Realization of a Dream: The New Generation of Meteorologial Satellites

James F.W. Purdom, PhD

Chair, International Conference Steering Committee
Asia Oceania Meteorological Satellite Users' Conference

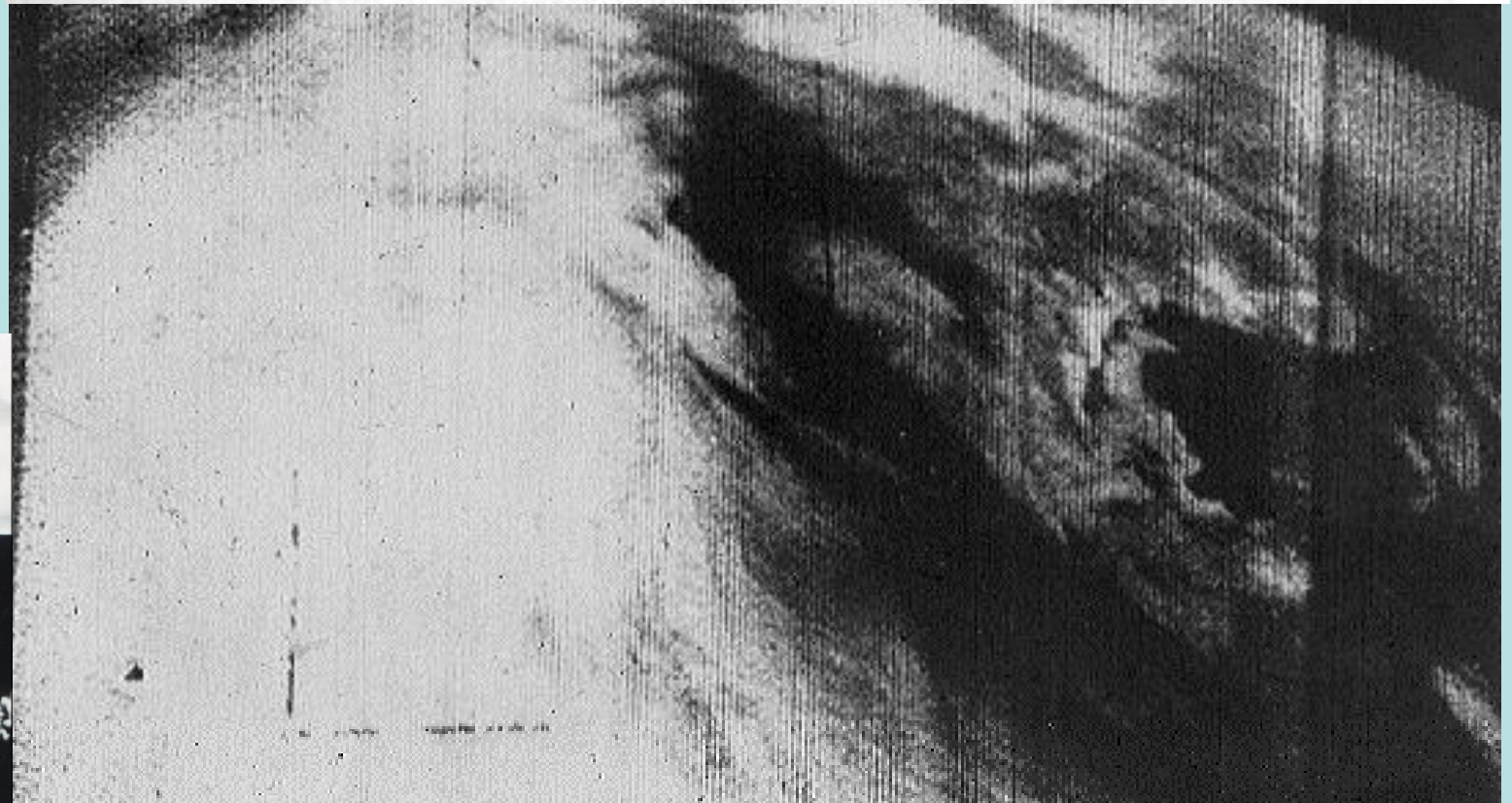
Senior Research Scientist emeritus
CIRA, Colorado State University

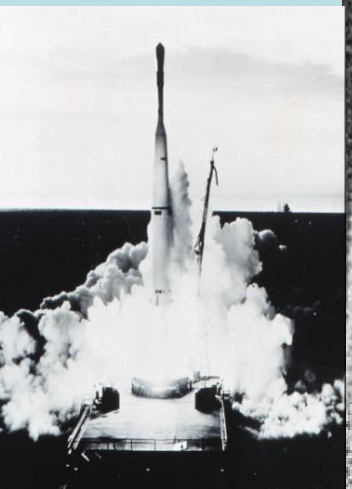
First TIROS-1 image April 1, 1960

The Beginning of the Met Satellite ERA

First Photo Mosaic, May 20, 1960

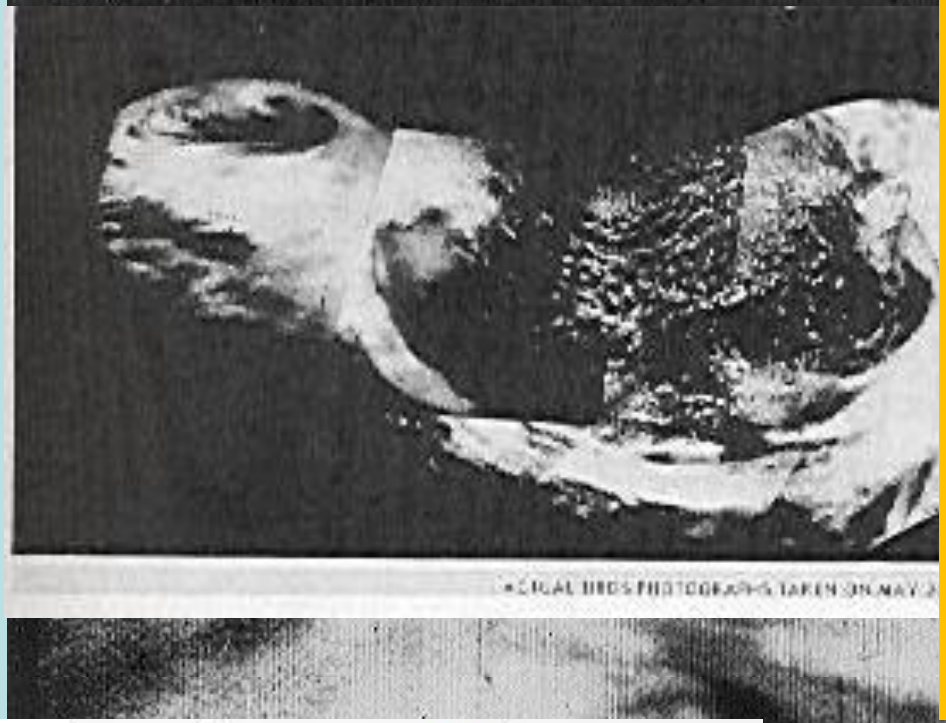
The Beginning of the Met Satellite ERA





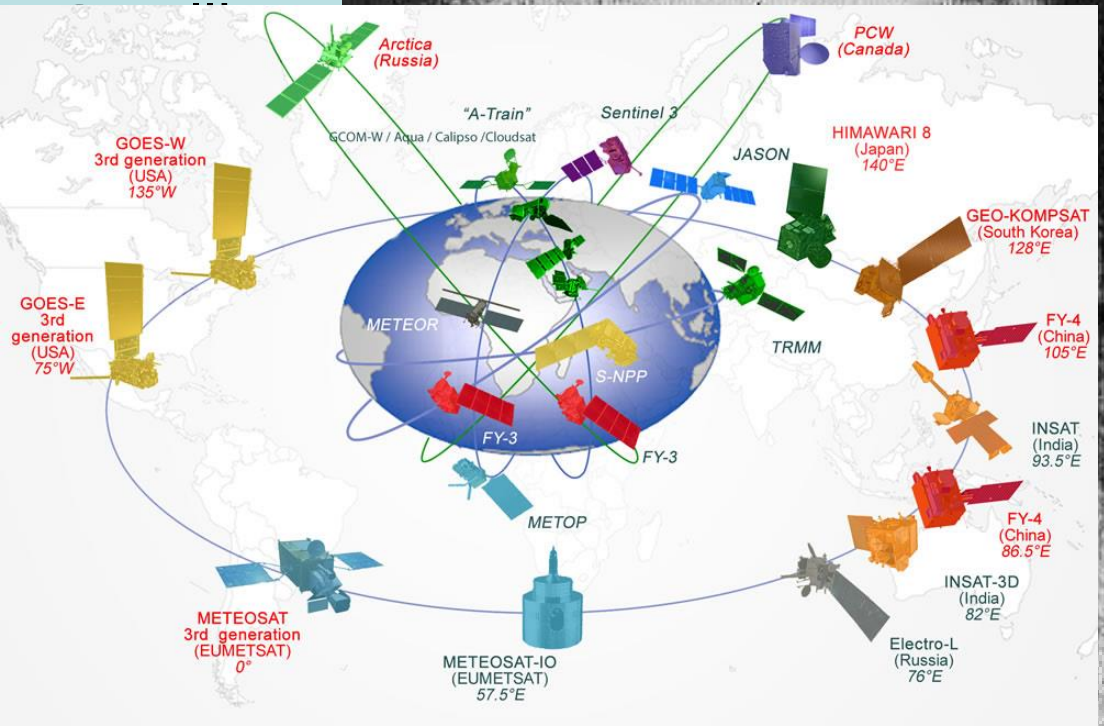
First Photo Mosaic, May 20, 1960

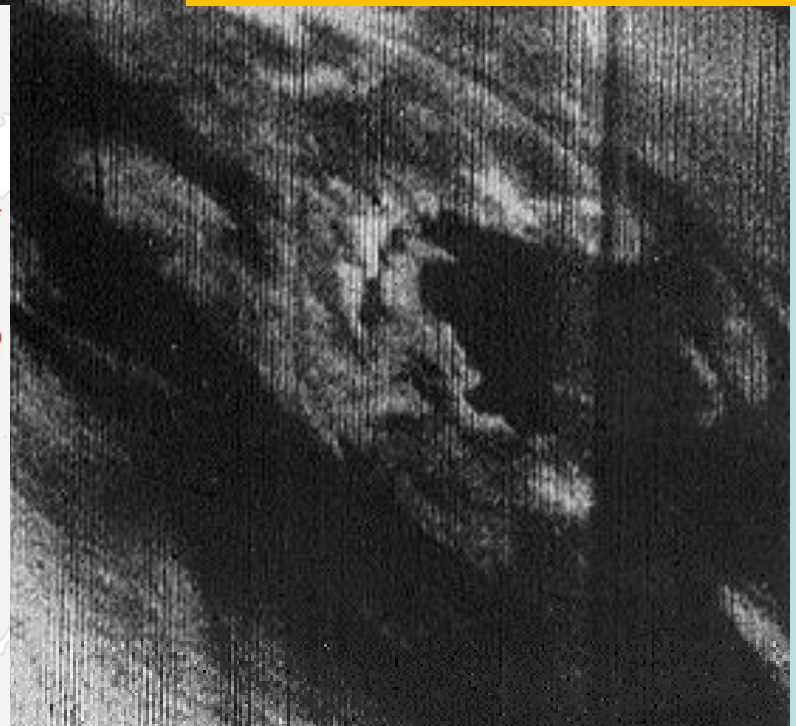
The Beginning of the Met

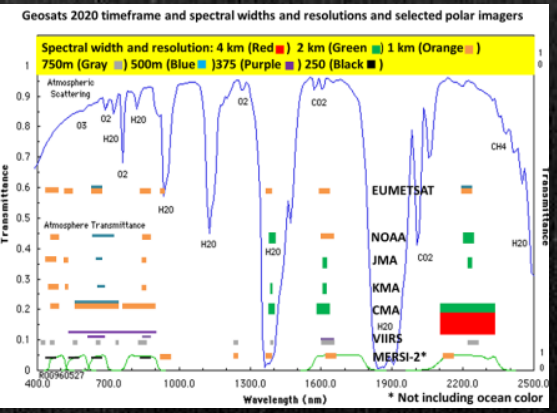


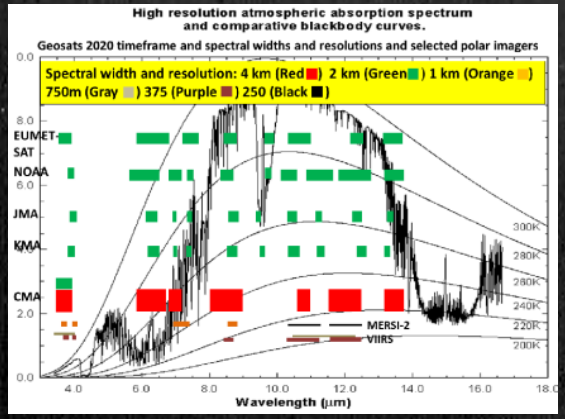
EVOLUTION TO TODAY'S OPERATIONAL SYSTEM

What got us from there to here?









Canada

Nova

EVOLUTION TO TODAY'S OPERATIONAL SYSTEM

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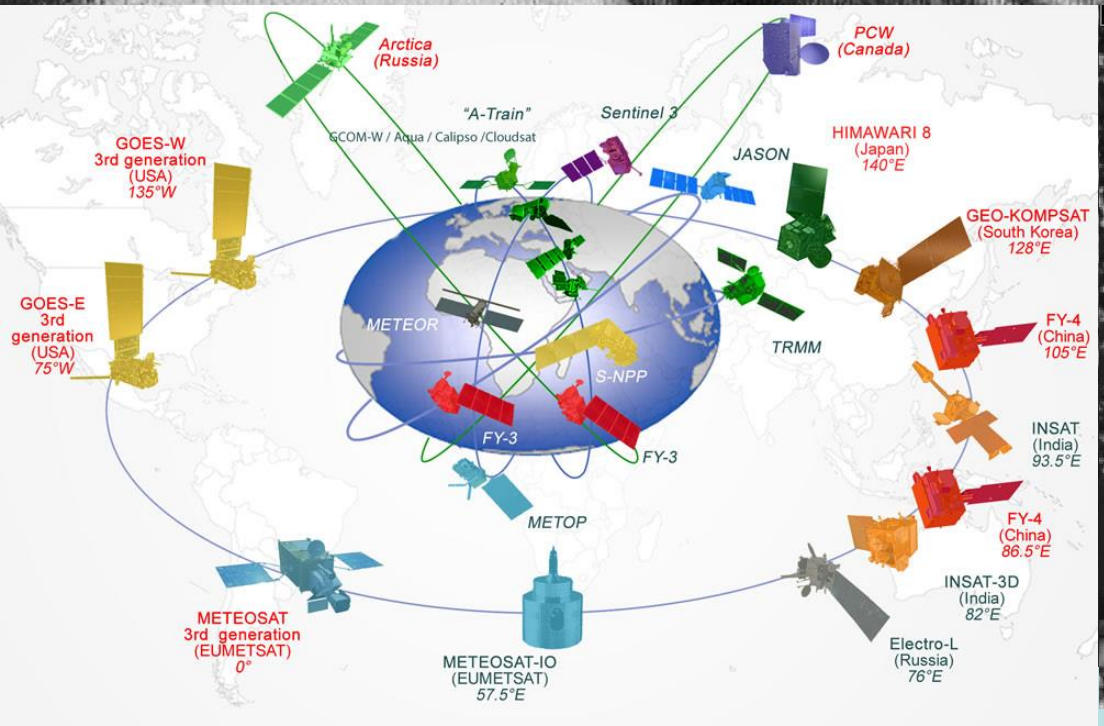
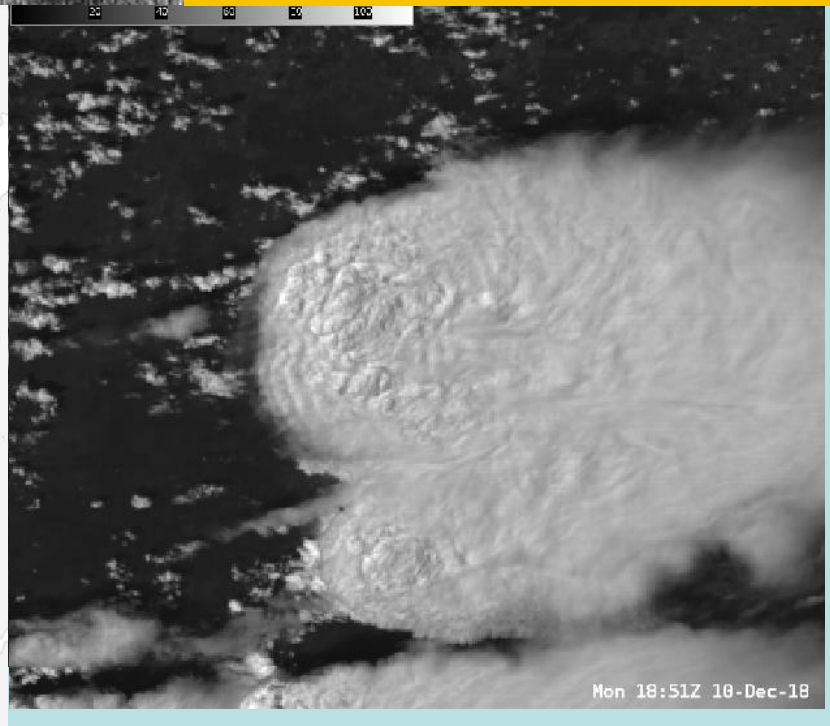




EVOLUTION TO TODAY'S OPERATIONAL SYSTEM
What got us here?

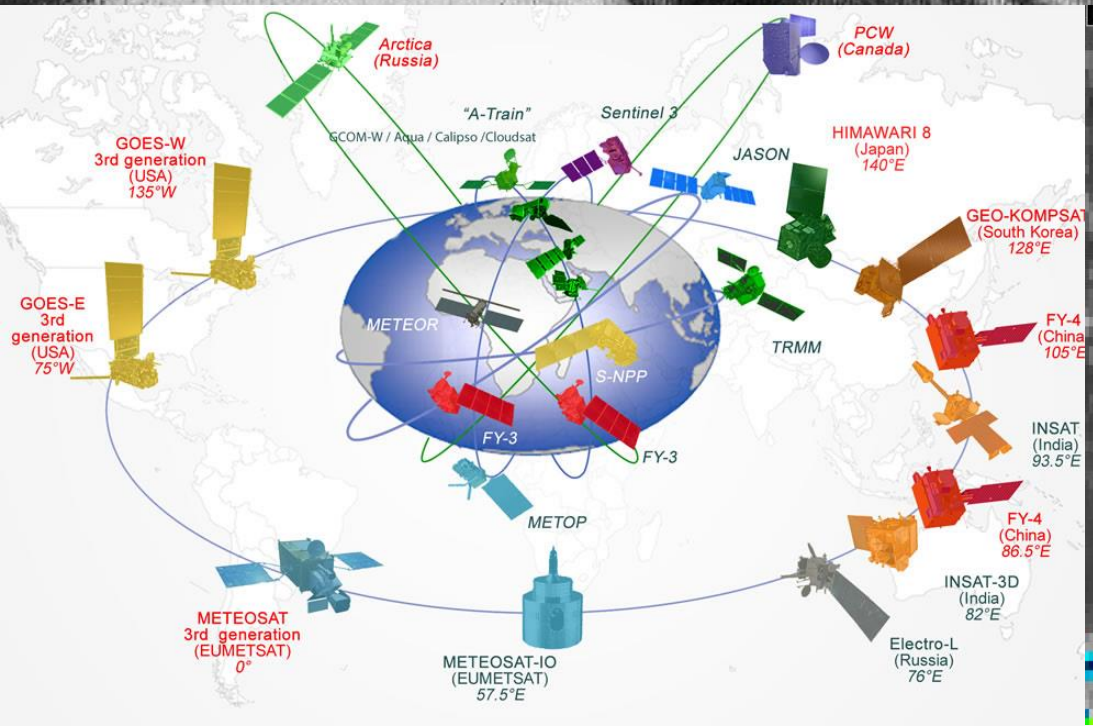
Canada

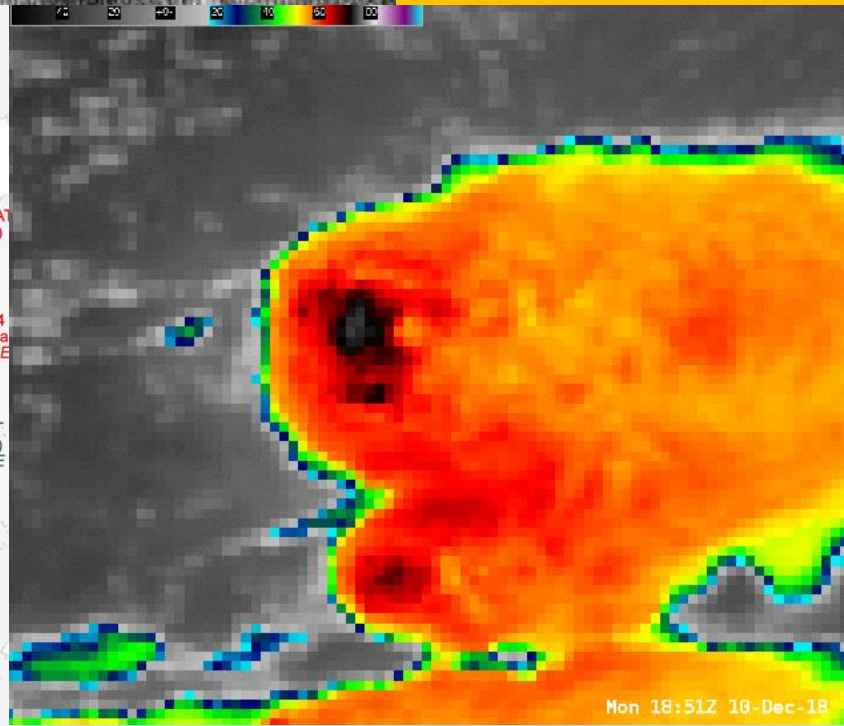
Nova Scotia

What was significant?

