

# CARBON DIOXIDE AND CLIMATE: A SCIENTIFIC ASSESSMENT

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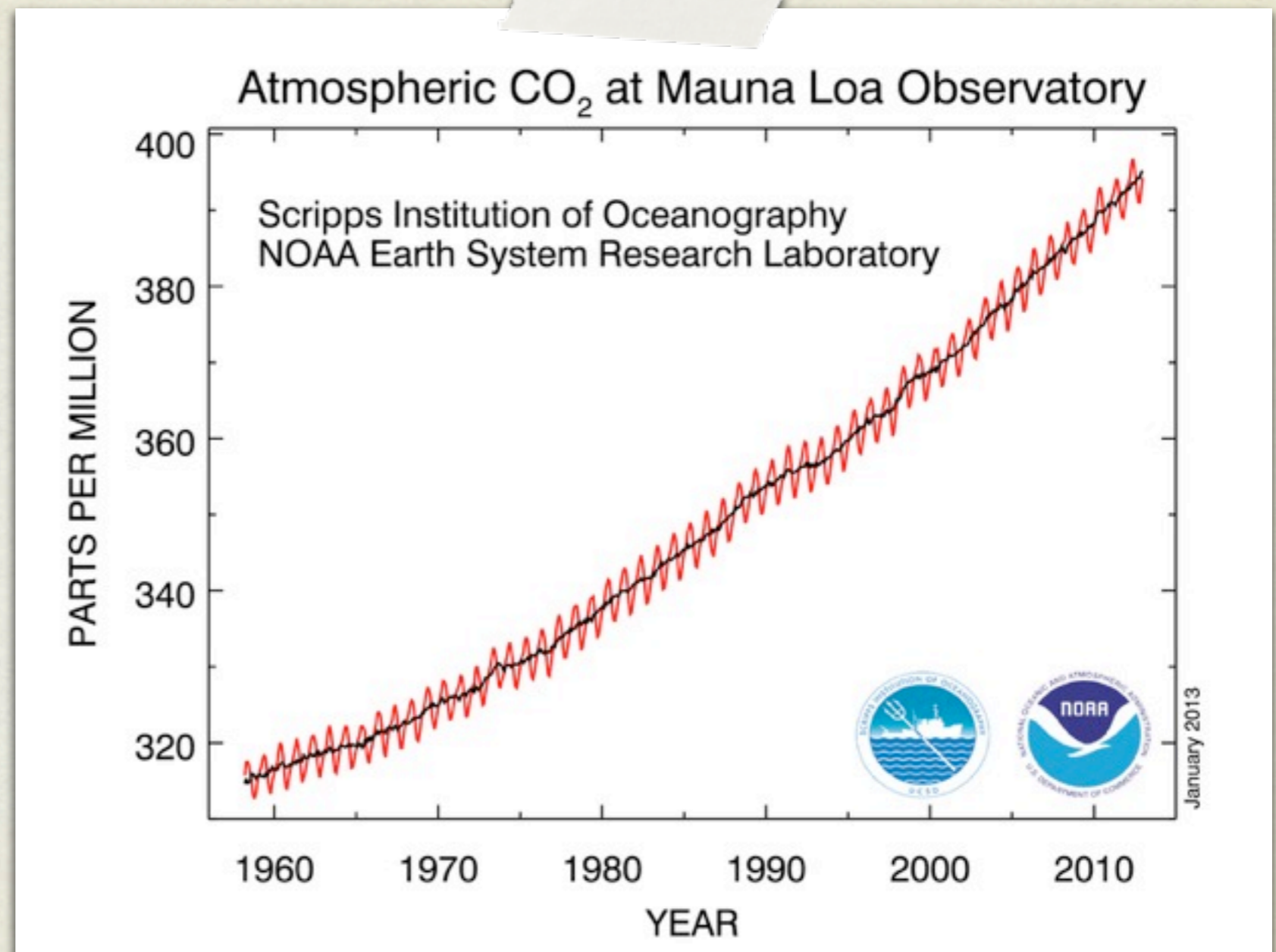
**July 27, 1979**

