The GEM Faulted Earth Subduction Interface Characterisation Project and SLAB 2

GLOBAL EARTHQUAKE MODEL
working together to assess risk

Ken Gledhill

GNS Science, New Zealand

GNS SCIENCE
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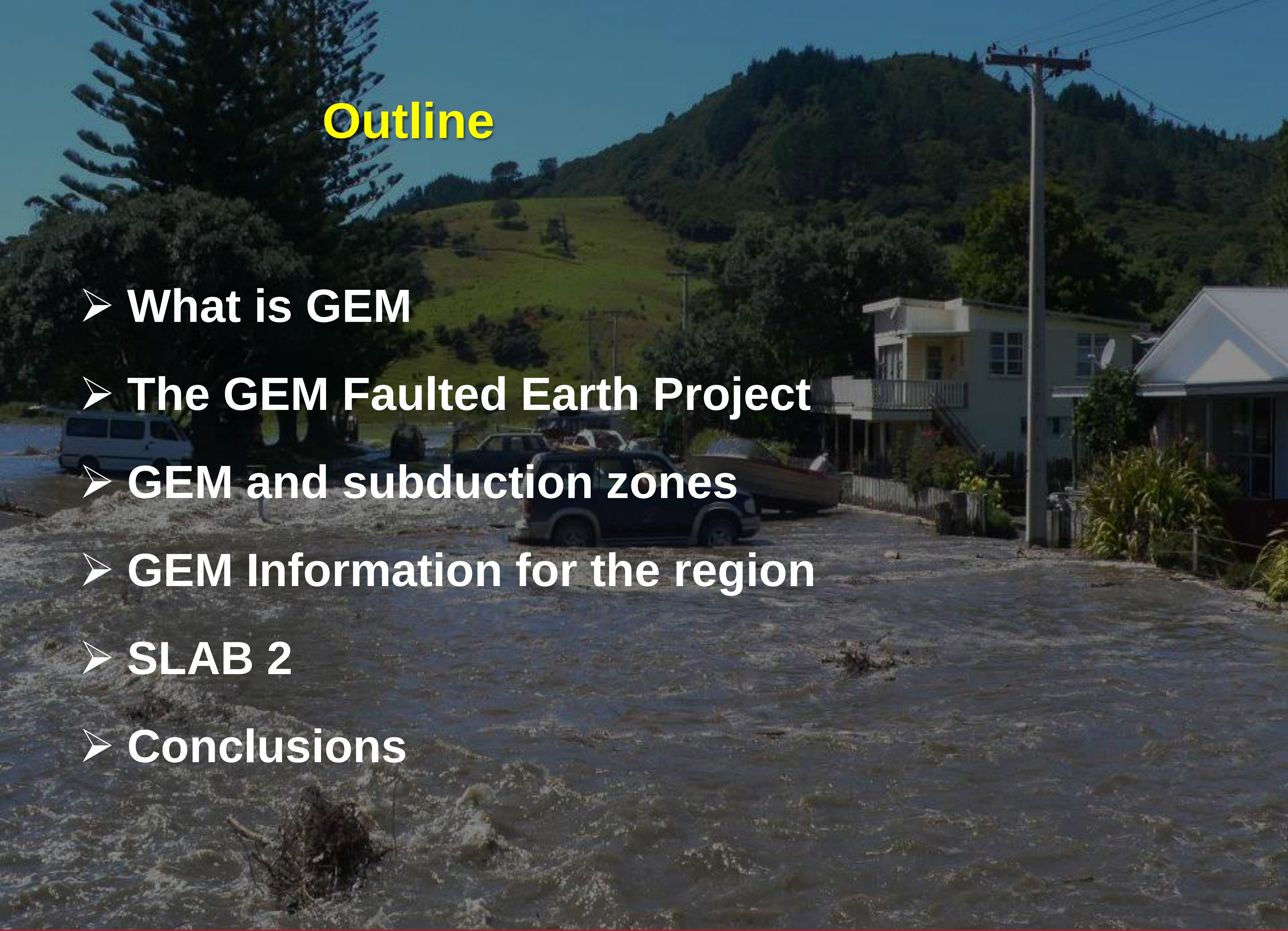


Outline

- What is GEM
- The GEM Faulted Earth Project
- GEM and subduction zones
- GEM Information for the region
- SLAB 2
- Conclusions

GEM

GLOBAL EARTHQUAKE MODEL

Working together to assess risk

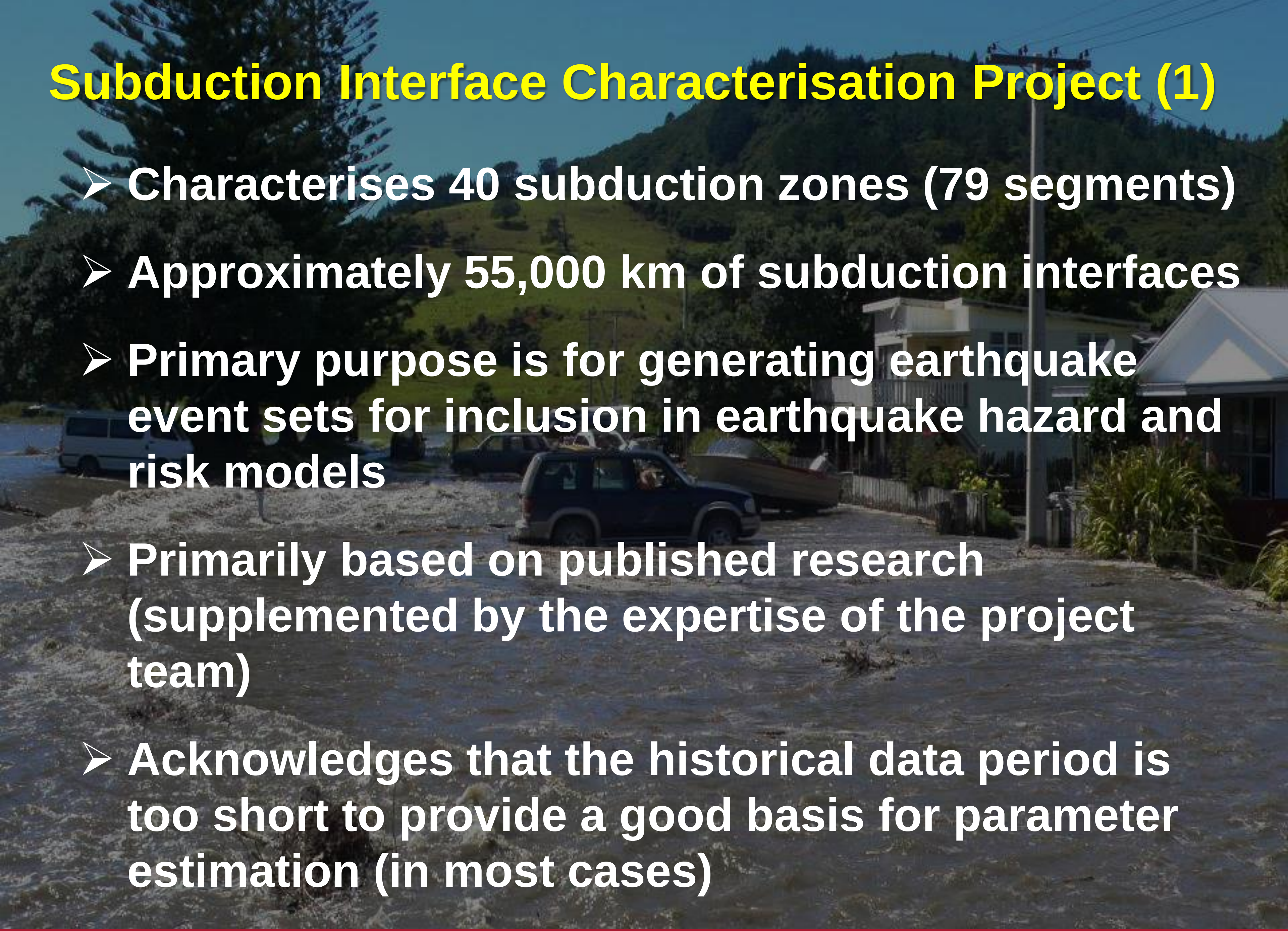
The GEM Faulted Earth Subduction Interface Characterisation Project

