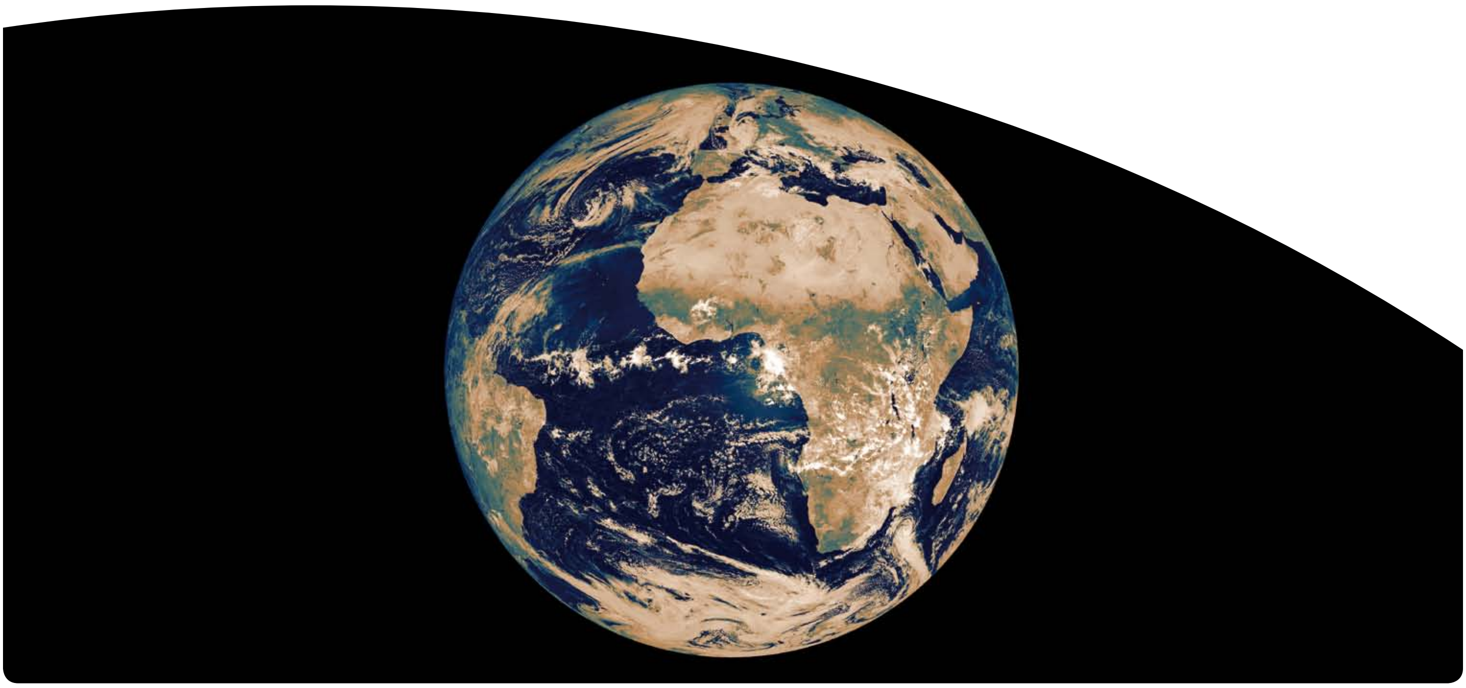
EDUCATION FOR SUSTAINABLE DEVELOPMENT

BOOKLET

Climate Change from above

An introduction to climate change from an outer-space perspective



GERMANWATCH

Contents

About this booklet

"The orbital view gives you a whole new perspective. You realise that each and everyone of us are interconnected and in this together. When you see the planet from space it puts the common challenges faced by all humans into perspective."

Ron Garan, US astronaut, 2013

Climate change is a global, man-made and complex threat, putting millions of livelihoods and ecosystems around the world at risk. To tackle this issue, a fundamental transformation of our societies is required in the fields of energy, nutrition, mobility and resources. The role of education for sustainable development in achieving this task cannot be overemphasised. In this context, Germanwatch organised an international workshop on climate change education as a starting point for dialogue to develop educational material for a South-North exchange.

This booklet is one result of that workshop and provides an introduction to global climate change by using satellite images. Germanwatch has experience of comparing live satellite images with archived footage of the earth, which has been successfully applied in educational work for almost ten years. Based on that experience, we have chosen an outer-space perspective as an entry point for education on climate change.

This booklet is aimed at teachers, leaders and other educators who work with students and young people in both Global South and Global North. The thematic and regional samples of satellite images in the booklet illustrate the current socio-economic challenges of climate change and those concerning the aspect of planetary boundaries. The satellite images impressively show examples of climate change impacts and causes. They also highlight regional differences and interrelations between other areas such as food, agriculture and energy consumption, and provide a basis for discussion on these topics. The images allow students to acquire insights from consequences to causes and to discuss vulnerability and resilience.

During the international workshop 'Climate change as a global educational task. Development of educational material in a South-North exchange', held in Warsaw on 8–9 November 2013 and supported by the Germanwatch Climate Expedition, climate change experts from non-governmental organisations in Bangladesh, Germany, India, Jamaica and South Africa selected the topics and images for this booklet: sea level rise, tropical cyclones, glaciers and ice sheets, as well as cross-cutting issues such as energy, agriculture, food and water. Each chapter contains satellite images related to a particular topic. A short description of them and more general and brief information on the topic are provided.

1 Introduction

"We live on a human dominated planet putting unprecedented pressure on the systems on earth. This is bad news. But perhaps this is surprising to you: it's also part of the good news. We are the first generation, thanks to science, to be informed that we may be undermining the stability and the ability of planet earth to support human development as we know it."

Johan Rockström, Stockholm Resilience Centre, 2010[1]

We only have this one planet, but we are using the earth's resources much faster than they can be replenished. Currently, Western-lifestyle societies consume the capacities of 1.5 planets – but we only have one. As a simple logical result, we are depleting our planet and living in an unsustainable way, which will affect present and future generations. Among other human activities, we use too much fresh water, cut too many trees, exploit too many resources, and add too much nitrogen to the ecosystems. We reduce biodiversity and we release too much carbon into the atmosphere. In order to survive in a safe environment, humans must respect and act within the planetary boundaries of the earth.[2]

One of these planetary boundaries is the amount of greenhouse gases in the atmosphere, which is at an unusual and dangerously high level as a result of human activities. In particular, the burning of fossil fuels and the clearing of forests has led to a high concentration of anthropogenic greenhouse gases in the atmosphere, which changes the climate massively.

The relatively stable climate in the Holocene period brought about the living conditions for humanity to create civilisation on planet earth. But now, the anthropogenic greenhouse effect is one characteristic of the Anthropocene period – a term popularised by Paul Crutzen which serves to mark the beginning of a new era on earth, an era essentially influenced by humans and whose onset is currently the subject of debate, although generally dated to the beginning of the Industrial Revolution in the 18th and 19th century. We continue to emit huge amounts of greenhouse gases, and if we continue in this way global temperatures will rise by about 4–6 °C by the end of the century.

The consequences and risks of climate change are unequally distributed across regions with significantly different environmental conditions. Poorer countries and vulnerable population groups cannot easily adapt to and cope with the consequences of climate change.

It is important to note that those countries which have contributed least to greenhouse gas emissions are, on the whole, the least developed countries. They are the worst hit by climate change, which represents an obstacle to development and human security.

Despite the unequal distribution of causes and consequences of climate change, a global solution for this man-made problem is needed. Unlike almost any other phenomena of our time, anthropogenic climate change and its consequences are significant challenges facing a globalised world.

With the consequences of climate change constantly being publicised through television, radio, newspapers and magazines, young people are increasingly familiar with the term and interested in it. Reports about weather catastrophes (e.g., Typhoon Haiyan, which hit the Philippines particularly hard in 2013), warnings from climate researchers and annual UN climate conferences all lead to a high level of public interest in the issue of climate change. To help understand this issue, the following chapters provide a selection of topics and examples. The satellite images will help to show the differences between regions and at the same time to see this phenomenon as a global issue – which must be tackled together.

1 Rockström (2010)
2 Rockström et al. (2009)

Figure 1: Bangladesh from above
(NASA/MODIS)

Figure 2: Cuba and Jamaica from above
(NASA/MODIS)

Figure 3: South Africa from above (NASA/MODIS)

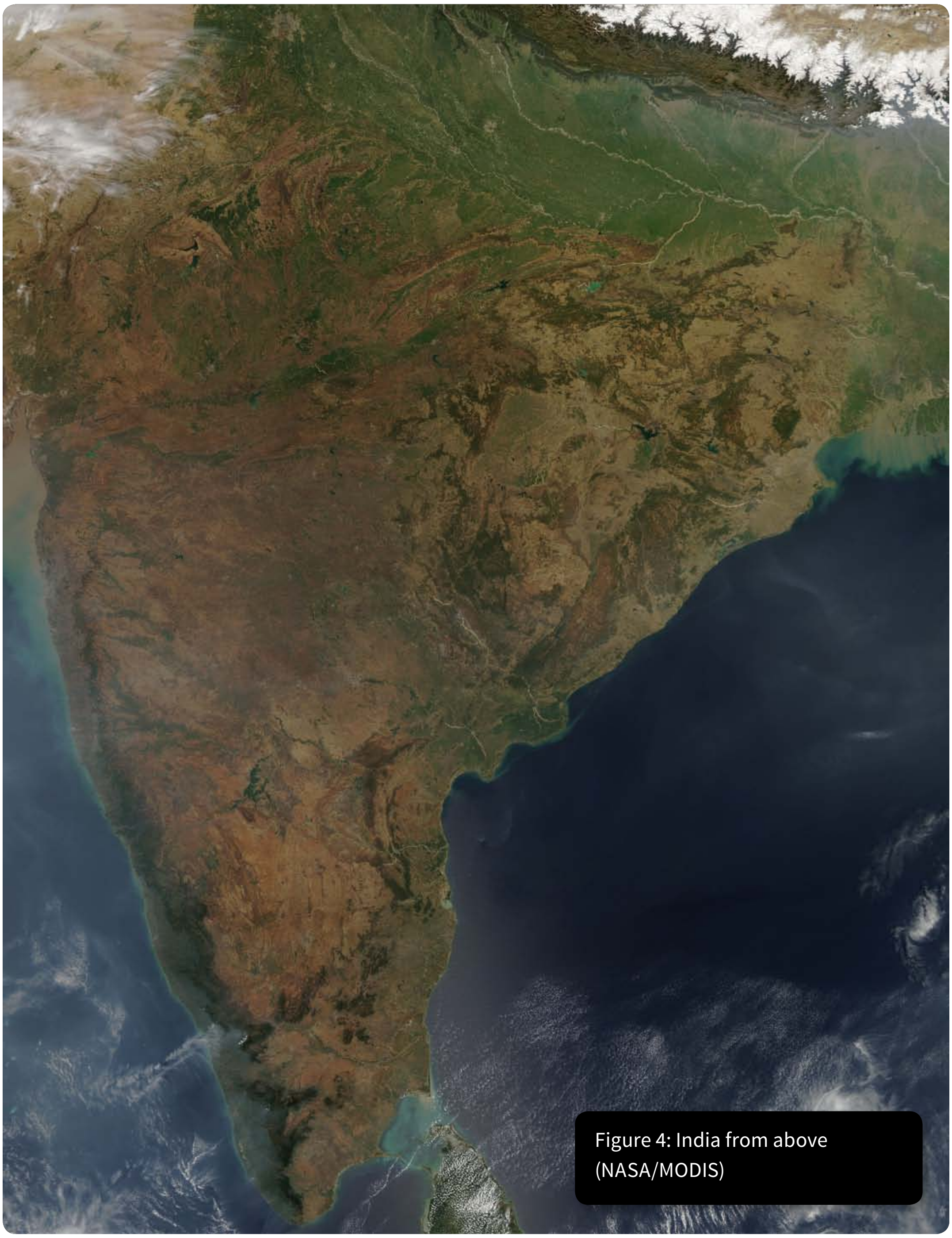


Figure 4: India from above (NASA/MODIS)

2 Global climate change

2.1 Natural greenhouse effect

The earth's climate is characterised by fluctuations that have different causes and driving mechanisms. The natural greenhouse effect is one of those characteristics; it leads to a rise in the average surface temperature by trapping some of the sun's incoming energy in the atmosphere.

Solar radiation heats the earth's surface, which absorbs and radiates some of the incoming radiation back into the atmosphere. Before that energy leaves the atmosphere into space, greenhouse gases in the atmosphere – for example, water vapour (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and ozone (O_3) – absorb parts of it and radiate it back to the earth surface, thereby giving it additional warming. On earth, this effect accounts for an additional 33 °C. Without the existence of natural greenhouse gases, global average temperature would be at around -18 °C, which would be too cold for development of life on earth as we know it.

2.2 Anthropogenic climate change

During the Holocene period (starting about 11,700 years ago) greenhouse gas concentrations in the atmosphere were quite stable. However, since the beginning of the industrial era in 1750, human activities, mainly burning of fossil fuels and clearing forests, have contributed to new levels of greenhouse gases unprecedented in at least the last 800,000 years.[3] Carbon dioxide concentration in 2012 has risen about 41% compared to 1750 and is now at 393 parts per million.[4] Additional anthropogenic greenhouse gases in the atmosphere lead to a stronger greenhouse effect.

Between 1880 and 2012, global average temperature increased by 0.85 °C.[5] Each of the last three decades has been warmer than any decade since 1850. It is very probable that during the whole Holocene period, temperatures never rose as fast as the current trends.[6]

The rise in temperature is unequally distributed across the world, and is more likely to be observed over land surfaces than over oceans, where warming is delayed in time.

In its Fifth Assessment Report (AR5), the Intergovernmental Panel on Climate Change (IPCC) confirmed in 2013, with a scientific certainty of more than 95%, that human activity and the consequent anthropogenic greenhouse gas emissions are the dominant factors of global climate change. The main causes of those factors are lifestyle and economic activities, predominantly seen in industrialised countries but also increasingly being seen among wealthier population groups in emerging and developing countries – and together these groups form a global middle-class. The main victims of the already noticeable and expected impacts are primarily, however, people in developing countries and, in particular, their poorest population groups.

