# The Geosynchronous Microwave (GEM) Sounder/Imager


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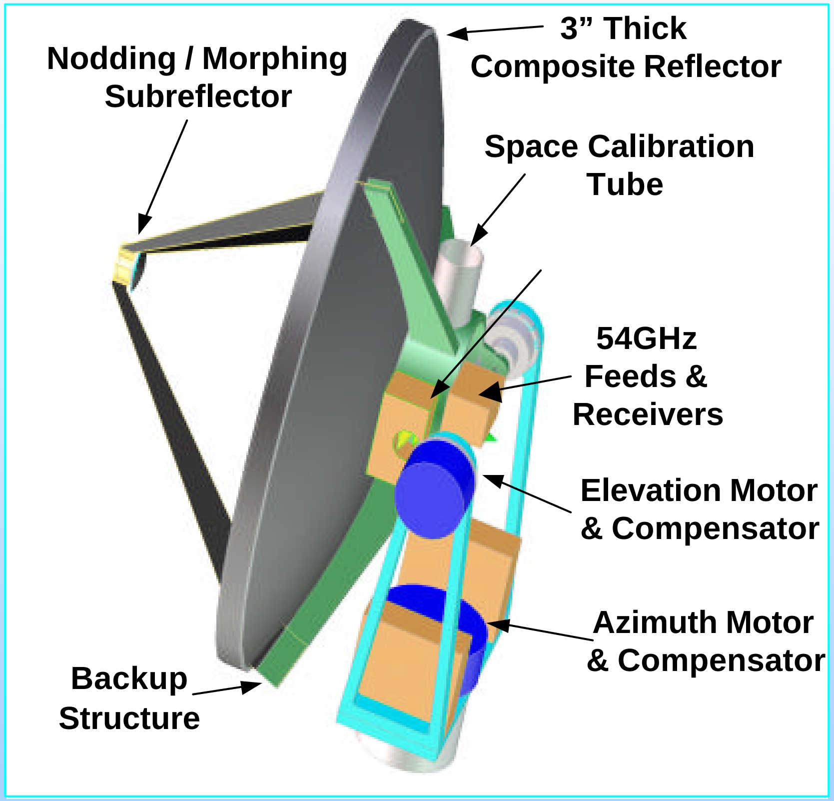
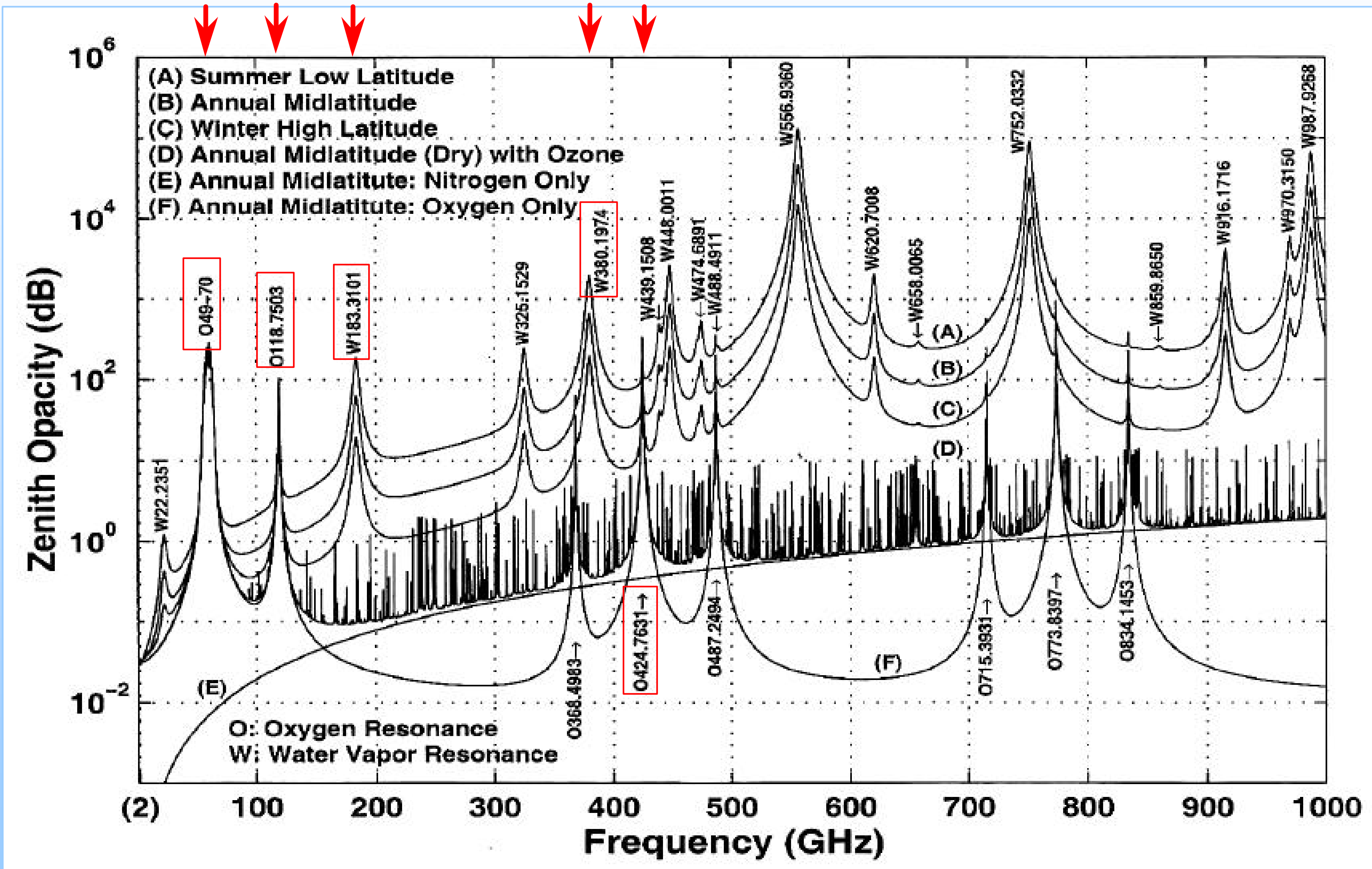
# GMSWG* Concept Summary

- Baseline system using 54, 118, 183, 380, and 424 GHz with 2-meter aperture.
- ~16 km equatorial resolution (11 km using oversampling) above 2-5 km altitude at highest frequency channels.
- The 380 and 424 GHz channels selected to map precipitation through most optically opaque clouds at sub-hourly intervals.
- Temperature and humidity sounding channels penetrate clouds sufficiently to drive NWP models with ~hourly data.
- Estimated 2002 costs: $31M non-recurring plus ~$28M/unit.