GEM Faulted Earth Global Component Project

Part of deliverable: 7 Completion of fault sources--subduction interfaces

Version: 2.0

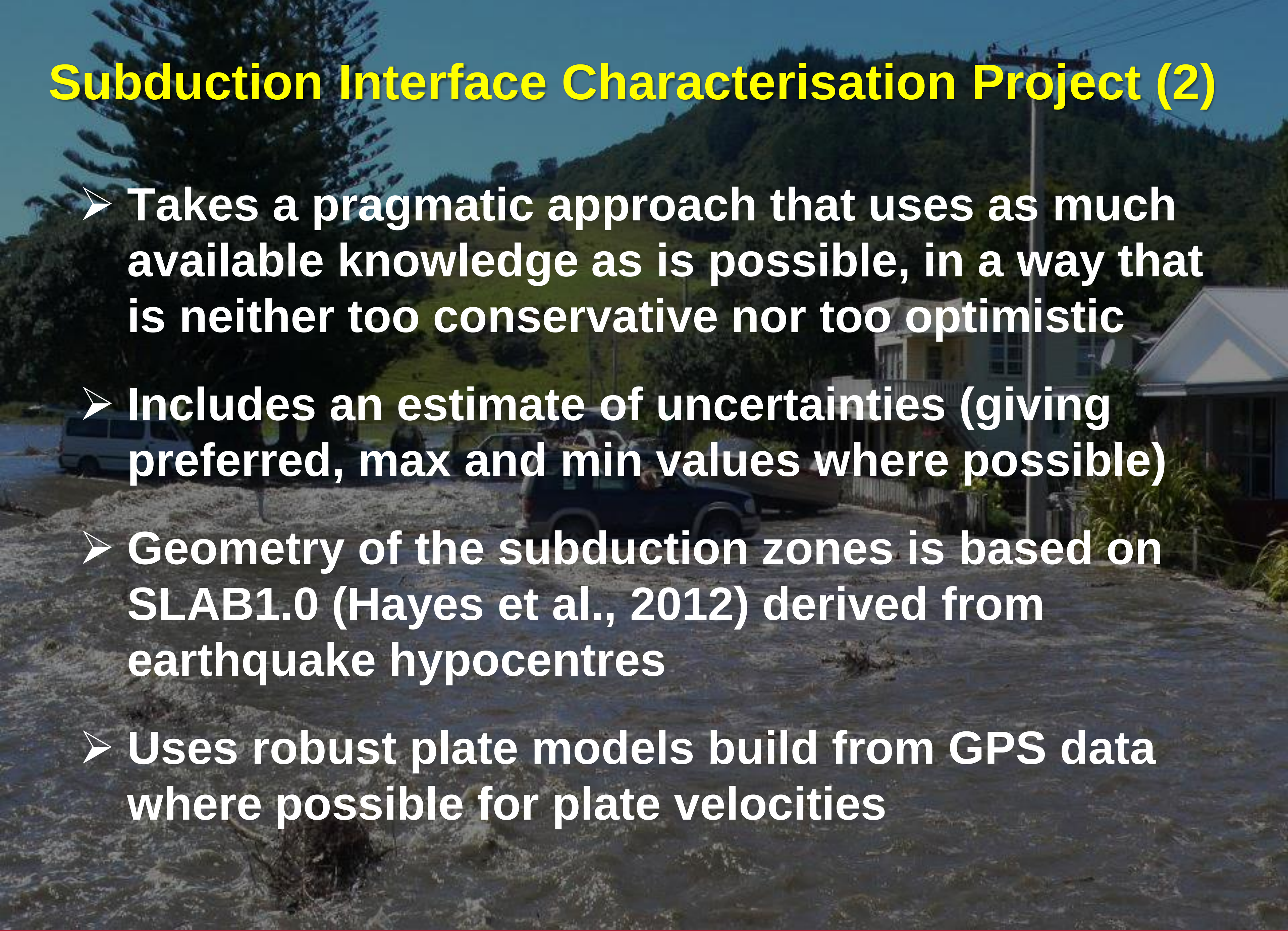
K. Berryman, L. Wallace, G. Hayes, P. Bird, K. Wang, R. Basili, T. Lay, M. Pagani, R. Stein, T. Sagiya, C. Rubin, S. Barreintos, C. Kreemer, N. Litchfield, M. Stirling, K. Gledhill, K. Haller, C. Costa



Subduction Interface Characterisation Project (1)

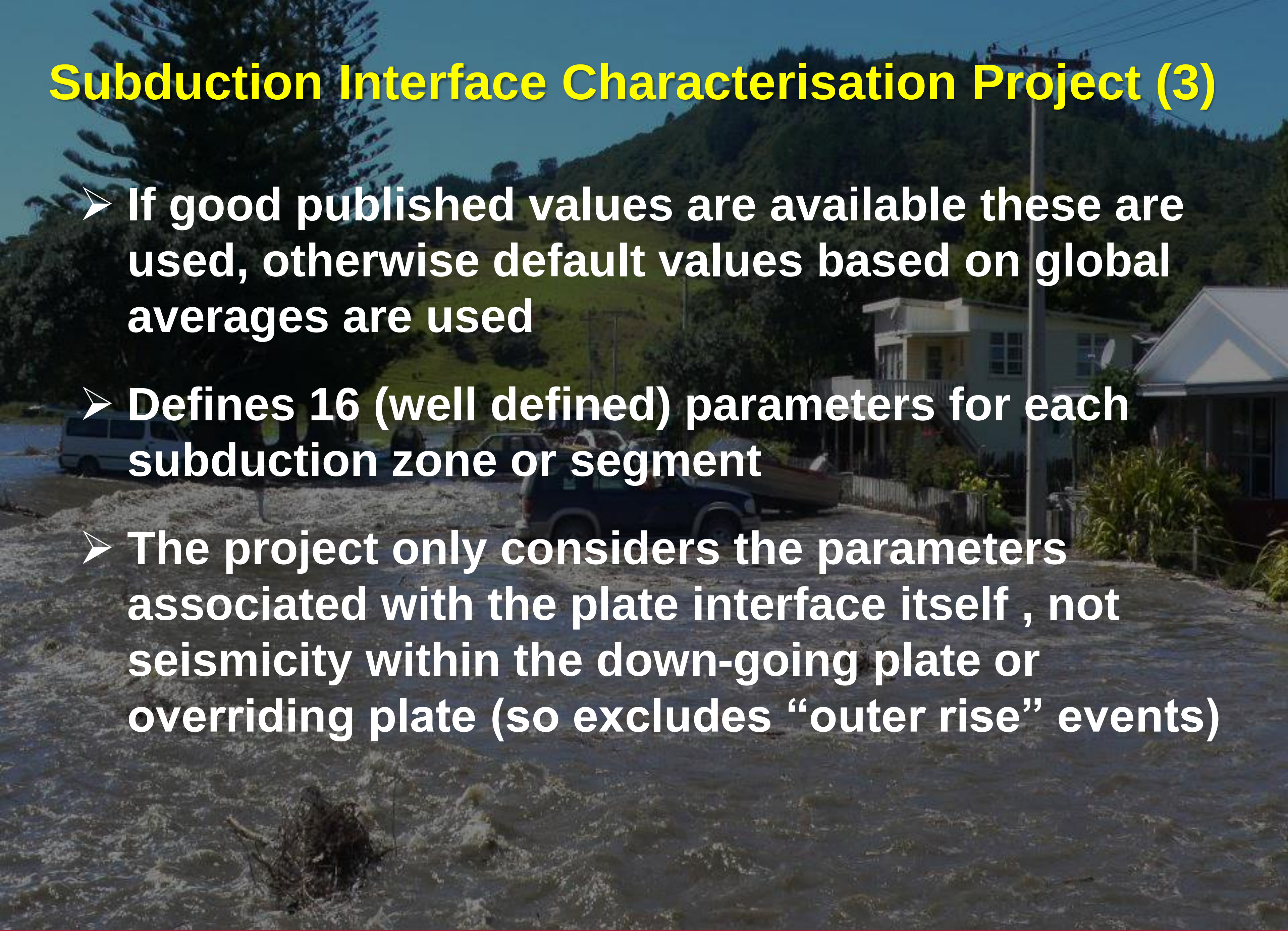
- Characterises 40 subduction zones (79 segments)
- Approximately 55,000 km of subduction interfaces
- Primary purpose is for generating earthquake event sets for inclusion in earthquake hazard and risk models
- Primarily based on published research (supplemented by the expertise of the project team)
- Acknowledges that the historical data period is too short to provide a good basis for parameter estimation (in most cases)

