



Government
Office for
Science

Threats and opportunities - the scientific challenges of the 21st Century

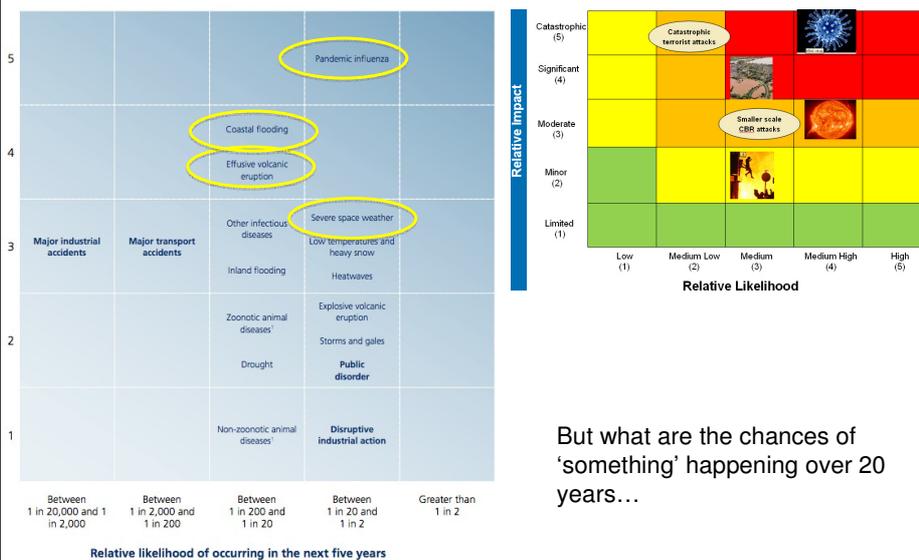
The Foundation of Science and Technology
6 February 2013

Professor Sir John Beddington
Chief Scientific Adviser to HM Government



Government
Office for
Science

The National Risk Register looks out five years



But what are the chances of 'something' happening over 20 years...



Government Office for Science

Emergencies: the 2009 H1N1 influenza virus (swine flu)

- 6 pandemics in 120 years.
- **Approximately 65% chance of another in 20 years...**
- Severity highly variable

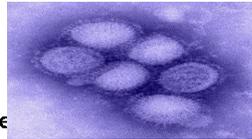
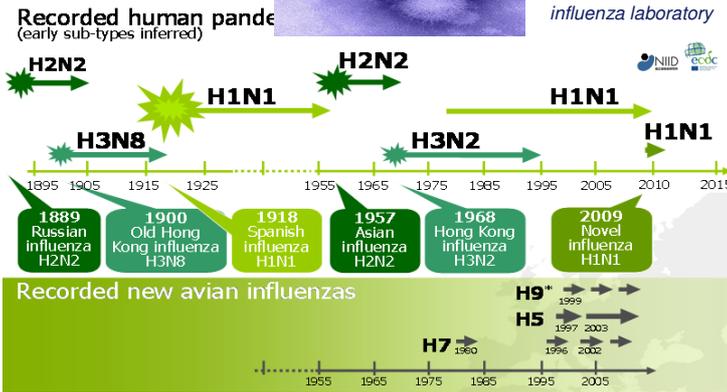


Image of HN1N virus
Source – US CDC influenza laboratory



Recorded human pandemics of influenza Source: NIID and ECDC 2009



Government Office for Science

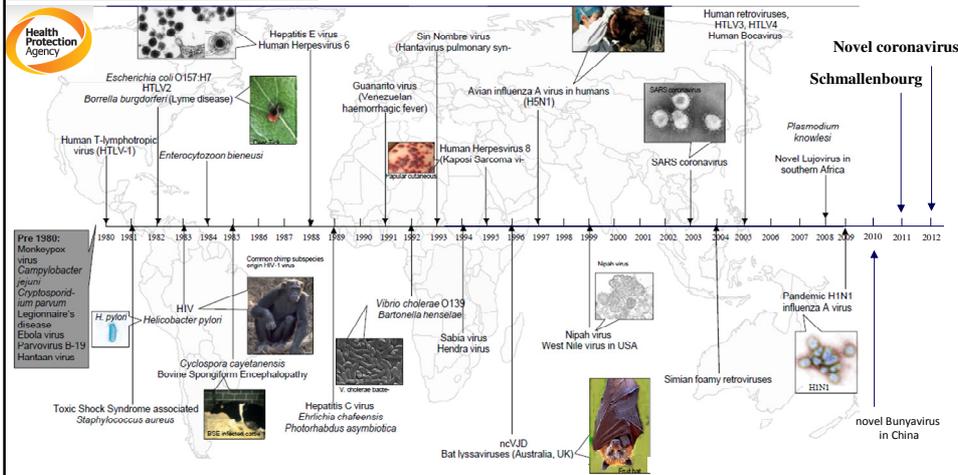
New diseases, animals and plants

Plant diseases also spreading globally: e.g. *Chalara fraxinea*



One consequence of a 'small world'

Animal and human diseases:

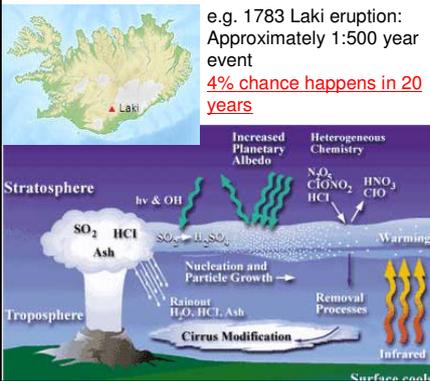




Volcanoes

Effusive eruption

- Potential for emission of huge amount of noxious gas, widespread:
- Chronic health effects on ground
- Acute health effects in cabins, ground aircraft
- Potential for significant global cooling and disruption to crop growing seasons



Explosive eruption

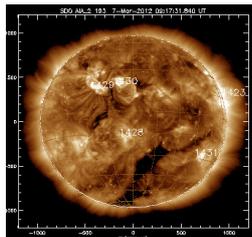
High altitude ash clouds ground aircraft in Northern Europe



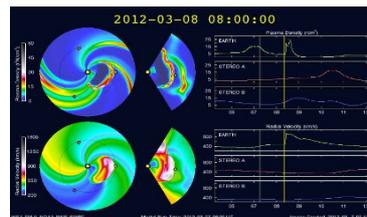
- Average of 25 Icelandic eruptions every 100 years
- **Chance of no further eruptions in 20 years: <1%.**
- Disruption dependent on wind direction and composition of ash



Space weather



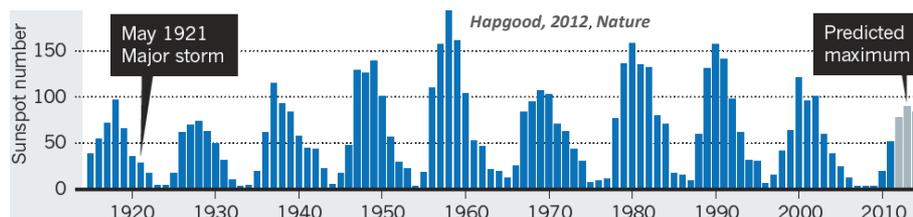
- Potential damage to National Grid
- GPS receivers unable to track satellites.
- Interference with high frequency communications



0015UTC on Wednesday 7th March 2012 a X-5 solar flare erupted from sunspot 1429 in the North West segment of the solar disk.

Solar storms approximately follow the Solar maximum (rough 11-year cycle). Next solar maximum is expected 2012/13.

Approximate chance of a Carrington type solar superstorm (e.g. 1859) in 20 years: 20%

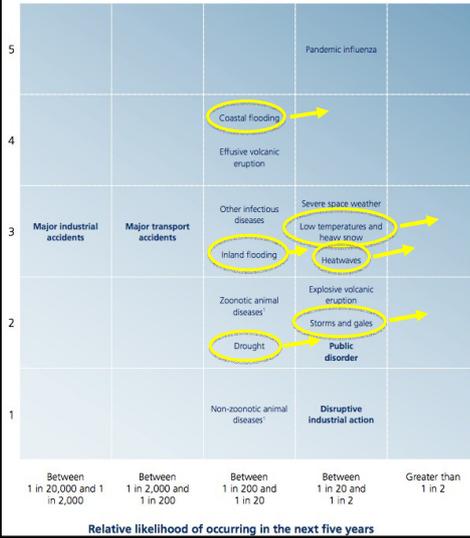




Government Office for Science

Many NRR events are climate dependent

Weather variability increasing with climate change



Other climate-related events....

2010: Record-breaking heat wave in **Russia**. Drought caused extensive wildfires, thousands of deaths and worldwide food commodity rises

2010: Floods in **Pakistan**. Over 300mm of rain between July 28th-30th in Peshawar leading to flooding that submerged 20% of Pakistan

2012: 40C (104F) temperatures sparking a wave of fires in New South Wales, Victoria and South **Australia**.

2012: Most severe and extensive drought in the **US** for at least 25 years. Serious impacts on the crop and livestock sectors



Government Office for Science

Global temperature anomalies

Expected area covered under "normal" historical conditions

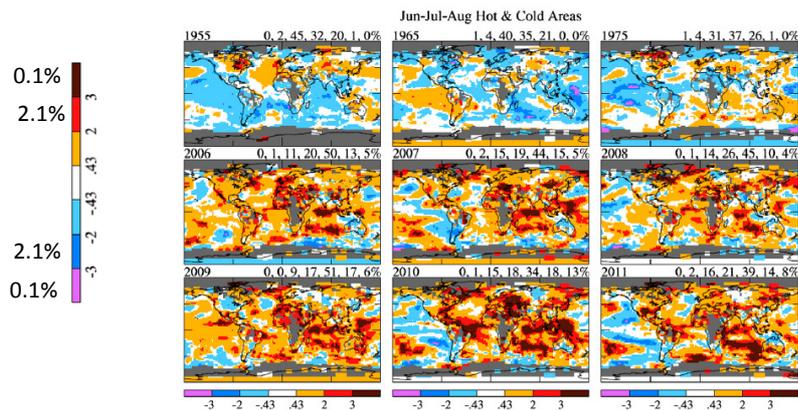


Fig. 3. June–July–August surface temperature anomalies in 1955, 1965, 1975, and in 2006–2011 relative to 1951–1980 mean temperature in units of the local detrended 1981–2010 standard deviation of temperature. Numbers above each map are percent of the area with data covered by each category in the color bar.

