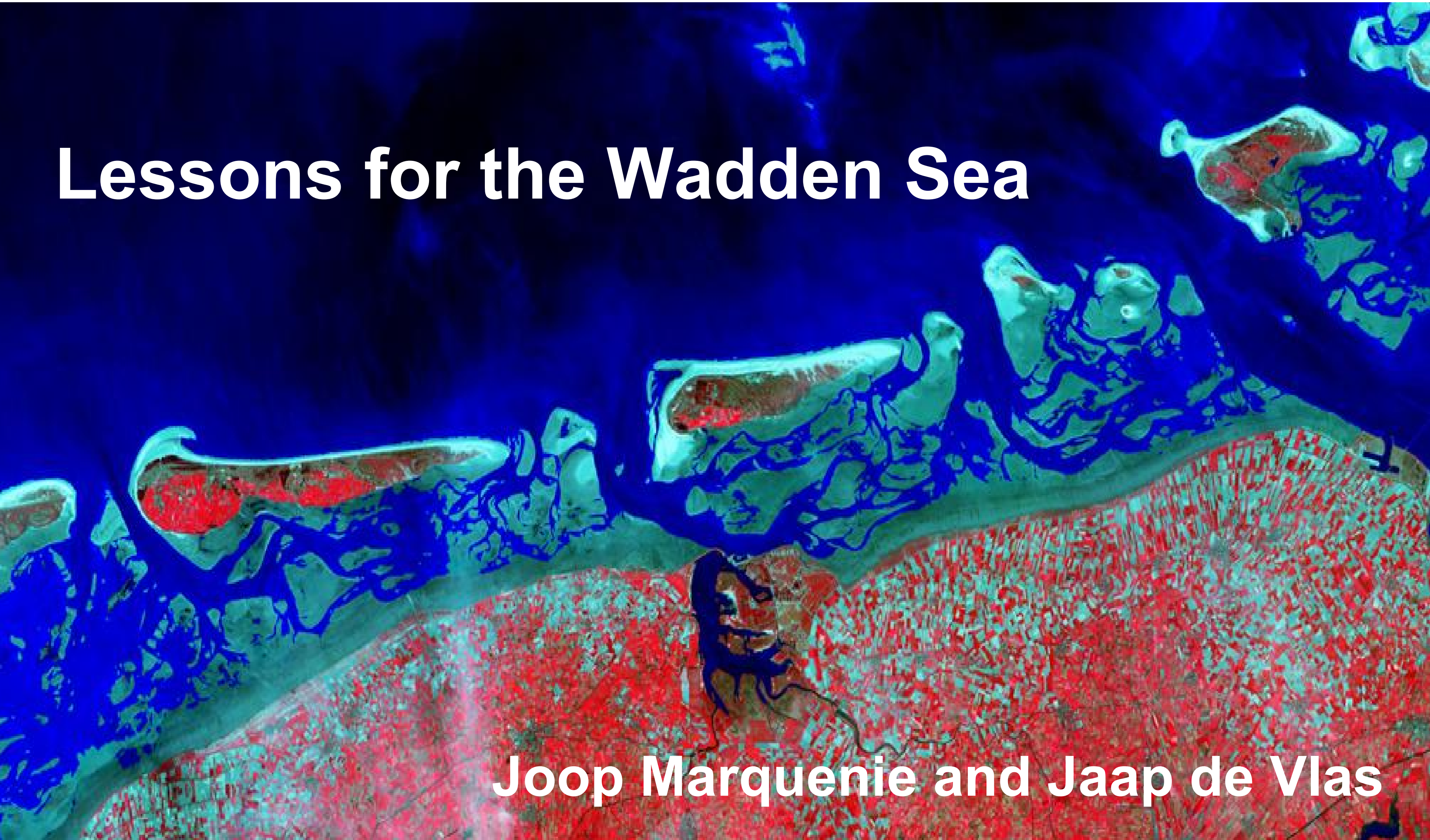
What we can learn from 18 years subsidence monitoring?



Lessons for the Wadden Sea

Joop Marquenie and Jaap de Vlas

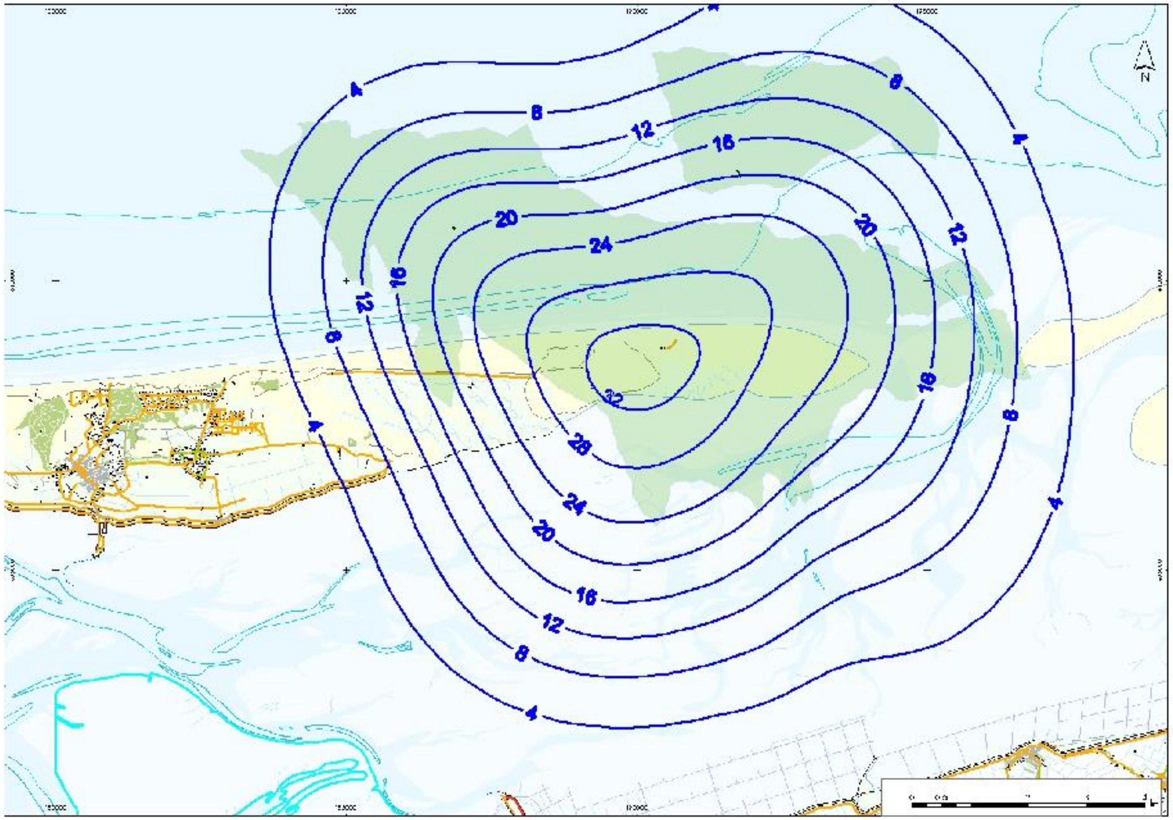
History of monitoring on Ameland

- 1962 Discovery gas field: 50-60 billion cubic meter
- 1972 Permit application
- 1983 Permits granted
- 1985 Prognoses subsidence, baseline study and impact assessment
- 1986 Start production
- 1987 Start monitoring
- 1994 1st report
- 2000 Report, review and adjustment of the program
- 2005 Report and review
- ?
- 2018 End production

Monitoring based on subsidence prognose for 2020

- Prediction 1985:
  - center: 20-34 cm
  - content: 24 x 10^6 m^3
  - diameter: 20 km

- Prediction 2003:
  - center: 31-37 cm
  - content: 22 x 10^6 m^3
  - diameter: 15 km



Winningsplan 2003

Commission Monitoring Subsidence Ameland

- Monitoring on request of the Provincial Association for Conservation of Nature “It Fryske Gea”
- Independent Commission
  - Task: Independency, quality and completeness
  - Directly involved stakeholders
  - Period 10 years (renewed in 2000 for 10 more years)
- Public evaluation every 5 years

