APPLICATIONS OF ISES FOR METEOROLOGY

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ABSTRACT

This presentation summarizes the results from an initial assessment of the potential real-time meteorological requirements for the data from Eos systems. Eos research scientists associated with facility instruments, investigator instruments, and interdisciplinary groups with data related to meteorological support were contacted, along with those from the normal operational user and technique development groups. Two types of activities indicated the greatest need for real-time Eos data: 1) technology transfer groups (e.g., NOAA's Forecasting Systems Laboratory and the DOD development laboratories), and 2) field testing groups with airborne operations. A special concern was expressed by several non-US participants who desire a direct downlink to be sure of rapid receipt of the data for their area of interest. Several potential experiments or demonstrations are recommended for ISES which include support for hurricane/typhoon forecasting, space shuttle reentry, severe weather forecasting (using microphysical cloud classification techniques), field testing, and quick reaction of instrumented aircraft to measure such events as polar stratospheric clouds and volcanic eruptions.

INTRODUCTION:

For the Information Sciences Experiment System (ISES) Meteorology Panel, the areas addressed included synoptic and mesoscale meteorological situations, considering clouds, temperature and humidity profiles, severe weather conditions, limits to visibility, and winds. The following contains a synopsis of the presentation given on 3 May 1989, with text material expanding on the content of the figures which were shown as part of the presentation.

BACKGROUND:

Over 40 scientists associated with various Eos instruments and NASA, NOAA, and DOD laboratories were contacted to discuss requirements for real-time meteorological data (see below). This broad spectrum of potential users provided a perspective which not only reflected current perceived needs, but also highlighted the need to better define the total capabilities envisioned by ISES.

FACILITY INSTRUMENTS:

    MODIS - 3
    AIRS - 4
    AMSR - 2
    LAWS - 3
    GLRS - 2

PI INSTRUMENTS:

    HIMSS - 1
    CERES - 2
    SAGE III - 2
    LIS - 1

INTERDISCIPLINARY:

    4D - 2
    OCEAN CLIMATE - 1
    AEROX - 2
    CERES - 1

ORGANIZATIONS:

    NASA:

        HQ - 1
        LaRC - 5
        MSFC - 3
        GSFC - 4
        JPL - 1
        JSC - 1

    NOAA:

        NMC - 2
        NESDIS - 3
        PROFS - 2

    DOD:
        OSD - 2
        AF - 1
            DMSP - 1
            AWS - 1
            AFGL - 2
        USN -
            ONR - 1
            NEPRF - 2
            NPS - 1
        ARMY - ASL - 3

    UNIVERSITIES:

        WISCONSIN - 2
        CSU - 2
        WASHINGTON - 2

    PRIVATE - TV/RADIO - 1
        OTHERS - 1

The results of this informal community-wide survey (see below) indicated the groups which perceived the greatest need for real-time data. The theoretical meteorological research community and the operational meteorological organizations did not see the need for real-time data from Eos polar platforms, but for very different reasons. Most researchers see later receipt of the data as sufficient, while the operational community, whose mission performance depends upon real-time data, felt the limited spatial and temporal coverage negated the potential benefit for day-to-day operational use. It was the experimentalists and scientists involved in field testing who, along with the technique developers for the operational meteorological organizations, expressed the greatest interest and need for ISES real-time data. An additional community of users of state-of-the-art (SOA) meteorological data, which is often ignored, is the value-added professional group composed of the radio/TV meteorologists and the private consulting firms. Both groups require the latest technology available for real-time data when the data produce the appropriate commercial benefits. The extensive use of Doppler radars and use of merged satellite and radar animated presentations by TV stations (well before the National Weather Service and DOD operational forecasters have access to the technology) are just two examples of their interest in SOA real-time data. However, this group usually requires demonstration of the capability first, before committing resources.

