Developing and validating the BIKER algorithm has provided a unique lense through which we can discuss riverine gas exchange theory. In that context, we next explore some considerations for future work on $k\_{600}$ upscaling in SWOT-observable rivers.

####4.2.1 Gas exchange under uniform and non-uniform flow conditions

Section 2.2 highlights that most upscaling studies to date have assumed uniform flow conditions (i.e. $S\_h \neq S\_0$) in order to train upscaling models using readily available slope data. However, the first-principles model previously used by @ulsethDistinctAirWater2019a and @raymondScalingGasTransfer2012a to define \*eD\* [@tsivoglouTracerMeasurementReaeration1976] does not make this simplifying assumption. Therefore, it is an open research question whether parameterizing $k\_{600}$ upscaling models via $S\_h$ can account for some of the unexplained residual variation in current upscaling models [@hallGasExchangeStreams2020]. Conveniently, SWOT will explicitly measure $S\_h$ at unprecendeted spatial and temporal resolutions and will be spatially joined to hydrography that provides $S\_0$. Thus, future researchers can use BIKER and SWOT in conjunction to directly answer this question.

####4.2.2 Bed roughness and gas exchange in SWOT rivers

Channel bed roughness affects riverine gas exchange mostly in high energy streams where slope is sufficiently steep for bubble-induced gas exchange to occur [@hallGasExchangeStreams2020]. @ulsethDistinctAirWater2019a showed bed roughness loosely scales with $k\_{600}$ in steep Alpine streams. However, they coarsely estimated bed roughness from arial imagery and to date most similar work has focused on labratory exercises [e.g. @chansonStreamReaerationNonuniform; @moogStreamReaerationNonuniform]. We argue that bed roughness is not controlling gas exchange in SWOT-observable rivers because they are so large and therefore flat. Instead, gas exchange in SWOT-observable rivers is presumably dominated by water-column, rather than bed friction, turbulence. We show in Figure S2 with the @ulsethDistinctAirWater2019a data that the 'effective bed roughness height' scales with $k\_{600}$ only in extremely steep streams (see Text S2 for the calculation of this bed roughness term). This relationship fundamentally breaks down in less steep rivers, and such steep slopes are functionally impossible in SWOT-observable rivers that are over 50m wide. This promising initial result indicates bed roughness controls some aspects of gas exchange and should be explicitly explored in future work, but is less relevant for BIKER's application to SWOT data. This is particularly important because small, steep rivers dominate global river networks and their GHG evasion [@horgbyUnexpectedLargeEvasion2019] due to the fractal nature of river systems [@tarbotonFractalNatureRiver1988].

####4.2.3 Wind-driven gas exchange in SWOT rivers

In wide rivers like those that SWOT will observe, wind begins to exert a non-trivial influence on gas exchange. It is well established that in lakes and the ocean, wind controls near-surface turbulence and thus gas exchange [@beaulieuControlsGasTransfer2012a; @readLakesizeDependencyWind2012]. Authors have argued that large rivers are a hybrid of the hydraulics-driven turbulence in small rivers and the wind-driven turbulence in lakes [@beaulieuControlsGasTransfer2012a]. As SWOT will measure only rivers wider than 50m, it follows that wind is likely exerting some influence on gas exchange in SWOT-observable reaches. Here, we opted to ignore wind effects in our upscaling model and in BIKER to favor global scalability and implementability for two reasons: 1) current upscaling efforts do not account for wind in their estimation of $k\_{600}$ either and 2) it is infeasible to parameterize every set of SWOT measurements with local wind data. Further, relying on an in situ understanding of wind defeats the purpose of BIKER for ungauged settings. Future work should explore the feasibility of assigning a Bayesian prior on wind speed for BIKER.