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National Environmental Satellite, Data, and Information Service

High Frequency Algorithm Development for Improved Precipitation Estimates Over Land*

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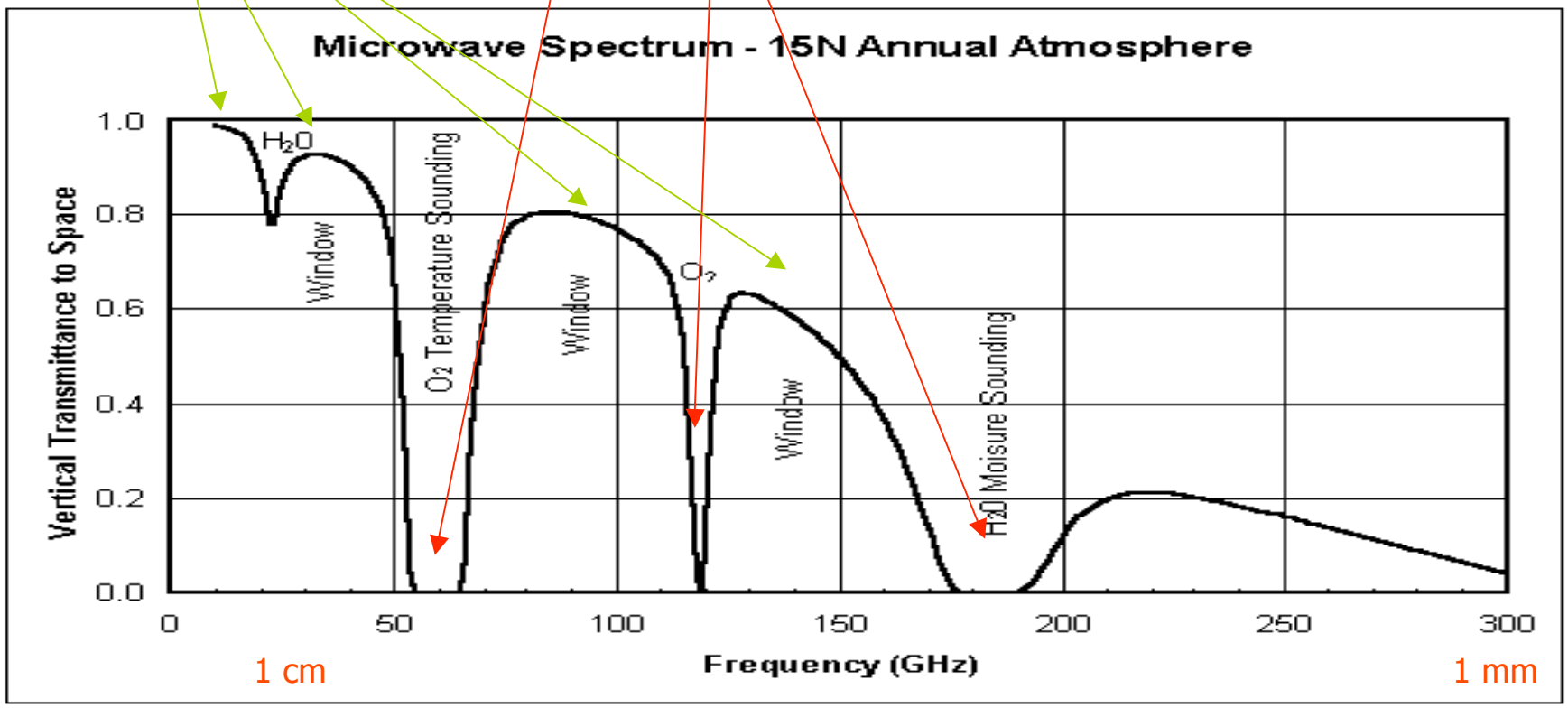
Outline

- Physical basis –
  - Absorption spectrum
  - Advantages of higher frequencies
  - AMSU Operational Algorithm and performance
- Future Use of AMSU and SSMIS; what do we gain?
  - Snowfall rates
  - More measurements/help constrain retrievals
  - Improved temporal sampling
  - Enhancements via Unified Retrievals

"Imaging Channels" "Sounding Channels"



Lower frequencies:

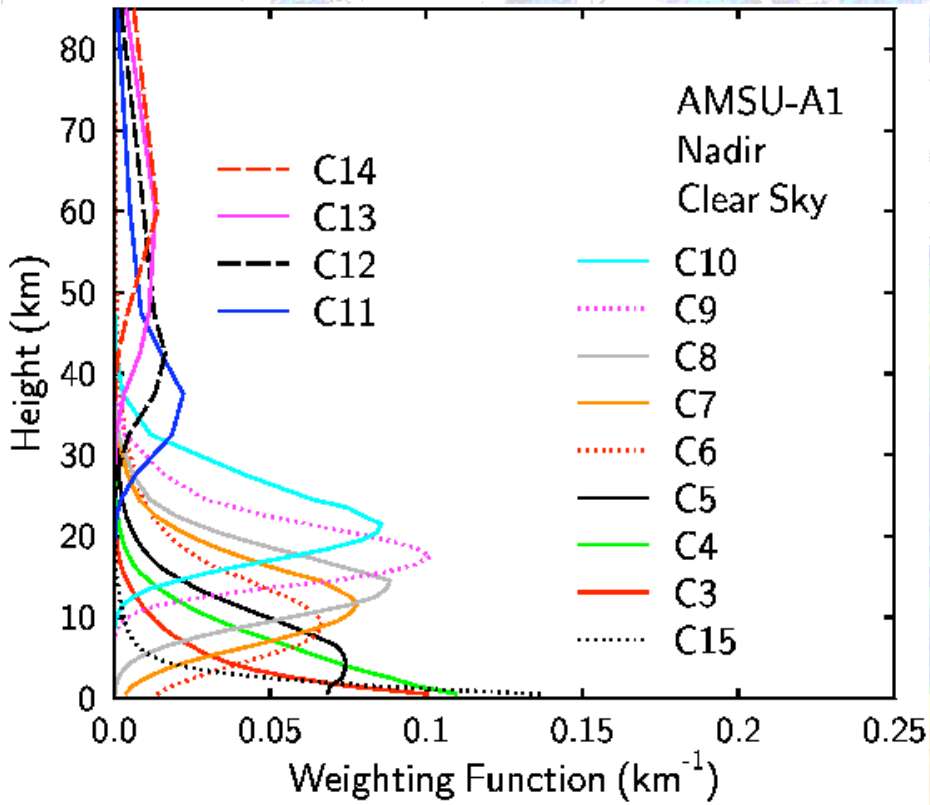
- 10, 18, 37, 85 GHz
- Cleaner windows
- Need estimate of _
- Large ice
- SSM/I, AMSR, TMI

