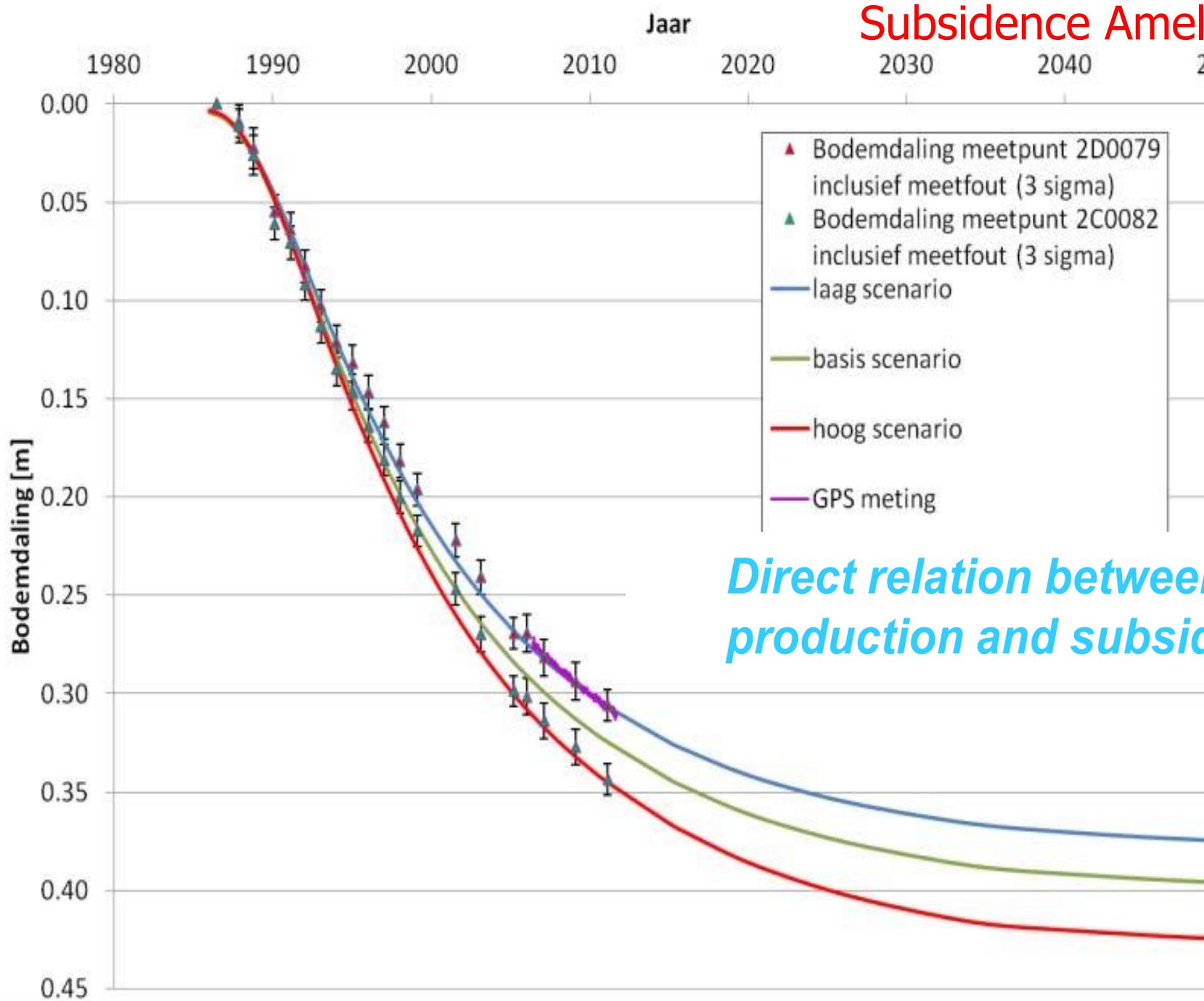


Subsidence Ameland



What is subsidence and how to manage?

Subsidence Ameland

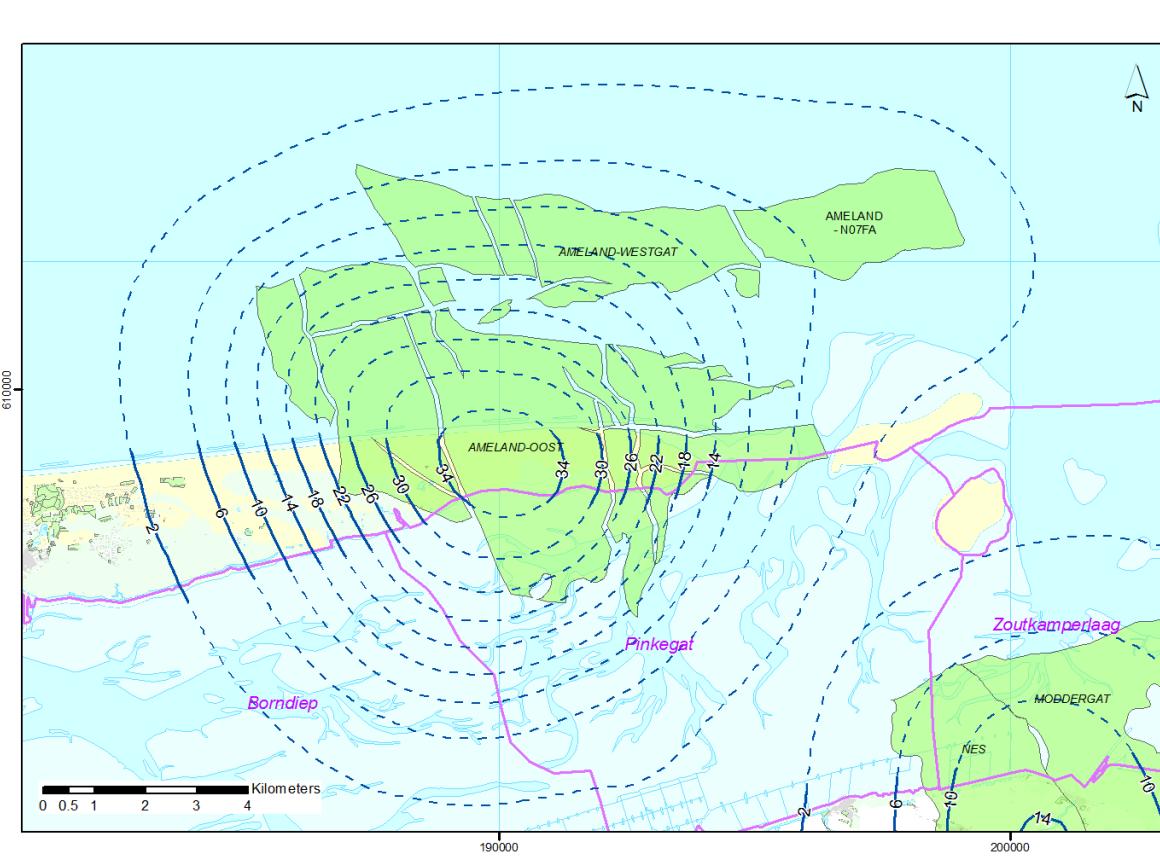


History of monitoring on Ameland

- 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
- 2011, 2017 reports
- 2022-2035 End production

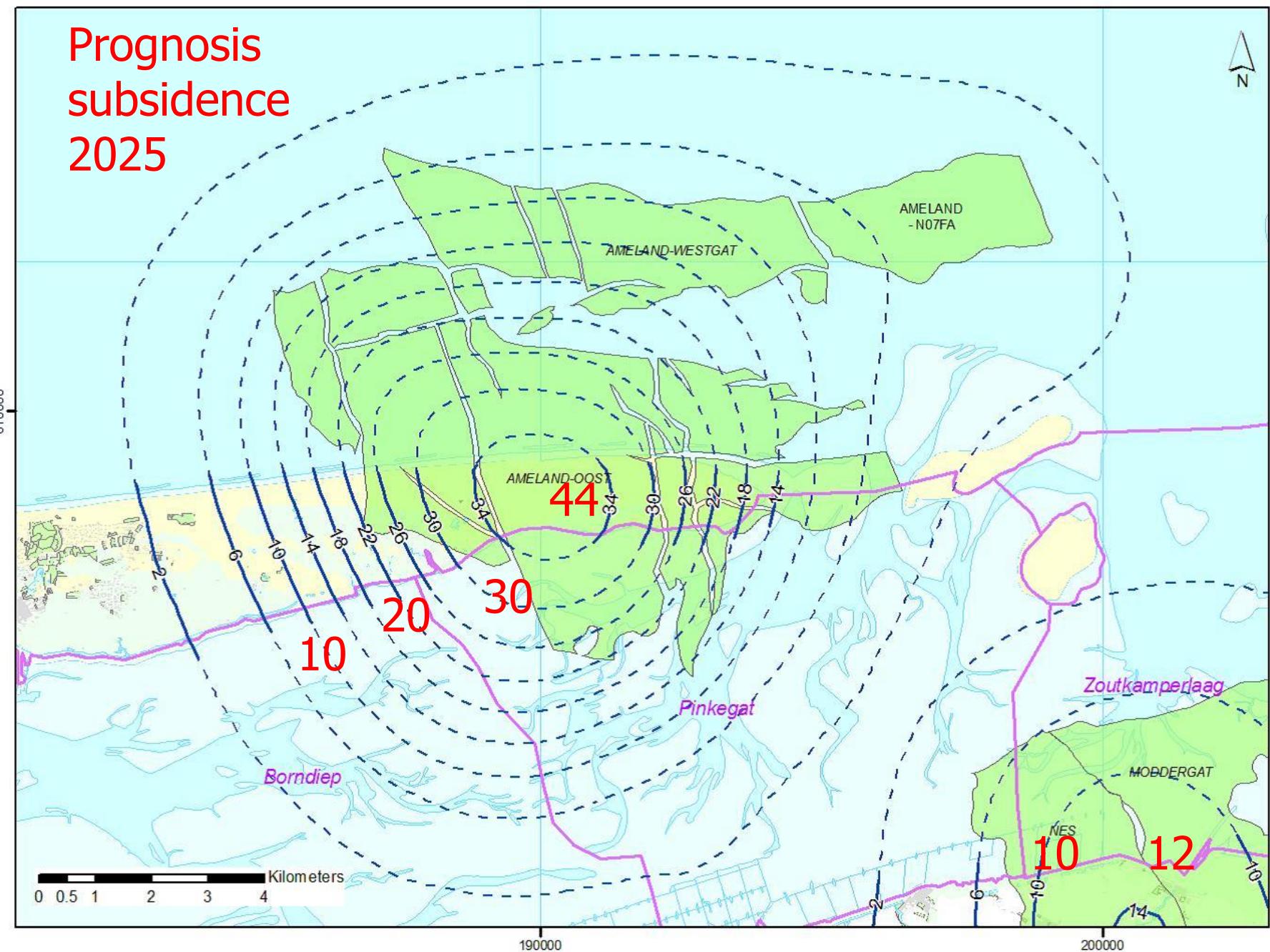
Monitoring based on subsidence prognose for 2020

- Prediction 1985:
 - center: 20-34 cm
 - content: $24 \times 10^6 \text{ m}^3$
 - diameter: 20 km
- Prediction 2003:
 - center: 31-37 cm
 - content: $22 \times 10^6 \text{ m}^3$
 - diameter: 15 km



