Systematics of run-up distributions from dislocation and landslide sources: A near-field discriminant

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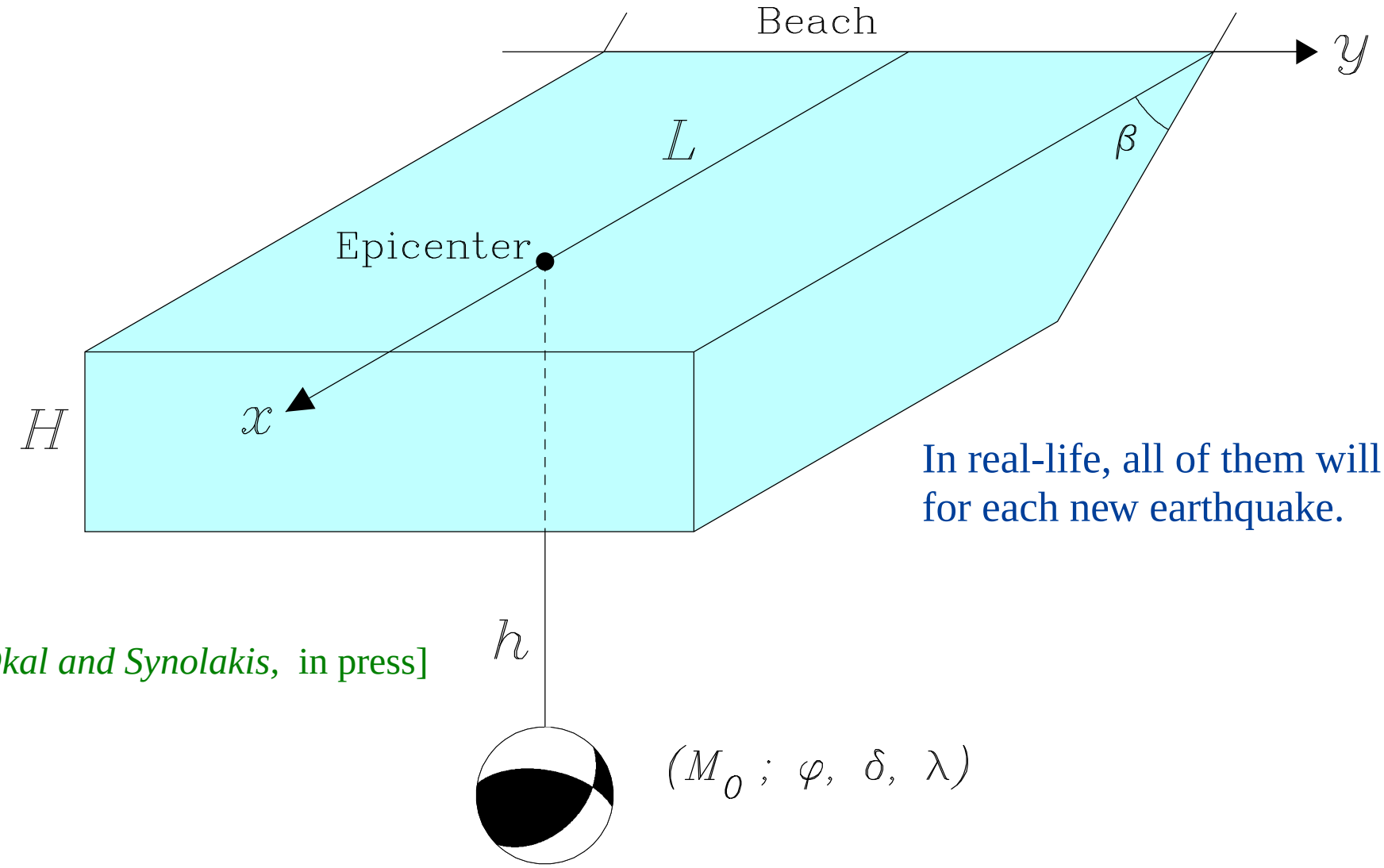
THE DISLOCATION SOURCE in the NEAR FIELD

A full description requires at least 8 parameters.



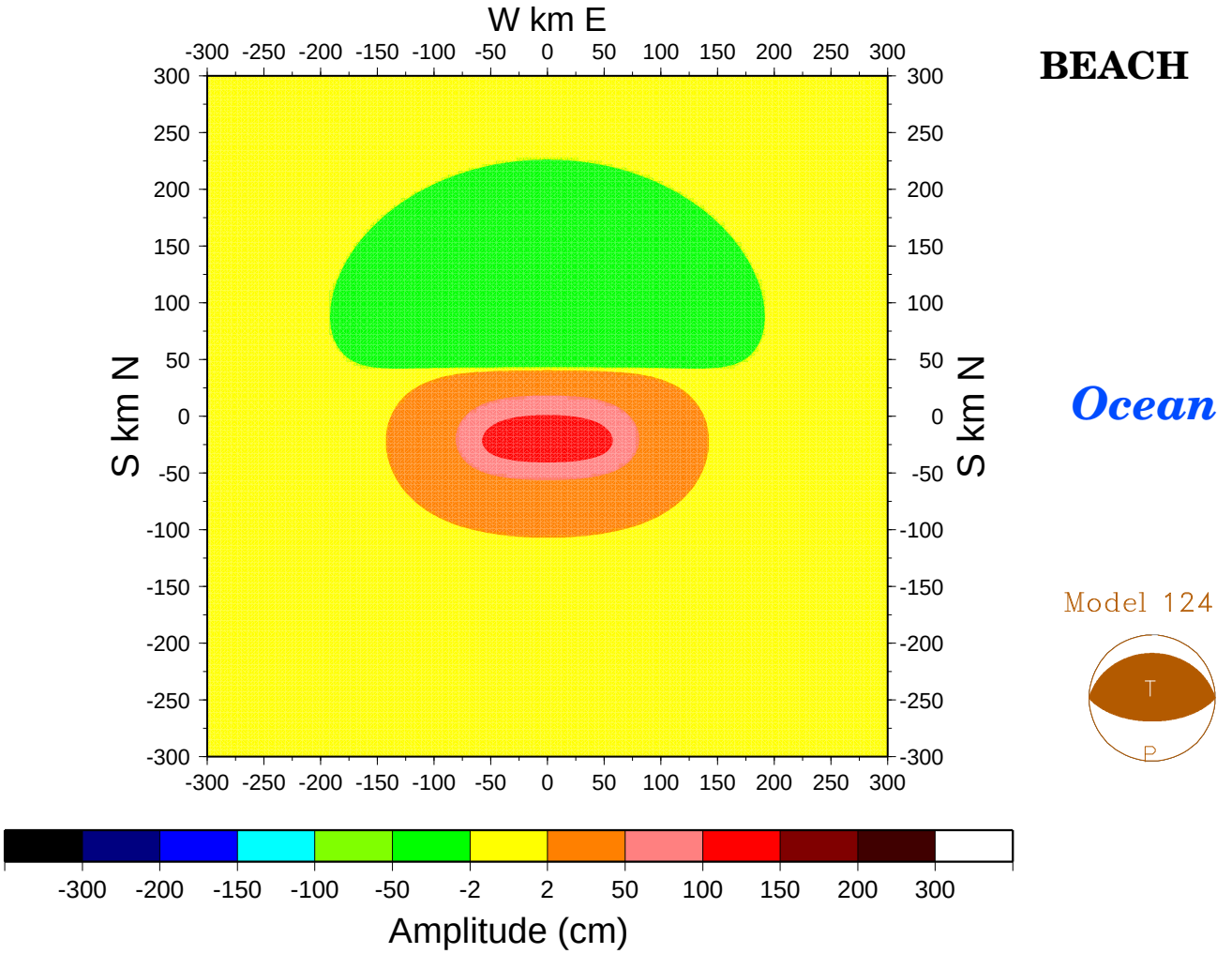
In real-life, all of them will vary for each new earthquake.

[*Okal and Synolakis*, in press]

We explore systematically their influence on run-up and seek to define INVARIANTS

NEAR-FIELD: *The Earthquake Dislocation*

- Compute Ocean-Bottom Deformation due to Dislocation



- Simulate Tsunami Propagation to Beach and Run-up

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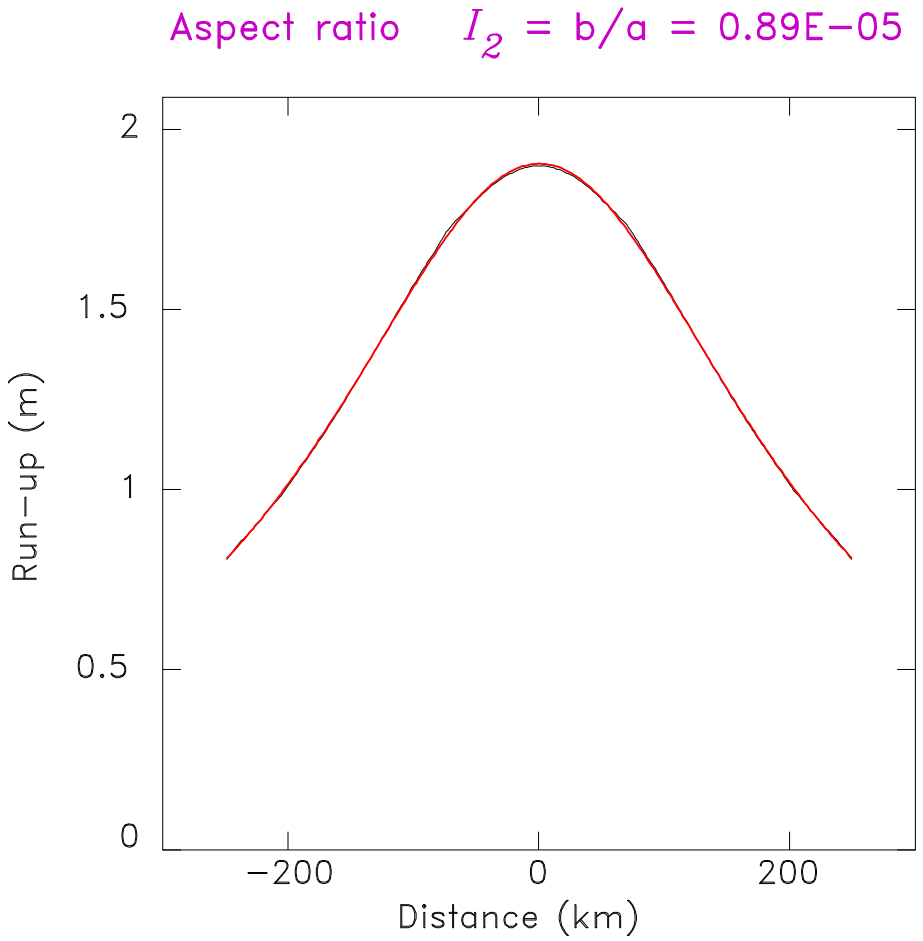
  - Fit Bell Curve

