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Testing new approaches to carbonate system simulation at the reef scale: the ReefSam model first results, application to a question in reef morphology and future challenges.

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Numerical simulation of the stratigraphy and sedimentology of carbonate systems (carbonate forward stratigraphic modelling - CFSM) provides significant insight into the understanding of both the physical nature of these systems and the processes which control their development. It also provides the opportunity to quantitatively test conceptual models concerning stratigraphy, sedimentology or geomorphology, and allows us to extend our knowledge either spatially (e.g. between bore holes) or temporally (forwards or backwards in time). The later is especially important in determining the likely future development of carbonate systems, particularly regarding the effects of climate change. This application, by its nature, requires successful simulation of carbonate systems on short time scales and at high spatial resolutions. Previous modelling attempts have typically focused on the scales of kilometers and kilo-years or greater (the scale of entire carbonate platforms), rather than at the scale of centuries or decades, and tens to hundreds of meters (the scale of individual reefs). Previous work has identified limitations in common approaches to simulating important reef processes. We present a new CFSM, Reef Sedimentary Accretion Model (ReefSAM), which is designed to test new approaches to simulating reef-scale processes, with the aim of being able to better simulate the past and future development of coral reefs. Four major features have been tested: 1. A simulation of wave based hydrodynamic energy with multiple simultaneous directions and intensities including wave refraction, interaction, and lateral sheltering. 2. Sediment transport simulated as sediment being moved from cell to cell in an iterative fashion until complete deposition. 3. A coral growth model including consideration of local wave energy and composition of the basement substrate (as well as depth). 4. A highly quantitative model testing approach where dozens of output parameters describing the reef morphology and development are compared with observational data. Despite being a test-bed and work in progress, ReefSAM was able to simulate the Holocene development of One Tree Reef in the Southern Great Barrier Reef (Australia) and was able to improve upon previous modelling attempts in terms of both quantitative measures and qualitative outputs, such as the presence of previously un-simulated reef features. Given the success of the model in simulating the Holocene development of OTR, we used it to quantitatively explore the effect of basement substrate depth and morphology on reef maturity/lagoonal filling (as discussed by Purdy and Gischer 2005). Initial results show a number of non-linear relationships between basement substrate depth, lagoonal filling and volume of sand produced on the reef rims and deposited in the lagoon. Lastly, further testing of the model has revealed new challenges which are likely to manifest in any attempt at reef-scale simulation. Subtly different sets of energy direction and magnitude input parameters (different in each time step but with identical probability distributions across the entire model run) resulted in a wide range of quantitative model outputs. Time step length is a likely contributing factor and the results of further testing to address this challenge will be presented.