# Some News clips and Comments

**relevant to:**

# The
# Peak Oil Presentations

**being made by**
**John Kaufmann**
**Oregon Department of Energy**

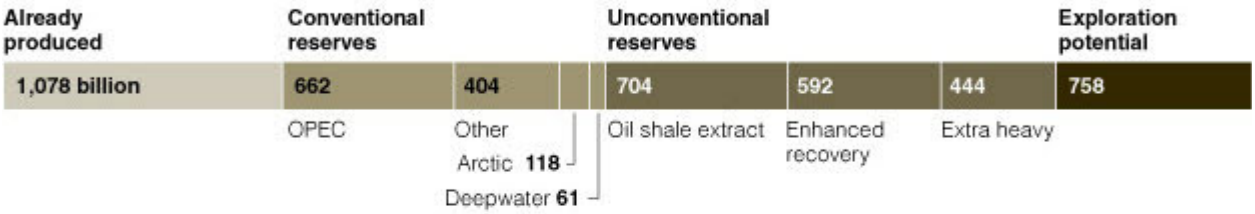
Prepared by Jim Karlock
SustainableOregon.com
Feb 2009

The New York Times

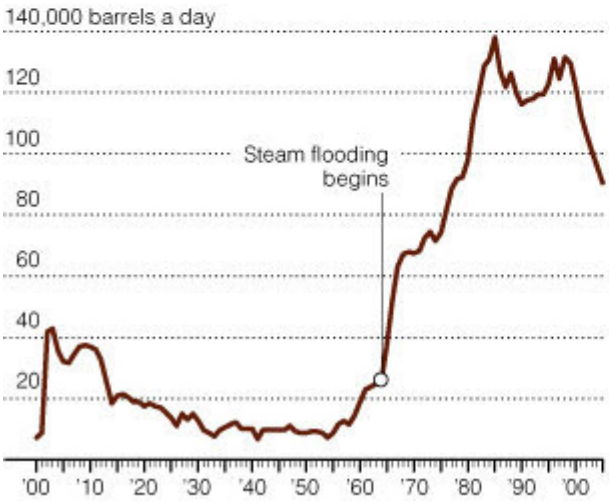
# The Reports of Oil's Demise Are Greatly Exaggerated

For decades, there have been warnings that oil would run out soon. But advanced technologies have made it possible to recover more oil from fields like Kern River in Bakersfield, Calif., that otherwise would have been exhausted long ago. Some experts say that sources that are not economical to develop when oil prices are low become commercially viable as prices rise, allowing for the recovery of huge amounts of oil that are not in current estimates of conventional reserves.

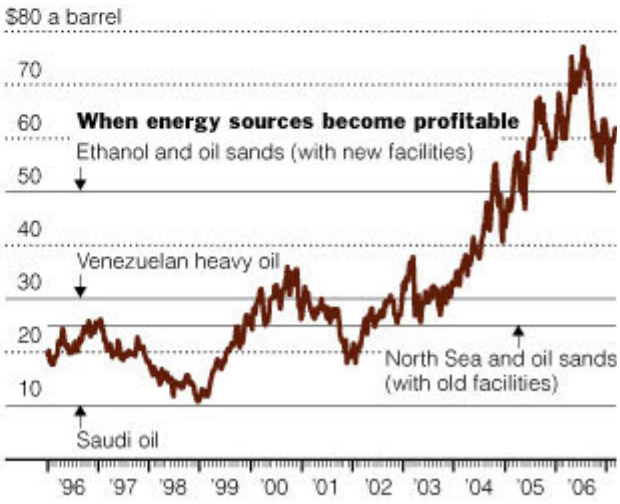
**GLOBAL OIL RESERVES** *Billions of barrels*




**KERN RIVER FIELD OIL PRODUCTION** *Bakersfield, Calif.*




**OIL PRICE** *Near-month contracts*




*Sources: Cambridge Energy Research Associates; Chevron; Simmons & Co.; Bloomberg Financial Markets*

The New York Times

washingtonpost.com

# It's Not the End Of the Oil Age

## Technology and Higher Prices Drive a Supply Buildup

By Daniel Yergin
Sunday, July 31, 2005; B07



We're not running out of oil. Not yet.

"Shortage" is certainly in the air -- and in the price. Right now the oil market is tight, even tighter than it was on the eve of the 1973 oil crisis. In this high-risk market, "surprises" ranging from political instability to hurricanes could send oil prices spiking higher. Moreover, the specter of an energy shortage is not limited to oil. Natural gas supplies are not keeping pace with growing demand. Even supplies of coal, which generates about half of the country's electricity, are constrained at a time when our electric power system has been tested by an extraordinary heat wave.

But it is oil that gets most of the attention. Prices around $60 a barrel, driven by high demand growth, are fueling the fear of imminent shortage -- that the world is going to begin running out of oil in five or 10 years. This shortage, it is argued, will be amplified by the substantial and growing demand from two giants: China and India.

Yet this fear is not borne out by the fundamentals of supply. Our new, field-by-field analysis of production capacity, led by my colleagues Peter Jackson and Robert Esser, is quite at odds with the current view and leads to a strikingly different conclusion: There will be a large, unprecedented buildup of oil supply in the next few years. Between 2004 and 2010, capacity to produce oil (not actual production) could grow by 16 million barrels a day -- from 85 million barrels per day to 101 million barrels a day -- a 20 percent increase. Such growth over the next few years would relieve the current pressure on supply and demand.

Where will this growth come from? It is pretty evenly divided between non-OPEC and OPEC. The largest non-OPEC growth is projected for Canada, Kazakhstan, Brazil, Azerbaijan, Angola and Russia. In the OPEC countries, significant growth is expected to occur in Saudi Arabia, Nigeria, Algeria and Libya, among others. Our estimate for growth in Iraq is quite modest -- only 1 million barrels a day -- reflecting the high degree of uncertainty there. In the forecast, the United States remains almost level, with development in the deep-water areas of the Gulf of Mexico compensating for declines elsewhere.

While questions can be raised about specific countries, this forecast is not speculative. It is based on what is already unfolding. The oil industry is governed by a "law of long lead times." Much of the new capacity that will become available between now and 2010 is under development. Many of the projects that embody this new capacity were approved in the 2001-03 period, based on price expectations much lower than current prices.

There are risks to any forecast. In this case, the risks are not the "below ground" ones of geology or lack of resources. Rather, they are "above ground" -- political instability, outright conflict, terrorism or slowdowns in decision making on the part of governments in oil-producing countries. Yet, even with the scaling back of the forecast, it would still constitute a big increase in output.

This is not the first time that the world has "run out of oil." It's more like the fifth. Cycles of shortage and surplus characterize the entire history of the oil industry. A similar fear of shortage after World War I was

at least 13 billion tons of oil and natural gas

http://english.people.com.cn/english/200010/09/print20001009_52191.ht

## Scientists Believe Oil Plentiful in West China

(approx **46 billion bbl**)

Chinese scientists have estimated that at least 13 billion tons of oil and natural gas are buried in the country's northwestern region.