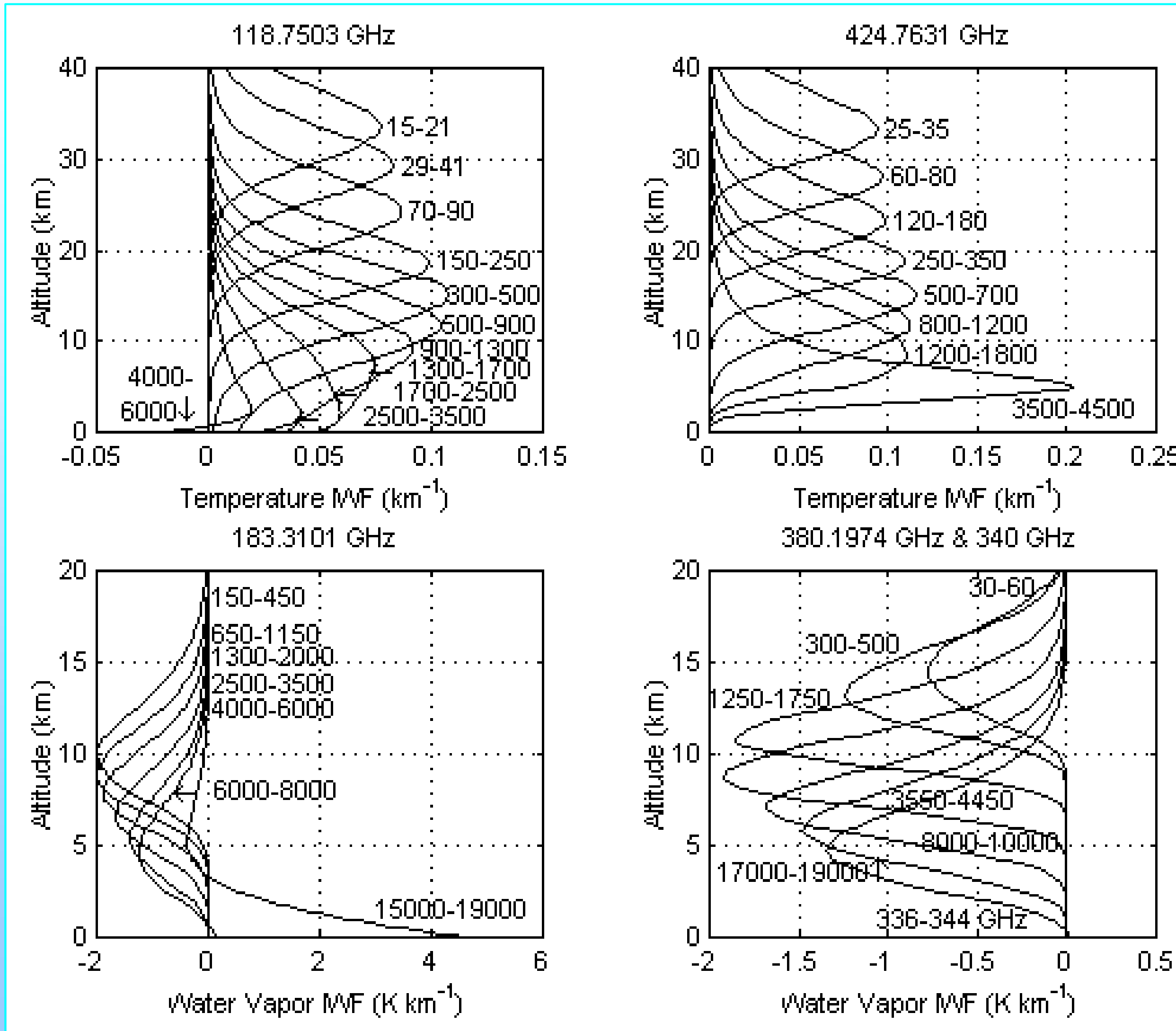


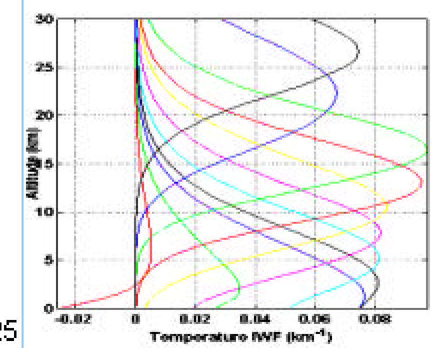

* Geosynchronous Microwave Sounder Working Group, Chair: D.H. Staelin (MIT)

