More SCHISM

(Signal and Clutter as Highly Independent Structured Modes)

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Dr. George R. Legters
SAIC, Satellite Beach, FL
legtersg@saic.com
(321)777-0061

Overview of Presentation

- SCHISM contrasted with typical STAP.
- Improved beam-Doppler resolution aids SCHISM but stresses STAP.
- SCHISM beam-Doppler frequencies are now perturbed at each iteration.
- Mysterious beam-Doppler clutter blob traced to backlobe leakage.
- Targets detected by simple receiver compared to ISL truth data.
- Heavy tapers can bias and split SCHISM beam-Doppler modes.
- Successful SCHISM analysis and focusing of MCARM data set 575.
- Huygens backpropagation reveals apparent reflection off wing (MCARM).

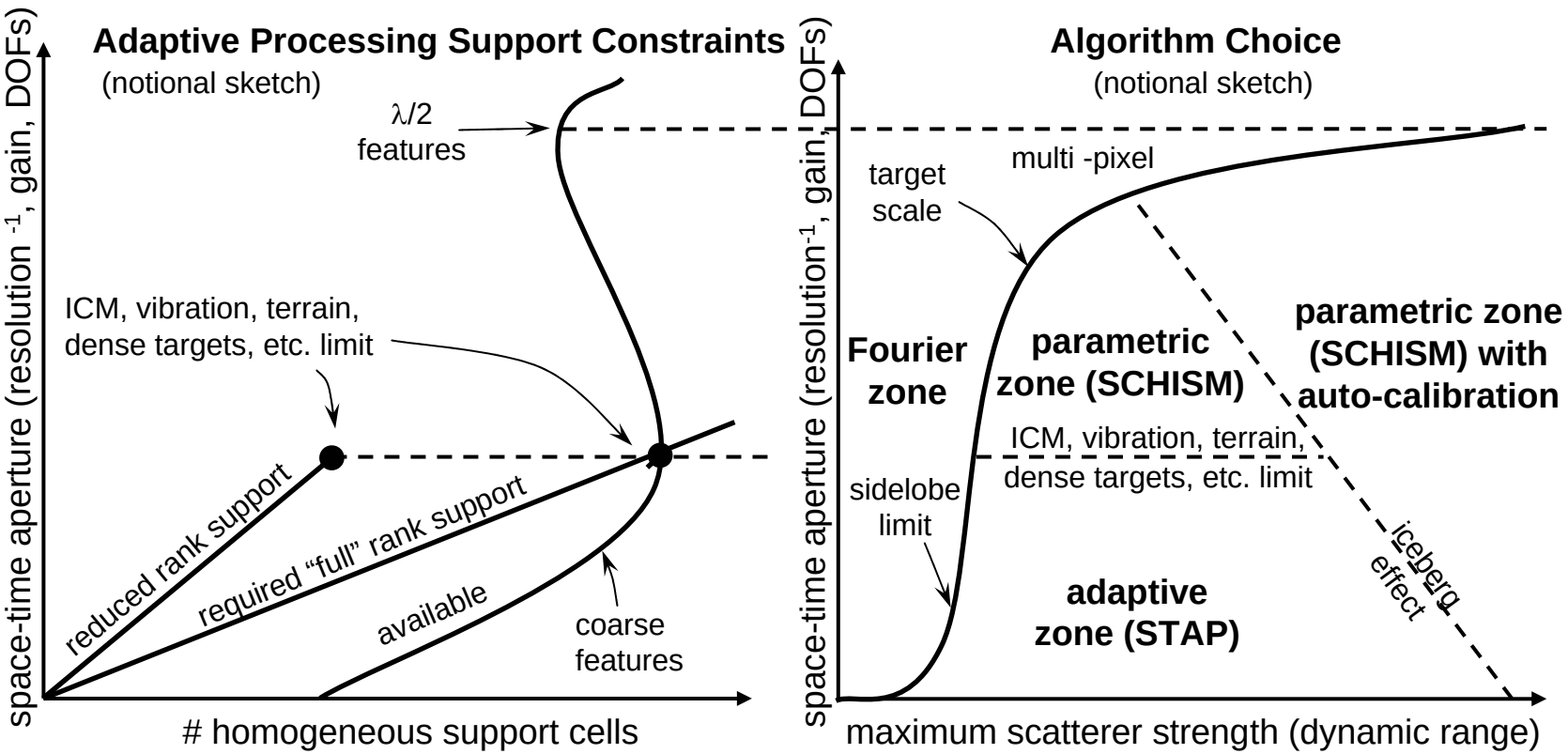
SCHISM and STAP Differences

- SCHISM: Estimate (**A,κ,ω**) to fit the data, $y_{n,m}(\mathbf{A},\boldsymbol{\kappa},\boldsymbol{\omega}) \equiv \sum_{p=1}^{P} A_p \cdot \exp\left[j \cdot \left(\kappa_p \cdot n + \omega_p \cdot m\right)\right]$

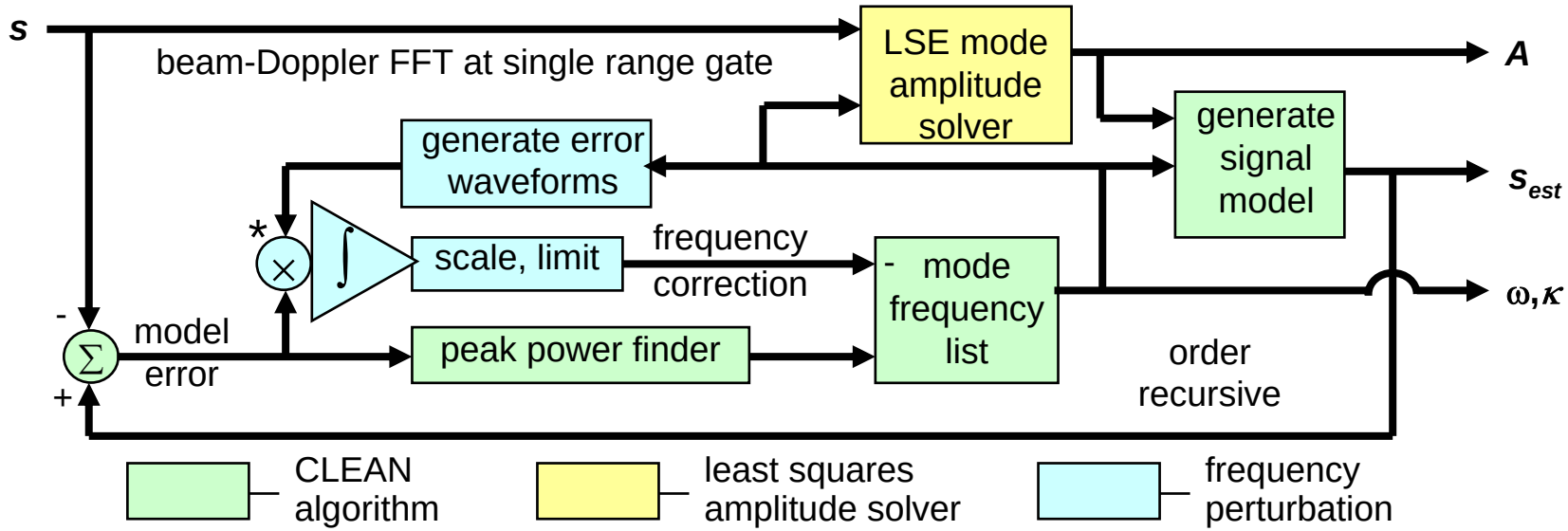
SCHISM	Typical STAP
Independent estimate for each range gate. No covariance matrix needed.	Covariance matrix based on nearby gates/cells and tends to widen nulls.
Precise signal frequency estimation based on beam-Doppler peaks.	Precise clutter nulling is implicit form of precise frequency estimation.
LSE estimate of all mode amplitudes.	Clutter mode amplitudes not found.
Target modes exhibit precise beam-Doppler frequency. Steering vector approach optional for weak targets.	Steering vector is matched filter for targets. Precise target beam-Doppler requires MUSIC, etc.
Physical signal model can be used to correct calibration errors or steering vectors, motion compensation, etc.	Adaptive nulling can automatically correct calibration errors. Steering vector may still need correction
Favors large space-time apertures that sample highly-structured signals. Provides needed precise calibration.	Large space-time aperture gain aggravates “iceberg” effect. Larger support invites inhomogeneity.

Motivation: STAP is Very Difficult in Urban Enviroments and Rough Terrain

- Target-rich and/or highly inhomogeneous urban and mountainous environments **require larger** airborne GMTI radar **space-time apertures**.
- More STAP sample support is required for larger apertures, but highly-resolved, target-rich, urban and mountainous clutter exhibits **insufficient homogeneity**.



Latest SCHISM Algorithm



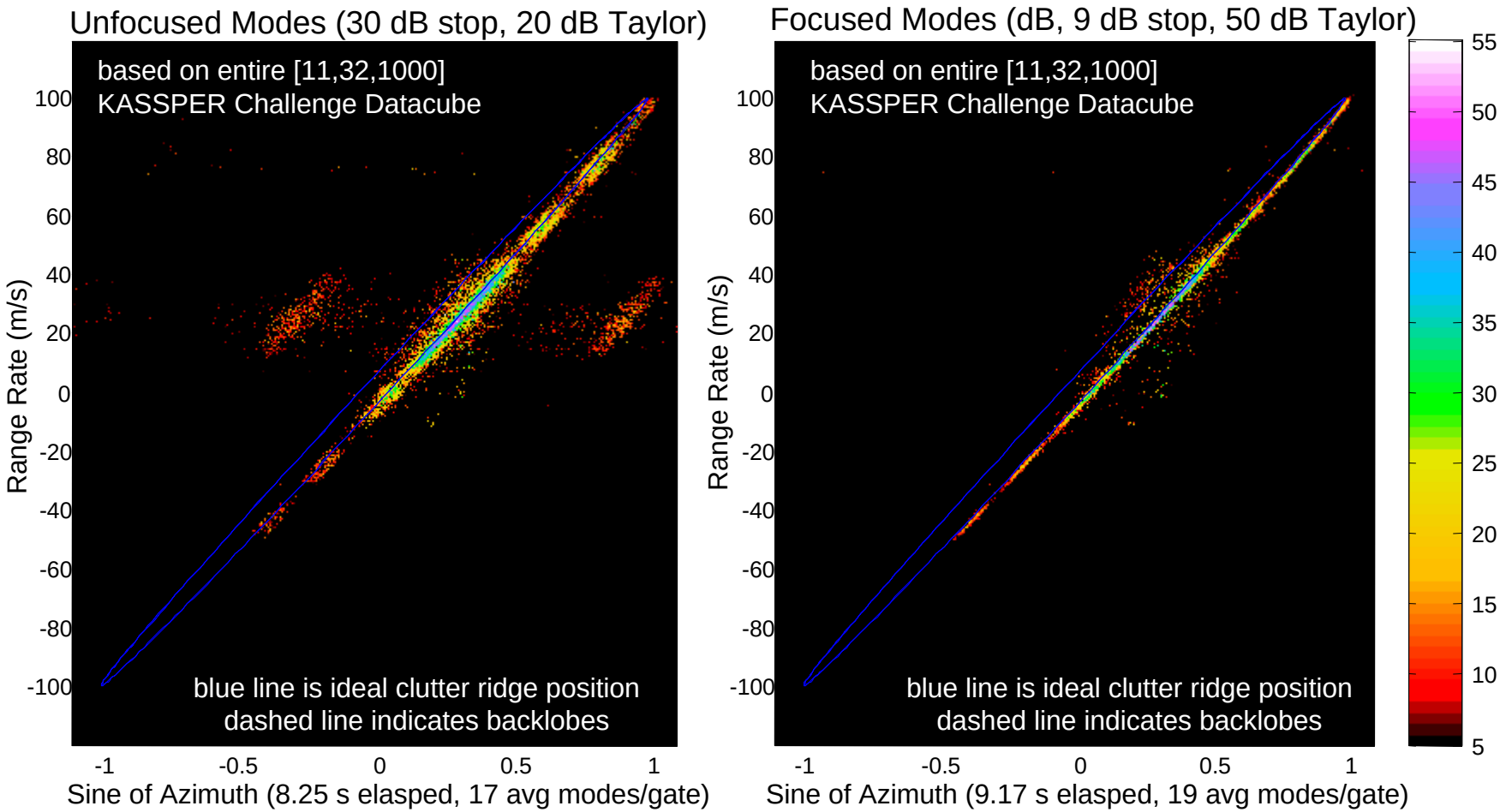
Repeat until residue power < desired threshold (e.g. noise floor + 9 dB).

