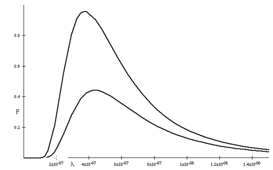
Weather and Climate

Peter Watson

- Two fundamental laws:
- Stefan- Boltzmann law
- Total Power radiated/unit area
- (remember: must work in absolute temp, K not °C)
- i.e double the temp, 16 times the energy

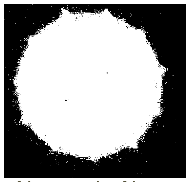
- Wien's law:
- Wavelength of peak i.e. as we heat up objects, they go
- black ⇒ red ⇒ orange ⇒ yellow ⇒ white

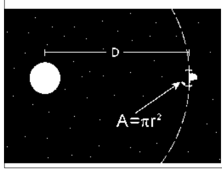


Can use this to figure out how hot the earth should be

- Our model: both earth and sun are perfect black bodies
- Sun is 7×10^5 km in radius, temp. of 5800 K. How much energy does it radiate?
- How much is absorbed by earth?
- What temp. would earth be at to re-radiate this?

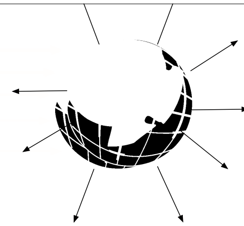
- Sun produces radiation
  Each square metre produces σT_{sun}^4, so total power output (luminosity) is
  $L = 4\pi R_{sun}^2 \sigma T_{sun}^4$





- This gets emitted into space,
- spreads out over an area $4\pi D^2$

- absorbed by earth



Earth then re-emits energy at a lower temp T_{earth}

Inflow from sun must balance outflow

Inflow

Outflow

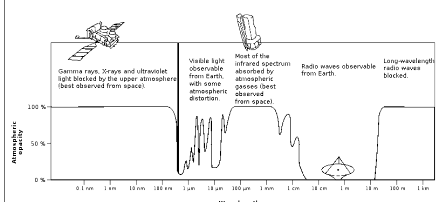
Must be equal (First Law!)

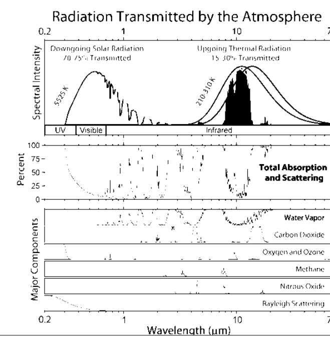
Predicts

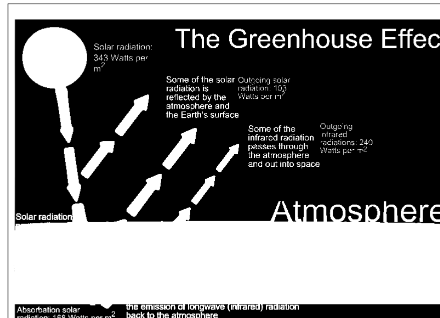
Temp of Earth is

- This gives ~ 278K
- ~ 5°C
- Note this is an average: is it reasonable?
- A bit cool (actually, about 20°C)
- Why?
- Note the earth is cool, so re-radiated heat is at a much lower temp
- Incident energy is (mostly) visible
- re-radiated is infra-red

- Atmosphere is mostly opaque except to visible light & radio waves

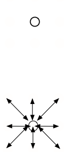






Weather

- "Primitive Equations" for weather written down by L F Richardson (1922). Can't be solved without computer
- Assume we know everything (temperature, pressure, humidity, radiation inflow...) at some points in space.
- Each point will affect it's neighbour, so can figure out how it will change
- Need to know how the energy can be transferred



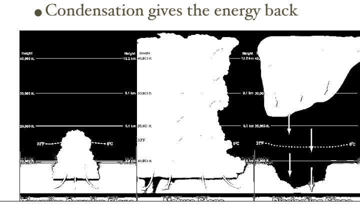
Convection

- Most fluids expand when heated
- Hot water is less dense than cold, so rises

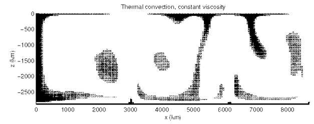
- In atmosphere:
- ground is heated by sun,
- transfers energy to air
- produces updraft
- in summer, humid air is heated, lifts upwards
- cools, water condenses out as cloud

Evaporation & Condensation

- Evaporation requires a lot of energy
- e.g boiling one litre of water takes ~ 2.3 MJ (million joules)
- Condensation gives the energy back

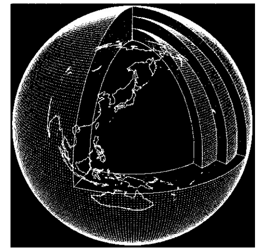


- Thunderclouds are evaporation-convection-condensation cycle



Weather

- For the earth, need a huge grid of points
-



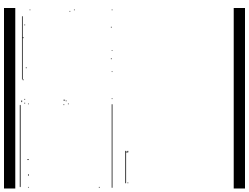
But

Butterfly effect found in 1950's: arbitrarily small perturbation of initial conditions have unpredictably large consequences.

