**Overview**

**The Saturn Atmosphere and Interior Sections in Cassini Mission Final Report (in preparation)** summarizes the status of Saturn science, in 2018, as a result of Cassini exploration of the Saturn system. It also includes open questions that will be explored by future scientists.

Charm Talks is a series of talks given by the team that provides insight into discovery and development of understanding.

**Mission Objectives:**

* Determine temperature field, cloud properties and composition of the atmosphere.
* Measure global wind field, including wave and eddy components; observe synoptic cloud features and processes.
* Infer internal structure and rotation of the deep atmosphere.
* Study diurnal variations and magnetic control of ionosphere.
* Provide observational constraints (gas composition, isotope ratios, heat flux) on scenarios for the formation and evolution of Saturn.
* Investigate sources and morphology of Saturn lightning (Saturn electrostatic discharges, lightning whistlers).

**Saturn Data Resources**

Included below are data resources that span the entire mission. These may help understand all of the sub-topics below.

**Search Tools**

The Event Calendar is one way to find data associated with particular events such as auroral observations.

OPUS is a tool used to search for CIRS, ISS, UVIS and VIMS data all in one place. This URL is pre-filled with an example search for Saturn images.

**Reference Tables**

The Full Saturn Observation Guide [CSV] [TXT] is a document filled with information about every Saturn observation made by Cassini, including primary and secondary instruments, start and end time, segment type, and science areas.

The Observation Key[TXT] describes the nomenclature used in the observation guide. **Is this the file you wanted?**

Digit is a geometry and trajectory visualization tool for pointing reconstruction across the mission, using SPICE information to represent targets accurately.

The Tour Atlas Readme File link is a collection of tables of geometric positions, velocities, timing, altitude, and spacecraft attitudes that were useful in planning Cassini's response. It also includes times of various Saturn occultations.

Saturn Flyby Information and Science Summaries [TXT] **This needs to be converted into an html page**

**Saturn Segment Table**

This table outlines each Saturn observation segment by name, start time, and end time, with links to segment movies (where available), legacy packages, and timeline visualizations. Also available to download as [XLSX] or [CSV]

Table of Time Periods with Saturn-Focused Observations

Segment Times, Movies, Legacy Packages and Visualizations **I think we’ve linked all you have given us**

**Saturn Formation and Evolution**

This section is associated with the objective to provide observational constraints on the formation and the evolution of Saturn. Cassini obtained measurements relevant to (1) the abundances of helium and volatiles such as ammonia and phosphine, (2) the D/H ratio from CH3D/CH4 measurements, and (3) the structure of the interior and core from gravity and magnetic field place constraints on how Saturn formed and evolved. Key instruments involved are CIRS, VIMS, MAG, and RSS. Science Objectives included:

Provide observational constraints (gas composition, isotope ratios, heat flux, ...) on scenarios for the formation and the evolution of Saturn.

**Key Review Publications**

In Saturn from Cassini-Huygens (M.Dougherty, L. W. Esposito, and S. M. Krimigis, Eds). Springer (2009)

Origin of the Saturn System. pp. 55-74. Johnson, T. V. and Estrada, P. R.

In Saturn in the 21st Century (K. H. Baines, F. M. Flasar, N. Krupp, T. Stallard, Eds). Cambridge University Press (2018)

The Origin and Evolution of Saturn, with Exoplanet Perspective. Atreya, S. K., Crida, A., Guillot, T., Lunine, J. I., Madhusudhan, N., and Mousis, O.

**Reference Data**

Observations from Saturn Observation Guide [CSV]]

Event Calendar provides a search interface to find Saturn observations focused on Saturn Evolution and Formation, or other science topics

**Saturn Segment Table**

The table below outlines the Saturn observation segments related to Saturn Formation by name, start time, and end time, with links to segment movies (where available), legacy packages, and timeline visualizations.