Speed processing by replacing some LSE matrix solutions with projections, vectorize code, adjust error feedback gain, skip degeneracy test, carefully manage memory, and limit with “atan” rather than “find”.

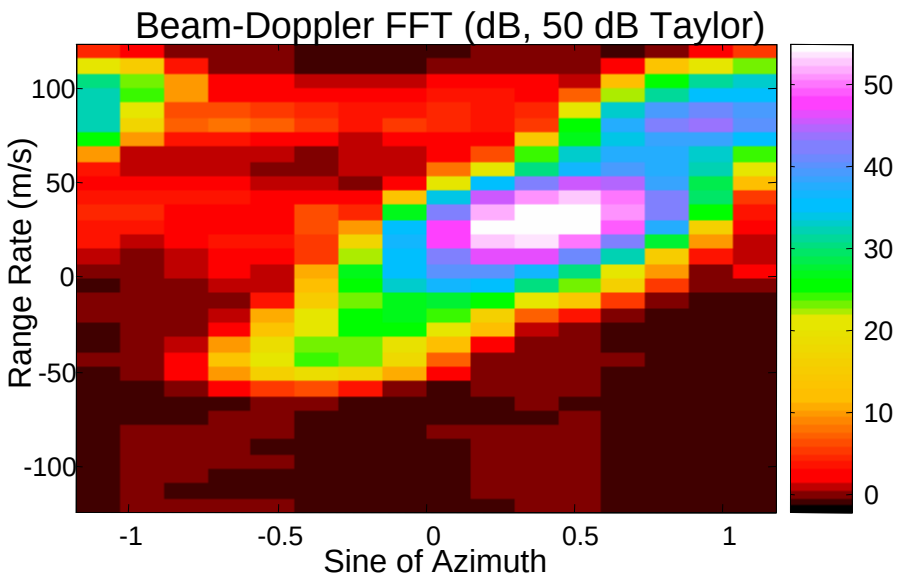
- Radically fewer modes than CLEAN (16 vs 260 average per range gate).
- Much faster than CLEAN (10 ms vs 259 ms per range gate, XP1900+)
- Tricky business (error modes can be linear combination of regular modes).

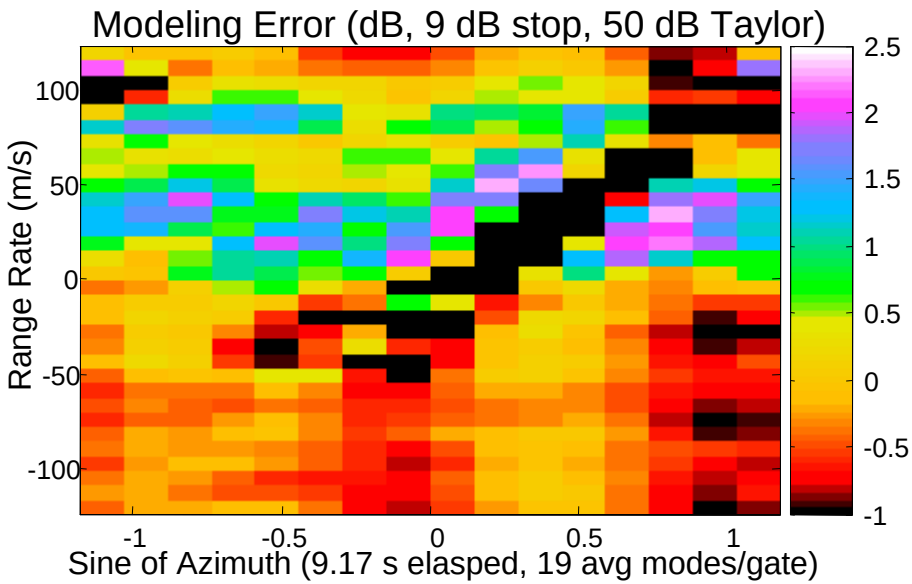
Focusing Accomplished without Knowledge of Clutter Ridge Position

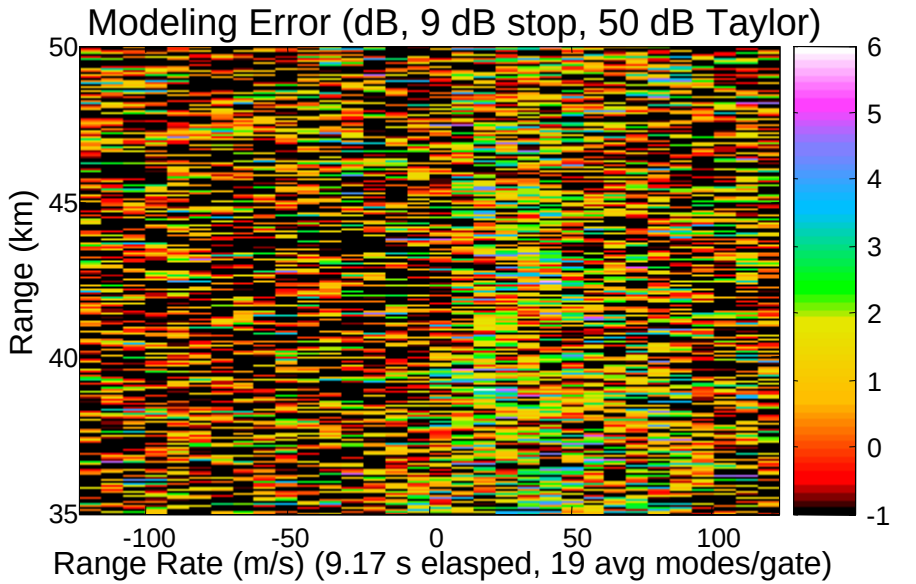
- Prior information: ideal time samples, space and beam calibration errors
- Procedure: mode model used to correct space-beam amplitude and phase.



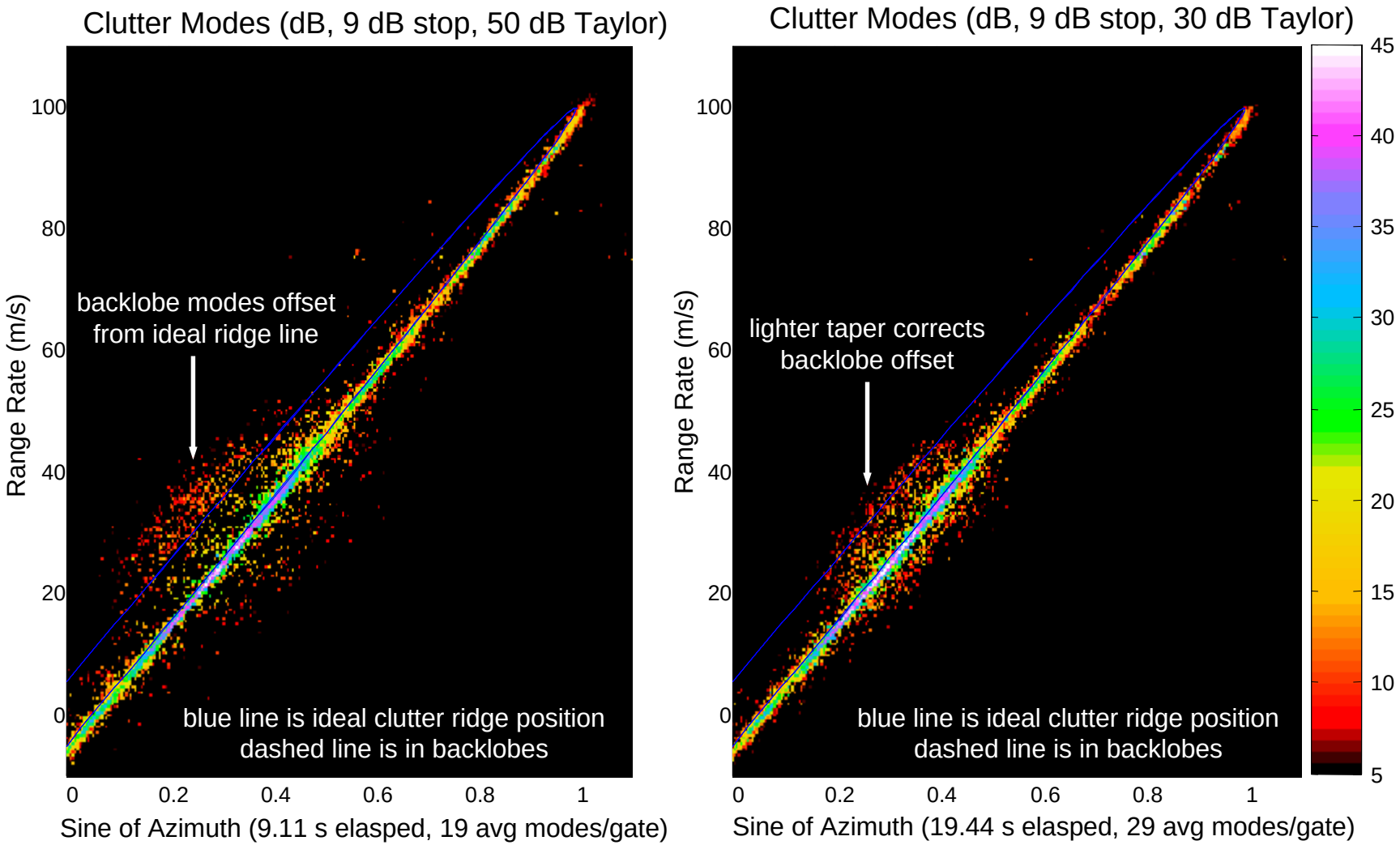
SCHISM Modeling Error FFT Power Exhibits Very Little Structure







Mysterious Asymmetric Mode Cluster Identified as Backlobe Clutter Leakage



Results based on targetless version of KASSPER Challenge Datacube from ISL (25 dB two-way front/back).

