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# Assessing climate vulnerability in disparate places–Alaska and South Florida

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## ABSTRACT

Florida and Alaska are opposites when it comes to many things. Alaska is cold; Florida is the land of eternal summer. Alaska has snow and blizzards; Florida has tropical storms with pound in grain. Sea level rise is a critical concern to much of Florida's coast, and loss of beach sand is an enduring issue where storms or development have occurred. In Alaska, the coast is a mix of mountains and huge lengths of coastline that is along low lying terrain which suffer from severe coastal erosion resulting of loss of seaice in the fall months. Temperatures melt the permafrost at ever-increasing depths in Alaska, but heat is not new in Florida, where permafrost has not existed in millions of years, if ever. So how the setwostates are located over 5000 miles apart, similar? That was the question posed before the Arctic-Florida conference in 2016. The result was that Alaska and Florida do share many commonalities, and there is much to learn from each other. For example, Alaska's population continues to grow as does Florida's. In both states there are changes in wildlife. Florida has incurred changes in migration patterns and native populations. In Alaska there is an increased incidence of diseases in wild animals which are a food source for many Alaskans. Warmer waters are causing fish to change migration patterns. Likewise diseases have impacted at-risk communities in Alaska; such a prediction has recently been discussed for Florida. Adaptation strategies are underway in Florida, which can help in Alaska. Roads, water supplies, water storage, waste water and storm water are all issues that pose challenges to both states, so there are answers in infrastructure adaptation strategies. Many common problems can be solved by sharing information. The Florida–Alaska connection is an example of looking outside the box to find ideas that can be useful to those deemed to be far different.

**Keywords:** climate change; adaptation strategies; water supply, infrastructure

## 1. INTRODUCTION

Global observations from satellites and long term data collection have made it possible to document and analyze patterns in the Earth's climate. As a result, a significant body of literature has developed that outlines the impact so climate change and general agreement within the scientific community on many climate change issues. Hundreds of scientists worldwide participate in the preparation and review of the Intergovernmental Panel on Climate Change (IPCC) and both the 2007 and 2013 reports indicate that there is global scientific consensus that the *"warming of the climate system is unequivocal, as is now evident from observations of increasing global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level"* (IPCC, 2007, 2013). While much of the focus of these scientists has been on the causes on the correlation between the changes in green house gas concentrations in the atmosphere and temperature changes, others have analyzed the impact of these changes to improve understanding of the driving forces and long-term impacts on human activities and water supply planning (http://www.research.noaa.gov/climate/tobserving.html).

Where one is located impacts attitudes toward climate change (Bloetscher, 2010). For much of the United States, there are signs that encourage people to act. There is strong evidence that global climate change is impacting the global water cycle, natural environments, the built environment, infrastructures systems and global water resources (IPCC, 2013; UNEP, 2009; Karl and Melillo, 2009; Heimlich, et al, 2009; NOAA, 2011; Bloetscher and Romah, 2015). Examples are rising global average air and ocean temperatures, increased and earlier snow and ice melt, shorter subtropical rainy seasons, shifted seasons, sea level rise and greater variations in temperature and precipitation (IPCC, 2013; Freas, et al 2008; Marshall, et al 2003; Bloetscher et al 2010). The National Oceanographic and Atmospheric Administration (NOAA) and IPCC (2013) predictions are that by 2100, the warming will be on the order of 2-3 degrees C and will increase sea level rise by upto 3 feet. Significant changes in precipitation patterns are expected in many areas creating increased drought frequency and duration in the Plains states, southeast and southwestern United States (Backlund, 2012; Grinstead, 2009; Rahmstorf, 2007). Accompanying these drivers are potential changes in storm frequency and intensity, desertification, population migration, ocean acidification and coastal flooding (IPCC, 2007), exacerbated by the land cover and use changes are substantially impacted the fluxes, timing and quality of precipitation, which in turn recharges aquifers and discharges to streams, rivers and wetlands (Adrians, et al, 2003; Scanlon et al 2005; Marshall, et al 2003; Salmun and Molod 2006), and leading to changes in the timing and volume of streamflow (Rischey and Coast-Cabral, 2006) and, flood and drought trends resulting from increased evapotranspiration (ET) (Moore & Rojstaczer, 2002; Scanlon et al 2005, TRB, 2008).

In addition, during the past 140 years, an increase in the sea level has been observed (Bloetscher, 2012)., the SFRCC (2015) adopted the US Army Corp of Engineer's methodology to derive scenarios of sea level change intermediate to high rates of SLR for years 2030 (3"to7") and 2060 (9"to24") as the consensus projection to guide future planning in Southeast Florida. The suggested cause of sea level rise is thermal expansion of the ocean due to rising temperatures and melting ice caps (Jevrejeva et al, 2010; Vermeer and Rahmstorf 2009). Sea level rise is a major concerns in early half the US population lives within 50 miles of the coast, involving most major commercial, leisure and import/export enterprises.

Climate change also has the potential to create a serious public health threat that affects human health outcomes and disease patterns (Kundzewicz et al. 2007; Mukherjee, 2016; Bloetscher et al 2016). Although preventative and adaptive strategies for climate change will helpless negative health impacts, human health will continue to be affected from present climate change conditions (Reilly et al 2009; Global Insight, 2006; Johns, 2003). It is expected that climate change will both aggravate existing human health risks and conditions and create new ones, while the health impacts will vary and have both direct and indirect effects (Global Insight, 2006; Kundzewicz et al. 2007). Populations with combined health, socio-economic, and place-based vulnerabilities will be most affected (Johns, 2003). The health impacts will be felt to different degrees depending on action taken to adapt (Nicholls, 2008; Bloetscher et al 2011). Roy Scranton (2015) calls this the Anthopocene.

What is indicated is that it does not appear that the current course cannot be reversed anytime in the near future (NOAA, 2013), so adaptation will be needed to protect infrastructure and property. Most of these protective efforts will happen at the local and regional level. In particular the authors focused on infrastructure issues – those associated with water, sewer, transportation, buildings and property protection. As a result the intent of this paper is to highlight how two apparently different areas, Alaska and Florida, share commonalities, may be at different points in their adaptation needs, and may be able to learn much from one another.

## 2. METHODOLOGY

The point of this paper is to compare the current conditions in Alaska and south Florida to determine the differences and commonalities between regions. To do this, information was gathered about the current economic and weather factors and how they manifest themselves in both regions. In addition, an analysis of infrastructure issues was discussed through a solution salon at the conference. From the literature review, conference presentations and the salon discussions, comparisons were made for climate factors and infrastructure risks, noting that cultural and natural risk issues cannot be separated from the prior factors. It should be noted that these are gross summaries, and individual communities may have differing conditions since much of climate change is local.

**The South Florida Condition**

Southeast Florida is a warm, water-driven region, having abundant water supplies are present as a result of an average of over 54 inches of rain each year and temperatures averaging over 70 degrees F (20 C). Snow does not occur, but the area is prone to tropical storm activity. The hydrologic budget of the state is characterized by heavy rainfall in the summer months, the Everglades, which is dominated by evaporation and transpiration that creates the storms, with surface runoff into Florida Bay composing a relatively small percentage of the annual rainfall. Historically, the Everglades were a giant marsh fed by rainfall. During the rainy wet season, sheets of water would moved own the state from Orlando, through the Kissimmee River, to Lake Okeechobee, then to the Everglades. Because the land was so flat, water could flow from lake to lake, spill over natural river channels and spread into flood plains which are there charge are as for the Biscayne aquifer. There were no barriers or can also director control the path of water. In the aftermath of large storms, water could stand for weeks and months. When few people lived here, that was not a problem, but the sunshine and proximity to beaches, called for change (Roy and Hossain, 2015). That change was to drain the coastal aquifer to reduce water levels and create developable property.