2.3 Climate change impacts

Anthropogenic climate change is one of the most significant threats to our global environment and living conditions and an impediment to development. Many of the consequences of anthropogenic climate change are already being seen around the world, including global sea level rise (section 3), the increasing number of extreme weather events such as tropical cyclones (section 4), the melting of glaciers and ice sheets (section 5) and the impacts on agriculture (section 7) and availability of fresh water (section 8).

The Germanwatch Global Climate Risk Index (CRI)[7] analyses countries that are suffering most from weather-related loss events (e.g., storms, floods, heat waves, etc). The CRI does not include slow-onset events like sea level rise, glacier melting and warmer seas. Honduras, Myanmar and Haiti are the countries that have been most affected in the period 1993–2012, followed by Nicaragua, Bangladesh and Vietnam. Poorer developing countries are hit much harder. The analysis highlights the particular vulnerability

3 IPCC (2013)
4 WMO (2013)
5 IPCC (2013)
6 Rahmstorf (2013)
7 Kreft, S. and D. Eckstein (2013)

of poor countries to climate risks, despite the fact that absolute monetary damages are much higher in richer countries.

Climate change is already affecting ecosystems and livelihoods in many communities in both the Global South and Global North – and the consequences are worsening, which means there are global challenges at all levels (from local to international) and for societies, politicians and scientists.

2.4 Dangerous climate change

In 2010, governments around the world agreed at the UN climate negotiations in Cancún to limit global average temperature rising to 2 °C in comparison to pre-industrial times in order to prevent a dangerous climate change. This was tightened to 1.5 ° in the final declaration of the Rio+20 summit in 2012.[8] Exceeding global warming beyond 1.5–2 °C would lead to a world with serious threats to living conditions, human security and development, including health, water availability and food production, and to ecosystems around the world. In a well publicised report, the World Bank warned that the consequences of a 4 °C warmer world could include extreme heat waves, droughts, sea level rise, ocean acidification and other extraordinary climate events.[9] Many communities and ecosystems would not be able to adapt adequately to these effects of climate change. Additionally, the risk of major abrupt changes in the earth's climate system, with their unprecedented consequences, increases as global warming proceeds and the 2 °C limit is exceeded. When certain temperature thresholds, or 'tipping elements', are crossed, then dangerous, irreversible and permanent large-scale disruptions in the climate system are possible. These could be, for example, the destabilisation of the West African or the Indian monsoon, the transformation of the Amazon forest, a slowing down of the Atlantic thermohaline circulation, or the collapse of the West Antarctic ice sheet.

2.5 Climate change mitigation

Staying below the 2 °C benchmark is essential. A recent IPCC report emphasises the urgent need for action and makes it clear that staying below 2 °C is still possible, but only if governments worldwide set themselves high ambitions. How humanity responds to this challenge in the coming years is vital to the issue of whether living conditions will change to a dangerous degree. Global CO_2 emissions must be reduced drastically and quickly. Next to energy saving and improving energy efficiency, governments must advance climate protection through increased use of renewable energies (section 6).

The Germanwatch Climate Change Performance Index (CCPI)[10] compares the climate protection performance of 58 countries that together are responsible for more than 90% of global energy-related CO_2 emissions. Four categories – emissions, efficiency, renewable energies and climate policies – are considered for the CCPI calculation. As the CCPI 2014 shows, no country is yet undertaking sufficient climate protection to prevent dangerous climate change. Because of this, the first three ranks on the CCPI remain open. Denmark clearly defended its fourth place in this year's Index. On the contrary, Germany dropped for the first time out of the top ten to number 19. India dropped six places, from 24 to 30, compared to the previous year. South Africa dropped two places, from 37 to 39.

However, the adherence of the 2 °C limit does not mean a safe future for all regions, countries and ecosystems. Many are already facing climate change dangers and, therefore, as well as mitigation activities, adaptation measures are becoming increasingly important to improve social and ecological resilience to a changing climate.

8 United Nations Sustainable Development Platform (2012)
9 World Bank (2012)
10 Burck et al. (2013)

3 Sea level rise

The first satellite image (figure 5) shows a part of the coastline of the Netherlands and north-western Germany that are affected by sea level rise. The second satellite image (figure 6) shows a part of the Netherlands coast with its dams. It was built as an adaptation measure to protect the country's long coastline and the lowland areas from sea level rise and floods.

The third satellite image (figure 7) shows the delta region of the Bangladesh coast, which is threatened severely by sea level rise. For mainly hydro-geological reasons, Bangladesh is not able to build a huge dam to adapt to rising sea levels.

Sea level rise is one consequence of global climate change. One main cause of rising sea levels is the thermal expansion of water due to rising water temperatures. Additional factors are the melting of mountain glaciers and the ice sheets in Greenland and Antarctica.

Sea levels react to global climate change slowly but persistently. During the 20th century, the average global sea level rose by 12–22 cm. Predictions of further sea level rises up until 2100 are very uncertain: the International Panel on Climate Change (IPCC) projects a global sea level rise of about 26–98 cm by 2100.[11] These projections do not include the danger of possible ice sheet slipping from Greenland and Antarctica, which could lead to a much higher rate of sea level rise. The mean rate of global average sea level rise is increasing. While between 1901 and 2010 the average rate was 1.7 mm per year, it was about 3.3 mm per year between 1993 and 2010 (IPCC, 2013). Even if the concentration of greenhouse gases in the atmosphere can be stabilised by 2100, sea levels will continue to rise for many centuries.

Because sea levels do not rise identically in every geographical region, local levels can differ significantly from the global average. It depends on many factors, for example, local currents or ocean floor topography. Changes in regional sea levels can also result from continental drifts or from land mass depressions or rises.

Regional impacts of rising sea levels do not depend only on environmental conditions, but also on the economic and social situation of a region as well as the options available to respond to and cope with these new challenges.[12] Poor developing countries, which until now have hardly contributed to the anthropogenic emissions, will generally be the most affected by climate change. A comparison of the Netherlands and Bangladesh, which are both seriously affected by rising sea levels, illustrates this aspect.

The Netherlands will be seriously affected by rising sea levels because of its low-lying coast. About one-quarter of the country lies below sea level. Without dams, this part of the country would already today be permanently flooded. Also, more than 60% of this area, with its 10 million inhabitants, would be threatened by storm surges. Because of the many safeguarding measures, the country's risk areas have been reduced to less than 1%.[13]

In the past, the sea level in the Netherlands rose about 20 cm within 100 years.[14] To continuously protect its coastline, the Netherlands will need stronger damns and broader dunes in the future. Without countermeasures, the risks of floods and groundwater salinisation are increasing. Both will have negative effects on water supply and agricultural production. However, existing infrastructure provides a high level of protection. Because of the technical and financial capacities available in the Netherlands, these measures can be further enhanced in order to meet future risks of sea level rise.

Bangladesh is one of the most populated regions of the world, with a population density of 1,174 individuals per 1 km^2, which is more than double the density of the Netherlands (World Bank, 2014). A large area of Bangladesh lies just a few metres above sea level and

11 IPCC (2013)
12 Butzengeiger and Horstmann (2004)
13 Butzengeiger and Horstmann (2004)
14 Butzengeiger and Horstmann (2004)

Figure 5: Coastline of the Netherlands and north-western Germany (NASA/MODIS)

Figure 6: Coastline of the Netherlands and dams (ESA/EUMETSAT/meteosat/Geoscopia)

in the estuary of the three large rivers – Brahmaputra, Ganges and Meghna. This makes the country highly vulnerable to sea level rise and flooding due to heavy rain and water from melting glaciers. Additionally, Bangladesh is prone to tropical cyclones and heavy monsoon rainfalls. Unlike the Netherlands, however, there is very little large-scale coastline protection such as dams. Currently, a sea level rise of one metre would permanently flood an area of 14,000 to 30,000 km^2 in Bangladesh, meaning that more than one-fifth of the country would be under water.[15] There are no areas left in Bangladesh to which affected people could move.

Moreover, there are serious indirect effects of rising sea levels, such as increases salinity of soil and ground water. In view of Bangladesh's already problematic food situation, a reduction in production of rice, vegetables, lentils, onions and other crops could be expected.

Both the Netherlands and Bangladesh are threatened by sea level rise. The difference is, however, they have different adaptation possibilities and ways to cope with that threat. The Netherlands already has an effective protection system and enough technical and financial capacity for future adaptation measures. Its financial capacities are built on fossil fuel-based industries. Bangladesh, however, has very little coastline protection and lacks the financial capacity for large-scale adaptation to sea level rise.

15 Butzengeiger and Horstmann (2004)

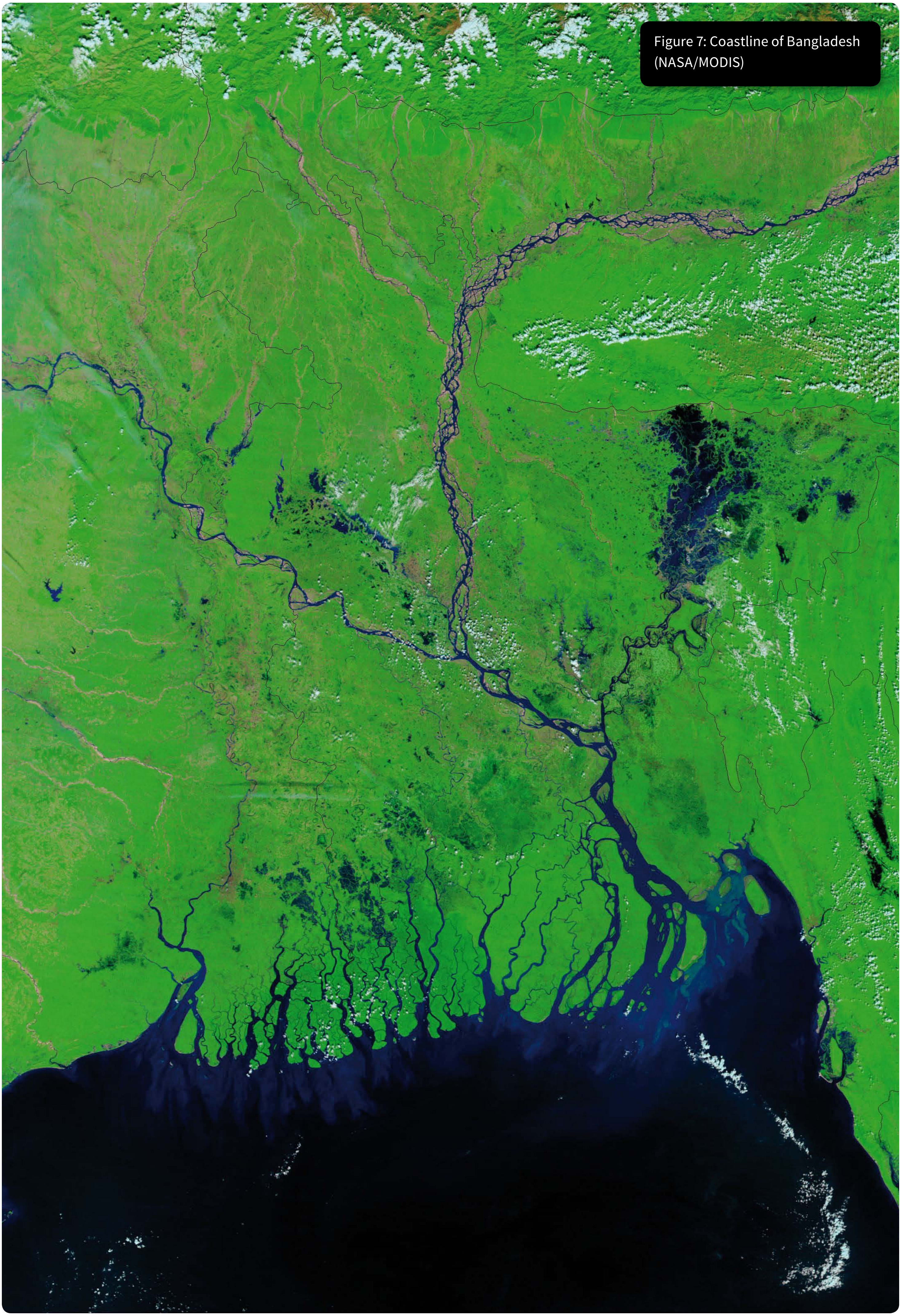


Figure 7: Coastline of Bangladesh (NASA/MODIS)

4 Tropical cyclones

The first two satellite images (figures 8 and 9) show Typhoon Haiyan, which hit the Philippines very hard in November 2013. Haiyan was one of the strongest-ever tropical typhoons, causing landfall and extensive damage, as well as the deaths of many people in the Philippines.

The next two images (figures 10 and 11) show the first tropical hurricane in Europe. The satellite image on the bottom shows a part of Europe in the array of infrared wavelength. The different colours refer to temperatures on the ground and on the surface of the clouds. Dark green represents temperatures between 0–5 °C. White, grey and black are temperatures below 0 °C, with black indicating very cold cloud surfaces with temperatures below -50 °C.

Figure 12 shows Hurricane Sandy, which hit the Caribbean and the USA in October 2012, causing serious damage.

Figure 13 shows Hurricane Catarina causing landfall on the coast of Brazil in 2004. Catarina was the first tropical cyclone with hurricane-intensity to ever be recorded in the Southern Atlantic Ocean. The damage was quite severe: thousands of houses and a large proportion of agricultural crops were destroyed.

Tropical cyclones have different names according to different regions. In the North Atlantic, in the Caribbean and the Gulf of Mexico they are called hurricanes. In the Indian Ocean, South-East Asia, Australia and New Zealand they are called tropical cyclones and in East Asia they are called typhoons.

Normally, tropical cyclones emerge in the outer tropics, between the 5th and 30th latitude south and north of the equator over the sea. There are several conditions needed for tropical cyclone formation, for example a given water surface temperature of minimum 26.5 °C up to a depth of at least 50 m. The difference in temperature between the ocean and the air mass above is also very significant, so that the air above the water is warming up and moistening. The saturation level of the air masses increases exponentially with the temperature: air masses with a temperature of 35 °C can absorb four times more steam than those with a temperature of 10 °C. Most tropical cyclones occur in the late summer and the autumn because of high water surface temperatures. Another necessary condition for tropical cyclone formation is the Coriolis effect, which causes tropical cyclones to start rotating and blowing clockwise in the Southern hemisphere and counter-clockwise in the Northern hemisphere. For that reason tropical cyclone formations always occur outside the area between the 5th latitude north and south of the equator, where the Coriolis effect is almost zero.

