Climate Change Uncertainty and Risk: from Probabilistic Forecasts to Economics of Climate Adaptation

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Schedule

26.02.18 (1) Logistics, Introduction to probability, uncertainty and risk management (RK, DB)
05.03.18 (2) Predictability of weather and climate (RK)
   Exercise 1 (toy model)
12.03.18 (3) Probabilistic risk assessment model and some insurance basics (DB)
19.03.18 (4) Detection/attribution (RK)
   Exercise 2 (toy model)
26.03.18 (5) Model evaluation & calibration (RK)
   Exercise 3 (toy model), preparation of presentation
02.04.18 Ostermontag (no course)
09.04.18 (6) Climate change and impacts, use of scenarios (RK, DB)
16.04.18 (7) Presentations of toy model work, discussion (DB, RK)
23.04.18 (8) 2-degree target and adaptation in UNFCCC (RK, DB)
   Exercise 4 (introduction to climada)
Schedule

30.04.18 (9) Basics of economic evaluation and economic decision making (DB)
07.05.18 (10) The cost of adaptation - in developing and developed regions (DB)
    Exercise 5 (impacts)
14.05.18 (11) Shaping climate-resilient development – valuation of a basket of adaptation options (DB)
    Exercises 6 (adaptation measures, preparation of presentation)
21.05.18 Pfingstmontag (no course)
28.05.18 (12) Presentations of climada exercise and final discussion (DB, RK)
Today’s agenda

- Why – the need for adaptation
- What – the challenge to ensure development, yet adapt to a changing climate (and reduce emissions, the mitigation piece)
- How – climate-resilient development (and the economics of it)
- The key steps to develop an adaptation strategy – shaping climate-resilient development
- Quantification of local total climate risk
  → The total climate risk waterfall chart
- Cost/benefit calculation of adaptation measures
  → The adaptation cost curve
Recap: The (im)morality of discounting

- Investing $100 now in a project that pays $300 ten years from now is a financial success: it is equivalent to an annual rate of return of more than 11%.

- A policy that kills 100 people now in order to save 300 other lives ten years from now is not equally successful: there is no way to compensate the 100 people who paid the initial cost.

- The discussion of values without prices has a long history: “Some things have a price, or relative worth, while other things have a dignity, or inner worth”.

- No price tag does justice to the dignity of human life or the natural world. Since some of the most important benefits of climate protection are priceless, any monetary value for total benefits will necessarily be incomplete.

Source: ¹Immanuel Kant, 1785: Grundlegung zur Metaphysik der Sitten. F. Ackerman, 2009: Can we afford the future, ZED book, New York
Recap: Reasons for concern

Avoid the unmanageable, manage the unavoidable

The need for climate-resilient development
Note on decision strategies

1. Problem definition, Goal
2. Decision criteria
3. Risk analysis
4. Identify options
5. Options appraisal
6. Decision (?)
7. Implementation
8. Monitoring

Problem defined correctly?
Criteria met?

CLIMADA platform

1 Souvignet, Wieneke, Müller & Bresch, 2016: Economics of Climate Adaptation (ECA) - Guidebook for Practitioners. Materials on Development Financing, UNU, KfW. Figure based upon IPCC and UKCIP
Climate-resilient development
Economics of climate adaptation (ECA)

Objectives
- Provide decision makers with the facts and methods necessary to design and execute a climate adaptation strategy

Key features of the methodology:
- Follow a rigorous risk management approach to assess local total climate risk, the sum of
  - today’s climate risk,
  - the economic development paths that might put greater population and value at risk (→ projection)
  - the additional risks presented by climate change (→ scenarios)
- Propose and prioritize a basket of adaptation options to address total climate risk on an economic basis
Recap: Risk

The “effect of uncertainty on objectives”\(^1\)

Risk is the combination of the probability [or likelihood] of a consequence and its magnitude:

\[
\text{risk} = \text{probability} \times \text{severity}
\]

or, to be more specific:

\[
\text{risk} = \text{hazard} \times \text{exposure} \times \text{vulnerability}
\]

\[
= (\text{probability} \times \text{intensity}) \times \text{exposure} \times \text{vulnerability}
\]

\(^1\) … a positive or negative deviation from what is expected [ISO 31000]
adaptation options (for example: prevention, spatial planning, building codes ...)

