GOES Users' Conference

May 22-24, 2001
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 next generation NOAA Geostationary Environmental Operational Satellite (GOES) series is in the early stage of planning—with first launch now scheduled for the 2012 timeframe. To ensure the optimal capability is acquired, NOAA is conducting a number of outreach efforts to exchange information with the user community, seeking a wide range of inputs. These recommendations are essential to optimizing the future system capability.

The goals of the conference were to:

- Inform GOES users of plans for the next generation (GOES-R Series) capabilities
- Provide information on the potential applications
- 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 the National Environmental Satellite, Data, and Information Service (NESDIS) and the GOES user community

These goals were fully attained since many useful recommendations were made that NOAA will consider as we develop the future GOES series. These recommendations are documented in this report. 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 over the next few years. These requirements form the basis for various technical studies and cost/benefit analyses.

NOAA organized this conference with co-sponsorship from the National Aeronautics and Space Administration, the American Meteorological Society, the National Weather Association, and the World Meteorological Organization. The National Institute of Standards and Technology (NIST) assisted by providing their meeting facilities in Boulder. We would like to thank all conference participants especially the invited speakers, the program committee, NIST personnel for the logistic support, and all those who provided valuable suggestions for improving the future GOES program.

Gary K. Davis
Director
Office of Systems Development

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Introduction—GOES Users' Conference

A myriad of activities are involved in planning for a future Geostationary Operational Environmental Satellite (GOES) series. One of the most important of these is an extended and continuing 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 now in the early stages of planning for the GOES-R Series, now planned for the first launch in 2012. While that may seem to be far in the future, it is not that long in terms of acquisition planning. NOAA has started technical planning for key sensors and setting mission requirements. So establishing the two-way dialog now is not too early.

To further NOAA/User information exchange, a 3-day GOES Users' Conference was held in May 2001 in Boulder Colorado, with close to 200 participants from the private sector, academia, government, and the international community. The goals of the conference were to:

- Inform GOES users of plans for the next generation (GOES-R Series) capabilities
- Provide information on the potential applications
- 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 the National Environmental Satellite, Data, and Information Service (NESDIS) and the GOES user community.

The conference was organized into specific sessions on:

- Planned and Potential Sensors for U.S. Geostationary Satellites
- User Requirements, Applications, and Potential Benefits from Future GOES
- Future International Geostationary Satellites
- Communications, Ancillary Services and Training Issues

The last day of the conference consisted of breakout sessions in which attendees provided input to ten specific questions on their future needs for products, services, data distribution, archiving, training and potential benefits of the anticipated next generation GOES capabilities to their future operations and to society at large.

This report summarizes the conference recommendations with special emphasis on the Advanced Baseline Imager (ABI) and the Advanced Baseline Sounder (ABS). The report also provides a proposed approach for continuing communication between NOAA and GOES users to ensure that the needs of the entire user community are considered in the design of future systems, products, and services.

1. Future Benefits

A key issue dealt with was that of potential benefits to users and society as a whole. Specifically:

> *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 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. This together with subjective use of the improved satellite data and products by forecasters, should result in more timely and accurate weather forecasts, including:

- Improvements in tornado warnings
- Forecasts of hurricane landfall
- Forecasts of flooding
- Forecast detail.

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

- Improved quality of life due to better recreational planning
- Improved safety and economic benefits to commercial, military and general aviation
- Improved management of energy resources
- Improved planning and management of ground and marine based transportation
- Improved 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.

To ensure realization of these benefits, the conference participants provided numerous recommendations regarding the ABI and ABS, as documented below.

1.1 Advanced Baseline Imager

One of the strongest messages from the conference was that a minimum of twelve spectral channels on the imager will be required to meet the diverse needs of the user community. These channels should include:

- 0.64 µm for daytime detection of clouds
- 0.86 µm for daytime detection of clouds, aerosols, vegetation and ocean properties
- 1.375 µm for daytime detection of thin cirrus
- 1.6 µm for distinguishing clouds from snow and water cloud from ice cloud (daytime only)
- 3.9 µm for detection of fires, and nighttime detection of low clouds and fog
- 6.15 µm for detecting upper tropospheric moisture and determining upper level flow
- 7.0 µm for detecting mid tropospheric moisture and determining mid level flow
- 8.5 µm determining cloud phase, detecting sulfuric acid aerosols and determining surface properties
- 10.35 µm for determination of cloud particle size and surface properties
- 11.2 µm for detection of clouds, generating cloud drift winds, and determination of low level water vapor
- 12.3 µm for detection of volcanic ash, low level water vapor, and sea surface temperatures
- 13.3 µm for determining cloud-top parameters and determining cloud heights for improved quality cloud drift winds

In addition to these channels, which are considered essential, there was a strong recommendation for at least two additional channels: the 0.47 µm and the 9.6 µm. The 0.47 µm channel would be important for generating true color images, and for detecting aerosols and haze in determining slant range visibility for aircraft operations. The 9.6 µm channel would be important for detecting ozone and for the detection and forecasting of clear air turbulence.

Beyond these additional channels, providing they would not result in major sensor complexity or expense, a 4.57 µm channel would be useful for improved determination of precipitable water and a 14.2 µm channel would be useful for more accurate cloud top heights. However, these products could also be generated by the hyperspectral sounder on the GOES-R series.

The participants strongly endorsed plans for improved spatial and temporal resolution. Current plans call for 0.5 km spatial resolution (at satellite subpoint) for the 0.64 µm channel and 2 km resolution for all other channels. Since there will be more quantitative applications for both the visible and IR channels, there was a recommendation that the resolution of the .86 µm channel match the 0.5 km resolution of the 0.64 µm channel. Also, the visible channels should be calibrated on-board because this would enable accurate radiation measurements, which will support such products as improved solar insolation at the surface, snow mapping, improved aerosol detection and image quality (especially when displaying an image from more than one sensor).

Participants expressed the need for improved temporal resolution to support simultaneous global, synoptic and mesoscale imaging needs. The ABI should be capable of providing full disk images every 5 minutes and a 1000 km by 1000 km area every 30 seconds.

1.2 Advanced Baseline Sounder

For geostationary soundings to provide the most useful complement to other observing systems, they must yield continuous, reliable, high spectral resolution data in the following locations:

- Areas not observed by other data sources (e.g., over the coastal waters and open oceans),
- Near gradients of data when these gradients occur between observations derived from other sources of data, and
- Between temporal gaps of polar-orbiting satellite observations, providing complete observations of the diurnal cycle. This is true for the radiances, the soundings themselves, and the derived sounding product images. Future GOES sounders must be capable of covering much larger areas every hour to satisfy the observational needs over both the continental U.S. and the data-sparse ocean areas.

While National Weather Service (NWS) forecasters find the products from the present GOES sounder to be a valuable observational tools in the forecast process (Schmit et al. 2001), and continue to develop more operational uses for the data, the relatively coarse vertical resolution of the filter wheel sounder has inherent limitations for some applications. The present generation of GOES sounder is limited to 2-3°C accuracy over a 3 to 5 km layer. Broderick et al. (1981) illustrates how soundings from radiometers with poor vertical resolution can easily miss meteorologically important features such as temperature inversions and dry/moist layers. The availability of GOES-derived soundings with improved vertical and temporal resolution would greatly enhance the ability to initialize numerical models with more realistic observational assessments of temperature, water vapor and wind (Aune et al. 2000).

A key message from the conference participants, was that while the current filter wheel sounder provides valuable information for both numerical models and for subjective use in the forecast offices, future applications will require a much faster coverage rate for the sounder with much improved spectral and spatial resolution. For numerical applications in the 2010 time frame and beyond, models with much improved physics and a spatial resolution of 1 to 2 km, will require detailed information on clouds, moisture and surface specifications as well as tendencies. In the seamless suite of products from the National Centers for Environmental Prediction (NCEP), with its essential climate, weather and water linkages, all model applications are essentially driven by the global model system, which in turn is driven by global observations, including observations from both polar and geostationary satellites. Improved spectral and spatial coverage of future GOES Sounders will be critical to meeting the National Weather Service's (NWS) future goals for numerical weather prediction, objective nowcasting and real time forecaster products.

Specific recommendations for the ABS are:

- Coverage rate should be much faster than the current sounder to eliminate the conflict between global and mesoscale observations. It should be able to scan an area close to full disk within one hour.
- It should be capable of operating in a rapid scan mode, sacrificing areal coverage for greater temporal resolution over a limited area when needed.
- It should have a field of view no larger than 4 km, to allow for more observations between clouds.
- It should be able to detect temperature inversions, which are critical for severe weather forecasting.
- Calibration information and algorithms to generate products should be made available to the user community.
- Soundings are needed in cloudy areas. Conventional GOES clear air soundings should be supplemented either by a microwave sounder in geostationary orbit, or with GOES IR soundings above the clouds and polar microwave soundings.
- Funding for research and development of new satellite products should be part of the satellite acquisition budget.
- For developing new satellite products there should be improved collaboration between research and operations.
- In operations there is a need for a blend of data and products from operational and research satellites.

If these recommendations are met, it is expected that the ABS will:

- Depict water vapor as never before by identifying small scale features of moisture vertically and horizontally in the atmosphere
- Track atmospheric motions much better by discriminating more levels of motion and assigning heights more accurately
- Characterize the life cycle of clouds and distinguish between ice and water cloud, and identify cloud particle sizes
- Accurately measure surface temperatures (both land and sea) by accounting for emissivity effects
- Distinguish atmospheric constituents with improved certainty, including volcanic ash, ozone, methane and other trace gases.

1.3 New Imager and Sounder Products

With the expected improvements for the ABI and ABS, the following new or improved operational products were suggested:

- Atmospheric aerosols
- Cloud phase
- Cloud particle size
- Surface properties
- Improved satellite derived winds
- Moisture flux
- Improved quantitative precipitation estimates
- Improved volcanic ash product
- Clear air turbulence threat areas
- Cloud emissivity
- Improved low cloud and fog product
- Cloud layers
- Probability of rainfall for each pixel
- Improved sea surface temperature product
- True color product
- Cloud optical depth
- Sulfur dioxide concentration (precursor to volcanic eruption)
- Aircraft icing threat
- Ocean color;
- Under (ocean) surface features (i.e. coral reefs)
- Improved sea ice products
- Improved vegetation index
- Ozone layers
- Surface emissivity

2. Space Weather

The GOES program has included space environment measurements since its inception, beginning with the launch of the Synchronous Meteorological Satellite (SMS-1 in 1974). These measurements have continued to grow in importance as the Nation's reliance on space and ground-based technology affected by the space environment increases, and as we embark upon an era of permanent human presence in space with the occupancy of the International Space

Station. For GOES-R, the established requirements for observations of disk-integrated solar x-ray flux, disk integrated extreme ultraviolet flux, solar x-ray imaging, energetic charged particles, and the local magnetic field are basically similar to those set for the GOES-N series. Proposed improvements include:

- Increasing the dynamic range of the Solar X-ray Imager (SXI) to better cover the full dynamic range of solar features and instrument modifications that may extend the measurements to other wavelengths
- Additional channels and increased cadence on the Solar Extreme Ultraviolet Sensor (EUVS) to obtain improved height resolution for thermospheric heating rates and ionization rates, and to monitor solar EUV flares
- Improved dynamic range and a lower threshold of the Solar X-Ray Sensor (XRS) so that the instrument will be able to monitor the solar x-ray flux even at low activity levels and to help in establishing secular (>10 year) trends in the solar x-ray flux;
- To extend the Energetic Particle Sensor (EPS) proton measurements down to 30 KeV to better monitor the bulk of Earth's ring current that contributes to spacecraft charging,
- To meet specifications that were requested, but not met with the GOES-N series.

