

# HEATING CAUSES EXPANSION

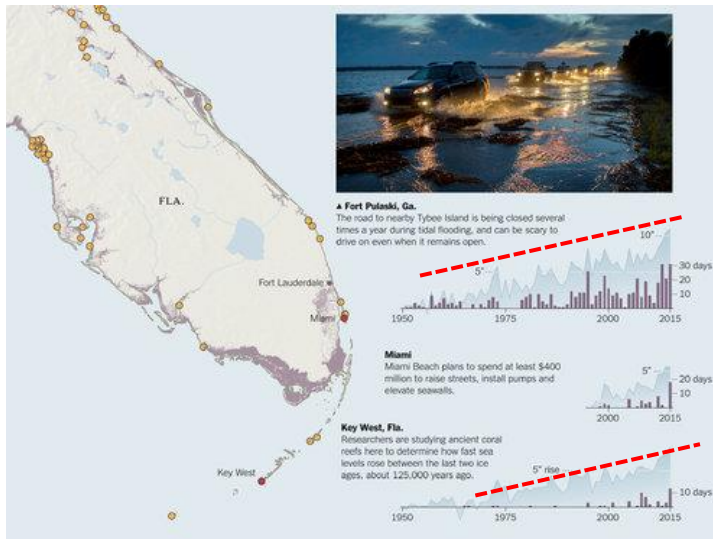
Unit 19 Temp. & Expansion, Dr. John P. Cise

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NORFOLK, Va. — Huge vertical rulers are sprouting beside low spots in the streets here, so people can judge if the **tidal floods that increasingly inundate their roads** are too deep to drive through. Five hundred miles down the Atlantic Coast, the only road to Tybee Island, Ga., is disappearing beneath the sea several times a year, cutting the town off from the mainland. And another 500 miles on, in Fort Lauderdale, Fla., increased tidal flooding is forcing the city to spend millions fixing battered roads and drains For decades, as the **((( global warming created by human emissions caused land ice to melt and ocean water to expand)))**, scientists warned that the accelerating rise of the sea would eventually imperil the United States' coastline. Now, those warnings are no longer theoretical. The inundation of the coast has begun.

## A Sharp Increase In 'Sunny Day' Flooding

Global warming and rising seas are increasing the amount of tidal flooding on the Atlantic and Gulf Coasts.



**INTRODUCTION 1:** The chart at left shows east coast USA Sea level rise to average 5 inches/past 40 year.

**QUESTION:** (a) Convert 5"/40 yr. to milli meters/yr.?

**HINTS:** 25.4 mm = 1 inch., **ANSWER:** (a) 3.175 mm/yr.

**INTRODUCTION 2:** Ocean Expansion(from Wikipedia) The connection between sea level rise and ocean thermal expansion follows from Charles's law (also known as the law of volumes) put simply states that the volume of a given mass is proportional to its temperature. This contribution to sea level is monitored by oceanographers using a succession of temperature measuring profiling instruments, which is then compiled at national data centers such as the United States National Oceanographic Data Center. The International Panel on Climate Change (IPCC) Fifth Assessment Report estimates that the upper ocean (surface to 750 m deep) has warmed by 0.09 to 0.13 degrees C per decade over the past 40

Naval bases, in particular, are threatened; they can hardly be moved away from the ocean, yet much of their land is at risk of disappearing within this century. "In the country, certainly in the Congress, it hasn't really resonated — the billions and perhaps trillions of dollars that we would need to spend if we want to live on the coast like we're living today," said David W. Titley, a retired rear admiral who was the chief oceanographer of the Navy, and now heads a climate center at Pennsylvania State U.

**INTRODUCTION 2 (con.):** Also from Wikipedia on Satellite data on sea rise: According to one study of measurements available from 1950 to 2009, these measurements show an average annual rise in sea level of 1.7 mm(0.067 in) ± 0.3 mm (0.012 in) per year during this period, with satellite data showing a rise of 3.3 mm(0.13 in) ± 0.4 mm (0.016 in) per year from 1993 to 2009.[5] In Fifth Assessment Report (2013), The IPCC found that recent observations of global average sea level rise at a rate of 3.2 mm per year is consistent with the sum of contributions from observed thermal ocean expansion due to rising temperatures (1.1 mm per year), glacier melt (0.76 mm per year), Greenland ice sheet melt (0.33 mm per year), Antarctic ice sheet melt (0.27 mm per year), and changes to land water storage .38 mm per year. **((( NOTE )))**: Adding these five contributions to sea rise = 2.84 mm/yr.(close to 3.2-3.3 mm./yr. mentioned above). Ocean expansion

Is thus  $[1.1/2.84] = 0.3873$  or 38.73 % of the total cause of sea level rise.  **$\Delta V = \beta V \Delta T$ , but  $\Delta V = A \Delta h$  where  $A =$  ocean area &  $\Delta h$  is sea level rise due to expansion. Also,  $V = h A$  where  $h =$  top 750 m affected by sea water temperature change. Thus,  $A \Delta h = \beta h A \Delta T$ ,  **$\Delta h = \beta h \Delta T$**  (eq. 1),  $\beta =$  coefficient of volumetric expansion for water = 0.000207/°C . **QUESTIONS:** (b) If oceans are warming up at 0.09 C°/10 yrs.(see above data), how much have the oceans warmed up in the past 40 years? (c) Find amount  $\Delta h$ (ocean rise) JUST from expansion in past 40 yrs.?, (d) Find  $\Delta h$ /yr. due to expansion?,(e) Expansion accounts for 38.73 % of total rise(see data above). Find TOTAL ocean rise from all Sources if expansion accounts for just 38.73 %? **ANSWERS:** (b) 0.36 C° , (c) 0.05589 m./40 yr., (d) 0.0013972 m./yr. or 1.4 mm/yr. due to expansion, (e) ~ 3.6 mm./yr. due to all sources. **COMMENT BY AUTHOR:** Amazing how close measurements by satellites (3.3 mm./yr.) & computations above are.**