Evaluating and Comparing SeaWinds Backscatter Image Formation Algorithms

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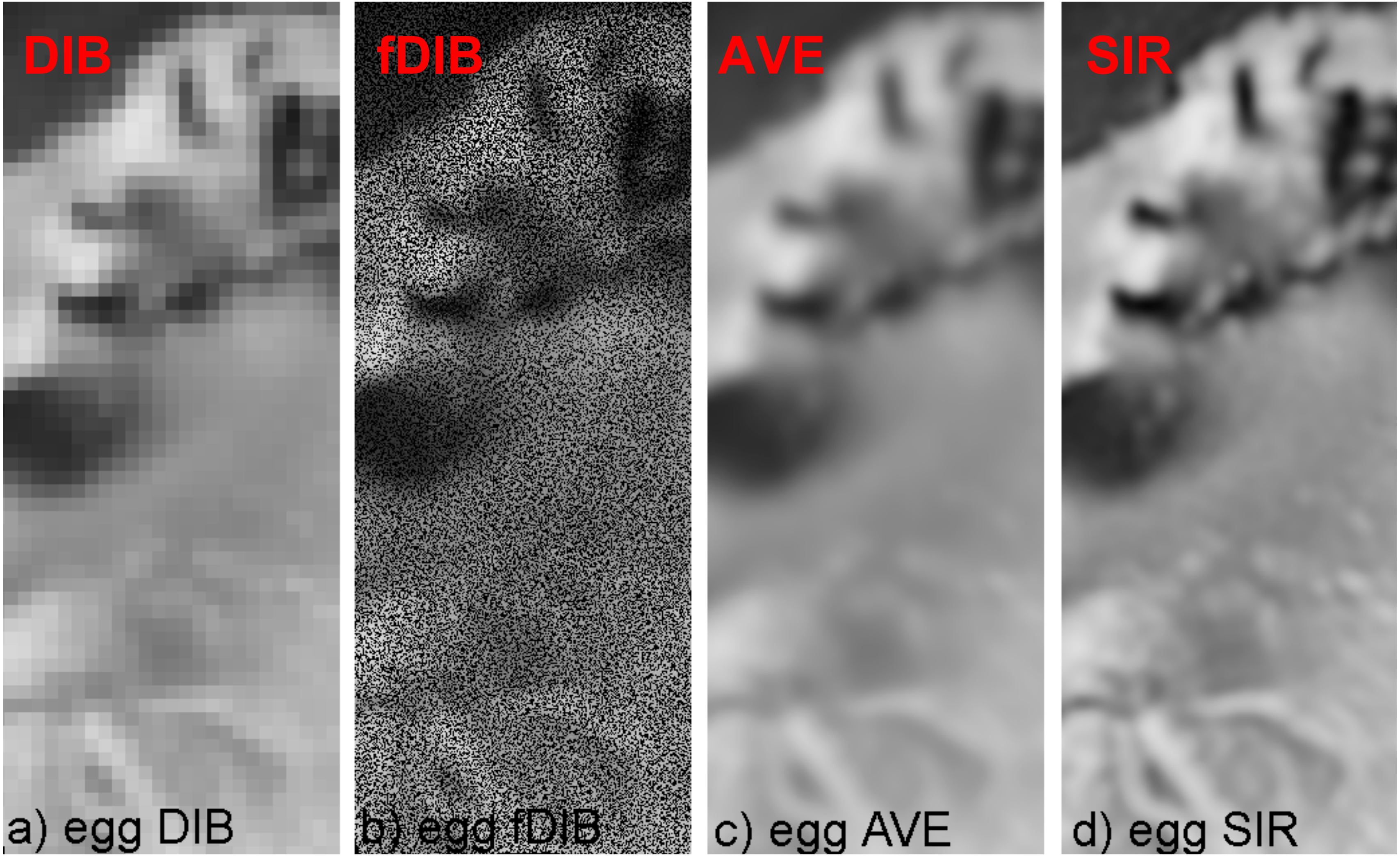
Scatterometer Climate Record Pathfinder www.scp.byu.edu

SeaWinds Sigma-0 Image Formation

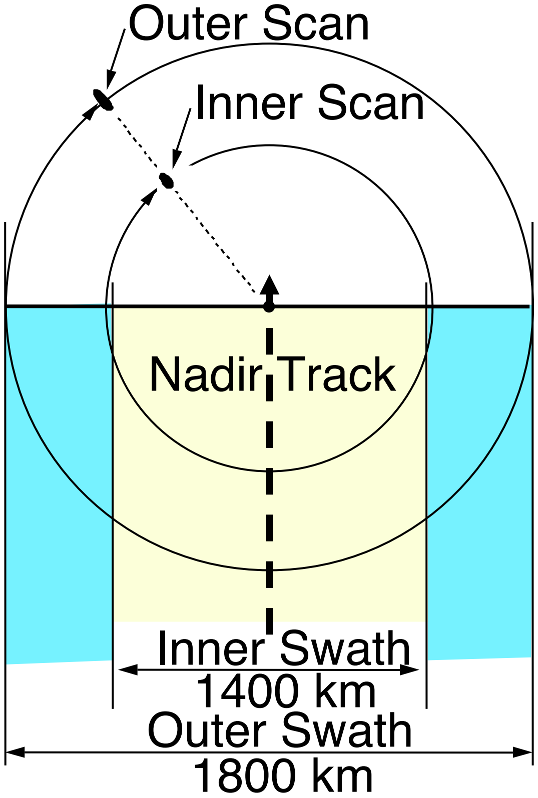
- Primarily used for land/ice applications
  - Tradeoff between noise and resolution
- Conventional imaging: "drop-in-bucket" **DIB**
  - Average measurements whose center fall within 25 km grid
- Fine resolution DIB (**fDIB**) (aka 'dense sampling method')
  - DIB with smaller pixel size
- Reconstruction: **SIR** (or **AVE**=first iteration of SIR)
  - Signal reconstruction on fine resolution grid
- Also considered Backus-Gilbert (**BG**)

