Journal of Sustainable Tourism

ISSN: 0966-9582 (Print) 1747-7646 (Online) Journal homepage: http://www.tandfonline.com/loi/rsus20

A review of the IPCC Fifth Assessment and implications for tourism sector climate resilience and decarbonization

Daniel Scott, C. Michael Hall & Stefan Gössling

To cite this article: Daniel Scott, C. Michael Hall & Stefan Gössling (2016) A review of the IPCC Fifth Assessment and implications for tourism sector climate resilience and decarbonization, Journal of Sustainable Tourism, 24:1, 8-30, DOI: 10.1080/09669582.2015.1062021

To link to this article: http://dx.doi.org/10.1080/09669582.2015.1062021

Journal of Sustainable Tourism, 2016
Vol. 24, No. 1, 8–30, http://dx.doi.org/10.1080/09669582.2015.1062021

Routledge
Taylor & Francis Group

A review of the IPCC Fifth Assessment and implications for tourism sector climate resilience and decarbonization

Daniel Scott[a,b]*, C. Michael Hall [c] and Stefan Gössling[b,d,†]

[a]*Department of Geography and Environmental Management, University of Waterloo, 200 University Ave. West, Waterloo, Ontario N2L 3G1, Canada;* [b]*Western Norway Research Institute, Research Centre for Sustainable Tourism, Box 163, 6851 Sogndal, Norway;* [c]*Department of Management, College of Business & Economics, University of Canterbury, Private Bag 4800, Christchurch 8140, New Zealand;* [d]*Department of Service Management, Lund University, Box 882, 25108 Helsingborg, Sweden*

(*Received 14 April 2015; accepted 3 June 2015*)

The Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) in 2013–2014 was the most comprehensive analysis of anthropogenic climate change, its impacts, and potential responses. It concluded that climate change is "unequivocal" and human activities are the dominant cause. Avoidance of "dangerous" climate change will require sustained substantial reductions of emissions by mid-century and that net emissions decrease to zero before 2100. This paper describes, reviews and explains the place of tourism in AR5 and AR5's relevance for tourism's future, including impacts, adaptation, vulnerabilities, and mitigation. Tourism's position in AR5 has strengthened, particularly with respect to the recognition of transboundary impacts, the sector's contribution to climate change and its mitigation requirements. Major regional knowledge gaps persist. A lack of understanding of the integrated impacts of climate change and the effectiveness of adaptation strategies potentially hinders the development of resilient tourism operations and destinations. Uncertainties regarding tourist response to climate change impacts and mitigation policy impede predictions of tourism demand. The implications of different decarbonization pathways for the future of international tourism represent a key knowledge gap. The limited response of key tourism organizations to AR5 contributes to the risks climate change poses to the sector.

Keywords: climate change; mitigation; adaptation; emissions; impacts; development

Introduction

This paper provides an overview of the key tourism-relevant themes in the fifth and latest set of reports from the Intergovernmental Panel on Climate Change (IPCC), published in 2013-14. It examines the place of tourism in the reports, and reviews the main tourism-relevant discussions from each Working Group. The conclusion explores the response of tourism sector leadership to these publications and the evolving policy context.

The pace of publication of new evidence about the state of the global climate system, and about the impacts of changes in its state on society and environmental systems, have been unrelenting in recent years. After a brief decrease in CO_2 emissions due to the 2008–2009 economic crisis, global emissions surged 5.9% in 2010, the largest annual

*Corresponding author. Email: dj2scott@uwaterloo.ca
†Present address: School of Business and Economics, Linnaeus University, Gröndalsvägen 19, Kalmar SE-39182, Sweden

increase recorded, and have continued to grow 2%−3% per year through to 2013 (Olivier et al., 2014). As a result, in April 2014 the atmospheric concentration of CO_2 surpassed the crucial 400 parts-per-million (ppm) threshold, the highest level in the last 800,000 years (NOAA, 2015). Although preliminary data from the International Energy Agency (IEA) indicated that global emissions of CO_2 from the energy sector did not increase from 2013 to 2014, IEA Executive Director Maria van der Hoeven stated that while encouraging, "this is no time for complacency − and certainly not the time to use this positive news as an excuse to stall further action" (IEA, 2015).

Land and sea surface temperatures continued the multi-decade warming trend, with 14 of the 15 warmest years on record occurring in the twenty-first century. 2014 was the 38th consecutive year that average global temperature exceeded the twentieth-century average and the warmest year since systematic instrument records began in 1880 (WMO, 2015). Extreme temperatures have also increased over the last three decades, with a number of studies finding that human alterations to climate have increased the probability and magnitude of heat waves. Hansen et al. (2012, p. e2415) conclude, "with a high degree of confidence, that extreme anomalies such as those in Texas and Oklahoma in 2011 and Moscow in 2010 were a consequence of global warming because their likelihood in the absence of global warming was exceedingly small". The record 2013 heat wave in Australia was estimated to be likely to occur only once in 12,300 years in the absence of recent climate change (Lewis & Karoly, 2014) or, in other words, virtually impossible without the human influence on climate (Knutson et al., 2014).

A warming planet also accelerates the hydrological cycle; generally wet areas are getting wetter and dry areas are getting drier (Durack et al., 2012). While the severe droughts over the last decade, such as the 100-year events in the Amazon in 2005 and 2010, south-central USA (2010−2013), California (since 2013), Horn of Africa and Sahel (2011) and Australia (2002−2012), have stressed natural ecosystems, caused significant economic losses, and in some cases famine and migration, studies warn these are only a precursor to the increased drought severity and frequency expected from climate change in the coming decades (Cook et al., 2015; Dai, 2011; van Huijgevoort et al., 2014).

Although media headlines tend to focus on overland temperatures, they are but one indicator of a changing global climate system. More than 90% of additional energy accumulated from the enhanced greenhouse effect is stored in the oceans. The upper layers of the oceans have warmed at a rate 50% faster than previously over the last four decades of twentieth century (Domingues et al., 2008; Durack et al., 2014). Warmer air and oceans are influencing polar ice. In 2014, the rate of decline for September minimum Arctic sea ice extent reached 13% per decade, relative to the 1981−2010 average (National Snow and Ice Data Center, 2014), a trend that if continued could result in near zero Arctic summer sea ice coverage as soon as sometime *later this decade* (Maslowski et al., 2012). Even the stability of Antarctic ice sheets is questioned by studies that found the West Antarctic Ice Sheet is thinning and the multi-century process of collapse may have already began (Paolo, Fricker, & Padman, 2015).

The global oceans have also absorbed much of the CO_2 released by human activity, cushioning the increase that would otherwise occur in the atmosphere, but with the result of increasing ocean acidity by up to 30% (Friedrich et al., 2012). The current rate of ocean geochemical changes appears unprecedented over the last 300 million years, raising the possibility that we are entering an era of far-reaching marine ecosystem change (Hönisch et al., 2012).

It is difficult to overstate the significance of these trends, which collectively demonstrate that current and future generations will increasingly experience greatly altered

climate and environmental systems. The need to respond continues to be recognized among global leaders of government, business, and civil society (IEA, 2013; World Bank, 2013).

The United Nations (UN), through the World Meteorological Organization (WMO) and UN Environment Program (UNEP), has mandated the IPCC to periodically (every 5−7 years) "assess on a comprehensive, objective, open and transparent basis the best available scientific, technical and socio-economic information on climate change from around the world" (IPCC, 2004, p. 1). The IPCC reports critically assess and synthesize the state of knowledge on observed and projected climate change, its causes, observed and possible impacts, and possible options for adaptation and mitigation.

The Fifth Assessment Report (AR5) distils seven years of effort by more than 830 core authors and review editors from over 80 countries and a wide range of scientific, technical and socio-economic expertise (IPCC, 2014a). Consistent with the Third (TAR) and Fourth Assessment Reports (AR4), the AR5 structure consisted of three Working Group (WG) reports: (1) *The Physical Science Basis* (released September 2013); (2) *Impacts, Adaptation and Vulnerability* (released March 2014), which was in turn divided into two parts: Part A on global and sectoral aspects (IPCC, 2014c) and Part B on regional aspects (IPCC 2014d); and (3) *Climate Change Mitigation* (released April 2014) (IPCC, 2014e). Cumulatively, the three Working Groups assessed more than 30,000 scientific papers and responded to the insights of over 2000 expert and government reviewers during three rounds of rigorous review (IPCC, 2014a). The *Synthesis Report*, written by the IPCC Secretariat and coordinating authors from all three Working Groups (IPCC, 2014a), distils and integrates the findings of first three volumes to succinctly answer key policy-relevant scientific questions posed to the IPCC by the international community. The final text of the *Synthesis Report − Summary for Policy Makers* (IPCC, 2014b) is approved (line by line) by the 194 IPCC member countries.

Tourism scholars and professionals have many questions about the salience and strategic implications of climate change and related mitigation and adaptation responses for the tourism sector (e.g. Weaver, 2011; Scott, 2011). Importantly, so do investors, insurers, economic development officials, community planners and many other stakeholders that work with the tourism sector worldwide.

