History of Science Discoveries and Weather Forecasting Advances from Early Weather Satellites, An Introduction

by

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Introduction

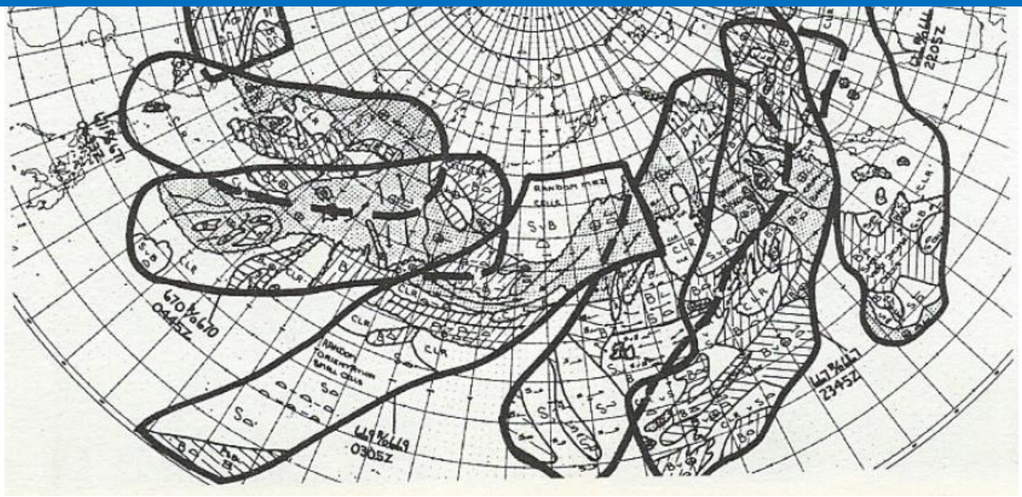
- Presenting today a draft of a work in progress covering the 1960’s-1980’s
- Leading to a report to NOAA, NESDIS and an AMS monograph (TBD) later this year
- Requesting your comments and questions…

(Thomas.Vonderhaar@colostate.edu)

Typical TIROS Nephanalysis in Northern Midlatitudes

Lesson Learned:

- **Nephanalyses provided immediate forecaster knowledge for synoptic maps, flight briefing etc.**
- **Today's cloud images are candidates for new AI methods**



Typical TIROS Coverage in Northern Middle Latitudes

Widger, 1966

Flat Plate Radiometer (FPR) on USAF sunsynchronous satellites (1964-1965)

JPSS

TIROS

WFOV Earth Radiation Budget sensor (one black plate and one white plate) flown on Pre-DMSP satellites in the mid 1960's.

The black sensor would see solar, terrestrial, and reflected radiation while the white sensor would see upwelling terrestrial radiation.

Suomi, Parent, Vonder Haar, et al.; Lewis, 2018 (AMS Books)

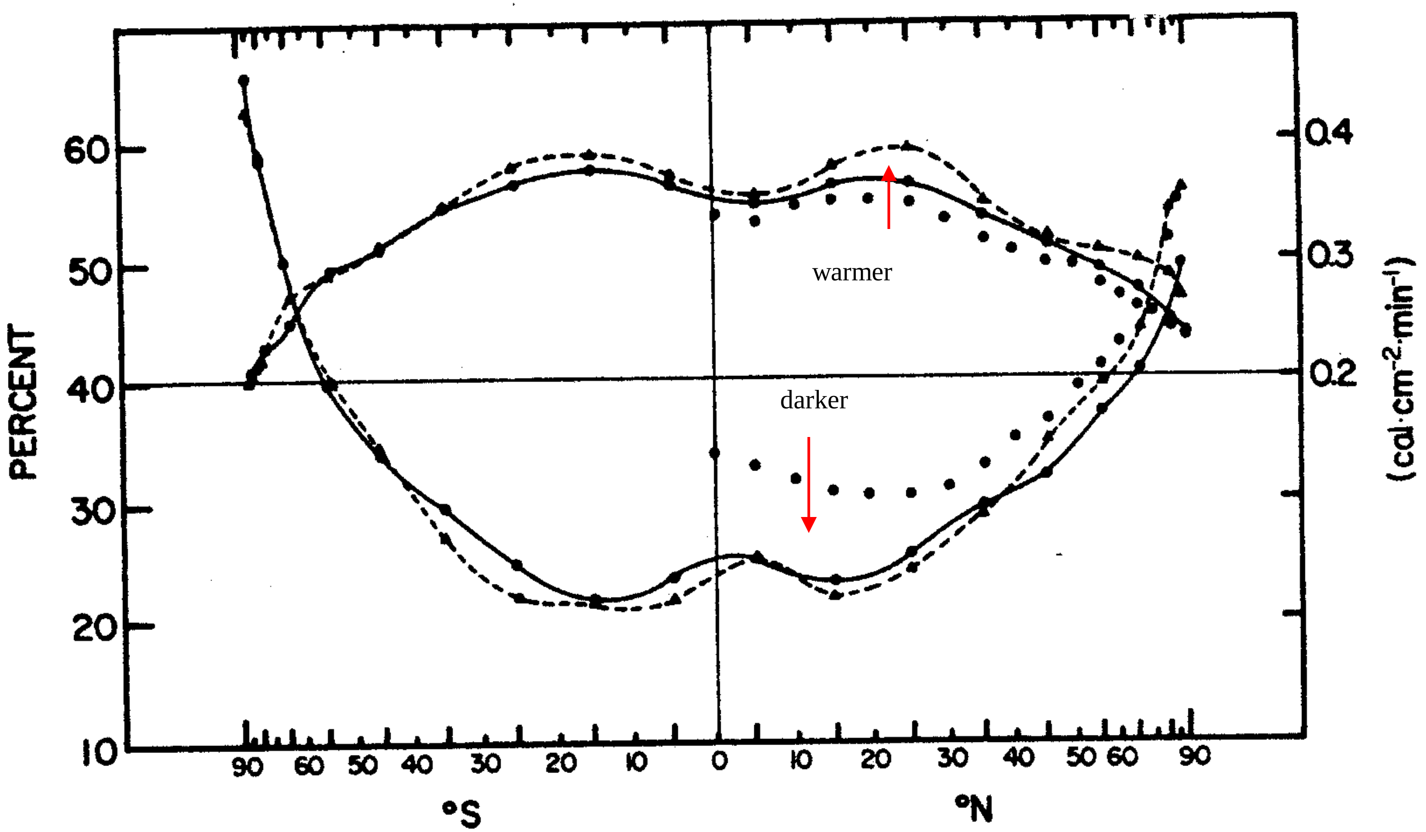


Figure 10.—Annual zonal averages of albedo (percent) and outgoing longwave radiation obtained from Nimbus 3 (dashed line) and earlier satellite (solid line: Vonder Haar and Suomi, 1971) and from calculations with climatological data (open circles: London, 1957).

So, Nimbus – 3 supports earlier satellite results!

“We found that Earth was a Warmer and Darker Planet than previously believed - - especially in the Tropical Regions. We found that 40% More Energy must be transported poleward by the Atmosphere and Ocean Circulations!”

(Vonder Haar and Suomi, 1969, 1971)

Lesson Learned: Early new science results lead to many decades of research.

Much more energy gain in the tropics

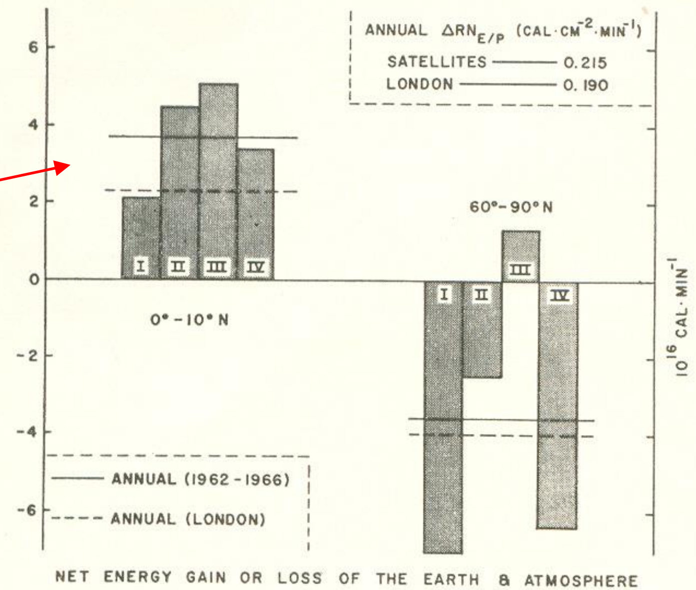
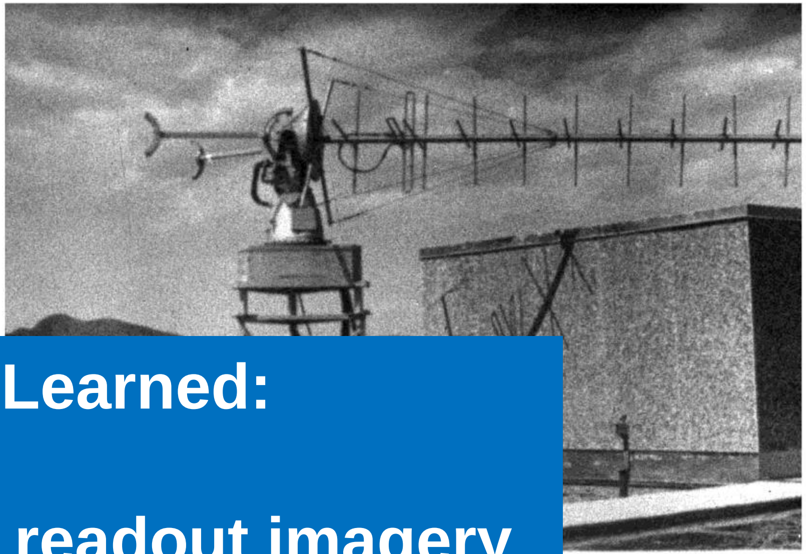


