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

- Background & Basics
- Initial Studies
- DeMarine-U
- Field Campaigns
- Recent SAR Data Analyses
- Summary

Background & Basics

Wesselburener Watt; from Tanck (1998)

Background & Basics (1)

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)

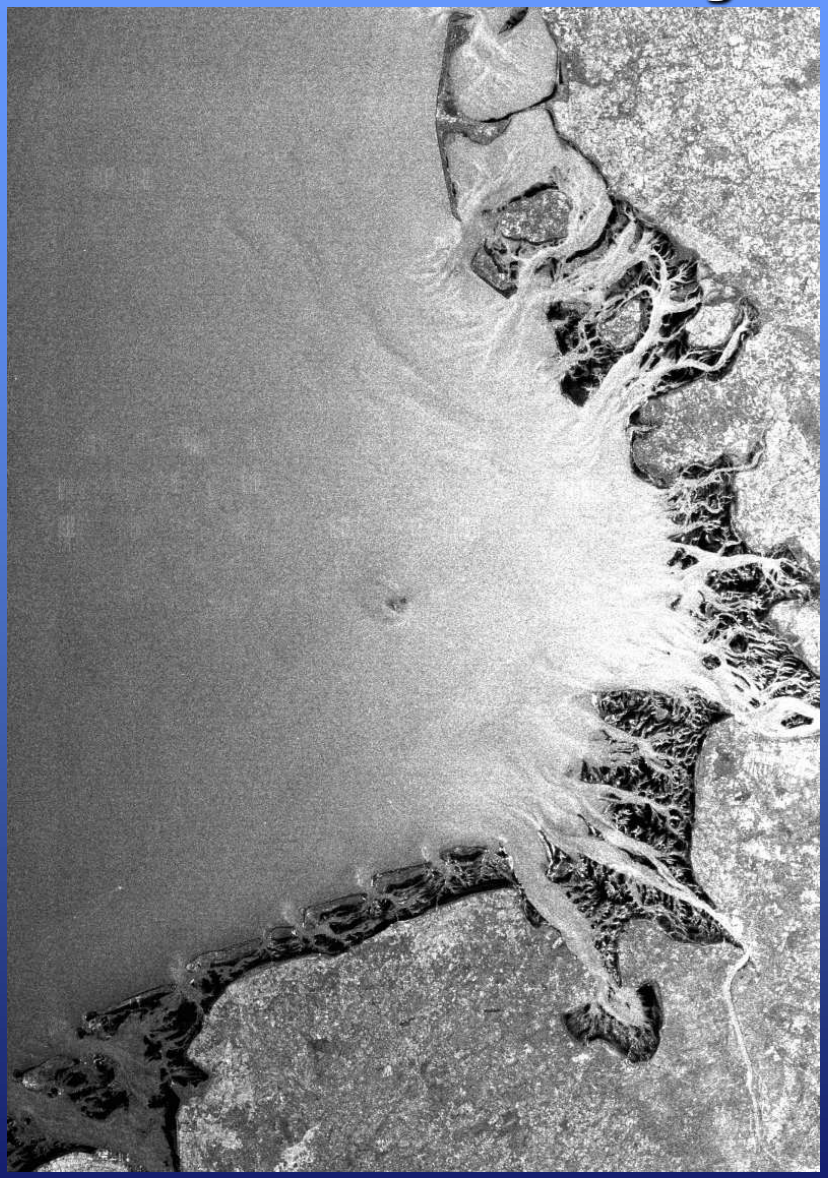
ENVISAT ASAR WS

24 Dec 2007, 0948 UTC

Wind 6 m/s, W

Low tide: 0420 @ Norderney

Background & Basics (3)



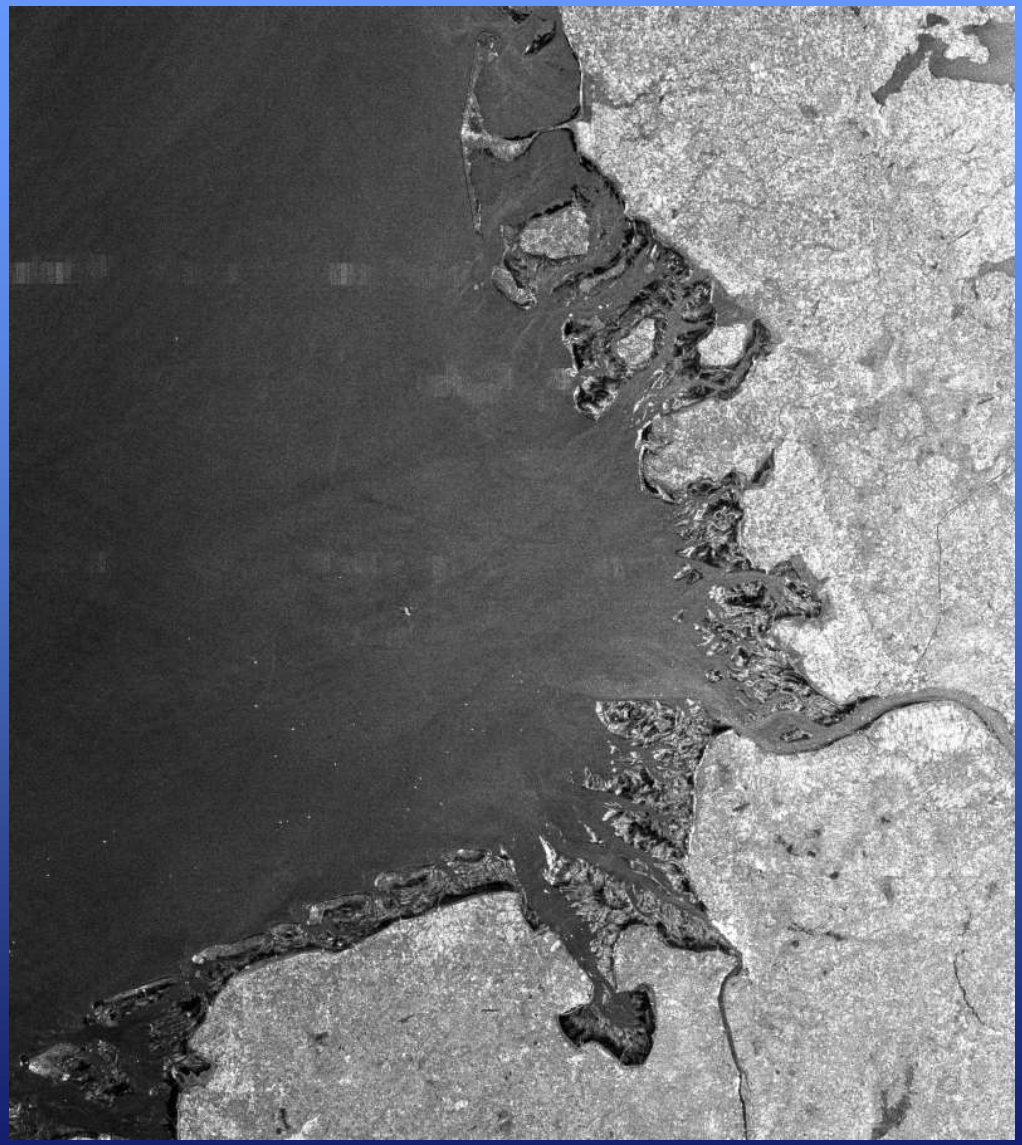
ENVISAT ASAR WS

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

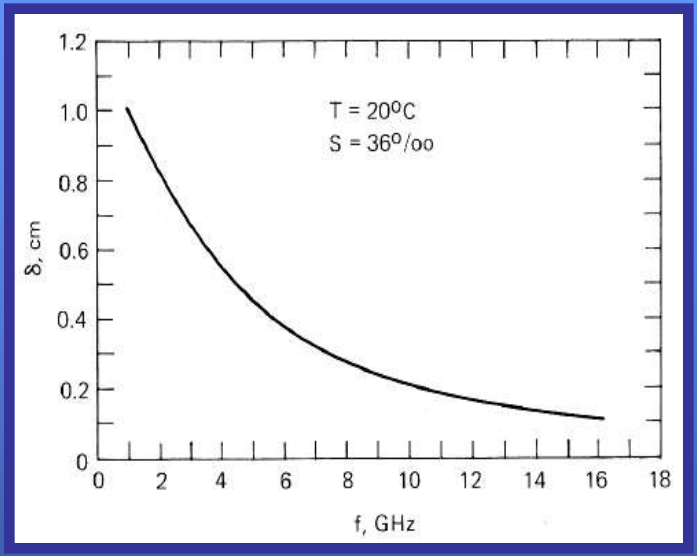
13 Feb 2008, 0946 UTC

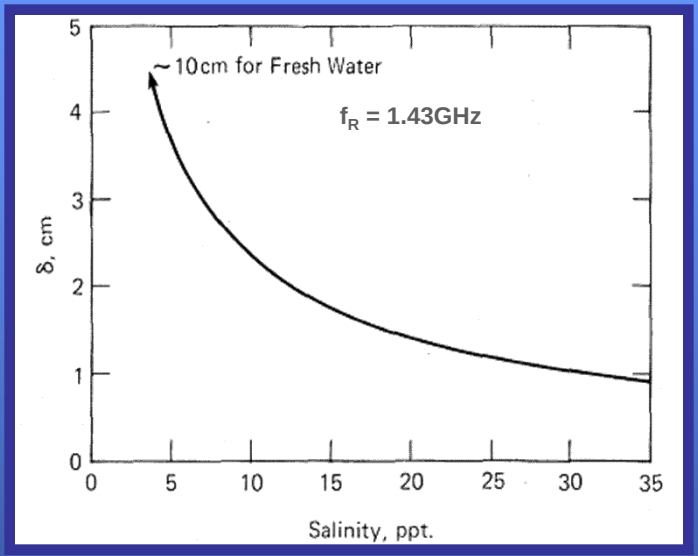
Wind 4 m/s, W

Low tide: 0839 @ Norderney
1148 @ Cuxhaven
1216 @ Husum

Background & Basics (6)

Penetration Depth of Microwaves into Water





[Swift, 1980]