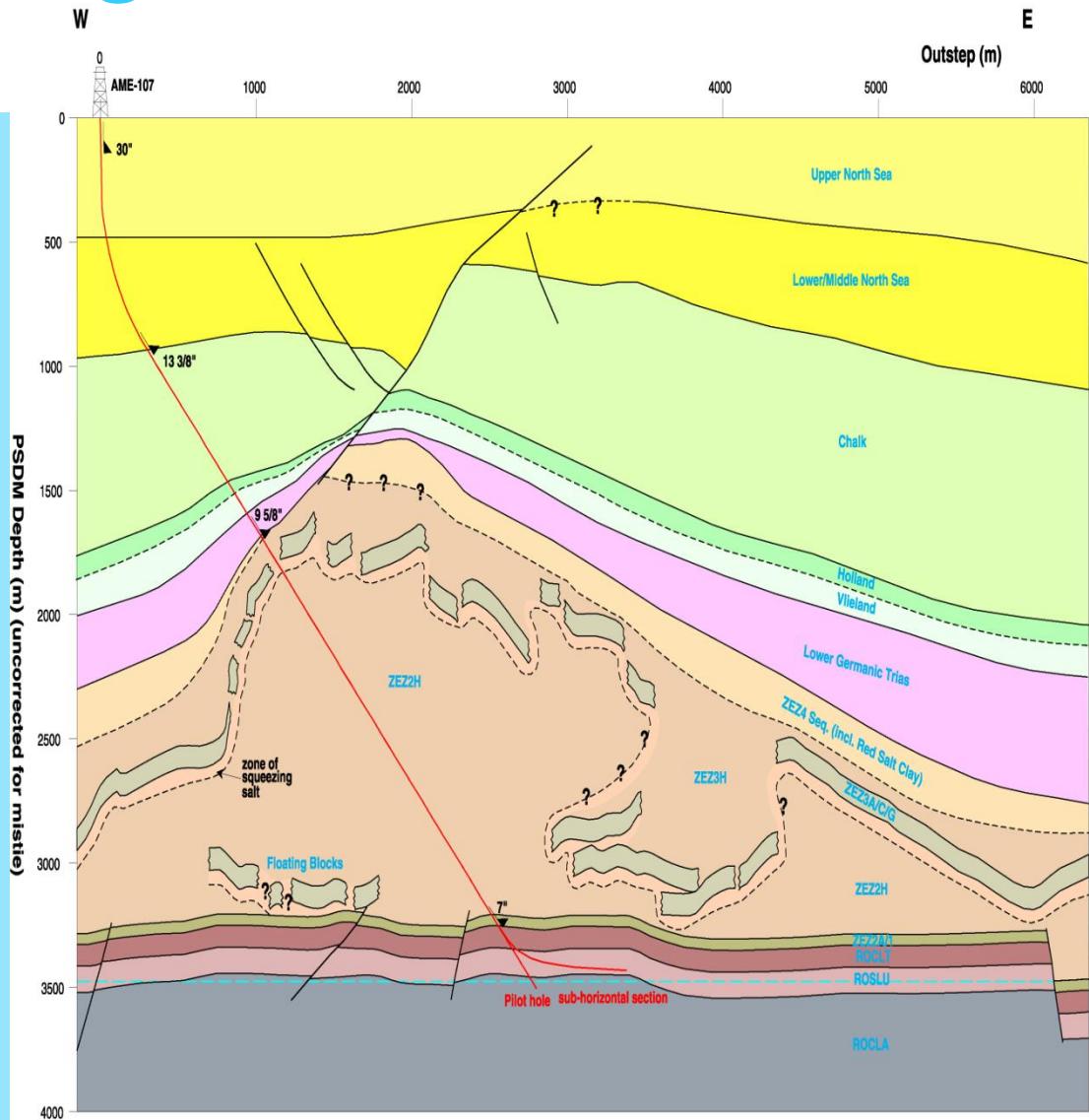
Prediction 2025

Prognosis subsidence 2025



Subsidence prognoses

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



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 till 2020)
- Public evaluation every 5 years (last 2011)

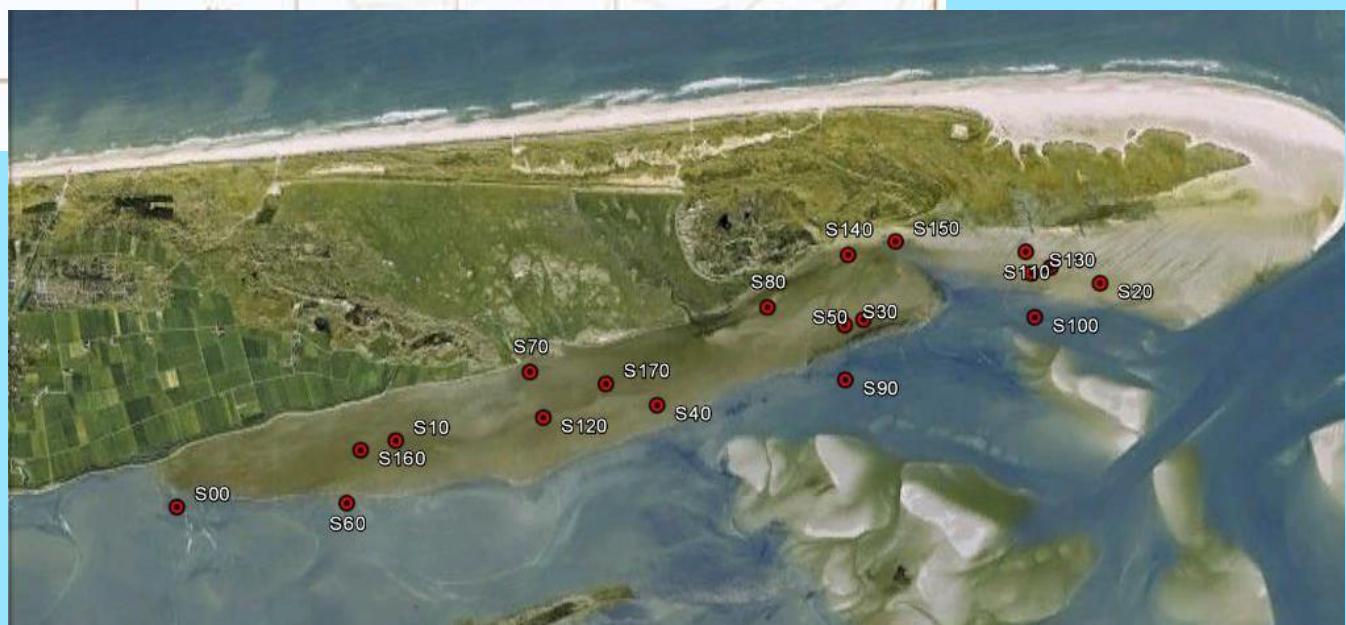
What did we monitor?

- 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

Overview of monitoring stations



Transects Points Area's



Subsidence and sea level rise

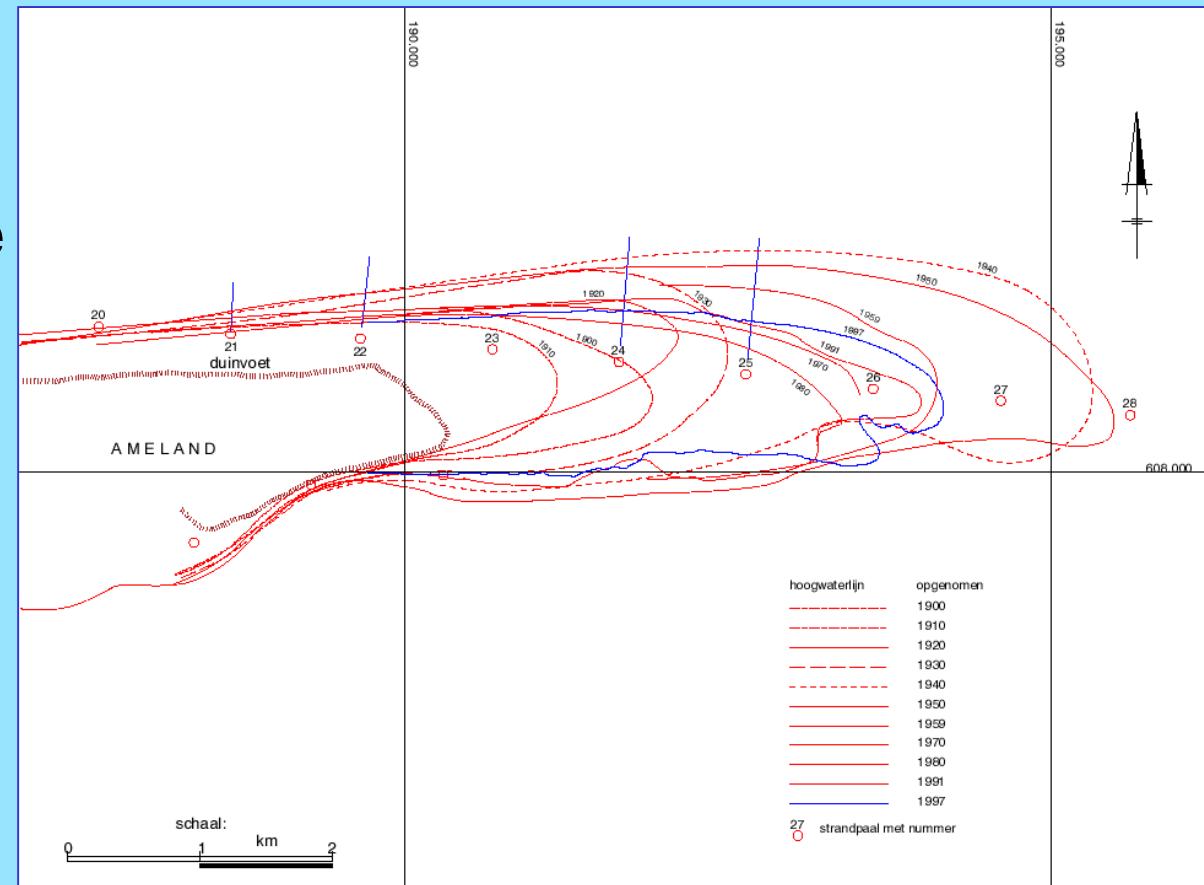
- Additive impact for marshes and tidal flats
- In 30 years we had:
 - 35 cm subsidence in center
 - 6 cm sea level rise (on global average but here?)
 - Max 15 cm year to year variation in Mean High Water
- 35 cm “subsidence + sea level rise” = locally 1,4 m sea level rise per century
- In 30 years we look a century ahead in worst case climate scenario

Island morphology develops as predicted

East Cape was growing, but has reached point of erosion

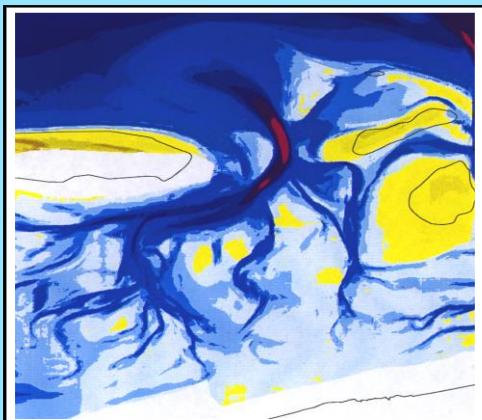
Beach nourishment
as predicted

Impact of subsidence
is within natural
variation

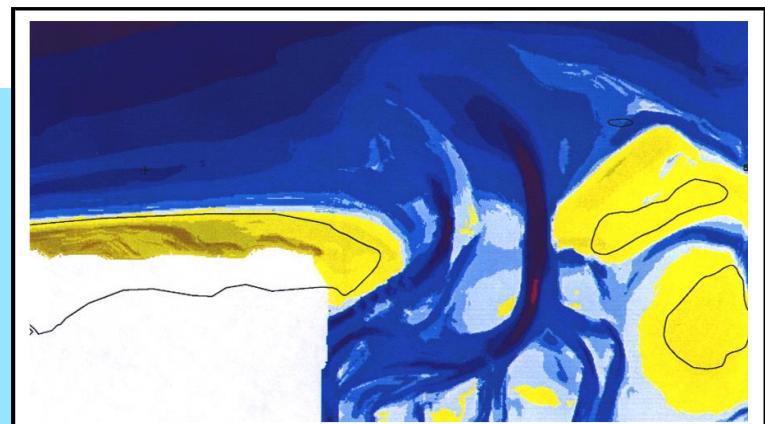
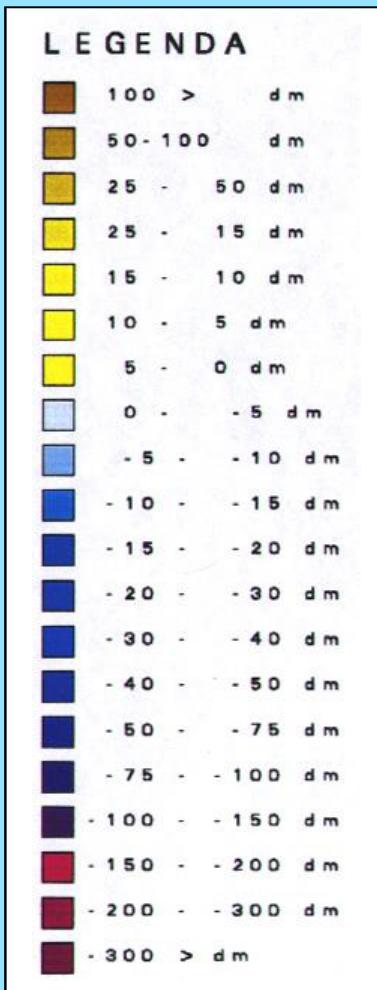
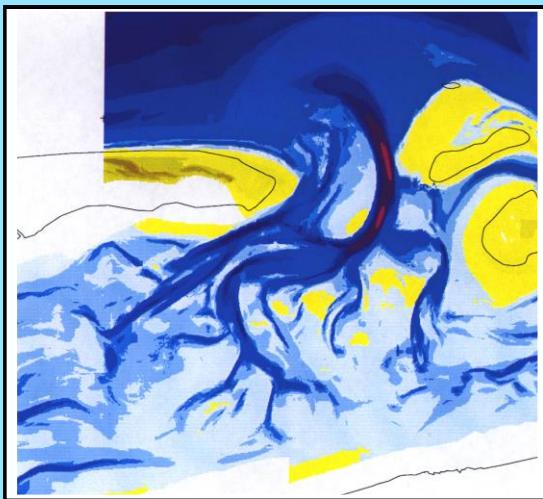


