Where to Tan and Buy Beach Property: An Overview on Global Warming

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&  
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Climate Change

- Science and Society
- Temperature and Climate Forcings
  - Past, Recent and Trends,
- Trends in Bio-indicators
- Future Projections
  - Role of Climate Change on Ecosystem Disturbance
    - Hurricanes
    - Sea-Level Rise
2014 launched the most recent, 5th Assessment Report (AR5) from the Intergovernmental Panel on Climate Change, AR5. These reports are available online. They have been written by hundreds of scientists from across the globe and have garnered thousands of comments during the review process.
Too often the conversation starts with ‘do you believe in global warming? Global Warming and climate change is not a religious issue. Our knowledge of Climate change is based on the scientific method, which uses experimentation, theory and the testing and falsification of hypotheses to advance our knowledge.

Science is Not Democratic. Hypotheses are Rejected and Accepted based on observation and test and falsification theoretical principles, not votes

   Hence, constructive criticism and reasonable skepticism is already integrated into the scientific process.

But it is transparent, anyone has access to do science
The issue of climate change has been over politicized. As a result the world has been slow to respond and change to the slow and chronic warming of the planet, with the emissions of greenhouse gases from fossil fuel combustion. If we keep business as usual we will soon approach a tipping point. In the medical field, doctors adopt the precautionary principle, 'do no harm'. Unfortunately, we have been unable to convince society to do the same. Problem is complicated by a society that remains willfully scientifically illiterate and is bombarded with misinformation from vested interests of the status quo and the fossil fuel industry.

While scientists feel inclined to be unbiased brokers of information to minimize and remove bias and conflict of interest, we also must face and consider our roles as citizens and the need for better outreach of information.
Years ago I almost dropped this lecture from this class. Al Gore and the IPCC had won the Nobel Peace Prize and Gore had just released his movie on climate change, so I felt a larger portion of the population was getting exposed to the data and message. I did not expect the political backlash that resulted. The tempo and assaults by the climate deniers increase. Hence, I retain this lecture as a preamble to the ecosystem ecology lectures on how ecosystems will respond to global change in general.
It is my opinion that the climate deniers are masters at using Fallacious Logic to bolster their arguments of climate change. It is important that we apply stronger logic to this topic, and others. Hence it is worth being familiar with some of the fallacious arguments that are often used to promote indefensible theories and ideas.

http://www.unc.edu/depts/wcweb/handouts/fallacies.htm
Let's step back and simply and coldly look at the evidence.
Fact 1. CO2 is increasing and is approaching 400 ppm
Fact 2. Current CO2 concentrations are the highest over the past million years. The rise started at the dawn of the Industrial Revolution
Fact 3. Various Independent Data Sets show Global Temperature are Rising

Global Temperature Change, IPCC 2014 Report

http://www.climatechange2013.org/images/figures/WGII_AR5_Fig2-14.jpg

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Fact 4. the rise in Temperature is consistent with other Climate Related Trends

http://www.climatechange2013.org/images/figures/WGI_AR5_FigFAQ2.1-2.jpg

Fact 5: Both Daily Minimum and Maximum Temperatures are Increasing

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http://www.climatechange2013.org/images/figures/WGI_AR5_FigFAQ2.2-1.jpg
CO₂ may be low in concentration, but it is a highly effective greenhouse gas. The atmosphere has an atmospheric window where long wave energy is lost to space. But the absorption spectra of CO₂ corresponds with this window, so increasing CO₂ makes this window more opaque.

Also recognize how we measure CO₂ in the atmosphere. We use infrared absorption spectroscopy. In other words, we pass infrared energy of a known, absorbing wavelength, through a tube of known length filled with gas and the amount of energy absorbed is proportional to the CO₂ concentration. This is another application of Beer’s Law.
The radiative heating of the surface as a function of CO2 and other greenhouse gases. Since the industrial age the CO2 forcing has increased from near zero W m$^{-2}$ to about 2 W m$^{-2}$.
Radiative forcing on the climate system. Note that not all changes are Positive. Aerosols and land use change, though albedo, can be offsetting. But bottom line is that total radiative forcing is exceeding 2 W m\(^{-2}\),

http://www.climatechange2013.org/images/figures/WGI_AR5_Fig8-15.jpg
Other Arguments

If water is such a strong greenhouse gas and is so Abundant (parts per thousand), why should we worry about tiny changes in CO₂ (parts per million) CH₄ and N₂O (parts per billion)?