One of the things that has changed in the past 100 years is the amount of rainfall. Modeling indicates that land use changes from 1900 to date reduced total rainfall by 12 percent, much of it in the summer. This confirms the finding of Pielke (1999) which reported that "it appears that development has exacerbated their severity since landscape changes over south Florida have already appear to have reduced average summer rainfall by as much as 11%" (Pielke, 1999). The majority of observed changes occur in the distribution of convective (ET driven) summer rainfall, which accounts for over 70 percent of rainfall for a given year. Marshall, et al., (2003) suggested the reason – a comparison of land use maps from 1900 and 1980 showed dramatic change in land use cover from marshland to agricultural and urban land cover. Marshall, et al., (2003) also found accompanying temperature changes for southeast Florida–temperatures are cooler in winter which increases freezes in the winter due to loss of moisture from the swamp lands, and both higher temperatures and more evapotranspiration in the summer. Both the observed and predicted patterns match. The variation is projected to worsen. The variation may impact wildfires which tend to peak in March and April, the end of the dry season when winds are highest.

The region incurs tropical storms on a regular basis, and while there may be changes in storm patterns, the impact will likely be a similar pattern of storms with some potential increase in frequency. However, sea level rise, for an area with an average elevation of 5 ft. NAVD88, and reliant on drainage systems designed to work in 1929 when the ocean level was 9-10 inches less, will be critical. Sea level has been steadily rising for over 100 years according to the tidal station at Key West, and is projected to continue to rise, likely at an accelerated rate. Sea level rise, combined with the end of the wet season in September, the king tides in late September and October and flat topography puts much of the region at risk (Bloetscher and Romah, 2015). Modeling by Bloetscher, et al., (2016) and Bloetscher and Romah (2015) indicates that flooding is not just a coastal issue, but also an inland issue as higher ground water levels in low-lying areas compounds problem. Soil storage is limited because the aquifer levels are often just below the surface in the wet season which leads to flooding leads to flooding. Sea level rise will increase regional groundwater tables, leading to more pumping facilities that will discharge large volumes of water during the wet season.

As a result of sea level rise, the mapping models indicate that infrastructure, primarily roadways, will be impacted first, followed by property Sanitary sewer systems which are constructed at depth that is below the groundwater level are already impacted. Submerged pipes increases the potential for infiltration though cracked pipes or old or poor construction, thereby consuming capacity in treatment plants. Inflow during rainstorms or other inundation will enter into the sanitary sewer system from unsealed manholes, open cleanouts and problem surface connections. Inflow leads directly to the sanitary sewer overflows, potential regulatory actions and property damage due to backflow. Water mains are shallower, but may periodically be submerged in groundwater. Near the coast, pipelines may suffer corrosion due to brackish and freshwater aquifer levels. This is particularly damaging to cast or ductile iron pipe which will leak with time. In both cases, the groundwater movement can alter the pipe bed, causing movement of the pipes.

The performance of the transportation infrastructure is related effectiveness of flood control and storm water drainage systems for the transportation corridors. Higher groundwater elevations created by sea level rise compromise storm water collection systems and transportation infrastructure in low-lying areas including access to roads, bridges, rail and rail transit (Bloetscher and Romah, 2015). Roadway embankments be damaged by higher water table levels (FDOT, 2012). Road bases become saturated under this scenario, causing premature pavement failure. Figure 1 is the typical representation of the problem with roadway bases before and after sea level rise. This diagram illustrates properly constructed FDOT roadways, which are main arteries for transportation as well as emergency evacuation routes. Many local roads that do not meet these standards would be more vulnerable to failure. The result is billions in infrastructure repairs to maintain the status quo.

Beach erosion is another impact of the combination of sea level rise and coastal storms. As the beach erodes, it puts coastal development more at risk and adversely impacts tourism which is beach dependent. Finally Bloetscher, et al (2016) suggested that certain vector and waterborne illness frequency will increase, although good data is currently lacking. A better understanding of future trends with mosquito spread diseases like Zika, dengue fever or chikungunya, or water borne diseases like giardia and cryptosporidium, is also necessary to adequately address the challenges posed by climate change.

In Florida, climate change can be characterized by warm, wet weather, slightly less rainfall, greater extremes in temperature, sea level rise that threatens infrastructure, economic, property and population risks, and the potential for an increase in diseases.

**The Alaska Condition**

In contrast to Florida, Alaska is a far larger land area, with significantly more diverse topography, that can be characterized by four climate zones, maritime, continental, transitional and arctic. The maritime climate zone is characterized by small temperature variations, heavy precipitation, and minimal freezing weather. Surface winds are strong and persistent. The transitional climate zone can be characterized by increased temperature variations, increased sunshine, lower precipitation and generally light surface winds. Mean annual temperatures are typically 25 to 35 ºF. The continental climate zone has large diurnal and annual temperature variations, low precipitation. Surface winds are generally light with a mean annual temperature of 15 – 25ºF. The arctic has lower temperature variations than the continental climate zone with the potential for high winds. Mean annual temperatures range from

10 to 20ºF. Annual rainfall ranges from 150 inches in Ketchikan to around 10 inches on the North Slope. Snowfall ranges from 800 inches in the mountains above Valdez to 40 inches in the Interior and North Slope.

Over the past 60 years, Alaska has warmed more than twice as rapidly as the rest of the United States, with state-wide average annual air temperature increasing by 3°F (Chapin et al 2014) and average winter temperature by 6°F (Stewart, et al 2013), with substantial year-to-year and regional variability. Warming intensified after 1976 when the Pacific Decadal Oscillation (PDO) shifted from a cooler pattern to a warmer one (Chapin et al 2014), but has moderated since 2000 when the PDO shifted back (Bieniek, 2014; Wendler, et al., 2012; CCSP, 2008; Chapin et al., 2014).

Alaska contains some of the largest glaciers on Earth. The hydrologic budget of the state relies on harsh winter snows that feed the snowpack of the glaciers that exist on most of the mountains in the state, and slow melting in the summer months. However, most have seen significant retreat in the past 30 years (Jacob, et al 2012, Larsen et al 2007) as a result of rising land temperatures (Arendt, et al 2002, 2009). Loss of glaciers results in changes to surface water runoff timing and volume. Earlier melt provides earlier surge s in rivers and streams. Lessening snowpack will result in less available water to those streams in the future during the last summer and fall, an issue seen in California and the Pacific Northwest already.

Eighty percent of land in Alaska is underlain by underlain by sporatic, discontinuous and continuous permafrost. Sporatic permafrost, its name implies, has segments of permafrost here and there. In discontinous areas, at least half the terrain is underlain by permafrost. Continuous is completely underlain by permafrost. Rising temperatures have begun to melt the permafrost (Jorgenson, et al 2008). Permafrost may melt as much as 50 m below the surface (Markham, 2015). Permafrost melt causes: subsidence, spongy surface conditions and the release of large amounts of methane to the atmosphere. The Alaskan Arctic coast has warmed 4°F to 5°F at 65 foot depth since the late 1970s and 6°F to 8°F at 3.3 foot depth since the mid-1980s (Osterkamp, and Romanovsky, 1999; Romanovsky, et al, 2008). While the permafrost in this region is still around 15 deg. F, the real problem is a thickening of the active layer which can result in seasonal thaw consolidation and heave.

Chapin et al (2014) predict changes in precipitation patterns and glacial melt will lead to greater runoff, a serious issue in built environments. However, due to higher air temperatures and longer growing seasons, increases in evaporation are expected to reduce water availability in most of the state (Hinzman, et al, 2005), and lessen the extent of wetland areas. Given the combined increase in temperature, drier ground due to wetland losses, and the thunderstorm activity resulting form increase evapo-transpiration, Kasischke, et al 2010 report more large fires in the last ten years than in any decade since the 1940s. Hu et al, (2010); Rosen, (2015) and NAS (2015) report that on the Alaskan tundra, cold, wet conditions have suppressed fires for over 5000 years until recently. 2015 saw Alaska with a record number of fires on the NOAA website. Mack et al., (2011) suggest that a single large fire in 2007 released as much carbon to the atmosphere as had been absorbed by the Arctic tundra in the prior 25 years (Chapin et al., 2014). While Alaska is a fire ecology that requires periodic burning for the well-being of our wild life and plant life. For many years

Alaskans tried to control fires but the current tendency is to let them burn unless there is potential loss of life or property. However, the outlook is that the area expected to burn each year is projected to double by 2050 and to triple by 2100 (Chapin et al., 2014; Blashi et al., 2008).

