Tropospheric Propagation Delay: A Bibliography

compiled by

Richard B. Langley, Wendy Wells, and Vírgilio de Brito Mendes

Geodetic Research Laboratory
Department of Geodesy and Geomatics Engineering
University of New Brunswick

2nd Edition • 22 April 1995

This list of 422 publications dealing in whole or in part with the propagation delay of electromagnetic waves in the troposphere has been extracted from *The GPS Bibliography* published by Canadian GPS Associates, Fredericton, N.B., and other sources. The publications listed mostly relate to the modelling and estimation of propagation delay (both the dry/hydrostatic and wet components) in Global Positioning System, very long baseline interferometry, satellite Doppler, and satellite altimetry observations, but some relevant publications dealing with the physics and chemistry of the troposphere and propagation at visible light wavelengths are also included.

We would like to make this bibliography as complete as possible — especially with regard to the most recent literature on the subject — and so welcome suggestions for additions to the list which will be incorporated into future editions. Thanks to Dr. Gunnar Elgered of Chalmers University's Onsala Space Observatory, Onsala, Sweden, for suggesting a number of items which have been included in this edition.

Please send your suggestions and comments to

Richard B. Langley
Geodetic Research Laboratory
Dept. of Geodesy and Geomatics Engineering
University of New Brunswick
P.O. Box 4400
Fredericton, N.B., Canada
E3B 5A3

Fax: (506) 453-4943
E-mail:lang@unb.ca

[1] Abshire, J. B., and C. S. Gardner (1985). Atmospheric refractivity corrections in satellite laser ranging. *IEEE Transactions on Geoscience and Remote Sensing*, July, Vol. GE-23, No. 4, pp. 414-425.

[2] Akhundov, T. A., and A. A. Stotskii (1992). Zenith angle dependence of path length through the troposphere. *Proceedings of Symposium on Refraction of Transatmospheric Signals in Geodesy,* Eds. J. C. de Munck, T. A. Th. Spoelstra, The Hague, The Netherlands, 19-22 May, Netherlands Geodetic Commission, Publications on Geodesy, Delft, The Netherlands, No. 36, New Series, pp. 37-41.

[3] Akhundov, T. A., V. N. Alexeev, G. B. Baykov, and A. A. Stotskii (1992). Tools of troposphere correction for VLBI network "Quasar. " *Proceedings of Symposium on Refraction of Transatmospheric Signals in Geodesy,* Eds. J. C. de Munck, T. A. Th. Spoelstra, The Hague, The Netherlands, 19-22 May, Netherlands Geodetic Commission, Publications on Geodesy, Delft, The Netherlands, No. 36, New Series, pp. 63-64.

[4] Alishouse, J. C., S. A. Snyder, J. Vongsathorn, and R. R. Ferraro (1990). Determination of oceanic total precipitable water from the SSM/I. *IEEE Transactions on Geoscience and Remote Sensing,* Vol. GE-28, pp. 811-816.

[5] Allnutt, J. E. (1989). *Satellite-to-Ground Radiowave Propagation: Theory, Practice and System Impact at Frequencies above 1 GHz.* Peter Peregrinus Ltd., London, United Kingdom, 413 pp.

[6] Altshuler, E. E., and P. M. Kalaghan (1974). Tropospheric range error corrections for the NAVSTAR system. Interim scientific report Air Force Cambridge Research Laboratories, Bedford, Mass., 16. April, AFCRL-TR-74-0198, 13 pp.

[7] Altshuler, E. E., and K. Mano (1982). Tropospheric refraction corrections using exoatmospheric sources. Rome Air Development Center, Air Force Systems Command, Griffiss Air Force Base, N. Y., January, RADC-TR-82-7, 18 pp.

[8] American Geophysical Union (1977). *National Geodetic Satellite Program.* National Aeronautics and Space Administration, Washington, D. C., NASA SP-365, Part I, pp. 110-113, 168, 494, 499, 860-861.

[9] Angus-Leppan, P. V. (1960). A study of refraction in the lower atmosphere. Department of Surveying, University of Natal, Natal, South Africa, Nos. 121, 122, pp. 62-119; 166-177.

[10] Armstrong, J. W., and R. A. Sramek (1982). Observations of tropospheric phase scintillations at 5 GHz on vertical paths. *Radio Science,* November-December, Vol. 17, No. 6, pp. 1579-1586.

[11] Ashkenazi, V., S. A. Crane, and R. M. Sykes (1982). The significance of various approaches to the tropospheric correction. *Proceedings of Third International Geodetic Symposium on Satellite Doppler Positioning,* DMA, NOS, Las Cruces, N. Mex., 8-12 February, Physical Science Laboratory, New Mexico State University, Las Cruces, N. Mex., Vol. I, pp. 463-474.

[12] Askne, J., and H. Nordius (1987). Estimation of tropospheric delay for microwaves from surface weather data. *Radio Science,* May-June, Vol. 22, No. 3, pp. 379-386.

[13] Askne, J. I. H., and E. R. Westwater (1986). A review of ground-based remote sensing of temperature and moisture by passive microwave radiometers. *IEEE Transactions on Geoscience and Remote Sensing,* May, Vol. GE-24, No. 3, pp. 340-352.

[14] Babin, S. M., R. E. Miller, and J. R. Rowland (1993). A high-power, dual-frequency monostatic acoustic sounder for studying the atmosphere boundary-layer. *Journal of Atmospheric and Oceanic Technology*, Vol. 10, No. 4, pp. 486-492.

[15] Baby, H. B., P. Golé, and J. Lavergnat (1988). A model for the tropospheric excess path length of radio waves from surface meteorological measurements. *Radio Science*, November-December, Vol. 23, No. 6, pp. 1023-1038.

[16] Barrell, H. (1951). The dispersion of air between 2500A and 6500A. *Journal of the Optical Society of America*, May, Vol. 41, No. 5, pp. 295-299.

[17] Barrett, A. H. and V. K. Chung (1962). A method for the determination of high-altitude water-vapor abundance from ground-based microwave observations. *Journal of Geophysical Research*, Vol. 67, pp. 4259-4266.

[18] Basker, G. A., I. E. Casewell, G. W. Hein, H. Landau, B. Forsell, and O. P. Håkegård (1993). A wide area differential GPS using code and carrier phase observations. Collected papers of DSNS 93, Second International Symposium on Differential Satellite Navigation Systems, Amsterdam, The Netherlands, 29 March-2 April, 8 pp.

[19] Bean, B. R. (1962). The radio refractive index of air. *Proceedings of IRE*, March, pp. 260-273.

[20] Bean, B. R., and E. J. Dutton (1966). Radio Meteorology. National Bureau of Standards Monograph 92, U.S.Government Printing Office, Washington, D. C., 435 pp.

[21] Bean, B. R., and R. E. McGavin (1967). A review of refraction effects on the apparent angle of arrival of radio signals. Chapter 5-8 in *Propagation Factors in Space Communications*, Proceedings of Ionospheric Research Committee of Avionics Panel of AGARD/NATO, Rome, Italy, 21-25 September 1965, Technivision, Maidenhead, England, AGARD Conference Proceedings No. 3, pp. 529-546.

[22] Bean, B. R., and G. D. Thayer (1959). Models of the atmospheric radio refractive index. *Proceedings of IRE*, May, Vol. 47, pp. 740-755.

[23] Becker, G. E. and S. H. Autler (1946). Water vapor absorption of electromagnetic radiation in the centimeter wave-length region. *Physical Review*, Vol. 70, pp. 300-307.

[24] Beckman, B. (1985). A water-vapor radiometer error model. *IEEE Transactions on Geoscience and Remote Sensing*, July, Vol. GE-23, No. 4, pp. 474-478.

[25] Belobrova, M. V., V. K. Ivanov, A. V. Kukushkin, M. B. Levin, and J. A. Fastovsky (1989). Prediction system on UH[F] radio propagation conditions over the sea. Institute of Radio Astronomy, U.S.S.R. Academy of Sciences, Moscow, U.S.S.R., No. 31, 38 pp. In Russian.

[26] Bender, P. L. (1992). Atmospheric refraction and satellite laser ranging. *Proceedings of Symposium on Refraction of Transatmospheric Signals in Geodesy*, Eds. J. C. de Munck, T. A. Th. Spoelstra, The Hague, The Netherlands, 19-22 May, Netherlands Geodetic Commission, Publications on Geodesy, Delft, The Netherlands, No. 36, New Series, pp. 117-125.

[27] Berman, A. L. (1970). A new tropospheric range refraction model. *Space Programs Summary* 37-65, Vol. II, Jet Propulsion Laboratory, Pasadena, CA, 30 September, pp. 140-153.

[28] Berman, A. L. (1976). The prediction of zenith range refraction from surface measurements of meteorological parameters. Jet Propulsion Laboratory, California Institute of

Technology, Pasadena, Calif., 15 July, National Aeronautics and Space Administration Technical Report 32-1602, 40 pp.

[29] Bernard, R., A. Lecornec, L. Eymard, and L. Tabary (1993). The microave radiometer aboard ERS-1 [1] Characteristics and performances. *IEEE Transactions on Geoscience and Remote Sensing*, Vol. GE-31, No. 6, pp. 1186-1198.

[30] Bevis, M., S. Businger, S. Chiswell, T. A. Herring, R. A. Anthes, C. Rocken, and R. H. Ware (1994). GPS meteorology — Mapping zenith wet delays onto precipitable water. *Journal of Applied Meteorology*, Vol. 33, No. 3, pp. 379-386.

[31] Beutler, G., and W. Gurtner (1987). The influence of atmospheric refraction on the evaluation of GPS phase observations. Satellitenbeobachtungsstation Zimmerwald, April, Bericht Nr. 16, 9 pp.

[32] Beutler, G., W. Gurtner, M. Rothacher, U. Wild, and E. Frei (1990). Relative static positioning with the Global Positioning System: Basic technical considerations. In: *Global Positioning System: An Overview*, Proceedings of International Association of Geodesy Symposium No. 102, Eds. Y. Bock, N. Leppard, Edinburgh, Scotland, 7-8 August 1989, Springer-Verlag, New York Berlin, pp. 1-23.

[33] Beutler, G., I. Bauersima, W. Gurtner, M. Rothacher, T. Schildknecht, and A. Geiger (1987). Atmospheric refraction and other important biases in GPS carrier phase observations. In: *GPS Papers Presented by the Astronomical Institute of the University of Berne in 1987*, Ed. W. Gurtner, Mitteilungen der Satellitenbeobachtungsstation Zimmerwald, University of Berne, Berne, Switzerland, Nr. 22, 26 pp.

[34] Bevis, M., S. Businger, T. A. Herring, C. Rocken, R. A. Anthes, and R. H. Ware (1992). GPS meterology: Remote sensing of atmospheric water vapor using the Global Positioning System. *Journal of Geophysical Research — Atmospheres*, Vol. 97, No. D14, pp. 15,787-15801.

[35] Bhattacharya, C. K., and G. S. Uppal (1987). Determination of cloud liquid and precipitable water vapor by ground-based microwave radiometers. *IEEE Transactions on Geoscience and Remote Sensing*, July, Vol. GE-25, No. 4, pp. 472-476.

[36] Bilitza, D. (1990). Solar-terrestrial models and application software. National Space Science Data Center, World Data Center A for Rockets and Satellites, Goddard Space Flight Center, Greenbelt, Md., July, NSSDC/WDC-A-R&S 90-19, 98 pp.

[37] Birnbaum, G. and S. K. Chatterjee (1952). The dielectric constant of water vapor in the microwave region. *Journal of Applied Physics*, Vol. 23, pp. 220-223.

[38] Bisagni, J. J. (1989). Wet tropospheric range corrections for satellite altimeter-derived dynamic topographies in the western North Atlantic. *Journal of Geophysical Research*, 15 March, Vol. 94, No. C3, pp. 3247-3254.

[39] Black, H. D. (1978). An easily implemented algorithm for the tropospheric range correction. *Journal of Geophysical Research*, 10. April, Vol. 83, No. B4, pp. 1825-1828.

[40] Black, H. D., and A. Eisner (1982). Correcting satellite Doppler data for tropospheric effects. Presented at Third International Symposium on the Use of Artificial Satellites for Geodesy and Geodynamics, Athens, Greece, 20-25 September.

[41] Black, H. D., and A. Eisner (1983). Correcting satellite Doppler data for tropospheric effects. Applied Physical Laboratory, The Johns Hopkins University, Laurel, Md., March, JHU/APL SDO 6777, 36 pp.

[42] Black, H. D., and A. Eisner (1984). Correcting satellite Doppler data for tropospheric effects. *Journal of Geophysical Research,* 20. April, Vol. 89, No. D2, pp. 2616-2626.

[43] Black, H. D., and A. Eisner (1986). A new technique for monitoring the water vapor in the atmosphere. *Journal of Geophysical Research*, 15. February, Vol. 91, No. C2, pp. 2331-2337.

[44] Boudouris, G. (1963). On the index of the refraction of the air, the absorption and dispersion of centimeter waves by gases. *Journal of Research of the National Bureau of Standards*, Vol. 67D, pp. 631-684.

[45] Brown, A., and F. van Diggelen (1994). Boundary layer tropospheric effects on airborne on-the-fly ambiguity resolution. *KIS94*, Proceedings of the International Symposium on Kinematic Systems in Geodesy, Geomatics and Navigation, Banff, Alberta, 30 August - 2 September, The University of Calgary, Calgary, Alberta, Canada, pp. 99-108.

[46] Brunner, F. K. (1979). Atmospheric turbulence: The limiting factor to geodetic precision. *Australian Journal of Geodesy, Photogrammetry and Surveying,* December, No. 31, pp. 51-64.

[47] Brunner, F. K. (1981). The atmospheric effects on electromagnetic distance measurements in geodetic networks. Presented at International Association of Geodesy VI International Symposium on Geodetic Networks and Computations, Munich, Germany, 31 August-5 September, Department of Geodetic Science, University of Stuttgart, Stuttgart, Germany, 12 pp.

