Preliminary modelling of shallow water waves off the Mackenzie Delta

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IPY: Impact of Arctic storms and climate change on coastal processes
Canadian Panel on Energy Research and Development

Outline/ motivation

- 1. Introduction to storm climate, tracks etc.
- 2. Coupled models
  - role of currents and ice
  - Arctic storm example
- 3. Observed data
  - winds, waves, currents, SST
  - physical processes
- 4. Wave model comparisons
  - Case studies
- 5. Conclusions

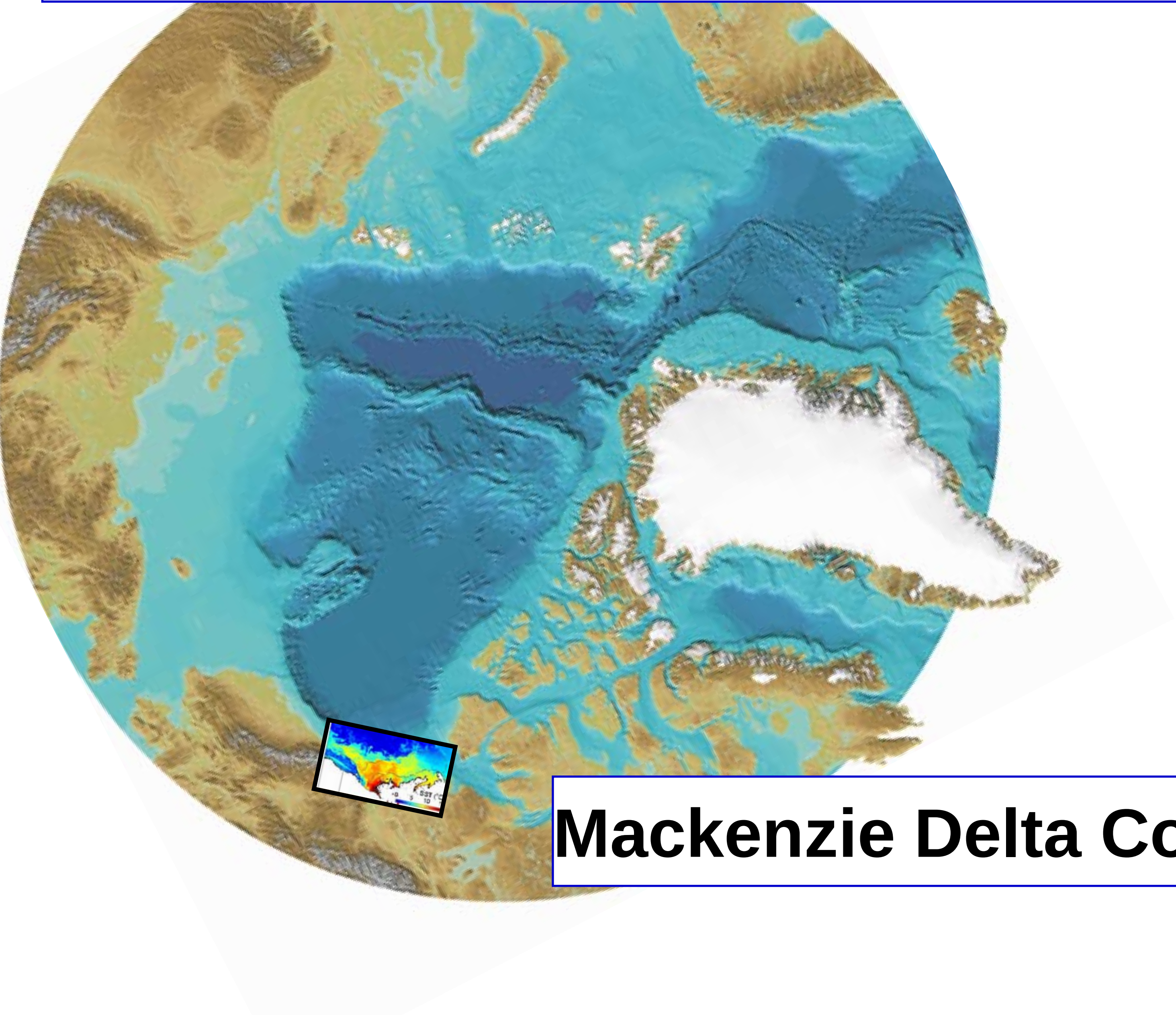
5. Concluding Remarks

- Model skills vary for different storms and buoys
- Triad interactions do not have beneficial effect on wave simulations.
- Simulations are sensitive to bottom friction, but bottom friction parameterizations do not give good results in the study area.

  → formulations need to be tuned for the fine sediment and shallow depth of the Mackenzie Delta.

- Of the two SWAN formulations for wave dissipation simulations, Westhuysen option is better than Komen option
- In most cases MIKE21 simulations are found to be close to the results of Westhuysen option in SWAN.

1. Introduction to storm climate, tracks etc.



Mackenzie Delta Coast

Change in sea ice extent

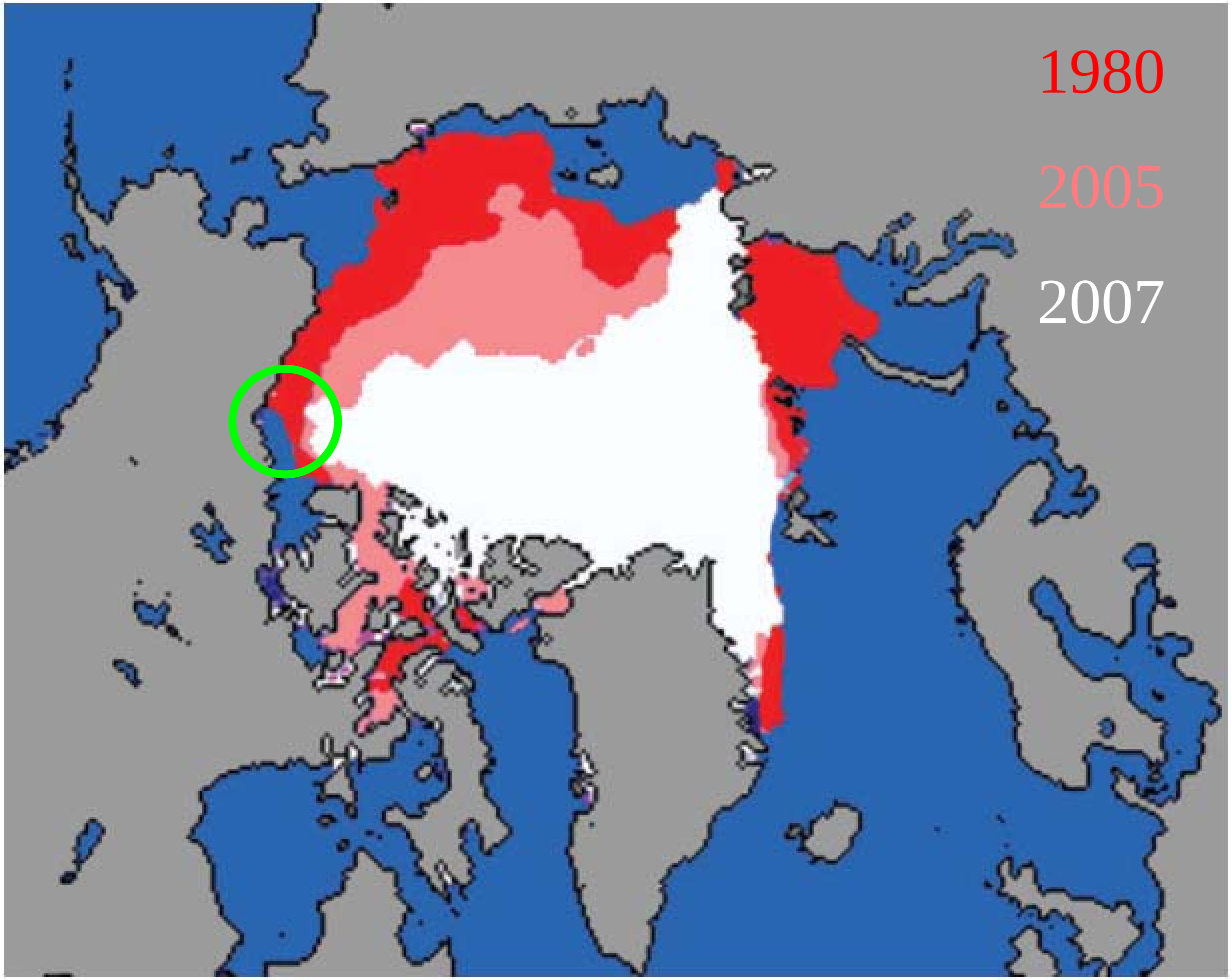
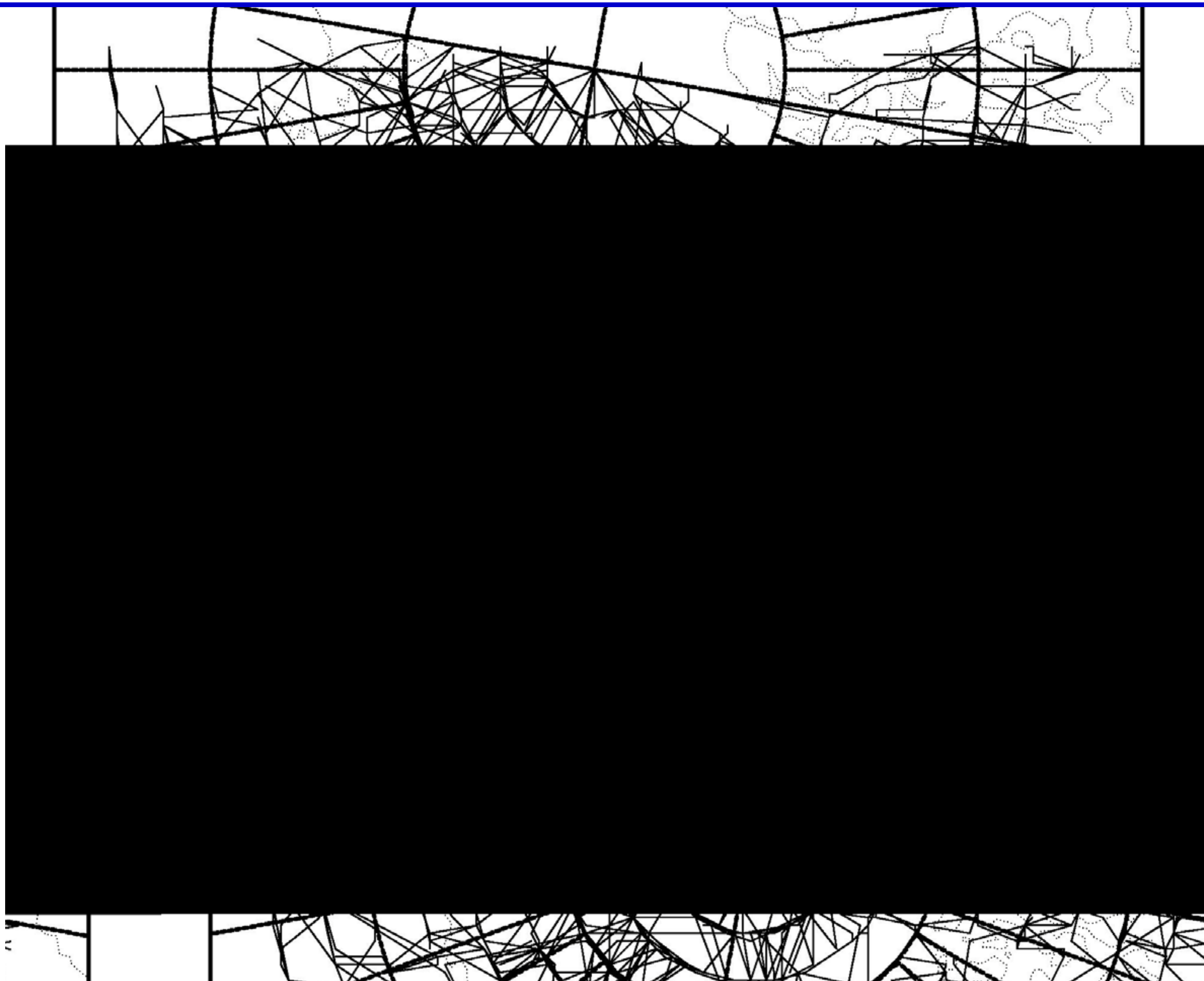


Figure 6

Comparison of September ice extent for 1980, 2005, and 2007, showing the 2007 ice extent (*white region*), the 2005 extent (*white region*), and the 1980 extent (*red, pink, and white regions*).

