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Towards A Political Solution For Salmon Recovery

Introduction:

The management and allocation of salmon in the Northwest, and more recently, the recovery of salmon runs has always been a political problem. The struggle over who got to catch the few remaining salmon in a given fishery pitted groups, regions, and even countries against one another. The salmon blame game has now entered a new phase where each group or region or country is trying to shift as much of the cost of salmon recovery away from themselves and onto another group. Contrary to special interest public relations, everyone is and has been responsible for the decline in salmon runs, everyone in the Northwest who uses electricity, who uses paper, who eats Northwest farm products, who works in Northwest industry.

What wild salmon need to survive is not hard to figure out: they need habitat to reproduce, and they need enough adults returning from the sea to produce the next generation of salmon. We have made the commitment under the Endangered Species Act not to let salmon go the way of the passenger pigeon, but no one seems to know how to get a handle on salmon recovery, and politicians are notoriously bad at saying no to their constituents.

Salmon occupy diverse human habitats, they support a large fishing and hatchery industry, not to mention their attendant government bureaucracies; they penetetrate most of the Northwest landscape and economy. It has been said that salmon recovery would make the spotted owl struggle of the 1980s look like a picnic. We need to find an equitable solution to the salmon problem. Every region involved in the salmon crisis is going to have to do something positive to contribute to their recovery.

We need to learn how to solve complex, multi-jurisdictional problems, because there are even larger, more complicated problems on the horizon: climate change, the next energy crisis, the collapse of marine ecosystems, population and poverty.

We spoke with Joseph Taylor III, professor of environmental history at Iowa State University, and author of *Making Salmon: An Environmental History of the Northwest Fisheries Crisis*, which won the George Perkins Marsh award for best book in environmental history in 1999[1].

ER: Professor Taylor, what is your training?

JT: I graduated from high school in 1976, went for a year and a half to California State University at Sacramento and another year to Portland State University. In the meantime, I got involved in commercial fishing and became disenchanted with college. In 1978 I dropped out and for about nine years I worked as a commercial fisherman. I started with the salmon fishery on the Oregon coast, working as a Pacific City doryman, but I eventually graduated to larger boats and other fisheries.

My timing was atrocious, though, because I got into it just as the Pacific Ocean went bad. That very hardship, though, is the reason I have the perspective I do now. It comes from watching everything go bad and seeing everybody confused, not just my buddies on the ocean, but also the fishery managers, the scientists, and the politicians. Nobody had a clear answer. The more I looked at this and the more I began to question it, the more I realized it was a complicated, entangling, and to a certain extent unsolvable problem.

The salmon crisis in the 1980s eventually forced me out of the fishery yet also sparked me to wonder what had gone wrong. That in turn sparked a

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whole bunch of historical questions, and eventually I got back into school in the late 1980s and into history. I graduated from the University of Oregon in 1990 with a history degree and got my masters from Oregon in 1992. I then transferred to the University of Washington, where I got my Ph.D. in 1996 and took a position as an Assistant Professor of history at Iowa State University. That's why somebody at Iowa State is writing about Pacific salmon.

ER: Salmon recovery by this time seems to be more a political problem than a scientific one.

JT: The political problem of salmon recovery and the scientific problem are deeply tangled together, and have been so since the 1860s. How we resolve problems with the fisheries has always only partly been about technology; it's also been a reflection of what we were willing and unwilling to do to control people's behavior. The adoption of fish culture in the 1870s was in part a move towards what seemed to be a hopeful technological solution to producing salmon, but it was also partly a reflection of the constitutional obstacles to regulating fisheries by the federal government.

ER: I didn't know there were constitutional issues involved in salmon protection.

JT: Yes. Spencer Fullerton Baird, who was the first U.S. Fish Commissioner, tried to suggest restrictions along the coast of southern New England involving the Atlantic scup fishery, in which Rhode Island and Massachusetts were rivals with each other, and in which rival gear groups controlled the respective legislatures.

Baird suggested some overarching proposals for restricting fishers all along the coast, but he quickly discovered that the states were unwilling to cooperate in this because influential fishing groups didn't want to accept all his restrictions. When the states balked, Baird threatened to have Congress intercede, but he in fact lacked the power to do this because the Constitution had relegated the control and regulation of fisheries to the states.

From the beginning Baird found himself understanding quite well the problems with fisheries but unable to do much about them because he didn't have sufficient enforcement power. His adoption of fish culture stemmed in part from his inability to do other things.

ER: Is the federal government still excluded from fishery management?

JT: There are only three areas where the federal government can intrude. One is in territories, such as Alaska before it became a state. The second area is offshore fisheries. Outside the three-mile line the federal government still has the power to regulate activities, and this was extended out to 200 miles following the Magnuson Act in 1976. The third area, and the one that we are most concerned with now, is with the Endangered Species Act. Through this, in an increasingly halting manner, federal agencies have tried to protect a number of species running the gamut from snail darters to chinook salmon.

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ER: So the Endangered Species Act is our only legal tool for saving salmon?

JT: Yes, but that's a tool that cuts both ways because, on the one hand, it gives regulators some power (and that's always being negotiated) to protect particular species. Now, that itself is a problematic assertion when it comes to salmon because, as we know, these species are not entirely endangered, but the sub-races, the individual runs, are indeed in serious trouble in certain

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areas. Thus because of their evolutionary significance, ecologically significant units, or individual runs, have become the fulcrum upon which regulators can step in and say, Okay, now we need to do something.

