# Analysis of the C-band spaceborne scatterometers thermal noise

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## Introduction

- Scatterometer receives backscattered power + noise power
- Noise power measured separately in a transmit-free window
- In this window the scatterometer works as a microwave radiometer
- Noise power = receiver noise + thermal Earth radiance (natural + RFI)
- Nature of the noise signal ?
- Noise power is subtracted from the total received power to compute  $\sigma \mathbf{0}$
- Relevance of noise subtraction for  $\sigma$ 0, wind speed and Kp processing
- The impact of the noise power misestimate (mis-subtraction) on  $\sigma_0$

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## Metop/ASCAT noise power map

- Geophysical signature: signal power depends on surface type
- Microwaves: thermal radiance proportional to brightness temperature  $T_b$
- $T_b$  depends on emissivity and physical temperature
- Relatively good radiometric resolution, bad spatial resolution



Data: 1-6 January (NH winter / SH summer)

## Metop/ASCAT noise power map - RFI

- $\bullet~\mbox{Noise signal} = \mbox{Natural thermal radiation} + \mbox{RFI}$
- Peaks exceeding threshold (800 counts equivalently 320 K) are not likely natural, probably RFI
- RFI mainly over land and over Europe
- RFI localization not precise due to low spatial resolution of the noise signal



Data: 1-6 January (NH winter / SH summer)

## ERS-2/AMI noise power map

- Data: December 2008
- ERS-2/AMI only distinguishes between land and sea
- ASCAT radiometric resolution higher than AMI
- radiometric resolution depends mainly (but not only) on the system bandwidth
- ASCAT bandwidth larger than AMI bandwidth





## Temporal variation

- Noise signal depends on the physical temperature
- Illuminated area temperature varies along the day
- Three days data moving average (1-3 January 2011) over same land area
- 24h period  $\Rightarrow$  Diurnal cycle
- Seasonal cycle ?



## Viewing geometry effect

- Mid antenna noise is lower than side antennas over ocean
- T<sub>b</sub> depends on emissivity and temperature
- Emissivity depends on the relative permittivity  $(\epsilon_r)$  and incidence angle  $(\theta)$
- Metop/ASCAT Mid antennas illuminates the swath with lower incidence angles than side antennas (Fore/Aft)



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## Comparison with AMSR-E radiometer

- AMSR-E microwave radiometer brightness temperature
  - 6.9 GHz channel
  - V-polarization
- Very good correlation (ho pprox 0.9)
- Three main clusters: Sea, land and ice
- Other sub-clusters: polar waters, tropical waters, sea ice, land ice, SH continents etc.



Image: A math a math

#### Noise Equivalent Sigma Zero - over ocean

$$NESZ = \frac{\sigma 0}{SNR} = \frac{(4\pi)^3 R^4 P_n}{P_t G_a^2(\theta) G_r \lambda^2 A}$$

- NESZ depends on the instrument parameters, mainly  $G_a(\theta)$
- NESZ and SNR vary with incidence angle, hence the shape of the antenna gain pattern across-swath
- ASCAT NESZ/SNR lower/higher than ERS-2/AMI



### Noise subtraction effect on $\sigma$ 0 - over ocean

- Comparison of  $\sigma_0$  processed with noise subtraction against  $\sigma_0$  processed without noise subtraction
- Difference increases slightly across-swath: [0.2, 1.4] dB
- Confirms the necessity and importance of noise subtraction



Figure: solid: with noise subtraction, dashed: without noise subtraction, red: difference - left: ASCAT, right: AMI

## Noise subtraction effect on wind speed

- Wind speed range: 2 < ws < 15 m/s (average = 6.5 m/s)
- Difference increases slightly across-swath: [0.2, 1.2] m/s
- Same trend observed in  $\sigma_0$  is reflected in wind speed



Figure: solid: with noise subtraction, dashed: without noise subtraction, red: difference - left: ASCAT, right: AMI

