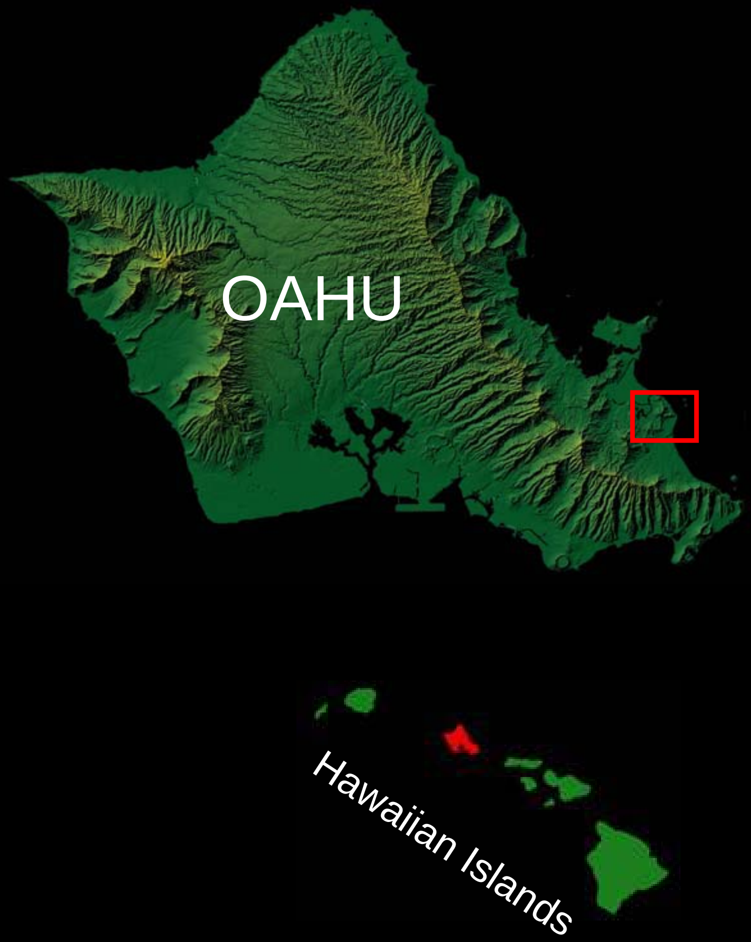
Where did Lanikai Beach go?: Applying sediment grain-size trend analysis (STA) to a chronically eroding beach.

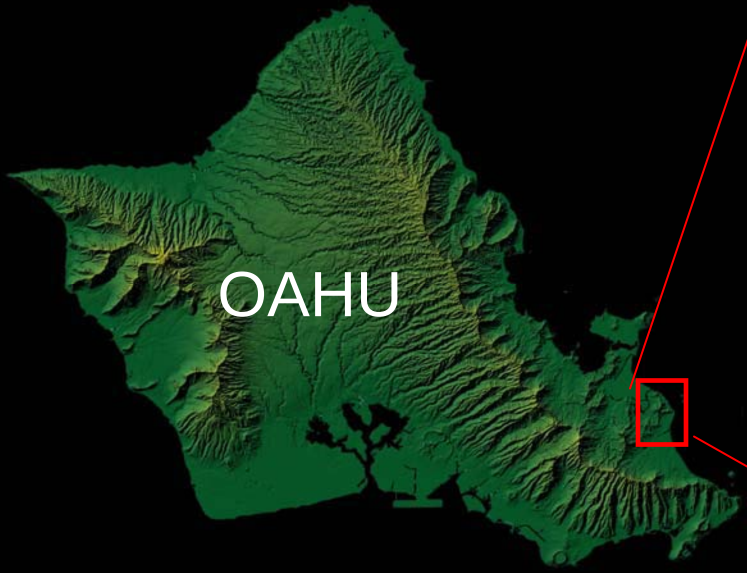
- Case Study:
  - STA never used for coastal erosion
  - Can STA give relevant insight into transport processes at an eroding beach?
- Approach:
  - Two methods of STA (Gao, Le Roux)
- Results:
  - Compatible results?
  - Predicted transport agree with historical observations?
- Conclusions:
  - Possible visualization of erosive processes



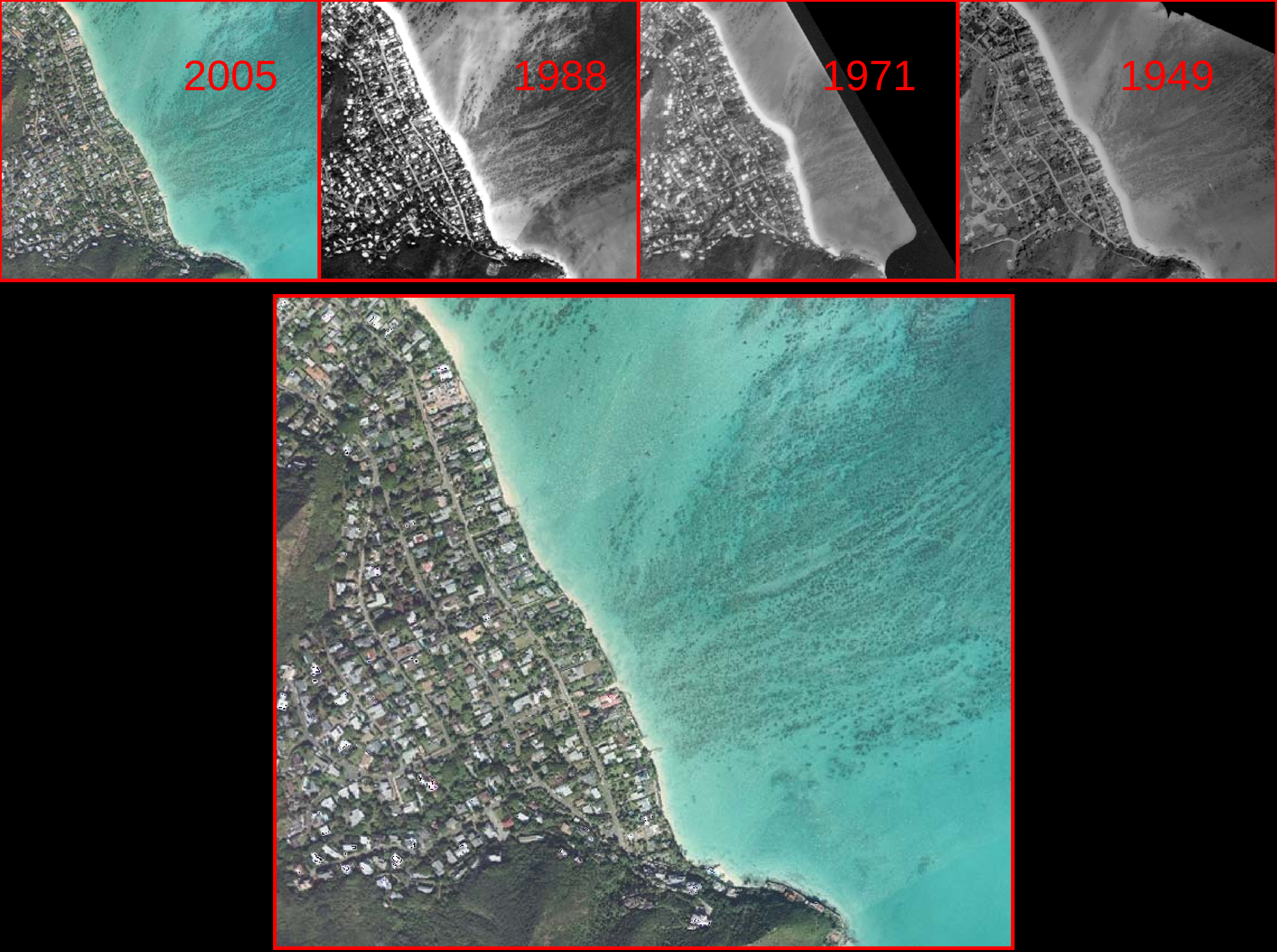
Chris Bochicchio – Univ. of Hawaii

Lanikai Beach
Windward Oahu, Hawaii

- Embayed headland
- North: Kailua Beach
- South: Bellows Beach




Lanikai Beach
Sandy Beach
Seawalls
Wailea Pt.
~30 years of chronic erosion
Bellows Beach


2005
1988
1971
1949

On Going Debate:
What caused the sudden accretion and erosion of Lanikai?