This paper provides an overview of the key tourism-relevant themes in the AR5 and the extent of progress in understanding the interactions of climate change and tourism. IPCC recommended nomenclature for referencing reports and chapters is adopted throughout. This paper first examines the place of tourism in the AR5 using methods consistent with Hall (2008) and Amelung et al. (2008) to allow for comparisons with the IPCC TAR and AR4. The subsequent section provides an overview of the main tourism-relevant discussions in each Working Group report, including notable progress over previous IPCC assessments and identification of knowledge gaps. The conclusion explores the response of tourism sector leadership to the AR5 and the evolving policy context for which it provides the foundational science. We do not digress from the science of climate change with responses to the misinformation of climate change deniers: that has been done elsewhere (see Hall et al., 2015a; 2015b).

The place of tourism in the AR5

The place of tourism in the IPCC assessments has evolved since the First Assessment (FAR) in 1990. Indicators of the level of knowledge and importance of particular subjects within the assessments can include chapters or sections within chapters that are dedicated to certain themes, the appearance of key concepts, or the frequency a theme or sector is

referred to. For this analysis, an electronic word search was performed on the three AR5 volumes using the core terms that Hall (2008) and Amelung et al. (2008) used to examine the AR4: tourism, tourist, and recreation. We also revisited FAR and the Second Assessment (SAR) volumes for comparative purposes. While the results should only be considered indicative, they provide a high level perspective on the relative change in tourism content throughout the IPCC assessments.

A number of major impacts that remain a focus of research today, including the impact of sea-level rise (SLR) on coastal tourism and recreation, impacts on skiing, and the effect of climate change on biodiversity for tourism and recreation (e.g. fishing), were identified in the early FAR and SAR WG2 reports. Tourism also received substantial recognition in the WG3 report of FAR (Table 1), a status it would not regain until the much-improved content in AR5. Much of the early commentary on tourism and recreation in the IPCC reports was speculative and often not based on tourism specific research. This began to change as the number of publications related to the interactions of tourism and climate change more than doubled between 1996−2000 and 2001−2005 (Scott et al., 2005), but remains a limitation of some regional chapters in AR5.

Recent comprehensive bibliographies (Scott et al., 2012b; Zeppel & Beaumont, 2011) and analyses (Becken, 2013) demonstrate that the volume of related inquiry has continued to grow substantially from 2005 to 2012, which was the cut off for potential inclusion in AR5. Table 1 compares reference to tourism and cognate terms in the chapters of AR5 against similar chapters in the TAR and AR4. The total number of references increased, by over 100 in WG2 chapters and three-fold in WG3 chapters. However, due to the much-expanded size of AR5, the citations per page actually declined among WG2 chapters. Tourism is competing with literature from other sectors and themes for the limited space available in IPCC reports. Even with AR5's expanded page numbers, because of very tight word limits not everything tourism related could be fully accounted for and there is no discussion or critique of the methods or limitations of the many studies cited. This is important to note, because critical review articles for the tourism sector (Scott et al., 2012a; Gössling et al., 2013) and comprehensive review volumes (Becken & Hay, 2012; Scott et al., 2012b) are required to fulfil these needs for the research community, and knowledge translations targeted to government and business decision-makers is a gap that should be filled by sectoral assessments like that commissioned by the UNWTO et al. (2008) after the AR4.

The place of tourism in regional chapters remains an important indicator of regional knowledge gaps. There was a slight decline in references to tourism in regional chapters, from roughly 185−200 in TAR and AR4 to 177 in AR5. References to tourism decreased in four regional chapters, including Africa, Asia, North America, and to a lesser extent in small islands. Three of these regions had been identified as visible regional knowledge gaps to be addressed after the AR4 (Amelung et al., 2008; Hall, 2008). Progress within the Africa, Asia and small-island regions remained limited. Although the literature on climate change and tourism in the Asia region is emerging (Su & Hall, 2014), the chapter still largely identified generic impacts, without discussion of their potential magnitude or timing, interactions with other major impacts in the region. Tourism content in the Africa chapter had similar limitations. Yet while the impacts of climate change on tourism in Africa are anticipated to be very salient, there are almost no tourism specific studies available on this continent: "there is a need to enhance practical research regarding the vulnerability and impacts of climate change on tourism, as tourism is one of the most important and highly promising economic activities in Africa" (Boko et al., 2007, p. 459). This important knowledge gap persists in the AR5. While tourism content in the North America chapter also declined, it did not do so because of limited new research being available,

Table 1. A Comparison of tourism content (Citations) in IPCC assessments.

	FAR 1990	SAR 1995	TAR[1] 2001	AR4[1] 2007	AR4[2] 2007	AR5 2013–2014
Working Group 2: Impacts, adaptation and vulnerability						
Regional						
Africa			3	28	25	6
Asia			9	7	7	1
Australia and New Zealand			22	31	29	27
Europe			34	40	37	35
Central and South America			10	10	11	10
North America			86	27	22	4
Polar regions			11	7	7	12
Small islands			26	47	48	40
Oceans						42
Regional chapter total			*201*	*197*	*186*	*177*
Sectoral						
Freshwater resources					2	3
Terrestrial ecosystems					9	4
Food, fiber, forests					3	2
Coastal and low-lying areas					30	37
Industry and society					60	139
Human health					1	3
Rural areas						37
Urban areas						15
All adaptation chapters					20	16
Emergent risks & key vulnerabilities						17
Sectoral chapter total					*125*	*273*
All WG2 chapters	*73*	*198*	*318*		*311*	*450*
Number of pages in WG2 report	*278*	*852*	*970*		*841*	*1731*
Average cites per page	*0.263*	*0.232*	*0.328*		*0.370*	*0.260*
Working Group 3: Mitigation of climate change						
All WG3 chapters	32	17	13		8	34
Number of pages in WG3 report	268	439	687		807	1246
Average cites per page	0.119	0.039	0.019		0.010	0.027

[1]From Hall (2008); [2]From Amelung et al. (2008).
Note: Citations refer to references in text, figures, and tables with respect to tourism, cognate terms. References to these terms in bibliographic information at the end of each chapter are not included in this analysis. Number of pages in report excludes appendices and prelims. FAR, SAR, and TAR WG3 analysis has been undertaken by the authors.

but because of the composition of the authorship team and the level of importance ascribed to the sector, which may or may not be consistent with its relative vulnerability or economic significance.

Tourism content in the Europe, Central and South America, and Australia and New Zealand regional chapters remained similar to previous assessments. Like Africa and Asia, the Central and South America chapter lacked empirical studies from within the region, and was limited to identifying broad vulnerabilities of mainly coastal destinations.

The Europe chapter (Kovats et al., 2014) presented evidence on diverse impacts and concluded that, "After 2050, tourism activity is projected to decrease in Southern Europe (low *confidence)* and increase in Northern and Continental Europe (medium *confidence)"* (p. 1271) and identified tourism as one of three sectors "most likely to be affected by climate change, and therefore with implications for economic activity and population movement (changes in employment opportunities)" (p. 1300).

Australia and New Zealand represented the most well developed tourism discussions, summarizing evidence on a range of impacts, the level of awareness and concern of tourism stakeholders, and the limits of adaptation. Reisinger et al. (2014, p. 1409) concluded that, "Climate change could affect international tourism to Australasia through international destination and activity preferences, climate policies, and oil prices. These potentially significant effects remain poorly quantified, however, and are not well integrated into local vulnerability studies". Furthermore, "Flow-on effects from climate change impacts and responses outside Australasia have the potential to outweigh some of the direct impacts within the region … but they remain among the least explored issues" (p. 1376).

Recognition of tourism impacts improved in the Polar and Ocean chapters. The opportunities and challenges of expanded open seas for cruise tourism dominate Polar chapter discussions. The combined impacts of ocean temperature and salinity changes on ocean ecosystems important to tourism, particularly reefs, were a central focus of ocean related discussions (IPCC, 2014c).

The major types of direct and indirect climate change impacts differed by region and are summarized, together with the relative state of knowledge, in Table 2. As in previous assessments, the possible consequences for winter tourism, alpine areas, coastal zones, and small-island states are the most prominent, but several obvious regional gaps exist with respect to tourism resources, such as biodiversity and water. Inter-linkages between international tourism and climate change induced political instability and security risks were also overlooked. Prolonged security risk significantly contracts tourism, further reducing development options and livelihoods.

With the exception of the *Terrestrial Ecosystems* chapter, tourism is equally or better represented in the AR5 in all other thematic and sectoral chapters (Table 1). As in previous assessments, tourism received its most extensive treatment in the chapter on *Key Economic Sectors and Services*. The chapter identified three most at risk tourism markets and destination types and the anticipated geographic impact of climate change on tourism demand, stating, "Climate change will affect tourism resorts, particularly ski resorts, beach resorts, and nature resorts (*robust evidence, high agreement)* and tourists may spend their holidays at higher altitudes and latitudes (medium evidence, high agreement)" (Arent et al., 2014, p. 663). It further indicated that even in the worst affected countries, the direct effect of climatic change slows, but nowhere reverses, growth in the tourism sector. Importantly, this conclusion does not take into account the full spectrum of climate change impacts on tourism destinations, because no studies are available that fully "consider all aspects of the impact of climate change for particular countries or regions" (Arent et al., 2014, p. 679). The chapter encourages greater emphasis on understanding sub-national and destination scale economic, social and environmental implications of climate change-induced changes in tourism demand and supply. Knowledge gaps related to climate adaptation, the limited understanding of tourist response to climate change impacts and different climate mitigation policies, climate sensitivity detection and attribution analysis (including analogue studies), are identified as research priorities. We shall return to some of these key gaps in the following section.

Table 2. Major tourism related climate impacts identified in regional chapters.