[48] Brunner, F. K. (1988). IAG Special Study Groups 2. 84 (atmospheric effects on geodetic space measurements), 4. 93 (wave propagation in refractive media). Final report for International Association of Geodesy, The University of New South Wales, School of Surveying, Kensington, New South Wales, Australia, April, 11 pp.

[49] Brunner, F. K. (1992). GPS high accuracy with long observation sessions: first results. *Proceedings of Sixth International Geodetic Symposium on Satellite Positioning*, IAG, AGU, ACSM, NOAA, U.S.GS, Columbus, Ohio, 17-20 March, Vol. II, pp. 935-944.

[50] Brunner, F. K. (1992). Wave propagation in refractive media: A progress report. Report of International Association of Geodesy Special Study Group 4. 93 (1987-1991), February, 12 pp.

[51] Brunner, F. K. (1994). On the deformation of GPS networks. *Proceedings of FIG XX Congress,* Melbourne, Australia, 5-12 March, Commission 5, No. TS 501. 4, 8 pp.

[52] Brunner, F. K., and S. McCluskey (1991). Tropospheric zenith delay parameteres: How many should be estimated in GPS processing. *Australian Journal of Geodesy, Photogrammetry, and Surveying,* December, No. 55, pp. 67-75.

[53] Brunner, F. K., and J. M. Rüeger (1992). Theory of the local scale parameter method for EDM. *Bulletin Géodésique*, Vol. 66, pp. 355-364.

[54] Brunner, F. K., and P. Tregoning (1994). Investigation of height repeatability from GPS measurements. *Australian Journal of Geodesy, Photogrammetry, and Surveying*, June, No. 60, pp. 33-48.

[55] Brunner, F. K., and P. Tregoning (1994). Tropospheric propagation effects in GPS height results using meteorological observations. *Australian Journal of Geodesy, Photogrammetry, and Surveying,* June, No. 60, pp. 49-65.

[56] Brunner, F. K., and W. M. Welsch (1993). Effect of the troposphere on GPS measurements. *GPS World,* January, Vol. 4, No. 1, pp. 42-51.

[57] Brunner, F. K., and D. C. Williams (1982). On the correction for humidity in two colour refraction measurement. *Zeitschrift für Vermessungswesen,* Vol. 3, pp. 108-118.

[58] Brussaard, G. (1981). Prediction of attenuation due to rainfall on earth-space links. *Radio Science,* September-October, Vol. 16, No. 5, pp. 745-760.

[59] Burki, B., M. Cocard, A. Geiger, R. Gyger, and H. G. Kahle (1992). Development of a portable dual frequency microwave water vapor radiometer for geodetic applications. *Proceedings of Symposium on Refraction of Transatmospheric Signals in Geodesy,* Eds. J. C. de Munck, T. A. Th. Spoelstra, The Hague, The Netherlands, 19-22 May, Netherlands Geodetic Commission, Publications on Geodesy, Delft, The Netherlands, No. 36, New Series, pp. 129-133.

[60] Callahan, P. S. (1971). Prediction of tropospheric wet-component range error from surface measurements. Jet Propulsion Laboratory, California Institute of Technology, Pasadena, Calif., JPL Technical Report 32-1526, Vol. XVIII, pp. 41-46.

[61] Canada Department of Transportation (1953). The bimetal thermograph Instrument Manual 21. Meteorological Branch, Department of Transport, Toronto, Ontario, 14. April, CIR 2270 INS 49, 6 pp.

[62] Canada Department of Transportation (1957). Barographs Instrument Manual 11. Meteorological Branch, Department of Transport, Toronto, Ontario, 19. July, CIR 2943, INS 82, 17 pp.

[63] Chao, C. C. (1971). A new method to predict wet zenith range correction from surface measurements. Jet Propulsion Laboratory, California Institute of Technology, Pasadena, Calif., JPL Technical Report 32-1526, Vol. XIV, pp. 33-41.

[64] Chao, C. C. (1971). New tropospheric range corrections with seasonal adjustment. Jet Propulsion Laboratory, California Institute of Technology, Pasadena, Calif., 15 December, JPL Technical Report 32-1526, Vol. VI, pp. 67-82.

[65] Chao, C. C. (1971). Tropospheric range effect due to simulated inhomogeneities by ray tracing. Jet Propulsion Laboratory, California Institute of Technology, Pasadena, Calif., 15 December, JPL Technical Report 32-1526, Vol. VI, pp. 57-66.

[66] Chao, C. C. (1971). The tropospheric calibration model for Mariner Mars 1971. Jet Propulsion Laboratory, California Institute of Technology, Pasadena, Calif., JPL Technical Report 32-1587, pp. 61-76.

[67] Chao, C. C. (1972). A model for tropospheric calibration from daily surface and radiosonde balloon measurement. Jet Propulsion Laboratory, Pasadena, Calif., 8. August, Technical Memorandum 391-350, 16 pp.

[68] Chao, C. C. (1973). A new method to predict wet zenith range correction from surface measurements. In: The Deep Space Network Progress Report, Jet Propulsion Lab, Pasadena, Calif., JPL Technical Report 32-1526, Vol. XIV, pp. 33-41.

[69] Chao, C. C. (1974). The tropospheric calibration model for Mariner Mars 1971. Jet Propulsion Laboratory, California Institute of Technology, Pasadena, Calif., March, JPL Technical Report 32-1587, pp. 61-76.

[70] Christensen, E. J., B. J. Haines, S. J. Keihm, C. S. Morris, R. A. Norman, G. H. Purcell, B. G. Williams, B. D. Wilson, G. H. Born, M. E. Parke, S. K. Gill, C. K. Shum,

B. D. Tapley, R, Kolenkiewicz, and R. S. Nerem (1994). Calibration of TOPEX/Poseidon at Platform Harvest. *Journal of Geophysical Research*, Vol. 99, No. C12, pp. 24465-24485.

[71] Clynch, J. R., and D. S. Coco (1986). Error characteristics of high quality geodetic GPS measurements: Clocks, orbits, and propagation effects. *Proceedings of Fourth International Geodetic Symposium on Satellite Positioning*, DMA, NGS, Austin, Tex., 28 April-2 May, Applied Research Laboratories, University of Texas at Austin, Austin, Tex., Vol. I, pp. 539-556.

[72] Claud, C., N. M. Mognard, K. B. Katsaros, A. Chedin, and N. A. Scott (1993). Satellite-observations of a polar low over the Norwegian Sea by special sensor microwave imager, Geosat, and TIROS-N operational vertical sounder. *Journal of Geophysical Research*, Vol. 98, No. C8, pp. 14487-14506.

[73] Cocard, M., V. Eckert, A. Geiger, B. Bürki, and B. Neininger (1992). Three-dimensional modelling of atmospheric parameters for automatic path delay corrections. *Proceedings of Symposium on Refraction of Transatmospheric Signals in Geodesy*, Eds. J. C. de Munck, T. A. Th. Spoelstra, The Hague, The Netherlands, 19-22 May, Netherlands Geodetic Commission, Publications on Geodesy, Delft, The Netherlands, No. 36, New Series, pp. 175-178.

[74] Coco, D. S., and J. R. Clynch (1982). The variability of the tropospheric range correction due to water vapor fluctuations. *Proceedings of Third International Geodetic Symposium on Satellite Doppler Positioning*, DMA, NOS, Las Cruces, N. Mex., 8-12 February, Physical Science Laboratory, New Mexico State University, Las Cruces, N. Mex., Vol. I, pp. 475-495.

[75] Cole, A. E., and A. J. Kantor (1978). Air Force reference atmospheres. Air Force Geophysics Laboratory, Meteorology Division, Hanscom AFB, Mass., 28 February, AFGL-TR-78-0051; AFGL-AFSG-382, 78 pp.

[76] Comoretto, G., B. Bertotti, L. Iess, and R. Ambrosini (1992). Doppler experiments with Cassini radio syatem. *Nuovo Cimento Della Societa Italiana di Fisica C - Geophysics and Space Physics*, Vol. 15, No. 6, pp. 1193-1198.

[77] Com-Rad Electronic Equipment Ltd. (1988). Correction of distance for the effects of refractive index of the atmosphere in the CR. 234 Geomensor. South Wales, United Kingdom, Working Paper CR. 234/1, 10 pp.

[78] Connor, J. (1984). Tropospheric propagation event. *QST*, December, p. 51.

[79] Coster, A. J., and E. M. Gaposchkin (1989). Use of GPS pseudo-range and phase data for measurement of ionospheric and tropospheric refraction. *ION GPS-89*, Proceedings Second International Technical Meeting of the Satellite Division of The Institute of Navigation, Colorado Springs, Colo., 27-29 September, The Institute of Navigation (U.S.), Washington, D. C., pp. 439-443.

[80] Crane, R. K. (1976). Structure of the neutral atmosphere. Chapter 2.3 in *Astrophysics, Part B: Radio Telescopes*, Vol. 12 of Methods of Experimental Physics, Ed. M. L. Meeks, Academic Press, New York, NY, pp. 136-141.

[81] Crane, R. K. (1976). Refraction effects in the neutral atmosphere. Chapter 2.5 in *Astrophysics, Part B: Radio Telescopes*, Vol. 12 of Methods of Experimental Physics, Ed. M. L. Meeks, Academic Press, New York, NY, pp. 186-200.

[82] Croskey, C. L., C. R. Philbrick, J. P. Martone, T. D. Stevens, P. A. T. Haris, J. J. Olivero, S. E. Puliafito, and S. C. McKinley (1993). A comparison of microwave

radiometer, lidar, and meteorological balloon observations of water vapor during the Ladimas campaign. Presented at COMEAS'93, Albuquerque, NM, 22-25 March.

[83] Crutcher, H. L. (1969). Temperature and humidity in the troposphere. Chapter 3 in *Climate of the Free Atmosphere*, Ed. D. F. Rex, Elsevier Publishing Company, Amsterdam, Vol. 4 of World Survey of Climatology, pp. 45-83. ISBN: 444-40703-0.

[84] Davis, J. L. (1986). *Atmospheric Propagation Effects on Radio Interferometry*. Ph.D. thesis, Massachusetts Institute of Technology, Cambridge, MA. Scientific Report No. 1, AFGL-TR-86-0243, Air Force Geophysics Laboratory, United States Air Force, Hanscom Air Force Base, MA, April, 276 pp.

[85] Davis, J. (1989). Preliminary results of September 1988 Colorado WVR/GPS experiment. Memo to NASA water-vapor radiometer panel Boulder, Colo. (?), 16 March, 22 pp.

[86] Davis, J. (1989). Preliminary results of September 1988 Colorado WVR/GPS experiment. Memo for members of IAG SSG 4. 93, U.S.Department of the Interior, Geological Survey, May, 22 pp.

[87] Davis, J. L. (1992). The effect of turbulence on atmospheric gradient parameters estimated from ground-based radiometric and space geodetic measurements. *Geophysical Research Letters*, Vol. 19, pp. 2183-2186.

[88] Davis, J., and T. Herring (1984). New atmospheric mapping function. Internal memo, Center for Astrophysics, Harvard College Observatory, Smithsonian Astrophysical Observatory, Cambridge, Mass., 30 July, 19 pp.

[89] Davis, J. L., T. A. Herring, and I. I. Shapiro (1991). Effects of atmospheric modeling errors on determinations of baseline vectors from very long baseline interferometry. *Journal of Geophysical Research,* 10 January, Vol. 96, No. B1, pp. 643-650.

[90] Davis, J. L., G. Elgered, A. E. Niell, and I. I. Shapiro (1992). Horizontal gradients in the "wet" atmospheric propagation delay. *Proceedings of Symposium on Refraction of Transatmospheric Signals in Geodesy*, Eds. J. C. de Munck, T. A. Th. Spoelstra, The Hague, The Netherlands, 19-22 May, Netherlands Geodetic Commission, Publications on Geodesy, Delft, The Netherlands, No. 36, New Series, pp. 25-28.

[91] Davis, J. L., T. A. Herring, I. I. Shapiro, A. E. E. Rogers, and G. Elgered (1985). Geodesy by radio interferometry: Effects of atmospheric modeling errors on estimates of baseline length. *Radio Science*, November-December, Vol. 20, No. 6, pp. 1593-1607.

[92] Davis, J. L., G. Elgered, A. E. Niell, and C. E. Kuehn (1993). Ground-based measurement of gradients in the "wet" radio refractivity of air. *Radio Science*, November-December, Vol. 28, No. 6, pp. 1003-1018.

[93] Decker, M. T., E. R. Westwater, and F. O. Guiraud (1978). Experimental evaluation of ground-based microwave radiometric sensing of atmospheric temperature and water vapor profiles. J*ournal of Applied Meteorology*, Vol. 17, pp. 1788-1795.

[94] de Jong, C. (1991). GPS — Satellite orbits and atmospheric effects. Delft University of Technology, Mathematical and Physical Geodesy, Delft, The Netherlands, February, Reports of the Faculty of Geodetic Engineering 91. 1, 112 pp.

[95] Demoz, B. B., and A. W. Huggins (1992). Comparison of two dual channel microwave radiometers in the Sierra Nevada. *Proceedings of the Specialist Meeting on Microwave Radiometry and Remote Sensing Applications*, Boulder, CO, Ed. E. R. Westwater.

[96] Dicke, R. H., R. Beringer, R. L. Kyhl, and A. B. Vane (1946). Atmospheric absorption measurements with a microwave radiometer. *Physical Review,* September, 5 & 6, Vol. 70, pp. 340-348.

[97] Dickinson, D. F., M. D. Grossi, and M. R. Pearlman (1970). Refractive corrections in high-accuracy radio interferometry. *Journal of Geophysical Research,* Vol. 75, No. 8, pp. 1619-1621.