All of these improvements are important for data products that support systems and human activity affected by conditions in the space environment.

3. Instrument of Opportunity

Each of NOAA's three-axis stabilized series of GOES satellites has a place reserved on the Earth-facing side for an Instrument of Opportunity (IOO). The IOO slot is a location for new technologies that provide space, time, and/or spectral resolution of the environment not possible with the preconceived Imager and Sounder. Candidate IOO's have been suggested to detect lightning, volcanic eruptions, ozone, sulfur dioxide, ocean color, vegetation and special weather events. The NOAA policy to qualify as an IOO on GOES, the proposed instrument must satisfy five conditions. The instrument must:

1. Have potential benefit to NOAA
2. Fit within the allocation constraints
3. Be independently funded, including pre-launch test equipment and the spacecraft accommodation costs
4. Be delivered two years before launch for integration and testing
5. Not interfere with the existing launch schedule or the operational instruments

Four of the breakout groups recommended a lightning mapper for an instrument of opportunity; four recommended a special event imager; and three recommended a microwave sounder. There was also a recommendation for NOAA to provide funding for spacecraft accommodation costs for an IOO.

4. Data Distribution

The current GOES transmits data with a rate of 2.1 Mbits per second. The GOES-R series, with about 2,000 bands on the sounder, as well as more channels on the imager with higher spatial and temporal resolution, the data rates will increase to 20 to 80 Mbits per second, depending on the amount of data compression used. Options include land line distribution, commercial satellite distribution, or rebroadcast from the GOES. The current L band broadcast may have to be changed to an X band transmission (which has problems with rain fade and low angle reception). This would require completely new reception equipment. The current L band is also the only approved method of transmission while the satellite is moving into position from a storage location. The conference participants were asked to convey their needs for data distribution and provide suggestions for optimum methods of distribution.

Some recurring themes among the user responses included:

- There is a wide spectrum of user needs with different tiers of data access. There should be a full range of methods of reception to accompany the broad range of data requirements.
- Data distribution should be timely and have low cost and low data rate options available.
- Data distribution options that should be considered include:
  - Commercial satellite broadcast
  - Direct broadcast from GOES
  - Internet
  - Dedicated land lines
  - Data acquisition by users from a central location
  - Some combination of above
- Re-use existing ground station assets and broadcast a subset of the ABI/ABS data streams from decommissioned GOES satellites.

5. Data and Product Archive Needs

The breakout groups recommended that a full spectrum of GOES products, ranging from raw data to highly processed products be available in an archive for applications ranging from the nowcasting scale to the climate scale. The products should be stored in a user friendly format, allowing for easy remote access at minimal cost to the user. The user must also have access to metadata, including information on data and product quality trends due to variations in instrument or satellite performance. Users should be able to browse, select and submit requests for products via the internet. Potential options for product distribution to the users include: File Transfer Protocol (FTP) for electronic transfer, CD-ROMs, and DVDs. Turnaround for most data requests should be less than 1 day, while one week should be allowed for extremely large requests (e.g., one or more year’s of data).

6. New Data Integration

Participants of the workshop provided several recommendations on ways to minimize the time required to integrate the new GOES-R data stream into operations:

- Leverage data from relevant instruments on other satellites to better understand GOES-R capabilities (i.e. use AIRS and GIFTS data to prepare for ABS; use MODIS to simulate ABI data)
- Provide correctly formatted sample data sets to the user community at least one year prior to the GOES-R launch
- Requirements for operational algorithms should be identified by the spring of 2002
- Operational algorithms should be developed 3 to 5 years prior to launch
- Establish a working group to develop plans to provide sample data sets and for development of new operational algorithms
- NOAA should provide in education, training, research, and product development to ensure optimal use of GOES-R products shortly after launch
- Provide an extended scientific checkout period following the GOES-R launch to allow use of current data and to ease the transition to new data sets.
- NOAA should have in place a fully operational infrastructure for reception, distribution, processing, and archiving, ready for use with test data sets prior to the GOES-R launch.

7. Education of User Community

To ensure maximum return on the investment in the next generation GOES, the breakout groups recommended that NOAA provide comprehensive education program for all levels of GOES users, including: forecasters, emergency managers, recreational users, academia, the media, industrial users, and commercial users. Education programs should be funded as part of the end-to-end GOES program.

Methods of education should include:

- Conferences and workshops
- Web-based training
- Teletraining
- CD-ROM or DVD based training
- Provide segments on the Weather Channel and other media
- Educational and information appropriate for Congress, upper level management, and business leaders.

8. Summary and Conclusions

The GOES User's Conference was a good first step in establishing communication between NOAA and the GOES User Community. Participants strongly supported a continuation of the two way dialogue between users and those planning the development of the next generation GOES. Recommendations for communication venues included:

- Regular conferences similar to the GOES Users' Conference
- Formation of working groups to deal with specific issues
- Provide a bulletin board for information exchange
- Hold informational sessions at end-user conferences (e.g. NWA, CWSA, AMS, Space Weather Week)
- Provide an updated, focused, supported web site;
- Provide information via e-mail
- Make an expert team available to users and instrument developers

In response to the user recommendations, a permanent working group has been established to deal with action items originating from the conference. Also, a bulletin board has been set up at: http://www.osd.noaa.gov/GOES/feedback/sign.asp for two-way communication between NOAA and the user community. Finally, plans for the next GOES User Conference are being prepared.

The participants strongly voiced the recommendation for improvements in spectral, spatial, and temporal resolution in both the future Imager and Sounder. Observations should be relevant for all spatial scales, from the global to the mesoscale, for multi-discipline applications in meteorology, climatology, hydrology and oceanography. In order to meet the needs of a wide cross section of the user community, at least 12 imager channels will be needed with .5 km resolution in the visible channels and 2 km resolution in the IR channels.

The Sounder should provide observations approaching radiosonde quality. It should:

- Provide an accurate three-dimensional picture of atmospheric water vapor
- Determine atmospheric motions much better by discriminating more levels of motion and assigning heights more accurately
- Distinguish between ice and water cloud and identify cloud particle size
- Provide a field of view no greater than 4 km to provide better viewing between clouds and near cloud edges
- Provide accurate land and sea surface temperatures and characteristics by accounting for emissivity effects

- Distinguish atmospheric constituents with improved certainty, including volcanic ash, ozone, and methane
- Detect atmospheric inversions

These improvements in the imager and sounder should lead to improved service to the user community, including improved:

- Quantitative precipitation forecasts;
- Size reduction of geographic areas affected by watches;
- Early detection of severe weather and flash floods;
- Forecasts of hail and hail size;
- Prediction of fog formation and dissipation;
- Forecasts of microburst potential;
- Forecasts of mesoscale convective systems; and
- Forecasts of hurricane intensity and motion.

Appendix 1—Conference Agenda

AGENDA
GOES Users' Conference
May 22-24, 2001

NIST Auditorium & the Millennium House
Boulder, CO

Goals for Workshop:

1. Inform users of future capabilities and potential applications of GOES
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
   – future training
3. Assess user and societal benefits of future systems
4. Develop methods to improve communication between NESDIS and the GOES user community
   – develop process for determining and updating requirements

Day 1 (Tuesday): NIST Auditoriim

7:30 am	Registration	
9:00 am	Introduction (logistics, conference format etc)	(Jim Gurka/ NESDIS)
9:05 am	Welcome/ Opening Remarks/ GOES: the NOAA Vision	(Mary Glackin/ NESDIS)
9:35 am	The GOES Program (overview)	(Gerald Dittberner/ NESDIS)
10:00 am	BREAK	
10:30 am	Keynote Address	(Dr. Elbert W. Friday)

Session 1: Planned Sensors for Domestic Geostationary Satellites

Chairperson: Dr. Paul Menzel

11:00 am	Introduction of Session 1	Gary Davis/ Paul Menzel
11:10 am	Advanced Baseline Imager (ABI)	(TimothySchmit/NESDIS)
11:55 am	Lunch (on your own)	
1:10 pm	Advanced Sounder	(Dr. Paul Menzel/ NESDIS)
1:55 pm	GIFTS	(Dr. William Smith/ NASA)
2:40 pm	Space Environment Monitor/ SXI	(Howard Singer/Steve Hill/OAR/SEC)
3:10 pm	BREAK	

Session 2: Additional Potential Sensors for Domestic Satellites

Chairperson: Dr. Marie Colton

3:40 pm	Session Introduction	(Dr. Marie Colton/ NESDIS)
3:50 pm	ESEI, Lightning Mapper, VolCam	(Dr Dennis Chesters/ NASA)
4:20 pm	NPOESS & GOES: complementary systems for the future	(Cpt. Craig Nelson/ IPO)
4:40 pm	Satellite Acquisition Strategies	(Del Jenstrom/ NASA)
5:10 pm	Day 1 wrap-up	(Gary Davis/ NESDIS)
5:25 pm	End of day 1 sessions	
6:00-7:30	Reception (Regal Harvest House)	

Day 2 (Wednesday): NIST Auditorium

Session 3: User Requirements, Applications and Potential Benefits from Future GOES

Chairperson: Donald Gray

8:15 am	Day 2 Introduction	(Gary Davis/ NESDIS)
8:20 am	Session 3 Overview	(Donald Gray/ NESDIS)
8:30 am	A Visionary Look at the Next Generation GOES	(Dr. James Purdom/ NESDIS)
9:00 am	Potential Impact of GOES Data in NWP Models	(Dr. Ralph Petersen/ NWS/ NCEP)
9:25 am	The Value of Improved GOES Products in the NWS Forecast Offices	(Greg Mandt/ NWS/ OS)
9:50 am	BREAK	
10:20 am	NCAR View of Future GOES	(Dr. David Johnson/NCAR/RAP)
10:50 am	Fisheries and Oceanographic Applications	(Dave Foley/ NMFS)
11:10 am	Value of Future GOES to Navy Operations	(Capt. Michael Pind)
11:30 am	LUNCH	
12:45 pm	Value of Future GOES to Army Operations	(Dr. Don Hoock)
1:05 pm	Value of Future GOES to USAF Operations	(Col. Robert Allen/AFWA)
1:25 pm	Commercial Aviation Issues	(Ed, Miller ALPA)
1:40 pm	Commercial Weather Services: Issues	(Maria Pirone/WSI)
1:55 pm	Climate and Hydrology Applications	(Dr. Paul Try/)
2:15 pm	BREAK	

Session 4: Future International Geostationary Satellites

Chairperson: Dr. James Purdom

2:35 pm	Session Overview	(Dr. James Purdom/ NESDIS)
2:40 pm	The Future of Meteosat	(Dr. Johannes Schmetz/ EUMETSAT))
3:15 pm	The Role of Geostationary Satellites in the Global Observing System: the WMO Perspective	(Dr. Don Hinsman/WMO)

Session 5: Communications, Ancillary Services & Training Issues

Chairperson: Anthony Mostek

3:50 pm	Opening remarks	(Anthony Mostek/NWS)
3:55 pm	Options for data distribution	(Peter Woolner/Mitretek)
4:15 pm	Ancillary Services	(Dane Clark/ NESDIS)
4:35 pm	Training Options	(Anthony Mostek / NWS)
5:00 pm	Day 2 Overview (Auditorium)	(Gary Davis/ NESDIS)
5:20 pm	End of day 2 sessions	
6:00 pm	Workshop Dinner (Regal Harvest House) Dinner Speaker: Ray Ban (Senior Vice President of the Weather Channel)	

Day 3 (Thursday): Regal Harvest House

Breakout Sessions

Facilitator: Jessica Hartung

8:30 am	Introduction to feedback process	(Jessica Hartung)
9:00 am	Breakout sessions begin Technical Leads: Paul Menzel, Peter Woolner, Fred Mosher, Don Gray, Dick Reynolds, Kevin Schrab, Jeff Hawkins, Gary Hufford	(Facilitators and Technical Leads)
10:00 am	BREAK	
10:30 am	Breakout sessions resume	
11:45 am	Working Lunch (provided)	
1:00 pm	Breakout sessions resume	
2:00 pm	Break	
2:20 pm	Highlights from each breakout group	Group representatives
4:00 pm	Closing remarks	(Gary Davis)

Day 4 (Friday):

Optional tours: NGDC, NCAR, NIST, SEC, FSL, NWS/ WFO

Appendix 2—Presentation Summaries

Session 1: Planned Sensors for Domestic Geostationary Satellites

Chairperson: Dr. Paul Menzel

Advanced Baseline Imager (ABI) **(Timothy Schmit/NESDIS)**

To keep pace with the growing need for GOES data and products, NOAA is evolving its geostationary imaging capabilities. The Advanced Baseline Imager (ABI), the next generation geostationary imager, addresses National Weather Service concerns by increasing spatial resolution (to better depict and range of phenomena), by scanning faster (improved temporal sampling and scanning additional regions) and by adding spectral bands (enabling new and/or improved products). ABI will have a minimum of eight and a maximum of twelve spectral bands. The minimum eight bands would be similar to the five bands on the current GOES-8 -11 imagers (0.64, 3.9, 6.15, 11.2, and 12.3 µm), plus a snow/cloud-discriminating 1.6 µm band, a mid-tropospheric 7.0 µm water vapor band, and a 13.3 µm band useful for determining cloud heights.