# GEM Spectral Selection



# GEM Vertical Response

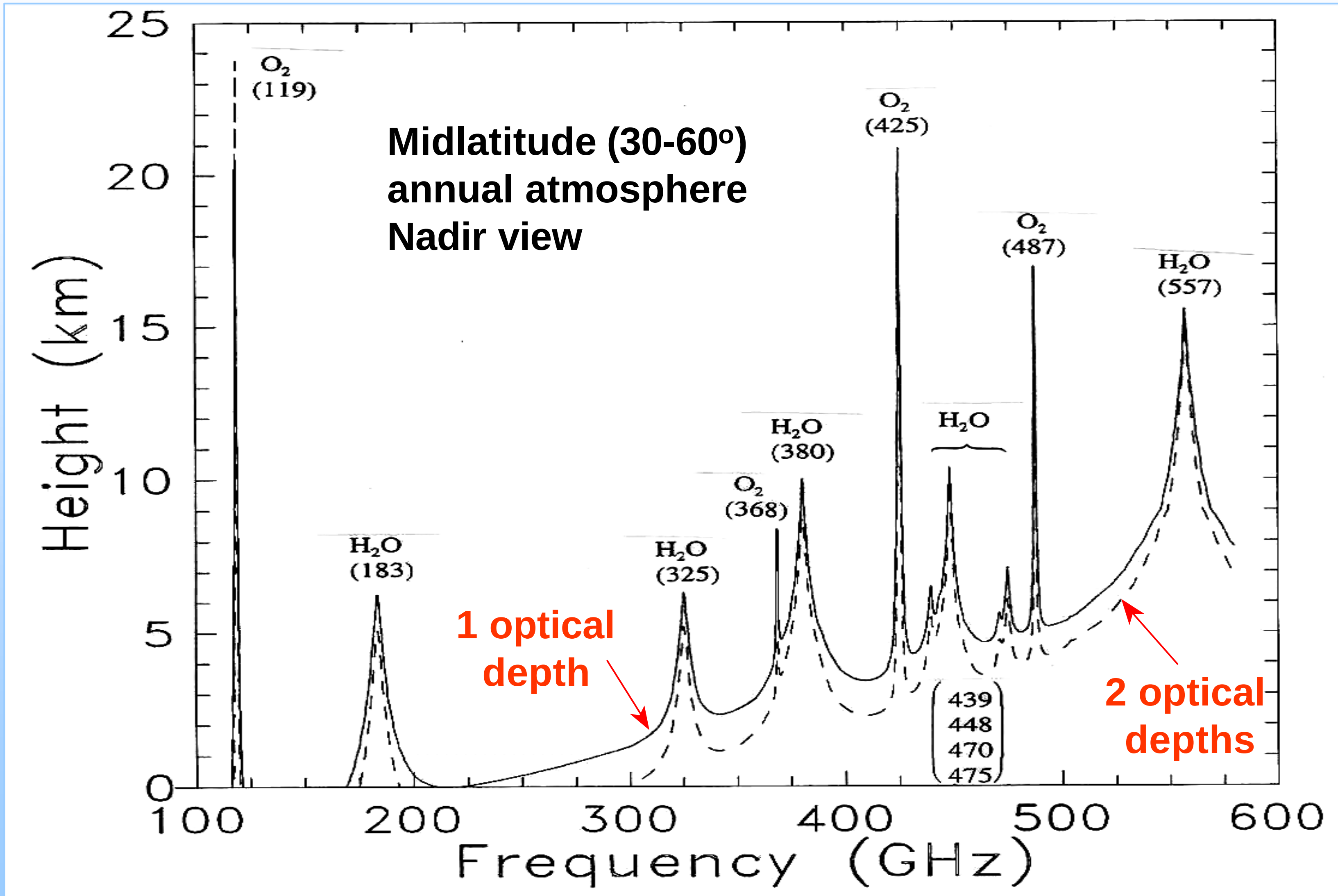



AMSU
5-MM

Klein & Gasiewski, JGR-ATM, July 2000.

