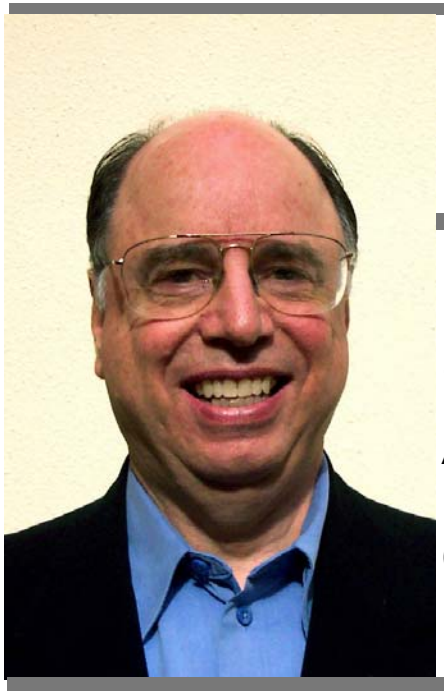
Contributions of Passive Microwave Sounders to Severe Weather Understanding and Predictive Capabilities



Presenter:
Prof. David H. Staelin
Massachusetts Institute of Technology

Professor of Electrical Engineering

Principal or Co-Investigator for multiple satellite-borne passive microwave imaging spectrometers

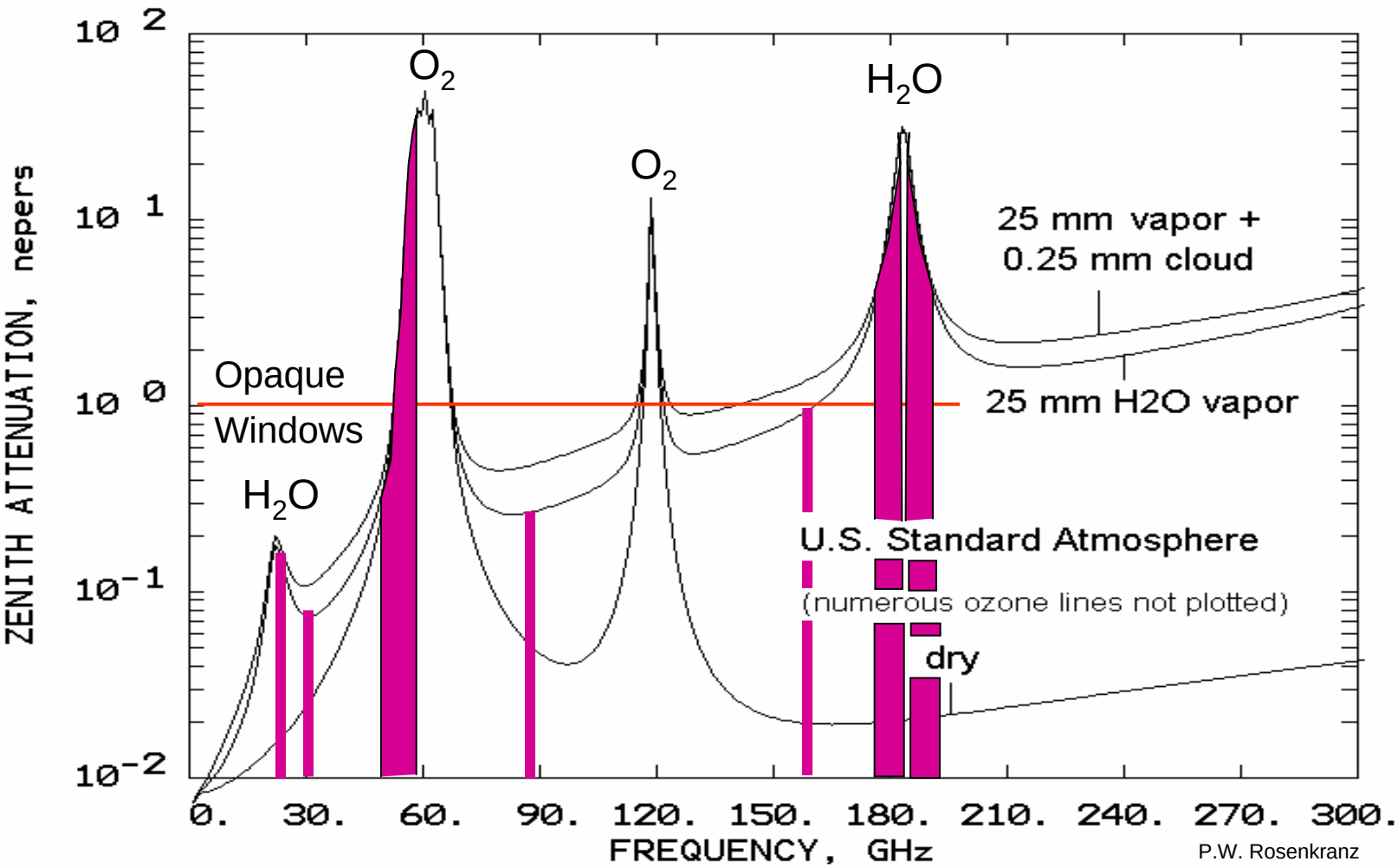
Assistant Director, MIT Lincoln Laboratory 1990-2001

Member, President's Information Technology Advisory Committee, 2003-

Fellow: IEEE and AAAS

Session Lead:
Dr. Stephen A. Mango
NPOESS Integrated Program Office

Spectral Coverage: Zenith Optical Depth



P.W. Rosenkranz

Evolution of Microwave Tropospheric Soundings

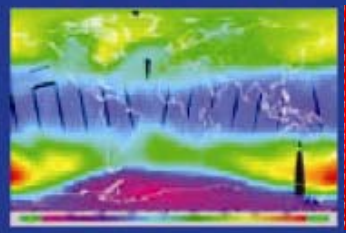
Nimbus 5
NEMS
(1972-1982)

First Microwave Sounder

Nimbus 6
SCAMS
(1975)

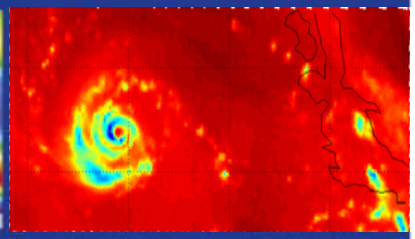
Cross Track Scanning

TIROS-N
MSU
(1978-1998)



Operational All Weather

NOAA
AMSU
(1998 - 2009)



Water Vapor, Precip & Temp

Aircraft
NAST-M
(1995 -)

Precip., Temp., Humidity

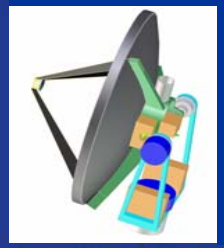
Aqua
AMSU/HSB
(2002 - 2007)

Enables All Weather High Vertical Res. (AIRS) Soundings

NPP/NPOESS
ATMS
(2006-2020)

New Technology Microwave Sounder

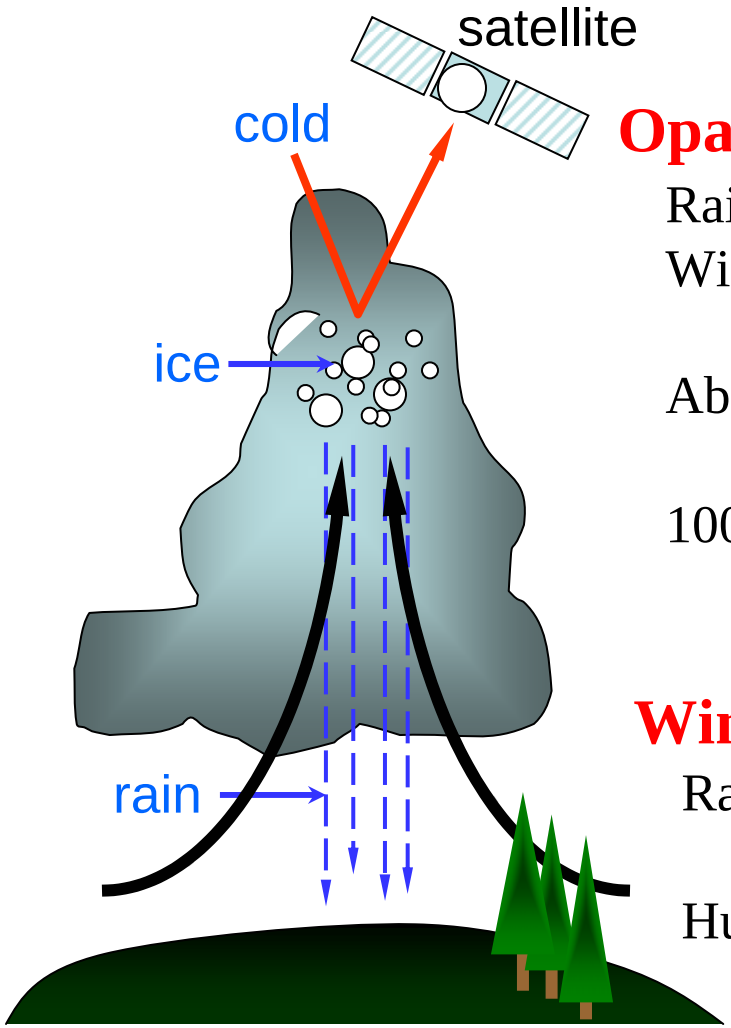
GOES
GEM



Precipitation All Wx Humidity Imaging

W.L. Smith and D.H. Staelin

Spectrum Physics: Opaque and Window Channels



Opaque Channels

Rain ∝ (vertical wind) x (absolute humidity)