Radar Bands

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

Background & Basics (7)

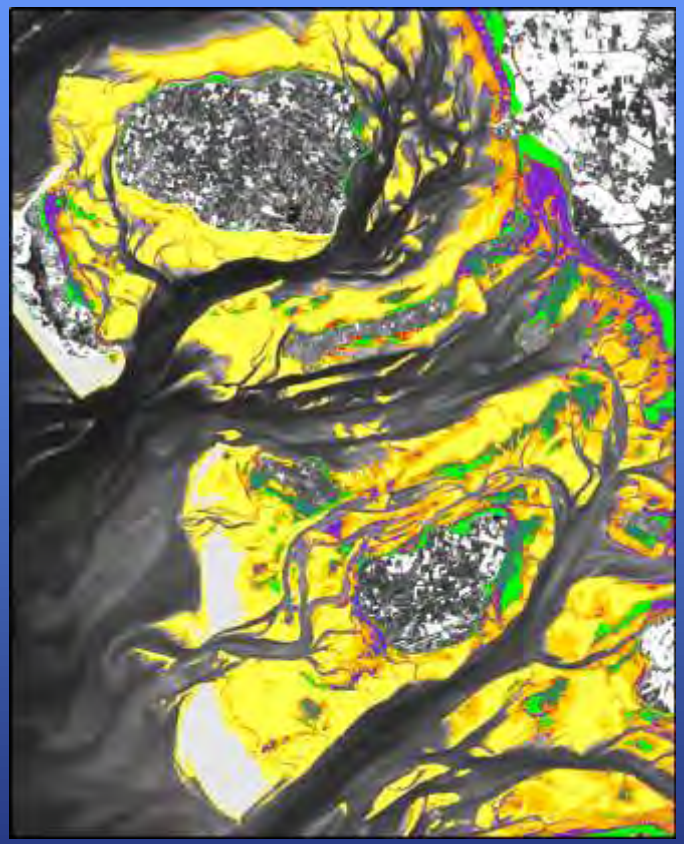
Surface depends on sediment types and water level ...

Background & Basics (8)

... and sometimes on other things ...

Existing Classification System

Data basis: optical RS data (SPOT-4)



Legend

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

0 5 10 20 Kilometers

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 !

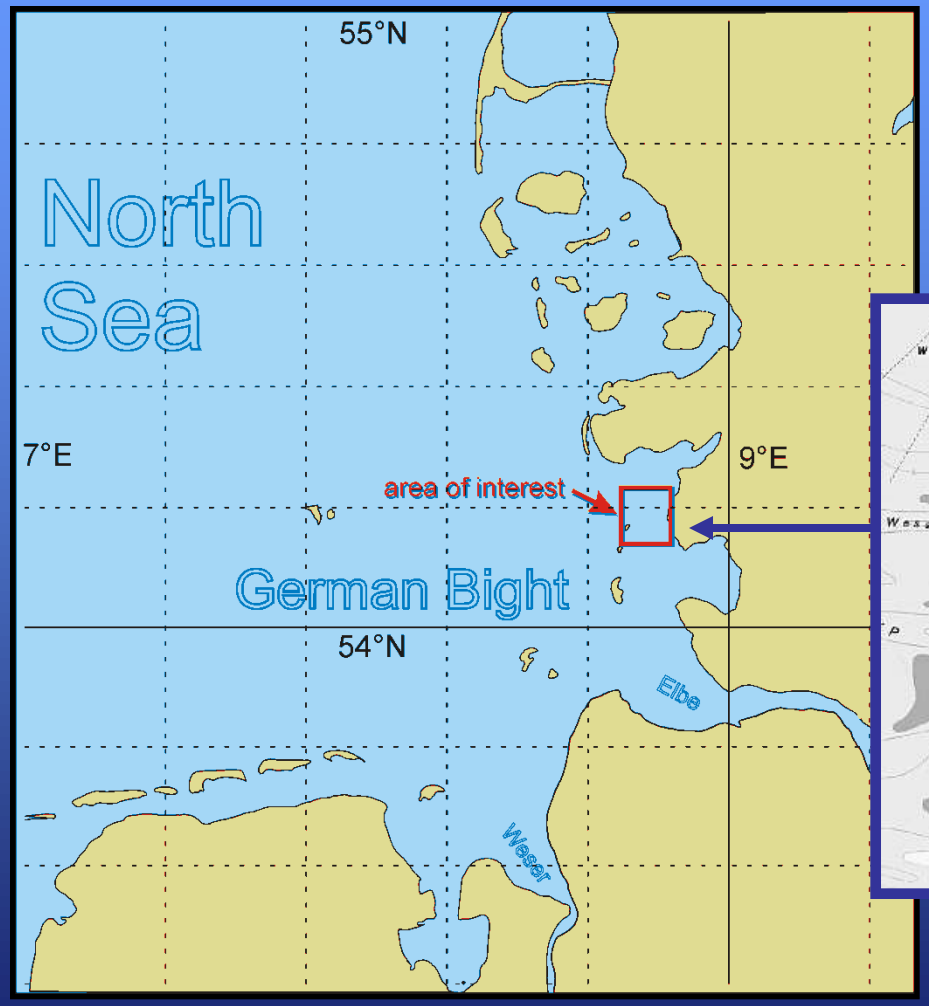
Initial Studies

Spaceborne Imaging Radar – C /X-Band Synthetic Aperture Radar (SIR-C/X-SAR) Mission 1994

[STS-59, April 1994]

[STS-68, October 1994]

Initial Studies (1)

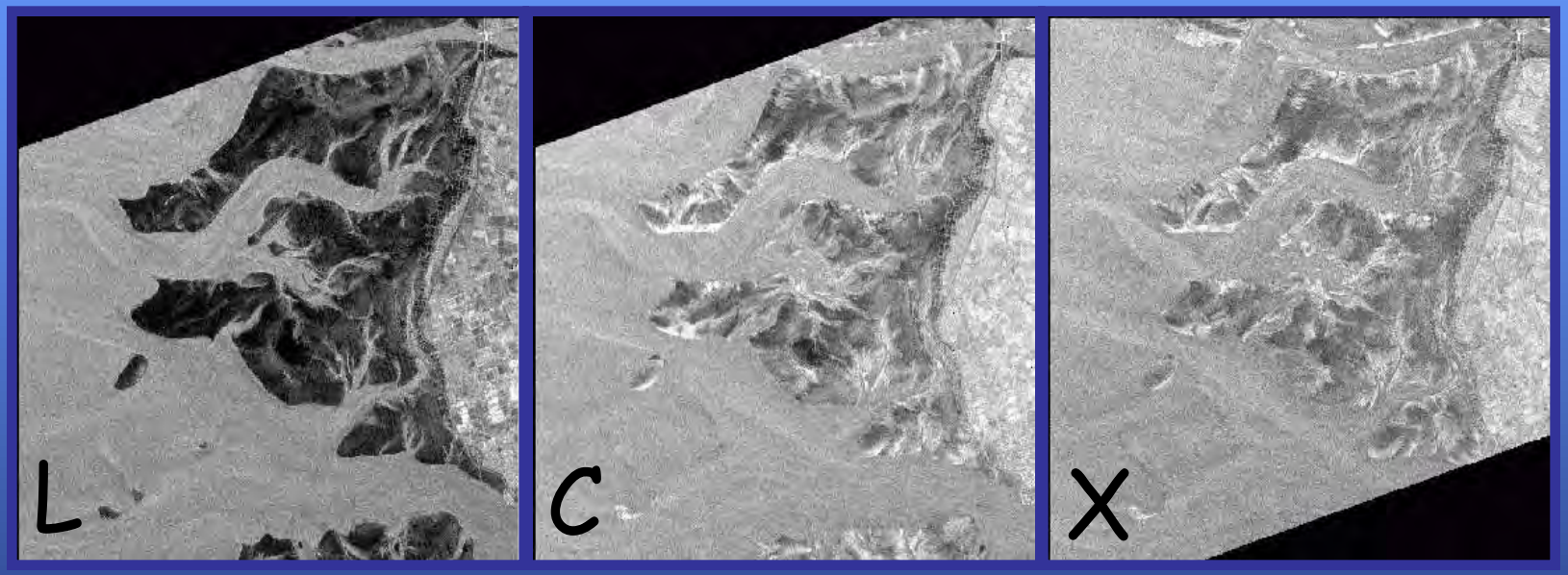


Radar Imaging of Dry-Fallen Intertidal Flats During SIR-C/X-SAR (1994)

Wesselburener Watt

Initial Studies (2)

(12 km x 12 km)



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

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

Initial Studies (3)

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

$$\sigma_{pp}^{0} = \frac{k^2}{2}\exp(-2k_z^2\sigma^2)\sum_{n=1}^{\infty}\left|I_{pp}^{n}\right|\frac{W^{(n)}(-2k_x,0)}{n!}$$

