POST GRADUATION PROGRAM IN SPACE GEOPHYSICS

Academic Coordinator

Marlos Rockenbach da Silva

Substitute Academic Coordinator

Esfhan Alam Kherani

Permanent Faculty Members

Alexandre Alvares Pimenta, PhD, INPE, 2002- FISAT

Alisson Dal Lago, PhD, INPE, 2003- MAGHEL

Antonio Lopes Padilha, PhD, USP, 1989 - GEOMA

Clezio Marcos De Nardin, PhD, INPE, 2003 - IONO

Cristiano Max Wrasse, PhD, INPE, 2004 - LUME

Delano Gobbi, PhD, INPE, 1993- LUME

Eliah Fernanda de Maria de São Sabbas Tavares, PhD., Alaska Univ., 2003 - LUME

Érico Luiz Rempel, PhD., Universidade de Cambridge, Reino Unido, 2009

Esfhan Alam Kherani, PhD., Physical Research Laboratory, Índia, 2002 – IONO

Eurico Rodrigues de Paula, PhD, INPE, 1986 - IONO

Ezequiel Echer, PhD, INPE, 2004 - MAGHEL

Fábio Becker Guedes, PhD., USP, São Carlos, 2001 - IONO

Flávia Reis Cardoso Rojas, PhD, INPE, 2010

Hisao Takahashi, Doutor, INPE, 1980- LUME

Inez Staciarini Batista, PhD, INPE, 1985- IONO

Jonas Rodrigues de Souza, PhD, INPE, 1997- IONO

Kleber Pinheiro Naccarato, PhD, INPE, 2007 – ELAT

Lívia Ribeiro Alves, PhD, INPE, 2011 - GEOMA

Luis Eduardo Antunes Vieira, PhD, INPE, 2002 - MAGHEL

Marcelo Magalhães Fares Saba, PhD, INPE, 1997- ELAT

Maria Paulete Pereira Martins, PhD, INPE, 1996 - FISAT

Maria Virgínia Alves, PhD, INPE, 1990 - MAGHEL

Marlos Rockenbach da Silva, PhD, INPE, 2009 - MAGHEL

Odim Mendes Júnior, PhD, INPE, 1992 - MAGHEL

Paulo Prado Batista, PhD, INPE, 1983 - FISAT

Collaborator Faculty Members

Alícia Luiza Clua de Gonzalez Alarcon, PhD, Univ. La Plata, 1973 - MAGHEL

Andreia Santos Matos, PhD, UNB, 2012 – GEOMA

Ivan Jelinek Kantor, PhD., Rice Univ., 1973 - IONO

Severino Luiz Guimarães Dutra, PhD, INPE, 1982- GEOMA

Walter D. Gonzalez Alarcon, PhD., Univ. Cal. Berkeley, 1973 - MAGHEL

SPACE GEOPHYSICS PROGRAM

Research Area 1 - Sciences of the Solar-Terrestrial Environment - AST

Research Area 2 - Atmospheric Sciences - ATM

Annual program for the Master's:

1st Period

Mandatory Courses for both Research Areas:

GES-200-4 Space Geophysics *

GES-203-1 Instrumentation in Space Geophysics *

GES-207-4 Mathematical Methods for Physics

GES-502-0 Seminars on Space Geophysics I

2nd Period

Mandatory Courses:

GES-205-4 Electrodynamics I

GES-300-4 Solar-Terrestrial Physics * (Research Area 1)

GES-305-4 Atmospheric Physics * (Research Area 2)

*** Mandatory for doctoral students who have not completed a master's degree at PGGES.**

3rd period

For both Research Areas: **In addition, two courses from the non-mandatory courses should be chosen among the elective courses.**

Mandatory for Doctorate

GES-503-0 Seminars on Space Geophysics II

Electives for the Master's and Doctorate:

GES-208-3 Statistical Methods in Geophysics

GES-301-4 Geomagnetism

GES-204-4 Plasma Physics I

GES-307-4 Aeronomy

GES-302-4 Electromagnetic Induction in the Earth

GES-303-4 Atmospheric Airglow

GES-304-4 Plasma Physics II

GES-306-4 Random Signals Analysis

GES-313-4 Atmospheric Chemistry

GES-314-4 Atmospheric Electricity

GES-315-4 Atmospheric Electrodynamics

GES-316-4 Numerical Simulation of Space Plasma Phenomena

GES-401-4 Ionospheric Physics

GES-402-4 Upper Atmosphere Dynamics

GES-403-4 Inner Magnetosphere: Plasmaspheric Physics and Radiation Belts

GES-404-4 Non-linear Processes in Plasmas

GES-405-4 Outer Magnetospheric Physics

GES-409-4 Special Topics in Upper Atmosphere

GES-410-4 Special Topics in Atmospheric Electricity

GES-411-4 Special Topics in Geomagnetism

GES-412-4 Special Topics in Ionosphere

GES-413-4 Special Topics in Atmospheric Airglow

GES-414-4 Special Topics in Magnetosphere and Heliosphere

GES-415-4 Special Topics in Middle and Lower Atmosphere

Scope of the Courses

1st Period

GES-200-4 Space Geophysics

Mandatory

The solar source, electromagnetic radiation, corpuscular matter, quiet and disturbed Sun. Magnetosphere and interplanetary medium, magnetospheric current systems. Intrinsic magnetic field, magnetic disturbances. Concepts of Space Weather, weather and climate, influences in the near space, in the lithosphere, and in the atmosphere. The atmosphere: origin, evolution and constitution, radiation, temperature and winds. Introduction to the atmosphere of other planets. Introduction to atmospheric chemistry. Airglow photochemistry. Condensation of clouds and electrification of the atmosphere. Ionosphere: ionization, formation of ionized layers, transport processes, electric fields, neutral winds, diffusion, and electric currents.

Bibliography

Campbell, W. H. Introduction to geomagnetic fields. Cambridge University, 1997. 290p.

Goody, R. M.; Walker, J. C. G. Atmospheres. Prentice-Hall, 1972. 150p.

Hargreaves, J. The upper atmosphere and solar-terrestrial relations. Van Nostrand Reinhold Company, 1979. 297p.

Haymes, R. C. Introduction to space science. John Wiley & Sons, 1971. 555p.

Kelley, M. C. The Earth´s ionosphere. Academic Press Inc., 1989. 484p.

Kippenhahn, R. Discovering the secrets of the Sun. John Willey and Sons, 1994. 261p.

Kirchhoff, V. W. J. H. Introdução à geofísica espacial. Edusp, 1991. 152p.

Kivelson, M. G.; RUSSELL, C. T. Introduction to space physics. Cambridge University, 1995. 568p.

Magono, C. Thunderstorms. Elsevier, 1980. 261p.

Parks, G. R. Physics of space plasmas: an introduction. Addison-Wesley, 1991. 538p.

Rishbeth, H. and Garriott, O. K. Introduction to ionospheric physics. Academic Press, 1969. 331p.

Salby, M. L. Fundamentals of atmospheric physics. California, Academic Press, 1996. 627p.

Schunk, R. W. and Nagy, A. F. Ionospheres, Physics, Plasma Physics and Chemistry. Cambridge University Press, 2000. 554p.

GES-203-1 Instrumentation in Space Geophysics

Mandatory

Introduction to instrumentation theory and practice, as well as scientific methodology of the Space Sciences in operation at INPE: Laser radar, Spectrophotometers Dobson, Ozone monitors, magnetometers, Receivers of VLF, Polarimeters VHF, Riometers, Ionosond (photometers, ionospheric plasma experiments) in a rocket payload, nuclear spectroscopy, electric field measurements, X ray and ELF waves in the Atmosphere, instrumentation to simulate space plasmas. It is necessary to make a review monography about one of the presented equipment's.

Bibliography

KIRCHHOFF, V.W.J.H. Elementos básicos sobre o Radar de Laser. São José dos Campos, INPE maio 1984 (INPE-3123-MD/025).

KIRCHHOFF, V.W.J.H. Elementos básicos sobre fotômetros de filtro inclinável. INPE-3124-MD/026, maio, 1984.

GES-207- 4 Mathematical Methods for Physics

Mandatory

Mathematical Preliminaries: Vectors, Matrices, Determinants, Applications of Linear Systems**.**

Linear Algebra: Euclidean Vector Spaces, General Vector Spaces, Linear Transformations, Eigenvalues and Eigenvectors, Matrix Calculus, Normed and Inner Product Spaces, Introduction to Tensors and Their Applications.

Complex Variables: Complex and Hypercomplex Numbers, Analytic Functions, Complex Integration, Taylor and Laurent Series, Isolated Singularities and Calculus of Residues, Evaluation of Real Integrals, Complex Potentials, Conformal Mapping and Applications.

Differential Equations: A Boundary Value Problem, Series Solutions of Second Order Differential Equations, Regular Singular Points and the Method of Frobenius, Special Functions.

Sturm–Liouville Theory and Its Applications: Space of Square-Integrable Functions (L^2), The Sturm–Liouville Problem, Fourier Series, Orthogonal Polynomials, Integral Transforms and Generalized Functions (Distributions), The Fourier Transform, The Laplace Transform.

Perturbation Techniques in Physics.

Bibliography

Al-Gwaiz, M. A. Sturm-Liouville Theory and Its Applications. Springer-Verlag, 2008.

Alpay, D. A Complex Analysis Problem Book. Birkhäuser Basel, 2011.

Anton, H.; Rorres, C. Elementary Linear Algebra with Applications. John Wiley & Sons, 10th edition, 2010.

Bean, S. E. P. C.; Kozakevich, D. N. Álgebra Linear I. Editora da UFSC, 2th edition (UFSC), 2011.

Bellman, R. Perturbation Techniques in Mathematics, Physics and Engineering. Dover Publications, reprint edition, 2003.

Bronson, R.; Costa, G. B. Linear Algebra: An Introduction. Academic Press, 5th edition, 2007.

Bronson, R.; Costa, G. B. Matrix Methods: Applied Linear Algebra. Academic Press, 3th edition, 2008.