$$\zeta = \frac{b}{\left(\frac{x-c}{a}\right)^2 + 1}$$

  - Retain aspect ratio $I = b/a$



a = 214.2 km

b = 1.90 m

c = 0.4 km

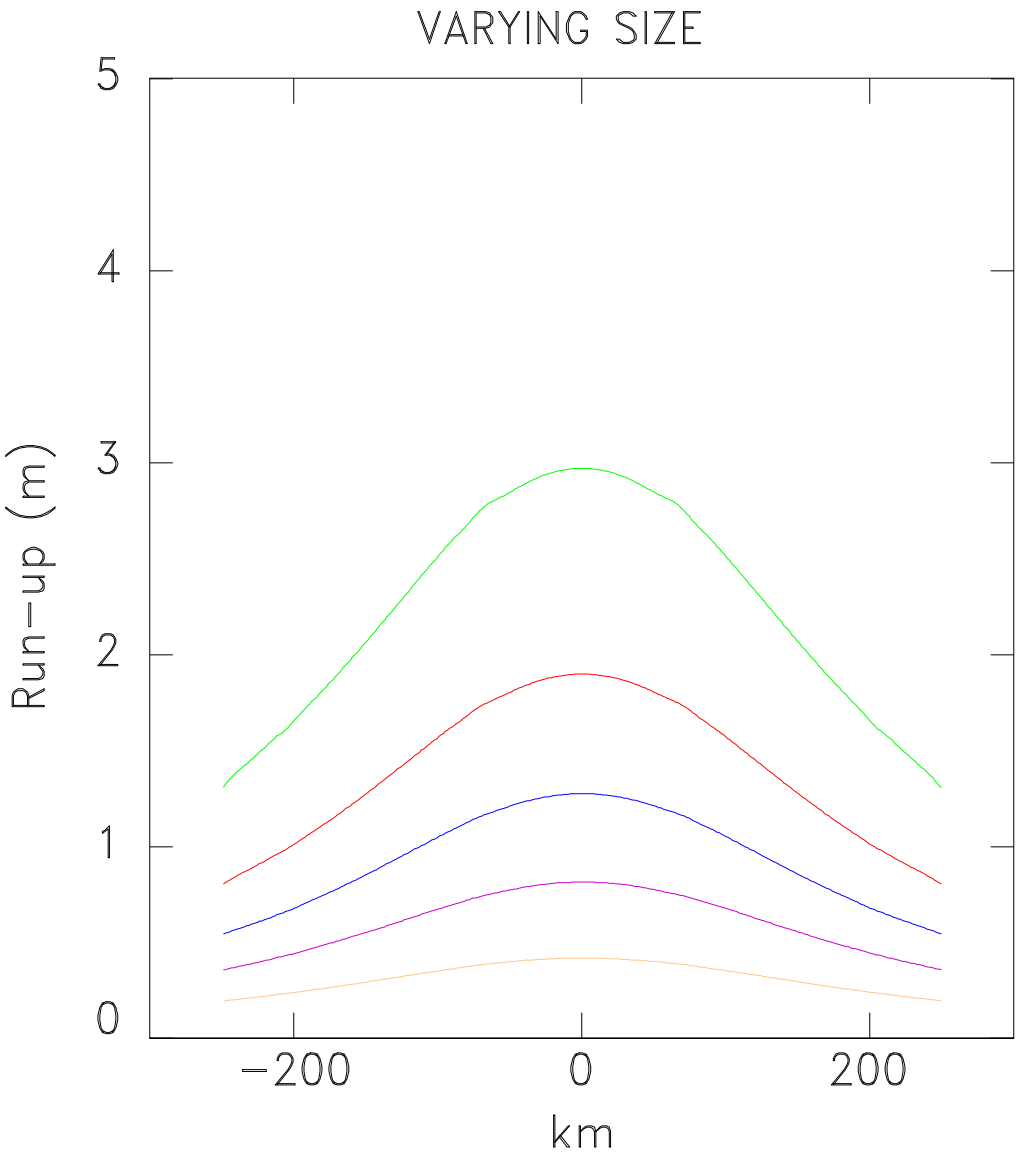
M_0 = 2. 10^{28} dyn−cm

Slip on fault

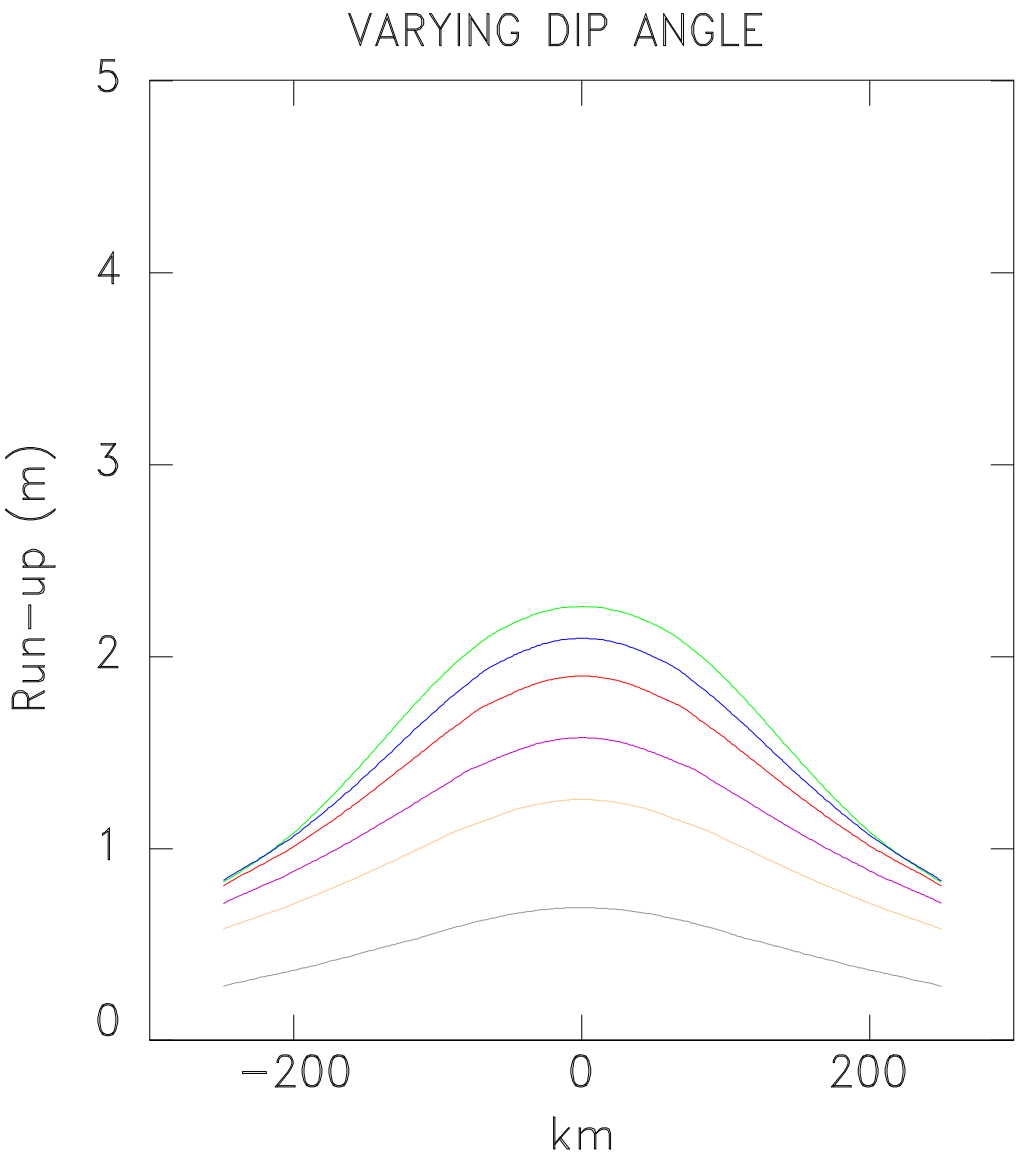
Δu = 4.13 m

I_1 = b/Δu = 0.46

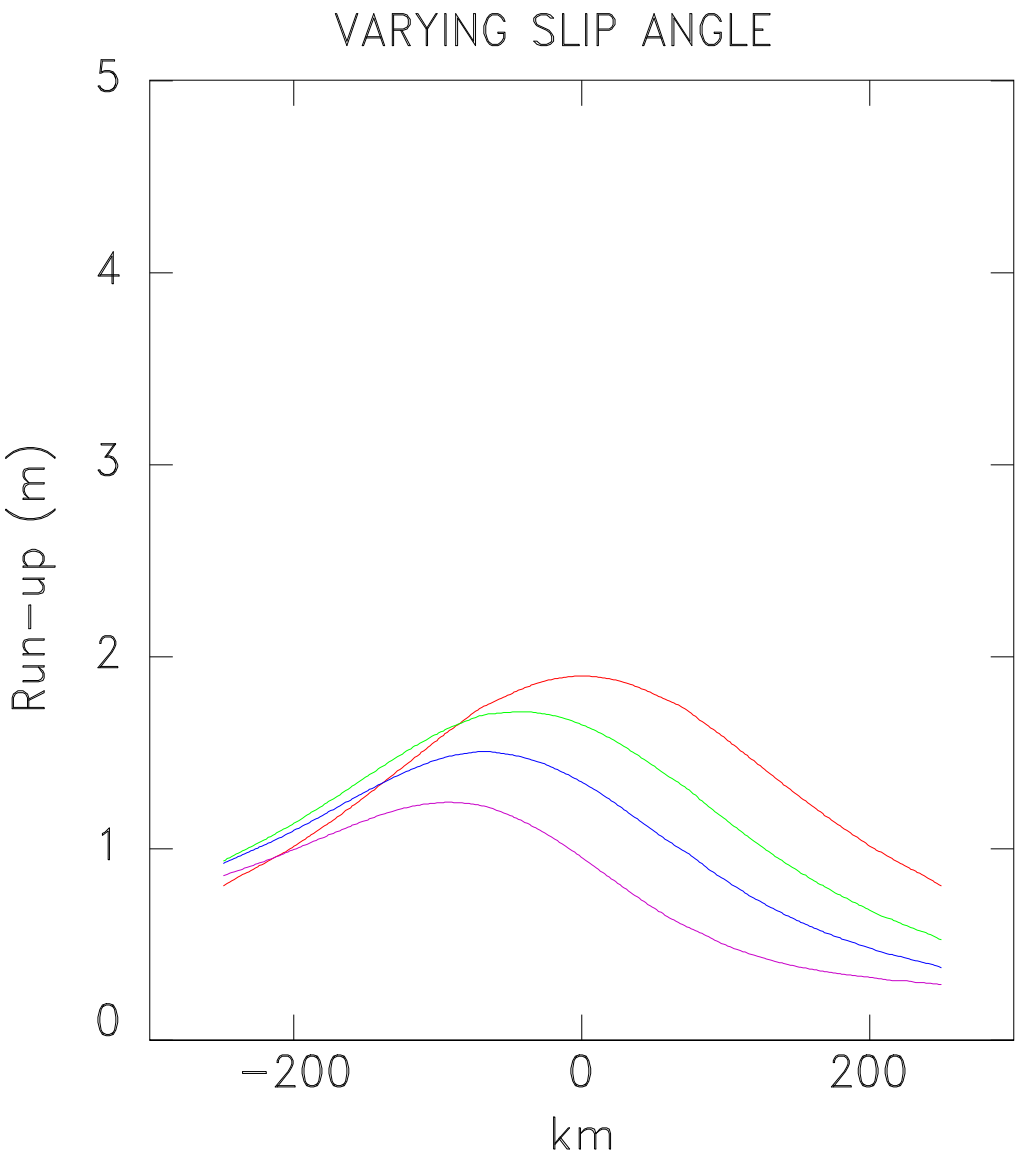
  - Vary source parameters: I no greater than 2.3×10^{-5}.



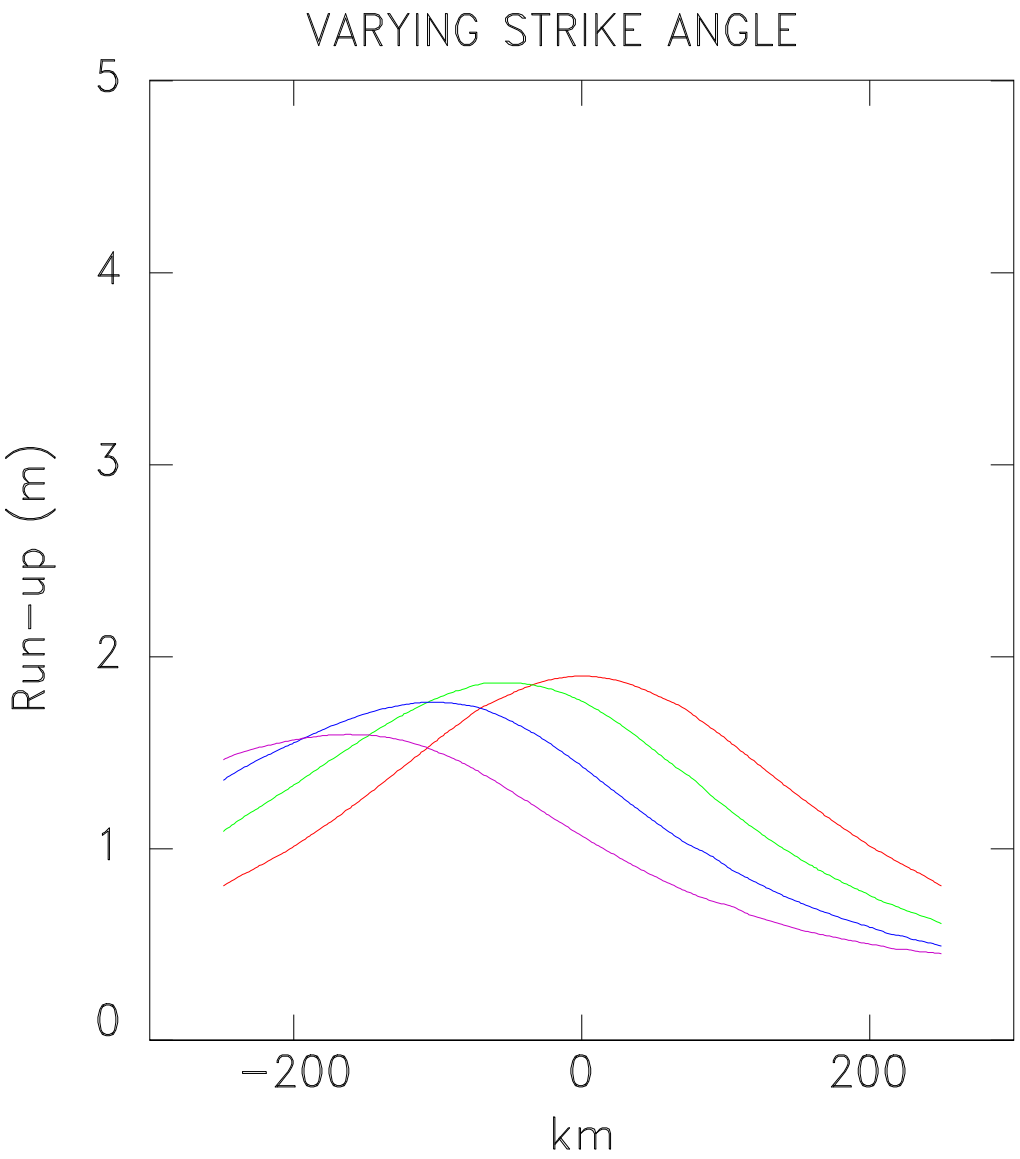
INDEX	MOMENT 10~27 dyn-cm	Aspect Ratio (10**-5)	b/Δu
124	20.	0.86	0.45
135	50.	1.30	0.53
136	10.	0.60	0.39
137	5.	0.37	0.32
138	2.	0.18	0.22



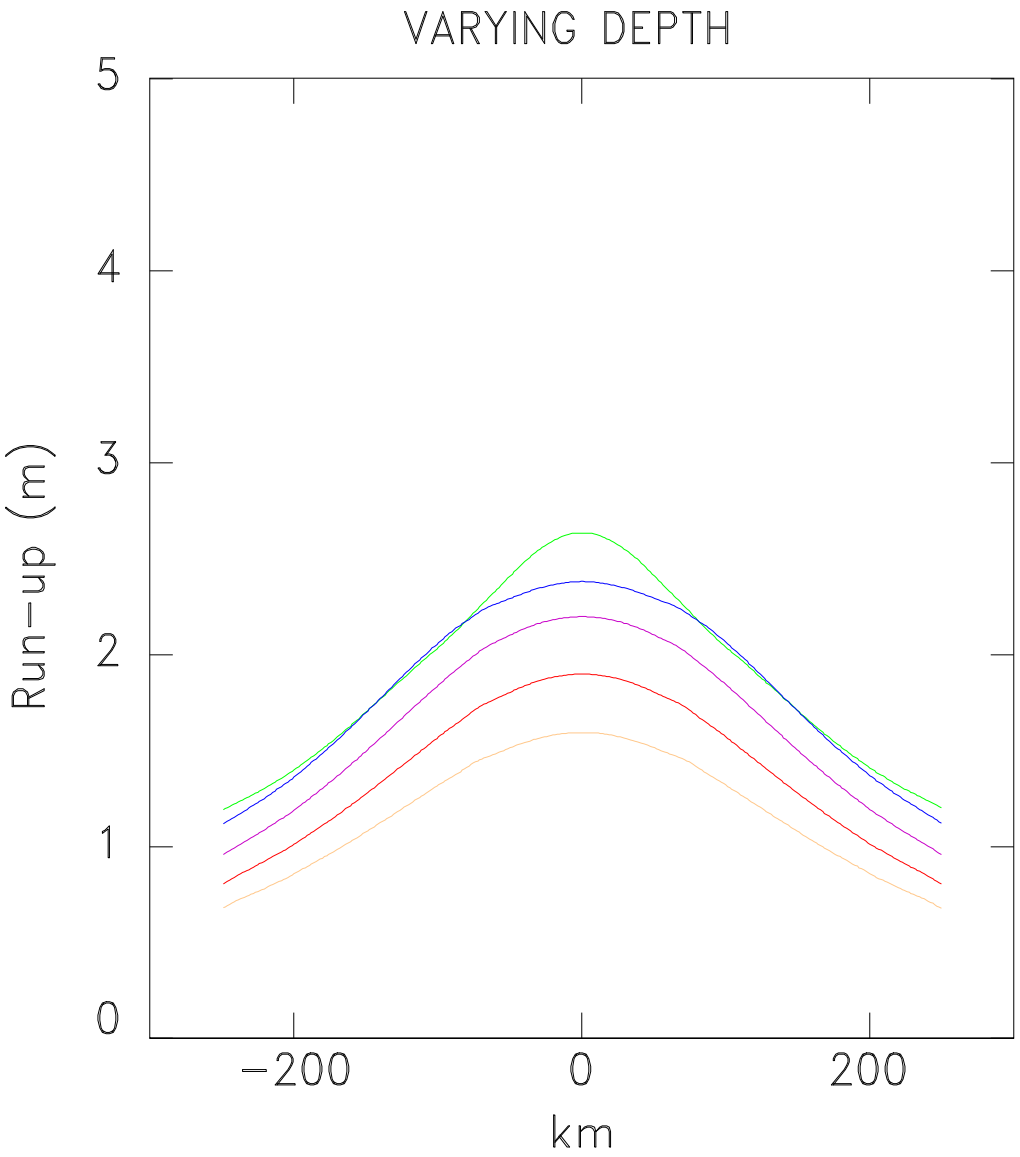
INDEX	DIP (deg.)	Aspect Ratio (10**−5)	b/Δu
124	30.	0.86	0.45
126	10.	1.20	0.56
125	20.	1.04	0.51
123	45.	0.70	0.38
122	60.	0.54	0.30
121	90.	0.33	0.17



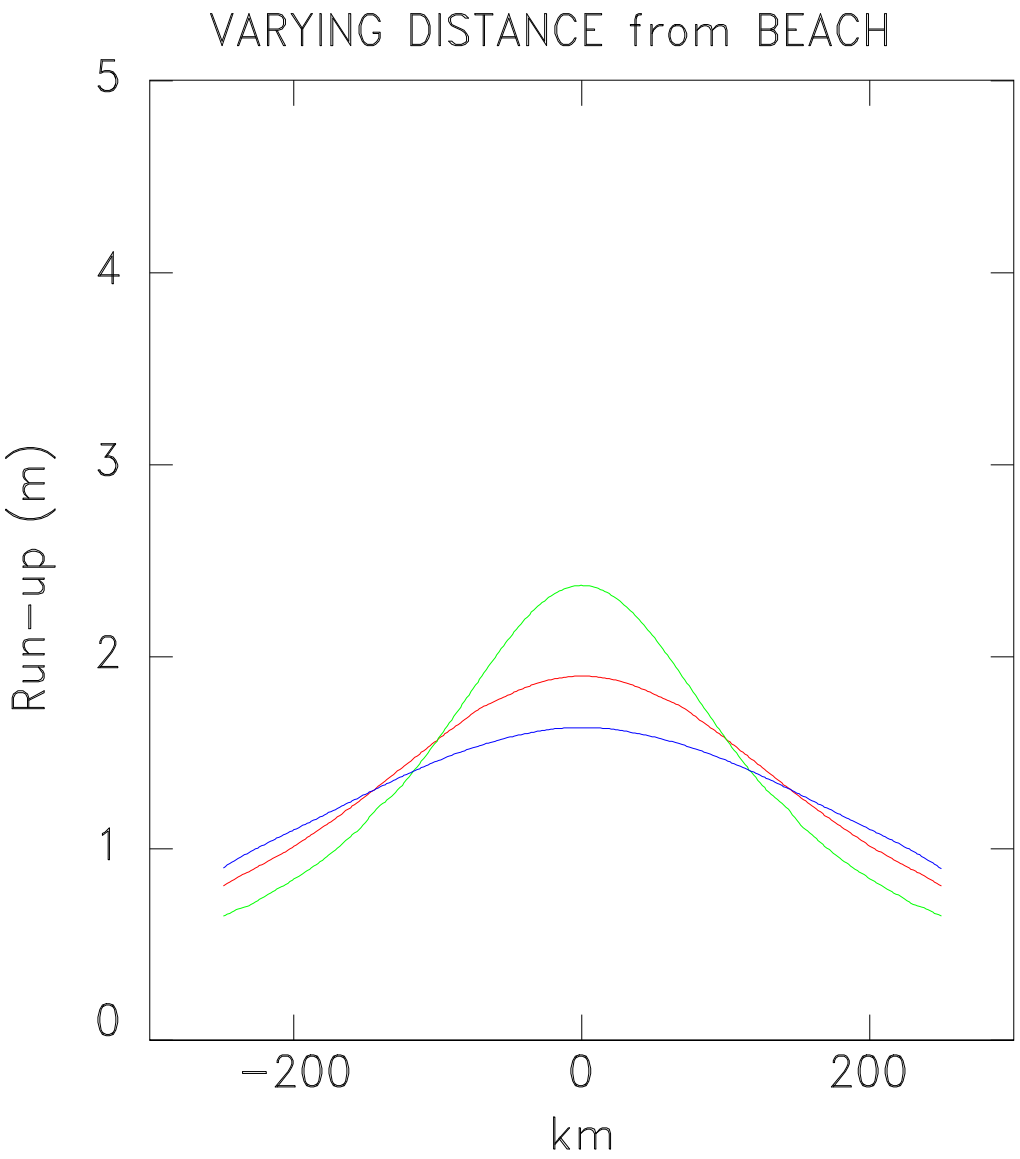
INDEX	SLIP (deg.)	Aspect Ratio (10**−5)	b/Δu
124	90.	0.86	0.45
127	60.	0.83	0.42
128	45.	0.77	0.37
129	30.	0.70	0.31



