
# Rapid Ecosystem & Coastscape Evolution of South Florida

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in response to
Sea Level Rise, Hurricane Events, and Human Stresses

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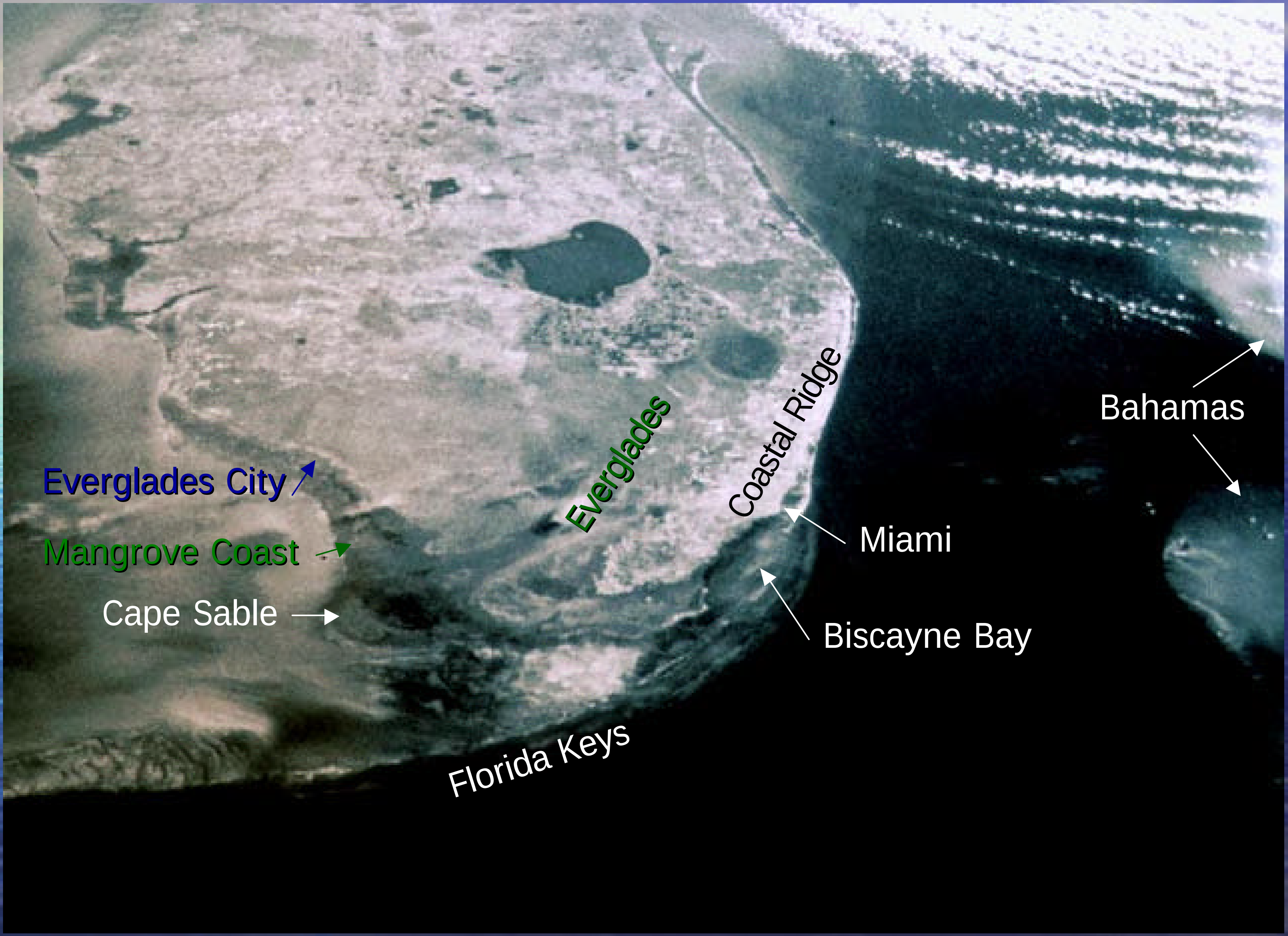

Everglades City
Mangrove Coast
Cape Sable
Everglades
Coastal Ridge
Miami
Biscayne Bay
Florida Keys
Bahamas


THE MANGROVE COAST
CAPE SABLE

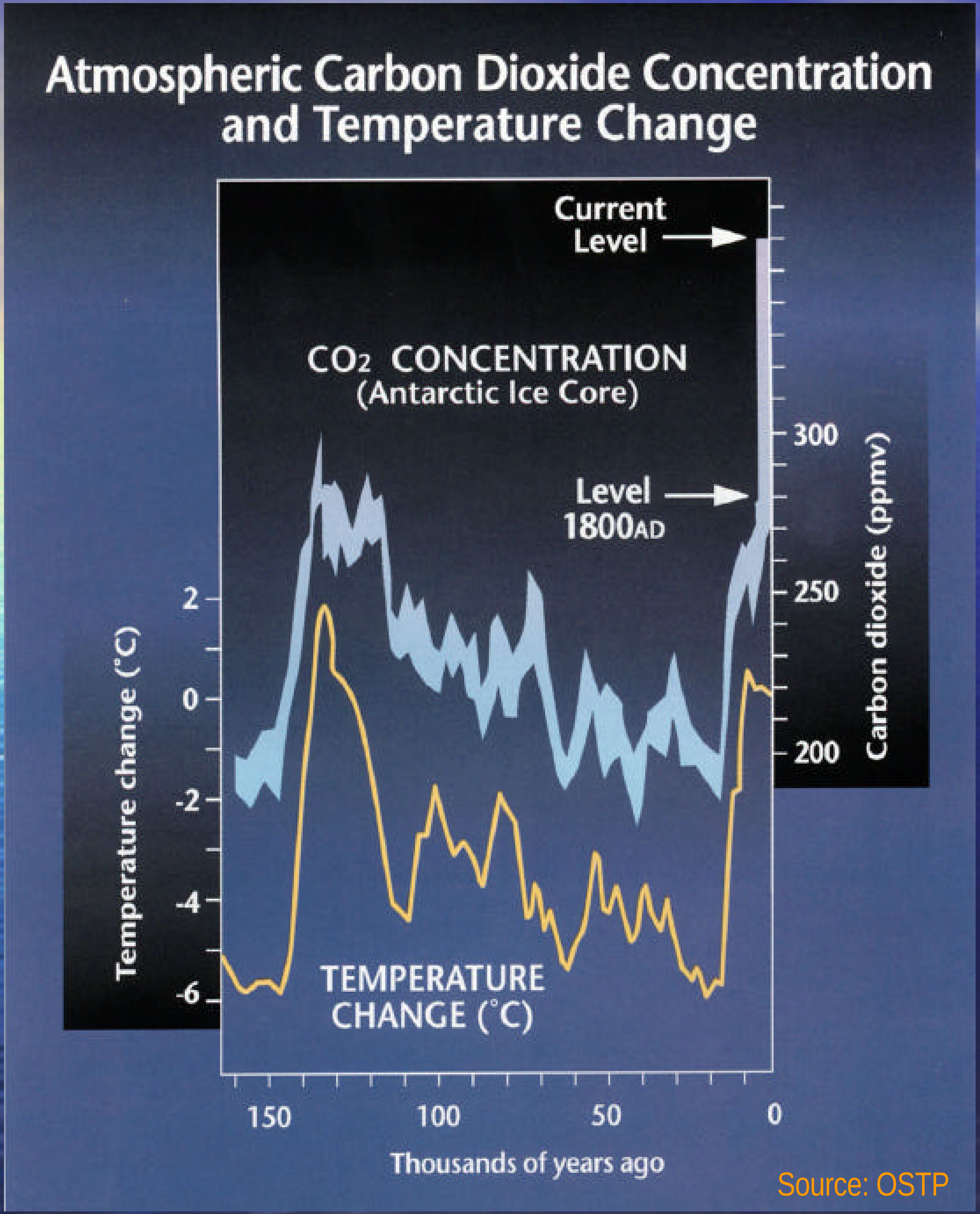
# BECAUSE OF GLOBAL WARMING:

- Rapid landscape/coastscape/seascape changes are now underway.
- Accelerated historical SEA LEVEL RISE has destabilized the Atlantic and Gulf Coastal System.
- CATASTROPHIC EVENTS and HUMAN MODIFICATIONS are catalysts for change and evolution in this destabilized coastal system.
- Rates of coastal system destabilization and evolution will further accelerate over the coming century.
- Research, monitoring, policy and management must increasingly focus on landscape-scale stresses, evolution, fluxes and pollution.

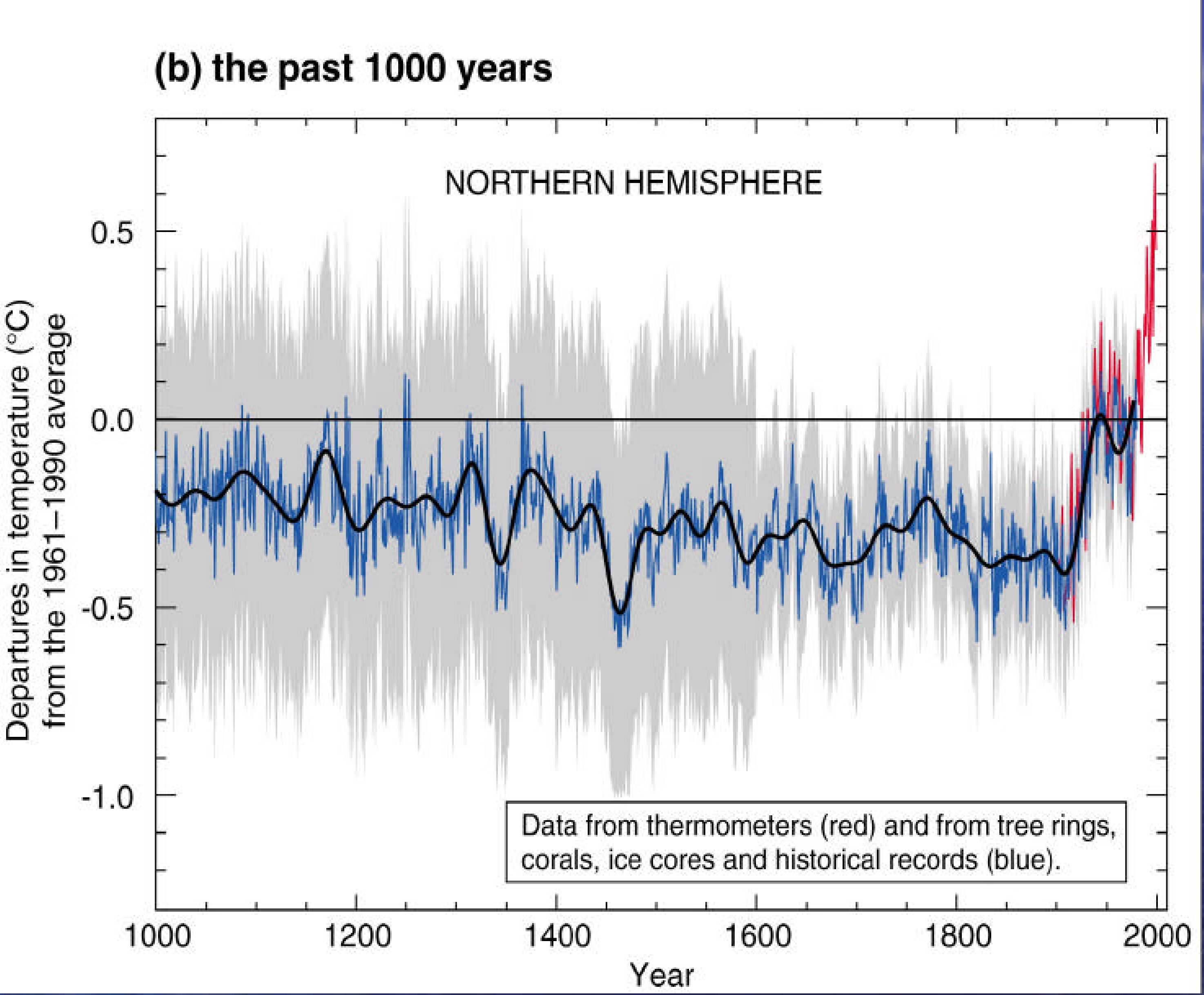
# Lessons from looking at the past

# 1

**$CO_2$ drives global warming.**




- Clear correlation between atmospheric $CO_2$ and temperature over last 160,000 years
- Current level of $CO_2$ is *outside* bounds of natural variability
- *Rate* of change of $CO_2$ is also unprecedented



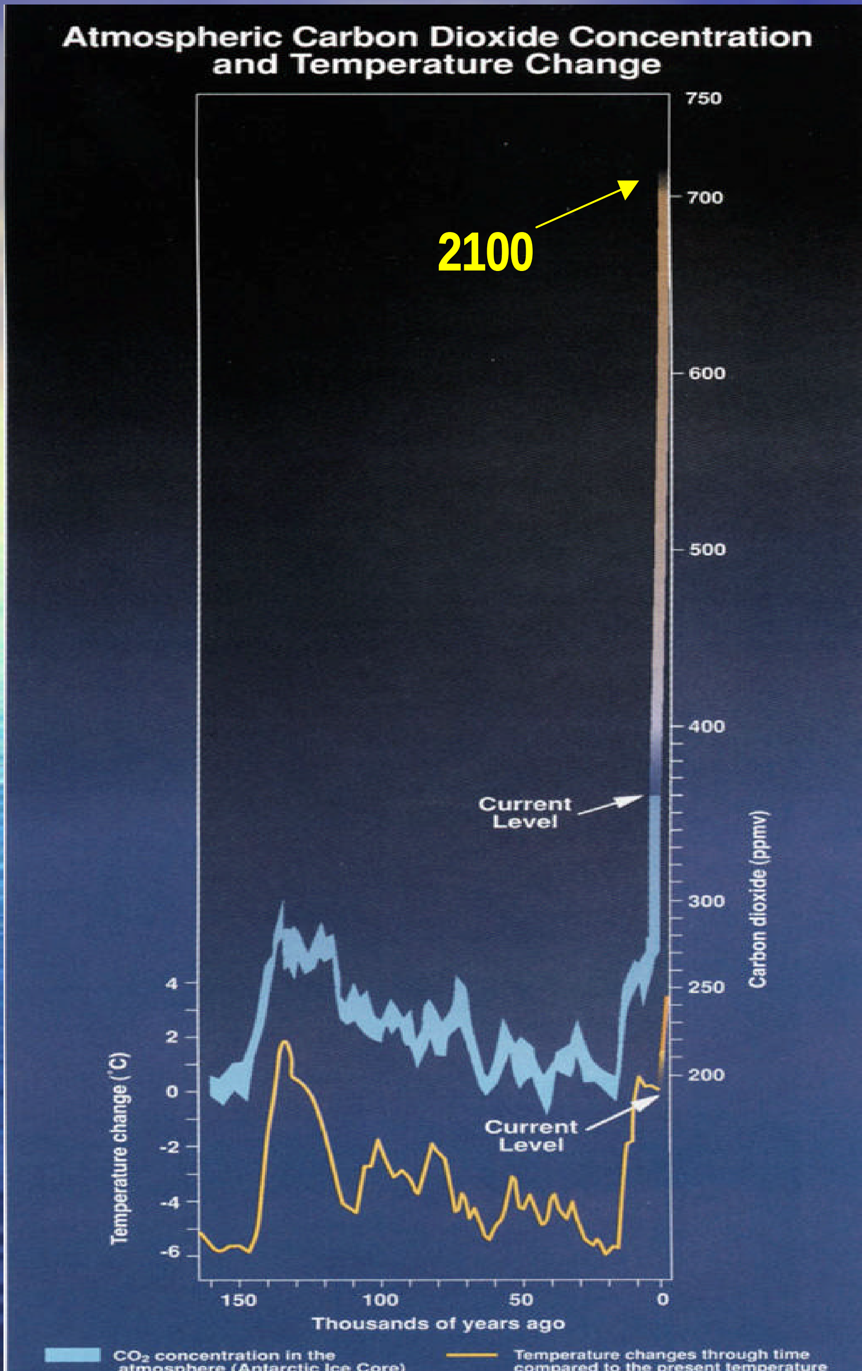

**Observed Variations of the Earth's Surface Temperature***

*relative to 1961-1990 average

Source: IPCC TAR 2001

# Lessons from looking at the past 2

We are in the process of dramatically exceeding the $CO_2$ levels of the previous interglacial when sea level was 6 meters higher.




## If nothing is done to slow greenhouse gas emissions. . .

- $CO_2$ concentrations will likely be more than 700 ppm by 2100
- Global average temperatures projected to increase between 2.5–10.4°F

Source: OSTP

# Lessons from looking at the past

# 3

A relative sea level rise of only

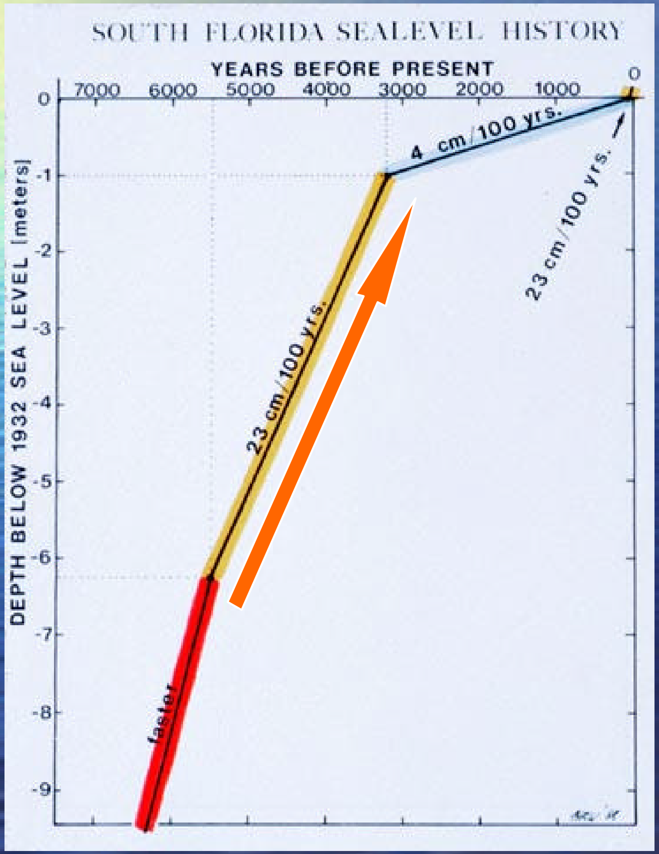
23 cm (9”) / 100 years is too fast for

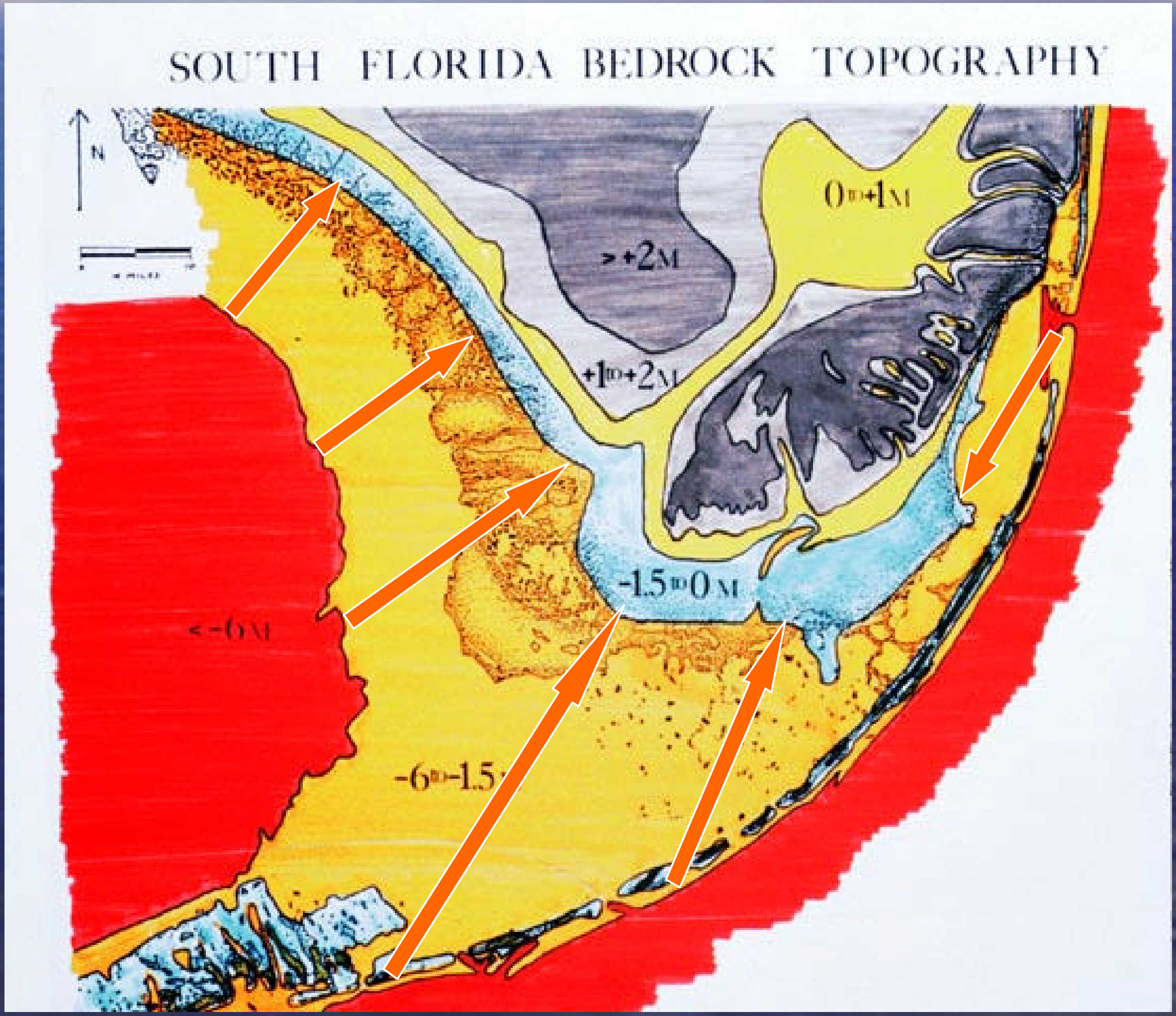
coastlines to withstand.

They retreat.

Sea Level rose at 23 cm (9 inches) / 100 years during the period 5,500 to about 3,200 years before present.

No coastal environment could hold back the landward advance of the sea.