# KEY POINTS

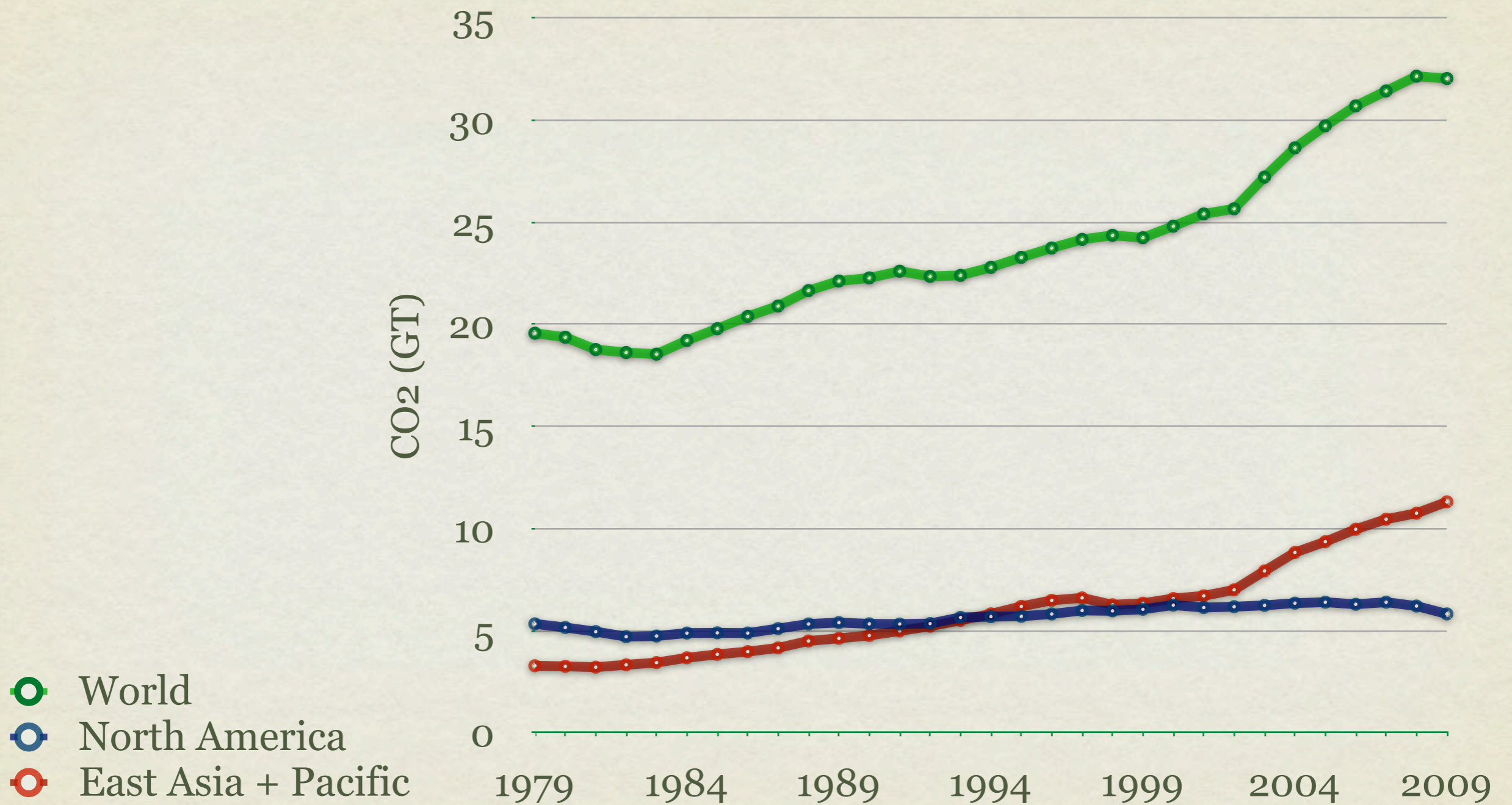
- ‘Incontrovertible evidence’ human activity is changing the atmosphere.
- A **wait-and-see policy** means waiting until it is too late.
- *When will CO<sub>2</sub> double? 2030—2050.*
- All models *mutually supporting*: 5 of 5 models predict warming.
  - **Upper bound** from H1: +3.5° (*Over-estimation of water vapour feedback*)  
**Lower bound** from M series: +2° (*Under-estimation of water vapour feedback*)
- *Best estimate of surface temperature change? +3° degrees (probable error of ±1.5°)*
- A historical document: Jules Charney and Jimmy Carter.
- Conclusions are *comforting for scientists* and *disturbing for policy makers*.
- Conclusions have generally held: +2.6°—4.1° clustering around +3°C.<sup>3</sup>

