P2.1 HIGHLIGHTS FROM THE SECOND GOES USERS' CONFERENCE: RECOMMENDATIONS FOR THE GOES-R SERIES

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1. INTRODUCTION

Two of the primary sources of recommendations for capabilities of the Geostationary Operational Environmental Satellite (GOES)-R series are the GOES Operational Requirements Working Group (GORWG), providing requirements from the line offices of the National Oceanic and Atmospheric Administration (NOAA), and the GOES Users' Conferences, providing the needs of a wide cross section of the GOES User community. There have been two conferences focusing on the GOES-R series. The first GOES Users' Conference was held from May 22 through 24, 2001 in Boulder Colorado, with approximately 200 participants from government, the private sector, academia and the international community. A second GOES Users' Conference was held in Boulder Colorado from October 1 to 3, 2002. The conferences were organized by NOAA with cooperation of the National Aeronautics and Space Administration (NASA), the American Meteorological Society (AMS, the National Weather Association, the World Meteorological Organization (WMO), and the National Institute of Standards and Technology. EUMETSAT and the Department of Defense (DoD) have also supplied observational requirements that have been incorporated into the GOES-R Program Requirements Document (GPRD Version I).

The goals of the Second GOES Users' Conferences were (1) to inform GOES users of plans for the next generation capabilities: (2) to provide information on the potential applications; (3) to determine user needs for new products, data distribution, and data archiving; (4) to assess potential user and societal benefits of GOES capabilities; and (5) to develop methods to improve communication between NOAA Satellite and Information Service (NESDIS) and the GOES user community. During each conference, the participants strongly supported the concept of instruments with dramatic advancements in spatial coverage, radiometric accuracy and spatial, and temporal resolution. If these recommendations are followed, the new instruments will offer the potential for improvements in environmental observations for weather, climate, hydrological, and oceanographic applications.

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This paper will focus on the highlights of the recommendations from the Second GOES Users' Conference and the expected instrument capabilities to meet user needs. The notional baseline for observational capabilities in GOES-R includes: 0.5 km resolution in visible imagery (other visible bands will be 1 km); 2 km resolution in infrared channels; up to 30 second image refresh rate over severe storms; up to 5 minute refresh rate over the entire full disk; up to 16 spectral channels in the imager; an IR (infrared) sounder (part of the Hyper spectral Environmental Suite (HES) with about 1500 narrow spectral bands for much improved vertical resolution; and a 4 km footprint on the sounder. Several of the spectral bands on the advanced imager are similar to those already on the Meteosat Second Generation's Spinning Environmental Visible and Infrared Instrument (SEVIRI). The new instruments will allow for dramatic improvements in estimating cloud heights, sea and land surface temperatures, vegetation under clear skies, fires, volcanic ash clouds, ice, haze, snow, cloud-drift and moisture-drift winds, cloud properties, such as particle size, and cloud phase, quantitative precipitation estimates, the three dimensional atmospheric temperature and moisture structure, and in determining the diurnal component of climatic fluctuations. The notional baseline also includes a lightning mapper. Recommendations for additional instruments, included a microwave sounder, which will be assessed in future trade studies.

2. GORWG

The GOES Operational Requirements Working Group (GORWG) comprised of representatives from each of the NOAA line offices, including NOAA's: Satellite and information (NESDIS), National Weather Service (NWS), Research (OAR), Ocean Service (NOS), Fisheries (NMFS), and Marine and Aviation Operations (NMAO), gathered, documented, and validated the NOAA requirements for GOES-R. The requirements were documented in the GOES Program Requirements Document, Version I (GPRD I), with formal NOAA line office approval scheduled for late CY2003. The GPRD I, which can be found at: http://www.osd.noaa.gov/GOES_R/forge.htm (note there is an "_" between "GOES" and "R") will form the foundation of the final GOES requirements document, GPRD II, scheduled for approval in 2005.

3. GOES USERS' CONFERENCES

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

To further NOAA and User information exchange, two GOES Users' Conferences were held in Boulder Colorado. The first was in May 2001 and the second in October 2003, each with nearly 200 participants from the private sector, academia, government, and the international community. The goals of the conferences are listed in the introduction.

4. RECOMMENDATIONS FROM THE SECOND GOES USERS' CONFERENCE

Regarding requirements for atmospheric applications, participants of the Second GOES Users' Conference re-stated many of the conclusions from the first conference including the need for dramatic improvements in spatial, temporal, and spectral resolution, and radiometric performance from both the Imager and HES. The Imager requirements were dealt with in great detail in the first conference. However, one additional recommendation for imaging capabilities called for the use of hyper spectral instruments over discrete channels, if it is not cost prohibitive.