where $k_z = k\cos\theta$, $k_x = k\sin\theta$ and

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

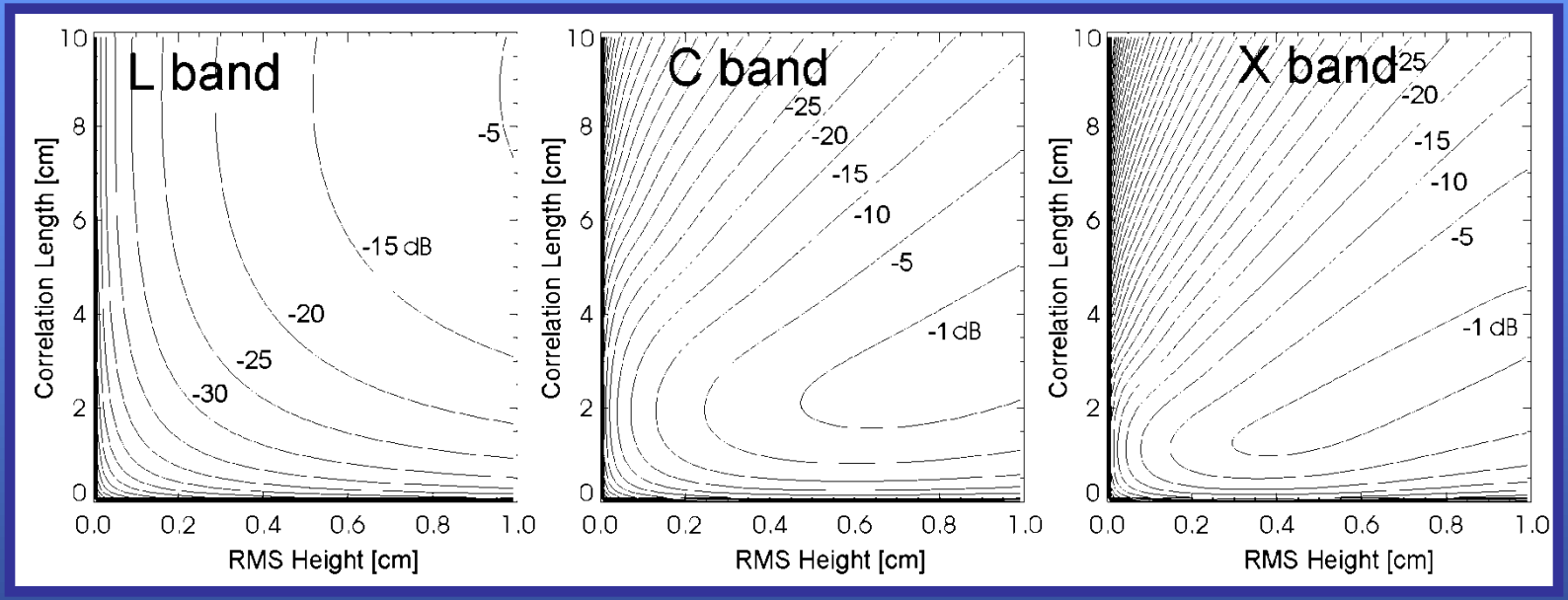
Backscattering of electromagnetic waves from a dielectric surface with random roughness modulation

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])

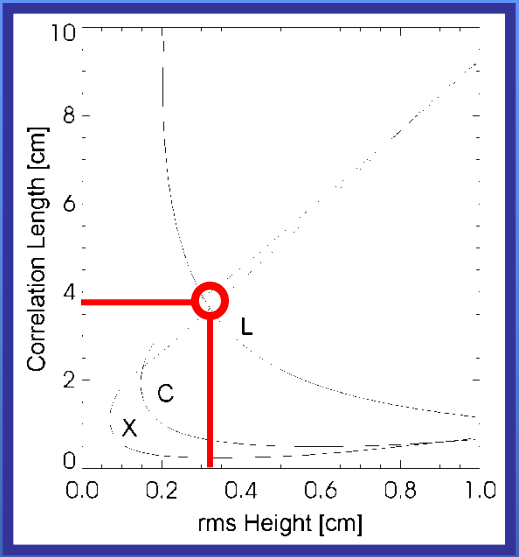


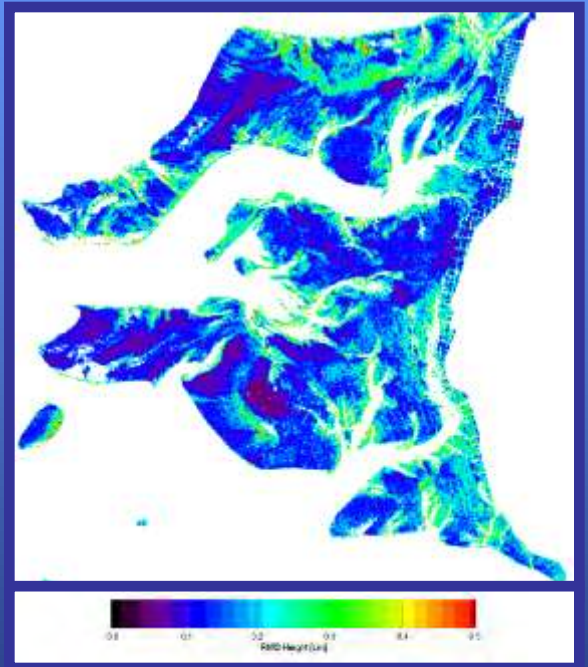
NRCS isolines as function of correlation lenth and rms height

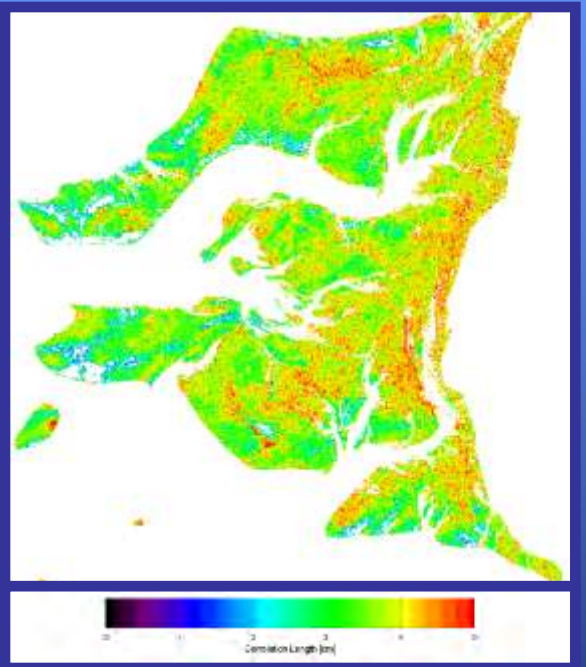
Gaussian autocorrelation of surface elevation

Initial Studies (5)

Deriving Maps of RMS Height and Correlation Length





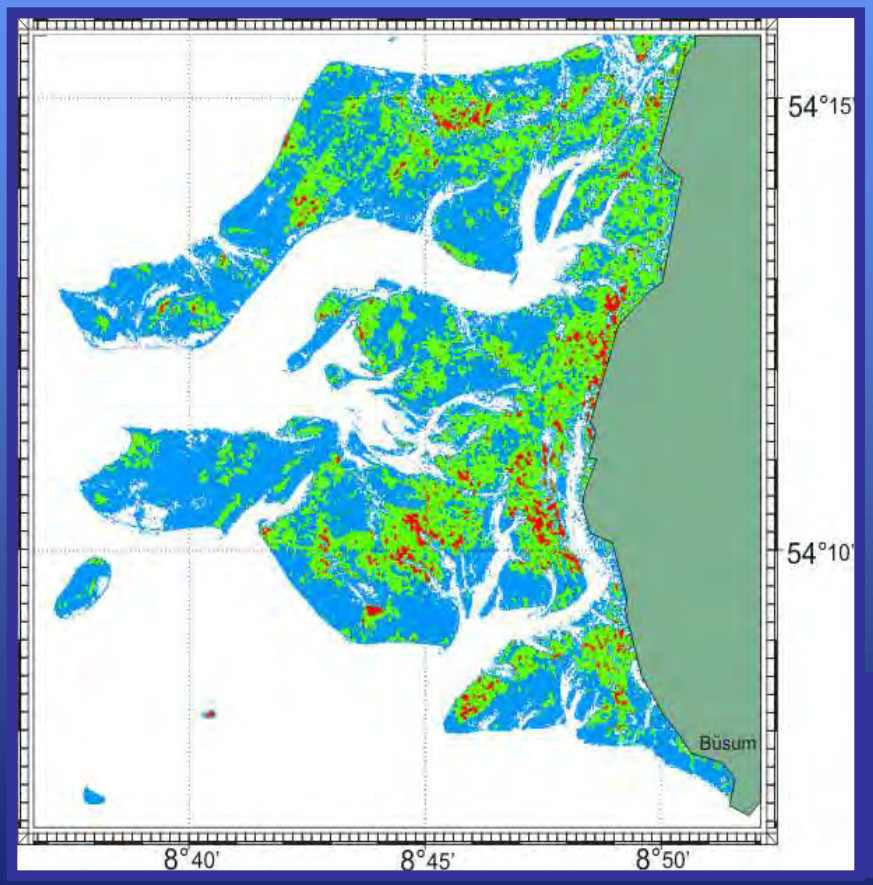


Example: NRCS (pixel) values at VV polarisation:
L band: -18 dB
C band: -9 dB
X band: -11 dB

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)



Micro Particles
- < 5%
- 5 – 10%
- 10 – 25%
- 25 – 50%
- > 50%
- Land

Source: National Park Agency

	< 10 %	sandy
	10 % - 25 %	mixed
	> 25 %	mixed / muddy

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

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"