On the other hand, the ESA is also a limiting approach because, as we also know, and have known since George Perkins Marsh back in 1856, fishery problems are usually connected to the broader environment. The problem with the Endangered Species Act, as we learned with the spotted owl and other conflicts, is that it is a species by species approach when in fact what we are often struggling with are much grander, more inclusive problems.

ER: As an historian how do you perceive the salmon crisis?

JT: As a historian, one of the things I'm always arguing is that the past matters, and that any serious effort to resolve current problems means taking seriously the complexity of past actions.

I can suggest several elements that can be instructive in this. One is thinking about what has caused the salmon decline over the long haul. The political rhetoric for a long time, going back to the 19th century, has tended to focus on single issues, but the more I looked at this issue, the less sense those explanations made and the more complicated the factors seemed, not only in terms of what happened on the water but also what happened on shore.

The upshot is that from an early point the problem of declining salmon has been attributable to just about everybody in the region. Most residents have always known this at some level, but when they speak in political settings, their explanations have narrowed down to simple, precise, and singular villains. A lot of specific finger pointing has taken place.

ER: For example?

JT: For example, the discussion of overfishing has for a long time been focused on one fishing group or another, whether it was fishwheels or traps or seines or gillnets or trawlers, when in fact, as fish regulators themselves were willing to say in private letters to one another, the problem was one of overall harvest being unrestrained. Eliminating one user group or another had simply shifted the allocations around without reducing the overall harvest.

In addition, all of the problems that were happening on the water were themselves also related to the altered landscape, the damming and logging and grazing and mining and irrigating and city building that was taking place simultaneously and also reducing salmon habitat.

... from an early point the problem of declining salmon has been attributable to just about everybody in the region.

The political rhetoric suggested that one or another group of fishers was the primary culprit, when in fact most everybody at least privately recognized that it was a much more complicated problem.

Another area would be to look at the long-term history of the solutions we've relied upon to save salmon, the most important of which has been the technology of fish culture, or hatcheries. For a long time the official pronouncements coming from state and federal fishery agencies suggested that this was a technology with great hope, that we were on the verge of finding the solution.

But in their private correspondence — you have to visit the national and state archives to see these sources — fishery officials were expressing doubts all the time. There was tremendous frustration among the superintendents and hatchery workers over the number of salmon that died in hatcheries, problems with disease, their inability to find an efficient, cost-effective food, and the constant recognition that runs were still declining. This was happening from the 1870s on, yet this is a technology we're still talking about as though it's on the verge of finding a solution 125 years later.

ER: Hatcheries have been called an ideologically-driven technology.

JT: I would disagree with that. I would say it has a lot more to do with politics. Fishery management is partly about ideology, I'll grant that, but it's also partly about the day-to-day problems of trying to find a workable political solution to declining salmon. Fishery management has always been mediated by politicians, who are notoriously bad at saying no to their constituents, so what we're talking about is a management system that has never been purely about technology or purely about ideology or purely about anything. It's a big mess.

ER: Were there any opportunities missed that might have avoided this?

JT: There are instructive alternatives. It's hard to say that there was a particular moment in time when, if someone had made this decision or that decision, we would have all ended up fine, partly because of the complexity of how we got into this mess in the first place. There was no one moment or one person or one event that explains why salmon vanished.

But, for example, if you look at the history of fish culture, there were moments in the 1880s and 1890s when federal fishery managers were expressing graver and graver doubts about its prospects, yet at the same time they also found themselves increasingly trapped by the inertia of their policies. Both federal and state fishery agencies quickly discovered that hatcheries were popular with politicians, and thus hatcheries became the cash cows of their agencies. Once they became fiscally dependent upon fish culture, though, it became very difficult to publicly criticize what they were relying on.

Nevertheless, in the 1930s, as a result of a series of scientific studies done in Canada and Alaska, there was increasing evidence of a highly rigorous nature that claims about hatcheries and fish culture producing more fish were invalid. As a result, fishery managers in British Columbia and Alaska did shut down their hatcheries, but even then it was driven more by the fiscal exigencies of the Depression than it was by the science. In both cases they eventually started up hatcheries again.

ER: Indians were taking salmon for hundreds of years before Lewis and Clark, which means they were fishing sustainably. What can we learn from that?

JT: I also argue that the Indian fisheries were far more complicated and far more significant than we often admit. The pre-contact fishery was large, intense, and sophisticated, and Indians were capable of capturing upwards of about 41 million pounds of salmon in the Columbia River every year, which is a number comparable to the largest commercial catches in the post-contact era.

Fishery management has always been mediated by politicians, who are notoriously bad at saying no to their constituents, so management has never been purely about technology, or purely about ideology, or purely about anything. It's a big mess.

The reason I mention this is because, once you accept that number, it becomes clear that this was a fishery that had a tremendous potential to harm runs, yet didn't. Looking at the ways Indians restrained themselves -- the way they claimed fishing sites, accorded fish respect through ceremonies, and restricted themselves through taboos -- and these various restraints probably had a significant impact on the long-term sustainability of their fisheries.

ER: They didn't build dams but they did build weirs.

JT: Weirs are instructive. They were an incredibly efficient technology, which blocked entire streams, and they were often accompanied by sophisticated traps that caught fish automatically.

But in all these cases, for a variety of reasons both cultural and material, weirs were temporary structures. Once Indians caught enough fish in the fall for their winter stores, they would disassemble their weirs. If they didn't take them down, the floods would. So there were both cultural reasons for taking them down out of respect to fish, and material reasons to protect the structure and ensure that enough fish escaped upstream for the next group of Indians, because these were social fisheries and politics was as deeply imbedded in fishing as anything else.

