Reviewer Comments #1

The manuscript by Jiang et al "the ANEMI_Yangtze v1.0: An Integrated Assessment Model of the Yangtze Economic Belt - Model Description" developed a system dynamics model for the coupled natural and human systems in the Yangtze region. The coupled human and nature models (CHNS) are the research frontiers in earth system science. They are also the key tool for achieving sustainable development (Fu 2020). There are different approaches to build such models, including the complicated global IAM, local and regional scale agent-based models, CGE, and SD models. Most existing models are at a global scale, while regional models are much needed for decision-making purposes. Therefore, this paper is valuable as it developed a CHNS model for the Yangtze river basin. I recommend that the authors refer to Fu 2020 to lay out the importance and value of this work.

Major comments:
I see the value of this work, but I also agree with other reviewers' comments. For GMD, a detailed model description is needed, including equations, parameters, and data. The authors refer to another paper for the model details. I still think that the necessary information for understanding the model is needed for this paper alone, because it is a model paper and not a model application paper. If space is a concern, details about equations can be placed into the supplements. Even with the vensim model file shared, it is still difficult to fully understand the processes without proper explanation.

- The authors appreciate you comment and have made substantial revisions in this new version, including: (1) the justification of the mechanism behind the feedbacks and citation of sources that support less certain feedback linkages within and between model variables in section 3; (2) the addition of detailed description of the new aspects of the model in section 4, including the stock and flow diagram for Population Sector, providing the equations, their underlying theoretical basis, and citation sources for the Population, Energy, and Water Sectors.
- The Vensim model is in public domain available on Zenodo platform. Information about where to download the code and how to view and run the model is included in the Code availability section of the paper.

The authors described the model as a "downscaled IAM" on which I don't agree. First, I disclaim that I am not familiar with the original ANEMI. Perhaps the model borrowed some ideas from ANEMI, but to my knowledge, the ANEMI_Yangtze presented here does not belong to IAM. It is an SD model with different modeling philosophies and implementation than IAM. It is fundamentally different from other regional IAMs like GCAM-China, which still retained the IAM framework and structure. For IAM, the authors could check van Vuuren 2012. ANEMI_Yangtze is an SD model, just like other SD models (see next comment).

- The authors agree with you and have clearly pointed that ANEMI and ANEMI_Yangtze are SD models.

- However, we disagree that SD models do not belong to IAMs. Actually IAMs and SD models are all MULTI-SECTOR models. Multi-sector modelling mainly occurs within two modelling paradigms: Integrated Assessment Modelling (IAM) and system dynamics simulation (SD). IAMs are developed and used for addressing complex interactions between socio-economic and natural sectors. They integrate knowledge from various disciplines into a single modelling environment and are used to investigate future adaptation pathways to globally changing conditions. There are many different methodological approaches used for the development of IAMs. The most often used is the *static approach* in which to connect disciplinary models output of one model is first obtained then given as input to another. This approach is not well suited for studying feedback relationships between different sectors.
- The second modelling paradigm – (b) *system dynamics simulation (SD)* – integrates all sectoral models into the endogenous structure. SD emphasizes the importance of feedback loops and considers the global system as more than the sum of its parts. Each SD model is built as a collection of coupled differential equations that determine state variables' behaviour over time. System dynamics is an aggregate approach that tends to emphasize the link between the system structure and dynamic behaviour through explicit consideration of multiple feedback relations. This approach is the only way to create and thoroughly study feedback relationships between different sectors.

For modeling CHNS using the SD approach, there have been important studies relevant to this study that worth mentioning. These models include the T21-China model (Qu 2020), iSDG model (Pedercini 2019), and a recent SD model in the Yellow river basin (Jia 2021). These earlier efforts should be included in the literature review or even discussed for similarities and differences. In particular, I found the ANEMI_Yangtze model has very similar sectors as the T21-China model.

- The authors appreciate you comment and have rewritten the introduction section. In this new version, the authors have classified multi-sector modelling paradigm into two catalogues: Integrated Assessment Modelling (IAM) and System Dynamics simulation (SD). A comprehensive review of System Dynamics based models in coupled human-natural systems is added. The similarities and differences between those SD models are briefly discussed.