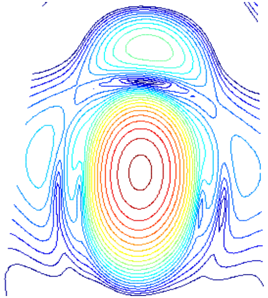
Egg image examples



SeaWinds Sampling

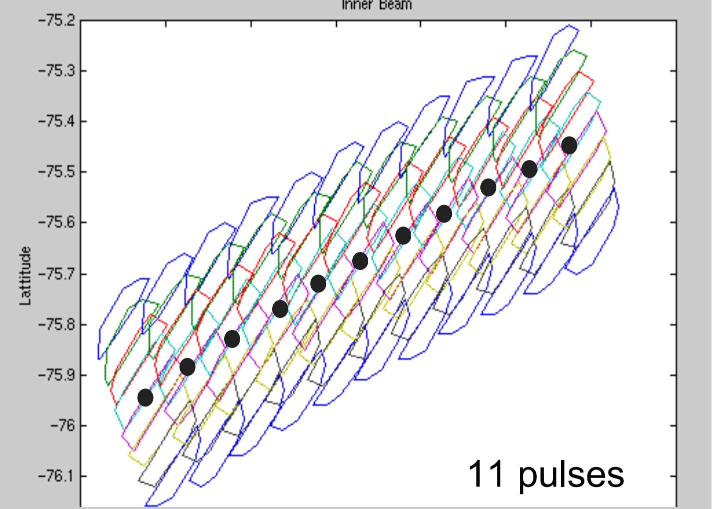
Local

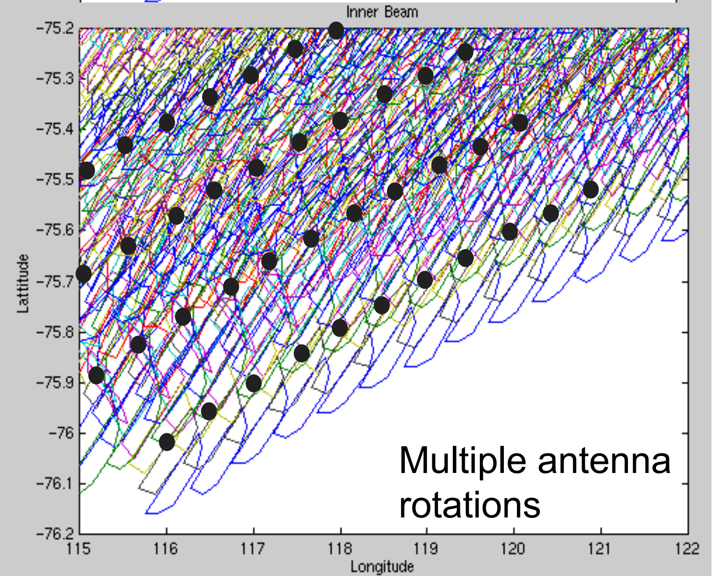




Egg
Response
24 x 31 km

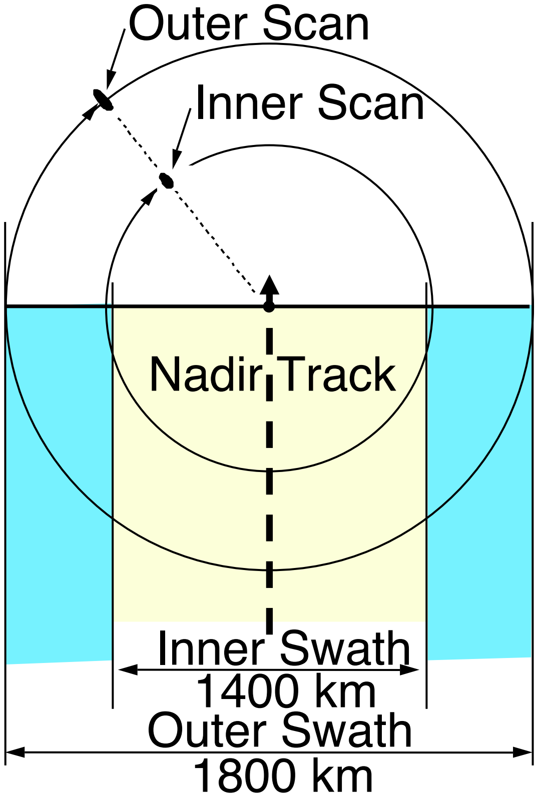
Slice
Response
~ 6 x 25 km





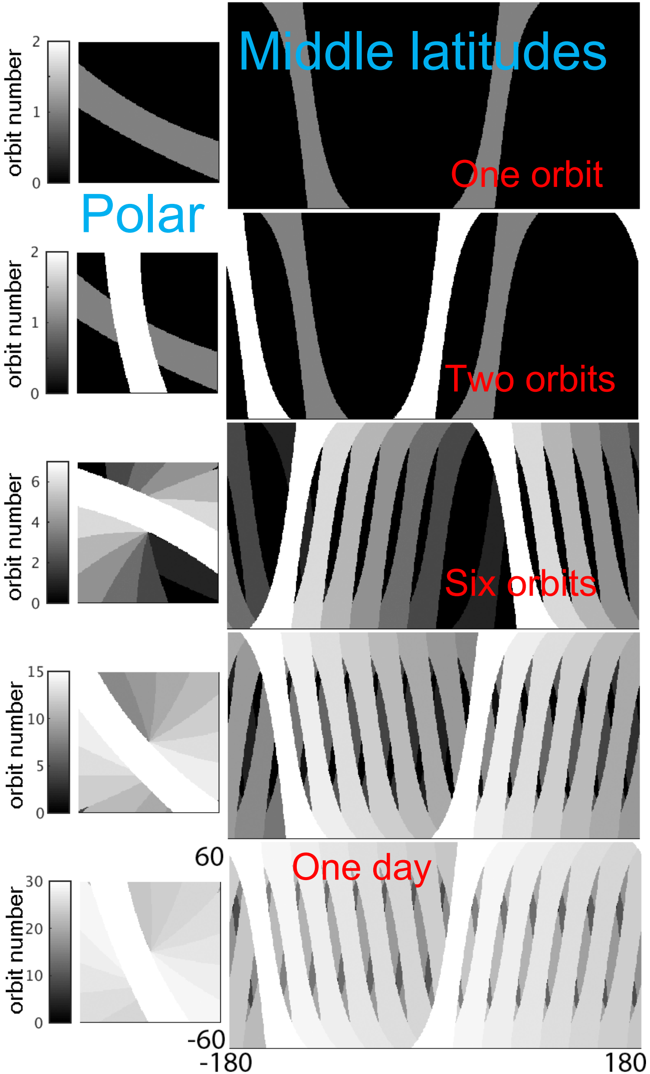
SeaWinds Sampling

Orbit

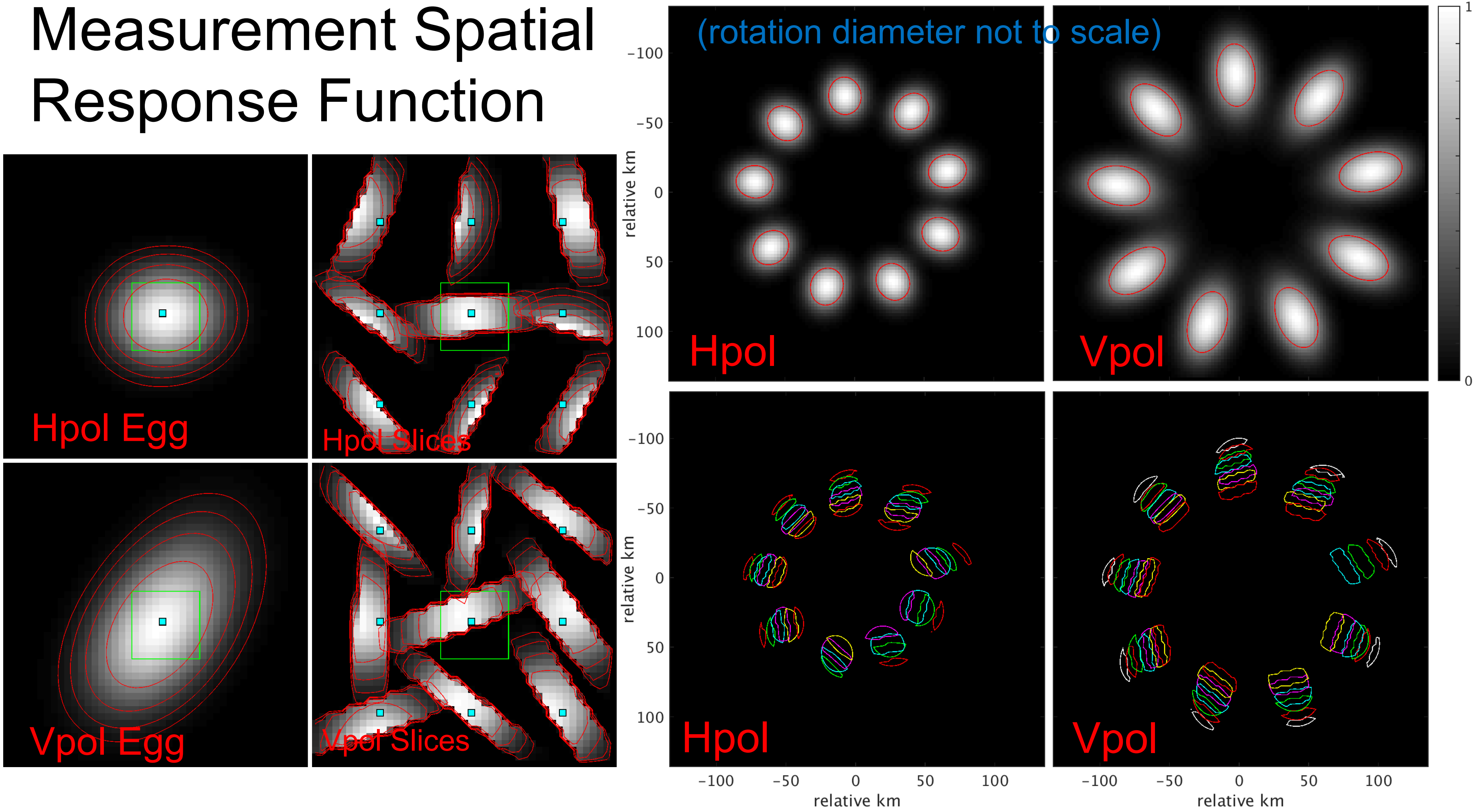


Combining multiple passes increases sampling density to improve resolution and effective SNR

Tradeoff between temporal change and SNR/resolution



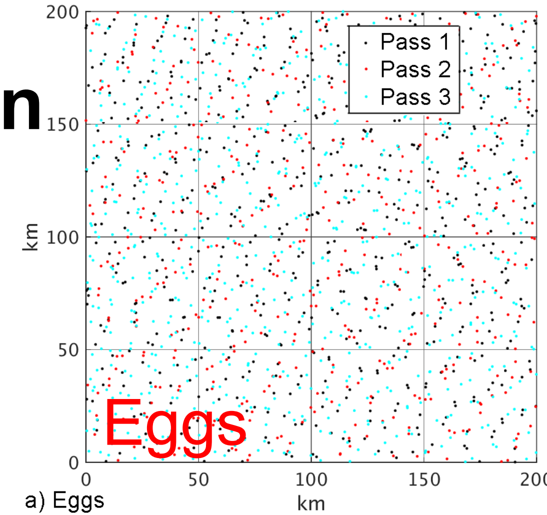
Measurement Spatial Response Function



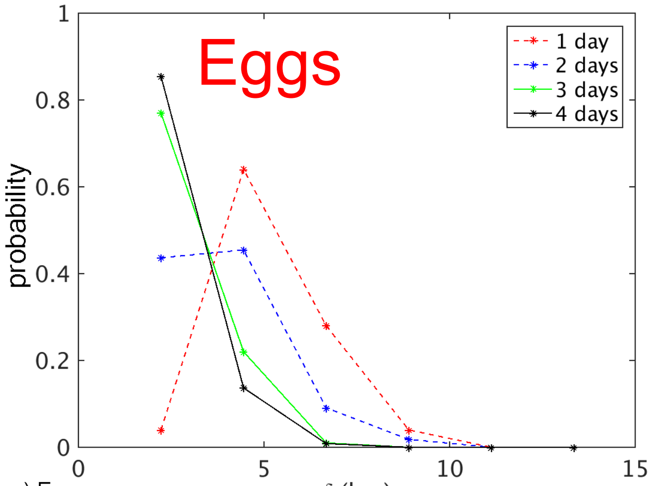
Sampling Density and Reconstruction

- ~3 km "delta-dense" sampling achieved
  - Within a few *days* for eggs
  - Within a few *passes* for slices

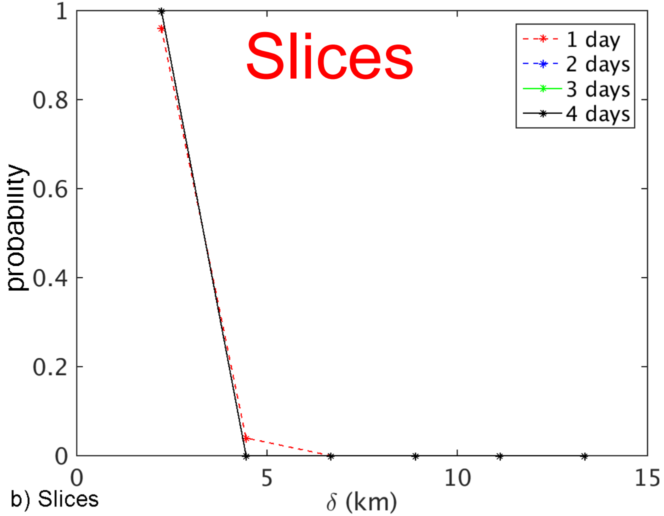
QuikSCAT sampling supports ~6 km reconstruction



