Luigi Cavaleri

“Missing the peaks”

or

“trying to understand nature”

-- evidence

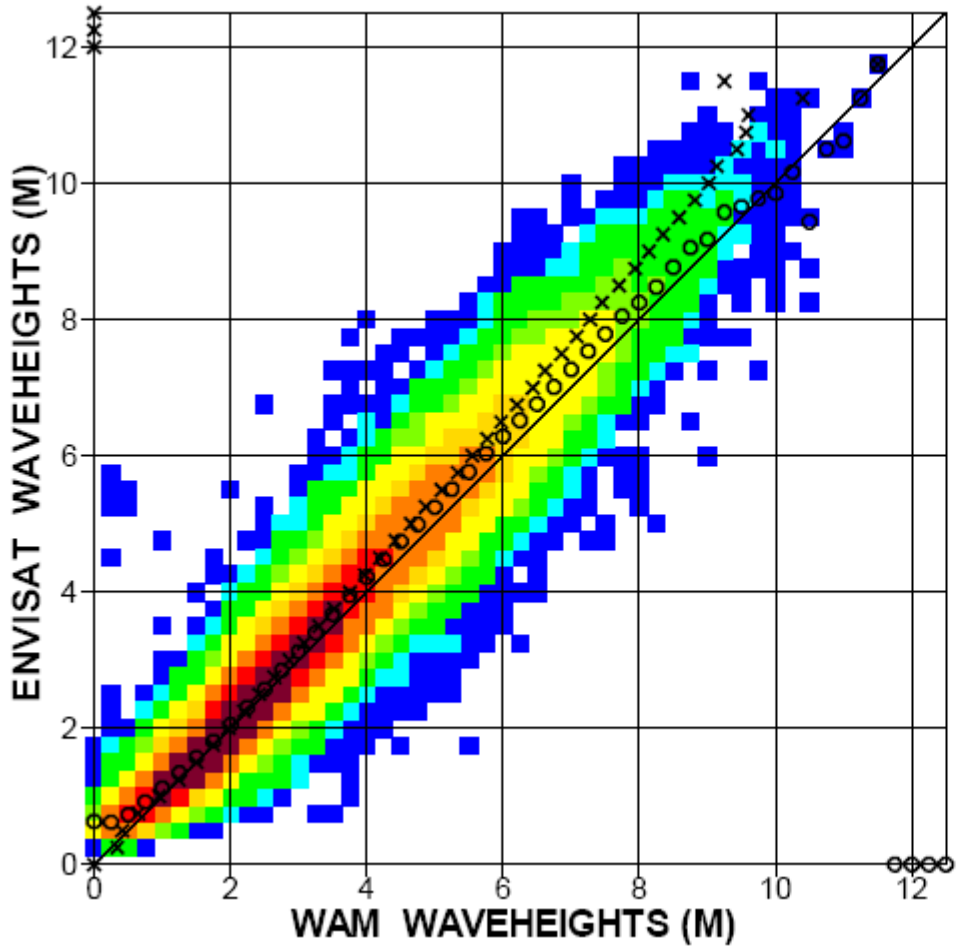
-- causes

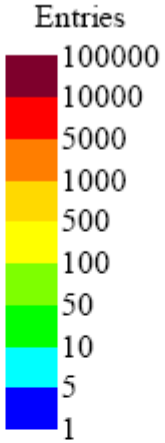
-- remedies (where possible)

-- evidence

-- causes

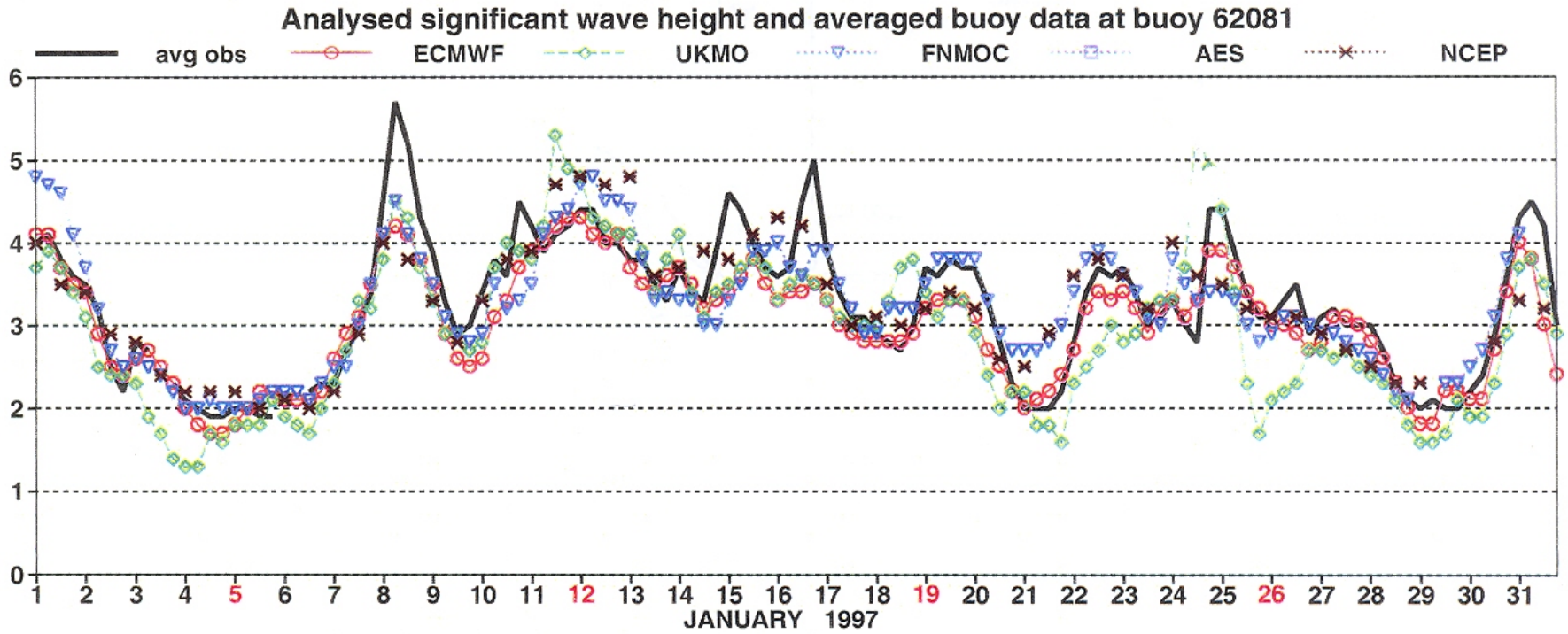
-- remedies (where possible)

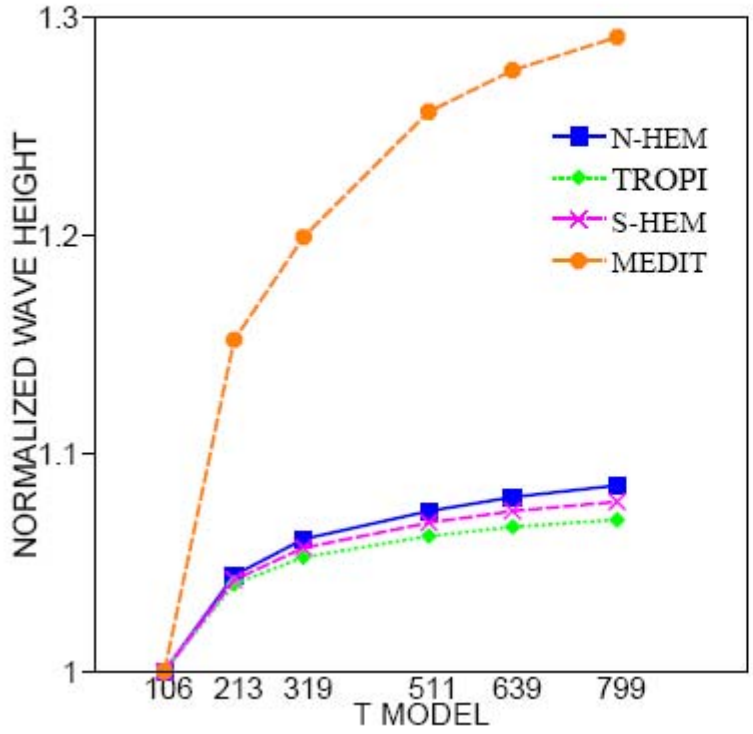


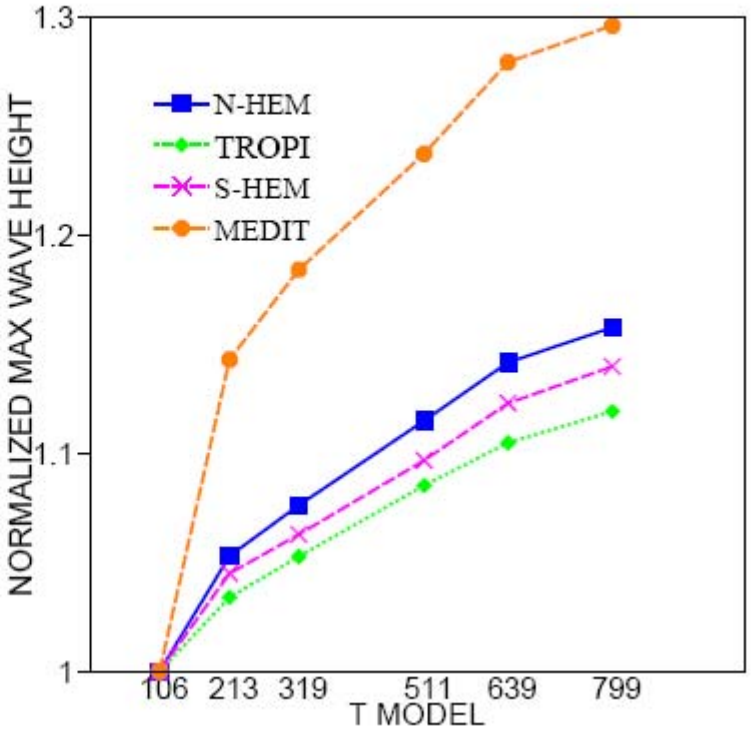


STATISTICS

ENTRIES	1045542
MEAN WAM	2.523
MEAN ENVISAT	2.637
BIAS (ENVISAT - WAM)	.114
STANDARD DEVIATION	.299
SCATTER INDEX	.118
CORRELATION	.972
SYMMETRIC SLOPE	1.049
REGR. COEFFICIENT	1.040
REGR. CONSTANT	.012


Analysed significant wave height and averaged buoy data at buoy 62081
avg obs
ECMWF
UKMO
FNMOC
AES
NCEP
6
5
4
3
2
1
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
JANUARY 1997


1.3
1.2
1.1
1
NORMALIZED WAVE HEIGHT
N-HEM
TROPI
S-HEM
MEDIT
106
213
319
511
639
799
T MODEL


1.3
1.2
1.1
1
NORMALIZED MAX WAVE HEIGHT
N-HEM
TROPI
S-HEM
MEDIT
106
213
319
511
639
799
T MODEL

Typical the sophisticated peak enhancement

(Caires and Sterl, 2005) required to produce

reasonable results out of the ECMWF 45 year reanalysis

-- evidence

-- causes

-- remedies (where possible)

