Timescale as Interface of Satellite Data Acquisition Systems against Coastal Water and Tidal Region Processes

As significant Problem for Remote Sensing

(An example of some phenomena and processes of coastal environment)
Regional example: wadden region of North Sea, east coast

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Abstract:

Some natural processes are of such time scale that a change of the phenomena is going on meanwhile a sensor system works on data acquisition.
The time-space problem of tidal coverage of wadden areas (tidal flats) is very important for remote sensing methods of coastal areas.
A preliminare matrix of relationship of time scale of processes of coastal waters versus time scale of data acquisition system is to be published at this place.

Text: Time-spatial design of coasts:

Waves and breakers with a time scale of a 6 sec period are of the same time scale as the pathway of the nadir of Landsat: the change detection of such a coastal phenomenon cannot be taken with this very MSS-system and coastal mapping cannot obtain sharp lines of land-sea boundaries (wadden - sea).
Flood-tidal water does cover tidal flats with a current velocity of 1 to 3 m/sec, i.e. during 30 sec a surface of a distance up to 90 m. This is a spatial dimension of more than 1 pixel of Landsat-MSS and a change in the scene during less as the 30 sec scanning time for one scene of the sensor data acquisition system of this very type.
Within the area of 1 scene of 1 Landsat-picture of 185 x 185 km square, there is a synoptic overview (physical quasi-synoptic), due to time of scanner process. But at this very short time, nearly a moment, the different areas of the scene do not have synchron the lowest tide water level of tidal range, because in the North Sea, for example, there is the tidal amphydromy, with some hours difference in high or low water level of tidal range of different locations along 100 km of the coastline, i.e. in one Landsat-scene, the stage of tidal coverage is locally different, i.e. the satellite-picture does not show the low water situation within the whole scene.

Example:

The coast of the North Sea from Elbe-river, Cuxhaven, to Blavandshook, Esbjerg (Nordfriesland to Denmark), a wadden landscape (intertidal)between the coastline and the sea including coastal waters.
Timescale problems concerning mapping with remote sensing of Landsat-MSS imagery.
The evidence of the need of mapping the intertidal area and other phenomena of this very region is evident for multiple purposes as coast protection of the dyke-line, traffic and sand transport.
Remember the ten-year-experiment: Sandbewegung im Küstenraum, Deutsche Forschungsgemeinschaft, published 1979.

The data material:

The Landsat-2-picture is taken with the MSS-system. The scene includes 180 x 180 km. The particular data are printed out on the margins of the pictures. The best MSS-band to be used for mapping is the band 6.

These picture data were taken on April 19, in 1976, MSS-Landsat-2, 9^{30} MOZ (mean local time).
The best topographic situation of intertidal area is given by band 6 MSS, but no better differentation of sand or mud, except the high sands called "Sände", which are dry under most tidal conditions. The contour of the intertidal area is, in the southern region, where at the time of data acquisition the low water level is reached, much more differentiated as on a nautical chart in scale 1 : 300 000 (DHI 1950 - 1970). But this is the case due to a generalization of this map for better overview of nautical charts in this particular scale.

Landsat-2-scene from 19. April 1976, 9^{30} local time:

The scene shows Schleswig-Holstein northwest of Elmshorn - Laboe and southern Juteland south of Blavands Huk. The scene shows MSS band 6 (700-800 nm). In MSS bands 6 and 7 wadden areas can be clearly distinguished from land as well as from water, such as tidal channels.
The scene was taken after mean low water. Due to the tidal time differences along the North Sea coast the scene shows different tidal stages between Blavands Huk and Cuxhaven. Thus, e.g., the wadden areas around Sylt are already partly flooded, whereas further south they are not yet covered by water.
The mapping of these areas by Landsat is problematical. Problems inherent in the scanning system.
A Landsat-scene is not strictly synoptical: During the 30 seconds scanning time of the MSS scanner local changes due to the flooding or falling-dry of wadden areas may occur. Current velocities of 2 m/sec cause a change of the water boundary of 60 m/30 seconds, which is slightly more than the pixel width of 59 m. Thus, a blurring of the momentary water-land boundary occurs even within the scanning time. These processes are known from measurements of wadden-areas by means of large-scale aerial photography (Wasserlinienverfahren. G. Hake 1978, N. Rüpke 1966).
Meso-scale processes, such as algae migration towards or below the surface with the tidal period (Biorhytmik) happens within one hour.