So weirs are interesting devices which again show Indians' awareness of their impact, their sophistication, and their awareness of what could possibly happen if they didn't think about the future, if they didn't act responsibly. Moreover, their neighbors were also making sure that they acted responsibly.

ER: Respect is a word that we haven't heard much in this context.

JT: It's deeply embedded in aboriginal culture, and there's no way to understand Indians' relationship with salmon without considering respect and dependence. Indians were at once both materially and culturally dependent upon these fish, not only for their sustenance but also their identity, so

they accorded salmon all sorts of respect in their daily activities and in the ceremonies and taboos they abided by. These fish were interwoven in almost every aspect of daily life in most Northwest groups. They still are.

That said, and I don't want to conflate these cultural differences too much, there are many non-Indian fishers who also depend upon these fish and respect them, not only commercial fishers but also anglers.

For people who live away from the river, who don't have a clear, direct relationship to these fish, those ties weaken quickly. This is one thing that shapes the arguments we're now having in the Northwest over what sort of relationships we should have with these fish and their environments, because not all Northwesterners value salmon equally.

I would argue that it's important for the environmentalists and fish advocates to recognize that there are other legitimate relationships with the environment, and not to get too smug or too superior about their own attitudes about these fish.

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ER: Most people would agree that the salmon should be here and we should do something to make sure that they are.

JT: Some people are more committed to that ideal than others. There is game theory involved in this, and some people have defined in their minds a point of diminishing returns beyond which, as your senator, Slade Gorton has already said publicly, we should rationalize extinction.

There may be more than one legitimate way of relating to nature.

ER: With the barging of fish around the dams and the fish ladders and the screens, and the small number of fish that make it, those are getting to be expensive fish.

JT: It gets quite expensive, and from a very narrow economic perspective, some people who have little vested in salmon, whose political support comes from people who depend upon the industrialized river, that has become their fulcrum for arguing, Well, we should just call it a lost cause and stop the funding. Other people in the Northwest, I think it's fair to say, would argue that every fish is priceless. And both are, within their own frameworks, legitimate arguments. That's part of the problem we have in the Northwest, bridging those cultural and material gaps.

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One argument I proposed for bridging these gaps is to recognize the intrinsic link between these fish and human beings. We're not simply talking about nature here. We're also talking about people and cultures and ways of life and ways of making a living.

I think it is on that level that we may have a more hopeful way of connecting, because while a Moses Lake irrigator or Lewiston dock worker has little sympathy for an Indian fisher or someone who lives at Astoria, who wants to make a living from fishing the river or the ocean, all these people do connect through their labors. It's at that level, when we're talking about people making a living, that we are able to reintroduce the issue of social equity. I think that's a potentially hopeful area where we can remake the connections.

ER: What kind of scenario are you suggesting?

JT: Well, I'm dubious about the efforts to find some governmental agency that could take control of this whole thing, because the history of salmon management suggests that nobody will give up their jurisdiction willingly. The Indians certainly are not going to abdicate their treaty rights. States jealously guard their constitutional right to control fisheries. Federal agencies that spend gobs of money and regulate the environment throughout the Northwest in a variety of ways that Northwesterners want are also unwilling to give up their authority in these matters. Then you have international treaties with Canada, North Pacific treaties involving Asian countries: all these entities are in play, and I don't think there's any way to construct one local or state or regional or federal agency that can somehow incorporate and supplant all these interests and people.

That's why I think it's important to embrace the complexity of the past and to recognize all the players and to bring them all to the table, but at the same time to force them to acknowledge the complexity of these issues and that they are part of the problem as well as part of the solution.

It's an idealistic notion, I will admit: that we could get everybody to a table and get them to sit down and begin to talk about how we reconcile these things, to get everyone at once to admit they are both culpable and have legitimate claims. Ideally, we'd get to a point where everybody would admit that all the players in this issue have legitimate vested interests. At that point I think it would be easier to get past the blame game, which I think is an insidious problem that stops us dead in our tracks far too often.

...we're all in this together, and it's only when we admit that fact, and stop trying to inhabit some moral high ground, that we're going to get somewhere.

ER: For the last 120 years.

JT: Yes, but you still see it. Wasn't it in the last election that the sport fishers again tried to outlaw gillnetters? This has been going on for a full century, and it has nothing to do with solving the problem. It's still about allocation issues.

The same goes for people blaming Indians or any other single group of people: a classic example is the urban environmentalist who lives in a wood framed house, eats meals from Northwest farms, and relies on Northwest dams for hydroelectricity, and then blames environmental problems on rural resource users. That's an argument which can only be sustained by deliberately ignoring the way we consume. In reality we're all in this together, and it's only when we admit that fact, and stop trying to inhabit some moral high ground, that we're going to get somewhere.

ER: How does game theory come in?

JT: The problem is not simply that we'll have cheaters, although it's certainly not cynical to assume that there will be cheaters. It's also that there is no one set of criteria shaping this issue; different people are going to evaluate their world and their legitimacy in tremendously different ways. This shouldn't surprise us. All we have to do is look at the history of religion to see how different people, all of whom are self-avowed Christians, constantly evaluate other people's claims to being Christian.

