AMSU observations of Arctic precipitation and global sets of rain gauges: Implications for ATMS and NPP

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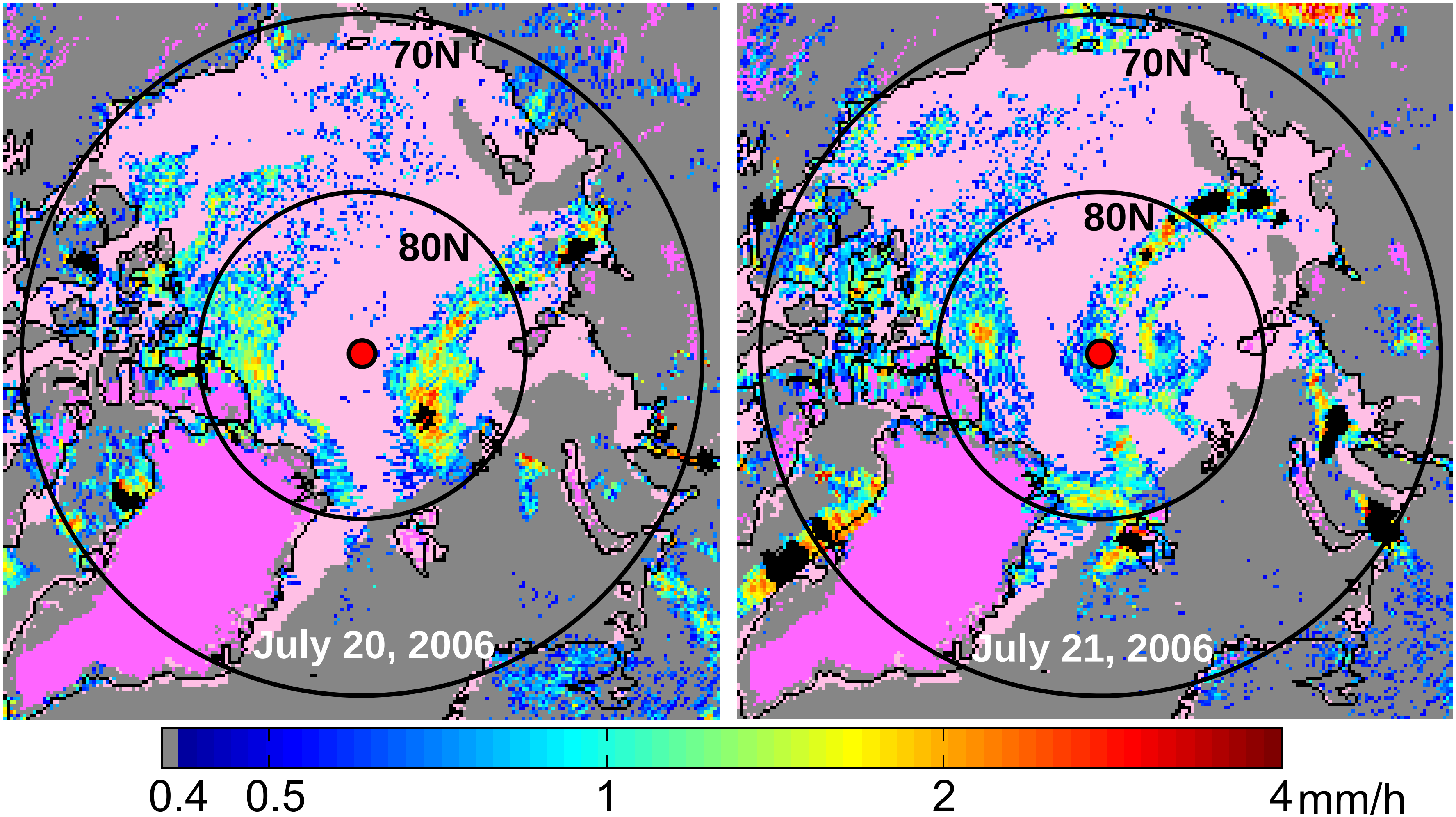
OUTLINE

- Physics-based stochastic retrievals -- a new approach
- Observational results and validation: Arctic and global
- Predicted advantages of ATMS and NPP
- Summary and Conclusions

