History of satellites, and implications for hurricanes monitoring and forecasting

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Precursor to U.S. Weather Satellite Program --- the “Seed”

- Traces back to Department of Defense (DOD) rocket, sensor, and satellite development projects after World War 2
- Learned from analyses of catastrophic failures
- Installed instruments on rockets to measure atmospheric conditions. Measurements recovered from salvaged recorders or radio transmissions.
- Cameras later added to payload. Recovered film showed images of earth’s surface and cloud cover from space.

Example, Viking Rocket 1954


View of Earth from a camera on V-2 #13, launched
October 24, 1946

V-2 ROCKET-EYE VIEW FROM 60 MILES UP

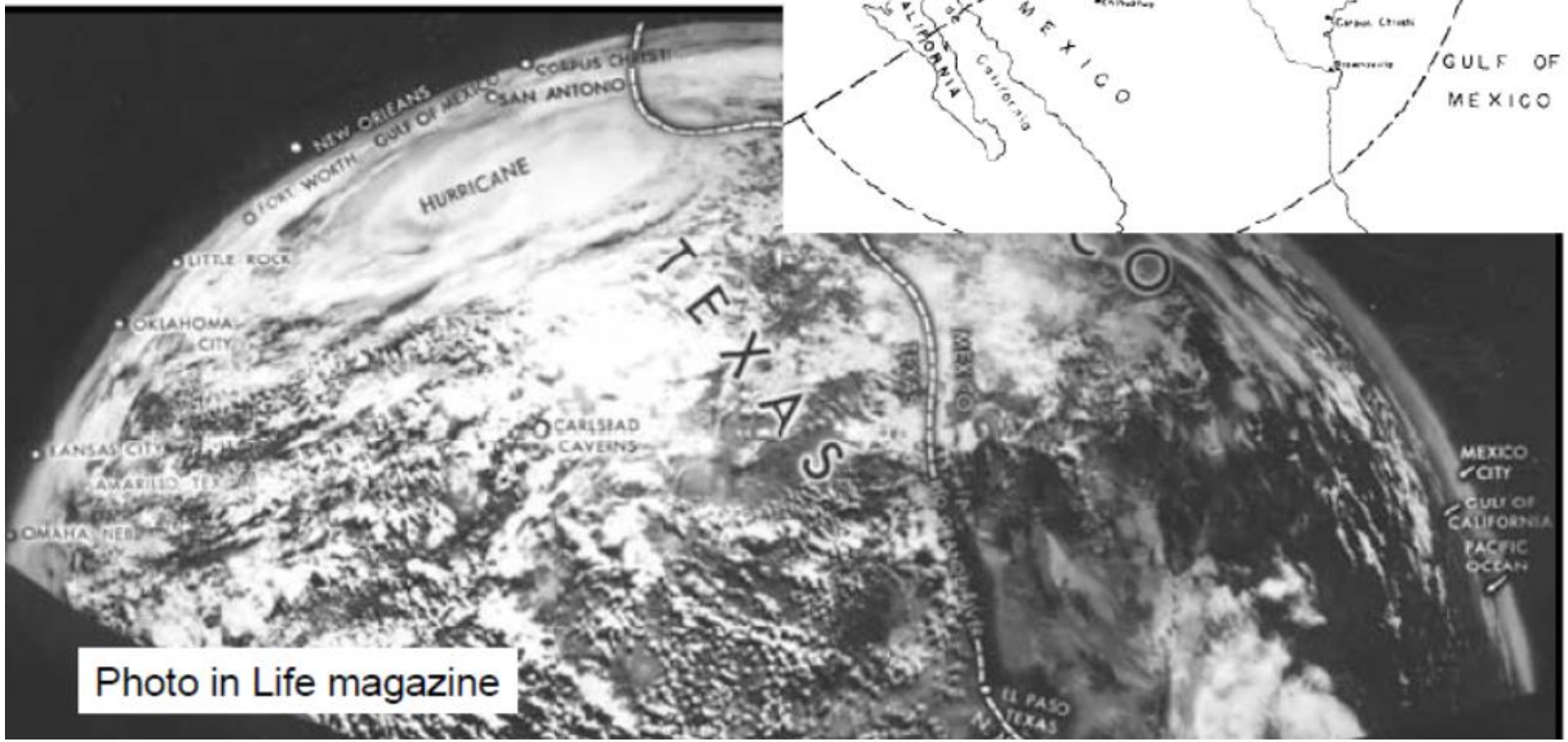
July 26, 1948

Sounding rocket launched at 1815 GMT on October 5, 1954 from White Sands, New Mexico

First Cyclone seen from space.

Touched up photo in Life Magazine

Still not in HURDAT. Was it a tropical cyclone or mid-latitude cyclone? May never know. But it certainly accelerated satellite ambitions



Birth of U.S. Weather Satellite Program

- The International Geophysical Year (IGY) of July 1, 1957 to Dec 31, 1958 was a global effort to advance the earth sciences
- Preparations for IGY prompted both the USA (July 1955) and Russia (Aug 1955) to announce they would launch an earth satellite. The space race was on!

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- October 4, 1957 – Russia launches Sputnik-1. This was unexpected and encouraged the US to make space exploration a priority. Sputnik was an earth-orbital satellite. One could infer drag and ionosphere information from its radio pulses
- November 3, 1957 – Sputnik-2; three times as large, and carried a dog as a passenger