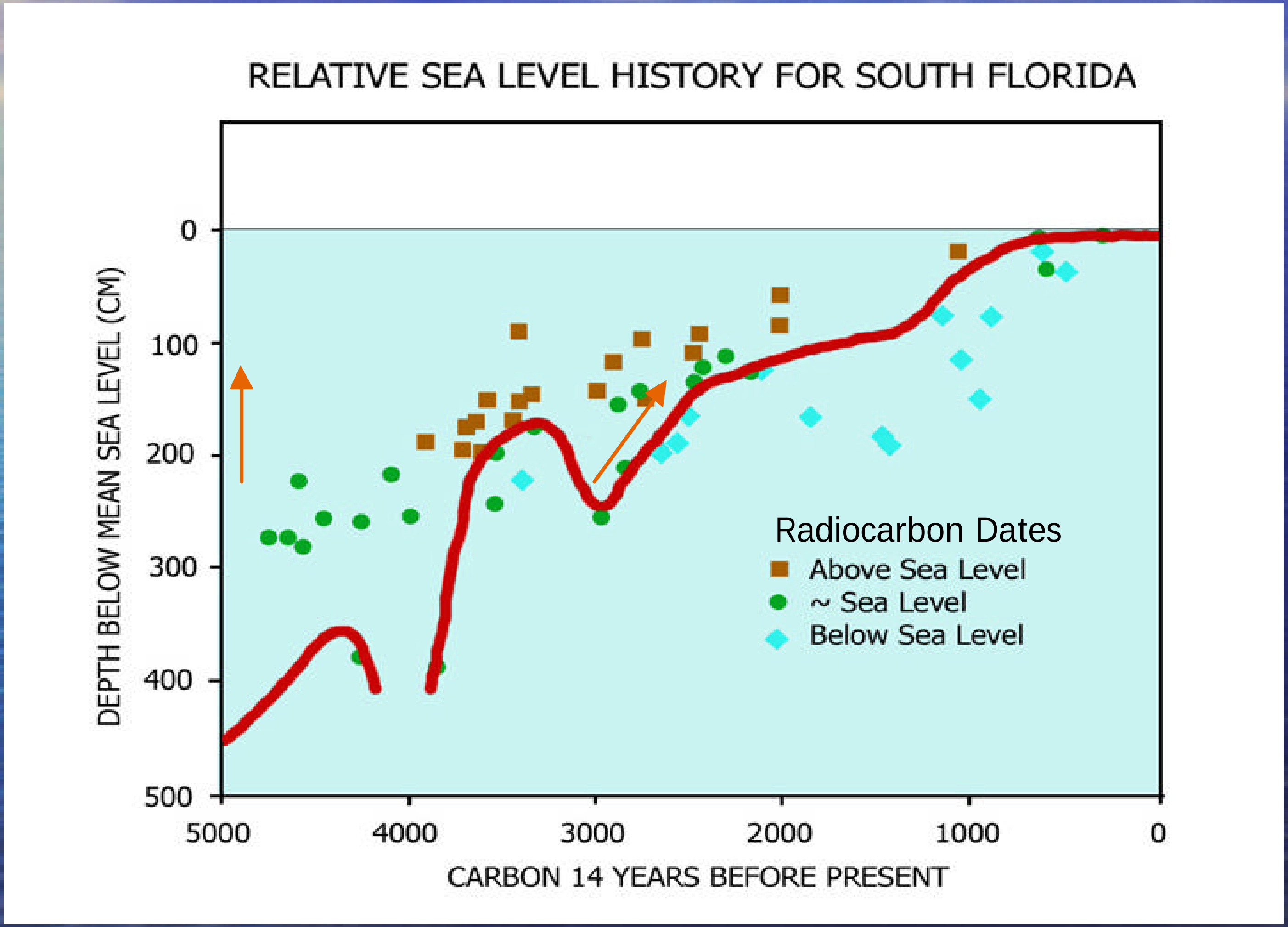



# Lessons from looking at the past

# 4

**Sea level does not tend to move in a gradual manner. It makes dramatic steps followed by pauses.**

# Recent research shows that relative sea level rise is not a simple trend or curve but one with significant stops, drops and rapid rises.




(Based on data from Gelsanliter, Dominguez and Wanless)

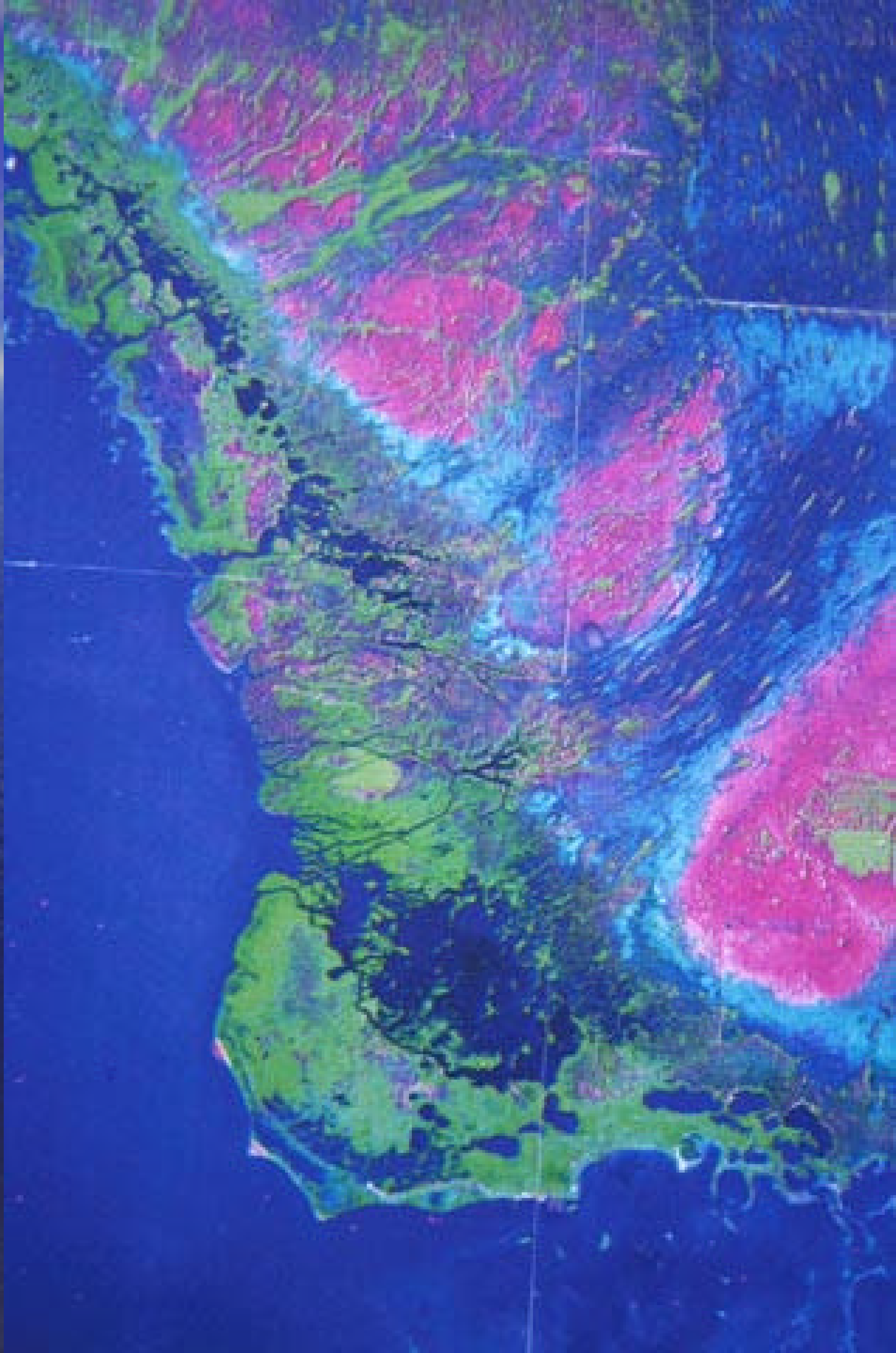
# Lessons from looking at the past

## 5

Times of rapid rise in sea level are associated with and followed by a chaotic time of coastal erosion, sediment redistribution, and high coastal turbidity and nutrient stress.

In south Florida, the rapid rise between 2,500 and 2,400 years ago (probably less than 1 meter) threw our coastal and shallow marine environments into erosional chaos for about 400 years as sediment was eroded and recycled elsewhere.

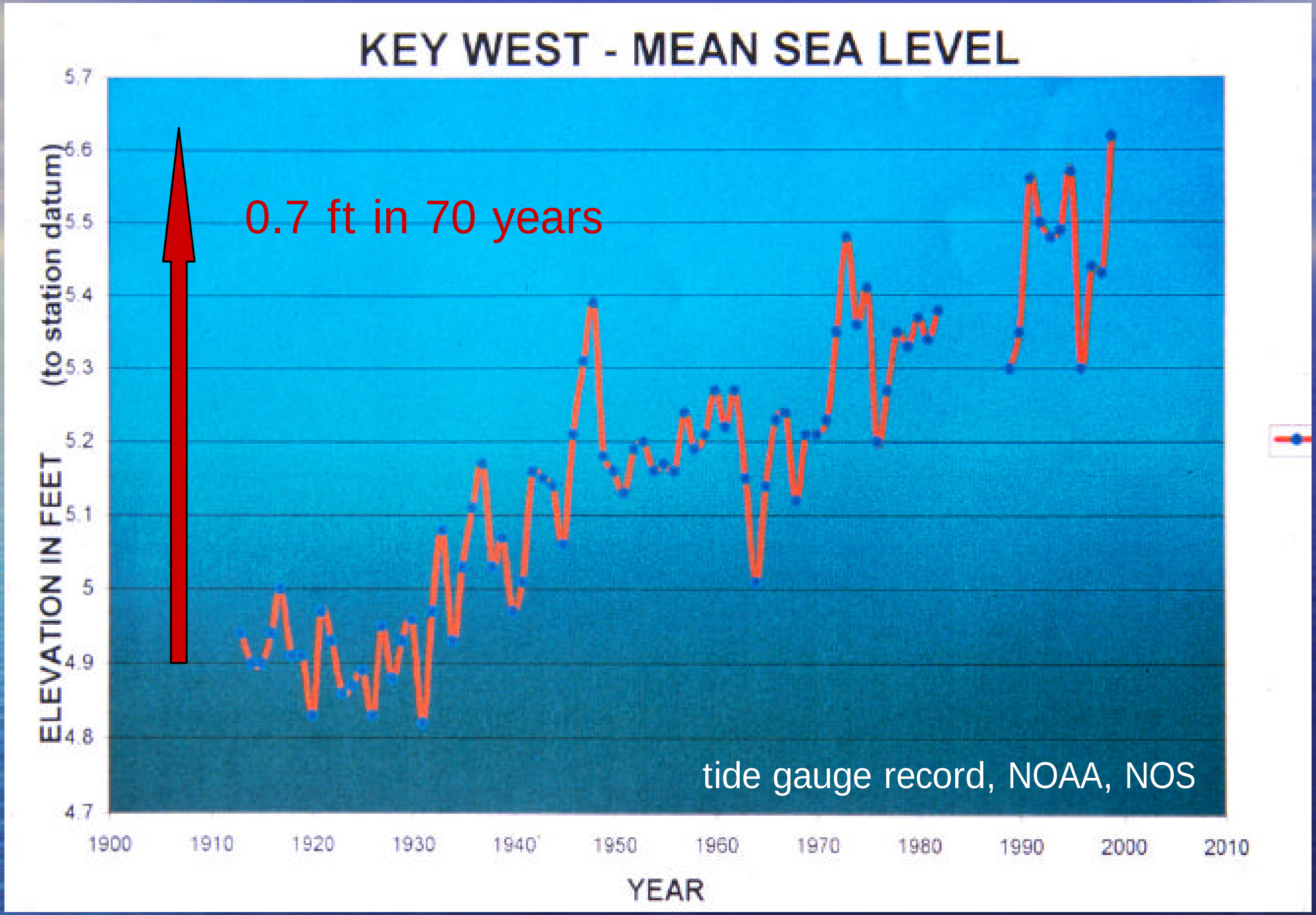
On the other hand, this chaotic time created the coast-scape from which our present patterns of environments evolved.



# 6. Hurricanes are effectors of change in our natural environments

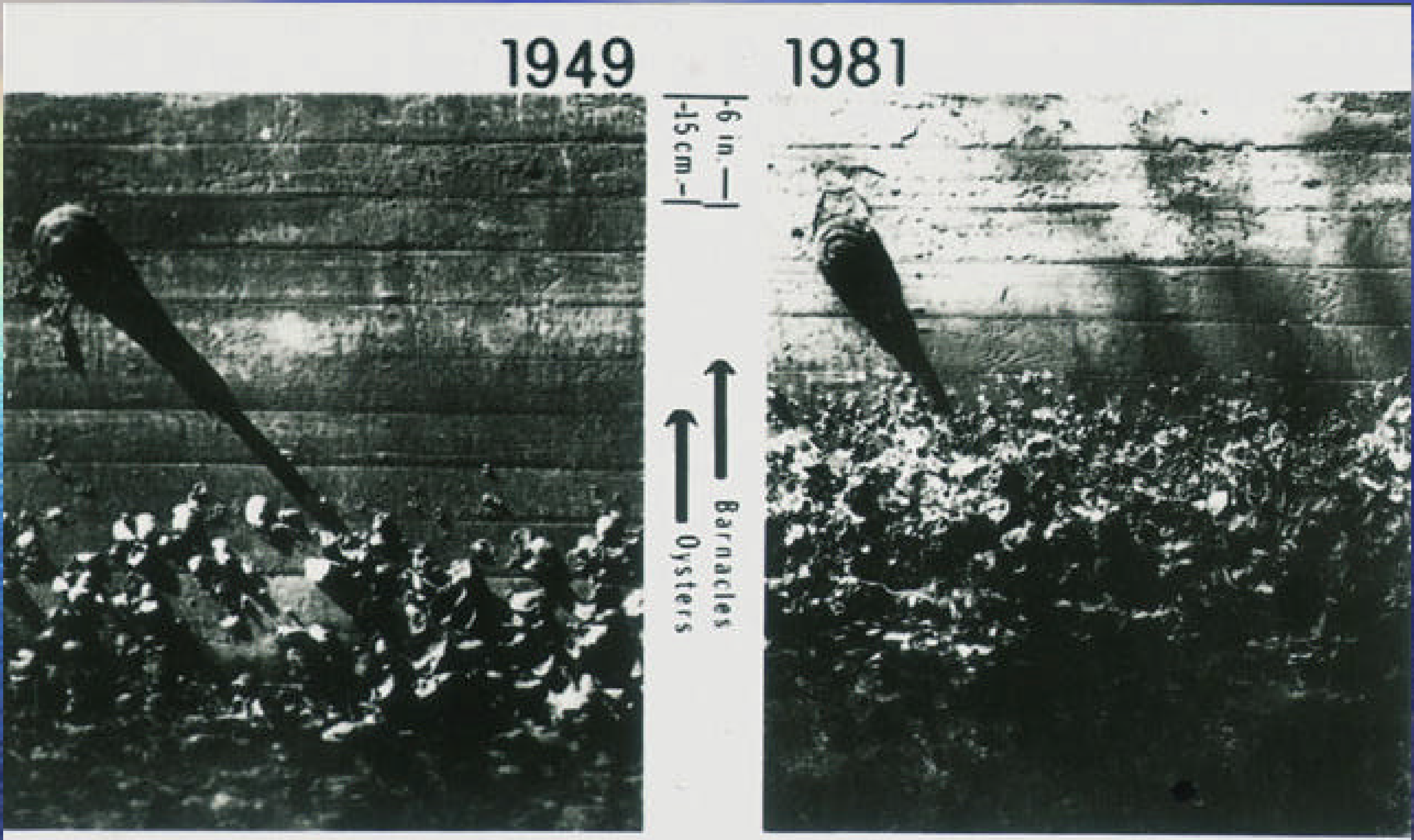
Hurricane Andrew, 1992

# So, what has been happening recently ?

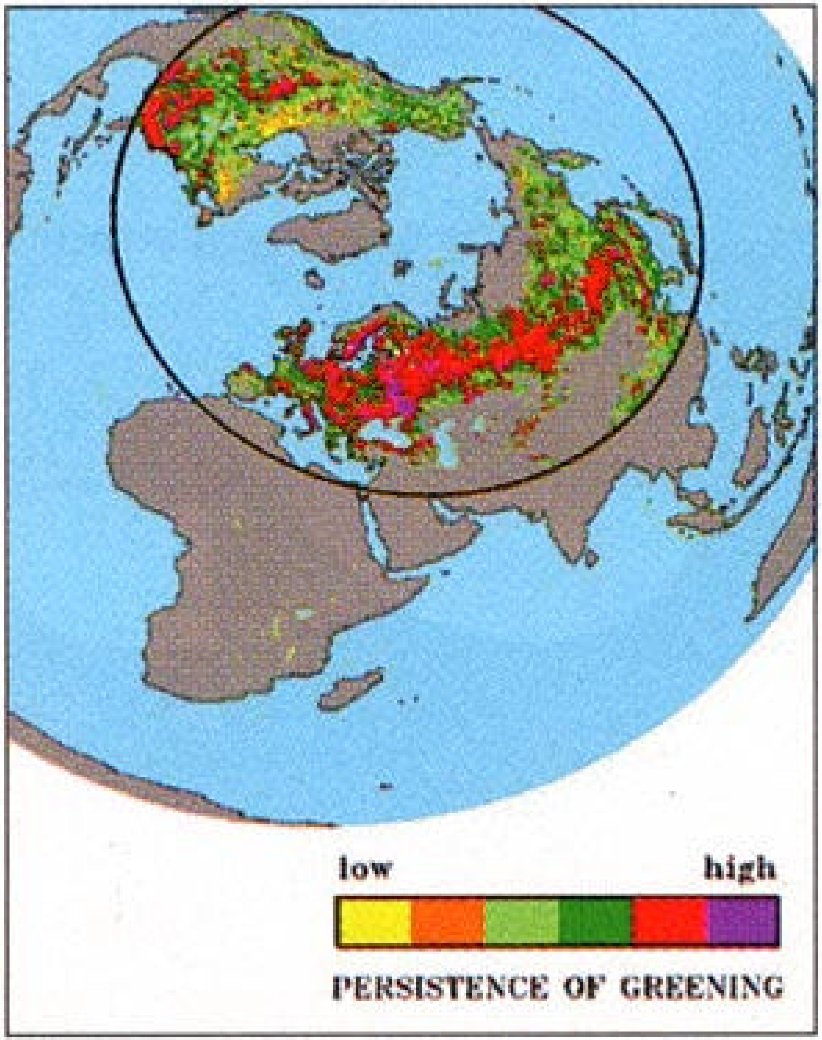



**Beginning in 1930, the rate of relative sea level rise increased about 8 fold over that of the past 2,000 years. It is presently rising at 30 cm (1') / 100 years!**

# On a concrete bridge pier, you can see the response of intertidal organisms.




Coral Gables Waterway and Le June Road – 32 of the 72 years of sea level rise




Increased vegetation density in the Northern Hemisphere above 30° latitude.

There has been an annual increase of 10-30 days with green vegetation in the north over the past 30 years.

# Glaciers world wide have been retreating at an accelerating rate for the past century

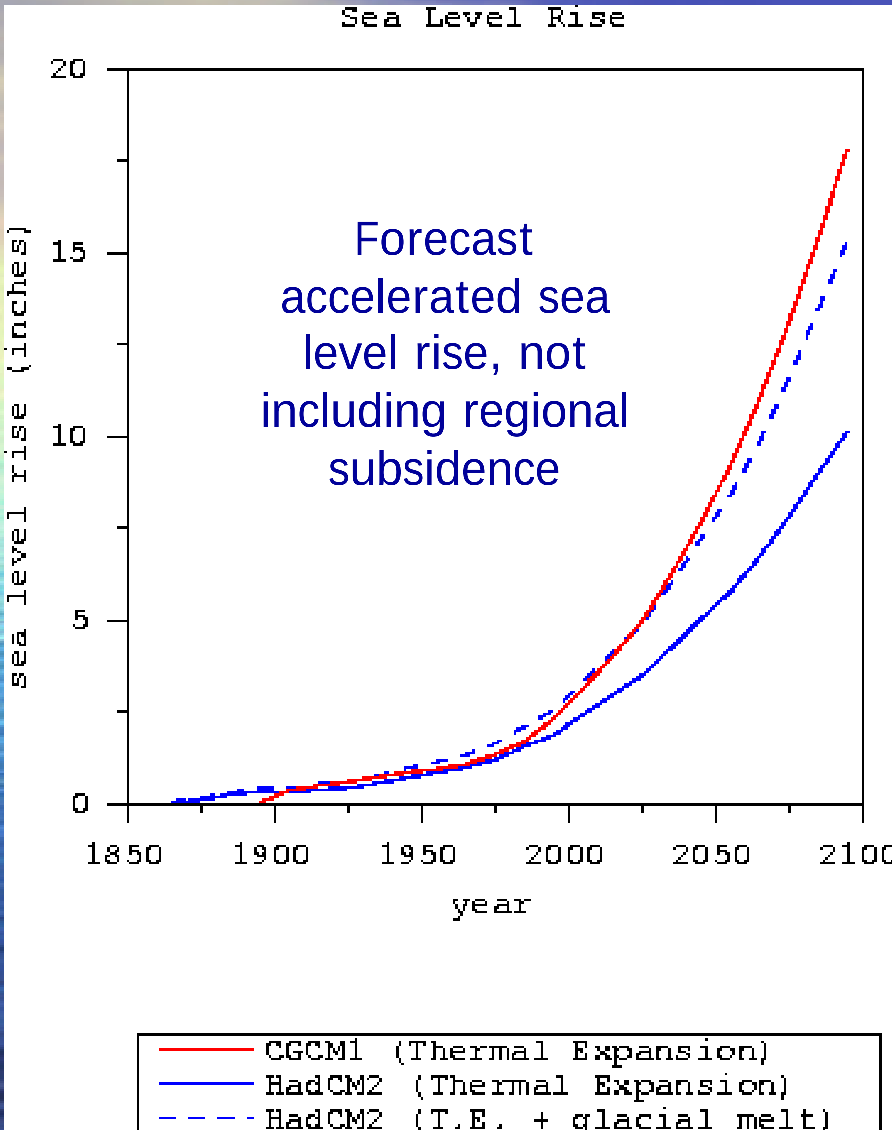
# This past 70 years of dramatic sea level rise has severely destabilized our coastal environments

All of our coastal environments are now unstable and eroding and shifting landward.

Coastal wetland are both shifting into the Everglades and dissipating.

Beaches are eroding as sand is overwashed landward and lost seaward.

Circulation is changing in our coastal bays and estuaries.




Canadian and Hadley
Sea-Level Rise Scenarios

- For the coming century, global-warming-induced sea-level rise is forecast to increase at an accelerated rate, likely at least another 2 feet in south Florida including local effects.
- All projections have assumed a smooth linear trend in response to CO2 increase.
- It probably will not be smooth and gradual and, if so, could be much more.