Natural development of channels around De Hon

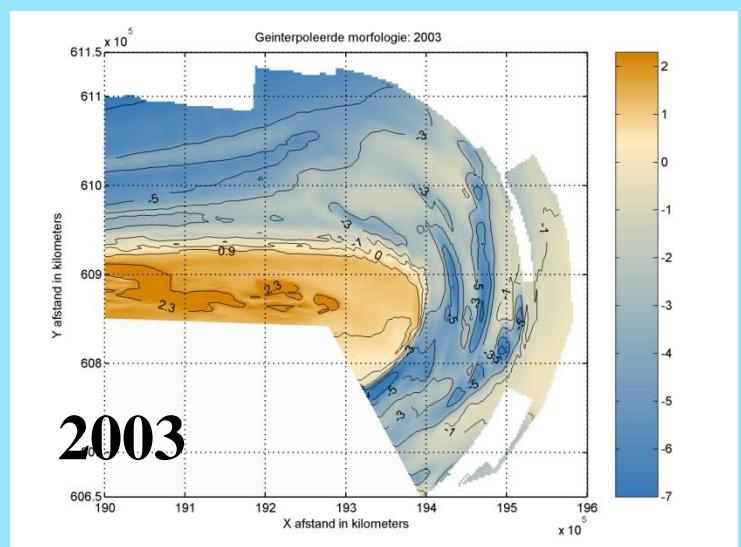
1987



1994



1997

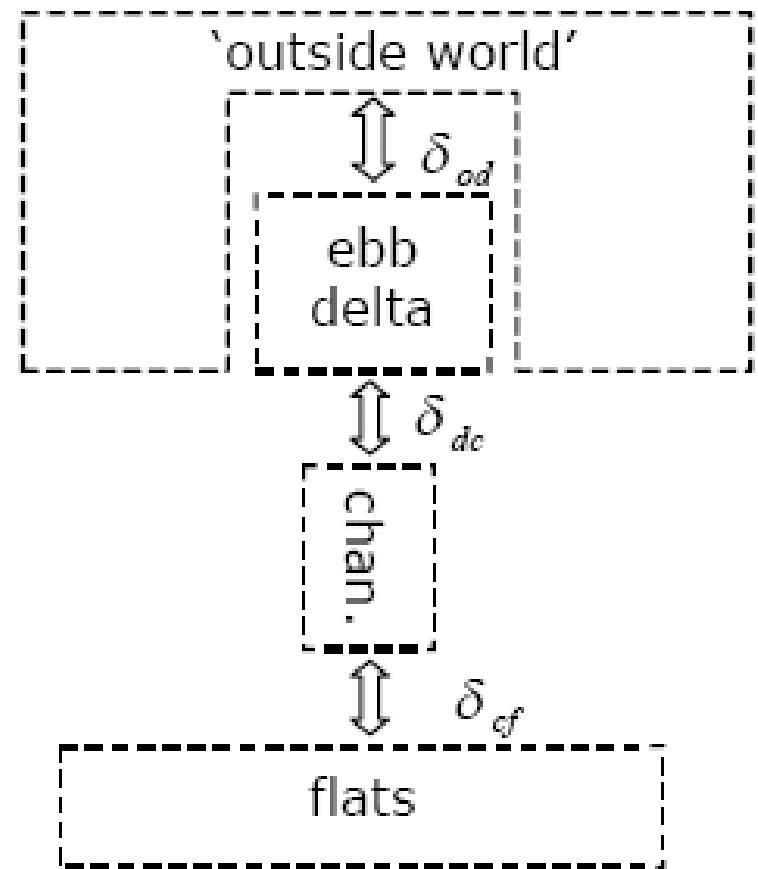
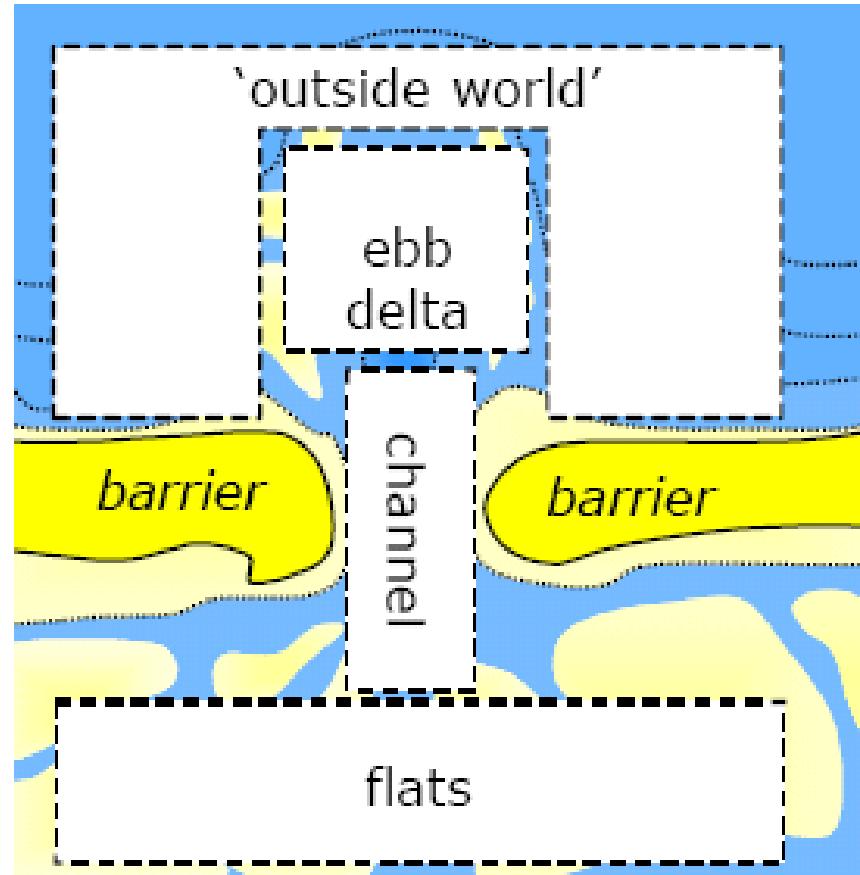


Data RWS
WL | Delft Hydraulics

Outerdelta is eroding



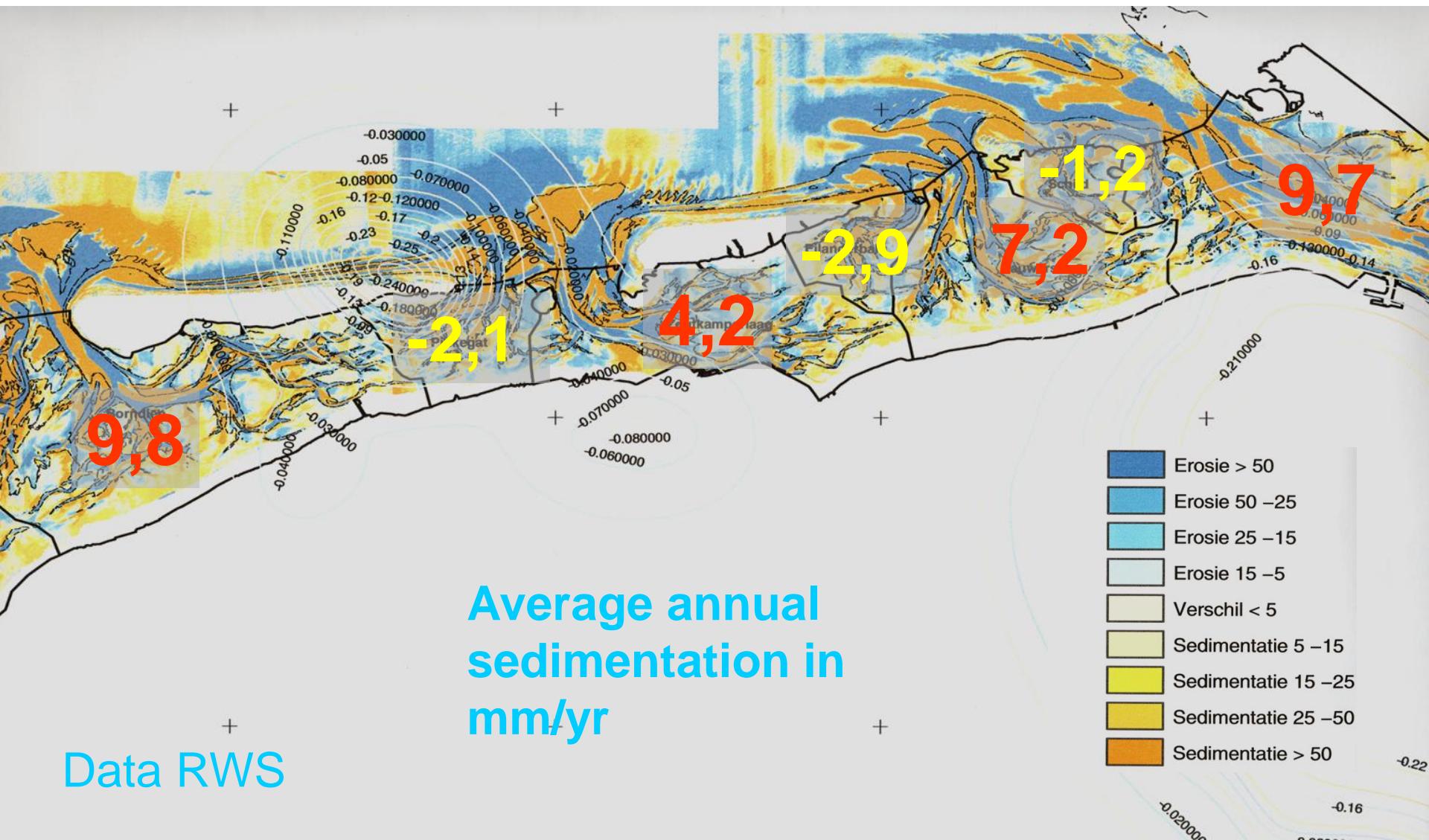
ASMITA



Aggregated Scale Morphological Interaction between Tidal system and Adjacent coast