Birth of U.S. Weather Satellite Program --- NASA and DOD

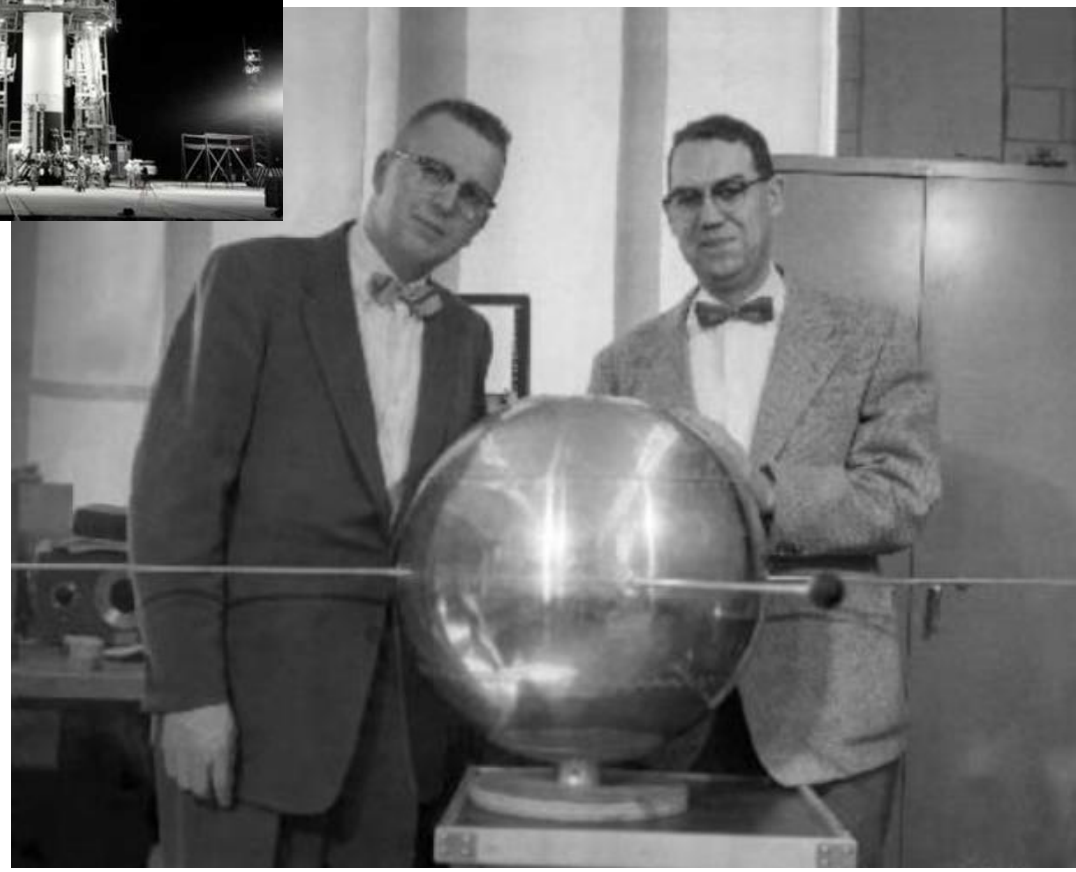
- Four days after Sputnik-1 – President Dwight Eisenhower named James Killian, head of the Massachusetts Institute of Technology, as Special Assistant for Science and Technology and chairman of the President's Science Advisory Committee on Government Organization.
- March 5, 1958 – Re-designated this committee as the National Advisory Committee for Aeronautics (NACA) and approved to lead civil space
- March 27, 1958 – Eisenhower approved plan for outer space exploration. Advanced Research Project Agency (ARPA) designated to undertake several DOD space projects
- April 2, 1958 – Eisenhower proposes NASA, which absorbs NACA for civilian programs. The National Aeronautics and Space Act is signed July 29, 1958.

Birth of U.S. Weather Satellite Program - NOAA

- The Department of Commerce U.S. Weather Bureau (USWB) started the Weather Satellite Program in the mid 1950s
- March 1958 – Established a special unit called the Meteorological Satellite Research Unit. Also establish the Meteorological Satellite Section.
- September 1958 – Weather Bureau would be designated as their meteorological agent "providing the meteorological instrumentation, data reduction, and analysis of observations taken by satellites." This establish NASA as the satellite development branch, and the Weather Bureau as the developer and user of mature satellite technology.
- Name was changed to the Meteorological Satellite Laboratory, a precursor to NOAA's NESDIS.

First US weather satellite ("semantics")

- DOD program JANUS renamed TIROS and transferred to NASA
- October 13, 1959 – Explorer VII
- Devised by Professor Verner Suomi and Robert Parent, University of Wisconsin
- Very basic measurement: balance between incoming radiation and outcoming radiation, which is the primary driving force of the atmospheric circulation
- Had a radiometer, and white and black ping pong balls on transmission antennas

