The Combined Radar-Radiometer Algorithm— GPM Version 06X

Bill Olson, Mircea Grecu, Sarah Ringerud, Joe Munchak, Ziad Haddad, Kwo-Sen Kuo, Dave Randel, Bart Kelley, Dave Bolvin, Liang Liao, Bob Meneghini, Walt Petersen, Pierre Kirstetter

with support from

the Radar and Radiometer Algorithm Teams, the GV Team, WG's, and Precipitation Processing System Personnel (special kudos to Larry Woltz, Patty McCaughey, John Kwiatkowski, and John Stout)

Primary Activities

The changes/additions to algorithm:

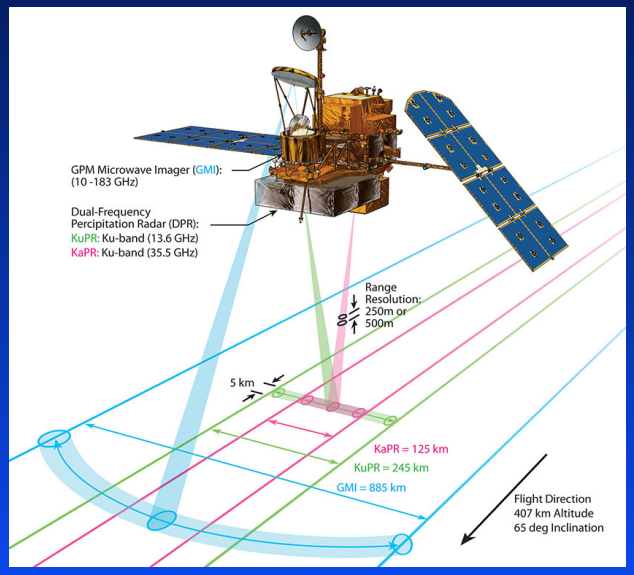
- adapt the Combined Algorithm to HS Ka data in the outer swath; i.e., use Ku / Ka / GMI observations over full DPR swath (V06X).
- produce a precip profile / brightness temperature database more directly suited to Radiometer Algorithm applications.

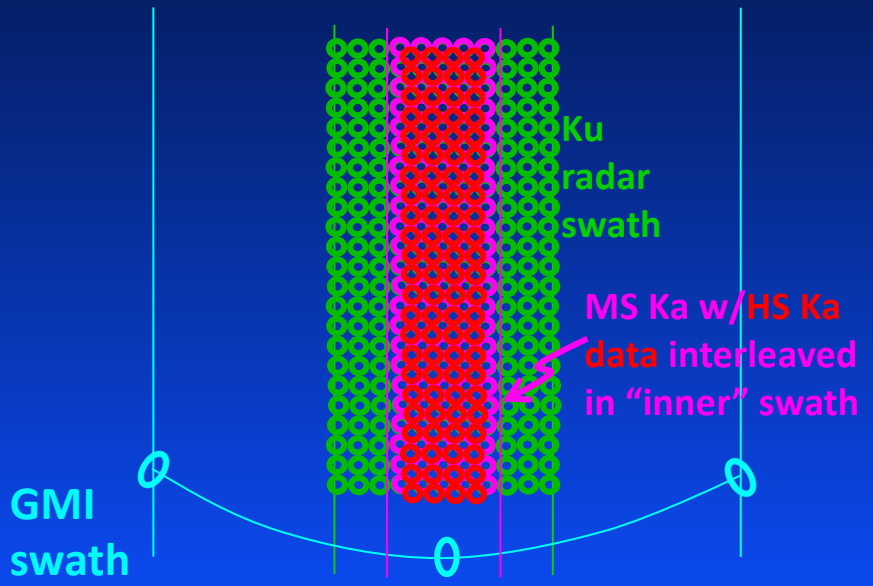
Now that V06X input from radar team has stabilized, trying to understand the impact of outer-swath Ka HS data on precip estimates.

Adaptation to HS Ka Data in the Outer Swath (Level 2)

Old system:

	NS mode	MS mode
	Ku + GMI	Ku + Ka + GMI
	full swath	inner swath





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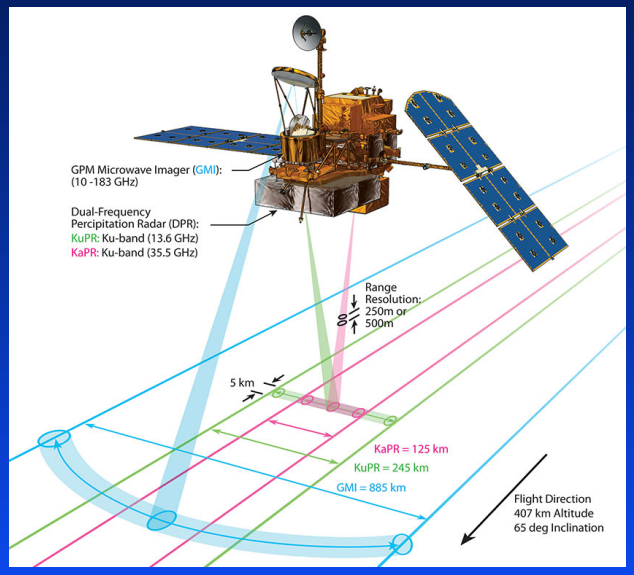
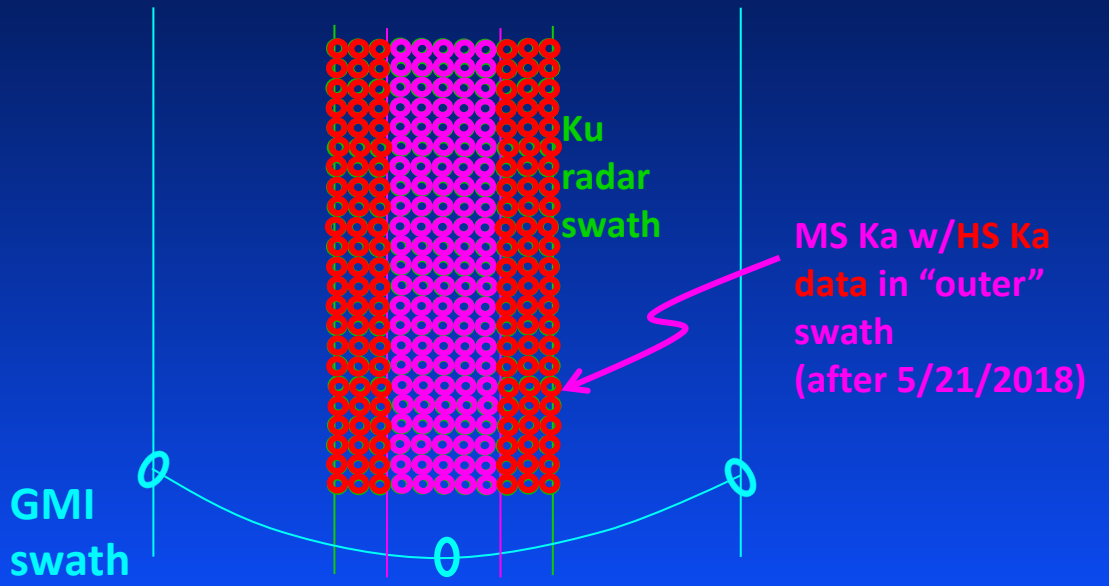




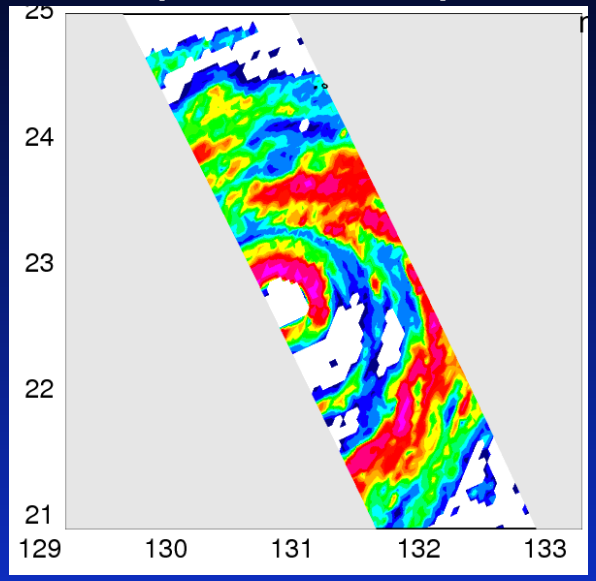
Adaptation to HS Ka Data in the Outer Swath (Level 2)

	NS mode	MS mode
Old system:	Ku + GMI full swath	Ku + Ka + GMI inner swath

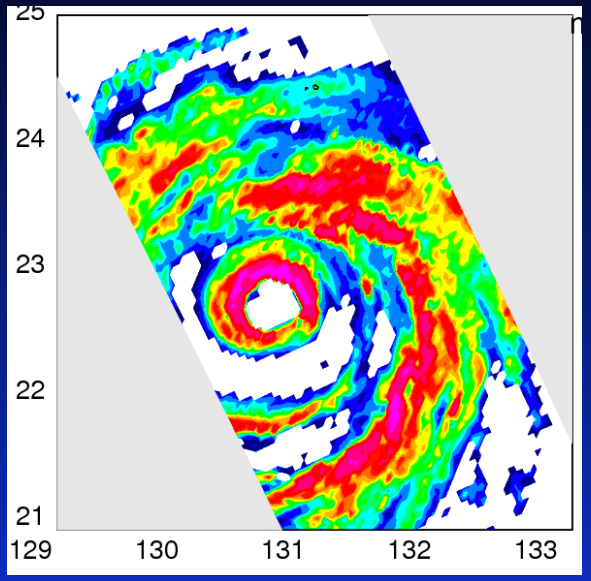
	NS mode	FS mode
New system:	Ku + GMI full swath	Ku + Ka + GMI → inner swath before 5/2018 → full swath after 5/2018

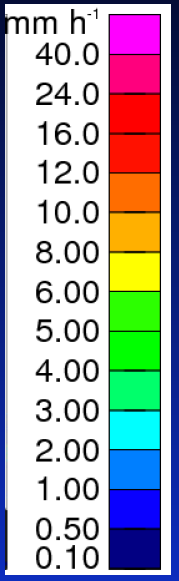
Example of Super Typhoon Maria (Jul. 9, 2018)

V06A MS Mode (Ku+Ka+GMI)

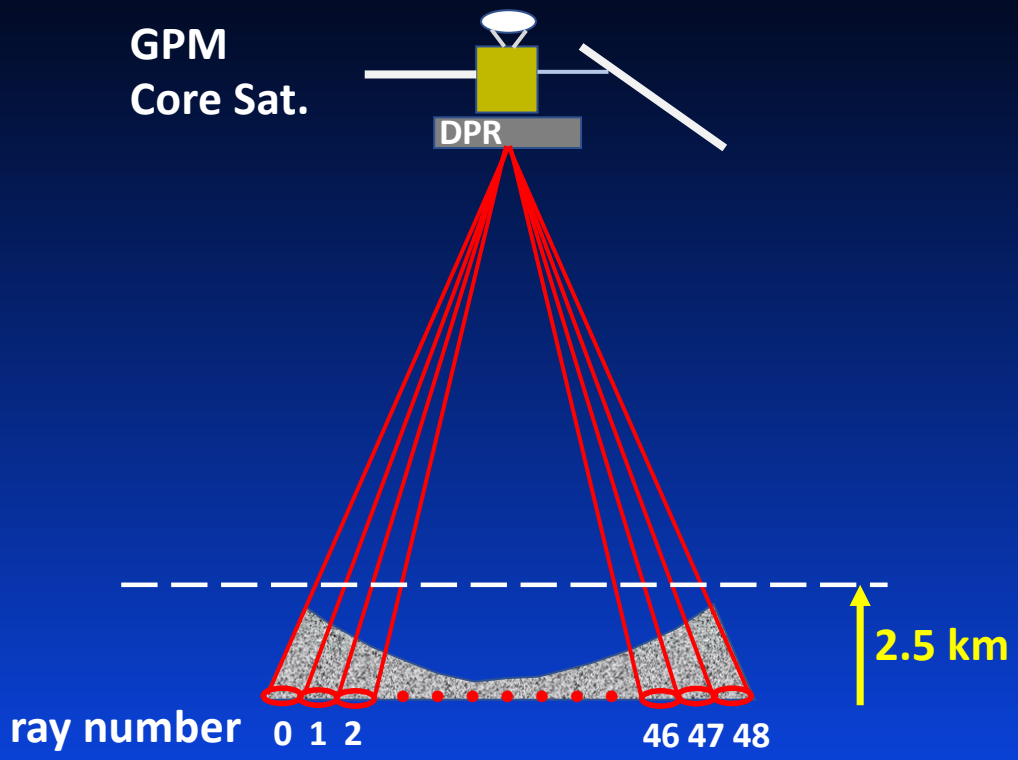


V06X FS Mode (Ku+Ka+GMI)





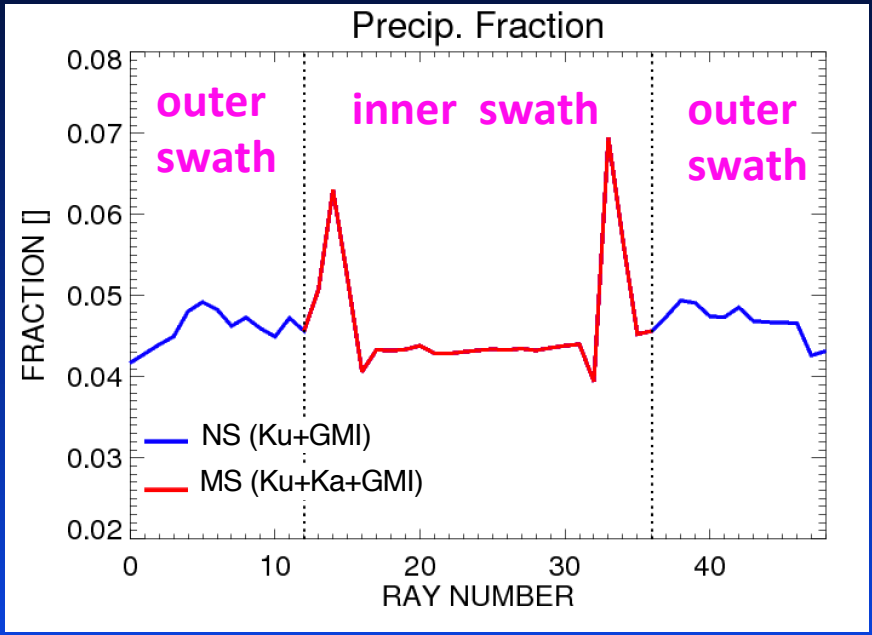
Calculating Angle-Means at 2.5 km over Ocean



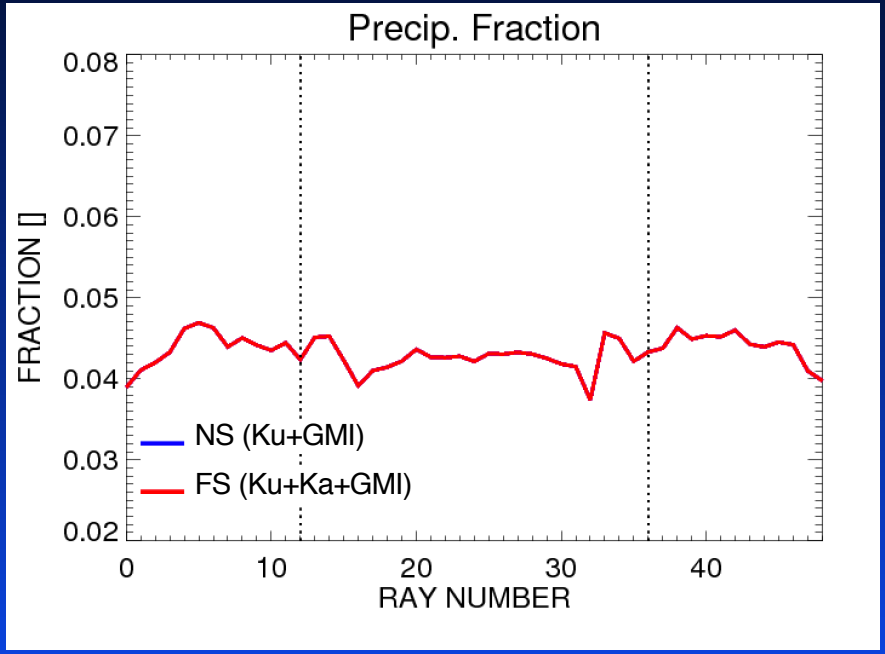
Do we see any anomalies across the swath?

