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Modeling the problem: thermodynamic approach

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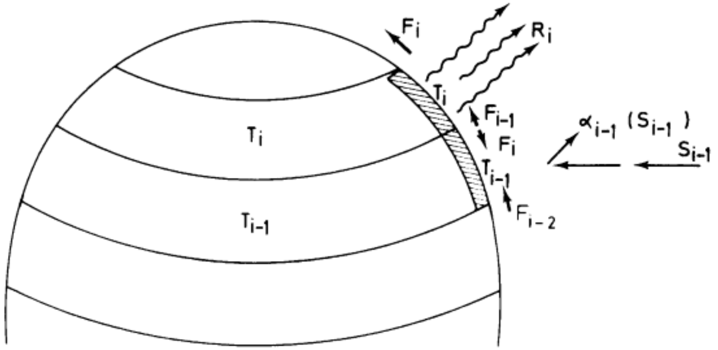
Climate models

The frame of reference is a local Cartesian coordinate placed on a rotating sphere.



The sum of Gravity, pressure, friction, Coriolis force, …, gives:

$$\frac{\partial \mathbf{u}}{\partial t} + (\mathbf{u} \cdot \nabla)\mathbf{u} = \nabla\Phi - 2\Omega \times \mathbf{u} - \frac{1}{\rho}\nabla p + \mathscr{F}$$ … Equation of motion

= gravitational potential, minus Coriolis, minus pressure gradient, plus friction term.

$$\frac{d\rho}{dt} + \rho\nabla \cdot v = 0$$ ……… The continuity equation

$$dQ = dU + dW = c_v dT + pdv = c_p dT - vdp$$ .. Energy Equation

Climate Models

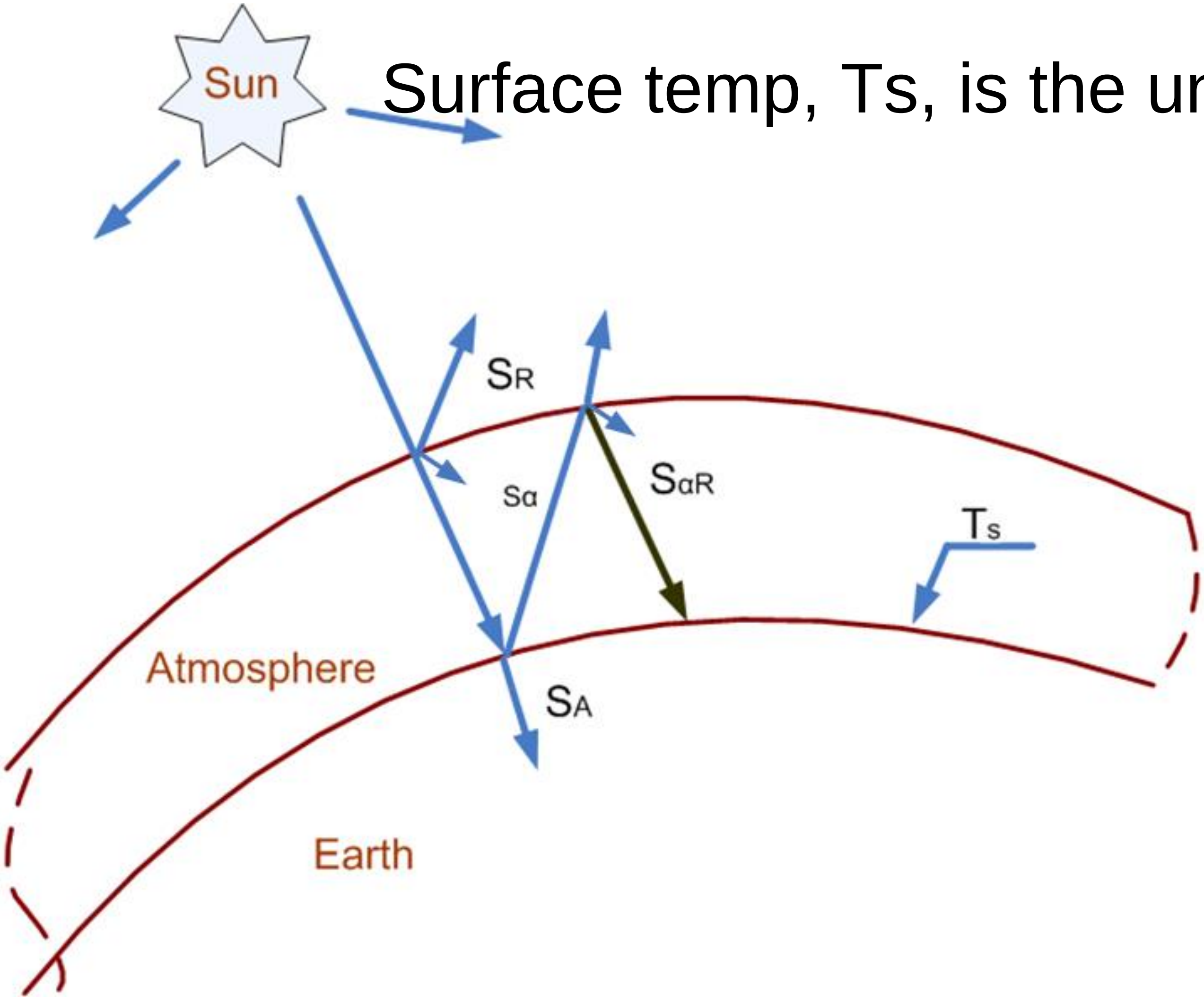
Our focus:

