SEA LEVEL RISE AND COASTAL IMPACTS

FUTURE USE OF NASA AIRBORNE PLATFORMS TO ADVANCE EARTH SCIENCE PRIORITIES

31 JULY 2020

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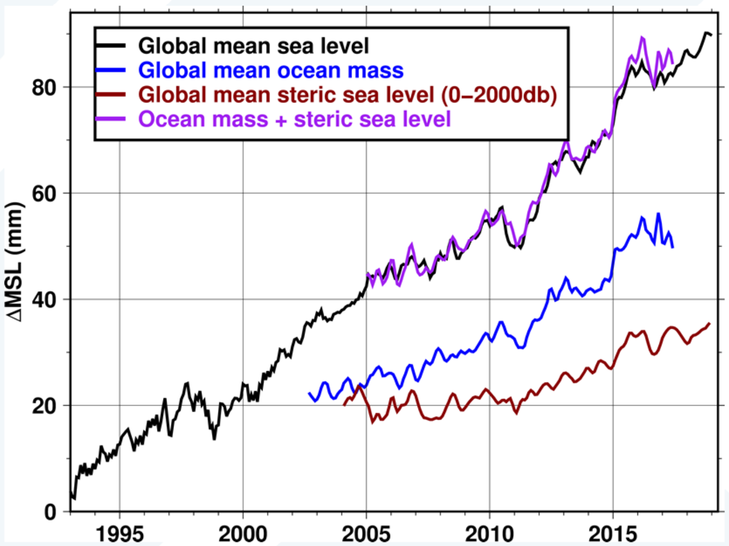
UC San Diego | SCRIPPS INSTITUTION OF OCEANOGRAPHY

Imperial Beach flooding, Jan. 2019. *Credit: Center for Climate Change Impacts and Adaptation*

SCIENCE & APPLICATION PRIORITIES

- How much will sea level rise, globally and regionally, over the next decade and beyond, and what will be the role of ice sheets and ocean heat storage?
- How will local sea level change along coastlines around the world in the next decade to century?

Leuliette (2019)



A VISION FOR THE DECADE 25

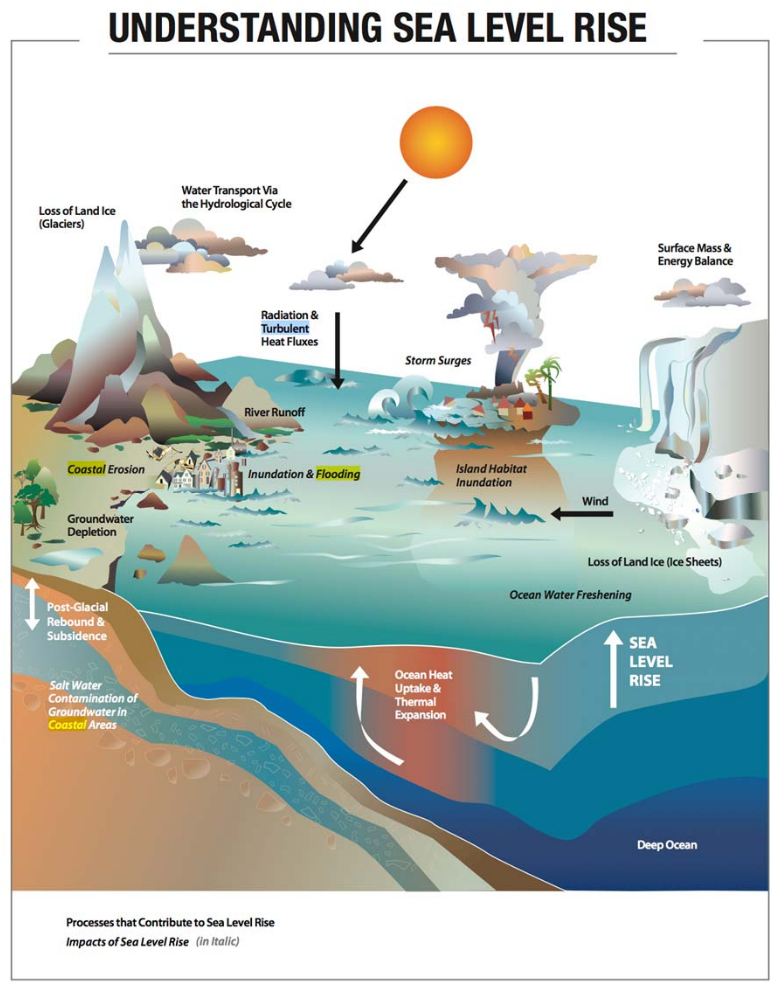
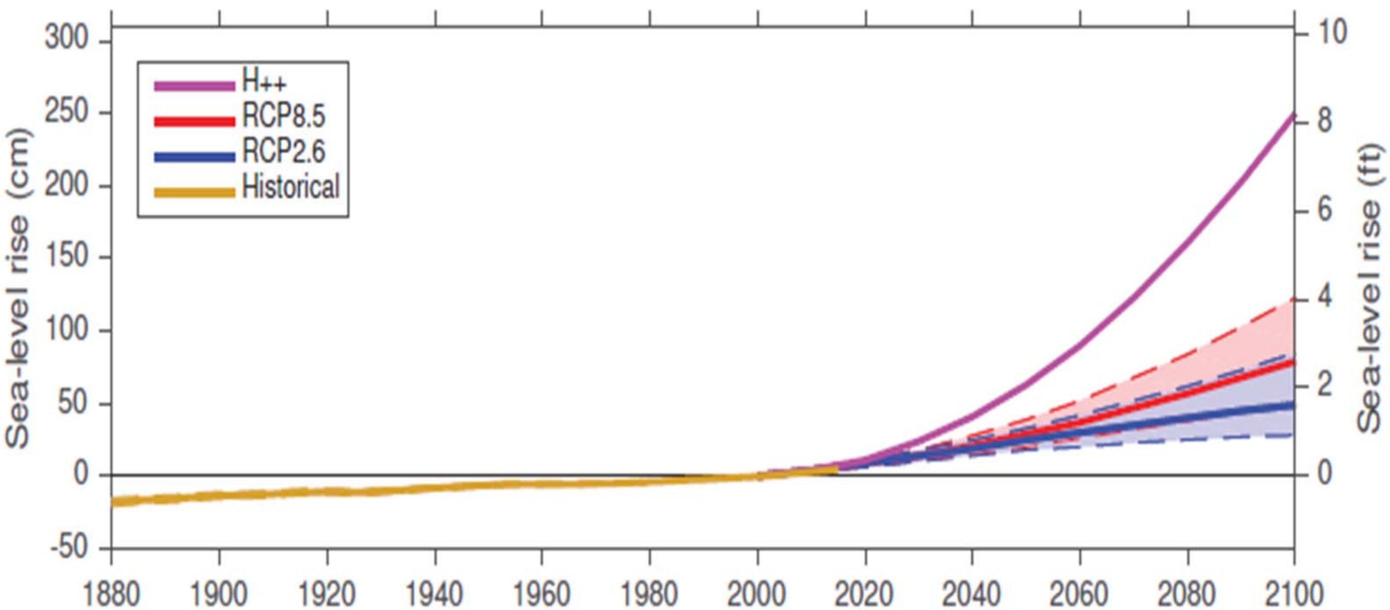


FIGURE 1.2 The complex interacting components of the Earth system that contribute to sea-level rise and its consequences.

NAS, Engineering, and Medicine 2018. *Thriving on Our Changing Planet: A Decadal Strategy for Earth Observation from Space*

SEA-LEVEL RISE PROJECTIONS



Commitment to observational capabilities that will enable substantial progress in:

"Examining movement of land and ice surfaces to determine..the likelihood of rapid ice loss and significantly accelerated rates of sea-level rise.."

NAS Decadal Strategy

Griggs et al. (2017) – Projections based on Kopp et al. 2014; H++ Extreme scenario associated with rapid Antarctic ice sheet mass loss (Sweet et al. 2017)

Ice sheet mass change 2003-2019 from satellite laser altimetry

Smith et al., 2020 *Science*

ICESat (September 2003 – October 2008)
ICESat-2 (October 2018 – February 2019)

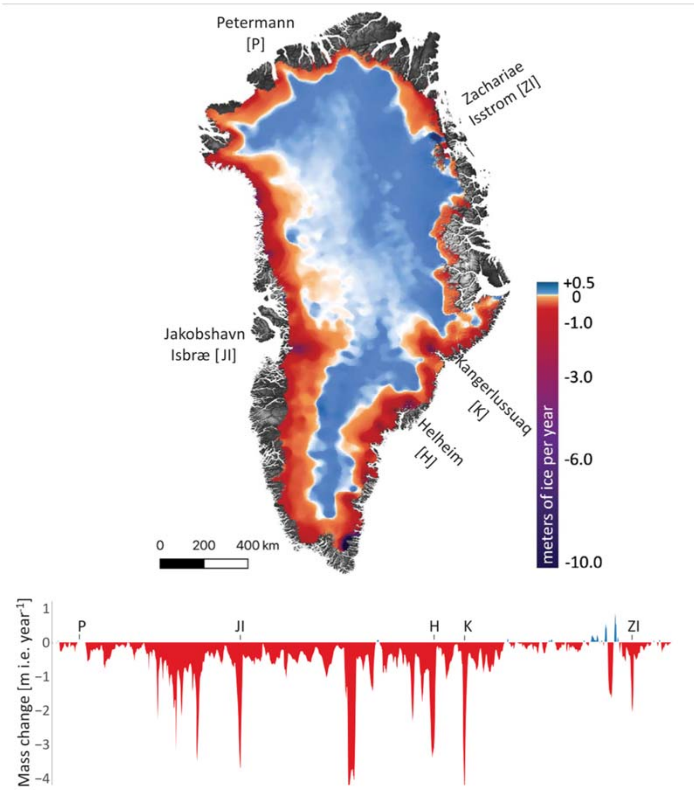


Fig. 2. Mass loss from Greenland Ice Sheet (2003 to 2019). (**Top**) Mass change for Greenland (meters of

