



# Hell and High Water: An Evolutionary Story

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# Our Evolutionary Story (Short Version)

- *H. sapiens* (for unknown reasons) evolved remarkable neurological capabilities for language, technological innovation, and social cooperation.
  - Some speculate that this may have been spurred by survival demands following Toba eruption about 75 thousand years ago.
  - By 50 kya modern humans are spreading throughout the world and displaying remarkable technological ingenuity, from weaponry to the sewing needle.
    - Energy + ingenuity fuel societal complexity.
    - A human society is a complex machine that requires energy to operate.
  - Fossil fuels enabled tremendous expansion of technology, population from 19<sup>th</sup> century onward.

# The Carbon Crisis

- But now we are faced with two urgent, related problems:
  - Rapid depletion of highest-quality fossil fuels.
  - Global warming, acidification of oceans, due to our use of fossil fuels.
  - T. Homer-Dixon: “we are on the cusp of a planetary-scale emergency.”
- Depletion:
  - Good evidence that the world has already passed “Hubbert’s peak” for conventional oil.
  - This is why billions of \$\$ are now invested in fracking, tar sands, deep off-shore deposits, which no one would have thought worth the cost thirty years ago.

# From Crude to Crud

- Most of the best-quality oil (the “low-hanging fruit”) has already been burned.
- We are forced to move increasingly to higher-carbon fuels (such as coal, bitumen) which increase carbon intensity; “recarbonization” of industrial society.
  - There is still a fair bit of natural gas, but we flare off vast amounts of it or waste it refining bitumen.
- Hence, the decline in quality of fossil fuel supplies is another factor that tends to increase climate change.

# The Problem of our Time

- Our ingenuity (capacity to arrive at new and more appropriate and effective ways of doing things) seems to be failing us precisely at a time when we need it the most.
  - We have a failure of technological and scientific ingenuity (better ways to energize our society) ---
  - And we have a failure of “social ingenuity” (T. Homer-Dixon), the ability to devise socio-political arrangements that better suit the human *and* technological needs of our time.
- Why?
  - Is this *merely* because this is the single largest problem that humanity has faced since the time of Toba?

# Zombies Walk the Earth

- In October 2013 the latest IPCC report (AR5) was released.
- Armies of “climate zombies” walk the Earth in response:
  - “The planet has not warmed in 16 years.”
    - This is the “faux pause”:
      - In fact, the atmosphere has warmed about 0.1° C, other heat has gone into ocean.
  - “It’s cosmic rays.”
    - No.
  - “It is volcanic activity.”
    - No; in fact, it is more likely that dust from volcanoes has caused slight cooling counter-effect in past 10-15 years.

# More Zombies

- “Arctic sea ice is recovering.”
  - A little less melted in 2013 than in 2012, but the trend is disastrous; February 2014 was lowest February on record.
- “The Earth was warmer in the Middle Ages.”
  - False.
- “The hockey stick was based on cherry-picked data and it has been refuted.”
  - False; data in IPCC report and other recent research reinforce and extend the hockey stick.
  - It was the *critics* of the hockey stick who cherry-picked the data.

# *More Zombies!*

- “Carbon dioxide is good for plants.”
  - Of course; but excessive heat is not. Our planet supported lush forests and grasslands for millions of years on 280 ppm.
- “It’s the sun.”
  - No; solar variations in the past few decades are not nearly enough to account for observed warming, and in fact the sun has been very slightly less active in recent years.
- “IPCC AR4 grossly over-estimated how soon a certain glacier in the Himalayas would melt, and therefore the whole report is rubbish.”
  - It was a typo.

# Still More Zombies

- “Global warming is a vast, international, socialist conspiracy (fomented by Maurice Strong, according to some), involving hundreds of scientists and UN officials, with the purpose of enriching themselves on research grants and taking over the world.”
  - Um...no, sorry, not true either.
- And my personal favourite:
  - The icecaps won't melt, because God promised Noah that he would not destroy the earth by flooding again. (Rep. John Shimkus (R), 2009.)
    - No comment.