Energy Equation, use the energy balance to estimate changes in temperature , humidity, etc.

- Assuming feedbacks are quantifiable,

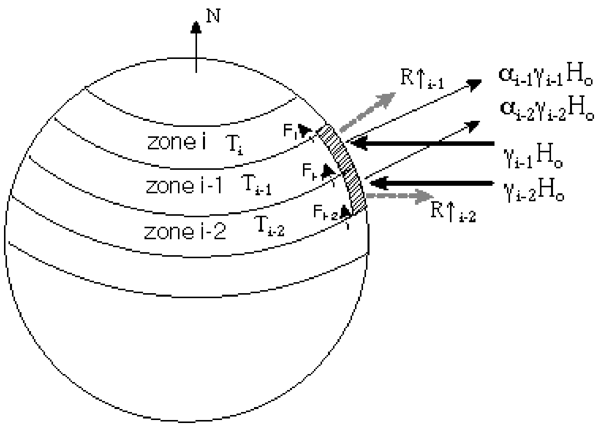
Energy balance, existing

Surface temp, Ts, is the unknown



The challenge is quantifying Sα and SαR

Existing models



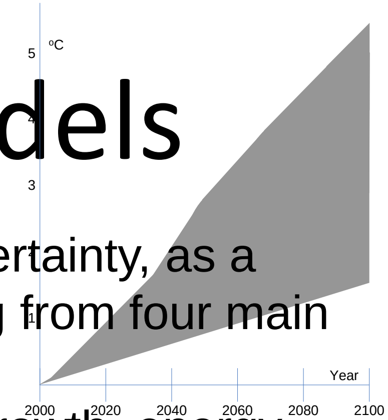
Energy balance eq. is imposed without establishing a control volume

All GCMs use a system in which the Earth's surface constitutes a coordinate surface.

The coordinate is used to determine the distribution of heat, vapor, CO2 and other trace substances, momentum, and impose conservation laws on the atmosphere's mass and energy.

However, these are not simulated for the atmosphere as a control volume.

Weaknesses of existing models



Projections of climate change are subject to a high degree of uncertainty, as a consequence of incomplete and unavailable knowledge - resulting from four main areas:

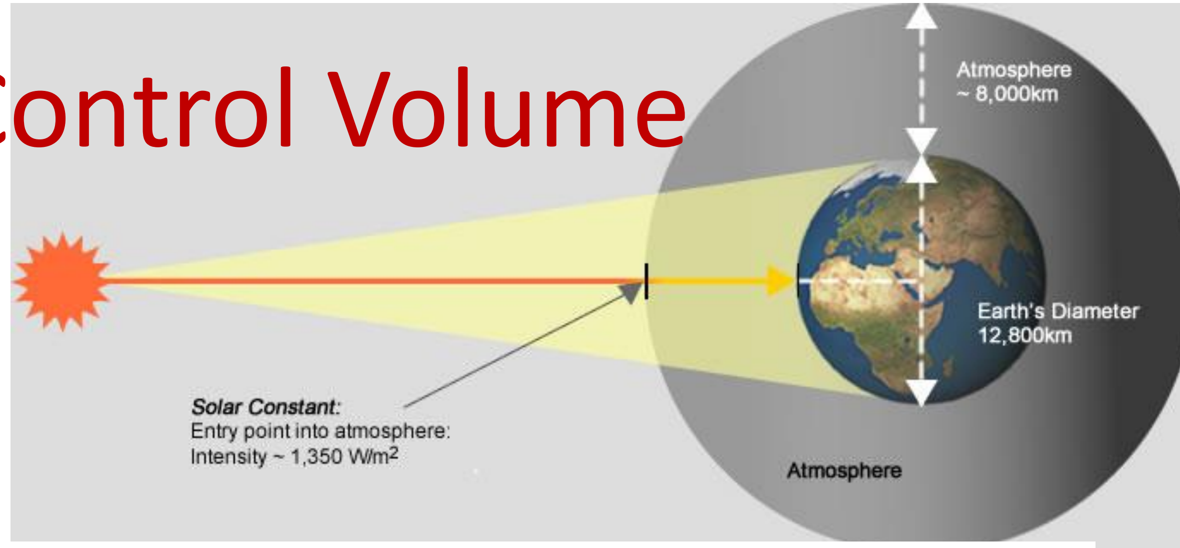
- Unpredictable emissions scenarios, influenced by population growth, energy use, economic activity which also remain unpredictable,
- Sensitivity of the climate system to greenhouse gas forcing. According to the IPCC, this sensitivity is in the 1.5ºC - 4.5ºC range.
- Climate system model accuracies, especially long-term variability and chaotic behavior of the models, and
- Sub-grid scale dynamics and computational limitations to capture smaller spatial scales for full 3-D analytical results.

