# INTERCOMPARISON OF WAVE DATA HINDCAST ON LAKE ERIE

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## 1. Introduction

In this study, wave hindcasting at 3 buoys on Lake Erie using a backward ray tracing model (BRTM) in shallow water, the first generation model, developed by the authors is conducted under the same bathymetry and wind input conditions as Lalbeharry et al. (2001), and

intercomparison is made among BRTM-based wave data, WAM-based wave height data given by Roop Lalbeharry and measurement wave data.

# Outline of Study

1) Discussion for measurement data of winds and waves

2) Verification of estimated winds and waves

 a) Conditions for wave hindcasting

 b) Intercomparison of wind and wave data

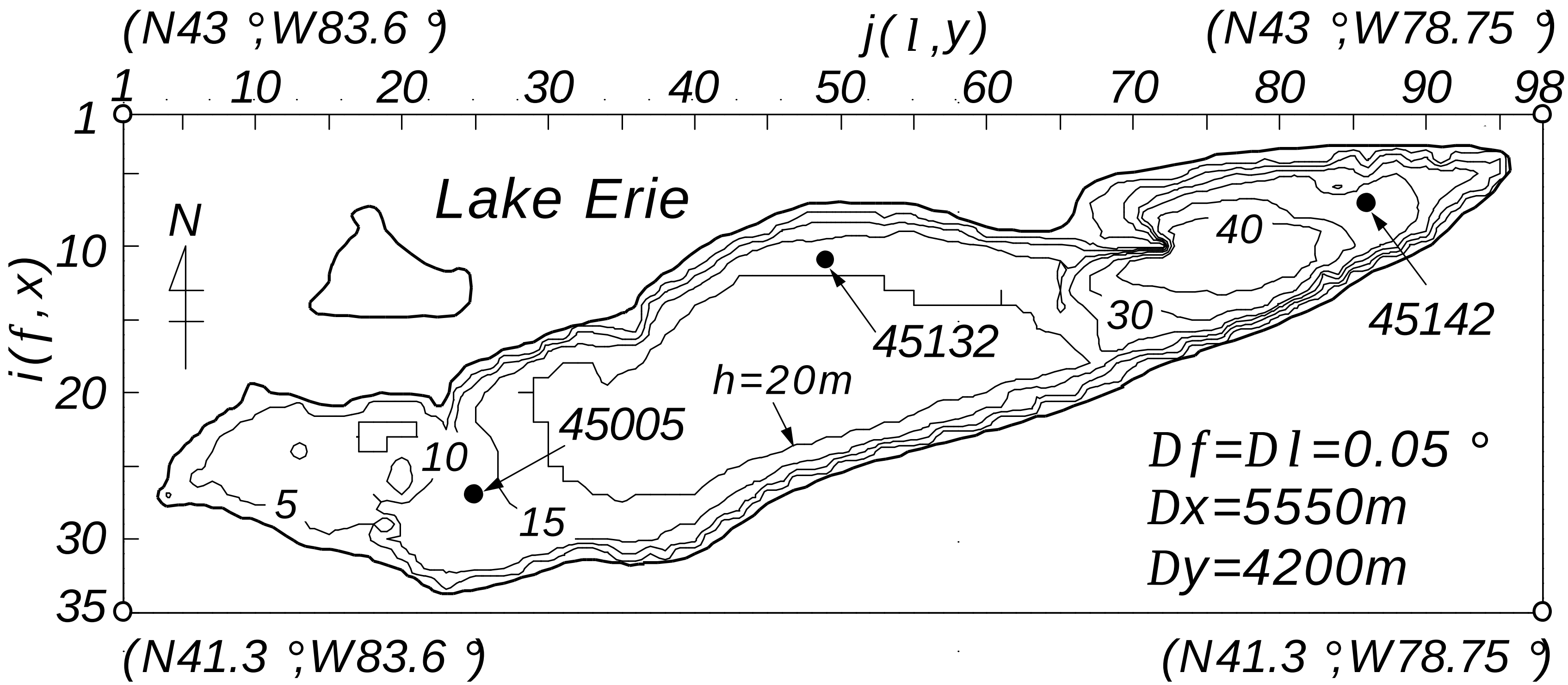
  (1) time series of winds and waves

  (2) statistics of winds and waves, and error statistics

  (3) comparison with Toba's 3/2 power law

3) Conclusions

# 2. Discussion for Measurement Data of Winds and Waves




0.05° grid on Lake Erie, contourline of water depth and location of 3 buoys.

1) laterally-prolonged scale of 400 km x 100 km

2) wide shallow water area from 5 m to 60 m deep

3) 3 buoys are deployed for wind(5 m height) and wave measurement

a) B45005 (14.6 m, USA), fetch: 20 - 300 km (< 45 degrees)

b) B45132 (22.0 m, Canada), fetch: 80 - 160 km (WSW - E)

c) B45142 (27.0 m, Canada) fetch: 20 - 300 km(< 45 degrees)

