**Facing Higher Sea Levels and Increased Coastal Flooding in New York City**

**Vivien Gornitz, Radley M. Horton, Daniel A. Bader, Cynthia Rosenzweig and Philip Orton**

**CCSR Columbia University, NASA Goddard Institute for Space Studies, and Stevens Institute of Technology**

**Geological Society of America Annual Meeting, Baltimore, November 3, 2015**

**Slide captions**

1. **Title page**.

2. **Hurricane Sandy over the mid-Atlantic states.** The New York City area has experienced many tropical cyclones and hurricanes. Westward winds from H. Sandy push water onshore—well-positioned to create a maximal surge. Geography: Surge amplification due to right angle bend between New Jersey and New York. Critical timing: H. Sandy hit NYC at high tide on full moon.

3. **Hurricane Sandy: Waves rushing down World Trade Center site**.

4. **The top 20 coastal storm events at the Battery, NYC**—last 77 years (since 1938). H. Sandy’s water level tops the list and may even surpass that of the 1821 hurricane (Sandy: 11.1 ft above NAVD; 13.88 ft above MLLW).

5. **NPCC2**—Following Sandy, former NYC Mayor Bloomberg convened NPCC2 to report on NYC risks from future sea level rise and coastal storms, as part of a citywide resiliency plan. Latest two reports: 2013, 2015.

6. **Global sea level trends:** **(Left)** Note the recent (last 100 yrs +) acceleration in SLR compared to late Holocene SLR (after Robert A. Rohde). **(Right): *SLR tide gauges****:*1900-2010--1.7±0.2 mm/yr; (IPCC 2013). ***SLR Satellites:*** 1993-2015--3.3±0.4 mm/yr (Nerem et al, 2010; <http://www.sealevel.colorado.edu> (posted 10/16/2015).

7. **Historic sea level rise,** **the Battery, New York City**. SLR 1856-2014 is **0.45 m (17.7 in** or **1.5 ft**) (NOAA, tidesandcurrents.noaa.gov, 2014).

8. **Regional sea level trends** 1856-2014 range from **2.44 to 4.1 mm/yr**, or **0.1-0.16 in/yr** (NOAA, 2013).

9**.** **Components of sea level rise.** (Insert, upper right). **Causes of sea level rise:** ***Climate change***: ice mass loss (glaciers/ice sheets); sea level “fingerprints”—land/ocean mass redistributions: gravitational/rotational/isostatic; thermal expansion; local changes in ocean height (steric, currents). ***Non-climate***: vertical land motions (including glacial isostatic adjustments (GIA), groundwater mining); land water storage. (Bottom). Components used to calculate future NYC SLR.

10. **New NPCC2 sea level rise and coastal flood methodology**. Updated ocean change, ice mass loss, and GIA data; IPCC 2013 emission scenarios and CMIP5 GCMS. New (to this report) sea level components: “fingerprints”; land water storage; storm surge modeling.

11. **Models/scenarios**. IPCC 2013 2 RCP scenarios (RCP 4.5 and 8.5); 24 CMIP5 GCM climate models; 10th, 25th, 75th and 90th percentiles from model-based distributions and estimated ranges from literature; 1-2 model-based grid cell(s) coverage.

12. **Schematic diagram of “fingerprinting”.** Redistribution of mass due to recent ice loss results in non-uniform sea level rise.

13. **Calculation of future SLR (NPCC2):** Sea level rise is sum of individual components: *Thermal expansion* (global)--CMIP5 data; *changes in dynamic ocean height* (local steric/currents)—CMIP5 data; *ice mass loss--ice sheets* (global)—expert judgment; probabalistic analysis, and literature survey; *ice mass loss--glaciers and ice caps* (global)—ranges taken from two recent studies and literature survey; *gravitational, rotational, and isostatic “fingerprints”* (local)—relates recent ice loss sources to local sea level changes—literature survey; *vertical land movements (GIA)* (local)--ICE-5G v1.3 VM2\_L90, Peltier, 2012 (PSMSL); 2004; and *land water storage* (global)—after IPCC 2013. **Time slices:** 2020s, 2050s, 2080s, 2100 (10-year average centered on decade); sea level rise relative to base period 2000-2004.

14. **Treatment of uncertainty** and risk management in NPCC2.

15. **Sea level rise projections** relative to 2000-2004 base period for the 10th (low), 25th to 75th (middle), and 90th percentiles (worst case) for the 2020s, 2050s, 2080s, and 2100. By mid-century, SLR could reach 0.27-0.54 m (11-21 in); 0.75 m (30 in) (worst case scenario). By 2100, SLR up to 0.56-1.27 m (22-50 in); 1.9 m (75 in) (worst case scenario).

16. **100-yr coastal flood heights with** **sea level rise**: 2050s and 2080s. By mid-century, 100-yr flood heights up to 3.7-4.0 m (12.2-13.1 ft); 4.2 m (13.8 ft) (worst case). By 2080s, 100-yr flood heights up to 3.9-4.45 m, (12.8-14.6 ft); 4.9 m (16.1 ft) (worst-case scenario).

17. **Annual chance of 100-yr flood (1%) by 2080s** increases from 1.7% (low) to 2-5.4% (mid-range); 12.7% (worst-case).

18. **Coastal flood risk maps.** 100-year flood zones with SLR for the 2020s, 2050s, 2080s, and 2100 for 90th percentile (worst case scenario) compared with FEMA’s 2013 100-year flood zone (Hunter College, CUNY).

19. “**Static” (superposition) vs hydrodynamic flood return curves**—100-year flood return period curves with SLR for three representative localities. Simple superposition of SLR + flood height (blue) vs FEMA flood height-return curve (green); SLR + flood heights from hydrodynamic modeling (red). Source: Philip Orton, Stevens Institute of Technology.

20. **Map of differences in 100-yr flood heights between hydrodynamic and static methods**. NPCC2 2050s SLR 90th percentile; combined extratropical and tropical cyclones. For most localities, their difference is under 0.5 ft.

21. **Increasing NYC’s coastal resilience**.

22. **NPCC3 climate change science goals.**