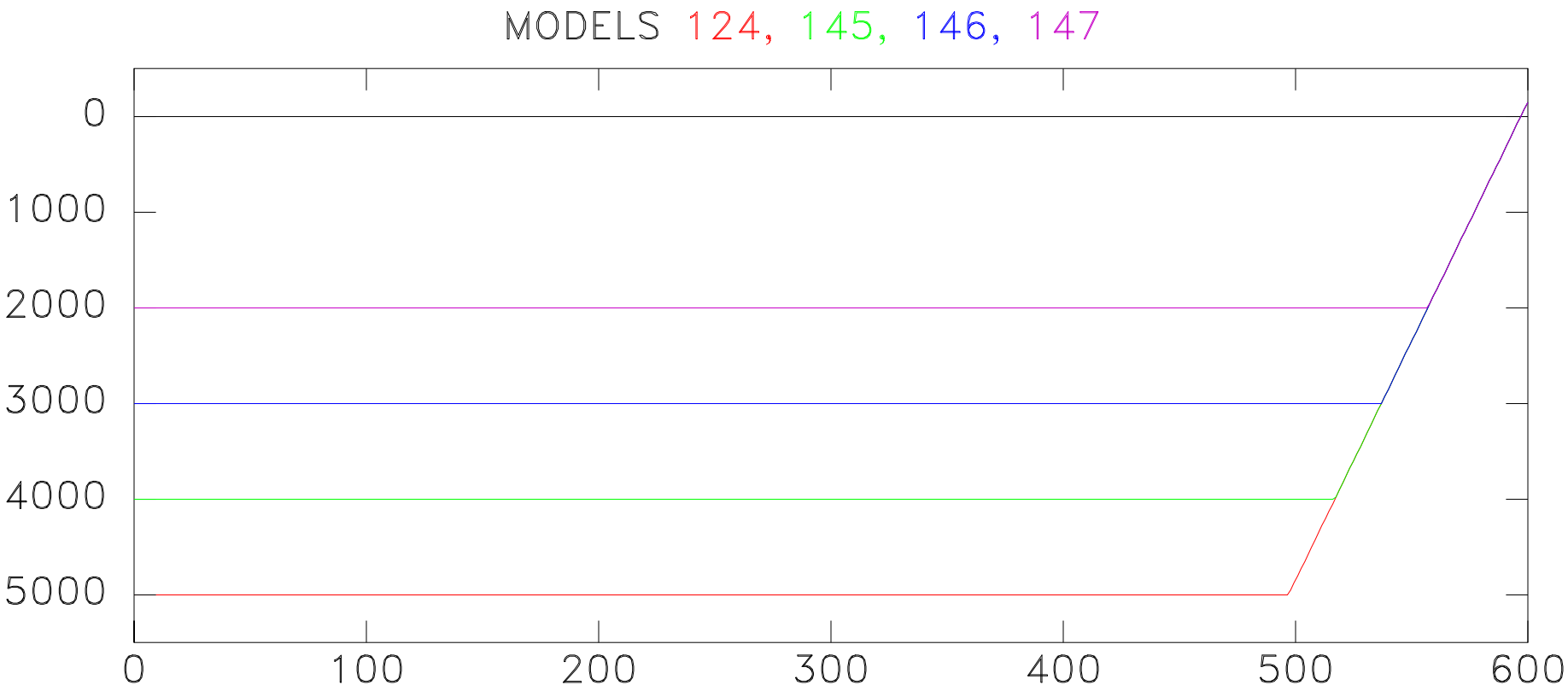
INDEX	STRIKE (deg.)	Aspect Ratio (10**−5)	b/Δu
124	270.	0.86	0.45
141	285.	0.86	0.45
139	300.	0.80	0.43
140	315.	0.67	0.28

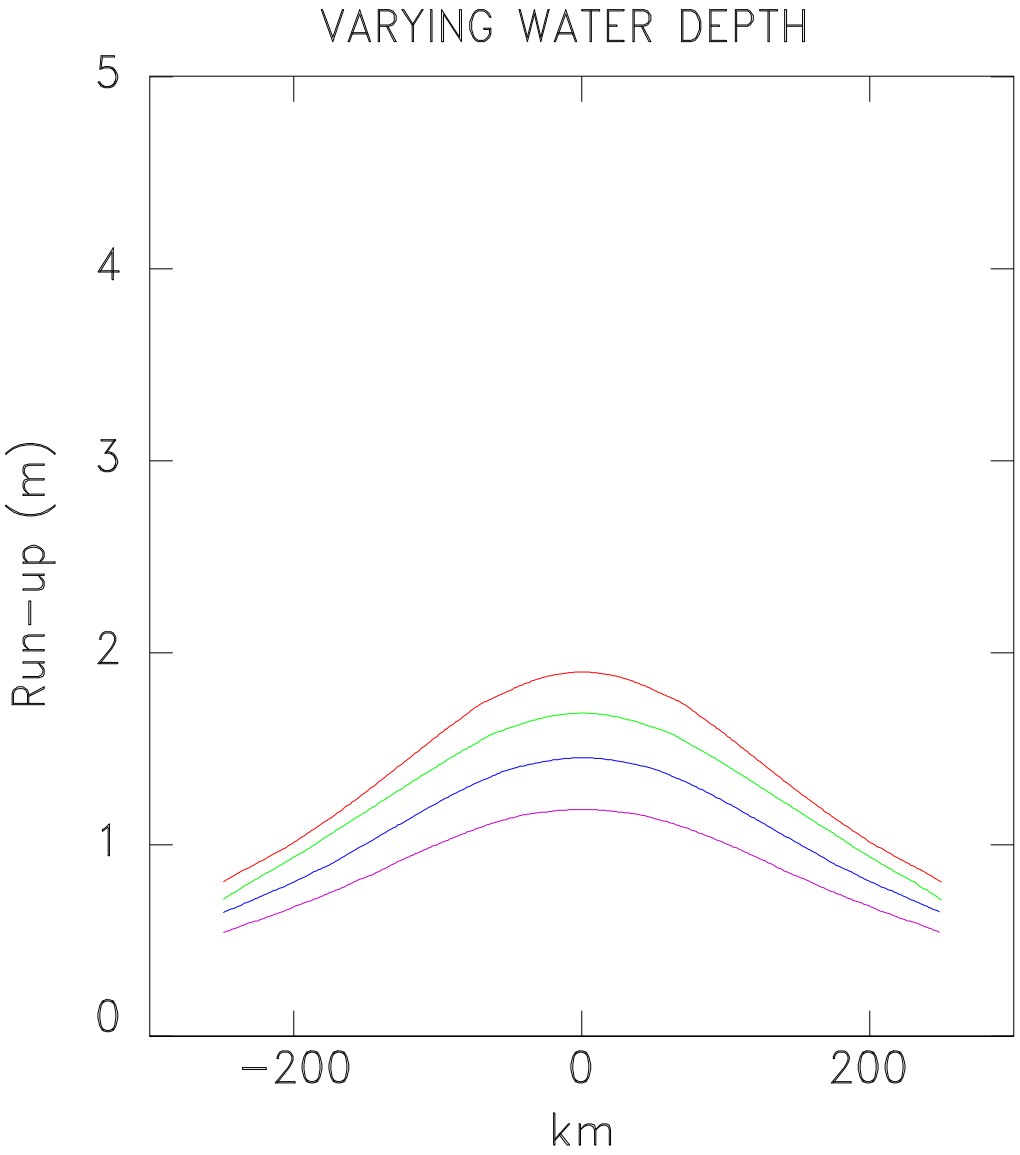


INDEX	DEPTH (km)	Aspect Ratio (10**−5)	b/Δu
124	35.	0.86	0.45
131	5.	1.20	0.62
132	15.	1.04	0.58
133	25.	1.01	0.54
134	45.	0.74	0.38

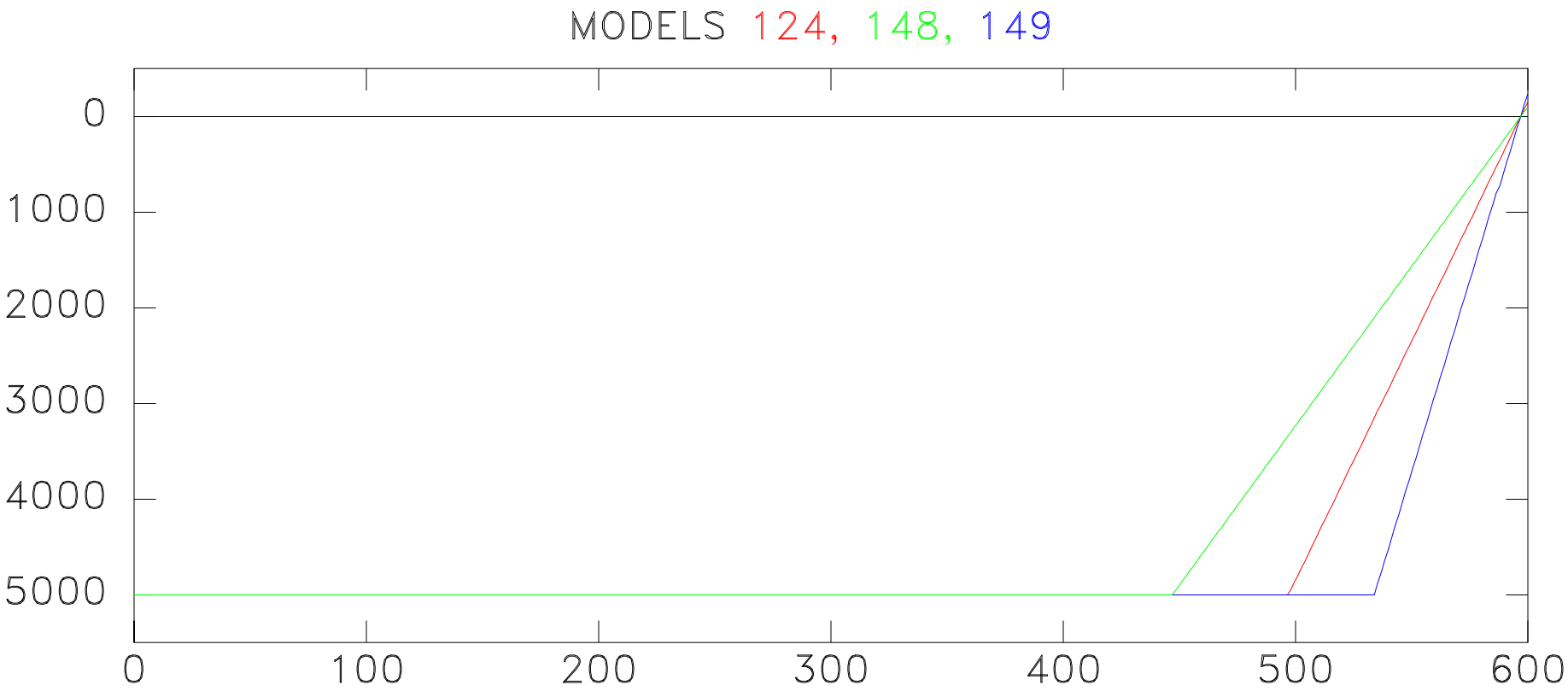


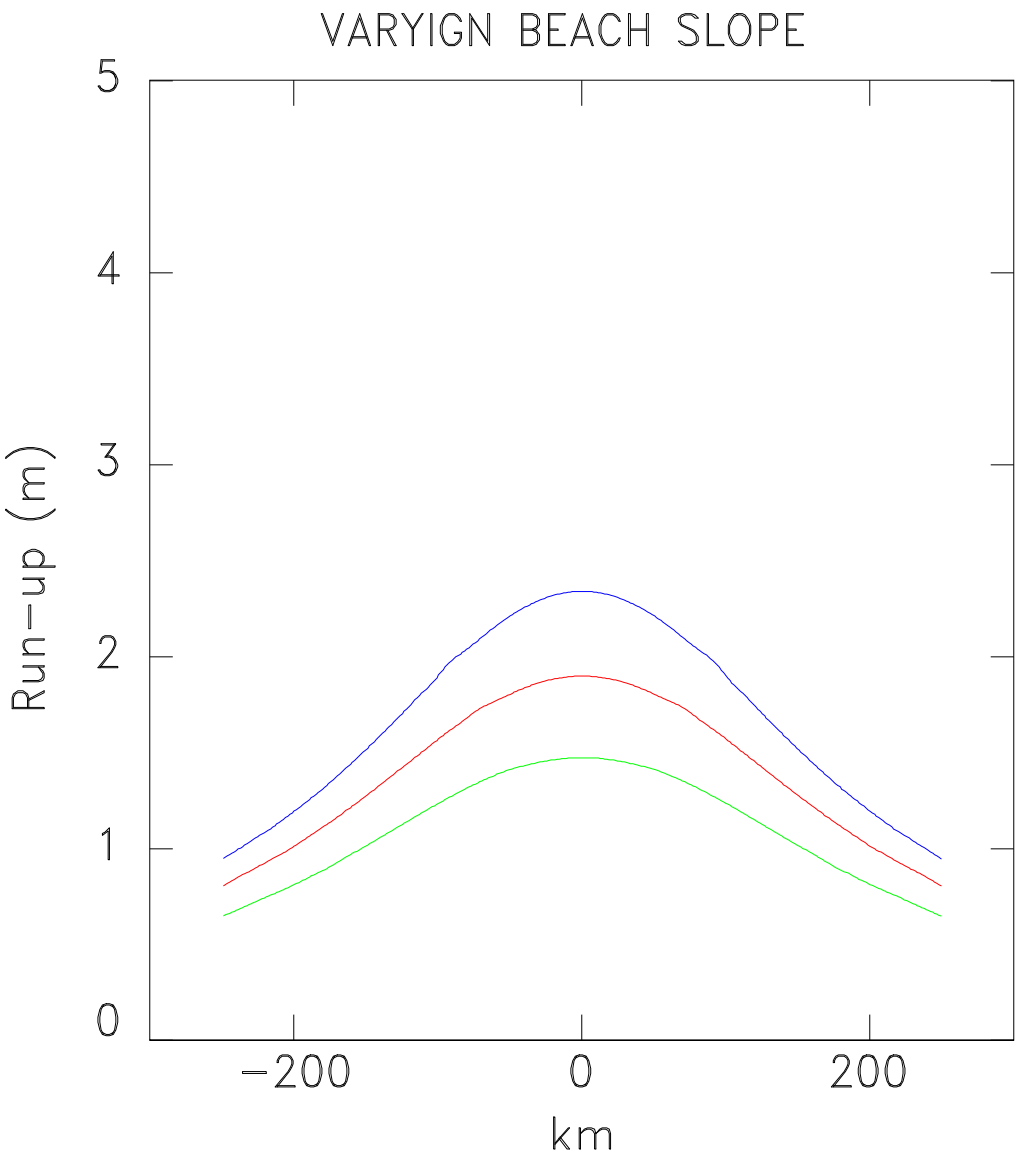
INDEX	INCREM. DIST (km)	Aspect Ratio (10**−5)	b/Δu
124	0.	0.86	0.45
143	−100.	1.59	0.57
144	100.	2.90	0.69