Also available to download as **[XLSX] or [CSV] Should be Saturn\_Segments\_Origin**

Table of Time Periods with Formation and Evolution Observations

Segment Times, Movies, Legacy Packages and Visualizations **I think we’ve linked all you have given us**

**Interior Fundamentals**

Sub-Topics:

Gravity and Other Fundamental Parameters

Shape of Saturn

Magnetic Field Structure

Rotation Rate

This section pertains to the current knowledge, circa Summer 2018, of properties associated with Saturn's interior structure and rotation rate of the deep atmosphere. These include the values of gravitational moments through J10 and higher, the present shape of Saturn as expressed by Legendre polynomial coefficients for the 1-bar level, the magnetic field structure, and current estimates of the rotational period as derived from analysis of kronoseismological signals observed in the rings and other techniques. Science Objectives include:

* Infer the internal structure and rotation of the deep atmosphere.
* Determine Saturn's rotation rate and internal structure despite the planet's unexpected high degree of axis symmetry.

Key instruments involved are CIRS, MAG, RSS, RPWS, UVIS, and VIMS.

**OVERVIEW**

**Key Review Publications**

In Saturn from Cassini-Huygens (M.Dougherty, L. W. Esposito, and S. M. Krimigis, Eds). Springer (2009)

The interior of Saturn. pp. 75 - 81. Hubbard, W. B., Dougherty, M. K., Gautier, D., and Jacobson, R.

In Saturn in the 21st Century (K. H. Baines, F. M. Flasar, N. Krupp, T. Stallard, Eds). Cambridge University Press. (2018)

The interior of Saturn. Fortney, J. J., Helled, R., Nettelmann, N., Stevenson, D. J., Marley, M. S., Hubbard, W. B., and Iess, L.

**Reference Data**

Observations from Saturn Observation Guide [CSV]

Event Calendar provides a search interface to find Saturn observations focused on Saturn's Interior, or other science topics

**Saturn Segment Table**

The table below outlines the Saturn observation segments related to Saturn Interior by name, start time, and end time, with links to segment movies (where available), legacy packages, and timeline visualizations.

Also available to download as [XLSX] or [CSV] **Should be Saturn\_Segments\_Interior**

Table of Time Periods with Interior Observations

Segment Times, Movies, Legacy Packages and Visualizations

**Gravity and Other Fundamental Parameters**

Data and higher order products related to Saturn's gravitational field, and internal structure can be found here. The key instrument contributing to this subject is RSS.

The following paper and Tables contain data useful for modeling of Saturn's gravity. The values are subject to change pending the analysis of Grand Finale orbit gravity data.

R. A. Jacobson et al., The Gravity Field Of The Saturnian System From Satellite Observations And Spacecraft Tracking Data. Astronomical J., 132, 2520-2526. (2006) [DOI: 10.1086/508812]

**Table 3: Saturnian System Gravity Field from Jacobson et al.**

**Table 4: Physical Properties from Jacobson et al.**

**Shape of Saturn**

Data and higher order products related to the shape of Saturn's "surface" can be found here. Key instruments contributing to this topic are: RSS and UVIS.

The seminal paper defining the Shape of Saturn is Lindal, et al. (1985). In this paper, the equatorial and polar radius at 100 mbar are given as 60367 km and 54438 km, respectively. The equatorial and polar radius at 1 bar are given as 60268 km and 54364 km, respectively.

Lindal, et al., The Atmosphere Of Saturn: An Analysis Of The Voyager Radio Occultation Measurements. Astronomical J., 90, 1136-1146. (1985)

Cassini used the NAIF reference ellipsoid. The values used for the equatorial and polar radii for 1 bar are given as 60268 km and 54364 km, respectively. A reference sphere of 60330 km was also used for 100 mbar in the planning.

The shape of Saturn is more complex than what a simple ellipsoid represents. Engineering models used by the Cassini Project used gravitational parameters, zonal winds and rotation rates known at the time to generate a surface represented by a series of Legendre polynomials.

**Saturn Shape Data**

**SPICE Ellipsoid**

**Legendre polynomial expansion**

**Winds at 1 bar**

**Rotation Rate**

Information on what we know of Saturn's unknown rotation rate can be found here. Key instruments contributing to this topic are: MAG, RPWS, RSS, and VIMS.

**Key Review Books**

In Saturn in the 21st Century. (K. H. Baines, F. M. Flasar, N. Krupp, T. Stallard, Eds) Cambridge University Press, 2018.

The mysterious periodicities of Saturn: Clues to the rotation rate of the planet. Carbary, J. F., Hedman, M. M., Hill, T. W., Jia, X., Kurth, W., Lamy, L., and Provan, G.

