



## The New Alliance Between Science, Policy and Religion in the Pursuit of Sustainability

Veerabhadran Ramanathan

University of California at San Diego

*\*This written version, while it retains the essential topics and ideas presented at the meeting, is a substantially expanded and modified version.*

### I. The need for the New Alliance

A series of meetings on climate change organized by the Pontifical Academy of Sciences since 2011, as well as meetings organized jointly with the Pontifical Academy of Social Sciences since 2014, have paved the way for an influential alliance between science, policy and religion. This alliance is already having a demonstrable impact on climate change dialogue by bringing the human dimension to the fore. If nurtured and developed further, the alliance has the potential for speeding up mitigation of climate change before it is too late. I am not implying that the alliance by itself can solve the climate change problem. My assertion is that it can become a transformative catalyzing agent. Currently we are at an impasse with respect to mitigating climate change. The Paris agreement of 2015 is a breakthrough step in the path towards mitigation but it lacks verifiable and enforceable mitigation actions. Nations are struggling hard to come up with such policies but thus far have not succeeded. In the meantime, human activities are dumping about 38 billion tons of carbon dioxide every year in addition to dumping other climate warming gases and particles which amplify the CO<sub>2</sub> warming by a third or more. Climate change is happening now and likely to get a lot worse a lot sooner than the century timescale assumed by most people. There is still time to prevent dangerous to catastrophic climate changes. But we must act with urgency now and it is in this matter of urgency that the alliance can be of great help.

What we need, in my opinion, is massive public support and outcry for urgent mitigation actions of the sort summarized later in this text. The global reception to Pope Francis' encyclical on climate change, destined to become a classic, is a case in point. The encyclical *Laudato Si'* published in 2015 demonstrates how religious catechism is aligned with the call of scientists and policy makers to protect nature and thus protect people. *Laudato Si'* is unique in its call to "...hear both the cry of the earth and the cry of the poor". That single poetic phrase captures the entire issue of climate justice, another topic discussed later. Religions and faith leaders have a unique authority and platform to humanize the climate change problem and highlight the ethics and morality of the actions of one billion wealthy people harming three billion poor and harming generations to be born.

By aligning with faith leaders, scientists and policy leaders can access a major potent tool in the toolkit for solving the defining problem of our day. The text will elaborate on the roles of the alliance and its accomplishments thus far. It will also make a case for how the alliance can move the dial towards a resolution to the climate change problem and thus pave the way for a sustainable planet and sustainable humanity.

### II. A natural scientist grappling with a human tragedy

I would like to start with some background on how a natural scientist like me transitioned into seeking an alliance with religion. There were two singular events that catalyzed this transition. The first happened in 1975 at NASA; the second in 2014 began at the Pontifical Academy of Sciences of the Vatican and culminated in a 2-minute briefing on climate change to Pope Francis at a parking lot inside the Vatican. These two events are not singular in the absolute sense of the word, but singular with respect to the events that enabled me to recognize the force that religion can be in helping us with the climate change problem.

**II.1 The delicate natural balance that maintains climate:** My PhD thesis work, completed in 1973, was on the climate of Mars and Venus, both of which are an integral part of the present narrative. The atmospheres of the two planets consist primarily (96% or more) of carbon dioxide, denoted by the chemical symbol CO<sub>2</sub>. Carbon dioxide, being the main villain of my narrative will occur repeatedly in the text and hence I will be frequently using its chemical symbol, CO<sub>2</sub>, as a short form. The greenhouse effect of CO<sub>2</sub> played a dominant role in determining the super-hot temperature of Venus but it was not potent enough to prevent Mars from being

frozen. The greenhouse effect is a metaphor (not an accurate one) for how CO<sub>2</sub> in the atmosphere warms the planet (see explanation in the box).

- Venus has too much carbon dioxide, about 150,000 times more than that of earth. As a result of the greenhouse effect of the massive amounts of CO<sub>2</sub> on Venus, its surface temperature is too hot at 570°C, compared with 15°C in our home planet, Earth. The common understanding is that Venus is hot because it is too close to the sun. Yes, Venus is closer to the sun than Earth and as a result receives about 90% more solar energy. Such a large amount of sunlight would have been sufficient to maintain its hot surface. However, Venus is overcast all the time with highly reflective (mirror-like) clouds. The cloud-covered planet bounces (reflects) about 70% of the incoming solar energy back to space, compared with Earth which bounces back only 29% due to its partial cloudiness. The net effect is that the solar energy entering the lower atmosphere of Venus is actually less (by 12%) than that reaching Earth's lower atmosphere and surface. The inescapable deduction is that Venus' hot climate is not due to its proximity to the sun, but instead maintained by the greenhouse effect of CO<sub>2</sub>.