Wind ∝ particle diameters

∝ 54/183-GHz perturbation ratio

Absolute humidity follows from T(h), 23.183-GHz

100% RH ⇒ ~constant 183-GHz T_B , lower T_B implies hydrometeors that scatter, absorb

Window Channels

Rain absorption/emission over ocean

∝ height, rate, ~f^2

Humidity absorption/emission has a different spectrum

Current NPOESS Aircraft Sounder Testbeds

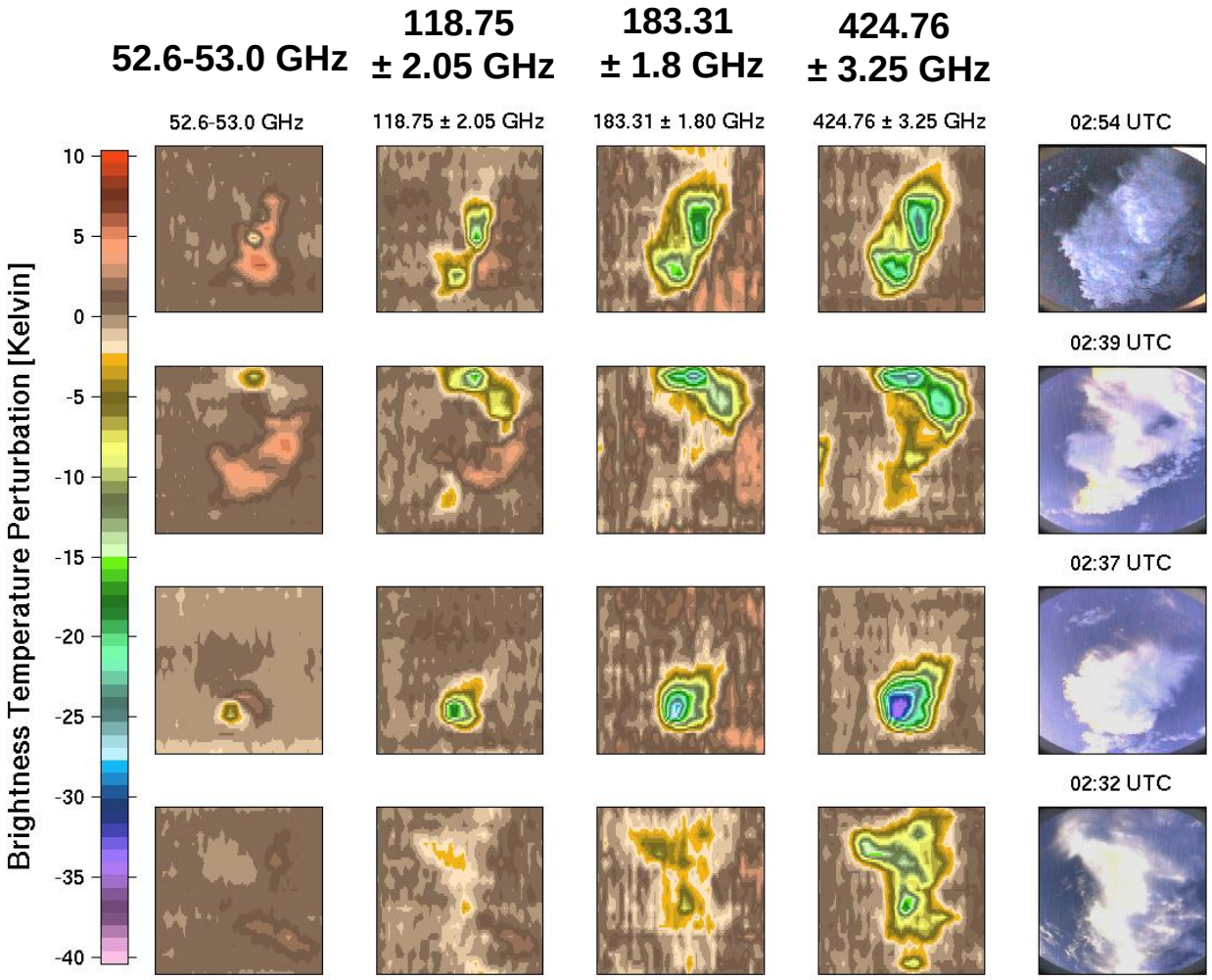
Dryden Flight Research Center EC99-45225-2 Photographed OCT1999
One of Dryden's two Airborne Science ER-2s which are used as science platforms for earth science, atmospheric research, satellite calibration and data validation. NASA/Dryden

Dryden Flight Research Center EC99-45110-7 Photographed 26JUL1999
ERAST's Proteus in flight over the Mojave Desert in California. Scaled Composites/Patrick Wright

