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Topografia dos *lagos e canais* da planície de inundação

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As planícies de inundação ao longo do rio Amazonas têm muitos lagos e canais que variam em extensão, profundidade e conectividade (Hess et al., 2015; Rudorff et al., 2014a; Trigg et al., 2012). Esta topografia complexa afeta o fluxo de água através das trocas de água entre rio e planície que, por sua vez, são importantes para os fluxos de carbono, nutrientes e sedimentos (Melack et al., 2009; Walcker et al., 2021). Informações topográficas precisas são essenciais para a caracterização das águas superficiais na planície de inundação, particularmente para modelagem numérica hidráulica (Baugh et al., 2013; Paiva et al., 2013a; Rudorff et al., 2014b). Além disso, o mapeamento topográfico é necessário para o entendimento da morfologia e morfodinâmica dos canais e lagos. O MDE do SRTM é um conjunto de dados topográficos globais, com 30 a 90 m de resolução espacial e precisão de 8 m (Rodríguez et al., 2006), gerado a partir de interferometria na banda C (Farr et al., 2007), que tem sido amplamente utilizado em simulações hidráulicas e caracterização geomorfológica das planícies de inundação amazônicas (**Figura 7a**). No entanto, os dados são afetados pela cobertura de vegetação e possuem erros como viés absoluto, ruídos do tipo *speckle* (aspecto granulado na imagem devido à presença aleatória de *pixels* com valores extremos) e *stripe noise* (ruído em forma de listras) (Rodríguez et al., 2006). Os dados também não são capazes de descrever a batimetria de corpos de água interiores.

A aplicação de dados topográficos, como o SRTM, juntamente com imagens de radar (por exemplo, RADAM, JERS-1) e ópticas (por exemplo, Landsat) permitiram a caracterização geomorfológica de planícies de inundação e canais da bacia Amazônica. Sippel et al. (1992) descreveram lagos de diferentes formas com base em mapas RADAM ao longo de diferentes seções do trecho principal do rio Solimões-Amazonas e seus principais afluentes. Latrubesse e Franzinelli (2002) e Mertes et al. (1996) descreveram regiões geomorfologicamente distintas ao longo do curso superior e médio do rio Amazonas. A topografia em barra (*Scroll-bar topography*), que forma lagos longos e estreitos, e lagos marginais (*oxbow lakes*), localizados em meandros abandonados de rios, são dominantes nos trechos a montante (Mertes et al., 1996; **Figura 7**). Os trechos a jusante são caracterizados por grandes lagos rasos formados pela deposição de sedimentos finos sobre a margem em uma topografia de planície de inundação muito plana (Latrubesse e Franzinelli, 2002; Mertes et al., 1996; **Figura 7**). A deposição ativa de sedimentos nas planícies de inundação também foi identificada e descrita por Lewin et al. (2017), Park e Latrubesse (2019) e Rudorff et al. (2018) usando dados de SR. Já Ahmed et al. (2019), Constantine et al. (2014), Peixoto et al. (2009), Rozo et al. (2012) e Sylvester et al. (2019)

caracterizaram a migração de canais de rios e planícies de inundação. O balanço de sedimentos tem um papel importante na evolução dos rios da Amazônia, pois os rios com altas cargas de sedimentos experimentam uma migração de meandros mais rápida e taxas de corte mais altas do que os rios com cargas de sedimentos mais baixas (Constantine et al., 2014). Mudanças geomorfológicas grandes e rápidas também podem surgir devido às pressões antropogênicas como a pecuária e a irrigação de canais. Essas podem ser as causas da erosão progressiva de um canal ao longo do trecho baixo do rio Amazonas que capturou quase toda a vazão do trecho baixo do rio Araguari, que anteriormente corria diretamente para o Oceano Atlântico (dos Santos et al., 2018; descrito em mais detalhes no capítulo 12).