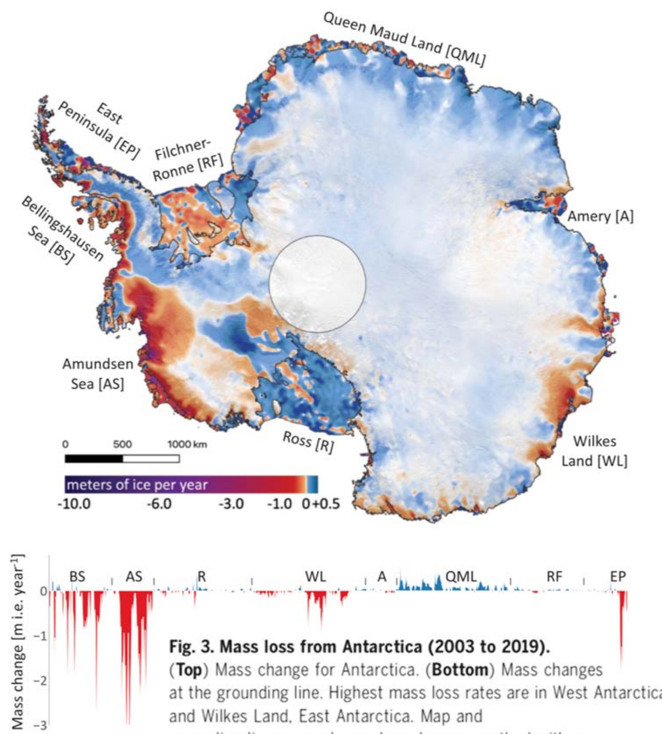


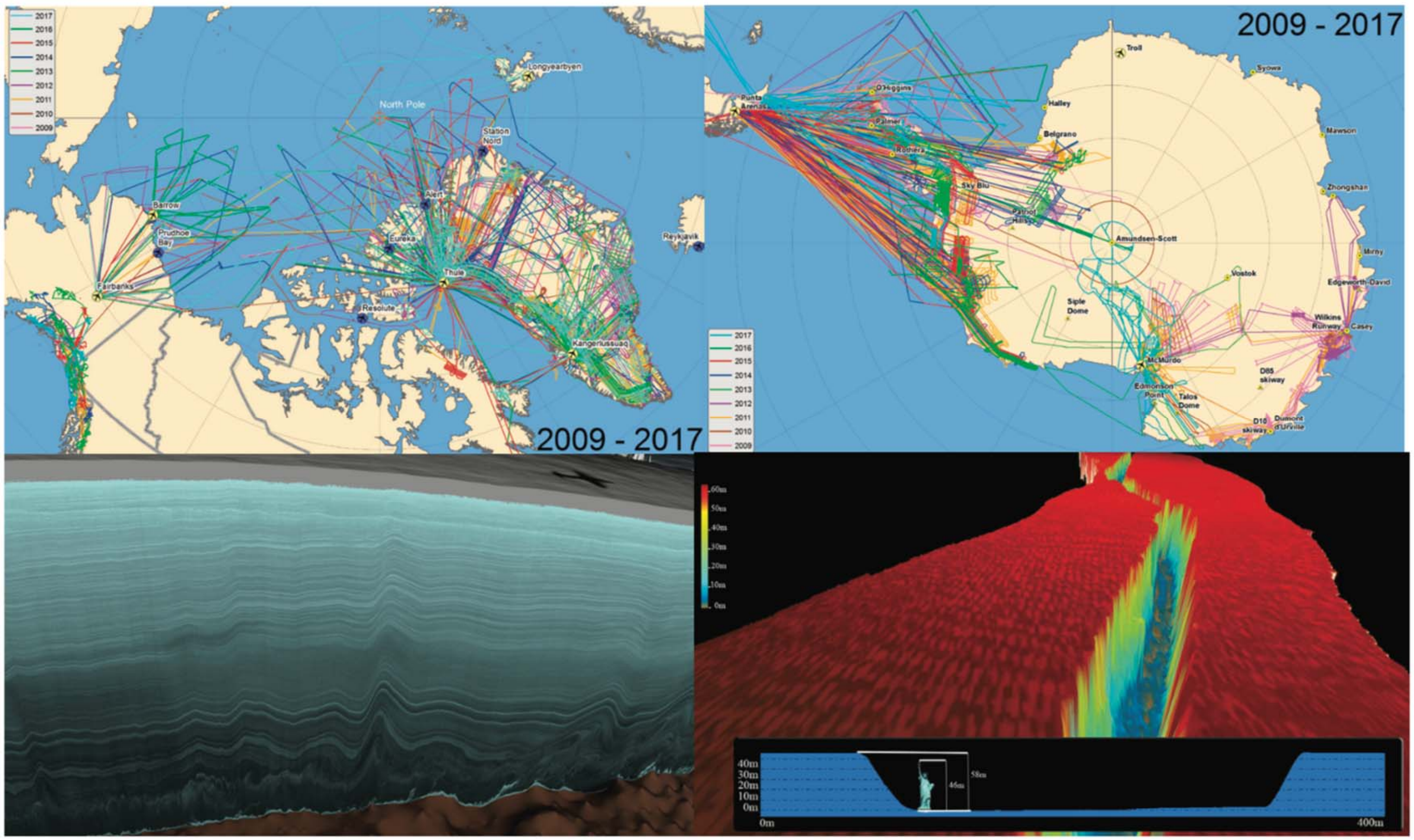
Fig. 3. Mass loss from Antarctica (2003 to 2019). (**Top**) Mass change for Antarctica. (**Bottom**) Mass changes at the grounding line. Highest mass loss rates are in West Antarctica and Wilkes Land, East Antarctica. Map and grounding line mass change have been smoothed with a 35-km median filter for improved visualization.

Kirsty Tinto, Lamont-Doherty

Operation IceBridge: 2009 - 2020

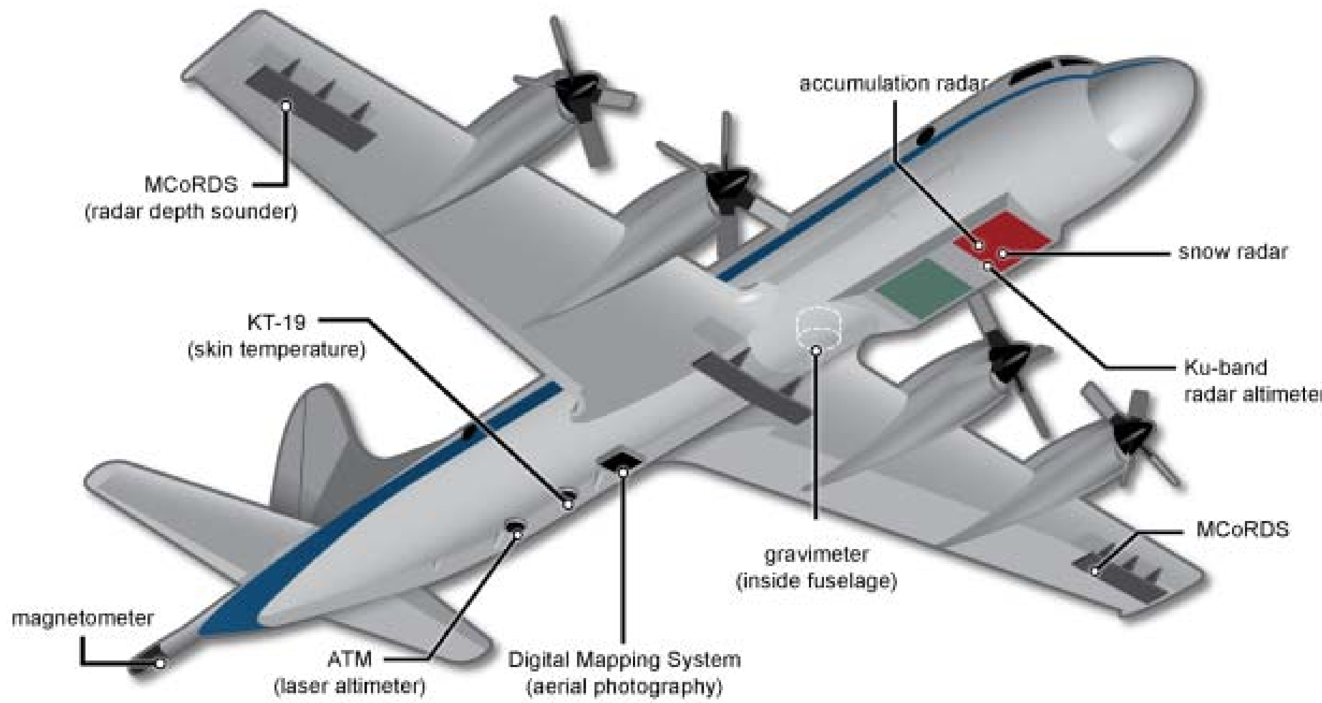
Airborne measurements bridge the satellite gap – and much more…

Image from: National Academies of Sciences, Engineering, and Medicine 2018. *Thriving on Our Changing Planet: A Decadal Strategy for Earth Observation from Space*. Washington, DC: The National Academies Press. https://doi.org/10.17226/24938.