- Mars on the other hand is so far away from the sun that the solar energy reaching Mars is only 56% of the energy than that reaching Earth. The CO<sub>2</sub> concentration on Mars is about 23 times than that of Earth. But the larger greenhouse effect is not sufficient to overcome the significantly smaller incoming solar energy. The net result is that the surface temperature of Mars is very cold at -55°C (minus 55°C).

Thus, Earth is sandwiched between a super-hot Venus and a super-cold Mars. Earth is not only at the “right” distance from the sun but also has the “right” amount of CO<sub>2</sub> to be a habitable planet with water existing in all three phases: it exists as a gas (vapor) in the atmosphere bringing us weather extremes such as storms and droughts; it exists as liquid and ice in clouds bringing us rain and snow; it exists as water forming the oceans, rivers and lakes without which life as we know it would not be possible; and as ice crystals so we enjoy snowcapped mountains, ski resorts and yes, all the majestic glaciers. There were times in the past when CO<sub>2</sub> was elevated by 5 to 10 times the present concentration and the surface temperature was warmer by 10°C to 15°C; earth was ice-free even in the Antarctic. On Mars water can only exist mostly as ice, while on Venus it can only exist as steam, at least from the surface through the entire lower atmosphere (about 30 km thick). In summary, there are numerous supporting empirical evidences, planetary as well as paleo-climatic, for concluding that CO<sub>2</sub> warms the climate and its concentration in the atmosphere is a major regulator of climate of Venus and Earth.

**II.2 Upsetting the delicate balance:** It is the delicate balance between the distance from the sun, the CO<sub>2</sub> amount and cloudiness which is a major if not the dominant factor for sustaining the habitability of the planet. See the box for a brief explanation of how these three forcing factors determine climate. This balance is being disturbed drastically by human activities. The technologies that propelled the industrial revolution, relying mostly on burning fossil fuels, dumped about 2.2 trillion tons of carbon dioxide into the air since the dawn of the industrial revolution. Mr. James Watt ushered in the industrial revolution through the improved steam engine he invented in the 1770s. The greenhouse effect of CO<sub>2</sub> began to increase more than 150 years ago and is increasing now at alarming rates. Until 1975, scientists assumed that CO<sub>2</sub> was the only manmade greenhouse gas pollutant we have to worry about. There were others and these were not considered or discovered by scientists then. This brings me to the first singular event that happened to me in 1975.

**II.3 The first singular event that drew me to climate change:** I completed my PhD thesis in early 1974 and started looking for a job to get deeper into the climate of Venus and Mars. There simply were no jobs, either in the USA or in India, devoted to research on the climate of Mars and Venus. Looking back now, it is obvious why there were no jobs (except for a select few) in that seemingly esoteric field... but at that time it came as a rude shock to me. My only option was to rely on my Indian undergraduate engineering degree and apply for jobs in industries. Before I went to the first job interview in a tire manufacturing company, NASA out of the blue (through the intervention of a former student of my thesis advisor) offered me a job in their space vehicle reentry division. The project, unusual for a space reentry division, was to examine the Paul Crutzen hypothesis that emissions from super-sonic transport (SSTs) aircraft will deplete the ozone layer in the upper atmosphere. My specific task was to develop a climate model to evaluate how the depletion of upper atmosphere ozone will impact climate near the earth's surface. Little did I know then that in about four years I would start a life-long collaboration with Professor Paul Crutzen. It was Professor Crutzen who thirty years later, in 2004, proposed me for membership at the Pontifical Academy of Sciences (PAS). PAS, as I mentioned at the beginning, was the location of the other singular event and I will return to this PAS narrative later.

While my day time job was to evaluate the climate impacts of ozone depletion (an easy task), in the evenings I started looking at the other gases released by human activities simply out of scientific curiosity. I was very curious about their climate effects. The quantum mechanics I learned during my attempts at graduate school to model the greenhouse effects of CO<sub>2</sub> came in handy. It is the quantum mechanical properties of molecules that

determine their climate warming effects. After about 6 months of these nighttime attempts, I stumbled on a major discovery that CO<sub>2</sub> was not the only manmade pollutant warming the climate but there were other greenhouse gases. This finding was published in 1975 (1). Among the non-CO<sub>2</sub> pollutant gases identified by me, were chlorofluorocarbons-11 and -12 (CFC-11 and CFC-12), which were used as refrigerants in refrigerators and air conditioners. They were also used as propellants in spray cans. The surprising finding was their warming potency compared with that of CO<sub>2</sub>. A ton of CFC-11 and a ton of CFC-12 in the air had the same warming effect of more than 10,000 times of a ton of CO<sub>2</sub>! Fortunately for the planet, CFC-11 and -12 were banned in the 1980s by the Montreal Protocol. Montreal banned CFCs not because of my climate warming findings, but due to their impact on the ozone layer. Three scientists who made pioneering discoveries of the impact of CFCs on the ozone layer received the Nobel Prize in Chemistry, two of whom, Paul Crutzen and Mario Molina, are also PAS Academicians.