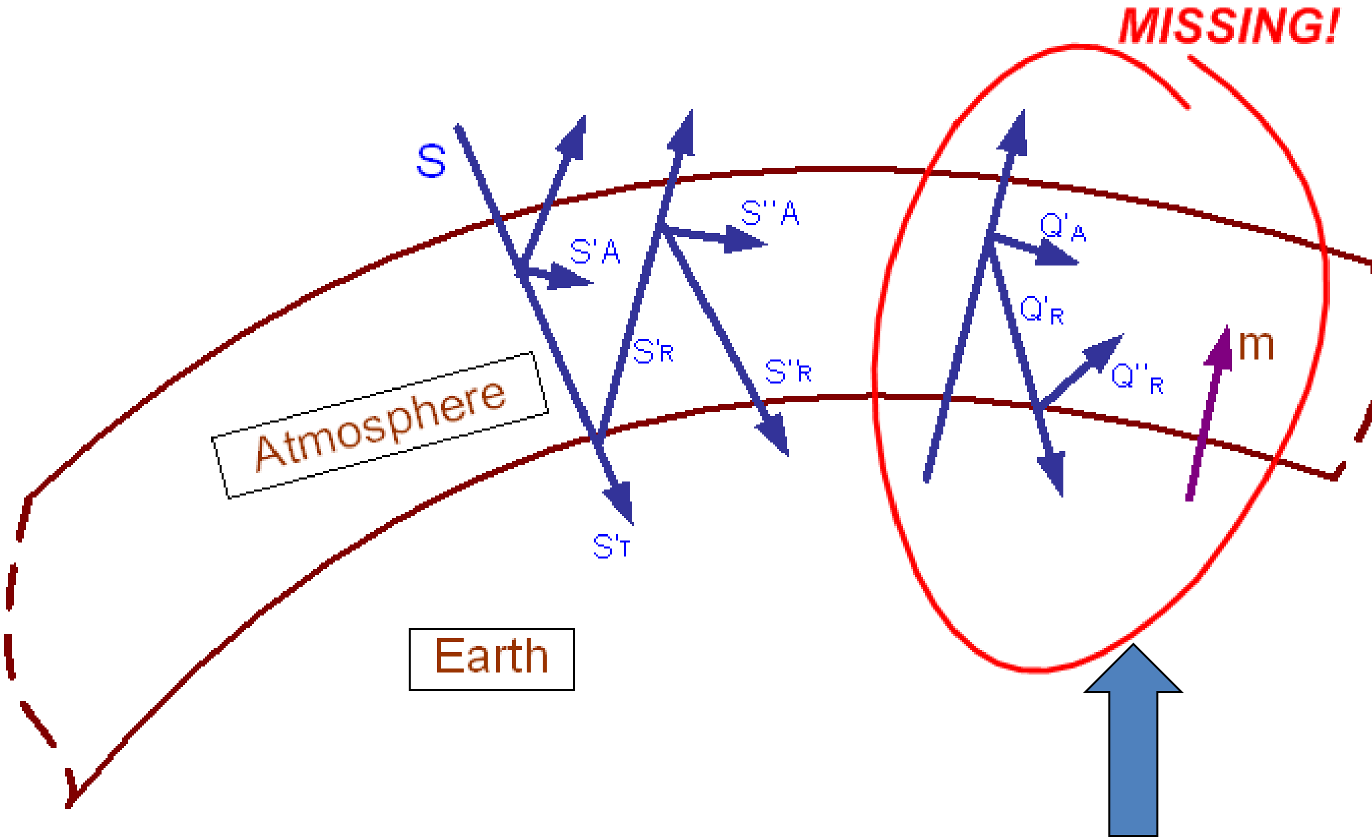
➔Estimates remain inconclusive and inconsistent ==> compounded by possible non-linear responses to anthropogenic forcing.

