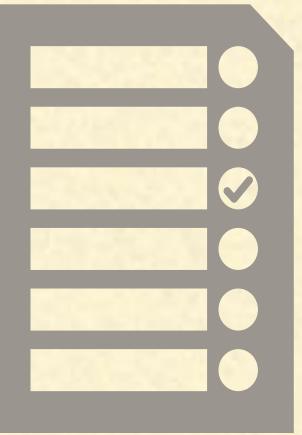


LONG-TERM EVOLUTION OF THE NORTHERN FRANCE COASTAL ZONE AND INFLUENCE ON HYDRODYNAMIC

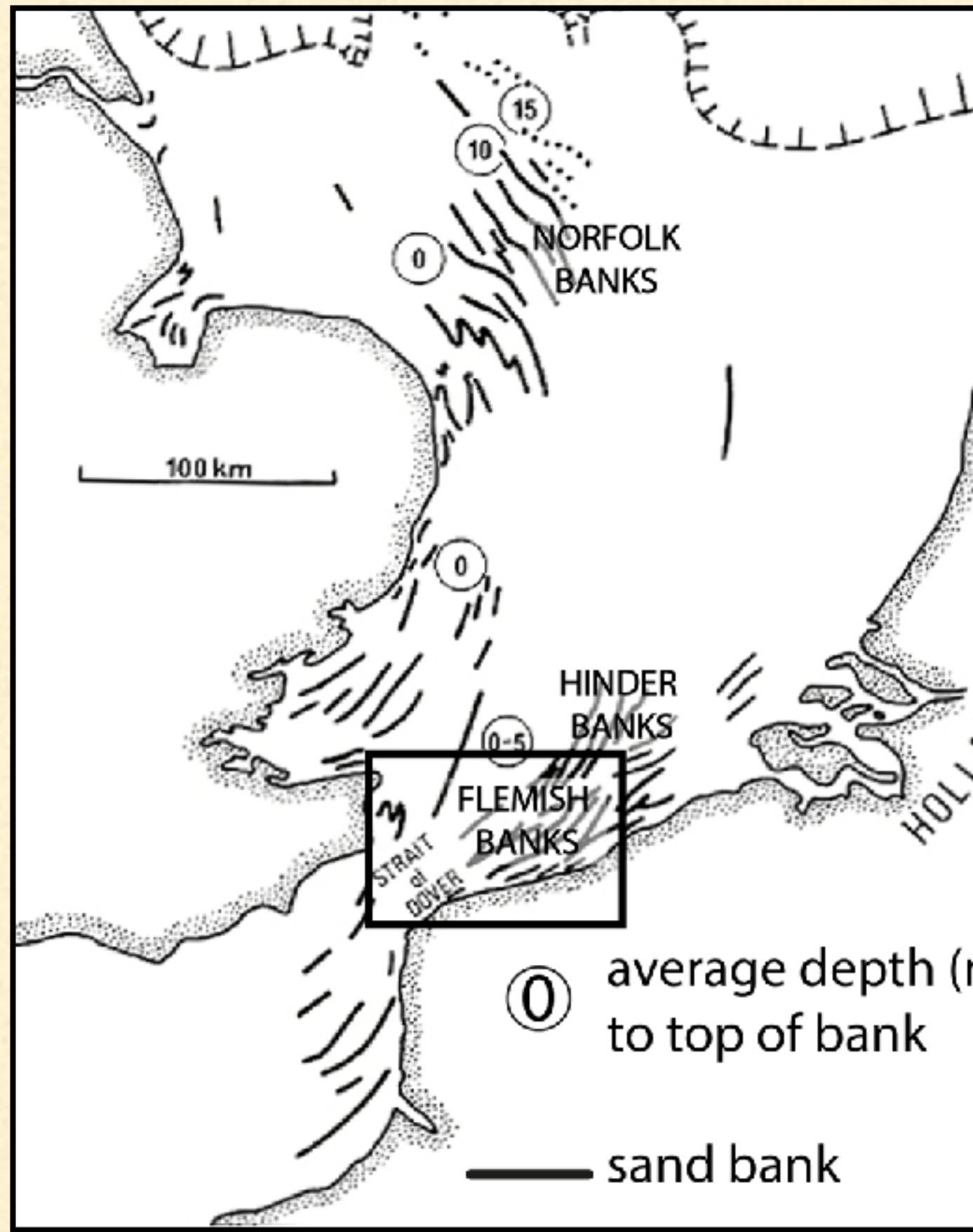
LATAPY Alexa (**ULCO**),
HEQUETTE Arnaud (ULCO),
NICOLLE Amandine (ENSTA Bretagne),
POUVREAU Nicolas (Shom),
WEBER Nicolas (Shom),
ROBIN—CHANTELoup Jean-Baptiste (Univ. la Rochelle)



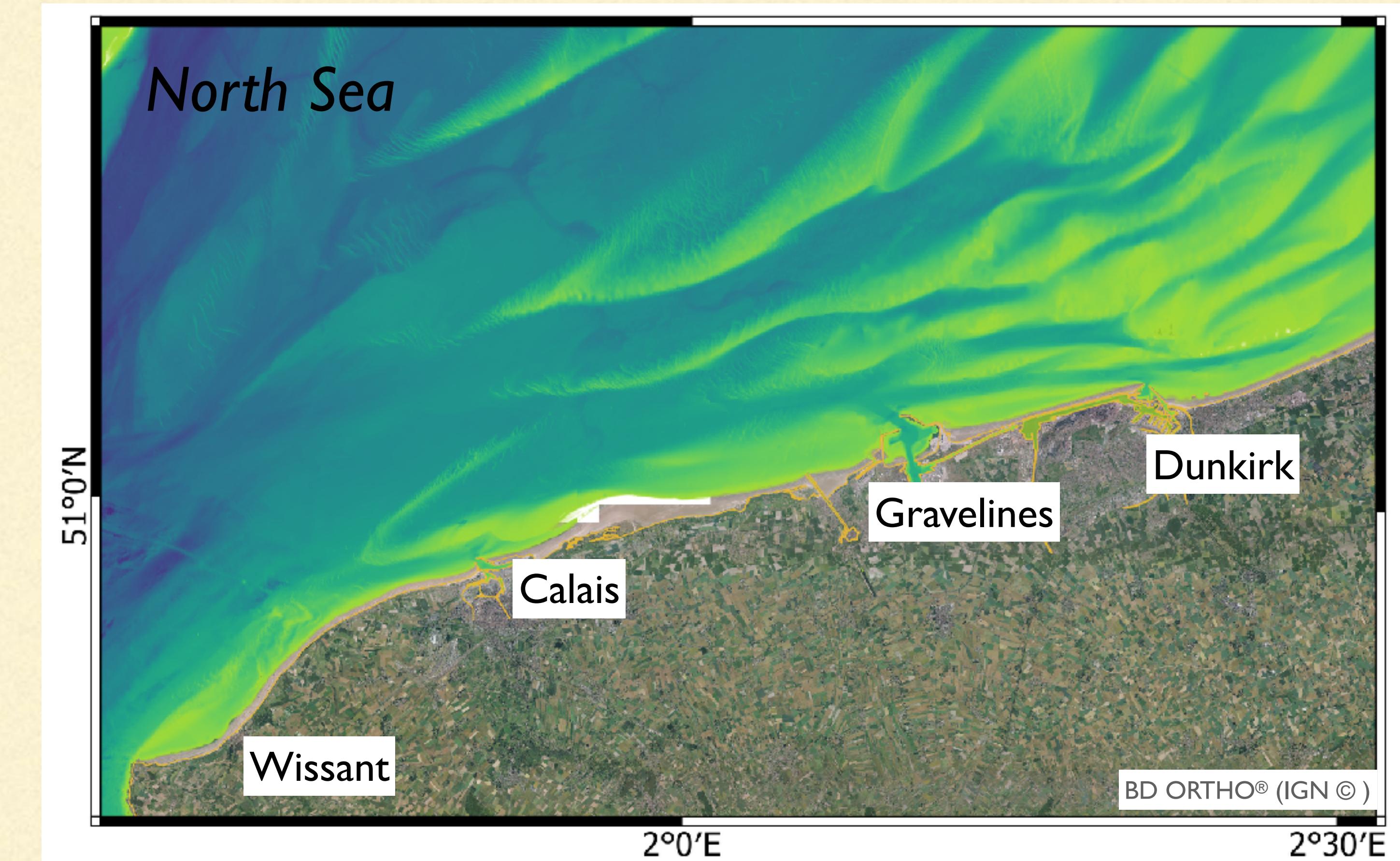
INTRODUCTION



■ Seabed morphology \leftrightarrow hydrodynamic & sediment transport (MacDonald & O'Connor, 1996 ; Thomas et al., 2011)



from Kenyon et al. (2009)



DEM HOMONIM (Shom, 2015) - diffusion.shom.fr

PROBLEMATIC

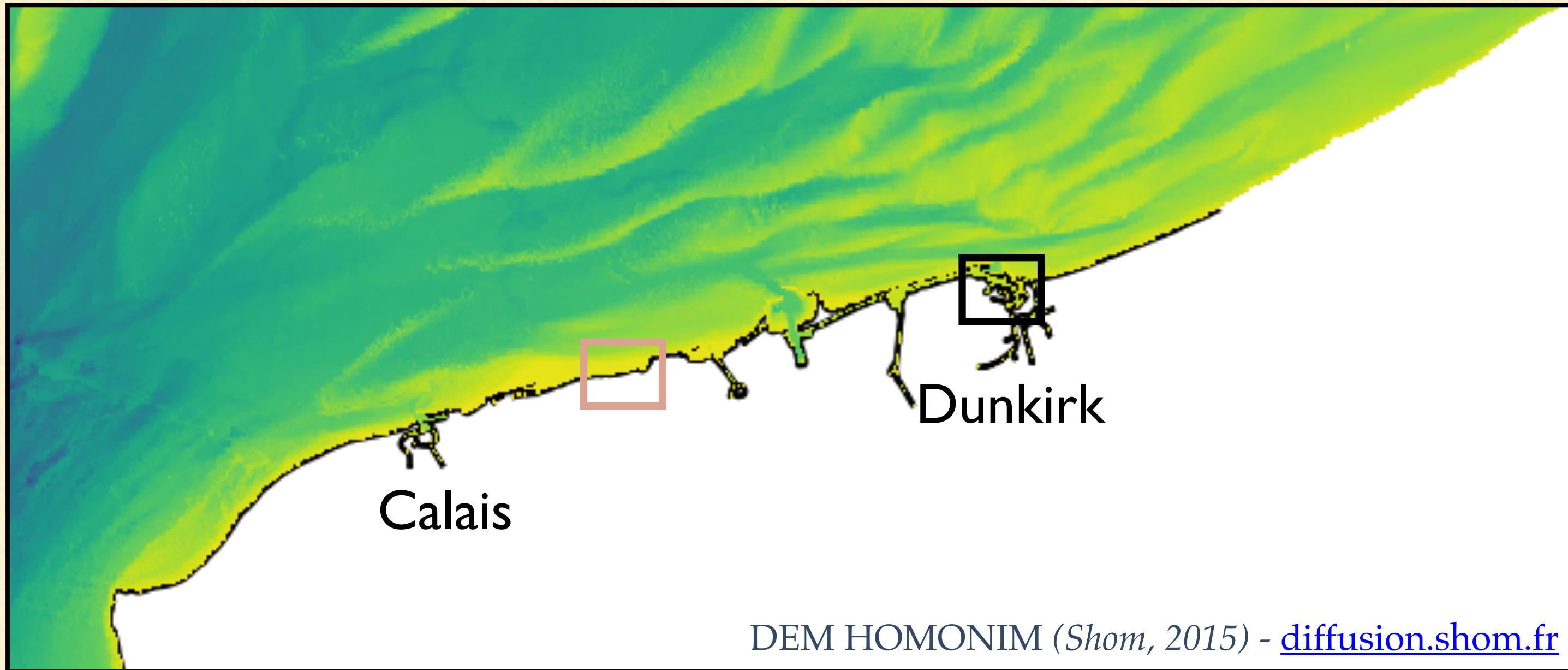
- How the seabed changed in almost two centuries along the Northern France coast ?
- What are the influence of coastal and morphological changes on hydrodynamic circulation ?

REGIONAL SETTING



MORPHOLOGICAL CHARACTERISTICS

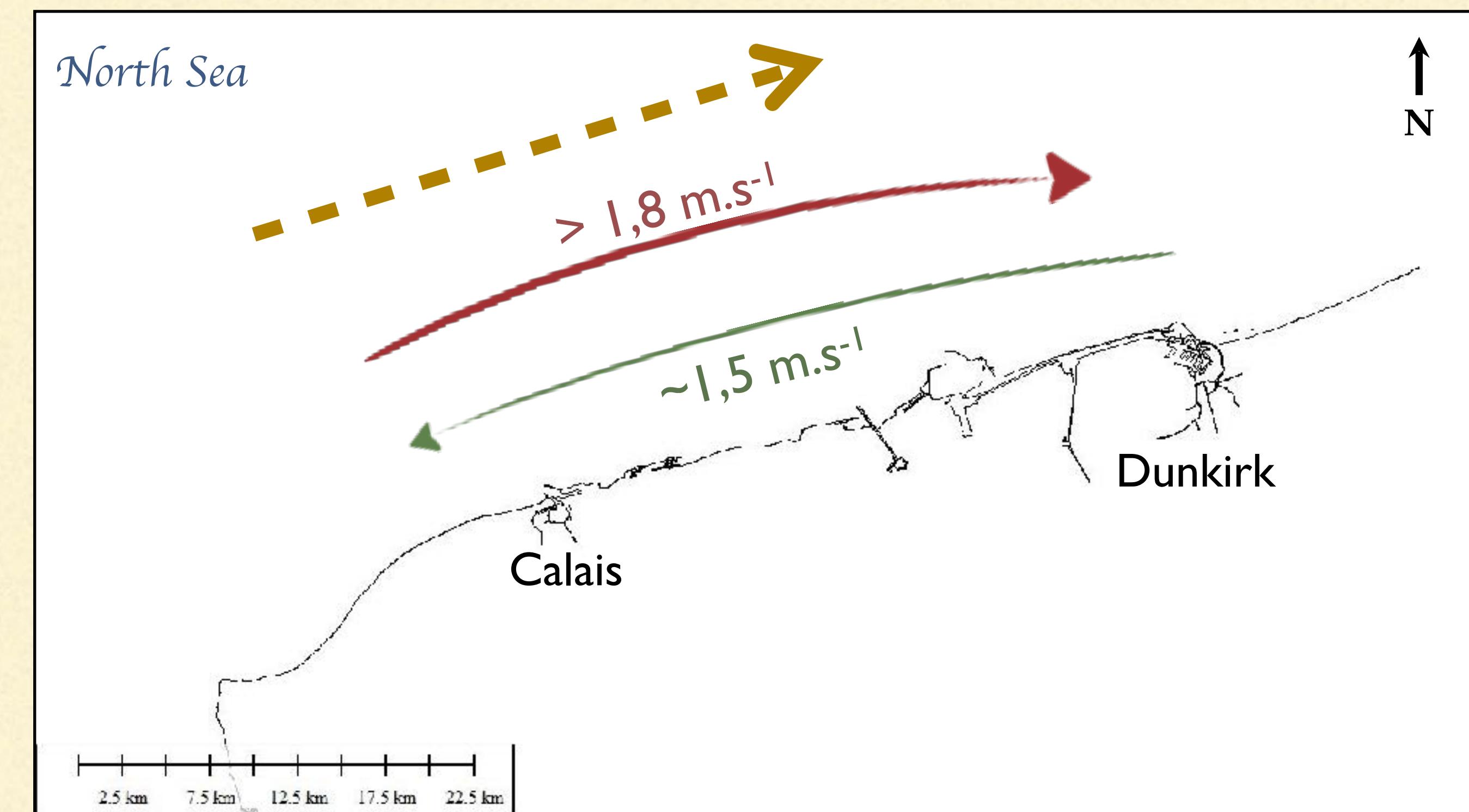
- Sandy beaches (wide, gently sloping)
- Anthropogenic impact : extension of the Dunkirk and Calais harbors
- Flemish sand banks (10-30 km long & 1-3 km wide)



www.megaconstrucciones.net

HYDRODYNAMIC

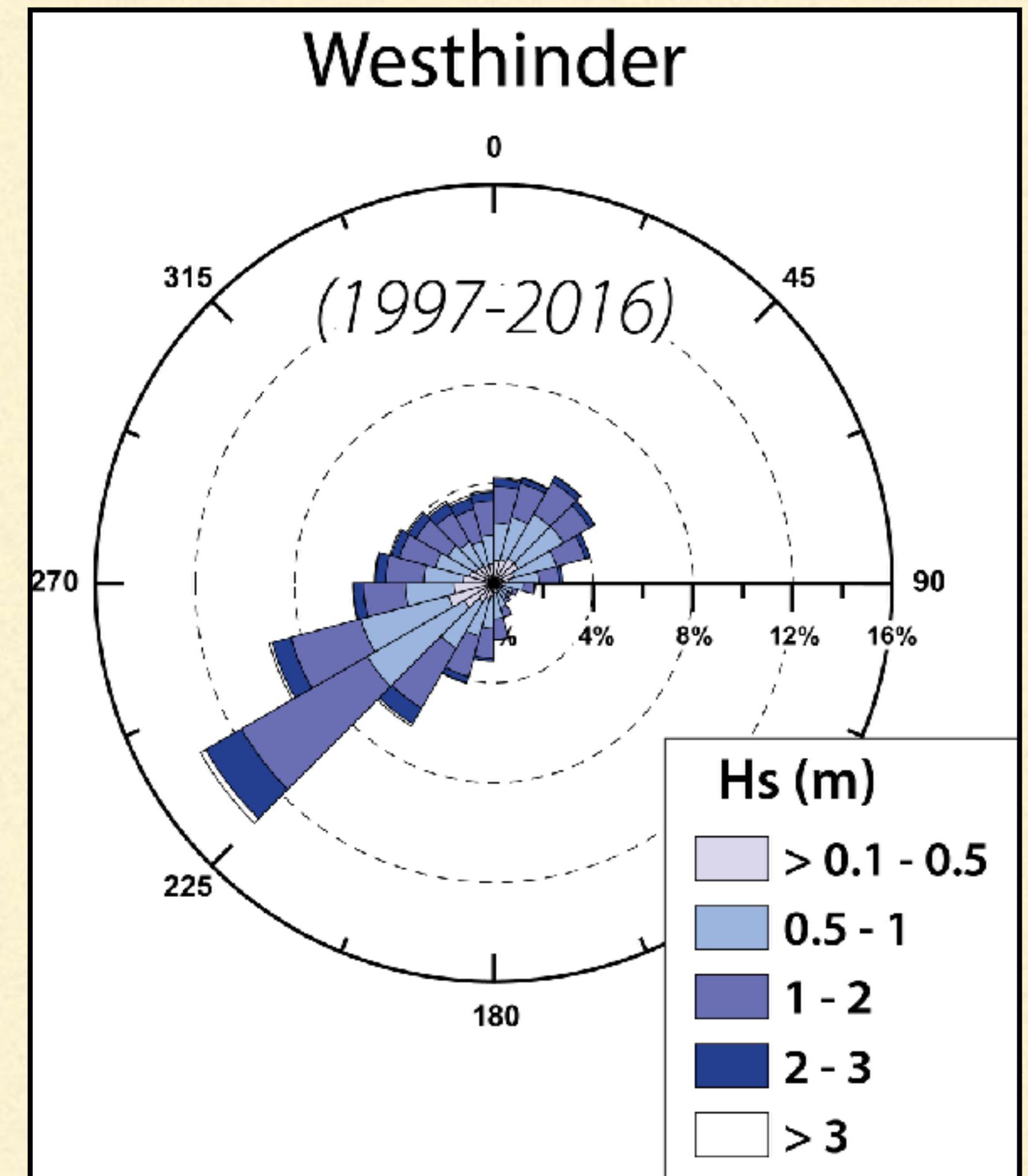
- Tide regime : semi-diurnal & macrotidal
- Strong tidal currents (flood > ebb) (*Shom, 2014*) → flood-dominated asymmetry (*Héquette et al., 2008*) → net regional sediment transport to the ENE



