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Vulnerability of oil and gas infrastructure to climate change and extreme weather events

Anna Maria Cruz

Consultant, Natural and Industrial Disaster Risk Management
Bordeaux
France

Vulnerability of oil and gas infrastructure to climate change and extreme weather events

ANA MARIA CRUZ, Ph.D
Consultant, Natural and Industrial Disaster Risk Management
Adjunct Professor, Kyoto University

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Outline

1. Introduction
2. Potential impacts
3. Vulnerability and mitigation and adaptation options
4. Other challenges
5. Conclusions

1. Introduction

- A changing climate and extreme weather events pose major challenges
- Identifying how these changes will affect the industry is vital to its security and reliability
- Sector is extremely complex and interlinked
- Impacts likely to have ripple effects

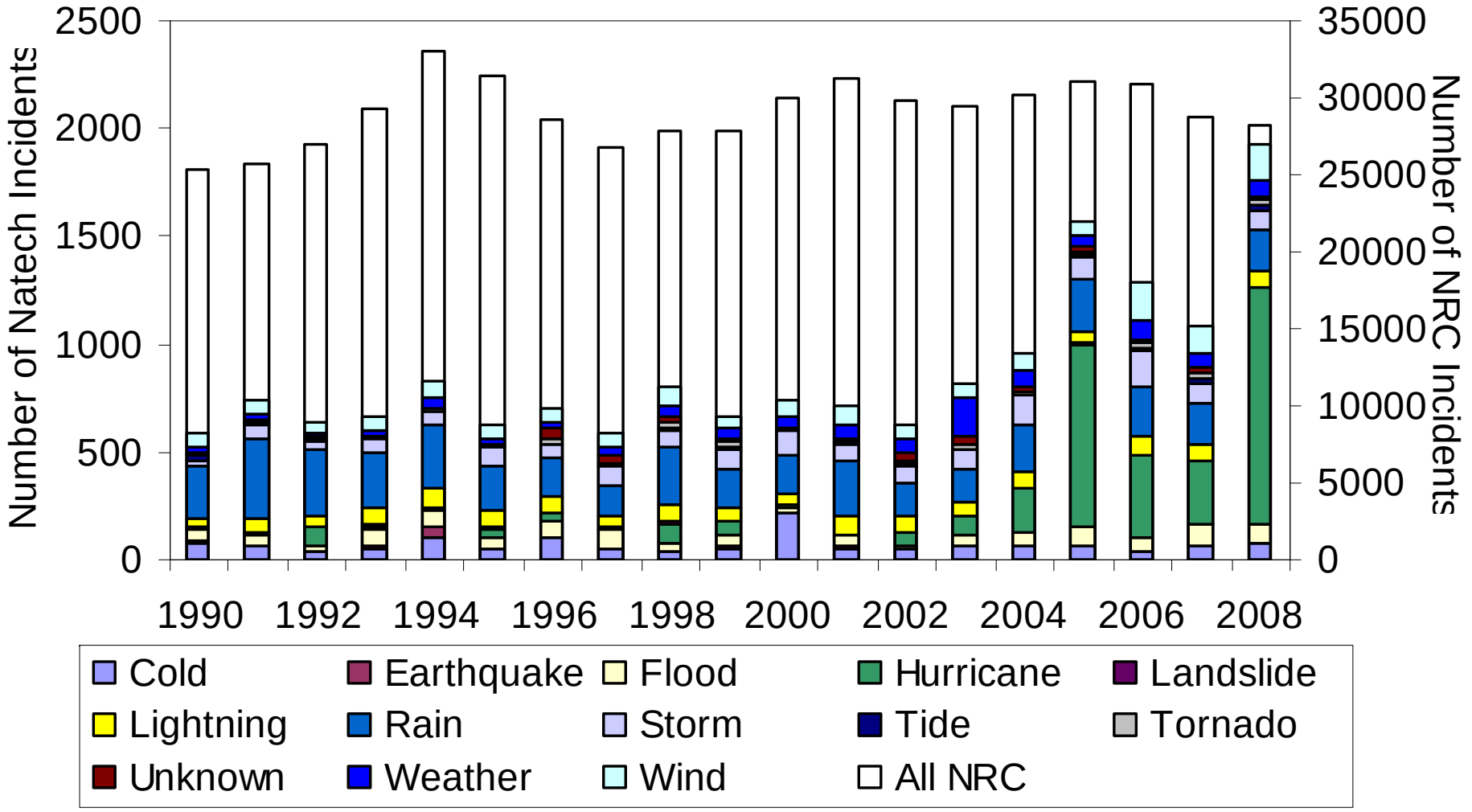
Significant safety and environmental risks from extreme weather events

- External hazards not generally factored in process safety analysis, industrial risk assessments and emergency response plans
- Most risk assessment requirements concern individual infrastructures and rarely includes systemic risks
- Potential for chemical releases and oil spills remain and may increase