North Pole Precipitation July 20-21, 2006

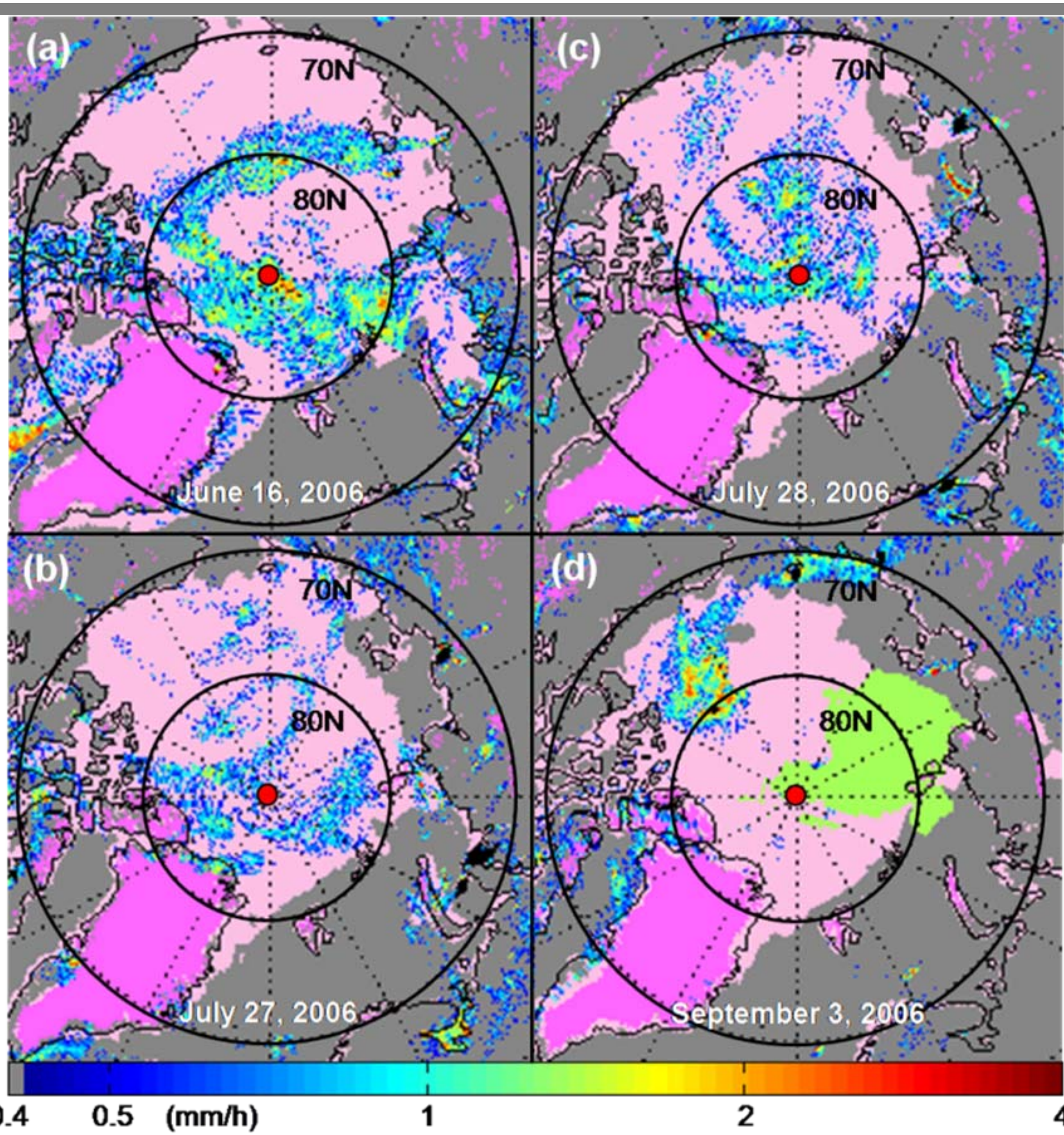


AMSU-derived precipitation over North Pole sea ice (pink) – evolution over 24 hours

NOAA-16 data. High surface elevation is problematic (dark pink)

North Pole Precipitation – NOAA-16

Early season rain and snow (visibility begins ~May 20)



Second day of sequence

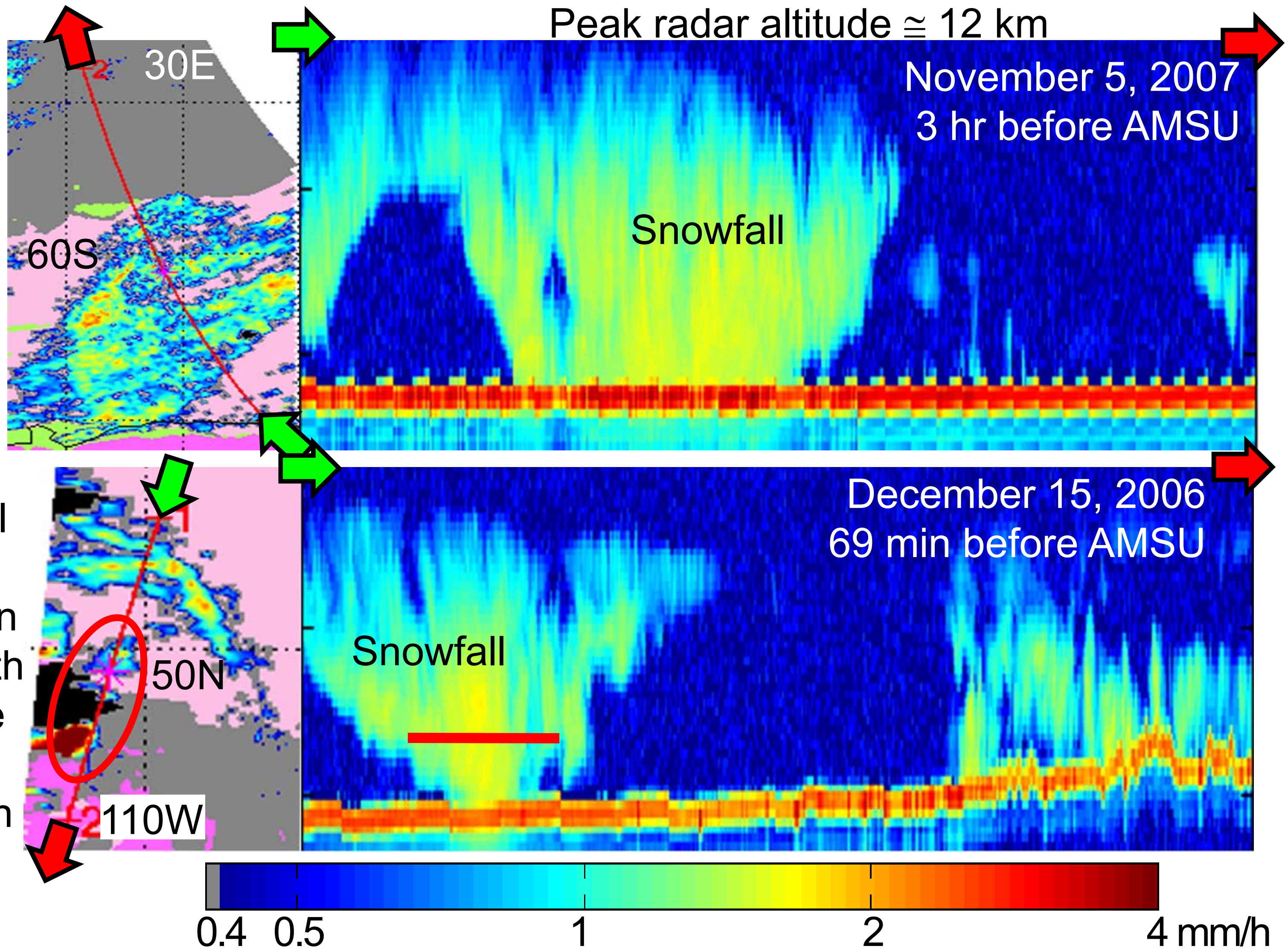
First of two-day sequence illustrating rapid evolution of storm systems

Late season rain and snow (visibility ends ~Sept. 20)