Further thermodynamic weaknesses:

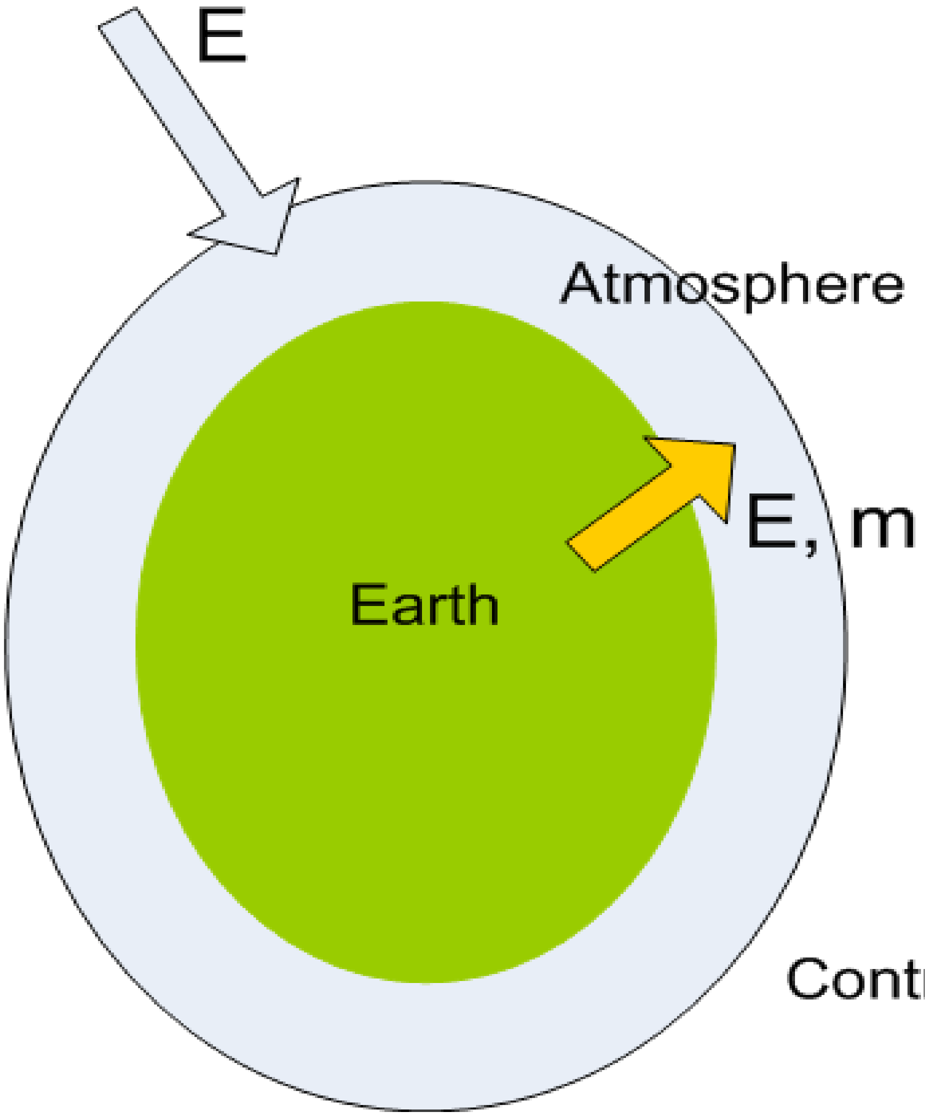
- By and large, temperature is selected as an indicator of climate change.
- The boundary of the earth-atmosphere system in all the existing climate models is defined only with the top, outer boundary.

Proposed Control Volume





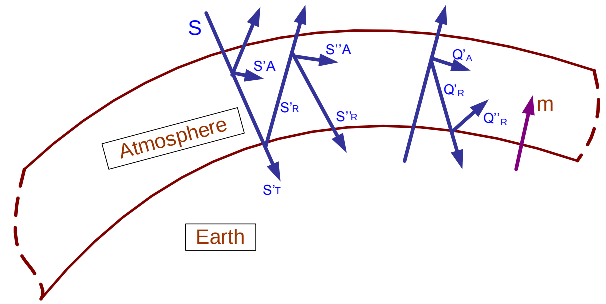
Energy and Climate Change



The CV represents the atmosphere. … enveloped by two spheres, the earth on the inside, and the furthest limit of the atmosphere on the outside. The outer boundaries of the CV is 20 to 30 km high, the troposphere and the lower stratosphere, - they house over 95% of the atmosphere's mass.