[98] Dixon, T. H. (1991). An introduction to the Global Positioning System and some geological applications. *Reviews of Geophysics,* Vol. 29, No. 2, pp. 249-276.

[99] Dixon, T. H., and S. K. Wolf (1990). Some tests of wet tropospheric calibration for the CASA UNO Global Positioning System experiment. *Selected Papers on The First Epoch Global Positioning System (GPS) campaign in Central and South America (CASA UNO),* reprinted from Geophysical Research Letters, Vol. 17, No. 3, pp. 203-206.

[100] Dodson, A. H. (1986). Refraction and propagation delays in space geodesy. *International Journal of Remote Sensing,* Vol. 7, No. 4, pp. 515-524.

[101] Dodson, A. H., P. Shardlow, G. Elgered, and P. O. J. Jarlemark (1992). Wet path delay effects on precise GPS height determinations. *Proceedings of Symposium on Refraction of Transatmospheric Signals in Geodesy,* Eds. J. C. de Munck, T. A. Th. Spoelstra, The Hague, The Netherlands, 19-22 May, Netherlands Geodetic Commission, Publications on Geodesy, Delft, The Netherlands, No. 36, New Series, pp. 111-114.

[102] Dugas, R. L. (1978). AOES refraction model improvements for model 15. 3A. Technical Memorandum of System Development Corporation, Santa Monica, Calif., 20 February, TM-(L)-6031/000/00, 26 pp.

[103] Elgered, G. K. (1982). Tropospheric wet path-delay measurements. *IEEE Transactions on Antennas and Propagation,* May, Vol. AP-30, No. 3, pp. 502-505.

[104] Elgered, G. (1982). Water vapor radiometry: Application to geodetic radio interferometry. *Geodetic Applications of Radio Interferometry,* Proceedings of International Association of Geodesy Symposium No. 5, Tokyo, Japan, 7-8 May, NOAA Technical Report NOS 95 NGS 24, pp. 192-200.

[105] Elgered, G. (1983). Water Vapor Radiometry with Applications to Radio Interferometry and Meteorology. Ph.D. thesis, Chalmers University of Technology, Göteborg, Sweden.

[106] Elgered, G. (1992). Correction of the electrical path delay by microwave radiometry. *Proceedings of the Specialist Meeting on Microwave Radiometry and Remote Sensing Applications,* Boulder, CO, Ed. E. R. Westwater, pp. 311-316.

[107] Elgered, G. (1992). Refraction in the troposphere. *Proceedings of Symposium on Refraction of Transatmospheric Signals in Geodesy,* Eds. J. C. de Munck, T. A. Th. Spoelstra, The Hague, The Netherlands, 19-22 May, Netherlands Geodetic Commission, Publications on Geodesy, Delft, The Netherlands, No. 36, New Series, pp. 13-19.

[108] Elgered, G. (1993). Tropospheric radio-path delay from ground-based microwave radiometry. Reprinted from Chapter 5 in: *Atmospheric Remote Sensing by Microwave Radiometry,* Ed. M. A. Janssen, John Wiley & Sons, Inc., pp. 215-258.

[109] Elgered, G., and G. Lundqvist (1984). A three-year study of radio wave propagation delays due to tropospheric water vapor. *IEEE Transactions on Antennas and Propagation,* April, Vol. AP-32, No. 4, pp. 390-395.

[110] Elgered, G. and G. Lundqvist (1984). *Calibration of the Excess Propagation Path for Radio Waves in the Neutral Atmosphere*. Onsala Space Observatory Technical Memorandum 1984.07.06, Onsala, Sweden.

[111] Elgered, G., J. M. Johansson, and J. L. Davis (1994). Comparison of wet delay estimates using VLBI, GPS, and WVR at the Onsala Space Observatory. International Earth Rotation Service Technical Note Number 16, Eds. J. O. Dickey and M. Feissel, Observatoire de Paris, Paris, France, Part IV, pp. 67-70.

[112] Elgered, G., J. M. Johansson, and B. O. Rönnäng (1990). Characterizing atmospheric water vapour fluctuations using microwave radiometry. Report for the European Space Agency, by Department of Radio and Space Science with Onsala Space Observatory, Chalmers University of Technology, Göteborg, Sweden, Research Report No. 165, 132 pp.

[113] Elgered, G., B. O. Rönnäng, and J. I. H. Askne (1982). Measurements of atmospheric water vapor with microwave radiometry. *Radio Science,* Vol. 17, No. 5, pp. 1258-1264.

[114] Elgered, G., J. L. Davis, T. A. Herring, and I. I. Shapiro (1991). Geodesy by radio interferometry: Water vapor radiometry for estimation of the wet delay. *Journal of Geophysical Research,* 10 April, Vol. 96, No. B4, pp. 6541-6555.

[115] Elgered, G., B. Rönnäng, E. Winberg, and J. Askne (1985). Satellite-Earth range measurements: 1. Correction of the excess path length due to atmospheric water vapour by ground based microwave radiometry. Research Laboratory of Electronics and Onsala Space Observatory, Chalmers University of Technology, Gothenburg, Sweden, Research Report No. 147, 112 pp.

[116] Emery, W. J., G. H. Born, D. G. Baldwin, and C. L. Norris (1990). Satellite-derived water vapor corrections for Geosat altimetry. *Journal of Geophysical Research,* 15 March, Vol. 95, No. C3, pp. 2953-2964.

[117] England, M. N., R. A. Ferrare, S. H. Melfi, D. N. Whiteman, and T. A. Clark (1992). Atmospheric water vapor measurements: Comparison of microwave radiometry and lidar. *Journal of Geophysical Research,* Vol. 97, No. D1, pp. 899-916.

[118] England, M. N., F. J. Schmidlin, and J. M. Johansson (1993). Atmospheric moisture measurements: a microwave radiometer - radiosonde comparison. *IEEE Transactions on Geoscience and Remote Sensing,* Vol. GE-31, No. 2, pp. 389-398.

[119] Environmental Science Services Administration, National Aeronautics and Space Administration, and United States Air Force (1966). U.S.Standard Atmosphere Supplements, 1966. U.S.Government Printing Office, Washington, D. C., 290 pp.

[120] Essen, L. and K. D. Froome (1951). The refractive indices and dielectric constants of air and its principal constituents at 24,000 Mc/s. *Proceedings of the Royal Society B,* Vol. 64, pp. 862-875.

[121] Estefan, J. A., and O. J. Sovers (1994). *A comparative survey of current and proposed tropospheric refraction-delay models for DSN radio metric data calibration*. JPL Publication 94-24, Jet Propulsion Laboratory, Pasadena, CA, October, 53 pp.

[122] Eymard, L., A. Lecornec, and L. Tabary (1994). The ERS-1 microwave radiometer. *International Journal of Remote Sensing,* Vol. 15, No. 4, pp. 845-857.

[123] Fante, R. L. (1975). Electromagnetic beam propagation in turbulent media. *Proceedings of the IEEE,* December, Vol. 63, No. 12, pp. 1669-1692.

[124] Fante, R. L. (1980). Electromagnetic beam propagation in turbulent media: An update. *Proceedings of the IEEE*, November, Vol. 68, No. 11, pp. 1424-1443.

[125] Fehsenfeld, F. C., and D. L. Albritton (1980). The role of water vapor in the ion chemistry of the atmosphere. In: *Atmospheric Water Vapor*, Eds. Deepak, Wikerson and Ruhnke, Academic Press, N. Y., pp. 587-597.

[126] Flock, W. L., S. D. Slobin, and E. K. Smith (1982). Propagation effects on radio range and noise in earth-space telecommunications. *Radio Science*, November-December, Vol. 17, No. 6, pp. 1411-1424.

[127] Fu, L. L., E. J. Christensen, C. A. Yamarone, M. Lefebvre, Y. Menard, M. Dorrer, and P. Escudier (1994). TOPEX/Poseidon mission overview. *Journal of Geophysical Research*, Vol. 99, No. C12, pp. 24369-24381.

[128] Gallini, T. E. (1994). A survey of tropospheric refraction models. Contract report for Space and Missile Systems Center, Air Force Materiel Command, Los Angeles, Calif., by satellite Navigation Department, Systems Engineering Division, The Aerospace Corporation, El Segundo, Calif., 20 April, Aerospace Report No. TOR-94(4488)-11, 32 pp.

[129] Gardner, C. S. (1976). Effects of horizontal refractivity gradients on the accuracy of laser ranging to satellites. *Radio Science*, Vol. 11, No. 12, pp. 1037-1044.

[130] Gardner, C. S. (1976). Effects of random path fluctuations on the accuracy of laser ranging systems. *Applied Optics*, October, Vol. 15, No. 10, pp. 2539-2545.

[131] Gardner, C. S. (1977). Correction of laser tracking data for the effects of horizontal refractivity gradients. *Applied Optics*, September, Vol. 16, No. 9, pp. 2427-2432.

[132] Gardner, C. S., J. R. Rowlett, and B. E. Hendrickson (1978). Ray tracing evaluation of a technique for correcting the refraction errors in satellite tracking data. *Applied Optics*, 1 October, Vol. 17, No. 19, pp. 3143-3145.

[133] Gary, B. L., S. J. Keihm, and M. A. Janssen (1985). Optimum strategies and performance for the remote sensing of path-delay using ground-based microwave radiometers. *IEEE Transactions on Geoscience and Remote Sensing*, Vol. GE-23, pp. 479-484.

[134] Goad, C. C., and L. Goodman (1974). A modified Hopfield tropospheric refraction correction model. Presented at American Geophysical Union Fall Annual Meeting, San Francisco, Calif., 12-17 December, 28 pp.

[135] Goldfinger, A. D. (1980). Refraction of microwave signals by water vapor. *Journal of Geophysical Research*, Vol. 85, No. C9, pp. 4904-4912.

[136] Goldfinger, A. D., G. Bush, W. L. Ebert, S. N. Foner, R. W. Hart, and I. Katz (1978). A two satellite technique for measuring atmospheric surface pressure. Committee on Space Research, The Johns Hopkins University, Applied Physics Laboratory, Laurel, Md., June, 7 pp.

[137] Goldhirsh, G. D. Dockery, and J. H. Meyer (1994). 3 years of C-band signal measurements for overwater, line-of-sight links in the mid-Atlantic coast [2] Meteorological aspects of sustained deep fades. *Radio Science*, Vol. 29, No. 6, pp. 1433-1447.

[138] Goldstein, H. (1951). Attenuation by condensed water. In *Propagation of Short Radio Waves*. Ed., D. E. Kerr, McGraw-Hill, New York.

[139] Gossard, E. E. (1981). Clear weather meteorological effects on propagation at frequencies above 1 GHz. *Radio Science*, Vol. 16, No. 5, pp. 589-608.

[140] Grafarend, E. (1971). Elektromagnetische Entfernungsmessung im Konzept stochastischer Prozesse. *Allgemeine Vermessungs-Nachrichten,* Vol. 2, pp. 41-49.

[141] Gu, M., and F. K. Brunner (1990). Theory of the two frequency dispersive range correction. To be published in *Manuscripta Geodaetica*, 5 pp.

[142] Guiraud, F. O., J. Howard, and D. C. Hogg (1979). A dual-channel microwave radiometer for measurement of precipitable water vapor and liquid. *IEEE Transactions on Geoscience Electronics,* October, Vol. GE-17, No. 4, pp. 129-136.

[143] Gurtner, W., G. Beutler, and R. Weber (1994). The use of meteorological data in large scale GPS networks. Presented at American Geophysical Union Spring Meeting, Baltimore, Md., 24 May, 18 pp (overheads).

[144] Gurtner, W., G. Beutler, S. Botton, M. Rothacher, A. Geiger, H. G. Kahle, D. Schneider, and A. Wiget (1987). The use of the Global Positioning System in mountainous areas. In: *GPS Papers Presented by the Astronomical Institute of the University of Berne in 1987,* Ed. W. Gurtner, Mitteilungen der Satellitenbeobachtungsstation Zimmerwald, University of Berne, Berne, Switzerland, Vol. Nr. 22, 21 pp.

[145] Gurtner, W., G. Beutler, S. Botton, M. Rothacher, A. Geiger, H. G. Kahle, D. Schneider, and A. Wiget (1989). The use of the Global Positioning System in mountainous areas. *Manuscripta Geodaetica,* Vol. 14, pp. 53-60.

[146] Hall, M. P. M. (1979). *Effects of the Troposphere on Radio Communication*. Peter Peregrinus Ltd., London, England, 203 pp.

[147] Hall, M. P. M., and L. W. Barclay (Eds.) (1989). *Radiowave Propagation*. Peter Peregrinus Ltd., London, United Kingdom, 277 pp.

[148] Halwani, T. O. and S. Rehman (1992). Variation of surface-water vapor-pressure and refractivity over the Arabian Peninsula. *Arabian Journal for Science and Engineering*, Vol. 17, No. 3, pp. 371-386.

[149] Hamaker, J. P. (1978). Atmospheric delay fluctuations with scale sizes greater than one kilometer, observed with a radio interferometer array. *Radio Science,* Vol. 13, No. 5, pp. 873-891.

[150] Han, Y., J. B. Snider, E. R. Westwater, S. H. Melfi, and R. A. Ferrare (1994). Observations of water-vapor by ground-based microwave radiometers and Raman lidar. *Journal of Geophysical Research,* Vol. 99, No. D9, pp. 18695-18702.

[151] Hardy, K. R., G. A. Hajj, and E. R. Kursinski (1994). Accuracies of atmospheric profiles obtained from GPS occulatations. *International Journal of Satellite Communciations*, Vol. 12, No. 5, pp. 463-473.

[152] Hargens, U. (1993). Fernerkundung des Flüssigwassergehaltes von Wolken (in German). *Berichte aus dem Institut für Meereskunde*, No. 232, Christian-Albrechts-Universität, Kiel, Germany.

[153] Hargens, U., C. Simmer, and E. Ruprecht (1994). Remote sensing of cloud liquid water. *Meteorology and Atmospheric Physics*, in press.