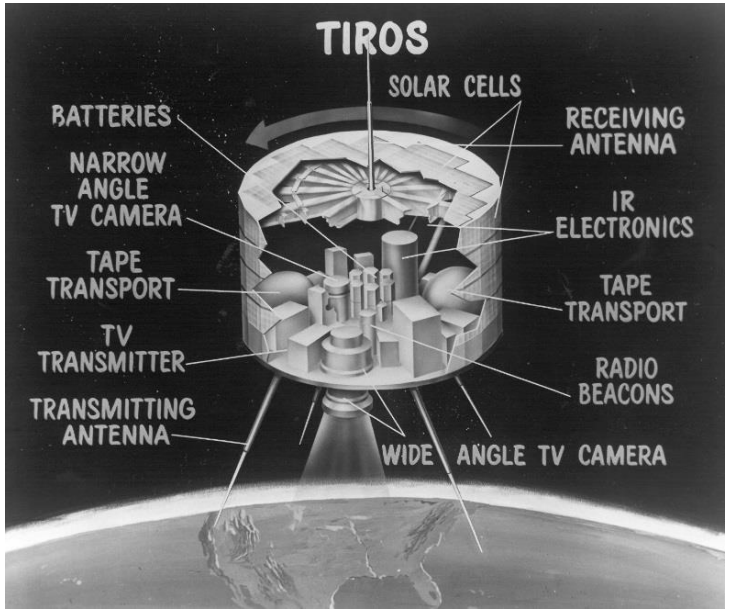


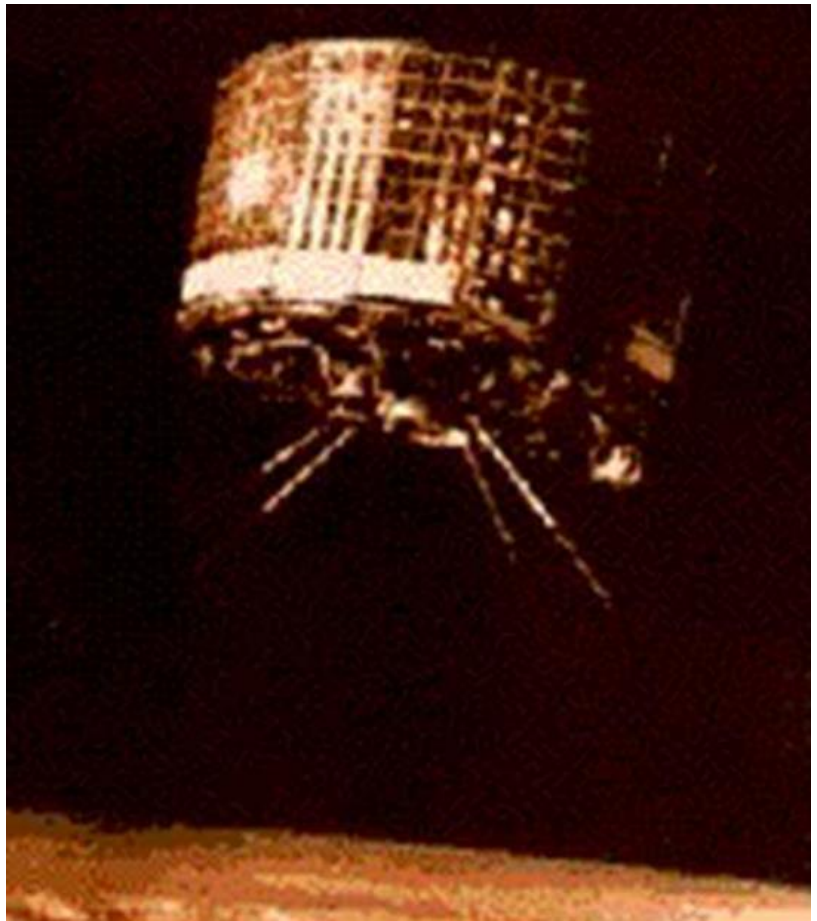
"VII" implies there were predecessors doing various technical tests. For example, Explorer I launched on Jan 31, 1958, and discovered the Van Allen radiation belt. Vanguard 1 successfully orbits, infers earth's shape. Explorer IV maps the Van Allen belt. But Explorer VII was the first atmospheric "measurement" from space involving an experiment.

There were also many Explorer and Vanguard failures in 1958 and 1959 Pioneer 1 and 2 had TV cameras in 1956, but the equipment failed

First pure weather satellite

- April 1, 1960 – TIROS-1, polar orbitting
- First television picture from space. Views of cloud formations makes international news.
- Captures image of previously unknown hurricane 800 miles east of Brisbane, Australia
- Impact for monitoring hurricanes was immediately obvious





Nine more TIROS followed in five years

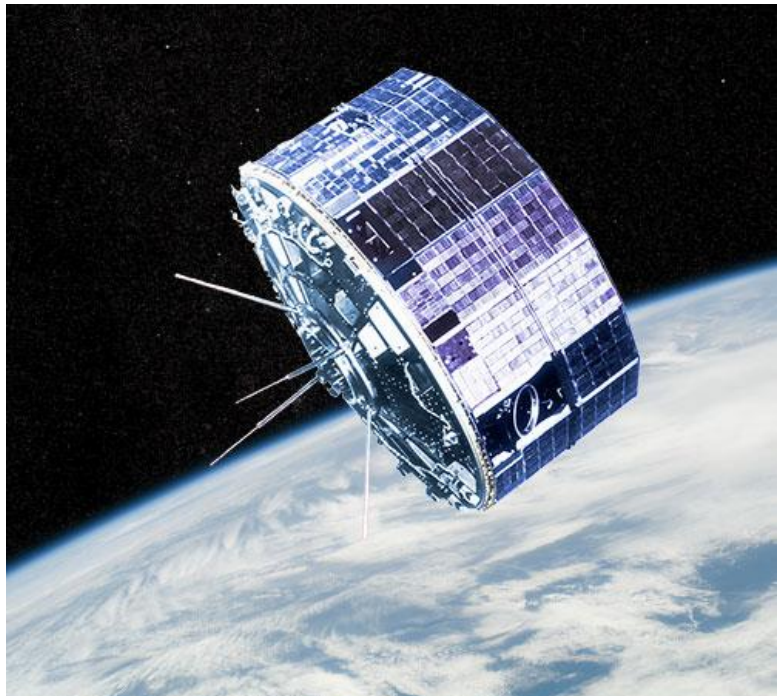
- Automatic Picture Transmission (APT) allowed direct transmission of real-time pictures
- Changes to a “wheel mode” operation allowed a sequence of overlapping pictures
- TIROS-9, January 1965, first complete view of world’s weather
- TIROS-9 is also first sun-synchronous orbit
- Spawned the Environmental Science Services Administration (ESSA). Evolved into NOAA.

NASA also conducted new satellite research

- August 24, 1964 – First of nine Nimbus satellites launched
- Nimbus-1 had first infrared radiometer, produced first high-quality image at night
- Other improvements
  a. Camera technology
  b. Radiometers
  c. Crude temperature and moisture profiles
  d. Roots of NASA's Landsat program (landcover classification)