It is unclear what the spatial unit of the model is. Figure 1 showed the study consists of different provinces and lower, middle, and upper basins. Is this spatial heterogeneity represented in the model, or is it a model for the whole basin without spatial division?

- In the model, the Yangtze Economic Belt was divided into three economic zones: the upper Chongqing-Sichuan upstream urban agglomeration, the middle central triangle urban agglomeration, and the lower Yangtze river delta agglomeration

Minor comments:
L265: what did all land cover changes have to be converted to agricultural land? What about the direct conversion from forest to grass?

- The initial transfer information (transfer from biome type *i* to biome type *j*) is obtained by averaging the transfers happened from 1992 to 2015. The transfers happened from

1992 to 2015 are compiled from The land cover data obtained from ESA Climate Change Initiative - Land Cover.

L569: how to get climate information for the future simulation?

- Future climate information (temperature and precipitation) can be obtained from previous research, for example from Yu et al. (2018).
  Yu, Z., Gu, H., Wang, J., Xia, J., and Lu, B.: Effect of projected climate change on the hydrological regime of the Yangtze River Basin, China, Stoch. Env. Res. Risk A., 32, 1-16, https://doi.org/10.1007/s00477-017-1391-2, 2018.

References:

Fu, B. (2020). Promoting Geography for Sustainability. Geography and Sustainability, 1(1), 1–7. https://doi.org/10.1016/j.geosus.2020.02.003

Jia, B., Zhou, J., Zhang, Y., Tian, M., & He, Z. (2021). System dynamics model for the coevolution of coupled water supply – power generation – environment systems : Upper Yangtze river Basin , China. Journal of Hydrology, 593(October 2020), 125892. https://doi.org/10.1016/j.jhydrol.2020.125892

Qu, W., Shi, W., Zhang, J., & Liu, T. (2020). T21 China 2050: A Tool for National Sustainable Development Planning. Geography and Sustainability, 1(1), 33–46. https://doi.org/10.1016/j.geosus.2020.03.004

Pedercini, M., Arquitt, S., Collste, D., & Herren, H. (2019). Harvesting synergy from sustainable development goal interactions. Proceedings of the National Academy of Sciences, 116(46), 23021–23028. https://doi.org/10.1073/pnas.1817276116

van Vuuren, D. P., Batlle Bayer, L., Chuwah, C., Ganzeveld, L., Hazeleger, W., van den Hurk, B., … Strengers, B. J. (2012). A comprehensive view on climate change: coupling of earth system and integrated assessment models. Environmental Research Letters, 7(2), 024012. https://doi.org/10.1088/1748-9326/7/2/024012

Reviewer Comments #2

The authors have substantially revised their paper and the result is much improved. For the most part, the authors have addressed my comments satisfactorily. Below are several suggested revisions to this new version:

Clarify the details of the companion paper. This paper is the first of two. It would be helpful to know the specific contents of the second paper, since it is otherwise difficult to know whether this paper contains sufficient information.

- The authors have added description of the other paper “This paper focuses on model description and the model application which helps us understand how the Belt will evolve under a particular set of conditions and how the system will change in response to a wide range of policy scenarios, is available in Jiang et al. (2021).” The main contents of the application paper include: a brief description the methodology, description of policy scenarios, discussion of simulation results under different policy scenarios, summary of the key findings and discussion, and offer of policy implications for the Belt.

Clarify the model description. Although much clearer than the previous version, the model description is still relatively vague. It would be very helpful to cite, where possible, sources that support less certain feedback linkages within and between model variables. The entire section 3 refers to one paper: Forester (1961). Even citing previous papers on ANEMI that explain these linkages and the assumptions behind them would be helpful.

- ➢ The authors appreciate this comment and have added the justification of the mechanism behind the feedbacks and citation of sources that support less certain feedback linkages within and between model variables in section 3.

Similarly, in section 4, what is the theoretical basis of many of the driving variables, like GDP difference factor, the pollution index, water demand (which is different from withdrawal, since the demand may not be satisfied), and the crowding factor, for example?