Perovich et al, 2008

NCEP reanalysis data storm tracks



2. Coupled models

- role of currents and ice
- Arctic storm example

Atmosphere model

MC2 **(*Mesoscale Compressible Community*)**

Oceanic component

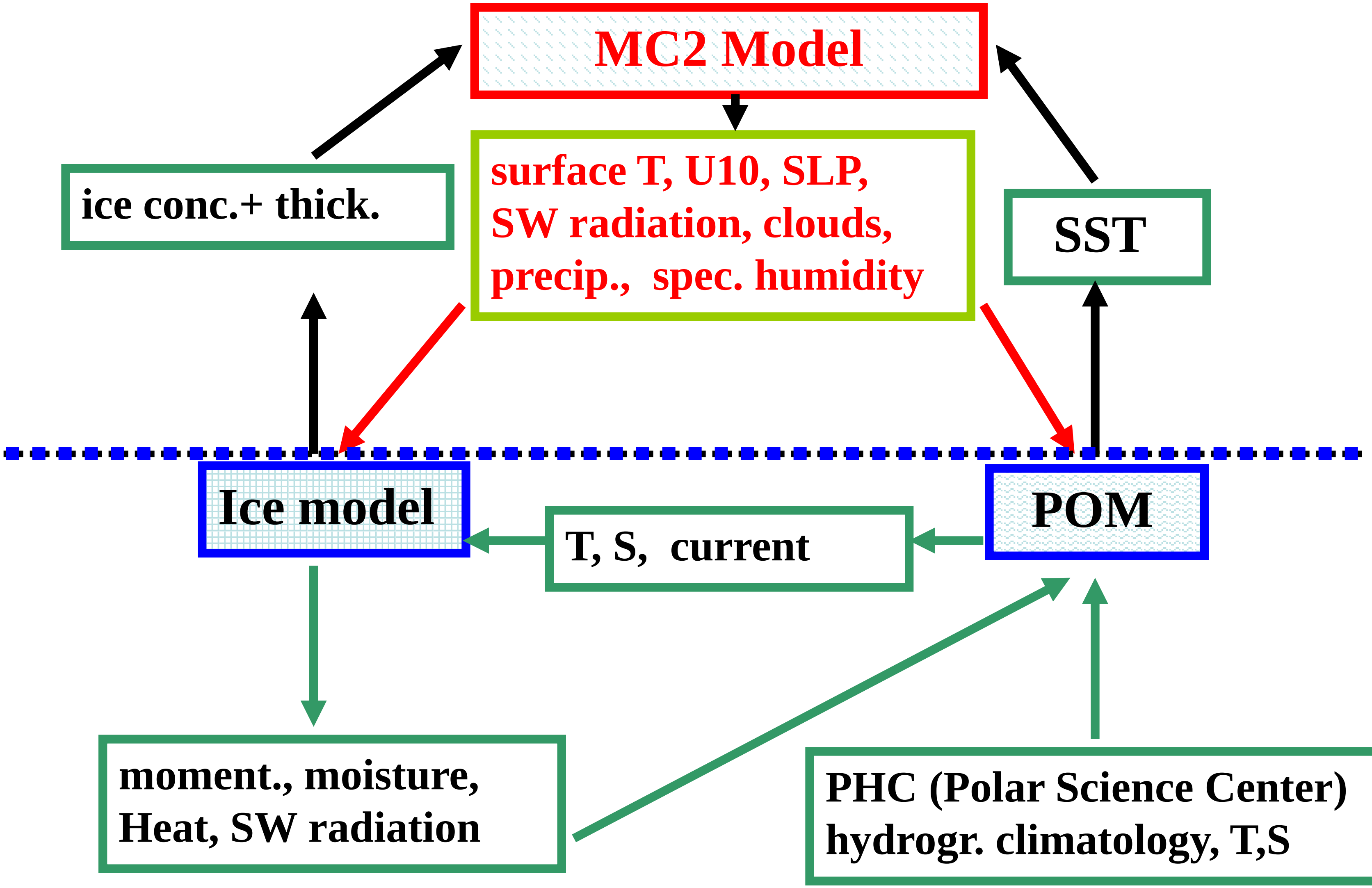
POM ***(Princeton Ocean Model)***

Ice component

Hibler Model

Coupled model

Atmosphere–Ocean–Ice Coupling

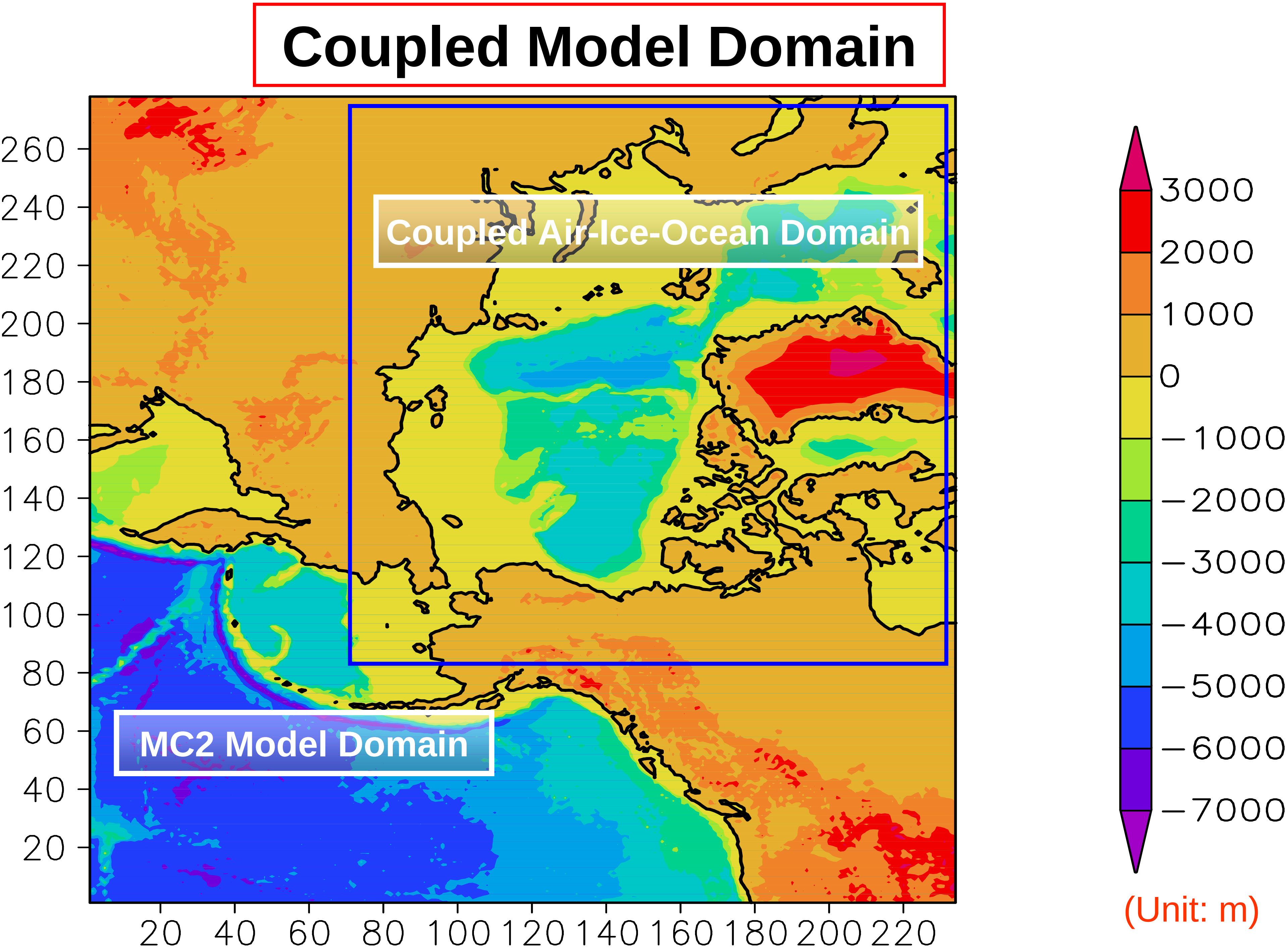


Experiment Design of models

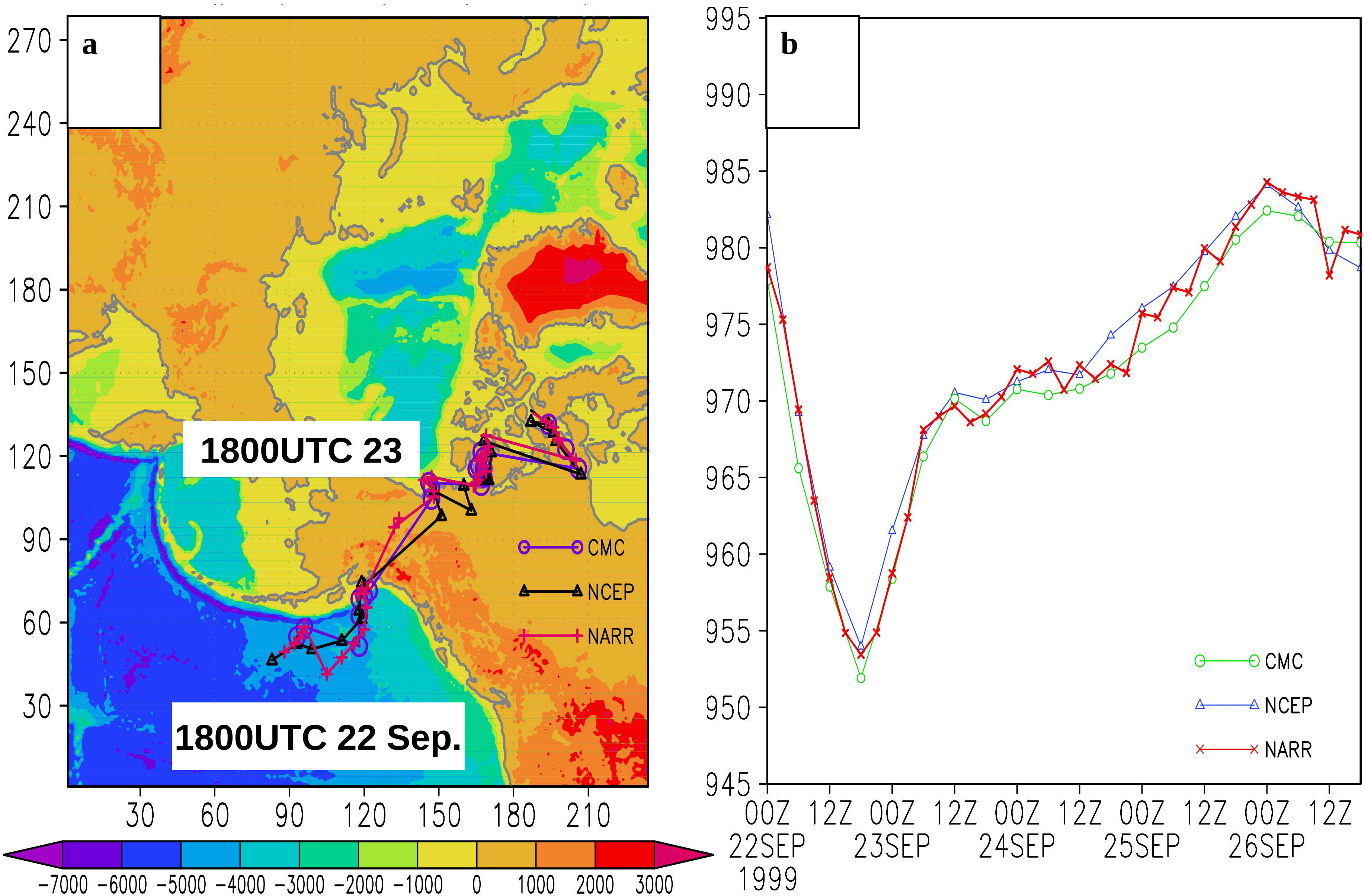
Coupled
Model

MC2:
25Km resolution
30 vertical layers
900s time step

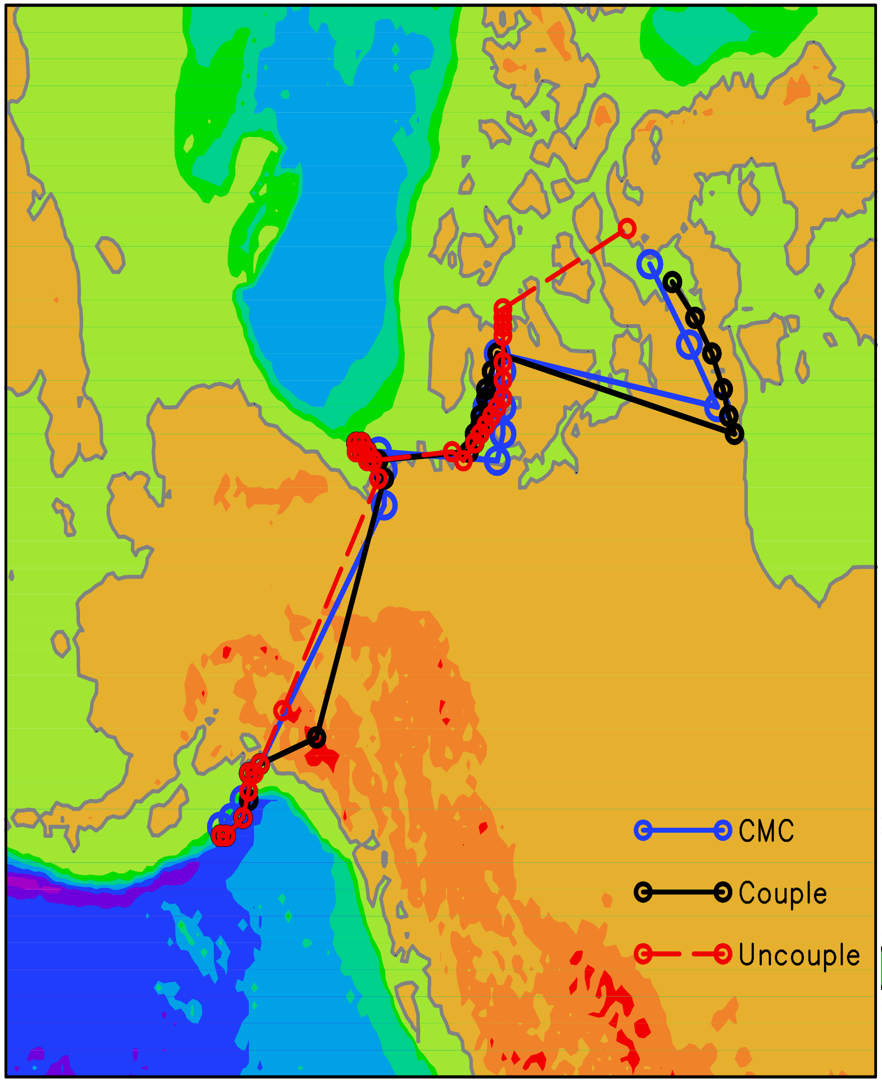
CIOM (Ice-Ocean)
≈ 27.5Km
23 vertical layers
900s time step
7 ice categories


Coupled Model Domain
Coupled Air-Ice-Ocean Domain
MC2 Model Domain
260
240
220
200
180
160
140
120
100
80
60
40
20
20 40 60 80 100 120 140 160 180 200 220
3000
2000
1000
0
−1000
−2000
−3000
−4000
−5000
−6000
−7000
(Unit: m)

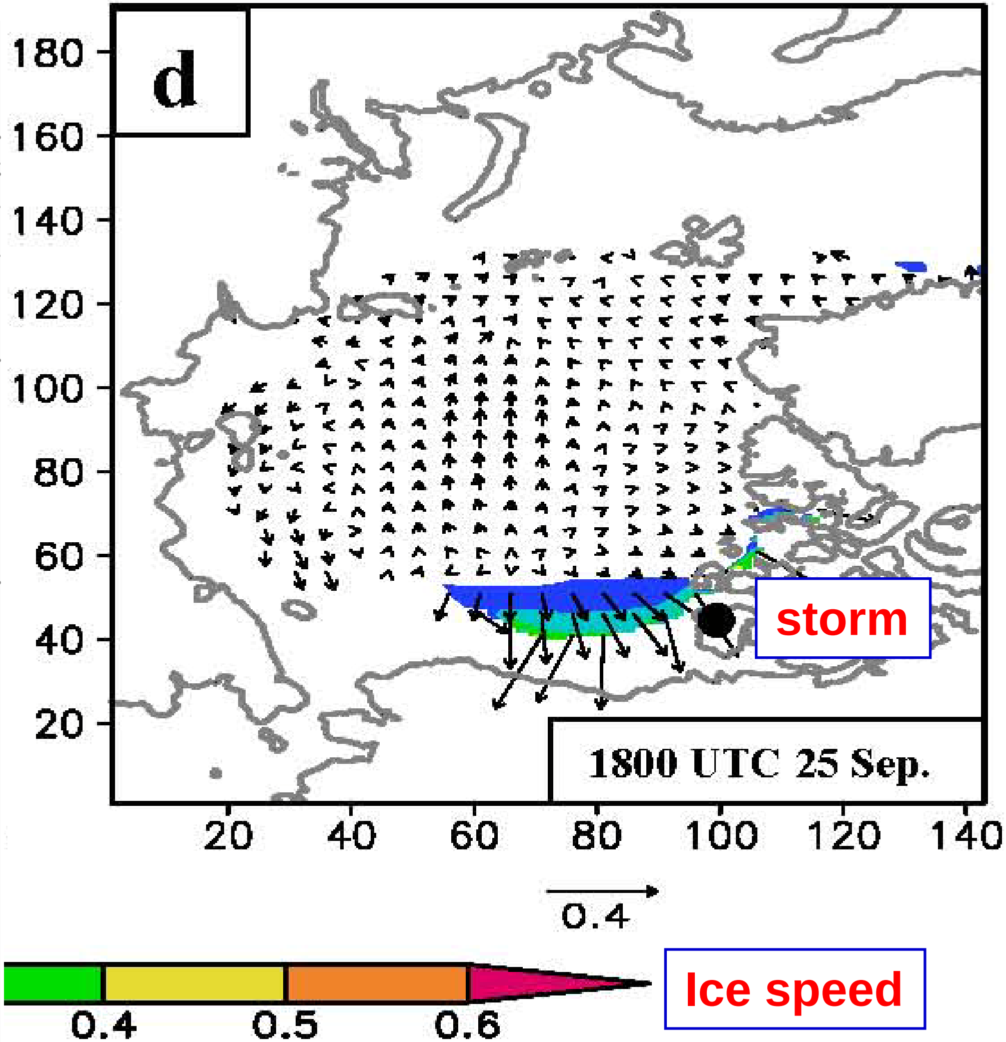
1999 Arctic Storm (Central SLP)