Kirsty Tinto, Lamont-Doherty

Operation IceBridge: Multi-instrument aircraft



Laser altimetry
Cameras
- Ice surface

Radars
- ice thickness/bed mapping
- Snow and ice structure

Gravity
Magnetics
- Offshore bathymetry
- Bed geology

https://icebridge.gsfc.nasa.gov/wp-content/uploads/2012/07/IceBridge_P3_cartoon_white_background_2014.png

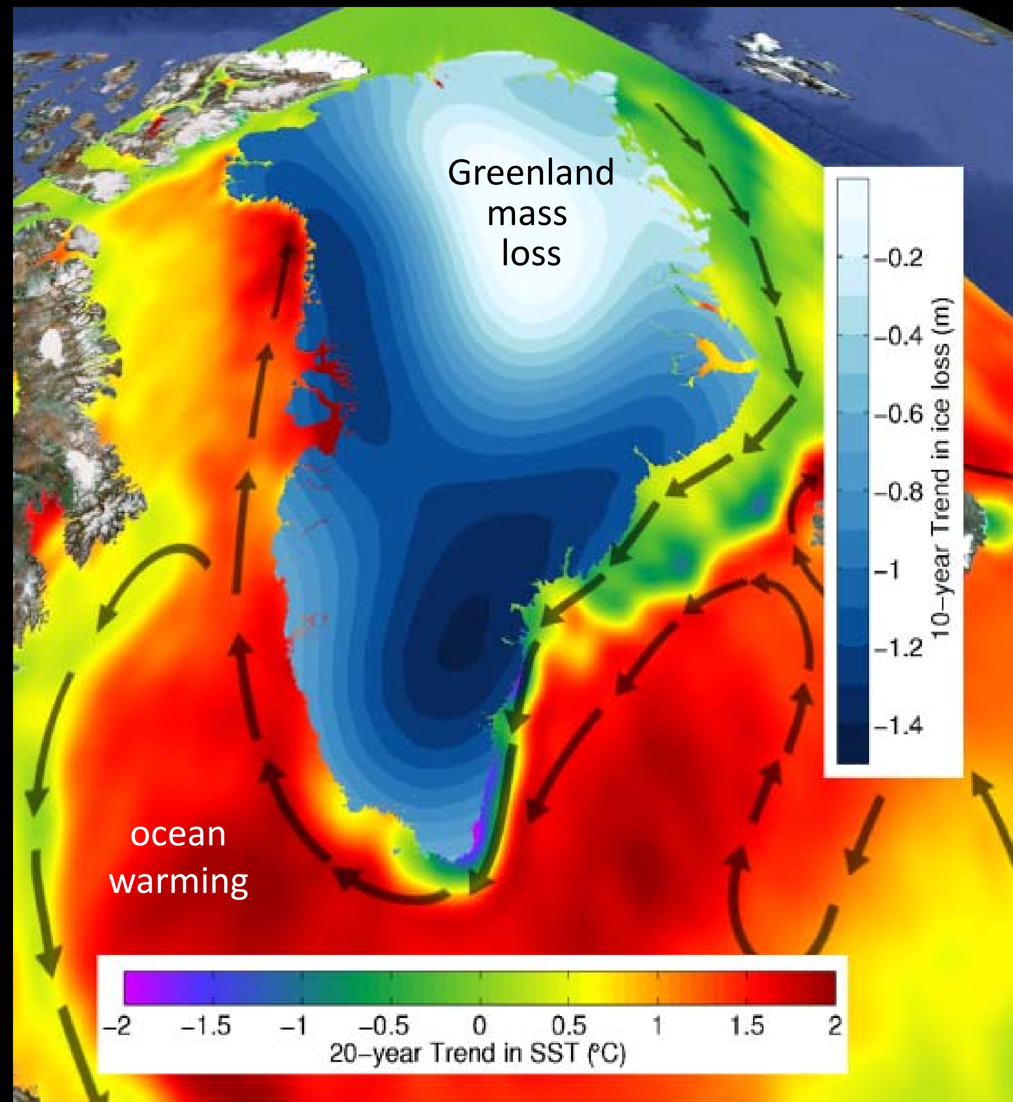
Kirsty Tinto, Lamont-Doherty

Oceans

OMG

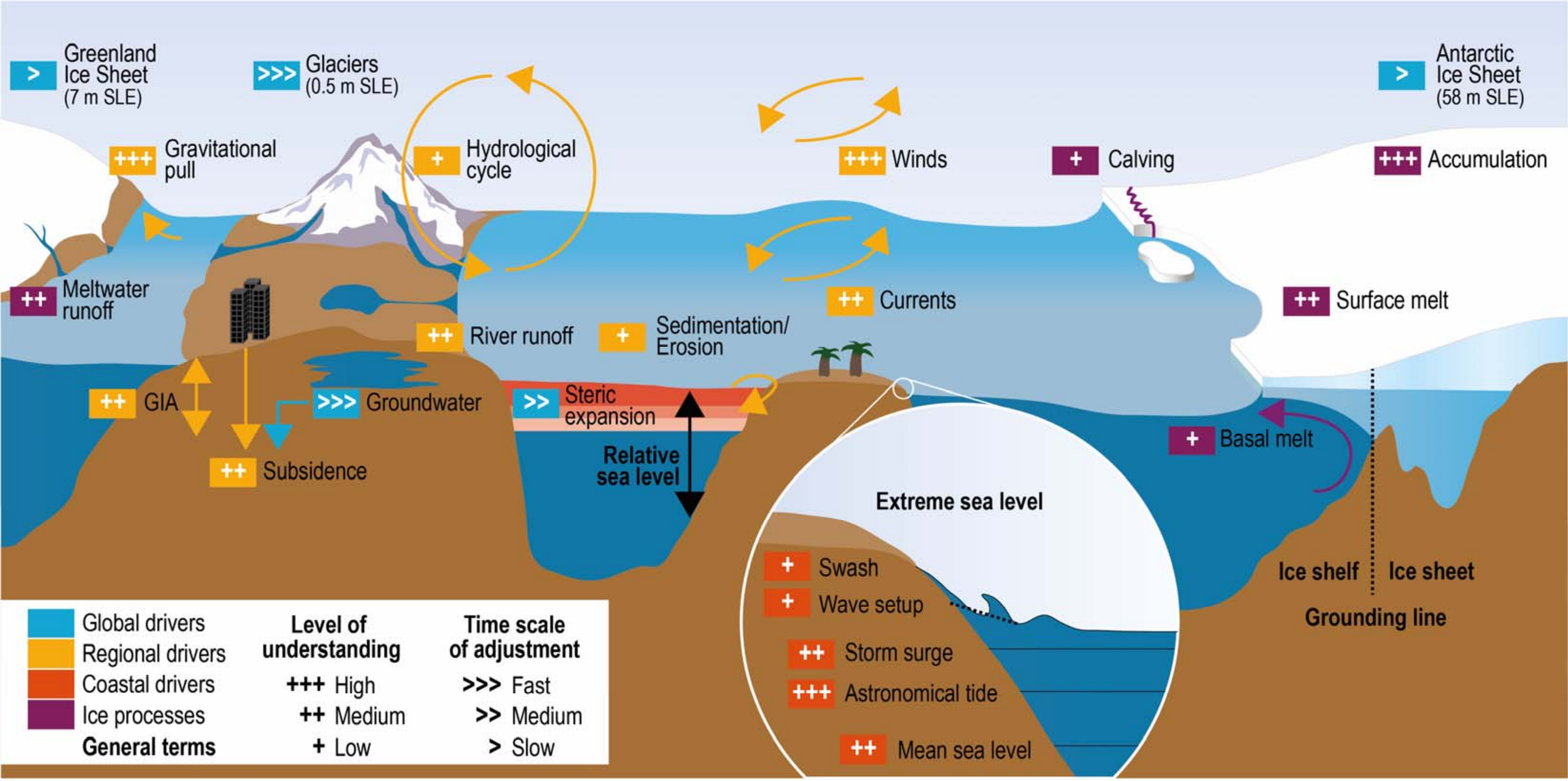
Melting Greenland

How much is Greenland melting from below?



Josh Willis - JPL

Influences on global, regional, relative and extreme sea level events along coasts

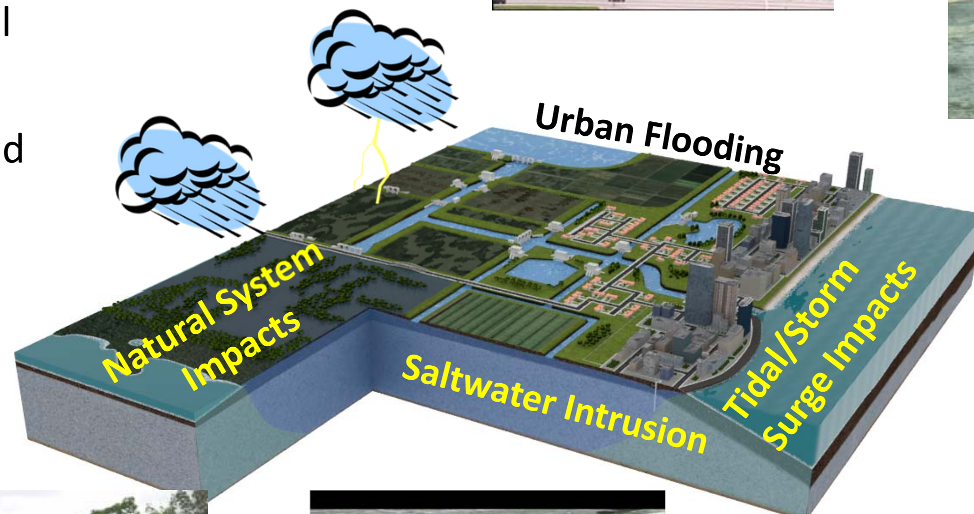


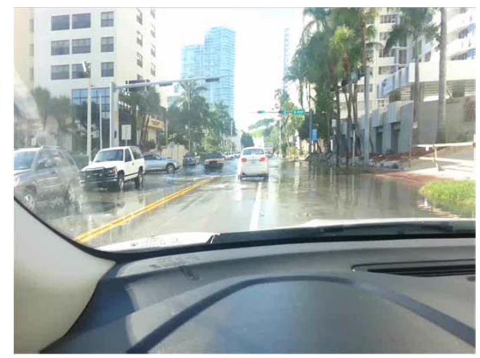
IPCC Special Report on the Ocean and Cryosphere in a Changing Climate (2019)

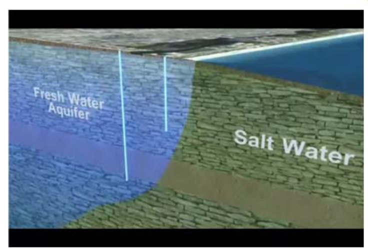
Impacts of Changing Climate and Rising Sea Levels

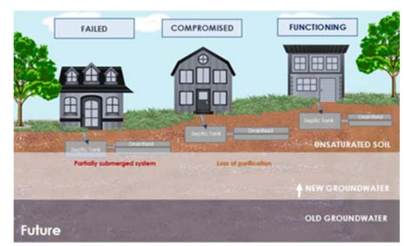
Coastal Hazards:

- Permanent submergence
- Coastal flooding
- Coastal erosion
- Loss and change of coastal ecosystems
- Salinization of soils, ground and surface water
- Impeded drainage