Tidal flats: 1989-2000

More detail needed close to Ameland



Simple and accurate Mudflat sedimentation

J. Krol, Natuurcentrum

Each station
4
underground
anchors







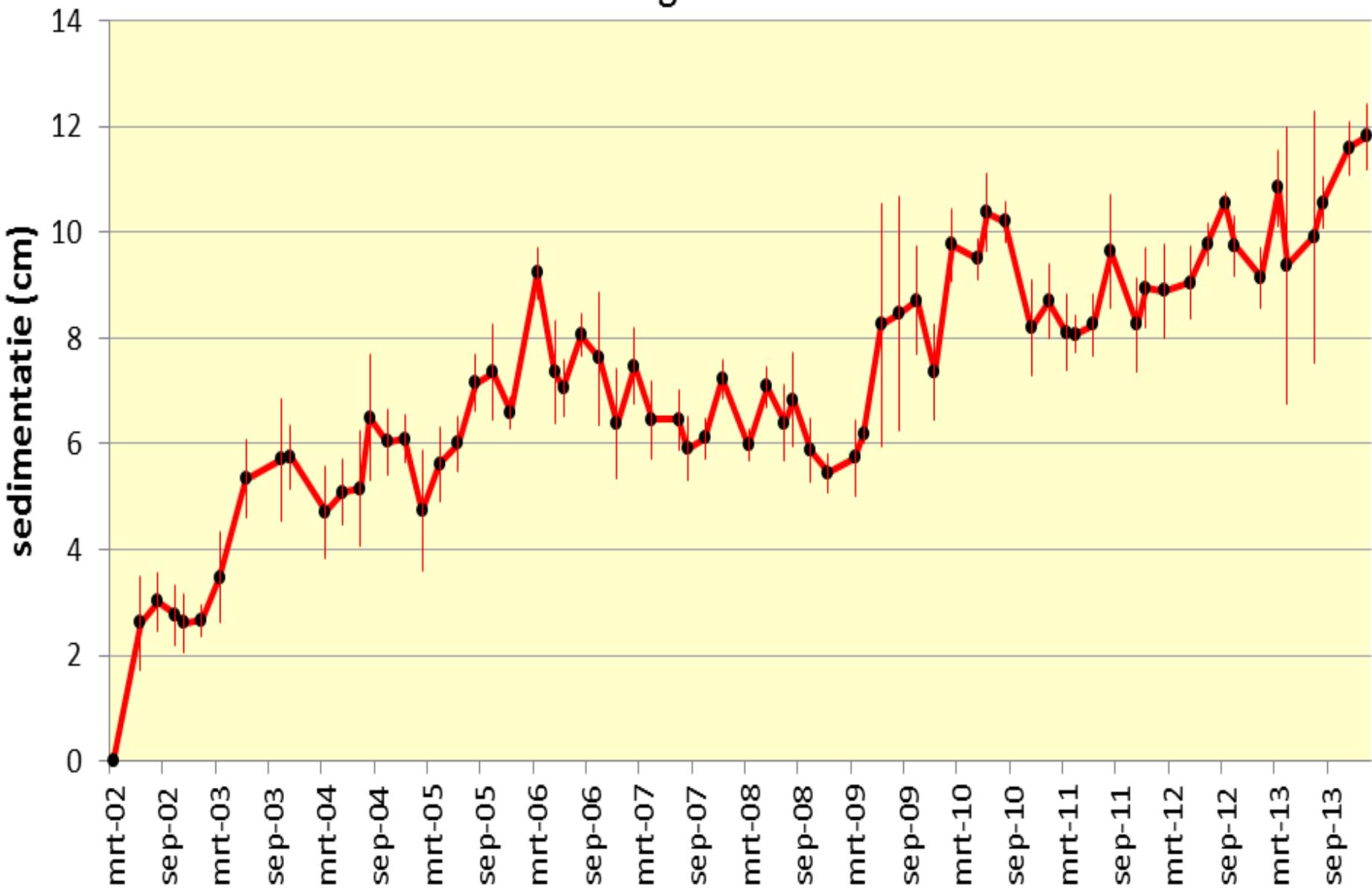




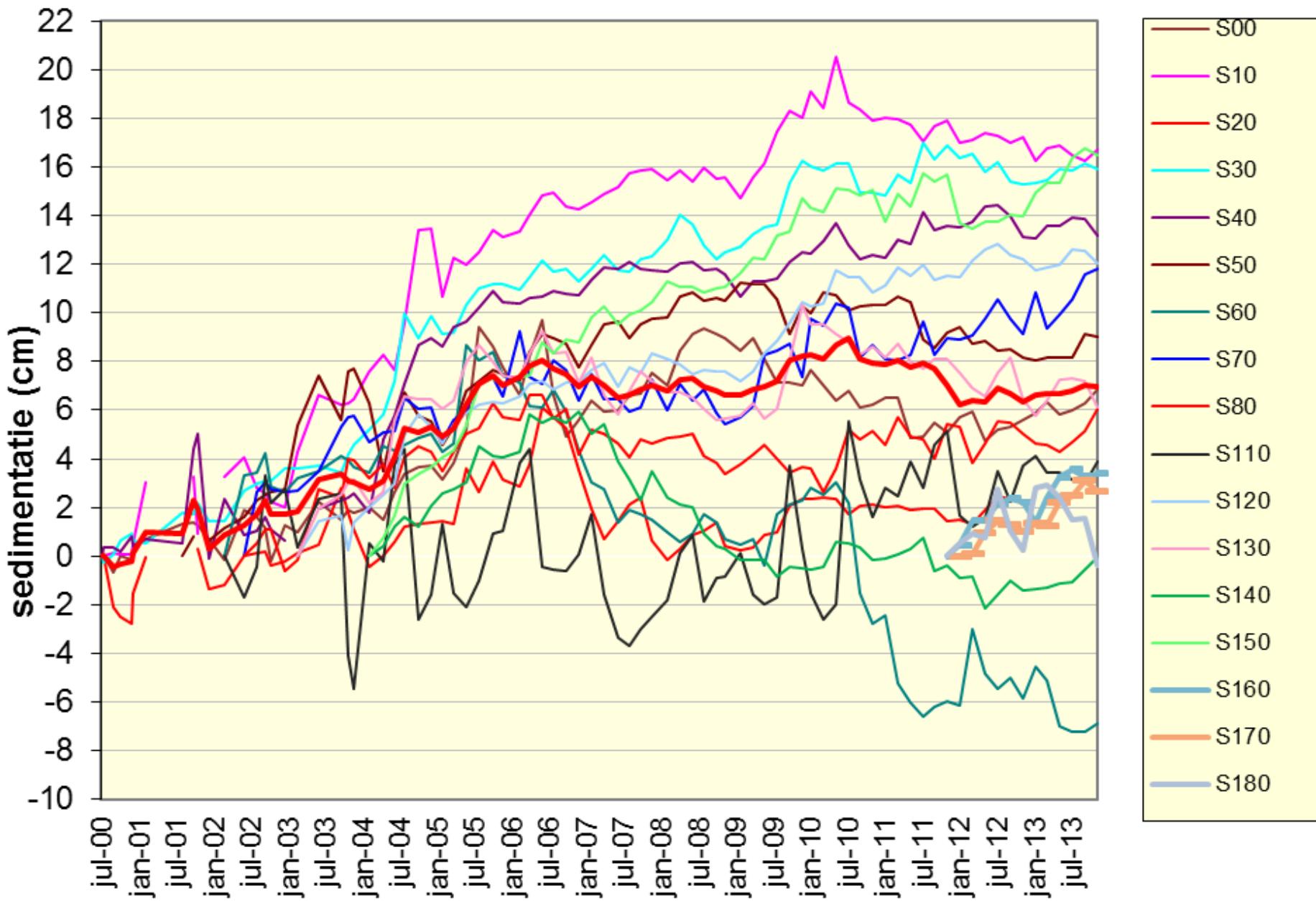


Oost-Ameland S70

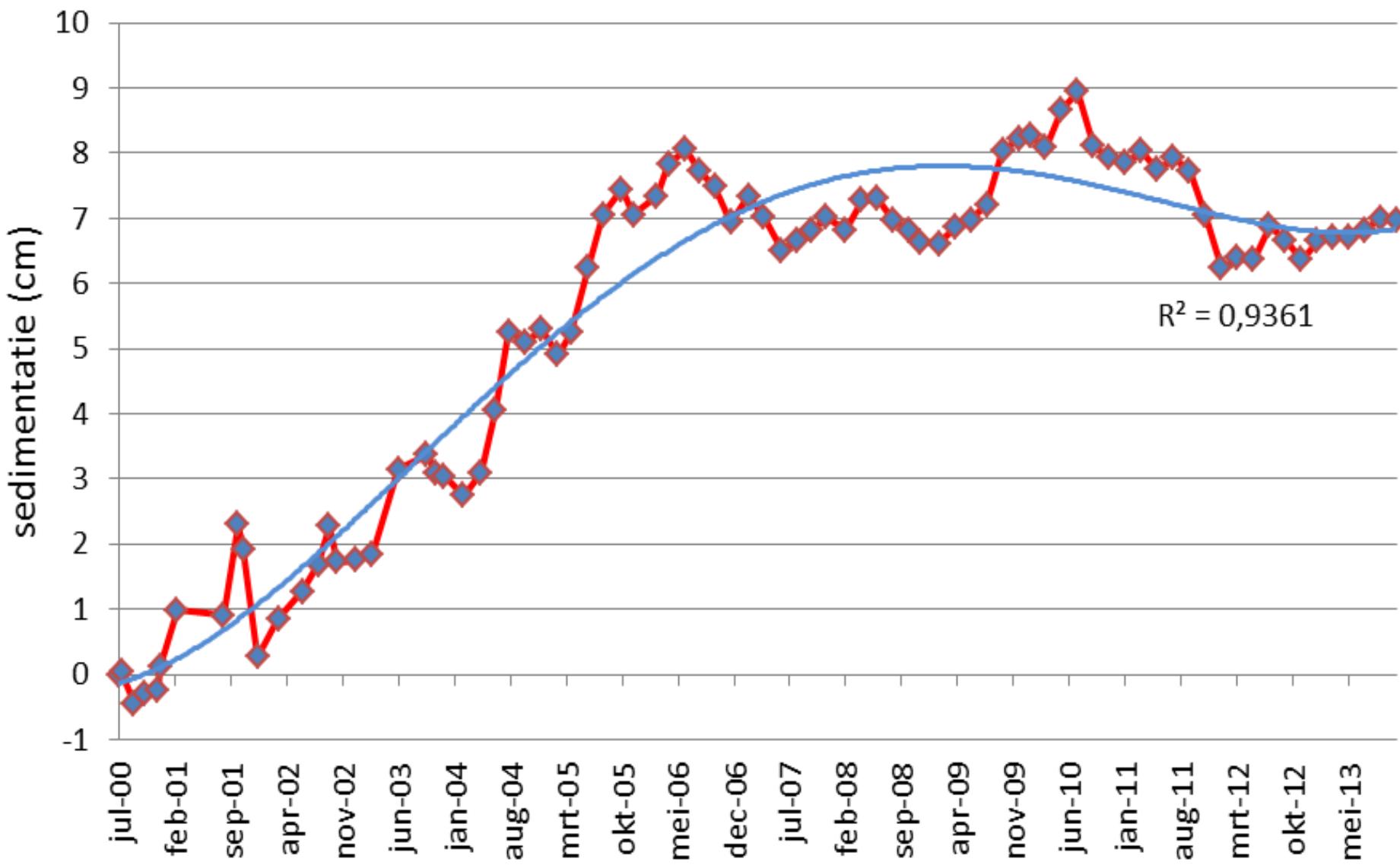
verschilmeting en SD



Oost-Ameland
gemiddelde per meetstation zonder S90 -S100



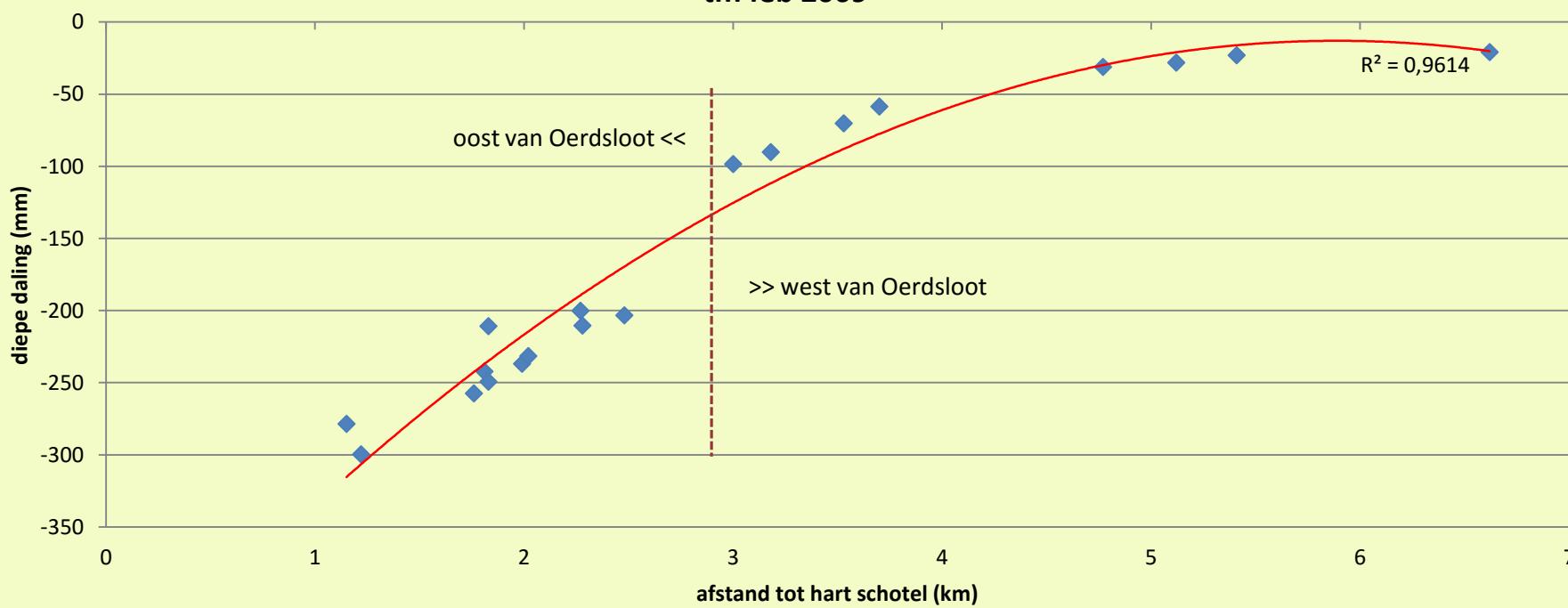
sedimentatie Oost-Ameland zonder S90 en S100