Two proposed additional bands, are centered in infrared windows at 8.5 µm and 10.35 µm. The 8.5 µm band, in conjunction with the 11.2 µm band, will enable detection of volcanic dust cloud containing sulfuric acid aerosols. In addition, the 8.5 µm band can be combined with the 11.2 and 12.3 µm channels to derive cloud phase. The 10.35 µm band will help to derive low-level moisture, cloud particle size and surface properties. Another proposed band is centered at 0.86 µm to help with the detection of aerosols and vegetation; this band may also enable monitoring of localized vegetation stress and fire danger. Finally, a near-infrared band is proposed at 1.38 µm to detect very thin cirrus not detected by other bands. Taken as a whole, the additional bands are intended to improve moisture, volcanic and conventional cloud, aerosol, and surface sensing capabilities. These additional bands have the goal of meeting NWS requirements and enhancing opportunities for weather and climate research and applications.

GOES Advanced Baseline Imager simulations, based on high spatial resolution Moderate Resolution Imaging Spectroradiometer (MODIS) data, have been compared to imagery from the current GOES imagers for a wide range of meteorological phenomena. These phenomena include wave clouds, severe convection, hurricanes, volcanoes, fires, lake ice, cloud phase and fog. ABI simulations show convincingly that the 12 channel version addresses NWS requirements for improved cloud, moisture, and surface products.

The need for the ABI is documented. The technology is proven. The time is right to update the GOES imager!

Advanced Sounder **(Dr. Paul Menzel/ NESDIS)**

The era of operational high-spectral-resolution infrared radiance measurements from the geostationary perspective is approaching. with the advent of the Advanced Baseline Sounder. These advanced sounders will have over one thousand channels with spectral widths on the order of half wavenumbers, while the current GOES Sounders have only 18 bands with spectral widths on the order of tens of wavenumbers. The ABS is likely to be an interferometer that overcomes several existing instrument limitations. Current GOES Sounders are limited in their hourly spatial coverage, their spectral resolution which restricts vertical resolution, and their ability to depict boundary layer small scale temperature and moisture changes.

Geostationary high spectral resolution infrared measurements will resolve high temporal and vertical fluctuations of moisture that are not resolved by current *in-situ* or satellite measurements. Only geostationary interferometers can observe critical meteorological parameters (temperature, moisture, clouds, winds) with necessary temporal, spatial and vertical resolutions to support future:

- Nowcasting,

- Short-range weather forecasting, and
- Longer-range numerical weather prediction.

ABS will enable monitoring the evolution of temperature and moisture inversions in clear skies; being able to characterize inversions is important for many reasons, including the detection of severe weather potential and possible fog formation, numerical model initialization, and sounding retrieval. High-spectral-resolution sounder radiances also allow an improved cloud-top pressure estimate.

Expectations from the Geo-Interferometer:

- depicts water vapor as never before by identifying small scale features of moisture vertically and horizontally in the atmosphere
- tracks atmospheric motions much better by discriminating more levels of motion and assigning heights more accurately
- characterizes life cycle of clouds (cradle to grave) and distinguish between ice and water cloud (which is very useful for aircraft routing) and identify cloud particle sizes (useful for radiative effects of clouds)
- measures surface temperatures (land and sea) by accounting for emissivity effects (the improved SSTs would be useful for sea level altimetry applications)
- distinguishes atmospheric constituents with improved certainty; these include volcanic ash (useful for aircraft routing), ozone, and possibly methane plus others trace gases.

GIFTS **(Dr. William Smith/ NASA)**

Important temporal and spatial coverage gaps in atmospheric data exist that can be filled with the next generation geostationary satellite sounding systems. Specifically, the Geosynchronous Imaging Fourier Transform Spectrometer (GIFTS) is a system of state of the art remote sensing technologies which will permit the observation of the three dimensional distribution of the basic atmospheric state parameters (i.e., temperature, moisture, and wind) with high spatial resolution and on a near continuous basis. Once implemented on the GOES, a revolutionary new weather nowcast capability is made possible through real-time displays of thermodynamic products of GIFTS data, combined with precipitation information observed from ground-based radars, accessed by the general public through palm type computers. Also, significant improvements in numerical weather predictions on both the regional and global scales is made possible through the continuous assimilation of the high spatial and temporal resolution GIFTS sounding data with atmospheric state observations from low altitude earth orbiting satellites, aircraft, and surface based systems. In this presentation, the technologies and the meteorological remote sensing capabilities of the GIFTS component of the future observing system is described. GIFTS capability is planned for space demonstration beginning in 2005. The planned infusion of GIFTS technology and measurement capability into the next generation GOES is discussed.

Space Environment Monitor **(Dr. Howard Singer /OAR/SEC)**

The GOES program has included space environment measurements since its inception about a quarter-century ago, beginning with the launch of the Synchronous Meteorological Satellites SMS-1 in 1974. These measurements have continued to grow in importance as the Nation's reliance on space and ground-based technology affected by the space environment accelerates, and as we embark upon an era of permanent human presence in space with the occupancy of the International Space Station. The GOES program can be proud that these observations demonstrate the program's commitment to solar and Earth environmental measurements that extends beyond GOES' primary meteorological mission. This presentation provides an overview of the NOAA Space Environment Center (SEC), the current GOES Space Environment Monitor (SEM) instruments and their products that benefit society, the GOES R+ SEM instrument baseline and proposed improvements, and discussion of trade studies and a request for user/partner participation.

The environment monitored by the SEM instruments includes both solar and the near-Earth magnetosphere. The SEM instruments provide much needed information on solar sources of near-Earth space environment effects through measurements of solar x-rays, solar EUV radiation, and solar/solar wind generated energetic particles. Other SEM instruments make critical measurements of the energetic particles and magnetic fields in the important, and unique, geosynchronous environment.

The GOES SEM measurements contribute to many aspects of SEC's mission. SEC is the Nation's official source of space weather alerts and warnings and we continually monitor and forecast Earth's space environment conditions to reduce adverse effects of space weather disturbances on human activities. The GOES data are vital for this portion of our mission, for use by private industry vendors, and for serving researchers who use the data deposited in the national archive at the National Geophysical Data Center (NGDC). Two of the three, recently established NOAA Space Weather Scales, Solar Radiation Storms and Radio Blackouts, depend on the GOES measurements for quantifying space weather effects, just as the Richter scale depends on seismometers.

The GOES data are used by the 24x7 SEC Space Weather Operations (SWO) at SEC where data are received, synthesized, and alerts and warnings are issued for numerous space weather customers including the US Government, the International Space Environment Services, and commercial users. SEC disseminates these data through a variety of systems and we are working towards improved methods by enhancing our coordination with the National Weather Service, one of our parent organizations. (SEC is one of the National Centers for Environmental Prediction (NCEP) as well as a research laboratory within NOAA's office of Oceanic and Atmospheric Research.) The Internet is growing in importance as one method of data dissemination and it is interesting to note that SEC Web pages, including GOES data, are now receiving roughly 300,000 accesses per day, with peak activity exceeding 1.7 million accesses per day during geomagnetic storms.

SEC participates in both national and international programs that depend on the GOES SEM instrument observations. The US National Space Weather Program (NSWP) rests on pedestals of Research, Observations, Models, and Education to transition technology into improved forecasting and space weather services at SEC that will support customer needs. GOES data contribute to the observations, models and research important to this program. The DoD has accepted a National Space Architecture Study Transition Plan that places the GOES SEM as a baseline monitoring system through the year 2025. The NASA human space flight program utilizes GOES solar energetic particle data to provide guidance for astronaut safety and extra-vehicular activity (EVA) from the space shuttle and the international space station. GOES magnetometer data provide crucial measurements of magnetopause crossings that interfere with satellite operations. The solar x-ray data from the XRS is the worldwide standard for solar flare magnitude and can be used to predict solar proton events that affect HF communications over the polar regions as well as HF radio wave absorption on Earth's dayside. The EUV sensor data are vital for input to satellite orbit prediction models and to provide knowledge about ionospheric properties that affect global communications. These are only a few examples of those who depend on the GOES SEM measurements. As our utilization and dependence on space increases, with numerous low-earth orbit satellites and increased GPS sales as examples, our dependence on data from GOES increases as well.

The current GOES SEM measurements of energetic particles, magnetic field, solar x-rays, and EUV (EUV begins with GOES N) provide data of practical benefit for commercial and government activities and for extensive basic research. GOES measurements protect the Nation from wide-ranging and severe environmental disturbances. The GOES NO/PQ enhancements include solar EUV measurements in 5 wavelength bands, an extension from high-energy electron and proton measurements to medium-energy electrons and protons. It is worth noting that beginning with GOES NO/PQ, NOAA will be making solar observations over an extensive region of the solar spectrum from x-rays, through EUV, and with the POES and NPOESS measurements extending observations to UV and the visible. These measurements will contribute to NOAA's ability to quantify and assess solar variability and its effects on climate.

For GOES R, the established requirements for observations of disk-integrated solar x-ray flux, disk integrated extreme ultraviolet flux, solar x-ray imaging, energetic charged particles, and the local magnetic field are basically similar to those set for the existing GOES NO/PQ spacecraft. Proposed improvements include: increasing the dynamic range of the Solar X-ray Imager (SXI) to better cover the full dynamic range of solar features and instrument modifications that may extend the measurements to other wavelengths (see SXI presentation for details); additional channels and increased cadence on the Solar Extreme Ultraviolet Sensor (EUVS) to obtain improved height resolution for thermospheric heating rates and ionization rates and to monitor solar EUV flares; improved dynamic range and a lower threshold of the

Solar X-Ray Sensor (XRS) so that the instrument will be able to monitor the solar x-ray flux even at low activity levels and to help in establishing secular (>10 year) trends in the solar x-ray flux; and to extend the Energetic Particle Sensor (EPS) proton measurements down to 30 KeV to better monitor the bulk of Earth's ring current that contributes to spacecraft charging, and to meet specifications that were requested, but not met with GOES NO/PQ. All of these improvements are important for data products that support systems and human activity affected by conditions in the space environment.