# Some Take-Aways from AR5

- Earlier predictions of warming have stood up very well.
- 95% certainty that observed warming is human-caused.
  - Up from 90% in 2007.
- Climate sensitivity between 1.5 to 4.5°C/doubling of [CO<sub>2</sub>].
  - Around 2.5—3°C is generally accepted value, but this remains subject of intense investigation.
- Bottom line:
  - “Limiting climate change will require substantial and sustained reductions of greenhouse gas emissions.”
    - Summary for Policymakers, IPCC AR5, SPM-13

# What IPCC AR5 Did *Not* Tell Us

- Critics of the IPCC accuse it of wild-eyed alarmism; in fact, it is *extremely* conservative; represents cautious consensus of 100s of scientists, with governments looking over their shoulders.
- Two major concerns were under-emphasized because of scientific uncertainties involved:
  - Possible sea level rise (SLR) due to “ice sheet dynamics.”
  - Possible bad news from paleoclimate.

# Sea Level Rise

- AR5 remains *conservative* in its prediction of sea level rise.
- This is *very important*, so let's talk about this a bit...
- Sea level can and does rise by several means:
  - Thermal expansion
  - Melting of mountain glaciers and icefields
  - Melting of continental glaciers (Greenland & Antarctica)
  - Collapse of marine ice domes (such as WAIS, the Western Antarctic Ice Sheet)
    - The latter is not well known outside the circle of professional glaciologists.

# Sea Level Rise

- IPCC: depending on how much emissions occur over next few decades, highest model range is 0.52 to 0.98 m SLR by 2100.
- Very bad; represents disaster for hundreds of millions of people.
- But this estimate *does not include collapse of the West Antarctic Ice Sheet* (WAIS).
- Why should we worry about WAIS?

# Antarctica: The Most Important Place on Earth?



# WAIS: The Restlessly Slumbering Giant

- WAIS (Western Antarctic Ice Sheet) is a grounded marine ice dome:
  - Mountain of ice filling up a large basin (Bentley Trench) that is up to 2500 m below sea level.
- There is evidence (partly from paleoclimate, partly from physical analysis) that if relatively warm sea water can get access to the base of such ice domes, they can collapse *catastrophically*, possibly even within a few years (though this remains controversial).
- Collapse of Bentley Trench would cause sea level to rise by about 3.3 m. (Prof. Richard Alley, AGU, Dec. 2013.)

# Battling Models

- Currently there is an intensely technical discussion among glaciologists & climatologists about how great is the risk of a catastrophic collapse of WAIS.
  - (There is a section of central Greenland that could also be vulnerable for similar reasons, but this is *probably* not such an immediate concern.)
- It was decided to leave this *out* of the predictions of AR5, since it was felt the scientific uncertainties are still too great.
- What is uncertain is *how fast* WAIS and Greenland will melt; there is *no question* that if it gets only a degree or two warmer than it is now, enough of them will melt to eventually raise sea level by several m.

# Pine Island Glacier Sends a Message

- Pine Island Glacier (PIG) is one of the major ice streams flowing out of WAIS.
- In January 2014, a study showed that it has calved far enough back that its grounding line (where the ice sheet sits on the sea floor) has retreated inside the sill and is now on the downslope leading into a deep trench.
- This is exceptionally bad news.
  - Reference: L. Favier, G. Durand, et al., Retreat of Pine Island Glacier controlled by marine ice-sheet instability, Nature Climate Change, 12 January 2014; DOI: 10.1038/NCLIMATE2094.

# Major Calving Event on PIG, Nov. 13/13



NASA Sat photo; B-31 was about 20 km x 45 km.