Higher frequencies:

- 50-60, 183 GHz
- Dirty windows
- Estimate of _ less important
- Smaller ice
- SSMIS, AMSU-B, MHS

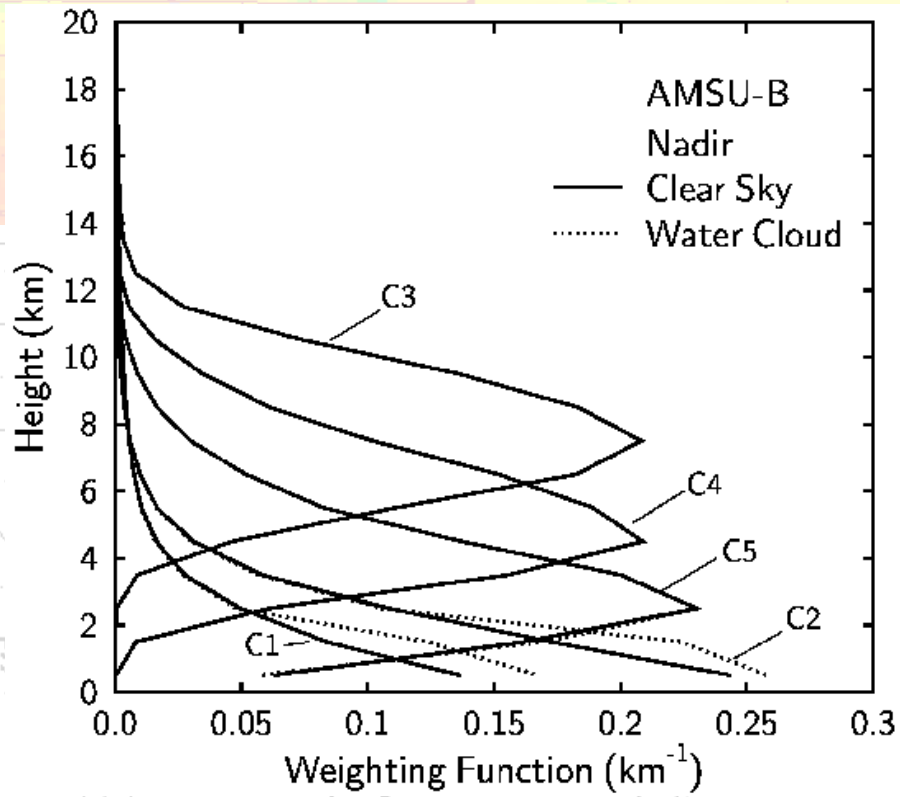
Profiling Capabilities – Improve Precipitation Retrieval

50 – 60 GHz O_2 bands



Atmospheric Temperature
Freezing level and cloud base height
Air Mass Classification

183 GHz H_2O bands



Atmospheric Moisture
Sensitive to scattering by precipitation
Convective vs. stratiform

