(Rules for)
Managing the Earth System

Dr. Alan K. Betts

Atmospheric Research

akbetts@aol.com

Solutions Semina

UVM

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Outline

- Huge topic
- Clash of Earth science & social values
- Climate system and water cycle
- Our choices; our responsibilities

- *Discussion*

Our present challenge

- How to integrate
  all that we know and understand

  – given the deep interconnectedness
    of life & climate on Earth

- **Strengths of science**:

  - integrity, honesty and communication

  - *particularly valuable in a society lost in ignorance and deceit*

- **Limits of science**:

  - tangible, measurable and communicable

  - *hard to deal with the complexity and interconnectedness of the living natural world*

The distinction between the human-made world and the natural world matters

- We understand the human-made world, the world of computers & technology – because we made it - it is more or less predictable.
- The same is not true of the natural world – which is far more complex and alive. We struggle to understand it and predict it.
- *E. F. Schumacher* called it the ‘created’ world.

Our choices are bounded

- *Whether we use religious, social or technical language*
- Humanity is an integral part of the earth system and dependent on its stability
- **We do not have the freedom to do what we wish, whatever our economic or theological doctrine**
- The response of the Earth system to our human-centered arrogance will be sufficiently large this century **that we will rethink our doctrine**
- **We would be wise to rethink sooner rather than later.**

Powerful but foolish

- In just 2 centuries, technology & fossil fuels have given us great power; and at first freedom from the mercy of the elements
- But with power has come *arrogance* and doctrinal beliefs that are incompatible with a sustainable Earth
- As limits are passed, ***either we change*** or we will be ‘managed’ by disasters.

Perspective for the 21st century

- Much of western political & economic doctrine [& theology] and was formed when humanity had a limited understanding of its relation to the Earth; but the structures of belief didn't matter too much
  as long as our impact was small.
- All this started to change with the industrial revolution powered by fossil fuels & has accelerated in the last 50 years. Now humanity has a *global impact on the natural world*, and understanding our relation to it is paramount.
- *Science and technology created this situation*, and must help us find a way out, by helping us understand the earth as a global system, now out-of-balance.

But science has become ‘valueless’

- Centuries-old split of science from ethics/religion
- Science preserved its factual integrity, but makes no value choices
- Theology (& political society) feel free to choose doctrine over understanding ‘reality’
- ***No-one accepts responsibility for the Earth***
- ***So collapse of our ‘human system’ is possible***

- The laws of science and the laws of the ‘creation’ are not separate: they show us the paths ahead. There is only one world and one reality:

  - *it is our understanding that is partial*

- We try to understand it with all the tools we have, because with understanding we get a clearer picture of what is truth:

  - *in all its paradox and complexity,*
    richness and tragedy

- For it is the truth that connects & sets us free:

  - *to face our responsibilities to each other*
    and to this world

The truth may be complex but it is critical: it takes honesty and understanding

- Industrialization, powered by fossil fuels
  has pushed the Earth out of balance
  and its time-scales are long
- It is more profitable in the short-term to spread
  uncertainty, confusion and delay
  than face the truth
- Climate science is now faced with an assault
  based on deception & manipulation

How do we intervene in complex systems?

- Dana Meadows classic paper on the twelve leverage points

- 3. Goal of system
- 2. Mind-set/paradigm of system
- 1. Transcend paradigms/change values

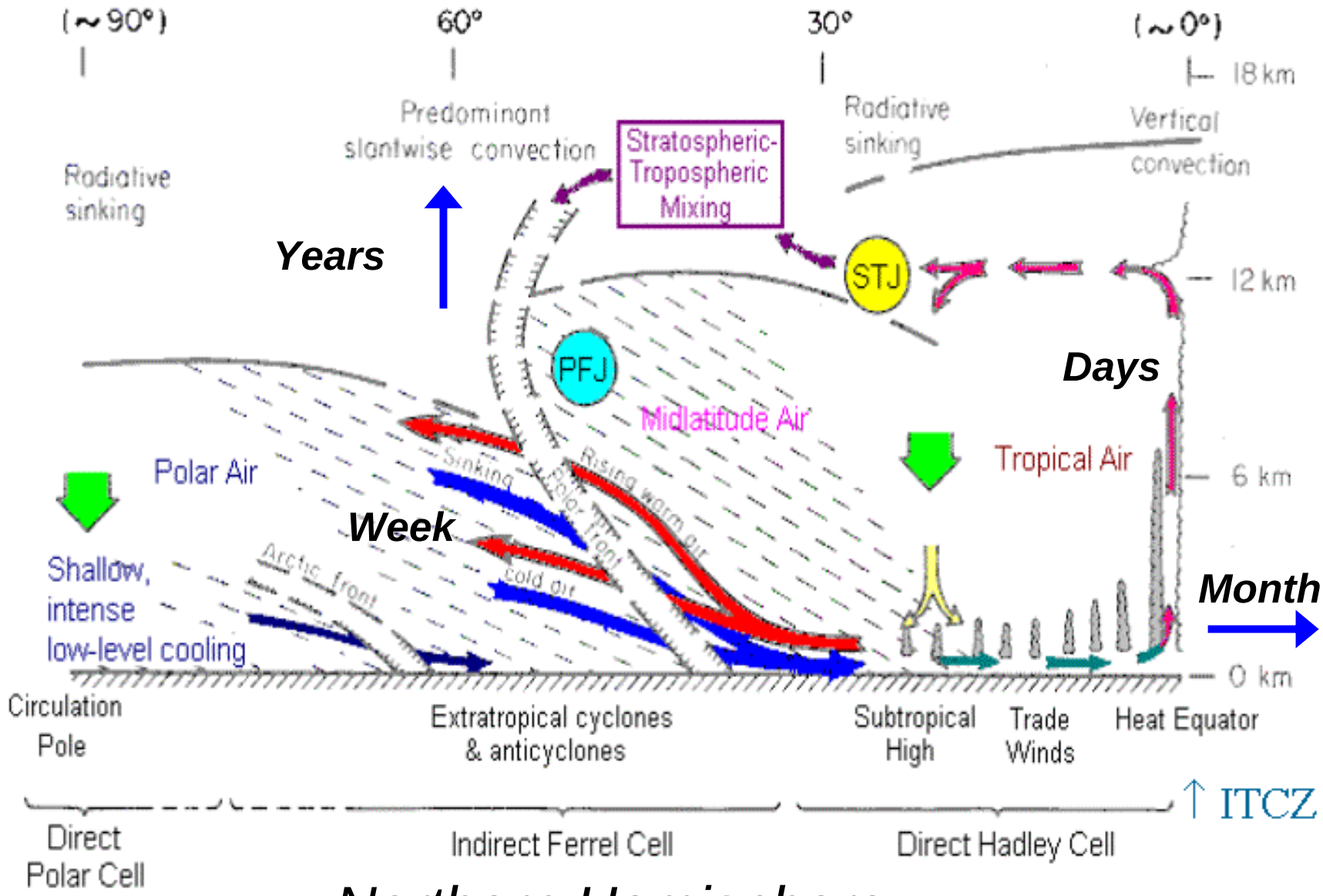
- **Propose that humanity base planning and decisions on *Earth system reasoning*, rather than traditional economic arguments**
- *Since it is likely that we have passed the carrying capacity of the planet.*