- ➢ The authors have made substantial revision in section 4, including: adding the stock and flow diagram for Population Sector, providing the equations, their underlying theoretical basis, and citation sources for the Population, Energy, and Water Sectors.

How is the energy requirement modelled, since it seems to combine primary energy consumption with electricity consumption? If there is not space to explain all these variables, perhaps the authors could point readers to specific sources?

- ➢ Energy requirement by sources is the production of total aggregate energy requirement and desired energy share. The total aggregate energy requirement scales with economy and is represented as the production of gross output and energy consumption per unit GDP. In the Energy Sector, only primary energy sources are considered. These sources include: three renewable sources (hydropower, nuclear, and new energy sources) and three non-renewable sources (coal, oil, and gas). Electricity generation is modeled in the Water Sector. In Water Sector, the industrial water demand is dominated by the generation of electricity. Electricity can be generated from coal-fired and gas-fired thermal power plants, hydropower, and nuclear power plants.

Explain more clearly where readers can look for the details of model sectors. Section 4.2 lists ten papers associated with ANEMI. The paper should explain which specific paper to check for the details of population (4.3), food (4.4), energy (4.5) and so on.

- ➢ The authors have revised these description as “For further information about the model, please also refer to ANEMI_Yangtze’s technical report by Jiang and Simonovic (2021) and Dr. Breach’s PhD dissertation (Breach, 2020).”

The results section shows graphs related to several of the major changes to the model – population, food, energy, and water (as mentioned on page 18) – but not the results from the new fish sector. It would be interesting to see results that highlight novel aspects of the model.

- The purpose of the application section in this paper is to test the utility of our model and to illustrate how the feedbacks drive the Belt's system behaviour. As the focus of this paper is model description, so we didn't include the results from the new fish sector. However, we did obtain some novel and interesting results through model application. For example, we find that the government's 10-year fishing ban policy cannot prevent the Yangtze fish stock from depletion in the long run. For development of policy scenarios and comprehensive simulation results, please refer to the application paper (Jiang et al., 2021).
  Jiang, H. , Simonovic, S. P., Yu, Z. , and Wang, W.: What are the main challenges facing the sustainable development of China's Yangtze Economic Belt in the future? An integrated view, Environ. Res. Commun., 3, 115005, https://doi.org/10.1088/2515-7620/ac35bd, 2021.

Although much improved, the paper still requires some editing for English. See particularly the second paragraph of the Introduction, but spelling and other errors also exist in other sections.

- The authors did our best to improve language use.

Specific comments follow:

Line 64: Preferably cite only a few ANEMI references here. Other sources can be cited in Chapter 4.

- The authors appreciate your suggestion and have revised correspondingly.

Line 90: Please change "eco-environmental" to "environmental".

- The authors appreciate your suggestion.

Line 244: At the beginning of 3.2 (and perhaps also at the beginning of 3.1), please introduce the subsection. Explain the process of feedback diagram/CLD development. Refer to other sources for the details of the feedbacks, if appropriate.

- Subsections are introduced in section 3.2. Explanation of the process of CLD and sources for the detailed mechanism are added.

Line 285: Either here or in section 4, explain the details of "energy capital". Is this electric power plants? Primary energy use? How is it connected to industrial capital stock?

- The authors have explained the details of "energy capital" in section 4. Energy capital in this research represents energy production capital stock and can be conceived of as developed fields or mines for fossil fuels and built plants for nuclear and hydropower. Energy capital and industrial capital are two different concepts. Energy capital is a type of industrial capital.

Line 308: I am still not clear on the definition of water demand. The revision states that "water demand" is an economic term. How does the model treat unsatisfied demand? Is water allocated among the different uses, and on what basis?

- Water demand is defined as the amount of water needed for the domestic, industrial, and agricultural sectors. We calculate water consumption as the desired consumption supposing that consumption and withdrawal can always be met, which means we do not simulate the unsatisfied demand directly. Instead, we use water stress as a measure of water shortage.