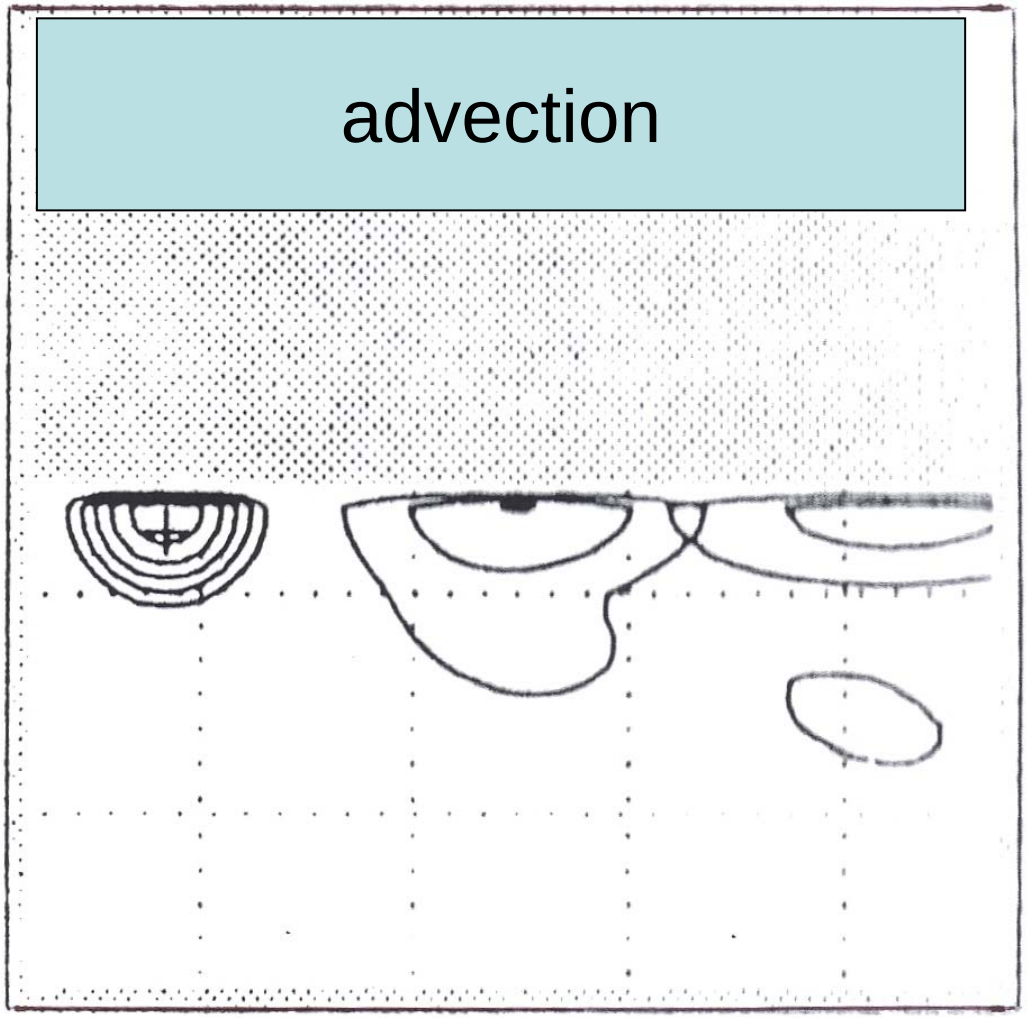
-- evidence

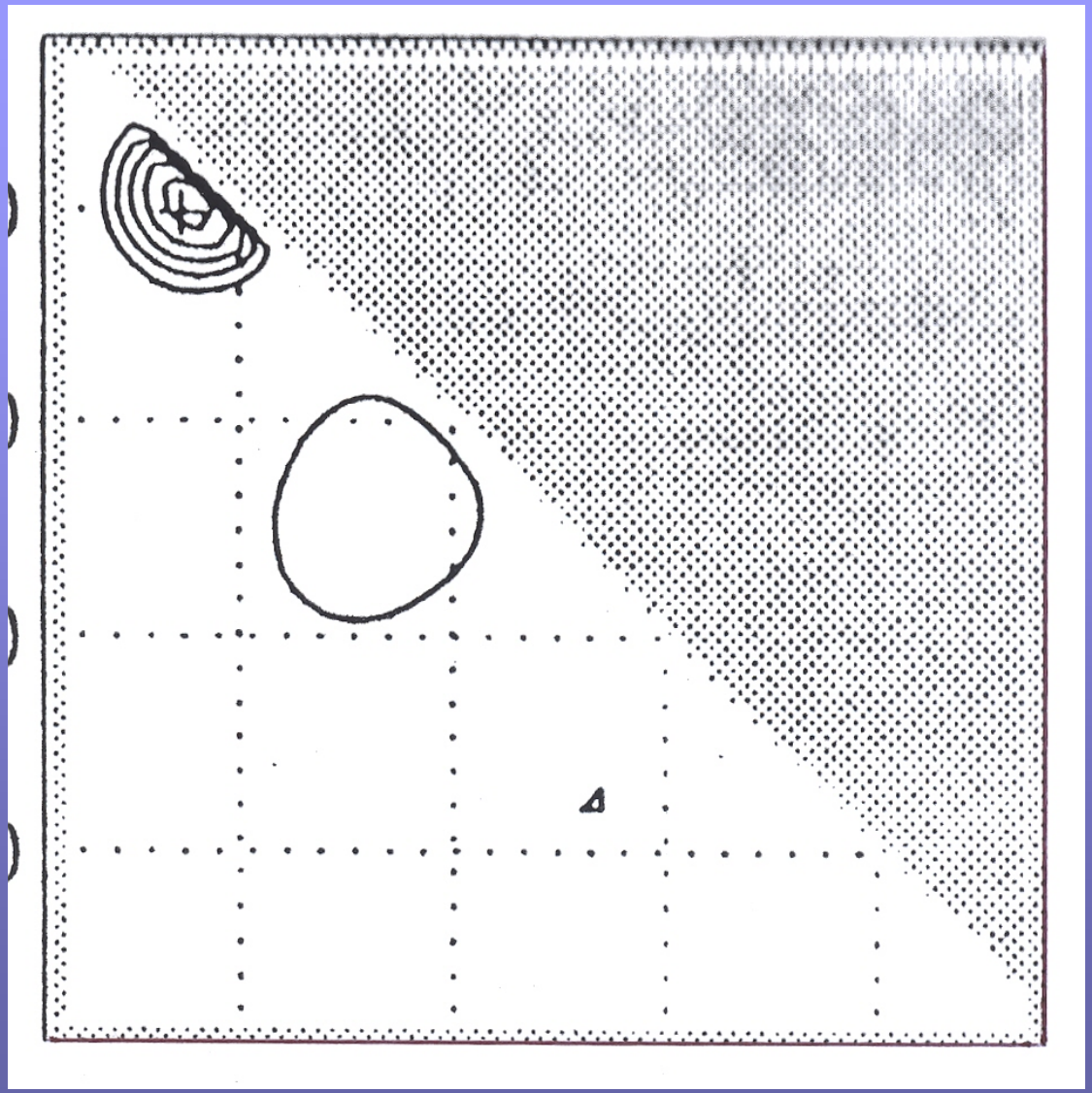
-- causes first local
then general

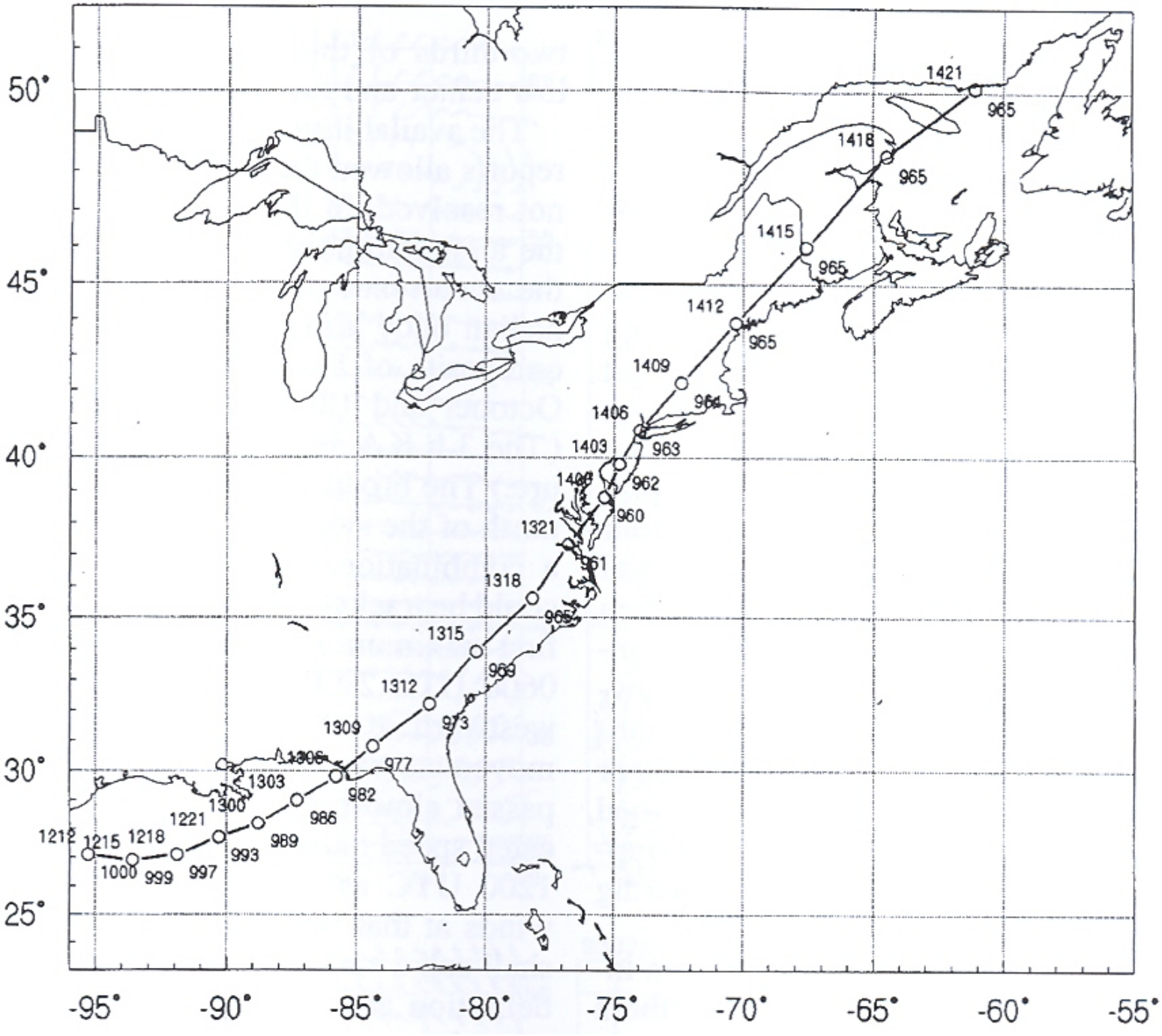
-- remedies (where possible)

advection

advection






50°
45°
40°
35°
30°
25°
-95°
-90°
-85°
-80°
-75°
-70°
-65°
-60°
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1406
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962
960
1321
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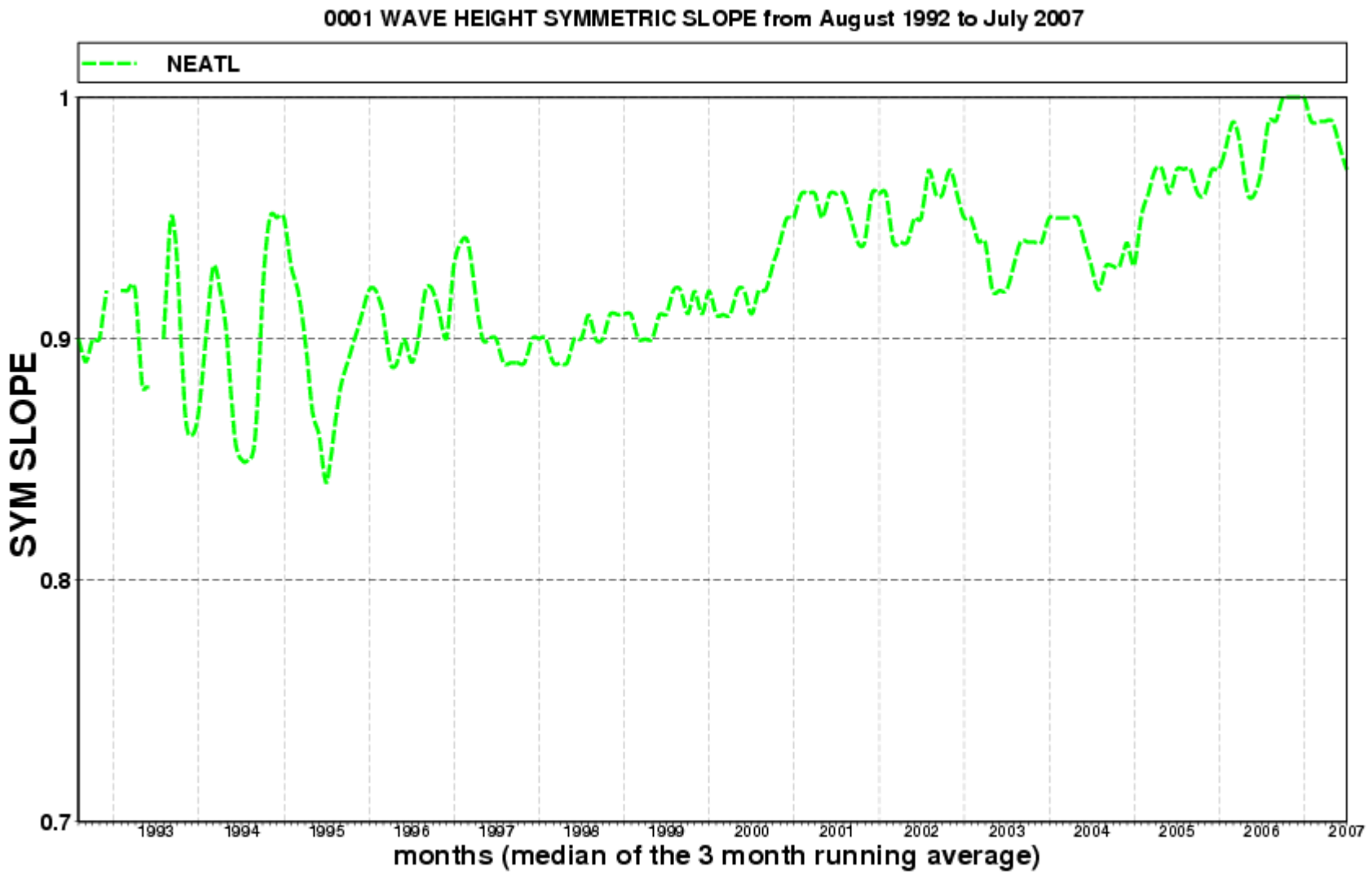
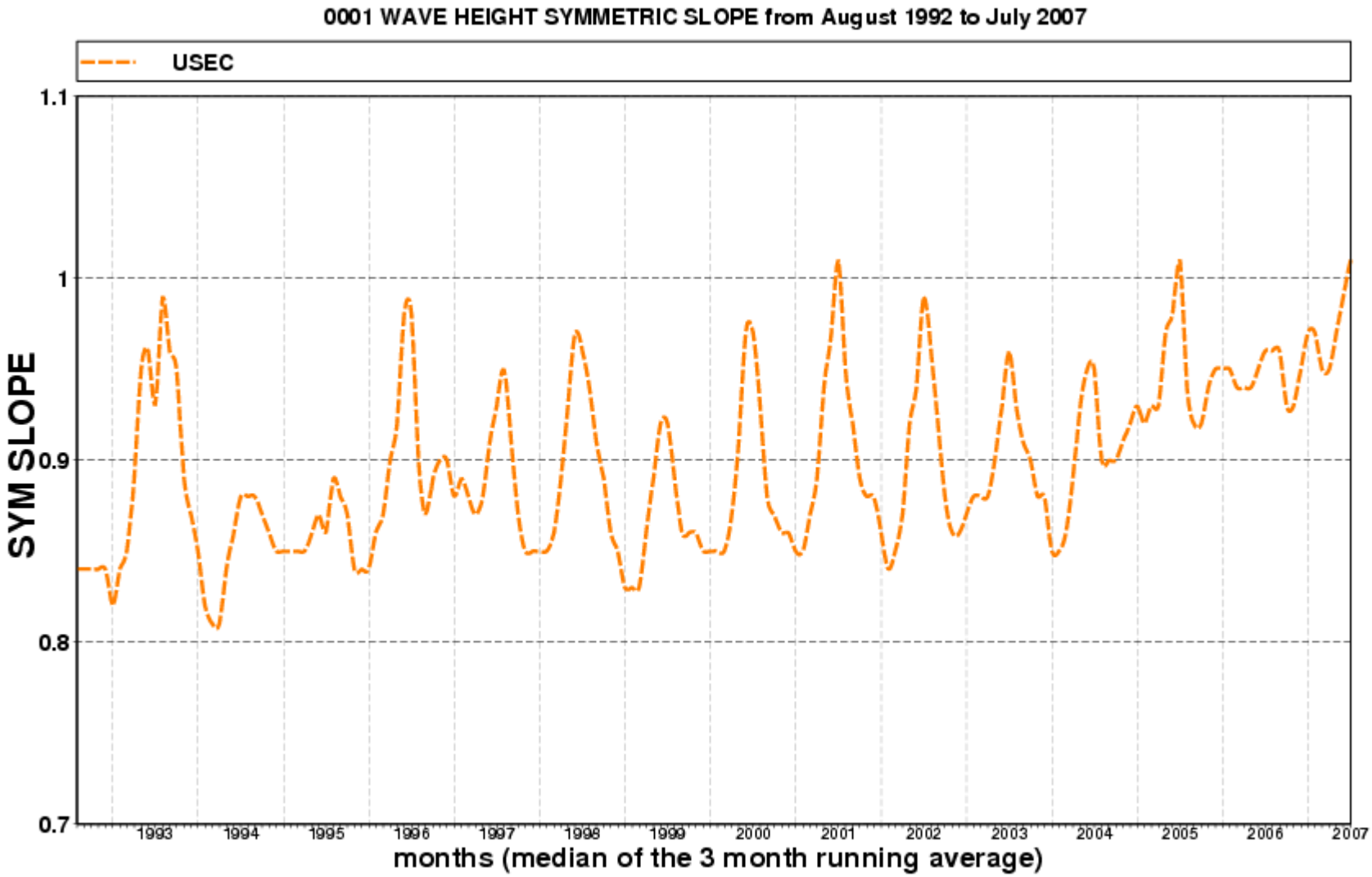
1318
965
1315
969
1312
973
1309
977
1306
1303
982
1300
986
1221
989
1218
993
1215
997
1212
999
1000

what about wind ?