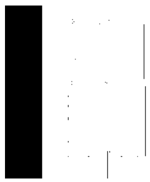
- The "Lorentz" equations: very simplified version of the "weather " equations, give rise to chaotic behaviour.

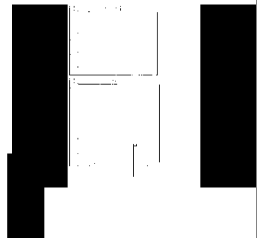
Double pendulum

- Small swings are predictable,



Medium swings are quasi-periodic





Large ones are chaotic

Weather is also chaotic

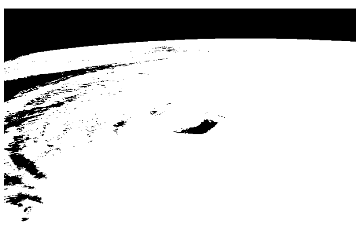
- You cannot predict the future weather precisely.
- However, buried in this are some predictable elements. e.g. we <u>cannot</u> predict an "el Nino" event, but we <u>can</u> predict the consequences once it has happened.
- Note "weather" prediction and "climate" prediction are (almost) unrelated

- Can predict globally, not locally

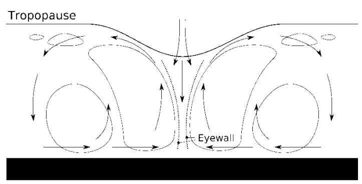
Can predict how fast a river will flow

- But not how it will behave on small scale

Hurricanes



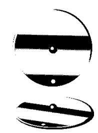
- Driven by same set of processes
- Warm water in Caribben is easy to evaporate,
- energy transferred from ocean to upper atmosphere
- converts to mechanical energy (i.e. wind)

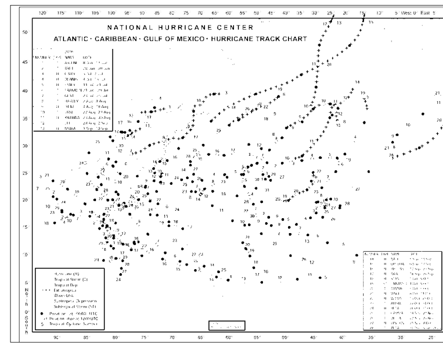


- Energy release ~ 10^{20} J/day
- power is 1PW = 10^{15} W ~ 100 times total power consumption of humanity

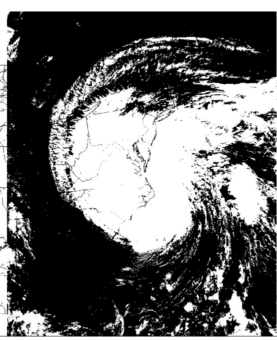
Hurricanes rotate anti-clockwise and drift west & north because of Coriolis force

Earth rotates, so it is a non-inertial frame of reference





Can do it over the short term Hurricane Isabelle



Jesse Brown

-If the earth were to start spinning in the opposite direction would that change the climate?
- I know the rotation of the earth causes night and day but does the rotation also have an effect on the climate?
- 3) I'm sure it can be explained but I don't believe it is a simple answer

Interesting!

1. Globally, no change, but ....
2. Hurricanes rotate anti-clockwise and drift west & north because of Coriolis force (effect of the earth being non-inertial frame of reference)
3. Now they would rotate clockwise and drift east,
4. California and Spain would become hurricane areas!

Text

Weather and global warming

- Global warming does **<u>not</u>** imply that all temperatures will just shift upwards.
- The range of conditions will become more extreme
- e.g Pellston Mich. had previous temp record for March 22nd 2012 broken by 17° (New Scientist)
- Snow at Coliseum in Rome!

Shifting weather

THE THEORY

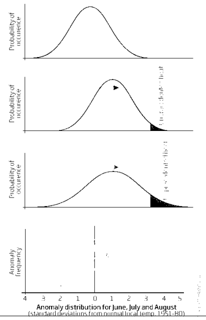
In a constant climate, temperatures should fit a bell curve - average temperatures are most likely and extremes of hot and cold are rare

If the climate warms, this probability distribution will shift. Even in the simplest scenario, if the distribution shifts but the shape remains the same, the probability of moderate heat increases slightly while the probability of extreme heat increases greatly

In theory, the distribution could not only shift but also widen, if weather becomes more variable as it warms. This is worse, as it means there will be an even greater increase in the probability of extreme heat, yet extreme cold will still occur occasionally too

WHAT'S REALLY HAPPENING

Land temperatures over the northern hemisphere show the bell curve is both shifting and widening as the planet warms



09 July 2012 by **Stephen Battersby**

- e.g summer of 2010 lies totally outside expected range
- extra heating is likely to increase number and strength of hurricanes

The Hot Summer of 2010: Redrawing the Temperature Record Map of Europe

Originally published in Science Express on 17 March 2011, doi: 10.1126/science.1201224
Science 8 April 2011:
vol. 332 no. 6026 220-224