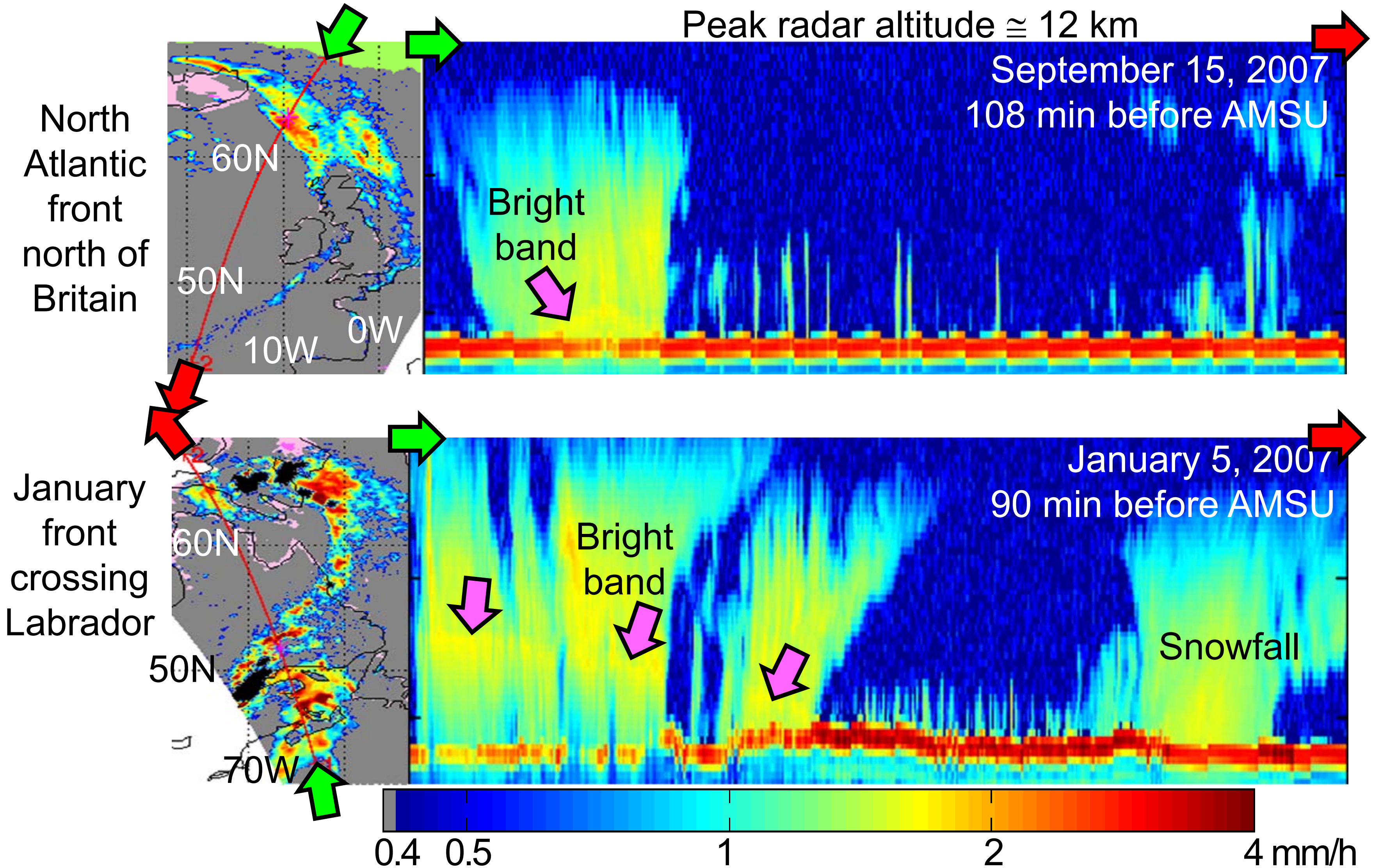
Antarctic Ice, Canadian Snow vs. CloudSat

Antarctic snowfall over the ice shelf

Snowfall over Canadian snow, with possible false detection



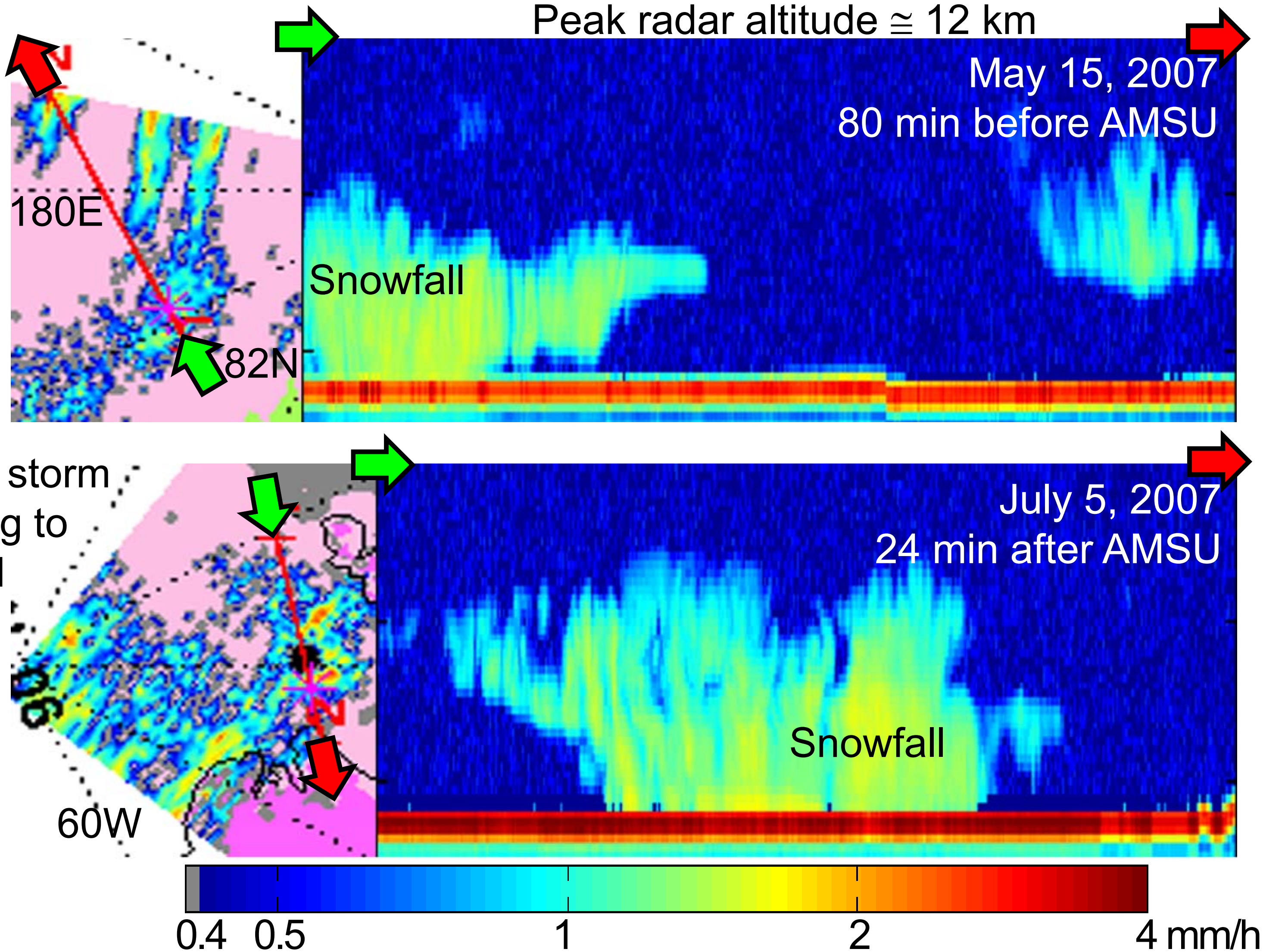
North Atlantic Precipitation vs. CloudSat



