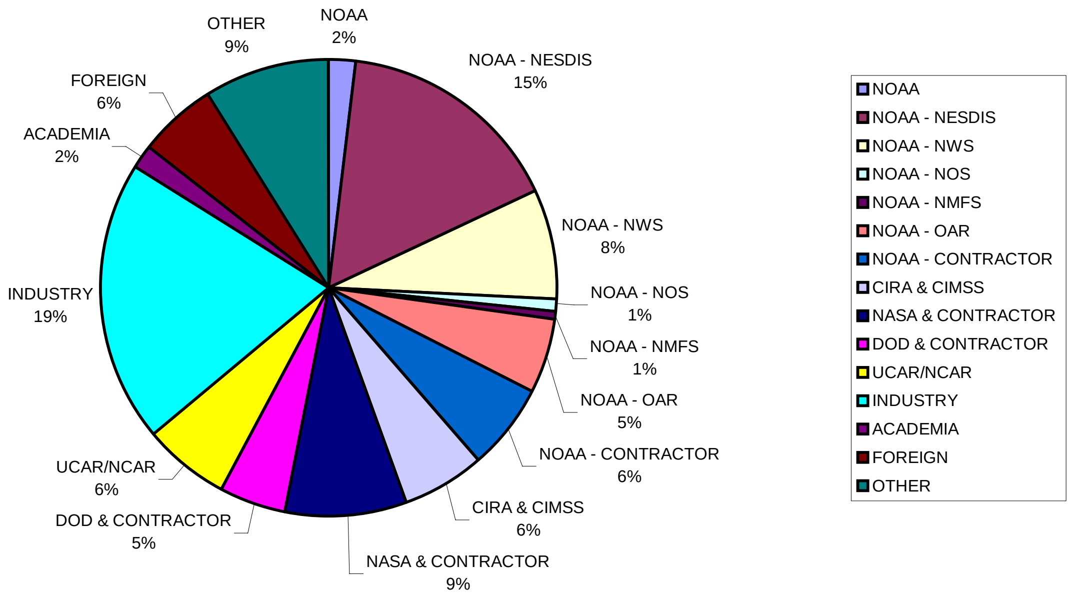
Day 3 (Thursday): Millennium Hotel

Breakout Sessions
Facilitator: Jessica Hartung

8:00 am Continental Breakfast
8:45 am Introduction to feedback process (Jessica Hartung)
9:00 am Breakout sessions begin (Facilitators and Technical Leads)

	Weather Forecasting (Tim Schmit and Gary Hufford)
	Climate Monitoring (Paul Try and Tom Karl)
	Oceanography (Kristina Katsoras, Chris Kent and Paul Twitchell)
	Natural Hazards (Gary Ellrod and Levin Lauritsen)
	Numerical Modeling (Steve Koch and Mark DeMaria)
	Hydrology and Land Surface (Andy Heidinger and Daniel Barrera)
10:00 am	BREAK
10:30 am	Breakout sessions resume
11:45 am	LUNCH (Provided)
1:00 pm	Breakout sessions resume
2:30 pm	BREAK
3:00 pm	Highlights from each breakout group Group representatives
5:00 pm	Closing remarks (Gary Davis)

Attendee representation spanned various fields across several different user groups. The chart below illustrates the attendee distribution.



After the conference, attendees were asked to provide their opinions on general features of the conferences. These are the results of that survey, along with specific comments.

2002 Goes Users' Conference II
October 1 - 3, 2002

With your cooperation we can continue to improve Conferences sponsored by NIST. Please take a few minutes to answer these questions, adding comments wherever appropriate. We are especially interested in getting comments about any items that you gave a "Poor" or "Fair" rating to.

How would you rate the Conference on average in the following areas:

a. Technical content (breadth, depth, relevance, practical utility, state-of-the-art and recent developments).

Excellent	Very Good	Good	Fair	Poor
11	***15***	***4***	***3***	-

b. Quality of presentations (expertise of presenters, quality of slides, manner of delivery, interaction with audience).