Tidal flats



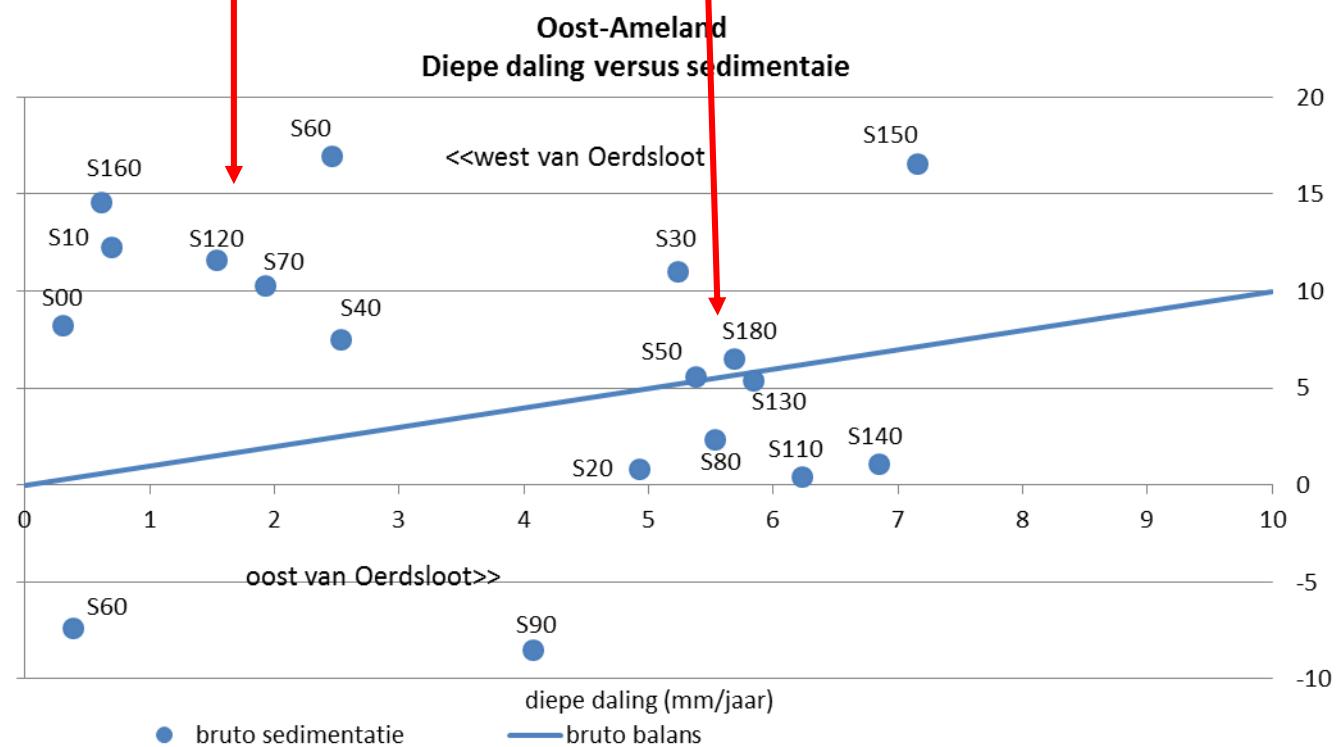
Oost-Ameland
afstand tot hart schotel en diepe daling
tm feb 2009



Tidal flats

2001-2013

Sedimentation average 5 mm/y
Subsidence average 5 mm/y



meland



Tidal flats

2013

Plaathoogteverandering in cm.