Arctic storm case



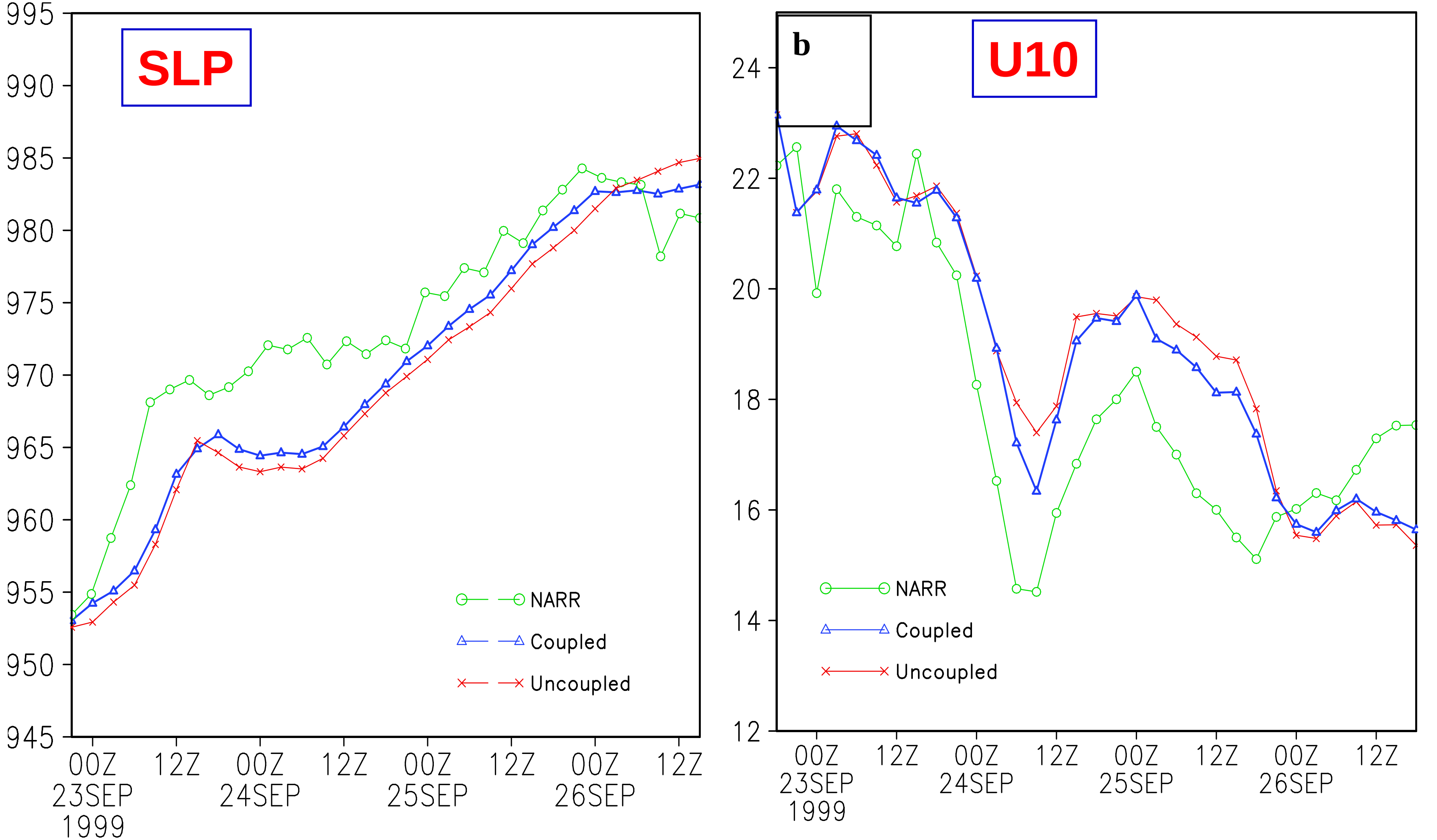
Model simulation results



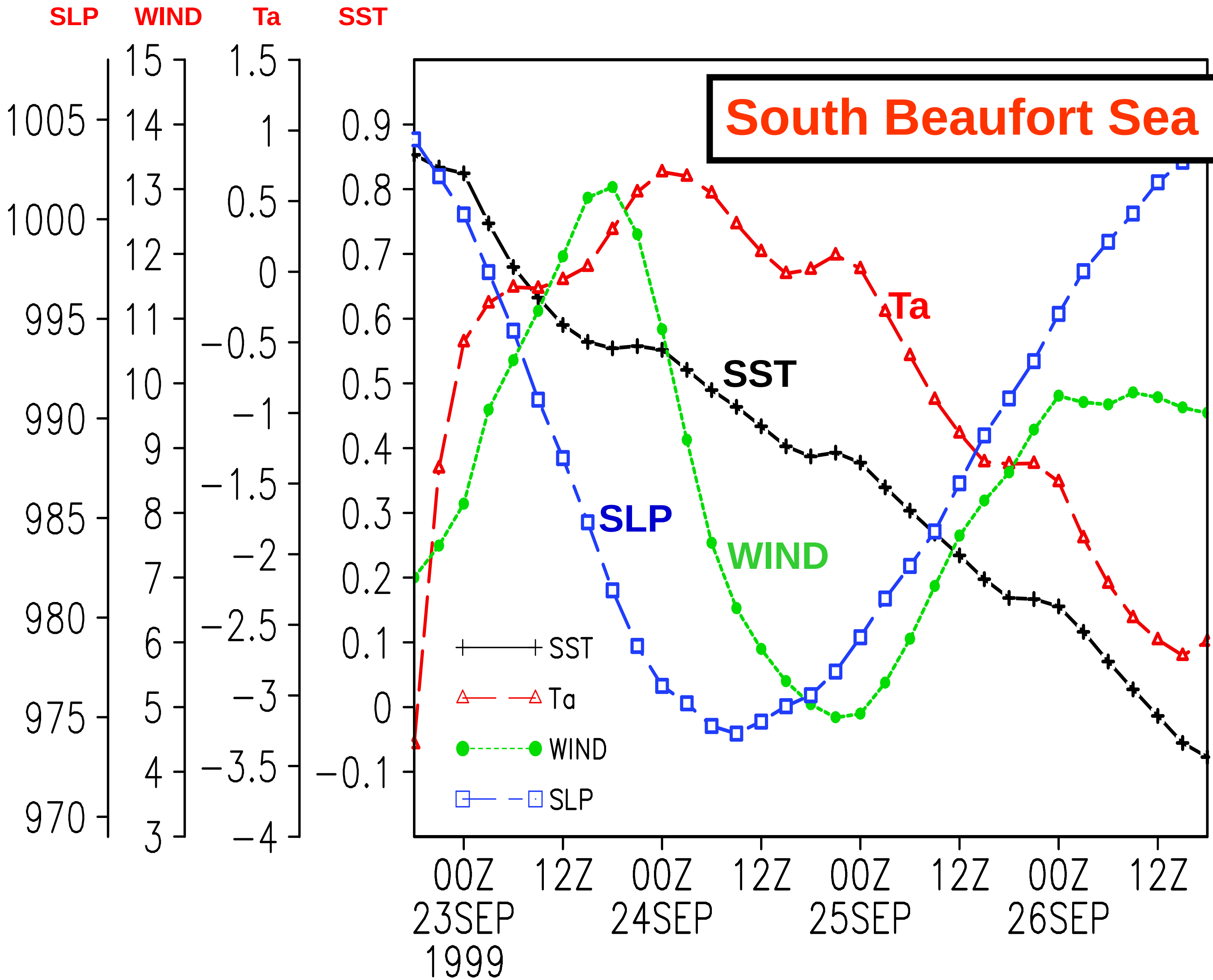
Ice current at 72h for the coupled model, after 1800 UTC 22 Sep., 1999.

Time series following storm centre

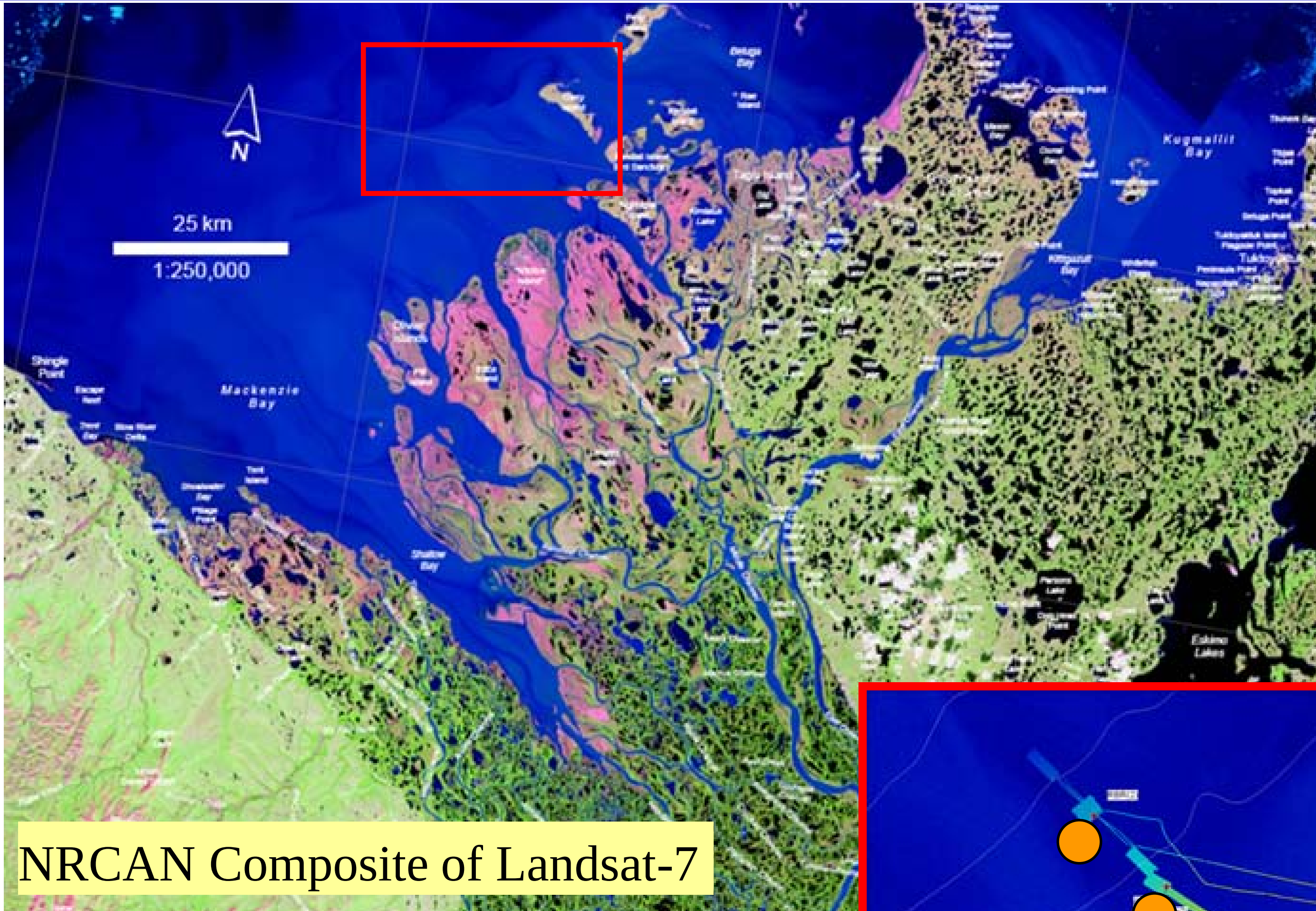
(after reaching the Beaufort Sea)



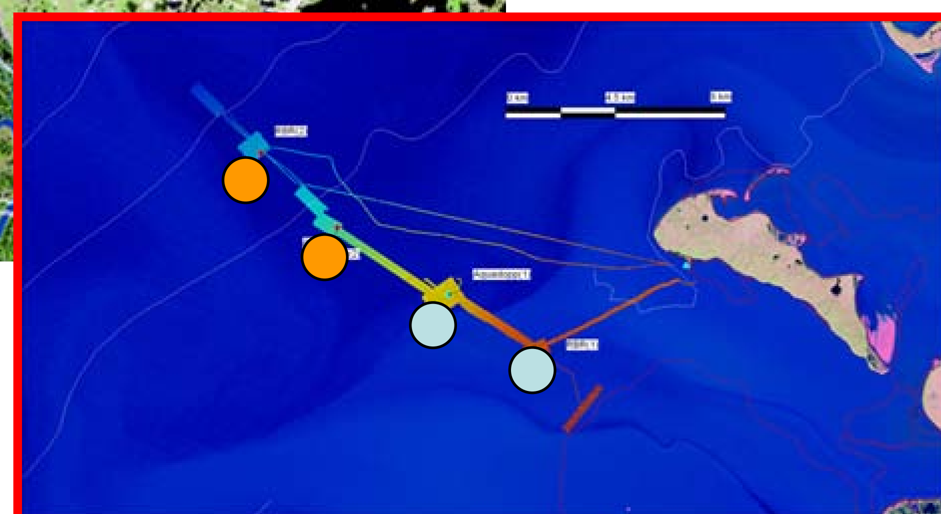
Time series of air temperature (2 m), (Ta), winds ($m \cdot s^{-1}$), SST (^0C), and SLP (hPa)

