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Portland District

Effects of Infragravity Energy and Storm-induced Current on Short Waves Beyond the Surf Zone

~ Mouth of the Columbia River, USA ~

Hans R. Moritz

US Army Corps of Engineers-Portland District

Sponsored by:

U.S. Army Corps of Engineers - Regional Sediment Management Demonstration Program

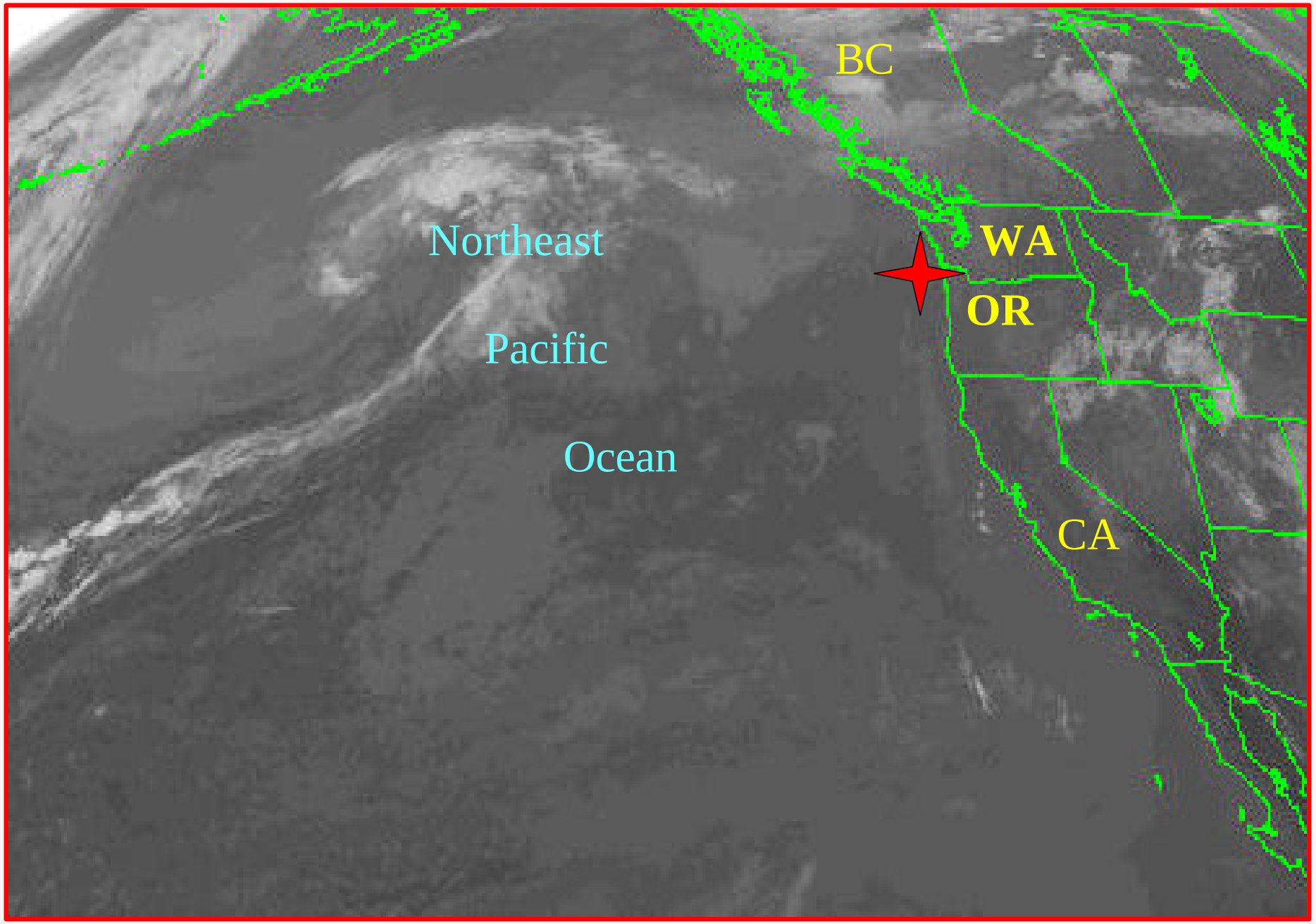
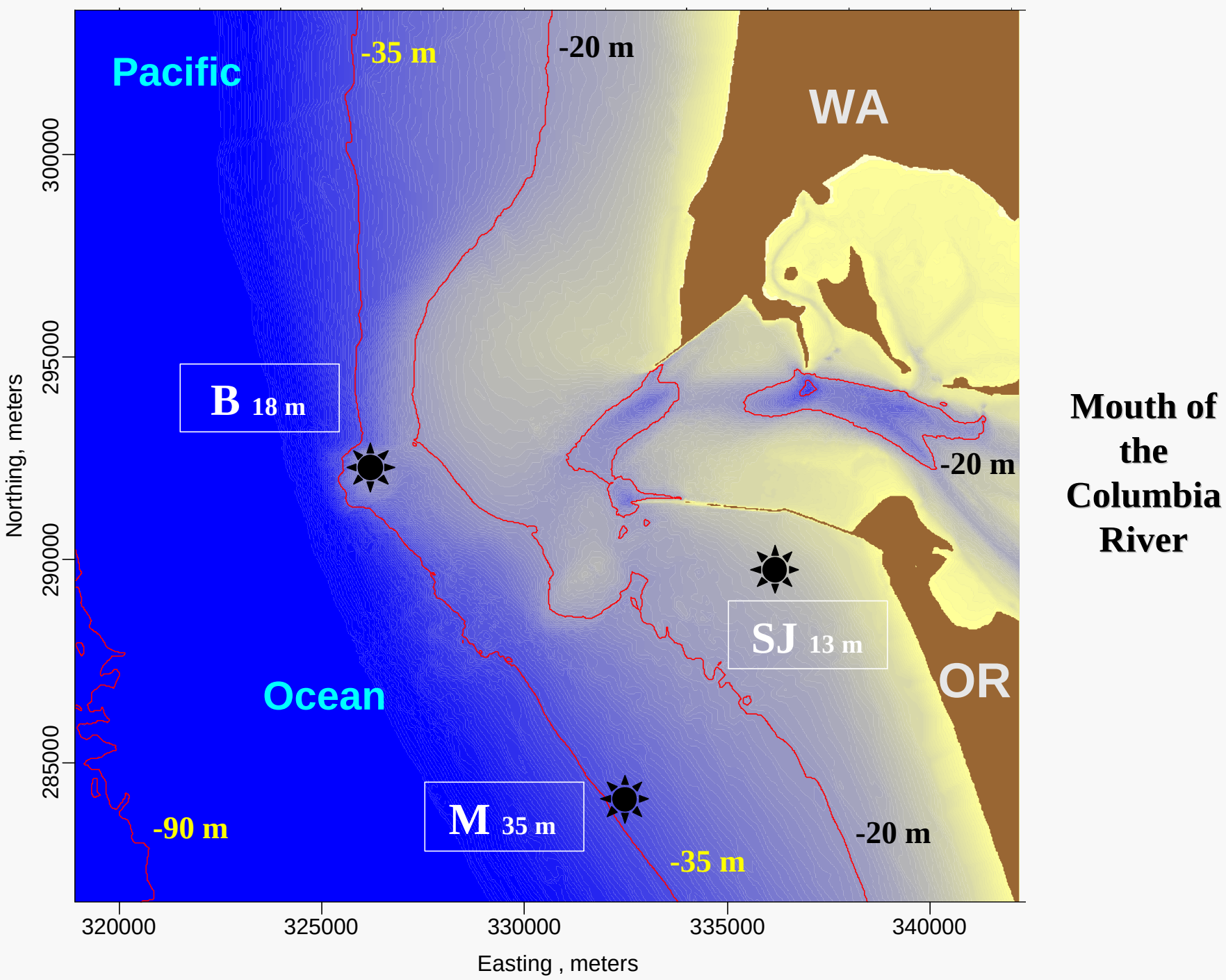


image courtesy of NOAA



Mouth of the Columbia River

OBSERVATIONS

I. Short-Waves Observed in 18 m and 35 m depth

The presence of a storm-induced coastal current (U_o) 75 to 100 cm/sec, created by sustained wind stress

Can bias the estimation of wave parameters by Doppler-shifting the observed higher frequency wave components.

II. Long-Wave Effects Observed in 35 m and 13 m depth

Significant Infragravity (IG) energy develops during storms and can affect WSE and bottom current.

The magnitudes of IG processes are interesting and may have implications for short-wave propagation, shoreline erosion, and shelf sediment transport.

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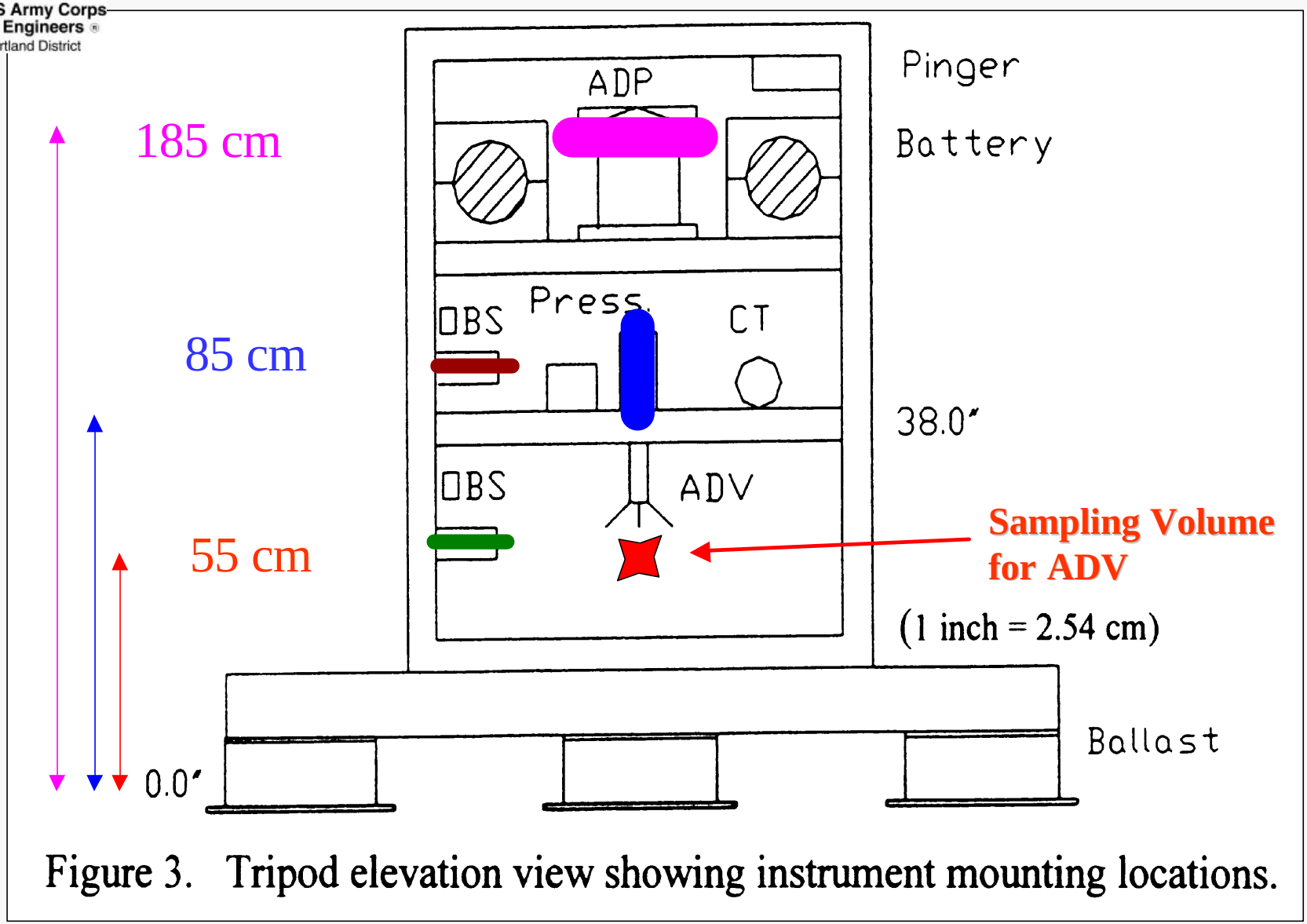

Figure 3. Tripod elevation view showing instrument mounting locations.

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Feature Instrumentation & Sampling

Instrument	Parameter	*Sampling Location* Distance Off Bottom		*Sampling* Rate	Duration	*Protocol* Interval
ADV	**Bottom Current *(U-V)***	55 cm	***(B)***	**4 Hz**	**1024 sec**	**3 hrs**
			(M)	1 Hz	2048 sec	3 hrs
			(SJ)	2 Hz	2048 sec	2 hrs
ADP	**Current Profile**	3 m to surface		**1 Hz**	**600 sec**	**2-3 hrs**
Paros	**Pressure (P)**	83 cm	***(B)***	**4 Hz**	**1024 sec**	**3 hrs**
			(M)	1 Hz	2048 sec	3 hrs
			(SJ)	2 Hz	2048 sec	2 hrs

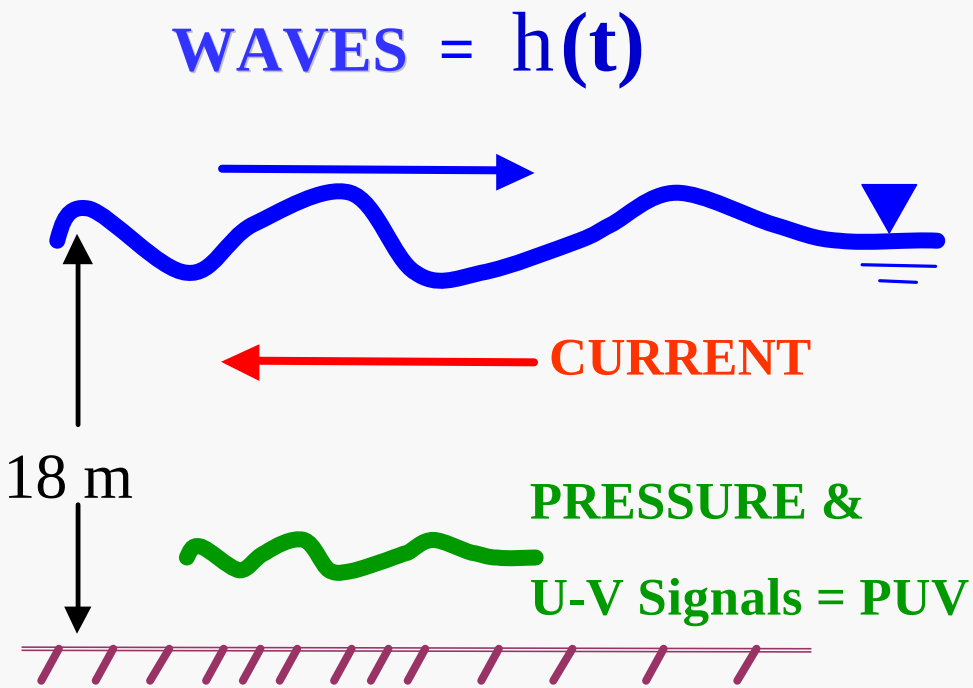
Site B----Depth = 18 meters

Site M----Depth = 35 meters

Site SJ----Depth = 13 meters

Processing directional surface **WAVES** using *bottom* **Dynamic Pressure** and **U-V** signal.