HYDRODYNAMIC

- Modal wave height : 0.6 m
- Period : 4-8 s
- Significant shoaling + energy dissipation over sand banks

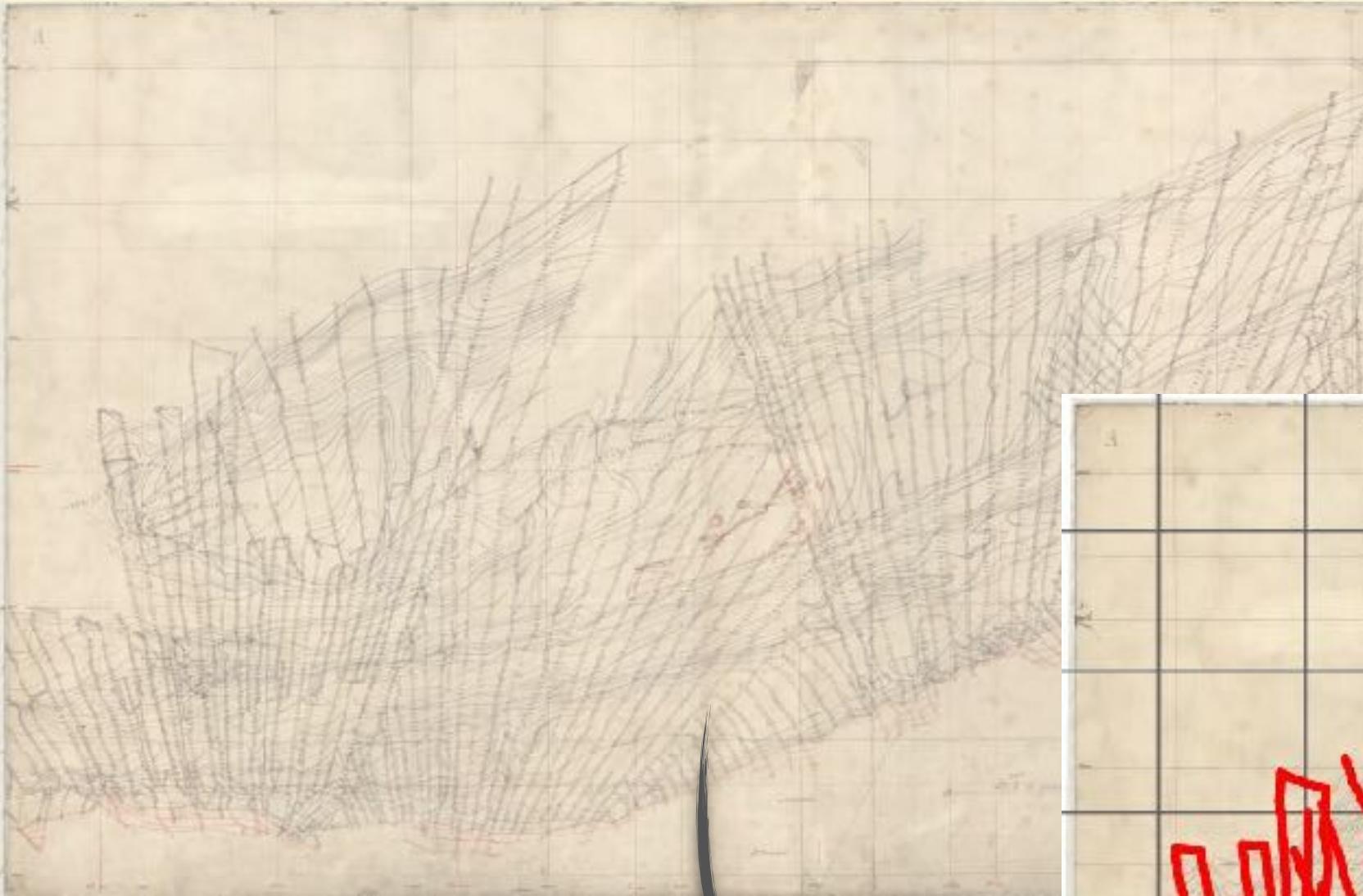
Wave rose at the Westhinder buoy (1997-2016) (Spodar et al., 2018)



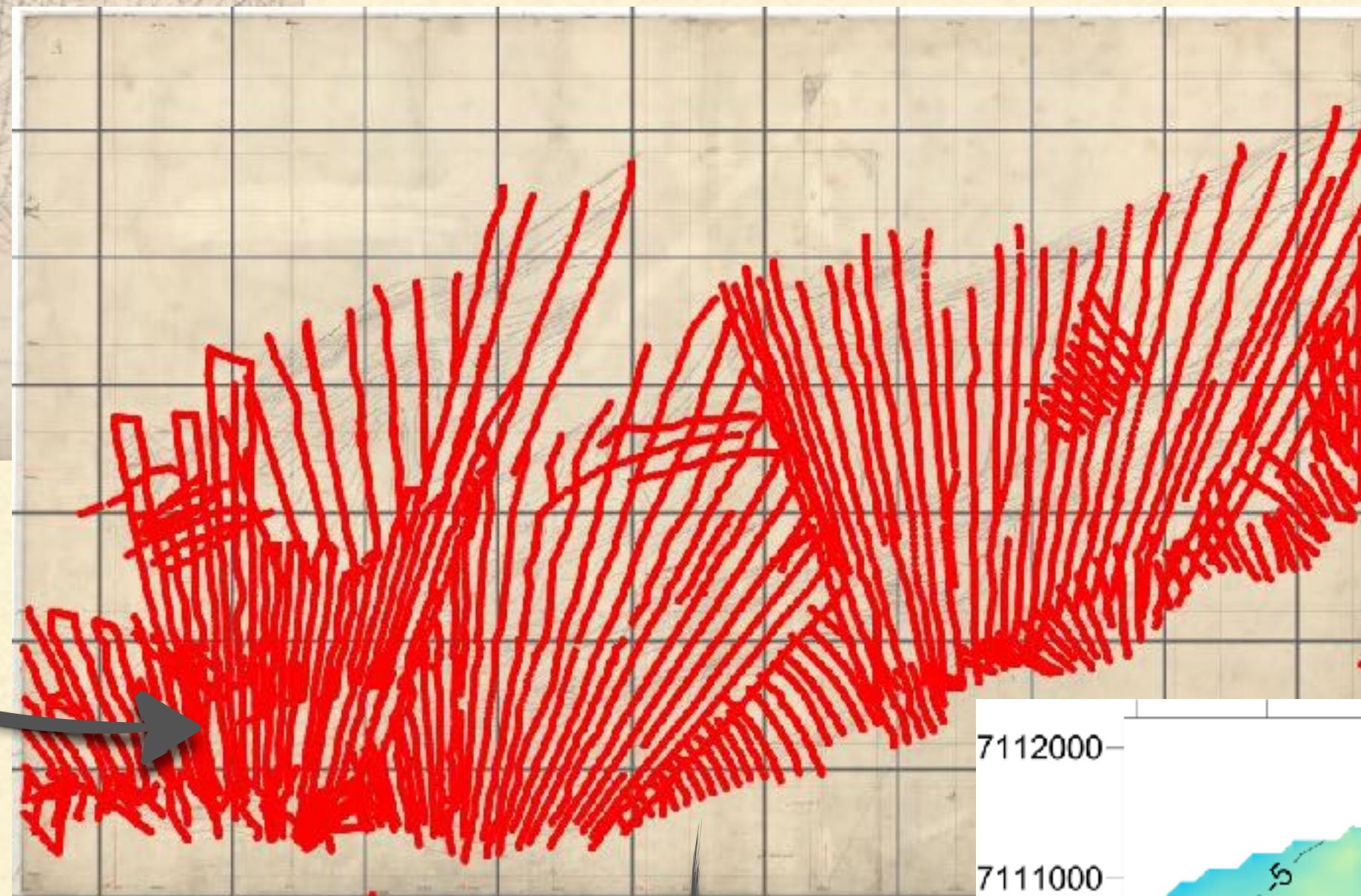
METHODOLOGY



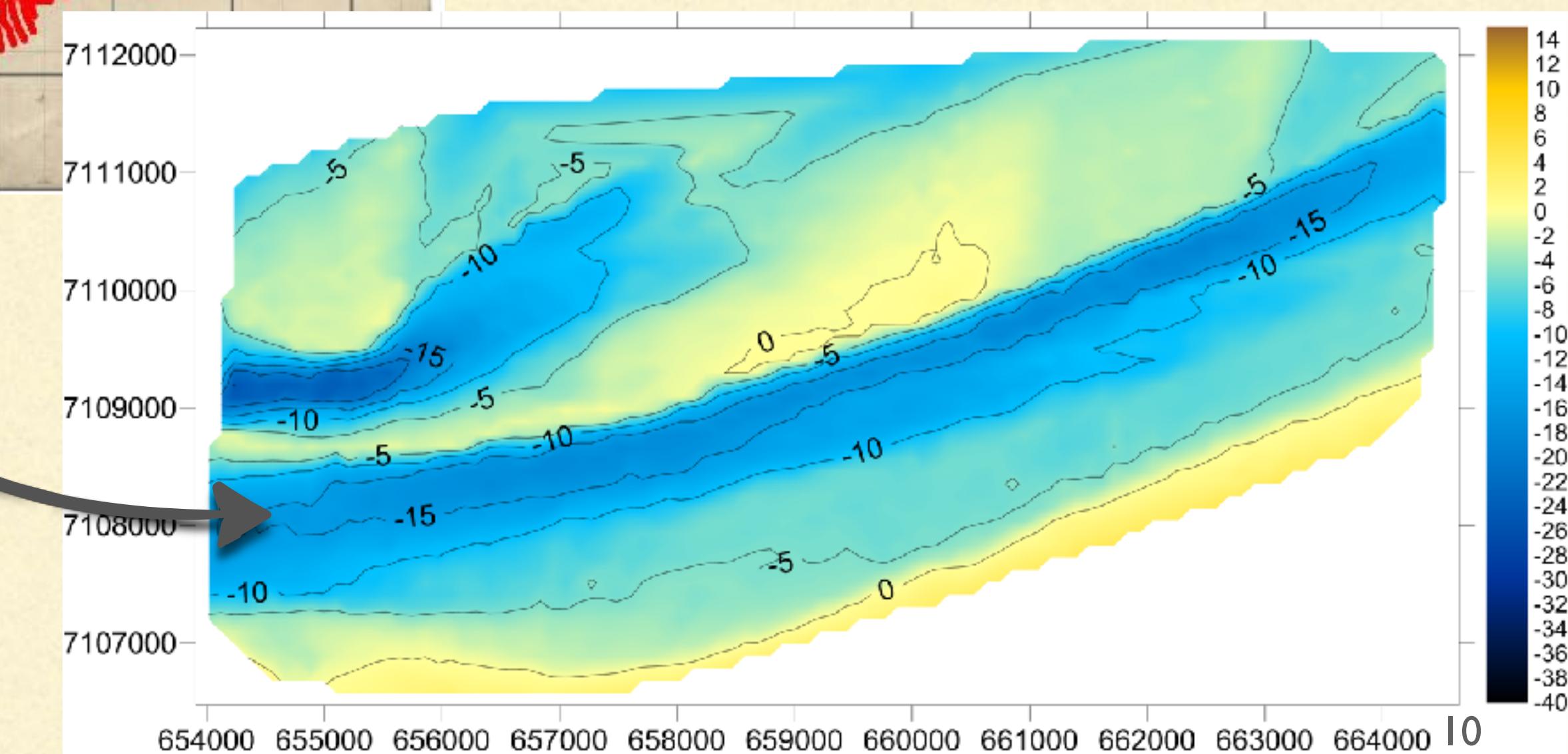
DIGITALIZATION OF OLD BATHYMETRIC CHARTS



ScanBathy
(GEBCO, 2016) :
Depth soundings
digitalization



- Export
- Conversion in present day geodesic system
- Positionning control
- DEMs

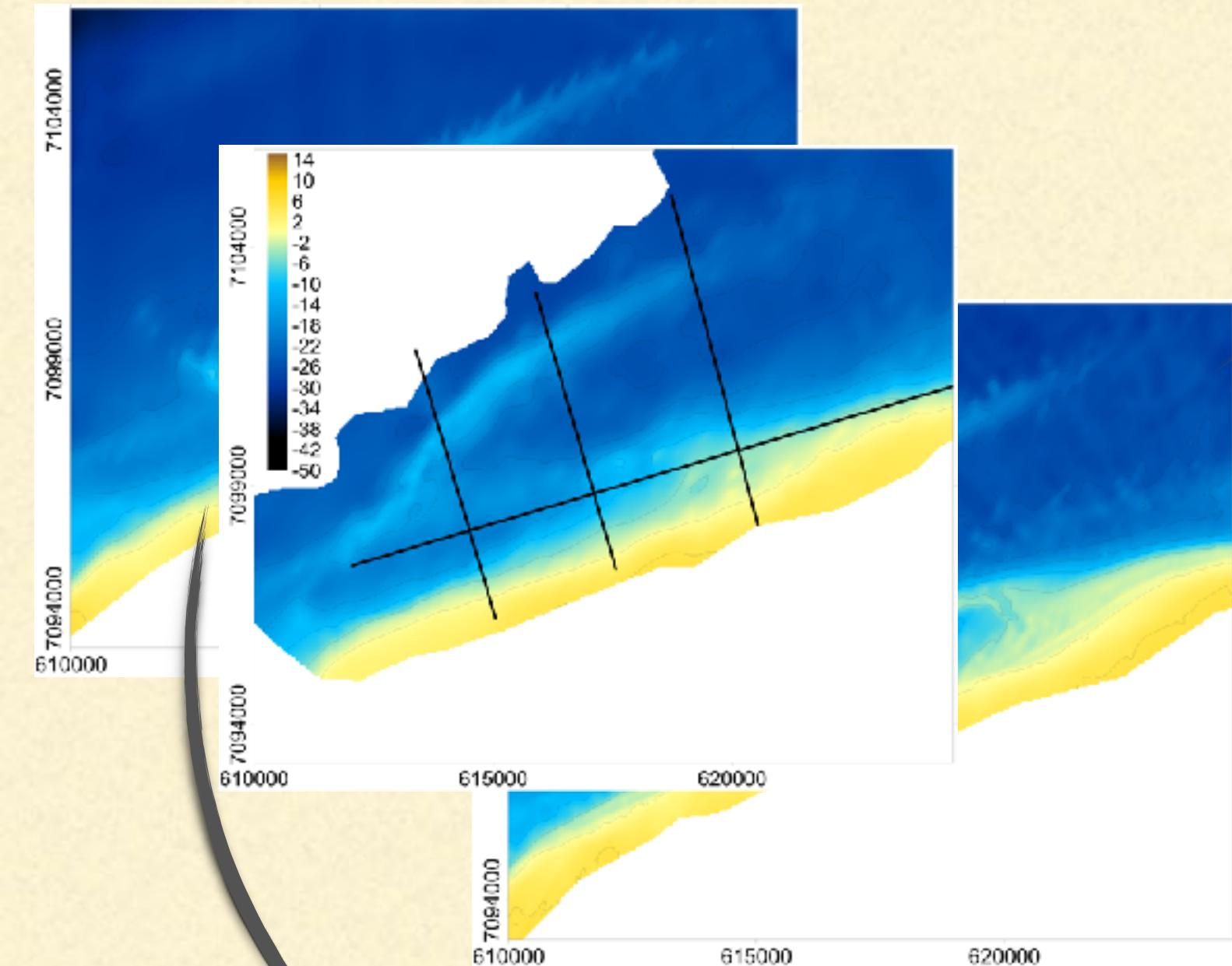


YEAR	SURVEY AREA
1836	Calais
1861	Dunkirk - Gravelines - Calais
1879	Dunkirk - Gravelines - Calais - Wissant
1894	Dunkirk
1910-1911	Dunkirk - Gravelines - Calais - Wissant
1929	Calais
1930-1932	Dunkirk - Gravelines - Calais
1962	Dunkirk
1974-1976	Gravelines - Calais - Wissant
1983	Calais
1994	Calais
2000	Dunkirk
2006	Dunkirk
2009	Calais

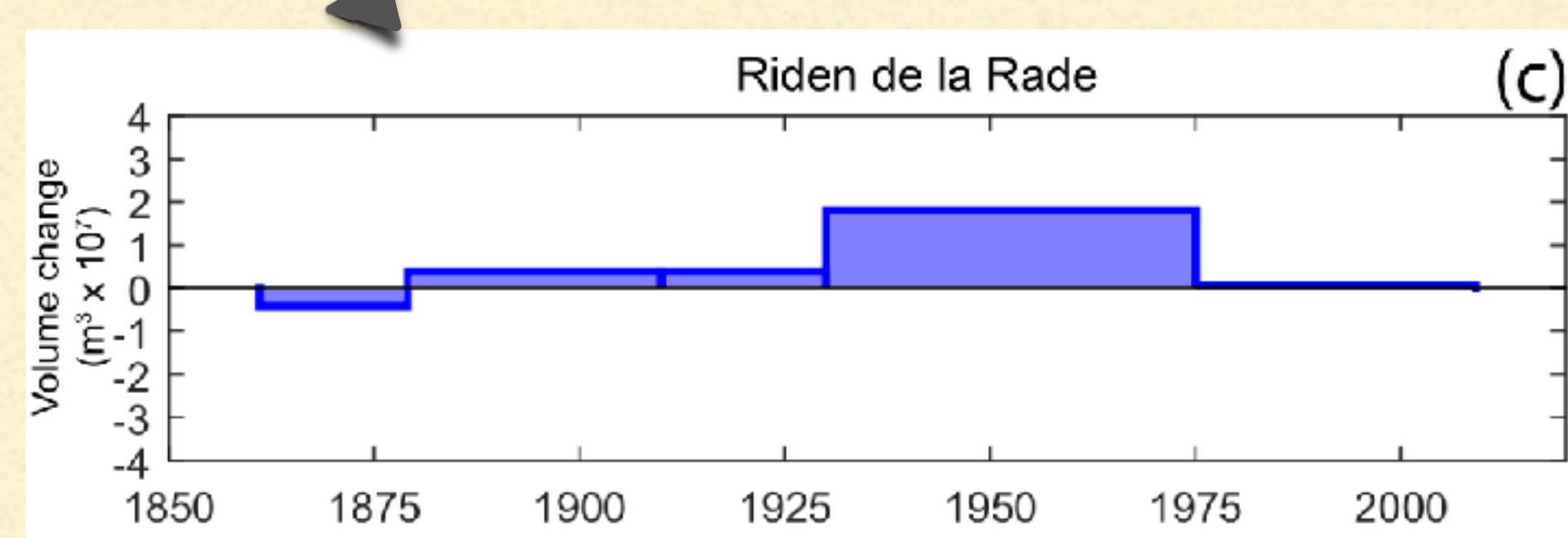
YEAR	SURVEY AREA
1836	Calais
1861	Dunkirk - Gravelines - Calais
1879	Dunkirk - Gravelines - Calais - Wissant
1894	Dunkirk
1910-1911	Dunkirk - Gravelines - Calais - Wissant
192	ais
1930-1962	Gravelines - Calais
1962	Dunkirk
1974-1976	Gravelines - Calais - Wissant
1983	Calais
1994	Calais
2000	Dunkirk
2006	Dunkirk
2009	Calais

