Forum Reply

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Global (latitudinal) variation in submarine channel sinuosity

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We thank Sylvester et al. (2013) for the opportunity to further consider the nature of, and controls on, sinuosity variation in submarine channels. However, in stating that we propose a Coriolis force (F_c) control on the correlation between peak sinuosity and latitude, and discounted slope and sediment supply, Sylvester et al. misquote us. We concluded "The most probable causative controls on [the] global distribution [of peak sinuosity with latitude] are the Coriolis force… and latitudinal variations in both the nature of flows and sediment type" (Peakall et al., 2012, p. 14). Slope was shown to be a very weak control on global channel sinuosity variation, though it is important in controlling sinuosity in individual channels (Peakall et al., 2012, our figures 1 and 2A).

Peak Sinuosity: Sylvester et al. argue that the use of peak sinuosity is unjustified, citing (1) the need to include all bends, and (2) the reliability in identifying it. We address these in turn.

(1) Sylvester et al. add all bends for several channels into their analysis, demonstrating that slope influences sinuosity. This replicates Clark et al.'s (1992) result that slope is an important control on downstream sinuosity in individual channels. However, Sylvester et al.'s approach conflates this universally recognized intra-channel relationship, with global changes in sinuosity between submarine channels. It was for this very reason that Clark et al. (1992) introduced the peak sinuosity concept, to enable comparison between channels.

(2) Peak sinuosity varies with the measurement length-scale (e.g., average over 3, 5, 10, etc., km/bends), and due to factors influencing individual bends (e.g., faults; sea-floor topography). Yet channels do reach their highest sinuosities in the mid-fan region, and show very marked variations, from highly sinuous to approaching straight. So while the *exact* values may have appreciable error bars, there is no ambiguity in the ability of peak sinuosity to differentiate overall variations in channel sinuosity.

Additional examples: Both the Danube Fan and Knight Inlet studies mentioned in Sylvester et al. exhibit high sinuosity at latitudes of ~44ºN and 51ºN. These are within or close to the cut-off for high-sinuosity systems of ~50º suggested by us. While adding examples (of both high and low sinuosity) will alter the precise strength of the relationship, this does not change the result that latitude accounts for the majority of the variation in peak sinuosity.

Coriolis Force: Sylvester et al. suggest that for typical channels, F_c is unlikely to affect those flow aspects that drive sinuosity development. This is based on an implicit assumption that to have an effect, $F_c \geq F_{cf}$, where F_{cf} is the centrifugal force, as given by a Rossby number, $Ro_R = U/fR = 1$ (U is downstream velocity, f is the Coriolis parameter, and R is the radius of curvature). A "typical" channel was given as $R = 2000$ m and $U = 2$ m/s, giving Ro_R of 7.1 at a latitude of 75º. Two points are pertinent. First, channelized flows are influenced when $F_c < F_{cf}$ (Cossu and Wells, 2010). Using a width (W)–based definition of the Rossby number, $Ro_W = U/fW$, Cossu et al. (2010) estimated that F_c significantly influenced flows for Ro_W <10, and Cossu and Wells (2013, their figure 1C) showed that low peak sinuosity correlates well with Ro_W <10. Data for R are rarely given for higher-latitude channels as sinuosities approach 1. Given this, a first-order approach to calculating Ro_R is to use the relationship $R = 2.7W^{1.44}$ (Pirmez and Imran, 2003), to calculate Ro_R (equal to $W/R\ Ro_W$); rearranging gives $W/R = 0.37\ W^{-0.44}$, and therefore for a W of 10 km, $W/R = 0.135$, and for 1 km, $W/R = 0.847$. This suggests that F_c becomes important when Ro_R <~1.4–8.5. Secondly, a key implication from our paper is that there is no "typical" submarine channel planform; this varies in large part as a function of latitude. Sylvester et al.'s values are perhaps typical of low-latitude sinuous channels, but as bend sinuosity decreases with latitude, radius of curvature increases. Given these two factors, then for a U of 1–2 m/s in the Northwest Atlantic Mid-Ocean Channel, an R of 14–63 km, and at 55–60ºN (Klaucke et al., 1997), Ro_R values are ~0.1–1.1.

These results suggest that channels at high latitude that initiate with relatively straight planforms will be heavily influenced by F_c. A mechanistic model for this maintenance of low sinuosity has been proposed based on physical modeling, where properties other than "latitude" were kept constant (Cossu and Wells, 2013). The sense of F_c-driven secondary circulation is constant downchannel, forcing the downstream velocity core to one side, restricting bend growth. This led Cossu and Wells (2013) to propose that F_c promotes low-sinuosity channels at high latitudes.

In conclusion, we counter the assertion that peak sinuosity cannot be used; to do otherwise is to confuse intra- and inter-channel variations of sinuosity. The changes in peak sinuosity with latitude are robust, and evidence has been presented that Coriolis forces may indeed play a major role in controlling this relationship. Nonetheless, as we argued, this is likely a multifactorial process, and flow type and sediment supply almost certainly play a role.

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