Planetary Atmospheres: Decadal Survey of Priorities for 2003-2013

*D. L. Huestis (SRI), N. G. Adams (U. Georgia), S. K. Atreya (U. Michigan),
K. H. Baines (JPL), R. F. Beebe (NMSU), S. J. Bolton (JPL), S. W. Bougher (U. Arizona),
A. Coustenis (Paris-Meudon Obs.), S. G. Edgington, A. J. Friedson (JPL),
M. Galand (Boston U.), C. A. Griffith (NAU), S. L. Guberman (ISR), H. B. Hammel (SSI),
M. D. Hofstadter (JPL), A. P. Ingersoll (Caltech), J. I. Lunine (U. Arizona),
M. Mendillo (Boston U.), J. Moses (LPI), I. Mueller-Wodarg (U. Col. London),
G. S. Orton (JPL), C. Porco (SwRI), K. A. Rages (NASA Ames), T. G. Slanger (SRI),
D. V. Titov (MPI Aeronomy), A. R. Vasavada (UCLA), A.-S. Wong (Caltech),
R. Yelle (NAU)*

NASA asked NAS/NRC to review current knowledge and key science questions with prioritized recommendations for solar system exploration over the next decade.

AAS/DPS organized 25 volunteer Community Panels to provide input to NAS/NRC.

This talk summarizes the conclusions of the Planetary Atmospheres Panel:
http://www-mpl.sri.com/decadal/PATM-draft.html

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The State of Knowledge Today

The current observational characterization of planetary atmospheres is roughly comparable to what had been learned about the Earth's atmosphere after the first rocket and satellite measurements in the 1950s and 1960s. From telescope observations and planetary missions we have determined the principal atmospheric constituents and the altitude profiles of pressure and temperature. We are able to classify the atmospheres of many of the larger solar system planets and moons into four groups:

1. Nitrogen atmospheres (Earth, Titan, Triton, Pluto)
2. Carbon dioxide atmospheres (Venus, Mars)
3. Hydrogen gas giants (Jupiter, Saturn, Uranus, Neptune)
4. Thin atmospheres, with three subgroups:
   - Rocky surfaces (Mercury, Moon)
   - Volcanic (Io)
   - Icy surfaces (Europa, Ganymede, Callisto)

Key Questions and Science Themes

- *Understanding Atmospheres*

  The historical attempts to understand planetary atmospheres have emphasized identification of the underlying chemical and physical processes responsible for many fascinating observations. It is appropriate that the focus should now shift toward comparative interpretation of what the atmospheric observations and discoveries on multiple planets can teach us about broader scientific goals.

- *Learning by Exploring Planets and Moons*

  Atmospheres are different each time we look at them. All future planetary mission campaigns should include explicit atmospheric components. Increased availability of observing time for planetary astronomy is essential on ground-based and near-Earth space-based telescopes.

Key Questions and Science Themes (cont.)

- *Providing the Required Research Infrastructure*

  Visiting planets is only one of the objectives. Lasting value comes from analyzing, interpreting, and using the data to establish broader implications, supported by independent programs for laboratory experiments, fundamental theory, modeling, and reanalysis of historical observations.

- *Assimilating Space and Planetary Science with Earth Science*

  From our near neighbors in the solar system we hope to acquire additional hints about our origins and the steps we should take to preserve our life-supporting environment. Better coordination between Earth science and space and planetary science can contribute to shared science goals, and justification and mobilization of additional funding resources for both disciplines.

Other Issues

- *Public Fascination with Planets*

  Planetary observations make good news and well-watched television. Unfortunately, atmospheres look too much like chemistry and plasma physics. Other than the Jupiter impact of Shoemaker-Levy 9, neat colorful pictures are rare. U.S. citizens are better educated and intelligent than we suppose. Atmospheric scientists can do much more to explain why what we do is interesting, understandable, and important.

- *International Collaboration*

  The European and Japanese space agencies are launching capable planetary missions and planning future ones. A high level of coordination with these efforts is needed in order for the U.S. program of solar system exploration to reach its ambitious science goals.

Summary and Discussion of Recommendations

The majority of the Decadal Survey Community Panels address individual solar system objects, or collections thereof. For many of these, the atmosphere is only one of several important topics of scientific interest. In contrast, the Planetary Atmospheres Community Panel is one of the few that focus on science themes that that apply to many solar system objects.