~350 000 soundings

QUANTIFICATION OF BATHYMETRIC CHANGES



Cross-shore and long-shore
transects

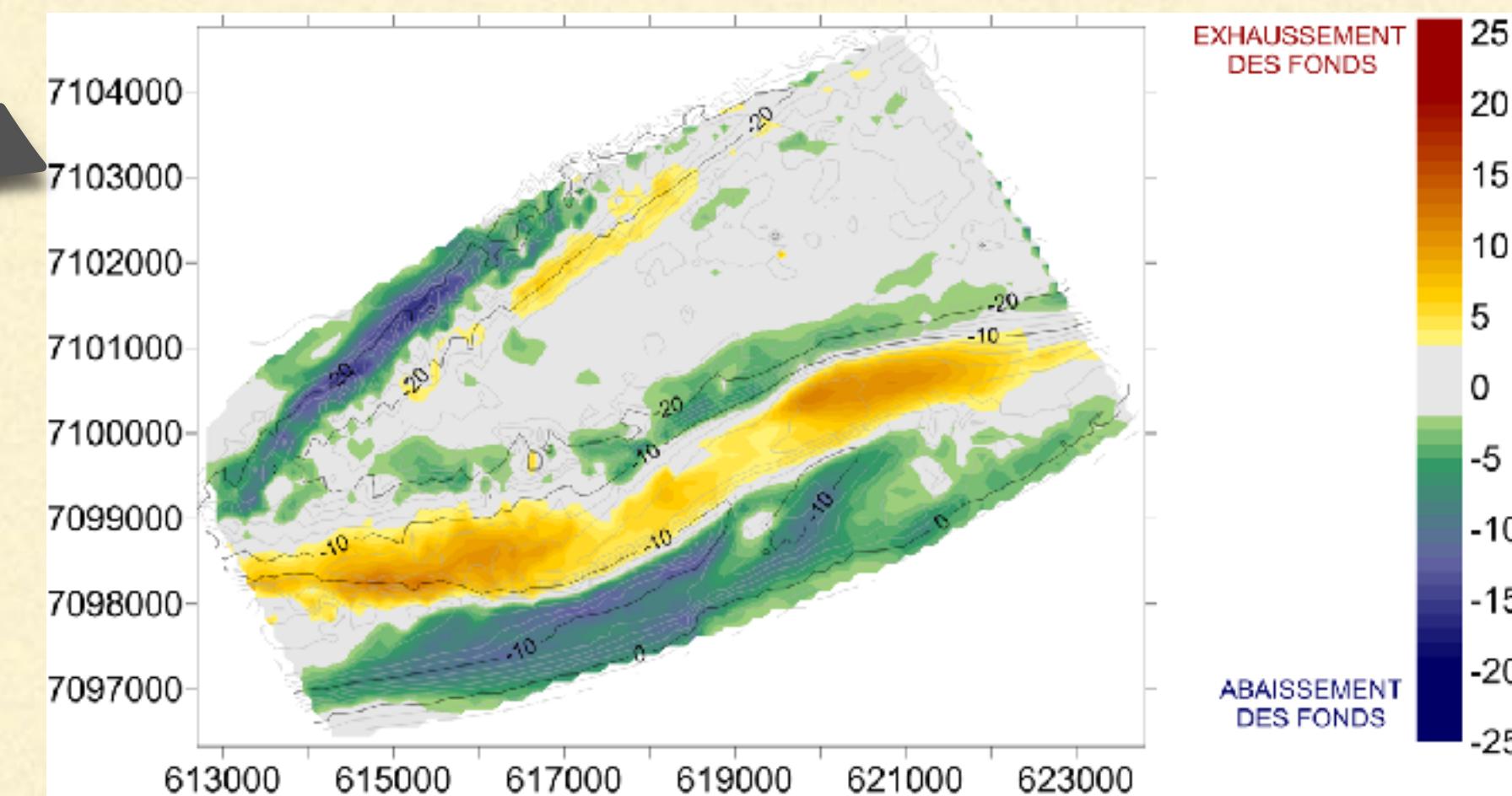
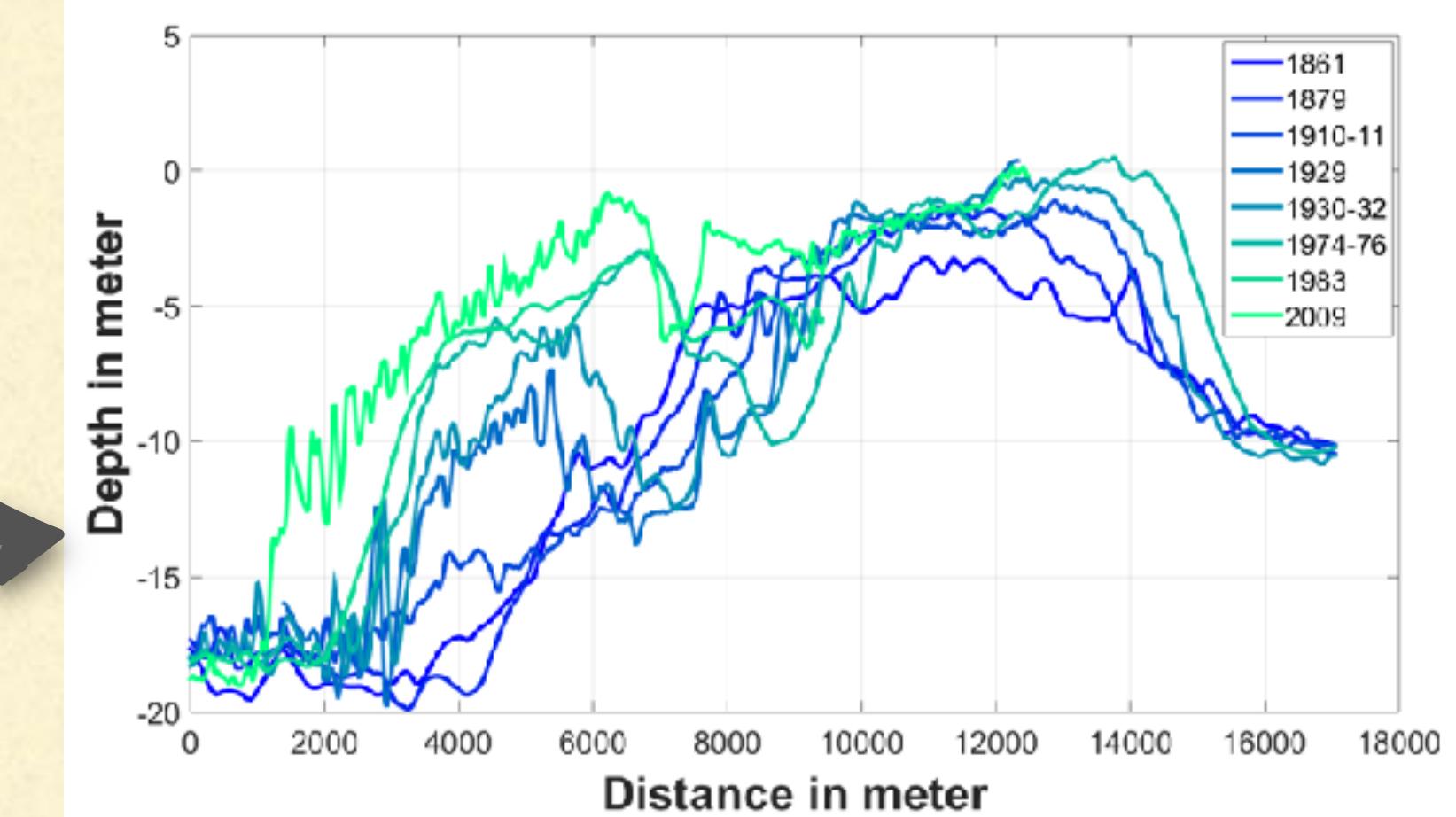


(c)

Volume changes computation



Shoreline digitalization



Bathymetric
difference map

NUMERICAL MODEL

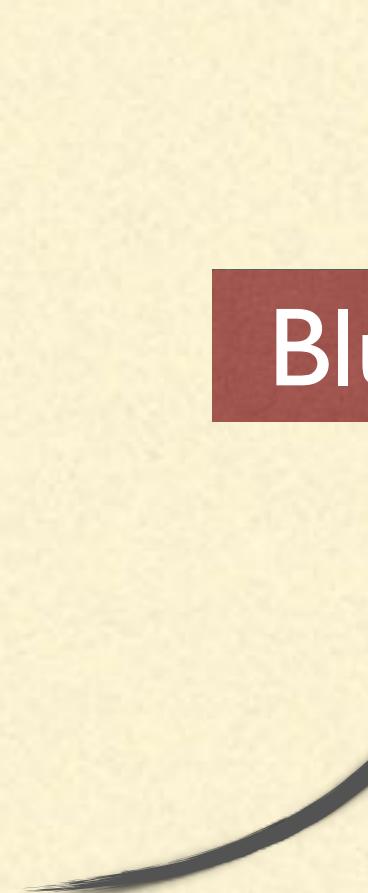
open TELEMAC-MASCARET
The mathematically superior suite of solvers

- TELEMAC 3D : finite element model simulate tidal propagation for different bathymetric settings
- Three-dimensional equations : transport-diffusion equation + Navier-Stockes equations + hydrostatic pressure hypothesis

YEAR	SURVEY AREA
1836	Calais
1861	Dunkirk - Gravelines - Calais
1879	Dunkirk - Gravelines - Calais - Wissant
1894	Dunkirk
1910-1911	Dunkirk - Gravelines - Calais - Wissant
1929	Calais
1930-1932	Dunkirk - Gravelines - Calais
1962	Dunkirk
1974-1976	Gravelines - Calais - Wissant
1983	Calais
1994	Calais
2000	Dunkirk
2006	Dunkirk
2009	Calais

NUMERICAL MODEL

Historical
shoreline



Blue Kenue

Geometry file
+
Boundary
condition file

Cst-France

TELEMAC
Cf calibration

Tidal currents



Sea surface
height



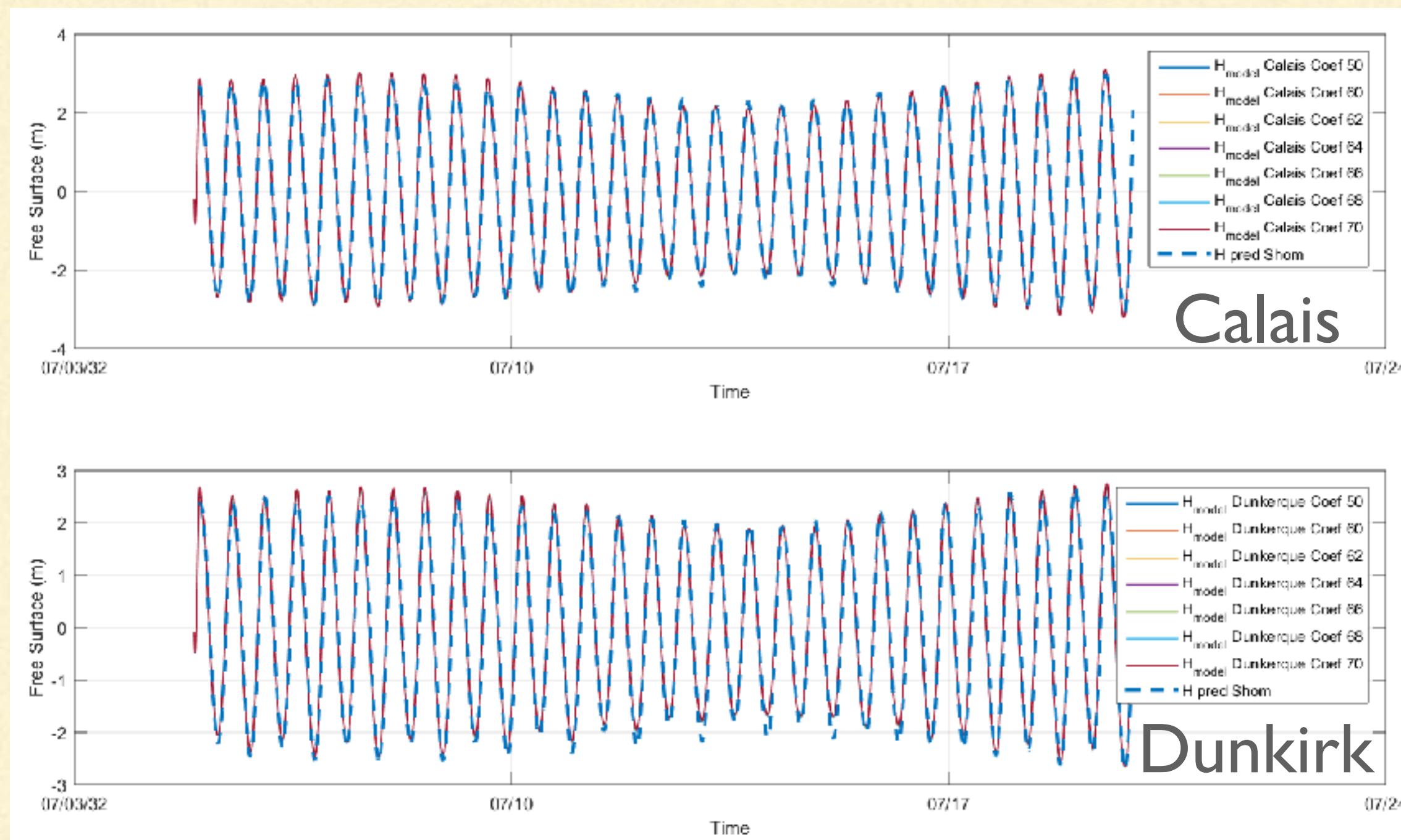
Comparison
 h_{model} and
 h_{pred} (MAS)

Comparison
current_model
and current_obs

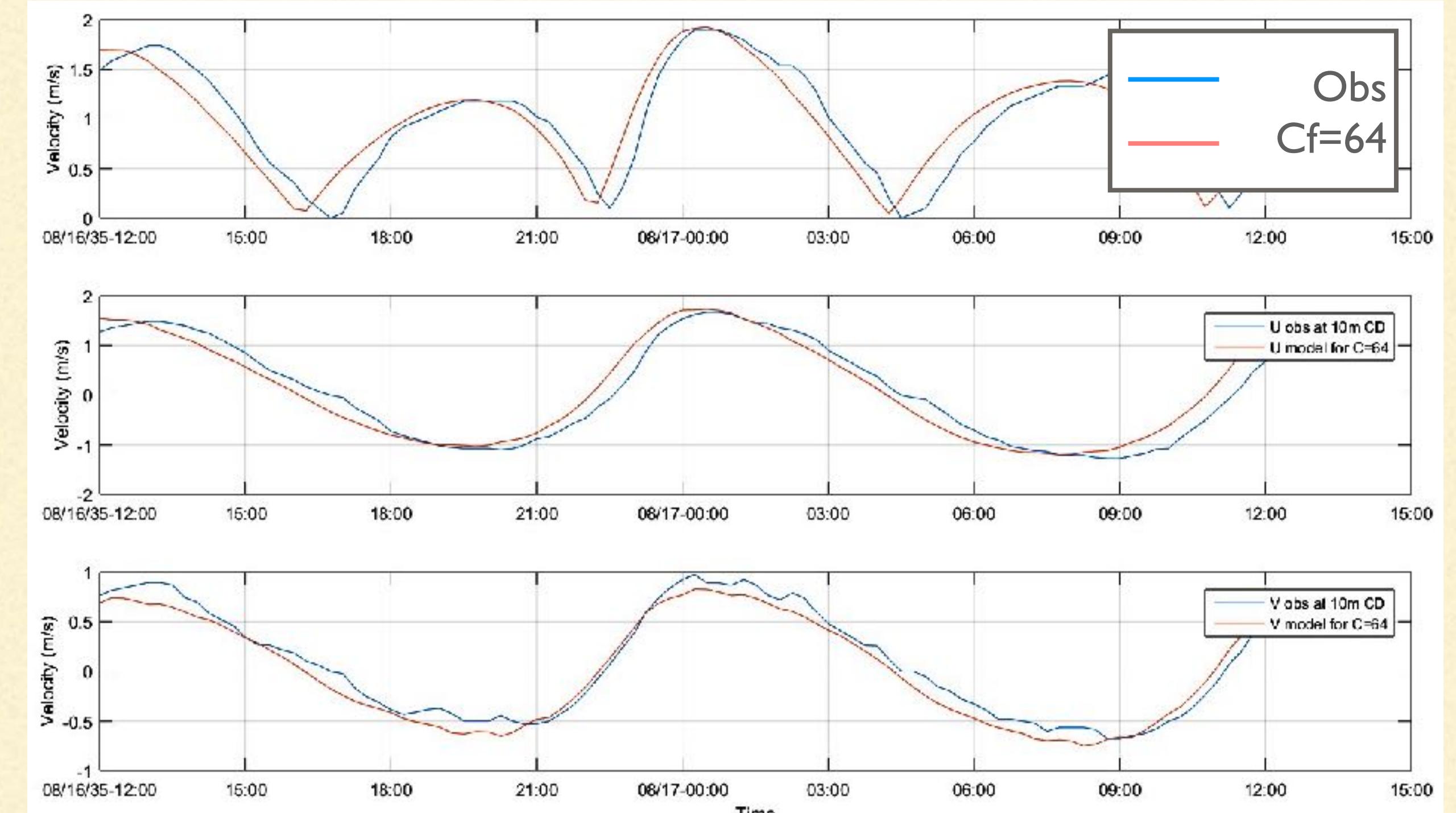
1930 MODEL : VALIDATION

VALIDATION - FRICTION COEFF : 64

- Sea surface height :
 - Mean range difference < 5.5 cm (< 2%)
 - Phase shift HT & LT < 2min