Being over water, a tropical cyclone can exist for some days and even weeks. But when it hits land, it immediately slows down, because its energy inflow from sea water evaporation stops. Tropical cyclones carry a high risk of extreme wind speeds of 120–300 km per hour, torrential rains and extreme storm floods with waves up to 10 m.

Tropical cyclones are very likely in the Caribbean, the Indian Ocean and South-East Asia, but have occurred also in other regions, e.g., Brazil and Europe, in the past decade.

It is difficult to predict tropical cyclones, but there is some confidence that we will see an increase in frequency and intensity. In some regions, it is more likely than not that the intensity will increase, for example in the Western North Pacific and North Atlantic.

[16] IPCC (2013)

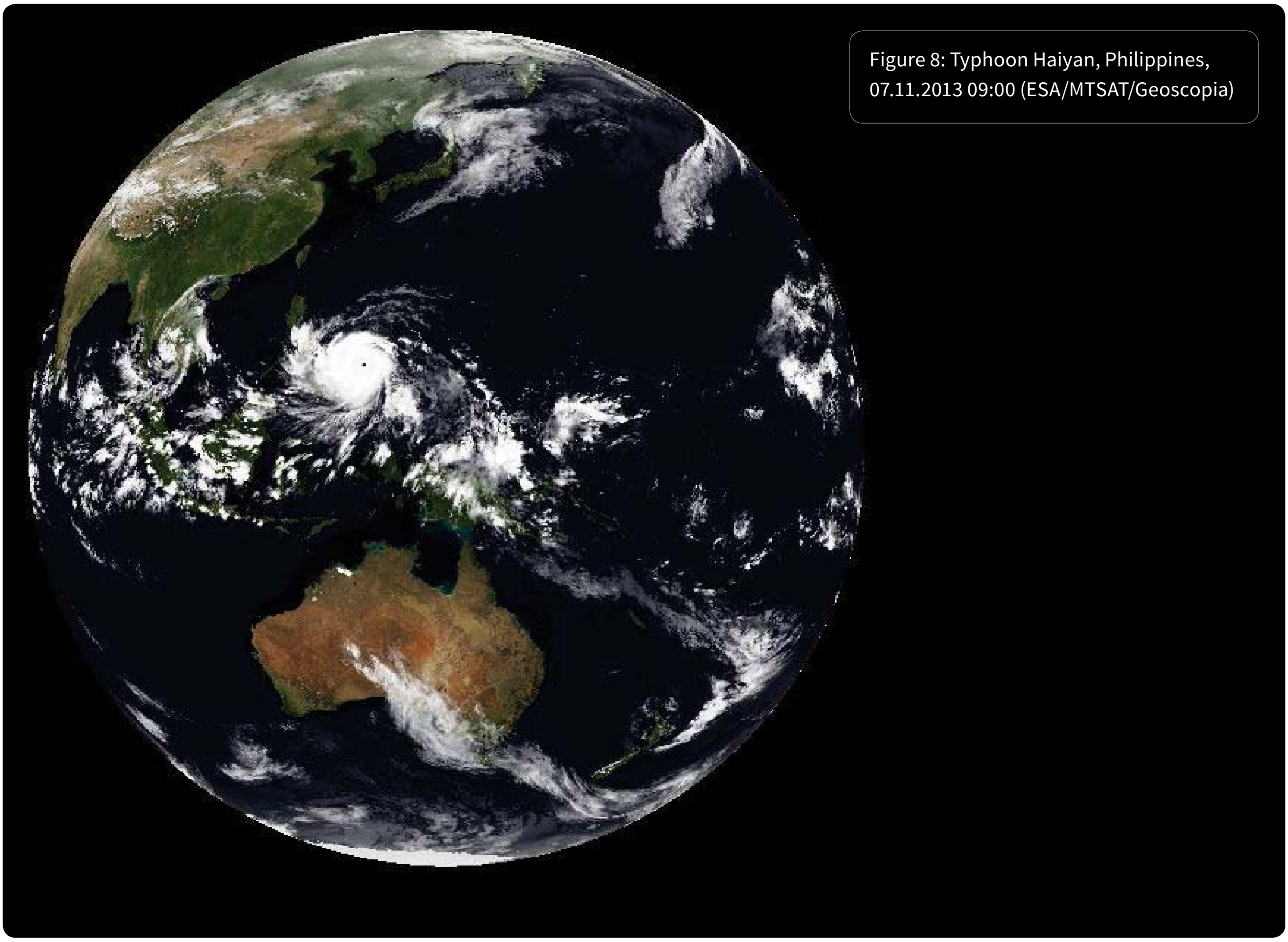


Figure 8: Typhoon Haiyan, Philippines, 07.11.2013 09:00 (ESA/MTSAT/Geoscopia)

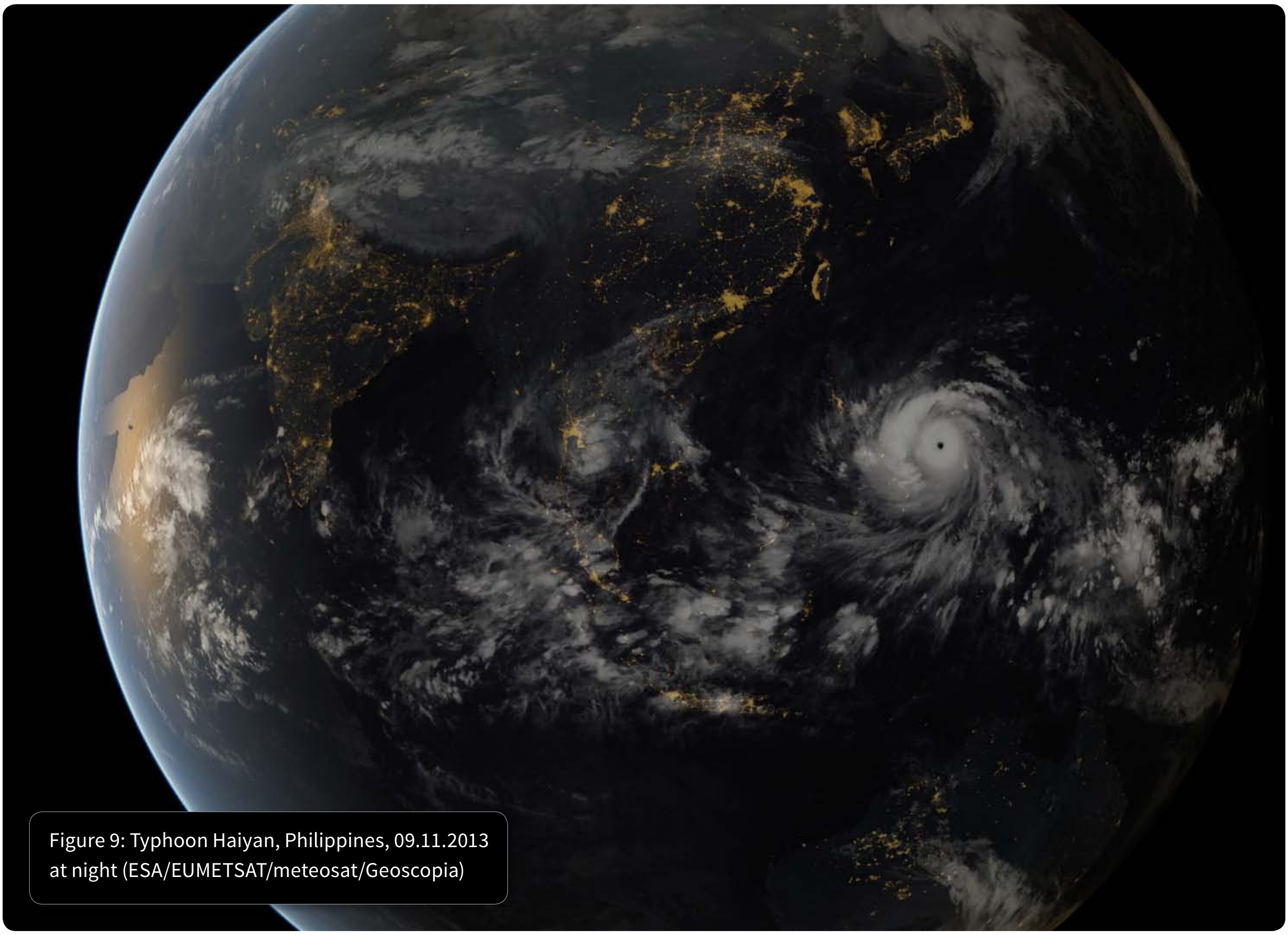


Figure 9: Typhoon Haiyan, Philippines, 09.11.2013 at night (ESA/EUMETSAT/meteosat/Geoscopia)

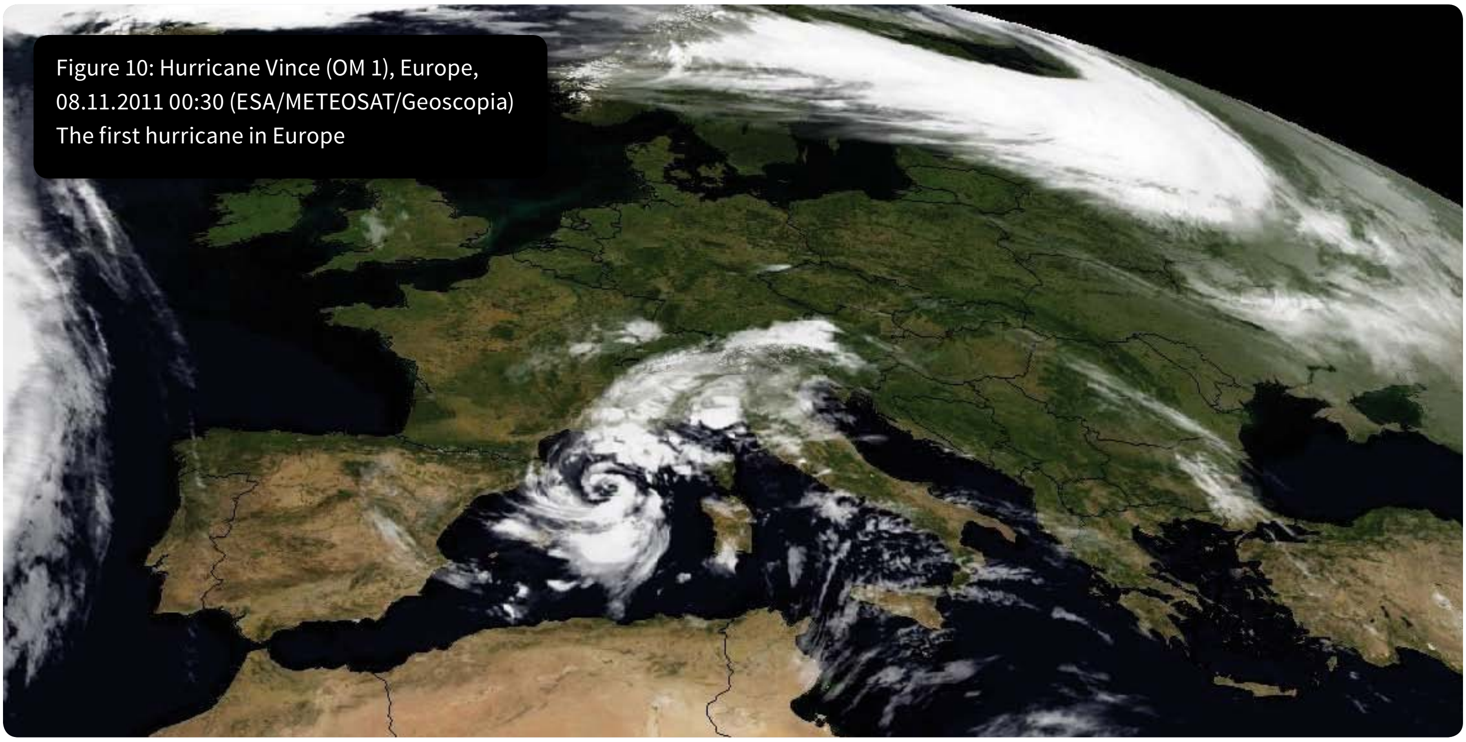


Figure 10: Hurricane Vince (OM 1), Europe,
08.11.2011 00:30 (ESA/METEOSAT/Geoscopia)
The first hurricane in Europe