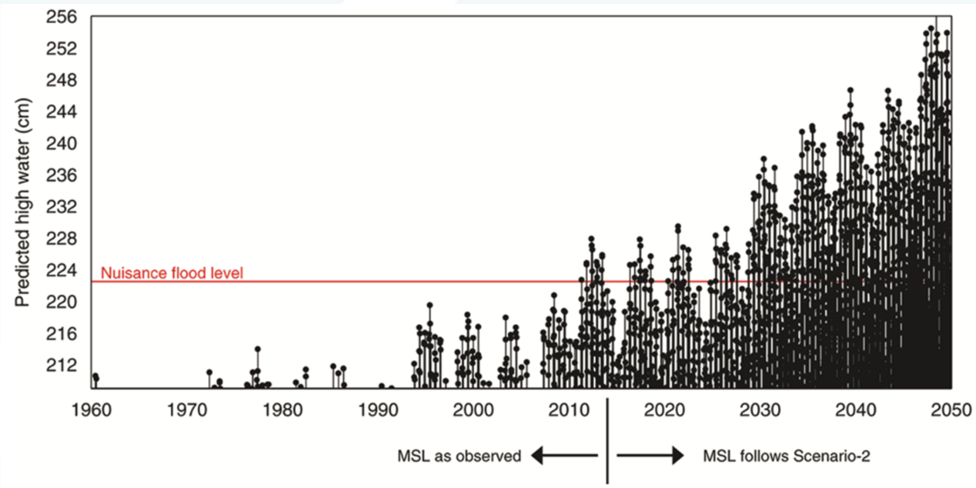


Jayantha Obeysekera, Florida International University

SEA LEVEL STACKING EFFECT

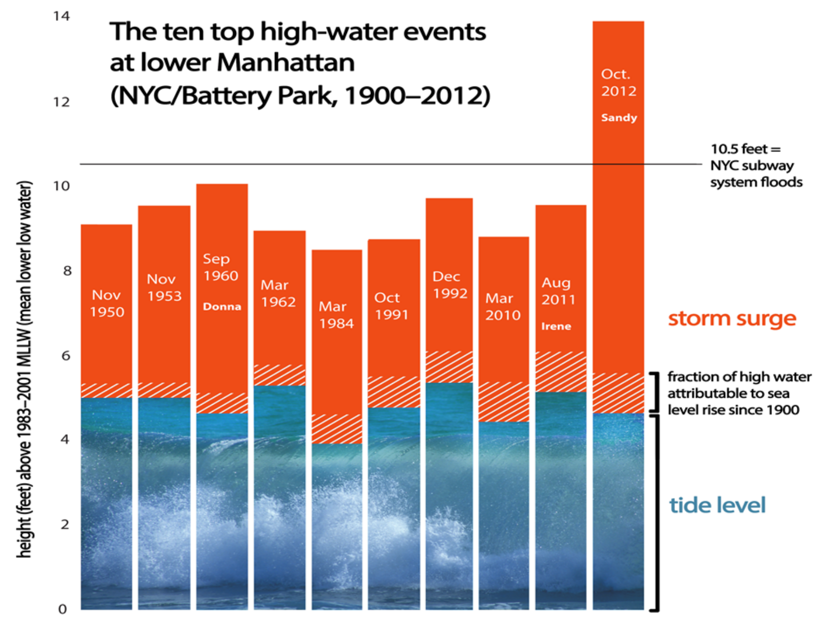
High tide flooding

Predicted high tides at Boston that exceed nuisance flood level



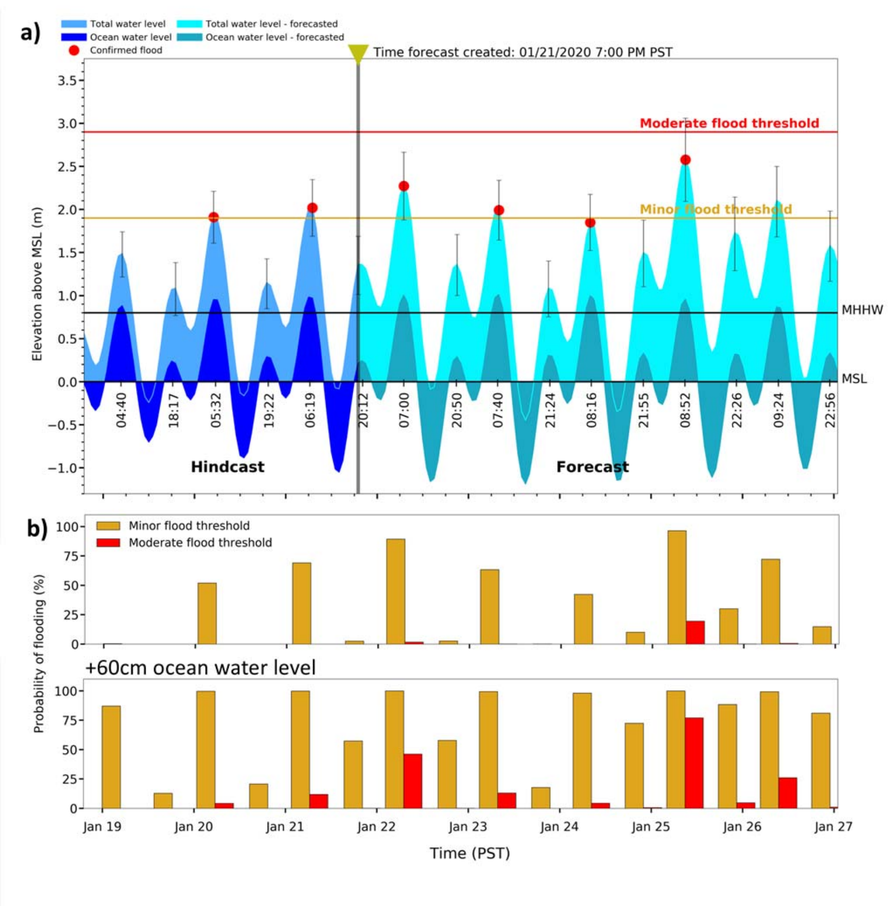
NAS, Engineering, and Medicine 2018. *Thriving on Our Changing Planet: A Decadal Strategy for Earth Observation from Space*

Storm surge



NCAR

IMPERIAL BEACH FLOOD FORECASTS



General needs:

Nearshore bathymetry

High-res DEM

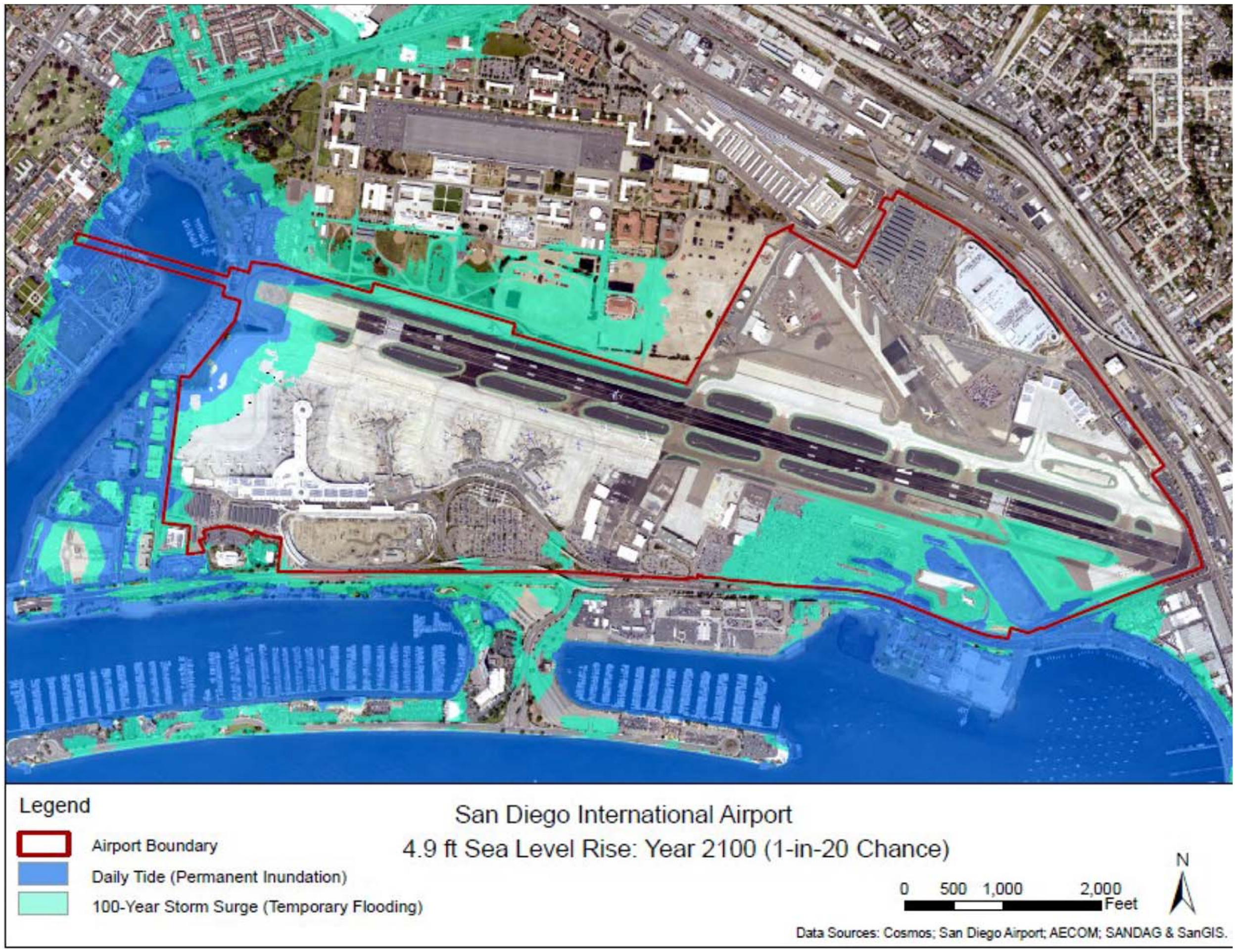
Coastal wave observations

Coastal water level

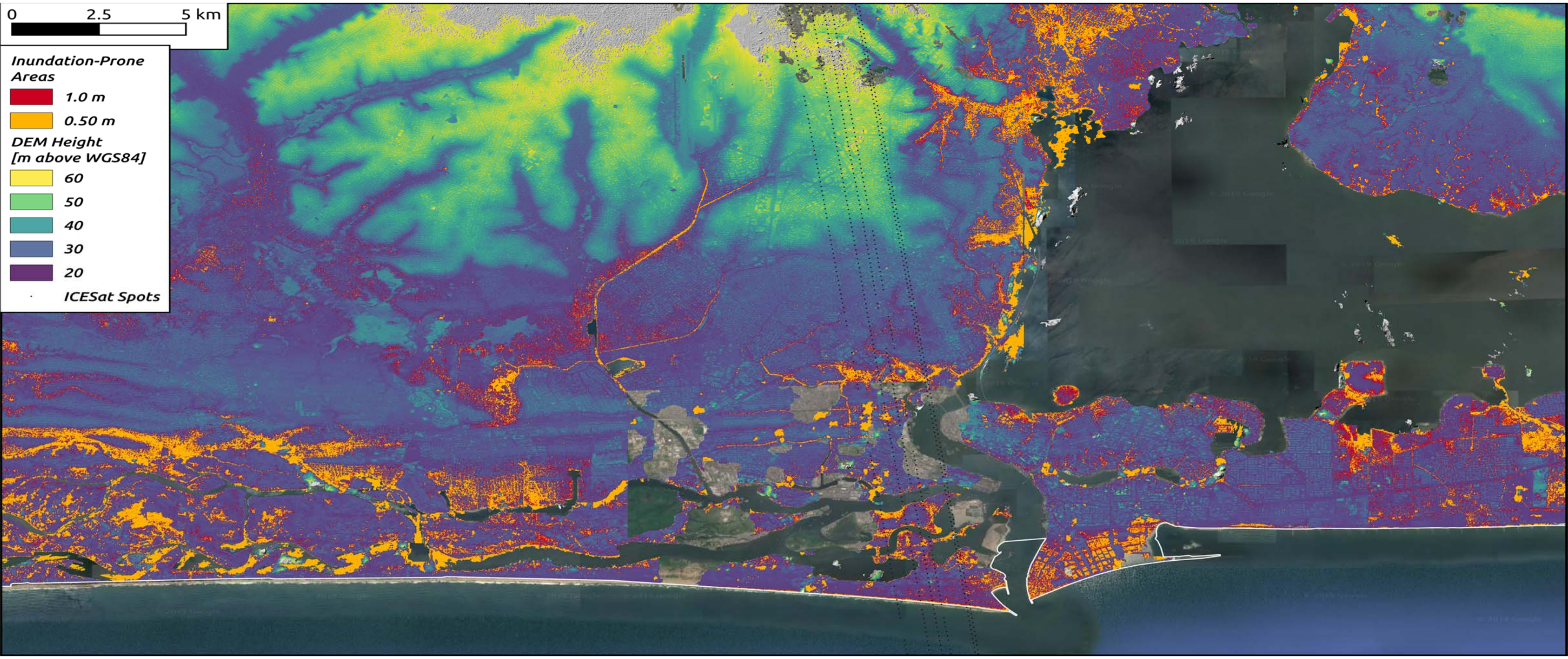
Needs for Coastal Hazards

- Coastal bathymetry/topography
- Near-shore sea surface and significant wave height measurements
- Beach and cliff erosion monitoring
- Flood extent
- Pre/post storm impacts

SAN DIEGO BAY
FLOOD RISK AND SEA-LEVEL RISE



DEM and Inundation of Lagos, Nigeria



Source: DigitalGlobe (imagery) & OpenStreetMap (coastal data)

Steve Nerem, University of Colorado, Boulder

Vertical land motion and relative sea-level rise

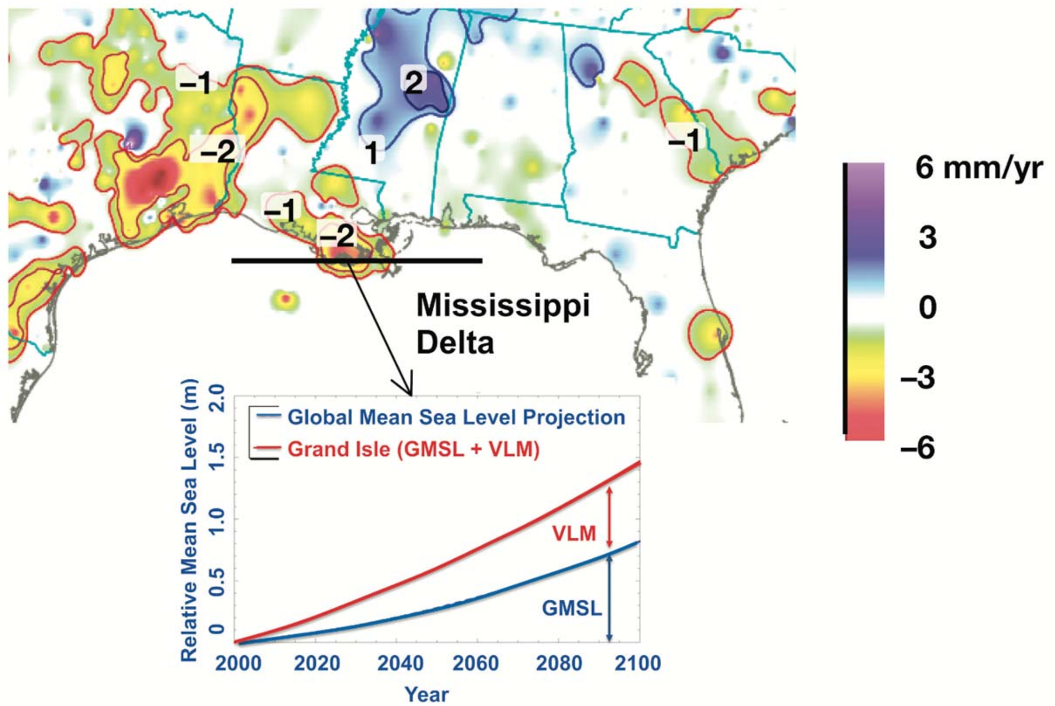
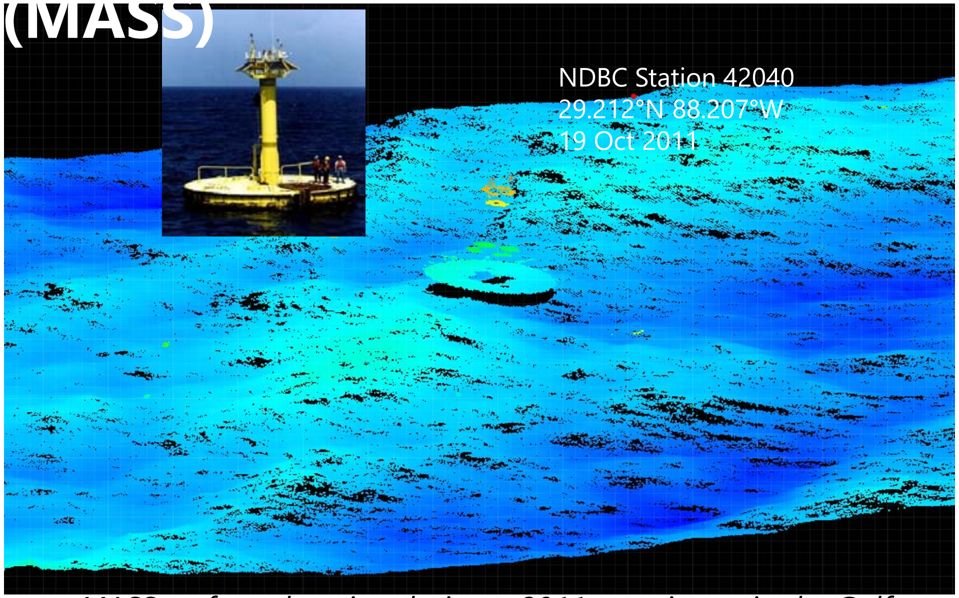


FIGURE 10.15 *Upper panel:* Vertical land motion (VLM) determined from GPS stations for the Gulf of Mexico coast. Positive values indicate uplift; negative values indicate subsidence. The inset shows the expected relative sea-level rise for the Mississippi Delta using a projection of global mean sea level (bottom curve) and a projection that also includes the observed vertical land motion over the past decade (top curve). SOURCE: Map from Donald Argus, Jet Propulsion Laboratory, California Institute of Technology (Argus and Shirzaei, in preparation, 2018). The sea-level projection is adapted from Figure 13.11 (RCP 8.5 scenario) in Church et al. (2013).

NAS, Engineering, and Medicine 2018. *Thriving on Our Changing Planet: A Decadal Strategy for Earth Observation from Space*

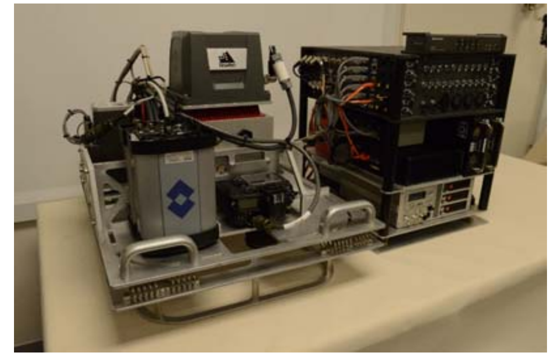
SIO Modular Aerial Sensing System (MASS)



MASS surface elevation during a 2011 experiment in the Gulf of Mexico, flying above NDBC buoy #42040.