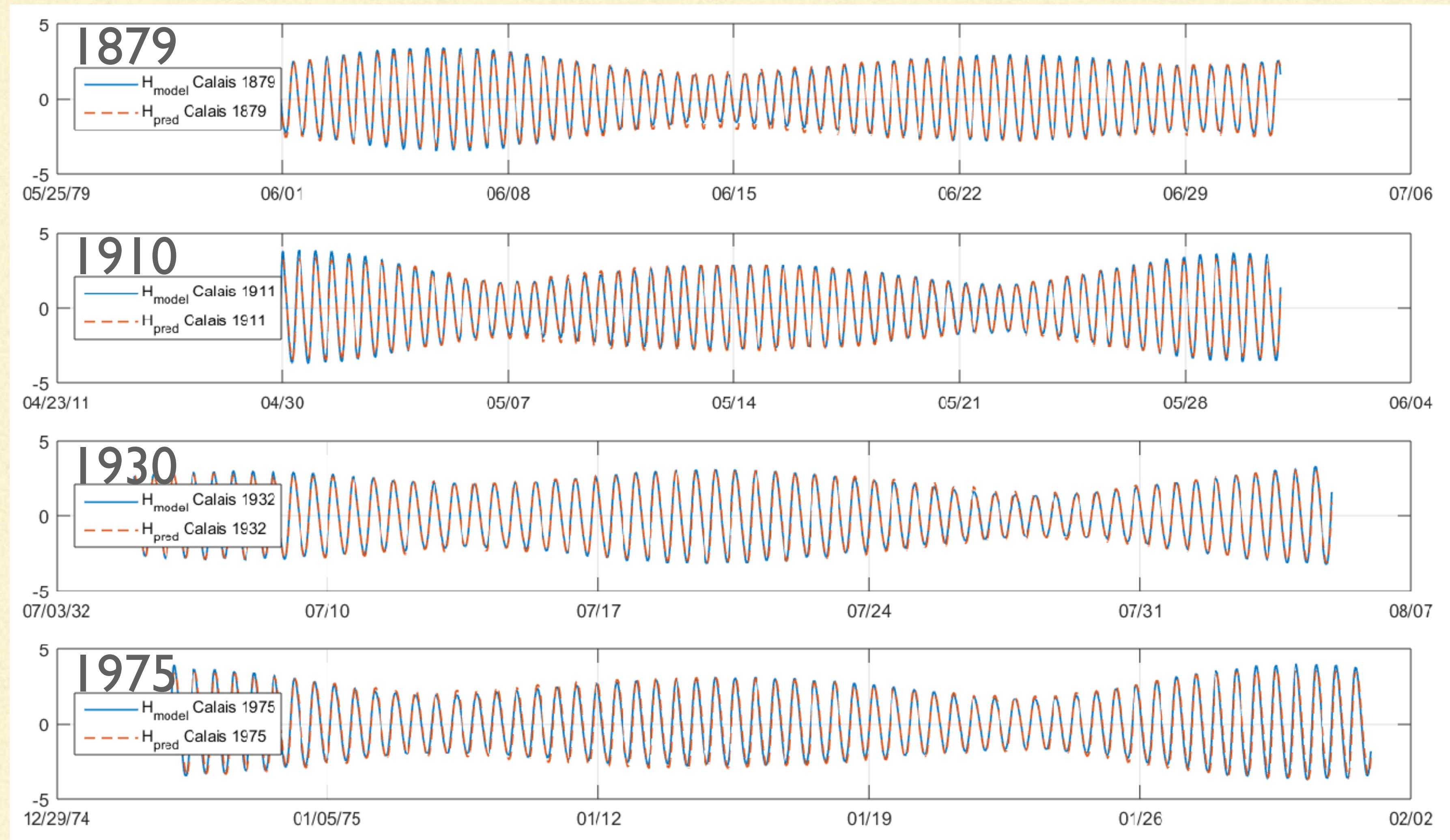


- Tidal currents :
 - Mean velocity difference : < 3 cm.s⁻¹ (< 1%)
 - Phase shift Flood & Ebb < 25 min



VERIFICATION

- Mean range difference < 10 cm
- Phase shift < 05 min
(except Low-Tide of 1975 model ~12 min)

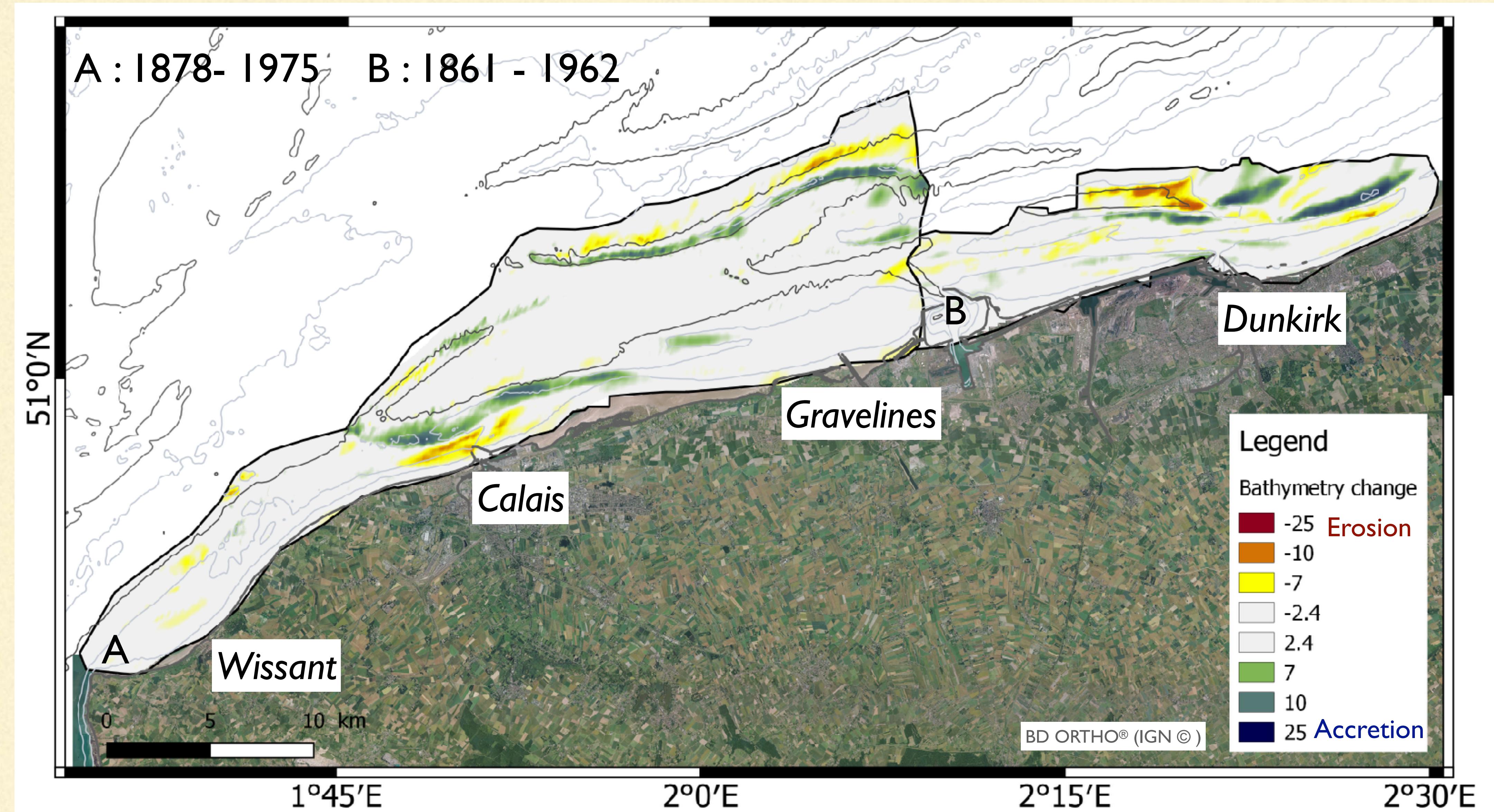


RESULTS

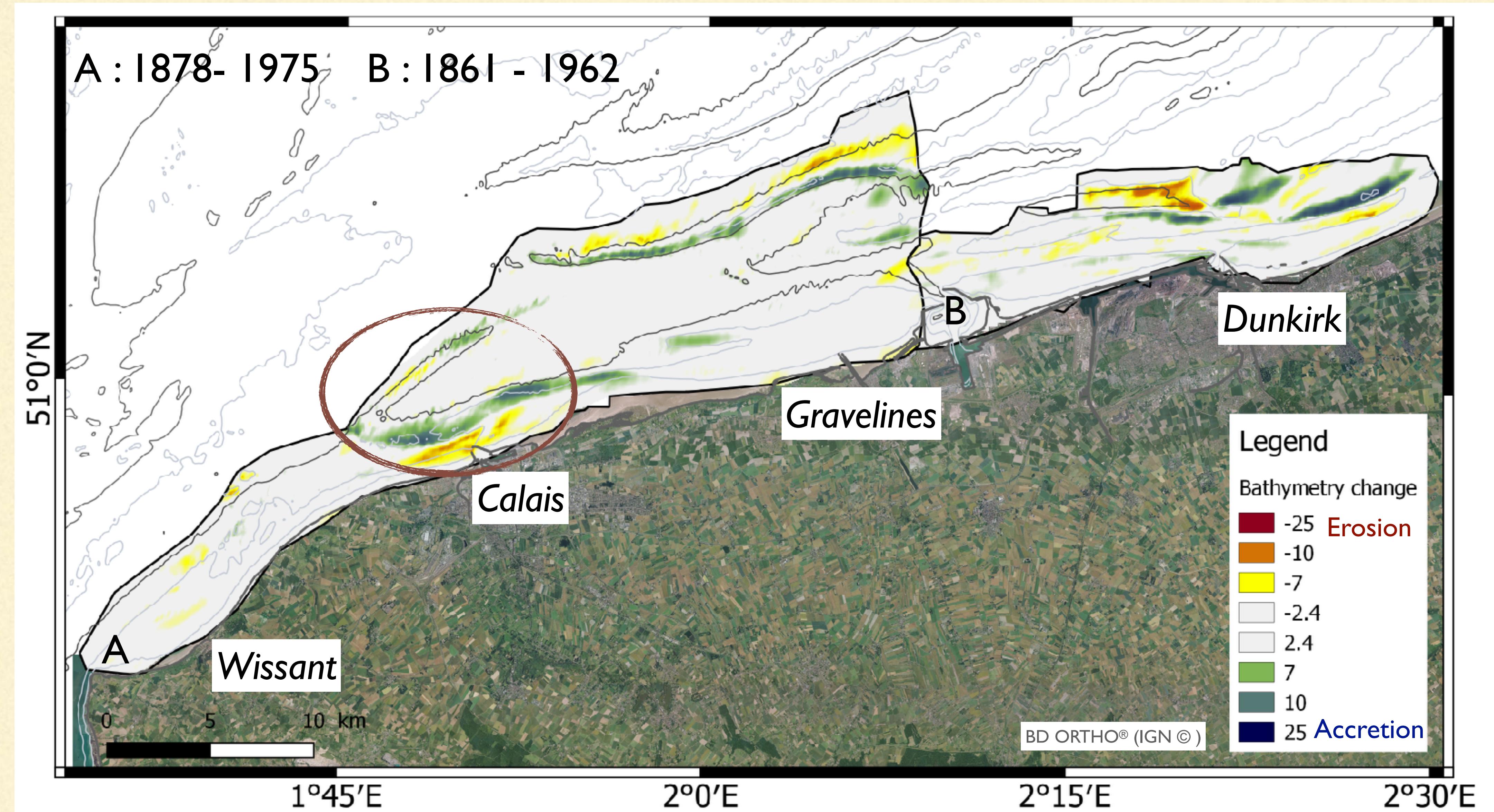
Bathymetry changes



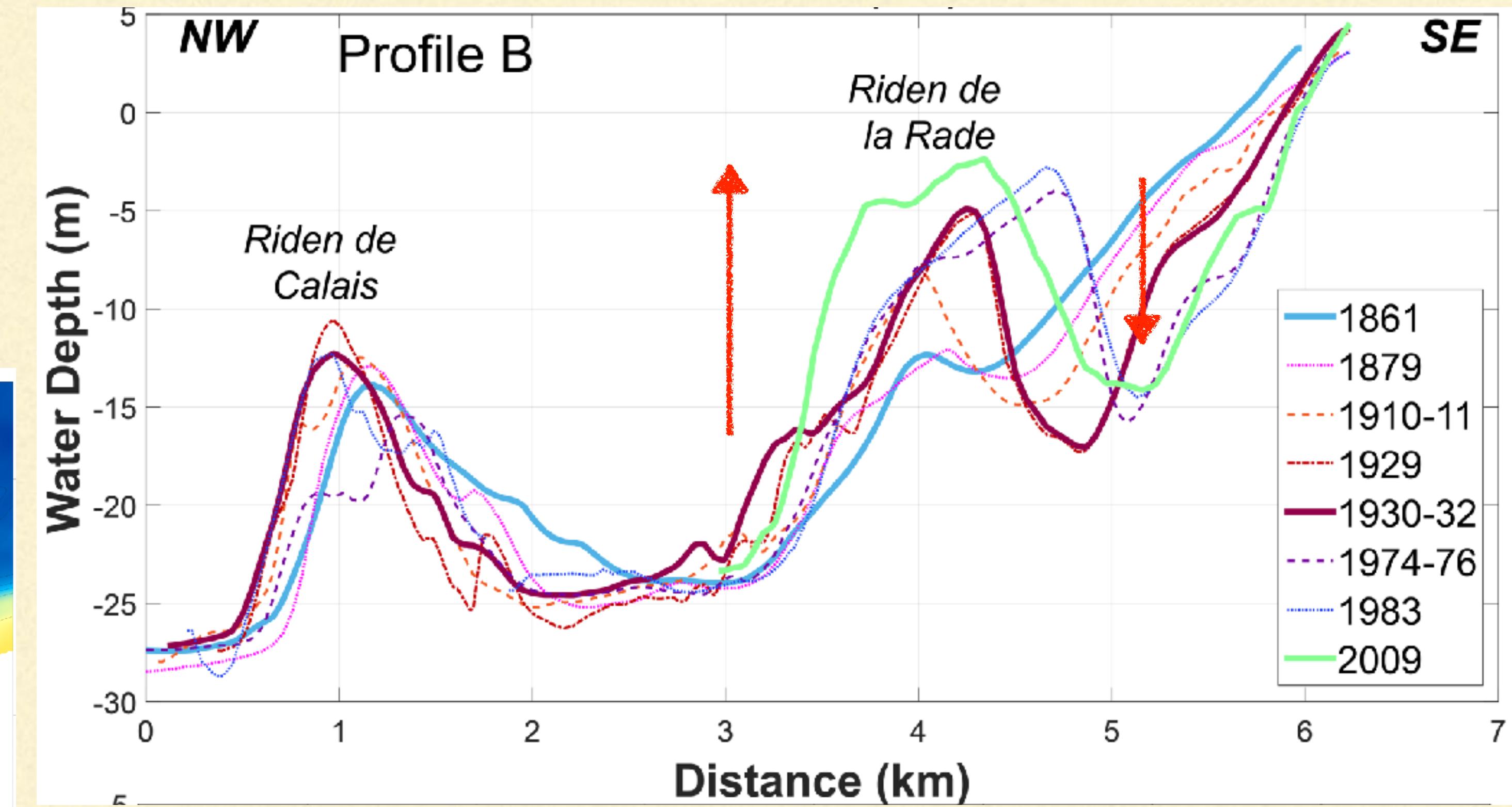
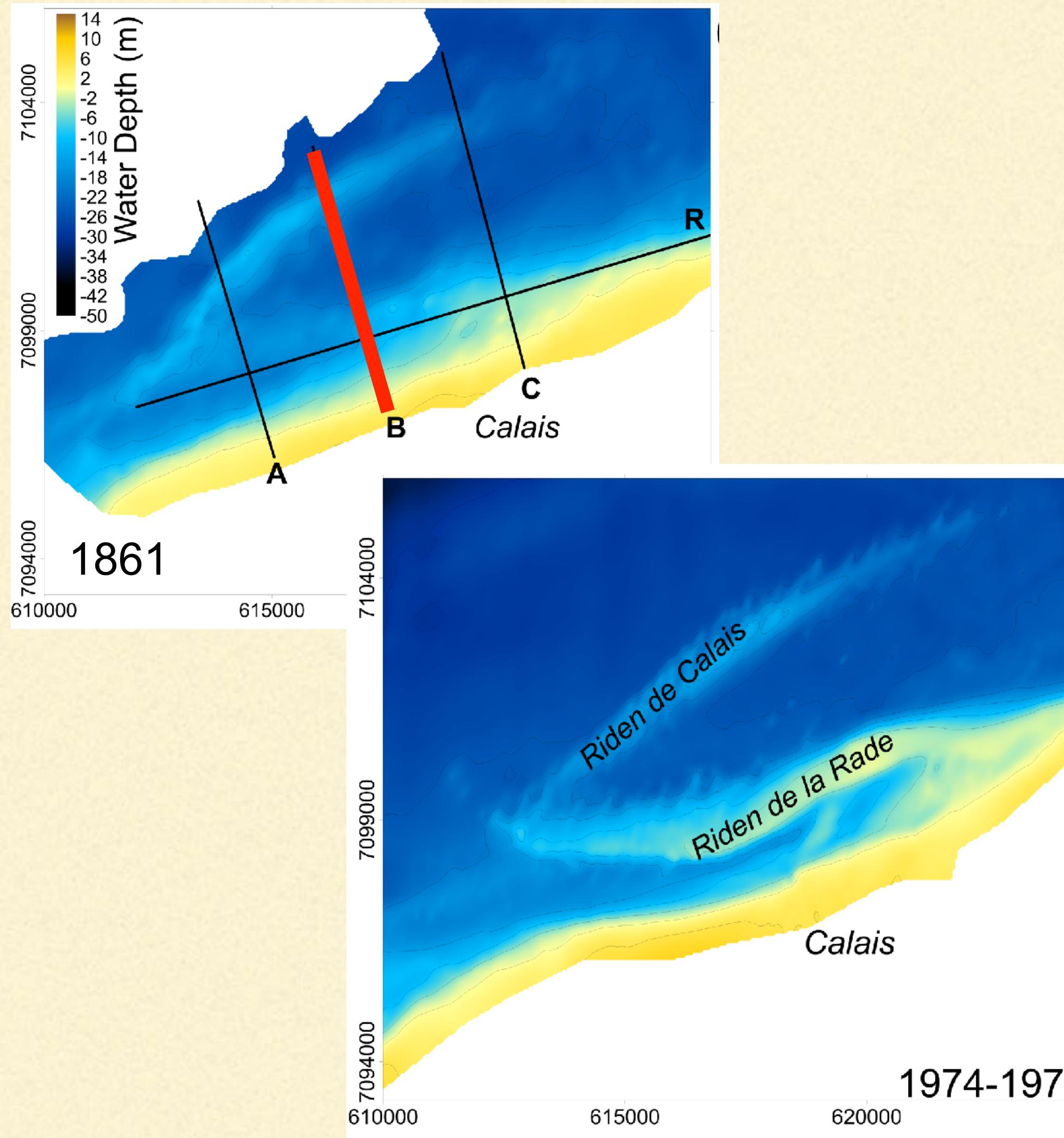
REGIONAL EVOLUTION