# Measurement data of winds and waves at 3 buoys

1) Hourly wind speed and direction, wave height
   and wave period

2) Period: October 22 - November 22, 2000

The Toba(1972) 3/2 power law between

dimensionless wave height $\tilde{H}_s (= gH_s / u_*^2)$ and

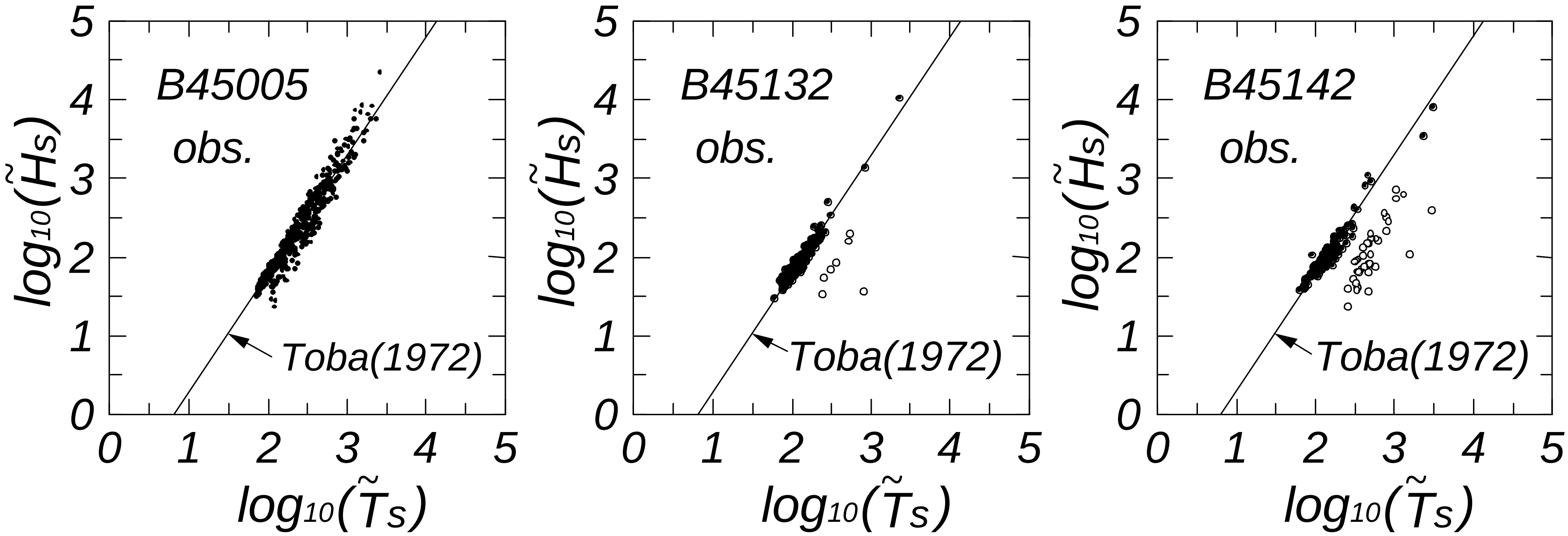
dimensionless wave period $\tilde{T}_s (= gT_s / u_*)$

$$\tilde{H}_s = 0.062 \tilde{T}_s^{3/2} \qquad (1)$$

$$\left[ \tilde{H}_s = a \tilde{T}_s^{3/2} \qquad (2) \right]$$

fitting

$H_s$ : significant wave height, $T_s$ : significant wave period
$g$ : acceleration of gravity,
$u_*$ : friction velocity defined by $C_d^{1/2} U_{10}$, $C_d$ : drag coefficient
$U_{10}$ : wind speed at 10 m height




Relation between dimensionless wave height and wave period
based on measured data at each buoy.

1) straight line: Toba's 3/2 power law

2) white circle: data corresponding to swell-like waves

at decaying stages

# 3. Verification of Estimated Winds and Waves

## 3.1 Conditions for wave hindcasting by BRTM

1) Original wind data: 10 m height winds estimated every 3 hours on a 24 km grid by CMC

2) Wind data provided by Roop Lalbeharry and used in wave hindcasting by BRTM: 10 m height winds interpolated onto a 0.05 ° grid

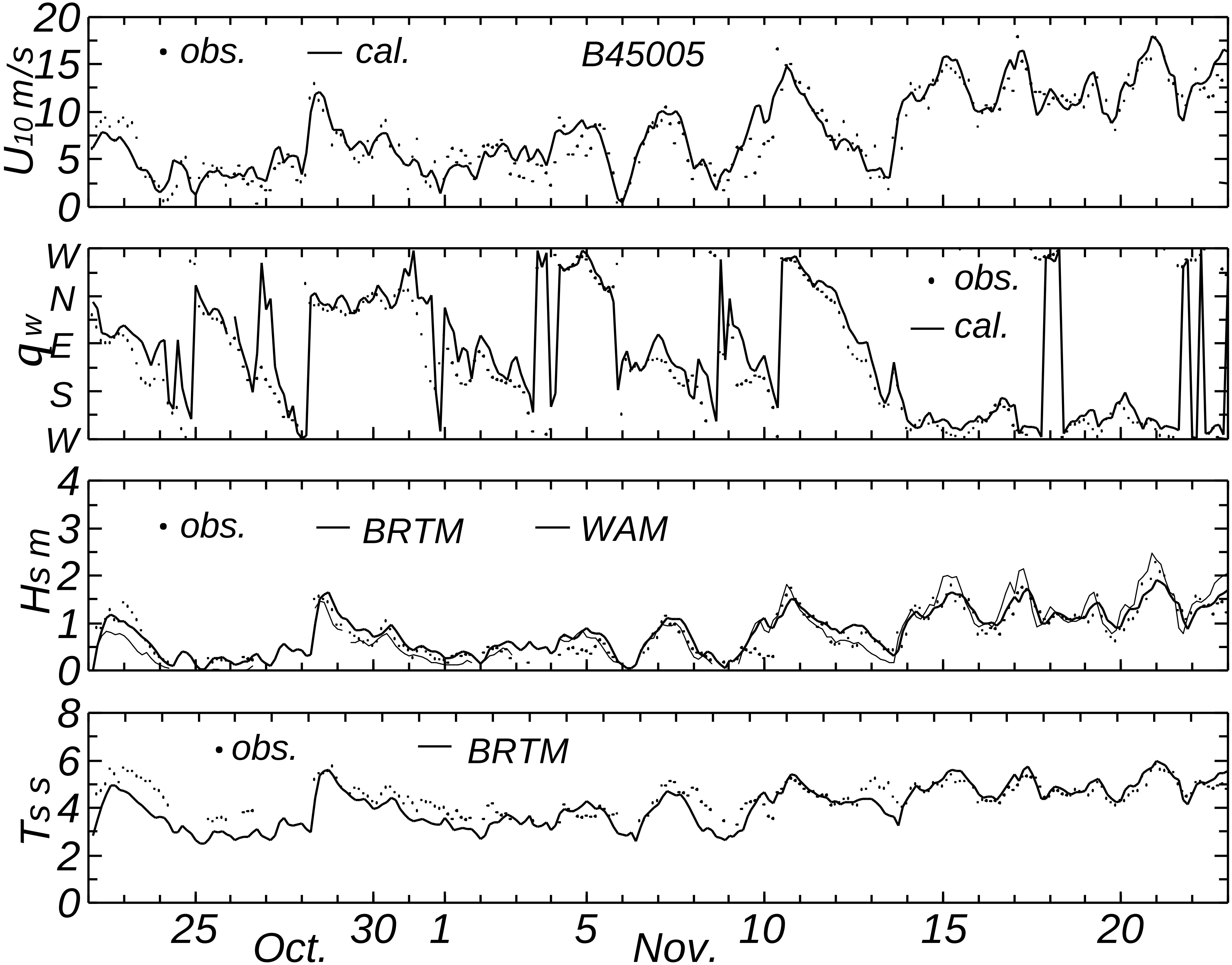
3) Period: October 22 - November 22, 2000