Three broad guide-lines or ‘rules’

Minimize impacts

- Minimize lifetime of human waste in the Earth system and eliminate waste with critical biosphere interactions
- Minimize the use of non-renewable raw materials; maximize recycling and remanufacturing
- Maximize the efficiency with which our society uses energy and water, and maximize the use of renewable resources.

Timescales



Northern Hemisphere

For all waste products..

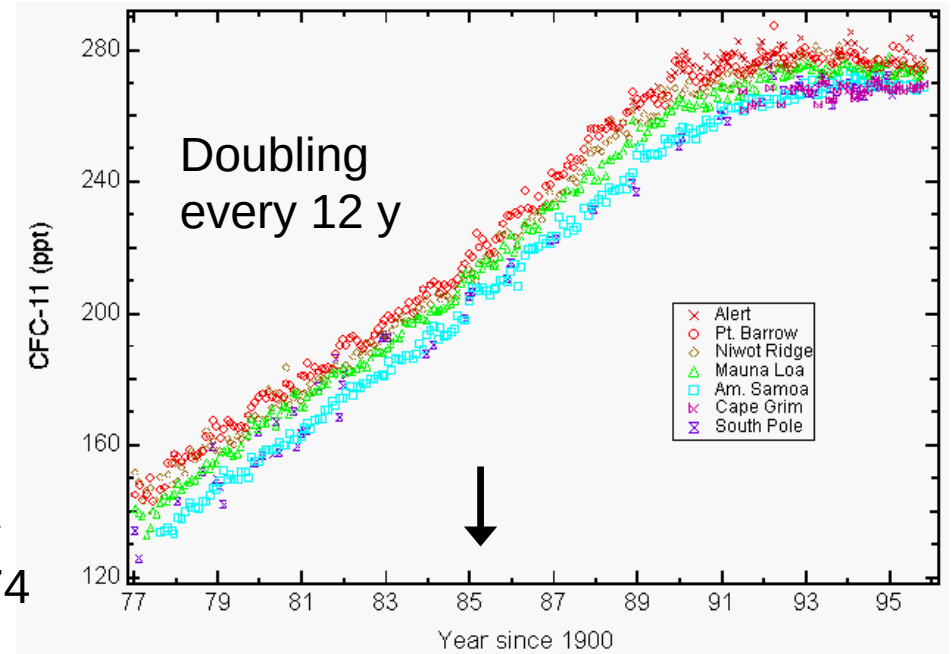
- Where will it be transported?

- What is its decay/transformation path?
- What is its impact on climate & biosphere?

- **If ignorant, don't make it !**
  Or go slow for 50 years! ***[What heresy!]***

Case Study: CFCs, HCFCs

- Chlorofluorocarbons: tightly bonded and inert in troposphere – refrigerants
- Technical triumph: *non-toxic*, non-flammable: cooling everywhere!
- Used as propellants for bug sprays, paints, hair conditioners



1935: Freon refrigerators

1974: Breakdown pathway found

1985: Antarctic ozone hole: discovered slow breakdown in stratosphere: century lifetime

- 1987 Montreal Protocol

Replaced with HCFCs

- Because with extra H atom, HCF_2Cl breakdowns faster – decade not century

- BUT more powerful greenhouse gas
- 'Global warming potential': 1810 x CO_2

- Phase-out by 2020

Climate system

- Beyond our control - except inputs!
- Geoengineering, except for direct removal of atmospheric CO_2, is a dream
- Barely measureable $2W/m^2$ drives large changes through positive feedbacks
- Climate system ‘unstable’ – ice ages
- Long response lags mean delayed feedback to human society
- One generation doesn’t see all the impact

