Scattering from Surf Zone Waves

Experimental Results and Modeling

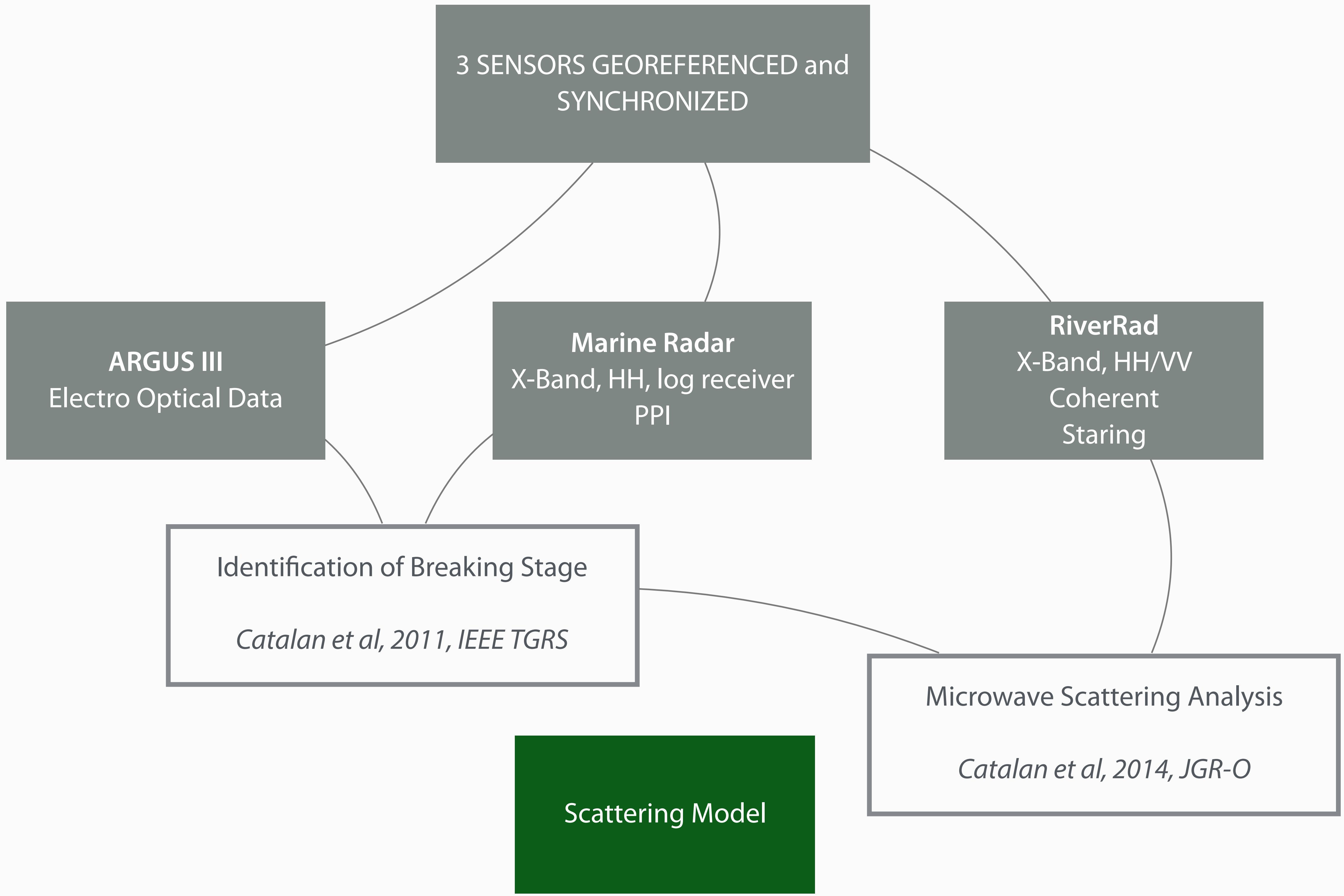
Patricio Catalan, Merrick Haller, Bill Plant

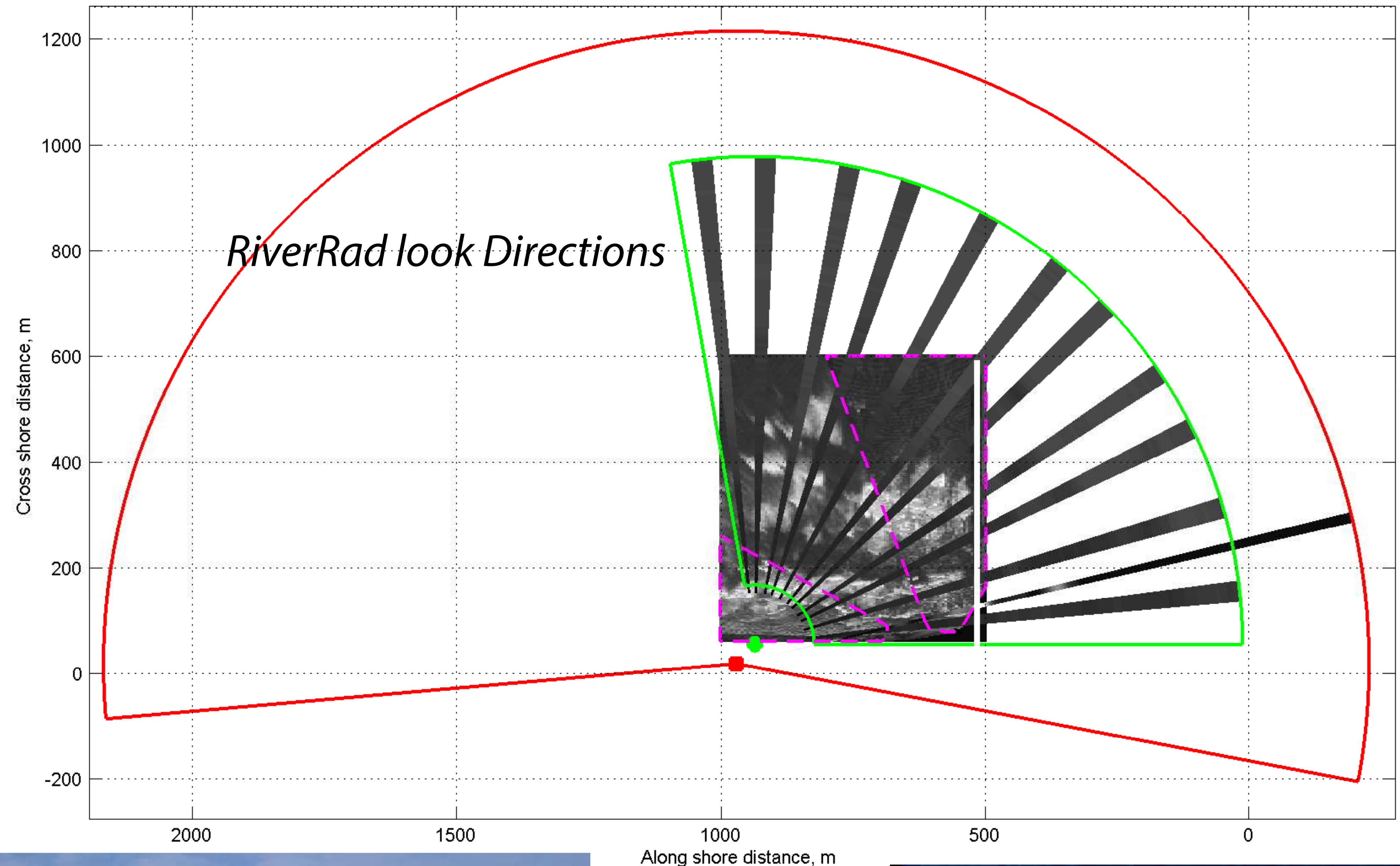
Associate Professor
Universidad Técnica Federico Santa María Chile

Motivation

Background on this Work

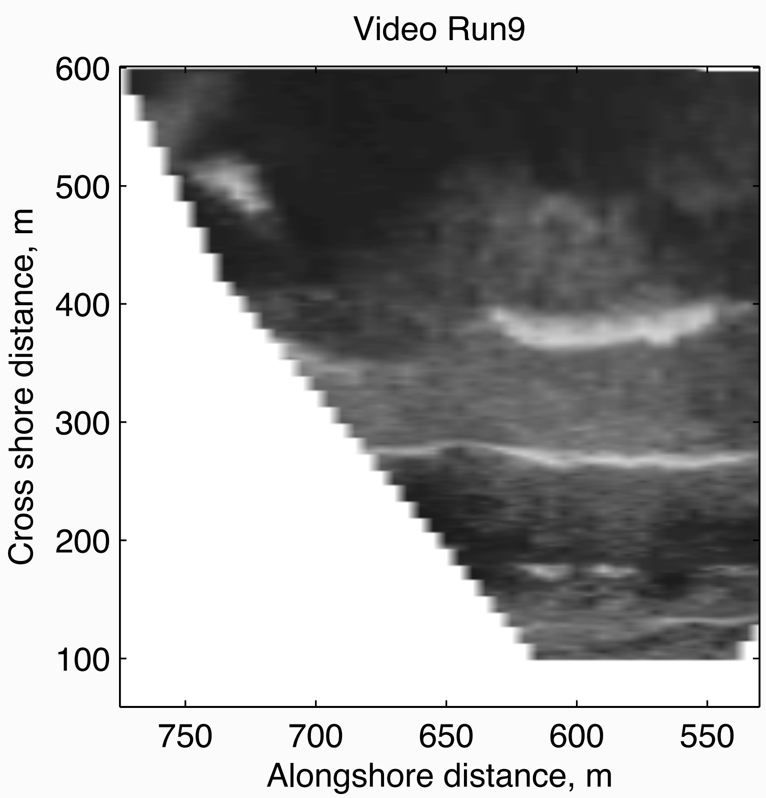
- Multi Remote SENsing Surfzone Observations: MR-SENSO
- 6 weeks at Duck, NC, in 2008

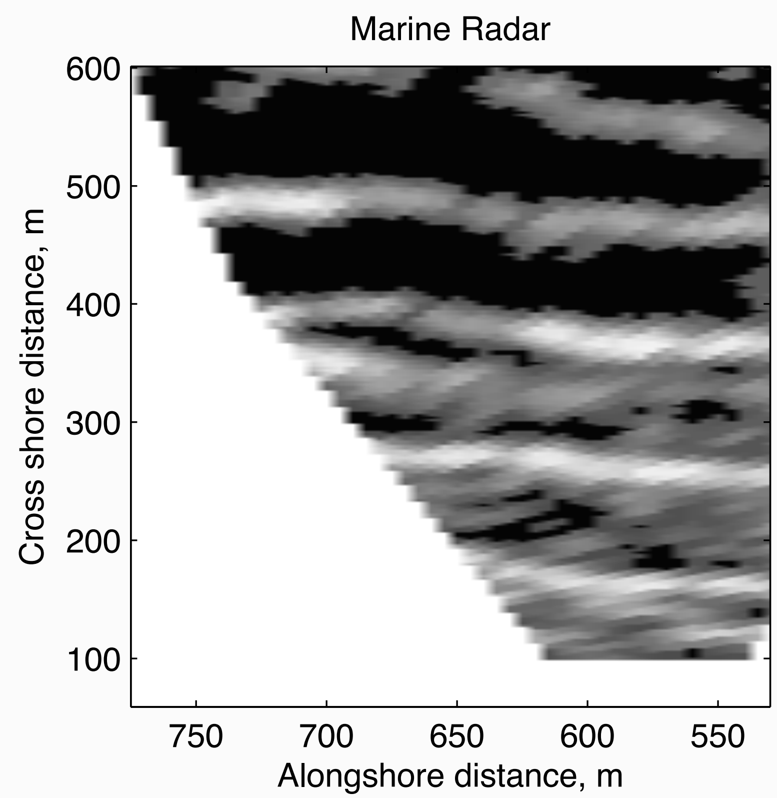


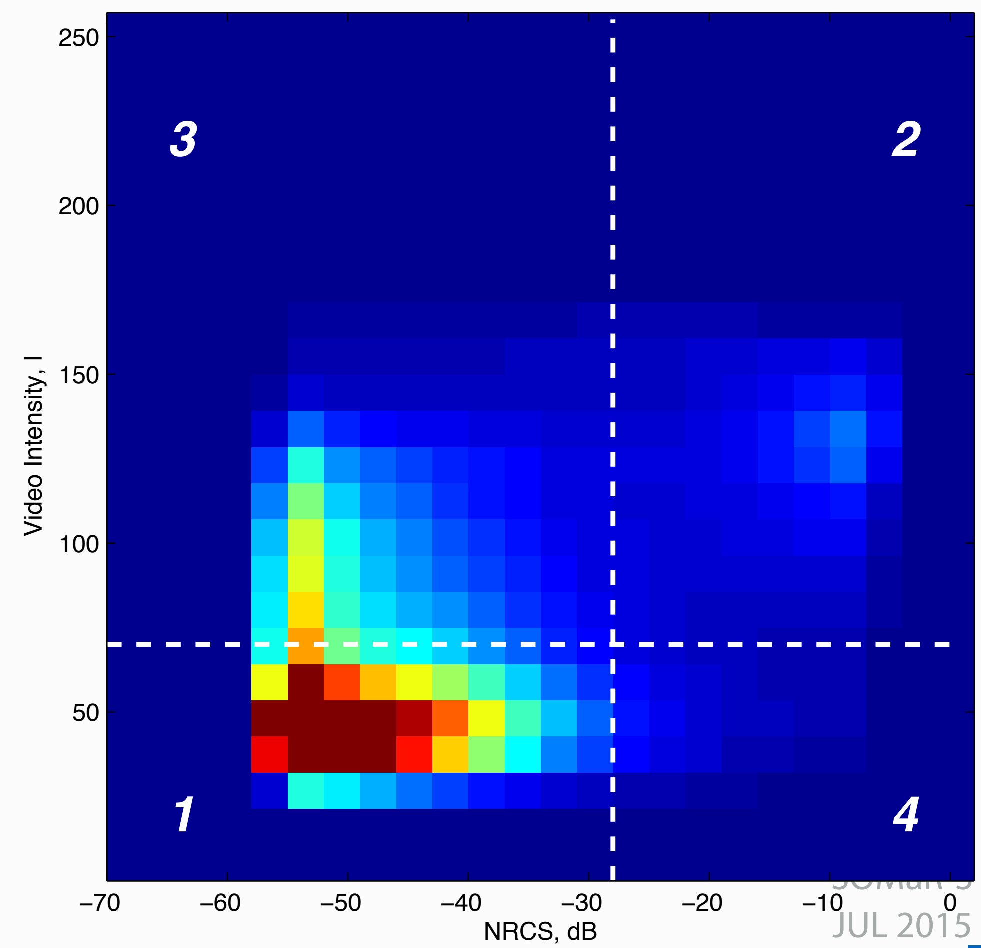

RiverRad look Directions
Cross shore distance, m
1200
1000
800
600
400
200
0
-200
2000
1500
1000
500
0
Along shore distance, m