Islam, N. Tensors and Their Applications. New Age International, 2006.

Kantor, I. L.; Solodovnikov, A. S. Hypercomplex Numbers: An Elementary Introduction to Algebras. Spring Verlag, 1989.

Kanwal R. P. Generalized Functions, Theory and Technique. Academic Press Inc, 1983.

Kristensson, G. Second Order Differential Equations: Special Functions and Their Classification. Springer Science, 2010.

Kwok, Y. K. Applied Complex Variables for Scientists and Engineers. Cambridge Univ. Press, 2010

Lay, D. C. Linear Algebra and Its Applications. Pearson, 4th edition, 2011.

Medrano-B., R.A. Campos Vetoriais, Espaços Lineares e Tensores na Física. Transtec, 1994.

Medrano-B., R.A. Equações Diferenciais Ordinárias. INPE (INPE-1753-RPE/144), 1980.

Medrano-B., R.A. Funções de Variáveis Complexas. INPE (INPE-1494-RPE/038), 1979.

Medrano-B., R.A. Funções Especiais. INPE (INPE-3479-RPE/472), 1985.

Medrano-B., R.A. Transformadas Integrais. INPE (INPE-4807-MD/40), 1989.

Moon, P; Spencer, D. E. Field Theory Handbook. Springer-Verlag, 2th edition, 1971.

Robinson, J. C. An Introduction to Ordinary Differential Equations. Cambridge University Press, 2004.

Watts, R. G. Essentials of Applied Mathematics for Scientists and Engineers. M&C Publish., 2007.

Wegert, E. Visual Complex Functions: An Introduction with Phase Portraits. Birkhäuser Basel, 2012.

Zill, G. D.; Shanahan, P. D. Complex Analysis: A First Course with Applications. Jones & Bartlett Learning, 2th, 2008.

GES-502-0 Seminars on Space Geophysics I

Mandatory for Master's

The seminars cover research topics related to the area of Space Geophysics.

GES-503–0 Seminars on Space Geophysics II

Mandatory for Doctorate

The seminars cover current research topics related to the area of Space Geophysics.

Scope of the Courses

2nd period

GES-205 – 4 Electrodynamics I

Electrostatics: Coulomb's and Gauss's Laws. The Divergence and Curl of Electrostatic Fields. Electric Potential. Work and Energy. Conductors. Laplace's and Poisson's Equations. Method of Images. Separation of Variables. Multipole Expansion. The Monopole and Dipole Terms. Electric fields in Matter: Polarization, Field of a Polarized Object, Electric Displacement, Dielectrics.

Magnetostatics: The Lorentz Force Law. The Biot-Savart Law. Ampère's Law. The Divergence and Curl of B. Magnetic Vector Potential. Magnetic Dipole. Energy in Magnetic Fields. Magnetic Fields in Matter: Magnetization, Auxiliary Field H, Linear and Nonlinear Media.

Electrodynamics: Electromotive Force. Electromagnetic Induction. Maxwell's Equations. Continuity Equation. Poynting's Theorem. Faraday's Law. Electromagnetic Waves.

Bibliography

COOK, D.M. The Theory of the Electromagnetic Field. New York, Prentice-Hall, 1975.

Griffths, J.D. Introduction to electrodynamics, Prentice Hall, New Jersey, 1999.

LORRAIN, P.; CORSON, D.R. Eletromagnetic Fields and Waves. San Francisco, Freeman, 1970.

Machado, K.D. Eletromagnetismo, Volumes 1, 2, 3, Ed. UEPG, 2007

PANOFSKY, W.H.H.; PHILLIPS, M. Classical Electricity and Magnetism, Reading, MA, Addison Wesley, 1962

REITZ, J.R.; MILFORD, F.J.; CHRISTY, R.W. Fundamentos da Teoria Eletromagnética. Rio de Janeiro, RJ, Campus, 1982.

GES-208-3 Statistical Methods in Geophysics

Introduction to data analysis. Probability and Statistics. Discrete and continuous random variables. Probabilistic distributions. Sampling. Statistical Inference. Hypothesis tests. Special topics: error propagation; mean and variance tests, linear regression.

Bibliography

Bevington, P. R., and D. K. Robinson, Data Reduction and Error Analysis for the Physical Sciences, Third Edition, McGraw-Hill Company, Inc. New York, 2003.

Bussab, W. O. e P. A. Morettin, Estatística Básica, Quinta Edição, Editora Saraiva, São Paulo, 2002

Casella, G. and R. L. Berger, Statistical Inference, Duxbury, Pacific Grove, CA, 2002. Freund, R. J. and W. J. Wilson, Statistical Methods, second edition, Academic Press, San Diego, 2003. Hoel, P. G., Introduction to Mathematical Statistics, John Wiley & Sons, New York, 1962.

Jenkins, G. M. and D. G. Watts, Spectral Analysis and its applications, Holden-Day, San Francisco, 1968.

Magalhães, M. N. e A. C. P. de Lima, Noções de Probabilidade e Estatística, 3ª Edição, IME – USP, São

Paulo, 2001.