So why was the large warming effect of CFCs a singular event for me personally? I was amazed at the capacity of technology and of human beings to change the environment. Even at tiny amounts of just a few parts per billion, a purely synthetic compound such as CFC-11 or CFC-12 can have such a huge impact on climate was a startling eye opener. Within two years, this discovery provided the incentive for other researchers to unearth other manmade greenhouse gases polluting the air. I knew then that the changes would be fast enough that I would live to see the predicted changes. To find out when, I teamed up with a meteorologist and predicted in 1980 that manmade climate change would become apparent (that is, the human signal will rise above the weather noise) by 2000. This was confirmed in 2001, when a team of several hundred scientists commissioned by the UN (the so-called Intergovernmental Panel on Climate Change, or IPCC), confirmed the finding of discernible human imprint on the observed temperature changes.

**II.4 Coming to grips with the human tragedy:** Until about 2000, the climate change problem was one of just scientific curiosity and I never thought about the human dimensions of the problem, or more appropriately, the human tragedy that could unfold with unchecked climate change. The profound importance of the climate change problem became apparent to me; in addition, the greenhouse effect of CO<sub>2</sub> on Venus was a constant reminder that the climate change problem could become lot worse if the pollution continued unchecked. The climate change issue began to nag me and I began to see my work not as a scientific curiosity (that brought publications in prestigious journals and honors) any more, but one that brought bad news to the world. I was finally beginning to see my papers for what they really were... obituaries for human beings likely to succumb to pollution and future climate tragedies. It was not until the encounter with Pope Saint John Paul II in 2004, that I saw a way to turn this feeling around to a more positive one. But scientific curiosity prevailed in the meantime and plenty more bad news was unearthed from research expeditions to my birth country India and the surrounding Indian Ocean. I will summarize these first before describing the singular Vatican encounter.

**II.5 Climate science is data-driven science:** Pollution not only continued unchecked but annual emissions of pollutants were increasing rapidly. In the meantime, I followed the 1975 paper on CFCs by working with NASA engineers to design a satellite experiment to understand better the delicate balance between incoming solar radiation, cloudiness and the steadily increasing atmospheric greenhouse effect. In scientific terms, there was no more balance, but imbalance between incoming solar radiation, atmospheric greenhouse effect and cloudiness. The satellite designed to measure this imbalance was launched by NASA in 1984. Teaming up with NASA and other university scientists, I led a study which showed that clouds had a large cooling effect on the planet. In addition, analyses confirmed the massive natural greenhouse effect of water vapor; and also showed that the warmer planet could become more humid and increase the water vapor greenhouse effect feeding back and amplifying the initial warming. These findings were already inferred from climate models by numerous scientists but the observational confirmation built significant confidence in climate models.

With my students and researchers in my lab, we started collecting data from ships, surface stations and air craft including autonomous drones since 2005. More bad news about the environment was uncovered from these expeditions. The major one was the Indian Ocean Experiment conducted with 50 scientists from around the world including Paul Crutzen, Jos Lelieveld of Germany and A.P. Mitra of India. We discovered widespread 1 to 3 kilometers thick brown clouds (of air pollution particles) over south and east Asia. Follow-on studies showed the ABCs were impacting Asian climate in multiple ways: slowing down the monsoon circulation; destroying millions of tons of crops; melting glaciers and sea ice and disrupting tropical weather systems. The toxic clouds were named ABCs for Atmospheric Brown Clouds. In essence, there is a climate change problem and an air pollution problem, both of them having global as well as regional and local impacts. The discovery of climate impacts of ABCs revealed that the climate impact of air pollution was for the most part worsening the climate effects of greenhouse gases.

The basic message I am trying to convey with the above detour on observational inferences is the following: climate change science is an intense data-driven science as opposed to the dismissal by skeptics that climate

change is done solely with models and hence untrustworthy. I am hoping that non-specialists, policy makers and faith leaders alike will take note of this point.