Phase 1: Identification of Breaking

- Target Detection using coupled Constant False Alarm approach







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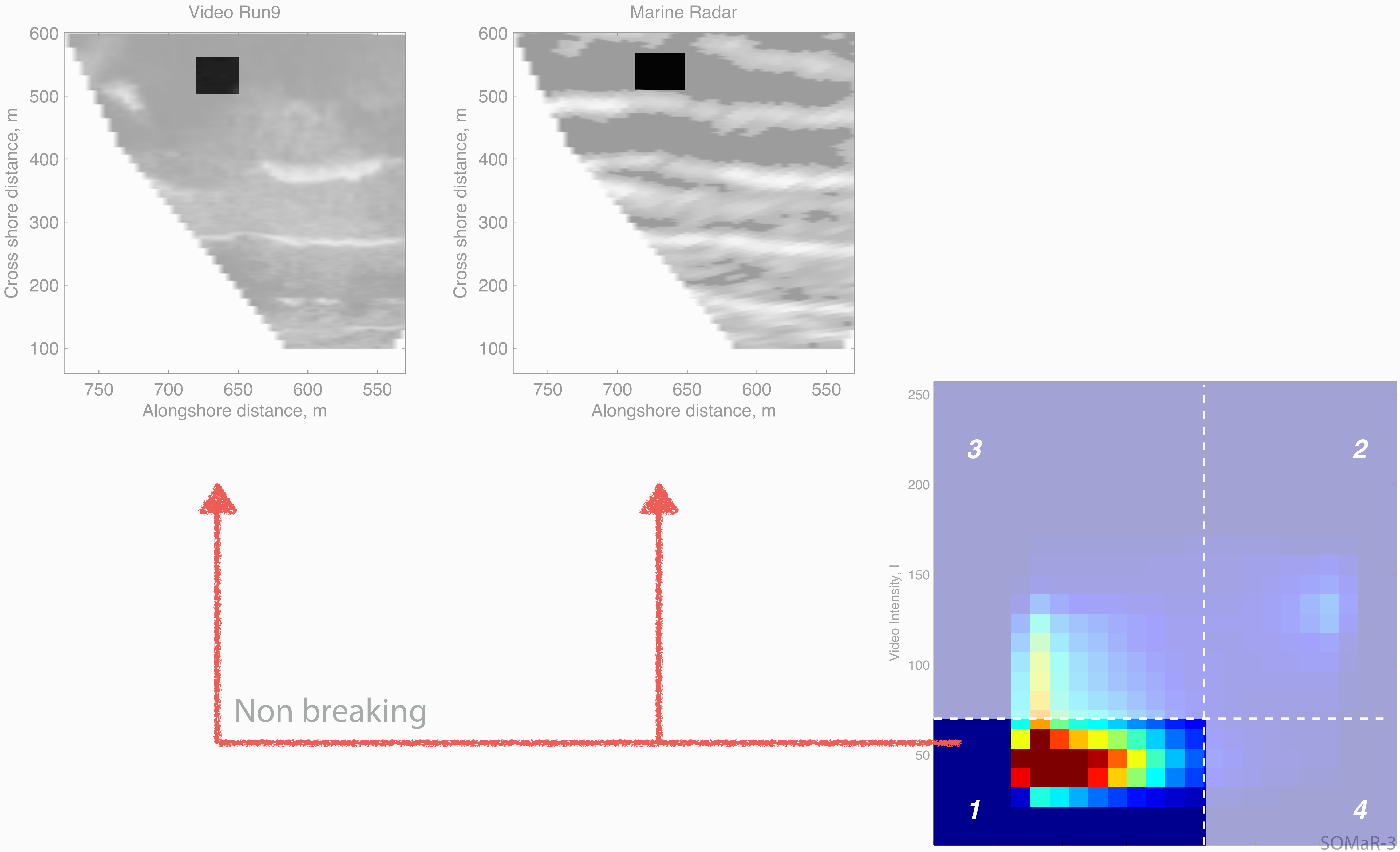
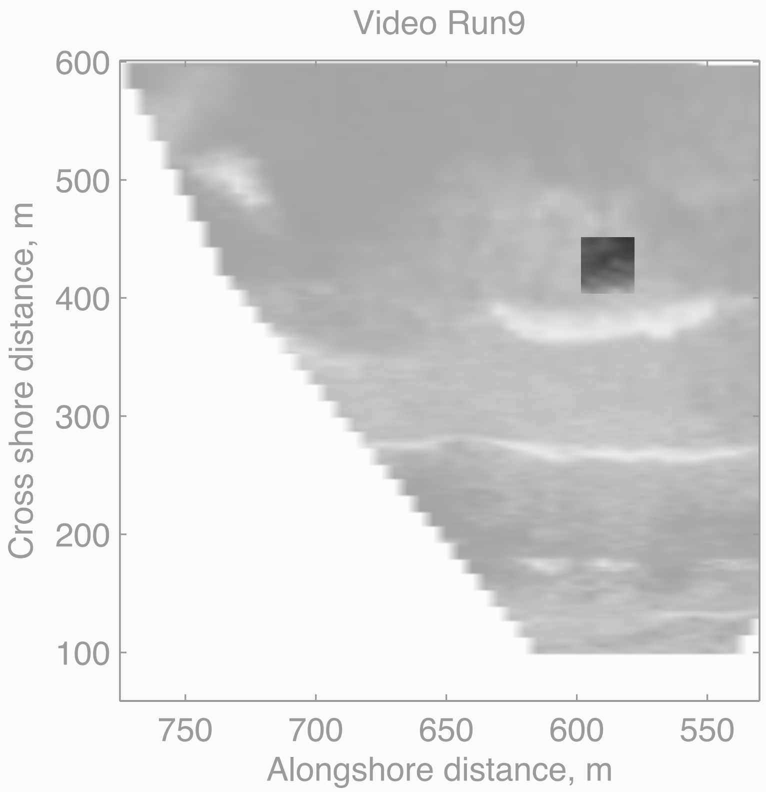
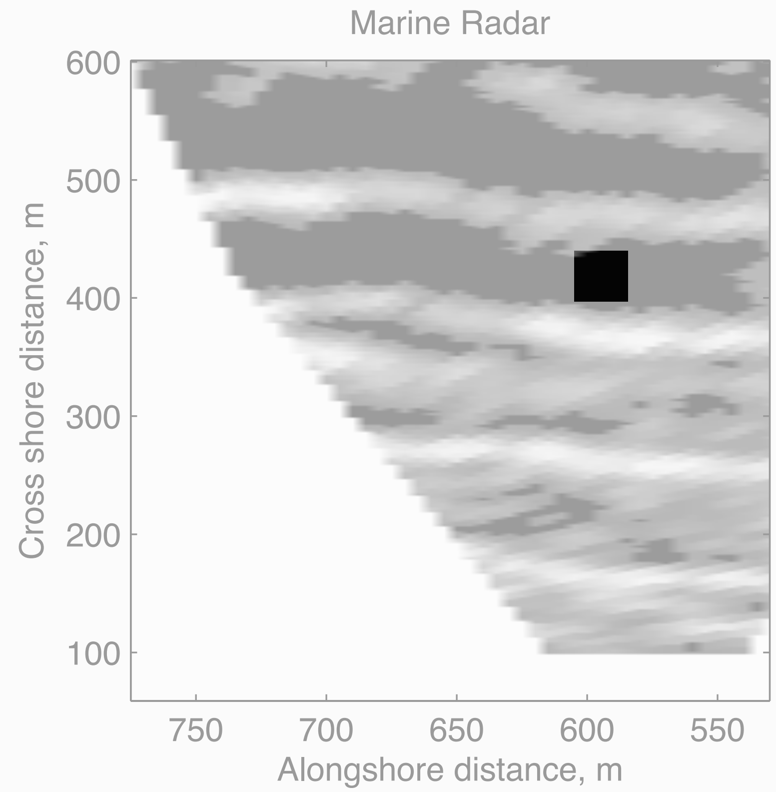


Phase 1: Identification of Breaking

USM Catalan

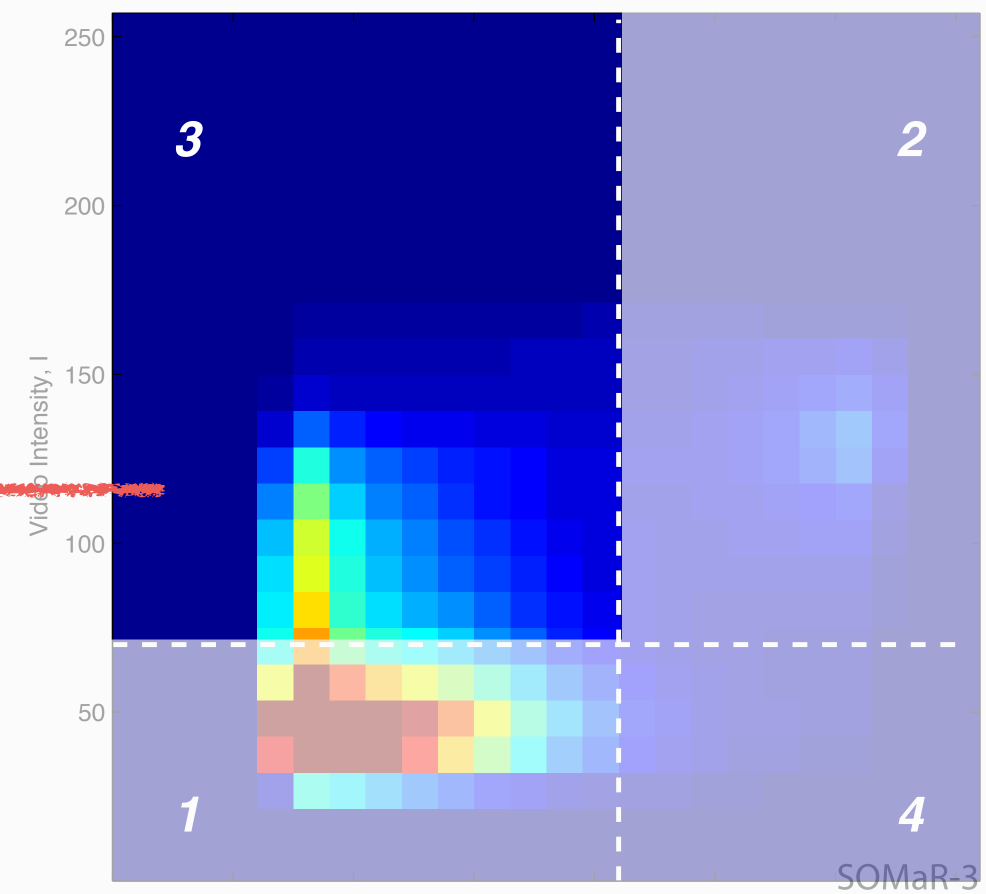
- Target Detection using coupled Constant False Alarm approach