TRENDS

SCIENTISTS: OPERATIONAL PROFESSIONALS:

        NASA   >   <   NOAA
        UNIVERSITY   >   "NOT NEEDED" <   DOD

        "LATER OK"   "COVERAGE TOO LIMITED"
                                         (time and space)

        FIELD TESTERS >   "YES - NEEDED"   <   TECHNIQUE DEVELOPERS
        AIRBORNE OPS   NOAA - PROFS
        CAL/VAL   DOD - 6.2 LABS
                                                       AFGL/NEPRF/ASL

VALUE-ADDED PROFESSIONALS:

        TV/RADIO >
        PRIVATE CCM >   "MAYBE - AWAIT PROVEN RESULTS"

DISCUSSION:

The potential uses of the ISES-derived Eos meteorological data can be divided into four primary areas (shown below) for further investigation.

PRIMARY USES OF REAL-TIME Eos DATA

1. COMPLEMENTARY REAL-TIME FORECASTING SUPPORT:
   (High Spatial/Spectral, Low Temporal Resolution)

   A. ENHANCEMENT (Known Results)

   B. IMPROVEMENT (Unknown Results)

   C. VALUE-ADDED (Proven Results)

2. FIELD TESTING:

   A. AIRBORNE OPERATIONS

      1) Find & Correlate

      2) Validate Satellite Algorithms

   B. QUICK RESPONSE TO EVENTS

      1) Fires & Dust Storm Plumes

      2) Volcanoes

3. RAPID ADJUSTMENTS TO RESEARCH APPROACHES:

   (Quick look, adjustment, and ancillary data requirements)

4. POSITIVE RECEIPT AND CONTROL OF DATA:

   ____ (Non-US and US)

1. COMPLEMENTARY REAL-TIME FORECASTING: Because of the inherent advantages (high spatial and spectral resolution) and disadvantages (low temporal resolution/limited coverage) of Eos data, the primary utility for real-time Eos data lies in in its complementary impact on operational forecasting. While the operational GOES, GMS, and METEOSAT satellites provide the routine, real-time high temporal and spatial coverage, the Eos sensors can provide the multispectral, high resolution data which can periodically complement the operational data with previously undetected characteristics of a meteorological situation. For example, an Eos pass over a known mesoscale convective complex (MCC), could provide the ice/water determination, accurate cloud top and temperature data, droplet size distribution, rainfall/liquid water content (LWC) estimates, and surrounding wind field data needed to more accurately predict the development stage, movement, and severity of the MCC. The continued use of these

complementary data should also provide unexpected improvements in the forecasts based on operational experience, and the proven results will then create a greater demand on ISES.

2. FIELD TESTING: The greatest perceived need of the research community is in the execution of planned field testing, with the most urgent requirement coming from those with mobile measurement platforms, aircraft, or ships. The ability to direct, in real-time, the mobile platforms to the specific area requiring in-situ data collection, and to provide immediate validation of satellite-aircraft data correlation is significant. The latter is of particular importance in the validation of satellite data processing algorithms for such detailed measurements as aerosol/droplet size distributions. Also, real-time or near real-time data are needed to meet the rapid response requirements for episodic events such as fires, dust storms, and volcanic eruptions. Not only general location and plume movement data are needed, but detailed information concerning the most dense or most complex areas is often required for direction of the aircraft.

3. RAPID ADJUSTMENT OF RESEARCH APPROACHES: This is the "quick look" requirement that is used to calibrate instruments, adjust collection methods and areas, add additional measurements to the data collection program, etc. While most data collection, analysis, and field programs have been planned over a long time, seldom does one expect to have anticipated all the questions which will arise during data analysis. The value here is the ability to correct for unforeseen circumstances during data collection.

4. POSITIVE RECEIPT AND CONTROL: Although the Eos program has provided for world-wide access to the data, there has been concern expressed by non-US investigators over the communications and handling necessary for them to receive the data. A direct real-time downlink for some of the data would be desired to ensure receipt of certain critical data and allow for immediate use in their local area.

POTENTIAL EXPERIMENTS:

This leads us to a discussion of a set of potential meteorological experiments which would depend upon and make use of real-time Eos data. A series of six complementary real-time forecasting and seven field test experiments are proposed as the type which could make use of ISES data and should be investigated further.