Subduction Interface Characterisation Project (2)

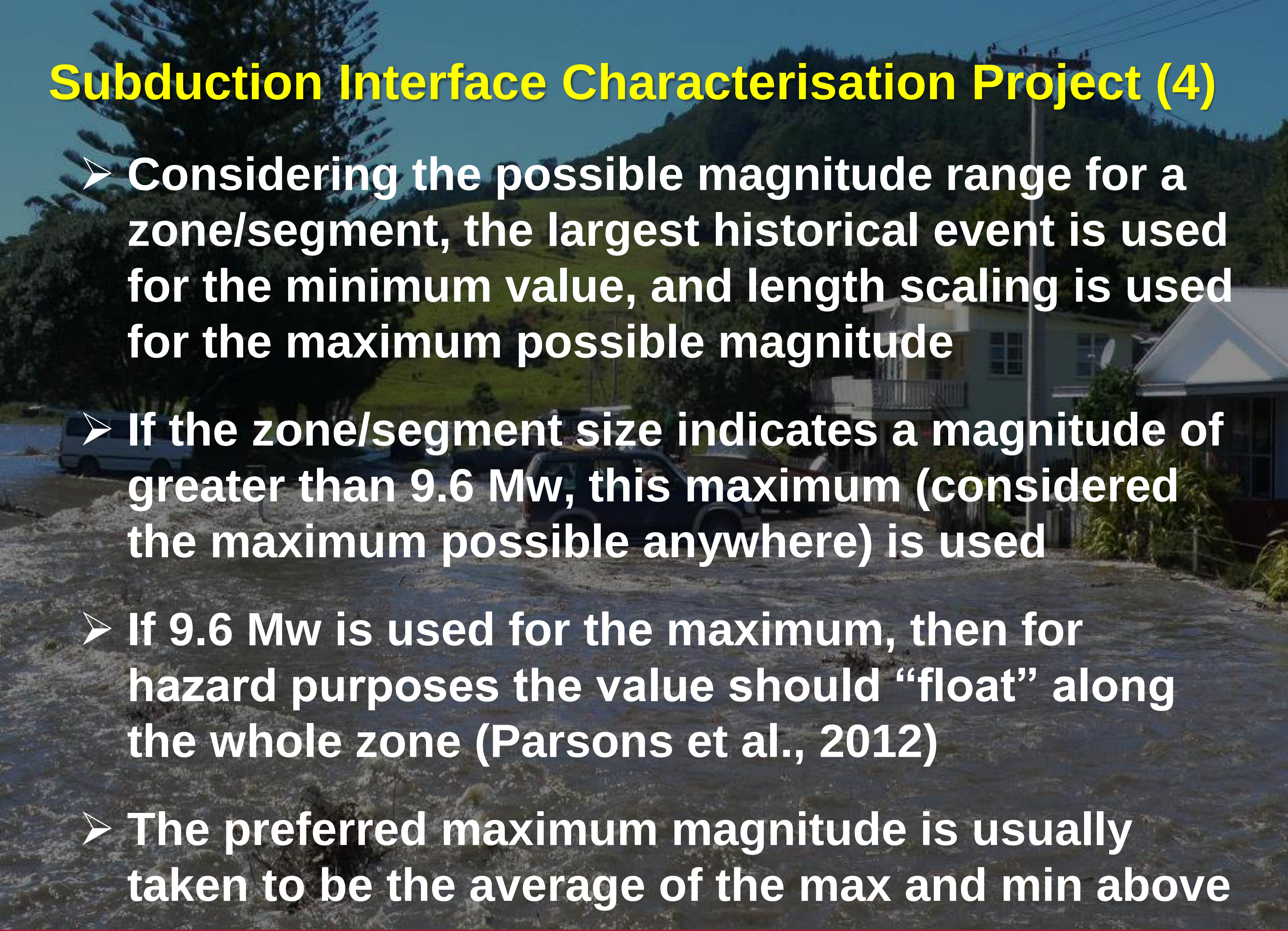


- **Takes a pragmatic approach that uses as much available knowledge as is possible, in a way that is neither too conservative nor too optimistic**
- **Includes an estimate of uncertainties (giving preferred, max and min values where possible)**
- **Geometry of the subduction zones is based on SLAB1.0 (Hayes et al., 2012) derived from earthquake hypocentres**
- **Uses robust plate models build from GPS data where possible for plate velocities**

Subduction Interface Characterisation Project (3)