Remnant Foam

Assumed not dynamically relevant



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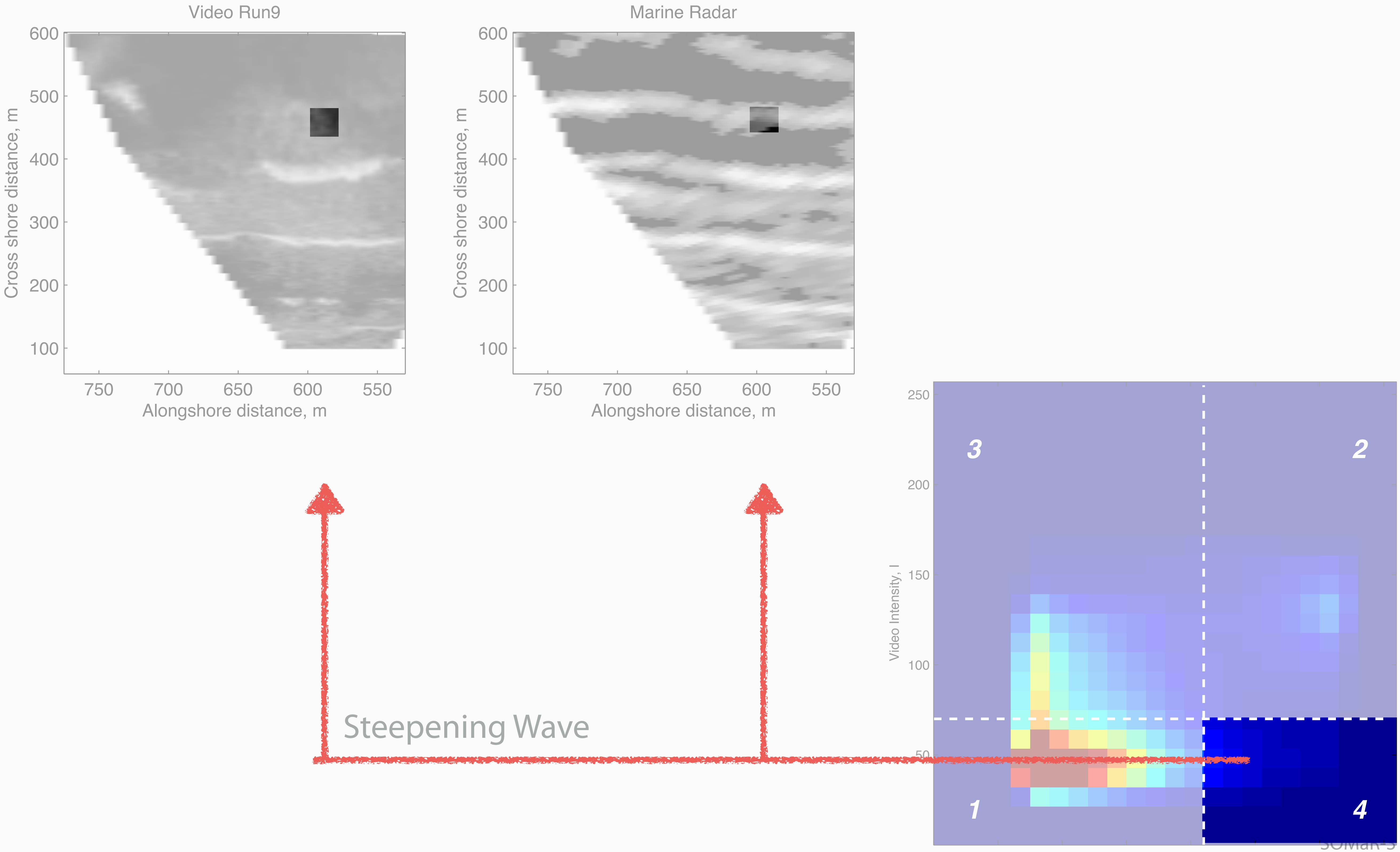
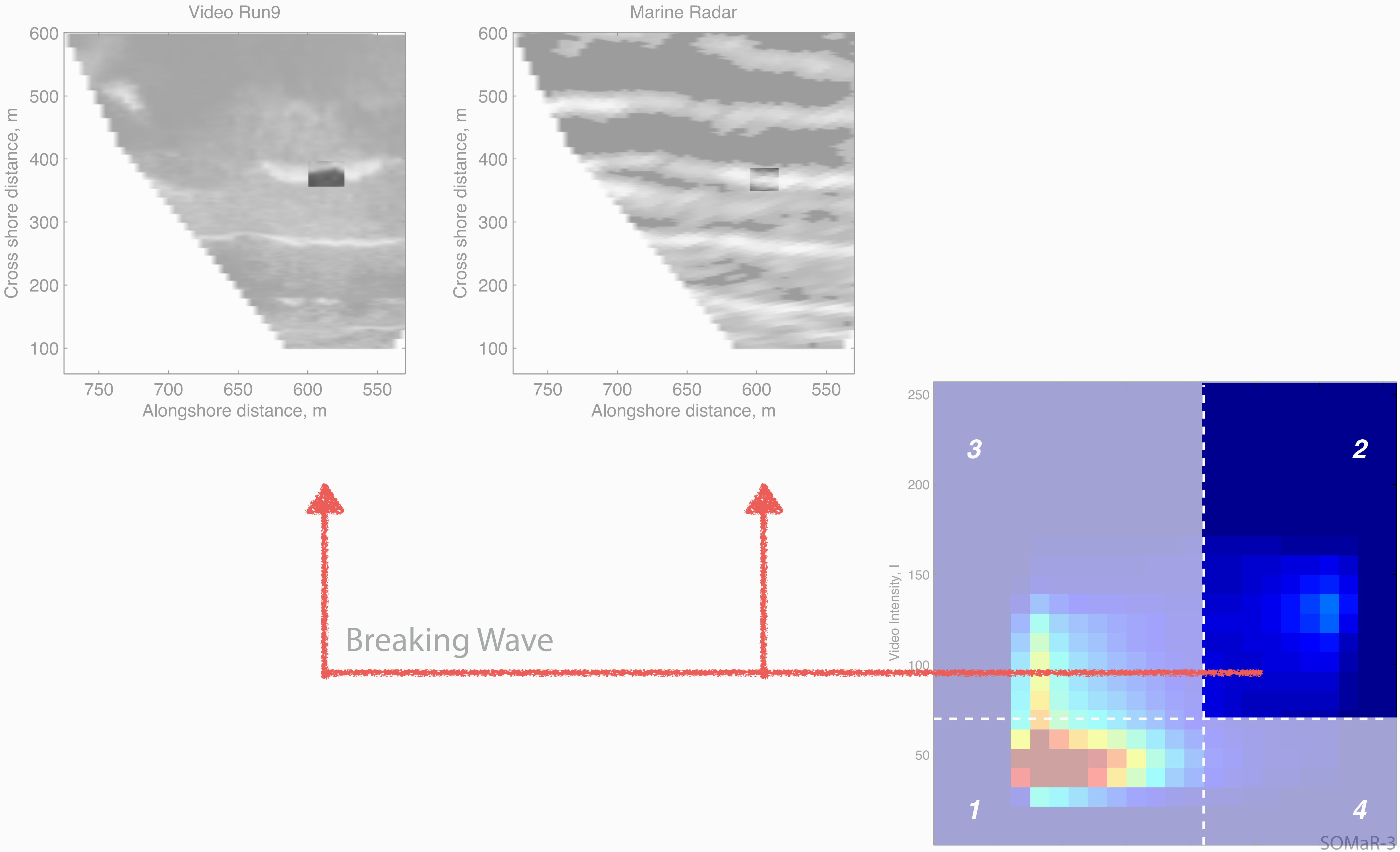
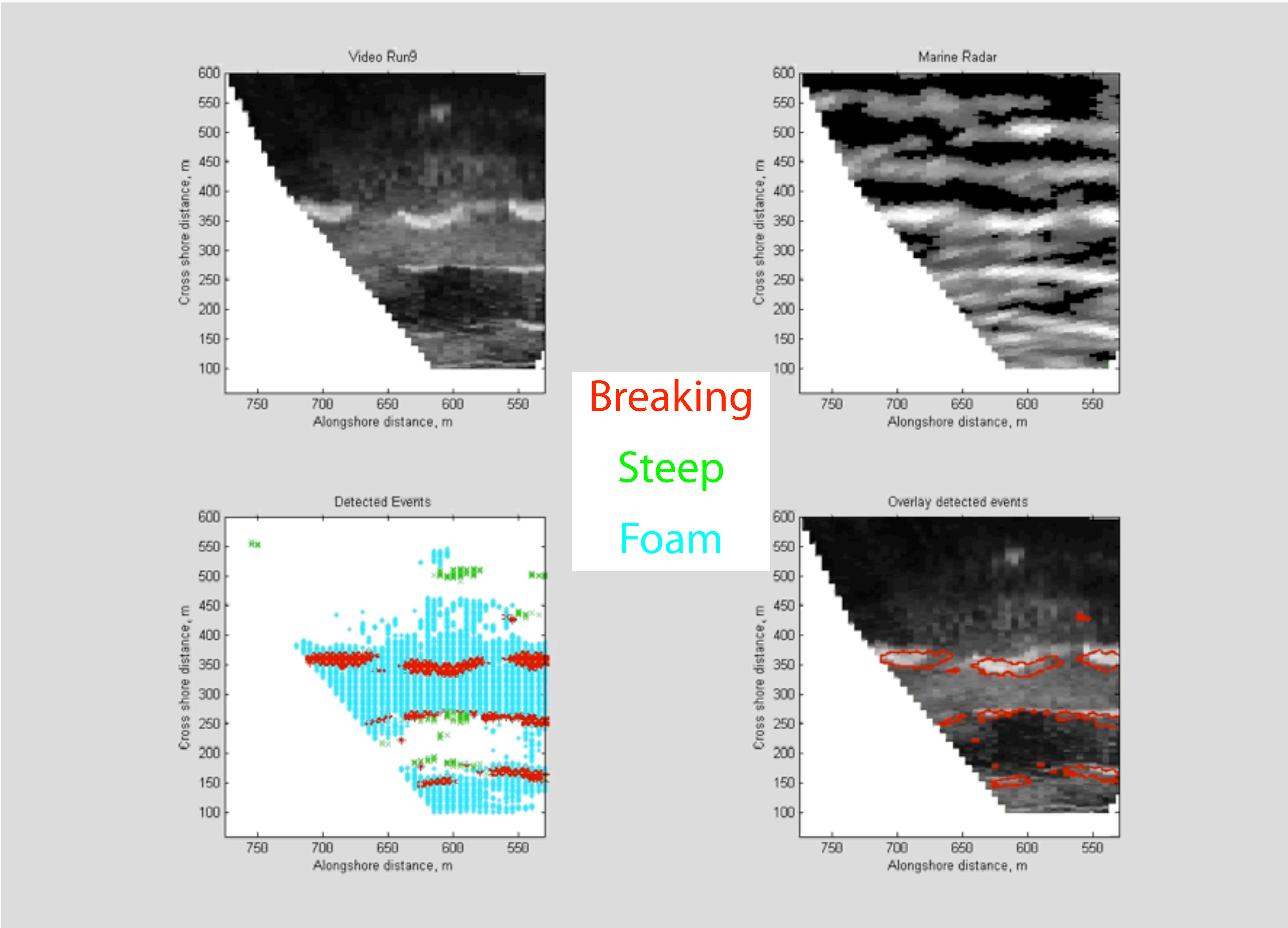


Phase 1: Identification of Breaking

- Target Detection using coupled Constant False Alarm approach



Well, how does it work?



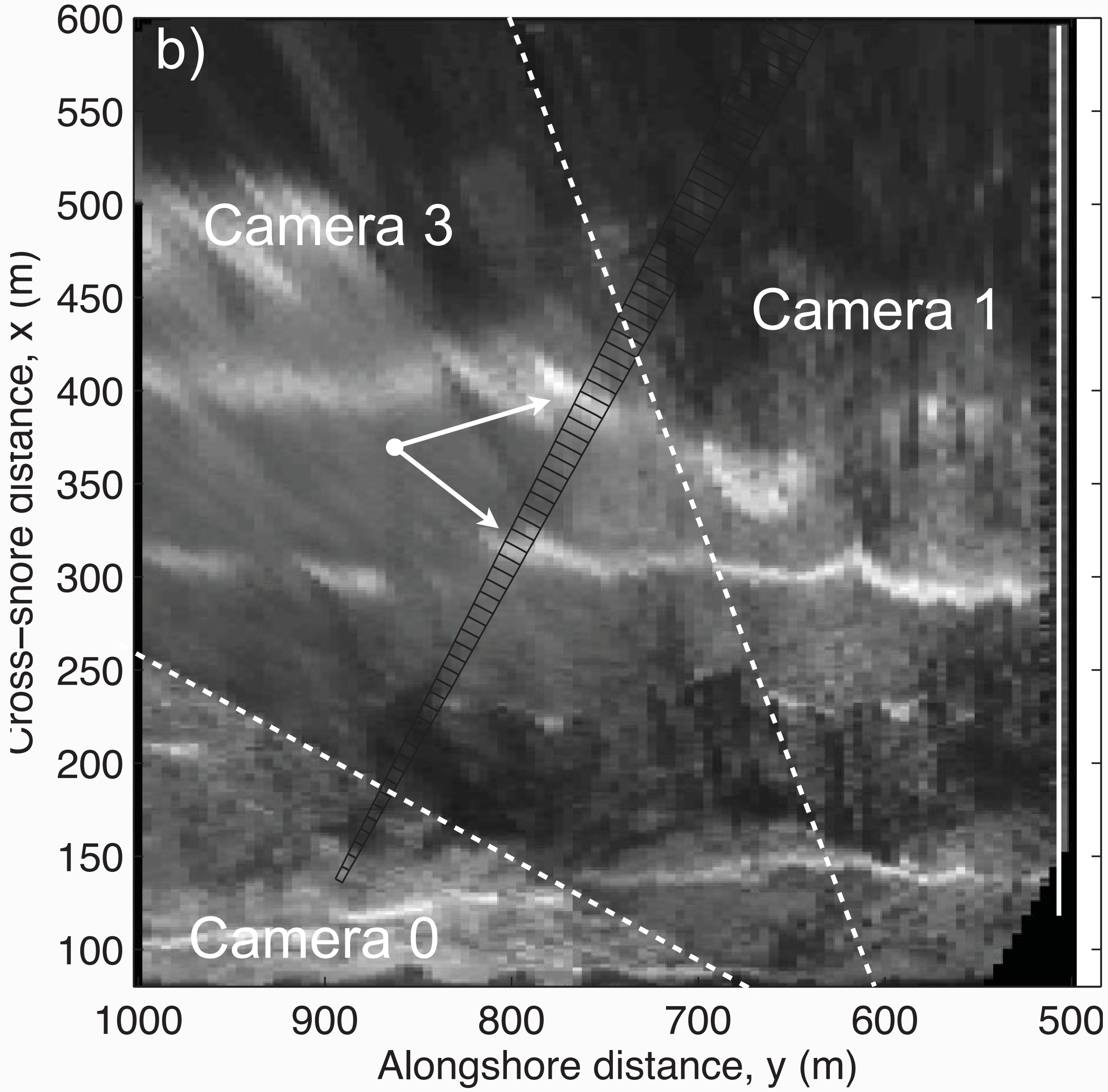
Phase 2: Microwave Scattering

- Goal:
  - Identify the backscattering characteristics of breaking waves
  - Improve our understanding of the scattering mechanisms