North Pole Precipitation vs. CloudSat

North Pole storm with possible false detection at end

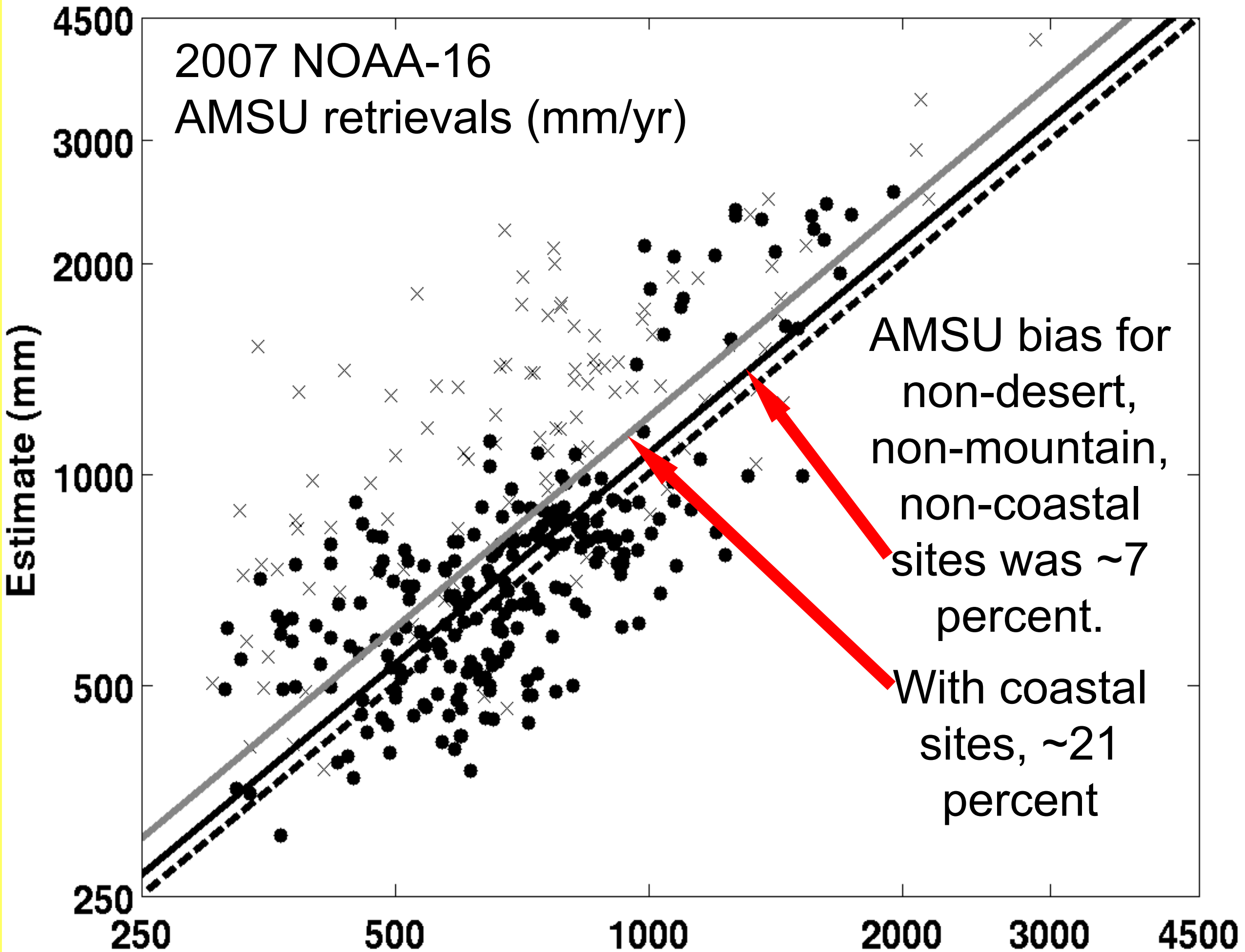
North Pole storm extending to ~80N



Comparisons with Global Rain Gauges

Annual accumulations (mm) for 345 cities that report all 12 months.

114 of these (×'s) are within 55 km of the coast. AMSU averaged ±0.4 degrees longitude and latitude every pass. Omitted were 195 sites with elevation changes > 500m in ±0.2 degrees, and 39 desert sites < 300 mm/yr.