Excellent	Very Good	Good	Fair	Poor
8	***21***	***4***	-	-

- *Need more audience participation…presenters did NOT allow enough time for questions.*

c. Conference (location, facilities, food).

Excellent	Very Good	Good	Fair	Poor
18	***12***	***3***	-	-

- ***Better coffee would help.***
- ***Prefer single conf. Location @ hotel.***
- ***Need better onsite cafeteria.***

d. Overall management of Conference (assistance before Conference, staff assistance on-site, organization, hand-out materials).

Excellent	Very Good	Good	Fair	Poor
20	***12***	***1***	-	-

e. Conference registration process (preliminary and on-site).

Excellent	Very Good	Good	Fair	Poor
17	***12***	***3***	***1***	-

- ***Deadline too early…on-line form confusing.***
- ***Couldn't register via fax; fax wouldn't respond. Therefore, I registered via hard copy – info didn't make it to Boulder. I was called one week prior requesting my data again. Web registration would only accept full payment registration.***

f. How would you rate the preliminary Conference brochure (style, information, usability)?

Excellent	Very Good	Good	Fair	Poor
3	***19***	***5***	***1***	-

- ***5 Individuals did not respond.***
- ***Didn't see.***

g. How would you rate the final Conference brochure (style, information, usability)?

Excellent	Very Good	Good	Fair	Poor
3	***19***	***3***	***1***	***-***

- ***7 Individuals did not respond.***
- ***Didn't see.***

h. How would you rate the bus transportation service?

Excellent	Very Good	Good	Fair	Poor
1	***-***	***1***	***4***	***2***

- ***25 Individuals did not respond.***
- ***Didn't use.***

Comments:

- ***Would have liked to see a larger percentage of actual users.***
- ***Water good to have available – thanks, esp. when drinks not allowed in auditorium.***
- ***Our group would have preferred to have secretary register us all on single credit card. So maybe two forms – one with security info and one with payment info.***
- ***Need second projector on side with title and name of presenter.***
- ***Need a large Welcome to GOES Users Conference sign at entrance (besides a sign warning you to stay away from doors).***
- ***Learned a lot – good for experts & folks new to GOES OBS.***
- ***Need better shuttle service from hotel to NIST – or set up at hotel closer to NIST (or at least more frequent – more than once!)***
- ***There needs to be more time in the first 2 days, for questions and discussion. Also, in the facilitation section that I attended, the facilitator needs to get users to talk, not just the NOAA people, who dominated.***

The most beneficial aspect of this Conference was:

- ***Exposure to US community.***
- ***Cross fertilization of disciplines.***
- ***Knowing more people/contacts.***
- ***Varied views of future system intentions.***
- ***People to people interaction.***
- ***Update on status & progress of GOES program***
- ***Users input to NOAA's NESDIS & Users to supplier, contractor etc… interaction.***
- ***All of the great presentations.***
- ***Diverse Group, Broad exposure to diverse perspectives***
- ***Interactions with the users.***
- ***Become acquainted with the process followed for establishment of requirements for establishment of the program.***
- ***Learning of diversified use of GOES and input on the GOES R.***
- ***Having others in similar field (oceanography/coastal mgt) in discussion group with targeted questions to answer.***
- ***The breakout sessions where I could hear opinions on what is needed and possible by experts.***
- ***User interaction and breakout sessions.***
- ***Learning the capabilities/uses of sensors/instruments.***
- ***Communication between diverse groups of users.***
- ***Presentations that showed how raw data are converted to user products.***