150°
120°
ARCTIC OCEAN
RUSSIA
ASIA
75°
60°
45°
Arctic Circle
CANADA
NORTH AMERICA
UNITED STATES
MEXICO
Gulf of Mexico
EUROPE
Prime Meridian
PORT.
LIBYA
ATLANTIC OCEAN
ALGERIA
SUDAN
MALI
AFRICA
Tropic of Cancer
Equator
SOUTH AMERICA
BRAZIL
Tropic of Capricorn
Microsoft MapPoint
©2007 Microsoft Corp.


0001 WAVE HEIGHT SYMMETRIC SLOPE from August 1992 to July 2007
NEATL
SYM SLOPE
1
0.9
0.8
0.7
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
months (median of the 3 month running average)


0001 WAVE HEIGHT SYMMETRIC SLOPE from August 1992 to July 2007
USEC
SYM SLOPE
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1
0.9
0.8
0.7
1993
1994
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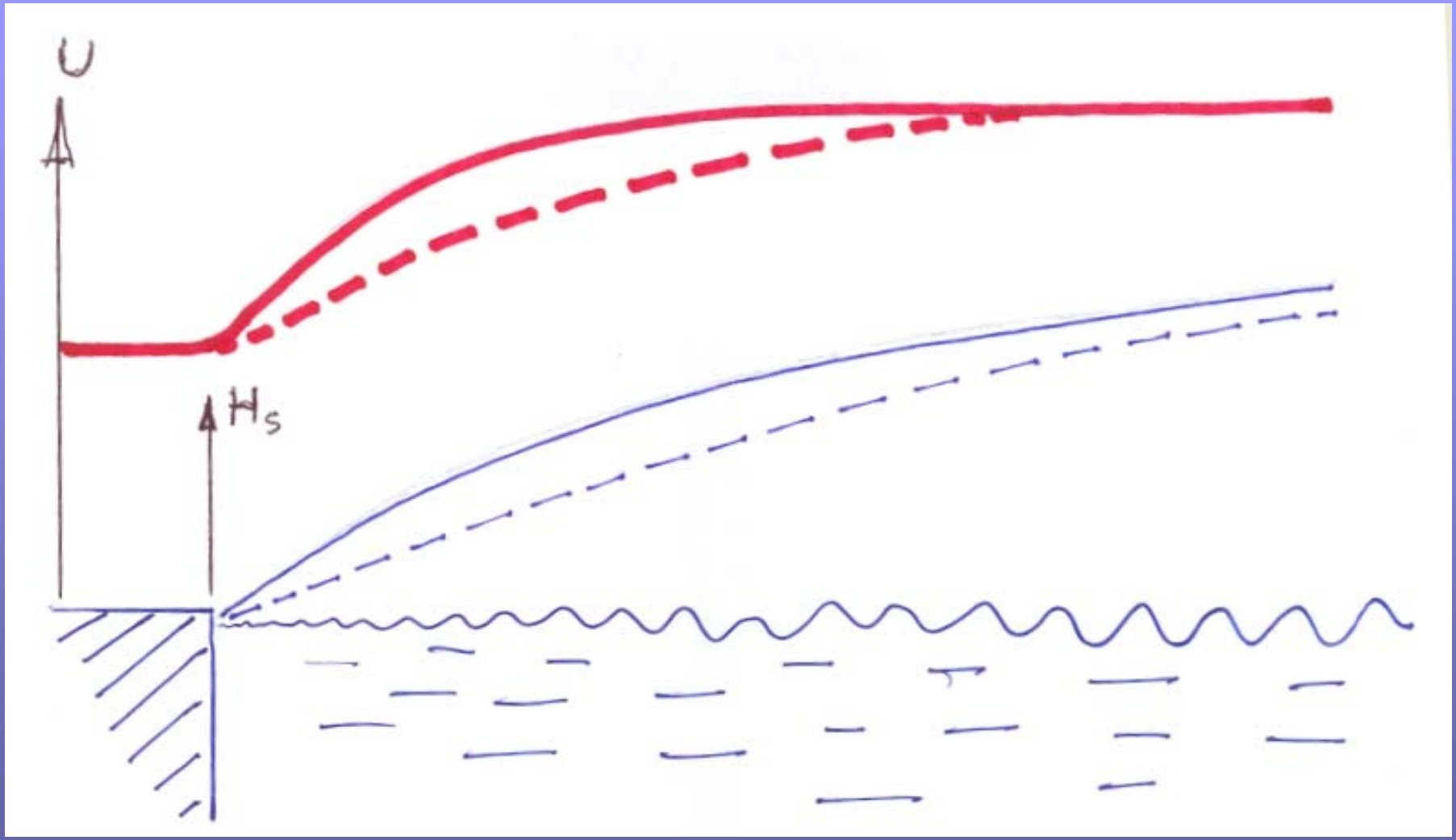
2004
2005
2006
2007
months (median of the 3 month running average)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H_s


150°
120°
ARCTIC OCEAN
RUSSIA
ASIA
75°
60°
45°
Arctic Circle
CANADA
NORTH AMERICA
UNITED STATES
MEXICO
Gulf of Mexico
EUROPE
Prime Meridian
PORT.
LIBYA
ATLANTIC OCEAN
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Microsoft MapPoint
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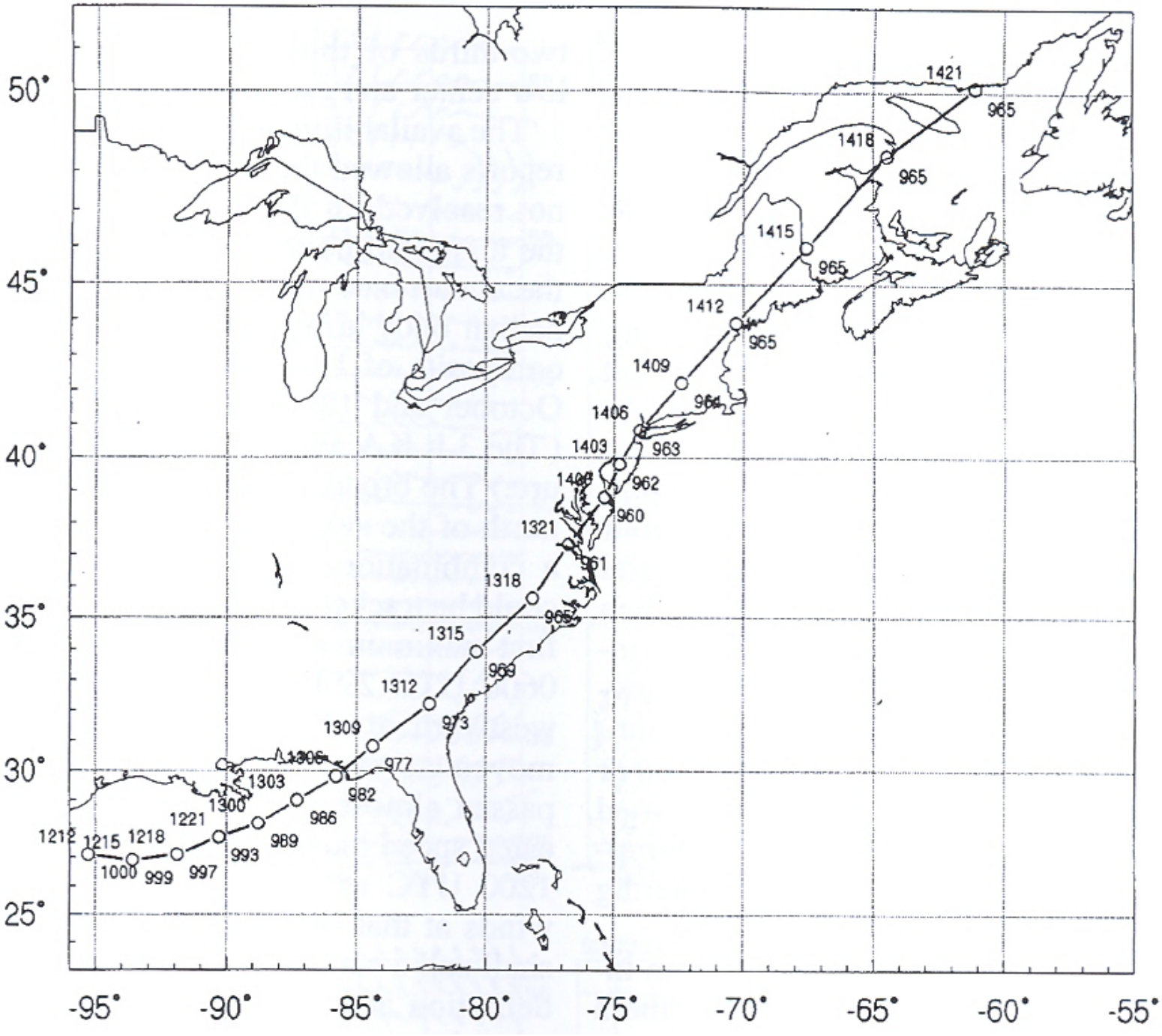
50°
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-65°
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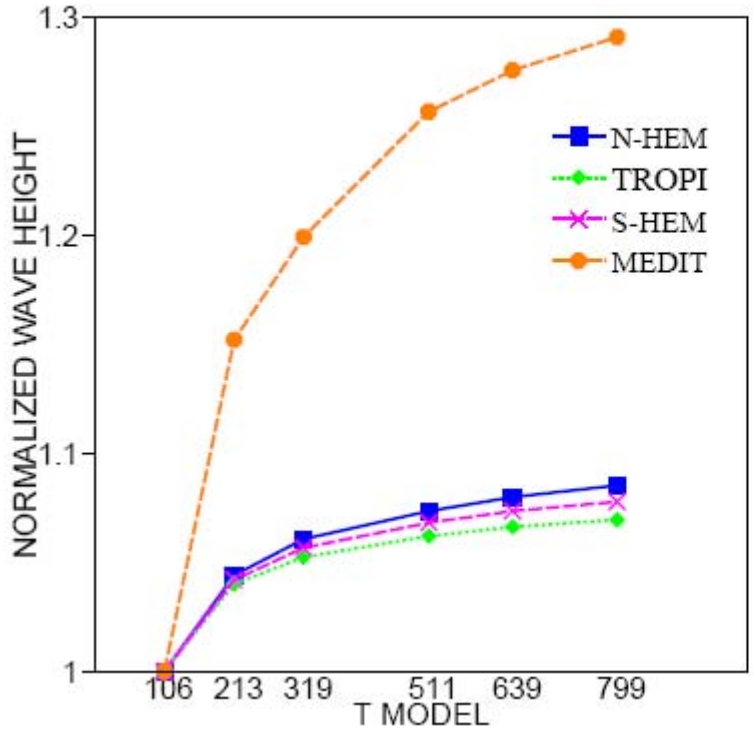
1000