NAST-M Location on Airborne Platforms

Proteus **ER-2**

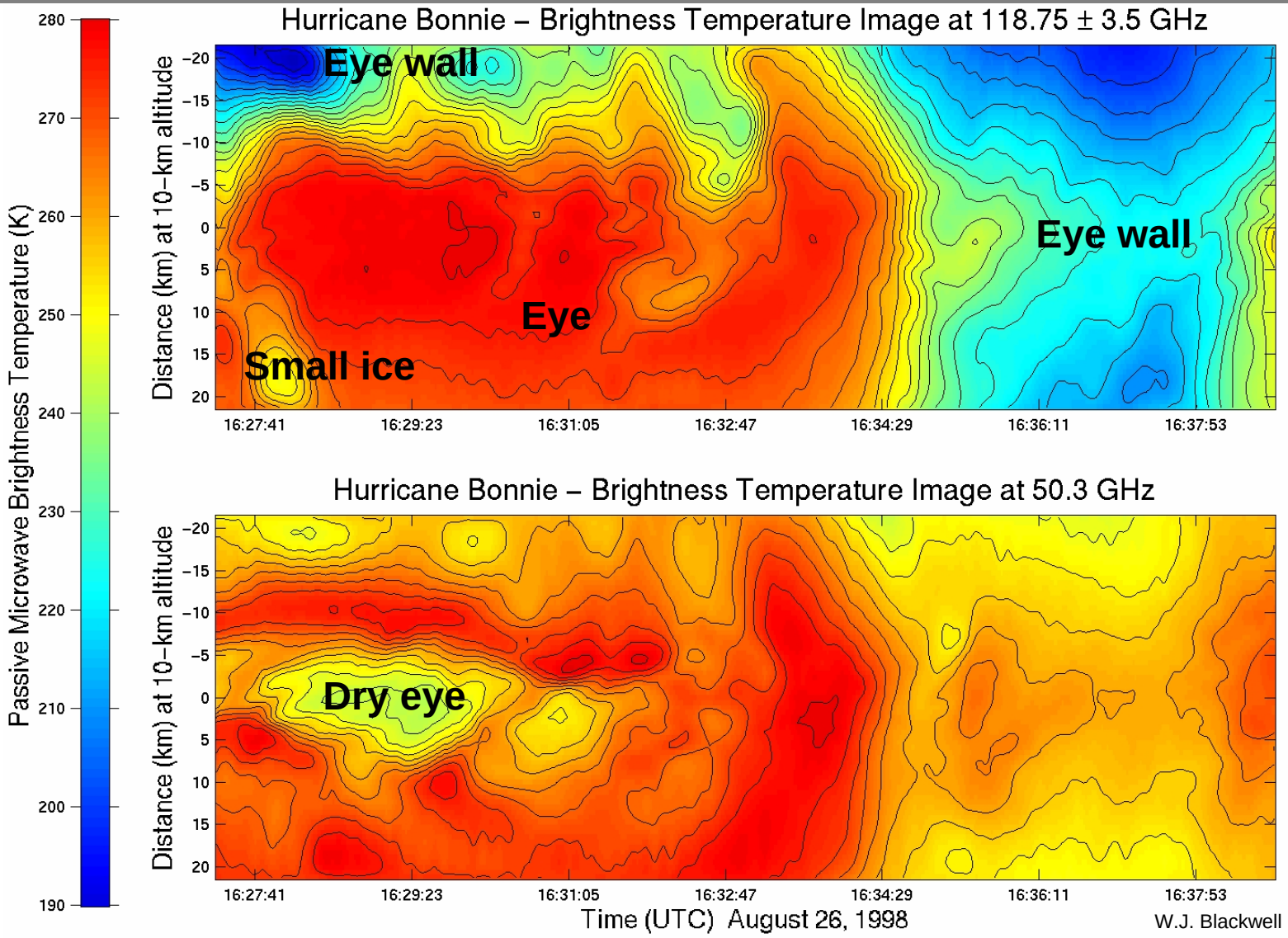
THORpex Cloud Signatures



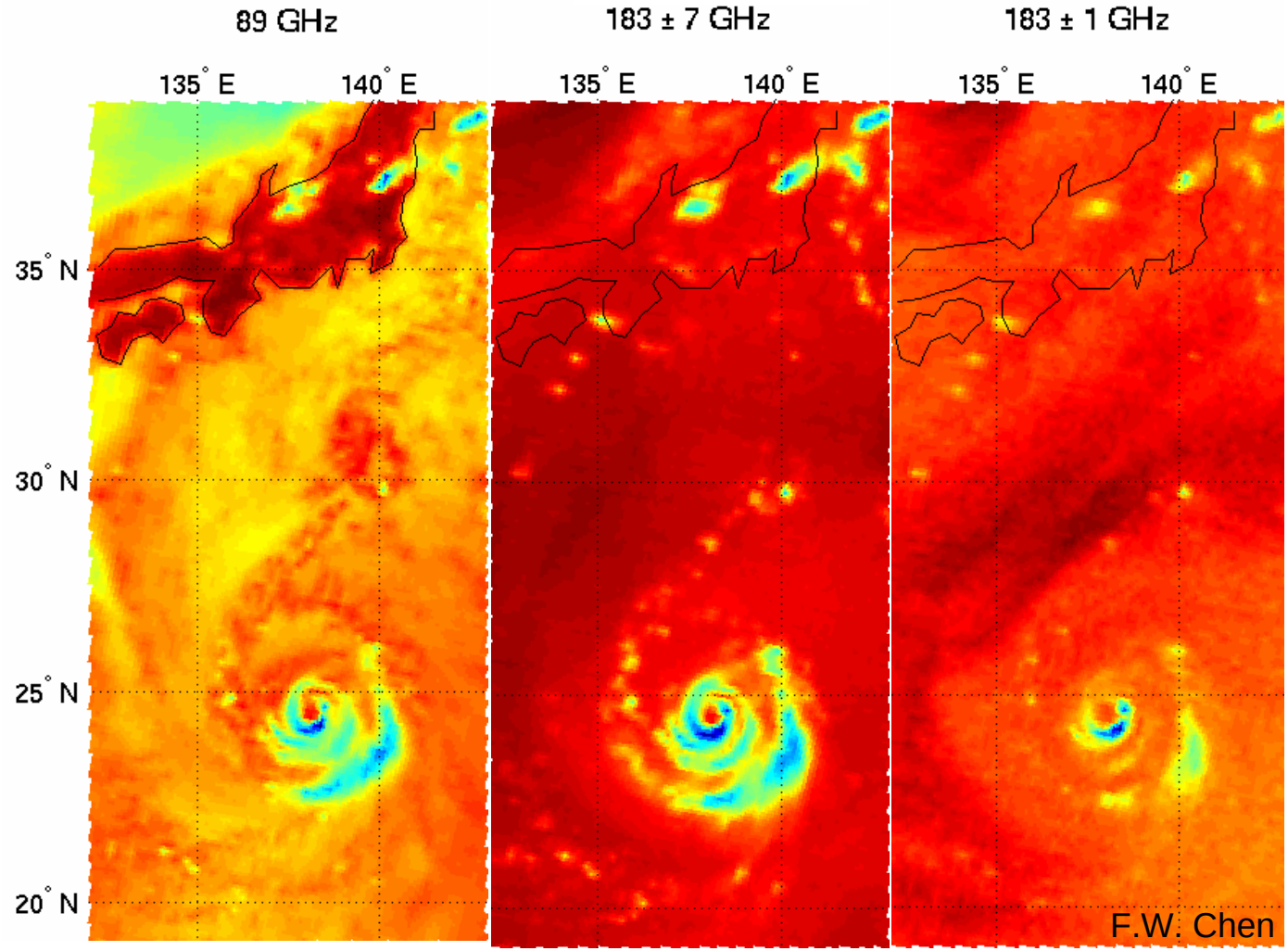
R.Vincent Leslie

- March 14, 2003
- ER-2 Platform
- Over Pacific Ocean
- Altitude = 20 km
- 54- & 183-GHz Tb baselines peak at 255 K
- 118- & 425-GHz Tb baselines peak at 250 K