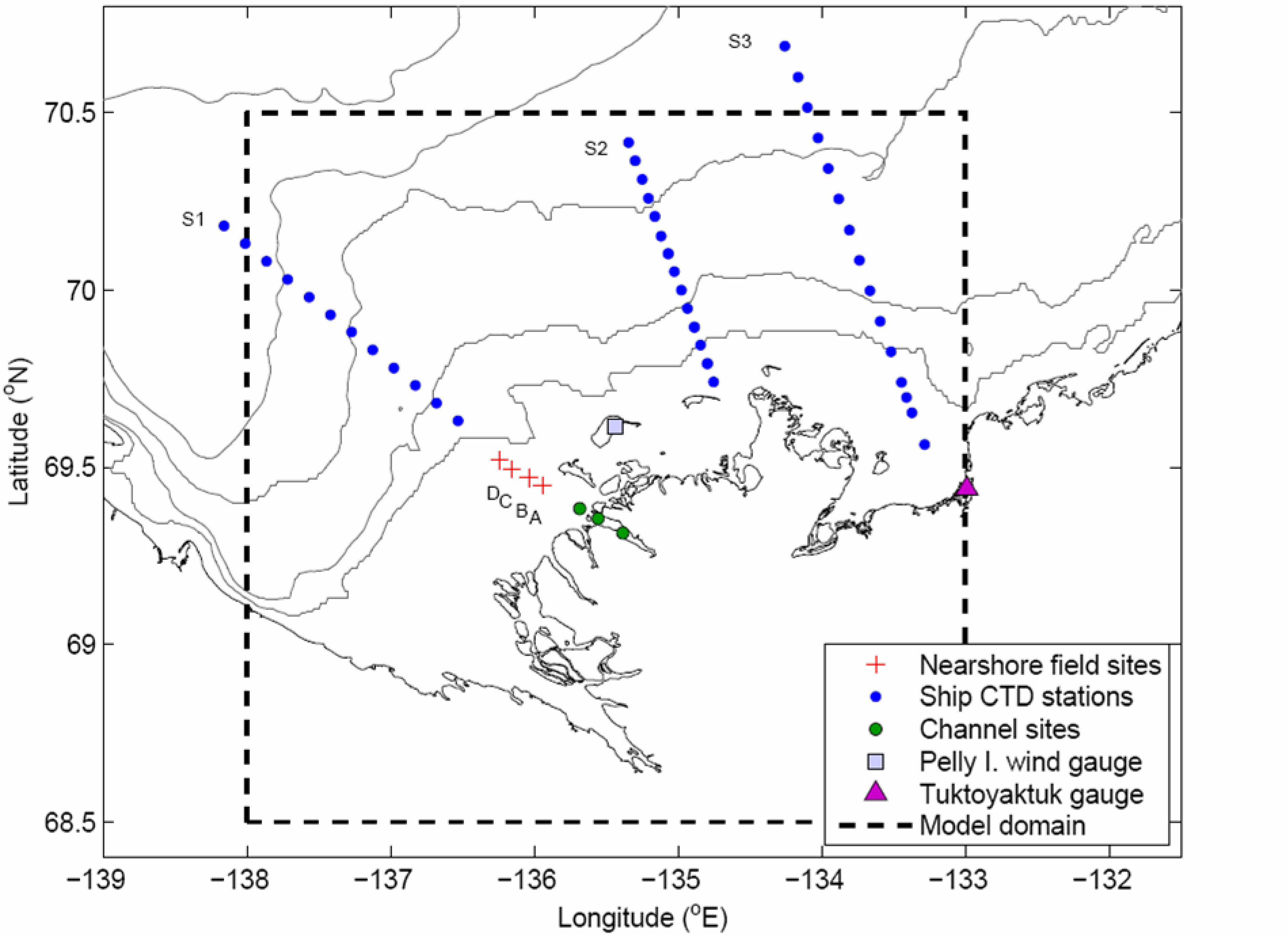


3. Observations: 2007 Field Experiment



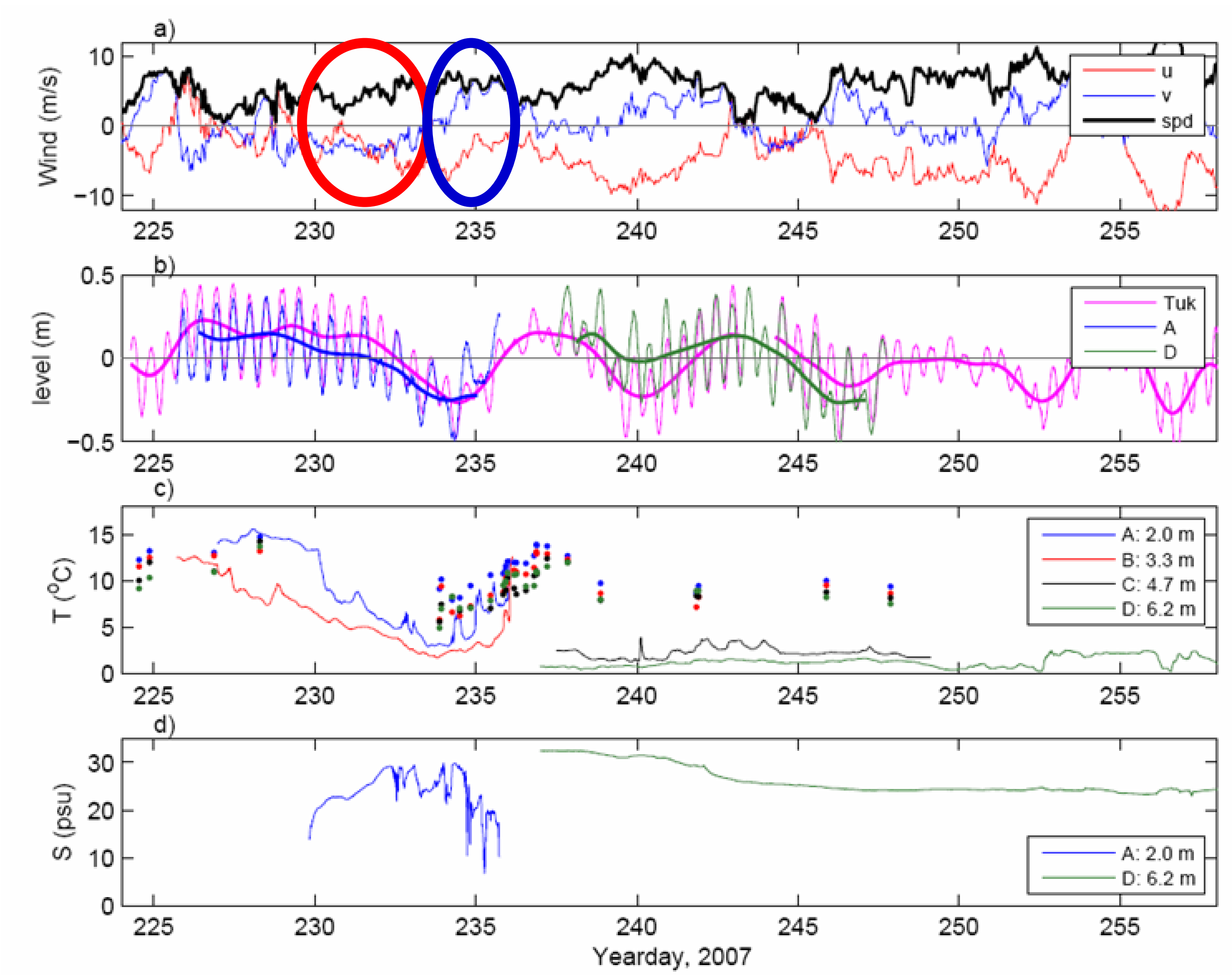
NRCAN Composite of Landsat-7





70.5
70
69.5
69
68.5
−139
−138
−137
−136
−135
−134
−133
−132
Latitude (oN)
Longitude (oE)
S1
S2
S3
D C B A
Nearshore field sites
Ship CTD stations
Channel sites
Pelly I. wind gauge
Tuktoyaktuk gauge
Model domain