1. COMPLEMENTARY REAL-TIME FORECASTING SUPPORT:

    A) integrated cloud classification and evaluation

    B) improved profiles of temperature, water vapor, and winds

    C) characteristics and occurrence of cirrus, subvisual cirrus, and noctilucent clouds

    D) improvements in tropical storm observation and forecasting

E) increased accuracy in surface visibility from data sparse areas

F) greater information for value-added professionals

A. INTEGRATED CLOUD CLASSIFICATION AND EVALUATION: The increasing resolution and coverage of the meteorological satellite sensors and the extensive data requirements of the many meteorological analysis and forecasting models have established the need for computerized handling of satellite data. This process requires a significant number of algorithms (Wielicki, 1989; Arking and Childs, 1985) beginning with the basic (but certainly not simple) cloud/no cloud algorithm. Whatever the wavelength (visual, IR, microwave), the definitive identification of cloud and precipitation areas is not trivial and often requires multispectral data analysis to successfully present the situation to the meteorologist. Shown are examples of the specific wavelengths which could be required to be cross correlated on-board and the resulting product (image) downlinked by ISES for real-time use. The ability of a meteorologist to accurately forecast the sensible weather parameters also may depend upon the knowledge of microphysical features of the meteorological situation. The ice/water cloud content, droplet size distribution, liquid-water content (LWC), and precipitation spatial distribution, and detailed cloud top and temperature data are all elements derivable from Eos ISES real-time data, and can influence real-time operational forecasting. The integration of the spatial and microphysical cloud data could provide the key complementary data set needed to enhance the forecast accuracy for many meteorological situations. The suggestion for ISES is the downlink of the individual bands referred to (priority of need is indicated) and the onboard processing results from three algorithms (to be modified by command) which merge the data from several sensors and provide the cloud classification and analysis results needed. The first algorithm would be an agreed-to standard to be maintained for consistency and comparison purposes, while the two others would be used on a trial basis and be modified as analysis and application dictate.

1 -   COMPLEMENTARY REAL-TIME FORECASTING

A -   INTEGRATED CLOUD CLASSIFICATION & EVALUATION:

PARAMETER	BAND	PRIORITY
1. CLOUD/NO CLOUD		
(over land, water, snow & ice)	.6u & Algorithm	4
	3.7u Black stratus (night)	2
	1.6u snow/cloud (day)	3
	18/37Ghz	
Coverage (fraction) & Size (cells)	Algorithm	
2. TYPE (ci/cu/st)		
Ice/Water (stage of (development)	1.6u/.75u	3
3. TOP/BASE (Temp or bkscat)	11u & 14u / Lidar*	1&7/+

(* indicates Lidar data from GLRS, LAWS or ATLID)

4. OPTICAL DEPTH (Brightness)	.75u	4
Droplet Size Dist	2.1u/.75u	
Aerosol Size Dist/Correction	.5u/.7u/Lidar	5
5. LWC & Precipitation	37&90Ghz/.75u/LIS	
6. WATER VAPOR	6.7u	6

- SUMMARY DOWNLOAD: 8-12 BANDS PLUS 3 MERGED ALGORITHM RESULTS
  (1stnd/2trial)

   (MODIS, AIRS, HIMSS, GLRS/LAWS/ATLID, and LIS)

B. IMPROVED PROFILES OF TEMPERATURE, WATER VAPOR, AND WINDS: A key factor in the accuracy of both the longer range (6 - 96 hrs)and shorter range (0-6 hrs) forecasting models and methods is the accuracy of the vertical profile data. Satellite-derived profile data (see below), while providing broad spatial coverage, have been unable to match the accuracy of the rawinsonde balloon (RAOB) data. Eos offers the opportunity to approach the accuracy of the RAOB by using sensors with greater spectral resolution and by merging the data from several sensors. For example, in addition to using higher resolution IR/MW sounders, by using lidar to pinpoint the planetary boundary layer (PBL) and the tropopause heights, a significantly more accurate profile (Westwater, et al., 1983) of temperature and moisture could be obtained for real-time application to short range severe weather, visibility, pollution, and surface wind forecasting. Also, the LAWS system offers the ability to greatly increase the coverage of wind profile data providing greater short range forecast accuracy as well as improved longer range forecast model accuracies. The downlink suggestion for ISES would be a standardized profile from a merged data set and two trial algorithms for research application.