MODELS 124, 145, 146, 147
0
1000
2000
3000
4000
5000
0
100
200
300
400
500
600

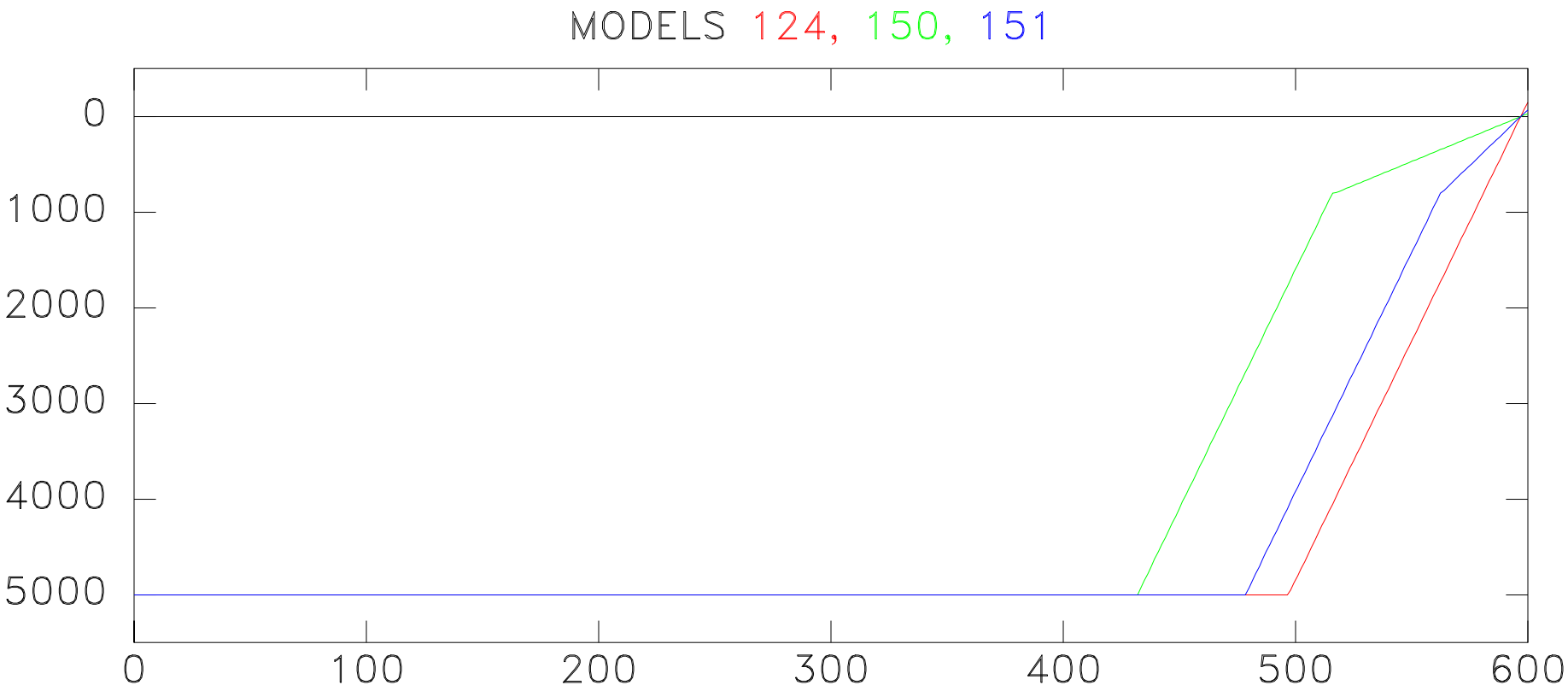


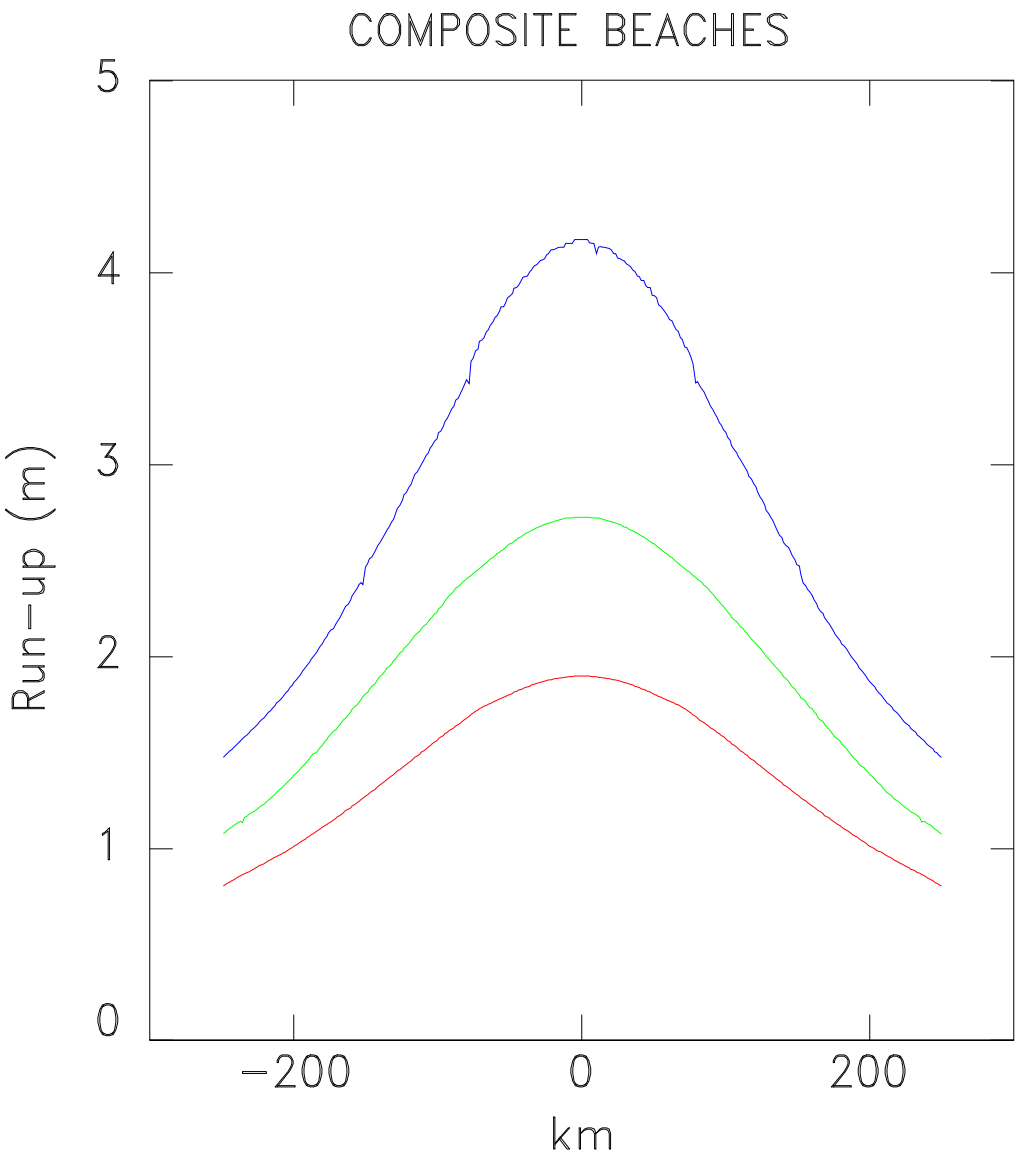
INDEX	WATER DEPTH (m)	Aspect Ratio (10**−5)	b/Δu
124	5000.	0.86	0.45
145	4000.	0.76	0.41
146	3000.	0.65	0.35
147	2000.	0.52	0.29


MODELS 124, 148, 149
0
1000
2000
3000
4000
5000
0
100
200
300
400
500
600



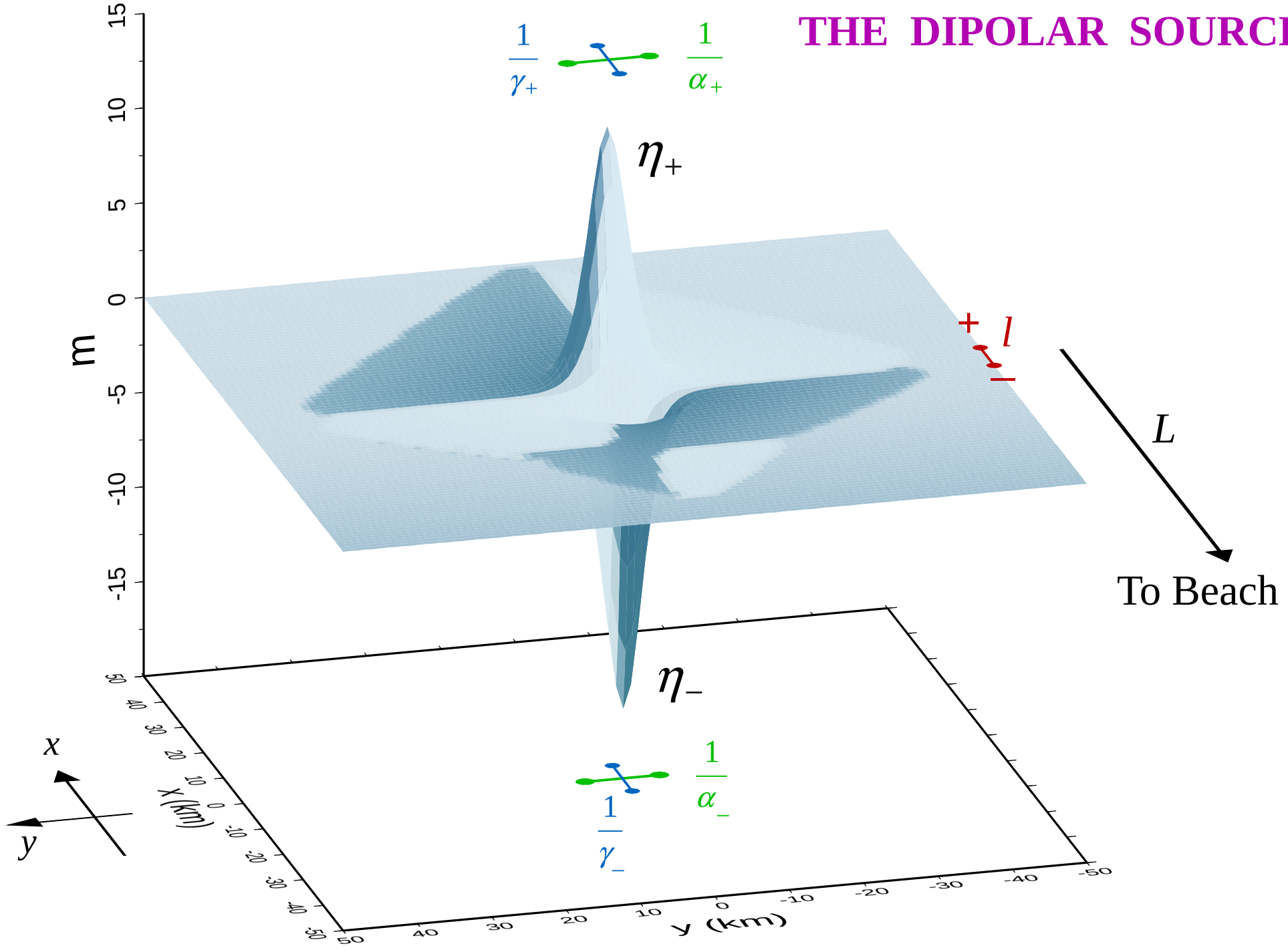
INDEX	SLOPE (m/km)	Aspect Ratio (10**−5)	b/Δu
124	50.	0.86	0.45
148	80.	0.68	0.36
149	33.	1.12	0.55


MODELS 124, 150, 151
0
1000
2000
3000
4000
5000
0
100
200
300
400
500
600



INDEX	BEACH No.	Aspect Ratio (10**−5)	b/Δu
124	0.	0.86	0.45
151	1.	1.30	0.65
150	2.	2.30	0.80

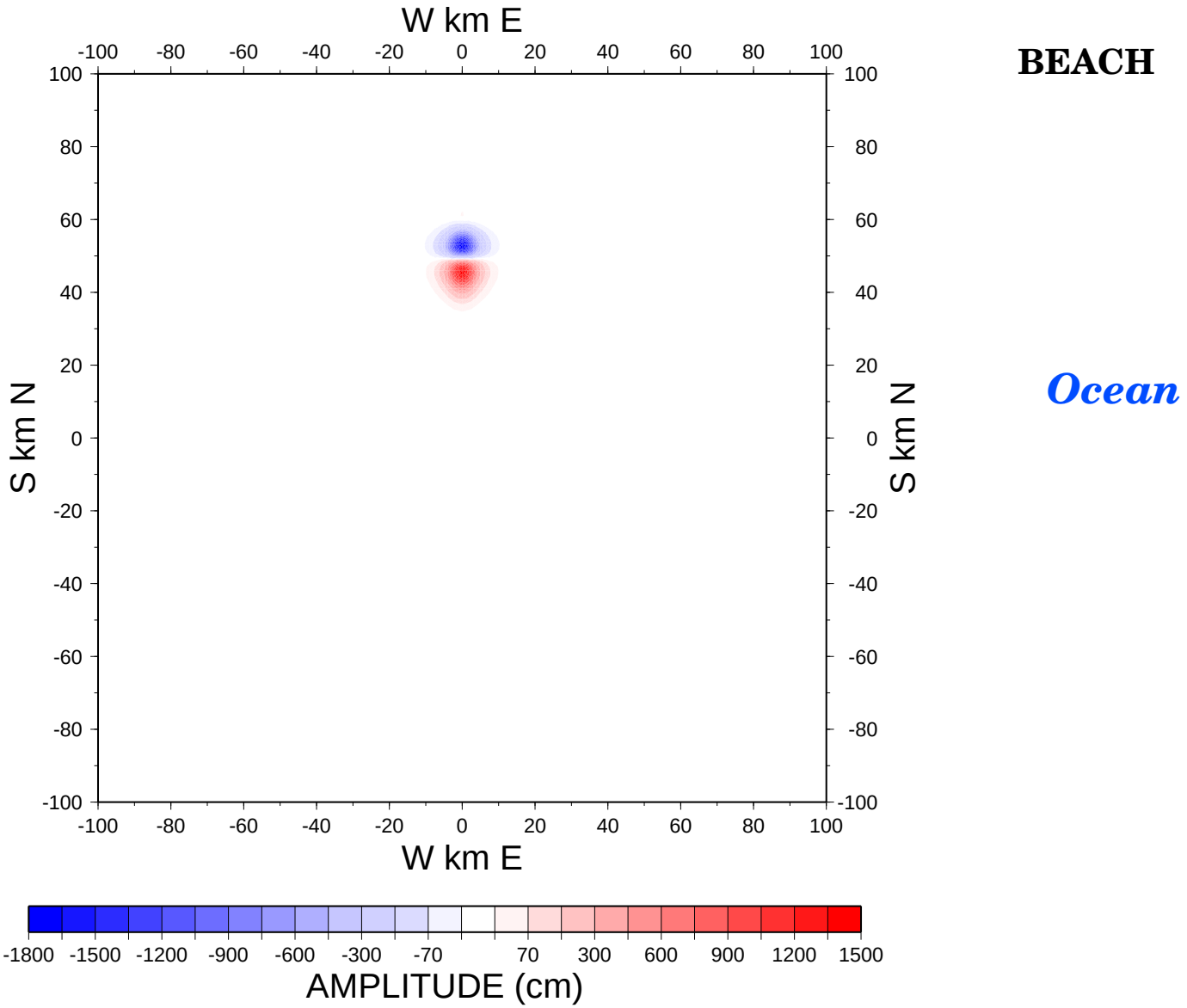
THE DIPOLAR SOURCE



[*Okal and Synolakis,* in press]