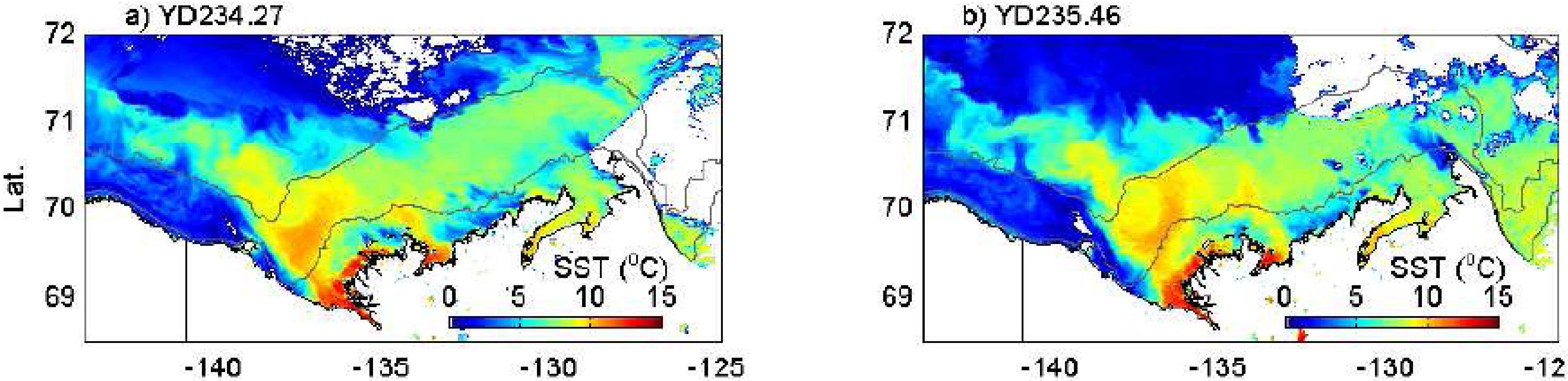
Nearshore Observations: Aug – Sept 2007



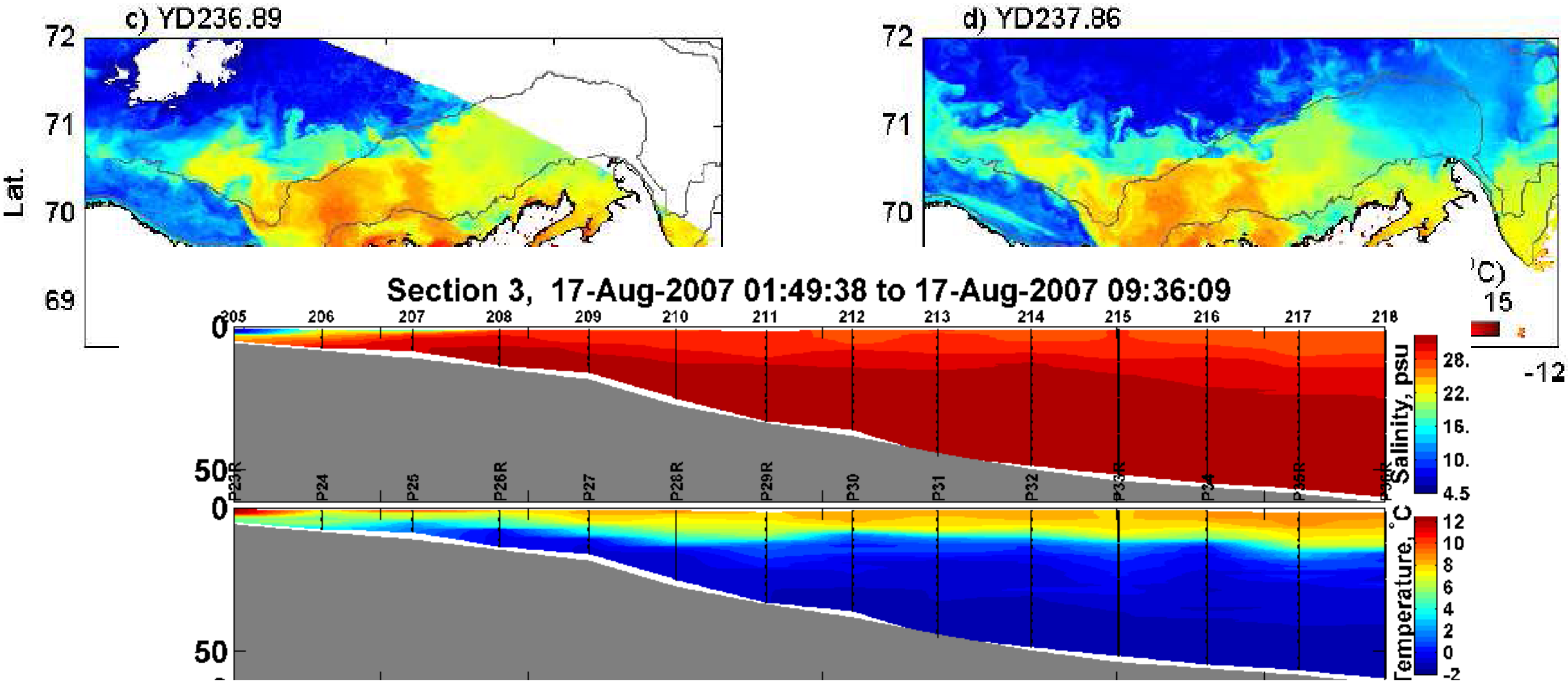
Field data

MODIS SST

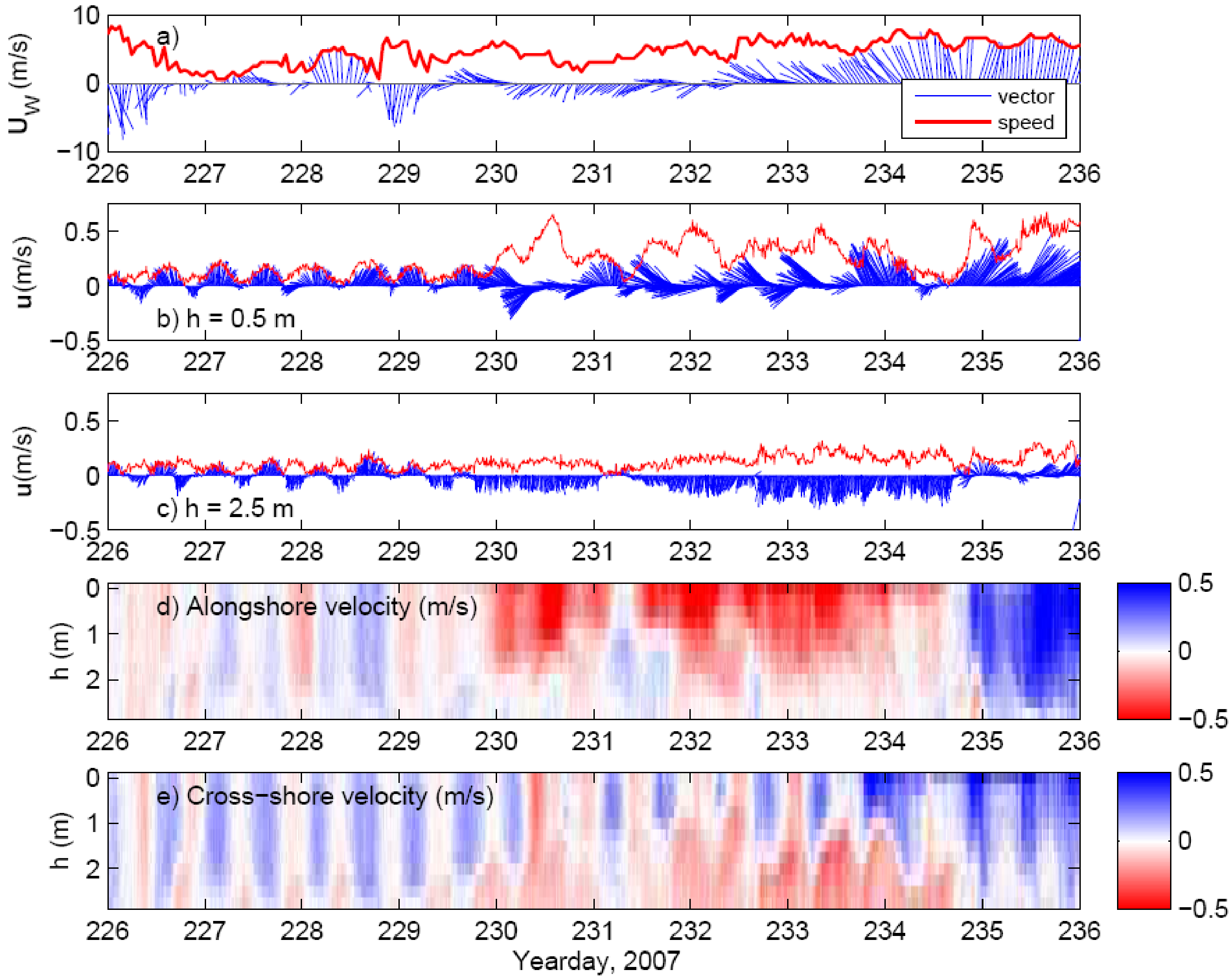
MODIS Satellite SST Observations



Moderate Resolution Imaging Spectroradiometer



Current velocity observations



4. Wave model comparisons

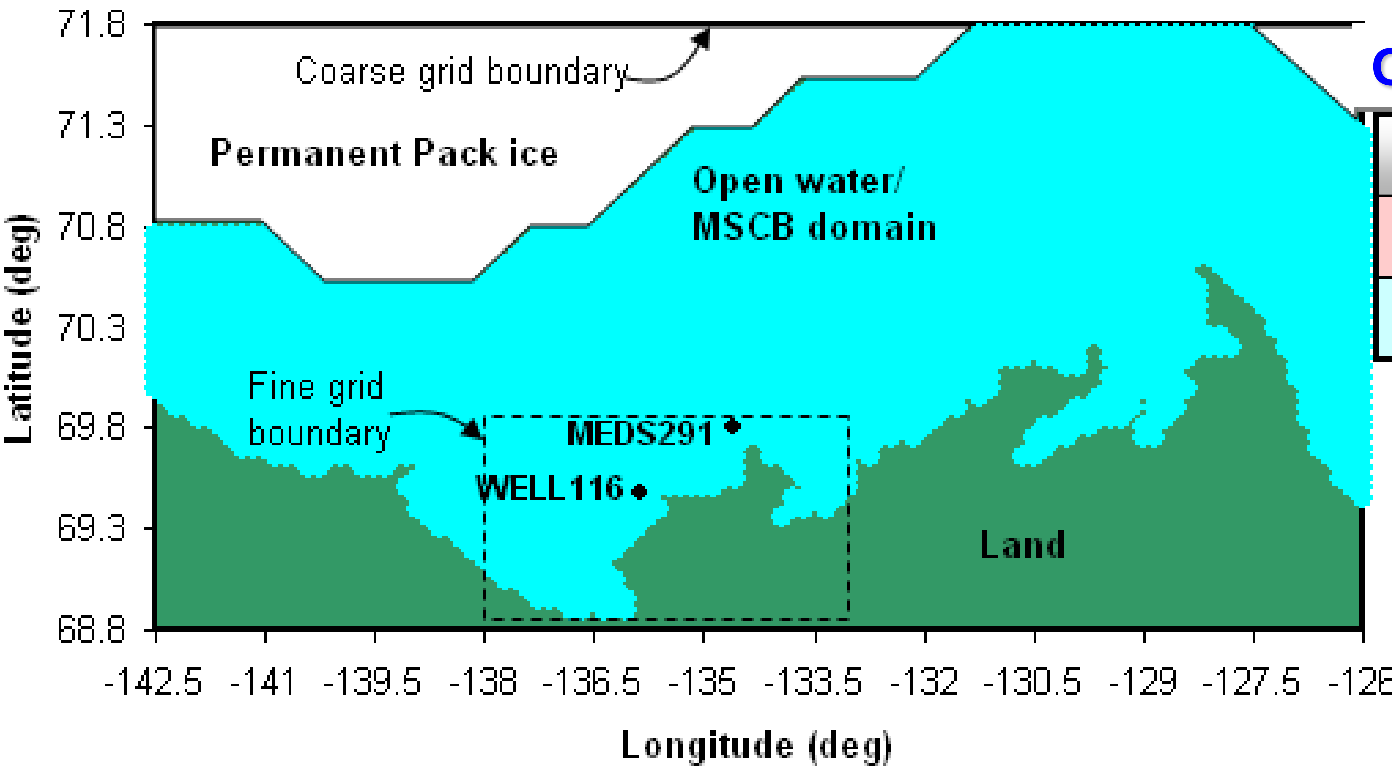
- **Test SWAN and MIKE21 SW In the Mackenzie Delta.**

- **Test sensitivity of shallow water processes:**
  - **bottom frictions**
  - **nonlinear triads**

$$S_{tot} = S_{in} + S_{wc} + S_{nl4} + S_{nl3} + S_{bf} + S_{br}$$

where, S_{in} : wind input
S_{wc} : whitecapping
S_{nl4} : 4-wave interactions
S_{nl3} : triads
S_{bf} : bottom friction
S_{br} : depth-induced breaking.

Computational Domains

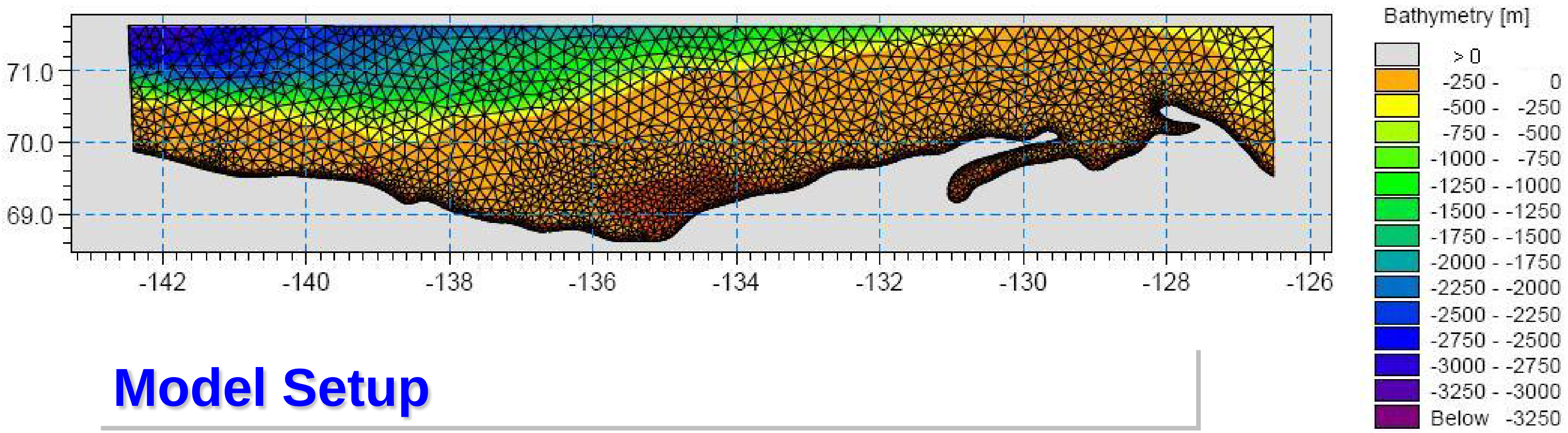


Observation stations

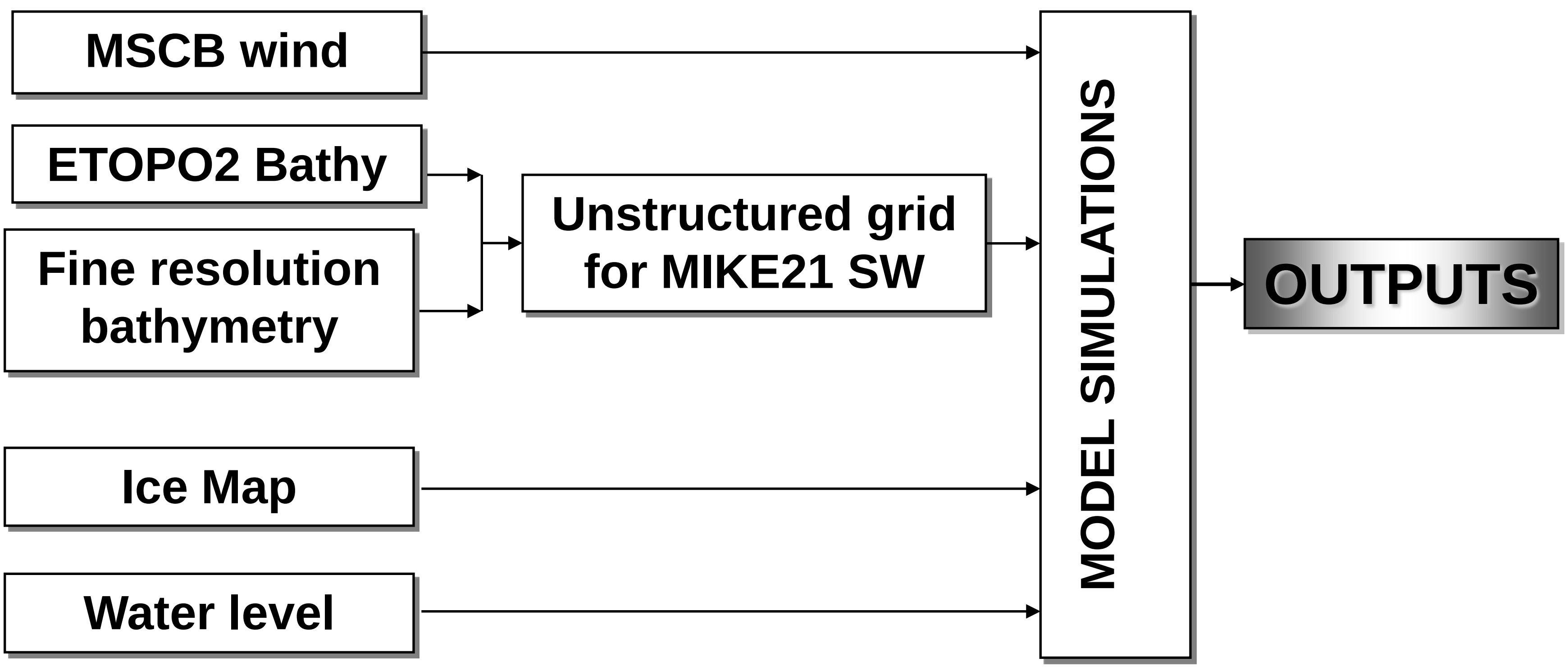
Buoy	Depth	Year
WEL116	2.24	1985
MEDS291	7.00	1991

Grid	Latitude, λ	Longitude, φ	Δ_λ	Δ_φ	$n\lambda$	$n\varphi$	Δt (min)
Coarse	-142.5º ~ -126º	68.9º~71.75º	0.15º	0.05º	111	58	5
Fine	-138º ~ -133.05º	68.9º-69.85º	0.03º	0.01º	331	191	5

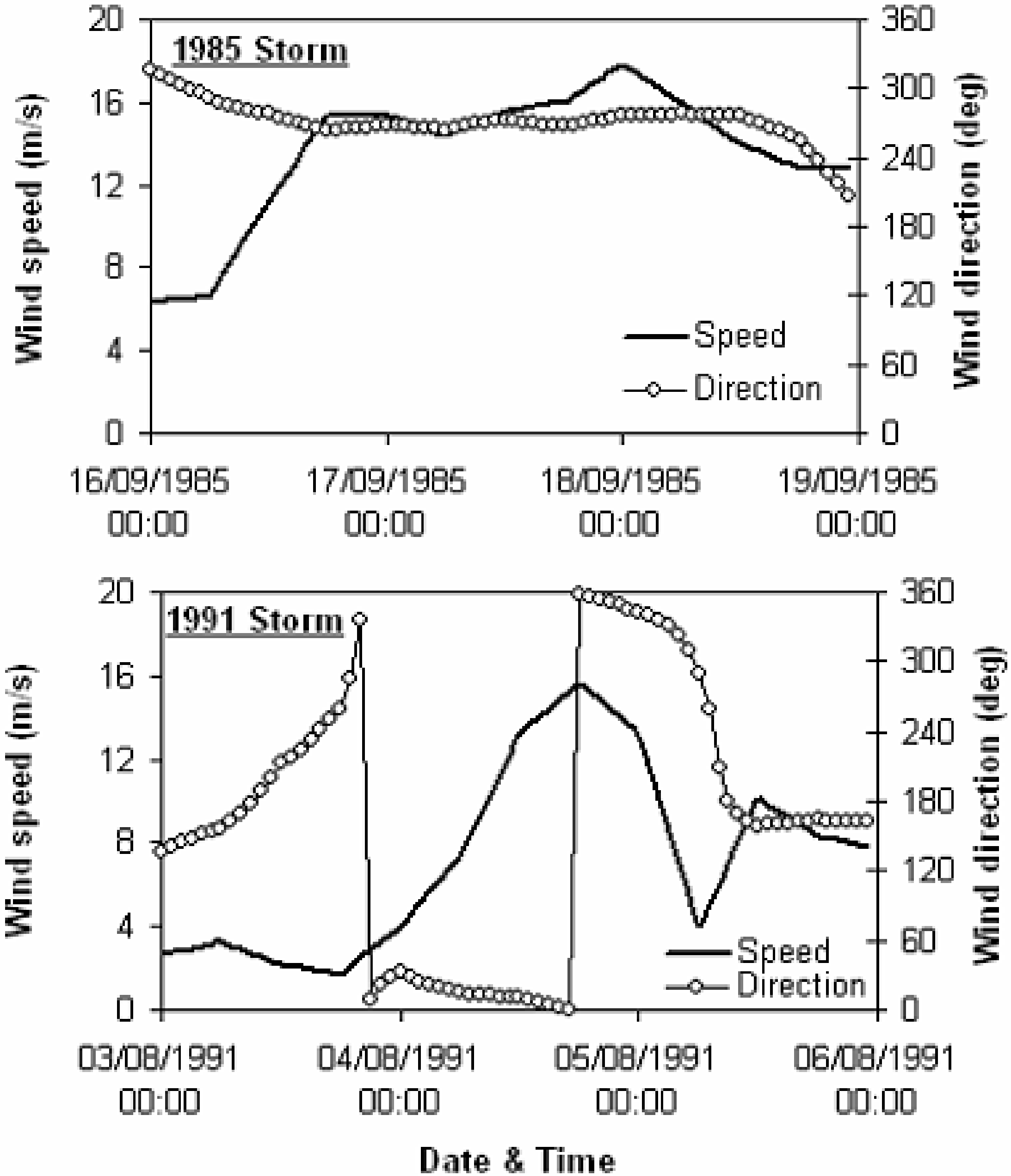
Unstructured Grids in MIKE21 Simulations



Model Setup



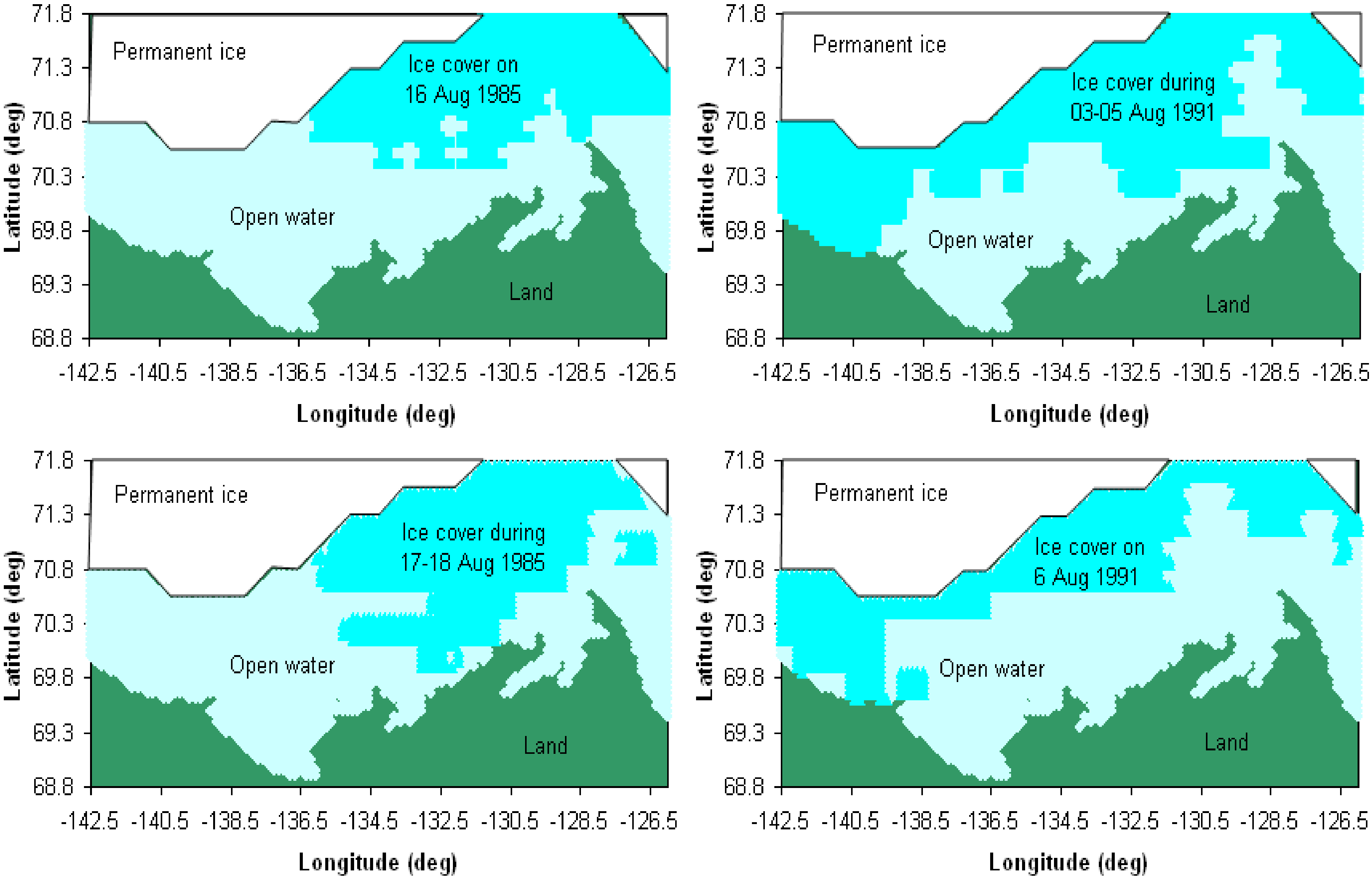
MSCB Winds at Tuktoyaktuk during 1985 & 1991 Storms