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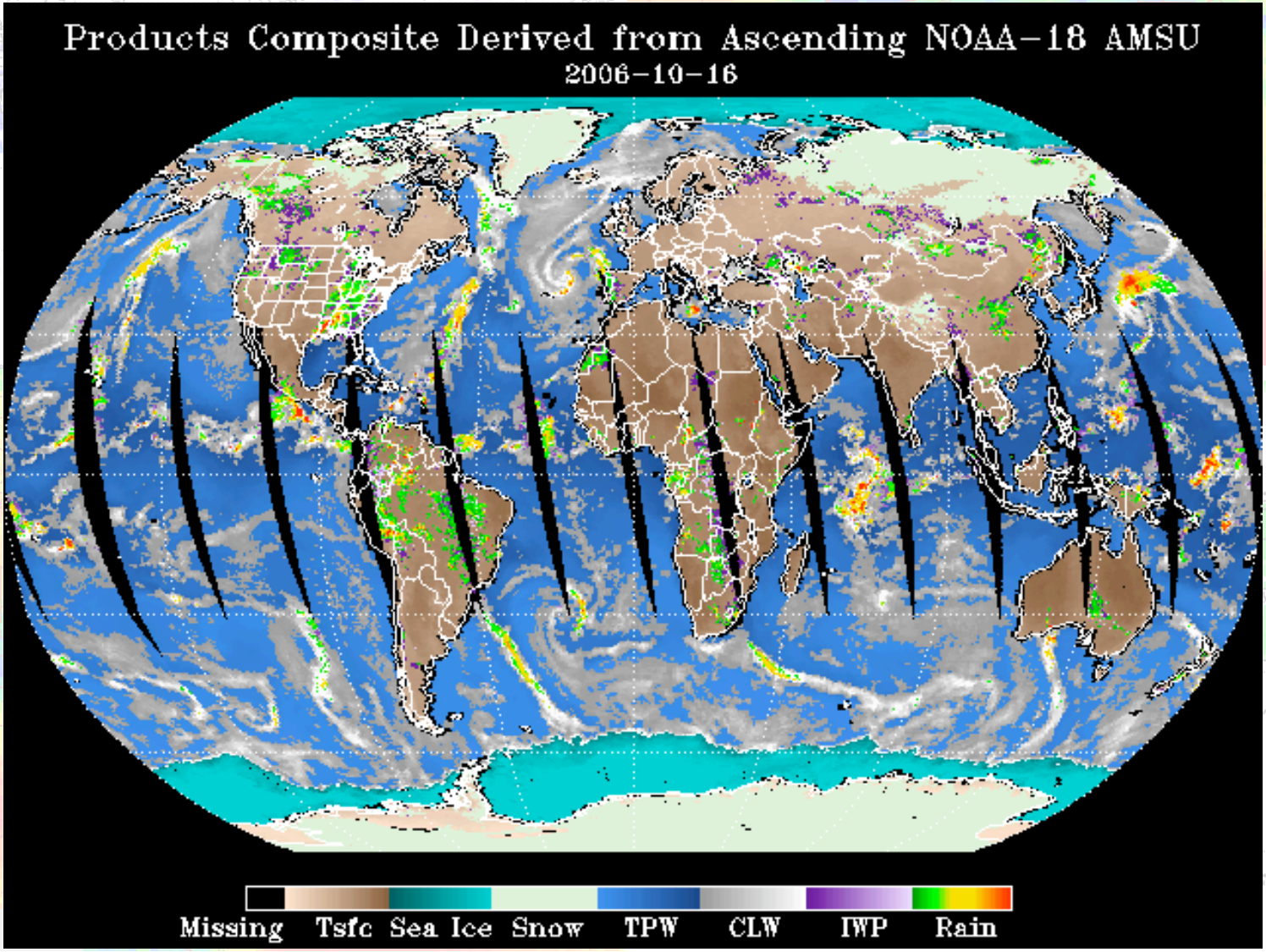
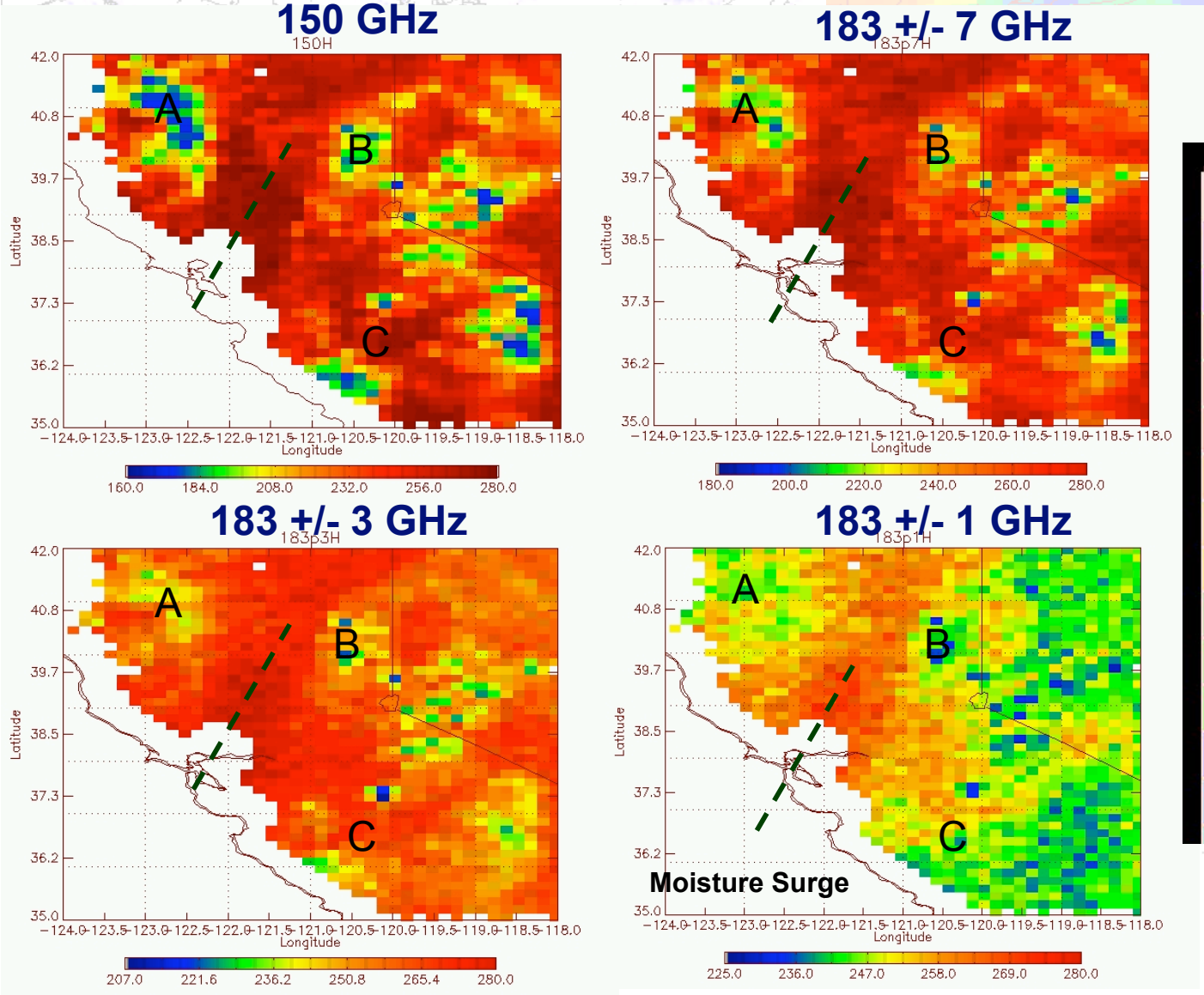
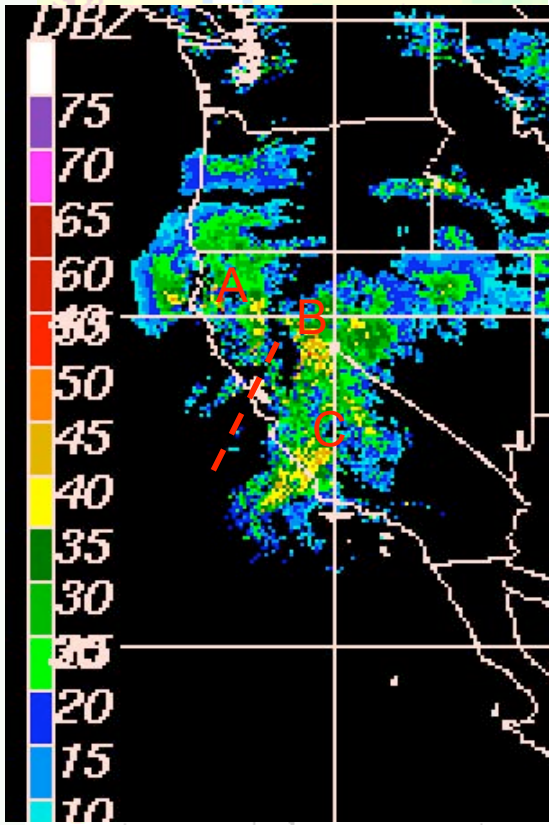
NOAA Produces Operational Products from AMSU



