Geodesign and Sea Level Rise:
Linking Coastal Flooding, Ecosystem Models, Drone Mapping, and Green Infrastructure for Coastal Resilience

Dr. Tom Allen, Dept. of Political Science & Geography
Mr. George McLeod, Center for Geospatial & Visualization Computing
Current Situation

• Maturation of numerous environmental models (hydrodynamics, shoreline and geomorphic changes, wetland response to SLRise)
• Rapid evolution drone mapping technology (outpacing policy)
• High fidelity 3D geovisualization tools

Challenges and Questions

• How can environmental modeling, UAS, and geovisualization be integrated and applied to improve risk perception?
• What are the accuracy of UAS (and impediments) to scaling up?
• Can we produce science-based, salient, and feasible future scenarios of green infrastructure and resilient coastal communities?
Scenario Selection

After Steinitz (2012)
A Geodesign Approach after Steinetz (2012)

**Constants**
- Climate
- Subsidence
- SLrise

**Requirements**
- Ecological Functions: R1
- Flood Reduction: R2
- Absorb Storm Impacts: R3
- Transport & Infrastructure: R4

**Timeline**
- History
- Present
- Future
Sea Level Rise

- Hampton Roads NOAA Tide Gage nearby Sewells Point
- USACE SLR curve calculator
- Subsidence

- Impacts
  - Flooding
  - Habitat losses/gains
  - Landform and sedimentation changes
  - Land use and navigation changes
Modeling Potpourri

• VDATUM for topobathy and vertical datums
• SLOSH, SCHISM, ADCIRC for storm surges
• USGS WAVES Toolbox for wave and bed shear stress
• SLAMM for marsh response and future site suitability
SLR and Tidal Flooding

Sea level rise is increasing the severity, frequency, and duration of flooding.

- 2018 was the highest annual water level since 1928.
- Hours of nuisance flooding 5th most per year since 1928.
- By 2050, floods that used to happen every 12 years will happen every year.

SLAMM and Wetland Response

• Background
• Scenario and input data
• SLR scenarios
  • 1m and 1.5 m 2075 w/ and w/o protection
  • Restoration
• Assumptions
  • Salinity, climate, sedimentation
SLAMM Protection
SLAMM No Protection
Drones in Coastal Mapping

• Digital surface model and elevation mapping and change
• Feature extraction for structures and digitization
  • Buildings
  • Shorelines
  • Dunes and other landforms
  • Vegetation and fine-scale cover types
  • Historical cultural resources
  • Bird and other species monitoring
  • Rapid damage assessment
Drone Mapping Approach

• Purpose and method
• Local constraints
  • Airspace constraints/FAA
  • Tide
  • Weather
• Commercial off the shelf tech.
• Testbed approach (a small watershed)
  • Data volume
  • Seasonal snapshot
Drone DSM to DEM

- DSM from UAV with Pix4D SfM
- Sampling DEM and DSM
- Adjustment of DSM to NAVD88
- LiDAR RMSE vertical accuracy
  \[ = 0.066 \text{ m} (0.092 \text{ m spec.}) \]
- FVA of the classified LiDAR
  \[ \text{RMSE}_z \times 1.960 = 0.129 \text{ m} (0.181 \text{ m spec.}) \]

- Phantom 4 Pro specs.
  \[ \pm 0.5\text{m} \text{ vertical with GPS positioning} \]
  \[ \pm 0.1\text{m} \text{ Vision positioning} \]

- Drone Derived DEM
  - Regression $R^2$ 0.766 ($<0.001$)
  - RMSE of Drone DEM 0.0332m
  - 0.065m linear error at 95%
  - Min. SLR increment to model = 13cm
  - Min. Time to model SLR increment = 28.9 yrs
Derived Current and Future DEM Contours

- MaxSurge33-SLR (2.44m + 0.67m) = 3.11m 1933 storm 8/23/33
- MHHW-SLR2050 (0.84m + 0.67m) = 1.51m
- MHW-SLR2050 (0.778m + 0.67m) = 1.448m
- MTL-SLR 2050 (0.408m + 0.67m) = 1.078m
- MHHW 0.84m
- MHW 0.778m
- MTL 0.48m
Visualization: Grey-Green Prescriptive Scenarios

**Scenario 1: Grey Infrastructure**
- Put a beefy riprap revetment along this shore and the 3ft yellow indicated length
- Tide gates here
- Bridge foot with seawall reinforced... piped and restrictive...

- Tide gates
- Retention pond

**Scenario 2: Green Infrastructure**
- Remove the riprap and make it marsh or living shoreline and beach behind it where current lot
- Plant cypress and marsh in the tennis courts P lot
- Place a grid of oyster reefs in here
- Remove street / cover with greenspace and trees
- Half this lot becomes marsh with a living shoreline sill in front OR make the whole lot pervious pavers and have a living shoreline sill in place of the riprap, keep the dock/ramp
- Remove the bridge completely
Drone Visualization Results

• Set of structural grey infrastructure and natural/nature-based green infrastructure
• 3D models and COLLADA>ArcGIS Pro conversion
• Site selection and placement
• Final visualizations and future dissemination
Modeling Discussion

• Scenario and Modeling Challenges
  • SLRise scenarios continue to have wide uncertainty over time
    • But improving LiDAR and Drone DEMs are allowing more refined flood modeling
      • Hydrocorrection, ditches, nuisance flooding
      • Runoff and subwatershed delineation
  • SLAMM & other wetland spatial models
    • Marsh parameters imported from distant locations
    • Lacking feedbacks between structures, sedimentation, and marshes
    • Hybrid changes (e.g. marsh restoration, or sedimentary restoration)
  • Today’s revetments and riprap as tomorrow’s oyster reef/sill
    • Rolling or phased retreat approach
    • Apply Life Cycle Assessment (LCA) to NNB?
  • Sedimentation and landform changes highly uncertain
    • Dredging and protective structure stabilization vs. comprehensive planning
    • Coastal circulation and sediment transport under SLR
Drone Discussion

• Drone mapping challenges and discoveries
  • DSM is good quality for ideal surfaces
  • Effort to model structures, adaptations, and visualization (vs. alternatives, e.g., CityEngine, GoogleEarth, or Pictometry)
  • Airspace and other constraints limit portability

• Immediate potential for site analyses or event and long-term monitoring

• Bathymetry is a limiting data factor in the shallow turbid estuary (potential for ASV)
Geodesign Integration Discussion

• Integration and limitations to geodesign
  • More participatory to ensure feasibility and salience
• GIS can assimilate, but bottlenecks and scale & accuracy issues emerge

• Visualizations
  • Ought to be tested
  • Scenario embedded with local planning
  • Perceptions vs. preferences
  • Improve sharing, opendata, and dissemination
Conclusions

• **Geodesign** poses strong potential to combine hydrodynamic and SLR modeling, flooding and built environment, and green infrastructure planning for resilience

• Modeling and drone mapping remain quite **siloed**

• Geospatial data still require careful integration (especially **vertically**)

• 3D models and viz are **enhanced** by UAV mapping (but logistics and model production and viz remain limiting)

• **ASVs** could fill some data gaps

• Future research: Landform and marsh evolution, fate of grey infrastructure, and designing with **life cycle**.