The same will go for the way people evaluate other people's claim to the environment. You can construct two theoretical individuals, one standing in Portland and the other standing in Pasco, both of whom will look at the Columbia River and see it in remarkably different ways. Both are all the time deciding what they want to look at and value and what they don't want to look at and not value. Portlanders tend to see the river as scenery and a conduit for fish. Pasco residents tend to see a source for irrigation and a conduit for trade. Even though they view the same river, where they stand, both in terms of their physical location and, I would argue, also their gender and class and racial perspectives, usually results in them

seeing it in remarkably different ways.

ER: This sounds rather old fashioned, but there may be another way to look at the river too, and that may be the salmon's way.

JT: Well, salmon don't have words; they don't have voices, they just are. They've evolved in a way to live in nature as a more or less hardwired existence. Your question brings us to the edge of a huge metaphysical issue, which is: Do salmon have culture? My thinking is no, nature is what it is. Salmon's ability to survive is based on what they encounter, not a question of effort or intent. So far this has been all about biological and ecological requirements of fish. Beyond that, though, trying to view the world like a fish gets a bit fantastic. I'm dubious of deep ecologists. It strikes me that there is a lot of blurring taking place in their arguments, that they are reading their grandest desires about nature and humans into an evidentiary vacuum. The problem, again, is different humans will answer those questions differently, and nature is not necessarily a useful or unambiguous arbiter.

ER: Aldo Leopold was a practical problem solver as well as a poet, and he said we should think like a mountain. In this case it would be to think like a salmon.

JT: Yes. But we don't, and ultimately we can't. While we can try to consider the evolutionary and biological and environmental criteria which sustain salmon, those things are still filtered through our particular cultural lenses as to what we find valuable or not valuable in nature. This is the conundrum we face: we can't ultimately think like a mountain or a fish because we are always also forced to think like humans. And as humans, we will invariably disagree about these things.

Power plant and fish ladder at the Dalles Dam on the Columbia River between Oregon and Washington.

Probably the most relevant example of this is dams. We don't all of us particularly like dams, but they are deeply imbedded in our lives, everyday in every way. We may not like the fact that dam turbines kill lots of fish. We don't like the fact that dams impound water and inundate spawning beds. We don't like the fact that they slow down the water so much that they prevent salmon from migrating in a timely fashion. We don't like the fact that fish ladders both enable passage and select against certain phenotypes of fish.

...the blame game is an insidious problem that stops us dead in our tracks far too often.

But if you're a sailboarder, you do like the fact that the current has slowed. If you live in north Portland or Troutdale, you do like the fact that those dams prevent floods. If you live in the Northwest and have previously lived anywhere else in the United States, you do like the fact that hydroelectricity is cheap.

In all these ways we find ourselves at odds with ourselves. I don't have easy solutions because it's not like we're saying, Well, we should just tear down these dams and go back to the time before rural electrification was widespread, or we should go back to a time when floods endangered many, many Northwesterners' lives. There are probably a majority of people who are willing to say, Well, if it comes down to whether we have sail boarding or bass fishing, well, okay, I can live without that. But the problem is these either/ors are

compound and not easily separated. Thus in trivial and not so trivial ways we find ourselves at odds with ourselves.

Sorry I don't have happy answers. I too would love consensus, and it would be nice to find some magic bullet or perfect constitutional solution that could empower a savior, the salmon czar, whatever you call it and however you want to imagine it. But the more I think about this problem, the more I realize that those are chimeric fantasies.

ER: One way would be to look at it would be as if you had absolute power to do whatever you want. That at least would give us a starting point to think about solutions.

JT: Yes. It would if you could have a benign ruler who would say, I'm going to do what it takes to have salmon runs recover to large, economically and ecologically viable populations, but within that agenda I am also going to manage in a socially equitable fashion. The first thing that you realize in this fantasy is that everybody will have limits imposed upon them, which is not something anybody wants to hear.

If I were in that position the first thing I'd do is eliminate the ocean fishery, reduce the number of fishers and move them back into the rivers, but that will enrage sport fishers and lots of people who believe that nets are some sort of absolute evil. I would also restrict logging by finally enforcing the current logging rules, rather than establish new ones, because I think the logging rules actually have adjusted considerably. I'd also enforce grazing rules more rigorously. Irrigating is trickier because we need to begin with a river-by-river evaluation to ensure that streams are not over-allocated, which many now are. A few dams would come down, but probably not many.

ER: The Grand Coulee?

JT: Grand Coulee is just one dam. Chief Joseph dam, which is downstream, also doesn't have a fish ladder, and you've also got all those Canadian dams. Grand Coulee is probably an unreasonable target because if you take it down you basically kill the economy of the Inland Empire, and that's not socially equitable. The real question right now is whether those four dams on the Snake go and do we draw down John Day dam or McNary dam. Any one of those scenarios would effectively kill upstream barging to Lewiston. If you talk to fishery managers, they will at least privately say that drawing down John Day would be much more effective for restoring salmon habitat than the four dams on the Snake. But Pasco will never allow this eventuality because it would kill their port. Again, it's a matter of distributing the limitations and the pain in a way that you get substantive recovery without overly burdening any one sector. Within that framework, some fishing and logging and farming and grazing and barging and development has to cease. As the grand salmon czar, I can imagine scenarios that get us there, but then I wake up.

If I were a salmon czar, the first thing I would do is eliminate the ocean fishery... I would restrict logging... I'd enforce grazing rules... a few dams would come down, but probably not many.

ER: I think you just describe the basis for a politically viable recovery.

JT: The politics of recovery is a lot more complicated than salmon advocates wish to admit. It's never going to happen quite on their terms, and there are probably good reasons why it shouldn't quite happen on any their or any other one person's or group's terms.