Annual accumulation (mm): Monthly Climatic Data for the World [NCDC/NESDIS/NOAA]

RMS Retrieval Errors for |lat| > 45°
via MM5 Simulations, 15-km resolution

MM5 (mm/h)	Land	Sea	Warm Sea	Rain	Snow	Con-vective	Strat-iform
0.25-0.5	*0.69*	0.45	0.46	*0.59*	0.46	*2.01*	0.49
0.5-1	0.88	0.54	0.51	0.70	0.71	*2.22*	0.61
1-2	1.26	**0.70**	**0.70**	**0.94**	**0.92**	*2.51*	**0.82**
2-4	2.05	**1.24**	**1.20**	**1.56**	**1.81**	2.86	**1.42**
4-8	**3.44**	**2.78**	**2.44**	**3.00**	**3.78**	**3.70**	**2.87**
8-16	**6.65**	**5.85**	**6.02**	**6.87**	**4.92**	**6.59**	**5.81**
16-32	**13.8**	**14.4**	**15.0**	**15.2**	**10.8**	**13.8**	-
32-64	**23.5**	**31.2**	**31.2**	**27.6**	**21.5**	**24.8**	-

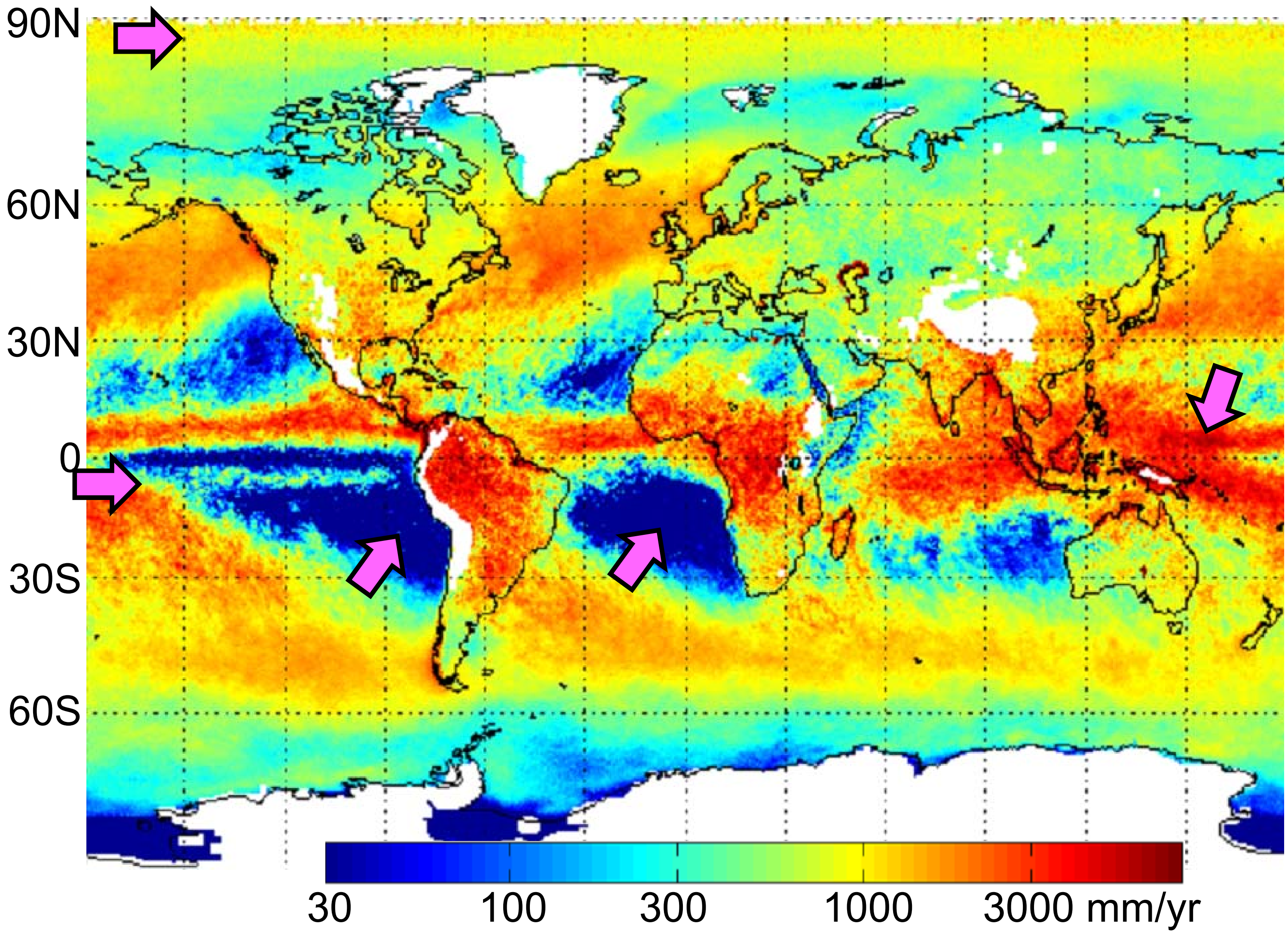
Poor (rms > upper bound U) Usable (rms < U) Good (rms < lower bound)

106 global storms ~1000-km square were simulated with 5-km cells using an NCEP-initialized cloud-resolving MM5 model, a 2-stream version of TBSCAT, a laminar atmospheric model, and fluffy spheres with frequency-dependent densities; these simulations roughly agreed with simultaneous 15-km AMSU observations. Snow-free and ice-free surfaces were assumed.

AMSU 2006 Annual Precipitation (mm)