A fim de melhorar a aplicabilidade dos dados SRTM na modelagem hidráulica

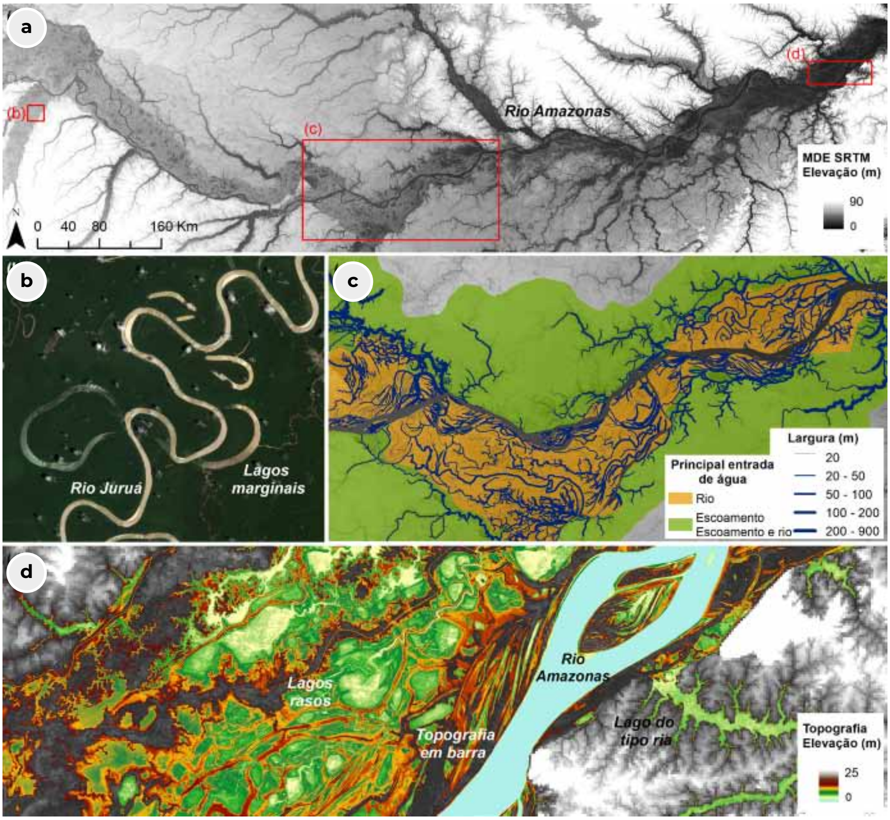

Figura 7: (a) SRTM MDE na Amazônia central. (b) Lagos marginais (*Oxbow lakes*) no rio Juruá (Sentinel-2, outubro de 2020). (c) Largura do canal na planície de inundação (Adaptado de Trigg et al., 2012). (d) Elevação topográfica dos canais e lagos da planície de inundação (Adaptado de Fassoni-Andrade et al., 2020b).