Meyer, P. L., Probabilidade, Aplicações a Estatística, 2ª. Edição, Livros Técnicos e Científicos Editora, Rio de Janeiro, 1983.

Press, W. H., B. P. Flannery, S. A. Teukolsky, and W. T. Vetterling, Numerical Recipes in C: The Art of Scientific Computing, Cambridge University Press, 2nd. ed., 2002.

Yates, R. D. and D. J. Goodman, Probability and Stochastic Processes, Second Edition, John Wiley and Sons, 2005.

GES-300-4 Solar-Terrestrial Physics

Mandatory – Research Area 1

The fundamental concepts in space plasmas. The origin and evolution of the geomagnetic field. The South America Magnetic Anomaly. The primary concepts in solar physics, solar activities, solar wind, and the interplanetary environment. Planetary magnetospheres. Magnetosphere regions. The physical and chemical processes of the ionosphere. Cosmic rays. The Sun-magnetosphere-ionosphere-atmosphere coupling. The geomagnetic activity, geomagnetic storms, and geomagnetic substorms.

Bibliography

BAUMJOHAN, W.; TREUMAN, R. A. Basic Space Plasma Physics, London, Imperial College, 2004. 329p

HARGREAVES, J. K. The solar-terrestrial environment. Cambridge, Cambridge University, 1992. 420p. (Cambridge atmospheric and space science series).

KIVELSON, M. G.; RUSSELL, C. T. Introduction to space physics. Cambridge, Cambridge University, 1995. 568p.

LYONS,, L. R.; WILLIAMS, D. J. Quantitative aspects of magnetospheric Physics. Boston, Reidel, 1984.

MERRIL, R,. T.; MCELHINNY, M. W. The Earth's magnetic field: its history, origin and planetary perspective. London, Academic Press, 1983.

PARKISON, W. D. Introduction to geomagnetism. Edinburgh, Scotish Academic Press, 1983.

PARKS, G. R. Physics of space plasmas: an introduction. California, Addison-Wesley, 1991. 538p.

VOLLAND, H. Atmospheric electrodynamics. New York, Spring-Verlag,(Physics and Chemistry in Space), 1984. 105p.

GES-305-4 Physics of the Atmosphere

Mandatory – Research Area 2

Atmosphere: composition of the atmosphere. Thermal structure. Hydrostatic equilibrium. Equations that govern the atmosphere. Unidimensional model. Atmospheric stability. Deviations of the equilibrium, geostrophic balance, trade winds, atmospheric waves. Airglow: Chemistry and ionic processes. Molecular

and turbulent diffusion. Elements of the chemistry kinetics. Composition and distribution of the chemistry species. Layers formation. Chimiolencence reactions. The airglow of the O, O2, OH e Na. Radiation: fundamental principles, electromagnetic spectrum, radiative process. Fundamental laws. Radiative transference. Atmospheric electricity: Atmospheric ionization processes. Atmospheric electric field. Atmospheric electric circuit. Thunderstorm cloud electrification processes. Atmospheric lightinings. Atmospheric electrodynamics.

Bibliography

BRASSEUR, G.; SOLOMON, S. Aeronomy of the Middle Atmosphere, D. Reidel Publishing Company, Dordrecht, 1986, 452p.

FLEAGE, R. G. Introduction to Atmospheric Physics. Academic Press, New York, 1963. 346p.

JOHNSON, J. C. Physycal Meteorology. Massachusetts Institute of Tecnology, Cambridge, 1963, 393p.

KIRCHHOFF, V. W. H. Introdução a Geofísica Espacial, Ed. Universidade de São Paulo, SP, 1991,149p.

RAKOV, V. AND UMAN, M. Lightning: physics and effects, Cambridge,2003.

REES, M. H. Physics and Chemistry of the Upper atmosphere, Cambridge atmospheric and Space Science Series, 1989, 289p.

SALBY, M. L. Fundamentals of Atmospheric Physics. Academic Press, London, 1996. 627p.

UMAN, M.The lightning discharge, Academic Press, 1997.

VAREJA-SILVA, M. A., Meteorologia e Climatologia.. INMET, Brasília, 2000,532p.

VIANELLO, R. L.; RAINIER ALVES, A., Meteorologia Básica e Aplicações. Universidade Federal de Viçosa, Viçosa, 1991, 449p.

Scope of the Courses

3rd period

Master's: Two courses must be taken from the elective courses.

Non-mandatory courses for Master's and Doctorate

GES-204-4 Plasma Physics I

Fundamental concepts on plasma physics. Orbital theory and adiabatic invariants. Magnetohydrodynamic theory. Kinetic theory. Fundamental concepts on plasma waves and instabilities.

Bibliography

BAUMJOHANN, W. & R. TREUMANN Basic Space Plasma Physics, Contemporary Physics Volume 54, Issue 3, 2013

BELLAN, P. M. Fundamentals of Plasma Physics, Cambridge Univ. Press, 2006

BITTENCOURT, J.A. Fundamentals of Plasma Physics. Oxford, Pergamon, 1986.