Extreme weather induced chemical releases and oil spills

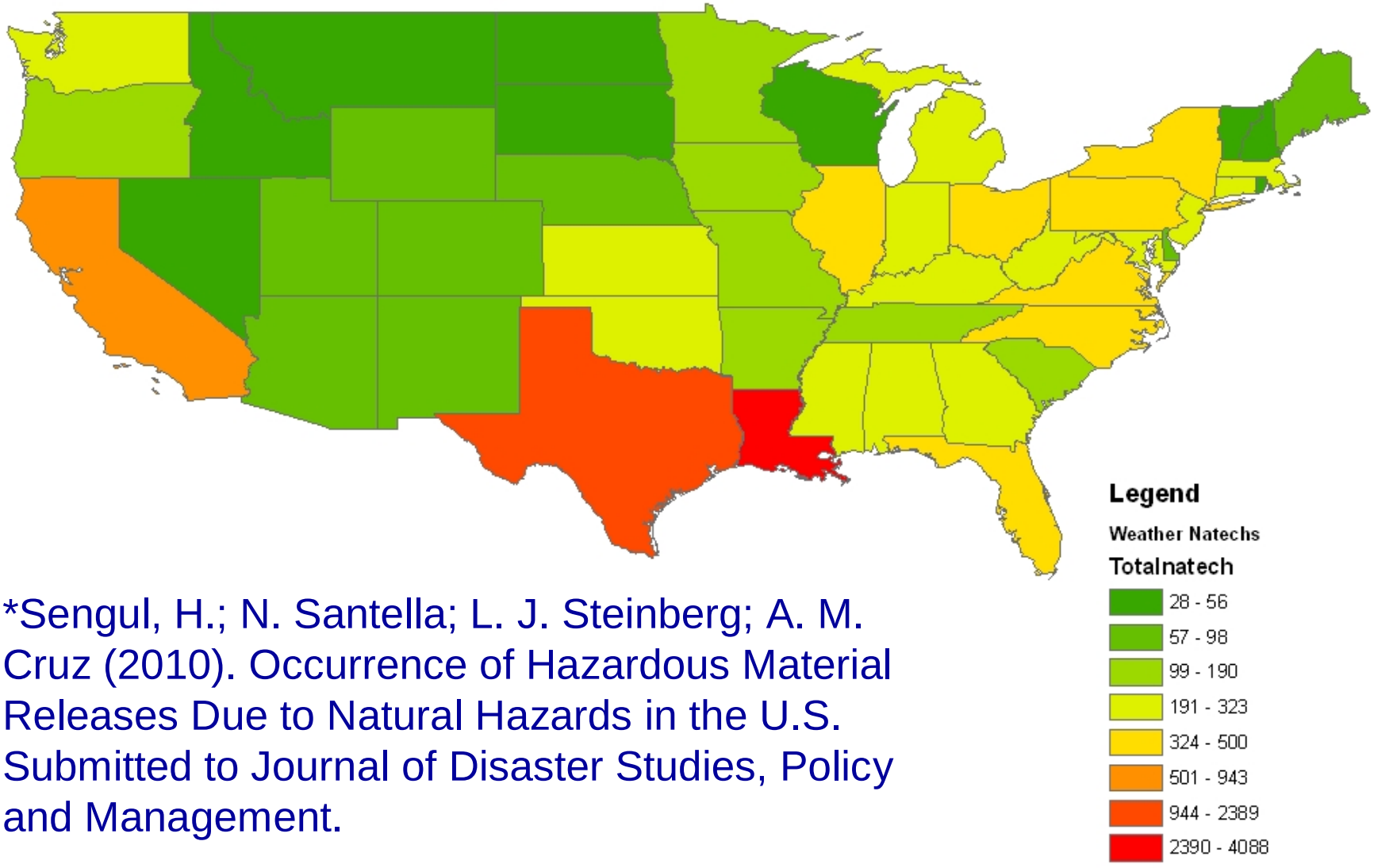
- Extreme event
  - simultaneous
  - multiple releases
- Response efforts
  - natural disaster
  - technological disaster
- Lifelines and safety systems
  - ~~mitigation~~
  - ~~response~~