**TABLE 1**

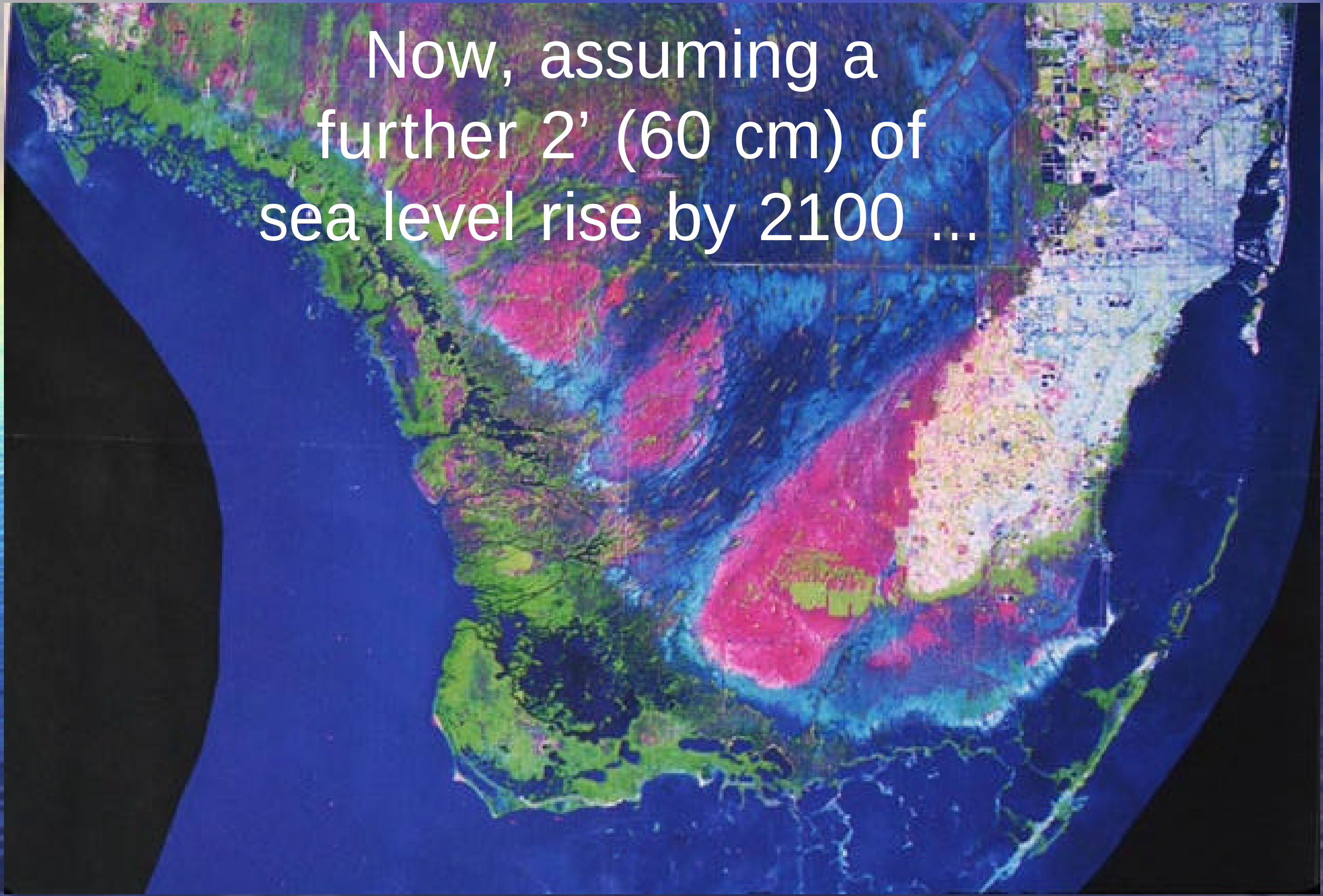
**ESTIMATED SEA LEVEL RISE FOR SOUTHWEST FLORIDA**

**Sea Level Projection by Year**

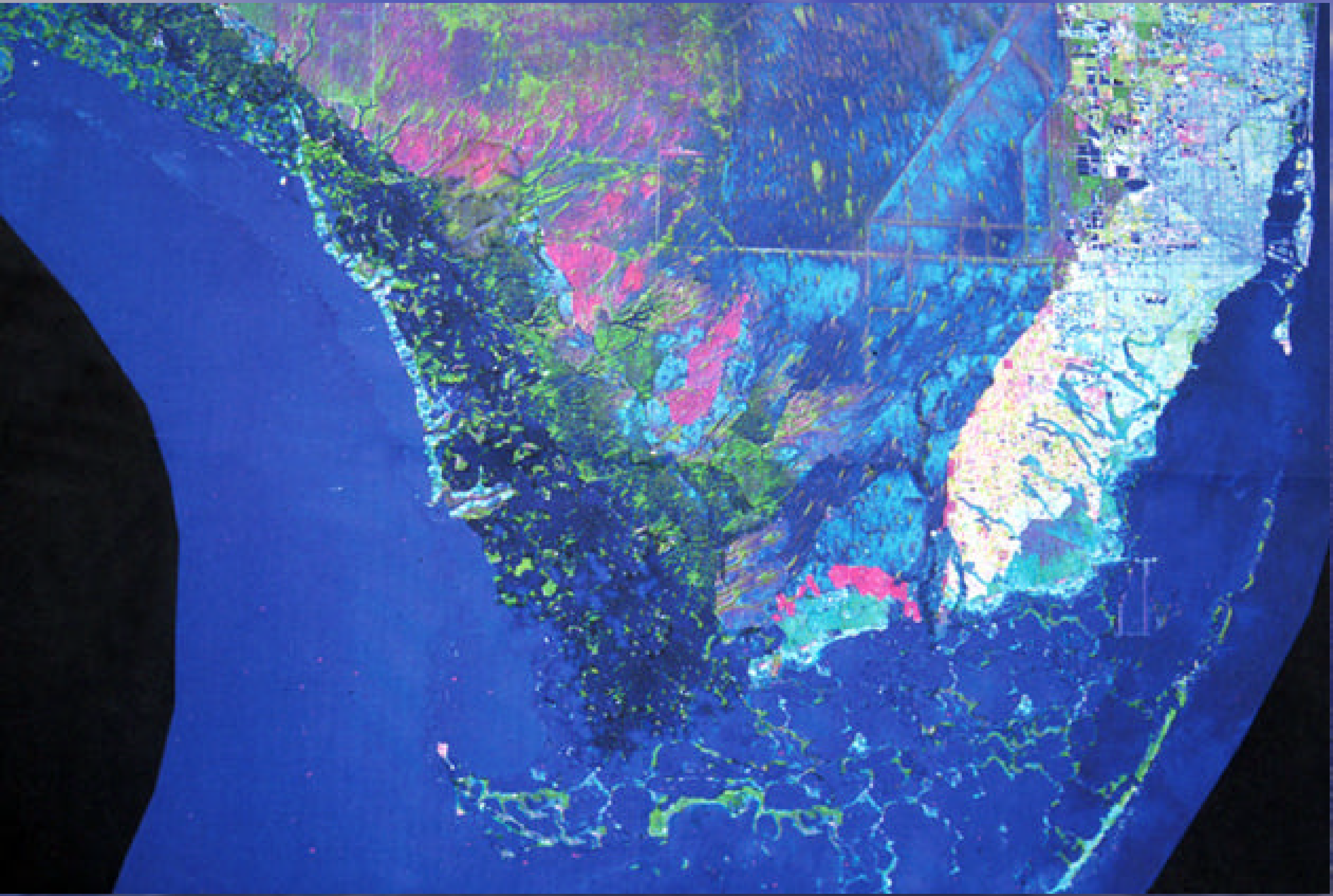
| Probability (%) | 2025 | | 2050 | | 2075 | | 2100 | | 2150 | | 2200 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | cm | inches | cm | inches | cm | inches | cm | inches | cm | inches | cm | inches |
| 90 | 7 | 2.8 | 13 | 5.0 | 20 | 7.7 | 26 | 10.4 | 40 | 15.7 | 53 | 21.0 |
| 80 | 9 | 3.6 | 17 | 6.6 | 26 | 10.1 | 35 | 13.9 | 53 | 20.8 | 71 | 28.1 |
| 70 | 11 | 4.4 | 20 | 7.8 | 30 | 11.6 | 41 | 16.3 | 63 | 24.7 | 85 | 33.6 |
| 60 | 12 | 4.7 | 22 | 8.6 | 34 | 13.2 | 45 | 17.8 | 72 | 28.3 | 99 | 39.1 |
| 50 | 13 | 5.1 | 24 | 9.4 | 37 | 14.4 | 50 | 19.8 | 80 | 31.4 | 112 | 44.2 |
| 40 | 14 | 5.5 | 27 | 10.6 | 41 | 16.0 | 55 | 21.8 | 90 | 35.4 | 126 | 49.7 |
| 30 | 16 | 6.3 | 29 | 11.3 | 44 | 17.1 | 61 | 24.1 | 102 | 40.1 | 146 | 57.6 |
| 20 | 17 | 6.7 | 32 | 12.5 | 49 | 19.1 | 69 | 27.3 | 117 | 46.0 | 173 | 68.2 |
| 10 | 20 | 7.9 | 37 | 14.5 | 57 | 22.3 | 80 | 31.6 | 143 | 56.2 | 222 | 87.5 |
| 5 | 22 | 8.7 | 41 | 16.1 | 63 | 24.6 | 91 | 35.9 | 171 | 67.2 | 279 | 110.0 |
| 2.5 | 25 | 9.9 | 45 | 17.6 | 70 | 27.4 | 103 | 40.7 | 204 | 80.2 | 344 | 135.6 |
| 1 | 27 | 10.6 | 49 | 19.2 | 77 | 30.1 | 117 | 46.2 | 247 | 97.2 | 450 | 177.3 |
| Mean | 13 | 5.1 | 25 | 9.8 | 38 | 14.8 | 52 | 20.6 | 88 | 34.6 | 129 | 50.9 |

*The results of this table is based on using Tables 9-1 and 9-2 of the EPA Report "The Probability of Sea Level Rise". Basically, the formula is multiplying the historic sea level rise (2.3 mm/yr) in Southwest Florida (closest point used is St. Petersburg, Fl., Table 9-2) by the future number of years from 1990 plus the Normalized Sea Level Projections in Table 9-1. In summary, the EPA Report has relied on various scientific opinions regarding sea level changes affected by factors such as radiative forcing caused by both greenhouse gases and sulfate aerosols, global warming and thermal expansion, polar temperatures and precipitation, and the contributions to sea level from Greenland, Antarctica, and small glaciers.

# South Florida 1995



# South Florida 2095

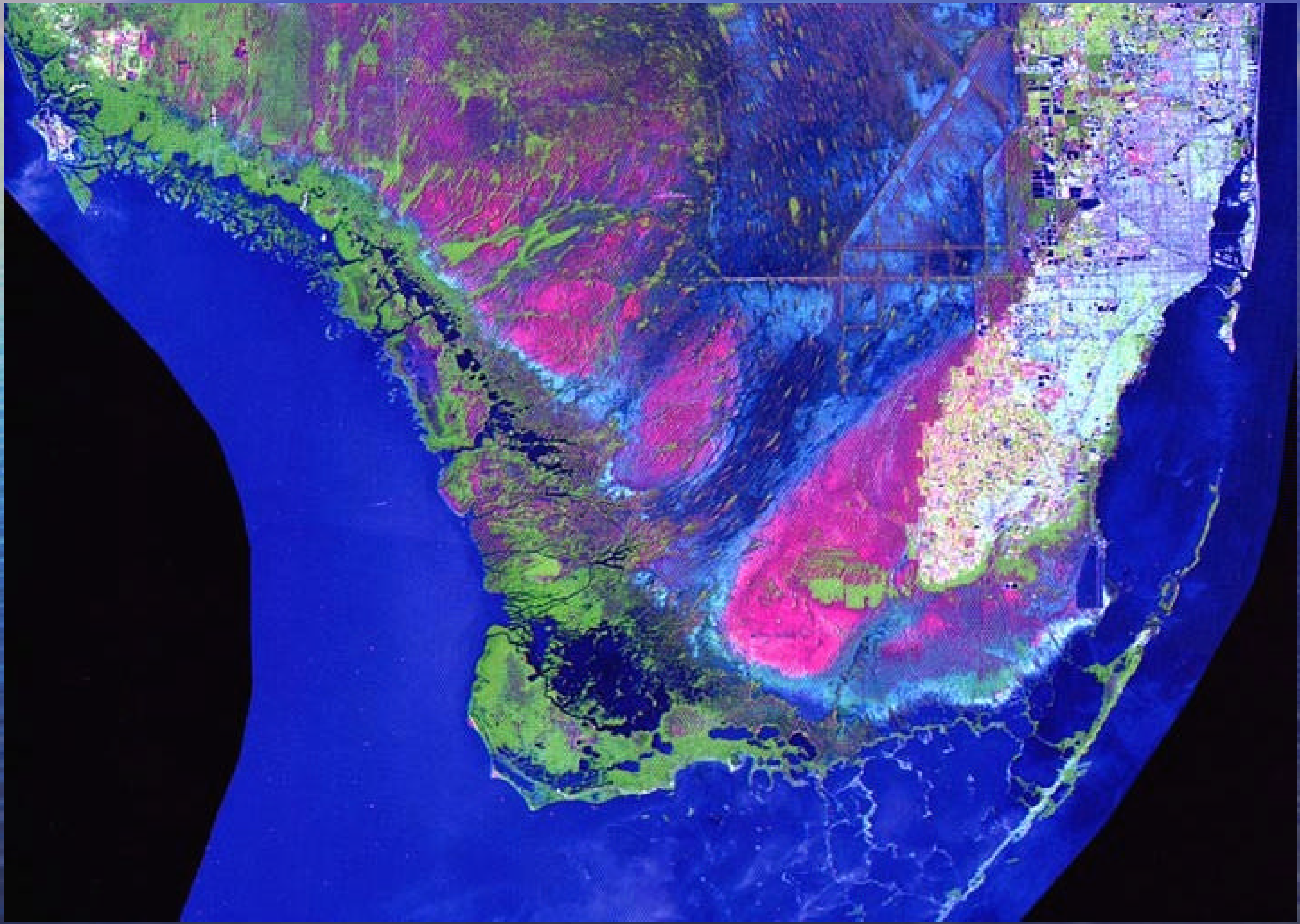


# Mangroves formed the coast to most of protected south Florida before human modifications

They formed a critical barrier between marine waters & freshwater marshes.

They provide a critical habitat for many organisms.

Lest the coastscape changes anticipated seem fanciful, consider the changes that have occurred over the past 70 years.



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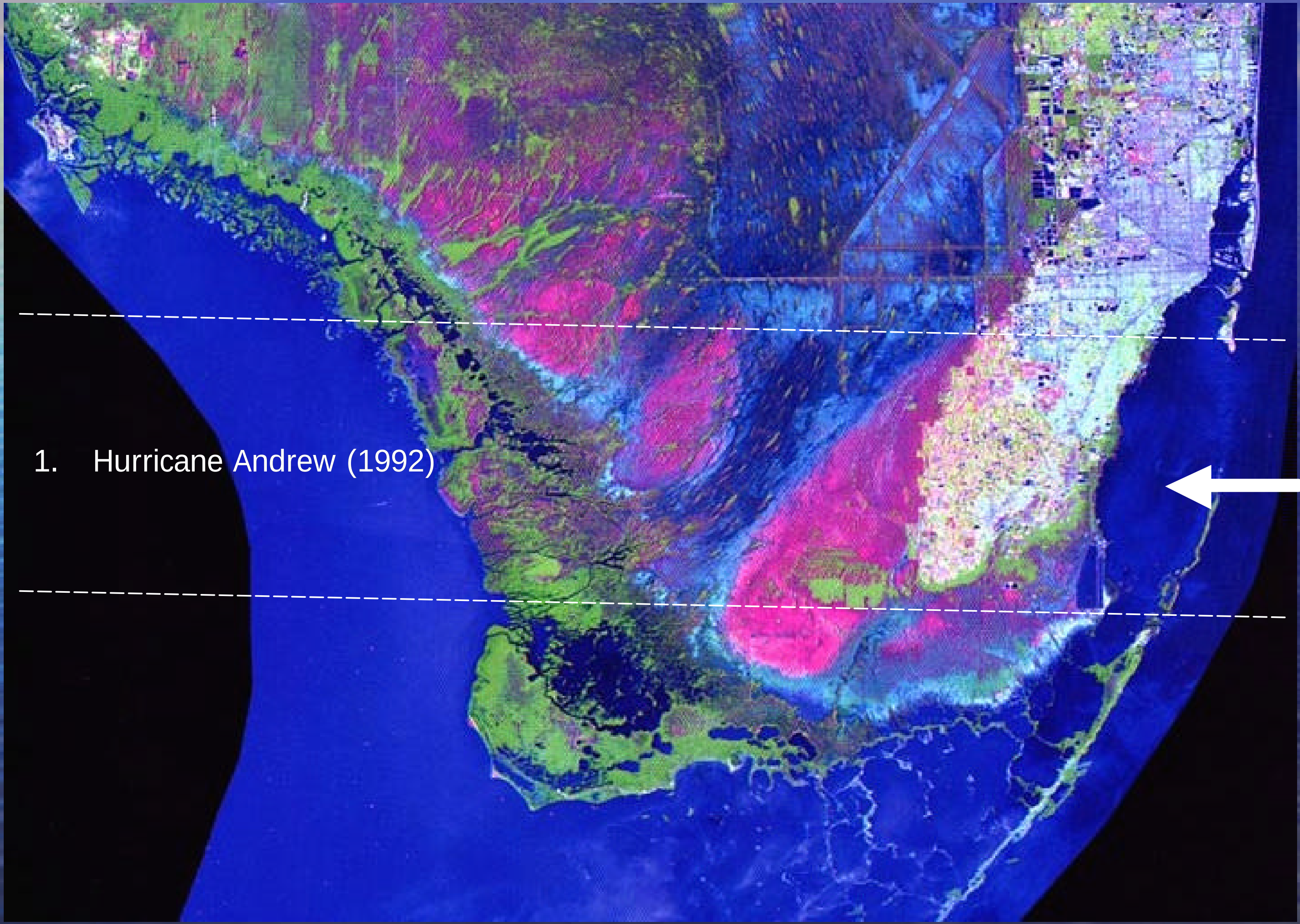


**In the big ones, this ... Becomes this.**

# Vast areas of mangrove swamp destroyed by the major hurricanes of 1935, 1960 and 1992 have evolved into shallow bays because –

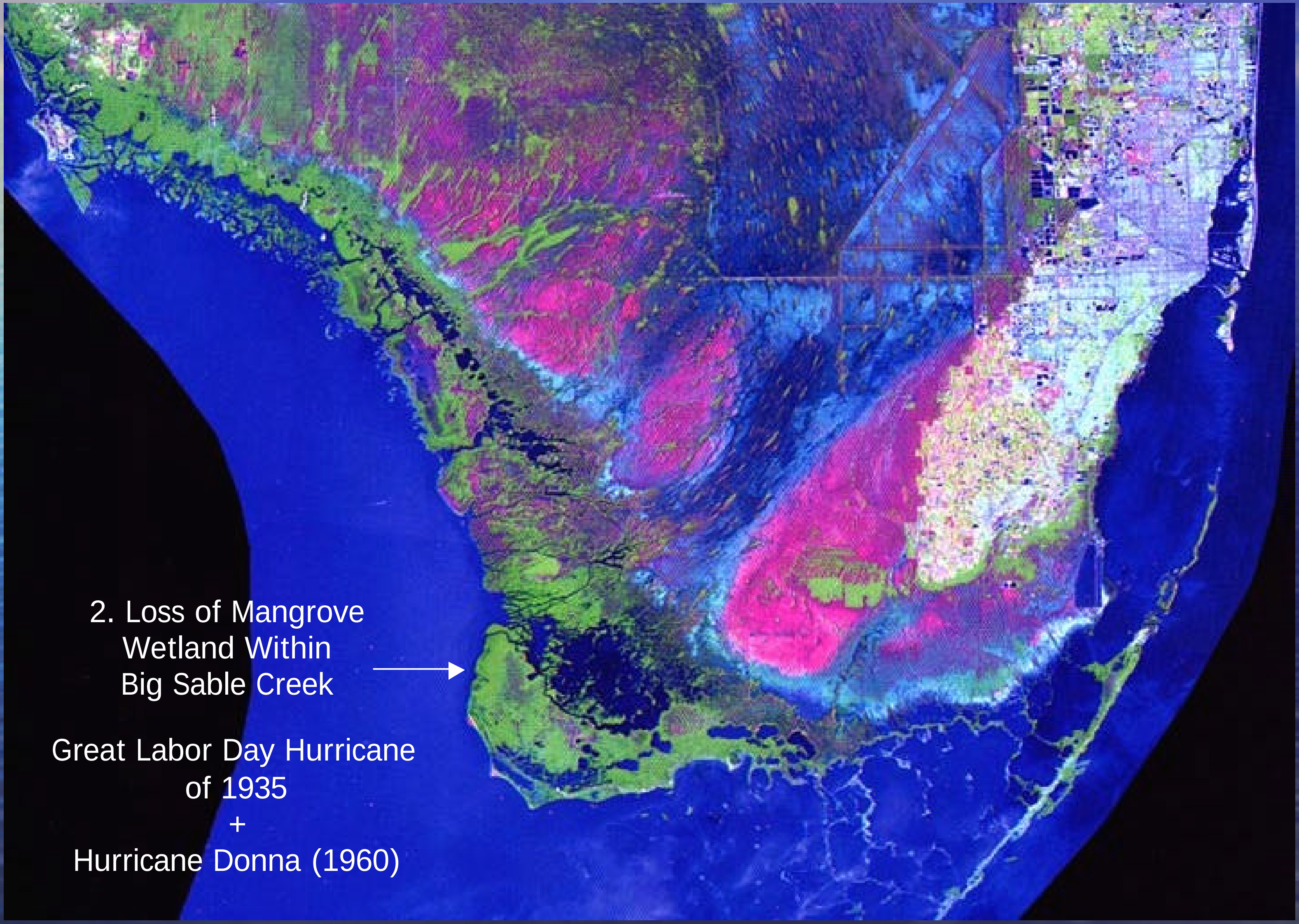
Biscayne Bay mainland shore, Hurricane Andrew

Arsenicker Keys, Hurricane Andrew

– the rapid subsidence of the root peat prevents recovery as a mangrove community.