#### *Climate System: The Delicate Balancing Act*

*The fundamental energy source for climate is solar energy. Not all of this energy is absorbed by the planet. The surface, the atmosphere, clouds and ice and snow cover over mountains and glaciers reflect some of the incoming energy back to space. About 29% of the solar energy is reflected back to space. The remaining 71% heats the planet and its atmosphere. In response, the surface gives off the energy as infrared (or alternately heat) radiation. But the CO<sub>2</sub> in the atmosphere blocks this heat radiation and radiates some back to the surface and the rest to space. The re-radiation back to surface warms the surface even more. This process goes on until what comes in as solar energy leaves the planet as heat energy and there is balance between incoming solar energy, reflected solar energy and outgoing heat energy.*

*The blocking of the heat energy is called as the greenhouse effect. CO<sub>2</sub> is not the only greenhouse gas. Water vapor, a naturally occurring gas is also a potent greenhouse gas. Clouds are the dominant regulators of climate. They reflect solar energy and cool the climate; but they also block heat energy which warms the climate.*

*It is the balance between incoming solar energy, reflected solar energy and outgoing heat energy that is upset by increasing the amount of CO<sub>2</sub>. The increased CO<sub>2</sub> blocks more heat energy and as a result the solar energy absorbed by the planet is not balanced by the outgoing heat energy. The planet begins to warm to restore the energy balance. During this process water vapor and clouds change too and alter the amount of solar energy reflected to space as well as the heat energy radiated to space and complex set of feedback processes interferes with the balancing act.*

### **III. A natural scientist seeking alliance with religion**

**III.1 Sixty years old and desolate:** The year was 2004. I was in a desolate state of mind not because I was turning 60 years that November, but because of the inaction in mitigation of climate change (the 1997 Kyoto Protocol notwithstanding) combined with my realization that climate change is slowly becoming a great human tragedy. The stage was set for the second singular event which began in October of 2004. I was in the Maldives islands test-flying a drone (unmanned aircraft) loaded with instruments to measure south Asian air pollution. I had envisioned this new tool (drones) to become the workhorse for monitoring climate change and air pollution and hence spearheaded an effort to develop lightweight (50 kg) drones into a viable platform. The campaign was frustrating because no one had attempted such complex measurements from small drones before and

every day in the field offered a new lesson in humility. The worst lesson was the day when the drone, fully loaded with sensors and instruments, dived from about 500 feet above and crashed into the runway. About this time, an email from the Pontifical Academy of Sciences (PAS) arrived. The email had an attachment which was a letter from PAS Chancellor Monsignor Marcelo Sánchez Sorondo, announcing my election to PAS. It also mentioned Pope John Paul II. The letter informed me that the election to the Academy would happen during the first week of November. I flew to the Vatican straight from the Maldives with my island-style clothes, while the field campaign was still going on. My younger colleagues took charge happily. Nothing prepared me to what was waiting at the Vatican. Upon arrival, I purchased a dark color suit in Rome, which I still wear when attending meetings at the Vatican.

**III.2 Beginning of the second singular event:** I was inducted to the Academy personally by the Pope himself (now a Saint), which was a complete surprise to me. To be in the presence of the spiritual head of 1+ billion Catholics was something I never dreamt of while growing up in small towns and villages in south India. I was so glad I purchased the suit. As the Pope offered his hand to congratulate me, I took it as a blessing from the Holy Father and I had the vague feeling of witnessing a singular moment in my life. But I did not know what shape or form it would take. I had to wait for nearly 10 years, when on May 6, 2014 I gave the so-called parking lot pitch on climate change to Pope Francis outside Domus Sanctae Marthae, his residence inside the Vatican. But that singular path from Pope John Paul II to Pope Francis took me through a conference co-organized under the sponsorship of Pope Benedict XVI in 2011 with Paul Crutzen and Msgr. Sánchez Sorondo.

The conference was held from Oct 2 to 4, 2011 and was titled *Fate of Mountain Glaciers in the Anthropocene*. Voluminous data on the climate change impacts on Alps and Tibetan-Himalayan glaciers took center stage. Austrian glaciologists showed how the Alps had already lost about 75% of their mass. The Indian glaciologist showed that about 70% of small glaciers were melting. In addition, Chinese data showed that high altitudes of Tibet-Himalayas were warming twice as much as the global warming. I reported on some of the Maldivian/Indian data collected by my lab and concluded that black carbon from cook stove smoke could be contributing as much as half of the observed large warming of Tibetan-Himalayas. It was sobering to listen for three days to all of the environmental destruction. However, the main surprise of the workshop as well as the turning point for me personally, was the conference declaration. The declaration was released with a supporting conference summary of fifteen pages. Both of the documents were prepared over the next several weeks. The fifteen-page document full of technical details typical of such statements written by scientists, concluded with the following declaration:[1]

*We call on all people and nations to recognize the serious and potentially irreversible impacts of global warming caused by the anthropogenic emissions of greenhouse gases and other pollutants, and by changes in forests, wetlands, grasslands, and other land uses. We appeal to all nations to develop and implement, without delay, effective and fair policies to reduce the causes and impacts of climate change on communities and ecosystems, including mountain glaciers and their watersheds, aware that we all live in the same home.*

The paragraph above ended with the following call for action:

*By acting now, in the spirit of common but differentiated responsibility, we accept our duty to one another and to the stewardship of a planet blessed with the gift of life. We are committed to ensuring that all inhabitants of this planet receive their daily bread, fresh air to breathe and clean water to drink, as we are aware that, if we want justice and peace, we must protect the habitat that sustains us. The believers among us ask God to grant us this wish.*

As we can discern from the above, it ended with an appeal to the spiritual side of each of us without alienating the non-believers.