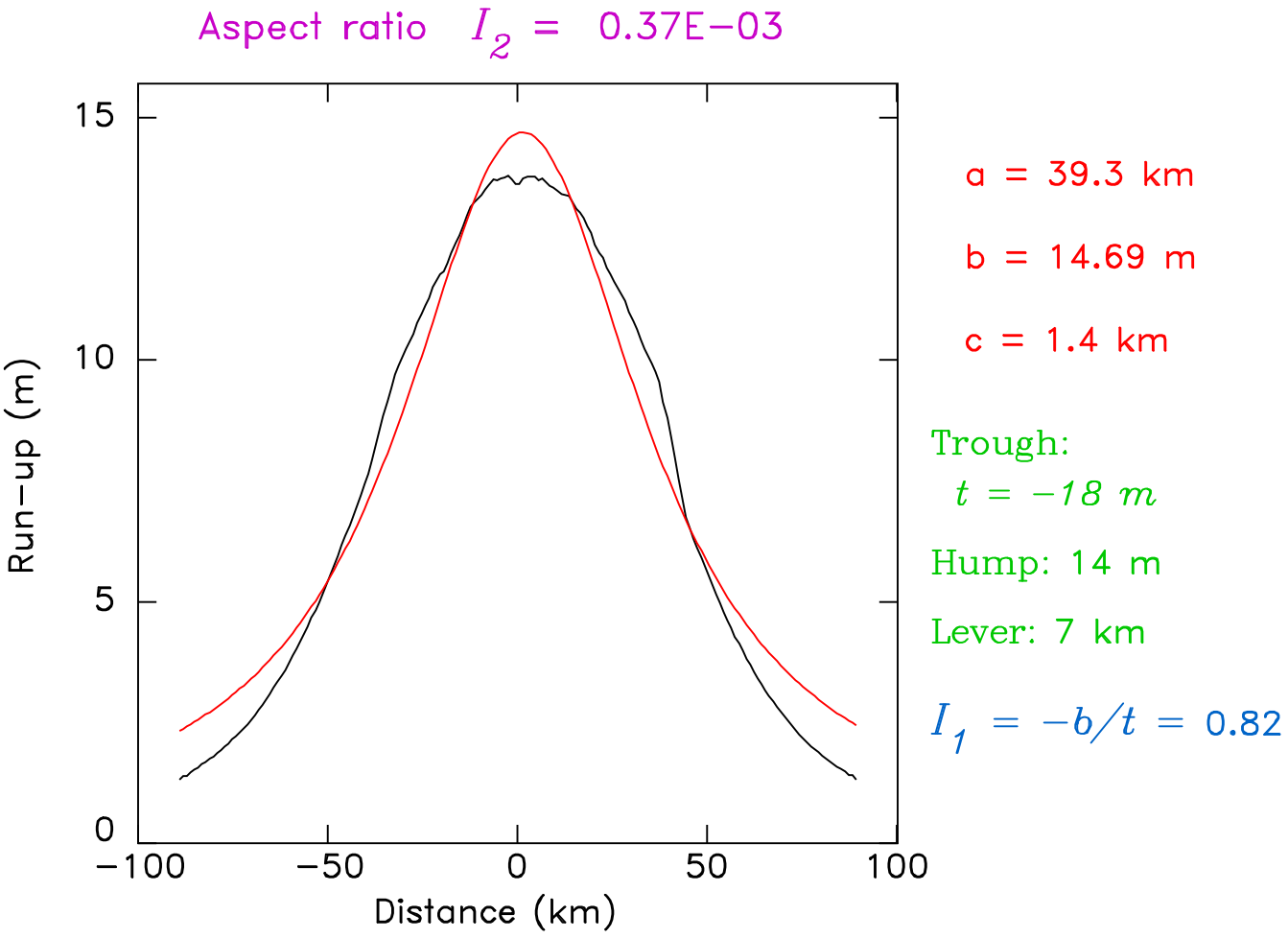
NEAR-FIELD: *The Landslide Source*

- Compute Ocean-Surface Deformation due to Landslide



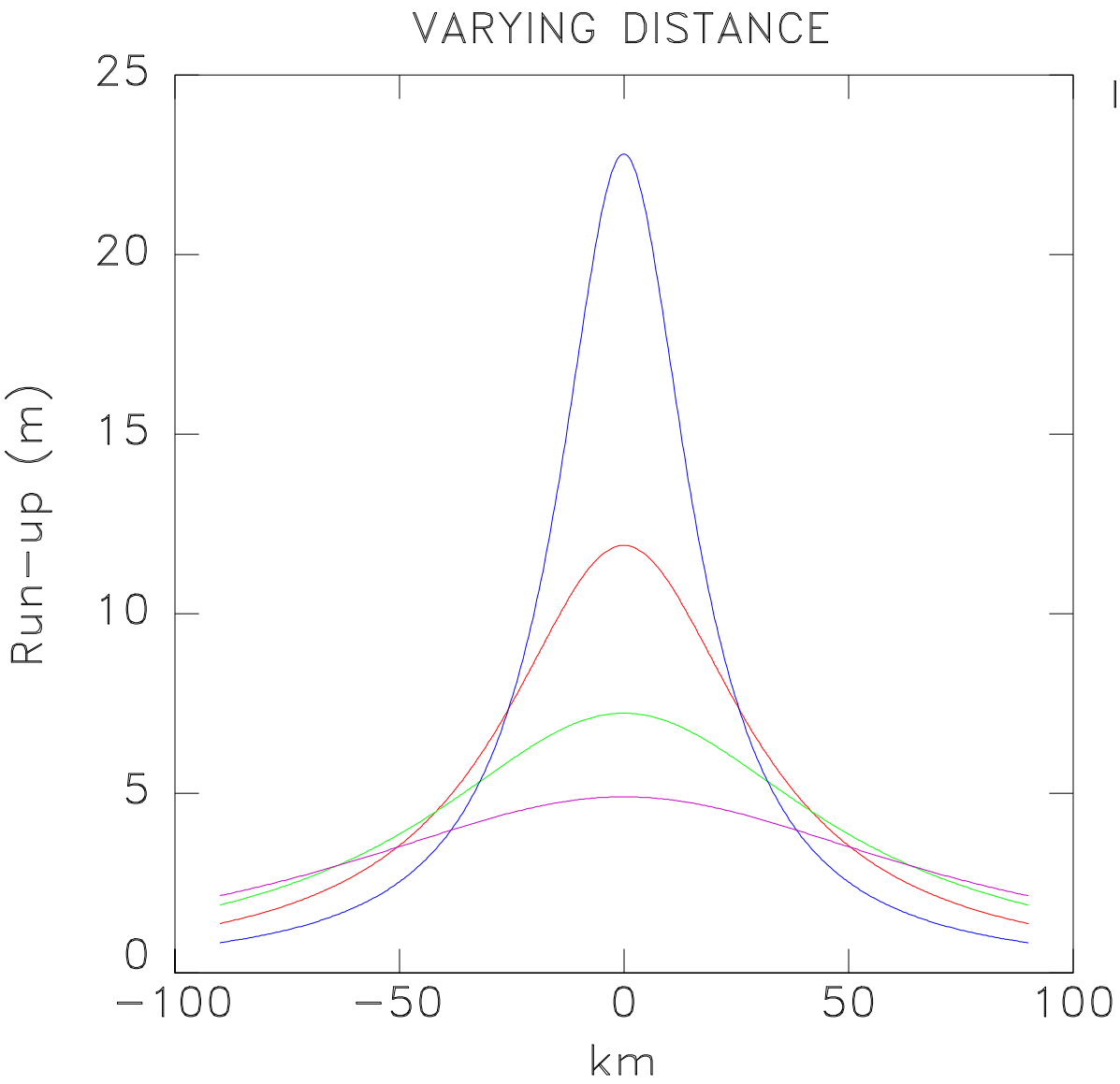
- Simulate Tsunami Propagation to Beach and Run-up

- Simulate Tsunami Propagation to Beach and Run-up
- Fit Bell Curve $$\zeta = \frac{b}{\left(\frac{x-c}{a}\right)^2 + 1}$$
  - Retain aspect ratio $I = b/a$

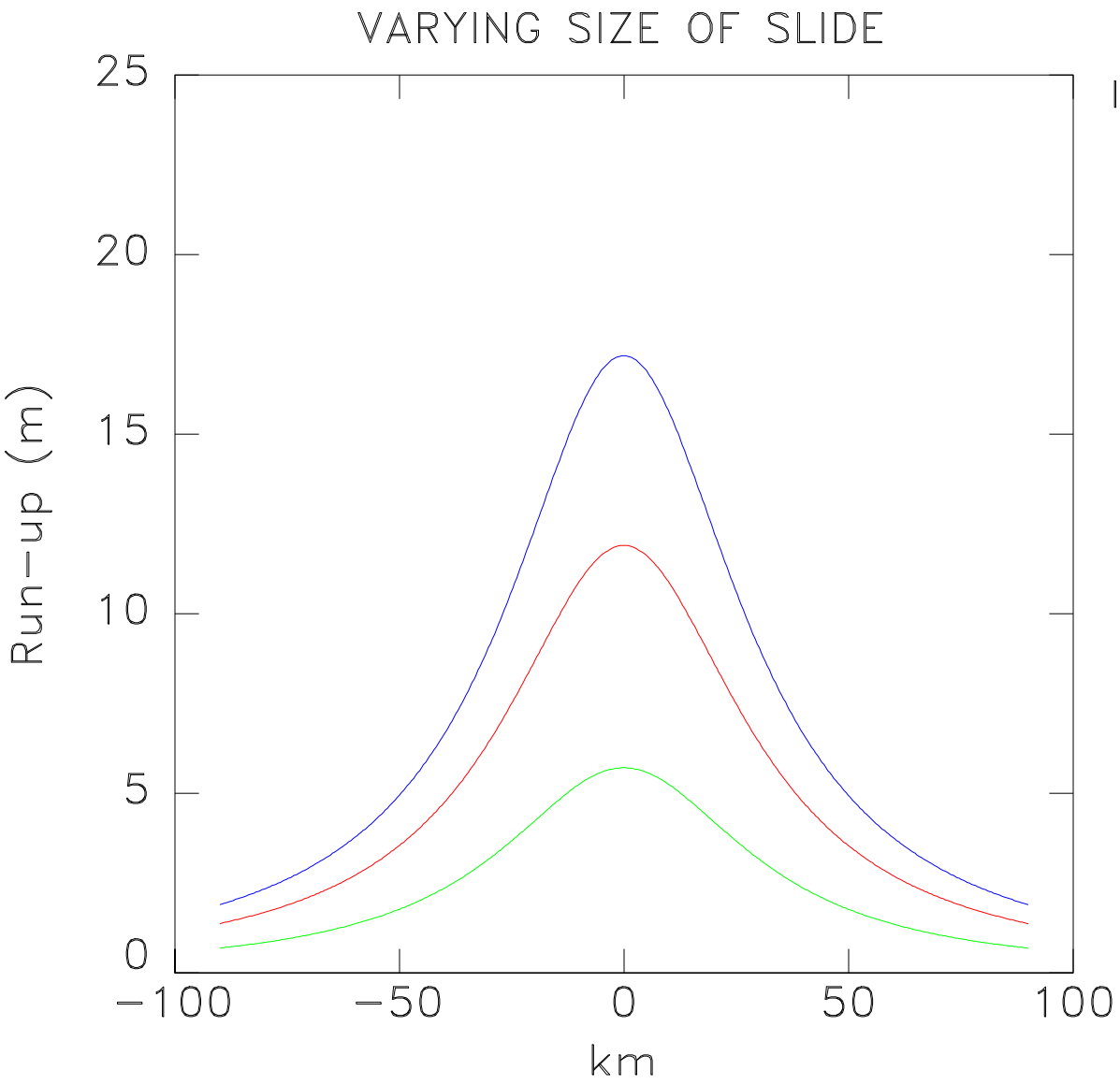


- Vary source parameters: I greater than 10^{-4}.

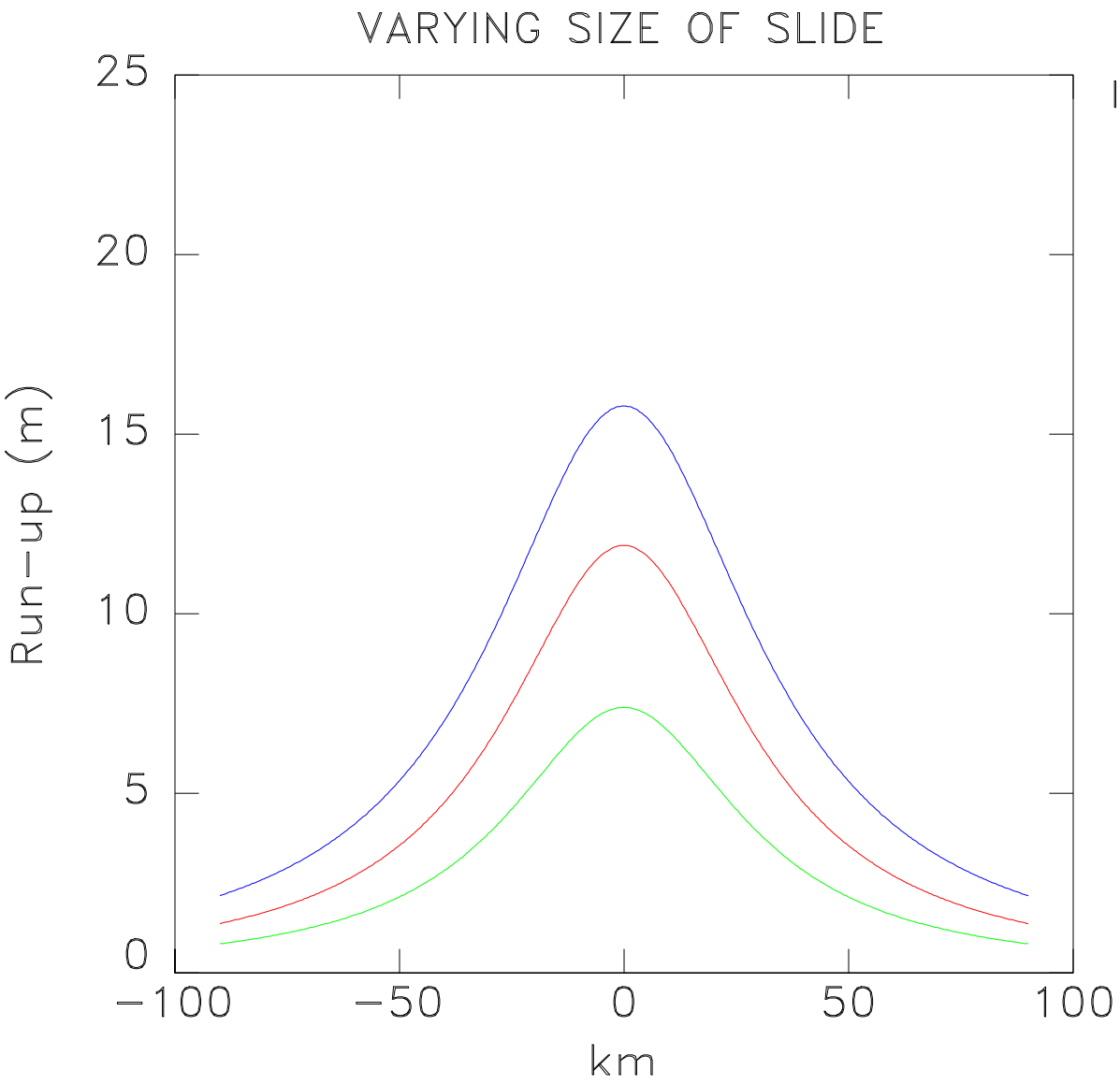
$I = b/a$ CAN SERVE AS DISCRIMINANT



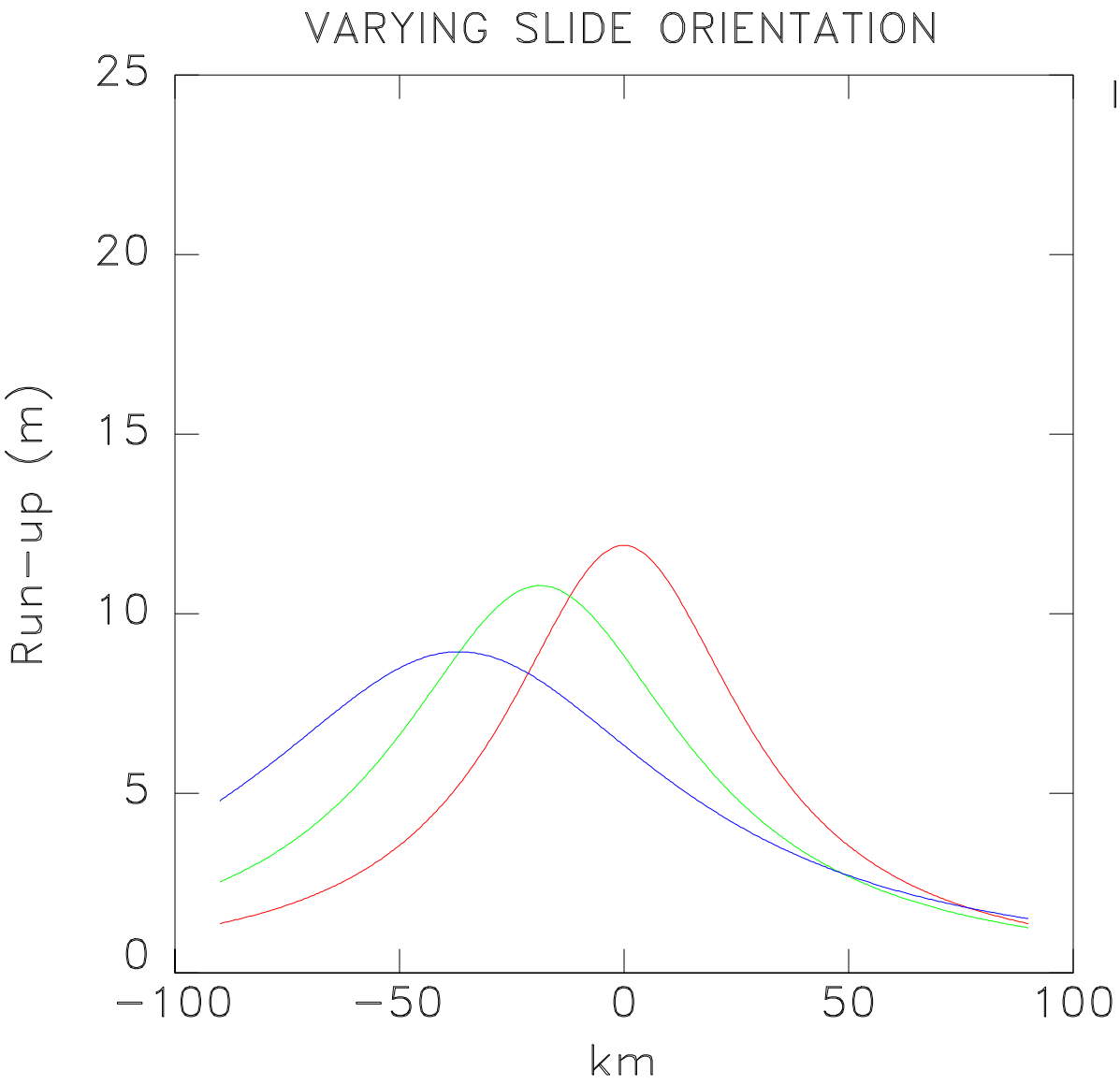
INDEX	DISTANCE (km)	Aspect Ratio (10**−4)
301	50.	3.65
302	75.	1.35
303	25.	12.89
304	100.	0.62