Number of chemical releases and spills associated with natural hazards*



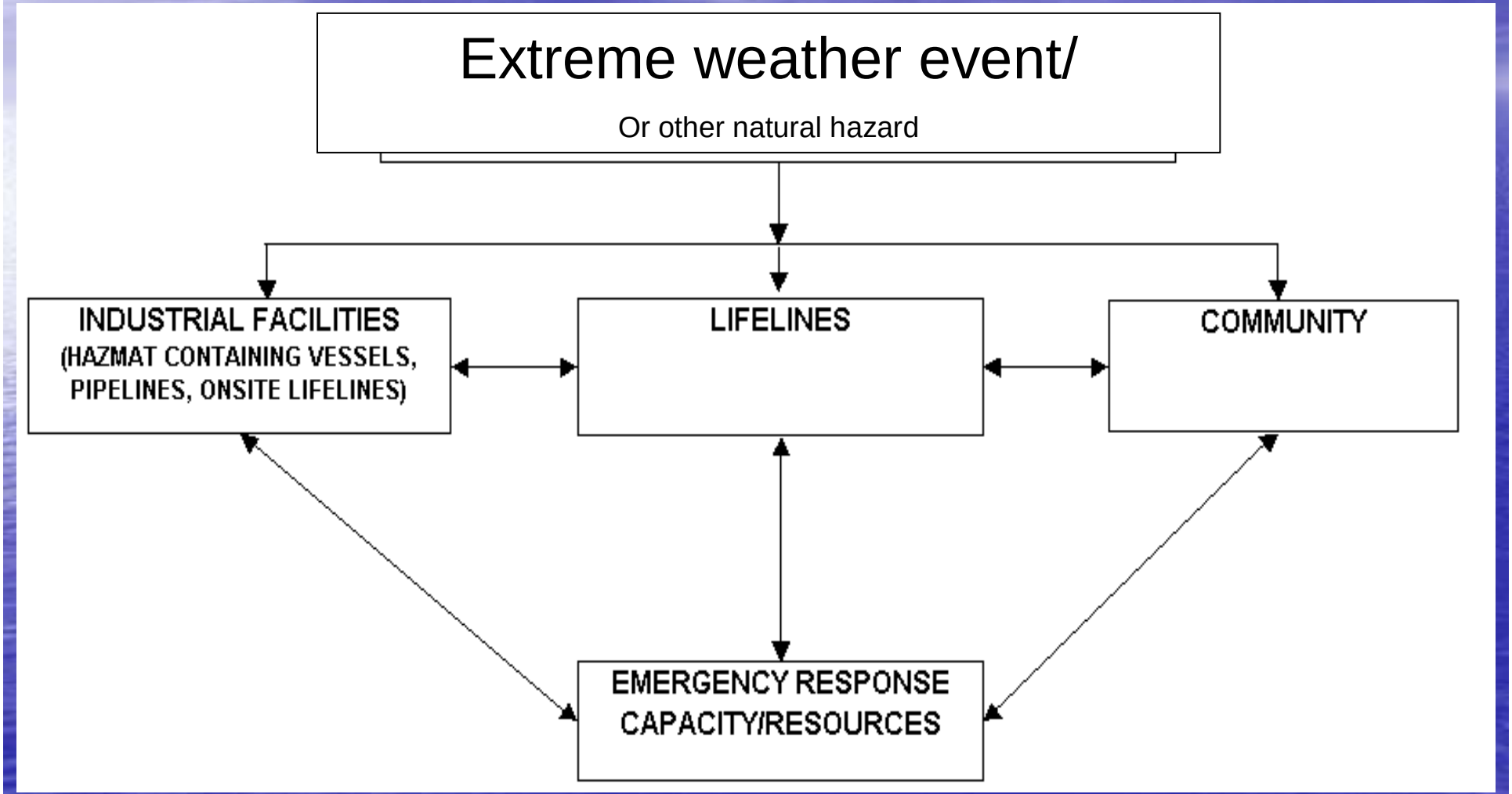
*Sengul, H.; N. Santella; L. J. Steinberg; A. M. Cruz (2010).

Weather-related hazardous materials releases and oils spills in the U.S. (1990-2008)*



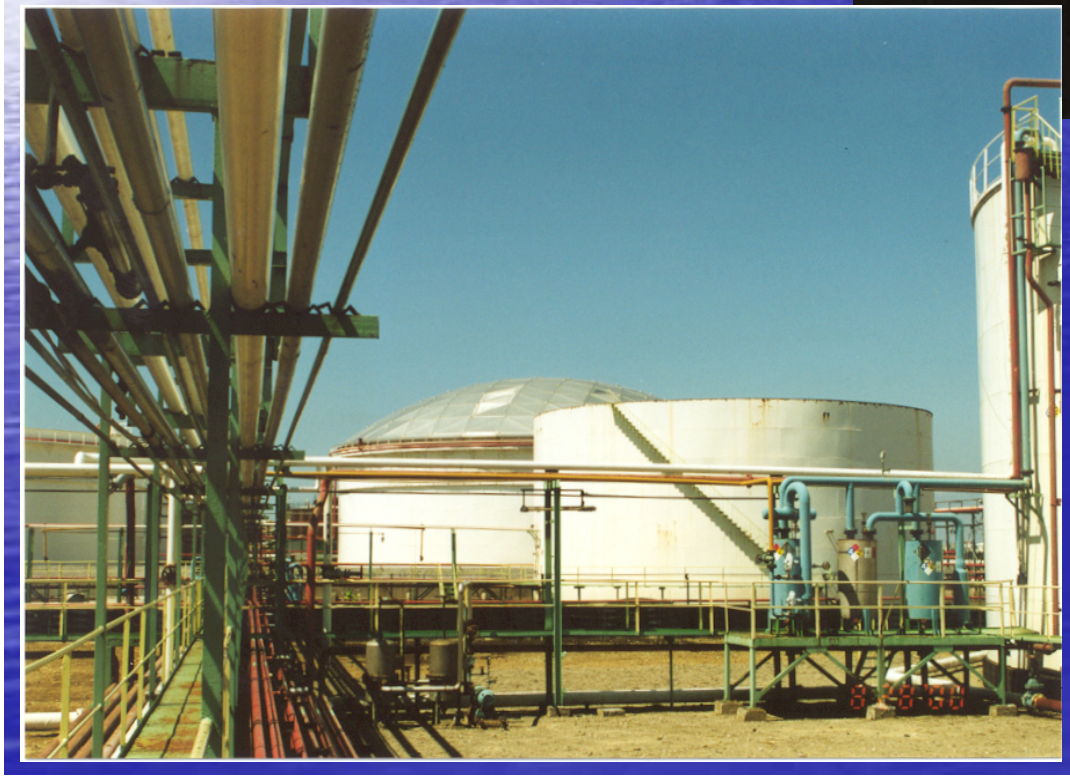
*Sengul, H.; N. Santella; L. J. Steinberg; A. M. Cruz (2010). Occurrence of Hazardous Material Releases Due to Natural Hazards in the U.S. Submitted to Journal of Disaster Studies, Policy and Management.