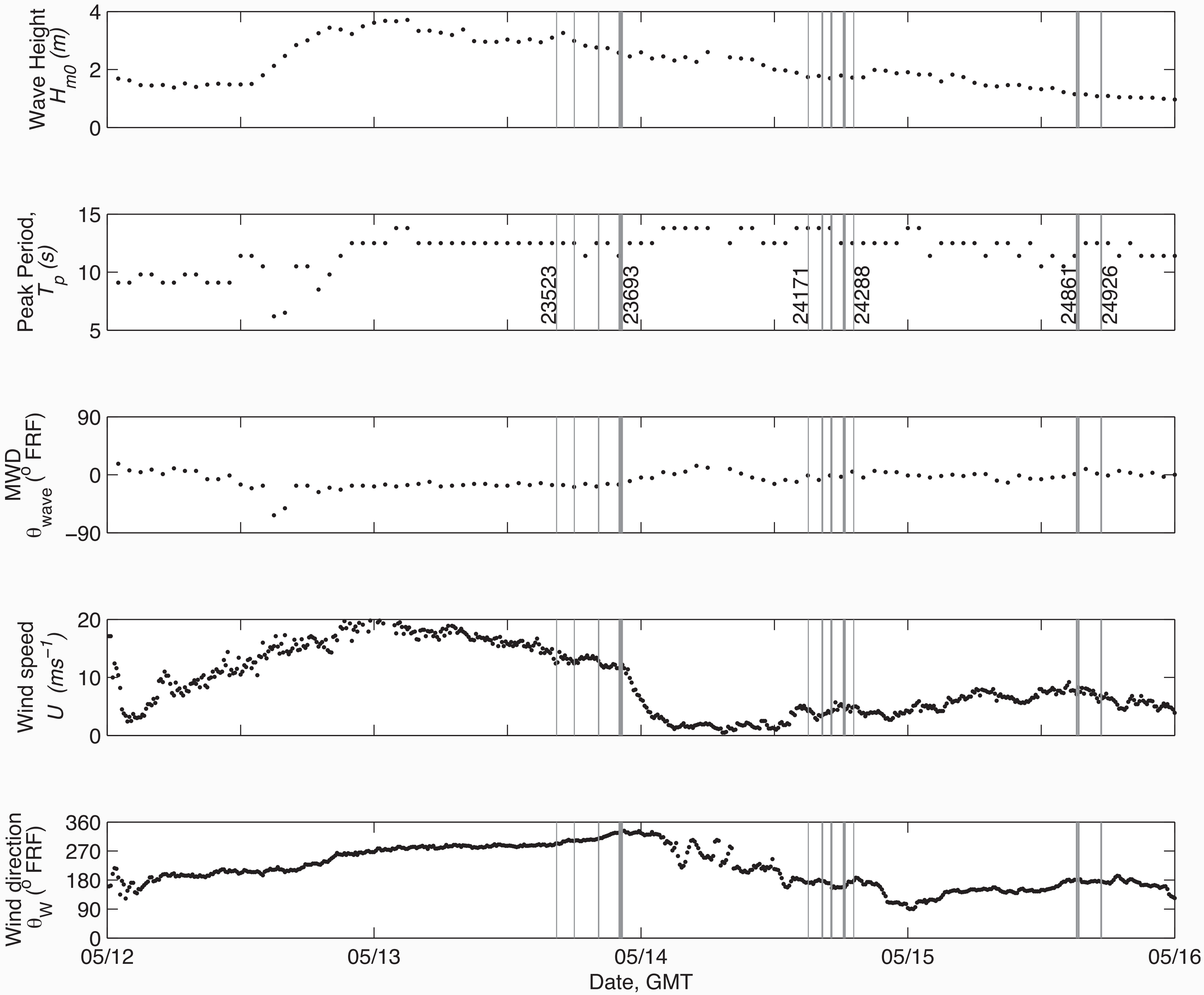
  - We can compare the RiverRad data for all wave stages
    - NRCS
    - Doppler Spectra
    - Doppler offset

  - RiverRad settings
    - 9.36 GHz
    - 2 min
    - 128 range bins @ 7.5 m
    - 0.53 s sampling