- ***To meet people involved in the process.***
- ***Getting NOAA's solicitations of inputs from users.***
- ***Good to hear from <u>some</u> users: NWS, Space Env. Center, DOD/ONR, CWSA.***
- ***Data dissemination.***
- ***International inputs on needs and potential restrictions (i.e. band width limitations).***
- ***Feedback to NOAA/education for User.***
- ***Emphasis on calibration.***
- ***Presentations.***
- ***The first morning: I had a good opportunity to hear what all the decision-makers were thinking.***
- ***Briefings on status from various pgms & needs.***
- ***Learning about future plans for GOES-R; ability to add input into planning stages; meeting people from across wide spectrum of GOES Users.***
- ***Status of GOES-R & fit w/ other systems.***
- ***Update on GOES status & research satellites.***
- ***Breadth & depth of presentations, both GOES program and users.***

Appendix 4 Geostationary Satellite Observations for Climate Studies

Value of Geostationary Satellite Observations for Climate Studies

William B. Rossow, NASA Goddard Institute for Space Studies

September 2002

1. Background Perspectives

The unique characteristic of measurements from a satellite in geostationary orbit is the capability to sample the same location at time intervals much smaller than the 12 hour sampling interval of satellites in (most) other orbits. Satellites in other highly-inclined orbits provide more geographic coverage but at the expense of significantly reduced time resolution. Hence the main purpose of geostationary satellites should be to observe key sub-synoptic atmospheric and surface events, particularly precipitating cloud systems (both convective and non-convective) and diurnal variations of the surface and atmospheric boundary layer. The climate is forced by absorption of solar radiation, mostly at the surface, with a strong diurnal and seasonal cycle. Hence the main source of energy for the atmosphere is transfer of the solar heating from the surface through the atmospheric boundary layer by various rapid processes, all of which are strongly modulated at diurnal and annual frequencies. These processes include convective heat and moisture transports, radiative fluxes modulated by clouds and latent heat exchanges (surface evaporation and precipitation). Since atmospheric processes rapidly integrate local forcing differences and couple local responses into a global response, it is essential to diagnose climate variations globally but at space-time-scales characteristic of the weather and the forcing variations. Note that the same argument leads to a requirement for global information for long-range weather forecasting. Moreover, since a climate change may appear as a change in the distribution of cloud-radiation precipitation magnitudes, rather than a change in their mean, time-resolved observations are needed to diagnose climate changes. Geostationary satellite observations are the only ones that can resolve the diurnal and other cloud-scale variations of the radiative fluxes, atmospheric boundary layer and precipitation. Routine observations of these phenomena would be a key contribution to weather forecasting, particularly for precipitation and severe weather, to research into these atmospheric processes, and to monitoring the climate variations associated with these processes.

To contribute to climate, however, the geostationary satellites must be part of and operated as a "globally complete" constellation that provides complete **and uniform** coverage (except for the polar regions, latitudes > 60°). For the constellation to be of use, the instruments on the geostationary satellites have to have a core of standard spectral characteristics that are similar enough that the measured radiances can be cross-calibrated. Note that in the first 20 years of operation, the geostationary satellite constellation has added exactly one new common wavelength to the two that it started with! With relatively little effort (cooperation), the number of common wavelengths could have been expanded to five. **To integrate the constellation's measurements, the radiances must be calibrated and cross-calibrated both between satellites in a particular series and among all geostationary satellites in operation.** The radiance data must be archived in similar formats and analyzed as a single dataset: production of geophysical products from all of the geostationary observations so be merged into “global” products. **Achieving these objectives would make a significant contribution even if no further instrument improvements were made.**