SSMIS Precipitation Signature Over Land – Winter Storm



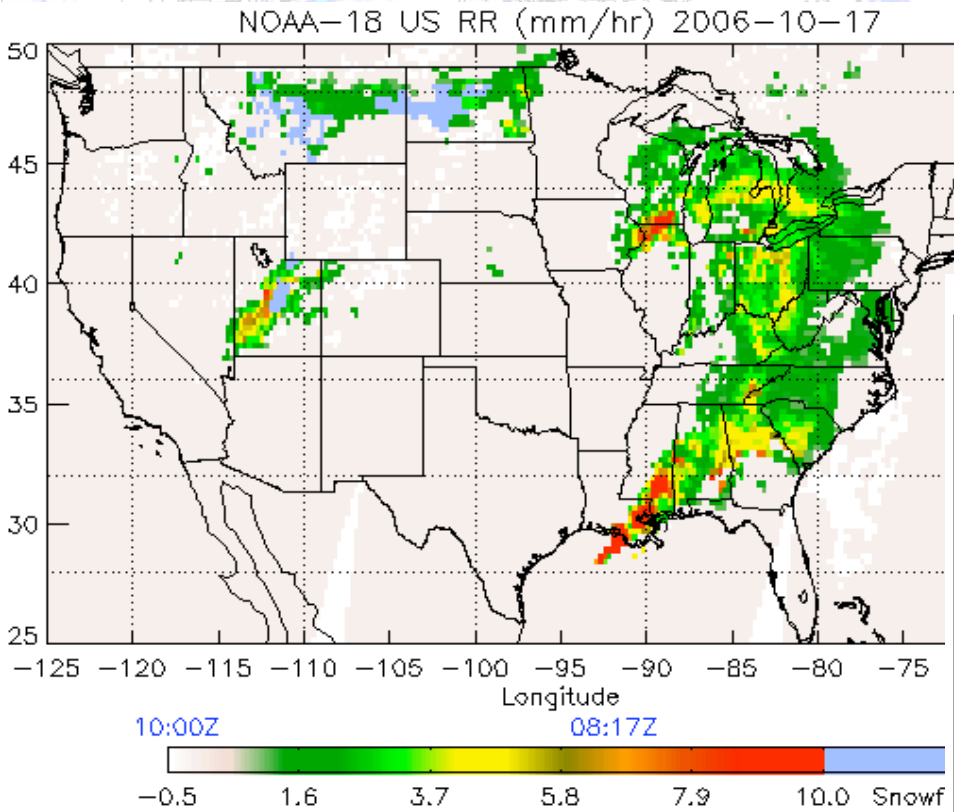
NEXRAD
30 Dec 2005

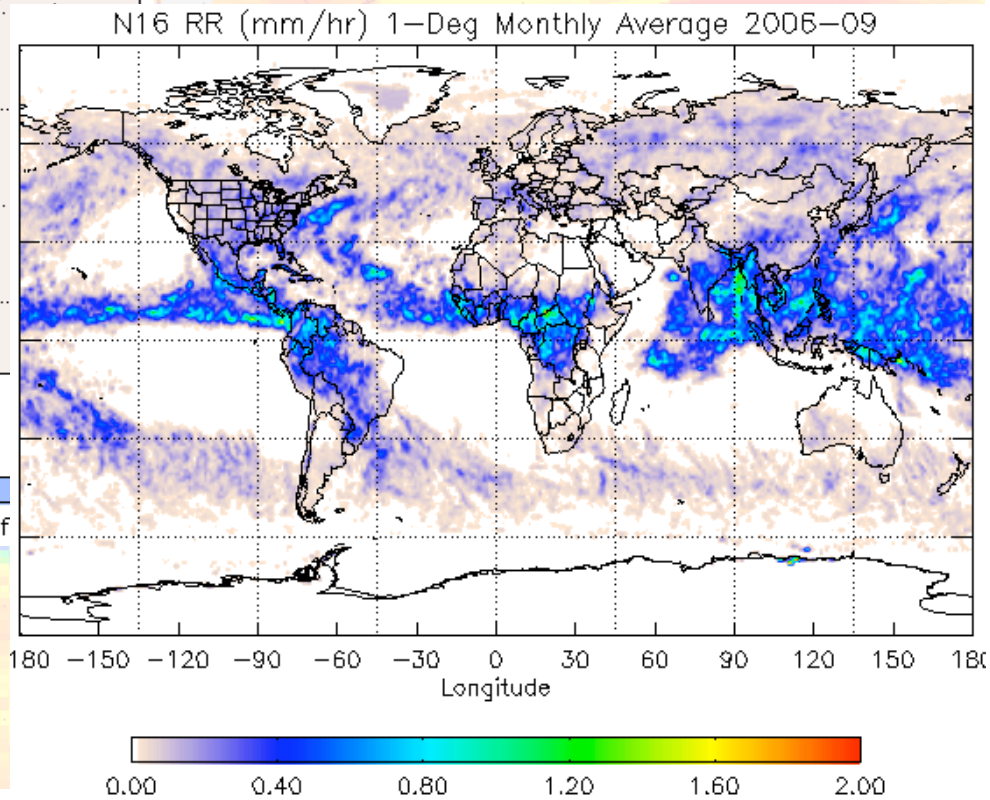


Characteristics of the NOAA AMSU Rain Rate Algorithm

- Physical retrieval of IWP and D_e – 89 & 150 GHz
  - Uses other window and sounding channels
    - Derive parameters for retrieval & filters for ambiguous surfaces
  - Use other AMSU derived products
    - TPW, CLW, Snow, Sea-Ice
- IWP to RR based
  - $RR = A_0 + A_1 * IWP + A_2 * IWP^2$
  - A's vary depending on strength of convection (183 GHz)
- 50 GHz bands used to identify snowfall over land
- 50 & 183 GHz bands used to identify rain along coast

Examples of AMSU Retrievals





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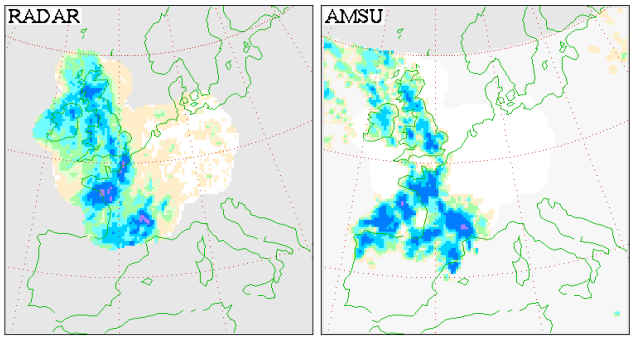
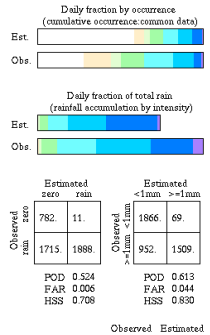
Continuous monitoring - IPWG validation sites





Observed rain	Estimated zero	Estimated rain
zero	782.	11.
rain	1715.	1888.