- Leadership
- Vision
- Understanding
- Utilization

- International Cooperation





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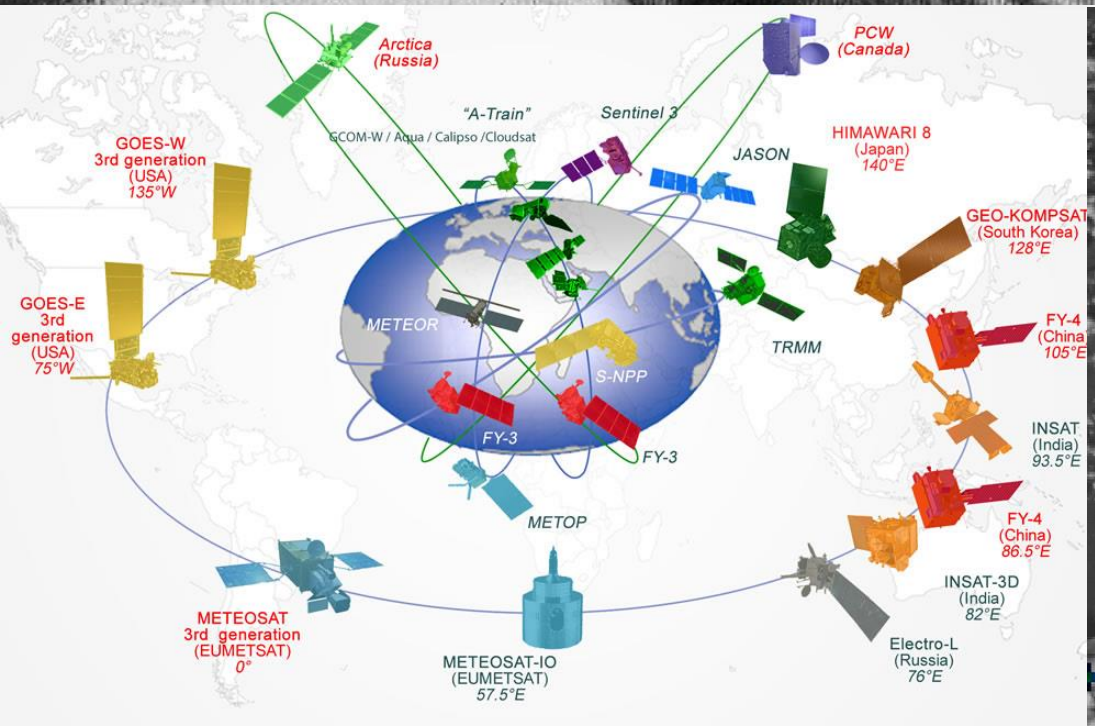

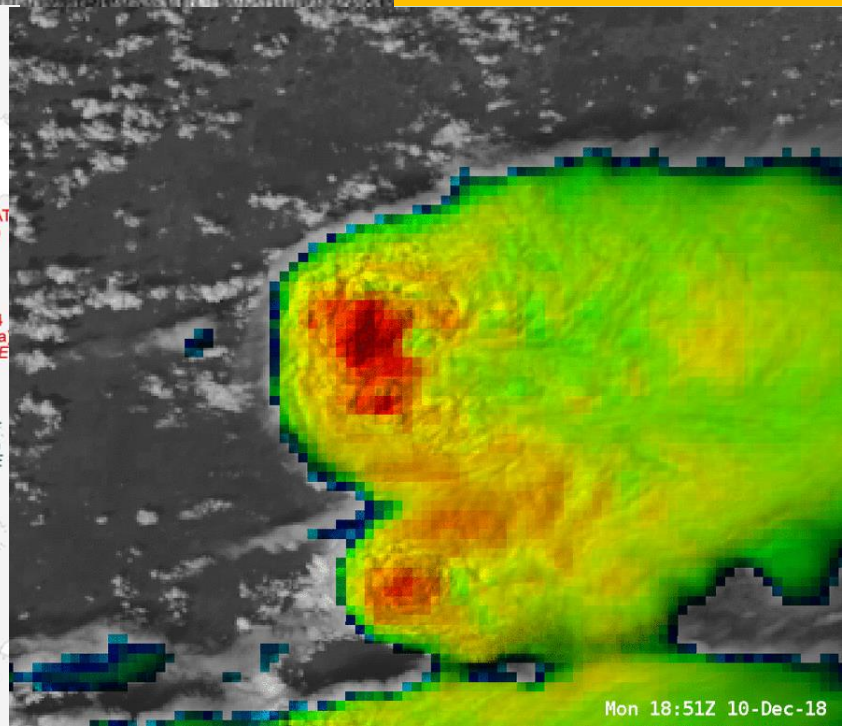

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As I go through this part of my talk, I want you to think of the people that influenced your growth.

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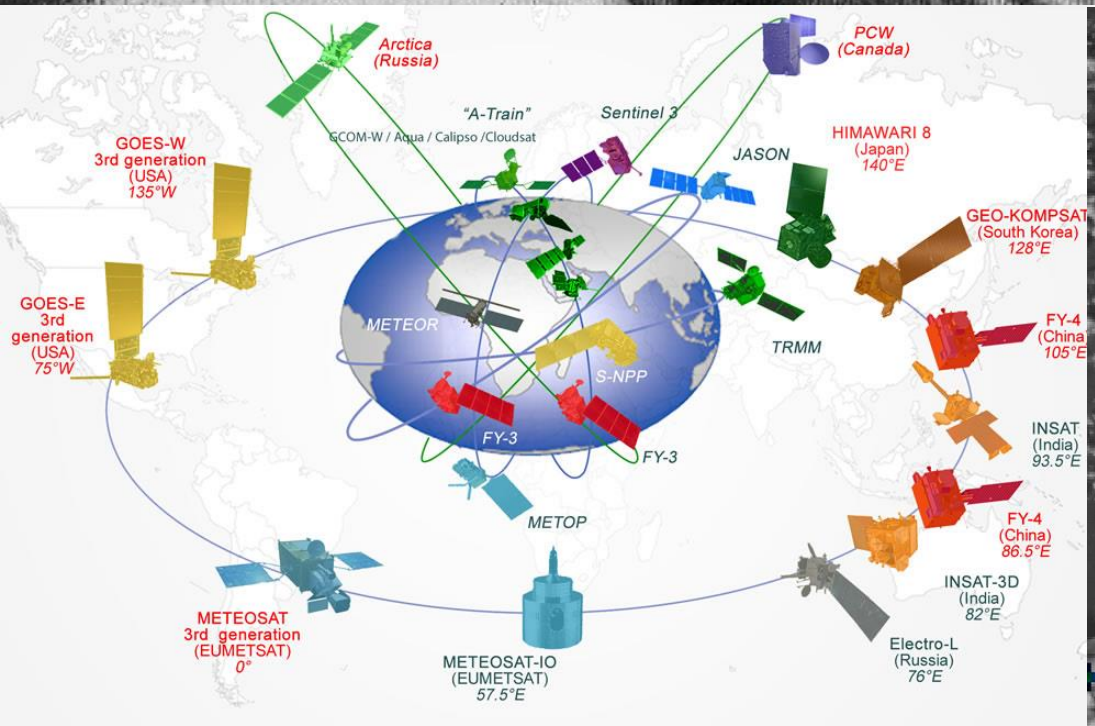
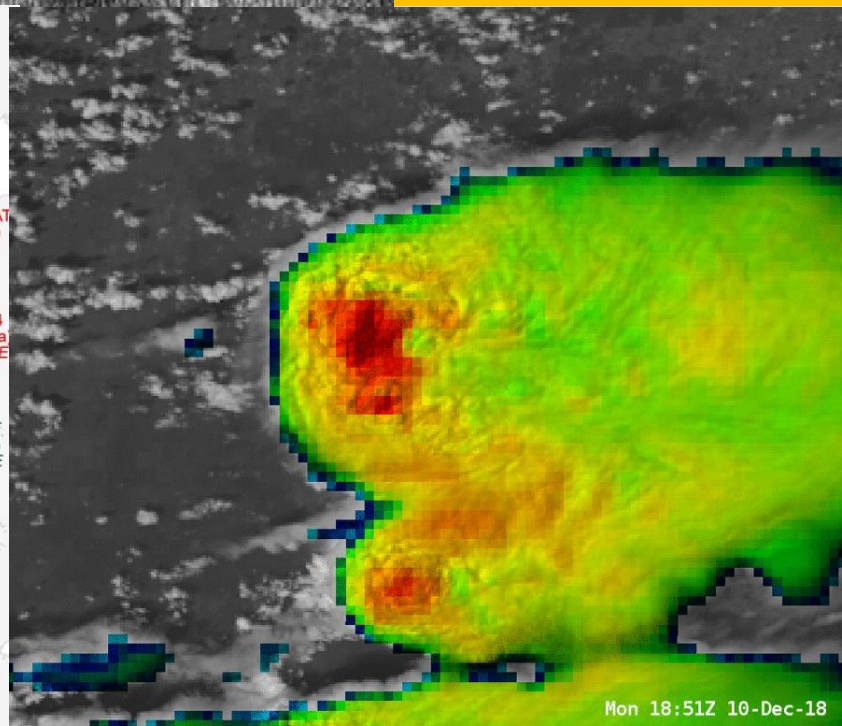
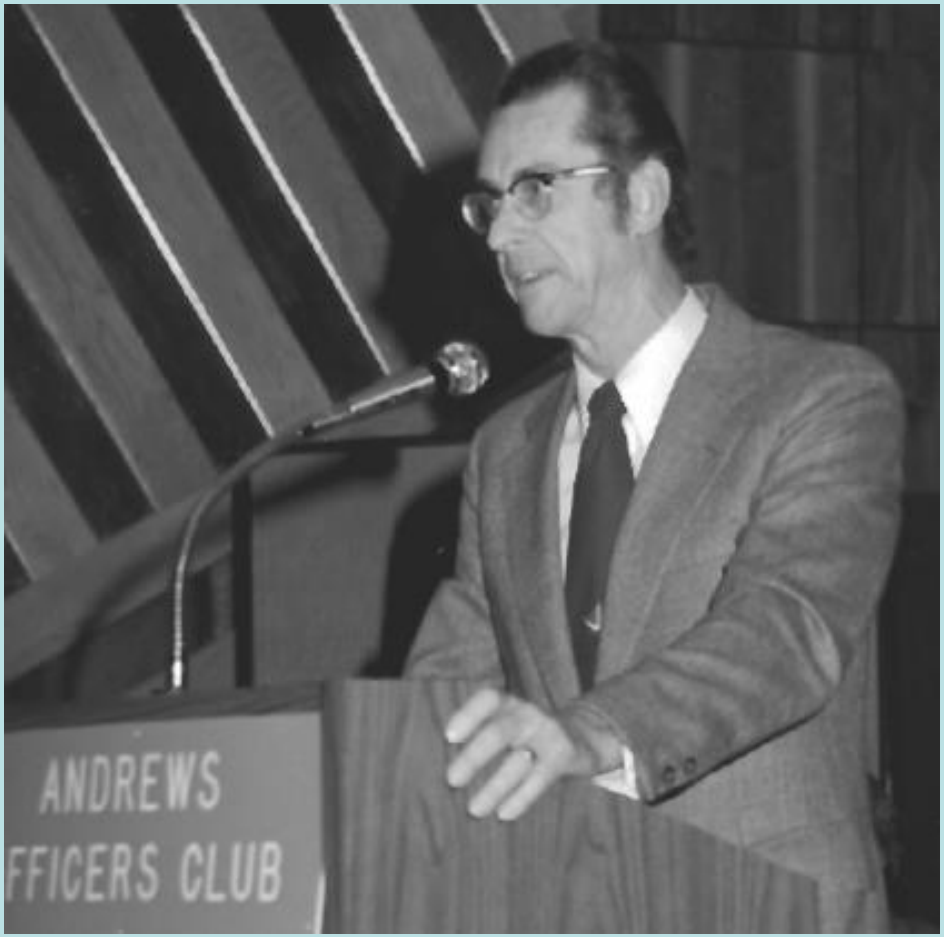




In 1985 at the 25th anniversary of weather satellites, Dave Johnson was recognized for his leadership

Dave was cited for exceptional accomplishments … while directing the U.S. Civil Operational Environmental Satellite Program. During his tenure, the United States established its preeminent position in the monitoring of the global environment and never had a break in operational weather service.

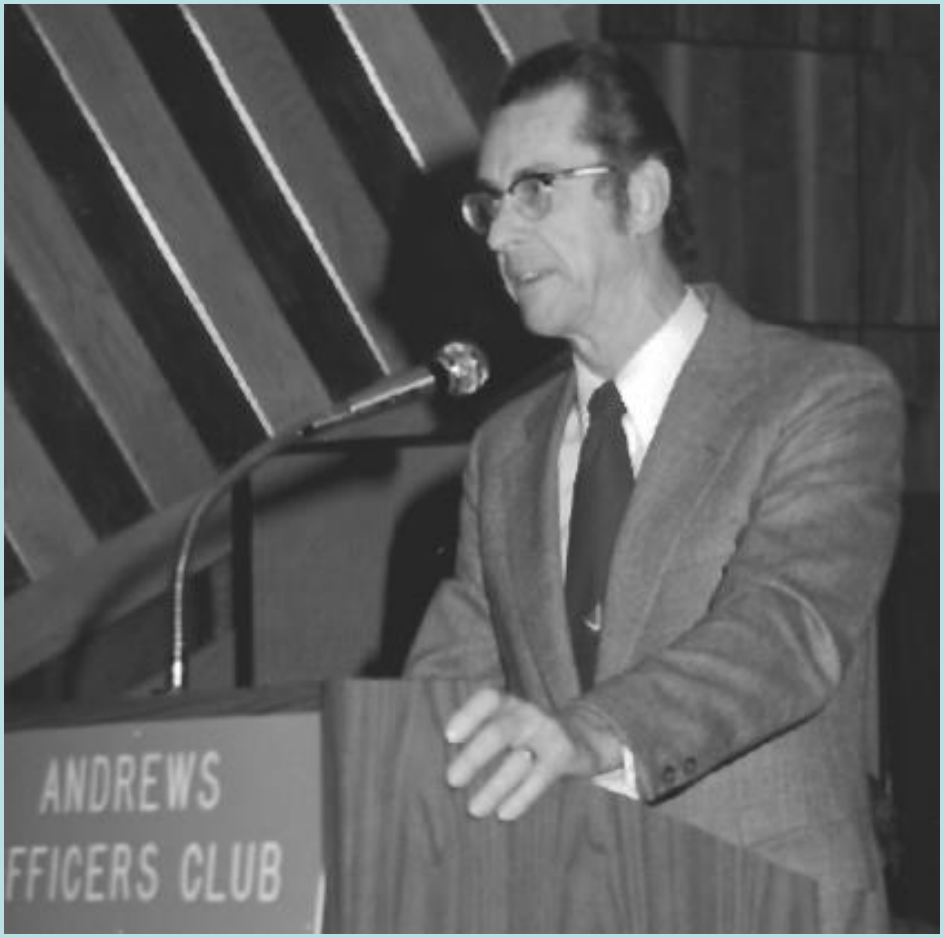


Leadership

Dave Johnson championed the international use of meteorological satellite data

He conceptualized and supported the direct broadcast of U.S. weather satellite data so that other countries could receive and use that imagery.

He led a delegation of American meteorologists who met with their counterparts in China in the1960's.



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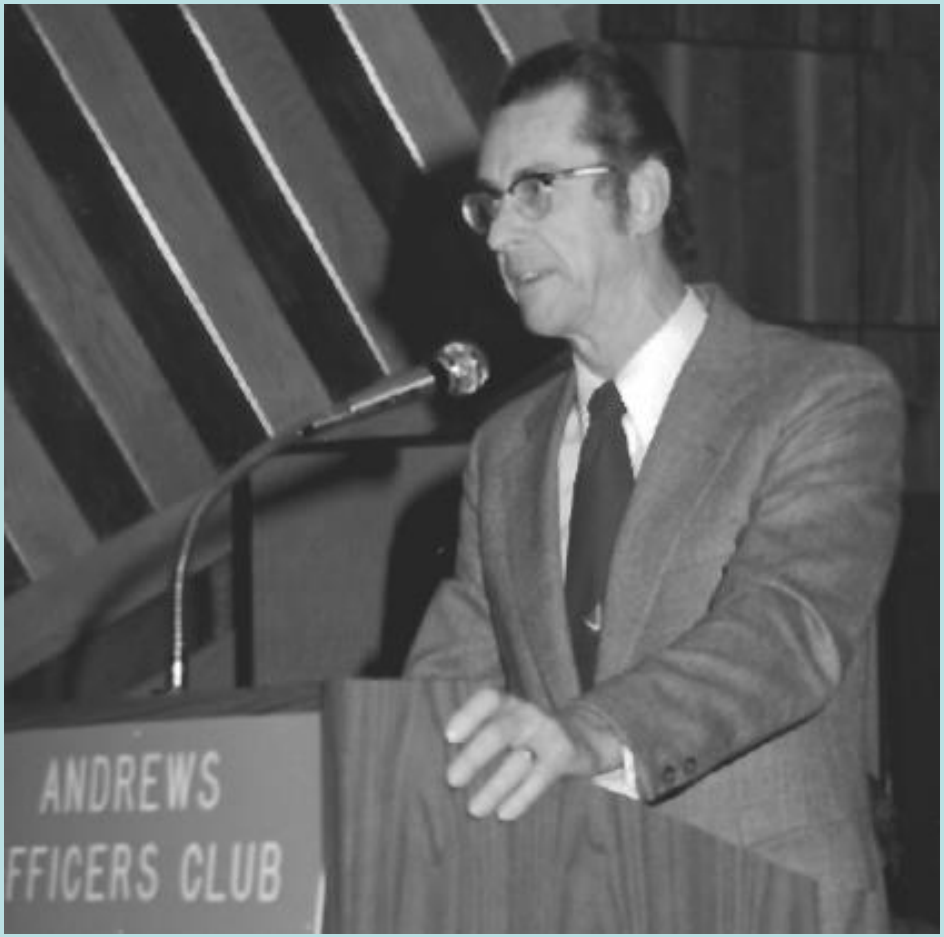
Dave Johnson and his staff championed the international use of meteorological satellite data

Over the following years American meteorologists met routinely with their counterparts in CMA/ NSMC.

John Leese



Leadership

John Leese was recognized for his contributions to China's Meteorological Satellite System

In 2008, John Leese became the only American ever to receive the Friendship Award from the Chinese government in honor of his contributions to the development of China's meteorological satellite system.