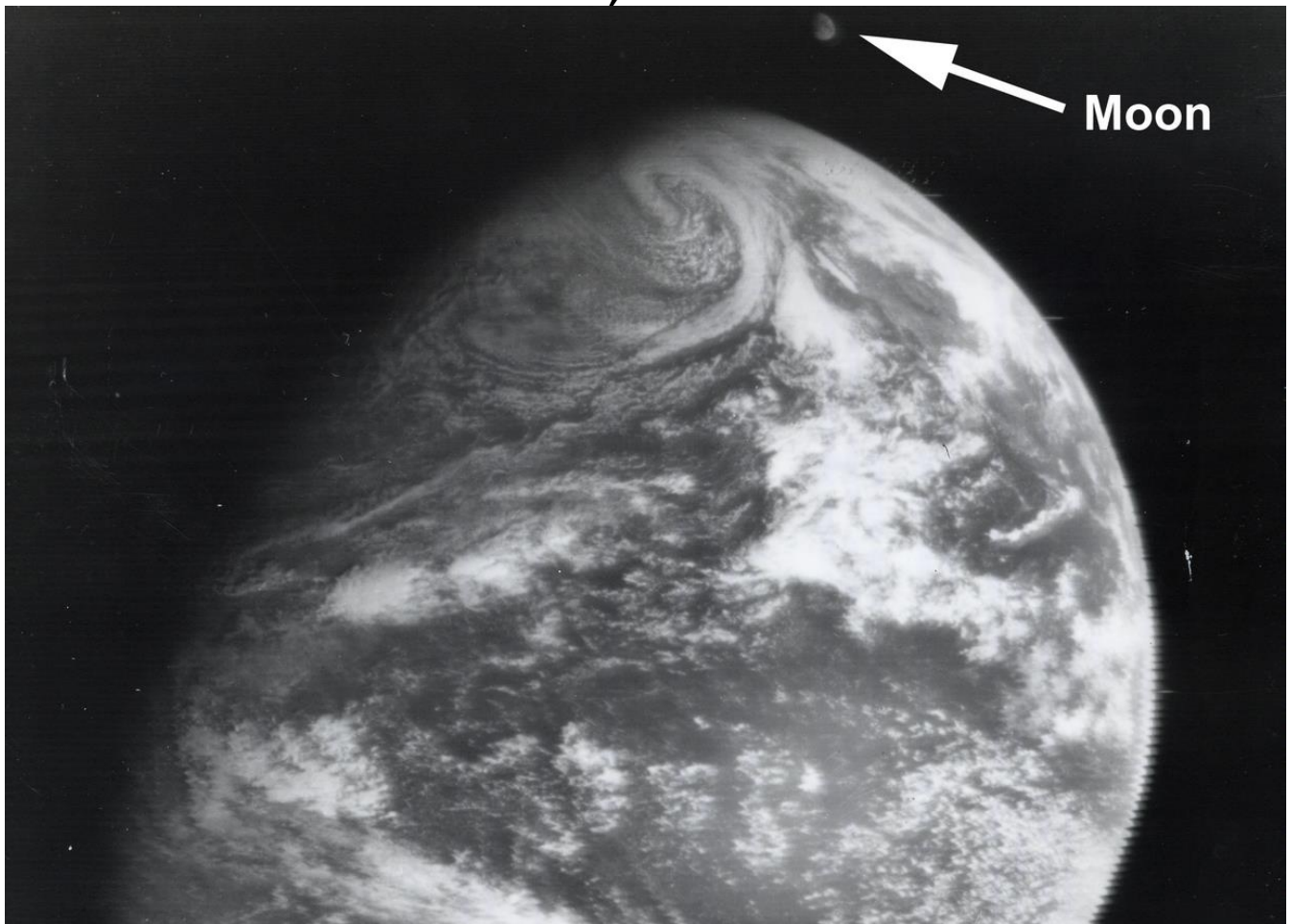
First operational satellites

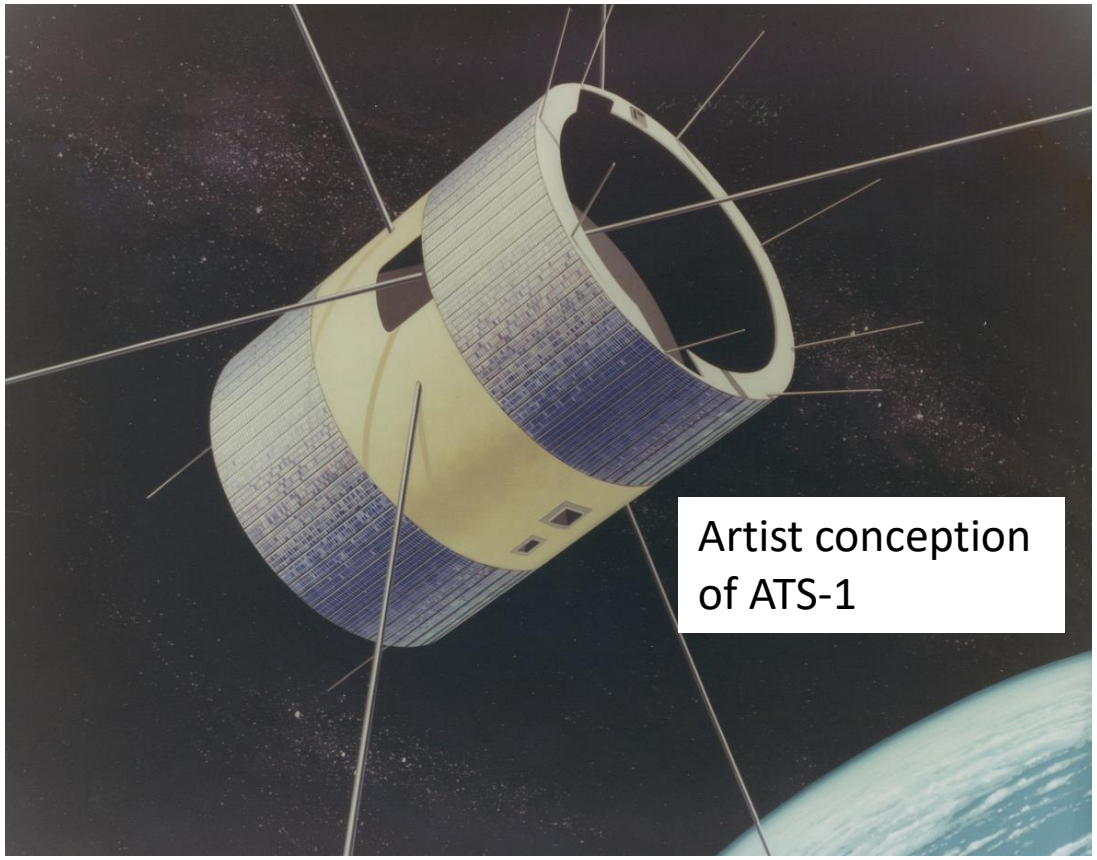
- February 3 and February 27, 1966
- ESSA-1 and ESSA-2
- Part of the TIROS Operational System (TOS)
- Odd-number provided photos and global weather data
- Even-number provided real-time APT pictures
- In 1970, combined these abilities (Improved TOS, or ITOS)
- ESSA satellites assured routine hurricane surveillance
- Also motivated hurricane forecasting and analysis techniques using satellite



First geostationary weather satellite

- December 6, 1966 – Applications Technology Satellite-1 (ATS-1) launched. First image shown below for December 22.
- Took advantage of spin-scan technology developed by Professor Suomi. Successive East-to-west scans. Full disk visible images! Movies! This astounded meteorologists.
- “Now the clouds move, not the satellite” – Professor Suomi