Comprehensive Analysis Framework*



*Steinberg and Cruz (2010)

2. Potential impacts



The challenges for the oil and gas sector in addressing climate issues will vary depending on location

Low-lying coastal areas:

- Home to major facilities (e.g., Ras Tanura, Saudi Arabia; Jamnagar, India; Jurong Island Refinery, Singapore; Rotterdam Refinery and major installations in the Niger Delta)
- Increased coastal flooding, storm surge, rising sea-levels, and ground subsidence and erosion
- Changing precipitation patterns and population growth will affect water supply regimes

Changes in ambient temperature:

- Changing temperatures and weather patterns may lead to water scarcity and hence higher water costs.
- Affecting energy production, water and water cooling requirements for refining, transportation, storage and distribution, and water discharge requirements in extraction and production

Arctic:

- Disproportionate warming will affect extraction and production
- Alaska: already 3^{o}C increase
- A reduction in sea ice may lead to increased off-shore oil exploration
- Melting of permafrost can severely affect the integrity of oil and gas extraction and transportation infrastructure
- North Sea may see stronger storms

U.S. Gulf Coast, Gulf of Mexico:

- More frequent coastal flooding or permanent inundation due to rising sea levels (higher sea level rise than any other ocean basin)
- More frequent extreme weather events
- Extreme weather events have already caused unprecedented damage and losses

Hurricanes Katrina and Rita impacts on oil and gas industry

- 2000/3000 platforms affected
- 163 oil and gas offshore platforms completely destroyed
- Hundreds of miles of oil and gas pipelines were displaced or broken (inland and offshore)
- In Feb 2006 over 46 % still shut down

Source: Cruz, A. M. and E. Krausmann (2008). Damage to offshore oil and gas facilities following hurricanes Katrina and Rita: An overview. *Journal of Loss Prevention in the Process Industries,* 21 (6), 620–626.

High number of spills

- Bass Enterprises, Venice, LA – 85,000 bs crude oil released
- Murphy Oil releases 8000 bs, affecting 1800 homes (cost: $330 million class action settlement)
- Over 200 releases from onshore facilities and 400 from offshore operations
- Oil spills totaled over 30.2 million lt.

Source: Cruz, A. M. and E. Krausmann (2009). Hazardous-materials releases from offshore oil and gas facilities and emergency response following Hurricanes Katrina and Rita. J*ournal of Loss Prevention in the Process Industries*, 22(1), 59-65.


Chalmette

Oil spill affected residential area

Oil sheen in flood waters


Hurricane Katrina
Chalmette
Over 1800 homes affected resulting in class action settlement for US $330 million.

3. Vulnerability and mitigation and adaption options

- Much of major oil and gas infrastructure located in areas subject to environmental and climate changes
- Vulnerability to storms, tornadoes, high winds, lightening, storm surge, flooding, and landslides
- More frequent severe episodes with increasing global temperatures

Storms, heavy rains and floods

- Climate model runs inconclusive with respect to precipitation
- Storms and extreme rainfall events with potential for flooding may be more likely
- Areas where storms & flooding are already a concern, conditions could deteriorate
- Increased rainfall could lead to more rapid deterioration of infrastructure, raising costs

Storms and heavy rain fall will impact delivery and distribution

- Deterioration of roads and rail infrastructure will affect product delivery and distribution
- Flooding can cause land subsidence and heave of embankments
- "Accelerated deterioration of transportation structures may occur where precipitation events and freeze-thaw cycles become more frequent, and in areas that experience acid rain" (U.S. CCSP report 2008).

Roads and railways: Mitigation and adaption measures include:

- Improvements in engineering design and construction methods and materials
- Regular maintenance and monitoring infrastructure conditions
- Planning and preparing for service delays or cancellations

Floods

- Flood disasters have been on the rise
- Account for 34% of all world natural disasters
- Facilities located in river basins and near large water bodies may be subject to flood loads

Damage to oil and gas pipelines France, 2002

Flood loads include:

- Standing or slowly moving water loads, buoyant loads, loads due to fast moving water, breaking wave loads, and impact loading (debris)
- Higher water velocities and higher water depths increase flood loads
- Flood loads can damage pipelines, buildings, steel structures, storage tanks, and roads, railways and bridges

Pipelines vulnerable to floods

- Preferred and safest method of transporting oil and gas
- Major pipelines are buried underground
- May be vulnerable to flooding in areas of high water velocities which cause soil erosion and lead to exposure
- Exposed sections such as valves, pump stations, and river crossings more vulnerable

San Jacinto River Flood
Houston, TX, 1994

- Severe flooding resulted in 8 pipelines ruptures and undermining of 29 others both at river crossings and new channels created in the flood plain
- More than 35000 barrels of oil were released into the river.
- Ignition of the released products within flooded residential areas resulted in minor burns and inhalation injuries to 547 people, and over US$23 million in losses.