Accounting for Ambient Current



Determine Short WAVES (sea/swell) h(t) from observed pressure signal

Pressure

$$P_{total} = mean\ press. + \underline{dynamic\ press.} \quad (P_D, waves)$$

-- Using Linear Wave Theory - LWT--

$$P_{D(t)} = \rho\ g\ h(t)\ \cosh[k(d-z)] / \cosh[kd]$$ {phase arg(t)}

P_D and z are known: calculate k ($2p/L$), and solve for h

Linear Wave Theory

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$$h(t) = P_{d(t)} / [\, r\, g\, K_{p(z)} \cosh[\mathbf{k}(d-z)] \,] \quad \{\text{phase arg}(t)\}$$

$K_{p(z)} \approx 1 / \cosh(\mathbf{k}d)$ = pressure response factor @ tripod

For Kp < 0.03, η(t) can not be detected

@ 35 meter depth, smallest resolved wave period = 7 sec

Recall, **k**=f(L) and **L**=f(T)

Dispersion Equation….with current

$$s = U_o k + (gk \tanh[kd])^{1/2}, \quad \text{solve for } \mathbf{k}$$

s = 2p/**T**, U_o = ***Ambient Current affecting waves***

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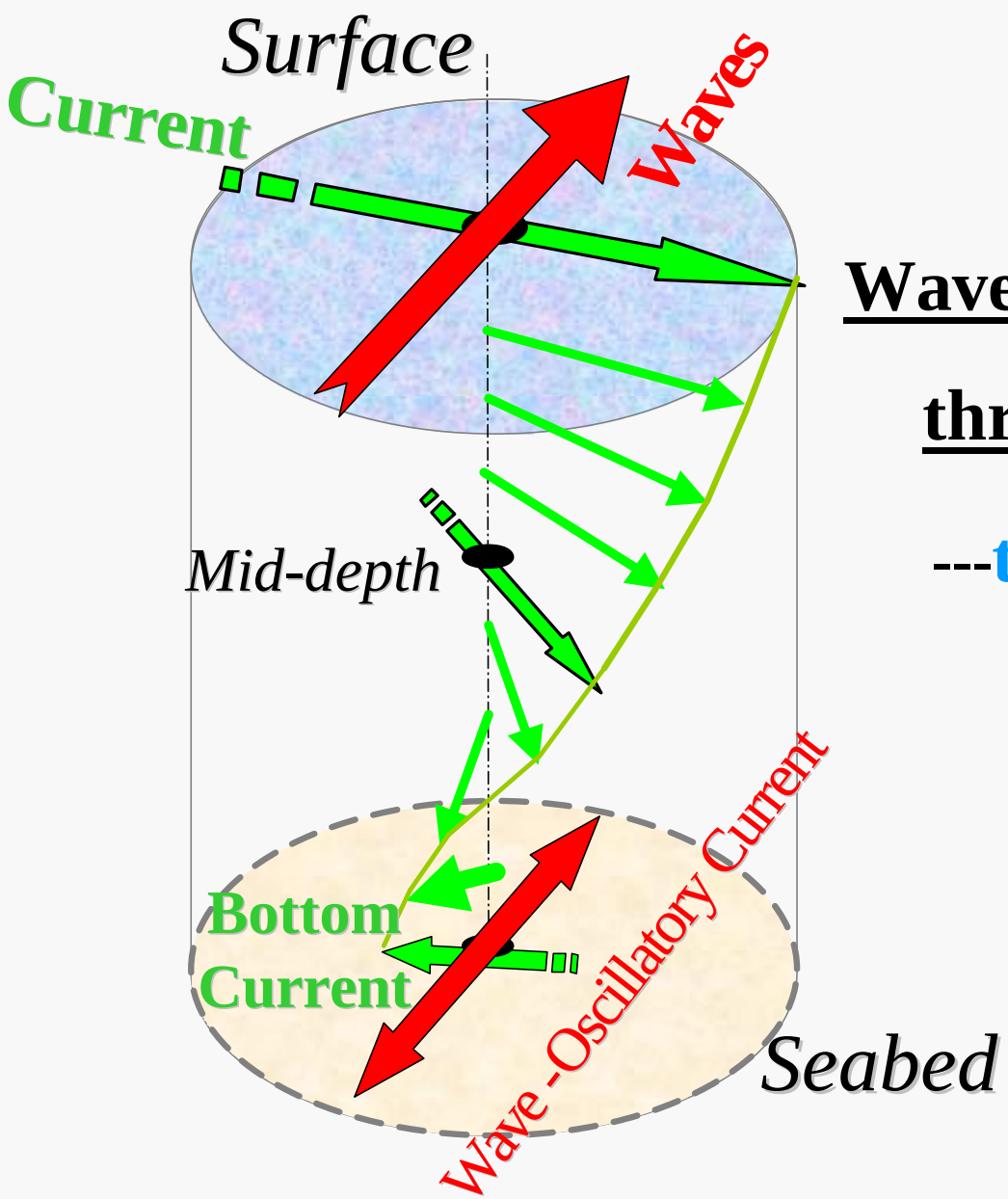
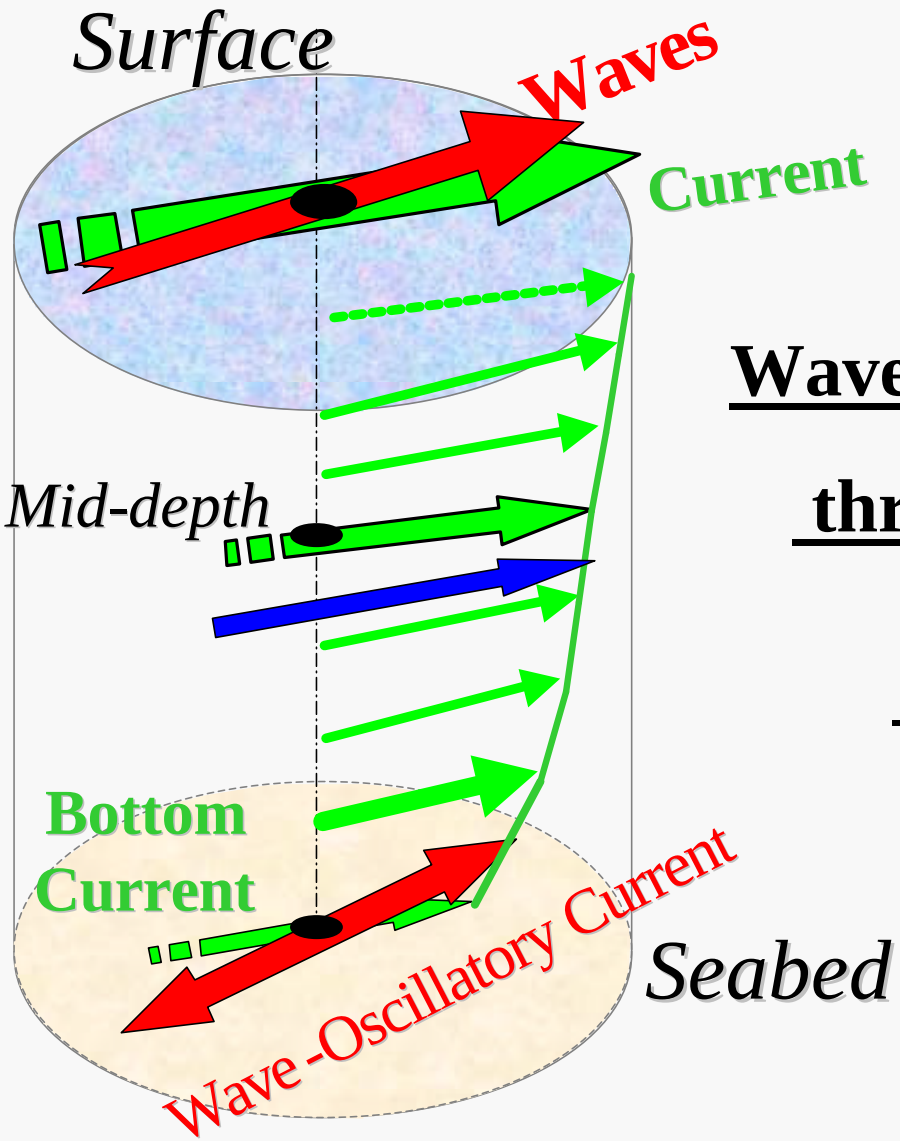


Wave & Current Effects thru Water Column

---typical condition---



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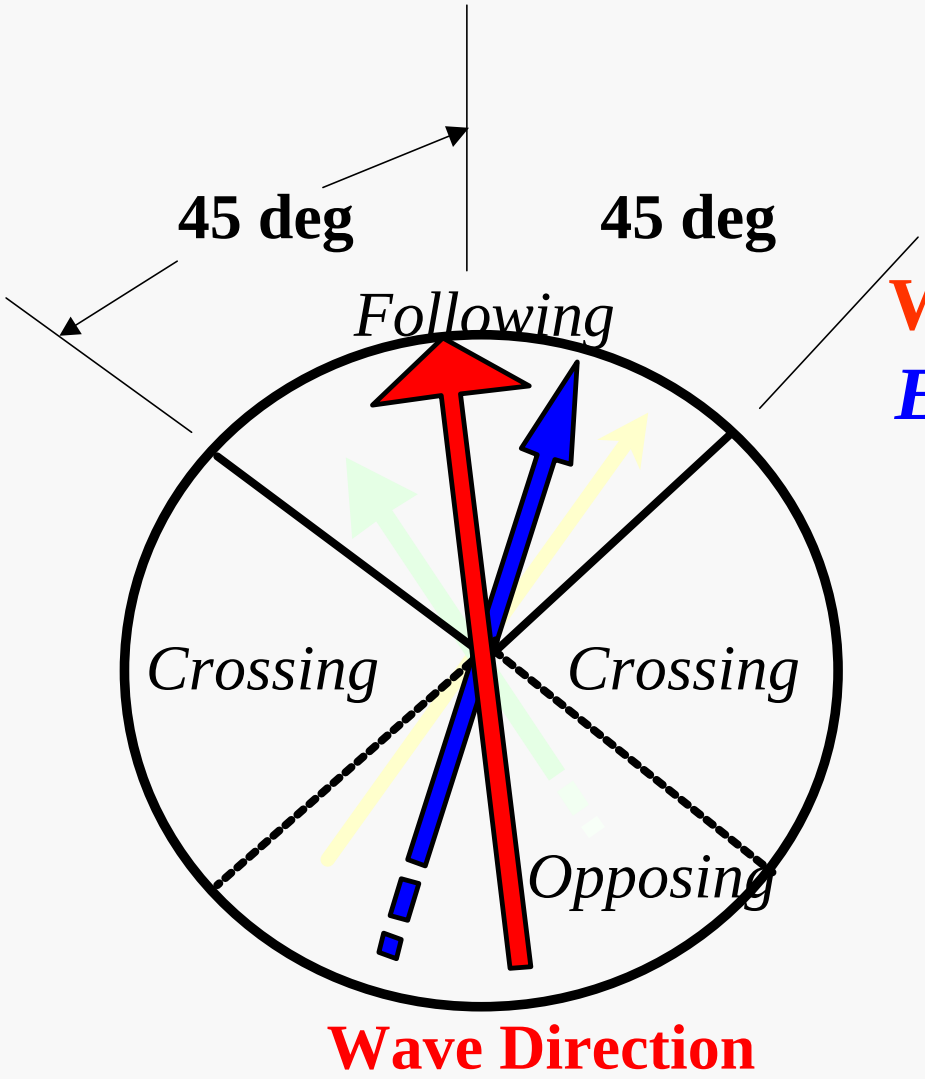
Wave & Current Effects thru Water Column

--**storm** condition--

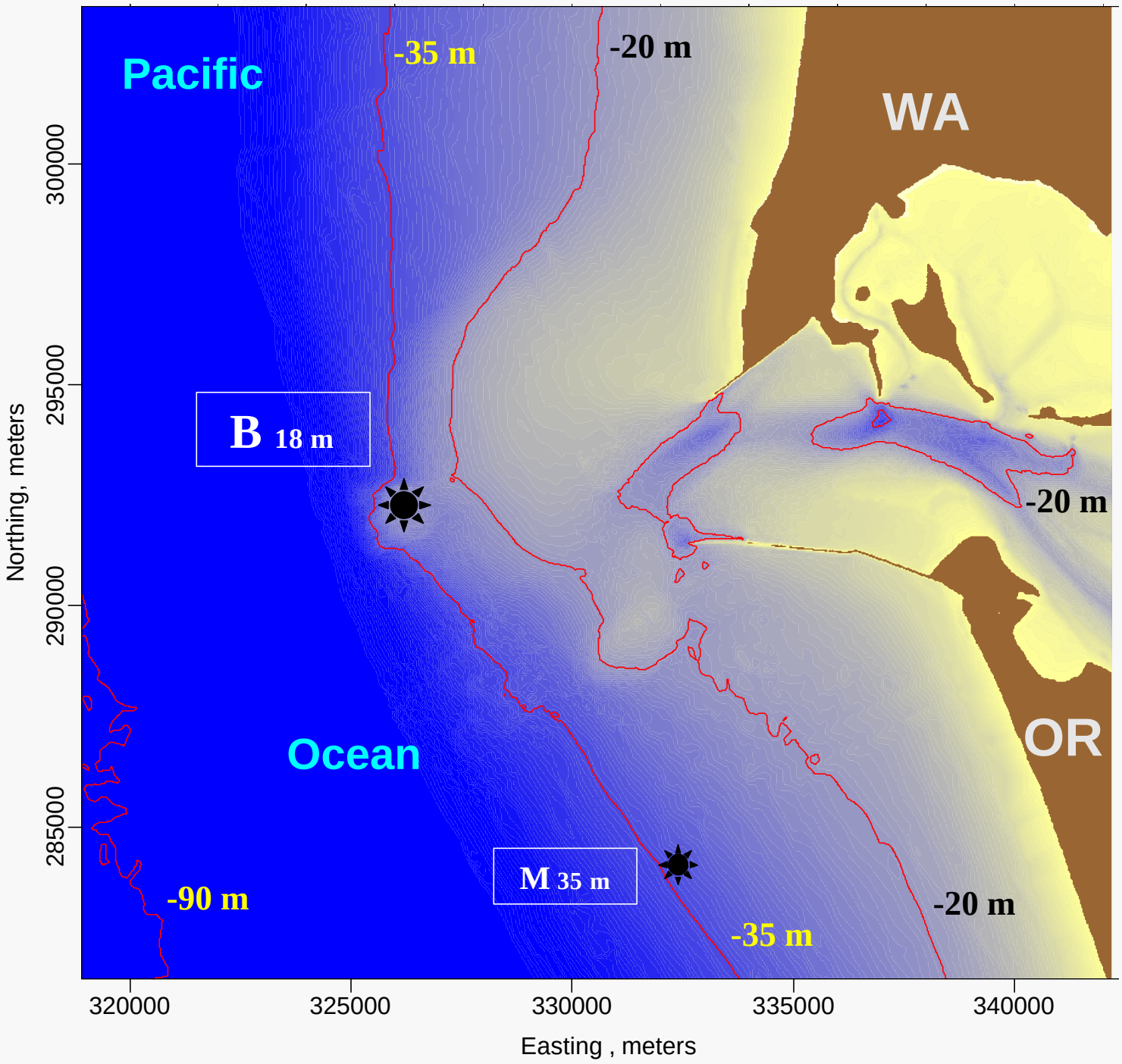
Effective Cur = [Lp*tanh(Keps*tot_depth)/(2*pi)]/tot_depth