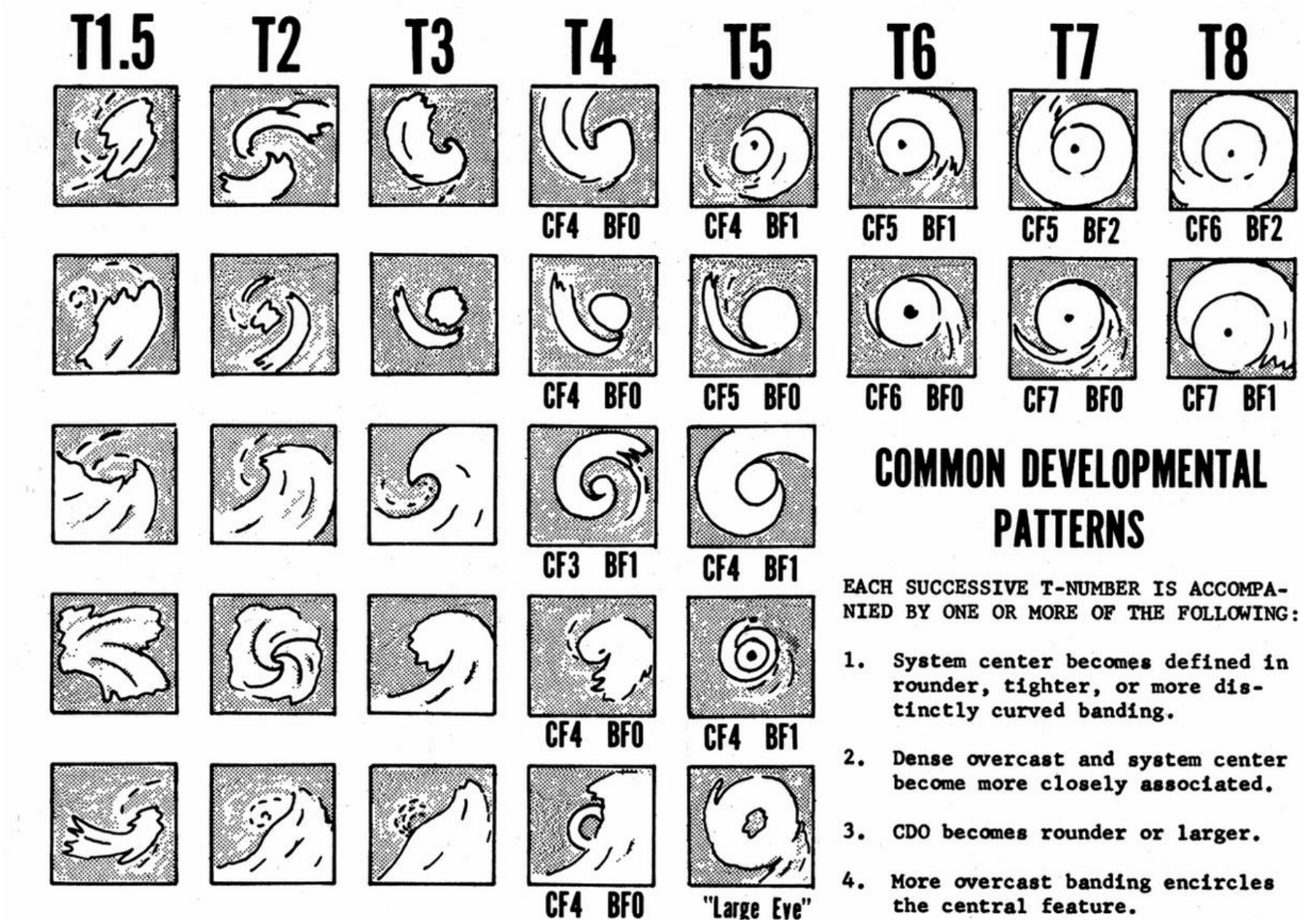


Artist conception of ATS-1

Repercussions and evolution of satellites next ten years

- DOD started satellite program in 1966 - the Defense Meteorological Satellite Program (DMSP)
- Aircraft reconnaissance begins to be reduced globally, ultimately leaving only Atlantic reconnaissance by 1987
- In 1972, Vern Dvorak develops technique to estimate hurricane intensity based on cloud shape and banding
- 1972 also marks beginning of multichannel sensing in different wavelengths of electromagnetic spectrum on NOAA-2
- Geostationary becomes officially operational in 1974.
  a. Prototype - Synchronous Meteorological Satellites (SMS)
  b. In 1975 – Geostationary Operational Environmental Satellite (GOES)
- Causes end of U.S. weather observation ship program in 1977, relying on volunteer reports from commercial ships
- Other countries launch satellites (Europe – METEOSAT) (Japan, GMS)
- SEASAT – scatterometer in 1978

Original Dvorak Technique



COMMON DEVELOPMENTAL PATTERNS

EACH SUCCESSIVE T-NUMBER IS ACCOMPANIED BY ONE OR MORE OF THE FOLLOWING:

1. System center becomes defined in rounder, tighter, or more distinctly curved banding.
2. Dense overcast and system center become more closely associated.
3. CDO becomes rounder or larger.
4. More overcast banding encircles the central feature.

The beginning of Meteosat in 1977

Tracking of tropical waves from Africa!