Outreach and Utilization

In 1985 at the 25th anniversary of weather satellites, Vern Suomi was recognized for his vision

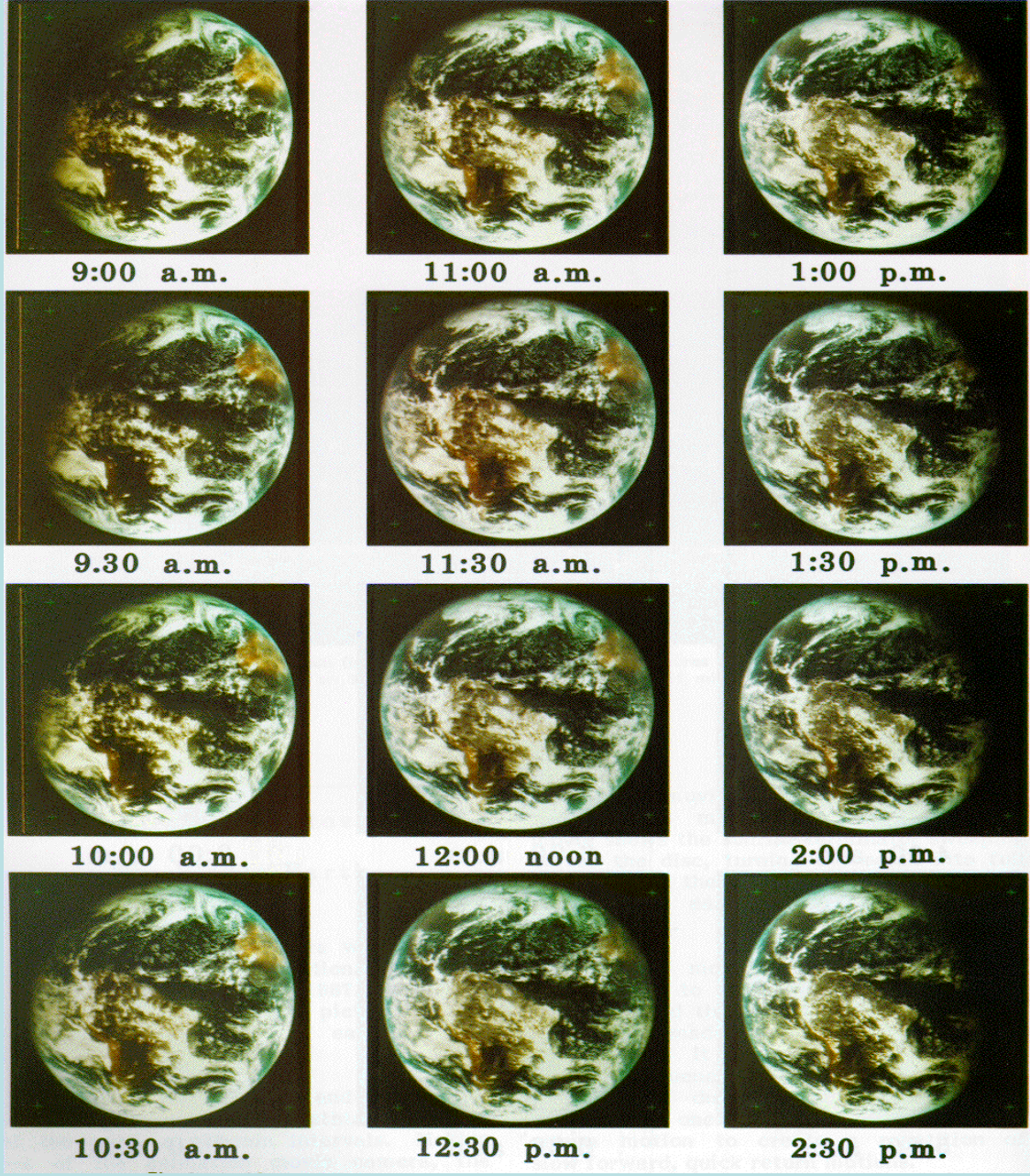
Vern was cited for unparalleled scientific leadership and innovative engineering design and development in conceiving new sensors and applications from the first TIROS satellite through the GOES series.

Vision

On 6 December 1966, a stellar day in satellite meteorology, the first Applications Technology Satellite (*ATS-1*) was launched. *ATS-1*'s spin–scan cloud camera (Suomi and Parent 1968) was capable of providing full disk visible images of the earth and its cloud cover every 20 minutes. The inclusion of the spin–scan cloud camera on *ATS-1* occurred because of an extraordinary effort by Verner Suomi, Dave Johnson and Homer Newell, who made it possible to add this new capability to *ATS-1* when the satellite was already well into its fabrication. Meteorologists were astounded by the first global views of clouds and cloud systems in motion. According to Johnson (1982), "as

1967

First multispectral geostationary imager: Suomi, Parent, and Fujita create first color movie of planet Earth with the three channel RGB ATS-III images on 19 Nov 1967. Unfortunately, the RGB capability failed after one day but two of the channels survived, and ATS-3 served us for many years.



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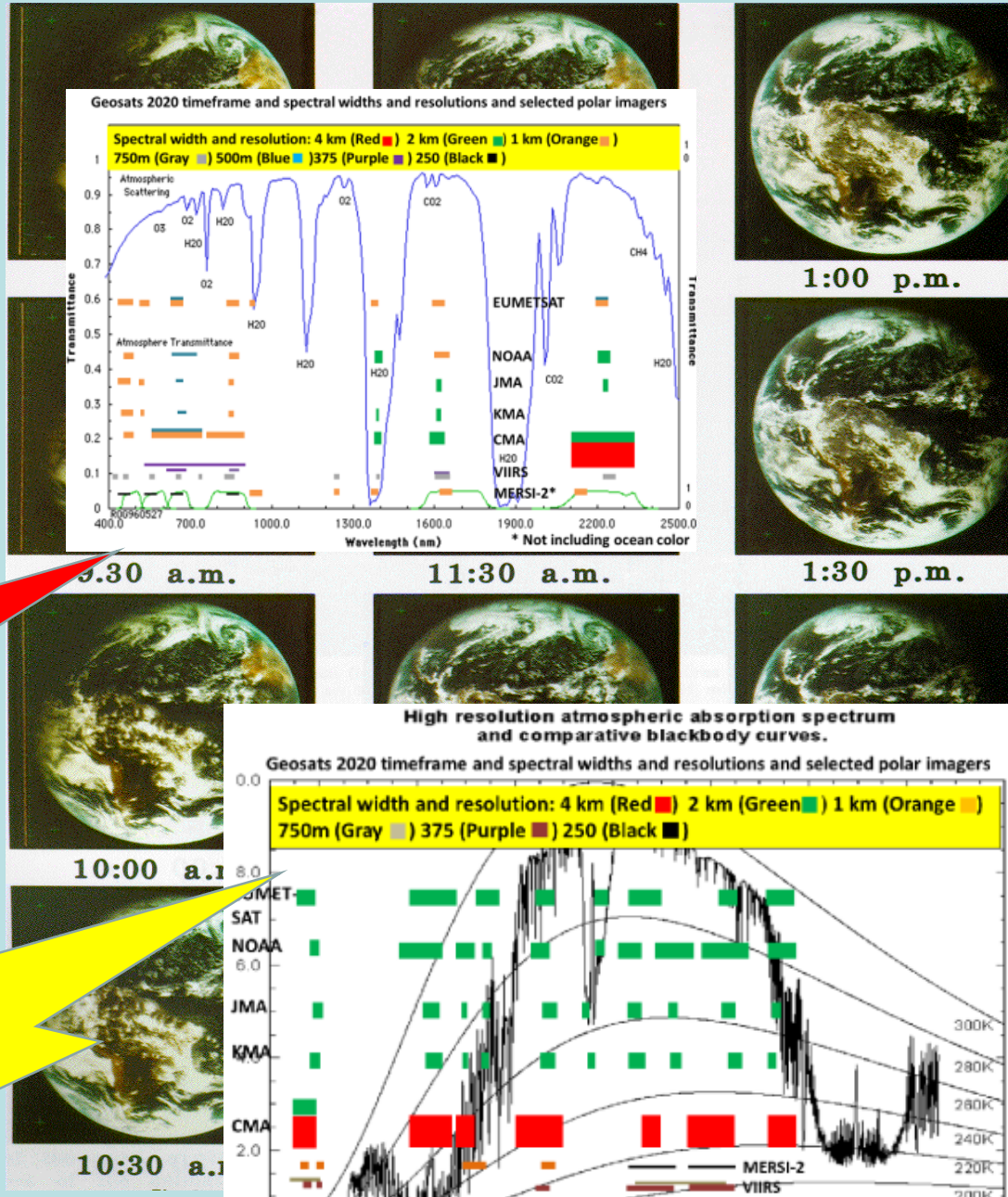
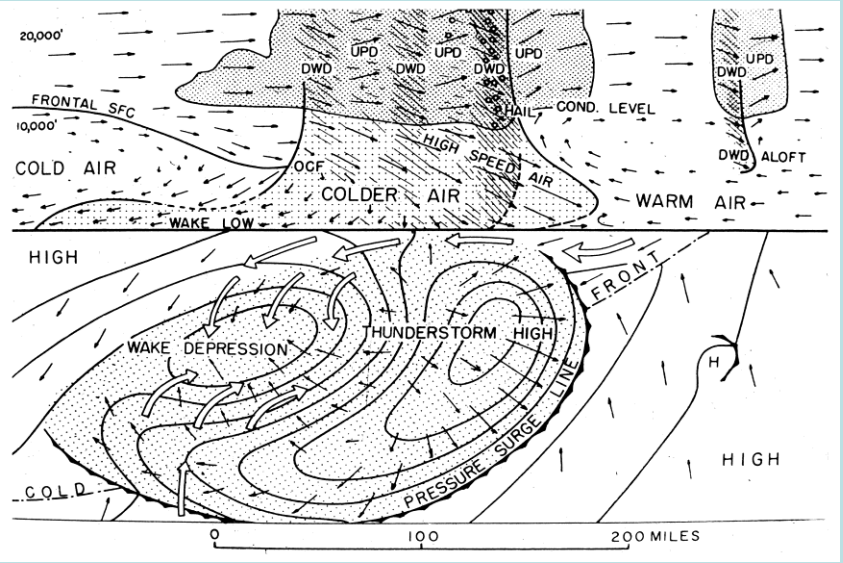
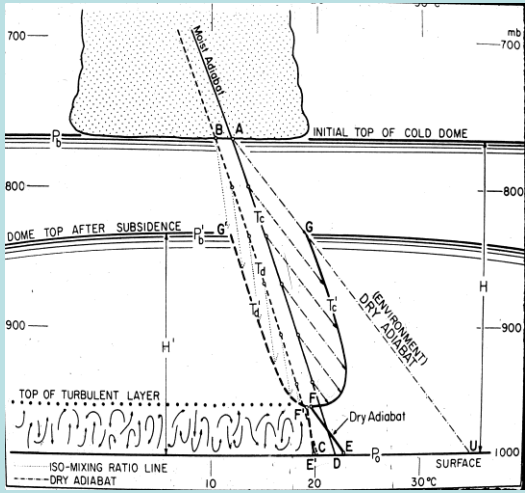


TODAY

15 High Resolution Channels

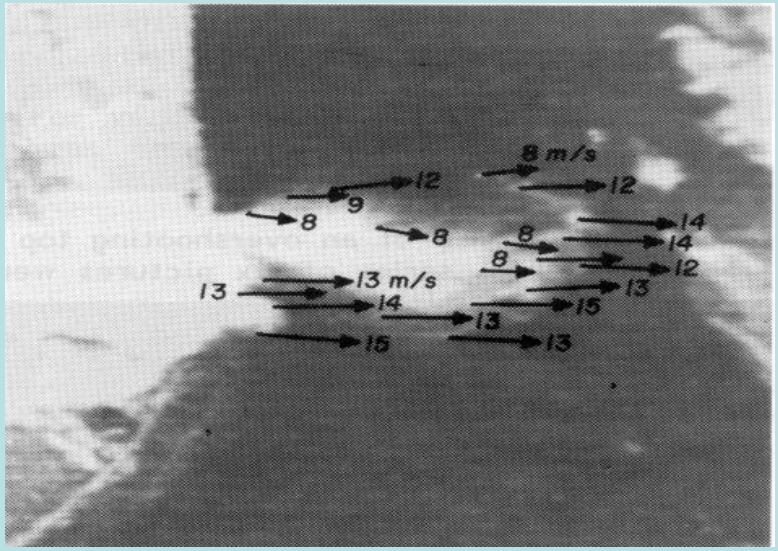
In 1985 at the 25th anniversary of weather satellites, Ted Fujita was recognized for 'creative scientific leadership as an enthusiastic pioneer in the use of satellite imagery to analyze and predict mesoscale weather phenomena and to understand severe thunderstorms, tornadoes, and hurricanes.'

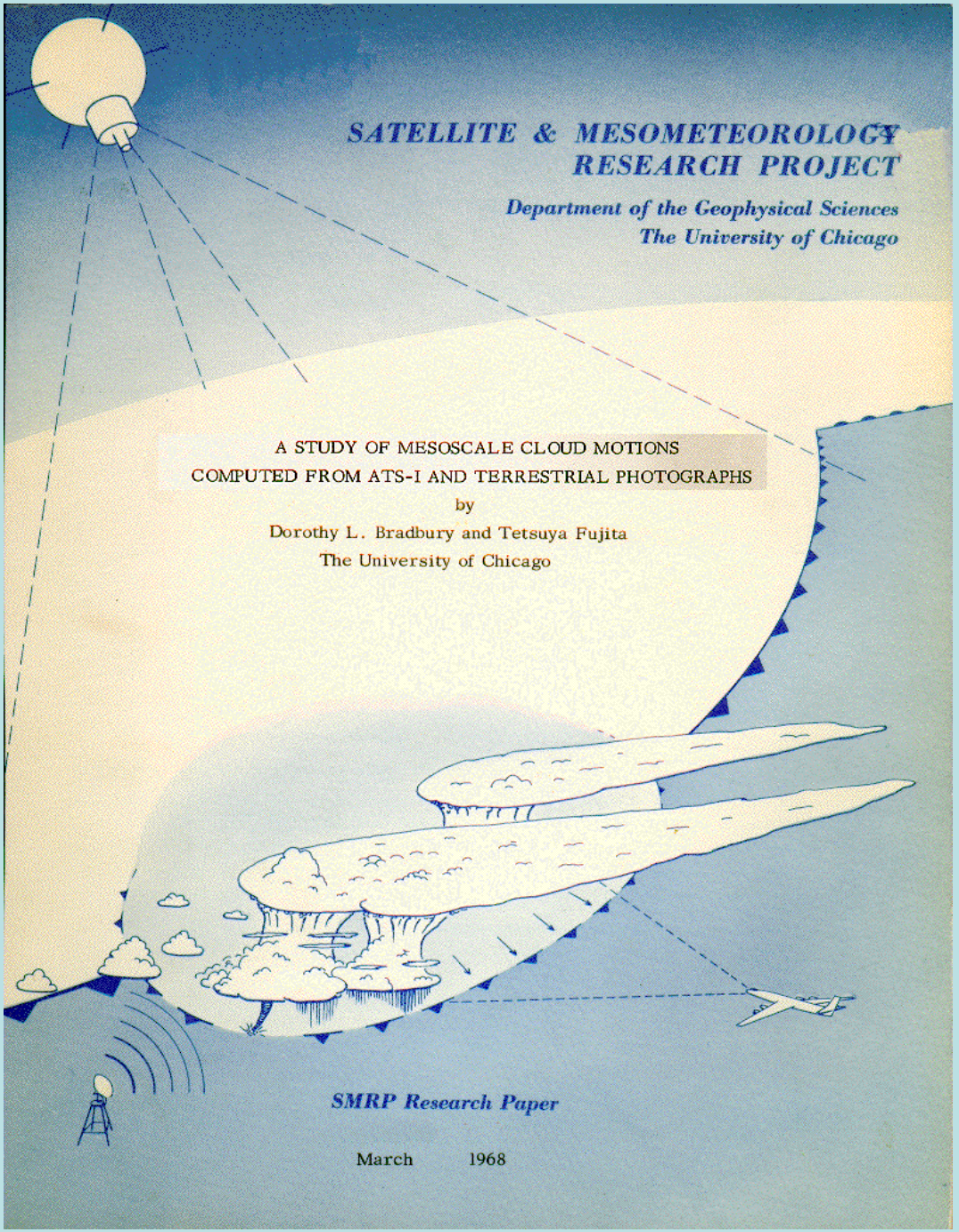




Understanding

The Mesometeorology Research Project added satellites and the SMRP papers from Ted and his U of Chicago colleagues became classics in atmospheric research