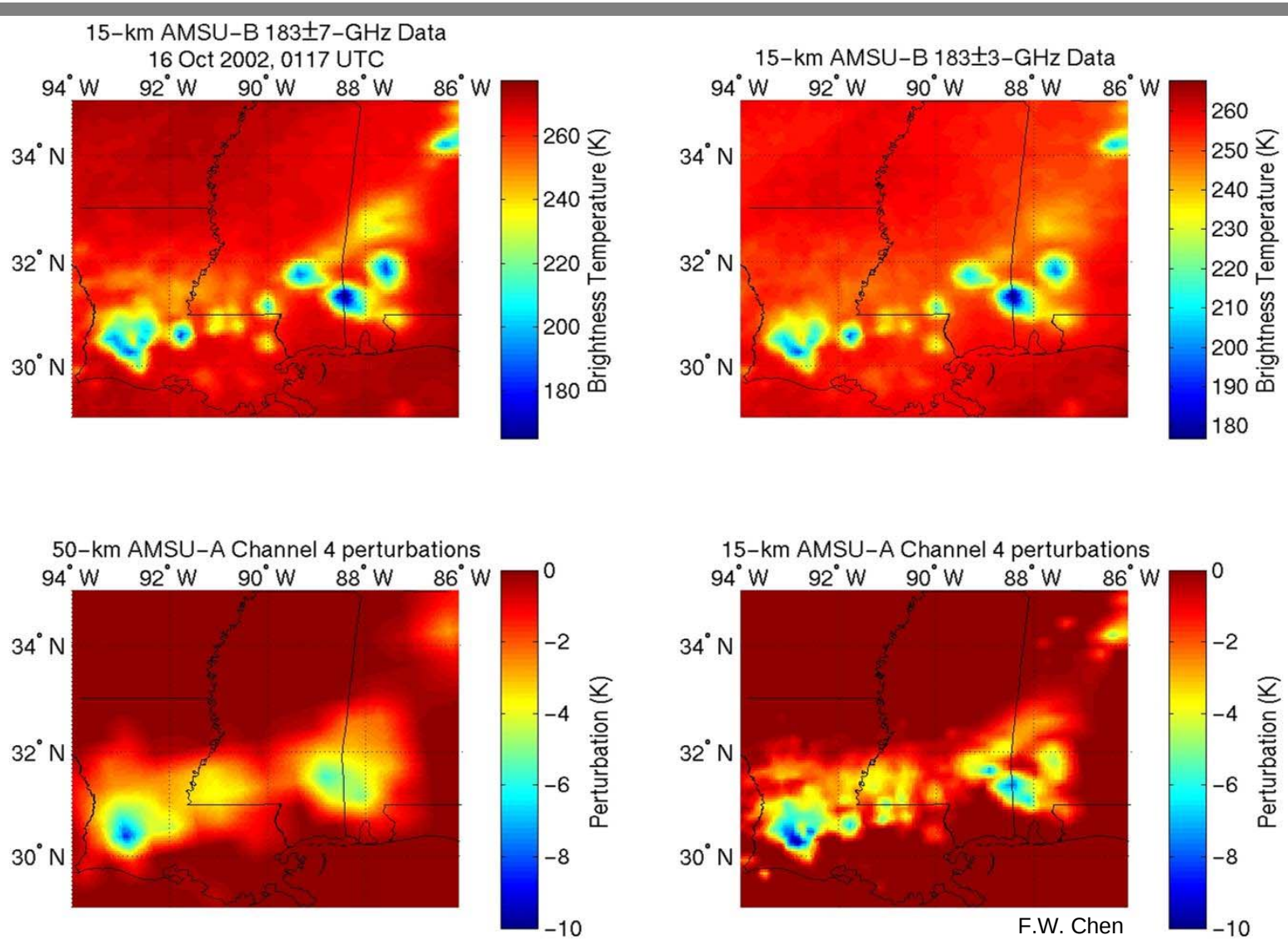
Hurricane Bonnie Eye, NAST-M, dry eye



Typhoon Rex – AMSU August 26, 1998

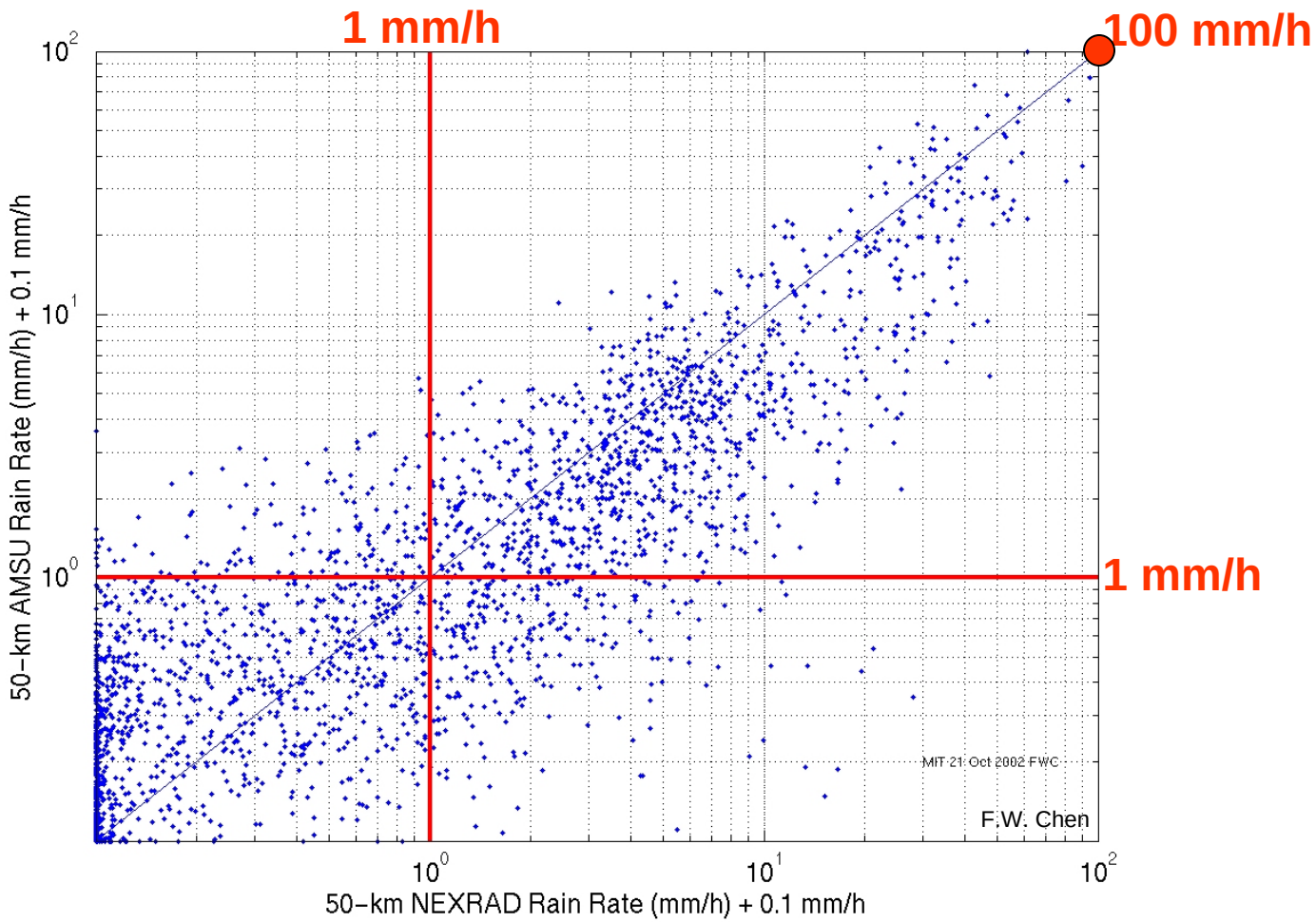


54-GHz Resolution Enhancement: 50 → 15 km



F.W. Chen

Instantaneous 50-km AMSU vs. NEXRAD

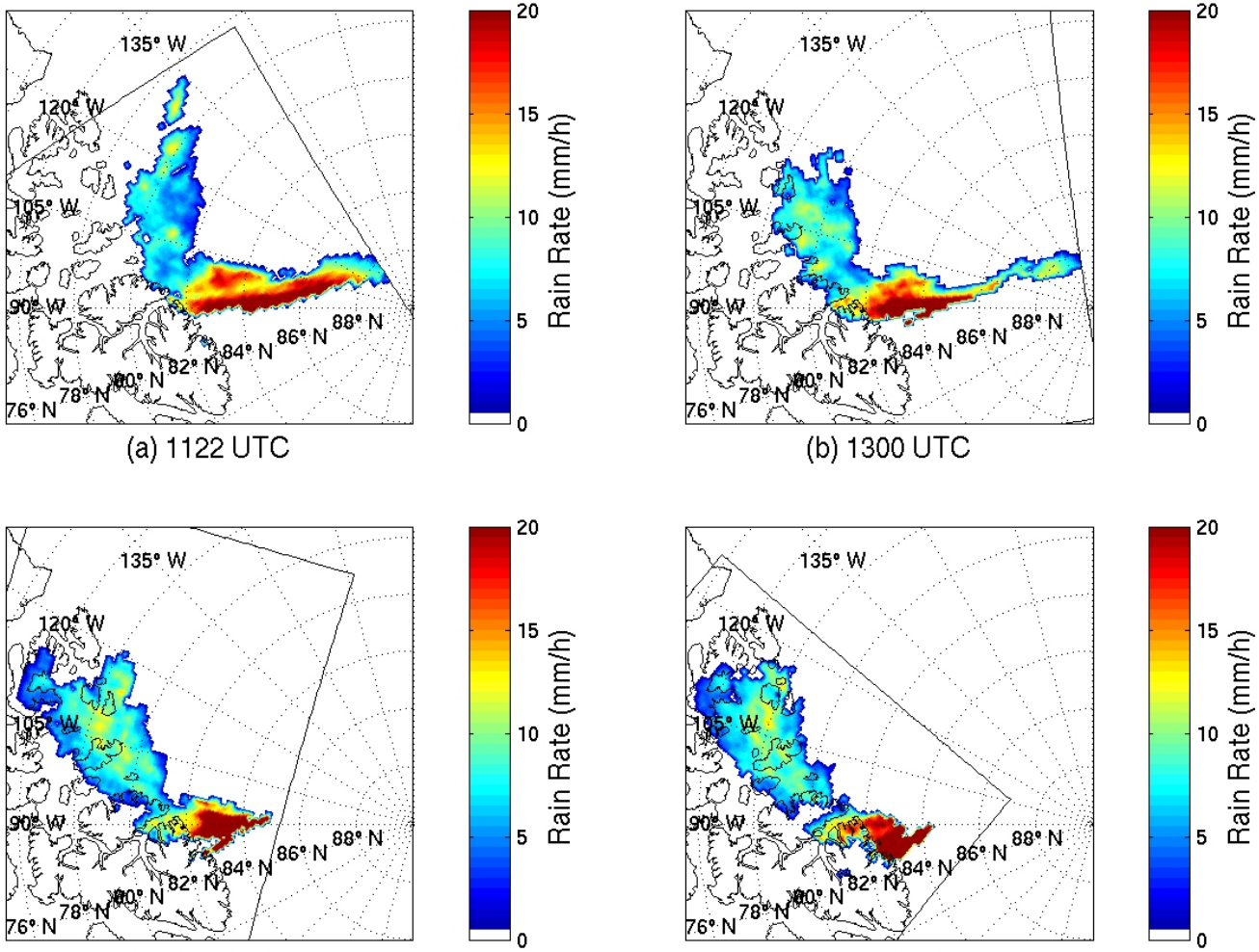


RMS Discrepancies (mm/h) between AMSU and NEXRAD

Range of NEXRAD rain rate	15-km (30-110 km from radar)	15-km (110-230 km from radar)	50-km (30-110 km from radar)	50-km (110-230 km from radar)
< 0.5 mm/h	1.0	1.4	0.5	0.5
0.5 – 1 mm/h	2.0	2.6	0.9	1.1
1 – 2 mm/h	2.3	2.7	1.1	1.5
2 – 4 mm/h	2.7	3.9	1.8	2.3
4 – 8 mm/h	3.5	7.4	3.2	5.2
8 – 16 mm/h	6.9	8.4	6.6	6.5
16 – 32 mm/h	19.0	17.2	12.9	14.6
> 32 mm/h	42.9	39.2	22.1	21.7