They said that the two resources are stored in the Jurassic stratum, a 180-million-year-old geological formation which was thought to be only good for producing coal.

may hold 8 billion barrels

Bloomberg.com http://www.bloomberg.com/apps/news?sid=aBUoYKhu7PWk&pid=20601086

### Brazil Oil Finds May End Reliance on Middle East, Zeihan Says

By Joe Carroll

April 24 (Bloomberg) -- Brazil's discoveries of what may be two of the world's three biggest oil finds in the past 30 years could help end the Western Hemisphere's reliance on Middle East crude, Strategic Forecasting Inc. Said.

Brazil's state-controlled Petroleo Brasileiro SA in November said the offshore Tupi field may hold 8 billion barrels of recoverable crude. Among discoveries in the past 30 years, only the 15-billion-barrel Kashagan field in Kazakhstan is larger.

May Hold 90 Billion Barrels of

Bloomberg.com http://www.bloomberg.com/apps/news?pid=20601082&sid=aqEDMhrCvp28

### Arctic May Hold 90 Billion Barrels of Oil, U.S. Says (Update2)

Email | Print | A A A

By Joe Carroll

July 23 (Bloomberg) -- The Arctic may hold 90 billion barrels of oil, more than all the known reserves of Nigeria, Kazakhstan and Mexico combined, and enough to supply U.S. demand for 12 years, the U.S. Geological Survey said.

One-third of the undiscovered oil is in Alaskan territory, the agency found in a study released today. By contrast, a geologic formation beneath the North Pole claimed by Russian scientists last year probably holds just 1.2 percent of the Arctic's crude, the U.S. report showed.

Bismarck Tribune, State est.: 200 billion barrels; USGS scientist: up to 400 billion barrels

http://www.bismarcktribune.com/articles/2006/06/20/news/state/doc4497e42f6e8e5430204114.txt



# North Dakota may be bigger oil player than Alaska

Jun 20, 2006 - 09:35:42 CDT

By LAUREN DONOVAN
Bismarck Tribune

A geologist who estimated the Bakken formation in western North Dakota has far more oil than the Arctic National Wildlife
Refuge died before other scientists could authenticate his study.

Leigh Price, a scientist with the U.S. Geological Survey, published a study in 1999 that estimates the Bakken shales formation, which underlies much of several western and northwestern counties, may hold up to 400 billion barrels of oil.

By comparison, the Arctic refuge oil reserve is estimated at 16 billion barrels.

Helms said the state agency supports an estimate of around 200 billion barrels in the Bakken formation, still a huge number.

Local Headlines:

North Dakota News

- Four legislative races decided
- Oil discounts hit state treasury
- Sex offender unit to get more employees
- Judge plans to reconsider gag order in Sjodin case
- Tax credits available for rural projects

Bismarck News

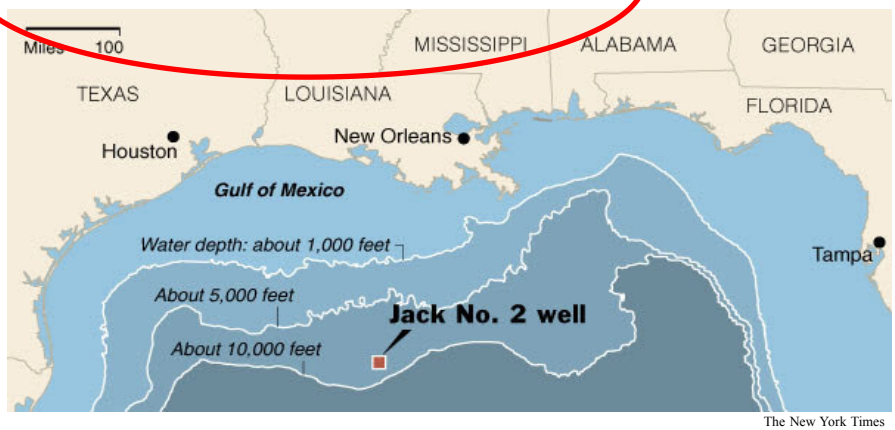
3 billion to 15 billion barrels

http://www.nytimes.com/2006/09/06/business/worldbusiness/06oil.html

The New York Times World Business



# Big Oil Find Is Reported Deep in Gulf




The New York Times

By CLIFFORD KRAUSS
Published: September 6, 2006

An announcement yesterday by three oil companies of a successful production test in the Gulf of Mexico — potentially the largest American oil find in a generation — was seen by experts as ushering in a new era in ultra-deepwater offshore drilling.

Chevron, Devon Energy and Statoil ASA, the Norwegian oil giant, reported that they had found 3 billion to 15 billion barrels in several fields 175 miles offshore, 30,000 feet below the gulf's surface, among formations of rock and salt hundreds of feet thick.

