RESEARCH ARTICLE SUMMARY

PLANETARY SCIENCE

The atmosphere of Pluto as observed by New Horizons

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INTRODUCTION: For several decades, telescopic observations have shown that Pluto has a complex and intriguing atmosphere. But too little has been known to allow a complete understanding of its global structure and evolution. Major goals of the New Horizons mission included the characterization of the structure and composition of Pluto's atmosphere, as well as its escape rate, and to determine whether Charon has a measurable atmosphere.

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RATIONALE: The New Horizons spacecraft included several instruments that observed Pluto's atmosphere, primarily (i) the Radio Experiment (REX) instrument, which produced near-surface pressure and temperature profiles; (ii) the Alice ultraviolet spectrograph, which gave information on atmospheric composition; and (iii) the Long Range Reconnaissance Imager (LORRI) and Multispectral Visible Imaging Camera (MVIC), which provided images of Pluto's hazes. Together, these instruments have provided data that allow an understanding of the current state of Pluto's atmosphere and its evolution.

RESULTS: The REX radio occultation determined Pluto's surface pressure and found a strong temperature inversion, both of which are generally consistent with atmospheric profiles retrieved from Earth-based stellar occultation measurements. The REX data showed near-symmetry between the structure at ingress and egress, as expected from sublimation driven dynamics, so horizontal winds are expected to be weak. The shallow near-surface boundary layer observed at ingress may arise directly from sublimation.

The Alice solar occultation showed absorption by methane and nitrogen and revealed the presence of the photochemical products acetylene and ethylene. The observed nitrogen opacity at high altitudes was lower than expected, which is consistent with a cold upper atmosphere. Such low temperatures imply an additional, but as yet unidentified, cooling agent.

A globally extensive haze extending to high altitudes, and with numerous embedded thin layers, is seen in the New Horizons images. The haze has a bluish color, suggesting a composition of very small particles. The observed scattering properties of the haze are consistent with a tholin-like composition. Buoyancy waves generated by winds flowing over orography can produce vertically propagating compression and rarefaction waves that may be related to the narrow haze layers.

Pluto's cold upper atmosphere means atmospheric escape must occur via slow thermal Jeans' escape. The inferred escape rate of nitrogen is ~10,000 times slower than predicted, whereas that of methane is about the same as predicted. The low nitrogen loss rate is consistent with an undetected Charon atmosphere but possibly inconsistent with sublimation/erosional features seen on Pluto's surface, so that past escape rates may have been much larger at times. Capture of escaping methane and photochemical products by Charon, and subsequent surface chemical reactions, may contribute to the reddish color of its north pole.

CONCLUSIONS: New Horizons observations have revolutionized our understanding of Pluto's atmosphere. The observations revealed major surprises, such as the unexpectedly cold upper atmosphere and the globally extensive haze layers. The cold upper atmosphere implies much lower escape rates of volatiles from Pluto than predicted and so has important implications for the volatile recycling and the long-term evolution of Pluto's atmosphere. ■

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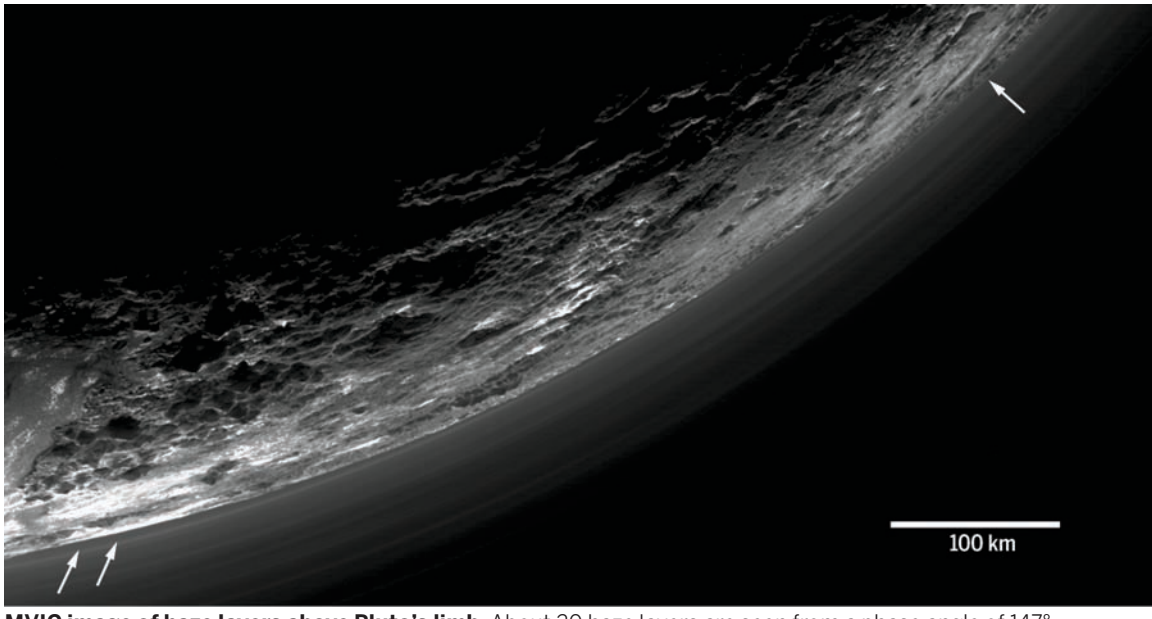

MVIC image of haze layers above Pluto's limb. About 20 haze layers are seen from a phase angle of 147°. The layers typically extend horizontally over hundreds of kilometers but are not exactly horizontal. For example, white arrows on the left indicate a layer ~5 km above the surface, which has descended to the surface at the right.