Region	Major impact categories								
	Climate resources and extremes	Ecosystems and biodiversity	Winter/ski tourism	Sea-level rise	Water resources	Security/ instability	Transport cost/access	Transboundary impacts	Adaptation options
Africa	N	−		+	N	N	N	+	N
Asia	N	+/++	−	N	N	N	N	N	N
Australia and New Zealand	+	++	++	+/−	N	N	++	+/−	+/−
Europe	++	N	++	N	+	N	++	+	+/−
Central and South America	N	+		+/−	N	N	N	N	N
North America	+	N	+/++	N	N	N	N	N	+/++
Polar regions	N	+/++		N	N	N	+/++	N	N
Small islands	+/++	+/++		+/−	++	N	+/−	+	+
Oceans	N	+/++		+/−			+/−		N

Note: − = knowledge gap specified, + = potential impact identified, ++ = impact evidenced, N/shading = impact not identified.

There is a much-expanded discussion of impacts on tourism and recreation for rural economies, both in developed and developing countries (Arent et al., 2014). The emphasis in rural areas has predominantly been on agriculture sector vulnerability. Limited awareness or concern over climate change risks to rural tourism has therefore impeded adaptive responses.

Tourism was also discussed for the first time in the context of urban areas. The importance of urban centres as destinations and transportation hubs that may be increasingly impacted by high temperatures (combined with urban heat island effects) and disruption from more frequent and severe extreme weather events. It was noted, however, that very little research has examined potential climate change effect on urban tourism.

Recognition of the substantive risks posed to coastal tourism from SLR and major storms was more visible in the Coastal chapter. The multi-dimensional impact of climate change on coastal tourism was recognized in both coastal and small-island chapters. "Coastal tourism continues to be highly vulnerable to weather, climate extremes, and rising sea levels with the additional sensitivity to ocean temperature and acidity for the sectors that rely on reef tourism" (Wong et al., 2014, p. 385). Developing countries and small-island states within the tropics relying on coastal tourism are among the most vulnerable to climate change. The need to better evaluate the potential impact of SLR and associated aggravated erosion on high value beach areas and to better understand the potential response of tourists to degraded beaches as well as adaptation responses (including beach nourishment, and soft and hard engineering approaches) was identified as a research priority. Greater analysis of the potential implications of adaptation by the insurance industry (e.g. uninsurability of high-risk coastal areas, see Scott et al., 2012b) was an overlooked research need.

Tourism remains all but absent in other WG2 chapters where some discussion might be expected, including human health (e.g. the changing geography of infectious disease and destination attractiveness and the health care costs of travellers), changing terrestrial and marine ecosystems (e.g. the reduction of wildlife abundance or loss of species is anticipated to affect nature-based tourism visitation in many destinations), security (e.g. instability or social unrest represent major deterrents to tourism development), and water (e.g. availability; inter-sectoral competition for freshwater resources). With regard to the latter, leading authorities on water futures assert that the non-substitutability and regional nature of water resources will make it one of the most important and geopolitically contentious resources issues worldwide (Michel & Pandya, 2009; UN Water, 2014). The treatment of tourism also remained very limited in the five chapters on climate change adaptation and its absence from the climate-resilient development pathways chapter is noteworthy.

By far the most significant change with respect to tourism content in AR5 was the substantial increase in the chapters of WG3 (IPCC, 2014e). The word count in WG3 increased four-fold over AR4. The contribution of the tourism sector to global CO_2 emissions (approximately 5% without accounting for radiative forcing – Scott et al., 2008; WEF, 2009) was recognized for the first time. The incompatibility of the sector's emission growth trend with the need to decarbonize the global economy was explicitly identified as a challenge for the future of tourism development. The technical challenges of mitigation in aviation were broadly discussed. The importance of developing sustainable biofuels as an emission reduction strategy for air transport was recognized and challenged the aviation sector's optimistic assumptions regarding the proportion of the commercial fleet that could be powered by biofuels by mid-century. The importance of consumer behaviour and lifestyle for mitigation in travel and tourism was also discussed in greater

detail. A notable remaining gap was a discussion of the impact of mitigation policy on mobility and the future geography of international tourism.

On balance, the place of tourism in AR5, as measured by the overall increase in word counts equates to a slight decline versus AR4. Nevertheless, the much-expanded coverage of tourism in the *Key Economic Sectors and Services* chapter and the WG3 report is significant. The lack of progress in terms of the geographical coverage in regions where tourism is a major or growing part of the economy represents a priority for tourism scholars and tourism organizations to attempt to redress before the Sixth Assessment Report (AR6) scheduled for sometime after 2020.

Tourism implications of key findings in the AR5

As outlined in the introduction, evidence of changes to the global climate system and how other environmental systems are responding to these changes continues to grow rapidly. The IPCC AR5 provides a more comprehensive synthesis that we do not restate here. Instead this section focuses on the key updates from the AR4 and new themes of most relevance to tourism. The discussion of WG1 focuses on two potential climate change outcomes from business-as-usual greenhouse gas (GHG) emissions (representing inaction on climate change) and what is required to achieve the objective of the United Nations Framework Convention on Climate Change (UNFCCC) to avoid dangerous interference with the global climate system. The implications of these two disparate outcomes for the tourism sector are then examined in the WG2 and WG3 sections.

Working group 1 – physical science of climate change

The report of WG1 presented overwhelming evidence of global atmospheric and oceanic warming and that all environmental systems and increasingly socio-economic systems are responding to these changes. The IPCC (2013) concludes that climate change is "unequivocal" and that human influence on the climate system is clear. GHG emissions, together with other anthropogenic drivers (e.g. land use change and aerosol emissions), have been the dominant cause of the observed warming since the mid-twentieth century and some changes in extreme weather and climate events are linked to human influences on the climate system (IPCC, 2013). Although there are differences between regions the impacts of contemporary climate change on natural and human systems have been observed globally. The IPCC (2013) emphasized that due to lags in the climate system, many aspects of climate change and associated impacts on environmental systems will continue for centuries (e.g. biodiversity change, SLR), even if anthropogenic emissions of greenhouse gases were stopped immediately.

The IPCC AR5 emphasizes that there remains considerable uncertainty over future GHG emissions and resultant climate change. To represent this uncertainty in the AR5, the IPCC adopted a new set of four scenarios to describe possible climate futures. These new suite of scenarios are referred to as representative concentration pathways (RCPs), for their relative influence on the global climate. For brevity we focus here on the two ends of the AR5 climate futures spectrum, with RCP8.5 representing business as usual (BAU) emissions trajectory that continues to rise throughout the twenty-first century and RCP2.6 that assumes global GHG emissions peak between 2010 and 2020 and declining substantially thereafter.

Despite 20 years of international climate negotiations under the United Nations Framework Convention on Climate Change (UNFCCC) and increasing efforts to reduce

GHG emissions by sub-national government and the business sector, current emission growth rates are roughly twice as large as in the 1990s. Global GHG emissions continue to track the IPCC's worst-case scenario (RCP8.5). The IPCC (2013) estimates that a continuation of the current emissions trajectory would increase global mean surface temperatures 2.0 °C (likely range of 1.4−2.6 °C) by mid-century and 3.7 °C (likely range of 2.6−4.8 °C) by the end of the twenty-first century (relative to 1986−2005). The IPCC (2014b, p. 8) concluded: "continued emission of GHG will cause further warming and long-lasting changes in all components of the climate system, increasing the likelihood of *severe, pervasive and irreversible* impacts for people and ecosystems" (emphasis added). The anticipated changes to environmental systems that would have the broadest impact on tourism globally include water security and SLR are evident in the work of WG2.

Changes in precipitation and water availability are one of the main mechanisms by which the impacts of climate change will be experienced at the local scale. Changes in precipitation will not be uniform, with annual mean precipitation under the RCP8.5 scenario expected to increase at high-latitudes and in many mid-latitude wet regions, while in many mid-latitude and subtropical dry regions, mean precipitation is expected to decrease (IPCC, 2014b). As a result, climate change is projected to reduce renewable surface water and groundwater resources in most dry subtropical regions and intensify sectoral and national competition for water in most already water stressed regions (IPCC, 2014b). Even by mid-century, increased water stress from population and economic growth in combination with climate change is expected in several major tourism regions like the Mediterranean, the Caribbean, and Australia, but also many areas of Northeast and Southeast Asia, Northern and Central Africa and the Middle East that are expected to lead global growth in tourism through the 2030s and beyond (Gössling et al., 2015).

The world's coastlines would be transformed under a high emission scenario. One of the most important improvements in the AR5 has been the understanding of potential sea-level change. In 2007, the IPCC projection of SLR did not include contributions from the melting of ice sheets in Antarctica and Greenland because of the high uncertainty. The consequent AR4 projection of a maximum 0.6 m rise in sea level in the twenty-first century was heavily criticized as conservative. The AR5 (IPCC, 2013) concluded that global mean SLR will be in the range of 0.45 to 0.82 m by the end of the century (relative to 1986-2005). SLR will not be uniform worldwide, but about 70% of coastlines are expected to experience a sea-level change within ±20% of the global mean (IPCC, 2013). A subsequent survey of 90 experts on SLR from 18 countries, found the probabilistic SLR by 2100 in unmitigated warming scenario (RCP 8.5) to be higher − ranging from 0.7 to 1.2 m (Horton et al., 2014).