There is a strong urge to reduce the pixel (field-of-view) size for operational satellite imagery below 1 km, based on claims of improved results, even though this design puts a huge strain on data handling resources and generally precludes **any research** use of the data. The large data volumes also encourage/require development of analysis procedures that take empirical short cuts that usually degrade data quality much more than supposedly gained from the pixel size reduction. These claims are, in fact, physically inconsistent or incorrect. At solar wavelengths, pixels smaller than about a few hundred meters are not radiatively independent (this problem is worse at thermal infrared wavelengths), so that observed radiance variations cannot be assigned uniquely (linearly) on a one-to-one basis to location. Current analyses of such high resolution data **never** take proper account of this characteristic. Accurate retrievals of physical quantities from radiance measurements require 3-D radiative transfer codes at spatial scales less than about 3 km, so unless such codes are to be used, retrieval accuracy is degraded, not improved, by reducing pixel sizes below about 3 km. Finally, although the instrument angular response may be well characterized, over-sampling pixels is usually a waste of resources because the necessary de-convolution of the radiance measurements is never performed. The argument for such measurements from a weather forecasting perspective is flawed since the forecast value of atmospheric measurements at scales at or smaller than a few kilometers is nil because the motions at these scales are not predictable (put another way, since this is the scale of convective instability, the memory of the system is rapidly lost). So, while high spatial resolution measurements may be needed to integrate properly over non-linear relationships, which can usually be achieved by sub-sampling high-resolution measurements, the information cannot be used directly (linearly) in atmospheric models at such small scales.

2. Current Uses of Geostationary Satellite Observations from the Whole Constellation

Currently, only four data products are systematically produced and merged from the observations of the **whole** constellation of geostationary weather satellites.

Cloud-tracked and Vapor-tracked winds. The first product is the operational cloud-tracked and vapor-tracked winds that are combined by assimilation into a global analysis of the atmospheric circulation; this product is used to initialize global weather forecasts made by a number of NWP centers and for research about atmospheric processes. If these products are occasionally reanalyzed with a consistent procedure to produce a homogeneous record, they can also be used for climate research.

Clouds. The second product is the International Satellite Cloud Climatology Project (ISCCP) cloud products that are used for climate research. **ISCCP currently provides the only systematic calibration and cross-calibration of radiances from the geostationary weather satellite constellation.** After 20 years, this has not become an operational data product.

Precipitation. The Global Precipitation Climatology Project (GPCP) also uses the geostationary observations to remove diurnal aliasing in its analysis of global precipitation. After more than a decade, this use of the geostationary data to augment precipitation measurements has not become operational.

Surface Radiative Fluxes. The Surface Radiation Budget (SRB) project calculates surface radiative flux products (also top-of-atmosphere radiative fluxes) using the ISCCP cloud products;

atmospheric properties (temperature, humidity) are obtained from a meteorological analysis (or re-analysis). A research version of this activity uses the operational temperature-humidity soundings to describe the atmosphere instead. This data product has now reached a maturity where it could be made operational.

3. Possible Additional Uses of the Current Constellation of Geostationary Satellites

Since the solar heating of the surface has a strong diurnal cycle, the forcing for the atmosphere also varies diurnally. Only observations from geostationary satellites resolve these diurnal variations. Although severe weather events (including convective systems) are considered local as far as the weather bureaus' use of geostationary imagery data, their diurnal variation has systematic climate implications. Note, for example, that the recent warming of the atmosphere has appeared, in part, as a change of the diurnal amplitude of near-surface temperatures. Hence monitoring the variations of the surface, atmospheric boundary layer, clouds and precipitation at diurnal resolution is a key (and unique) contribution to climate change monitoring that can only be made by geostationary satellites.

Surface skin temperature. In addition to the current products produced from the whole geostationary weather satellite constellation, it would be straightforward to add surface (skin) temperatures (clear-sky) from infrared radiance measurements; such a product is already produced by ISCCP and could have become operational long ago. This product should be analyzed in conjunction with microwave measurements to provide all-weather results (the diurnal sampling from microwave instruments will be much better in the future than it has been to date). Development of this measurement capability would also improve microwave sounder analyses by providing better characterization of the land surface in the microwave. When the skin temperature data are combined with surface air temperature measurements from surface weather stations and surface radiative fluxes, their diurnal variations can provide an estimate of surface latent plus sensible heat fluxes that are indicative of surface moisture over land areas. These results would also provide indirect indications of atmospheric boundary layer changes that relate to the transfer of energy and water from the surface to the troposphere.