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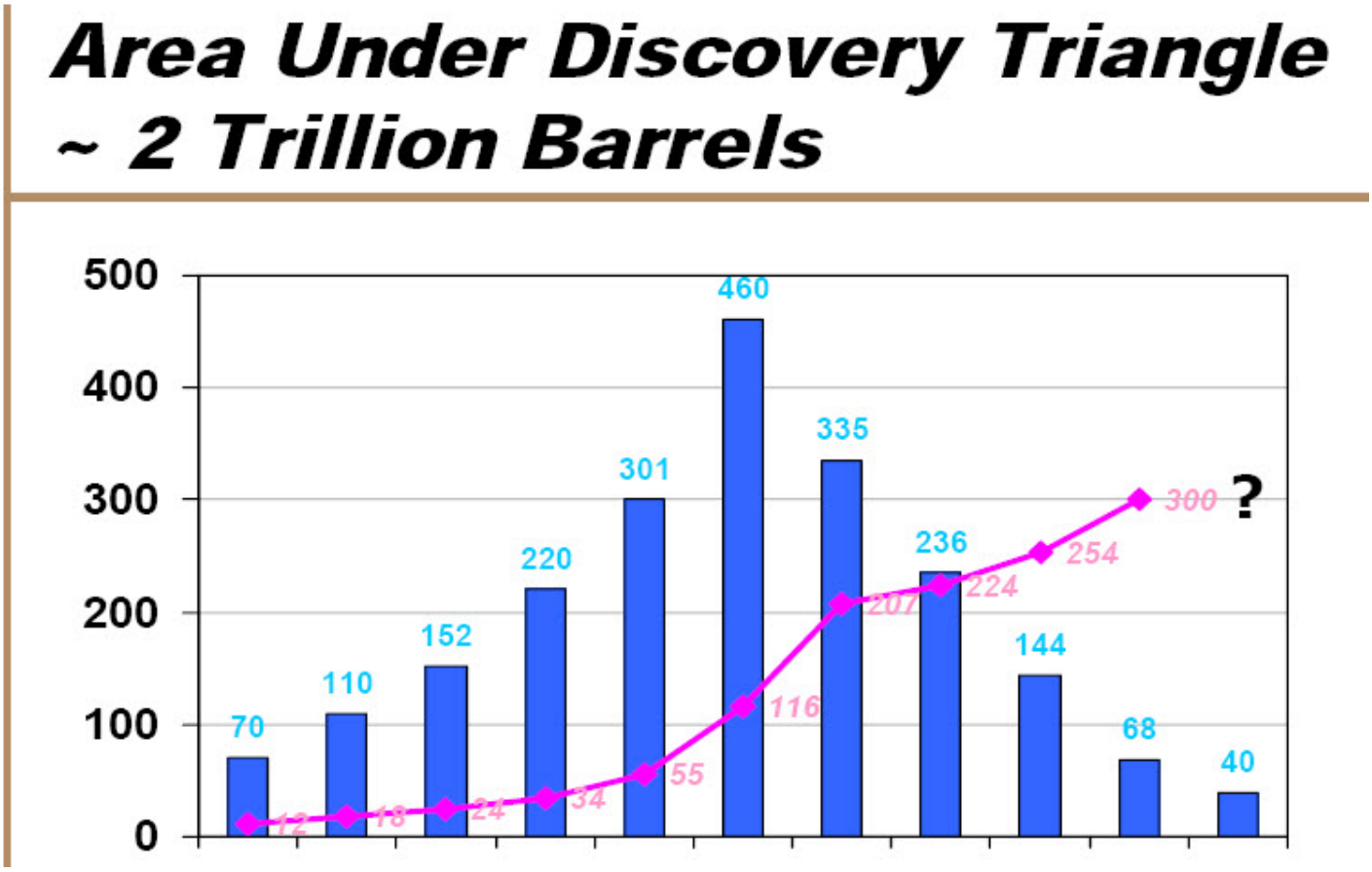
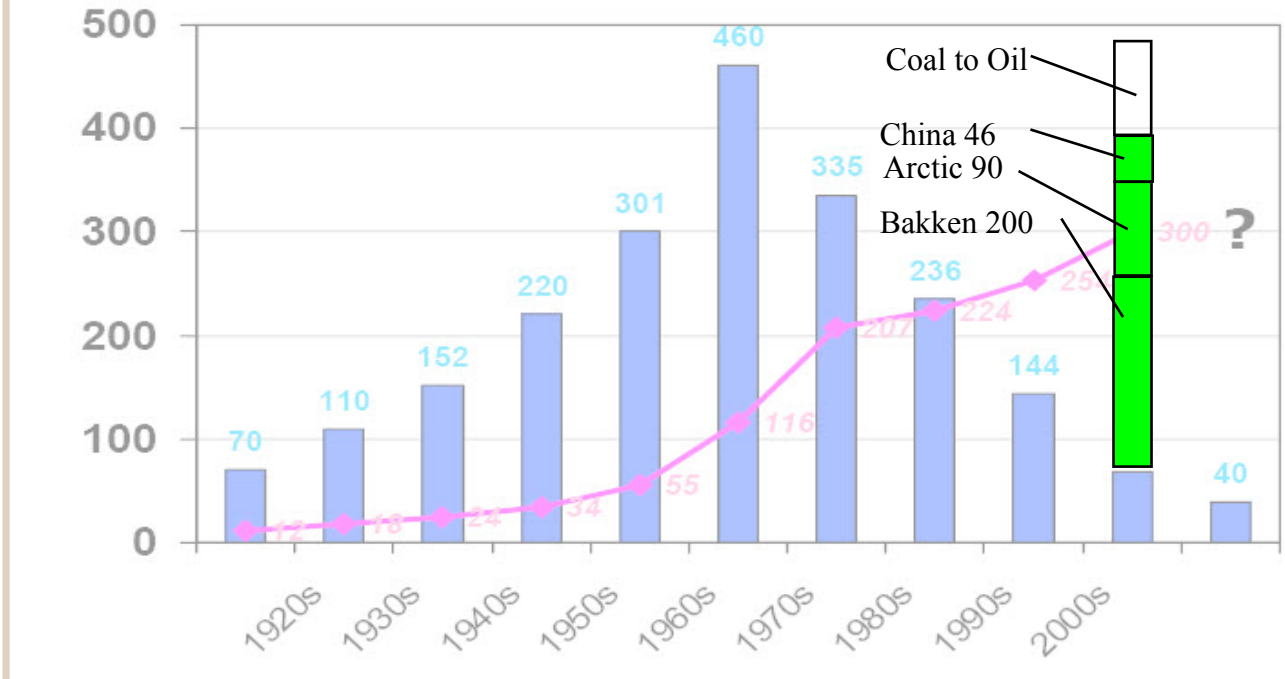
Kaufman's chart:

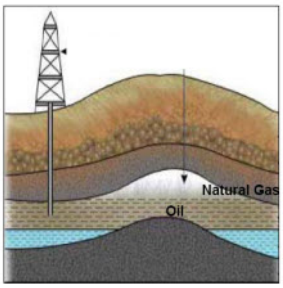



# Same chart - Recent discoveries added:



### Finding More Middle East Sized Fields is Unlikely

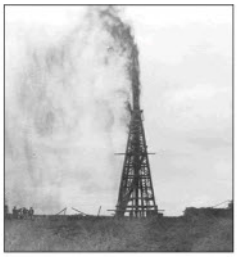
- We understand geologic causes
- Seismic imaging
- Millions of wells
- Computer mapping
- Find big/easy first




**Unlikely? Here are some recent discoveries that are ignored in this report**
(see news articles on previous pages)

China:13 billion tons estimated (approx **46 billion bbl**)
Arctic: **90 Billion bbl**
Bakken: **200 Billion bbl**
Brazil: **8 billion bbl**
**Coal to Diesel improvements**
It just took the **price increase** of a few years ago and now technology. The recent price increase (before the fall) has probably caused more, yet unannounced, discoveries.

### Ease of Production: Past Vs Present



Today's technology has made the complex as cheap as the simple of years ago

500 MPH jets transport us faster and cheaper than steam trains of 100 years ago.

Sure deep sea oil costs more than shallow land drilling, but the oils is still cheaper than 100 years ago.