GOES Space Environment Monitor measurements provide crucial data to our nation and the world for commercial and government applications and for basic research. NOAA services must expand to meet the needs of our nation's increasing use of and reliance on the space environment, and the baseline requirements and enhancements have been defined to carry out our mission. After considering NPOESS plans, some of the initial instruments that were under consideration were eliminated. However, a continuing process of User/Instrument-provider/Partnership workshops are needed to determine the highest priority needs and implementation strategy for space environment monitoring. There is a need to conduct trade studies and to consult with partners in NOAA, DoD, and especially the USAF and NASA to ensure that we pursue the most important measurements needed by NOAA and its customers, and to evaluate the future need for measurements such as the extension of whole disk integrated x-ray measurements to hard x-rays which may be predictors of solar energetic particle events and to assess the value and ability to make heavy ion measurements which are important contributors to the damage of human tissue in space. While we at SEC are continuously assessing our user needs for space weather services, and thinking about changes and improvements to current measurements, these activities are not a substitute for the systematic phased studies that are needed to best define a clear and cost-effective rationale for future operational instruments and the best platform/orbit for some space environment measurements.

Solar X-ray Imager (SXI) Dr. Steve Hill/OAR/SEC)

GOES Solar X-ray Imager (SXI) will provide critical information for forecasting geoeffective space weather events. These events originate in the outer atmosphere of the sun and propagate through the interplanetary medium where they may intersect Earth's space environment. Like all atmospheres, the sun's has a temperature and density profile. The level that we see in visible wavelengths originates at the photosphere – this is the effective 'surface' of the sun. The temperature of the photosphere is about 6000 K. Density decreases rapidly through the overlying chromosphere. Above the chromosphere is the corona, where temperatures rapidly climb to $\sim10^6$ K. This is where all the 'action' that affects Earth happens and most of the emission at these temperatures happens in X-rays.

SEC has generated the NOAA space weather scales that provide three categories of space weather effects: Radio blackouts, radiation storms, and geomagnetic storms. Solar flares, which are explosive releases of energy resulting in orders of magnitude increases in X-ray output, can cause radio blackouts by affecting the ionosphere and can also result in radiation storms at satellite altitudes. Coronal Mass Ejections (CMEs) are releases of plasma from the sun that can result in radiation storms and can generate geomagnetic storms. High-speed solar wind streams originating in coronal holes cause recurring geomagnetic storms.

The effects of flares on communications (radio blackout) can be dramatic, for instance, GPS errors doubled during the storm originating with a flare on July 14, 2000. Energetic particles (radiation storms) from the same event resulted in a 'blizzard' effect on a number of imaging instruments in orbit and included attitude upsets due to star tracker errors. Geomagnetically induced currents affected power grids across the east coast causing capacitor banks to trip and damaging some transformers.

To help forecast such events, the SXI requirements have been set:

- Locate coronal holes for recurring geomagnetic storm predictions
- Monitor for changes indicating coronal mass ejections (CMEs) for non-recurring geomagnetic storm forecasts
- Locate flares for particle events predictions, including flares beyond the west limb
- Active regions beyond east limb, rotating onto the solar disk, for activity forecasts
- Active region complexity for flare forecasts

Without SXI, the NOAA Space Environment Center gets only two numbers from the XRS to reflect solar X-ray activity. Having only XRS data would be analogous to having a sounder with only one pixel for the entire Earth.

The current (GOES M, N/Q) observational performance for the SXI provides a great leap over non-imaging instruments or non-operational imagers. However, this performance reflects minimal first generation requirements. As the first SXI approaches operations, we have come to understand its particular strengths and weaknesses that flow from its requirements.

Requirements can be categorized into four areas: response, temperature, spatial coverage and resolution, and temporal coverage and resolution. Each of these is an area for specific improvement in meeting observational needs. First, to directly image coronal holes, active regions, and flares, SXI must image in the soft X-ray regime with sufficient sensitivity and dynamic range. These features have a dynamic range greater than 10^6 and the SXI needs to cover this range with a minimum operational effort. The current generation of SXIs has a dynamic range of ~100. With this limited range, 3-4 images are taken and combined on the ground. This not only complicates operations and data handling, it results in temporal 'smearing' as rapidly evolving features change during the time period. Providing sufficient dynamic range will simplify forecasting since a single product set will be used for both short-term and mid-term forecasts.

Second, soft X-rays originate in the corona at temperatures of 1 to 10 MK. To differentiate and characterize features, temperature resolution must be 10%.

Third, spatial coverage of $1.8\times10^6 \times 1.8\times10^6$ km is necessary to cover the largest arcade features. This is about 1.3 solar radii. Resolution of 5,000 km (properly sampled by 1,800 km pixels) is necessary to locate features such as flares and coronal hole boundaries.

Fourth, temporal resolution of 1 minute is needed because of the time-scale of the most rapid events. As for data continuity, no imaging interruptions can be longer than 2 minutes. This is one of the original requirements for the SXI. Full implementation implies that each GOES spacecraft be equipped with an SXI to cover eclipse and housekeeping periods. A second major advantage is that when the instruments are not needed for full redundancy, e.g., not at eclipse season, each observing plan can be tailored to provide a more useful and complete product suite.

The GOES M (planned launch on July 12, 2001) SXI pathfinder instrument implements most of the original SXI requirements. Though the SXI will be controlled from SOCC, the raw data is also directed to SEC in Boulder, Colorado. In Boulder, all the SXI data are processed in real-time. This real-time data are provided to our forecast center and other real-time users. In addition, the data are routed to the NOAA National Geophysical Data Center (NGDC), co-located with SEC in Boulder. NGDC archives the data and provides it in near real-time to the public via the web.

The requirements and implementation for GOES R+ solar X-ray imaging are clear. However, there exists a range of observations coincident with X-ray imaging that calls for trade studies. These could possibly be accomplished within the planned SXI 'foot-print' as an additional co-axial instrument. For instance, expanding to cooler temperatures could provide better insight into causative phenomena lower in the corona. This could be an EUV telescope similar to SOHO's EIT, nested inside the SXI's grazing incidence objective mirrors.

Other instruments are also possible. Imaging the sun in the narrow Hα line provides a look at the chromosphere and may provide advance warning of coronal events. However, a ground-based network of observatories currently performs Hα imaging. Moving this measurement to space would be mainly a consideration of cost and reliability versus the constraints of network management and cloudy days. The same statement applies to imaging the lower corona in the He I 10,830 Å line.

In summary, solar coronal imaging offers the best hope for medium to long term forecasting of geoeffective space weather events. Although the current (2001) GOES SXI provides essential information on the solar atmosphere, necessary improvements focus on dynamic range and data continuity. And, many other imaging possibilities exist to help with space weather forecasting. In conjunction with user need and technological advances these should be explored in trade studies.

Session 2: Additional Potential Sensors for Domestic Satellites

Chairperson: Dr. Marie Colton

ESEI, Lightning Mapper, VolCam **(Dr Dennis Chesters/ NASA)**

NOAA's three-axis stabilized series of GOES satellites have a place reserved on the Earth-facing side for an Instrument of Opportunity (IOO). The IOO slot is a location for new technologies that provide space-time-spectral resolution of the environment not possible with the preconceived Imager and Sounder. For example, candidate IOO's have usually proposed to use large-format staring arrays of detectors. The size, weight, power, data rate, and interface allocations for the IOO are modest in comparison to the Imager and Sounder, but the resources are large enough to allow for the collection of useful real time data. Because, the geosynchronous location is ideal for monitoring rapidly changing unpredictable events, IOO's have been suggested to detect lightning, volcanism, ozone and sulfur dioxide, ocean color, vegetation, special weather events, and even broadcast color TV. To become an IOO on GOES, the proposed instrument must: 1) have potential benefit to NOAA, 2) fit within the allocation constraints, 3) be independently funded, including pre-launch test equipment and the spacecraft accommodation costs, 4) be delivered two years before launch for integration and testing, and 5) not interfere with the existing launch schedule or the operational instruments.

NPOESS & GOES: Complementary Systems for the Future **(Cpt. Craig Nelson/ IPO)**

Satellite Acquisition Strategies **(Del Jenstrom/ NASA)**

The initial steps toward development of the next generation GOES satellites, beginning with GOES-R, are currently underway. This presentation summarizes the instrument and mission procurement strategies and their current status.

Requirements:

Formal mission-level requirements for next generation series of GOES satellites are currently under development by NOAA through NOAA/NASA working groups. Four groups (a lead group and three study subgroups) have been established to develop Level-1 mission requirements and the associated operations concept. In the interim, the NOAA GOES program has established an initial set of mission development guidelines so that instrument formulation activities can be initiated. These guidelines are:

- GOES-R launch ready in 2008
- Flight system lifetime ≥ 7 years
- Baseline imager/sounder
  - Advanced Baseline Imager (ABI)
  - Advanced Baseline Sounder (ABS)
- Other instrument/capability requirements are TBD

The requirements for the imager instruments were delivered to NASA in the form of the ABI Technical Requirements Document (TRD) in February, 2000. The ABI TRD calls for a factor of 2 or 3 improvement in the primary performance parameters over the current generation imager (e.g., number of channels, coverage rate, and spatial resolution). An equivalent TRD for the ABS was delivered to NASA in December, 2000. It calls for a high spectral resolution sounder with much higher ground coverage rates and tighter radiometric requirements than the current filter wheel sounder.

Mission Development Plan:

One of the important considerations in establishing the GOES-R development plan is to ensure that sufficient fallback options are built into the plan so that a protracted delay in GOES-R development, such as occurred with GOES-I in the late '80's, does not result in an operational coverage gap. To address this consideration, the launch readiness date for GOES-R has been set to be in the same time frame as that of GOES-Q, in 2008, rather than the nominal readiness date of 2010. This provides a 2 year cushion in case of developmental difficulty before a loss in continuity of coverage is a concern. Since the decision to procure the GOES-Q spacecraft does not need to be made until 2005, GOES-Q can become an optional mission that is exercised only if development of GOES-R is not proceeding as planned. By 2005, the ABI and ABS will have completed building of their engineering models and testing will be underway. Thus, the degree of risk associated with achieving the launch readiness date of 2008 should be well understood by 2005. If GOES-R runs into developmental difficulty and GOES-Q is exercised, then the GOES-R readiness will be delayed until 2010.

The next generation GOES spacecraft for the GOES-R series will be procured through a competitive process, and will be made to accommodate ABI, ABS, and the other sensing and communication payload elements. We are targeting January, 2002 for release of an RFP for mission-level formulation studies. Multiple awards are planned for 1-year studies.

A 6-month spacecraft accommodation study is currently underway at five spacecraft vendors to assess the ability of 2003-era GEO busses to accommodate the planned GOES payload, with the goal of establishing outer bounds on the envelope size of ABI and ABS. The accommodation studies will be completed by September of 2001 to support development of the mission formulation study RFP and also to provide guidance to the ABI and ABS formulation efforts concerning instrument envelope requirements. The accommodation study vendors are also investigating a number of communications options to assist in forming the communications architecture for the advanced GOES system. In addition to these formal studies being done by industry, other investigations concerning key mission factors, such as image navigation and registration, are also underway within NASA, NOAA, MIT/LL, and support contractors.

Three contracts were awarded for ABI Formulation Studies in May, 2001 to Ball Aerospace, ITT, and Raytheon SBRS. The formulation phase for the ABI will be 18 months long, and is broken into an initial 6 month period where trade studies and requirement analyses will be performed. Soon after completing these trade studies and analyses, NASA plans to issue refined ABI requirements to the vendors for preliminary design development during the remaining 12 months. A down-select to a single vendor will occur for ABI implementation.