Upper-tropospheric humidity. Since 1996, all of the geostationary satellites make measurements sensitive to upper tropospheric water vapor, so it would also be straightforward to add an uppertropospheric humidity (and cirrus) product. No such comprehensive global product has yet been produced. The upper tropospheric humidity may well exhibit a diurnal variation associated with deep convection. This product should combine the geostationary infrared measurements with polar orbiter infrared sounder measurements and incorporate the microwave humidity results into a single upper tropospheric water vapor (cirrus) product. Since cloud detection governs the accuracy of any infrared measurement, the analysis of these data should be consistent with the cloud products.

4. Proposed Enhanced Observations from Geostationary Orbit (decreasing priority order but increasing feasibility): Precipitation, ABL T-Q, Better Clouds

The variations of the free troposphere are predominately synoptic scale and are more than adequately sampled in all-weather conditions by combined infrared-microwave T-Q sounders on 2-3 polar orbiters as planned for the NPOESS era. Adding “standard” infrared-only T-Q sounder systems to geostationary satellites will contribute very little to increasing the sampling of the free troposphere because of clouds. If finer scale temperature-humidity information is needed (see

ABL instrument suggestion below), it should be achieved by adding selected wavelength channels to an imager to be analyzed using the polar-orbiter-based temperature-humidity profiles.

Precipitation. Satellites in geostationary orbit are the only observing systems that are capable, in principle, of resolving the precipitation process at the space-time scales at which it occurs and of also covering the range of space-time scales needed to observe the interaction of the convective and synoptic scale atmospheric motions. Therefore, the highest priority contribution to both weather forecasting and climate monitoring would be made by placing a "precipitation" sensor on the geostationary weather satellites. This sensor does not even need to provide a quantitatively accurate measure of precipitation. intensity; it would be a significant contribution even if the sensor could only detect the presence of precipitation and provide some qualitative indication of intensity. This might be done with only two channels (dual polarization) at 37 and 85 GHz. In this idea, the sensor would have to operate in the microwave and have a spatial resolution better than 10 km; however such a sensor, while literally possible, may be too costly. However, even a microwave capability at lower resolution (100 km, say) for detection of the presence of liquid water and precipitation-sized ice could provide a crucial augmentation of cloud observations from geostationary orbit that would provide a value, though indirect indication of the presence of precipitation. The key objective is to provide information about precipitation occurrence at much higher time resolution (if the GPM mission provides the correct estimate of precipitation totals over longer time periods (4 hours), then these observations could be used to dis-aggregate the GPM results.

ABL T-Q. The main source of energy for the atmosphere comes from the transfer of the solar heating of the surface into the "free" atmosphere through the atmospheric boundary layer in the form of both sensible and latent heat. This energy transfer is strongly modulated at diurnal time scales by radiation processes, on relatively small spatial scales by surface processes and is intermittent because of hydrodynamical instabilities. The free troposphere does not respond very rapidly to variations of this forcing, rather it integrates (non-linearly) over the energy transfers. Hence, the most rapid response of the atmosphere to changes in surface forcing appears in the atmospheric boundary layer; any ability to predict the onset of convective precipitation would come from monitoring the state of the boundary layer at high time resolution. Thus, instead of adding a standard infrared T-Q sounding system to geostationary satellites, it would be much more useful and a unique contribution to design an instrument specifically to measure the rapid variations of the boundary layer T-Q (single values in the first 1000 m above the surface), which are directly forced by solar heating of the surface and are directly related to deep (precipitating) convection onset. Although very difficult to measure -requiring an infrared-microwave combination for all-weather capability, an instrument tailored to provide an estimate of the boundary layer temperature and humidity would be much more useful as a complement to the normal T-Q sounder suites that will be flown on three polar orbiters in the NPOESS era (providing 4 hr sampling).