Lee and Hedges

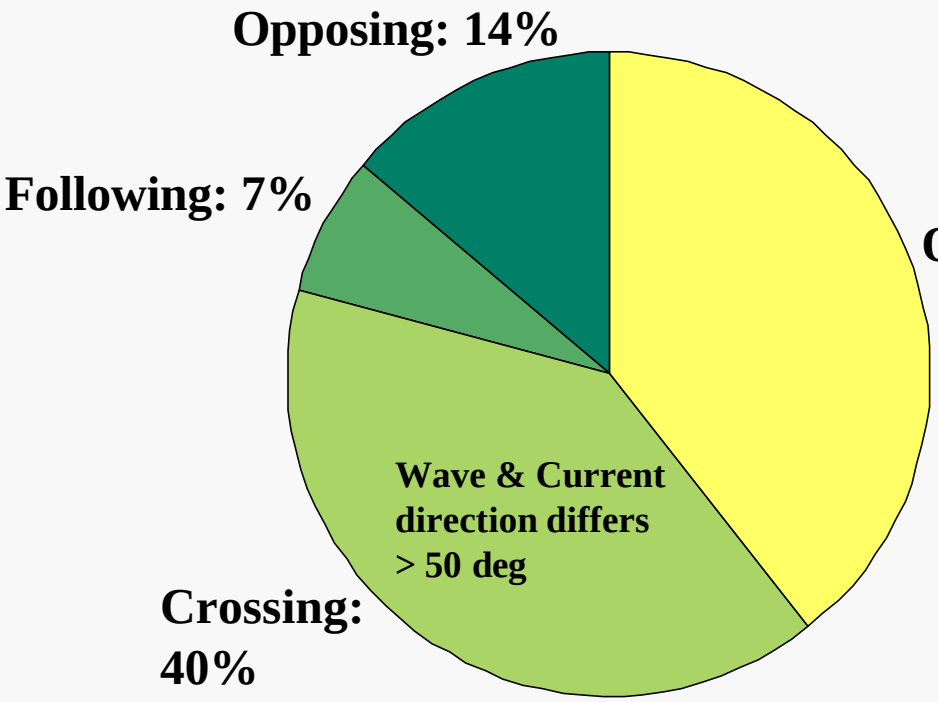
Selection Criteria: WAVE-CURRENT Interaction



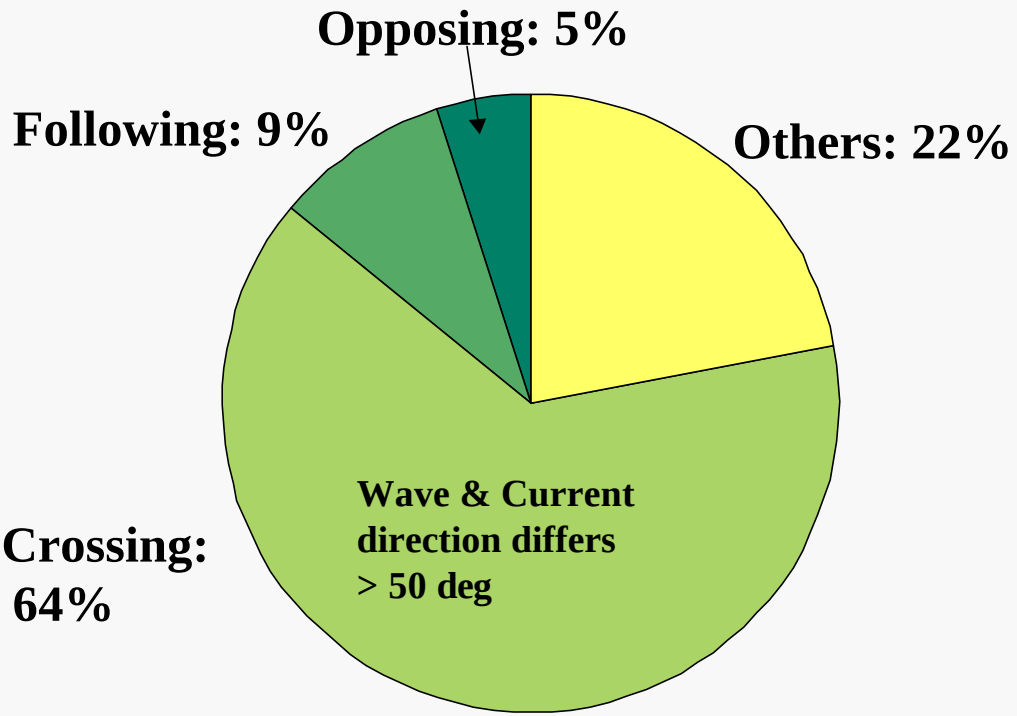
Wave Direction (Dp) and *Effective Current* must be within +/- 45 degrees



Mouth of the Columbia River

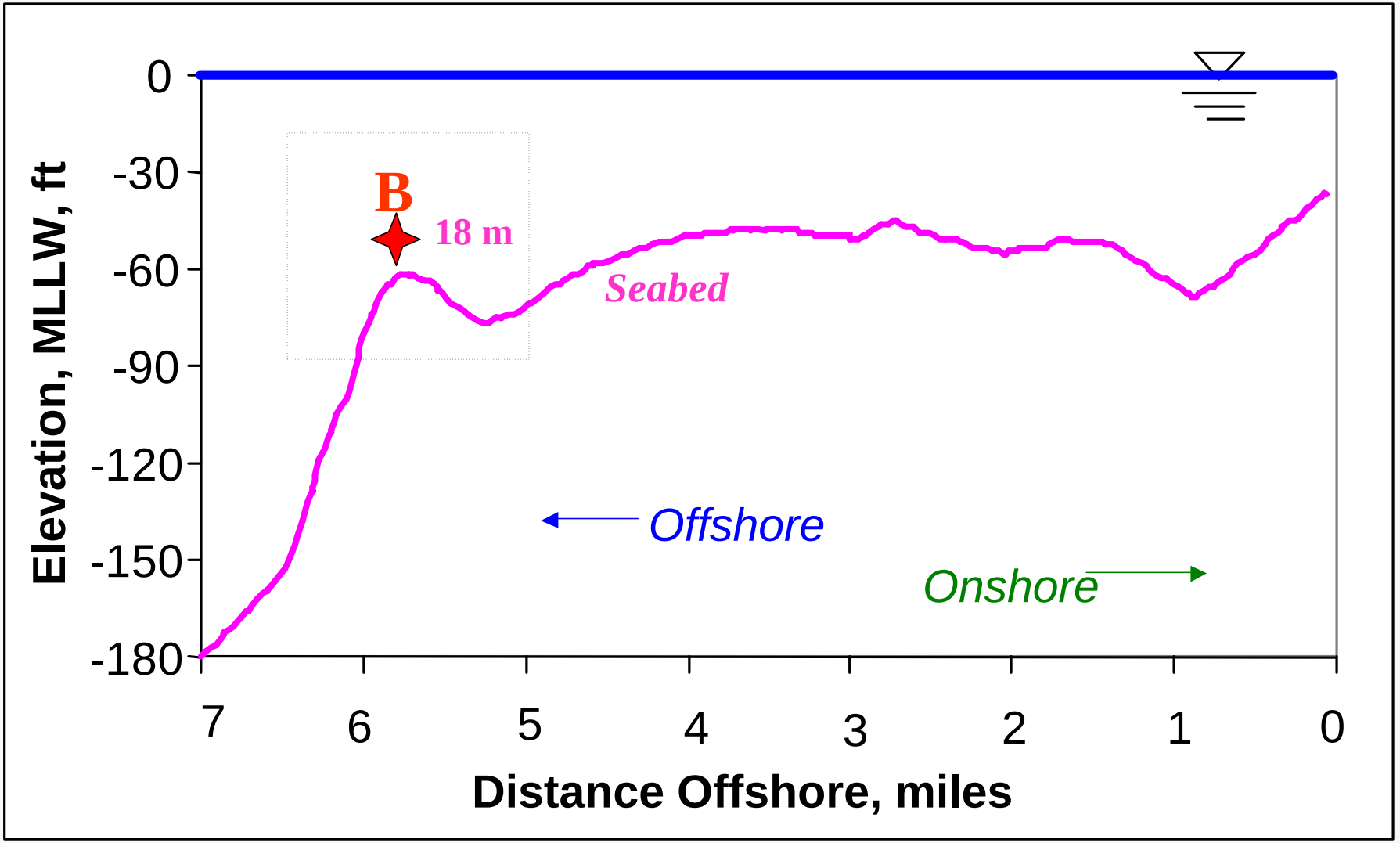

Opposing: 14%
Following: 7%
Others: 39%
Wave & Current direction differs > 50 deg
Crossing: 40%

Site B


Opposing: 5%
Following: 9%
Others: 22%
Wave & Current direction differs > 50 deg
Crossing: 64%