Timescale problems for the interaction between Landsat and tides

The most suitable time of a Landsat scene for the mapping of the above named phenomena would be the low water level at mean low water spring. Landsat scenes are taken synchronously with the sun always at 9^{30} local time at the equator and $\pm$ 30 minutes towards the poles. Mean low water spring (after full and new moon) occurs, due to the lunar phases, in time intervals of 15 days, datum sometimes 14 days, due to principal lunar period of $^{1}/2 \cdot 29$d 18h 44m (Syzigienphasen).
Low water levels similar to mean low water spring (at 9^{30}h) occur between 1 and 20 times per year. The coincidences occur in such time intervals that periodical phenomena, such as ice cover and vegetational cover of lateral areas by the plant salicornia may happen (interference).
The setting in of tidal phases can be found in the tidal calendar, or tidal tables of the Deutsche Hydrographische Dienst (pre-calculated values without meteorological influences). Actual tidal levels are recorded within the Deutsches Gewässerkundliches Jahrbuch, as retrival data one year later publ.
A further problem of the time scale: the tidal phases of high and low water set in at different times along the German North Sea coast:
a) due to the amphidromy there is a difference of 2 hours from the south to the north between Cuxhaven and Blavands Huk,
b) due to a different seaward exposition there is a time difference of 2 hours from the outer sands to the shoreline,

c) due to the local relief there may be a time difference of up to 1 1/2 hours.

Result: A Landsat scene of 185 x 185 km records a part of the North Sea coast quasi-synoptically by scanner. During scanning time different regions of the scene are scanned at times of different water levels of tidal phase.

Natural hydrographic condition

Approximate Low Water, ebb-tide in the southern area of the scene, around the estuary of the Elbe, and about 1 hour and 30 minutes before Low Water in the northern area of the scene around Island Fanö: The satellite image is a synoptic one but due to the amphidromic tidal wave of the North Sea at this very moment of the data acquisition of the scene, there is a 1 to 2 hour difference between the tidal data of the lowest ebb-tide water level on different locations along the 180 km coastline. The tidal range in the southern part is 3 m, in the northern part is 1,5 m.

Low Water on the German North Sea coast in the morning of the 19.April 1976 was: water-mark Cuxhaven 11^{06} h tidal range 308 cm, Büsum 10^{26} h 286 cm, Eidersperrwerk 11^{34} h 291 cm, Husum 11^{42} h 258 cm, Strucklahnungshörn 10^{55} h 260 cm, Wittdün 11^{18} h 304 cm, Schlüttsiel 12^{10} h 278 cm, Dagebüll 12^{03} h 282 cm, List 11^{51} h 353 cm.

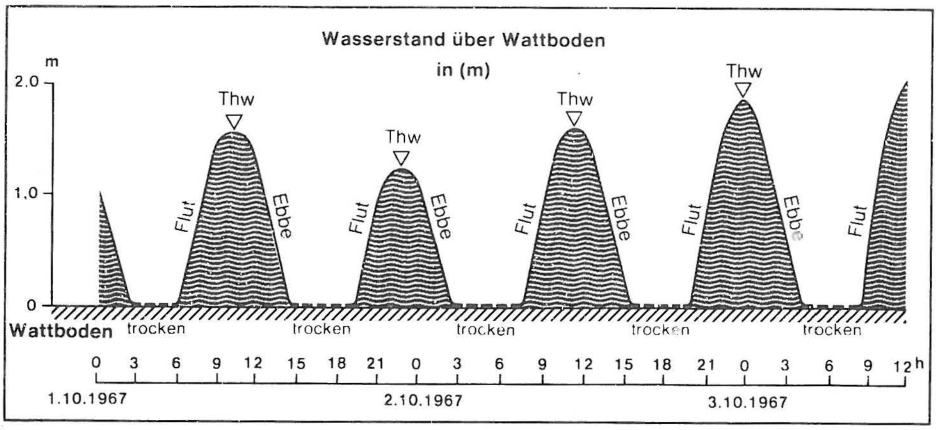


Abb. 1 Water cover, ebb and tidal curve over wadden and visibility of exposed wadden areas

The waterlevels within the tides fall below the wadden level so that the wadden are not flooded for certain periods, i.e. they fall dry ("exposed"). The tidal curve of wadden areas is thus intermittent. Only upper sections are represented. The sea bottom, i.e. the wadden, appears in the horizontal dimension periodically as sea or land (along the time axis, x-axis). The water above the wadden (vertical dimension) appears periodically present or absent (y-axis).