Highland Beach and mangroves, Hurricane Andrew

# Lest the coastscape changes anticipated seem fanciful, consider the changes that have occurred over the past 70 years.



# Big Sable Creek

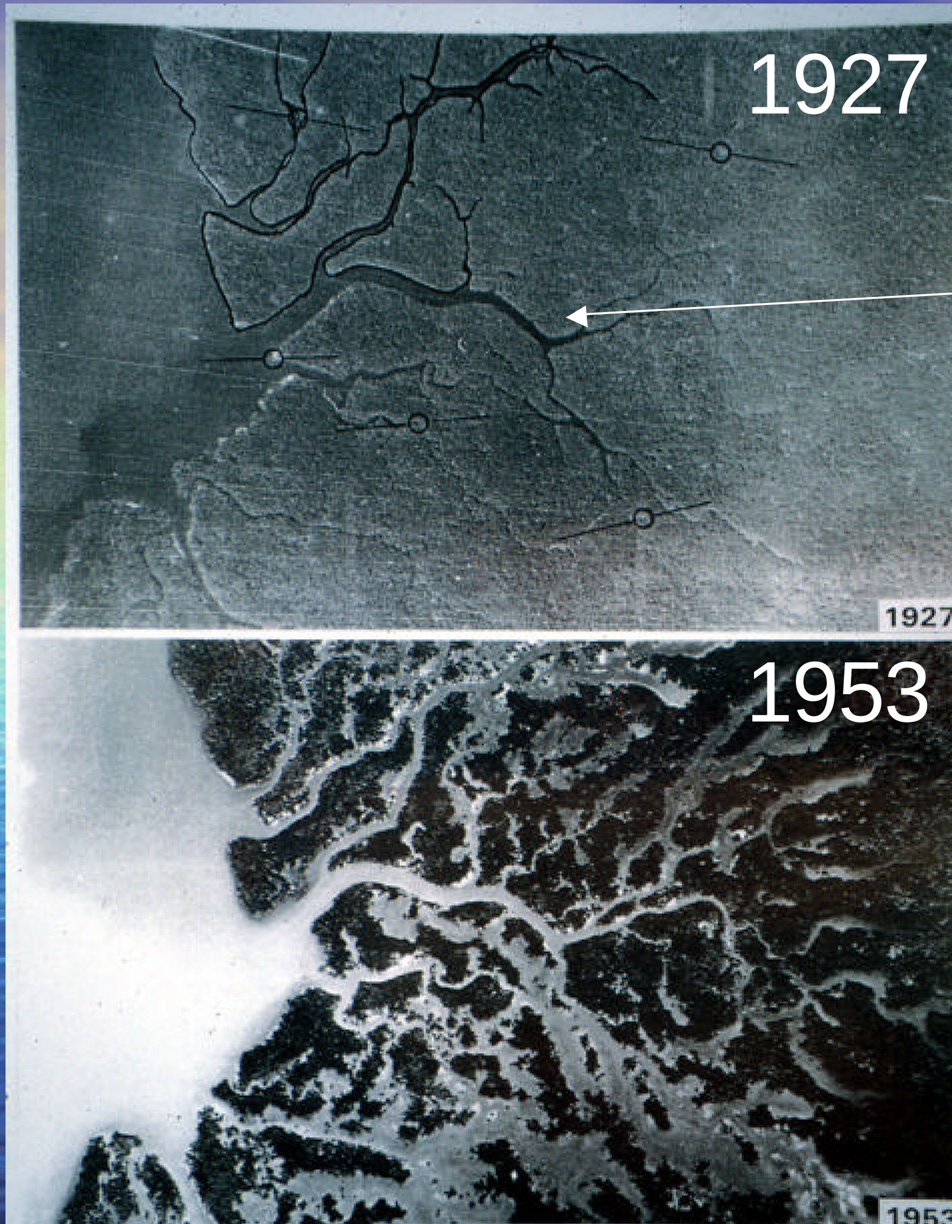



Figure 3-5. Sequential aerial photographs showing the impact of the Great Labor Day Hurricane of 1935 on Big Sable Creek and minimal recovery in the subsequent 18 years. The area was mature black mangrove forest with narrow tidal creeks prior to the storm. See Figures 3-6 to 3-10 for sequential maps.


The Great Labor Day Hurricane of 1935 decimated the mature mangrove forest of Big Sable Creek.


1935
1960


Big Sable Creek A45
N
1927 ➡ 1992
1 kilometer

1962

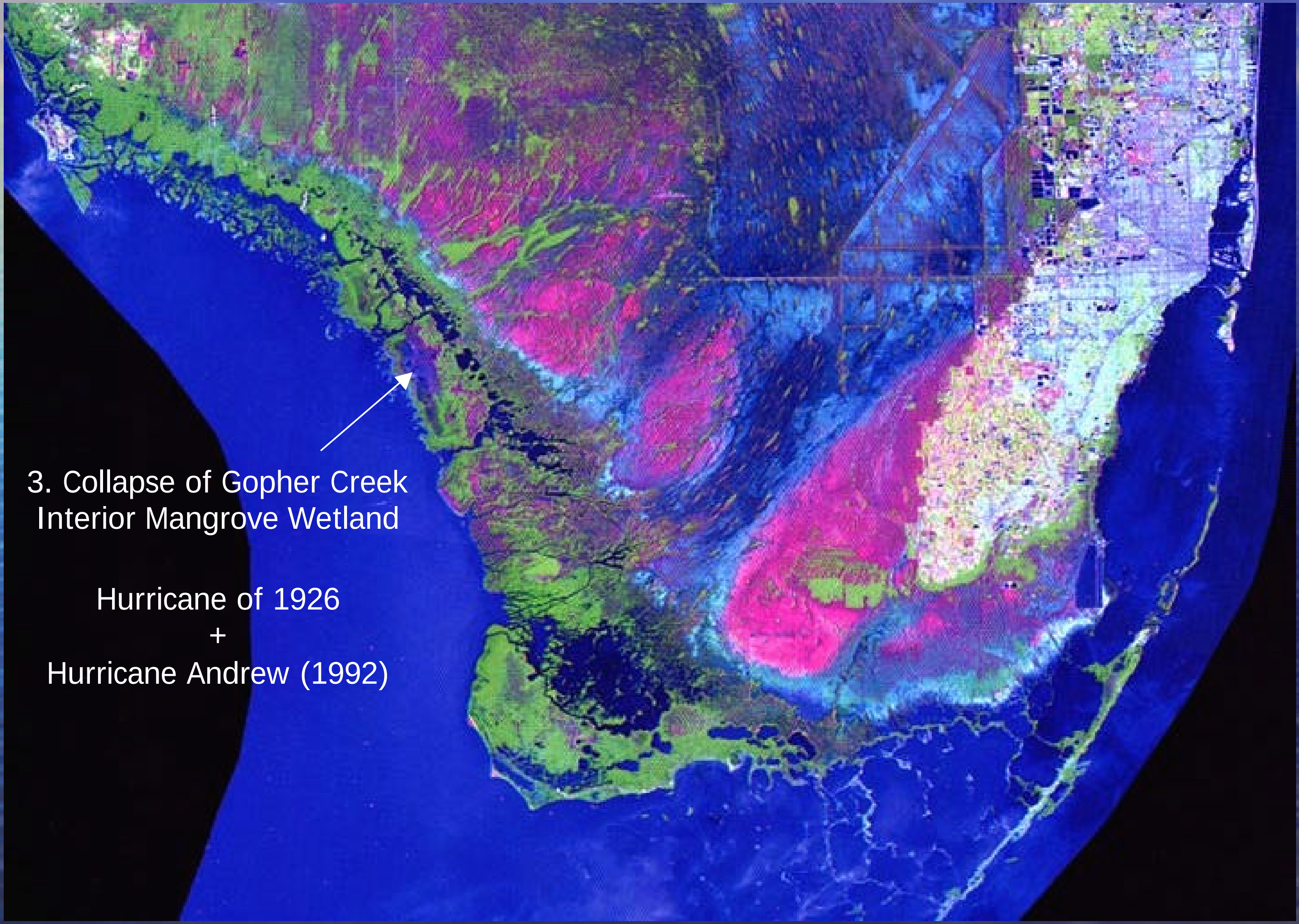
1981

Dead peat surface is now about 3’ (1 m) lower than living mangrove surface.

Oysters on subsiding peat

Now in the lower intertidal, excavating burrowers are accelerating the deepening process.

# Lest the coastscape changes anticipated seem fanciful, consider the changes that have occurred over the past 70 years.



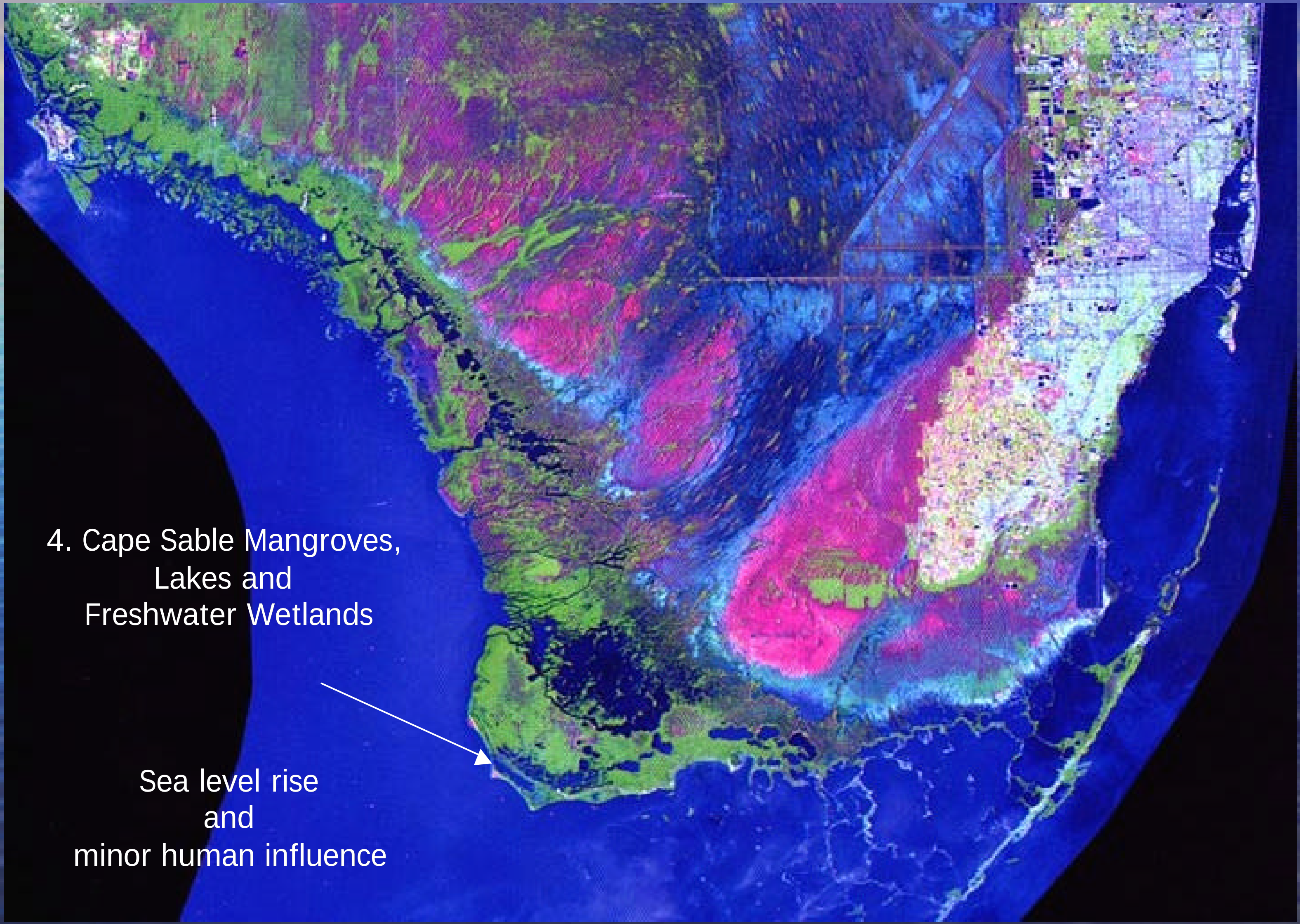
Gopher Creek
Interior Wetland
1996

Hurricane of
1926

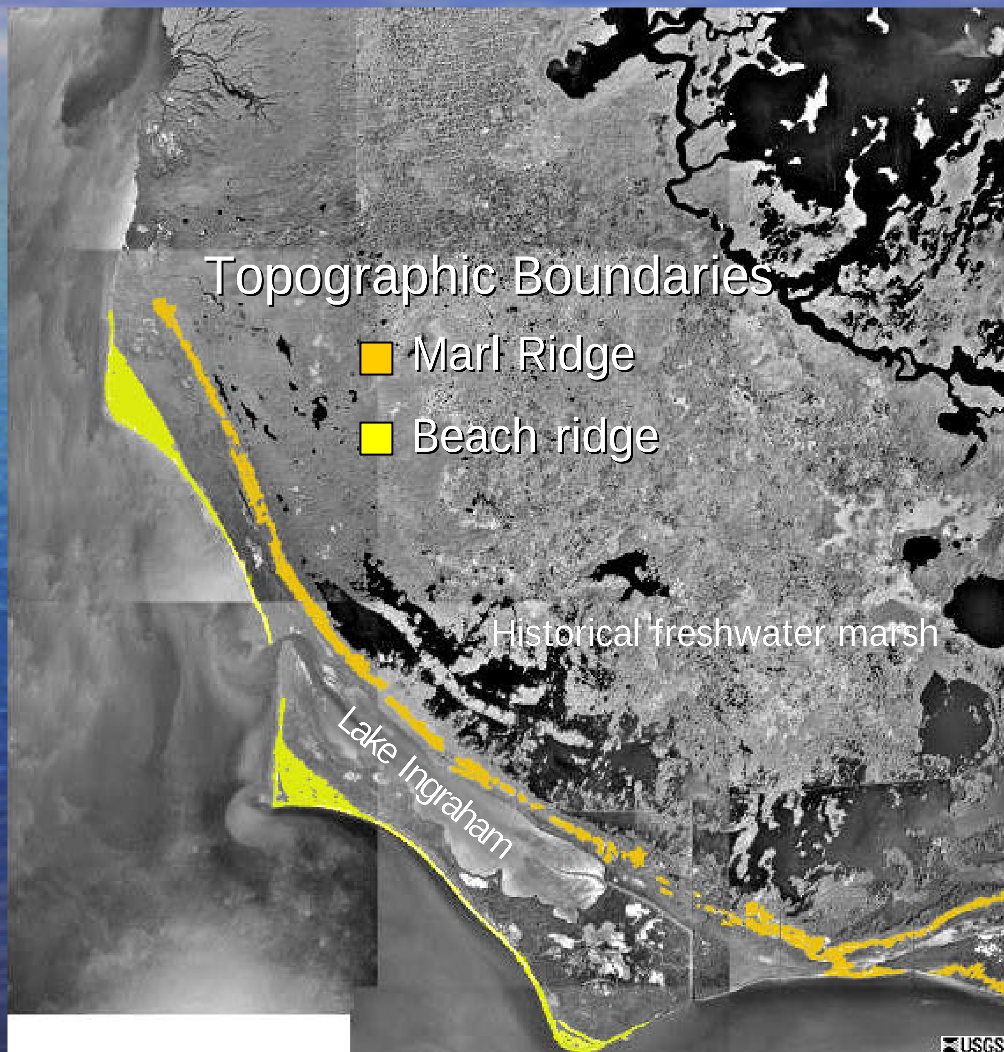
+

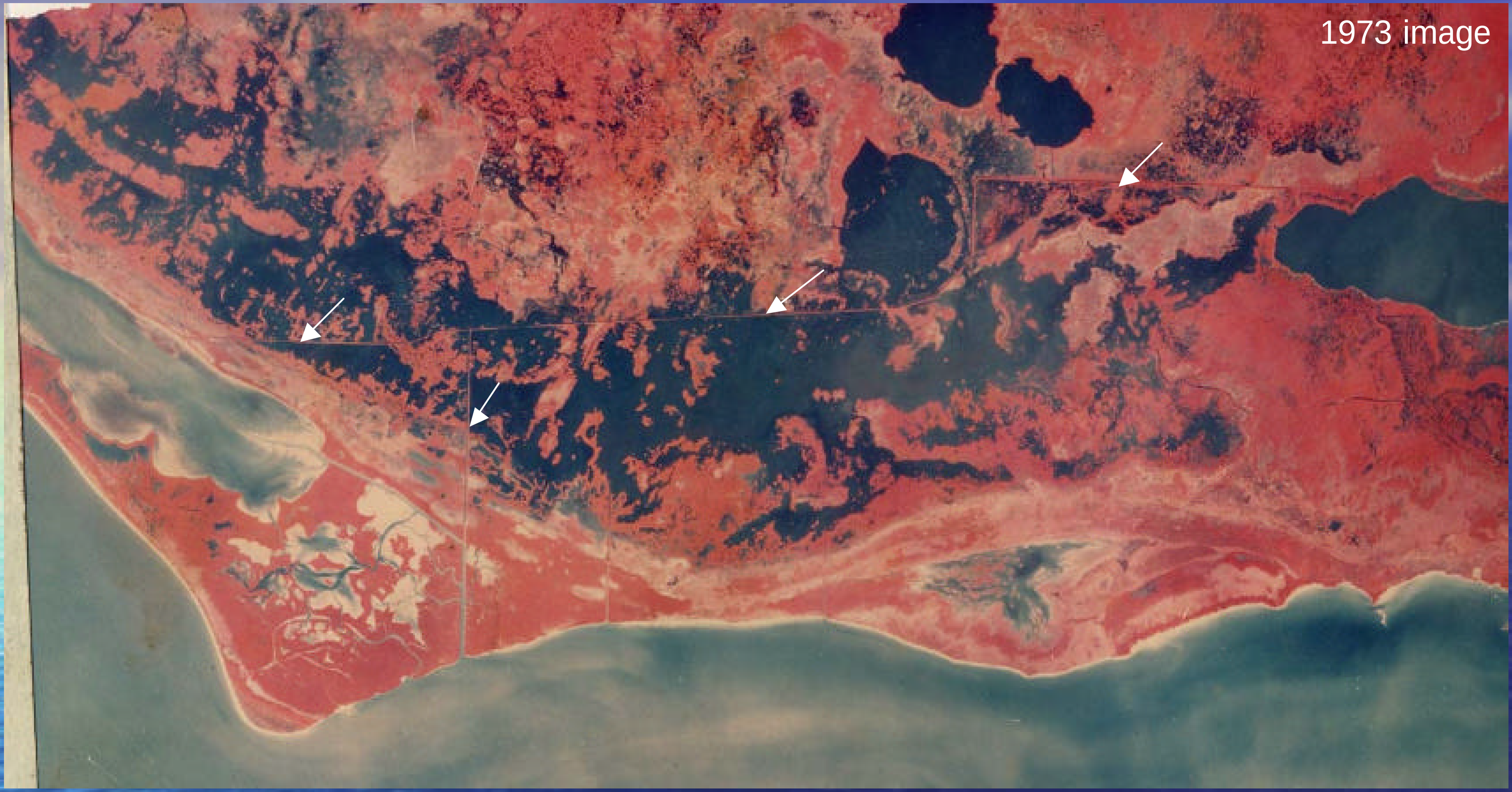
Hurricane
Andrew (1992)

# Lest the coastscape changes anticipated seem fanciful, consider the changes that have occurred over the past 70 years.



# Topographic ridges of sand and marl separated both Lake Ingraham and the landward historical freshwater wetlands from marine waters.

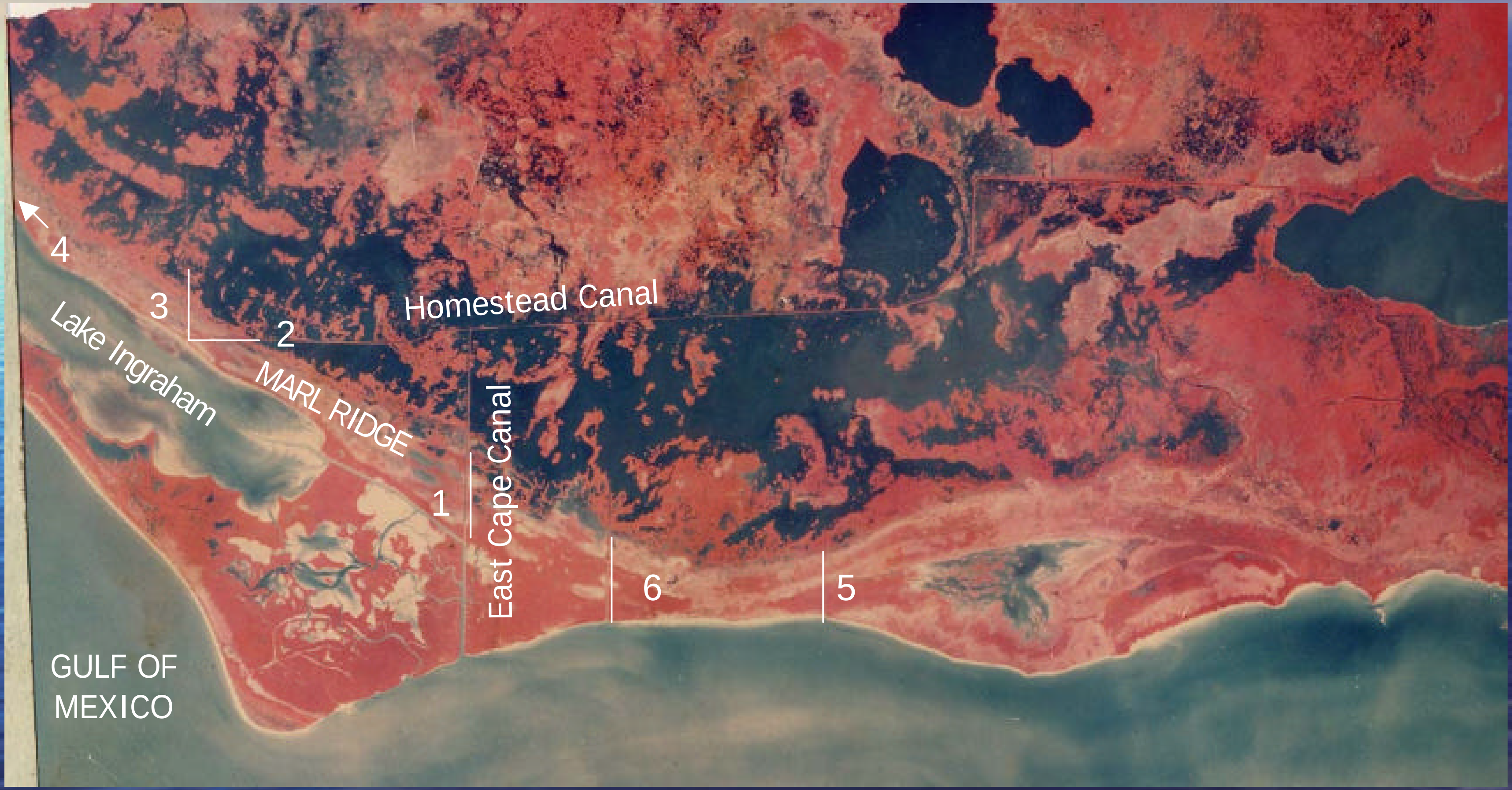





Narrow canals were dredged across the (then) freshwater wetland of Cape Sable in the 1920s in an effort to drain the wetland.