NOAA-16
365 days

Ascending Node ~4PM



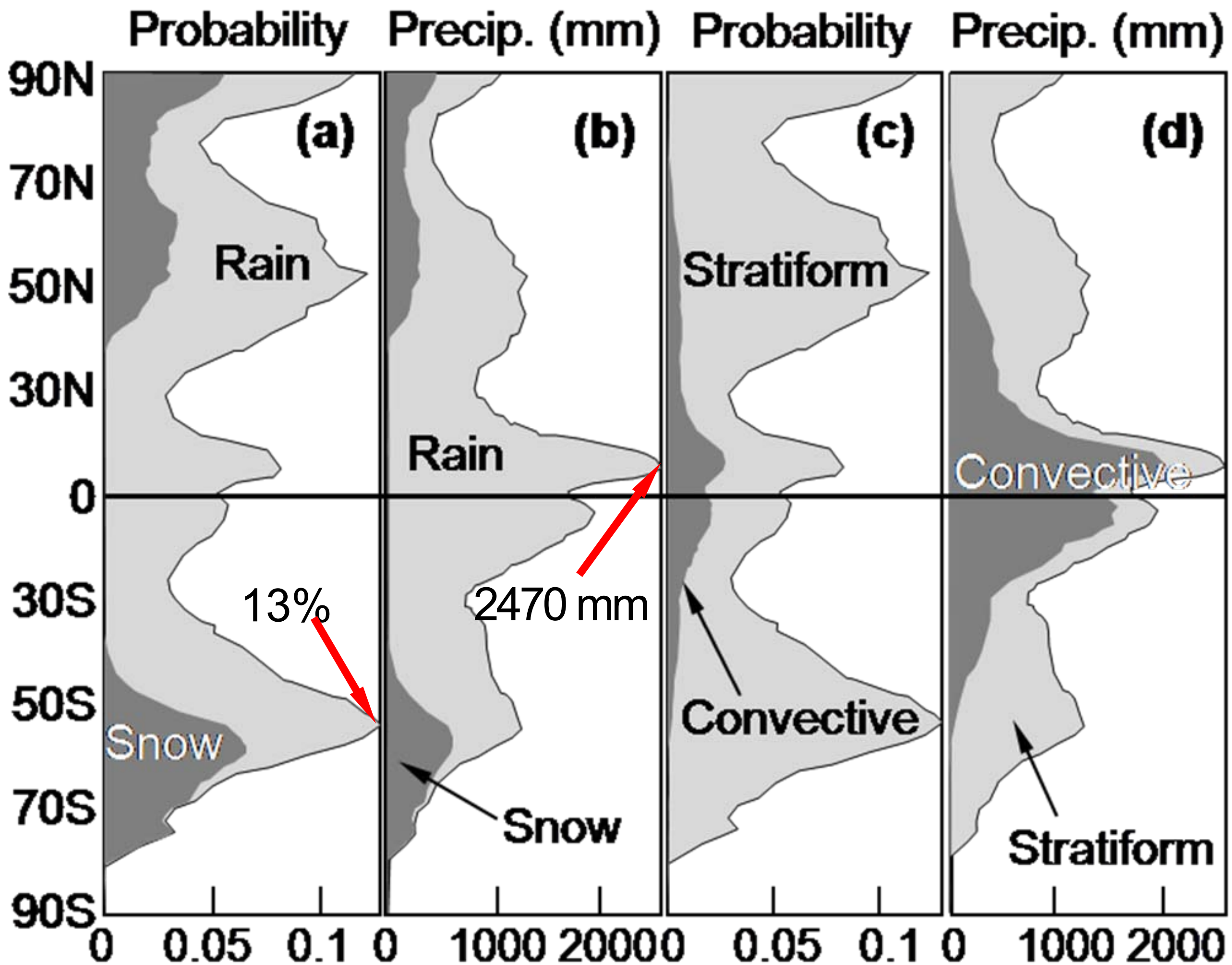
AMSU Annual Precipitation: Probability and Amount vs. Latitude

NOAA 16
2007

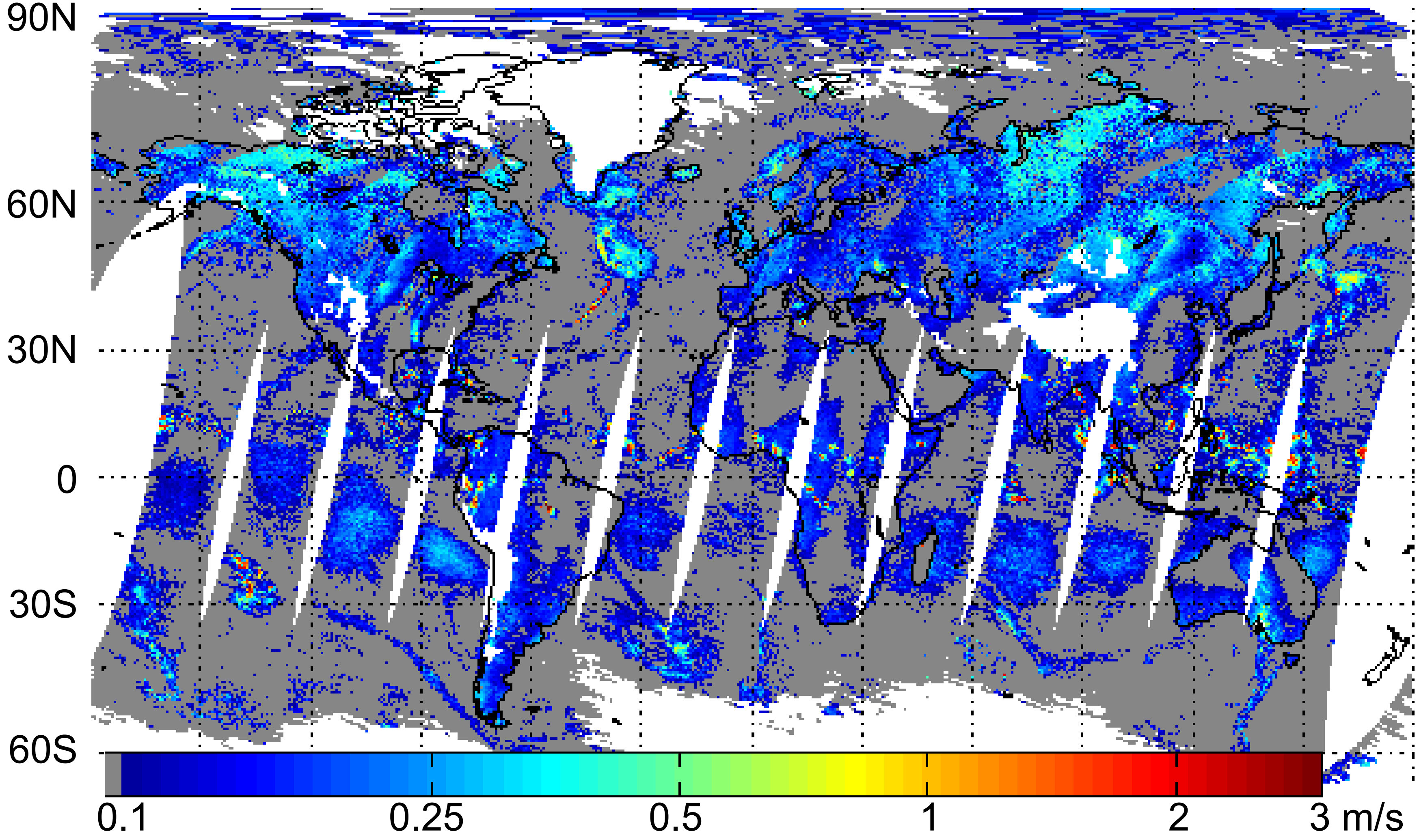
Precipitation threshold is 0.5 mm/h at 15-km resolution