1.3
1.2
1.1
1
NORMALIZED WAVE HEIGHT
N-HEM
TROPI
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106
213
319
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639
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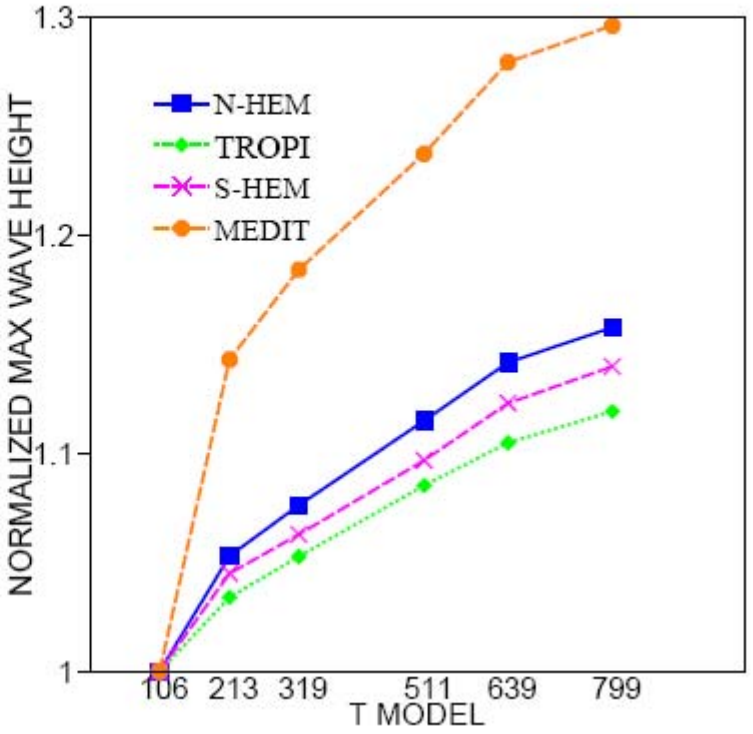
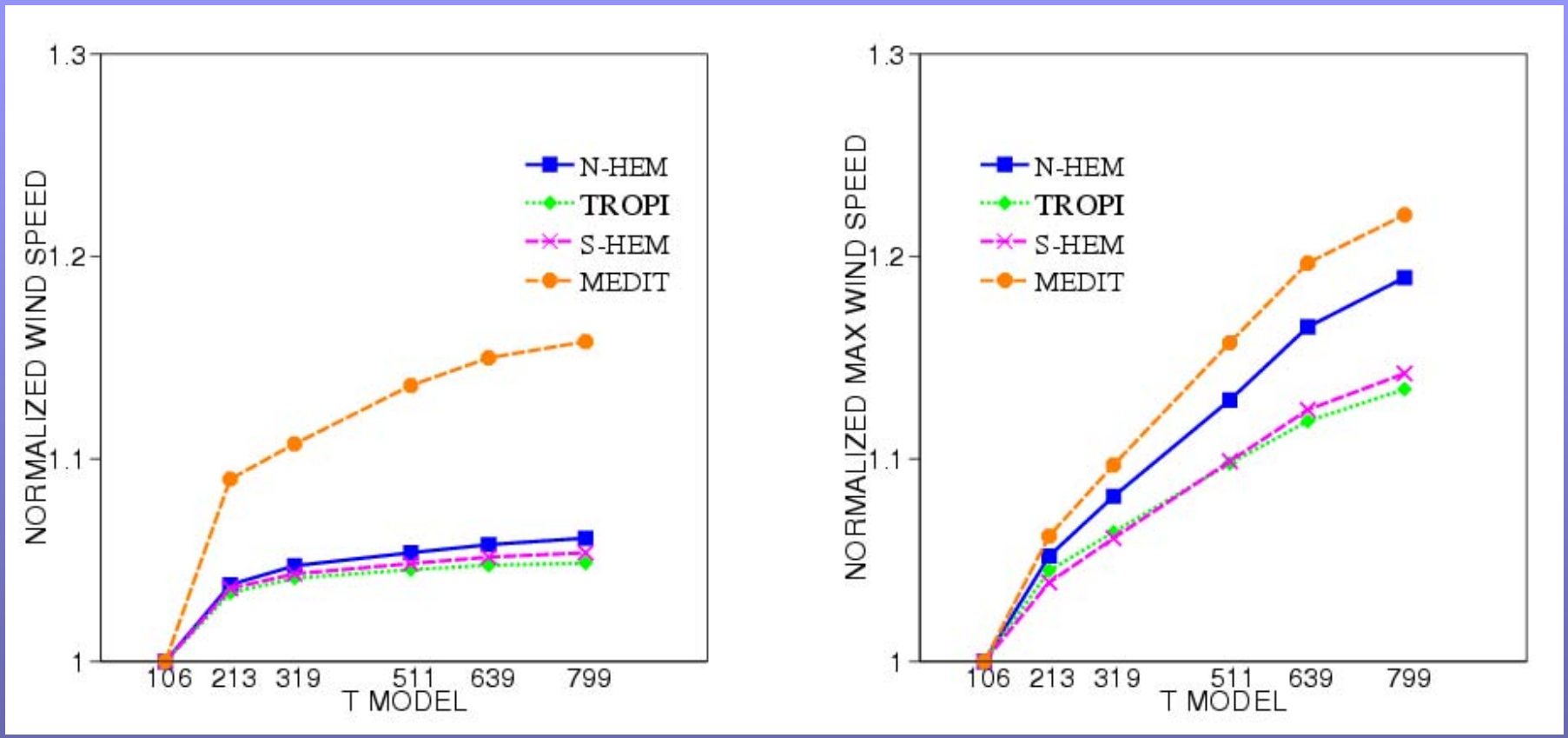
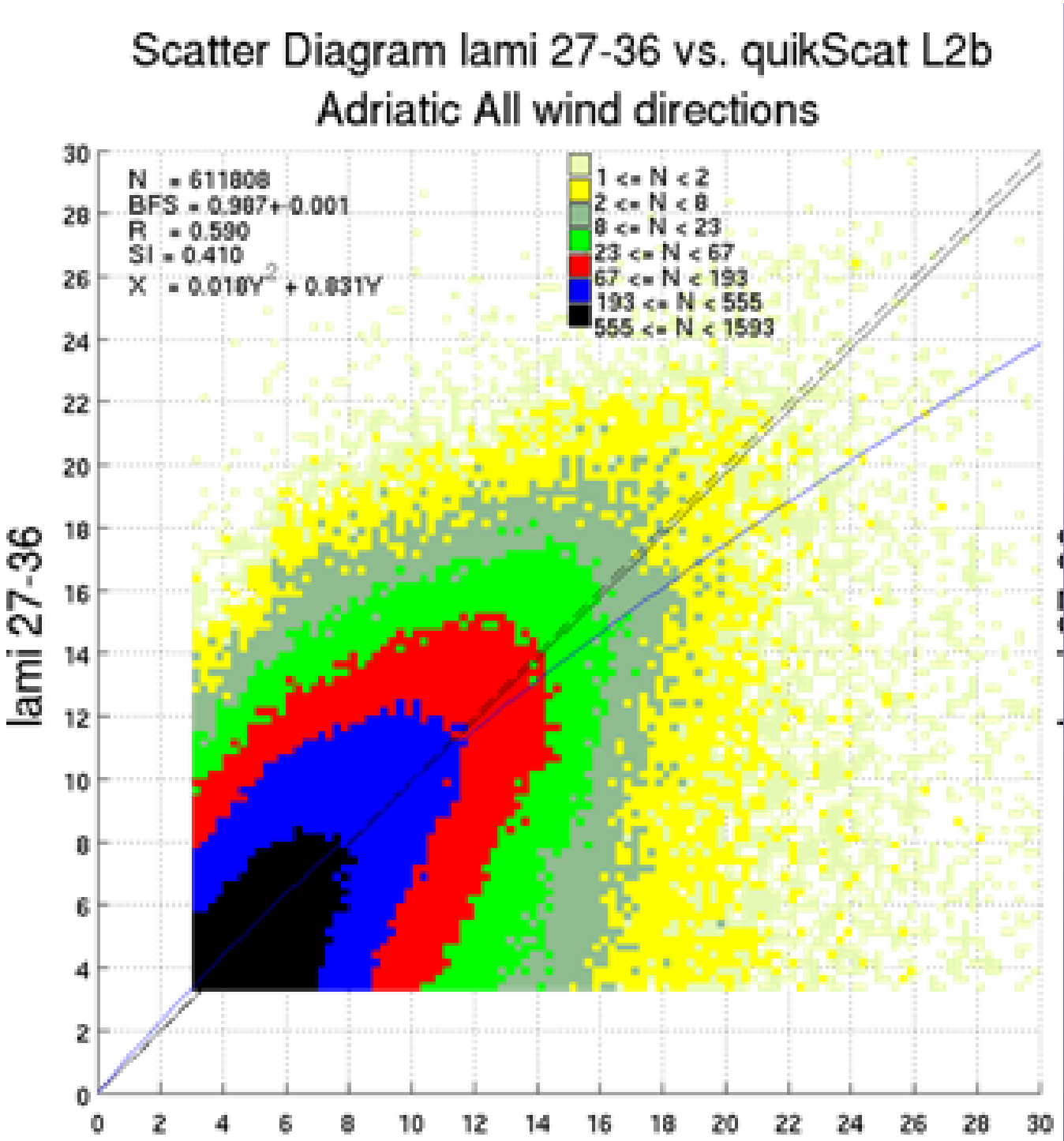

1.3
1.2
1.1
1
NORMALIZED MAX WAVE HEIGHT
N-HEM
TROPI
S-HEM
MEDIT
106
213
319
511
639
799
T MODEL


1.3
1.2
1.1
1
NORMALIZED WIND SPEED
N-HEM
TROPI
S-HEM
MEDIT
106
213
319
511
639
799
T MODEL
1.3
1.2
1.1
1
NORMALIZED MAX WIND SPEED
N-HEM
TROPI
S-HEM
MEDIT
106
213
319
511
639
799
T MODEL


Scatter Diagram lami 27-36 vs. quikScat L2b
Adriatic All wind directions
N = 611808
BFS = 0.987+-0.001
R = 0.590
SI = 0.410
X = 0.010Y^2 + 0.831Y
1 <= N < 2
2 <= N < 8
8 <= N < 23
23 <= N < 67
67 <= N < 193
193 <= N < 555
555 <= N < 1593
lami 27-36
0
2
4
6
8
10
12
14
16
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22
24
26
28
30

Wind resolution

Models fail where there are strong gradients,
e.g. sharp peaks

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highly smoothed for numerical stability

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smoothing is often stronger in data assimilation

Wind resolution

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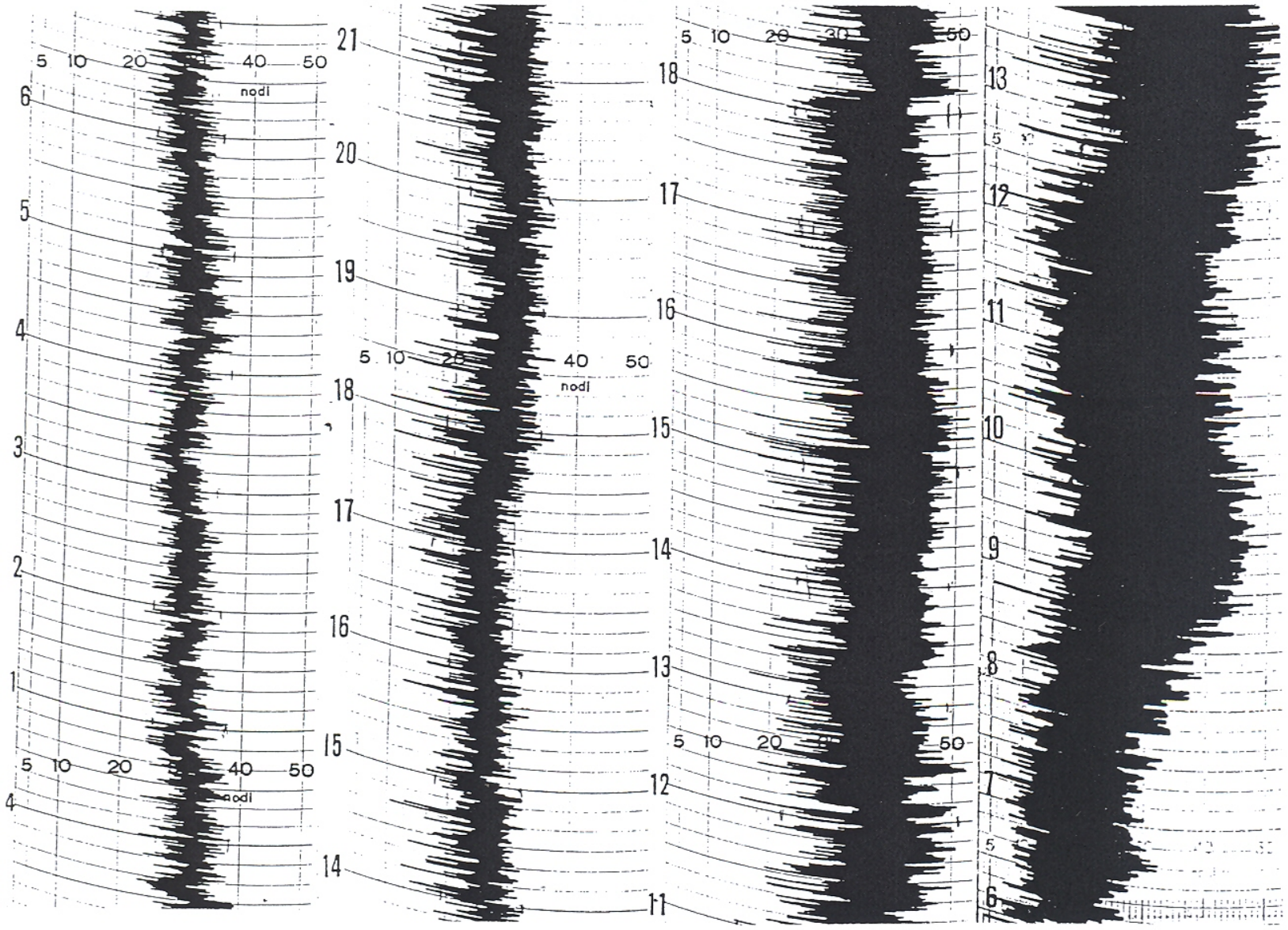
e.g. sharp peaks