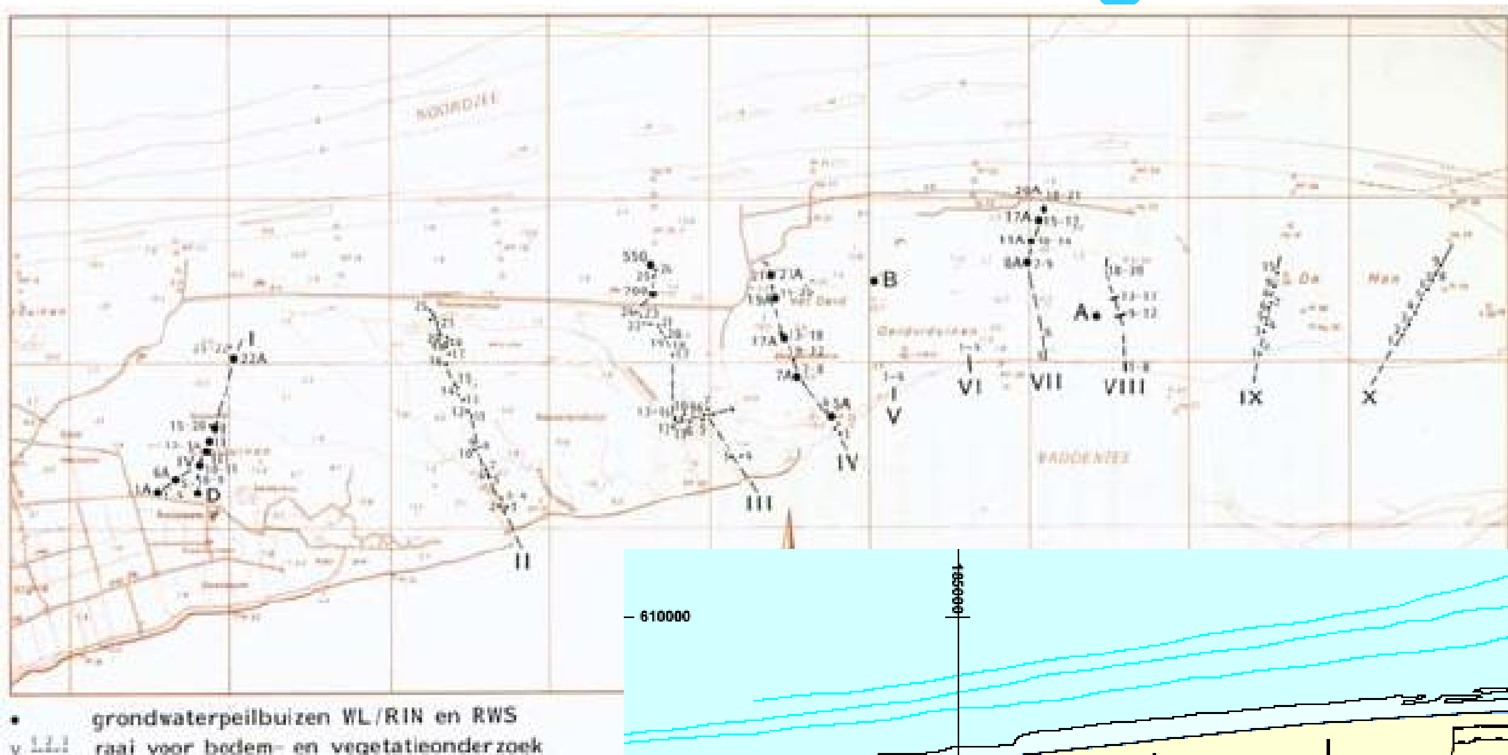
What did we monitor? 1987-2000

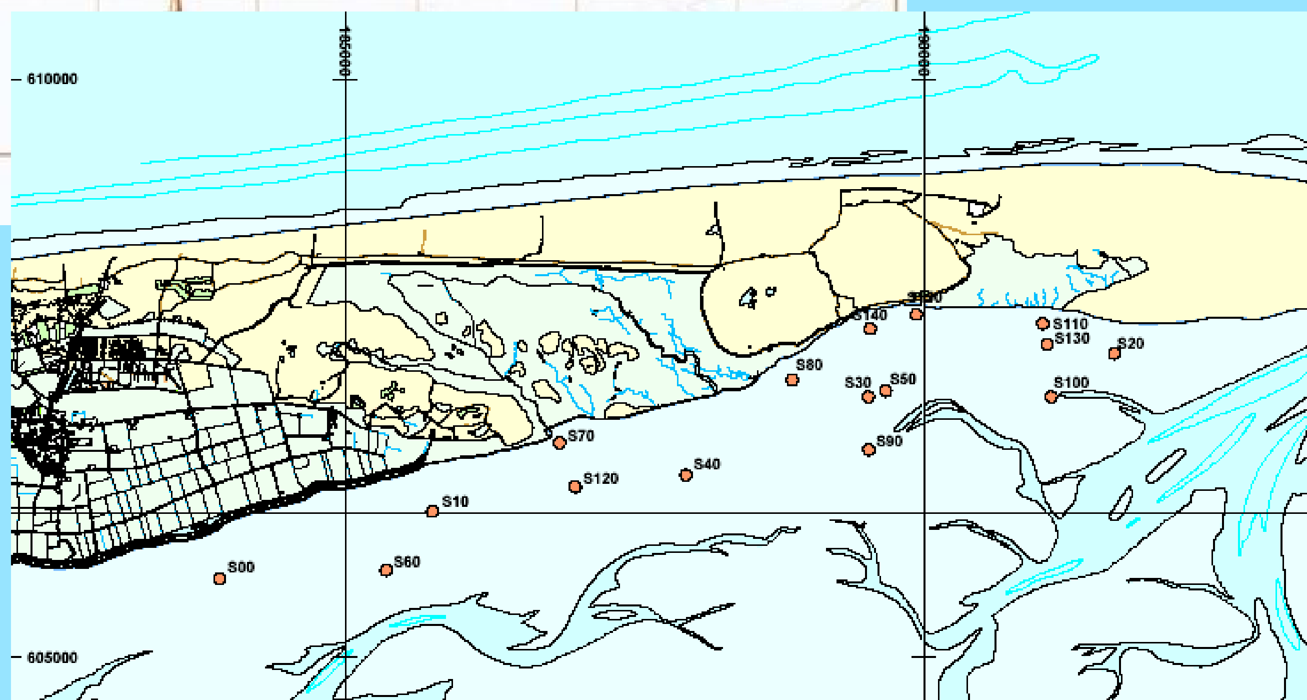
- Subsidence
- Sea level, rainfall, evaporation
- Island morphology
- Beach nourishment
- Tidal flats (elevation and depth chart)
- Groundwater
- Salt marshes (grazed and non-grazed)
- Dunes (vegetation)
- Birds

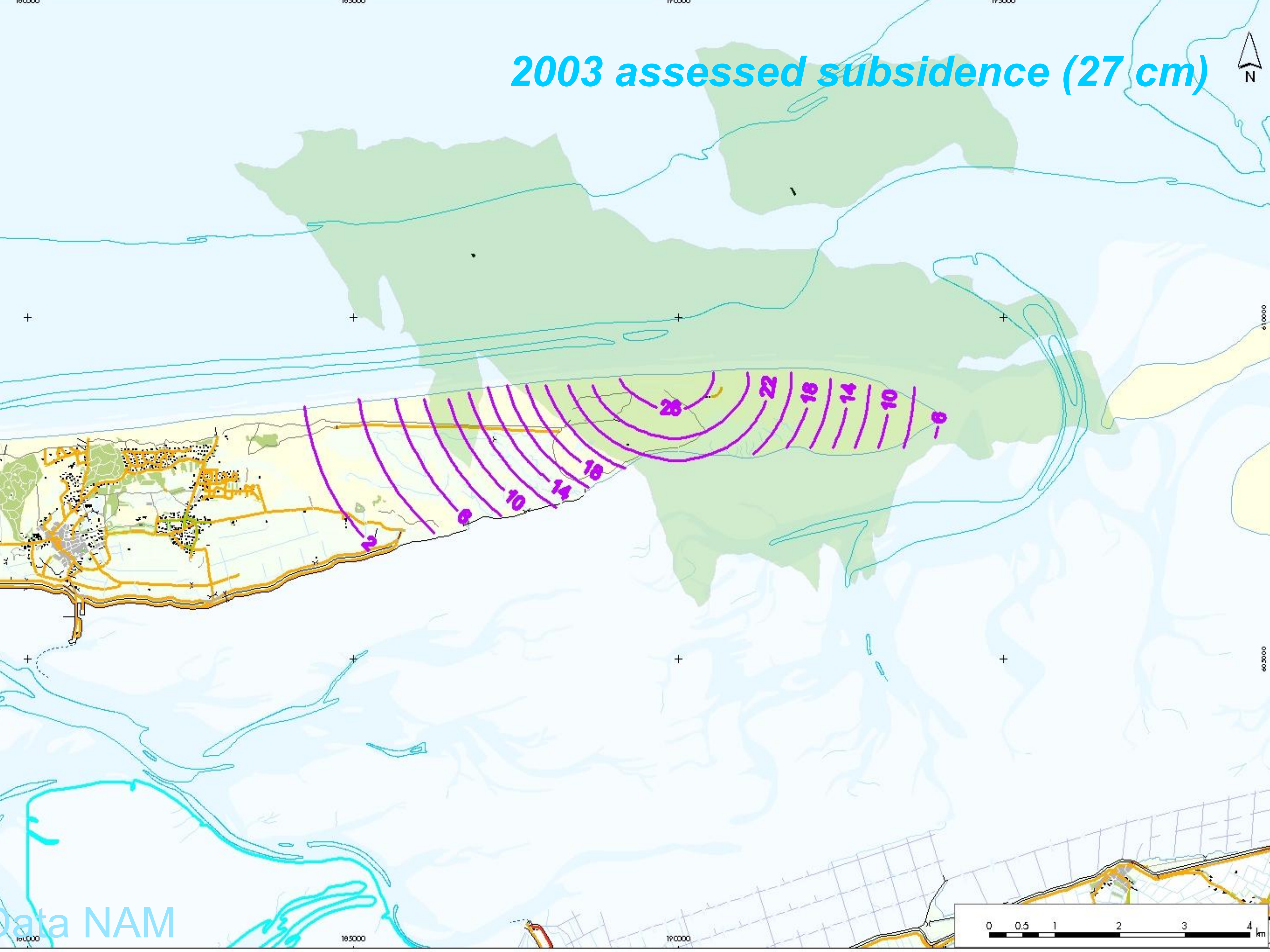
What did we change? 2000-2005

- Subsidence: lower frequency
- Tidal flats: ***NEW METHOD***, frequent erosion and sedimentation assessments
- Salt marshes: increased frequency
- Lower dune valleys: ***NEW***
- Dunes: lower frequency
- Birds: assessment of feeding areas

Overview of monitoring stations






2003 assessed subsidence (27 cm)
N
2
6
10
14
18
26
22
18
14
10
6
0 0.5 1 2 3 4 km
185000
190000
Data NAM

Subsidence and sea level rise

- Additive impact for marshes and tidal flats
- In 18 years we had:
  - 27 cm subsidence in center
  - 3 cm sea level rise (on global average)
  - 20 cm year to year variation in Mean High Water
- 30 cm “subsidence + sea level rise” = 1,5 m sea level rise per century
- In 18 years we look a century ahead