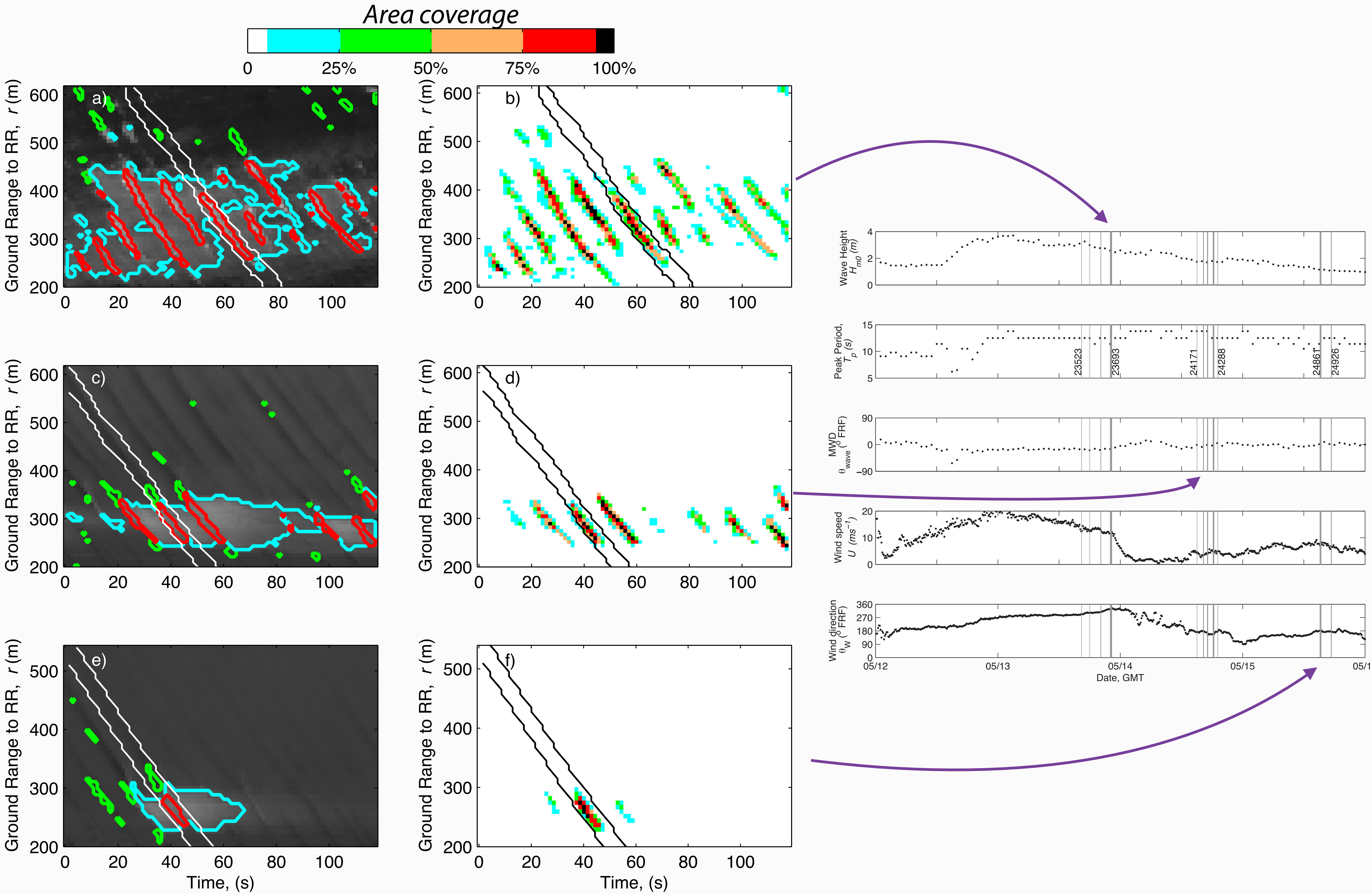
    - 31 two-minute runs were used



Enviromental conditions

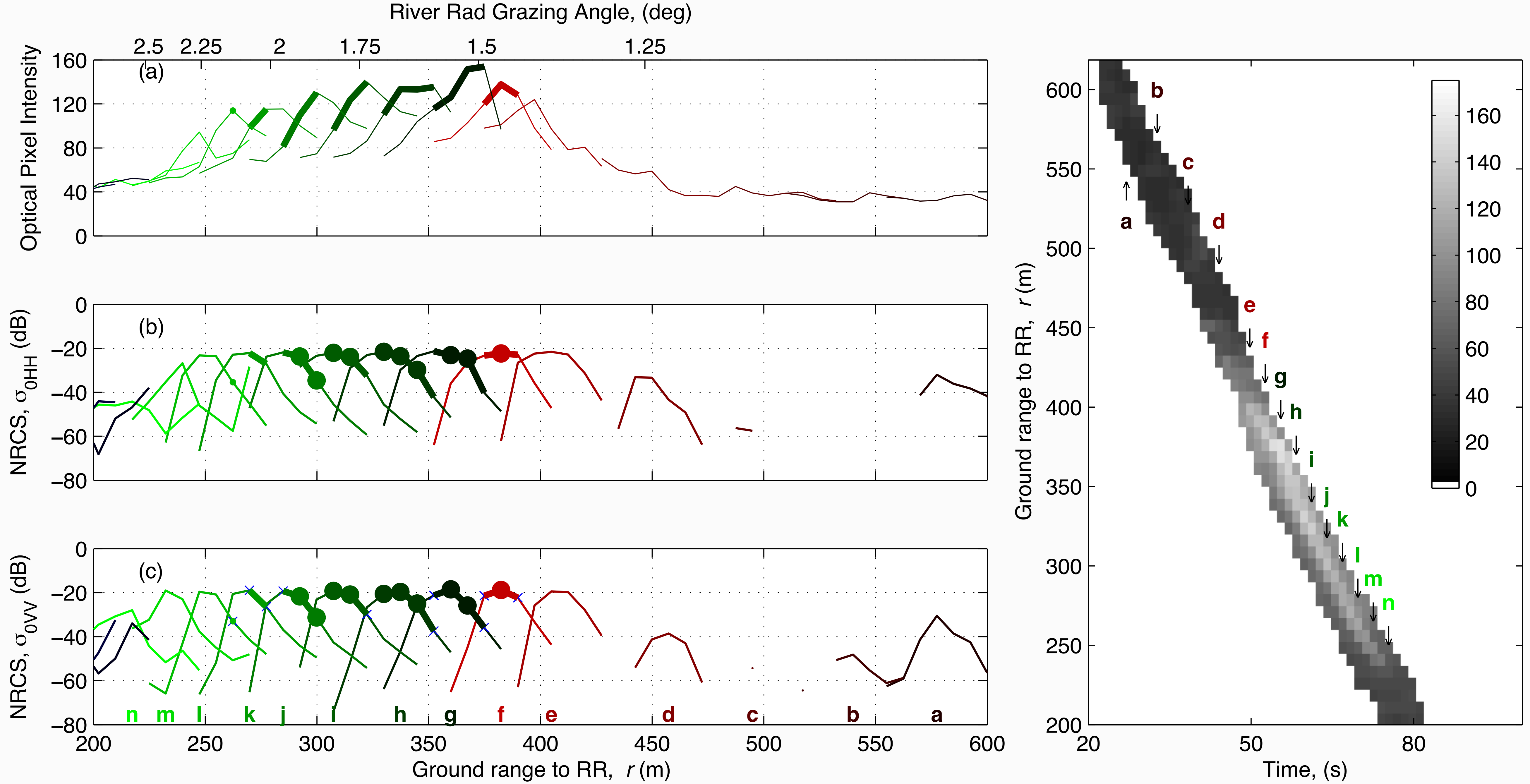


Detection

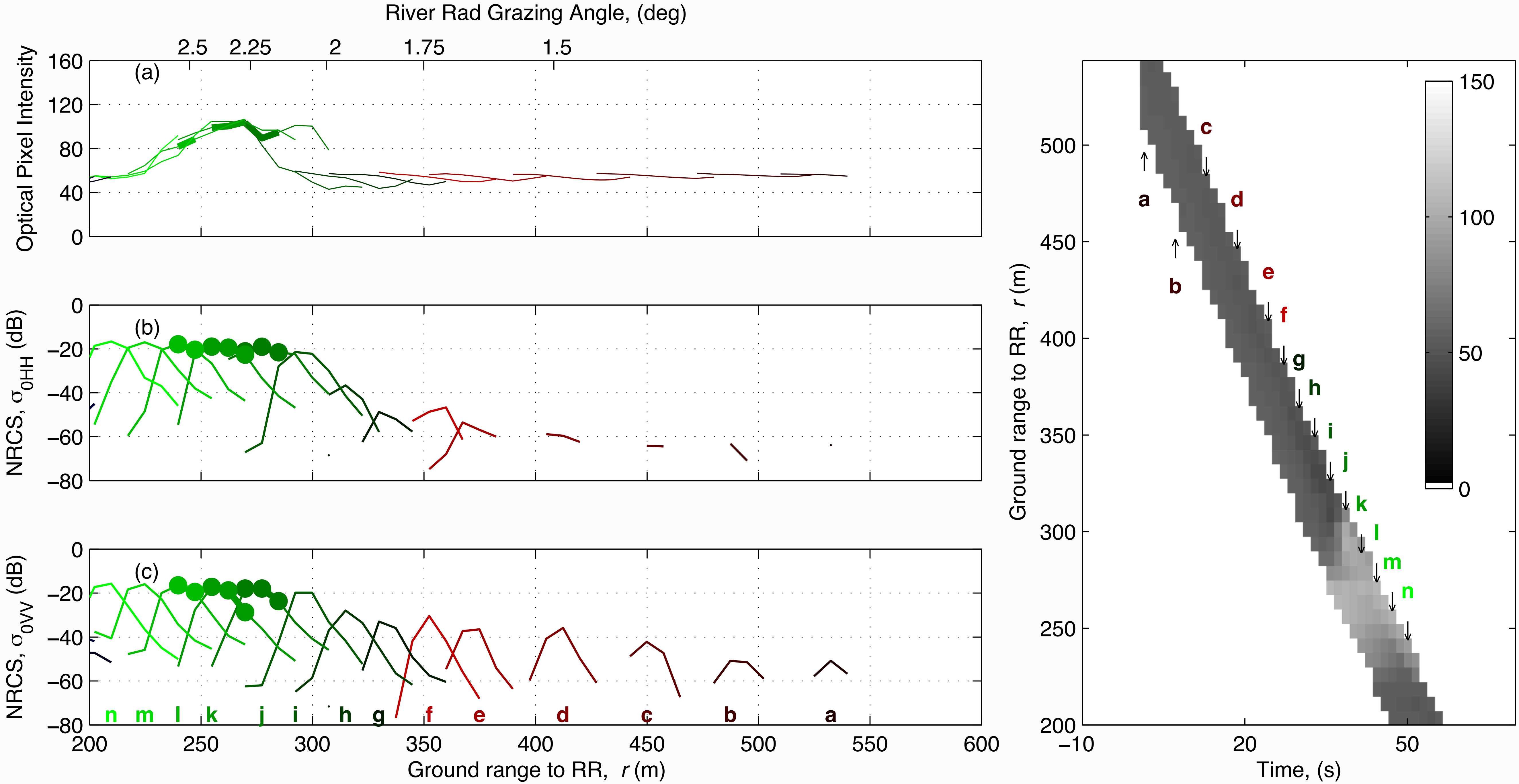


Area coverage
0
25%
50%
75%
100%
a)
b)
c)
d)
e)
f)
Ground Range to RR, r (m)
Time, (s)
Wave Height H_{m0} (m)
Peak Period, T_p (s)
MWD θ_{wave} (° FRF)
Wind speed U (ms^{-1})
Wind direction θ_W (° FRF)
23523
23693
24171
24288
24861
24926
05/12
05/13
05/14
05/15
Date, GMT

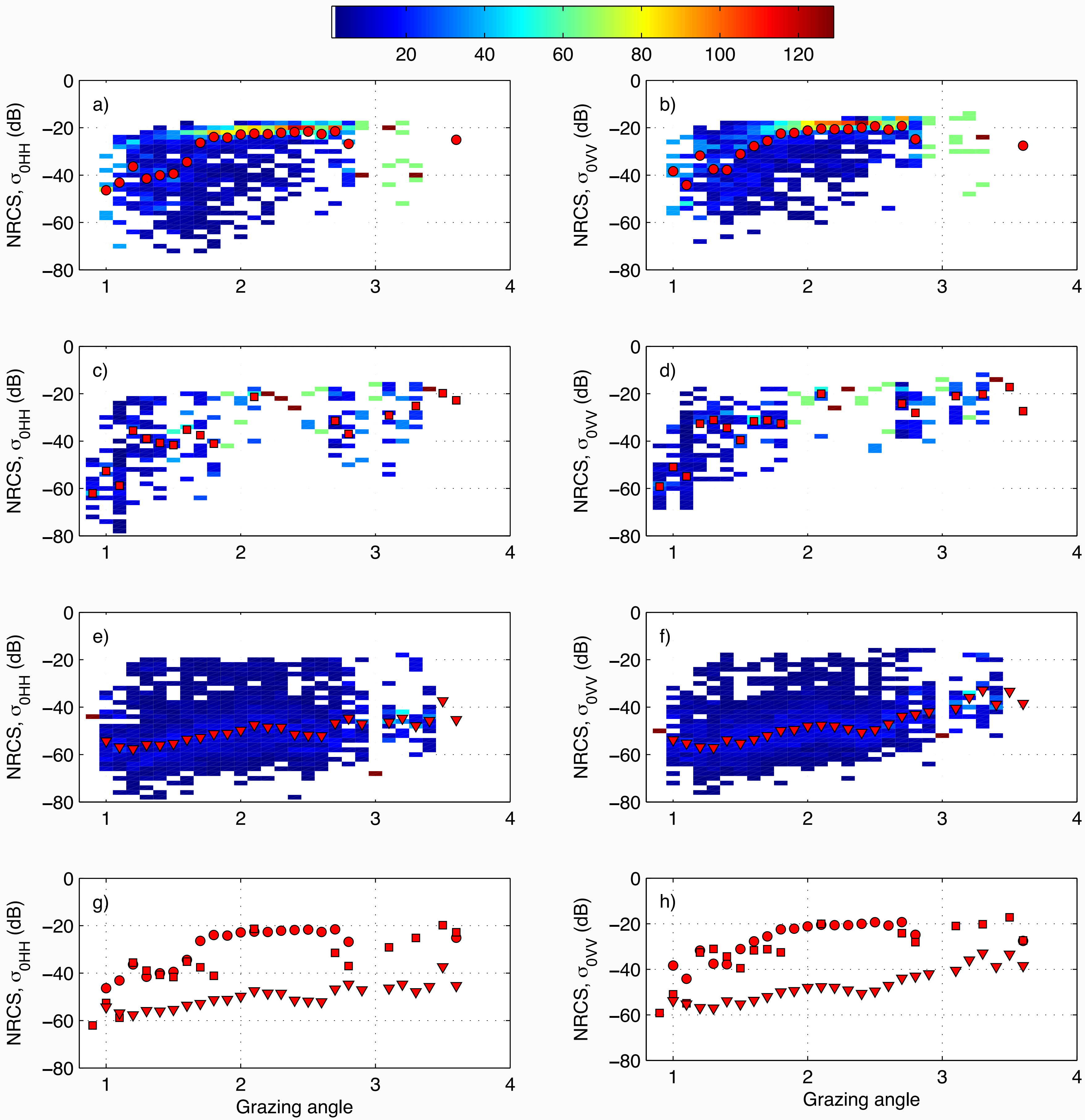
Wave by Wave NRCS Evolution: Energetic Cond.



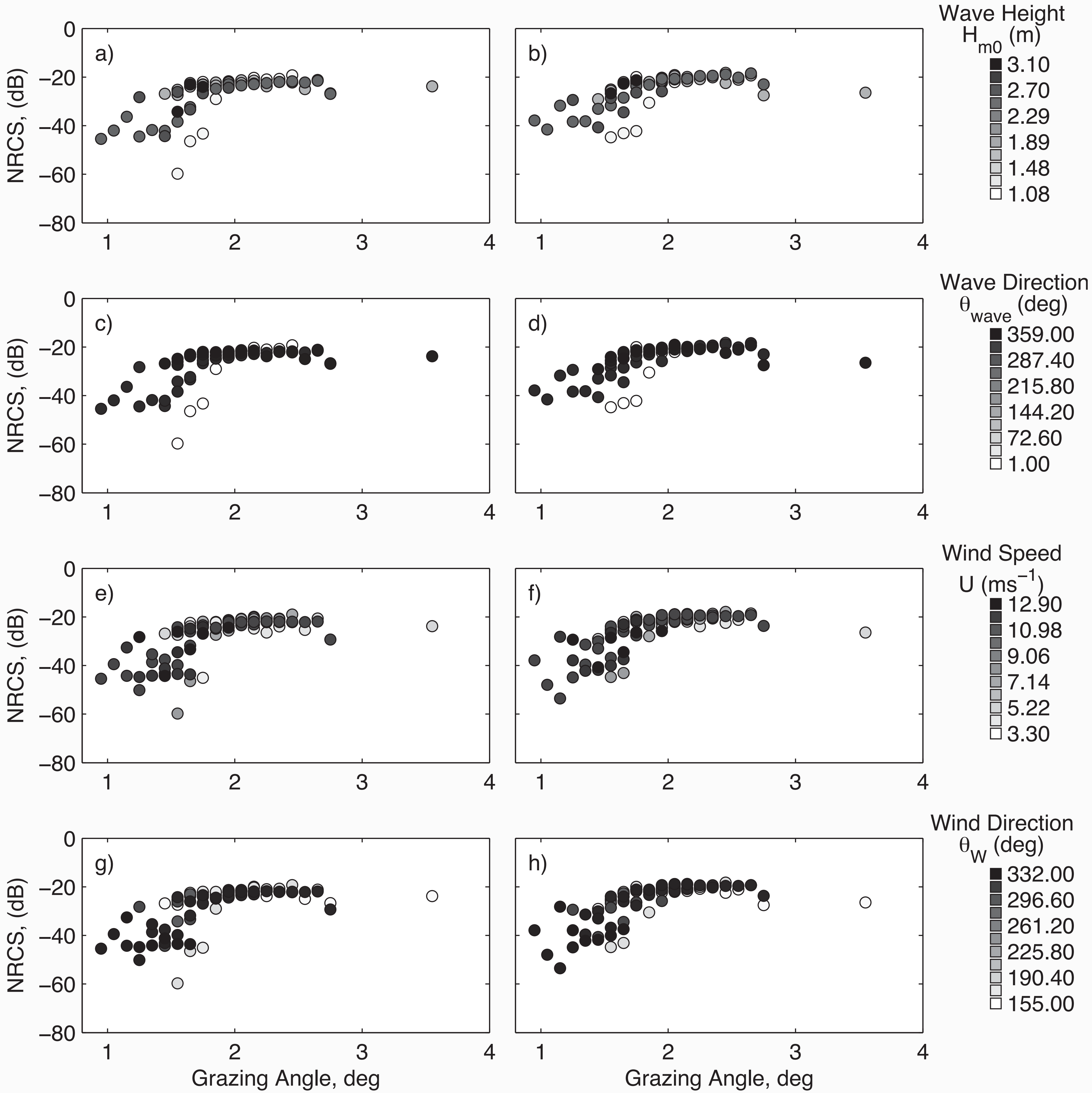
Wave by Wave NRCS Evolution: Low Energy Cond.