The primary objective of the UNFCCC is to achieve the "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent *dangerous* anthropogenic interference with the climate system" (IPCC, 2014e, p. 4). Based on available understanding of the consequences of climate change, in 2010 the 195 state parties to UNFCCC translated that objective to holding the increase in global average temperature below 2 °C relative to pre-industrial levels (1861−1880 as baseline). The Cancún agreement also included the provision to lowering the threshold temperature of dangerous climate change to 1.5 °C as scientific understanding of the relative consequences of lower levels climate change improved (Conference of Parties (COP), 2011).

The AR5 (IPCC, 2014e) concludes that to have a likely chance (probability of >66%) of achieving the goal of limiting global warming in the twenty-first century to below 2 °C, atmospheric GHG concentrations would need to be limited to approximately 450 ppm CO_2-eq. This would require cumulative (past, present and future) CO_2 emissions

from all anthropogenic sources to remain below 1000 GtC (3670 $GtCO_2$) (IPCC, 2014e). In other words, there is a maximum CO_2 emission budget that cannot be exceeded in order to achieve the objective of limiting global climate change to no more than +2 °C. WG3 (IPCC, 2014e) estimates that global GHG emissions will need to be reduced 40%−70% by 2050 and that net CO_2 emissions must decrease to zero before 2100 to remain within this budget. Net-zero does not imply absolute zero CO_2 emissions, but that the remaining very limited emissions are balanced with carbon sequestration strategies that remove equivalent CO_2 from the atmosphere. Other assessments have concluded that at emission rates anticipated over the next two decades, the remaining CO_2 emission quota with a 50%−66% probability of not exceeding the 2 °C temperature limit could be exhausted between 2039 (Meinshausen et al., 2009) and 2042 (Friedlingstein et al., 2014). The sharp contrast between net-zero emissions trajectory and that of tourism and aviation are discussed by WG3.

Importantly, whether a +4 °C or a net-zero emissions outcome is realized, either would have major influences on the competitiveness, sustainability and geography of tourism in the twenty-first century. Neither is a future the tourism sector understands well or is prepared for.

Working group 2 – climate change impacts and adaptation

The report of WG2 presented the anticipated impacts of the range of climate change projections established by WG1. WG2 (IPCC, 2014c) concluded that while some risks of climate change are considerable with a global mean temperature increase of 1 °C or 2 °C above preindustrial levels (temperatures are currently 0.85 °C warmer (IPCC, 2013)), risks of "severe, pervasive, and irreversible impacts" (IPCC, 2014c, p. 14) are greatly increased with global mean temperature increase of 4 °C. A +4 °C world would result in areas of the earth being transformed, greatly increased extinction risk, regional water and food insecurity, massive displacement, and aggregate economic losses (IPCC, 2014b; see also World Bank, 2013; New et al., 2011). The overarching message is not dissimilar to AR4 but is significantly strengthened by the considerable increase in evidence.

Three main cross-cutting themes of particular salience to the tourism sector emerged across the chapters of WG2: climate change as a threat to sustainable development, the need for integrated climate change risk assessments at the destination scale that also incorporate transboundary impacts, and the challenges and limitations of adaptation.. Each of these key themes is explored below.

Climate change as a threat to sustainable development

The IPCC (2014b) indicated that insufficient adaptation responses to emerging climate change impacts are already eroding the basis for sustainable development, and by extension sustainable tourism, but emphasized that greater magnitudes of climate change represent a broad and severe threat to future sustainable development. While aggregate economic impacts of climate change remain highly uncertain, accelerated losses are anticipated with increasing temperature (IPCC, 2014b).

The IPCC (2014b) stressed that the risks of climate change are very unevenly distributed and are generally greater for developing countries and disadvantaged people in countries at all levels of development (rural and coastal areas, small-island states (SIS) and least-developed countries (LDCs) in particular). "Climate change exacerbates other threats to social and natural systems, placing additional burdens particularly on the poor"

(IPCC, 2014b, p. 31). Poverty alleviation would become much more difficult or reversed in some regions. Through SLR, higher exposure to extreme weather events, changes in water and food security, and reduced economic development, climate change is projected to increase the displacement of people and contribute to increased risk of violent conflicts (IPCC, 2014b). In awarding of the Nobel Peace Prize to the IPCC in 2007, the Nobel committee recognized climate change as a global security issue, beyond its well established environmental, economic and development policy relevancy. AR5 (IPCC, 2014c, p. 73) noted that climate change, "can indirectly increase risks of violent conflicts in the form of civil war and inter-group violence by amplifying well-documented drivers of these conflicts such as poverty and economic shocks', and that its impacts "are expected to influence national security policies" (e.g. see Center for Climate & Security, 2014; US Department of Defense, 2014).

Any phenomenon that is estimated to directly adversely affect economic growth in many areas of the world, harm or displace more than a billion people, and progressively threaten security is not compatible with sustainable development. Inaction to prevent a +4 °C world fundamentally conflicts with extant global tourism growth projections as well as the sector's sustainability ambitions. Moreover, tourism has aligned itself with the poverty alleviation agenda, which will be greatly hindered by climate change (Gössling et al., 2009). Business cannot succeed where society and communities fail. Tourism therefore needs to be part of the process of envisioning climate resilient development of the future.

Integrated assessments for destinations

One of the largest barriers to understanding the implications of climate change for tourism destinations has been the lack of integrated sectoral assessments that analyse the full range of potential impacts and their interactions. Figure 1 presents an interpretation of the evidence in AR5 as to when six key types of impacts will materially affect the tourism sector at various scales (from community destination to the global sector).

Transboundary impacts can result from the direct and indirect impacts of climatic change, as well as tourism and non-tourism adaptation and mitigation responses to climate change. For example, Reisinger et al. (2014, p. 91) indicated that, "effects from climate change impacts and responses outside Australasia have the potential to outweigh some of the direct impacts within the region, particularly economic impacts on trade-intensive sectors such as agriculture and tourism, but they remain among the least-explored issues". Small-island developing states (SIDS) are even more vulnerable to the suite of impacts included in Figure 1, yet these impacts remain poorly quantified for any SIDS and have not been integrated into community scale adaptation studies. The risks of not including multi-scale climate change risks in local scale adaptation planning are illustrated in Figure 2. For this island destination example, SLR is anticipated to cause greater beach erosion and flooding impacts over time. Beach nourishment is an expensive adaptation option, but one preferred by tourists over artificial engineered coastlines (Hamilton 2007). If competing communities on the island or nearby island competitors cannot implement beach nourishment the competitiveness of this destination would increase through this adaptation. However, if the insurance industry deems the coastal risks in this area too high to continue property insurance, the loss of insurability, an ex situ and non-tourism sector adaptation, would negate the benefit from beach nourishment. Similarly, regardless of any innovative local scale adaptation by the destination, if an international climate change mitigation policy regime increases the cost of air travel substantially

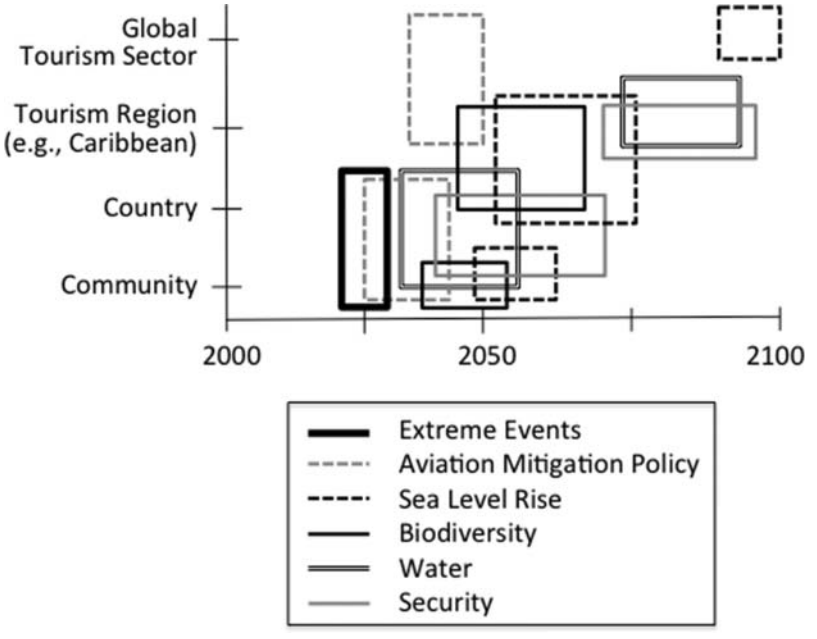

Figure 1. Understanding the integrated impacts of climate change.
Source: Authors

enough to alter traveller mobility and destination choice, arrivals to this destination could be affected. The choice of climate change adaptation strategies at the destination scale is therefore potentially heavily influenced by external factors not adequately represented in conventional vulnerability assessment approaches that do not account for transboundary effects. The need for innovative vulnerability assessment approaches capable of examining the critical transboundary risks associated with tourism, are a clear research priority before the IPCC Sixth Assessment.