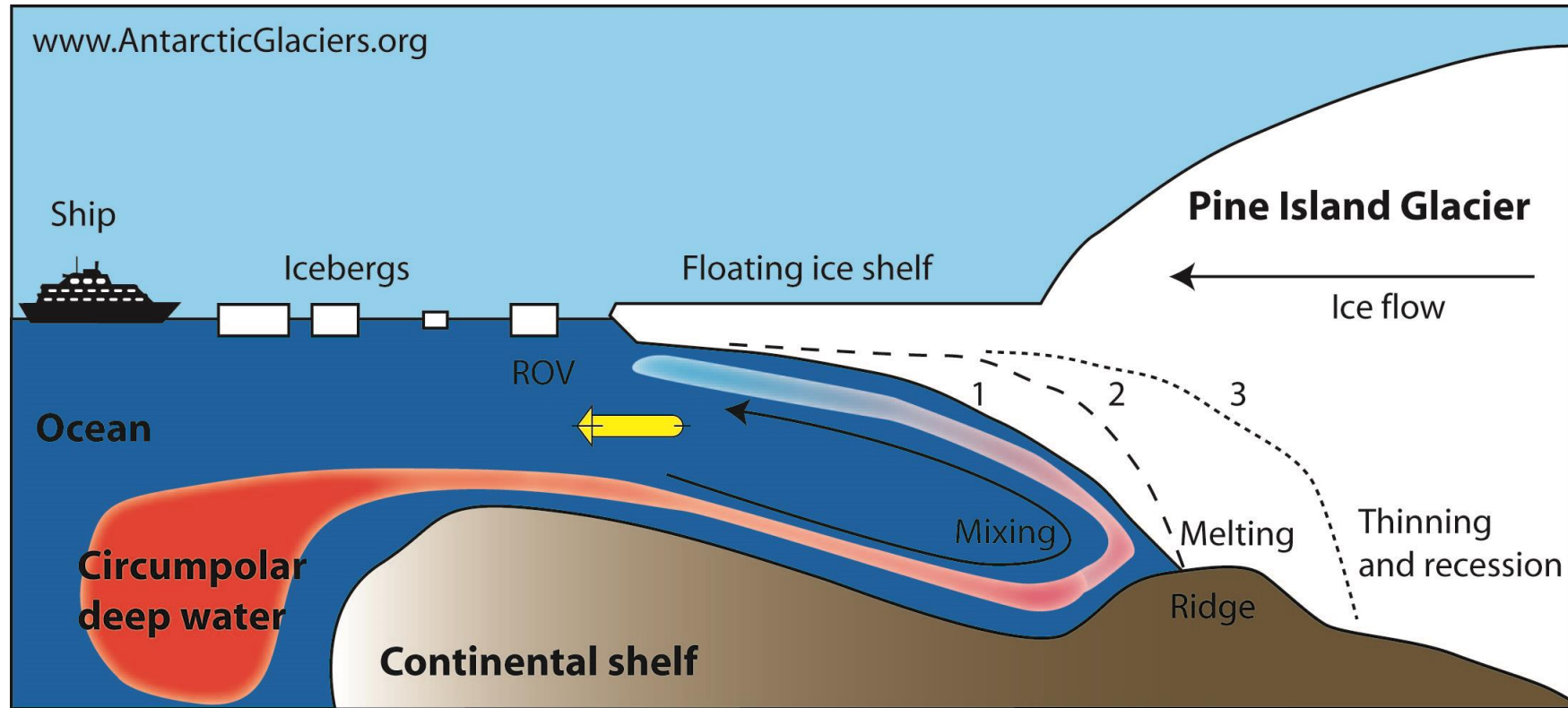
# Warning from a Glaciologist

- “West Antarctic ice sheet and CO<sub>2</sub> greenhouse effect: A threat of disaster,” J. H. Mercer, *Nature* 271, 26 January 1978, 321—5.
  - “One of the warning signs that a dangerous warming trend is under way in Antarctica will be the breakup of the ice shelves on both coasts of the Antarctic Peninsula, starting with the northernmost and extending gradually southward.”
  - Larsen A (1995), Larsen B (2002), ...
  - Mercer also correctly predicted that the centre of WAIS would begin to thin.



John H. Mercer  
1922—1987

# The Weak Underbelly of WAIS



1. Early 1970s. Pine Island Glacier is grounded at a bedrock ridge.
2. Warm, inflowing Circumpolar Deep Water melts the base of the glacier. The glacier steepens and accelerates.
3. Present day, observed by a remotely operated vehicle (ROV). Glacier is thinning and receding.

# Death by Calving Bay

- A marine ice dome can remain stable for tens of thousands of years, but if the grounding line retreats inside the sill, a calving bay opens up inside the basin.
- It brings warm sea water into the basin, risking rapid collapse of the ice sheet:
  - “...a relatively minor climatic fluctuation along the ice shelf calving barrier can unleash glacial dynamic processes independent of climate that cause calving bays to remorselessly carve out the living heart of a marine ice sheet.”
    - T. Hughes, “West Antarctic Ice Streams,” *Reviews of Geophysics and Space Physics* 15(1), February 1977, 43.