One thing I'm constantly doing in my environmental history classes is getting people to understand that there may be more than one legitimate way of relating to nature. It's not easy for people to accept that their way of thinking about the universe is not the only right way. I get accused of being a moral relativist for arguing this position, but it's not about my moral relativity at play here. All you have to do is look around to realize that there is more than one way of relating to this world.

I think if you push people, they'll admit that they're not comfortable with imposing their values on everybody. They usually retain enough self-reflection to realize that, if the tables were turned, they'd be appalled by such power and arrogance. Thus I'm trying to restore a sense of civility that may, in turn, help us resolve the salmon crisis and other important issues.

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Causes of Climate Change Over the Past 1000 years

Introduction:

The average temperature in the Northern Hemisphere has gotten warmer during the last twenty five years. Is this part of the normal ups and downs of a dynamic climate system? After all, the climate has gone through some pretty dramatic changes in recent history. Who can forget the Little Ice Age of the 1600s? And there was a warm period in Europe during the thirteenth century where average temperatures were about the same as 1950.

To get a meaningful context for all this climate information scientists have been collecting field data to extend the climate record as far back as possible. Thomas Crowley has compiled a large number of these local climate records into a history of climate variability for the Northern Hemisphere that now goes back 1,000 years[1].

A problem with climate studies has been the role of volcanoes and changes in output from the sun. Volcanoes can cause temporary cooling of the global climate; and solar output is also known to vary. Crowley incorporated volcano effects and solar variablity into a state of the art climate model and found that the model agreed with historical climate from 1000 to 1850 AD, including the Little Ice Age in the 1600s and the Medieval warm period.

The weight of circumstantial evidence is now quite strong that the unprecedented warming in the Northern Hemisphere in the last fifty years is due to greenhouse gases. While the overall change appears modest, 0.8 degrees Celsius, it has already meant large changes in higher latitudes, Canada and Russia for example. By comparison the great drought in the American Midwest in the 1930s, the Dustbowl, coincided with a 1 degree increase in average surface temperature.

We have only burned 5 percent of the available fossil fuels, so we are early in the process of global warming. If we continue with business as usual we can expect greenhouse gases to double sometime in the next century. The result of that is anybody's guess, but it will certainly mean further increases in global average temperature and more changes in climate patterns.

Scientists have been collecting data from tree rings and corals and ice cores for several decades, and each sample is by definition a record of local climate change

ER: Professor Crowley what is your academic background?

TC: I am a professor of oceanography at Texas A&M. I got my Ph.D. in geology at Brown University in 1976 using marine sediments to interpret climate change during the last Ice Age. Throughout my career I've been interested in the study of climates, primarily past climates but also present climate, and more and more interested in interpreting future climate projections within the context of the past. That has been using geological data, and over the years I've become more familiar with using climate models to understand these observations.

ER: There has been a lot of progress in climate modeling in the last few years.

TC: There's been a tremendous increase of understanding of past climate change in the last three to five years. Scientist have been collecting data from tree rings and corals and ice cores for several decades, and each sample is by definition a record of local climate change.

Over the last few years scientists have assembled these data and created summaries of temperature that now extend over the last 1,000 years for the Northern Hemisphere. And a consistent picture has emerged about how climate has changed on a regional scale, but it puts it more within a hemispheric context. For example, back in the Middle Ages (from 1000 to 1200 or 1300 AD) climate was generally moderate: it was mild in some places, in some cases it was as warm or even a little warmer than now. Then there was an intervening period when it got relatively cold, and then beginning around 1600 it was significantly colder in most of the Northern Hemisphere. It has been called a little Ice Age: alpine glaciers advanced; there was severe freezing in rivers that don't freeze now; it was colder in many places.

ER: And crop failures.

TC: Crop failures during bad years, yes. These recent climate studies not only reinforce the picture that has been put together in a fragmentary way from individual sites, but they allow us to answer several important questions.

May 18, 1980 Mt. St. Helens injected tons of gases and particles into the atmosphere. Such eruptions can cause temporary climate cooling by blocking sunlight.

Scientists have looked at individual sites from the Middle Ages where it was clearly warmer than the present. So one could argue that the 20th-century warming is no big deal since the air was warm at that site in the Middle Ages.

The point that's emerged from looking at these hemispheric syntheses is that, yes, it was warm there and some days it was significantly warmer than at present, but other places were cold, and when you take a hemispheric average, the Middle Ages doesn't come out warmer than the present. When we add these geological estimates together, the hemispheric average for the Middle Ages comes out to be some intermediate temperature, more like what it was in the middle part of the 20th century rather than the late 20th century.

The first-order result that's come out now from a number of different historic climate syntheses is that, first off, we can get a general picture of the trends. We can also demonstrate that the late 20th-century warming is unusual within the context of the last 1,000 years.

ER: Can you tell how big the temperature changes were, or are all these numbers relative?

TC: We are getting better estimates of the magnitude of temperature changes through time. For the paper that I wrote in *Science* we conducted a study asking how warm it was during the Middle Ages. We came up with our own hemispheric index and when we developed a temperature calibration for that, we got values of hemispheric temperature change that were quite close to what had been previously estimated by an independent method. So we had two different estimates of mean annual temperature change going back 1,000 years, and both indicate that the warmth of the late 20th century is very unusual within the context of the last 1,000 years.

... the late 20th century warming is unusual within the context of the last 1,000 years.

