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Velocity Field of Active Deformation In China Determined by the Crustal Movement Observation Network of China (CMONOC)

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Active deformation, e.g., faulting, folding, and rifting are clearly manifested over the vast territory of China. Quantifying active deformation into its amount, distribution, and timing is prerequisite for an understanding of the nature of geological evolution, climate-tectonics interaction, and ultimately the geodynamic aspects that control these processes. In 1997–2001, a big scientific infrastructure was constructed for a nationwide geodetic network CMONOC, which refined a relatively poor description of active deformation of China with a total of 1056 survey mode sites and 27 continuously recording stations (cGPS). However, this network was still heterogeneous in site distribution. A limited spatial coverage provided insufficient information about the tectonic processes in critical tectonic zones such as the Tibetan Plateau and its adjacent areas. In 2007–2011, a continued construction of the CMONOC was implemented with addition of 1000 survey-mode sites and 233 cGPS stations.

We analyzed all observations acquired from the enhanced CMONOC and others obtained in the past two decades to present the most comprehensive velocity field of tectonic deformation in China. Our velocity field is based primarily on all GPS data obtained at 1056 sites from 1998 to 2007 and two campaigns for a total of 2023 sites respectively in 2009 and 2011. A data set of over 2100 velocity vectors defined on the ITRF2005. The new result with uncertainties less than 2 mm/yr has a much higher resolution than the previous velocity fields. After subtracting rigid rotations of the Eurasia plate from these velocity vectors, the residual components represent a steady tectonic deformation with amplitudes in range of 0–40 mm/yr relative to stable Eurasia plate (see Fig.).

Active deformation of China is characterized with

contrasting features between two equally-sized areas divided roughly by longitude 105°–106°E. In the east, the pattern of deformation illustrated by the CMONOC velocity field is quite simple, characterized by a coherent movement directed southeasterly or east-southeasterly with decreasing magnitude from north to south. The overall motion in the northeastern China amounts to 2–7 mm/yr in rate, and roughly 4–9 mm/yr for most part of North China as well as 6–11 mm/yr for South China. Differential motion less than 2 mm/yr across two adjacent regions is evident from the densified velocity field, though no boundaries are defined unambiguously between them. Furthermore, the denser networks for the northeastern China and South China do not observe any abrupt velocity gradient within their interiors either, consistent with a previous interpretation of little deformation throughout themselves. In North China, differential motions at level of a few mm/yr across several grabens along the southern and eastern margins of the Ordos block are observed and the slip rate across the east-west trending Zhangjiakou-Bohai fault is constrained as low as 1–3 mm/yr. In the west, there appears most of deformation associated with an abrupt rise of the Tibetan Plateau. Diverse types of ongoing tectonics have attested to this spectacular process with reverse faulting and crustal shortening normal to the margins as well as normal and strike-slip faulting responsible for crustal extension within the high mountains.

The continental deformation in response to the India's northward motion is not confined to the plateau, but extends farther north into the Tianshan, Altay, Mongolia and even Baikal, ~3000 km northeast of the Himalayas. The GPS velocity field based on either the new or the old dataset in this region has shown ongoing tectonics in Tibet that can be dominated by three kinds of deformation