- Longshore transport direction poorly understood.
  - –North to Kailua?
  - –South to Bellows?
  - –Offshore Sand Fields

- Drifter drogues no clear trend

- Two month ADV deployment: > 0.10 m/s

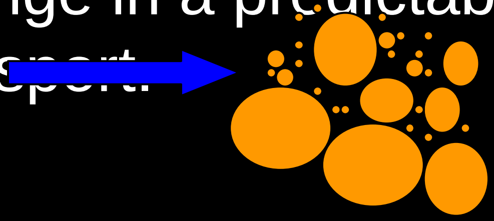
Methodology:

Sediment Grain-size Trend Analysis

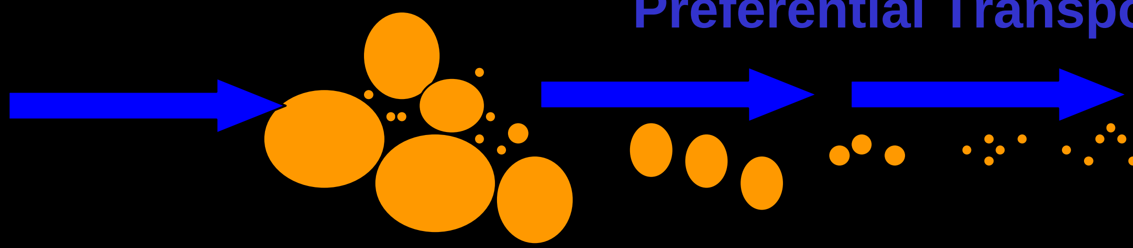
Assumption:

Sediment will become better sorted in the direction of transport.

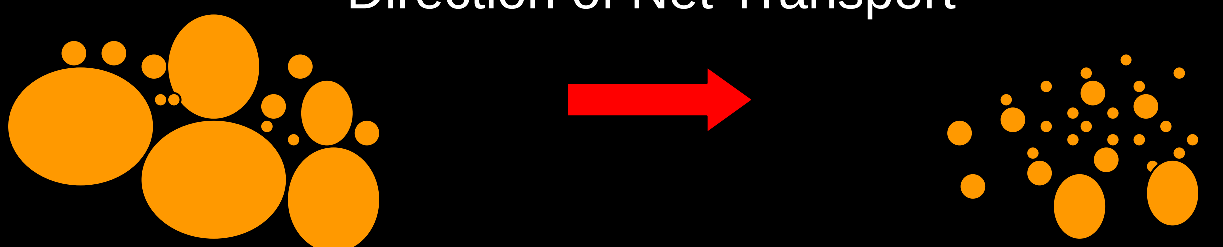
Sediment grain-size distributions of successive samples will change in a predictable manner along the direction of net transport.



Preferential Transport = Better Sorting



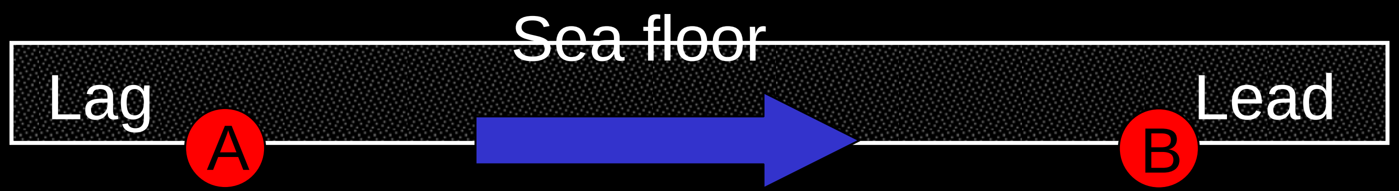
Direction of Net Transport



Lag Deposit

Lead Deposit

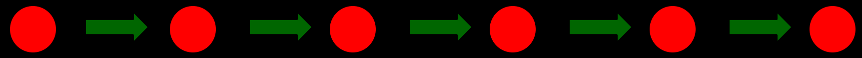
1D STA Methodology (McLaren and Bowles, 1985)



I
MEAN SIZE: Finer
SORTING: Better
SKEWNESS: Negative

II
MEAN SIZE: Courser
SORTING: Better
SKEWNESS: Positive

Successive deposits



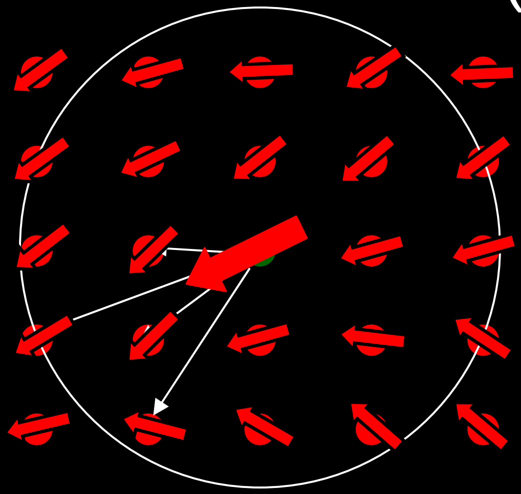
III
MEAN SIZE: Courser
SORTING: Better
SKEWNESS: Negative

IV
MEAN SIZE: Finer
SORTING: Better
SKEWNESS: Positive

(Le Roux, 1994)

Summary of 2D Trend Analysis Methods:

Gao and Collins (1992)

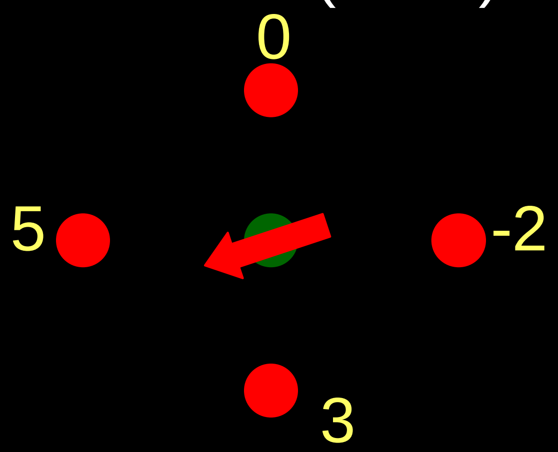


Looking for ALL trends:
Point-to-point search within a radius

Sums positions of all matching points for a discrete integer unit vector

Vector magnitude from number of matching points

Le Roux (1994)