[154] Hartmann, G. K. (1993). The determination of tropospheric conditions (especially H_2O) affecting the accuracy of position measurements. *Environmental Effects on Spacecraft Positioning and Trajectories*, Ed. A. Vallance Jones, American Geophysical Union Geophysical Monograph 73, pp. 73-82.

[155] Hartmann, G. K., and R. Leitinger (1984). Range errors due to ionospheric and tropospheric effects for signal frequencies above 100 MHz. *Bulletin Géodésique*, Vol. 58, pp. 109-136. 1097.

[156] Hellings, R. W. (1980). The effect of tropospheric fluctuations on spacecraft-tracking gravity wave experiments. In: *Atmospheric Water Vapor,* Eds. Deepak, Wikerson and Ruhnke, Academic Press, N. Y., pp. 283-290.

[157] Hendy, M. R., and F. K. Brunner (1990). Modelling the zenith wet component of the tropospheric path delay for microwaves. *Australian Journal of Geodesy, Photogrammetry and Surveying*, December, No. 53, pp. 53-73.

[158] Herben, M. H. A. J. (1988). Multipath propagation experiments on 8. 2-km line-of-sight path at 30 GHz. *Radio Science,* May-June, Vol. 23, No. 3, pp. 419-427.

[159] Herben, M. H. A. J., and W. Kohsiek (1984). A comparison of radio wave and in situ observations of tropospheric turbulence and wind velocity. *Radio Science*, July-August, Vol. 19, No. 4, pp. 1057-1068.

[160] Herring, T. A. (1992). Modeling atmospheric delays in the analysis of space geodetic data. *Proceedings of Symposium on Refraction of Transatmospheric Signals in Geodesy,* Eds. J. C. de Munck, T. A. Th. Spoelstra, The Hague, The Netherlands, 19-22 May, Netherlands Geodetic Commission, Publications on Geodesy, Delft, The Netherlands, No. 36, New Series, pp. 157-164.

[161] Herring, T. A., J. L. Davis, and I. I. Shapiro (1990). Geodesy by radio interferometry: The application of Kalman filtering to the analysis of very long baseline interferometry data. *Journal of Geophysical Research,* 10 August, Vol. 95, No. B8, pp. 12561-12581.

[162] Hill, R. J. (1988). Dispersion by atmospheric water vapor at frequencies less than 1 Thz. *IEEE Transactions on Antennas and Propagation,* Vol. 36, No. 3, pp. 423-430.

[163] Hill, R. J., R. S. Lawrence, and J. T. Priestley (1982). Theoretical and calculational aspects of the radio refractive index of water vapor. *Radio Science,* Vol. 17, No. 5, pp. 1251-1257.

[164] Hinson, D. P. (1986). Strong scintillations during atmospheric occultations: Theoretical intensity spectra. *Radio Science,* March-April, Vol. 21, No. 2, pp. 257-270.

[165] Hogg, D. C. (1980). Ground-based measurements of microwave absorption by tropospheric water vapor. In: *Atmospheric Water Vapor,* Eds. Deepak, Wikerson and Ruhnke, Academic Press, N. Y., pp. 219-228.

[166] Hogg, D. C., and F. O. Guiraud (1979). Microwave measurements of the absolute values of absorption by water vapour in the atmosphere. *Nature,* Vol. 279, No. 5712, pp. 408-409.

[167] Hogg, D. C., and J. B. Snider (1987?). Microwave radiometry in measurement of radio pathlength through the troposphere. NOAA/ERL, Wave Propagation Laboratory, Boulder, Colo., 6 pp.

[168] Hogg, D. C., F. O. Guiraud, and M. T. Decker (1981). Measurement of excess radio transmission length on earth-space paths. *Astronomy and Astrophysics,* Vol. 95, pp. 304-307.

[169] Hogg, D. C., F. O. Guiraud, and W. B. Sweezy (1981). The short-term temporal spectrum of precipitable water vapor. *Science,* Vol. 213, pp. 1112-1113.

[170] Hogg, D. C., F. O. Guiraud, J. B. Snider, M. T. Decker, and E. R. Westwater (1983). A steerable dual-channel microwave radiometer for measurement of water vapor and liquid in the troposphere. *Journal of Climate and Applied Meteorology*, May, Vol. 22, pp. 789-806.

[171] Hogg, D. C., F. O. Guiraud, J. Howard, A. C. Newell, D. P. Kremer, and A. G. Repjar (1979). An antenna for dual-wavelength radiometry at 21 and 32 GHz. *IEEE Transactions on Antennas and Propagation,* November, Vol. AP-27, No. 6, pp. 764-770.

[172] Hollinger, J. P., J. L. Pierce, and G. A. Poe (1990). SSM/I instrument evaluation. *IEEE Transactions on Geoscience and Remote Sensing,* Vol. GE-28, pp. 781-790.

[173] Hopfield, H. S. (1963). The effect of tropospheric refraction on the Doppler shift of a satellite signal. *Journal of Geophysical Research,* 15. September, Vol. 68, No. 18, pp. 5157-5168.

[174] Hopfield, H. S. (1969). Approximation to the tropospheric range correction. Applied Physics Laboratory, Silver Spring, Md., 12. November, S1A-572-69, 4 pp.

[175] Hopfield, H. S. (1969). Two-quartic tropospheric refractivity profile for correcting satellite data. *Journal of Geophysical Research,* 20. August, Vol. 74, No. 18, pp. 4487-4499.

[176] Hopfield, H. S. (1971). Tropospheric effect on electromagnetically measured range: Prediction from surface weather data. *Radio Science,* March, Vol. 6, No. 3, pp. 357-367.

[177] Hopfield, H. S. (1971). Tropospheric range error at the zenith. Presented at Fourteenth Plenary Meeting of the Committee on Space Research, Seattle, Washington, 17 June-2 July, June, 31 pp.

[178] Hopfield, H. S. (1972). Tropospheric range error at the zenith. *Space Research XII,* Akademie-Verlag, Berlin, pp. 581-594.

[179] Hopfield, H. S. (1972). Tropospheric range error parameters: Further studies. Applied Physics Laboratory Space Systems, The Johns Hopkins University, Silver Spring, Md., June, Report CP 015, 40 pp.

[180] Hopfield, H. S. (1972). Tropospheric refraction effects on satellite range measurements. *APL Technical Digest,* March-April, Vol. 11, No. 4, pp. 11-21.

[181] Hopfield, H. S. (1973). Tropospheric effect on electromagnetic range measurement at oblique angles. The Johns Hopkins University, Applied Physics Laboratory, Laurel, Md., 22. March, preliminary draft, 10 pp. For AGU meeting, April 1973.

[182] Hopfield, H. S. (1976). Tropospheric effects on signals at very low elevation angles. Applied Physics Laboratory, Johns Hopkins University, Laurel, Md., March, Technical Memorandum TG 1291, 44 pp.

[183] Hopfield, H. S. (1976). Tropospheric effects on signals at very low elevation angles. The Johns Hopkins University, Applied Physics Laboratory, Laurel, Md., March, APL/JHU TG 1291, 41 pp.

[184] Hopfield, H. S. (1978). Tropospheric correction of electro-magnetic ranging signals to a satellite: Study of parameters. In: *Proceedings of International Symposium on Electromagnetic Distance Measurement and the Influence of Atmospheric Refraction,* Ed. P. Richardus, Wageningen, The Netherlands, 23-28 May 1977, Netherlands Geodetic Commission, Delft, The Netherlands, pp. 205-215.

[185] Hopfield, H. S. (1979). Improvements in the tropospheric refraction correction for range measurement. *Philosophical Transactions of the Royal Society of London,* Vol. 294, pp. 341-352.

[186] Ichikawa, R. (1994). Assessment of wet troposphere delay from numerical prediction data and its implications for space geodesy. Ph. D. thesis Faculty of Science, Hokkaido University, Hokkaido, Japan.

[187] Ichikawa, R., M. Kasahara, N. Mannoji, and I. Naito (1994). An evaluation of positioning error for space geodetic technique due to azimuthal asymmetry of wet troposphere delay based on JMA 10 km spectral model data. *Proceedings of the Eight International Symposium on Recent Crustal Movements (CRCM'93)*, Kobe, Japan, 6-11 December 1993, pp. 181-187.

[188] Ifadis, I. (1986). The atmospheric delay of radio waves: Modeling the elevation dependence on a global scale. School of Electrical and Computer Engineering, Chalmers University of Technology, Göteborg, Sweden, November, Technical Report No. 38L, 115 pp.

[189] Ifadis, I. M. (1993). Space to earth techniques: Some considerations on the zenith wet path delay parameters. *Survey Review*, Vol. 32, No. 249, pp. 130-144.

[190] Institute of Electrical and Electronics Engineers, The (1990). IEEE standard definitions of terms for radio wave propagation. The Institute of Electrical and Electronics Engineers, Inc., New York, N. Y., IEEE Std 211-1990 (Revision of IEEE Std 211-1977), 24 pp.

[191] International Business Machines Corporation (1989). Observation modeling. Section 20. 3 in Part 1 of *Computer program development specification for tracking and orbit determination (TRORD)*, Systems Integration Division, IBM, Santa Clara, Calif., 4 December, Command & Control Sustaining Engineering control No. 7940173-1, Specification Number CG-SCF-202C, Code Ident 23892, pp. 20-9 to 20-26. Supersedes specification no. CG-SCF-202B, 19 November 1986.

[192] Iribarne, J. V., and W. L. Godson (1973). *Atmospheric Thermodynamics.* D. Reidel Publishing Company, Dordrecht, Holland, Vol. 6 of Geophysics and Astrophysics Monographs, 220 pp. ISBN: 90 277 0370 1; 90 277 0371 X (pb).

[193] Ishiguro, M., T. Kanzawa, and T. Kasuga (1990). Monitoring of atmospheric phase fluctuations using geostationary satellite signals. *Proceedings of the Symposium on Radio Astronomical Seeing*, Eds. Baldwin and Wang, International Academic Publishers, Oxford, England, pp. 60-63.

[194] James, M. B., and D. J. Griffiths (1992). Why the speed of light is reduced in a transparent medium. *American Journal of Physics*, Vol. 60, No. 4, pp. 309-313.

[195] Janes, H. (1986). Troposphere. Section 2. 7 in: *On Modelling of Tropospheric Effects in Ultra-High Frequency Radio Positioning*, Department of Surveying Engineering, University of New Brunswick, Fredericton, N. B., January, Technical Report No. 119, 27 pp.

[196] Janes, H. W., R. B. Langley, and S. P. Newby (1989). A comparison of several models for the prediction of tropospheric propagation delay. *Proceedings of Fifth International Geodetic Symposium on Satellite Positioning*, DMA, NGS, Las Cruces, N. Mex., 13-17 March, Physical Science Laboratory, New Mexico State University, Las Cruces, N. Mex., Vol. II, pp. 777-788.

[197] Janes, H. W., R. B. Langley, and S. P. Newby (1991). Analysis of tropospheric delay prediction models: comparisons with ray-tracing and implications for GPS relative positioning (A summary). *GPS'90*, Proceedings of the Second International Syposium on Precise Positioning with the Global Positioning System, Ottawa, Canada, 3-7 September, pp. 444-450.

[198] Janes, H. W., R. B. Langley, and S. P. Newby (1991). Analysis of tropospheric delay prediction models: comparisons with ray-tracing and implications for GPS relative positioning. *Bulletin Géodésique*, Vol. 65, pp. 151-161.

[199] Janssen, M. A. (1985). A new instrument for the determination of radio path delay due to atmospheric water vapor. *IEEE Transactions on Geoscience and Remote Sensing*, July, Vol. GE-23, No. 4, pp. 485-490.

[200] Janssen, M. A., C. S. Ruf, and S. J. Keihm (1993). TOPEX/Poseidon microwave radiometer (TMR): II. Antenna pattern correction and brightness temperature algorithm. Submitted to *IEEE Transactions on Geoscience and Remote Sensing.*

[201] Jarlemark, P. O. J. (1994). Microwave radiomertry for studies of variations in atmospheric water vapor and cloud liquid content. Licentiate thesis, School of Electrical and Computer Engineering, Chalmers University of Technology, Göteborg, Sweden, Technical Report No. 181L.

[202] Johansson, J. (1985). The site and seasonal dependence of the wet path delay algorithm used in water vapor radiometry. *Proceedings of the 4th Working Meeting on European VLBI for Geodesy and Astrometry*. Eds., B. Rönnäng and G. Tang, Onsala Space Observatory, Onsala, Sweden, 3 June.

[203] Johansson, J. M., G. Elgered, and J. L. Davis (1987). Geodesy by radio interferometry: Optimization of wet path delay algorithms using microwave radiometer data. Department of Radio and Space Science with Onsala Space Observatory, Chalmers University of Technology, Gothenburg, Sweden, Research Report No. 152, 50 pp.

[204] Johansson, J. M., G. Elgered, and J. L. Davis (1993). Wet path delay algorithms using microwave radiometer data. *Contributions of Space Geodesy to Geodynamics: Technology*, Eds. D. E. Smith and D. L. Turcotte, American Geophysical Union Geodynamics Series, Vol. 25, pp. 81-98.

[205] Kaniuth, K., K. Stuber, and H. Tremel (1989). A comparative analysis of various procedures for modelling the tropospheric delay in a regional GPS network. *Proceedings of Fifth International Geodetic Symposium on Satellite Positioning*, DMA, NGS, Las Cruces, N. Mex., 13-17 March, Physical Science Laboratory, New Mexico State University, Las Cruces, N. Mex., Vol. II, pp. 767-776.

[206] Kaniuth, K., and H. Tremel (1992). Analysis of spatial and temporal correlations of meteorological parameters associated with tropospheric delay modelling. *Proceedings of Symposium on Refraction of Transatmospheric Signals in Geodesy*, Eds. J. C. de Munck, T. A. Th. Spoelstra, The Hague, The Netherlands, 19-22 May, Netherlands Geodetic Commission, Publications on Geodesy, Delft, The Netherlands, No. 36, New Series, pp. 21-24.