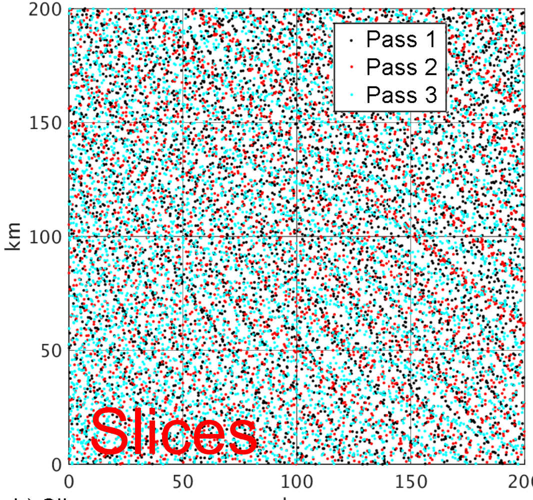
a) Eggs



a) Eggs



b) Slices

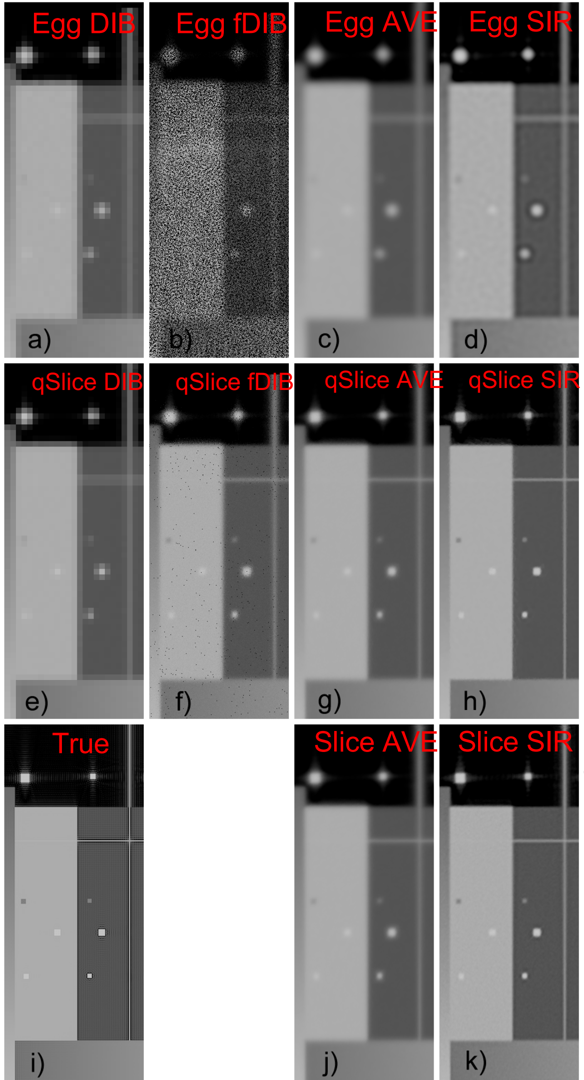


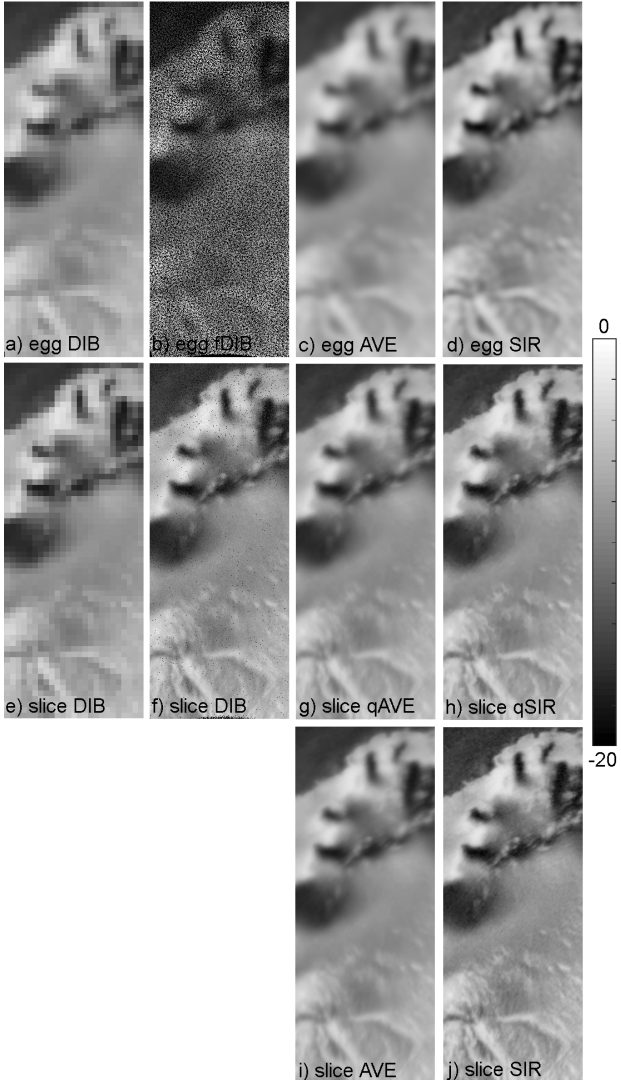
b) Slices

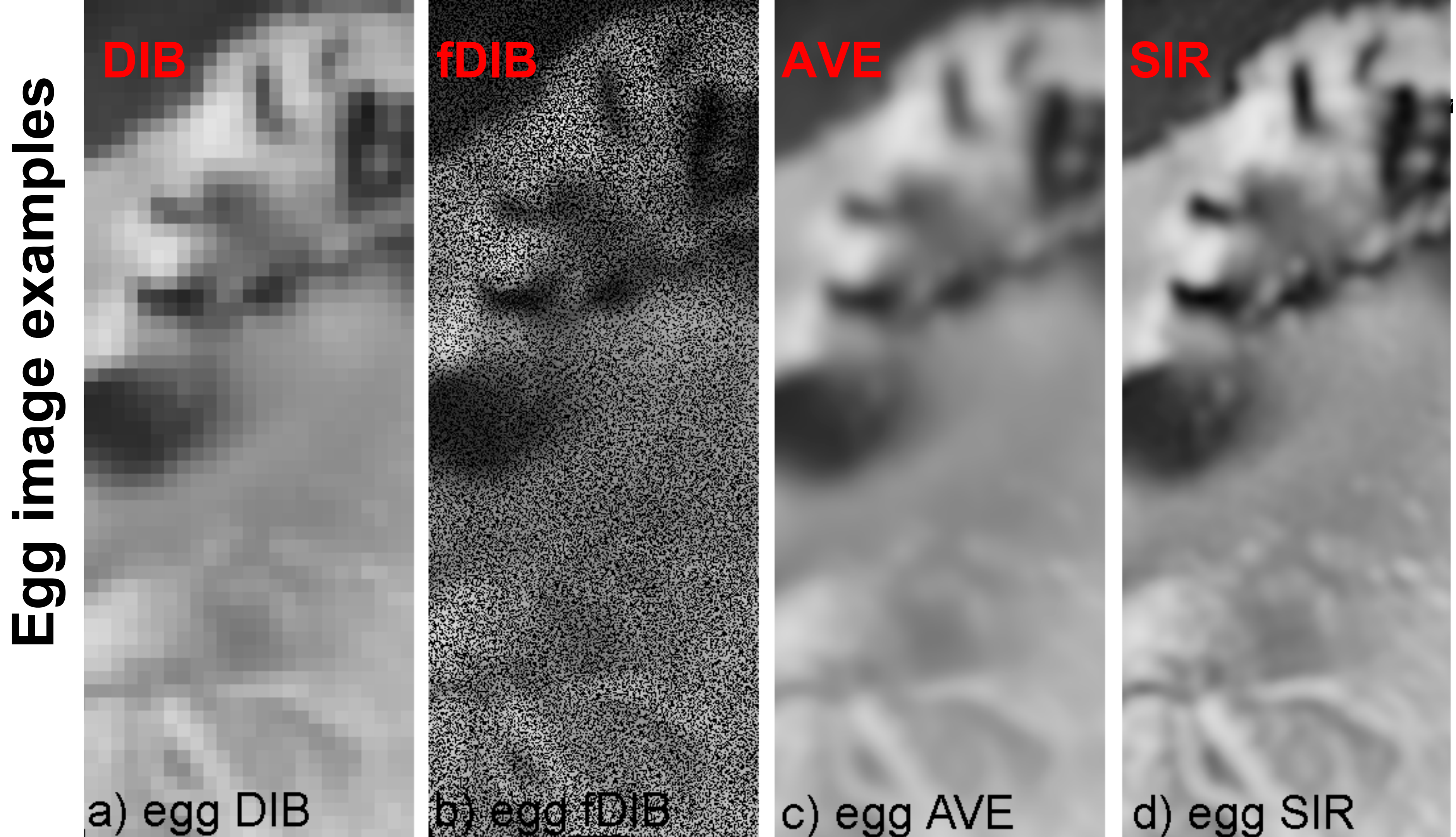
Simulation & Actual Results

For simulation, actual SRFs and sample locations used w/Monte Carlo noise

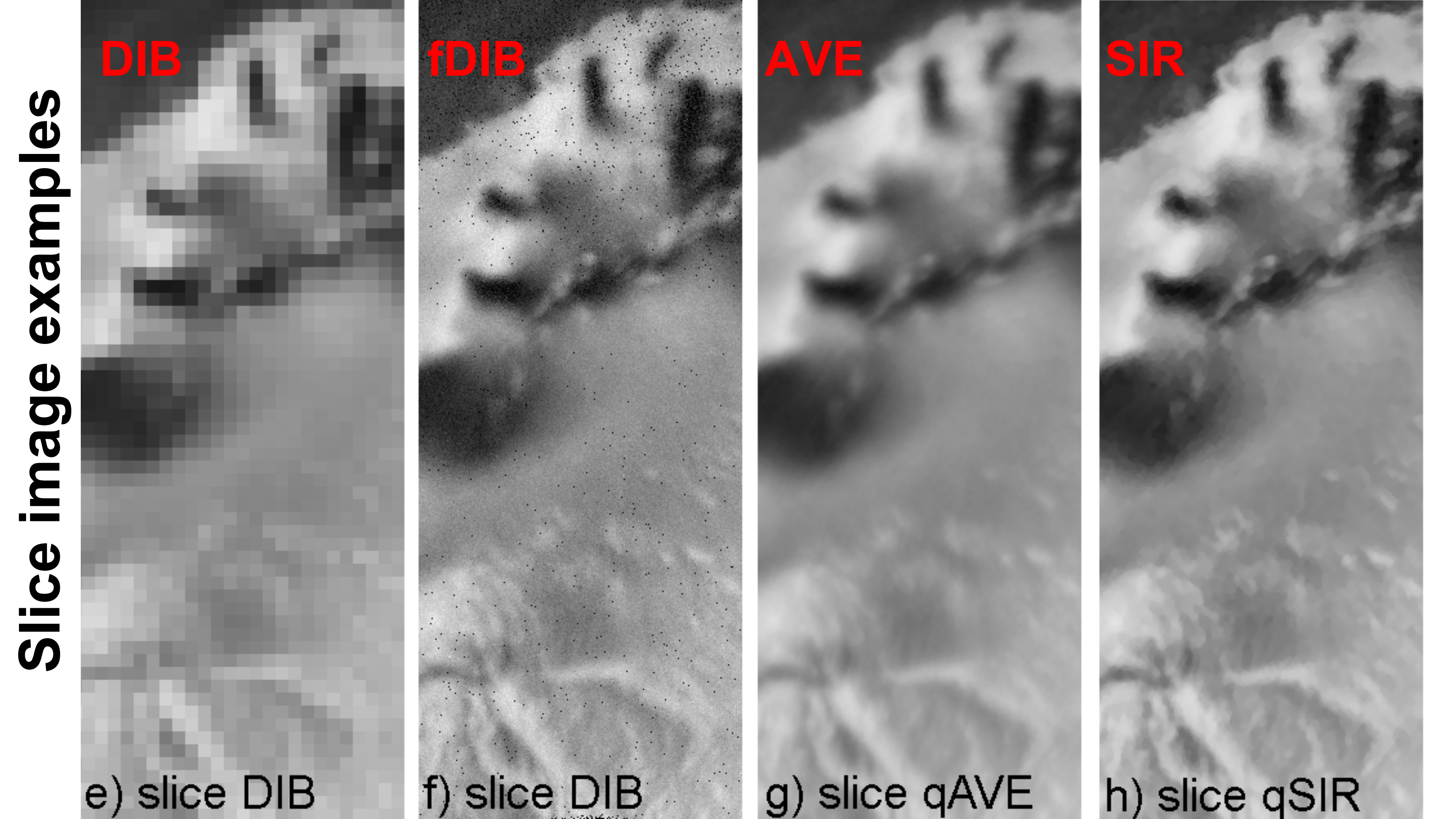
For real data, similar resolution enhancement and performance relative to DIB observed