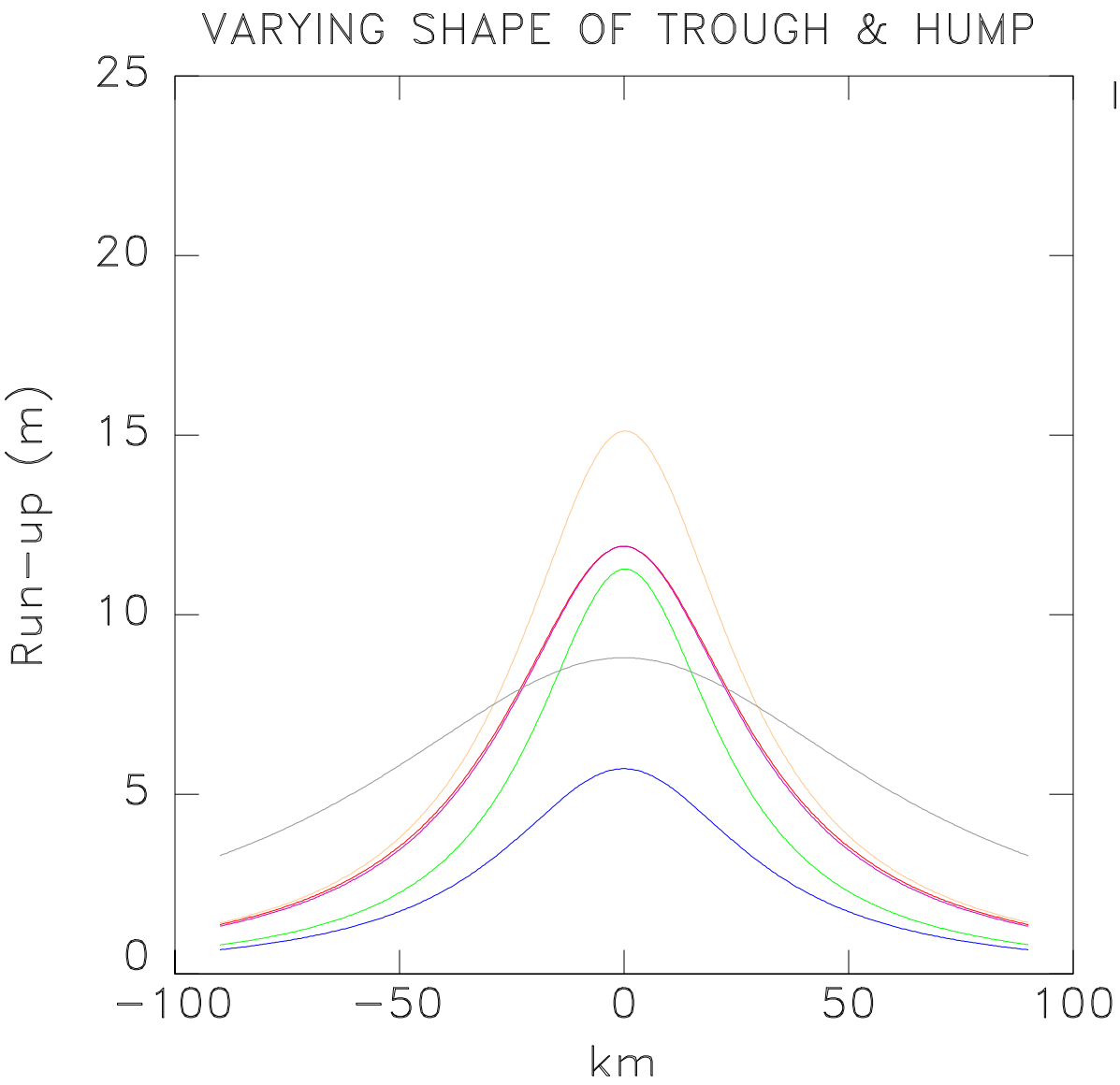
INDEX	TROUGH (m)	Aspect Ratio (10**-4)
301	-18.	3.65
309	-9.	1.70
310	-26.	5.41



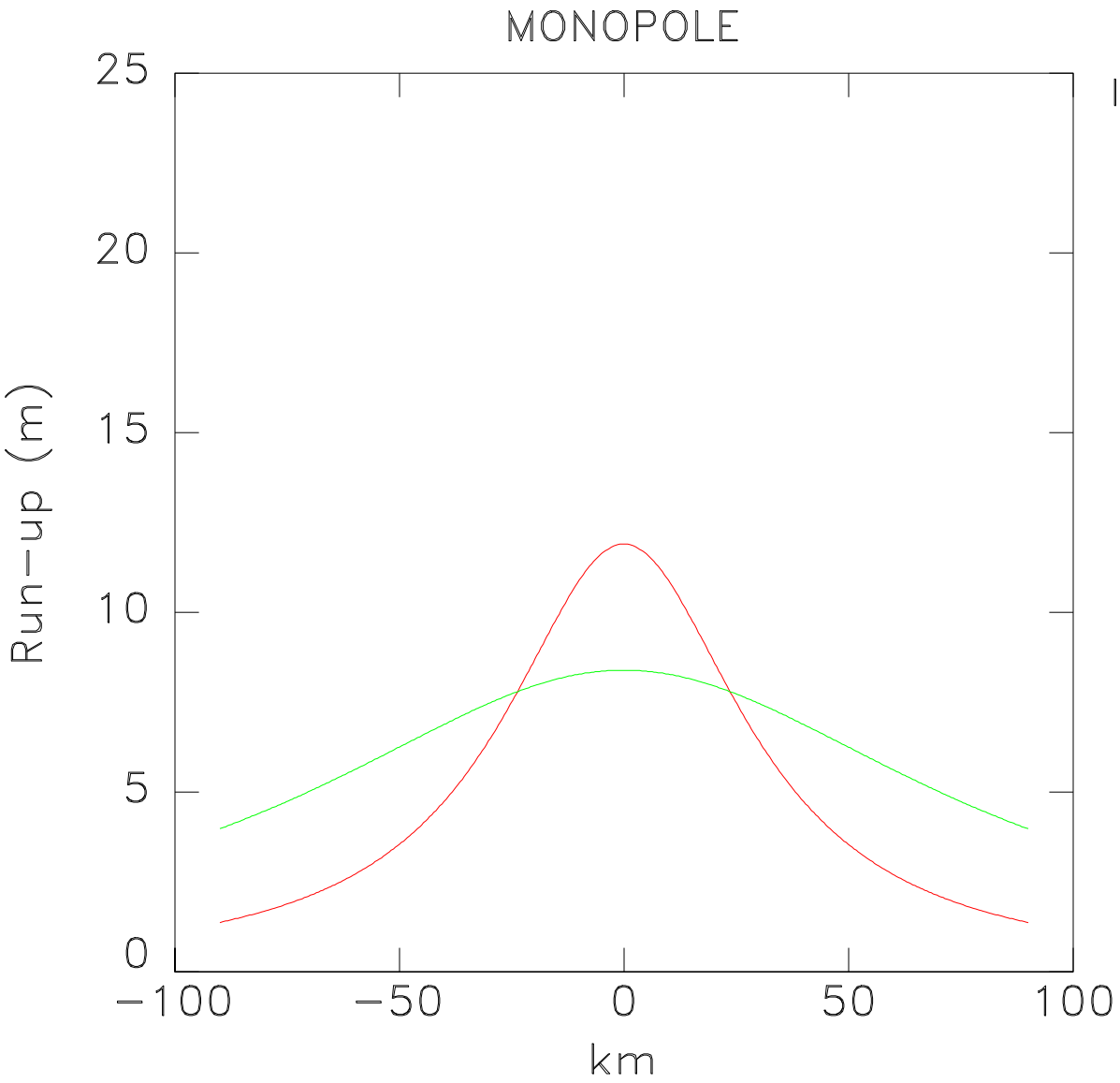
INDEX	LEVER (km)	Aspect Ratio (10**−4)
301	7.	3.65
311	4.	2.33
312	12.	4.41



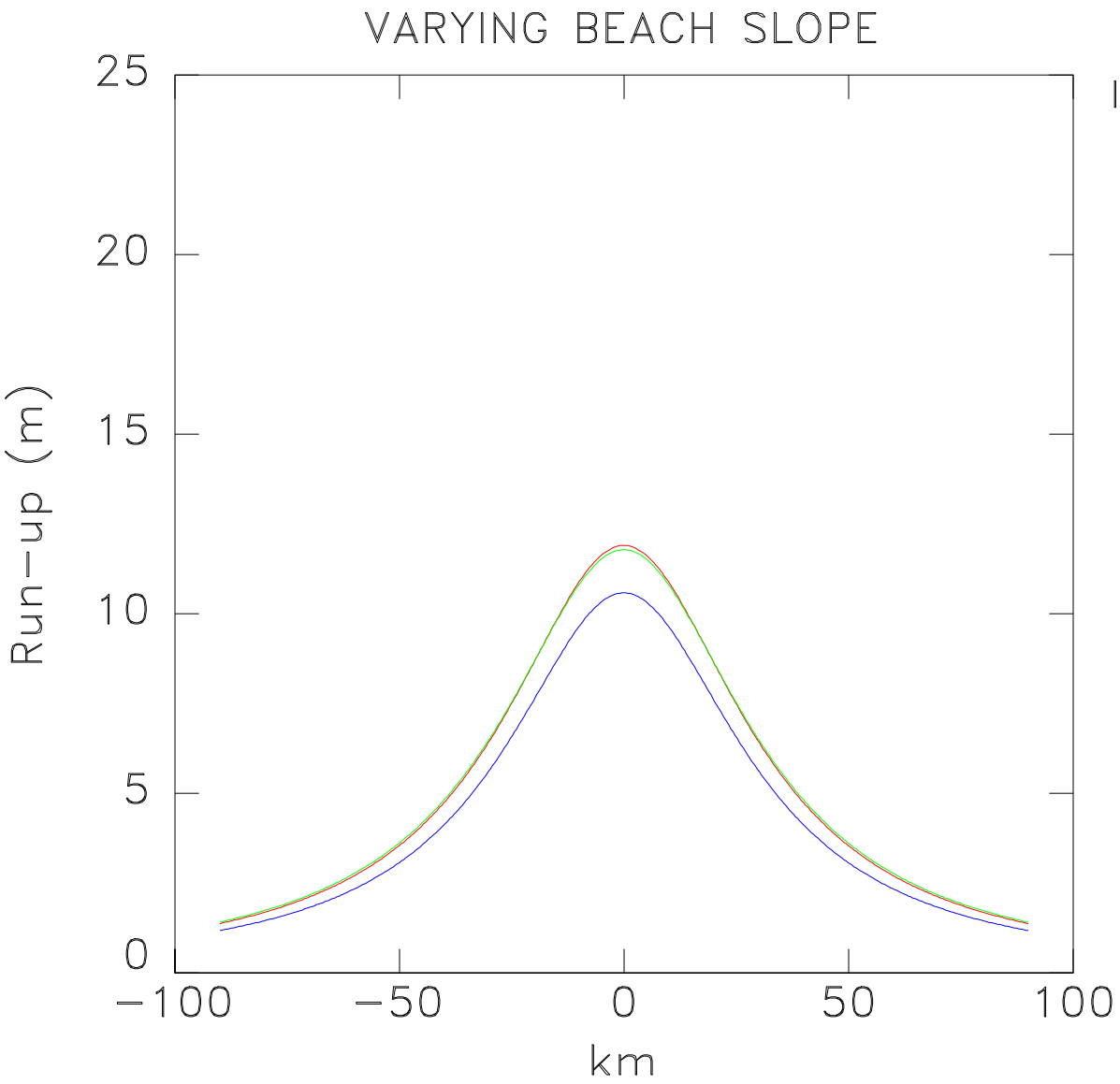
INDEX	AZIMUTH (deg.)	Aspect Ratio (10**−4)
301	180.	3.65
313	165.	2.72
312	150.	1.56



INDEX	SOURCE NO.	Aspect Ratio (10**−4)
301	0.	3.65
305	1.	4.48
306	2.	1.73
307	3.	3.72
337	4.	5.20
319	5.	1.27



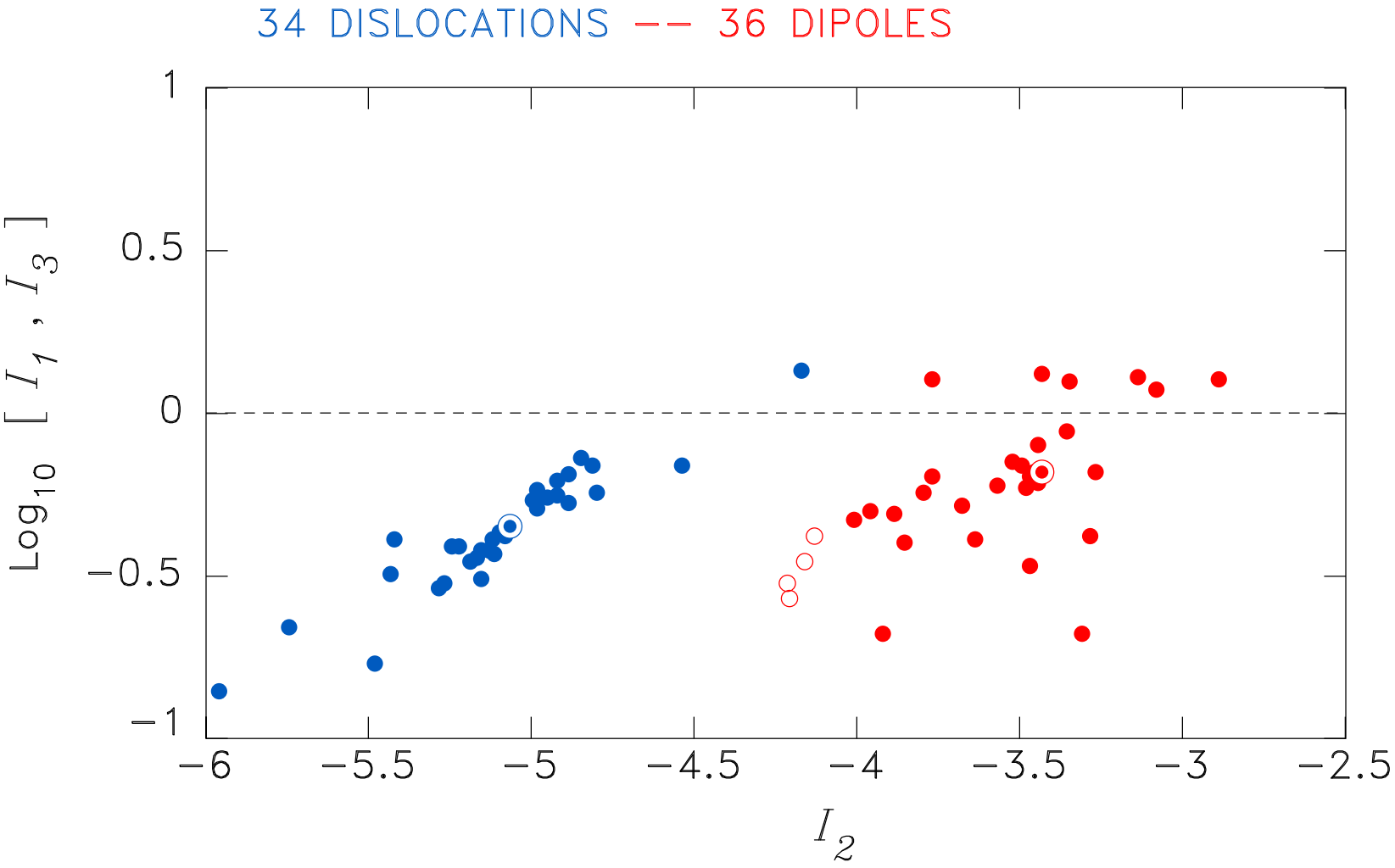
INDEX	SOURCE NO.	Aspect Ratio (10**-4)
301	0.	3.65
321	1.	0.98