4) Wave data (1): WAMS(WAM)-based wave heights at 3 buoys provided every 3 hours by Roop Lalbeharry

5) Wave data (2): BRTM-based wave heights and wave periods at 3 buoys hindcast on a rectangular grid of 5550 m by 4200 m under the conditions of 28 frequencies (0.073 - 0.959 Hz), 37 directions on the full circle and integration time step of 30 min.

## 3.2 Intercomparison of Wind and Wave Data

Comparison of estimated or hindcast data and measured data for time series of winds and waves at B45005 (West), B45132 (Middle) and B45142 (East).



B45005
obs.
cal.
U10 m/s
qw
Hs m
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WAM
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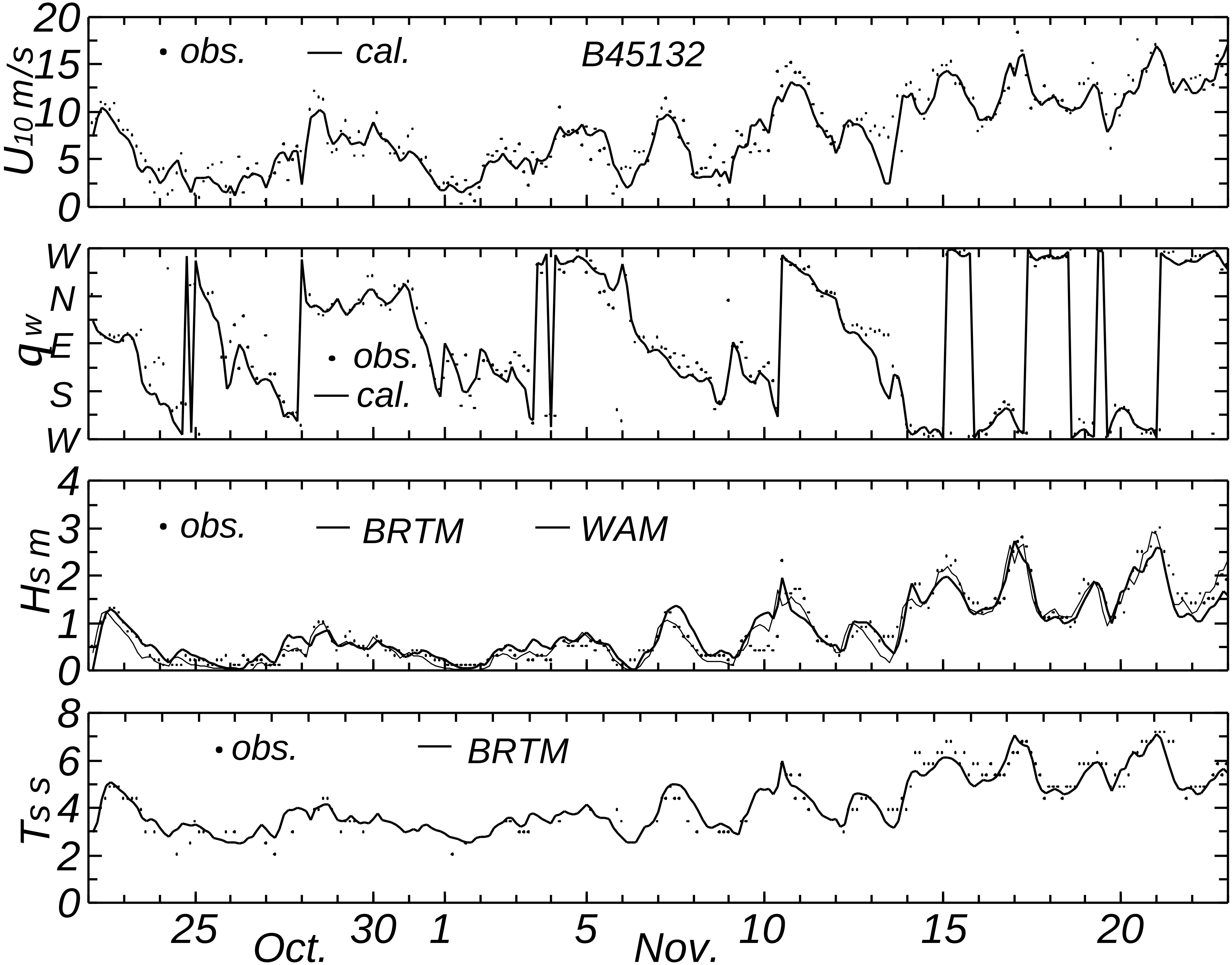
W
N
E
S
25
Oct.
30
1
5
Nov.
10
15
20