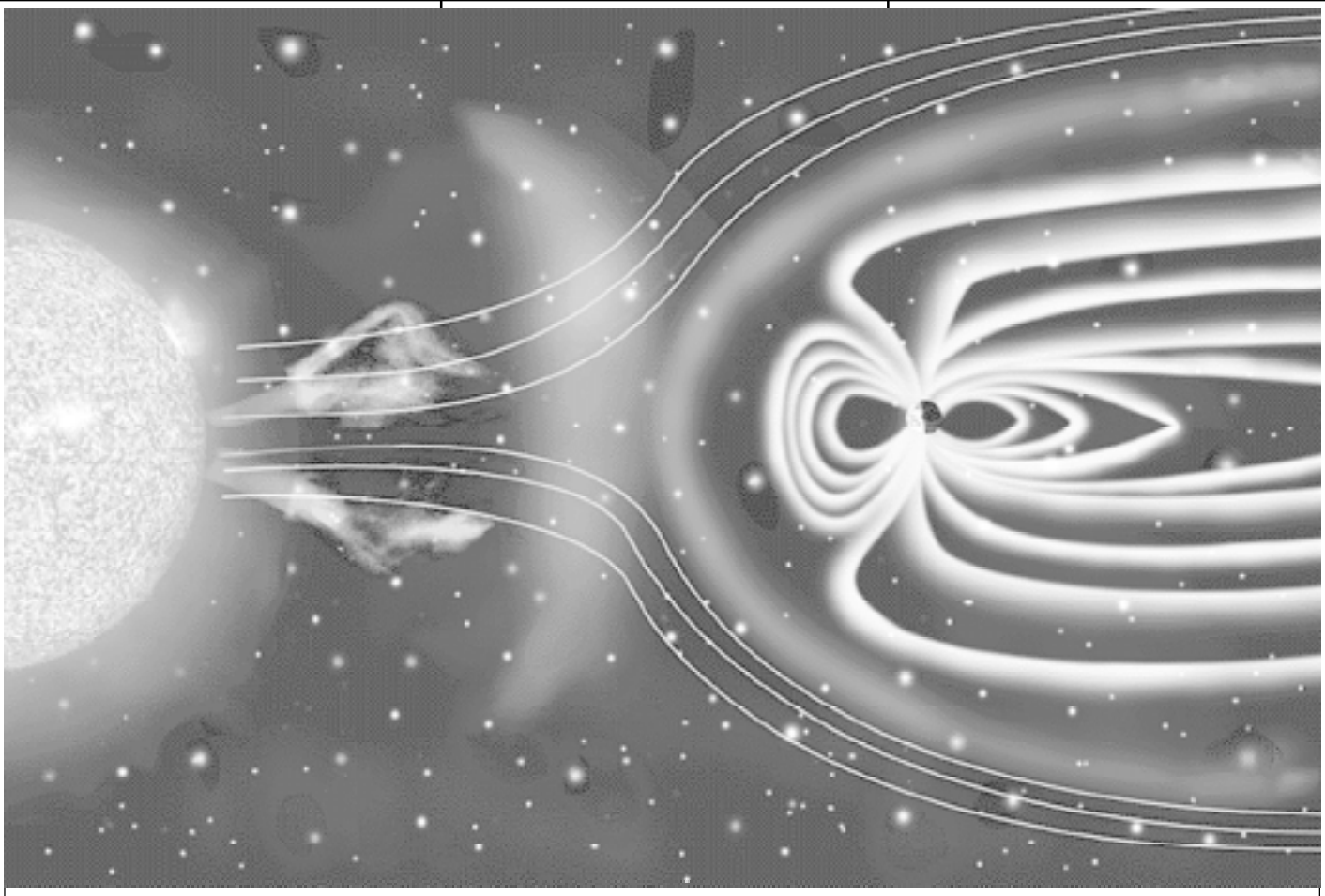
ER: How does your work relate to the cause of global warming?

TC: Many studies indicate that greenhouse gases may have been responsible for the 20th-century warmth. But the standard objections have been that we don't have a good enough understanding of other factors that can cause climate change: changes in the output of the sun, or changes in volcanism, or chaotic processes in the ocean-atmosphere system like El Niño, or things that happen on longer time scales. All of these can cause climate changes and we did not have a tight enough handle on the magnitude of these changes.

But when you have a thousand-year time series, you can cut off the last 150 years that has been influenced by man and you still have an 850-year time series of temperature variation that is long enough that you can do some pretty robust statistics. Scientists had looked at these climate fluctuations going back to 1600; we'd even published a paper a year ago on fluctuations back to 1400.

ER: Solar variability and volcanism have both been suspects in climate change.

TC: I evaluated the role of solar variability and the role of volcanism. In doing so, an unexpected result appeared: when we used estimates of volcanism and solar variability in a simple climate model to look back and predict historic temperature and compared that with the actual time series that had been reconstructed, there was a surprisingly good agreement between them, and they were also highly statistically significant; that is, the agreement



Schematic of Earth's magnetic field and solar wind, not to scale. Charged particles, mostly protons and electrons, escape the sun's magnetic field (left). These charged particles are called the solar wind and are deflected by the Earth's magnetic field. Thin white lines represent the flow of solar wind around the Earth's magnetic field (larger white lines). Every eleven years magnetic storms on the sun (sun spots) cause an increase in solar wind powerful enough to knock out satellite communications and disrupt radio and power transmissions on Earth.

Scientists have thought that changes in solar output might help explain climate change. Solar changes do affect climate but not enough to explain the late 20th century warming.