   1 - COMPLEMENTARY REAL-TIME FORECASTING

   B - PROFILES (Temperature, Water Vapor, Winds)

      (Est 50% improvement in profiles)

      MERGED -- Lidar PBL & Tropopause Data with high resolution
                AIRS (8-14u) and HIMSS (50-60Ghz) sounders.

-SUMMARY: DOWNLINK 3 profile sets, 1 stnd & 2 trial sets.

C. CHARACTERISTICS AND OCCURRENCE OF CIRRUS, SUBVISUAL CIRRUS, AND NOCTILUCENT CLOUDS: From a real-time perspective, the characteristics and probability of occurrence of particulates at high altitudes are parameters of considerable interest for the reentry of the Space Transportation System (STS) and the National Aerospace Plane (NASP). Since these particles provide the potential for structural damage as well as forced deviation from a planned reentry path (Corvault, 1988), the ISES requirement is for near-real time broad area measurements along and near the proposed reentry path. Ground-based lidar measurements of subvisual cirrus clouds have indicated that this upper air feature occurs routinely. With the normal 25-35% probability of occurrence for cirrus clouds and added effects of noctilucent clouds, the potential probability of ice crystal cloud particulate interaction with the STS/NASP vehicles on reentry appears to be significant (Wylie, 1989). While more detailed analyses by recovery location and further investigation into the aerosol interactions with the STS/NASP airframes will size the problem better, there is an area of potential real-time observational need associated with these high altitude features. The merging of lidar measurements with visual/IR imagery and apparent cloud top temperature data may be able to identify the features needed for real-time decisions related to reentry. The suggested downlink

information would be the lidar high altitude return along with three
algorithm products for continuing analysis.

    1 -   COMPLEMENTARY REAL-TIME FORECASTING

    C -   CIRRUS, SUBVISUAL CIRRUS & NOCTILUCENT CLOUDS

           (STS and NASP real-time reentry decisions)

           MERGED -- Lidar with MODIS (10.5u/.65u) & AIRS (CO2 slicing)
                     (New .4-.7u algorithms)

    -SUMMARY: DOWNLINK - Lidar DATA & 3 ALGORITHM (1stnd/2trial)

D. IMPROVEMENTS IN TROPICAL STORM OBSERVATION AND FORECASTING: Since
the lack of surfaced based observations in the tropics makes the
satellite the dominant observational platform for tropical meteorology,
there is considerable information concerning tropical storm development
and movement which could be obtained from Eos data. Hurricanes/typhoons
are relatively slow moving and can be easily tracked by geostationary
and operational polar orbiting satellites; however, it is the detailed
characteristics of the mass of the storm and the surrounding pressure,
wind, temperature, and moisture fields which govern the all important
forecast track. ISES can provide these data. Since actions required to
protect from storm damage take many hours of preparation, adequate
warning lead-time is required, and there is a need for real-time
updates of the detailed storm environment. For example, the subsidence
in the storm eye produces a warm core measurable from satellite and can
be used to estimate the minimum pressure, maximum winds, and overall
storm intensity (Kidder, et al., 1978). The surrounding cold cloud tops
from overshooting cumulnimbus clouds also help define the intensity and
locations of the more severe weather. Infrared sounder data with <15-km
resolution coupled with lidar cloud top measurements should be able to
provide these estimates. The precipitation areas, which are visually
obscured, are particularly important since flooding is often the most
significant consequence of a tropical storm. Microwave imager and
lightning detector data should outline the areas and intensity of the
precipitation. Finally, the dominant impact of the surrounding wind and
pressure fields on the forecast track makes the satellite-derived
surface wind measurements vital for real-time forecasting of storm
movement. Both the scatterometer and microwave imager have capabilities
in this area. Many of the sounder and imager algorithms are well known
and viable for onboard processing; however, the interpretative nature
of the microwave image and other requirements for spatial analyses will
probably require significant level-2 data to be downlinked.