Thawing permafrost has severe local impacts including damage to infrastructure such as homes, schools, clinics, airports and roads accelerated erosion along the coast. Properly constructed ADOT roadways now use a conscience decision to let the permafrost melt because the cost of protecting against melt is too high. Older roads that assumed permafrost which is now melting making sub-bases less stable. The state has identified at risk roads in the states. In rural Alaska, permafrost thaw will likely disrupt community water supplies and sewage systems, with negative effects on human health. Related to the transportation infrastructure is the related effectiveness of flood control and storm water drainage systems for the transportation corridors. Larsen et al., (2008) reported $3.6–$6.1 billion (+10% to +20% above normal wear and tear) to future costs for public infrastructure between 2005 and 2030, and $5.6–$7.6 billion (+10% to +12%) by 2080.

Road concerns impact the economy. There are few roads in rural Alaska. Winter travel is often done by snowmobiles over frozen rivers. As a result of permafrost vulnerability, these winter roads are no longer frozen, compromising access across the state. Behind, oil, mining, fishing and tourism are the largest industries in Alaska (Leask, et al 2001). Alaska's marine, tundra, boreal forest, and rainforest ecosystems include resting places and summer homes for millions of migratory birds, thousands of caribou, the largest US salmon runs and half of the total US fish catch, along with a significant proportion of the nation's marine mammals (NMFS, 2010). However loss of ice, increased runoff in rivers, changes in turbidity, and higher temperatures will lessen commercial fish abundance. Ocean acidification is having an adverse impact on fisheries. The tourism industry might appreciate warmer springs and autumns, but lessened winter activities, loss of fish population, less birds and wildlife and increased summer smoke from wildfires may offset these gains (Yu, et al 2009; Trainor, et al 2009; Chapin et al 2014).

While sea level rise is a minor concern at this point at this point, the anticipated sea level changes are generally negative because of plate rebound or the uplift of the plates along the coast. In areas where we anticipate sea level rise, coastal erosion will require moving the community so we simply need to take sea level rise into acount when selecting the new village site.Reductions in sea ice increase the amount of the sun's energy that is absorbed by the ocean. This leads to a self-reinforcing climate cycle, because the warmer ocean melts more ice, leaving more dark open water that gains even more heat. In autumn and winter, there is a strong release of this extra ocean heat back to the atmosphere, hence winter temperatures are rising faster. Damage due to fall storms is increasing because the fall sea ice that has historically protected the shores is no longer there. The western coast is particularly vulnerable. Already population is looking at migration as the solution to coastal erosion. In Newtok, the village landfill, barge ramp, sewage treatment facility, and fuel storage facilities were destroyed or severely damaged in recent storms (Rosen, 2015). The loss of the barge landing, which delivered most supplies and heating fuel, created a fuel crisis. Saltwater is intruding into the community water supply. Erosion is projected to reach the school, the largest building in the community, by 2017. 26 communities have erosion problems that warrant immediate response, including relocation. Shishmaref, Newtok and Kivalina are working on relocations (Rosen, 2015).

The warmer coastal waters create a climate for disease. The northernmost documented case of *Vibrio parahaemolyticus* among humans involved tourists who ate Prince William Sound oysters in 2004 (Rosen, 2015). It is suspected that 30 dead whales found in the western Gulf of Alaska succumbed to toxins produced by such a bloom in 2015 (Rosen, 2015). Persistent organic pollutants like pesticides and PCBs that were once trapped in sea ice can also be released as ice thaws. Alaskans are seeing more game animals which are the food supply with more diseases. This is probably the greater threat.

Hence the Alaska condition is represented by cool, wet weather, slightly less rainfall but greater extremes in temperature and precipitation, sea level rise and permafrost thawing that threatens infrastructure, economic, property and population risks, and the potential for an increase in diseases due to warming coastal waters.

**Workshop Outcomes**

Based on a review of the data for both Alaska and southeast Florida, tables were created to compare natural risks, climate factors, cultural risks and infrastructure risks. Table 1 shows that when looking at natural risks, there are many similarities. Both states have increasing risks from wildfires, temperatures, temperature variations, and sea level rise. Both states incur hurricane force winds, albeit in different forms. Florida has seen tornados increase as a result of temperatures. Alaska is impacted by non-climate natural risks like earthquakes and volcanos, but neither appears impacted by climate change.

**Table1** Comparison of Natural Risks

| Natural Disaster Risks | Florida | Alaska | Comments |
|---|---|---|---|
| Earthquakes | n | y | Fault on Pacific Rim |
| Volcanos | n | y | Active in Alaska |
| Rogue waves/tsunamis | unclear | y | Impacts low-lying coastal areas, more prone in earthquake regions |
| Hurricanes | y | y | However hurricane force winds from blizzards not unheard of in Alaska |
| Tornados | Low risk | unclear | Risk appears to be increasing for both |
| Wildfires | y | y | Increasing for both |
| Snow/Blizzards | n | y | Increasing variability of precipitation all seasons in Alaska, less overall precipitation in Florida, especially summer convective rainfall |

Table 2 outlines climate impacts only. What this table indicates is that both states will incur similar impacts, except for permafrost melt. The amount of runoff is already noticeable in both states. Timing has been altered in Alaska. Precipitation patterns have changed in Florida (shorter wet season). Both states have incurred higher temperatures, and sea level rise. Groundwater is less studied in Alaska, so its impact is unknown.

