Comparative Aeronomy (Ionospheres).

Andrew F. Nagy
In this letter he suggested that the term aeronomy should replace meteorology, writing that the association of the word “meteor with meteorology is now irrelevant and misleading”.

Chapman’s Original Suggestion in *Nature*, 1946
Chapman’s Follow-Up Suggestions.

His original proposal was apparently not received with much support so in a short note in *Weather*, in 1953, Chapman, (1953) wrote:

“If, despite its obvious convenience of brevity in itself and its derivatives, it does not commend itself to aeronomers, I think there is a case for modifying my proposal so that instead of the word being used to signify the study of the atmosphere in general, it should be adopted with the restricted sense of the science of the *upper* atmosphere, for which there is no convenient short word.”

In a chapter, he wrote in a 1960 book (*Chapman*, 1960), he give his final and definitive definition, by stating that “Aeronomy is the science of the upper region of the atmosphere, where dissociation and ionization are important”.

The Ionosphere of the Earth.
Venus’ Thermosphere.
Diurnal Thermospheric Temperature Variations at Venus.
Major Chemical reactions in the Ionospheres of Venus (and Mars)

\[
\begin{align*}
\text{CO}_2 & \rightarrow h \nu \rightarrow \text{CO}_2^+ + e \\
\text{CO}_2^+ + \text{O} & \rightarrow \text{O}_2^+ + \text{CO} \\
& \rightarrow \text{O}^+ + \text{CO}_2 \\
\text{O} + h \nu & \rightarrow \text{O}^+ + e \\
\text{O}^+ + \text{CO}_2 & \rightarrow \text{O}_2^+ \rightarrow \text{CO} \\
\text{O}_2^+ + e & \rightarrow \text{O} + \text{O}
\end{align*}
\]
Calculated Ion Density Profiles at Venus.
Venus Ionosphere

Pioneer Venus OIMS orbit 185 SZA = 11° day

Altitude (km)

Ion density (ions/cm³)

H₂⁺, H⁺, He⁺, CO₂⁺, C⁺, O⁺, O₂⁺
Diurnal Variation of Ion Density.

Solar Zenith Angle
1 = 0 - 30 deg
2 = 30 - 60 deg
3 = 60 - 90 deg
4 = 90 - 120 deg
5 = 120 - 150 deg
6 = 150 - 180 deg
Plasma Temperatures in Venus’ Ionosphere.
Ionopause and Magnetic Field.
Variations in Ionopause Altitude.
Venus’ Overview
Thermospheric Densities at Mars.
Mars’s Ionosphere.
Zenith Angle Variation of the Peak Electron Density.
Titan in the Saturn System.
Titan’s Thermosphere.
Ion Chemistry at Titan.
1D Model of Ion Composition at Titan.
Measured Ion Composition.

1075 - 1125 km
T5 (nightside) vs T18 OB (dayside)

Average Density Normalized to C2H5+
Measured Electron Densities and Temperatures at Titan.
Jupiter/Saturn Ion Chemistry (1)

\[ \text{H}_2 + h\nu \rightarrow \text{H} + \text{H} \]

\[ \rightarrow \text{H}^+ + \text{H} \]

\[ \rightarrow \text{H}_2^+ + \text{H} + e \]

\[ \text{H} + h \rightarrow \text{H}^+ + e \]

\[ \text{H}_2^+ + \text{H}_2 \rightarrow \text{H}_3^+ + \text{H} \]

\[ \text{H}_3^+ + e \rightarrow \text{H}_2 + \text{H} \]
Jupiter/Saturn Ion Chemistry (2)

\[ H^+ + e \rightarrow H + h \]

\[ H^+ + H_2 (v > 4) \rightarrow H_2^+ + H \]

\[ H^+ + H_2O \rightarrow H_2O + H \]

\[ H_2O^+ + H_2O \rightarrow H_3O^+ + OH \]

\[ H_3O^+ + e \rightarrow H_2O + H \]
A Model of Saturn’s Ionosphere.
Measured Electron Densities at Saturn
Inferred Diurnal Peak Electron Density Variations.
“Take Away” Points.

• Ionospheres are ionospheres! (Thermospheres are thermospheres!)

• Chemistry, dynamics, energetics, gravity etc maybe different, but if you know/understand one, it takes very little to work on other ionospheres (thermospheres).

• Theoretical model formulations, as well as instruments to make measurements, are relatively easy to change/adopt for different ionospheres (thermospheres).

• Thus there is much to be learned from studying and observing different ionospheres (thermospheres).
A prize of the book on the 2007 conference on ‘Comparative Aeronomy’ sponsored by ISSI in Switzerland and edited by Andrew Nagy was given to the student in the audience with the best question. This went to William Archer, PhD student of Dr. David Knudsen, of the University of Calgary, Canada. His philosophical question was whether the differences or the similarities were more important between planetary atmospheres and the Earth’s atmosphere. The answer was ‘It depends.’

(This page added by CEDAR organizer Barbara Emery of HAO/NCAR.)