- June 2018 2.5 km mean precip fraction at each scan angle over ocean:

V06A



V06X

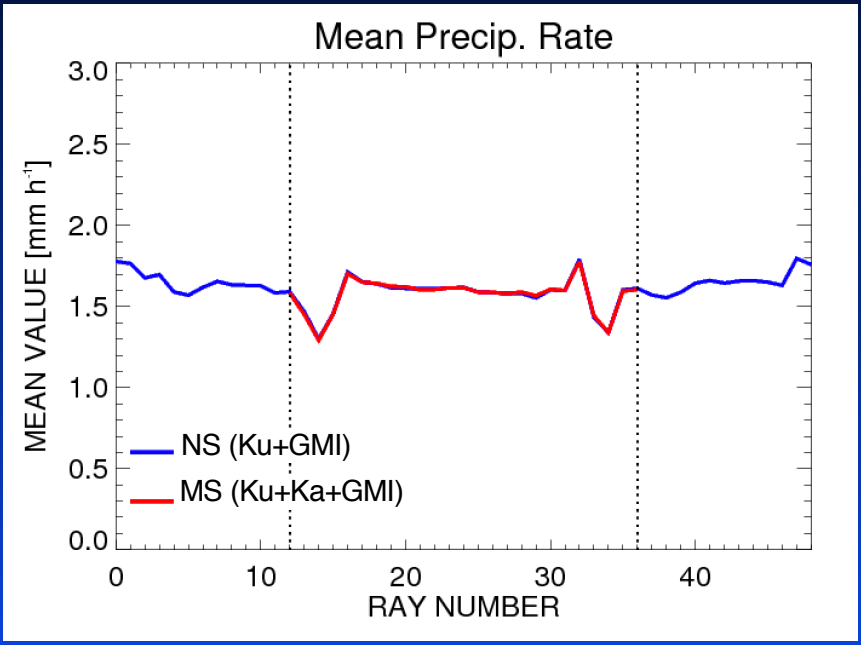


- impact of sidelobe anomalies obvious in V06A; controlled in V06X.

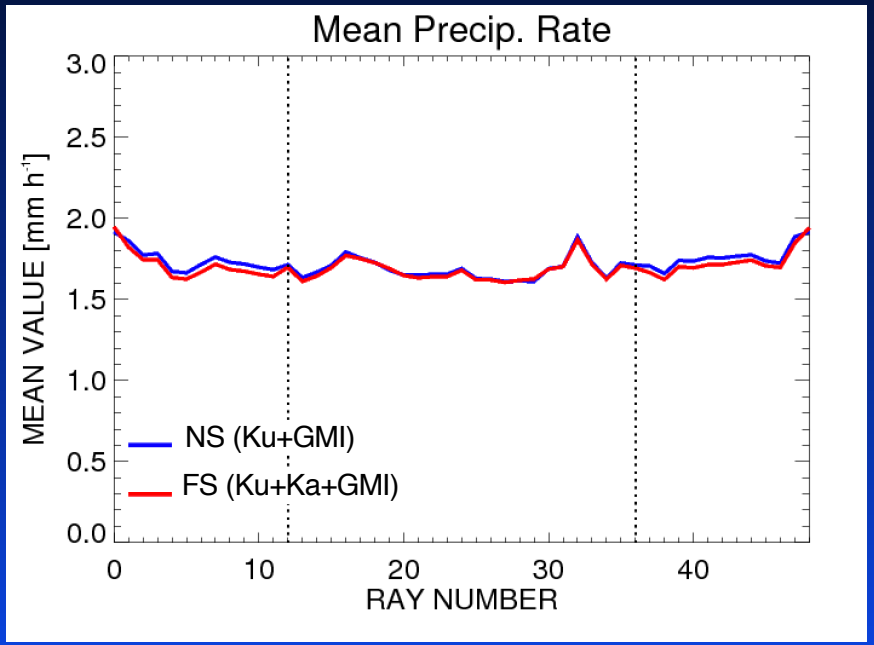
Do we see any anomalies across the swath?

- June 2018 2.5 km conditional mean precip rate at each scan angle over ocean:

V06A



V06X

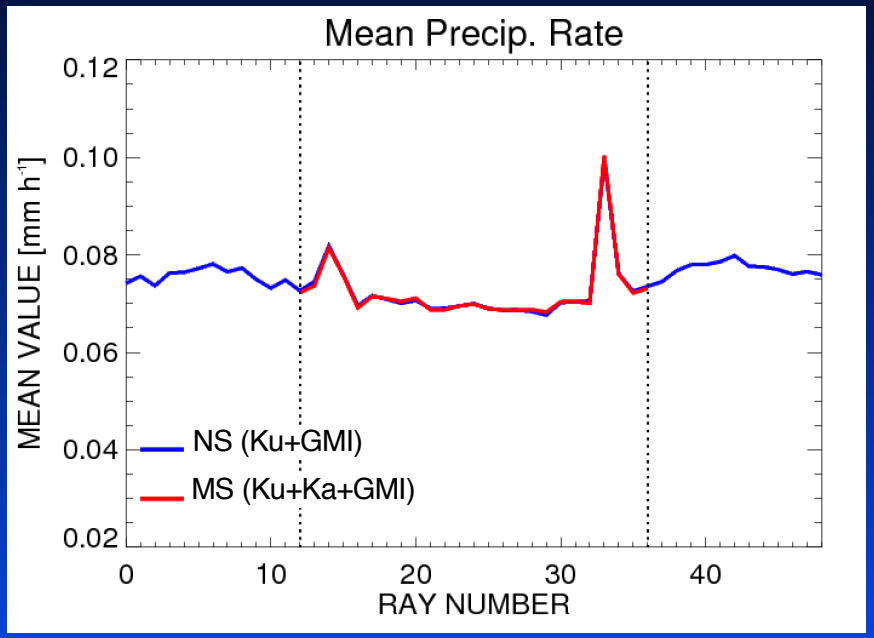


- aside from sidelobe anomaly effects, V06A and V06X means look very similar.

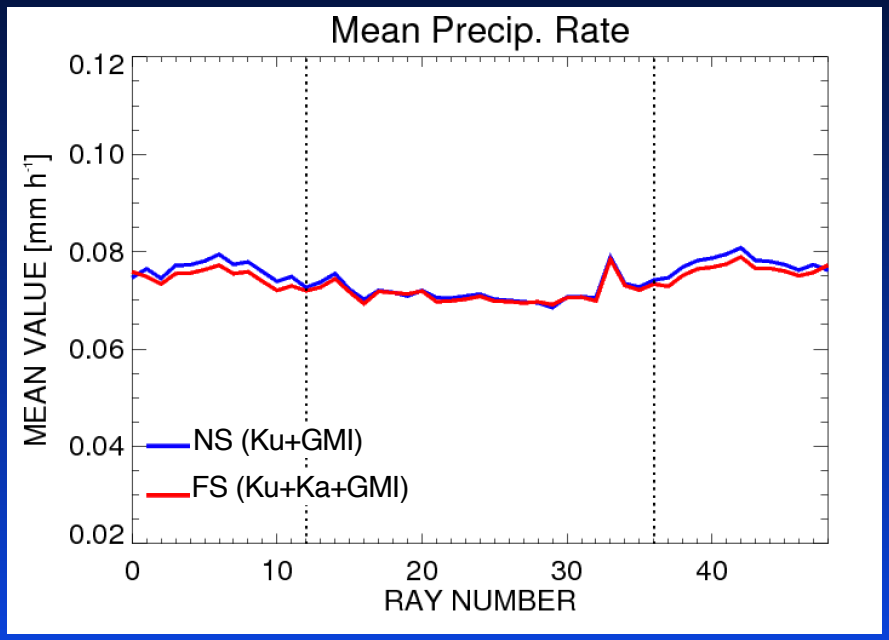
Do we see any anomalies across the swath?

- June 2018 2.5 km unconditional mean precip rate at each scan angle over ocean:

V06A



V06X



- aside from sidelobe anomaly effects, V06A and V06X means look very similar.

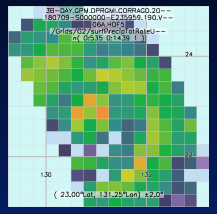
More generally, why to we see trends of conditional rain between inner and outer swaths?

…implications for V07?

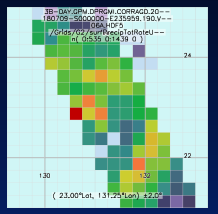
Adaptation to HS Ka Data in the Outer Swath (Level 3)

Old system:

Ku + GMI
gridded
full swath



Ku + Ka + GMI
gridded
inner swath



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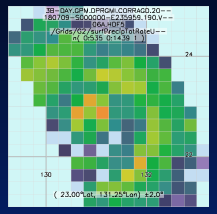

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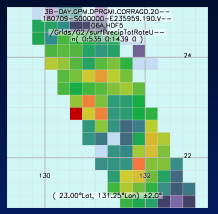

New system:

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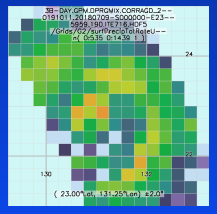

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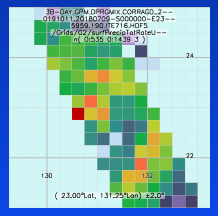
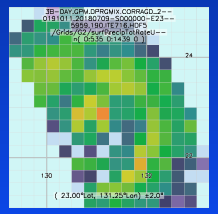
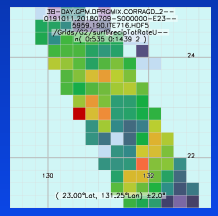