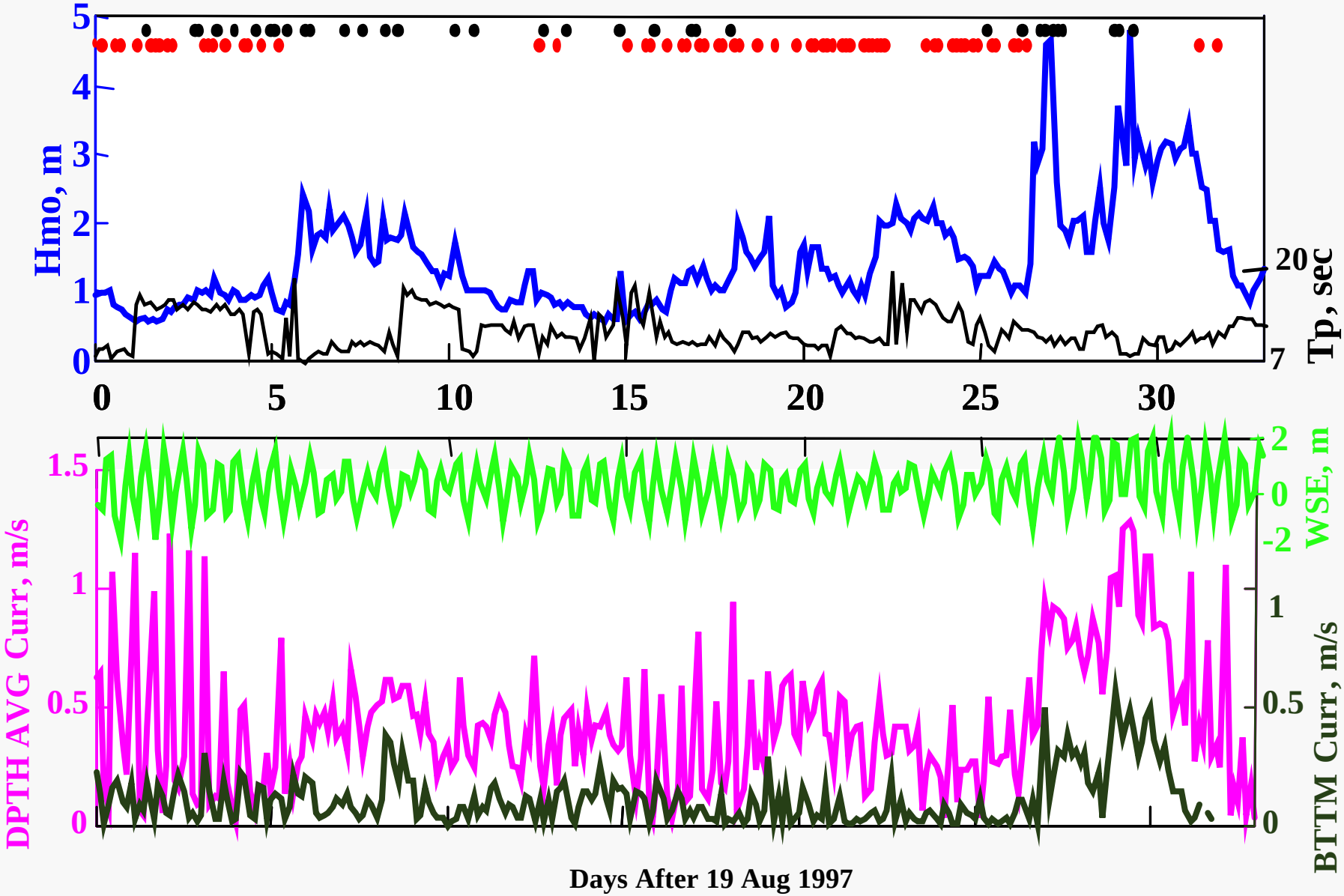
Site M

Cross-Shore Profile - Site B: Columbia River mouth

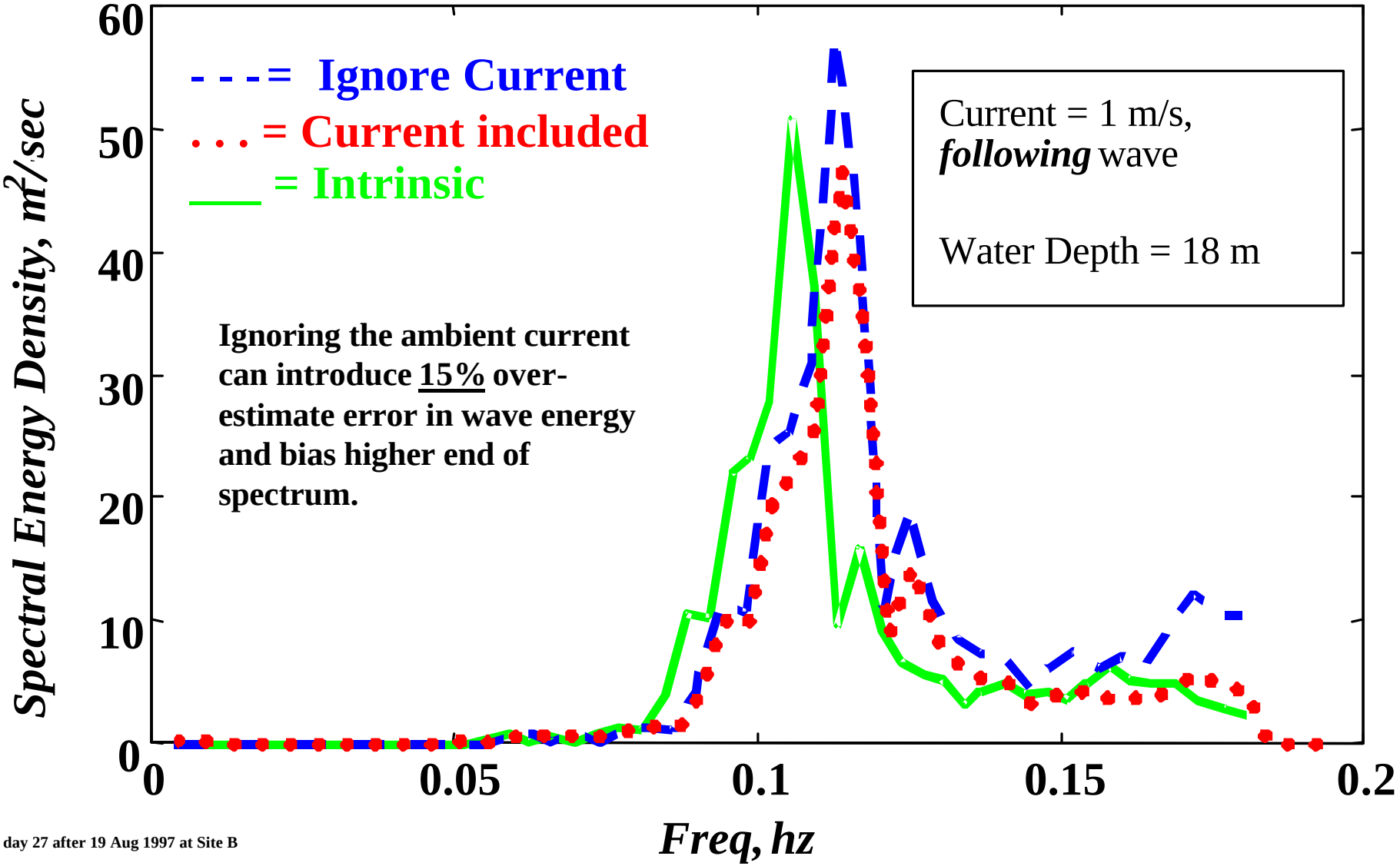


Summary of "B" Deployment

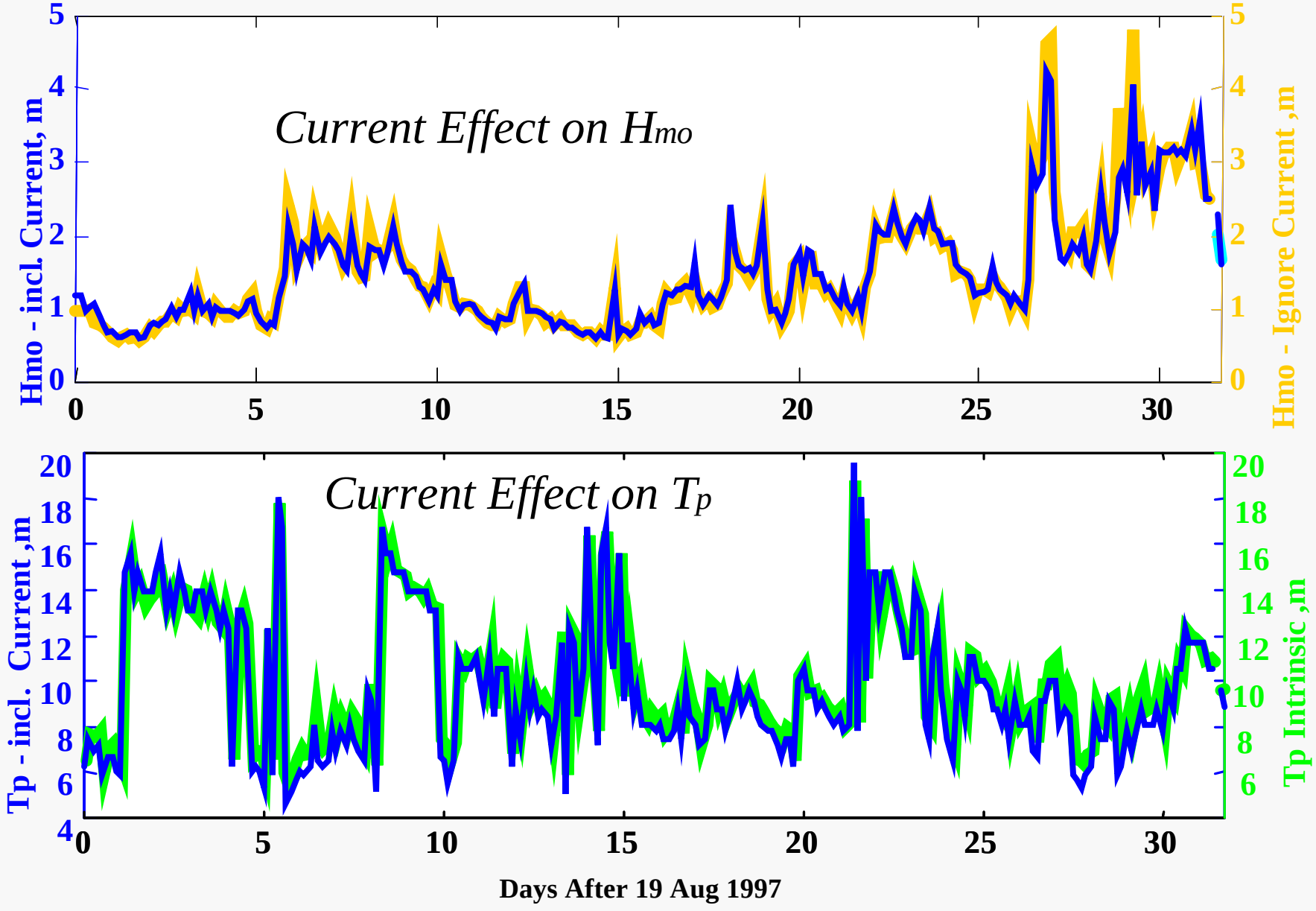
Depth = 18 m

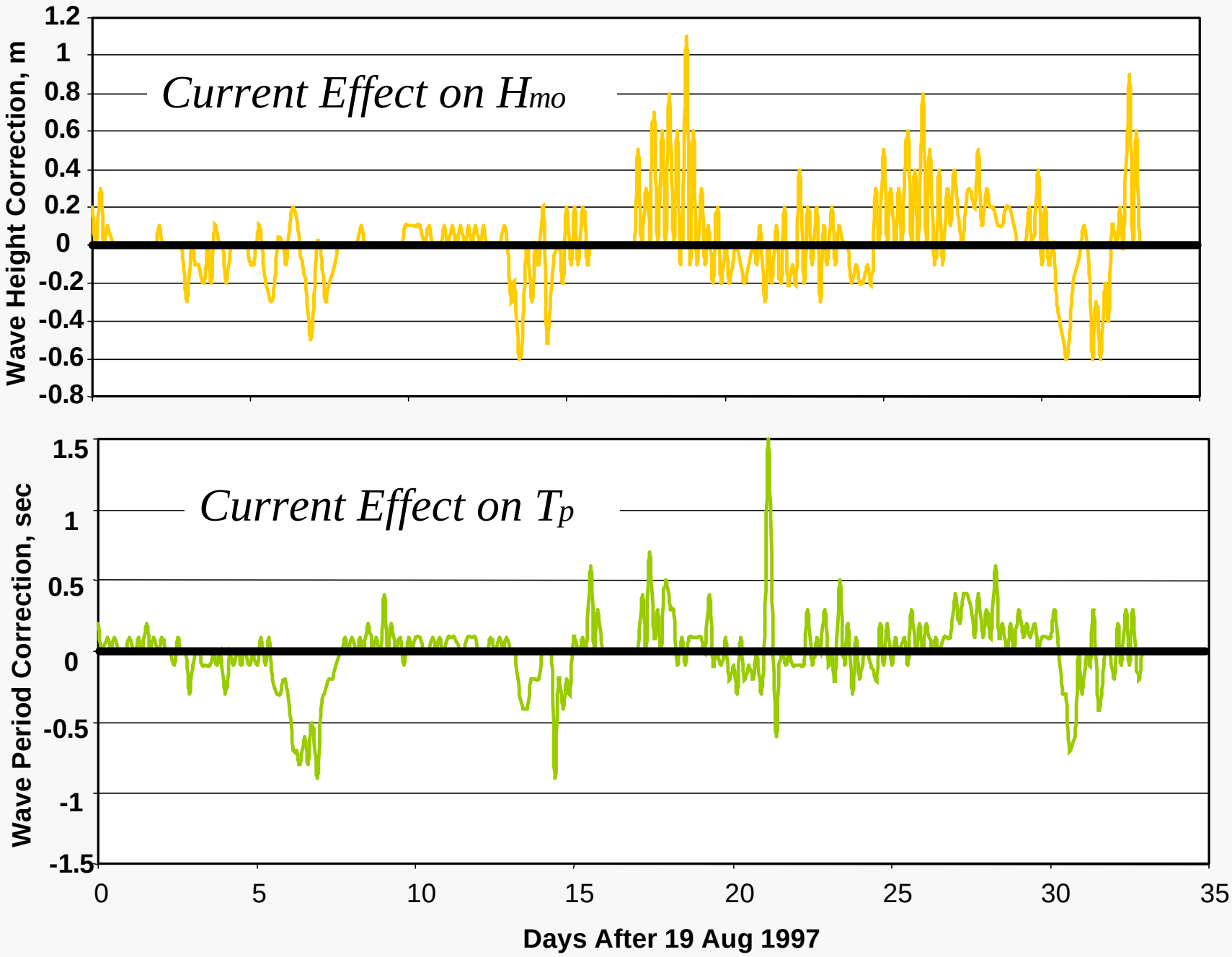


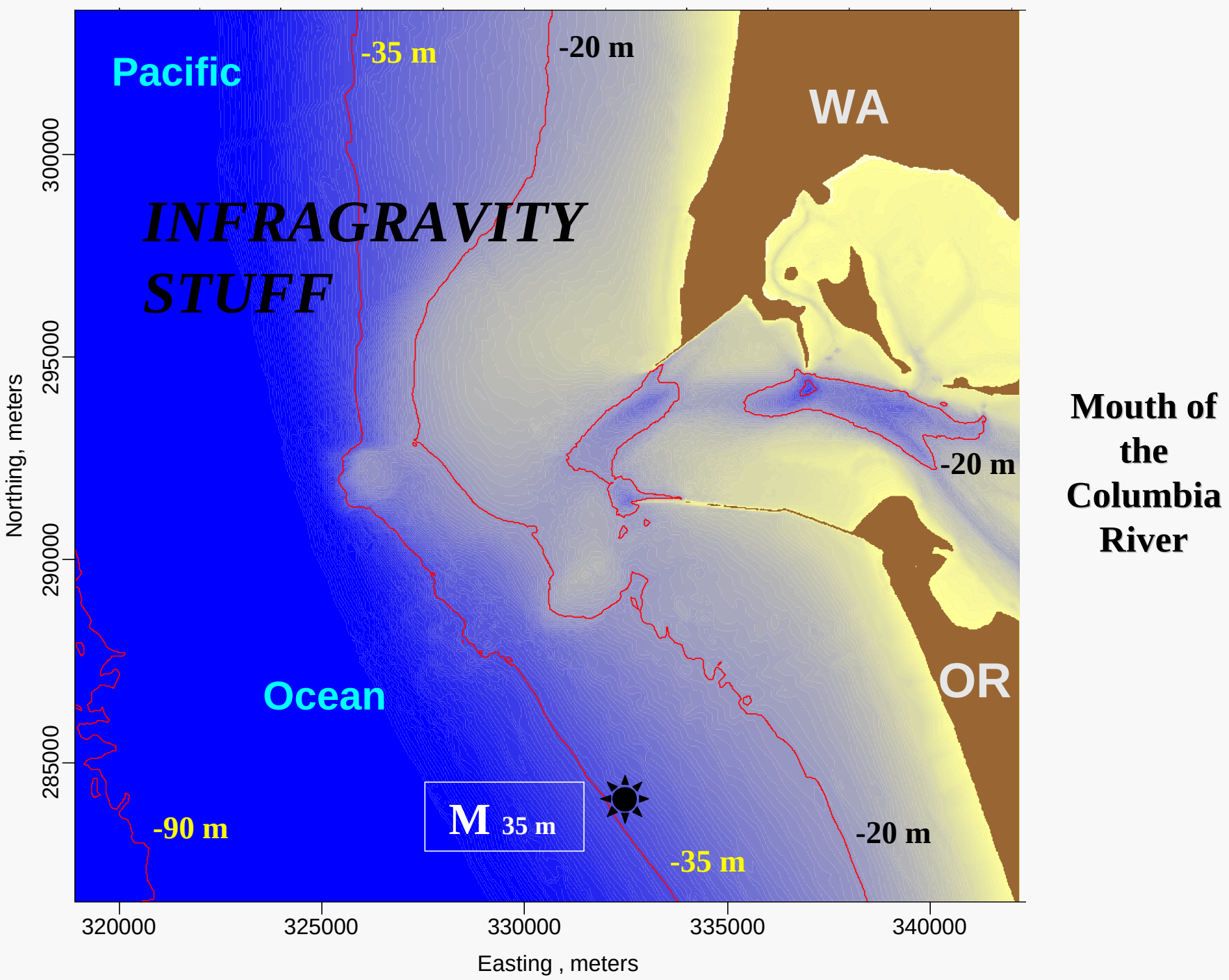
The effect of Uo -current on PUV-based spectral density estimates for h.