highly smoothed for numerical stability

smoothing is often stronger in data assimilation

short term forecasts better than analysis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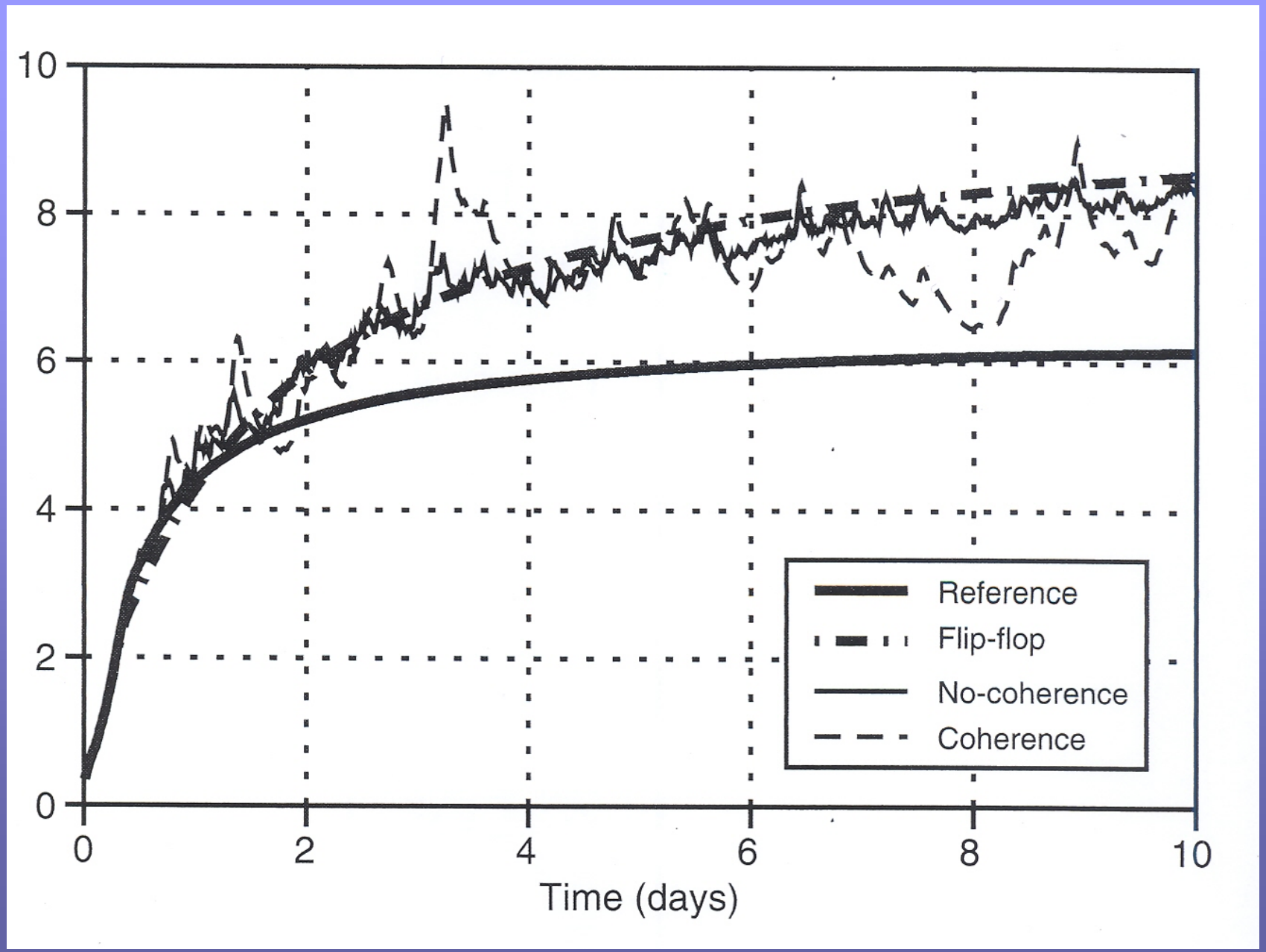
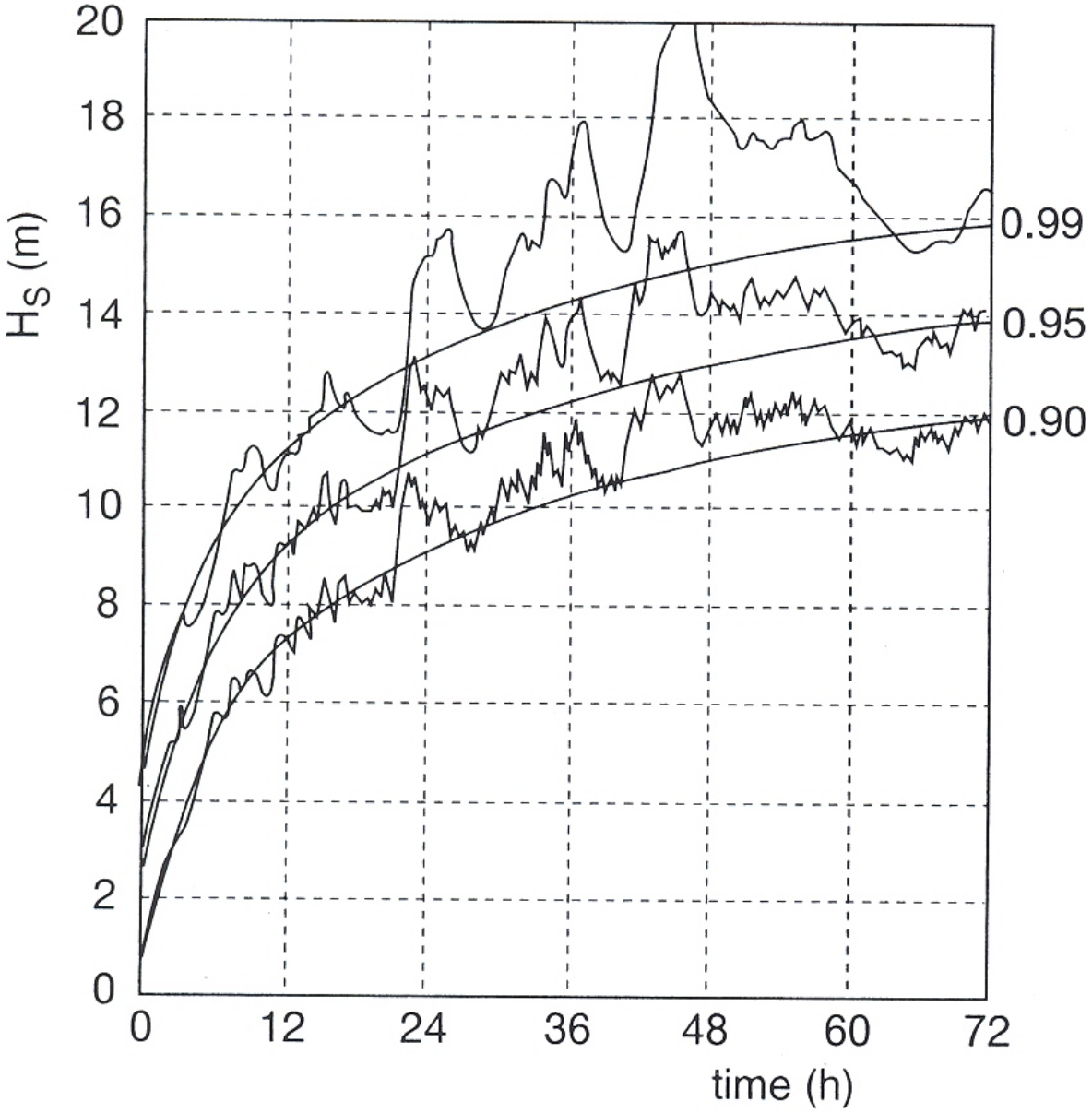
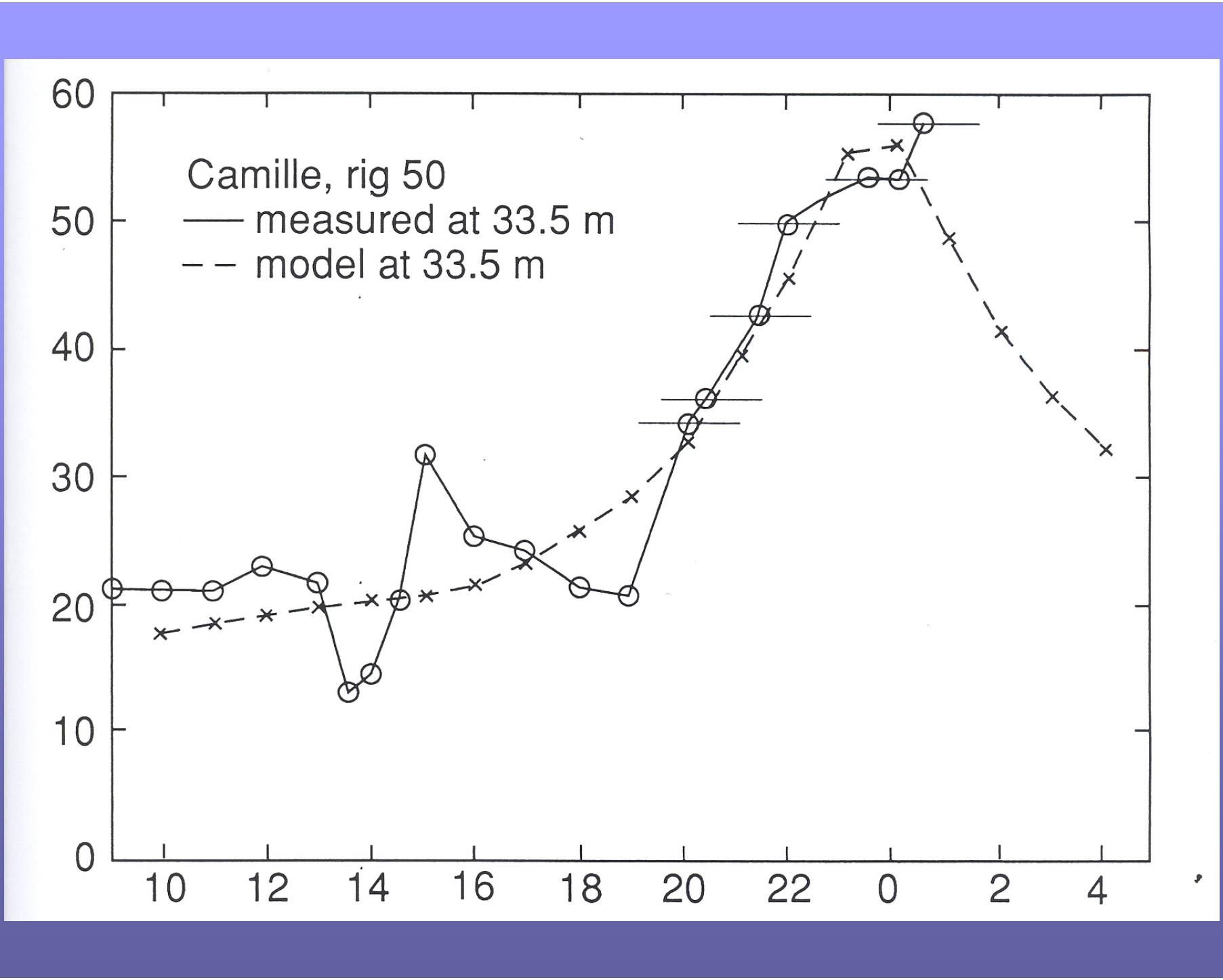
7
6


10
8
6
4
2
0
0
2
4
6
8
10
Time (days)
Reference
Flip-flop
No-coherence
Coherence


20
18
16
14
12
10
8
6
4
2
0
H_S (m)
0
12
24
36
48
60
72
time (h)
0.99
0.95
0.90


Camille, rig 50
measured at 33.5 m
model at 33.5 m
60
50
40
30
20
10
0
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12
14
16
18
20
22
0
2
4


150°
120°
ARCTIC OCEAN
RUSSIA
ASIA
75°
60°
45°
Arctic Circle
CANADA
NORTH AMERICA
UNITED STATES
MEXICO
Gulf of Mexico
EUROPE
Prime Meridian
PORT.
LIBYA
ATLANTIC OCEAN
ALGERIA
SUDAN
MALI
AFRICA
Tropic of Cancer
Equator
SOUTH AMERICA
BRAZIL
Tropic of Capricorn
Microsoft MapPoint
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Advection (of wave fields)

advection algorithms lead to spreading,
hence to smoothing of the fields,
particularly of the peaks

...

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advection algorithms lead to spreading,
hence to smoothing of the fields,
particularly of the peaks

feed-back :
lower peaks, less generation, lower peaks, ……..

Generation

still based on 8-10 m/sec winds (Bight of Abaco, 1980's), then modified by Janssen

Generation

still based on 8-10 m/sec winds (Bight of Abaco, 1980's), then modified by Janssen

model input basically linear to single components

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model input basically linear to single components

you would never believe this in a storm

generation not continuous, but by bursts

Generation

still based on 8-10 m/sec winds (Bight of Abaco, 1980's), then modified by Janssen

model input basically linear to single components

you would never believe this in a storm

generation not continuous, but by bursts

At extremes, physics changes, we do not know how

White-capping, the least understood process

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still clinging on Hasselmann 1974, then updated with different or more constants – not much physical

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still clinging on Hasselmann 1974, then updated with different or more constants – not much physical

Recently new approaches by Babanin and Young, Banner, not yet in models

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still clinging on Hasselmann 1974, then updated with different or more constants – not much physical

Recently new approaches by Babanin and Young, Banner, not yet in models

basically tuning knob of models

4th order NL interactions

DIA very crude – substantial differences from Exact

4th order NL interactions

DIA very crude – substantial differences from Exact

DIA two problems, especially for extremes:

4th order NL interactions

DIA very crude – substantial differences from Exact

DIA two problems, especially for extremes:

1) it shifts too much energy to low frequency range

4th order NL interactions

DIA very crude – substantial differences from Exact

DIA two problems, especially for extremes:

1) it shifts too much energy to low frequency range

2) directional distribution too wide

4th order NL interactions

DIA very crude – substantial differences from Exact

DIA two problems, especially for extremes:

1) it shifts too much energy to low frequency range

2) directional distribution too wide

both decrease input

Some more general considerations :

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The existence and use of alternative theories
still means uncertainty on truth

different models use different solutions

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still means uncertainty on truth

different models use different solutions

all good results ? Means lot of tuning

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The existence and use of alternative theories still means uncertainty on truth

different models use different solutions

all good results ? Means lot of tuning

proof: exchanging physics not possible,

Hs results change up to 40%

Tuning is not a problem in itself,
but it has a basic problem

tuning is done on the bulk of data,

but extremes are different,
often they have a different physics,

so models often fail at extremes

Example of simple physics: advection

Example of simple physics: advection

phase and group speeds: still clinging to linear theory,

but sea, especially in extremes, is nonlinear -

large waves run faster

Example of simple physics: advection

phase and group speeds: still clinging to linear theory,

but sea, especially in extremes, is nonlinear -

large waves run faster

this decreases wind input, but makes waves longer,

hence possibly growing higher

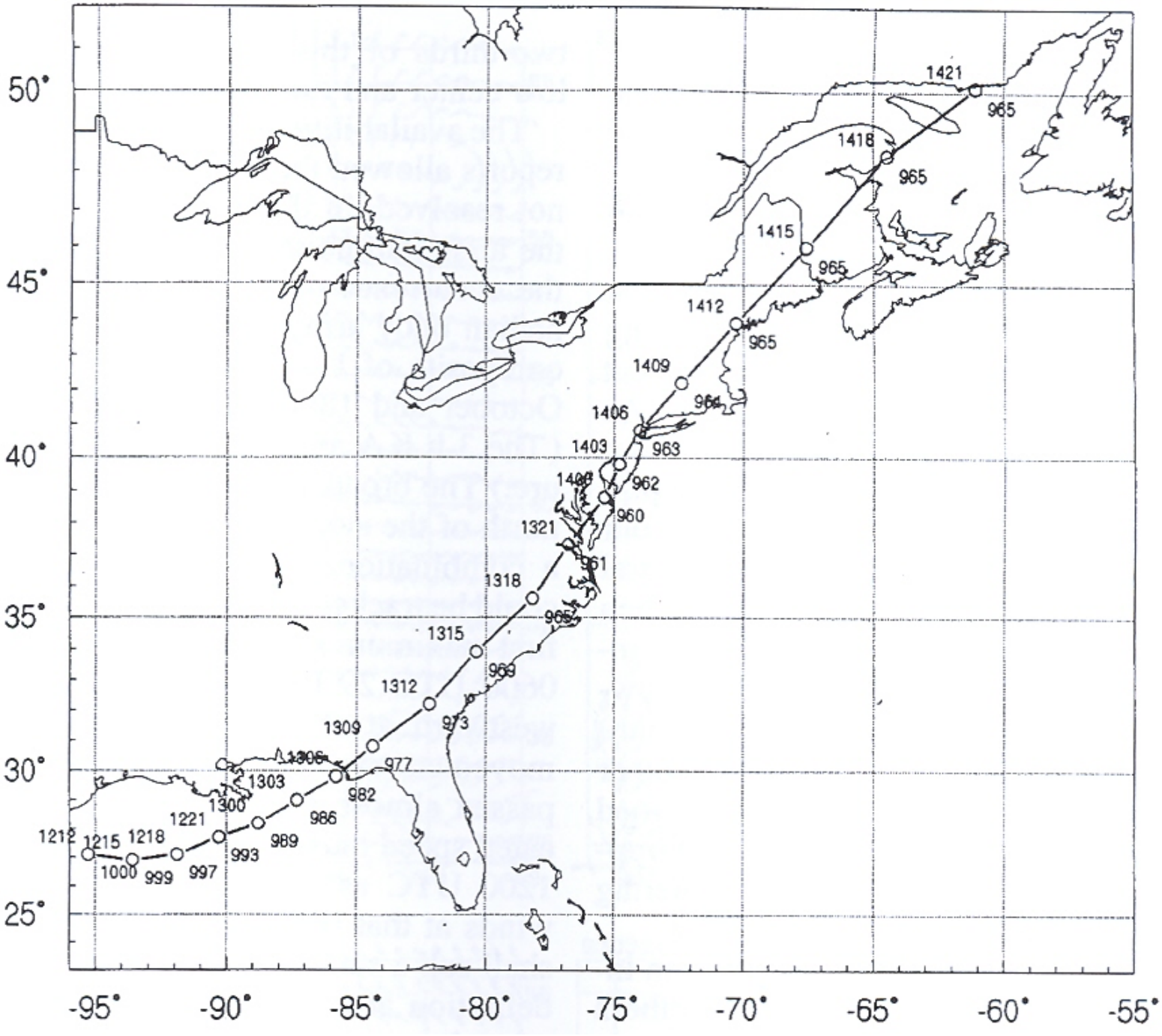
Phase and group speeds critical in dynamical fetch,