# GEM Probing Depths

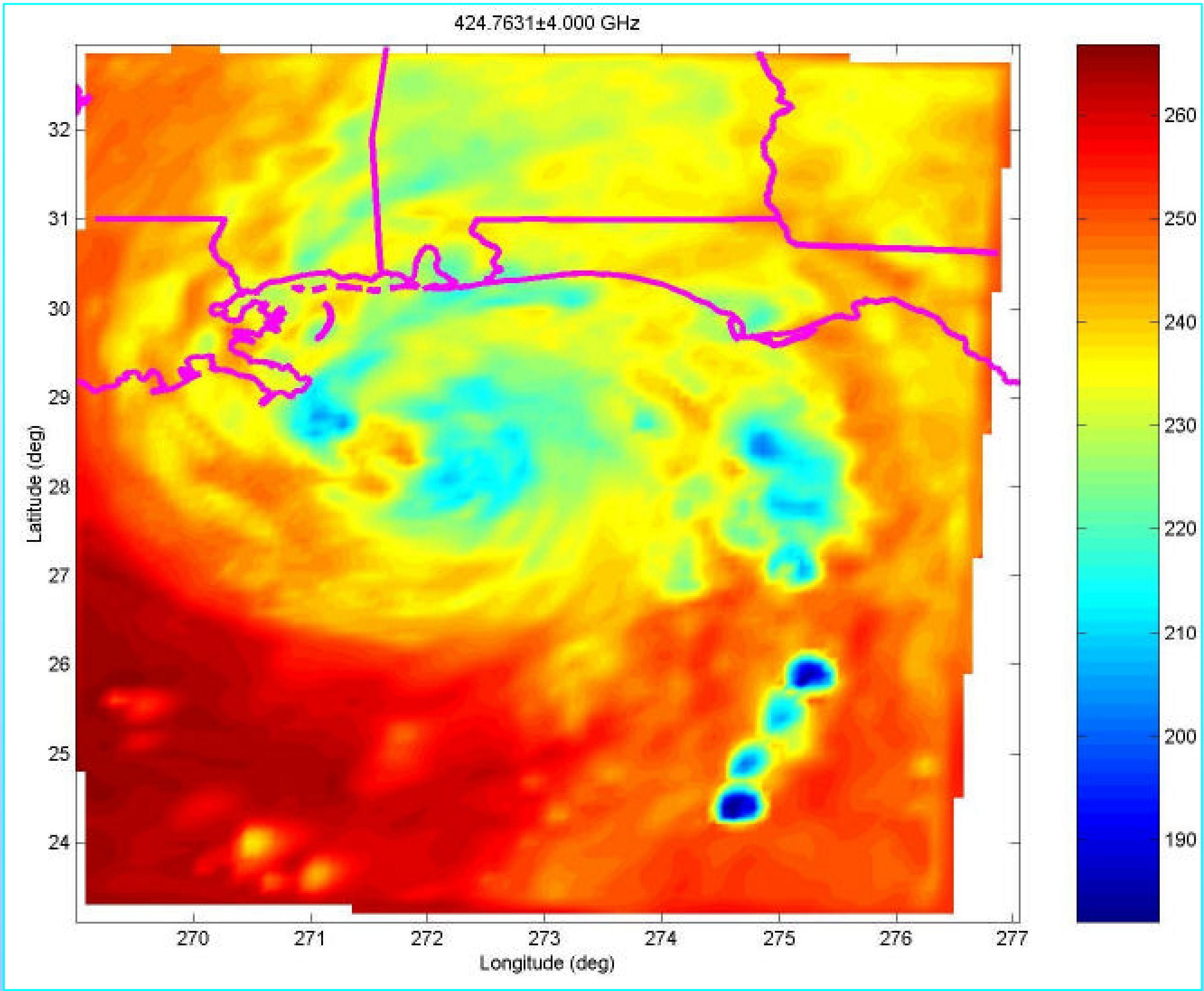


# GEM Spatial Resolution

| Frequency (GHz) | | Aperture size (m) 0.1 | 0.25 | 0.5 | 1 | 1.5 | 2 | 4.4 | 8 | 15 | 30 | Tolerance (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6.8 | W | 19611.0 | 7844.4 | 3922.2 | 1961.1 | 1307.4 | 980.5 | 445.7 | 245.1 | 130.7 | 65.4 | 1.764 |
| 10.7 | W | 12463.1 | 4985.2 | 2492.6 | 1246.3 | 830.9 | 623.2 | 283.3 | 155.8 | 83.1 | 41.5 | 1.121 |
| 18.7 | W | 7131.3 | 2852.5 | 1426.3 | 713.1 | 475.4 | 356.6 | 162.1 | 89.1 | 47.5 | 23.8 | 0.641 |
| 37.0 | W | 3604.2 | 1441.7 | 720.8 | 360.4 | 240.3 | 180.2 | 81.9 | 45.1 | 24.0 | 12.0 | 0.324 |
| 56.0 | O2 | 2381.3 | 952.5 | 476.3 | 238.1 | 158.8 | 119.1 | 54.1 | 29.8 | 15.9 | 7.9 | 0.214 |
| 89.0 | W | 1498.4 | 599.3 | 299.7 | 149.8 | 99.9 | 74.9 | 34.1 | 18.7 | 10.0 | 5.0 | 0.135 |
| 118.8 | O2 | 1123.0 | 449.2 | 224.6 | 112.3 | 74.9 | 56.1 | 25.5 | 14.0 | 7.5 | 3.7 | 0.101 |
| 166.0 | W | 803.3 | 321.3 | 160.7 | 80.3 | 53.6 | 40.2 | 18.3 | 10.0 | 5.4 | 2.7 | 0.072 |
| 183.3 | H2O | 727.5 | 291.0 | 145.5 | 72.8 | 48.5 | 36.4 | 16.5 | 9.1 | 4.9 | 2.4 | 0.065 |
| 220.0 | W | 606.2 | 242.5 | 121.2 | 60.6 | 40.4 | 30.3 | 13.8 | 7.6 | 4.0 | 2.0 | 0.055 |
| 325.1 | H2O | 410.2 | 164.1 | 82.0 | 41.0 | 27.3 | 20.5 | 9.3 | 5.1 | 2.7 | 1.4 | 0.037 |
| 340.0 | W | 392.2 | 156.9 | 78.4 | 39.2 | 26.1 | 19.6 | 8.9 | 4.9 | 2.6 | 1.3 | 0.035 |
| 380.2 | H2O | 350.7 | 140.3 | 70.1 | 35.1 | 23.4 | 17.5 | 8.0 | 4.4 | 2.3 | 1.2 | 0.032 |
| 424.8 | O2 | 313.9 | 125.6 | 62.8 | 31.4 | 20.9 | 15.7 | 7.1 | 3.9 | 2.1 | 1.0 | 0.028 |
| 448.0 | H2O | 297.7 | 119.1 | 59.5 | 29.8 | 19.8 | 14.9 | 6.8 | 3.7 | 2.0 | 1.0 | 0.027 |
| 556.9 | H2O | 239.5 | 95.8 | 47.9 | 23.9 | 16.0 | 12.0 | 5.4 | 3.0 | 1.6 | 0.8 | 0.022 |
| 620.0 | H2O | 215.1 | 86.0 | 43.0 | 21.5 | 14.3 | 10.8 | 4.9 | 2.7 | 1.4 | 0.7 | 0.019 |
| 752.0 | H2O | 177.3 | 70.9 | 35.5 | 17.7 | 11.8 | 8.9 | 4.0 | 2.2 | 1.2 | 0.6 | 0.016 |
| 916.2 | H2O | 145.6 | 58.2 | 29.1 | 14.6 | 9.7 | 7.3 | 3.3 | 1.8 | 1.0 | 0.5 | 0.013 |
| 987.9 | H2O | 135.0 | 54.0 | 27.0 | 13.5 | 9.0 | 6.7 | 3.1 | 1.7 | 0.9 | 0.4 | 0.012 |

- 3-dB best resolution degrades by ~1.3x to ~21 km at 50º latitude.
- Oversampling by ~2x above Nyquist expected to recover ~30-40% of this lost resolution for high SNR cases.

# GEM Simulated Imagery




**MM5/Reisner 5-phase simulation of Hurricane Opal, 1995**

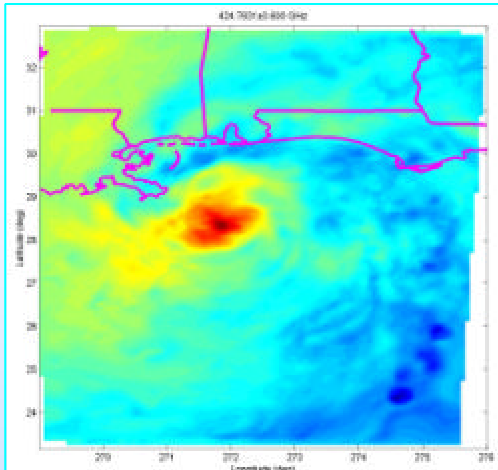
Nested 5-km inner grid with iterative multi-stream scattering-based RT model