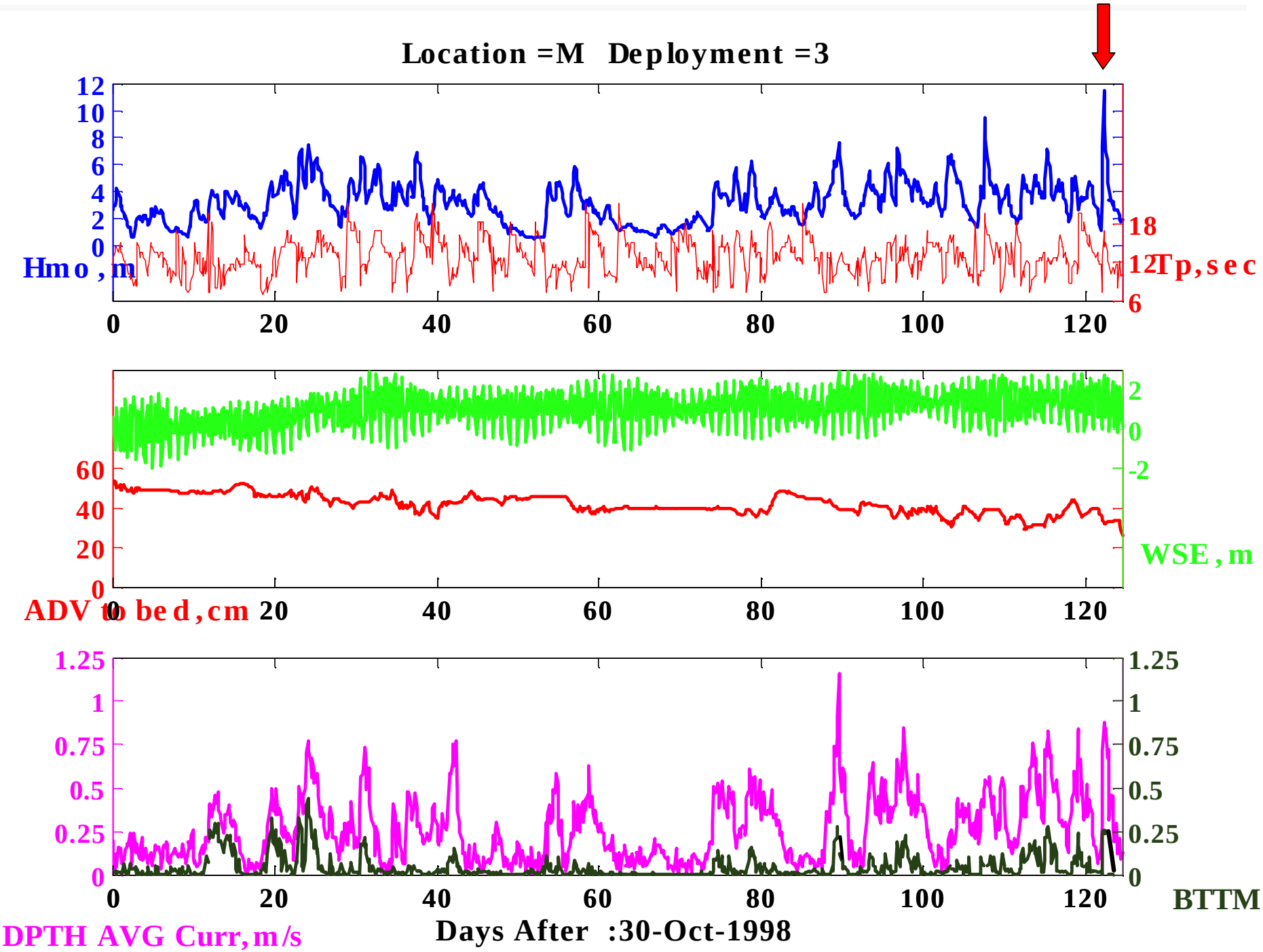
Influence of Effective Current ON Summary Wave Parameters: **Site B**




Current Effect on H_{mo}
Wave Height Correction, m
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
Current Effect on T_p
Wave Period Correction, sec
1.5
1
0.5
0
-0.5
-1
-1.5
0
5
10
15
20
25
30
35
Days After 19 Aug 1997



Mouth of the Columbia River


Location =M Deployment =3
Hmo, m
Tp, sec
ADV to bed, cm
WSE, m
DPTH AVG Curr, m/s
BTTM Cu
Days After :30-Oct-1998

LONGWAVE OBSERVATIONS at Site M - 35 m depth

1 Burst is Shown Here;

but many of the 800 bursts collected at Site M show the same qualitative results

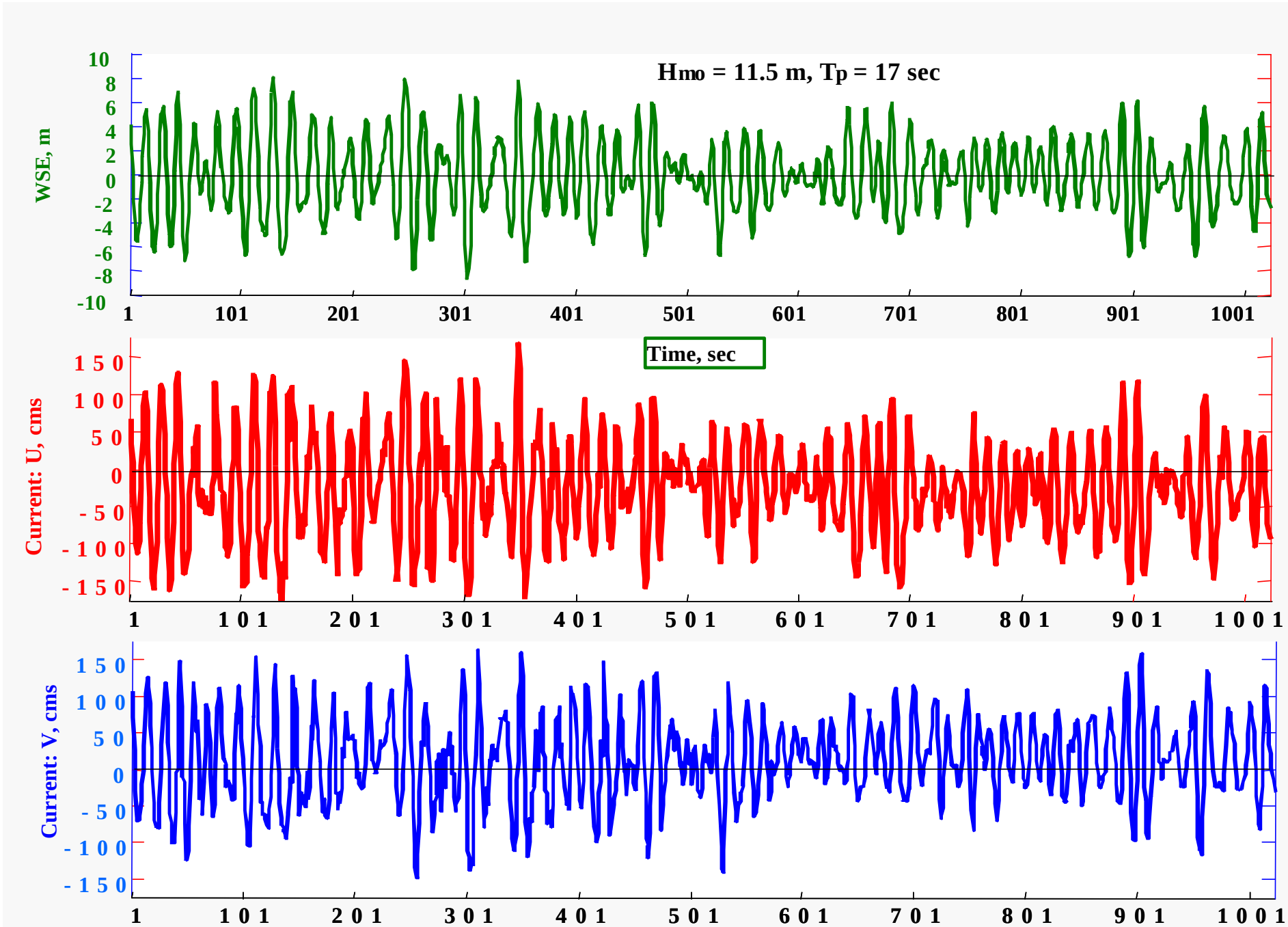
Burst Details:

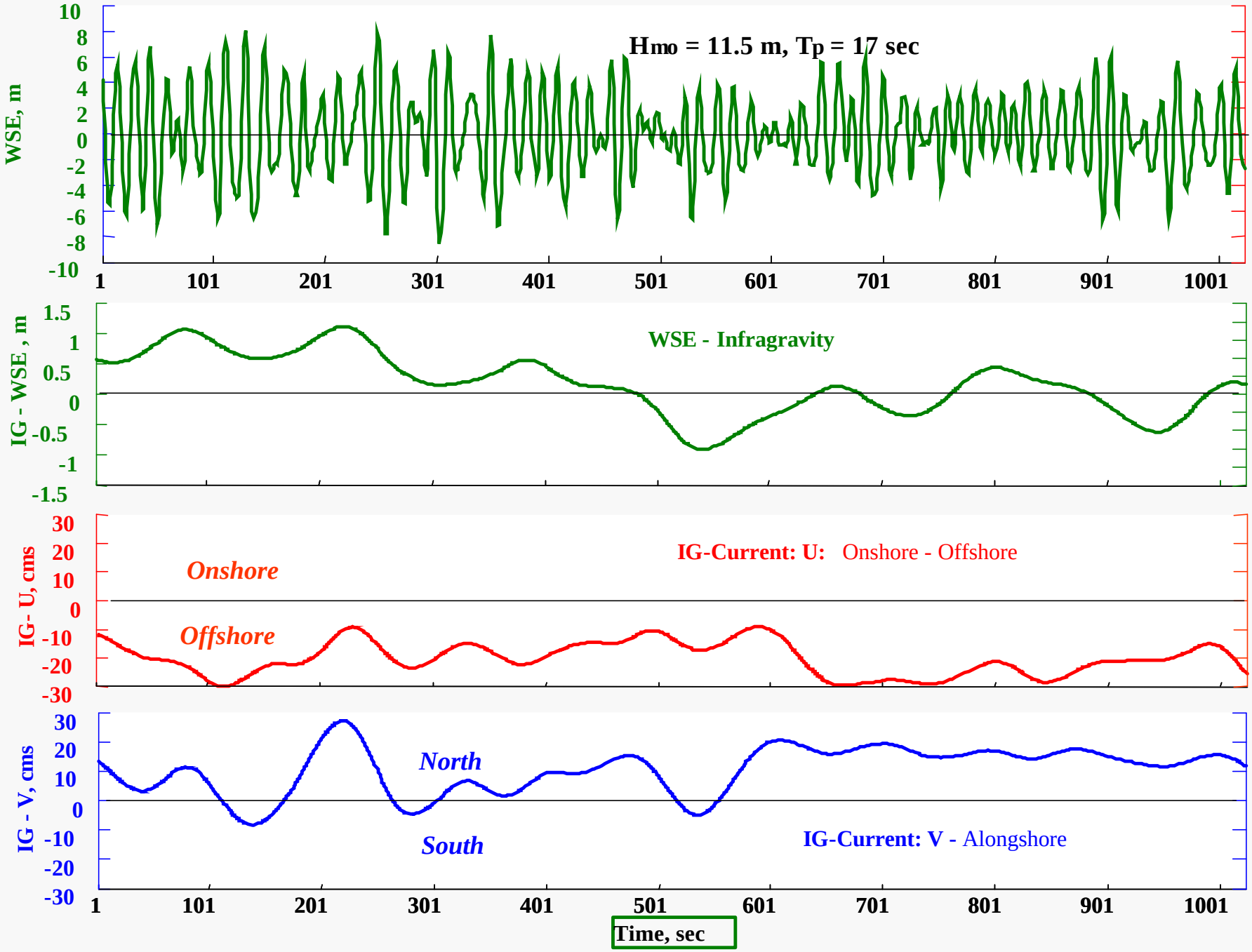
1 Hz sampling for Press.(wse), bottom current - 2048 sec

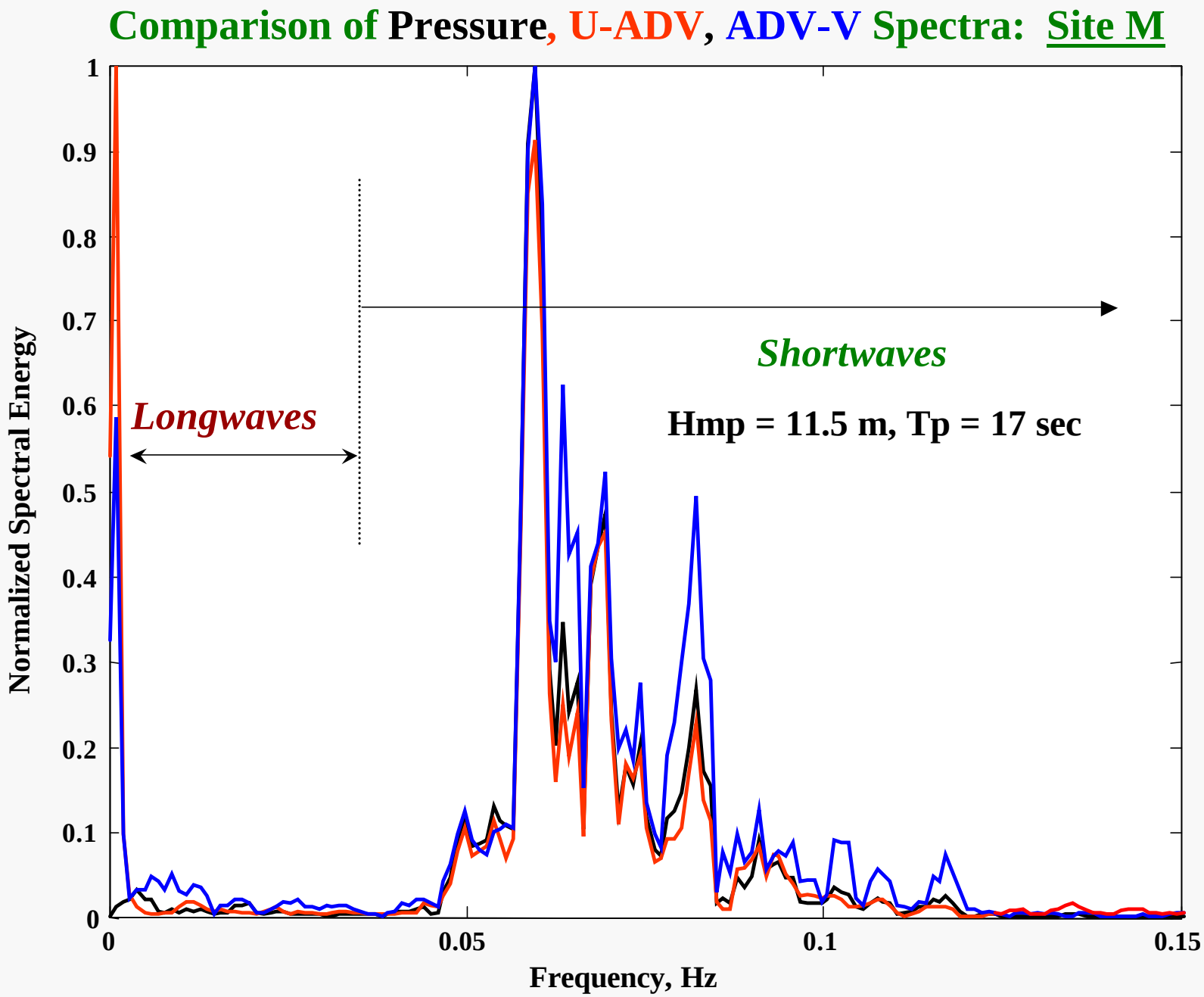
Hmo = 11.5 m. Tp = 17 sec. Dir = 228 deg. (SW)

