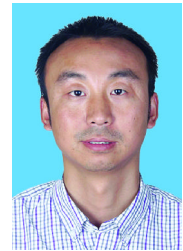


ITRF2008 与 CGCS2000 坐标系的转换

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摘要: 由于当前精密星历所对应解算的 ITRF 框架坐标为 ITRF2008 参考框架, 而在 1:10 000 基础测绘生产项目要求提供 CGCS2000 坐标系成果, 论述了 ITRF2008 到 CGCS2000 间的框架转换的方法及转换后精度分析, 并重点分析了转换的关键性问题。

关键词: ITRF2008; CGCS2000; 框架转换; 历元转换; 速度场

中图分类号: P226.3

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2011 年新疆 1:10 000 基础测绘正式启用 CGCS2000 坐标系, CGCS2000 坐标与 ITRF97 框架定义一致, 参考历元为 2000.0 历元。而新疆的大地测量成果多数是基于 1954 年北京坐标系和 1980 西安坐标系, 已有的 CGCS2000 成果大部分采用转换成果, 精度较差不能满足生产精度要求, 怎么去求解出 CGCS2000 坐标是我们疆内测量工作者面临的一个问题。目前求解方法大致分为 2 种^[1]: 1) 基线平差法, 即联测已知 CGCS2000 坐标成果的测量控制点, 而新疆的 CGCS2000 控制点大都为国家的 A、B 级点, 其点位密度分布不均而且边长较长, 不便于联测; 2) 框架转换法, 先采用高精度 GPS 处理软件解算出 ITRF2008 框架坐标, 然后利用 IGS 网站已公布的 14 个转换参数, 转换至 CGCS2000 坐标系成果, 限于篇幅, 本文只讨论研究坐标框架转换方法。

1 ITRF2008 与 CGCS2000 转换模型

ITRF 国际地球参考框架是基于 VBVI、LLR、SSR、GPS 和 DORIS 等空间技术所建立起的现代全球地面参考框架, 它是一个地心四维坐标参考框架, ITRF 是 IERS 的具体实现, 也是全球 IGS 站坐标和速度场的具体实现。IERS 已经发布了 ITRF88 - ITRF94、ITRF96、ITRF97、ITRF2000、ITRF2005、ITRF2008 全球参考框架。ITRF2008 与 CGCS2000 的转换实质为 ITRF2008 与

ITRF97 Epoch=2000.0 的转换, 由参考框架的定义可知, 各个分量是同通过观测获得的, 其观测手段和精度会有所不同, 加上时间基准的演变, 使得 ITRF 框架之间有细微的差别, 不同的框架可以通过坐标转换求得, 坐标转换模型采用布尔莎-沃尔夫模型, 该模型采用了 7 个参数, 分别是 3 个旋转参数、3 个平移参数加上 1 个尺度比参数。其公式如下^[4]:

$$\begin{bmatrix} X_s \\ Y_s \\ Z_s \end{bmatrix} = \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} + \begin{bmatrix} T_1 \\ T_2 \\ T_3 \end{bmatrix} + (1+D) \begin{bmatrix} 1 & -R_3 & R_2 \\ R_3 & 1 & -R_1 \\ -R_2 & R_1 & 1 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} \quad (1)$$

式中, T_1 、 T_2 、 T_3 、 D 、 R_1 、 R_2 、 R_3 为 ITRF_{xx} 到 ITRF_{yy} 的转换参数, 这些参数等于基准历元的参数 $P(t_0)$ 加上历元 t_0 到转换历元 t 的变化量:

$$P(t) = P(t_0) + \dot{P}(t-t_0) \quad (2)$$

2 ITRF2008 与 CGCS2000 参考框架基准转换

由于目前最新精密星历计算的坐标为 ITRF2008 框架, 通过公式 (1)、(2) 可以实现 ITRF08 到 ITRF97 的框架转换, 然而 ITRF 所公布的框架转换参数是 ITRF08 到 ITRF05、ITRF05 到 ITRF00 和 ITRF00 到 ITRF97 的转换参数, ITRF08 到 ITRF97 没有直接的转换参数, 需通过间接转换计算。所以 ITRF08 到 ITRF97 = ITRF08 到 ITRF05 到 ITRF00 到 ITRF97。

表 1 ITRF_{xx} 到 ITRF_{yy} 框架之间的转换参数及参数速率

转换参数	T_1 (mm)	T_2 (mm)	T_3 (mm)	D (ppb)	T_1 (mas)	T_2 (mas)	T_3 (mas)	Epoch
参数速率	\dot{T}_1 (mm/y)	\dot{T}_2 (mm/y)	\dot{T}_3 (mm/y)	\dot{D} (ppb/y)	\dot{R}_1 (mas/y)	\dot{R}_2 (mas/y)	\dot{R}_3 (mas/y)	
ITRF08 ITRF05	-0.5	-0.9	-4.7	0.94	0.00	0.00	0.00	2005.0
	0.3	0.0	-0.0	0.00	0.00	0.00	0.00	
ITRF05 ITRF00	0.1	-0.8	-5.8	0.40	0.00	0.00	0.00	2000.0
	-0.2	0.1	-1.8	0.08	0.00	0.00	0.00	
ITRF00 ITRF97	0.67	0.61	-1.85	1.55	0.00	0.00	0.00	1997.0
	0.00	-0.06	-0.14	0.01	0.00	0.00	0.02	