F.W. Chen and D.H. Staelin

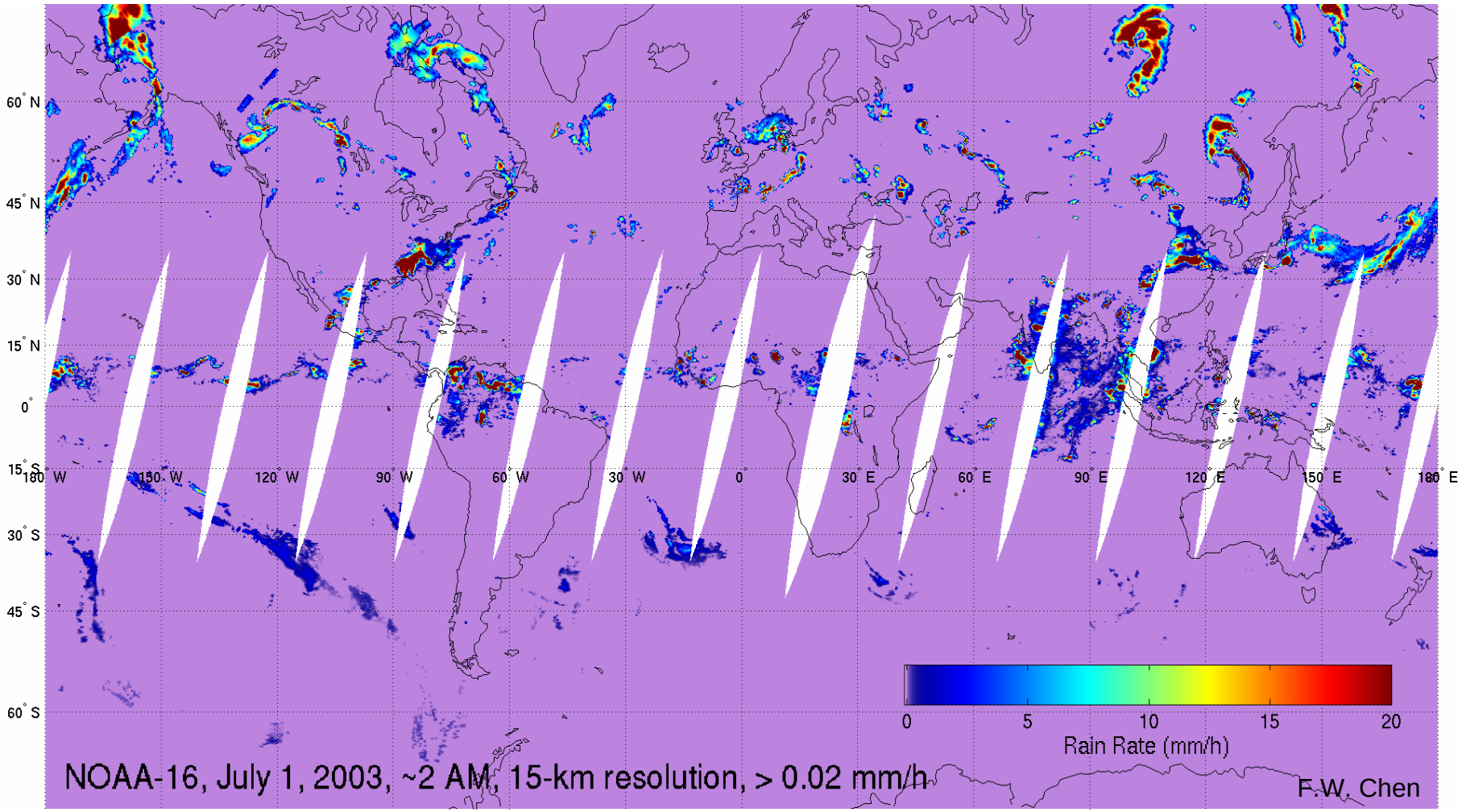
Polar Precipitation, 20 July 2002



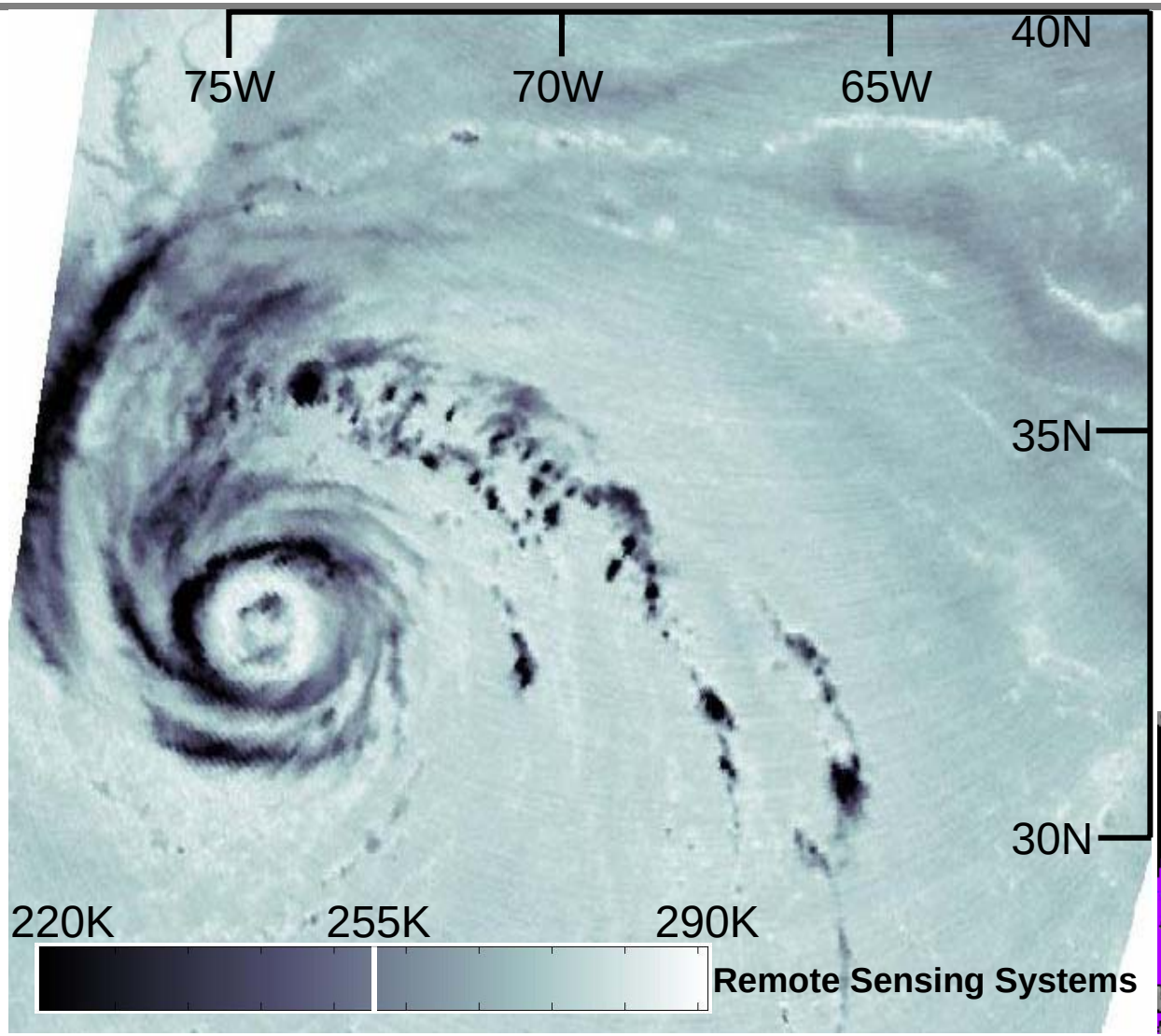
(a) 1122 UTC (b) 1300 UTC (c) 1438 UTC (d) 1615 UTC