[207] Kantor, A. J., and P. Tattelman (1984). Profiles of temperature and density based on 1- and 10-percent extremes in the stratosphere and troposphere. Air Force Geophysics Laboratory, Hanscom AFB, Mass., 27 December, AFGL-TR-84-0336, AFSG No. 447, 64 pp.

[208] Kasuga, T., T. Kanzawa, and M. Ishiguro (1990). Studies of the atmospheric phase fluctuations using Nobeyama millimeter array. *Proceedings of the Symposium on Radio Astronomical Seeing*, Eds. Baldwin and Wang, International Academic Publishers, Oxford, England, pp. 54-59.

[209] Keihm, S. J. (1991). Water vapor radiometer intercomparison experiment: Platteville, Colorado, March 1-14, 1991. Final Report. Jet Propulsion Laboratory, Pasadena, CA.

[210] Keihm, S. J. (1992). Atmospheric absorption from 20-32 GHZ: radiometric constraints on the vapor and oxygen components. *Proceedings of the Specialist Meeting on Microwave Radiometry and Remote Sensing Applications*, Boulder, CO, Ed. E. R. Westwater, pp. 211-218.

[211] Keihm, S. J., M. A. Janssen, and C. S. Ruf (1993). TOPEX/Poseidon microwave radiometer (TMR): III. Wet troposphere range correction algorithm and pre-launch error budget. Submitted to *IEEE Transactions on Geoscience and Remote Sensing.*

[212] Keihm, S. J., and C. S. Ruf (1994). The role of water vapor radiometers for in-flight calibration of the TOPEX microwave radiometer. Submitted to *Journal of Marine Geodesy*.

[213] Koblinsky, C. J., J. Ryan, L. Braatz, and S. M. Klosko (1993). A direct evaluation of the Geosat altimeter wet atmospheric range delay using very long-base-line interferometry observations. *International Journal of Remote Sensing*, Vol. 14, No. 9, pp. 1723-1733.

[214] Kolchinskii, I. G. (1968?). Some problems in the investigation of light refraction in the earth's atmosphere. pp. 56-61.

[215] Kouba, J. (n. d.). 'Tropospheric correction' in Atmospheric delays. Section of *Satellite Doppler Positioning*, pp. 29-30. 4 pp. Portion of a chapter only with comments on DIPOP.

[216] Kouba, J. (1986?). Global Positioning System (GPS) capabilities and limitations for geodynamics. Internal report draft Earth Physics Branch, Energy, Mines and Resources Canada, Ottawa, Ontario, 17 pp.

[217] Kozu, T., J. Awaka, H. Fukuchi, and K. Nakamura (1988). Rain attenuation ratios on 30/20- and 14/12-GHz satellite-to-earth paths. *Radio Science*, May-June, Vol. 23, No. 3, pp. 409-418.

[218] Kuehn, C. E., and D. S. MacMillan (1991). Sensitivity of geodetic parameter estimates to the assumed distribution of the "wet" troposphere. *Proceedings of the American Geophysical Union Chapman Conference on Geodetic VLBI: Monitoring Global Change*, Washington, D. C., 22-26 April, U.S.Department of Commerce, Washington, D. C., NOAA Technical Report NOS 137 NGS 49, pp. 135-146.

[219] Kuehn, C. E., W. E. Himwich, T. A. Clark, and C. Ma (1991). An evaluation of water vapor radiometer data for calibration of the wet path delay in very long baseline interferometry experiments. *Radio Science*, Vol. 26, No. 6, pp. 1381-1391.

[220] Kuehn, C. E., G. Elgered, J. M. Johansson, T. A. Clark, and B. O. Ronnang (1992?). A microwave radiometer comparison and its implication for the accuracy of wet delays. Draft, Interferometrics Inc., Vienna, Va., 35 pp.

[221] Kuehn, C. E., G. Elgered, J. M. Johansson, T. A. Clark, and B. O. Ronnang (1993). A microwave radiometer comparison and its implication for the accuracy of wet delays. *Contributions of Space Geodesy to Geodynamics: Technology*, Eds. D. E. Smith and D. L. Turcotte, American Geophysical Union Geodynamics Series, Vol. 25, pp. 99-114.

[222] Kuo, Y. -H., Y. -R. Guo, and E. R. Westwater (1993). Assimilation of precipitable water measurements into a mesoscale numerical model. *Monthly Weather Review*, Vol. 121, pp. 1215-1238.

[223] Langley, R. B. (1992). The effect of the ionosphere and troposphere on satellite positioning systems. *Proceedings of Symposium on Refraction of Transatmospheric Signals in Geodesy*, Eds. J. C. de Munck, T. A. Th. Spoelstra, The Hague, The Netherlands, 19-22

May, Netherlands Geodetic Commission, Publications on Geodesy, Delft, The Netherlands, No. 36, New Series, pp. 97 (abstract only).

[224] Lanyi, G. (1984). Tropospheric delay effects in radio interferometry. Jet Propulsion Laboratory, California Institute of Technology, Pasadena, Calif., April-June, TDA Progress Report No. 42-78, pp. 152-159.

[225] Laurila, S. H. (1969). Statistical analysis of refractive index through the troposphere and the stratosphere. *Bulletin Géodésique,* Vol. 92, pp. 139-153.

[226] LeVine, D. M. (1972). Propagation delay in the atmosphere. *Radio Science,* Vol. 7, No. 6, pp. 625-629.

[227] Lewandowski, W., G. Petit, and C. Thomas (1992). GPS standardization for the needs of time transfer. *Proceedings of the 6th European Frequency and Time Forum,* Noordwijk, The Netherlands, 17-19 March, June, ESA SP-340, pp. 243-248.

[228] Lichten, S. M. (1987). Strategies for precision GPS orbit determination: Multi-day arcs and stochastic troposphere models. Presented at Second GPS Technology Workshop, Pasadena, Calif., 23. March, 10 pp.

[229] Lichten, S. M. (1990). Precise estimation of tropospheric path delays with GPS techniques. Jet Propulsion Laboratory, California Institute of Technology, Pasadena, Calif., TDA Progress Report 42-100.

[230] Lichten, S. M., and S. K. Wolf (1989). Stochastic GPS estimation of tropospheric path delays. Presented at American Geophysical Union Fall Meeting, San Francisco, Calif., 4-8 December, 15 pp. (Abstract: *EOS, Transactions of the American Geophysical Union,* Vol. 70, pp. 1047.).

[231] Liebe, H. J. (1981). Modeling attenuation and phase of radio waves in air at frequencies below 1000 GHz. *Radio Science,* Vol. 16, No. 6, pp. 1183-1199.

[232] Liebe, H. J. (1985). An updated model for millimeter wave propagation in moist air. *Radio Science,* September-October, Vol. 20, No. 5, pp. 1069-1089.

[233] Liebe, H. J. (1992). Atmospheric spectral properties between 10 and 350 GHz: new laboratory measurements and models. *Proceedings of the Specialist Meeting on Microwave Radiometry and Remote Sensing Applications*, Boulder, CO, Ed. E. R. Westwater, pp. 189-196.

[234] Lindqwister, U. J., J. F. Zumberge, G. Blewitt, and F. Webb (1990). Application of stochastic troposphere modeling to the California permanent GPS geodetic array. Presented at American Geophysical Union Fall Meeting, San Francisco, Calif., 6. December, 14 pp.

[235] Linkwitz, K., and J. Bahndorf (1993). Wet component of tropospheric delay for microwaves from surface meteorological data. *Artificial Satellites and Planetary Geodesy*, Vol. 28, No. 20, No. 3.

[236] List, R.J. (1951). *Smithsonian Meteorological Tables.* Sixth Revised Edition. Smithsonian Miscelleaneous Collections, Vol. 114. Fifth reprint issued 1984. Smithsonian Institution Press, Washington, D.C., U.S.A., 527 pp.

[237] Liu, W. T., and D. Mock (1990). The variability of atmospheric equivalent temperature for radar altimeter range correction. *Journal of Geophysical Research,* 15 March, Vol. 95, No. C3, pp. 2933-2938.

[238] Mätzler, C. (1992). Ground-based observations of atmospheric radiation at 5, 10, 21, 35, and 94 GHz. *Radio Science*, Vol. 27, pp. 403-415.

[239] MacMillan, D. S., and C. Ma (1994). Evaluation of very long baseline interferometry atmospheric modeling improvements. *Journal of Geophysical Research*, 10 January, Vol. 99, No. B1, pp. 637-651.

[240] Madrid, G. A., F. G. Winn, J. W. Zielenbach, and K. B. Yip (1974). Calibration effects on orbit determination. Jet Propulsion Laboratory, California Institute of Technology, Pasadena, Calif., March, JPL Technical Report 32-1587, pp. 83-96.

[241] Mallet, C. and J. Lavergnat (1992). Beacon calibration with a multifrequency radiometer. *Radio Science*, Vol. 27, No. 5, pp. 661-680.

[242] Mano, K., and E. E. Altshuler (1981). Tropospheric refractive angle and range error corrections utilizing exoatmospheric sources. *Radio Science*, Vol. 16, No. 2, pp. 191-195.

[243] Marini, J. W. (1972). Correction of satellite tracking data for an arbitrary tropospheric profile. *Radio Science*, February, Vol. 7, No. 2, pp. 223-231.

[244] Marini, J. W. and C. W. Murray (1973). Correction of laser range tracking data for atmospheric refraction at elevations above 10 degreees. Goddard Space Flight Center, Greenbelt, Md., Report X-591-73-351.

[245] Martner, B. E., D. B. Wuertz, B. B. Stankov, R. G. Strauch, E. R. Westwater, K. S. Gage, W. L. Ecklund, C. L. Martin, and W. F. Dabberdt (1993). An evaluation of wind profiler, RASS, and microwave radiometer peformance. *Bulletin of the American Meteorological Society*, Vol. 74, No. 4, pp. 599-613.

[246] Mathur, N. C., M. D. Grossi, and M. R. Pearlman (1970). Atmospheric effects in very long baseline interferometry. *Radio Science*, Vol. 5, No. 10, pp. 1253-1261.

[247] Matsakis, D. N., and T. M. Eubanks (1992). Analysis of NAVNET geodetic VLBI post-fit delay residuals. *Proceedings of Symposium on Refraction of Transatmospheric Signals in Geodesy*, Eds. J. C. de Munck, T. A. Th. Spoelstra, The Hague, The Netherlands, 19-22 May, Netherlands Geodetic Commission, Publications on Geodesy, Delft, The Netherlands, No. 36, New Series, pp. 55-58.

[248] May, D. A. (1993). Sea surface temperature estimation from the DMSP operational linescan system using a SSM/I-derived water vapor correction. *Geophysical Research Letters*, Vol. 20, pp. 583-586.

[249] McCarthy, D. D. (1992). *IERS Standards (1992)*. IERS Technical Note 13, International Earth Rotation Service, Central Bureau of IERS, Observatoire de Paris, Paris, France, July, pp. 116-120.

[250] Meeks, M. L. (n. d.). Radar propagation at low altitudes. Lincoln Laboratory, Massachusetts Institute of Technology, Boston, Mass., 11 pp.

[251] Meeks, M. L. (Ed.) (1976). Astrophysics. Part B of *Radio Telescopes*, Academic Press, New York, N. Y., Vol. 12 of Methods of Experimental Physics, 304 pp.

[252] Melbourne, W. G., J. D. Mulholland, W. L. Sjogren, and F. M. Sturms (1968). Constants and related information for astrodynamic calculations, 1968. Jet Propulsion Laboratory, California Institute of Technology, Pasadena, Calif., 15 July, JPL Technical Report 32-1306, 57 pp.

[253] Mendes, V. B., and R. B. Langley (1993). Application of the Global Positioning System to the assessment of crustal deformation in the Charlevoix seismic zone. *ION GPS-93*, Proceedings of the Sixth International Technical Meeting of the Satellite Division of The

Institute of Navigation, Salt Lake City, Utah, 22-24 September, The Institute of Navigation, Alexandria, Va., Vol. II, pp. 1205-1219.

[254] Mendes, V. B., and R. B. Langley (1994). A comprehensive analysis of mapping functions used in modeling tropospheric propagation delay in space geodetic data. *KIS94*, Proceedings of the International Symposium on Kinematic Systems in Geodesy, Geomatics and Navigation, Banff, Alberta, 30 August - 2 September, The University of Calgary, Calgary, Alberta, Canada, pp. 87-98.

[255] Miller, L. F., V. J. Ondrasik, and C. C. Chao (1971). A cursory examination of the sensitivity of the tropospheric range and Doppler effects to the shape of the refractivity profile. Jet Propulsion Laboratory, California Institute of Technology, Pasadena, Calif., 15 February, JPL Technical Report 32-1526, Vol. I, pp. 22-30.

[256] Millman, G. H. (1967). A survey of tropospheric, ionospheric, and extra-terrestrial effects on radio propagation between the earth and space vehicles. Chapter 1-1 in: *Propagation Factors in Space Comunications*, Proceedings of Ionospheric Research Committee of Avionics Panel of AGARD/NATO, Rome, Italy, 21-25 September 1965, Technivision, Maidenhead, England, AGARD Conference Proceedings No. 3, pp. 1-55.

[257] Minster, J. -F., D. Jourdan, E. Normant, C. Brossier, and M. -C. Gennero (1992). An improved special sensor microwave imager water vapor correction for Geosat altimeter data. *Journal of Geophysical Research*, Vol. 97, No. C11, pp. 17,859-17,872.

[258] Moffet, J.B. (1973). Program requirements for two-minute integrated Doppler satellite navigation solution. Technical Memorandum TG 819-1, Applied Physics Laboratory, The Johns Hopkins University, Laurel, MD.