**Key Review Publications**

Cassini Ring Seismology as a Probe of Saturn's Interior I: Rigid Rotation. Mankovich, C., M.S. Marley, J.J. Fortney, N. Movshovitz, 2018. Astrophysical J., **##, ####-####. This has been revised and accepted – not published**

**Atmospheric Properties**

**Sub-topics**

Atmosphere Data Vertical Pressure and Temperature Structure Composition Zonal and Meridonial Temperature Fields Zonal Clouds and Haze Structure and Properties Seasonal Variation of the above properties

Cassini conducted a unique multi-seasonal tour over 13 years that utilized an unprecedented range of viewing geometries and multi-wavelength studies to provide a plethora of new insights into the thermal, haze/cloud, and gaseous structure of the planet and their seasonal variability. The wide variety of orbital inclinations repeatedly achieved by the Cassini orbiter - from equatorial to nearly polar - provided direct and repeated viewing of all latitudes during the mission, from the poles to the equator by its broad array of synergistic instruments that spanned wavelengths from the UV to the far infrared. Science objectives included:

* Determine temperature field, cloud properties, and composition of the atmosphere of Saturn.
* Observe seasonal changes in the winds at all accessible altitudes coupled with simultaneous observations of clouds, temperatures, composition, and lightning.
* Measure the spatial and temporal variability of trace gases and isotopes.

This section breaks these observations down into major sub-topics to help the user to focus in on what they might need.

**Key Review Publications**

In Saturn in the 21st Century (K. H. Baines, F. M. Flasar, N. Krupp, T. Stallard, Eds). Cambridge University Press, 2018.

* Saturn's seasonally changing atmosphere: Thermal structure, composition and aerosols. Fletcher, L. N., Greathouse, T. K., Guerlet, S., Moses, J. I., and West, R. A.
* Saturn's polar atmosphere. Sayanagi, K. M., Baines, K. H., Dyudina, U. A., Fletcher, L. N., Sanchez-Lavega, A., and West, R. A.

**Reference Data**

* Observations from Saturn Observation Guide [CSV]
* Event Calendar provides a search interface to find Saturn observations focused on Saturn Atmospheric Properties, or other science topics

**Saturn Segment Table**

The table below outlines the Saturn observation segments related to Saturn atmosphere by name, start time, and end time, with links to segment movies (where available), legacy packages, and timeline visualizations.

Also available to download as **[XLSX]** or **[CSV]** **The should be Saturn *Segments\_*Atmospheres**

Table of Time Periods with Atmospheric Property Observations

Segment Times, Movies, Legacy Packages and Visualizations

**Vertical Pressure and Temperature Structure**

Information pertaining to the pressure (i.e., pressure vs. altitude) and temperature structure of Saturn's atmosphere are included in this section. Topics include UV and IR occultations and vertical and 3D temperature profiles. Key instruments contributing to this section are: CIRS, RSS, UVIS, and VIMS.

**Key Review Publications**

In Saturn from Cassini-Huygens (M.Dougherty, L. W. Esposito, and S. M. Krimigis, Eds). Springer (2009)

* Saturn Atmospheric Structure and Dynamics. pp. 113 -160. Del Genio, A.D., Achterberg, R.K., Baines, K.H., Flasar, F.M., Read, P.L., Sánchez-Lavega, A. and Showman, A.P.

**Vertical Pressure and Temperature Structure Data**

**Thermal Maps (CIRS)**

Constructed using CIRS data; including temporal variation.

**Upper-Atmosphere Density Profile**

UVIS profiles; one per occultation.

**Lower-Atmosphere Density Profile**

RSS profiles; one per occultation.

**Analysis of VIMS Occultations**

**Composition**

Data sources and products relevant to the composition (both molecular and haze/cloud composition) of Saturn's atmosphere are included in this section. Key instruments contributing to this subject are CIRS, INMS, MIMI, RADAR, RSS, UVIS, and VIMS.

**Key Review Publications**

In Saturn from Cassini-Huygens (M.Dougherty, L. W. Esposito, and S. M. Krimigis, Eds). Springer 2009

* Saturn: Composition and chemistry. pp. 83 -112. Fouchet, T., Moses, J. I., and Conrath, B. J.