A formulation approach similar to that of ABI is planned for ABS development. One of the issues being addressed in planning for ABS development is the degree to which its design can leverage that of the GIFTS geosynchronous sounder instrument being developed for the NASA New Millennium Program EO-3 mission. ABS formulation activities will include careful evaluation of GIFTS and coordination with the GIFTS development team at NASA Langley. Negotiations are currently underway between the GOES program and the NASA New Millennium Program to evaluate technical and programmatic options to infuse the GIFTS developments into ABS.

Session 3: User Requirements, Applications and Potential Benefits from Future GOES

Chairperson: Donald Gray

A Visionary Look at the Next Generation GOES **(Dr. James Purdom/ NESDIS)**

Throughout the presentation an important focus will be on addressing the advantages of very high resolution observations, both spectrally and temporally, for analysis of meteorological phenomena. Examples of the advantage of high spectral resolution observations will be illustrated using hyperspectral data in the visible to near infrared (0.4 - 2.4 microns) portion of the spectrum. Information will be presented on how that data may be analyzed to obtain the maximum information for extracting information on clouds, water vapor, and certain hazards such as fires and smoke. While the specific example of hyperspectral imagery will focus on the visible to near infrared portion of the spectrum, the complementary nature of infrared interferometry and active and passive microwave radiometry will also be touched upon. Finally, high temporal resolution GOES data (30 second to one minute intervals) will be used to illustrate how that data may be used to study convection, severe storms, hurricanes, and extra tropical phenomena. To be addressed in this presentation:

- Historical Perspective
- Into the digital world
- Where we are today
  - Major impacts, but under utilization
- Future U.S. systems and sensors
- The merging of research and operations
- Ensuring full utilization
- Cooperative science
- A view to the future
- Future NWP will cover scales from nowcasting to climate, with high spatial resolution models
- Hyper spectral in space and time

There are three obvious conclusions: a) Satellite data are an integral part of our weather forecast system, and must be fully exploited; b) We should expect great strides forward with improvements to the global space based observing system; c) The advancement to improved microwave sensors and hyper-spectral imaging and sounding is a ***natural progression***, and provides exciting new opportunities and challenges with truly adaptive observing systems. The expected growth in satellite observing capability, which will result in over 5 orders of magnitude increase in data over the next decade, reemphasizes the need for improved satellite data utilization in data assimilation and numerical weather prediction.

Potential Impact of GOES Data in NWP Models (Dr. Ralph Petersen/ NWS/ NCEP)

In NCEP's Seamless Suite of Products, with its essential Climate -Weather -Water linkages, ALL model applications are essentially driven by the global model system ,which in turn is driven by global observations - both POES and GOES. This suite of products covers events from climate to weather to oceans, and spans ranges of time from seasons to weeks to days to hours in the future. Lindzen's recent statements underwrite the broad impact of GOES: *"Improved Spectral and Spatial coverage of Future GOES Imagers and Sounders will be critical to meet NCEP's future goals"*

GOES coverage is important for: NWP; Objective Nowcasting; and Realtime Forecaster Products. For it to be useful, however, It must:

- Eliminate the conflict between supporting ASOS and forecast products
- Fill in the time, space and information gaps left by other observations

Where will NCEP's models be after 2012? Model Resolution improvements will have neared completion by then, with Domestic models at about 2-3 km, and Threats models finer than 1 km. There will be major improvements in model physics:

- In the Atmosphere: Detailed Moisture/Cloud Characteristics
- Over land: Details of Surface Properties
- Over oceans: diurnal SST structure
- Probabilistic Forecasts:
  - Will need better measures of analysis (and therefore data) confidence
  - Ensembles of physics packages will use detailed cloud, moisture, aerosol and surface specifications, as well as tendencies

There will also be new service areas, e.g., air quality models. All this leads to major needs for observations, both domestically and internationally.

If we compare the role of future GOES to other data systems, we see that GOES is a major source of hemispheric/domestic forecaster information. It's strengths are high temporal and spatial resolution, increasing vertical resolution, good cloud/surface detail, it captures diurnal changes, and provides the only observations of detailed horizontal moisture structure and time changes. Its weaknesses are that it is IR-only "profile" information, has no polar coverage, is limited by "cloud contamination", and is underutilized in NWP.

GOES however, offers spatial details and time tendencies that make it a major source of moisture observations, including:

- Horizontal and vertical moisture gradients
  - Future systems will observe 6-8 individual layers
- Moisture fluxes possible with sufficient horizontal resolution
  - Need identified by NAOS
- Cloud properties
  - Cloud location, top height, ice vs. water, . .

GOES also observes surface properties, including:

- Land–Vegetation, Surface emissivity,
- Oceans–SST, Ocean color, surface motion…

Additionally, GOES observes Trace Gases, etc.:

Fire, smoke, dust, O3, CO2…

Improvements can be seen in a GOES Sounder Emulation Test. Radiance data from a "truth"

Atmosphere were used to simulate satellite observations from the current GOES operational radiometers and from the GIFTS advanced interferometers. Time-series of thunderstorm prediction parameter Lifted Index were also derived using a surface-based parcel. The findings were:

- GIFTS traces evolution of 800 hPa inversion with 60-80% error reduction
- GIFTS captures important vertical temperature variations at ~1 km resolution
- GIFTS traces moisture peaks and gradients with greatly reduced errors
- GIFTS captures important vertical moisture variations at ~1.5 km resolution

GIFTS depicts LI values and rapid atmospheric destabilization prior to onset of convection better than current GOES.

Let's look at 3 categories of use of future GOES observations for Weather Forecasting: NWP, Objective Nowcasting, and Subjective forecaster use of real-time Image Products. Note that in each case, there is a need to integrate all data sources.

In Numerical Weather Prediction GOES impact on weather forecasts is likely to be greatest in first two days. For Precipitation forecasting, it will be important in the specification of precipitation location and intensity, and could be the key to location and timing of "Storm Initiation," a major problem with current non-hydrostatic models. Assimilation over land will be easier for smaller IR FOVs. We can directly use radiances for vertical moisture and temperature gradients. There will be direct use of cloud imagery for cloud composition, placement, removal, motion and trends. A measure of confidence in the observation can be applied which will be especially important for enseble and targeting strategies.

In the zero to six-hour "watch period," forecasters by 2012 will not be able to look at all observations individually. Emerging new users will need frequent updates. For example, the Energy Sector will want Max/Min temperatures for days and hours. We will need to provide the forecaster tools that depict all data as closely as possible. This will allow users to see high-res, 4-D depictions of "Gridded Obs." The watch period has the advantage that is less dynamically constrained than the longer-range NWP, and tools for this time range will need fast turn-around, with "instant integration" and combining of best of all systems. New ideas are needed.

In the zero to two-hour "warning period" we will continue to rely on products instead of radiance. Derived product image information will become increasingly easy to interpret, more easily integrated with Nowcasting products, and will need techniques for "Auto-Alerting" of: Pre-convective storm location/intensity, icing, fog-development/dissipation, and wild fires. Model products will be displayed as "Synthetic GOES Images."

How do we get there? We must Build Upon Planned Research/Development Programs – Like GIFTS. We need to include the total infrastructure (ground receivers, data ingest systems…); applications development (data assimilation, product generation, user information displays); and data system emulations. And, most important to success, we must remember the needs of the end user.

The Value of Improved GOES Products in the NWS Forecast Offices **(Greg Mandt/ NWS/ OS)**

Beginning in 1996 the Office of Meteorology (now the Office of Climate, Water, and Weather Services) initiated a series of assessments of the effectiveness of the digital data from the new GOES-I/M satellites. The assessments were primarily focused on validating the quality and meteorological utility of the new higher resolution data, determining necessary modifications to "day-one" (initial) products, providing input to modifications for GOES-I/M and follow-on GOES system requirements, providing input to GOES training requirements, and providing input for effective use of GOES-I/M data on Advanced Weather Interactive Processing System (AWIPS).

The first assessments were somewhat limited in scope, since only locations with direct readout capability, or workstations developed by the Cooperative Institute for Research in the Atmosphere (CIRA) at Colorado State University called the Regional and Mesoscale Meteorology (RAMM) Branch Advanced Meteorological Satellite Demonstration and Interpretation System (RAMSDIS), or the pathfinder AWIPS sites of Boston and Pittsburgh could participate. These locations could view the CONUS every 15 minutes vice half-hourly from the old spinners. More frequent updates and new channels (e.g. 3.9 Φm) led to major improvements in GOES products and enhanced the utility of the satellite data. Use of rapid scan operations (RSO) (updates every 7 ½ minutes) saved NASA $1M in shipping costs each time the quick cycle imagery showed sufficient openings in cloud cover to allow the Space Shuttle to land at Kennedy Space Center and not the alternate site of Edwards AFB, California. The Peach Tree Forecast Office's Olympic Weather Support Office provided a unique opportunity to assess the GOES-8 data in an operational environment through the use of RAMSDIS. The high resolution digital imagery received in a timely fashion made RAMSDIS invaluable from a mesoscale forecasting point of view.

During this same time a lake effect snow study was taking place with cooperation of CIRA and National Weather Service (NWS) forecast offices. The study started out as retrospective only, since the NWS offices did not have access to the digital data. With the delivery of more RAMSDIS and AWIPS systems, these offices were able to use the data first hand and apply lessons learned from the early retrospective studies. The high resolution digital data gave forecasters a good view of multi-lake interactions and how they influence the evolution of lake effect snow bands. The data also helped pinpoint synoptic and mesoscale disturbances that may enhance or initiate lake effect activity.

The Office of Meteorology conducted evaluations of the satellite cloud product (SCP), which supplements the Automated Surface Observing System (ASOS) observations, and the satellite precipitation estimates (SPEs) from 1996 through 1999. During this time the SCP product was significantly expanded from a couple hundred reports to over 1,200 reports per hour. Bottlenecks in the delivery of the SCP to the field were identified and resolved. Science problems (e.g., low-level temperature inversions producing false clouds) were identified and ameliorated. Specific feedback on the quality and reliability of the SPE was provided by NWS Forecast Offices. An orographic correction was implemented resulting in more accurate SPEs, particularly on the west coast. Increased frequency of SPEs resulted in greater product utility.

The National Centers for Environmental Prediction's (NCEP's) Environmental Modeling Center (EMC) evaluated the four-layer total precipitable water (TPW) data. Their assessment showed a positive impact, primarily drying out non-precipitation areas. The TPW product became operational in April 1996.

In 1997, more products were available for NWS Forecast Offices to utilize and assess their usefulness to operations. These new products were developed by the National Environmental Satellite, Data, and Information Service's (NESDIS') Office of Research and Applications (ORA) Forecast Products Development Team (FPDT) and the Cooperative Institute for Meteorological Satellite Studies (CIMSS) and placed on their web sites. Many of these same products were also made available to the NWS Western Region for distribution on their frame relay network (FRN). As a result of these assessments the field, through their Regional Headquarters, developed a list of new satellite products and applications they wanted to see on AWIPS. The Office of Services and NESDIS are working off the list to provide operational products and select applications to the field. It is slow going, but the derived product imagery (DPI) of Lifted Index, Total Precipitable Water, Skin Temperature and Cloud Top Pressure (to be Cloud Top Height with the next AWIPS software release) are available over the satellite broadcast network (SBN) and displayed on AWIPS. A sophisticated Cloud Height Algorithm, written by NCEP's Aviation Weather Center (AWC), is planned for the next AWIPS software release.

Also in the 1997 time-frame CIMSS and FPDT made the high density cloud drift and water vapor winds available for NCEP's EMC and Tropical Prediction Center (TPC) to evaluate. The results were very favorable. EMC is using the data in their models and TPC is using the data to aid in their hurricane track forecasts. This was followed by high density winds from the visible imagery to show the low level circulation. TPC uses the data to locate surface low pressure centers to monitor for possible cyclogenesis.