F.W. Chen and A. Leckman

AMSU 24-hr Precipitation Image, July 2003



AMSR-E Hurricane Isabel 89V GHz – 9/18/03

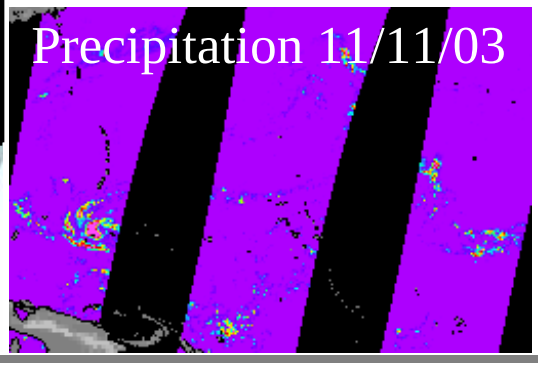


AMSR-E

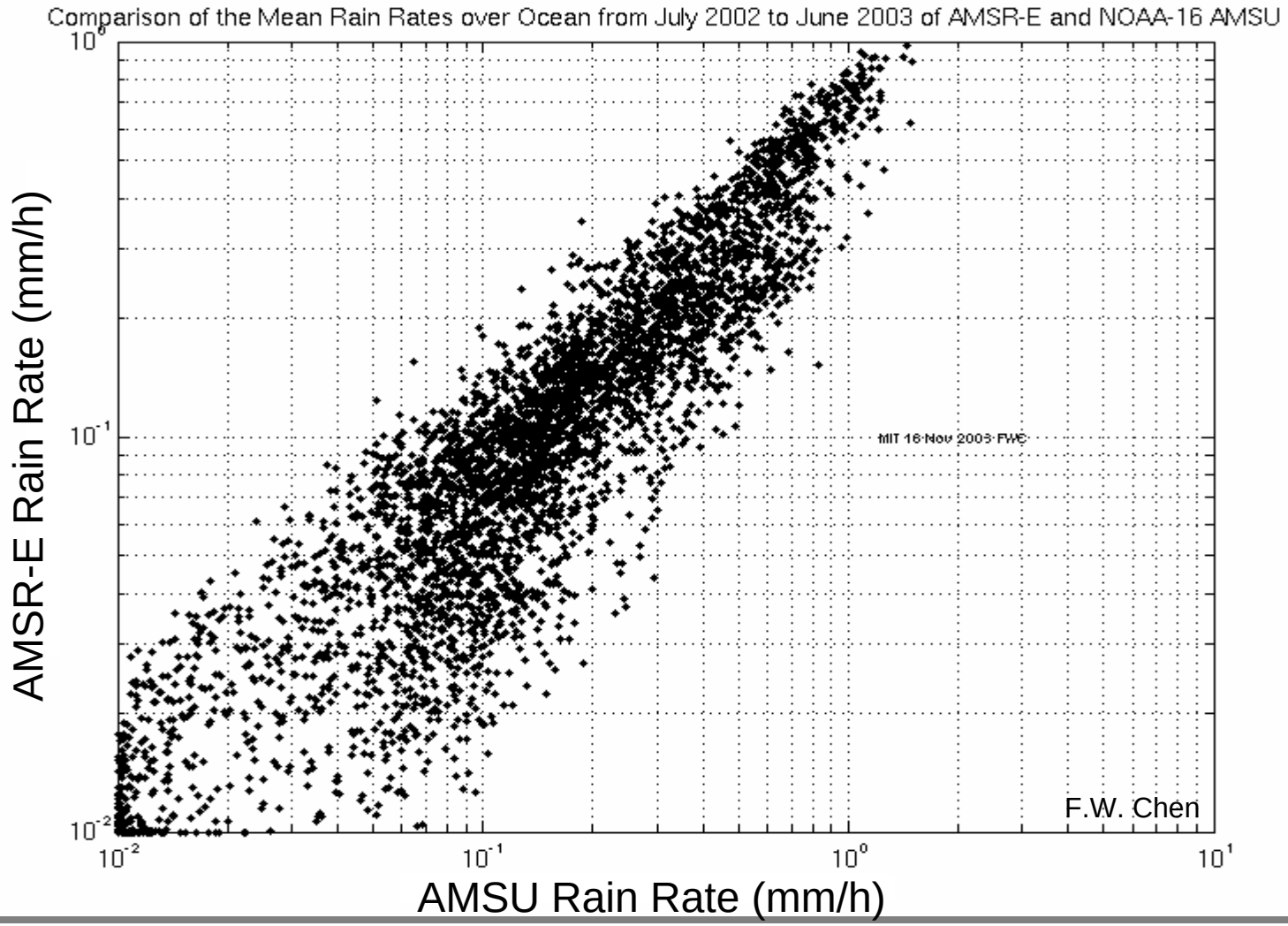
6.9, 10.6, 18.7, 23.8, 36.5, and 89 GHz

4x6-km beam at 89 GHz

1445-km swath

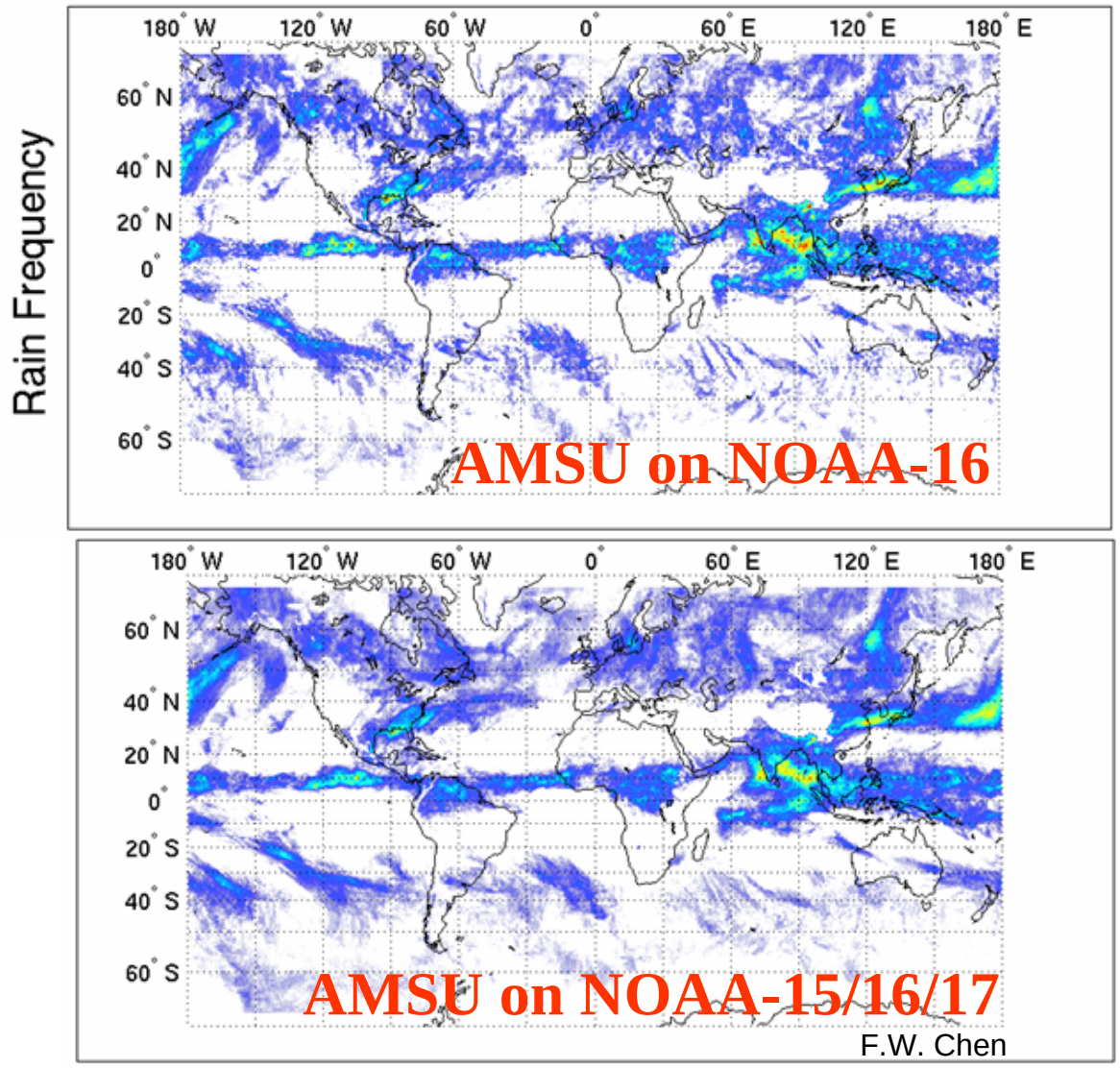