Without Greenhouse effect, Earth would be frozen and water effect would be tiny.

Water Vapor Saturates its IR Absorption Wavebands, while other Greenhouse Gases fill open Niches in infrared Spectrum
The radiative forcing of greenhouse gases warms the surface temperature due to re-radiation. The whole atmosphere does not warm because energy is conserved. Instead energy is redistributed in the vertical column of the atmosphere. So there ends up being stratospheric cooling, too.
Let's look at other sources of information on global warming. Remember, as scientists we must be self consistent.
Stable isotopes in ice are great proxies for studying paleo climates
Paleo record of temperature and CO2. Yes, climate has changed in the past and it will again in the future. But this change is slow, over thousands and tens of thousands of years, not over several decades, like today.
CO₂ Leads Warming during Last Deglaciation

Shakun et al 2012 Nature  
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Past climates changes are initiated by changes in the Earth’s orbit around the sun and the tilt of its axis. Obliquity affects the length of the summer season as it is inversely related to Earth’s distance to sun (Huybers). 40 ky cycles induce 100 ky oscillations.
Temperature records become more uncertain as we try and reconstruct historical records before the 1850s when thermometers were commonly used across cities of the world. But the message remains the same. Over 250 years, current temperatures are the warmest
Climate deniers argue that the climate has not warmed lately. Yes there is a plateau, probably due to oceanic effects, but the most recent years remain the warmest. We also need to remember 1998 was extremely warm due to the El Nino.
Tree rings have been used as proxies for temperature. Complicated because both rain and temperature affect tree ring growth. But with careful analysis and adjustments for artifacts and confounding effects, time series can be extended back a 1000 years. We see the famous hockey stick curve with the increase in temperature over the past century.
Canary in the Mine are things like Sea ice. While we many not measure temperature perfectly everywhere, all the time, how do we explain the steep drop in sea ice in the Arctic.
Tipping point may NOT occur because longwave energy lost during the winter from ice free sea is great Tietsche et al 2011 GRL
Conditional Trends in Arctic Ice

**Figure 5.** Anomalies of (a) melt onset and (b) freezeup from the PMW data (solid lines) and POLES data (dashed lines) for the entire Arctic.
Picture took flying over Greenland this past Nov. I was astounded to see Rivers of melt water on the Glaciers. First this is a cold time of year, so there should not be liquid water and this water was surrounded by more glaciers, indicating to me a warm area.

Think about the feedback effects on ice-water albedo. Snow is white and highly reflective. Water is dark and absorbs energy, leading to a positive feedback
Heat capacity of the ocean is increasing, too. But it has thermal inertial
http://www.nodc.noaa.gov/OC5/3M_HEAT_CONTENT/
http://www.climatechange2013.org/images/figures/WGI_AR5_Fig13-27.jpg
One prediction of global warming is thermal expansion of the oceans and melting ice caps, which together will cause sea level rise. Here is what is happening near home.
Climate Trends:
Pardee, CA

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Future Conditions

IPCC SRES Scenarios: CO2 Concentrations used for AR4 Simulations

- Observations
- A2
- A1B
- B1

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Climate Model Refinements

- Sulfate aerosols
- Transient Changes in Trace Gases
- Suite of Radiative trace gases, CO$_2$, H$_2$O, CFC, N$_2$O
- Coupled ocean and atmosphere
- Cloud/water vapor feedbacks
- Finer Resolution, 19 layers, 250 km grid
- Improved Land Surface schemes

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There remain lots of questions about the accuracy and representativeness of the climate models. They do a good job predicting climate, long term, global averages. They are shown to predict past and natural climate variations well and only predict future condition if they include all forcings, positive and negative.
Blue band, models with natural forcing, red models with natural and anthropogenic forcings
Emissions, concentrations, and temperature changes corresponding to different stabilization levels for CO$_2$ concentrations.