CFAR thresholds should take into account backlobe and associated mode smearing.

Transform ISL Truth Data to Datacube Coordinates and SCHISM Parameters

- Target power scaled by transmit and receive antenna gains.
- Observed -230 dB truth data noise floor shifted to 0 dB level of datacube.
- Two-way range and range rate converted to one-way.
- Inertial azimuth angle in degrees converted to sine relative to array.

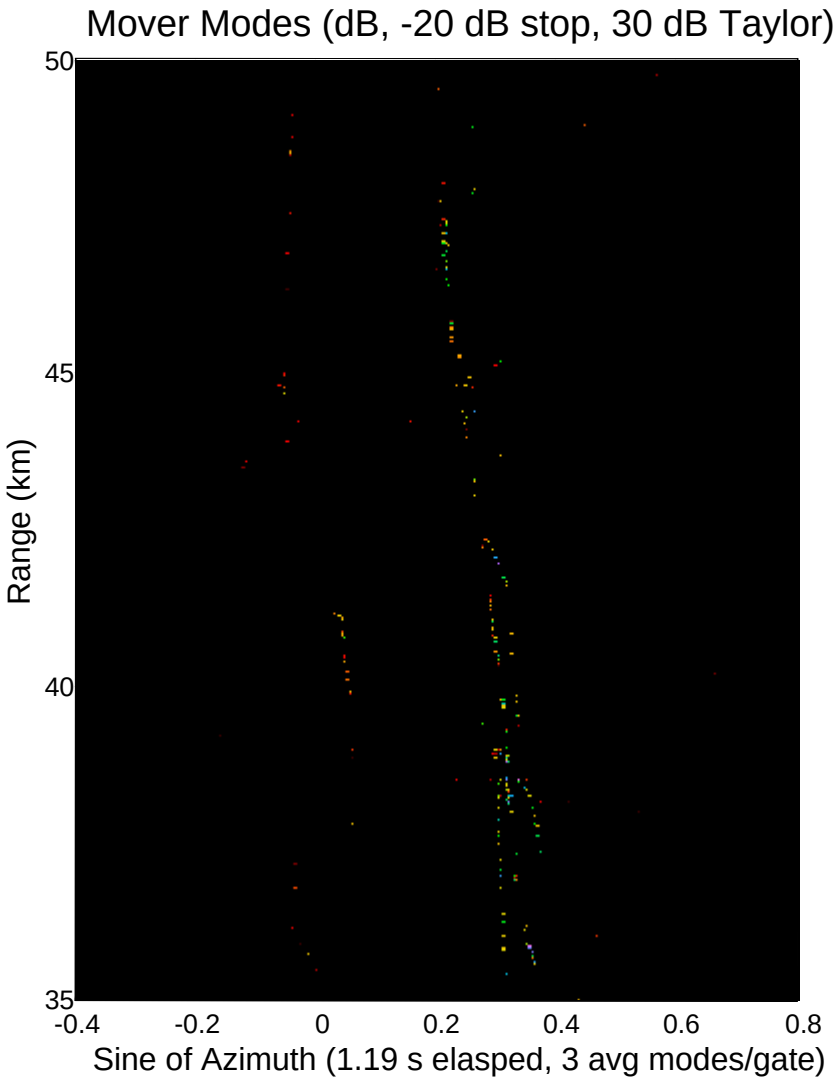
- Note: “Truth” power is actually mean of random # generator used to create datacube.

Compare Target-Only Datacube, SCHISM Modes, and Truth Data

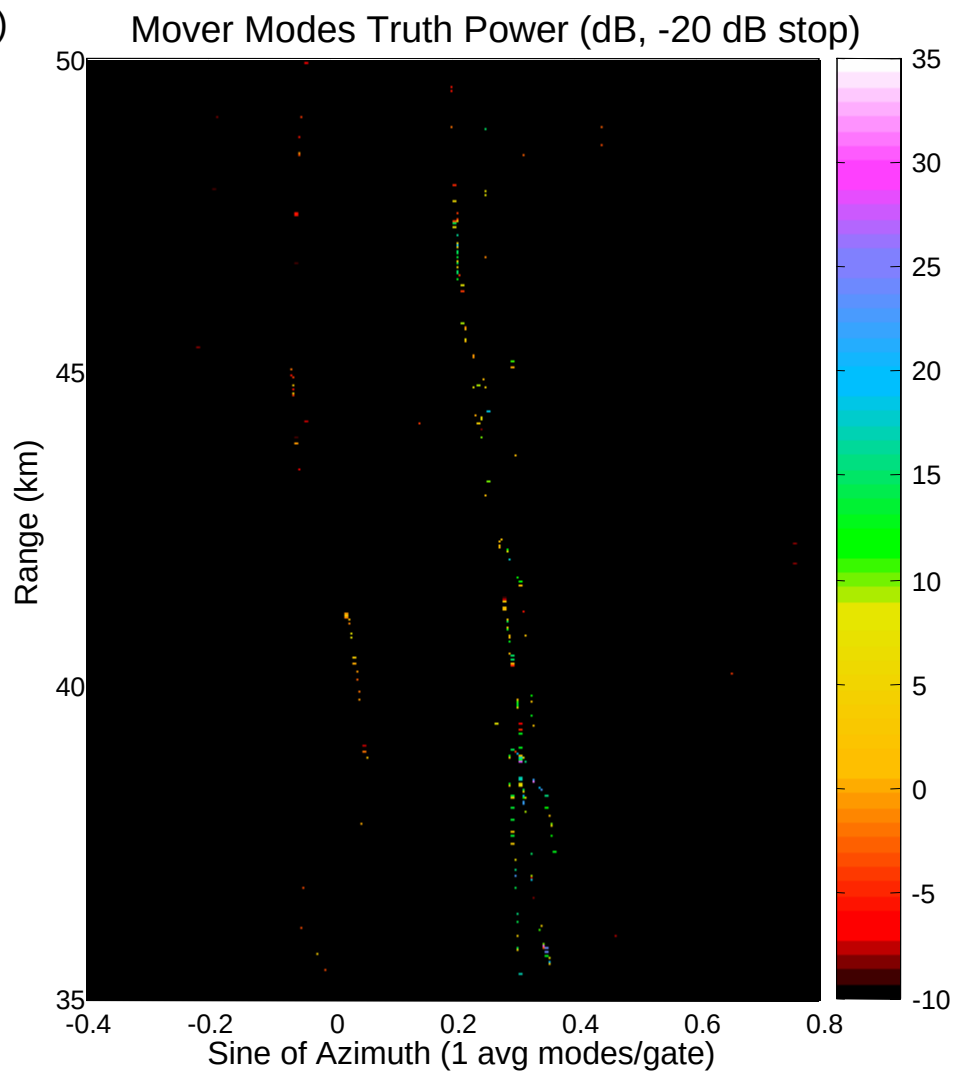
parameter		datacube	SCHISM	truth (appx)
# used gates	:	223	221	238
# multi-target	:	0	36	48
# movers	:	223	271	293
max power(dB)	:	35.62	35.60	34.89
sum power(dB)	:	43.47	43.41	43.63

note: datacube # movers was based on only one target per gate.
note: targets with power less than -6 dB were ignored.

SCHISM Matches Truth Data Nicely for Target-Only Datacube (beam-range)

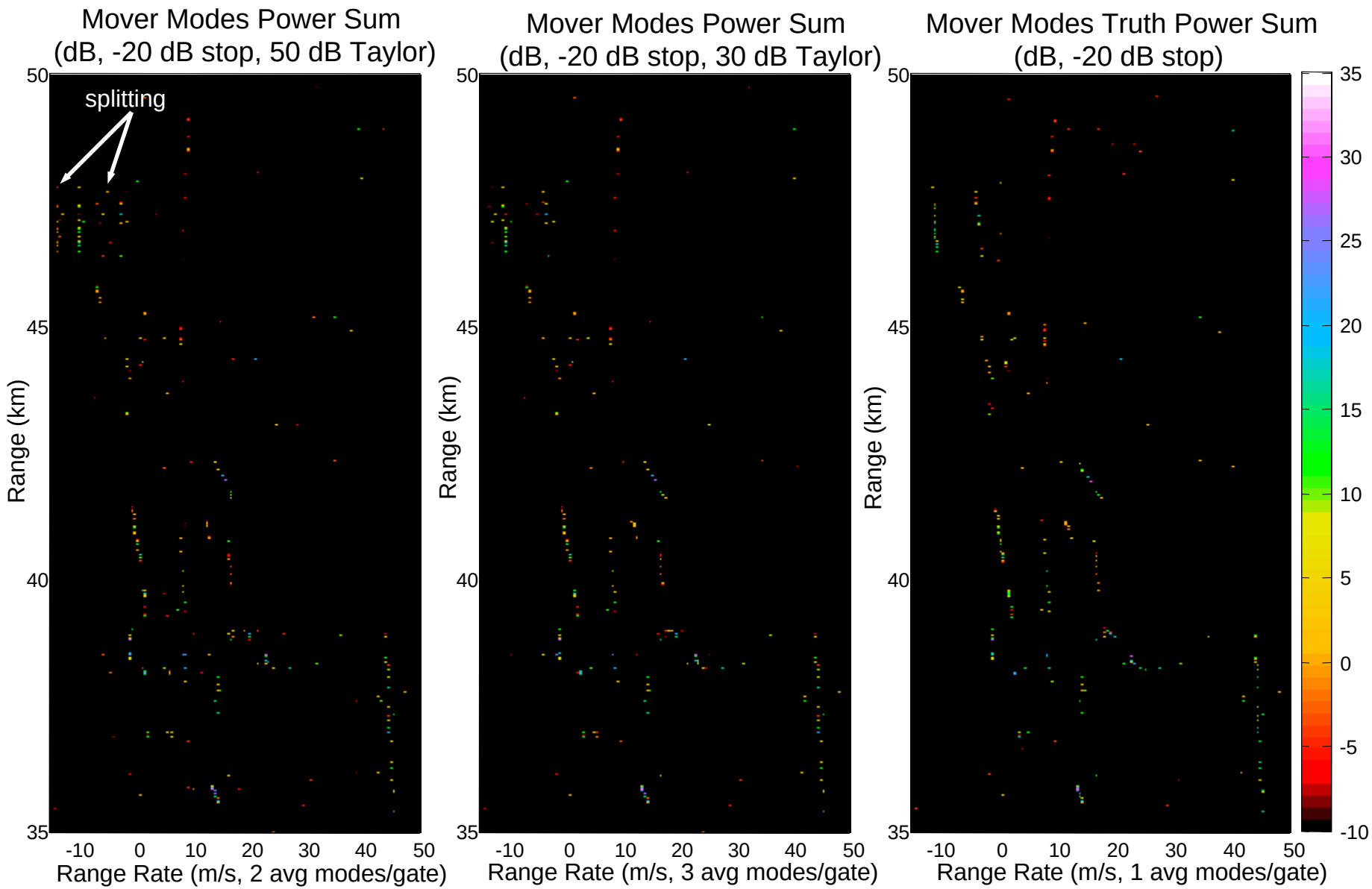


SCHISM mode analysis of noise-free target-only datacube derived from ISL original and targetless datacubes.



Based on target position and velocity truth data provided by ISL (mean power levels).