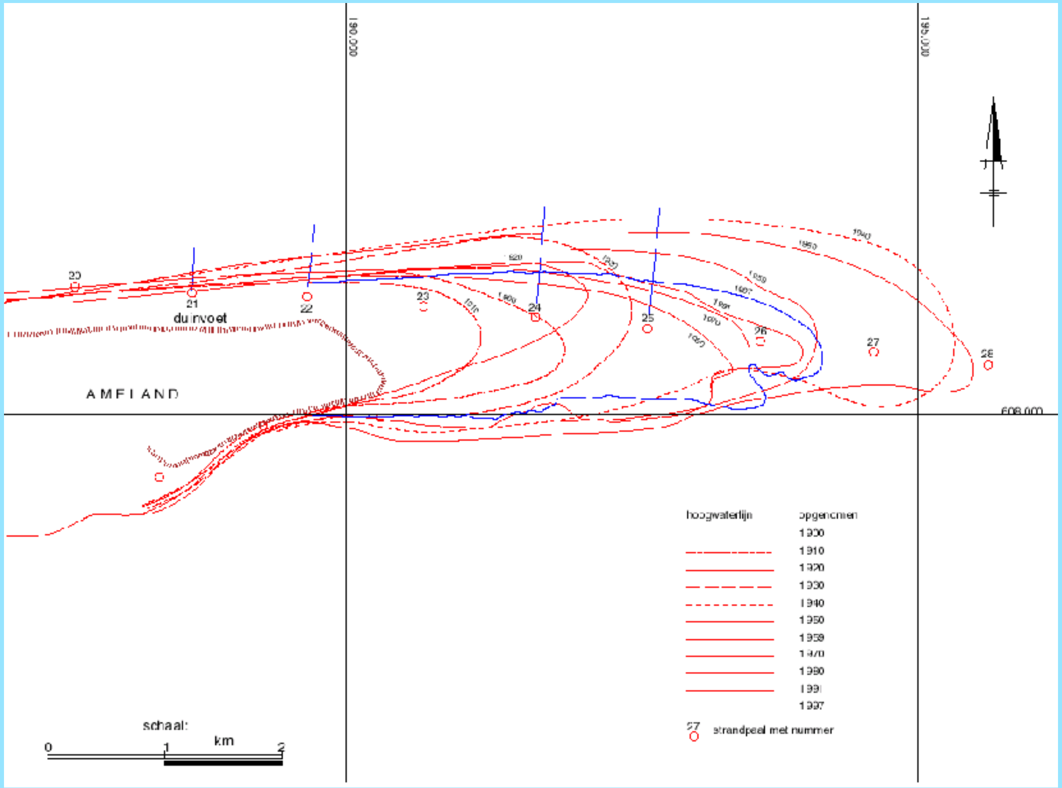

Photo Jaap de Vlas

Island morphology develops as predicted

East Cape was growing, but has reached point of erosion

Beach nourishment as predicted

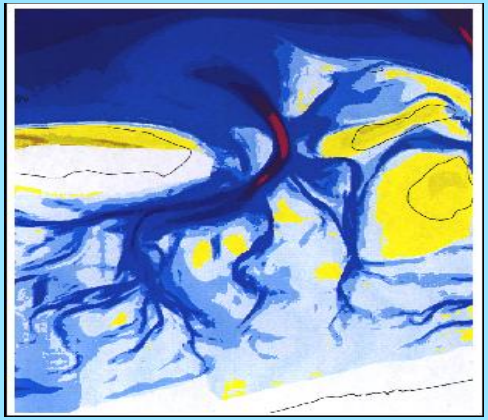
Impact of subsidence is within natural variation



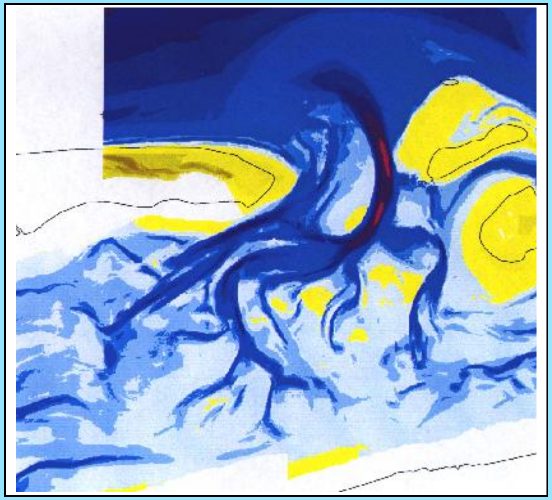
W. Eysink
WL | Delft Hydraulics

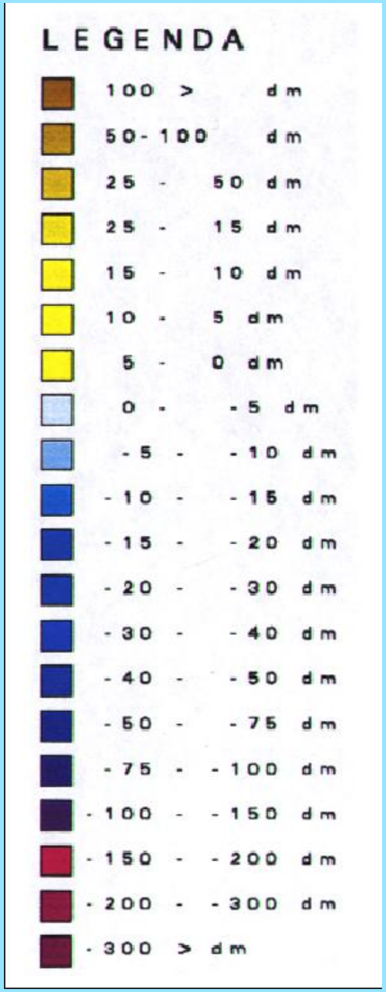
Natural development of channels around De Hon

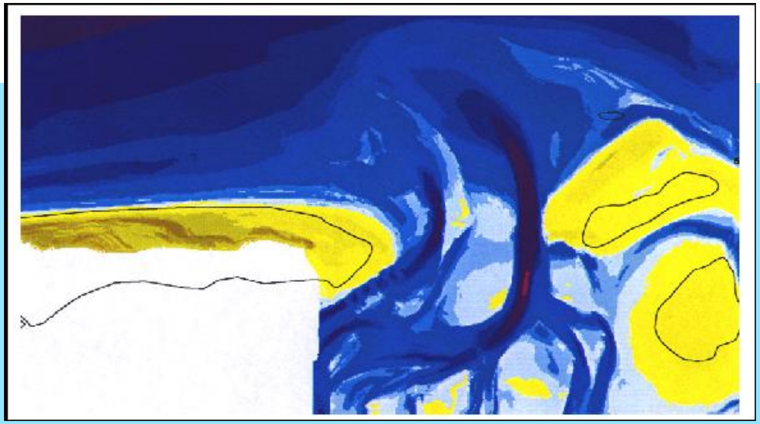
1987



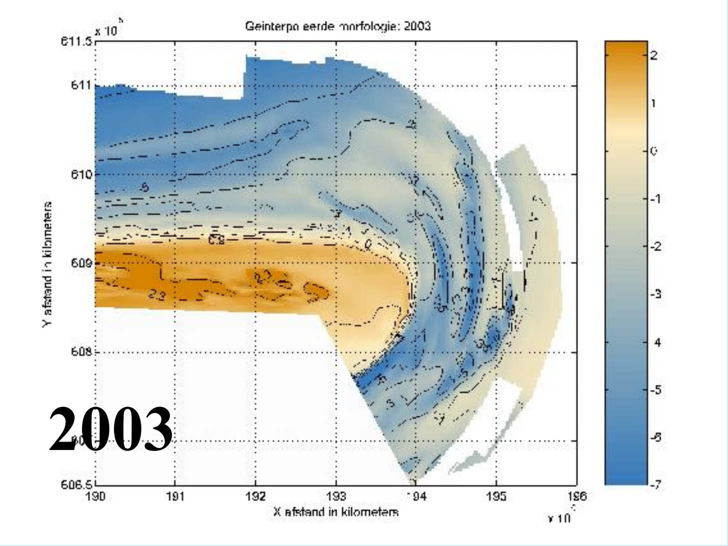
1994







1997



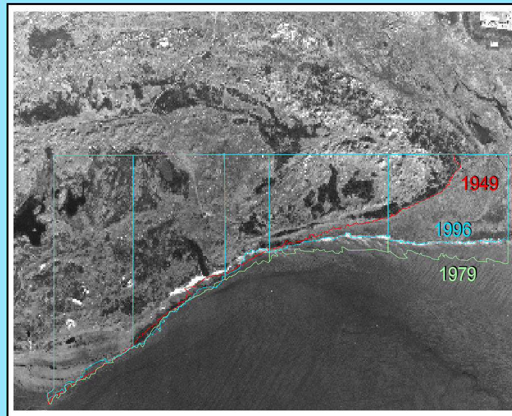
2003

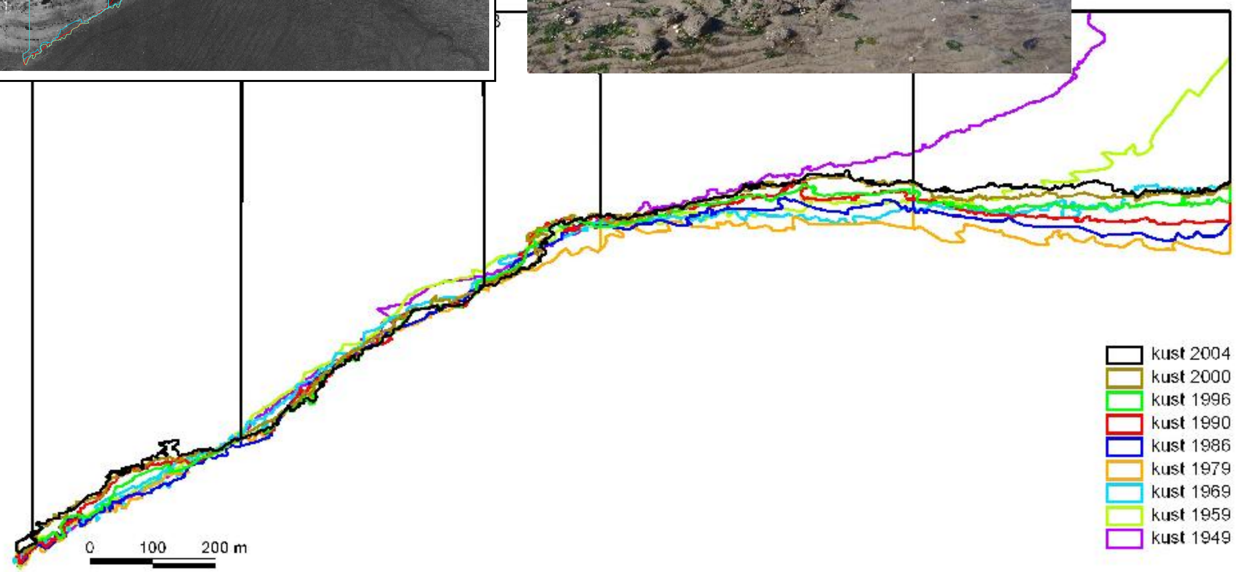
Data RWS
WL | Delft Hydraulics

Aerial photo analysis of erosion: no increase attributed to subsidence

Erosion of the marsh south of Oerder dune does not seem to be influenced by subsidence,