424.763+/-4.0 GHz channel

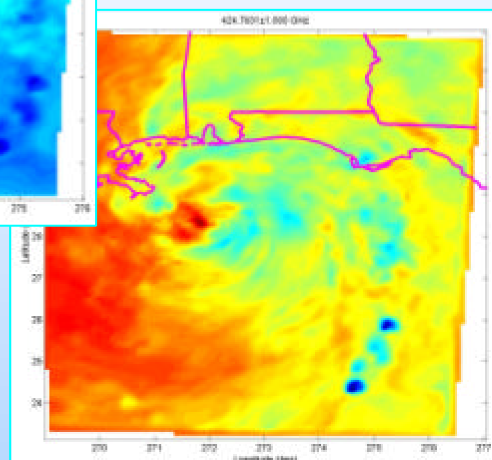
# GEM Simulated Imagery

**Opaque**

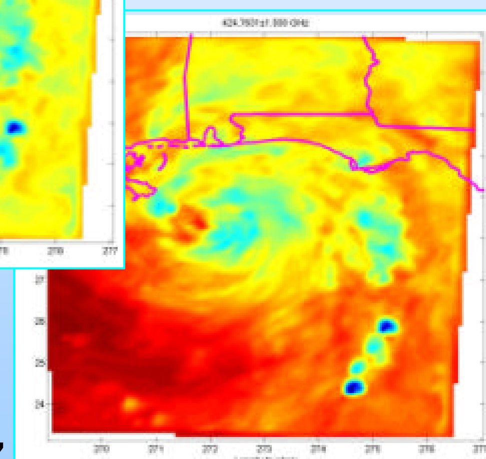
***Hurricane Opal 1995***



**+/-0.6 GHz**

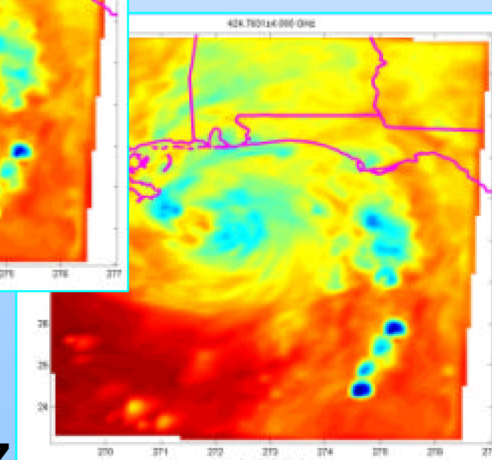


**+/-1.0 GHz**



**+/-1.5 GHz**

**Transparent**

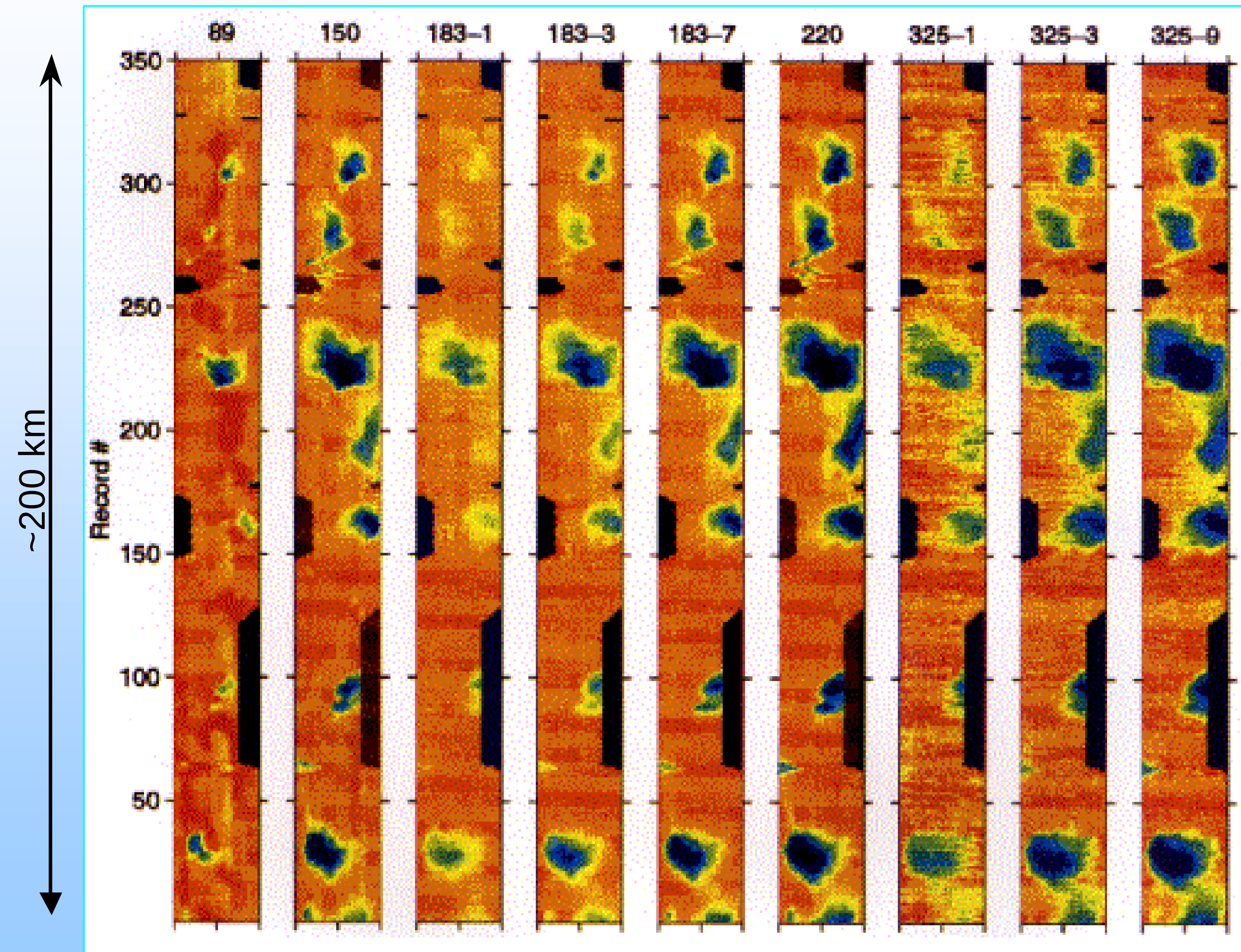