First image Meteosat-1

VIS

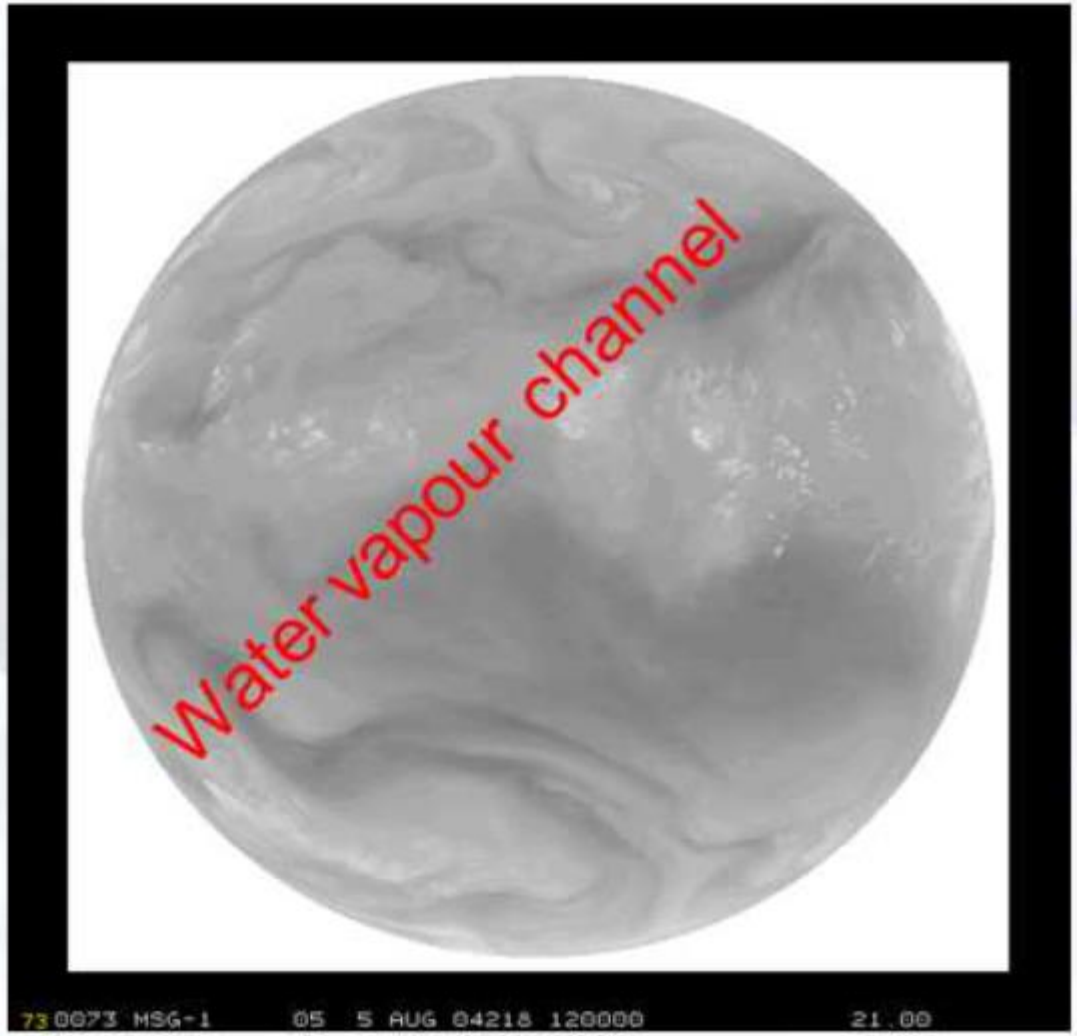
9. Dec. 1977

- 3 channels: VIS, WV, IR

- every 30 Min. 'full disk'

- first geo with WV channel

Meteosat had the first water vapour channel in a geostationary orbit



correspondence

A New Insight into the Troposphere with the Water Vapor Channel of Meteosat

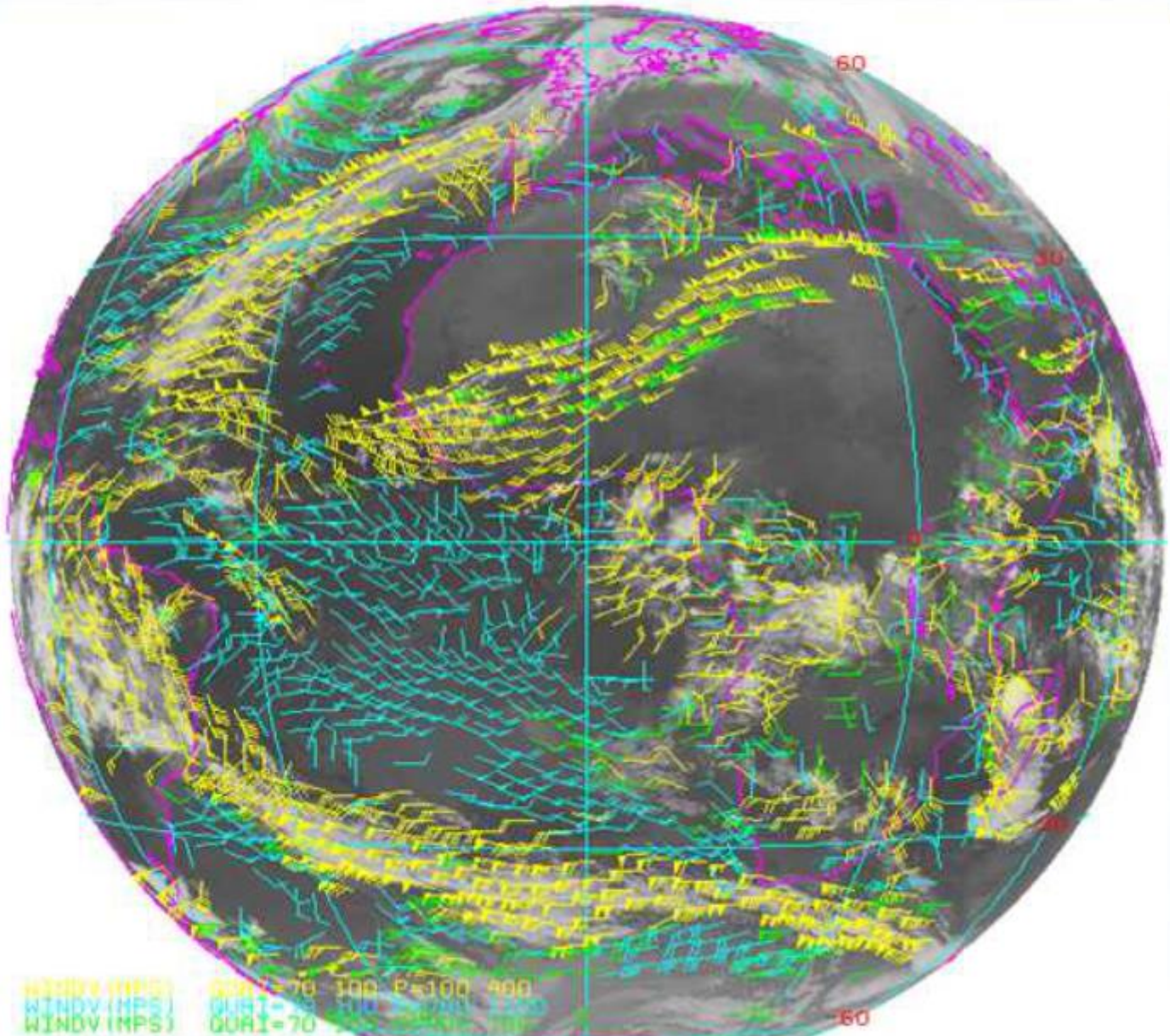
Pierre Morel, Michel Desbois, and Gérard Szejwach,
Laboratoire de Météorologie Dynamique, Centre National de la Recherche Scientifique, École Polytechnique, Palaiseau, France 91120

Abstract

Meteosat images in the three channels—visible (0.4–1.1 μm), thermal infrared (10.5–12.5 μm), and water vapor (5.7–7.1 μm)—are presented. The new possibilities offered by the water vapor channel on a geostationary satellite are outlined.