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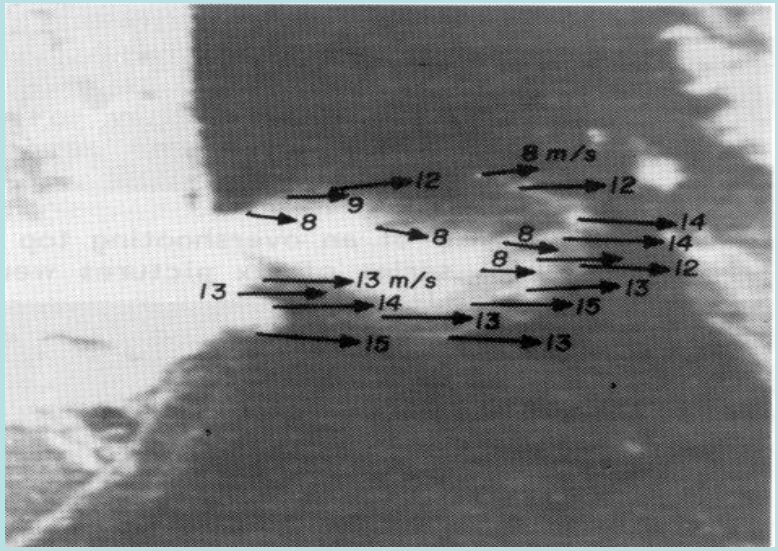
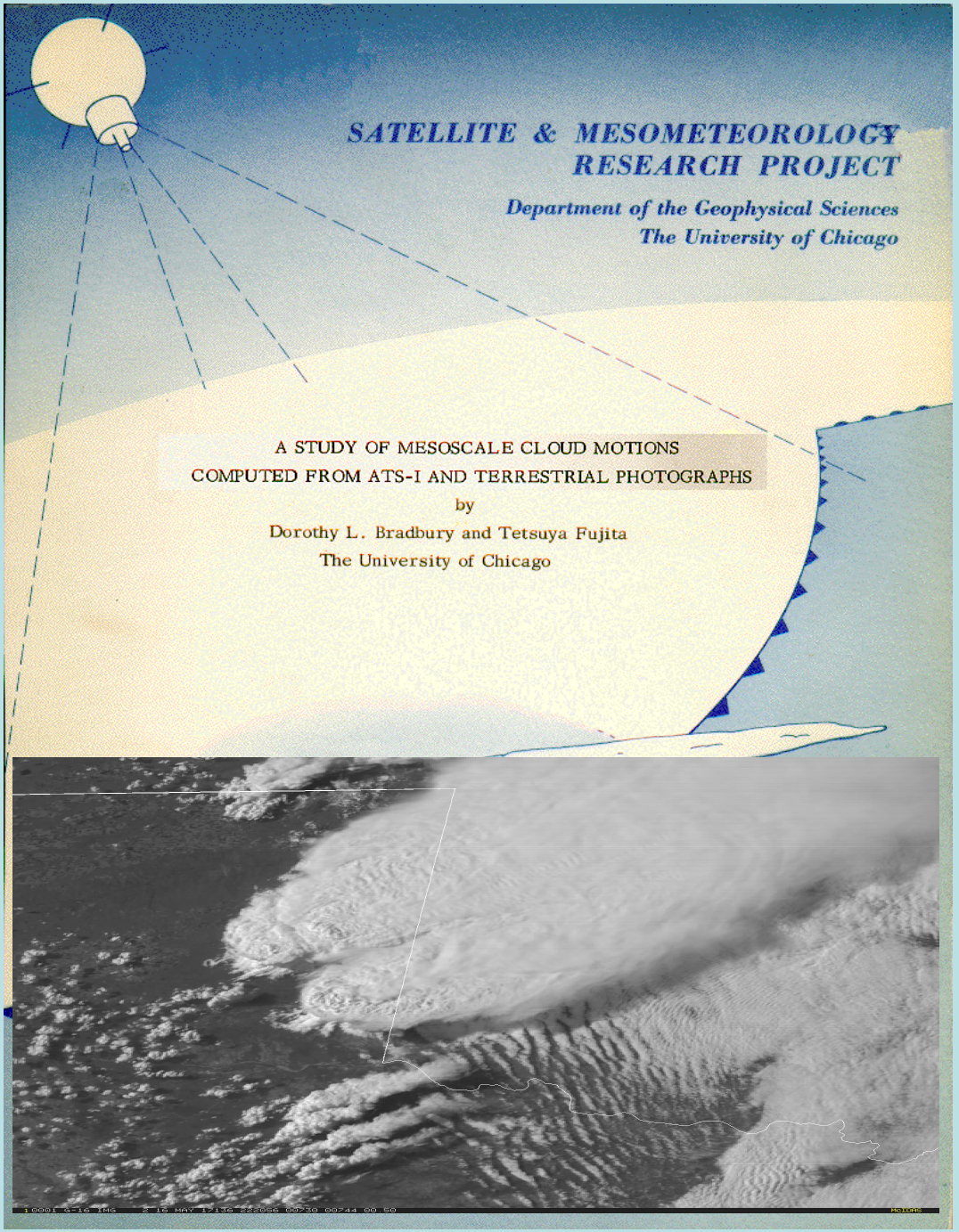
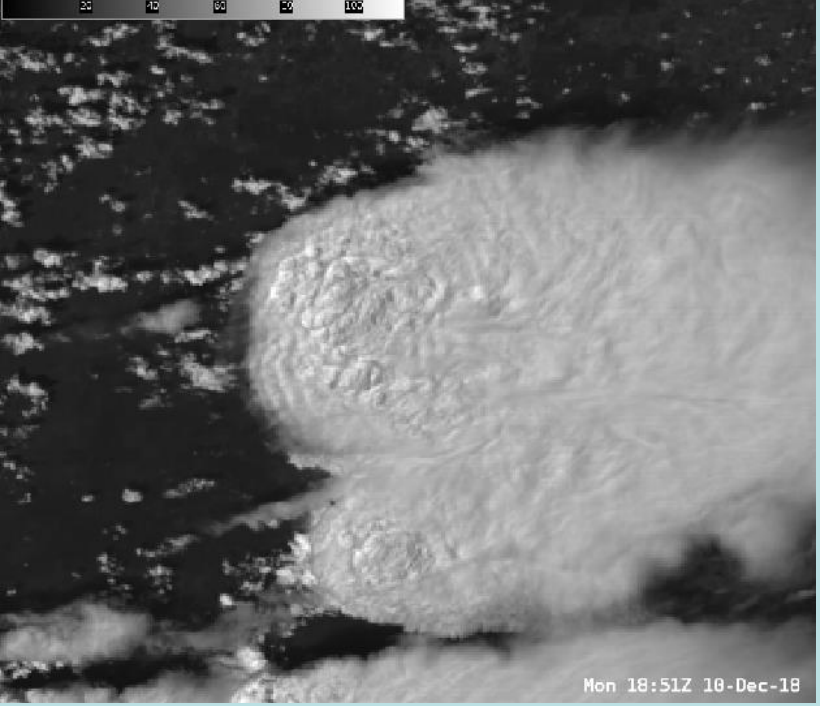
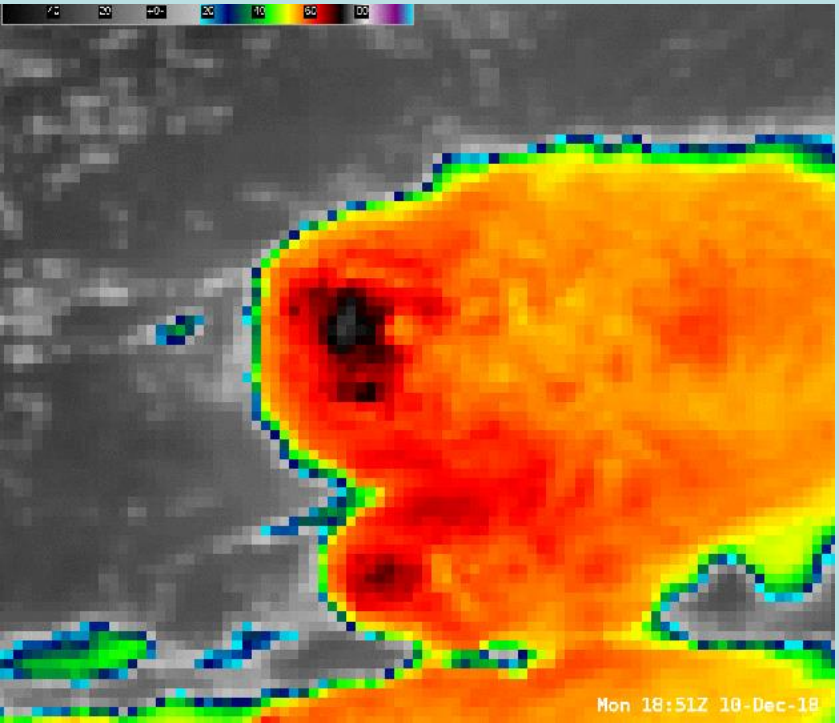
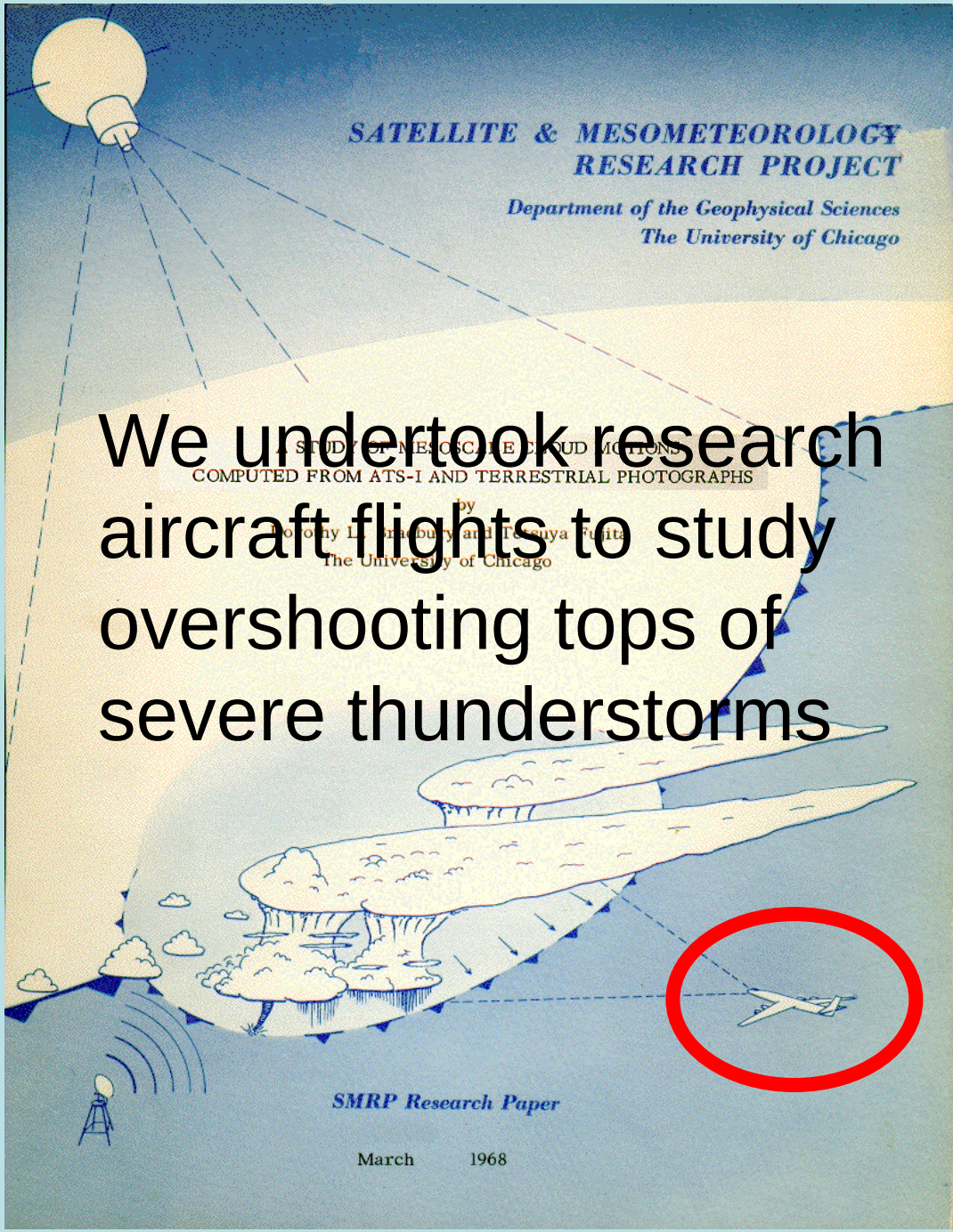










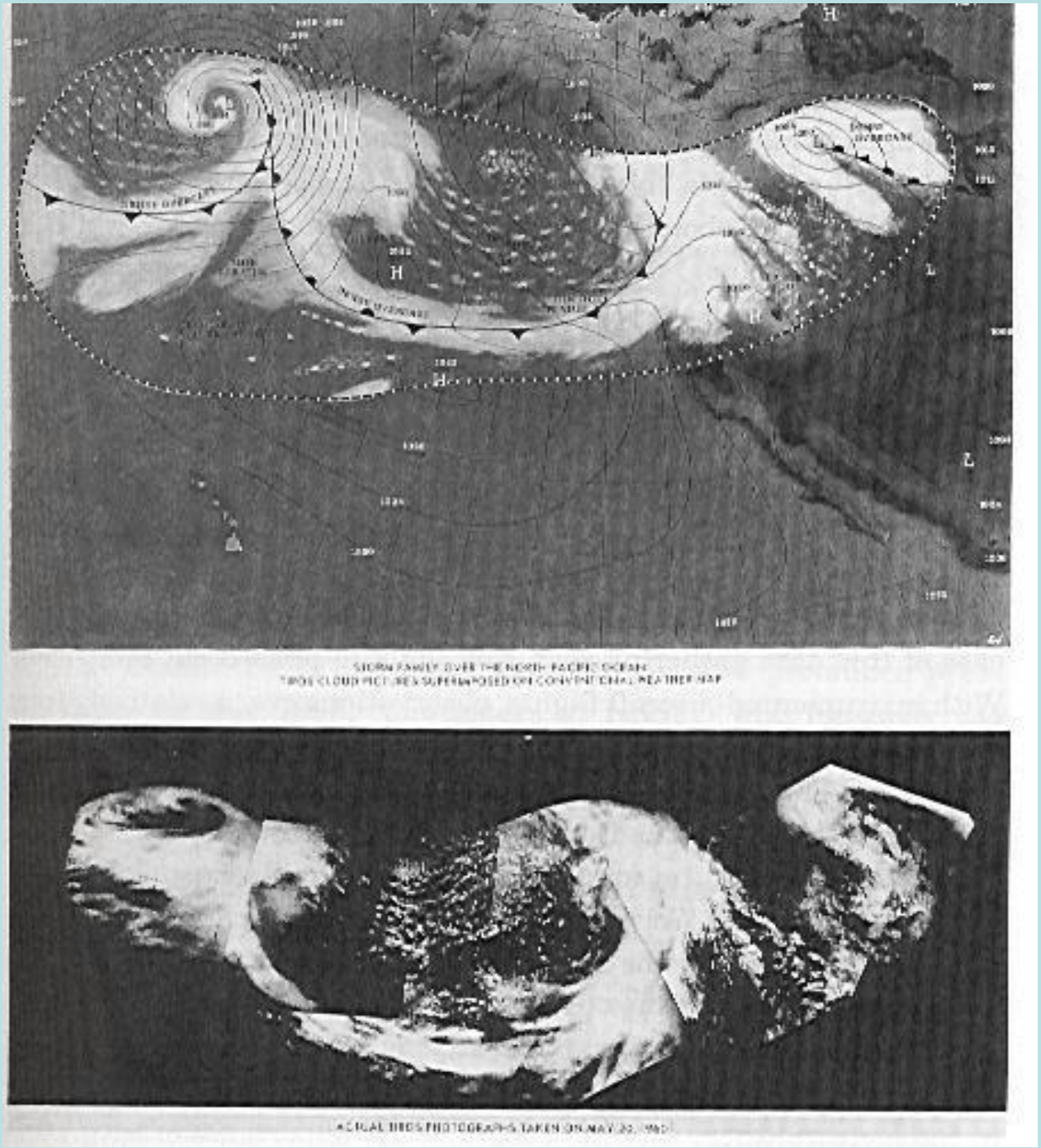
We undertook research aircraft flights to study overshooting tops of severe thunderstorms

In 1985 at the 25th anniversary of weather satellites, Vince was recognized for utilization

Vince was innovative, outstanding scientific leadership…that developed many of the techniques used in daily weather forecasting operations in the United States and throughout the world. He developed techniques to determine a variety of weather related phenomena from satellite images

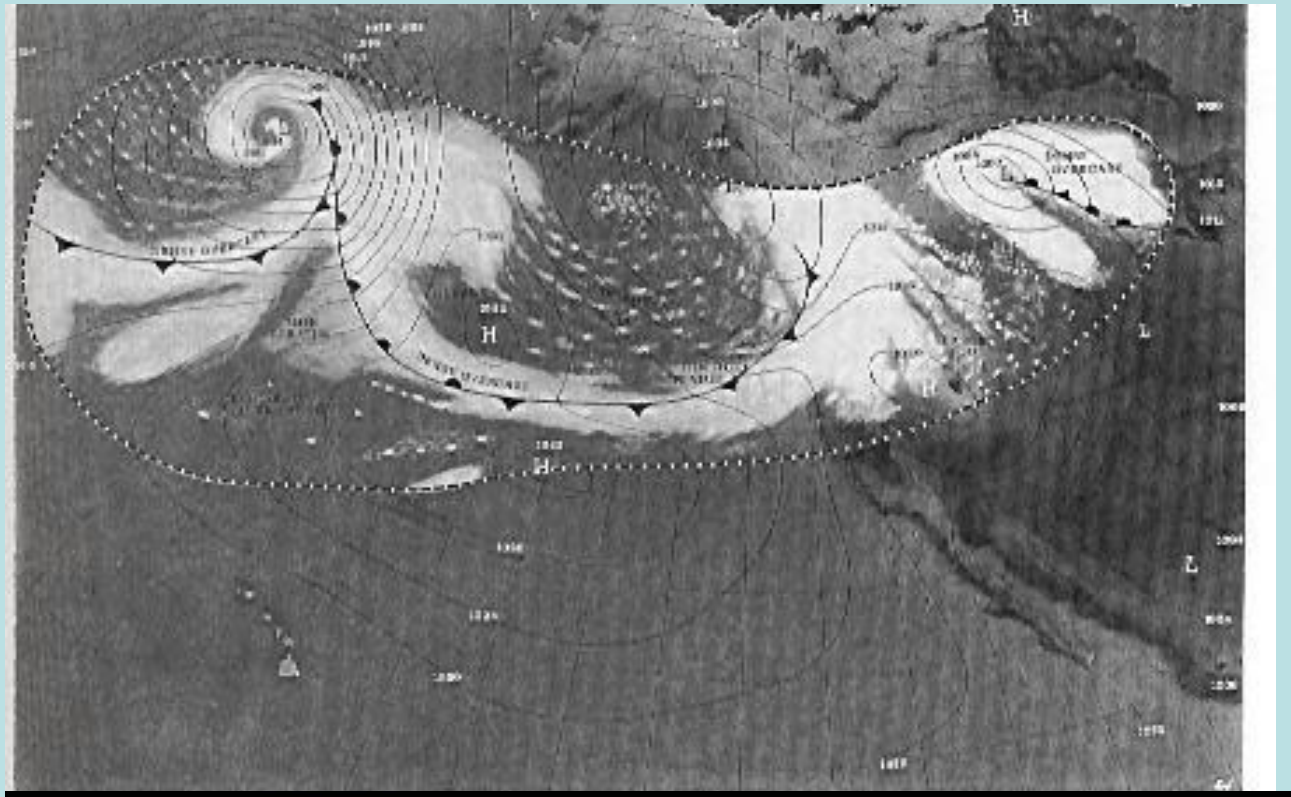
Utilization

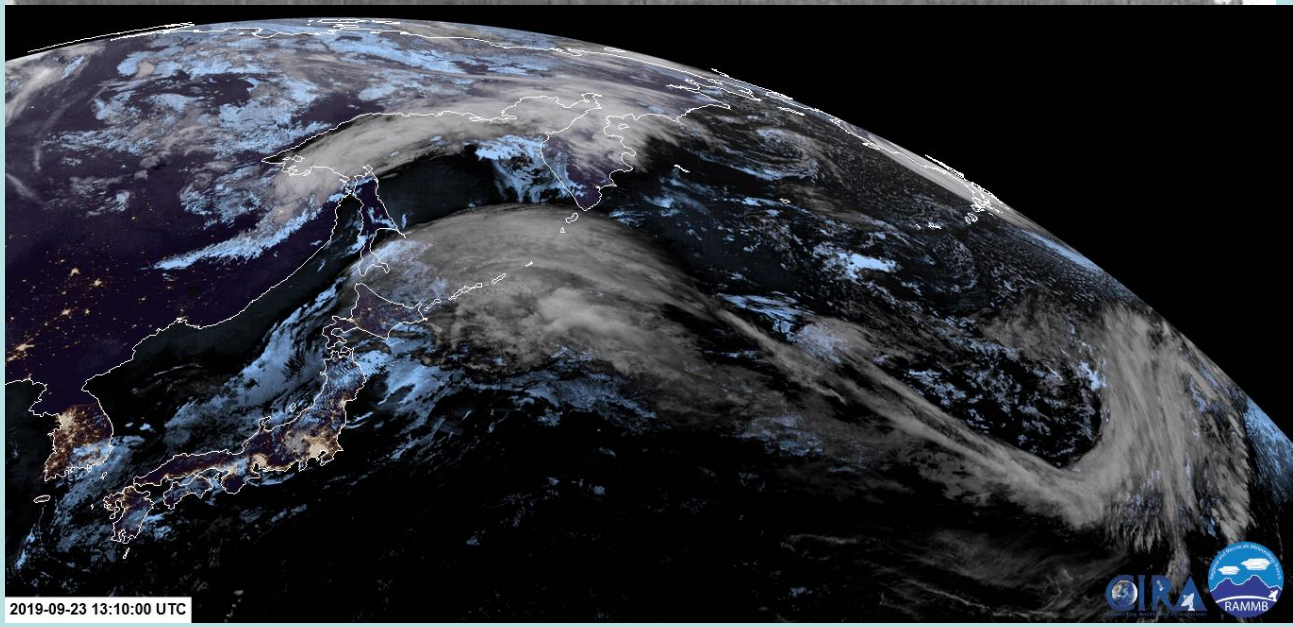
- **Weather map from May 20, 1960 (top) with artist rendering of clouds from the TIROS-1 photographic-mosaic taken that same day (bottom)**



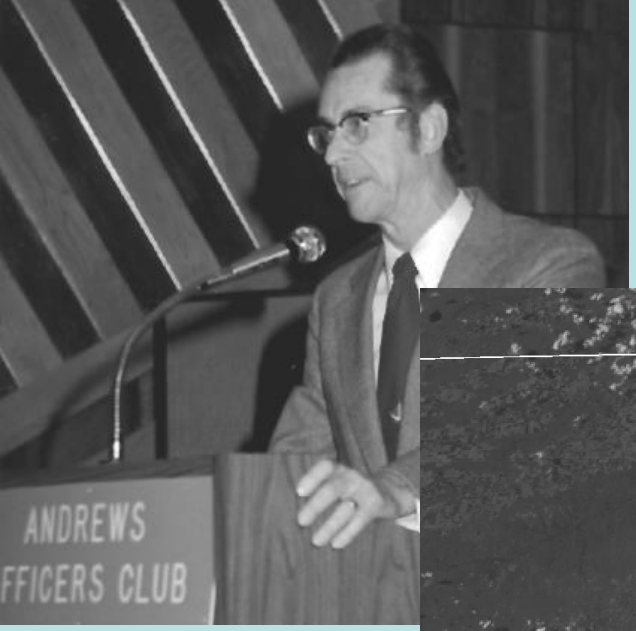
- **Weather map from May 20, 1960 (top) with artist rendering of clouds from the TIROS-1**