Four canals cut across a low marl ridge connecting the Cape Sable interior with Lake Ingraham.

Two others cut south across the marl ridge to the Gulf,

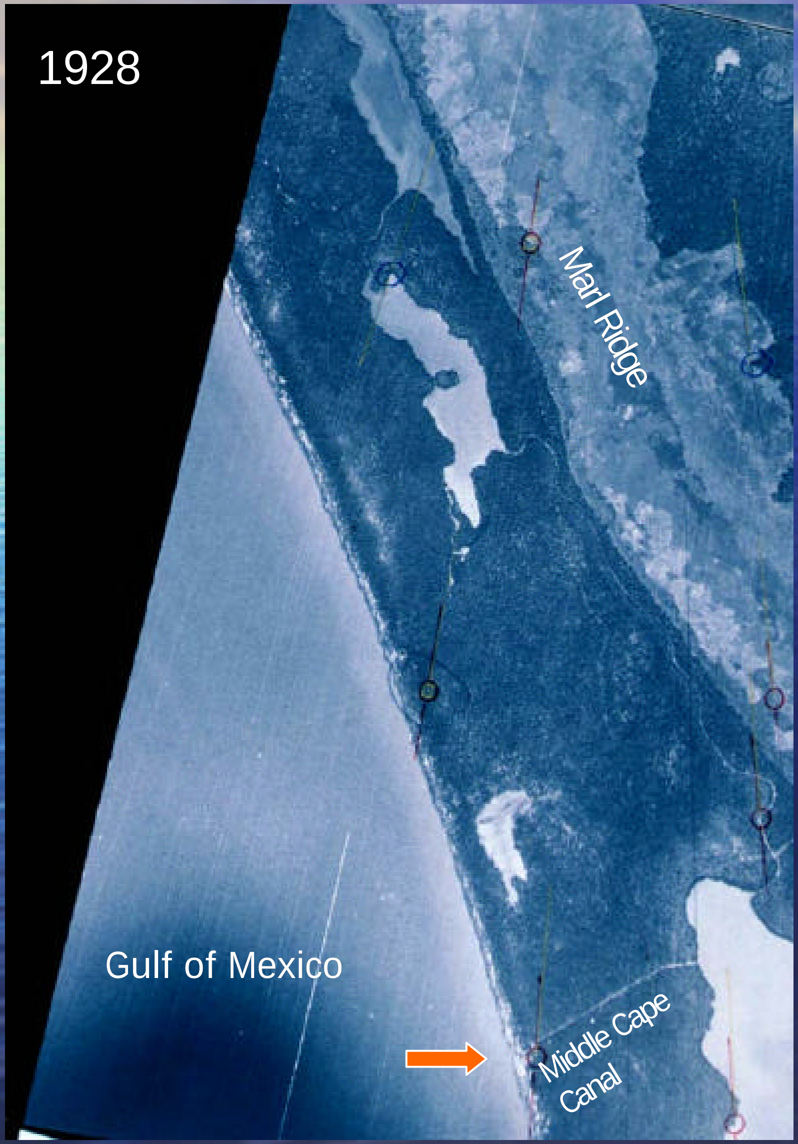


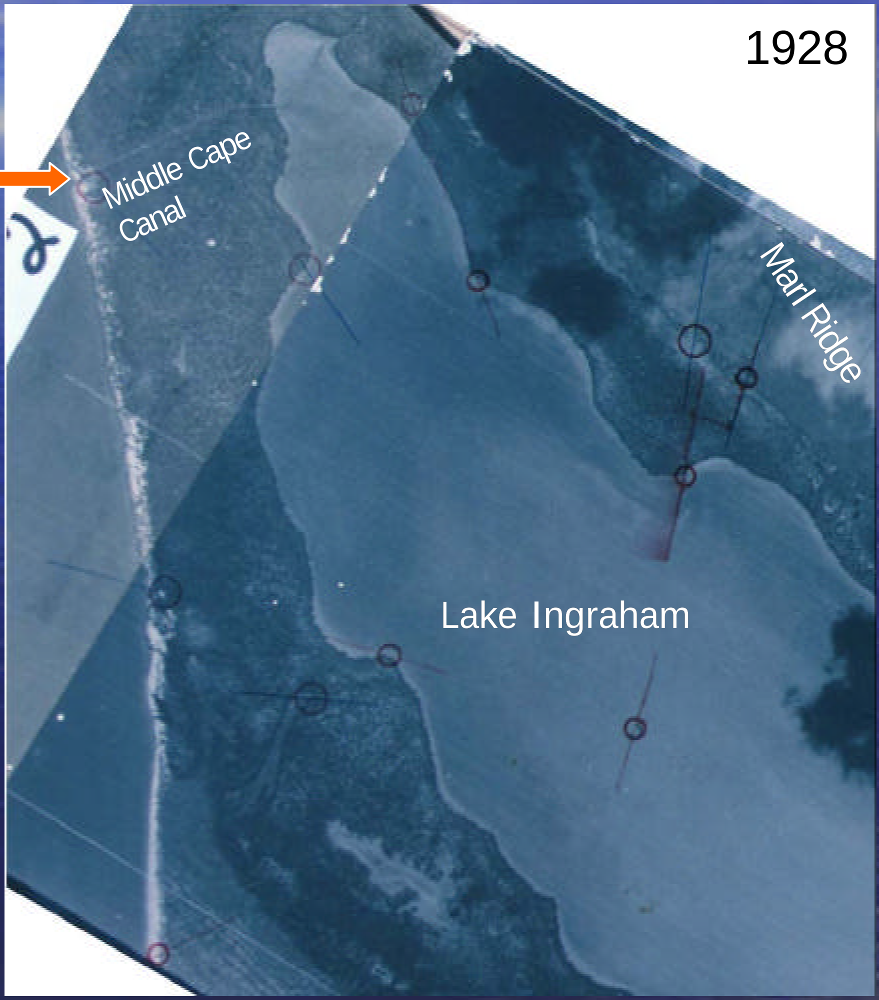

and two canals connected Lake Ingraham to the Gulf

# Middle Cape Canal at the north end of Lake Ingraham was dredged only 18 feet wide.

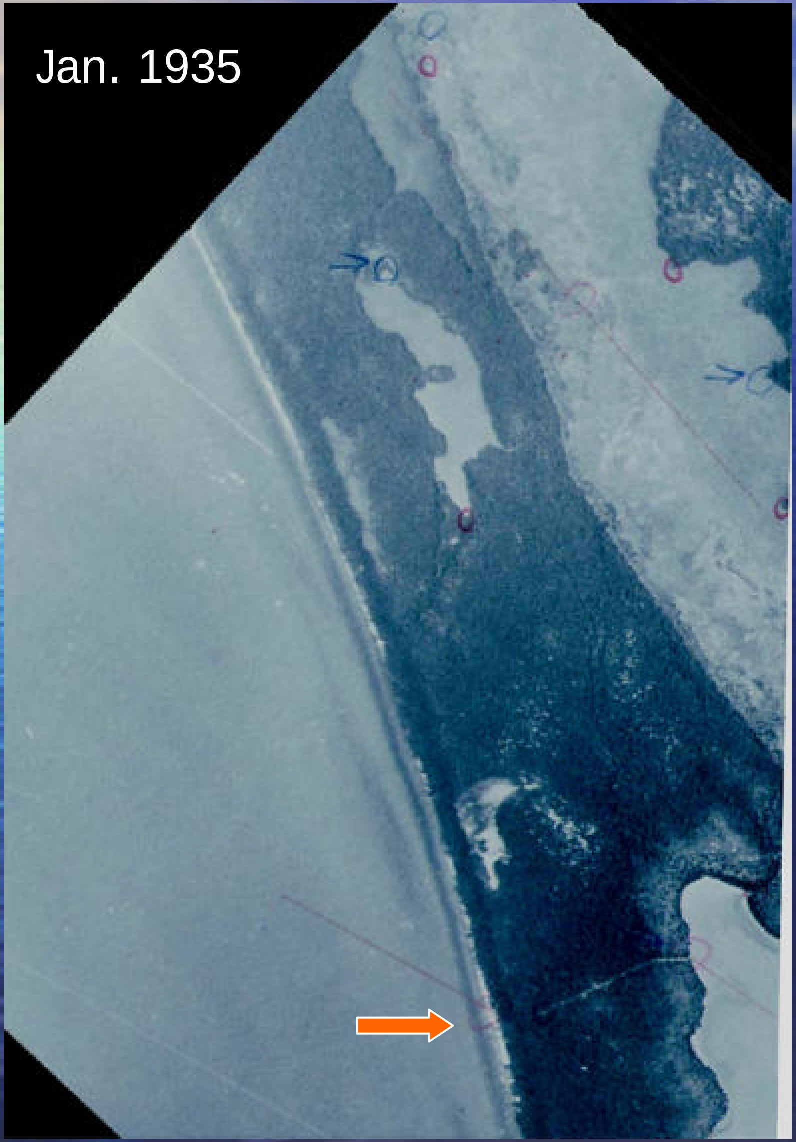
**Connection to north end of Lake Ingraham:**

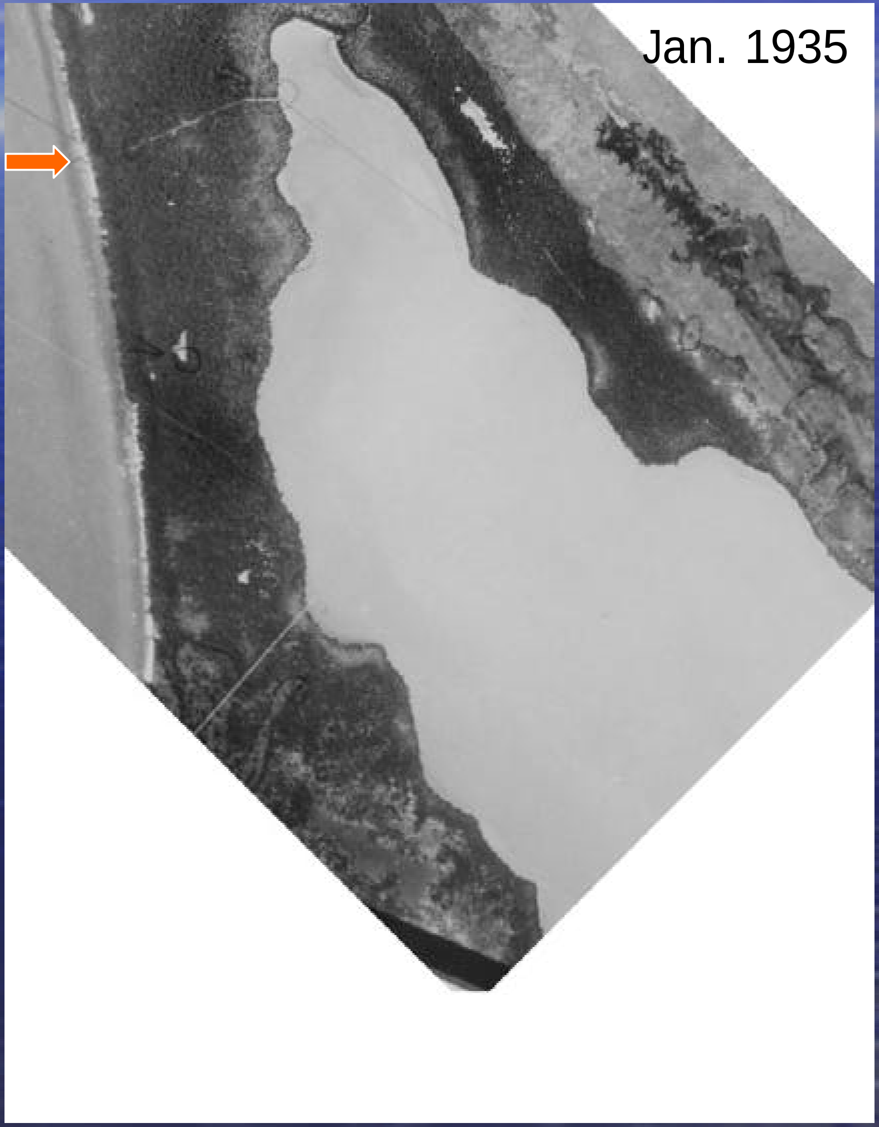
# Two aerial views of Middle Cape Canal in 1928



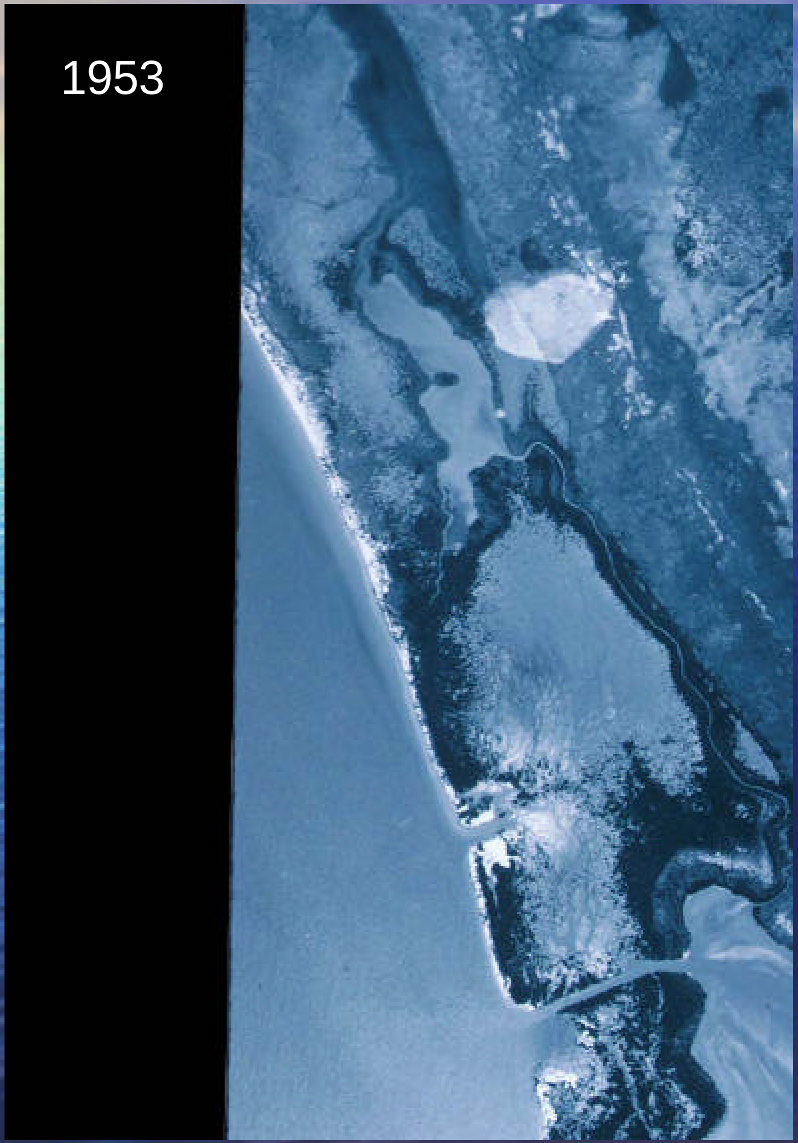



January 1935 – Slight shore erosion. Middle Cape Canal unchanged, the mouth probably blocked by shore sand. The Great Labor Day Hurricane occurred in September, 1935.

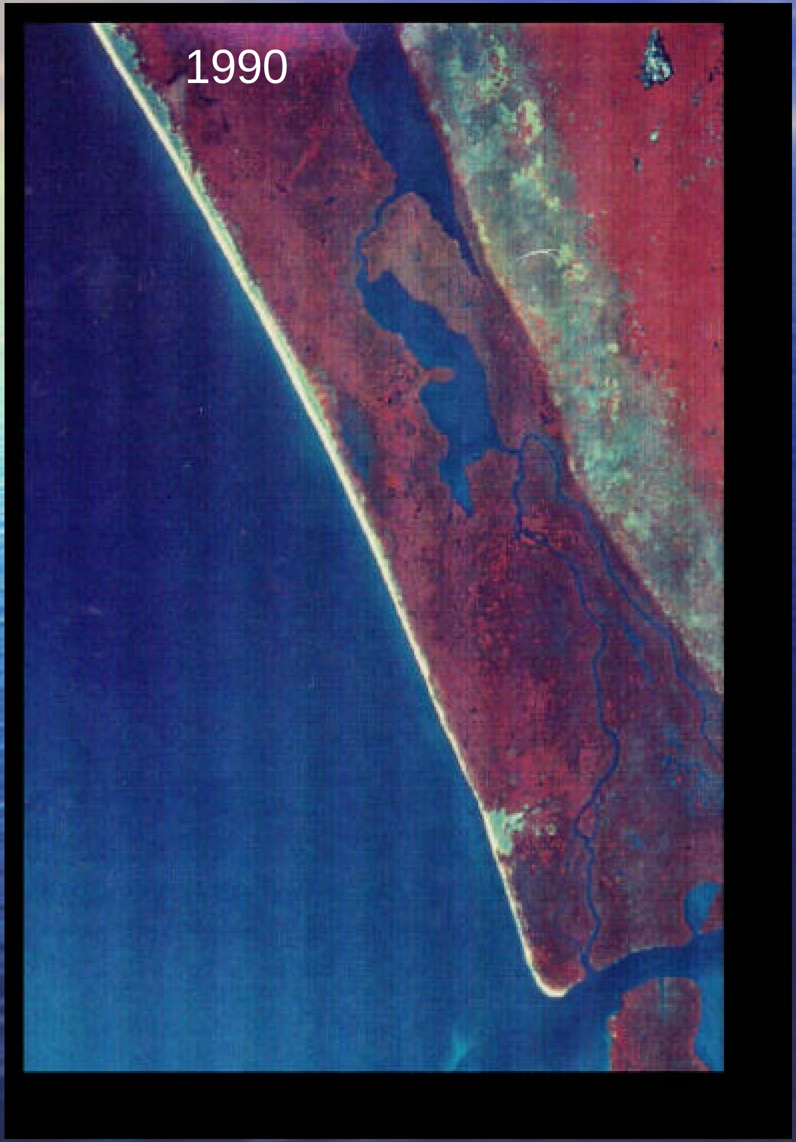


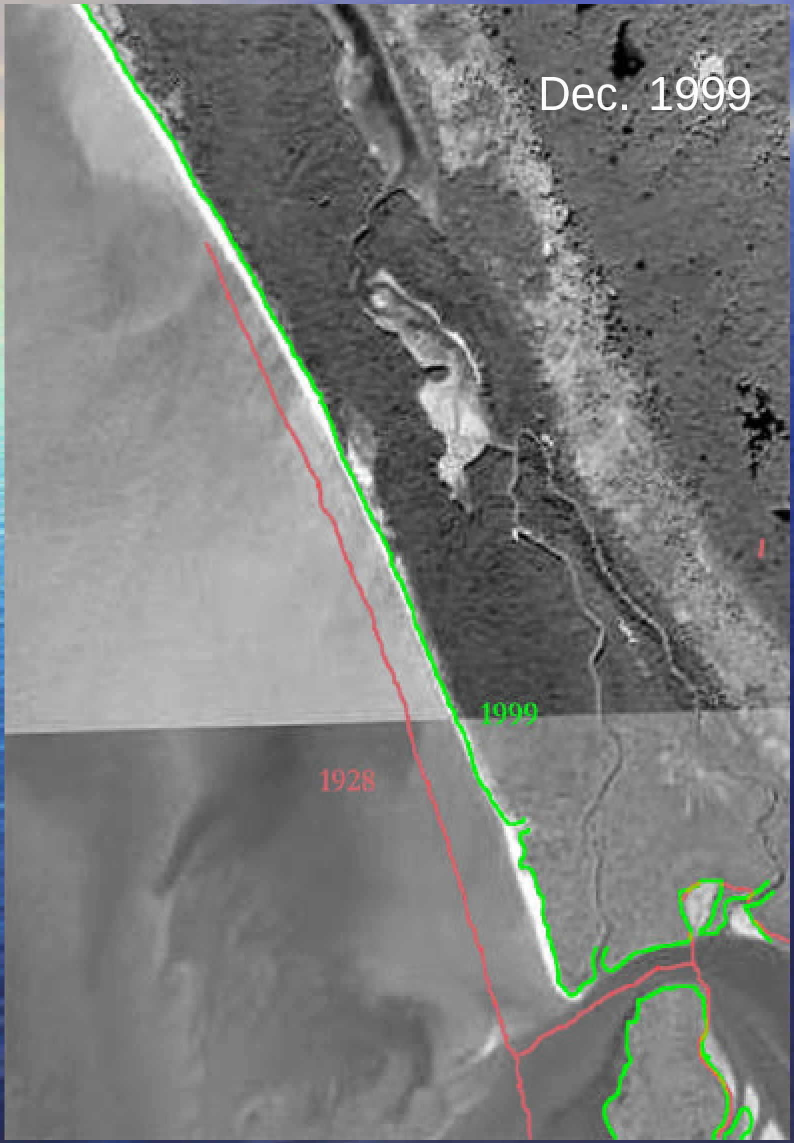
1953 – Hurricane of 1935 destroyed coastal wetland, eroded shore, and swept sand from Canal mouth initiating progressive enlargement by currents from tidal flow and winter storms.