Following the May 1997 Jarrell, Texas F-5 Tornado, FPDT developed a GOES sounder case study demonstrating the utility of the data to spot areas of instability which bear further monitoring. The data indicated the area was dramatically destabilizing several hours before any clouds started to form. This case study was widely disseminated via the web and in hard copy form and presented at AMS Conferences.

In 1998 GOES-10 was launched. The extra satellite provided an opportunity to view test images on AWIPS at five-minute intervals. The data were shipped over the GOES-West SBN and viewed on the Western Region's AWIPS and RAMSDIS systems. The data proved to be of significant value during convective situations and aided in monitoring pre-convective environments, defining warning areas and in increasing warning lead times.

Also during 1998, the Office of Meteorology conducted an assessment of the automated precipitation estimation product. The evaluation indicated the product was not ready for operational implementation. Several suggestions for improvement were provided and subsequently incorporated.

1999 saw another assessment of the automated precipitation estimation product and the first full blown field assessment of the GOES sounder. The purpose of the sounder assessment was to assess the operational value of the GOES sounder products to the NWS Forecast and Warning Program. The products assessed included Total Precipitable Water, Lifted Index, Convective Available Potential Energy, Convective Inhibition, Vertical Temperature/Moisture Soundings , Skin Temperature, and Cloud Top Pressure. The results were definitive and in the majority of cases very positive. GOES sounder products increased forecasters' confidence convection would/would not develop, heightened their situational awareness, and led to the issuance of improved forecast products. The forecasters noted the sounder data were especially valuable for: locating maximum instability and atmospheric moisture axes prior to convective development; observing temporal changes in stability and moisture; and judging validity of numerical model forecasts.

The 1999 automated precipitation estimation assessment yielded favorable results, subsequently leading to operational implementation during the Spring of 2000. Situations exist (e.g., tropical cyclones making landfall and warm top convection) where the manual precipitation estimates will still be done, but the automated process was heralded as a success since NESDIS can now provide more areal estimates at greater frequency than ever before.

There was a planned assessment of the new products on AWIPS, but because of delays in getting the products into AWIPS no assessment was done in 2000.

Over its several year span the GOES Assessment has significantly aided the NWS in its satellite requirements process. The results of the GOES-10 imagery AWIPS test led to the requirement to have CONUS updates every 5 minutes as a routine mode of operations. Conflicts arising from a need for simultaneous RSOs for northern hemisphere mesoscale systems, high density winds to feed the hourly models, and southern hemisphere data for the global models led to the requirement for full disk updates every 15 minutes. This will allow the simultaneous monitoring of severe weather over the great plains and tropical cyclones in both oceans. The outages due to eclipse and keep-out-zones, which were not a real problem with the spinners, has caused problems with NWS operations, since severe weather can happen around local midnight. The request to operate through eclipse and keep-out-zones was added to the GOES-N/Q satellites and carried forth into the GOES-R requirements document.

The success with the sounder data over the CONUS and surrounding oceans led to the requirement to expand the capability of the sounder and provide hourly updates to locations not presently scanned or only scanned once every 6 hours. This will mean places like Puerto Rico and Hawaii will receive the same sounder products as the mainland. And since Hawaii has responsibility in the Southern Hemisphere, they want to be able to provide the same level of support. The sounder data will be able to cover the full domain of the future ETA model, thus providing hourly inputs and being able to provide inputs to the global model at the frequency of the model run, particularly in the Southern Hemisphere. The data might be able to aid the AWC in their icing, turbulence, and severe weather outlooks in both hemispheres.

The NWS looks forward to research with the interferometer and new imager to produce new products for use in the models and the forecaster in the field.

Polar orbiting sensors have their way into the GOES requirements. The lightning mapper on the Tropical Rainfall Measurement Mission and the ability of microwave to see through clouds for both imagery and soundings (Defense Meteorological Satellite Programs's Microwave Imager and NOAA microwave sounders) are two potential candidates to fly on GOES. Thus the requirement for additional space to accommodate future sensors. Both of these will enhance the capability of the services of the NWS.

NCAR View of Future GOES (Dr. David Johnson/NCAR/RAP)

Fisheries and Oceanographic Applications (Dave Foley/ NMFS)

The recent emergence of high-quality sea surface temperature (SST) from geostationary meteorological satellites (GOES) adds an important tool to the suite of satellite-based measurements used for environmental monitoring in the central Pacific Ocean. The primary advantage of the GOES SST data set is the high sampling rate (1 image every hour). This allows the production of high quality composite images with virtually full spatial coverage. These images are ideal for use in GIS or data fusion. Specific applications of experimental SST products from the GOES-10 satellite include guiding fisheries research vessels to regions and phenomena of interest, monitoring the formation and propagation of oceanic vortices, locating essential fish habitat, and identifying regions associated with the transport of marine debris. If data streams of this kind continue through the GOES-R program we can expect to profoundly improve our capacity to include timely and relevant environmental information at many stages of decision-making processes within the fisheries and oceanographic communities.

Value of Future GOES to Navy Operations (Capt. Michael Pind/Asst. Chief-of-Staff for Plans and Programs at HQ, Naval Meteorology and Oceanography Command)

Capt. Mike Pind will describe current Navy and Marine Corps GOES usage, our future GOES needs, and the exciting potential uses to bring improved Meteorological and Oceanographic support to operations.

Value of Future GOES to Army Operations (Dr. Don Hoock/U.S. Army Research Laboratory)

This is an information briefing on the relevance of future GOES and meteorological satellite data to Army operations. There are many Army users for real-time meteorological satellite data. As you will see, the current transformation of the Army to better support small scale contingencies with lighter, agile forces will place even greater emphasis in the future on having near real-time environmental information at high spatial and temporal resolution. Future GOES will certainly help support that mission.

Meteorological corrections for artillery firing solutions have historically been one of the oldest Army requirements for meteorological data. Field artillery met units collect balloon vertical profile and surface data at the gun locations. In the past, the profile at the gun has been applied along the entire trajectory. Today, however, with longer-range artillery and rockets, the approach is being developed to include the changing met along the trajectory through a combination of local forecast modeling (currently involving MM5 as the model) and inferring information from Meteorological Satellites, MetSat.

Knowledge of weather in the target area has become absolutely critical to effective use of smart munitions. Not only can smart sensors become obscured, but also the terminal munitions can be significantly impacted by winds, turbulence, icing and precipitation. Satellite sensors provide key information on target area met conditions.

R&D concepts explored by the Army Research Lab have involved the fusion of ground-based and space-based remote sensing to produce automated wind and virtual temperature profiles. The future GOES ABS, for example, promises excellent mean temperature and moisture retrievals, all the way down to the surface, approaching 1 deg RMSE. Combined with a ground-based, passive millimeter wave radiometer and/or a 924 MHZ active wind radar to augment the GOES visible and IR sensors could produce significantly improved virtual temperature and winds, and more frequent monitoring of dynamic changes in target area. Potential concerns are relevance of GOES coverage areas to Army operations, getting data to the field, effects of cloud cover on retrievals, and individual retrieval errors from ABS, especially near the surface and tropopause.

The Army needs a mix of high resolution and low resolution MetSat data from both polar orbiter and geostationary satellites. Over the past few years the Army Digitization Program has transformed its tactical Command and Control systems into a unified Command, Control, Communications, Computer and Intelligence (C4I) Battle Command System. Weather situational awareness and weather forecast information, including MetSat imagery overlaid digitally on the Common Operational Picture and tactical maps can be very powerful tools for decision makers. How the Army will get that data is being worked out, but it will be a combination of low-res direct receive and distribution through Air Force data channels of high resolution data and products. The Army's battlefield weather C4I system is the Integrated Meteorological System (IMETS).

IMETS is operated by Air Force Combat Weather Teams who deploy with Army units in the field. The IMETS requirement is for three types of data: forecast databases transmitted from the Air Force Weather Agency and high-resolution, near surface battlescale forecasts generated on-scene; surface and upper air observations; and MetSat data. IMETS products and decision aids are accessible by any of the Army Battle Command Systems.

The details of data flow to the Weather Effects Workstation (WEW) on the IMETS shows that Air Force and Navy forecasts, observations and MetSat data are transmitted to the field over T-VSAT communications. The IMETS is connected to the other Battle Command Systems in a Tactical Operations Center over a LAN.

IMETS Combat Weather Team forecasters have a range of forecasting tools for analyzing and displaying products, including a tactical web page. The IMETS database can be accessed to pull forecast contours, weather impact decision aids and the Joint Common Database with IMETS current weather for the Common Tactical Picture.

IMETS has been deployed at Division and higher echelon operations centers, where mission planning out to several days is performed, along with mission execution. The Army is undergoing a transformation, however. Future Combat Systems will support lighter operations. Command and control will be mobile and will assimilate data from sensor networks. Not surprisingly, MetSat information will become even more important for lower-echelon daily planning and mission execution.

This year the digital maps will be able to display MetSat images as one layer of the weather intelligence. The IMETS web page will support time loops of data.

The Army will receive most satellite data from the Air Force. There will be substantial numbers of IMETS fielded, ranging from vehicle-mounted systems complete with Air Force Small Tactical Terminal (STT) ground stations, on down to a two-man lift laptop configuration. The Air Force and Army are in the process of re-engineering MetSat data efforts. In the near term we will be working to reduce the "antenna farm" by having data sent by com-sat from the Air Force and processed on the STT . In the mid term we will move through a program called JMIST to a combination of processed MetSat data sent directly to the IMETS WEW and low-res direct receive as an organic backup when comms are not available or not timely.

There are a number of environmental quantities required by the Army, many of which will be available through next generation POES and GOES. These are outlined on the next few slides, and they include a lot of information about ground state (especially soil moisture, surface state and vegetation), boundary layer conditions (especially aerosols and obscurants), and weather (clouds, precip, …).

We should also mention a few other applications for the Army. Space weather and decision aids supporting impact on communications are operationally important. The Army Engineers work the terrain, hydrology, mobility, and trafficability modeling and information on the battlefield. And, Army weather installations on test ranges through the US provide mission and daily range support for which timely MetSat data is essential.

In conclusion, the transformed Army will need better real-time situational awareness at resolutions and time updates certainly supported by future GOES. We are particularly excited about the potential improvements to artillery and Command and Control functions. The issues of how the Army will receive these data in the field are being resolved.

Value of Future GOES to USAF Operations (Col. Robert Allen/AFWA)

The Air Force Weather Agency (AFWA) provides weather data and forecasting support, including cloud analyses and forecasts, aviation hazards forecasts, severe weather warnings for AF/Army installations, mission-tailored forecasts, tropical cyclone reconnaissance, and space environment observations, analyses, forecasts, and warnings. AFWA customers range from the National Command Authorities, through the unified major commands, and down to individual combat weather teams at Army posts and Air Force bases.

Air Force Weather has reorganized into a strategic center/hub/combat weather team structure. The strategic center provides broad, overarching support to all of Air Force Weather. Each hub, or Operational Weather Squadron, is responsible for a certain area of the world. The base or post combat weather team provides weather information tailored for each individual mission or customer.

The Advanced Baseline Imager (ABI) will be used by AFW in a manner similar to that of other users, such as for aviation hazards, severe weather, and so forth. Detecting aerosols, thin cirrus, and volcanic ash should be improved by the ABI and is greatly anticipated. Our automated cloud analysis and forecast system will be enhanced, and direct radiance assimilation of the data into mesoscale models will improve their performance.

