Field:

Earth Science/Environment

Session Topic:

Venus' Atmosphere

Speaker:

Takeshi IMAMURA, Japan Aerospace Exploration Agency

1. Introduction

The first Venus probe of Japan, Akatsuki, was launched in May 2010. Akatsuki is a Japanese word meaning 'dawn', the scene of the morning star. The Venus orbit insertion maneuver conducted in December 2010 has failed due to a malfunction of the propulsion system, and at present the spacecraft is orbiting the Sun. Akatsuki will have a chance to encounter Venus in 2015; the project team is examining the possibility of conducting an orbit insertion maneuver again at this opportunity.

Venus is one of the most attractive targets in the solar system when we seek to understand how terrestrial planets differentiate into various states. Venus is our nearest neighbor, and has a size very similar to the Earth's; however, previous spacecraft missions discovered an extremely dense (92 bar) and dry carbon dioxide atmosphere with sulfuric acid clouds floating around 60 km altitude, and exotic volcanic features covering the whole planet. The abundant carbon dioxide brings about a high atmospheric temperature (740 K) near the surface via greenhouse effect, in spite of the fact that the solar energy absorbed by Venus is less than the energy absorbed by the Earth due to the large reflectivity of the cloudy planet.

It is possible that Venus was created with an appearance similar to the ancient Earth 4.6 billion years ago and once had oceans. The abundant water may have been lost on the geological time scale through the photo-dissociation of water vapor and the subsequent escape of the constituent elements to space. The escape process is not well understood; the strong ultraviolet heating of the upper atmosphere or the impingement of the solar wind (energetic ionized particles from the sun) may have played a key role.

2. Exploration of Venus

The former Soviet Union sent many entry probes and orbiters named Venera to Venus from the 1960s to the 1980s and studied the atmospheric composition and structure, surface composition, and topography. The Pioneer Venus orbiter and entry probes of U. S., which were launched in 1978, also provided plenty of new information on the atmosphere and the surface. The Vega balloons were dropped into the cloud layer of Venus by the Soviet Union and France in 1985 and observed meteorological processes. The U. S. probe Magellan, which took off for Venus in 1989, radar-mapped the Venusian surface precisely. After these missions, the exploration of Venus was interrupted for more than 10 years, in

spite of the fact that most of the fundamental questions raised so far still remain unsolved. This is partly because people were focusing on Mars and the Moon as places that are easier for human beings to land on.

It was not until the 21st century that Venus exploration was restarted. The European Space Agency launched a Venus orbiter named Venus Express in November 2005. Akatsuki was developed almost in parallel with Venus Express.

3. Mysterious meteorology

A westward circulation of the entire atmosphere, called the super-rotation, characterizes the atmosphere of Venus. The wind speed increases with height and reaches 100 m/s near the cloud top; this speed is 60 times greater than the equatorial rotation speed of the solid planet of 1.6 m/s, which corresponds to a rotational period of 243 Earth days. Such a wind system is considered strange because the standard meteorology predicts that planetary-scale winds should have speeds comparable to or smaller than the planetary rotation speed. The Earth's westerly wind (around 30 m/s) is localized in the mid-latitude and is much slower than the Earth's rotation (460 m/s on the equator). Recent studies suggest that Mars has a wind system similar to the Earth's, while Titan, a Saturnian moon, has a super-rotating atmosphere. The mechanism of the super-rotation and the critical parameters that determine the dynamical regime are not well understood.

The formation of sulfuric acid clouds that completely cover the planet is another mystery. Sulfuric acid will be produced near the cloud top via the oxidation of sulfur dioxide and water vapor in the presence of ultraviolet radiation, and thus the clouds have characteristics of photochemical aerosols, which also exist in the Earth's stratosphere. Condensation of sulfuric acid vapor in vertical air motions is also considered important in the formation of the observed thick clouds. The air motions that supply source materials and sulfuric acid vapor to the cloud height are unknown.

Lightning discharge is considered closely related to cloud formation. Recently the Venus Express magnetometer detected electromagnetic waves that might come from lightning discharges in the Venus atmosphere. However, the occurrence of lightning on Venus is still under debate, since the standard theory of charge separation in terrestrial thunderstorms requires water ice particles, which will not exist in the Venus atmosphere.

Venus Express has provided key information on the mysteries mentioned above. Akatsuki aims to become a meteorological satellite of Venus after the arrival in 2015 and will explore the meteorological processes further in detail.

4. Conclusion

Comparative studies of the atmospheres of twin planets, Venus and the Earth, will offer valuable insight for the formation and diversity of the planetary climates. Noticeable progresses are expected in this field in the next decade thanks to the continuing mission of Venus Express and the possible start of Akatsuki’s observation as well as theoretical studies.