Today multichannel animation from Himawari with City lights from JPSS





Our Early Standard Bearers

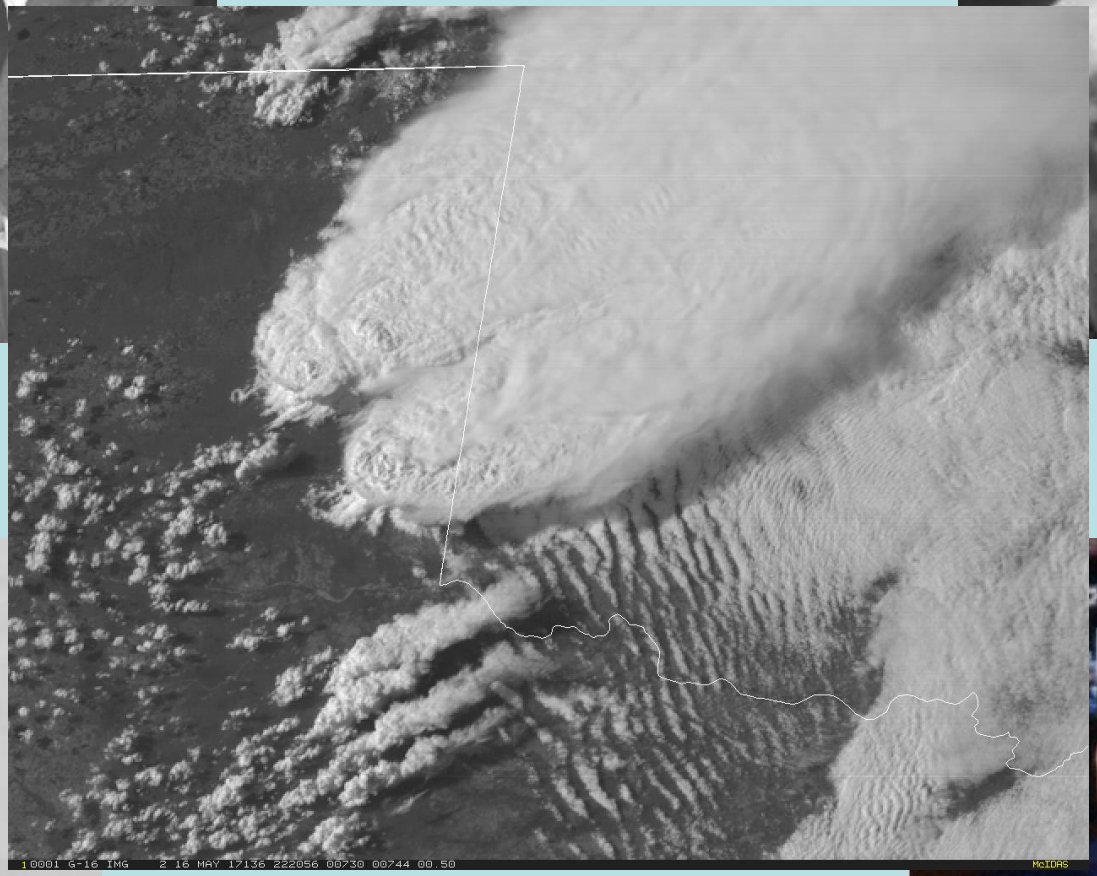


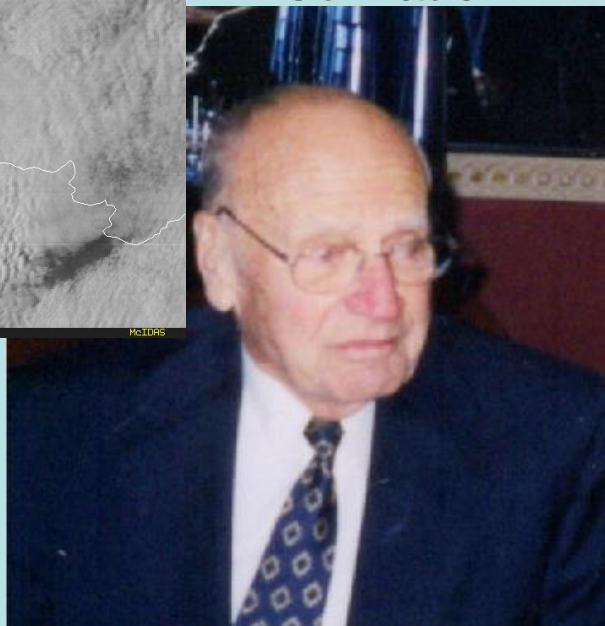
Leadership

Understanding

Vision

Utilization

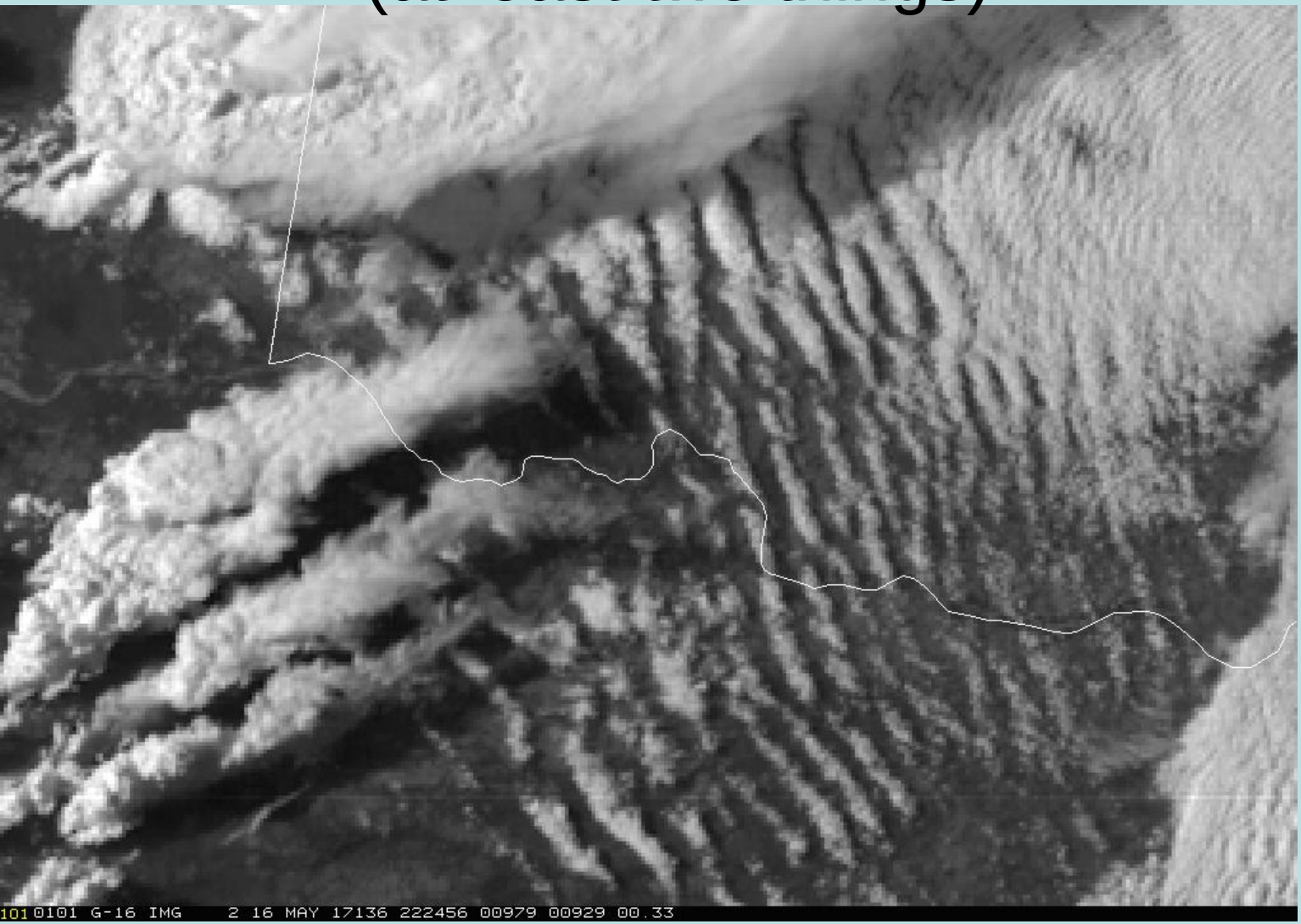




We now see further because we stand on the shoulders of giants.

(Var, Bernard de Chartres, 12th century)

Two things to note in this animation (at least two things)



The cloud streets moving Northward in the loop appear to be almost rolling, which actually is a reflection of shear across that stably capped cloud street layer (water clouds).

Inspection of the two prominent storms as they evolve: the cloud streets can be seen being "tilted" upward into the storm due to increasing vertical motion and buoyancy.

A visual representation of the "tilting term" in the vorticity equation

$$\left(\frac{\partial w}{\partial y} \frac{\partial u}{\partial z} - \frac{\partial w}{\partial x} \frac{\partial v}{\partial z} \right)$$

EVOLUTION TO TODAY'S OPERATIONAL SYSTEMS

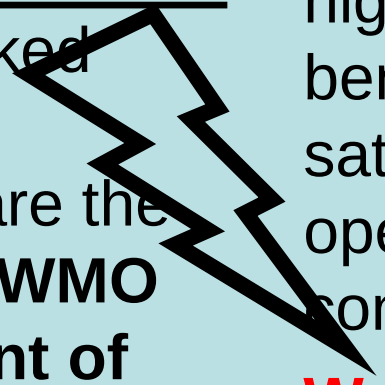
What was significant?

- **Leadership**
- **Vision**
- **Understanding**
- **Utilization**
- **International Cooperation**

(Focus on roles of WMO and CGMS)

1962: An important landmark

Two world recognized leaders in the young science of satellite meteorology, **Dr. Harry Wexler, USA, and Academician Bugaev from the then USSR** worked together in Geneva, Switzerland to prepare the **First Report of the WMO on the Advancement of Atmospheric Sciences and Their Application in the Light of Developments in Outer Space.**



Eventually, there would be four reports but the first was to have the largest impact on WMO Members.

Wexler and Bugaev vividly highlighted potential benefits resulting from satellite data to both operational and research communities.

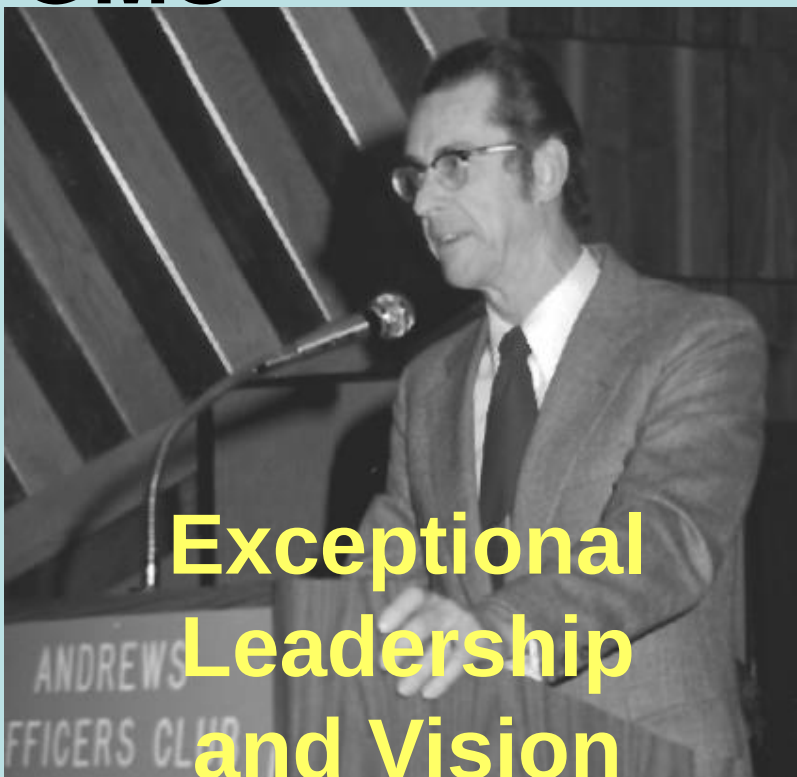
Wexler and Bugaev then proposed a new structure: the WorldWeather Watch.

(thanks to Don Hinsman**)**

Coordination Group for *Geostationary Meteorological Satellites* (CGMS) came into being in **1972**, It evolved to include all Meteorological Satellites thus the Coordination Group for Meteorological Satellites (CGMS).

Dave Johnson is recognized as the "father" of CGMS

CGMS has expanded both in terms of its membership and its objectives.



WHAT CGMS DOES

Coordination of observing systems and protection of assets

- **Compatibility and possible mutual back-up**
- **Similarity of channels and scan modes on satellites**
- **Orbit configuration (both Geostationary and Polar constellations)**

•Data dissemination, direct read out services and contribution to the WIS

Enhance the quality of satellite-derived data and products

- **CGMS/WMO sponsored working groups**

Outreach and training activities

- **Virtual Laboratory for Satellite data Utilization**

Cross-cutting issues and new challenges

- **Sustained, Co-Ordinated Processing of Environmental Satellite Data for Climate Monitoring (SCOPE-CM)**
- **Strategy Towards an Architecture for Climate Monitoring from Space**

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Similarity of channels and scan modes on satellites

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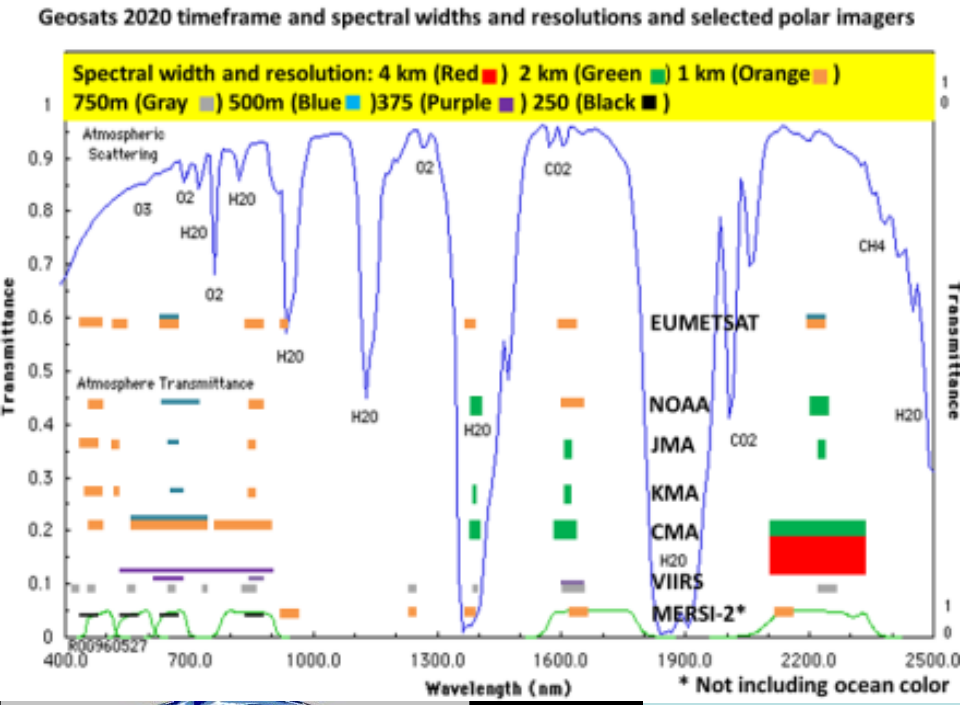
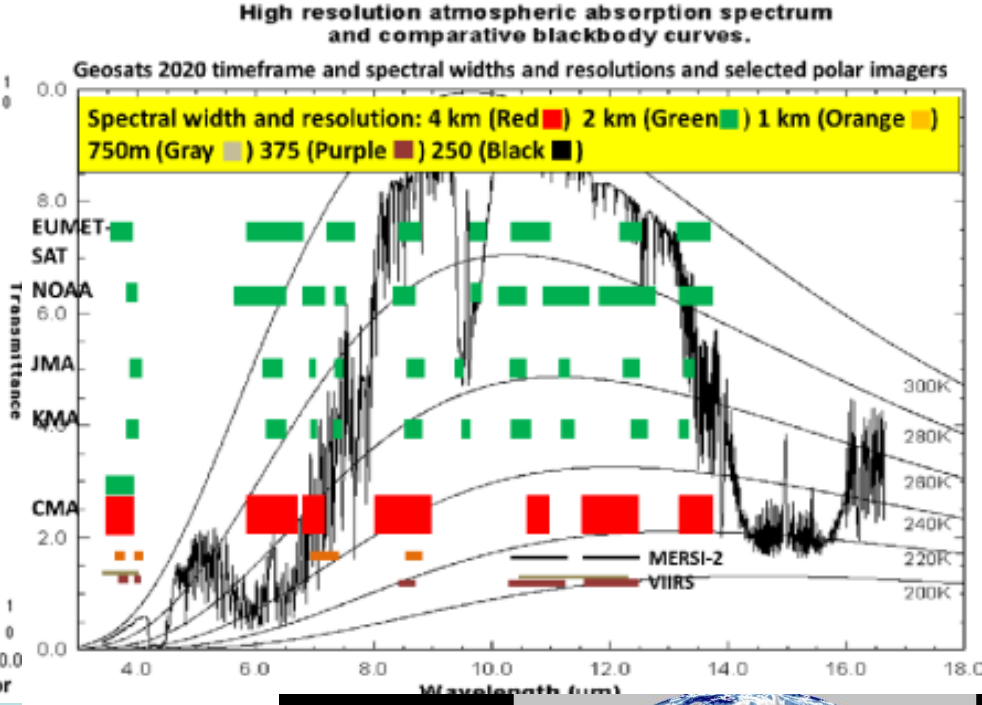
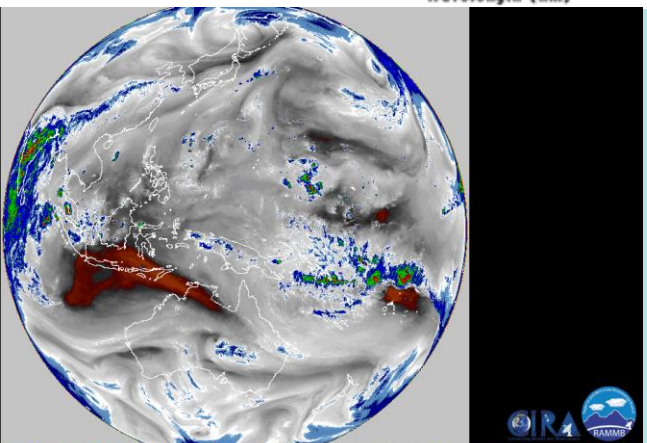
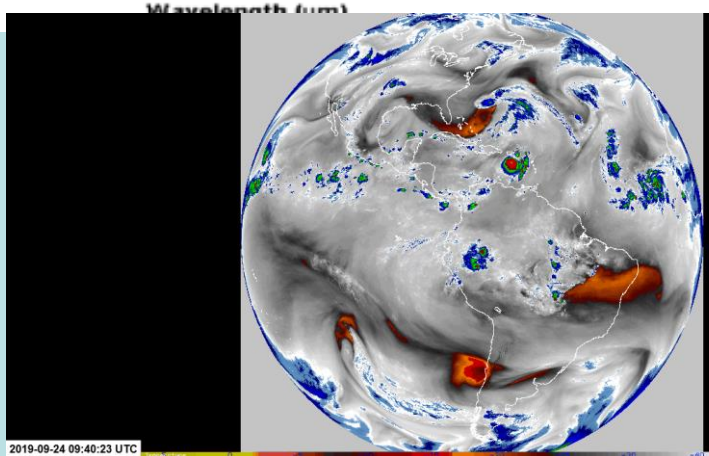






Himawari (left) and GOES-16 (right)

10-minute imagery animation @ 6.2 microns



Orbit configuration (both Geostationary and Polar)

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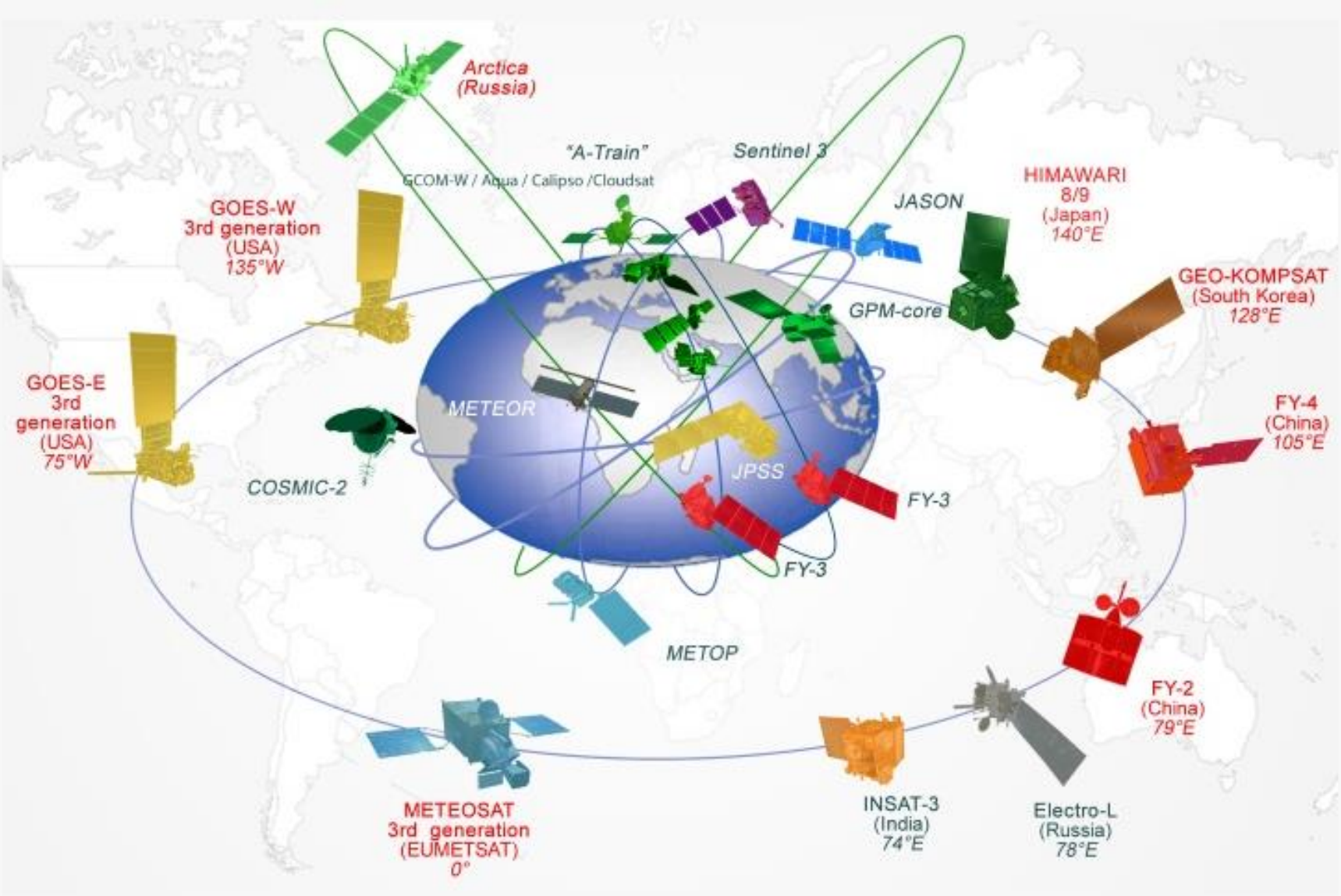