# CO<sub>2</sub> LEVELS

- 1850: ~290
- 1958: 314
- 1979: 334
- 2013: 395
- *2050: 580?*



# CO<sub>2</sub> EMISSIONS



# ASSUMPTIONS

- ~50% of CO<sub>2</sub> stays in Atmosphere, the rest is absorbed by Forests and Oceans.
- *Positive feedback* from moisture *will overwhelm* all conceivable *negative feedback* mechanisms.
- Fossil Fuel **Consumption**: 2% increase (1.9% actual<sup>1</sup>).
- Fossil Fuel **Reserves**: 5000 x 10<sup>9</sup> — 10% is Oil and Gas (As of 2011<sup>2</sup>: 3600 x 10<sup>9</sup> — 21.8% is Oil and Gas)

# DETAILS

- $\Delta Q$  = Change in Heating of Troposphere, Oceans, and Land (RF).  
 $\Delta Q = 4\text{Wm}^{-2} \pm 25\%$  (2001 IPCC revised to  $3.7\text{W/m}^2$ )
  - $W$  = Amount of *Sunlight*?
- $\Delta T$  = Change in Surface Temperature.  
 $\Delta T = \Delta Q/\emptyset$ ,
- $\emptyset$  = effect of feedback processes: Humidity, Albedo  
 $\emptyset = 1.7 \pm 0.8 \text{ Wm}^{-2} \text{ K}^{-1}$  or about 2.4 K
  - $K$  = Amount of *Heat*?
- **Limitations:**  
Carbon Cycle, Clouds, Heat Transport in Oceans, Simple Feedback models.

# THE MODELS

Model Characteristics	Model Predictions				
	M1 <sup>a</sup>	M2 <sup>a</sup>	M3 <sup>a</sup>	H1 <sup>b</sup>	H2 <sup>b</sup>
<b>Domain</b>	0°<λ<120°, 0°<θ<81.7° <sup>c</sup>	0°<λ<120°, 0°<θ<90° <sup>c</sup>	Global	Global	Global
<b>Land-ocean distribution</b>	Ocean for 60°<λ<120°, 0°<θ<66.5°	Ocean for 60°<λ<120°, 0°<θ<90°	Realistic	Realistic	Realistic
<b>Ocean</b>	Swamp	Swamp	Mixed layer	Mixed layer	Swamp
<b>Seasonal change</b>	No	No	Yes	Yes	No
<b>Cloud feedbacks</b>	No	Yes	No	Yes	Yes
<b>Snow and ice albedo</b>	When T<-25°C: 0.7 When T>-25°C: 0.45 for snow 0.35 for ice	When T<-10°C: 0.7 When T>-10°C: 0.45 for snow 0.35 for ice	Depends on depth and underlying surface albedo For deep snow, 0.8 For thick ice, 0.7	For snow, depends on snow age, snow depth, underlying surface albedo, etc. For ice, 0.45	Same as H1
<b>Horizontal resolution</b>	About 500 km on a mercator projection	5° in longitude 4.5° in latitude	Spectral model with the maximum zonal wave number 15	10° in longitude 8° in latitude	Same as H1
<b>Vertical resolution</b>	9 layers	9 layers	9 layers	7 layers	7 layers

<sup>a</sup> Models developed by S. Manabe and colleagues at the NOAA Geophysical Fluid Dynamics Laboratory, Princeton, N.J.

<sup>b</sup> Models developed by J. Hansen and colleagues at the NASA Goddard Institute for Space Studies, New York, N.Y.

<sup>c</sup> Cyclic continuity assumed at boundaries.

# REFERENCES

1. IPCC (2007), **Climate Change 2007: Working Group III: Mitigation of Climate Change**. *[http://www.ipcc.ch/publications\\_and\\_data/ar4/wg3/en/ch1s1-es.html](http://www.ipcc.ch/publications_and_data/ar4/wg3/en/ch1s1-es.html)*
2. U.S. Energy Information Administration (2013), **Proved Reserves**. *<http://www.eia.gov/countries>*
3. Rahmstorf, Stefan (2008). **Anthropogenic Climate Change: Revisiting the Facts**. In Zedillo, E. *Global Warming: Looking Beyond Kyoto*. Brookings Institution Press. pp. 34–53.
4. World Bank (2013), **CO<sub>2</sub> Emissions**. *<http://data.worldbank.org/indicator/EN.ATM.CO2E.KT/countries>*



# APPENDIX

# EAST ASIA & PACIFIC

- Cambodia, China, Fiji, Indonesia, Kiribati, Korea, the People's Democratic Republic of Lao (Lao PDR), Malaysia, Marshall Islands, FS Micronesia, Mongolia, Palau, Papua New Guinea, the Philippines, Samoa, Solomon Islands, Thailand, Timor-Leste, Tonga, Vanuatu, and Vietnam.