Fig. 2. Mean annual and seasonal energy exchange with space, measured from satellites during 1962–66, for two latitude zones. Bar graph represents seasonal values (I=Dec., Jan., Feb.; II=Mar., Apr., May; etc.). $\Delta RN_{E/P}$ is the net radiation gradient between equator and pole.

Automatic Picture Transmission (APT) 1963 →

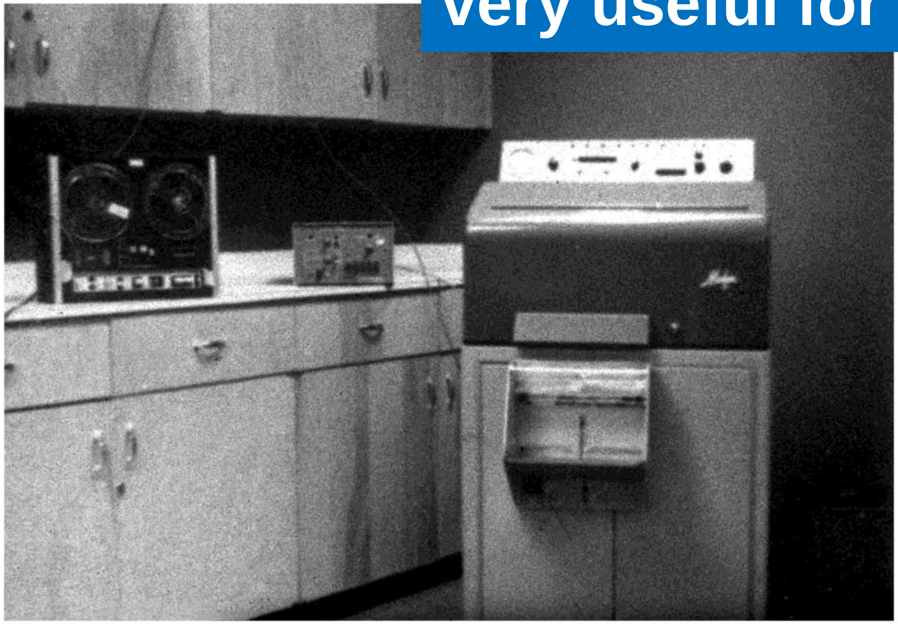
NOAA-3 Launched 1973



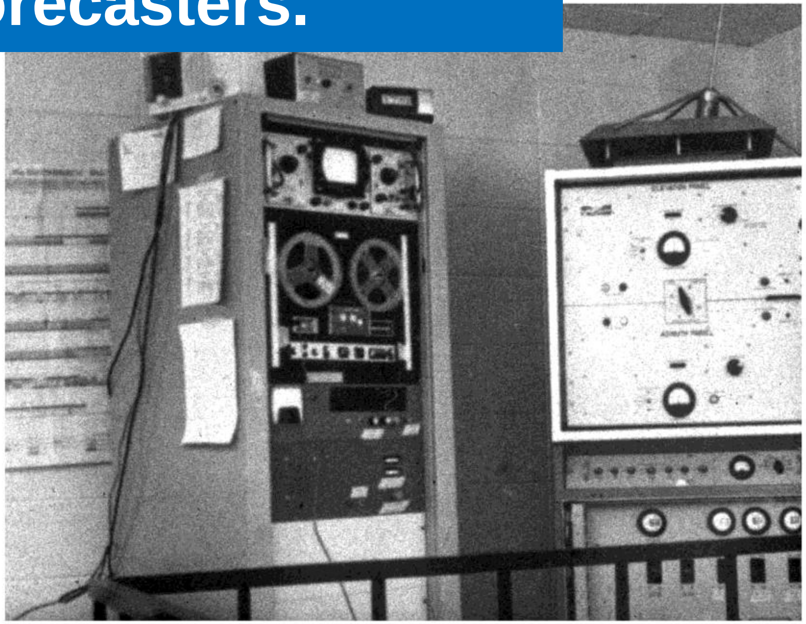
ENNA

Lesson Learned:

Local area direct readout imagery very useful for forecasters.



PHOTOFASCIMILE (FAX) PICTURE SYSTEM



CONTROL AND DATA RECORDING

The first computer-derived wind vectors from cloud motion (1967)

Gridded average cloud drift winds from ATS-1 over broad area of the Pacific. [Note height assignment problem when 2 vectors were measured……the first IR data arrived from SMS-1 in 1974.] (V. Suomi, 1968 Op. cit.)

It took several decades of R & D for global atmospheric motion vectors to impact global model forecasts.