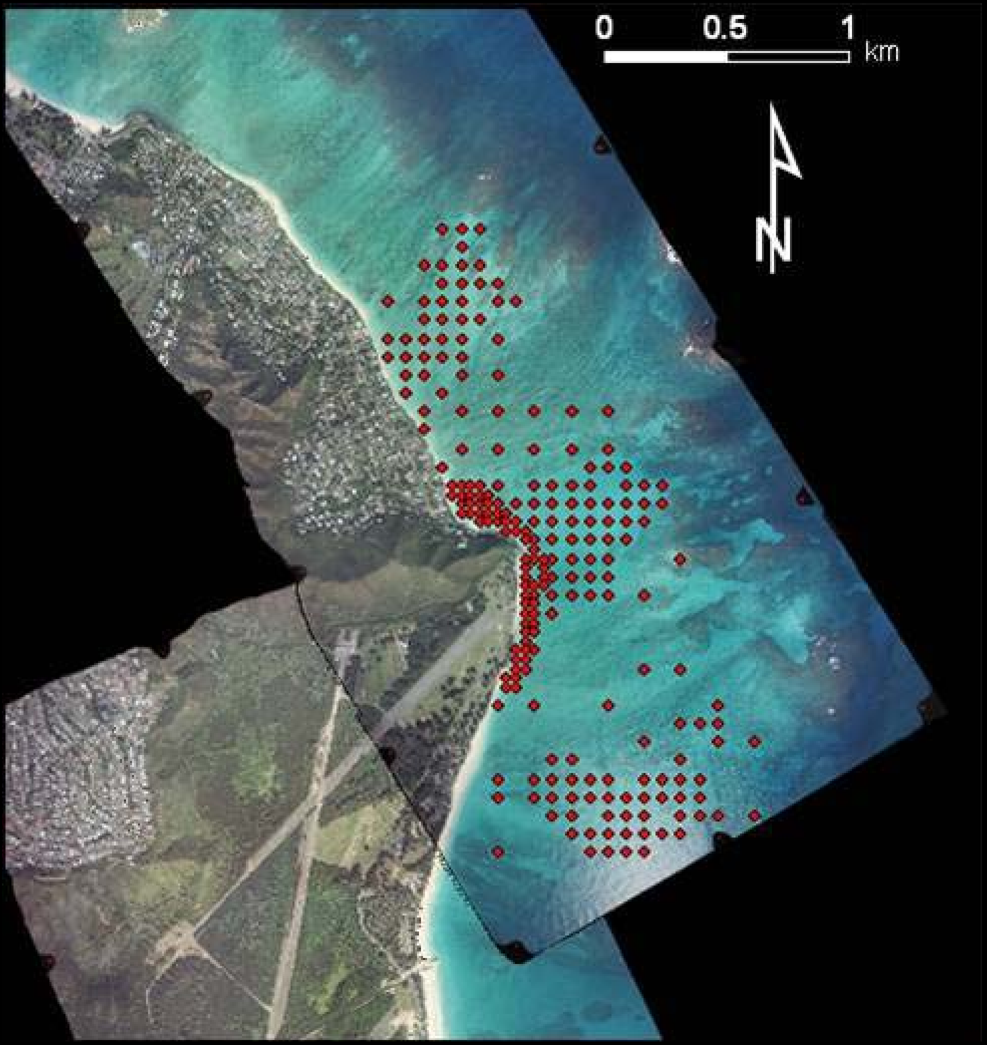


Looking for EACH trend:
Compare grain parameters to 4 adjacent points

Normalization so that higher values reflect trend direction

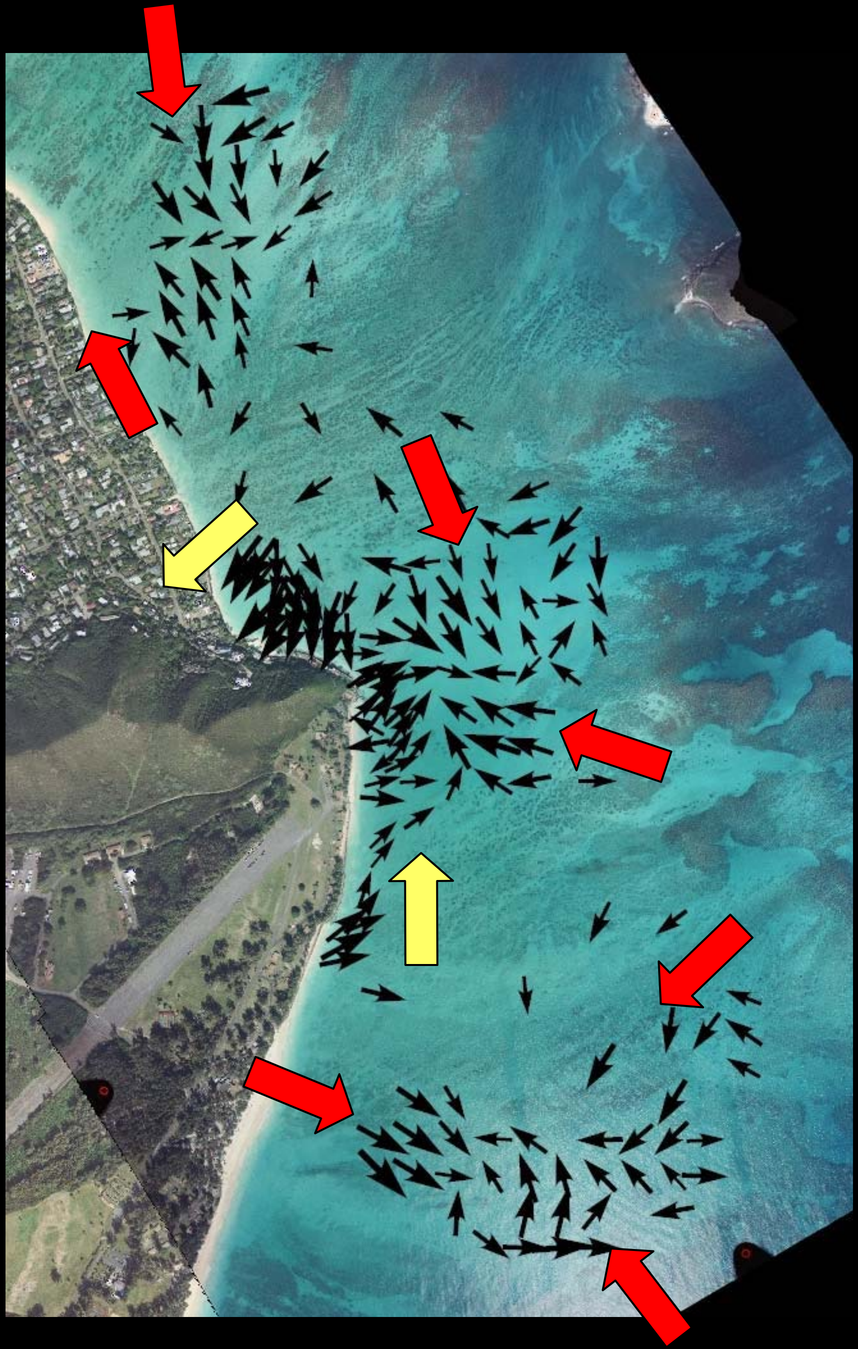
Relative difference in grain-size parameters.

Sample Collection

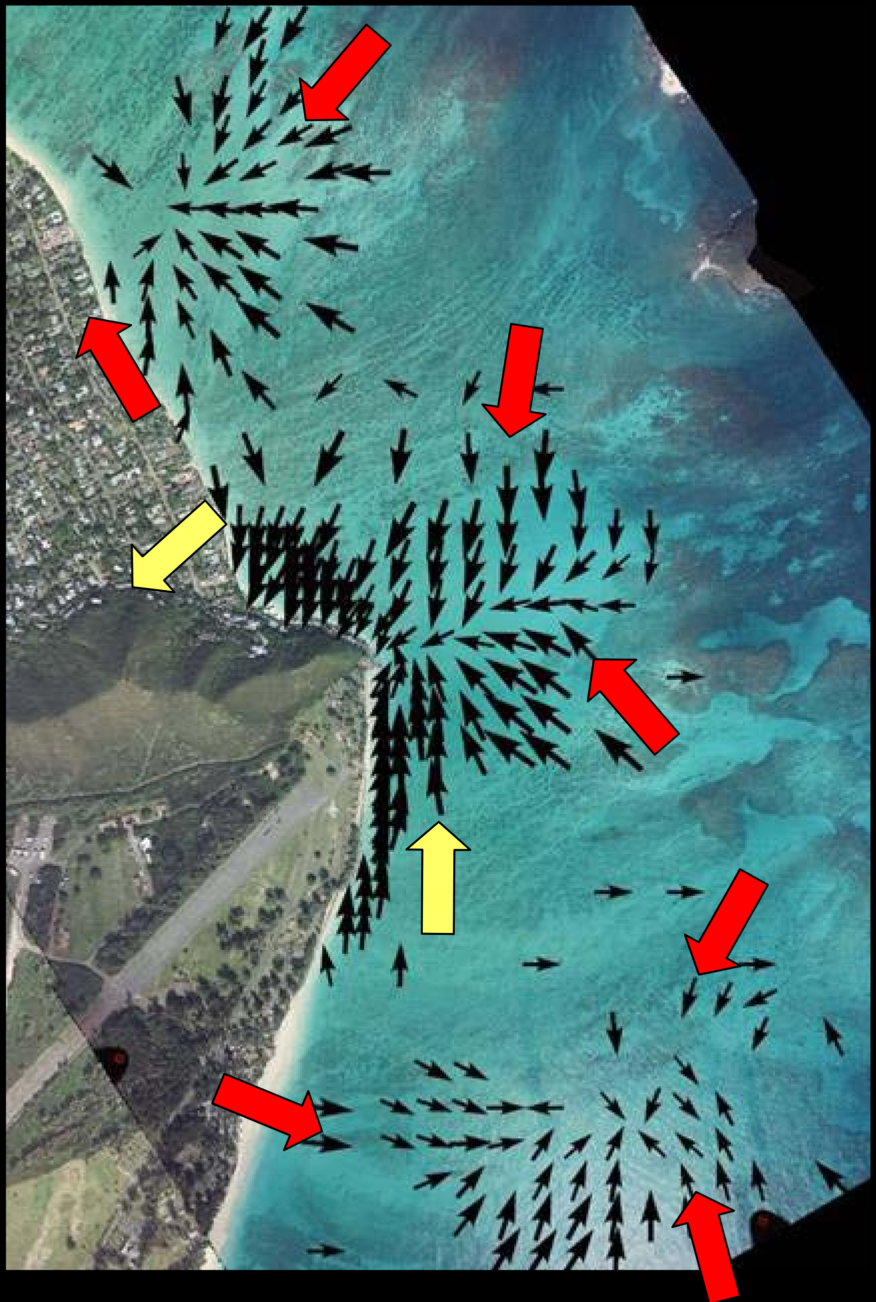


- 250 collected
- 214 Sieved
- Wet and dry sieving between Phi –2 and 5 (0.5 intervals)