INDEX	SLOPE	Aspect Ratio (10**−4)
301	0.	3.65
332	0.	3.54
330	0.	3.31

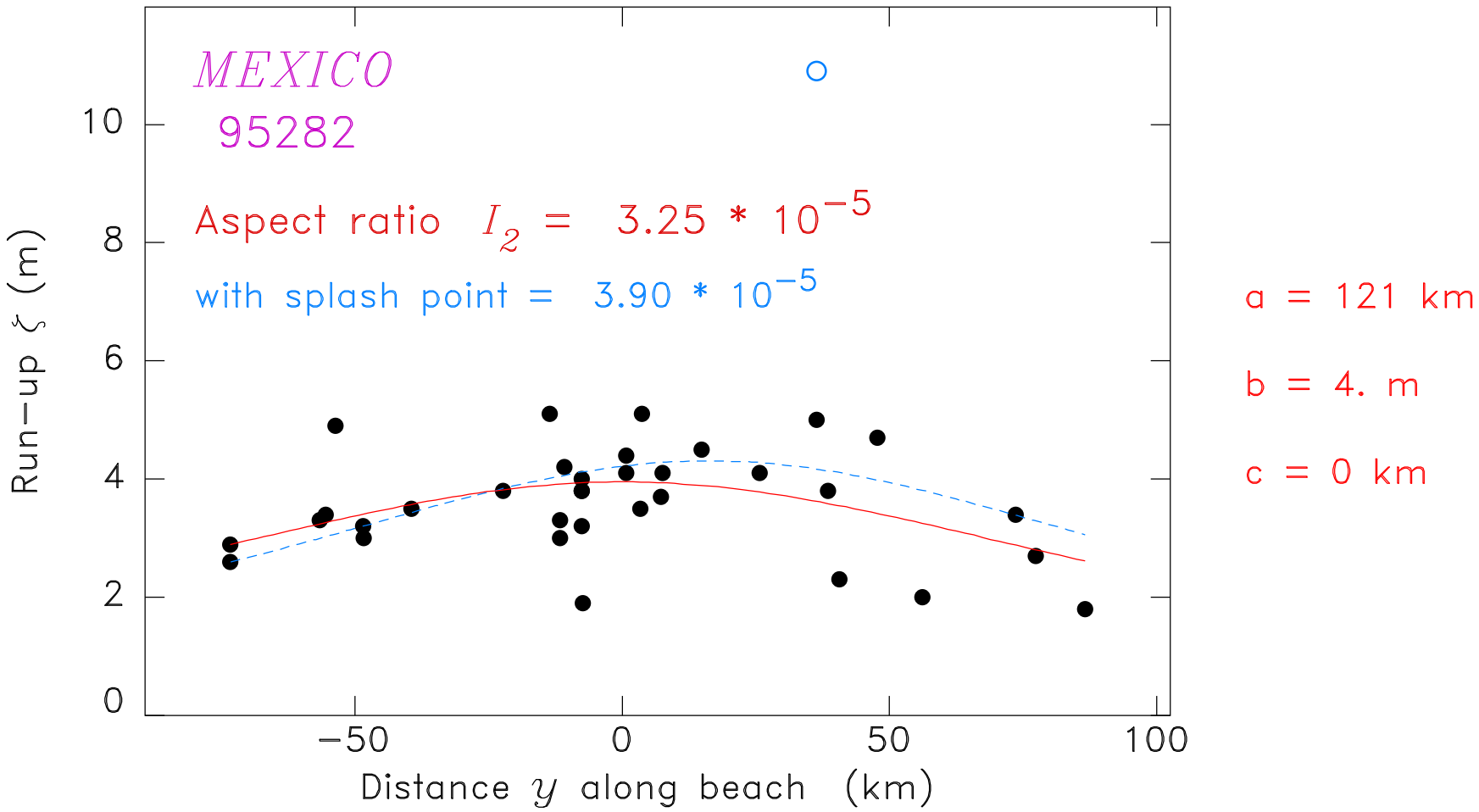
MAX. RUN-UP SCALED TO FAULT SLIP

MAX. RUN-UP SCALED TO INITIAL TROUGH



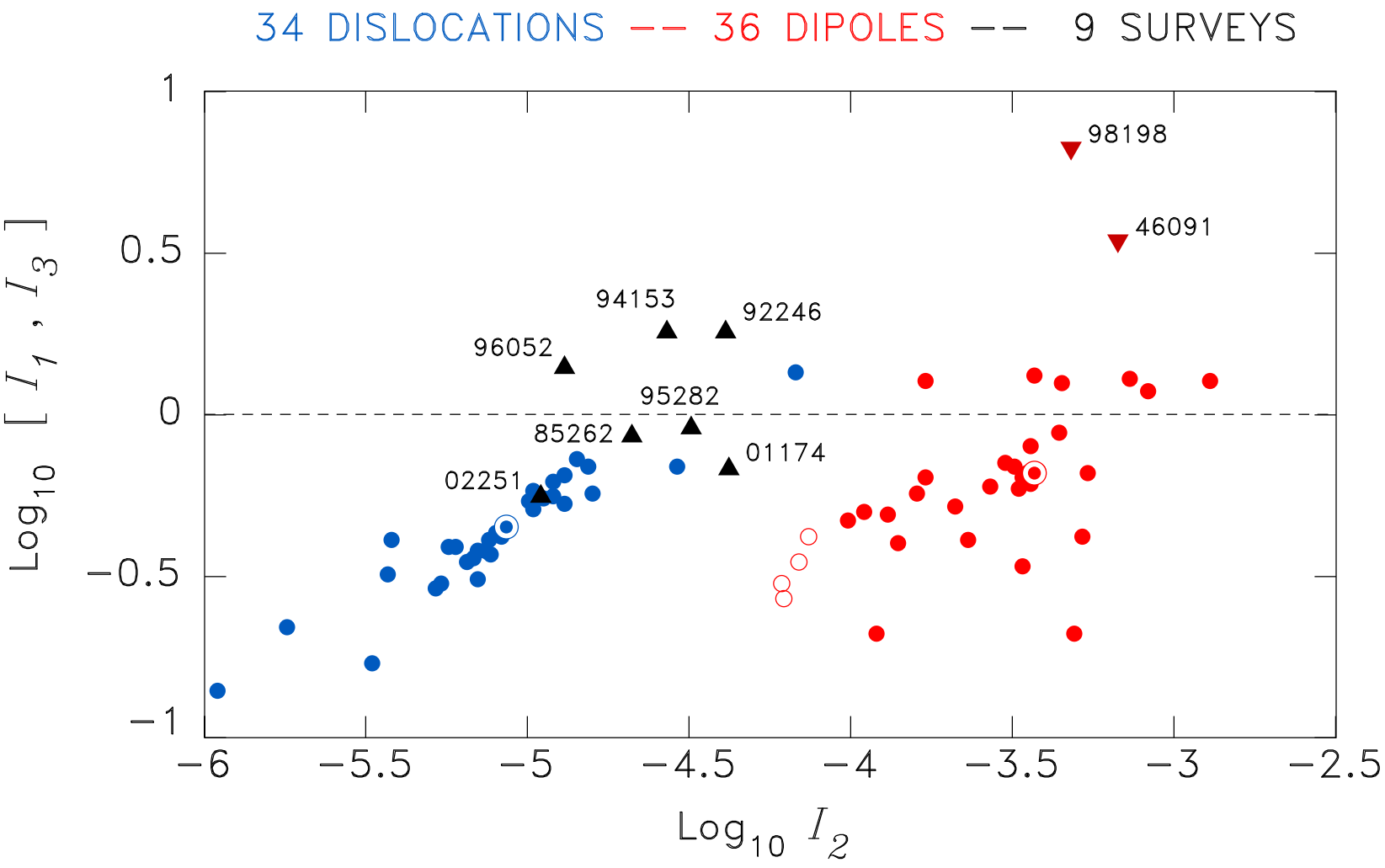
ASPECT RATIO OF RUN-UP DISTRIBUTION ALONG BEACH

[*Okal and Synolakis,* in press]


MEXICO
95282
Aspect ratio I_2 = 3.25 * 10^{-5}
with splash point = 3.90 * 10^{-5}
a = 121 km
b = 4. m
c = 0 km
Run-up ζ (m)
Distance y along beach (km)
0
2
4
6
8
10
−50
0
50
100

MAX. RUN-UP SCALED TO FAULT SLIP

MAX. RUN-UP SCALED TO INITIAL TROUGH



ASPECT RATIO OF RUN-UP DISTRIBUTION ALONG BEACH

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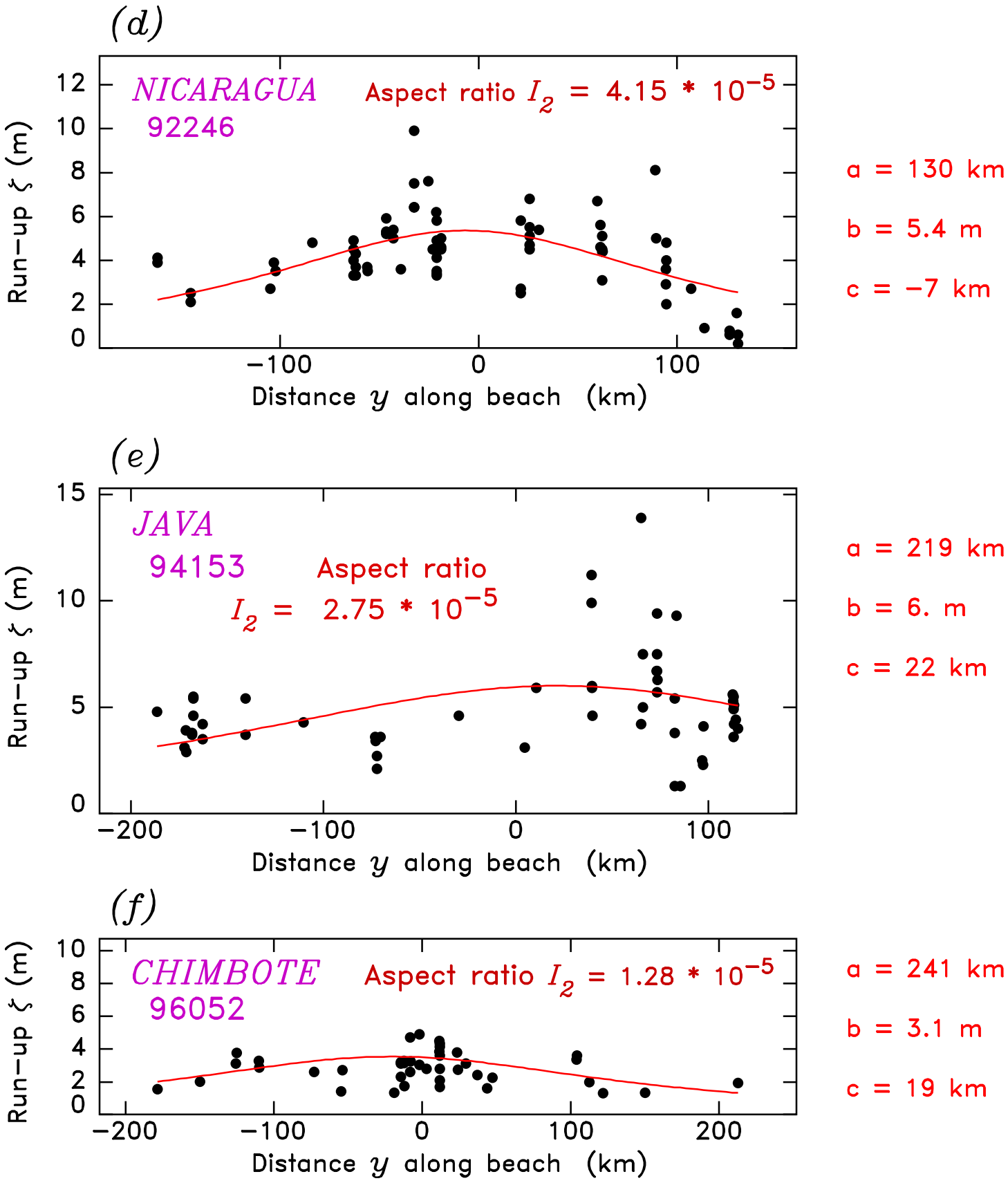

(d)
NICARAGUA
92246
Aspect ratio I_2 = 4.15 * 10^{-5}
Run−up ζ (m)
Distance y along beach (km)
a = 130 km
b = 5.4 m
c = −7 km
(e)
JAVA
94153
Aspect ratio
I_2 = 2.75 * 10^{-5}
Run−up ζ (m)
Distance y along beach (km)
a = 219 km
b = 6. m
c = 22 km
(f)
CHIMBOTE
96052
Aspect ratio I_2 = 1.28 * 10^{-5}
Run−up ζ (m)
Distance y along beach (km)
a = 241 km
b = 3.1 m
c = 19 km