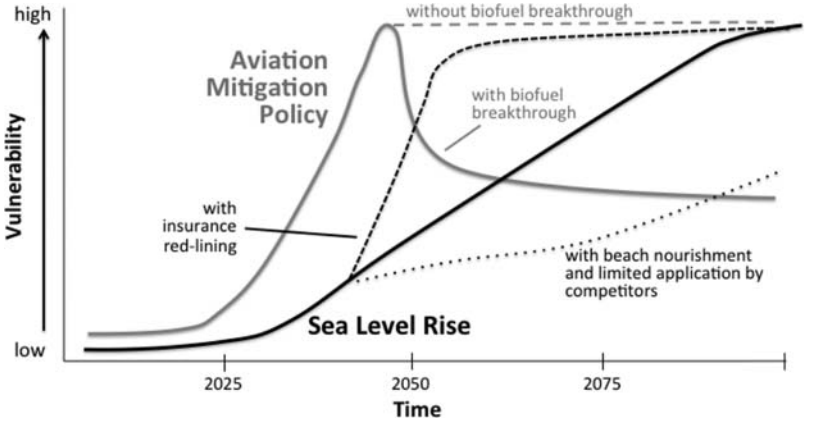

Figure 2. Adaptation potential and impact permanence.
Source: Authors

Challenges and limitations of adaptation

Within the tourism system, tourists have the largest capacity to adapt to the consequences of climate change and climate policy, because they have very large capacity for temporal, spatial and activity substitution. As a consequence, understanding the response of tourists to a changing climate, mobility costs, and destinations is integral to robust predictions of seasonal and geographic shifts in tourism demand (Gössling et al., 2012; Scott et al., 2008, 2012a). The need to improve understanding of tourist perceptions and responses to the direct and indirect impacts of climate change was again reinforced in several WG2 chapters of AR5. With respect to the direct implications of changing climate on tourism demand, Arent et al. (2014, p. 694) concludes that, current studies

> … either have a rudimentary representation of the effect of weather and climate but a detailed representation of substitution between holiday destination and activities, or a detailed representation of the immediate impact of climate change but a rudimentary representation of alternatives to the affected destinations or activities.

With respect to climate-induced environmental change, uncertainties and gaps are highlighted across several chapters. Tourist response to marginal snow conditions and evolving regional ski tourism marketplaces remains largely unknown. Increased travel to see disappearing ecosystem types, or so-called "last chance tourism" (Lemelin et al., 2010), is identified as a tourism phenomenon requiring greater investigation (IPCC, 2014d). Nurse et al. (2014, p. 1623) concluded that while extreme-weather events and degraded environmental conditions will significantly influence visitors' perception of destinations,

> There is currently no evidence that observed climatic changes in small-island destinations or source markets have permanently altered patterns of demand for tourism to small islands, and the complex mix of factors that actually determines destination choices under a changing climate still need to be fully evaluated.

Further uncertainties associated with differential responses of tourism markets and consistencies in the response of generational cohorts are discussed elsewhere in the literature (e.g. Scott et al., 2012a).

Adaptation can reduce the risks and take advantage of new opportunities associated with climate change, with benefits already realizable from addressing current climatic risks. With strong links between climate resiliency and sustainable development, climate change adaptation received greater attention throughout the WG2 chapters of AR5. The IPCC (2014b) is careful to note that there exist many important potential co-benefits associated with adaptation, as well as potentially important trade-offs among sectors and stakeholders, that require greater consideration. Understanding of the adaptive capacity and need for participation of stakeholders was stressed, especially the relative lack of knowledge on private sector adaptation (Klein et al., 2014). The limits of adaptation effectiveness, especially with greater magnitudes and rates of climate change, were strongly emphasized. Nevertheless, there is limited understanding of the potential consequences of 4 °C warming and even less on how natural systems and society could adapt to it (New et al., 2011; IPCC, 2014b; UNFCC, 2015).

The AR5 echoed the broader literature (Hall, 2010; Scott & Becken, 2010; Scott et al., 2008) that ability of the tourism sector to cope with a range of macro-scale shocks, including terrorism attacks, natural disasters, disease outbreaks, and the global financial

crisis in 2008/2009, suggests that, "the adaptive capacity of the tourism industry is high overall, except for destinations where climate change is projected to degrade core natural assets and diversification opportunities are limited" (Reisinger et al., 2014, p. 1401). However, several chapters indicated that the extent of adaptation by tourism operators and destinations and its capability to cope effectively with future climate change remains poorly evaluated or accounted for. Furthermore, the external control over some key adaptation strategies or the ability of adaptation of other sectors to significantly influence the effectiveness of destination level adaptation (see Figure 2) has rarely been recognized. Path dependency associated with certain adaptation strategies has also not been discussed in tourism beyond the context of beach nourishment (Scott et al., 2012c).

The importance of local government and the private sector in adaptation received greater emphasis in AR5. However, the adaptation needs and priorities of tourism and the communities it is embedded in are not always identical, so it is important for the tourism industry to consider the co-benefits and dis-benefits of adaptation so that it fosters the well-being of local populations, the security of infrastructure and other assets, and the maintenance of ecosystem services important to community and tourism sustainability. Kovat et al. (2014, p. 1299) note that, in "tourism, adaptation and mitigation may be antagonistic", so that greater adaptation generates greater GHG emissions. However, the GHG emission footprint of the specified adaptations (snowmaking and desalination are identified) has not been assessed from a broader tourism systems perspective, where the net emissions of holidays are compared. Tourism adaptation and mitigation are, "not always trade-offs, but can be regarded as complementary components in the response to climate change" (Nurse et al., 2014, p. 1616). These perspectives underscore the need to examine climate-resilient tourism development pathways for destinations.

A number of impediments to adaptation in the tourism sector are identified in AR5: uncertainties, low level of awareness and limited concern over climate change impacts, lack of leadership, and limited coordinated forward planning. A similar range of barriers to adaptation has been identified in the literature along with a high optimism about capacity to overcome the challenges of climate change (see Scott et al. 2012a for a summary). Capacities to cope with the impacts of climate change are not supported by evidence, indicating tourism stakeholders may likely be overestimating their ability to adapt under mid- to high-emission scenarios (Scott & Becken, 2010). Most national governments have not undertaken strategic reviews of the vulnerabilities and potential adaptation strategies within the tourism sector (OECD & UNEP, 2011). Yet, the AR5 makes clear that *all* tourism destinations will need to adapt to climate change, whether to minimize risks or to capitalize on new opportunities, but the adaptation imperative has yet to translate into discernible action within the tourism sector.

Working group 3 – climate change mitigation

Previous reviews of the place of tourism within IPCC assessments have lamented the virtual absence of discussion of tourism sector GHG emissions and its potential role in mitigation (Amelung et al., 2008; Hall, 2008). To be fair to the IPCC, no estimate of GHG emissions for the tourism sector was available prior to the AR5. A very visible advancement in the AR5 was the inclusion of tourism sector emission estimates and projected emission trends in the WG3 report, including those commissioned by UNWTO et al. (2008): "GHG emissions triggered by tourism significantly contribute to global anthropogenic CO_2 emissions. Estimates show a range between 3.9% to 6% of global emissions, with a best estimate of 4.9%" (Fischedick et al., 2014, p. 756). The origin of emissions

from within the tourism sector was discussed, with the prominence of the travel component (75% of emissions) emphasized as a daunting mitigation challenge. The IPCC (2014e) also noted that a minority of travellers (e.g. frequent long haul travellers) are responsible for the largest share of tourism related emissions and that increased demand for tourism is expected to continue to be a driver for all transport modes.

Emission trends within the tourism sector and their incompatibility with global climate change policy did not go unnoticed by WG3 (Fischedick et al., 2014, p. 756):

> A business-as-usual scenario projects emissions from tourism to grow by 130% from 2005 to 2035 globally; notably the emissions of air transport and accommodation will triple. … Several studies show that for some countries (e. g., the UK) an unrestricted growth of tourism would consume the whole carbon budget compatible with the +2 °C target by 2050.

Baseline estimates of tourism sector emissions and BAU trajectories to 2035 from UNWTO et al. (2008) and an independent analysis by the WEF (2009) are displayed in Figure 3, along with two emission reduction scenarios for the sector, the WTTC (2009) "aspirational" emission reduction target, and the emission reduction requirement needed to achieve the +2 °C policy objective of the UNFCCC set out by AR5 (IPCC, 2013). There is a clear gap between the current tourism sector emissions trajectory and emissions pathways compatible with the +2 °C policy objective. No available emission reduction scenario for the tourism sector, either those put forward by Scott et al. (2008) or the UNEP Green Growth scenario, have been able to achieve the stated "aspirational" emission reduction target of the tourism sector or a level commensurate with the emission reduction range recommended by the IPCC AR5 (Scott & Gössling, 2015a). Fischedick et al. (2014, p. 756) commented that, "alternative scenarios show that the contribution of technology is limited in terms of achievable mitigation potentials and that even when combining technological and behavioural potentials, no significant reduction can be achieved in 2035 compared to 2005". In other words, the IPCC has reinforced concerns

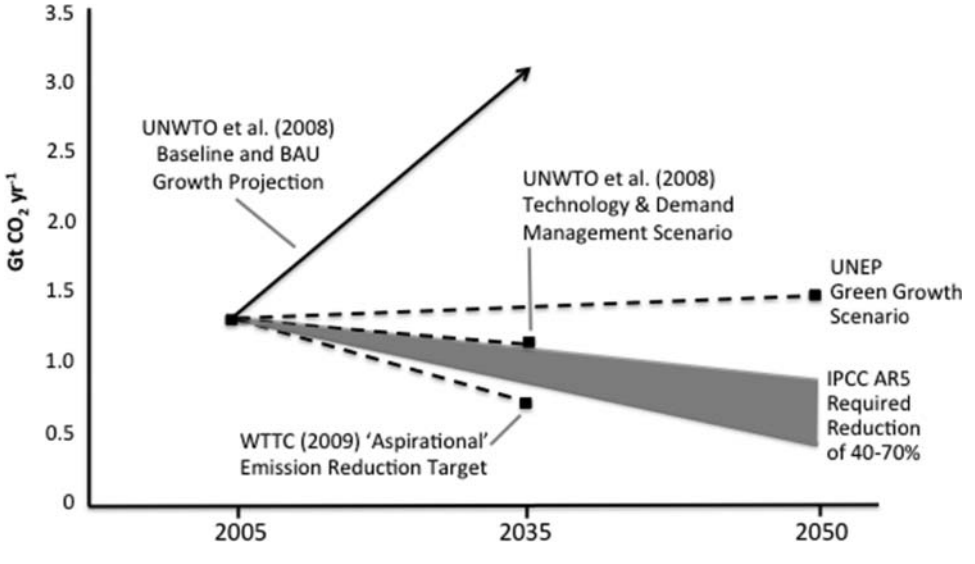

Figure 3. A comparison of tourism emission trajectories and reduction targets.
Source: Authors

that the tourism sector is not only unprepared to become part of a decarbonized global economy but it is also increasingly unlikely that it will achieve its global emission reduction goals (Gössling 2010; Gössling et al., 2013; Scott et al., 2010).