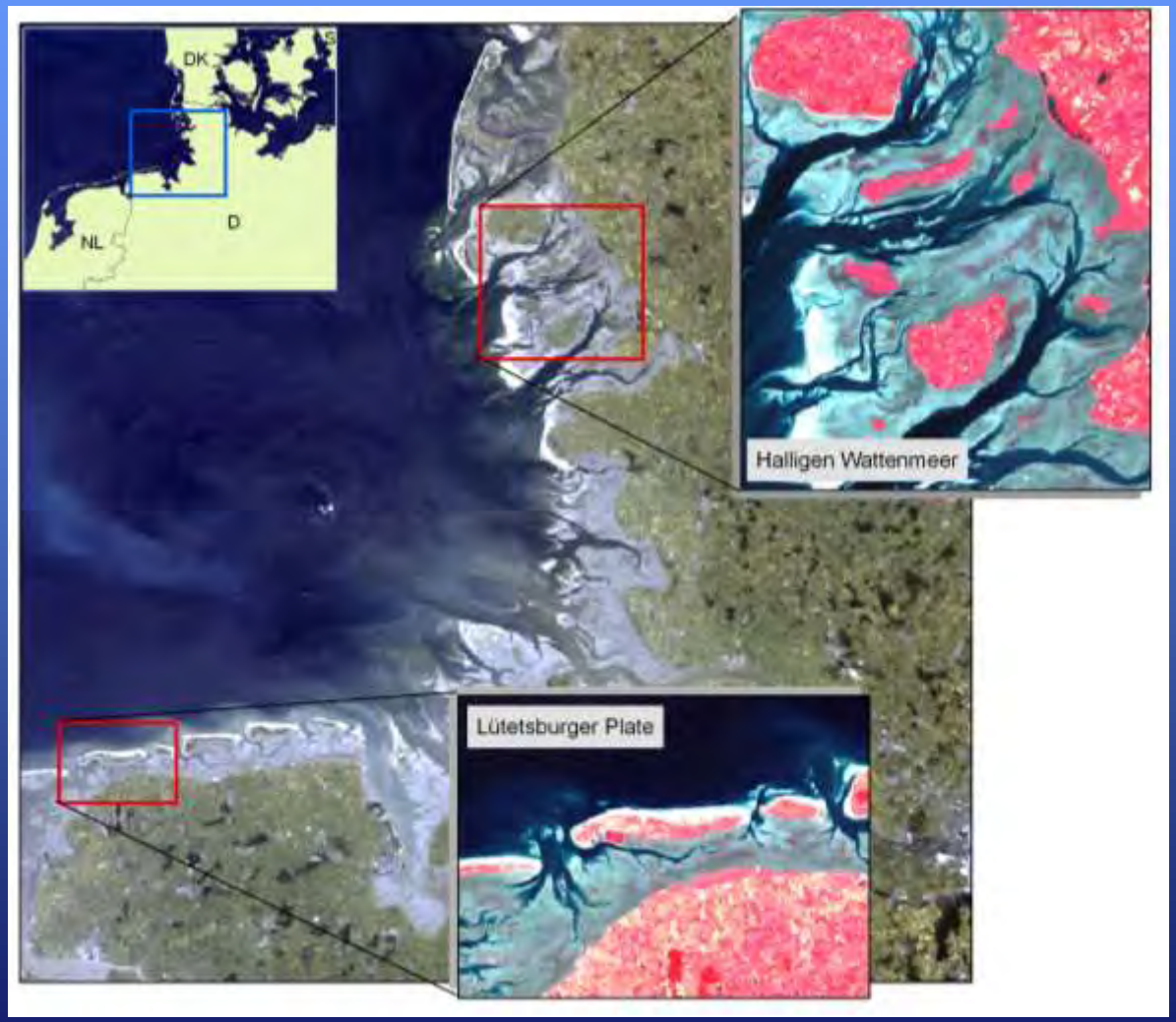
Brockmann Consult, UHH, National Park Agencies (Schleswig Holstein, Niedersachsen)

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

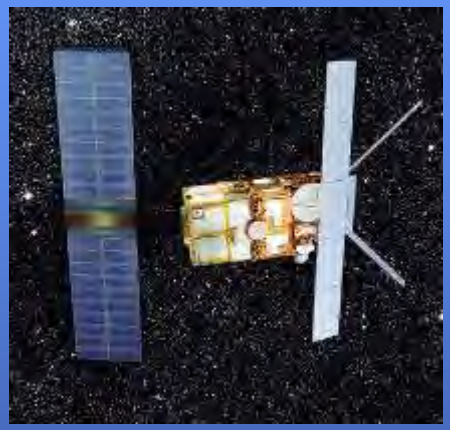
DeMarine-U (2)

Test Sites



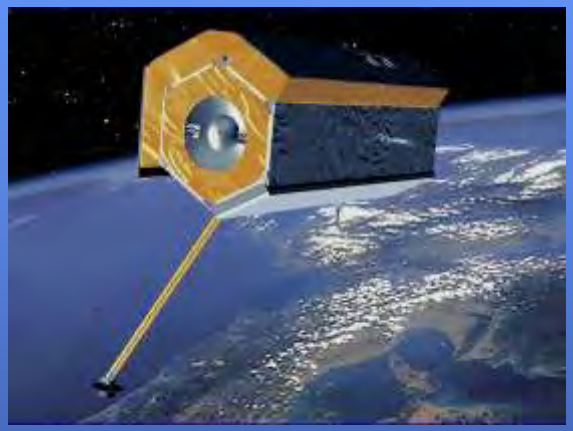
DeMarine-U (3)

Use of SAR Data from Various Satellites



ERS-1/2 (1991 / 1995)

ENVISAT (2002)



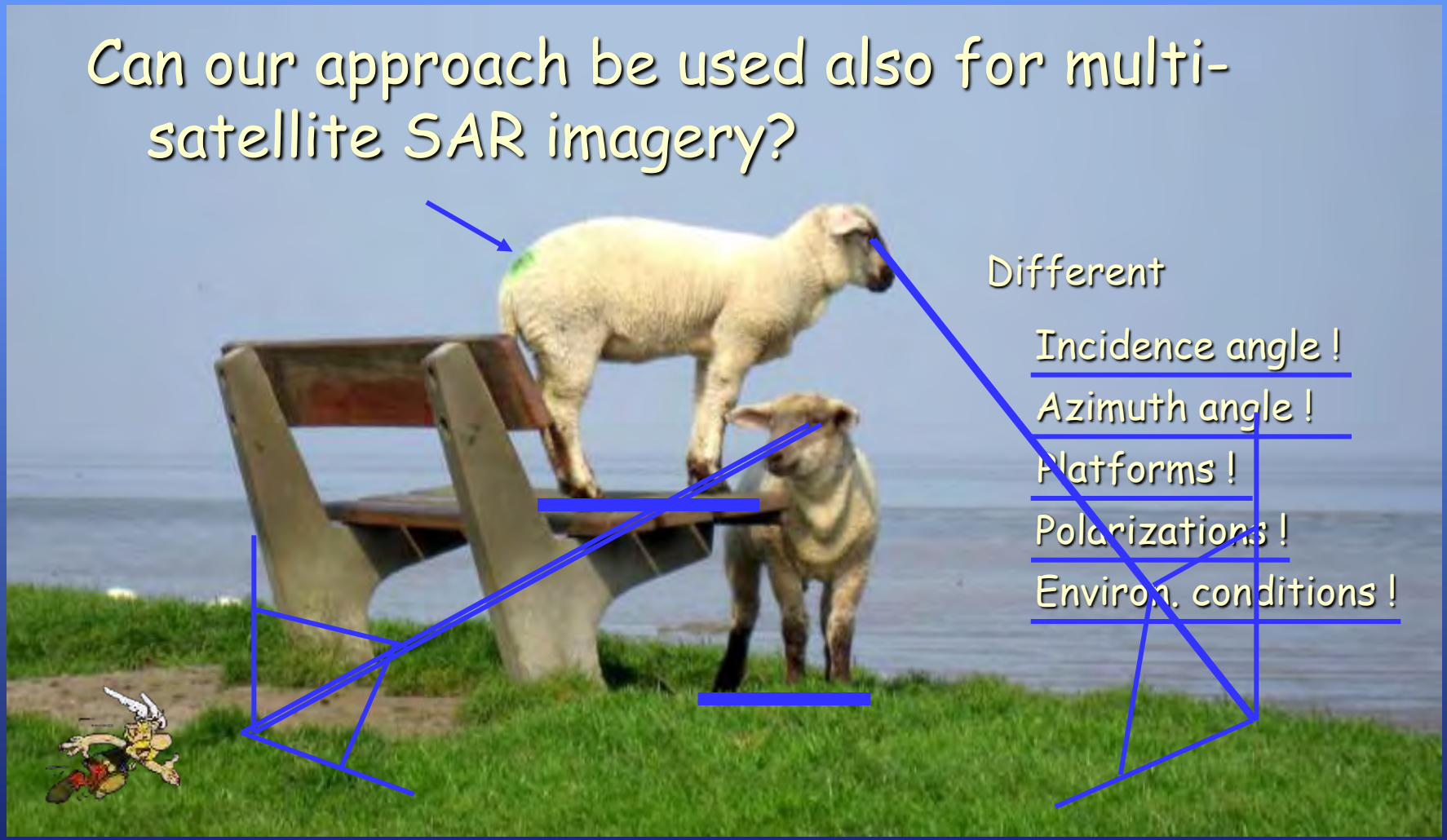
TerraSAR-X (2007)

RADARSAT-1/2 (1995 / 2007)

ALOS (2006)

DeMarine-U (4)

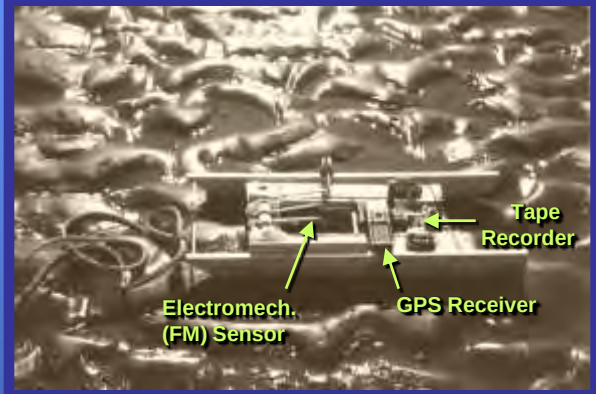
Can our approach be used also for multi-satellite SAR imagery?