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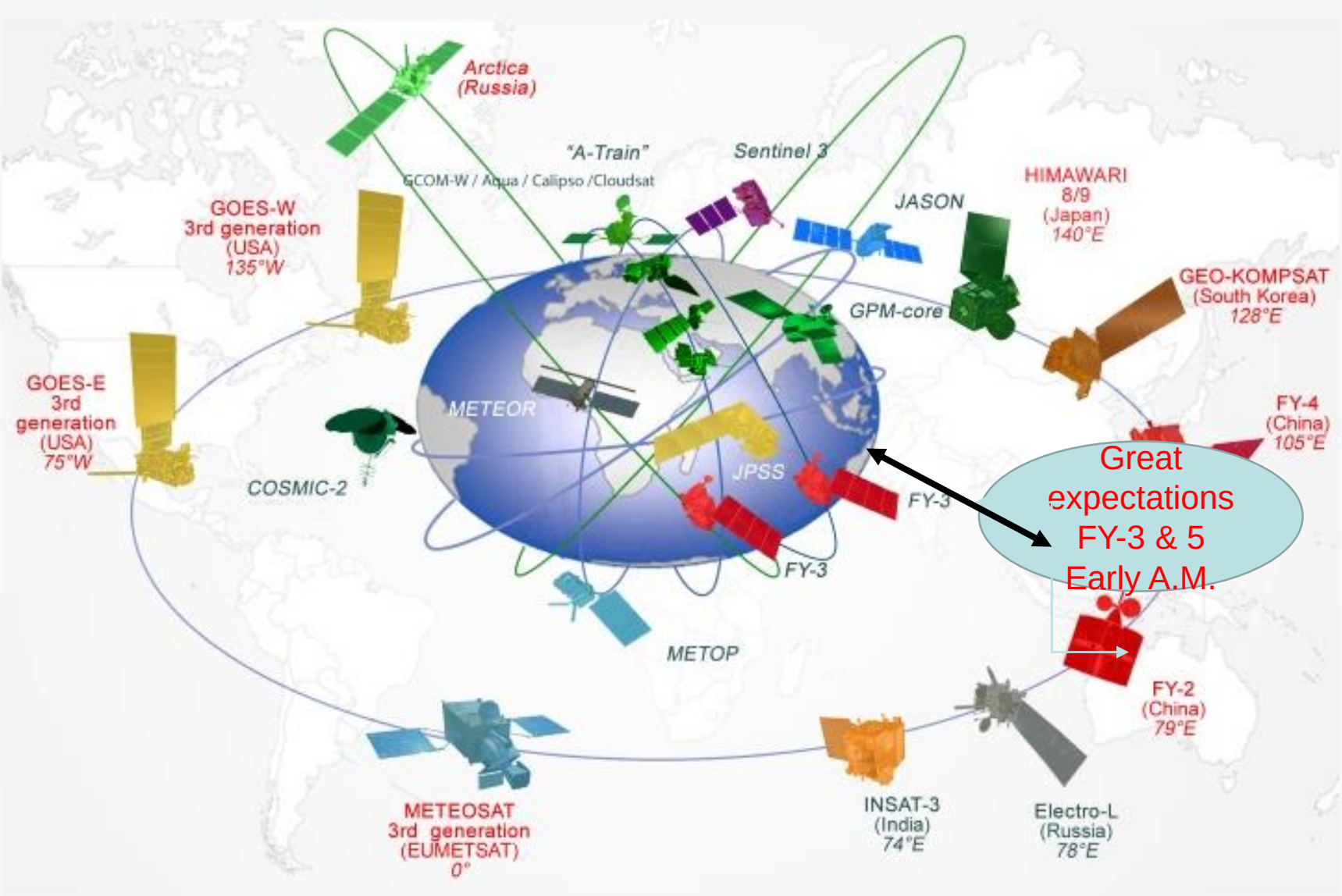

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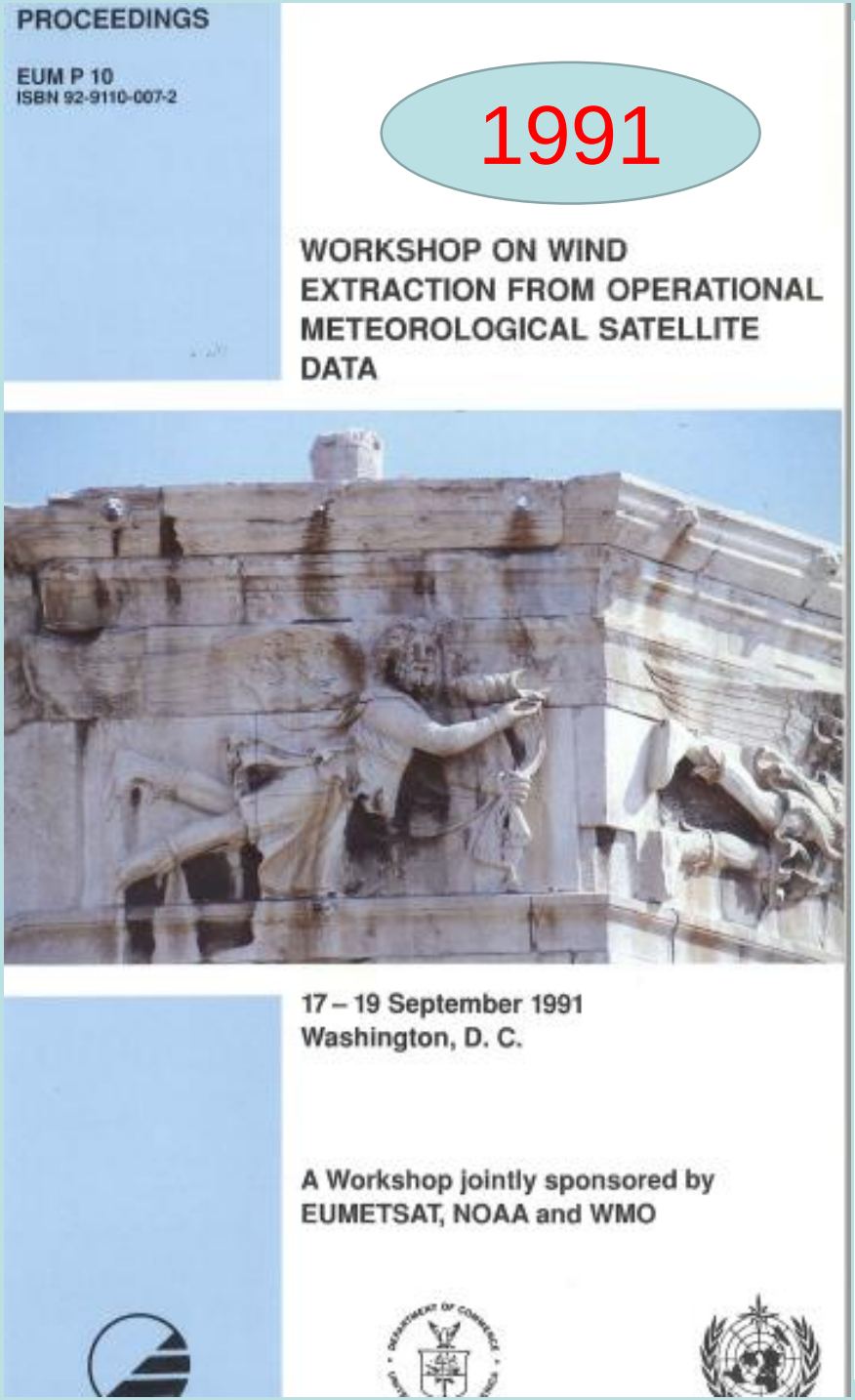
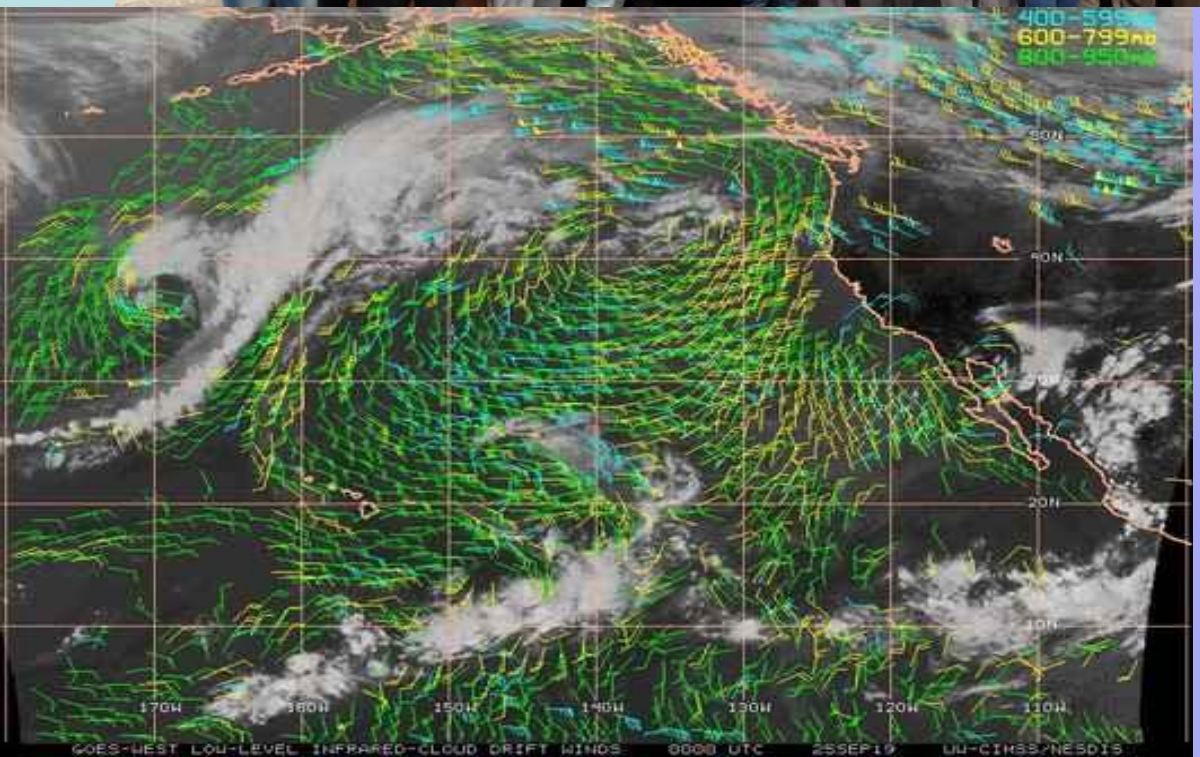


Anderson, R. K.
Arnold, C. P.
Büche, G.
Fujita, T.
Gérard, F.
Gopala Rao, U. V.
Hayden, C. M.
Herman, L. D.
Hinsman, D.
Holmlund, K.
Julian, P. R.
Karpov, A.
Laurent, H.
Le Marshall, J.
Lowe, D. A.
Lubich, D. A.
Lunnon, R. W.
Lure, Y. M. F.
Menzel, W. P.
Purdom, J. F.
Schmetz, J.
Shenk, W. E.
Smith, W. L.
Strauss, B.
Szantai, A.
Thoss, A.
Uchida, H.
Velden, C. S.
Woick, H.
Yeh, H. Y. M

Australia
Canada
France
Germany
India
Japan
Kenya
Switzerland
UK
USA
USSR

2016 Monterey, CA



Activities

Back to IWWG home page

A number of actions and recommendations are m
recent meetings are provided in:

- CGMS actions and recommendations
- IWW recommendations

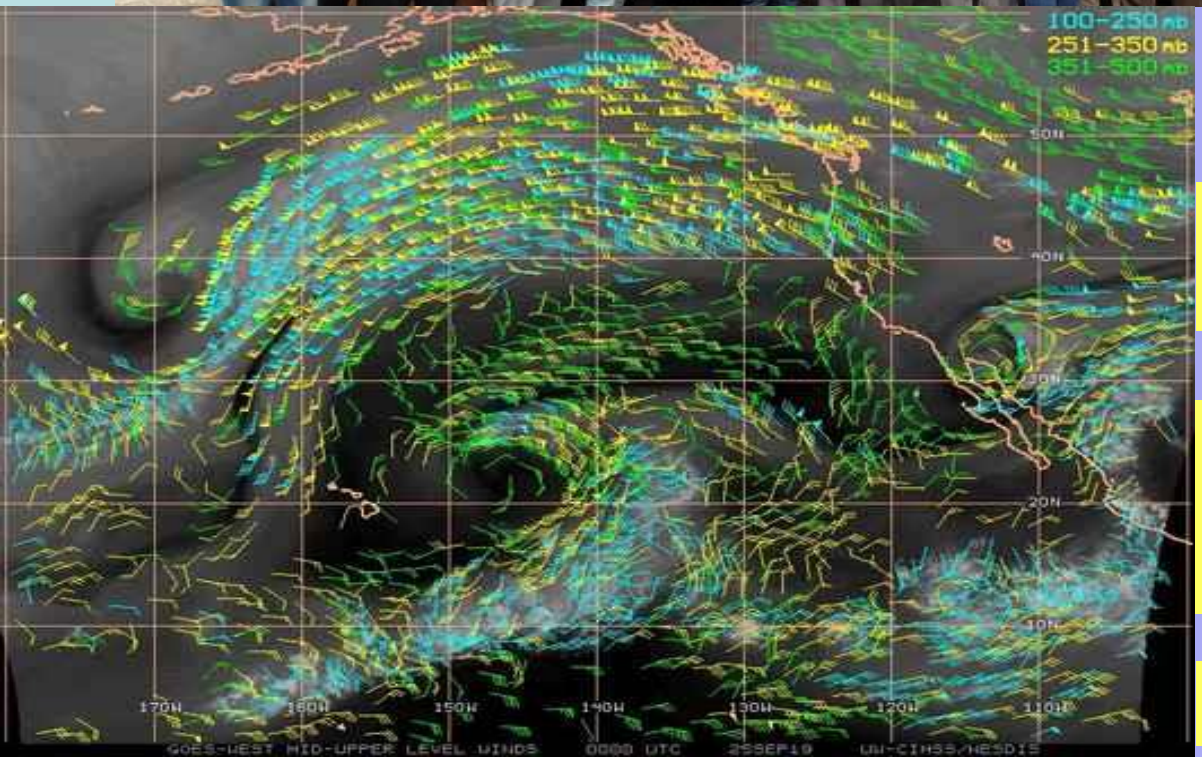
To address these a number of collaborative proje
Members of the IWWG community are encourage

Active projects

- Portable AMV software
- High resolution wind products
- Simulated imagery AMV studies
- Investigating AMV error characteristics
- Adding extra information to BUFR sequence

Completed projects

- NWP winds impact study
- AMV intercomparison study 2



Activities

Back to IWWG home page

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recent meetings are provided in:

CGMS Actions and Recommendations

proj
urage

Active projects

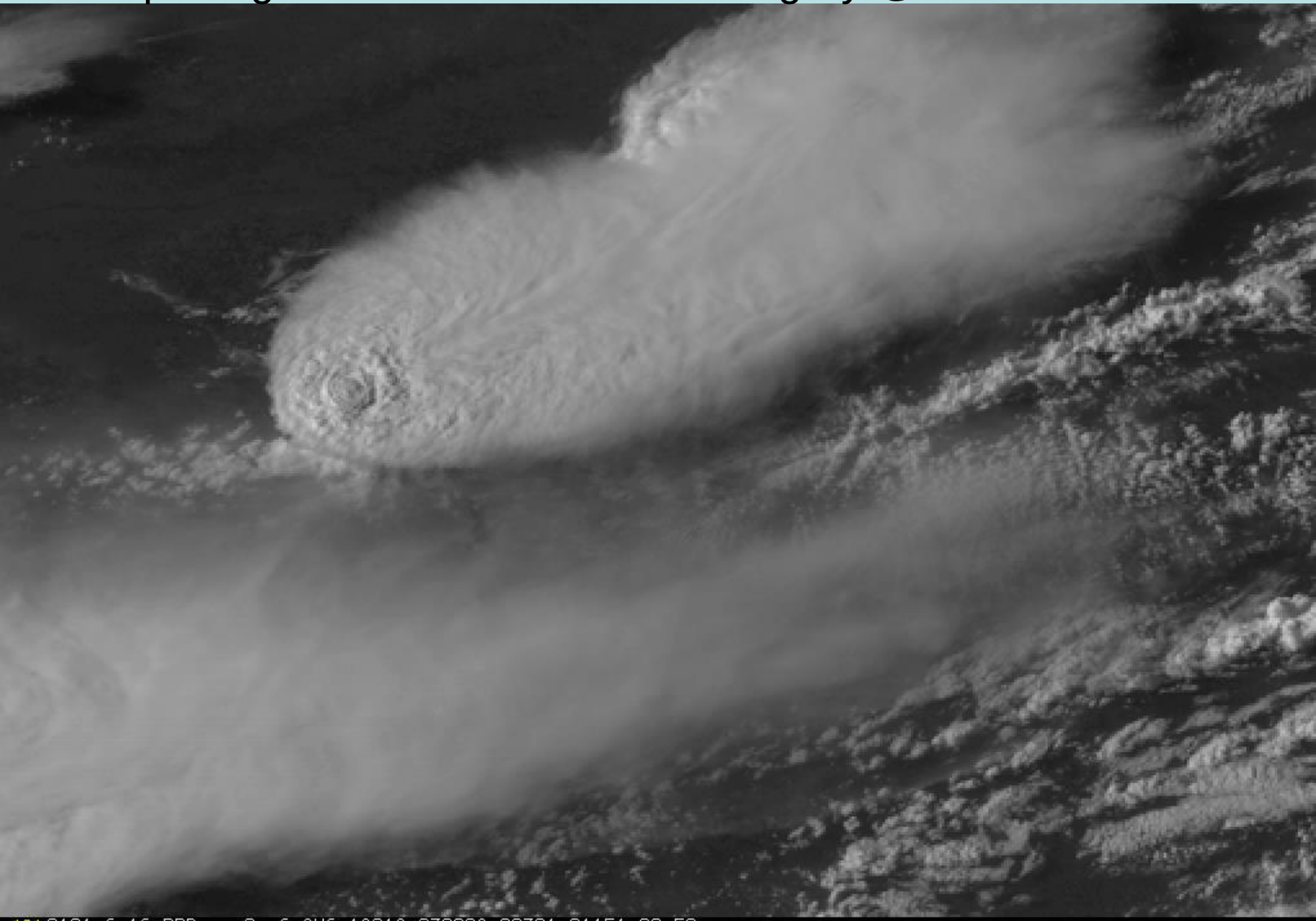
Portable AMV Software
High resolution AMVs
Error Characteristics

nce

Completed projects

NWP Impact Studies

Exploring the limits with 0.5 km imagery @ 6 sec. intervals



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The First International TOVS Study Conference