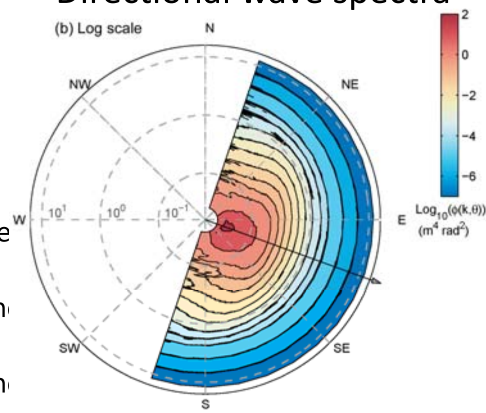
System had mostly flown on Partenavia P68 to date, but MASS is quite portable; P68 has limited speed and range

Spatial resolution 0.25x0.25m



Technical description in Melville et al. 2016

Directional wave spectra



Lenain, L. and W.K. Melville, 2017

Instrumentation		**Measurement**
Scanning Waveform Lidar	Riegl Q680i	Surface wave, surface slope, directional wave spectra (vert. accuracy ~2-3cm)
Long-wave IR Camera	FLIR SC6000 (QWIP)	Ocean surface processes, wave kinematics an breaking, frontal processes
High-Resolution Video	JaiPulnix AB-800CL	Ocean surface processes, wave kinematics an breaking, frontal processes
Hyperspectral Camera	Specim EagleAISA	Ocean surface and biogeochemical processes
GPS/IMU	Novatel SPAN-LN200	Georeferencing, trajectory

Luc Lenain - SIO

Reciprocal Passes Across the Loop Current

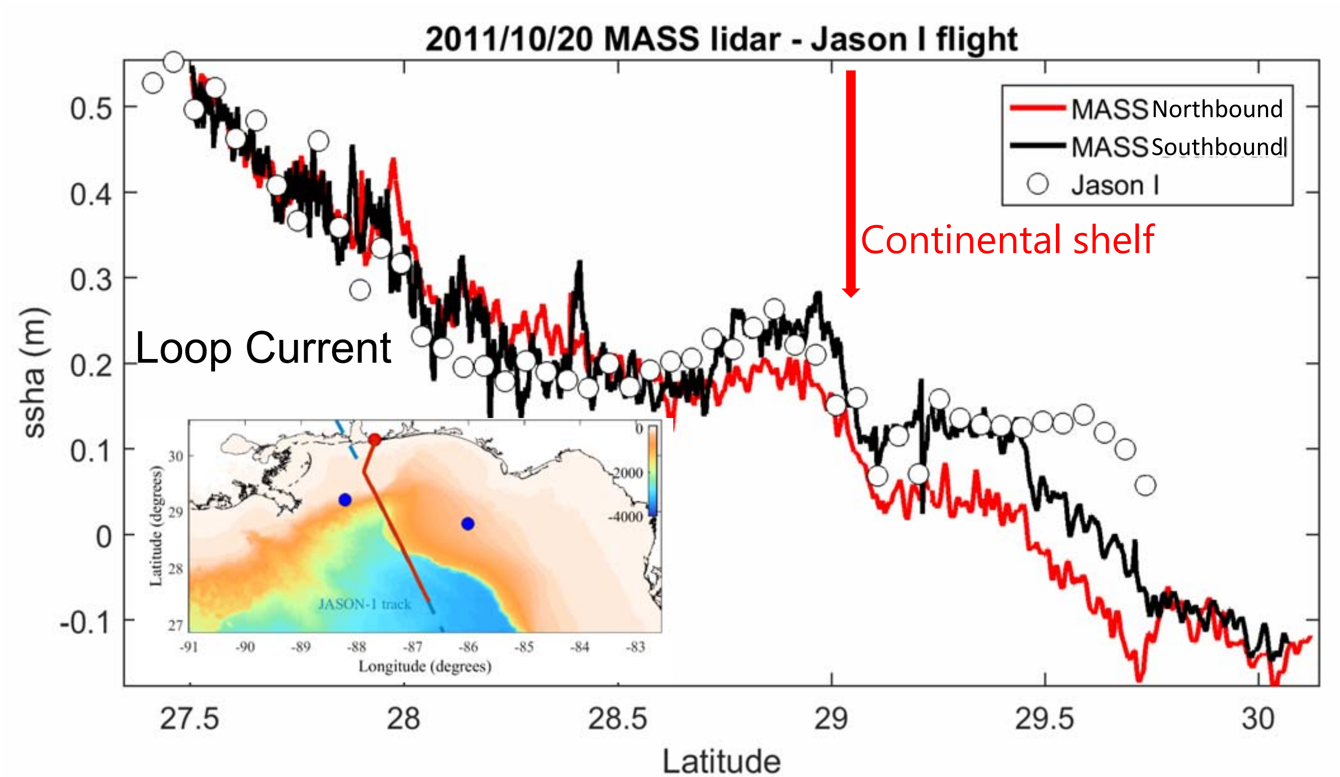
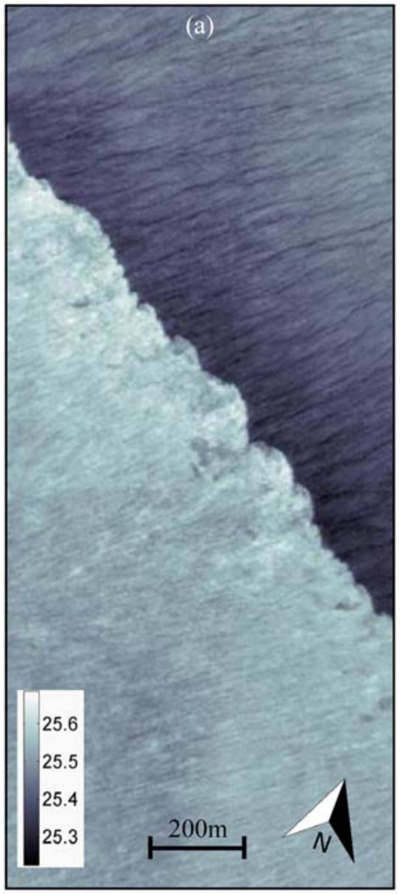


Fig. 6: SSHA estimated from two MASS lidar passes ("northbound" and "southbound") over the same Jason-I track (see insert). Note that the satellite pass occurred in the middle of the southbound lidar pass (black).

Luc Lenain - SIO

Beyond MASS SSH lidar measurements:
Using IR imagery to infer surface velocity



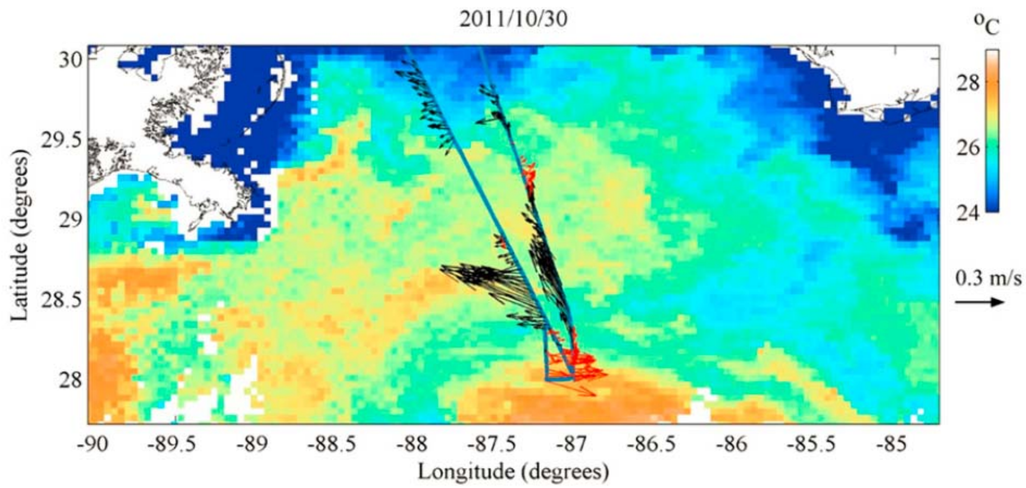


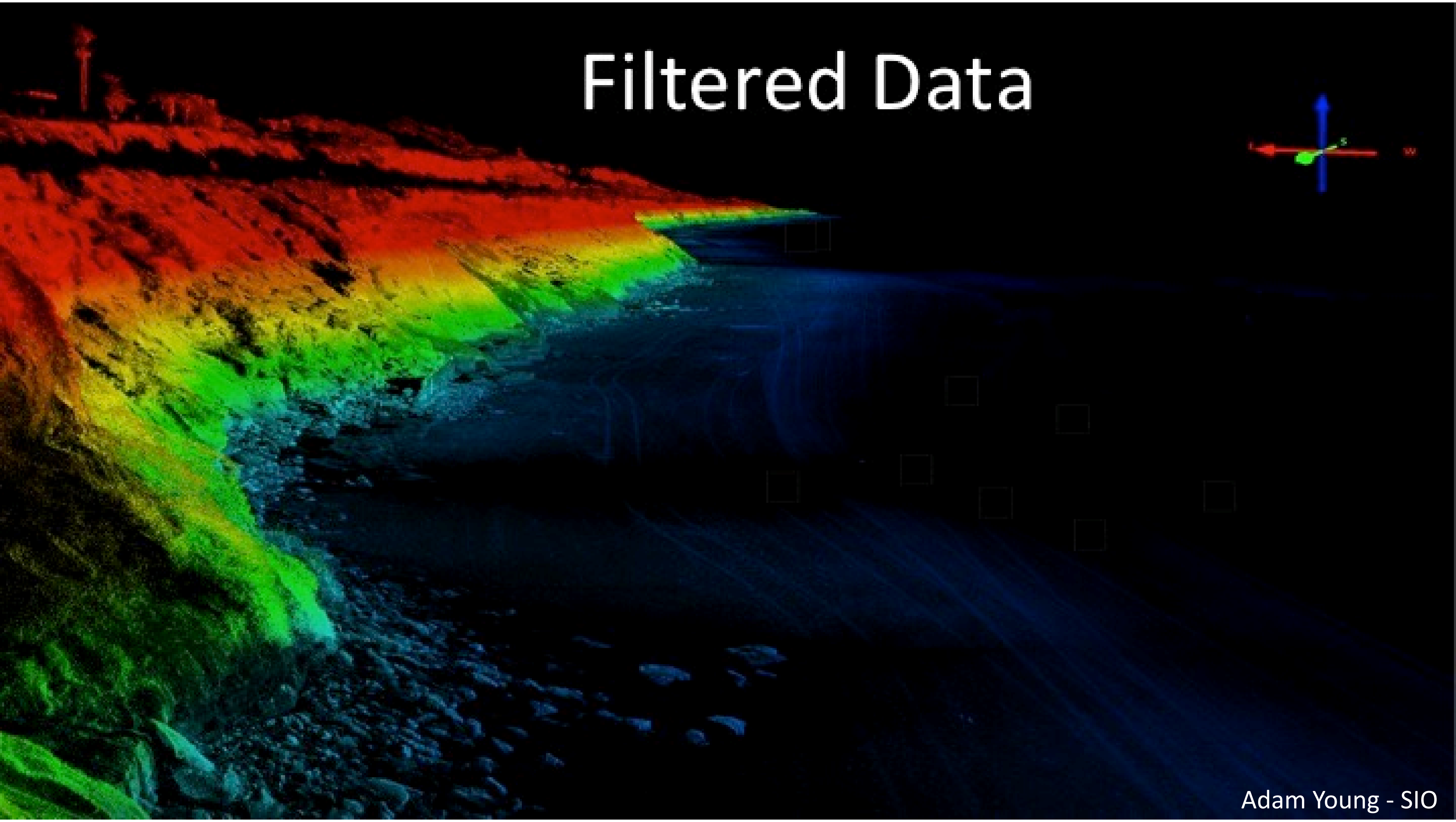
FIG. 7. SST estimated from *Terra* level 3 daily product (°C) on 30 Oct 2011, 10 h prior to the airborne survey conducted the same day. The flight track is shown in blue. The average surface velocities derived from the thermal imagery are shown as vectors along the flight track (red, positive easterly velocity; black, negative easterly velocity). Note the sharp change in surface velocities as the aircraft went across the Loop Current front.