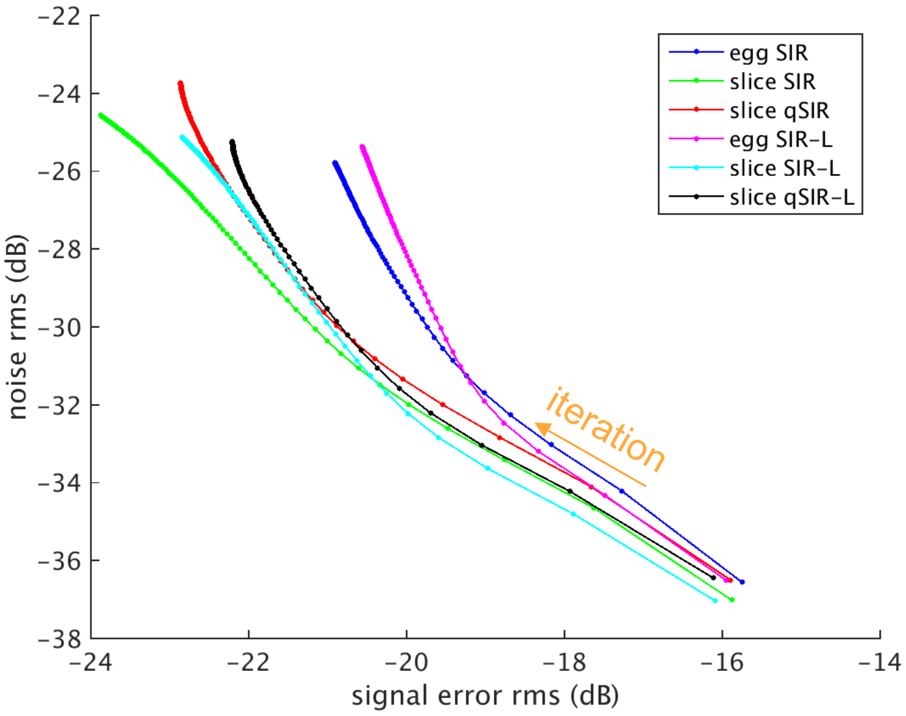


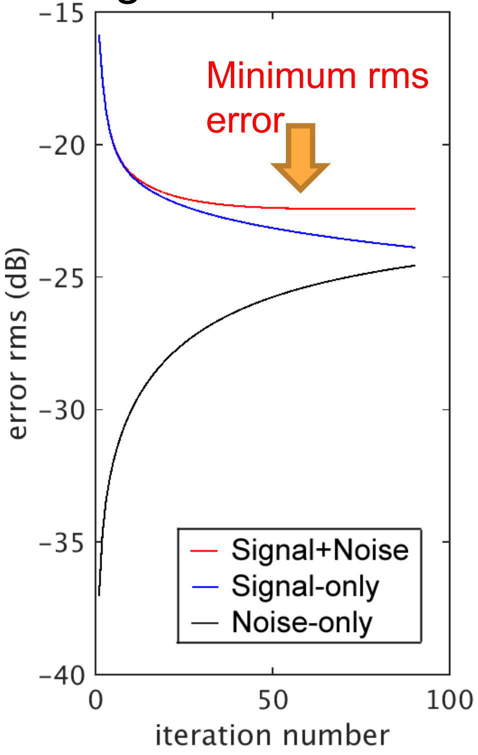
Egg image examples
DIB
fDIB
AVE
SIR
a) egg DIB
b) egg fDIB
c) egg AVE
d) egg SIR


Slice image examples
DIB
fDIB
AVE
SIR
e) slice DIB
f) slice DIB
g) slice qAVE
h) slice qSIR

SIR Noise and Resolution Tradeoffs

SIR enables tradeoff between noise and signal reconstruction by selection of the number of iterations used to create image