**III.3 Formation of a science-religion alliance on climate change:** The glaciers meeting declaration reproduced above was surely an unusual and atypical declaration for a predominantly scientific gathering. I have never encountered such a paragraph written by any reports such as IPCC and hundreds of other climate change reports written by scientists. But it is not atypical for a religious document. There is a huge gap between science and religion in how scientific findings are communicated to the public. Scientific facts are usually inaccessible and incomprehensible to the public; on the other-hand religious documents bring forth clearly the human dimension of the problem in such a manner that they can be understood by everyone. But religious documents on matters of science written without participation by scientists risk compromising scientific rigor and potentially misrepresenting the needed actions. And this danger can be avoided by the sort of alliance that is made possible by a prestigious science academy such as the PAS, located within the premises of the Church. The fact that the place of worship in this instance is also the Vatican, a truly historic place, helps... more so because it has a following of more than one billion worshippers from around the world with one faith leader, the Pope, to guide them. This juxtaposition of the historic Vatican and the faith leader of 1+ billion, with the Pontifical Academy of Sciences and its 80 preeminent scientists from around the world elected on

scientific merit (irrespective of their nationality, race, culture and religious affiliations), turned my despair and desolateness into a profound sense of hope and optimism. My conviction then and now is that this unique combination of people and location can be a new force for the solution of the climate change problem.

I left the 2011 glaciers meeting with an understanding that the PAS-Church alliance has the potential to translate the complex scientific facts of climate change into a clear statement of the human tragedy that can be comprehended by everyone. I saw this as one avenue for transcending the current all-consuming and unproductive American debate on the reality of climate change and reach out to the public about the dangers of unchecked climate change and the urgent need to do something about it.

**III.4 Sustainable Humanity, Sustainable Nature: Our Responsibility:** Now that the human dimension of climate change can be expressed in such a bold and forthright fashion (the glaciers declaration described above), the need to bring in social scientists became apparent. An opportunity to do just that happened rather miraculously. About a year after the Glaciers meeting, I had an accidental meeting at the Vatican in May of 2013 with Professor Partha Dasgupta, an economist at Cambridge University and an Academician of the Pontifical Academy of Social Sciences (PASS). We both were attending a meeting organized by PASS. After the meeting, we bumped into each other and after half an hour of pleasantries, I found myself face to face with Partha in a restaurant not too far from the Vatican. At the end of this rather long dinner which began at 7PM and ended by about 10PM, we had developed a rather detailed plan for a joint meeting between the two academies on the general topic of sustainability of nature and sustainability of humanity. Partha proposed it next day to the Chancellor who accepted it right away very enthusiastically and asked us to start organizing it under Pope Benedict's sponsorship. PASS brought in Archbishop Minnerath from France as co-organizer, which completed the alliance between natural sciences, social sciences and religion. Archbishop Minnerath inserted the phrase "our responsibility" to the title. That was a big awakening for me since until then I had not perceived the climate change problem as my responsibility. Pope Benedict stepped down before we could organize the meeting. So the meeting was convened in May 2-6, 2014 with a message from Pope Francis. The title of the meeting was *Sustainable Humanity, Sustainable Nature: Our Responsibility*. Befitting the ambitious title and the grand setting offered by the Vatican, we managed to invite many thought leaders, including religious scholars, to conduct one of the most inter-disciplinary and broadest discussion of issues to-date. Excerpts from the long declaration are reproduced below:

*Humanity has entered a new era. Our technological prowess has brought humanity to a crossroads.*

*Human action which is not respectful of nature becomes a boomerang for human beings that creates inequality and extends what Pope Francis has termed "the globalization of indifference" and the "economy of exclusion"... which themselves endanger solidarity with present and future generations.*

*The massive fossil fuel use at the heart of the global energy system deeply disrupts the Earth's climate and acidifies the world's oceans. The warming and associated extreme weather will reach unprecedented levels in our children's life times and 40% of the world's poor, who have a minimal role in generating global pollution, are likely to suffer the most.*

*These are matters on which all religions and individuals of goodwill can agree. These are matters that today's young people around the world will embrace, as a way to shape a better world. Our message is one of urgent warning, for the dangers of the Anthropocene are real and the injustice of globalization of indifference is serious. Yet our message is also one of hope and joy. A healthier, safer, more just, more prosperous, and sustainable world is within reach. The believers among us ask the Lord to give us all our daily bread, which is food for the body and the spirit.[2]*