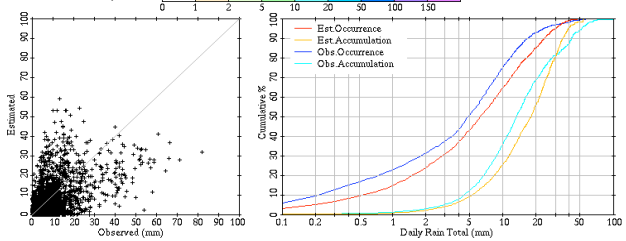
POD 0.524
FAR 0.006
HSS 0.708

Observed >=1mm	Estimated <1mm	Estimated >=1mm
<1mm	1866.	69.
>=1mm	952.	1509.

POD 0.613
FAR 0.044
HSS 0.830

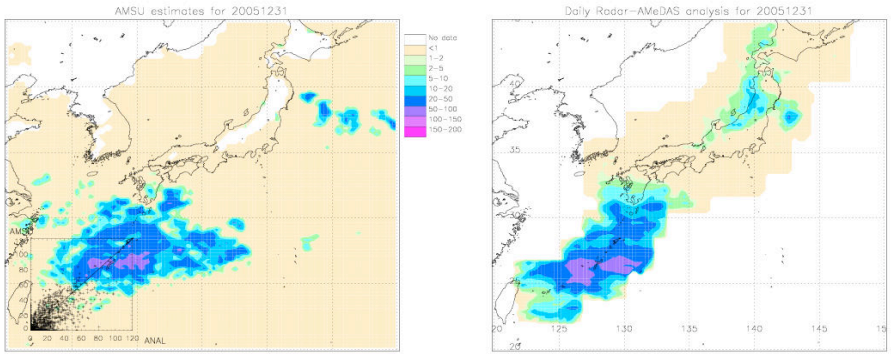
	Observed	Estimated
Number of points	4396.	4396.
Raining points	3603.	1899.
Raining points >1mm	2460.	1578.
Mean rain total	5.42	4.02
Conditional rain total	6.61	9.30
Maximum rain total	110.45	59.12

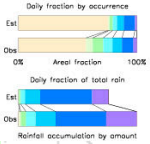
Bias	-1.40
Ratio	0.741
RMSE	7.3
Correlation	0.618
#samples	4396.



24h to 24Z
20061011

C.Kidd'06



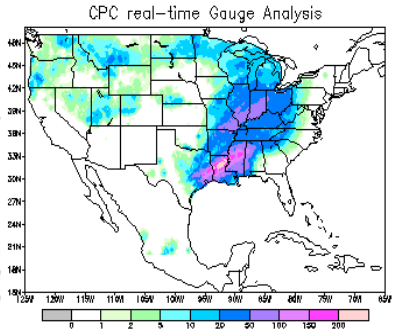


Observed	AMSU <1	AMSU ≥1
<1	2033	80
≥1	768	813

Verification statistics for 20051231 n=3694 Verif. grid=0.25° Units=mm/day

	Analysed	AMSU
# gridpoints raining	1581	893
Average rain	6.8	5.2
Conditional rain	15.9	21.5
Rain volume (mm*km²x10⁶)	16.4	12.5
Maximum rain	101.1	83.4

Mean abs error = 4.1
RMS error = 8.5
Correlation coeff = 0.795
Frequency bias = 0.565
Probability of detection = 0.514
False alarm ratio = 0.090
Hanssen & Kuipers score = 0.476
Equitable threat score= 0.337

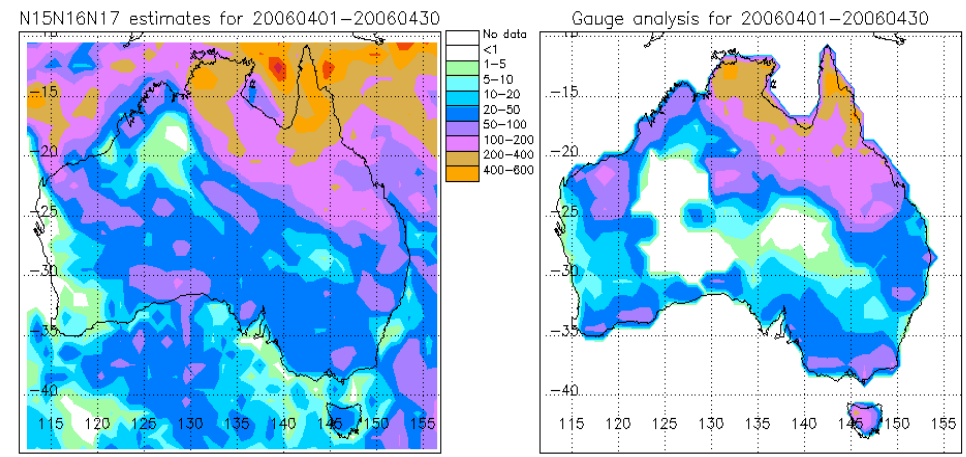


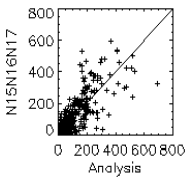
	gauge	AMSU-B	radar
Number of points:	13950.	13950.	13950.
# points w/rain:	8147.	7416.	6466.
Mean rain rate:	10.32	13.10	7.14
Cond. rain rate:	17.52	24.62	15.22
Max. rain rate:	279.84	209.30	210.37

	G-S	G-R	R-S
Correlation:	0.817	0.931	0.808
Mean Absolute Error:	7.38	4.48	8.17
RMSE (mm/day):	13.35	8.84	14.34
RMSE (normalized):	1.29	0.86	2.00
Probability of Detection:	0.769	0.705	0.799
False Alarm Ratio:	0.155	0.112	0.302
Bias Ratio (rain:no rain):	0.910	0.794	1.145
Heidke Skill Score:	0.561	0.557	0.493
Hanssen-Kuipers Score:	0.572	0.580	0.498
Equitable Threat Score:	0.390	0.386	0.328

gauge	AMSU-B < 1	AMSU-B ≥ 1
< 1	4655.	1148.
≥ 1	1879.	6268.

gauge	radar < 1	radar ≥ 1
< 1	5078.	725.
≥ 1	2406.	5741.