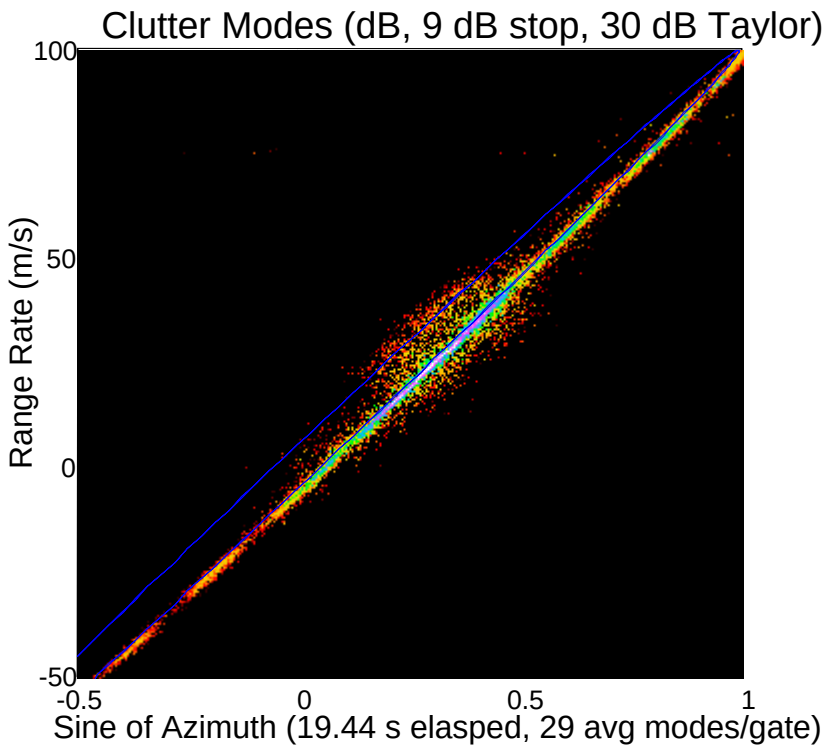
Heavy Taper Causes Splits Modes in Multi-Target Bins (Doppler-range)

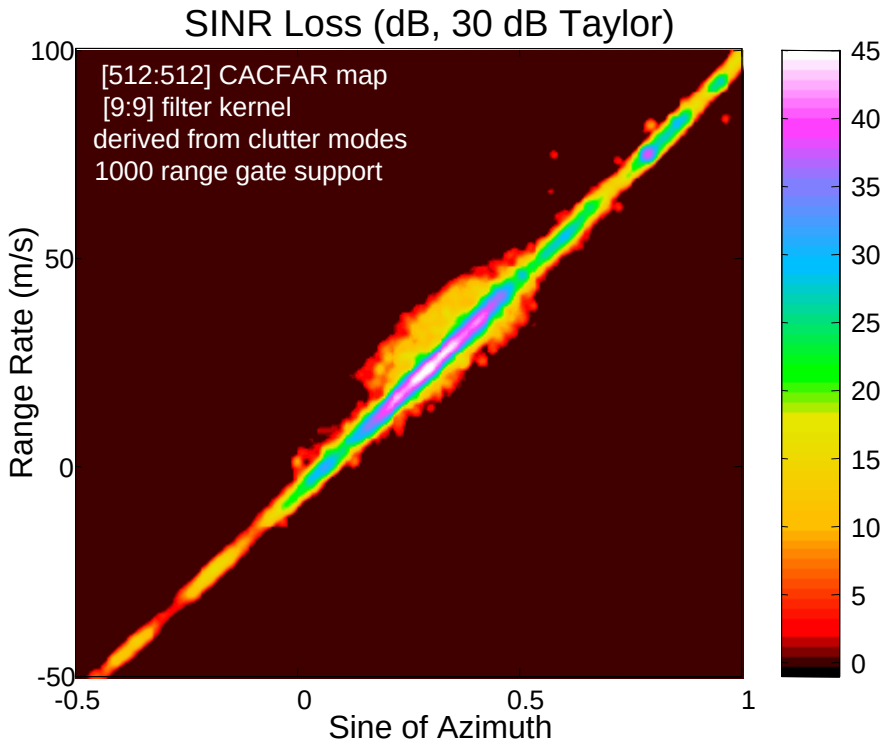


SINR Loss (CACFAR Power Map)

(Misusing SCHISM for Comparison to STAP Performance)

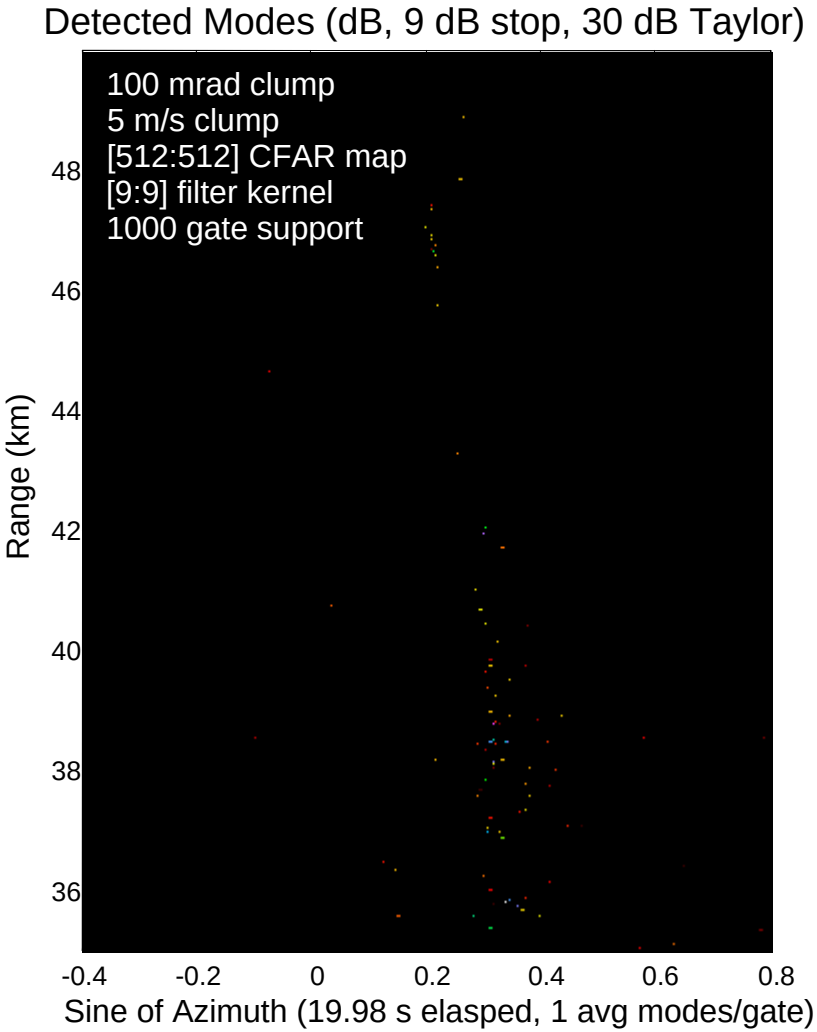
- CACFAR map = filtered targetless Challenge Datacube mode power.



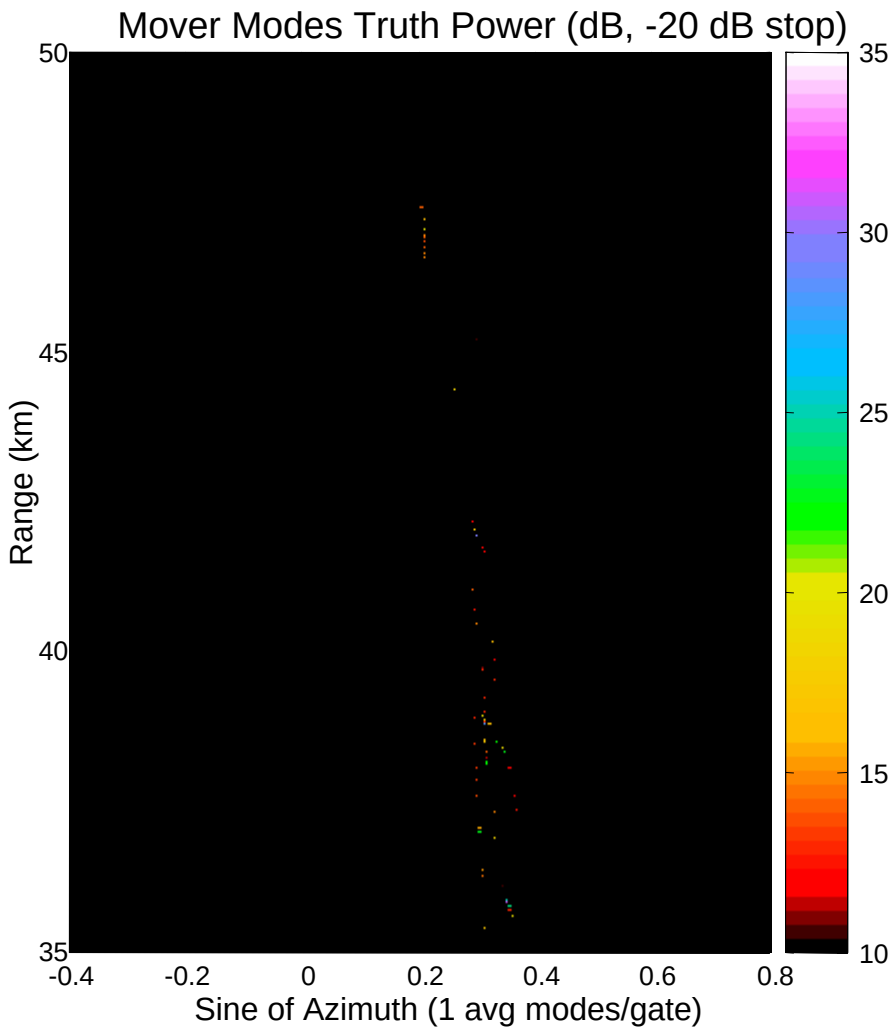


- "Range-averaged" CACFAR map is poor way to utilize SCHISM modes.
- SCHISM detection should be based on mode evolution over multiple CPIs.
- SCHISM may be able to track slow-moving targets buried in "moving" clutter.

CACFAR-SCHISM Detections (beam-range, 10 dB threshold)



Detected SCHISM modes match general truth pattern. Some false alarms and missing targets evident.