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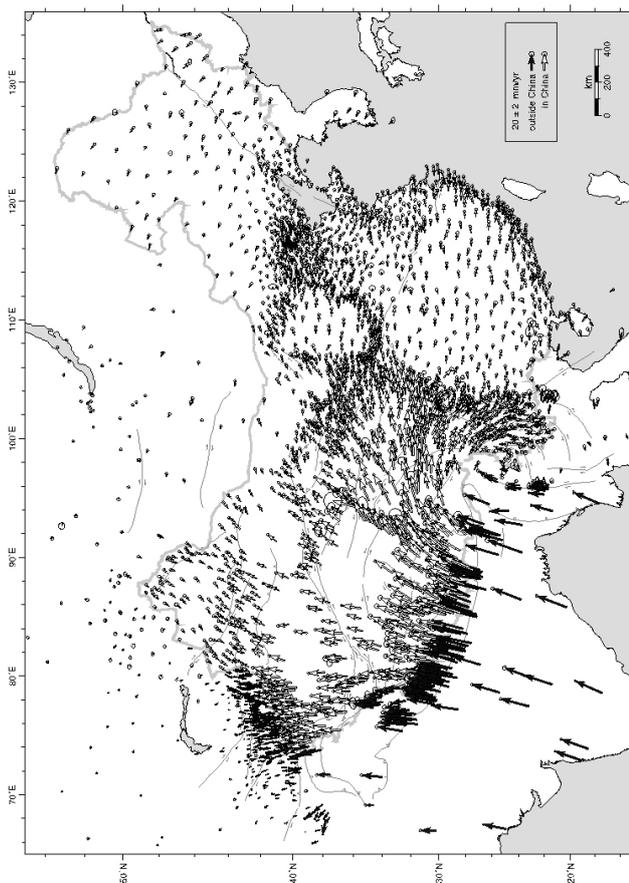


Fig.1 CMONOC velocity field for active deformation in China. The grayed arrows with ellipses on the tips represent GPS velocity vectors with 95 % confident limits. The black arrows denotes those GPS vectors freely available from various published papers

regimes. That is, the continuously-distributed contraction across the plateau with gradually-decreasing velocity components along the direction of the plate convergence; the approximately east-west extension manifested by velocity vectors changes in orientation from north-northeast in the south to due east in the north; and the clockwise rotation of crustal material around the eastern Himalayan Syntaxis as illustrated by opposite orientation for the velocity vectors in Lhasa and Yunnan, all of which show a clockwise rotation of almost 180° from north-northeast to southwest. Furthermore, the new results have revealed new aspects of the pattern of deformation. For example, one velocity profile running roughly along the Qinghai-Tibet highway shows GPS sites moving to northeast with a nearly-linear decrease in rate along the profile direction. A total of 36–38 mm/yr of the plate convergences is distributed uniformly along a section of

2000 km-long across the Himalaya, Tibet, and Mongolia. In contrast, another profile running roughly along longitude 80°E demonstrates a heterogeneous contraction. GPS sites along the profile move to north or north-northwest at the rates that decline northward in a non-linear fashion. Approximately a half of the India's 33–36 mm/yr northward motion is accommodated by the contraction across the northwestern Himalaya and southern margin of the Tibetan Plateau.

The densified GPS measurements in the Tarim and Dzungar Basins attest to no deformation. The basins separated by Tien Shan rotate as rigid blocks clockwise towards northeast or north-northeast. The western Tien Shan (west of longitude 80°E) takes up a convergent deformation of 16–18 mm/yr, almost another half of the India's northward motion so that a vast region in the Kazakh platform exhibits little deformation. By contrast, the eastern Tien Shan (east of 88°E) deforms at a convergent rate of 2–6 mm/yr. As a result, the region north of Tien Shan including the Dzungar Basin and Gobi Altay moves northeasterly at an average rate of 7–9 mm/yr, which is absorbed in part by 4–6 mm/yr of contraction deformation in Altay and the western Mongolia. The remaining convergence deformation between India and Eurasia is partitioned finally by a modest eastward extrusion of Mongolia and its adjacent area to the north.

One of the goals of pursuing a comprehensive mapping of active deformation is to accurately constrain the kinematics of continental tectonics. Although, geodetic measurements in the Tibetan Plateau were growing steadily in the past two decades, an unambiguous kinematical model has not yet been completed. The debate persists on which of the two end-member models- rigid block motions as opposed to diffusive deformation of continuum materials is a better kinematics for the Tibetan Plateau, or if a combination of the two models is most appropriate. The previous GPS velocity field failed to differentiate the two end-members in that the data with limited site density and velocity accuracy actually fitted both of them equally well. It is anticipated that a refined velocity field with the help of new data coming from subsequent CMONOC campaigns (in 2013 and later) would provide much better constraints on the kinematic models, thereby improving our understanding of the dynamics of continental tectonics.

Key words: Active deformation, GPS, Velocity Field, CMONOC