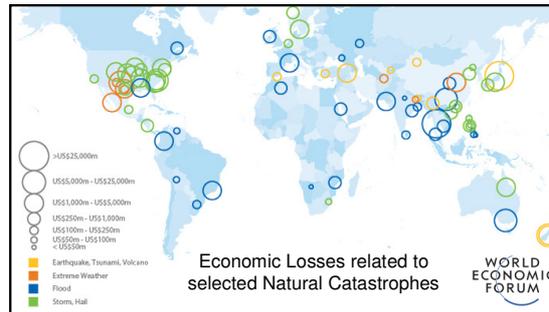
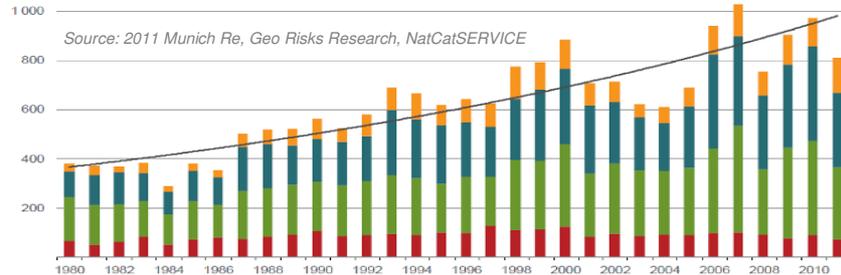
Perception of climate change PNAS, online Aug 2012

Courtesy of Tim Benton and Mike Bushell

James Hansen¹, Makiko Sato², and Reto Ruedy³



Increase in severe weather events and cost of natural catastrophes



Last year >3200 monthly extremes passed in US alone

US heatwave last summer 60x more likely than it would have been without climate change

IPCC (2012) indicates 1-in-20 year heat events will become 1-in-2 by end of C

Patterns of global supply threatened

Courtesy of Tim Benton and Mike Bushell

PERSPECTIVE

NATURE CLIMATE CHANGE DOI: 10.1038/NCLIMAT1454

Table 1 | List of record-breaking meteorological events in the past decade and their impacts.

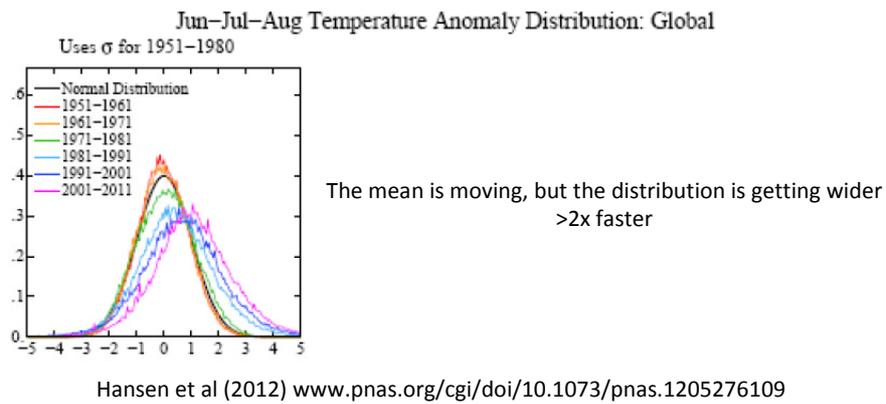
Year	Region	Meteorological record-breaking event	Impact, costs
2000	England and Wales	Wettest autumn on record ³³ since 1766.	£1.3 billion (ref. 27).
2002	Central Europe	Highest daily rainfall record in Germany ⁴² since at least 1901.	Flooding of Prague and Dresden, US\$15 billion (ref. 84).
2003	Europe	Hottest summer in at least 500 years ³⁹ .	Death toll exceeding 70,000 (ref. 31).
2004	South Atlantic	First hurricane in the South Atlantic ⁴³ since 1970.	Three deaths, US\$425 million damage ⁴⁸ .
2005	North Atlantic	Record number of tropical storms, hurricanes and category 5 hurricanes ⁴² since 1970.	Costliest US natural disaster, 1,836 deaths (Hurricane Katrina).
2007	Arabian Sea	Strongest tropical cyclone in the Arabian Sea ⁴³ since 1970.	Biggest natural disaster in the history of Oman ⁴⁹ .
	England and Wales	May–July wettest since records began in 1766 (ref. 43).	Major flooding causing ~£3 billion damage.
	Southern Europe	Hottest summer on record in Greece ³⁹ since 1891.	Devastating wildfires.
2009	Victoria (Australia)	Heatwave breaking many station temperature records (32–154 years of data) ³⁴ .	Worst bushfires on record, 173 deaths, 3,500 houses destroyed ³⁴ .
2010	Western Russia	Hottest summer since 1500 (ref. 69).	500 wildfires around Moscow, grain-harvest losses of 30%.
	Pakistan	Rainfall records ⁴⁴ .	Worst flooding in Pakistan's history, nearly 3,000 deaths, affected 20 million people ⁴⁴ .
	Eastern Australia	Highest December rainfall recorded since 1900 (ref. 45).	Brisbane flooding in January 2011, costing 23 lives and an estimated US\$2.55 billion ⁴⁶ .
2011	Southern United States	Most active tornado month on record (April) ³ since 1950.	Tornado hit Joplin causing 116 deaths.
	Northeastern United States	January–October wettest on record ³ since 1880.	Severe floods when Hurricane Irene hit.
	Texas, Oklahoma (United States)	Most extreme July heat and drought since 1880 ³ .	Wildfires burning 3 million acres (preliminary impact of US\$6–8 billion).
	Western Europe	Hottest and driest spring on record in France ³ since 1880.	French grain harvest down by 12%. Not yet documented.
	Western Europe	Wettest summer on record (The Netherlands, Norway) ³ since 1901.	
	Japan	72-hour rainfall record (Nara Prefecture) ³ .	73 deaths, 20 missing, severe damage.
	Republic of Korea	Wettest summer on record ³ since 1908.	Flooding of Seoul, 49 deaths, 77 missing, 125,000 affected.