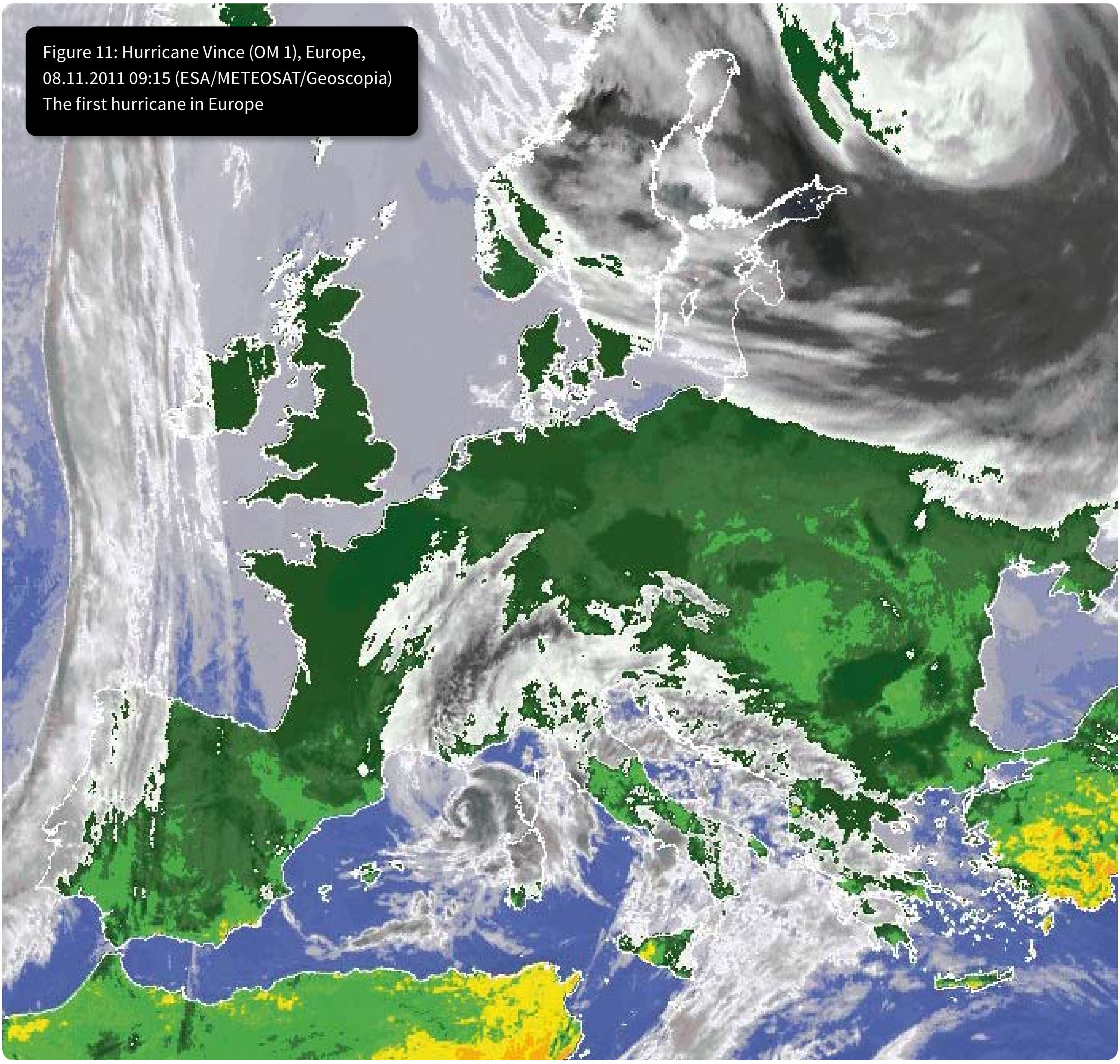


Figure 11: Hurricane Vince (OM 1), Europe,
08.11.2011 09:15 (ESA/METEOSAT/Geoscopia)
The first hurricane in Europe

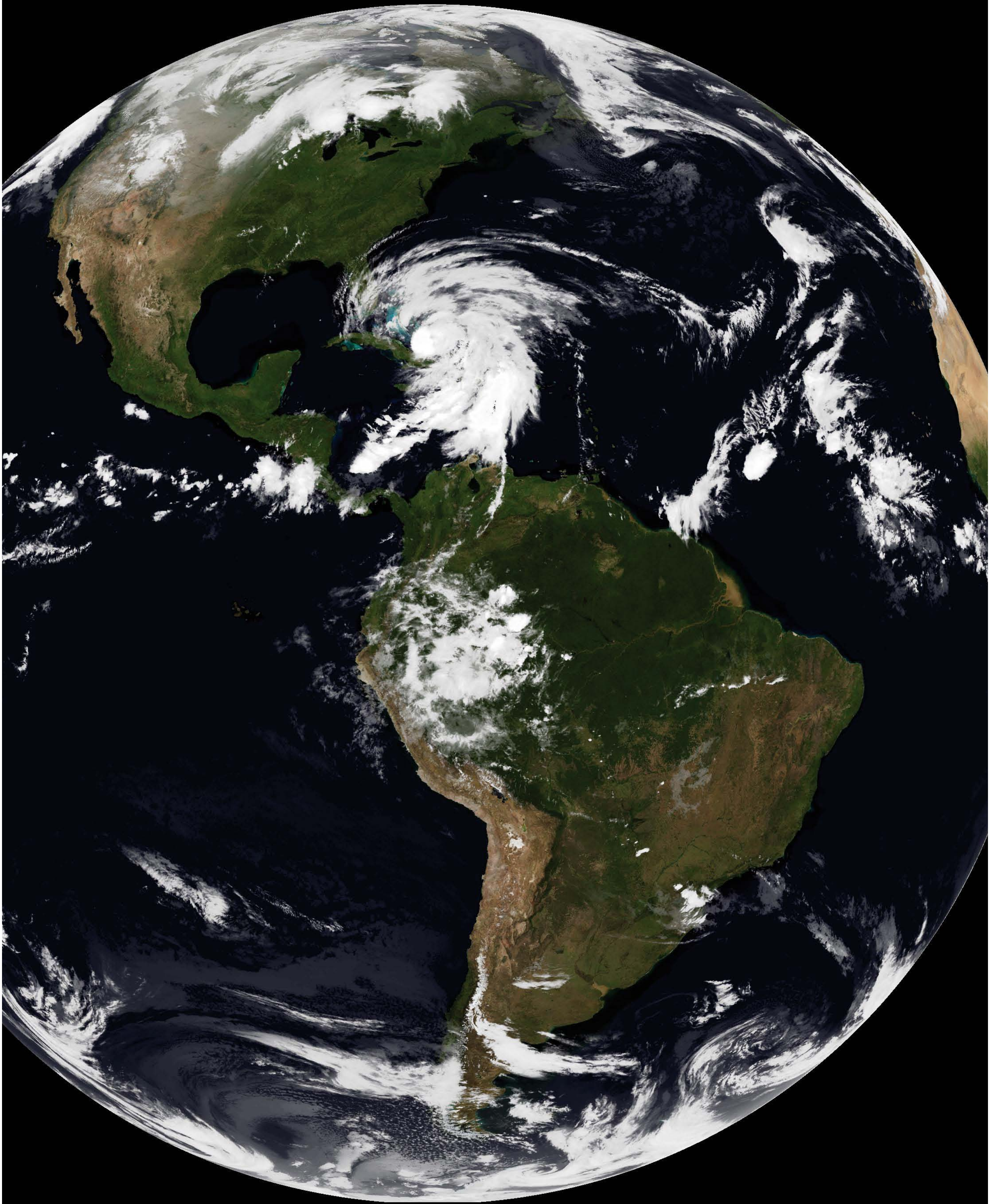


Figure 12: Hurricane Sandy, October 2012
(NASA/GOES 14/Geoscopia)

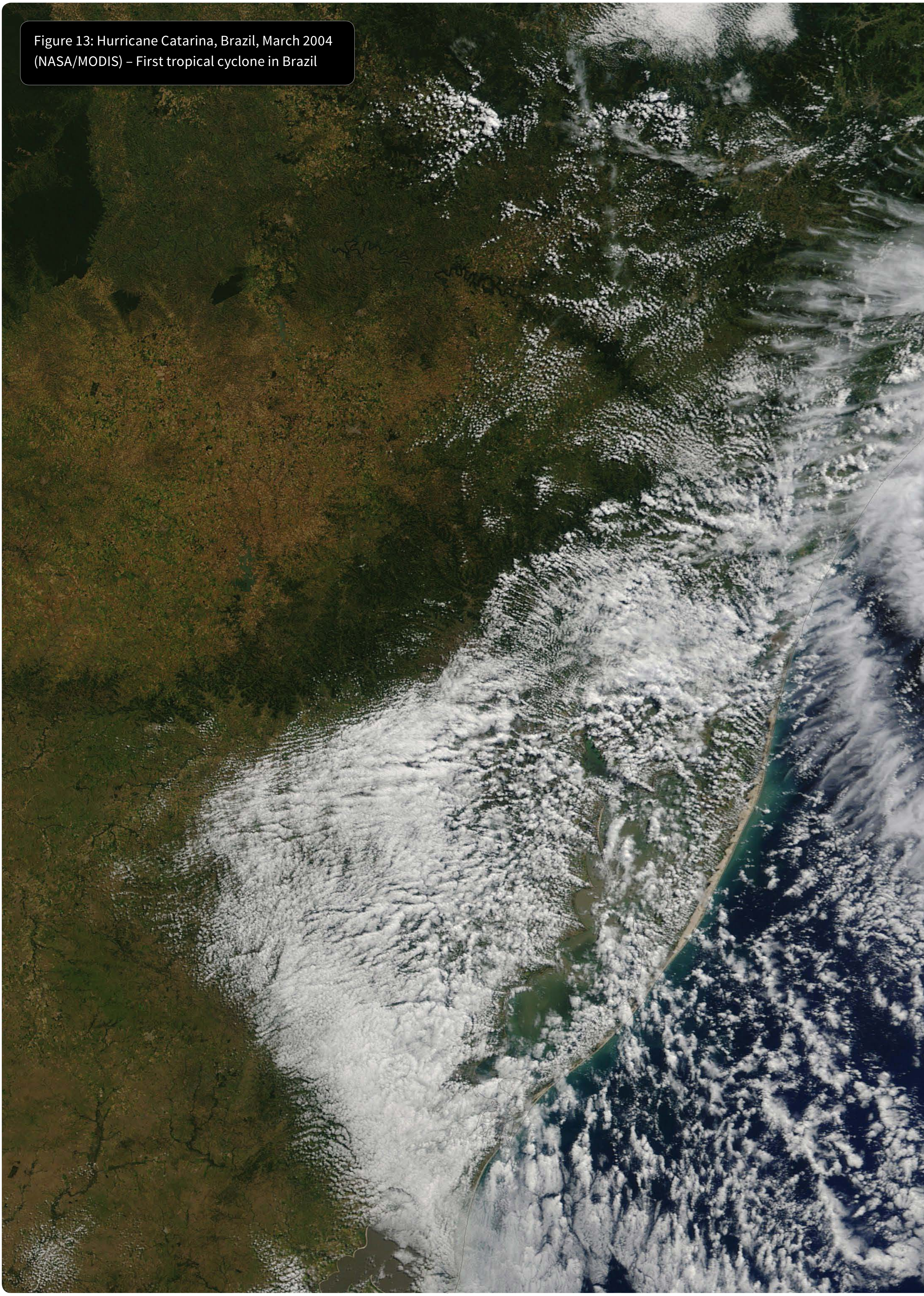
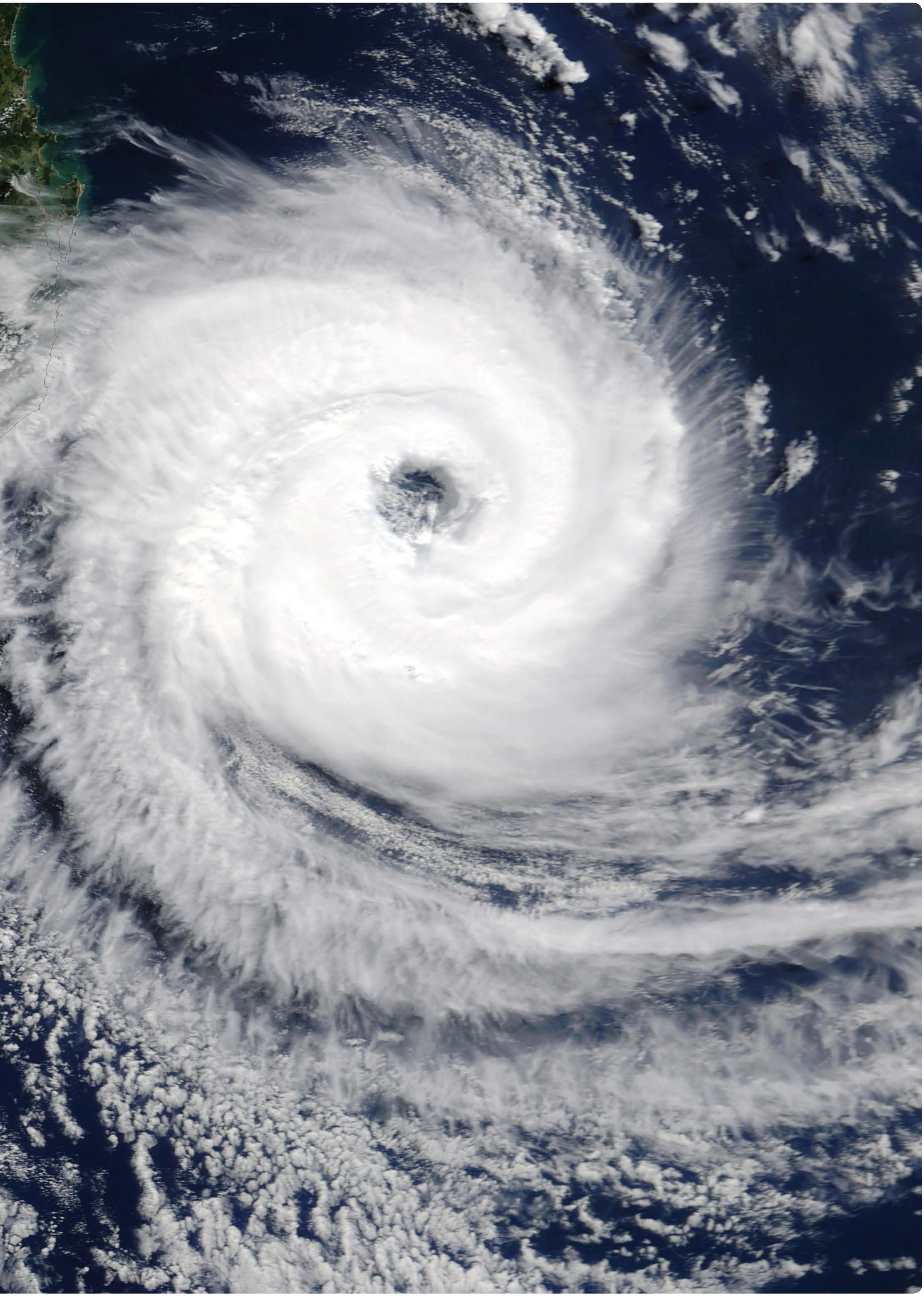


Figure 13: Hurricane Catarina, Brazil, March 2004 (NASA/MODIS) – First tropical cyclone in Brazil



5 Ice sheets and glaciers

5.1 Ice sheets

Figure 15 shows Greenland and the extent of its covering ice sheet during September 2012, when the ice extent is at its yearly minimum after the warm summer period. Figure 14 (not a satellite image) shows Greenland and the melting areas of the ice surface on 8 and 12 July 2012 (left and right respectively). The red colour illustrates those areas where thawing processes are observable on the surface. The pink colour shows areas where thawing is probable. On 8 July 2012 this was nearly 40% of the ice's surface, a more or less normal summer situation. Only four days later, on 12 July, almost 97% of the surface was thawing, a situation never observed before.