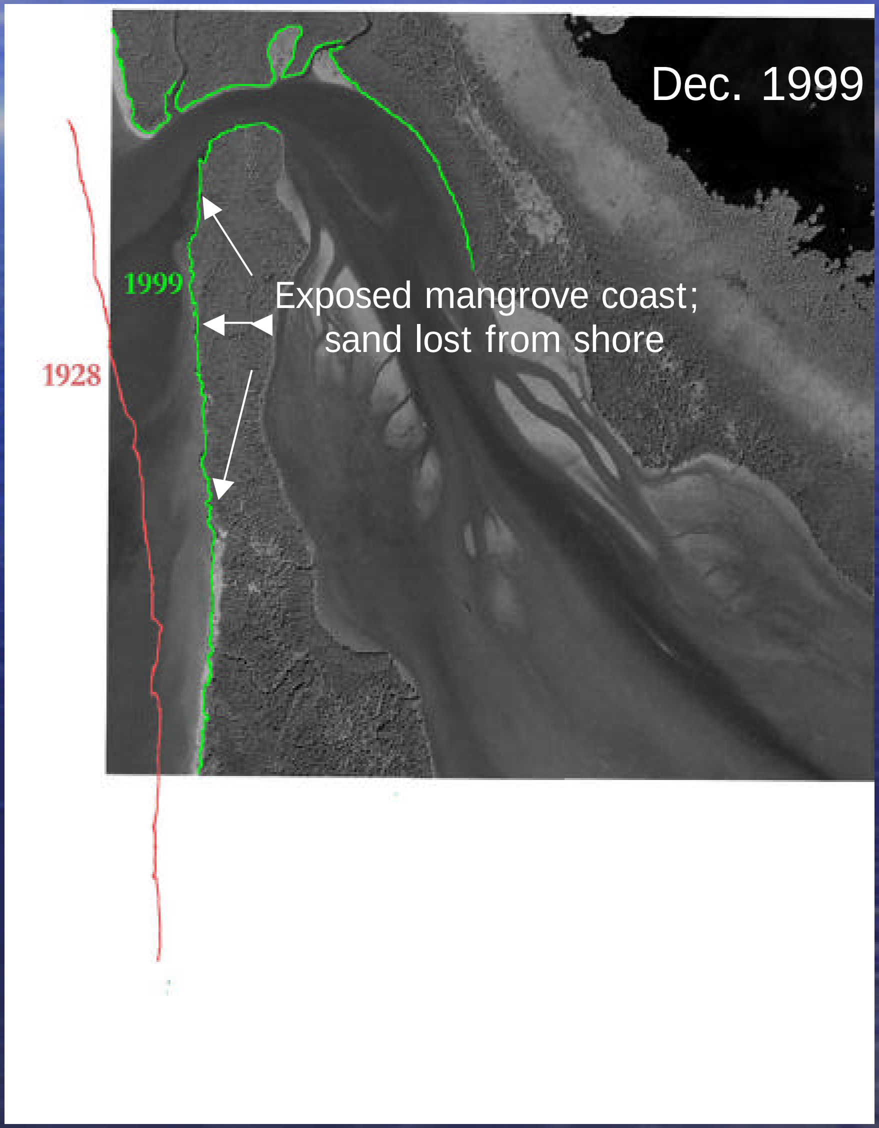



# 1990 – Continued shore erosion and widening of Middle Cape Canal. Well-formed channel appears off north side of inlet.

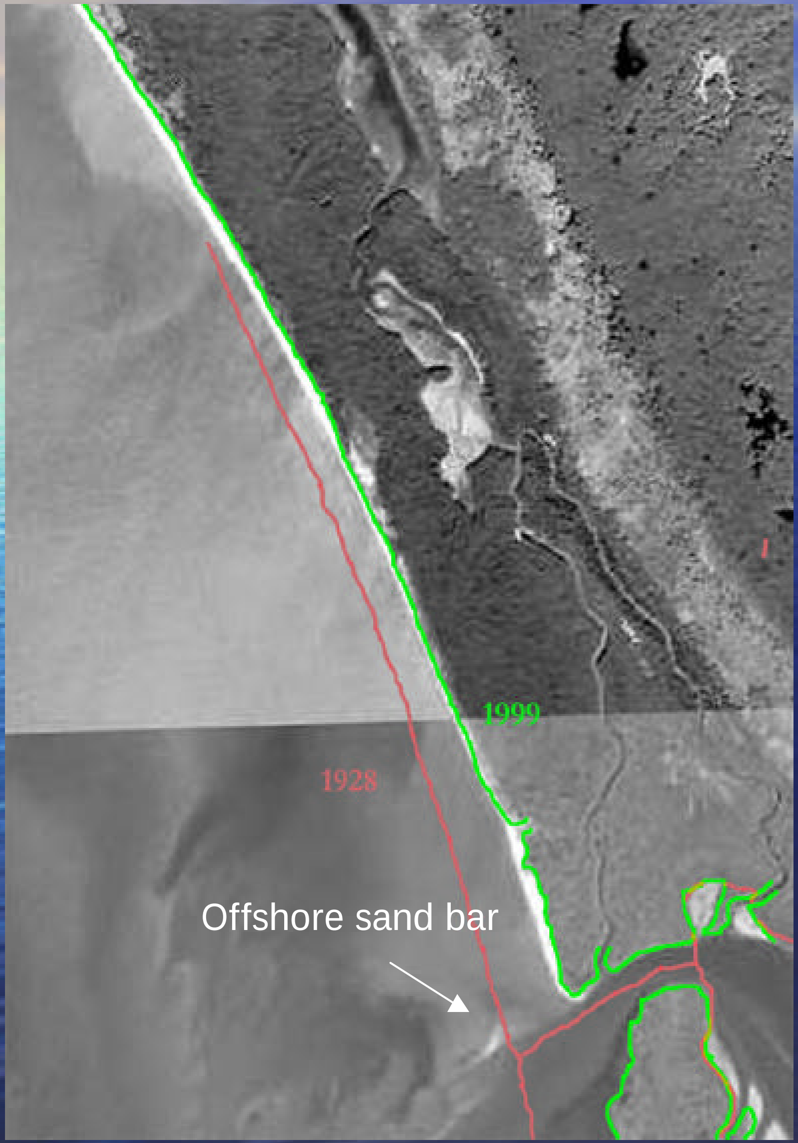


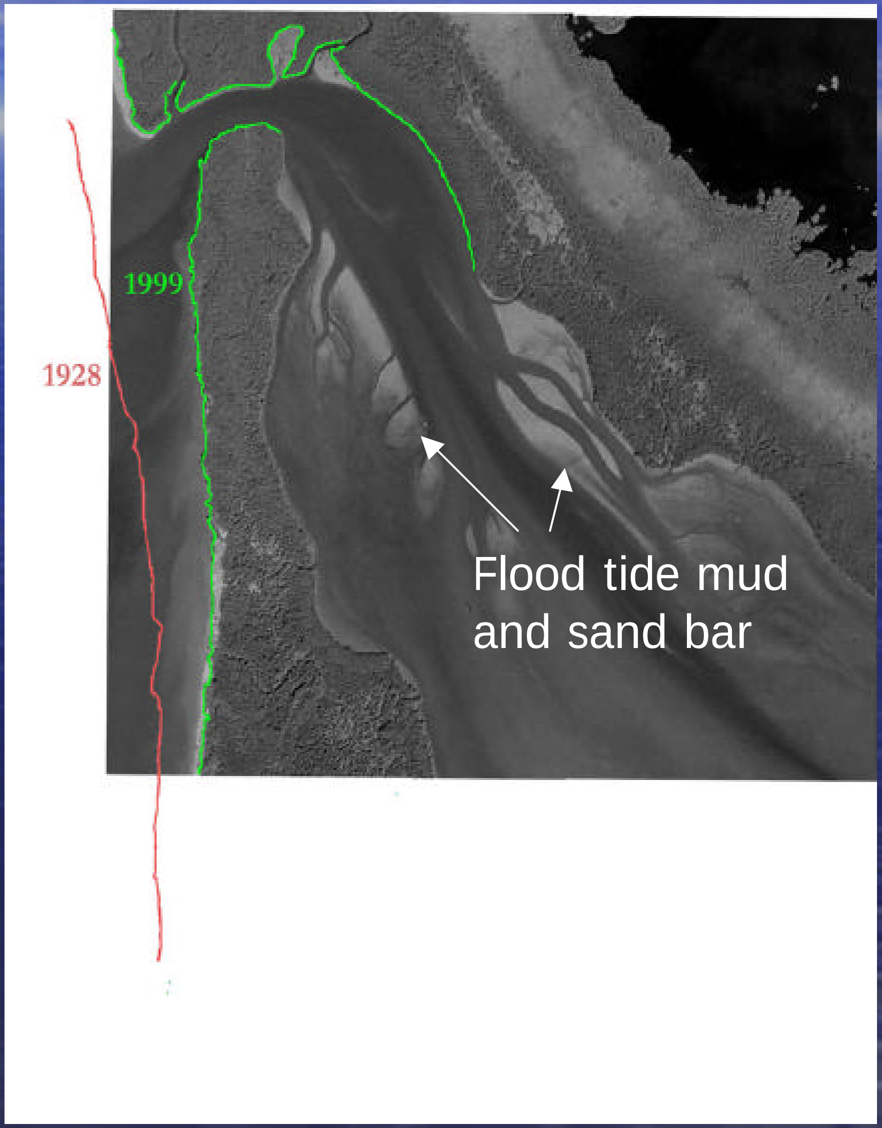

# 1999 – Continued shore erosion and widening of canal and side channels. Over 1000’ shore erosion since 1928. Loss of all sand at shore south of inlet.



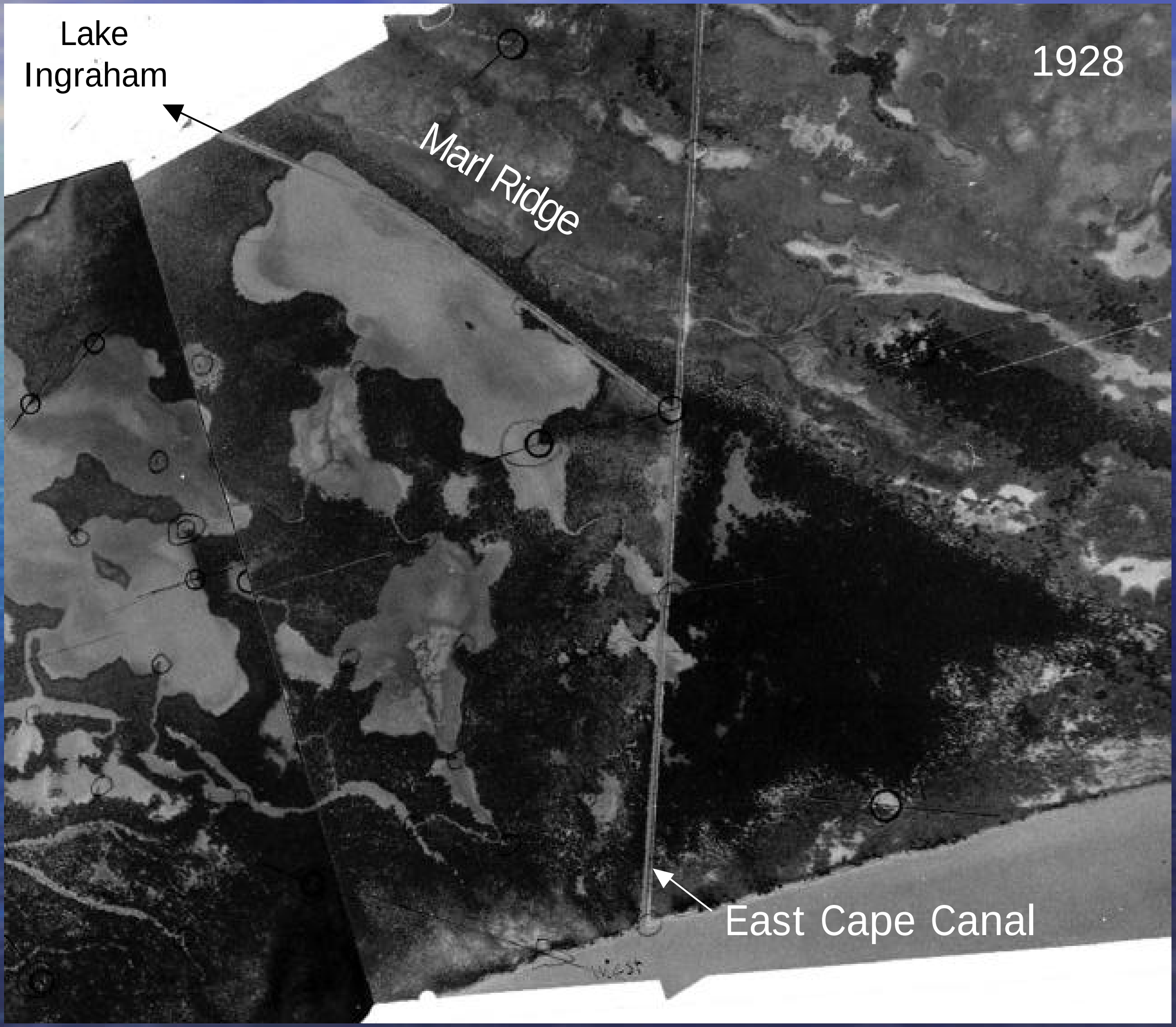



# Shore erosion decreases north and south from Middle Cape Canal. The Canal is causing accelerated shore erosion by washing sand into the inlet and forming it into a bar offshore



East Cape Canal has a similar history, except that there was never significant beach sand at the shore. As a result, the channel began widening immediately following construction.



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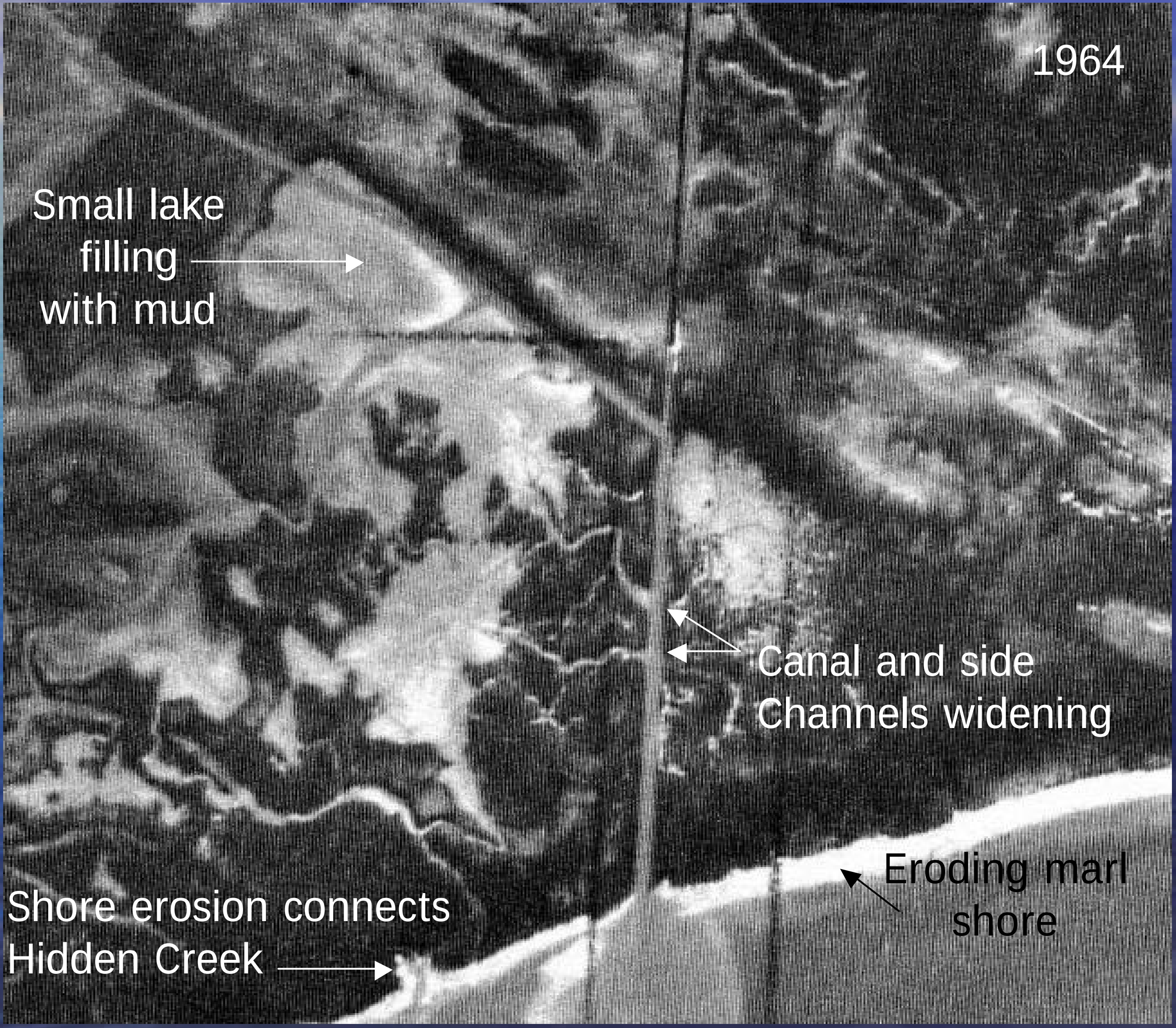

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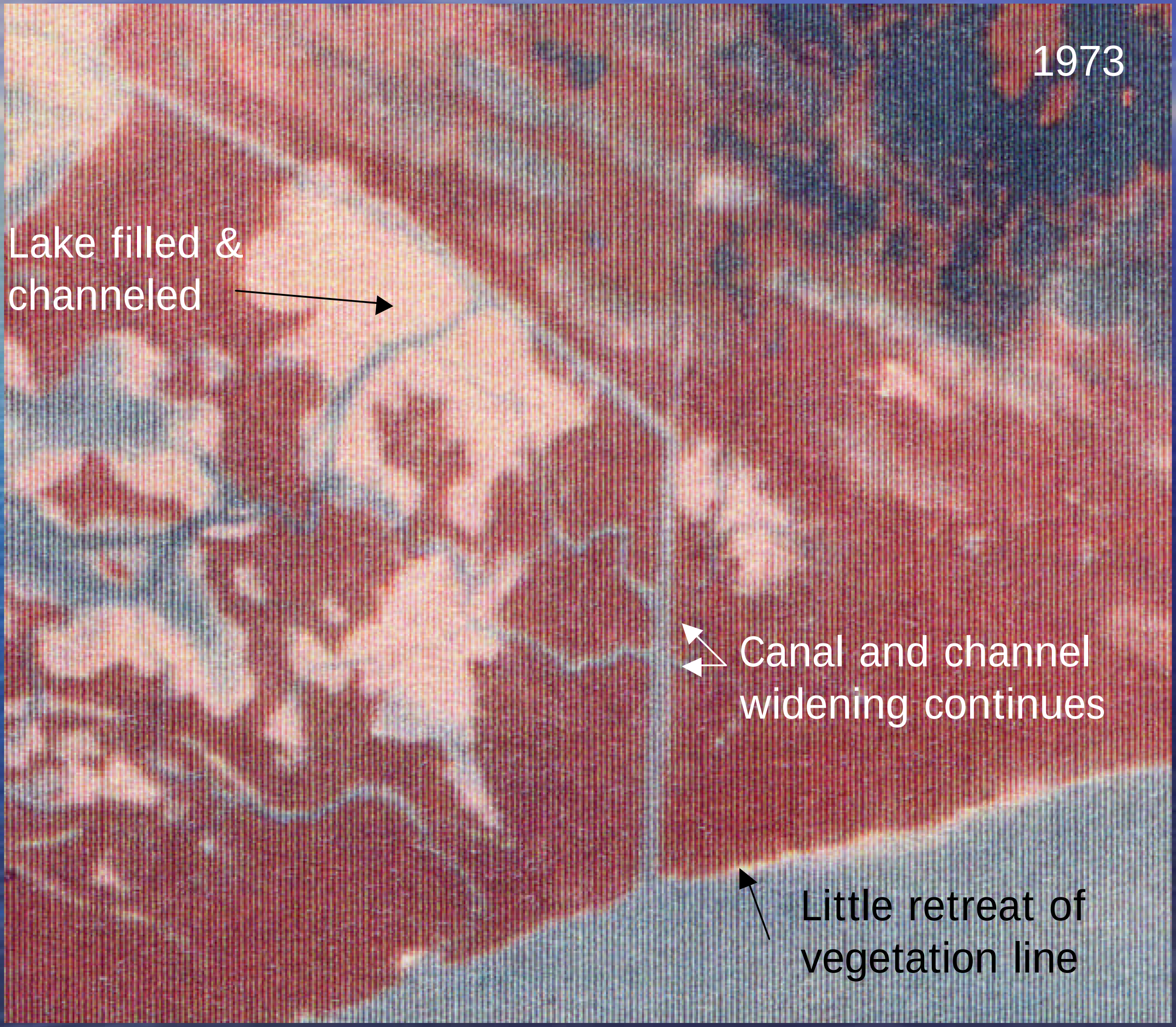
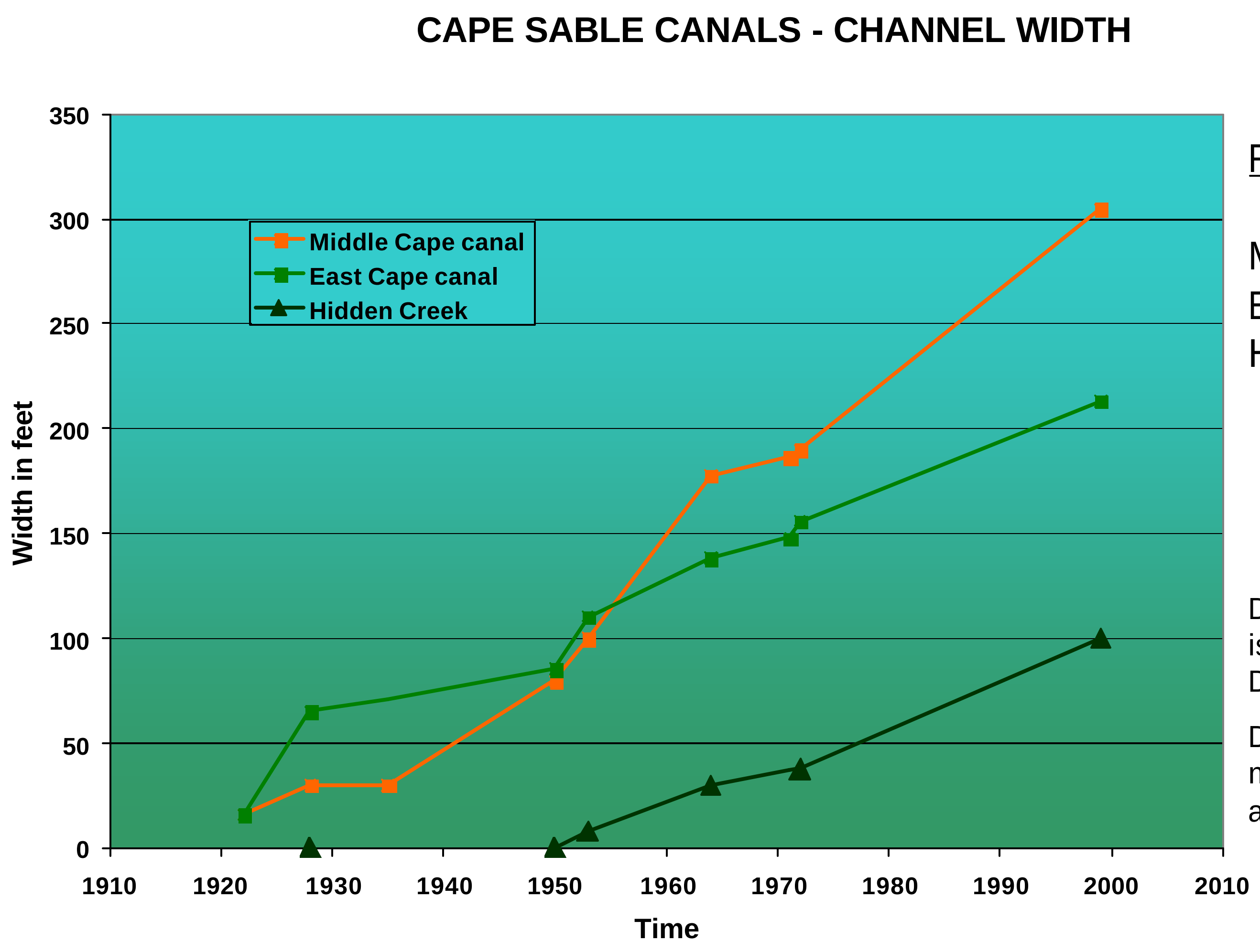


East Cape Canal has a similar history, except that there was never significant beach sand at the shore. As a result, the channel began widening immediately following construction.