Aviation remained a salient transport sector in the WG3 report, with the importance of international tourism as a driver of future emission growth and the growing importance of air travel for the tourism sector's emissions forecast clearly recognized in AR5. The aspirational goal of the International Civil Aviation Organization (ICAO) (2010) to stabilize the carbon emissions of international aviation at 2020 levels and pursue a 50% reduction (from 2005 levels) by 2050 were commended but questioned. It was noted that aviation industry projections of GHG emission reductions from the future use of biofuels ranged between approximately 20% (Sustainable Aviation, 2008) and 50% (IATA, 2009), while external estimates of biofuels as a share of total aviation fuels by 2050 were far more conservative (IPCC, 2011) because of technological and production challenges.

To this could be added uncertainties associated with the supply and price of carbon credits that are an integral pillar of ICAO's "Carbon Neutral Growth 2020" (CNG2020) strategy between 2020 and 2040, as well as the increasing number of jurisdictions implementing carbon pricing on all emissions. ICAO (2013) estimated the future price of CO_2 (per tonne in 2010 USD) to be $30 in 2020 and $45 in 2035, and would be needed to reduce or offset an estimated 16.5 billion tonnes of CO_2 from 2020 to 2050. What carbon reduction credits might be available to international aviation remains uncertain and dependent on future regulatory framework established under the UNFCCC, perhaps as early as the COP21 (Conference of Parties) conference in Paris in December 2015. Internal analysis by ICAO (2013) identified only about 25% of the required offsets.

Trends in broader carbon pricing increase uncertainty over the CNG2020 strategy. Over 40 countries and more than 20 cities, states and provinces have already implemented carbon pricing mechanisms or are preparing to implement them and prior to the UN Summit on Climate Change in 2014 an even broader alliance of 73 countries, 11 states/provinces and over 1,000 businesses and investors signalled their support for carbon pricing (World Bank, 2014). According to a Carbon Disclosure Project (2013) survey, many major publically traded companies have already adjusted to the expectation of eventual carbon pricing by setting an internal "shadow price" on carbon for operational and strategic planning (the average exceeded USD30/tonne). This price would apply to all of aviation emissions, not just a small portion of carbon credits needed to stabilize aviation emissions at 2020 levels.

The emphasis on the importance of consumer behaviour and lifestyle for energy use and mitigation in travel and tourism was another advance in the WG3 report of AR5. Tourism is explicitly identified as a sector where mitigation is not only technology-driven, but strongly influenced by lifestyles, with important implications for consumption patterns and consequent transboundary effects. Assessment of the mitigation potential associated with service sector demand reduction was categorized as nascent, but a major remaining knowledge gap (IPCC, 2014e). More specifically, the need for better knowledge of consumer travel behaviour to better predict mobility and assess the willingness of people to change to low-carbon transport options was emphasized. Improved insight into behavioural dimensions of air travel was stressed, as it has been in the tourism literature for years (Becken 2007; Gössling et al., 2012; Gössling et al., 2013). Fischedick et al. (2014) acknowledged that trans-boundary spillover effects from transport mitigation policies might pose risks for SIDS and LDCs, a concern emphasized by the UNWTO (2007), but that tools to understand and manage these interactions remain limited.

Just as the impacts of climate change itself pose different kinds of risks to tourism destinations worldwide, so too does climate change mitigation. There are multiple mitigation pathways that have been proposed to achieve the UNFCCC policy objective of limiting global warming to below 2 °C relative to pre-industrial levels. While all pathways require significant emission reductions over the next few decades, how these are accomplished varies substantially. Assessing the differential implications of alternate emission pathways for tourism remains an important knowledge gap that limits the capacity of the sector to influence international negotiations. Notably, a review of energy scenarios consistent with the 2 °C policy target found that none explicitly considered implications for international tourism, yet all assumed demand management played a large role in aviation achieving required emission reductions (Scott & Gossling, 2015b).

Conclusion

The periodic assessment process of the IPCC offers an opportunity to reflect upon the state of knowledge on what has been recognized by UNWTO et al. (2008) as one of the greatest challenges to sustainable tourism in the twenty-first century. There were a number of notable improvements in the place of tourism in the AR5. The stronger connection between the impacts of climate change and climate policy on tourism and prospects for sustainable development were recognized in several chapters, particularly the transboundary nature of these impacts and the salience for SIDS, LDCs and long-haul destinations. The discussion of the contribution of tourism to global GHG emissions and the challenges of mitigation in the sector was another visible improvement.

Nevertheless, considerable challenges remain, including persistent major regional knowledge gaps in some of the regions where tourism is anticipated to grow the fastest in the next 30 years. The lack of integrated assessments and limited knowledge of tourist responses to climate change impacts and climate policy interventions remain substantive barriers to tourism sector mitigation and adaptation responses at the destination level. Furthermore, there remains very limited understanding of the potential impacts and consequences of 4 °C warming, and even less on how environmental, economic and social systems, of which tourism is a part, could adapt to it. While some scholars have questioned whether the tourism research community can afford to dedicate increased efforts to understand the implications of climate change for tourism (Weaver, 2011), the findings of the AR5 only serve to reinforce the message of Gössling et al. (2013), Scott and Becken (2010), and Scott (2011), that tourism absolutely cannot afford not to.

The political and business case for a sectoral response on climate change has never been stronger with the upcoming watershed UNFCCC summit in Paris in 2015, but as yet no plan has been proffered by the UNWTO or WTTC to respond to the issues highlighted in AR5. Not assessing the implications of carbon pricing and climate risk is increasingly seen as not meeting fiduciary responsibilities of business leaders (e.g. UNEP, 2014; Climate Disclosure Standards Board, 2012; Ceres, 2011; Mercer, 2011). Unless the UNWTO or WTTC re-emerge with major new initiatives, it is difficult to see how the tourism sector can be well represented in post-2020 mitigation targets and new adaptation capacity building frameworks.

The AR5 *Summary for Policy Makers*, approved by 194 national governments has overtly linked climate change to sustainable development strategies:

> Limiting the effects of climate change is necessary to achieve sustainable development and equity, including poverty eradication. At the same time, some mitigation efforts could

> undermine action on the right to promote sustainable development, and on the achievement of poverty eradication and equity. Consequently, a comprehensive assessment of climate policies involves going beyond a focus on mitigation and adaptation policies alone to examine development pathways more broadly, along with their determinants. (IPCC, 2014a, p. 5)

The UNWTO and WTTC have overtly positioned tourism as "one of the new growth poles of the green economy". Yet the absence of a viable strategy to be part of the decarbonized economy raises fundamental questions about its understanding of the contemporary drivers of sustainable development. The tourism industry issues millions of wake up calls daily. In terms of policy making, continuing to hit the snooze button and failing to envisage a roadmap to be part of the decarbonized and climate resilient economy of the future runs the risk that "Quae non possunt non manent' (things that can't last−don't)".

Disclosure statement

No potential conflict of interest was reported by the authors.

Notes on contributors

Daniel Scott is a university research chair in Global Change and Tourism at the University of Waterloo in Canada and a Research Fellow at the Western Norway Research Institute. He has worked on the human dimensions of climate change for over 15 years and been a contributing author and expert reviewer for the United Nations Intergovernmental Panel on Climate Change Third, Fourth and Fifth Assessment Reports.

C. Michael Hall is a professor at the University of Canterbury, New Zealand and docent, University of Oulu, Finland. He also holds positions at Linneaus University, Sweden; the University of Eastern Finland; the University of Johannesburg, South Africa; and the University of Mauritius.

Stefan Gössling is a professor at the School of Business and Economics, Linnaeus University, Sweden and the research co-ordinator at the Western Norway Research Institute's Research Centre for Sustainable Tourism. He has worked on many aspects of sustainable tourism, including emissions of greenhouse gases and tourism.

ORCID

C. Michael Hall http://orcid.org/0000-0002-7734-4587

References

Amelung, B., Moreno, A., & Scott, D. (2008). The place of tourism in the IPCC Fourth Assessment Report: A review. *Tourism Review International, 12*(1), 5−12.