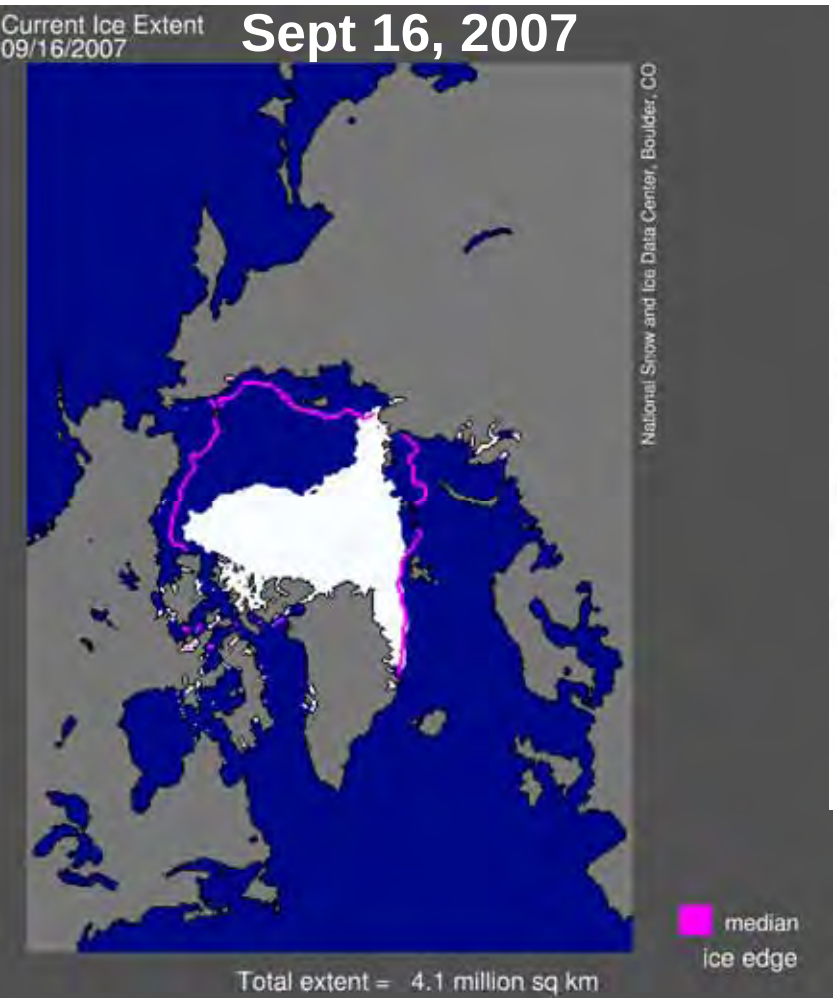
Atmosphere is transparent to ‘light’ but not to ‘infrared’ radiation

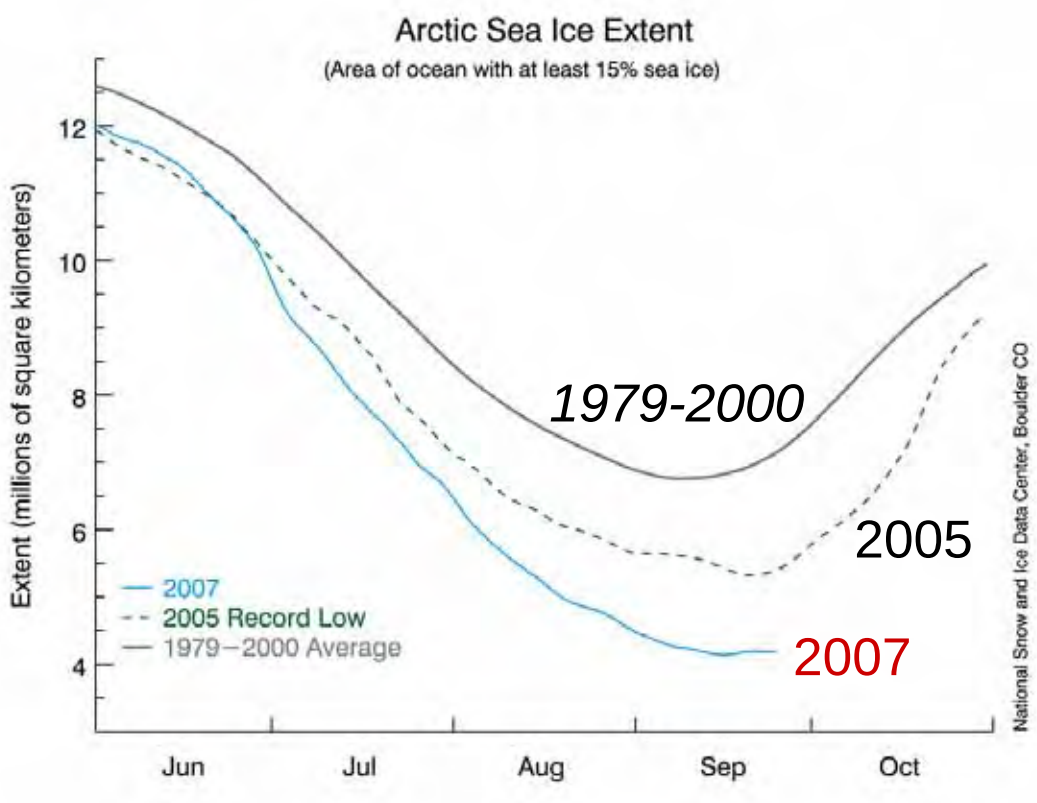
- **The earth cools by emitting infrared or heat radiation, but molecules H_2O, CO_2, CH_4 and O_3, CFCs, N_2O etc vibrate and absorb it:**
- **‘Greenhouse gases’**
- Atmosphere blankets the earth and keeps it about 59^{o}F warmer - so oceans don’t freeze
- Increasing greenhouse gases are warming earth further: ≈ 5^{o}F this century, unless emissions reduced