**Additional Publications**

**Zonal and Meridonial Temperature Fields**

This section highlights the latitudinal and longitudinal temperature fields for noting seasonal variations and dynamical changes. Key instruments contributing to this section are: CIRS and VIMS.

**Key Review Publications**

In Saturn from Cassini-Huygens (M.Dougherty, L. W. Esposito, and S. M. Krimigis, Eds). Springer (2009)

* Saturn Atmospheric Structure and Dynamics. pp. 113 -160. Del Genio, A.D., Achterberg, R.K., Baines, K.H., Flasar, F.M., Read, P.L., Sánchez-Lavega, A. and Showman, A.P.

Thermal structure and dynamics of Saturn's northern springtime disturbance. Science 332, 1413-1417. Fletcher, L. N., Hesman, B. E., Irwin, P. G. J., Baines, K. H., Momary, T. W., Sanchez-Lavega, A., Flasar, F. M., Read, P. L., Orton, G. S., Simon-Miller, A., Hueso, R., Bjoraker, G., Marmoutkine. A, del Rio-Gaztelurrutia, T., Gomez, J. M., Brown, R. H., Buratti, B., Clark, R. N., Nicholson, P. D., and Sotin, C. (2011).

**Zonal and Meridonial Temperature Field Data**

**Thermal Maps**

**Clouds and Haze: Zonal Structure and Properties**

This section highlights the data relevant to the zonal cloud and haze structure within Saturn's atmosphere. This includes both visual imaging and spectroscopic data. Key instruments contributing to this section are: ISS, UVIS, and VIMS.

**Key Review Publications**

In Saturn from Cassini-Huygens (M.Dougherty, L. W. Esposito, and S. M. Krimigis, Eds). Springer (2009)

* Clouds and aerosols in Saturn's atmosphere. pp. 161-179. West, R. A., Baines, K. H., Karkoschka, E., and Sánchez-Lavega, A.

In Saturn in the 21st Century (K. H. Baines, F. M. Flasar, N. Krupp, T. Stallard, Eds). Cambridge University Press 2018

* The Great Storm of 2010-2011. Sánchez-Lavega, A., Fisher, G., Fletcher, L. N., García-Melendo, E., Hesman, B., Perez-Hoyos, S., Sayanagi, K. M., and Sromovsky, L. A.
* Saturn's polar atmosphere. Sayanagi, K. M., Baines, K. H., Dyudina, U. A., Fletcher, L. N., Sánchez-Lavega, A., and West, R. A.

**Additional Publications**

**Seasonal Variation of Atmospheric Properties**

Data relevant to seasonal variations within Saturn's atmosphere are included in this section. Some of the material included here will overlap with other sections on this website. Key instruments contributing to this subject section are: CIRS, ISS, RSS, UVIS, and VIMS.

**Key Publications**

In Saturn from Cassini-Huygens (M.Dougherty, L. W. Esposito, and S. M. Krimigis, Eds). Springer (2009)

* Saturn Atmospheric Structure and Dynamics. ppp. 113 -160. Del Genio, A.D., Achterberg, R.K., Baines, K.H., Flasar, F.M., Read, P.L., Sánchez-Lavega, A. and Showman, A.P.

**Global Circulation and Dynamics**

**Sub-topics**

Zonal Winds Global Circulation and Convection Seasonal Variation of Global Circulation and Dynamics Polar Regions 2010-2012 Great Storm

Repeated multi-wavelength observations over a single or sometimes several rotations by ISS and VIMS allowed the motions of clouds to be measured, resulting in direct measurements of zonal winds at various altitudes that could be compared to the thermal wind structure derived from the temperature field measured by CIRS. Such observations were repeated throughout the 13-year orbital mission, providing insights into the seasonal variability of the zonal winds and their associated zonal wind shears.

The polar regions - including the uniquely shaped North Polar Hexagon - and the Great Storm of 2010-2011 provided fundamental new insights into the global circulation and local meteorology of the planet. Science objectives included:

* Measure the global wind field, including wave and eddy components; observe synoptic cloud features and processes.
* Investigate the sources and the morphology of Saturn lightning (Saturn Electrostatic Discharges (SED), lightning whistlers).
* Observe seasonal changes in the winds at all accessible altitudes coupled with simultaneous observations of clouds, temperatures, composition, and lightning.
* Observe the aftermath of the 2010-2011 storm. Study the life cycles of Saturn's newly discovered atmospheric waves, south polar hurricane, and rediscovered north polar hexagon.
* Monitor the planet for new storms and respond with new observations when the new storms occur.