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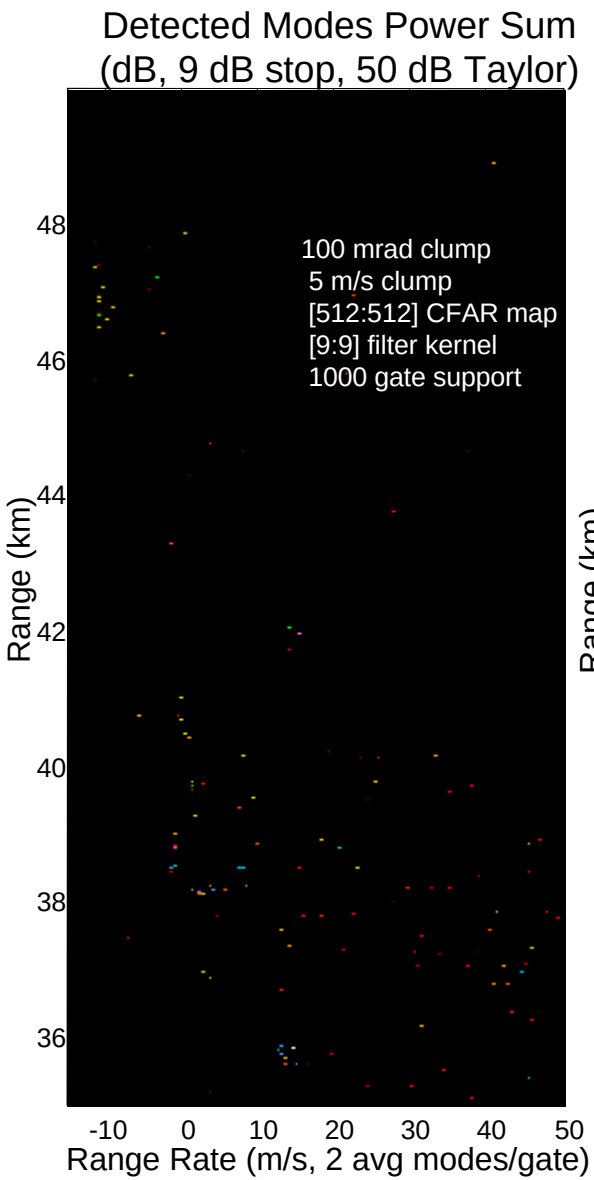
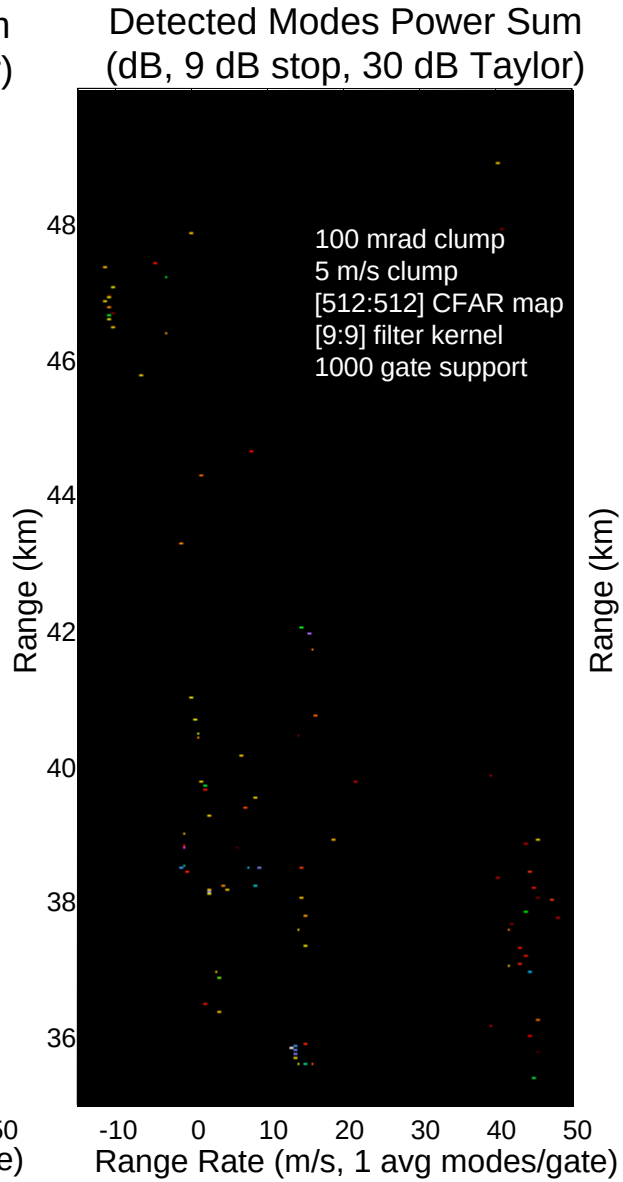
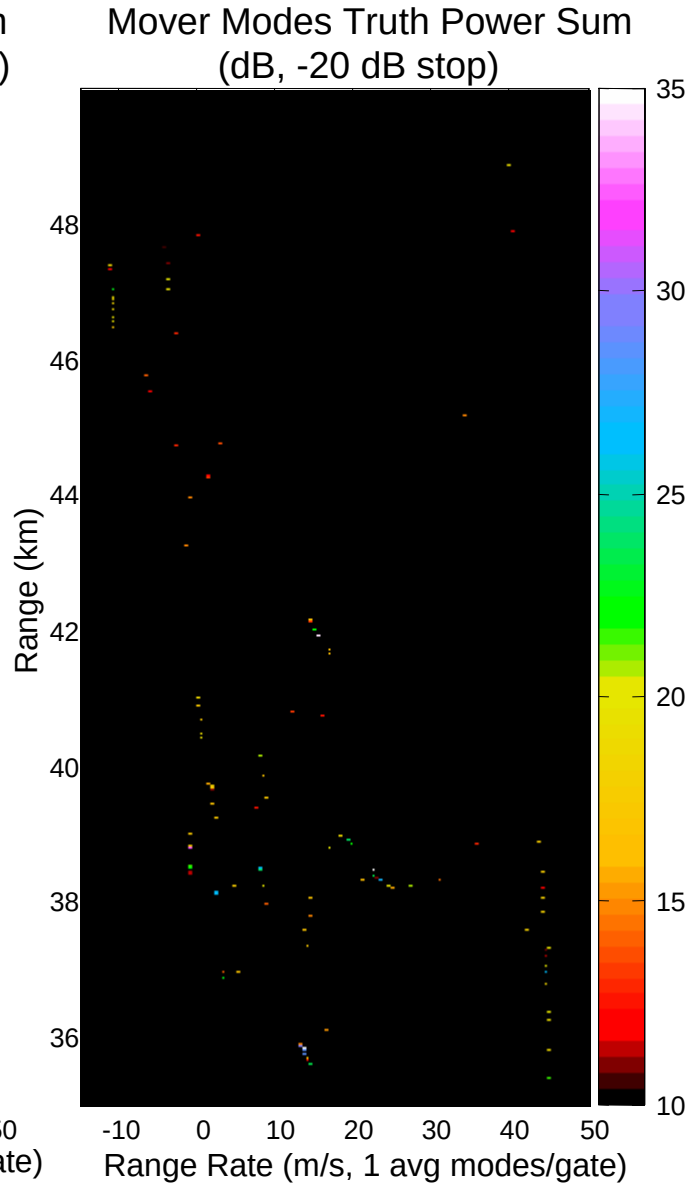
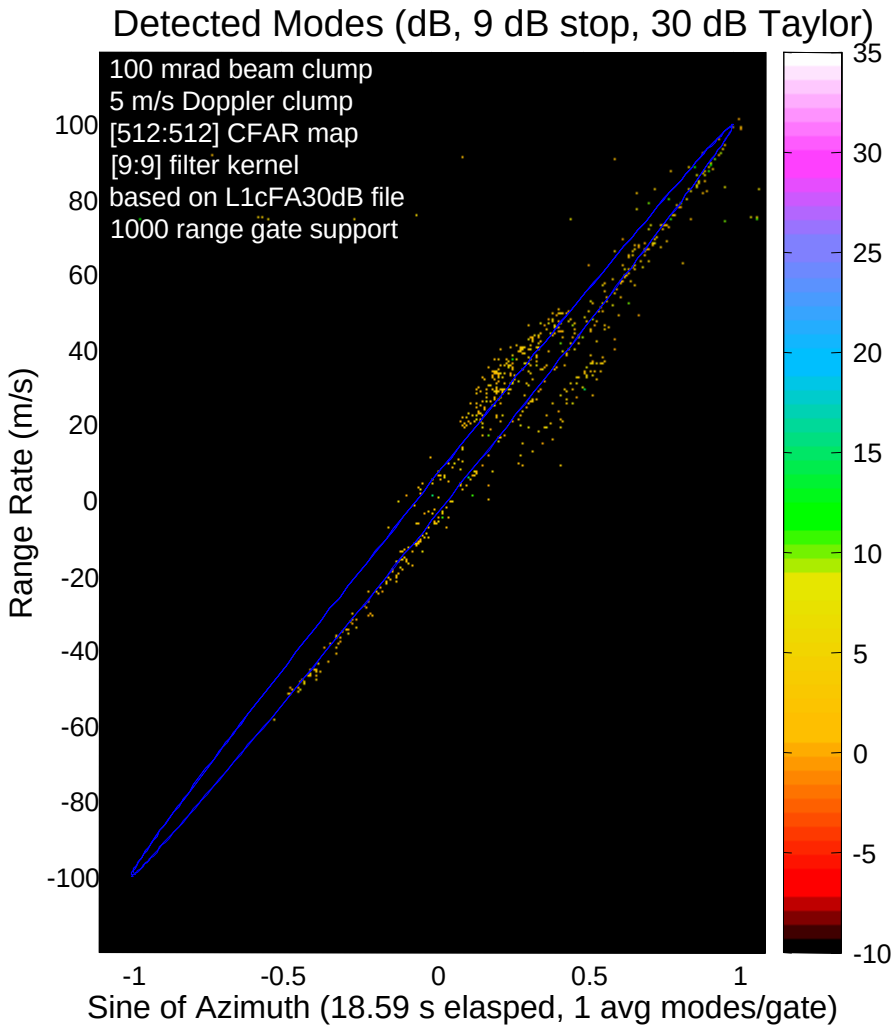
CACFAR-SCHISM Detections (Doppler-range, 10 dB threshold)



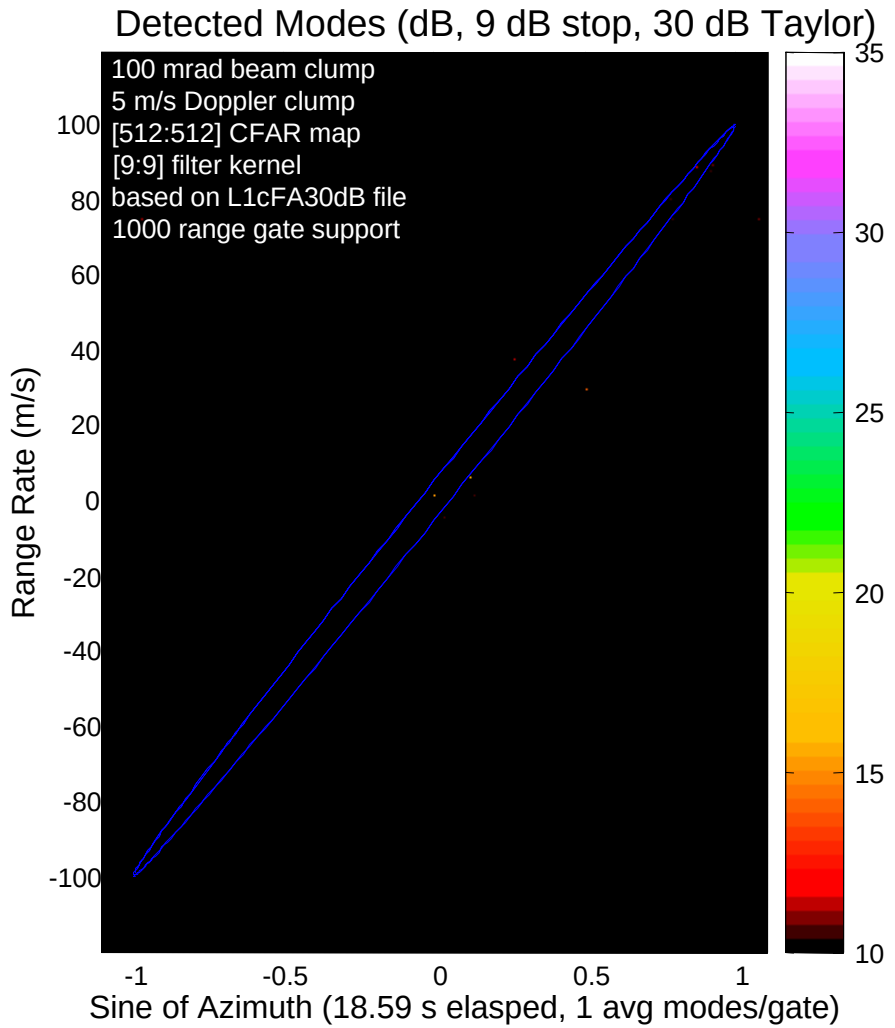




CACFAR-SCHISM Detections for Targetless Datacube (beam-Doppler)