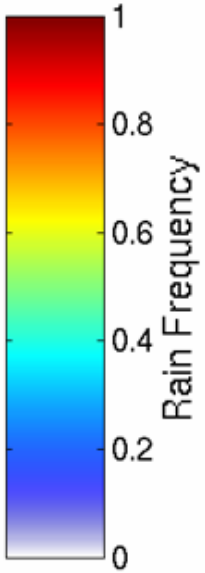
Annual AMSR-E vs. AMSU/NOAA-16, 1-deg.



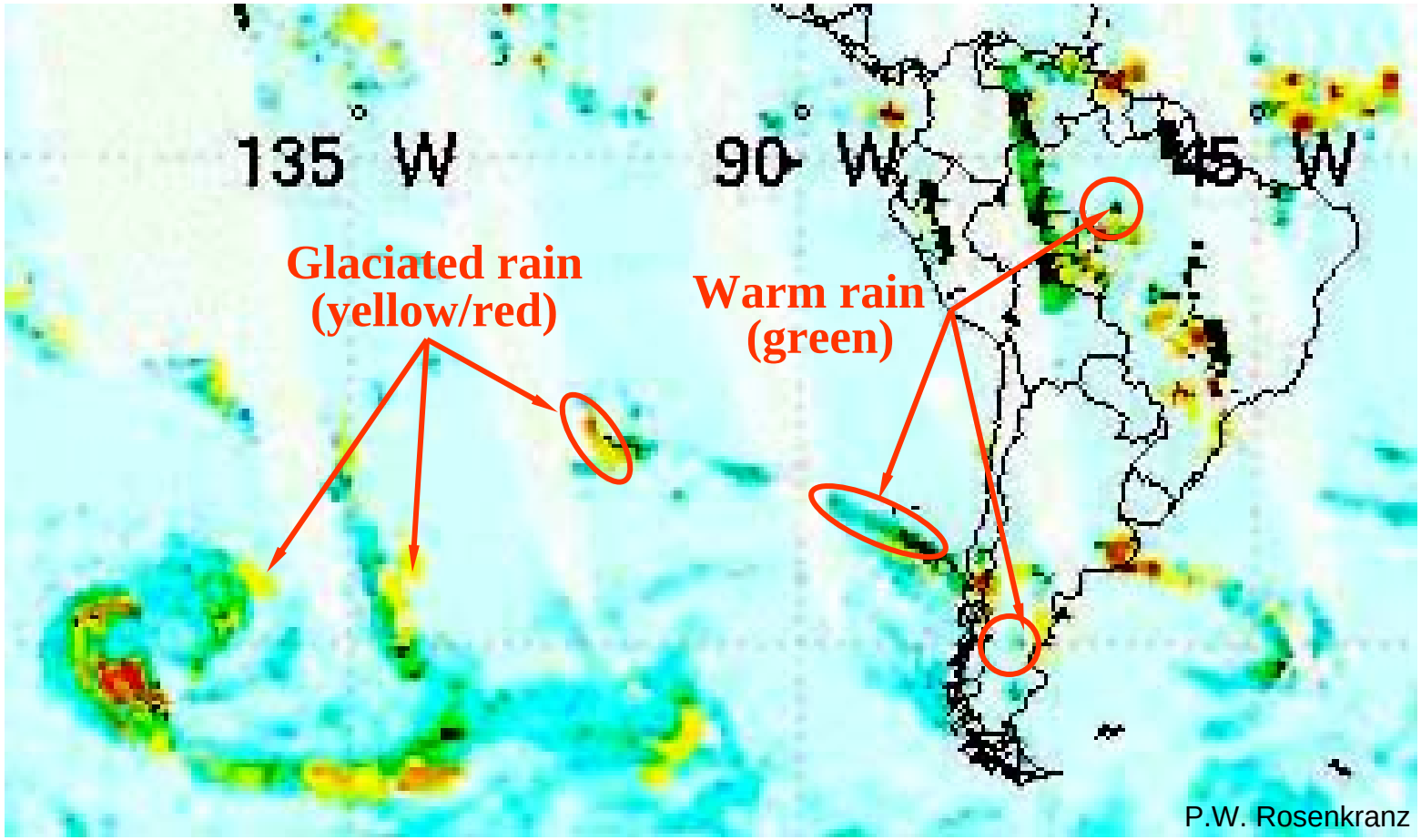
Rain Frequency

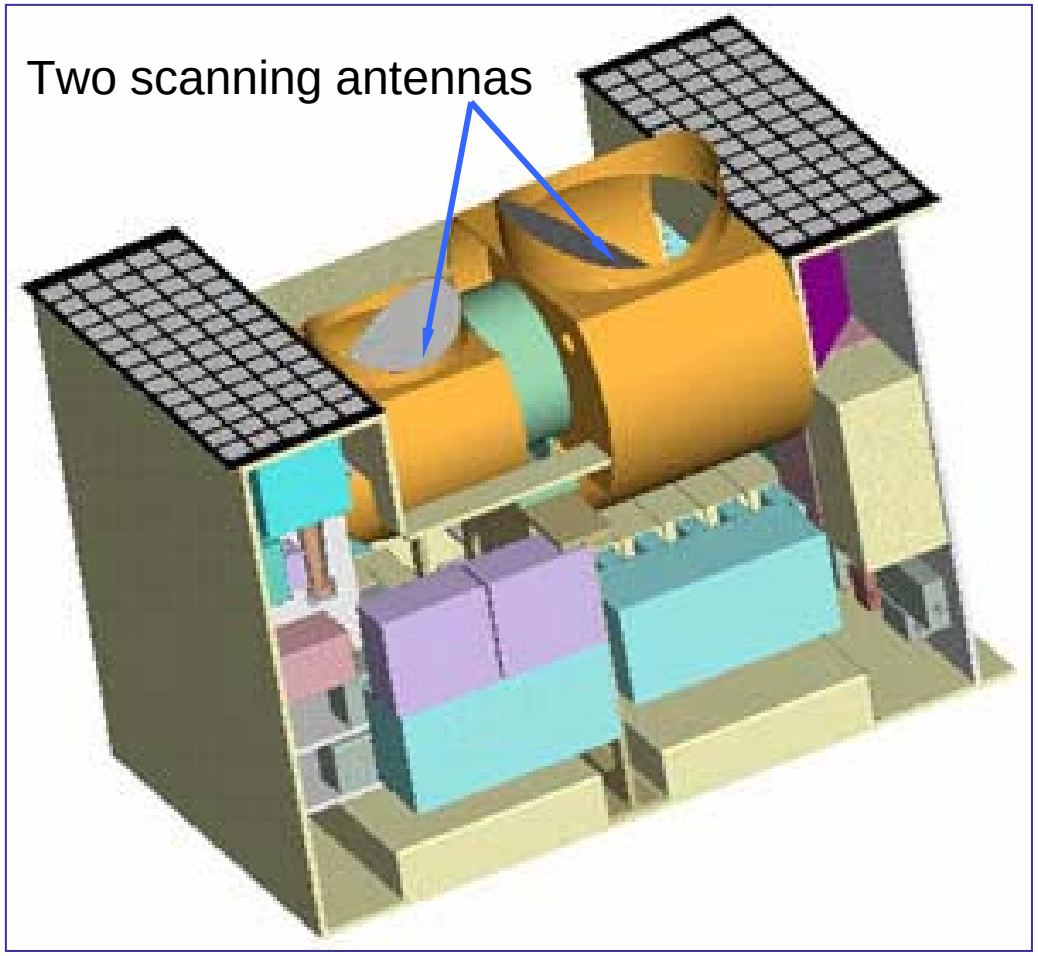
July 1-7, 2003
0.5 x 0.5 degrees





Aqua/AMSU/HSB 50-km Precipitation





ATMS Changes from AMSU

No inter-swath gaps

50 → 33 km resolution T(h)