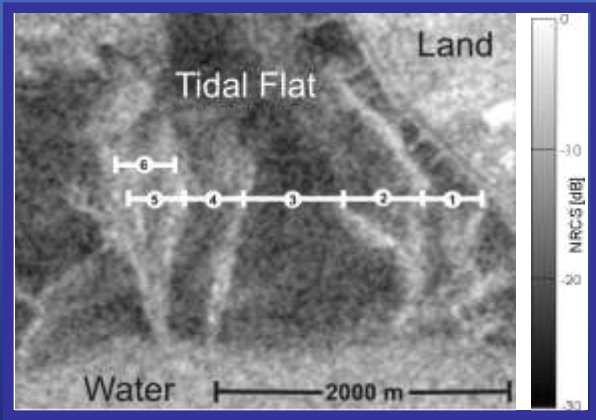


Field Campaigns

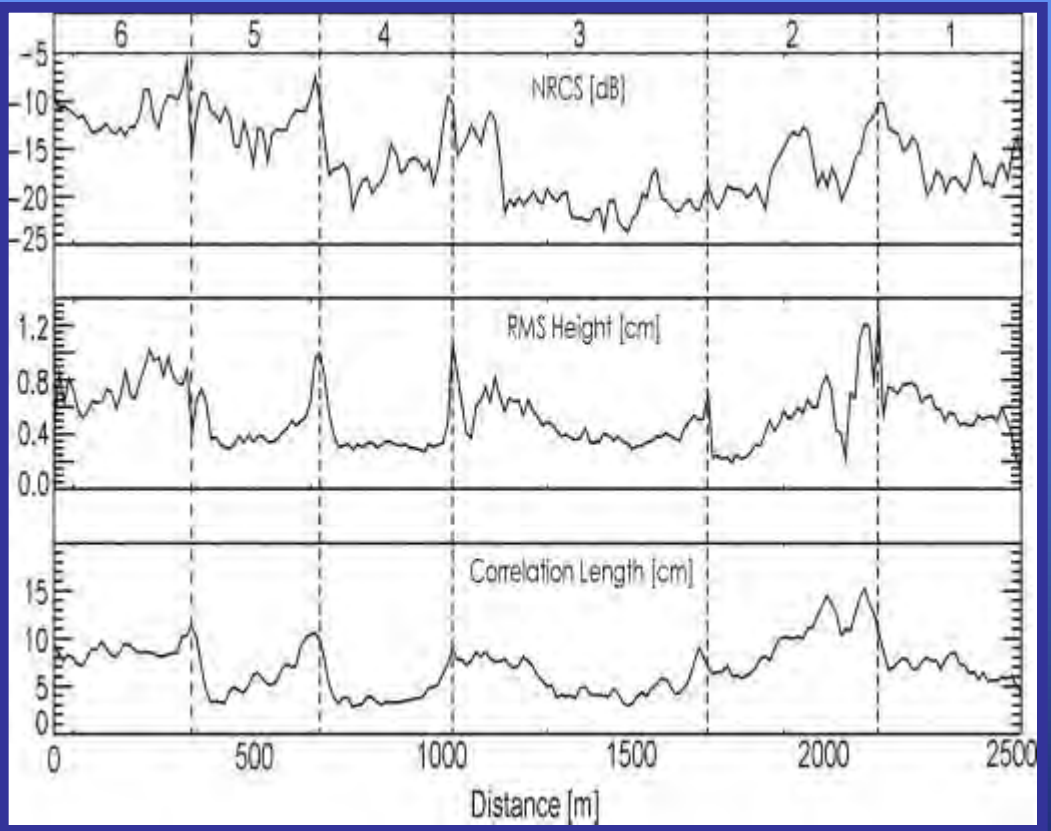
Field Campaigns (1)

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

German Wadden Sea, Norderney Riffgatt, 14 April 2008

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

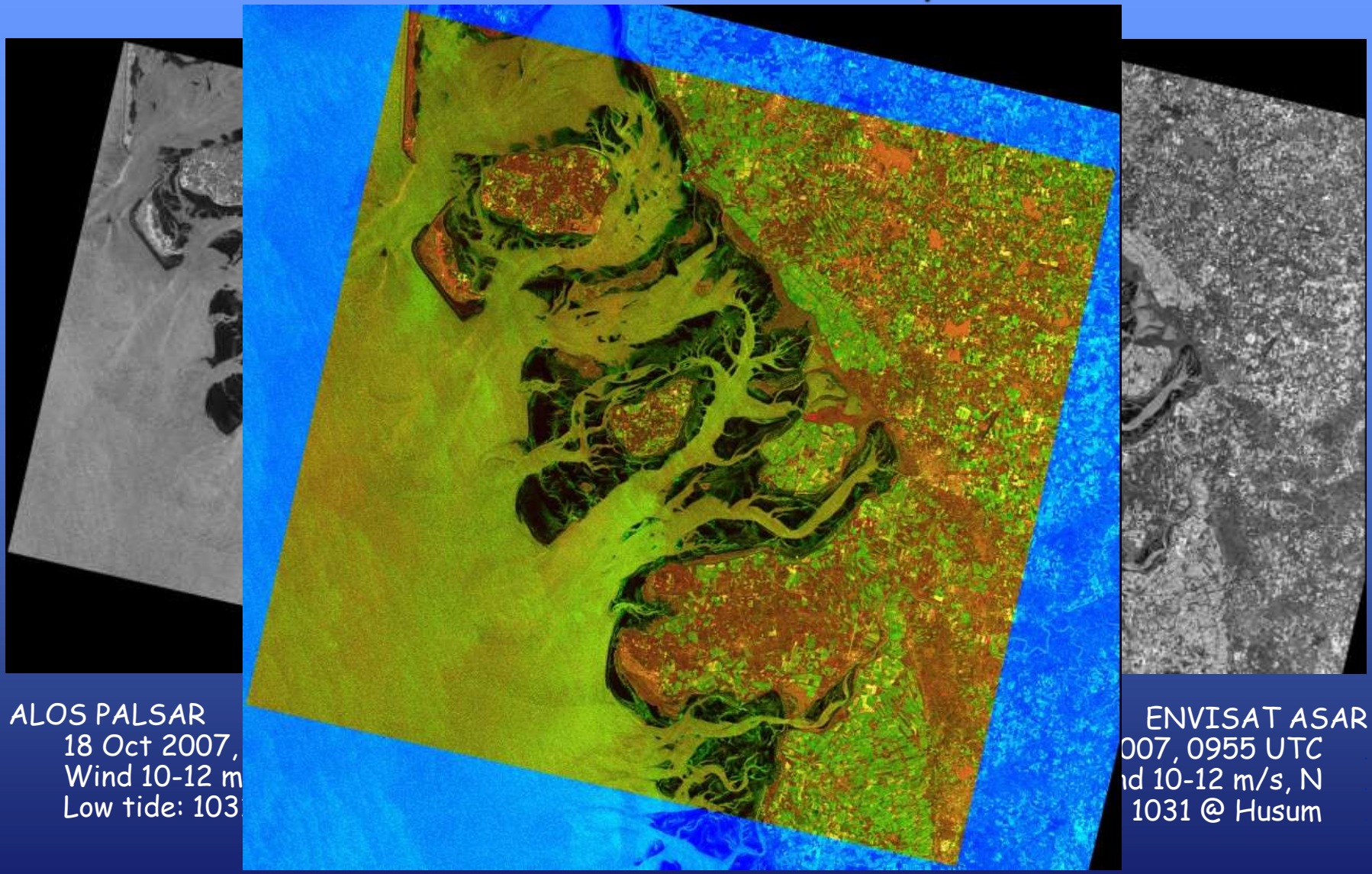
- Slope/inclination
- Surface structure
- Colour
- Sediment
- Surface layers
- Redox conditions
- Micro-, Macroalgae
- Macrophytes. –fauna
- Weather conditions
- Station info

Field Campaigns (3)

DeMarine-TP4 April/August 2008

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

Recent Satellite Data Analyses (1)

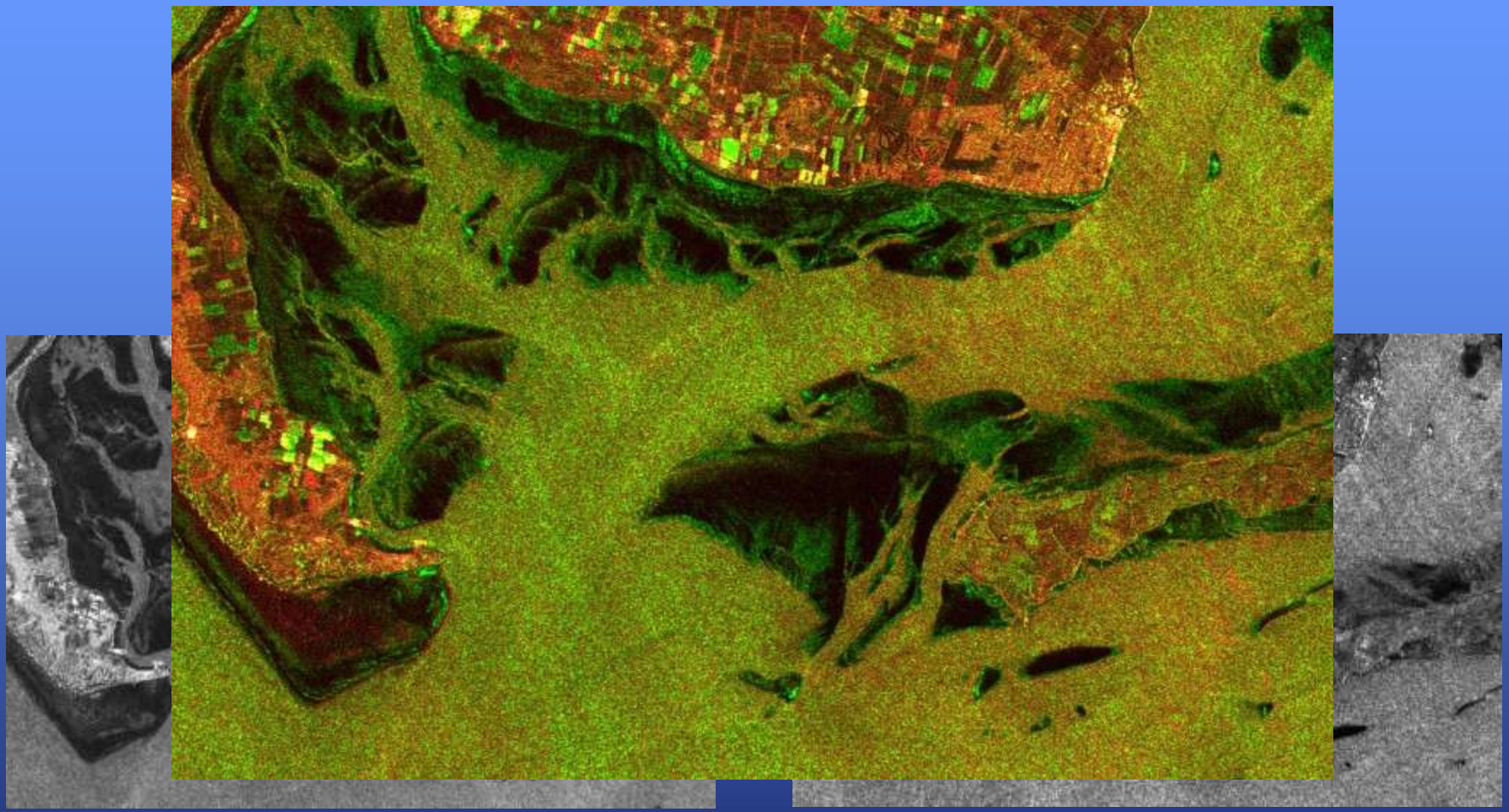


ALOS PALSAR
18 Oct 2007,
Wind 10-12 m
Low tide: 103

PALSAR ASAR Diff(P-A)