Better Clouds. Currently ISCCP only retrieves two cloud properties from geostationary satellites because there have been only two common wavelengths for the imaging radiometers until the past few years. If a split-window channel (12 μm wavelength in addition to the usual 11 μm channel) and a water vapor channel (6.7 μm wavelength) were common (they almost are), then these wavelengths would mainly be used to identify cirrus better. However, a few additional wavelengths, if available, would extend the description of clouds in ways that are related to the microphysical processes, particularly precipitation. The main additional quantity is cloud particle size, which can be determined most completely from measurements at four additional wavelengths (1.6 μm, 2.2 μm, 3.7 μm and 8.5 μm). These measurements would also be well supported by adding oxygen A-band channels to supplement the thermal infrared determination of cloud top location. **Note that accurate retrievals of these cloud properties are practical only at satellite pixel sizes of a few kilometers at smallest. If a passive microwave instrument is added to indicate the presence of precipitation, then its determination of cloud liquid water path as a complement to a determination of total column cloud water path from the solar wavelength channels would provide key information about cloud vertical structure that would help resolve the evolution of precipitating cloud systems.**

Appendix 5 Oceans Presentation and Recommendations

The presentations and recommendations of the Oceanography, Marine Transportation, and Fisheries Observations Panel follow. In her conference presentation and during the breakout, Kristina Katsaros discussed the application of multi/hyper spectral sensors such as described in the presentation of Hsaio-hua Burke, MIT Lincoln Laboratory. The multi/hyper spectral sensor capabilities were noted as having significant potential in achieving coastal, scientific, and societal observation needs.

Harmful algal blooms detected by a GOES instrument will provide necessary information to decision makers. Ms. Katsaros provided the example of toxic tides that kill birds, and can cause human death and paralytic conditions when people eat infected shellfish. Toxic red tide events can close down the local shellfish industry in very large regions, such as in the 1970s when coastal shellfisheries were closed down in Massachusetts, New Hampshire, Maine, and the Maritime Provinces of Canada. In this cold-water region, the toxic bloom is known to thrive when the ocean surface temperature and salinity are lower than normal, often due to heavy rains and ice flows discharging from rivers. Native Americans knew the danger from red tide and advised the Pilgrims in Plymouth not to eat shellfish if the bay was red. On the other hand, fishermen can benefit from satellite data in locating good phytoplankton blooms.

Communication between a provider of knowledge and the user of that knowledge is a traditional problem. Most provider-user communication is improved by personal interactions and not by additional bureaucratic rules. The Oceanography session participants' recommendations to enhance two-way communications between NESDIS and the GOES user community are:

- Facilitate personal interaction
- Encourage user registration
- Initiate a Help Desk
- Create or exploit existing interagency employee exchange programs
- Increase outreach to other agencies and users

User community training was discussed at length by the Oceanography Session participants and for the purpose of brevity is best summarized by the following:

- Who?
  - Decision-makers, technical specialists, and end-users
  - General Public
- When***?***
  - Can initiate process 5 years pre-launch
  - Educate advocates and policy-makers early
  - Train users close to launch
- Methods – education and training
  - Use Geosynchronous Imaging Fourier Transform Spectrometer as a testbed "GOES Preparatory Program" risk reduction
  - Expand upon existing models
  - Cooperative Program for Operational Meteorology, Education, and Training, Visual Institute for Satellite Integration Training, and Next Generation Radar