Floating Sea-Ice

- Floating sea-ice: fast response: years
- Ice has thinned from multi-year ice to mostly annual ice
- **Reduced albedo increases polar warming; more evaporation increases water vapor 'greenhouse'**
- Open water - more storms and wind-driven ice
- Sea-level affected very little; energetics a lot

Arctic sea-ice loss is accelerating



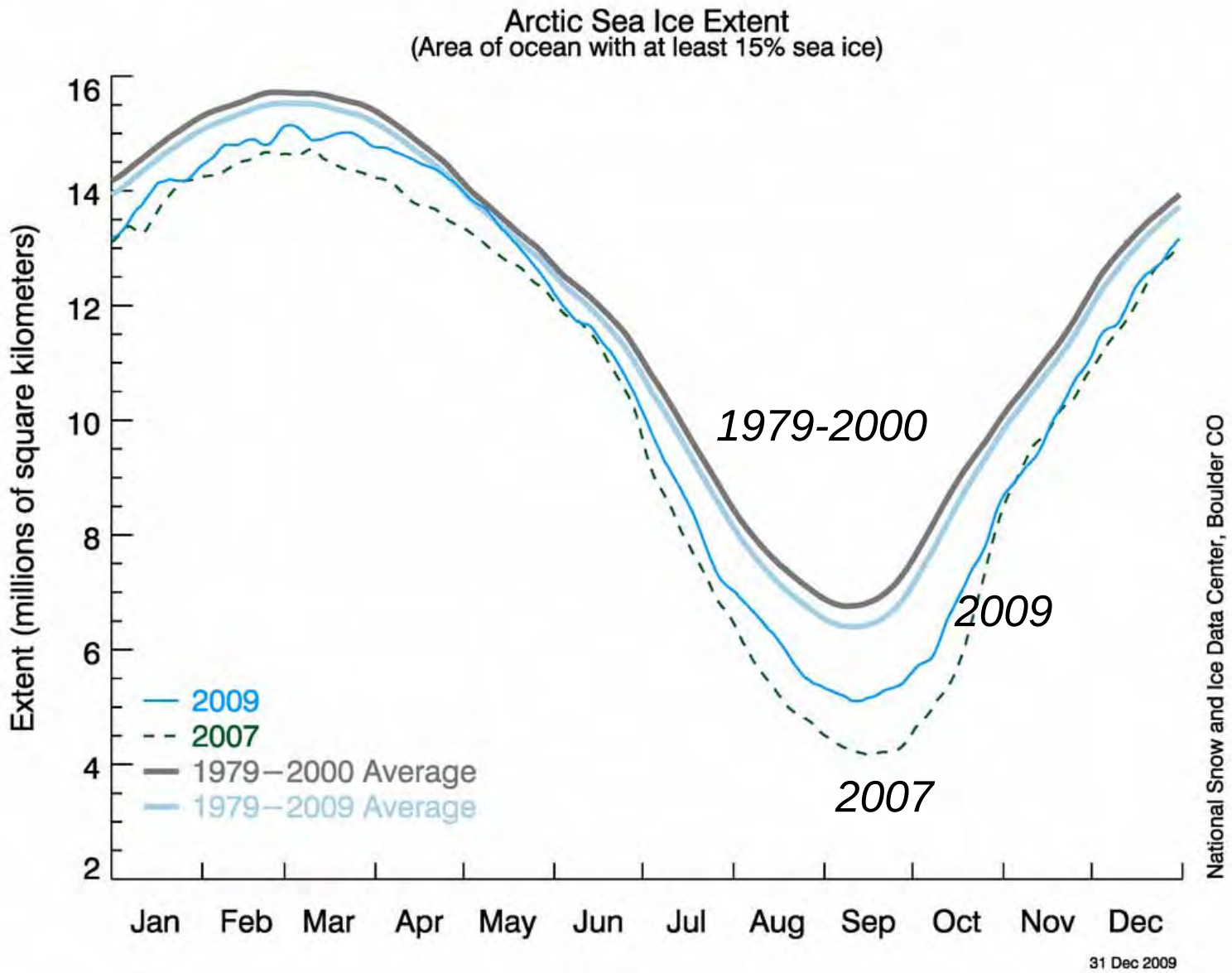


Double feedback: loss of reflective ice and increased water vapor greenhouse from more evaporation

(www.nsidc.org)

- 2007 saw new record ice-loss by huge margin
- 40% melted by September → warm Fall