According to NASA in 2012 Greenland's ice surface was melting across a much greater area than during the previous 30 years of satellite observation.[17] The cause of this enormous melting was a ridge of warm air over Greenland. A reason for the high temperatures in Greenland was the smallest extent of Arctic sea ice in that year since observations began. Northwest Greenland and north-eastern Canada are warming five times faster than the rest of the world.[18]

17 NASA (2012a)
18 Geoscopia (2012b)

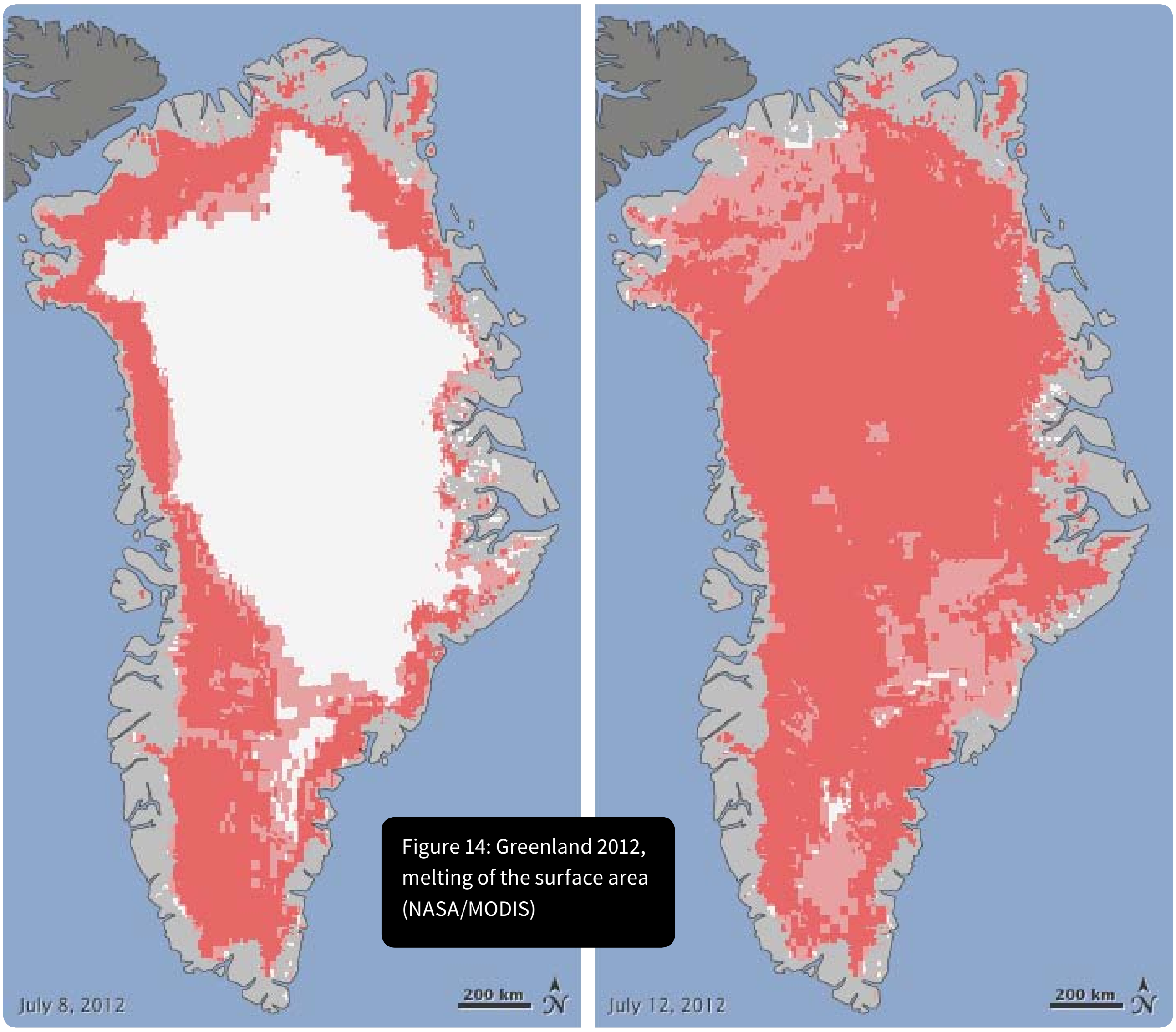


Figure 14: Greenland 2012, melting of the surface area (NASA/MODIS)

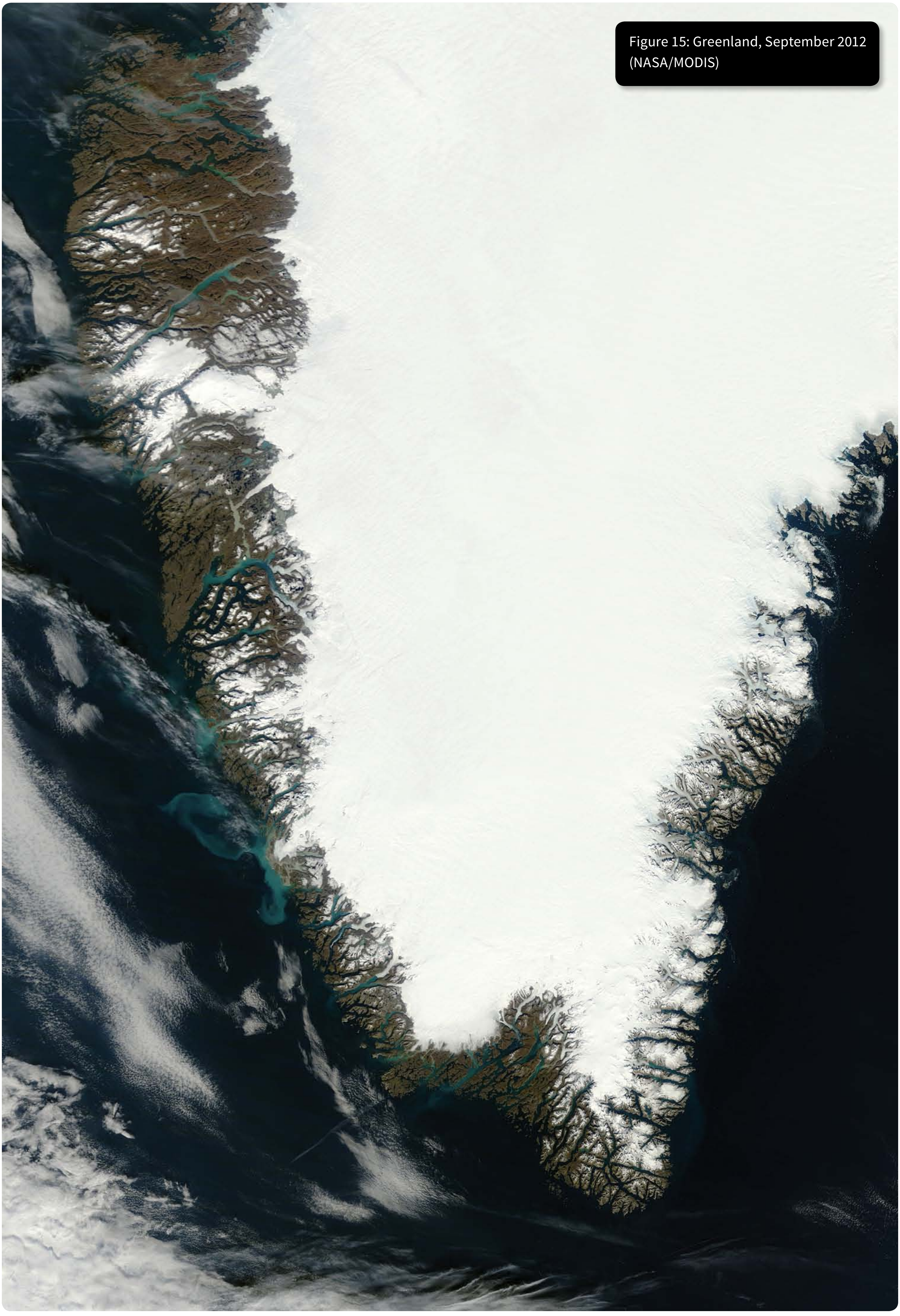


Figure 15: Greenland, September 2012 (NASA/MODIS)

5.2 Glaciers

Figure 16 shows Himalayan glaciers in Bhutan in 2009. Figure 17 shows the Columbia Glacier, which flows directly into the sea. The false-colour images show the landscape elements: bright cyan shows ice and snow; green shows vegetation; white and light orange show clouds; gray and brown show rocks; and dark blue is the ocean water. The image above shows the glacier in July 1986 and the image below in May 2011 with more snow. "As the glacier has retreated, it has also thinned substantially, as shown by the expansion of brown bedrock areas. Rings of freshly exposed rock, known as trimlines, are prominent in the later image. Since the 1980s, the glacier has lost about half of its total thickness and volume."[19]

The worldwide retreat of mountain glaciers has been one of the most reliable indications of global climate change since the mid-19th century. Although a global temperature rise of about 0.85 °C since 1880 might seem negligible, its impacts are tremendous (IPCC, 2013). By the 1970s, the glaciers of the Alps had already lost around one-third of their surface area and half of their volume. While glaciers in the Alps lost around 1% of their volume per year from 1975 to 2000, the loss rate nearly tripled in the 21st century. With a few exceptions, similar wide-ranging losses can be observed in all alpine regions of the world. All glaciers, from the Andes to Alaska as well as from the Himalaya to the Alps, are shrinking four times faster than they were 30 years ago.[20]

In countries with high mountainous regions such a development evokes concern, as the melting of glaciers increases the risk of glacial hazards. One is the risk of glacial lake outburst floods. As glaciers retreat, glacial lakes form behind dams of ice, rocks and/or sediment. These dams are comparatively weak and can breach suddenly, leading to a discharge of huge volumes of water and debris. Such outbursts have the potential of releasing millions of cubic metres of water in a few hours, causing catastrophic flooding downstream with serious damage to life, property, forests, farms and infrastructure.[21] Glacial lake outburst floods are not a new phenomenon but with rising temperatures and the worldwide receding of glaciers, the probability of their occurrence is much higher. This phenomenon illustrates dramatically the possible impacts of global climate change at local level. At the same time, it must be remembered that industrialised and developing countries have different possibilities and financial potential to react to such impacts.

The increasing risk of glacial lake outburst floods is not the only risk from mountain glacier melting. For many regions, glaciers are one of the most important sources of drinking water. During winter, glaciers accumulate valuable fresh water in the form of snow and ice, delivering this to rivers in summer in the form of melting water. This assures a water supply for millions of people. In particular, the receding of ice masses affects many cities in the Himalaya basin, where the seven biggest rivers in Asia are recharged. Losing this source of water in future will have severe impacts on water access and conflicts in these regions.

19 NASA (2012b)
20 WGMS (2008)
21 Horstmann (2004)

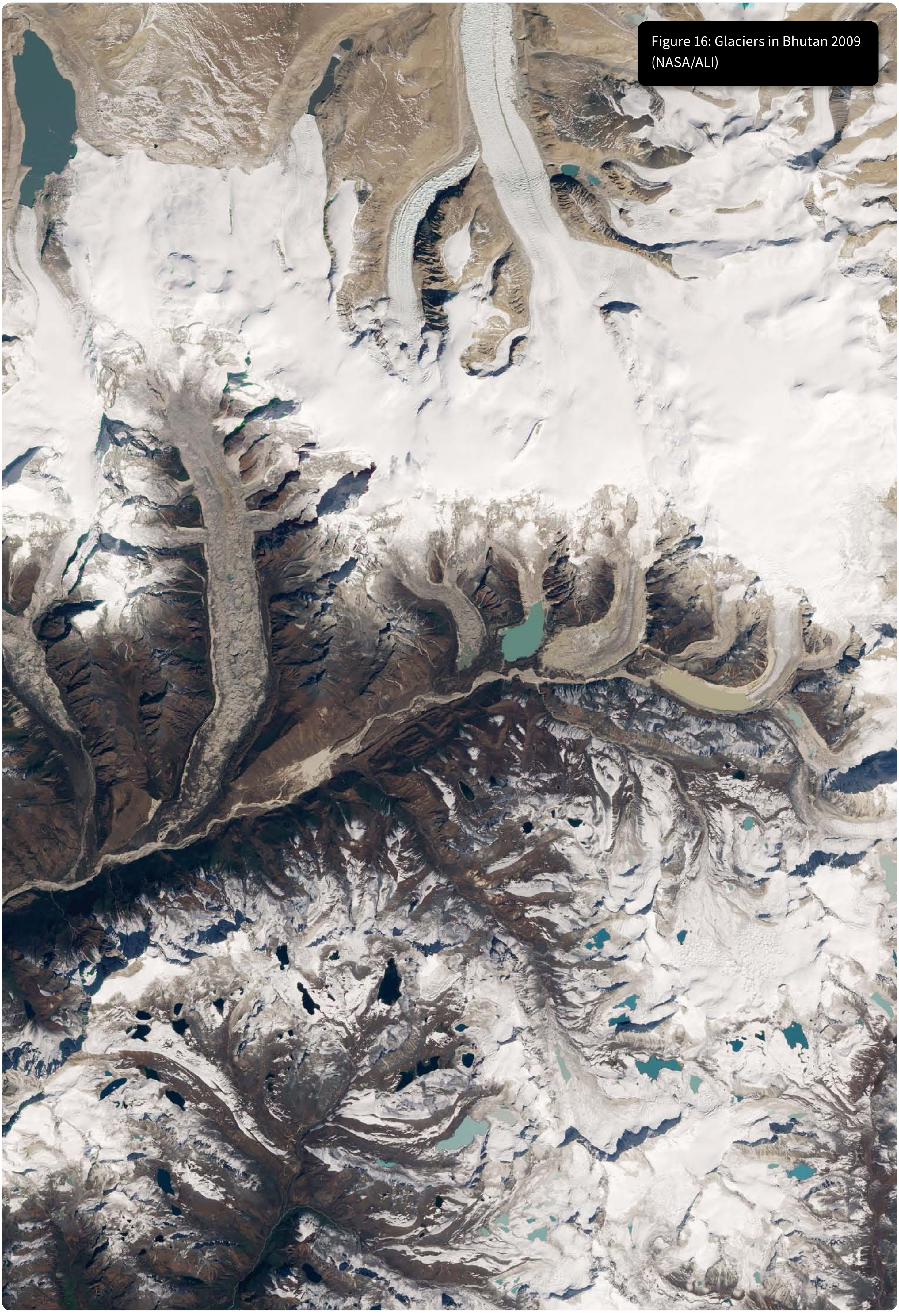


Figure 16: Glaciers in Bhutan 2009 (NASA/ALI)