[259] Monaldo, F. (1990). Path length variations caused by atmospheric water vapor and their effects on the measurement of mesoscale ocean circulation features by a radar altimeter. *Journal of Geophysical Research*, 15 March, Vol. 95, No. C3, pp. 2923-2932.

[260] Moran, J. M. (1989). The effects of propagation on VLBI observations. *The Techniques and Applications of Very Long Baseline Interferometry*, Proceedings of the NATO Advanced Study Institute, Eds. M. Felli, R. E. Spencer, Bologna, Italy, 12-23 September, Kluwer Academic Publishers, Dordrecht, The Netherlands, pp. 47-59.

[261] Moran, J. M., and B. R. Rosen (1981). Estimation of the propagation delay through the troposphere from microwave radiometer data. *Radio Science*, March-April, Vol. 16, No. 2, pp. 235-244.

[262] Morduch, G. E. (1978). A formula for computing refraction effects on range measurements. *Radio Science*, Vol. 13, No. 3, pp. 509-510.

[263] Moritz, H. (1967). Application of the conformal theory of refraction. *Osterr. Zeitschrift f. Vermessungswesen*, Vol. 25, pp. 323-334.

[264] Morrissey, J. F., J. D. Pickle, V. J. Falcone, and M. K. Griffin (1993). Effects of radiosonde type on satellite-derived humidities. *Proceedings of COMEAS'93*, Albuquerque, NM, 22-25 March, pp. 199-202.

[265] Mousa, A. E-K., and T. Tanaka (1994). A preliminary evaluation of mapping functions by water vapor radiometer observations at Shionomisaki. Presented at American Geophysical Union Fall Annual Meeting, San Francisco, Calif., 5-9 December, 13 pp. (Abstract: *EOS, Transactions of the American Geophysical Union*, Vol. 75, No. 44, Supplement, pp. 173-174.)

[266] Moyer, T. D. (1971). Mathematical formulation of the double-precision or bit determination program (DPODP). Jet Propulsion Laboratory, California Institute of Technology, Pasadena, Calif., 15 May, JPL Technical Report 32-1527, pp. 83-87 only.

[267] Muijlwijk, R. (1988). Update of the Edlén formulae for the refractive index of air. *Metrologia,* Vol. 25, No. 3, p. 189.

[268] Nahvi, M. J. (1988). An expert system approach to determination of tropospheric error in microwave ranging. *Acta Astronautica,* Vol. 17, No. 3, pp. 359-366.

[269] National Oceanic and Atmospheric Administration, National Aeronautics and Space Administration, and United States Air Force (1976). U.S.Standard Atmosphere, 1976. U.S.Government Printing Office, Washington, D. C., October, NOAA-S/T 76-1562, 227 pp.

[270] Newby, S. (1989). The spatial correlation of meteorological measurements in tropospheric delay modelling. SE 6910 graduate seminar, UNB, 3 March, 15 pp.

[271] Newby, S. (1992). The refraction of electromagnetic signals in the atmosphere. Department of Surveying Engineering, University of New Brunswick, Fredericton, N. B., July, 10 pp.

[272] Newby, S. P., R. B. Langley, and H. W. Janes (1989). The spatial correlation of meteorological measurements in tropospheric delay modelling. *Proceedings of Fifth International Geodetic Symposium on Satellite Positioning,* DMA, NGS, Las Cruces, N. Mex., 13-17 March, Physical Science Laboratory, New Mexico State University, Las Cruces, N. Mex., Vol. II, pp. 757-766.

[273] Niell, A. E. (1991). Vertical change and atmosphere correction in VLBI. *Proceedings of the American Geophysical Union Chapman Conference on Geodetic VLBI: Monitoring Global Change,* Washington, D. C., 22-26 April, U.S.Department of Commerce, Washington, D. C., NOAA Technical Report NOS 137 NGS 49, pp. 147-158.

[274] Niell, A. E. (1993). A new approach for the hydrostatic mapping function. *Proceedings of the International Workshop for Reference Frame Establishment and Technical Development in Space Geodesy*, Communications Research Laboratory, Koganei, Tokyo, Japan, 18-21 January, pp. 61-68.

[275] Niell, A. E. (1993). Improved global atmospheric mapping functions for VLBI and GPS. *Abstracts of the URSI/IAU Symposium on VLBI Technology – Progress and Future Observational Possibilities*, Tokyo, Japan, 6-10 September, p. 19.

[276] Noréus, J. P. (1992). Effect of water vapor corrections for satellite altimeter measurements of the geoid. In: *From Mars to Greenland: Charting Gravity with Space and Airborne Instruments; Fields, tides, methods, results,* Proceedings of International Association of Geodesy Symposium No. 110, Ed. O. L. Colombo, Vienna, Austria, 20 August 1991, Springer-Verlag, New York, Berlin, pp. 139-148.

[277] North, G. R. (1990). Satellite measurements of moisture variables and global change. In *Modern Radio Science,* Ed. J. B. Andersen, Oxford University Press, Oxford, England, pp. 103-112.

[278] Ohba, M. (1994). On improvement of GPS surveying precision using water vapour radiometer. M. Sc. thesis Faculty of Science, Kyoto University, Kyoto, Japan.

[279] Olmi, L. and D. Downes (1992). Interferometric measurement of tropospheric phase fluctuations at 86 GHz on antenna spacings of 24 m to 288 m. *Astronomy and Astrophysics*, Vol. 262, No. 2, pp. 634-643.

[280] Ophir Corporation (1987). Ophir microwave water vapor radiometer. Ophir Corporation, Lakewood, Colo., July, multiple insert brochure.

[281] Owens, J. C. (1967). Optical refractive index of air: Dependence on pressure, temperature and composition. *Applied Optics*, January, Vol. 6, No. 1, pp. 51-59.

[282] Pan, W. Y. and H. M. Shen (1994). The influence of random variations in the tropospheric refractive-index on the focusing of an intense microwave beam from a phased-array. *Radio Science*, Vol. 29, No. 5, pp. 1231-1236.

[283] Papatsoris, A. D. and P. A. Watson (1993). Calculation of absorption and dispersion spectra of atmospheric gases at millimeter-wavelengths. *IEE Proceedings-H Microwaves, Antennas, and Propagation*, Vol. 140, No. 6, pp. 461-468.

[284] Parsons, J. D. (n. d.). *The Mobile Radio Propagation Channel*. Pentech Press, London, United Kingdom, 314 pp.

[285] Peter, R., and N. Kämpfer (1992). Radiometric determination of tropospheric water vapour and liquid water for the correction of ground-based mm-wave measurements of stratospheric trace gas spectra. *Proceedings of the Specialist Meeting on Microwave Radiometry and Remote Sensing Applications*, Boulder, CO, Ed. E. R. Westwater.

[286] Peter, R., and N. Kämpfer (1992). Radiometric determination of water vapor and liquid water and its validation with other techniques. *Journal of Geophysical Research*, Vol. 97, No. D16, pp. 18,173-18,183.

[287] Peter, R., and B. Schmid (1993). Comparison of columnar water vapor determined from microwave emission and solar transmission measurements. Presented at COMEAS'93, Albuquerque, NM, 22-25 March.

[288] Phoebus, P. A., and J. D. Hawkins (1990). The impact of the wet tropospheric correction on the interpretation of altimeter-derived ocean topography in the Northeast Pacific. *Journal of Geophysical Research*, 15 March, Vol. 95, No. C3, pp. 2939-2952.

[289] Pisacane, V. L., and M. M. Feen (1974). Propagation effects at radio frequencies on satellite navigation systems. The Johns Hopkins University Applied Physics Laboratory, Silver Spring, Md., May, AD-784 373, 41 pp.

[290] Prabhakara, C., and G. Dalu (1980). Passive remote sensing of the water vapor in the troposphere and its meteorological significance. In: *Atmospheric Water Vapor*, Eds. Deepak, Wikerson and Ruhnke, Academic Press, N. Y., pp. 355-374.

[291] Prabhakara, C., I. Wang, A. T. C. Chang, and P. Gloersen (1983). A statistical examination of Nimbus-7 SMMR data and remote sensing of sea surface temperature, liquid water content in the atmosphere and surface wind speed. *Journal of Climate and Applied Meteorology*, December, Vol. 22, pp. 2023-2026.

[292] Radiometrics Corporation (1990). Commercialization of WVR-1000 Microwave Water Vapor Radiometer. Radiometrics Corporation, Lakewood, Colo., June, Advertising brochure and price list, 5 pp.

[293] Radiometrics Corp. (1990). Microwave Water Vapor Radiometer (WVT). *GPS World*, May/June, products, Vol. 1, No. 3, pp. 61.

[294] Rahnemoon, M. (1988). Ein neues Korrekturmodell für Mikrowellen — Entfernungsmessungen zu Satelliten. Dr. -Ing. dissertation Bayerischen Akademie der Wissenschaften, Deutsche Geodätische Kommission, Munich, F. R. G., 188 pp.

[295] Raustein, E., H. Sundqvist, and K. B. Katsaros (1991). Quantitative comparison between simulated cloudiness and clouds objectively derived from satellite data. *Tellus*, Vol. 43A, pp. 306-320.

[296] Rawer, K. (1985). Study of ionospheric and tropospheric models. Final contract report for European Space Agency, by University of Freiburg, Freiburg, F. R. G., September, 88 pp. 2082.

[297] Rawer, K., D. Bilitza, and M. Pallaschke (1985). Study of ionospheric and tropospheric models. Contract report of European Space Agency, 88 pp.

[298] Reagan, J. A., K. J. Thome, and B. M. Herman (1993). A simple instrument and technique for measuring columnar water vapor via near-IR differential solar transmission measurements. *Proceedings of COMEAS'93*, Albuquerque, NM, 22-25 March, pp. 189-192.

[299] Reagan, J., K. Thome, B. Herman, R. Stone, J. DeLuisi, and J. Snider (1993). A comparison of columnar water vapor retrievals obtained with a near-IR solar radiometer and microwave radiometer. *Proceedings of COMEAS'93*, Albuquerque, NM, 22-25 March.

[300] Reber, E. E., and J. R. Swope (1972). On the correlation of the total precipitable water in a vertical column and absolute humidity at the surface. *Journal of Applied Meteorology*, December, Vol. 11, pp. 1322-1325.

[301] Reichert, G. (1986). A new water vapor radiometer design. *Proceedings of the Fourth International Geodetic Symposium on Satellite Positioning*, DMA, NGS, Austin, Tex., 28 April-2 May, Applied Research Laboratories, The University of Texas at Austin, Austin, Tex., pp. 603-614.

[302] Reid, G. C., and K. S. Gage (1981?). On the annual variation in height of the tropical tropopause. Aeronomy Laboratory, National Oceanic and Atmospheric Administration, Boulder, Colo., 40 pp.

[303] Resch, G. M. (n. d.). Atmospheric limitations to clock synchronization at microwave frequencies. Jet Propulsion Laboratory, California Institute of Technology, Pasadena, Calif., 10 pp.

[304] Resch, G. M. (n. d.). Water vapor radiometry in geodetic applications. Contract report for National Aeronautics and Space Administration, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, Calif., 33 pp.

[305] Resch, G. M. (1980). Water vapor — the wet blanket of microwave interferometry. In: *Atmospheric Water Vapor*, Eds. Deepak, Wikerson and Ruhnke, Academic Press, N. Y., pp. 265-282.

[306] Resch, G. M. (1983). Another look at the optimum frequencies for a water vapor radiometer. TDA Technology Development Office, TDA Progress Report 42-76, October-December, pp. 1-11.

[307] Resch, G. M. (1983). Inversion algorithms for water vapor radiometers operating at 20. 7 and 31. 4 GHz. TDA Technology Development Office, TDA Progress Report 42-76, October-December, pp. 12-26.

[308] Resch, G. M. (1984). Water vapor radiometry in geodetic applications. Chapter E in *Geodetic Aspects of Electromagnetic Wave Propagation Through the Atmosphere*, Ed. F. K. Brunner, Springer-Verlag, N. Y., pp. 53-84.

[309] Resch, G. M., and E. S. Claflin (n. d.). Microwave radiometry as a tool to calibrate tropospheric water-vapor delay. *Radio Interferometry*, pp. 377-384.

[310] Resch, G. M., D. E. Hogg, and P. J. Napier (1984). Radiometric correction of atmospheric path length fluctuations in interferometric experiments. *Radio Science*, Vol. 19, No. 1, pp. 411-422.

[311] Resch, G. M., M. C. Chavez, N. I. Yamane, K. M. Barbier, and R. C. Chandlee (1985). Water vapor radiometry research and development phase. Final report for the National Aeronautics and Space Administration,, by the Jet Propulsion Laboratory, California Institute of Technology, Pasadena, Calif., April, JPl Publication 85-14, 121 pp.

[312] Rex, D. F. (1969). Introduction. Chapter 1 in *Climate of the Free Atmosphere*, Ed. D. F. Rex, Elsevier Publishing Company, Amsterdam, Vol. 4 of World Survey of Climatology, pp. 1-3. ISBN: SBN: 444-40703-0.

[313] Rice, D. D., R. D. Hunsucker, L. J. Lanzerotti, G. Crowley, P. J. S. Williams, J. D. Craven, and L. Frank (1988). An observation of atmospheric gravity wave cause and effect during the October 1985 WAGS campaign. *Radio Science*, November-December, Vol. 23, No. 6, pp. 919-930.

[314] Richter, J. H., and H. V. Hitney (1980). The effects of atmospheric refractivity on microwave propagation. In: *Atmospheric Water Vapor*, Eds. Deepak, Wikerson and Ruhnke, Academic Press, N. Y., pp. 203-218.

[315] Robertshaw, G. (1986). How accurate is range correction? *Microwaves & RF*, March, pp. 129-132.

[316] Robinson, S. E. (1985). Algorithm accuracy for delay estimation from WVR data. Report presented at American Geophysical Union Fall Meeting, by the Jet Propulsion Laboratory, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, Calif., 12. December, 14 pp.