The intervals of the exposed times of the wadden depend on lunar time and is not in coincidence with solar day time, i.e. changing through the day, i.e. not in coincidence with Landsat data acquisition local day time.

Acc. to: W. HANSEN (1973): Der Einfluß des geplanten Tiefwasserhafens im Wattgebiet Neuwerk-Scharhörn auf Wasserstände und Strömungsgeschwindigkeit in der inneren Deutschen Bucht. Hamburg. Küstenforschg., Heft 26.

Darstellung der Landschaften im Stockwerkbau der Küste auf dem Satellitenbild:

Festland u. Inseln	Land	weiß bzw. fleckig
Sandstrände u. Sande	oberes Stockwerk	weiß
Watten	mittleres Stockwerk	dunkelgrau
Priele	unteres Stockwerk	schwarz
Meer	Meer	schwarz

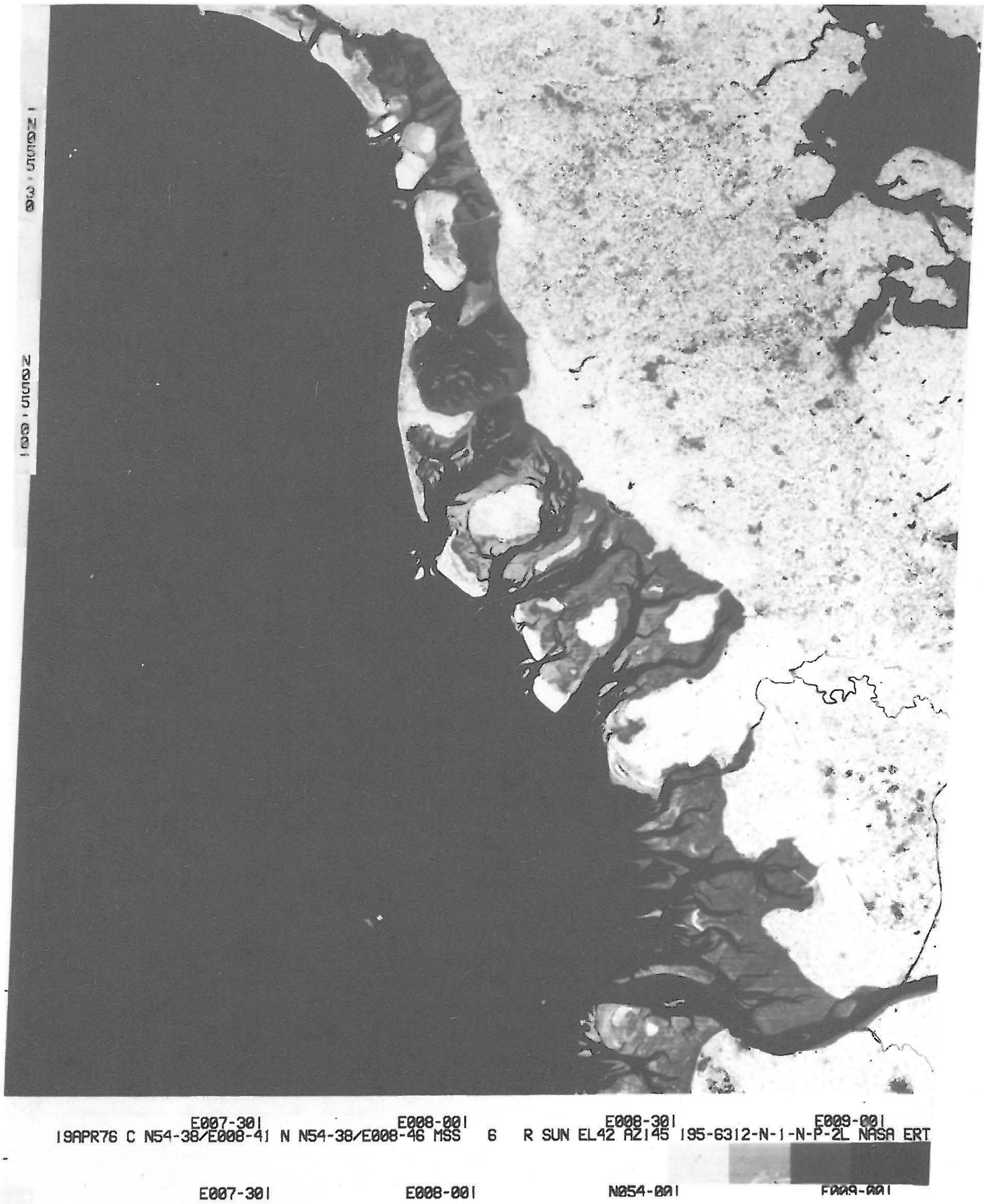


Abb.2 Satellitenbild, NASA-Landsat-2, Kanal 6 des MSS (Multispektral-scanners
Aufzeichnung: DFVLR Oberpfaffenhofen, Archiv-Nr. 04, L-00006, Aufnahme: 19. April 1976, 9^{30} h MOZ (mean local time), Bildmaßstab 1 : 1 Million, Aufnahme: Niedrigwasserstand (NW), Low Water, Innere Deutsche Bucht. Nicht für die gesamte scene tidewasserstandssynchron!