Line 342: What does the data system reside? Is it a standalone database or an Excel spreadsheet, or are values entered into the system dynamics model as constants?

- In Vensim model, time series data enter into the model either as Excel spreadsheet (by using the GET XLS DATA() function) or as auxiliary variable using the WITH LOOKUP(Time) function. In ANEMI_Yangtze, We treat the time series data as an auxiliary variable (In other words, the external time series data is "built in" the model, so people can run the Vensim model file .mdl without accessing the external .xls data). Some of the data are entered into the model as constants.

Line 367: Why was persistent pollution omitted? It would seem to be a clear consequence of China's rapid economic development.

- The reason why we didn't include persistent pollution in our model is because the data is currently not available. So, we envisage including this in our future work when more data becomes available.

Line 402: The text refers to "the country". Is China represented separately in the model from the Yangtze basin?

- Sorry, our mistake. China is not represented separately in the model from the Yangtze basin.

Line 442: It seems the model includes separate representations of coal, oil, gas, hydro, etc. energy sources. Are these for both primary and secondary energy? How are they simulated, and what is the balance between them? This is not explained clearly.

- Yes, six types of energy sources are considered in the energy sector, including three renewable sources (hydropower, nuclear, and new energy sources) and three non-renewable sources (coal, oil, and gas). They are all for primary energy.
- Energy production is determined by the supply of producing capital for each energy source, the effectiveness of energy capital inputs augmented by energy technology, and the depletion and saturation effects which limit productivity in the nonrenewable and renewable sources. Technology progress is resulted in the accumulation of energy capital. Investment in energy capital is mainly driven by production pressure (section 3.2.5), i.e., energy stress (defined as the ratio of energy requirement to energy production). As energy requirement by source is the production of total aggregate energy requirement and desired energy share (desired energy share is exogenously specified), so, the production balance between different sources is fundamentally driven by government policy and resource endowment.

Line 457: How is the South-to-North water transfer simulated?

- The South-to-North water transfer is a subtracted from the stream flow (see equation 16). The values of the South-to-North water transfer are exogenously specified.

Line 476: How are changes in the relative fractions of OT, RC, and DRY cooling systems modelled?

- The fractions are exogenously specified.

Line 565: What does the "S_" in the scenario names mean?

- "S" means scenario. For example, S_base means the baseline scenario.

Line 602: Why does the industrial sector replace the agricultural sector? What is the driver?

- Agricultural water demand depends on grain planting area and per hectare withdrawals (m^3/hectare). Industrial water demand depends on energy or electricity consumption (electricity generation typically dominates water withdrawals in the industrial sector) and water withdrawal factor (m^3/MWh). Technology lowers per hectare withdrawals and water withdrawal factor. Agricultural water demand has a ceiling because grain planting area cannot expand forever due to land availability. But Industrial water demand does not. As long as economy grows, energy (electricity) consumption goes up accordingly, driving up the water demand. This situation exists supposing that energy requirement can always be met through production and trade.

Line 605: Which industries exist in the Yangtze basin that drive N and P releases?

- We do not distinguish between industries in the Belt that drive N and P releases. The values of N and P concentrations of domestic/industrial wastewater are from Henze and Comeau (2008), and the value of N and P leaching coefficients of agricultural runoff is obtained from FAO (http://www.fao.org/3/w2598e/w2598e06.htm).

Line 620: Why does reduced energy consumption decrease economic output? Should not greater efficiency allow greater production and greater GDP? Unless I misunderstand, it seems that a more sustainable future produces a relatively poorer society.

- The answer is in calculation of the gross output by using the Cobb-Douglas production function,

$$Y = Y_0 A_t (\frac{L}{L_0})^{\alpha} (\frac{KO}{KO_0})^{(1-\alpha)}$$

  where, Y = gross output, L = labour force, KO = operating capital, A_t = factor productivity, α = value share of labour, Y_0 = initial gross output, L_0 = initial labour force, KO_0 = initial operating capital.

  In this scenario, a decrease in energy requirement decreases the capital-energy aggregate, which then decreases the operating capital, leading to the decline in economic output.