## Claim:

"When will peak oil hit? There is wide variety of opinion on that. You can see it from top to bottom. ... Anybody who's talking about 2020 or thereafter is an economist, anybody above that line is a petroleum geologist or a retired petroleum geologist." (Transcribed From Kaufman's 2006 presentation)

### When Will Oil Production Peak?

| | | | |
|---|---|---|---|
| 2005 | Deffeyes | Oil Geologist, Princeton | |
| 2006-2007 | Bakhtiari | Former VP, Iranian National Oil Co. | |
| 2007-2009 | Simmons | Energy Investment Banker, Houston | |
| Before 2010 | Goodstein | Physicist, CalTech | |
| 2010 | Campbell | Oil Geologist, Ireland | 0-5 yrs |
| 2010 | Weng; Pang Xiongqi | Chinese National Oil Co. | |
| 2010 +/- 2 | Skrebowski | Editor, "Petroleum Review" | |
| 2010-2012 | Intl. Energy Agency | (Supply tightness; plateau) | |
| 2012-2015 | Maxwell | Wall Street Oil Analyst | |
| 2008-2018 | Univ. of Uppsala | Sweden | |
| Before 2015 | ASPO-USA | U.S. | |
| 2016 | Douglas-Westwood | Oil & Gas Market Analysis | 5-10 yrs |
| After 2014 | Wood MacKenzie | Energy/Scientific Consultant | |
| 2010-2020 | Laherrere | Oil Geologist, France | |
| After 2025 | Shell Oil | Major Oil Company | 10+ yrs |
| After 2030 | CERA | Energy Economics Consulting firm | |
| 2037 | EIA | U.S. Govt. | |

**Analysis:**

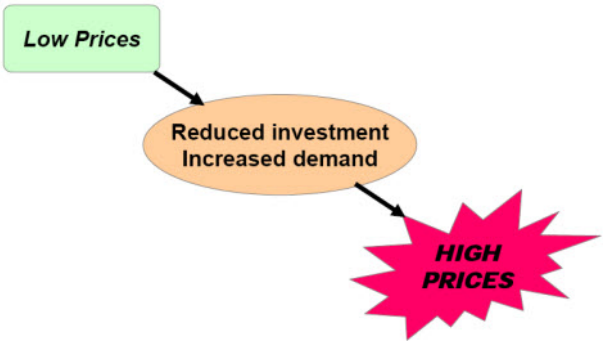
Economists know markets and how they work, petroleum geologists may not. Briefly, as something gets scarce, the price gets bid up. This has two effects:

**1.** People use less. (for gasoline, there is both an immediate, moderate, reduction in driving and the next time one buys a car, one tends to buy a more efficient one.)

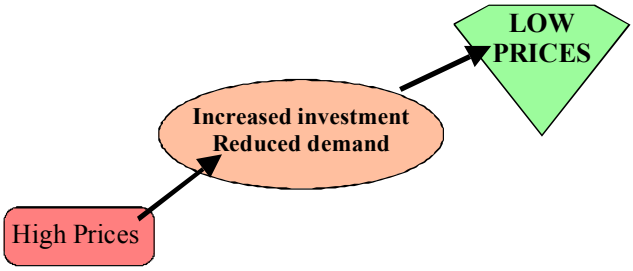
**2.** A higher price brings more supply. A higher price makes it profitable to get known oil that is costly to extract. It encourages more explorations. More importantly, it opens up new sources such as oil sands and, perhaps, the coal to gas process used in WWII Germany. See http://www.fischer-tropsch.org

**Important:** Oil reserves are estimated based on price and are vastly greater at $100 per barrel than at $30.

## Temporary Lull




## Of course the converse is also true:




## Domestic Natural Gas Replacement: LNG

- Intense competition
- Expensive
- Best use?
  - Heat existing homes?
  - Feedstock?
  - Displace coal?
  - Transport fuel (CNG)?
  - Heat new homes?
  - New elec. generation?
- Transition fuel?


**Intense competition?**

Natural gas is a byproduct of oil extraction. It is frequently wasted as there, all too often, no pipeline to get it to market.

This new technique (LNG) is allowing this formerly wasted product to be transported to markets to add supply to existing markets. Added supply usually lowers prices.

## Coal

- 3X – 4X increase
- Runaway global warming
- Peak coal


This ignores the fact that we have over 200 years worth of coal in the ground.

There is no runaway global warming - only dubious computer models. As Retired senior NASA atmospheric scientist, Dr. John S. Theon said: "there is no rational justification for using climate model forecasts to determine public policy"

See the next page for a story about coal

*Source:* Rutgers, the State University of New Jersey

*Date:* April 14, 2006

*More on:* Petroleum, Fossil Fuels, Chemistry, Organic Chemistry, Inorganic Chemistry, Fuel Cells

# Coal-to-diesel Breakthrough Could Drastically Cut Oil Imports

*Science Daily* — Professor Alan Goldman and his Rutgers team in collaboration with researchers at the University of North Carolina at Chapel Hill have developed a way to convert carbon sources, such as coal to diesel fuel.

This important advance could significantly cut America's dependence on foreign oil -- what President Bush called "an addiction" in his 2006 State of the Union address. According to the U.S. Department of Energy, our 286 billion tons of coal in the ground translate into energy reserves 40 times those of oil.

*Postdoctoral Associate Ritu Ahuja demonstrates catalyst material to graduate student Elizabeth Pelczar and Prof. Alan Goldman. (Credit: Joseph Blumberg)*



Goldman explained that the breakthrough technology employs a pair of catalytic chemical reactions that operate in tandem, one of which captured the 2005 Nobel Prize in Chemistry. This dynamic chemical duo revamps the Fischer-Tropsch (FT) process for generating synthetic petroleum substitutes, invented in 1920 but never developed to the point of becoming commercially viable for coal conversion.

The FT process recently gained national attention through the efforts of Brian Schweitzer, governor of coal-rich Montana, who has been publicly extolling the potential of Fischer-Tropsch. The Goldman group's innovations eliminate shortcomings in the process that can finally make it a workable solution to dwindling domestic oil reserves.

"The key to energy independence in the next five decades is Fischer-Tropsch chemistry, amended and enhanced," said Goldman, a professor in the department of chemistry and chemical biology at Rutgers, The State University of New Jersey. "The study of catalysts, the little molecular machines that control chemical reactions, is my field. With our new catalysts, one can generate productive, clean burning fuels with Fischer-Tropsch, economically and at unsurpassed levels of efficiency."

This discovery is reported in the April 14 issue of the journal Science by Goldman and his colleagues. The work grew out of a National Science Foundation-funded research consortium, the Center for the Activation and Transformation of Strong Bonds, based at the University of Washington.

Fischer-Tropsch yields a wide distribution of molecular weight hydrocarbon products but without any way to control the desired mix. The molecular weight is the weight of a molecule of a substance, or the sum of the weights of all atoms in the molecule. The low-weight and the high-weight Fischer-Tropsch products are useful -- the light as gas and the medium-heavy as diesel fuel, Goldman explained.

"The problem -- the greatest inefficiency of the process -- is that you also wind up with a substantial quantity of medium-weight products that are not useful and you are stuck with them," Goldman said. "What we are now able to do with our new catalysts is something no one else has done before. We take all these undesirable medium-weight substances and convert them to the useful higher- and lower-weight products."