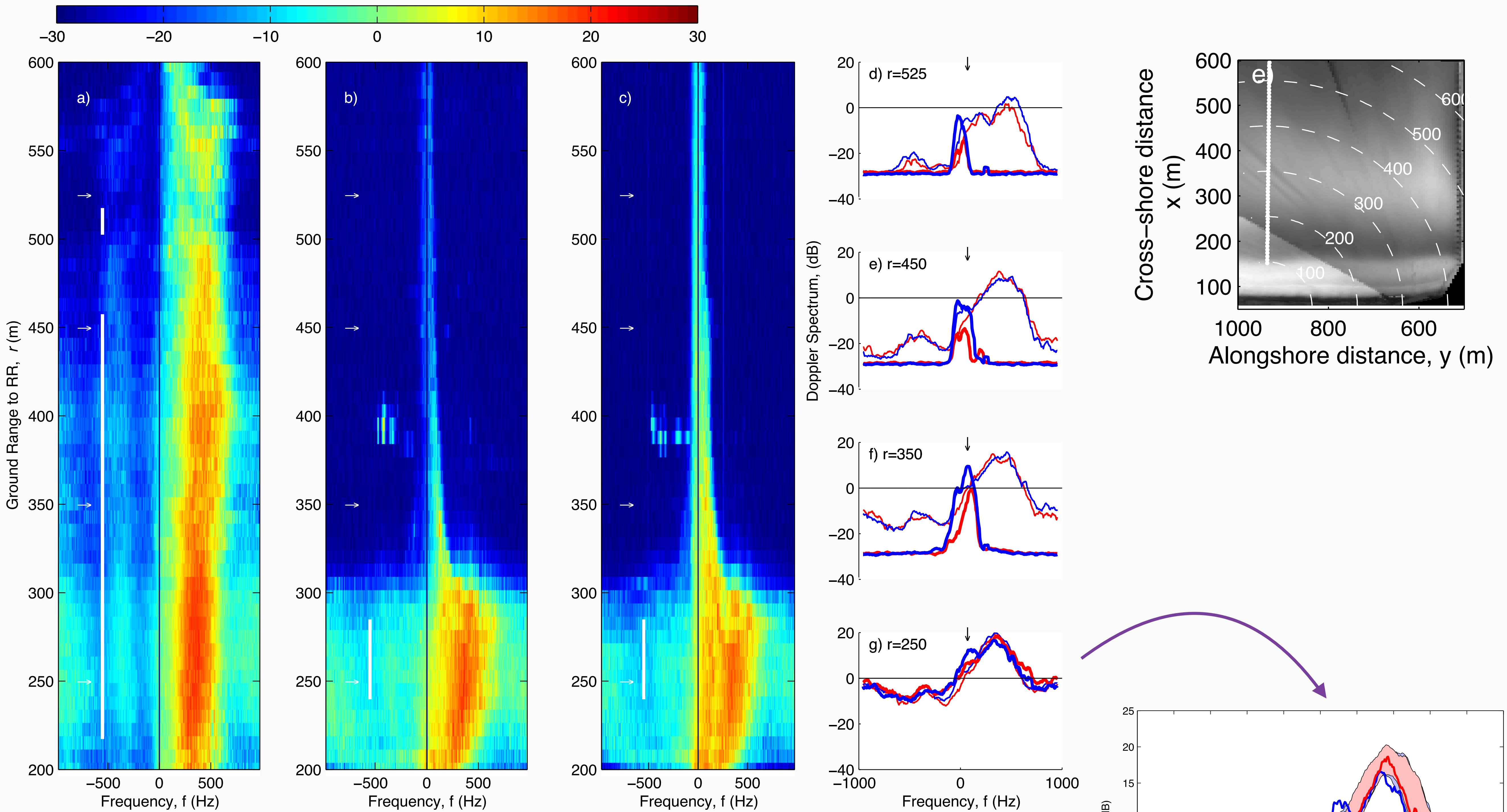
Ensemble Results

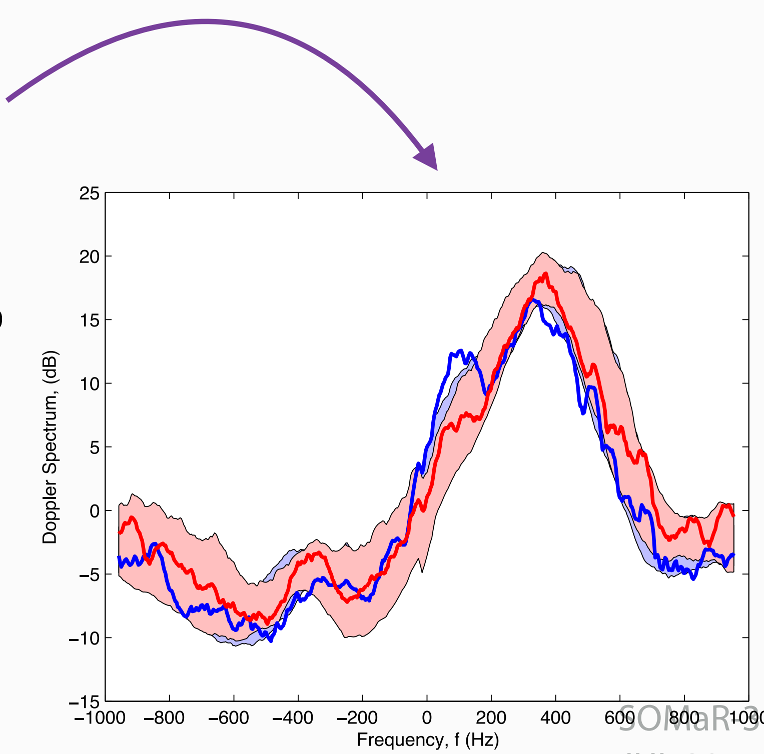


Environmental Dependency (or lack of)