Coffeyville Refinery
Coffeeville, Kansas, 2007

- Flooded refinery resulted in the spill of an estimated 40,000 gallons of crude oil
- Oil spill flowed into streets, homes and businesses affecting some 2,500 homes and buildings
- Contaminated the Verdigris River, and threatened to contaminate lakes in Oklahoma

High water hazards at oil fields and refineries

- Flood electrical equipment and utilities
- Cause short circuiting or power failure resulting in process upsets, unexpected shutdown
- Flooding around storage tanks can make them float off their foundations
- Internal drainage systems containing waste oil can flood, causing oil to float up and out of the drainage system

Samir refinery in Mohammedia Morocco, 2002

- Flooding of the El Maleh River resulted in water levels of about 1.5 m inside the refinery
- Flooded internal oil drainage system caught fire and triggered explosions
- Two people died and over 70% of the thermo-electric power plant that was part of the refinery complex was destroyed

Source: Krausmann, E., and F. Mushtaq (2008). A qualitative Natech damage scale for the impact of floods on selected industrial facilities. *Natural Hazards* (2008) 46 (2), 179–197.

Flood protection and adaptation measures include:

- Re-assessment of flood prone zones
- Avoiding building in flood-prone areas
- Water proofing (buildings, equipment)
- Adoption of slowing, steering and blocking water techniques
- Elevation of buildings or building components above the 100-yr flood contour level can protect building functionality and contents

Regulatory framework

- Most developed countries limit or prohibit development in the 100-year flood plain
- Laws generally apply to new construction
- Changing precipitation patterns and more frequent extreme rain fall events may result in 100-yr flood events that occur more often
- New developments should include flood hazard assessments that consider environmental changes in the coming decades due to climate change

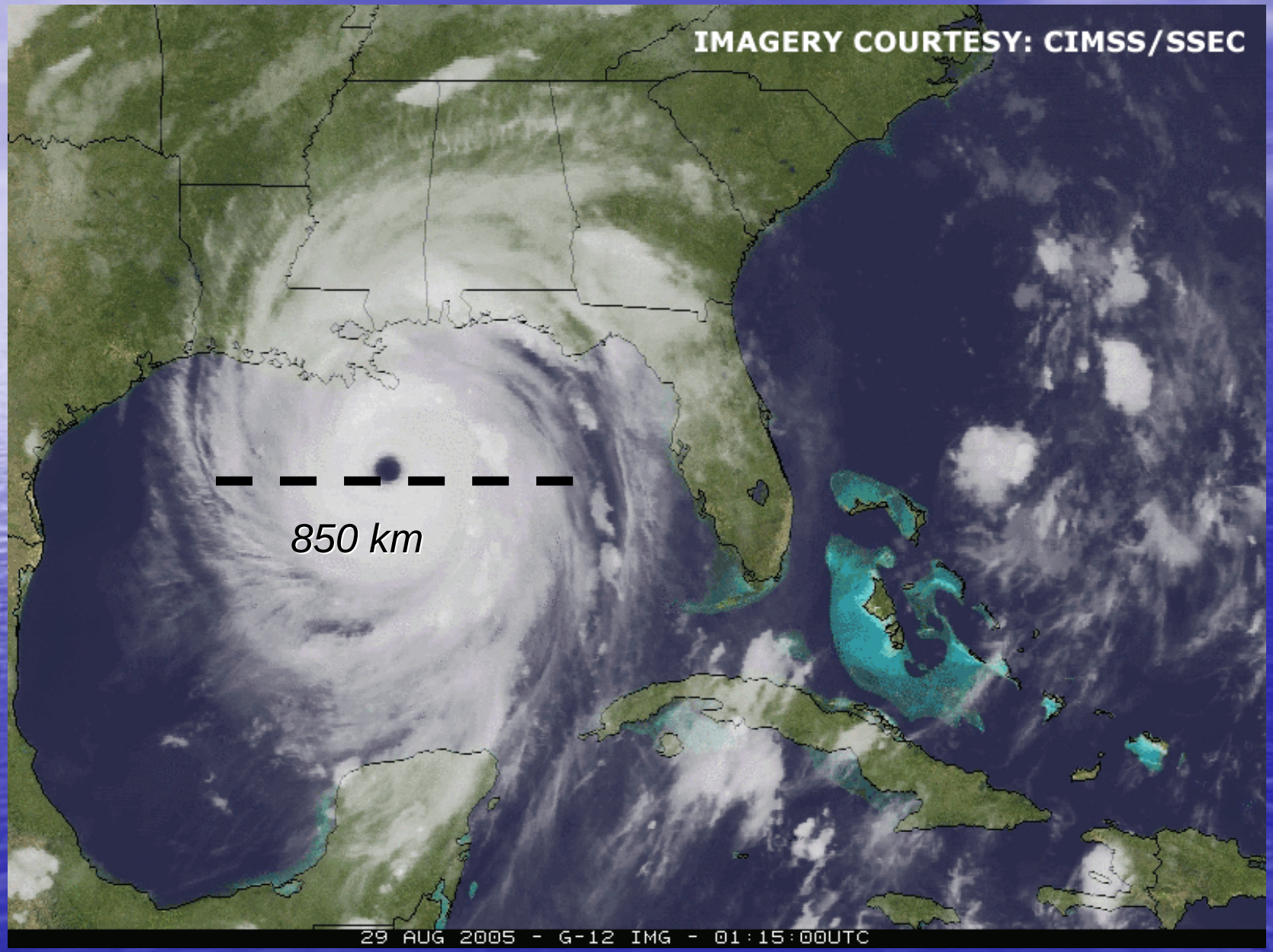
Tropical cyclones:

- Originate over warm waters of the North Atlantic Ocean, the Caribbean Sea, and Gulf of Mexico; and in the Central, Eastern, and South Pacific Oceans
- Likely to be more intense, with higher wind speeds and heavier precipitation
- Future storms such as Hurricanes Katrina and Rita are very likely

Hurricanes and typhoons are particularly destructive:

- Large storms, with impact radii of as much as 500 km, although damaging winds usually limited to a 100-km radius
- Accompanied by high wind speeds, tornadoes, heavy rains, storm surge, flooding, and lightning

Hurricane Katrina, 2005



Hurricanes winds and tornados:

- May damage buildings and structures by toppling equipment, processing units or storage tanks, and dislodging roofs
- Protruding parts such as rails, piping and connections between storage and process units vulnerable to high wind speeds
- Projectiles can damage equipment, break pipes and connections, and puncture tanks

Chevron refinery affected by Hurricane Georges* 1998

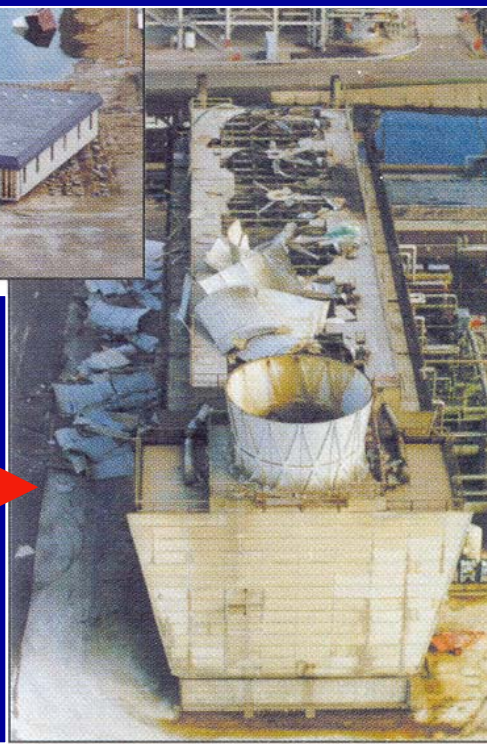
Hurricane Georges in 1998, Pascagoula, MS

Salt-water intrusion on control panel

Flooded naphtha tank farm

Control center moved by storm surge

Tornado damages cooling tower



(*Cruz *et al.*, *Natural Hazards Review*, 2001)