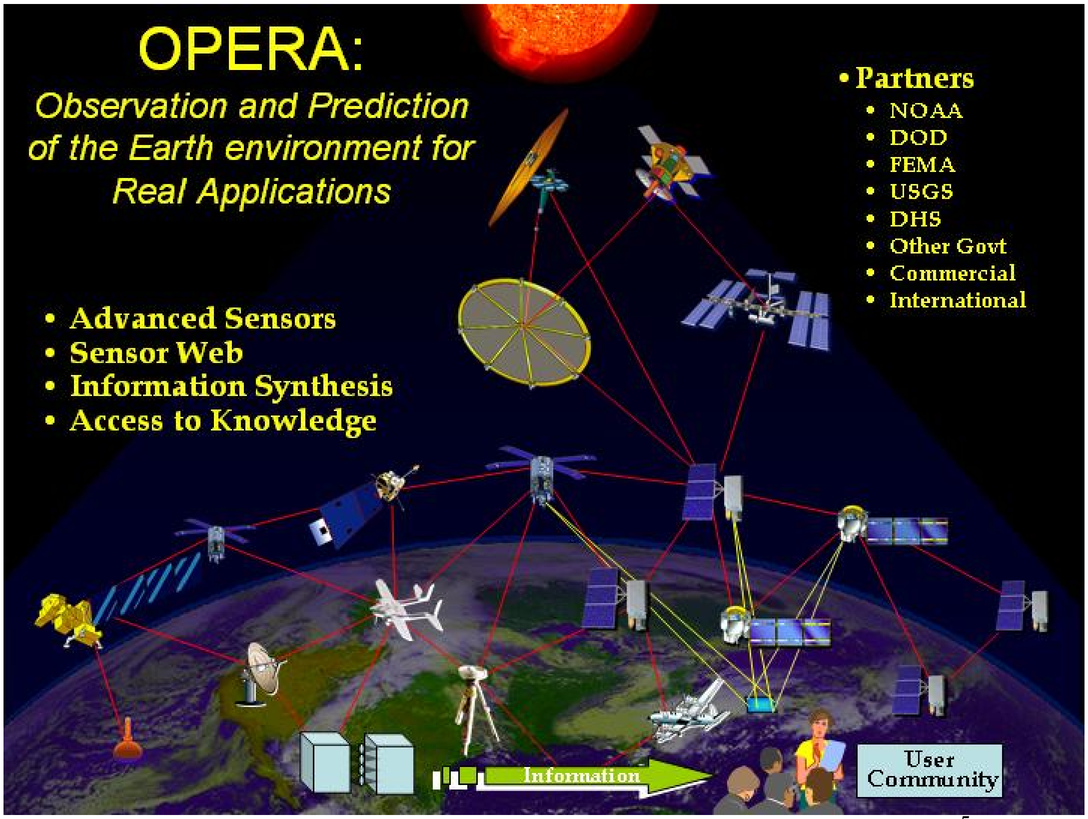
- NOS Coastal Services Center training
- Expand University role via curriculum and research
- Opportunity for synergy with National Polar-orbiting Operational Satellite System

The advent of the next geostationary imager schedule for GOES-R having at least 12 spectral bands and improved spatial and temporal sampling will usher in an observing period that will produce a high data volume. Very few in the oceanography user community will possess the capacity to handle the full data stream by direct broadcast. For the oceanography user, a flexible data/product solution to the high volume data stream is important. It is envisioned that production centers will receive full level 1b data. The user will obtain a desired subset of information from product centers and, when appropriate, value-added distributors will also meet the needs of the end user.

Benefits to the oceanography community from geostationary satellites envisioned beyond GOES-R include improved marine resource management through timely and frequent observation of ocean features even under cloudy conditions, including sea surface temperature, ocean current patterns (e.g., eddies, meanders) and low level atmospheric boundary conditions (water vapor and wind vectors). These improved data will contribute to better ocean and coupled ocean-atmospheric models. Effectively the improved ocean feature measurements and models will lead to marine transportation efficiencies and fisheries productivity.

For future geostationary operational satellites there is a need for ocean color systems to link the geophysical environment and the ecosystem. Also, ocean color system measurements will significantly contribute to resolving mesoscale features at frequent (hourly) intervals and high resolution (1 km).