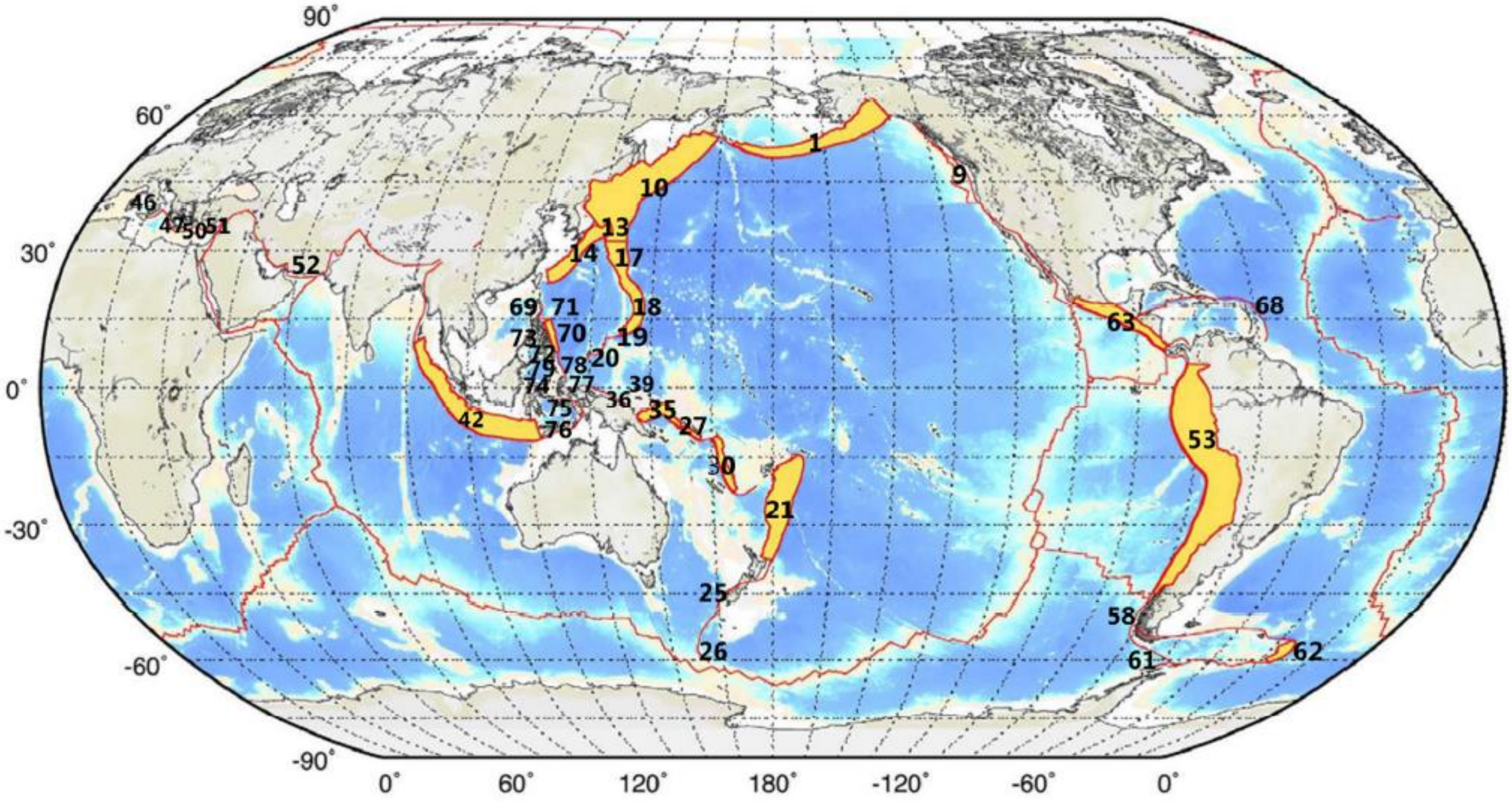


- If good published values are available these are used, otherwise default values based on global averages are used
- Defines 16 (well defined) parameters for each subduction zone or segment
- The project only considers the parameters associated with the plate interface itself , not seismicity within the down-going plate or overriding plate (so excludes “outer rise” events)



Subduction Interface Characterisation Project (4)

- Considering the possible magnitude range for a zone/segment, the largest historical event is used for the minimum value, and length scaling is used for the maximum possible magnitude
- If the zone/segment size indicates a magnitude of greater than 9.6 Mw, this maximum (considered the maximum possible anywhere) is used
- If 9.6 Mw is used for the maximum, then for hazard purposes the value should “float” along the whole zone (Parsons et al., 2012)
- The preferred maximum magnitude is usually taken to be the average of the max and min above


90°
60°
30°
0°
-30°
-60°
-90°
0°
60°
120°
180°
-120°
-60°
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1
9
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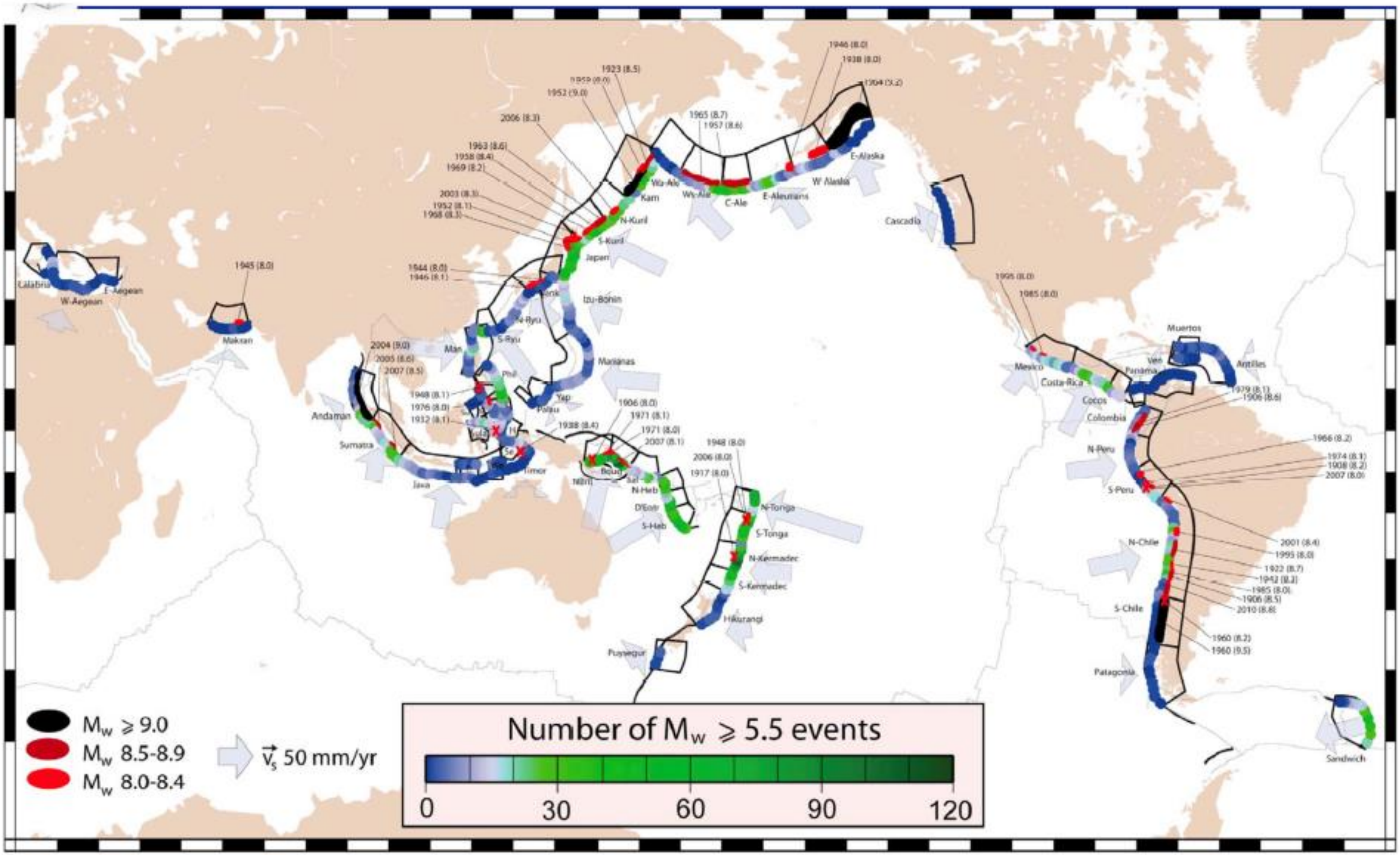
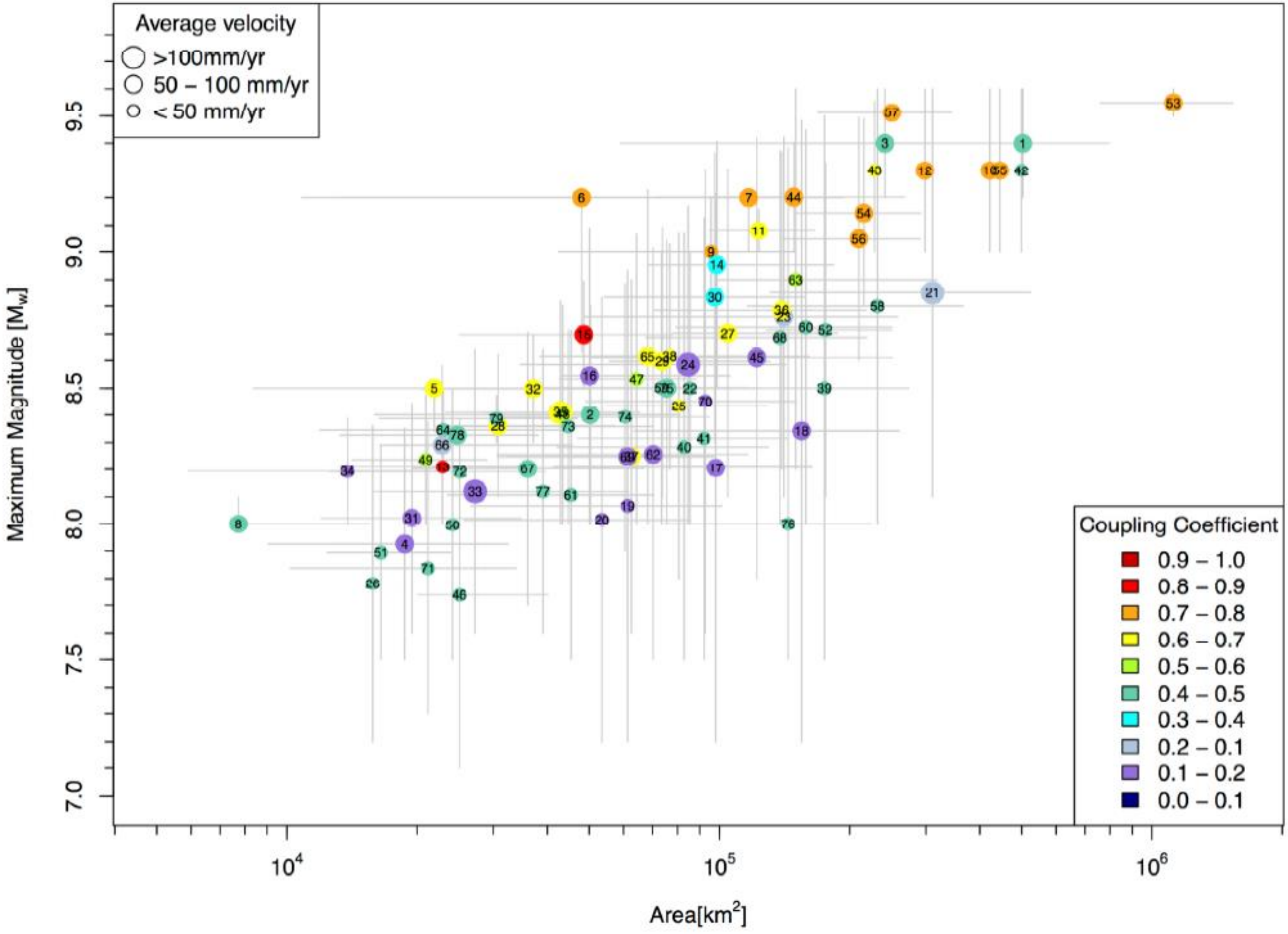