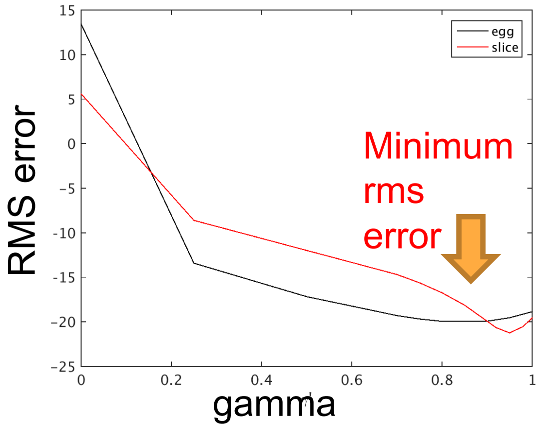


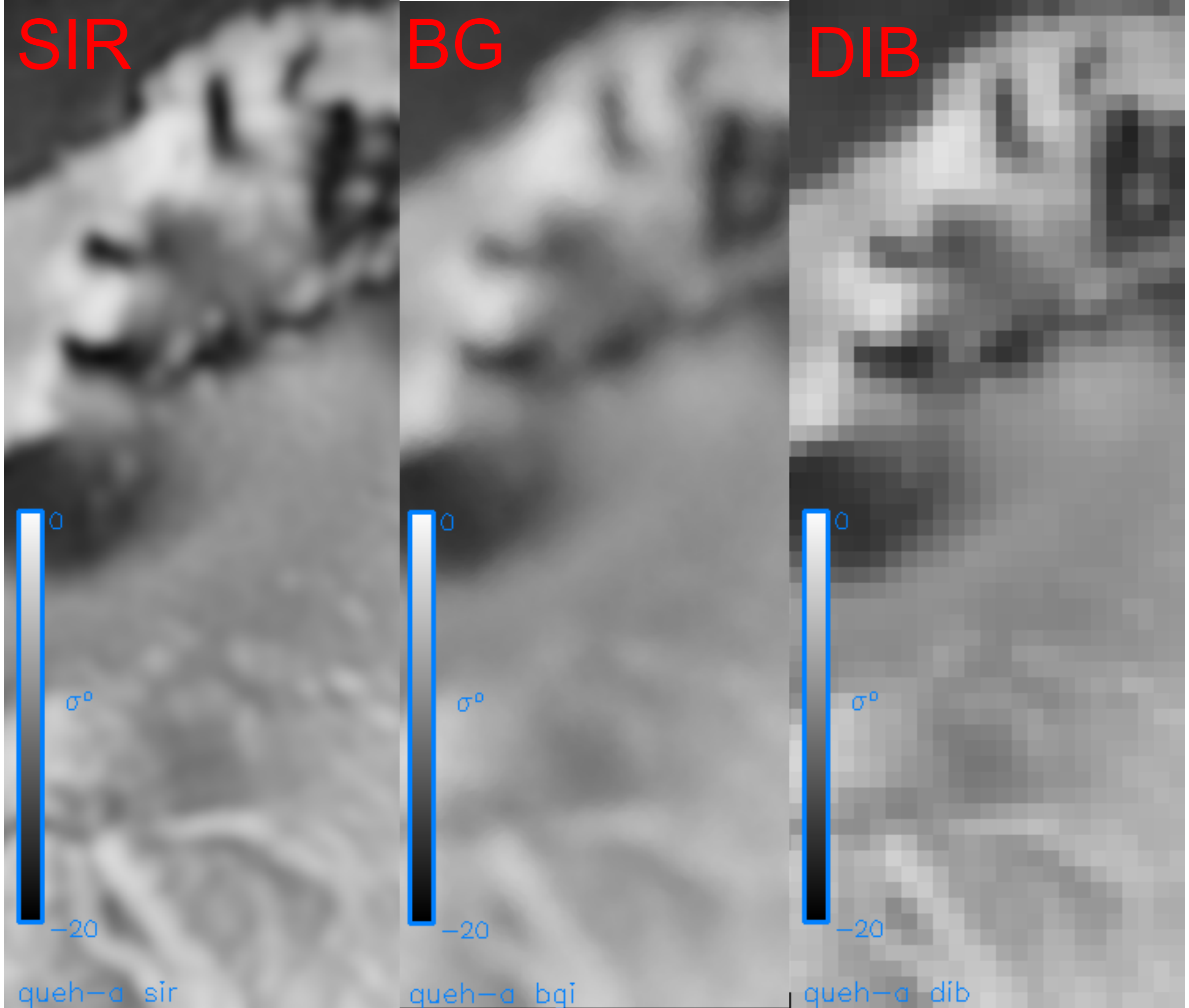


Backus Gilbert

Least-squares method
explicit noise/resolution
trade parameter gamma

BG with optimum gamma
not as good as SIR

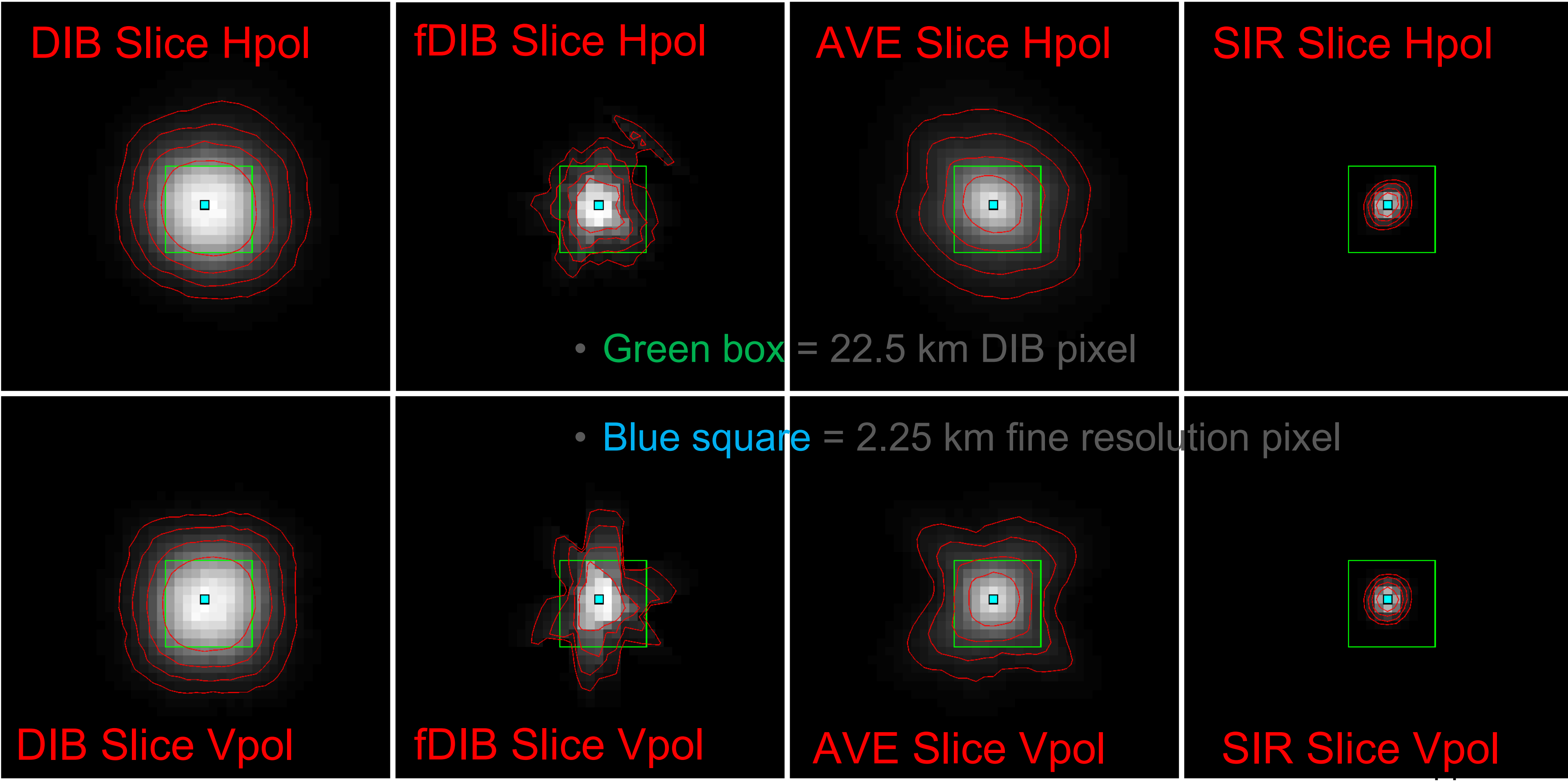




Derived Image Pixel Response Functions

- Green box = 22.5 km DIB pixel
- Blue square = 2.25 km fine resolution pixel
- Evaluated analytically or via simulation
- SIR achieves finest resolution with best regularity