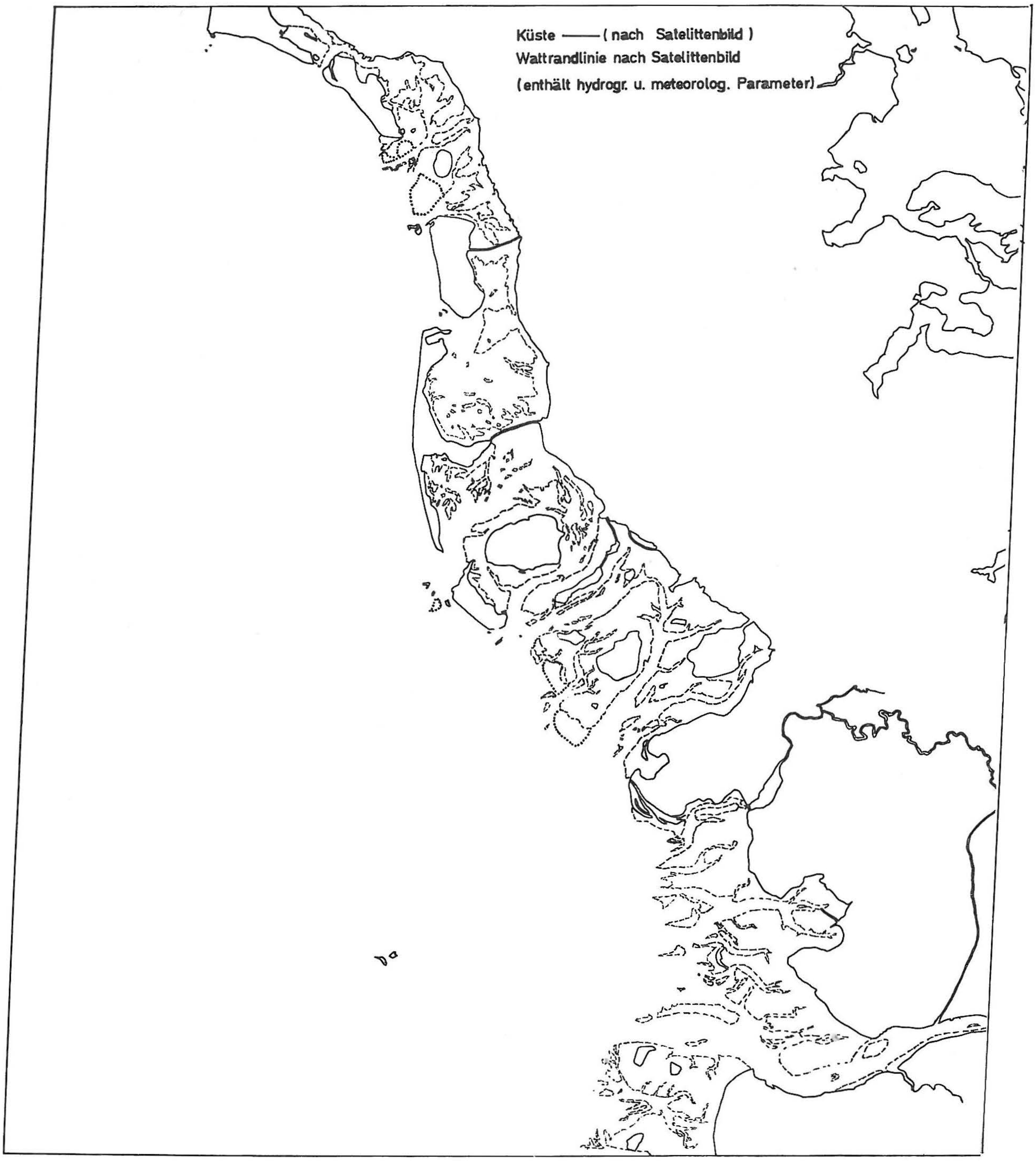
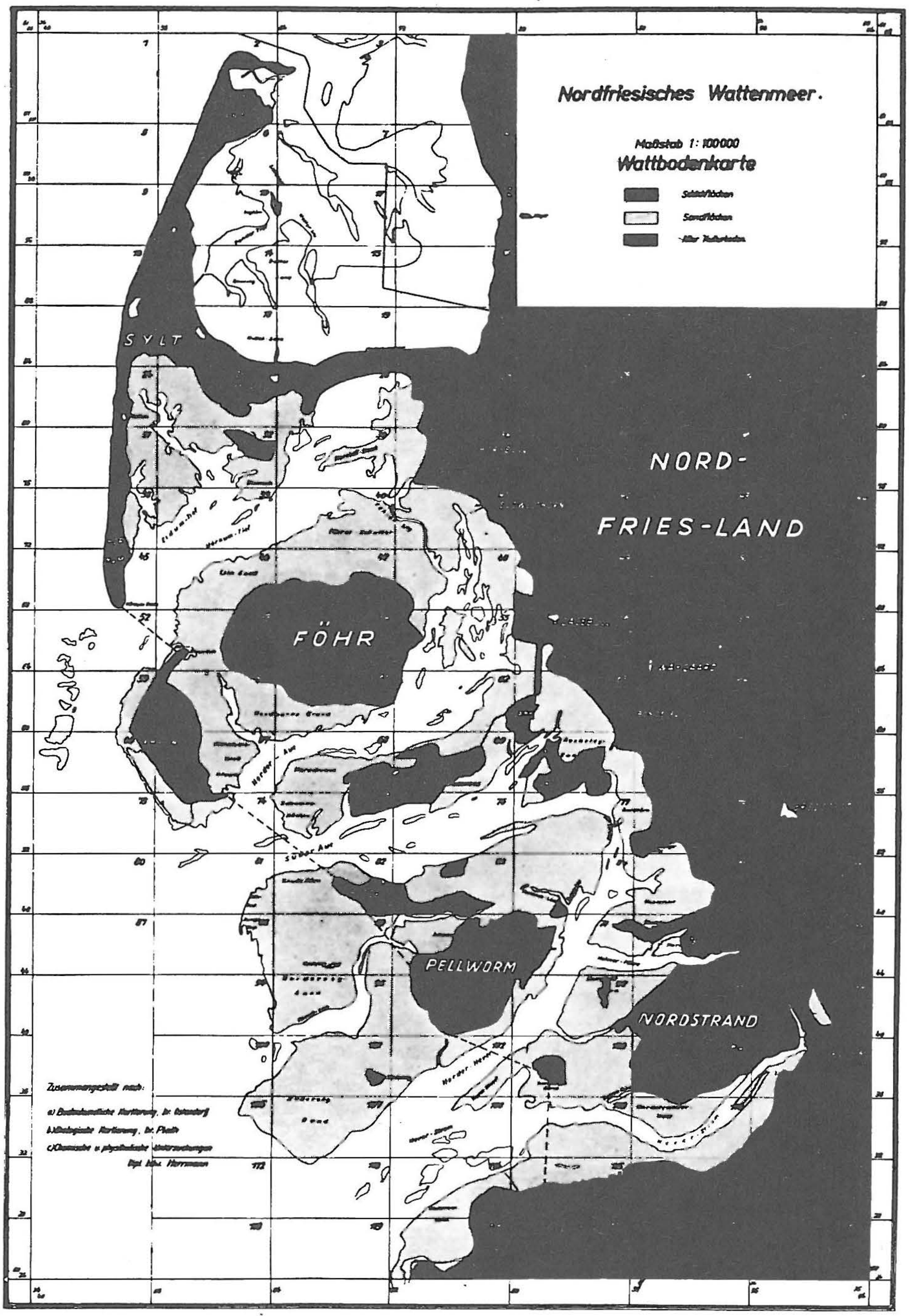


Abb.3 Coastline and visible boundary of exposed wadden versus water as mapped from satellite image Landsat MSS 6 of 19. April 1976

Region: Coast of North Sea from Elbe river to the island of Fanö. It is obvious that the northern part of the wadden is still more covered with water as it is visible on a map of Low Water tide all around as on nautical charts.



