Geophysical Research Abstracts
Vol. 18, EGU2016-16519, 2016
EGU General Assembly 2016

Documenting human transformation and establishing the reference condition of large river systems using Corona images: a case study from the Ganga River basin, India

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The Ganga basin in northern India is one of the most populous river basin in the world with nearly half a billion inhabitants. In the post-independence era, population expansion and human interventions have left the ecosystem of the Ganga in a severely damaged state with dwindling water levels, pollution due to human activity and natural sediment transport severely perturbed by dams and barrages. Fortunately, there is a growing recognition by the policy managers in India that the restoration of the Ganga to a healthier status, closer to its original unperturbed state, would set a strong foundation to future, greener, economic growth in Northern India. However, given the past six decades of fast development, efforts to restore the Ganga to its original condition are faced with a fundamental question: What was the original state of the Ganga? Answering this question will require some knowledge of the former course of the Ganga and of the farming and urban density of the surrounding plains before the impacts of human disturbance could be felt. We have made use of the Corona spy satellite program that collected a large number of earth observation photos in the 1960s. These photos, now declassified, offer us a unique view of the Ganga at the very early stages of intense development and thus before the worst ecological damages occurred. However, actual usage of these images poses significant technical challenges. In the design of the Corona cameras, very high resolution comes at the cost of complex distortions. Furthermore, we have no information on the exact position and orientation of the satellite at the time of image acquisition so an accurate reprojection of the image into conventional map coordinates is not straightforward. We have developed a georectification process based on polynomial transformation to achieve a positional accuracy of $\pm$20m for the area of our interest. Further, We have developed an object-based classification method that uses both texture and raw DN values in order to establish the LULC of the Ganga plain in the 1960s. Finally, geomorphic mapping within the Ganga valley margin in selected reaches was performed using on-screen feature identification with some validation from Bing maps and Google images. A comparison of our LULC and geomorphic maps generated from Corona images with those from modern data shows large changes in the position and form of the river as well as the land cover in the Ganga valley during the last five decades primarily in response to anthropogenic forcings. In certain areas, the urban centres have grown 4-5 fold and channel morphology has changed remarkably in response to the construction of barrages and other interventions. Several reaches of excessive sediment aggradation and significant channel area reduction are identified. The identification of such ‘hotspots’ of geomorphic changes and their causal factors can help the river managers prioritizing the river rehabilitation efforts in selected reaches and establishing the ‘reference’ conditions to target in near future.