The specific user recommendations for the HES IR sounder follow:

1) 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.

2) It should be capable of operating in a rapid scan mode, sacrificing areal coverage for greater temporal resolution over a limited area when needed.

3) It should have a field of view no larger than 4 km, to allow for more observations between clouds.

4) It should be able to detect temperature inversions, which are critical for severe weather forecasting.

5) Calibration information and algorithms to generate products should be made available to the user community.

6) 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.

7) Funding for research and development of new satellite products should be part of the satellite acquisition budget.

8) For developing new satellite products there should be improved collaboration between research and operations.

9) In operations there is a need for a blend of data and products from operational and research satellites.

Participants also recommended the need for flexibility in HES operations. In some situations scanning the full disk would provide maximum benefits, while in other cases, such as forecasting a severe thunderstorm outbreak, scanning a smaller area at higher spatial resolution more frequently would provide greater benefits.

5. MICROWAVE SOUNDER

In order to provide information within and below cloud decks, and to improve precipitation estimates, participants recommended that a microwave sounder be considered for the GOES-R Series. Both theoretical studies and data from polar orbiting meteorological satellites make clear the superiority of combined infrared and microwave sounder systems relative to either system operating alone (Staelin et al, 1995). Observing system simulation experiments (OSSEs) have also pointed to the potential improvement in numerical forecasts of extra tropical cyclones associated with microwave soundings from geostationary orbit. Infrared sounders alone do not have adequate cloud penetration ability to satisfy most forecast-initialized requirements of increasingly improved numerical weather prediction models, while microwave sounders alone do not have sufficient numbers of sensitive narrow bandwidth channels to rival the high performance offered by modern hyper spectral infrared sounders. Not only do useful numerical weather predictions require both sensor types, but also certain nowcasting products require the unique physical information available in these two widely separated spectral bands. For example, information from infrared channels provides cloud-top temperatures in areas useful for precipitation estimates, while multi-channel microwave imagery reveals the altitudes and sizes of convective cells, which provide additional precipitation signatures, which are most useful when these cell tops are obscured by cirrus or other clouds. Similarly, infrared observations characterize cirrus and other thin clouds, whereas microwave sensors extend this diagnostic capability to heavier cumulus clouds and light precipitation.

Input to numerical models is another example of an application of microwave data that would provide benefits to the meteorological community. To date, GOES satellite soundings for potential numerical weather prediction applications have been limited to areas with adequate breaks between clouds, excluding many of the more significant and damaging weather events. Microwave sensors on polar-orbiting satellites and aircraft have demonstrated their value for cloudy soundings, and simulations of such microwave sensors in combination with future hyper spectral GOES sounders are particularly encouraging. Improved assimilation of active weather areas including vertical motions and rainfall rates are essential for hourly model runs.

6. LIGHTNING MAPPER

As recommended by conference participants, a lightning mapper will be an integral part of the GOES-R instrument suite. Lightning data provides useful information for a number of forecast operations that is not available from radar or current satellite data. Commercial ground-based lightning detection processing systems are designed to display only cloud-to-ground strokes, and not the much more plentiful cloud-to-cloud flashes. Research data, through limited, indicates that cloud-to-cloud lightning typically precedes the cloud-to-ground type in the life cycle of a thunderstorm. A lightning mapper would detect both cloud-to-cloud lightning and cloud-to-ground strokes. This dual capability makes such an instrument complementary to any ground based system. Such an instrument on GOES will greatly aid forecast operations dealing with convection, and supplement data sources particularly in mountainous areas where radar data are limited. In-flight experience with lightning mapper data demonstrates that it is a useful proxy for intense convection related to ice flux, updraft strength, convective rainfall, diabatic and latent heating, and upper tropospheric water vapor (Goodman et al., 1988; Williams et al., 1989). Continuous observations from geosynchronous viewpoint provide a database to investigate seasonal, annual and interannual variability for studying short-term climate change. With uniform day-and-night detection efficiency greater than 90% over large areas, a very complete lightning climatology of the western hemisphere will certainly be generated.

A geosynchronous lightning mapper is capable of filling in the enormous fraction of lightning not observed by the Tropical Rainfall Measuring Mission (TRMM) follow-on satellites in the great thunderstorm belts of the western hemisphere, including the southeastern United States, the Gulf of Mexico, the Inter-Tropical Convergence Zone (ITCZ), and the Amazon basin. Continuous observations combined with the sparse sampling pattern used by TRMM should bolster TRMM's goal of obtaining reliable monthly mean precipitation estimates.

Finally for atmospheric chemistry, lightning plays a significant role in generating nitrous oxides. The natural nitrous oxide budget is a matter of great uncertainty at this time, and long-term observations of on of its sources will prove valuable as the subject develops (Chesters, 1997).