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## Noise subtraction effect on Kp

• Noise subtraction increases Kp:

$$var[P_{s+n} - P_n] = var[P_{s+n}] + var[P_n]$$

- Difference increases slightly across-swath: [0.45, 1.25] %
- Similar trend observed in  $\sigma_0$  and wind speed



## Land-sea contamination

- ASCAT and AMI are Fixed fan beam scatterometers
- Antenna patterns are narrow in azimuth ( $\approx$  30 km) and wide in range ( $\approx$  500 km)
- For  $\sigma_0$  measurement (range gated), land contamination depends on the PSF and its orientation
- For noise power measurement (not range gated), land contamination depends on the antenna pattern and its orientation toward the continents
- $\bullet\,$  In most cases the satellite will be heading the continents  $\Rightarrow\,$  Fore/Aft earlier and larger contamination
- WVC's near the transition between two different surfaces (e.g., land/sea or sea-ice/sea) are probably processed with over/under estimated noise power

#### Land-sea contamination - $\sigma$ 0 - right swath

- Right swath along track transition sea-land
- Nominal  $\sigma$ 0 (25 km): range gated and spatially filtered
- PSF dominated by Hamming spatial filter (width pprox 86 km)
- Step slope is inversely proportional to the width of the PSF
- Sharp transition for both side and mid antennas



#### Land-sea contamination - $\sigma$ 0 - left swath

- Left swath along-track double transition sea-land-sea
- Nominal  $\sigma$ 0 (25 km): range gated and spatially filtered
- PSF dominated by Hamming spatial filter (width  $\approx$ 86 km)
- Sharp transition for both side and mid antennas



#### Land-sea contamination - noise - mid antenna

- Noise signal not range gated (averaged along-track)
- PSF dominated by antenna gain pattern
- Step slope is inversely proportional to the width of the PSF
- Mid antenna footprint parallel to the coast line  $\Rightarrow$  relatively sharp transition



#### Land-sea contamination - noise - Fore antenna

- Fore antenna footprint quasi-perpendicular to the coast line  $\Rightarrow$  smooth transition
- Over-estimation of the noise power for ocean WVC's and under-estimation for land WVC's



Figure: Land-sea transition, red: Mid antenna, black: Fore antenna

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## Land-sea contamination - noise - left swath

- The swath partially over land
- $\bullet~$  Noise signal not range gated  $\Rightarrow~$  noise power averaged across-swath
- One mean noise power value attributed to all the WVC's of the same row
- Over estimation of the noise power for the ocean WVC's Ocean-land transition NESZ



#### NP misestimation Vs $\sigma$ 0 bias - right swath

- Impact of under/over subtraction of noise on coastal  $\sigma 0$
- $\sigma_0$  error = ideal subtraction biased subtraction
- For land WVC's (negative peak) the bias is negligible for both antennas, Mid antenna the  $\sigma_0$  bias is also negligible over ocean, Fore antenna, bias very small (max 0.1 dB)



## NP misestimation Vs $\sigma$ 0 bias - left swath

- For land WVC's the bias is negligible for both antennas as the previous case
- For Mid antenna,  $\sigma_0$  bias is slightly higher than previous scenario but still under 0.1 dB
- Fore antenna,  $\sigma_0$  bias reach 0.2 dB (at far range WVC's)



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## Conclusion

- Noise signal carries useful geophysical signature (proportional to brightness temperature)
- Relatively good radiometric resolution, but bad spatial resolution
- Noise signal varies with time, target and viewing geometry
- Noise subtraction is important for  $\sigma$ 0 and wind speed processing, more important over ocean than over land
- The effect of under/over subtraction of the noise power near the coast was assessed using land-sea transitions
- The error on coastal  $\sigma_0$  is probably negligible (max 0.1 dB)
- In some extreme scenarios  $\sigma_0$  bias due to noise power misesimate could reach 0.2 dB

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