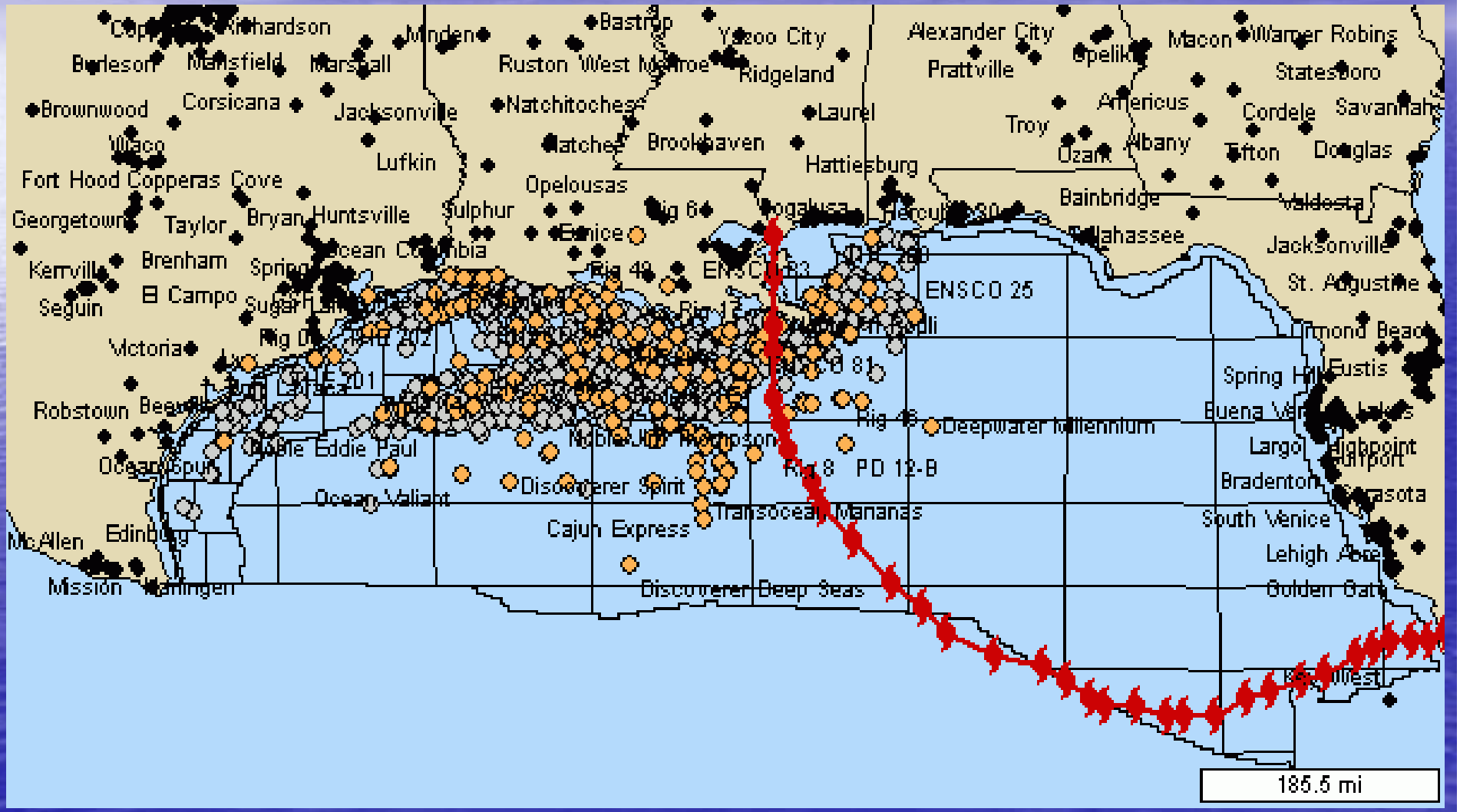
Torrential rain fall and flooding:

- Torrential rain fall (even Cat. 1 & 2) can cause inland flooding and landslides (e.g. Mitch in Honduras; Irene in Florida, 1998)
- Heavy rains and flooding can cause major disruption and damage to oil and gas inland extraction, transportation, refining, and delivery

Storm surge and coastal flooding:

- Storm surge and high winds can affect offshore oil and gas operations, vessel and pipelines
- Wave inundation and underwater wave loads can severely compromise structural integrity of platforms
- Damage to host platform or its risers, and the impact of dragging objects damage pipelines

The path of Hurricane Katrina in the GoM. Grey circles represent fixed manned platforms; orange circles symbolise mobile rig locations. (Source: Rigzone, 2006)



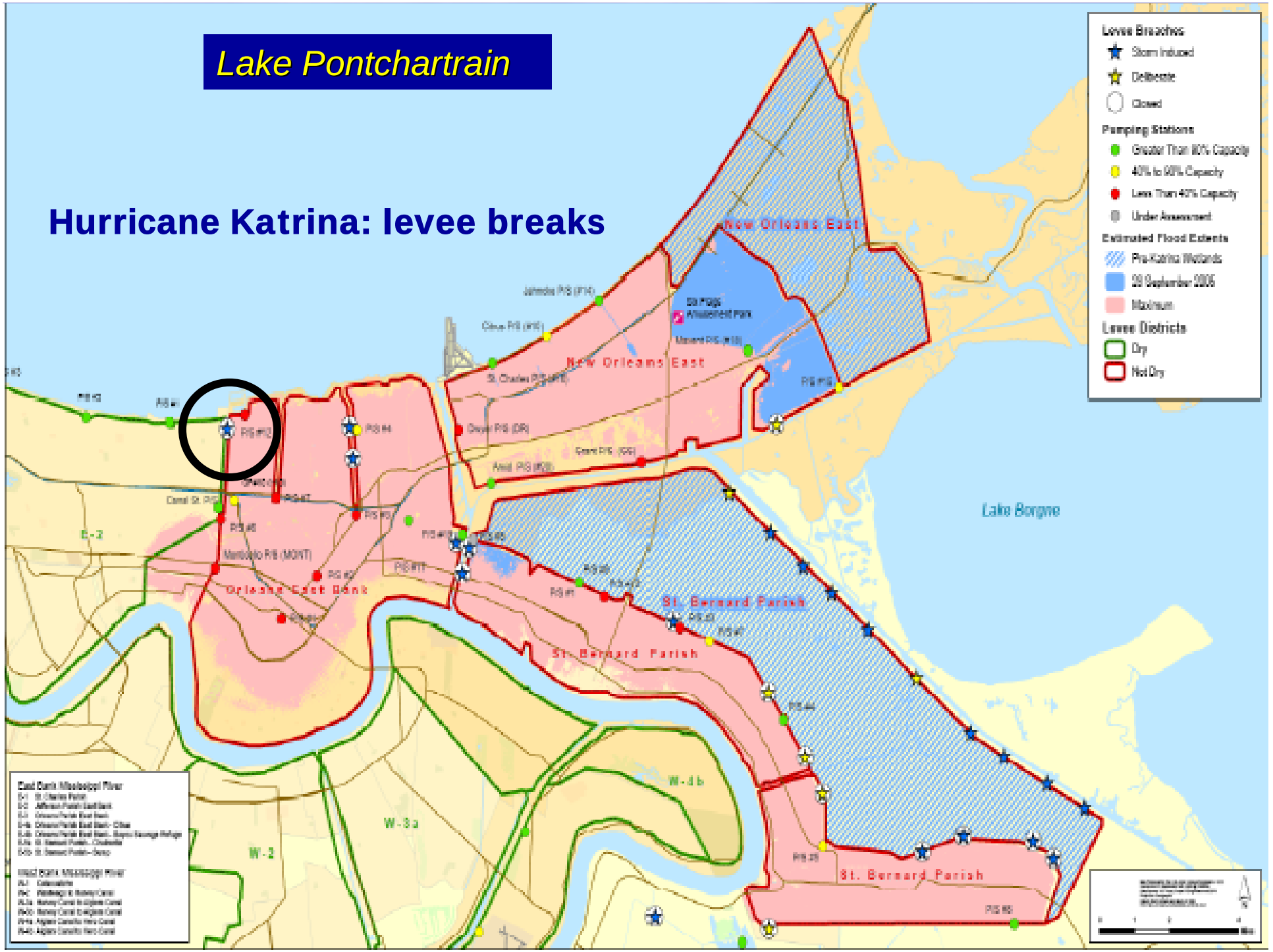
Damage to mobile offshore drilling units (MODUs)