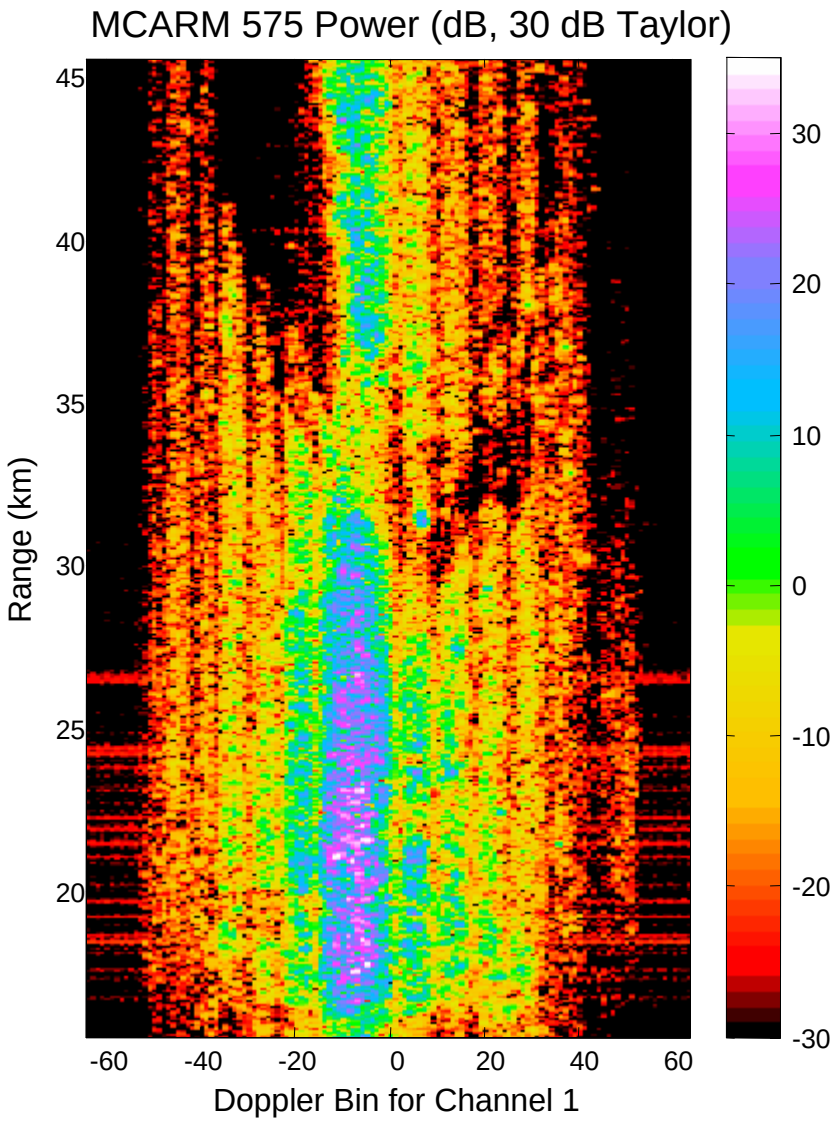


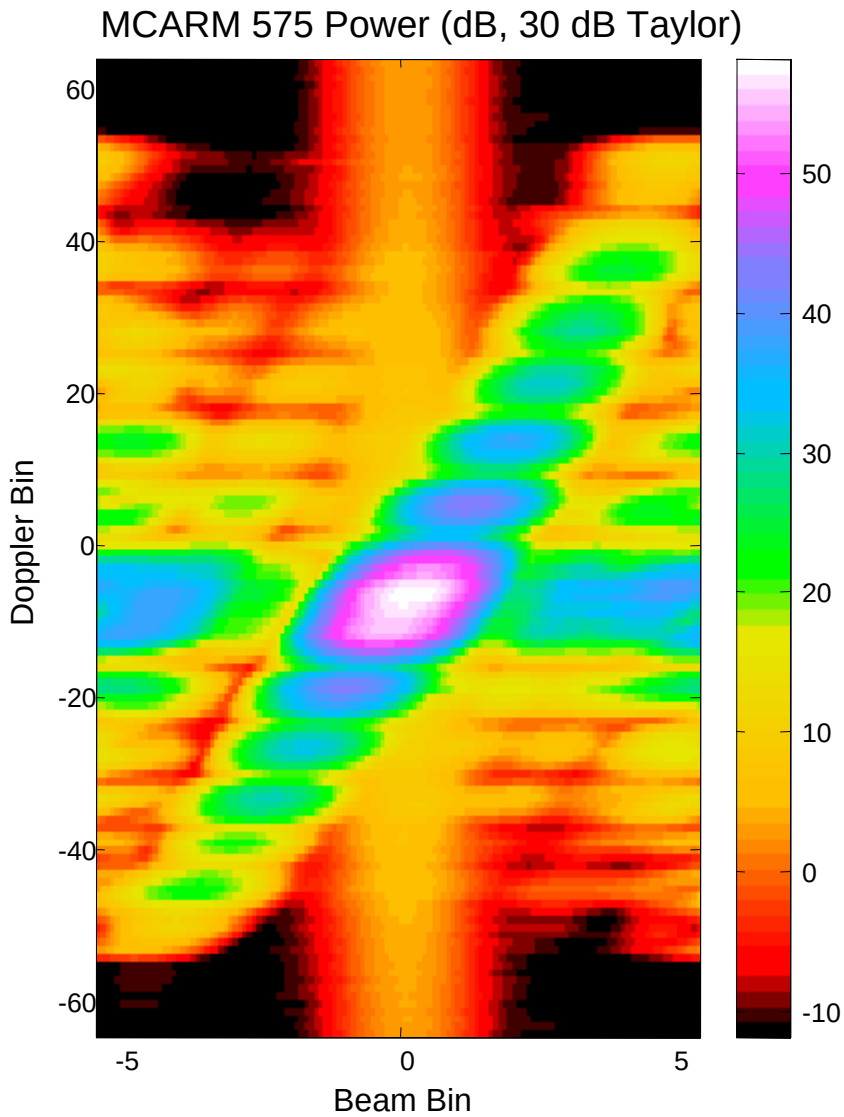
CACFAR scaled SCHISM mode power for the targetless version of the Challenge Datacube provided by ISL.



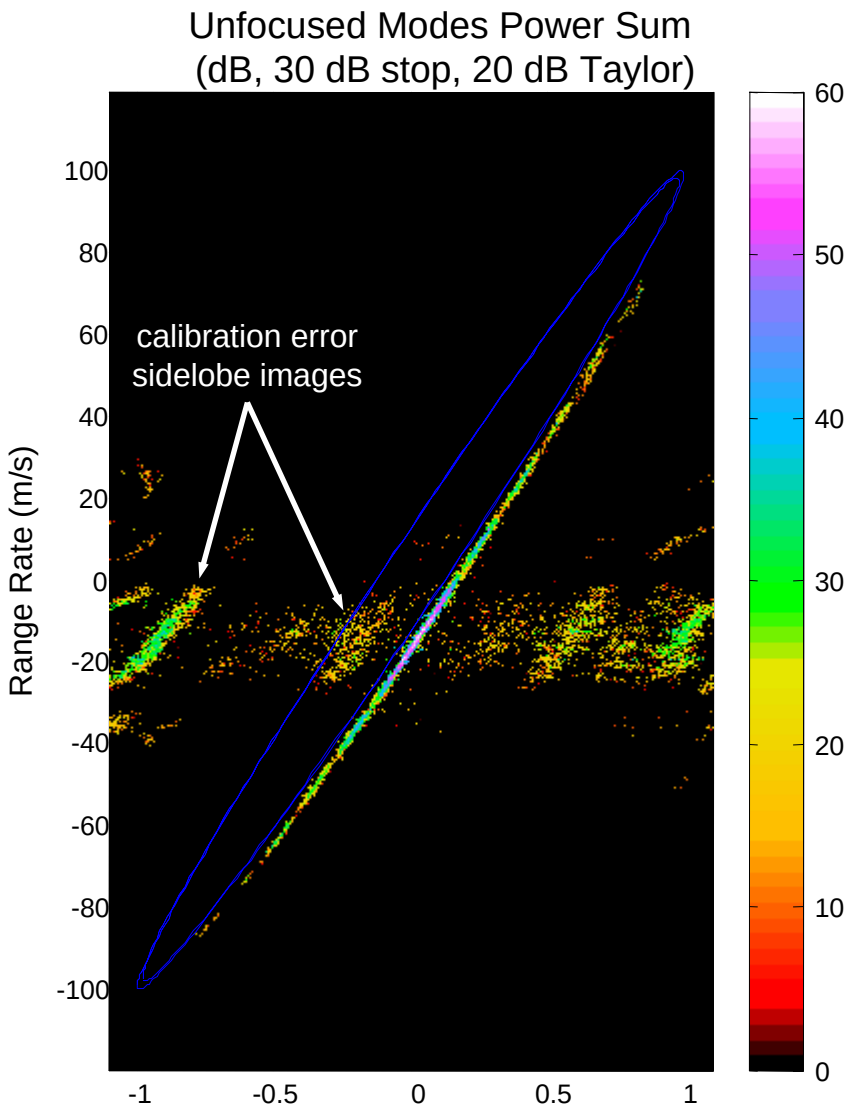
With a 10 dB detection threshold, false alarms are scarce (perhaps too scarce, CACFAR averaging method?).