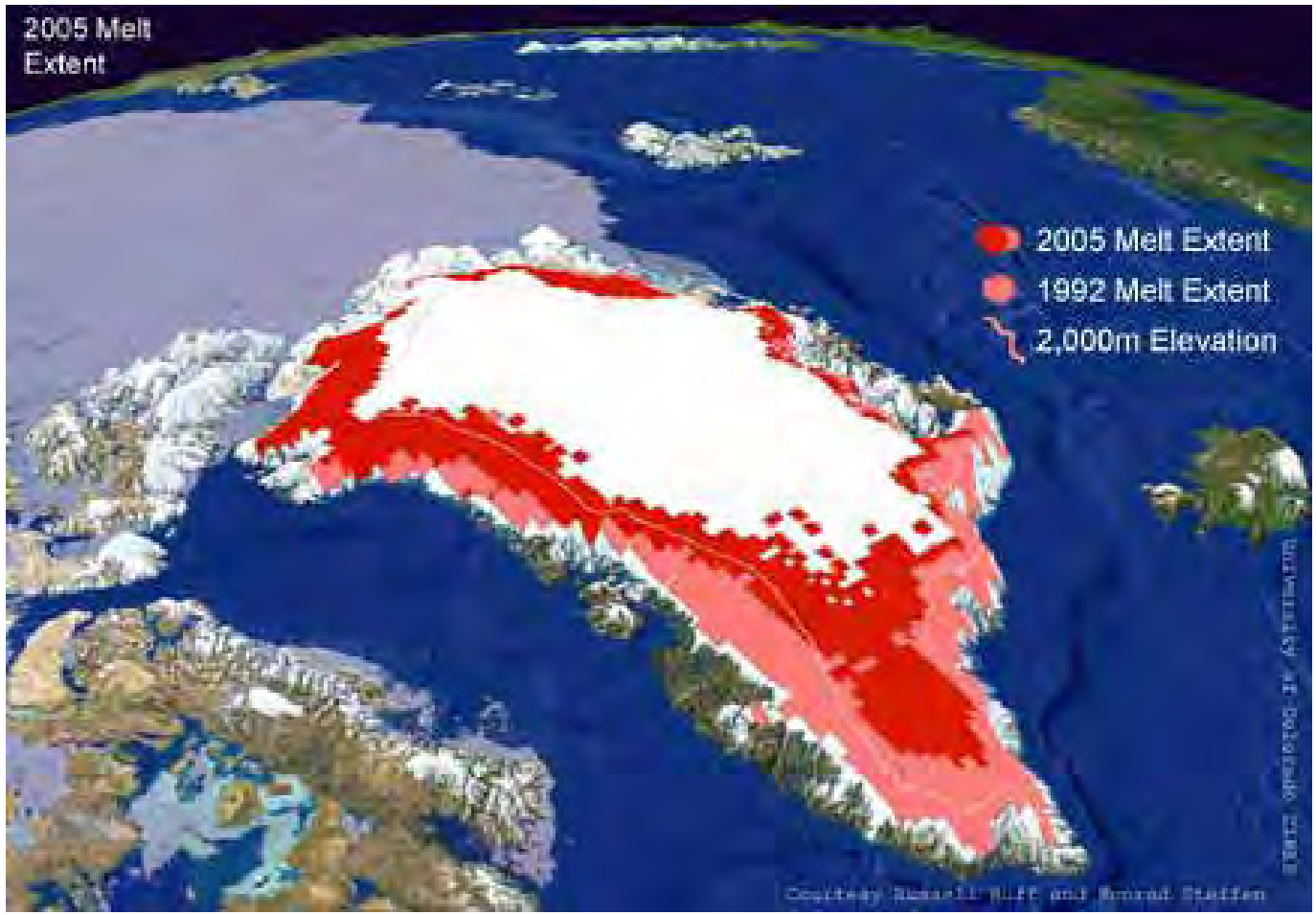
2007 and 2009 Sea-Ice



Grounded ice-sheets

- Longer timescale: decades, centuries +
- Slowly soak up a little of energy imbalance
- Melt increases sea-level: now +2mm/year
- Soot pollution reduces albedo & increases melt
- Ocean (3^{o}C) melts glaciers from below
- Past melt rates: > +2m/century
- Breakup unstable process [active research]

Greenland melt is rapidly increasing



- Summer melt area increase from 1992 to 2005
- Ice loss doubled 1996 to 2005 *[10% more in 2007]*

Melting water cascades down a crevasse to the base of the Greenland ice sheet in summer

Glaciers speeding up: will the ice-sheet become unstable?

Beyond our control!

- except inputs!

Source: Roger Braithwaite, University of Manchester (UK)