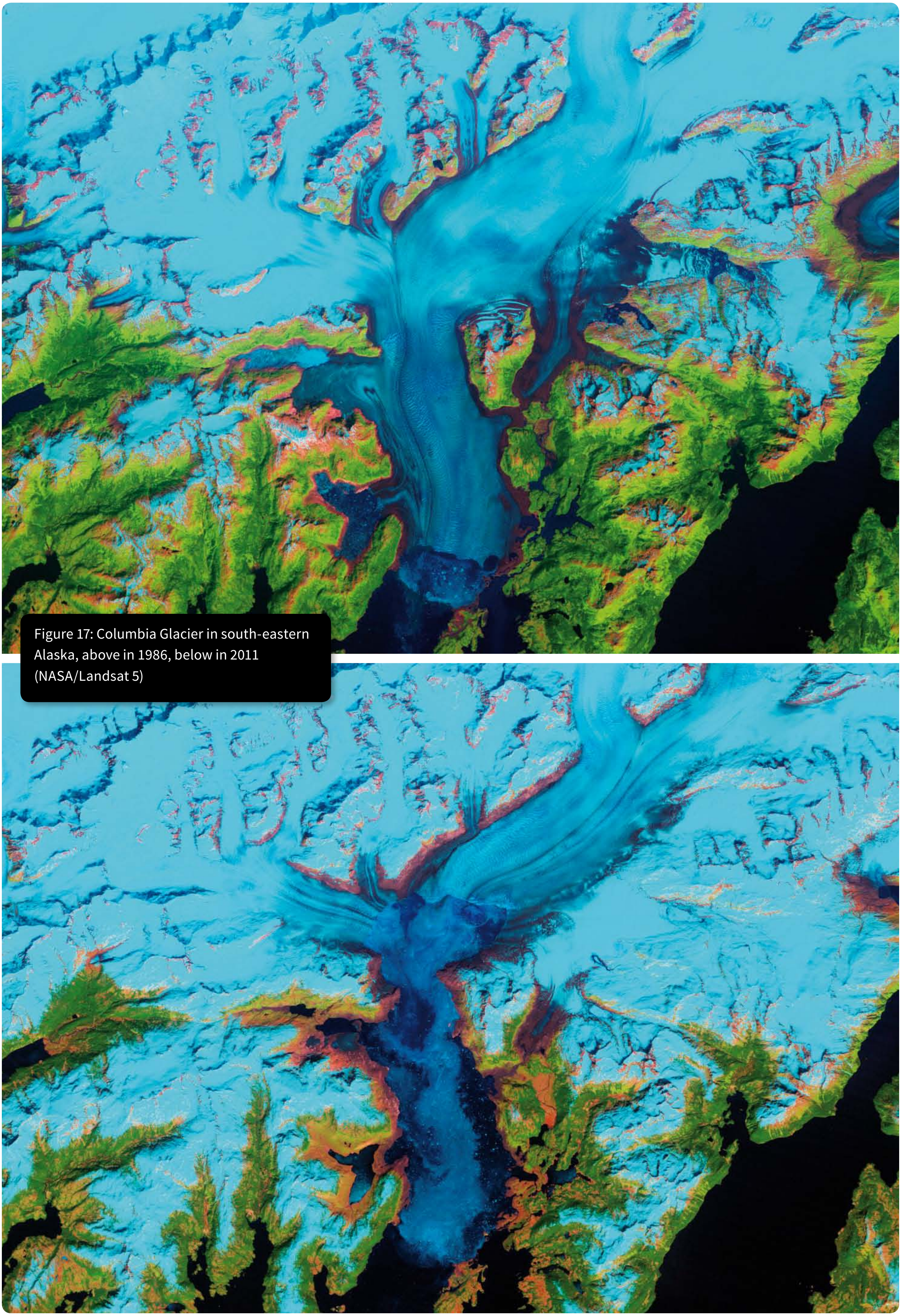


Figure 17: Columbia Glacier in south-eastern Alaska, above in 1986, below in 2011 (NASA/Landsat 5)

6 Energy: energy consumption, coal mining, renewable energies

6.1 Energy consumption

All three satellite images (figures 18–20) were recorded at night. The first one (figure 18) shows the world illuminated by night. The greatest illumination is in the north-eastern part of the USA, Europe, parts of East Asia and South Asia. Most parts of Africa, South America, and North and Central Asia are still dark.

The second satellite image (figure 19) shows India on 11 November 2012. This was a special day because of the Diwali Festival taking place. The Festival of Lights, as it is also called, is an important festive season in Hindu culture. While in former times candles and small oil lamps were lighted on the entrances and windows of buildings, today it is mostly electric lights that are used to decorate houses, shops and streets.

The third satellite image (figure 20) shows the distribution of illuminated areas in parts of central Europe, mainly Germany. Lights can be seen nearly everywhere, and there are some heavily concentrated light areas.

The lights by night are a mirror of energy consumption, which can be interpreted as economic development in different regions. Although bright lights do not mean that in these regions every person enjoys prosperity, in general they indicate areas of high economic standards and high energy consumption. Also, mega-cities, metropolises and congested areas can easily be identified.

Since 2007, the majority of the world's population lives in cities rather than rural areas and urban migration continues. The urban population consumes more than three-quarters of total energy. By 2050, nearly 80% of the predicted worlds' nine billion people are expected to be living in cities. In Asia, especially in India, structures are growing rapidly. Each year the Indian population is growing at by more than 15 million people approximately. Due to high economic growth rates, the per capita income in India and other countries increased as well.[22]

Between 2000 and 2010, the global share of greenhouse gas emissions from developed countries went down from 51.8% to 40.9%, whereas developing country emissions increased from 48.2% to 59.1%.[23] Man-made greenhouse gas emissions were at a record high in 2012.

The combination of rapid urbanisation and increasing prosperity intensifies greenhouse gas emissions and hence climate change and its impacts. Today's built infrastructure in the world's cities will affect emissions for decades or even longer. Thus, a climate-smart urban development is important as it can play a crucial role in transforming our societies into more sustainable ones.

22 Geoscopia (2013)
23 UNEP (2013)

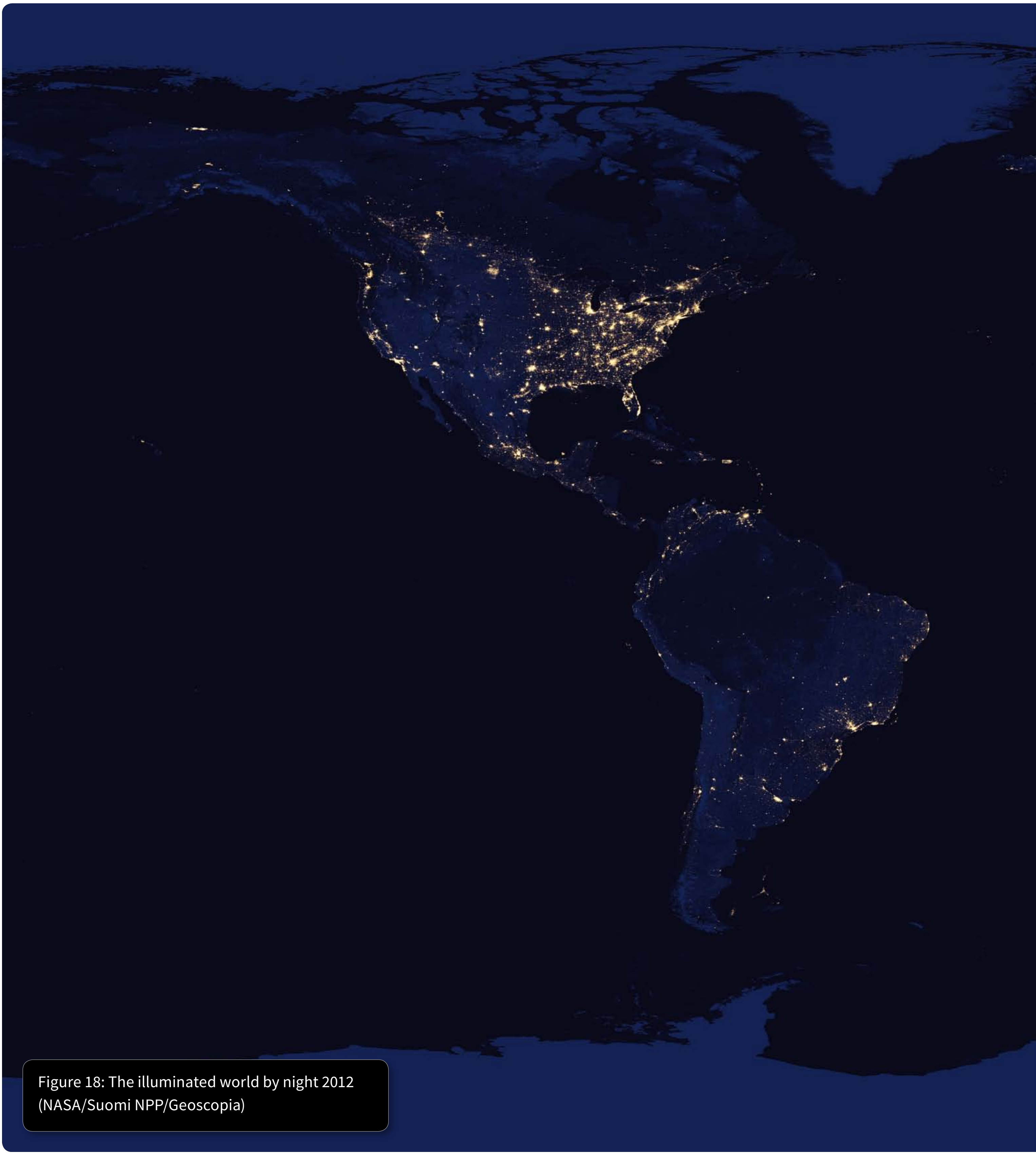


Figure 18: The illuminated world by night 2012 (NASA/Suomi NPP/Geoscopia)

Figure 19: India illuminated at night during Diwali Festival (‘the festival of lights’), 11.11.2012 (NASA/Suomi NPP/Geoscopia)

Figure 20: Central Europe illuminated at night, 2012 (NASA/Suomi NPP/Geoscopia)

6.2 Coal mining and renewable energy

The burning of fossil fuels such as oil, gas and coal discharges huge amounts of CO_2 and other greenhouse gases and is mainly responsible for global warming. Coal is, next to tar sands, the most 'dirty' energy source on the planet, in particular brown coal, or lignite as it is also called. In addition to the high contribution of burning coal to global climate change, coal mining also directly destroys large areas of the environment; to get the coal out of the ground, very often old villages and huge amounts of soil and vegetation must be destroyed (see also Figure 21).

South Africa obtains more than 90% of its energy from coal-fired power plants.[24] It is the world's fifth largest producer of coal, and is already the sixth largest consumer of it. Two of the largest coal-fired power plants in the world are located in South Africa, while less than 1% of South Africa's electricity currently comes from renewable energies.[25] The renewable energy sector has a huge growth potential and could create employment opportunities if a transition towards more sustainable energy is implemented. In Germany, for example, where a transformation of the energy sector has been attempted, nearly 25% of the country's electricity is produced through renewable energy (in 2012). At the same time, Germany has a record high since 1990 in electricity from lignite-fired power plants due to very low coal and emission permit prices.

Globally, the renewable energy industry has been experiencing explosive growth since the 1990s. Between 2005 and 2010 the installed capacity of wind grew by 333%, while solar photovoltaic grew by over 700%. In 2011, renewable energy supplied an estimated 19% of global final energy consumption. In 2012, wind power accounted for about 39% of renewable power capacity, followed by hydropower and solar photovoltaic, each accounting for approximately 26%.[26]

Investment for renewable energies is high in the beginning but once in use the only costs are for maintenance. In contrast, fossil resources such as coal constantly need new resource inputs, as they have to be dug out or imported. Due to advances in technology and a high demand for renewable energy, investment costs for renewables are steadily decreasing.