Wattbodenkarte.
(Westküste 1943, S. 67)

Abb.4 The boundary water - land on this map is a geodetic one, and is not in congruence with the boundary of land - water visible on band 6 MSS Landsat.
Chart of tidal flats (intertidal area) of Nordfriesland (Wattenmeer) with sandy bottom (light grey tone) and with slick (mud) bottom (medium grey tone) with old culture areas lost to the sea (dark dashed tone), small areas, polder land and the continental higher areas in black tone.
Acc. to: M. Petersen (1978): Der Heverstrom - Schicksalsstrom Nordfrieslands, Nordfriesisches Jahrbuch, NF. 1979, Nr. 46.

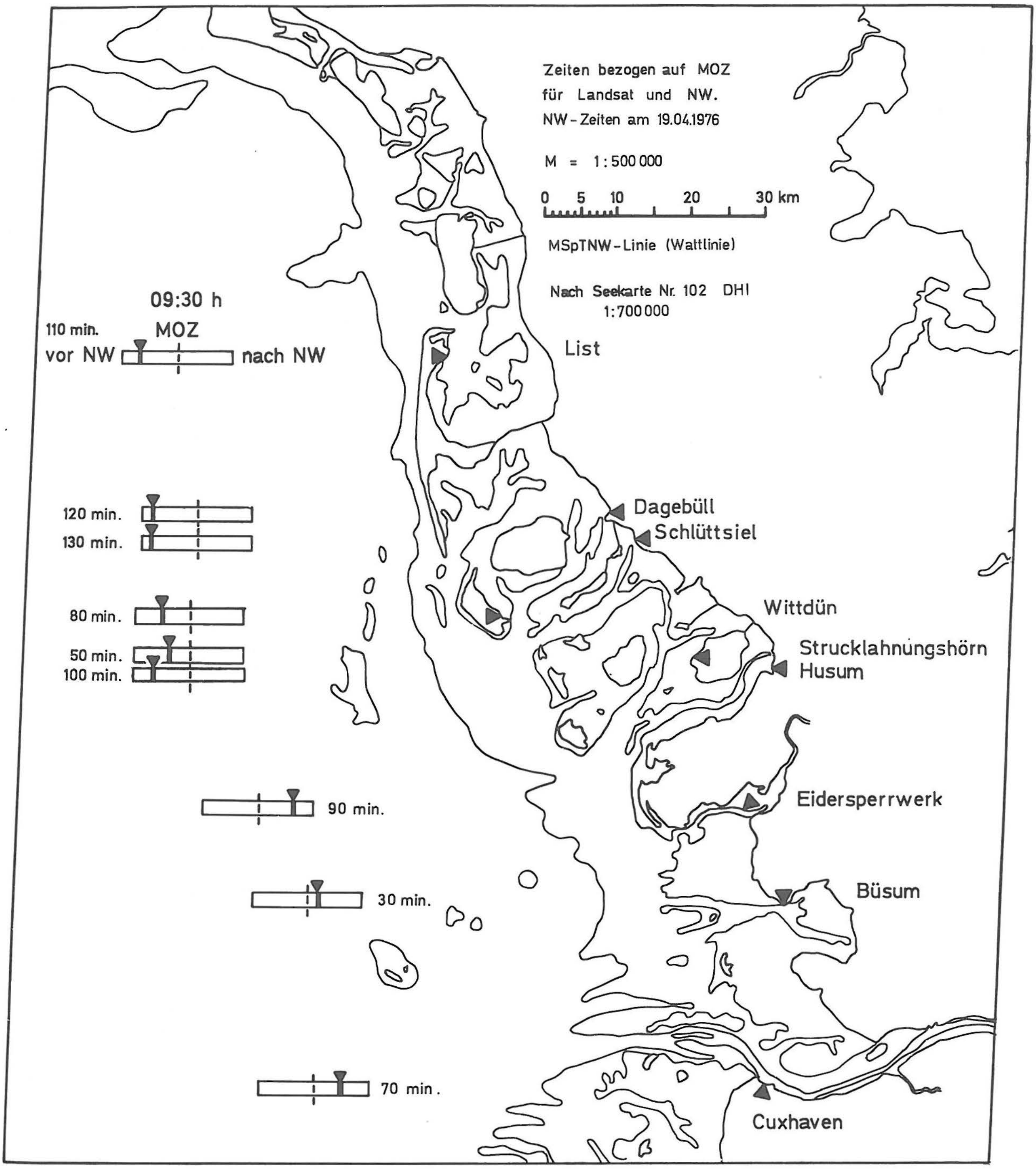


Abb.5 Tidal data (time of Low Water of MOZ) on the coast of the North Sea at the 19. April 1976

Data acquisition time of Landsat is 9^{30}h MOZ. At this very time the time of Low Water of the location is different, shown at the side in minutes after and before 9^{30}h MOZ.
Entwurf: H.G. Gierloff-Emden 1979

Time Scale Datas of Remote Sensing System *Landsat*

(ERTS-1 - renamed LANDSAT - NASA Satellit)
Orbit : polar, sun - synchron,
1 Orbit = 103 min
14 Orbits per day, repetition rate of LANDSAT = 18 days
Pathway of Nadir 6 km/h = Kinematic of System
Scanning process 1 scene = 30 sec (quasi synoptic)

Time dependent characteristic of Remote Sensing Images:

System	time	character	versus natural process
Photograph :	($1 \cdot 10^{-2}$ sec)	synoptic	(for large space scale (tidal data) process-synchron by mosaic)
Scanner Image:	($3 \cdot 10^{1}$ sec)	not strictly synoptic	(for large space not process-synchron (tidal data))
Repetition: chronologique intervall to reference-image = multitemporal			

Time scale problems involved, dependent on environmental processes:	
1 wave effects- non linear boundary land-sea on beach	.(micro scale)
(long shore-current (statistic, not real time)	.(sec - min)
(rip-current)	(sec - min)
2 tidal effects- time dependent variability of water covering exposure, depending on tidal excursion, this with regional differentiation in space of 1 scene	.(micro-meso macro scale sec-hour, day-month)