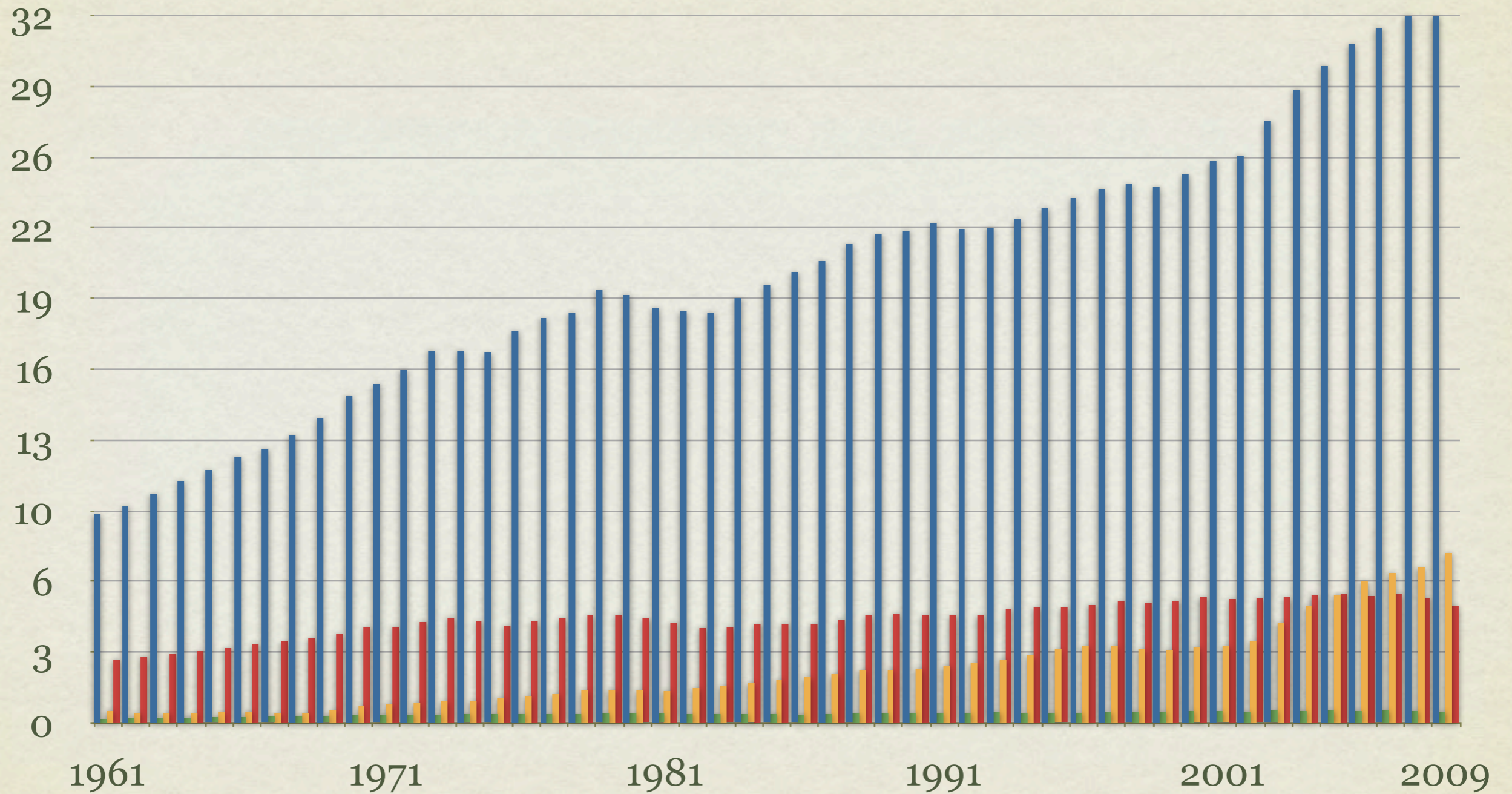
Source: [www.wikiprogress.org/index.php/File:East\\_asia\\_pacific.png](http://www.wikiprogress.org/index.php/File:East_asia_pacific.png)

# RESERVES

- How I calculated Fossil Fuel Reserves:
  - *Coal* —  $995 \times 10^9$  tonnes: Tonne = 2870 kg of  $\text{CO}_2$
  - *Oil* —  $1317 \times 10^9$  barrels: Barrel = 317 kg of  $\text{CO}_2$
  - *Gas* —  $1161 \times 10^9$  barrels (eqv.): Barrel = 317 kg of  $\text{CO}_2$
  - Total =  $2856 + 417 + 368 = 3600 \times 10^9$

# CO<sub>2</sub> EMISSIONS

World Canada China USA



# VOSTOK ICE RECORD