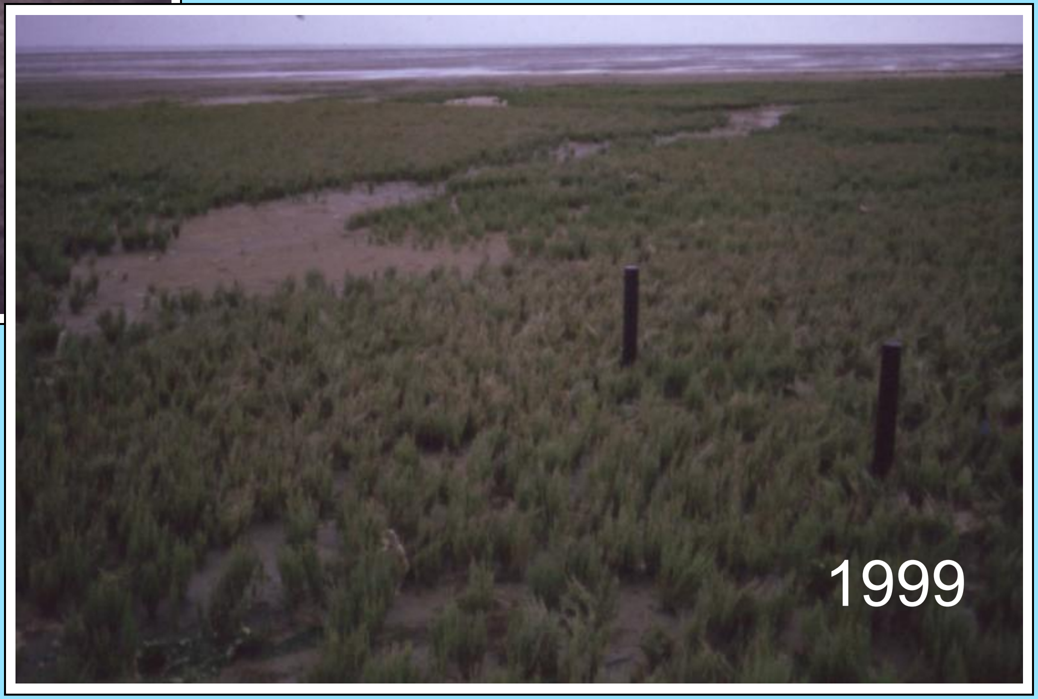
Further to the east, the marsh is growing





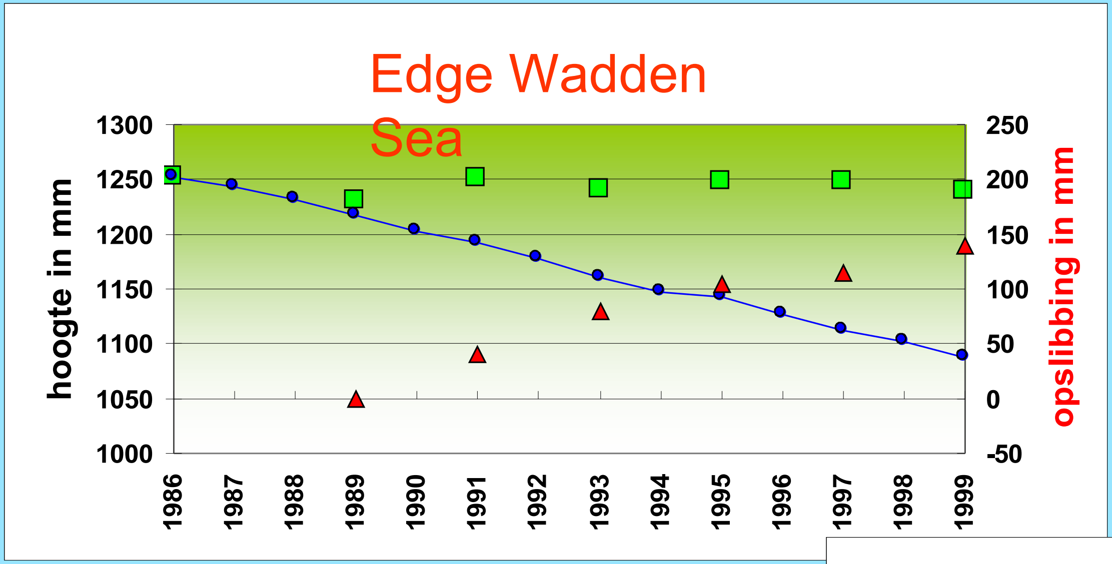
P. Slim
Alterra

Extension of the marsh vegetation, subsidence 20 cm



K. Dijkema
Alterra

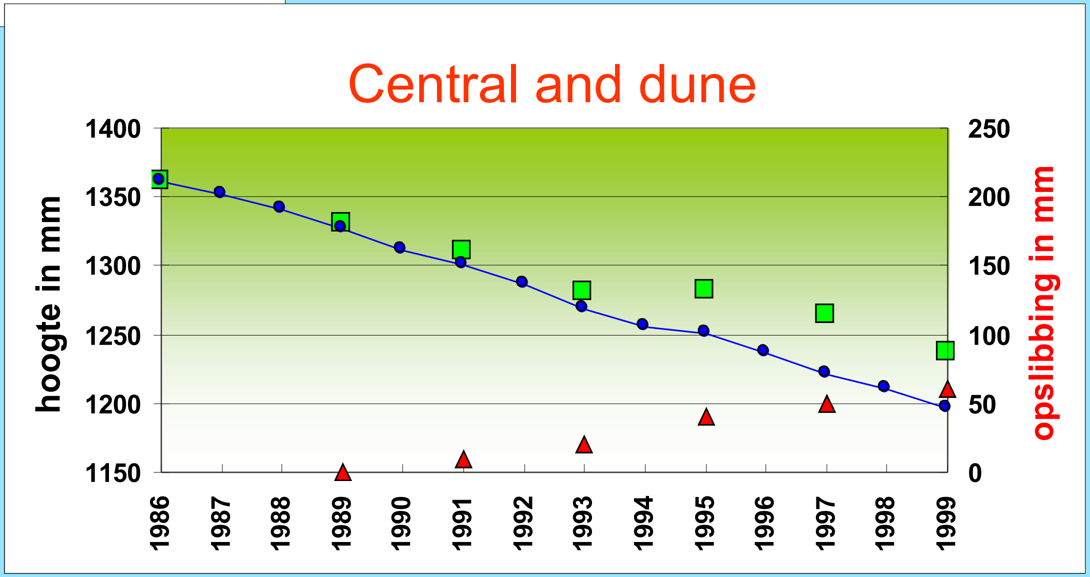
Subsidence and sedimentation De Hon



MAAIVELD PQ GEMETEN

MAAIVELD ZONDER OPS.