## Science Video News

Jump to: ... select topic:

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**Crude Oil Report**
See who's pumping cash by making oil for $13.21. And selling for $59
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Learn How Colorado and Alberta Sit on More Oil Than the Middle East
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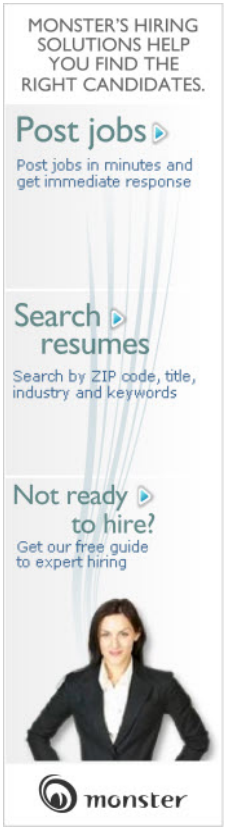


## In Other News ...

**Report: Israel does not block torture**
(2 hours ago)

**Rocket hits Israeli apartment**
(2 hours ago)

**Palestinians make pitch for cease-fire**

## Nuclear

- 10X increase
- Peak uranium

Simply reprocessing our used fuel, instead of throwing it away will increase supply many times over.

We have vast amounts of thorium which cna be used as a fuel

We have huge stockpiles of warheads that are currently being converted for fuel.

## Oil Sands / Oil Shale

- CO2 emissions
- Land, water pollution
- Low energy return
- Low flow rates

This ignores hundreds of years of experience that processes are always improved. (this is a new process)

**Oil sands are now in production - see the next page**

## Impacts – Food & Agriculture

- Food sector = 14% of energy
- Higher food prices
  - ➪ *Production, distribution*
- Fertilizer → lower productivity
  - ➪ *Demand-driven price increases*
- No grapes in January


*Time Magazine, April 9, 1973*

The big scare here is the shortage of fertilizer which is made from natural gas.

However when one looks at the process, the natural gas is just a source of hydrogen to make ammonia. As in many processes, natural gas is used only becasue it is the cheapest way.

Hydrogen can also be obtained from water using the, century old, coal gas process or electrolysis.

## Expand Energy Efficiency Programs

- (Dramatically) ramp up existing programs
- More and faster


The problem that most people forget is that it may be cheaper to pay higher energy cost than to improve efficiency.

A classic example is the cost of a Hybrid car. Currently they don't save money unless you drive far more than most people and gas stays above $4/gal.

To do this more and faster is just to waste money more in faster.


- The Syncrude Project is a joint venture undertaking among Canadian Oil Sands Limited Partnership (5%); Canadian Oil Sands Limited (31.74%); Conoco Phillips Oilsands Partnership II (9.03%); Imperial Oil Resources (25%); Mocal Energy Limited (5%); Murphy Oil Company Ltd. (5%); Nexen Oil Sands Partnership (7.23%); and Petro-Canada (12%).
- The Syncrude Project is operated and administered by Syncrude Canada Ltd. on behalf of the participants.
- The Syncrude consortium was formed in 1964 with the official opening of the project and the first barrel shipped in 1978.
- Located near Fort McMurray, Alberta, Syncrude operates large oil sands mines, utilities plants, bitumen extraction plants and an upgrading complex that processes bitumen into a light sweet crude oil.
- The crude oil produced by Syncrude is referred to as Syncrude Sweet Blend® ("SSB"), which is a high quality, light sweet crude oil with no residual bottoms and with the lowest sulphur content of any crude in North America. As part of the Stage 3 expansion, Syncrude will further enhance the quality of its production to a new level that will be referred to as Syncrude Sweet Premium, or "SSP".
- Syncrude is one of the largest holders of Alberta's mineable oil sands leases with eight leases covering approximately 100,000 hectares.
- Syncrude has proven and probable reserves of 5 billion barrels of SSB, which represent a lifespan of approximately 35 years using today's infrastructure with the potential to extend reserve life beyond the year 2050 as the leases are developed.
- Syncrude is in the midst of a large expansion program called Syncrude 21, which is designed to more than double productive capacity post 2016 to reach about 500,000 barrels per day of a premium quality, light sweet oil. Stages 1 and 2 of the expansion have been completed. Stage 3 of the program is expected to come on-stream by mid 2006 at a capital cost of Cdn $8.4 billion plus post start-up costs of about $150 million, and is anticipated to result in productive capacity expanding to average approximately 350,000 barrels per day post 2006. The next expansions are referred to as the Stage 3 debottleneck and Stage 4, which have not yet been approved and are in the conceptual planning phase. The Stage 3 debottleneck will leverage and optimize the potential of the Stage 3 expansion, which included pre-investment to enable further production expansion. Stage 4 is currently envisioned as another major expansion with further expansion of upgrading capacity, primarily through the construction of a fourth coker, and additional mining trains on one of Syncrude's undeveloped leases.
- In 2005, Syncrude shipped 78.1 million barrels of SSB.
- Syncrude is a leader in technological innovation of oil sands recovery and has pioneered many of the technologies used throughout the oil sands industry today, including low energy extraction and hydrotransport. These innovations have reduced energy requirements, leading to lower operating costs and emissions.

# The Tired Old "Solution" is Always the Same - Give Up Our Lifestyle


Have you noticed that the solutions to most of our problems seems to be to live as people did 100 (or more) years ago? A simpler life. A slower life. A life more in touch with nature. A life closer to our neighbors.

Unfortunately few advocates of such a return to the past also tell us that it was a life of massive poverty, rampant diseases like smallpox, polio, dysentery and short life spans where very few people traveled 100 miles form their birth place and could die from a cut finger if it got infected.

This is the life being presented as an ideal by many of the proponents of coming doom unless we change our ways. Make no mistake, little self sufficient villages are simple incapable of developing lifesaving technologies like MRI, cat scan, heart monitors, pacemakers, antibiotics, microelectronics, implacable devices, cell phones, or computers.

To go back to that lifestyle is also to give up any hope of continued human progress and probably will result in losing many life saving technologies, because they cannot even be manufactured without large corporations in large urban areas. The advocates of a simple life in small, self sufficient, villages are actually proposing the deaths of millions, if not billions, of people.

# Why We Will NEVER Run Out of Raw Materials

The speculations of running out of basic raw materials are based on the flawed concept that population and demand will increase at a faster rate than supply because people making these claims do not understand basic economics. The reality is that when demand gets ahead of supply, the price rises which causes supply to increase and demand to reduce. It is self regulating.

They also fail to understand that innovation is three dimensional (or more), not two dimensional. For example, they incorrectly claim that all of the earths surface has been explored (it hasen't) and therefore we know that there is no unknown supply. They fail to consider that, as technology improves, we can go deeper into the earth, a third dimension. Arguably there is a fourth dimension of increased efficiency at extracting whatever materials are discovered. And, perhaps, a fifth dimension of increased efficiency of usage of those materials. These dimensions overwhelm any linear (or exponential) increases in demand and ensure that we will never run out of anything really important. (An exception is if government interferes, with proven disastrous measures, like price controls of restriction on exploration.)