# The rate of erosional widening of Canal's margins has been essentially linear since construction (East Cape) or 1935 opening (Middle Cape).



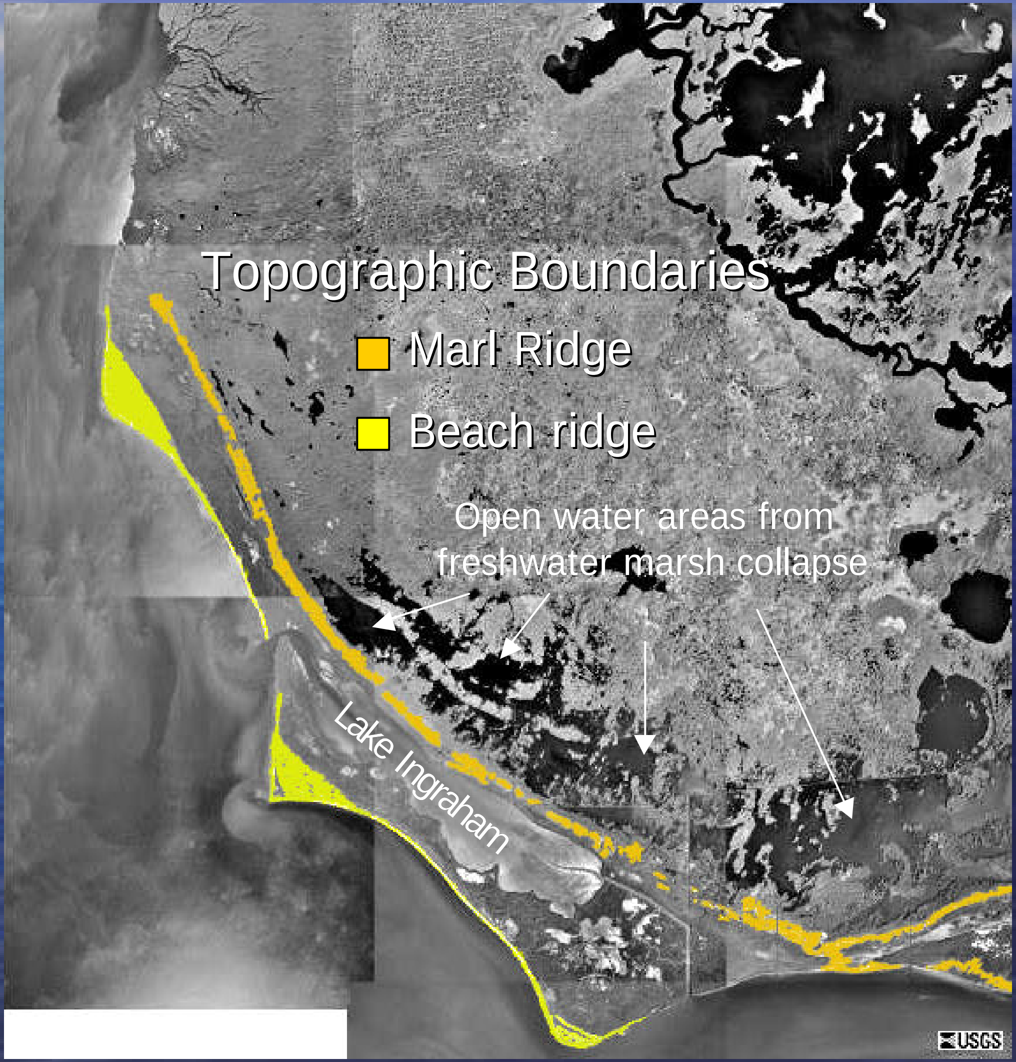

<u>Rate of widening</u>

Middle = 4'/yr
East = 2'/yr
Hidden = 2'/yr

Data for 1922- 1972 is from:
Davis, G.E., 1972.

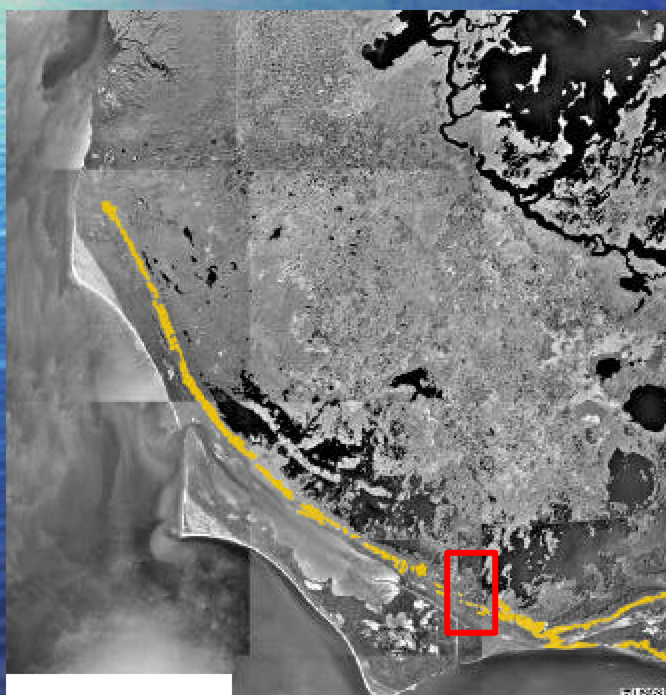
Data for 1999 is measured from aerial photograph.

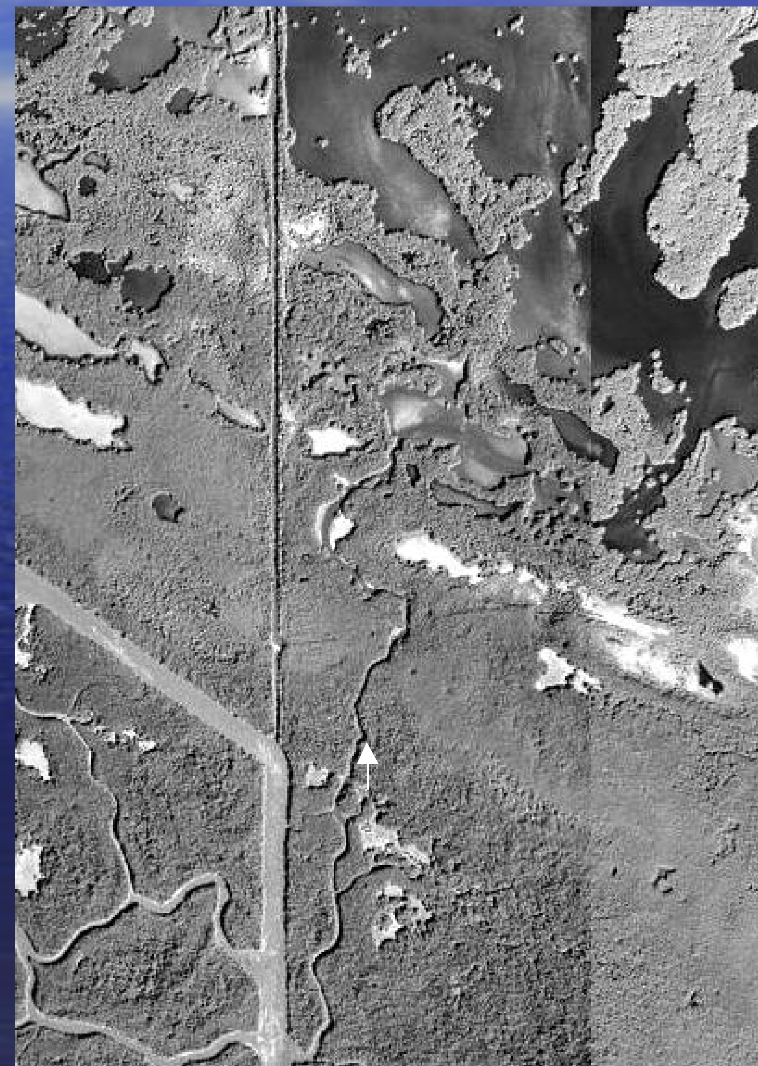
# With rising sea level, the Marl Ridge is being inundated and the landward freshwater marsh is collapsing.



# Four marl ridge sites are presently being inundated -

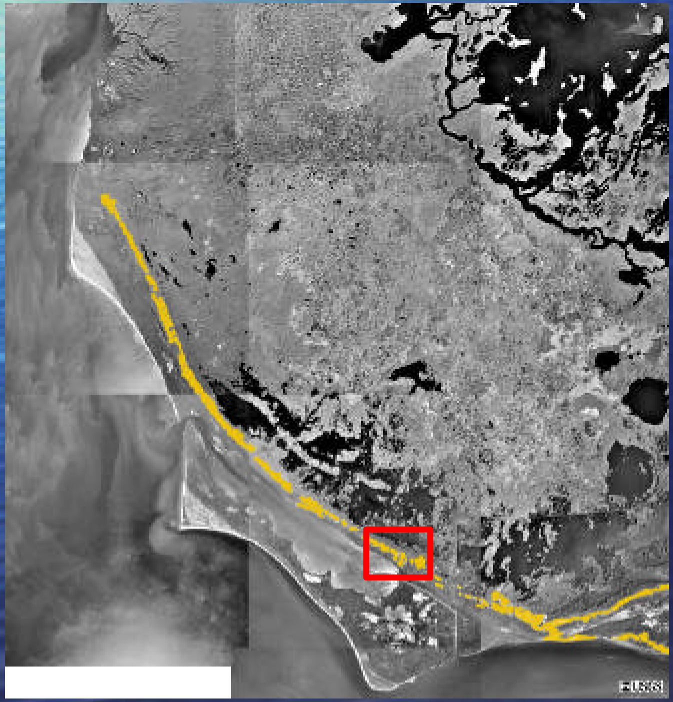
1. 'East Side Channel' has cut through the marl ridge just east of East Cape Canal.

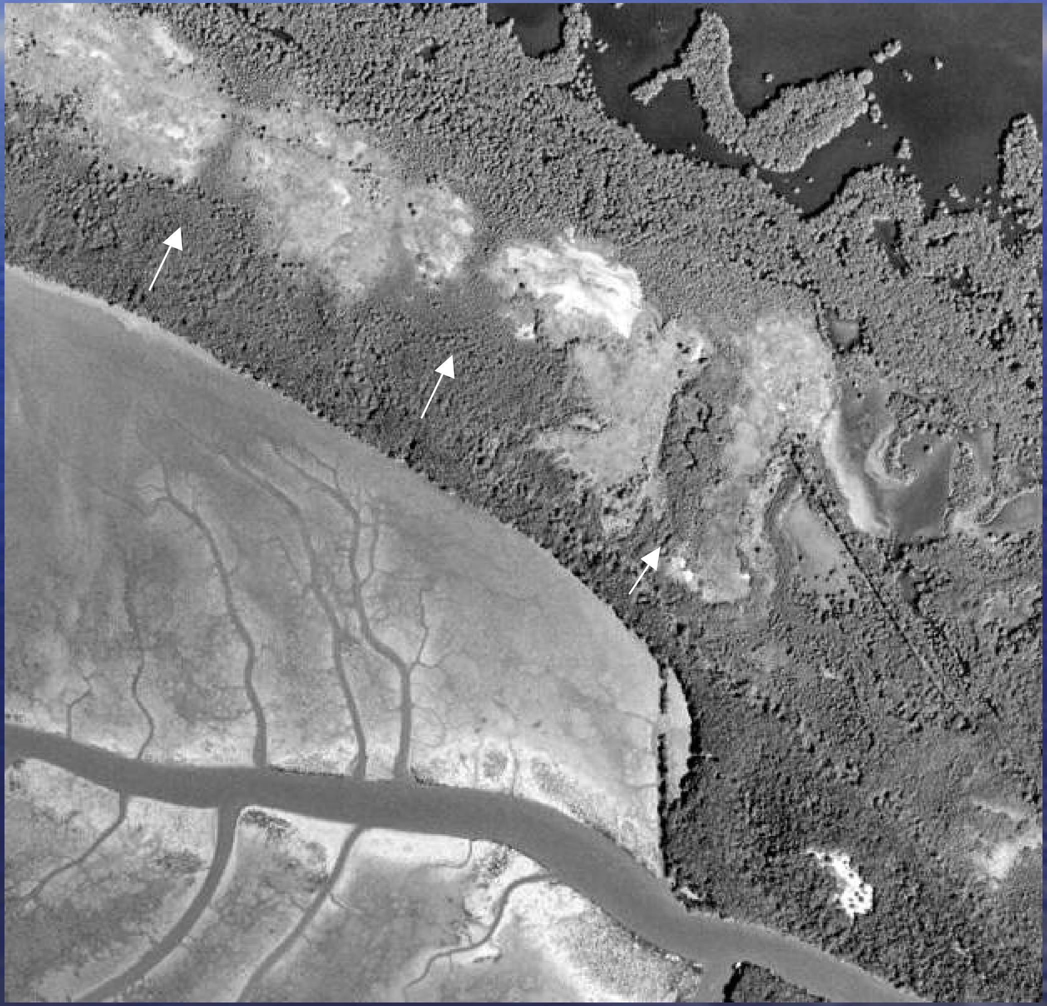




# Four marl ridge sites are presently being inundated -

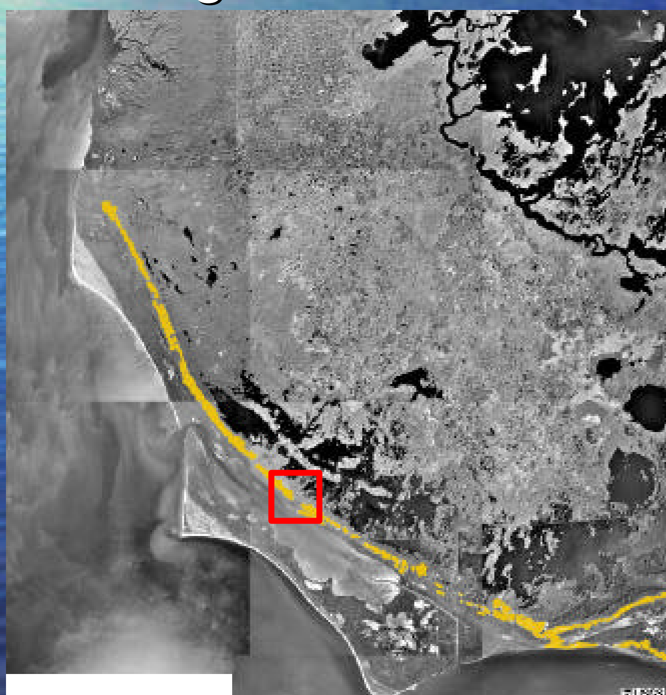
2. ‘Several depressions (dark) in the ridge occur in the southeast corner of Lake Ingraham.

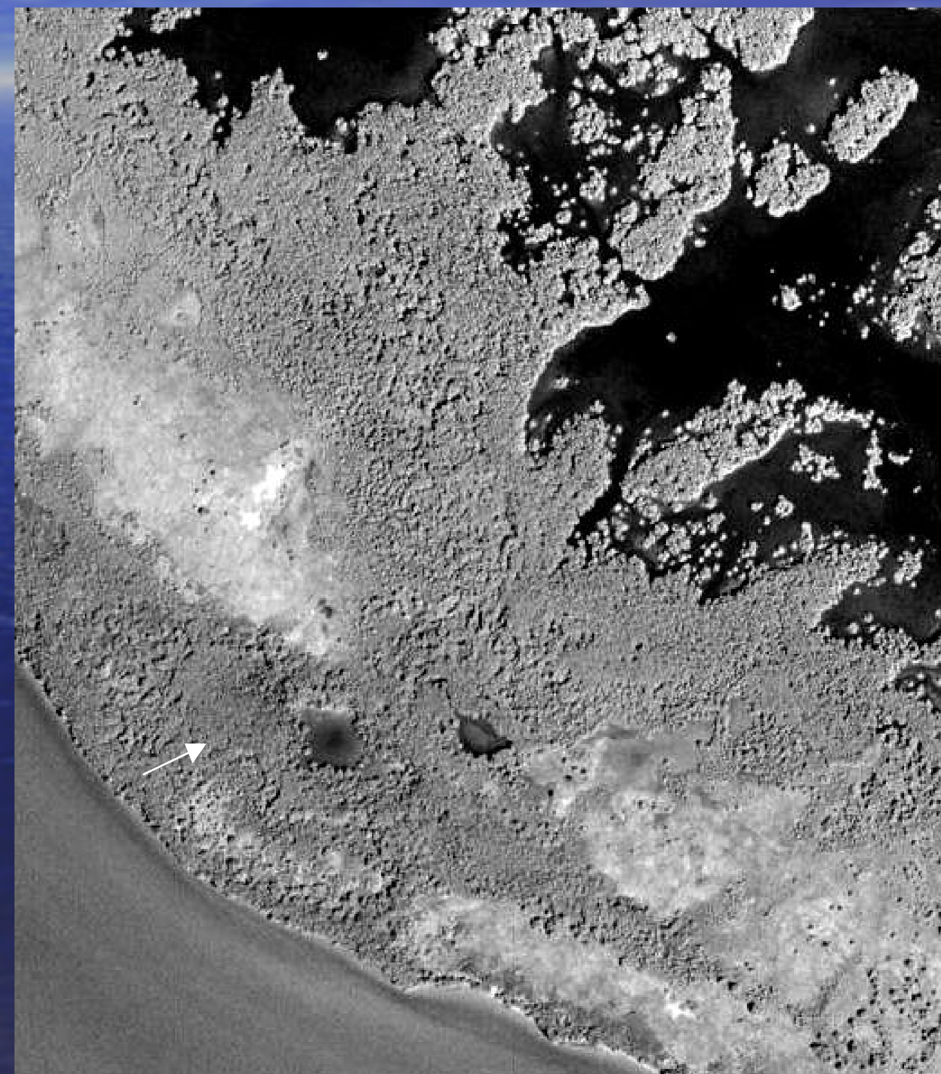




Four marl ridge sites are presently being inundated -

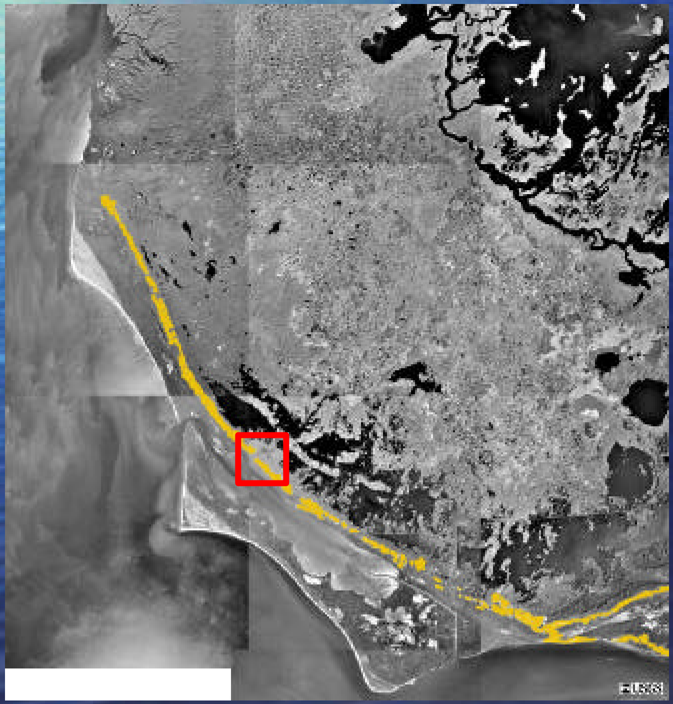
3. A pronounced depression in the marl ridge occurs north-east of mid Lake Ingraham. A channel may be starting.