Water vapor winds from Meteosat:
Stimulated by Prof. Verner Suomi

Winds from geostationary satellites for NWP and reprocessing

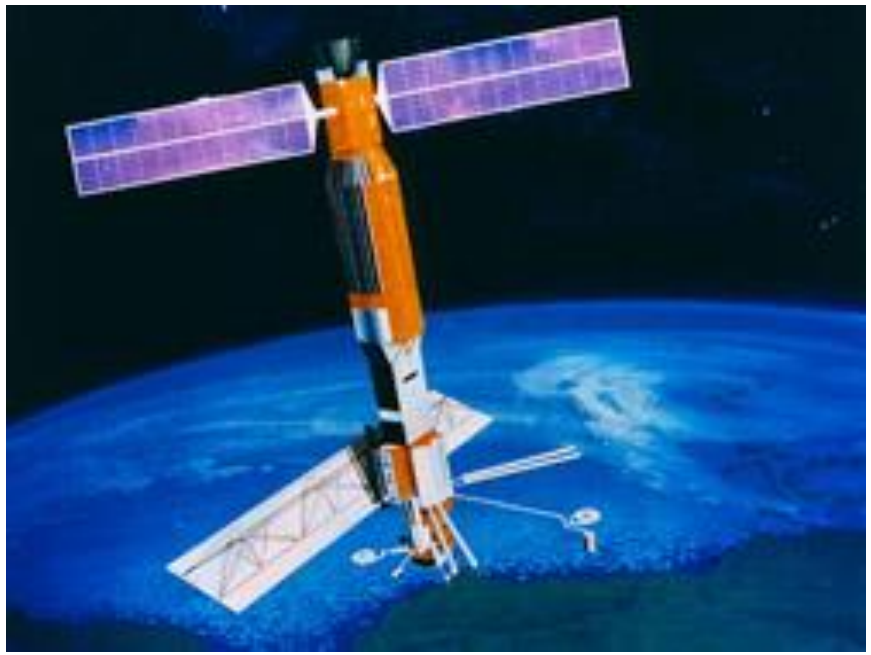


Winds from tracking atmospheric motions

=> Important data for numerical weather prediction (NWP)

here:
10.8 µm channel

Scatterometers



Seasat 1978

Indirectly measures surface wind speed by emitting microwave radiation toward the ocean and computes the amount of radiation scattered by short, centimeter-scale (capillary) ocean waves.

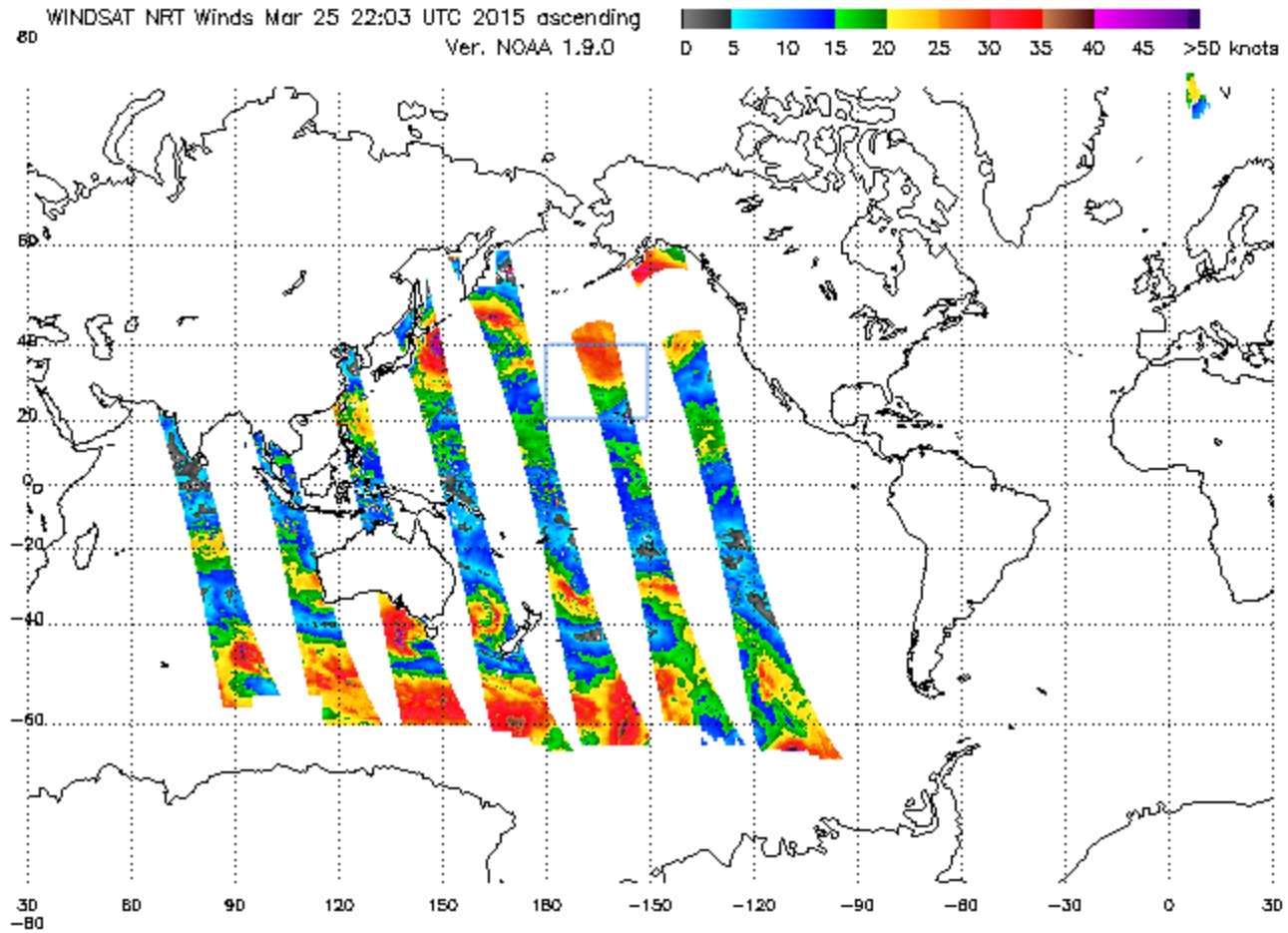
Microwave can “see” through non-convective clouds