Arent, D.J., Tol, R., Faust, E., Hella, J., Kumar, S., Strzepek, K., … Yan, D. (2014). Key economic sectors and services. In C. B. Field, V. Barros, D. Dokken, K. Mach, M. Mastrandrea, T. Bilir, … L. White (Eds.), *Climate change 2014: Impacts, adaptation, and vulnerability. Part A: Global and sectoral aspects* (pp. 659−708). Cambridge: Cambridge University Press.

Becken, S. (2007). Tourists' perception of international air travel's impact on the global climate and potential climate change policies. *Journal of Sustainable Tourism, 29*, 695−705.

Becken, S. (2013). A review of tourism and climate change as an evolving knowledge domain. *Tourism Management Perspectives, 6*, 53−62.

Becken, S., & Hay, J. (2012). *Tourism and climate change mitigation and adaptation: From policy to practice*. London: Earthscan.

Boko, M., Niang, I., Nyong, A., Vogel, C., Githeko, A., Medany, M., … Hanson, C.E. (eds) (2007). *Climate change 2007: Impacts, adaptation and vulnerability* (pp. 433−467). Cambridge: Cambridge University Press.

Carbon Disclosure Project (2013). Use of internal carbon price by companies as incentive and strategic planning tool. Retrieved 15 March 2015 from https://www.cdp.net/CDPResults/companies-carbon-pricing-2013.pdf.

Center for Climate & Security (2014). Secretary Hagel on climate change affecting the security environment, October 12, 2014, Retrieved 30 March 2015 from http://climateandsecurity.org/2014/10/12/secretary-hagel-on-climate-change-affecting-the-security-environment/.

Ceres (2011). *Physical risks from climate change: A guide for companies and investors on disclosure and management of climate impacts*. Boston: Author. Retrieved 28 October 2013 from http://www.ceres.org/resources/reports/physical-risks-from-climate-change.

Climate Disclosure Standards Board (2012). Fiduciary duty and climate change disclosure. Retrieved 1 March 2015 from http://www.ethosfund.ch/upload/publication/p516e_140925__Statement_on_Fiduciary_Duty_and_Climate_Change_Disclosure.pdf.

Cook, B.I., Ault, T., & Smerdon, J. (2015). Unprecedented 21st century drought risk in the American Southwest and Central Plains, *Science Advances, 1*(1), e1400082.

COP (2011). *FCCC/CP/2010/7/Add.1: Report of the Conference of the Parties (COP) on its sixteenth session, held in Cancun from 29 November to 10 December 2010. Addendum. Part two: Action taken by the Conference of the Parties at its sixteenth session*. Geneva, Switzerland: UN Office.

Dai, A. (2011). Drought under global warming: A review. *WIREs Climatic Change, 2*, 45−65.

Domingues, C.M., Church, J., White, N., Gleckler, P., Wijffels, S., Barker, P.M., & Dunn, J. (2008). Improved estimates of upper-ocean warming and multi-decadal sea-level rise. *Nature, 453* (7198), 1090−1093.

Durack, P.J., Gleckler, P. J., Landerer, F.W., & Taylor, K.E. (2014). Quantifying underestimates of long-term upper-ocean warming. *Nature Climate Change, 4*, 999−1005.

Durack, P., Wijffels, S., & Matear, R. (2012). Ocean salinities reveal strong global water cycle intensification during 1950 to 2000. *Science*, *336*(6080), 455−58.

Fischedick M., Roy, J., Abdel-Aziz, A. Acquaye, A., Allwood, J., Ceron, J., … Tanaka, K. (2014). Industry. In O. Edenhofer, R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, … J. Minx (Eds.). *Climate change 2014: Mitigation of climate change* (pp. 739−810). Cambridge: Cambridge University Press.

Friedlingstein, P., Andrew, R., Rogelj, J., Peters, G., Canadell, J., Knutti, R., … Le Quéré, C. (2014). Persistent growth of CO_2 emissions and implications for reaching climate targets. *Nature Geoscience, 7*(10), 709−715.

Friedrich, T., Timmermann, A., Abe-Ouchi, A., Bates, N., Chikamoto, M., Church, M., … Santana-Casiano, J. (2012). Detecting regional anthropogenic trends in ocean acidification against natural variability. *Nature Climate Change, 2*(3), 167−171.

Gössling, S. (2010). *Carbon management: Mitigating tourism's contribution to climate change*. London: Routledge.

Gössling, S., Scott, D., & Hall, C.M. (2009). The challenges of tourism as a development strategy in an era of global climate change. In *Rethinking Development in a Carbon-Constrained World* (pp. 100−119). Helsinki: Ministry of Foreign Affairs.

Gössling, S., Scott, D., & Hall, C.M. (2012). Consumer behaviour and demand response of tourists to climate change. *Annals of Tourism Research, 39*(1), 36−58.

Gössling, S., Scott, D., & Hall, C.M. (2013). Challenges of tourism in a low-carbon economy. *Wiley Interdisciplinary Reviews − Climate Change, 4*(6), 525−538.

Gössling, S., Hall, C.M., & Scott, D. (2015). *Tourism and water*. Bristol: Channel View Publications.

Hall, C.M. (2008). Tourism and climate change: Knowledge gaps and issues. *Tourism Recreation Research, 33*, 339−350.

Hall, C.M. (2010). Crisis events in tourism: subjects of crisis in tourism. *Current Issues in Tourism, 13*, 401−417.

Hall, C.M., Amelung, B., Cohen, S., Eijgelaar, E., Gössling, S., Higham, J., … Scott, D. (2015a). On climate change skepticism and denial in tourism. *Journal of Sustainable Tourism, 23*(1), 4−25.

Hall, C.M., Amelung, B., Cohen, S., Eijgelaar, E., Gössling, S., Higham, J., … Weaver, D. (2015b). Denying bogus skepticism in climate change and tourism research. *Tourism Management, 47*, 352−356.

Hamilton, J. (2007). Coastal landscape and the hedonic price of accommodation. *Ecological Economics, 62*, 594−602.

Hansen, J., Sato, M., & Ruedy, R. (2012). Perception of climate change. *Proceedings of the National Academy of Sciences, 109*(37), E2415−E2423.

Hönisch, B., Ridgwell, A., Schmidt, D., Thomas, E., Gibbs, S., Sluijs, A., … Williams, B. (2012). The geological record of ocean acidification. *Science, 335*(6072), 1058−1063.

Horton, B.P., Rahmstorf, S., Engelhart, S., & Kemp, A. (2014). Expert assessment of sea-level rise by AD 2100 and AD 2300. *Quaternary Science Reviews, 84*, 1−6.

International Air Transport Association (IATA) (2009). *Aviation and climate change pathway to carbon-neutral growth in 2020*. Geneva: Author.

International Civil Aviation Organization (ICAO) (2010). Climate change action plan 2012. Retrieved 27 October 2012 from www.icao.int/environmental-protection/Pages/action-plan.aspx.

International Civil Aviation Organization (ICAO) (2013). Overview − market based measures. Retrieved 15 March 2015 from http://www.icao.int/Meetings/GLADs-2015/Documents/ENV_Report_MBMs_2013.pdf.

International Energy Agency (IEA) (2013). *Redrawing the energy climate map*. Paris: Author.

International Energy Agency (IEA) (2015). *Global energy-related emissions of carbon dioxide stalled in 2014. Preliminary IEA data point to emissions decoupling from economic growth for the first time in 40 years.* Press Releases & News, 13 March. Retrieved 30 March 2015 from http://www.iea.org/newsroomandevents/news/2015/march/global-energy-related-emissions-of-carbon-dioxide-stalled-in-2014.html.

IPCC (2004). Why the IPCC was created. Retrieved 15 March 2015 from http://www.ipcc.ch/pdf/ipcc-faq/ipcc-introduction-en.pdf.

IPCC (2011). IPCC special report on renewable energy sources and climate change mitigation. O. Edenhofer, R. Pichs-Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, T. Zwickel, P. Eickemeier, G. Hansen, S. Schlömer, C. von Stechow (Eds). Cambridge: Cambridge University Press.

IPCC (2013). Summary for Policymakers. In T.F. Stocker, D. Qin, G.-K. Plattner, M. Tignor, S. Allen, J. Boschung, … P. Midgley (Eds.), *Climate change 2013: The physical science basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press.

IPCC (2014a). Climate change 2014: Synthesis report. Contribution of working groups 1, 2, and 3 to the fifth assessment report of the intergovernmental panel on climate change. R.K. Pachauri & L.A. Meyer (Eds.). Geneva: Author.

IPCC (2014b). *Climate change 2014 − synthesis report summary for policymakers*. Geneva: Author.

IPCC (2014c). Climate change 2014: Impacts, adaptation, and vulnerability. part A: Global and sectoral aspects. C.B. Field, V. Barros, D. Dokken, K. Mach, M. Mastrandrea, T. Bilir, … L.White, (Eds.). Cambridge: Cambridge University Press.

IPCC (2014d). Climate change 2014: Impacts, adaptation, and vulnerability. Part B: Regional aspects. C.B. Field, V. Barros, D. Dokken, K. Mach, M. Mastrandrea, T. Bilir, … L.White (Eds.). Cambridge: Cambridge University Press.

IPCC (2014e). Climate change 2014: Mitigation of climate change. Contribution of working group 3 to the fifth assessment report of the intergovernmental panel on climate change. O. Edenhofer, R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K., Seyboth, … J. Minx (Eds.). Cambridge: Cambridge University Press.