That is why prediction after prediction of doom due to shortages has failed to come true. And will continue to come true. Including this one.

# Some well known climate scientists appear to think that it is OK to paint scary scenarios to panic people:

From Discover magazine October 1989, page 47:
Stephen Schneider of the National Center for Atmospheric Research described the scientists' dilemma this way: "On the one hand, as scientists, we are ethically bound to the scientific method, in effect promising to tell the truth, the whole truth, and nothing but-which means that we must include all the doubts, the caveats, the ifs, ands, and buts. On the other hand, we are not just scientists but human beings as well. And like most people we'd like to see the world a better place, which in this context translates into our working to reduce the risk of potentially disastrous climatic change. To do that we need to get some broad based support, to capture the public's imagination. That, of course, entails get ting loads of media coverage. So **we have to offer up scary scenarios, make simplified, dramatic statements, and make little mention of any doubts we might. have**. This `double ethical bind' we frequently find ourselves in cannot be solved by any formula. Each of us has to decide what the right balance is between being effective and being honest. I hope that means being both."

**Al Gore:** *I think the answer to that depends on where your audience's head is. In the United States of America, unfortunately we still live in a bubble of unreality. And the Category 5 denial is an enormous obstacle to any discussion of solutions. Nobody is interested in solutions if they don't think there's a problem. Given that starting point,* ***I believe it is appropriate to have an over-representation of factual presentations on how dangerous it is****, as a predicate for opening up the audience to listen to what the solutions are...* Al Gore in Grist, 09 May 2006, http://www.grist.org/news/maindish/2006/05/09/roberts/ bold added.

BTW, a British court found several inaccuracies in Gore's film ("over-representation of factual presentations"?) See: http://newparty.co.uk/articles/inaccuracies-gore.html

**Jim Hansen:** (He controls NASA's historical climate records):
***Emphasis on extreme scenarios may have been appropriate at one time****, when the public and decision-makers were relatively unaware of the global warming issue, and energy sources such as "synfuels," shale oil and tar sands were receiving strong consideration. Now, however, the need is for demonstrably objective climate forcing scenarios consistent with what is realistic under current conditions.* from http://naturalscience.com/ns/articles/01-16/ns_jeh6.html, bold added

**In this time of worry about the climate, here are two comforting articles from peer-reviewed journals.**

The first (below) argues that the famous Arctic ice loss is actually due to shifting wind patterns, not warming.

The second (next three pages) reports the discovery that both Northern Hemisphere temperature and Arctic ice closely follow the length of the sunspot cycle and have for thousands of years. If true, this would indicate that CO2 has a very minor role in global temperature and we may not need to spend huge amounts of money on climate or force people to choose between being able to afford energy to heat their homes and affording food.

"You've got several bad alternatives," says Burns. Puzzled ring scientists hope that three Cassini close flybys of Enceladus this year, the first on 17 February, will improve their choices.

## Scary Arctic Ice Loss? Blame the Wind

The past three Septembers have seen the Arctic ice pack shrink dramatically to a record low amid signs that greenhouse warming could be melting the ice, threatening to clear the Arctic Ocean within decades. Researchers are still worried, but a study presented at the meeting offers some reassurance. A natural, temporary shift in the wind may have been largely to blame for the recent shrinkage.

Winds of the high northern latitudes are the domain of the Arctic Oscillation (AO), an erratic atmospheric pressure seesaw (*Science*, 9 April 1999, p. 241). Over weeks, years, or even decades, pressure can fall over the pole while rising around a circle near the latitude of Alaska. The resulting steeper pressure drop across high latitudes increases the generally westerly

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sity of Washington, Seattle, created a model that keeps track of ice as it forms and blows around the Arctic Ocean, thickening with

into a permanent positive phase, he says, which would favor still-greater ice losses.

–RICHARD A. KERR

## Snapshots From the Meeting

**No vestige of a beginning.** Seismologists got their most detailed look at an earthquake last fall when 30 kilometers of the San Andreas fault ruptured through the town of Parkfield, California, and its dense array of instruments, but they still missed something. "This is the best data we've got," said geophysicist Malcolm Johnston of the U.S. Geological Survey in Menlo Park, California, but there is still no sign of the slow, hesitant onset of the fault rupture that some seismologists have been looking for (*Science*, 6 January 1995, p. 28). If earthquakes were to begin as slow slippage on a small patch of fault, well-placed instruments might detect it days or even weeks before the slippage took off and produced a quake. But the Parkfield data limit any such nucleation patch to a few tens of meters or less in size, says Johnston. So, even if nucleation occurs, detecting it looks improbable.

**A nudge toward magnetic flip-flop.** Two paleomagnetists found themselves presenting adjacent posters that argued for a previously unrecognized precursor to the most recent reversal of Earth's magnetic field. Researchers had thought that the field generated by the churning molten iron of the outer core had simply weakened and reorganized itself for a few thousand years as it got ready to flip about 775,000 years ago. Not so fast, say Laurie Brown of the University of Massachusetts, Amherst, and Bradley Singer of the University of Wisconsin, Madison. Brown, working on the paleomagnetic record frozen into lavas of central Chile, and Singer, studying lavas in Tahiti, found that the field had actually weakened and moved toward a reversal 18,000 years earlier. The prolonged precursory move toward reversal may have given the liquid outer core time to overcome the stabilizing influence of the solid inner core.

–R.A.K.

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# Length of the Solar Cycle: An Indicator of Solar Activity Closely Associated with Climate

E. FRIIS-CHRISTENSEN AND K. LASSEN

**It has recently been suggested that the solar irradiance has varied in phase with the 80- to 90-year period represented by the envelope of the 11-year sunspot cycle and that this variation is causing a significant part of the changes in the global temperature. This interpretation has been criticized for statistical reasons and because there are no observations that indicate significant changes in the solar irradiance. A set of data that supports the suggestion of a direct influence of solar activity on global climate is the variation of the solar cycle length. This record closely matches the long-term variations of the Northern Hemisphere land air temperature during the past 130 years.**

MUCH SCIENTIFIC EFFORT HAS been exercised in order to understand the effects on climate of the release of increased quantities of $CO_2$ into the atmosphere. Because realistic experiments on a global scale are not possible, verification of physical theories have relied on model simulations or observations. Model simulations are limited by the necessary assumptions, and observations suffer from the lack of sufficiently long time series of fundamental quantities.

One of the most fundamental quantities in relation to the terrestrial climate is the sun's radiation. This is one of the parameters of which we have the least exact knowledge. Eddy (*1*) pointed out that apparent long-term relations between solar activity and certain indicators of the global climate might be caused by changes in the solar irradiance. Only recently, however, during the satellite era, have reliable measurements of the variability of the sun's irradiance been obtained (*2*), but these measurements are for a time scale shorter than a solar cycle.