Control Volume Approach

Control Volume



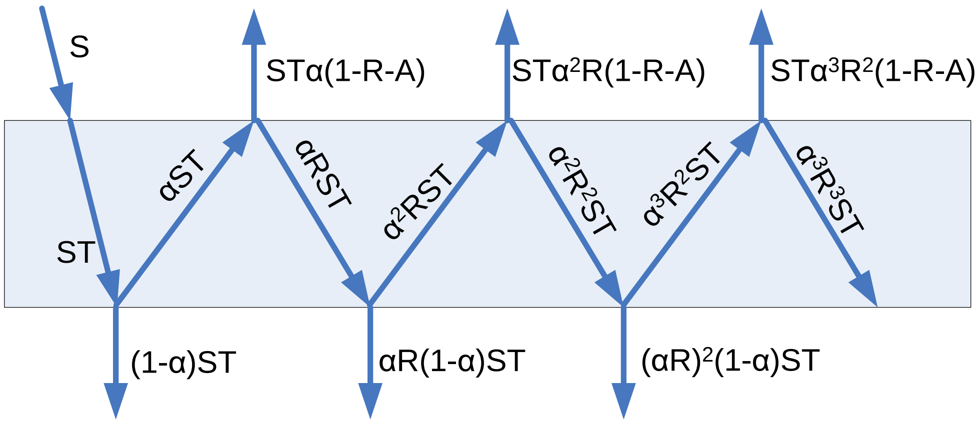
Solar energy absorbed by the atmosphere, SA

$$SA = S - [ST(1-\alpha)(1+\alpha R+(\alpha R)^2+\cdots)+\ \alpha ST(1-R-A)(1+\alpha R+(\alpha R)^2+\cdots)]$$

$$1+x+x^2+\cdots = \frac{1}{1-x}$$

$$SA = S -\ ST[\frac{1-\propto}{1-\propto R}+\frac{\propto(1-R-A)}{1-\propto R}]$$

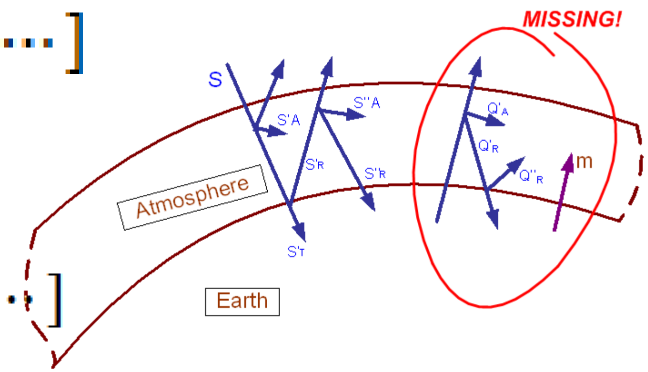
$$SA = S - \frac{ST}{1-\propto R}[1-\propto R-\propto A]$$



Control Volume

Fossil energy absorbed by the atmosphere, QA

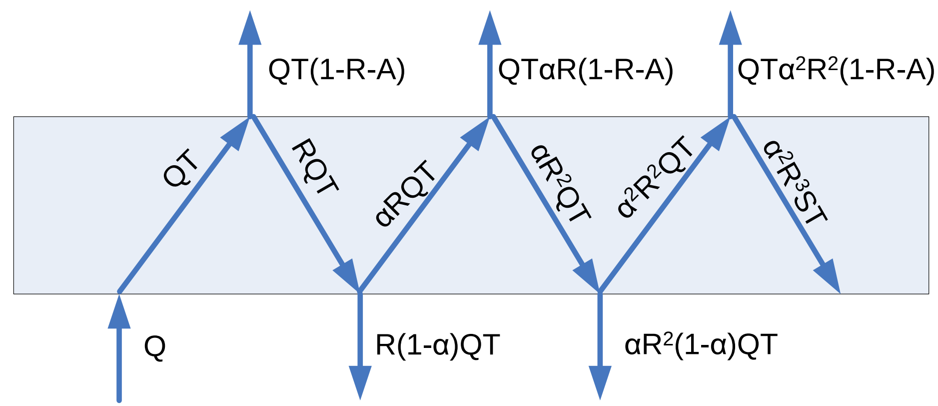
$$QA = Q - [QT(1 - A - R) + \alpha RQT(1 - A - R) + \propto^2 R^2 QT(1 - A - R) + \ldots + RQT(1 - \propto) + \propto R^2 QT(1 - \propto) + \cdots]$$



$$QA = Q - QT(1 - A - R)[1 + \alpha R + (\propto R)^2 + \cdots] - RQT(1 - \alpha)[1 + \alpha R + (\propto R)^2 + \ldots]$$

$$QA = Q - [QT\frac{1 - A - R}{1 - \propto R} + RQT\frac{1 - \propto}{1 - \propto R}]$$

$$QA = Q - \frac{QT}{1 - \propto R}[1 - A - \propto R]$$



Control Volume Total energy absorbed, EA

$$EA = SA + QA = S - \frac{ST}{1-\propto R}[1-\propto R-\propto A] + Q - \frac{QT}{1-\propto R}[1 - A-\propto R]$$

This is the magic equation

Spatial resolutions both in the horizontal and the vertical levels and assumed **flow patterns** for a control volume could remain the same as in the current models.

Effects of radiant energy transfer, **the absorption and emission of electromagnetic waves** by air molecules and atmospheric particles, could be computed without procedural changes but magnitude.

Parameterizations involving clouds, turbulence and sub-grid scale mixing will need to be modified for the control volume approach, to account for QA and mE.