The selection criterion for this (incomplete) list was that the event was documented to be record-breaking (that is, unprecedented) in a long measurement series.



Government Office for Science

As climate change occurs variability in weather increases



Courtesy of Tim Benton and Mike Bushell

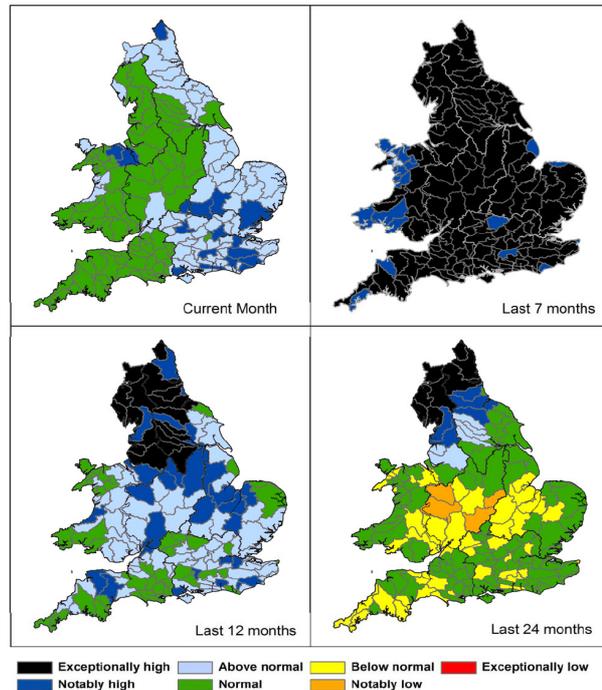


Government Office for Science

A parochial view

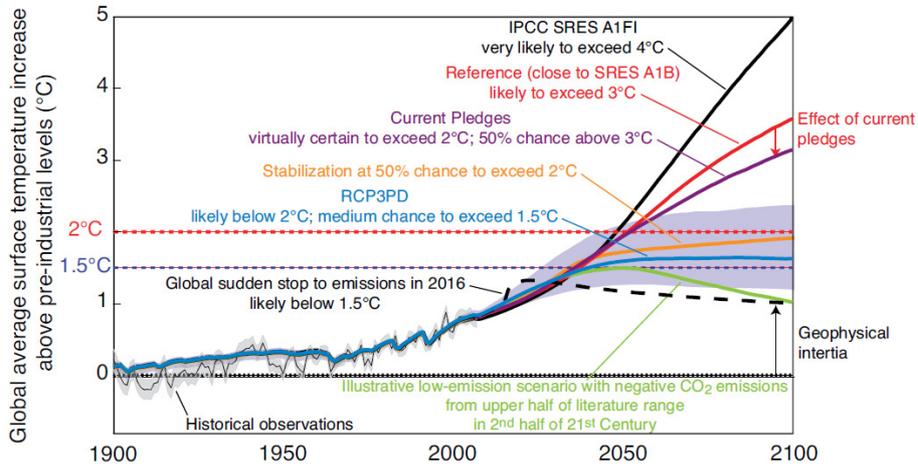
Rainfall in England and Wales

Source: Environment Agency: October 2012





Current projections indicate 2° C targets will be exceeded

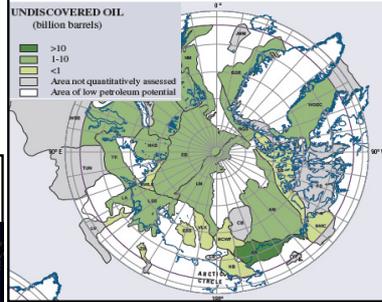


'Turn Down the Heat': World Bank/Potsdam Institute for Climate Impact research for Climate Analytics 2012