Reid (*3*) discussed a striking similarity between the globally averaged sea-surface temperature (SST) and the long-term record of solar activity, as represented by the 11-year running mean Zürich sunspot number. He pointed out that although not identical, the two time series had several features in common. Most noteworthy was the prominent minimum in the early decades of this century, the steep rise to a maximum in the 1950s, a brief drop during the 1960s and early 1970s followed by a final rise, which apparently has not stopped.

Reid used these observations to show that the solar irradiance may have varied by approximately 0.6% from 1910 to 1960 in phase with the 80- to 90-year cycle (the Gleissberg period) represented by the envelope of the 11-year solar activity cycle. To estimate the response of the upper ocean to changes in the solar constant, Reid used a simple one-dimensional ocean thermal model of Hoffert *et al.* (*4*). He found that the necessary range of variation in the solar constant required to account for the temperature increase during the 130-year period is less than 1%, which is consistent with the magnitude of the long-term trend that could be derived from the measurements of the solar irradiance.

Correlations regarding sun-weather relations have traditionally been attacked for two main reasons. The first, and perhaps most serious one, is the lack of a physical mechanism that could lead to the claimed relations. The second has been the poor statistical significance of the correlations.

Kelly and Wigley (*5*) argued that the required change in the sun's energy output largely exceeds the changes that are suggested by direct measurements. On the basis of directly measured irradiance data from the short time period of satellite measurements, Foukal and Lean (*6*) constructed a model of the total solar irradiance variation between 1874 and 1988. Variations of less than 1.1 W/m$^2$, which is less than 0.1% of the total output, were predicted. However, they explicitly noted that additional low-frequency changes in the irradiance might be present that could not be deduced from the limited series of irradiance data.

Even for a change in the solar energy output compatible with the value estimated by Reid, model calculations by Kelly and Wigley (*5*) indicated that solar forcing is unlikely to have accounted for more than a small part of the observed temperature variation. An important reason for this conclusion was the limited statistical correlation between the two time series used by Reid.

There is, however, no a priori reason to believe that the long-term changes of solar irradiance are perfectly represented by the number of sunspots. In this paper we pre-

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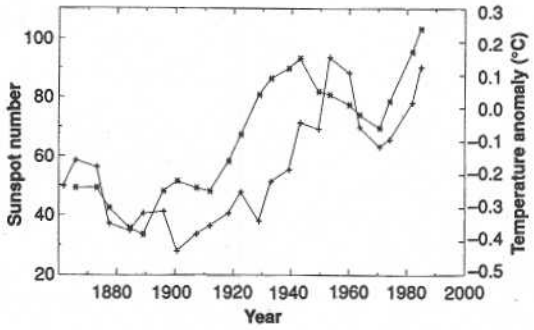


**Fig. 1.** Northern Hemisphere temperature anomalies from 1861 to 1989 (right-hand scale). The symbols (*) represent average values of the temperature record corresponding to individual solar cycles from solar maximum to solar maximum and from solar minimum to solar minimum, respectively. The second curve (+) shows the corresponding 11-year running mean values of the Zürich sunspot number (left-hand scale). For both curves, the abscissas of the plotted points correspond to the central time of the individual solar cycles.

sent a set of data that supports the idea that a change in solar activity could be related to global temperature.

Both solar activity and temperature records are subject to serious deficiencies. The land and sea-surface temperature records show similar behavior, but the SST record as well as the air temperatures over the ocean show a lag of several years relative to the land temperature. Reid (7) concluded that the lack of the long-term consistency between the two curves suggests that there was some slowly varying systematic error in one or the other, or in both, time series. A lag of the SST could, however, be explained by a significant response time of the ocean to possible changes in solar forcing. The Northern Hemisphere land temperature record presented by Hansen and Lebedeff (*8*) and Jones *et al.* (*9*) is probably the most reliable indicator of the global temperature because it is based on the largest systematic set of temperature measurements. Therefore, we have used the land air temperature for the Northern Hemisphere, expressed as anomalies relative to the interval 1951 to 1980, smoothed by Jones [see (*10*)].

From the plotted time series (Fig. 1), it is apparent that the variation of the Northern Hemisphere land air temperature has some similarity with the 11-year smoothed sunspot number, as was also the case for the SST record shown by Reid. But the data show that the land air temperature record leads the sunspot record. Therefore, if a relation between solar activity changes and surface temperature is to be maintained, the smoothed sunspot number cannot be a usable index of solar forcing.

There are independent measures of solar activity that indicate that the sunspot number is probably not necessarily also a good indicator of long-term changes. An example is the geomagnetic activity that is caused by the interaction between the solar wind and the geomagnetic field. There is a fundamental difference in the long-term behavior of the sunspot number and the geomagnetic activity (*11*). Whereas the sunspot number returns to near zero at each 11-year minimum, the 11-year geomagnetic activity variations are superposed on a long-term variation of similar amplitude including a nearly monotonic increase from 1900 to 1950. From the statistical relation between geomagnetic activity and satellite measurements of the solar wind velocity, Feynman and Crooker (*11*) estimated that solar wind velocities were low at the beginning of the century. A plausible physical mechanism for a direct effect on climate of a varying solar wind has not yet been demonstrated, however. But the observed long-term variation in solar energy output by means of the solar wind suggests that similar long-term changes in other manifestations of solar energy output may have occurred.

A different solar parameter showing long-term changes is the length of the sunspot cycle. This parameter is known to vary with solar activity so that high activity implies short solar cycles whereas long solar cycles are characteristic for low activity levels of the sun. Gleissberg (*12*) demonstrated that the variation occurred in a systematic manner with a long-term periodicity of 80 to 90 years, now known as the Gleissberg period.

We determined the length of the sunspot cycle using epochs of maxima and minima found by the secular smoothing procedure introduced by Gleissberg (*12*) (Fig. 2). This procedure corresponds to the application of a low-pass filter with coefficients 1, 2, 2, 2, 1 to the series of individual sunspot maximum and minimum epochs. This particular filter was selected because it has been generally used in the determination of long-term trends in solar activity, but the use of a different filter would not change the results significantly, as long as the short-term variations related to the 11-year cycle and shorter periods are removed. For the last two extrema, the available data do not allow full smoothing. Therefore, we filtered the second to last extrema by estimating the next extremum (because this is included in the filtering with a weight of one-eighth only); the last extrema express the unfiltered epochs. The consistency between the independent determinations of the cycle length based on the epochs of maximum and minimum of the sunspot number, respectively, indicates that the sunspot cycle length may be associated with a physically meaningful index of solar activity.