Ku + Ka + GMI

gridded
full swath

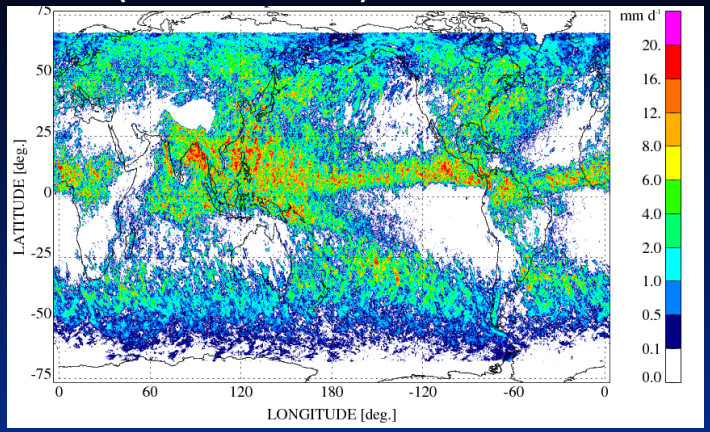


gridded
inner swath

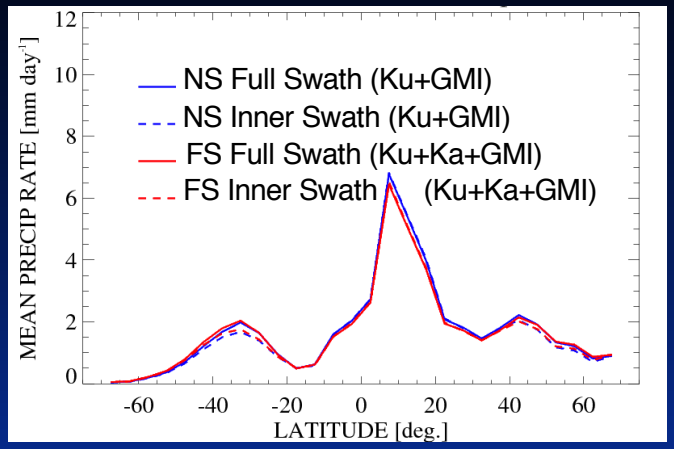


V06X JJA 2018 Averages of FS Full vs Inner Swath

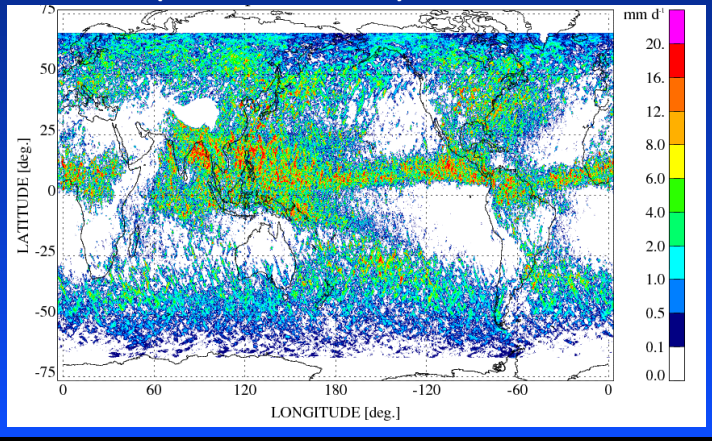
FS Full (Ku+Ka+GMI) 3.0 km Estimates



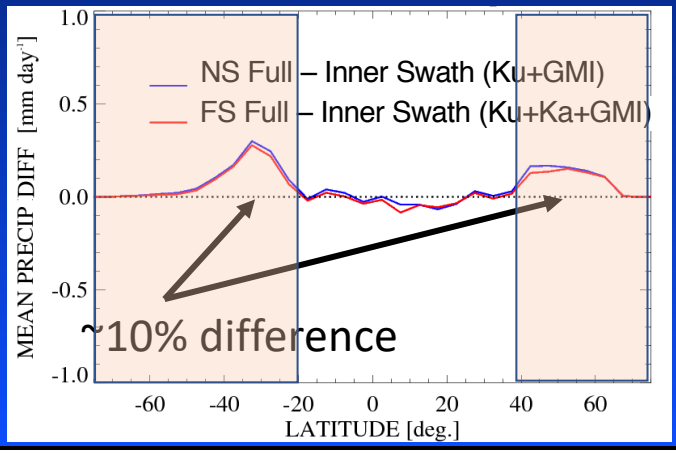
NS and FS Zonal Means over Ocean



FS inner (Ku+Ka+GMI) 3.0 km Estimates

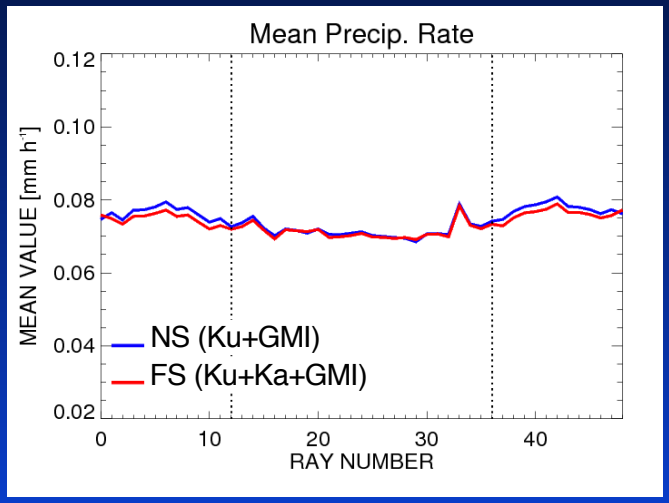


NS and FS Zonal Full – Inner Differences



Calculate Angle-Means but for Different Regions over Ocean

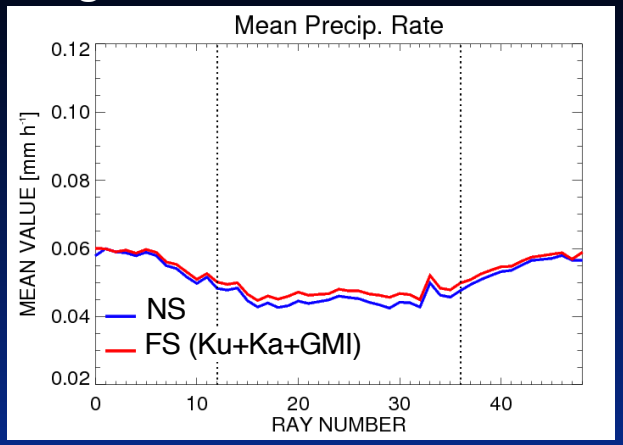
Global



storm tracks

"lower" latitudes

Region lat < 20 S or lat > 40 N



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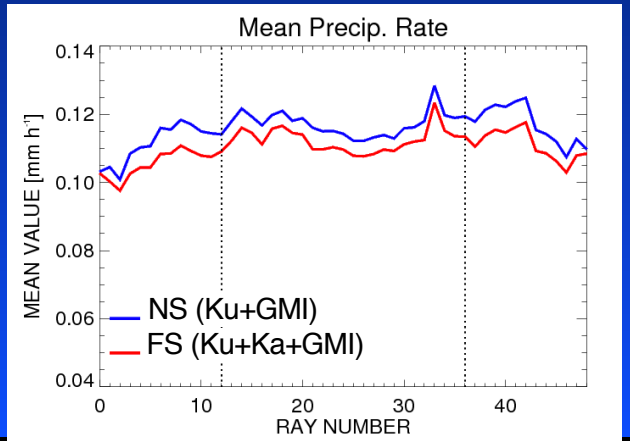
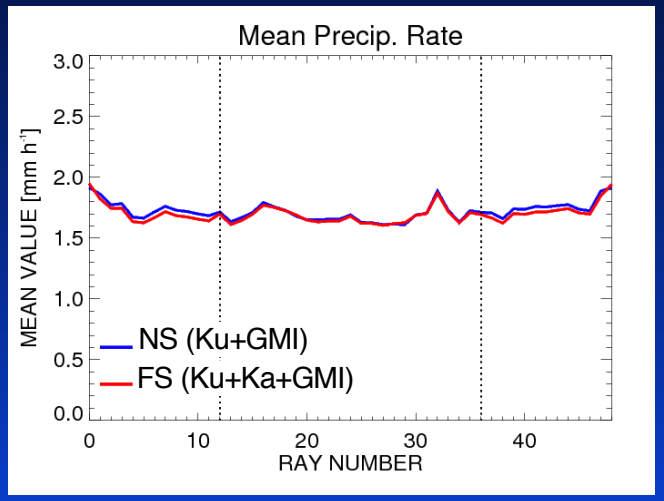


Calculate Angle-Means but for Different Regions over Ocean

(Conditional Rates)

Global



storm tracks

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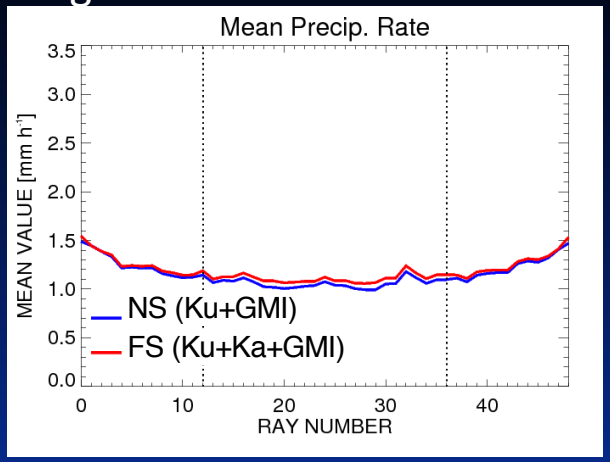

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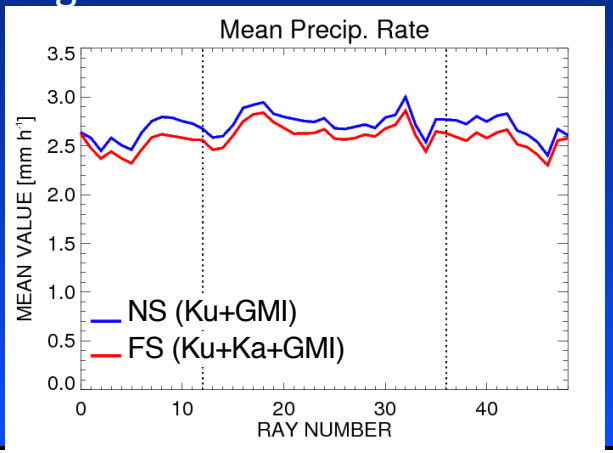
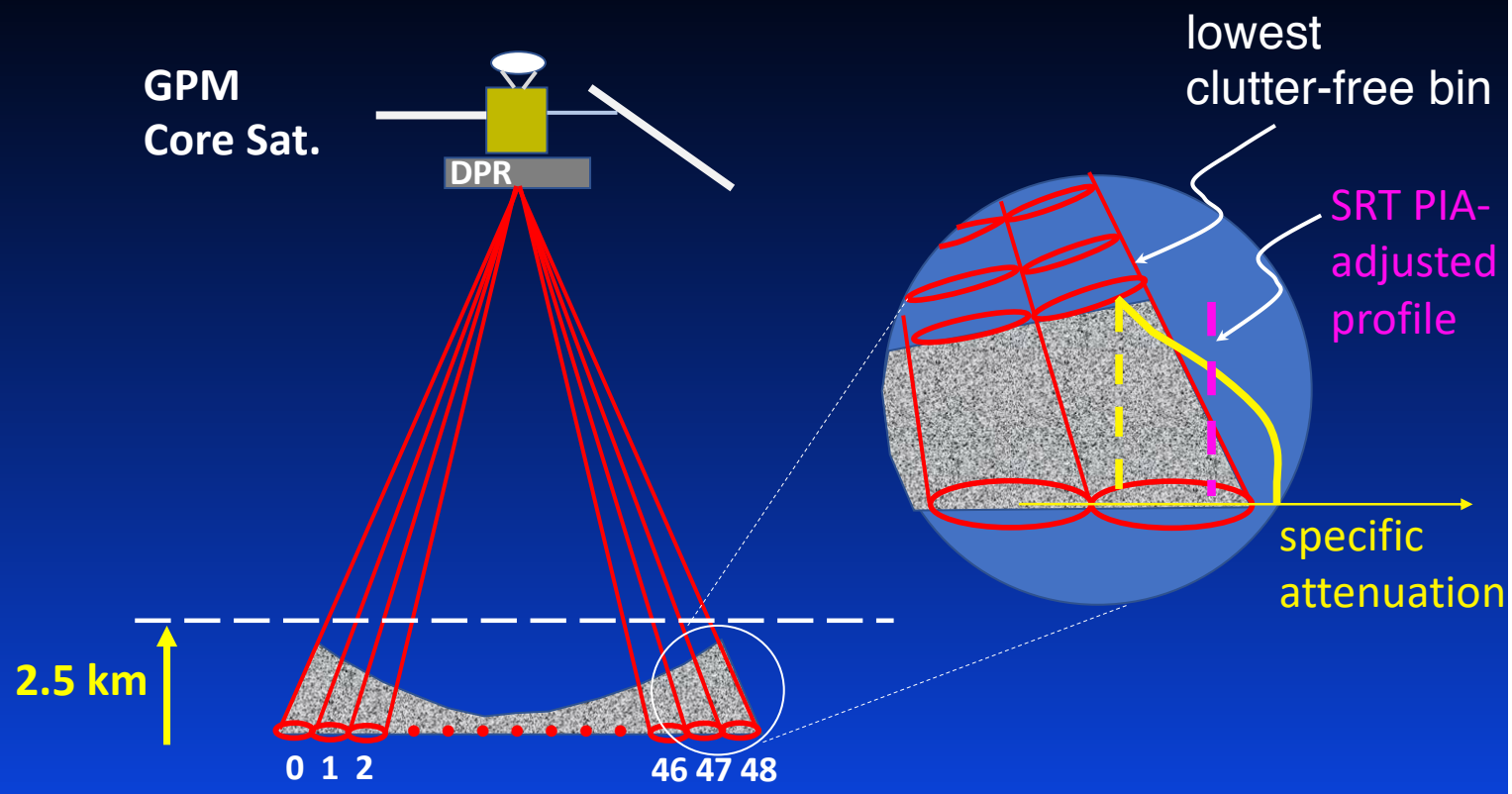
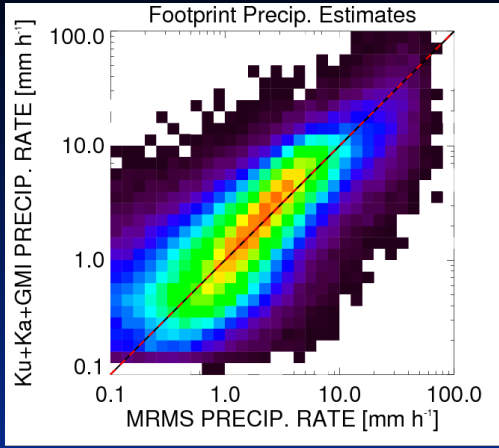


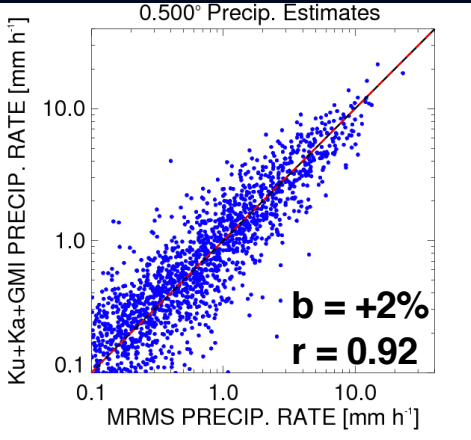
Hypothesis for High Bias in Outer-Swath Bins

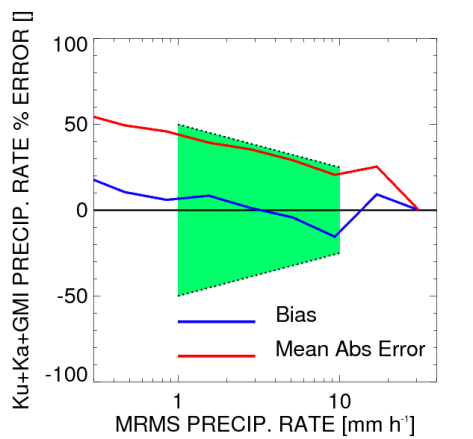


FS Comparisons with MRMS Calibrated Radar (JJA 2018 only)