OPSLIBBING PAAL

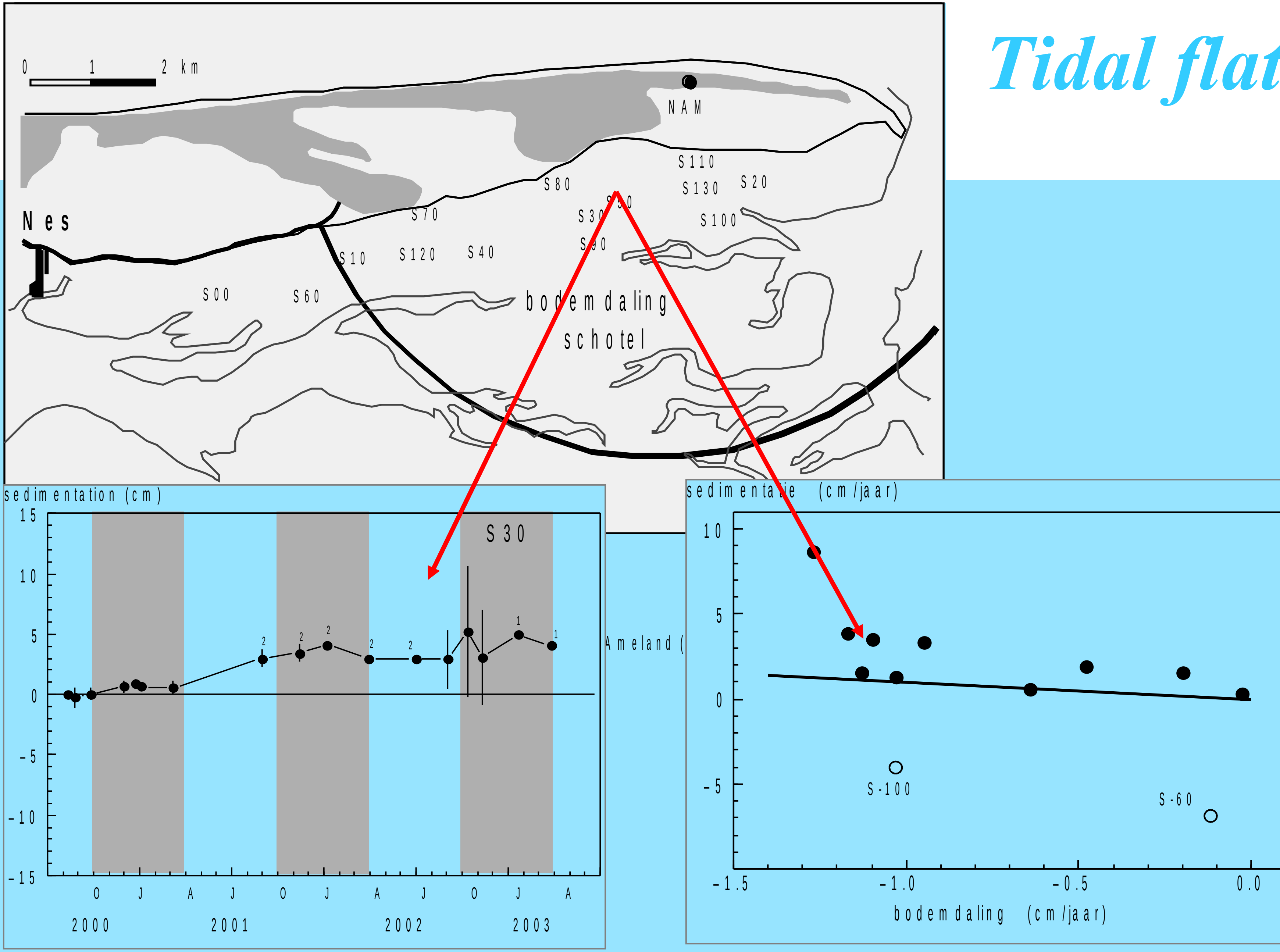


K. Dijkema
Alterra

Conclusion morphology

- Large scale processes behave in a predicted manner
  - Sea side morphology
  - Coastal nourishment
  - Marsh edge
- Sedimentation and erosion of salt marshes
  - Edge of marsh and creeks
    - Keeps up with subsidence and sea level (2 cm/yr)
    - More as expected
  - Central and higher marsh
    - As expected and lags behind (0.5 cm/yr)
- A short spurt in sea level rise may not pose a problem