**III.5 The parking lot pitch to Pope Francis:** Before the meeting ended on May 6, Pope Francis met with the whole group of about 50 participants outside his modest residence at the Vatican. It was a parking lot. He got out of the front seat of a Ford Focus and headed straight towards us. I was completely unprepared for this encounter since my mental picture until that moment was the breathtaking hall in the Basilica where I had had my previous audiences with Pope John Paul II and Pope Benedict... Partha and I were each given two minutes to summarize the meeting. I had prepared for a 20-minute briefing, but just before meeting the Pope was told to cut it short to two minutes, due to unexpected demands on the Pope's schedule. Mercifully Partha spoke before me but I did not listen to what he said because of the mental trauma I was in, trying to reduce 20 minutes to a 2-minute summary. I summarized the meeting outcome as follows (recounting from memory and hence only approximates what I said): *Climate Change has become a serious problem and all of us assembled here are concerned; About half of the climate pollution is caused by the wealthiest one billion, while the poorest three billion who contributed less than 5% would suffer the worst consequences.* Pope Francis asked me in Spanish what he could do about it. I replied: *You as the moral leader of the world can ask people to be good stewards of the planet.*

Fifteen days later at a massive audience at the Vatican on May 22, 2014, Pope Francis reflected as follows:

*The gift of knowledge helps us to avoid falling prey to excessive or incorrect attitudes. The first lies in the risk of considering ourselves masters of Creation. Creation is not a property, which we can rule over at will; or, even less, is the property of only a few: Creation is a gift, it is a wonderful gift that God has given us, so that we care for it and we use it for the benefit of all, always with great respect and gratitude.*

*And he urged people to nurture and safeguard Creation as God's greatest gift to us, because while God always forgives, Creation never forgives and – he warned – if we destroy Creation, in the end it will destroy us.[3]*

That reflection is all I needed to be reassured that the Church is solidly behind PAS as well as the science of climate change. But the real sign that the science community is ready for such an alliance came when we were asked, four months after the May 2014 Vatican meeting, to write an editorial in the prestigious American magazine *Science*. In our editorial, we emphasized the main finding of the meeting, which was: *there is a need to reorient our attitude toward nature and, thereby, toward ourselves.*[4] For the benefit of non-scientists, there are two magazines in the world, *Nature* and *Science*, where most of the major discoveries in natural sciences are published. In addition, the two journals published editorials dealing with the nexus of science-policy-society.

**III.6 The momentous 2015:** The year 2015 was momentous for climate change, sustainability and human wellbeing. On top of the list of events that happened that year was the release of the climate encyclical, *Laudato Si'*, by Pope Francis, followed by his US visit during which climate change was one of his main agendas. Two major summits were held on climate change at the Vatican: *The Summit of Mayors from Major Cities of the World*, and a summit with UN Secretary General Ban Ki-moon. The novel aspects of these summits was that climate change was discussed along with human trafficking, slavery and poverty, in a seamless manner. Next came the United Nations (UN) declaration of sustainable development and its 17 Sustainable Development Goals at an historic UN summit in September. The culmination of this trendsetting year was the Paris Climate Summit in December and the historic agreement that resulted. As the science advisor to the Holy See delegation for this summit, I had the front row seat to see the science-policy-religion alliance in play. Many of the developing nations, including the African Alliance, came to the Holy See delegation to champion the cause of small nations that would go underwater due to sea level rise.

#### **IV. Where do we go from here?**

**IV.1 Alliance with other religions:** The fact that scientists and policy makers in academia are beginning to view this alliance with religion in a new positive light was firmly established when *Science* magazine asked us again in 2016, to reflect on the impressive developments during 2015. Monsignor Marcelo Sánchez Sorondo and I wrote the editorial in which we made an appeal: *Pope Francis' effort to unite science, policy, and religion toward an integral ecology approach is just a start. We hope that other religions and moral and political leaders will join this new synergy and nudge society toward equitable solutions to ecological and social justice problems without losing sight of the values of the human person and the common good.*

Most if not all other religions were already in a similar path as described below:

- Islamic leaders, including faith leaders, senior international development policy makers, academics and other experts, have called on the world's 1.6 billion Muslims to play an active role in combatting climate change. The leaders released *The Islamic declaration on climate change* signed in August 2015.[5]

The carefully and thoughtfully written declaration included the following call to action:

*Finally, we call on all Muslims wherever they may be – Heads of state; Political leaders; Business community; UNFCCC delegates; Religious leaders; and scholars Mosque congregations; Islamic endowments (awqaf); Educators and educational institutions; Community leaders; Civil society activists; Non-governmental organizations; Communicators and media: to tackle habits, mindsets, and the root causes of climate change, environmental degradation, and the loss of biodiversity in their particular spheres of influence, following the example of the Prophet Muhammad (peace and blessings be upon him), and bring about a resolution to the challenges that now face us.*