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不同历元下框架间的转换，不考虑板块漂移和地壳形变等因素，ITRF2008 与 ITRF97 框架变化值应该较小，这里选取参数历元间隔为 14 年的全球若干个 IGS 跟踪站在 ITRF2008 2011.0 下的站坐标，然后转换至 ITRF97 1997.0 历元下，分析结果如图 1 所示，说明框架间的转换参数随时间的演变在 Z 方向比 X 和 Y 方向变化量大，其精度在 2-3 cm，与文献 [1] 中分析坐标框架基准转换的精度相同。

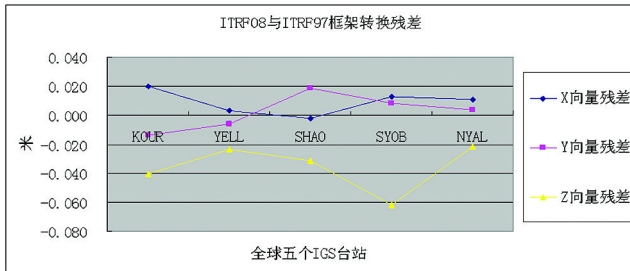


图 1 ITRF08 与 ITRF97 框架间的比较

3 ITRF2008 与 CGCS2000 坐标历元基准的归算

地球不是一个刚体，板块会有漂移和形变，板块与板块之间还有挤压、抬升、下降等运动，它们的运动趋势从长期分析是一个非线性非匀速运动，但是从局部和短期内可以把它认为是一种线性匀速运动。地球表面的观测点都会随时间进行漂移和升降，不同历元基准的坐标应进行坐标历元基准的归算，公式如下^[4]：

$$\begin{bmatrix} X_{t2} \\ Y_{t2} \\ Z_{t2} \end{bmatrix} = \begin{bmatrix} X_{t1} \\ Y_{t1} \\ Z_{t1} \end{bmatrix} + (t2 - t1) \begin{bmatrix} V_x \\ V_y \\ V_z \end{bmatrix} \quad (3)$$

基于当前历元观测求解 ITRF2008 框架下的坐标和 CGCS2000 的框架历元跨度都在 10 年以上，如果没有精确的点位速度场，经公式 (3) 计算的点位误差有可能达到 dm 量级。新疆地区又无 CORS 站来维持本地区的速度场模型，所以在实际的生产中很难获得非框架点的精确速度场。在计算速度场的方法中，可以采用加权平均法^[2]和 NNR-NUVEL-1A 运动板块模型^[5]获得，板块上某一点的速度公式可以采用如下公式^[4]：

$$\begin{bmatrix} V_x \\ V_y \\ V_z \end{bmatrix} = \begin{bmatrix} 0 & -Z & Y \\ Z & 0 & -X \\ Y & X & 0 \end{bmatrix} \begin{bmatrix} \omega_x \\ \omega_y \\ \omega_z \end{bmatrix} \quad (4)$$

4 结 语

作者依照上文原理 编制了 ITRF2008 到 CGCS2000 坐标转换程序，计算了全球 5 个 IGS 站从 ITRF2008 2011.0 转换至 ITRF97 2000.0 台站坐标，然后与这 5 个 IGS 台站的真实 ITRF97 2000.0 坐标进行了比较，分析结果如图 2 所示，说明 SYOB 站的 X 方向较差较大，但台站间各个方向的精度优于 2 cm。

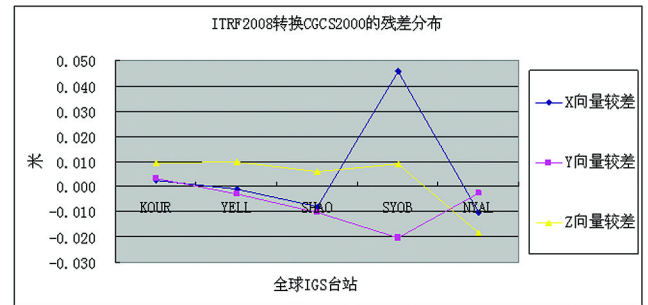


图 2 ITRF2008 成果转换至 CGCS2000 坐标系成果的残差分布

通过上述数据可知，本文阐述的 ITRF2008 框架至 CGCS2000 坐标的转换方法及精度满足生产要求^[6]，但是在转换过程中还需注意以下几个方面：

- 1) 在转换时，可以先转换框架再转换历元，也可以先转换历元再转换框架，两者转换的结果是一致的。
- 2) 尽量获得转换点精确的速度场，如果速度场不精确会影响转换的精度。
- 3) NNR-NUVEL-1A 运动板块模型计算的点位速度场误差较大，不建议采用。
- 4) 速度场的获取可以参考中国地震局的中国地壳运动监测网络站。

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deformation in the application, which first introduced the definition of regression model, and then described the multiple regression equations, the regression equation was significant and the regression coefficient was significant, the last light of the specific examples of the regression equation analysis, modeling, and forecast charts to show the true value of the curve, as well as the remnant of the margin curve on regression analysis model of the actual value.