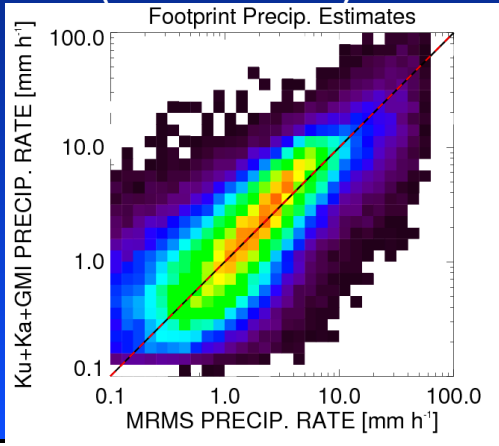
V06X FS (Ku+Ka+GMI) Full Swath

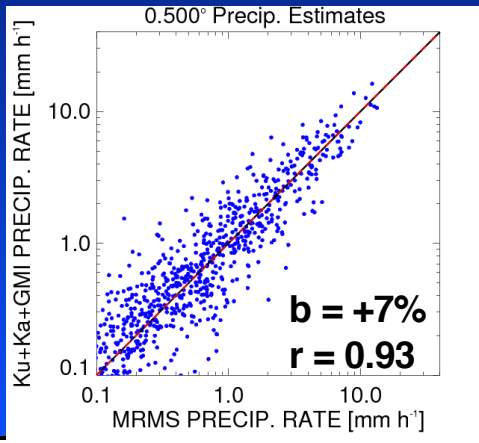


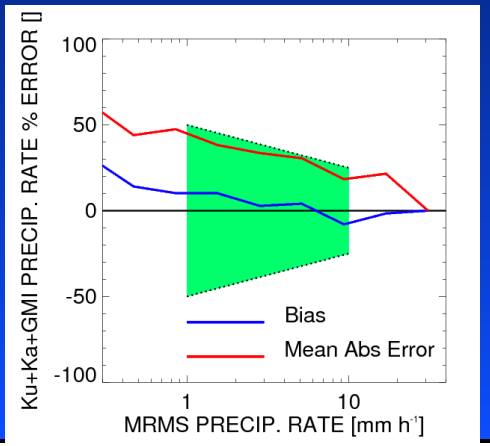




V06X FS (Ku+Ka+GMI) Inner Swath







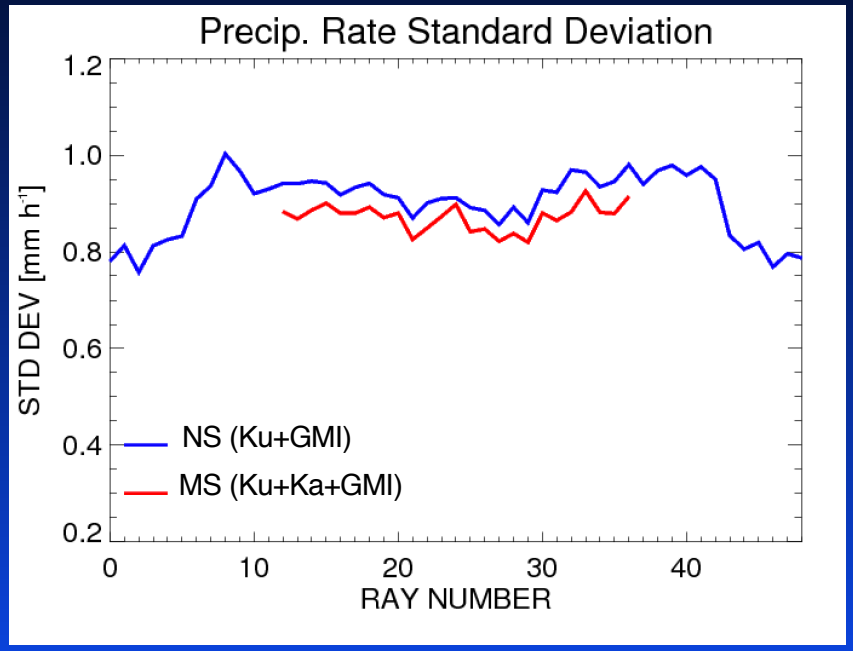
Concluding Remarks

- we have adapted the L2/L3 code to HS Ka data in the outer swath.
- so far, no obvious discontinuities across the Ka MS/HS swath boundary; trends of Ku + Ka + GMI estimates follow trends of Ku + GMI.
- would like to give the V06X algorithm a more thorough check: larger set of data; other variables, etc.
- specialized radiance module added to MS/FS processing stream – will adjust ice-phase precipitation similar to what is done by the Radiometer Team.
- we will return to “science” improvements in V07; i.e. address low bias over land etc.

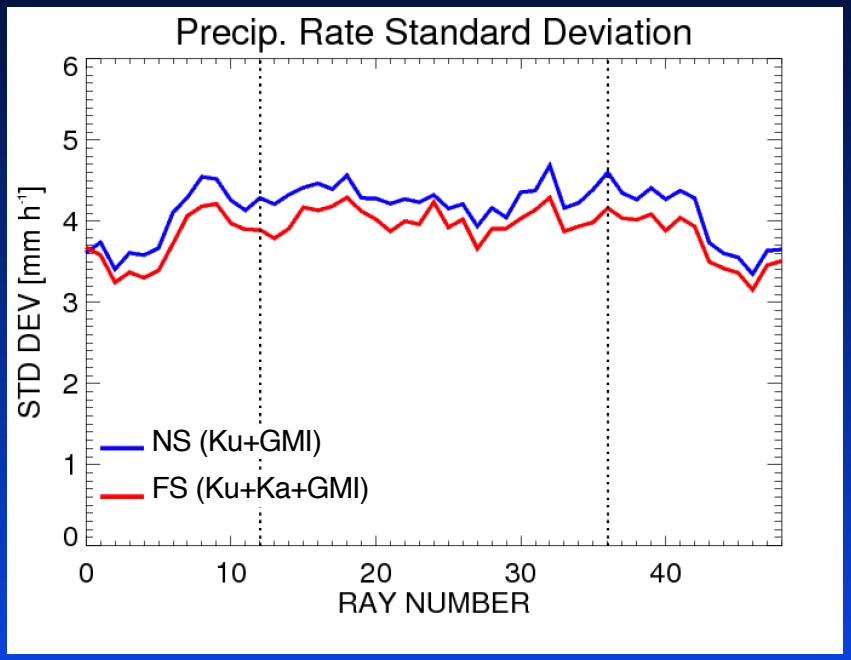
Do we see any anomalies across the swath?

- June 2018 2.5 km conditional precip std. dev. at each scan angle over ocean:

V06A



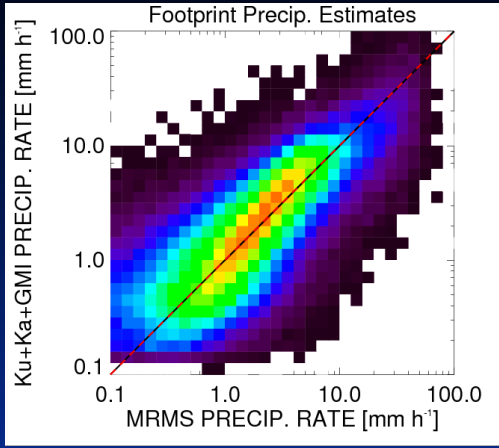
V06X

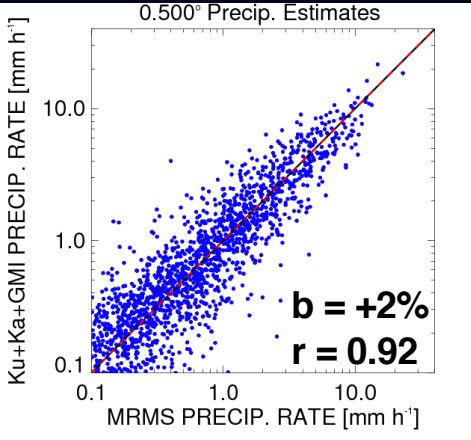


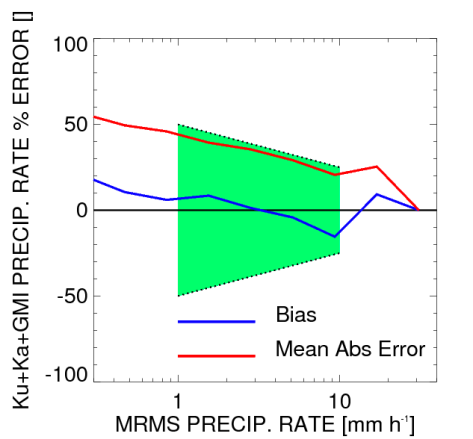
- falloff in variation at swath edge likely due to lack of GMI information.

FS Comparisons with MRMS Calibrated Radar (JJA 2018 only)

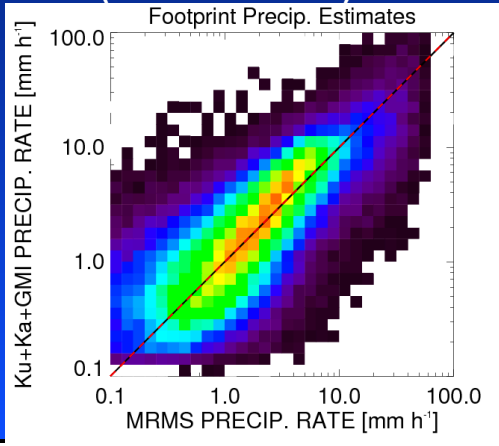
V06X FS (Ku+Ka+GMI) Full Swath

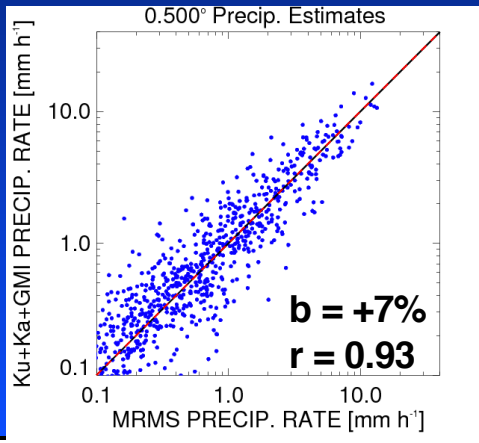


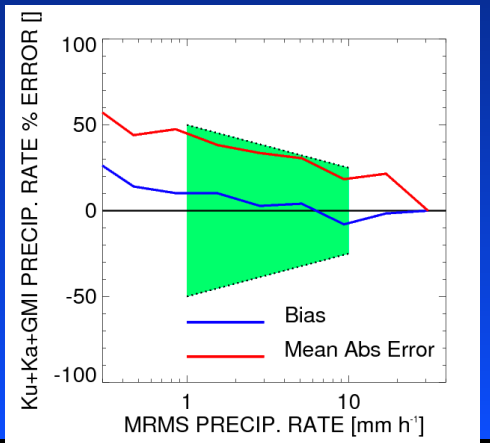




V06X FS (Ku+Ka+GMI) Inner Swath

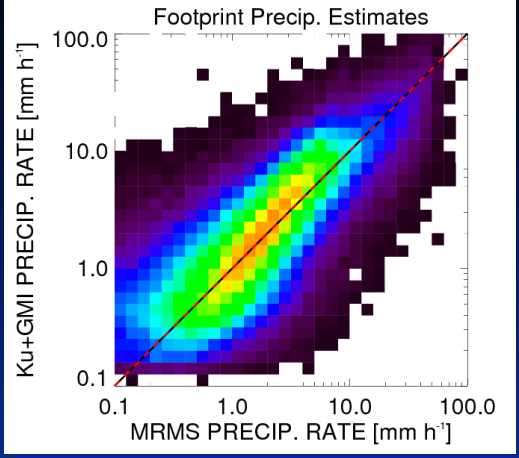


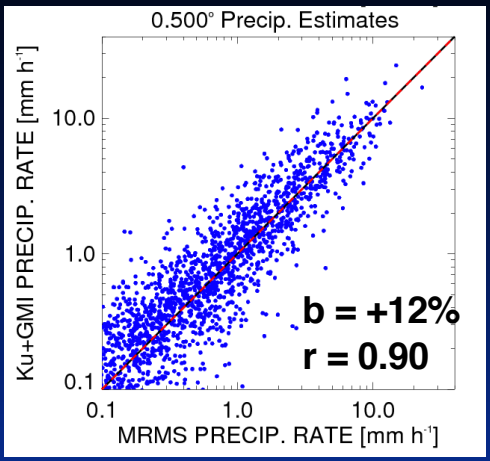


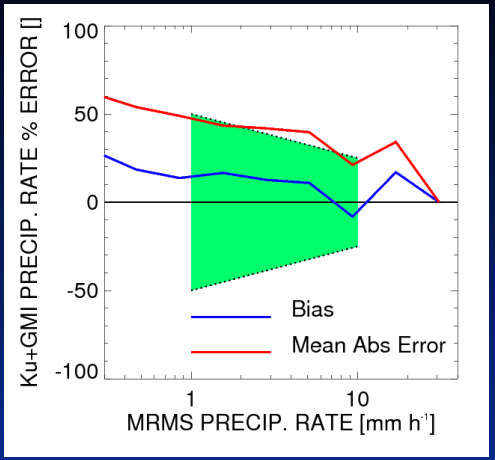


NS Comparisons with MRMS Calibrated Radar (JJA 2018 only)