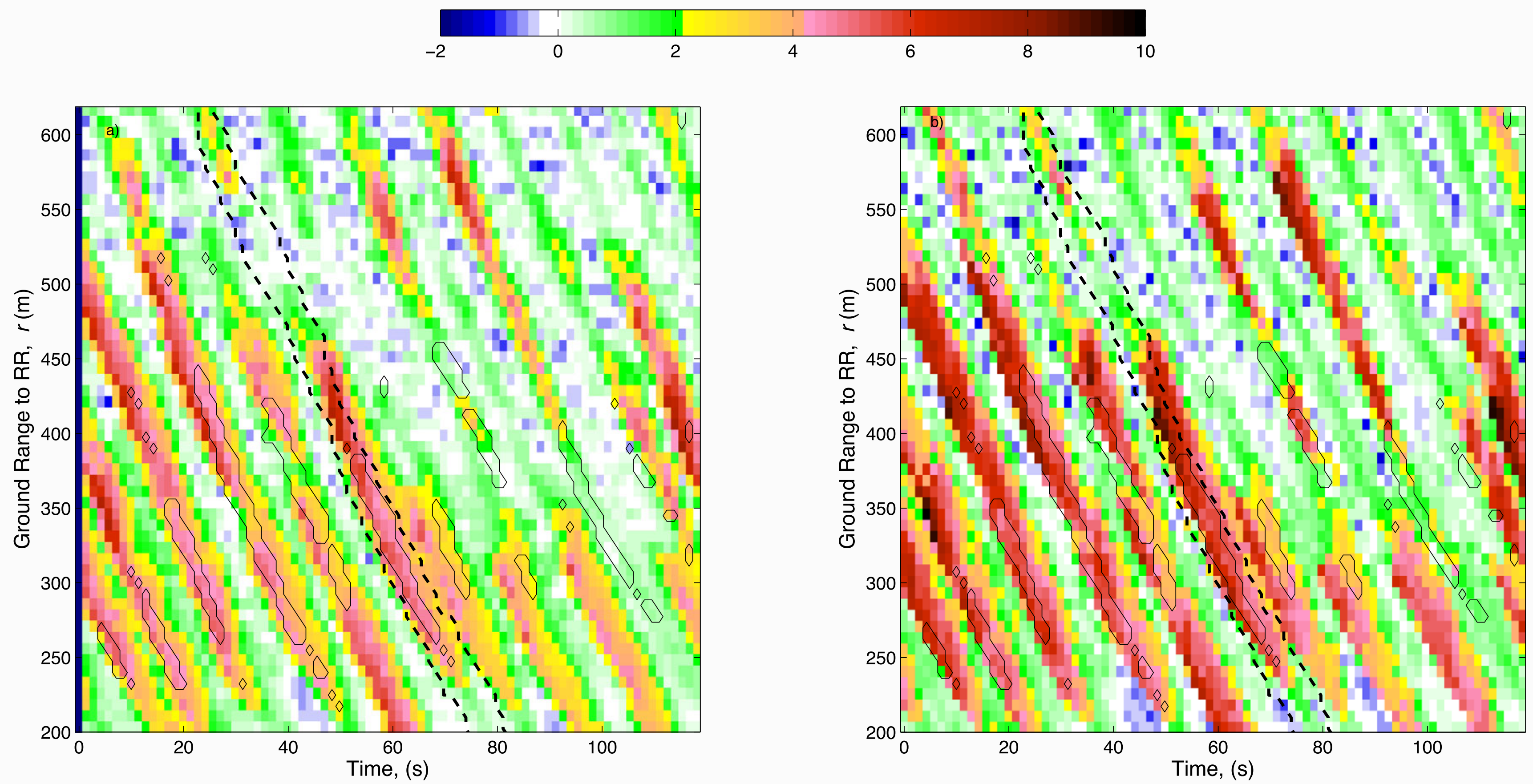


Doppler Spectra

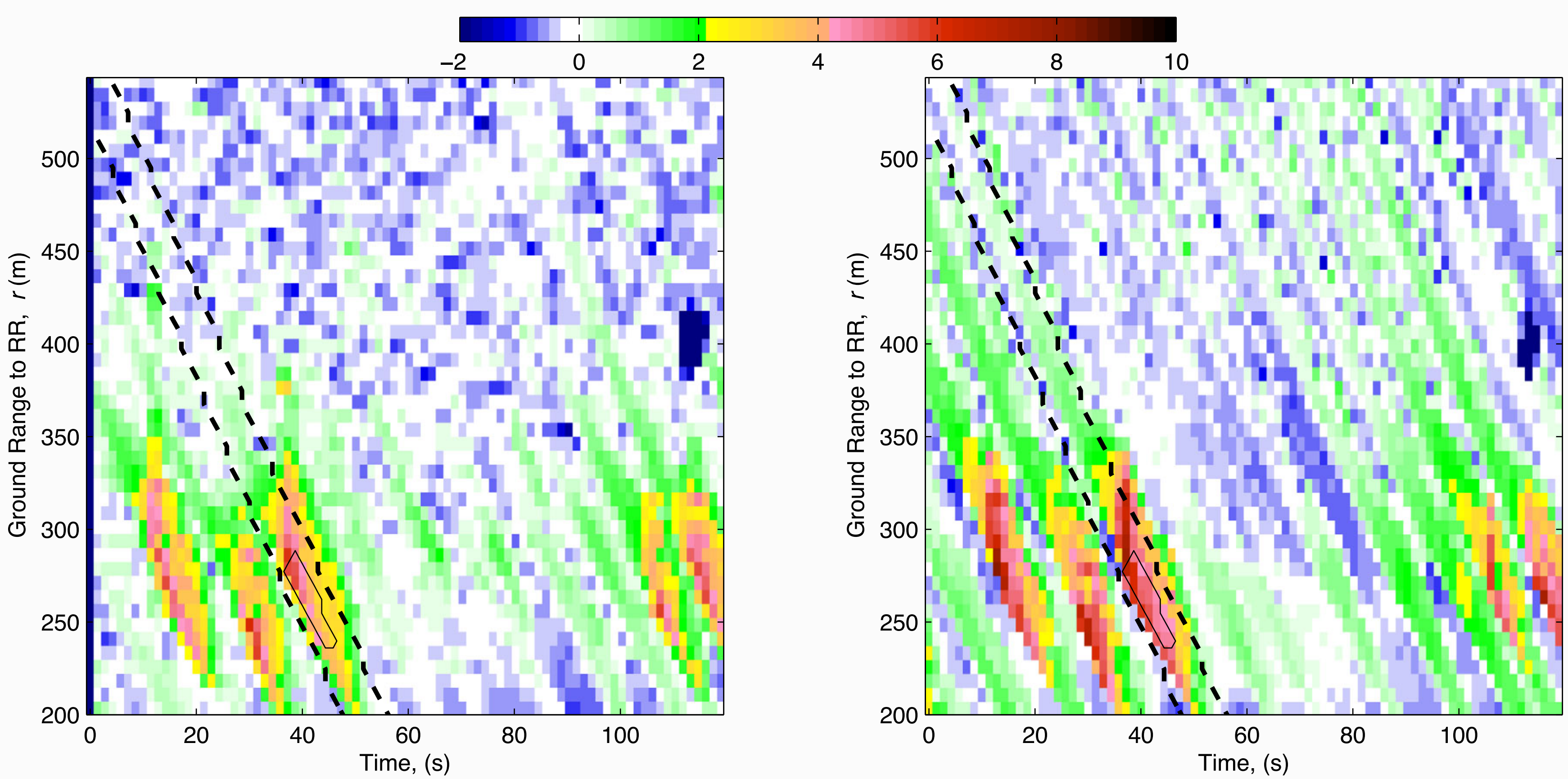




Doppler Offset

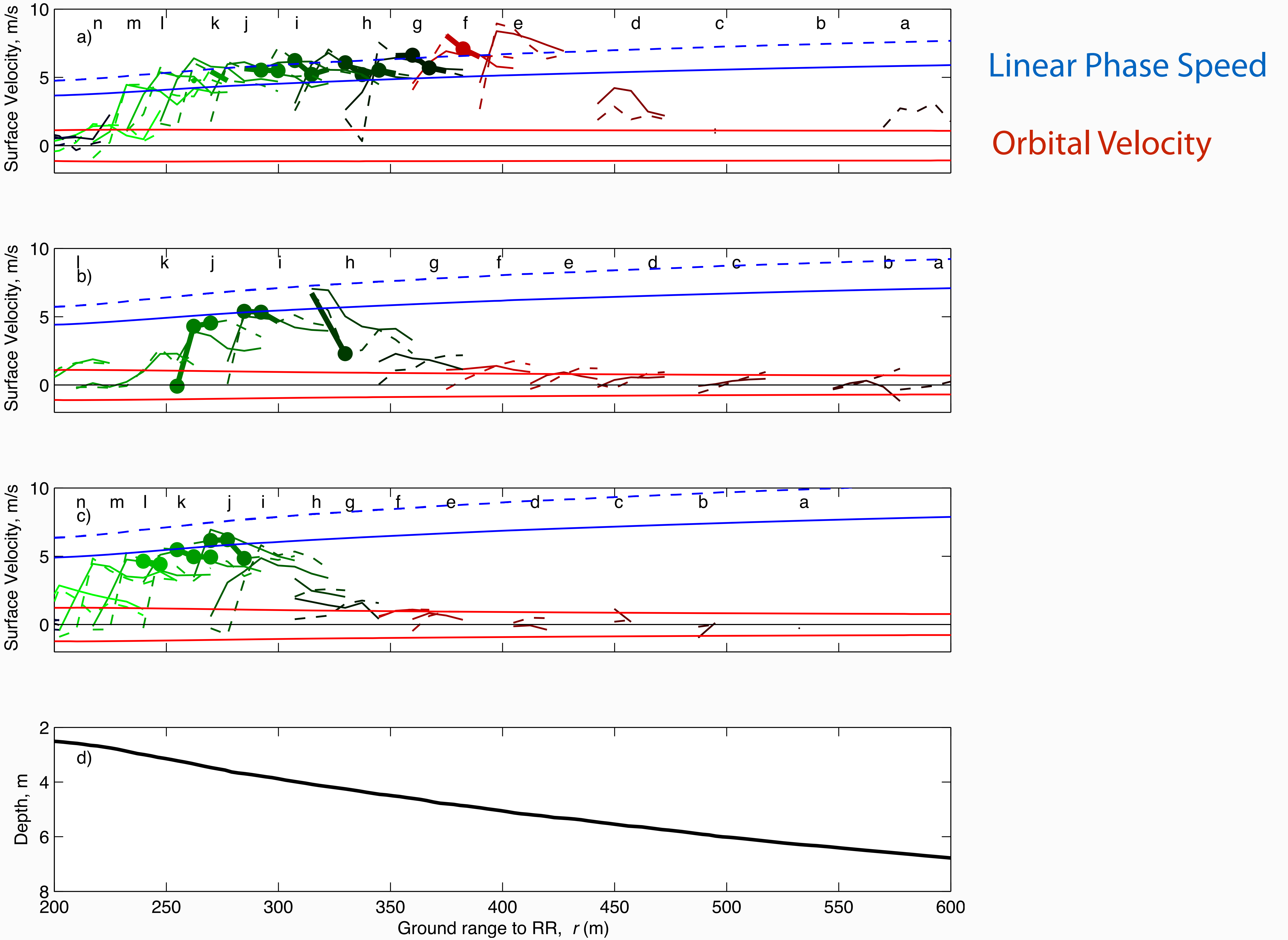


High Energy



Low Energy

Comparison with Linear Theory



Summary so far…

- Breaking waves source of large backscattered power , several dB above non breaking waves

- Maximum NRCS seems to have a limiting value

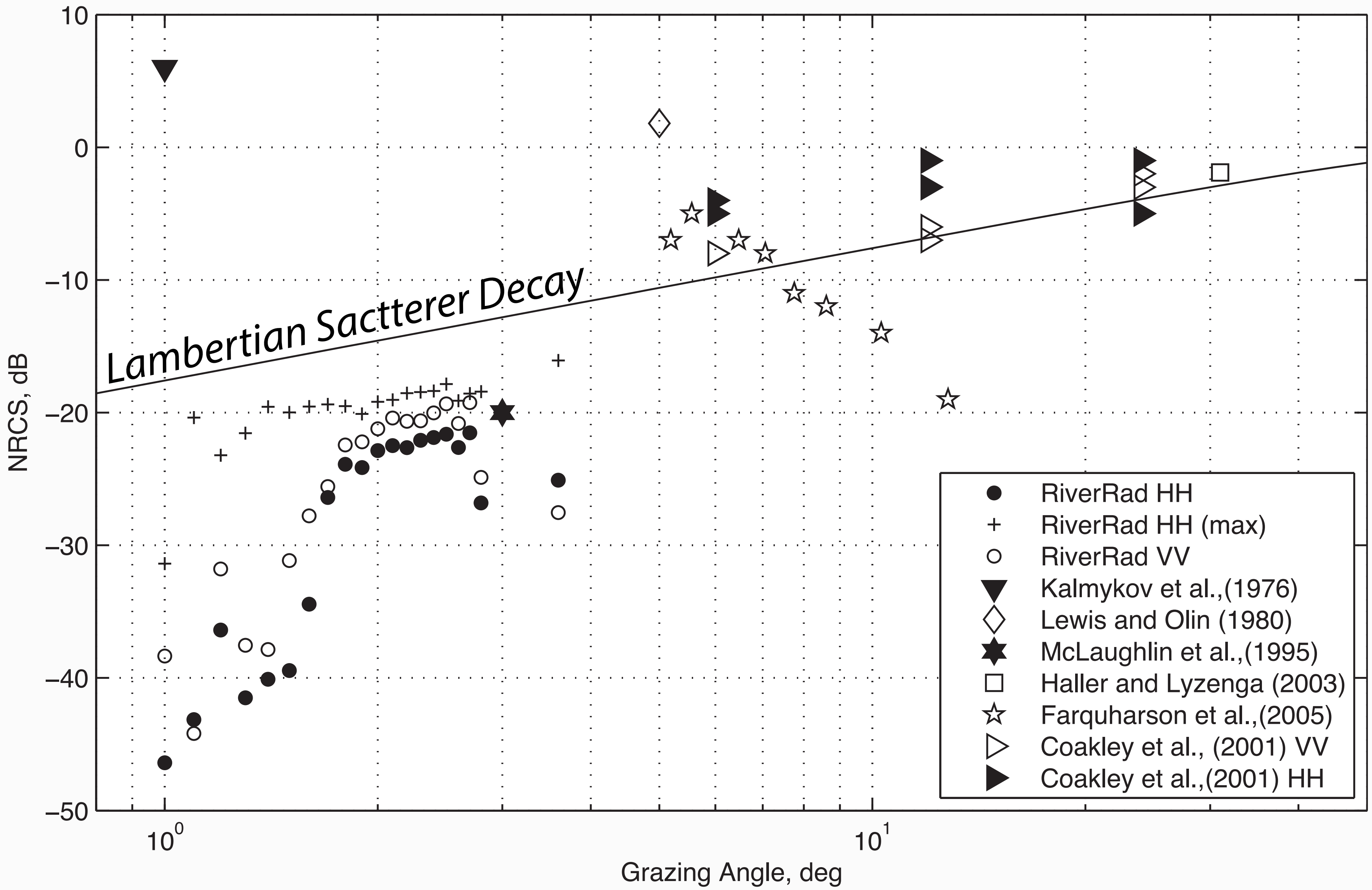
  - Weak dependency on viewing geometry ($\boldsymbol{\theta_g}, \boldsymbol{\varphi}$)
  - Subtle polarization dependency
  - No discernible dependency on environmental parameters

- Large polarization ratio but not necessarily greater than 1

- Few breaking events suffice to broaden the Doppler spectrum

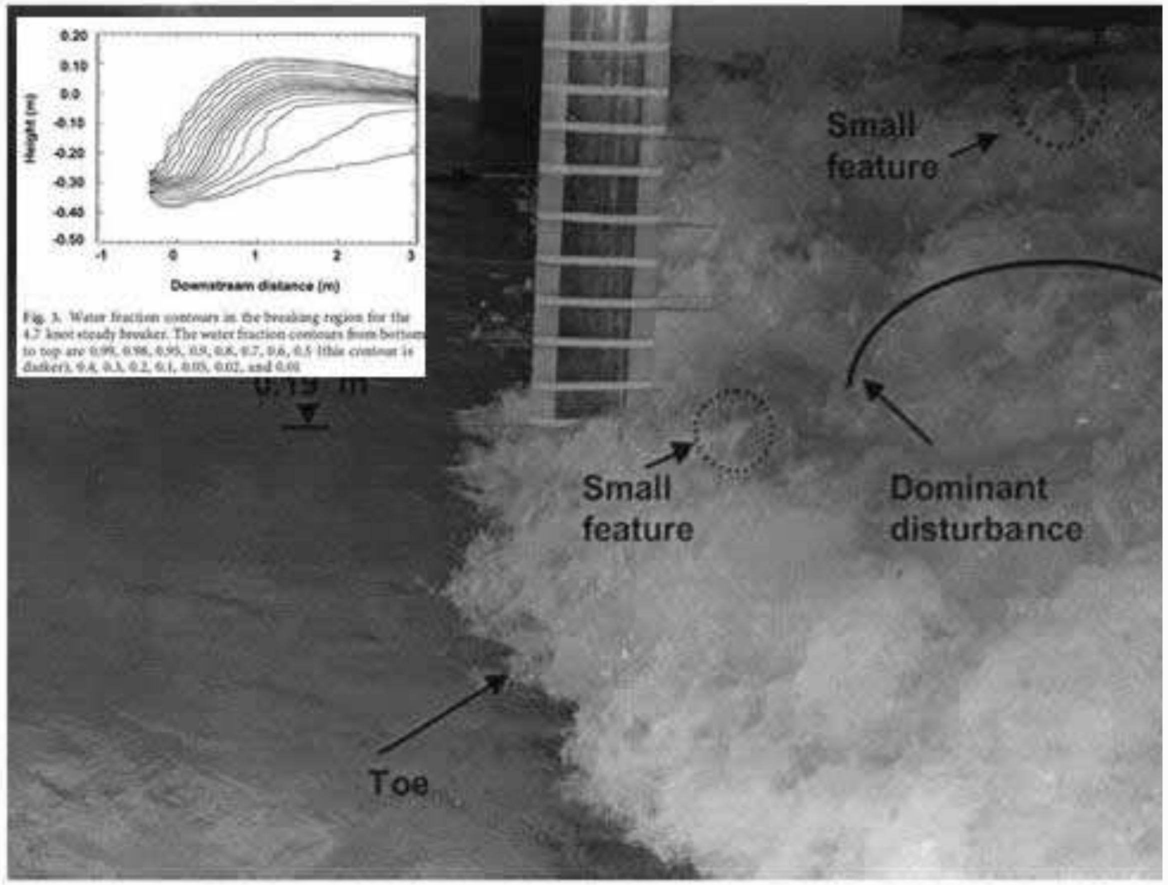
- Peak speeds well correlated with speed of the carrier wave

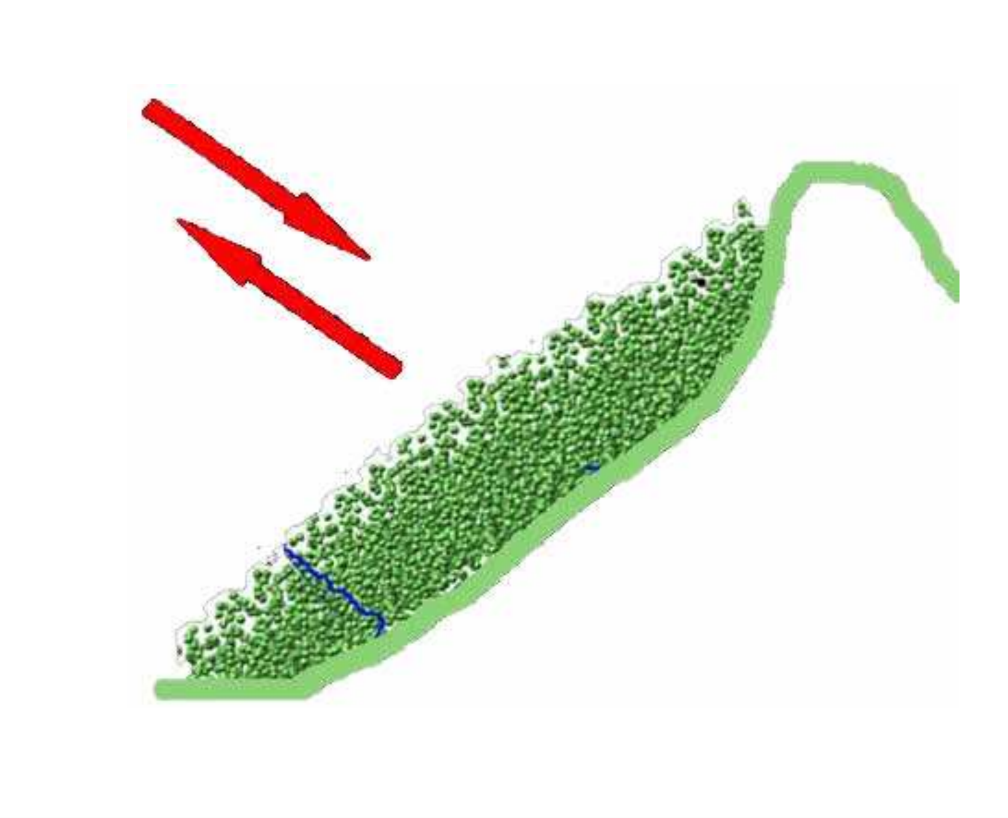
How does it compare with other data ?