D - TROPICAL STORM OBSERVATION AND FORECASTING IMPROVEMENTS

    A. EYE TEMPERATURE (PRESS/WINDS) -- AIRS (15-km res)

    B. COLD CLOUD TOPS -- AIRS/LIDAR

    C. PRECIP -- HIMSS & LIS

    D. WINDS (STORM & AREA) -- HIMSS & SCANSAT

-SUMMARY: DOWNLINK - LEVEL 2 & MERGED ALGORITHM DATA central
           pressure/max winds (1stnd/2trial)

E. INCREASE ACCURACY OF SURFACE VISIBILITY FROM DATA SPARSE AREAS: The
real-time requirement for surface visibility (as impacted by the
aerosol, water vapor, and related temperature profile) is primarily
from DOD. This requirement is for support to operations which would
take place in areas without ground-based observations. Many military
missions are affected by low altitude restrictions to visibility. The
detailed spectral data from visual/IR imagery coupled with lidar data
of the aerosols in the boundary layer should provide much of the
information needed for immediate direct mission support and short range
forecasting (see below). The multispectral data from MODIS can provide
some of the needed visibility information through extraction of optical
depth data. Also, the lidar data should significantly improve the
overall accuracy of the concentration and vertical distribution of
aerosol by more accurate measurements of the planetary boundary layer
(PBL).

1 -   COMPLEMENTARY REAL-TIME FORECASTING

E - DERIVED SURFACE VISIBLILITY
    (DOD Requirement -- Data Denied/Data Sparse Areas)

    A. MODIS image data
       (background catalog)

    B. MERGED LIDAR data (PBL/profiles)

F. GREATER INFORMATION FOR VALUE-ADDED PROFESSIONALS: The commercial
value of meteorological data when used in tailored forecasts for
industry can be significant. This proven economic value and the
competitive desire of TV meteorologists to show the latest SOA data
provide an additional category of users who will show greater interest
as the data become available. An example of the commercial value of
meteorological support to a small segment of the population is

illustrated by the data presented here (Carlson, 1989). A survey of agricultural users in Michigan indicated their priority for information and the potential savings they perceived was available from accurate meteorological support. The fruit and vegetable growers indicated the greatest impact from their small and concentrated operations. With the potential of $10-20,000/yr savings for individual farmers, this commercial application of Eos real-time data should be considered. While the ability to use the higher resolution data from Eos to improve short range forecasts of the key agricultural parameters may not prove to be feasible for the individual farmer, it should be for the several private forecast services which support the larger US-wide agricultural and other commercial communities.

1 - COMPLEMENTARY REAL-TIME FORECASTING

F - VALUE-ADDED PROFESSIONALS

(RADIO/TV, PRIVATE CCM, AND DIRECT USERS; E.G., AGRICULTURE)

EXAMPLE -- AGRICULTURE IN MICHIGAN

PRIORITY - 1 PRECIP

2 MAX/MIN TEMP

3 FREEZING DATA

4 DEGREE DAYS

5 SOIL MOISTURE

50 % $1-10,000/YR SAVINGS

20 % > $10,000/YR SAVINGS

FRUIT & VEG -- SMALL CONCENTRATED -- BIGGEST IMPACT -- 25 % > $10,000 SAV

2. FIELD TESTING:

Field testing with mobile platforms, especially aircraft, is the most apparent research requirement for ISES meteorological data. There are seven types of experimental field tests (shown below) for which investigators have indicated a need or expressed desire for real-time data. The first group of experiments involves aerosol transport and relates to the improved ability to rapidly find the plume and be directed into the appropriate area of the plume. This allows the possibility for Lagrangian-type measurements over long distances, directing the aircraft from day-to-day to the appropriate altitude and location within the plume to follow the same parcel of air. For large meteorological features such as areas of Arctic haze or polar stratospheric clouds, accurate vectoring of the aircraft is needed to rapidly find and traverse the cloud area. Another field test with special interest in real-time data is the Global Atmospheric Sampling Program (GASP) supporting the testing of laminar flow control for airfoils. Cirrus and subvisual cloud crystals are of particular concern since they break up the laminar flow across the aircraft wing (Davis, et al., 1989); therefore, successful tests must be flown in perfectly clear air (undetectable from normal meteorological satellite images) and ISES data can identify the appropriate test areas in real-time. The final category for ISES data is that based on the need for quick reaction and detailed vectoring of instrumented aircraft to episodic events. Forest fires and volcanic eruptions are two examples of events where complex airborne sampling is needed with a rapid reaction capability.

