Radar Remote Sensing of Exposed Intertidal Flats

Synthetic Aperture Radar Data Help Improving Sediment Classification on the German North Sea Coast

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Outline

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• Field Campaigns
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Background & Basics

Wesselburener Watt; from Tanck (1998)
Background & Basics

Intertidal Flats

- Distance of about 10 km offshore
- German and Dutch North Sea coast, S Korean coast
- Fall dry once during each tidal cycle
- Usually non-vegetated
- Consist of fine sediments (sand, mud)
- Impacted by the stress of a changing world (e.g. sea level rise)

Surveillance

- Important because of high morpho-dynamics
- Regulated through national and international laws
- Difficult task by boat, foot, or land vehicles

Optical Remote Sensing

- Promising classification results, but
- strong dependence on cloud cover
Background & Basics (2)

ENVISAT ASAR WS
24 Dec 2007, 0948 UTC
Wind 6 m/s, W
Low tide: 0420 @ Norderney
Background & Basics

ENVISAT ASAR WS
15 Jan 2008, 0957 UTC
Wind 5-8 m/s, SW
Low tide: 0901 @ Norderney
1210 @ Cuxhaven
1235 @ Husum
Background & Basics (4)

ENVISAT ASAR WS

28 Jan 2008, 0948 UTC

Wind 4 m/s, W

Low tide: 0820 @ Norderney
1132 @ Cuxhaven
1202 @ Husum
Background & Basics (5)

ENVISAT ASAR WS
13 Feb 2008, 0946 UTC
Wind 4 m/s, W
Low tide: 0839 @ Norderney
1148 @ Cuxhaven
1216 @ Husum
Background & Basics (6)

Penetration Depth of Microwaves into Water

**Radar Bands**

- L 1.0 GHz 30 cm
- C 5.3 GHz 6 cm
- X 9.8 GHz 3 cm

[Swift, 1980]
Background & Basics

Surface depends on sediment types and water level ...
Background & Basics (8)

... and sometimes on other things ...

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[Image of intertidal flats and mudflats]
Existing Classification System

Data basis: optical RS data (SPOT-4)

Legend
- Sand
- Sand-Mix
- Mix
- Dense Vegetation
- Dense Mud
- Mud-Dry
- Vegetation
- Mussel/Oyster Beds
- Bright Dry Sands

Data Source: SPOT-4. © SPOT Image 2006
Data Processing: Brockmann Consult © 2008
Project: DeMarine TP-4

Strong dependence on cloud cover and daytime → only very few scenes per year!
Initial Studies


[STS-59, April 1994]

[STS-68, October 1994]
Initial Studies (1)

Radar Imaging of Dry-Fallen Intertidal Flats During SIR-C/X-SAR (1994)

Gade: SAR Data for Classification of Intertidal Flats
Initial Studies (2)

Different radar signatures at the three SIR-C/X-SAR bands

10 April 1994, 0804 UTC, 2h45' after low tide

(12 km x 12 km)
Initial Studies (3)

Integral Equation Model (IEM; Fung et al. [1992])

\[
\sigma_{pp}^{\mu} = \frac{k^2}{2} \exp(-2k_z^2\sigma^2) \sum_{n=1}^{\infty} I_{pp}^n \frac{W^{(n)}(-2k_x,0)}{n!}
\]

where \( k_z = k \cos \theta \), \( k_x = k \sin \theta \) and

\[
I_{pp}^n = (2k_z \sigma)^n f_{pp} \exp(-k_z^2 \sigma^2) + \frac{(k_z \sigma)^n}{2} \left[ F_{pp}(-k_x,0) + F_{pp}(k_x,0) \right]
\]

Backscattering of electromagnetic waves from a dielectric surface with random roughness modulation

Limiting cases: Bragg model and Kirchhoff model

Special form of surface autocorrelation function important
Initial Studies (4)

Integral Equation Model (IEM; Fung et al. [1992])

NRCS isolines as function of correlation length and rms height

Gaussian autocorrelation of surface elevation
Initial Studies (5)

Deriving Maps of RMS Height and Correlation Length

Example: NRCS (pixel) values at VV polarisation:
- L band: -18 dB
- C band: -9 dB
- X band: -11 dB

Derived roughness parameters:
- rms height: 3.1 mm
- corr. length: 3.7 cm
Initial Studies (6)

Sediment Map Derived Using SIR-C/X-SAR Data (50 m geometrical resolution)

Dependence of sediment type and micro particles after Pröber [1981]

Source: National Park Agency
DeMarine-U (1)

German Contribution to GMES

DeCOVER, DeMARINE, DeSECURE

DeMarine-U (Environment), Task 4: "Integration of optical and SAR Earth RS Data into the Monitoring of Intertidal Flats"

Brockmann Consult, UHH, National Park Agencies (Schleswig Holstein, Niedersachsen)

Tasks of UHH:
Investigate dependence of SAR signatures on imaging and environmental parameters

Extension of IEM inversion process for the use of SAR data from multiple satellites
DeMarine-U (2)

Test Sites
DeMarine-U (3)

Use of SAR Data from Various Satellites


Can our approach be used also for multi-satellite SAR imagery?