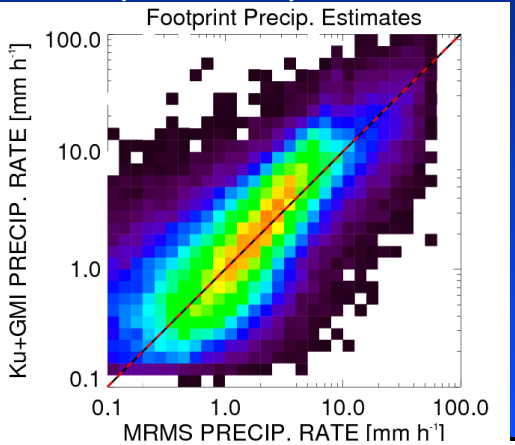
V06X NS (Ku+GMI) Full Swath

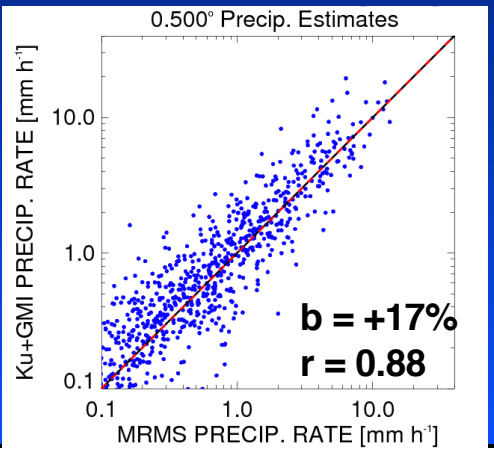


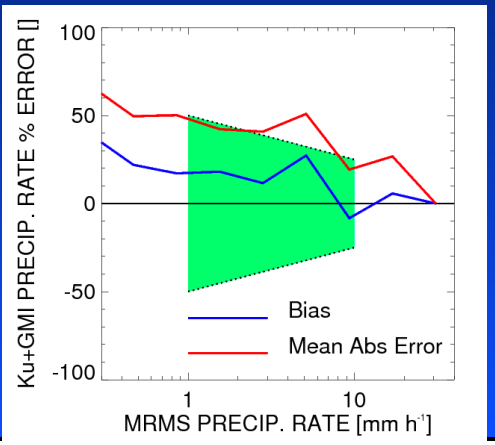




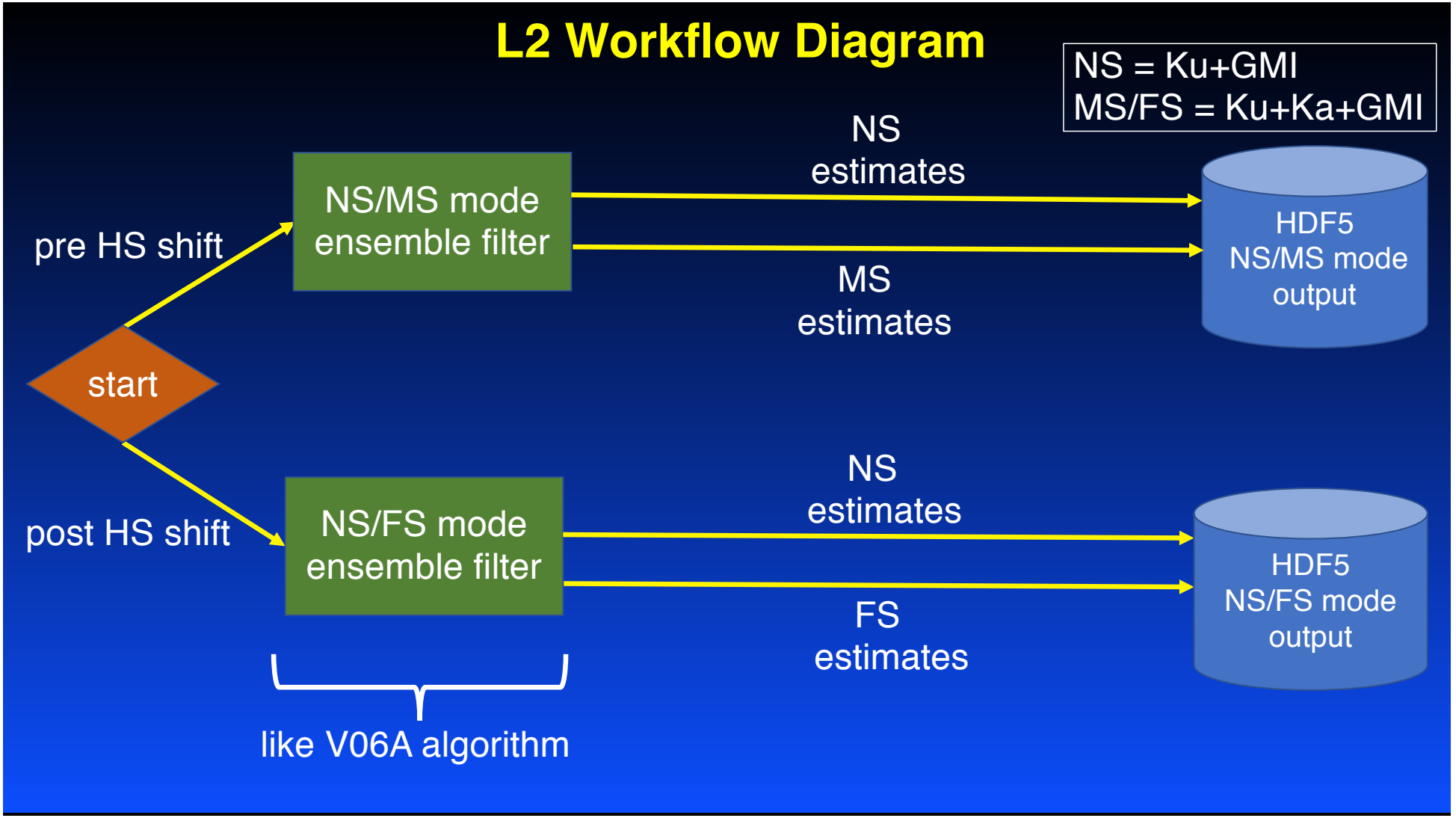
V06X NS (Ku+GMI) Inner Swath

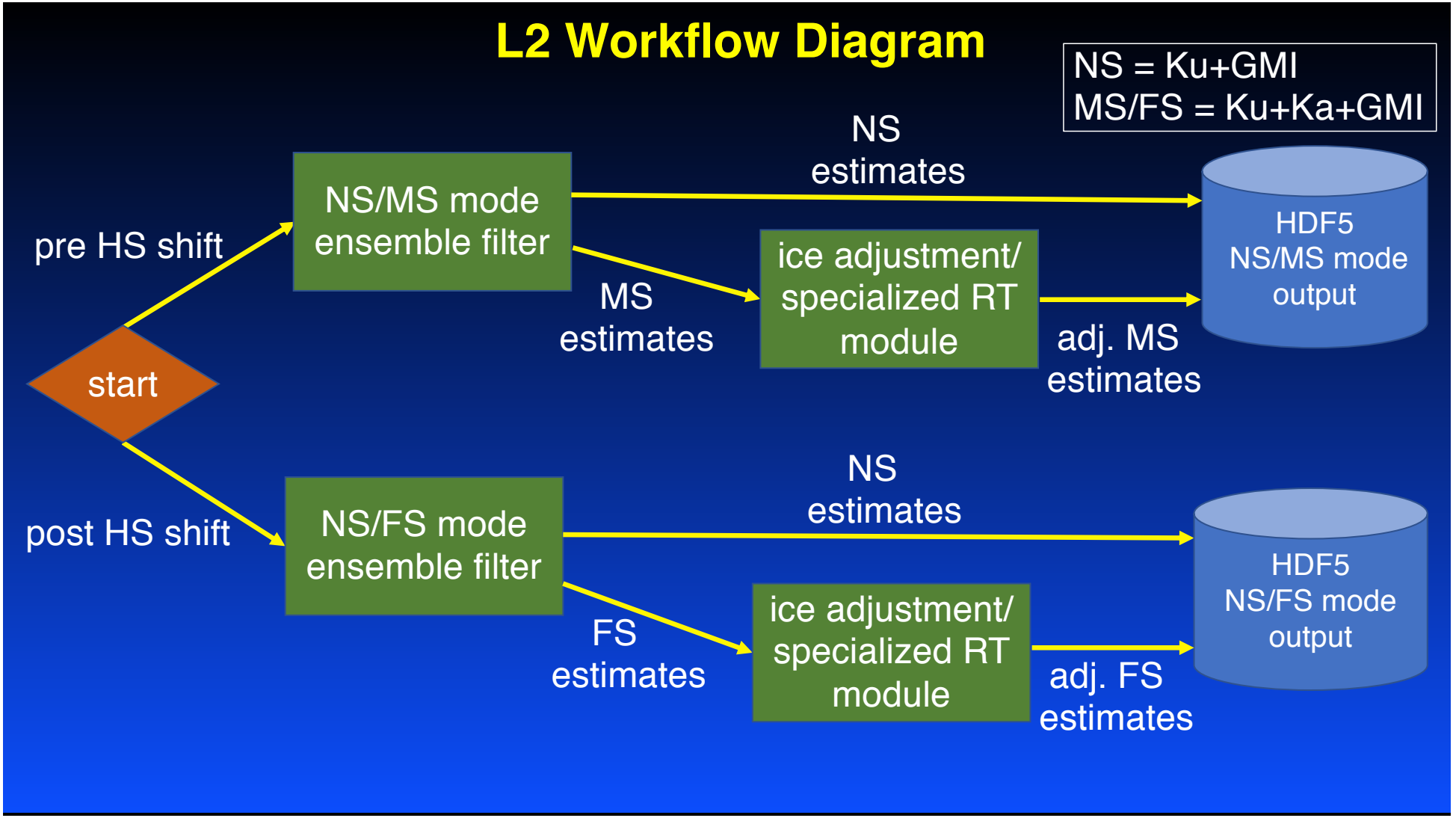






extras


L2 Workflow Diagram
NS = Ku+GMI
MS/FS = Ku+Ka+GMI
pre HS shift
start
post HS shift
NS/MS mode ensemble filter
NS/FS mode ensemble filter
like V06A algorithm
NS estimates
MS estimates
NS estimates
FS estimates
HDF5 NS/MS mode output
HDF5 NS/FS mode output

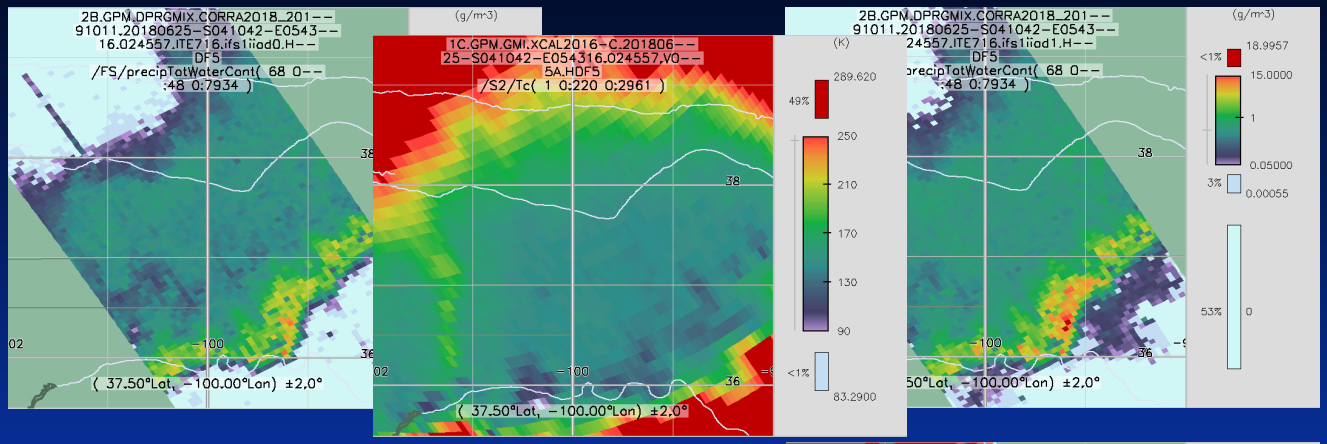

L2 Workflow Diagram
NS = Ku+GMI
MS/FS = Ku+Ka+GMI
pre HS shift
start
post HS shift
NS/MS mode ensemble filter
NS/FS mode ensemble filter
NS estimates
MS estimates
FS estimates
ice adjustment/ specialized RT module
ice adjustment/ specialized RT module
adj. MS estimates
adj. FS estimates
HDF5 NS/MS mode output
HDF5 NS/FS mode output