Calabria
W-Aegean
E-Aegean
1945 (8.0)
Makran
2006 (8.3)
1923 (8.5)
1959 (8.0)
1952 (9.0)
1963 (8.6)
1958 (8.4)
1969 (8.2)
2003 (8.3)
1952 (8.1)
1968 (8.3)
1944 (8.0)
1946 (8.1)
1965 (8.7)
1957 (8.6)
1946 (8.0)
1938 (8.0)
1964 (9.2)
Wa-Ale
Wc-Ale
C-Ale
E-Aleutians
W Alaska
E-Alaska
Kam
N-Kuril
S-Kuril
Japan
Nank
Izu-Bonin
N-Ryu
S-Ryu
Man
Marianas
Phil
Yap
Palau
Cascadia
2004 (9.0)
2005 (8.6)
2007 (8.5)
Andaman
Sumatra
Java
Timor
Se
1948 (8.1)
1976 (8.0)
1932 (8.1)
1938 (8.4)
1906 (8.0)
1971 (8.1)
1971 (8.0)
2007 (8.1)
NBrit
Boug
Sol
N-Heb
D'Entr
S-Heb
1948 (8.0)
2006 (8.0)
1917 (8.0)
N-Tonga
S-Tonga
N-Kermadec
S-Kermadec
Hikurangi
Puysegur
1995 (8.0)
1985 (8.0)
Mexico
Costa-Rica
Cocos
Colombia
Ven
Panama
Muertos
Antilles
1979 (8.1)
1906 (8.6)
N-Peru
S-Peru
1966 (8.2)
1974 (8.1)
1908 (8.2)
2007 (8.0)
N-Chile
S-Chile
2001 (8.4)
1995 (8.0)
1922 (8.7)
1942 (8.2)
1985 (8.0)
1906 (8.5)
2010 (8.8)
1960 (8.2)
1960 (9.5)
Patagonia
Sandwich
$M_w \geqslant 9.0$
M_w 8.5-8.9
M_w 8.0-8.4
$\vec{v}_s$ 50 mm/yr
Number of $M_w \geqslant 5.5$ events
0
30
60
90
120