Energy Balance

Hs

$$EA + I = C\frac{\partial T(x,y,z,t)}{\partial t} + H_L + SS + H_D$$

Where,

- EA+I is net radiation (solar + infrared radiation),
- C is the heat capacity,
- H_S is the sensible heat flux**, the T function**,
- H_L is the latent heat flux,
- SS is subsurface heat flux, sea plus ground,
- H_D is corrective heat due to dynamic effects, **internal**.

Computationally, we step this eq. forward in time.

How to determine QA

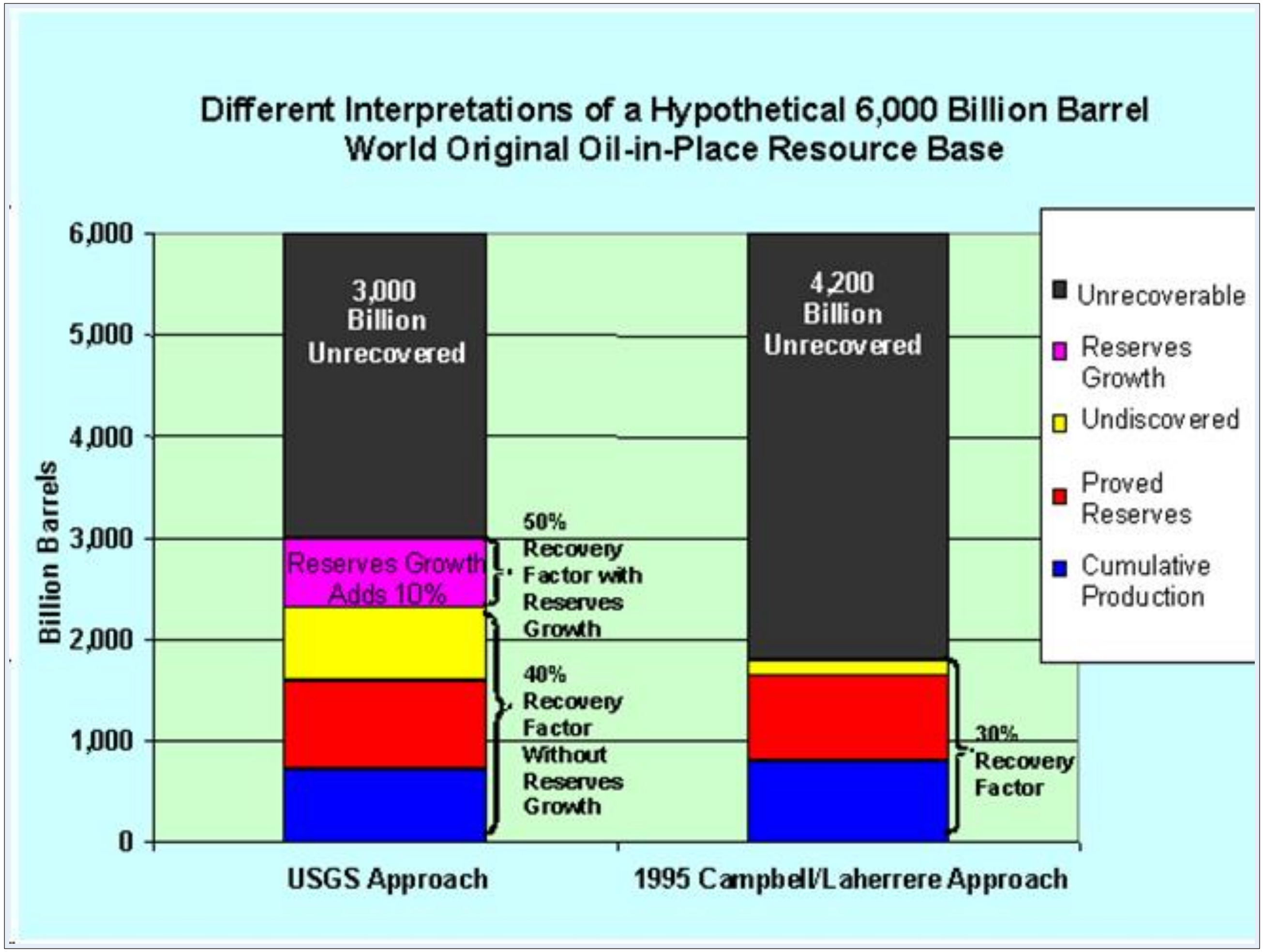
Peak-extraction production approach

There are several estimates that show the peak production year:

- Laherrere's 1997 estimate predicted the peak would occur around 2010 ("Future Sources of Crude Oil Supply and Quality Considerations," DRI/McGraw-Hill/French Petroleum Institute, June 1997).
- L. F. Ivanhoe's estimate also showed peak production around 2010 ("Get Ready For Another Oil Shock!," The Futurist, Jan-Feb, 1997).
- Duncan and Youngquist's estimate of peak production is 2005-2007. ("The World Petroleum Life-Cycle: Encircling the Production Peak," http://www.dieoff.org/page133.htm)
- EIA's International Energy Outlook 2000 predicts that the global conventional oil production peak will occur after 2020, since production is still growing in 2010.