# Marine Ice Sheet Instability

- If a calving bay forms in WAIS, several processes take over *that are largely irrespective of air temperature*:
  - WAIS stands up to 1000 m above sea level; however, no ice cliff can stand more than about 100 m high since ice simply is not strong enough; thus, the walls of the calving bay will tend to collapse *rapidly*.
  - Simultaneously, it will crumble from below: ice will lose compressive strength as warm sea currents soften it.
  - Ice will tend to float away from the sea bed; buoyancy will cause it to lift, fragment, and overturn.
  - Channels in seabed underneath Bentley Trench will carry warm seawater far underneath the sheet.

# Marine Ice Sheet Instability

- Pressure inside calving face could literally lead it to explode, analogous to rock bursts in a quarry.
- These processes will *accelerate* as the calving face eats its way deeper into the basin.
- Conversation at Fall AGU, San Francisco, December 2013:
  - KP: That [pressure fracturing] could clear out the whole Bentley Trench in a few months.
  - Prof. Richard Alley: Yes, that's what we're afraid of.
- (Bentley Trench = 3.3 m of SLR)
- No glaciologist doubts that what I've described here is essentially what would happen if the sea water impinging on WAIS stays warm enough for long enough.
- Crucial question: *how long will this take? I.e., how much time do we have?*

# Good Philosophy from a Glaciologist

- “Nature’s best thermometer, perhaps its most sensitive and unambiguous indicator of climate change, is ice. When ice gets sufficiently warm, it melts. Ice asks no questions, presents no arguments, reads no newspapers, listens to no debates. It is not burdened by ideology and carries no political baggage as it crosses the threshold from solid to liquid. It just melts.”  
— Henry Pollack (*A World Without Ice*, Penguin/Avery, 2009, 114)

# The Second Problem: Back to the Pliocene

- Our current CO<sub>2</sub> level (around 400 ppm) is comparable to Pliocene epoch 3 to 3.5 mya:
  - Global mean temperature was 2 – 3 °C higher than today, and sea level was upwards of 25 m higher.
  - We have the CO<sub>2</sub> level sufficient to take us back to the Pliocene!
  - But how long will it take for the atmosphere to come to equilibrium?
  - That determines how much time we have in order to have a chance of correcting the problem.

# This Brings Us to the *Other* Problem

- Because we are already at a CO<sub>2</sub> level consistent with (+/-) 25 m SLR, stopping emissions *may not be good enough*.
  - This uncomfortable fact is beginning to be recognized.
- We may have to develop technology not only to replace fossil fuels as a source of energy, but *also* technology that can draw down CO<sub>2</sub> to safe levels (estimated to be 350 ppm but even a bit less could be wise; pre-industrial level was 280 ppm).
  - And we would have to do this rather soon.
  - In fact, this is recognized by the IPCC, but they have little to say about how it could be done.

# Message from the Pliocene

- In order to prevent catastrophic sea level rise and the equatorial regions becoming nearly uninhabitable by large vertebrates, it is increasingly evident that it is *not* good enough to stabilize [CO<sub>2</sub>] at 400 to 450 ppm.
  - *That* is probably a feasible goal, though not guaranteed.
- It is imperative that we reduce [CO<sub>2</sub>] to 350 or even 300 ppm as soon as possible.
- *How do we do that?*

# How Bad Could It Get?

- Burning most or all of the fossil fuel there is to be burned, at roughly the present rate (BAU, business as usual) would take [CO<sub>2</sub>] to 1000+ ppm, and that could take us to “moist runaway greenhouse” (Ward 2006, Hansen et al. 2013):
  - Near-total melting of icecaps;
  - Equatorial regions uninhabitable by humans or other large animals;
  - Oceans would go partially anoxic;
  - Some areas of oceans would go *euxinic*, meaning they become dominated by H<sub>2</sub>S-releasing anaerobic bacteria.
    - Such conditions are associated with major mass extinctions in Earth’s geological history.
    - *We do not want to go there!*