Nyquist sampling for T(h)

More 183-GHz channels

50 → 75 km humidity < 2km

2 or 3 simultaneous orbits

CMIS – Main Capabilities

2.2-meter antenna for 6 – 89 GHz

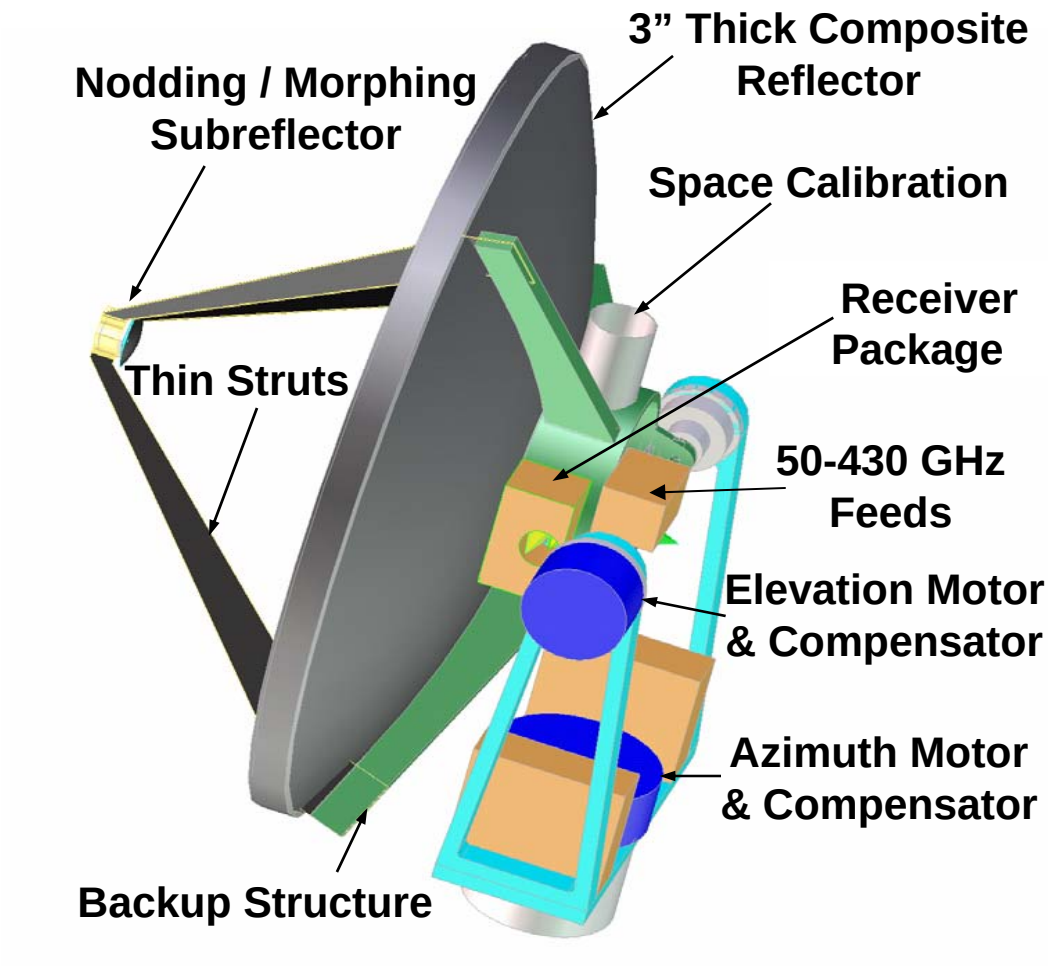
0.5 × 0.7 m antenna for 166-192 GHz

40x68 to 12x16-km spot sizes

1700-km swath width

30+ channels for humidity profiles, clouds and precipitation, surface properties, tropospheric to mesospheric temperatures

Geostationary Microwave (GEM) Concept



M. Shields

Practical 2-m antenna

Nodding-subreflector scanning

425-GHz oxygen and 380-GHz water vapor bands (others?)

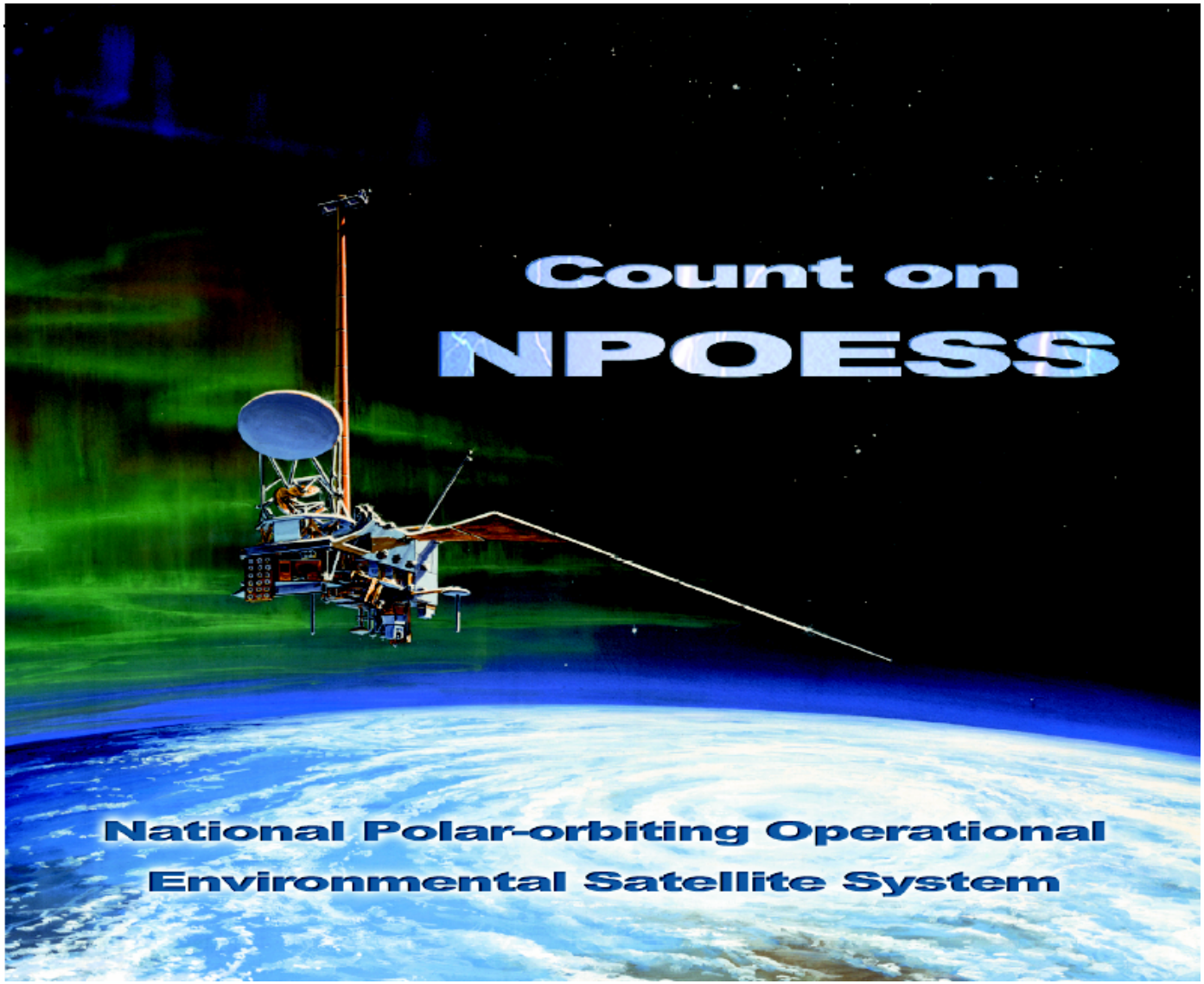
16-18 km resolution at nadir

Continual severe storm mapping

Summary

- Passive microwave sensors, in concert with other sensors and improved assimilation and modeling techniques, have considerably extended the nowcast and forecast capabilities of operational NOAA and DoD severe weather systems.

- Further significant improvements will result from the NPOESS assets to be launched later this decade.


Count on
NPOESS
National Polar-orbiting Operational
Environmental Satellite System