Roux Results

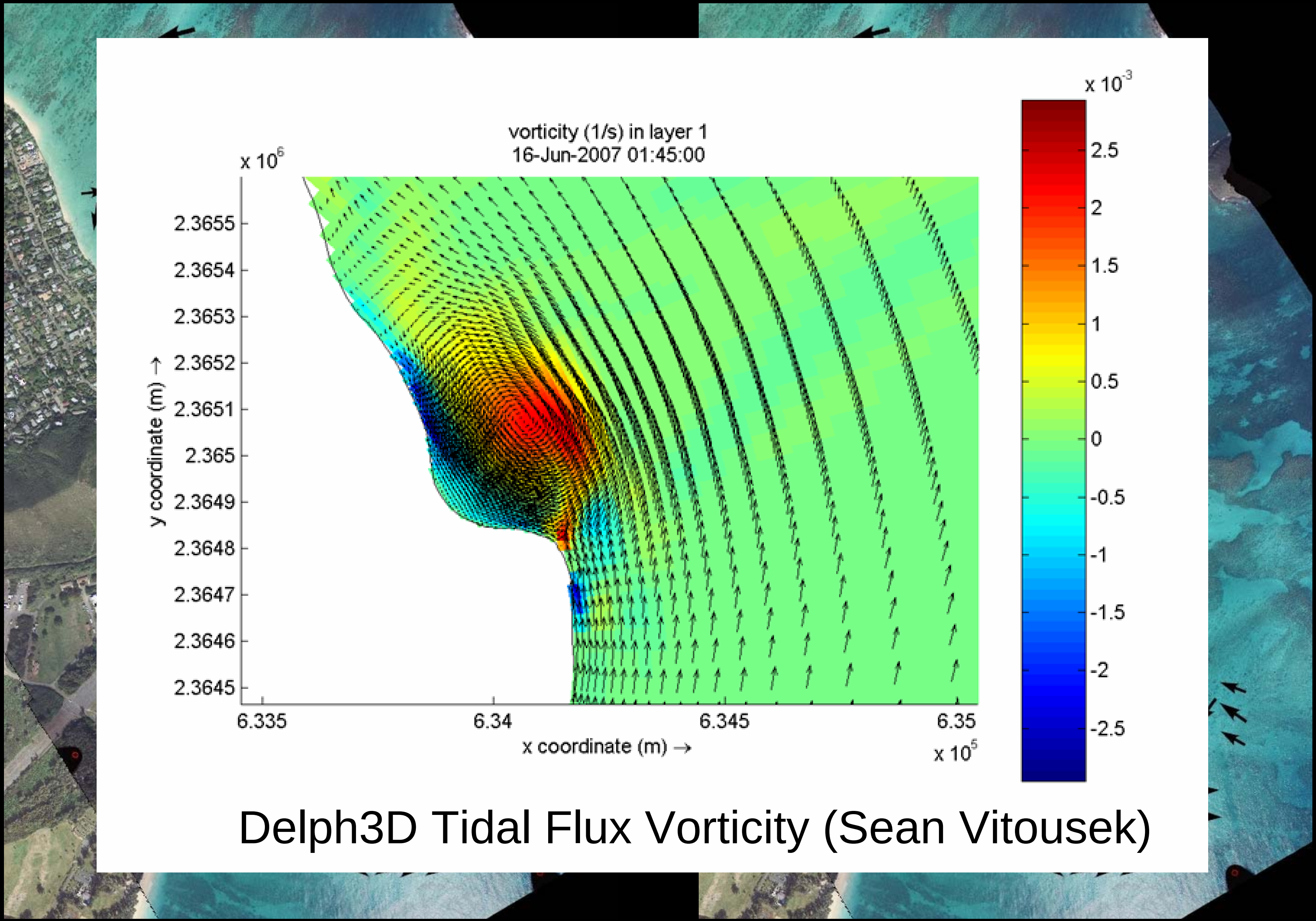


Gao Results

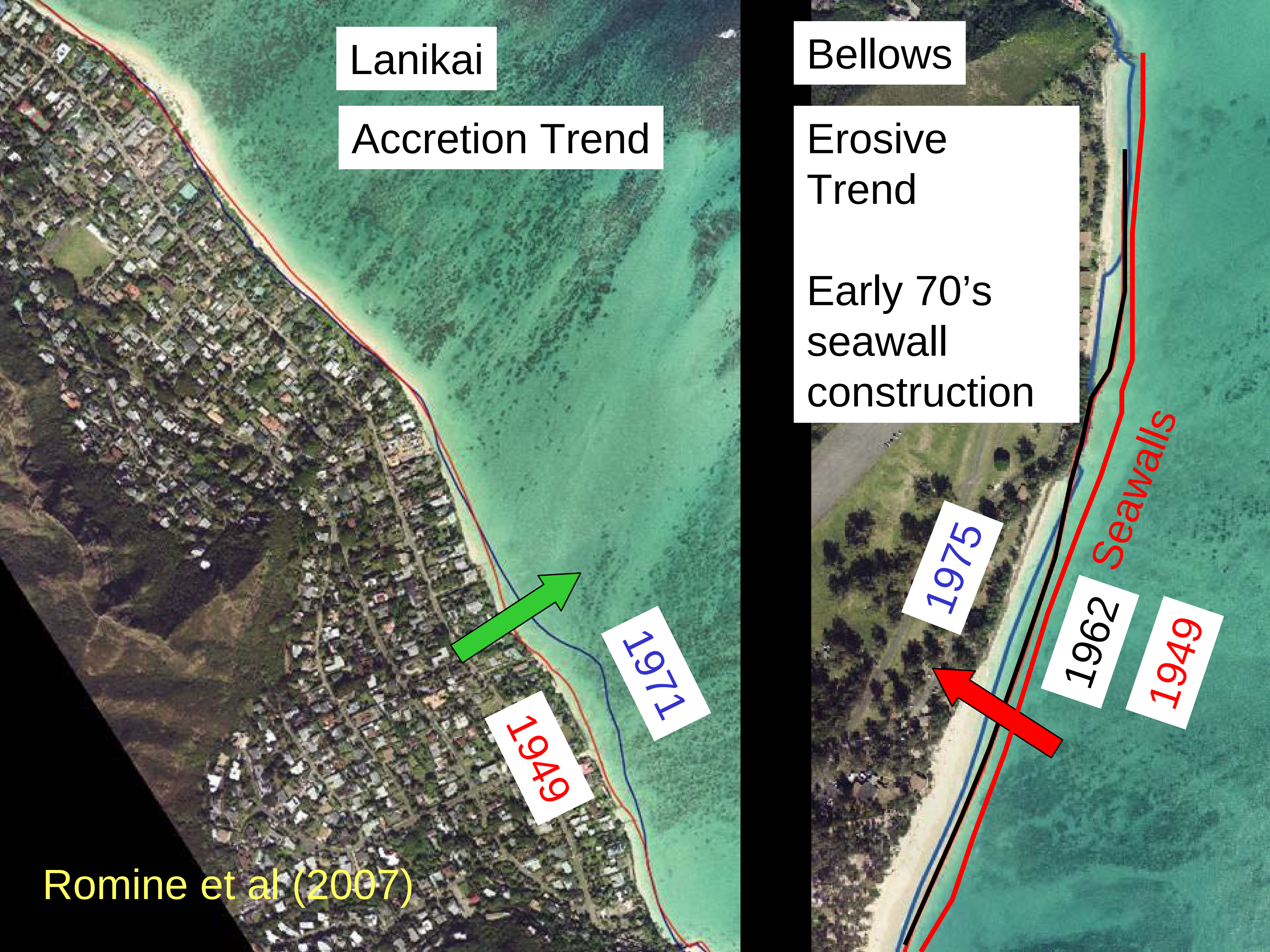


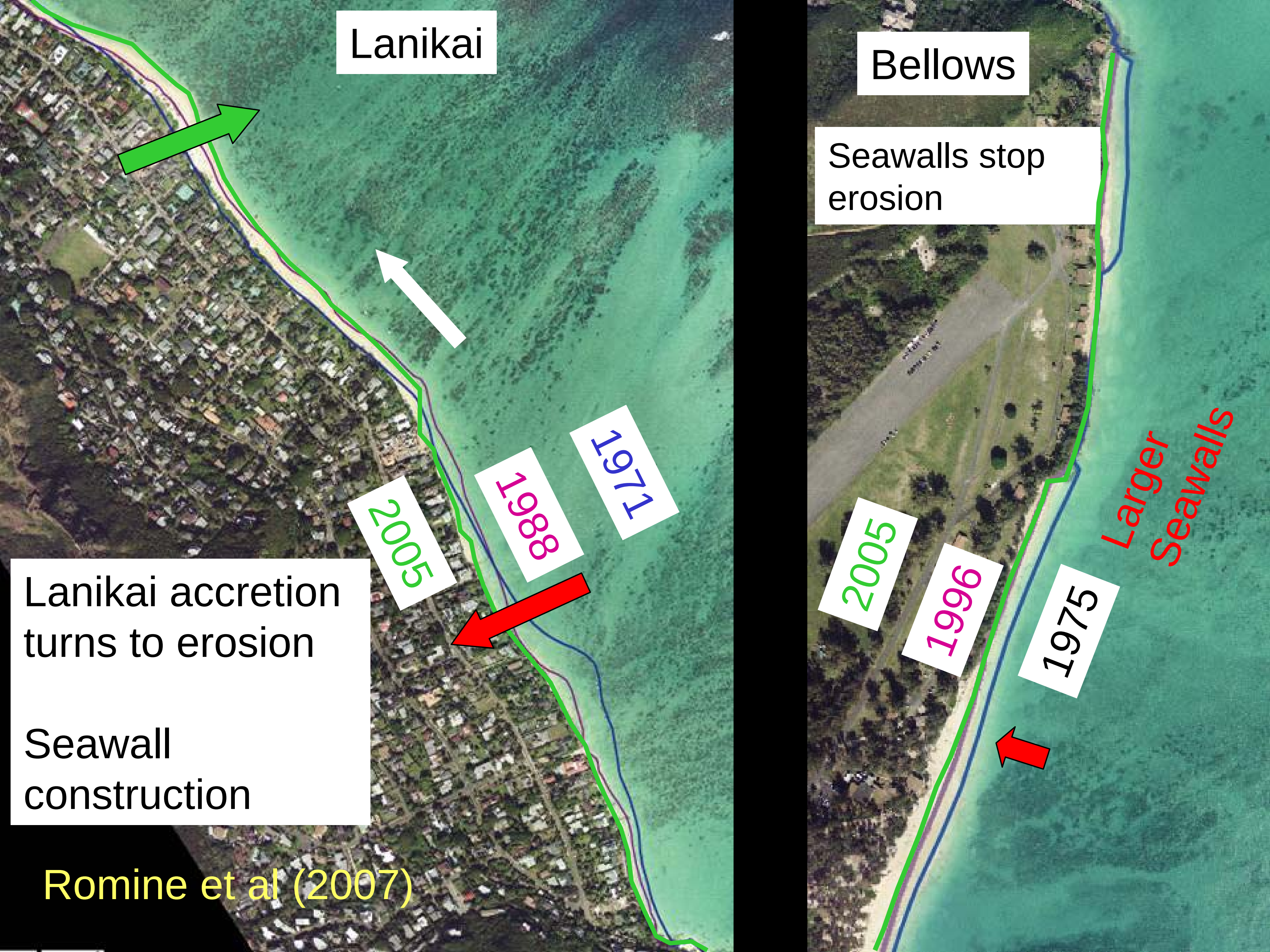
Gao Results

Interpretation



Delph3D Tidal Flux Vorticity (Sean Vitousek)


Lanikai
Accretion Trend
1971
1949
Romine et al (2007)
Bellows
Erosive Trend
Early 70's seawall construction
Seawalls
1975
1962
1949


Lanikai
1971
1988
2005
Lanikai accretion turns to erosion
Seawall construction
Romine et al (2007)
Bellows
Seawalls stop erosion
Larger Seawalls
2005
1996
1975