53.6 GHz > 248K implies rain.

Estimated peak vertical wind > 0.45 m/s implies convection



AMSU-Retrieved Vertical Wind (m/s) September 25, 2008

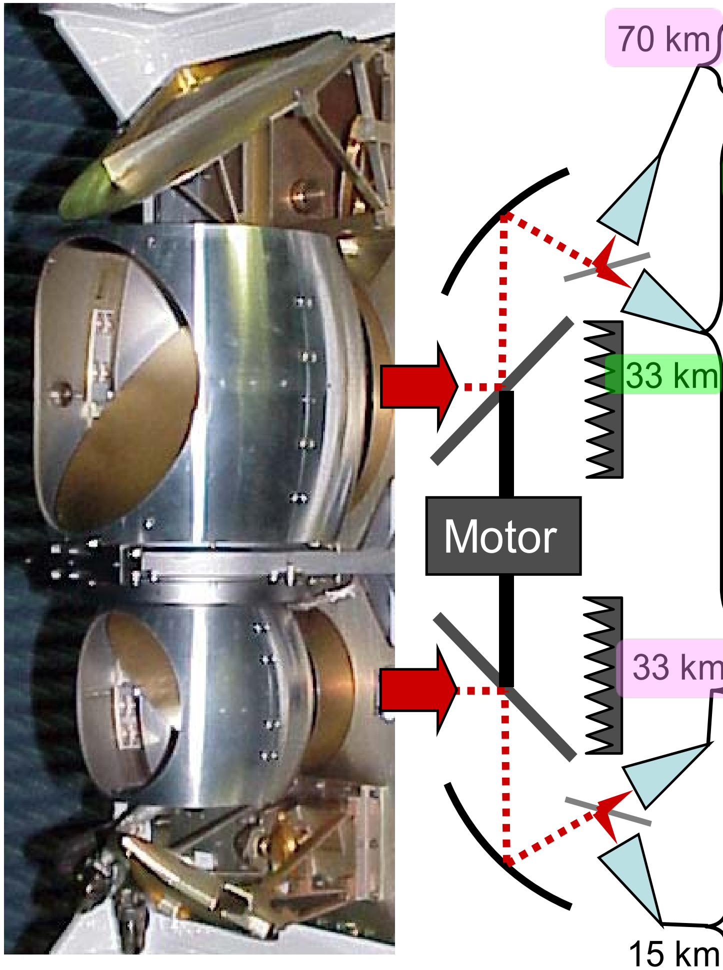


Millimeter-wave Precipitation Physics

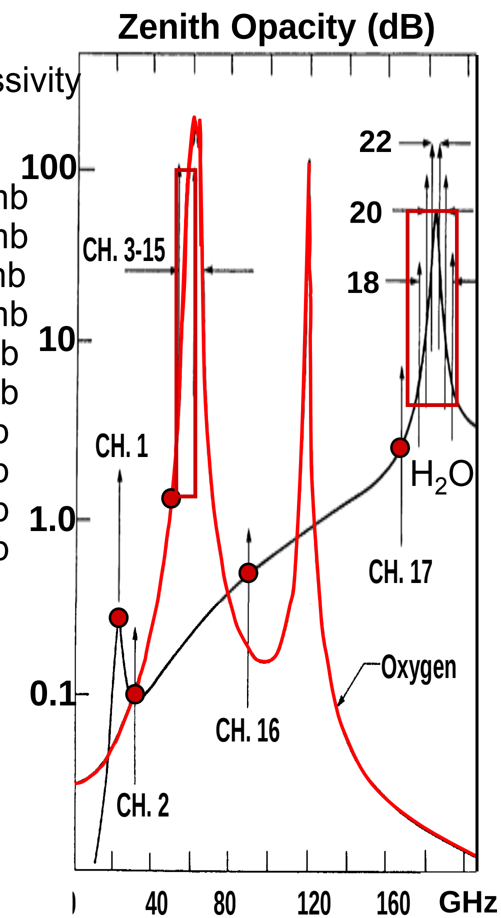
- AMSU senses 20 frequency bands:
  "Windows": 23.8, 31.4, 50, 89 and 150 GHz
  "Opaque": O_2: 52.8-55.6 GHz $\Rightarrow$ T(h), and H_2O:183-GHz $\Rightarrow$ RH(h)
- Precipitation rate is correlated with [vertical wind] times [absolute humidity H]
- Scattering differences between 50 and 183 GHz reveal drop size spectrum
  Hydrometeor size spectrum reveals vertical wind velocities
- $T_{B\ 183\ GHz} < T_{B\ min\ (RH\ =\ 100)}$ indicates ice content and therefore vertical wind
- Surface-blind opaque channels "altitude slice"; cell-top altitude suggests wind
- 50-GHz spectrum yields surface reflectivity if surface spectral shape is known
- Known reflective surfaces (e.g. ocean) permit opacity and RR measurements

Precipitation has several independent mm-wave signatures

ATMS Configuration



23.8 GHz	H_2O 10 cm
31.4	H_2O 50 cm
50.3 GHz	window, emissivity
51.76	window
52.8	T(h) 0-3 km
53.6 ± 0.115	4 km ~700 mb
54.4	9 km ~400 mb
54.94	11 km~250 mb
55.5	13 km~180 mb
57.29	17 km ~90 mb
57.29 ± 0.217	19 km ~50 mb
$57.29\pm0.322\pm0.048$	~25 mb
$57.29\pm0.322\pm0.022$	~10 mb
$57.29\pm0.322\pm0.010$	~6 mb
$57.29\pm0.322\pm0.004$	~3 mb
88.2 GHz	H_2O 15 cm
164-7 GHz	H_2O 18 mm
183.31 ± 7	H_2O 18 mm
183.31 ± 4.5	H_2O 4.5 mm
183.31 ± 3	H_2O 2.5 mm
183.31 ± 1.8	H_2O 1.2 mm
183.31 ± 1	H_2O 0.5 mm