**424.763+/-4.0 GHz**

***MM5/MRT***

***Reisner 5-phase***

# SMMW Aircraft Imagery

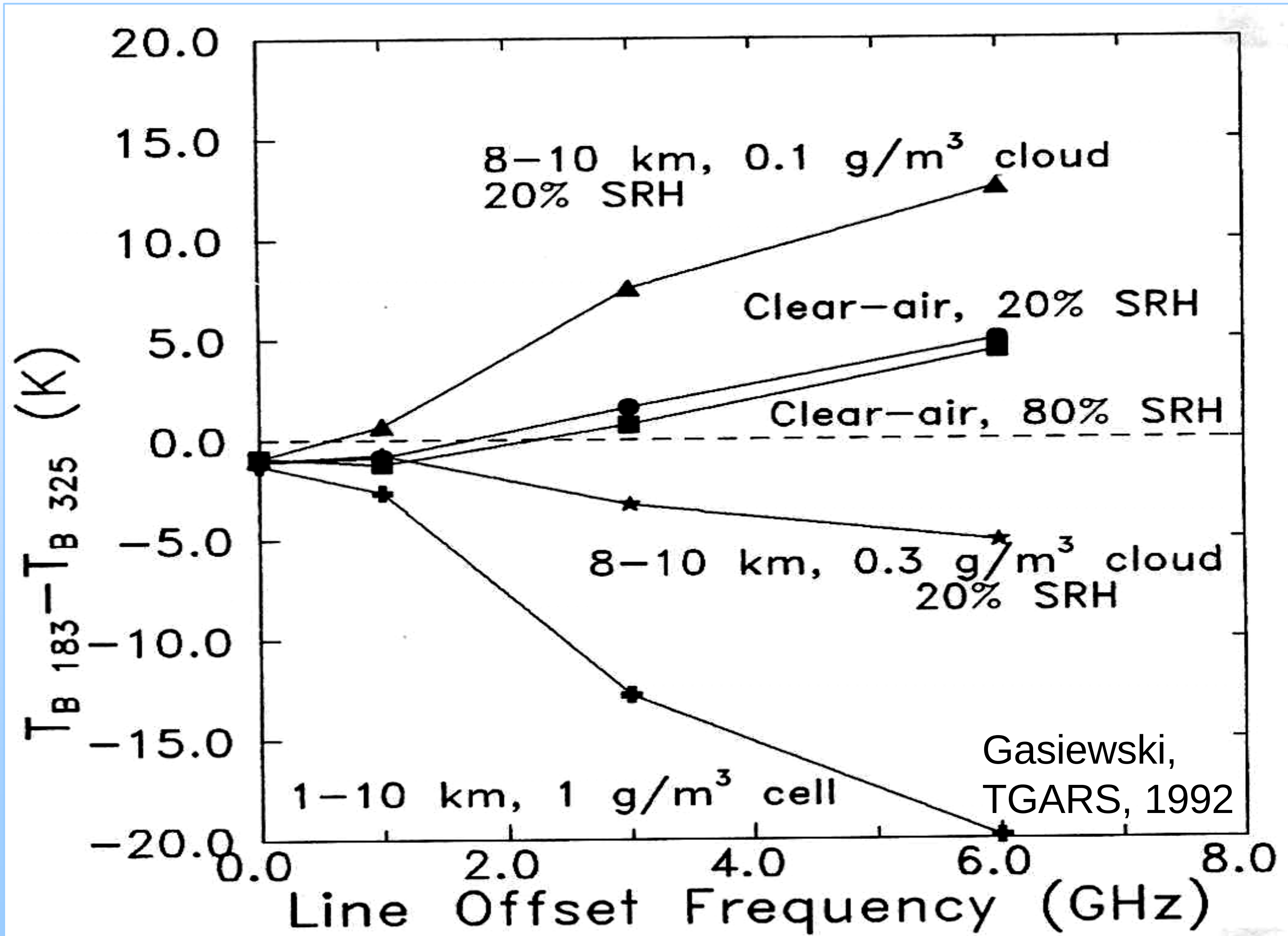



**Maritime convection observed at 20 km altitude.**

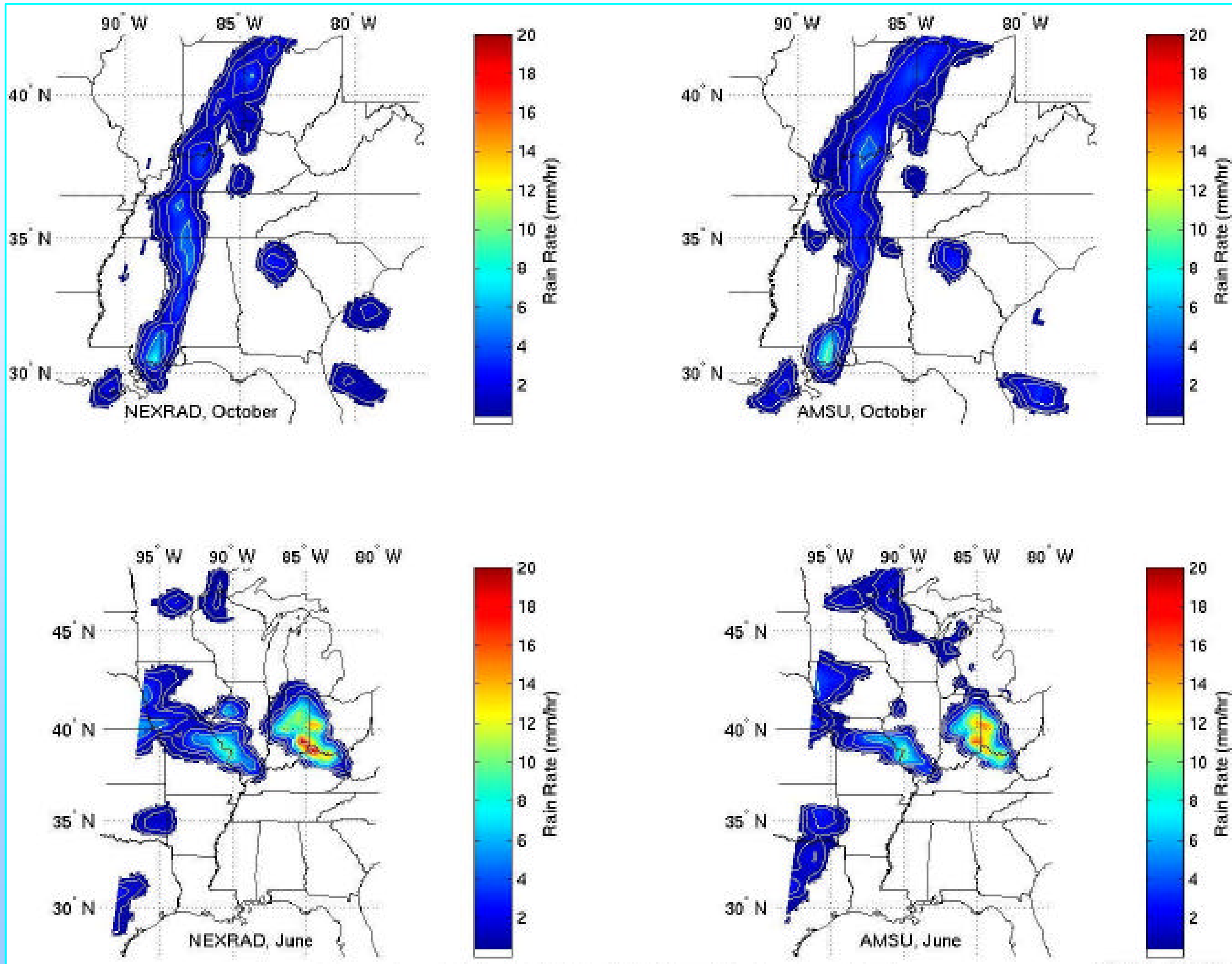
***Many cells missed at 89 GHz!***

Gasiewski, et al, Proc. 1994 IGARSS, Pasadena, USA.