3 vegetation-climatic → time dependent spectral quality- (phenologie) (multitemporal))	.(macro-scale (month))

Time scale parameters: of 1,2,3 versus Remote Sensing System

scale	time intervall	character	versus Remote Sensing
1 microscale	. sec - min	. periodic	. scanning process
2 mesoscale (out of 24^h tidal-per.vers.diurnal)	. hour- day time scale	. periodic	. position-path of Sat. (orbit)
3 macroscale	. week- months	. periodic	. repetition of Sat. (multitemporal)

Time Scale Facing :	• remote sensing system dependant timescale parameters MSS - Landsat • object - natur processes dependant time scale parameters (coastal environment)	ISP- 1978 Freiburg	

Time Scale -				Micro -		Meso -		Macro -
	Time Scale -			sec	min	hour - day	weeks	months (year)
		Processes -		Remote sensing bounded				
				6-30 sec (Orbit) = Nadir Path.,	30 sec scanning process data acquisition	1) overlapping 2) fixtime : 9^{00} (Orbit)	18 day repetition multitemporal	4-8 months repetition 1) singularity 2) multitemporal
micro	min. - sec.	processes	0-15 s illuminat.	hot spot location				
			8-15 s waves 30-12°s rip curr. 50-80 s longshore curr. (unsteady)	tidal water cover. in minutes distances over 1 pixel - 2 p. - diffe-rent spectral cond. of pixel due to scanning pr.	breaker zone water line kinematic (spectral change)			
meso	days - hours -	object	12^{25} - 24^{50} h tidal periodic high-w - low-w. bidiurnal - diurnal tideperiodic 24 h + 50 min. versus 24 h day - night 1-24 h wind 3-6 h biology			tidal flats: tidal coverage waterline translation (spectral change) coverage exposure = colour of alges (biological clock)		
macro	months - weeks -	bounded	tidal range 2 weeks spring tide nipp tide (tidal expos. time)				tidal coverage waterline spring - tide nipp - tide salt flats evaporation (spectral change)	
			climatic period summer - winter vegetation freezing					vegetation types contrast, discriminating different (spectral change) Ice: Albedo
			tidal date 18 1/2 year					coverage-multitemporal

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