A. Programmatic and Infrastructure Recommendations

- A.1 Secure Funding for Mission Data Analysis and Interpretation
- A.2 Dedicated Telescopes for Planetary Astronomy
- A.3 Comparative Understanding of Planetary Atmospheres (CUPA)

B. Mission Recomendations

- B.1 Jupiter Microwave Sounder
- B.2 Deep Penetration Probes to Determine Elemental Compositions of Giant Planet Atmospheres
- B.3 Jupiter Polar Orbiter
- B.4 Mars Atmospheric Mission
- B.5 Post-Cassini/Huygens Atmospheric/Surface Mission to Titan
- B.6 Neptune and Triton

A.3 Comparative Understanding of Planetary Atmospheres (CUPA)

Current knowledge indicates that the atmospheres of the Earth, planets, and moons are quite diverse; yet share a number of characteristics, from which each can teach us something about the others. Comparing and contrasting planetary atmospheres provides the best near-term means of addressing the broad scientific goals of identifying the conditions that are favorable for producing and supporting biological activity, managing the effects of human activity on the Earth's atmosphere, and planning and evaluating observations of extra-solar planets.

In contrast to this unifying "comparative approach" the communities of scientists studying atmospheric processes, the sections of professional societies, and the organization of programs at research funding agencies (NASA and NSF) tend to emphasize four separate categories: (1) planets and moons, (2) space physics [Earth upper atmosphere], and (3) atmospheric chemistry [Earth lower atmosphere], and (4) astrophysics. These separations weaken both scientific productivity and prospects for research funding for all atmospheric scientists.

(CUPA) Recommendations:

- NASA and NSF should establish a multi-agency multi-program multi-year long-term initiative for Comparative Understanding of Planetary Atmospheres (CUPA).

- Additional funding from Congress would be required, which the benefits of the comparative theme would justify. CUPA is a way to explain the importance of R&A programs.

- The initiative must be supported by strong endorsement from NAS/NRC. The planetary atmospheres research community must contribute to the campaign.

- Annual program solicitations should be issued with coordinated proposal evaluations. The resulting grants would be administered by the most relevant existing program.

- The solicitations might have an annual theme, but the main criterion should be that the research be truly "comparative."

- Much can be learned from the largely unsuccessful 1998 attempt to launch a similar joint NASA/NSF program. The justification was weak, lower atmosphere program managers were not convinced, and the solicitation required proposers to focus on Mars rather than explicit comparisons between planets.

B.1-3 Jupiter and Other Gas Giants

Problem #1: Elemental Composition -- Galileo Probe showed "heavy" elements C, N, S, Ar, Kr, and Xe to be enriched by a factor of 2-3 relative to solar proportions. The H_2O mole fraction was still increasing at the deepest level probed (21 bars). The probe entered a meteorologically anomalous region known as a 5 micron hot spot.

Problem #2: Little is known about the influence on the global neutral atmosphere of energetic polar processes (e.g. aurora).

Mission B.1: Microwave Sounder Flyby

Mission B.2: Deep Penetration Multiprobes

Mission B.3: Polar Orbiter

B.4 Mars Atmospheric Explorer

Problem #1: Photochemical stability of CO_2 atmosphere -- Need Altitude profiles of H_2O, OH, H, O, etc.

Problem #2: History of water -- Need escape rates for H, D, and O

Problem #3: Couplings among condensation and release of polar volatiles, dust storms, atmospheric dynamics and winds, thermal structure, and chemistry.

Mission B.4:

- Orbiter with UV/vis/IR and mass spectrometers
- Descent probes and balloons

B.5 Titan Atmosphere and Surface

Problem #1: Nature and distribution of particulates

Problem #2: Long-term observation of atmospheric photochemistry, dynamics, and circulation.

Problem #3: Geographical variability of surface composition.

Mission B.5: Orbiter and lander

B.6 Neptune and Triton

Problem #1: Neptune -- Atmospheric winds, chemical basis for visible features, magnetic fields.

Problem #2: Triton -- Atmospheric composition, changes since Voyager, surface geology and composition. Analog of a Kuiper Belt object?

Problem #3: Rings and small satellites -- Are the ring arcs the precursor of a major ring system? Do the inner satellites show tital stress?

Problem #4: Technology challenges -- In-space propulsion, electrical power, low temperature electronics.

Mission B.6:

- Neptune orbiter
- Neptune descent probes
- Triton Lander
- Alternate Neptune and Kuiper-belt flyby

The Path Forward

- The "white papers" from the Community Panels have been submitted to the NRC Discipline Panels. They will be published independently as a reference book.

- The NAS/NRC Decadal Survey Report is expected to be released in the spring of 2002.

- The Comparative Understanding of Planetary Atmospheres (CUPA) recommendation should be of particular interest to the Space Physics and Aeronomy ("SPA") community.

- The big challenge is proving that space physics, aeronomy, and planetary atmospheres have essential contributions to make to understanding the lower atmosphere of the Earth (e.g. "A" section). You can help by suggesting some really compelling examples.