Phase and group speeds critical in dynamical fetch,

Examples:

Storm of the century, East coast of US, March 1993

Mediterranen Sea, January 1987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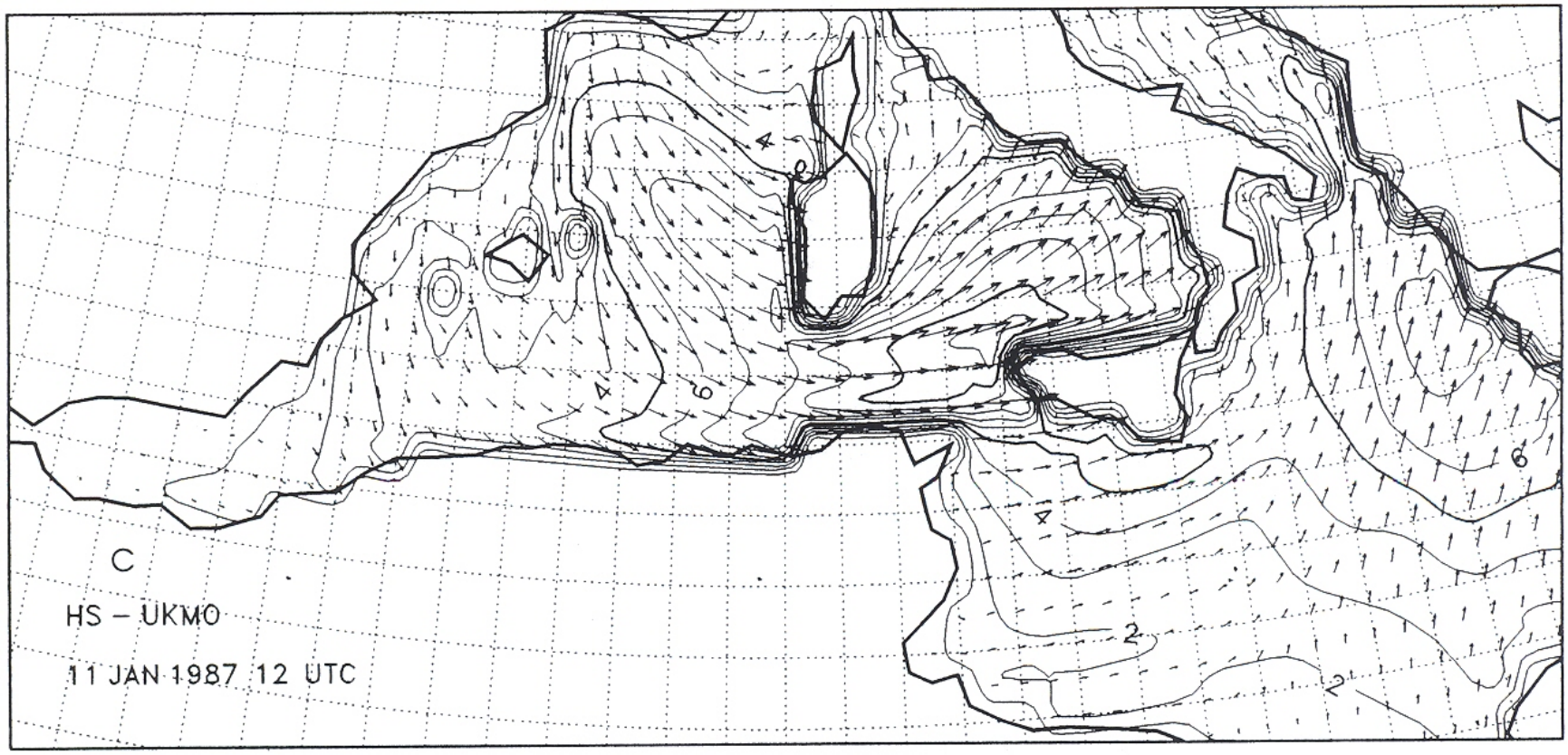
C
HS – UKMO
11 JAN 1987 12 UTC
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6

waves – current interactions

waves – current interactions

trapping, opposing, refraction, focusing

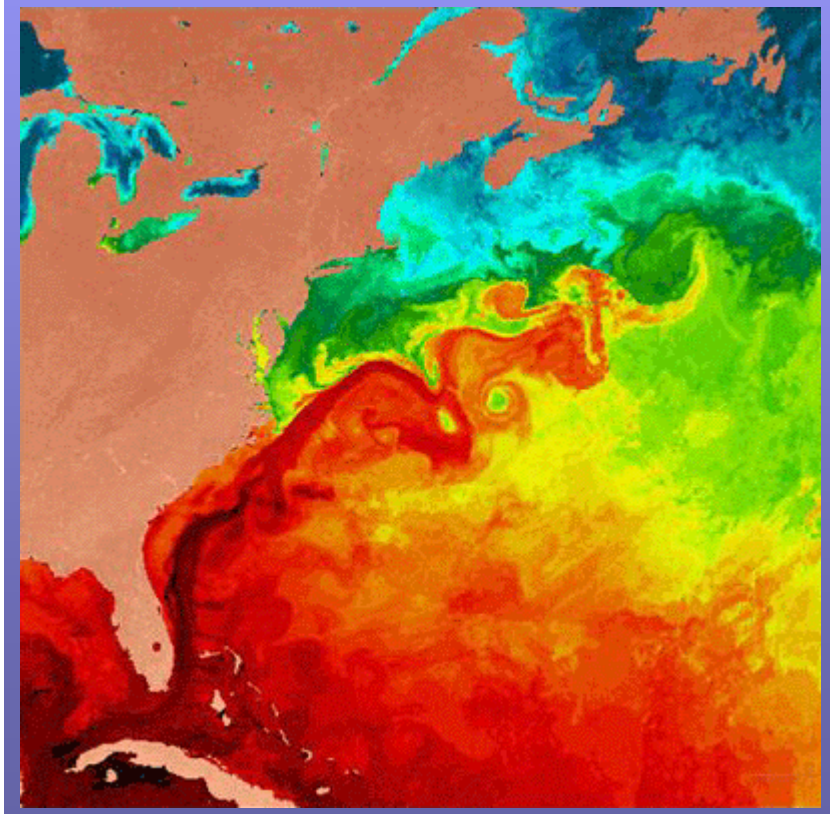
all these effects can lead to substantial enhancements

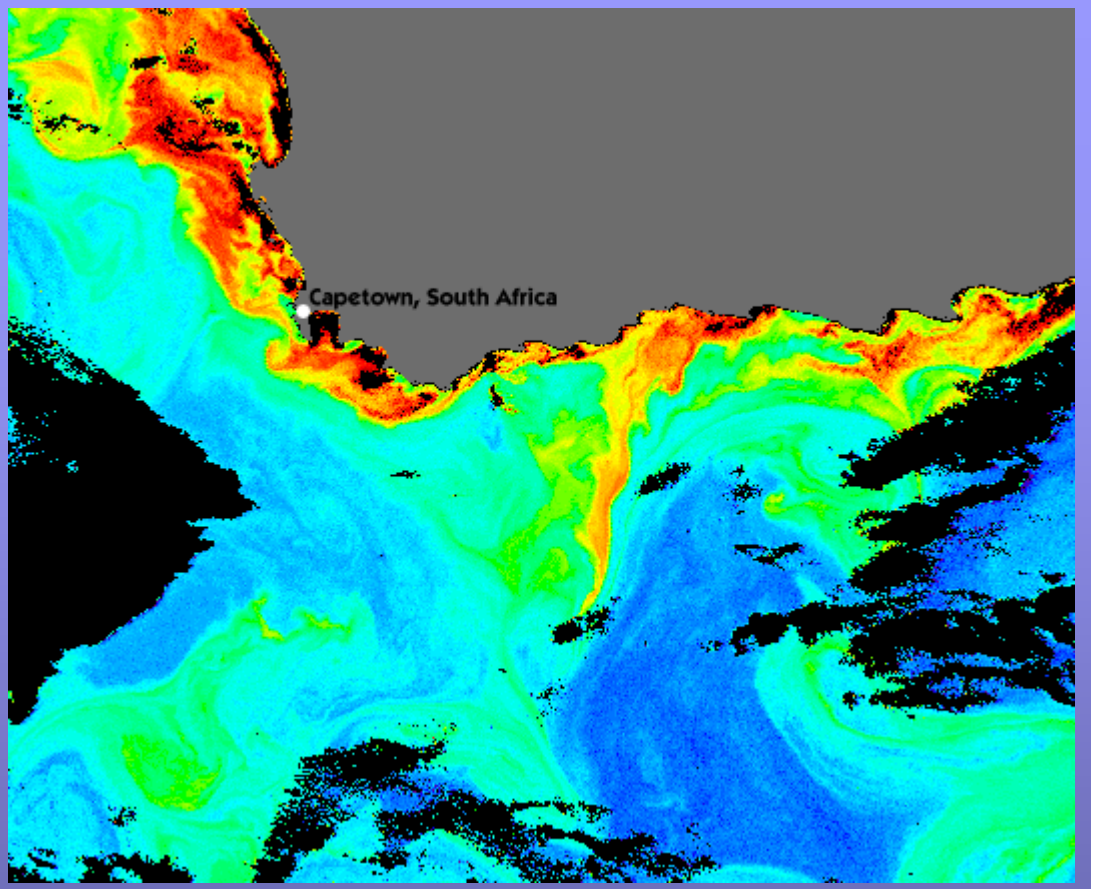
waves – current interactions

trapping, opposing, refraction, focusing

all these effects can lead to substantial enhancements

Obvious examples are Kuroshio, Gulf Stream, Agulhas




Capetown, South Africa

waves – current interactions

trapping, opposing, refraction, focusing

all these effects can lead to substantial enhancements

Obvious examples are Kuroshio, Gulf Stream, Agulhas

Circulation models still not good enough,
or information is not available or used