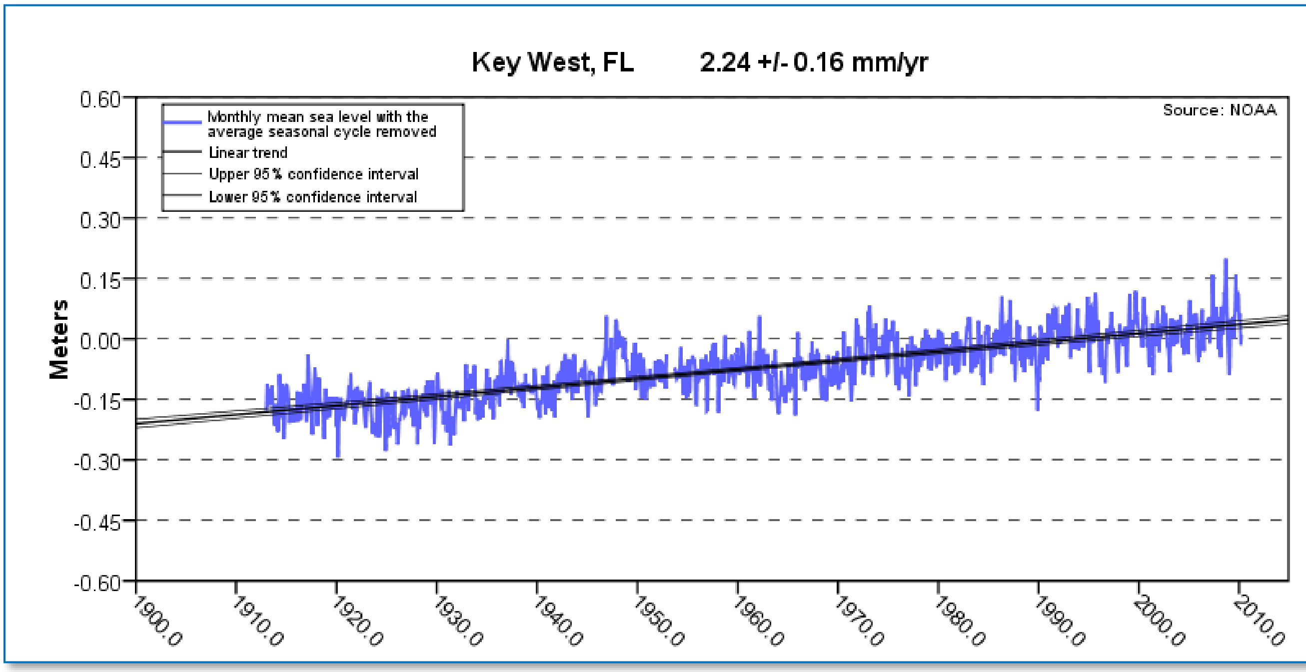
**Table 2** Comparison of Climate risks

| Climate Effect | Florida | Alaska | Comments |
|---|---|---|---|
| Sea Level Rise | y | y | Increasing for both, but critical in southeast Florida and western Alaska slope. Some areas in Alaska are seeing a drop in sea level. |
| Higher highs and Lower Low Temperatures | y | y | Citrus moved south, not north in Florida; much warmer temperature alter ecosystems and stream flow data in Alaska |
| Warming | y | y | Increasing for both, much higher rate in Alaska |
| Rising Groundwater | y | unk | Impacts low-lying coastal areas in Florida. Due to the diverse topography, this will vary from one area to the next in Alaska |
| Permafrost melt | n | y | Applicable to Alaska only, major release of methane gas and disruption of soils |
| More runoff/stormwater | y | y | Risk appears to be increasing for both, glacial melt being the larger concern in Alaska |
| Changes in Precipitation | y | y | Increasing variability of precipitation all seasons in Alaska, less overall precipitation in Florida, especially summer convective rainfall |
| Increases Precipitation Intensity | y | y | Increasing variability of precipitation all seasons in Alaska, higher intensity in Florida |
| Increased Incidence Disease | unkr | Y | Noticedin Alaska, Florida data inconclusive but expecting increases |

Sea level rise is already having impacts in both communities and the commentary from the solutions salons indicated that "way of life" was the major impact of climate issues. "Way of life" can be defined in many ways:

- Communications
- Economic

- Tourism/Ecotourism
- Agriculture
- Fisheries
- Infrastructure



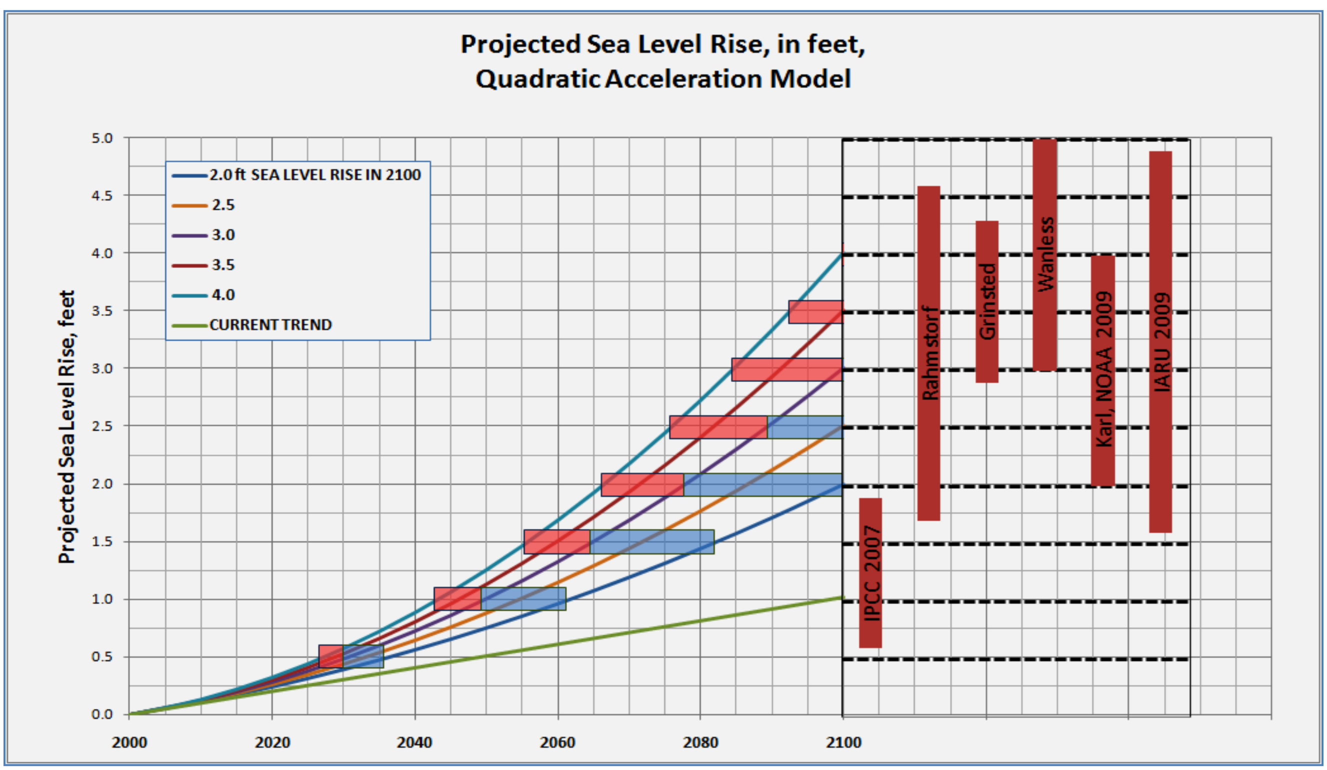




**Figure 1** But sea level is rising, and expected to continue to rise

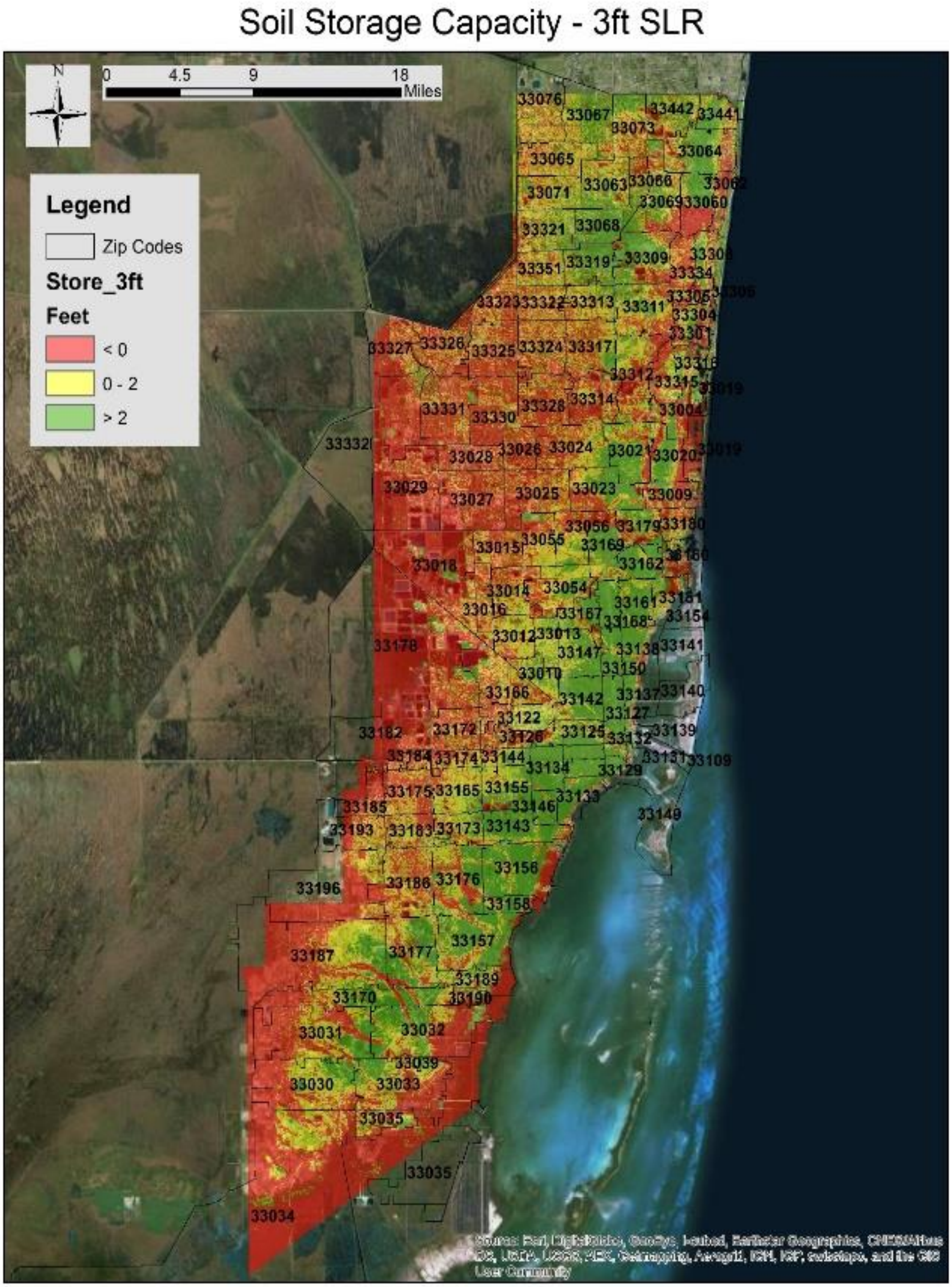



**Figure 2** Rising Seas will imperil much of southeast Florida

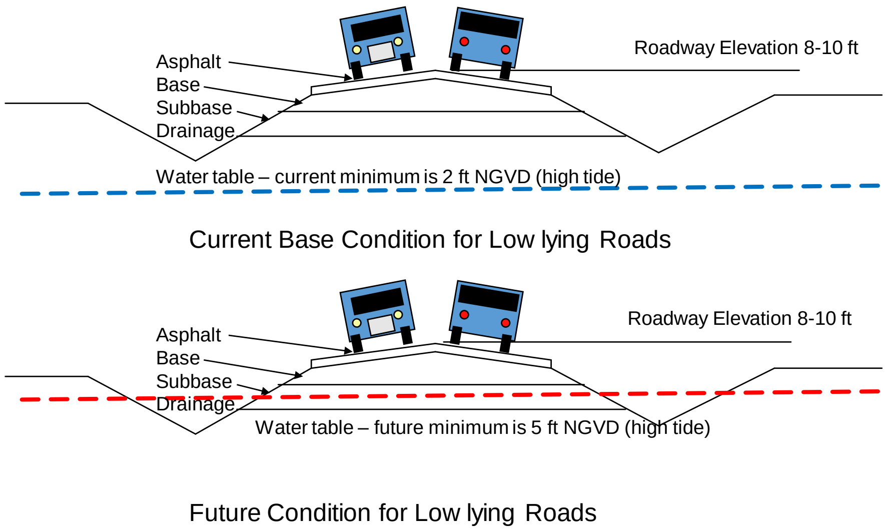



**Figure 3** Typical representation of the problem before and after sea level rise

**Figure 4** Beach Erosion is common

**Figure 5** Retreating Glacier increase runoff

**Figure 6** Sea Level rise imperils roadways

Within "infrastructure" was power, water, sewer, communications, storm water, public facilities like schools and parks, roads and bridges, buildings and transportation systems (ports, air, etc.). It should be noted that much of Alaska can only be accessed by boat and/or plane so transportation systems are vital for outlying villages. Also many schools and health clinics are actually located in at-risk areas in outlying villages in Alaska. Because transportation and communication networks are limited, weather outages can be exacerbated much like the collapse of communication and utility grids throughout southeast Florida after a storm.

An issue affecting both areas is data limitations. Alaska has fewer assets, but fewer systems to identify infrastructure. Florida has more infrastructure, but much of it is poorly documented. As a result, vulnerability assessments and asset management programs may be beneficial, but incomplete due to missing information (although Alaska is expecting to complete this in 2017).

- An Inventory of infrastructure
- A vulnerability assessment/risk
- Deciding when to do something (risk/vulnerability) and what to do
- Incremental costs
- Level of service metrics

Other solutions were varied and often fit both states. First was the suggestion that both states mainstream resiliency principles, implement short term and long-term plans and prioritize infrastructure needs to protect economic and social systems.

A variety of suggested tools to improve resiliency are noted in Table 3.

**Table 3** Summary of solutions to improve community resiliency

| Item | Florida | Alaska | Comments |
|---|---|---|---|
| Plan for ecosystem expansion | y | y | Florida at risk in coastal areas |
| Revise growth to go more vertical | y | n/a | Shrinking developable land makes this a higher priority in densely populated south Florida, not really an issue in Alaska |
| Revise building codes (foundations particularly) | y | y | permafrost melt and saturated foundations are different assumptions than some codes currently assume Alaska has few codes for rural |

| | | | |
|---|---|---|---|
| | | | communities. |
| Revise building codes to assume 50 or 100 year SLR projections | y | y | If buildings are to last 50+ years, they should meet future codes based on changing requirements for construction and sustainability |
| Revise development codes in repetitive loss areas | y | y | More of a Florida issue, but high risk in western Alaska |
| Eliminate septic system in many areas | y | y | Wetter conditions; more of a Florida issue |
| Incentivize technology | y | y | Better means to harden technology systems (communications, power, etc.) would benefit residents |
| Incentivize natural (green) solutions | y | y | Would help to use ecosystem to protect built environment as indicated after hurricane Katrina |
| Incentivize P3 partnerships | y | y | May be a bigger potential in areas to redevelop or in rural Alaska where funds are limited |
| Incentivize sustainable solutions/technologies | y | y | development code issue |
| Increase community awareness | y | y | Incorporate local knowledge |
| Perform vulnerability assessments | y | y | Applicable to both communities Currently underway in Alaska. |
| Develop comprehensive resiliency plans | y | y | |
| Repurpose existing infrastructure | y | y | |
| Revise infrastructure standards. | y | y | Need to update to include assumptions about changing conditions for soils, delivery |

Building codes were a major discussion item for infrastructure. For the most part, building codes are stricter and more enforced in Florida as a result of the damage sustained after Hurricane Andrew in 1992. However there were impediments:

- Hard to change w/o stakeholders
- Seismic/permafrost vs wind load conflicts

- Data lacking on cost/benefit to harden with codes
- Awareness of repetitive losses

Alaska has fewer codes and not enforce them which adds to the state's risk. Likewise, development codes (zoning, etc.) are rare in Alaska, making development practices more difficult, while in Florida there is a need to education the populace on the need to go vertical to encourage redevelopment.

With respect to infrastructure systems, the assumption was that the engineers could solve problems, it the policy issues and funding were in place. Hence much of the discussion focused on policy vs hard infrastructure solutions as noted in Table 3. However, there were a number of issues. Both regions experience flooding as a result of sea level rise resulting in displacement of populations. Communities in Alaska have been impacted by coastal erosion and are already planning for their move, something south Florida officials should observe as the future in southeast Florida will involve displacement of coastal populations. The solution to this seems lacking as the communities that want to move, have not in years due to funding. This is an area where a P3 with a developer might be useful. The developer would create a "subdivision" with all services at a new location, build it and then residents could move en-mass to the new community. The developer would then get paid for the move with appropriate funding. This might resolve some of the bureaucratic limitations the currently are a barrier to service provision. Unakleet is a good model where public infrastructure is put in place which encourages people to move over a period of time. Perhaps consider providing tax incentives. Orderly movement is generally better than en-mass.

Economic issues associated with loans and insurance will be a bigger issue in south Florida because of the value of the property. Both economies have been affected already - Alaska's economy has been affected in the area of oil and gas exploration, fishing and mining. Florida has impacts to coastal corals, the Everglades, property, water supplies. Large volumes of water drained offshore in both states impacts the quality of the coastal oceans. Florida's long-term concern may involve a change in how insurance companies view property risk, and the impact that will have on lending practices. Both regions need adaptation strategies, and fortunately it appears both recognize the need for same. Both have estimated costs for improvements, and the cost is in the billions for both. It is unlikely federal funds will flow to address these concerns, so local funding will be required.

Finally, the permafrost in Alaska and rising groundwater in Florida will create the following conditions:

- spongy conditions and heave in soils.
- piping systems and road base will be stabilized leading to premature failure.
- power poles, building foundations and underground utilities may be adversely impacted even if properly maintained.
- Sanitary sewers can be overwhelmed by runoff and infiltration if not property maintained (despite being separate systems).