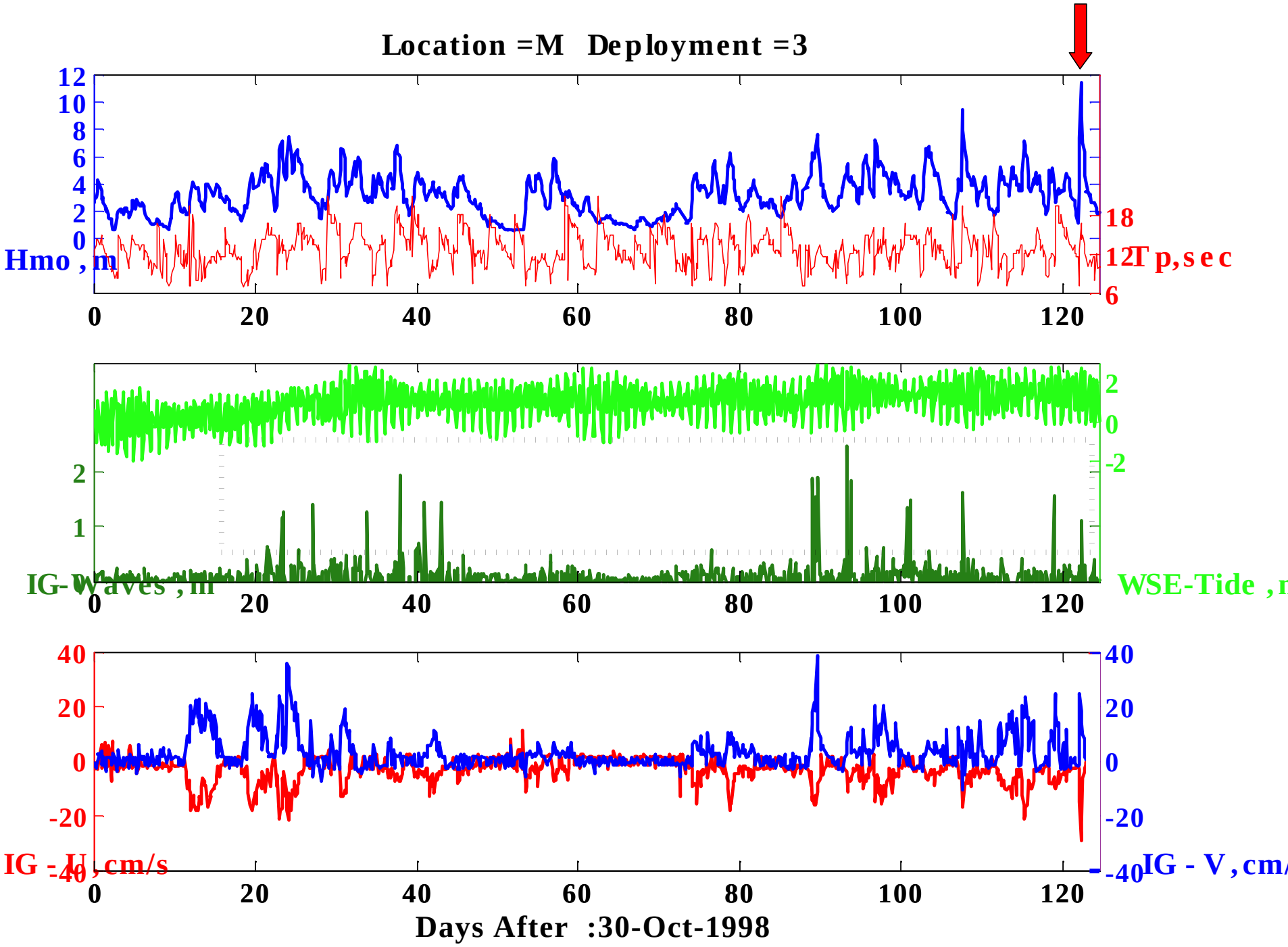
Mean bottom Current = 29 cms @ 297 deg (WNW)

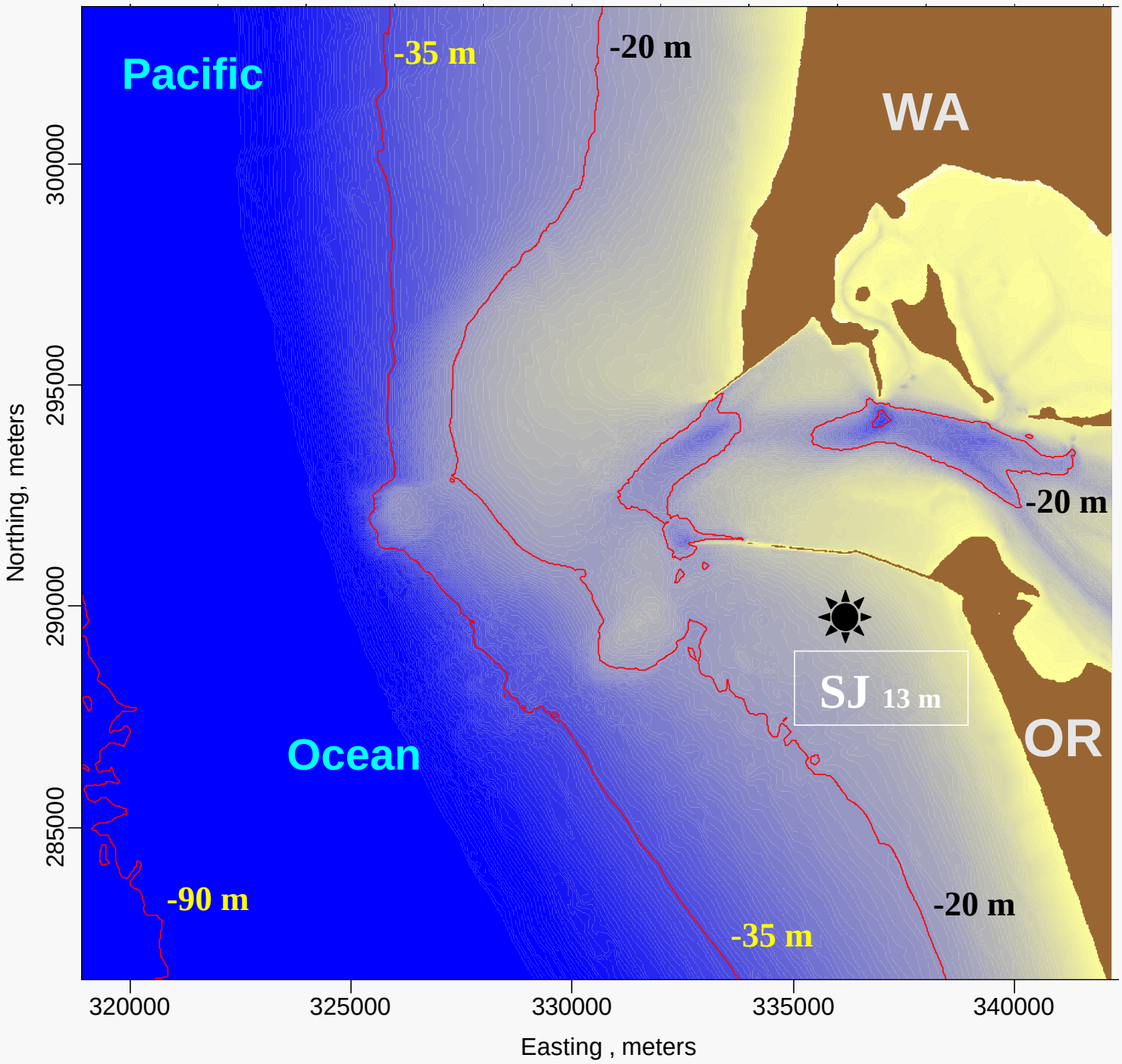
Depth Avg. Current = 88 cms @ 320 deg (NW)


Hmo = 11.5 m, Tp = 17 sec
WSE, m
10
8
6
4
2
0
-2
-4
-6
-8
-10
1
101
201
301
401
501
601
701
801
901
1001
Time, sec
Current: U, cms
150
100
50
0
-50
-100
-150
1
101
201
301
401
501
601
701
801
901
1001
Current: V, cms
150
100
50
0
-50
-100
-150
1
101
201
301
401
501
601
701
801
901
1001


Hmo = 11.5 m, Tp = 17 sec
WSE, m
WSE - Infragravity
IG - WSE , m
IG-Current: U: Onshore - Offshore
Onshore
Offshore
IG- U, cms
North
South
IG-Current: V - Alongshore
IG - V, cms
Time, sec


Comparison of Pressure, U-ADV, ADV-V Spectra: Site M
Normalized Spectral Energy
Frequency, Hz
Longwaves
Shortwaves
Hmp = 11.5 m, Tp = 17 sec
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
0.05
0.1
0.15


Location =M Deployment =3
Hmo , m
Tp,sec
IG-Waves ,m
WSE-Tide ,m
IG - U , cm/s
IG - V , cm/
Days After :30-Oct-1998