With the increased data volume, there is a requirement to expand data collection and relay systems to accommodate anticipated increases in space, airborne, ships, buoys, and coastal platforms. It was the consensus of the oceanography breakout session participants that GOES programs consider their role in the Integrated Global Observing Strategy (IGOS), an international partnership for cooperation in Earth observations. IGOS partners include the Committee on Earth Observation Studies, the Global Ocean Observing System, Integrated Global Water Cycle Observations, and global water cycle projects such as the Coordinated Enhanced Observing Period (2002-2007) and NASA's Earth Observing System, as envisioned in the figure that follows.



GOES as part of a multifaceted global observing system to serve users[5]

The preparation of this summary was in large part based on the professional notes recorded by CDR Christopher Kent USN, Naval Meteorology and Oceanography Command and John Forsythe, Colorado State University. In addition CDR Kent provided information on the Navy's requirements for geostationary satellite data, and John Forsythe on the user needs in the development of global data sets for weather and climate prediction. The authors are particularly grateful to David Foley for presentations at the Oceanography Session Summary to the GOES II participants and compliment all the breakout group contributors.

[5] From Peter Hildebrand's presentation at the 2nd GOES II Users' Conference

ABI	Advanced Baseline Imager
ABS	Advanced Baseline Sounder
ADEOS	Advanced Earth Observing Satellite
AIRS	Atmospheric Infrared Sounder
Aqua	NASA Earth Science satellite mission named for the large amount of information that the mission will be collecting about the Earth's water cycle
AMS	American Meteorological Society
AO	Announcement of Opportunity
CIMSS	Cooperative Institute for Meteorological Satellite Studies
CONUS	CONtinental United States
CWSA	Commercial Weather Services Association
DoD	Department of Defense
ENVISAT	ENVIronmental SATellite
EOS	Earth Observing System
ESA	European Space Agency
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
GCOM	NASDA mission
GIFTS	Geostationary Imaging Fourier Transform Spectrometer
GIFTS-IOMI	Indian Ocean METOC Imager
GOES	Geostationary Operational Environmental Satellite
GOS	Global Observing System
GPS	Global Positioning System
HES	Hyperspectral Environmental Suite
IASI	Infrared Atmospheric Sounding Interferometer
IOO	Instrument of Opportunity
IR	InfraRed
ISCCP	International Satellite Cloud Climatology Project
METEOR	Russian meteorological satellite
MODIS	MODerate-resolution Imaging Spectroradiometer
MSG	Meteosat Second Generation
MTSAT	Multi-functional Transport Satellite
NASA	National Aeronautics and Space Administration
NASDA	Japanese Space Agency
NCDC	National Climatic Data Center
NESDIS	National Environmental Satellite, Data, and Information Service
NGDC	National Geophysical Data Center
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NPP	NPOESS Preparatory Project
NWA	National Weather Association
NWP	Numerical Weather Prediction
NWS	National Weather Service
OAR	Office of Oceanic and Atmospheric Research
OFCM	Office of the Federal Coordinator for Meteorological Services and Supporting Research
ONR	Office of Naval Research
SEC	Space Environment Center

SEVIRI	Spinning Environmental Visible and InfraRed Instrument
SST	sea surface temperature
Terra	the EOS flagship satellite (EOS AM)
UCAR	University Corporation for Atmospheric Research
WMO	World Meteorological Organization

Appendix 7 Conference Committee

Jim Gurka (Chair)	NOAA/NESDIS/OSD
Dennis Chesters	NASA/GSFC
Gerry Dittberner	NOAA/NESDIS/OSD
Gary Ellrod	NOAA/NESDIS/ORA
Donald Gray	NOAA/NESDIS/OSD
Michael Hales	NOAA/NESDIS/IA
Jeff Hawkins	USNavy/NRL
Colby Hostetler	NOAA/NESDIS/ITM
Robert Masters	NOAA/NESDIS/IA
Tony Mostek	NOAA/NWS/OS
Donald Nortrup	NOAA/NESDIS/OSD
John Pereira	NOAA/NESDIS/OSD
Thomas Renkevens	NOAA/NESDIS/OSDPD
Dick Reynolds	Short & Associates, Inc.
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