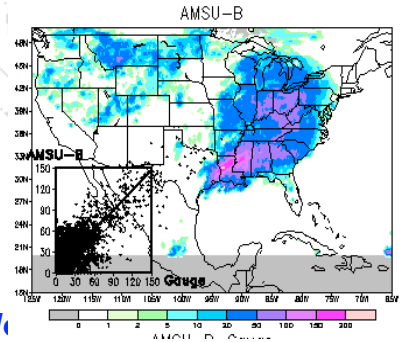


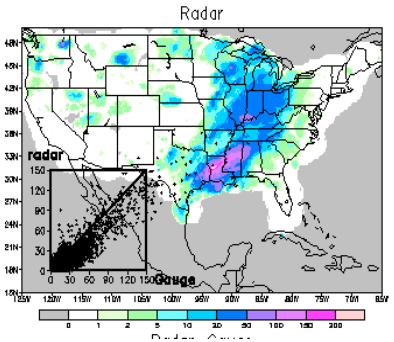
Observed	N15N16N17 <1	N15N16N17 ≥1
<1	0	18
≥1	17	567

Verification statistics for 20060401-20060430 n=602 Verif. grid=1.00° Units=mm

	Analysed	N15N16N17
# gridpoints raining	584	585
Average rain	74.9	83.9
Conditional rain rate	77.2	86.4
Rain volume (mm*km²x10⁶)	30.9	34.6
Maximum rain	692.2	594.0

Mean abs error = 39.4
RMS error = 62.2
Normalized mean abs error = 0.53
Normalized RMS error = 0.83
Area ratio = 1.002
Volume ratio = 1.121
Correlation coeff = 0.813





Strengths and Weaknesses

Surface / Instrument	Ocean	Land	Coast	Cold Surfaces	Snow over land and ocean	Snow over sea ice
"Legacy" Imager (≤90 GHz)	Direct measure of LWP and its vertical profile √	Scattering at 90 GHz	Some accounting for coast	Retrievals extremely limited	Snow over ocean possible via profiling algorithm √	Not seriously attempted
Sounder and "Advanced" Imager	Limited measure of LWP	Scattering at 150 and 183 GHz – smaller ice, minimize surface effects √	Recent upgrade using sounding channels √	Retrievals likely over temperate climate zones √	Snow over land under certain situations in temperate climate zones √	Feasibility demonstrated by other researchers √

Where do we go from here?

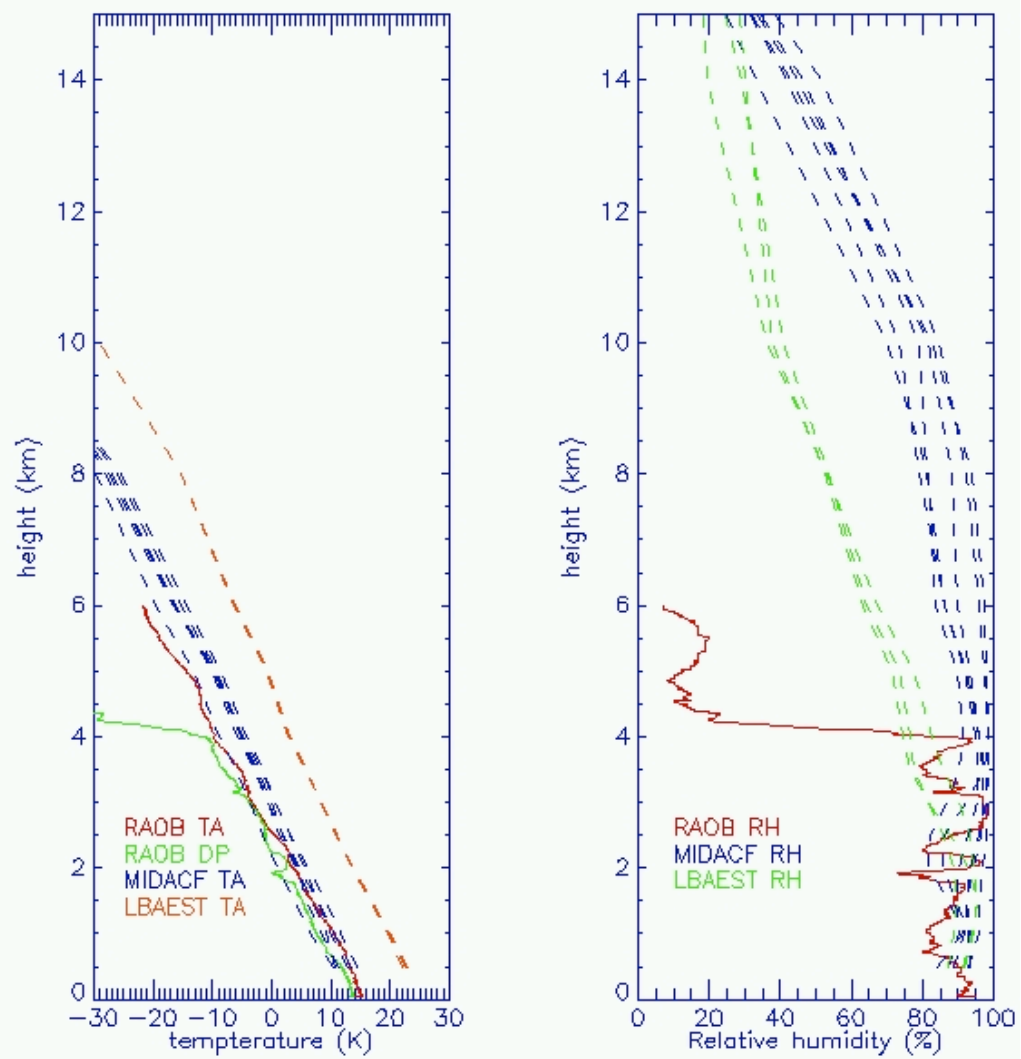
- Utilize full set of measurements to help constrain retrievals
  - Need winter season profiles!
- Adding sounders to GPM constellation
  - Achieve ≤ 3 hour sampling over land
    - NOAA/EUMETSAT → 0530, 0930, 1330 constellation
- Improved retrieval in cold season regimes
  - Expanded regions of retrievals
  - Potential for snowfall rates
- Enhancements via Unified Retrievals