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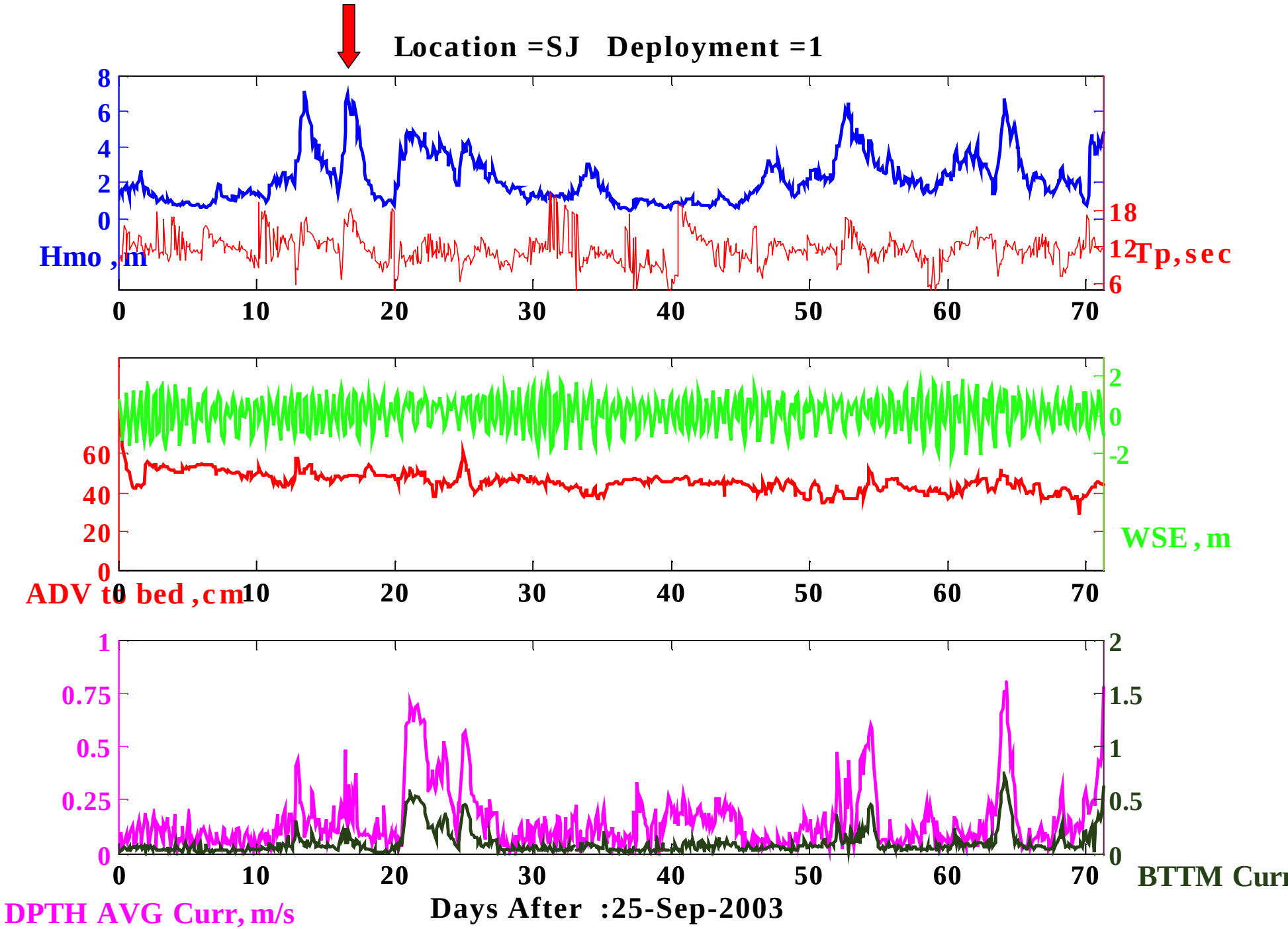
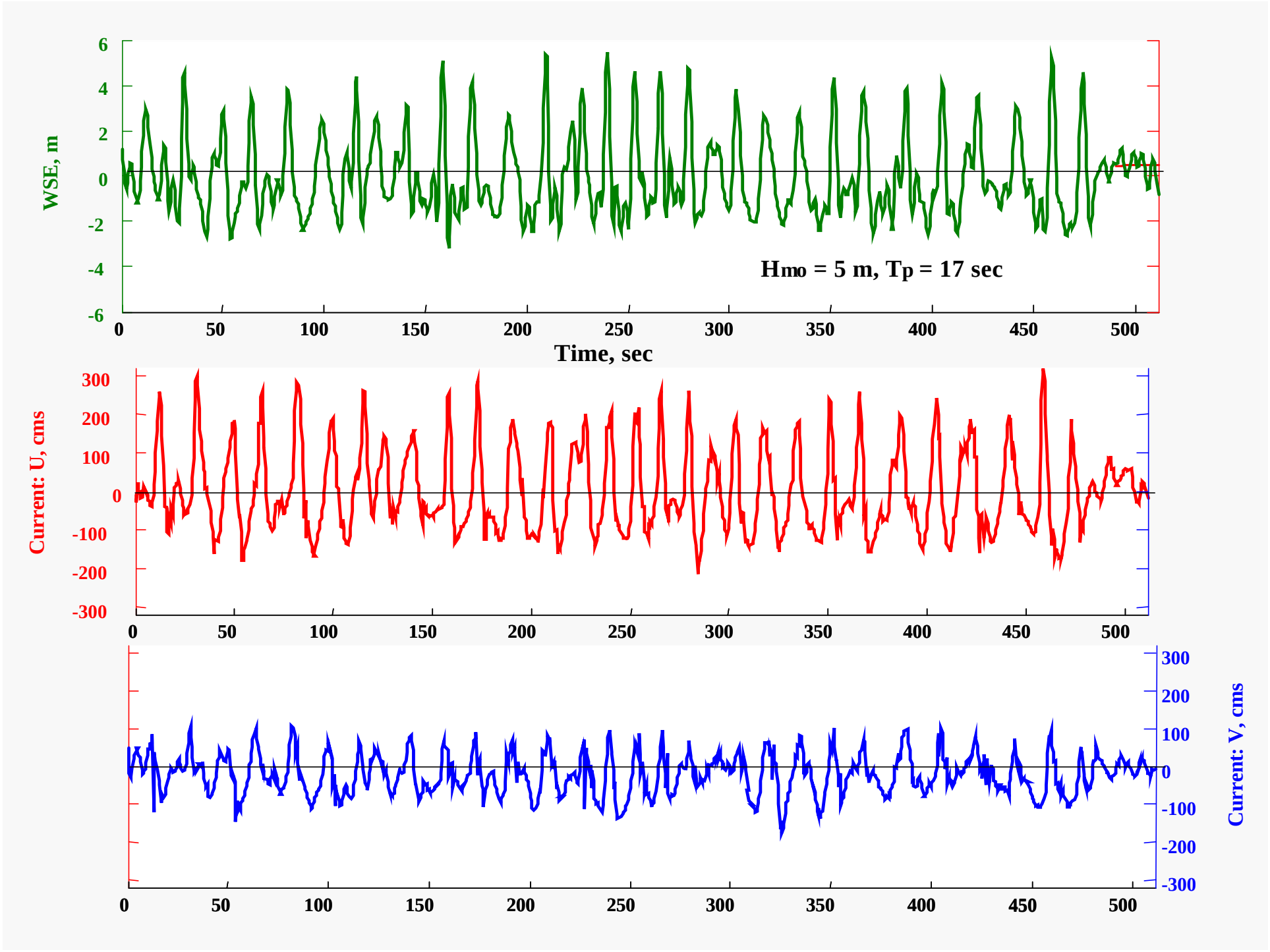
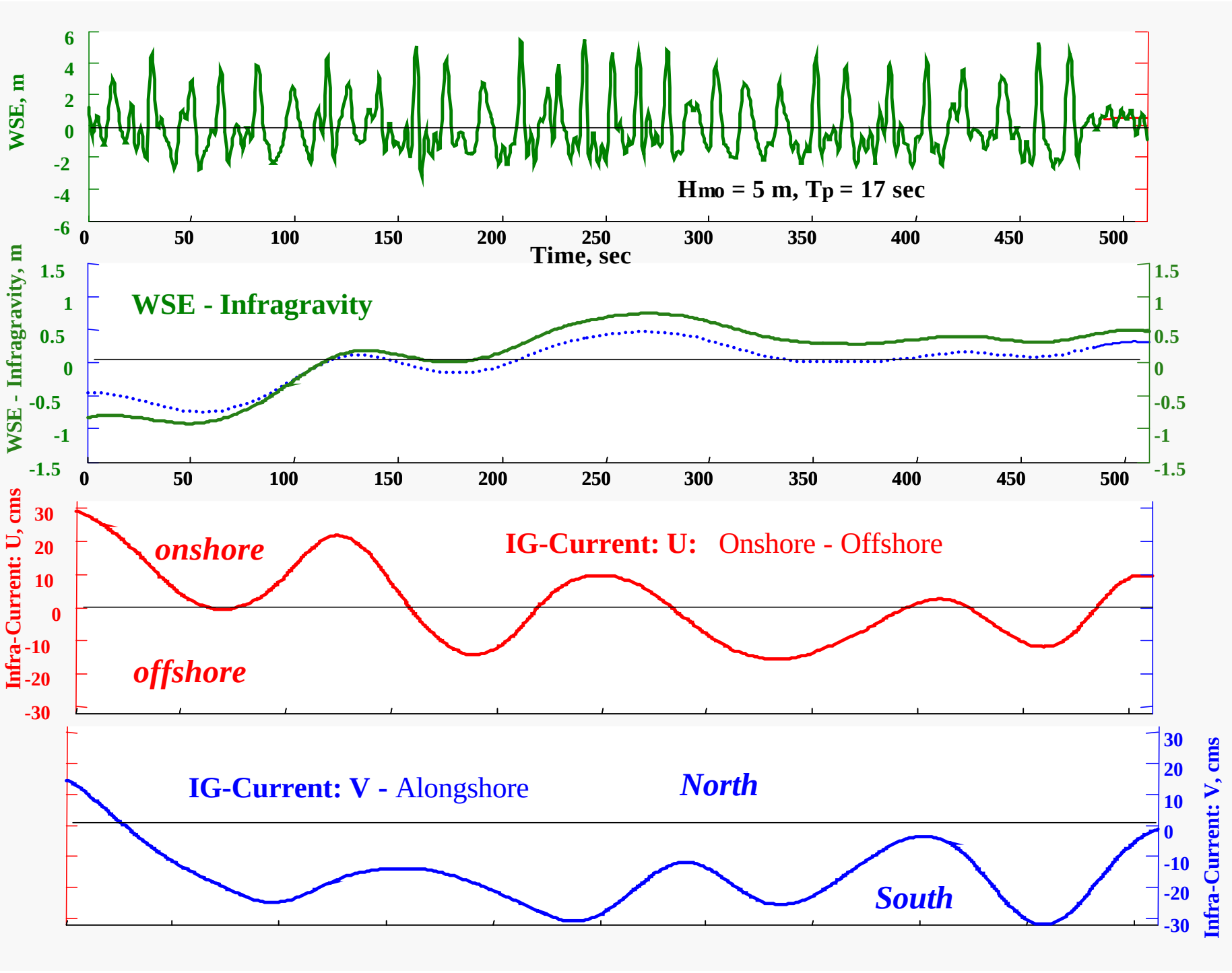
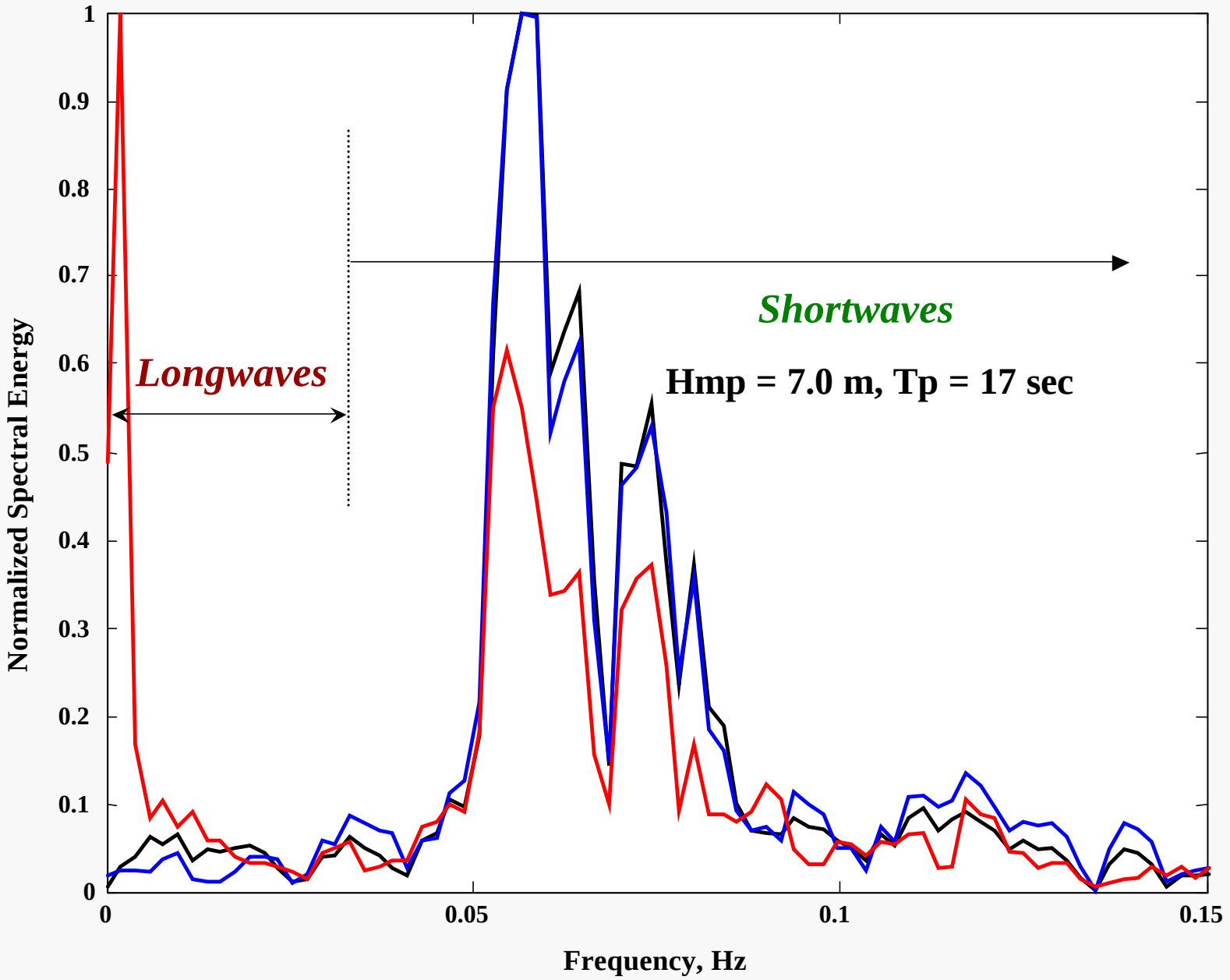
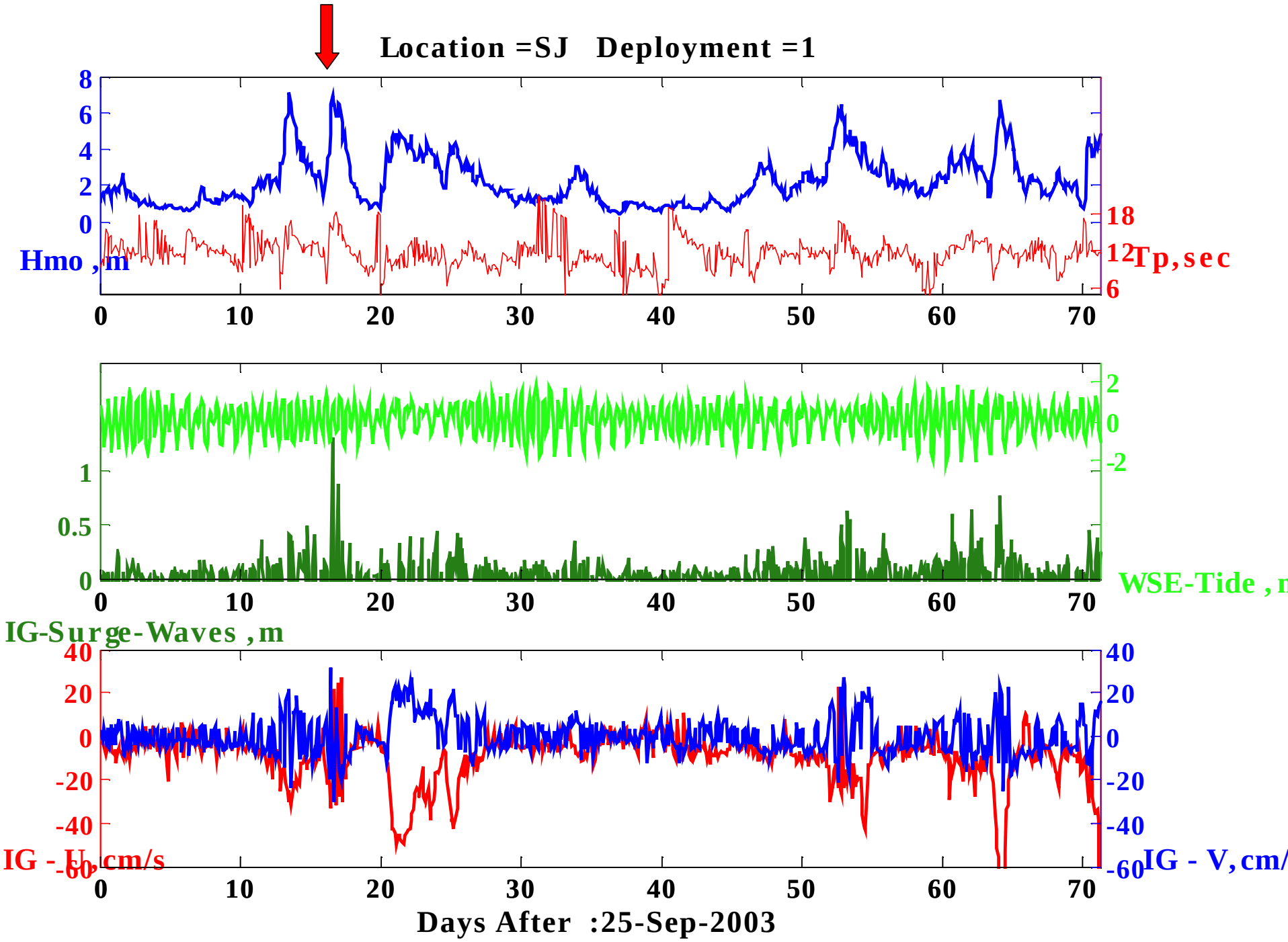

Location =SJ Deployment =1
Hmo ,m
Tp,sec
ADV to bed ,cm
WSE ,m
DPTH AVG Curr, m/s
BTTM Curr
Days After :25-Sep-2003