Graphic courtesy of the Solar and Heliospheric Observatory.

between the model and the historical record has a very small probability of being explained by chance alone.

ER: Was there a relationship between volcanic activity and the cold period in the 1600s?

TC: Oh, yes. We could simulate many of the smaller variations in the temperature record in the 17th century. In particular, even brief periods of decades or so of cooling and warming, many of those corresponded to pulses of volcanism or periods of less volcanism, and some solar variation. There was a surprising level of agreement between the models and the observation over that interval.

ER: How do volcanoes influence climate?

TC: When volcanoes erupt they produce two main disturbances in the atmosphere: there is pulverized mineral dust which falls out in a couple months; and sulfur dioxide is also emitted in volcanic eruptions. If the eruption is powerful enough, it can push sulfur dioxide into the upper atmosphere, into the stratosphere; once something gets in the stratosphere it can stay up there for a year or two. If it just stays in the

lower atmosphere it gets washed out in a month or two, but once it gets up in the upper atmosphere it can be distributed by the winds over the hemisphere.

If it's a big eruption it can produce a global veil of sulfate aerosols. These particles can reflect some of the sun's radiation so they shield the Earth from the sunlight and make it a little bit colder. For example, when there was the big eruption of Mount Pinatubo in the Philippines in June of 1991, there was a significant cooling of the Earth's surface for the next two years as a consequence of that blocking of the sunlight; on a regional scale it was manifested as more frequent, more intense outbreaks of cold air from Canada.

ER: How did you get a thousand-year record for sulfates?

TC: When sulfate particles get into the upper atmosphere and are distributed by the winds, they eventually settle out onto the ice sheets and are incorporated into snow. When scientists drill ice cores from glaciers, they can count the annual layers and they can find higher than normal concentrations of sulfur at certain intervals, and they can relate the sulfate-enriched layers to individual volcanic eruptions like the great eruption on Krakatoa in 1883 or an even bigger one that took place on Tambora, Indonesia in 1815. They can see evidence of these sometimes in both Antarctic and Greenland ice cores.

I used this ice core data to build an index of intensity variations of volcanism through time, and that would be how you can come up with an index of volcanism for the last 1,000 years.

ER: Can you tell when the volcanoes erupted during the Little Ice Age?

TC: Oh, yes. There was a big volcanic eruption in the late 1580s, probably two. There was another one in 1600, another one in 1605, and 1622. It's almost like a salvo going off.

ER: Do we know where they were?

TC: We know where many of them were. Once the age of exploration began around 1600, it's surprising how many of these we're able to identify pretty good candidates for. There are still some that are unknown but from 1600 on, we know. Prior to that time the record is spotty. If there were eruptions in Japan or China we might know where they were.

ER: How do you get an historical record for solar variation? There were no instruments for that until recently.

TC: Since development of the telescope there were. Early observations from Galileo and others saw spots on the sun, and from nearly continuous observations from 1610 forward they quickly identified an 11-year cycle of periods of intense solar activity and periods of quiescence.

... we've only utilized 5 percent of the available fossil fuel resevoir so far, so we're actually at the early stages of this whole warming process.

Now we know from satellite observations that the solar output changes due to the 11-year cycle are actually pretty small. Everybody that's ever tried to do a climate model simulation says if solar output is the only thing that changed, it's not enough to affect the Earth's climate in a significant way. But there's always been a suspicion that the sun was capable of lower frequency changes, on a century time scale or longer.

When the magnetic activity of the sun is high, it shields the upper atmosphere of the Earth from cosmic rays. It's not complete shielding, but there is a constant influx of cosmic rays from outside our own galaxy.

ER: Is this where your beryllium-10 data comes from?

TC: That's where the beryllium and the carbon-14 data come from. These are naturally occurring compounds in the upper atmosphere. The main form of carbon is carbon-12 of course, but when it is bombarded by cosmic rays it can be converted into what's called a cosmogenic isotope. The production rate of these cosmogenic isotopes is a function of the magnetic shielding from the cosmic rays. Beryllium can be

found on ice cores and the carbon-14 changes can be found in tree rings. So scientists have two different indices for cosmogenic activity, one from looking at carbon-14 variations in tree rings and the other from looking at beryllium-10 in ice cores.

ER: How did you use this data?

TC: I used these estimates of carbon-14 and beryllium-10 to get an index of solar forcing. I used three different indices of solar forcing going back to 1000 AD. We don't know which index is correct so it gave me a spread of possible solar forcings, whereas the volcanism correlation is tighter, the solar forcing estimates are more spread out. I have one estimate for volcanism and three different estimates for solar forcing, so you just run all the different combinations of the forcing through a climate model and compare them to the observations.

There had been this long-standing question about whether the sun and the volcanism might have caused these late 20th-century increases in temperature. We now have a moderately good handle on the magnitude of solar and volcanic changes and yes, they are important, we can demonstrate this by looking at the climate change prior to 1850. But when you apply these variables to the 20th century record, they can only explain about one quarter of the 20th-century temperature increase.

ER: The residual, what's left over, should explain the unforced response but that would still include greenhouse gases.

TC: We can also simulate a response to unforced climate change. I subtracted that solar and volcanic forcing from the historic observations, and what's left is an estimate of climate change that can't be explained from forcing. This is called the unforced response; and the estimates of the unforced variability from 1000 to 1850 were spot on what you see in the state of the art climate models.

So my study not only provides constraints on the role of forced variability, from solar variability and volcanism, but it also provides evidence that supports what the climate models have been saying: that greenhouse gas forcing explains global warming.