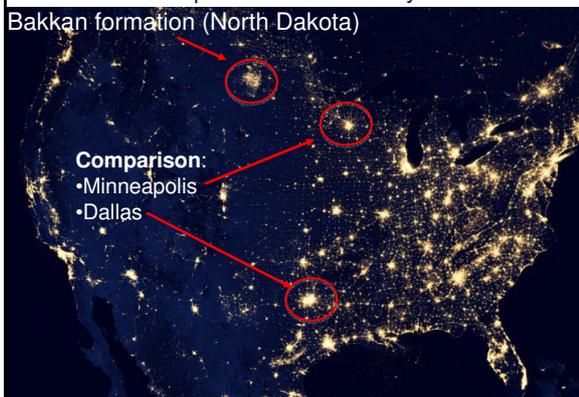
Major reserves of fossil fuels

Potentially huge Arctic resources

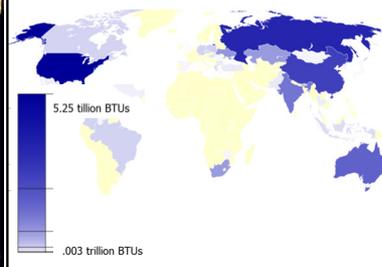


US Shale oil/gas reserves having significant impact on US economy

Bakkan formation (North Dakota)



Coal Reserves (10¹² BTU)





Delay in the climate system

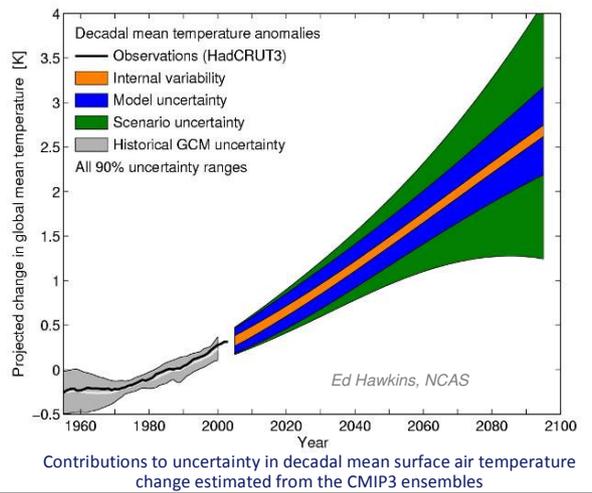
• There are uncertainties around predicting precise impacts due to difficulties of:

• Scenario uncertainty:

- Setting targets
- Achieving consensus
- Keeping to targets

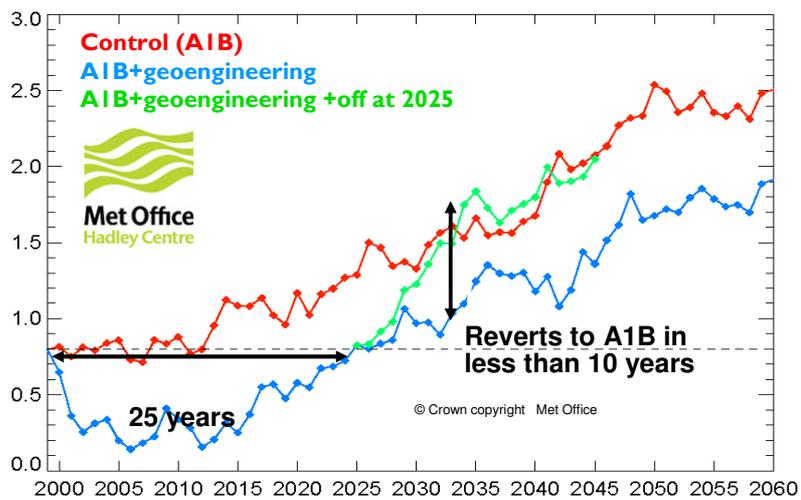
• Model uncertainty:

- Knowledge limitations
- Chaotic nature of the climate system



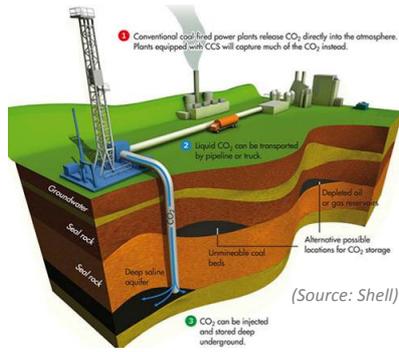
Geo-engineering

Potential Global Temperature Change from Cloud Ships





Geo-engineering by CCS, less problematic



Carbon Capture and Storage

- £1bn funding made available for CCS projects
- £125 million cross-government CCS R&D programme up to 2015