obs.
cal.
B45132
U10 m/s
20
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5
0
q w
W
N
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S
W
obs.
cal.
Hs m
4
3
2
1
0
obs.
BRTM
WAM
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8
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obs.
BRTM
25
Oct.
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Nov.
10
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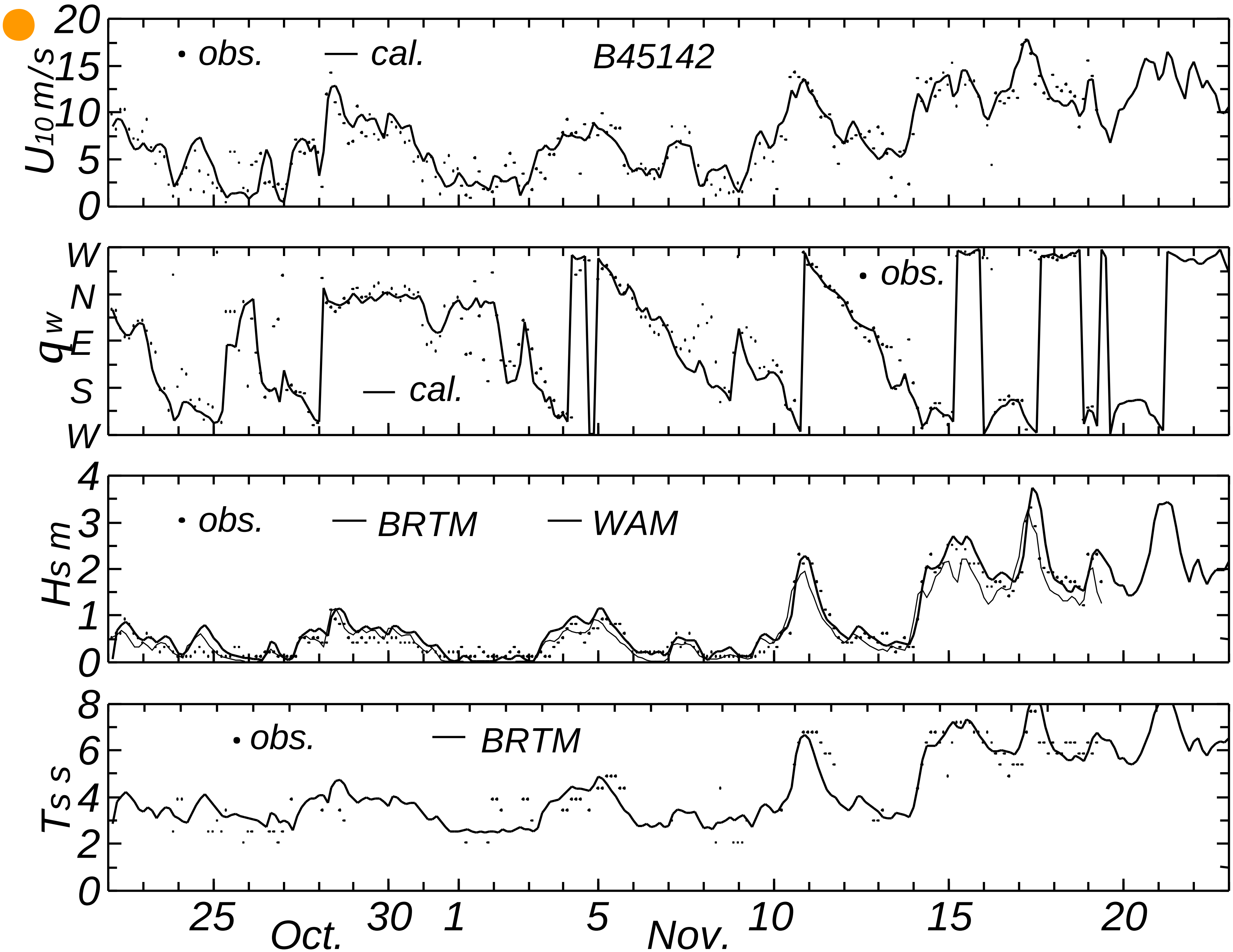


U10 m/s
• obs.
— cal.
B45142
20
15
10
5
0
qw
• obs.
— cal.
W
N
E
S
W
Hs m
• obs.
— BRTM
— WAM
4
3
2
1
0
Ts s
• obs.
— BRTM
8
6
4
2
0
25
Oct.
30
1
5
Nov.
10
15
20

# 2) Statistics of Winds and Waves, and Error Statistics

- climate parameters H (  or U)