ENVISAT ASAR
007, 0955 UTC
d 10-12 m/s, N
1031 @ Husum

Recent Satellite Data Analyses (2)

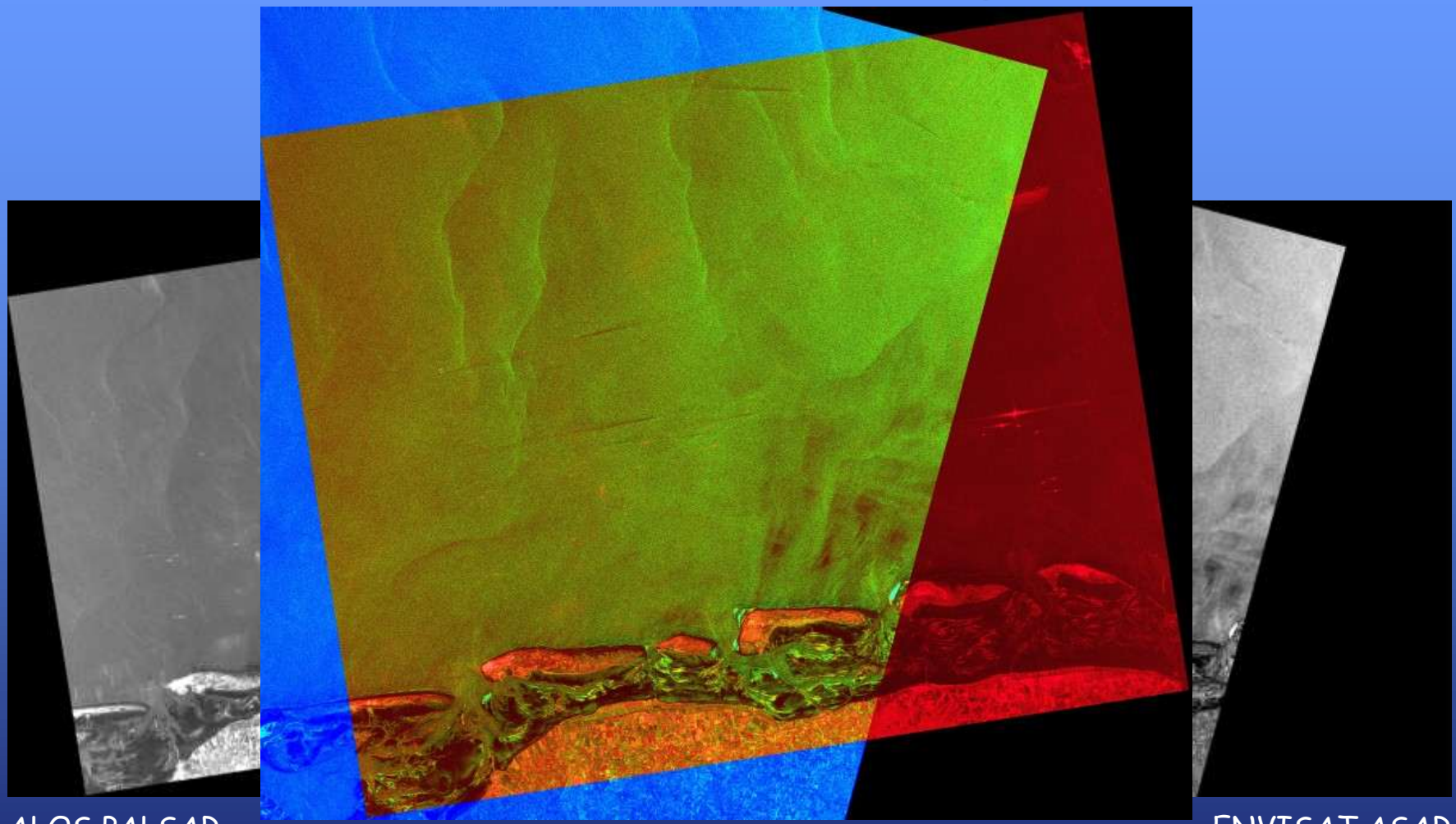


ALOS PALSAR
18 Oct 2007, 1023 UTC
Wind 10-12 m/s, N
Low tide: 1031 @ Husum

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 (3)