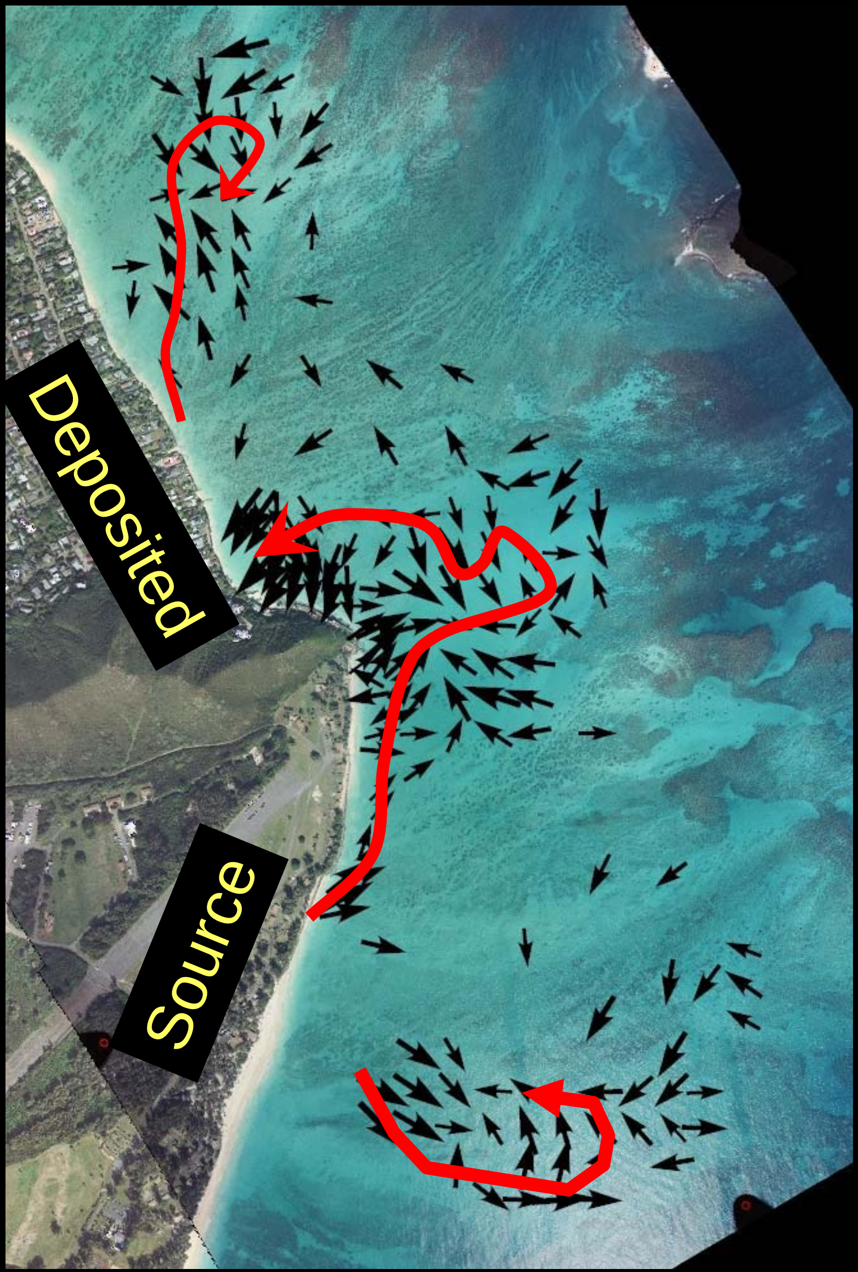
Historical Transport

1950 – 1975:
Accretion in Lanikai
Erosion in Bellows

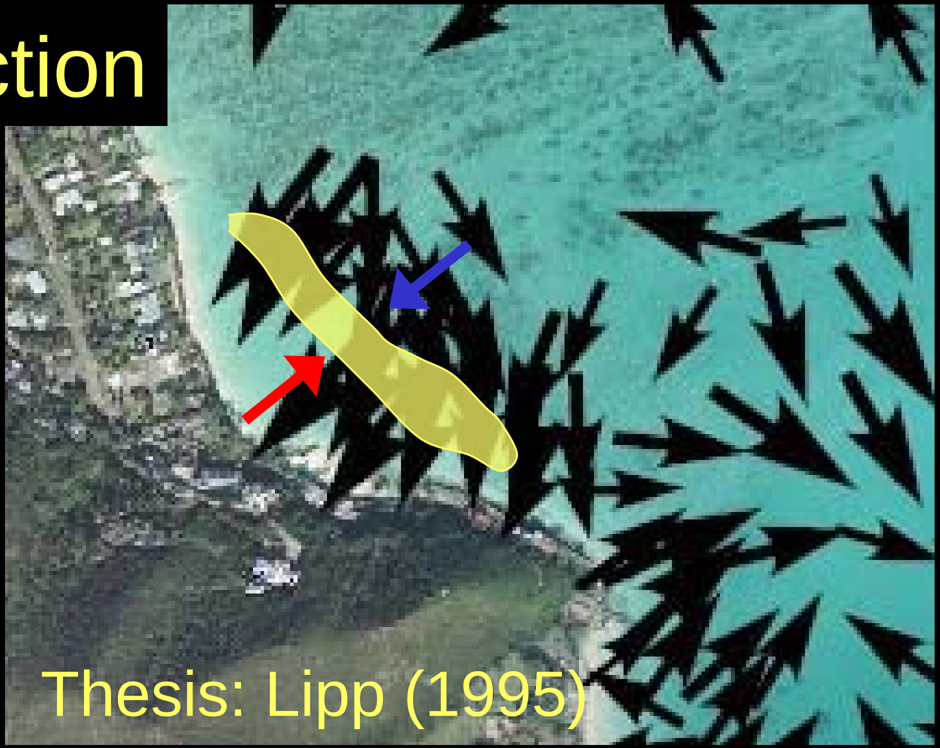
~1970 – current:
Bellows expands seawalls

1975 – current:
Heavy erosion of S. Lanikai
Slight accretion in N. Lanikai

Historical trends suggest transport results are valid.



Stronger Seawall Reflection



- Sand bar has formed off Lanikai: volume = 5000 m^3
- Sand bar distance from shore = 1/2 * mean annual wave length
- Incoming = reflected (wave energy)
- Enhanced seawall reflection & lack of sediment = sediment deficit
- Relict sedimentology of transport

Conclusion

Two methods (Roux and Gao):
similar results

Visualize 2D littoral Transport:
Bellows sand feeding Lanikai from the South

Historical and modern Observation:
Support the STA results

Successful case study for the application of STA in studying instances of coastal erosion.

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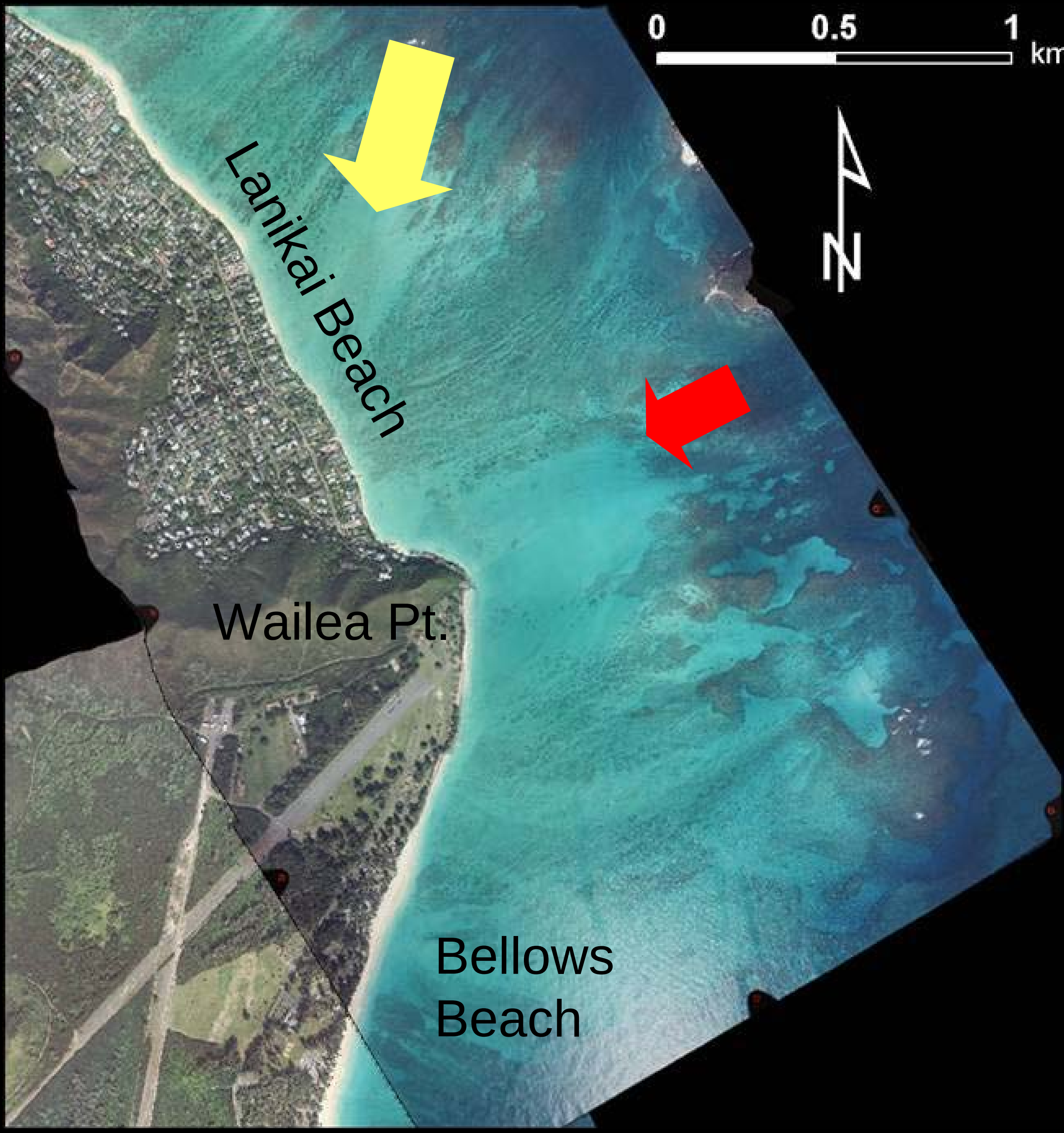
US Army Corps of Engineers