Ice Cover

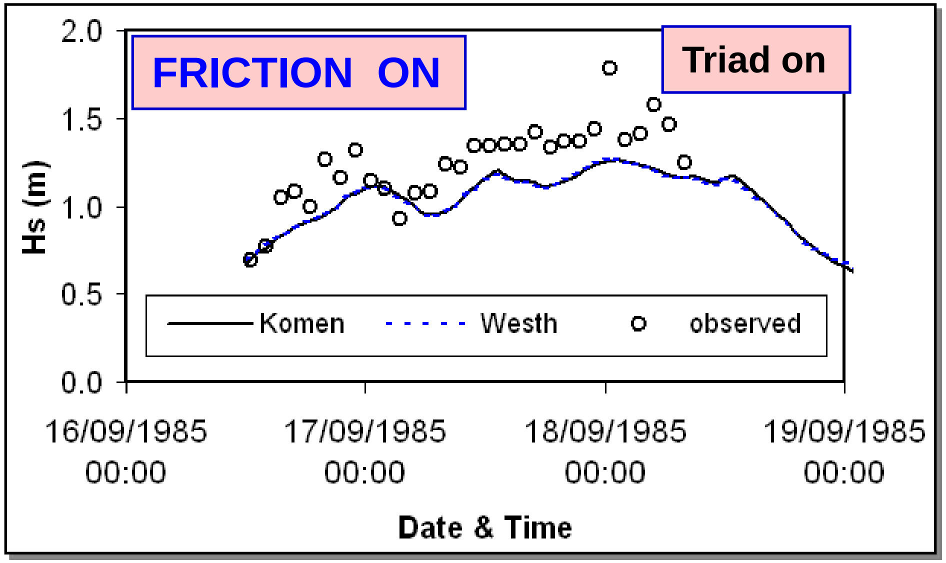
16-18 Aug. 1985 storm

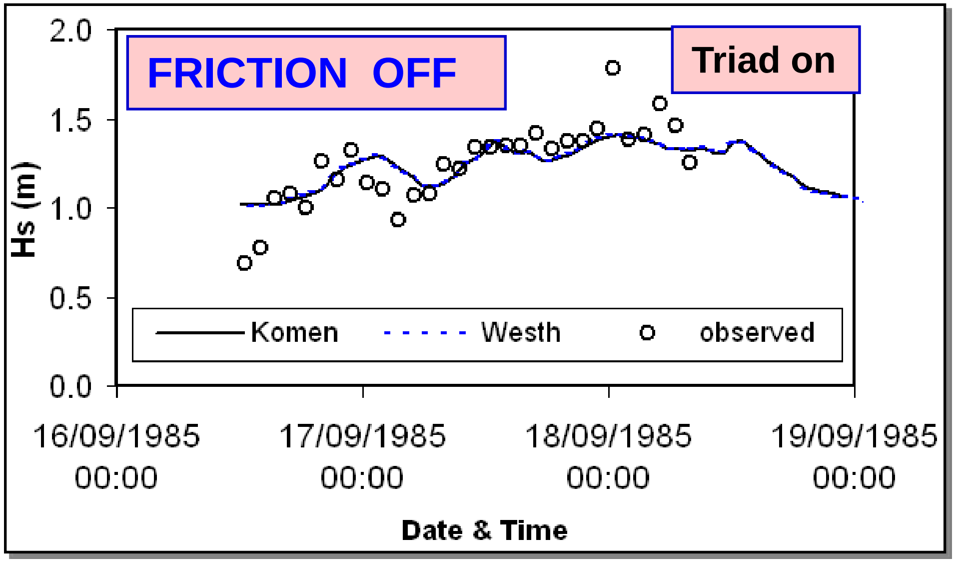
03-06 Aug. 1985 storm



SWAN Sensitivity to Bottom Friction

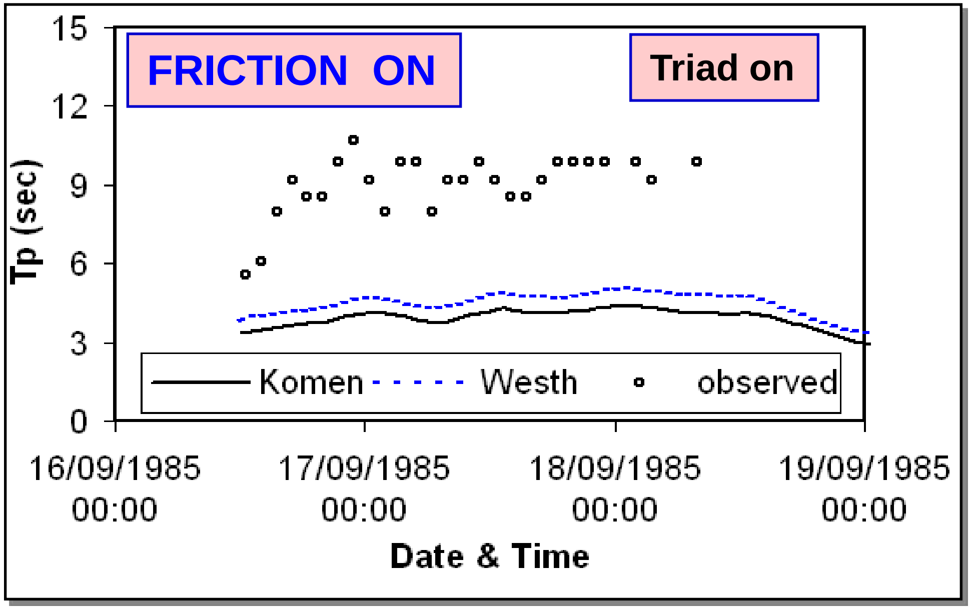
Hs during 1985 Storm at WELL116 (2.24 m water depth)

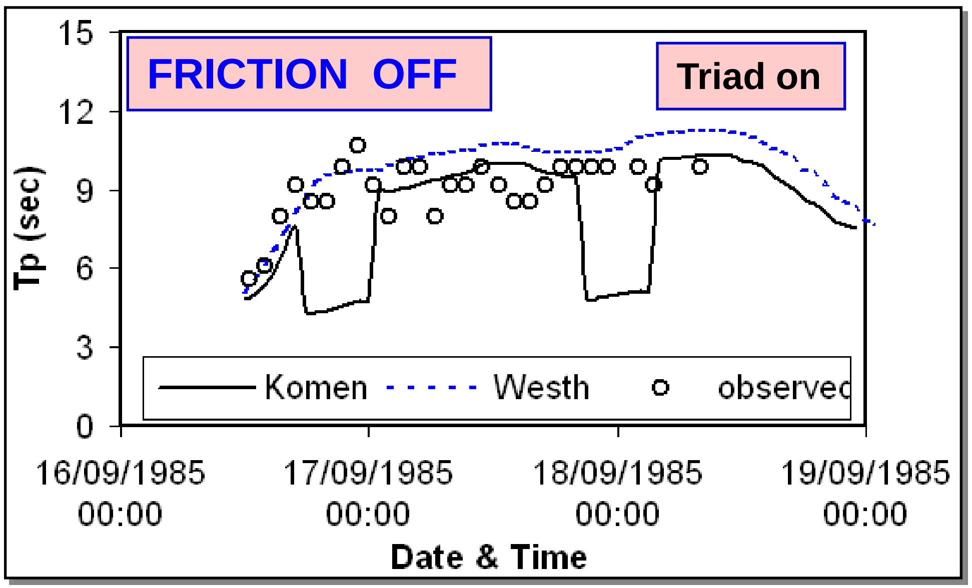




SWAN Sensitivity to Bottom Friction

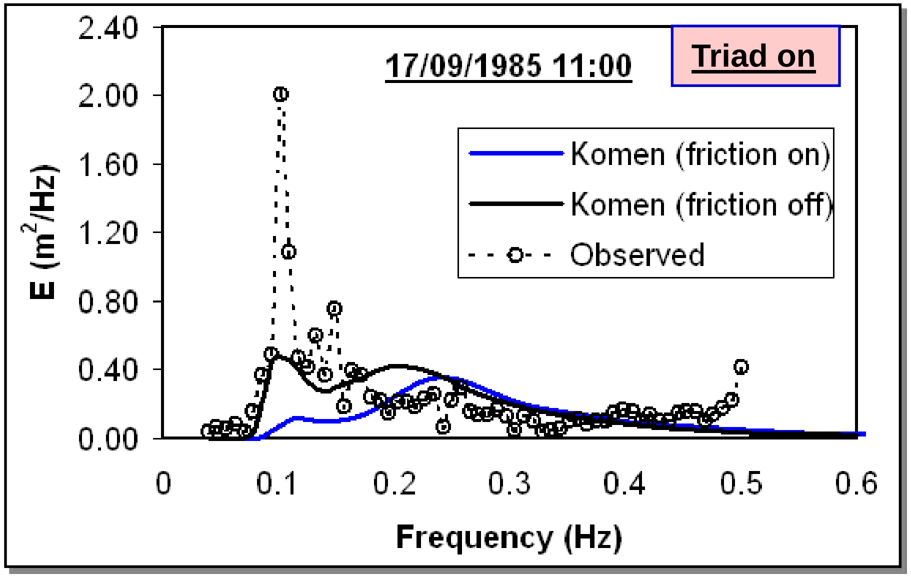
Tp during 1985 Storm at WELL116 (2.24 m water depth)

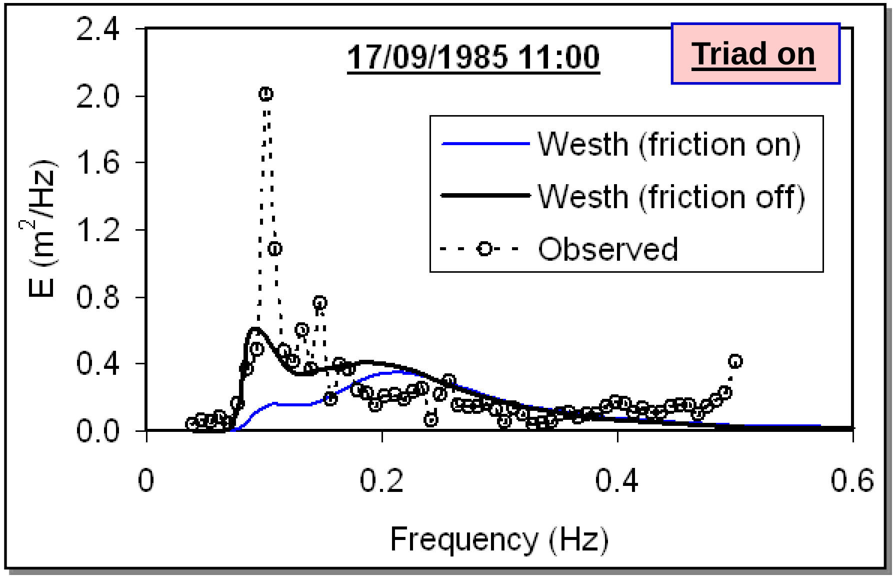




SWAN Sensitivity to Bottom Friction

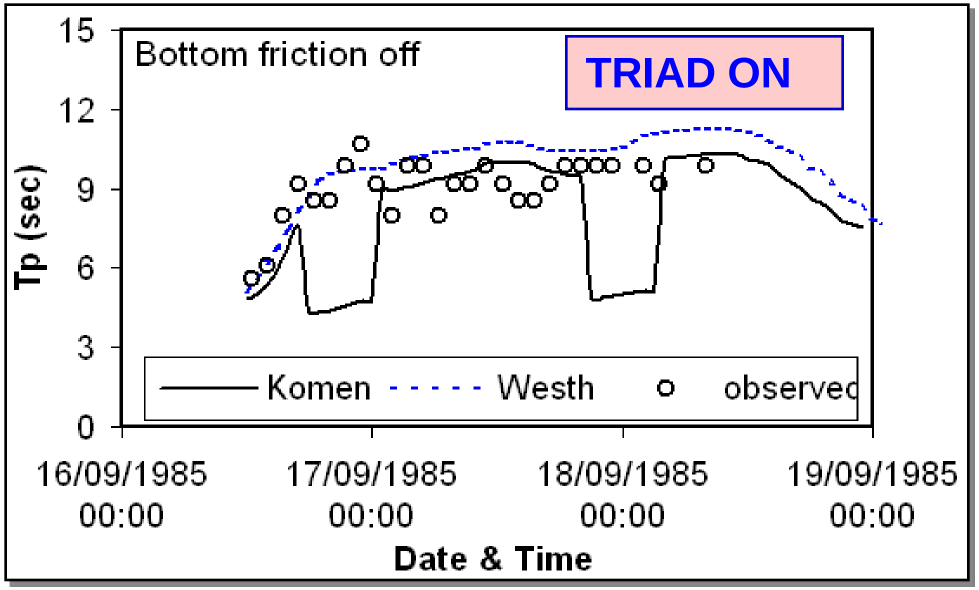
1-d spectra during 1985 Storm at WELL116

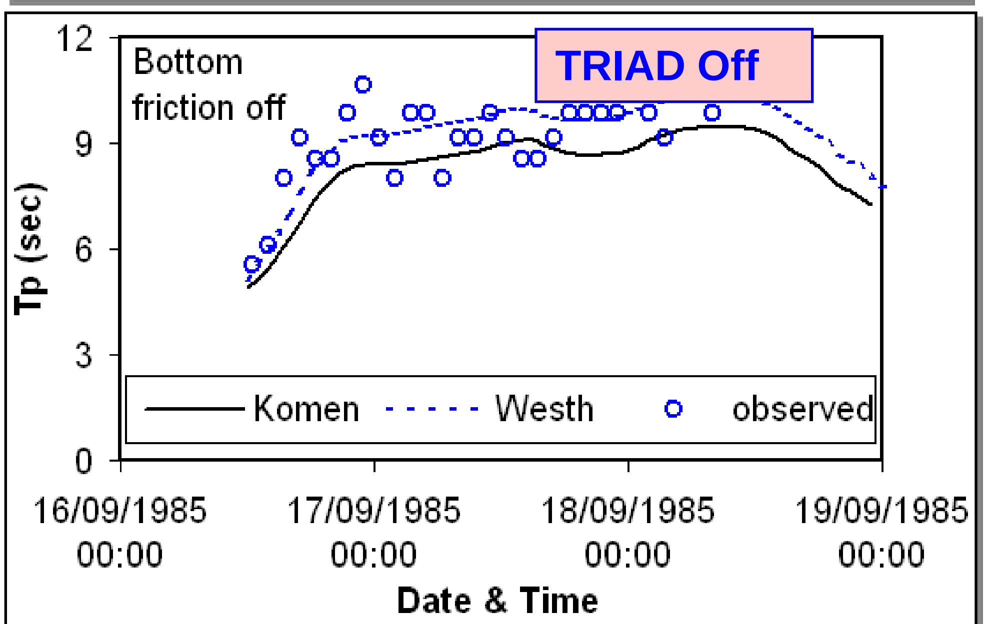




SWAN Sensitivity to Triad Interactions

Tp during 1985 Storm at WEL116 (2.24 m water depth)