Hurricane	**Number of MODUs** (Mobile offshore drilling unit-MODU)
Andrew	3
Lili	1
Ivan	5
Katrina	6
Rita	13

Source: Cruz and Krausmann (2008).

Storm surge and coastal flooding:

- Storm surge can cause abnormal rise in water levels of canals, lakes, and rivers connected to the sea
- Leading to inland flooding
- Can disrupt river and canal navigation


Lake Pontchartrain
Hurricane Katrina: levee breaks
Levee Breaches
Storm Induced
Deliberate
Closed
Pumping Stations
Greater Than 80% Capacity
40% to 80% Capacity
Less Than 40% Capacity
Under Assessment
Estimated Flood Extents
Pre-Katrina Wetlands
29 September 2005
Maximum
Levee Districts
Dry
Not Dry
New Orleans East
New Orleans East
Lake Borgne
Orleans East Bank
St. Bernard Parish
St. Bernard Parish
St. Bernard Parish
E-2
W-3a
W-2
W-4b

Mitigation and adaption options

- Avoiding building in coastal areas subject to hurricane impacts
- Adopt flood and storm surge protection measures to slow, block, and/or steer water away from critical infrastructure
- Revise building code requirements, storm surge and flood load requirements, and wind loads for onshore refinery steel structures and buildings

Mitigation and adaption options

- Evaluate adequacy of design standards of offshore platforms, mooring systems for mobile rigs and pipe-laying
- Performance of MODUs can be improved with increase in no. of lines, upgrading materials and chain mechanisms, upgrading anchors, and better site planning and mooring analysis

Lightning

- Up- and downstream oil and gas industry activities vulnerable to lightning impact
- Experience shows that existing lightning-protection measures, such as e.g. grounding of equipment or the installation of lightning rods or circuit breakers, may not be sufficient
- Poses a safety risk due to the possible fire, explosion and release of hazardous materials

Lightning

- Can cause power surges, process upsets, and power failure
- Lightning tends to strike tallest structures (e.g., vents, roofs, stacks, towers)
- Frequency of lightning events expected to increase with the predicted rise in frequency/ intensity of meteorological hazards

Mitigation and adaptation measures

- Development of methodology for the analysis of lightning risk at industrial facilities
- More research into the dynamics of the impact of lightning on equipment is required to guarantee sufficient protection of oil and gas infrastructures from lighting strikes in the future

4. Other challenges

- Much of existing infrastructure built when impacts of climate change were not yet understood, thus not factored in
- Huge investment needed to bring infrastructure to new requirements
- Investment needed for new development
- How to insure that the new infrastructures incorporate the likely effects of environmental change, particularly in areas where there is high uncertainty

5. Conclusions

- Oil and gas extraction, transportation, refining, and delivery subject to climate impacts
- Facilities subject to extreme weather events most vulnerable
- Need for comprehensive risk assessment and analysis framework
- Some mitigation and adaptation options will require large investments to upgrade facilities
- Adequate contingency planning and emergency response and recovery will be essential to insure business continuity

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Ana Maria Cruz, Ph.D.

International Consultant
Natech risk management
Bordeaux, France

GCOE Adjunct Professor
Disaster Prevention Research Institute
Kyoto University, Kyoto, Japan

cruzanamaria2000@yahoo.com
anamaria@drs.dpri.kyoto-u.ac.jp


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