CLIMADA
probabilistic event-based simulation
open-source¹

outputs:
risk analysis, -mapping
+ (impact-oriented) warnings ...

e.g. cyclone footprints

weather → hazard

core scenarios

development scenarios

vulnerability

impact

intensity

example: direct economic impact

impact animation:
https://vimeo.com/202068551

+ appraisal of adaptation options (effectiveness, cost/benefit ...)
+ quantification of uncertainty

¹ https://github.com/davidnbresch/climada (MATLAB/Octave) und https://github.com/davidnbresch/climada_python
Recap: Risk Management Cycle

- Identify
- Analyze
- Plan measures
- Implement
- Review

Options:
- Avoid
- Reduce
- Prevent
- Transfer
- Retain
Climate-resilient development – the methodology

Identify

- Where and from what is the region most at risk?
  - Map of areas at risk
  - Identify most relevant hazard(s) in case location
  - Identify areas that are most at-risk, by overlaying hazard(s) on:
    - Population
    - Economic value (GDP)

Analyze

- What is the magnitude of the expected loss?
  - Estimate of potential loss
  - Hazard: Develop frequency and severity scenarios
  - Assets: Quantify assets and income value in area at risk
  - Vulnerability: Determine vulnerability of assets and incomes to the hazard

Plan measures

- What measures should be considered?
  - Set of adaptation measures
  - Identify potential adaptation measures
  - Determine societal costs and benefits and basic feasibility
    - Interviews with experts
    - Economic analysis

Implement

- How can measures be implemented?
  - Implementation assessment
  - Assess current progress against the measures
  - Understand requirements to implementation
  - Determine actions required to implement measures

Input into adaptation strategy
Recap: Parameterized impact: TC Florida case study (1/3)

<table>
<thead>
<tr>
<th>Hazards</th>
<th>Impact</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hurricane</td>
<td></td>
<td>• Hurricane damage likely to increase with climate warming</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Primary cause of flooding and responsible for the majority of hazard induced damages</td>
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<tr>
<td>Sea level rise</td>
<td></td>
<td>• Expected to be a critical issue in long term; less potential for impact in 2030 timeframe</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Storm surge and water supply are likely to be adversely impacted, particularly in southern Florida</td>
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<tr>
<td>Temperature increase</td>
<td></td>
<td>• Drought events may be exacerbated by an increase in global temperature. However,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Precipitation forecasts(^1) not expected to change and impact on humidity unclear</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Measures already in place to handle high temperatures</td>
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</tbody>
</table>

- While sea level rise and temperature increase are important risks to Florida, the focus of our work was on hurricanes
- More hurricanes hit Florida than any other State in the USA (30 between 1992-2005)
Where and from what is the region most at risk?

Recap: Parameterized impact: TC Florida case study (2/3)

1. Expected increase in wind speed per increase in SST °C

<table>
<thead>
<tr>
<th>Percent</th>
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<tbody>
<tr>
<td>Webster</td>
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<tr>
<td>Emanuel</td>
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<tr>
<td>Knutson</td>
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<tr>
<td>Bengtsson</td>
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2. Increase in wind speed by 2030 using A2 scenario

<table>
<thead>
<tr>
<th>Percent</th>
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</thead>
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<tr>
<td>Webster</td>
</tr>
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</table>

3. Increase in wind speed for hazard scenarios

<table>
<thead>
<tr>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Today's</td>
</tr>
<tr>
<td>Moderate</td>
</tr>
<tr>
<td>High</td>
</tr>
</tbody>
</table>

* Assumes 2.6°C increase by 2100; interpolated to 0.6°C increase by 2030

Source: IPCC AR4 ECHAM5 model and average across models (Fig. 11.22)
Recap: Parameterized impact: TC Florida case study (3/3)

- **High level of uncertainty around predicting hurricanes**
  - Many climate factors play a role in the development and strength of hurricanes

- Narrowed focus and scope to address only **hurricane intensity and height of sea level rise**

- Using expert input, **three climate scenarios were developed**
  - Intensity forecasts based on the link between sea surface temperature and wind speed
  - Sea level rise projections were based on projections across two ice flow outcomes