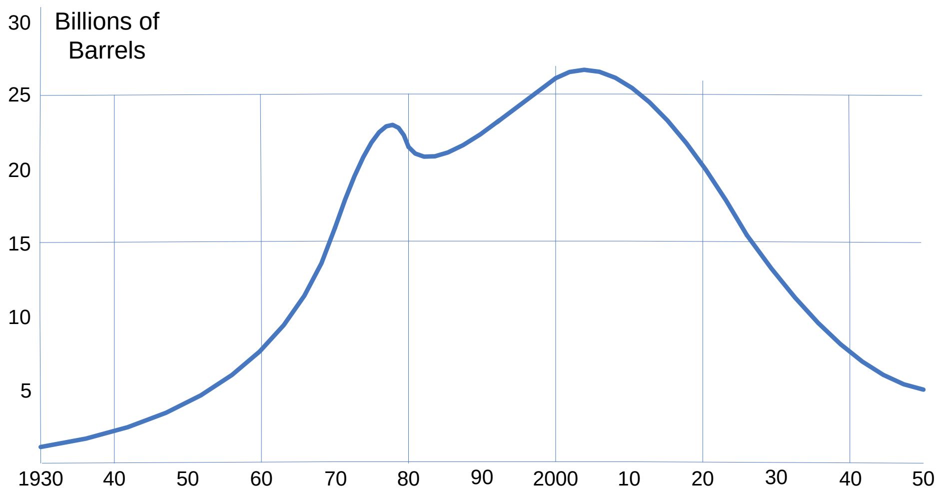
Fossil Fuel Energy Estimate

Peak estimate differences



Fossil Fuel Energy Estimate

$$\int_{t1}^{t2} F(t)\,dt$$



Campbell-Laherrere oil production model

5.8 MMBtu/barrel

About 1808 Billion barrels by 2050 = 10486.4 MMBtu

About 1158 Billion barrels by 2010 = 6716.4 MMBtu

1 kJ = 0.94782 Btu

1 Btu = 1.055056 kJ

1808	billion by 2050	1.04864E+13	MMBtu	=	1.10637E+16 MJ energy in the atm.
1158	billion by 2010	6.7164E+12	MMBtu	=	7.08618E+15 MJ energy in the atm.
25	billion peak	1.45E+11	MMBtu	=	1.52983E+14 MJ energy in the atm.

Fossil Fuel Energy, Is it Significant?

Campbell-Laherrere oil production model

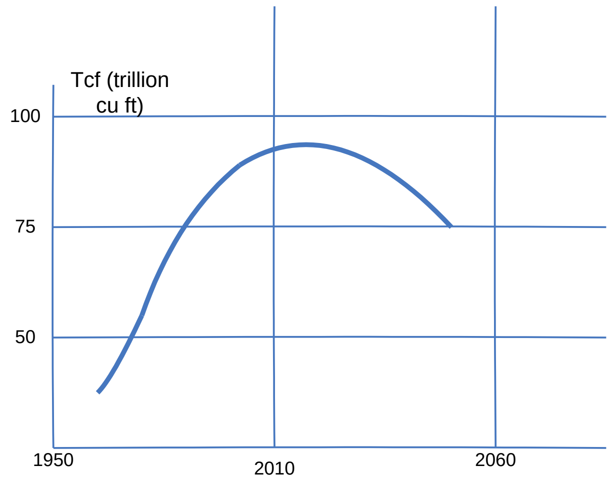
Enthalpy of vaporization =	2257	kJ/kg =	2.257MJ/kg

Increased Annual Rate of Evaporation for 25 billion barrels/yr:

6.77816E+13	kg/yr of evaporation
6.77816E+13	liter of water/yr

Nile: 109,500,000,000,000 liter/yr	**= About 62% of Nile**

Fossil Fuel Energy, Is it Significant?



Multicyclic Hubbert model shows global conventional gas output peaking in 2019

Asher Imam, Richard A. Startzman

Natural gas peak

1 MMcf = 1,000,000 ft^3
1 Tcf = 1,000,000,000,000 ft^3

1 cu ft = 1000 Btu
About 90 Tcf peak = 90,000,000,000,000 ft^3/ yr peak

90 Tcf = 90,000,000,000,000,000 Btu
= 90,000,000,000 MMBtu of energy per yr

9.4955E+13	MJ of energy in the atm.
4.20714E+13	liter of water/yr

Fossil Fuel Energy, Is it Significant?