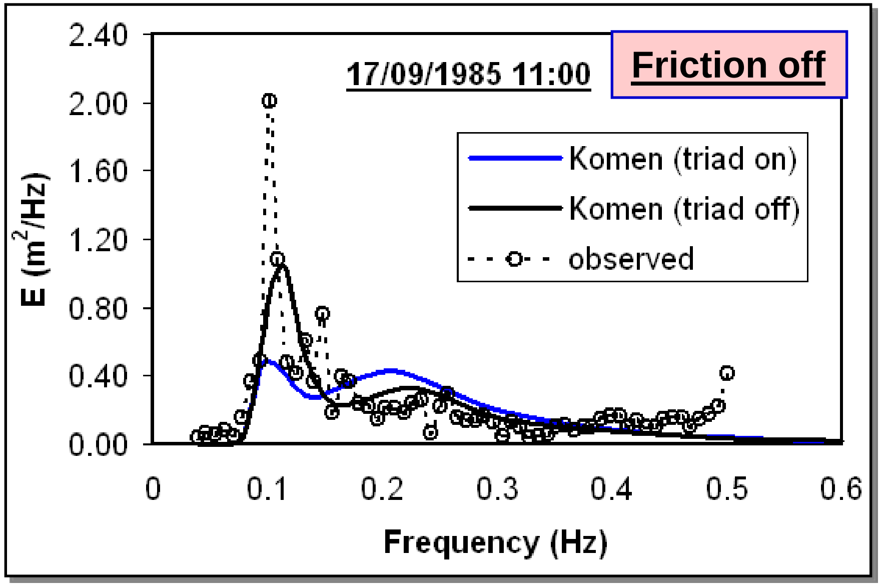


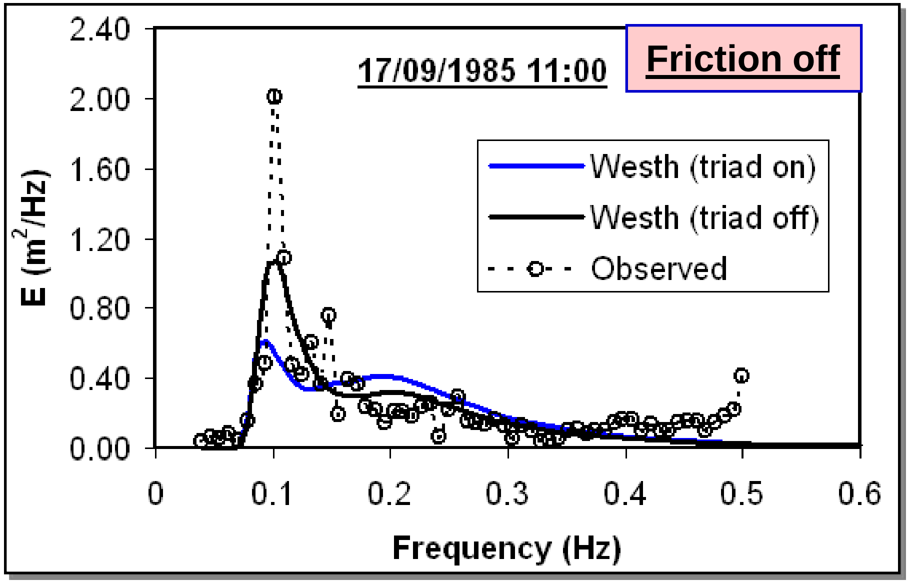


Tp is same with and without TRIAD

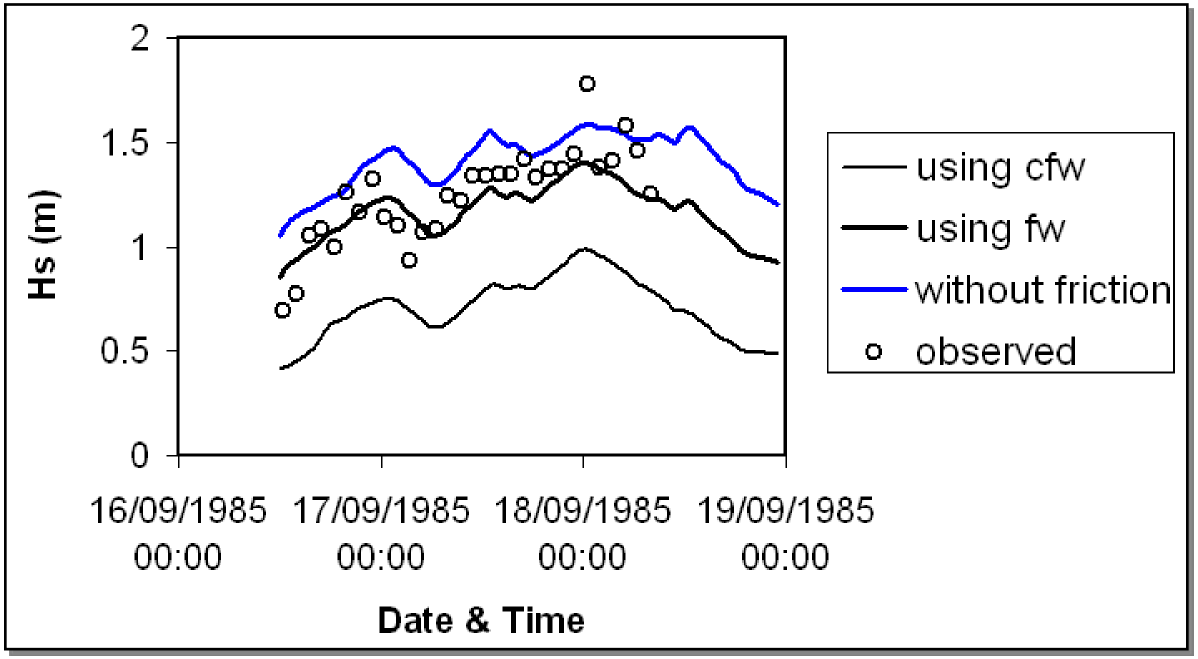
SWAN Sensitivity to Triad Interactions

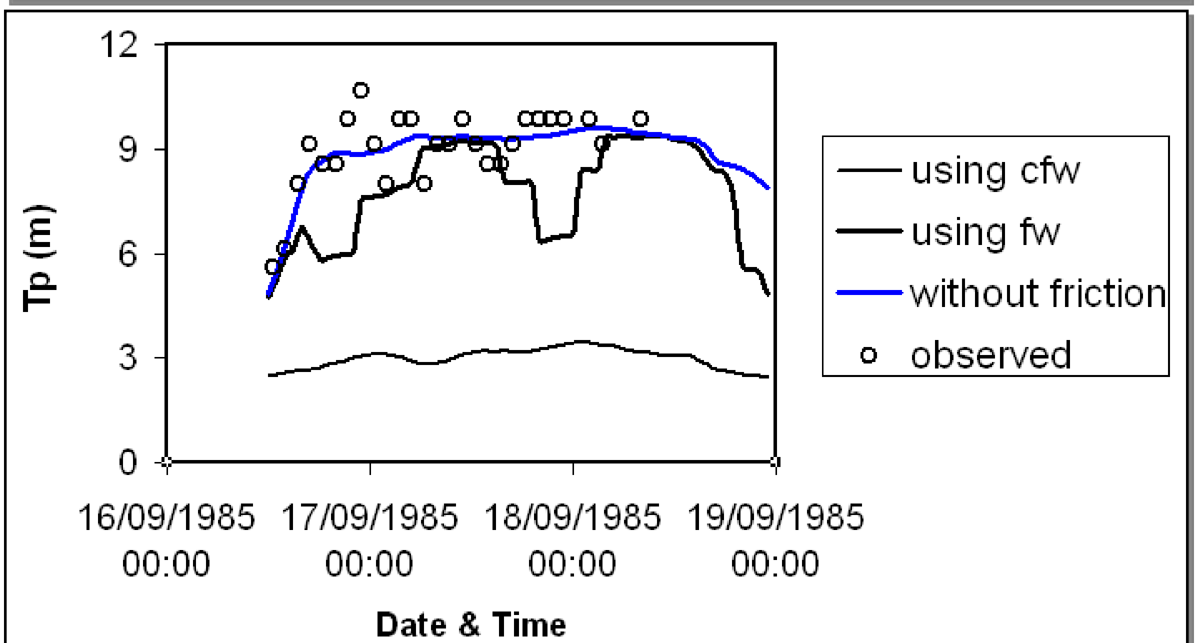
1-d spectra during 1985 Storm at WEL116





MIKE21 Sensitivity to Bottom Friction





1985 Storm

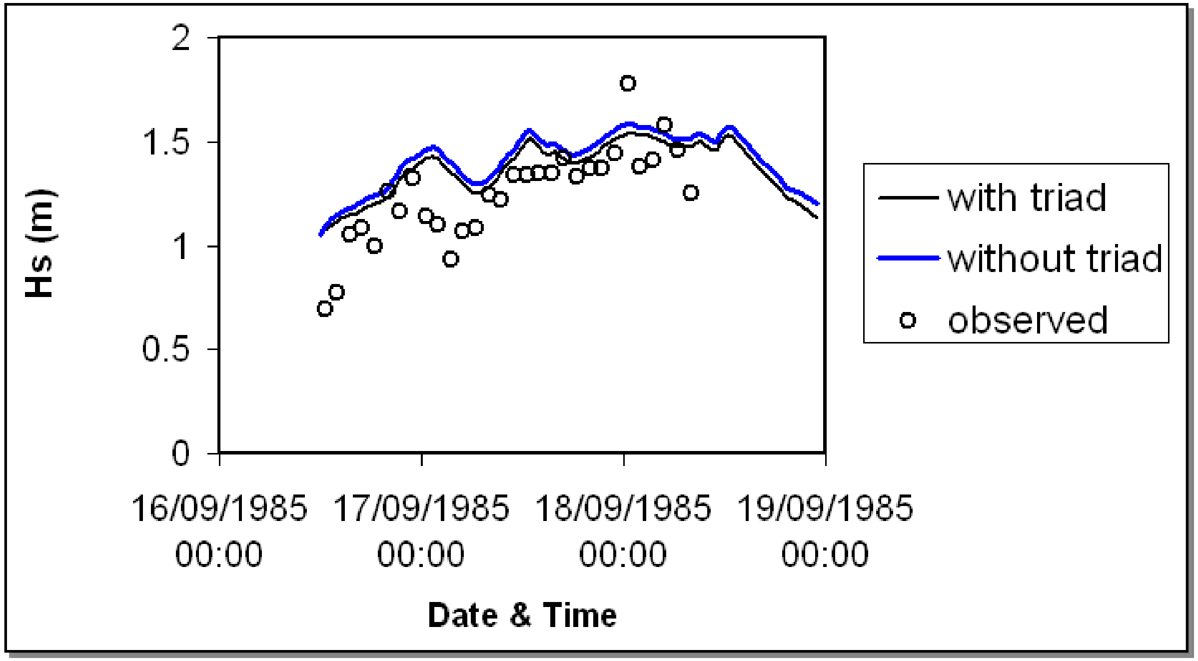
WEL116
Water depth
2.24 m

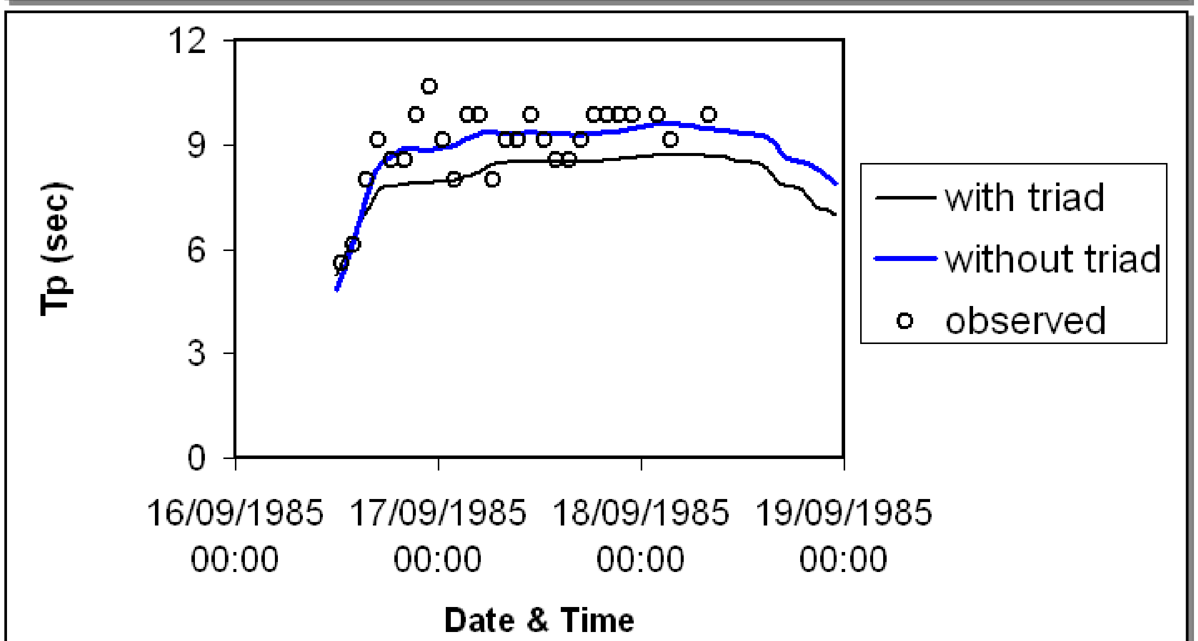
TRIAD OFF

cfw: friction co-efficient
default value: 0.0075

fw: friction factor
default value: 0.0212

MIKE21 Sensitivity to Triad Interactions



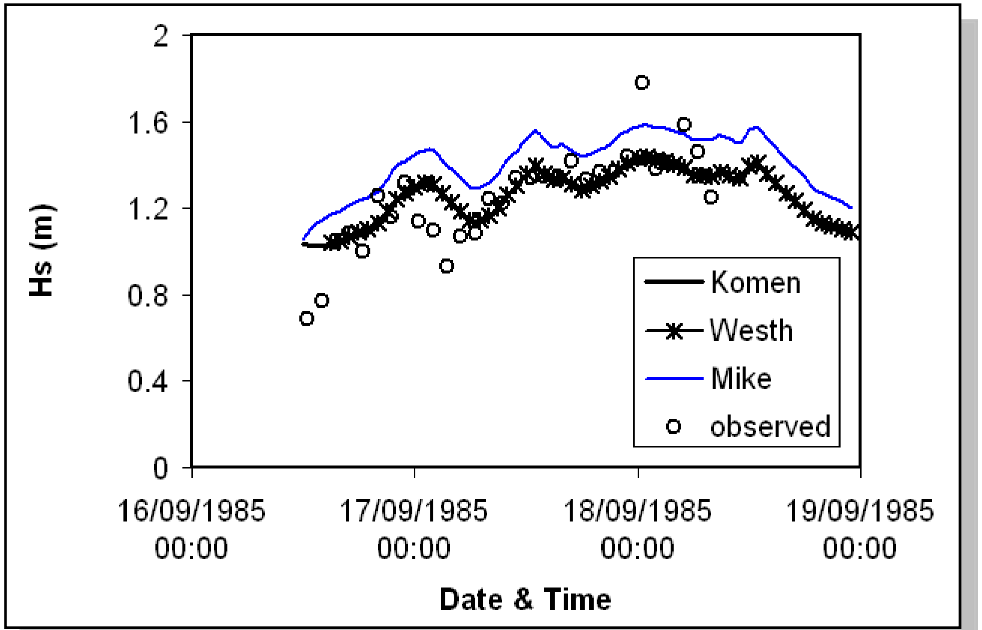


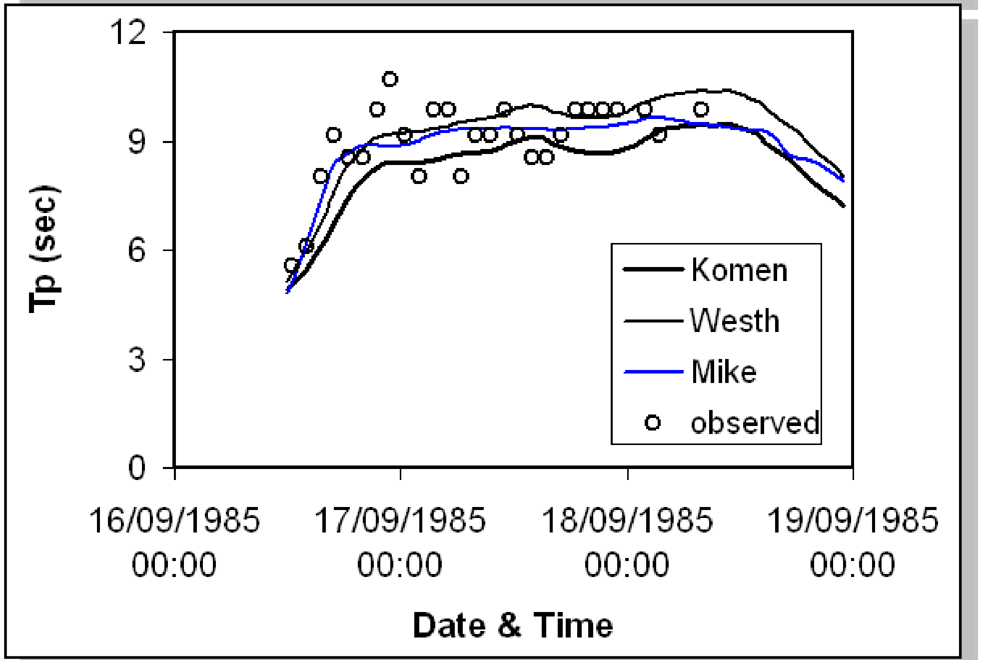
1985 Storm

WEL116
Water depth
2.24 m

FRICTION OFF

Comparisons of SWAN & MIKE21 Simulations





1985 Storm: Wave Heights & Peak periods

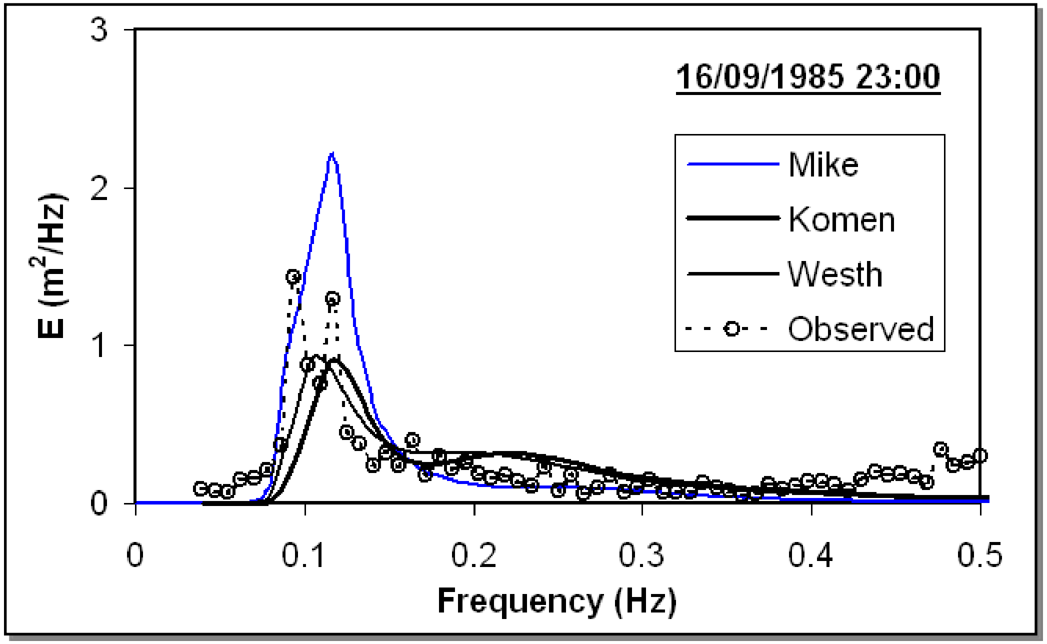
Without bottom friction & triad interaction

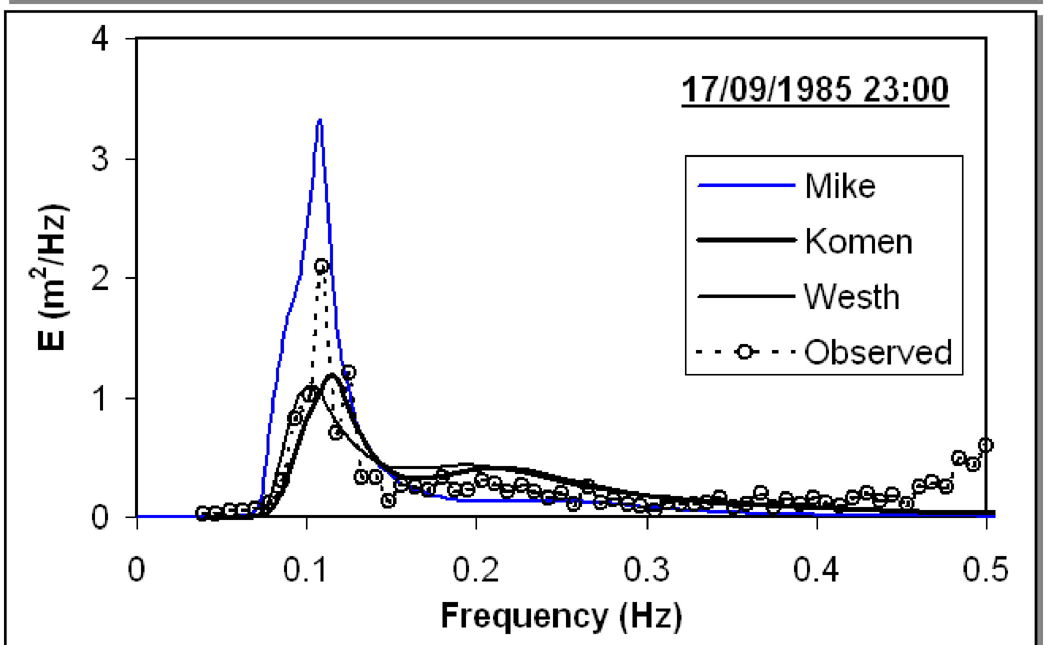
WEL116