Scattering model

- Previous research assumed surface scattering e.g. Bragg, specular, etc.
- Roller has a complex structure and its morphology is usually disregarded (e.g. Coakley et al., 2001)
- Proposition:
  - Model based on Volumetric Scattering
  - Roller as a two-phase medium (air + water)
  - Scattering from water droplets (Mie regime)



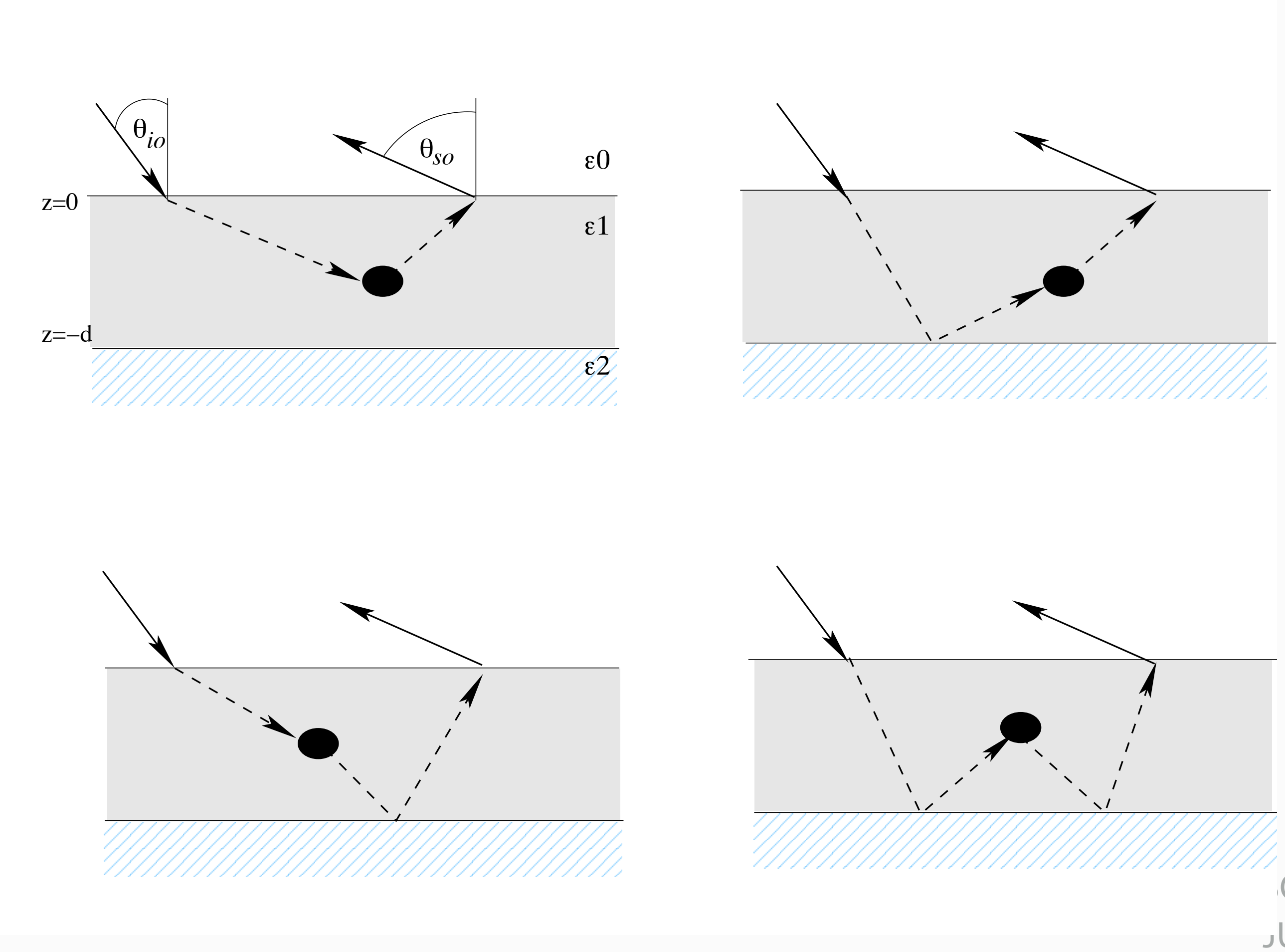


EM model

- Roller is a collection of water droplets scattering in the Mie regime
- Multiple scattering interactions among particles
- Interactions using the Quasi-Crystalline Approximation
    - Allows estimation of extinction, absorption and scattering coefficients
- Wave propagation through media using Dense Media Radiative Transfer Theory

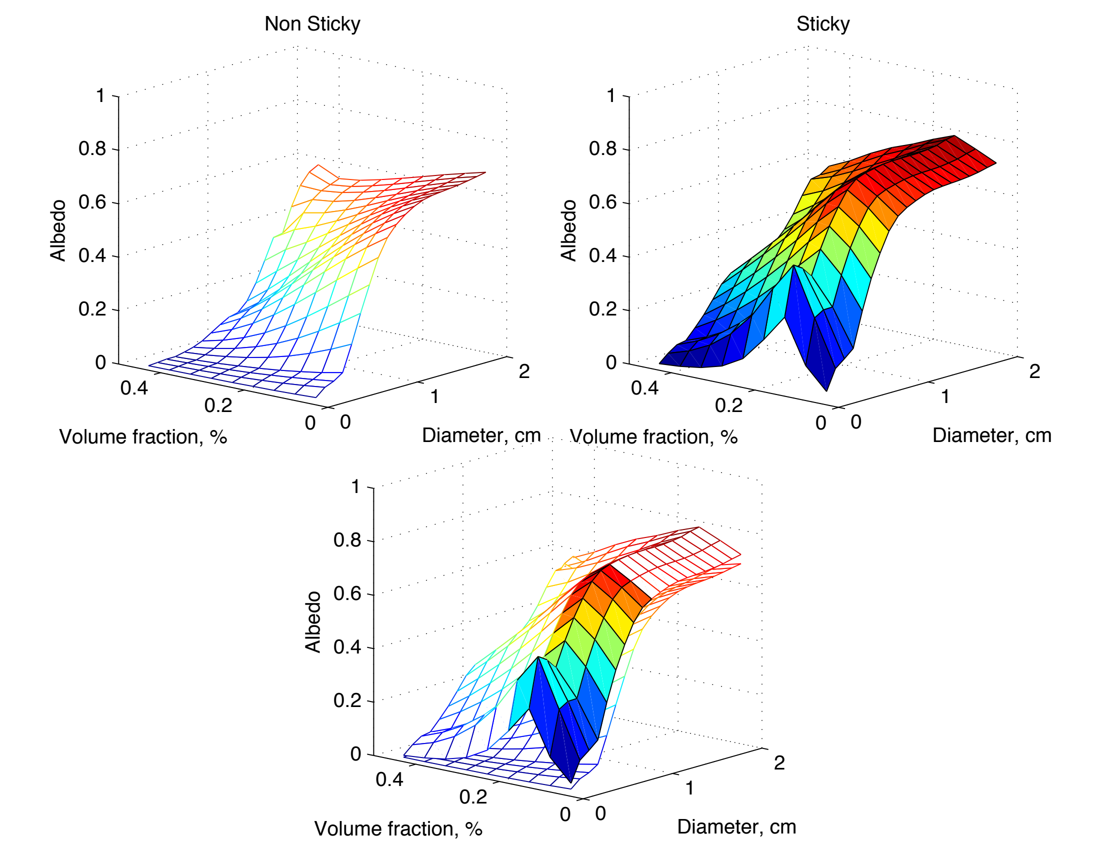
Tsang et al., 2007

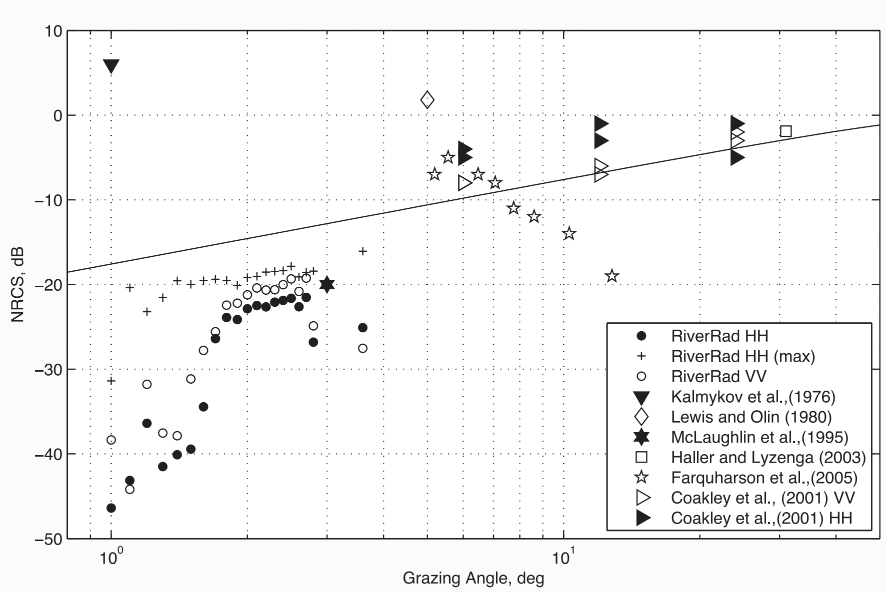
- Interactions with boundaries
- Model parameters
    - Droplet size 0.1 - 2 cm
    - Seawater permitivitty
    - Volume fraction (max 50 %)
    - **Stickiness parameter**

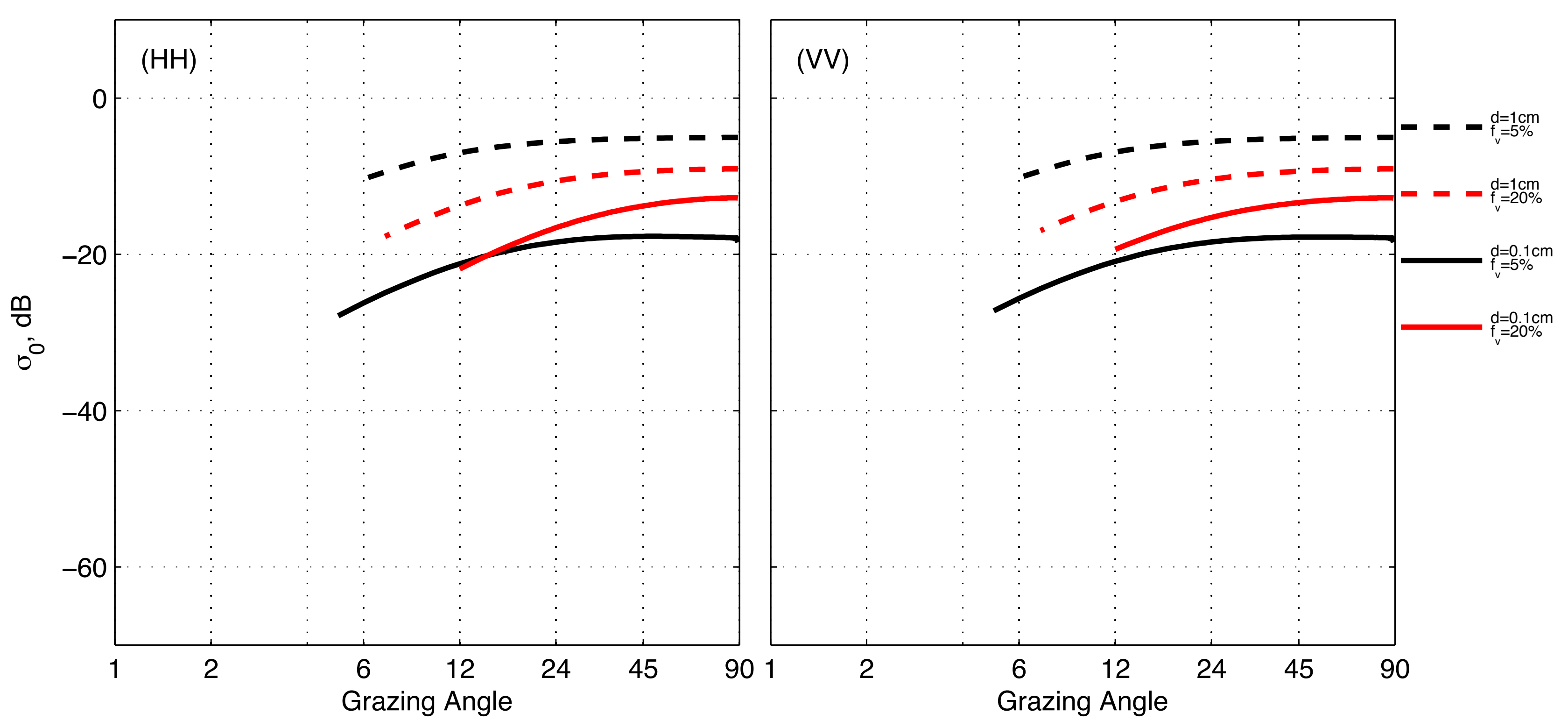


Results

- Thin but finite layers of droplets suffice to explain scattering levels
- Albedo shows that small volume fractions and relative small particles O(1)cm can yield large reflectivity
- Weak dependency on grazing angle
- Subtle polarization dependency.







Model summary

- Volume scattering can be relevant
- Small volume fractions suffice (upper roller layers)
- Complex formulation but requires physical parameters only
    - Can we measure a droplet distribution to validate this?
- Model output shows good agreement with measured data
    - Median NRCS
    - Grazing angle dependency
    - Small polarization ratios
    - Roller travels with the wave at its phase speed.

Tack
Vielen Dank
Obrigado
Merci
ありがとうございます
Bedankt
Takk
感謝您
Terima Kasih
谢谢
Grazie
ขอบคุณ
Спасибо
Thank You
Kiitos
Tak
Teşekkür Ederiz
감사합니다
Gracias
Dziękujemy
Σας ευχαριστούμε