2 -   FIELD TESTING

A -   DIRECT FIELD TESTING AIRBORNE OPERATIONS

    1. AEROSOL TRANSPORT

        a) FIND PLUMES & CORRELATION WITH ALGORITHMS

        b) LAGRANGIAN CAPABILITIES FOR LONG DISTANCE TRANSPORT

    2. CLOUD/AEROSOL LOCATION

        a) ARCTIC HAZE

        b) POLAR STRATOSPHERIC CLOUDS

        c) GASP/ LAMINAR FLOW CONTROL

B - QUICK REACTION TO EVENTS

    1. FOREST FIRE PLUMES

    2. VOLCANOES

3. RAPID ADJUSTMENT OF RESEARCH APPROACHES:

The third category of requirements for ISES meteorological data relates to the value of seeing the Eos research quality data and its relationship to all other available information in a time perspective which allows the adjustment of the data collection program. Using the ISES-derived data for "quick look" analyses, adjustments to algorithms, sampling rates, spectral band selection, and addition of new data types are just a few of the actions which could be of significant benefit when unforeseen circumstances arise. Also, in the meteorological community, the "book binding" effect can occur and restrict the access to ancillary relevant data. This effect occurs when real-time meteorological data are not immediately extracted and must be retrieved (usually a long process) from a climatological/archival center, which may or may not have saved the data required or retained the data in the form needed. This has been a particular problem in the past for high resolution meteorological satellite data, much of which has not been archived or saved at all. For some types of investigations, especially those using multispectral imagery, this benefit from ISES should be thoroughly considered.

3 - RAPID ADJUSTMENT OF RESEARCH APPROACHES

"QUICK LOOKS"

4. POSITIVE RECEIPT AND CONTROL OF DATA:

The last category of use is one which relates to the previous categories, but adds the concern from those where communications and other data handling problems related to overseas access are involved. Also, some of the concern is over the ability of the Eos system to handle their needs. Some of the many international participants have expressed a strong interest in having access to Eos real-time data with the coverage and capability to immediately use the data in their local areas of interest.

4 - POSITIVE RECEIPT AND CONTROL OF DATA

INTEREST SHOWN BY NON-US PARTICIPANTS FOR LOCAL RECEIPT OF DATA

CONCLUSIONS:

As summarized below, there appear to be two categories of primary users and two key types of uses for real-time meteorological data from ISES. First, the technique developers responsible for improving the real-time forecasting capabilities of our civil and military weather services and, second, the experimental research scientists involved in field tests with mobile platforms, especially those with instrumented aircraft. From within these groups, ISES will have its greatest requirements for meteorological data and the potential specific uses of ISES capability, discussed earlier, can be a starting point for further investigation.

SUMMARY

-- TWO PRIMARY USERS:

1 - COMPLEMENTARY REAL-TIME FORECASTING (MESOSCALE)

Level 2 Enhancement data at 3-hr increments

2 - FIELD TESTING

(Find, correlate, validate & quick reaction)

Level 1A/B & 2 Data

** VALUE ADDED USERS EXIST **

(must prove worth and provide level 3 data)

-- EXPERIMENT DETAILS STILL TO BE WORKED OUT

1 - ALGORITHM SELECTION

2 - DATA INTEGRATION SCHEMES

3 - ONBOARD SIZING REQUIREMENTS

4 - RECEIPT FORMAT

****
*** NEED IS RECOGNIZED

BUT BY FEW TECHNOLOGY TRANSITION GROUPS

THEREFORE;

SOME IDEAS WILL NEED IMPETUS PROVIDED (CONCEPTS AND SOME FUNDING)

Many details have yet to be worked out; however, the need for ISES is recognized by those involved with meteorology. Any current reluctance in support is mostly due to the outyear nature of the program and the usual concern over funding. Therefore, with the appropriate maturing and better definition of the ISES program, greater direct support should develop from the meteorological research and support community.

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