- Evangelical leaders worldwide, including over 300 leaders in the US, have been climate champions for at least a decade and have released strong statements in favor of urgent actions on climate change. Their declarations and call to action can be seen in the links below.[6]

- The major religions have all released strong statements in support of climate mitigation as can be seen from the website of the Yale Forum on religion and ecology. These efforts were pioneered by Professor Mary Ann Tucker of Yale University.[7]

**IV.2 Climate change morphing into an existential threat:** Beginning in 2010, along with my students and young researchers under my mentorship, I went back to the satellite/ship/aircraft/surface data collected during the past thirty years with a single question: What is the worst possible outcome of unchecked emissions of climate-warming pollutants? My hope in asking this question was that the data would reassure us that the change would not be catastrophic. Instead, the data-driven analyses informed us that there is a small chance (5% probability, i.e., a chance of 1 in 20) the warming by end of the century could be in the 4°C to 6°C range, taking us back to the ice-free hot climates of 30 million years ago. Simultaneously, paleontologists and ecologists including PAS and PASS Academicians such as Profs. Peter Raven and Partha Dasgupta, were informing us that the stage was being set for mass extinction due to habitat destruction and land use alterations. Climate change in excess of 4°C could commit 20% or more of known species to extinction. Simultaneously epidemiologists and meteorologists were concluding that a 4°C warming could expose more than 75% of the population to deadly heat. These independent studies along with our analyses led my student Professor Yangyang Xu and myself to conclude that climate change resulting from unchecked emissions of pollution would pose existential threat to all of humanity.

**IV.3: Can we solve the problem in time?** The answer to this question is a definite and unqualified Yes. Solutions have been published in numerous documents by many international groups and publications. Any solution has to take the following projections into account:

- The planetary warming will reach 1.5°C by 2030; The last time the planet was about 1°C to 1.5°C warm was 130,000 years ago and the sea level rose by 5 to 7 meters. The planet is already warmer by 1°C compared with pre-industrial temperatures.
- If the current rate of emissions continues past 2030, the warming will reach 2°C by 2050. Most scientists consider 2°C as the threshold for dangerous climate warming. Some argue that even 1.5°C is dangerous.
- If the current rate of emissions continues beyond 2050, the warming has a 50% probability of reaching 4°C before the end of the century. It has a 5% probability of reaching 6°C. Warming in the range of 4°C to 6°C will pose existential threats to all people, young and old as well as poor and rich.

There are two separate but related issues: the warming reaching dangerous levels within the next 12 to 32 years (from 2018). This is the near-term problem. Next is the warming posing catastrophic to existential risks some time during 2050 to 2100. This is the longer-term problem.

The first step towards a solution is to recognize that fossil fuels have become an outdated energy source. Fossil fuels should also be recognized as hazardous in view of the health impacts of fossil fuel-related air pollution and climate change. There are other environmentally safer energy sources and that too in abundance. In order to protect people and the planet from both the near-term and longer-term threats, we need to pull on the following three levers:

- **Carbon Lever:** We have to achieve carbon neutrality by 2050. Carbon neutrality is scientific jargon for zero emissions of carbon dioxide. Carbon dioxide currently contributes 50% to 60% of the warming and will become the dominant source of warming beyond 2050. This is a complex matter and involves global energy use and energy access, industrial processes, agriculture, transportation and others. There are scalable technological solutions to achieve about half to 2/3 of the required reductions; and for the remaining 1/3 to half, promising new technologies are being developed. Simply stated, carbon neutrality can be achieved by converting all end uses, including transportation to electricity, and generating that electricity using renewable sources such as solar, wind, geothermal and hydro power. Electricity can be stored in batteries. It can also be stored in hydrogen, provided hydrogen is produced using solar power and water. The stored hydrogen can be burned using fuel cells. For those applications for which electricity is not a viable option (e.g. air transportation), transportable fuels can be produced (e.g. jet fuel) using algal sources. These climate mitigation steps are already well under way. More than 8 million people are employed in the renewable industry: more than half of the new energy during the past few years was generated through solar and wind. About 55 cities and 62 major industries have already put in place climate mitigation plans to reduce their carbon emissions by more than half by 2040.
- **Short-Lived Climate Pollutants Lever:** There are four other climate warming pollutants which currently contribute 40% to the warming: Methane; Black Carbon; Ozone & Hydrofluorocarbons (HFCs). Methane, ozone and HFCs are greenhouse gases; while black carbon is a particle and warms the climate by trapping solar radiation in the air. Their lifetimes are much shorter (1 week to about 12 years) compared with the 100 to 1000 years lifetime of carbon dioxide, and hence their warming effect will decrease quickly in response to mitigation actions. There are also many technologies off-the-shelf that can be deployed on large scales. California has already passed laws to drastically reduce their emissions. The United Nations Environment Program has already created a Climate and Clean Air Coalition with 80 member countries to mitigate the emissions of short-lived climate pollutants. In addition, the Montreal Protocol ratified by almost all nations, was amended in 2016



to include the phase-out of HFCs. If available mitigation technologies are implemented globally beginning in 2020, the projected warming from now until 2050 can be cut by half. Thus, this lever can prevent the warming from exceeding 2°C in the near-term.