Tidal flats



J. Krol and M. Kersten, Natuurcentrum Ameland

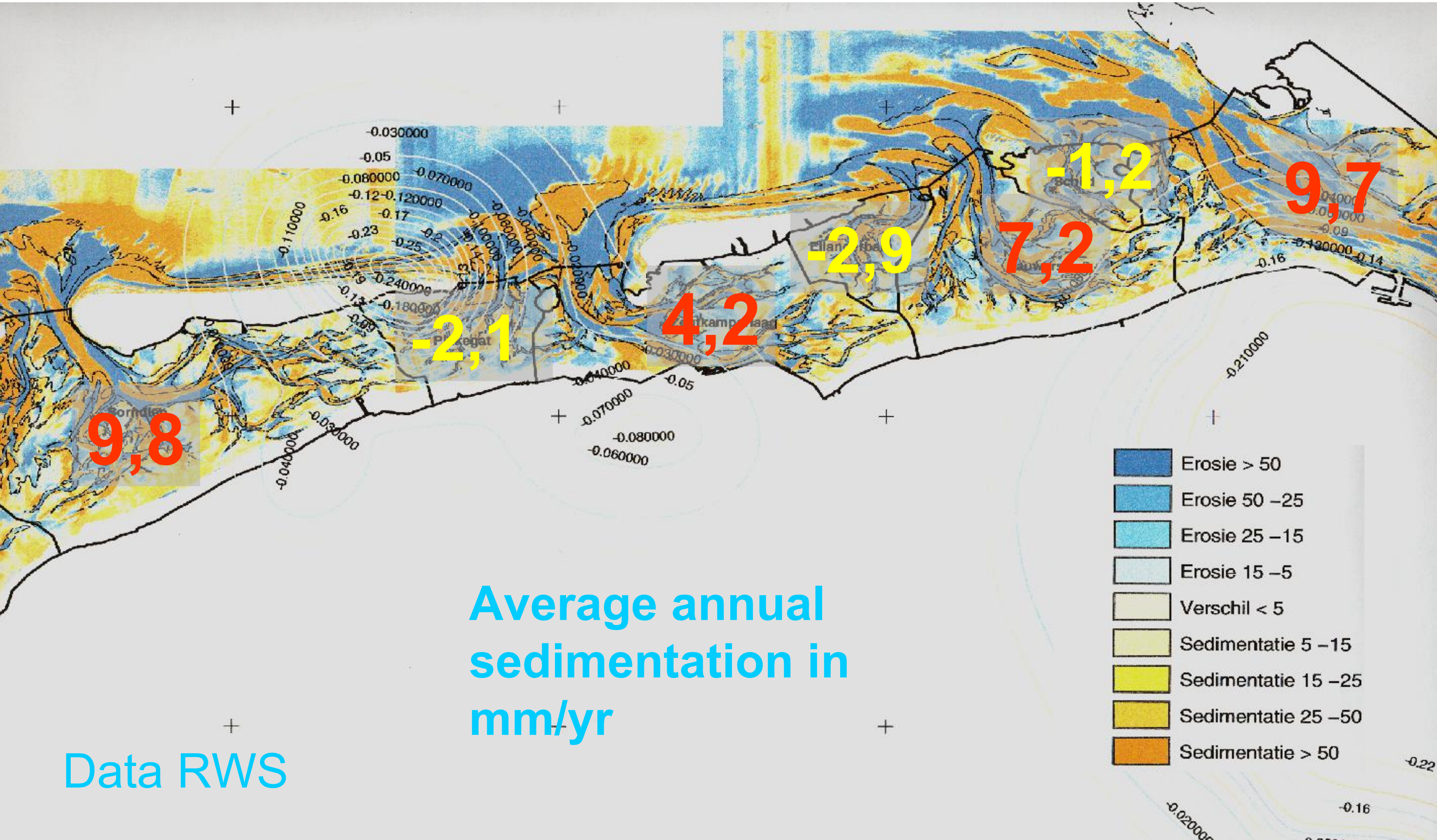
Simple and accurate

M. Kersten, Natuurcentrum

16 Stations (duplicate)

Each station 4 anchors at 0.5 m

Tidal flats: 1989-2000



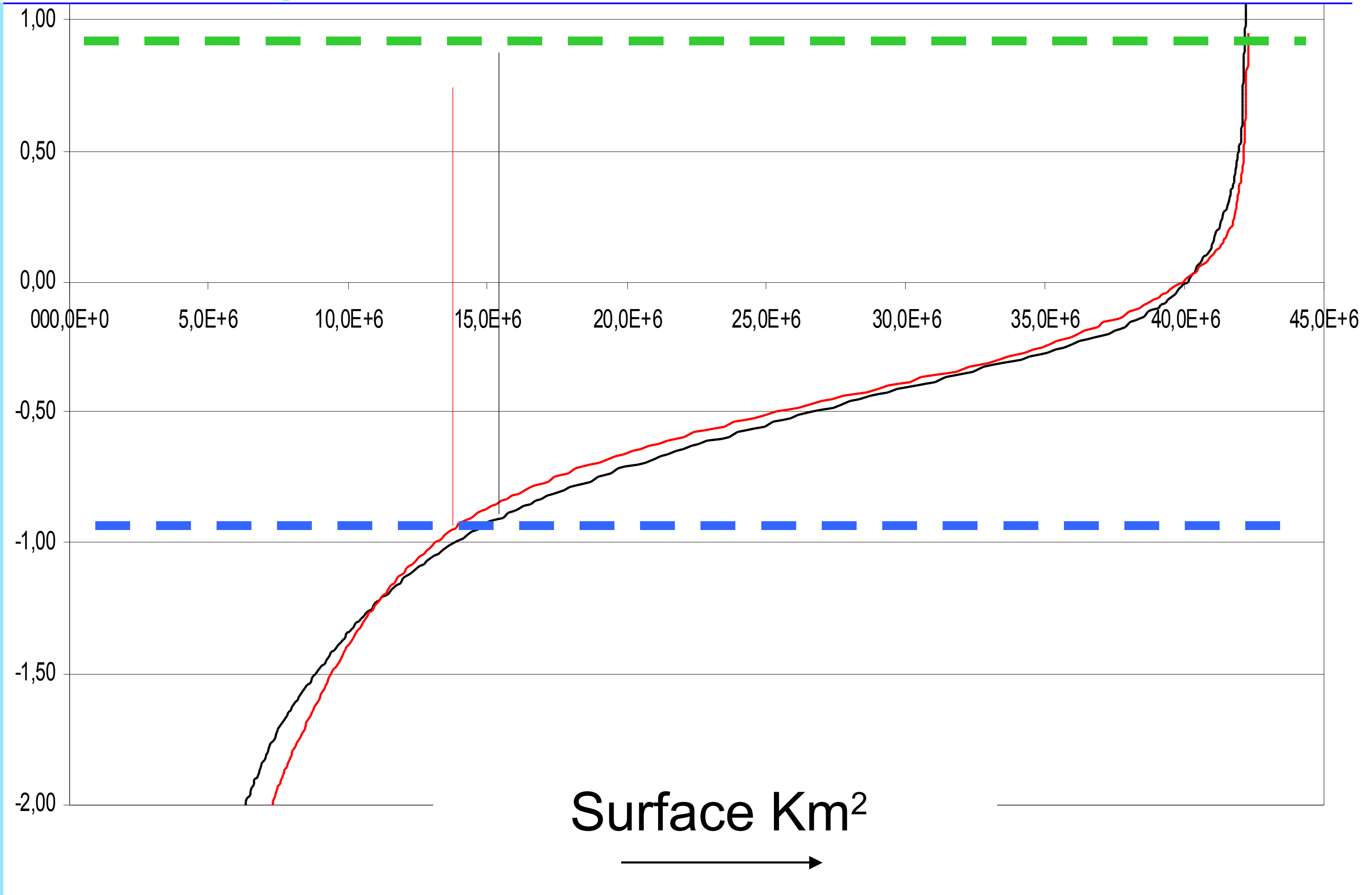
Average annual sedimentation in mm/yr

Data RWS

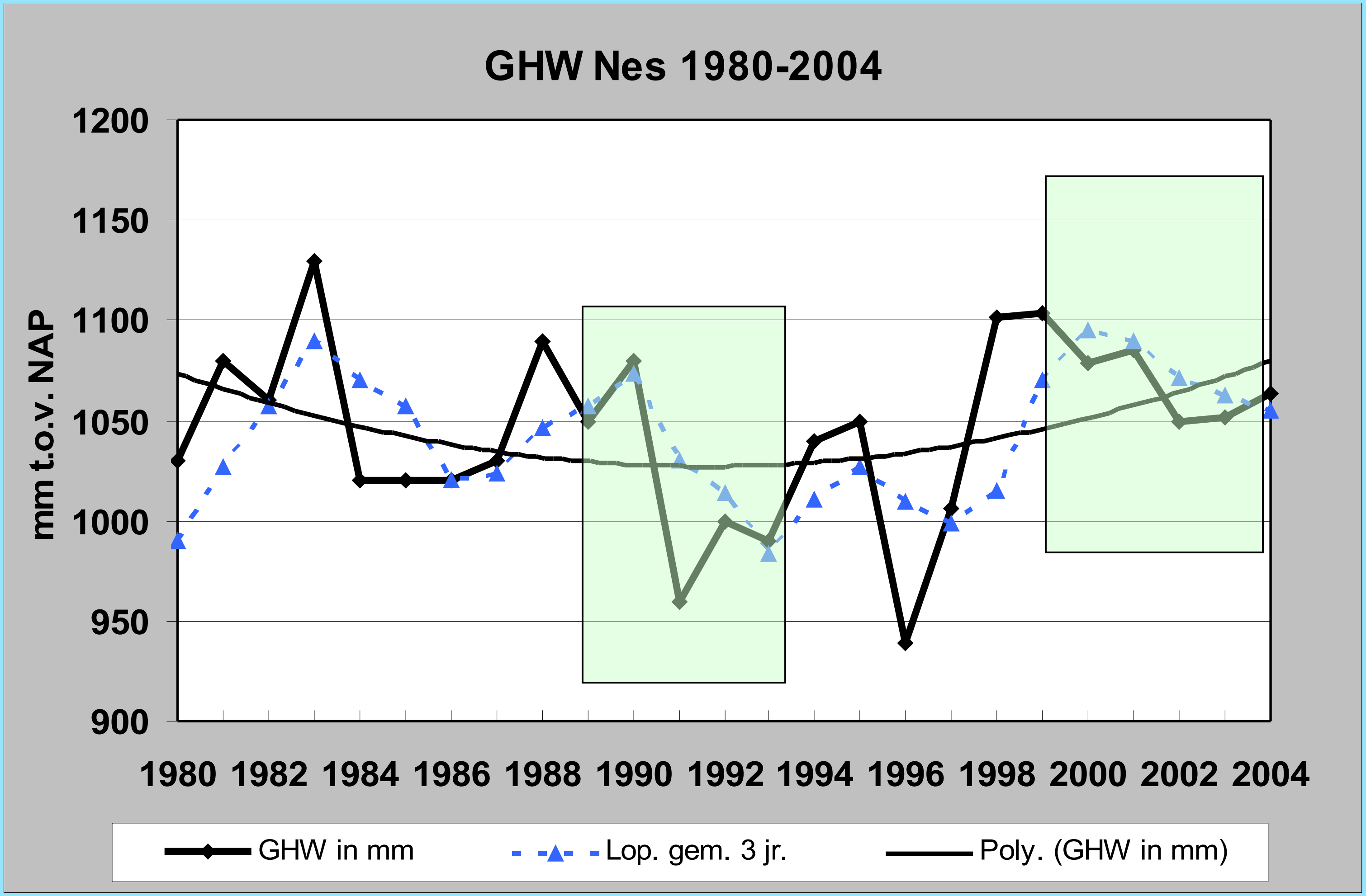
Pinkegat NW van -4 cm

Hypsometric graph

- Tidal flats increased in height with about 5 cm
- Channels got wider

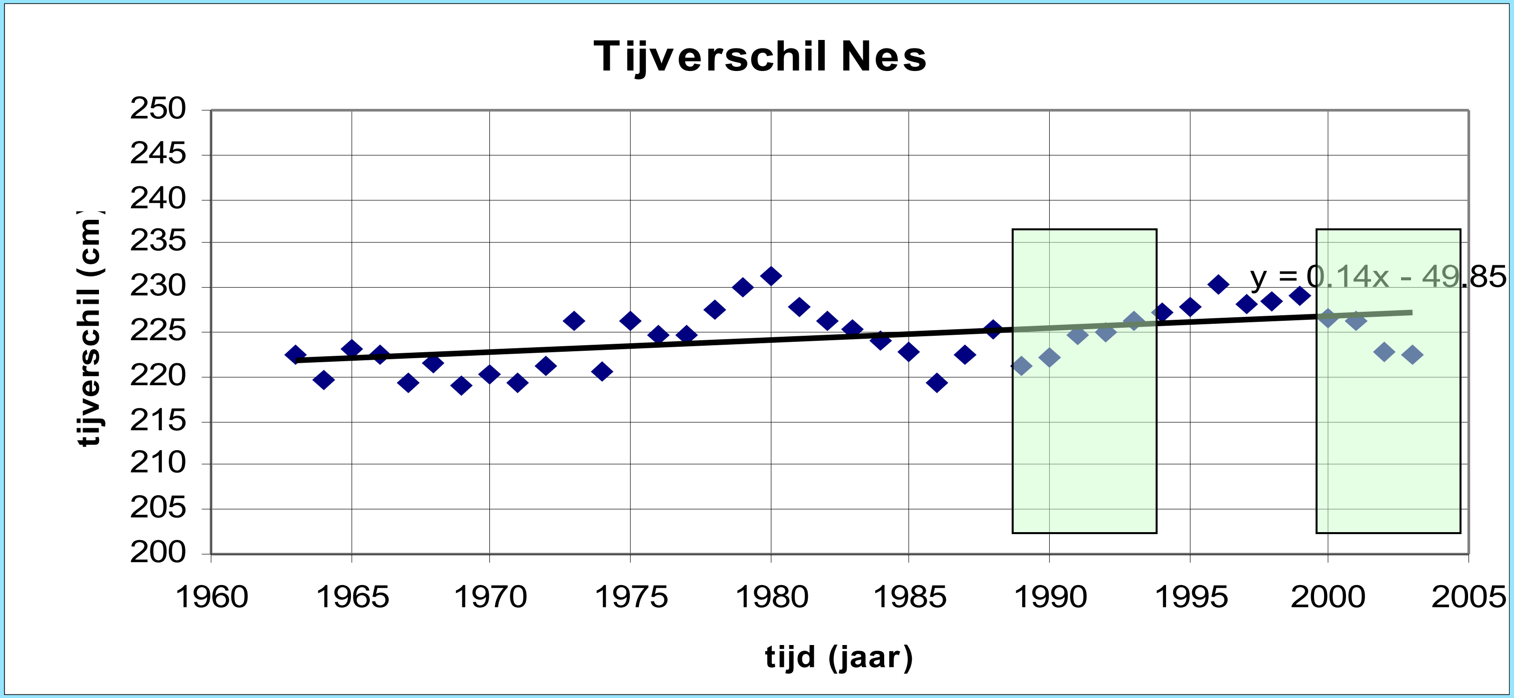


Mean High Water variations



K. Dijkema, Alterra

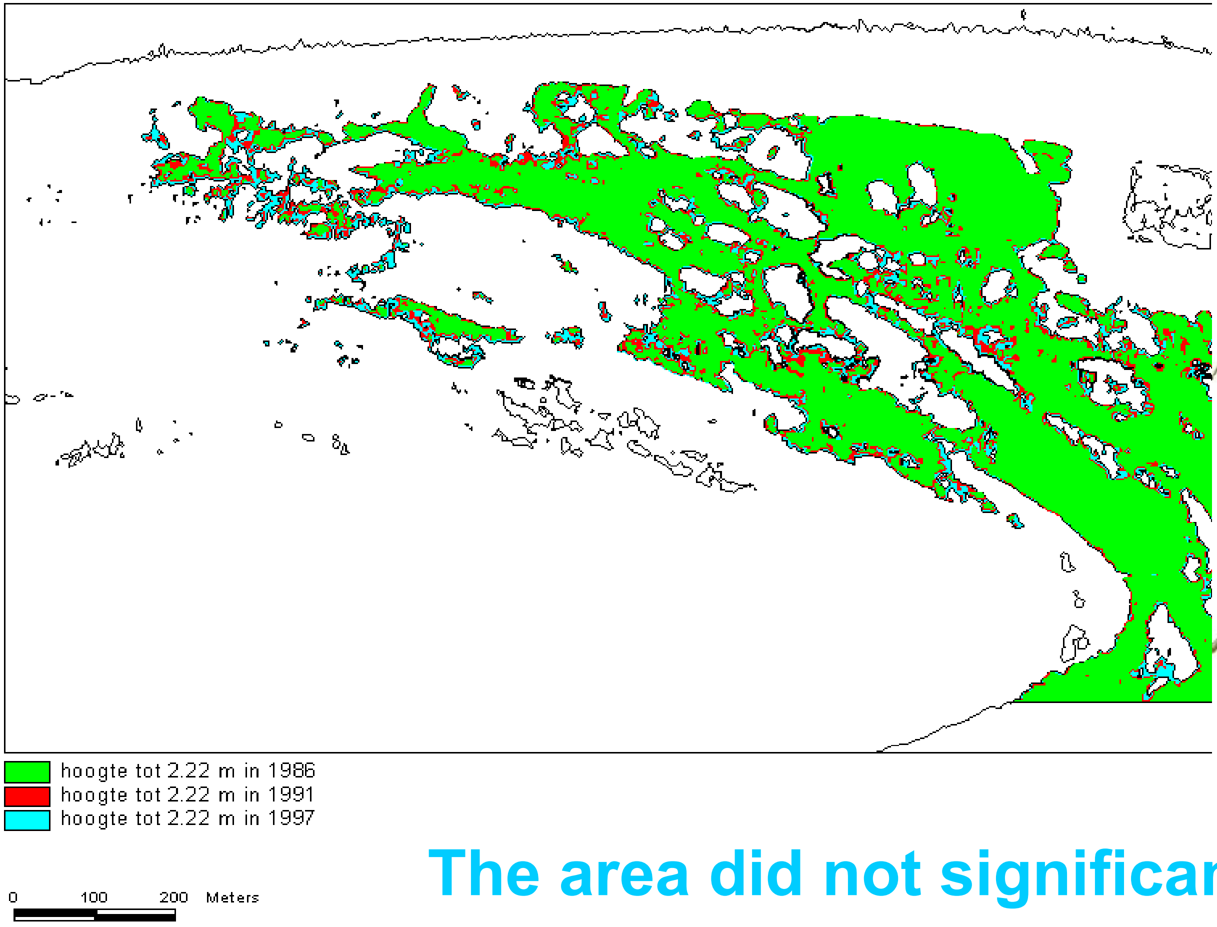
The 18-year cycle



Conclusions tidal flats

- Subsidence is locally compensated at rates up to at least 1.3 cm per year