# Similar Channel (183 / 325 GHz) Response to Clouds



# AMSU Precipitation Retrievals

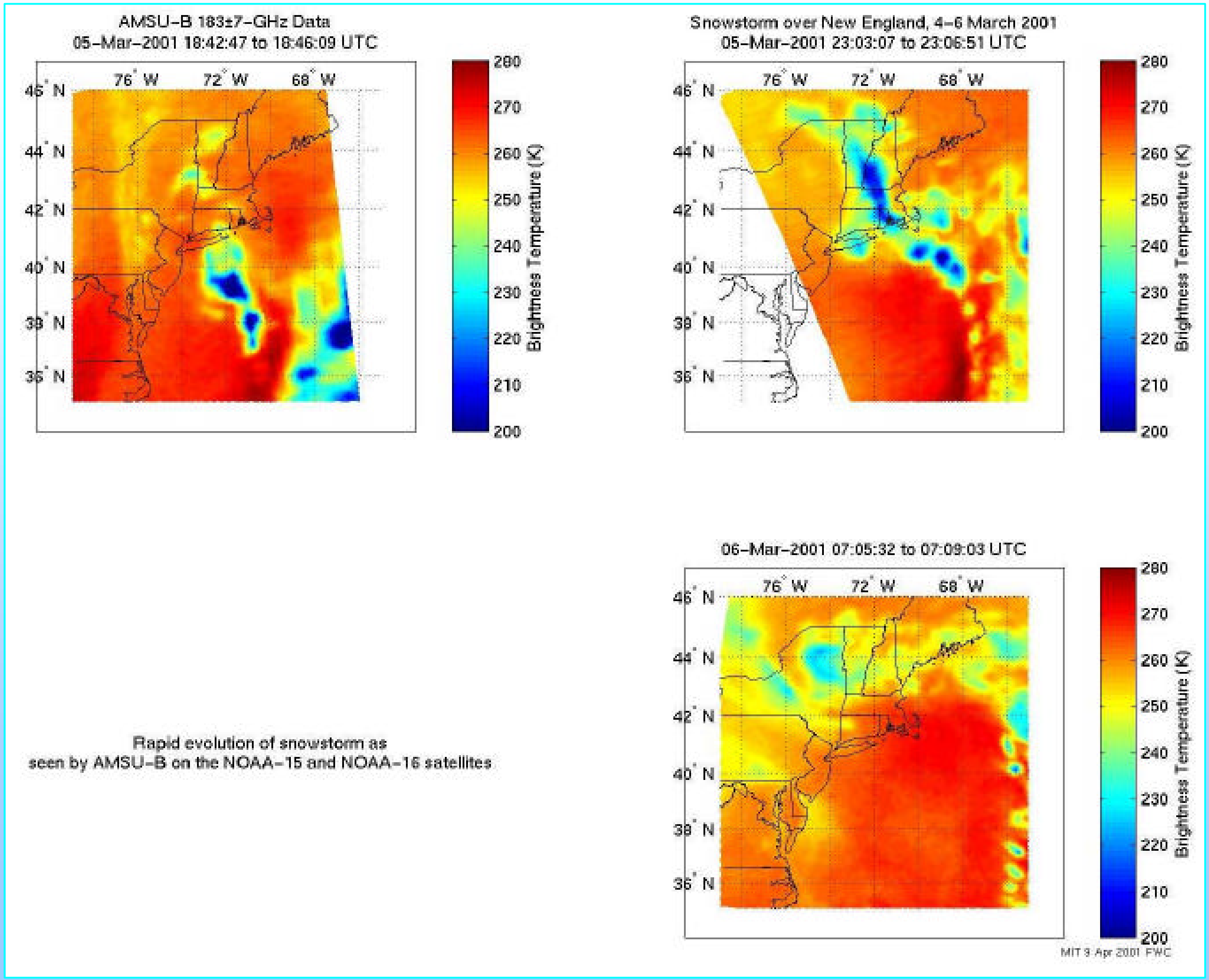



Comparison of 50–km NEXRAD and AMSU precipitation–rate retrievals
for 11 June 1999, 13:37 UTC, and 7 Oct 1999, 13:43 UTC

**NOAA-15 AMSU with neural net retrieval, 50 km resolution**

Staelin & Chen, *IEEE TGARS,* September 2000.

# Rapid Precipitation Evolution




**March 5-6 2001 snowstorm observed using AMSU-B**

**4 and 8 hr time gaps**

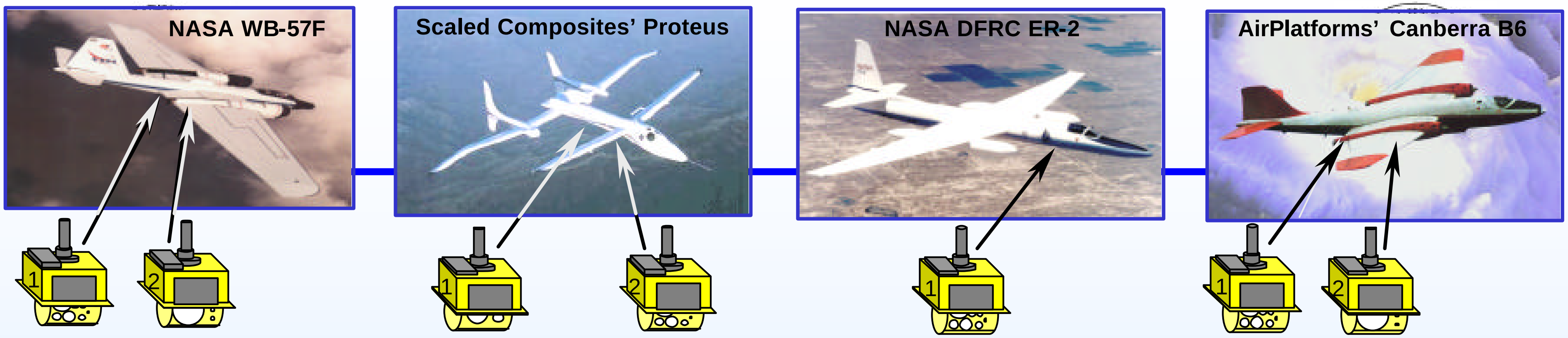
***Major evolution can occur on short time scales!***