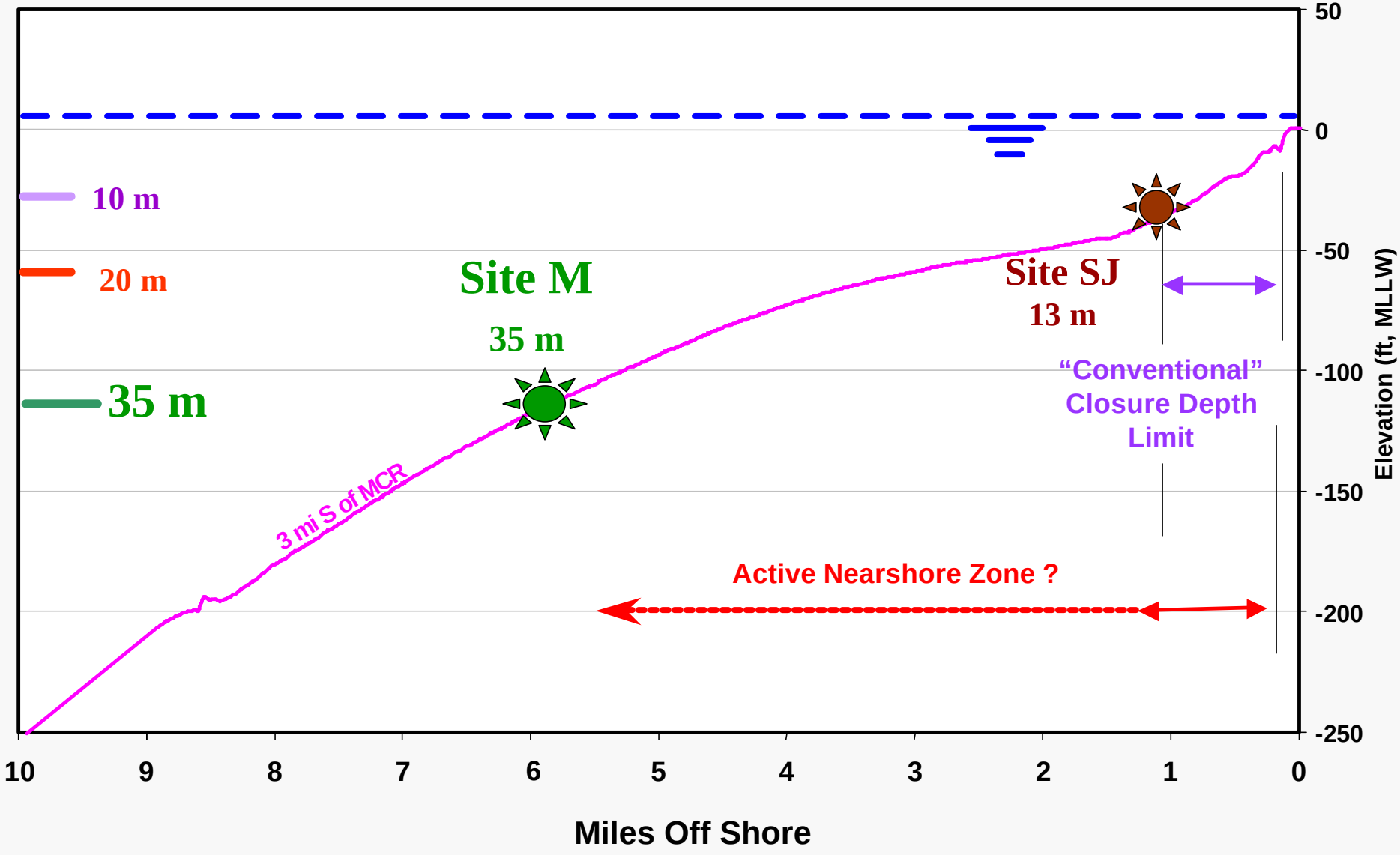

WSE, m
6
4
2
0
-2
-4
-6
Hmo = 5 m, Tp = 17 sec
0
50
100
150
200
250
300
350
400
450
500
Time, sec
Current: U, cms
300
200
100
0
-100
-200
-300
Current: V, cms


WSE, m
Hmo = 5 m, Tp = 17 sec
Time, sec
WSE - Infragravity, m
WSE - Infragravity
Infra-Current: U, cms
onshore
offshore
IG-Current: U: Onshore - Offshore
IG-Current: V - Alongshore
North
South
Infra-Current: V, cms


Comparison of Pressure, U-ADV, ADV-V Spectra: Site B
Normalized Spectral Energy
Frequency, Hz
Longwaves
Shortwaves
Hmp = 7.0 m, Tp = 17 sec
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
0.05
0.1
0.15


Location =SJ Deployment =1
Hmo ,m
Tp,sec
WSE-Tide ,m
IG-Surge-Waves ,m
IG - U, cm/s
IG - V, cm/
Days After :25-Sep-2003

Cross-Shore Profile - Site M: 5 km South of Columbia River mouth



CONCLUSIONS

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Can bias the estimation of wave parameters by Doppler-shifting the observed higher frequency wave components.

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Significant Infragravity (IG) energy develops during storms and can affect WSE and bottom current.

The magnitudes of IG processes are interesting and could have implications for wave propagation, shoreline erosion, and shelf sediment transport.

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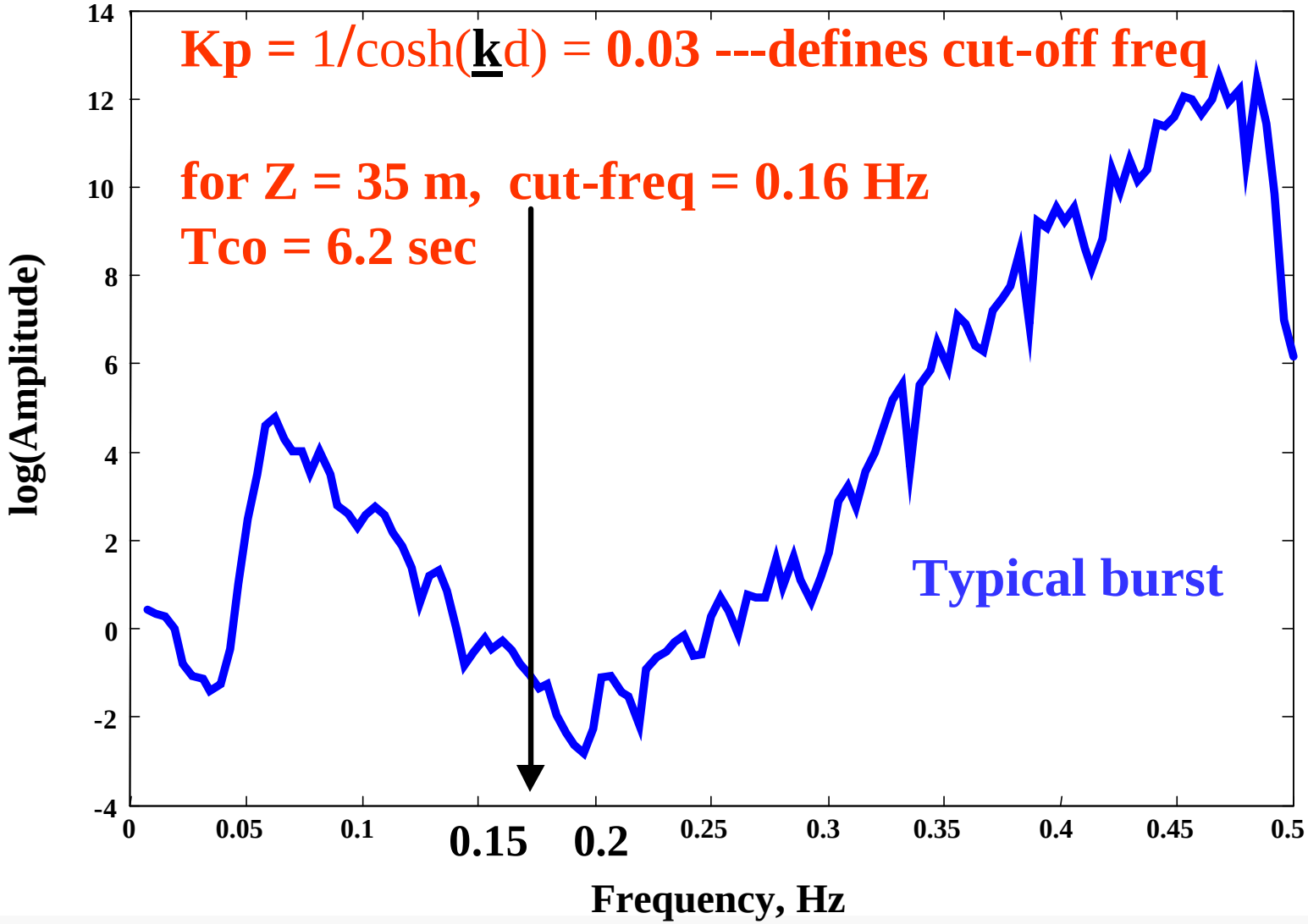
Ratio of Pressure Spectrum to Kp: Sp(f)/Kp(f)



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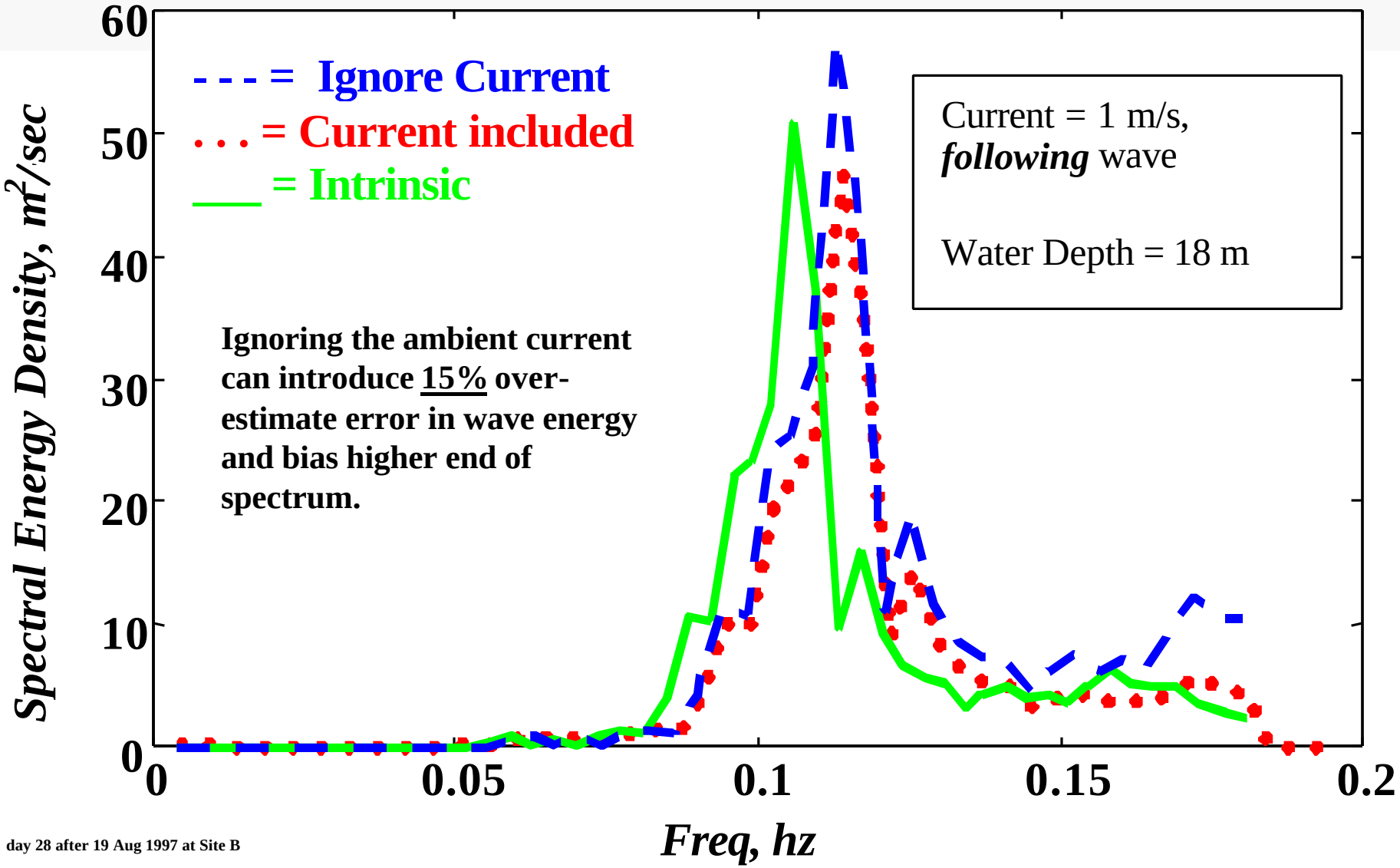

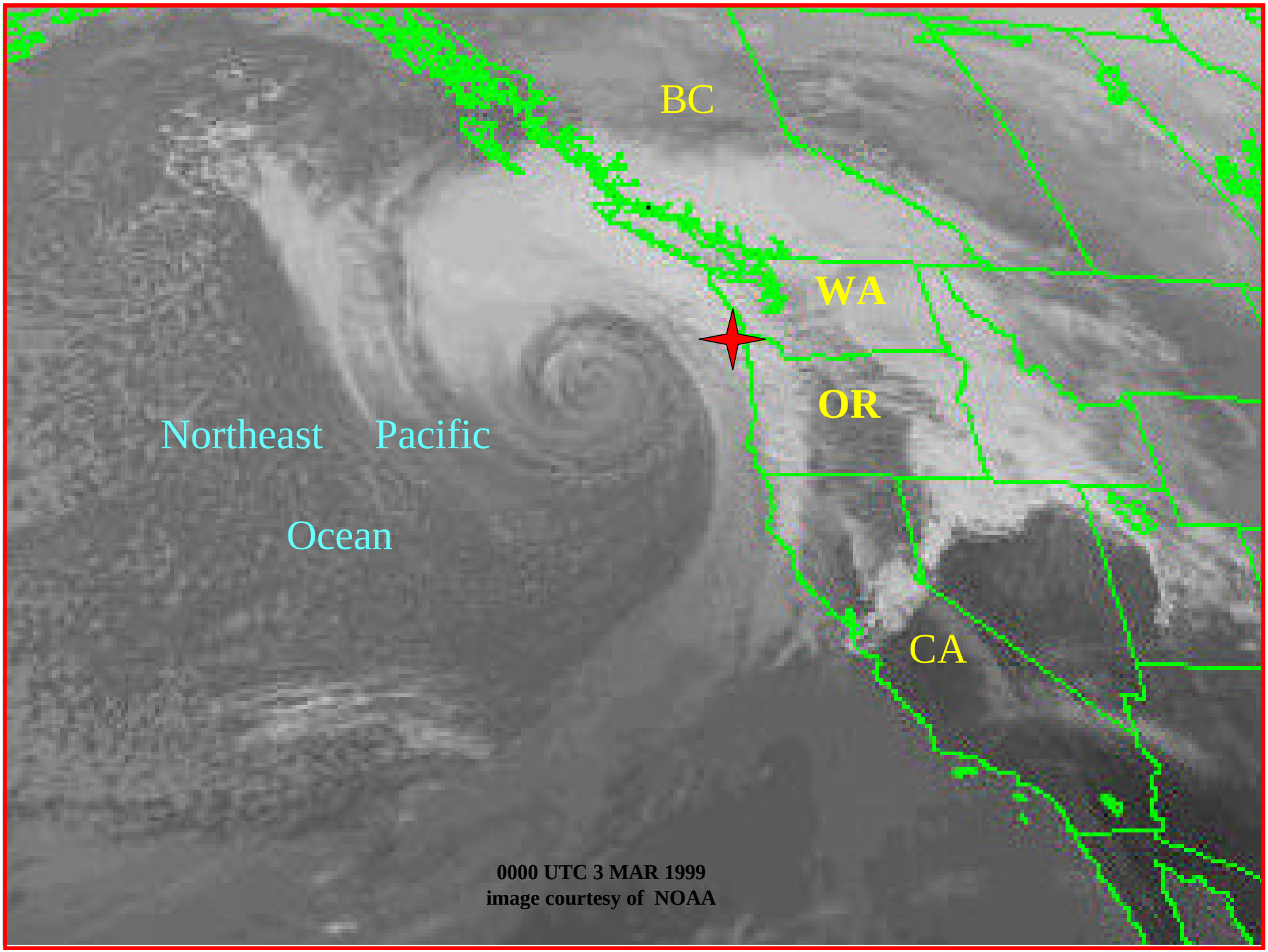
BC
WA
OR
CA
Northeast Pacific
Ocean
0000 UTC 3 MAR 1999
image courtesy of NOAA