David Q. Wark

1983

T. Aoki (Japan)
L.A. Baranski (Poland)
H. Billing (FRG)
H.J. Bolle (Austria)
M.T. Chahine (USA)
A. Chedin (France)
Y. Durand (France)
J.R. Eyre (UK)
H. Fischer (FRG)
G.A. Kelly (Australia)
P. King (Canada)
T.J. Kleespies (USA)
J.F. LeMarshall (Australia)
F. Loechner (FRG)
M.J. Lynch (Australia)
L. McMillin (USA)
W.P. Menzel (USA)
M.J. Munteanu (USA)
K. Paetzold (FRG)
T. Phulpin (France)
F. Prata (UK)
G. Rochard (France)
H. Rott (Austria)
N. Scott (France)
D. Spänkuch (GDR)
J. Susskind (USA)
J. Svensson (Sweden)
B.F. Taylor (New Zealand)
R.J. du Vachat (France)
H.M. Woolf (USA)
F.X. Zhou (PRC)

Breakthrough in Utilization of Satellite Data in NWP

=> Direct Use of Radiances rather than Soundings

‚Assimilation of TOVS radiance information through one-dimensional variational analysis', J. Eyre et al. (1993)

John Eyre, Gramme Kelly, Tony McNally, Eric Anderson, A. Persson

- *... difficulties in exploiting satellite sounding in NWP in the form of independently retrieved temperature and humidity profiles ..*
- *... radiance measurements may be assimilated more directly into the NWP system...*

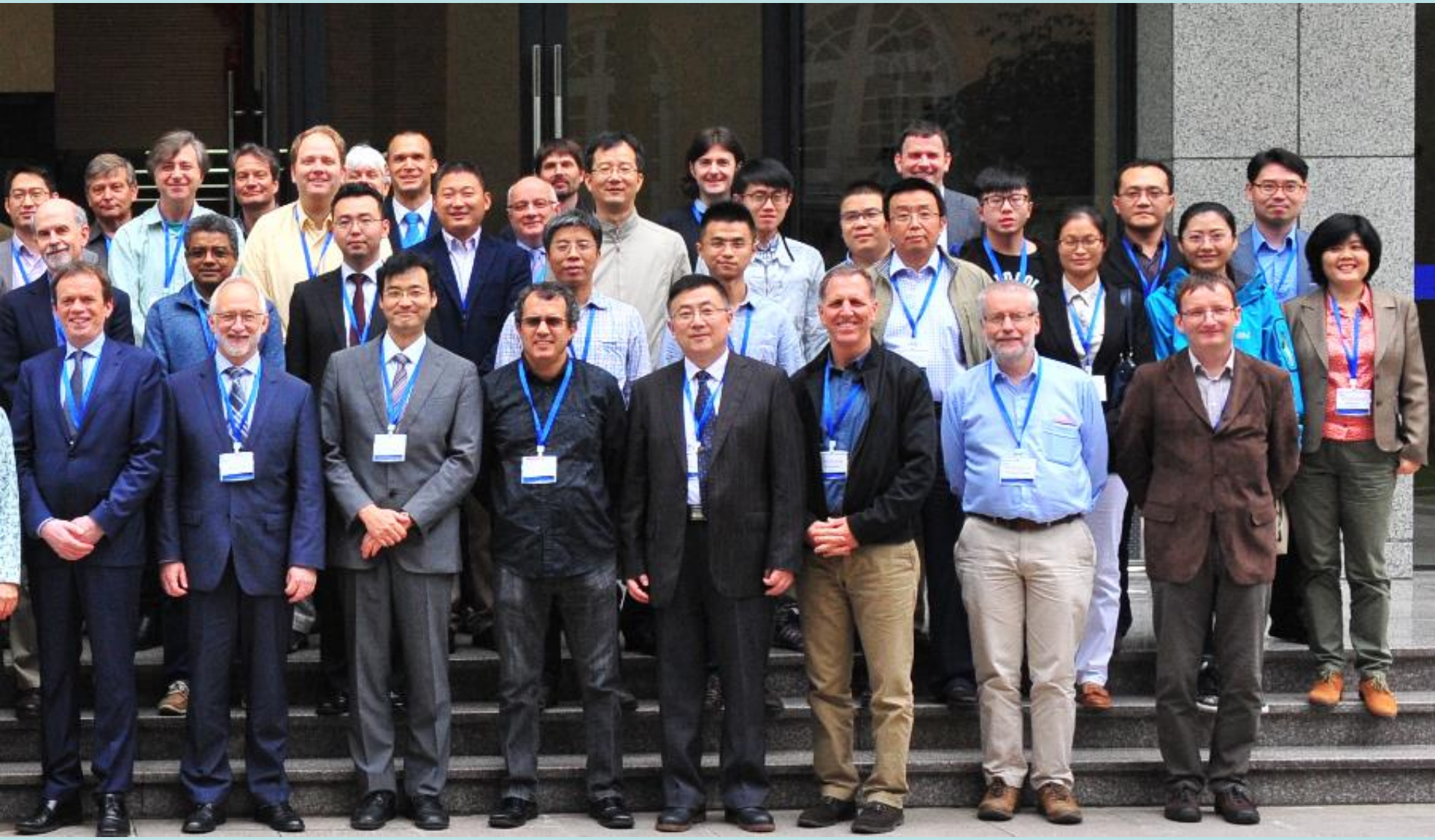
The 14th International TOVS Study Conference

第 14 届国际泰罗斯业务垂直探测研讨会

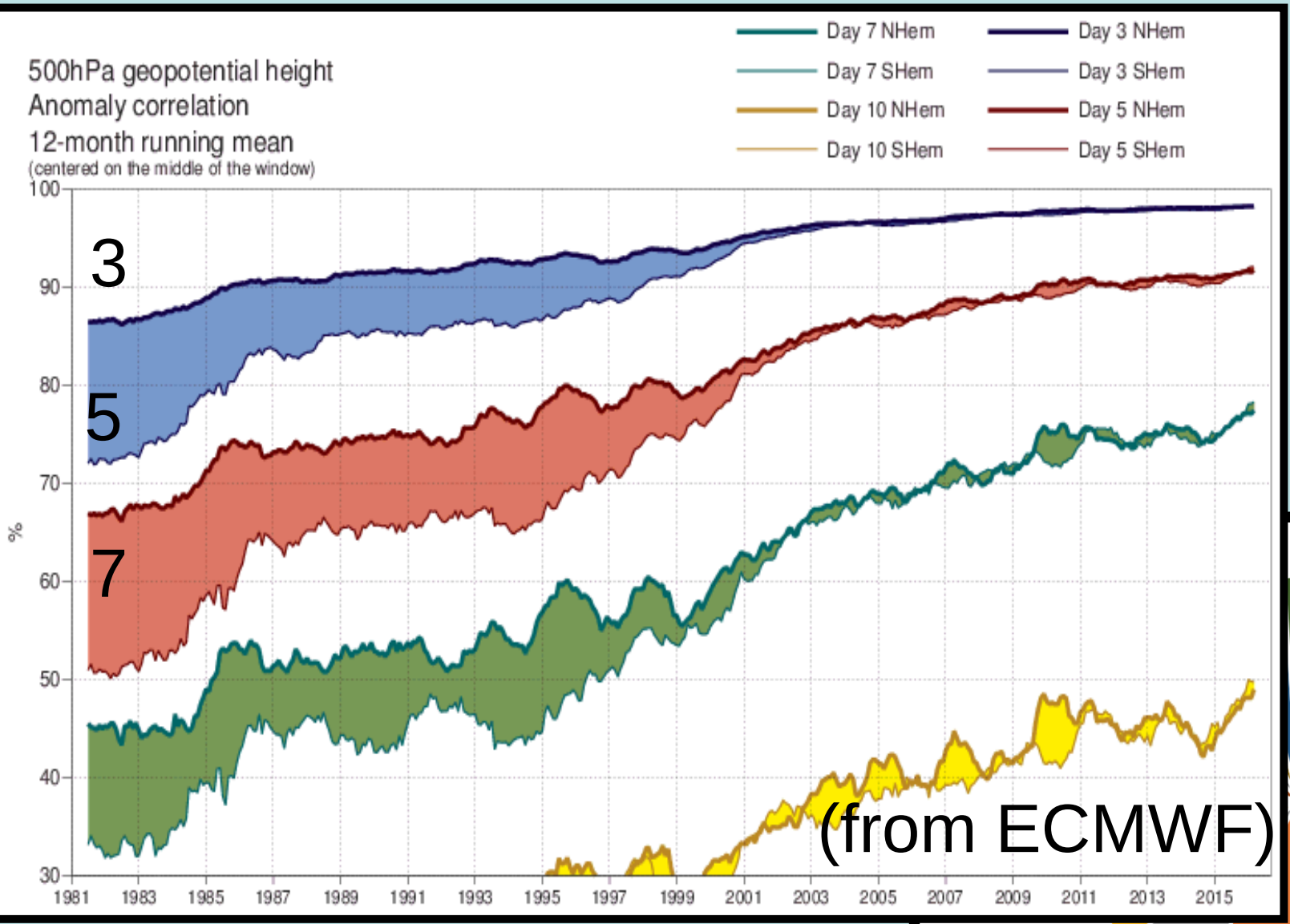
(25–31 May, Beijing, China)

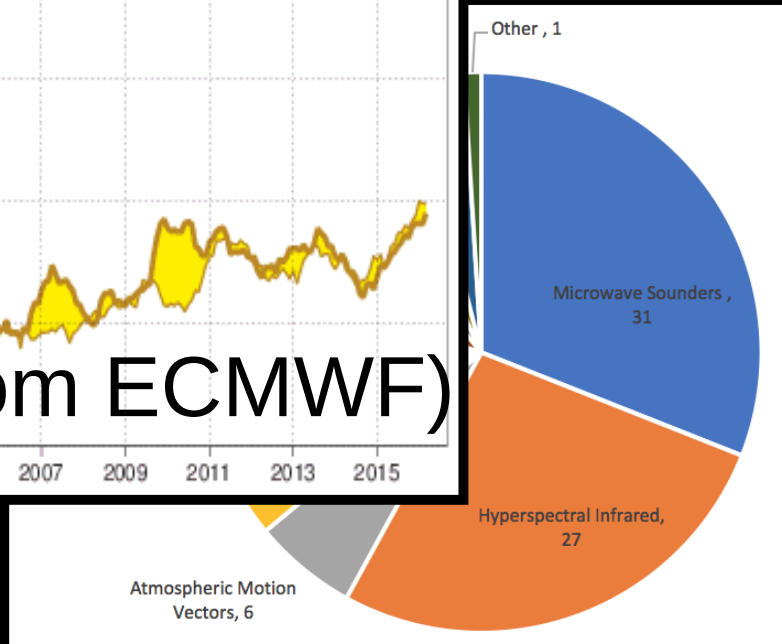
6th Workshop on the Impact of Various Observing Systems on NWP, Shanghai, May 2016

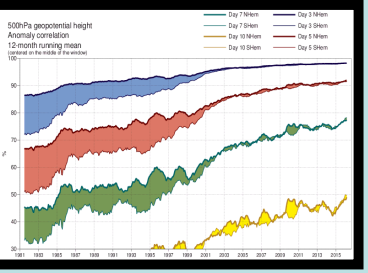
About 90 experts from ECMWF, China, U.S., Canada, U.K., Germany, Norway, Japan, S. Korea, Australia, etc. attended this workshop. The focus was on the development of integrated, optimized observing systems with high efficiency for improving the numerical weather prediction through impact studies, and to provide evidence for designing the global observing system. (From SSEC web site)



Satellite data impact on NWP

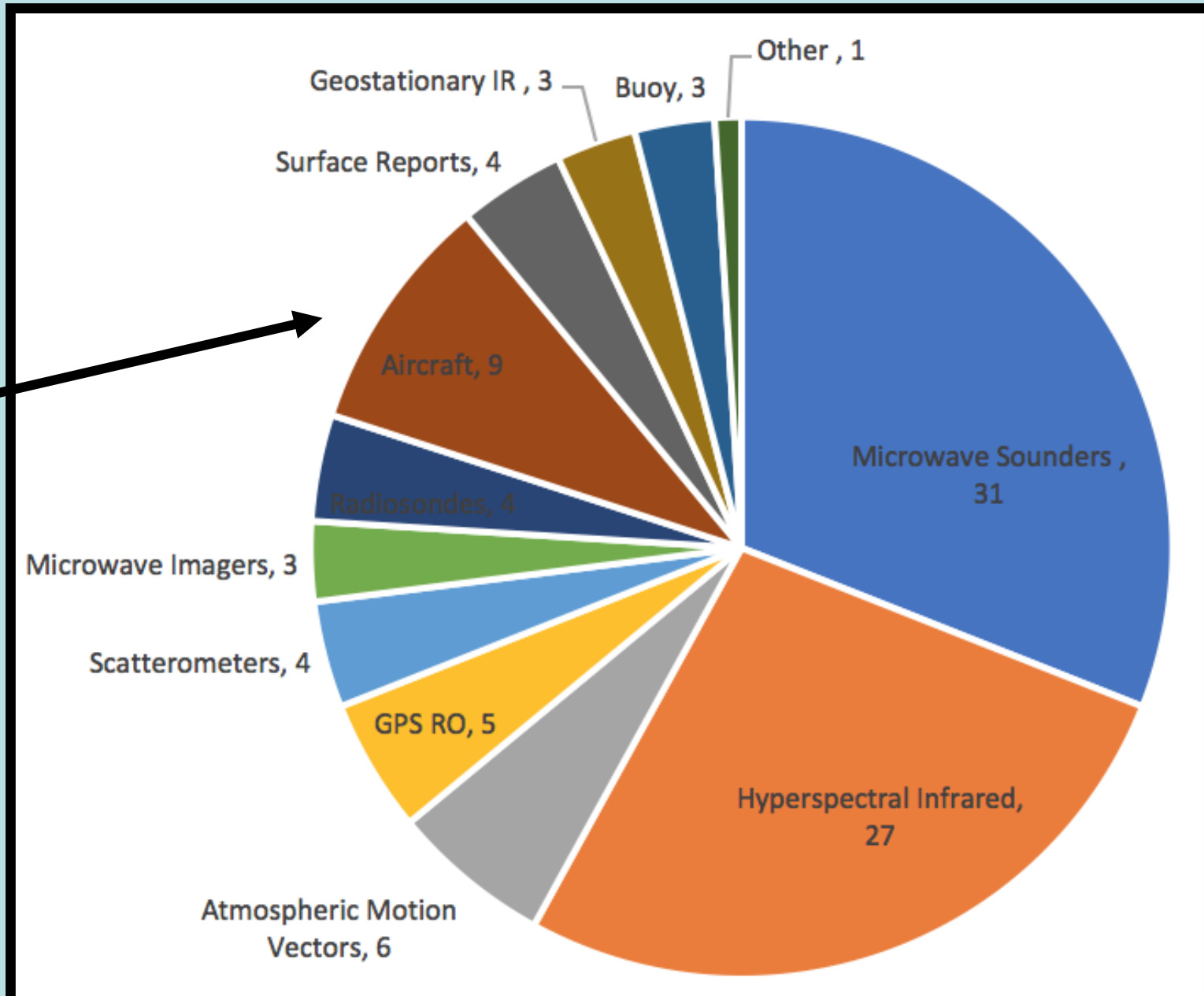






Satellite data impact on NWP

Observation Type and % Impact to Reducing Forecast Errors



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ET-Evolution of the GOS

- Review and report on capability of surface and space based observing systems
- Perform Rolling Requirements Review of applications areas using subject matter experts and produce Statements of Guidance for those areas (include emerging observing systems)
- Review with NWP centers changes to the GOS (OSE and OSSE)
- Develop Vision for GOS and Implementation Plan for Evolution of GOS

(Integration point of both surface and space-based WMO Expert Teams and WMO NWP Workshops)

2015 Vision for GOS

for the Space based component

- **6 operational GEOs all with multispectral imager (by this we meant 12-16 channels from vis-nir-IR with improved resolution spatially, spectrally, temporally and s/n); some with hyperspectral sounder (IR)**

- **4 operational LEOs optimally spaced in time, all with multispectral imager (MW/IR/VIS/UV), all with sounder (MW), 3 with hyperspectral sounder (IR), all with radio occultation (RO), 2 with altimeter, 3 with conical scan MW or scatterometer**

- **Several R&D satellites, constellation small satellites for radio occultation (RO), LEO with wind lidar, LEO with active and passive microwave precipitation instruments, LEO and GEO with advanced hyperspectral capabilities, GEO lightning, possibly GEO microwave and hoping for Molniya orbit**

- **Improved intercalibration and operational continuity**

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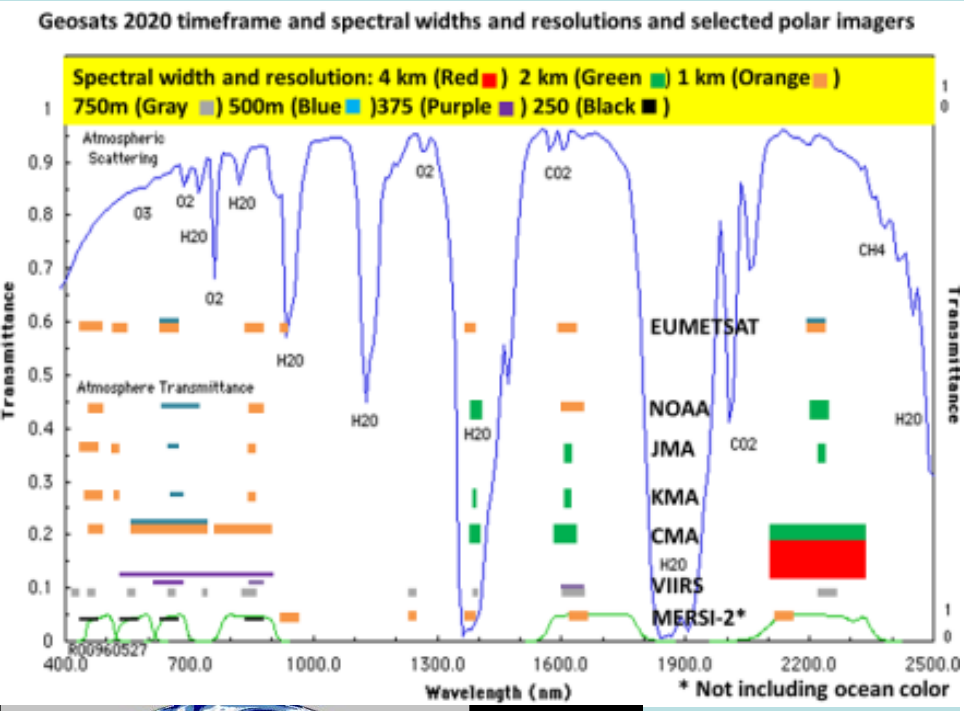
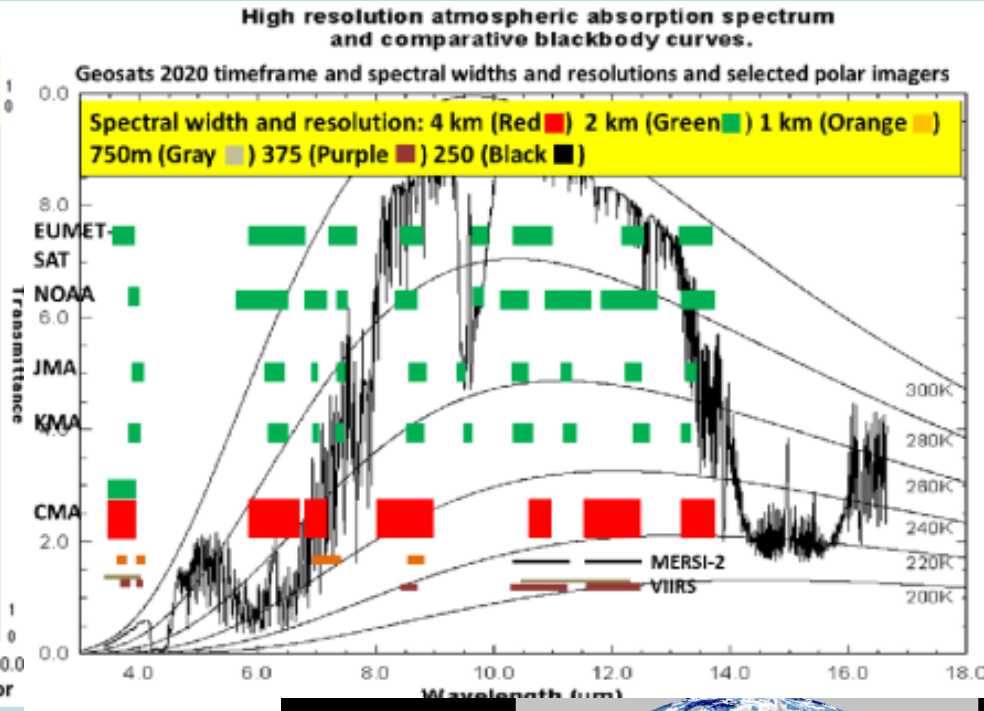
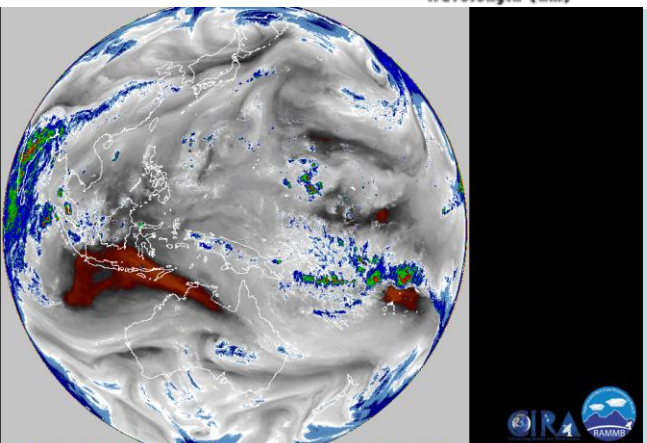
- Coordination of observing systems and protection of assets