(a) CO$_2$ emissions (Gt C)
- A2
- A1B
- B1

(b) CO$_2$ concentration (ppm)
- A2
- A1B
- B1

(c) Global mean temperature change (°C)
- A2
- A1B
- B1

Legend:
- WRE profiles
  - WRE 1000
  - WRE 700
  - WRE 500
  - WRE 300
  - WRE 600
- B1 profiles
- SRES scenarios
Future climate depends upon cumulative Carbon emission, not pathway

Allen et al 2009 Nature

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Multi model average A1B scenario
Caveat Emptor

- The ability of climate models to reproduce past is no guarantee of predicting future if new processes come into play, and they are not well parameterized or modeled
  - Physics of Melting ice caps
  - Timing and Extent of melting tundra
    - 1500+ GtC is in the tundra permafrost
    - Methane emissions from wetlands
  - Cloud physics
  - Aerosols and Black Carbon
  - Portending future changes in Land Use
  - Portending future CO2 levels
    - Effects of technology and adapting alternative energy
    - Changes in population and World economy
    - Pandemics, wars, water scarcity

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Further Refinements

- Coupling Climate, Biogeochemistry and Ecosystem Dynamic models
  - Climate Change is needed to predict Vegetation Changes
  - Changes in Vegetation affects land/surface interactions and Climate
  - Mass and energy fluxes are constrained by links to Biogeochemistry
  - Assess changes in landcover due to mankind

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Conclusions, p1

- Climate system is inherently noisy, but Trends are Emerging
  - We view climate system with multiple tools at multiple time and space scales
  - Consistent and Repeatable Patterns are Arising
- Climate Forecasts are based on fundamental principles of Physics, Biology and Chemistry
- Climate Change is Associated with many complex feedbacks
  - Change can be slow at first, but accelerate later as ice-caps melt, albedo decreases and moisture in the atmosphere increases
- Science is Not Democratic
  - Hypotheses are Rejected and Accepted based on observation and theoretical principles, not votes
  - Hence, constructive criticism and reasonable skepticism is already integrated into the scientific process
  - But it is transparent, anyone has access to do science

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The sea level rise is not anticipated to be uniform over all regions of the globe due to the influence of ocean circulation changes, as well as land movements unrelated to global warming. A more realistic projection of the geographical distribution of sea level rise remains as a problem for future research. However, to crudely illustrate the effect of various hypothetical spatially uniform sea level rise scenarios, the red areas in Fig. 5 indicate regions of the southeastern United States that would be below sea level for regionally uniform rises of one, two, four, and eight meters, respectively.
According to a new simulation study by a group of scientists at NOAA's Geophysical Fluid Dynamics Laboratory (GFDL), a 5-12% increase in wind speeds for the strongest hurricanes (typhoons) in the northwest tropical Pacific is projected if tropical sea surfaces warm by a little over 2 degrees C (Figure 1). Although such an increase in the upper-limit intensity of hurricanes with global warming was suggested on theoretical grounds a decade ago, this investigation is the first to examine the question using a hurricane prediction model that is being used operationally to simulate realistic hurricane structures.
2x CO$_2$ and ground Temperature

http://www.giss.nasa.gov/cgi-bin/co2hansen.cgi
• Wm Ruddiman Claims Anthropogenic Influences started with the dawn of Agriculture (8000 yr BP) rather at dawn of Industrial Age (200 yr BP) due to Forest Clearing, Wide-Spread Rice Production in Asia and Animal Husbandry

• Contends this may have staved off the next ice age

Ruddiman, Climatic Change, 2003

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Energetics of Greenhouse Gas Forcing:
Doubling CO₂ provides a 4 Wm⁻² energy increase (ΔR), Worldwide

\[ ΔT = \frac{ΔR \text{Gain}}{(1 - \text{feedback})} \]
**Attribution of the present-day total greenhouse effect**