Surface velocity computed from feature tracking of the MASS SST imagery, then averaged to remove orbital wave motion

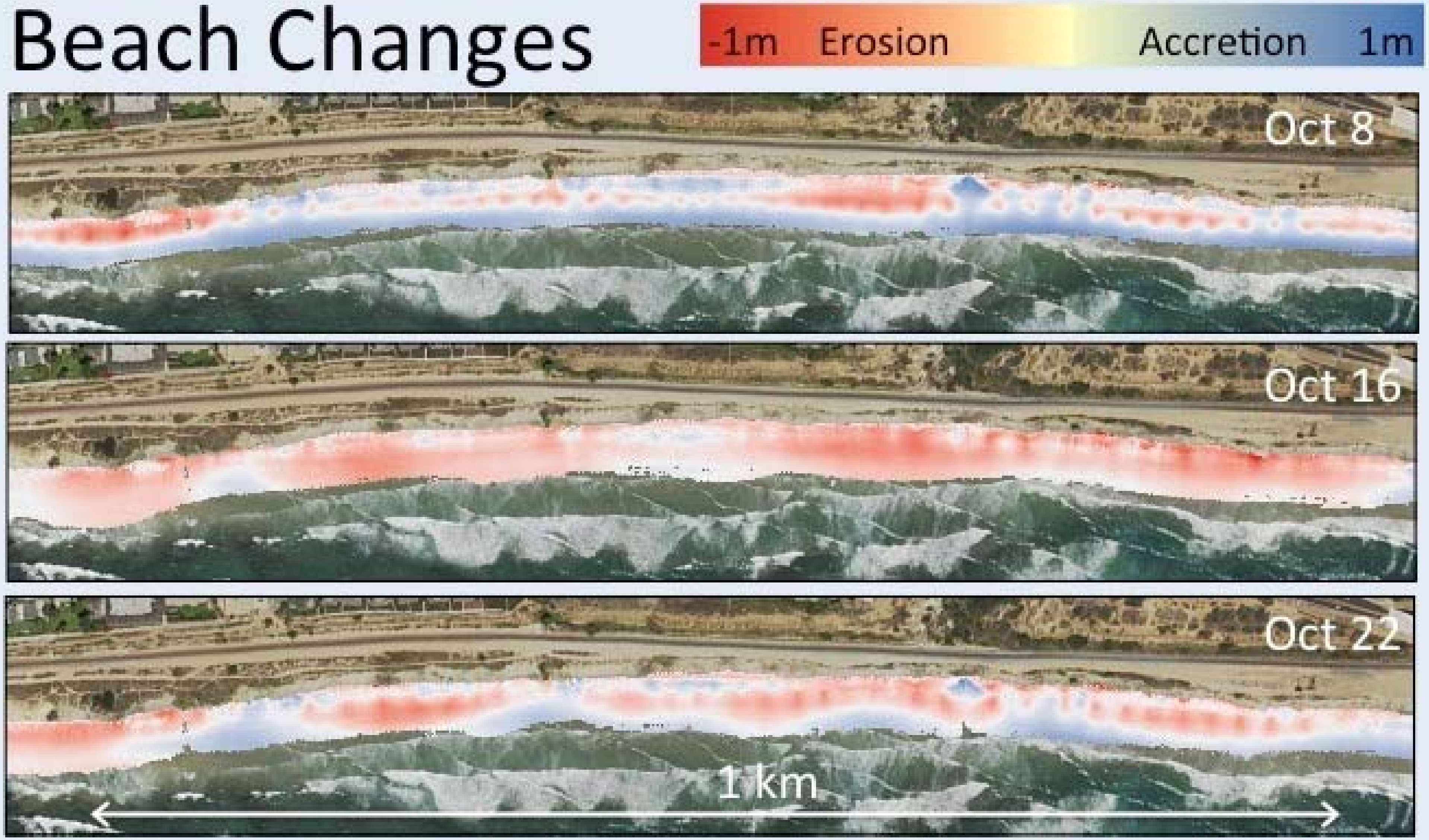
Luc Lenain - SIO

Drone Lidar

Adam Young - SIO

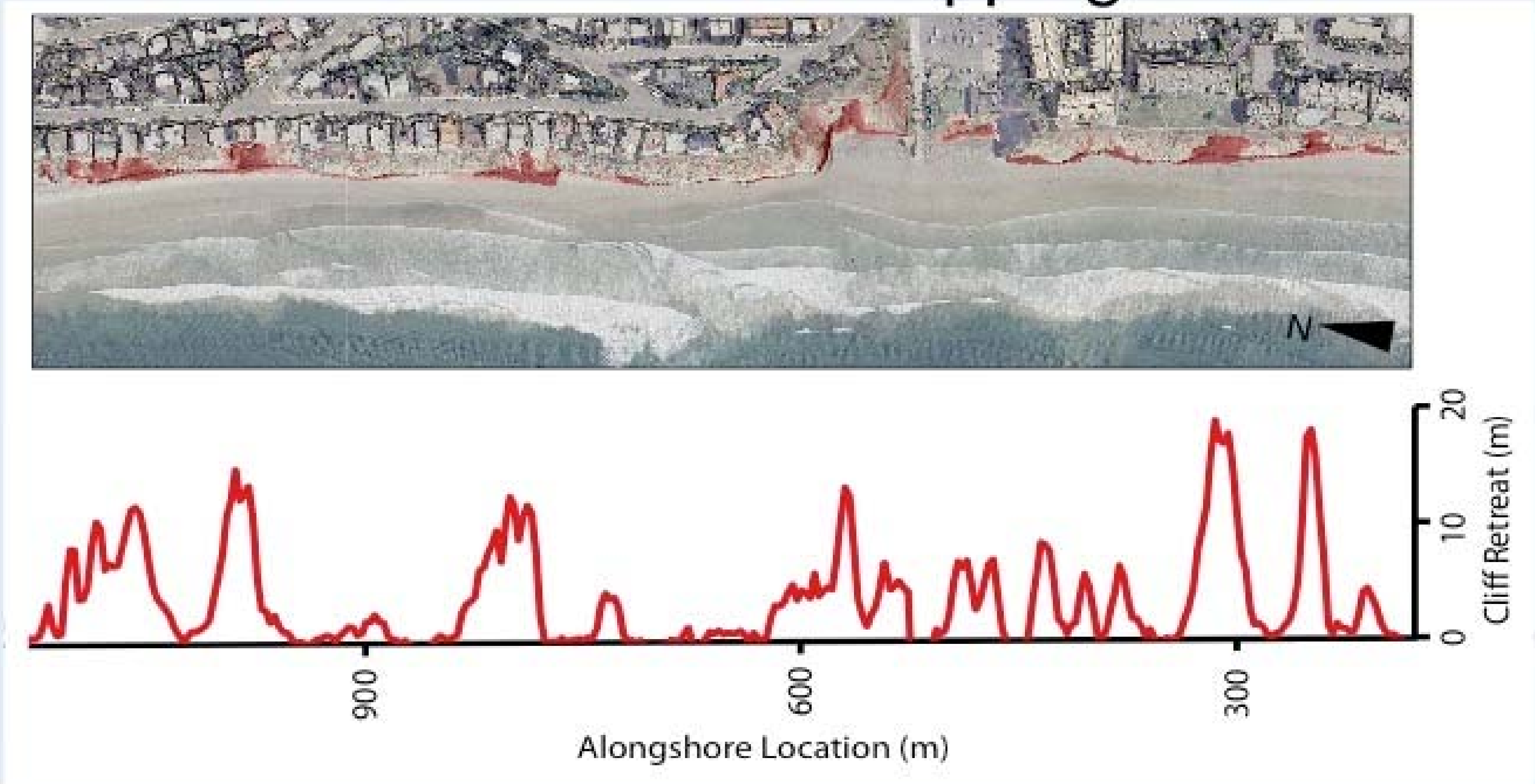

Filtered Data
Adam Young - SIO

Beach Changes



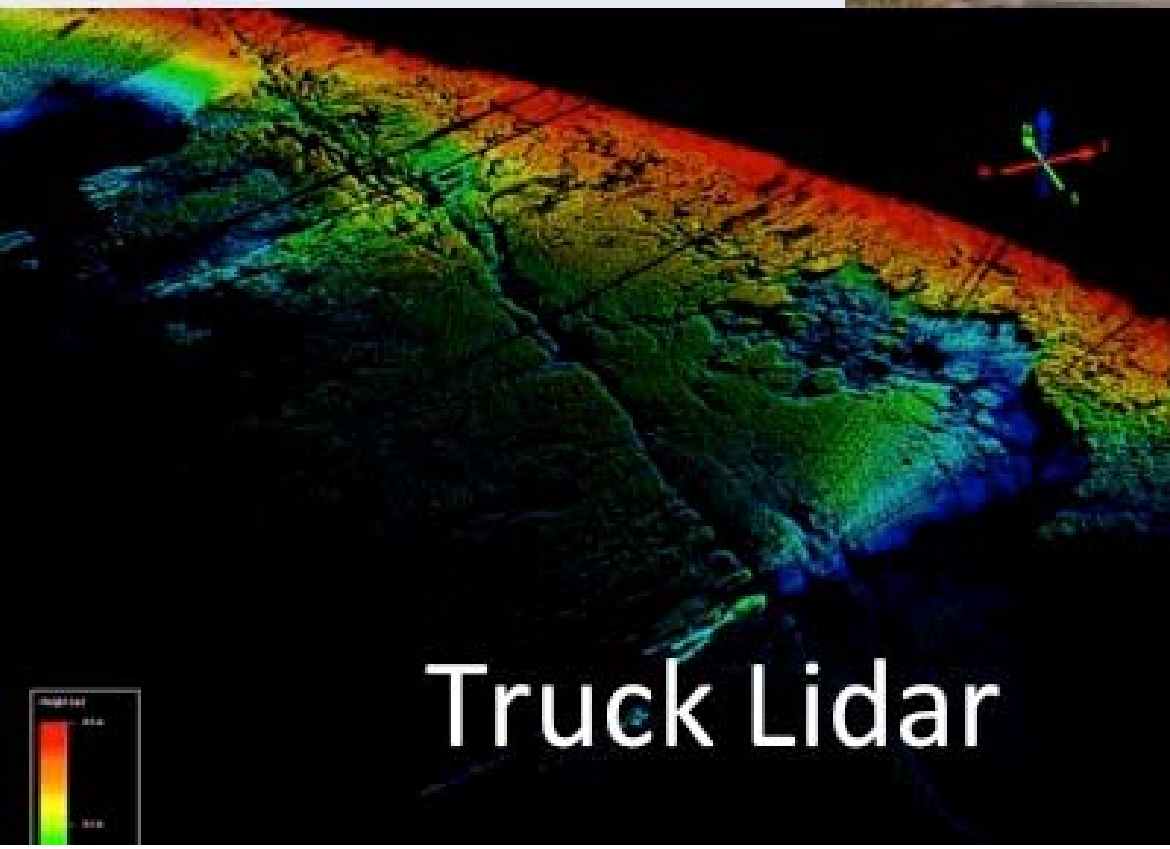
Adam Young - SIO

Cliff Erosion Mapping



Adam Young - SIO

Platform Mapping



Adam Young - SIO

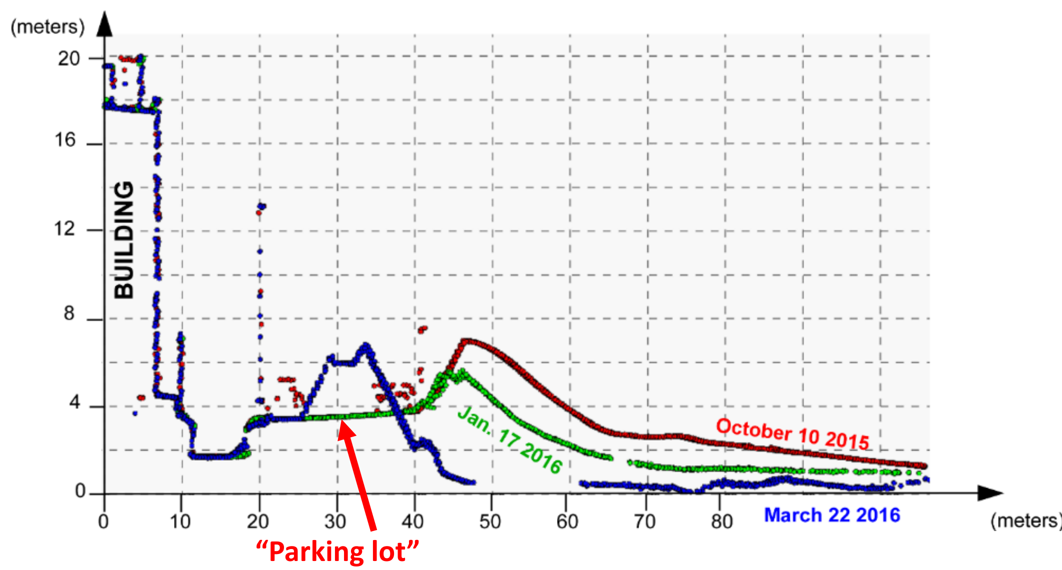
Naval Base Coronado –berm to protect buildings

Luc Lenain - SIO