- Climate scenarios were later used to develop 3 hazard scenarios

<table>
<thead>
<tr>
<th>2030 scenarios</th>
<th>Description</th>
</tr>
</thead>
</table>
| **1** Today’s climate | ▪ **Current climate data used** as the baseline for wind speed and sea level rise  
▪ Frequency of hurricane events based on historical and is not varied |
| **2** “Moderate” Change | ▪ **Wind speed increase of 3% and sea level rise of 0.08m**  
▪ Uses an average of various wind speed to sea surface temperature relationships  
▪ Storm surge increases due to sea level rise |
| **3** “High” Change | ▪ **Wind speed increase of 5% and sea level rise of 0.24m**  
▪ Uses a maximum wind speed to sea surface temperature relationship  
▪ Storm surge increases further |

**SOURCE:** IPCC, 2007; S. Rahmstorf; K. Emanuel; J. Kurry; L. Bengtsson; T. Knutson
Loss calculation – Florida case study

Annual expected loss in 2008 and 2030
$ Billions, 2008 dollars

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>2008 Today’s Climate</th>
<th>2030 Today’s Climate</th>
<th>2030 Moderate change</th>
<th>2030 High change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rain</td>
<td>17</td>
<td>26</td>
<td>30</td>
<td>33</td>
</tr>
<tr>
<td>Storm surge</td>
<td>6</td>
<td>10</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>Wind</td>
<td>10</td>
<td>15</td>
<td>17</td>
<td>19</td>
</tr>
</tbody>
</table>

Percent of 3 Counties¹ GDP
8.5 8.4 9.4 10.1

Source: ¹ Moody’s, Swiss Re, eca workgroup analysis
Florida case study: The total climate risk waterfall chart

Expected loss from exposure to climate
Moderate climate change scenario, USD billions

2008, today’s expected loss: 17
Incremental increase from economic growth; no climate change: 9
Incremental increase from change in climate: 4
2030, total expected loss: 30

Potential impact from economic growth
Potential impact from change in climate

+76%
Climate-resilient development – the methodology

What measures should be considered?

Hazards

Vulnerabilities

Total Climate Risk

Portfolio of responses

Infrastructure and asset-based responses

Technological and procedural optimization responses

Systemic and behavioral responses

Risk transfer and contingent financing

Assets

Value

Portfolio of responses

Risk transfer and contingent financing

Systemic and behavioral responses

Technological and procedural optimization responses

Infrastructure and asset-based responses

Value

Assets

Vulnerabilities

Total Climate Risk

Hazards
What measures should be considered?

Awareness and education measures - Florida

Southern Florida is very aware of the threat of hurricane
What measures should be considered?

Beach nourishment measure – Florida case study

Extend beach 50 – 100 ft in width by adding similar sand from another location
Opening protection measure – Florida case study
Cost/benefit calculation of adaptation measures (1/3)

1. Determine the **discount rate**
   - local government infrastructure-related decision discount rates
   Given e.g. 2030 timeframe, the government investment discount rate usually is preferred to a more long-term social discount

2. Gather cost, benefit and expected useful lifetime **data on each measure** to prepare the bottom-up calculation of the present value of costs and benefits of implementing the measure. This includes:
   - up-front expenditures, operating costs (for example, labour and maintenance)
   - asset growth, extent of coverage or penetration (for example, the number of houses to be protected)
   - value of location, assuming both current and future use.
Cost/benefit calculation of adaptation measures (2/3)

3. Define the **scope** of the measure by determining the maximum potential of implementing the measure in the local context.
   - total costs and averted loss will depend on the extent of the measure’s implementation.

4. Calculate **costs** of each measure. Based on the bottom-up assessment, we calculate:
   - capital expenditures (CAPEX, basically the investment)
   - operating expenditures (OPEX)
   - operating expenditure savings (OPEX savings) compared to current approach. If OPEX savings are available for the measure, a negative bar may appear on the adaptation cost curve.
5. Calculate the benefits, i.e. the averted loss due to the specific measure

- Perform probabilistic total climate risk assessment without and with measure → difference is averted loss

5. Determine if additional benefits from societal revenue upside is possible. In some cases, implementing an adaptation measure will have economic benefits in addition to reducing the loss from the climate risk.

6. Calculate cost-benefit ratio based on net present value of the streams of costs and benefits over time (including terminal value) in 2008 currency. This provides the y-axis location of the measure on the adaptation cost curve.
How can measures be implemented? 

