Sediment export from coastal watersheds in central California: landscape response to hydroclimatic extremes, and implications for the nearshore zone

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Sediment flux from steep, tectonically active terrain

- Small, mountainous watersheds in tectonically active regions are largest sediment-producers, globally
- This type of terrain is highly sensitive to changes in climate and hydrology

Warrick et al., USGS
Sediment flux from Central Coast terrain

- Small, mountainous watersheds are highly sensitive to changes in climate and hydrology
- Storm magnitude, frequency could increase during 21st century
- Climate models suggest future major droughts alternating with major atmospheric-river storm years (as in 2012-2017)
Sediment flux from Central Coast terrain

• How does sediment flux from small, steep watersheds respond to extreme dry vs. wet years?
• Coastal sediment (>70%) in CA derived from watershed inputs
• Implications: hazards, coastal sediment management, nearshore ecosystems, water-resource security (reservoir sedimentation)
Central Coast climatic conditions

Precipitation varies by factor of 2-3 along Central Coast (PRISM data)
Extreme rainfall, winter 2017

**Atmospheric River** (image from Ralph et al., 2011)

- Narrow filaments transporting >90% of mid-latitude water vapor flux
- Most NorCal floods (and landsliding) from atmospheric rivers
- Record atmospheric-river activity on west coast in 2017
Sediment export from the San Lorenzo River

- Extreme variations in sediment export from San Lorenzo watershed over drought, average, wet years
- 2017: Major increase in sediment yield, even without a catastrophic flood
San Lorenzo hydrology

2016 rainfall: 88-104% of average

2017 rainfall: 163-167% of average
San Lorenzo River annual sediment export

2017 sediment load was 10 times that of an average year, 600 times that of very dry years...

Orders of magnitude variation in sediment mass reaching nearshore zone!
Sediment fluxes during extreme wet year

Carmel River (Harrison et al., in review)
Landslide occurrence

- Road- and property-damaging landslides (data: Santa Cruz County)
- Actual number may be ~double, based on our 15-km road survey
Landslides: increased suspended-sediment flux, coarser grain sizes in transport
Coastal effects

- Net sediment deposition 210,000 m³ at river mouth in winter 2017
- That’s sediment mass 330,000 t, or 1-2 years worth of net longshore sediment flux
- Similar volume and elevation (morphology) to the 100-yr flood deposit of 1982
- Sediment ‘pile’ still sitting at river mouth as of March 2018

USGS data from A. Stevens, P. Barnard, D. Hoover et al.
Relation to ENSO cycle?

- Generally, CA coastal sediment flux (and landslides) correlate with El Niño phase of El Niño/Southern Oscillation (ENSO) cycle.
- But, it may be easier for atmospheric rivers to reach West Coast in non-El Niño (ENSO-neutral) years (Bao et al., 2006).
- Jan 1982 storm and 2017 storm series occurred in ENSO-neutral conditions.
- Strong 2015-16 El Niño = big waves but un-spectacular river discharge.
Landscape disturbance effects

- Logging, mining, cannabis
- Fire effects
- Increase sediment yield for 5 to >100 years depending on activity type and sediment-source area

Keller et al., 1997

Warrick et al., 2013

Burned Carmel watershed, summer 2016
Effects of climate change?

• On top of human land use effects, anticipate greater wildfire risk (disturbances causing higher sediment yield)

• More severe droughts, more severe storms (infer landslide and flood risk increases, increasing sediment flux to coast per event)
Summary & Implications

- Future climate likely to swing more strongly between very dry, very wet years
- 600-fold variation (or more?) in Central Coast watershed sediment export between drought and very wet years, affecting nearshore morphology, sediment transport, and habitat: management implications!
- Human land use and wildfire also affect terrestrial sediment flux to the coast
- Some ENSO-neutral years (e.g., 1982 and 2017) export more sediment to coast than El Niño years
How high were flow peaks? How well did our sampling capture them?

Sediment concentration normalized by discharge

Grain size during flow peaks