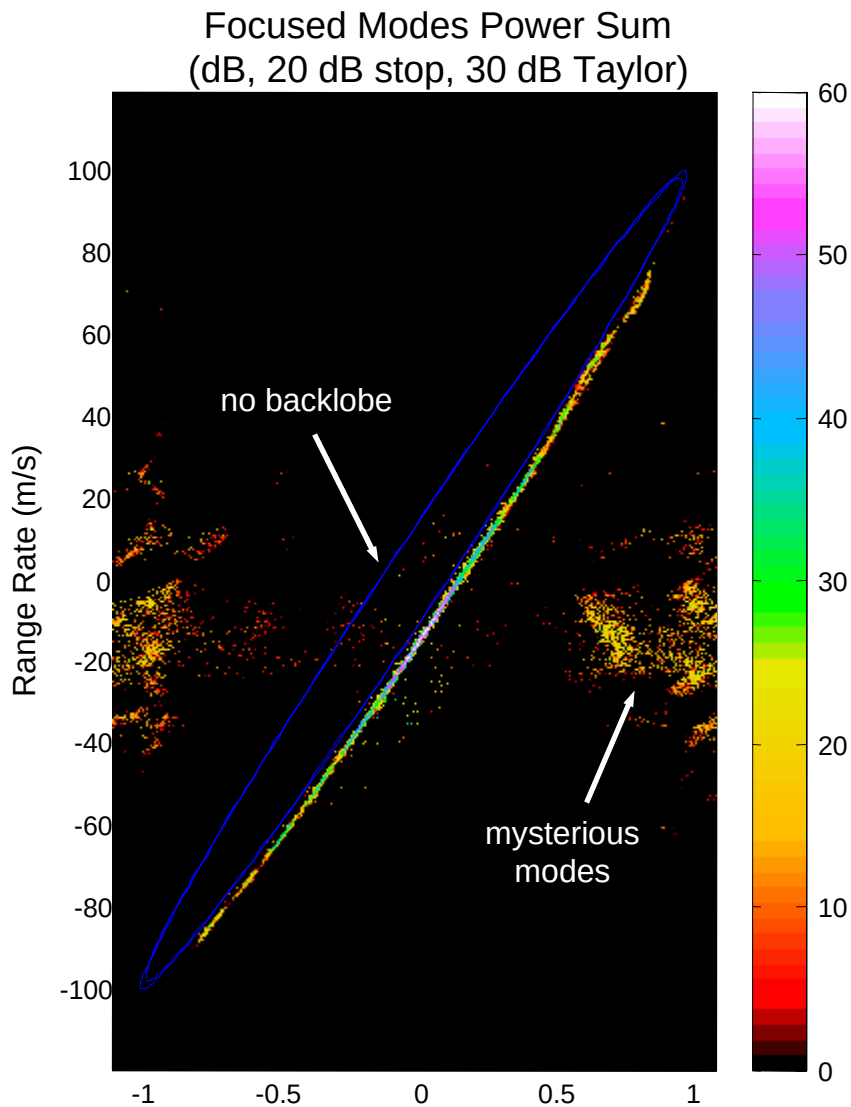
MCARM Data Set 575
(11 Upper Elements, 128 time samples)