ATMS Image Sharpening vs. MM5, AMSU

~"BEST"

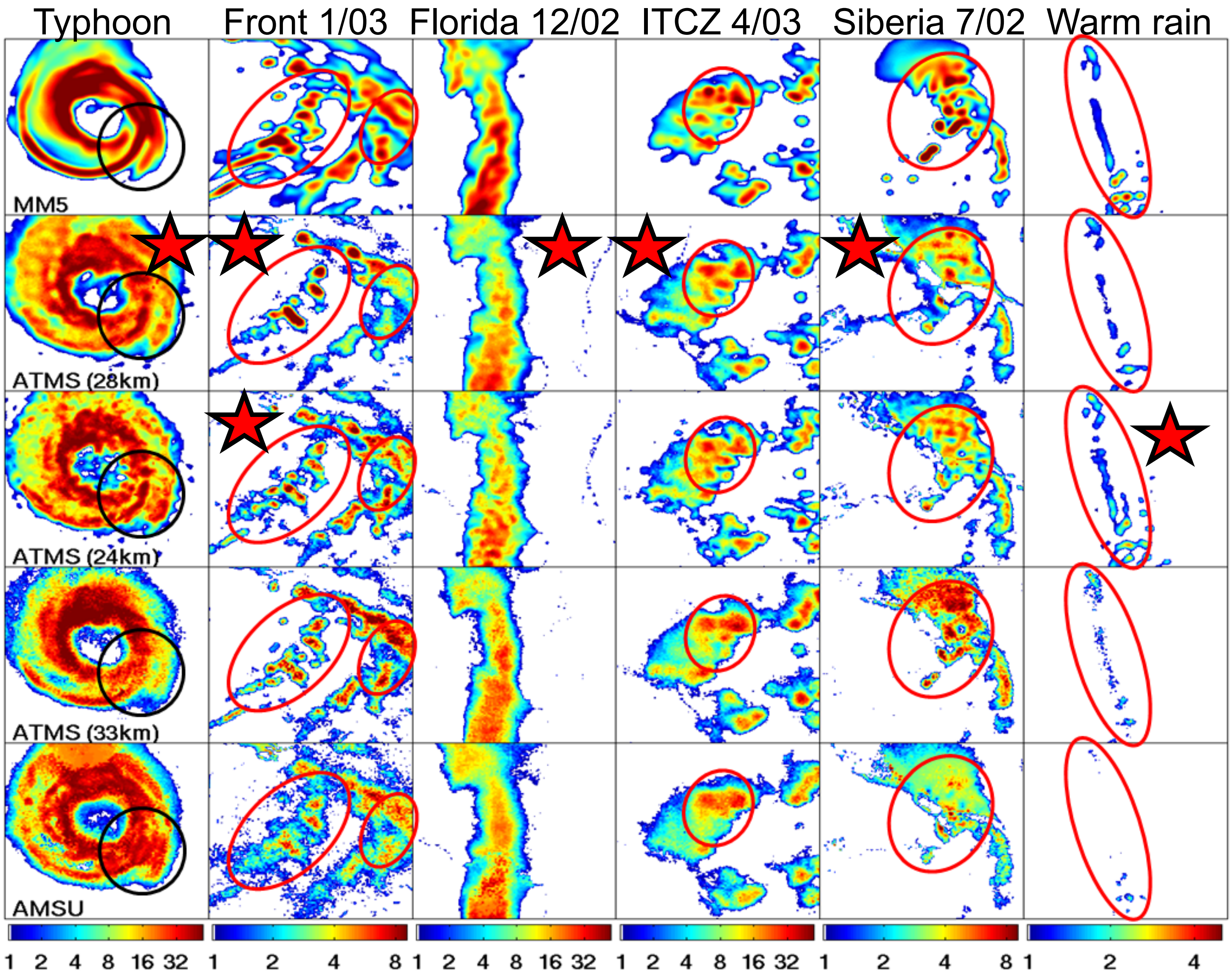
MM5 "Truth"

ATMS 28-km sharpening

ATMS 24-km sharpening

ATMS no sharpening

AMSU sharpening impossible



555-km images

Retrieved precipitation rates (mm/h)

Staelin and Surussavadee

RMS Precipitation Retrieval Accuracies

MM5 Range (mm/h)	AMSU			ATMS			ATMS with 24-km Sharpening		
	Land	Sea	All	Land	Sea	All	Land	Sea	All
0.5-1	*1.04*	*1.24*	*1.15*	0.76	0.91	0.85	*1.17*	*1.35*	*1.27*
1-2	1.62	1.45	1.52	1.33	1.26	1.29	1.66	1.40	1.50
2-4	2.24	2.13	2.17	2.22	**1.81**	**1.99**	2.74	2.42	2.56
4-8	**3.82**	4.46	4.18	**3.60**	**3.16**	**3.36**	4.40	4.20	4.29
8-16	**6.52**	8.01	**7.28**	**6.48**	**6.52**	**6.50**	**6.75**	**7.67**	**7.21**
16-32	**11.6**	**11.4**	**11.5**	**10.8**	**10.9**	**10.8**	**11.3**	**12.1**	**11.7**
32-64	**19.3**	**22.2**	**21.1**	**17.0**	**19.7**	**18.6**	**21.6**	**22.5**	**22.1**
>64	**53.2**	**42.8**	**45.0**	**45.6**	**36.9**	**38.7**	**54.9**	**42.1**	**44.9**

Poor (rms > upper bound U) Usable (rms < U) Good (rms < lower bound)

Summary and Conclusions

- Physics-based stochastic retrievals offer advantages
  - widely applicable, underused
- Arctic AMSU precipitation retrievals extend to 1999
  - unique climate data resource
- AMSU global precipitation coverage is excellent for PMM
  - ~twice daily per satellite,15-km resolution, ≤ 4 satellites
- ATMS (NPP and NPOESS) will yield better precipitation retrievals
- Geostationary microwave precipitation satellites are feasible
  - 15-minute repeats could track convective-cell velocities.

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