J. Krol, Natuurcentrum Ameland

Tidal flats

Sedimentatiesnelheid tm 2013
mm per jaar

+7,3

West-Ameland

+4,8

Oost-Ameland

+8,0

Schiermonnikoog

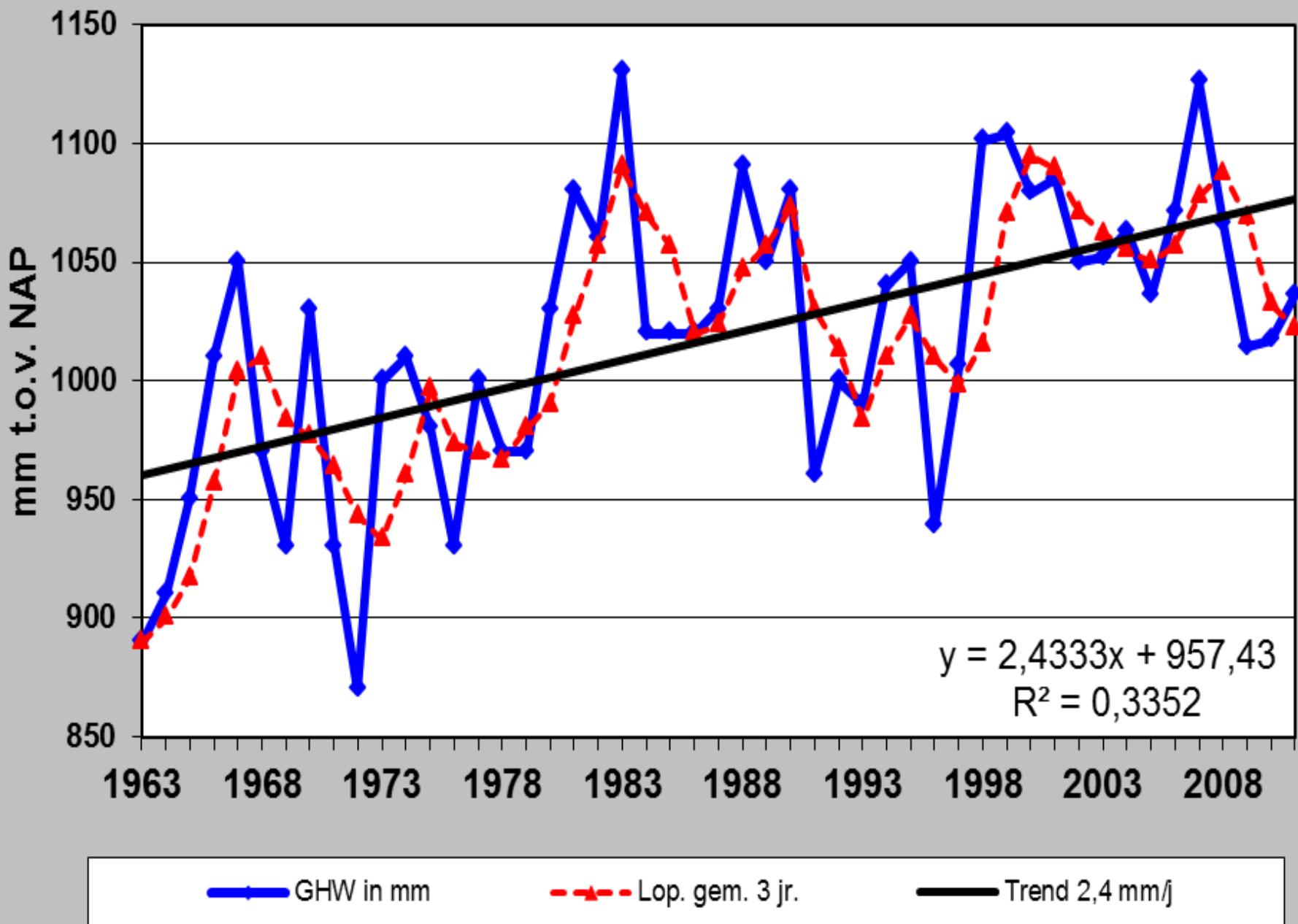
+2,8

Engelsmanplaat
Paesens

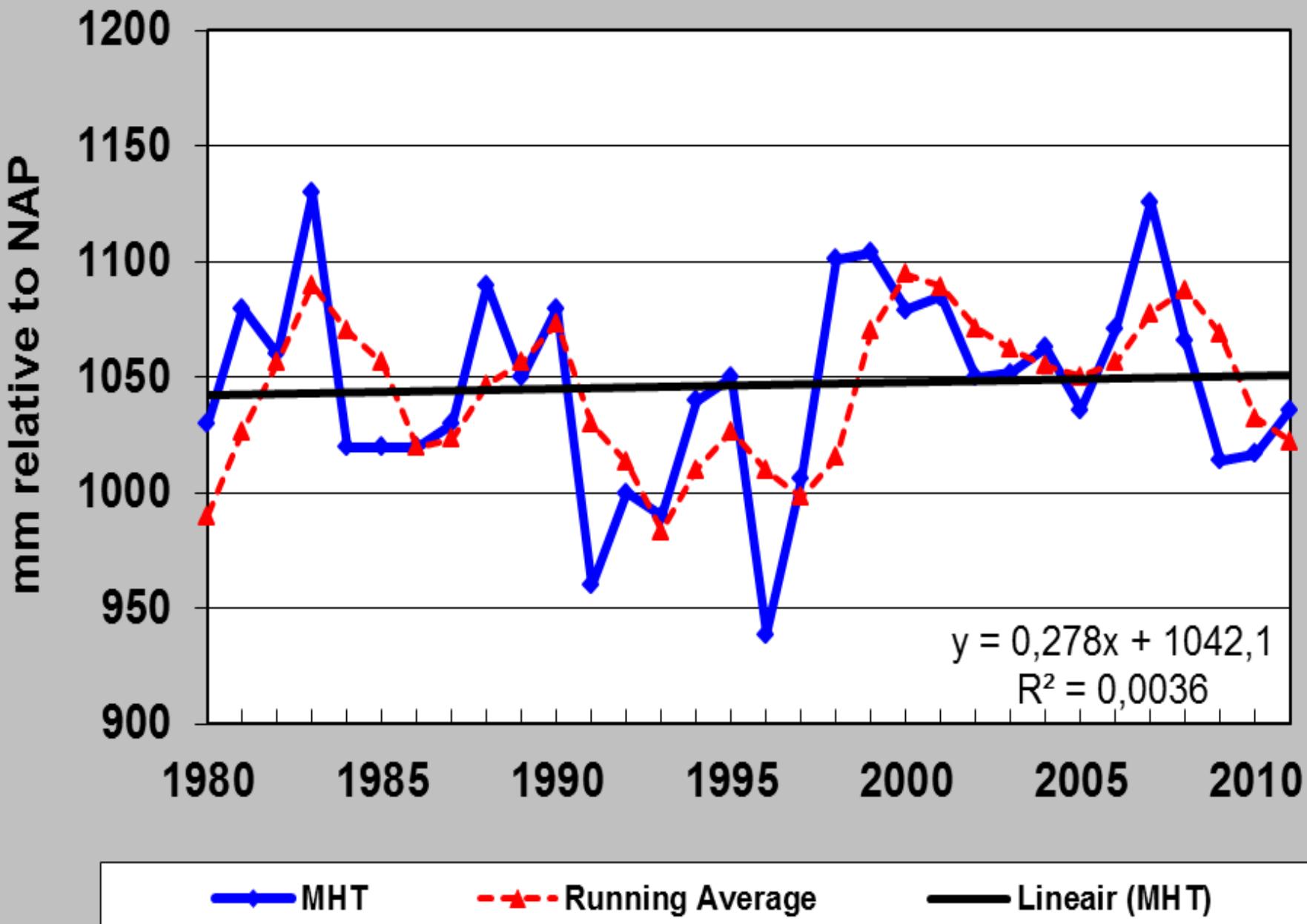
+9,4

Fe

MHT Nes 1963-2011



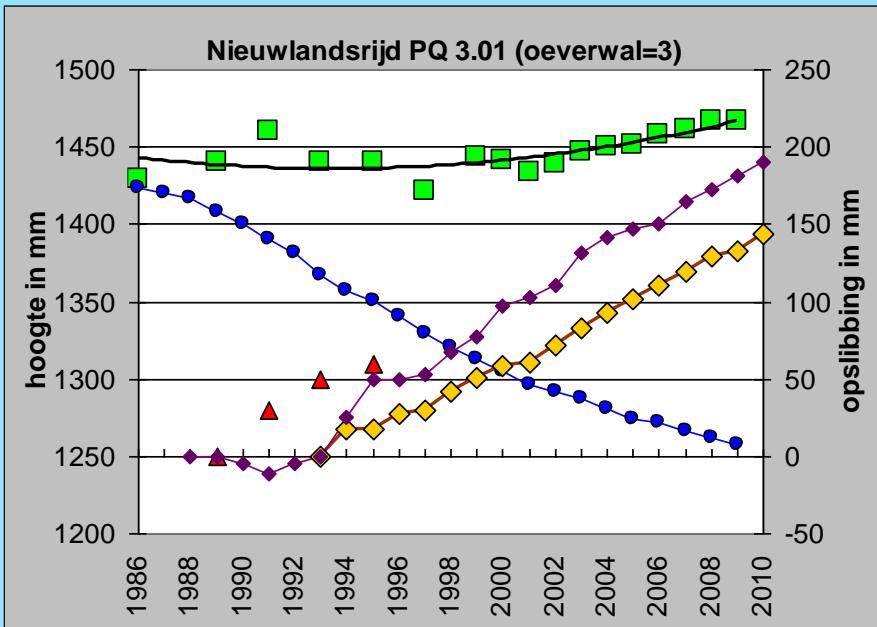
MHT Nes 1980-2011



Subsidence and sedimentation

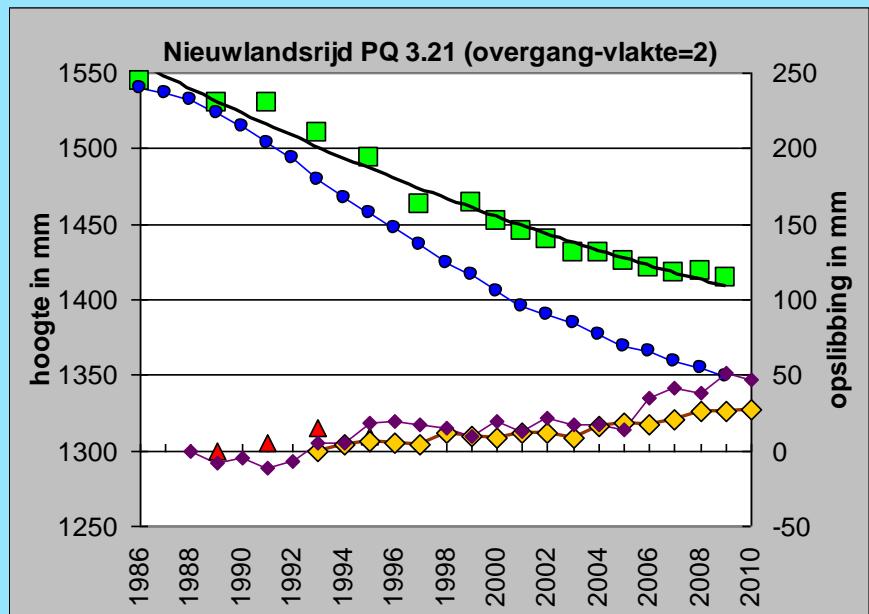
Saltmarsh

Edge Wadden Sea



■ MAAIVELD PQ GEMETEN
● MAAIVELD ZONDER OPS.
▲ OPSLIBBING PAAL

Central and dune



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

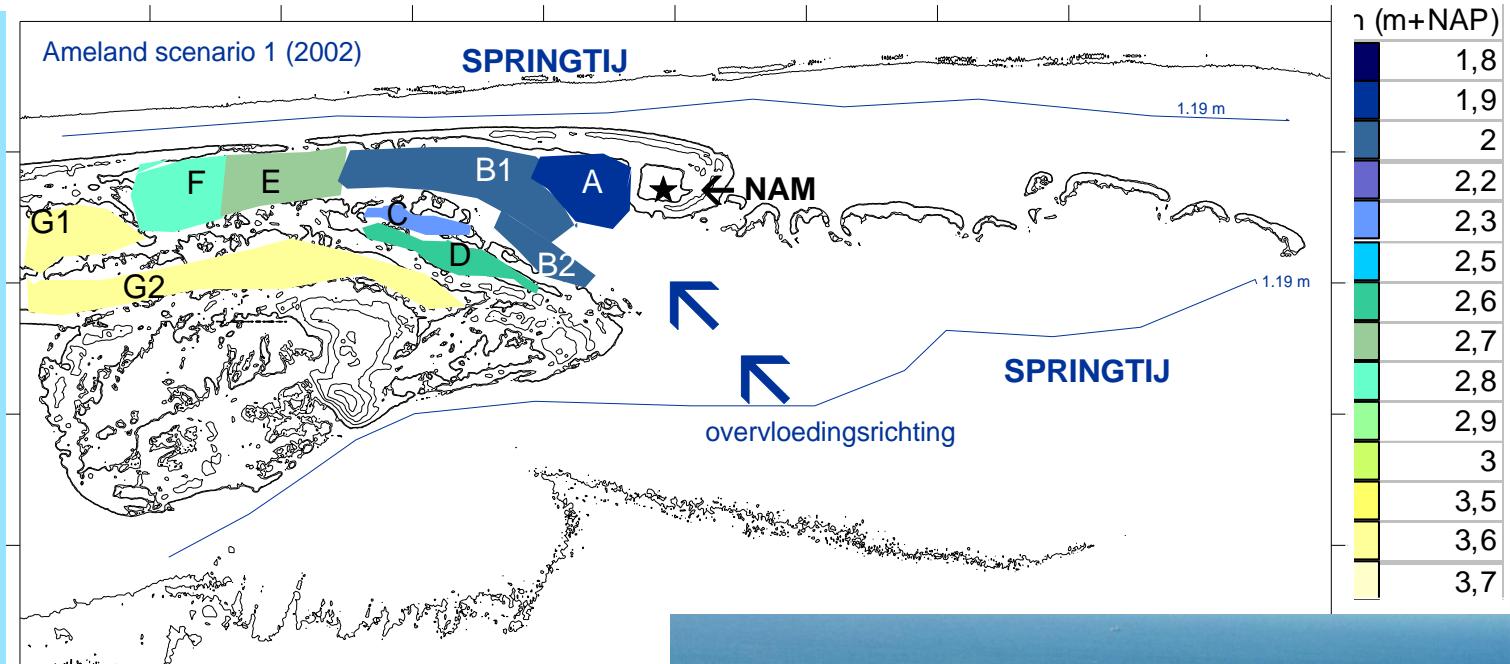
Conclusions tidal flats

- Subsidence is locally compensated at rates up to at least 1.3 cm per year: no impact on ecology(birds)
- The mechanism seems a rapid exchange between flats and channels: deepening channels and outer-delta
- The natural 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

Dune valleys

Flooding frequency was calculated to increase significantly

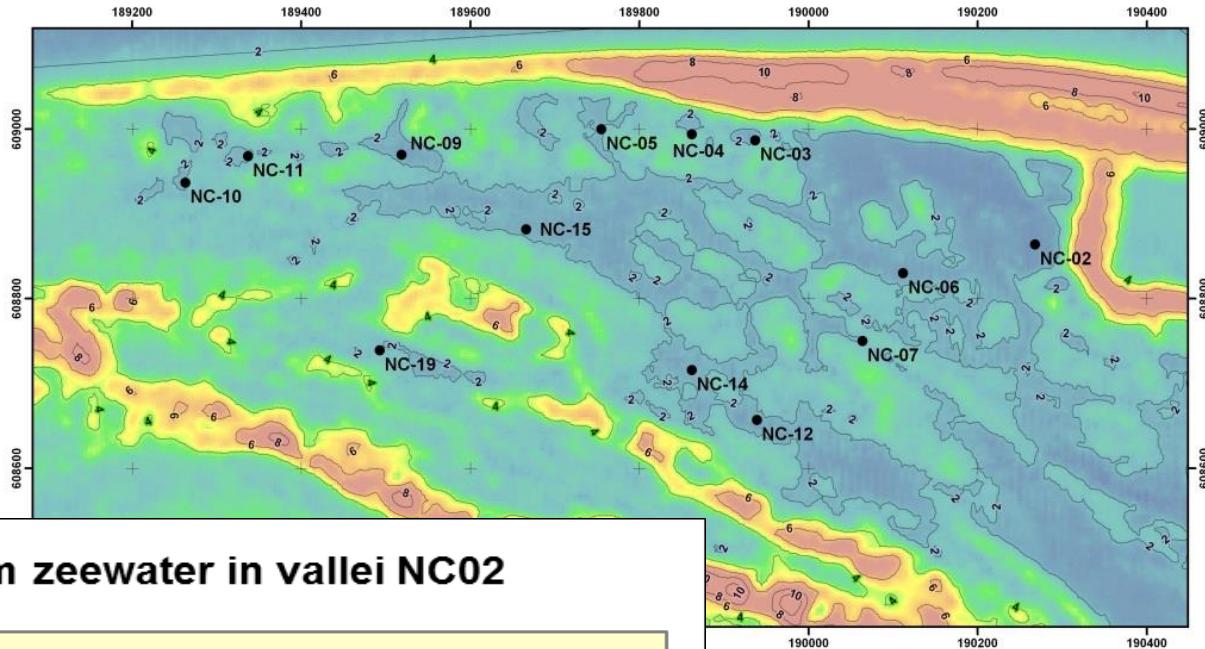
- more flooding events
- more sedimentation



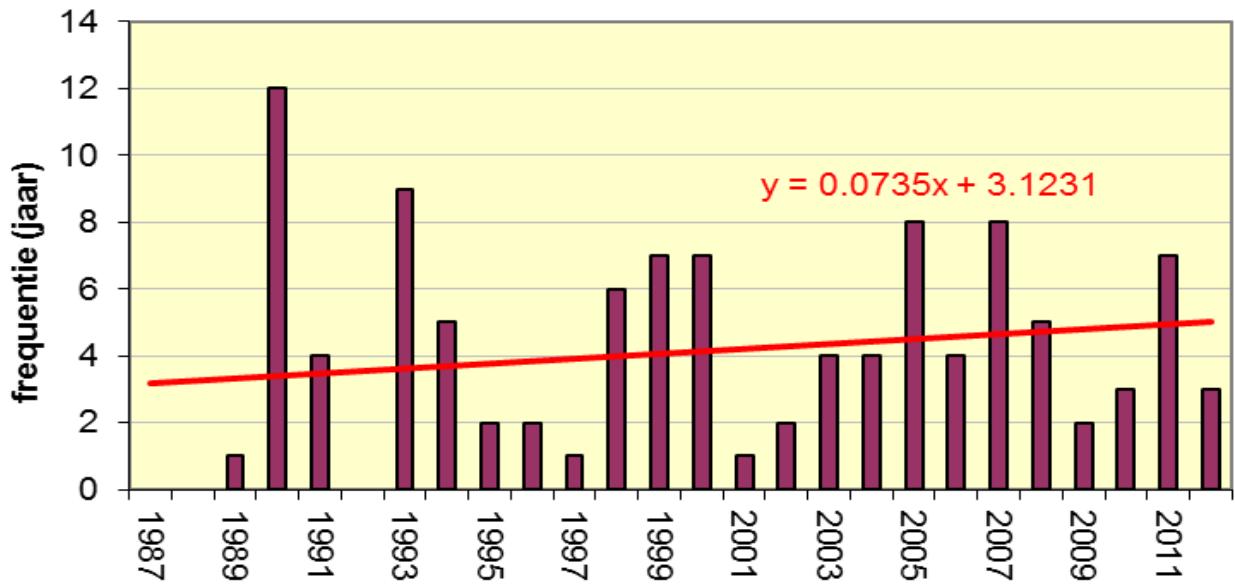
vallei	f (1987)	f (2002)	f (2007)
A	4	13	20
B	3	9	14
C	2	3	5
D	0,5	1	2
E	0,3	1	1
F	0,2	0,5	1
G	0,02	0,03	0,05