Expanded Channel Bayesian Retrievals

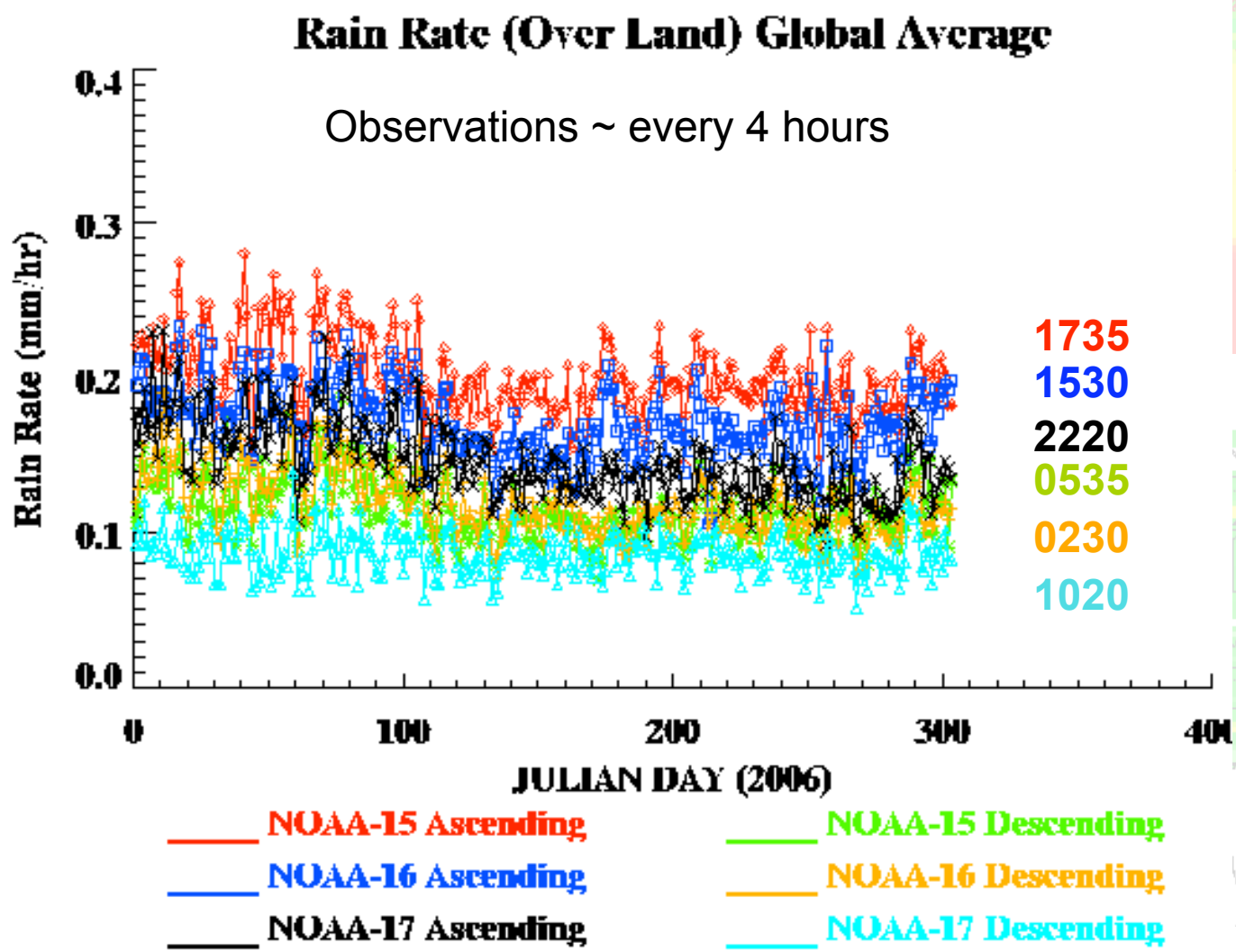
- Utilize all MW channels on POES & DMSP
  - Improve under constrained retrievals
  - Improve GPROF data base
    - Precipitation Regimes
      - Cold season land!
    - Use of temperature/moisture profiles
      - Cloud base and depth
      - Freezing level
  - Reduce surface effects by relying on opaque channels
  - Improved coastline retrievals

GPROF Database issues

- Scarcity of Land-based hydrometeor database
- Need to get out of the tropics!
  - Current databases biased towards just a few regimes
  - Scarcity of information on land, winter regimes
- Accuracy of CRM microphysical details
- Database lacks information on wide array of constellation members