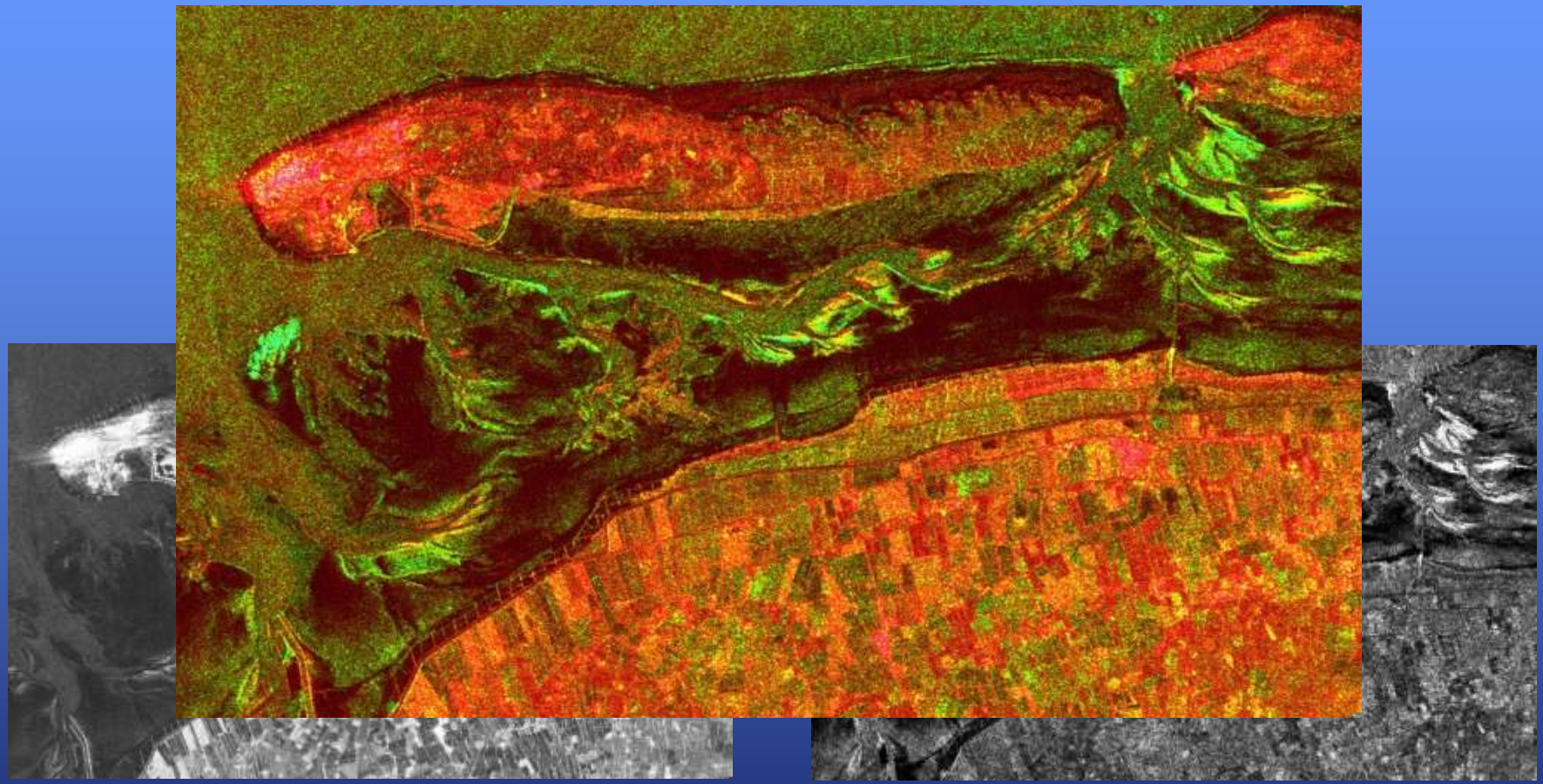


ALOS PALSAR
12 Apr 2008, 2143 UTC
Wind 3-4 m/s, W
Low tide: 2120 @ Norderney

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

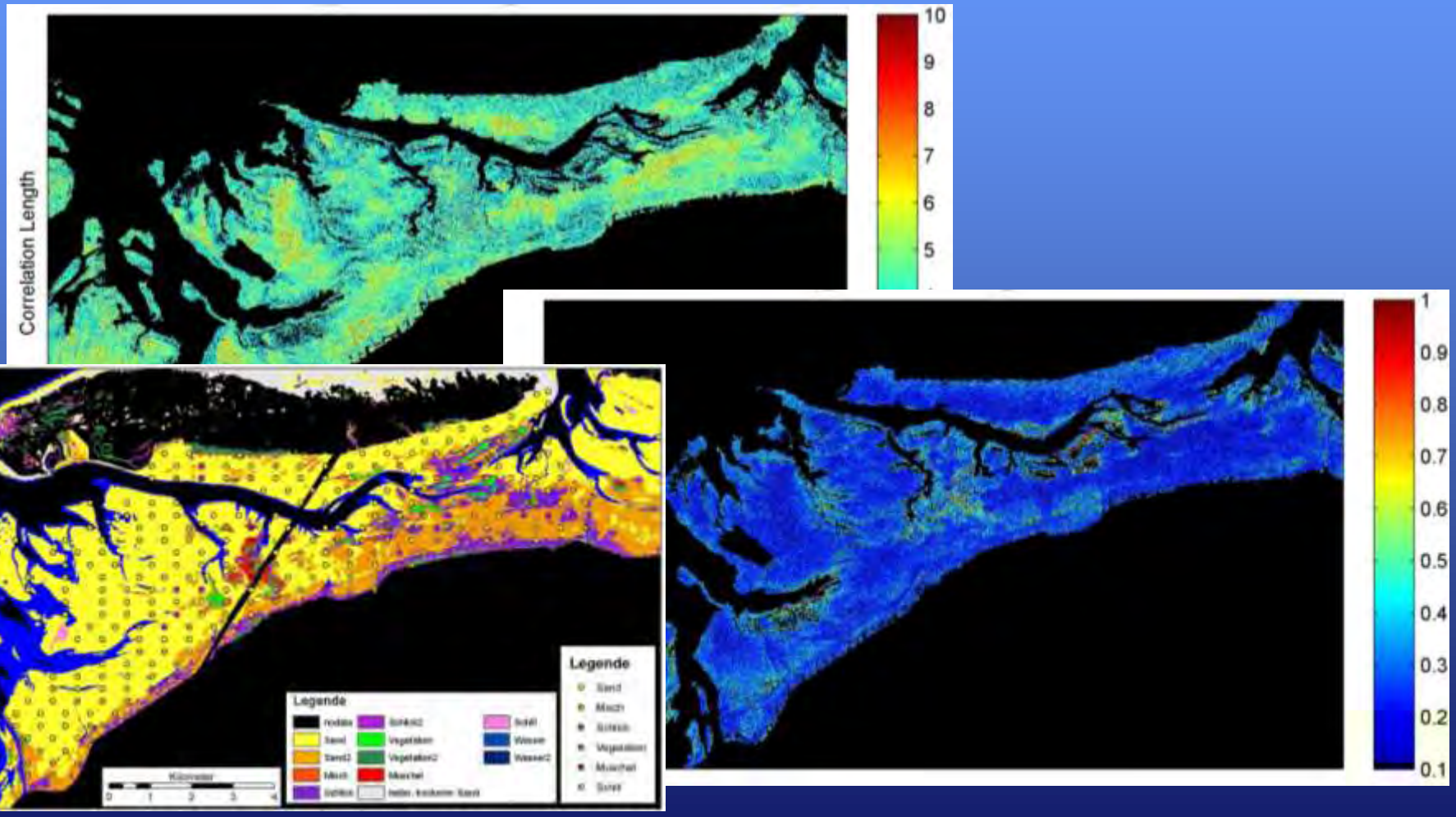
PALSAR ASAR Diff(P-A)

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

Recent Satellite Data Analyses (5)

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

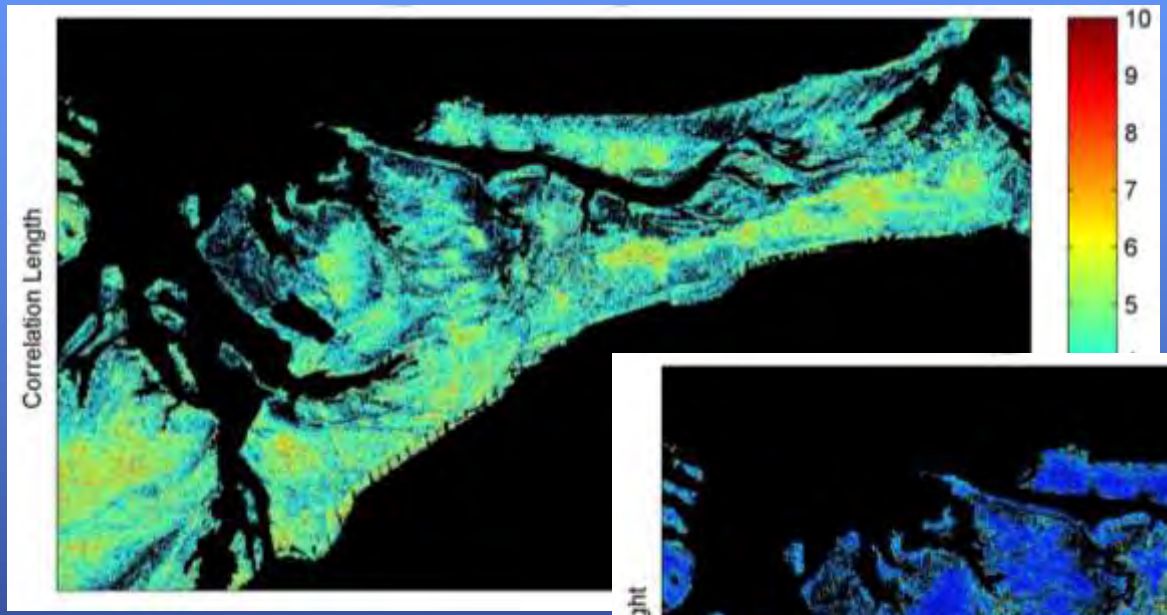
ENVISAT ASAR
13 April 2008, 10:01 UTC
Wind 5-6 m/s (SW), LT 09:35 UTC

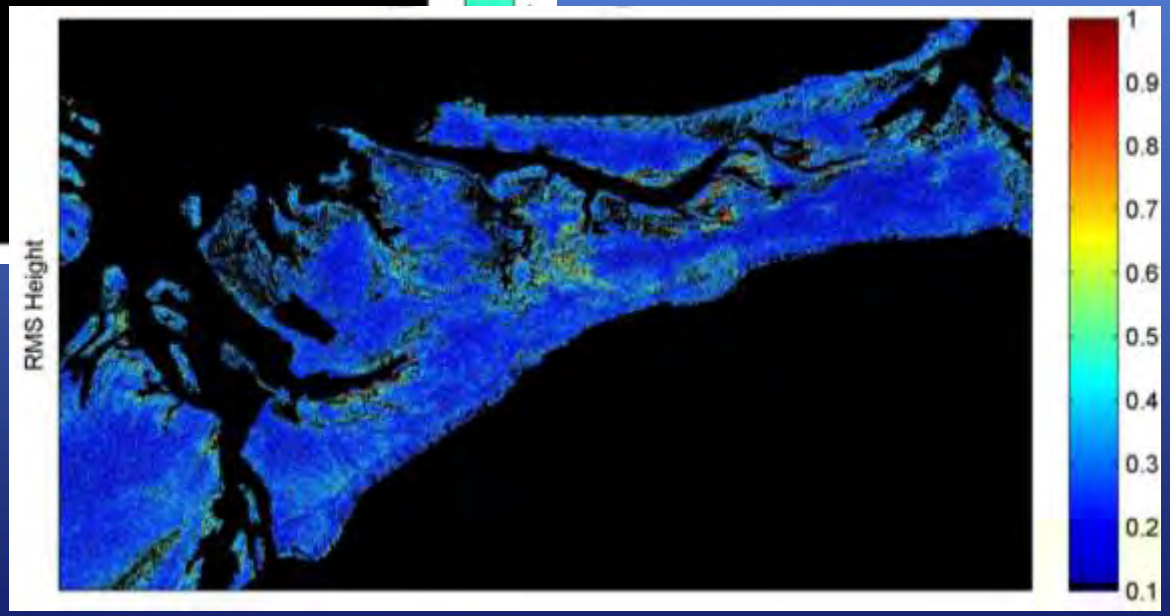


Recent Satellite Data Analyses (6)