What measures should be considered?

The adaptation cost curve

- Benefits include the loss averted and additional revenues (if applicable)
- Costs include capital and operating expenses as well as potential operating savings generated – and therefore can be negative

Cost per unit of benefit ratio

Actions below ratio line on the y axis are defined as cost effective

Measures below 0 line are beneficial also in terms of cost reduction

Loss averted Dollars

Reduction of the expected loss by implementing the measure

Costs and benefits calculated using existing practices and costs

Cost per unit of benefit is a NPV calculation discounted at local rates

1The ‘how’ refers primarily to the sequence or priority and the financials, not the physical implementation
Adaptation cost curve – the recipe (one measure)

1. Calculate PV of costs of measure
2. Today (year 2012): assets, hazard as per 2012
   1. calculate annual expected loss with no measures
   2. calculate annual expected loss with measure applied
      → difference 2.1) minus 2.2) gives you benefit of measure today
3. Future (year 2030): assets, hazard as per 2030
   1. calculate annual expected loss with no measures
   2. calculate annual expected loss with measure applied
      → difference 3.1) minus 3.2) gives you future benefit of measure
4. Discount benefits → horizontal axis of adaptation cost curve
   compare with PV of costs → vertical axis of adaptation cost curve
Adaptation cost curve – Florida case study

~40% of total expected loss can be averted cost-effectively

Measures below this line have net economic benefits

Calculated in 2008 dollars for the average climate scenario
Adaptation cost curve – Florida case study

Reduced loss per USD invested (USD)

- Cost-efficient measures
- Non-cost-efficient

- Beach nourishment, vegetation mgmt
- Roof cover (new buildings)
- Home elevation (new buildings)
- Levees, floodwall, sandbags
- Roof, opening protection (retrofit)
- Underground power transmission
- Home elevation (retrofit)

Total climate risk
33 mn USD

Cost-efficient adaptation
Residual loss 2030
Further case studies (http://www.wcr.ethz.ch/research/casestudies.html):

- **US Gulf Coast**: Hurricane risk to the energy system
- **New York**: Cyclones and surge risk to a metropolis
- **Hull, UK**: Flood and storm risk to urban property
- **China**: Drought risk to agriculture
- **Bangladesh**: Flood risk to a fast-developing city
- **Florida**: Hurricane risk to public and private assets
- **Caribbean**: Hurricane risk to small islands
- **El Salvador**: Flood and landslide risk to vulnerable people
- **Guyana**: Flash flood risk to a developing urban area
- **Mali**: Risk of climate zone shift to agriculture
- **Tanzania**: Drought risk to health and power generation
- **Samoa**: Risk of sea level rise to a small island state

Barbados case study: Risk assessment

Annual expected tropical cyclone damage to assets in Barbados [USD millions 2009 values]
Barbados case study: Risk assessment

Annual expected tropical cyclone damage to assets in Barbados [USD millions 2009 values]
Barbados case study: Options appraisal

Cost-effective measures can substantially reduce risk

Moderate climate impact
Barbados case study: Options appraisal

Cost-effective measures can substantially reduce risk

High climate impact

Moderate climate impact for comparison

Risk 2030
USD 3.1 bn
Barbados case study: Options appraisal

Cost-effective measures can substantially reduce risk

High climate impact

But: HURDAT2 instead of Best Track/HURDAT tropical cyclone dataset

High climate impact for comparison

Risk 2030
USD 2.7 bn
Barbados case study: Options appraisal

Cost-effective measures can substantially reduce risk

High climate impact

But: annual discount rate 5% instead of 1.4%

High climate impact (1.4%) for comparison

Risk 2030
USD 2.3 bn
Samoa case study: Risk transfer for low frequency/high severity events

- 250-year damage
- Cost-efficient adaptation
- Residual risk to be covered
- Maximum bearable damage

Costs to address the residual risk (mn USD)

- Risk transfer can absorb 100% of residual risk for annual costs of ~7 million USD
- Further non-cost-efficient measures can cover ~50% of residual risk for annual costs of 23 million USD
Case study selection – your choice!

https://services.iac.ethz.ch/survey/index.php/335513/lang-en

A short list of proposed case studies to learn more about, please make your choice… this defines the content of the next lecture
Appendix
Measures: emergency response (1/2)

Even with measures to reduce risk, effective emergency response is necessary
Southern Florida has a thorough and effective emergency response network and shares best practices across the State.