Water depth 2.24 m

SWAN outperforms MIKE21 in simulating Hs.

MIKE21 similar to SWAN for Tp.

Comparisons of SWAN & MIKE21 Simulations



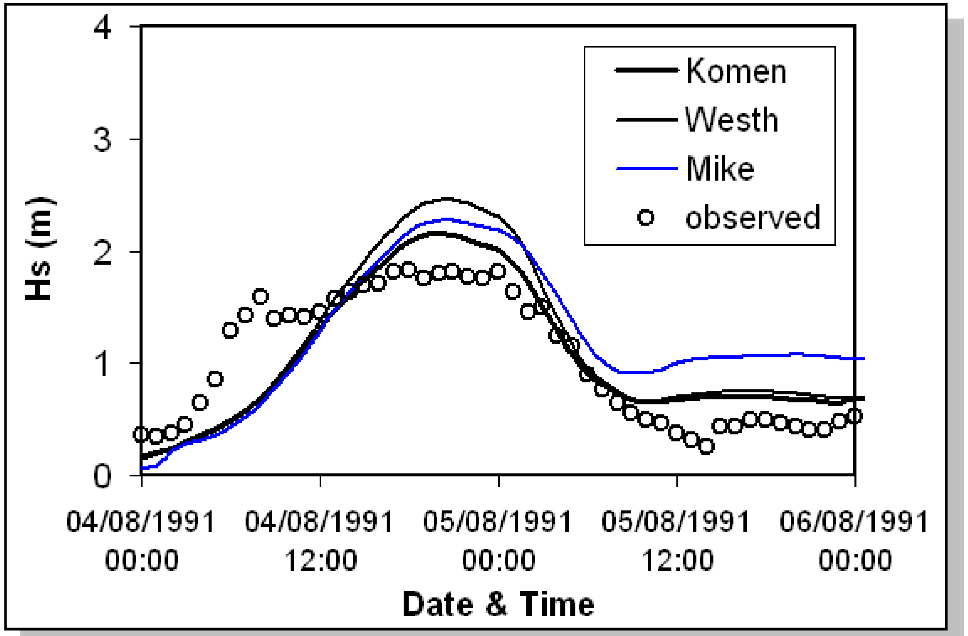


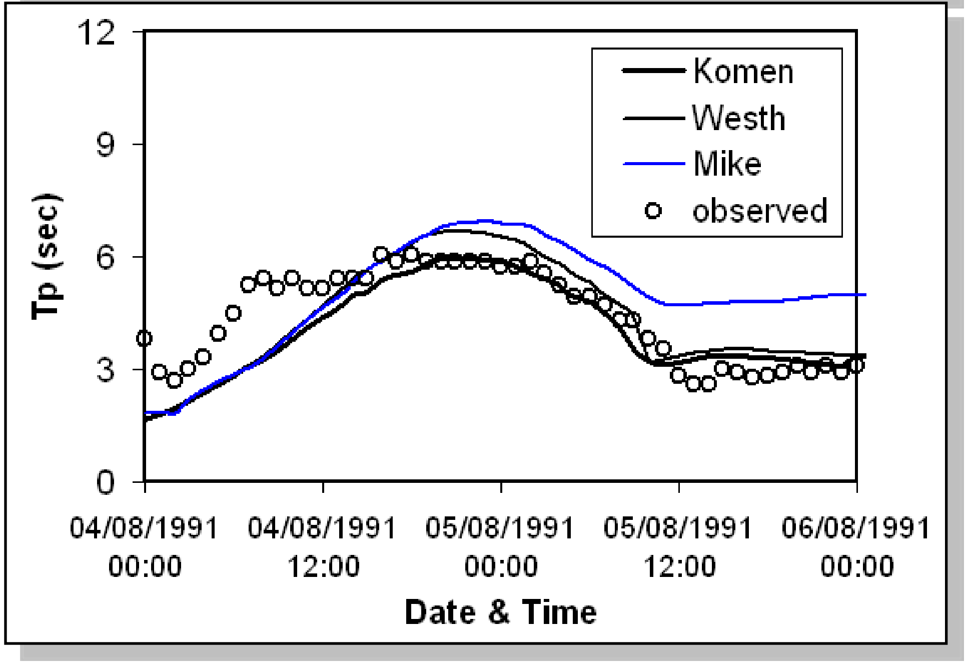
1985 Storm:
1-d Spectra

MIKE21 overpredicts spectral peaks, whereas

SWAN underpredicts spectral peak

Comparisons of SWAN & MIK21 Simulations



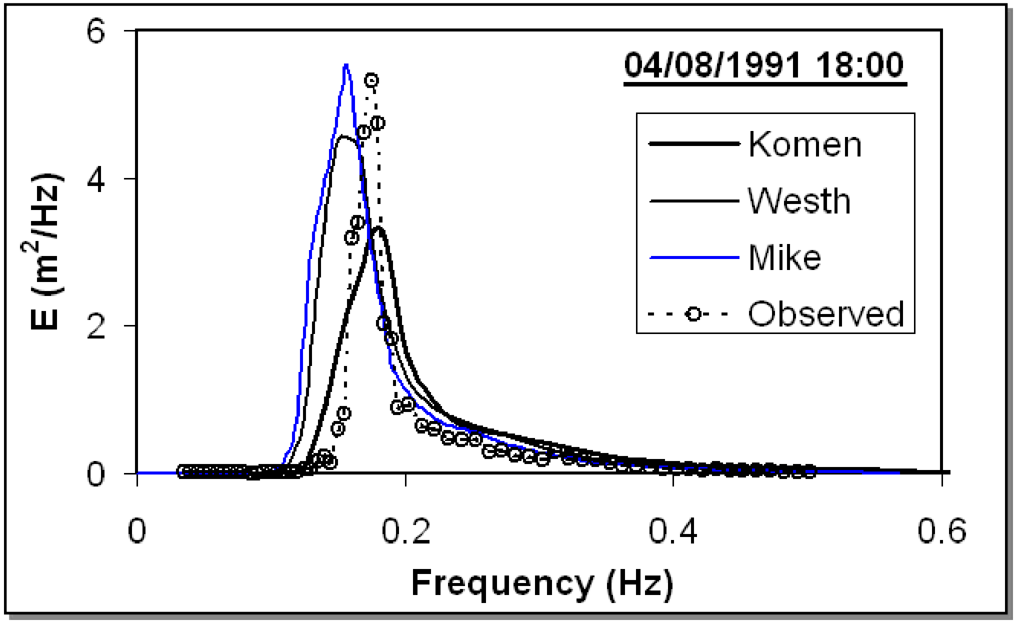


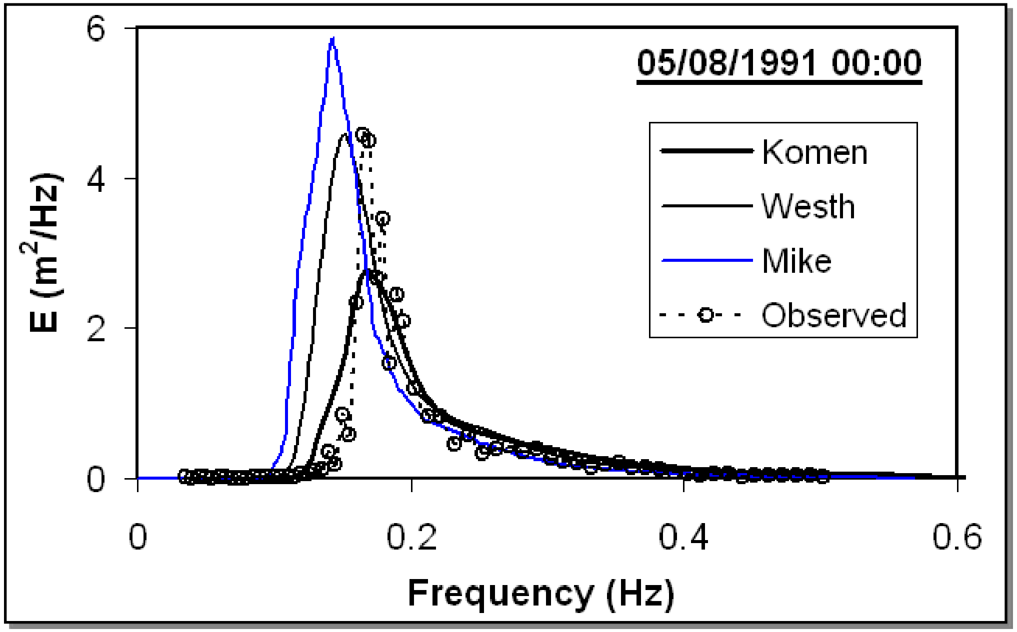
1991 Storm: Wave Heights & Peak Periods

Without bottom friction & triad interaction

MEDS291
Water depth 7m

Comparisons of SWAN & MIK21 Simulations





1991 Storm:
1-d Spectra

MEDS291
Water depth 7m

5. Concluding Remarks

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- **Of the two SWAN formulations for wave dissipation simulations, Westhuysen option is better than Komen option**
- **In most cases MIKE21 simulations are found to be close to the results of Westhuysen option in SWAN.**