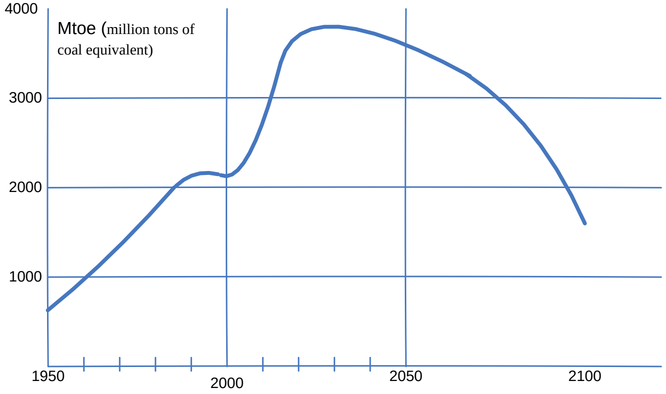


Fig. Worldwide possible coal production, Background paper prepared by the Energy Watch Group, March 2007, EWG-Series No 1/2007

Coal:

4000 M toe peak
1 ***toe*** = 41.868 GJ = 39.683 MM***Btu***
1 million toe = 41,848,000 GJ = 39,683,000 MMBtu
4000 M toe = 4X39,683,000 MMBtu

4000 M toe = 1.67471E+14 MJ of energy in the atm.

7.42008E+13 liter of water/yr

Fossil Fuel Energy, Is it Significant?

Total, oil, natural gas, and coal

Total Energy at peak:	4.15409E+14	MJ/yr	
Total water at peak:	1.84054E+14	liter/yr	1.7 times Nile

Fossil Fuel Energy, Is it Significant?

Use of specific humidity

$\omega = m_v/m_a = 0.662P_v/(P-P_v)$

At 25C DBT, and 40% Φ, relative humidity, ω = 8g/kg

Assume: At 25C DBT, and 40% relative humidity, ω = 8

Total kg of atmospheric air mass = 5.15E+18 kg

Total kg of vapor in the atmosphere = 4.12E+16 kg

Increase in air humidity: 0.447 % for the yr

With the assumed Φ, we can determine the ΔP and ΔTe.

sciencebase
science news and views

Jan 16, 2013
Climate change makeover
Posted in Science at 9:08 pm by David Bradley

Often a name change, a brand re-launch or a corporate makeover becomes a matter of urgency when a company gets seriously bad press. I could list a few examples but will spare their blushes (#subtweet). Of course, when it comes to a phenomenon, the same thing can happen. Think global warming morphing into climate change. Of course, that was more about greater scientific understanding, public acceptance of the various trends and issues that arise and a dawning realisation that rising global average temperatures, through the greenhouse effect, are just one factor.

…………

The team has introduced the concept of “Equivalent Rate of Evaporation” (ERE), which they say provides better estimates of how enthalpy of vaporization affects climate change. “This approach offers a more lucid understanding of the climate model, with indubitably more accurate results,” the team says. The researchers point out that the earliest models of climate change did not distinguish between vertical and horizontal energy or include a temperature stratification. Later, models took this into account but this led to there being two parallel modelling systems, which the researchers suggest widens the error bars on predictions. All of which has provided denialists with ammunition over the years.

Beyene and Zevenhoven are, one might now suggest, reclaiming climate change science and putting it on a firmer, thermodynamic, footing. Two boundaries are proposed to form a control volume of the atmosphere – one, the traditional boundary at the top of the atmosphere, and the other inner boundary, at some superficial depth of the earth. Energy and mass that cross the inner boundary of the control volume are the only possible causes of anthropogenic climate change, Beyene explains. Moreover, the team asserts that temperature is just another “coordinate” in the system and so the only accurate measure of climate change must look at the energy balance of the atmosphere as a whole. From such an approach those other factors, wind, pressure, humidity as well as temperature change will feed into a new model with tighter error bars, a reduction in secondary modelling artefacts and a better chance of predicting global warming and thence climate change. **This would not be so much a makeover as a much-needed complete overhaul of climate science.**

Beyene A. (2013). Thermodynamics of climate change, International Journal of Global Warming, 5 (1) 18-29. DOI:

Conclusion

- Secondary effects, known as feedbacks, a nut to crack
- Thermodynamically, temperature is just another variable
- The only accurate measure of climate change ➔ energy/exergy
- Control volume approach - **valid**
- Equivalent Rate of Evaporation (ERE) ➔ better insight into deemphasizing the role of T
- A comparison of the contributions of fossil-carbon fuel use, nuclear fission electricity production and tidal + geothermal energy shows that the exergy streams passing the boundary given by the earth's surface are primarily (> 92%) from fossil-carbon fuel use, and 7% from nuclear fission electricity generation and < 0.5 % form tidal + geothermal energy.
- At a rate of ~ 4×10^{14} MJ/yr the rate of exergy transfer is ~1/10000 of the incoming solar and cosmic exergy. This can be used to estimate a temperature effect.

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THANK YOU!

Questions ?

Thank you

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