  $H_S$:    mean significant wave height

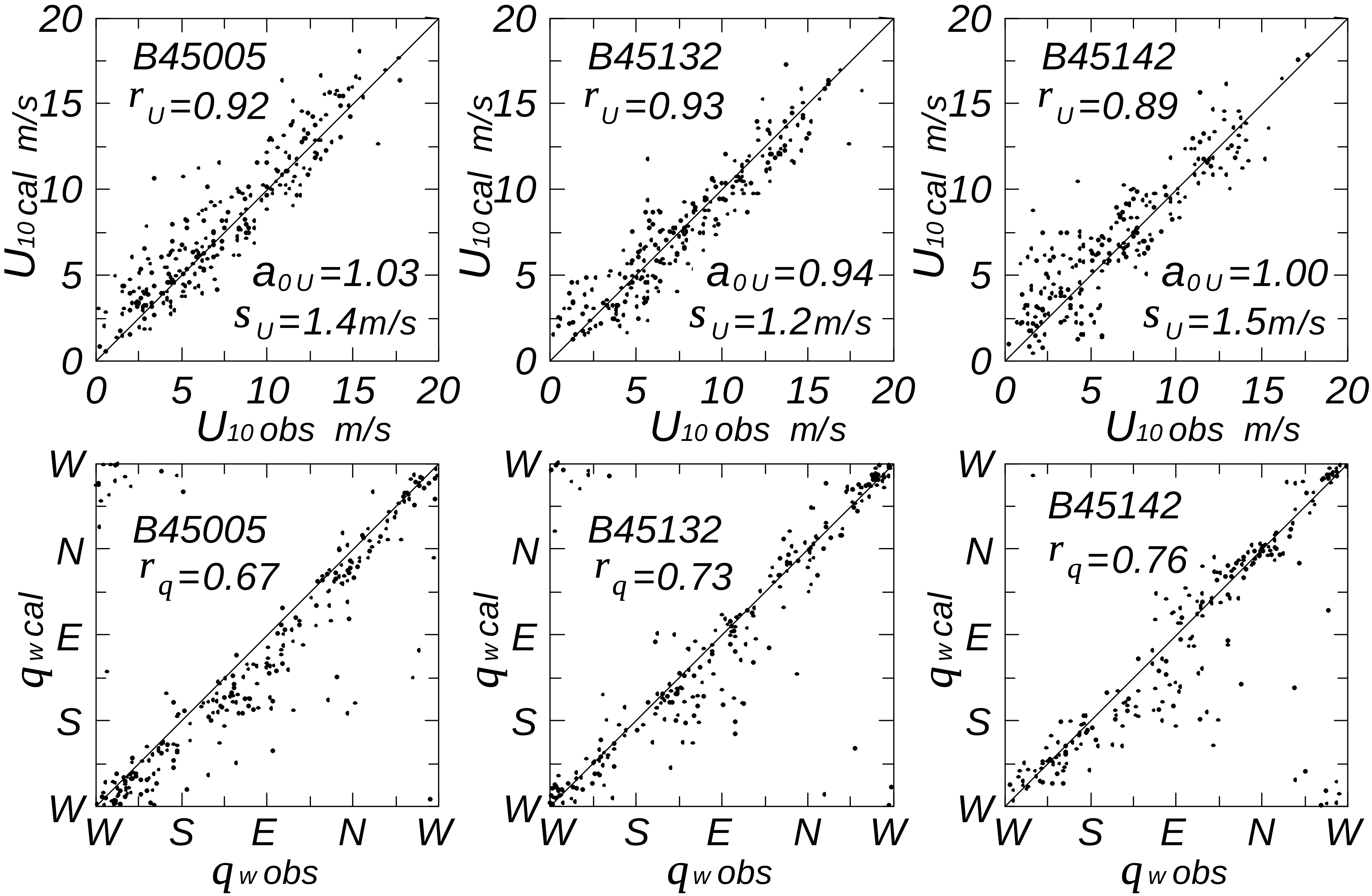
  $H_s$ : standard deviation of significant wave height data

- Error statistics of H or U data

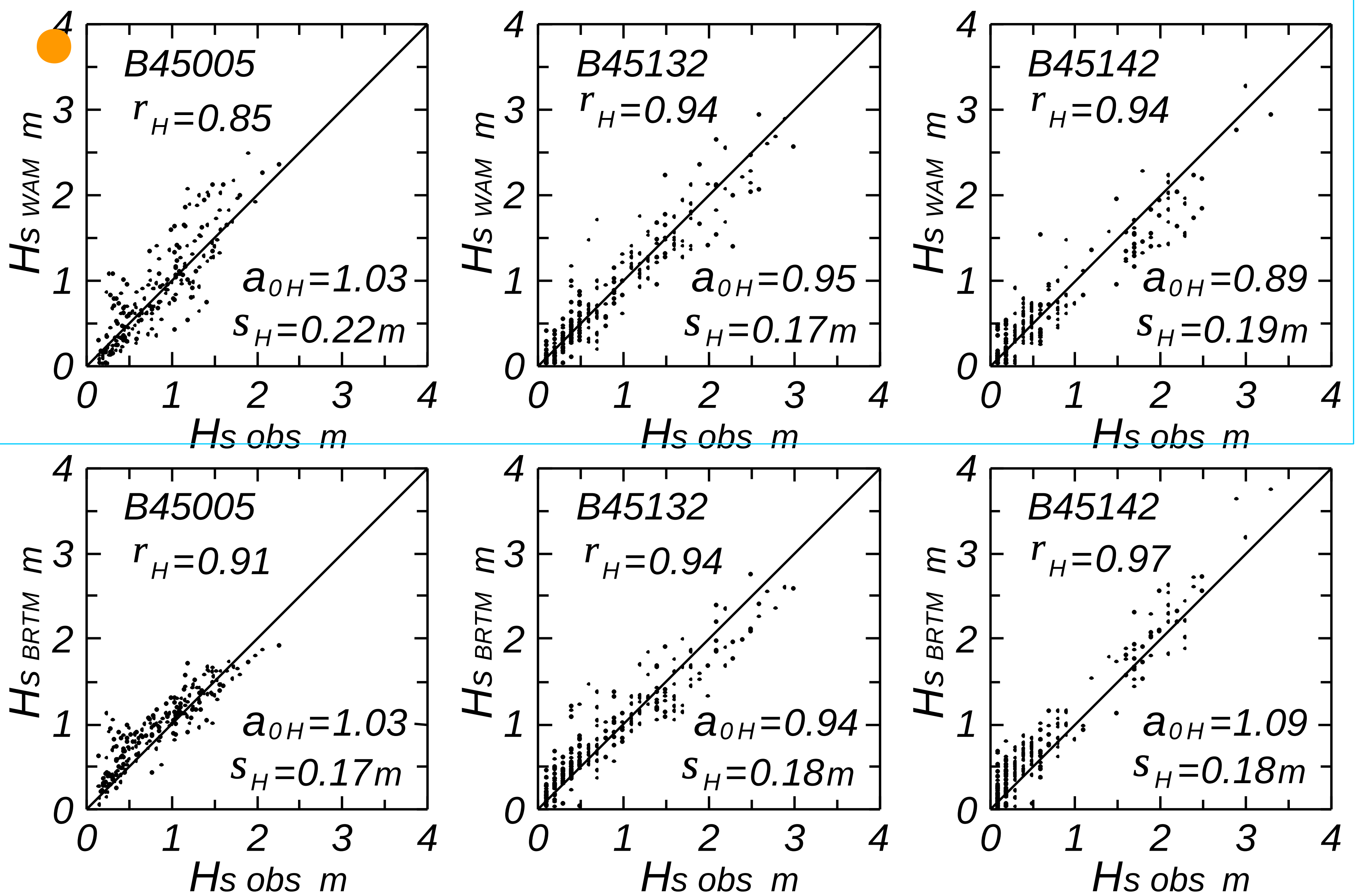
  ? $_H$: correlation coefficient between hindcast and measured wave height data