Effects of Precipitating Ice Adjustment

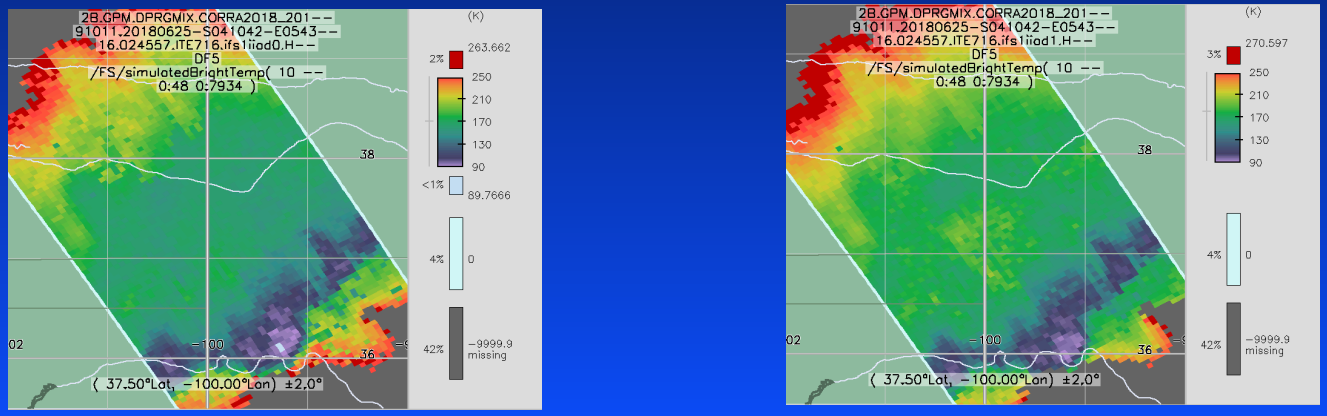
V06X

Adjusted V06X

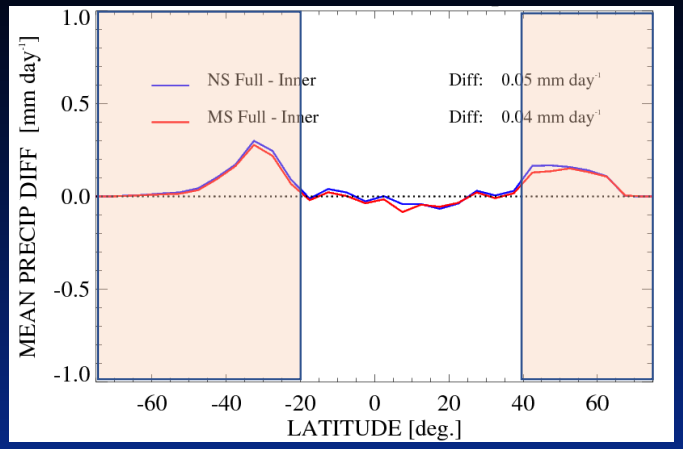
Precip at ~4.5 km



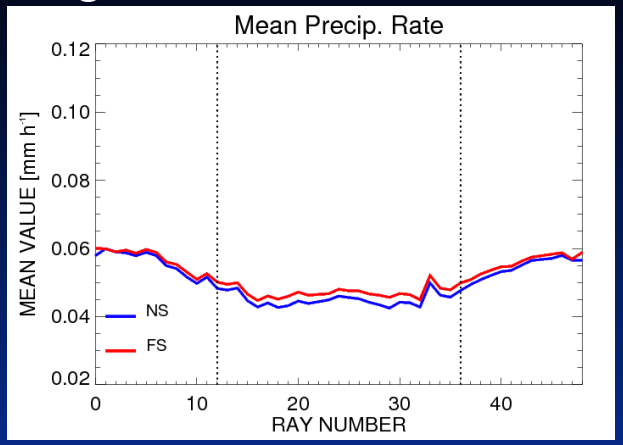
Simulated 166 GHz H

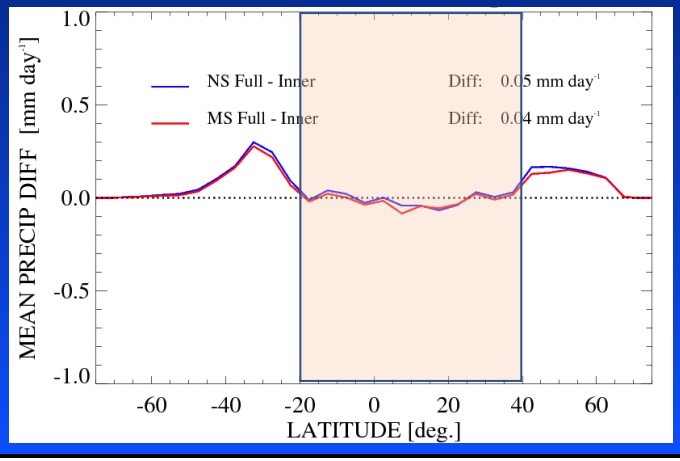


V06X JJA 2018 Averages of FS Full vs Inner Swath

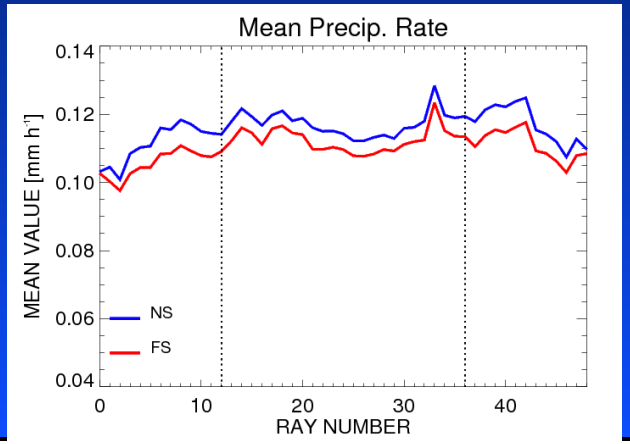


Region lat < 20 S or lat > 40 N





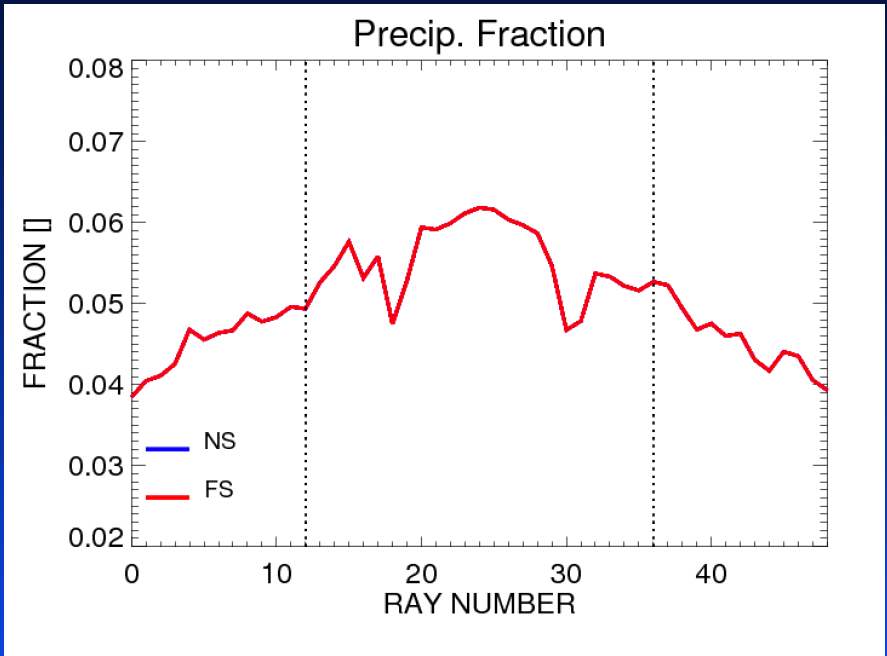
Region lat > 20 S and lat < 40N



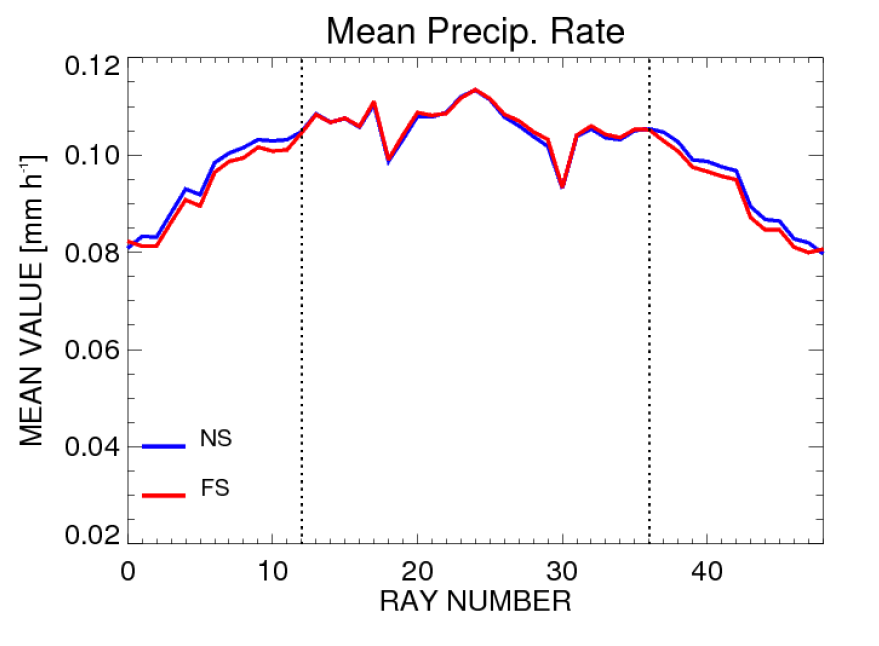
Do we see any anomalies across the swath?

- June 2018 mean surface rain fraction and rate at each scan angle over ocean:

V06X



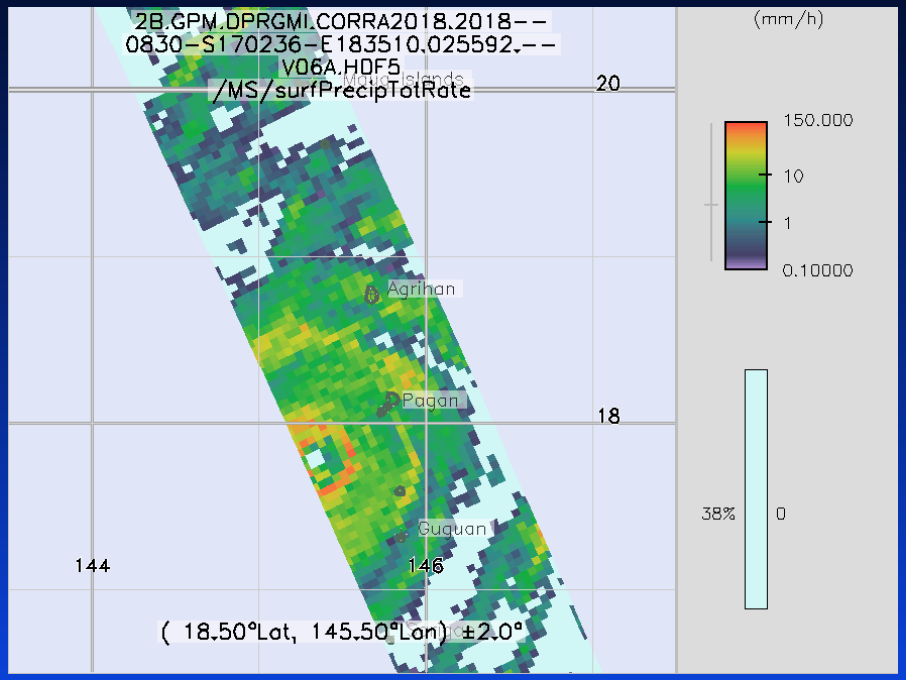
V06X



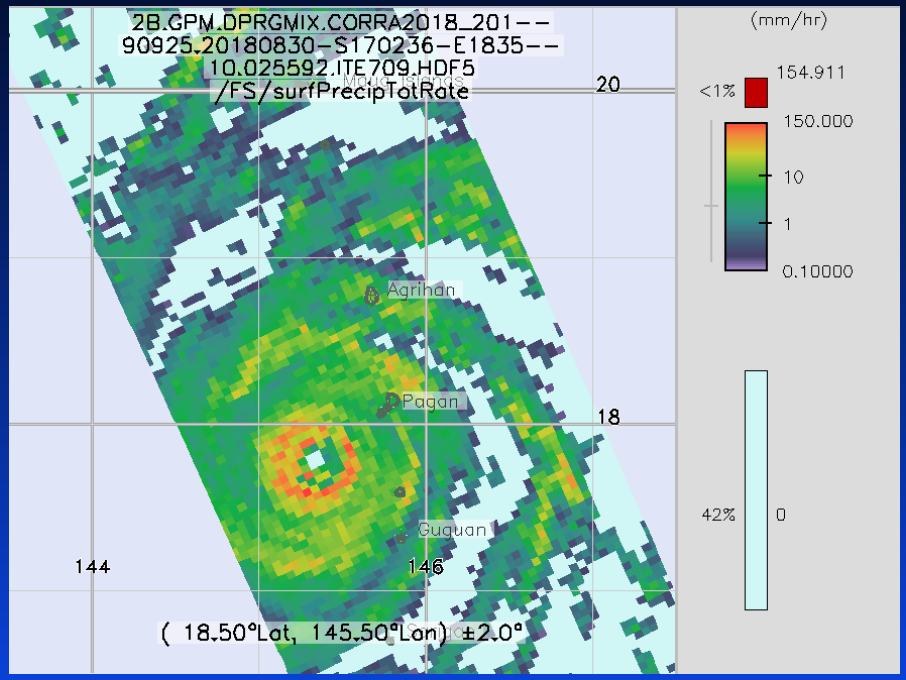
- need estimated surface rain rate product, but how good will that be?

Example of Super Typhoon Jebi (Aug. 30, 2018)

V06A MS Mode (Ku+Ka+GMI)

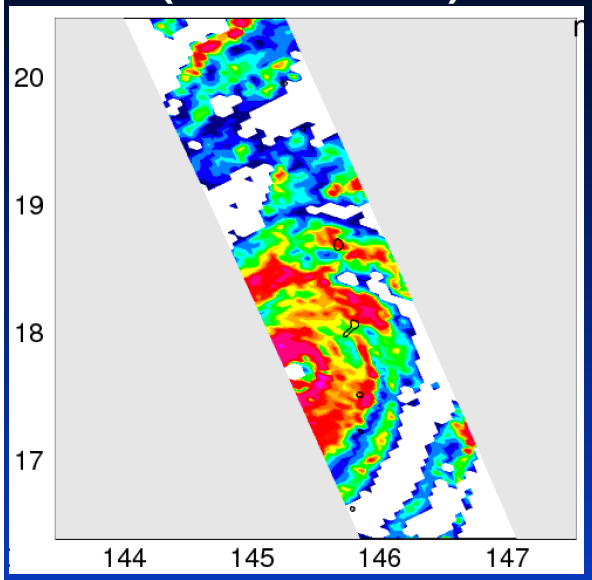


V06X FS Mode(Ku+Ka+GMI)

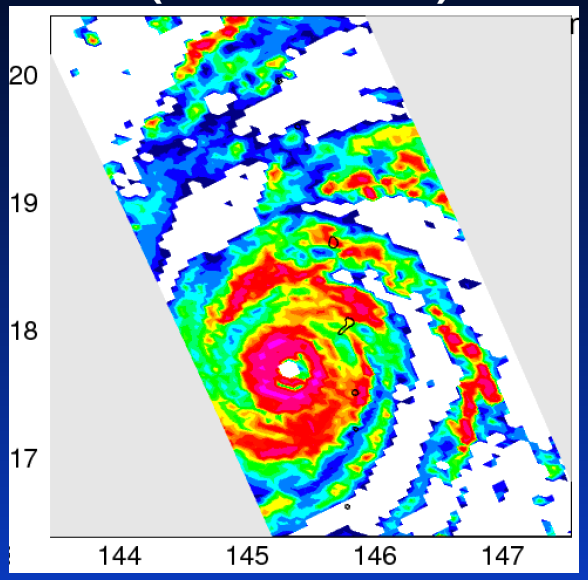


Example of Super Typhoon Jebi (Aug. 30, 2018)

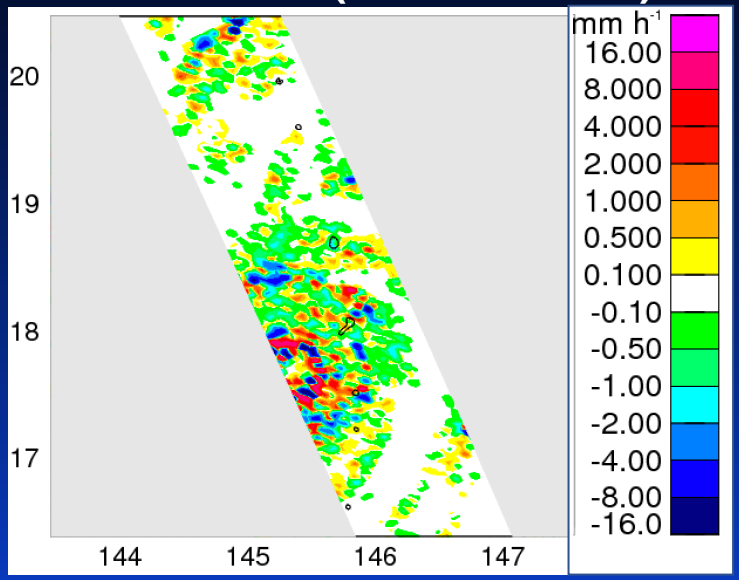
V06A MS Mode (Ku+Ka+GMI)



V06X FS Mode (Ku+Ka+GMI)

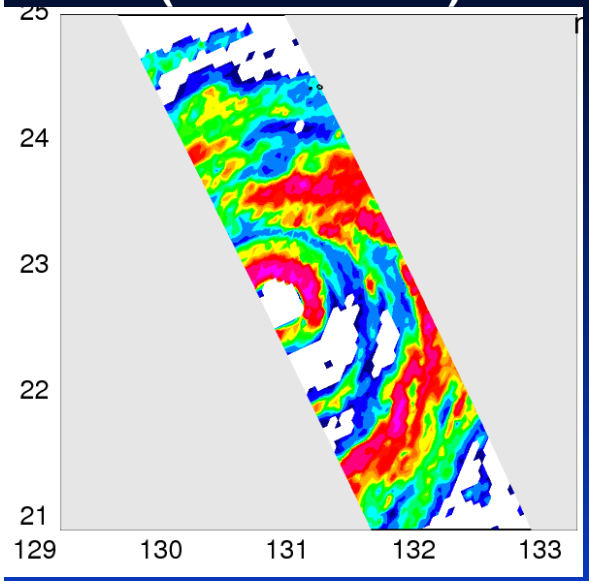


Difference (V06X – V06A)