Primary need to reduce green house gases



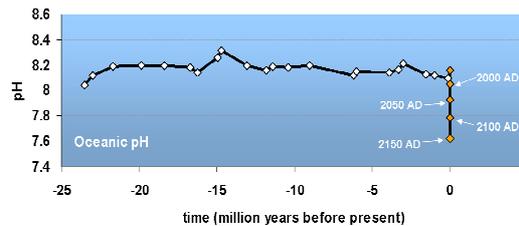
There are other solutions, for example:

- Hydrogen
- Wind
- Solar
- Geothermal
- Wave
- Natural Gas Hydrate
- Biofuels
- Nuclear
- Energy efficiency engineering

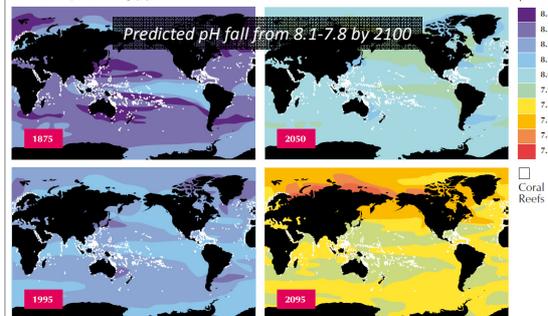


Challenge: Ocean acidification

- Oceans have absorbed around 30% of anthropogenic CO₂ emissions, altering chemical composition of the ocean
- Dissolved CO₂ since 1850s has decreased Ocean pH by 0.1 (Log scale → 30% increase in acidity)
- Ocean pH decreasing at an unprecedented rate – species will struggle to keep up
- Dissolution or inhibition of calcium carbonate formation
- Calciferous species affected e.g. crustaceans, corals.
- Impacts for: food security, tourism, coastal economies



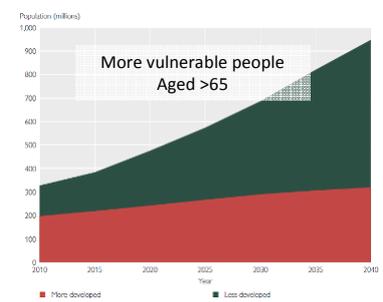
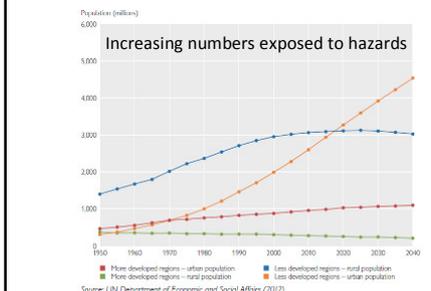
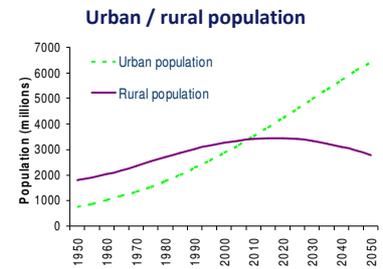
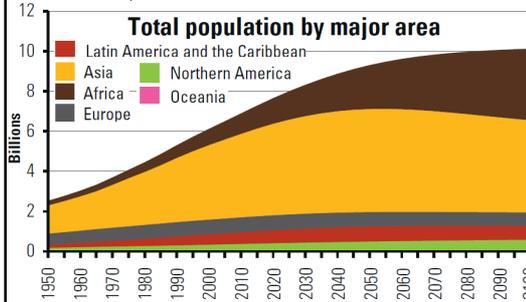
National Center for Atmospheric Research Community Climate System Model 3.1 (CCSM3) modelled decadal mean pH at the sea surface for 1875, 1995, 2050 and 2095. Source: after Feely et al., *Oceanography* (2008).





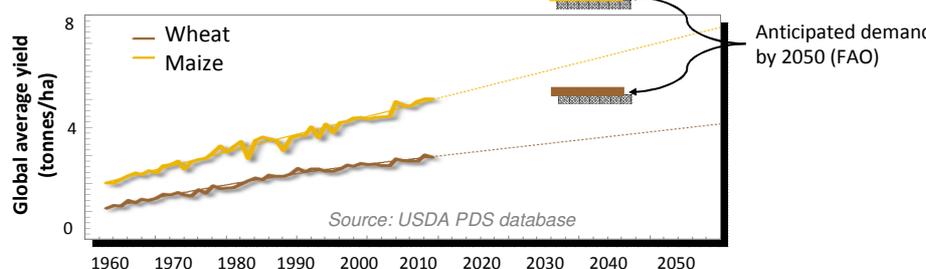
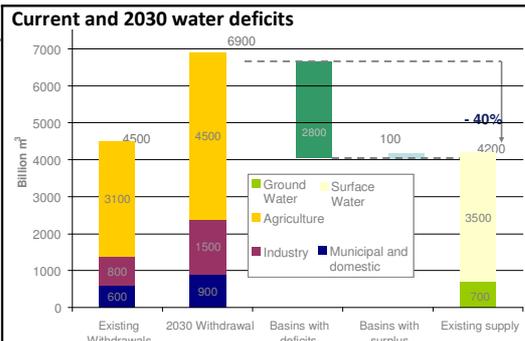
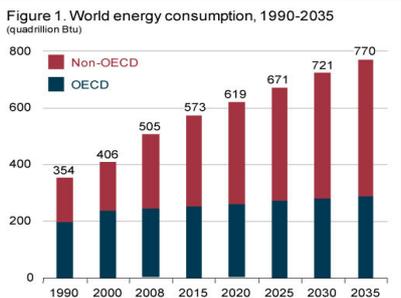
Government Office for Science