BOYD, T.J.M. & J. J. SANDERSON The Physics of Plasmas, Cambridge Univ. Press, 2003

CALLEN, J.D. Fundamentals of Plasma Physics, University of Wisconsin, 2006

CHEN, F.F. Introduction to Plasma Physics and Controlled Fusion. New York, Plenum, 1984. vol.1

GOEDBLOED, J. P. & S. POEDTS, Principles of Magnetohydrodynamics: With Applications to Laboratory and Astrophysical Plasmas, Cambridge University Press, 2004 – 613p

GOLDSTON, R. J. & P. H. RUTHERFORD, Introduction to plasma physics, IOP Publishing LTD, 1995

GURNETT, D. A. & A. BHATTACHARJEE Introduction to Plasma Physics: With Space and Laboratory Applications, Cambridge University Press, 2005

KIVELSON, M. G.; RUSSELL, C. T. Introduction to space physics. Cambridge, Cambridge University, 1995. 568p.

KRALL, N. & A.W.TRAVELPIECE Principles of Plasma Physics, McGraw-Hill, 1973, 674p

SCHUNK, R. & A. NAGY Ionospheres: Physics, Plasma Physics, and Chemistry, Cambridge University Press, 2009

PARKS, G.K. Physics of Space Plasmas: an Introduction. Redwood City, California, Addison-Wesley, 1991.

PIEL, A. Plasma Physics: An Introduction to Laboratory, Space, and Fusion Plasmas, Springer, Germany, 2010

PRIEST, E. Magneto hydrodynamics of the sun, Cambridge University Press, 2014

GES-307- 4 Aeronomy

The neutral atmosphere: Thermal structure; Absorption of solar radiation; Primitive equations; Average winds; Atmospheric waves; Molecular and turbulent diffusion; Elements of chemical kinectics; Composition and distribution of chemical species; Airglow; Magnetosphere energy input.

The ionized atmosphere: The ionosphere formation (Chapman's layer theory); Photochemical and transport processes (ambipolar diffusion); Ionospheric regions D, E, F1 and F2; Exosphere; Airglow; Diurnal and nocturnal variations; Fundamentals of geomagnetism; Mobility and electrical conductivity; Electric current systems; Phenomena in middle and low latitudes (anomalies, storms and irregularities);

Phenomena in high latitudes (storms, polar cap, aurora); Principles of radio propagation.

Bibliography

EARL E GOSSARD; WILLIAM H. HOOKE. Waves in the atmosphere: Atmospheric infrasound and gravity waves - their generation and propagation, Elsevier Scientific Pub. Co., 1975.

GUY BRASSEUR; SUSAN SOLOMON. Aeronomy of the Middle Atmosphere, Kluwer Academic Publishers, 1987.

H. RISHBETH; O. K. GARRIOTT. Introduction to Ionospheric Physics, Academic Press Inc., 1969.

JOHN KEITH HARGREAVES. The Solar-Terrestrial Environment : An Introduction to Geospace - the Science of the Terrestrial Upper Atmosphere, Ionosphere and Magnetosphere, Cambridge University Press, 1995.

JOSEPH W. CHAMBERLAIN. Physics of the Aurora and Airglow, American Geophysical Union, 1995.

M. H. REES. Physics and Chemistry of the Upper Atmosphere, Cambridge University Press, 1989.

MICHAEL C. KELLEY. The Earth's Ionosphere: Plasma Physics and Electrodynamics, Academic Press Inc., 1989.

GES-301-4 Geomagnetism

Introduction to geomagnetism and historical aspects. Introduction to paleomagnetism. The Earth's main magnetic field and its secular variation. Scalar magnetic potential for representation of the main geomagnetic field. Transient magnetic variations: Solar quiet, Lunar variation, ionospheric disturbances. Latitudinal dependence of transient magnetic variations. South Atlantic Anomaly. Van Allen Belts. Introduction to waves in plasmas. Coordinate systems (B-L, GSE, GSM, SE, SM). Solar-terrestrial coupling. Geomagnetic Pulsations. Geomagnetic Storms. Geomagnetically induced currents. Geomagnetic indices.

Bibliography

AKASOFU, S.; CHAPMAN, S. Solar Terrestrial Physics. Oxford, Oxford University Press, 1972.

CAMPBELL, W.H. Introduction to Geomagnetic Fields. Cambridge, Cambridge University Press, 2003.

CHAPMAN, S.; BARTELS, J. Geomagnetism. Oxford, Claredon Press, vols. 1–2, 1962.

JACOBS, J.A. (ed.) Geomagnetism. London, Academic Press, vols. 1–4, 1987–1991.

MERRIL, R.T.; MCELHINNY, M.W. The Earth’s Magnetic Field: Its History, Origin and Planetary Perspective. London, Academic Press, 1983.

PARKINSON, W.D. Introduction to Geomagnetism. Edinburgh, Scottish Academic Press, 1983.