If low-light imaging is included on the ABI, AFW can take advantage of its long experience with such data from the DMSP satellites. Depending on the ABI's performance, nighttime visible imaging is possible with > 25% lunar illumination may be possible, and the visible data's usefulness could be extended by 2-3 hours per day.

AFW has the mission to provide space weather analyses, forecasts, and warnings to DoD operators and decision-makers. The Solar X-ray Imager will improve AFW capabilities for monitoring and forecasting solar events.

The Advanced Baseline Sounder (ABS) will greatly enhance our mesoscale modeling efforts by improving the analyses, which will in turn give better support to Air Force and Army training missions in the US and operations all over the Western Hemisphere.

The Special Events Imager (SEI) and Lightning Mapper (LM) will provide important new sources of data that would be unavailable from any other source. The SEI's high-resolution multispectral capability will help detect and analyze small-scale transient events. The LM will improve our detection and forecasting of thunderstorms, especially in areas outside of the CONUS.

AFW has customers that require regular geostationary imagery over all of South America. With the current GOES scan strategy, those customers are negatively impacted during rapid-scan ops. The expected ABI capability of full-disk coverage every 15 minutes will meet DoD requirements as documented in MJCS 154-86.

Data outages due to satellite eclipses in the spring and fall also have a negative impact, and AFW is strongly interested in minimizing or eliminating these outages.

Deployed users will require a signal that can be acquired by lightweight, portable, and rugged equipment. The receive antenna should be easily aligned and not require tracking. The Low-rate Imagery Transmission (LRIT) signal is likely to be the signal of choice.

For strategic centers, and other users that are not mobile/deployable, more choices for data distribution are available. Direct broadcast, comm satellite, and landline are among the possibilities. These users will require the best data available, from the High-rate Imagery Transmission (HRIT) or GVAR-equivalent signal.

In summary, Air Force Weather is eagerly anticipating the improved capabilities these advanced instruments will provide for our diverse customer base.

Commercial Aviation Issues **(Ed Miller Project Manager, Volcanic Ash and Aviation Safety, Aviation Weather Program, ALPA)**

GOES without a word to the users went from water vapor column to cloud cover. This resulted in the dropping of the 12 micron channel used in the split window detection of volcanic ash. The ability to detect volcanic ash via split window is not scheduled to return until 2008.

In 1999, ALPA was a member of the group that urged NASA to earmark the NASA VOLCAM research project for inclusion on future GOES spacecraft. VOLCAM project passed the initial NASA recognition and processing phase and there was space available on the then schedule. GOES "N" – January 2003 and GOES "O" to be launched early in 2005. Inclusion of VOLCAM on either or both would have eliminated the five-year blind spot for detection of volcanic ash. Unfortunately, though the need for or detection capability like VOLCAM is obvious to aviation's users, the FAA has never formally requested the information that such a system could provide as a "product". Consequently since NOAA has not received a formal FAA request and since NOAA budget constraints force frugal management, NOAA has been reluctant to commit the approximately 10 million dollars necessary to put the VOLCAM server on a GOES satellite. In addition, the National Weather Service (NWS), a part of NOAA, has not supported VOLCAM because they have insisted that "something better" was allegedly being developed. The "something better" has not materialized, nor is anything other than VOLCAM on the current research and development horizon. Therefore, VOLCAM appears to be the only immediate solution.

Aviation is a major piston in the economic engine of this country. We will not remain so if basic government services are not supplied. Moreover, let's remember, planes carry people. Human lives are at risk when ash clouds go undetected. I for one do not wish to witness a body count on my watch especially when the technology and the funds exist to mitigate this hazard.

Commercial Weather Services: Issues **(Maria Pirone/WSI)**

NESDIS has successfully developed and supported the GOES Satellite Program through the current generation. The discussions we have this week must take us to the next generation --- to the vision for 2020. From a Global perspective to the most local view, we must strive to cover the distance between our neighbors and we must lead the world in what can be accomplished.

Ed Barton, "Futurist", stated at the NOAA Constituent Workshop that - "To stay current with technology, industry must re-invent 20% of their business every year. This means that in 5 years, successful companies have totally changed the way they do business." If this is true, than we must ask ourselves if we are approaching this from the right direction--maybe we should be trying to streamline the 10 year process.

Industry Uses of the Data today include: Operational Forecasting & Nowcasting; Visualizations for Media; Numerical Weather Prediction, specifically Mesoscale modeling; Derived Products; Fog Images; Fire & Smoke; Lifestyle Products; and as a tool for monitoring the National Radar network. It is also used for Aviation, for Icing Models, International flightplanning, specifically to data sparse Latin America, winds for flightplanning models, and trans-oceanic flightplanning. In Agriculture, it is used for crop planning and farm maintenance. It's oceanic uses include Ocean color for fishing and Coastal & Ocean Modeling.

New Media include: Free Web Sites, Remote Devices, Pagers, Handheld PC's, and Desktop Alerting via E-mail.

Commercial weather Services' sensor requirements include dividing the spectrum to further define layers and particle size This is critical--the current plan to maximize the ranges is sound. Also, the Visible, Shortwave IR, Water Vapor, IR Window Channels (1,2,3,4) and Sounder data are critical. For IOO, our needs are for a Special Events Instrument, Lightning, and a True Color imager. Spatial Resolution is adequate for today's needs at 1 and 4km, however, 1/2 km and 2km should be a goal. Temporal Resolution for CONUS updates is adequate today at 15 minutes. However, to take advantage of 1/2 km spatial resolution, 5 minute updates may be necessary.

For operational considerations , the split scanning schedule currently in place requires 25 minutes for a full disk scan every 3 hours--impacting animation sequences. The planned 15 minute scan is preferred. What if…..We had a 3 satellite constellation….Move GOES-East to 45^{O}, Move GOES-West over 140^{O}, and put new GOES at 90^{O}. Then rapid scans would not impact the operational scans, and we might begin to have a seamless global network…someday.

In summary, technology is changing so fast that applying today's costs to tomorrow's technology is misleading. There are two choices: 1. Speed up the implementation/launch phases so the planning can have a realistic lead time, or 2. Use the current schedules and assume that the technology to move the data will be available in a cost-effective form. Also that ground station technology will keep pace with the lowering cost/higher performance business model.

Climate and Hydrology Applications **(Dr. Paul Try/ Director, International GEWEX Project Office**

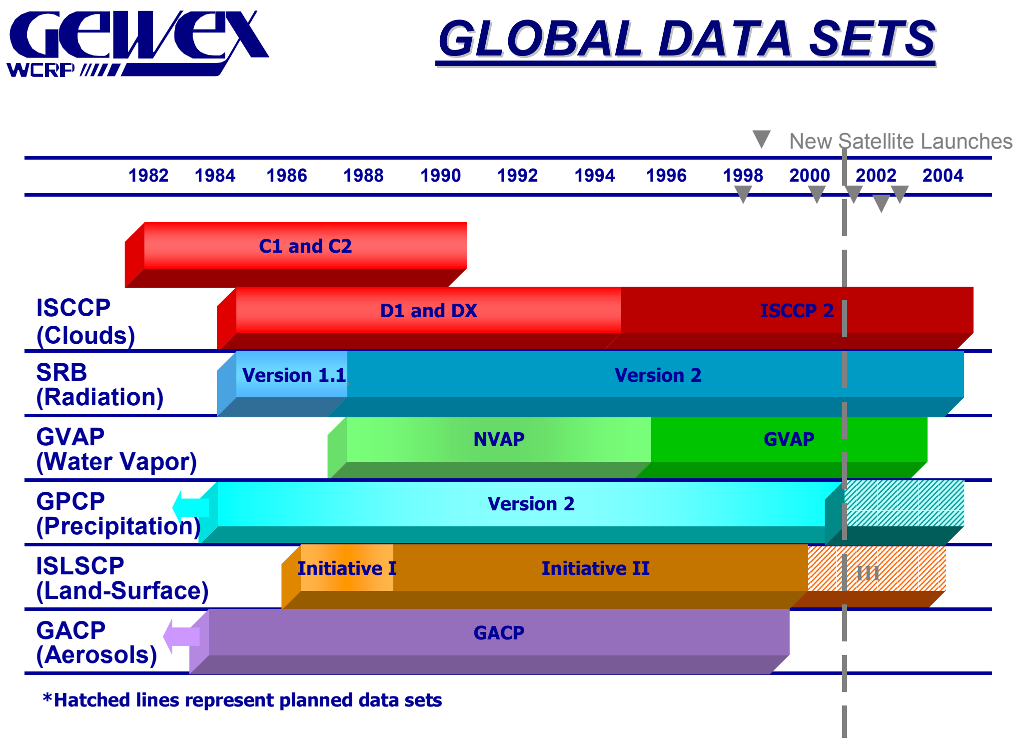
GOES and the other geostationary meteorological satellites are playing a significant role in climate and hydrology research through the Global Energy and Water Cycle Experiment (GEWEX) project. The GEWEX project was initiated by the World Climate Research Programme (WCRP) to observe, understand and model the hydrological cycle and energy fluxes in the atmosphere, at land surface and in the upper oceans. It is an integrated program of research, observations, and science activities ultimately leading to the prediction of global and regional climate change.

The implementation of GEWEX involves the development of global data sets, improved parameterizations for regional and global models, and continental-scale experiments to observe and understand regional processes worldwide. It is the first objective of GEWEX, " to determine the hydrological cycle and energy fluxes by means of global measurements of atmospheric and surface properties", that has been the focus of the GEWEX global data set development and has exploited the GOES satellites extensively. The International Satellite Cloud Climatology Project (ISCCP), the Surface Radiation Budget (SRB) Project, and the Global Precipitation Climatology Project (GPCP) are producing up to 20 year global data sets with significant use of GOES data. These data sets are then being used to address several key questions on climate variations raised by the Intergovernmental Panel on Climate Change (IPCC). The GEWEX Water Vapor Project (GVaP) also is exploiting the 6.7 mm data to address water vapor distribution and transport. These GOES data sets, while having calibration deficiencies which limit their research use, are able to provide both a global view (showing regional and daily variations of the key climate parameters) and a critical 20 year context for the new series of environmental satellites (TERRA, TRMM, AQUA, ADEOS II, ENVISAT, etc.,) being launched by NASA, NASDA and ESA over the next few years(see figure 1).

The hydrological research community needs very high temporal and spatial resolution (up to 1km and hourly) precipitation data over land areas worldwide, and several projects exploiting higher resolution GOES data have been developed. While the original GOES applications for climate research had early success in providing monthly, 2.5x2.5 degree precipitation data, more recent 0.5x0.5 degree / daily and higher resolution GOES driven precipitation data sets are being evaluated and further developed. These higher resolution data sets are critical for hydrological modeling since precipitation must be resolved at high spatial/temporal resolution to provide the runoff accuracy needed to address both weather and climate science questions.

In addition, several of the GEWEX Continental-scale Experiments (GCIP/GAPP and LBA) are now producing shortwave high resolution SRB data sets based promarily on GOES data to meet their requirements.

In summary, during Phase I of the GEWEX Project (the buildup phase leading up to the exploitation of the new environmental satellites in Phase II), GOES has been the mainstay for three primary data components of GEWEX (ISCCP, SRB and GPCP) and greater use of GOES is being planned to meet the higher resolution precipitation needs of the hydrology research community.



Session 4: Future International Geostationary Satellites

Chairperson: Dr. James Purdom

The Future of Meteosat **(Dr. Johannes Schmetz/ EUMETSAT))**

The paper commences with an overview of EUMETSAT, the European Orgnaisation for the Exploitation of Meteorological Satellites. Then the current geostationary satellite generation of the Meteosat series is briefly described. This satellite system is still going strong with the nominal mission covered by Meteosat-7 at 0° longitude, and an Indian Ocean Data Coverage mission performed by Meteosat-5 at 63° E. In addition the back-up satellite for the nominal mission, Meteosat-6 at 10°, is used to provide a rapid scan service to the meteorological community with a repeat cycle of 10 minutes. This novel service started in 2000 and will be operational by mid 2001.