Challenge: An inevitable increase in population, urbanisation and vulnerability



Government Office for Science

Future challenge: Increasing demands on resources

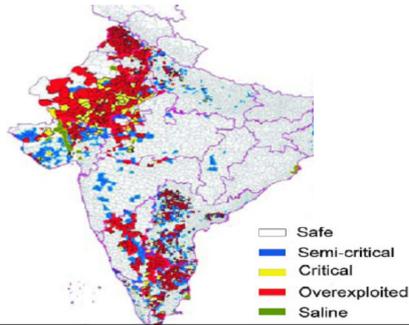




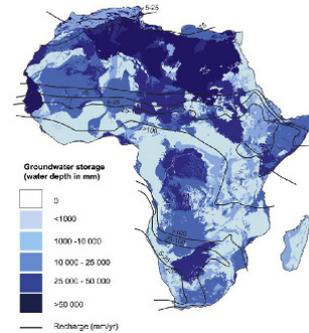
Government Office for Science

Groundwater extraction

Many aquifers have been over exploited in India



Recent mapping shows significant resources in Africa, which must be used sustainably

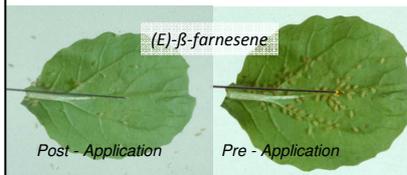


Government Office for Science

New technology: food production

Transforming wheat to emit the aphid alarm pheromone - a natural insect repellent

- uses less chemical pesticide;
- is non-toxic;
- has a lower carbon footprint;
- repels rather than kills the aphid;
- promote biodiversity (the pheromone attracts the natural predator);
- uses a naturally occurring process
- increases wheat yields; and therefore
- provides more sustainable agriculture



Role of engineering in driving efficient agriculture

- National Centre for Precision Farming
 - Knowledge exchange to develop "smart" agricultural machinery
- e.g. developing new robotic systems





Regulation - the need to keep pace with innovation and be proportionate to Risk

Risk = Hazard x Exposure

- Need for an evidence base to formulate regulation
- Consider the wider risks: unintended consequences

Bisphenol A – Baby Bottles

26 November 2010 Last updated at 00:13



EU bans bisphenol A chemical from babies' bottles

The European Commission has announced a ban on the use of bisphenol A (BPA) in plastic baby bottles from next year.

The commission cited fears that the compound could affect development and immune response in young children.

There has been concern over the use of BPA for some time, with EU-US trade negotiators



GM Organisms

- Potential for significant advances whilst addressing existing problems of high intensity agriculture
- Harmonised EU regulations stifle innovation with decade long approval process

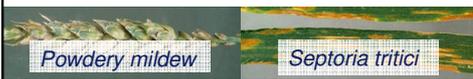
UK: a world leader in biotech but all practical application goes on overseas



Use of pesticides

- The UK is the 5th largest user of pesticides in Europe
- Regulations/Directives on pesticides in last 26 years has limited availability and made introduction of new products expensive

Loss of pesticide capability through regulation or crop resistance could have major impact, with yield loss of up to 25%



Clearly though, we do need additional (sensible) regulation:

Area for regulation:

Shale gas – to address environmental and safety concerns e.g. earthquakes and water pollution

Need to draw on evidence: e.g.

Royal Society and Royal Academy of Engineering have reviewed potential risks of shale gas extraction



Qualitative analysis can produce Yes or No answers which force action:

- Regulation needs to be proportionate
- Need open and realistic evidence base, to set safe or appropriate levels

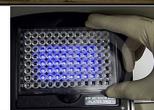
2010: Volcanic Ash

- Initially, 'safe' levels of ash set at an arbitrary level of presence or absence
- Difficult to justify to passengers and industry



