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Why can big rivers take so long to mix downstream of tributary junctions

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Airborne and satellite observations show that when big rivers join, they can take hundreds of kilometres to mix completely but, on occasion, may mix very rapidly. We do not know why this is the case. The first measurements of mixing processes at a large river junction (Ríos Paraná and Paraguay, Argentina, combined width $\sim$2.8 km) are presented at times when they mix in $>$ 400 km and in only 8 km distance downstream. When mixing was slow, point surveys showed formation of three-dimensional flow structures which resulted in local mixing. However, they only formed close to the junction (to 0.272 multiples of the post-confluence width downstream). Transect surveys showed penetration of more turbid water from the Paraguay underneath the Paraná, but this was insufficient to promote rapid mixing. There was no clear channel-scale circulation present. Slow mixing was compounded by reverse topographic forcing on the mainstream Paraná side of the river. This kept more turbid water on the Paraguay side of the river, close to the bed. These observations contrasted with the rapid mixing case, where we found clear channel-scale circulation. The momentum ratio between the combining flows reinforced the effects of confluence bed discordance and allowed penetration of more turbid Paraguay water further across the channel width at depth. The importance of momentum ratio makes mixing rates dependent upon basin-scale hydrological response, something that is more likely to differ between large confluent rivers than small rivers, as a result of the different climatic zones that they may capture.