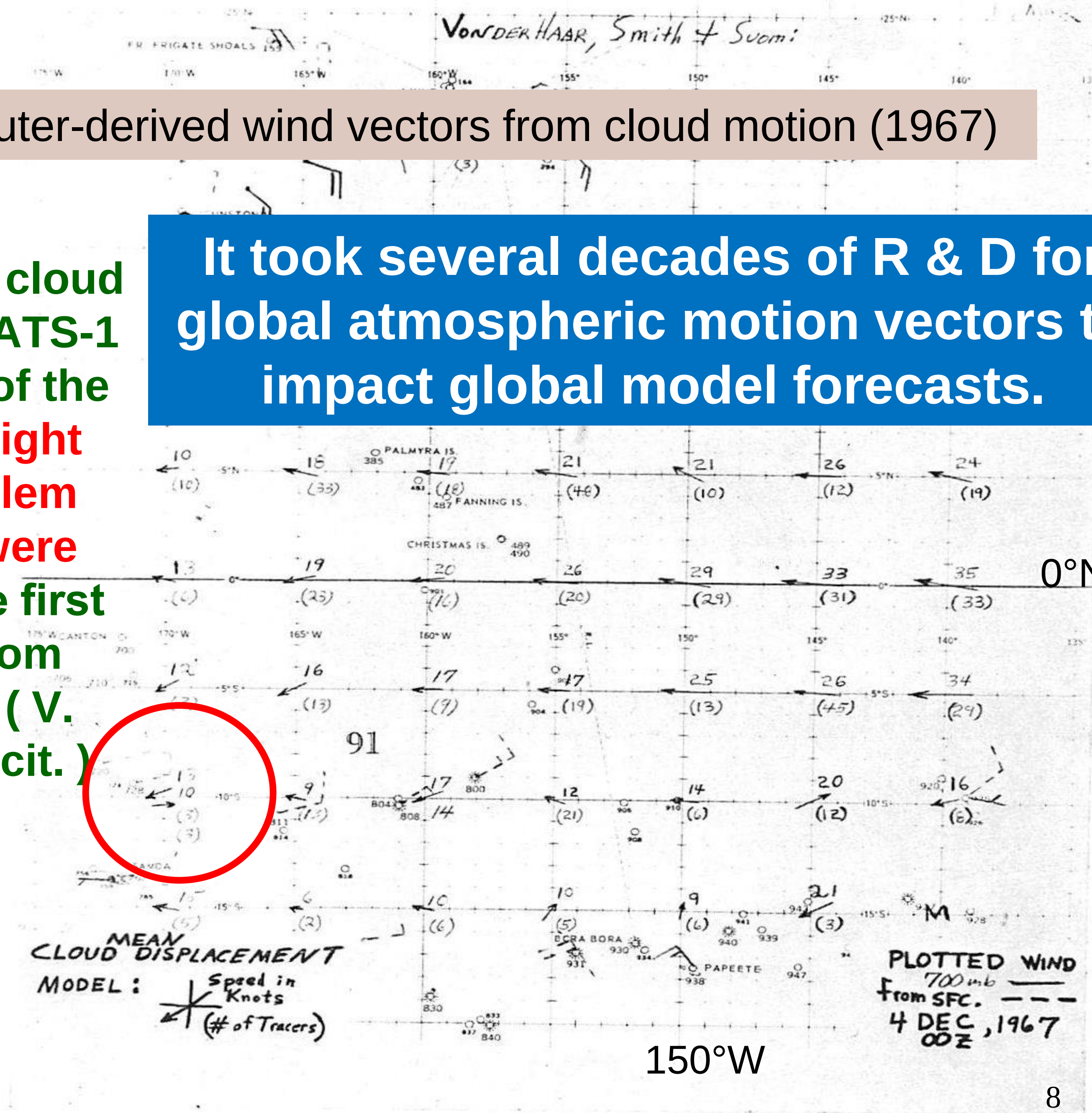
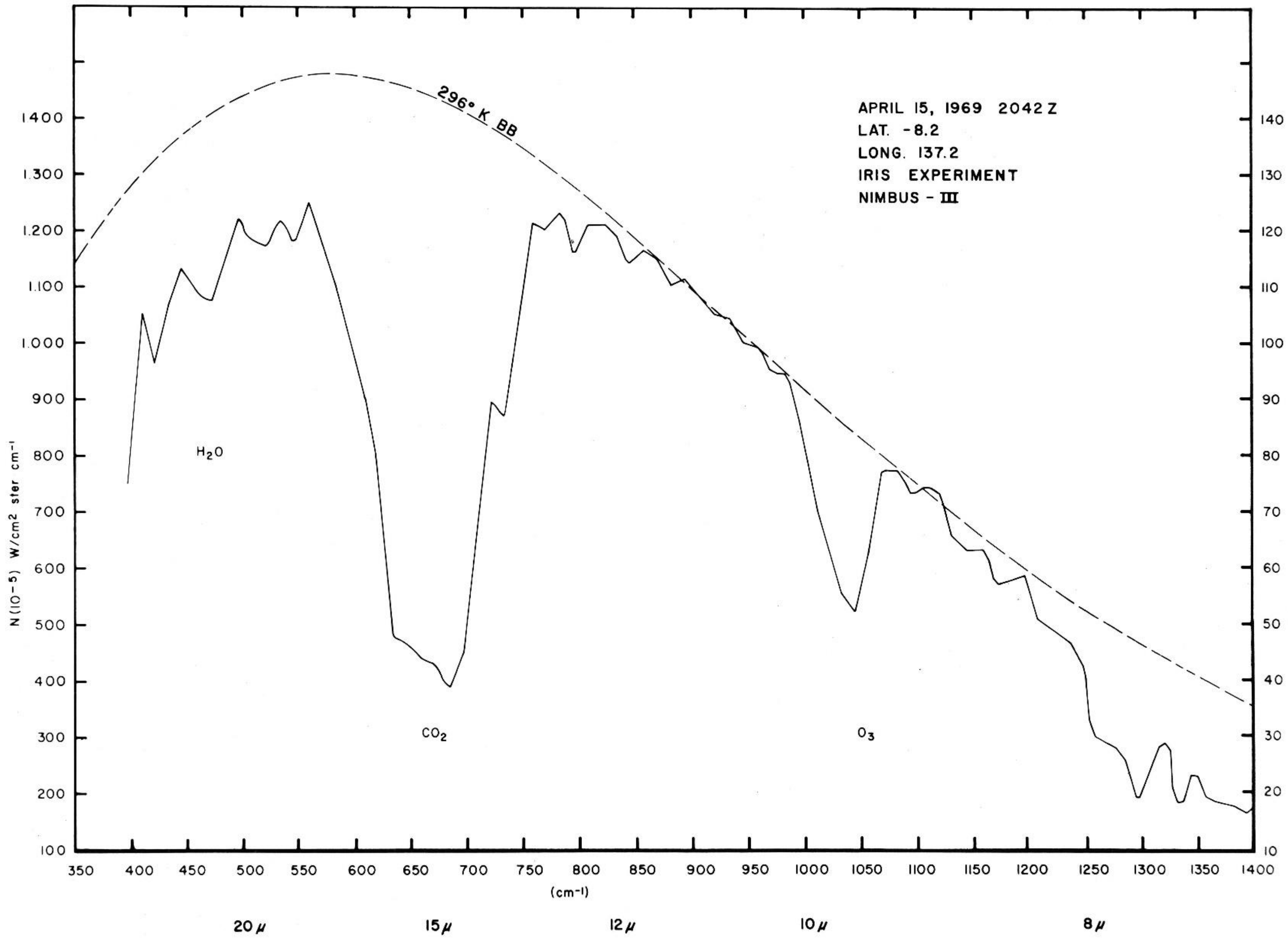
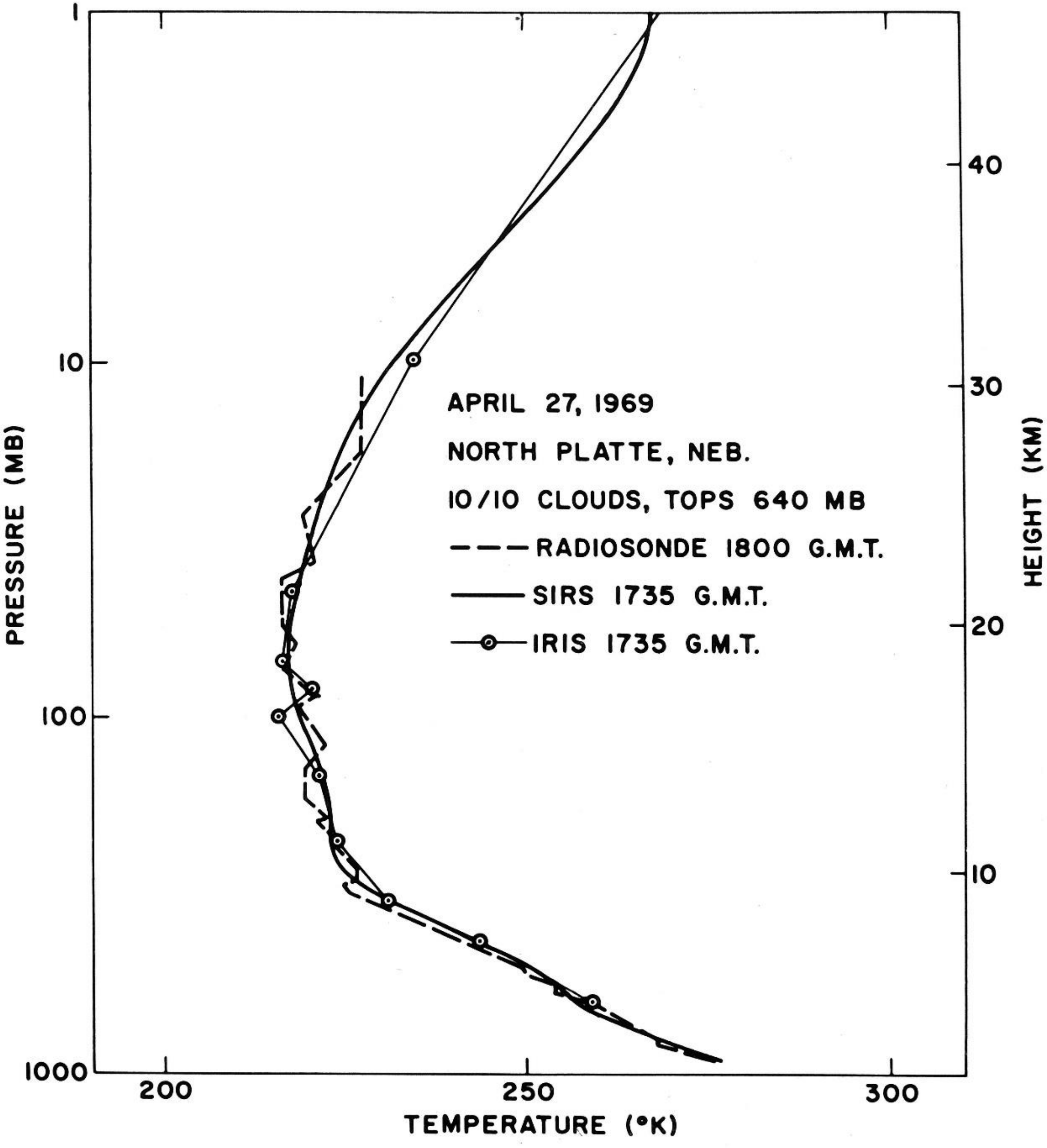


Figure 8. (b) Computer derived winds.