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

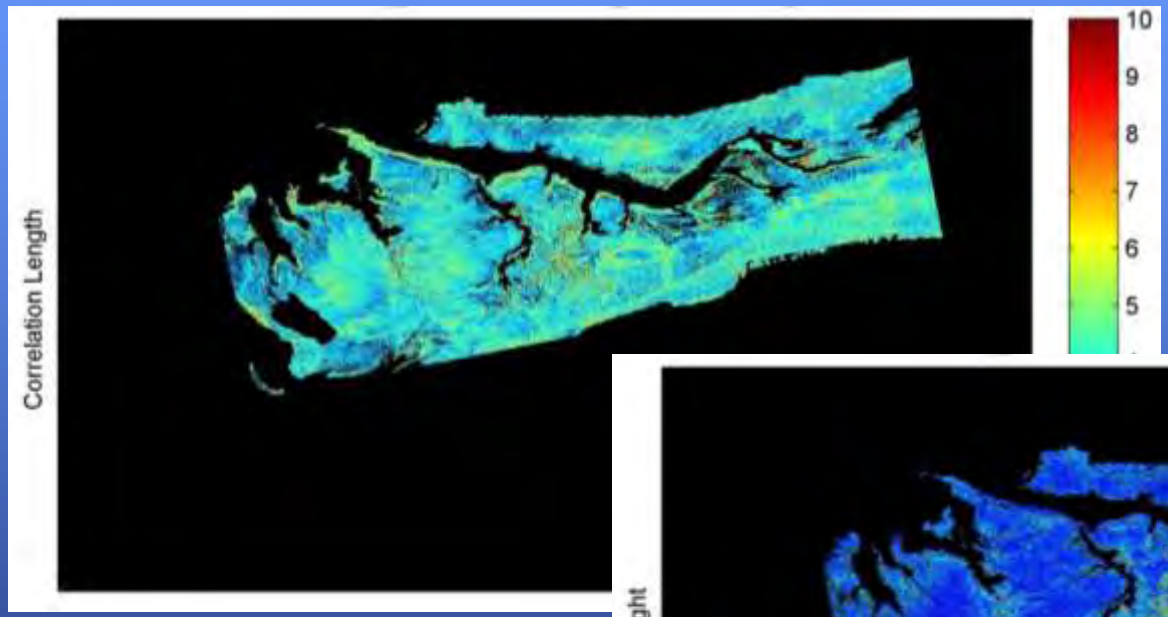


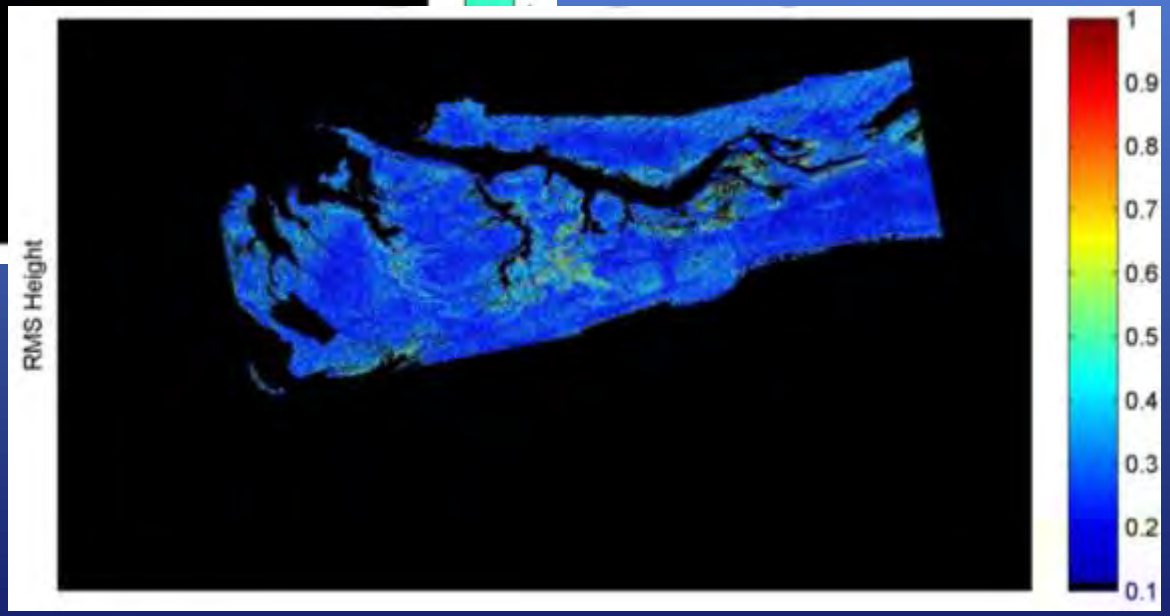


Recent Satellite Data Analyses (7)

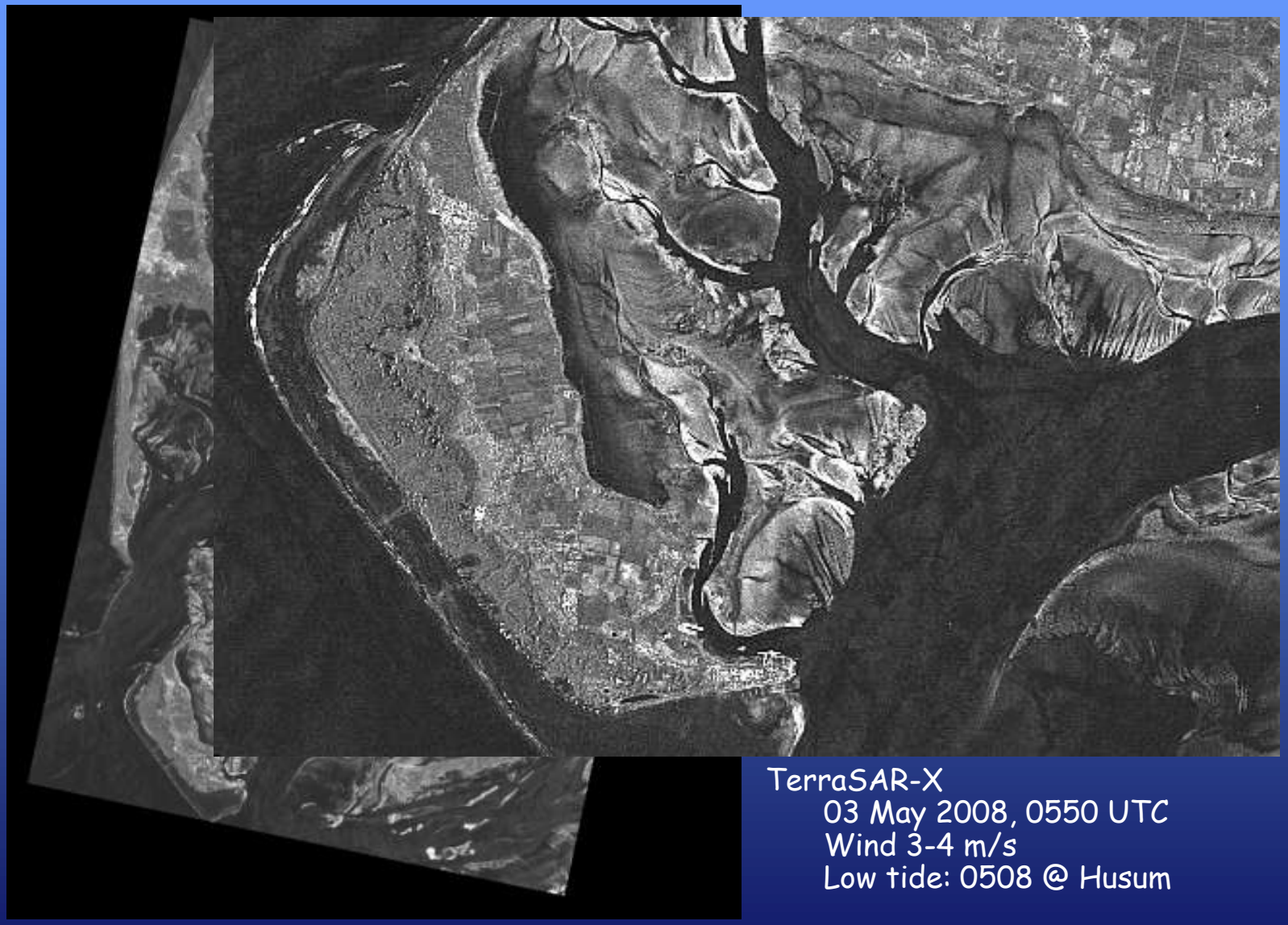
ALOS PALSAR
12 April 2008, 21:43 UTC
Wind 7-8 m/s (SSW), LT 21:20 UTC

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





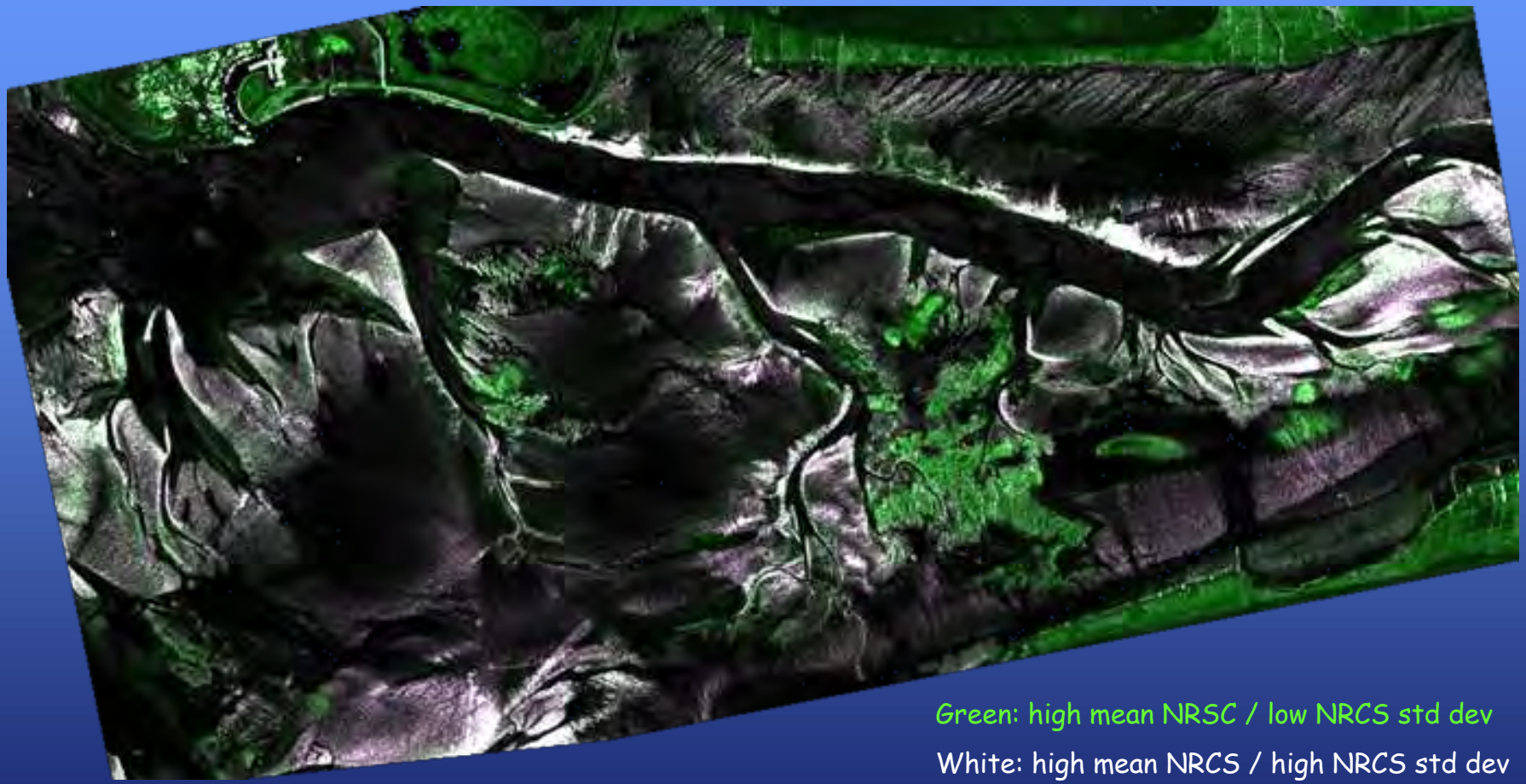
Recent Satellite Data Analyses (8)



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

Recent Satellite Data Analyses (9)

Multi-temporal analyses: Indicators for mussel beds



Green: high mean NRSC / low NRCS std dev

White: high mean NRCS / high NRCS std dev

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

Summary

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 !