- The mechanism seems a rapid exchange between flats and channels
- The variation in Mean High Water levels may play a dominant role
- Longer and more time-series of the erosion and sedimentation measurements are needed in relation to tidal variation

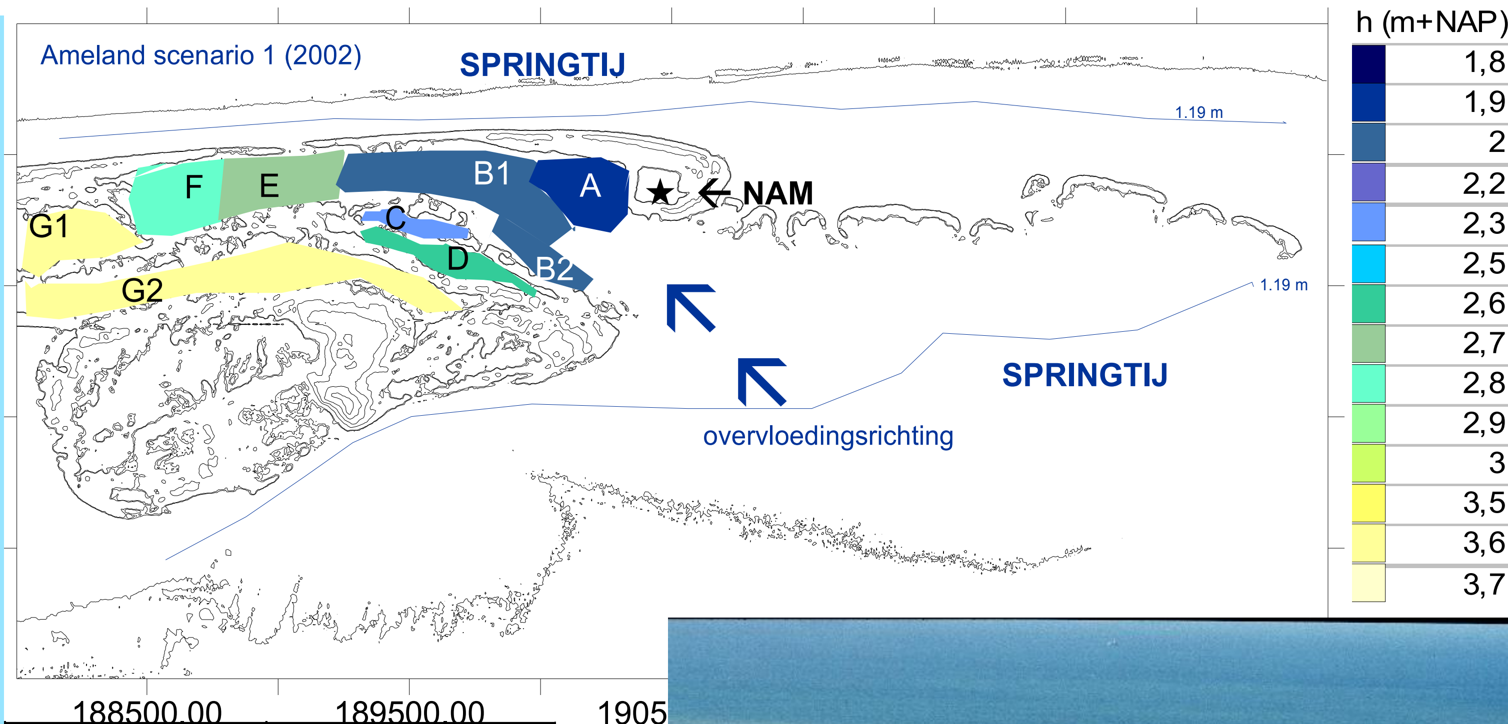
Sea buckthorn mortality after flooding Ameland-Oost 1994



The area did not significantly increase

D. Schouten, UU

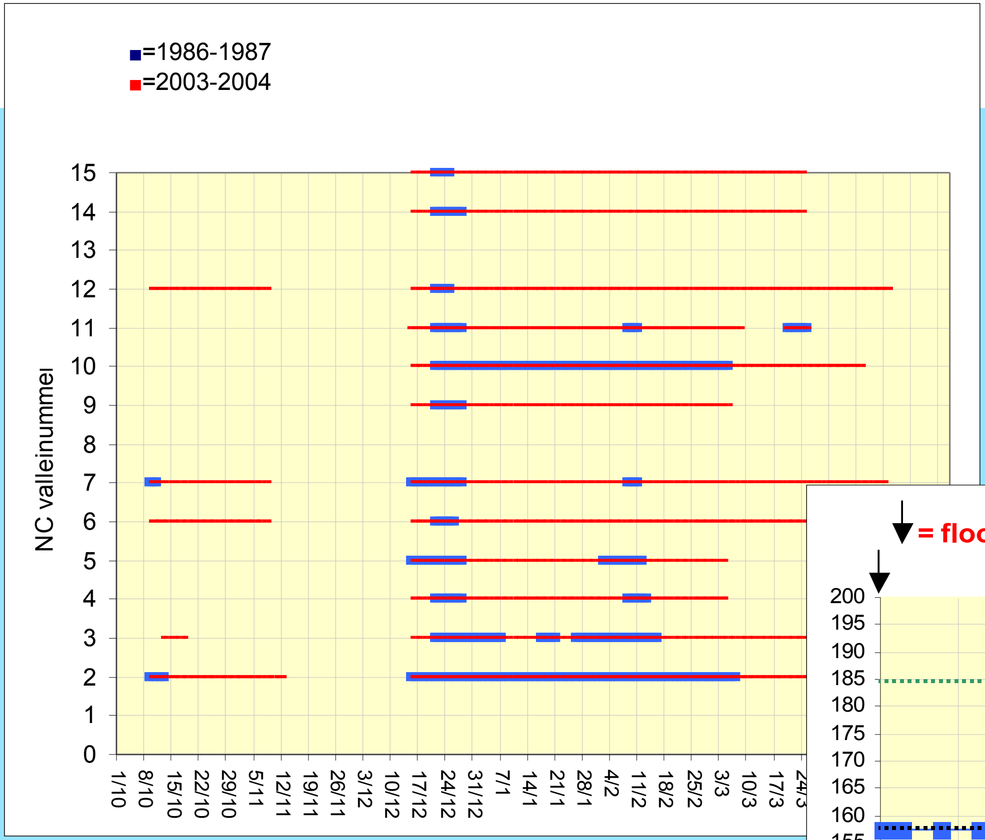
Flooding frequency was calculated to increase significantly
- *more flooding events*
- *more sedimentation*

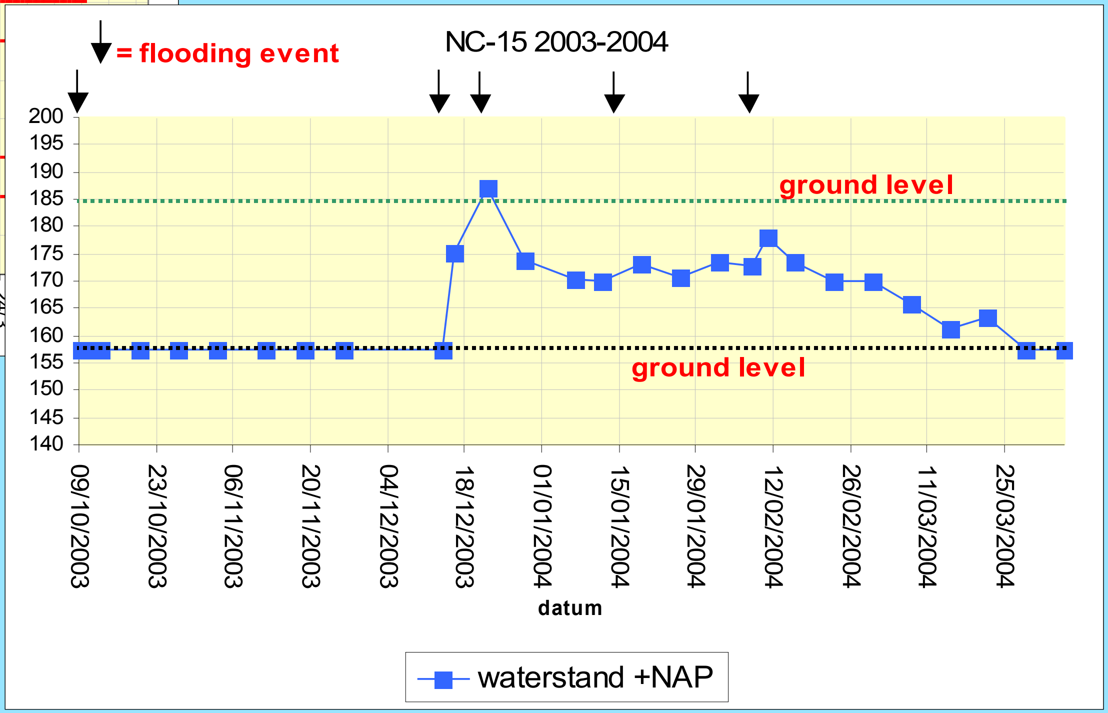


vallei	f (1987)	f (2002)	f (2007)
A	4	13	20
B	3	9	14
C	2	3	5
D	0,5	1	2
E	0,3	1	1
F	0,2	0,5	1
G	0,02	0,03	0,05