- Water supplies and saltwater intrusion may be limited to Florida as problems, until the glacial melt creates limited water supplies in the early Fall in Alaska.
- Bridges may need to be raised for boat traffic to address sea level rise and increased storm water systems.
- storm water systems may be inadequate in many places today.

Table 4 outlines the infrastructure risks. However the discussion about solutions to this risk was interesting.

**Table 4** Infrastructure at risk

| Infrastructure at Risk | Florida | Alaska | Comments |
|---|---|---|---|
| Road Bases | y | y | Heave, road base, base failure in both states |
| Storm water | y | y | Increased runoff, undersized systems/pipes, potential flooding risks in both states |
| Water Distribution Piping | y | y | Heave, thawing permafrost damage corrosion with changing soil conditions |
| Sanitary Sewer/Piping | y | y | Infiltration, inflow, pipe failure due to heave or thawing permafrost |
| Water Supply | y | n | Florida drained the aquifer to develop, draining off water supply. No place to store water. Water supply in Alaska's North Slope is in jeopardy as the permafrost melts. |
| Saltwater intrusion | y | unk | Issue in SE Florida. Unclear how this will change in either state. |
| Power grid | y | y | Wind, soil conditions change, |
| Bridges | y | y | Sea level rise impacts bridge height, as does storm water runoff in both states |
| Private property/buildings | y | y | Risk of flooding or loss of access/utility |

| | | | |
|---|---|---|---|
| | | | services including increasing risks including flooding, erosion, melting permafrost |

The solution salon participants identified a series of more social issues that should be monitored. These are noted in Table 5. However these are far harder to monitor because there are no real metrics to evaluate them easily.

**Table 5** Comparison of Cultural Risks

| Cultural Risks | Florida | Alaska | Comments |
|---|---|---|---|
| Displacement | Future | y | Current plans in Alaska, future issue for SE Florida |
| Need for Adaptation | Y | y | Coastal as well as economic in both states |
| Cost | Y | y | Billions for each, local money, and a lack of funding sources |
| Economic Risk | Yes | y | Alaska's economy has been affected. Oils, fishing, mining, indigenous populations affected. Florida has impacts to corals, property values water supplies; long term property values may be major factor. |
| Ecosystem risk | y | y | Everglades in Florida, tundra populations in Alaska. Both impacted by wet dry cycles/ flood-fire cycles that are different than the past. |
| Disease Risk | y | y | Already seen in Alaska. Unclear if impacts exist already in SE Florida |

## 3. CONCLUSIONS

The goal is this paper was to compare and contrast climate issues in Alaska and Southeast Florida. There are three issues identified as drivers with climate change in Florida: changes in precipitation patterns, temperature increases and sea level rise, with sea level rise the primary risk at present. These three factors appear to be the perfect scenario to create disruption to the state's long-term economic growth and development. In Alaska the same three issues are risks, although temperature appears to be the primary risk at present as it affects glacial and permafrost melt, issues Florida does not deal with. Communities and the economy have been affected in both states.

Understanding climate variability and sea level rise are important to understanding the potential impacts in both states. With respect to climate change vulnerability both state will see significant effects on their economic, natural and built environmental systems. Protection of developed land is almost certain for most of the coastline to protect the economic value of coastal resources. A framework, toolbox of options and analysis of regional and local conditions should be pursued by local, regional and national policymakers to create that cohesive climate change strategy that has been so elusive to date. Some solutions for road bases, water, sewer, storm water, public health and other public infrastructure can work in both locations, so sharing data may be a useful concept.

The vulnerability of transportation and utility infrastructure will require the design of more resistant and adaptive infrastructure and network systems. This would, in turn, involve the development of new performance measures to assess the ability of transportation infrastructure (e.g., roadways, bridges, rail, sea ports, airports) in preparation for sea level rise and to enhance resilience standards and guidelines for design and construction of transportation facilities (Bloetscher, et al 2016, submitted). Specifically, considerations must include retrofitting, material protective measures, rehabilitation and, in some cases, the relocation of a facility to accommodate sea level rise impacts.

While a variety of solutions have been suggested, the most significant barrier to a cohesive approach to climate adaptation is the failure from the public and policy-makers to realize how their area will be affected. Different solutions one area may identify and respond to challenges in their location, others should be supportive of those efforts, realizing that while such actions may be neither desirable nor appropriate for them, they may need support for solutions in the future in their areas. This project was designed to compare solutions and demonstrate differences between regions based on field conditions. The intent is that the results of this project will lead to a series of recommendations and action steps for policy makers to conserve the state's assets.

## REFERENCES

1. Adriaens, P.; Goovaerts, P.; Skerlos, S.; Edwards, E.; and Egli, T. (2003), Intelligent Infrastructure for Sustainable Potable water: a roundtable for emerging transnational research and technology development needs, *Biotechnology Advances*, Vol. 22, pp 119-134.
2. Arendt, A. A., K. A. Echelmeyer, W. D. Harrison, C. S. Lingle, and V. B. Valentine, 2002: Rapid wastage of Alaska glaciers and their contribution to rising sea level. Science, 297, 382-386, doi:10.1126/ science.1072497.
3. Arendt, A. A., S. B. Luthcke, and R. Hock, 2009: Glacier changes in Alaska: Can mass-balance models explain GRACE mascon trends? Annals of Glaciolog y, 50, 148-154, doi:10.3189/172756409787769753.
4. Backlund, P. Synthesis and Assessment Product 4.3: The Effects of Climate Change on Agriculture, Land Resources,

Water Resources, and Biodiversity in the United States; 27 May 2008. Available online: http://www.climatescience.gov/Library/sap/sap4-3/finalreport/default.htm#EntireReport (accessed on 22 February 2012).

5. Balshi, M. S., D. A. McGuire, P. Duffy, M. Flannigan, J. Walsh, and J. Melillo, 2008: Assessing the response of area burned to changing climate in western boreal North America using a Multivariate Adaptive Regression Splines (MARS) approach. *Global Change Biology*, 15, 578-600, doi:10.1111/j.1365-2486.2008.01679.x.
6. Berthier, E., E. Schiefer, G. K. C. Clarke, B. Menounos, and F. Rémy, 2010. Contribution of Alaskan glaciers to sea-level rise derived from satellite imagery. *Nature Geoscience*, 3, 92-95, doi:10.1038/ngeo737.
7. Bieniek, P. A., J. E. Walsh, R. L. Thoman, and U. S. Bhatt, 2014: Using climate divisions to analyze variations and trends in Alaska temperature and precipitation. *Journal of Climate*, in press, doi:10.1175/JCLI-D-13-00342.1.
8. Bloetscher, F. 2012. Protecting People, Infrastructure, Economies, and Ecosystem Assets: Water Management and Adaptation In The Face Of Climate Change, *Journal of Water*. *Water* 2012, 4; doi:10.3390/w40x000x
9. Bloetscher, F.; Romah, T.; Berry, L.; Hernandez Hammer, N. and Cahill, M.A. 2012. Identification of Physical Transportation Infrastructure Vulnerable to Sea Level Rise, *Journal of Sustainability*, Vol. 5, No. 12.
10. Bloetscher, F.; Romah, T. 2015. Tools for Assessing Sea Level Rise Vulnerability. *Journal of Water and Climate Change* Vol 6 No 2 pp 181–190 © IWA Publishing 2015 doi:10.2166/wcc.2014.045.
11. Bloetscher, Frederick; Polsky, C.; Bolter, K.; Mitsova, D.; Pablicke Garces, K.; King, R.; Cosio Carballo, I.; and Hamilton, K. 2016, Assessing Potential Impacts of Sea Level Rise on Public Health and Vulnerable Populations in Southeast Florida and Providing a Framework to Improve Outcomes, *Sustainability* (in press).
12. Bloetscher, F.; Heimlich, B.N.; Meeroff, D.M. Development of an adaptation toolbox to protect Southeast Florida water supplies from climate change. *Environ. Rev*. 2011, 19, 1–21.
13. Bloetscher, F.; Meeroff, D, Heimlich, B.N., Brown A.R., Bayler D. Loucraft M. 2009. *Improving the Resilience of a Municipal Water Utility against the Likely Impacts of Climate Change—A Case Study; Florida Water Utility: Pompano Beach, FL*, Florida Atlantic University, Boca Raton, FL.
14. Bloetscher, F.; Heimlich, B.N.; Romah, T. Counteracting the effects of sea level rise in Southeast Florida. *J. Environ. Sci. Eng*. 2011, 5, 1507–1525.
15. Bloetscher, F.; Muniz, A. Climate Change Impacts on Florida Water Supplies. Presented at *America Water Works Association Annual Conference and Exposition Proceedings*, Denver, CO, USA, 2009.
16. California 2009 California Climate Adaptation Strategy: A Report to the Governor of the State of California in Response to Executive Order; S-13-2008; California Natural Resources Agency: Sacramento, CA, USA, 2009.
17. CCSP, 2008: *Weather and Climate Extremes in a Changing Climate - Regions of Focus - North America, Hawaii, Caribbean, and U.S. Pacific Islands*. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. Vol. 3.3T.R. Karl, G.A. Meehl, C.D. Miller, S.J. Hassol, A.M. Waple, and W.L. Murray, Eds. Department of Commerce, NOAA's National Climatic Data Center, 164 pp.
18. Chapin, F.S., S.F.Trainor, P. Cochran, H. Huntington, C. Markon, M. McCammon, A.D. McGuire, and M. Serreze, 2014: Ch. 22: Alaska. *Climate Change Impacts in the United States: The Third National Climate Assessment*, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds, U.S. Global Change Research Program, 514536. Doi:10.7930/J00Z7150.
19. FDOT. 2012. BDK79 977-01 Development of a methodology for the assessment of sea level rise impacts on Florida's transportation modes and infrastructure. Summary [PDF - 470 KB], Final Report. [PDF - 13,326 KB].
20. Freas, K.; Bailey, R.; Muneavar, A.; Butler, S. Incorporating climate change in water planning. J. Am. Water Works Ass. 2008, 100, 93–99.
21. Global Insight. The role of metro areas in the US Economy; Reported for The United States Conference of Mayors,