24 Greenpeace (2011)
25 Greenpeace (2011)
26 REN21 (2013)

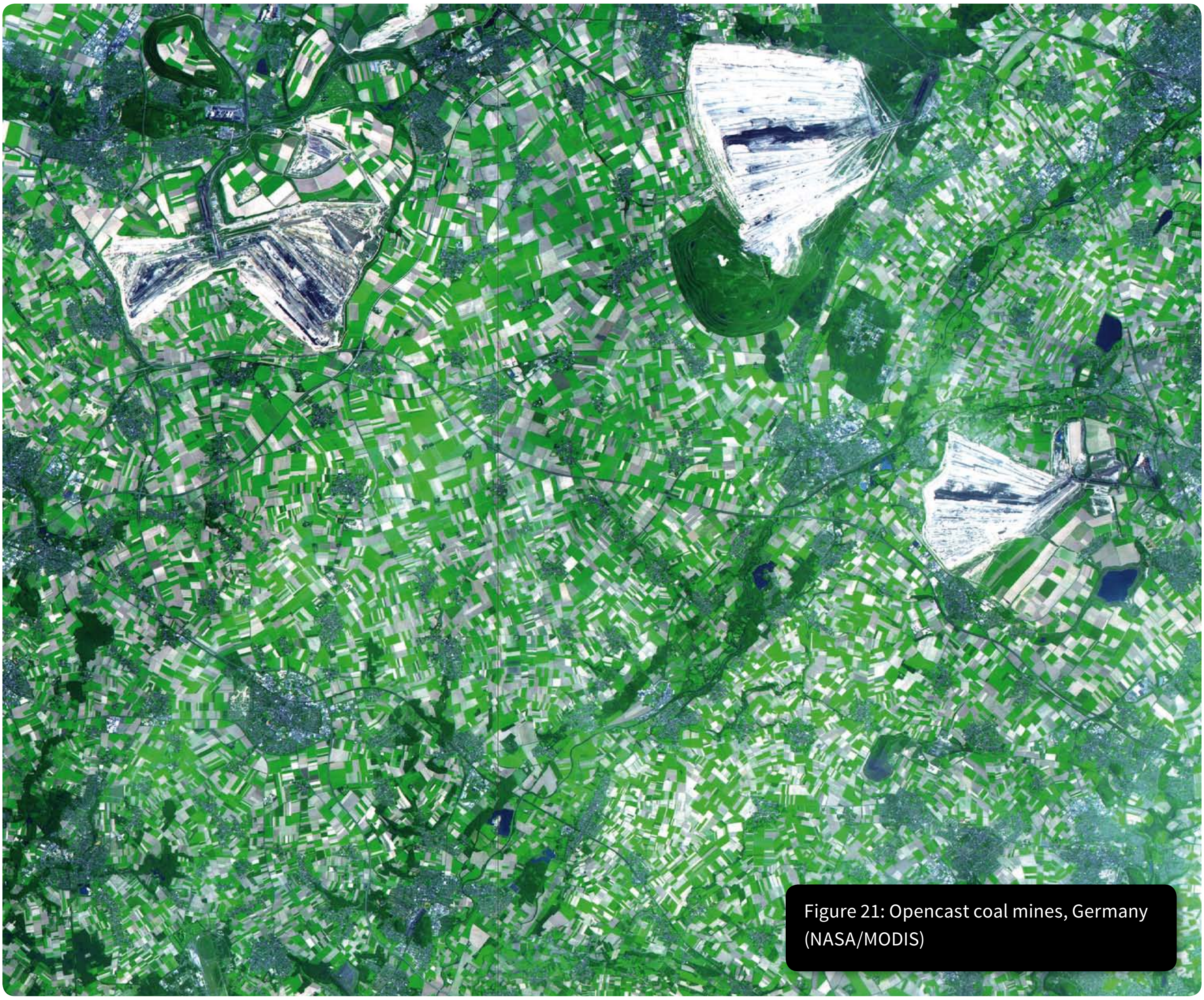


Figure 21: Opencast coal mines, Germany (NASA/MODIS)

7 Agriculture and food

The first two satellite images (figures 22a and 22b) show the department of Santa Cruz in east Bolivia. The first satellite image (figure 22a) shows areas used for agriculture in 1984. In the north-west of the department some small-scale farming structures can be seen. The second satellite image (figure 22b) shows the development of areas used for agriculture in 2000. It is clear that agricultural areas have been extended significantly. The line structures are conspicuous, long fields surrounded by 20 to 40 metre-wide wind shield strips of primary forest. For 20 years soya, mainly exported for animal feed, has been the main agricultural crop in this area and its cultivation area increased more than tenfold from 1984 to 2000. In that time, 25% of the primary forest area has been cleared.

The third and fourth satellite images (figures 23a and 23b) show Riau, a Sumatran province in Indonesia and its land use. The grids and lines suggest that the area is almost entirely devoted to agriculture. The upper satellite image (figure 23a) shows the area before the burning episode in May. The dark green fields are mature forest, likely palm oil and timber plantations. Paler green areas are either less-mature trees or other crops, and red areas represent bare soil or burned land. Figure 23b shows the same area at the height of the burning episode only one month later in June. The blue smudge across the scene is smoke, while higher clouds are white. Fires glow orange, and newly burned land is dark red. Bare soil or older burn scars are a lighter shade of red. Many fires are burning within well-defined rectangular fields. This shows that these fires were probably set to clear the land for farming. The contrast between the two images shows that both mature forest and other types of land cover were burning in June.

Land is primarily used for the cultivation of agricultural crops and raising of livestock for food, followed by the production of raw materials for clothes. An increasing amount is also used as a source of energy. The different and conflicting uses of agricultural products, and a growing world population, increase the pressure on agricultural land. Global food production is already under stress and factors such land degradation, meat consumption, production of biofuels, and fluctuating prices of staple food worsen the situation. Moreover, food security is affected by political and ecological conditions, local production potentials and the different diets, especially in agriculture-dependent societies.

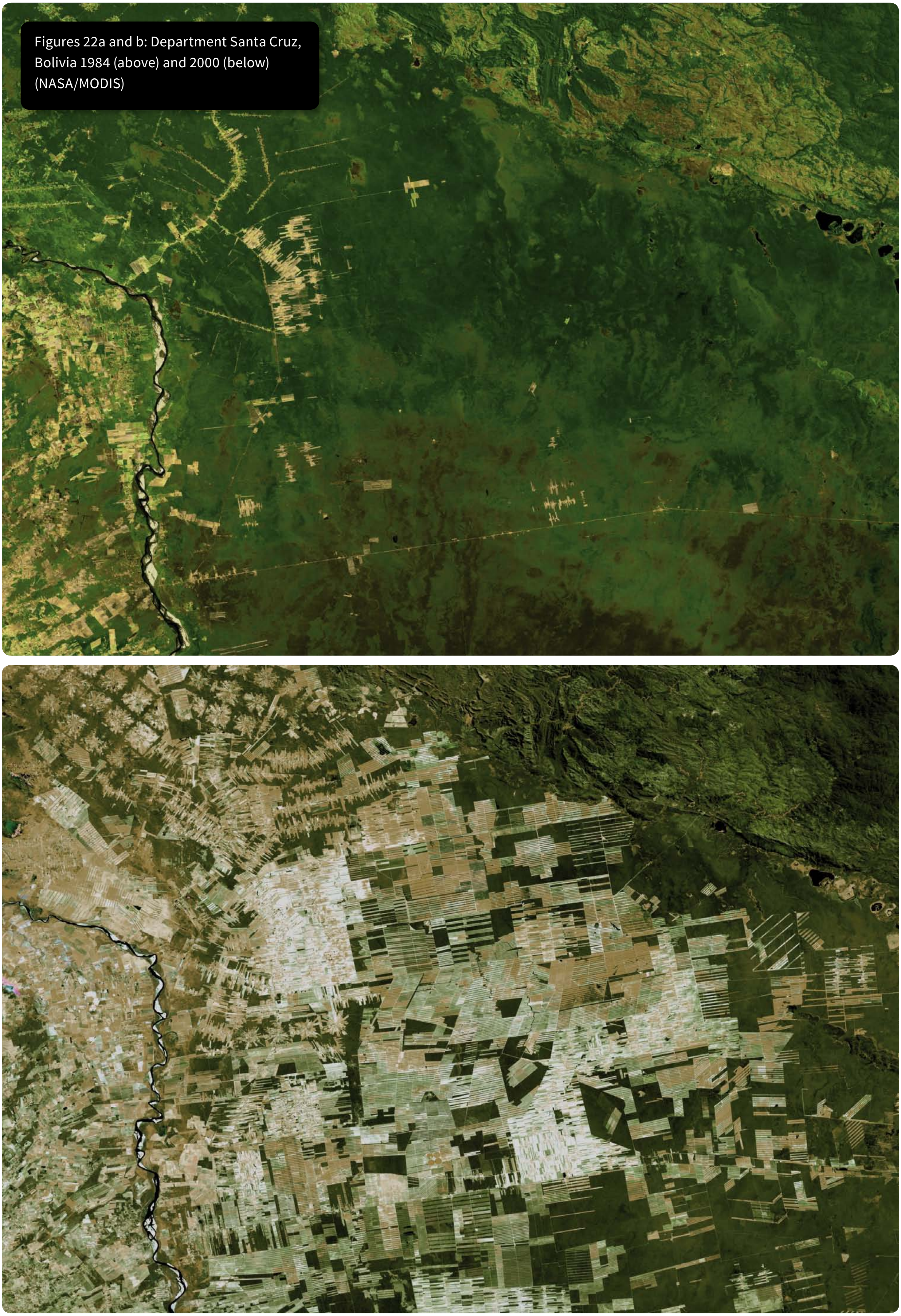
Globally, the impacts of climate change are putting additional pressure on agriculture. Because agriculture is largely dependent on climate patterns, it is exceptionally vulnerable to climate change. Rising temperatures and changes in rainfall patterns have direct impacts on agriculture. Rising temperatures, especially heat waves, have disastrous impacts on agriculture. With rising temperatures, the natural conditions for the growth of crops are changing. Because of this, crop yields decline and crops requiring particular conditions have to be grown further north and south respectively or in the highlands.

With a global temperature rise of just 1 °C, yields of maize, sorghum and barley would decrease most, while rice and soya yields would decrease a little. Countries in central and northern Europe could benefit temporarily from rising temperatures through an increase in agricultural productivity, but these possible gains could be overcompensated by more frequent weather extremes leading to crop destruction. For countries in the South, rising temperatures mean dramatically less crop yields. But weather extremes also occur more often, exacerbating the situation. Furthermore, dry areas are getting dryer so that more water for irrigation, if available, is needed. In areas where water is already scarce, different agriculture possibilities have to be considered. Similarly, erosion and desertification are favoured. Extreme weather events are occurring more often and are more intense, destroying considerable parts if not the whole yield. Another consequence of climate change is sea level rise, threatening agriculture in terms of flooding very fertile agricultural areas in river deltas and salinisation of groundwater and soil.

Conclusions of previous studies indicate that the negative impacts of climate change on crop productivity, and therefore on food security, will mostly affect those regions that already experience hunger and malnutrition.

Agriculture combines three of the greatest challenges of the 21st century: achieving food security, adapting to climate change and mitigating climate change. At the same time, critical resources such as water, energy and land are becoming increasingly scarce. Therefore, farming practices need to move to a climate-smart agriculture, which is composed of three main elements: 1) sustainably increas-

22 Geoscopia (2013)
23 UNEP (2013)



Figures 22a and b: Department Santa Cruz, Bolivia 1984 (above) and 2000 (below) (NASA/MODIS) ing agricultural productivity and incomes; 2) adapting and building resilience to climate change; 3) reducing and/or removing greenhouse gas emissions, where possible.[27]

7.1 Rice

Rice is fundamental to the food security of approximately three billion people, about half of the world's population, who eat rice every day. Many of the poorest and most undernourished people in Asia depend on rice as their staple food. Rice production is and will be affected by changes in climate. Factors like irregular rainfall, drier spells in the wet season, droughts and floods are affecting yields. They have also caused outbreaks of disease and increased presence of pests, with large losses of crops and harvest products. For example, rising temperatures, especially at night, cause losses of 10–20% of harvests in some locations.[28] Rice paddies need a lot of water, so that irrigation is needed. To address these challenges, a number of methods and practices must be adopted. Some adaptations already been carried out, e.g., altering cropping patterns, planting dates, and using different farm management techniques. For instance, embankments have been built to protect rice farms from floods. Also drought- and submergence-tolerant varieties of rice are being produced and distributed by government institutions and the private sector. Additionally, many farmers are diversifying their production systems with other cereals such dry-seeded rice, vegetables and animals.

At the same time as rice production is threatened by climate change, the waterlogged and warm soils of the rice paddies are a large emitter of the greenhouse gas methane.

7.2 Soya

Soya cultivation has been extended considerably in recent years, especially in Latin America: the cultivated area increased from 54.06 million hectares in 1988 to 108.71 million hectares in 2013.[29] And the area will probably increase in the next few years. The largest percentage of soya production is needed to feed livestock for the increasing meat consumption among the global middle-class. Meat consumption has increased with rising income, especially in the BRIC countries (Brazil, Russia, India and China); from 2009 to 2013, meat consumption increased by 5.5% from 229.28 to 241.9 million tonnes.[30] The amount of soya needed to feed the animals depends on the type of meat. For example, the production of one pound of beef needs six to seven times more soya than the production of one pound of chicken.

The increasing production of soya leads to massive destruction of the rainforest, which affects biodiversity and causes drying-out of whole land areas. Additionally, after some years of intensive soya cultivation the soil is polluted and the land unusable.

Soya production generates high income but only a few people in producer countries are the winners. Small-scale farmers cannot compete with large companies and often have to sell their land to them. Similarly, indigenous people are suffering because rainforest destruction is a real threat to their livelihoods, which are highly dependent on the ecosystem. Altogether this leads to a situation where people in producer regions are suffering from hunger, as cultivable land is used to produce animal feed particularly for meat consumption by the global middle-class.

7.3 Palm oil

Palm oil is used in many different ways. Food (very often chocolate), detergents, cosmetic products, oils, soap and many other products contain palm oil. It is also used for the production of metals, plastics, rubber, textiles, colours, paper and electronic elements. During the last few years it has also been used as fodder and to produce energy.

The production of palm oil increased between 2001 and 2012 by 113.33% to 51.86 million tonnes per year.[31] A further increase was expected for 2013. The steadily rising demand for palm oil leads to large-scale destruction of rainforest for palm oil plantations. Palm oil is mainly cultivated in Malaysia and Indonesia, which have seen a rapid expansion of plantations since 1990. Monocultures threaten biodiversity and push certain species, like the orangutan and the tiger, out of their living environments and close to extinction. Many indigenous people are also affected directly, because they have to leave their land and lose their livelihoods for expanding palm oil plantations.

Another negative aspect is that rainforest on peat land soils are big stores of carbon, which is often released after a change of land-use. Tropical peat lands are found especially in Indonesia, where palm oil plantations are installed. This is one reason why Indonesia climbed up to being one of the world's biggest greenhouse gas emitters.