Klein, R.., Midgley, G., Preston, B., Alam, M., Berkhout, F., Dow, K., & Shaw, M. (2014). Adaptation opportunities, constraints, and limits. In C.B. Field, V. Barros, D. Dokken, K. Mach, M. Mastrandrea, T. Bilir, … L. White (Eds.), *Climate change 2014: Impacts, adaptation, and vulnerability. Part A: global and sectoral aspects* (pp. 899−943). Cambridge: Cambridge University Press.

Knutson, T., Zeng, F., & Wittenberg, A.T. (2014). Multimodel assessment of extreme annual-mean warm anomalies during 2013 over regions of Australia and the western tropical Pacific. *Bulletin of the American Meteorological Society, 95*(9), S26−S30.

Kovats, R.S., Valentini, R., Bouwer, L., Georgopoulou, E., Jacob, D., Martin, E., … Soussana, J-F. (2014). Europe. In C.B. Field, V. Barros, D. Dokken, K. Mach, M. Mastrandrea, T. Bilir, … L. White (Eds.), *Climate change 2014: Impacts, adaptation, and vulnerability. Part B: Regional aspects* (pp. 1267−1326). Cambridge: Cambridge University Press.

Lemelin, H., Dawson, J., Stewart, E.J., Maher, P., & Lueck, M. (2010). Last-chance tourism: The boom, doom, and gloom of visiting vanishing destinations. *Current Issues in Tourism, 13*(5), 477−493.

Lewis, S., & Karoly, D. (2014). The role of anthropogenic forcing in the record 2013 Australia-wide annual and spring temperatures. *Bulletin of the American Meteorological Society, 95*(9), S31−S34.

Maslowski, W., Clement Kinney, J., Higgins, M., & Roberts, A. (2012). The future of Arctic sea ice. *Annual Review of Earth and Planetary Sciences*, *40*, 625−654.

Meinshausen, M., Meinshausen, N., Hare, W., Raper, S.C., Frieler, K., Knutti, R., … Allen, M.R. (2009). Greenhouse-gas emission targets for limiting global warming to 2 C. *Nature*, *458* (7242), 1158−1162.

Mercer (2011). Climate change scenarios − implications for strategic asset allocation. London: Mercer. Retrieved 28 October 2013 from http://www.mercer.AQ8com/articles/1406410.

Michel, D., & Pandya, A. (2009). *Troubled waters: Climate change, hydropolitics and transboundary resources*. Washington, DC: Henry L. Stimson Center.

National Snow and Ice Data Center (2014). September 2014 compared to previous years. Retrieved 1 March 2015 from http://nsidc.org/arcticseaicenews/.

New, M., Liverman, D., Schroder, H., & Anderson, K. (2011). Four degrees and beyond: The potential for a global temperature increase of four degrees and its implications. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 369*(1934), 6−19.

NOAA (2015). Trends in atmospheric carbon dioxide. Retrieved 1 March 2015 from http://www.esrl.noaa.gov/gmd/ccgg/trends/history.html.

Nurse, L.A., McLean, R., Agard, J., Briguglio, L., Duvat-Magnan, V., Pelesikoti, N., … Webb, A. (2014). Small islands. In V. Barros, C. Field, D. Dokken, K. Mach, M. Mastrandrea, T. Bilir, … L. White (Eds.), *Climate change 2014: Impacts, adaptation, and vulnerability. Part B: Regional aspects* (pp. 1613−1654). Cambridge: Cambridge University Press.

Olivier, J., Janssens-Maenhout, G., Muntean, M., & Peters J. (2014). *Trends in global CO_2 emissions 2014 report*. The Hague: PBL Netherlands Environmental Assessment Agency.

Organisation for Economic Co-operation and Development (OECD) and United Nations Environment Program (UNEP) (2011). *Sustainable tourism development and climate change: Issues and policies*. Paris: Author.

Paolo, F. S., Fricker, H., & Padman, L. (2015). Ice sheets: Volume loss from Antarctic ice shelves is accelerating. *Science*, Published Online March 26, doi: 10.1126/science.aaa0940

Reisinger, A., Kitching, R., Chiew, F., Hughes, L., Newton, P., Schuster, S., … Whetton, P. (2014). Australasia. In C. B. Field, V. Barros, D. Dokken, K. Mach, M. Mastrandrea, T. Bilir, … & L. White (Eds.), *Climate change 2014: Impacts, adaptation, and vulnerability. Part B: Regional aspects* (pp. 1371−1438). Cambridge: Cambridge University Press.

Scott, D. (2011). Why sustainable tourism must address climate change. *Journal of Sustainable Tourism, 19*(1), 17−34.

Scott, D., Amelung, B., Becken, S., Ceron, J.-P., Dubois, G., Gössling, S., . . . Simpson, M. (2008). Technical report. In *Climate change and tourism: Responding to global challenges* (pp. 23−250). Madrid: UNWTO.

Scott, D., & Becken, S. (2010). Adapting to climate change and climate policy: Progress, problems and potentials. *Journal of Sustainable Tourism, 18*(3), 283−295.

Scott, D., & Gössling, S. (2015a). Scenarios and forecasts in tourism. In C.M. Hall, S. Gössling, & D. Scott (Eds). *Handbook of tourism and sustainability* (pp. 305−319). London: Routledge.

Scott, D., & Gössling, S. (2015b, forthcoming). What could the next 40 years hold for global tourism? *Tourism Recreation Research*.

Scott, D., Gössling, S., & Hall, C.M. (2012a). International tourism and climate change. *Wiley Interdisciplinary Reviews − Climate Change, 3*(3), 213−232.

Scott, D., Gössling, S., & Hall, C.M. (2012b). *Climate change and tourism: Impacts, adaptation and mitigation*. London: Routledge.

Scott, D. Sim, R., & Simpson, M. (2012c). Sea level rise impacts on coastal resorts in the Caribbean. *Journal of Sustainable Tourism, 20*(6). 883−898.

Scott, D., Wall, G., & McBoyle, G. (2005). The evolution of the climate change issue in the tourism sector. In C.M. Hall & J. Higham (eds), *Tourism, recreation and climate change* (pp. 44−60). Clevedon: Channel View Publications.

Su, Y-P., & Hall, C.M. (2014). Climate change and tourism in Asia: a review, In L. Ruhanen (ed.), *Responding to climate change: Tourism initiatives in Asia and the Pacific* (pp. 27−40). Madrid: UNWTO.

Sustainable Aviation (2008). *Sustainable aviation CO_2 roadmap*. Sustainable Aviation, UK. Retrieved 23 May 2014 from http://www.sustainableaviation.co.uk/wp-content/uploads/sa-road-map-final-dec-08.pdf.

UNEP (2014). Financial institutions taking action on climate change. Retrieved 1 March 2015 from http://www.unepfi.org/fileadmin/documents/FinancialInstitutionsTakingActionOnClimateChange.pdf.

UN Water (2014). *Water and energy: The United Nations world water development report 2014*. New York, NY: United Nations.

UNWTO (2007). From Davos to Bali: A tourism contribution to the challenge of climate change. Retrieved 30 March 2015 from http://sdt.unwto.org/sites/all/files/docpdf/ccbrochdavbalmembbg.pdf.

UNWTO, UNEP, & WMO (2008). *Climate change and tourism: Responding to global challenges*. Madrid: UNWTO.

US Department of Defense (2014). *Climate change adaptation roadmap*. Retrieved 1 March 2015 from http://www.acq.osd.mil/ie/download/CCA-Rprint.pdf.

Van Huijgevoort, M., Van Lanen, H., Teuling, A., & Uijlenhoet, R. (2014). Identification of changes in hydrological drought characteristics from a multi-GCM driven ensemble constrained by observed discharge. *Journal of Hydrology, 512*, 421−434.

Weaver, D. (2011). Can sustainable tourism survive climate change? *Journal of Sustainable Tourism, 19*(1), 5−15.

World Economic Forum (WEF) (2009). *Towards a low carbon travel and tourism sector*. Davos: Author.

WMO (2015). Warming trend continues in 2014. Retrieved 1 March 2015 from http://www.wmo.int/media/content/warming-trend-continues-2014.

Wong, P.P., Losada, I., Gattuso, J., Hinkel, J., Khattabi, A., McInnes, K., … Sallenger, A. (2014). Coastal systems and low-lying areas. In C. B. Field, V. Barros, D. Dokken, K. Mach, M. Mastrandrea, T. Bilir, … L. White (Eds.), *Climate change 2014: Impacts, adaptation, and vulnerability*. *Part A: global and sectoral aspects* (pp. 361−409). Cambridge: Cambridge University Press.

World Bank (2013). *Turn down the heat: Climate extremes, regional impacts, and the case for resilience*. Washington, DC: Author.

World Bank (2014). 73 countries and over 1,000 businesses speak out in support of a price on carbon. Retrieved 30 March 2015 from http://www.worldbank.org/en/news/feature/2014/09/22/governments-businesses-support-carbon-pricing.

WTTC (2009). *Leading the challenge on climate change*. London: Author.

WTTC (2010). *Climate change − a joint approach to addressing the challenge*. London: Author.

Zeppel, H., & Beaumont, N. (2011). *Climate change and Australian tourism: A research bibliography*. Australian Centre for Sustainable Business and Development, University of Southern Queensland. Working Paper No. 1.