**Key Review Publications**

In Saturn (Gehrels, T., Matthews, M. S, eds). Univ. Arizona Press, Tucson. (1984)

* Structure and dynamics of Saturn's atmosphere. pp. 195-238. Ingersoll, A. P., Beebe, R. F., Conrath, B. J., and Hunt, G. E.

In Saturn from Cassini-Huygens (M. K. Dougherty, L. W. Esposito, and S. M. Krimigis, Eds). Springer (2009)

* Saturn atmospheric structure and dynamics, pp. 113-159. Del Genio, A. D., Achterberg, R. K., Baines, K. H., Flasar, F. M., Read, P. L., Sánchez-Lavega, A., and Showman, A. P.

In Saturn in the 21st Century. (K. H. Baines, F. M. Flasar, N. Krupp, T. Stallard, Eds). Cambridge University Press. in press. (2018)

* The global atmospheric circulation of Saturn. Showman, A. P., Ingersoll, A. P., Achterberg, R., and Kaspi. Y.

**Reference Data**

Observations from Saturn Observation Guide [CSV] [TXT]

Event Calendar provides a search interface to find Saturn observations focused on Saturn Global Circulation and Dynamics, or other science topics

**Saturn Segment Table**

The table below outlines the Saturn observation segments related to Saturn's Dynamics by name, start time, and end time, with links to segment movies (where available), legacy packages, and timeline visualizations.

Also available to download as **[XLSX] or [CSV] This one should be Saturn\_Segment\_Dynamics**

Table of Time Periods with Circulation and Dynamics Observations

Segment Times, Movies, Legacy Packages and Visualizations

**Zonal Winds**

Determination of zonal wind speeds at various pressure levels in the atmosphere are included in this section. Key instruments that contributed to this topic are: ISS, VIMS and CIRS.

**Key Publications**

In Saturn from Cassini-Huygens (M.Dougherty, L. W. Esposito, and S. M. Krimigis, Eds). Springer (2009)

* Saturn Atmospheric Structure and Dynamics. pp. 113 -160. Del Genio, A.D., Achterberg, R.K., Baines, K.H., Flasar, F.M., Read, P.L., Sánchez-Lavega, A. and Showman, A.P.

**Additional Publications**

**Wind Data**

**Zonal Winds vs. Latitude (ISS)**

**Zonal winds at 60-250 mbar**

**Zonal winds at 350-500 mbar**

**Zonal winds at 20 bar**

**Global Circulation and Convection**

Global circulation and energy budget of Saturn's atmosphere are included in this section. Instruments contributing to this study are: CIRS, ISS, UVIS, VIMS.

**Key Review Publications**

In Saturn from Cassini-Huygens (M.Dougherty, L. W. Esposito, and S. M. Krimigis, Eds). Springer (2009)

* Saturn Atmospheric Structure and Dynamics. pp. 113 -160. Del Genio, A.D., Achterberg, R.K., Baines, K.H., Flasar, F.M., Read, P.L., Sánchez-Lavega, A. and Showman, A.P.

**Additional Publications**

**Seasonal Variation of Global Circulation and Dynamics**

Many changes in the visible atmosphere of Saturn can be traced back to seasonal variations. This section focuses on its attention on solar and seasonally driven phenomena. Instruments contributing to this study are: CIRS, ISS, UVIS, VIMS.

**Key Publications**

In Saturn from Cassini-Huygens (M.Dougherty, L. W. Esposito, and S. M. Krimigis, Eds). Springer (2009)

* Saturn Atmospheric Structure and Dynamics. pp. 113 -160. Del Genio, A.D., Achterberg, R.K., Baines, K.H., Flasar, F.M., Read, P.L., Sánchez-Lavega, A. and Showman, A.P.

**Polar Regions**

Dynamics and phenomena occurring near the vicinity of both north and south poles of the planet are included in this section. Instruments contributing to this study are: CIRS, ISS, UVIS, VIMS.