GES-302-4 Electromagnetic Induction in the Earth

Electromagnetic methods: overview. Electrical resistivity of rocks and minerals. Theory of electromagnetic field propagation in the Earth. Magnetotelluric method (MT). Theory of magnetotellurics over a one-dimensional Earth. Theory of magnetotellurics over a two-dimensional Earth. Field techniques. Origin of the electromagnetic signals. Time series analysis. Processing and modeling. Geophysical applications.

Bibliography

BERDICHEVSKY M.N.; DMITRIEV, V.I. Models and Methods of Magnetotellurics. Berlin, Springer, 2008.

CHAVE, A.D.; JONES, A.J. (EDS.) The Magnetotelluric Method: Theory and Practice. Cambridge, 2012.

SIMPSON, F.; BAHR, K. Practical Magnetotellurics. Cambridge, 2005.

GES-303-4 Airglow

Airglow basic concepts. Historical aspects and first observations. General view on atmospheric emissions. Energy excitation and loss mechanisms present in photochemical airglow processes. Seazonal and nocturnal variations. Spatial variation and propagation of gravity waves. Temeprature and Winds obtained from airglow spectrum. Instrumentation: photometers and spectrophotometers. Current research topics in airglow.

Bibliography

ROACH, F.E. The Light of the Night Sky. D. Reidel, 1973.

CHAMBERLAIN, J.W. Physics of the Aurora and Airglow. New York, Academic, 1961.

McCORMAC, B.M. Aurora and Airglow. Londres, Reinhold, 1967.

REES, M.H. Physics and Chemistry of the Upper Atmosphere. Cambridge

University Press, 1989.

GES-304-4 Plasma Physics II

Prerequisite: GES-204-4

MHD waves. Waves in warm plasmas. Waves in hot plasmas. Charged particle interactions. Instability and equilibium. Landau damping. Boltzmann and Fokker-Planck equations. Transport phenomena in plasmas.

Bibliography

BITTENCOURT, J.A. Fundamentals of Plasma Physics. Oxford, Pergamon Press, 1986.

KRALL, N.A.; TRIVELPIECE, A.W. Principles of Plasma Physics. New York, McGraw-Hill, 1973.

SCHMIDT, G. Physics of High Temperature Plasmas. New York, Academic, 1979.

GES-306-4 Random Signals Analysis

Prerequisite: GES-208-3

Deterministic and random data. Introduction to time series. Fourier analysis. Fourier transform. Linear systems and convolution. Digital filters. Stochastic processes. Autocovariance and autocorrelation functions. Introduction to spectral analysis. Notions on wavelet signal processing

Bibliography

BENDAT, J. S. AND A. G. PIERSOL. Random Data: Analysis and measurement Procedures, Wiley-Interscience, New York, 1971.

DAUBECHIES, I., TEN. Lectures on Wavelets, Society for Industrial and Applied Mathematics, Philadelphia, 1992.

JENKINS, G. M. AND D. G. WATTS. Spectral Analysis and its applications, Holden-Day, San Francisco, 1968.

KING, R., Digital Filtering in One and Two Dimensions: Design and Applications, Plenum Publishing Corporation, 1989.

MALLAT, S. A Wavelet tour of Signal Processing, Academic Press, San Diego, 1998.

GES-313- Atmospheric Chemistry

Introduction: atmosphere, ocean, solid Earth. General description of the atmosphere, layers, regions, extensions. Solar radiation: spectrum, solar emission characteristics and Earth absorption, greenhouse effect. Atmospheric chemistry: Production and loss processes, minority constituents: O2, N2, CO2. Minority constituent cycles. Oxides of N, H and S. Photochemistry of the ozone: stratosphere and troposphere: action of the nitrogen and hydrogen compounds. Pollution effects and its action over the ozone.

Bibliography

KIRCHHOFF, V.W.J.H. Química da atmosfera. São José dos Campos, INPE, 1984. (INPE-3190-PRE/554).

SALBY, M. L. Fundamentals of the Atmospheric Physics. Academic Press, San Diego. 627p. 1996.

SEINFELD J. H. and PANDIS, S. N. Atmospheric Chemistry and Physics – From Air Pollution to Climate Change. John Wiley & Sons, INC. New York. 1326 p. 1998.

GES-314-4 Atmospheric Electricity

Introduction: electric properties of the atmosphere, fair weather electric field, orographic electric field, atmospheric ions and conductivity. Cloud physics: cloud classification, development of a storm cell, electric fields and charge centers in thunderstorms, identification and classification of clouds in meteorological satellite photographs. Storm electrification: separation of charges in clouds on a molecular scale, separation of charges in micro-scale, separation of charges due to gravitational force. Lightning: Phenomenology of lightning, field changes and neutralization of charges by lightning, electric pulses produced by lightning, consequences of lightning in the Ionosphere and Magnetosphere. Global Atmospheric Electric Circuit. Atmospheric Electric Fields.

Bibliography

PIRIBARNE, J.V.; CHO, H.R. Atmospheric Physics. Dordrecht, Reidel, 1980.

MAGONO, C. Thunderstorms. Amsterdam, Elsevier, 1980. (Development in Atmospheric Science, 12).