FIGURE 6 *d*−*f*

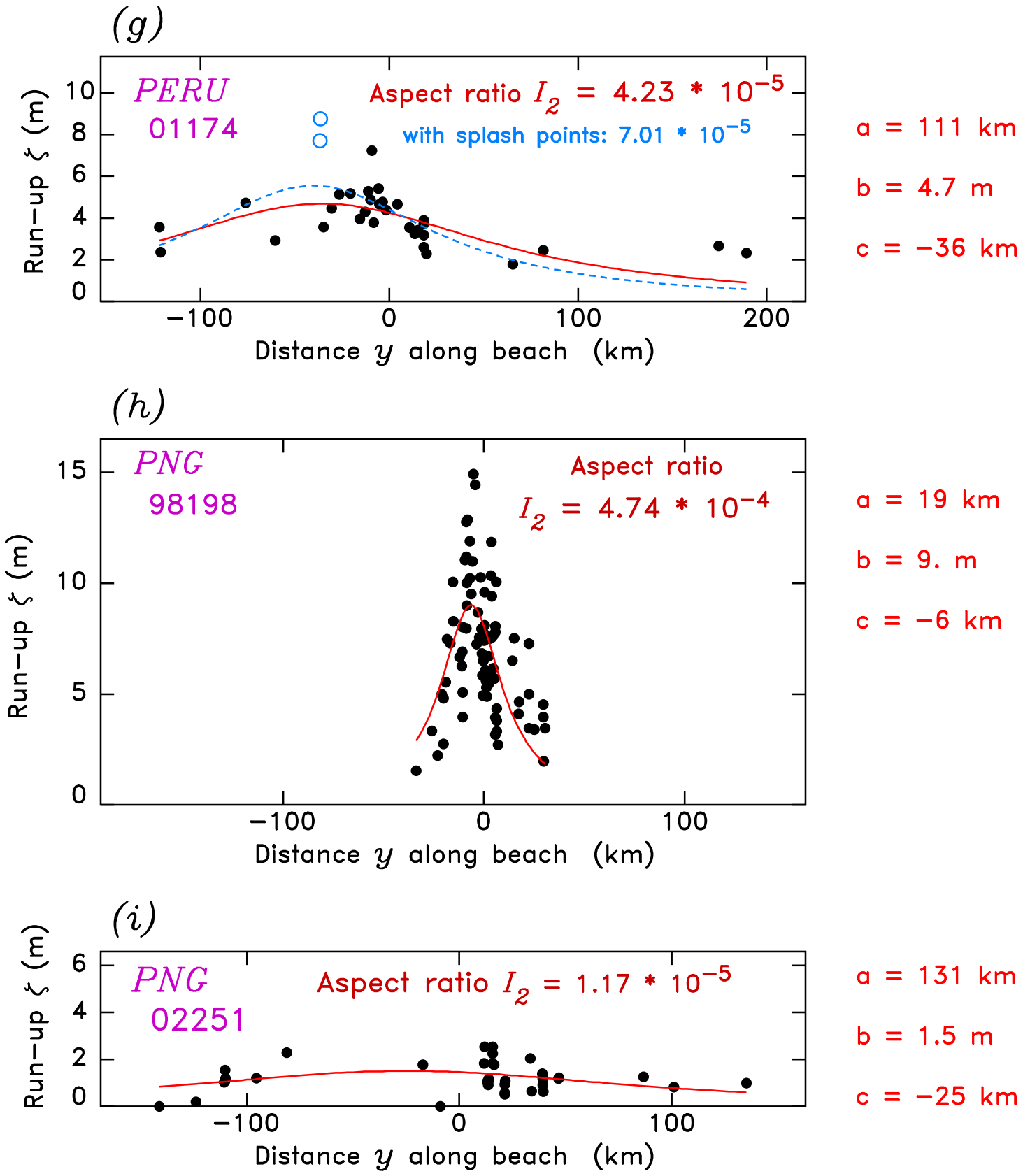
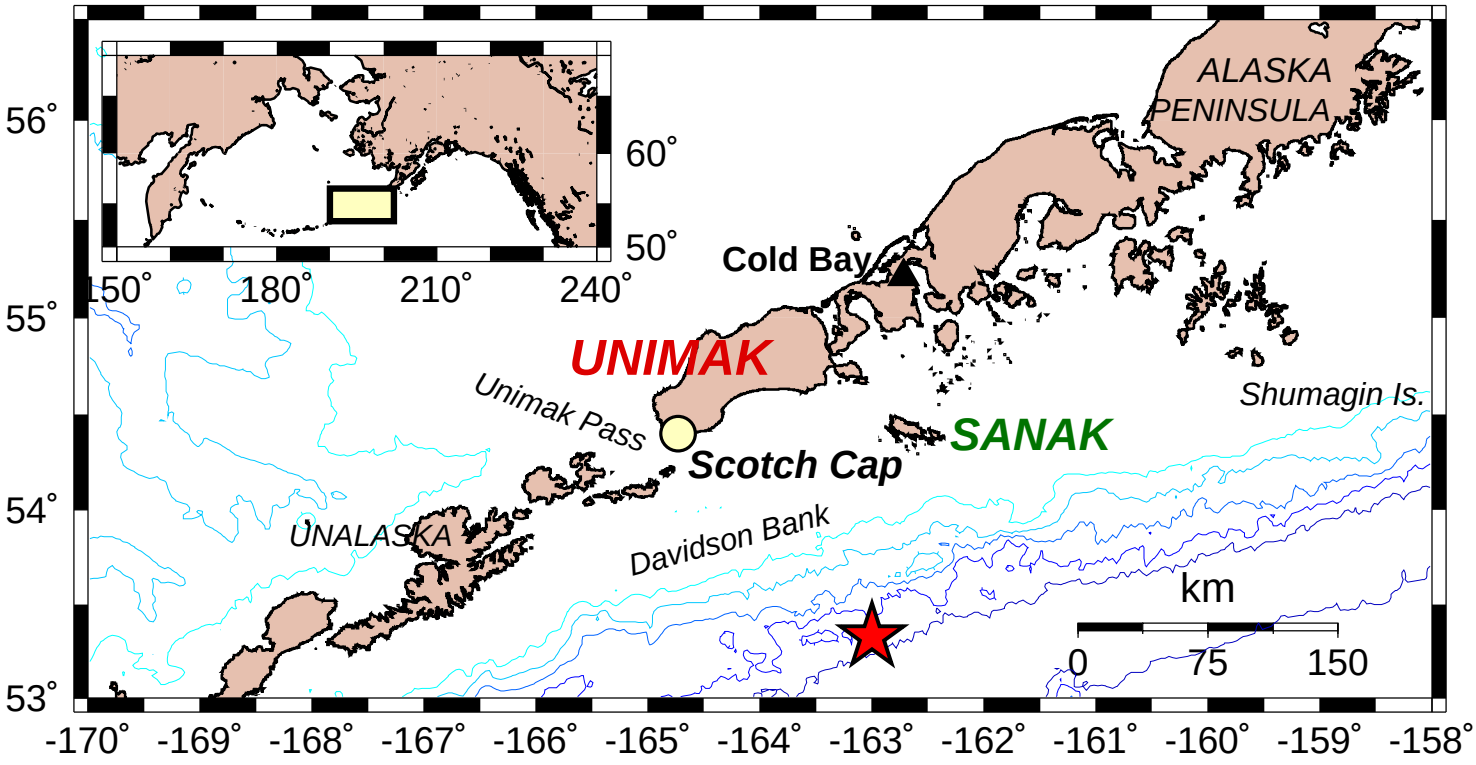

(g)
PERU
01174
Aspect ratio I_2 = 4.23 * 10^{-5}
with splash points: 7.01 * 10^{-5}
Run-up ζ (m)
Distance y along beach (km)
a = 111 km
b = 4.7 m
c = −36 km
(h)
PNG
98198
Aspect ratio
I_2 = 4.74 * 10^{-4}
Run-up ζ (m)
Distance y along beach (km)
a = 19 km
b = 9. m
c = −6 km
(i)
PNG
02251
Aspect ratio I_2 = 1.17 * 10^{-5}
Run-up ζ (m)
Distance y along beach (km)
a = 131 km
b = 1.5 m
c = −25 km

FIGURE 6 *g* – *i*

THE 1946 ALEUTIAN TSUNAMI: A PERSISTING CHALLENGE

- A rather moderate earthquake ($M_{PAS} = 7.4$)
- A devastating transpacific tsunami
- A catastrophic local tsunami

  Scotch Cap lighthouse eradicated.



THE QUESTION REMAINS

How to model the source of the tsunami: A gigantic earthquake source, or a large underwater landslide, triggered by the seismic event?

DESTRUCTION OF THE LIGHTHOUSE AT SCOTCH CAP, UNIMAK Is.

[Photog. *H. Hartman*; Courtesy G. Fryer]

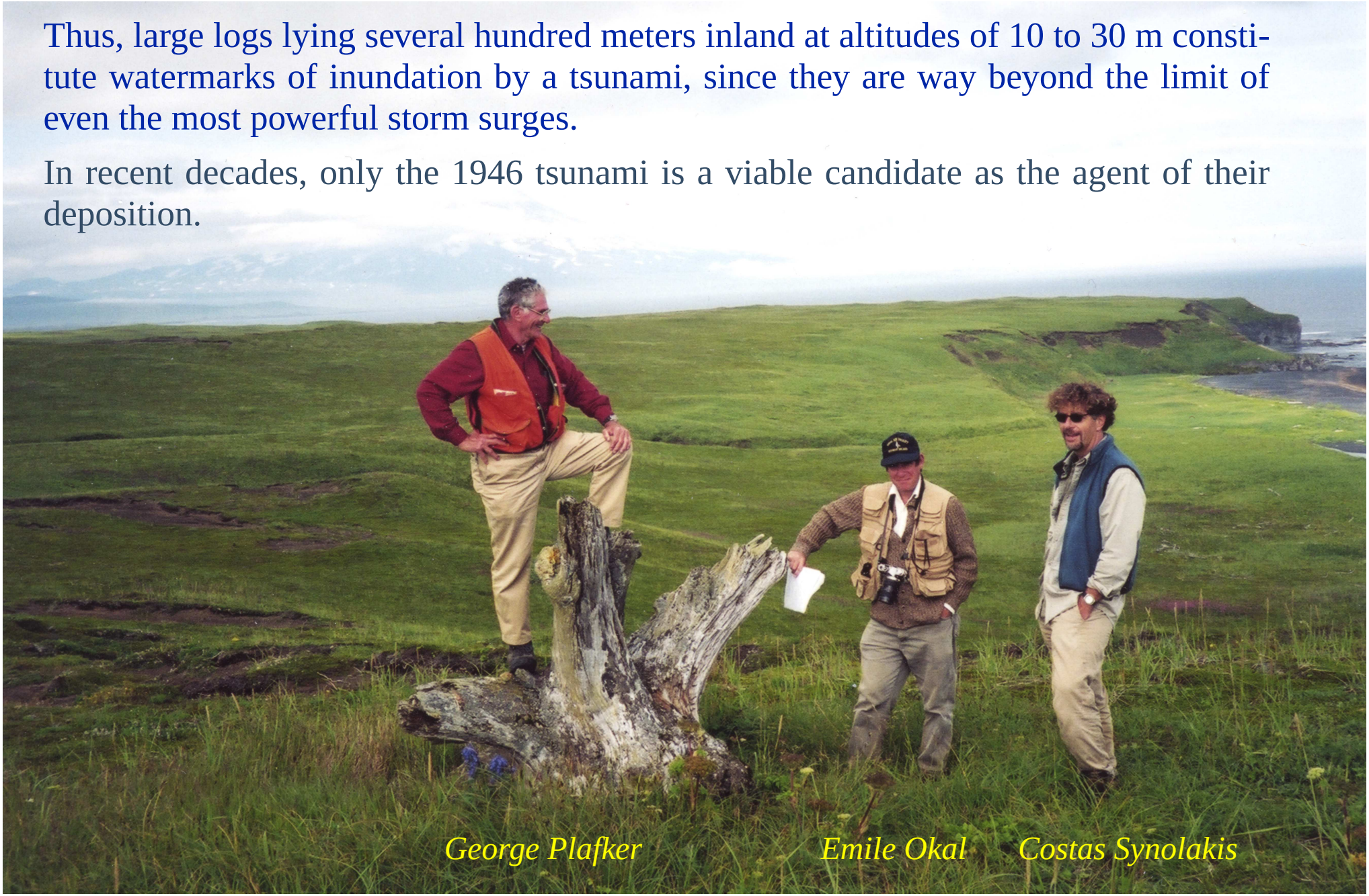
Before (1945)

After **(est. 03-04 (?) Apr. 1946)**

No trees grow on the Eastern Aleutian Islands...

Thus, large logs lying several hundred meters inland at altitudes of 10 to 30 m constitute watermarks of inundation by a tsunami, since they are way beyond the limit of even the most powerful storm surges.

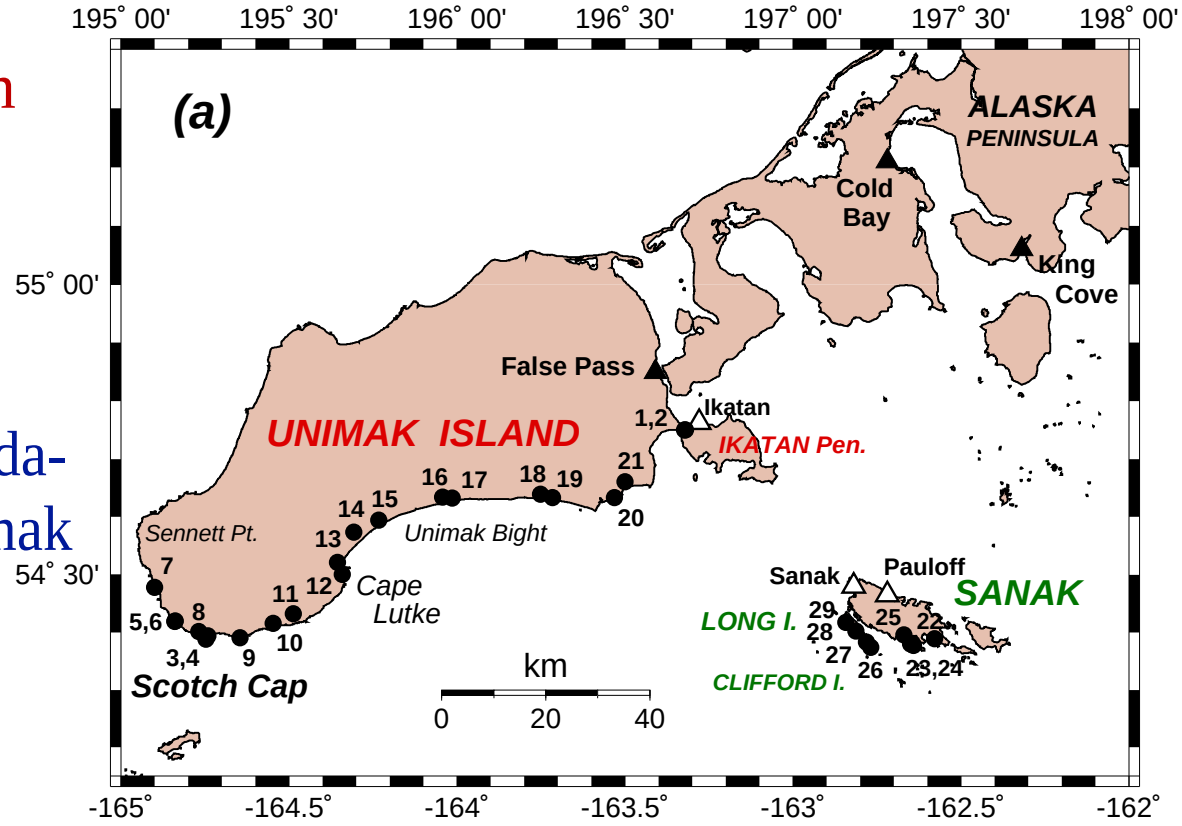
In recent decades, only the 1946 tsunami is a viable candidate as the agent of their deposition.

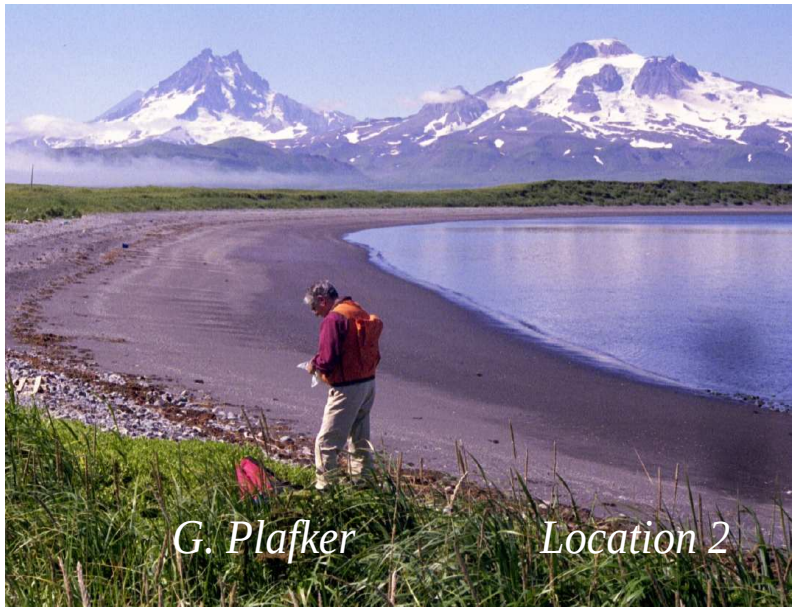


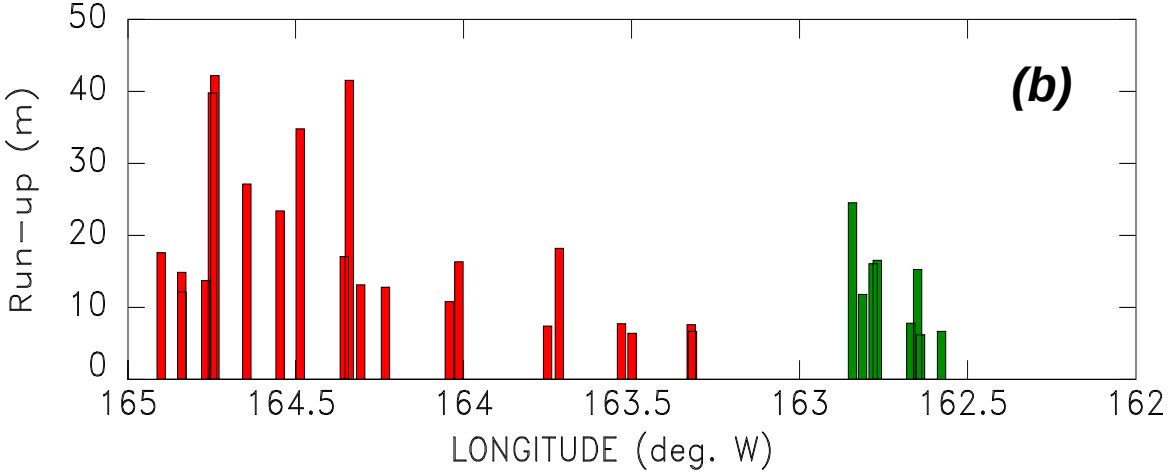
Cape Lutke, UNIMAK ISLAND

1946 RESULTS IN NEAR FIELD

- Run-up at Scotch Cap: 42 m (Ruins of Radio Station)
- Extreme run-up concentrated along 40 km of coast line.
- Run-up "only" 15 m, but inundation up to 2 km along Unimak Bight
- Run-up up to 24 m on Sanak







Near-field *Aspect Ratio* of Run-up Distribution at Unimak (6.4×10^{-4}) even larger than for PNG-1998, thus

REQUIRING LANDSLIDE SOURCE