REGIONAL EVOLUTION

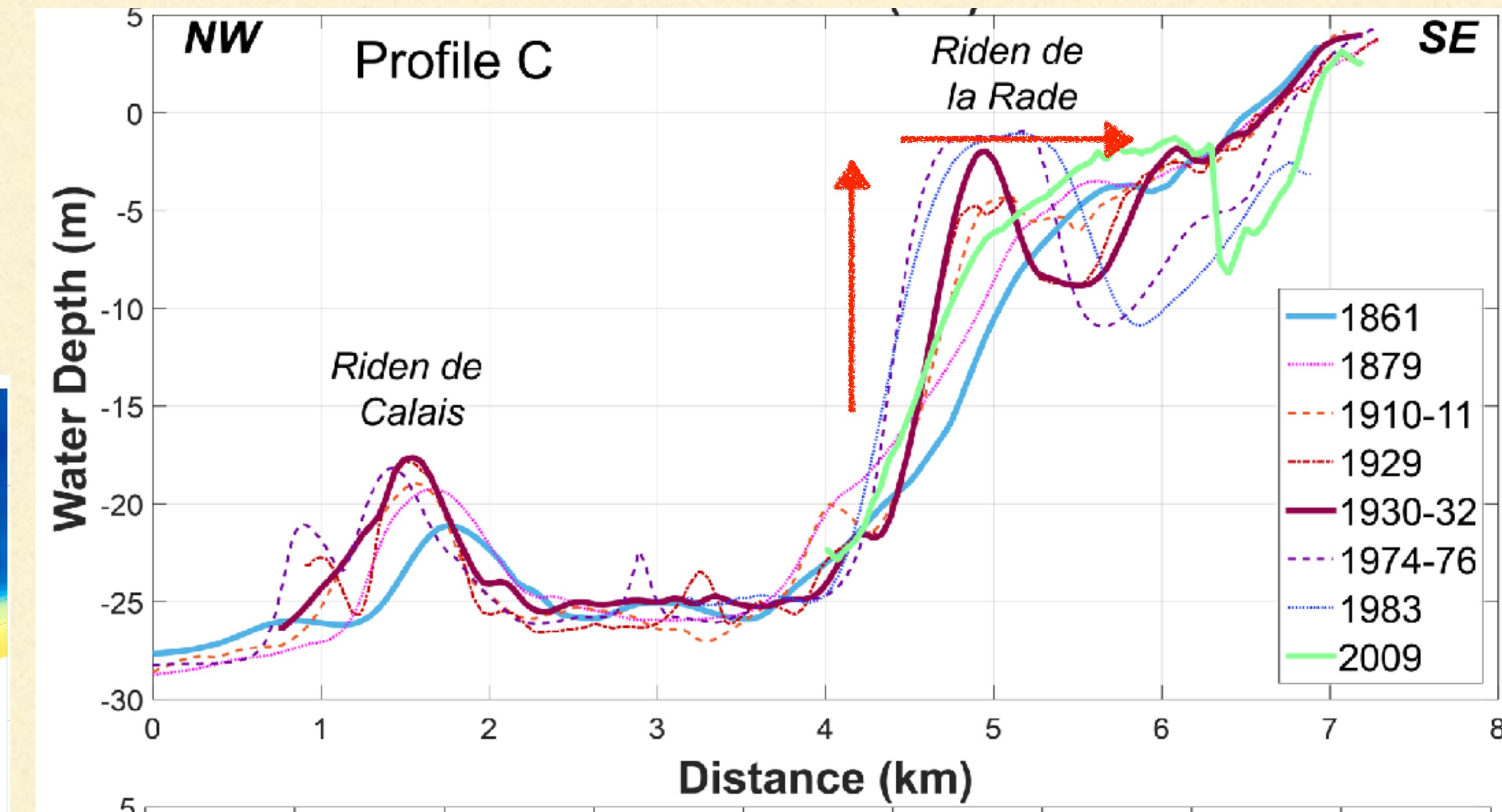
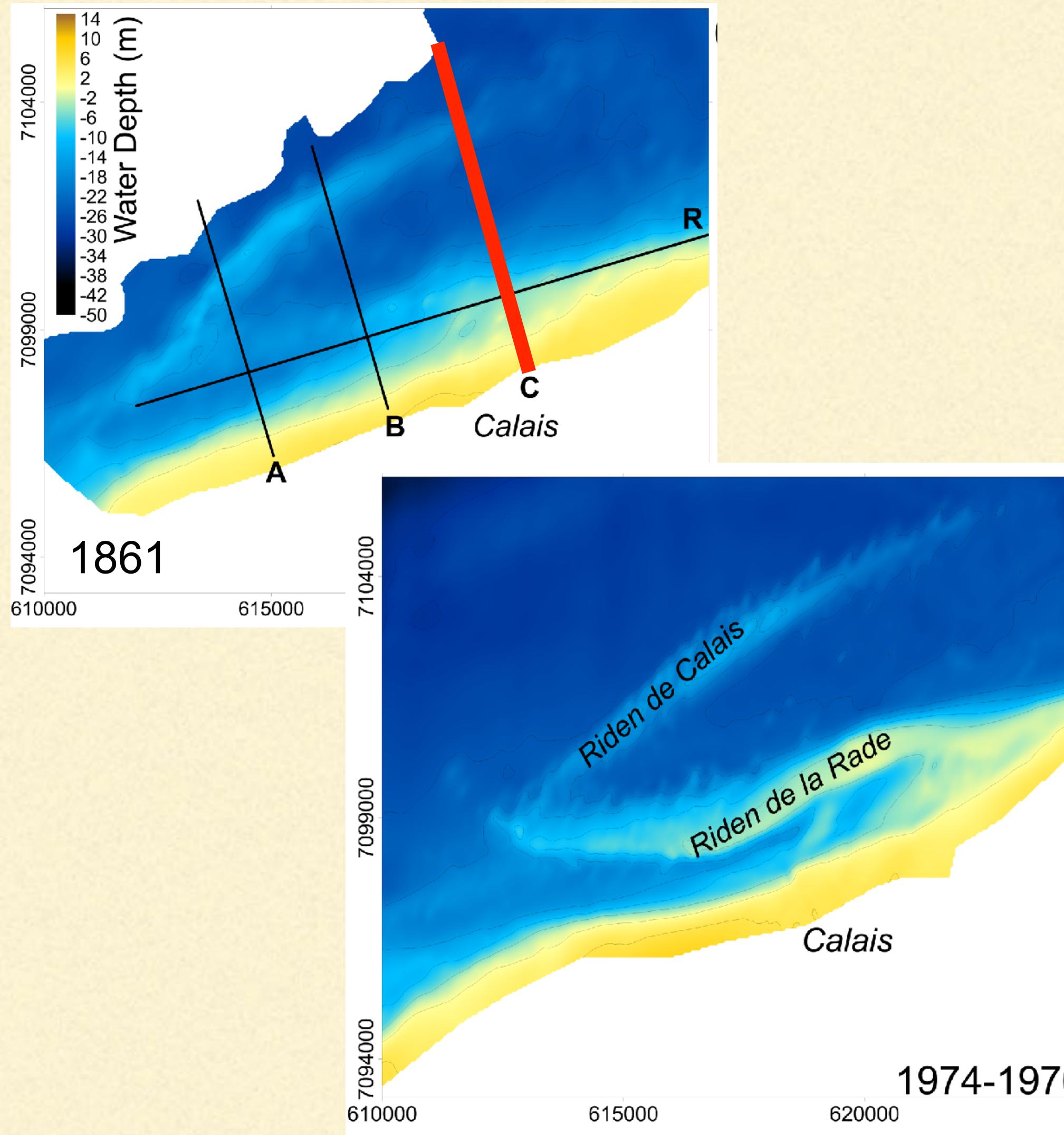


ZOOM : CALAIS NEARSHORE

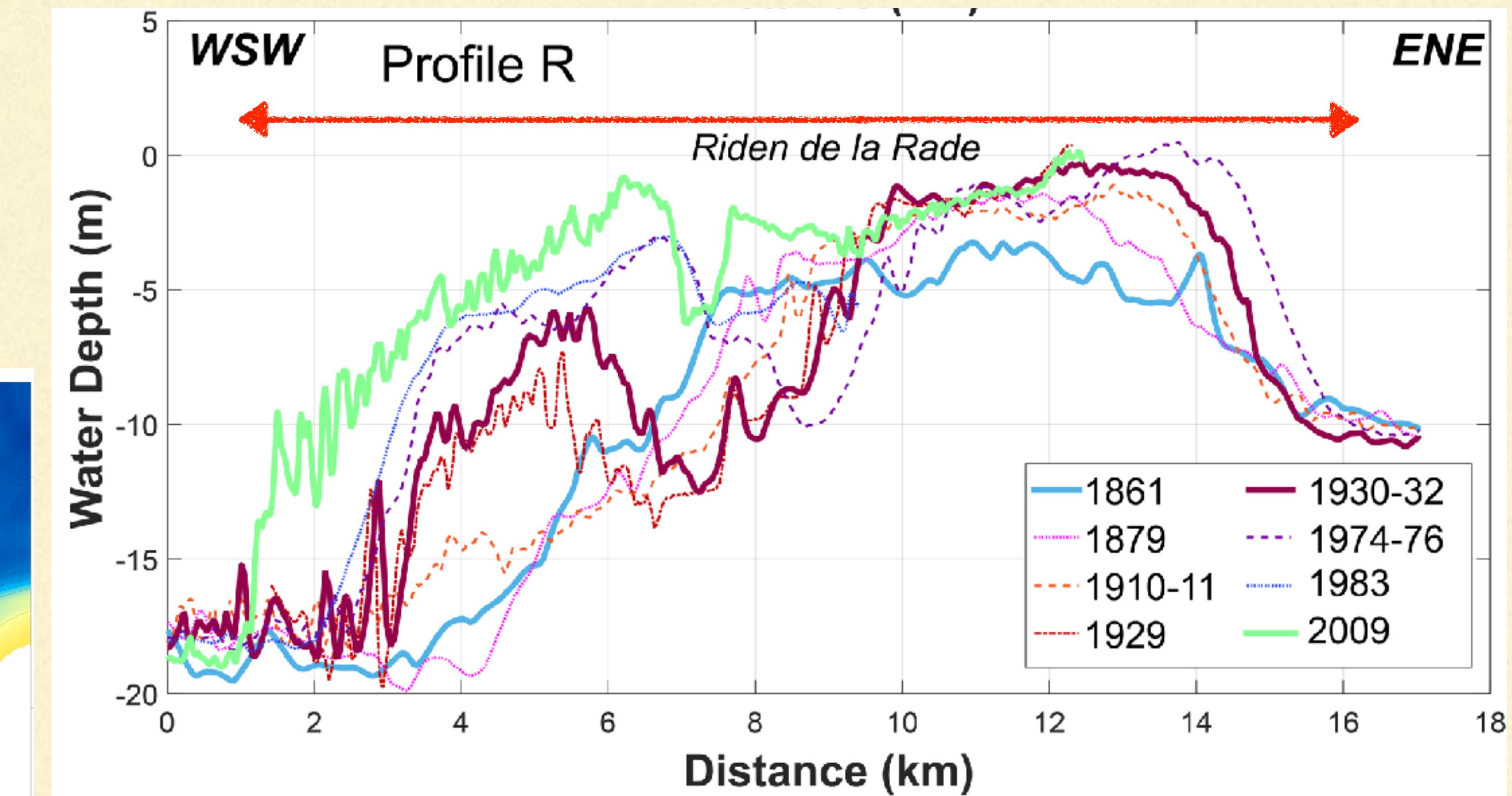
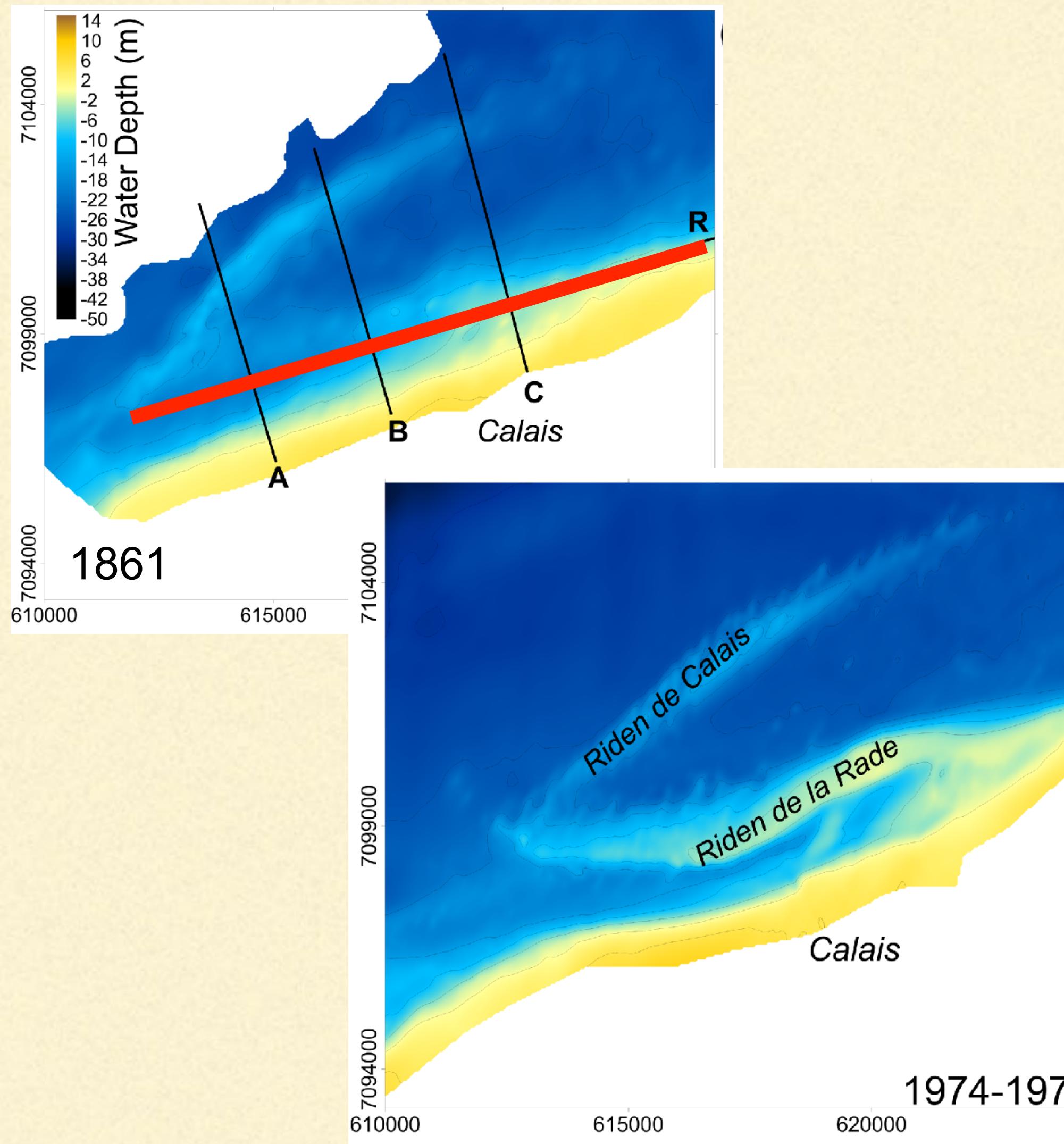


(Latapy et al., 2019)

ZOOM : CALAIS NEARSHORE



ZOOM : CALAIS NEARSHORE



(Latapy et al., 2019)

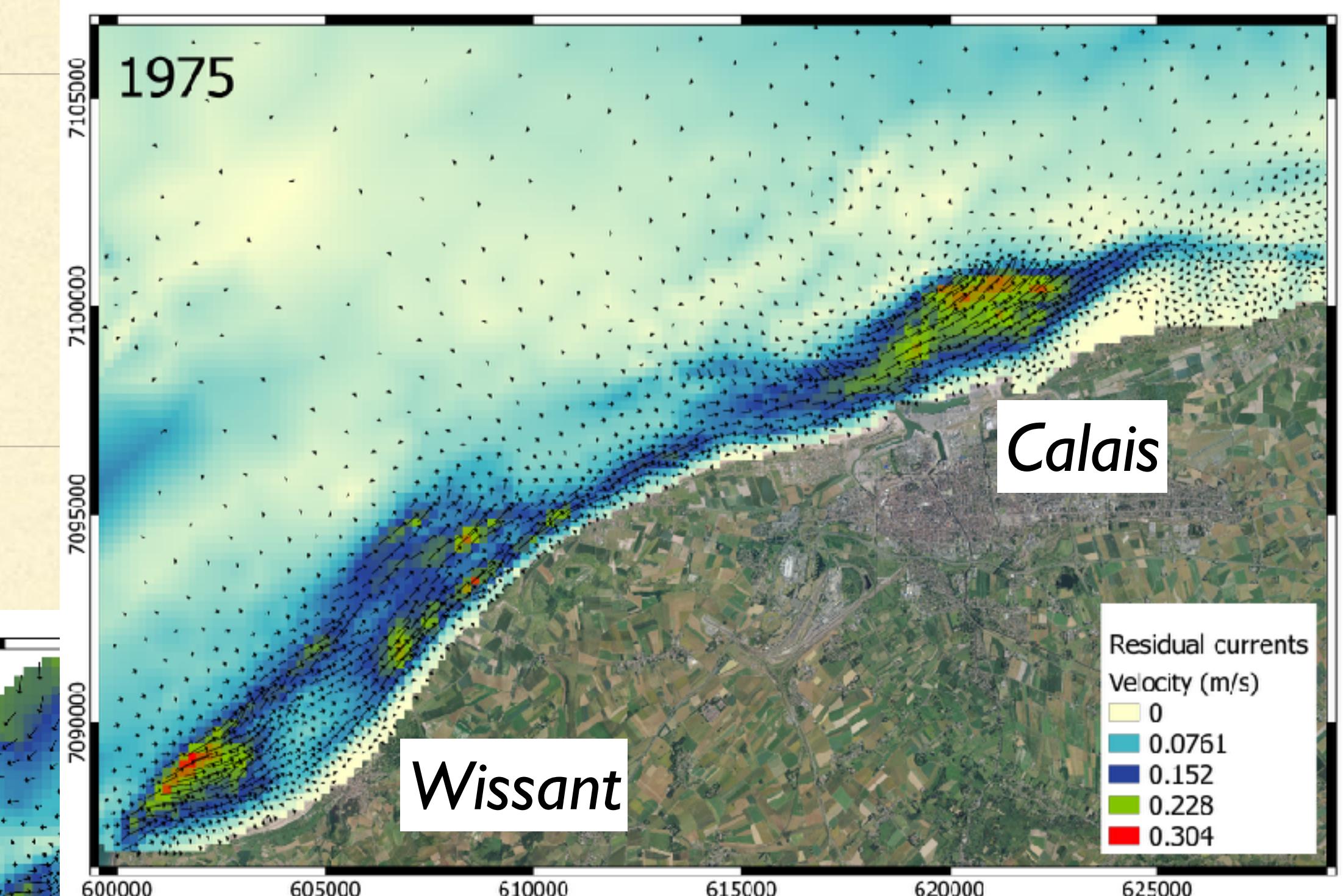
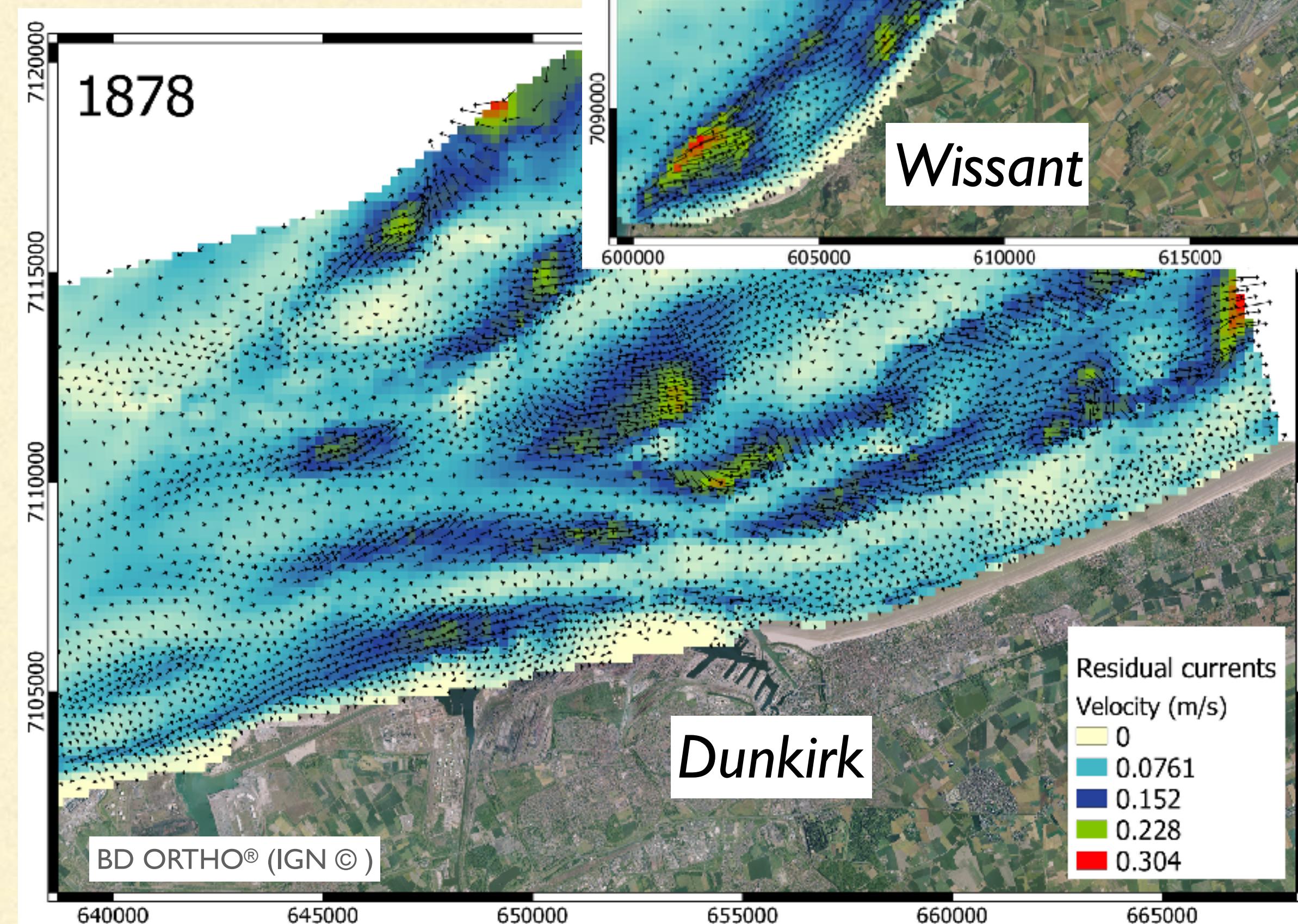
RESULTS

