The sense of disarray in the global effort to address climate change deepened Thursday with the resignation of Yvo de Boer, the stolid Dutch bureaucrat who led the international climate change negotiations over four tumultuous years.

His departure, which takes effect on July 1, comes after a largely unsuccessful meeting in Copenhagen in December that was supposed to produce a binding international treaty but instead generated mostly acrimony and a series of unenforceable pledges by nations to reduce their global warming emissions.

Mr. de Boer did not directly link his decision to step down to the chaos at Copenhagen. But he was known to be frustrated and exhausted by the meeting's failures. His resignation was seen by some as a further sign that the United Nations framework, which for almost two decades has been viewed as the best approach to tackling global warming, may have outlived its usefulness. And it raised questions about whether any significant progress toward a global treaty would be made by December, when the next United Nations climate talks are to be held in Cancún, Mexico.

"If Yvo de Boer thought that there would be a legally binding treaty at the end of this year, I suspect he would be sticking around to take some of the credit for it," said Michael A. Levi, an expert on climate change at the Council on Foreign Relations. "He has put in a lot of time toward a very well-defined end."

The international climate effort has been hampered by tensions between the world's two largest emitters of greenhouse gases, the United States and China, over how to measure and report emissions. The United States, which had promised to lead global climate talks, appears nowhere near passing legislation to control its own climate-altering pollution, and China, now the world's largest emitter of greenhouse gases, seems determined to go its own way.

At the same time, the scientific underpinnings of the global effort to address climate change have been under steady attack in recent months. Those who are skeptical of global warming science have been
invigorated by a small number of errors in the landmark 2007 report from the United Nations Intergovernmental Panel on Climate Change. The head of that panel, Rajendra K. Pachauri, is facing criticism for those mistakes as well as accusations of conflicts of interest for taking consulting fees from business interests. (Dr. Pachauri has said that he donates all such fees to the nonprofit research institute in New Delhi that he runs.)

"We have seen a situation where the politics of climate change are really, really difficult among a number of key actors, and nobody, not even Mr. de Boer, was able to cut through that," said Kim Carstensen, the director of the Global Climate Initiative of the World Wildlife Fund.

Janos Pasztor, the top climate change adviser for the United Nations secretary general, Ban Ki-moon, said that Mr. de Boer called Mr. Ban two days ago to inform him of the decision. Mr. Pasztor rejected the idea that Mr. de Boer's resignation was linked either to the lack of an outcome at Copenhagen or to the controversy over the intergovernmental panel. But others noted that, although the international system might have been at fault for Copenhagen's failures, some rancor was inevitably directed at Mr. de Boer, as the United Nations' central representative, and it probably speeded his departure.

"It is probably the right time to get a fresh face in. It has been a pretty grueling two years from Bali to Copenhagen," said Mark Kenber, the policy director for the Climate Group, an international organization pushing for a climate change agreement. "A fresh face would respark the whole process."

Some critics said that the United Nations should have moved faster to find areas where agreement among the more than 190 nations gathered at Copenhagen could be reached -- rainforest preservation, for example -- and designated a smaller, more manageable forum to negotiate more intractable issues blocking the talks. And Mr. de Boer, some said, was perceived as too confrontational by some nations, and some saw him as too enthusiastic in raising expectations for an international treaty, even after it became obvious that no such treaty would be forthcoming.

"His role as much as anything else was to be a cheerleader," Mr. Kenber said. "It was probably the right thing to do; maybe he was too effusive."

The renewed debate over the science may have also contributed to the pressures on Mr. de Boer, other critics noted.

In a statement announcing his departure, Mr. de Boer expressed disappointment about the Copenhagen talks and said that while governments could provide a framework for action on climate, the solutions must come from the businesses that produce and consume the fuels that add to global warming.

"Copenhagen did not provide us with a clear agreement in legal terms, but the political commitment and sense of direction toward a low-emissions world are overwhelming," said Mr. de Boer, whose formal title is executive secretary of the United Nations Framework Convention on Climate Change.

Even before the Copenhagen meltdown -- the American climate negotiator Todd Stern called it a "snarling, aggravated, chaotic event" -- global leaders were exploring other avenues for addressing the climate problem.

The United States last year assembled a group of 17 nations called the Major Economies Forum, which took up climate as one of its major issues and which will continue discussions in parallel to the United Nations process. The Group of 20 also put climate change on its agenda. France, Mexico, Norway and others are looking for ways to address discrete aspects of the issue, including financing for low-carbon development projects. And many nations, including the United States and China, are embarking on bilateral
energy projects, wholly independent of the United Nations, with the goal of reducing emissions and developing nonpolluting alternatives.

"The U.N. system has significant weaknesses and it is probably important to develop ways to have dialogues in other, more narrow forums where we don't have 180 people around the table at the same time," Mr. Carstensen said.

No one was more frustrated with the Copenhagen talks than Mr. de Boer, who had traveled incessantly for four years trying to prod nations to produce a treaty on global warming by the end of 2009. In a statement, the United Nations said Mr. de Boer was joining KPMG, an international consulting group, as global adviser on climate and sustainability.

In an interview in Amsterdam on Thursday with The Associated Press, he said that the high point of his tenure at the United Nations was the agreement in Bali at the end of 2007 under which nations agreed to a December 2009 deadline to produce a worldwide treaty. That treaty was to have been signed at Copenhagen, which produced instead a much weaker political agreement after nearly two weeks of bitter and largely fruitless argument. Participants refused to ratify the three-page Copenhagen Accord that emerged from the meeting, agreeing only to "take note" of it.