Department of Land and Natural Resources State of Hawaii

Study Area



Primary Swell:
1.2 – 3 m
E – NE
90% Summer

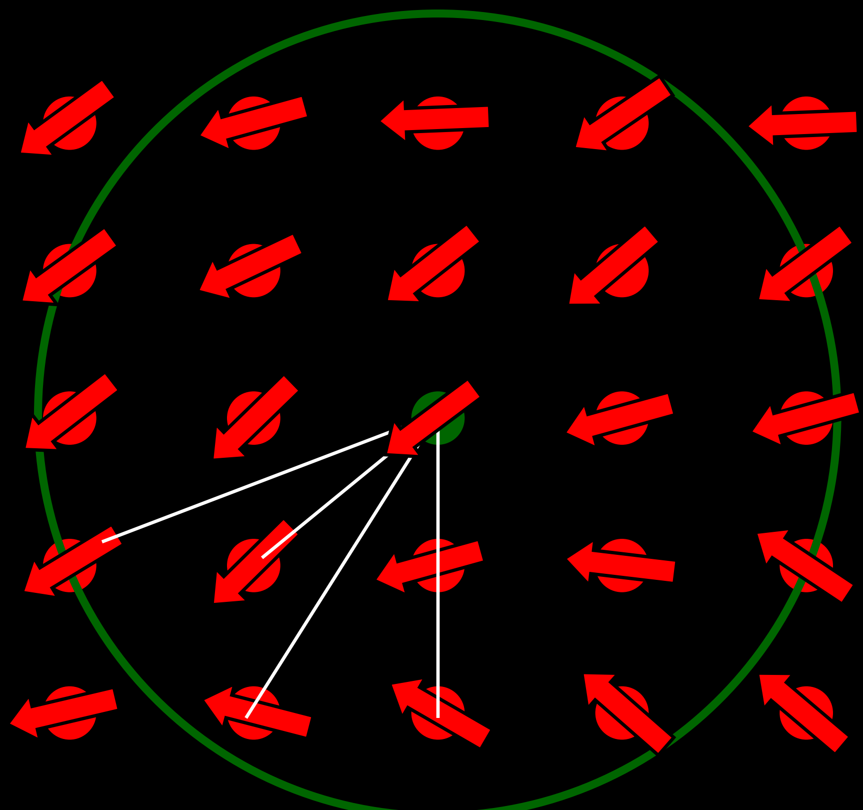
Secondary:
1.5 – 4.5 m
WNW – NNE
40% Winter

Tidal range:
Less than 1 m

Gao and Collins (1992)

- 2D approach
- Automated (Matlab)
- Search Radius

1) Points within a radius
2) Check for trend types
3) Sum valid unit vectors
4) Repeat for every point



$$R(x, y) = \sum r(x, y)_i$$

r(x,y)$_I$ = *satellite point*

R(x,y) = final vector

r(x , y)
0 , -2
-1 , -2
-1 , -1
+ -2 , -1
R(-4 , -6)

Type 1

$$mn_1 < mn_2 \quad var_1 > var_2 \quad sk_1 > sk_2$$

$$mn_e = \left(33.33 - \left[\frac{33.33}{mn_{max} - mn_{min}}(mn - mn_{min})\right]\right)$$

$$var_e = \frac{33.33}{var_{max} - var_{min}}(var - var_{min})$$

$$sk_e = \frac{33.33}{sk_{max} - sk_{min}}(sk - sk_{min})$$

Type 2

$$mn_1 > mn_2 \quad var_1 > var_2 \quad sk_1 < sk_2$$

$$mn_e = \frac{33.33}{mn_{max} - mn_{min}}(mn - mn_{min})$$

$$var_e = \frac{33.33}{var_{max} - var_{min}}(var - var_{min})$$

$$sk_e = \left(33.33 - \left[\frac{33.33}{sk_{max} - sk_{min}}(sk - sk_{min})\right]\right)$$

Type 3

$$mn_1 > mn_2 \quad var_1 > var_2 \quad sk_1 > sk_2$$

$$mn_e = \frac{33.33}{mn_{max} - mn_{min}}(mn - mn_{min})$$

$$var_e = \frac{33.33}{var_{max} - var_{min}}(var - var_{min})$$

$$sk_e = \frac{33.33}{sk_{max} - sk_{min}}(sk - sk_{min})$$

Type 4

$$mn_1 < mn_2 \quad var_1 > var_2 \quad sk_1 < sk_2$$

$$mn_e = \frac{33.33}{mn_{max} - mn_{min}}(mn - mn_{min})$$

$$var_e = \left(33.33 - \left[\frac{33.33}{var_{max} - var_{min}}(var - var_{min})\right]\right)$$

$$sk_e = \frac{33.33}{sk_{max} - sk_{min}}(sk - sk_{min})$$

raw parameters

	mn	var	sk
0	2.50	2.00	0.00
1	3.65	1.25	-0.37
2	2.57	1.95	-0.02
3	1.09	2.94	0.47
4	2.75	1.83	-0.08

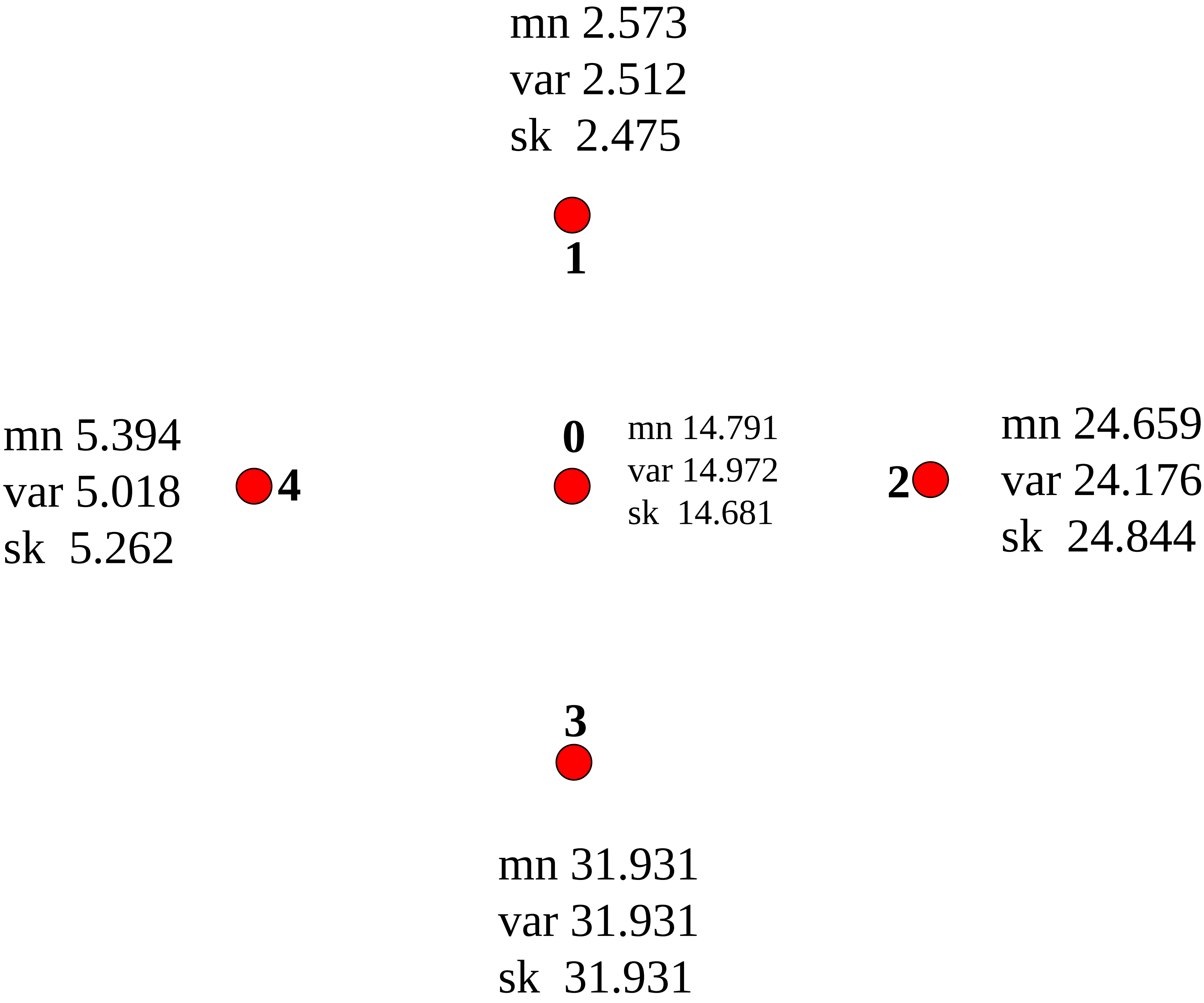
$$mn_e = \left(33.33 - \left[\frac{33.33}{mn_{max} - mn_{min}}\left(mn - mn_{min}\right)\right]\right)$$