Washington, DC, USA, 1 March 2006. Available online: http://usmayors.org/metroeconomies/Top100_2006.pdf (accessed on 14 February 2012).

22. Grinsted, A.J. Reconstructing sea level from Paleo and projected temperatures 200 to 2100 AD. Clim. Dyn. 2009, 34, 461–472.
23. Heimlich, B.N.; Bloetscher, F.; Meeroff, D.E.; Murley, J. Southeast Florida's Resilient Water Resources: Adaptation to Sea Level Rise and other Climate Change Impacts; Florida Atlantic University: Boca Raton, FL, USA, 2009. Available online: http://www.ces.fau.edu/files/projects/climate_change/SE_Florida_Resilient_Water_Resources.pdf (accessed on 26 March 2012)
24. Hinzman, L. D. et al., 2005: Evidence and implications of recent climate change in Northern Alaska and other Arctic regions. Climatic Change, 72, 251-298, doi:10.1007/s10584-005-5352-2.
25. Hu, F. Sheng, P. E. Higuera, J. E. Walsh, W. L. Chapman, P. A. Duffy, L. B. Brubaker, and M. L. Chipman, 2010: Tundra burning in Alaska: Linkages to climatic change and sea ice retreat. Journal of Geophysical Research, 115, G04002, doi:10.1029/2009jg001270. URL
26. IPCC. 2007. Intergovernmental panel on climate change. In Climate Change 2013: The Physical Science Basis; Cambridge University Press: Cambridge, UK, 2007.
27. Intergovernmental Panel on Climate Change (IPCC) 2013. *Climate Change 2013: The Physical Science Basis; Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, New York, NY
28. Jacob, T., J. Wahr, W. T. Pfeffer, and S. Swenson, 2012: Recent contributions of glaciers and ice caps to sea level rise. Nature, 482, 514-518, doi:10.1038/nature10847. [Available online at http://www.nature.com/doifinder/10.1038/nature10847]
29. Jevrejeva, S.; Moore, J.C.; Grinsted, A. How will sea level respond to changes in natural and anthropogenic forcings by 2100? *Geophys. Res. Lett.* 2010, *37*, 256–265.
30. Johns, G.; Leeworthy, V.R.; Bell, F.W.; Bonn, M.A. Socioeconomic Study of Reefs in Southeast Florida: Final Report; Hazen and Sawyer: Hollywood, FL, USA, 2003.
31. Jorgenson, T., K. Yoshikawa, M. Kanevskiy, Y. Shur, V. Romanovsky, S. Marchenko, G. Grosse, J. Brown, and B. Jones, 2008: Permafrost characteristics of Alaska. Extended Abstracts of the Ninth International Conference on Permafrost, June 29-July 3, 2008. , D. L. Kane, and K. M. Hinkel, Eds., University of Alaska Fairbanks, 121-123. [Available online at http://permafrost.gi.alaska.edu/sites/default/files/AlaskaPermafrostMap_Front_Dec2008_Jorgenson_ etal_2008.pdf
32. Karl, T.R.; Melillo, J.M. 2009. U.S. Global Change Research Program, Global Climate Change Impacts in the United States, Peterson, T.C., Eds.; Cambridge University Press, Cambridge, UK. 2009. Available online: http://www.globalchange.gov/publications/reports/scientific assessments/us-impacts/full-report (accessed on 26 March 2012).
33. Kasischke, E. S., D. L. Verbyla, S. T. Rupp, D. A. McGuire, K. A. Murphy, R. Jandt, J. L. Barnes, E. E. Hoy, P. A. Duffy, M. Calef, and M. R. Turetsky, 2010: Alaska's changing fire regime — implications for the vulnerability of its boreal forests. Canadian Journal of Forest Research, 40, 1313-1324, doi:10.1139/X10-098. Cherry, J. E., S. Walker, N. Fresco, S. Trainor, and A. Tidwell, 2010: Impacts of Climate Change and Variability on Hydropower in Southeast Alaska: Planning for a Robust Energy Future. 28 pp.
34. Kundzewicz,Z. W.; Mata, L. J.; Arnell,N. W.;Döll,P ;Jimenez, .;Miller, K.; Oki, T.; Şen, Z. and Shiklomanov, I (2007), "The implications of projected climate change for freshwater resources and their management," *Hydrological Sciences Journal*, Volume: 53, Issue: 1, Page(s): 3-10.
35. Larsen, C. F., R. J. Motyka, A. A. Arendt, K. A. Echelmeyer, and P. E. Geissler, 2007: Glacier changes in southeast Alaska and northwest British Columbia and contribution to sea level rise. Journal of Geophysical Research, 112, F01007, doi:10.1029/2006JF000586.