Average velocity
>100mm/yr
50 – 100 mm/yr
< 50 mm/yr
Maximum Magnitude [M_w]
9.5
9.0
8.5
8.0
7.5
7.0
Area[km^2]
10^4
10^5
10^6
Coupling Coefficient
0.9 – 1.0
0.8 – 0.9
0.7 – 0.8
0.6 – 0.7
0.5 – 0.6
0.4 – 0.5
0.3 – 0.4
0.2 – 0.1
0.1 – 0.2
0.0 – 0.1
53
57
3
1
40
12
10
55
42
6
7
44
54
11
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26
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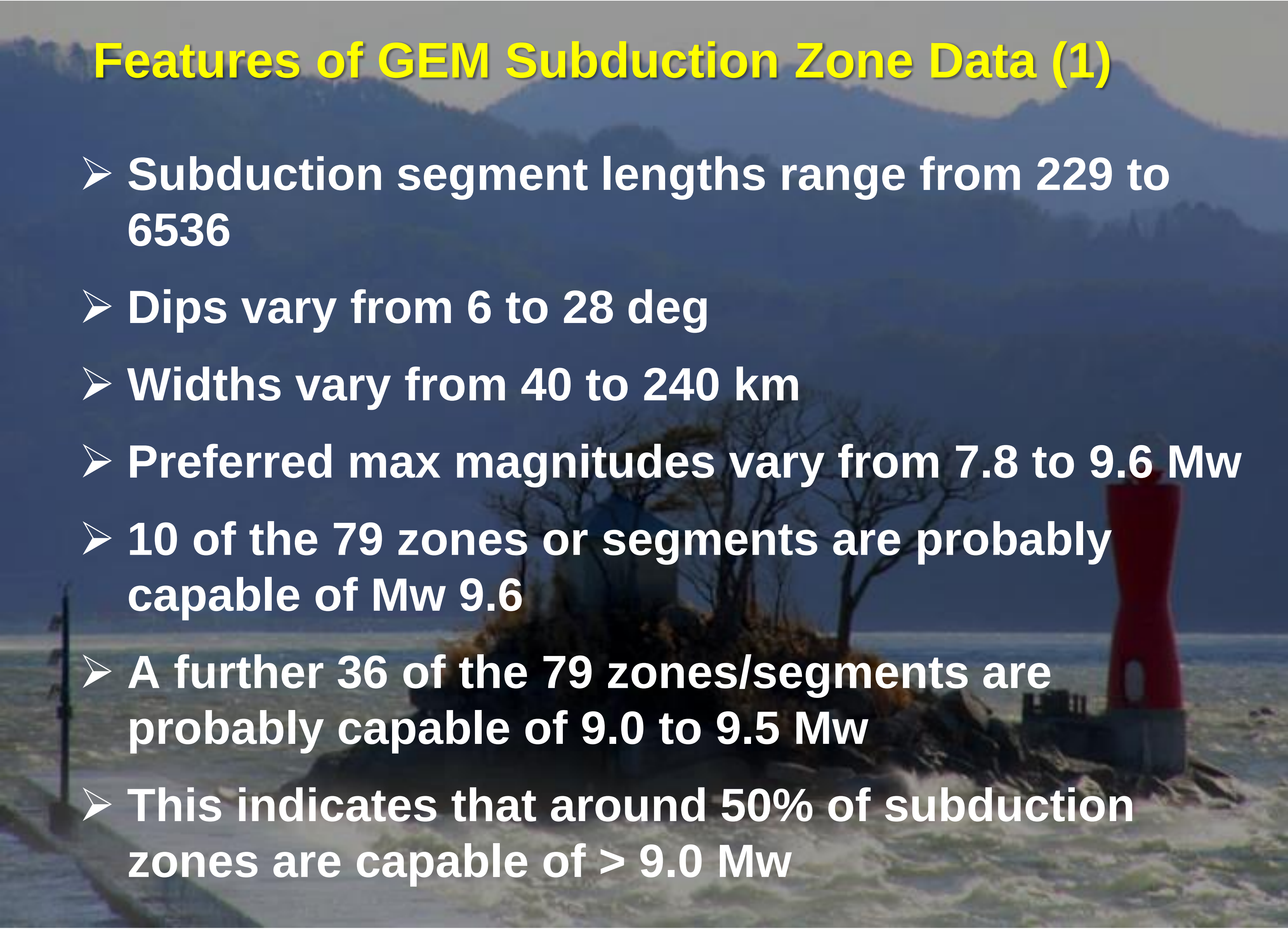
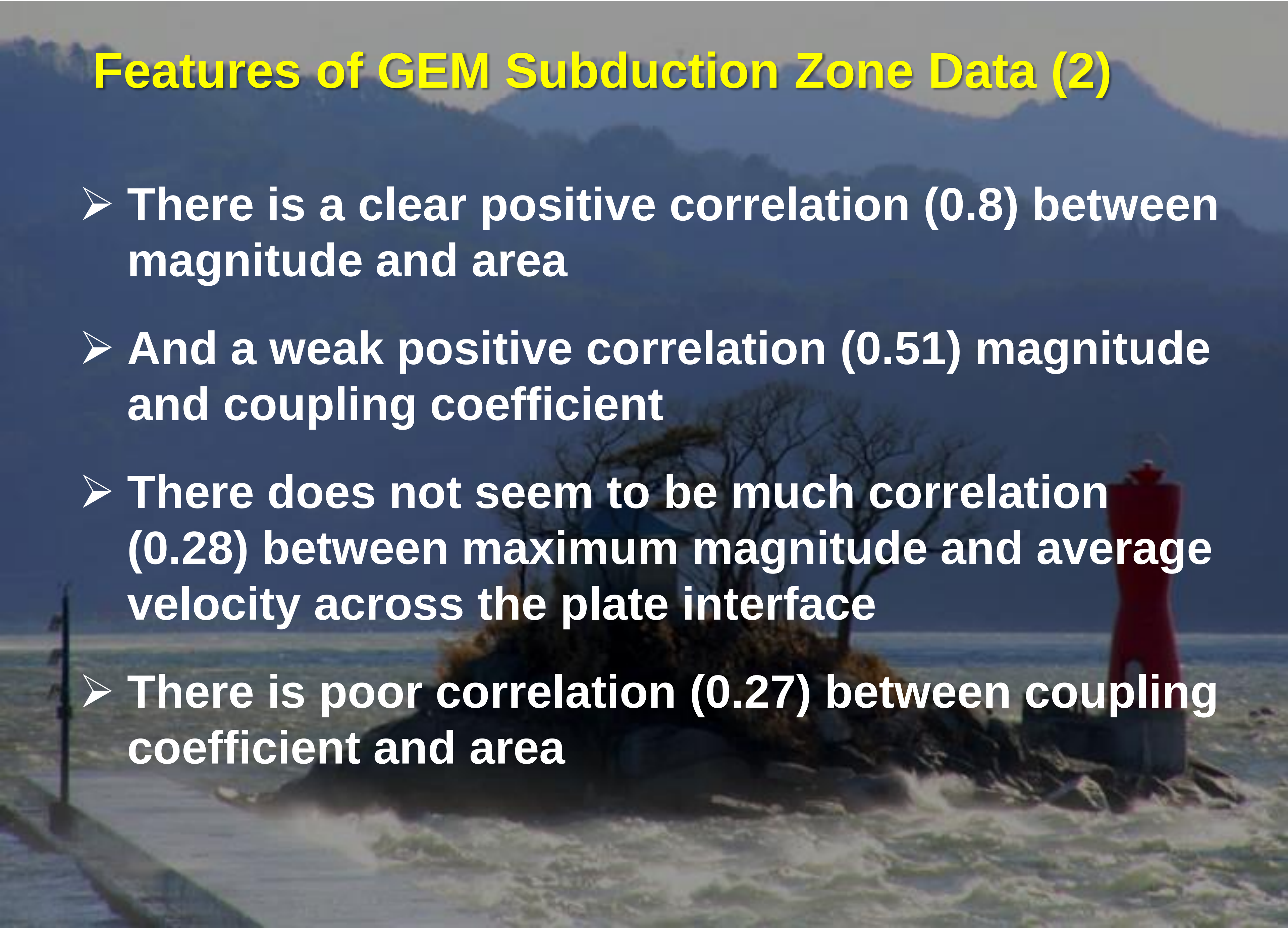


Features of GEM Subduction Zone Data (1)

- Subduction segment lengths range from 229 to 6536
- Dips vary from 6 to 28 deg
- Widths vary from 40 to 240 km
- Preferred max magnitudes vary from 7.8 to 9.6 Mw
- 10 of the 79 zones or segments are probably capable of Mw 9.6
- A further 36 of the 79 zones/segments are probably capable of 9.0 to 9.5 Mw
- This indicates that around 50% of subduction zones are capable of > 9.0 Mw

Features of GEM Subduction Zone Data (2)



- There is a clear positive correlation (0.8) between magnitude and area
- And a weak positive correlation (0.51) magnitude and coupling coefficient
- There does not seem to be much correlation (0.28) between maximum magnitude and average velocity across the plate interface
- There is poor correlation (0.27) between coupling coefficient and area

Zone	Relative Velocity (mm/year)	Length (km)	Width (km)	Coupling coefficient	Mmax	b-value
New Britain Trench	49-160	660	65 (35-99)	0.7 (0.6-0.8)	8.4 (8.0-8.8)	0.9 (0.6 -1.2)
Solomons Trench	88-91	1460	72 (53-129)	0.7 (0.6-0.8)	8.7 (8.1-9.3)	0.9 (0.6 -1.2)
New Hebrides (Vanuatu) Trench	46-95	1923	51 (33-74)	0.5 (0.3-0.7)	8.3 (8-9.3)	0.9 (0.6 -1.2)

No	Subduction Zone	Segment	Coupling coefficient - min	Coupling coefficient - max	Mmax - pref	Mmax - min	Mmax - max	B-value - pref	B-value - min	B-value - max
27	**Solomon**	**Whole Margin**	**0.60**	**0.80**	**8.70**	**8.10**	**9.31**	**0.90**	**0.60**	**1.20**
28	Solomon	Northwest	0.60	0.80	8.36	8.10	8.62	0.90	0.60	1.20
29	Solomon	Southeast	0.60	0.80	8.60	8.10	9.09	0.90	0.60	1.20
30	**New Hebrides**	**Whole Margin**	**0.27**	**0.73**	**8.83**	**8.30**	**9.37**	**0.90**	**0.60**	**1.20**
31	New Hebrides	North	0.15	0.70	8.02	7.60	8.44	0.90	0.60	1.20
32	New Hebrides	Central	0.6	0.80	8.50	8.30	8.70	0.90	0.60	1.20
33	New Hebrides	South	0.15	0.70	8.12	7.60	8.64	0.90	0.60	1.20
34	New Hebrides	Matthew-Hunter	0.15	0.70	8.19	8.00	8.39	0.90	0.60	1.20
35	**New Britain**		0.60	0.80	8.41	8.00	8.82	0.90	0.60	1.20

B.16 Northwest Solomon

This segment comprises the eastern end of the New Britain Trench adjacent to Bougainville, and north of the triple junction between the Woodlark, Pacific, and Australian Plates. Clusters of Mw 7.3-8.1 earthquakes have been observed in the northwest Solomons approximately every 30 years for the last century (Lay and Kanamori, 1980). More recently, the 2007 Mw 8.1 earthquake ruptured the southern half of this segment (as well as the northern part of the San Cristobal Trench, south of the triple junction.) We define a minimum Mmax of 8.1, consistent with historical seismicity. We use relatively high coupling coefficients for this subduction source (0.7 ± 0.1) based on the large (Mw >8.0) that occur along this trench on a relatively regular basis.