  $a_{0H}$: slope value of a straight line passing through the origin in the correlation diagram between hindcast and measured wave height data

  s $_H$: root mean square error of wave height



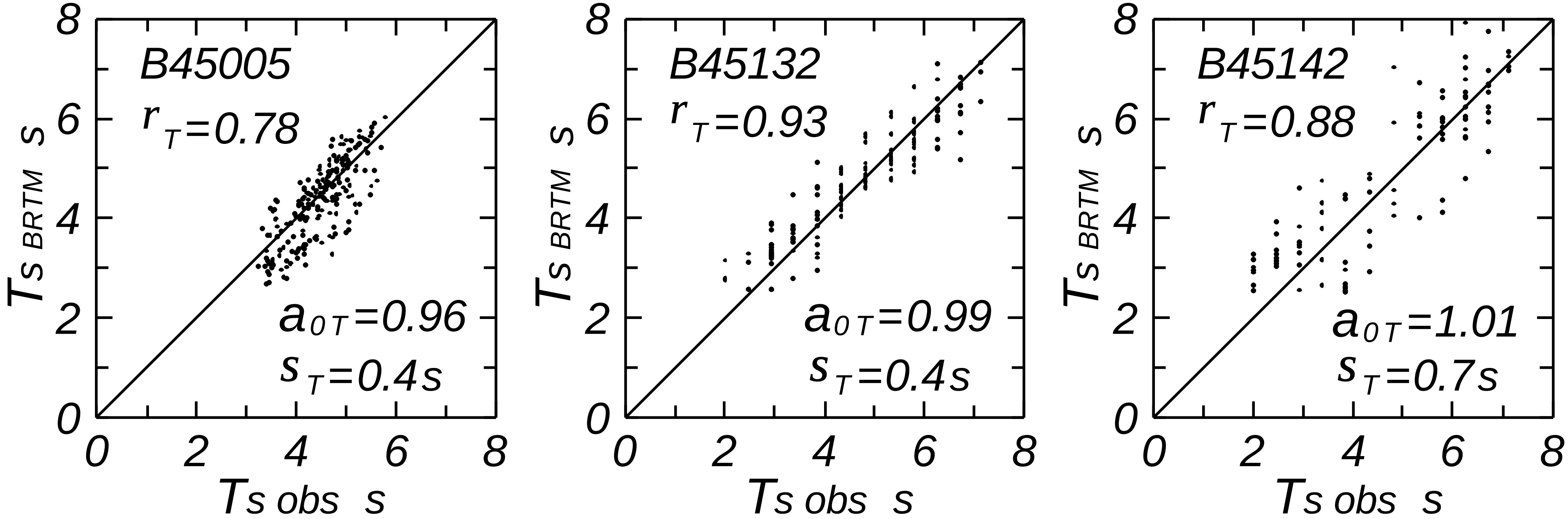

1) Accuracy of the estimated wind data at each buoy is rather high.




Scatter diagram between WAM-based or BRTM-based data and measured data for wave height at each buoy.

Table 2 Wave height statistics and error statistics obtained from WAM-based data, BRTM-based data and measured data at each buoy.

| buoy | model | $\overline{H}_{s\ obs}$ m | $\overline{H}_{s\ cal}$ m | $H_{s\ obs}$ m | $H_{s\ cal}$ m | $r_H$ | $a_{0H}$ | $s_H$ m |
|---|---|---|---|---|---|---|---|---|
| 45005 | WAM | 0.84 | **0.87** | 0.48 | 0.58 | 0.85 | **1.03** | 0.22 |
| | BRTM | 0.84 | 0.93 | 0.48 | **0.42** | **0.91** | **1.03** | **0.17** |
| | B-W | | | | | 0.93 | 0.95 | 0.21 |
| 45132 | WAM | 0.85 | 0.82 | 0.69 | **0.68** | **0.94** | **0.95** | **0.17** |
| | BRTM | 0.85 | **0.87** | 0.69 | 0.61 | **0.94** | 0.94 | 0.18 |
| | B-W | | | | | 0.96 | 0.97 | 0.16 |
| 45142 | WAM | 0.72 | **0.67** | 0.74 | 0.67 | 0.94 | 0.89 | 0.19 |
| | BRTM | 0.72 | 0.83 | 0.74 | **0.78** | **0.97** | **1.09** | **0.18** |
| | B-W | | | | | 0.96 | 1.18 | 0.21 |