Hydrodynamic circulation

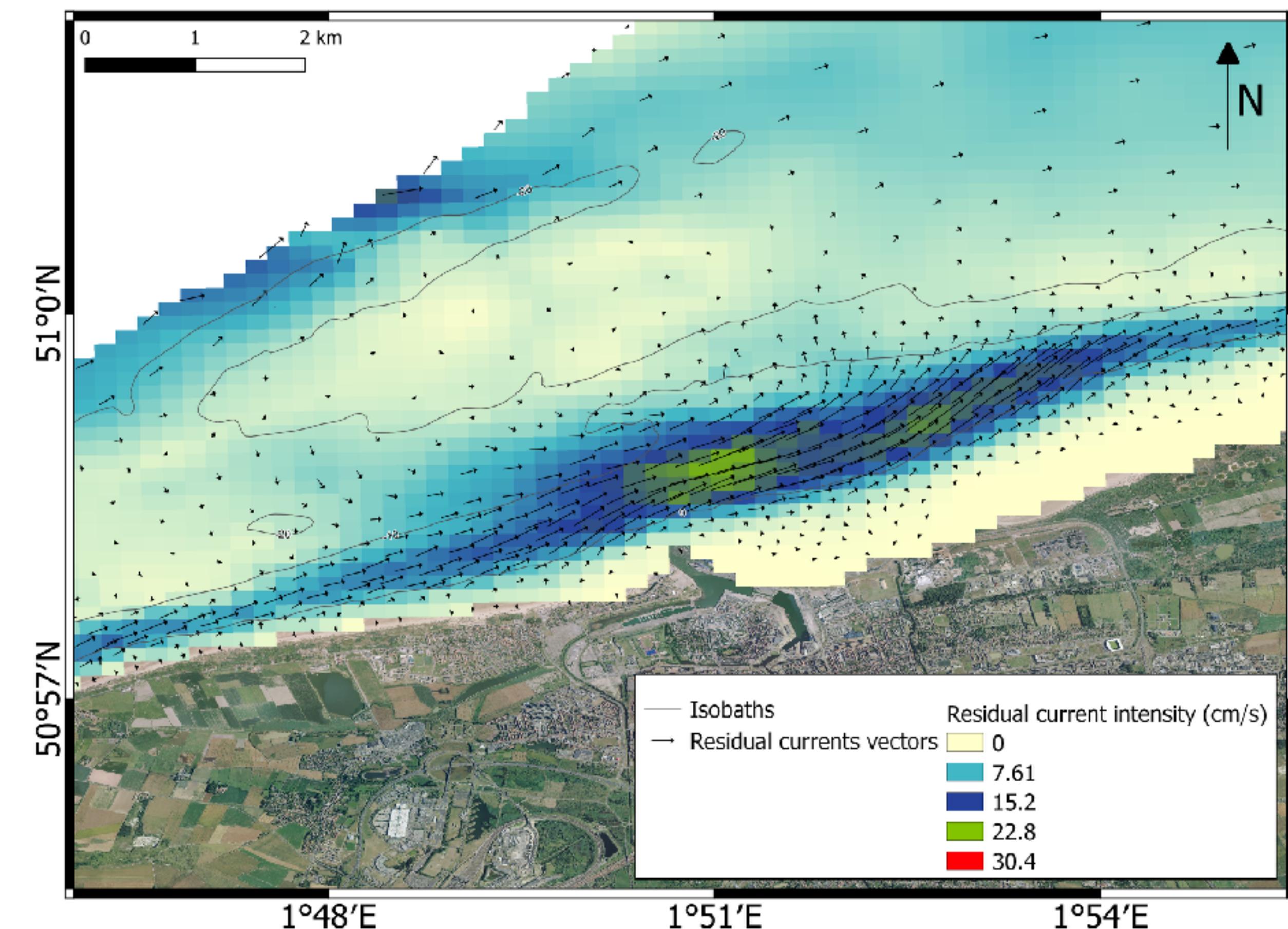
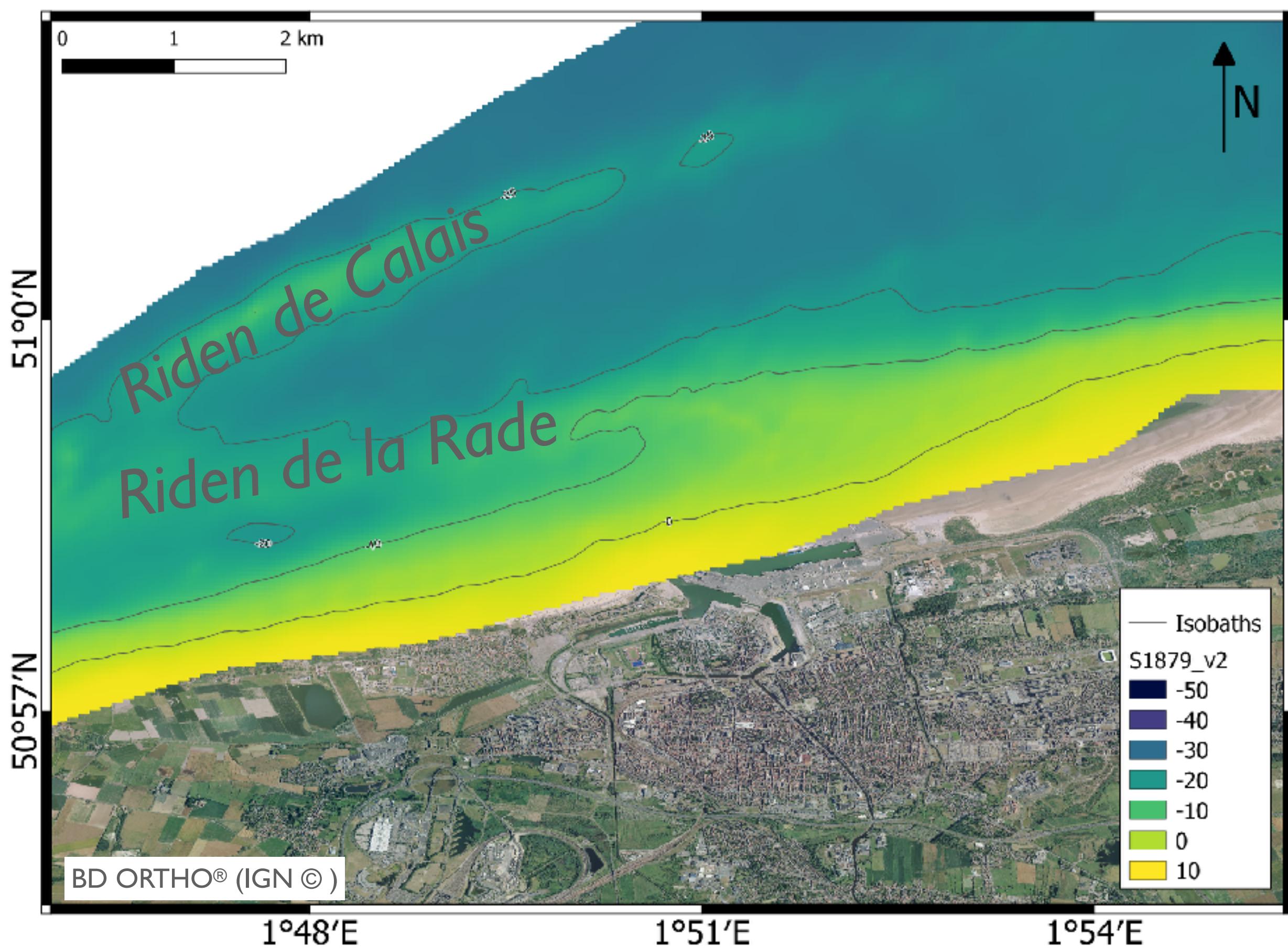


TIDAL SIMULATION

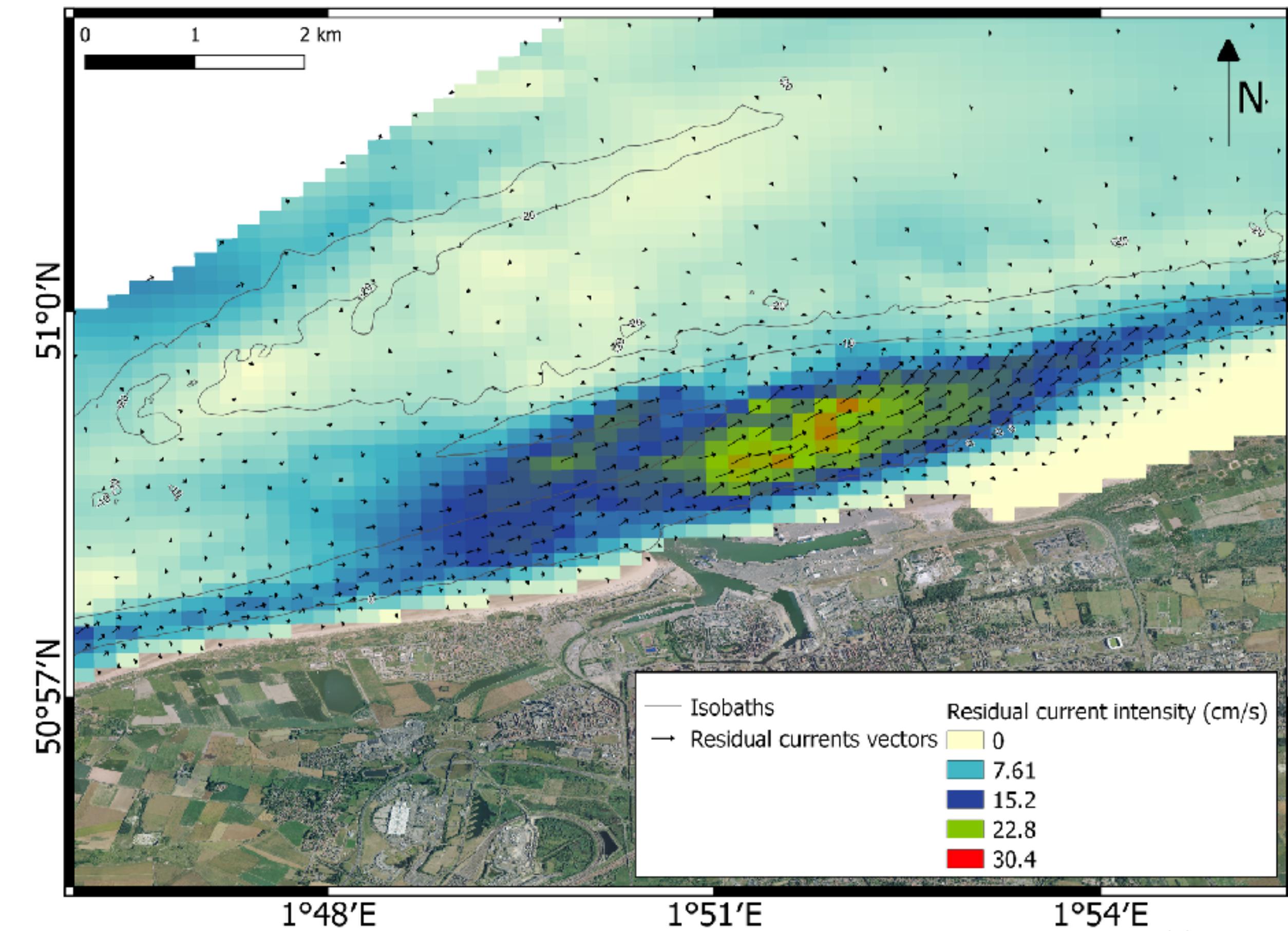
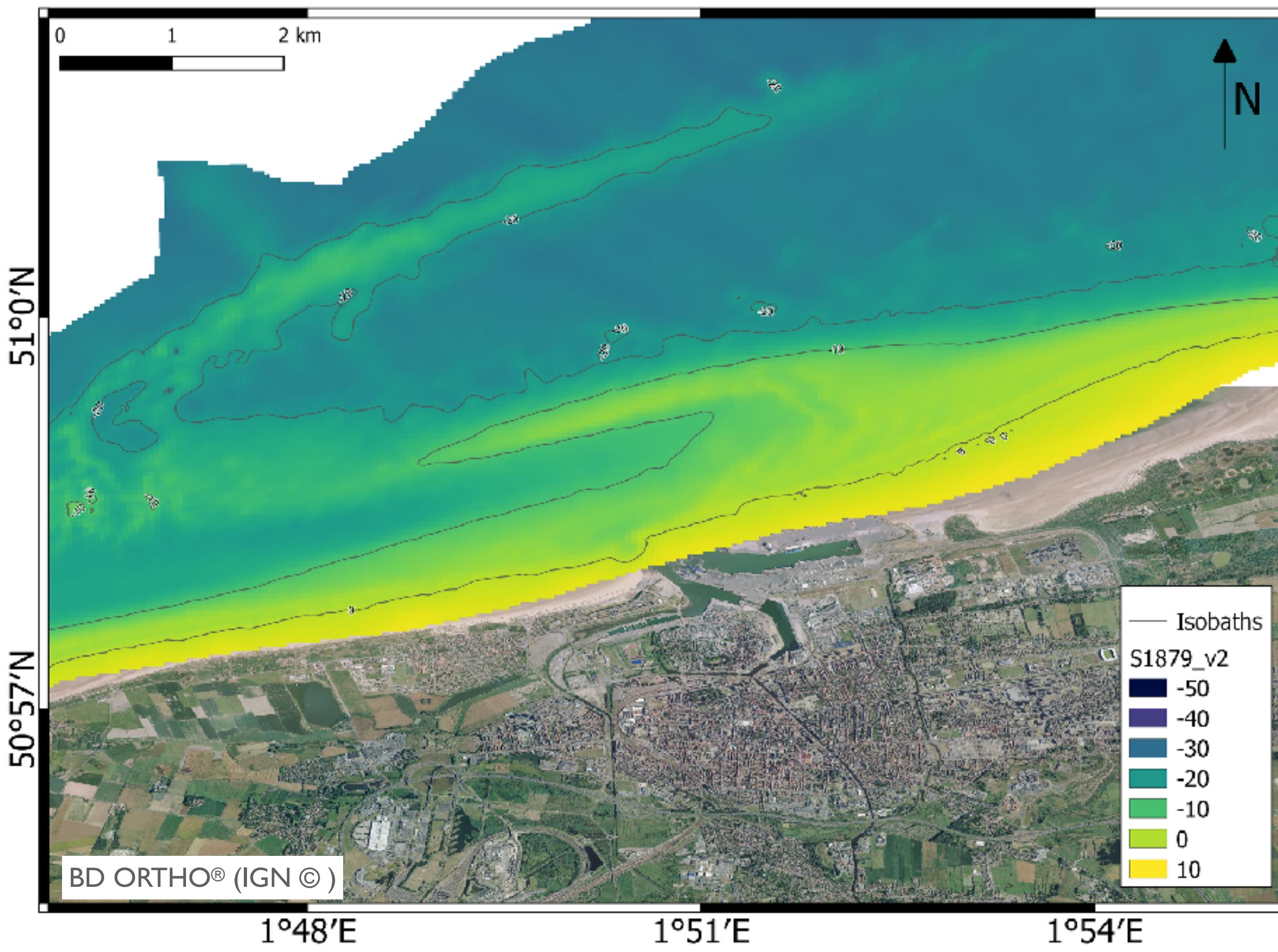
- 01/03/2015 → 15/04/2015 (equinox tides)
- Residuals currents computation