B.17 Southeast Solomon

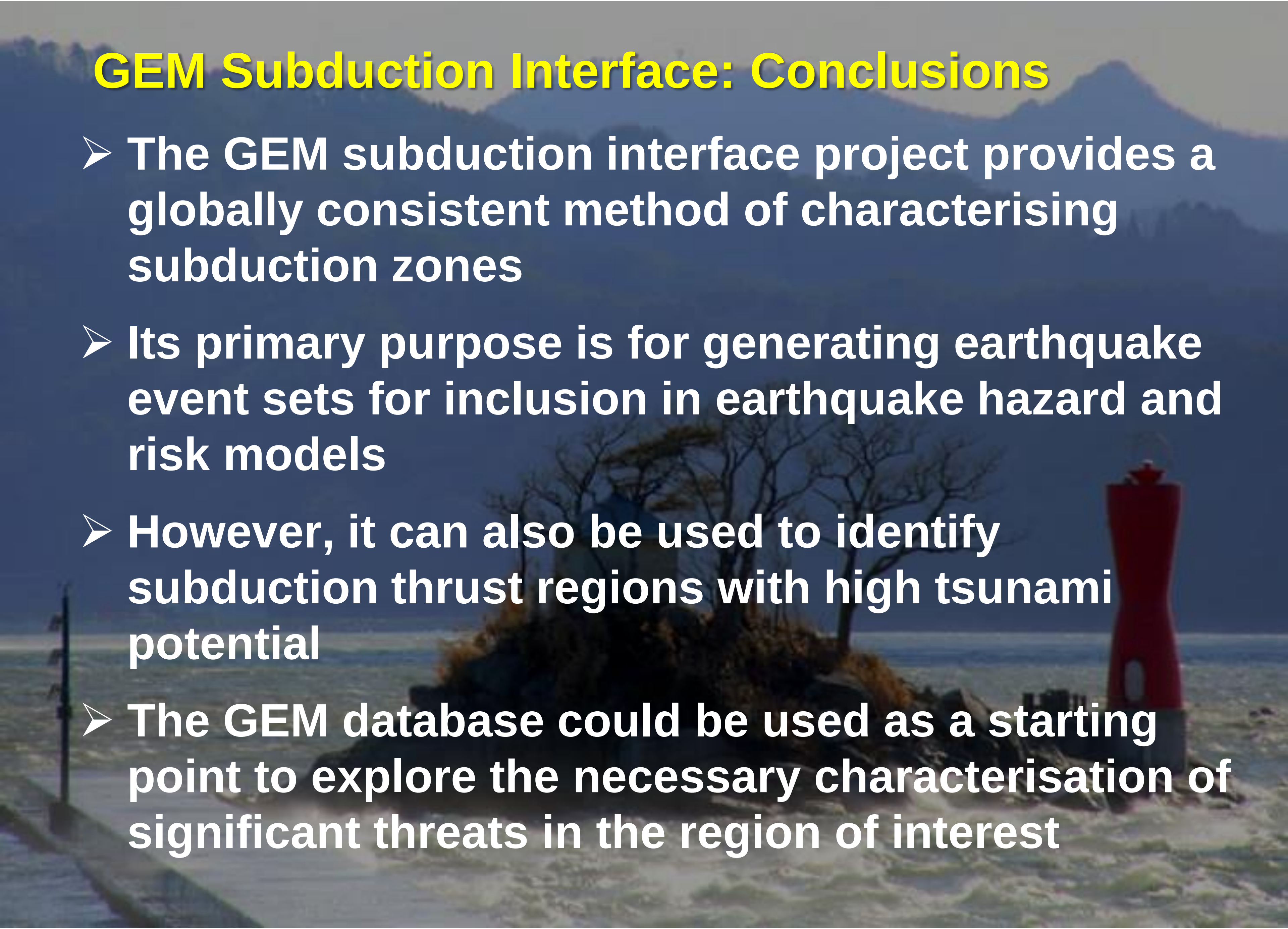
This segment comprises the San Cristobal Trench, east of the triple junction between the Woodlark, Pacific, and Australian Plates. The eastern boundary of this source is where a 90° turn is taken in the orientation of the trench near Vanuatu. Overall, we use similar values for this subduction segment to those used for the northwest Solomons. Possibilities for simultaneous rupture across northwest and southeast Solomons segments must also be accounted for, as was observed to occur during the 2007 Mw 8.1 earthquake (Taylor et al., 2008a).

B.19 New Britain

We consider the western end of the New Britain Trench as the point where the Ramu Markham Fault goes offshore near Lae, Papua New Guinea. The eastern end is the cusp in the New Britain Trench where it bends strongly to the southeast near 153°E. Convergence rates at the New Britain Trench reflect motion of the Woodlark Plate relative to the South Bismarck Plate using poles of rotation from Wallace et al. (2004b). This subduction zone is very seismically active, with frequent moderate to large events. The largest historical subduction interface earthquakes that have occurred on the New Britain Trench have been Mw ~8.0 (e.g., Park and Mori, 2007), so we use this as our minimum Mmax estimate. Due to the occurrence of some subduction thrust events down to ~40 km depth (Park and Mori, 2007) we use this as the preferred down-dip limit of seismogenic zone. Due to the similarities in the level of seismicity and tectonic setting as the San Cristobal Trench offshore the Solomon Islands, we use the same coupling coefficients.

