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顾及双差残差反演 GPS 信号方向的斜路径水汽含量

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摘　要:给出了顾及 GPS 双差残差反演斜路径水汽 SWV 的解算流程;然后详细给出了双差残差到非差残差的转化算法,并对算法进行了改进;最后利用并址的 GPS 和 WVR 实测数据对反演 SWV 算法进行了验证,结果证实改进的反演算法能以优于 4 mm 精度近实时估算 SWV 值,与目前国际研究精度在同一量级。

关键词:双差残差;非差残差;天顶可降水量;斜路径延迟

中图法分类号:P228.42

自 1992 年 Bevis 等提出了用地基 GPS 探测大气水汽含量的技术后[1,2],GPS 遥感水汽技术在气象业务和研究中的潜在应用受到了广泛关注。国内外多种试验均已证明,利用 GPS 可以高效反演测站上空大气可降水量 PWV(perceptible water vapor),精度可达 1～2 mm[1,3]。随着国内许多城市(北京、上海、广东、江苏等)GPS 连续运行参考站的建设,国内气象部门对地基 GPS 遥感水汽的研究日益重视起来,并开始建立地基 GPS 近实时遥感水汽运行系统。

地基 GPS 测定的测站上空 PWV 是天顶总的可降水量,不能提供测站上空大气中水汽的垂直剖面信息,而水汽的廓线分层信息对于发展和校正中尺度数值天气预报模式的初始场是非常重要的,特别是对于水汽时空变化比较激烈的地区。利用地基 GPS 网探测水汽空间三维分布,必须得到 GPS 信号方向的斜路径延迟量(STD,slant-path total delay),而 STD 进一步可转换为倾斜路径水汽(SWV, slant-path water vapor)。1997 年 Ware 等人[4]开始 GPS 斜路径延迟的研究工作,采用 GPS 双差解算的方法证实了获取 STD 的可行性;2000 年 Alber 等[5]提出了一种从双差中获得信号路径相位延迟的方法;Braun 等[6,7]通过试验对比分析得出,在一定的高度角下,利用 GPS 遥感斜路径水汽 SWV 的精度可达 mm 量级;曹云昌[8]和毕研盟等人[9,10]也基于双差方法验证了利用 GPS 遥感 SWV 在精度上的可行性;宋淑丽等[11]则基于非差算法提出一种以 mm 级精度直接计算 SWV 的方法。本文将在现有研究基础上,进一步改善和提高利用 GPS 估计斜路径水汽的反演精度,以期对层析空间水汽和其他领域应用研究提供高精度的 SWV。

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目前,国际上反演 SWV 主要采用后拟合双差残差分析方法。设利用 GAMIT 估计的天顶总延迟为 ZTD(zenith total delay),干延迟分量 ZHD(也称天顶静力学延迟,zenith hydrostatic delay)由地面气象元素或三维数值天气预报模型确定[12],从 ZTD 中减掉 ZHD 则得到湿延迟分量 ZWD(zenith wet delay)。估算出 ZTD 后,顾及每个历元测站到各卫星倾斜路径信号会留下后拟合残差,再考虑 GAMIT 软件中大气水平梯度模型的影响,则倾斜路径总延迟 STD 为:

$$\mathrm{STD}(e,\phi)=M_{\mathrm{dry}}(e)\mathrm{ZHD}+M_{\mathrm{wet}}(e)\mathrm{ZWD}+M_{\Delta}(e)\times(G_{\mathrm{NS}}\cos\phi+G_{\mathrm{WE}}\sin\phi)+R_e \quad (1)$$

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Retrieval of Water Vapor Along the GPS Slant Path Based on Double-differenced Residuals

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Abstract: Many experiments have shown that zenith integrated precipitable water vapor (PWV) can be readily obtained with better than 2 mm absolute accuracy using GPS instruments. However, PWV measurements do not provide any information on the spatial distribution of water vapor. The measurements of slant precipitable water vapor (SWV) along each path contain much information which has the potential to be useful for numerical weather prediction. In order to get precise SWV, firstly the principle of remote sensing of SWV and computed diagram are described; secondly improved algorithm of converting double-differenced residuals to zero-differenced residuals is developed; finally a real example is given to demonstrate the algorithm involved using GPS and WVR data at one site. It is shown that the improved algorithm can be used to estimate SWV and the root-mean square error is less than 4mm between GPS and SWV. The accurately estimated SWV can be used to retrieve the three dimensional information of water vapor which is useful for numerical weather prediction, geodetic surveying and interferometer synthetic aperture radar (InSAR).

Key words: double-differenced residuals; zero-differenced residuals; perceptible water vapor

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Direct Calculation of Ambiguity Resolution in GPS Short Baseline

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Abstract: A new method that calculates ambiguities in GPS short-baseline through the combination with different carrier phase observations when the deformation is relatively large (0.7 m). A condition that should be satisfied to make sure that the ambiguities of L_1 carrier phase and L_2 carrier phase are integer, is also drived. The DC algorithm proposed in the reference[1] can not only be used to large deformation , but also to the ambiguity resolution in GPS short baseline. Furthermore, the difficulty of the quickness and effectiveness of ambiguity resolution in GPS short baseline, is solved.

Key words: GPS short-baseline; deformation monitoring; integer ambiguity; DC algorithm

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