Similarity of channels and scan modes on satellites

Orbit configuration (both Geostationary and Polar constellations)

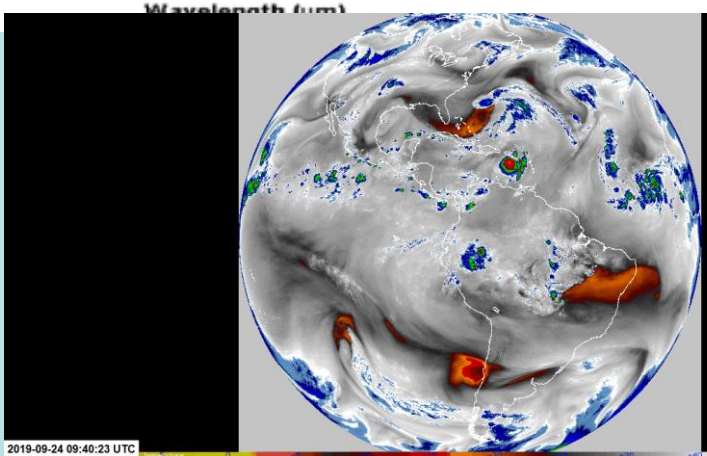






Himawari (left) and GOES-16 (right)

10-minute imagery animation @ 6.2 microns



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Similarity of channels and scan modes on satellites

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Coordination Group for Meteorological Satellites

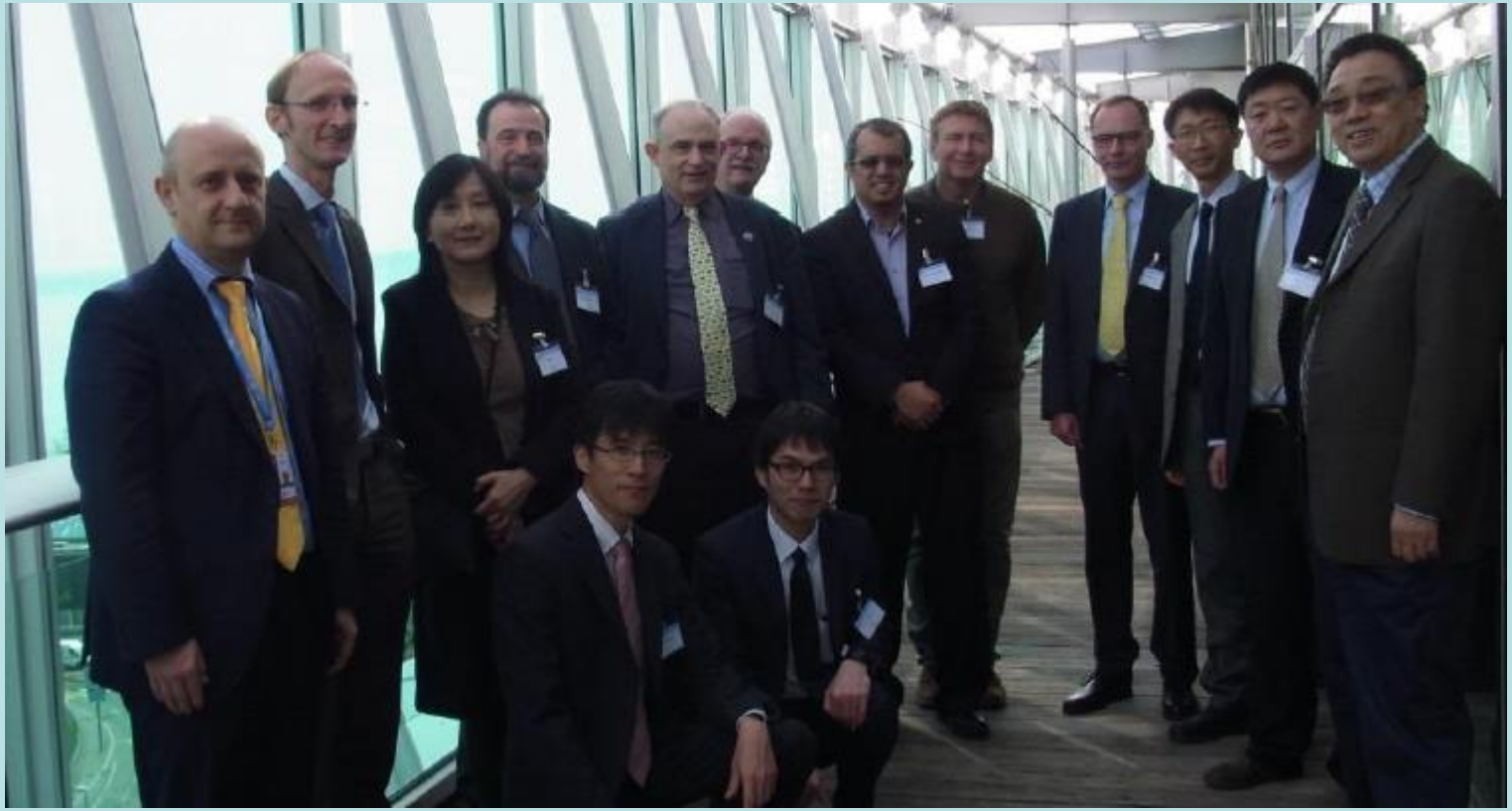
Today's Membership includes all operational meteorological satellite agencies, WMO and some R&D space agencies. EUMETSAT is permanent secretariat.

WHAT CGMS DOES

- Coordination of observing systems and protection of assets
  - **Compatibility and possible mutual back-up**
  - **Similarity of channels and scan modes on satellites**
  - **Orbit configuration (both Geostationary and Polar constellations)**

- Cross-cutting issues and new challenges
  - **Sustained, Co-Ordinated Processing of Environmental Satellite Data for Climate Monitoring (SCOPE-CM)**
  - **Strategy Towards an Architecture for Climate Monitoring from Space**

11th Meeting ET-SAT, Geneva, April 2017



WMO Secretariat

RESEARCH		OPERATIONAL
NASA	(USA)	NOAA
JAXA	(Japan)	JMA
ESA	(Europe)	EUMETSAT
DLR (Germany)		CMA (China)
CSA (Canada)		KMA (Korea)

Assess and document, in the framework of the WMO Rolling Review of Requirements, the actual and planned capabilities of operational and R&D satellites … and their adequacy to meet the WMO requirements for satellite data and products.

Provide technical advice with respect to both operational and R&D environmental satellites to assist in the implementation of integrated WMO-coordinated observing systems;

Assess progress of R&D and demonstration satellite systems, and identify opportunities and/or problem areas concerning satellite technology and plans;

BOTTOM LINE: Close link established between research and operational satellite data and products for operational utilization

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International Precipitation Working Group Founding Meeting, Ft Collins, CO, USA, 20-22 June 2001

Applications WG

Research WG

Validation WG

Growth in scope

Applications WG

Research WG

Validation WG

Data Assimilation WG

Scattering WG

GEWEX IPWG International Precipitation Working Group

Major collaborative validation project underway

IPWG
International Precipitation Working Group

8TH IPWG & 5TH IWSSM JOINT WORKSHOP
BOLOGNA, 3-7 OCTOBER, 2016

IWSSM-5
Fifth International Workshop on Space-based Snowfall Measurement

Closer look going from left to right

IPWG
International Precipitation Working Group

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Expert Team on Satellite System Utilization and Products

Chair: H.P. Roesli

First Virtual Lab management Group Meeting EUMETSAT in Darmstadt, Germany – May 2001

VL Management group is composed of Satellite Operators and WMO Centers of Excellence Sponsored by a Satellite Operator. It is cochaired by COE rep and Sat Op rep

Expert Team on Satellite System Utilization and Products

WMO-CGMS Virtual Laboratory
for Education and Training in Satellite Meteorology

Education and Training Capacity building

A network of Centers of Excellence sponsored by satellite operators

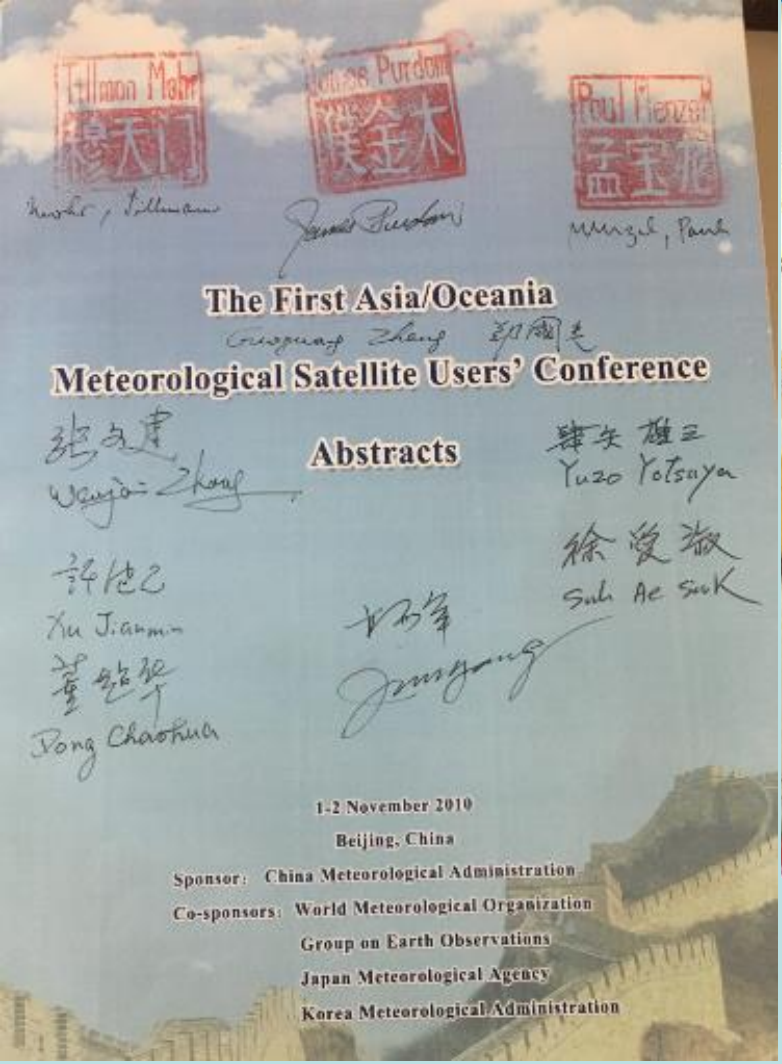
- To provide training on meteorological and environmental satellite systems, data, products and applications;

- To foster research and the development of applications for societal benefit at the local level by the NMHS.

So What's it all about?

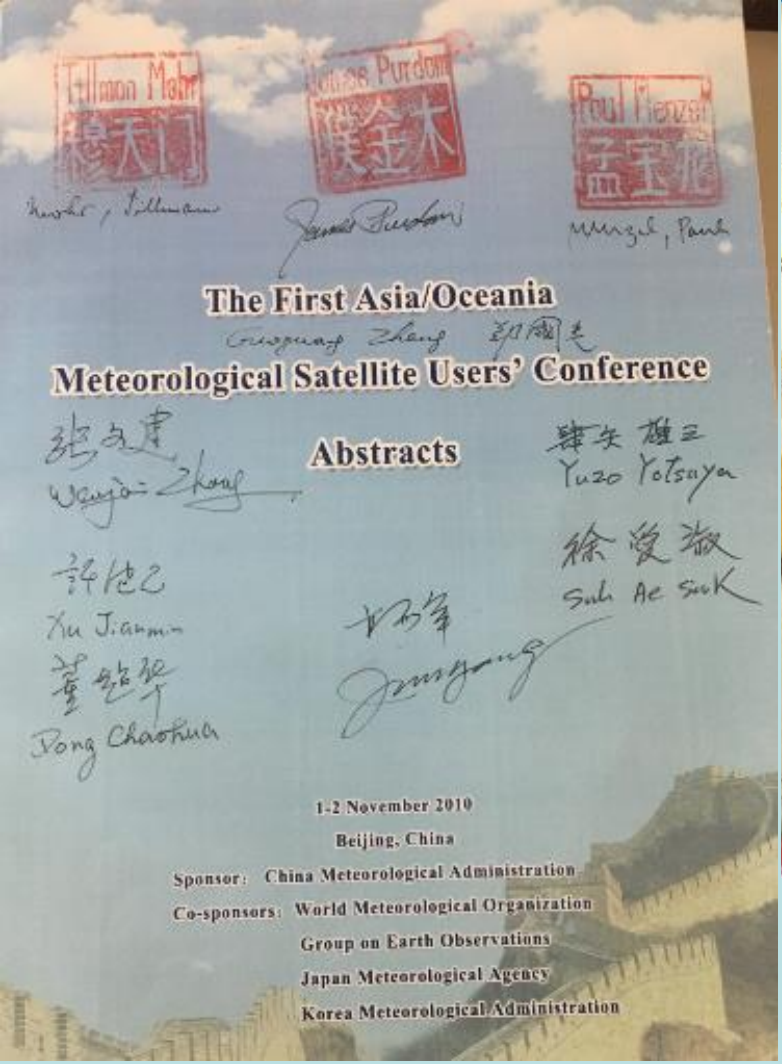
- **Promoting satellite observations and highlighting their utility (Utilization)**
- **Advancing satellite remote sensing science (Knowledge)**
- **Fostering the dialogue between satellite operators and the user community on current and future satellites (Leadership)**
- **Engaging young scientists (Vision)**

- promoting satellite observations and highlighting their utility, with a focus on regional issues;
- advancing satellite remote sensing science;
- fostering the dialogue between satellite operators and the user community on current and future satellites;
- engaging young scientists.

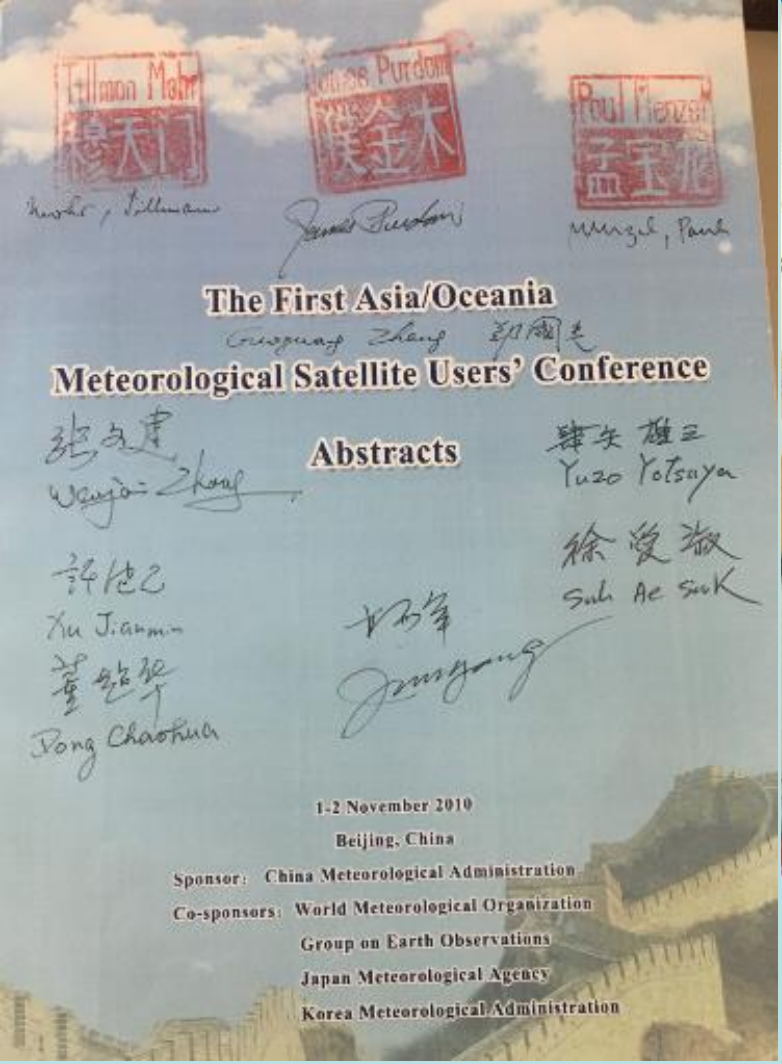


Abstract book from AOMSUC-1. Note the signatures!

Some good friends at a banquet celebrating the success of AOMSUC-1.



2-Day Training
3-Day AOMSUC Conference
1-Day WIGOS
RA II/V Meeting



AOMSUC-11
CHINA in the Fall of 2020

2-Day Training
3-Day AOMSUC Conference
1-Day WIGOS
RA II/V Meeting

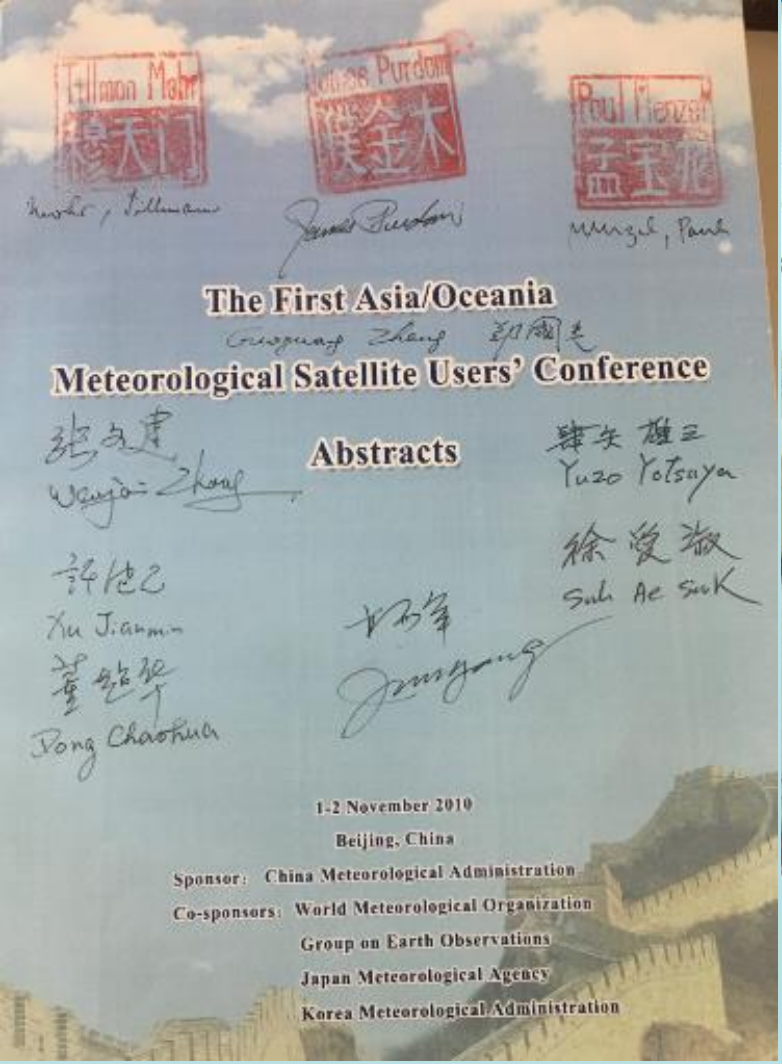
MOVING FORWARD: THOUGHTS AND CHALLENGES

- advanced technology on operational polar satellites
- sophisticated operational geostationary satellites
- Array of research missions
- All applications areas will have the opportunity to exploit multiple satellite data sets from a variety of research and operational satellites, all at different spectral, spatial, radiometric and temporal resolutions

Full exploitation is being realized as a global community in partnership: over the decades this has fostered fundamental changes to the way we do business and interact as a community

As We Move Forward, What Will Be Significant?

- Leadership
- Vision
- Understanding
- Utilization
- International Cooperation



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