**Key Review Publications**

In Saturn in the 21st Century. (K. H. Baines, F. M. Flasar, N. Krupp, T. Stallard, Eds). Cambridge University Press. in press. (2018)

* Saturn's polar atmosphere. Sayanagi, K. M., Baines, K. H., Dyudina, U. A., Fletcher, L. N., Sanchez-Lavega, A., and West, R. A.

**Additional Publications**

**2010-2012 Great Storm**

Once every 20-30 years, Saturn erupts with planet-wide storms. Cassini was there to see this rare event up-close and personal. Instruments contributing to this study are: CIRS, ISS, RADAR, RPWS, UVIS, VIMS.

**Key Publications**

In Saturn in the 21st Century. (K. H. Baines, F. M. Flasar, N. Krupp, T. Stallard, Eds). Cambridge University Press. in press. (2018)

The Great Storm of 2010-2011. Sánchez-Lavega, A., Fisher, G., Fletcher, L. N., García-Melendo, E., Hesman, B., Perez-Hoyos, S., Sayanagi, K. M., and Sromovsky, L. A.

**Additional Publications**

**Auroral Observations**

Auroras on Saturn occur in a process similar to Earth's northern and southern lights. Particles from the solar wind are channeled by Saturn's magnetic field toward the planet's poles, where they interact with electrically charged gas (plasma) in the upper atmosphere and emit light. At Saturn, however, auroral features can also be caused by electromagnetic waves generated when the planet's moons move through the plasma that fills Saturn's magnetosphere.

**Science objectives includes**

* Observe the magnetosphere, ionosphere, and aurora as they change on all time scales—minutes to years—and are affected by seasonal and solar cycle forcing. Here the focus is on contributions from optical remote sensing instruments: CIRS, ISS, UVIS, and VIMS.

**Key Review Publications**

In Saturn from Cassini-Huygens (M.Dougherty, L. W. Esposito, and S. M. Krimigis, Eds). Springer (2009)

* Auroral Processes. pp. 333-374. Kurth, W.S., Bunce, E.J., Clarke, J.T., Crary, F.J., Grodent, D.C., Ingersoll, A.P., Dyudina, U.A., Lamy, L., Mitchell, D.G., Persoon, A.M., Pryor, W.R., Saur, J., and Stallard, T.

In Saturn in the 21st Century (K. H. Baines, F. M. Flasar, N. Krupp, T. Stallard, Eds). Cambridge University Press. (2018)

* Saturn's Aurora. Stallard, T., Badman, S., Dyudina, U., Grodent, D., and Lamy, L.

**Additional Publications**

**Auroral Data**

**Search Tools**

The Event Calendar is one way to find data associated with particular events such as auroral observations.

OPUS is a tool used to search for CIRS, ISS, UVIS and VIMS data all in one place. This URL is pre-filled with an example search near the south pole.

**Auroral Observation Reference Tables**

* The Aurora Observation Table [CSV download] [TXT]has a list of all planned auroral observations and their time stamps.
* List of coordinated HST and ground-based observing campaigns [XLS]
* HST (Hubble Space Telescope) information can be found at Aurora Planetary Imaging and Spectroscopy and MIST
* Detailed information and data from John Clarke's Hubble Space Telescope (HST) Auroral Campaign (Jan 13 - 26 2007 and Jan1 - Feb 16 2008) for comparison with Cassini data
* Detailed schedule for 2013 joint Cassini - ground-based **Auroral Campaign (xlsx, txt)**

**Processed data**

**UVIS Auroral Guidebook** with images and movies

**Aurora Observation Data Book** from UVIS

**Reference Data**

Observations from Saturn Observation Guide [CSV]

Event Calendar provides a search interface to find Saturn observations focused on Saturn Aurorae, or other science topics

**Saturn Segment Table**

The table below outlines the Saturn observation segments related to Saturn Aurorae by name, start time, and end time, with links to segment movies (where available), legacy packages, and timeline visualizations.

Also available to download as [XLSX] or [CSV]  **Should be Saturn\_Segment\_Aurora Many of these observations occurred outside the time intervals bracketed by the segments. I think this file is MUCH more useful than the table. I think we should stress this file and remove the Table.**

Table of Time Periods with Auroral Observations

Segment Times, Movies, Legacy Packages and Visualizations

**Analysis of Aurora Data**

**Ancillary Data**

* The Magnetospheric Science page references a variety of magnetic field models, which may be used in conjunction with the remote-sensing measurements to relate the interactions of ions with the magnetic field.
* SPICE geometry information is important to correct the alignment of the atmosphere with the observations and with alignment to the magnetic field lines.