The introduction of this parameter of solar activity instead of the smoothed sunspot number removes the apparent lag of the solar activity curve relative to the surface temperature (Fig. 2). Furthermore, a strikingly good agreement between these two curves is revealed. There is a close association between the two curves in the up-going trends from 1900 to 1940 and since 1970, as well as in the important decrease from 1945 to 1970. For the total data, this approach gives a much closer fit to the temperature data than that for the smoothed sunspot number obtained by Reid (7). We therefore find that this agreement supports (although it does not prove) the suggestion of a direct solar activity influence on global temperature.

The temperature record is only available for the last 130 years, which is about 1.5 cycles of a possible 80- to 90 year oscillation. The official Zürich sunspot number, however, extends back to 1715, and it is therefore possible to calculate the smoothed sunspot cycle length from 1740. This in principle allows a comparison between the length of the solar cycle and a parameter that could be regarded as a reasonable estimate of the

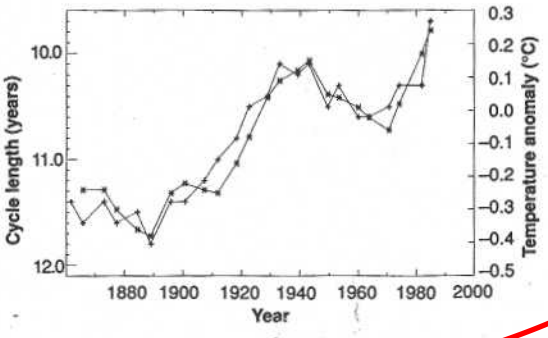


**Fig. 2.** Variation of the sunspot cycle length (left-hand scale) determined as the difference between the actual smoothed sunspot extremum and the previous one. The cycle length is plotted at the central time of the actual cycle (+). The unsmoothed last values of the time series have been indicated with a different symbol (×) which represents, as in Fig. 1, the Northern Hemisphere temperature anomalies.

Sea Ice is also closely associated with solar cycle length

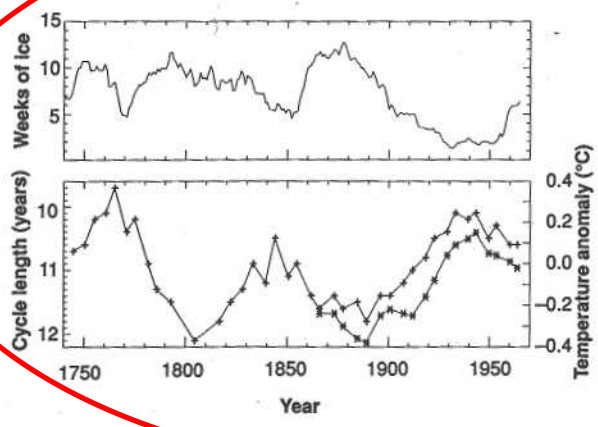


**Fig. 3.** (**Top**) 22-year running mean of the amount of sea ice around Iceland from 1740 to 1970 during summer months (represented by the number of weeks when ice was observed). (**Bottom**) Smoothed sunspot cycle lengths from 1740 to 1970 (left-hand scale) and Northern Hemisphere mean temperature (right-hand scale).

global temperature. One parameter covering this long time period is an index of the North Atlantic sea ice, which is known to show similar long-term variations. Although the individually measured extensions of sea ice suffer from a number of different influences and probably cannot be used directly as a temperature index, it seems reasonable that the absence of considerable amounts of ice would be associated with relatively high global, or at least hemispheric, average temperatures. We therefore compared (Fig. 3) the smoothed sunspot cycle lengths and a 22-year running mean of the extent of sea ice around Iceland (*13, 14*). The comparison clearly shows that each maximum in the long-term solar activity around 1770, 1850, and 1940 has been accompanied by a corresponding minimum in the 22-year running mean value of the extent of sea ice around Iceland.

We have presented observations that support the suggestion by Eddy (*1*) and Reid (*3*) that long-term changes in the solar activity influence the terrestrial climate. Using a perhaps more suitable parameter of the terrestrial climate than the one used by Reid, namely the Northern Hemisphere land air temperature difference and a possibly more direct indicator of long-term solar activity, namely the solar cycle length, we were able to improve the goodness of fit relative to that obtained by Reid.

Kelly and Wigley (*5*) argued that a change in the solar constant is unlikely to have accounted for more than a small fraction of the observed warming in global mean surface temperature since the mid-19th century. They used data compatible with the data used by Reid (*3*) to investigate temperature changes simulated in a model of the climate system, and they extended their analysis over a range of different climate sensitivities and solar-forcing scaling factors. They examined the departure of the observed temperature from the modeled one for the various processes. Their results indicated that since the mid-19th century, the influence of the enhanced greenhouse effect on global mean temperature has almost certainly dominated over direct influence of solar variability.

A major contribution to the enhanced greenhouse effect is due to a nearly exponential increase in the concentration of $CO_2$ in the atmosphere. Although the Northern Hemisphere temperature record includes a significant net increase during the last 130 years, which could partly be caused by the increased greenhouse effect, the temperature record does show a considerable departure from this long-term trend from 1940 to 1970. During these years the temperature decreased, simultaneously with a decrease in solar activity as indicated by the variation of solar cycle length (Fig. 2).

The use of the solar cycle length as a measure of solar activity instead of the 11-year running mean of the sunspot number would significantly affect the analysis by Kelly and Wigley (*5*). The high correlation between the two series, based on intervals of increasing as well as decreasing temperatures, could reduce the importance of measured greenhouse gases relative to the direct influence of solar variability. This result would not necessarily indicate that an increased greenhouse effect does not exist —it could just mean that other effects may be counteracting the greenhouse effect. In particular it has been debated whether increased cloudiness due to increased global pollution could have a cooling influence on the climate, similar to the effects due to volcano eruptions, as discussed by Lamb (*15*).

A different argument against the suggestion of solar irradiance changes as causes of climate changes is the question of whether the available satellite observations of the solar irradiance could be used as an indication of long-term changes. There are several indications that there are low-frequency changes in the solar constant that are not yet distinguishable in the satellite data. Reid (*7*) referred to data published by Fröhlich (*16*) based on pre-satellite era measurements from rockets and balloons. From these data he concluded that there was a real change in the solar output from 1968 to 1978 of 4 W/m$^2$ which is about 0.3% of the total output. Comparing this value with the data shown in Fig. 2, it is seen that the corresponding change in solar cycle length from 1968 to 1978 was about half of a year. From this change we can expect that the corresponding change in the solar constant from 1890 to 1984 was about 1%, which is consistent with the number estimated by Reid (*3*).

The observations we have presented suggest that long-term variations in Earth's temperature are closely associated with variations in the solar cycle length, which therefore appears to be a possible indicator of long-term changes in the total energy output of the sun. If this result can be related to a real physical mechanism there is a possibility to determine the greenhouse warming signal and predict long-term climate changes by appropriate modeling of the sun's dynamics. Estimation of the natural variability of the Earth's climate and its causes are needed before any firm conclusion regarding anthropogenic changes be made.

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