Different

- Incidence angle
- Azimuth angle
- Platforms
- Polarizations
- Environ. conditions
Field Campaigins (1)

Field Campaign During ERS Overpass 1998

ERS SAR Image (3 km × 2.5 km)
(4 April 1998, 1045 UTC)
Field Campaigns (2)

DeMarine-U Field Campaign April 2008

Aim: to record all parameters that are important for the interpretation of satellite data

• Slope/inclination
• Surface structure
• Colour
• Sediment
• Surface layers
• Redox conditions
• Micro-, Macroalgae
• Macrophytes -fauna
• Weather conditions
• Station info

German Wadden Sea, Norderney Riffgatt, 14 April 2008
Field Campaigns

DeMarine-TP4 April/August 2008

TerraSAR-X Scene, 30 August 2008, 1710 UTC (34 min. after low tide)
Recent Satellite Data Analyses

ALOS PALSAR
18 Oct 2007,
Wind 10-12 m/s,
Low tide: 1031 @ Husum

ENVISAT ASAR
18 Oct 2007, 0955 UTC,
Wind 10-12 m/s, N

PALSAR ASAR Diff(P-A)
Recent Satellite Data Analyses (2)

ALOS PALSAR
18 Oct 2007, 1023 UTC
Wind 10-12 m/s, N
Low tide: 1031 @ Husum

PALSAR ASAR Diff(P-A)

ENVISAT ASAR
18 Oct 2007, 0955 UTC
Wind 10-12 m/s, N
Low tide: 1031 @ Husum
Recent Satellite Data Analyses

ALOS PALSAR
12 Apr 2008, 2143 UTC
Wind 3-4 m/s, W
Low tide: 2120 @ Norderney

PALSAR ASAR Diff(P-A)

ENVISAT ASAR
13 Apr 2008, 1001 UTC
Wind 4-5 m/s, W
Low tide: 0935 @ Norderney
Recent Satellite Data Analyses (4)

- **ALOS PALSAR**
  - 12 Apr 2008, 2143 UTC
  - Wind 3-4 m/s, W
  - Low tide: 2120 @ Norderney

- **PALSAR ASAR Diff(P-A)**

- **ENVISAT ASAR**
  - 13 Apr 2008, 1001 UTC
  - Wind 4-5 m/s, W
  - Low tide: 0935 @ Norderney
**Recent Satellite Data Analyses**

**ALOS PALSAR**
- 12 April 2008, 21:43 UTC
- Wind 7-8 m/s (SSW), LT 21:20 UTC

**ENVISAT ASAR**
- 13 April 2008, 10:01 UTC
- Wind 5-6 m/s (SW), LT 09:35 UTC
Recent Satellite Data Analyses

ALOS PALSAR
12 April 2008, 21:43 UTC
Wind 7-8 m/s (SSW), LT 21:20 UTC

ENVISAT ASAR
27 July 2008, 10:01 UTC
Wind 2-3 m/s (SW), LT 11:21 UTC
Recent Satellite Data Analyses

ALOS PALSAR
12 April 2008, 21:43 UTC
Wind 7-8 m/s (SSW), LT 21:20 UTC

TerraSAR-X
21 July 2009, 17:01 UTC
Wind 3 m/s (E), LT 15:58 UTC
Recent Satellite Data Analyses (8)

TerraSAR-X
03 May 2008, 0550 UTC
Wind 3-4 m/s
Low tide: 0508 @ Husum
Recent Satellite Data Analyses

Multi-temporal analyses: Indicators for mussel beds

Data: Four TerraSAR-X Scenes of 2009 (1h before/after low tide)

Green: high mean NRSC / low NRCS std dev
White: high mean NRCS / high NRCS std dev
Summary

AND THE MESSAGE? HOW ABOUT THE MESSAGE... EY?!
Summary

Use of multi-frequency satellite SAR data to derive surface roughness parameters of intertidal flats

Inversion of Integral Equation Model, based on previous studies (1994/1998)

DeMarine-U:
Improved classification system for Wadden Sea surfaces types based on optical RS data
Include multi-frequency satellite SAR data: derive surface roughness parameters of intertidal flats through inversion of Integral Equation Model using multi-satellite SAR data
Multi-temporal SAR data: detection of mussel/oyster beds
Благодарю за внимание!