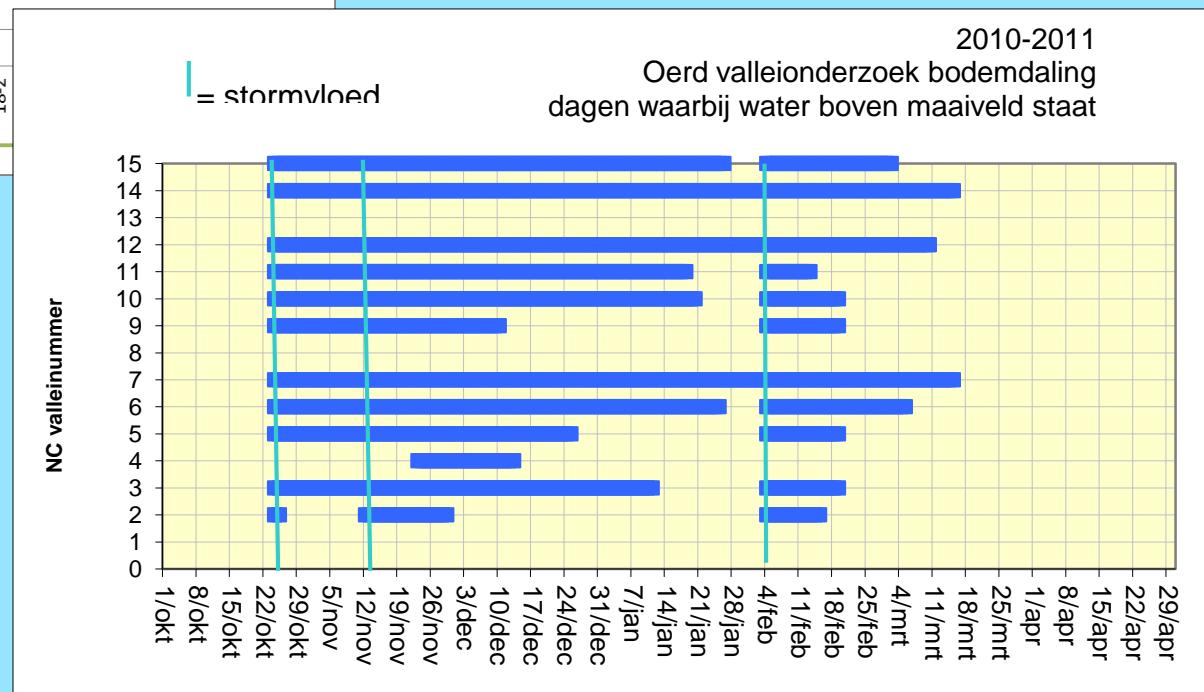
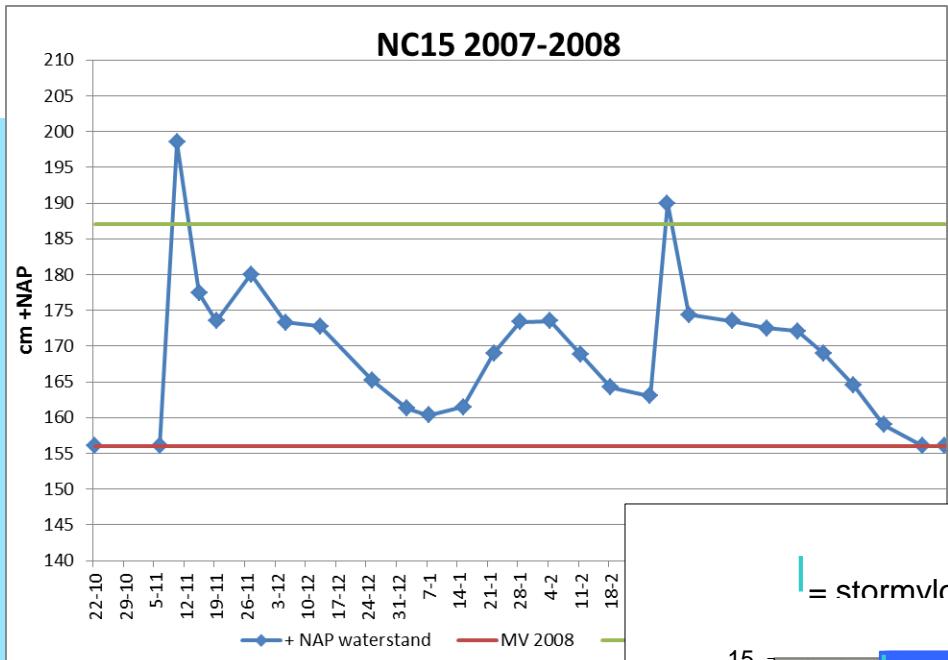
Dune valleys



f (jaar) van instroom zeewater in vallei NC02



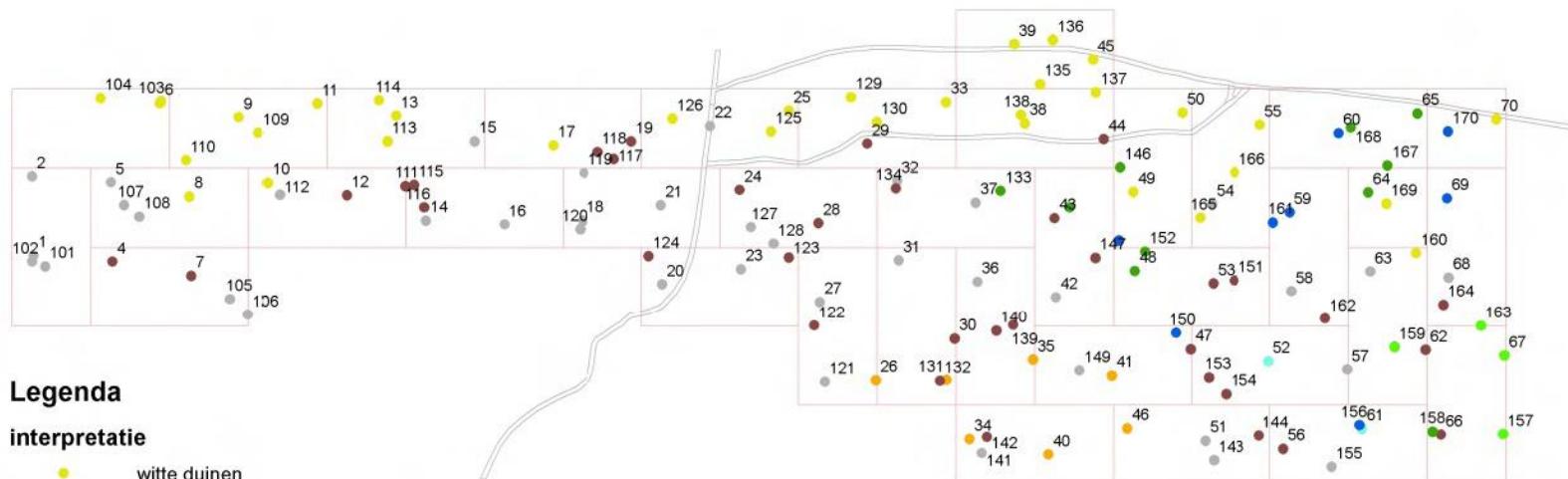
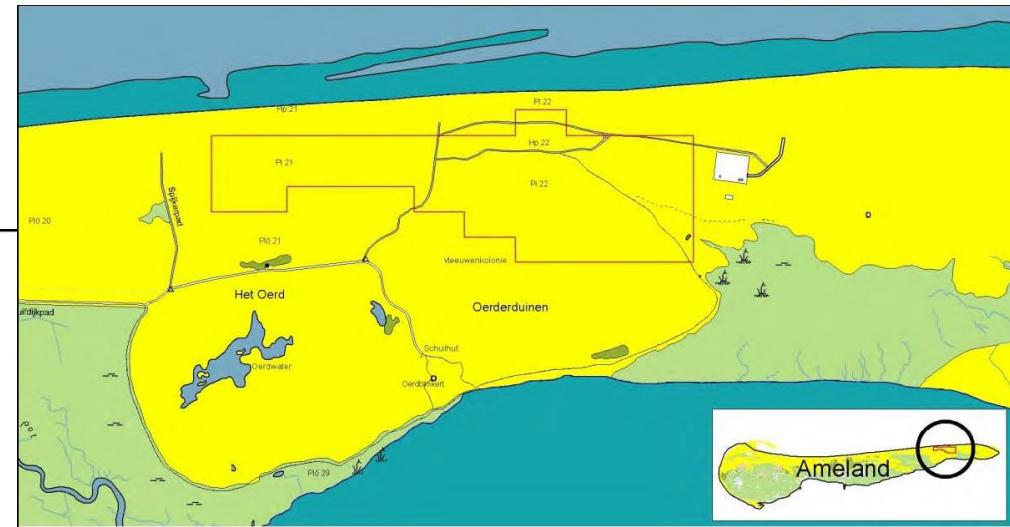
Inundation increased from days to months



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

Dune vegetation



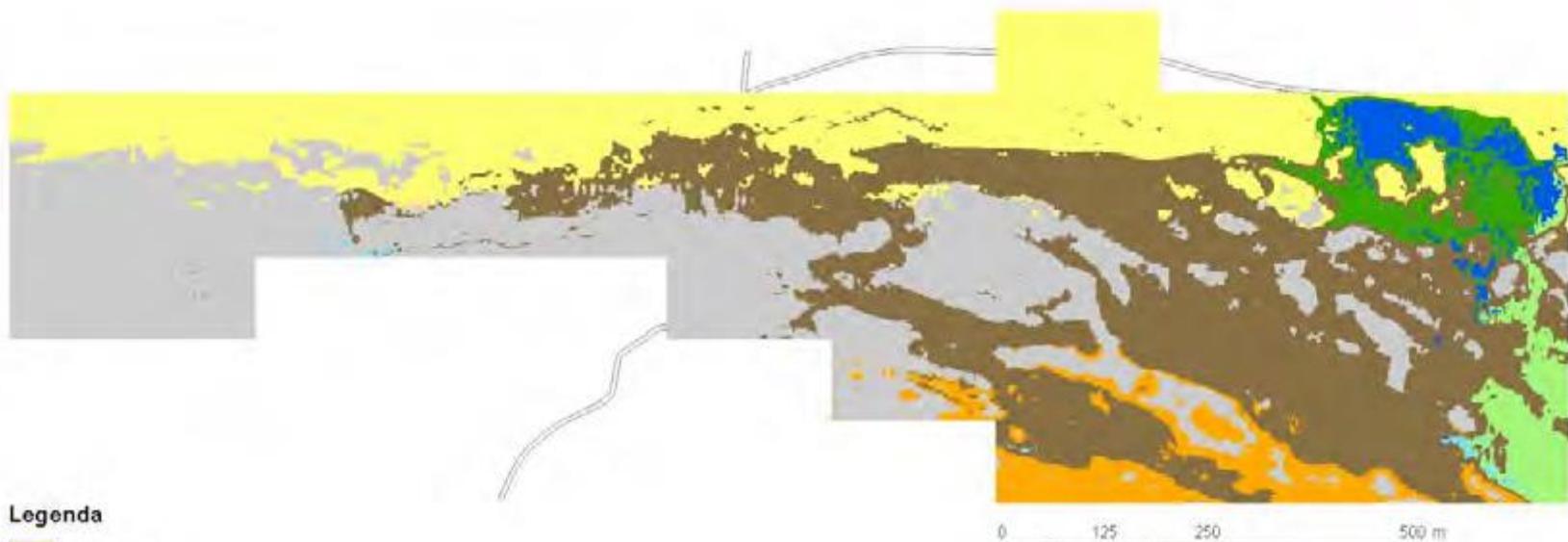
Legenda

interpretatie

- witte duinen
- grijze duinen
- verruigde en verstruweelde duinvalleien
- duindoornstruweel
- hoge kwelder: meer zout
- hoge kwelder: minder zout
- lage kwelder: minder zout
- lage kwelder: meer zout