da Amazônia, foram desenvolvidas várias técnicas como a remoção da altura da vegetação (Baugh et al., 2013; O'Loughlin et al., 2016; Paiva et al., 2013a, 2011b; Pinel et al., 2015; Rudorff et al., 2014b; Yamazaki et al., 2017), do viés interferométrico (Pinel et al., 2015; Rudorff et al., 2014b), bem como a suavização e remoção de depressões espúrias (Yamazaki et al., 2012a). Apesar de se ter alcançado uma melhor representação topográfica com a utilização desses métodos, as informações topográficas abaixo da superfície da água não podem ser recuperadas a partir do SRTM. Além disso, o conjunto de dados SRTM conta com uma única passagem em fevereiro de 2000. Portanto, alguns processos, como enchimento e drenagem da planície de inundação, podem não estar bem representados nos modelos numéricos. A batimetria do rio é também uma informação fundamental que não é resolvida sistematicamente. Recentemente, Brêda et al. (2019) demonstraram o potencial de assimilar dados de altimetria por satélite em modelos hidráulicos para sua estimativa. Para estimar a topografia em áreas sazonalmente alagadas, Bonnet et al. (2008) combinaram o nível da água superficial com extensões de inundação derivadas de imagens JERS-1 para estimar um MDE batimétrico da planície de inundação do Lago Grande de Curuai. Park et al. (2020) relacionaram a lâmina da água e um mapa de frequência de inundação, derivado do mapeamento das águas superficiais, para inferir a batimetria do Lago Grande de Curuai. Fassoni-Andrade et al. (2020b) desenvolveram e aplicaram um método sistemático para estimar a topografia de planície de inundação usando uma combinação de mapas de frequência de inundação derivados de SR óptico e dados de nível da água *in situ* (**Figure 7d**). Esse foi o primeiro mapeamento sistemático e extensivo da batimetria de uma área inundada sazonalmente, mostrando profundidades de planície de inundação inferiores a 5 m (15 m) em águas baixas (altas), e volume de armazenamento ativo na planície de inundação de águas abertas variando em média 104,3 km^3 cada ano. Esse conjunto de dados foi complementado sobre regiões permanentemente inundadas por uma compilação de cartas náuticas digitalizadas da Marinha do Brasil. Recentemente, Fassoni-Andrade et al. (2021) aplicaram esta metodologia ao estuário do rio Amazonas mostrando a morfologia da planície de inundação em zonas de maré.

As informações batimétricas em áreas permanentemente inundadas dependem de medições em campo. Entre os estudos citados aqui, apenas alguns obtiveram informações batimétricas *in situ* nas planícies de inundação (Bonnet et al., 2008; Fricke et al., 2019; Pinel et al., 2015) e em rios (Wilson et al., 2007). Estudos adicionais com batimetria detalhada incluem Lesack e Melack (1995), Barbosa et al. (2006), Panosso et al. (1995), e Trigg et al. (2012). Como parte do primeiro balanço hídrico de um lago de planície de inundação da Amazônia, Lesack e Melack (1995) obtiveram a batimetria do lago, que foi posteriormente utilizada no modelo hidrológico de Ji et al. (2019). Panosso et al. (1995) realizaram um levantamento batimétrico do Lago Batata, localizado próximo à confluência dos rios Trombetas e Amazonas. Esse lago recebeu rejeitos do processamento de bauxita e a estimativa foi utilizada para estudos de conservação e recuperação. Barbosa et al. (2006) conduziram um extenso levantamento batimétrico da planície de inundação do Lago Grande de Curuai, na parte leste da bacia Amazônica. A batimetria foi usada para estimar o volume de água armazenada, em simulação hidráulica (Rudorff et al., 2014b) e avaliação topográfica (Fassoni-Andrade et al., 2020a). Trigg et al. (2012) ilustraram a primeira caracterização sistemática de canais de planície de inundação na Amazônia central com base em imagens Landsat e dados *in situ* (**Figura 7c**). As larguras dos canais das planícies de inundação variam consideravelmente (10-1000 m), e as profundidades dos canais estão relacionadas com a amplitude local da onda de cheia do rio Amazonas (~10 m), sendo mais profundas quando sujeitas ao escoamento local.

Muitos avanços têm sido alcançados para a caracterização da topografia de rios e planícies de inundação com a utilização do SR, incluindo as perspectivas promissoras dos novos MDEs. A banda L, por exemplo, reduz o viés positivo sistemático da vegetação por causa da sua capacidade de penetrar na copa das árvores. As imagens da missão NISAR, um satélite SAR de duas bandas a ser lançado em 2023, com cobertura global e períodos de revisita de 12 dias, aumentarão a disponibilidade dos dados de radar de banda L. A missão SWOT irá medir, simultaneamente, o nível da água superficial e a extensão de água, abrindo novas oportunidades para criar e melhorar as técnicas para estimar a topografia de rios e planícies de inundação. Novos dados, ainda não explorados, do satélite ICESat-2 (lançado em 2018), poderão ser úteis para a estimativa e validação da topografia.

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