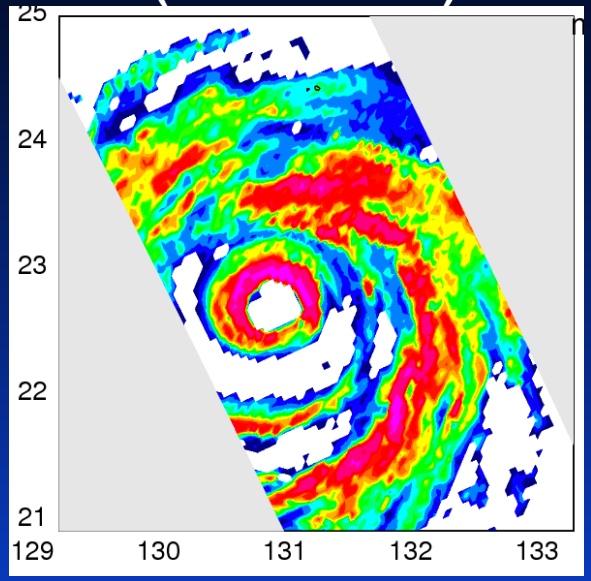


Example of Super Typhoon Maria (Jul. 9, 2018)

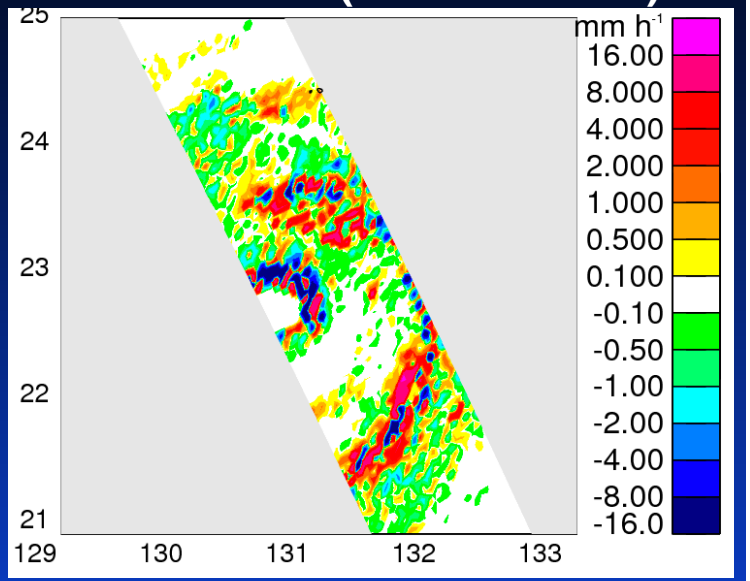
V06A MS Mode (Ku+Ka+GMI)



V06X FS Mode (Ku+Ka+GMI)

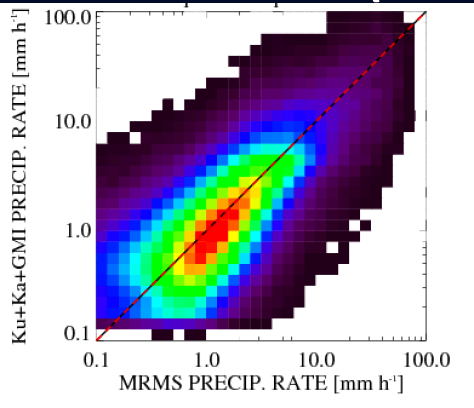


Difference (V06X – V06A)

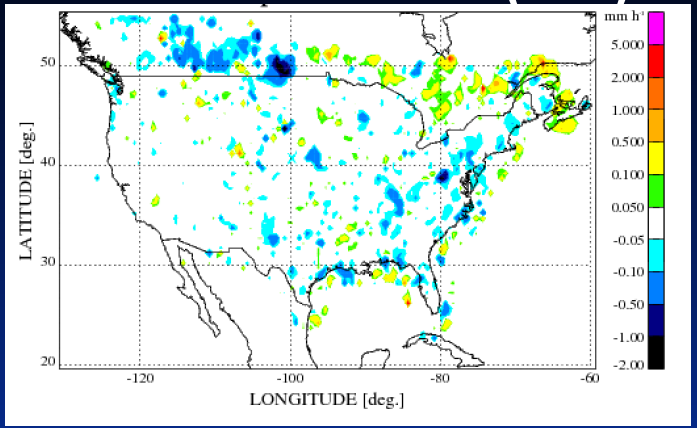


September, 2014 - August, 2015, GPM vs MRMS Comparisons

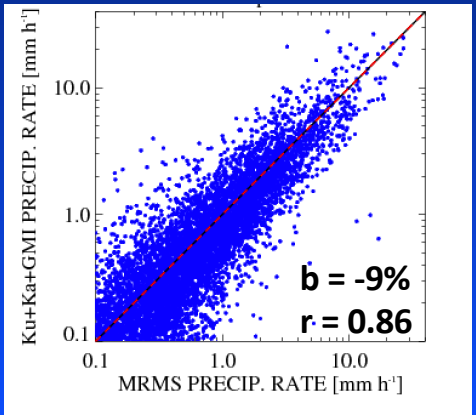
GPM V06 vs. MRMS (Footprint)



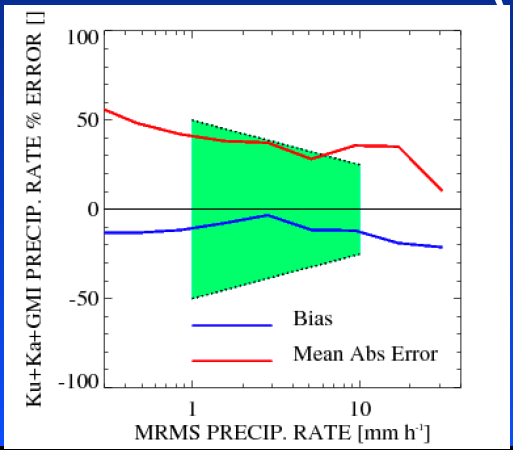
GPM V06 – MRMS (0.5°)



GPM V06 vs. MRMS (0.5°)



GPM V06 Error vs. MRMS (0.5°)



Synopsis, and Looking Ahead

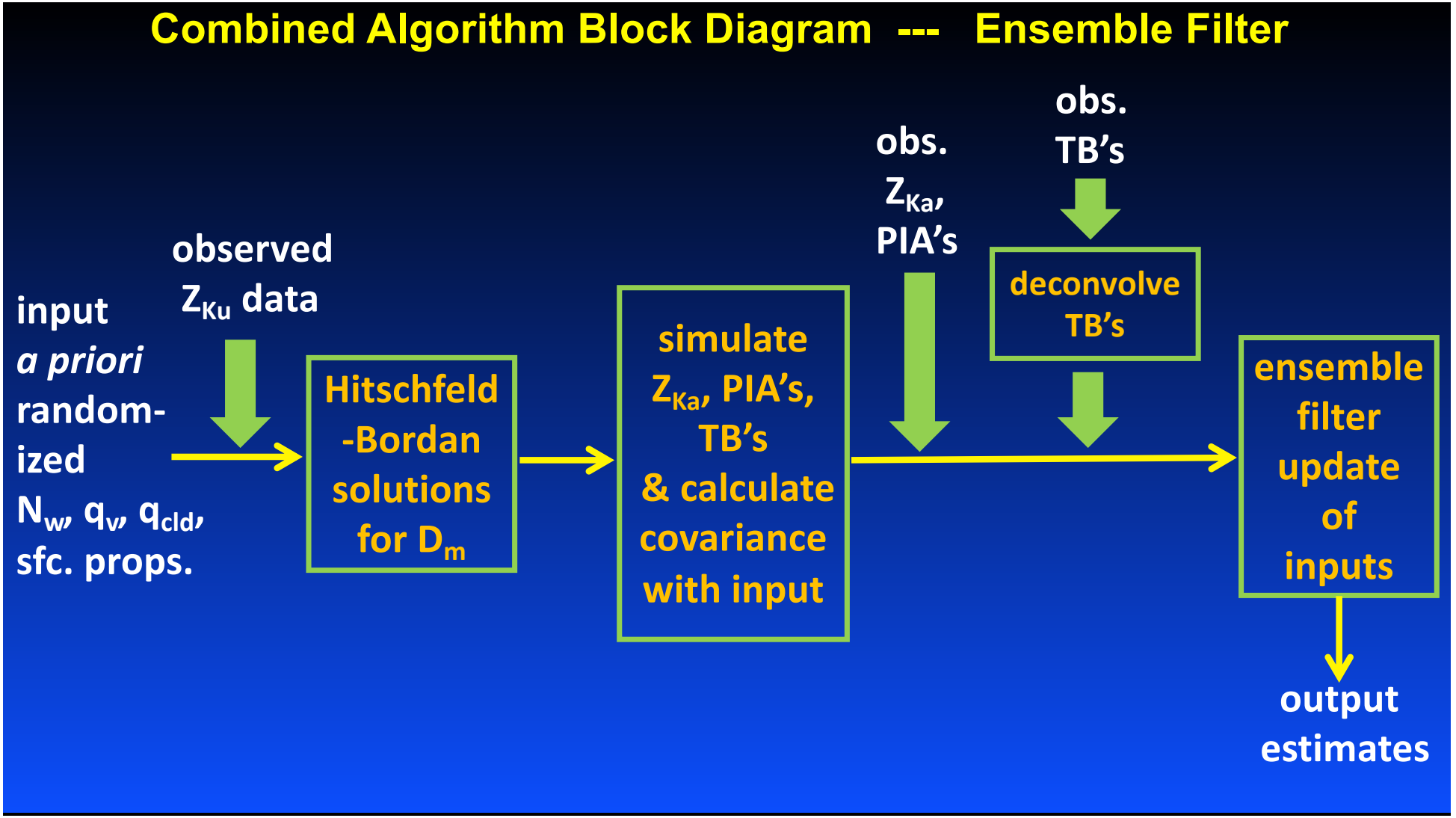
- Succeeded in creating TRMM V08 algorithm that shares the same core as GPM V06.
- TRMM estimates sensitive to deconvolution; more testing needed.

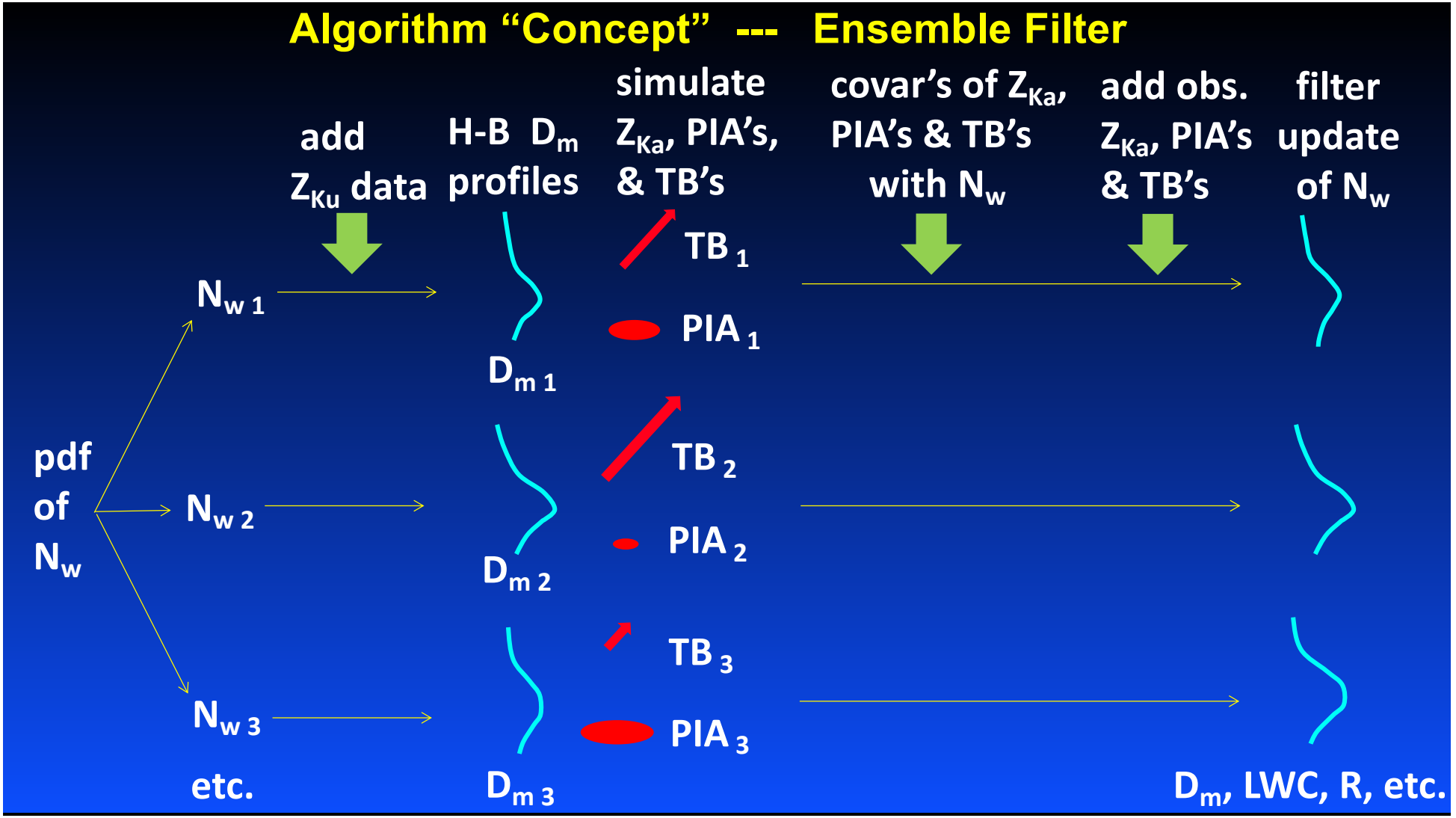
◆ Radiometer-based estimates when radar signal fails to detect precip.

◆ Improved physics of ice/mixed-phase precipitation, multiple scat., etc.

◆ Need to link *a priori* assumptions to meteorological conditions – 2 step process.

◆ Outer swath HS Ka-band application will be implemented.