## 2° Or Bust

- It is assumed that if we can keep temperature increase below 2°C over pre-industrial levels, we can avoid irreversible runaway effects.
- The 2° C target is a politically constructed guess; there is no firm scientific evidence that irreversible tipping points (such as WAIS collapse) would not occur before that temperature is reached.
- Many scientists (including James Hansen) now say that 2° is too high.
- Many *non*-scientists say that Hansen and others are “alarmist.”
  - But I doubt that they have read Hansen’s recent scientific papers!
    - See James Hansen, Makiko Sato, Gary Russell and Pushker Kharecha, “Climate sensitivity, sea level and atmospheric carbon dioxide,” *Philosophical Transactions of the Royal Society A* 371, 20120294, 16 September 2013.

# Doubling Down on Oil, Gas, and Coal

- What we see in many governments today is obstinate rejection of the scientific verdict:
  - In the UK, Dept for Business, Innovation, and Skills: “UK oil and gas: Energising Britain. £13.5bn is being invested in recovering UK oil and gas this year, more than any other industrial sector.”
  - In Australia, new PM Tony Abbott said science of global warming is “absolute crap”; he has decided to not appoint a Science Minister to his cabinet, and has scrapped their carbon tax.

# Homegrown Obstinacy

- And in Alberta:
  - New \$5.7bn refinery announced in Edmonton last September; will refine bitumen into diesel over 30-year life-span.
  - Guess what: “if the plant stopped operating for any reason, the government would still be on the hook for North West Upgrading’s outstanding debt.” (*Globe and Mail*, Sept 19/13).
    - Cost of this plant is now approaching \$9bn; investors are trying to bail out.
  - This gives the gov’t of Alberta a strong financial incentive to *not* support R & D into energy alternatives.
  - Is there intelligent life in Alberta?

# Barriers to the Innovation We Need

- As these examples suggest, there are several social pathologies and cognitive biases that seem to inhibit the exercise of appropriate human ingenuity precisely when we need it the most.
- To have any hope of overcoming these barriers to innovation, we have to understand them.
- I'll survey (i) some of the obvious barriers, and (ii) one that is not quite as obvious.

# A Familiar Cognitive Problem

- We have raised [CO<sub>2</sub>] to Pliocene levels in a geological instant.
- It could take decades or even a few centuries for oceans and ice caps to absorb all of the extra solar energy that it's going to absorb, and for the earth system to come to equilibrium with space again.
- The full force of the effects are not immediately apparent –
- Hence it is very easy to deny that they are happening, or that they are important.
  - Old joke about a man falling from a high building...
  - Let's call this the "Empire State Building Fallacy."

# “I Just Can’t Believe It”

- This is another very common cognitive handicap.
- When faced with imminent, radical change or disruption, it is too common for individuals and societies to react with incomprehension, disbelief, or virtual paralysis even in the face of strong evidence.
- People do not rise to the occasion but fall to the level of their training; what if the challenge is something that is outside all of human experience?

# “Follow the Money...”

- There is one especially obvious reason for the refusal to accept the scientific verdict:
  - Estimates show that there is still about \$27 trillion worth of recoverable fossil fuels remaining;
    - Hundreds of billions of \$\$ in fossil fuel infrastructure as well.
  - All this would be “foregone asset” if we walk away from fossil fuels.
  - However (!), if we accept the 2° figure as the highest increase we are willing to risk, then there is *four to five* times as much fossil fuel left as we can safely risk burning.
    - If (as some glaciologists fear) 2° is too high, we can burn even less.

# Climate Brinksmanship

- Nuclear brinksmanship: US and Soviet leaders from 1950s to 1980s were willing to risk nuclear destruction of humanity to achieve political goals.
  - Chomsky: In the Cuban missile crisis, “Kennedy himself was estimating the likelihood of nuclear war at a third to a half.”
    - Noam Chomsky, *Guardian*, 4 June 2013, <http://www.theguardian.com/commentisfree/2013/jun/04/us-disaster-race-noam-chomsky>
- The Cold War shows that it is *possible* for highly educated men to consciously gamble *the fate of the world* for their ends.
- I suspect this is part of what is going on now: the CEO of Exxon *knows* the scientists are right but he is willing to gamble the future of the world to get his share of that \$27 tr.