7. CLIMATE RECOMMENDATIONS

The climate community, represented in a special panel discussion, and a climate breakout group, also expressed numerous requirements for climate information from the GOES-R series. GOES-R observations together with data from polar orbits, are critical to help understand the diurnal and annual cycles. While a polar- orbiting satellite can observe the entire globe at high resolution, it cannot resolve the diurnal cycle. While a geosynchronous satellite can resolve the diurnal cycle, it is limited to one-quarter of the earth's surface. Therefore a combination of remote sensing data from both sun and earth synchronous orbits yields a synergistic system for studying both the processes and resulting changes in weather and climate.

According to Jedlovec (1994), many of the physical processes that affect climate change, such as clouds, atmospheric chemistry, biological processes and others, have strong diurnal cycles. The magnitude of the diurnal changes is frequently larger than the seasonal or decadal means that will represent global changes. The diurnal changes of these processes must be fully observed and understood before predictions of long-term variability can be made. Only geostationary satellites can view the effects of the diurnal cycle. Also, geostationary satellites have the unique capability to filter out transient phenomena. Many near-surface processes occur under cloud cover. The extent of scene change between subsequent polar-orbiter images makes compositing difficult for slow processes and impossible for transient processes. Geostationary observations can persevere until clouds move or dissipate. Multiple images can often be composited to provide a clear view of near-surface processes slowly varying over areas of interest. The frequent views from geostationary orbit can allow the multiple looks necessary to see the surface through transient cloud cover.

The key recommendation from the climate community is that onboard calibration in all visible and infrared channels is critical for climate applications. Calibration is required to make reliable measurements of climate parameters from GOES-R. The GOES observing location is well suited to determine the diurnal component of chaotic processes like clouds and precipitation, which play a large part in the Earth's synergy and water budget. Long term trends and changes in the diurnal cycle can be measured reliably only by a consistently calibrated time-series of daily processes over decades. Furthermore, GOES-R calibration must be controlled and determined across the spectrum and over the field of regard, before and after launch. Instrumental effects that affect calibration as a function of wavelength and viewing angle should be minimized. For example, the sensitivity to polarized light from the Earth should be minimized among the solar reflective bands. Pre-launch calibration should be traceable to standards. Post-launch calibrations should be validated periodically. Another key point is that GOES-R calibration must be correlated with other satellite radiometers. For climate use, GOES-R instruments require radiometric calibration accuracy and precision that are comparable to the other satellite radiometers on operational and research satellites. The pre-launch and post-launch calibration procedures should facilitate cross-calibration among all the other satellites.

8. OCEAN RECOMMENDATIONS

The Oceanography, Marine Transportation, and Fisheries Session also included a panel discussion and a breakout session. The participants concluded that the planned GOES-R instruments and potential new instruments offer many potential benefits, including: (1) Advances in understanding the role of oceans in coupled geophysical and ecological process; (2) Cost savings and increased safety for marine transportation; (3) Enhanced fisheries production and conservation through science-based knowledge; and (4) Improved numerical prediction (ocean, atmosphere, and coupled) models.

Recommendations to achieve these benefits included: (1) Validated pre- and post-launch calibration on all bands; (2) For coastal zones, spatial resolution on the order of 100 m in the visible and 1 km in the IR bands is needed. (3) There is a need for ocean color systems to link the geophysical environment and the ecosystem.

9. GOES-R NOTIONAL BASELINE

In order to meet the requirements documented by the GOES user community, the instruments included in the GOES-R notional baseline, include an advanced imager (ABI), a Hyper spectral Environmental Suite (HES), a lightning mapper, and advanced space and solar observing instruments. The Advanced Baseline Imager is a new state of the art, 16-channel imager covering 6 visible to near-IR bands (0.47, 0.64 µm, 0.86, 1.38, 1.61, and 2.26 µm), and 10 IR bands (3.90 µm to 13.3 µm). Spatial resolution is band dependent, 0.5 km at nadir for broadband visible, 1.0 km for near IR and 2.0 km for IR. The ABI will provide three imaging sectors: Full Disk (FD), CONUS, and Mesoscale. Full Disk includes the full Earth view from space. The CONUS sector covers a 5000 km x 3000 km area and Mesoscale covers a 1000 x 1000 km square at nadir.

The HES is a multi channel imager and sounder instrument suite with three threshold tasks. HES will provide high-resolution Hemispheric Disk Soundings (DS), Severe Weather Mesoscale (SW/M) soundings, and Coastal Waters (CW) imaging.