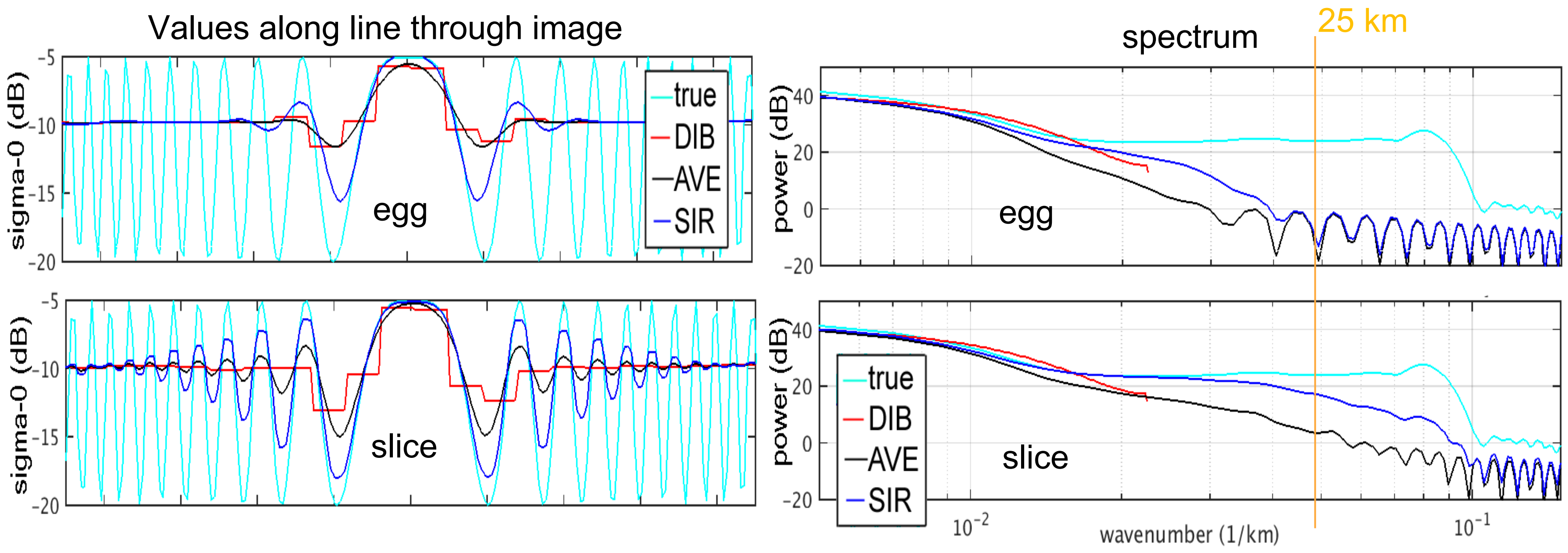
Derived Image Pixel Response Functions



- Green box = 22.5 km DIB pixel
- Blue square = 2.25 km fine resolution pixel

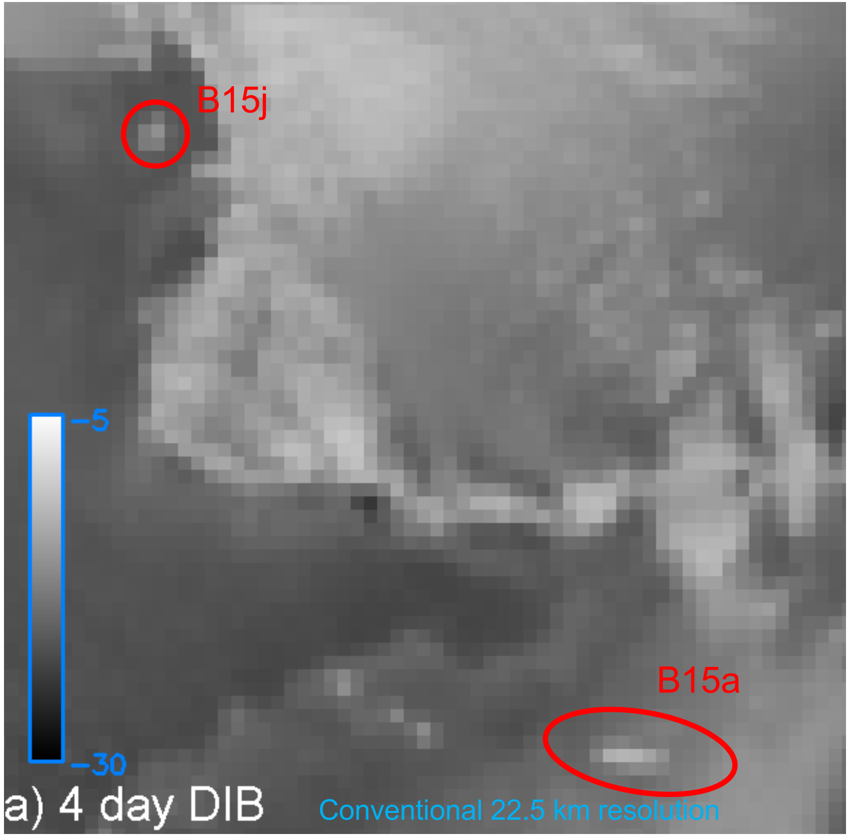
Image Frequency Response

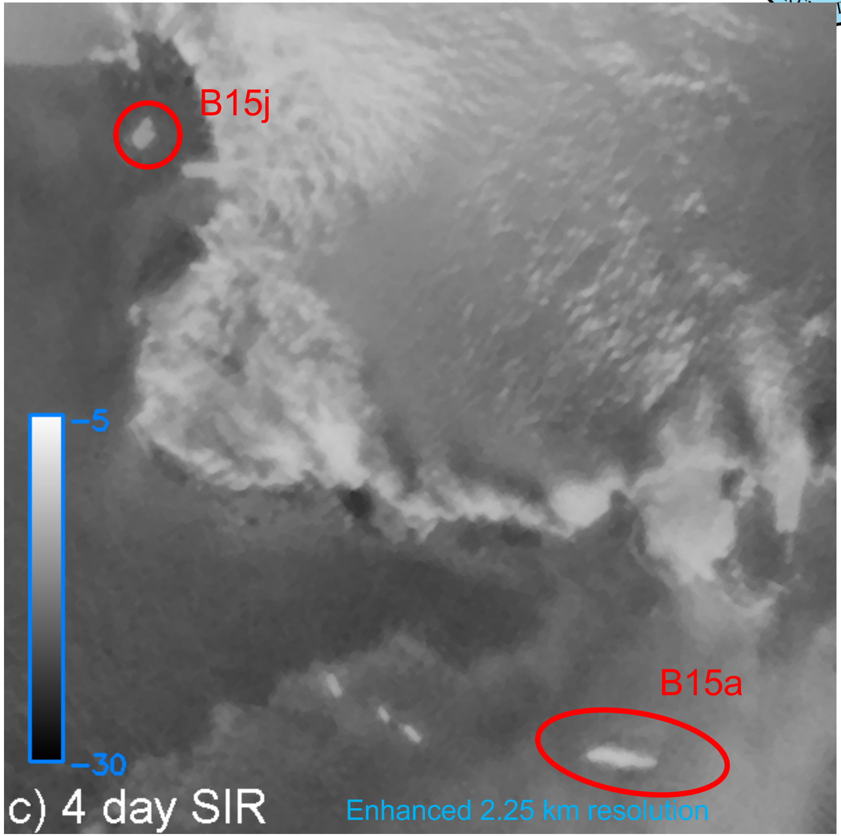
Use simulation w/ actual sampling, and SRF to estimate frequency response of DIB, AVE, SIR compared to true



DIB vs SIR Comparison 4 day Images

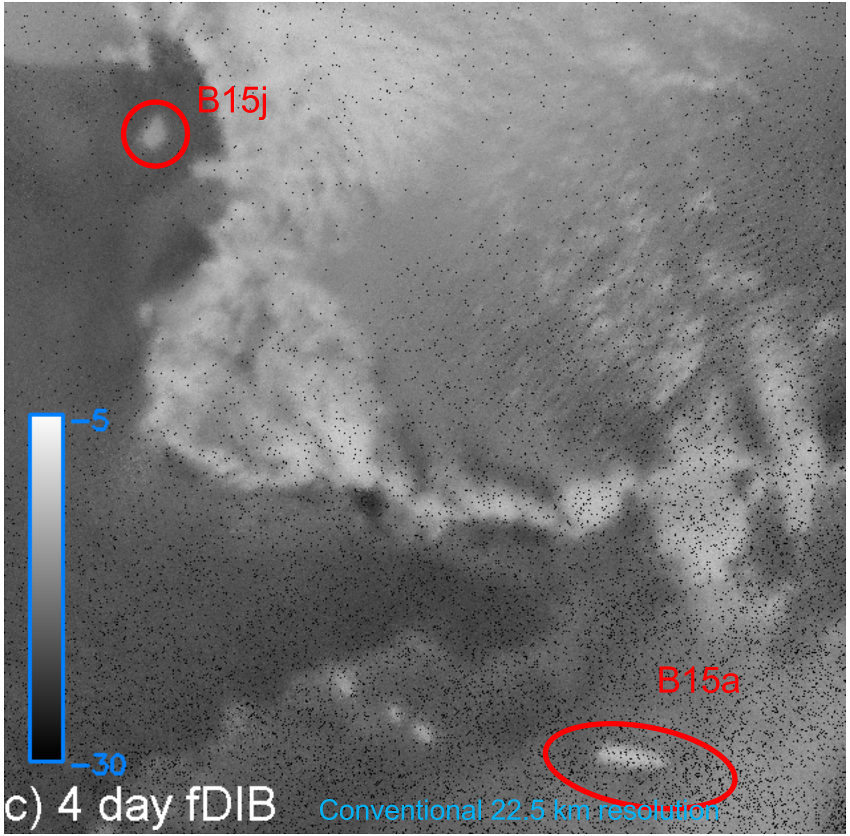
Ku-band (QuikSCAT)