Spectral Infrared Measurements Allowed Atmospheric Temperature and Moisture Soundings

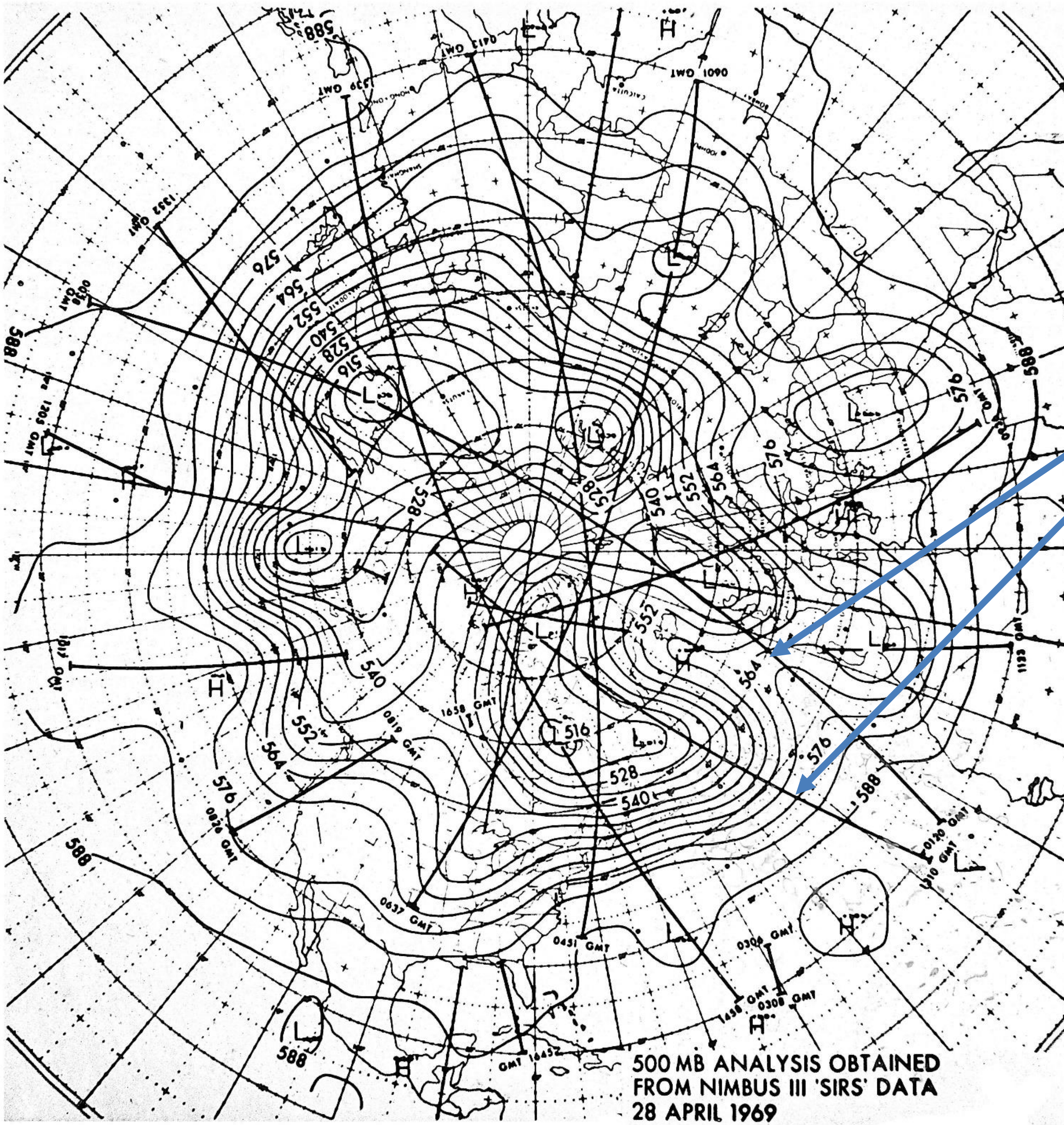


Hanel et al. ~ 1970


APRIL 27, 1969
NORTH PLATTE, NEB.
10/10 CLOUDS, TOPS 640 MB
RADIOSONDE 1800 G.M.T.
SIRS 1735 G.M.T.
IRIS 1735 G.M.T.
PRESSURE (MB)
1
10
100
1000
HEIGHT (KM)
10
20
30
40
TEMPERATURE (°K)
200
250
300

W. L. Smith
D. Wark et al.

(Smith, W. L., 1985 *Handbook of Applied Meteor*.)



Nimbus-3 orbit tracks

500 hPa height field forecast improved as more and more satellite infrared and microwave soundings were assimilated – especially in the Southern Hemisphere

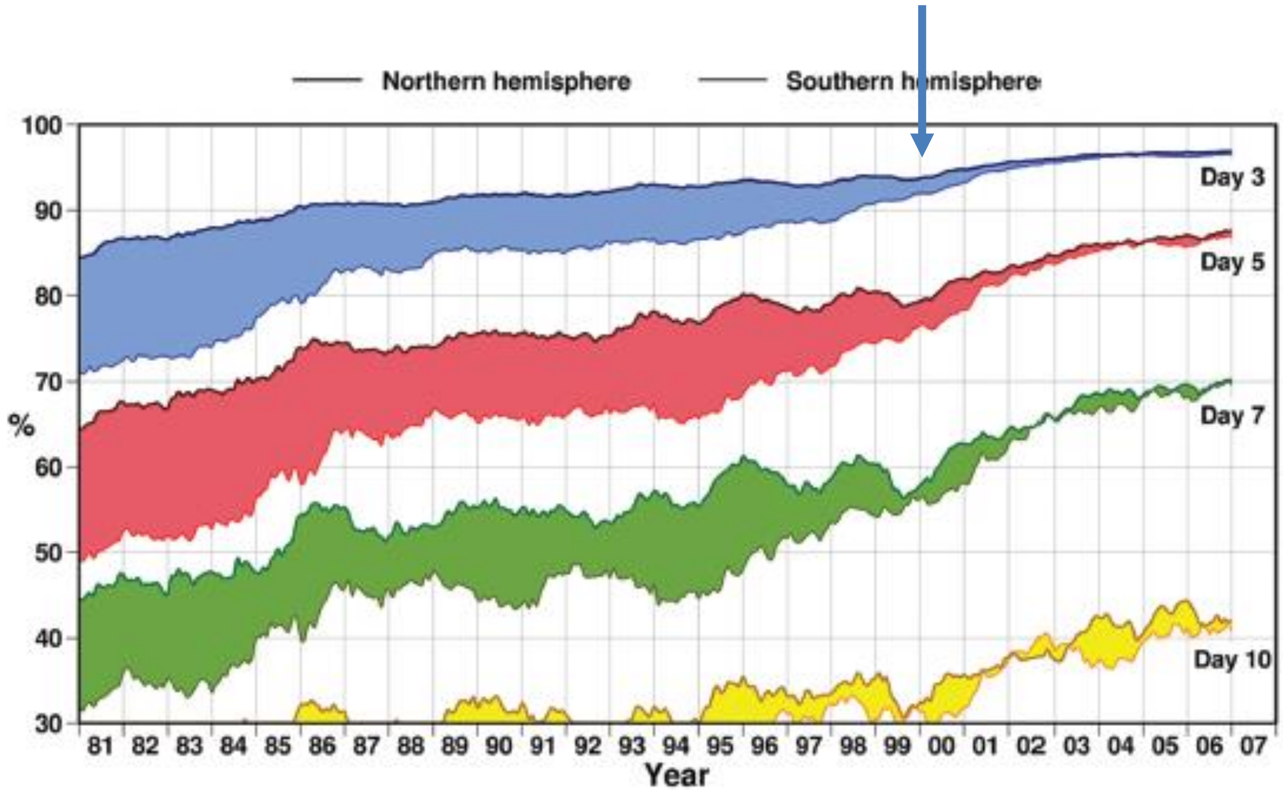


FIGURE 3.8 Anomaly correlation of 500 hPa height forecasts by the European Centre for Medium Range Forecasting. SOURCE: Updated from Simmons and Hollingsworth (2002). Reprinted with permission from the Royal Meteorological Society, copyright 2002.