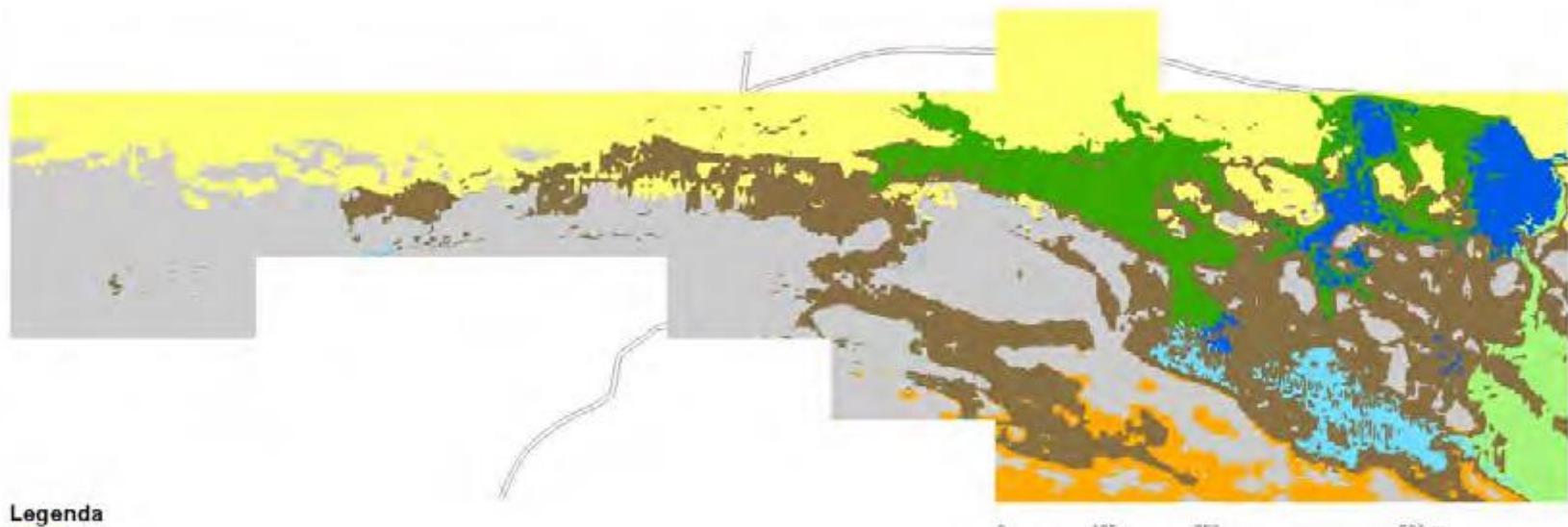
P. Slim/H. van Dobben, Alterra

Dominante vegetatietype 2001



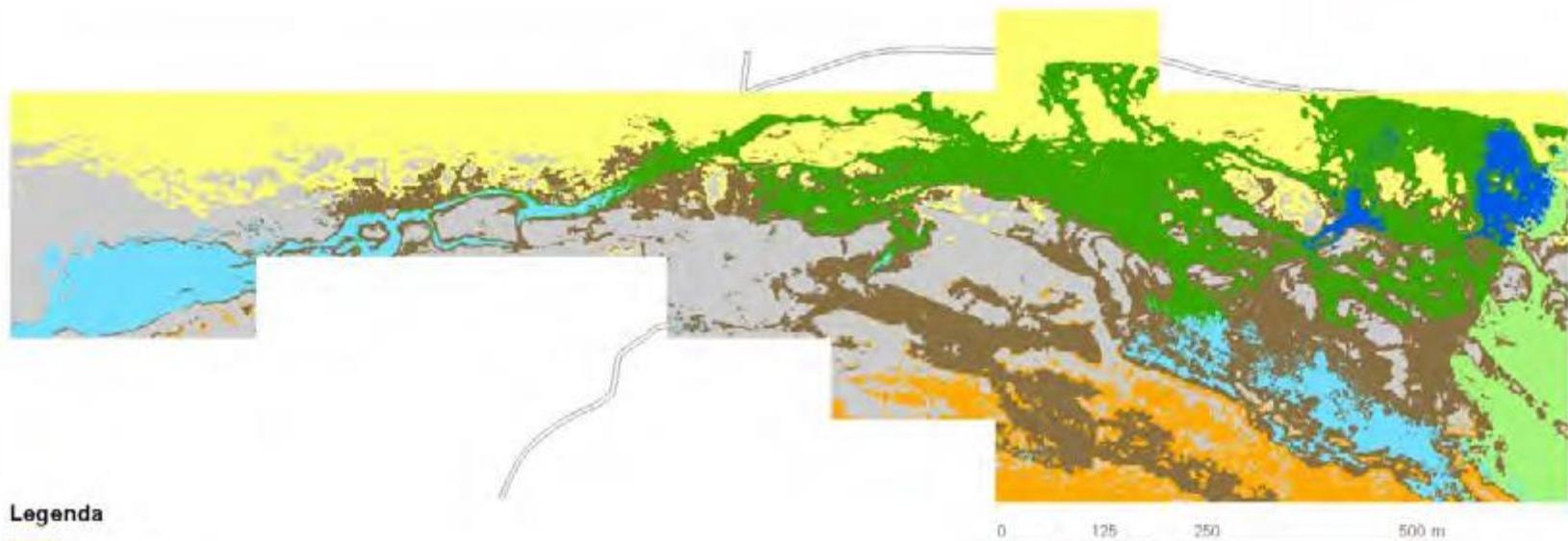
P. Slim/H. van Dobben, Alterra

Dominante vegetatietype 2004



P. Slim/H. van Dobben, Alterra

Dominante vegetatietype 2006

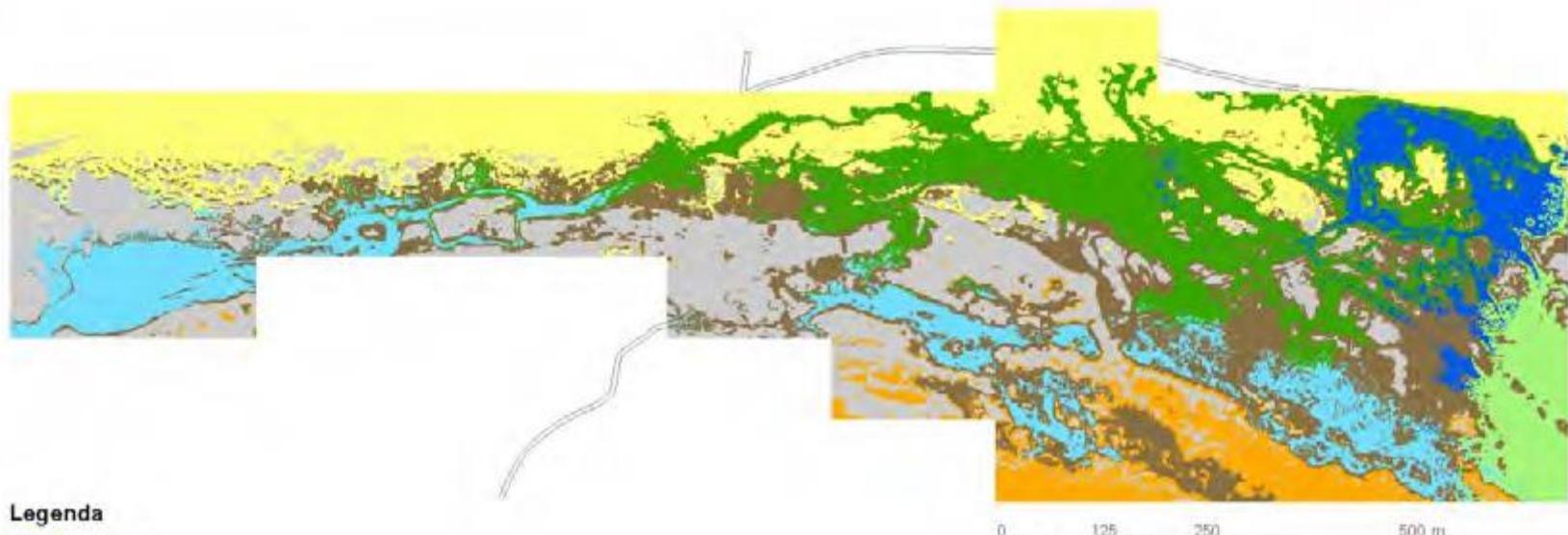


Legenda

- [Yellow square] 'witte duinen'
- [Light grey square] 'grijze duinen'
- [Dark brown square] 'vernuigde en verstruweelde duinvalleien'
- [Orange square] 'duindoornstruweel'
- [Dark green square] 'hoge kwelder: meer zout'
- [Light green square] 'hoge kwelder: minder zout'
- [Light blue square] 'lage kwelder: minder zout'
- [Dark blue square] 'lage kwelder: meer zout'

P. Slim/H. van Dobben, Alterra

Dominante vegetatietype 2008



P. Slim/H. van Dobben, Alterra

Dominante vegetatietype 2010



Legenda

- 'witte duinen'
- 'grijze duinen'
- verruigde en verstruweelde duinvalleien
- duindoornstruweel
- hoge kweelder: meer zout
- hoge kweelder: minder zout
- lage kweelder: minder zout
- lage kweelder: meer zout

P. Slim/H. van Dobben, Alterra

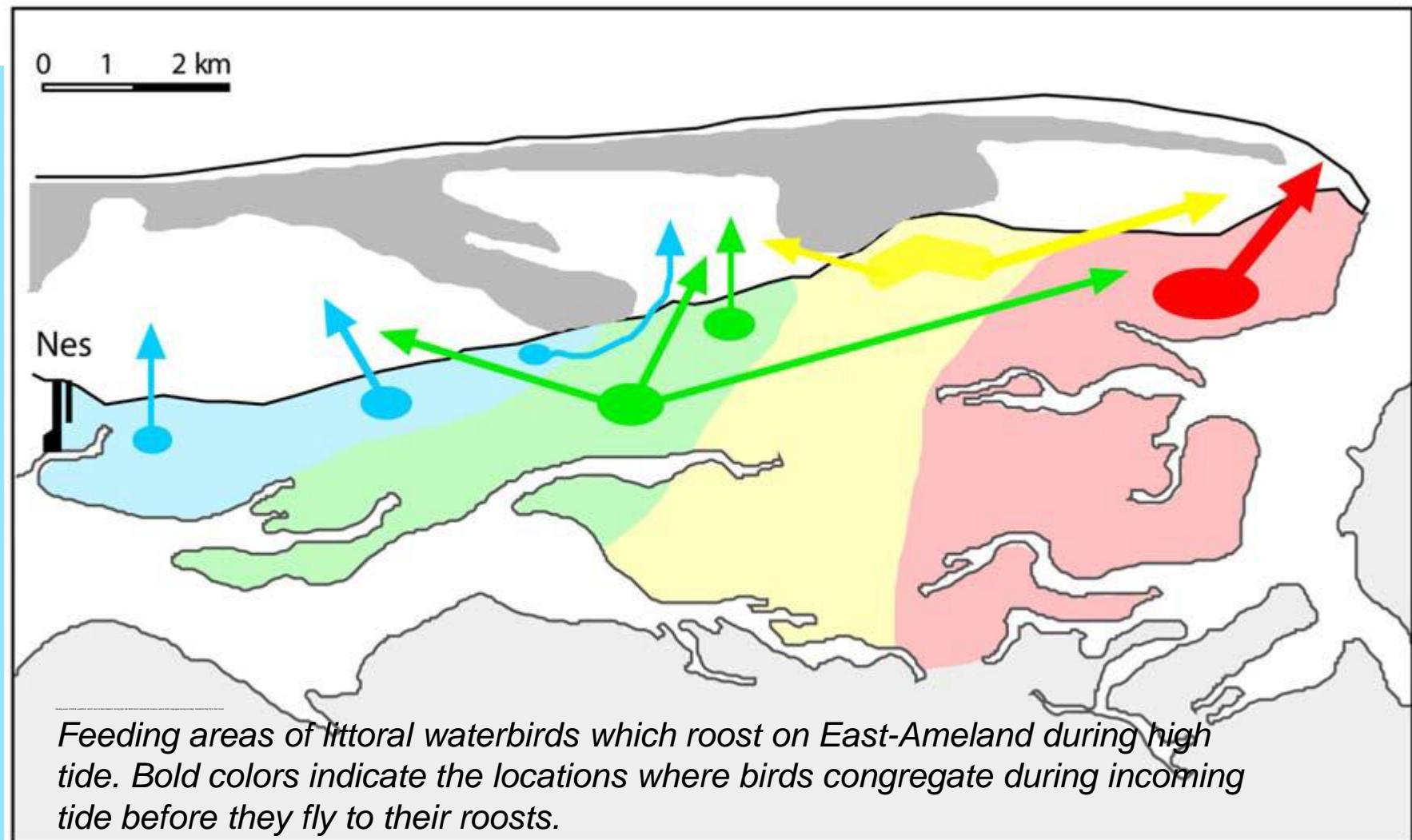
Dune vegetation



On balance there was succession towards increasing density and increasing wetness, and towards more saltmarsh-type vegetation

P. Slim/H. van Dobben, Alterra

Birds



M. Kersten/K. Rappoldt

Birds

- On East-Ameland, the numbers of 12 of the 14 selected bird species have changed significantly between 1972–1986 and 2005–2010. Most changes can be related to the disappearance of mussel beds, the decrease of silty areas, the decline of molluscs and the increase of worms.
- For 10 species the change of the number of birds on East-Ameland is consistent with those in the control areas. This indicates that the phenomena that drive these changes are not restricted to East-Ameland, but act on a much larger scale.
- In four species there is a discrepancy between the trends on East-Ameland and those in the control areas. In these instances local changes in the environment may be responsible for the aberrant trends.

Ruddy Turnstone -- in autumn migration /no musselbed

Red Knot ++ all seasons /more sandy

Common Redshank – winter /? also on WA

Dunlin ++ winter /?

M. Kersten/K. Rappoldt

What to monitor in relation to sea level rise?



Conclusions after 30 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