· *Atmospheric Carbon Extraction (ACE) Lever:* Pulling on the two levers above as hard as possible beginning 2020 (that is in two years) would be able to keep the warming below 2°C with about 50% probability. A 10-year likely delay would necessitate pulling on the third lever, which would remove the carbon dioxide that is already up there. A 10-year delay would require us to take out as much as one trillion tons of carbon dioxide before 2100. One trillion is: 1000 x 1000 x 1000 x 1000. That is a huge amount of carbon that has to be taken out. There are no scalable technologies or measures to pull on this lever now, but various promising measures are being explored. These include: afforestation; soil restoration to increase its ability to store carbon for centuries or more; chemically removing CO<sub>2</sub> and finding industrial use for the removed carbon; enhance ocean fertilization; produce bioenergy sustainably and sequester the carbon in natural reservoirs; and others. We have to accelerate efforts to develop scalable methods for this lever to be cost effective.

While the solutions above are feasible in principle, implementation would require behavioral changes, global to local governance, market mechanisms, technology development, forest and soil management. Above all societal transformation is required to create massive public support for implementing the solutions with urgency. Alliance with religion could be a major factor in effecting transformational changes in public support.

#### *VI: The role of the science-policy-religion alliance*

First, places of worship usually offer a politically neutral forum to reach out to the public about climate change. Such a measure, would help offset the crippling politicization of climate change.

Second, behavioral change is essential to achieve carbon neutrality, and faith leaders have more authority than scientists to appeal for behavioral changes directly to the public. The needed behavioral changes include: i) avoiding wastage of food. A third of the produced food is thrown away and avoiding this waste could reduce CO<sub>2</sub> emissions by billion tons or more a year; ii) energy and natural resources are also wasted and these wastage should be avoided; iii) in many regions it is already cost-effective and economical to switch to renewables and in such locations the public can be urged to switch; iv) As much as possible rely on plant based diets for they are less carbon intensive and also healthy; v) educate family, friends and fellow citizens about the climate urgency and the available solutions; vi) Urge people to support governmental measures to protect the poor and vulnerable from extreme climate events such as droughts, fires, floods and sea level rise.

Third, places of worship offer a unique forum to bring up ethical and moral issues of climate change. Melting of glaciers and sea level rise will last centuries to thousands of years and hence generations of children and grandchildren yet to be born will suffer because of our unsustainable actions today.

Fourth, faith leaders have the moral authority to establish clearly the equivalence between protecting creation and protecting the poor; protecting nature and protecting all species.

Last, climate mitigation actions taken by religious institutions within their jurisdictions will serve as a huge role model and living laboratory for others to follow.

#### *VII: Returning to Mars, Venus and the sandwiched planet Earth*

There is a fundamental planetary quantity called Albedo. Albedo is the percent of sunlight reflected back to space by a planet. Venus reflects 70% of the incident sunlight. So, albedo of Venus is 70%. Earth's albedo is 29% and Mars' albedo is 15%. Why is Venus' albedo so high or more colloquially, why is Venus so bright? Because it is completely cloud covered, that is, its cloud cover is 100%. Earth in the absence of clouds will reflect only about 14%. I know this because I measured it from the satellite experiment I designed with NASA in late 1970s. Clouds on Earth, although only partially filling the sky except during rainy days, double the albedo from 14% to 29%. With that background, let me conclude with my nightmare about climate change. If, due to climate change the earth's albedo decreased slightly to 27% (instead of 29%) it would be hotter by about another 5°C, beyond the 4°C warming predicted by 2100. Many studies predict that sea ice would eventually disappear if the warming continues. This single process alone, when it happens, would decrease the albedo from 29% to 28.5%. It is not inconceivable that if the planet is allowed to warm to 4°C, cloudiness can shrink (due to the heat) and decrease the albedo by another 1.5% to 27%. Climate models may claim this is not probable. But, do we want to risk our entire future to reassurance by climate models?

Solutions are available. Because of the trillions of dollars cost of the impact of fossil fuels on human health and on the ecosystem, we must choose the safer as well as cost-effective option and begin mitigation actions immediately. My claim is that alliance with faith leaders can help guide people towards that safer option.

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Since this article is largely a biographical exposition, it relies mainly on author's papers. There is no claim on the part of the author that the references below are the only major papers on the topic of the paper.

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## END NOTES

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