Satellite Observations of the Earth's Environment: Accelerating the Transition of Research to Operations (NRC 2003)

First Satellite Observations of "Cloud Surges or Tropical Intrusions" Reported in 1970

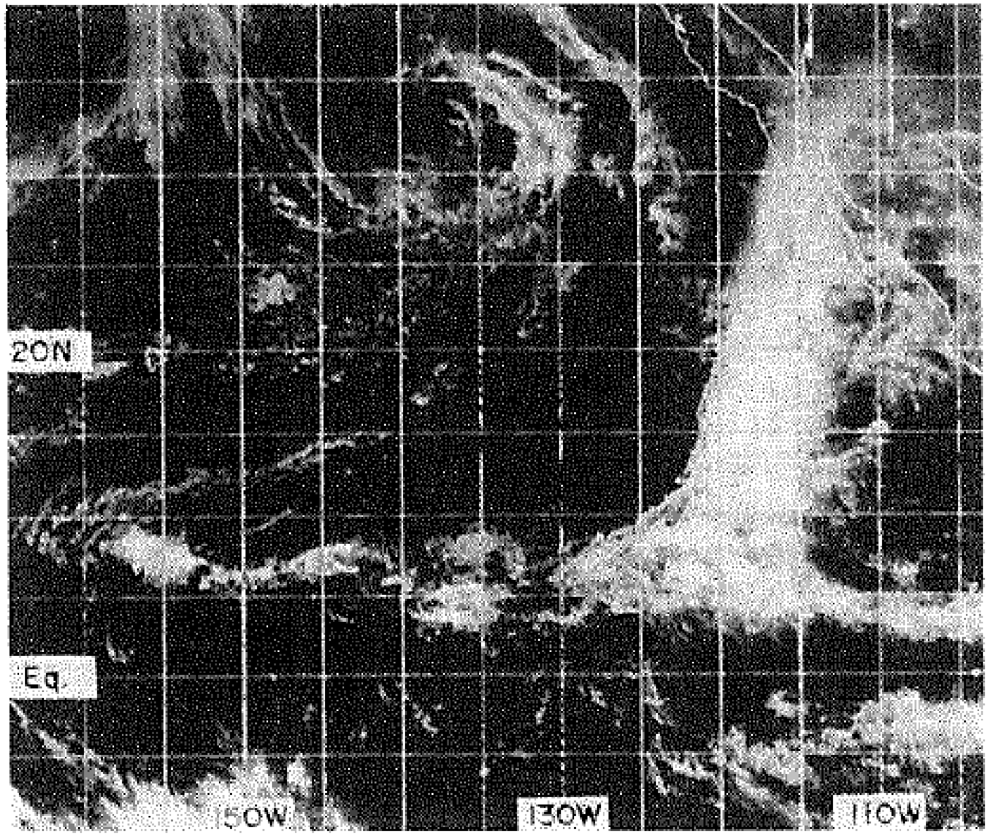


Figure 1. Cloud surge, Eastern Pacific, February 26, 1970. ATS-I picture mapped by computer to mercator projection.

From the first experimental geosynchronous satellite carrying the first spin scan cloud radiometer / camera (Suomi and Parent) with only one visible light channel.

Anderson and Oliver, 1970: Some examples of the use of synchronous satellite images for studying changes in tropical cloudiness. Proceedings AMS Tropical Meteorology Conference.

GOES IR allowed detections of Mesoscale Convective Clusters (MCC's) which became very important in forecasting heavy precipitation over the U.S. and other regions.

Maddox (MWR, 1981)

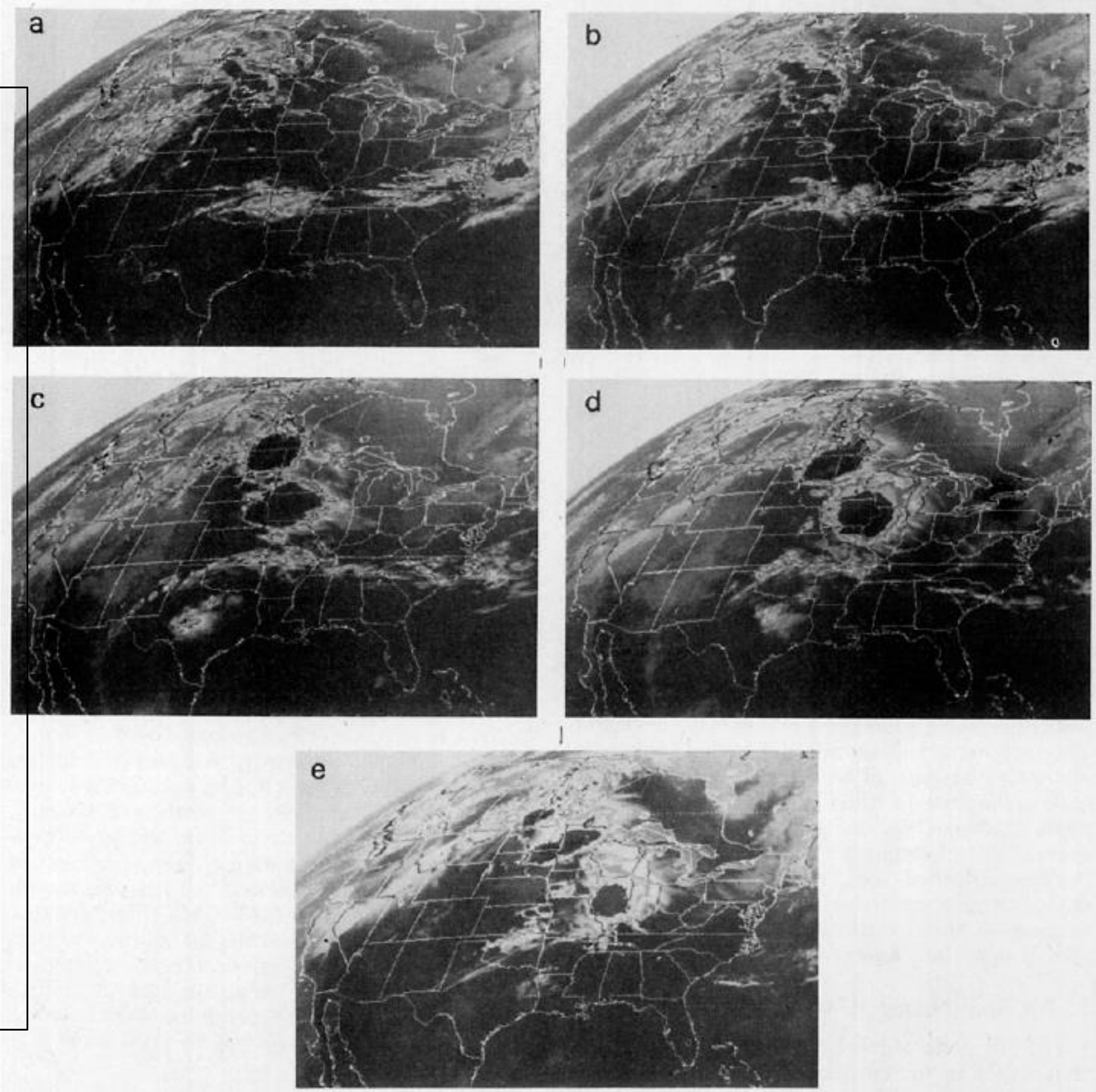


FIG. 1. Enhanced IR satellite images showing the development and evolution of the Grand Island MCC. Image times are (a) 2345, (b) 0145, (c) 0730, (d) 1130, (e) 1500 GMT on the 3rd and 4th of June 1980. All images are from GOES-East and the MB enhancement curve (medium gray −32 to −41°C, light gray −41 to −52°C, dark gray −52 to −58°C, black −58 to −62°C and repeat gray to white shades < −62°C) is used throughout.

Early GOES research showed formation of new thunderstorms on outflow boundaries **(OFB's)** and cell mergers

- This was a major aid for forecasters

Some satellite discoveries stimulated new science and also immediately helped forecasters at the mesoscale

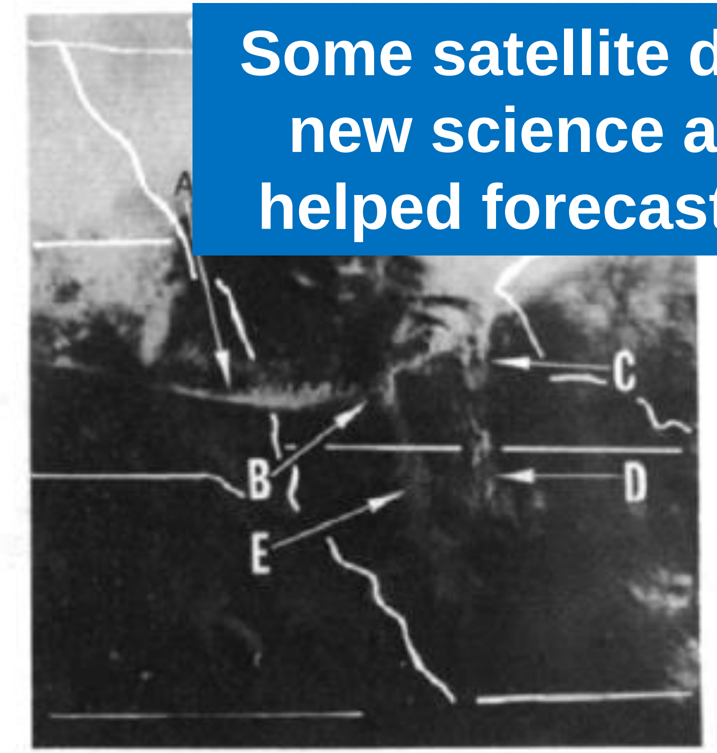


FIG. 5c. GOES-2, 1 km visible imagery, 29 June 1975, 1545 GMT.