The presentation continues with a detailed description of the new generation of geostationary satellites in Europe called Meteosat Second Generation (MSG). Capabilities of MSG are greatly enhanced over the current Meteosat series: The twelve channel imager, called SEVIRI (Spinning Enhanced Visible and Infrared Imager) observes the full disk of the Earth with an unprecedented repeat cycle of 15 minutes. Pixels are sampled with a distance of 3 km and the high resolution visible channel has a 1 km sampling distance. Thermal IR channels have an onboard calibration and for the solar channels an operational vicarious procedure is developed aiming at an accuracy of 5%. Meteorological products are derived in so-called Satellite Application Facilities (SAF) and in the central Meteorological Product Extraction Facility (MPEF) at EUMETSAT in Darmstadt; those products are briefly introduced. As additional scientific payload MSG carries a Geostationary Earth Radiation Budget (GERB) instrument observing the broadband thermal infrared and solar radiances exiting the Earth-atmosphere system. The first launch of MSG is scheduled for mid 2002.

The paper concludes with a summary of the User Consultation Process that has been started in January 2001 in order to establish user requirements for a generation of geostationary satellites that ought to follow MSG.

The Role of Geostationary Satellites in the Global Observing System: the WMO Perspective **(Dr. Don Hinsman/WMO)**

The Global Observing System (GOS) was established during the formation of the World Meteorological Organization (WMO) World Weather Watch (WWW). During the nearly four decades since the formation of the WWW, the space component of the GOS has evolved from a constellation of one or more polar-orbiting meteorological satellites to two constellations comprised at least of two near-polar-orbiting satellites and at least five geostationary environmental observation satellites.

The space-based GOS has had a profound impact on WMO Members since the inception of the WWW. Its present observational capabilities permeate almost all products and forecasts provided by the National Meteorological and Hydrological Services (NMHS) in meeting their national mandates. Indeed, observations are fundamental to the NMHS and without them almost all other services would not be possible. These facts alone would justify the high value placed on the GOS by WMO Members. However, the space-based GOS was also the genesis of the WWW. While it is possible that a WWW may have evolved, it was the new and exciting possibilities for observations from space that acted as the catalyst to bring together some of the world's leading experts and allowed them to provide a blueprint, the WWW, for international cooperation that is unparalleled within the meteorological communities.

There are two major constellations in the current space-based GOS. One constellation is the various geostationary satellites, which operate in an equatorial belt and provide a continuous view of the weather from roughly 70°N to 70°S. At present there are satellites at 0° longitude and 63°E (operated by the European Organisation for the Exploitation of Meteorological Satellites - EUMETSAT), a satellite at 76°E (operated by the Russian Federation), a satellite at 105°E (operated by the People's Republic of China), a satellite at 140°E (operated by Japan), and satellites at 135°W and 75°W (operated by the USA).

The second constellation in the current space-based GOS comprises the polar-orbiting satellites operated by the Russian Federation, the USA and the People's Republic of China. The METEOR-3 series has been operated by the Russian Federation since l991. The polar satellite operated by the USA is an evolutionary development of the TIROS satellite, first launched in April l960. The present NOAA series, based on the TIROS-N system, has been operated by the USA since l978. FY-1C, the third in the series of China's polar-orbiting satellites, is now operational. These spacecraft provide coverage of the polar regions beyond the view of the geostationary satellites and fly at altitudes of 850 to 900 km.

The ability of geostationary satellites to provide a continuous view of weather systems make them invaluable in following the motion, development, and decay of such phenomena. Even such short-term events such as severe thunderstorms, with a life-time of only a few hours, can be successfully recognized in their early stages and appropriate warnings of the time and area of their maximum impact can be expeditiously provided to the general public. For this reason, its warning capability has been the primary justification for the geostationary spacecraft. Since 71 per cent of the Earth's surface is water and even the land areas have many regions which are sparsely inhabited, the polar-orbiting satellite system provides the data needed to compensate the deficiencies in conventional observing networks. Flying in a near-polar orbit, the spacecraft is able to acquire data from all parts of the globe in the course of a series of successive revolutions. For these reasons the polar-orbiting satellites are principally used to obtain: (a) daily global cloud cover; and (b) accurate quantitative measurements of surface temperature and of the vertical variation of temperature and water vapour in the atmosphere. There is a distinct advantage in receiving global data acquired by a single set of observing sensors. Together, the polar-orbiting and geostationary satellites constitute a truly global meteorological satellite network.

WMO Members access the data, products and services from the space-based component of the GOS in a variety of ways including direct reception and the World Weather Watch's Global Telelcommunication Systems. Most WMO Members have the ability to receive data directly from the satellites. The World Weather Watch implementation goals for the direct reception of satellite data states that each WMO Member should be equipped with at least one polar-orbiting satellite data receiver and one geostationary satellite data receiver. At present there are over 1,300 receivers world-wide in the National Meteorological and Hydrological Services which equates to over 80 % implementation.

In the near future, the analogue direct dissemination systems called APT and WEFAX from polar-orbiting and geostationary satellites respectively, will start to transition into digital services. During 2002 and 2003, users in Europe, Asia, South, Central and North America will start this process. WMO has worked closely with the satellite operators through the Coordination Group for Meteorological Satellites (CGMS) in order to keep its Members informed of the status of the change and actions that should be taken to enable utilization of this new and power service.

Session 5: Communications, Ancillary Services & Training Issues

Chairperson: Anthony Mostek

Options for data distribution **(Peter Woolner/Mitretek)**

The GOES-R spacecraft will support seven types of data re-broadcast to users: GOES Re-Broadcast (GRB), the corollary to today's GVAR, but from the new ABI, and ABS or GIFTS instruments; SEM and SXI, the solar environment instruments; Instrument(s) of Opportunity (IOO), e.g., SEI, Volcam, etc.; Low Rate Information Transmission (LRIT); Emergency Managers Weather Information Network (EMWIN); Data Collection System (DCS); and Search and Rescue Satellite Aided Tracking (SARSAT). Due to the significant change in data rate for the GRB over GVAR, multiple options for this downlink are being evaluated, including a low-rate and a high-rate version utilizing L-Band, X-Band, and combinations of the two bands. Continuation of the Multi-use Data Link is being considered as a CCSDS formatted downlink supporting the solar and IOO instruments, as well as special spacecraft engineering data. The LRIT, EMWIN, DCS, and SARSAT services will experience date rate or functional expansion, and changes in frequency and/or modulation type, but otherwise be the basic downlink they are to users today.

Ancillary Services **(Dane Clark/ NESDIS)**

Several critical user services have been developed using the communications segment of the GOES Satellite. These are Data Collection, Direct Broadcast and Search and Rescue. Users easily exceed one hundred thousand for these GOES direct services. These services are used directly U.S. Government agencies, foreign governments, private companies and the general public to support life-saving applications.

The GOES Data Collection System (DCS) is a relay system used to collect information from earth-based platforms. These platforms transmit environmental data observed by the sensors on the platform, to the NOAA GOES geostationary satellites. The transponder on board the satellite detects this signal, rebroadcasting it to the Wallops Command and Data Acquisition station, in Wallops Island, Virginia. During this rebroadcast any ground receiving equipment with the correct configuration can also receive this signal.

Platforms can be placed in remote locations and left to operate with minimal human intervention. Initial installation and regular maintenance are usually the extent of operator involvement. This allows observations from sites that may not be readily accessible during parts of the year, and for more frequent and geographically complete environmental monitoring. Data collected in real-time supports forecasting and warnings for Forest Fires, Flash Flood, Hurricanes, Earthquakes, Tsunamis, Oil-spills, and other environmental applications.

The NOAA GOES satellites continuously transmit their image and environmental data. Through satellite direct readout, anyone can receive these data without a license or prior approval from NOAA. Users of direct readout services include meteorological services, various state and Federal agencies, the military, colleges and universities, primary and secondary schools, television stations, commercial enterprises, recreational sailors, and many private individuals.

The NOAA geostationary GOES satellites provide the WEFAX (Weather Facsimile) service. This is a broadcast of processed pictures from the GOES satellites, some non-U.S. satellites, and some National Weather Service charts. The GOES GVAR (GOES VARiable) service is the digital high resolution data transmission from GOES instruments. WEFAX can be received with low cost equipment, while GVAR require more sophisticated, expensive receivers to process the digital data.

The Data Services Team is the focal point within the Direct Services Division for users of the GOES DCS and operators of direct readout stations that receive real-time data from the NOAA GOES satellites. The Data Services Team strives to continuously improve the management of the GOES and Argos DCS programs, the accessibility of critical information for ground station operators, and coordination of direct readout services. To help accomplish this mission, Team members can be found at meetings of GOES DCS and direct readout users. Technical satellite operational and administrative information is provided through our web site, E-mail and a limited number of technical publications.

Since the late 1970's the SARSAT Program has utilized the NOAA polar-orbiting series of environmental satellites to save thousands of lives world-wide. Over the past few years, Cospas-Sarsat (the International Program) has been experimenting with 406 MHz receivers on geostationary earth orbiting (GEO) satellites. These experiments have proven the capability of GEOSAR to provide immediate alerting and identification of 406 MHz beacons and in combination with a GPS receiver can provide rescue forces additional time and exact location. Since every few minutes saved in reaching the scene of a distress amounts to an increased chance of survival, the early warning capability of GEOSAR provides a valuable tool to increase the effectiveness of the Cospas-Sarsat system and, ultimately, save more lives.

Training Options **(Anthony Mostek / NWS)**

The presentation will cover the following topics:

- Distance Education - VISITview Teletraining Tool
- VISIT (Virtual Institute for Satellite Integration Training) – Some Teletraining Metrics
- Examples of VISITview Teletraining Sessions
- Lessons Learned from GOES–I/-M
- Too Early for Training?Issues for Next Generation GOES The teletraining approach used by the National Weather Service (NWS) and developed by the Virtual Institute for Satellite Integration Training (VISIT) program is presented. Teletraining is one component of distance learning utilized by the NWS to provide cost-effective training to the operational weather forecasters located in offices across all 50 states. The training is open to all operational weather forecasters including staff from the Department of Defense and from other countries. The VISIT program brings together diverse training activities that have traditionally focused on individual sensors such as radar, satellite, and other observing systems. Information on the VISIT program can be accessed at www.cira.colostate.edu/ramm/visit/visithome.asp.

To support the evolving training needs of the operational weather forecaster, the VISIT program is developing a series of instructional components that utilize various training approaches. Training sessions and modules are developed using both remote Web-based and remote-or-local teletraining approaches. To get instructors connected directly with the forecasters in the field, an interactive teletraining tool called VISITview was developed. VISITview (www.ssec.wisc.edu/visitview/) is a platform-independent distance learning and collaboration software program. It allows multiple users located in different offices to view the same series of images, and provides a large number of features, including annotation, color enhancements, zooming, animations, multi-panel displays, etc. The presentation will provide a short overview of the latest developments of VISITview program, a review of the number offices and students participating in teletraining, and include some examples from teletraining sessions that use VISITview.

The presentation will then cover some examples of the lessons learned from the current GOES I/M series (need for user assessment and feedback, delays in sounder products, etc.). The question is asked if it is too early to be planning for training with the next generation of GOES. The presentation will conclude with issues to consider for the next generation of GOES with a focus on the need for rapid technology transfer.

Appendix 3—References

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