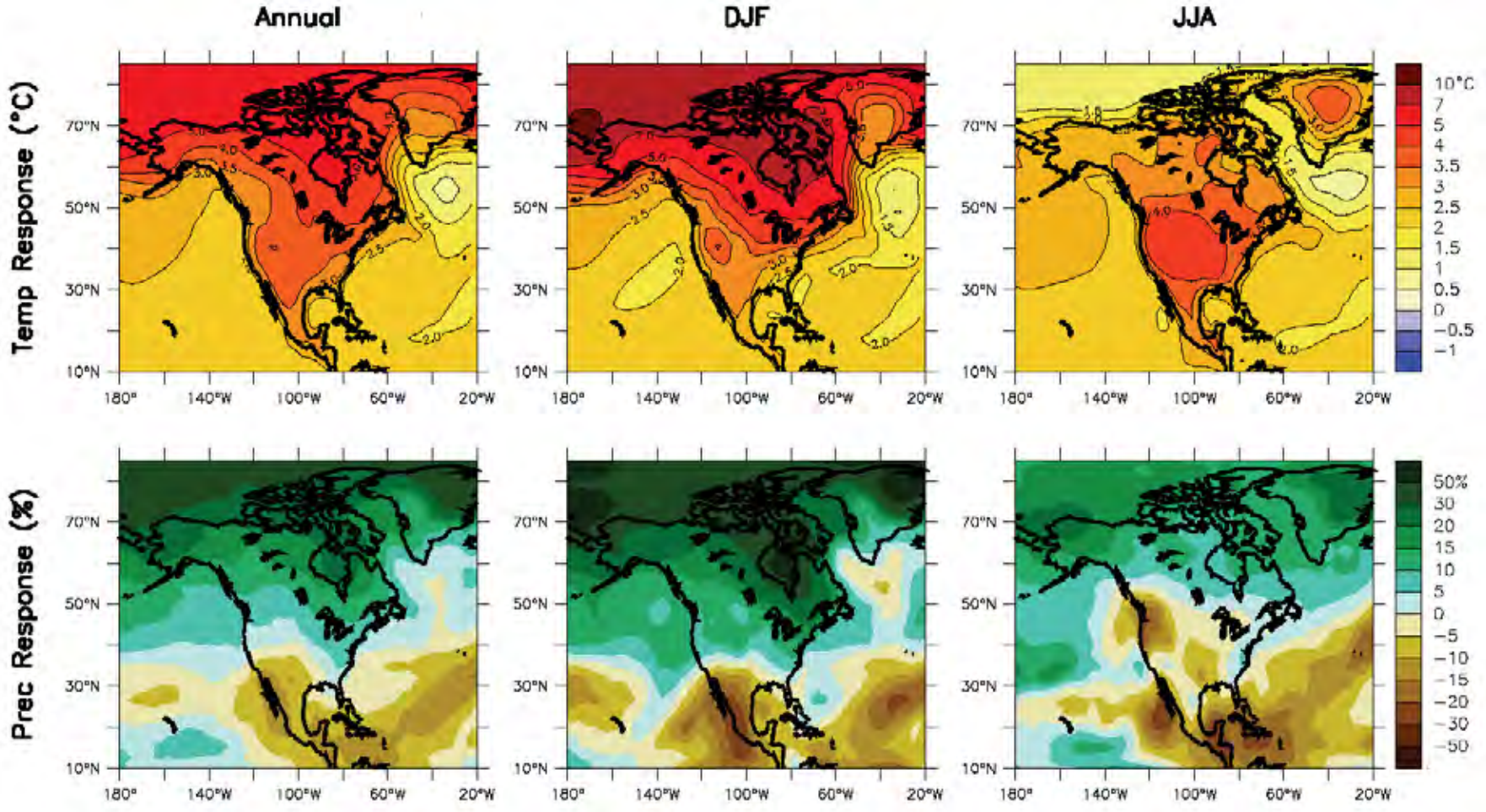
Sea-water flows under glacier - speeding melt

- Calving front of Eqip Sermia glacier, West Greenland [*Rignot et al. Nature Geoscience, 2010*]

Water cycle

- Central to climate to life and humanity
- We can model the future, but what is real?
- From the seasonal cycle you can see & grasp many key aspects

North American Changes: T, Precip.



- Temperature and precipitation changes over North America from an average of 21 AOGCM projections for A1B (high emission) scenarios.
- Top row: Annual mean, winter (DJF) and summer (JJA) temperature change between 1980 to 1999 and 2080 to 2099. **[VT winter: 4.5C, 8F]**
- Bottom row: same as top, but for fractional change in precipitation. **[VT winter: 25%]**

Spring 4/15/2008

- *Weather:*

  Sunny, dry week

- *Climate:*

  After snowmelt before leaf-out 'warm & dry' (little evaporation)

- *Climate change:*

  'Spring' earlier than 30 years ago

Spring transition

- Warm dry week to ten days in Spring, after snowmelt, past equinox
- Followed by drop of temperature of 3-5C with leaf-out – in a wave up the eastern seaboard
- **Many key climate processes:**

- Seasonal lags-melt of frozen soils
- Vegetation-evaporation coupling
- Latent heat of evaporation reduces surface T
- Evaporation-RH-cloud-WV greenhouse
- RH- LW_{net}-diurnal temperature range-frost

Summer transition

- Summer dry-down; soil moisture falls, evaporation falls, BL drier, θ_E falls, no precipitation
- May lock into a dry spell, a ‘drought’ till upset by strong weather system
- But it can go either way…
- 2008 and 2009, we had wet VT summers with + evaporation-precipitation feedback

Wet summers

- Both 2008 and 2009 were wet!
- Direct fast evaporation off wet canopies
- Positive evaporation-precipitation feedback

Farmer's delight

- Wet in spring
- Summer dry-down
- Low RH & no rain
- Hay dries fast!

Fall transition

- ***Mirror of Spring transition***
- **Vegetation tries to postpone first killing frost**
- By October 1, sun is past equinox and sinking
- Deciduous trees still evaporating, BL moist, BL cloud
- WV & cloud greenhouse reduces outgoing LW, reduces drop of T at night and prevents frost
- Till one night, dry air advection from north gives first frost, vegetation shuts down, frosts become frequent
- Dry atmos., large LW_{net} → large diurnal cycle
- Warm days and cool nights: 'Indian summer'
- Didn't happen in 2009 – wet soils and rain!