[317] Robinson, S. E. (1985). Path delay estimation algorithms. Memo to D. W. Trask Jet Propulsion Laboratory, California Institute of Technology, Pasadena, Calif., 17. January, 7 pp.

[318] Robinson, S. E. (1988). The profile algorithm for microwave delay estimation from water vapor radiometer data. *Radio Science*, May-June, Vol. 23, No. 3, pp. 401-408.

[319] Rocken, C., R. Ware, T. V. Hove, F. Solheim, C. Alber, J. Johnson, M. Bevis, and S. Businger (1993). Sensing atmospheric water vapor with the Global Positioning System. *Geophysical Research Letters*, Vol. 20, No. 23, pp. 2631-2634.

[320] Rocken, C., J. M. Johnson, R. E. Neilan, M. Cerezo, J. R. Jordan, M. J. Falls, L. D. Nelson, R. H. Ware, and M. Hayes (1991). The measurement of atmospheric water vapor: Radiometer comparison and spatial variations. *IEEE Transactions on Geoscience and Remote Sensing*, Vol. GE-29, No. 1, pp. 3-8.

[321] Rogers, A. E. E., R. J. Cappallo, B. E. Corey, H. F. Hinteregger, A. E. Niell, R. B. Phillips, D. L. Smythe, A. R. Whitney, T. A. Herring, J. M. Bosworth, T. A. Clark, C. Ma, J. W. Ryan, J. L. Davis, I. I. Shapiro, G. Elgered, K. Jaldehag, J. M. Johansson, B. O. Rönnäng, W. E. Carter, J. R. Ray, D. S. Robertson, T. M. Eubanks, K. A. Kingham, R. C. Walker, W. E. Himwich, C. E. Kuehn, D. S. MacMillan, R. I. Potash, D. B. Shaffer, N. R. Vandenberg, J. C. Webber, R. L. Allshouse, B. R. Schupler, and D. Gordon (1993). Improvements in the accuracy of geodetic VLBI. In: *Contributions of Space Geodesy to Geodynamics: Technology*, Eds. D. E. Smith and D. L. Turcotte, Geodynamics Series, American Geophysical Union, Washington, D. C., Vol. 25, pp. 47-62.

[322] Ronnang, B. O. (1989). Geodesy-VLBI observables. *The Techniques and Applications of Very Long Baseline Interferometry*, Proceedings of the NATO Advanced Study Institute, Eds. M. Felli, R. E. Spencer, Bologna, Italy, 12-23 September, Kluwer Academic Publishers, Dordrecht, The Netherlands, pp. 289-302.

[323] Rothacher, M. (1992). Orbits of satellite systems in space geodesy. Geodätischgeophysikalische Arbeiten in der Schweiz, Vol. 46, Schweizerischen Geodätischen Kommission.

[324] Rotheram, S. (1989). Clear air aspects of the troposphere and their effects on propagation mechanisms from VHF to millimetre waves. Chapter 9 in: *Radiowave Propagation*, Eds. M. P. M. Hall and L. W. Barclay, Peter Peregrinus Ltd., London, United Kingdom, pp. 150-172.

[325] Ruf, C. S., S. J. Keihm, and M. A. Janssen (1993). TOPEX/Poseidon microwave radiometer (TMR): 1. Instrumental description and antenna temperature calibration. Submitted to *IEEE Transactions on Geoscience and Remote Sensing*.

[326] Ruf, C. S., S. J. Keihm, B. Subramanya, and M. A. Janssen (1994). TOPEX/Poseidon microwave radiometer performance and in-flight calibration. *Journal of Geophysical Research*, Vol. 99, No. C12, pp. 24,915-24,926.

[327] Runge, T. F. (1993). Tropospheric calibration software. *TDA/DSN Document* No. SRD-NVI-5454-OP Rev. A, Jet Propulsion Laboratory, Pasadena, CA, 31 August.

[328] Ryan, J. W., C. Ma, and W. E. Himwich (1991). NASA crustal dynamics project results: Sensitivity of geodetic results to clock and atmosphere estimation models. *Proceedings of the American Geophysical Union Chapman Conference on Geodetic VLBI: Monitoring Global Change*, Washington, D. C., 22-26 April, U.S.Department of Commerce, Washington, D. C., NOAA Technical Report NOS 137 NGS 49, pp. 99-105.

[329] Saastamoinen, J. (1972). Atmospheric correction for troposphere and stratosphere in radio ranging of satellites. *The Use of Artificial Satellites for Geodesy*, Papers presented at the Third International Symposium on The Use of Artificial Satellites for Geodesy, Eds. S. W. Henriksen, A. Mancini, B. H. Chovitz, AGU, AIAA, NOAA, U.S.ATC, Washington, D. C., 15-17 April 1971, American Geophysical Union, Washington, D. C., Geophysical monograph 15, pp. 247-252.

[330] Saastamoinen, J. (1973). Contributions to the theory of atmospheric refraction. *Bulletin Géodésique*, No. 105, and 107, pp. 279-298, and 13-34. In two parts.

[331] Saastamoinen, J. (1973). Contributions to the theory of atmsopheric refraction; Introduction to practical computation of astronomical refraction. *Bulletin Géodésique*, No. 105, 106, and 107, pp. 279-298, 383-397, and 13-34. In three parts.

[332] Saastamoinen, J. (1973). Introduction to practical computation of astronomical refraction. *Bulletin Géodésique*, Part II, Vol. 106, pp. 383-397.

[333] Santerre, R. (1987). Tropospheric refraction effects in GPS positioning. SE 6910 graduate seminar Department of Surveying Engineering, University of New Brunswick, Fredericton, N. B., December, 22 pp.

[334] Santerre, R. and G. Beutler (1993). A proposed GPS method with multi-antennae and single receiver. *Bulletin Géodésique*, Vol. 67, No. 4, pp. 210-223.

[335] Schaper, L. W., D. H. Staelin, and J. W. Waters (1970). *The estimation of tropospheric electrical path length by microwave radiometry*. Peroceedings of the IEEE, Vol. 58, pp. 272-273.

[336] Schellekens, P., G. Wilkening, F. Reinboth, M. J. Downs, K. P. Birch, and J. Spronck (1986). Measurements of the refractive index of air using interference refractometers. *Metrologia*, Vol. 22, pp. 279-287.

[337] Schenewerk, M. S., and J. R. MacKay (1992). The effects of troposphere modeling strategies upon baseline repeatability. *Proceedings of Sixth International Geodetic Symposium on Satellite Positioning*, IAG, AGU, ACSM, NOAA, U.S.GS, Columbus, Ohio, 17-20 March, Vol. I, pp. 273-280.

[338] Schiavon, G., D. Solimini, and E. R. Westwater (n. d.). Performance analysis of a multi-frequency radiometer for predicting atmospheric propagation parameters. Dipartimento di Ingegneria Elettronica, Università Tor Vergata, Rome, Italy, 19 pp.

[339] Schiavon, G., D. Solimini, and E. R. Westwater (1993). Performance analysis of a multi-frequency radiometer for predicting atmospheric propagation parameters. *Radio Science*, Vol. 28, No. 1, pp. 63-76.

[340] Schmidt, J. R. (1975). Computer error analysis of tropospheric effects for the NAVSTAR Global Positioning System. MS thesis U.S.Air Force Institute of Technology, January, GE/EE/75-7, 62 pp.

[341] Segal, B. (1985). The measurement of tropospheric refractive index relevant to the study of anomalous microwave propagation — Review and recommendations. Radio Propagation Laboratory, Radar and Communications Technology Branch, Ottawa, Ontario, June, CRC Report No. 1387, 40 pp.

[342] Sen, A. K., A. Mitra, S. K. Datta, R. Bera, and S. Swarup (1992). Shift of millimeter-wave window frequencies in relation to tropospheric radio meteorological parameters. *International Journal of Infrared and Millimeter Waves*, Vol. 13, No. 8, pp. 1183-1203.

[343] Senff, C., J. Bosenberg, and J. Peters (1994). Measurement of water-vapor flux profiles in the convective boundary-layer with lidar and radar-RASS. *Journal of Atmospheric and Oceanic Technology*, Vol. 11, No. 1, pp. 85-93.

[344] Sheppard, B. E., R. E. Stewart, G. A. Isaac, and T. B. Low (1991). Nonlinear optimal estimation of temperature and integrated water vapor and liquid using a ground-based microwave radiometer in coastal winter storms. *Journal of Atmospheric and Oceanic Technology*, Vol. 8, pp. 812-825.

[345] Shibuya, Shigekazu (n. d.). *A Basic Atlas of Radio-Wave Propagation*. John Wiley & Sons, New York, 770 pp.

[346] Sissenwine, N. (1969). Standard and supplemental atmospheres. Chapter 2 in *Climate of the Free Atmosphere*, Ed. D. F. Rex, Elsevier Publishing Company, Amsterdam, Vol. 4 of World Survey of Climatology, pp. 5-44. ISBN: SBN: 444-40703-0.

[347] Sjöberg, L. E. (1992). Systematic tropospheric errors in geodetic positioning with the Global Positioning System. *Manuscripta Geodaetica*, Vol. 17, pp. 201-209.

[348] Skoog, B. G., J. I. H. Askne, and G. Elgered (1981). Experimental determination of water vapor profiles from ground-based radiometer measurements at 21. 0 and 31. 4 GHz. Research Laboratory of Electronics and Onsala Space Observatory, Chalmers University of Technology, Gothenburg, Sweden, November, 26 pp. Accepted for publication in Journal of Applied Meteorology.

[349] Smith, E. K., and S. Weintraub (1953). The constants in the equation for atmospheric refractive index at radio frequencies. *Proceedings of I. R. E.*, August, Vol. 4, pp. 1035-1037.

[350] Smith, W. L. (1966). Note on the relationship between total precipitable water and surface dew point. *Journal of Applied Metrology,* October, Vol. 3, pp. 726-727.

[351] Snider, J. B. and E. R. Westwater (1969). *Atmospheric Attenuation at 15, 31, and 53 GHz*. ESSA Technical Report ERL 156-WPL 11, U.S. Department of Commerce, Boulder, CO.

[352] Snider, J. B., H. M. Burdick, and D. C. Hogg (1980). Cloud liquid measurement with a ground-based microwave instrument. *Radio Science,* May-June, Vol. 15, No. 3, pp. 683-693.

[353] Solheim, F. S. (1993). Use of pointed water vapor radiometer observations to improve vertical GPS surveying accuracy. Ph. D. thesis Department of Physics, University of Colorado, 128 pp.

[354] Sovers, O. J., and J. L. Fanselow (1987). Observation model and parameter partials for the JPL VLBI parameter estimation software "MASTERFIT" — 1987. Jet Propulsion Laboratory, California Institute of Technology, Pasadena, Calif., 15 December, JPL Publication 83-39, Rev. 3, 60 pp.

[355] Sovers, O. J., and G. E. Lanyi (1994). Evaluation of current tropospheric mapping functions by Deep Space Network very long baseline interferometry. *TDA Progress Report* 42-119, Jet Propulsion Laboratory, Pasadena, CA, 15 November, pp. 1-11.

[356] Spoelstra, T. A. T. (1986). Correcting refraction in radio astronomy. Internal report Netherlands Foundation for Radio Astronomy, Dwingeloo, The Netherlands, 43 pp.

[357] Staelin, D. H. (1966). Measurements and interpretation of the microwave spectrum of the terrestrial atmosphere near 1-centimeter wavelength. *Journal of Geophysical Research,* Vol. 71, pp. 2875-2881.

[358] Staelin, D. H. (1969). Passive remote sensing at microwave wavelengths. *Proceedings of IEEE,* Vol. 57, No. 4, pp. 427-439.

[359] Staelin, D. H. (1981). Passive microwave techniques for geophysical sensing of the earth from satellites. *IEEE Transactions on Antennas and Propagation,* July, Vol. AP-29, No. 4, pp. 683-687.

[360] Stotskii, A. A. (1992). Path length fluctuations through the earth troposphere: Turbulent model and data of observations. *Proceedings of Symposium on Refraction of Transatmospheric Signals in Geodesy,* Eds. J. C. de Munck, T. A. Th. Spoelstra, The Hague, The Netherlands, 19-22 May, Netherlands Geodetic Commission, Publications on Geodesy, Delft, The Netherlands, No. 36, New Series, pp. 179-182.

[361] Stotskii, A. A. (1993). Determination of cloud layer characteristics by using microwave radiometric observations. *Proceedings of COMEAS'93*, Albuquerque, NM, 22-25 March, pp. 224-226.

[362] Stotskii, A. A., and M. N. Kaidanovskii (1992). Fluctuations of atmospheric radio emission. *Proceedings of the Specialist Meeting on Microwave Radiometry and Remote Sensing Applications*, Boulder, CO, Ed. E. R. Westwater, pp. 358-362.

[363] Stotskii, A. A., and I. M. Stotsksya (1990). Fluctuation characteristics of pathlength through the troposphere. Presented at URSI XXIII General Asembly, Prague, Czechoslovakia, 28 August-5 September, Preprint No. 26, 14 pp.

[364] Stotskii, A. A., and I. M. Stotskaya (1992). Analysis of tropospheric pathlength fluctuations using geostationary satellite observations. Astronomical and Astrophysical Transactions, Vol. 2, pp. 327-339.

[365] Stotskii, A. A., and I. M. Stotskaya (1993). Search of correlation between wet and dry components of path delay in the troposphere. XVIII General Assembly, Wiesbaden, Germany.

[366] Straiton, A. W. (1975). The absorption and reradiation of radio waves by oxygen and water vapor in the atmosphere. *IEEE Transactions on Antennas and Propagation,* July, pp. 595-597.

[367] Stull, R. B. (1988). *An Introduction to Boundary Layer Meteorology*. Kluwer Academic Publishers, Dordrecht, The Netherlands.