27 FAO (2013)
28 FAO (2010)
29 Van de Sand (2013)
30 Van de Sand (2013)
31 Van de Sand (2013)

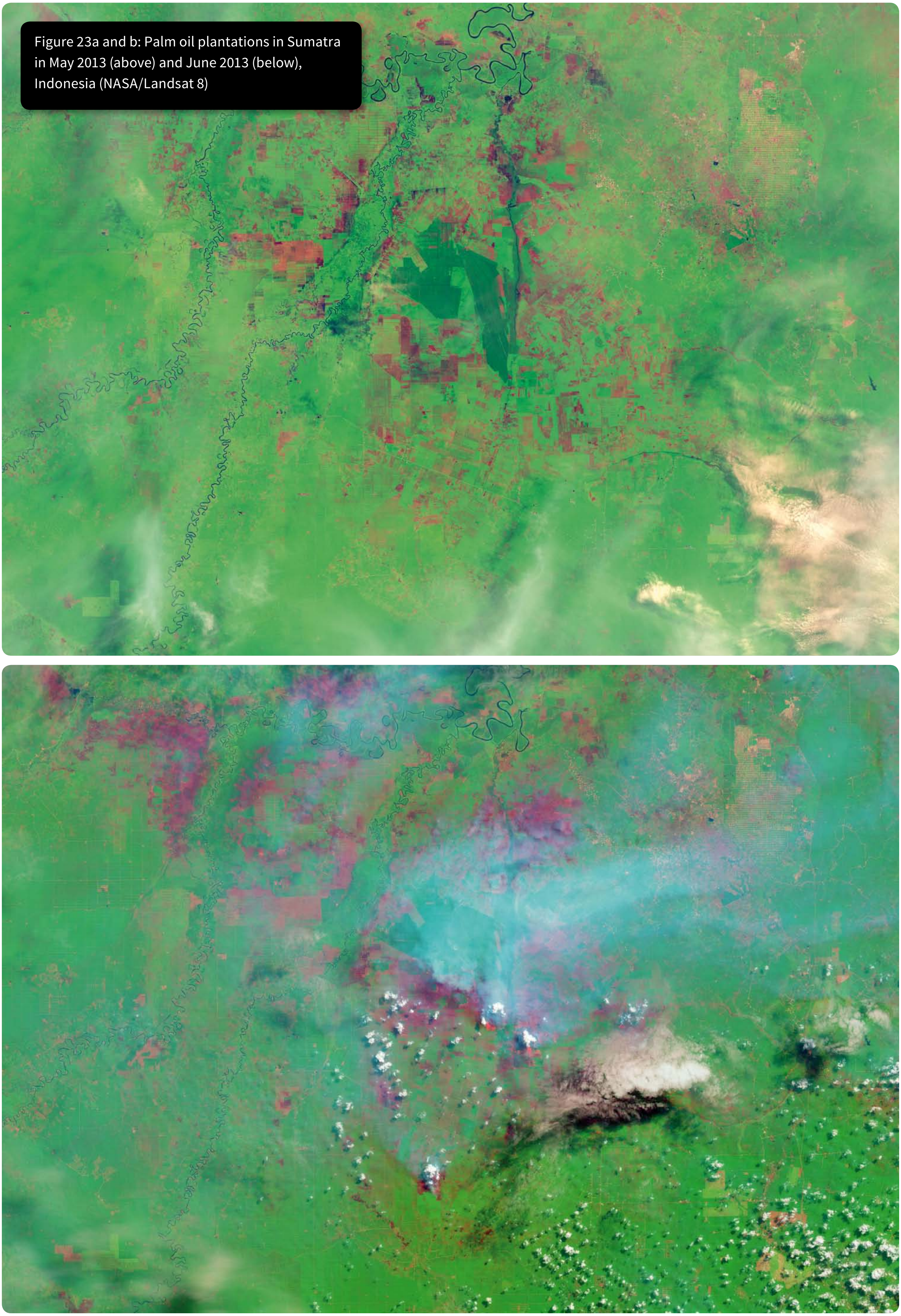


Figure 23a and b: Palm oil plantations in Sumatra in May 2013 (above) and June 2013 (below), Indonesia (NASA/Landsat 8)

8 Water availability – the example of Lake Chad

Figure 24a shows Lake Chad in 1963 and is one of the first satellite images available for Lake Chad. Figure 24b shows the same lake in 2012 and illustrates, in comparison with the older image, the extent of diminishment in nearly 40 years.

Four countries border Lake Chad: Chad, Cameroon, Niger and Nigeria. Nearly 6,000 years ago, Lake Chad had a size of about 300,000 to 400,000 km², but since that time it has shrank substantially. The process of shrinking has quickened enormously in the last few decades. Lake Chad is the only big freshwater basin on the surface in the Sahel. In the 1960s Lake Chad was the fourth biggest lake in Africa and provided water for more than 20 million people. During that time, after the rainy season the lake had a surface of around 20,000 km² (see also figure 24a). Figure 24b instead shows the lake in 2012 when it has just 1,500 km² surface after the rainy season. The low average water depth always fluctuates between the rainy and the dry season, but the lake had lost more than 90% of its surface during the previous 50 years. The reasons for the shrinkage are complex and interrelated; climate change is just one factor.

The period between 1973 and 1984 saw a nearly ceaseless drought and millions of people starved. At the beginning, the cause of the lake's shrinkage was thought to be only overuse of water by humans, but it is has since become evident that climatic changes are dominant factors. The average water temperature of the Indian Ocean rose. Thus the difference in temperature between the land and the ocean declined, air pressure changed and humid air masses from the sea were not able to get far enough inland as they had in the past.[32] Additionally, the Sahara expanded southwards.

Human activities are significant factors in the steady decline of the lake area, for example the construction of water reservoirs or dams, which lead to a higher evaporation from their bigger water surfaces. A possibly more severe impact on the lake is the expansion of irrigation farming around the lake and its tributaries, often for export-oriented cotton production. Due to changing rainfall patterns, it is necessary to irrigate rain-fed agriculture. In the Lake Chad region the situation was complicated, as many stock farmers lost their livestock because of droughts and then tried to work in farming to sustain their livelihoods. Additional pressure on the scarce water supply has been created by the fast population growth in the region. In combination with climate change, water scarcity in the Lake Chad area could lead to conflicts over water.

32 Geoscopia (2012a)

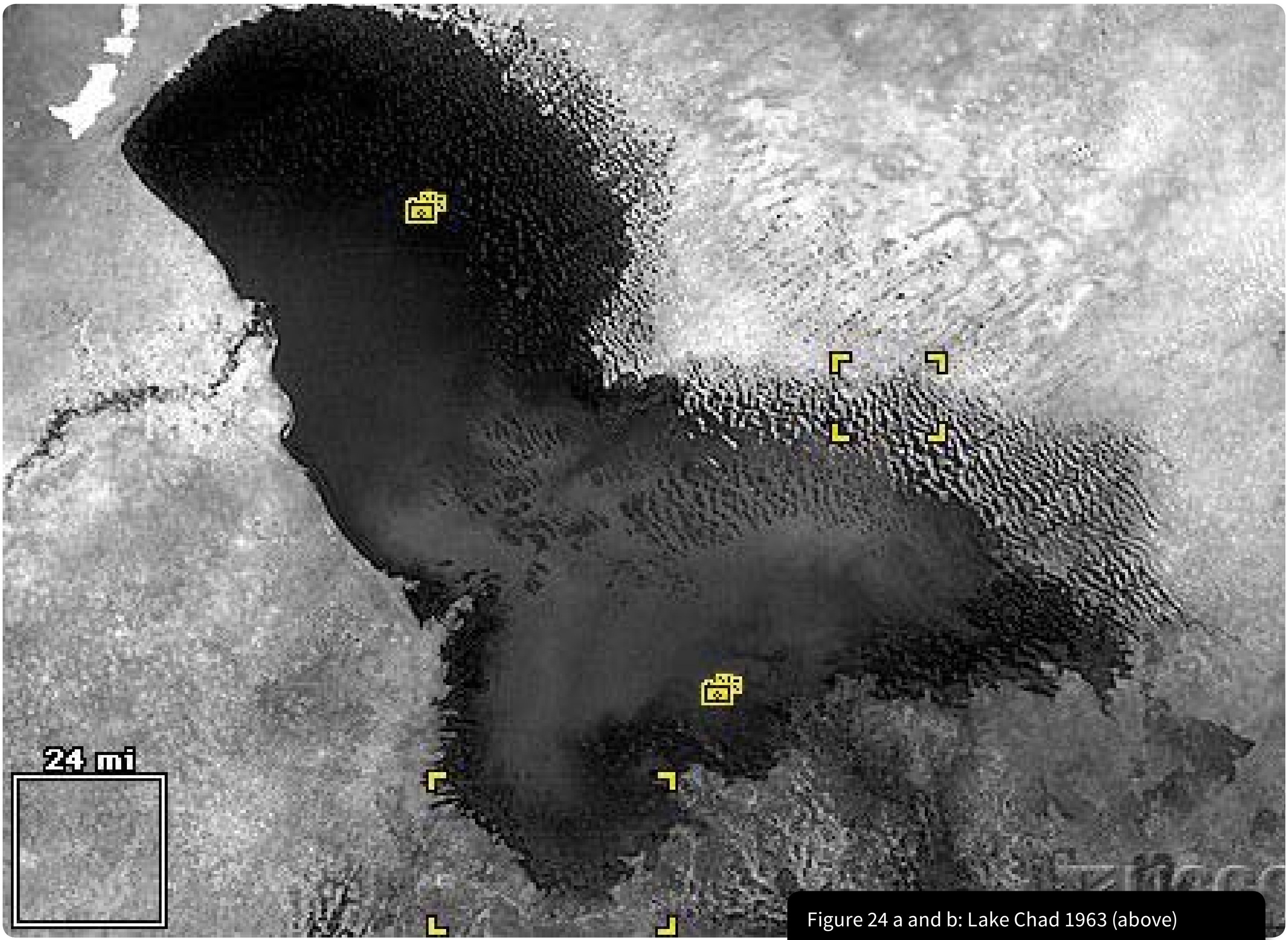
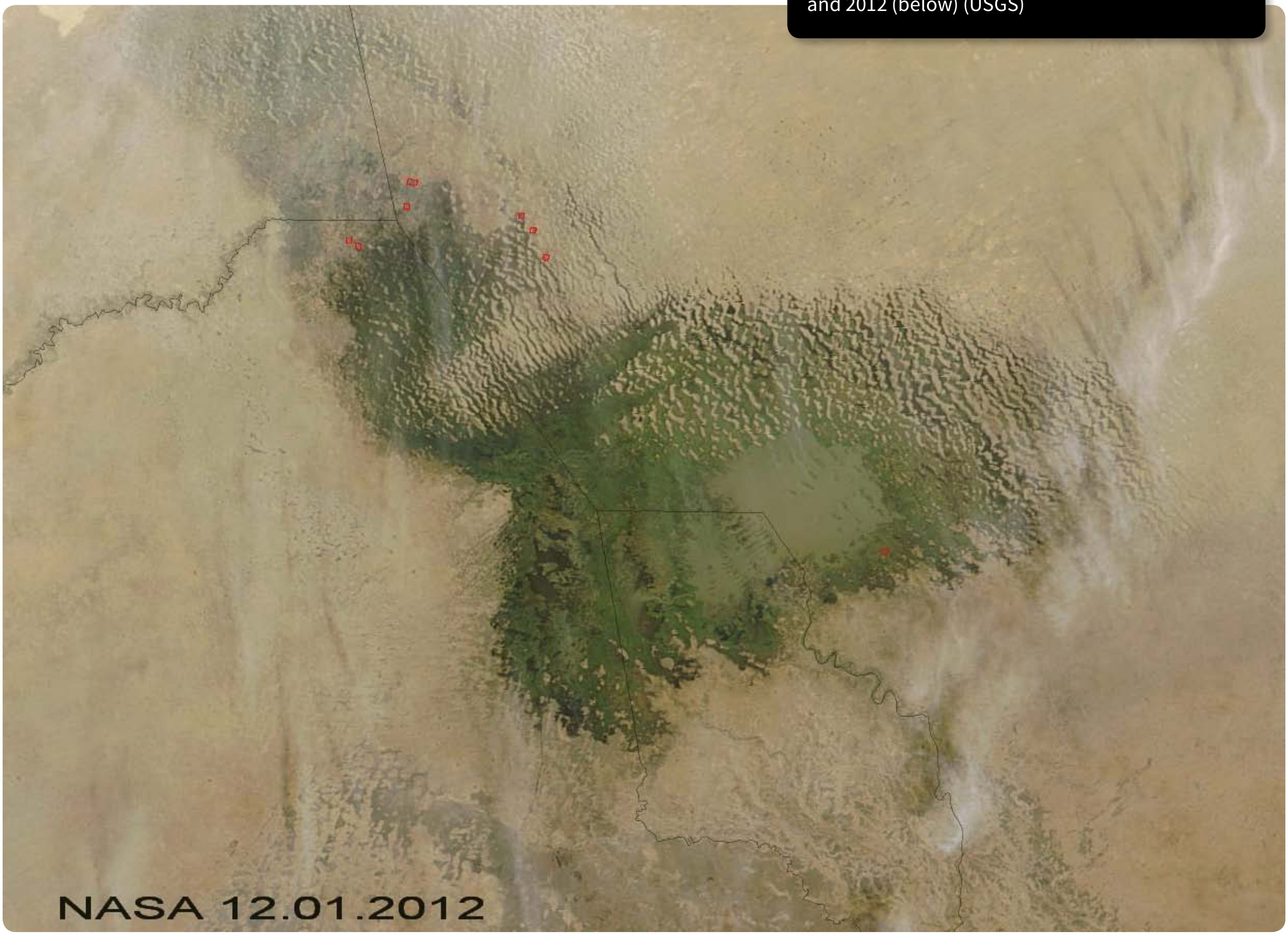


Figure 24 a and b: Lake Chad 1963 (above) and 2012 (below) (USGS)



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Following the motto "Observing, Analysing, Acting", Germanwatch has been actively promoting global equity and the preservation of livelihoods since 1991. In doing so, we focus on the politics and economics of the North and their worldwide consequences. The situation of marginalised people in the South is the starting point of our work. Together with our members and supporters as well as with other actors in civil society, we intend to represent a strong lobby for sustainable development.

We attempt to approach our goals by advocating for the prevention of dangerous climate change, food security, and compliance of companies with human rights.

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Imprint

February 2014

Authors: Alexander Reif, Desirée Rudolf

Editing: Paula McDiarmid, Daniela Baum

Design: Dietmar Putscher, Cologne

Cover image: ESA/EUMETSAT/Meteosat/Geoscopia

Purchase Order Number: 14-6-14e

This publication can be downloaded at:
www.germanwatch.org/en/8198

More information about the Germanwatch Climate Expedition: www.klimaexpedition.de

This Project Is financially supported by:

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

Umwelt Bundesamt

The publisher is responsible for the content of this publication.

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