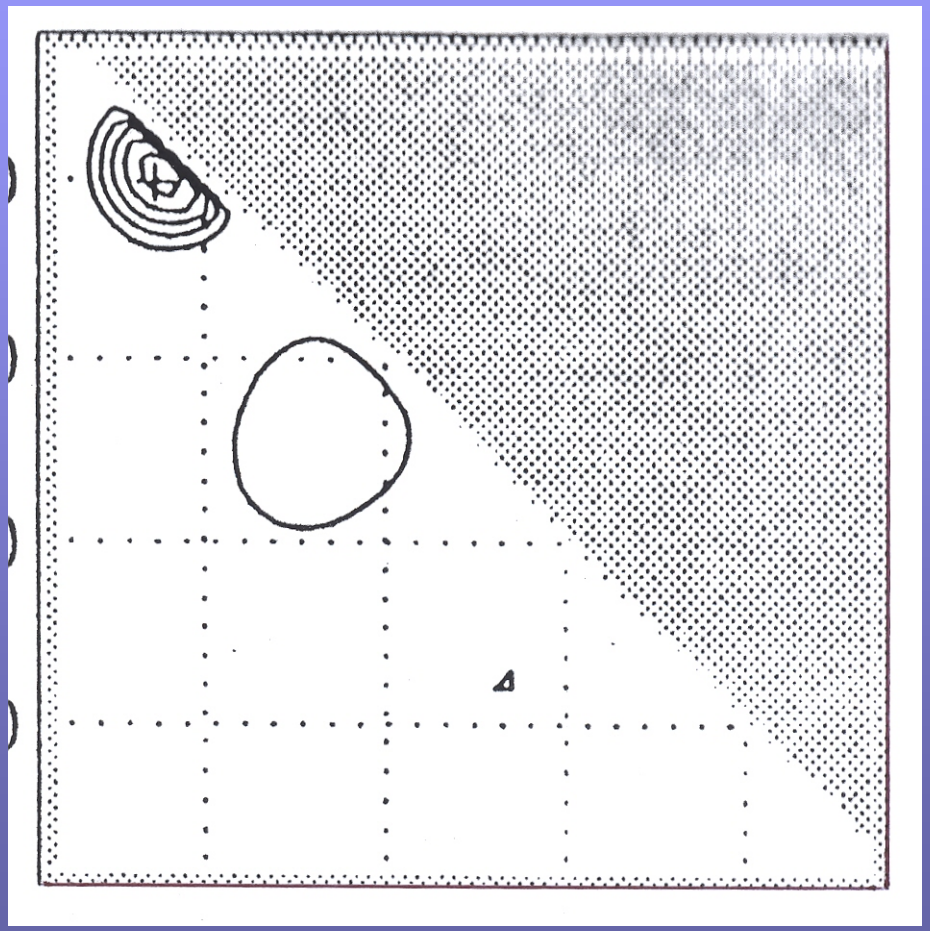
Special cases close to coasts

-- evidence

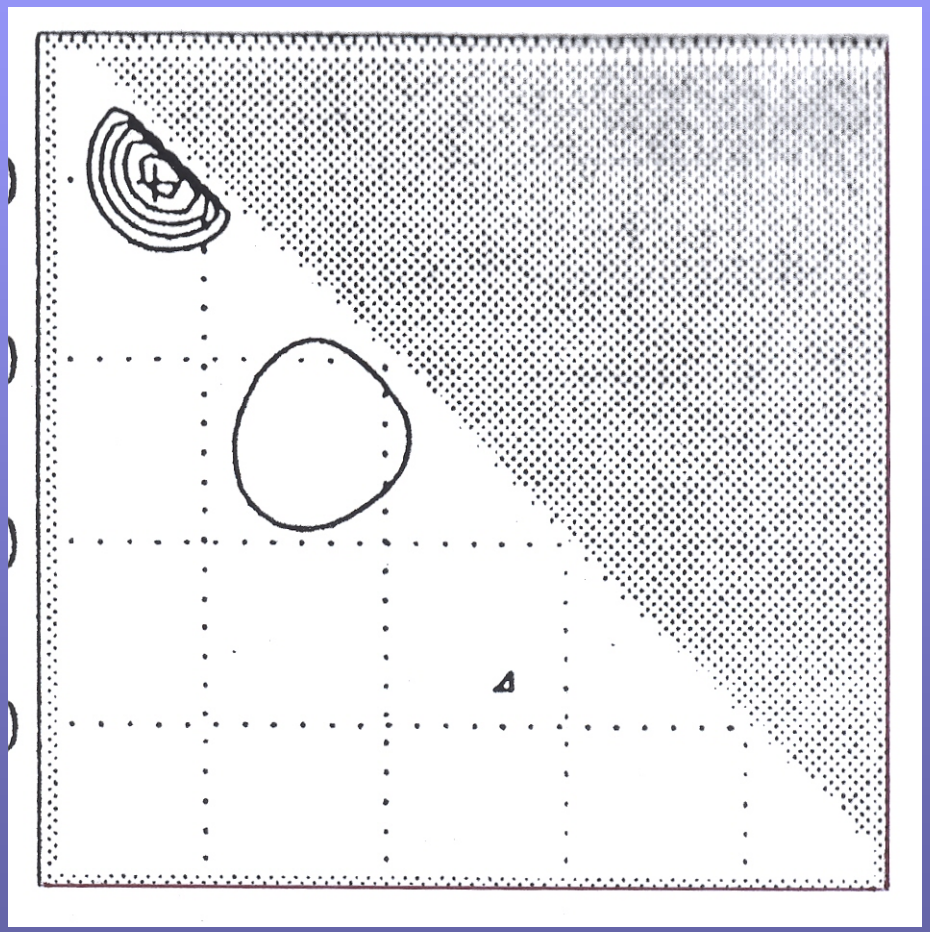
-- causes

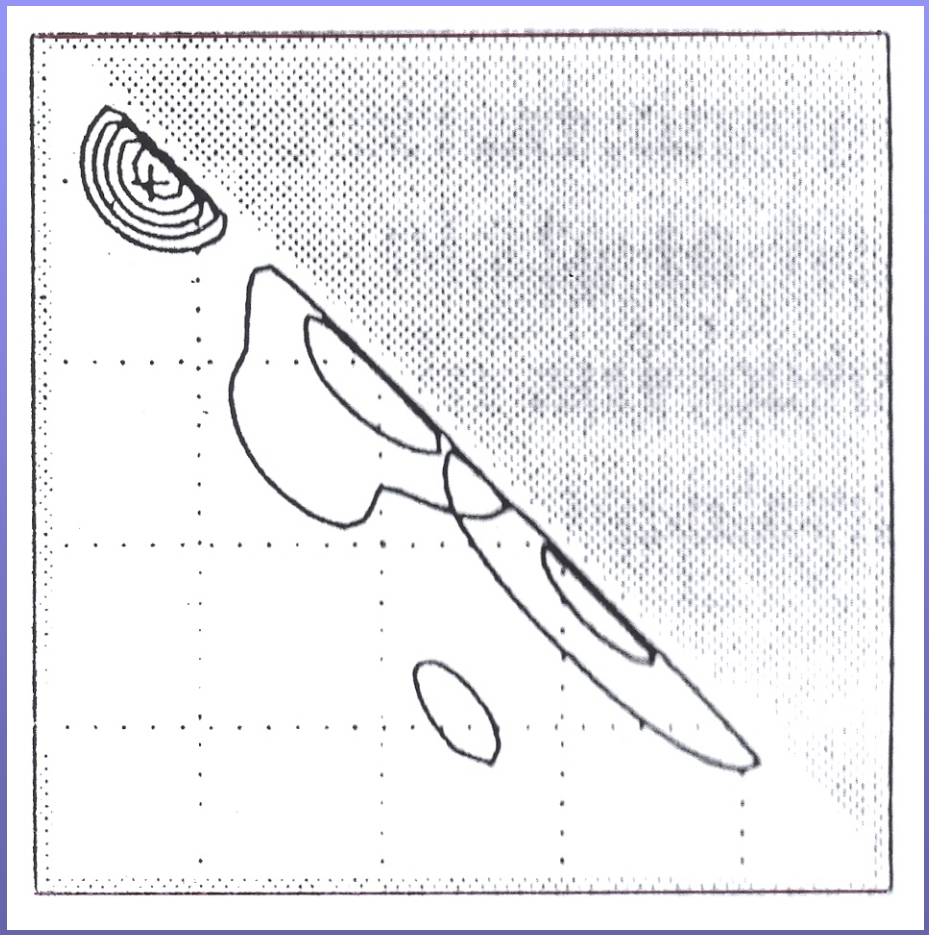
-- remedies (where possible)

advection



Octant advection scheme





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advection algorithms lead to spreading,
hence to smoothing of the fields,
particularly of the peaks

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hence to smoothing of the fields,
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Higher order schemes are a possible solution,

(see Tolman for swell advection),

but beware of false peaks

Wind resolution

Models fail where there are strong gradients,
e.g. sharp peaks

highly smoothed for numerical stability

smoothing is often stronger in data assimilation
(typically half resolution)

short term forecasts better than analysis

Wind resolution

Wind resolution

use higher resolution
LAM
kinematic analysis (not as a rule – needs a lot of time,
an experienced person and a lot of data/measurements)

Wind resolution

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LAM
kinematic analysis (not as a rule – needs a lot of time, an experienced person and a lot of data/measurements)

Resolution required where strong gradients

Wind resolution

use higher resolution
LAM
kinematic analysis (not as a rule – needs a lot of time, an experienced person and a lot of data/measurements)

Resolution required where strong gradients

Solution:
make grid with resolution variable in space and time, dynamically fitted to the fields

Gustiness

implement gustiness into the generation function
(already done, at least at some centres)

Gustiness

implement gustiness into the generation function
(already done, at least at some centres)

However, two problems left:

Gustiness

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(already done, at least at some centres)

However, two problems left:

1 - present meteorological models do not produce, justify, the gustiness levels found in the field

Gustiness

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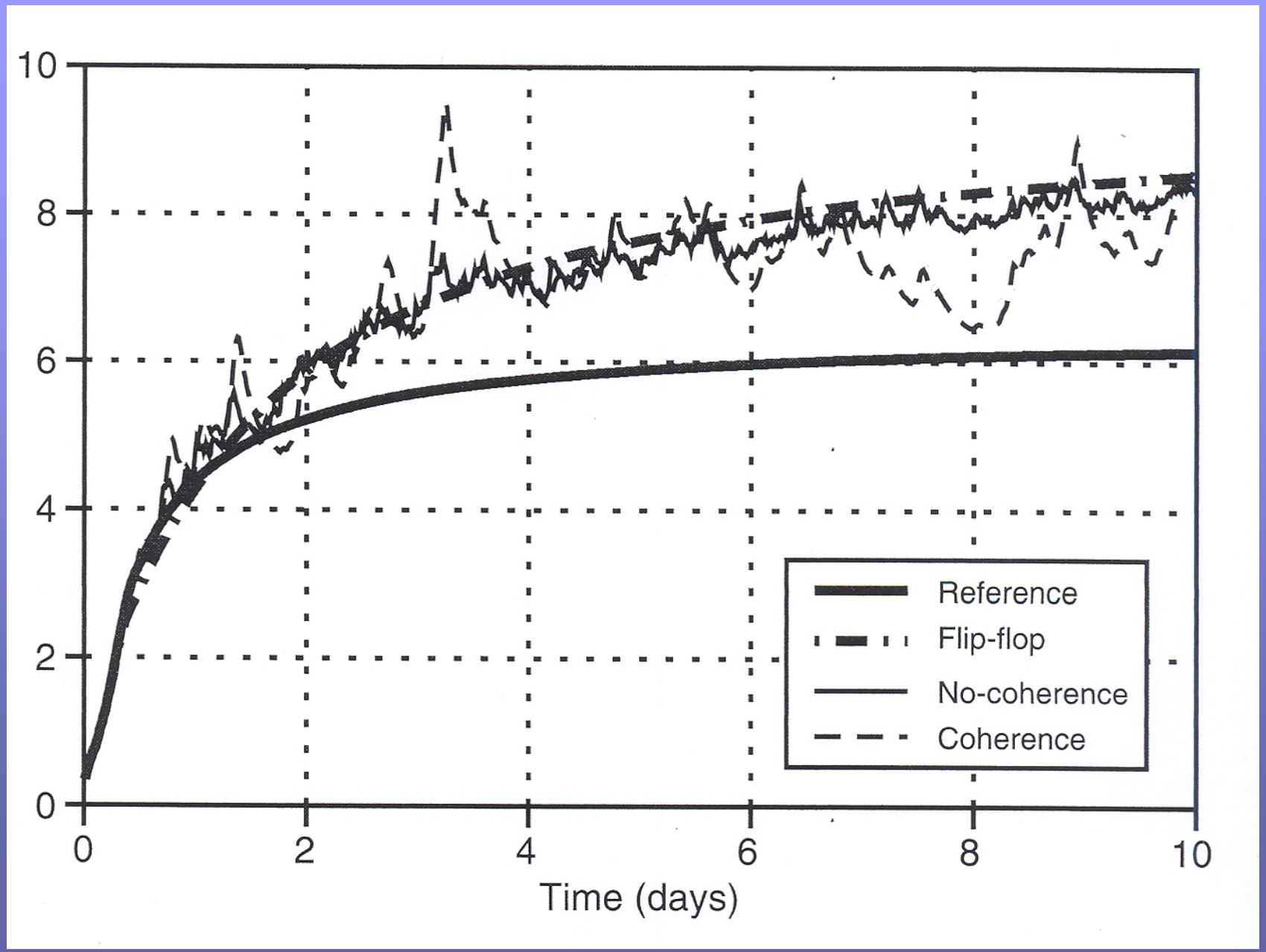
(already done, at least at some centres)

However, two problems left:

1 - present meteorological models do not produce,
justify, the gustiness levels found in the field

2 - besides, only smooth input, no randomisation,
i.e. no longer term large oscilations of Hs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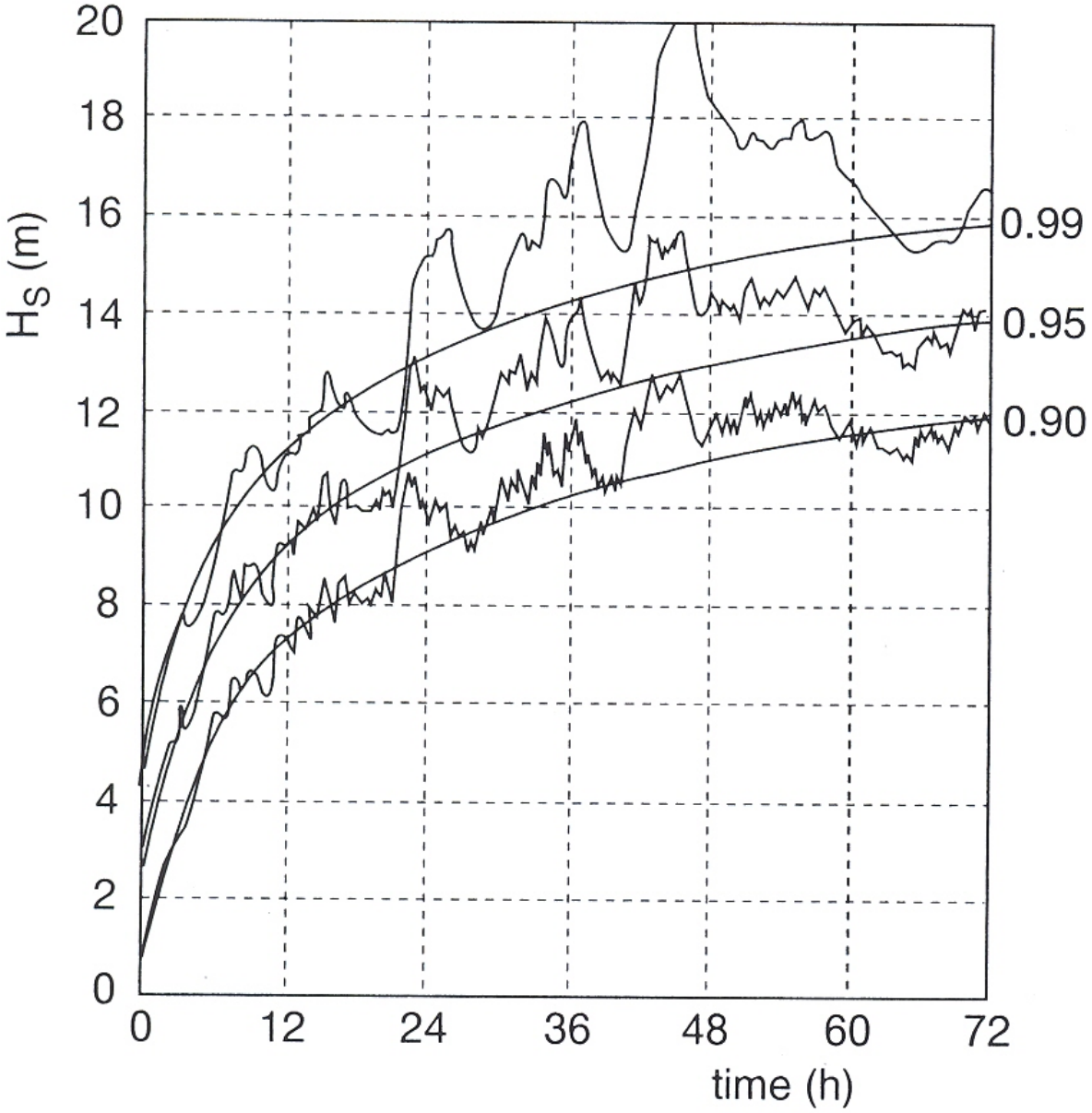
4
6
8
10
Time (days)
Reference
Flip-flop
No-coherence
Coherence