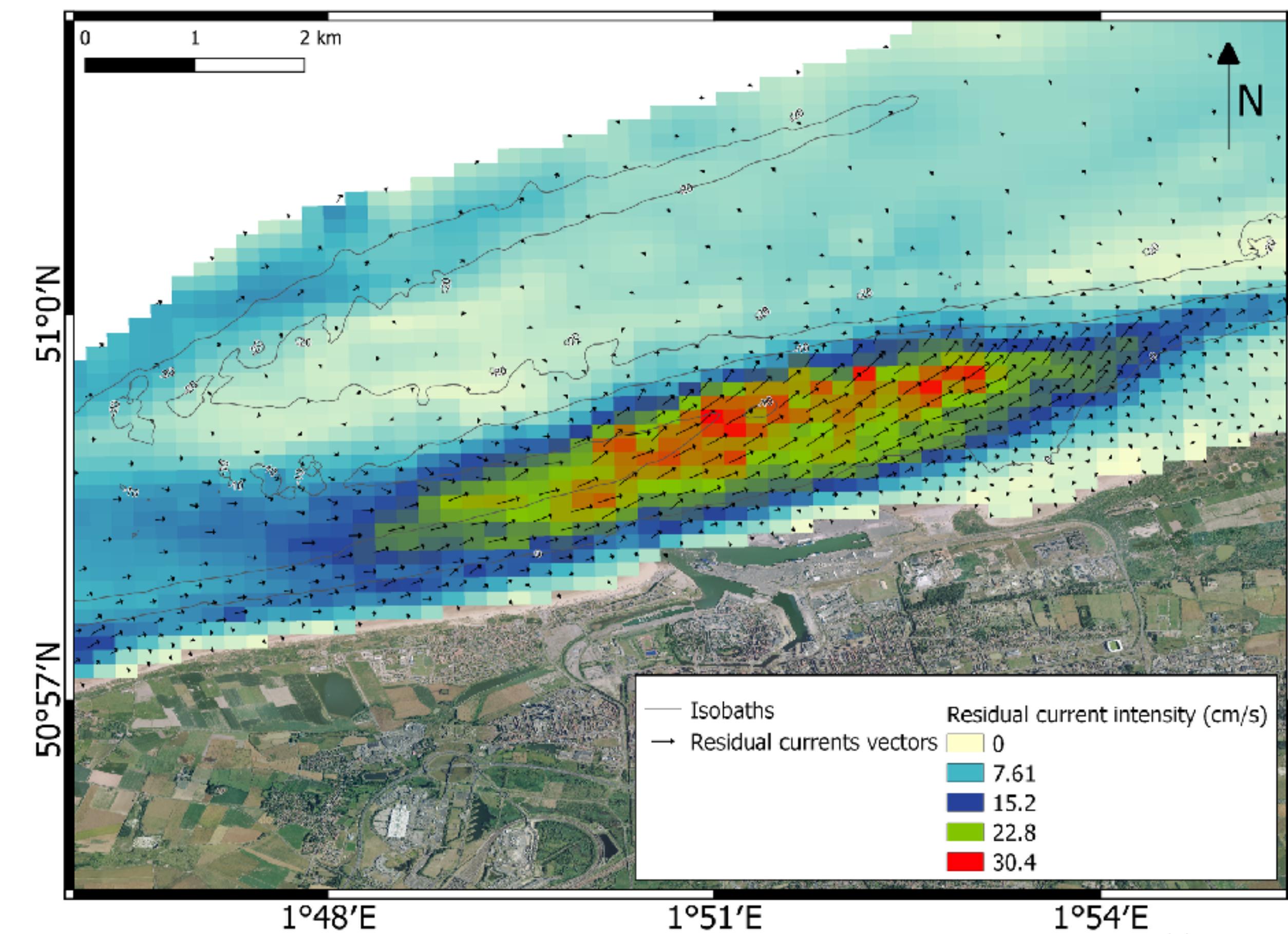
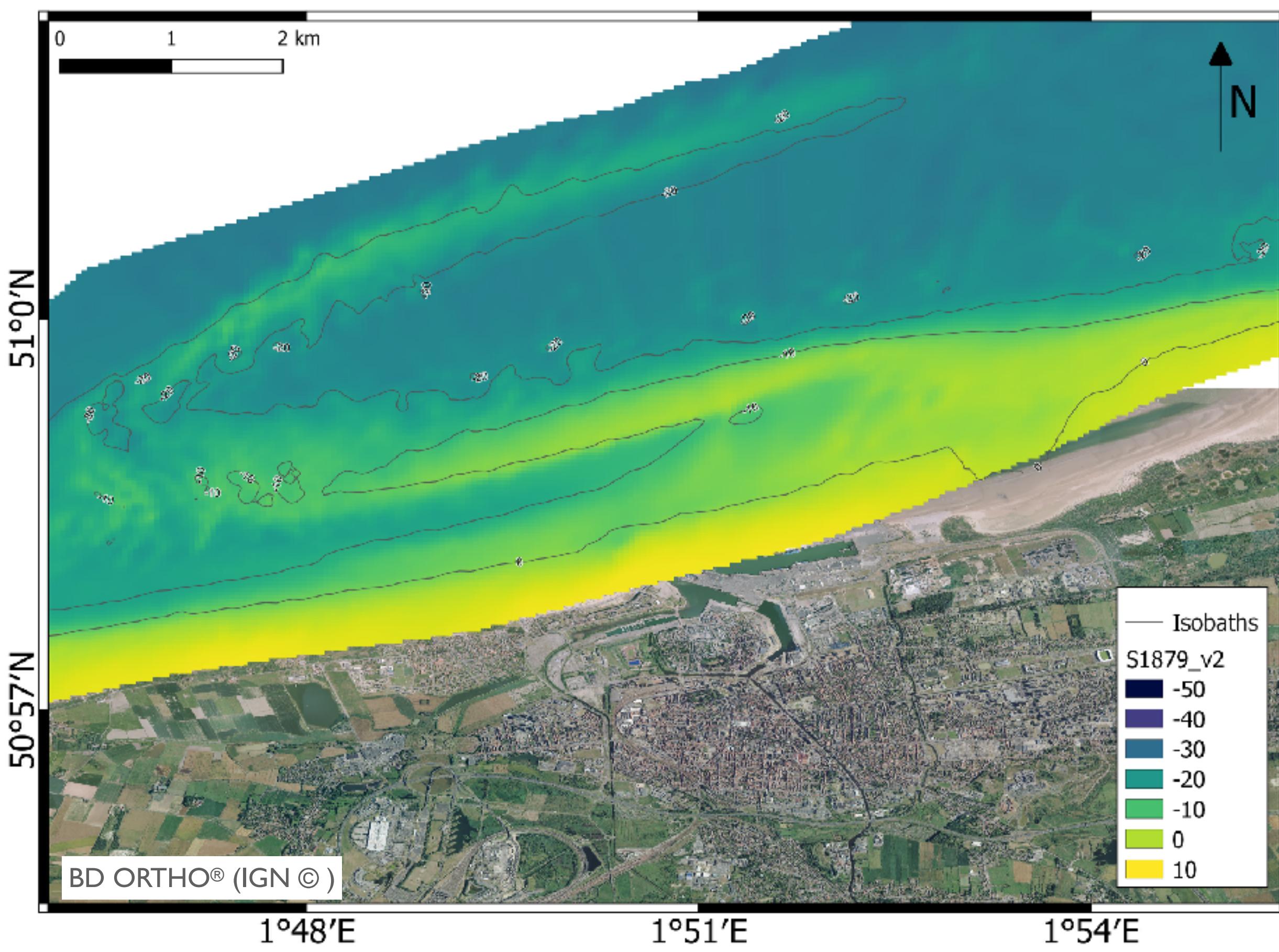
CALAIS - 1878



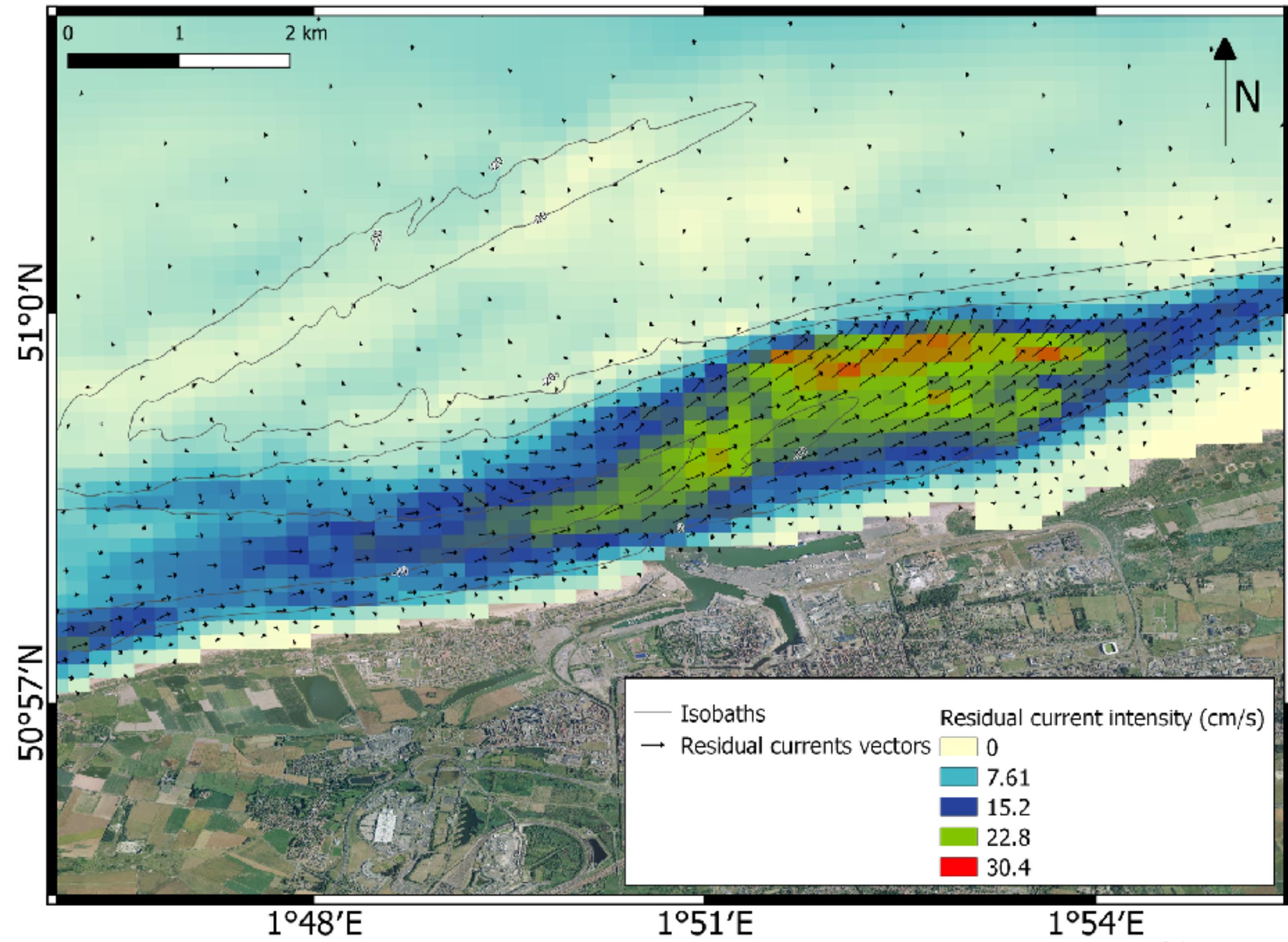
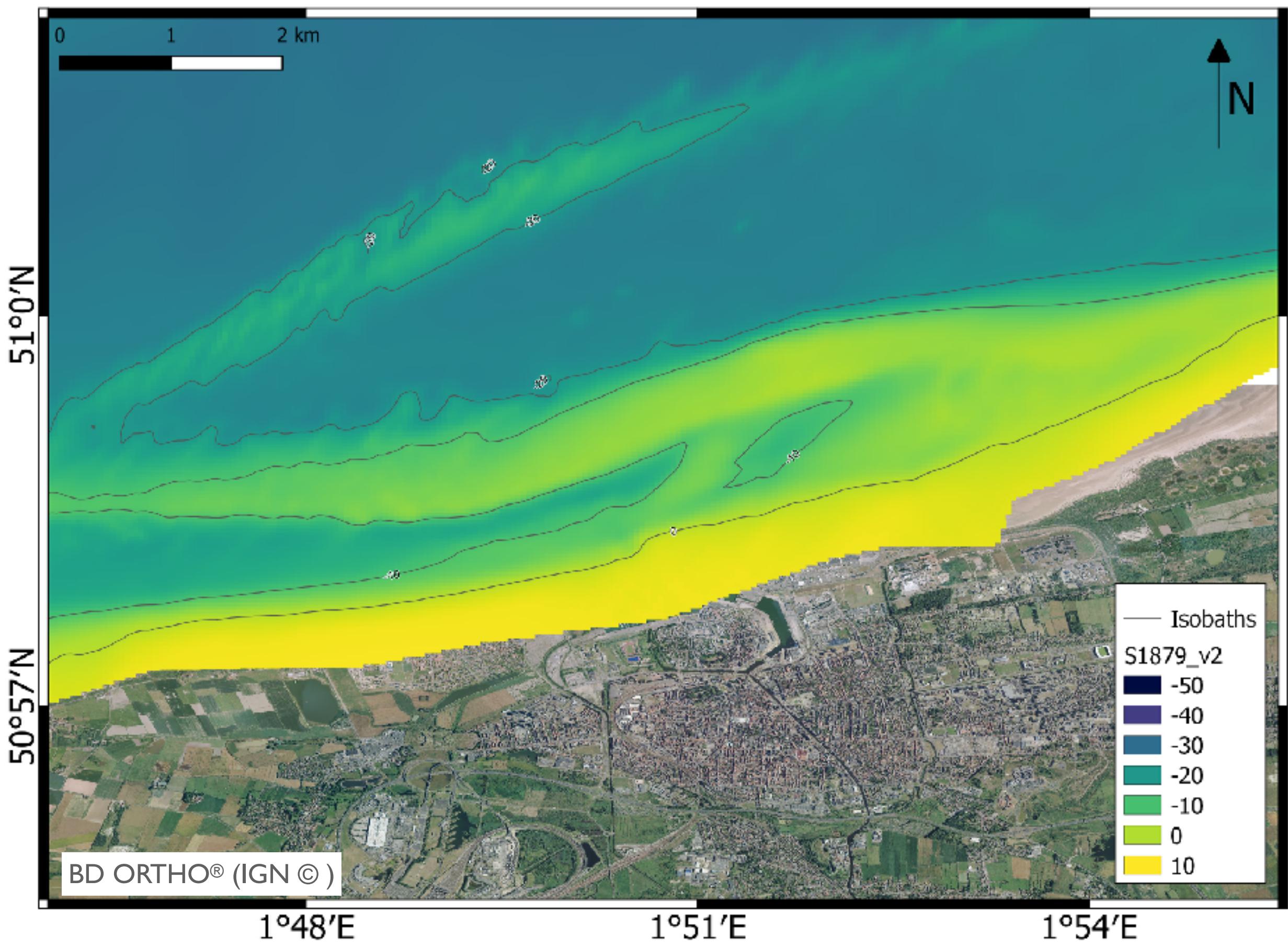
CALAIS - 1910



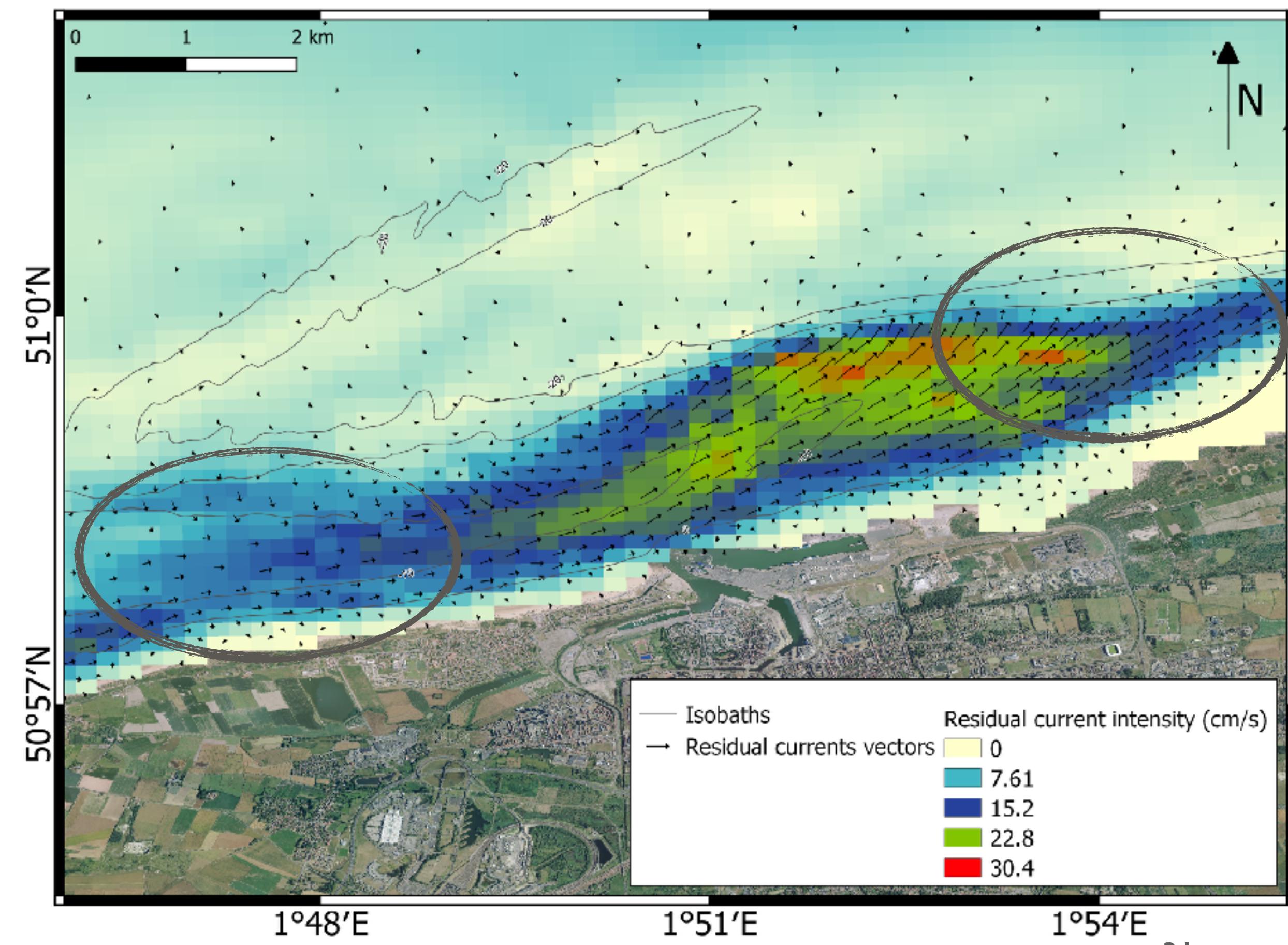
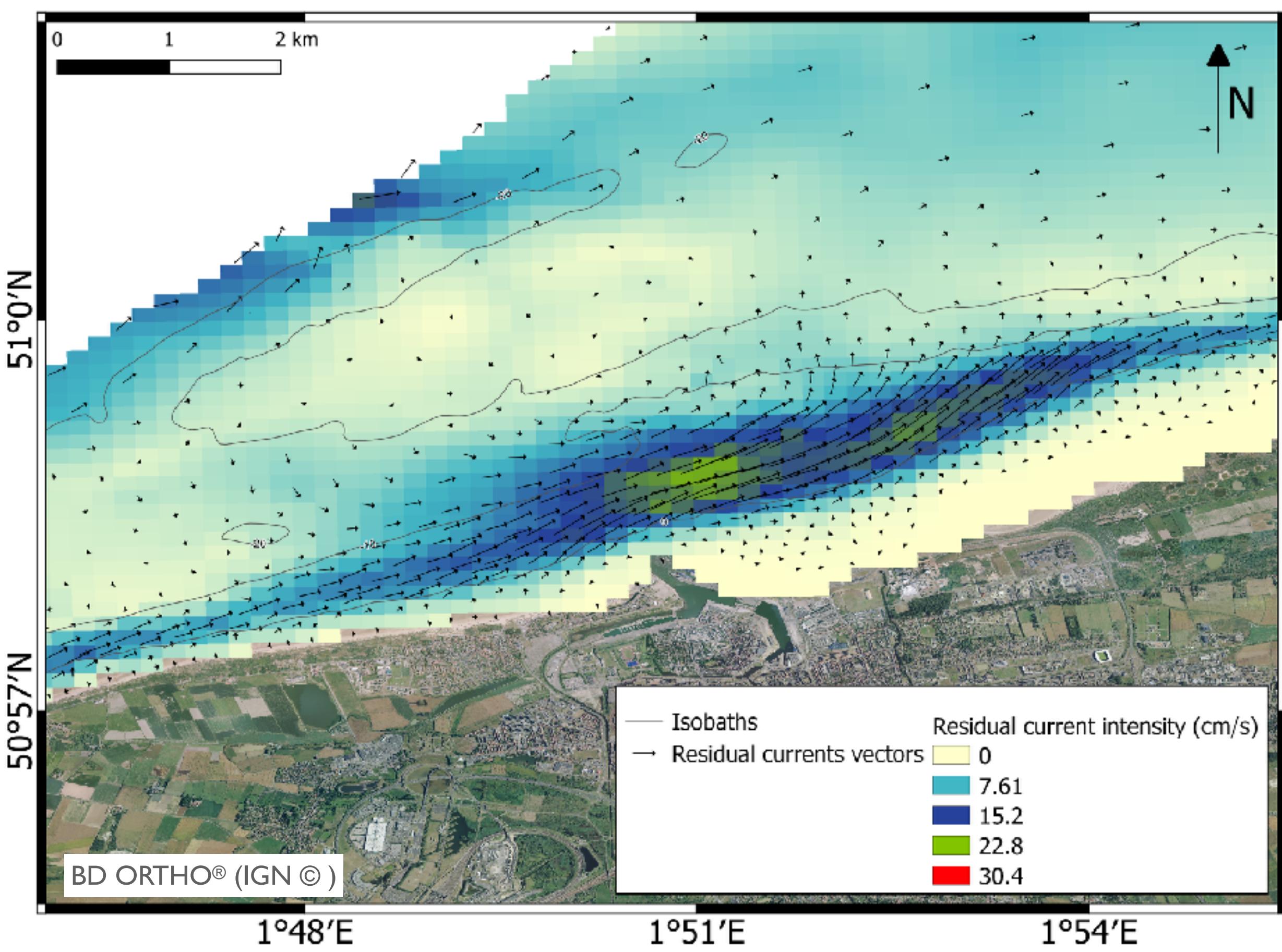
CALAIS - 1930