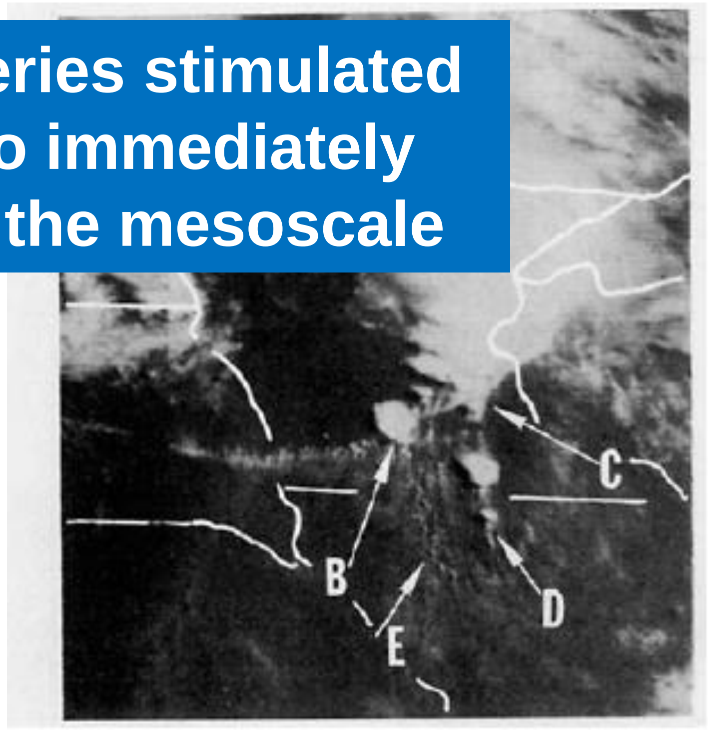


FIG. 5d. GOES-2, 1 km visible imagery, 29 June 1975, 1645 GMT.

(Purdom, MWR 1976)

Estimating Tropical Cyclone Central Pressure and Outer Winds from Satellite Microwave Data

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(Manuscript received 24 April 1978, in final form 10 July 1978)

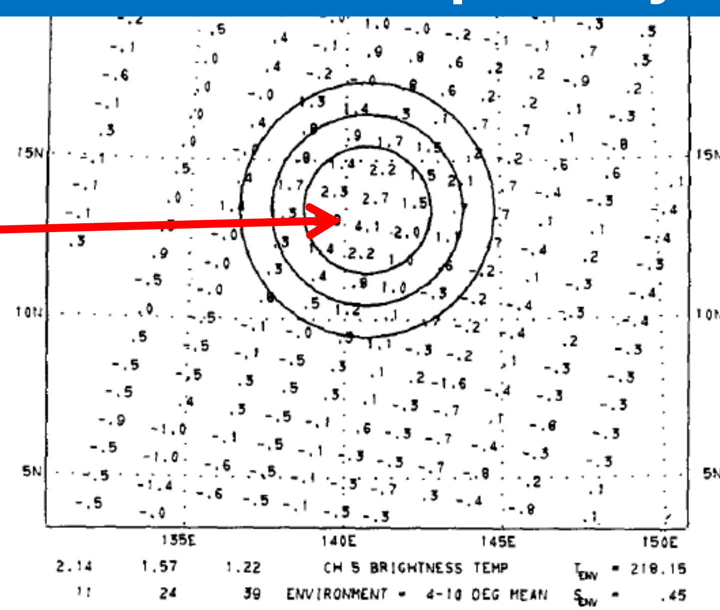
ABSTRACT

A technique is proposed for estimating tropical cyclone central pressure and surface wind speeds outside of the radius of maximum wind speed from the 55.45 GHz channel of the Scanning Microwave Spectrometer on board the Nimbus 6 satellite. The method was developed using measurements over eight typhoons and five hurricanes during 1975.

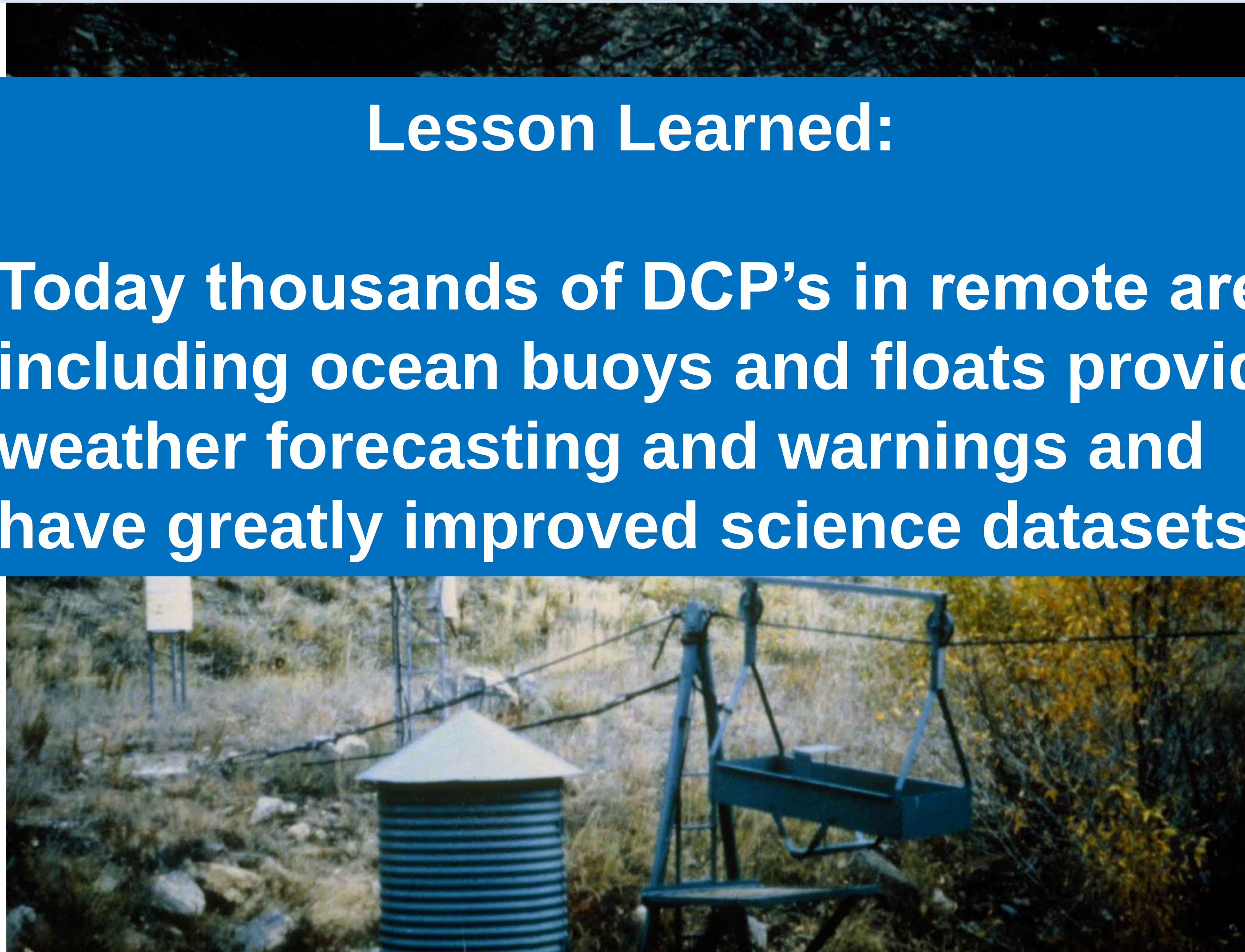
Detection, tracking and new science studies in the area of tropical cyclones