# A Less Obvious Explanation: Two Kinds of Intelligence

- I offer a theory that could partially help to explain the problem.
- Go back to our Pleistocene hunter-gatherer ancestors:
- In order to survive, there were *two kinds* of skills they needed:
  - They had to deal with *biophysical* reality --- surviving extremes of weather, hunting, searching for food, orienteering, defending themselves from predators, coping with the engineering demands of fashioning the artifacts they needed (weapons, tools, shelters, clothing, etc.).
  - And they had to deal with *social* reality --- cooperating or negotiating with others (in the hunt, over distribution of the spoils, etc.).

# Negotiable and Non-negotiable Realities

- Social reality demands what I will call (broadly speaking) negotiating skills or political skills;
  - Absolutely essential for survival; unless you can catch all your own food, by yourself, you have to persuade someone else to share theirs with you!
- Dealing with biophysical reality demands *other* kinds of skills than negotiation;
  - The hunter, the scout, the gatherer, the artisan must attend to largely non-human factors that *cannot be negotiated with*.

# Two Cultures

- Some endeavours demand both sorts of skills: e.g., agriculture, medicine, childcare, the arts of governance and war.
- However, sometimes those who are good at one kind of skill are not very good at the other.
  - They sometimes have difficulty understanding each other.
- This is the *real* “two cultures” gap (borrowing from C. P. Snow).

# Religion Rears Its Head

- When abundance runs out, sometimes societies may further weaken themselves by misplaced efforts to negotiate with that which does not negotiate.
  - We pray for rain, pray that the fish might return, that the forests might grow back, that the volcano might not threaten, that the icecaps might not melt...
- This is called “religion.”



# The Balance Shifts

- In our hunter-gatherer days:
  - The demands of biophysical reality were immediate;
  - Most members of a society had to cope with both kinds of realities.
- However, agriculture, technology, and our increasing ability to tap into stores of natural resources eventually made it possible for some, and later *many* people, to not have to deal directly with biophysical survival demands.

# Making Room for Bach

- This permitted the creation of science, art, music, and this allowed the human animal to realize some fraction of its potential.
  - We are very fortunate that J. S. Bach did not have to pick berries all day long in order to get enough to eat.
- Arguably these apparently useless things (such as art) in some respects increased the potential for human survival, but I won't pursue that point here.

# Abundance – A Blessing and A Curse

- Abundance is a “catch-22”: we need it to flourish but abundance lulls us into forgetting the factors that made it possible in the first place.
  - This produces “*ecological indolence*.”
- As abundance increases, societies tend to become dominated by those whose main skills are political.
  - They don’t have to worry about biophysical reality all that much, because someone else takes care of that.
- After a while, people forget that there is such a thing as “reality”!
  - They view those who deal with non-negotiable reality (e.g., scientists and engineers) as subversive of political authority or economic privilege.
  - (E.g., Stalin’s purge of the *spesty*, the engineers, in the 1920s.)

# Reality Trumps Rhetoric

- I suspect (though cannot prove) that when Mr. Harper hears a scientist explaining the risks of global warming, he thinks that the scientist is just trying to sell him something ---
  - Because that is what *he* would do.
- Climate scientists are more like scouts who have been roaming around and have discovered that the weather is about to change and the tribe needs to move.
  - Those who benefit from their present location may not want to move.
  - But tribes who listen to such people (instead of the scouts) tend to die out!

# We Can Learn

- My “two intelligences” theory is not a neurological hypothesis; rather, it is about what we have learned to do.
  - Implicitly, therefore (and hopefully), we could learn to do otherwise.
- The really hopeful thing about the human animal is its enormous capacities for learning, innovation, and creativity.
- Societies where these capacities are allowed and encouraged to flourish are the ones with the best chance of survival.

# *We Must Learn*

- We have reached a bottleneck in our evolutionary history where the *other* kind of thinking, the kind that deals with the non-negotiable parts of reality, has to be taken far more seriously than it has been recently.
- So the message we are getting from the climate scientists is *not* a political message –
- Rather, it is a message that we are entering a zone where political skills alone *will not help us*.
- WAIS *does not* negotiate!!