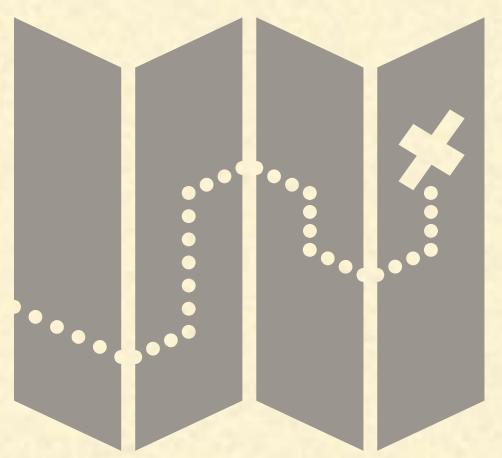
CALAIS - 1975



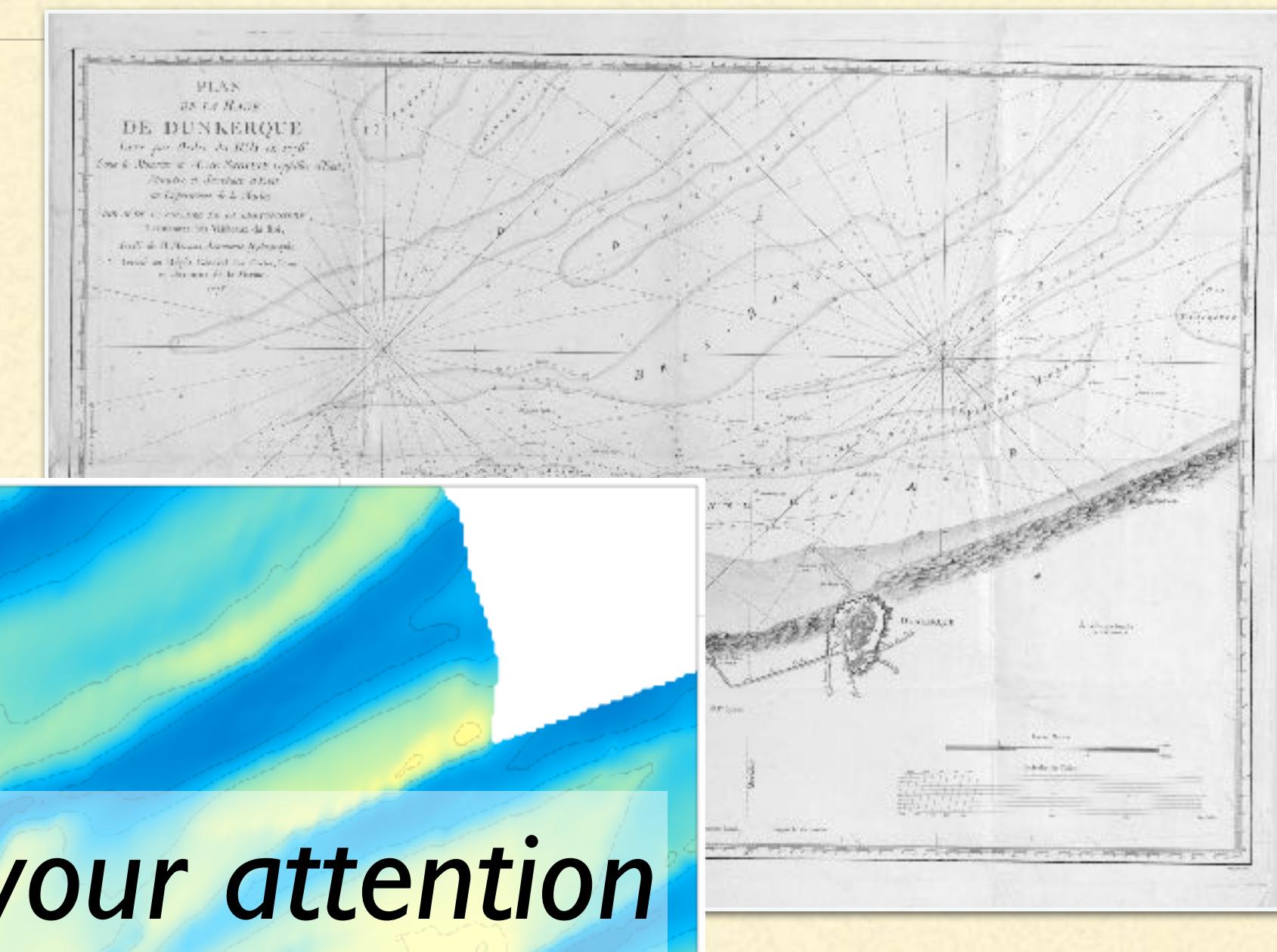
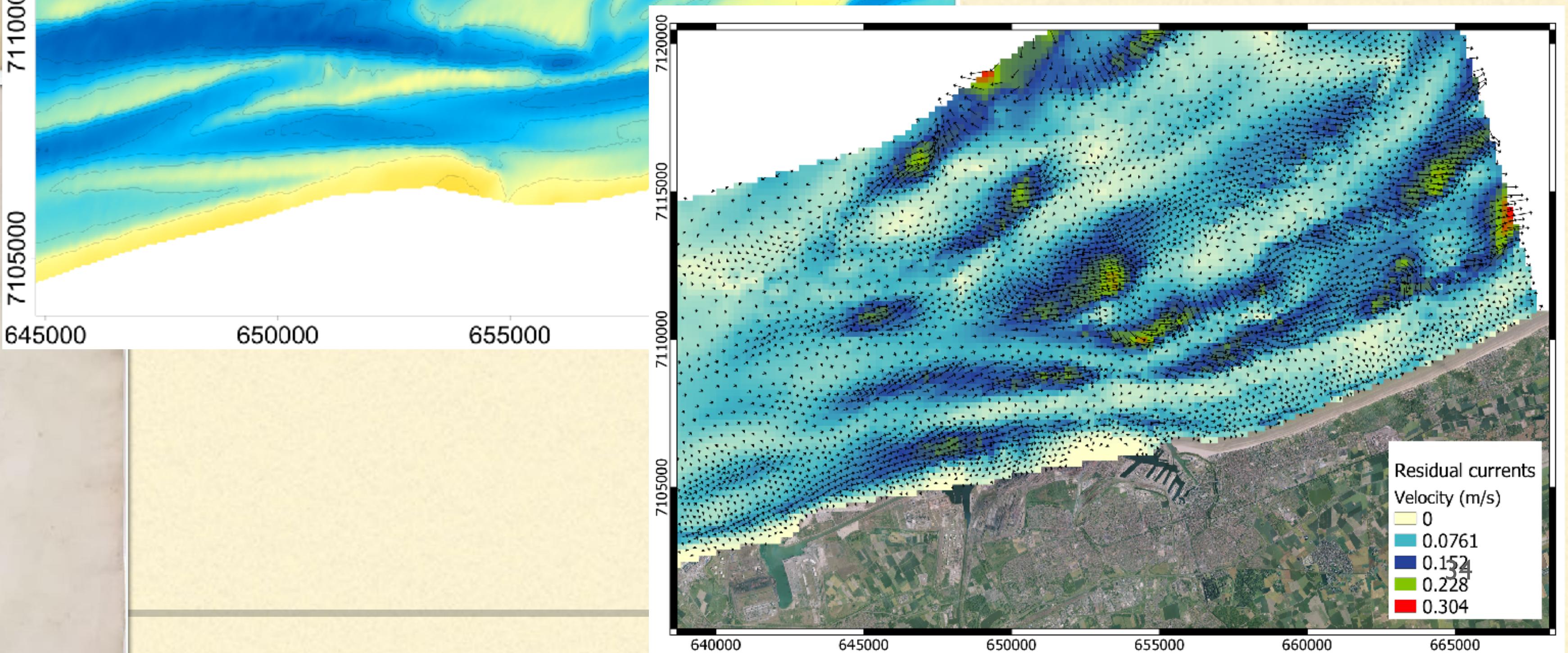
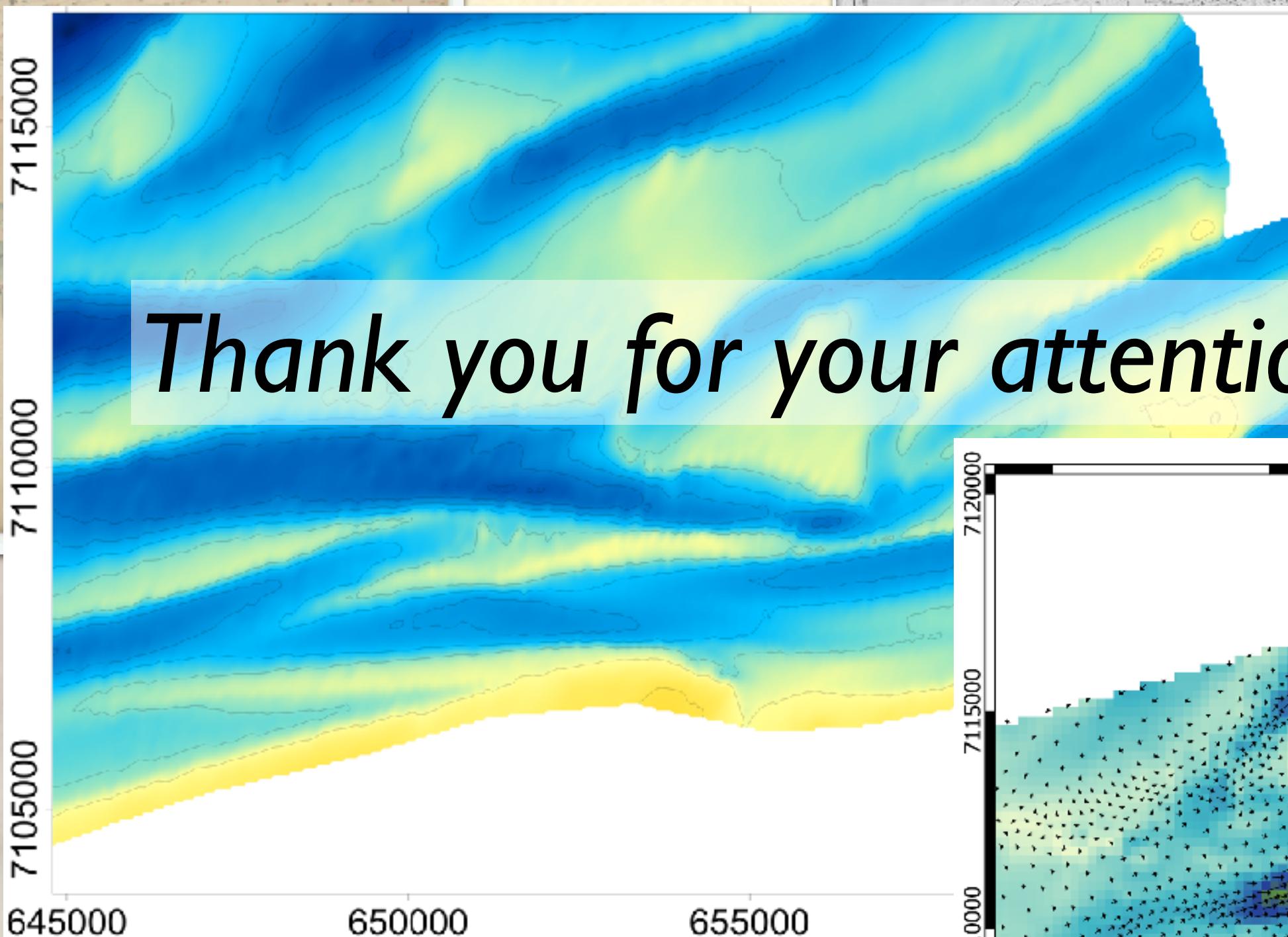
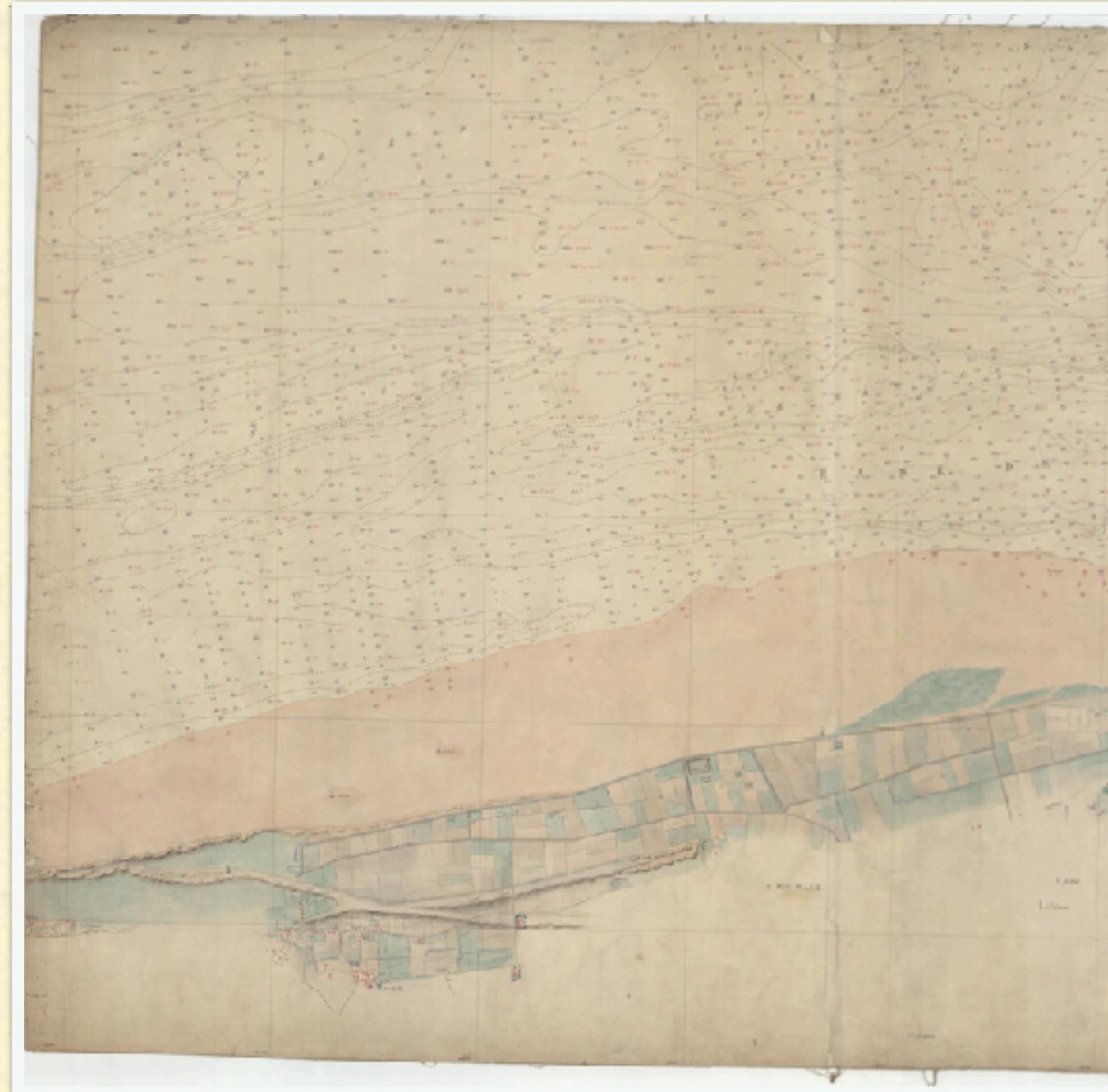
CALAIS - 1878 - 1975



CONCLUSION



- Significant morphological changes in the Northern France coastal zone
 - * Calais nearshore
 - * Wissant bay
 - * Dunkirk nearshore
- Overall onshore migration of sand banks → storm-waves
Along-shore movements : elongation + migration toward the ENE → tidal currents
- Tidal simulation : tidal residual currents changed over a century
- Wave model with TOMAWAC (+ coupling) : in progress...



MÉTHODES
POUR LA LEVÉE ET LA CONSTRUCTION
DES
CARTES ET PLANS HYDROGRAPHIQUES,

PUBLIÉES EN 1808,

Sous le titre d'Appendice, à la suite de la Relation du Voyage du
Contre-Amiral BRUNY-DENTRECASTEAUX;

PAR C. F. BEAUTEMPS-BEAUPRÉ.

Membre de l'Institut et de la Légion d'honneur, Chevalier de l'ordre de la
Couronne de fer, Hydrographe Sous-Chef du Dépôt général de la Marine
et des Colonies.

ET RÉIMPRIIMÉES PAR ORDRE DE SON EXCELLENCE LE COMTE DECRES,

Vice-Amiral, Grand-Officier de l'Empire, Inspecteur général des côtes de la
Méditerranée, Grand-Aigle, Chef de la 10^e Cohorte de la Légion d'honneur,
Ministre de la Marine et des Colonies.



A PARIS,

DE L'IMPRIMERIE IMPÉRIALE.