Fall colors

- Fall color after killing frost
- If delayed then less color as leaves die slowly
- Note blue sky – dry atmosphere
- First frost in VT getting later

Winter transition

- First heavy snow brings plunge of Temp. because reflection of sunlight drops net radiation below zero – *[plus reduced water vapor greenhouse]*
- Related to snow/ice-albedo feedback in climate system
- Related to accelerated warming & melting in the Arctic
- *Sublimation of snow by residual SW_{net} reduces surface solar heating to zero [& evaporation is reduced]*
- **Coupled to water vapor greenhouse feedback:** *evaporation falls with frozen temperatures & cloud decreases. Clear sky outgoing LW_{net} increases and locks in colder temperatures*

Rough Energetics

- Winter SW_{down}(clear) ≈ 130 Wm^{-2}
- 10cm fresh snow changes albedo from 0.15 to 0.75 & drops SW_{net} from 110 to 30 Wm^{-2}
- Residual 30 Wm^{-2} sublimes 1cm snow/day
- Snow loss increases as snow ages
  - snow lasts ≈ 5 days,
  - reducing solar heating to ≈ zero

Vermont winter, 2006

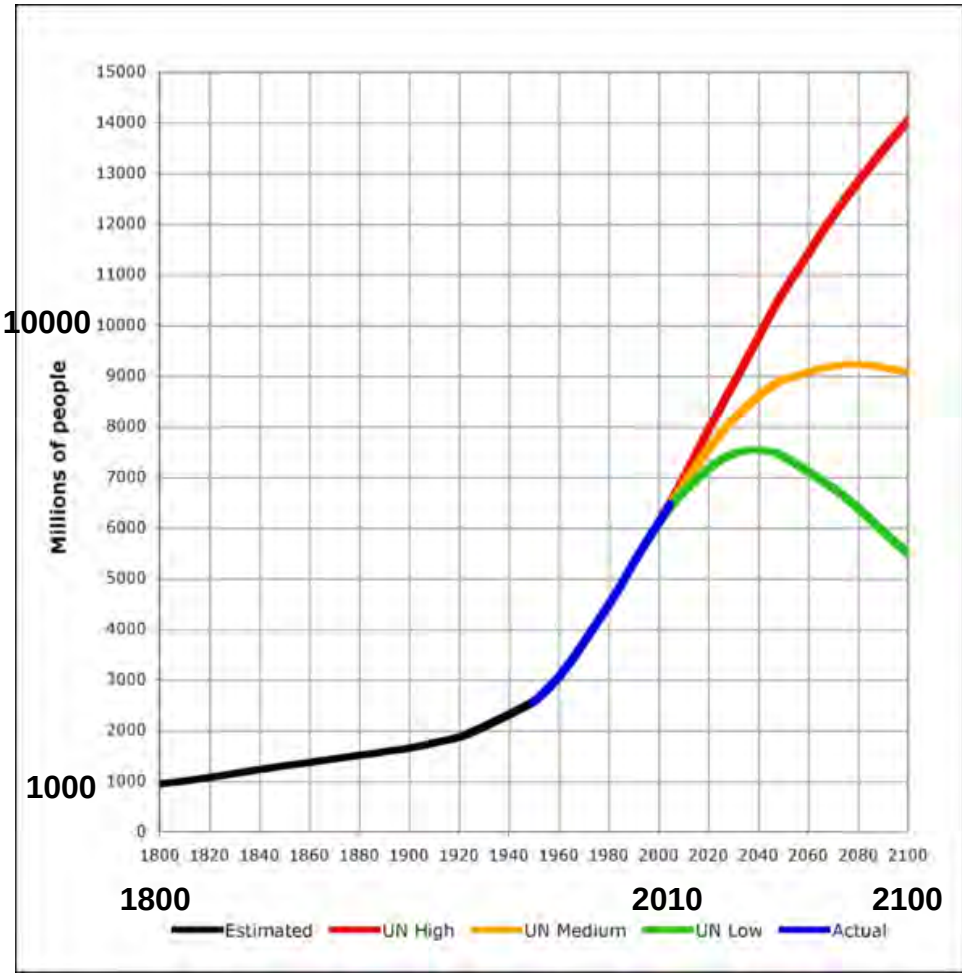
- **Sun is low; and snow reflects sunlight, except where trees!**
- **Sunlight reflected, stays colder; little evaporation, clear sky**

January 7, 2007

- Rain, not snow; grass still green, evaporation continues
- Sunlight absorbed, not reflected; stays warmer, sky cloudy