Key words regression analysis , deformation monitor, model
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Method of GPS-RTK Technique to Route Cross-section Survey
by YANG Kang

Abstract The paper introduced the basic ideas and operation method of measuring route cross-section with GPS-RTK, including how to figure out tangent azimuth angle of random central stake points and cross-sectional line in the work with GPS-RTK. It would improve the efficiency and data accuracy in the cross-section survey.

Key words GPS-RTK technique , cross-section survey , tangent azimuth angle
(Page:139)

Research on Short-distance Precise Trigonometric Leveling Instead of Second-class Leveling
by Han Junsheng

Abstract The traditional geometrical leveling is inconvenient in fluctuating area .This article discussed the viability of monitoring the vertical displacement in small area, using the common Total Station instead of second-class leveling. Base on the formula of precise trigonometric leveling, it discussed the error resources and accuracy in Short-distance. Observed data were acquired by the common Total Station, and then verified the reliability of this method. At last it also gave out several precise measures, strengths and weaknesses.

Key words Total Station , trigonometric leveling ,short-distance , second-class leveling , precise leveling
(Page:141)

Transformation of Coordinate Axis between ITRF2008 and CGCS2000
by MIAO Long

Abstract Based ITRF2008 reference frame on ITRF frame coordinate which is related to present precise ephemeris ,and the achievement of CGCS2000 coordinate axis which is required in the basic mapping producing project about scale of one to a ten thousand, the thesis mainly discussed the conversion method of frame from ITRF2008 to CGCS2000 and the precision analysis after conversion. It also mainly analysed some key problems about transformation.

Key words ITRF2008 , CGCS2000 , frame conversion , epoch conversion , speed field
(Page:144)

Research and Practice for the Independent Experimental Course of Remote Sensing
by XU Yongming

Abstract This paper analyzed the defects of traditional teaching mode which used in remote sensing experimental courses and the necessity of establishing independent experimental courses. Teaching reform and practice were carried out in the independent experimental course of Comprehensive Practice of Using Remote Sensing Software. The teaching reform of the course content, teaching method, teaching material and assessment model were clearly discussed, and the comprehensiveness characteristic of the course was highlighted. Practices show that the teaching mode of this independent experimental course can effectively promote students' technology level and application capability, and improve the teaching quality.

Key words Remote Sensing ,Comprehensive Practice ,independent course ,teaching practice
(Page:146)

Application of Project Study to Teaching of Remote Sensing Major Courses
by SUN Deyong

Abstract This paper takes ocean remote sensing as an example, and shows the application of project study in remote sensing major courses. Teaching practice results demonstrate that this method can obtain good teaching effect. Students' learning interest can be stimulated, and their capability in problem analysis and solving can be greatly improved.

Key words Project study; Remote sensing major courses; Teaching design; Practical ability
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Analysis of the Progress of Compelling 《Atlas of Republic of China Province District Border》's Examination and Receive
by CHEN Zhongyuan

Abstract This article introduced the progress of comparing 《Detailed Atlas》's necessary and principle, examing and receieving the result of the work. Beside that, it also give us the details of main idea and implementation plan.

Key words 《Detailed Atlas》, examing, receieving
(Page:150)

Research on Several Issues of Map Annotation Design
by HE Lihua

Abstract Map is marked by Annotation for identifying object. The choice of the font style and size is an important part of map design. The paper described the importance of Annotation on the map, and introduced the design of the font style, size and color etc. And the general design principles and the transform between several kinds of annotation sizes were summarized further. Finally, it investigated several factors which had impact on the color design of annotations.

Key words map, Annotation, design
(Page:153)

Data Conversion from MapGIS to ArcGIS Using FME
by ZHENG Shike

Abstract Through the analysis of data formats of MapGIS and ArcGIS and the discussion of traditional methods of data conversion, the paper proposed the technical route of using FME to achieve the transition from MapGIS data to ArcGIS data.Comparative analysed the differences of point,line,surface elements in target data and source data.A lot of practice shows that by converting into Geodatabase (MDB) is the best way to achieve the transition from MapGIS data format to ArcGIS data format.

Key words FME ,MapGIS ,ArcGIS ,Data conversion
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Electronic Tachometer Eccentric Lofting New Method for Measuring and its Reliability
by WU Wei

Abstract Currently in engineering surveying, electronic tachometer has been widely used, based on electronic tachometer lofting applications in engineering requirements for lofting points with measurement site must pass visual, however, in the actual work of these two points are often impassability visual. Therefore, this paper presents a new electronic tachometer lofting method, and a detailed discussion on the lofting principle, accuracy and reliability. At the same time, this paper based on the Datang crown close mountain GongSiJi units on the big power limited pressure small project main workshop of pile foundation A standard engineering projects, demonstrates the method of lofting results within and outside precision. It has been found that, this paper expounds the lofting method in different accuracy requirements engineering is feasible and reliable.

Key words eccentric lofting; precision estimation; error analysis; mean square error of a point
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