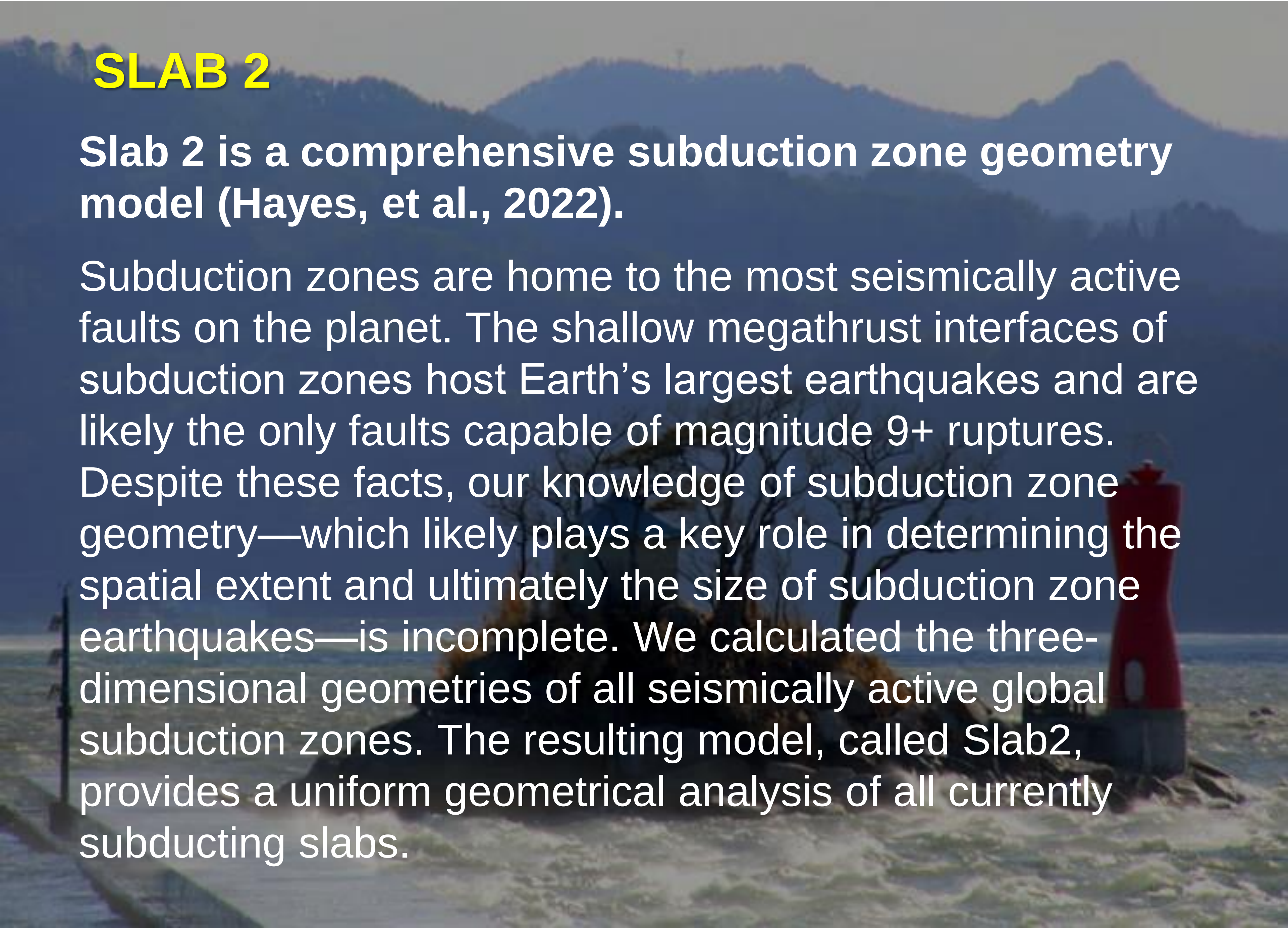
B.18 New Hebrides

The New Hebrides Trench is divided into four segments, northern, central, southern, and the Matthew-Hunter segment. Scenarios involving rupture across the first three segments should be considered. The relative motion at the New Hebrides trench is determined by elastic block modelling of GPS velocities and earthquake slip vectors (Power et al., 2011). The relative motion at the central and southern New Hebrides segments are the New Hebrides forearc/arc blocks relative to the subducting Australian Plate, while the relative motion at the Matthew-Hunter segment reflects the motion of the Matthew and Hunter Islands relative to the Australian Plate. The northern segment reflects motion between the Australian and Pacific Plates. GPS models of interseismic coupling suggest deep, high interseismic coupling along the northern New Hebrides segment, while interseismic coupling appears lower on the southern New Hebrides segment. The degree of interseismic coupling on the Matthew Hunter segment is not well-resolved. We use the down-dip limit of interseismic coupling on the central New Hebrides segment (Power et al., 2011) to define our preferred down-dip limit in that area. We make the down-dip limit on the southern and northern segment slightly shallower due to the lack of geodetic evidence for deep interseismic coupling. Much of the upper plate for the Matthew Hunter segment is recently rifted oceanic crust (related to north Fiji Basin development), so the depth to the down-dip limit of possible rupture is likely to be lower than for the north and south New Hebrides segments. Using subduction thrust events on the Matthew Hunter segment, Power et al. (2011) estimate a b-value of 0.74, which we use as the minimum value for this segment. The largest historical earthquake on the Matthew Hunter segment (in 1901) is estimated at Mw 8.4, although the data are somewhat ambiguous (see review in Power et al., 2011), so we use this for our preferred Mmax value and Mw 8.0 as our minimum Mmax value. The Mmax in a PSHA model developed for Vanuatu (Suckale and Grünthal, 2009) is Mw 8.3 for the northern segment, and Mw 7.6 for the southern segment. These Mmax values are based on historical data, so we adopt these as our minimum Mmax value. The slab is difficult to define in the Matthew Hunter segment due to the relatively lower level of seismicity there, so we adopt an average dip of 28° for the Matthew Hunter segment, following the slab geometry model developed by Power et al. (2011).



GEM Subduction Interface: Conclusions

- The GEM subduction interface project provides a globally consistent method of characterising subduction zones
- Its primary purpose is for generating earthquake event sets for inclusion in earthquake hazard and risk models
- However, it can also be used to identify subduction thrust regions with high tsunami potential
- The GEM database could be used as a starting point to explore the necessary characterisation of significant threats in the region of interest

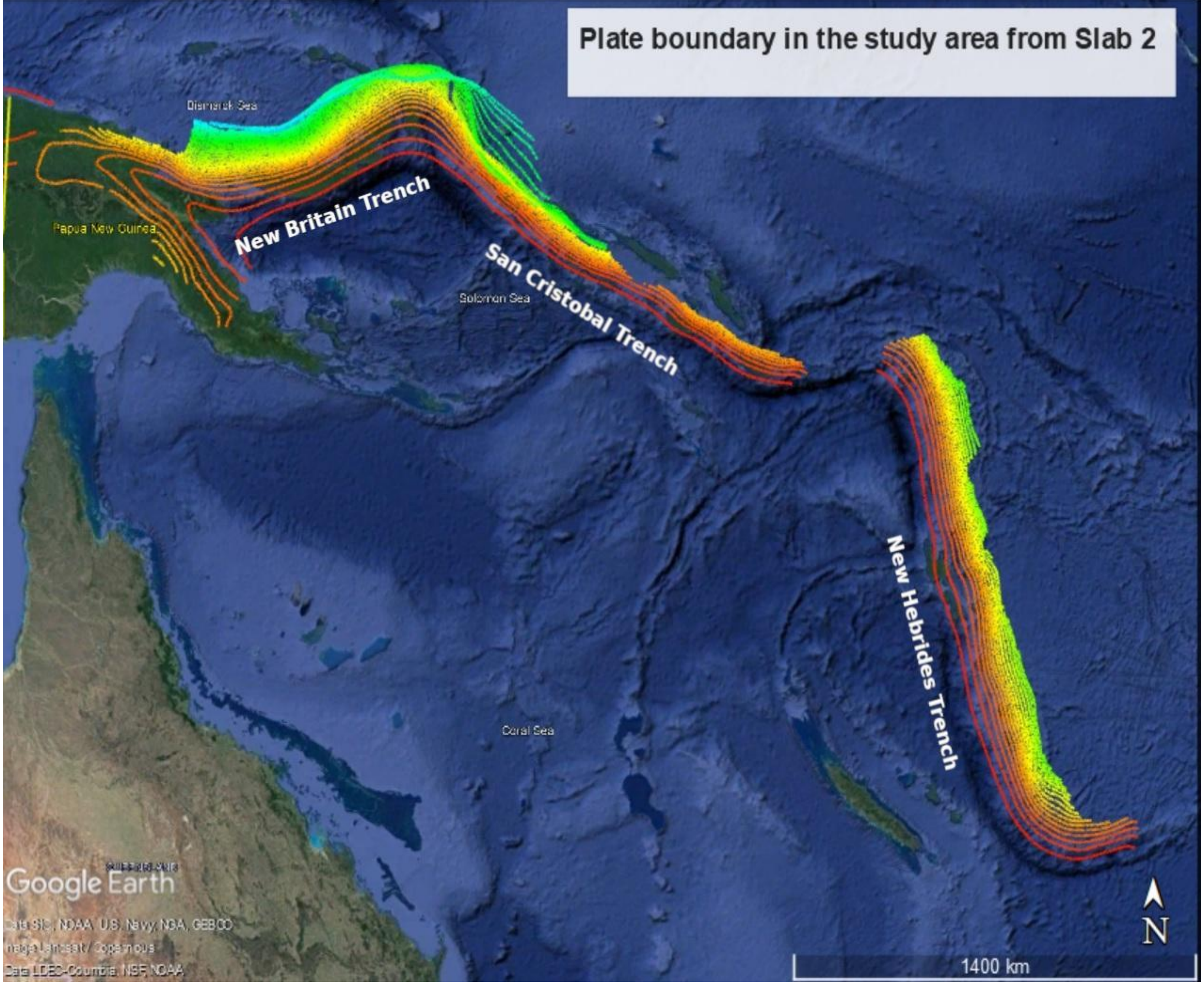


SLAB 2

Slab 2 is a comprehensive subduction zone geometry model (Hayes, et al., 2022).

Subduction zones are home to the most seismically active faults on the planet. The shallow megathrust interfaces of subduction zones host Earth's largest earthquakes and are likely the only faults capable of magnitude 9+ ruptures. Despite these facts, our knowledge of subduction zone geometry—which likely plays a key role in determining the spatial extent and ultimately the size of subduction zone earthquakes—is incomplete. We calculated the three-dimensional geometries of all seismically active global subduction zones. The resulting model, called Slab2, provides a uniform geometrical analysis of all currently subducting slabs.

Plate boundary in the study area from Slab 2



Earthquakes > M 6.9 since 1900