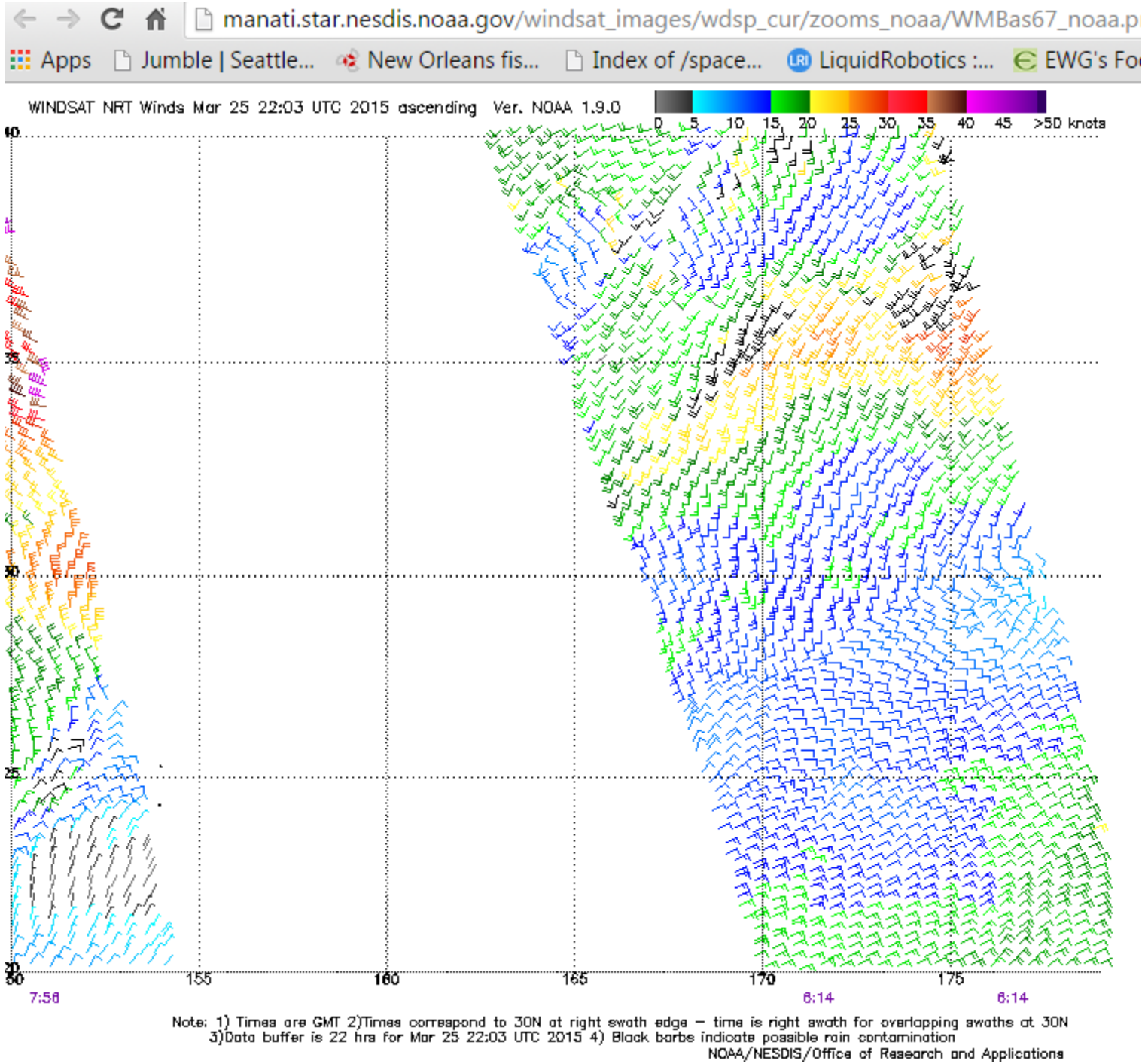
Data from Satellite/Instruments: WindSat/Coriolis Measurements

Additional Products	Year	Month	Day	
Wind Vectors 20X30 (25Km)	2015	3	27	Global(80N80S-180E180W)

Get Images

Ascending Pass

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Apps
Jumble | Seattle...
New Orleans fis...
Index of /space...
LiquidRobotics :...
EWG's Fo
WINDSAT NRT Winds Mar 25 22:03 UTC 2015 ascending Ver. NOAA 1.9.0
0 5 10 15 20 25 30 35 40 45 >50 knots
40
35
30
25
20
150
155
160
165
170
175
7:58
6:14
6:14
Note: 1) Times are GMT 2)Times correspond to 30N at right swath edge – time is right swath for overlapping swaths at 30N
3)Data buffer is 22 hrs for Mar 25 22:03 UTC 2015 4) Black barbs indicate possible rain contamination
NOAA/NESDIS/Office of Research and Applications

Other clever uses of microwave

- 1980s – Various satellites began using employed
- 1987 – DOD's Special Sensor Microwave/Imager (SSM/I)
  a. Sensitivity to convective clouds allows detection of hurricane structure, especially eyewalls and spiral bands
  b. Also can estimate surface wind speed
  c. Water temperature estimates
- 1997 – Tropical Rainfall Measuring Mission (TRMM)
  a. Spaceborne radar measures rainfall
  b. Microwave Imager measures vertical distribution of moisture
  c. Three-times resolution of SSM/I
- 1998 – Advanced Microwave Sounding Unit (AMSU)
  a. Captures 3D structure of hurricanes
  b. Warm-core measured
  c. Can infer wind profiles, surface pressure

Other satellite hurricane achievements

- 1970s – “Rapid-scan”; matured by early 1990s
- 1990s – Data assimilation in models of satellite radiance
- 2000s – New specialized hurricane products
  a. Morphing microwave satellites to create animations (University of Wisconsin MIMIC product)
  b. Saharan Air Layer monitoring

More information

AMS 2010 Conference

Symposium on Meteorological Satellites Observing Systems:
From 50 years ago to 15 years ahead

https://ams.confex.com/ams/90annual/webprogram/Session24084.html

Also see:

http://www.met.fsu.edu/orgs/explores/satellites/

http://www.osd.noaa.gov/download/JRS012504-GD.pdf

http://climate.geog.udel.edu/~tracyd/geog674/geog674_history.html

http://www.eumetsat.int/website/home/Data/Training/TrainingLibrary/DAT_2042875.html

http://www.eumetrain.org/resources/satellites_an_overview_2011.html