Table 1. Effect of Each Absorber on the Percentage Net LW Absorbed by the Circa 1880 Atmosphere for Each Absorber Being Removed (Minimum Effect) and for That Absorber Acting Alone (Maximum Effect)*

<table>
<thead>
<tr>
<th>Absorber</th>
<th>Single Factor Removal (% of Total G)</th>
<th>Single Factor Addition (% of Total G)</th>
<th>Attribution (Including Overlaps)</th>
<th>All Sky</th>
<th>Clear Sky</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₂O (Vapor)</td>
<td>39.0</td>
<td>61.9</td>
<td>50</td>
<td>67</td>
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<tr>
<td>CO₂</td>
<td>14.0</td>
<td>24.6</td>
<td>19</td>
<td>24</td>
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<tr>
<td>Clouds</td>
<td>14.5</td>
<td>36.3</td>
<td>25</td>
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<tr>
<td>All Others</td>
<td>4.9</td>
<td>9.2</td>
<td>7</td>
<td>9</td>
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<tr>
<td>N₂O</td>
<td>1.0</td>
<td>1.6</td>
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<td>Ozone</td>
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<td>CH₄</td>
<td>0.7</td>
<td>1.6</td>
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<td>CFCs</td>
<td>0.1</td>
<td>0.5</td>
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<tr>
<td>Aerosols</td>
<td>0.3</td>
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<td>18.8</td>
<td>32.0</td>
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<tr>
<td>H₂O + Clouds</td>
<td>66.9</td>
<td>88.9</td>
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<td>57.6</td>
<td>79.1</td>
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<td>H₂O + Clouds + CO₂</td>
<td>90.8</td>
<td>95.1</td>
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<td>28.9</td>
<td>42.4</td>
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*“All GHGs” encompasses CO₂, CH₄, N₂O, CFCs, and O₃. “All Others” refers to all absorbers other than H₂O, CO₂, and clouds. The attribution columns account for overlaps for “all-sky” and “clear-sky” conditions. Multiply all percentages by 155 W/m² to get the equivalent change in radiative flux units.

Schmidt et al 2010  
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JGR Atmos
Global Dimming

Mishchenko et al. 2007 Science

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Solar Dimming and DTR:
More Particles Reduce Daytime Warming from Sun
More Greenhouse Gases Reduce Nighttime Cooling

Wild et al, 2007 GRL
Hurricane storm duration and intensity are scaling with SST
Temperature over the past 800,000 years

Vostok and EPICA Ice core

Data of Barnola, Raynaud and Lorius

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Trends in Growing Season Length and Last Frost Date

Feng and Hu, 2004, J Theor Appl Clim

United States

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Trends in Phenology across Europe

Leafing and flowering

Change in Days/Year

Menzel et al. 2006 GCB  ESPM 111 Ecosystem Ecology
Downward Trend in Chill Hours near Orland, northern Sac Valley

50+ year Record, Coop Data

Baldocchi and Wong, Climatic Change, 2008

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Radiation and Tri-Molecular Compounds

- High Energy (uv) dissasociates/ionizes molecules
- Medium energy (IR) vibrates
- Low Energy (microwave) rotates

http://www.wag.caltech.edu/~home/jang/genchem/infrared.htm

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Tipping points and Arctic sea ice???

feedback, but in winter the excess oceanic heat is lost to the atmosphere due to a lack of insulating sea-ice cover. This leads to an anomalously warm atmosphere, which in turn causes increased heat loss by longwave radiation at the top of the atmosphere and decreased heat gain by atmospheric advection from lower latitudes. A lasting impact of the ice-albedo feedback is not possible because the large-scale heat fluxes quickly adapt to release the excess oceanic heat from the Arctic.

Tietsche et al 2011 GRL
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Berkeley Earth Temperature Project Confirms Global Warming

http://berkeleyearth.org/
Natural Solar Forcing of Climate Variability

Zachos et al Science 2001
Temperature Anomaly Trends: Instrument Record

Global Mean Temperature over Land & Ocean
Preliminary New-GOAA Surface Temperatures

The 20 Hottest Years on Record*

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Dust and CO₂ Amplify Feedbacks on Climate

Bender, GBC, 2003

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