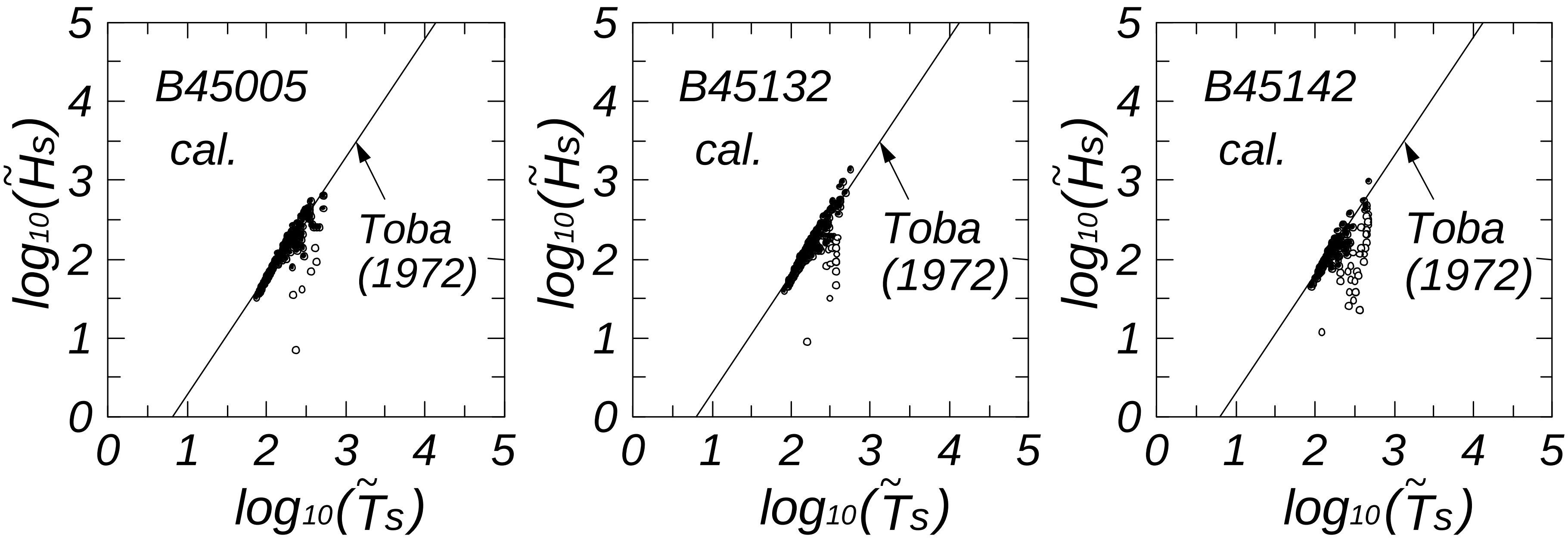



- Comparison of BRTM-based and measured wave period data at each buoy.

Table 3 Wave period statistics and error statistics obtained from BRTM-wave data and measured data.

| buoy | $\bar{T}_{s\ obs}$ s | $\bar{T}_{s\ cal}$ s | $T_{s\ obs}$ s | $T_{s\ cal}$ s | $r_T$ | $a_{0T}$ | $s_T$ s |
|---|---|---|---|---|---|---|---|
| 45005 | 4.5 | 4.3 | 0.6 | 0.8 | 0.78 | 0.96 | 0.4 |
| 45132 | 4.7 | 4.7 | 1.3 | 1.1 | 0.93 | 0.99 | 0.4 |
| 45142 | 4.7 | 4.4 | 1.7 | 1.6 | 0.88 | 1.01 | 0.7 |

It may be said that BRTM-based data is in acceptable agreement with measured data on a mean sense.




Relation between dimensionless wave height and wave period obtained using estimated wind speed data and BRTM-based wave data.

# 4. CONCLUSIONS

Analysis of measured wind wave data at 3 buoys over one month on Lake Erie and intercomparative tests using WAM-based and BRTM-based wave data which were calculated under the same bathymetry and over-lake wind conditions lead to the results such as

1) Relation between dimensionless wave height and wave period based on the measurement data is approximated by Toba's 3/2 power law with a slightly smaller coefficient. This means predominance of wind waves during this period.

2) The wind data estimated by CMC has a rather high quality.

3) As a whole, BRTM-based wave height data yields as close an agreement with the measured data as does WAM-based data. Also, BRTM-based wave period data agrees well with measured data on average.

4) Error statistics of wave height may suggest a slightly higher accuracy of BRTM-based data over WAM-based data, although WAM-based data yields an estimate closer to measured data than BRTM-based data for wave statistics such as mean wave height.