DNA testing of food

- Extremely high sensitivity raises issues where there had not been concerns





Area for regulation: Computer trading

Worst price decline and reversal since 1929



Key interactions between regulatory measures

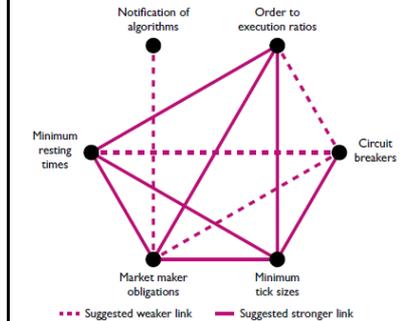
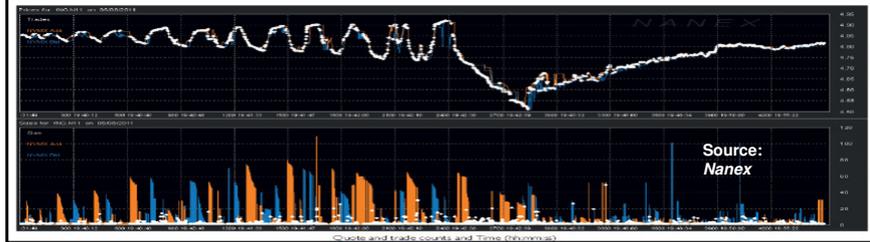
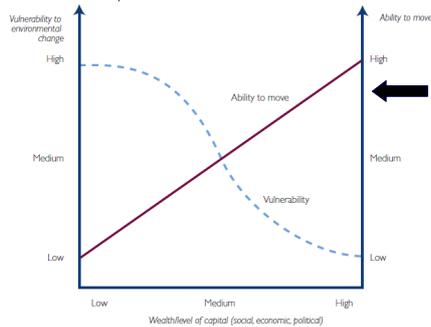


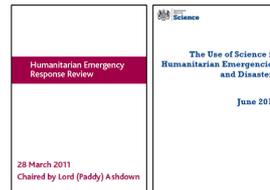
Figure 4.3: Violent cycling of natural gas futures prices on NYMEX, 8 June 2011 with a resulting crash and subsequent recovery



Disasters and Resilience



Foresight: level of capital correlates with vulnerability and the ability to move



Reducing Risks of Future Disasters



Storms, floods and droughts could all be fairly reliably forecast by 2040

Following from: Higher resolution modelling, next generation satellites for earth observation, better integration between models

Hydrometeorological hazards	Ability to Produce Reliable Forecasts					
	Now		2040			
	Spatial	Magnitude	Temporal	Spatial	Magnitude	Temporal
6 days ahead						
Storms	3	3	4	3	3	3
Floods	3	3	4	3	3	3
Droughts	5	5	5	5	5	5
6 months ahead						
Storms	2	2	2	3	3	3
Floods	2	2	2	4	4	4
Droughts	2	2	2	4	4	4
low ability	1	2	3	4	5	5

UK Met Office supported Philippines during Typhoon Bopha





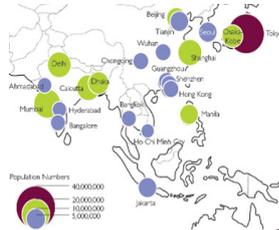
Government Office for Science

Vulnerability of cities and coasts

Geology, coastal erosion processes, oceans



NATURAL ENVIRONMENT RESEARCH COUNCIL British Geological Survey



Ordnance Survey
3D supports enhanced analysis

Met Office
What next?
Developing future capability in modelling and predicting coastal environments

Weymouth Bay Olympic showcase Coupled 333m atmosphere, 250m wave model



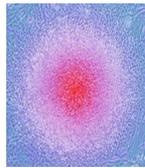
Government Office for Science

Are we running out of innovation?

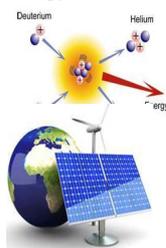
The big data revolution



Regenerative medicine



The transition to new energy sources



The Economist
Obama's controversial new men
Pressure for change builds in China
Men close the longevity gap
The ghastry gurus of personal finance
Microchipping your children

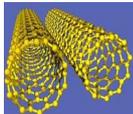
Will we ever invent anything this useful again?

The growing debate about dwindling innovation

Satellites and commercial use of space



Advanced materials



Agricultural technology - the next green revolution

Robotics



Synthetic biology



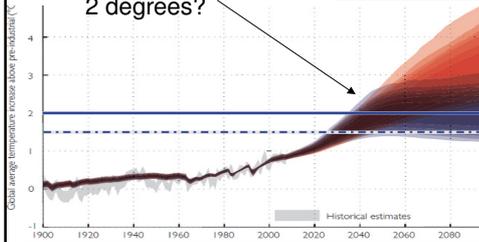
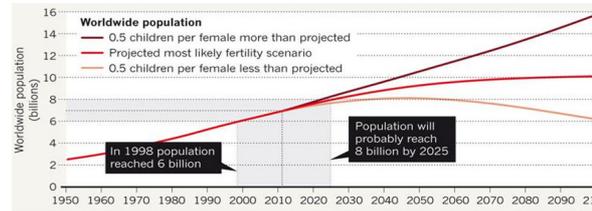


Challenges up to 2050

Tipping points

Population

Climate change
2 degrees?



- Population – 2.3 billion more people
- Urbanisation – 70%
- A more prosperous world?
- Complex demographic trends
- Migration to vulnerable areas
- Climate change

Requirements	2050	Source
Food	+60%	FAO (TOWARDS 2030/2050)
Water	+55%	OECD Environmental Outlook to 2050
Energy	+80%	OECD Environmental Outlook to 2050
Emissions (GHG)	+52% (with no policy change)	OECD Environmental Outlook to 2050