Up to 4 K warm core anomaly from SCAMS 55.45 GHz channel

Typhoon June, 19 November 1975



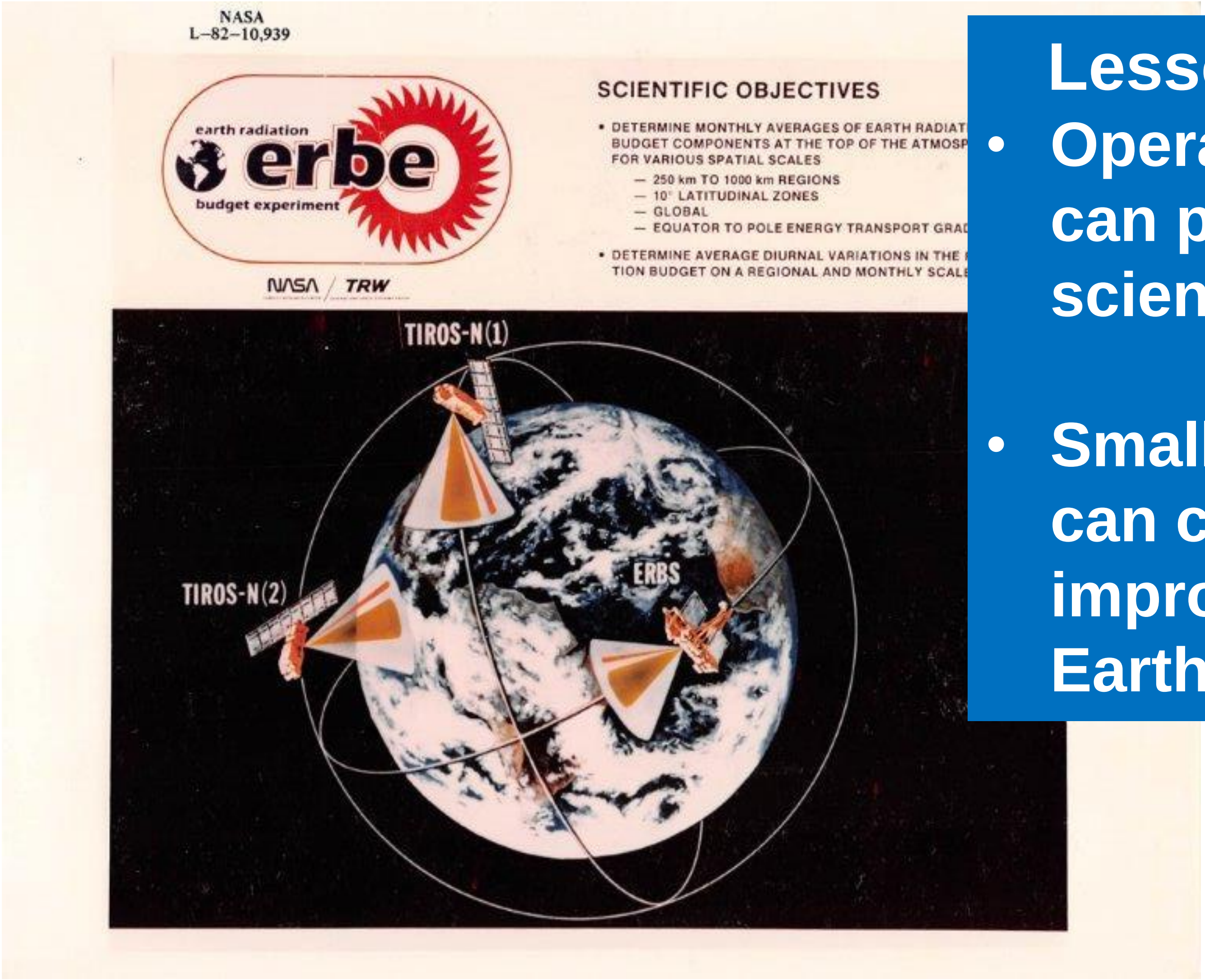
Data Collection Platforms (DCP) reported surface and ocean measurements through the GOES and POES operational satellites in the late 1970's and early 1980's.



Lesson Learned:

- **Today thousands of DCP's in remote areas including ocean buoys and floats provide weather forecasting and warnings and have greatly improved science datasets.**

The ERBE 3-satellite constellation plan (note: ERBS was launched into a 57° orbit from Shuttle Challenger Oct. 4, 1984) and the other two instruments were onboard the NOAA-9 and NOAA-10 sunsynchronous weather satellites



Lessons Learned:

- **Operational satellites can participate in science missions**
- **Small constellations can create big improvements in Earth science**

ERBE results were the second confirmation of the global Earth radiation budget values first measured in the 1960's

TABLE 5. Time and Space Global Averages and Percent Difference From ERBS/N9 Scanner, 4-Month Average

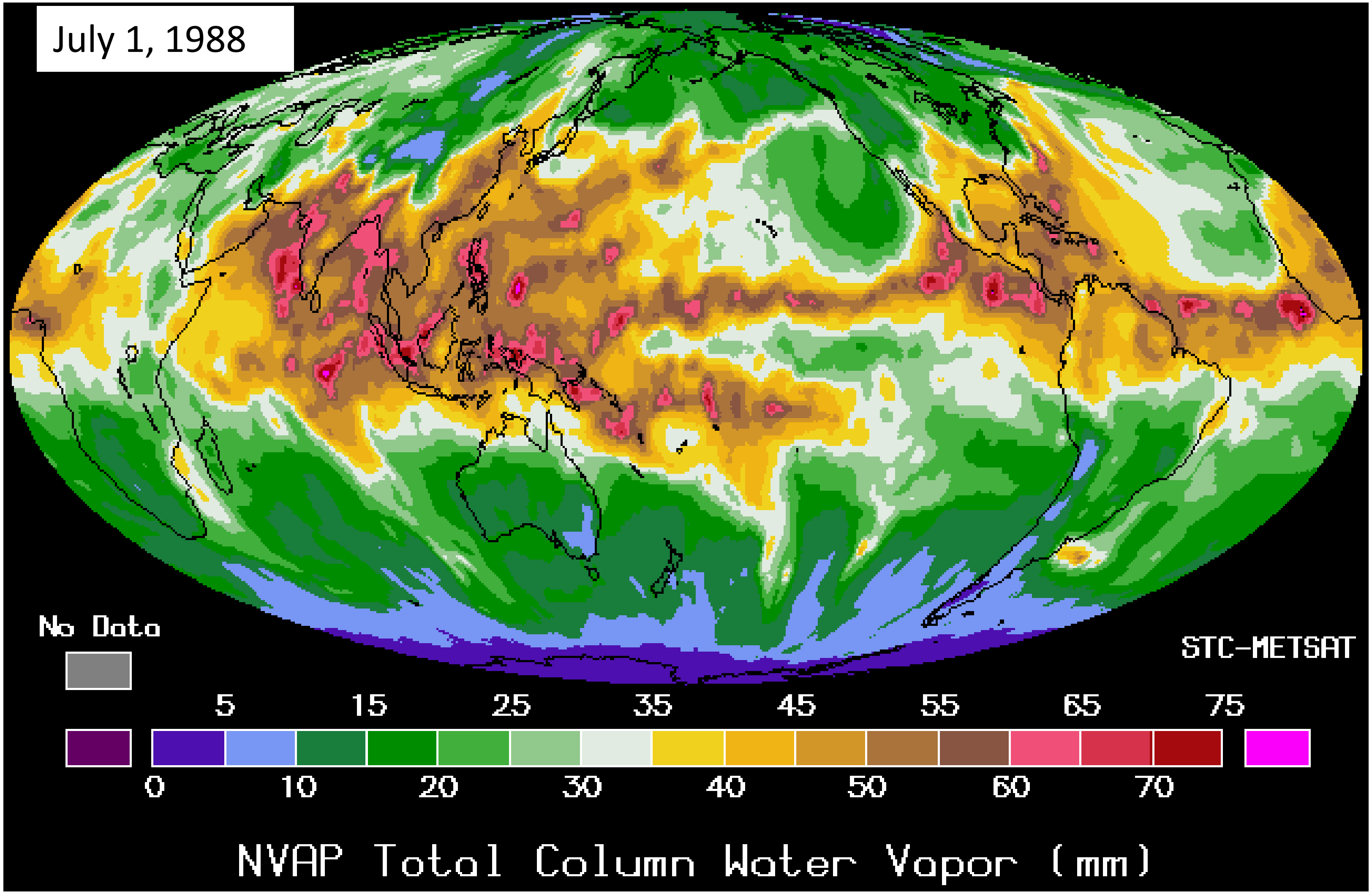
		F_{LW}, W/m^2	A, %	NR, W/m^2
Scanner				
ERBS/NOAA 9		234.50	29.89	4.79
NOAA 9 only		234.24 (−0.10%)	29.72 (−0.57)	5.63
WFOV				
ERBS/NOAA 9	NF	235.25 (+0.32%)	28.25 (−5.49%)	9.67
	SF	234.11 (−0.17%)	28.83 (−3.55%)	8.89
NOAA 9 only	NF	237.1 (+1.11%)	28.13 (−5.89%)	8.28
	SF	235.43 (+0.40%)	28.75 (−3.81%)	7.72
Nimbus 7 WFOV	SF	234.88 (+0.16)	29.88 (−0.03)	5.62

Units are watts per square meter.