Then the final thing I did was to say, well, let's remove all these other forcings and see how much we can explain. I took out all the forcing from the whole 1,000-year time series and there's this huge anomaly in the late 20th century, this big warming that you can't explain. And then when you put in the effect from greenhouse gas increases, it to a first approximation explains that warming.

So it's a three-step process: we can get a handle on mechanisms of solar variability and volcanism and chaotic processes and say it can't explain them, yet greenhouse gases can.

... if you adopt a business as usual approach to industrialization and expansion in Third World countries, the carbon dioxide level of the atmosphere will have doubled sometime in the next century.

ER: There's been a terrific amount of scientific activity compiling weather data. It's become a large industry in the last 10 or 20 years. You were the beneficiary of a lot of work.

TC: Oh yes. It's built on a mountain of observations that have been made over the last thirty or forty years. I've been involved in a small amount myself with collecting some of these data from coral records in the Pacific Ocean, and I realize how time consuming and long and difficult and painstaking it is to collect these data. So I have a very good appreciation of the huge amount of work that went into putting together these databases, which were essential. I could not have written that *Science* paper if not hundreds of people had not done prior work on all these different areas.

ER: So looking back over 1,000 years of climate history, we think we have a good understanding of the mechanisms of climate change?

TC: We have a reasonable understanding of the observations. Scientists can still argue about them, but we have independent estimates and they agree. That doesn't necessarily make them right, but it makes a stronger case that they're right. And at the same time we have estimates of the forcing that says we can explain these. It doesn't mean that we're positive about it, but you can make a statistical case.

There's no such thing as a smoking gun. What you do is you pile up evidence. It's like trying to reach a jury conclusion based on weight of circumstantial evidence. The way I view this is that the weight of the circumstantial evidence has been increased now in support of the

Once more with feeling.
Two months after the first eruption Mt. St. Helens made one of several more large contributions to the atmosphere.

conclusion that the late 20th century's warming is very unusual and that it can be explained. The other scenarios cannot explain the magnitude of that warming, whereas greenhouse gases can.

ER: How much warming are we talking about?

TC: It appears modest on a hemispheric scale. The warming for the 20th century is on the order of seven to eight-tenths of a degree Celsius. *[One degree Celsius is 1.8 degrees Farenheit Ed.]* On a regional scale changes can be much larger; they're much larger in the high latitudes; for example, Canada and Russia. But when we had the Dustbowl years in Texas and Oklahoma in the 1930s, and a great drought in the 1950s, there was a change of mean annual temperature on the order of one degree C for those years. So eight-tenths may sound like a small number, but on a regional scale it's a pretty significant amount.

Even with a number that's only eight-tenths of a degree, there's clearly been significant changes in many places. Not everywhere, but we've only utilized 5 percent of the available fossil fuel reservoir so far, so we're actually at the early stages of this whole warming process.

ER: Can we evaluate what temperature changes may be coming in the future?

TC: It's tricky, but I think we can do a reasonable job. You have to estimate, for example, population growth and industrialization levels, and if pollution controls are put in, and utilization of natural resources. But nevertheless, a range of warming scenarios have been produced. There's a big spread, but if you adopt what's called a business as usual approach to industrialization and expansion in Third World countries, the carbon dioxide level of the atmosphere will have doubled sometime in the next century.

... if solar output is the only thing that's changed, it's not enough to affect the Earth's climate in a significant way.

You can use the same climate models we are using now to make projections for the future. They indicate that you could get another degree and one-half Celsius of global warming by the end of the next century, which is at least twice as what we've had this century. That is a significant global warming within the context of the last 1,000 years.

ER: How does the 20th Century warming compare to the warming in the 1300s?

TC: The present is vastly greater than the warming in the Medieval warm period. The Medieval warm period was no warmer than the mid 20th-century warm interval. There's been roughly seven to eight-tenths of a degree Celsius warming since then, so the Middle Ages would be most comparable to the early 20th-century warming. We're way outside that already.

ER: Is temperature going to keep going up at a linear rate?

TC: Actually the growth rate is not linear with time, it's more like an exponential because of population growth. As the economy of any particular country develops, per capita production of carbon dioxide increases. We expect a substantial amount of the carbon production increases in the next century to be from China and India, for example, where their standard of living is increasing. So it's more like an exponential growth rate.

With respect to the climate response to that, people may say, Oh, something will happen to stop it. But I think that's wishful thinking. You could just as easily imagine something

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happening that will amplify the warming trend. We don't know. I think the conservative approach would be not to say there's going to be a small climate change. The conservative approach is that there is a reasonable chance this is going to be a large climate change, and that you have to look that square in the eyes. You may choose to do nothing from that; that's your personal choice, but I think it would be irresponsible to say it's just not significant.

ER: The tough part is going to be the political decisions to deal with it.

TC: I try to separate the science from the policy because I'm not a policy expert. People can say, Well, it's just too much; we can't afford this. It's just too bad, but we can't afford it. To me there's a range of reasonable responses that one can take; what I wouldn't want to hear is people who say, Oh, it's just no big deal. I think that would be a big mistake. I think it would be wrong for people to say it's just no big deal or that somehow everything will work out for the best. I don't know if you have read *Candide* but I always think of Voltaire when people say that somehow it'll all work out. Not everything always works out for the best. We need only look at the 20th century to make that point.

NEXT MONTH

BLACK FOOTED FERRET RECOVERY
Della Garell

EFFECTS OF PCBS ON WILDLIFE
Peter Ross

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