D. Schouten, UU

Inundation increased from days to months





J. Krol, Natuurcentrum

Conclusion lower dune valleys

- Not in original program, lessons from doing and observing
- Relative groundwater table is main driving force for change
  - Flooding frequency adds to it to a lesser extend
  - No significant change in surface area
- Vegetation is expected to change
- Monitoring will continue

Dunes and birds

- Dunes (see contribution Han van Dobben)
  - Natural succession
  - Eutrophication
- Birds
  - Increase of species that associate with sandy flats
  - Decrease of species that prefer silt conditions and mussel beds
- Changes are not related to subsidence

What to monitor in relation to sea level rise?

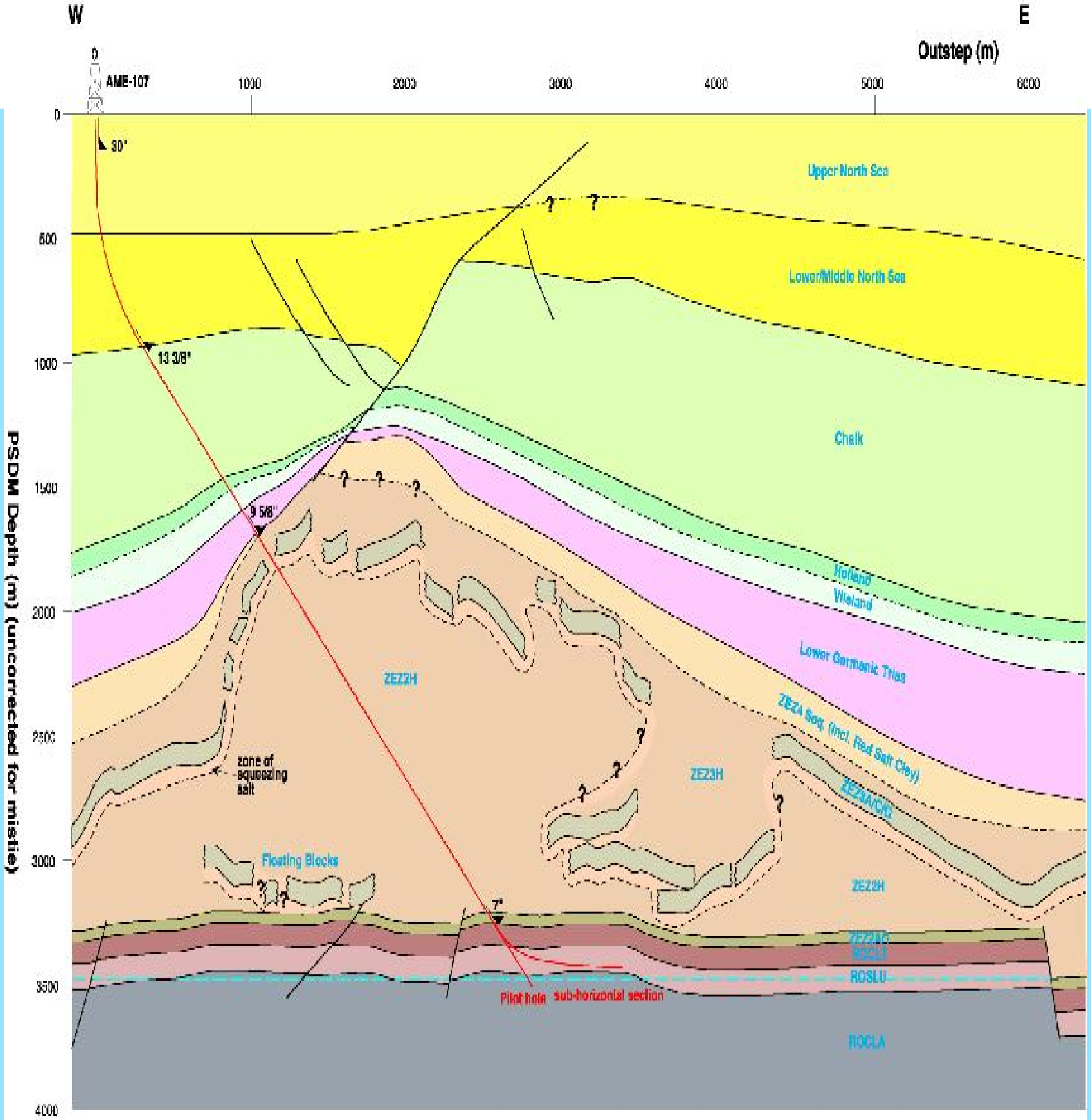
Conclusions after 18 years: learning from doing

- The erosion – sedimentation measurements on the tidal flats, gave interesting clues for underlying processes. Longer time-series are needed.
- The whole ecosystem seems extremely resilient to subsidence and therefore sea level rise
- Changes can be expected to be measurable in the lower dune valleys
- These valleys are not part of any structural program at this time, related to sea level rise and should be considered as candidates

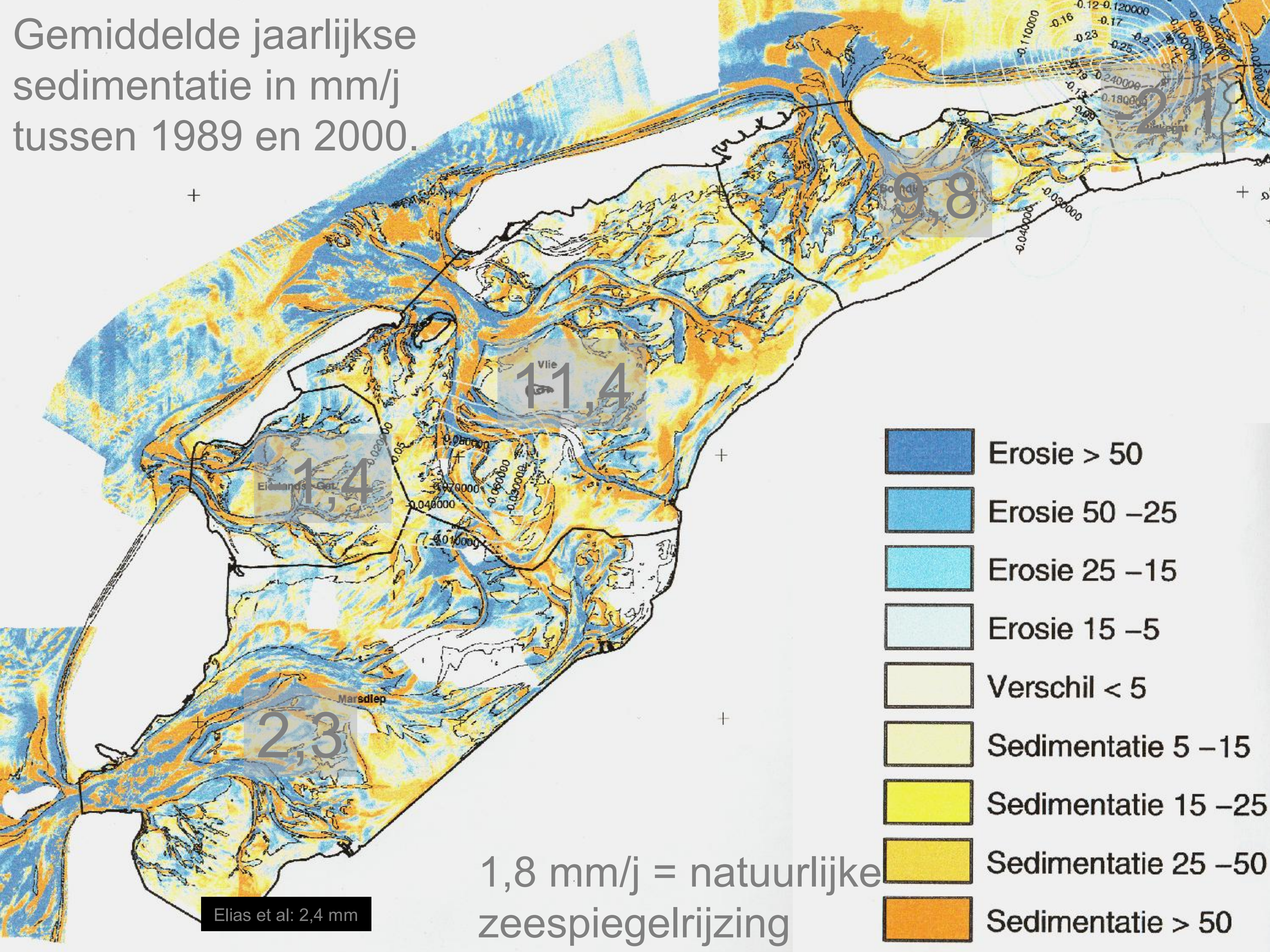
Wash-over east of locationon Ameland-Oost

Subsidence prognoses hampered by salt

Salt rock (Zechstein) is a complexing factor in the prediction of subsidence behaviour



Gemiddelde jaarlijkse sedimentatie in mm/j tussen 1989 en 2000.



Elias et al: 2,4 mm

1,8 mm/j = natuurlijke zeespiegelrijzing