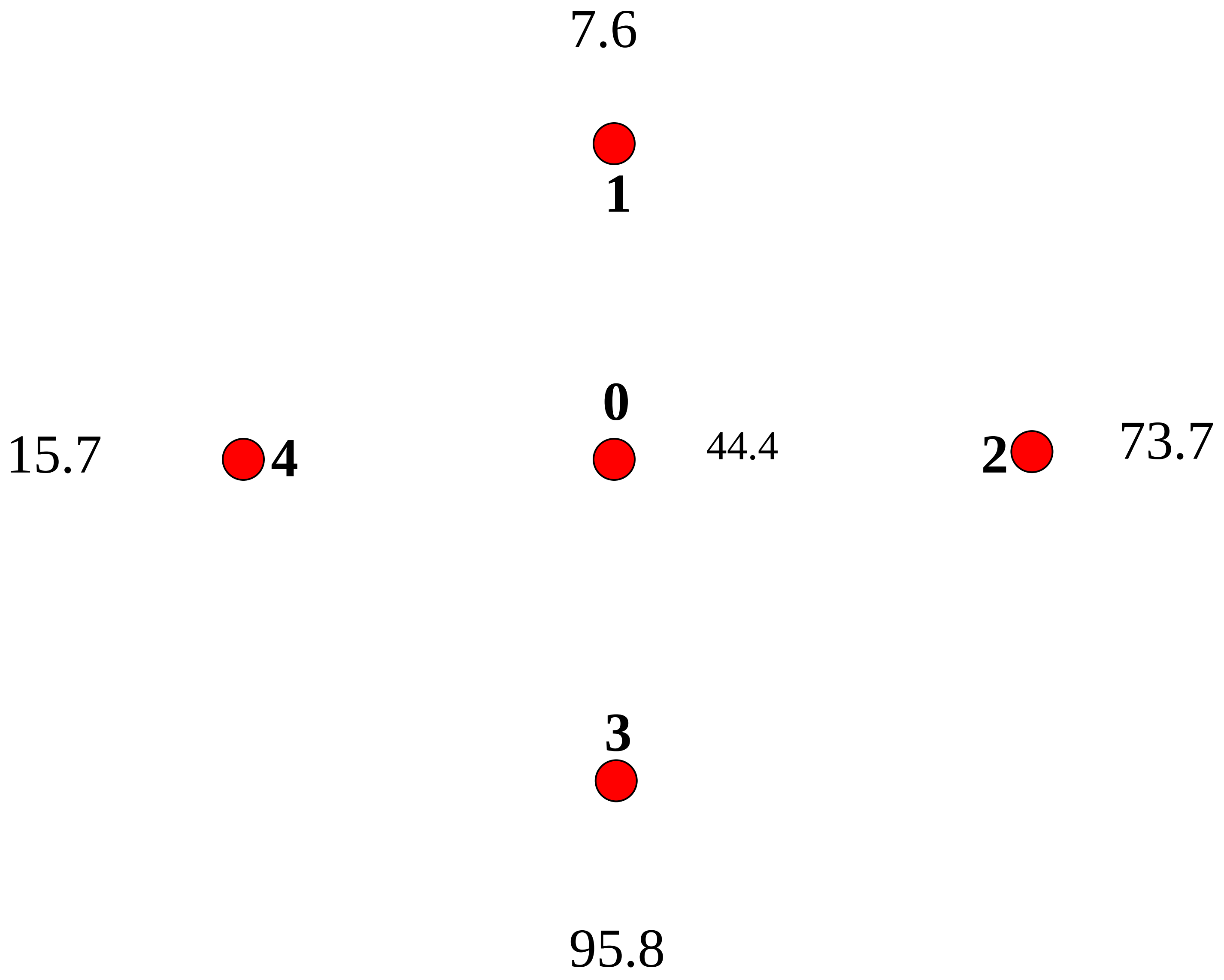
$$var_e = \frac{33.33}{var_{max} - var_{min}}\left(var - var_{min}\right)$$

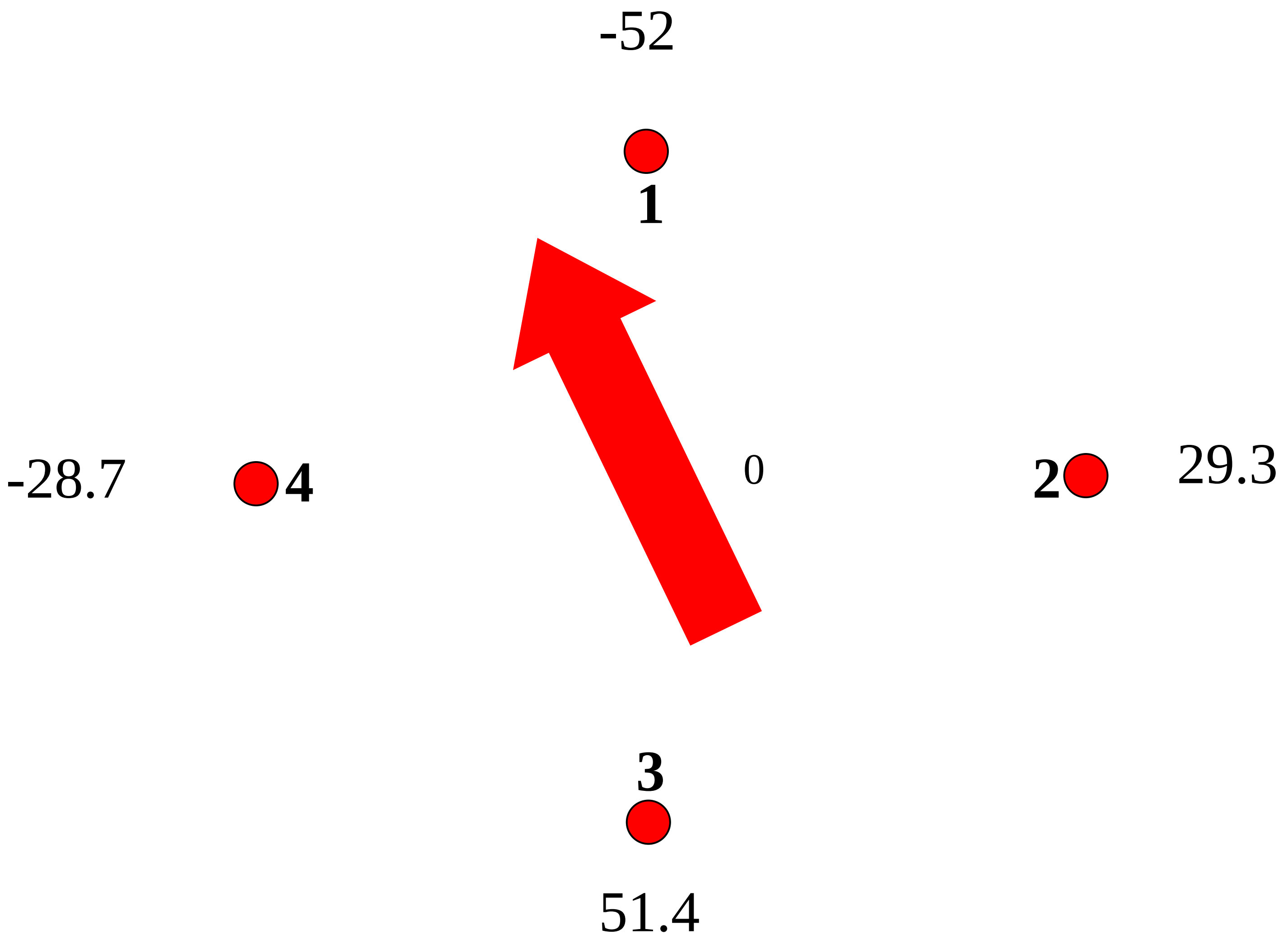
$$sk_e = \frac{33.33}{sk_{max} - sk_{min}}\left(sk - sk_{min}\right)$$

relative values

	mn	var	sk
0	14.791	14.972	14.681
1	0.00	0.00	0.00
2	14.061	13.805	13.888
3	33.33	33.33	33.33
4	11.718	11.439	11.507


mn 2.573
var 2.512
sk 2.475
1
mn 5.394
var 5.018
sk 5.262
4
0
mn 14.791
var 14.972
sk 14.681
2
mn 24.659
var 24.176
sk 24.844
3
mn 31.931
var 31.931
sk 31.931


7.6
1
0
15.7
4
44.4
2
73.7
3
95.8



$$\text{Magnitude} = \sqrt{\left[\sum\left(f\ \sin\phi\right)\right]^2 + \left[\sum\left(f\ \cos\phi\right)\right]^2} + 1 - \frac{1}{\sqrt{2}\sin\left(45 + \text{vec mean}\right)}$$