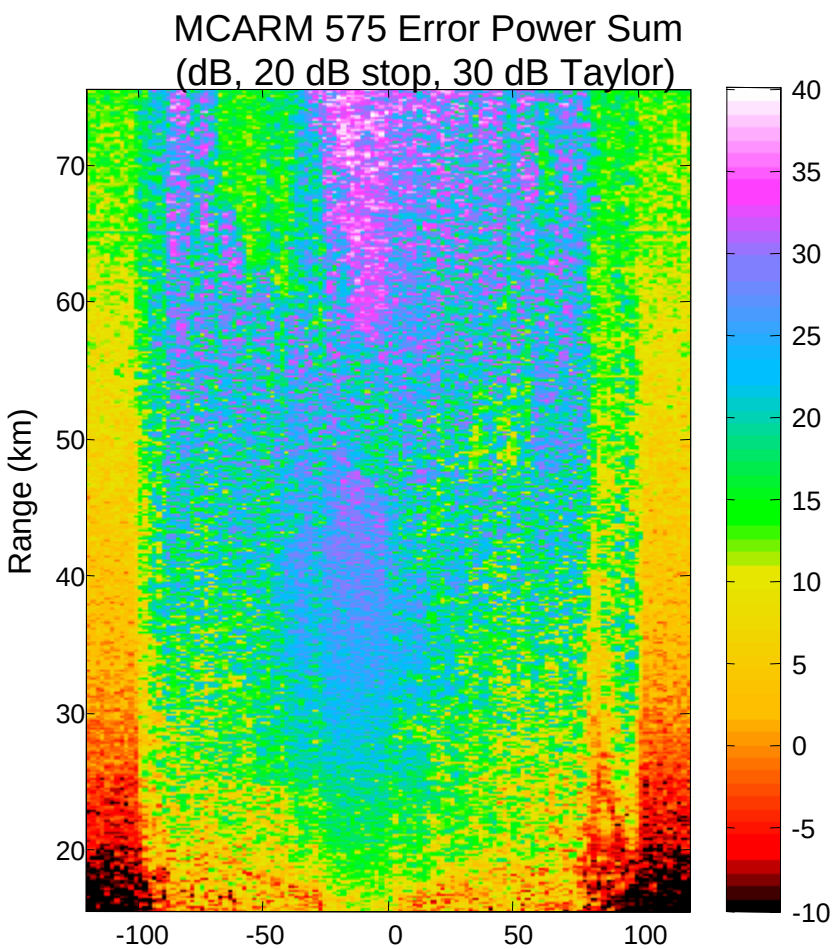


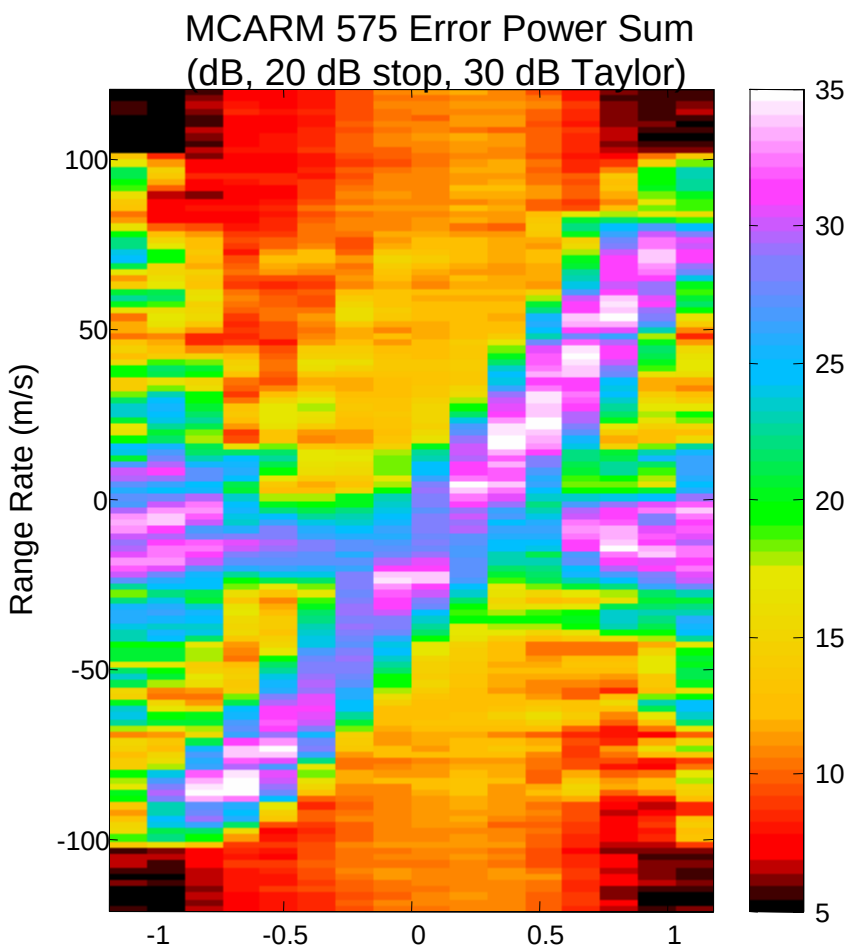
MCARM Data Set 575 Focusing Results





MCARM Data Set 575 SCHISM Modeling Error

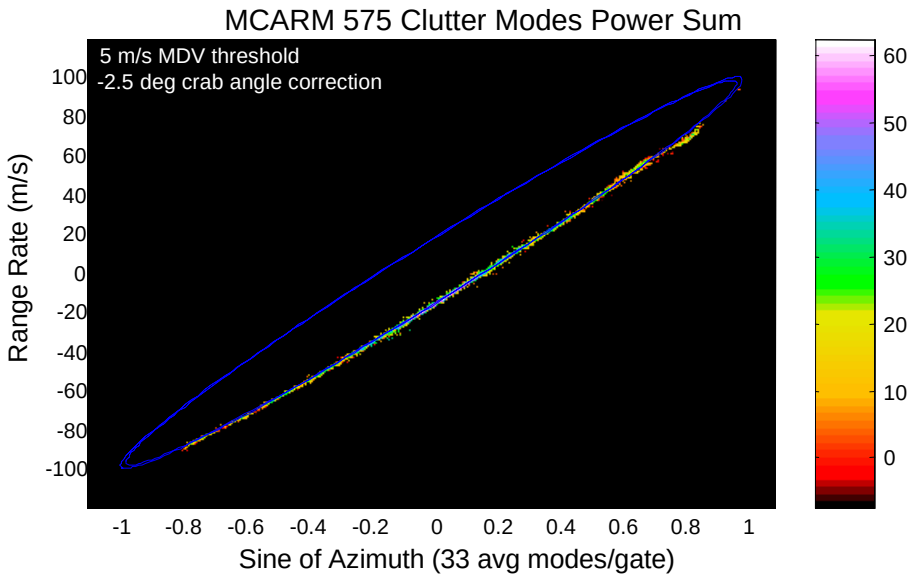


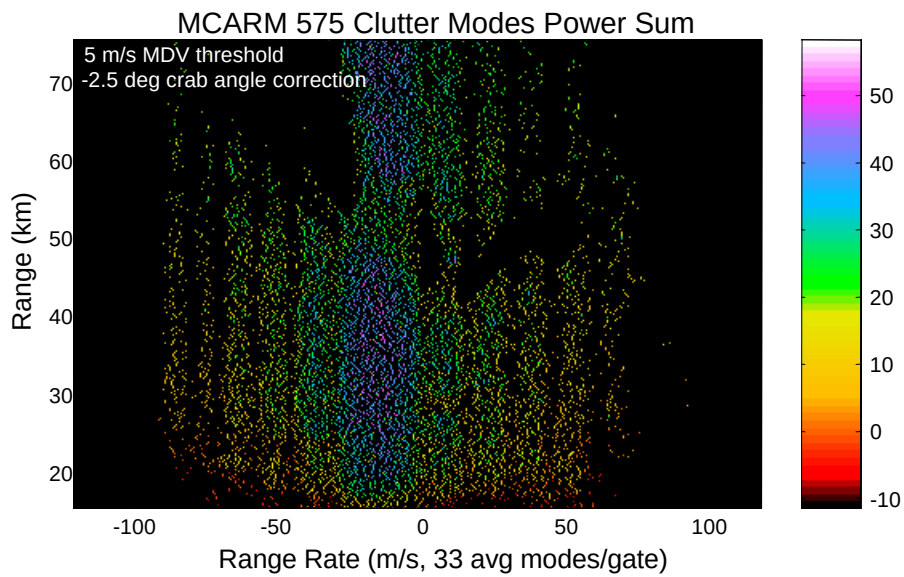


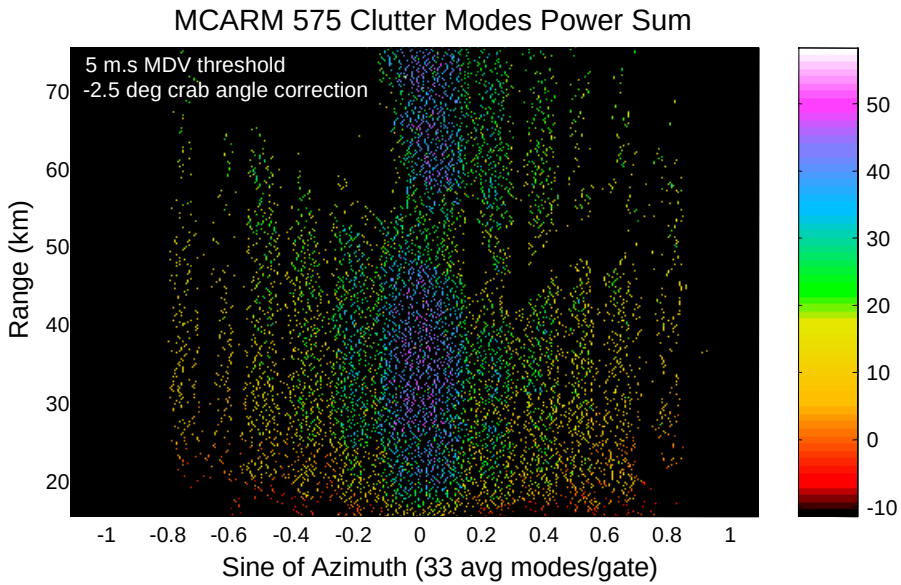
Variable noise floor at left and right of plot probably caused by AGC

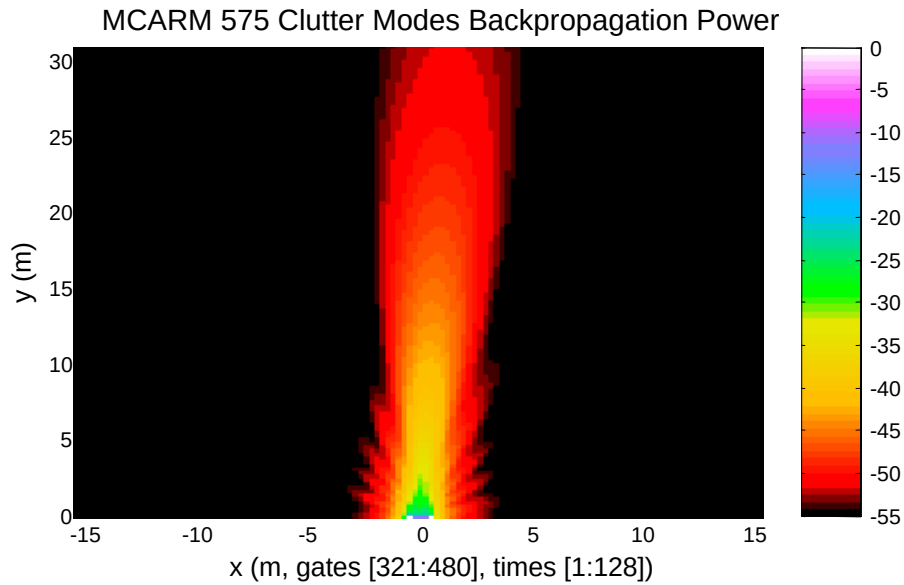
Modeling error is dominated by return signal modes, not random noise.

MCARM Set 575 Clutter Modes Huygens Backpropagation

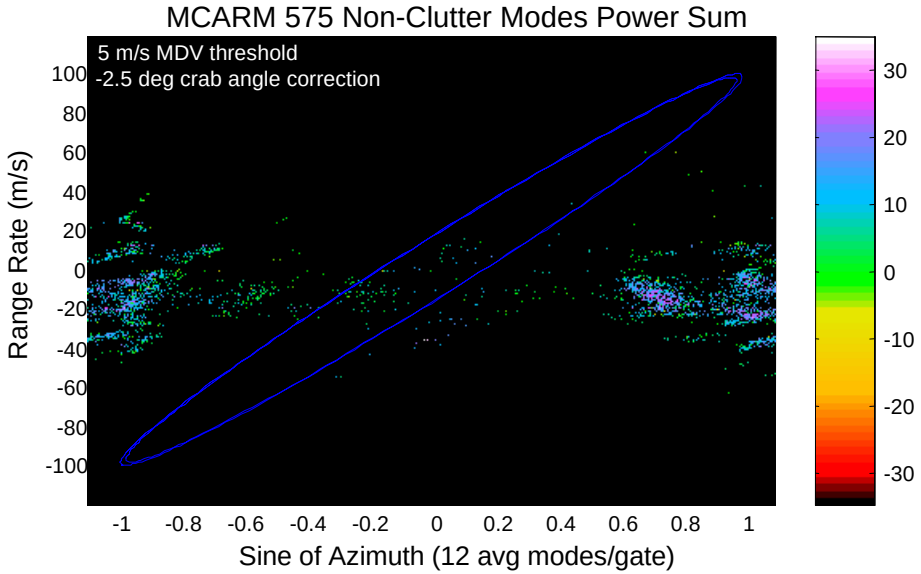


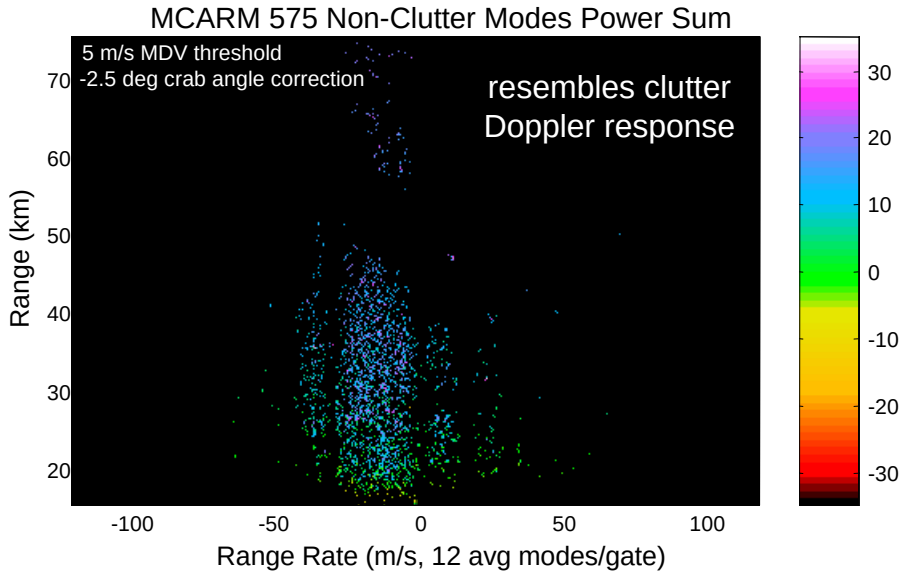


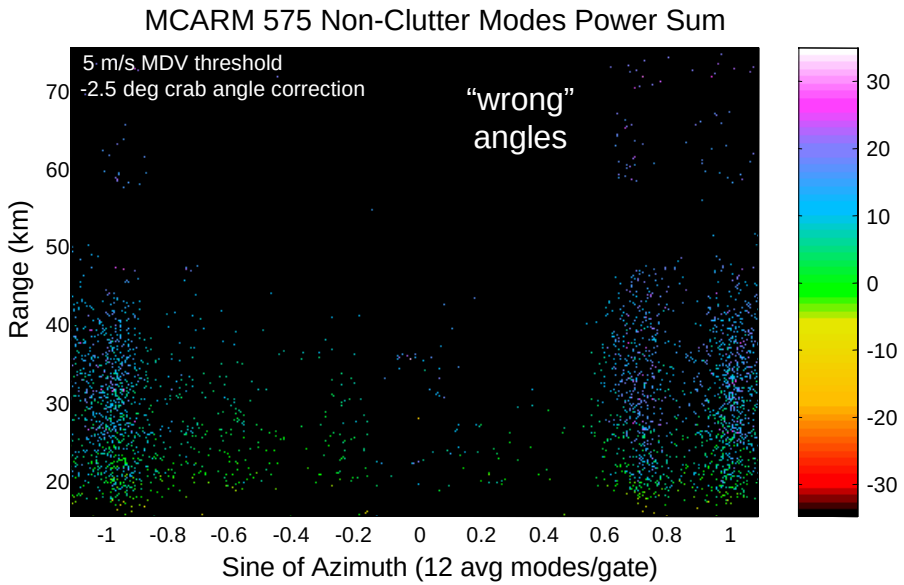


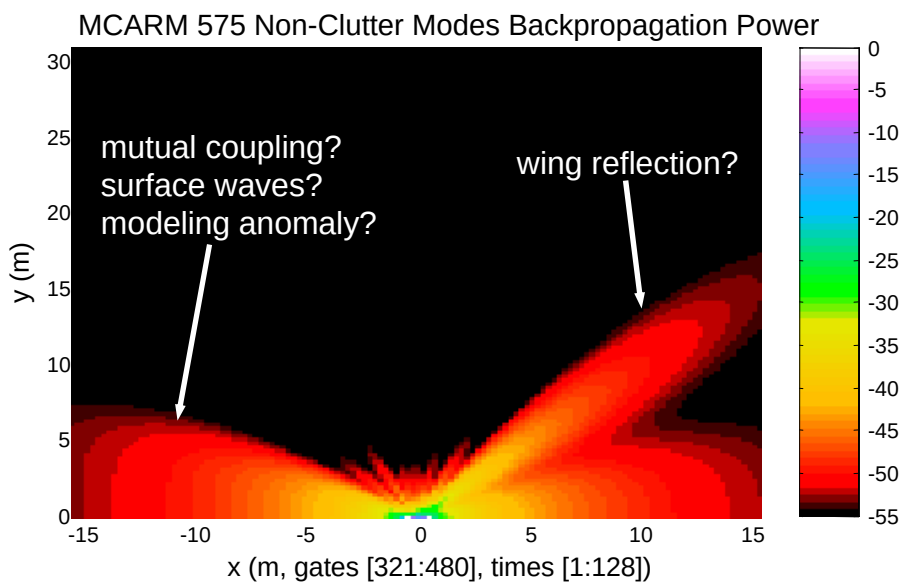


MCARM Set 575 Non-Clutter Modes Huygens Backpropagation









Comments

- ✓ SCHISM avoids covariance estimation problems (isolated range-gates).
- ✓ SCHISM operates simultaneously in MTI and "SAR" modes.
- ✓ SCHISM analysis and focusing of “real” MCARM data was successful.
- ✓ Scattered and distorted MCARM signal was well above the noise floor.
- ✓ A simple CACFAR detector easily finds strong, isolated targets.
  - Heavy tapers (50 dB) aggravate target-clutter mode cross-talk.
  - Light tapers (20 dB) produce spurious modes from sidelobe leakage.

SCHISM mode “tracking” over multiple CPIs to expose slower targets.

Clutter model as reference for merging CPIs (motion-compensation, etc.).

Clutter model for navigation or for registering targets to ground coordinates.