The Earth's Electrical Environment Studies in Geophysics. Washington, DC, National Academic Press, 1986.

UMAN, M.A. All about Lightning. New York, Dover 1986.

GES-315-4 Atmospheric Electrodynamics

Electromagnetic waves. Maxwell equations. Generation and propagation of waves in the atmosphere. Electrostatic, induction and radiation components. Waveguides. Large-scale electric and magnetic fields in the atmosphere. Field mapping. Electromagnetic fields generated by lightning. Current models for discharges. Electrodynamic structure of the atmosphere.

Bibliography

JACKSON, J.D. Classical Electrodynamics. New York, Wiley, 1975.

VOLLAND, H. Atmospheric Electrodynamics. New York, Springer, 1984.

GES-316-4 Numerical Simulations of Space Plasma Phenomena

Introduction to the elements of finite differences. Euler methods. Leapfrog methods. Lax-Wendrof squeme. Runge-Kuta and implicit methods. Particle simulation: an introduction. Space grids, Weighting function. MHD Simulation: an introduction. Hibryd models.

Bibliography

BIRDSALL, C.K. and LANGDON, A.B. Plasma Physics via Computer Simulation. MacGraw-Hill, 1985.

DAWSON, J.M. Particles Simulations of Plasmas. Rev. Mod. Phys, 55:403-447, April, 1983.

MATSUMOTO, H. and OMURA, Y. Computer Space Plasma Physics, Simulation Tecnhiques and Software, Terra Scientific Pub. Co., Tokio, 1993.

POTTER, D. Computational Physics. John Wiley & Sons., 1973.

GES-401-4 Ionospheric Physics

Prerequisite: GES-205-4

Part I - Formation of the ionosphere. Ionospheric Processes. Chemical processes: main chemical reactions for the formation of E, F1 and F2 layers; chemical reactions for the formation of the D region, negative ions and cluster ions. Physical processes: transport processes, diffusion, and electrodynamical processes in the ionosphere. Ionospheric phenomena: irregularities, spread-F, scintillation, TID's sporadic E-layer, magnetic storm effects in the ionosphere.

Part II - Irregularities of equatorial and low latitude F region; Prompt penetration electric fields in equatorial and low-latitude sectors; Disturbance ionospheric dynamo; Ionospheric modeling: theoretical and empirical.

Part III - Propagation of electromagnetic waves in vacuum and in the ionosphere. Wave polarization. Appleton-Hartree equation. Snell's Law. Phase and group velocity. GNSS and Total Electron Content of the ionosphere. Calculation of TEC. Scintillation. Incoherent scatter radar.

Bibliography

AKASOFU, S.; CHAPMAN, S. Solar Terrestrial Physics. Oxford, Oxford Univ. Press, 1972.

Bailey, G. J., and N. Balan, A low latitude ionosphere-plasmasphere model, in STEP Hand Book of Ionospheric Models, edited by R. W. Schunk, pp. 173-206, Utah State Univ., Logan, 1996

BANKS, P.M.; KOCKARTS, G. Aeronomy. New York, Academic, 1973. Parts A/B.

BRASSEUR, G., SOLOMON, S. Aeronomy of the Middle Atmosphere. Dordrecht, Reidel, 1984.

Davies,K. Ionospheric Radio. Peter Peregrinus Ltd, 1990.

Hoffmann-Wellenhof,B., Lichtenegger,H. ,Wasle,E. GNSS-Global Navigation Satellite Systems - GPS, GLONASS, Galileo, and more. Springer-Verlag Wien, New York. 2008.

KELLEY, M.C. The Earth's Ionosphere: Plasma Physics and Electrodynamics. San Diego, Academic, 1989.

Monico, J.F.G. Posicionamento pelo GNSS. 2ª edição. Editora UNESP, 2008.

RISHBETH, H.; GARRIOTT, O.K. Introduction to Ionospheric Physics. New York, Academic, 1969.

GES-402-4 Dynamics of the Upper Atmosphere

Pre-requirement: GES-200-4

Notions of Fluid Mechanics. Lagrangean and Eulerian flow description. Equation of Continuity, of Motion and Energy of a fluid applied to the atmosphere. The Brunt-Vaissala frequency. The stability of the atmosphere. Approximations in basic equations: quasi-geostrophic flow, plane beta equations, Mean Eulerian model, linearized perturbations. Acoustic-Gravity Waves: mathematical development, dissipative effects, TID's, interactions of Gravity Waves with the ionosphere and Observations. Atmospheric Tides: Classical Theory, observation and recent progress. Planetary Waves. Electrodynamics of the Upper Atmosphere. Effects of wind shear. Dynamo Theory. Thermospheric Dynamics.

Bibliography

ANDREWS, D.G.; HOLTON, J.R.; LEOVY, C.B. Middle Atmosphere Dynamics. New York Academic Press, 1987.

BEER, T. Atmospheric Waves. Adam Hilger, 1975.

CHAPMAN, S.; LINDZEN, R. Atmospheric Tides. Gordon and Breach, 1970.