How it works: In the event of a crisis, local contacts escalate the information to the Emergency Operations Centre (EOC), where the Duty Officer assesses the situation and deploys the necessary resources, including further State involvement if necessary.

Who is involved: There are two groups that provide emergency assistance, the government and a system of volunteers (CERT). These two groups have ongoing training and have a clear order of command and structured reporting. They are easily activated through a series of mechanisms including telephone, radio and pre-determined meeting locations. These groups, although managed at the local level, communicate and share best practices.

Example – Hurricane shelters: The government has proactively addressed the need for adequate shelter space. Many communities have two tiers of space available to meet the needs of displaced individuals. Shelters are designated for specific groups, including people with special needs and pets and all individuals are accounted for through a registration process.
Measures: beach nourishment (1/2)

Extend beach 50 – 100 ft in width by adding similar sand from another location
Measures: beach nourishment (2/2)

- **Description:** Extend beach 50 – 100 ft in width by adding similar sand from another location
- **Current Scenario:** Currently, ~50 of the ~150 miles of coastline in Broward, Palm Beach and Miami-Dade counties have already been nourished.
- **Opportunity for Improvement:** Add nourishment to the highest risk areas that have yet to be protected.
- **Cost:** Direct cost usually ranges from $6 - $15 per cubic yard of sand. Approximately 25% of the original sand is lost every 6 years due to erosion and has to be replaced. Indirect costs include environmental impact to the area (changing natural habitat of numerous creatures).
- **Benefits:** Research done in Florida shows that hurricane damage can be reduced 20 – 50% by adding nourishment to existing beaches. Experience also shows that nourishment increases tourism, property values and tax revenues.
- **Key to implementation success:** Properly assess environmental impacts prior to implementation, and design strategy to minimize these impacts. Alignment between local, state and federal officials in terms of funding and timeline

Sources:
Measures: building codes (1/2)

Build new homes in accordance with building codes and building code “plus”.
Measures: building codes (2/2)

- Description: Build new homes in accordance with building codes and building code “plus”.
- Current Scenario: New home construction is regulated by the Florida building codes.
- Opportunity for Improvement: Protect the building envelope and secure the roof.
- Cost: Marginal costs range from $400 to upgrade the quality of shingles for the roof cover to $2,000 to upgrade the quality the resiliency of the windows, doors, and garage door. Total cost for all upgrades will be $15,000-$20,000. Indirect costs may include additional builder mark-up, and aesthetic options available.
- Benefits: Benefits range from 5% (masonry) – 35% (roof shape). A home built to code can reduce losses by 60%. Code “plus” building will result in a loss reduction of up to 80%. Additional benefits include a reduction in energy consumption (better insulation).
- Key to implementation success: Proper education for individuals on the benefits of resilient building relative to the higher up front costs. Continuous investment in building code design/improvements and enforcement. Testing of new engineering techniques and materials.
Measures: roof protection (1/2)

Protect the roof from being damaged by trussing and roof-deck attachment
Measures: roof protection (2/2)

- **Description:** Protect the roof from being damaged by trussing, improving the strength of the cover and the roof-deck attachment, and changing the shape.

- **Current Scenario:** New home construction is regulated by the Florida building codes.

- **Opportunity for Improvement:** Utilize latest engineering techniques for new homes. Homes built prior to 1995 have significant opportunity for upgrades.

- **Cost:** Roof-deck attachment and roof shape can only be effected for new builds, and marginally cost $500 and $3,500, respectively. Trussing and upgrading covering (shingling) combined costs $1,500 for new builds vs. $12,000 to upgrade old homes. Indirect costs may include the aesthetic look of your roof.

- **Benefits:** Improving the protection of the roof can increase the resiliency of your home by 25%-60%. It can also reduce leakages and save repair and energy costs.