20
18
16
14
12
10
8
6
4
2
0
H_S (m)
0
12
24
36
48
60
72
time (h)
0.99
0.95
0.90

Gustiness

2 - besides, only smooth input, no randomisation,
i.e. no longer term large oscilations of Hs

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possible solution :

two model runs, with and without “smooth” gustiness;

at each time step the difference provides a scale
to estimate the probability of larger Hs

Physics of waves

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Generation – not much on sight

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Dissipation – possible developments

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NL – wait for faster computers and/or better algorithms

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Currents – we need good representation of currents
(two-way coupling not essential in deep oceans)

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Currents – we need good representation of currents
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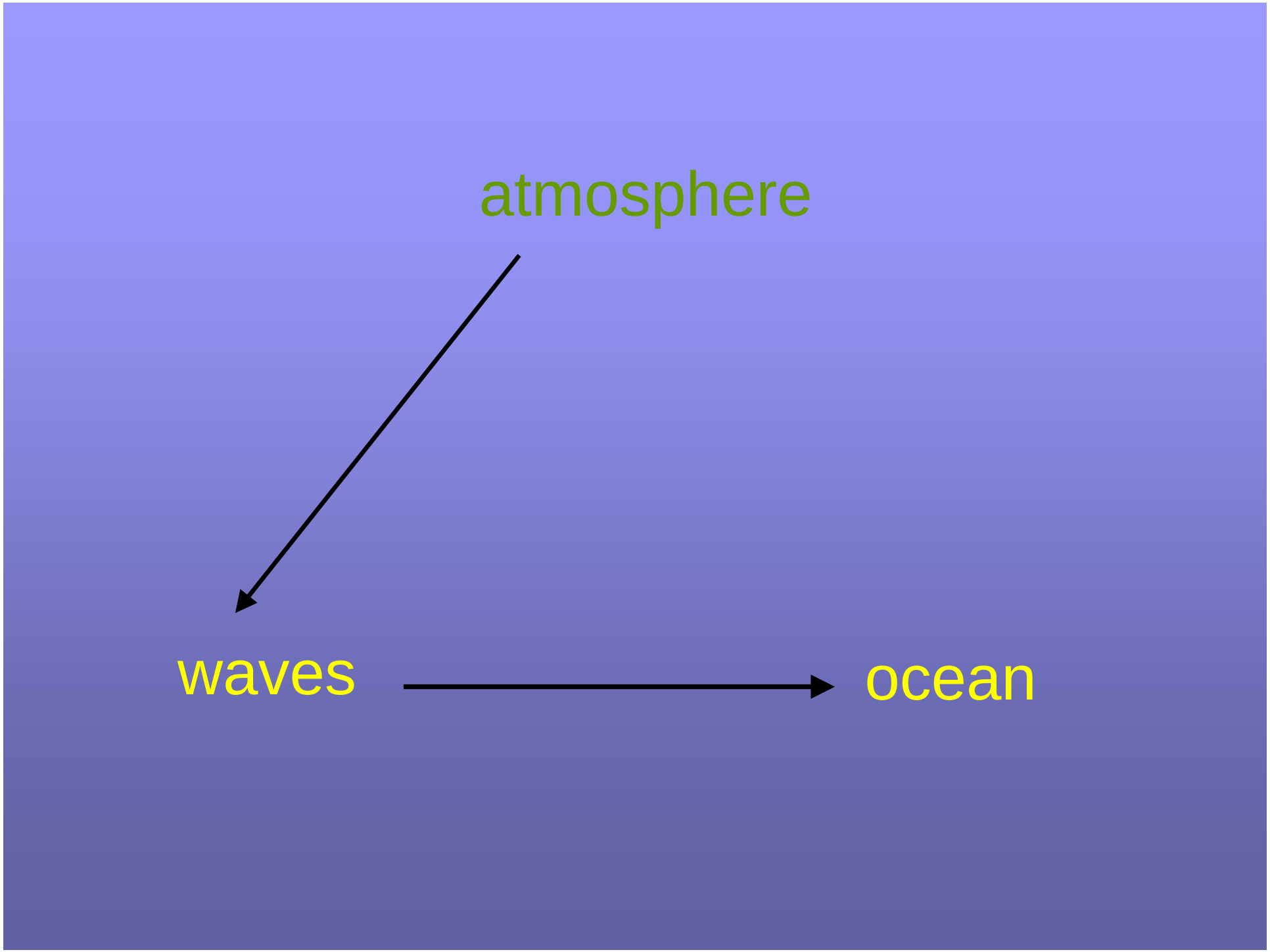
Coastal areas are a different matter –
two-way coupling essential

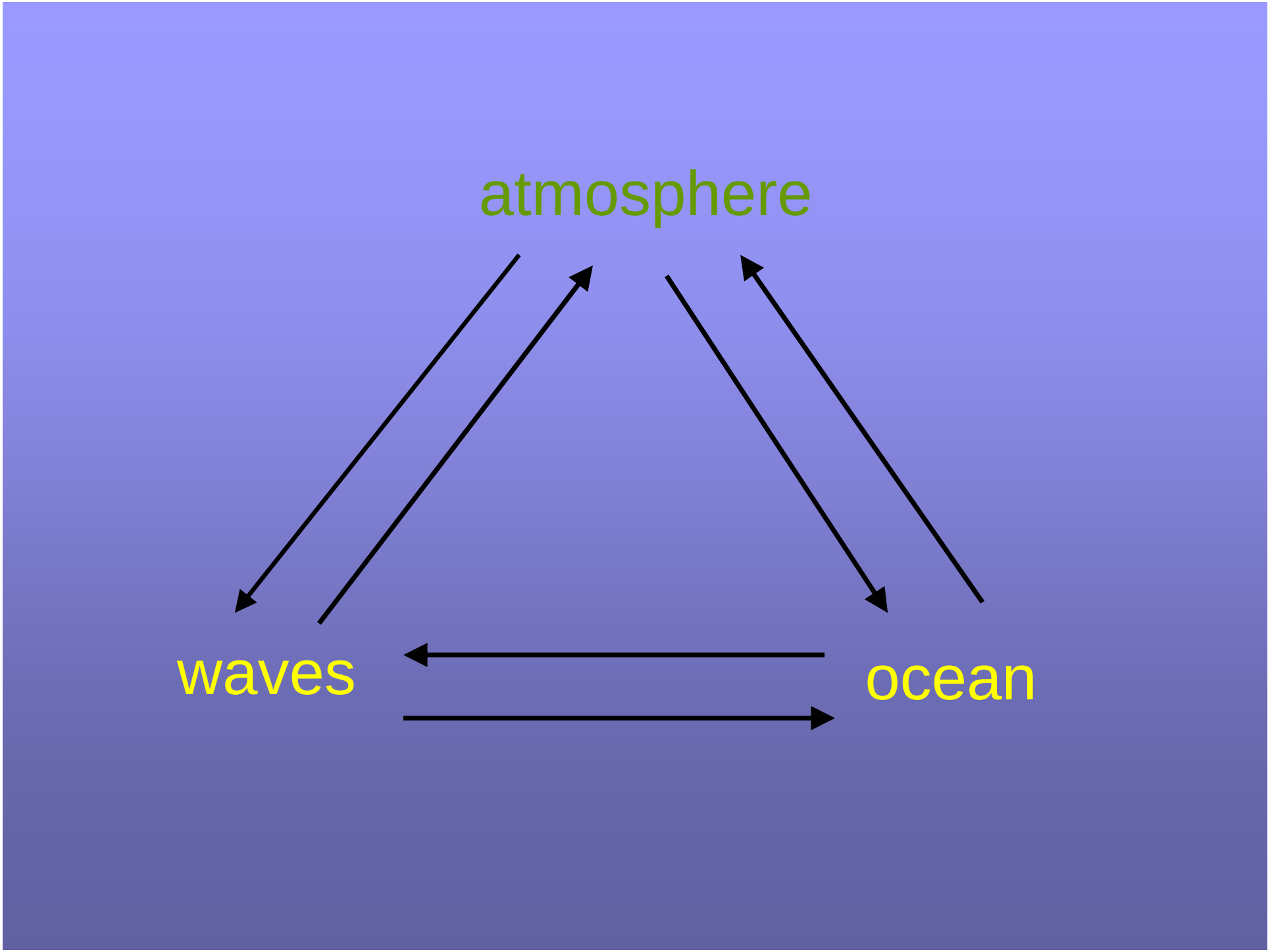
3 general considerations:

1) **The Model** of the future must be fully coupled

atmosphere – waves – circulation

Sequence not by chance – this is how nature works


atmosphere
waves
ocean


atmosphere
waves
ocean

2) we need to sort out “generation + dissipation”

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suggestion :

conceive a numerical experiment

to simulate wind + waves in 3D

using first principle equations,

starting from high wind and wave conditions

3) a more fundamental question

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"Despite the progress, we are not yet able to make predictions that always fall within the error bounds of the observations. One may wonder if it will be possible to ameliorate modelling of the sea state by introducing "better" physics, better numerics or higher resolutions. In view of the progress that has been made going from second to third generation models, one should not be too optimistic about the effect of further refinements …"

(Komen et al., 1994)

3) a more fundamental question

“ when results from all four models differ from observed wave data during a storm episode, yet agree with one another, the differences are most likely due to inaccuracies in the interpolated wind field, but when results from the models differ from observed data, and from each another, the differences are most likely due to inadequacies of the models”

(Liu et al., 2002)

3) a more fundamental question

"Additional model verification and model comparisons may lead to further refinement or improvement for particular case studies, but we believe that there may be an underlying limitation to further improvement of models based on the concept of a wave energy spectrum. Fresh and new approaches to wave modelling may be required for further substantial improvement."

(Liu et al., 2002)

3) a more fundamental question

"… . For these reasons we believe that the traditional approach to wave modeling based on the wave energy spectrum may have reached its limit in terms of reproducing observed wave characteristics and that a whole new approach to wind wave modeling focused specifically on the wave group processes and nonstationaty energy transfer processes might be an appropriate route for further development."

(Liu et al., 2002)

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Bad first:
plenty of work to do, a long way to go

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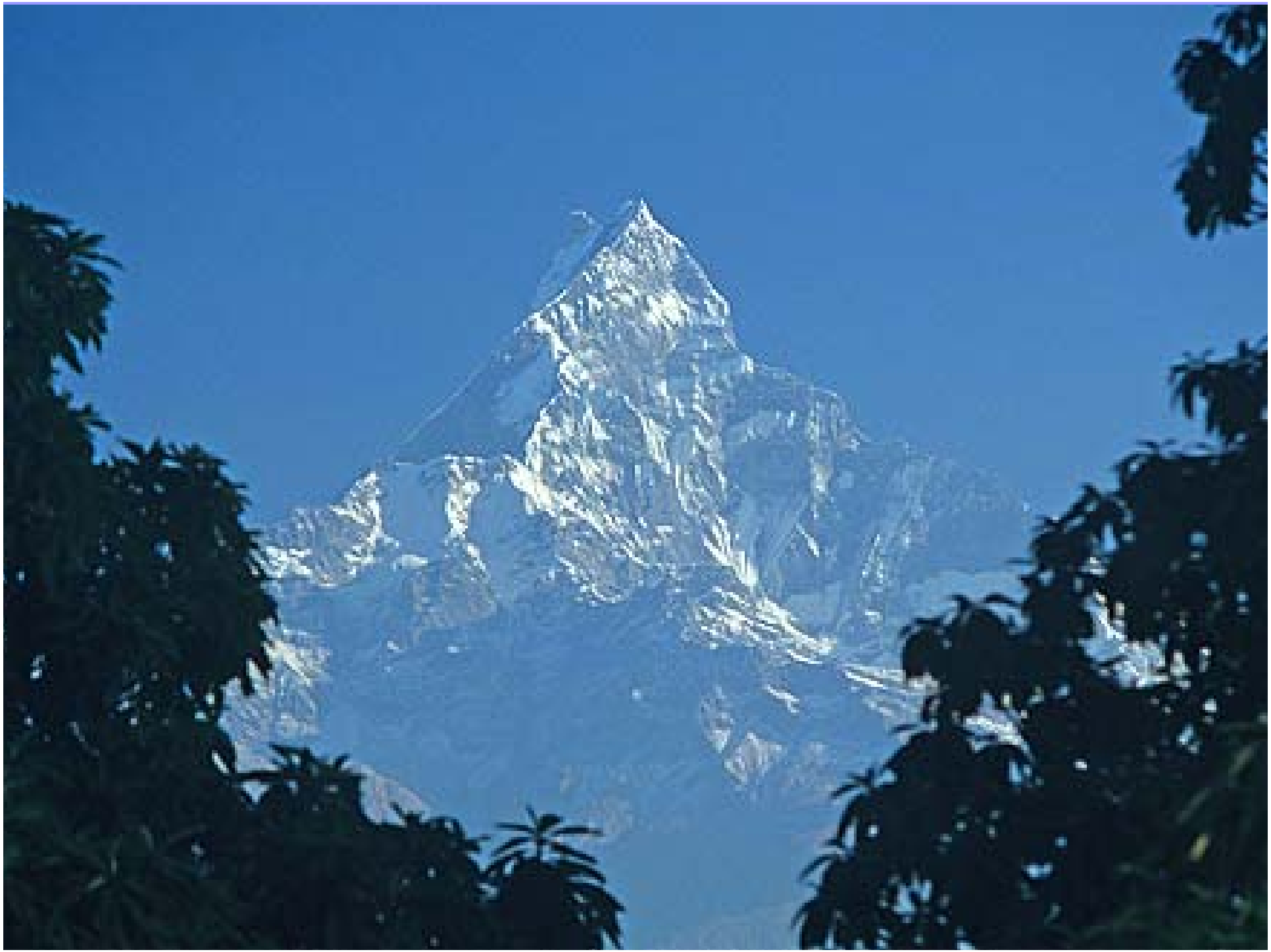
Bad first:
plenty of work to do, a long way to go

Good:
not all these actions need to be acted on at once



have a nice climb

(of waves of course)

thank you