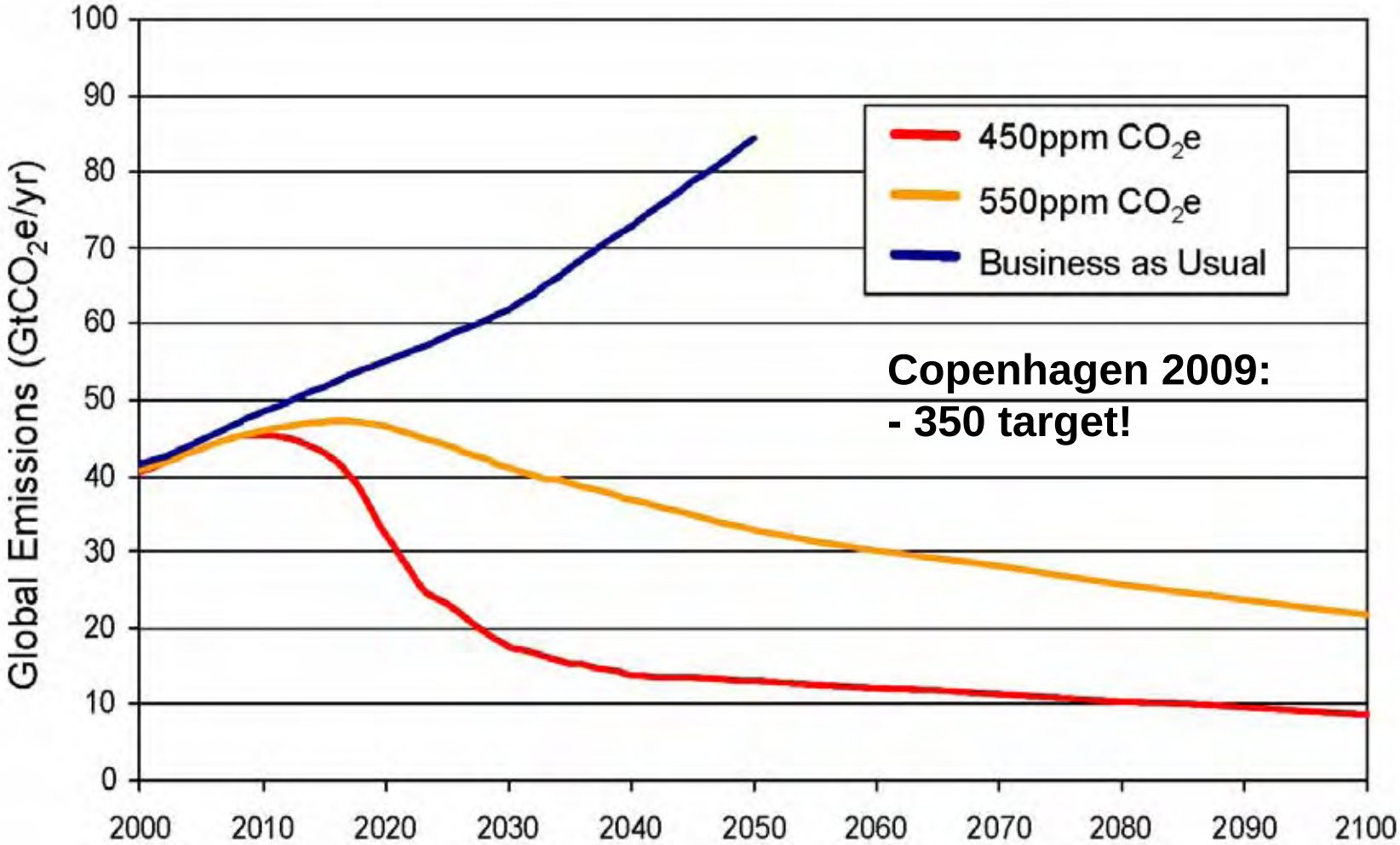
We passed the carrying capacity of the Earth in the 1980s [±]

- **Population is still rising**
- **Consumption is still rising**
- **Fossil energy use is still rising**
- ***We still 'believe' in Growth***
- ***Global poverty & suffering are growing***



How do we avoid 'Dangerous Climate Change"?

Emissions Paths to Stabilisation *[Stern, 2006]*



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- Maximize the efficiency with which our society uses energy and water, and maximize the use of renewable resources.
- SEEMS SIMPLE? Replace infrastructure: 40y.
- WHY NOT?

WHY NOT?

- It would impact our '*standard of living*'
- It would require '*management*' from local to global scales
- It conflicts with deeply held '*values*', both political & economic, especially *Growth*
- We believe that somehow technology will save us and *business as usual* can continue

- Our political systems won't consider it

(Self)-deception is a deep issue

- ***Three pillars of American dream are crumbling***
- "Economic growth" based on **fossil fuels, debt and consumerism** is **unsustainable**

  - and a disaster for the planet!

- **Individual "rights"** & needs of humanity must be balanced against the needs of the **earth's ecosystem**

  - *but the Constitution gives no rights to the Earth*

- **We have no workable paradigm to guide and manage technology** – so result is tremendous successes and catastrophic failures

What do we need?

- So we need honest, truthful but smart pathways forward
- That will not frighten people into paralysis
- That will spread hope, not anger
- That sidestep the ideological barriers with new language
- That develop adaptive governance
- That respect Earth system processes & limits

Discussion

What will this mean for you?

- ***Society needs to rethink its relationship to the natural environment and its ecosystems in less than one generation***
- ***Our 'lifestyle'*** is disconnected from what the earth can sustain
- **The large inertia** of the earth system is masking the extent of the crisis we face
- **The cost of fossil fuels is spiraling**
- Individual can rethink priorities but **societal changes are needed** at all levels: from towns to global
- **Local food; local power; community solutions**
- **Ask: Is this an efficient and sustainable way of doing this?**

The reality we face

- Competition for resources: water, food & energy.
- Fossil energy is transforming the earth and stressing its ecosystems: current path means loss of 30% of species and 100 millions of environmental refugees
- Efficient society, based on renewable energy is the only solution: huge transformation; but technically possible at reasonable cost

- **It will take honesty, courage, compassion and decades of sustained effort, starting now**