HES DS provides 10 km IR resolution from 3.7 µm to 15.4 µm with a one-hour refresh rate of the full disk, 62° local zenith angle. Visible resolution will be 1 km from a single broadband channel (0.4 µm to 1.0 µm). SW/M will cover a 1000 x 1000 km square at 4 km resolution for IR and 1 km for visible from a single broadband channel for cloud detection. HES CW task will provide at least 14 channels coverage from 0.4 µm to 1.0 µm, with a 300 m visible resolution and a 1-hour refresh rate. Coastal Waters are defined as the 400 km zone adjacent to CONUS.

The Space Environment Monitor (SEM) suite on GOES monitors the near-Earth particle and electromagnetic environment as well as the solar EUV (extreme ultraviolet) and X-ray output. Its instruments include a three-axis vector magnetometer, energetic particle sensors (EPS), an extreme ultraviolet sensor (EUVS), and a solar X-ray sensor (XRS). The entire set of instruments is designed to provide real-time measurement of solar activity, the charged particle environment, and the Earth's magnetic field at synchronous orbit. In addition, the Solar X-ray imager (SXI) and the coronagraph provide continuous images of the solar disk in X-ray and white light images of the solar corona, respectively. All SEM instruments will be capable of operating and transmitting data during eclipses, and each instrument will be capable of independent operation.

Of the instruments in the SEM suite, the long history of archived data from the magnetometer, particle sensors, extreme ultraviolet sensor and solar X-ray sensor has proved to be especially useful for many areas of research. It is thus highly desirable that future GOES SEM instruments provide continuity with prior measurements.

The GOES lightning mapper will continuously map all forms of lightning discharges with a high spatial resolution and detection efficiency, and should thus be an invaluable tool in severe storms forecasting. The threshold horizontal resolution will be 8 km. The measurements will be disseminated in real time (within 1 min) and could thus be related on a continuous basis to other observable data, such as radar returns, cloud images, and other meteorological variables.

The notional baseline for GOES-R spacecraft is a distributed architecture with 2 East spacecraft (near 75 deg. West) and 2 West spacecraft (near 135 deg West). Also under consideration is a central spacecraft position.

10. PRE-PLANNED PRODUCT IMPROVEMENTS (P3I)

Several products listed as requirements from GORWG members and from participants of the GOES Users' Conferences require a microwave instrument on GOES-R. While a microwave instrument is not in the notional baseline for GOES-R, and there are presently no funds allocated to building a microwave instrument for GOES-R, it is listed in the GOES-R Version I Program Requirements Document as a Pre-Planned Product Improvement, slated for further study for potential inclusion in the latter stages of the GOES-R series.

One of the proposals for a microwave instrument is the Geosynchronous Microwave (GEM) /Sounder, a 5 band, multi-channel radiometer that will provide time-resolved precipitation imagery and atmospheric vertical temperature and water vapor profiles through many types of cloud cover. The instrument uses frequencies from 50 GHz through 425 GHz.

11. SUMMARY AND CONCLUSIONS

The GOES Operational Requirements Working Group (GORWG) and GOES Users' Conferences provided the foundation for requirements found in the GOES-R Program Requirements Document, Version I. Participants in the requirements gathering process, including representatives from within NOAA, other federal agencies outside of NOAA, private industry, and international partners strongly voiced the requirement 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.

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

1) provide an accurate three-dimensional picture of atmospheric water vapor;

2) determine atmospheric motions much better by discriminating more levels of motion and assigning heights more accurately;

3) distinguish between ice and water cloud and identify cloud particle size;

4) provide a field of view no greater than 4 km to provide better viewing between clouds and near cloud edges;

5) provide accurate land and sea surface temperatures and characteristics by accounting for emissivity effects;

6) distinguish atmospheric constituents with improved certainty, including volcanic ash, ozone, and methane; and

7) detect atmospheric inversions.

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

1) improved quantitative precipitation forecasts;

2) reduced size of geographic areas affected by watches;

3) improved early detection of severe weather and flash floods;

4) improved forecasts of hail and hail size;

5) improved prediction of fog formation and dissipation;

6) improved forecasts of microburst potential;

7) improved forecasts of mesoscale convective systems; and

8) improved forecasts of hurricane intensity and motion.

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

1. Improved safety and economic benefits to commercial, military and general aviation
2. Improved management of energy resources
3. Improved planning and management of ground and marine based transportation
4. Improved fisheries management
5. Improved guidance for State Emergency Managers
6. Cost savings for agricultural applications from better planning of watering, and application of pesticides, herbicides and fertilizers

GOES users and potential users will continue to refine the requirements for GOES-R Series applications and algorithms at the Third GOES-R Users' Conference (May 10-13, 2004 in Boulder, CO see: http://www.osd.noaa.gov/announcement/index.htm).

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