- **Key to implementation success:** Proper education for individuals on the importance of protecting their roofs for both new and old homes. Continuous investment in building code design/improvements and enforcement. Education/incentives for owners of old homes to maintain and improve their roofing.
Measures: vegetation management (1/2)

Aggressively monitor and remove trees and other vegetation that can damage transmission distribution lines during a storm
Measures: vegetation management (2/2)

- **Description:** Aggressively monitor and remove trees and other vegetation that can damage transmission distribution lines during a storm.
- **Current Scenario:** Tree lines and vegetation are currently monitored in 8 year cycles.
- **Opportunity for Improvement:** Best practice from comparably dense areas indicate a 5-year cycle is possible.
- **Cost:** Costs of vegetation management are estimated at $4-6,000/mile. This includes patrolling and action to remove the hazards. The estimated increase in miles to shorten the current monitoring cycle is 5,000 miles/year. Indirect costs include the visual impact and environmental effects of removing trees.
- **Benefits:** Trees and flying debris cause 40% of utility outages during a storm. An aggressive vegetation management program can reduce 20% of that damage.
- **Key to implementation success:** Take the type of tree, expected growth of the tree, and location into consideration in order to reduce the need to “manage” vegetation in the future. Public awareness to help identify potentially hazardous tree lines before damage occurs.
Bundling measures – residential home (1/2)

Example includes both wind and flood adaptation measures:

- Built to withstand 130 mph winds
- Elevated on concrete piles 25 ft above sea level
- 2\textsuperscript{nd} story designed as an outdoor entertainment space which will break away in storm surge
- Roof secured from wind damage with metal straps and 6 inch nails
- Hardwood floors increase water resiliency
Bundling measures – residential home (2/2)

- Bundling creates synergies between individual adaptation measures:
  - Reinforced windows and secured roof prevent wind from entering home and exerting additional pressure on remaining roof/windows
  - Securing roof with both metal straps and larger nails makes it more resistant to wind
  - Caulking and securing wood siding with metal straps keeps walls stronger
- Evidence that these building systems work can be seen in Gilchrist, Texas: 10 of the 13 fortified homes survived, whereas almost all other homes were destroyed
- Crown Team Texas, builder of these fortified homes, experienced costs that were only 10% higher than their typical home
Measures: mobile barriers (1/2)

Used to temporarily protect buildings and isolated openings

e.g. www.floodbarriers.com
Measures: mobile barriers (2/2)

- Sandbags: Used to protect buildings against water intrusion by constructing 2 ft sandbag barriers in front of doors/entranceways (most applicable for Category 3 storms). Temporary Floodwall: e.g. 4 ft concrete blocks used to temporarily protected isolated openings (e.g., doors) in coastal properties from flooding.

- Current Scenario: Sandbags and temporary floodwalls are rarely used as a means of protection from water intrusion.

- Opportunity for Improvement: Use sandbags and floodwalls to protect from water intrusion in situations where water is under 4 feet.

- Cost: Sandbags approximately $2.50 for 70 lb bag. Temporary floodwalls approximately $140 per linear foot.

- Benefits: Experts expect a 20% reduction in damage from sandbags and a 20% reduction in damage from temporary floodwalls. These benefit calculations reduction in both asset damage and business interruption, where applicable.

- Key to implementation success: Sandbags: Launch awareness campaign to educate community on benefits and proper use of sandbags. County can distribute bags to individual homes. Temporary Floodwall: Launch awareness campaign to educate community on benefits and proper use of temporary floodwalls.
Measures: levees (1/2)

Placed strategically along the coast to protect the highest risk areas

see http://www.satelliteviews.net/cgi-bin/g.cgi?state=FL&ftype=levee
Measures: levees (2/2)

- Levee and Floodwall: E.g. a 20 ft structure made up of a T-wall embedded in a levee, placed strategically along the coast to protect the highest risk areas.
- Current Scenario: Levees are currently used at ‘strategic locations’, see e.g. http://www.satelliteviews.net/cgi-bin/g.cgi?state=FL&ftype=levee
- Opportunity for Improvement: Build levees strategically along the coast.
- Cost: Cost of levees is $10’000 per linear foot.
- Benefits: Flood experts expect a 70% reduction in damage from levees.
- Key to implementation success: Strategically placed, complemented by mobile barriers. Properly assess environmental impacts such as retention of inland flood, effects on groundwater aquifers prior to implementation, and design strategy to minimize these impacts. Align local, state and federal officials in terms of responsibilities, funding and timeline.