36. Leask, K., M. Killorin, and S. Martin, 2001: Trends in Alaska's People and Economy. 16 pp., Institute of Social and Economic Research, University of Alaska, Anchorage, Alaska.
37. Littell, J.S.; M. McGuire, L.C.; Whitely B. The Washington Climate Change Impacts Assessment: Evaluating Washington's Future in a Changing Climate; Climate Impacts Group, University of Washington: Seattle, WA, USA, 2009. Available online: http:// www.cses.washington.edu/db/pdf/ wacciaexecsummary638.pdf (accessed on 26 March 2012).
38. Mack, M. C., S. M. Bret-Harte, T. N. Hollingsworth, R. R. Jandt, E. A. G. Schuur, G. R. Shaver, and D. L. Verbyla, 2011: Carbon loss from an unprecedented Arctic tundra wildfire. Nature, 475, 489-492, doi:10.1038/nature10283
39. Markham Adam September 01, 2015 Six Ways Climate Change in Alaska Will Affect You *The Equation Blog / Union of Concerned Scientists*.
40. Marshall, C.H.; Pielke, R.A.; Steyaert, L.T.; Debra, A.W. The impact of anthropogenic land—Cover change on the Florida Peninsula sea breezes and warm season sensible weather. Mon. Wea. Rev. 2004, 132, 28–52.
41. Moore N, Rojstaczer S (2002), "Irrigation's influence on precipitation: Texas High Plains, U.S.A," *Geophysical Research Letters*, 29, 2-1–2-4.
42. Mukherjee M. Climatic Shock and Health Demand-Supply Nexus in the Sundarbans Delta Region in India. *Climate Change*, 2016, 2(5), 11-24
43. Mulkey, S. Climate change and land use in Florida: Interdependencies and opportunities. Presented at Century Commission for a Sustainable Florida: Tallahassee, FL, USA, 2007.
44. Murley, J. Charting the Course, Where is South Florida Heading; Florida Atlantic University: Boca Raton, FL, USA, 2006.
45. NAS 2015. Arctic Matters, http://dels.nas.edu/resources/ static-assets/materials-based-on-reports/booklets/Arctic Matters.pdf. accessed 2/29/2016
46. NCA 2014. globalchange.gov/highlights/regions/alaska
47. NMFS, 2010: Fisheries Economics of the United States, 2009. U.S. Department of Commerce, NOAA Technical Memorandum NOAA NMFS-F/SPO-118. 172 pp.,National Marine Fisheries Service, Silver Spring, MD
48. NOAA, 2013 Regional Climate Trends and Scenarios for the US National Climate Assessment, Part 7, NOAA Technical Report NESDIS 142-7, NOAA, Washington, DC.
49. Nichols, R.J. Ranking Port Cities with High Exposure and Vulnerability to Climate Extremes; OECD Environment Working Papers: Paris, France, 2008.
50. NYCDEP. 2008. Assessment and Action Plan—A Report Based on the Ongoing Work of the DEP Climate Change Task Force; Department of Environmental Protection: New York, NY, USA, 2008.
51. Obeysakara, J.; Park, J.; Irizarry Q.M.; Trimble, P.; Barnes, J.; van-Arman, J.; Said, W.; Gadzinski E. Past and Projected Trends in Climate and Sea Level for South Florida, Hydrologic and Environmental Systems Modeling Technical Report; The South Florida Water Management District: West Palm Beach, FL, USA, 2011, p. 171.
52. Obeysekera, J.S. Climate change and water management: Planning for sea level rise. Presented at Broward Climate Change Task Force, Science and Technology Subcommittee, Broward County, FL, USA, 2009.
53. Osterkamp, T. E., and V. E. Romanovsky, 1999: Evidence for warming and thawing of discontinuous permafrost in Alaska. Permafrost and Periglacial Processes, 10, 17-37, doi:10.1002/(SICI)1099- 1530(199901/03)10:13.0.CO;2-4. [Available online at http://onlinelibrary.wiley.com/doi/10.1 002/(SICI)1099-1530(199901/03)10:1%3C17::AID-PPP303%3 E3.0.CO;2-4/pdf] 67.
54. Palmer, R.N.; Hahn, M. The Impacts of Climate Change on Portland's Water Supply: An Investigation of Potential Hydrologic and Management Impacts on the Bull Run System; Portland Water Bureau: Portland, OR, USA, 2002. Available online: http://cses.washington.edu/db/pdf/ palmerhahnportland111.pdf (accessed on 26 March 2012).
55. Pielke, R.A.; Steyaert, L.T.; Vidale, P.L.; Liston, G.E.; Lyons, W.A.; Chase, T.N. The influence of anthropogenic landscape changes on weather in south Florida. Weather Rev. 1999, 127, 1663–1673.

56. Portland Climate Change Efforts; Office of Sustainable Development: Portland, OR, USA, 2003. Available online: http://www.portlandonline.com/bps/index.cfm?a=112117&c=41917 (accessed on 26 March 2012).
57. Rahmstorf, S. A semi-empirical approach to projecting future sea-level rise. Science 2007, 315, 368–370.
58. Reilly, T.E.; Dennehy, K.F.; Alley, W.M.; William L.C. Ground Water Availability in the United States; USGS: Reston, VA, USA, 2009.
59. Richey, J E.; Costa-Cabral, M. (2006), "Floods, Droughts, and the Human Transformation of the Mekong River Basin," *Eos Trans. AGU*, 87(52), Fall Meet. Suppl., Abstract.
60. Risk and Vulnerability Assessment Tool (RVAT); NOAA Coastal Services Center: Charleston, SC, USA, 2011. Available online: http://www.csc.noaa.gov/rvat/ (accessed on 26 March 2012).
61. Rosen Yereth August 29, 2015
62. RMCO. Colorado Climate Scorecard: The Implementation Status of the Colorado Climate Action Plan and RMCO's Climate Action Panel Recommendations, Rocky Mountain Climate Organization: Denver, CO, USA, 2009. Available online: http://www.rockymountainclimate.org/images/CO%20Scorecard%20Update.pdf (accessed on 26 March 2012).
63. Romanovsky, V. E., S. L. Smith, H. H. Christiansen, N. I. Shiklomanov, D. S. Drozdov, N. G. Oberman, A. L. Kholodov, and S. S. Marchenko, 2012: [The Arctic] Permafrost [in "State of the Climate in 2011"]. Bulletin of the American Meteorological Society, 93, S137-S138, doi:10.1175/2012BAMSStateoftheClimate.1. [Available online at http://www1.ncdc.noaa.gov/pub/data/cmb/bams-sotc/climate-assessment-2011-lo-rez.pdf]
64. Roy TK, Hossain ST. Role of Sundarbans in Protecting Climate Vulnerable Coastal People of Bangladesh. *Climate Change*, 2015, 1(1), 40-44
65. Salmun, Haydee and Andrea Molod (2006), "Progress in modeling the impact of land cover change on the global climate," *Progress in Physical Geography* 30, 6 (2006) pp. 737–749
66. Scanlon, Bridget R., Robert C. Reedy, David A. Stonestrom, David E. Prudic and Kevin F. Dennehy (2005), "Impact of land use and land cover change on groundwater recharge and quality in the southwestern US," *Global Change Biology* 11, 1577–1593.
67. Scranton, Roy. 2015. *Learning to Die in the Anthropocene: Reflections on the End of a Civilization*, City Lights Open Media, City Lights Publishers,San Francisco, CA.
68. Southeast Florida Regional Climate Change Compact Technical Ad hoc Work Group. 2011. *A Unified Sea Level Rise Projection for Southeast Florida. A document prepared for the Southeast Florida Regional Climate Change Compact Steering Committee*. Accessed from: http://southeastfloridaclimatecompact.org/pdf/Sea%20Level%20Rise.pdf.
69. Stewart, B. C., K. E. Kunkel, L. E. Stevens, L. Sun, and J. E. Walsh, 2013: Regional Climate Trends and Scenarios for the U.S. National Climate Assessment: Part 7. Climate of Alaska. NOAA Technical Report NESDIS 142-7. 60 pp.
70. Trainor, S. F., S. F. Chapin, III, D. A. McGuire, M. Calef, N. Fresco, M. Kwart, P. Duffy, A.;Lauren Lovecraft, S. T. Rupp, L. 'O. DeWilde, O. Huntington, and D. C. Natcher, 2009:;Vulnerability and adaptation to climate-related fire impacts in rural and urban interior Alaska. Polar Research, 28, 100-118, doi:10.1111/j.1751-8369.2009.00101.x.
71. Transportation Research Board 2008. Committee on Climate Change and U.S. Transportation. Potential impacts of climate change on U.S. transportation / Committee on Climate Change and U.S. Transportation, Transportation Research Board and Division on Earth and Life Studies, National Research Council of the National Academies. p. cm.
72. UNEP. Climate Change Science Compendium 2009; United Nations Environmental Programme: New York, NY, USA, 2009.
73. Vermeer, M.; Rahmstorf, S. Global sea level linked to global temperature. *Proc. Natl. Acad. Sci.USA* 2009, *106*, 21527–21532.
74. Wendler, G., L. Chen, and B. Moore, 2012: The first decade of the new century: A cooling trend for most of Alaska. The

Open Atmospheric Science Journal, 6, 111- 116, doi:10.2174/1874282301206010111.

75. Yu, G., Z. Schwartz, J. E. Walsh, and W. L. Chapman, 2009: A weather-resolving index for assessing the impact of climate change on tourism related climate resources. Climatic Change, 95, 551-573, doi:10.1007/s10584-009-9565-7.