[368] Sun, J. (1993). Effects of vertical distribution of water vapor and temperature on total column water vapor retrieval error. *Journal of Geophysical Research,* Vol. 98, No. C4.

[369] Tanaka, T., M. Ohba, K. Hirahara, and K. Nakamura (1993). Preliminary results of water vapor radiometer observations for correction of excess path delay on precise positioning by GPS. *Journal of the Geodetic Society of Japan,* Vol. 39, No. 2, pp. 97-105.

[370] Thayer, G. D. (1974). An improved equation for the radio refractive index of air. *Radio Science,* October, Vol. 9, No. 10, pp. 803-807.

[371] Thome, K. J., B. M. Herman, and J. A. Reagan (1992). Determination of precipitable water from solar transmission. *Journal of Applied Meteorology,* Vol. 31, pp. 157-165.

[372] Thompson, A. R., J. M. Moran, and G. W. Swenson, Jr. (1986). Neutral atmosphere. Chapter 13.1 in *Interferometry and Synthesis in Radio Astronomy*, John Wiley & Sons, Inc., New York, NY, pp. 406-439.

[373] Thompson, M. C. (1971). A radio-optical dispersometer for studies of atmospheric water vapor. *Remote Sensing of Environment,* Vol. 2, pp. 37-40.

[374] Thompson, M. C. (1975). Effects of the troposphere on the propagation time of microwave signals. *Radio Science,* Vol. 10, No. 7, pp. 727-733.

[375] Thuleen, K. L., and V. J. Ondrasik (1971). The repetition of seasonal variations in the tropospheric zenith range effect. Jet Propulsion Laboratory, California Institute of Technology, Pasadena, Calif., 15 December, JPL Technical Report 32-1526, Vol. VI, pp. 83-98.

[376] TOPEX Science Working Group (1981). Satellite altimetric measurements of the ocean. Excerpt Jet Propulsion Laboratory, California Institute of Technology, Pasadena, Calif., 1. March, pp. 25-27, 51-55.

[377] Tralli, D. M., and S. M. Lichten (1990). Stochastic estimation of tropospheric path delays in Global Positioning System geodetic measurements. *Bulletin Geodesique,* Vol. 64, No. 2, pp. 127-160.

[378] Tralli, D. M., T. H. Dixon, and S. A. Stephens (1988). Effect of wet tropospheric path delays on estimation of geodetic baselines in the Gulf of California using the Global Positioning System. *Journal of Geophysical Research,* June, Vol. 93, No. B6, pp. 6545-6557.

[379] Tralli, D. M., S. M. Lichten, and T. A. Herring (1992). Comparison of Kalman filter estimates of zenith atmospheric path delays using the Global Positioning System and very long baseline interferometry. *Radio Science,* Vol. 27, No. 6, pp. 999-1007.

[380] Tranquilla, J. M., and H. M. Al-Rizzo (1993). Investigation of GPS precise relative static positioning during periods of ice clouds and snowfall precipitation. *IEEE Transactions on Geoscience and Remote Sensing,* January, Vol. 31, No. 1, pp. 295-299.

[381] Tranquilla, J. M., and H. M. Al-Rizzo (1993). Range errors in Global Positioning System during ice cloud and snowfall periods. Radiating Systems Research Laboratory, Department of Electrical Engineering, University of New Brunswick, Fredericton, N. B., May, 36 pp. To be published in *IEEE Transactions on Antennas and Propagation*.

[382] Tranquilla, J. M., and H. M. Al-Rizzo (1993). Theoretical and experimental evaluation of precise relative positioning during periods of snowfall precipitation using the global positioning system. *Manuscripta Geodaetica,* Vol. 18, pp. 362-379.

[383] Trenberth, K. E., J. R. Christy, and J. G. Olson (1987). Global atmospheric mass, surface pressure, and water vapor variations. *Journal of Geophysical Research,* Vol. 92, No. D12, pp. 14,815-14,826.

[384] Treuhaft, R. N. (1992). Tropospheric and charged particle propagation errors in very long baseline interferometry. *Proceedings of Symposium on Refraction of Transatmospheric Signals in Geodesy,* Eds. J. C. de Munck, T. A. Th. Spoelstra, The Hague, The Netherlands, 19-22 May, Netherlands Geodetic Commission, Publications on Geodesy, Delft, The Netherlands, No. 36, New Series, pp. 45-53.

[385] Treuhaft, R. N., and G. E. Lanyi (1987). The effect of the dynamic wet troposphere on radio interferometric measurements. *Radio Science,* March-April, Vol. 22, No. 2, pp. 251-265.

[386] Tsuda, T., P. T. May, T. Sato, S. Kato, and S. Fukao (1988). Simultaneous observations of reflection echoes and refractive index gradient in the troposphere and lower stratosphere. *Radio Science,* July-August, Vol. 23, No. 4, pp. 655-665.

[387] United States Department of Commerce (1967). A world atlas of atmospheric radio refractivity. U.S.Government Printing Office, Washington, D. C., 130 pp.

[388] Vandam, T. M., G. Blewitt, and M. B. Heflin (1994). Atmosphere-pressure loading effects on Global Positioning System coordinate determinations. *Journal of Geophysical Research*, Vol. 99, No. B12, pp. 23939-23950.

[389] Van Hove, T. M., C. Alber, and J. M. Johnson (1993). Atmospheric water vapor delay as noise and signal for Global Positioning System applications. *ION GPS-93,* Proceedings of the Sixth International Technical Meeting of the Satellite Division of The Institute of Navigation, Salt Lake City, Utah, 22-24 September, The Institute of Navigation, Alexandria, Va., Vol. I, pp. 797-804.

[390] Van Vleck, J. H. (1947). The absorption of microwaves by oxygen. *Physical Review*, Vol. 71, pp. 413-424.

[391] Van Vleck, J. H. (1947). The absorption of micowaves by uncondensed water vapor. *Physical Review*, Vol. 71, pp. 425-433.

[392] von Roos, O. H. (1971). Tropospheric and ionospheric range corrections for an arbitrary inhomogeneous atmosphere (first-order theory). Jet Propulsion Laboratory, California Institute of Technology, Pasadena, Calif., 15 December, JPL Technical Report 32-1526, Vol. VI, pp. 99-105.

[393] Walter, S. J., and P. L. Bender (1992). The slant path atmospheric refraction calibrator: an instrument to measure the microwave propagation delays induced by atmospheric water vapor. *IEEE Transactions on Geoscience and Remote Sensing,* Vol. GE-30, pp. 462-471.

[394] Ware, R. H., C. Rocken, and K. J. Hurst (1986). A Global Positioning System baseline determination including bias fixing and water vapor radiometer corrections. *Journal of Geophysical Research,* August, Vol. 91, No. B9, pp. 9183-9192.

[395] Ware, R. H., C. Rocken, C. C. Goad, and J. B. Snider (1985). Experimental verification of improved GPS-measured baseline repeatability using water-vapor radiometer corrections. *IEEE Transactions on Geoscience and Remote Sensing,* July, Vol. GE-23, No. 4, pp. 467-473.

[396] Ware, R., C. Rocken, F. Solheim, T. V. Hove, C. Alber, and J. Johnson (1993). Pointed water vapor radiometer corrections for accurate Global Positioning System surveying. *Geophysical Research Letters,* Vol. 20, No. 23, pp. 2635-2638.

[397] Ware, S. (1987). Platteville-Stapleton, bias free solution. 1 p.

[398] Waters, J. W. (1976). Absorption and emission by atmospheric gases. Chapter 2. 3 in *Methods of Experimental Physics,* Ed. M. L. Meeks, Academic Press, New York, Part B, Radio Telescopes, Vol. 12, Astrophysics, pp. 142-176. ISBN: 0-12-475952-1 (v. 12, pt. B).

[399] Webster, A. (1994). The effect of atmospheric water-vapor on radio interferometers with very short base-lines. *Monthly Notices of the Royal Astonomical Society,* Vol. 268, No. 1, pp. 299-303.

[400] Weiffenbach, G. C. (1965). Tropospheric and ionospheric propagation effects on satellite radio-Doppler geodesy. *Proceedings of EDM Symposium,* Oxford, U. K., September, Hilgore Watts, London, U. K., pp. 339-352.

[401] Weisbrod, S., and L. J. Anderson (1959). Simple methods for computing tropospheric and ionospheric refractive effects on radio waves. *Proceedings of the IRE,* October, Vol. 59, pp. 1770-1777.

[402] Wesely, M. L. (1976). The combined effect of temperature and humidity fluctuations on refractive index. *Journal of Applied Meteorology,* January, Vol. 15, pp. 43-49.

[403] Westrop, J. (1991). Analysis of the 1990 and 1991 Maracaibo GPS survey data. Unpublished report, Department of Surveying Engineering, University of New Brunswick, Fredericton, N. B., December, 47 pp.

[404] Westwater, E. R. (1978). The accuracy of water vapor and cloud liquid determination by dual-frequency ground-based microwave radiometry. *Radio Science,* July-August, Vol. 13, No. 4, pp. 677-685.

[405] Westwater, E. R. (1993). Ground-based remote sensing of the atmosphere by combined passive and active sensors. *Proceedings of COMEAS'93,* Albuquerque, NM, 22-25 March, pp. 179-184.

[406] Westwater, E. R. (1993). Ground-based sensing of meteorological variables. In *Atmospheric Remote Sensing by Microwave Radiometry,* Ed. M. Janssen, Wiley and Sons, pp. 145-213.

[407] Westwater, E. R., and F. O. Guiraud (1980). Ground-based microwave radiometric retrieval of precipitable water vapor in the presence of clouds with high liquid content. *Radio Science,* September-October, Vol. 15, No. 5, pp. 947-957.

[408] Westwater, E. R., J. B. Snider, and M. J. Falls (1990). Ground-based radiometric observations of atmospheric emission and attenuation at 20. 6, 31. 65, and 90. 0 GHz: a

comparison of measurements and theory. *IEEE Transactions on Antennas and Propagation*, Vol. AP-38, pp. 1569-1580.

[409] Wilcox, J. Z. (1992). The effect of tropospheric fluctuations on the accuracy of water vapor radiometry. *TDA Progress Report* 42-110, April-June 1992, Jet Propulsion Laboratory, Pasadena, CA, 15 August, pp. 33-51.

[410] Wilcox, J. Z. (1994). Line-of-sight tropospheric calibration from measurements in arbitrary directions. *TDA Progress Report* 42-116, October-December 1993, Jet Propulsion Laboratory, Pasadena, CA, 15 February, pp. 10-23.

[411] Wilheit, T. T., and A. T. C. Chang (1980). An algorithm for retrieval of ocean surface and atmospheric parameters from the observations of the scanning multichannel microwave radiometer. *Radio Science,* May-June, Vol. 15, No. 3, pp. 525-544.

[412] Williams, D. C. (1975). A theory of the curvature correction in electromagnetic distance measurement. *Survey Review,* Vol. XXIII, No. 178, pp. 166-172.

[413] Winn, F. B., and R. K. Leavitt (1971). Refractivity influence on DSS Doppler data. Jet Propulsion Laboratory, California Institute of Technology, Pasadena, Calif., 15 February, JPL Technical Report 32-1526, Vol. I, pp. 31-41.

[414] Winn, F. B., S. C. Wu, G. M. Resch, C. C. Chao, O. H. von Roos, and H. S. Lau (1976). Atmospheric water vapor calibrations: Radiometer technique. Jet Propulsion Laboratory, California Institute of Technology, Pasadena, Calif., April, JPL Deep Space Network Progress Report 42-32, pp. 38-49.

[415] Wu, Sien-Chong (1979). Optimum frequencies of a passive microwave radiometer for tropospheric path-length correction. *IEEE Transactions on Antennas and Propagation,* March, Vol. AP-27, No. 2, pp. 233-239.

[416] Xu Peiyuan (1992). Water vapor radiometer for Chinese VLBI and GPS geodesy. *Proceedings of Symposium on Refraction of Transatmospheric Signals in Geodesy*, Eds. J. C. de Munck, T. A. Th. Spoelstra, The Hague, The Netherlands, 19-22 May, Netherlands Geodetic Commission, Publications on Geodesy, Delft, The Netherlands, No. 36, New Series, pp. 147-150.

[417] Yan, H. J., K. Sauermann, and E. Groten (1992). The ray bending corrections in tropospheric refraction. *Proceedings of Sixth International Geodetic Symposium on Satellite Positioning*, IAG, AGU, ACSM, NOAA, U.S.GS, Columbus, Ohio, 17-20 March, Vol. I, pp. 291-301.

[418] Yang, Z. G. (1993). Definition of very long-base-line interferometry (VLBI) group delay and relativistic correction model with picosecond precision. *Science in China Series A - Mathematics, Physics, Astronomy, and Technological Sceinces*, Vol. 36, No. 8, pp. 991-997.

[419] Yionoulis, S. M. (1970). Algorithm to compute tropospheric refraction effects on range measurements. *Journal of Geophysical Research,* 20. December, Vol. 75, No. 36, pp. 7636-7637.

[420] Yuan, L. L., R. A. Anthes, R. H. Ware, C. Rocken, W. D. Bonner, M. S. Bevis, and S. Businger (1993). Sensing climate-change using the Global Positioning System. *Journal of Geophysical Research*, Vol. 98, No. D8, pp. 14,925-14,937.

[421] Yunck, T. P. (1993). Coping with the atmosphere and ionosphere in precise satellite and ground positioning. *Environmental Effects on Spacecraft Positioning and Trajectories*, Ed. A. Vallance Jones, American Geophysical Union Geophysical Monograph 73, pp. 1-16.

[422] Zimbelman, D. F., and A. J. Busalacchi (1990). The wet tropospheric range correction: Product intercomparisons and the simulated effect for tropical Pacific altimeter retrievals. *Journal of Geophysical Research,* 15 March, Vol. 95, No. C3, pp. 2899-2922.