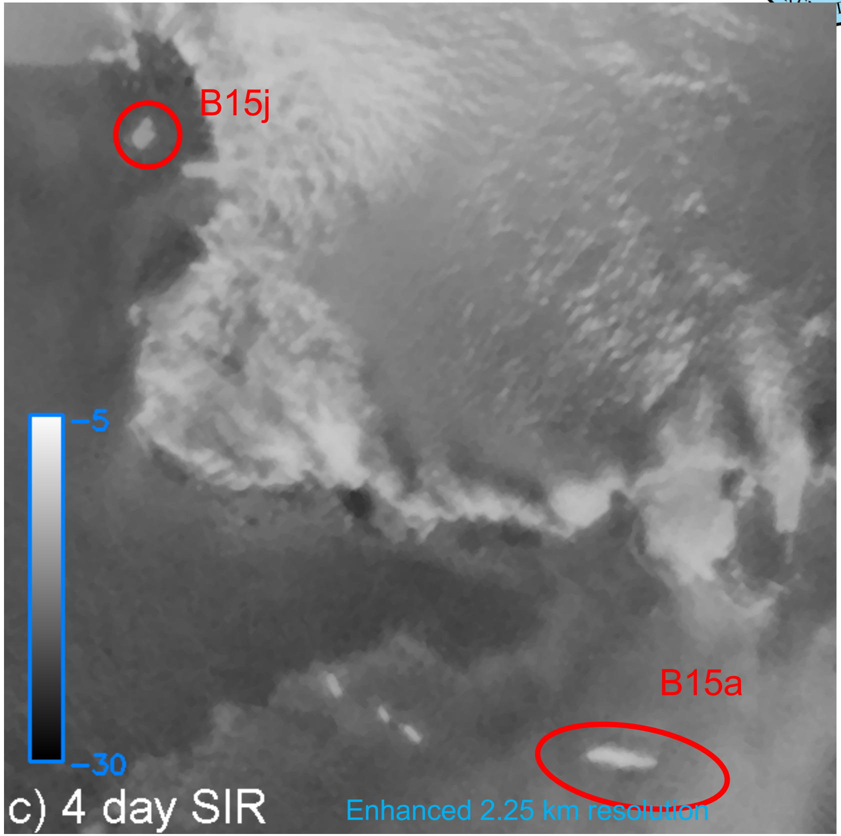




fDIB vs SIR Comparison 4 day Images

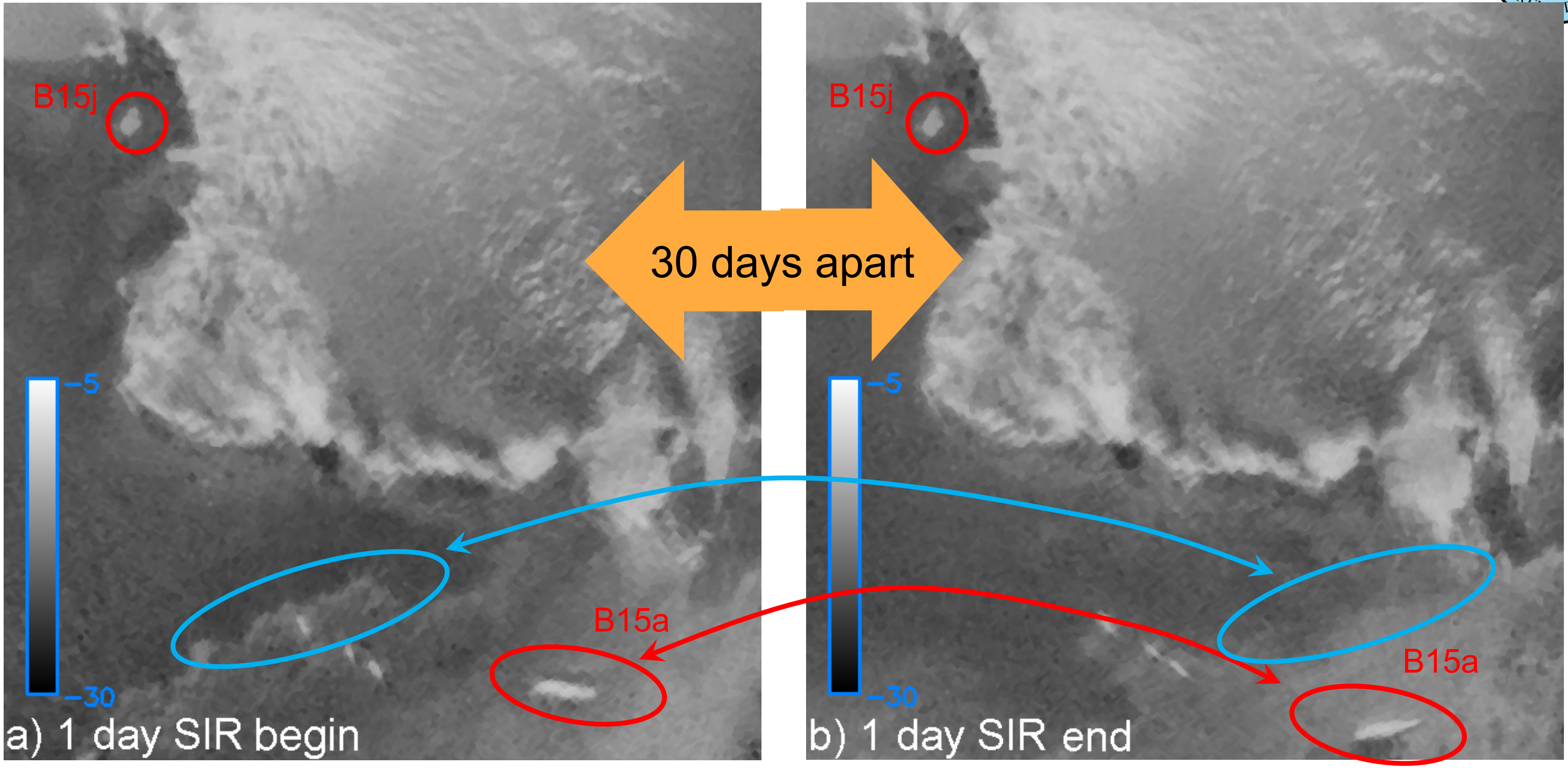
Ku-band (QuikSCAT)





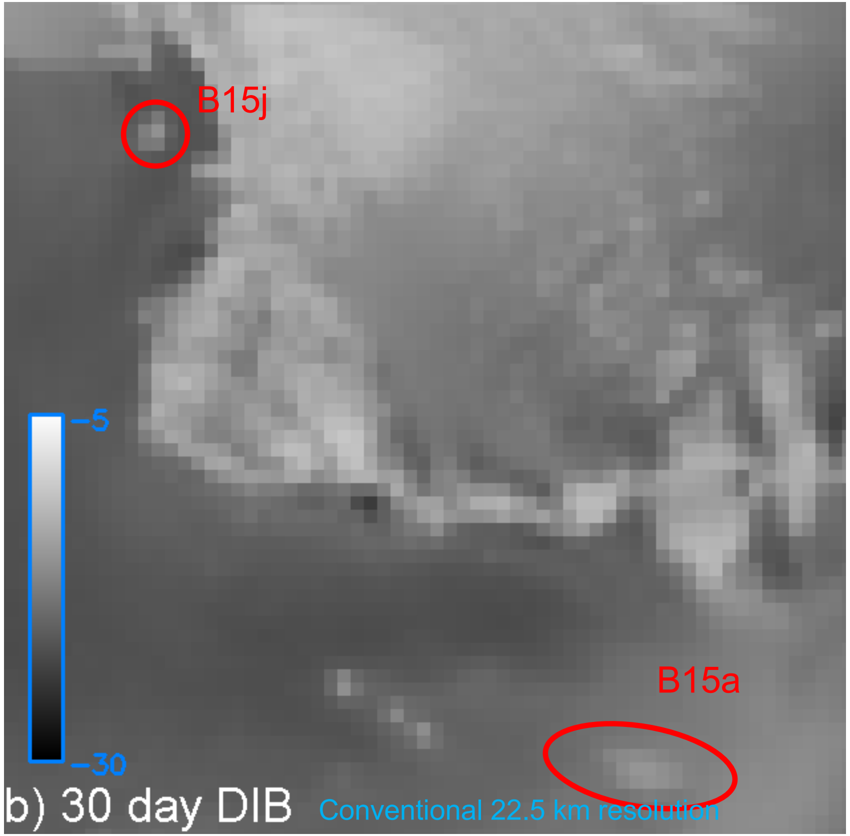
Iceberg Movement Before/After

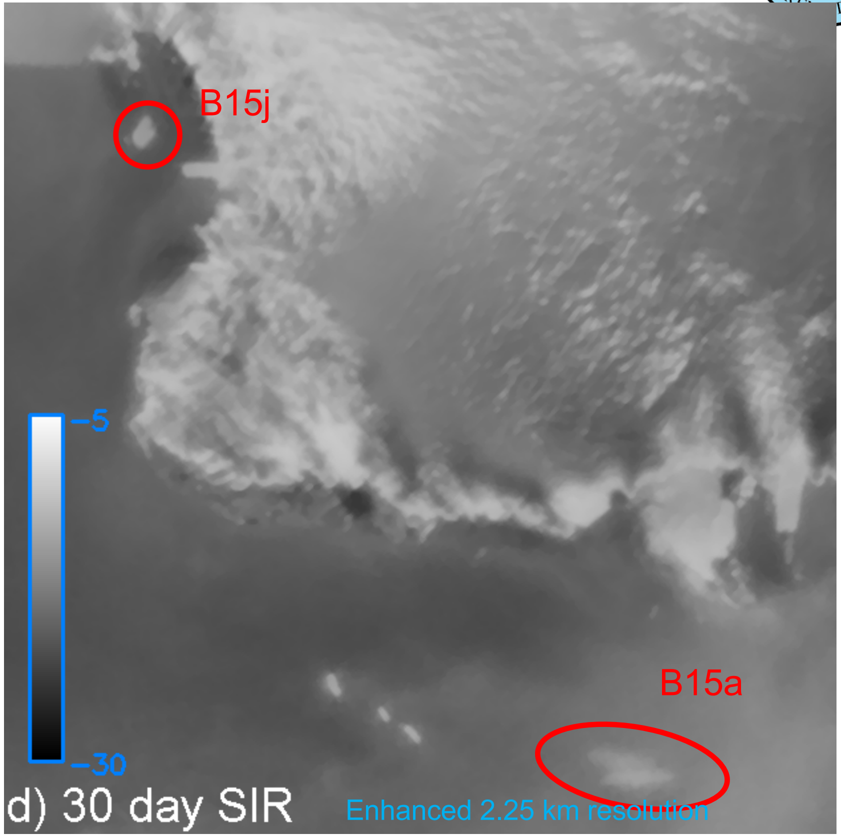
Ku-band (QuikSCAT)



DIB vs SIR Comparison 30 day Images

Ku-band (QuikSCAT)





