Application of the XT3D Multi-Point Flux Approximation to Vertically Staggered Grids or maybe Application of the XT3D Multi-Point Flux Approximation and Enhanced Grid Connectivity to Improve Accuracy of Flows in MODFLOW 6 Models With Steeply Sloping Layers Xt3d Enthusiast1, Affiliation1 Xt3d Enthusiast2, Affiliation2 Xt3d Enthusiast3, Affiliation3 Xt3d Enthusiast4, Affiliation4 10 August 26, 2022 11 Conflict of interest: None. **Key words:** Key words ... 13 Article impact statement: Article impact statement ... 14 Abstract 15 This is the best paper ever... 16

$_{\scriptscriptstyle 7}$ 1 Introduction

Some intro stuff here about MODFLOW (Hughes et al., 2017; Langevin et al., 2017, 2022) and XT3D

9 (Provost et al., 2017)... Horizontal tops and bottoms of cells... Connection length issue...

- Reference and summarize VO results in Bardot et al. (2022). This is an extreme case (virtually imperme-
- able domain surrounding the channel) that nicely accentuates the problem, but there should be some error
- in any application involving VO grids. Obviously expect it to be a bigger issue for greater offsets. XT3D
- 23 didn't help, which was initially surprising since it takes into account connection angles and lengths. Not
- specifying all the angles in the NPF input would cause XT3D to default to "nozee" and therefore assume
- 25 "horizontal" connections are strictly horizontal, but that was not the case in Bardot et al. (2022).
- We explain in this note that it's not just a connection angle and length issue, though that has an effect.
- 27 The main problem with a VO grid is insufficient hydraulic communication between grid cells in adjacent
- layers. (It's not restricted to layered models, but it's convenient to describe it in terms of layers.) We propose
- 29 and test a solution to the problem that involves enhanced connectivity between cells.
- We present three test models that demonstrate 1) how a VO grid effectively creates wormholes for flow,
- 2) results on an unmodified VO DIS grid, 3) results on corresponding DISU grid with enhanced connectivity.
- 32 Results suggest that enhanced connectivity resolves the issue.

33 2 Theoretical Background

- Explain vertically offset (VO) grids and the connection angle/length issue in more detail than in the Intro.
- Discuss areas.
- 36 Summarize XT3D and how it accounts for connection angle/length. Reference demonstration by Bardot
- et al. (2022) that, in spite of that, XT3D doesn't really improve things for a steeply sloping grid. Must be
- 38 something else going on in VO grids.
- Explain wormholes and how they induce horizontal flow in the sloping channel regardless of XT3D.
- Grid with "connector cells"
- Role of flows between layers
- Shutting off flows between layers using extreme anisotropy in connector cells
- Sloping flow in connector cells
- Horizontal flow in flat-top cells
- Squashing of connector cells VO grid with horizontal flows and "wormholes"
- Proposed solution is to introduce cross-connections between layers.

47 3 Approach

- Summarize the overall approach here.
- Will use a DISV plan-view model with connector cells and XT3D to demonstrate the "wormhole" effect
- 50 discussed in the Theoretical Background in the limit as connector cells are squashed out. (Also can look
- 51 at the other limit, as flat-top cells are squashed and connector cells dominate, so grid follows the channel
- 52 boundary.)
- Will use a DIS cross-sectional model to show results you get on a vertically staggered grid (without cross-
- connections), with and without XT3D. Basically show that we can reproduce what Bardot et al. (2022)
- 55 found.
- Will convert the DIS grid to a DISU grid with cross-connections and show improved results, with and
- 57 without XT3D.

58 4 Description of Test Problems

- Describe the test problem setups here.
- 60 4.1 Test problem 1 (DISV plan-view with connector cells)
- 61 Test problem 1...
- 4.2 Test problem 2 (DIS cross-sectional)
- 63 Test problem 2...
- 4.3 Test problem 3 (DISU cross-sectional with cross-connections)
- 65 Test problem 3...

₆₆ 5 Results and Discussion

6 Conclusions

7 Acknowledgments

⁶⁹ Thank all those reviewers.

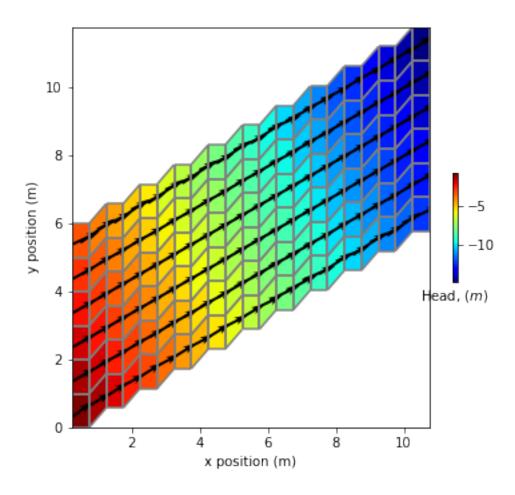


Figure 1: Connector cells are conceptually useful.

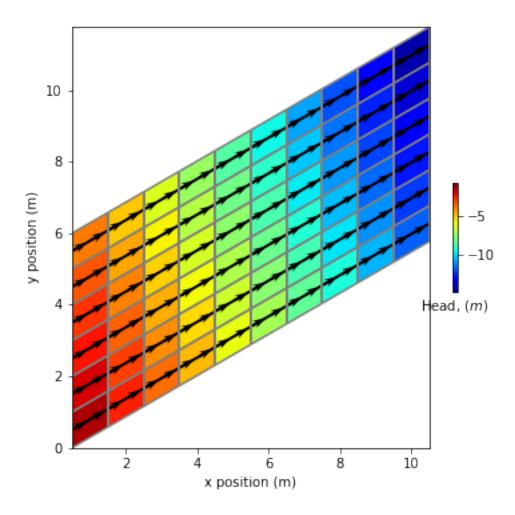


Figure 2: Smooth is good.

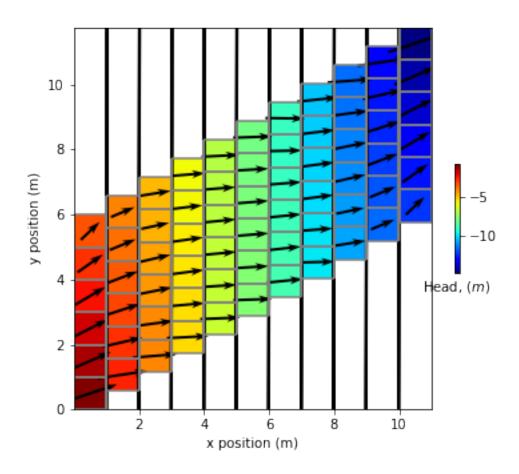


Figure 3: Wormholes are bad.

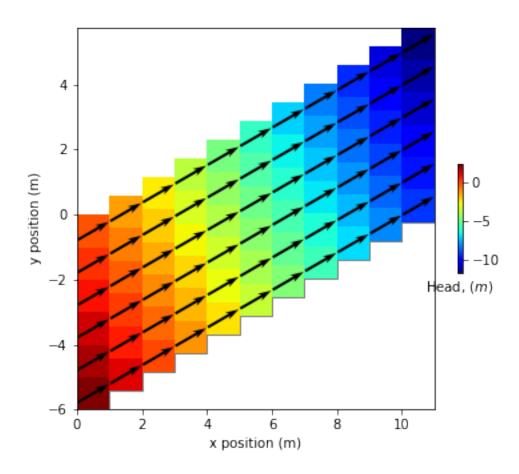


Figure 4: Cross-connections are good.

70 8 Supporting Information

9 Appendix

72 References

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