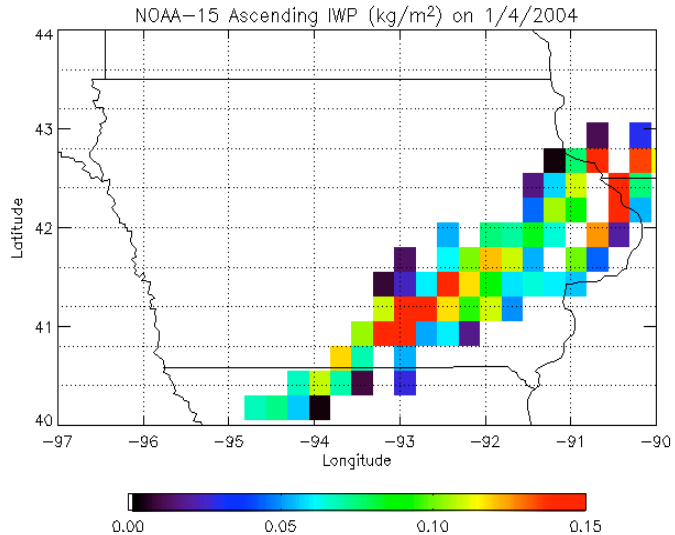
Sounders Capture the Diurnal Cycle

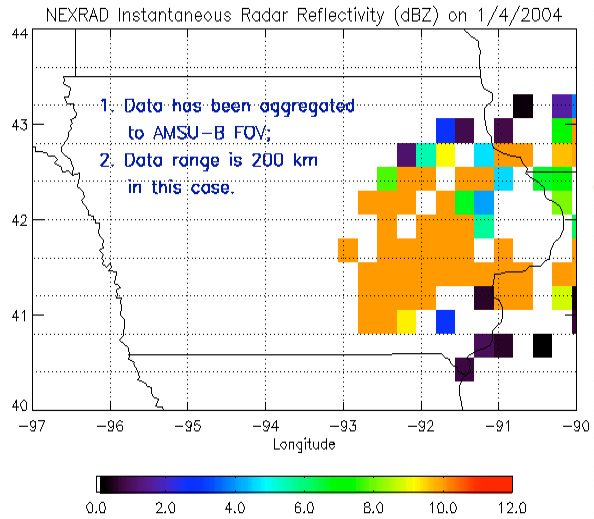


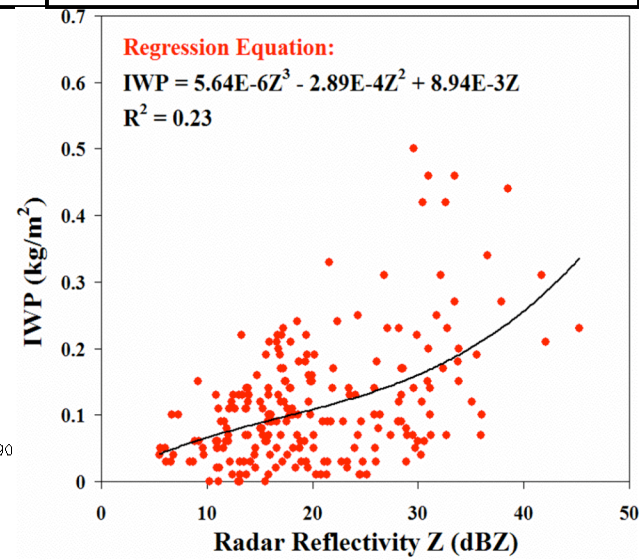
Snowfall Rate Algorithm Development

- Feasibility study - A combination of theoretical and empirical models
  - RTM to retrieve IWP under snow conditions
  - Radar tuning for IWP-Z and Z-S (previous) relationships

Retrieved AMSU IWP	NEXRAD Reflectivity	Z – IWP Relationship

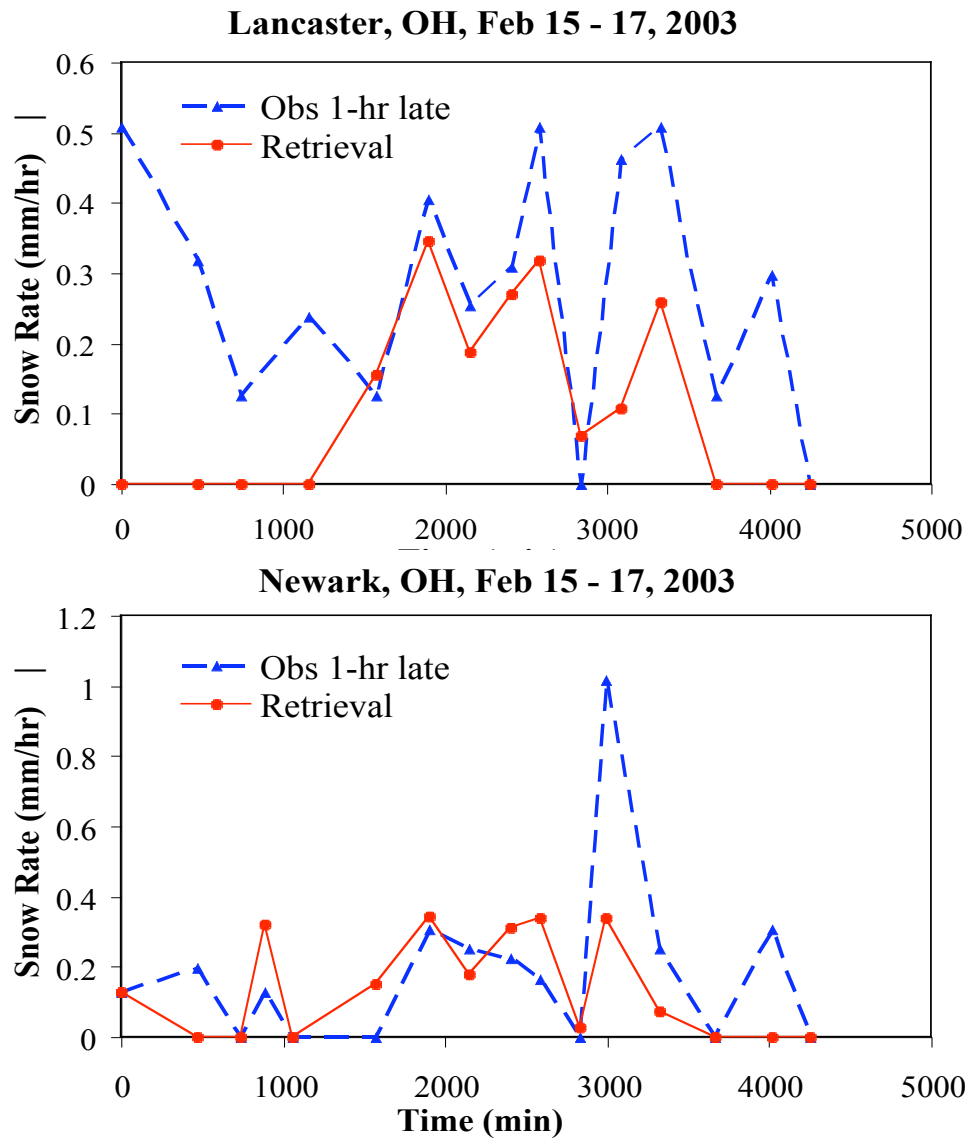






Example of Snow Rate Retrievals

- Catch basic snowfall patterns when compared to surface observations
- Cannot capture all snow events
- Underestimate high snowfall rates



The Future - MIRS

- Need exists to:
  - Further exploit information on sounders
  - Develop improved physics package portable to all sensors
- NOAA's Microwave Integrated Retrieval Systems – MIRS
  - AMSU/MHS
  - SSMIS
  - NPP/ATMS
  - NPOESS

Introduction to MIRS Concept

Variational Assimilation Retrieval (1DVAR)

CRTM as forward operator, validity-> clear, cloudy and precip conditions

Emissivity spectrum is part of the retrieved state vector

Algorithm valid in all-weather conditions, over all-surface types

Cloud & Precip profiles retrieval (no cloud top, thickness, etc)

EOF decomposition

Sensor-independent

Highly Modular Design

Flexibility and Robustness

Selection of Channels to use, parameters to retrieve

Modeling & Instrumental Errors are input to algorithm

Summary

- Benefit of Sounders/HF radiometers
  - Vital for constellation (esp. over land/winter season)
  - Distinct advantages over "legacy" imagers (esp. in difficult climate regimes)
  - Full sounding capability being underutilized
    - Should pursue Bayesian with full channel complement
- What's ahead to prepare for GPM
  - Better understanding of usefulness of HF channels
    - Precipitation Identification
    - Regime classification
    - Use in Bayesian schemes
    - Limitations
  - CRM, RTM, profiles focus on cold season, land precipitation