Comparison of Nimbus-7 and the new ERBE results in 1985

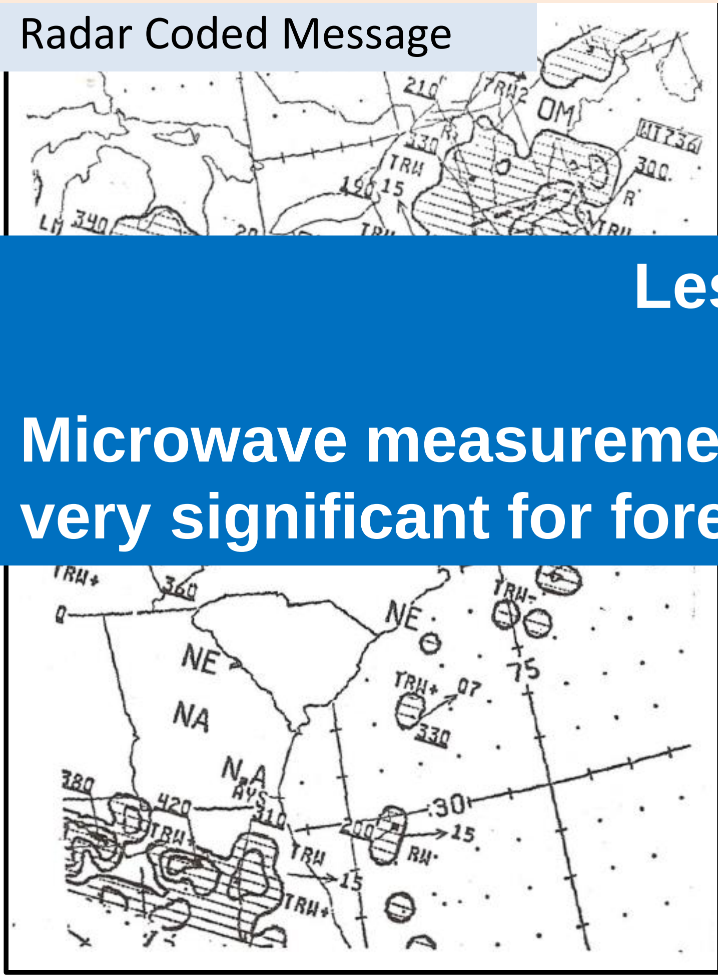
(after Kyle et al, 1990)

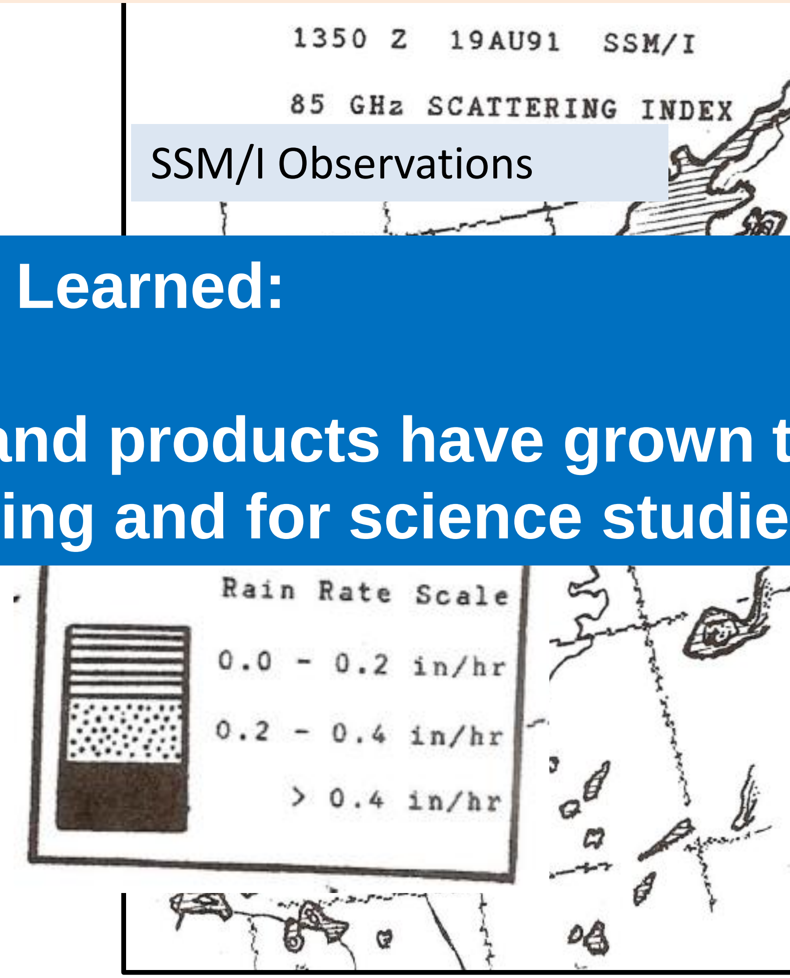
New operational microwave observations from DMSP combined with infrared moisture soundings and rawinsondes allowed the beginning of a multiyear global water vapor climatology for climate process studies and forecasting products



From John Forsythe after Randel et al. (1996) BAMS

NESDIS operational use of microwave began with SSM/I measurements in the late 1980's

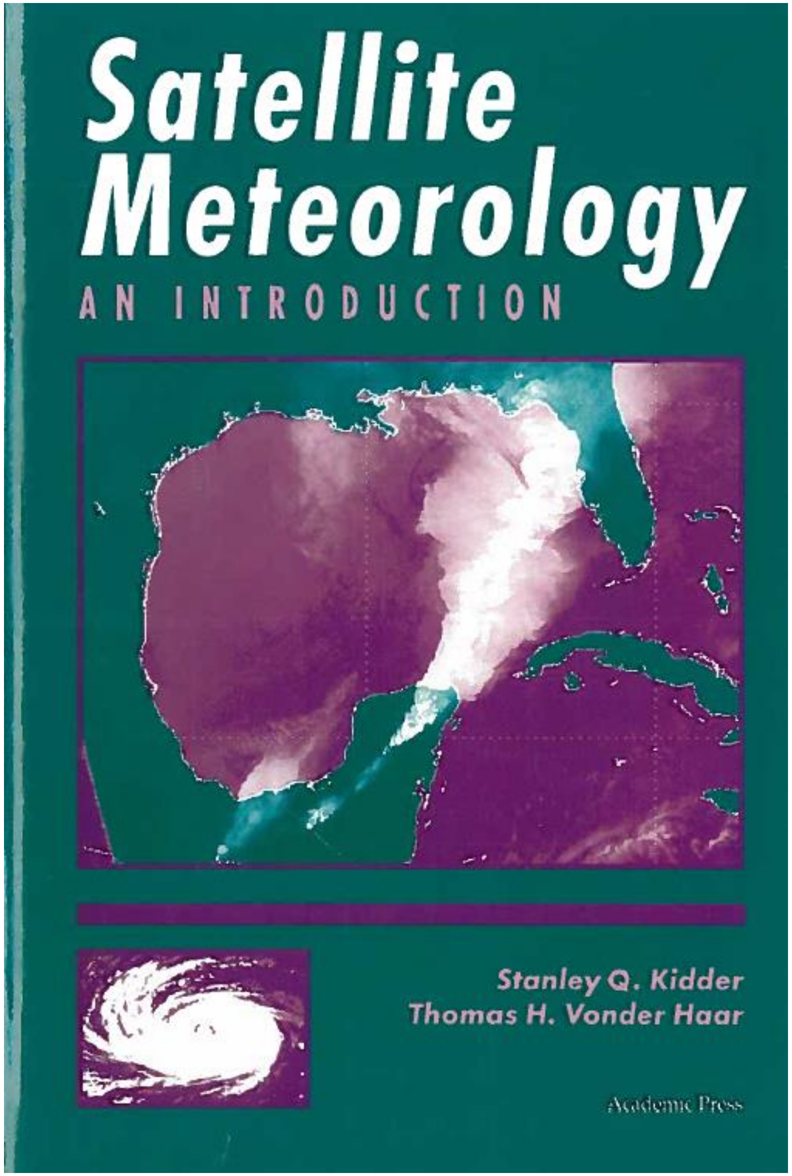




Lesson Learned:

- **Microwave measurements and products have grown to be very significant for forecasting and for science studies.**

Courtesy of Sheldon Kusselson, NESDIS Satellite Analysis Branch (SAB)



Ref:

1. Kidder, S. and T. Vonder Haar, 1995: Satellite Meteorology, An Introduction. Academic Press (now Elsevier), 466 pp. ISBN-13:978-0-12-406430-0 E-version available at (http://www.elsevier.com)

2. Many more TBD

- Study the Past
- Relate to the Present
- Plan for the Future

Overarching Lesson Learned

Each phase of U.S. operational satellites provided good information for improvement in the next phase because of excellent communication and collaboration among agencies, aerospace companies and university research centers.