DIB vs SIR Comparison 30 day Images

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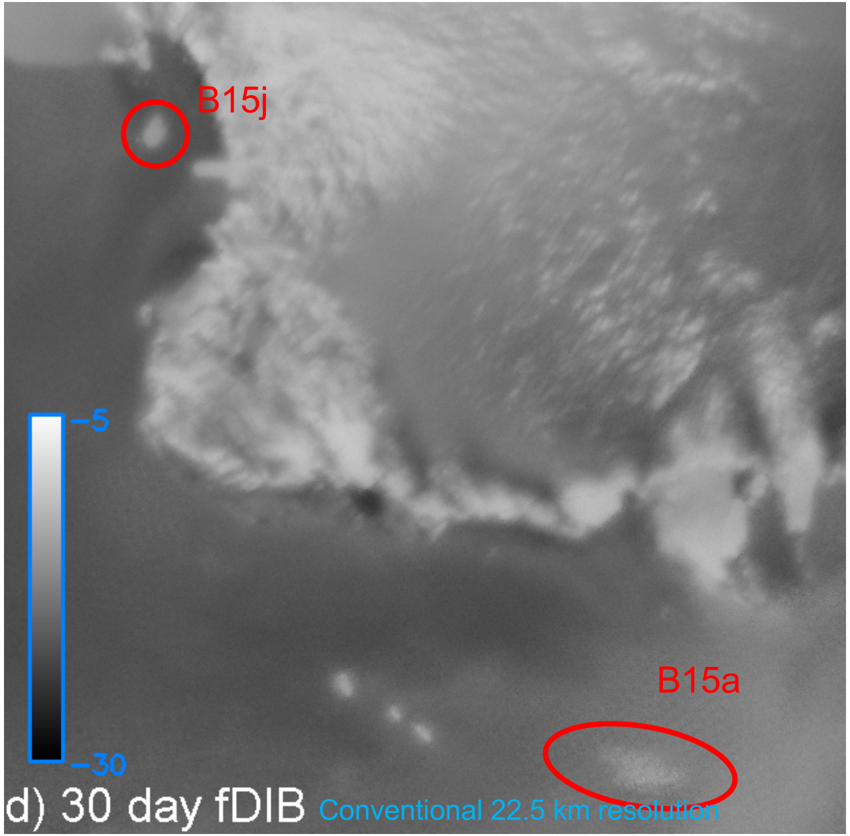
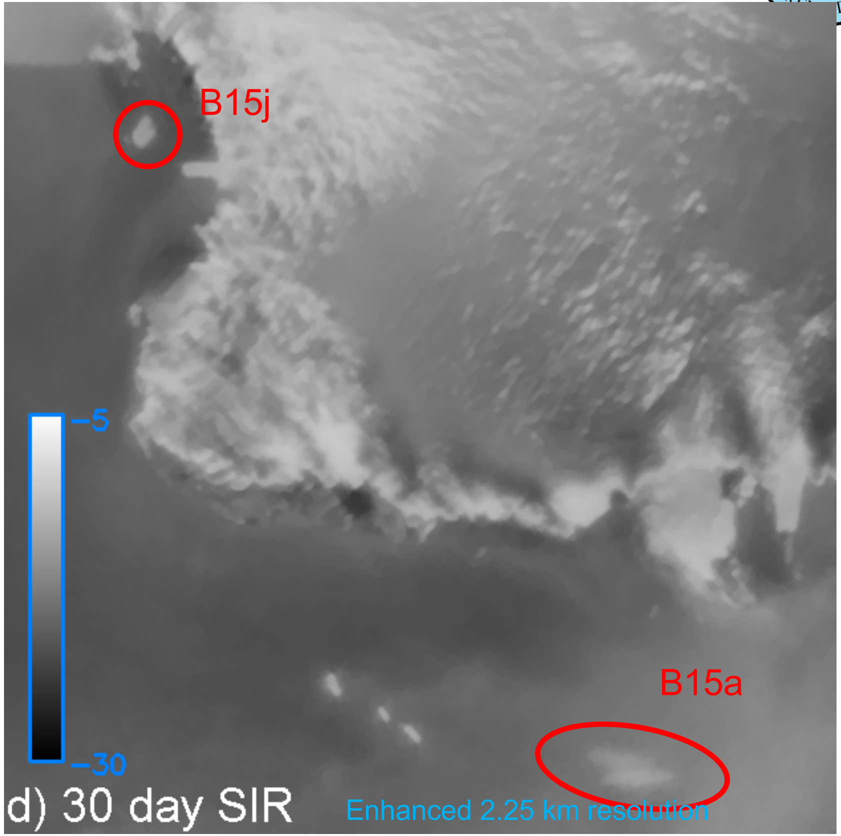
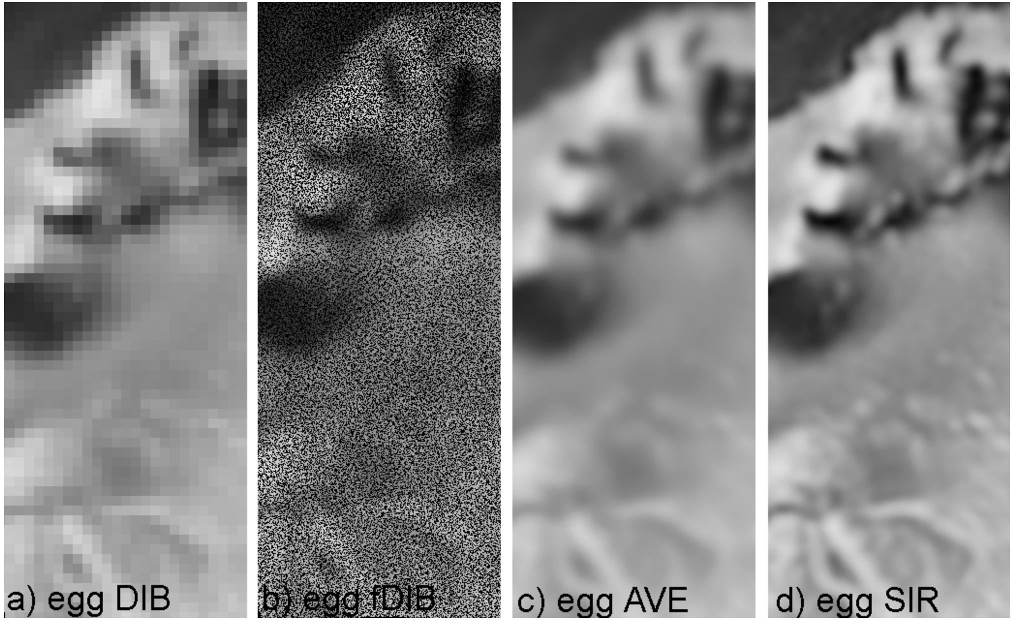




Other observations

- Change (motion) during averaging interval nicely handled by SIR
- Fine (over-sampled) DIB (fDIB) can yield high resolution *only* if stationary surface and long integration time
  - Noisiest of the techniques
- dB vs linear space averaging
  - Both effective
  - Geometric average is less "noisy" when noise is multiplicative and is thus the preferred method



Summary

- Multiple scatterometer imaging algorithms have been compared for SeaWinds to better understand strengths and weaknesses
- Lowest noise: conventional DIB -- lowest resolution
- Highest resolution: SIR -- only slightly higher niose level
- SIR handles motion well
- Averaging in dB less sensitive to noise than linear average

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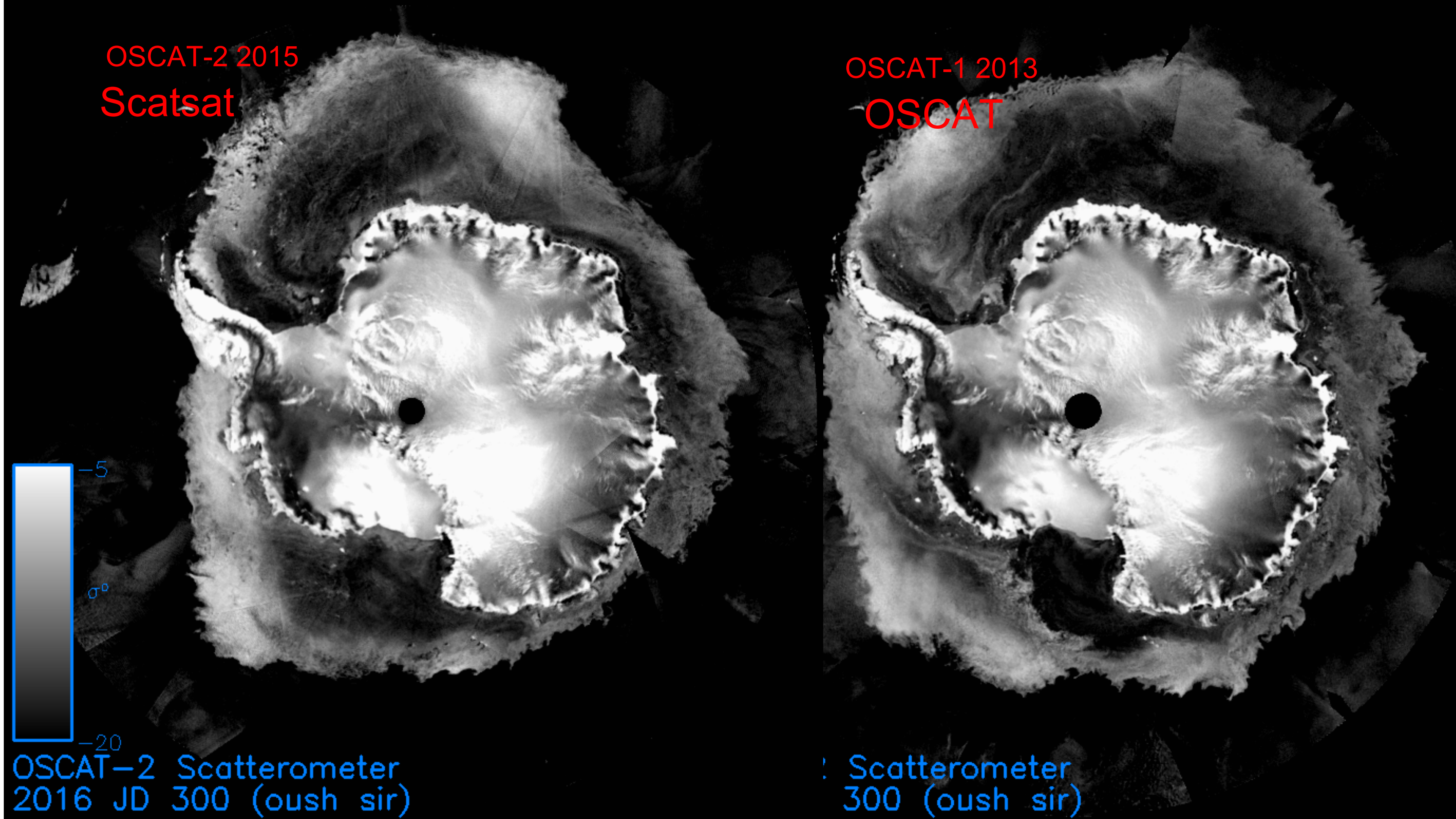
OSCAT-2 2015
Scatsat
OSCAT-1 2013
OSCAT
-5
σ°
-20
OSCAT-2 Scatterometer
2016 JD 300 (oush sir)
Scatterometer
300 (oush sir)