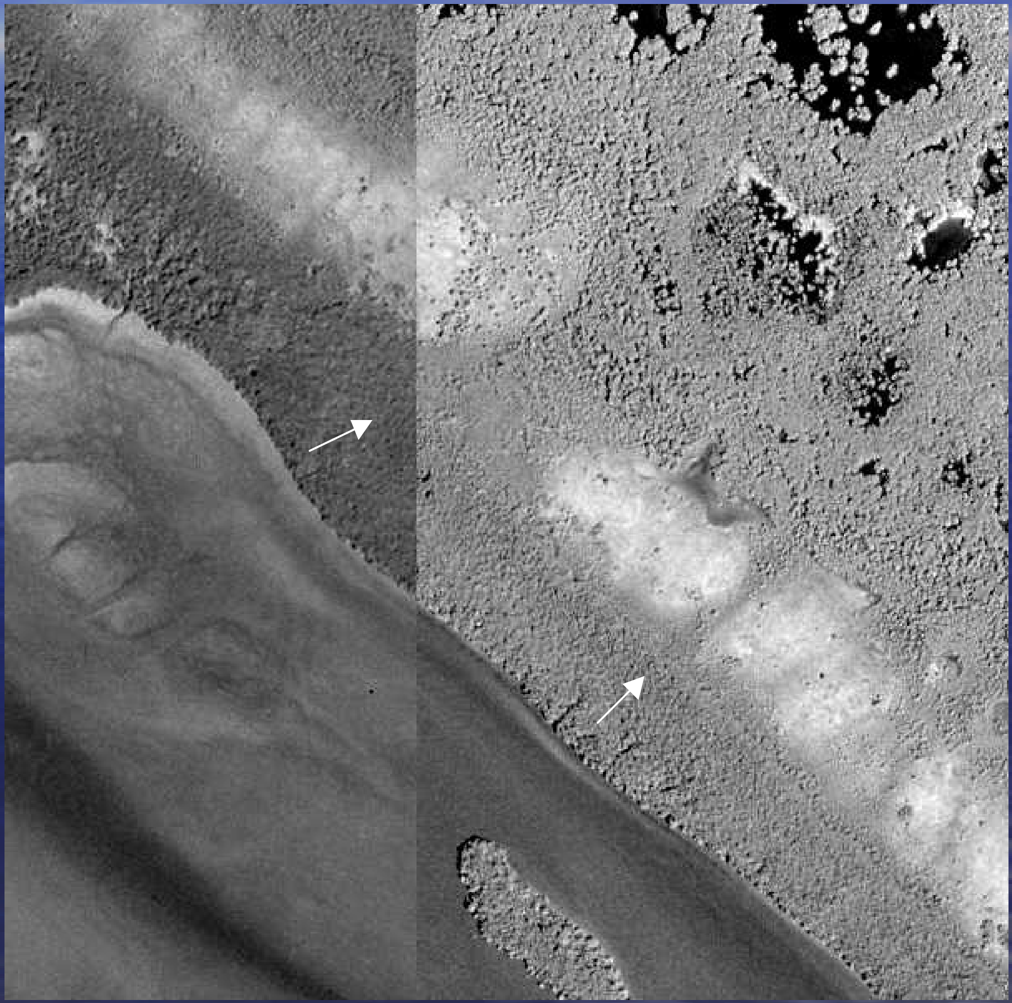




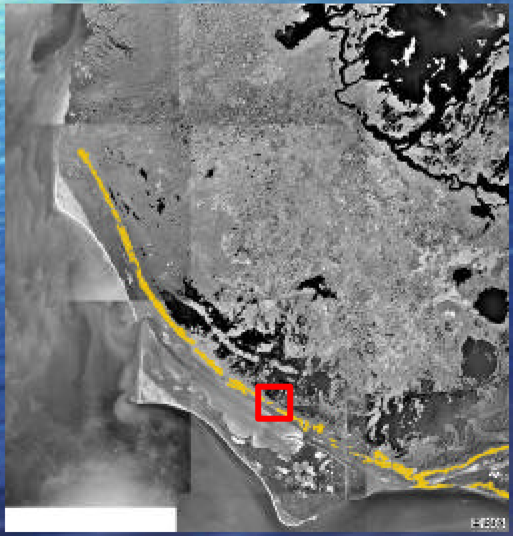
# Four marl ridge sites are presently being inundated -

4. Depression in marl ridge northeast of northwestern Lake Ingraham.





# Structures have been created to limit saline intrusion.





Homestead Canal was enlarging until a plug was put in. This Canals is through a low area in the marl ridge, making containment of high water levels difficult.

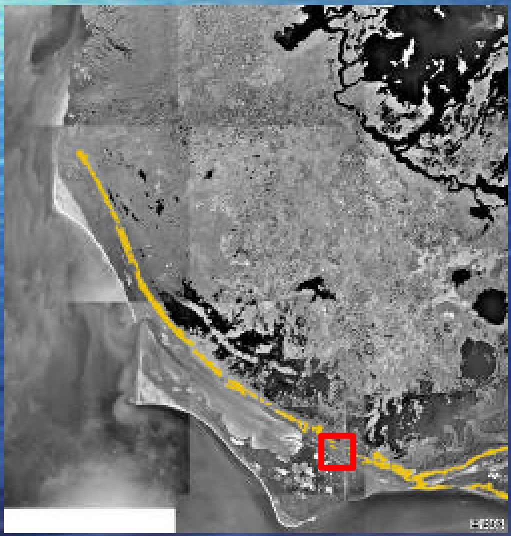
# Existing structures designed to block flow in canals through marl ridge are being overwhelmed by rising sea level.


Tide from Lake Ingraham overtopping dam structure at end of Homestead Canal.

# Existing structures designed to block flow in canals through marl ridge are being overwhelmed by rising sea level.

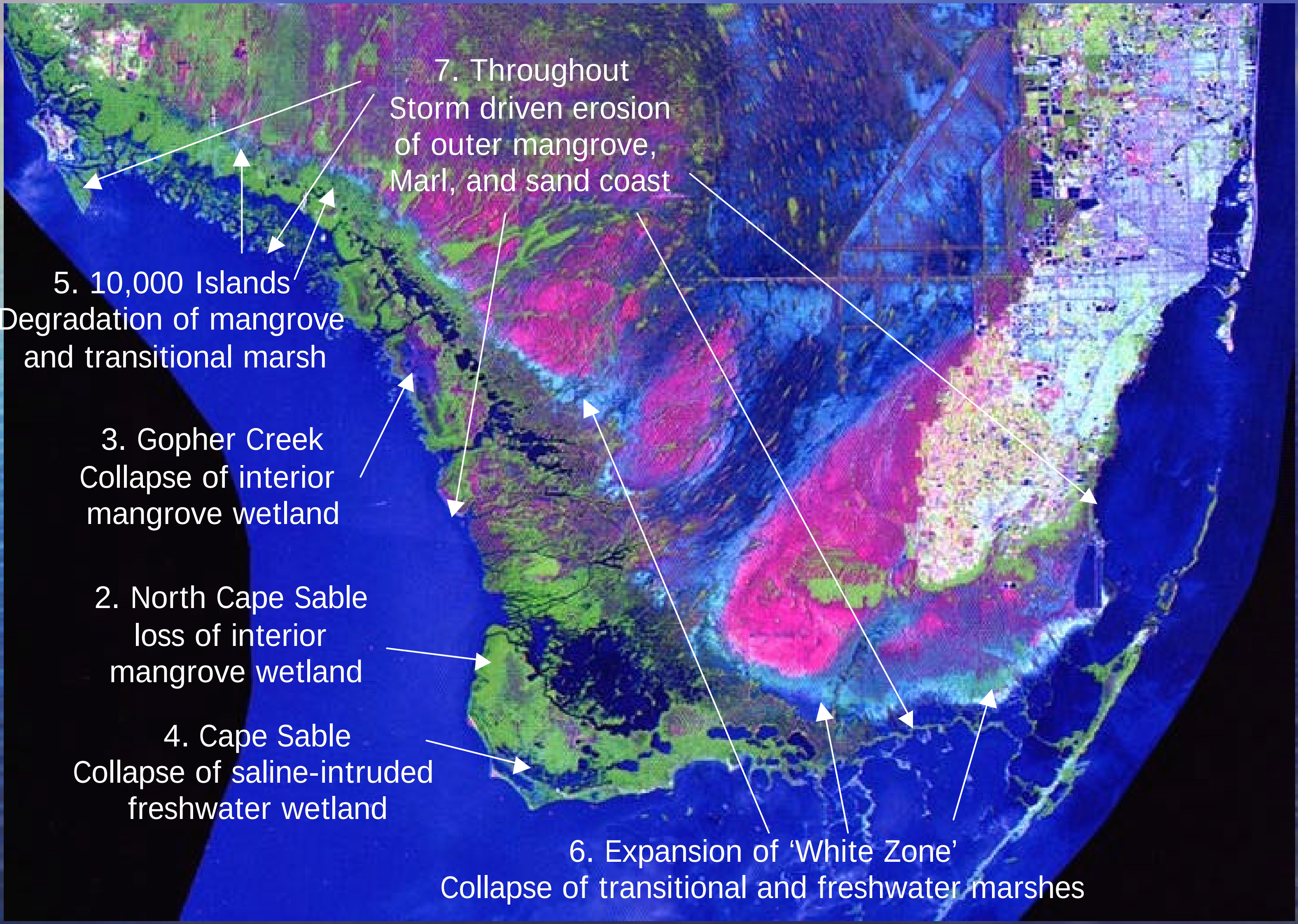
Tide coming in East Cape Canal is eroding marl around edge of dam along northern extension, February, 2002.

# Structures cannot block advancing seas as rising sea level inundates adjacent land.

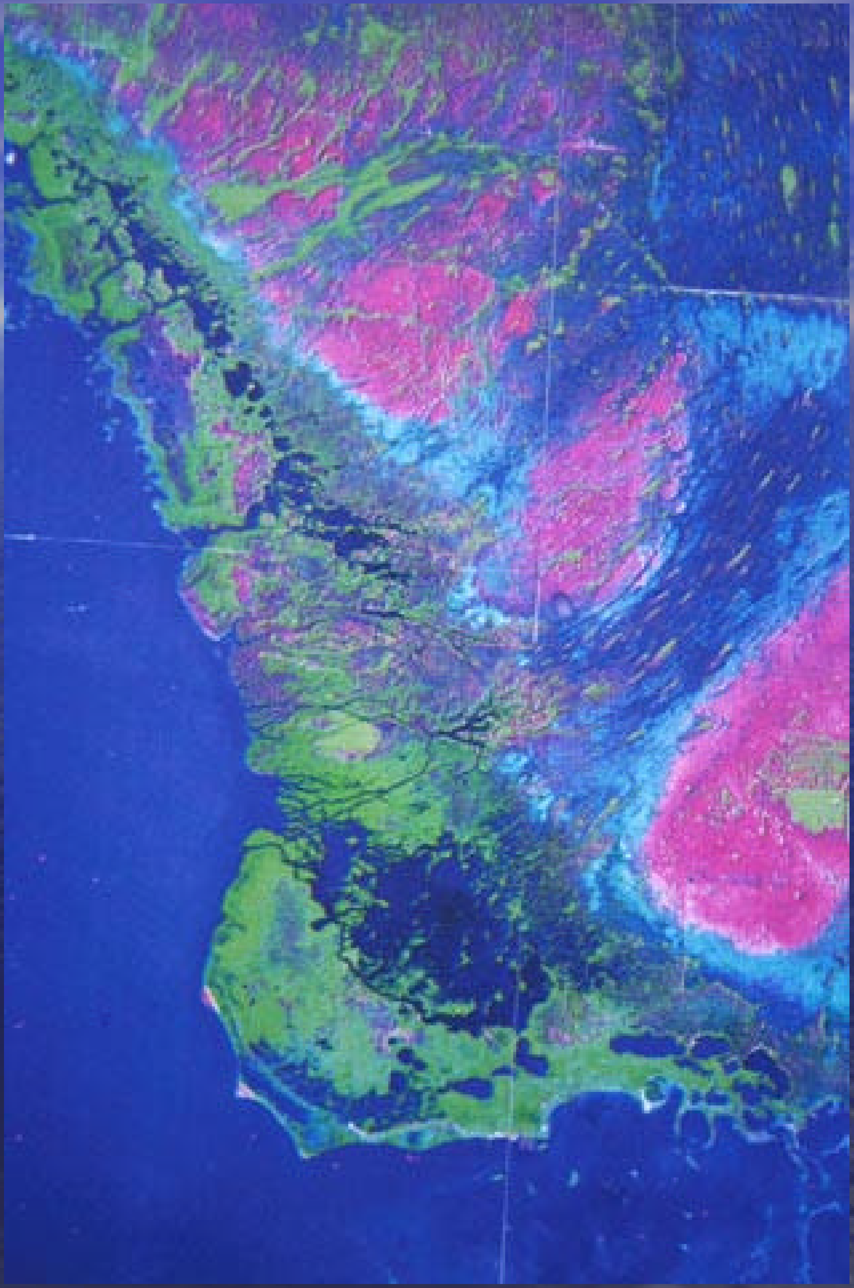



East Cape Canal has widened somewhat. The plug, in a low area in the marl ridge, cannot block high water levels. A channel has cut around the right side of the structure.

# Similar landscape-scale degradation of mangrove and freshwater wetland is occurring throughout south Florida

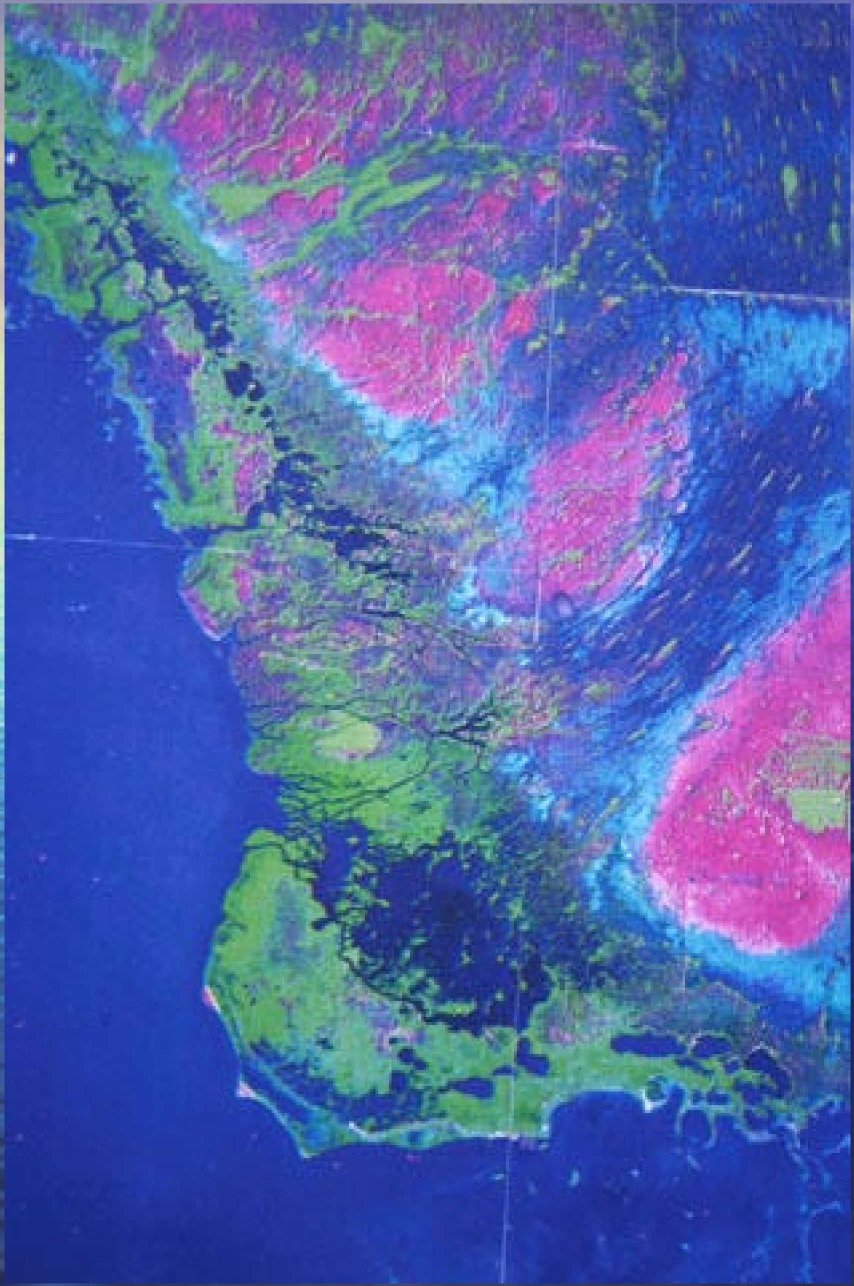
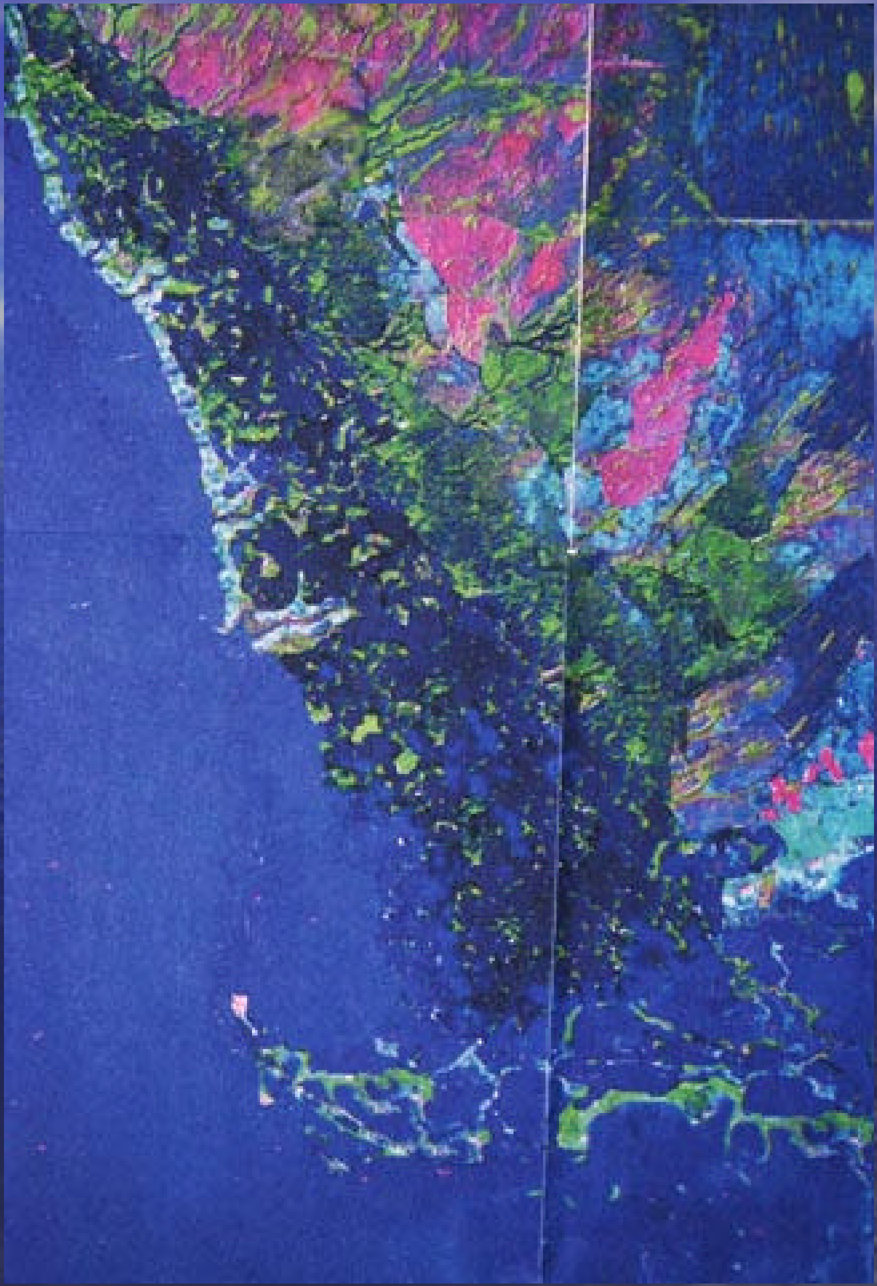


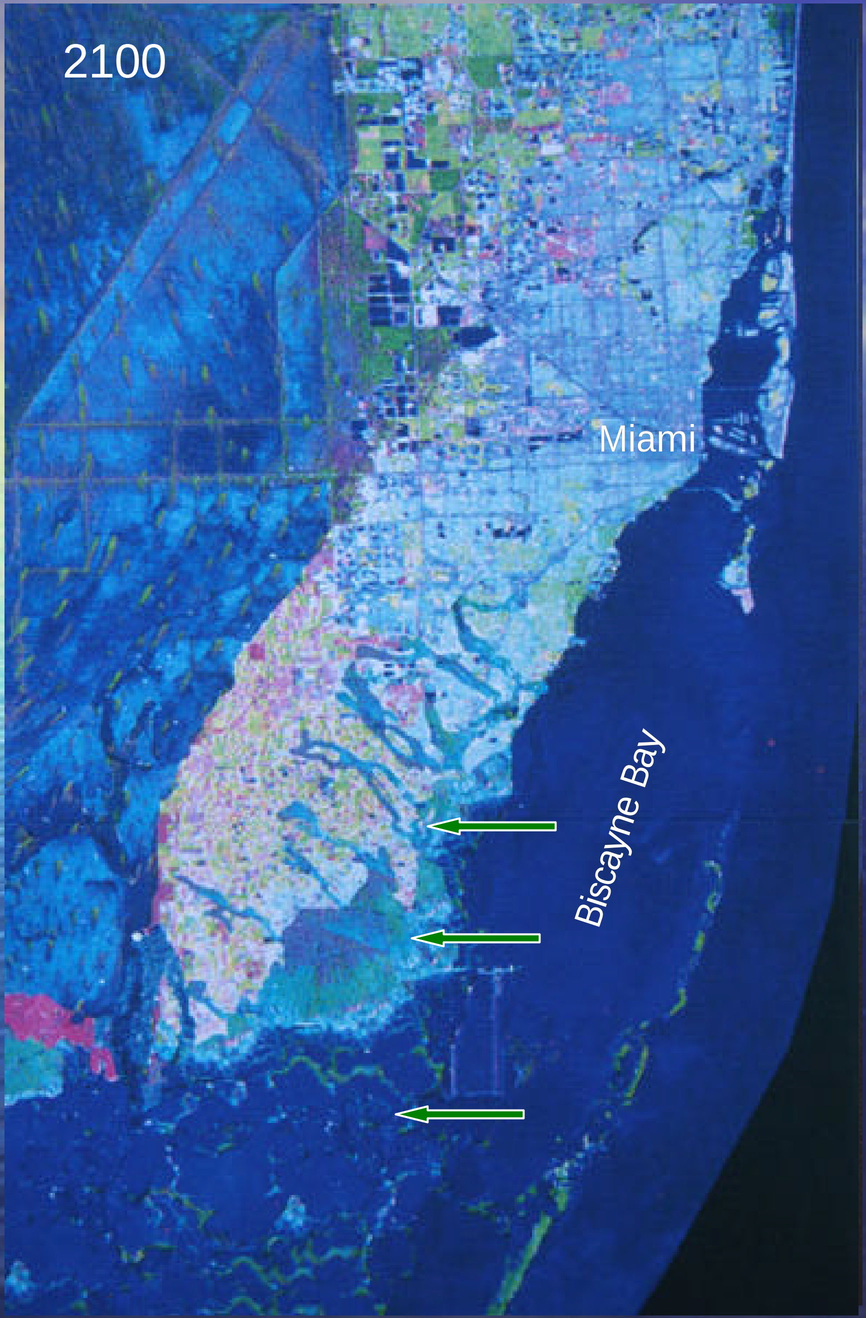
A rapid and dynamic landscape evolution is already underway in south Florida.



and with this evolution is coming a
landscape-scale release
of sediment, organics and nutrients


18 October 2000




We need to understand the coastscape dynamics of the future so we do not make policy, management and restoration goals the will fail and squander taxpayers money.

Loss of coastal wetlands and landward advance of mangrove communities.

# BECAUSE OF GLOBAL WARMING:

- Rapid landscape/coastscape/seascape changes are now underway.
- Accelerated historical SEA LEVEL RISE has destabilized the Atlantic and Gulf Coastal System.
- CATASTROPHIC EVENTS and HUMAN MODIFICATIONS are catalysts for change and evolution in this destabilized coastal system.
- Rates of coastal system destabilization and evolution will further accelerate over the coming century.
- Research, monitoring, policy and management must increasingly focus on landscape-scale stresses, evolution, fluxes and pollution.

Spoonbills on
Lake Ingraham, 2000

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October 2002