Naval Base Coronado- berm breached and reconstructed

Luc Lenain - SIO

Naval Base Coronado



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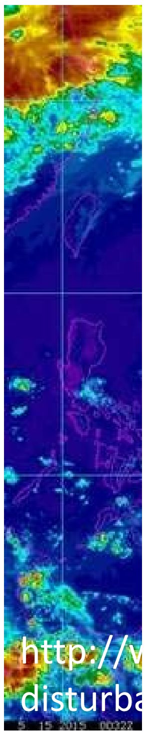
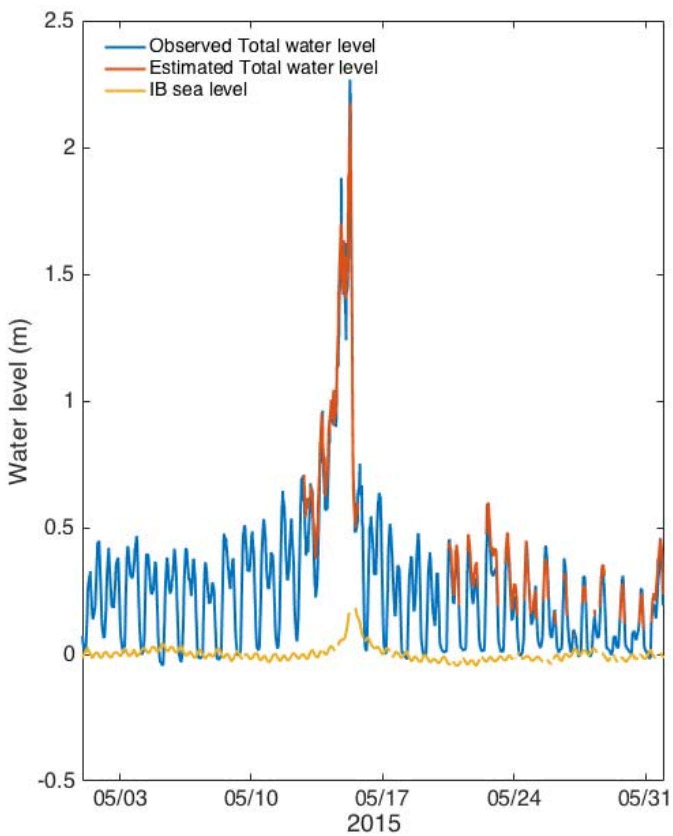
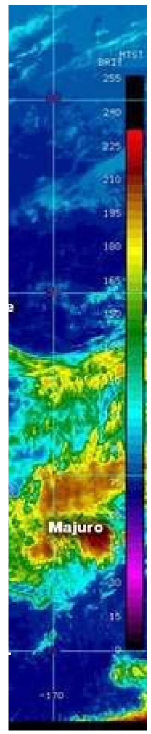
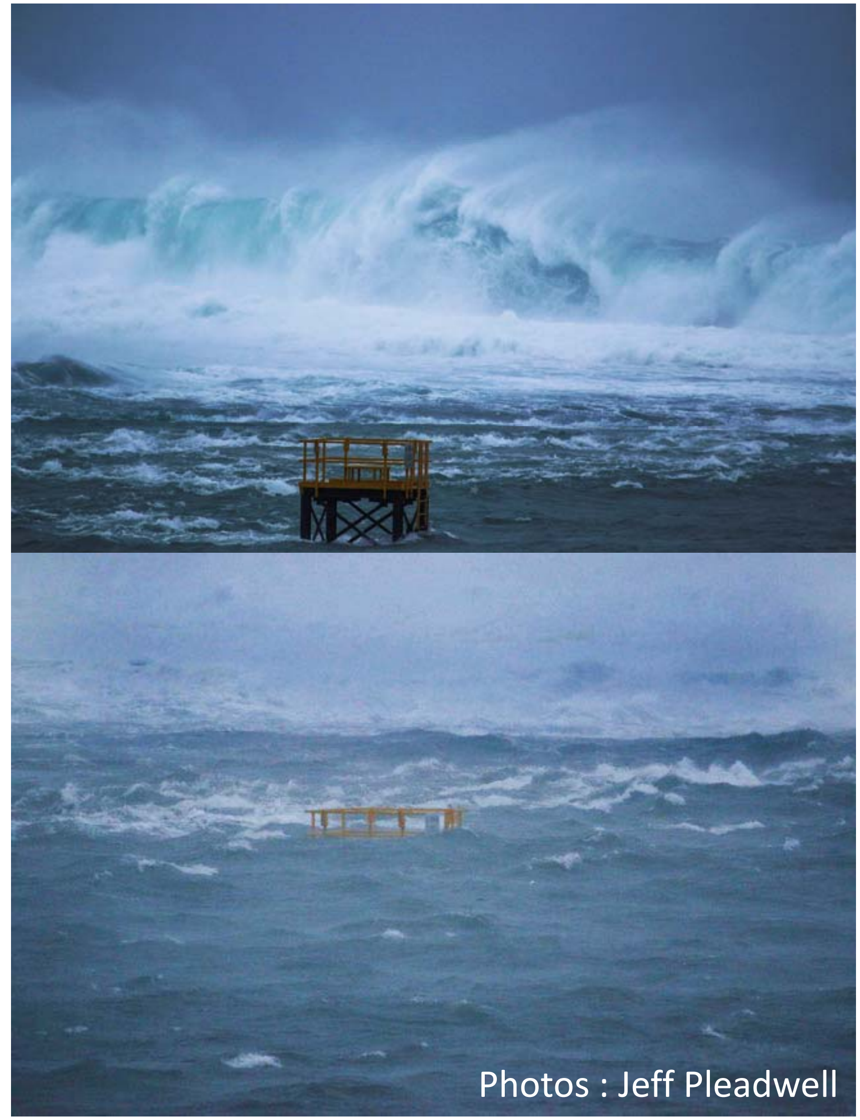
Typhoon Dolphin over Guam on May 15, 2015








Photos : Jeff Pleadwell

SEA-LEVEL RISE AND COASTAL IMPACT RESEARCH & OPERATIONAL NEEDS

- Ice sheet monitoring, ocean boundary processes
- Coastal bathymetry/elevation
- Waves and currents
- Shoreline change
- Extreme event mapping