# GEM Cost/Benefit for GPM

| #Additional Drones | Repeat Time | Cost ($M) | |
|---|---|---|---|
| 1 | 2.4 (hrs) | 40 | |
| 2 | 2.0 | 80 | Single HS cost break-point |
| 3 | 1.7 | 120 | |
| 4 | 1.5 | 160 | |
| 5 | 1.3 | 200 | |
| 6 | 1.2 | 240 | Global cost break-point |
| 7 | 1.1 | 280 | |
| 8 | 1.0 | 320 | |
| 9 | 55 (mins) | 360 | |
| 10 | 51 | 400 | |
| 15 | 38 | 600 | |
| 20 | 30 | 800 | |
| 25 | 25 | 1000 | |
| 30 | 21 | 1200 | |
| 35 | 18 | 1400 | |
| 40 | 16 | 1600 | |

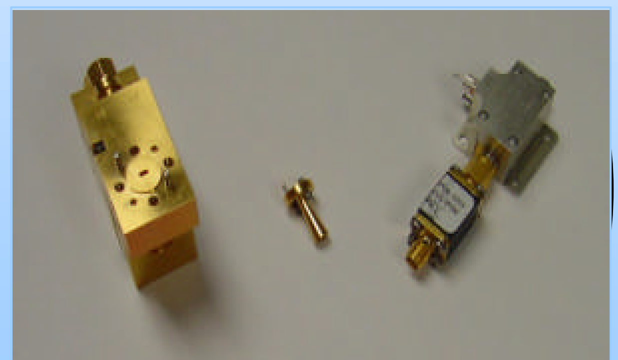
**Assumptions:**

GEM recuring cost of $30M + $60M bus & launch = $90M
TMI-class passive drone cost of $10M + $30M bus+launch = $40M
3 NPOESS + GPM PR as GPM baseline system – costed as fixed
3 GEMs required for global tropical/midlatitude coverage




| | | | | |
|---|---|---|---|---|
| **PSR/CX:** | 5.82-6.15 | (v,h) | $10^o$ | |
| *1999 (C)* | 6.32-6.65 | (v,h) | $10^o$ | |
| | 6.75-7.10 | (v,h,U,V) | $10^o$ | |
| | 7.15-7.50 | (v,h) | $10^o$ | |
| *2002 (CX)* | 10.6-10.8 | (v,h,U,V) | $7^o$ | |
| | 10.68-10.70 | (v,h) | $7^o$ | |
| | 9.6-11.5 um IR | (v+h) | $7^o$ | |

| | | | | |
|---|---|---|---|---|
| **PSR/S:** | 18.6-18.8 | (v,h,U,V) | $8^o$ | |
| *~2002* | 21.4-21.7 | (v,h) | $7^o$ | $H_2O$ |
| | 36-38 | (v,h,U,V) | $7^o$ | |
| | 52.6-57.5x7 | (v) | $3.5^o$ | $O_2$ |
| | 86-92 | (v,h,U) | $3.5^o$ | |
| | 118.750 x 7 | (v) | $3.5^o$ | $O_2$ |
| | 183.310 x 7 | (v) | $1.8^o$ | $H_2O$ |
| | 325.153 x 3 | (v) | $1.8^o$ | $H_2O$ |
| | 337-343 | (v,h,U) | $1.8^o$ | |
| | 380.197 x 5 | (v) | $1.8^o$ | $H_2O$ |
| | 424.763 x 5 | (v) | $3.5^o$ | $O_2$ |
| | 496-504 | (v,h) | $1.8^o$ | |
| | 9.6-11.5 um IR | (v+h) | $1.8^o$ | |



**GEM Airborne Simulator**

*PSR Scanhead Suite*

*& Aircraft Compatibility*

# Recent U.S. GEM Proposals

- **Geostationary Microwave (GEM) Observatory** – Concept proposal to NASA/HQ in response to Instrument Incubator Program AO – Based on 2-meter antenna and channels at 54/118/183/380/424 GHz (Staelin et al, 1998).

- **EO-3 Geosynchronous Microwave (GEM) Observatory** New Millennium proposal submitted by NOAA/ETL, NASA/GSFC, MIT/LL to NASA/HQ. Based on a GEM demonstration unit with spatial resolution of 13-20 km, 2-meter antenna (Gasiewski et al, 1998).

- **GEosynchronous Microwave (GEM) Precipitation Sounder** – Phase B proposal submitted by NASA/LaRC, NOAA/ETL, MIT/LL to NASA/HQ. Focussed on antenna technology development and demonstration (Lawrence et al, 2001).

# GOMAS Proposal to ESA

- Proposal to ESA Earth Explorer Opportunity Missions: "Geostationary Observatory for Microwave Atmospheric Sounding" – submitted Jan 2002.
- PI: B. Bizzarri, many European and U.S. partners.
- Based on U.S. GEM baseline design but with larger antenna (3m) to compensate for latitudinal resolution loss (antenna cost ~$d^{2.5}$).
- 3-year science demo phase, 5-yr design lifetime, 10 km best resolution w/o deconvolution, 15 minute best update. Launch >2006.
- Cost: 160 M€ total, including ground segment.

# GEM Summary

- GEM will be a cost-effective AMSU-class sounder/imager but with time-resolved observations of precipitation – complementary to ABS, GIFTS.
- Convective PR anticipated to be measurable over both land and water along with sounding products within clouds, ~15 km midlatitude spatial resolution.
- GEM concept study completed, antenna and scanning technology under development (MIT/LL)
- Aircraft demonstrations under development (NOAA, MIT)
- RT model and retrieval simulations in progress (NOAA)
- European GOMAS proposal submitted to ESA (Jan 2002)
- Demonstration of operational system possible within GPM and NPOESS timeframe.  GOES R+ 2010+(?)