When performing an analysis of Aurorae, it is may be useful to visualize the visible-spectra data with SPICE geometry data in order to align the data with Saturn's atmosphere. The built-in backplane (geometry) data for some data sets like VIMS can be made more accurate using SPICE to indicate the atmospheric "height" from the typical one-bar surface.

**Ionosphere and Magnetic Fields**

This section focuses on observations of the ionosphere and magnetic field and subsequent plasma measurements. Key instruments contributions made by INMS, MAG, MIMI, RPWS, RSS.

Cassini has a variety of instruments to study Saturn's magnetic field and associated plasma interactions. Information on ionosphere studies can be found below; please see the Cassini Magnetospheric Science page for other information.

**Mission Objective**

* Study the diurnal variations and magnetic control of the ionosphere of Saturn.

**Key Publications**

In Saturn from Cassini-Huygens (M.Dougherty, L. W. Esposito, and S. M. Krimigis, Eds). Springer (2009)

* Upper atmosphere and ionosphere of Saturn. pp. 181-291. Nagy, A. F., Kliore, A. J., Mendillo, M., Miller, S., Moore, L., Moses, J. I., Müller-Wodarg, I., and Shemansky, D.

In Saturn in the 21st Century (K. H. Baines, F. M. Flasar, N. Krupp, T. Stallard, Eds). Cambridge University Press 2018

* Saturn's ionosphere. Moore, L., Galand, M., Kliore, A. J., Nagy, A. F., and O'Donoghue, J.
* Saturn's variable thermosphere. Strobel, D. F., Koskinen, T., and Müller-Wodarg, I.

**Additional Publications**

**Analysis of Ionosphere Data**

**Ancillary Data**

* The Magnetic Field Model [CSV download] is used in conjunction with the optical measurements to relate the interactions of ions with the magnetic field.
* SPICE geometry information is important to correct the alignment of the atmosphere with the observations and with alignment to the magnetic field lines.

Reference Data

Observations from Saturn Observation Guide [CSV]

Event Calendar provides a search interface to find Saturn observations focused on Saturn Ionosphere and Magnetosphere, or other science topics

**Saturn Segment Table**

The table below outlines the Saturn observation segments related to Saturn's Ionosphere and Magnetosphere by name, start time, and end time, with links to segment movies (where available), legacy packages, and timeline visualizations.

Also available to download as [**XLSX] or [CSV**] **Should be Saturn\_Segments\_Magnetosphere\_Ionisohere**

Table of Time Periods with Ionosphere and Magnetosphere Observations

Segment Times, Movies, Legacy Packages and Visualizations

**Magnetic Field Structure**

Materials related to the formation and subsequent morphology of Saturn's interior magnetic field can be found here. The key instrument contributing to this subject is: MAG.

**Key Review Publications**

In Saturn in the 21st Century. (K. H. Baines, F. M. Flasar, N. Krupp, T. Stallard, Eds) Cambridge University Press, 2018.

* The mysterious periodicities of Saturn: Clues to the rotation rate of the planet. Carbary, J. F., Hedman, M. M., Hill, T. W., Jia, X., Kurth, W., Lamy, L., and Provan, G.
* Saturn's magnetic field and dynamo. Christensen, U. R., Cao, H., Dougherty, M., Khurana, K.
* Model of Saturn's internal planetary magnetic field based on Cassini observations. Burton, M.E., M.K. Dougherty, and C.T. Russell. Planetary and Space Sciences, 57, 1706-1713. (2009)
* Saturn's magnetic field revealed by the Cassini Grand Finale Dougherty, M.K., H. Cao, K.K. Khurana, G.J. Hunt, G. Provan, S. Kellock, M.E. Burton, T.A. Burk, E.J. Bunce, S.W.H. Cowley, M.G. Kivelson, C.T. Russell, D.J. Southwood, Science, **##, ####-####** (2018)

**Interior Magnetic Field Data**

**Magnetic Field Moments** Check CAPS page????