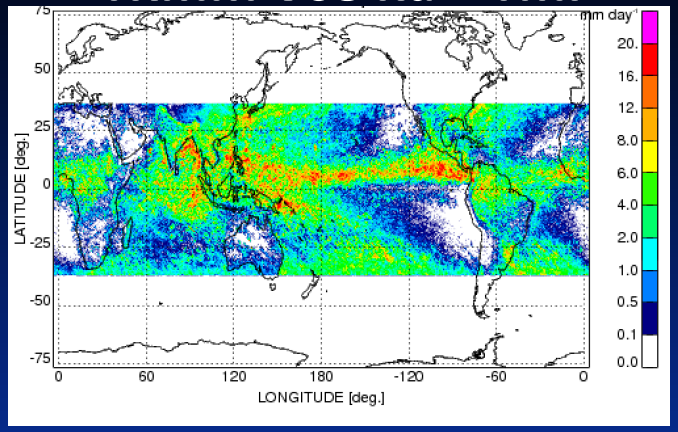

Combined Algorithm Block Diagram --- Ensemble Filter
input
a priori
random-
ized
N_w, q_v, q_cld,
sfc. props.
observed
Z_Ku data
Hitschfeld
-Bordan
solutions
for D_m
simulate
Z_Ka, PIA's,
TB's
& calculate
covariance
with input
obs.
Z_Ka,
PIA's
obs.
TB's
deconvolve
TB's
ensemble
filter
update
of
inputs
output
estimates


Algorithm "Concept" --- Ensemble Filter
add Z_{Ku} data
H-B D_m profiles
simulate Z_{Ka}, PIA's, & TB's
covar's of Z_{Ka}, PIA's & TB's with N_w
add obs. Z_{Ka}, PIA's & TB's
filter update of N_w
pdf of N_w
$N_{w\,1}$
$N_{w\,2}$
$N_{w\,3}$
etc.
$D_{m\,1}$
$D_{m\,2}$
$D_{m\,3}$
TB_1
PIA_1
TB_2
PIA_2
TB_3
PIA_3
D_m, LWC, R, etc.

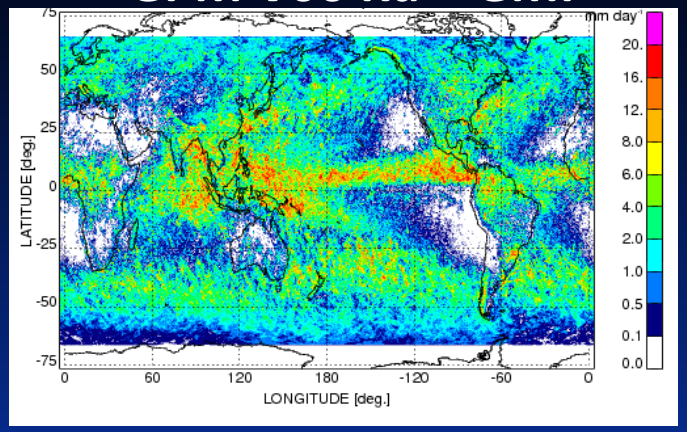
April – September, 2014, Average Plan Views

0.25°

TRMM V08 Ku + TMI

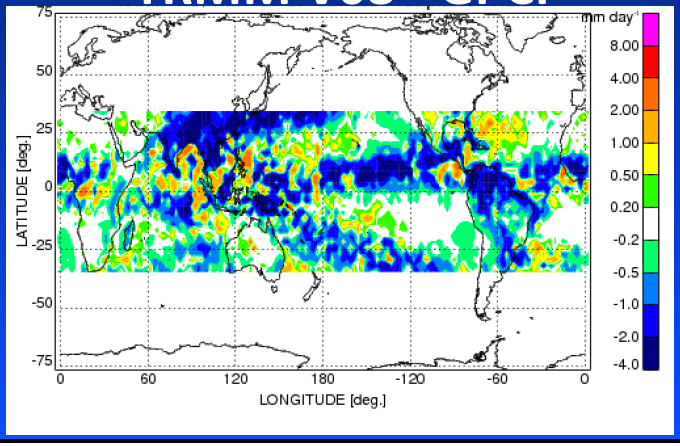


GPM V06 Ku + GMI

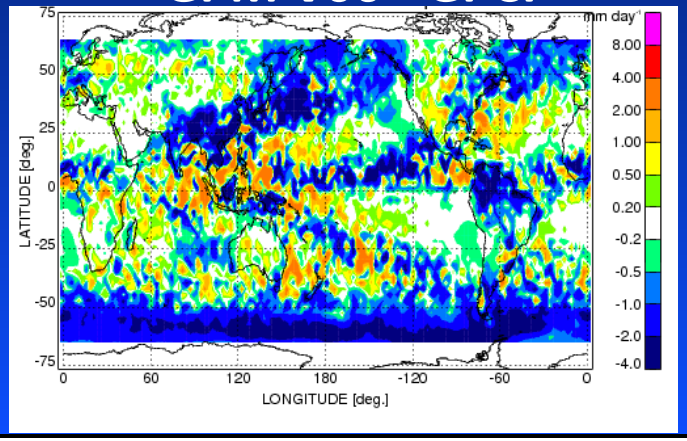


2.5°

TRMM V08 - GPCP



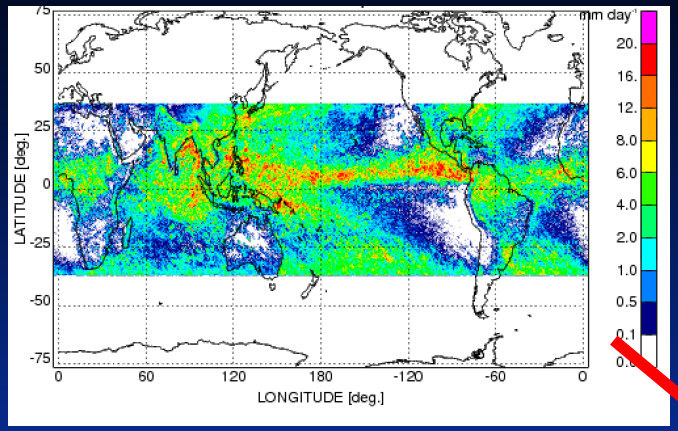
GPM V06 - GPCP



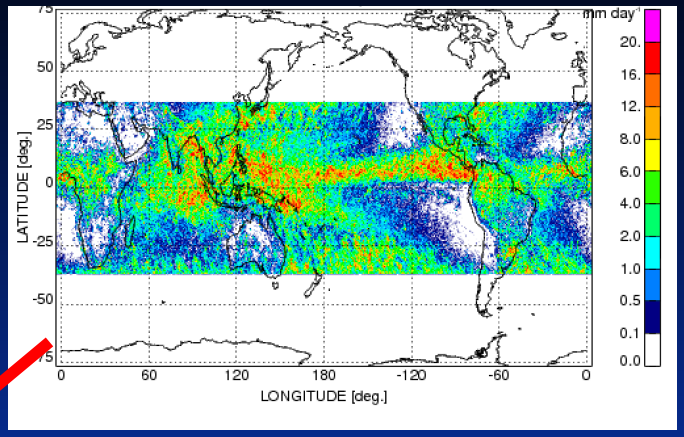
April – September, 2014, Average Plan Views

0.25°

TRMM V08 Ku + TMI

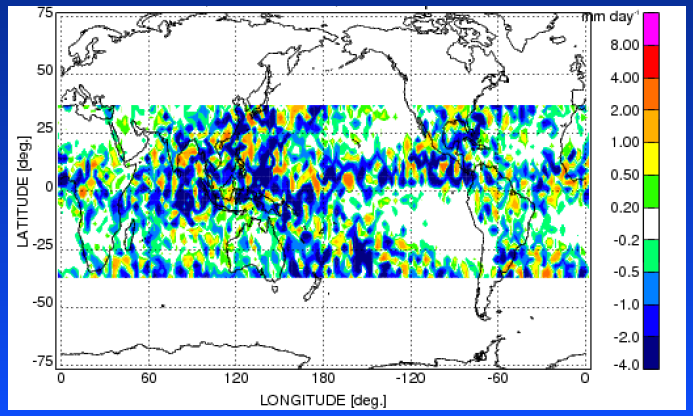


GPM V06 Ku + GMI



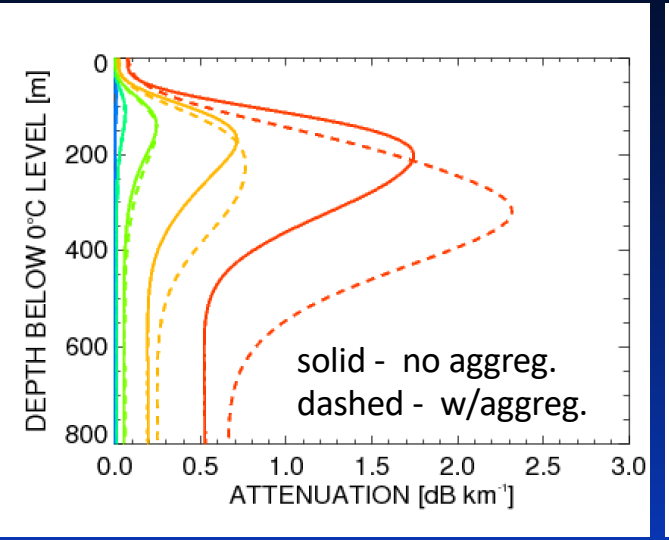
2.5°

TRMM V08 – GPM V06

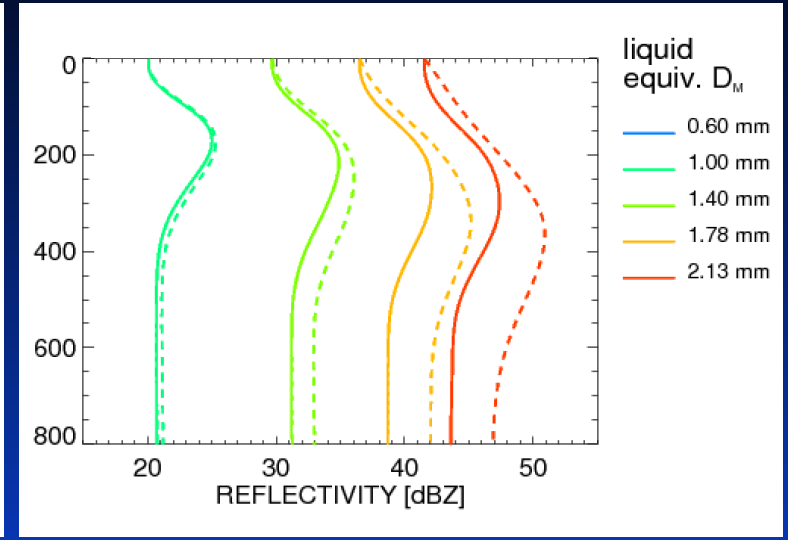


Effect of Aggregation on Attenuation/Reflectivity

13.6 GHz Attenuation



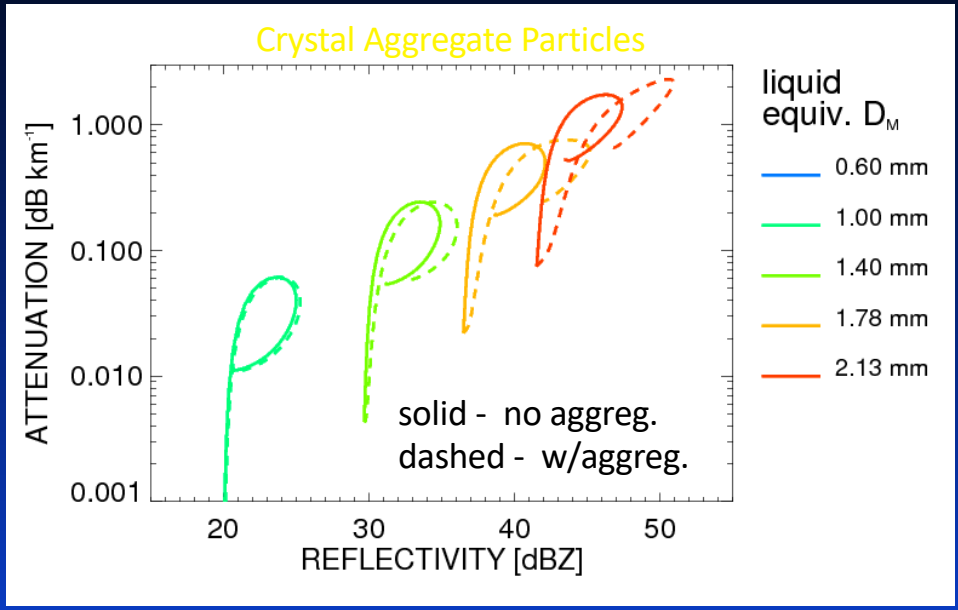
13.6 GHz Atten. Reflectivity



solid- no aggregation
dashed- with aggregation

Effect of Aggregation on Attenuation/Reflectivity

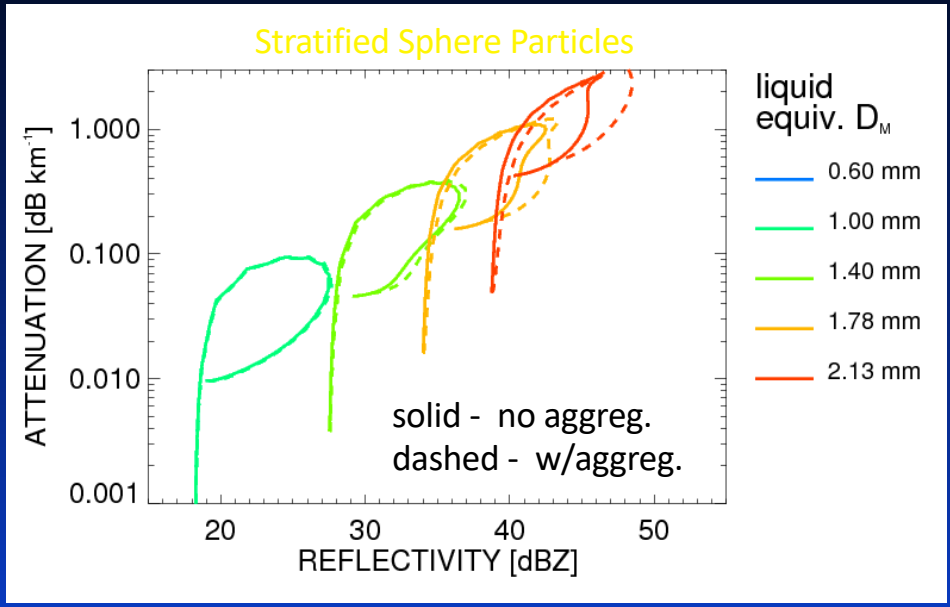
13.6 GHz Attenuation vs. Reflectivity



solid- no aggregation
dashed- with aggregation

Effect of Aggregation on Attenuation/Reflectivity

13.6 GHz Attenuation vs. Reflectivity



solid- no aggregation
dashed- with aggregation