HOUGHTON, JOHN. The Physics of Atmospheres: Cambridge University Press,2007.

KATO, S. Dynamics of the Upper Atmosphere. Dordrech, D.Reidel, 1980.

GES-403-4 Inner Magnetosphere: Plasmaspheric Physics and Radiation Belts

Prerequisite: GES-202-4

Particle drifts and the first adiabatic invariant. Drift shells and the second and third adiabatic invariant. Particle fluxes, distribution functions and violation of invariants. Collisionless plasmas. Ring Current. Wave-particle and wave-wave interactions. Particle precipitation and, X-ray and ionization in the auroral zone and South Atlantic Anomaly. Dynamics of the Plasmasphere.

Bibliography

Baumjohann, W.; Treumann, R. A. Basic space plasma physics. Imperial College, 1999.

LYONS, L.R.; WILLIANS, D.J. Quantitative Aspects of Magnetospheric Physics. Reidel, 1984.

NORTHROF, T.G. The Adiabatic Motion of Charged Particles. New York, Wiley, 1963.

ROEDERER, J.G. Dynamics of Geomagnetically Trapped Radiation. Berlin, Springer, 1970.

SCHULZ, M.; LANZEROTTI, L.J. Particle Diffusion in the Radiation Belts. Berlin, Springer, 1974

GES-404-4 Non-linear Processes in Plasmas

Prerequisite: GES-204-4

Langmuir non-linear oscilations. Solitons and ion acoustic shock waves. Double layers. Non-linear electromagnetic waves. Ponderomotive force. Non-linear wave-wave interactions. Cavitons and envelope solitons. Turbulence.

Bibliography

DAVIDSON, R. C. Methods in Nonlinear Plasma Theory. New York, Academic, 1972.

HASEGAWA. A. Plasma Instabilities and Nonlinear Effects. Berlin, Springer, 1975.

SAGDEEV, R. Z. and GALEEV, A. A. Nonlinear Plasma Theory. New York, Benjamin, 1969.

Recent papers on the subject.

GES-405-4 Physics of the Outer Magnetosphere

Prerequisite: GES-204-4

Interaction between the solar wind and the geomagnetic field. Open and closed magnetosphere. Geomagnetic storms and substorms. Bow shock. Magnetopause. Magnetic layer. Magnetotail. Plasma sheet and neutral sheet. Solar – interplanetary medium – magnetosphere coupling. Planetary magnetospheres.

Bibliography

KAMIDE, Y.; SLAVIN, J.A. Solar Wind-Magnetosphere Coupling. Dordrech, Reidel, 1986.

KENNEL, C.; LANZEROTTI, L.J.; PARKER, E.N. Solar System Plasma Physics. North Holland, 1979.

LEMAIRE, J.; RYCROFT, M.J., ed. Solar System Plasmas and Fields. Advances in Space Research, 2(1): 01-87, 1982.

NISHIDA, A. Geomagnetic Diagnosis of the Magnetosphere. New York, Springer, 1978.

PARKS, G.K. Physics of Space Plasmas: an Introduction. Redwood City, California, Addison-Wesley, 1991.

GES-409-4 Special Topics in Upper Atmosphere

Advanced topics are covered in Upper Atmosphere. Content varies according to the interest of the moment.

Bibliography

Articles of Specialized Journals.

GES-410-4 Special Topics in Atmospheric Electricity

Advanced topics are covered in Atmospheric Electricity. Content varies according to the interest of the moment.

Bibliography

Articles of Specialized Journals

GES-411-4 Special Topics in Geomagnetism

Advanced topics in Geomagnetism are covered. Content varies according to the interest of the moment.

Bibliography

Articles of Specialized Journals

GES-412-4 Special Topics in Ionosphere

Advanced topics are covered in Ionosphere. Content varies according to the interest of the moment.

Bibliography

Articles of Specialized Journals

GES-413-4 Special Topics in Airglow

Advanced topics are covered in Airglow. Content varies according to the interest of the moment.

Bibliography

Articles of Specialized Journals

GES-414-4 Special Topics in Magnetosphere-Heliosphere

Advanced topics are covered in Magnetosphere-Heliosphere. Content varies according to the interest of the moment.

Bibliography

Articles of Specialized Journals

GES-415-4 Special Topics in Middle and Lower Atmosphere

Advanced topics are covered in Middle and Lower Atmosphere. Content varies according to the interest of the moment.

Bibliography

Articles of Specialized Journals

The auxiliary or final works of the Postgraduate program will be identified in the form indicated below:

GES-730 Master's Degree in Space Geophysics *

0 credits

GES-750 Master's Dissertation in Space Geophysics

24 credits

GES-780 Doctoral Thesis on Space Geophysics *

0 credits

GES-800 Doctoral Thesis on Space Geophysics

36 credits

* Mandatory activity, in each academic period for every student in the Research phase, defined by the formalization of their Research Supervisor that will evaluate the student's performance in this activity. Compulsory, also, before the officialization mentioned for the student who is not enrolled in any discipline; in this case, the orientation and evaluation should be made by a Faculty member approved by the Academic Coordinator.