# Acknowledgements

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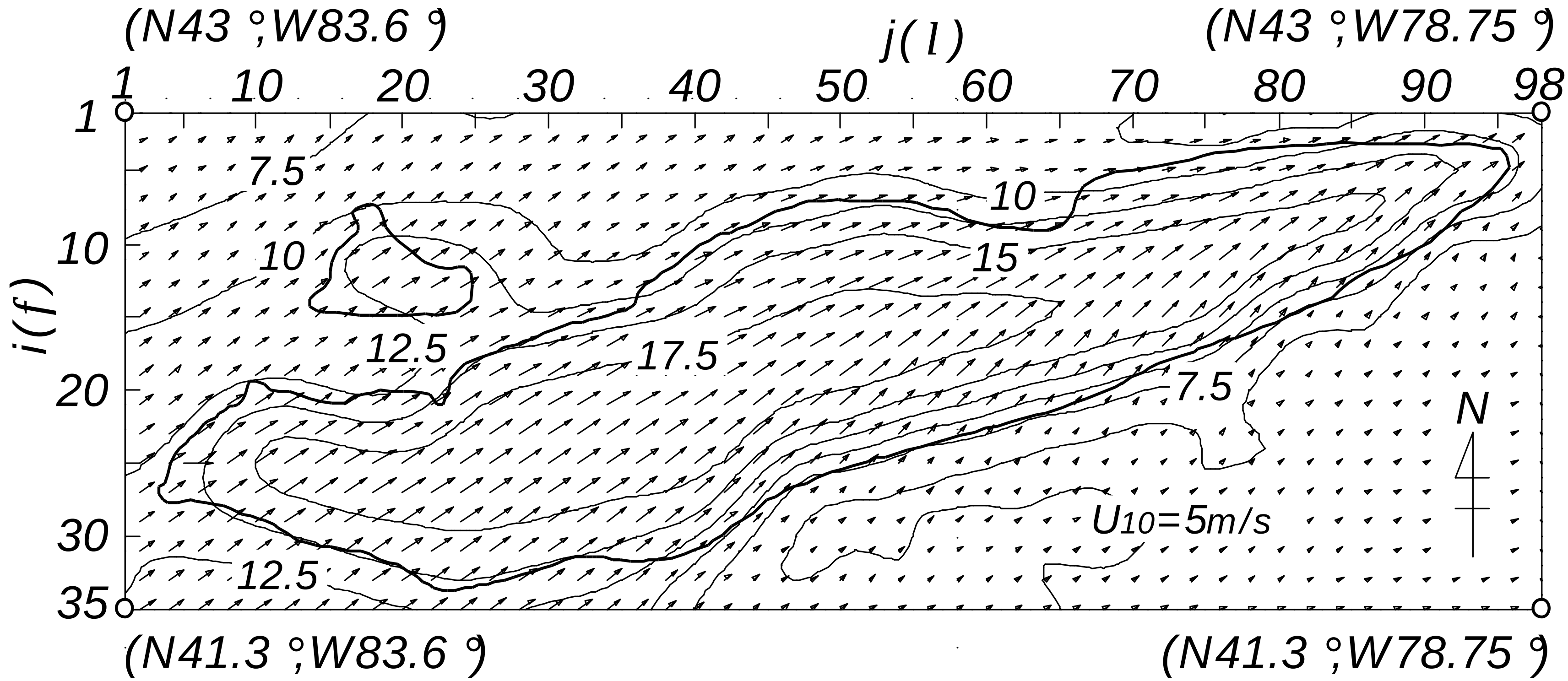
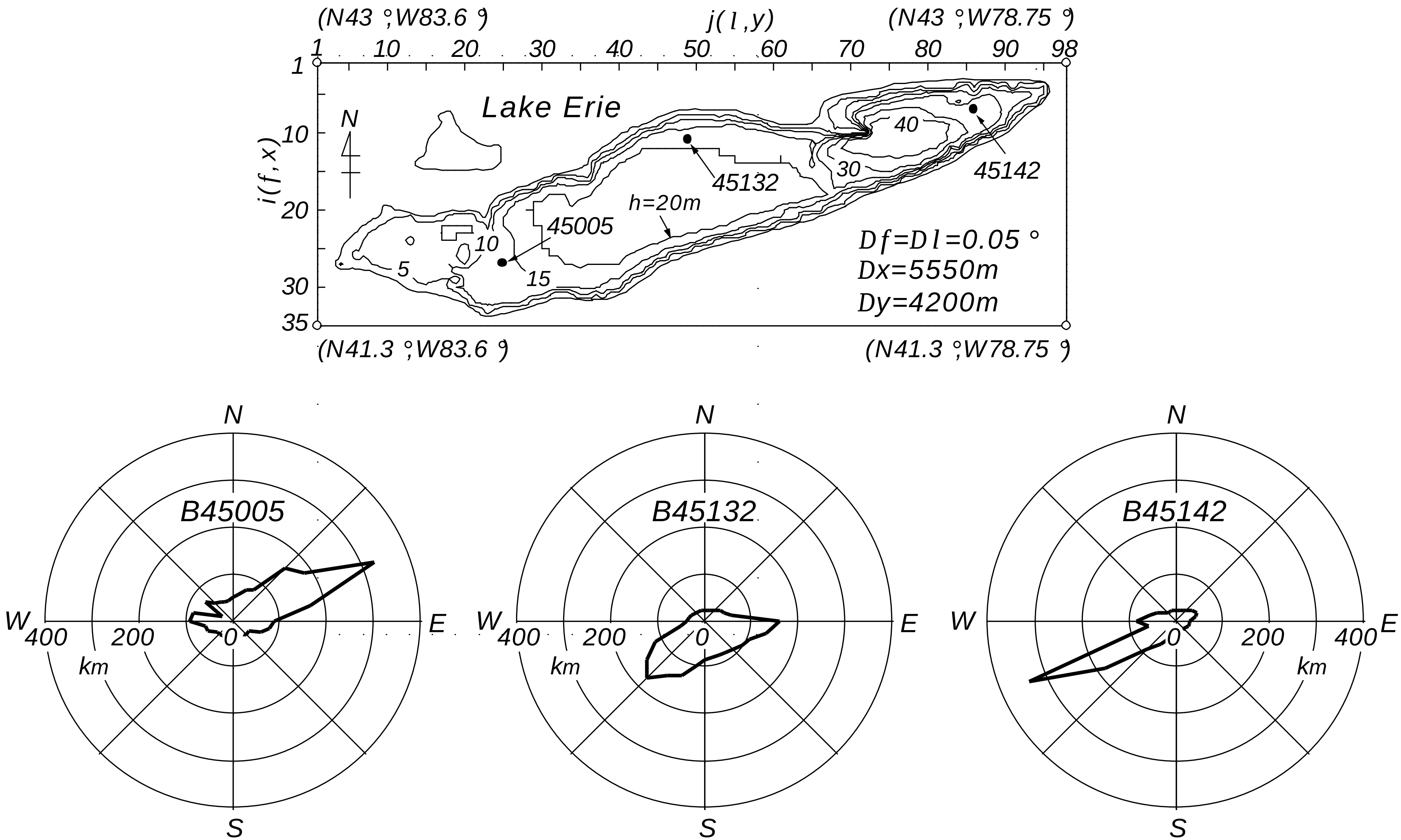
of the Meteorological Service of Canada, Environment Canada, who kindly provided with the bottom bathymetry data, over-lake wind data estimated by CMC and WAM- based wave height data at 3 buoys.




Example of distribution of winds estimated over Lake Erie




Distribution of directional fetch at each buoy

Wind speed statistics:

a) mean value $U_{10}$ over an entire period

b) standard deviation $U_s$ for wind speed data

Error statistics of wind speed and wind direction:

a) correlation coefficient $r_U$,

b) slope value of a regression line passing through the origin in a scatter diagram $a_{0U}$

c) root mean square error $s_U$ for wind speed data

d) correlation coefficient $r_q$ for wind direction data

Table 1 Wind speed statistics and error statistics of wind speed and wind direction at each buoy.

| buoy | $\overline{U}_{10\ obs}$ m/s | $\overline{U}_{10\ cal}$ m/s | $U_{s}$ obs m/s | $U_{s}$ cal m/s | $r_{U}$ | $a_{0U}$ | $s_{U}$ m/s | $r_{q}$ |
|---|---|---|---|---|---|---|---|---|
| 45005 | 7.6 | 8.0 | 4.1 | 4.1 | 0.92 | 1.03 | 1.4 | 0.67 |
| 45132 | 8.0 | 7.7 | 4.1 | 3.9 | 0.93 | 0.94 | 1.2 | 0.73 |
| 45142 | 6.8 | 7.2 | 4.0 | 3.8 | 0.89 | 1.00 | 1.5 | 0.76 |

These indices indicate that the estimated wind data has a rather high accuracy.