General Comments

The paper submitted by Li et al. describes a permafrost dataset compiled from measurements made along an oil pipeline route in NE China. The dataset includes information on ground temperatures, soil moisture along with results of geophysical surveys and meteorological data. Instrumented sites are located at various distances from the pipeline and are both on the right-of-way (ROW) and in undisturbed terrain off the ROW which facilitates characterization of impacts of pipeline characterization, similar to that done along other pipelines (e.g. Burgess and Smith 2003; Burgess et al. 2010; Johnson and Hegdel 2008). Such datasets and associated analysis are valuable because they can be utilized for model calibration and validation and also to evaluate mitigation techniques to reduce impacts and improve design of future infrastructure projects (e.g. Burgess et al. 2010). For these reasons, the paper and associated database should of interest to engineers and those involved in environmental impact assessment. However the manuscript does require a number of revisions before it can be accepted for publication.

Response:
Thank you very much for your positive evaluation of our work. We have made a thorough revision to the original manuscript based on your constructive comments and suggestions, and here we give the responses one by one.

As mentioned above, this is not the first time monitoring programs have been established along pipeline routes in permafrost regions and the data utilized to evaluation design performance, effectiveness of mitigation techniques as well as the lessons learned being used for design of other projects. For example, there are several papers and reports on two pipeline corridors in NW North America (Norman Wells to Zama (NWZ) oil pipeline NWT Canada and Alyeska oil pipeline in Alaska). These include for example Burgess et al. (2010); Burgess and Smith (2003); Smith and Burgess (2010); Croft et al. (2021); Mosely et al. (2021); Johnson and Hegdel (2008), as well as other reports referenced in these. Data compilations are available for the NWZ pipeline (Smith et al. 2004, 2008) and may also be available for the Alyeska oil pipeline. It would be useful to refer to these other studies in both the introduction to provide the rationale for compilation of similar databases and also when interpreting the results of data analysis.

Response:
What you said is absolutely right. Pipelines constructed in permafrost have been inevitably faced to many problems related to thaw settlement, frost heave, slope failure, icing, and frost mounds, which were forced to establish monitoring systems for permafrost environmental and stability evaluation such as along the Norman Wells pipeline and the Trans-Alaska oil pipeline, and to obtain field data for understanding how the permafrost foundation performed when pipelines went through or above it. Correspondingly. Such datasets and associated analyses are valuable for this manuscript because they do provide references and implications for CRCOPs when preparing this manuscript. According to your suggestion, most of these studies have been introduced and referred to in this revised manuscript as follows:

As a result, a permafrost monitoring network along the CRCOPs route was gradually established

by referring to the experiences and lessons from other oil/gas pipelines (e.g. Norman Wells to Zama oil pipeline in Canada, Alyeska oil pipeline in the U.S., and Nadym–Pur–Taz natural gas pipeline in Russia) in permafrost regions (Burgess and Smith, 2003; Johnson and Hegdal, 2008; Smith and Riseborough, 2010; Oswell, 2011). Boreholes were instrumented to measure GTs in the active layer and near-surface permafrost on and off the right-of-way (ROW) of the CRCOPs and electrical resistivity tomography (ERT) surveys were used to delineate frozen and unfrozen ground in the vicinity of the CRCOPs (Kneisel et al., 2008; Farzamian et al., 2020).

Newly added references as follows:

Burgess M M, Smith S L. 17 years of thaw penetration and surface settlement observations in permafrost terrain along the Norman Wells pipeline, Northwest Territories, Canada. Proceedings of the Eighth International Conference on Permafrost, 2003: 107-112.

Johnson E R, Hegdal L A. Permafrost-related performance of the Trans-Alaska oil pipeline[C]. Proceedings of 9th International Conference on Permafrost, Fairbanks, AK, USA. 2008: 857-864.

Smith S L, Riseborough D W. Modelling the thermal response of permafrost terrain to right-of-way disturbance and climate warming[J]. Cold Regions Science and Technology, 2010, 60(1): 92-103.

Oswell J M. Pipelines in permafrost: geotechnical issues and lessons[J]. Canadian Geotechnical Journal, 2011, 48(9): 1412-1431.

The paper could be better organized and some important information should be provided. In particular, Section 2 (Study site and instrumentation) could be better written and include some information from Section 3 (Data description). It would be better to clearly describe the instrumentation used to measure each variable (i.e. ground temperature, moisture content, air temperature etc.) and use a table to indicate which variables are measured at each site/borehole. This would reduce repetition and enhance clarity. Some of the information in Section 3 also describes instrumentation and should be moved to Section 2 so that all methods appear in the same section.

Response:

Thank you very much for your comments. In the revised manuscript, Section 2 (Site description) and Section 3 (Data description) have been re-organized referring to your comments and the recently published papers in ESSD (e.g. Boike et al., 2019; Wu et al., 2022). Section 3 is divided into three sub-sections: meteorological data, ground temperature and soil water content data, and subsurface electrical resistivity data.

Information on distance of boreholes from the pipe centre line for those on the ROW needs to be clearly provided. Also, the ROW width at each site should be provided as well as the distance from the ROW edge for boreholes that are in the undisturbed terrain off the ROW. This information is important as it provides information on the amount of disturbance there might be at each site. This information could be provided in a table or as site plans in the supplementary information.

Response:

Thanks for your better suggestions. We are sorry that we did not provide the exact locations of

boreholes and the pipeline ROW width. The ROW width of the CRCOPs is approximately 20 m along its route. The distances of boreholes from the pipe centerline of CRCOP I have been added in Table 3 in the revised manuscript as follows. Four boreholes of JS-B-1, JS-B-2, SL-B-1, and SL-B-2 were drilled on the ROW of CRCOP II. Their distances from the centerline of CRCOP II are provided. In turn, the distances of off-ROW boreholes from the ROW edge are easily determined.

Table 3 Summary of monitoring information of ground temperature boreholes, water content monitoring pits, and ERT profiles along the CRCOPs in Northeast China.

Variable	Borehole/ ERT profile	Maximum monitoring depth (m)	Distance from pipe centreline (m)	Data logger	Measuring internal	Operation period
Soil/permafrost temperature at the natural site (off-ROW)	XA-B-I	60.5	100	CR 3000	2h, AUTO	Nov 2018 – Nov 2020
	XT-B-I	20	80	RTB37a36V3	2h, AUTO	Jul 2019 – Aug 2021
	JS-B-I	20	24.8	CR 3000	2h, AUTO	Dec 2018 – Jun 2021
	SL-B-I	25	12.6	Fluke 87/89 RTB37a36V3	Monthly, MANU 2h, AUTO	Sep 2017 – Oct 2019 Aug 2020 – Dec 2020
	JB-B-I	60.6	80	CR 3000	2h, AUTO	Jun 2018 – Aug 2020
	JB-B-II	20	16.6	Fluke 87/89 CR 3000	Monthly, MANU 2h, AUTO	Nov 2011 – Sep 2017 Oct 2017 – Aug 2021
Soil/permafrost temperature on pipeline ROW (on-ROW)	JS-B-1*	19.8	2	CR 3000	2h, AUTO	Oct 2017 – May 2021
	JS-B-2*	20	5	CR 3000	2h, AUTO	Oct 2017 – Aug 2021
	SL-B-1*	24.8	3	Fluke 87/89 RTB37a36V3	Monthly, MANU 2h, AUTO	Sep 2017 – Oct 2019 Aug 2020 – May 2021
	SL-B-2*	24.8	5.9	Fluke 87/89 RTB37a36V3	Monthly, MANU 2h, AUTO	Sep 2017 – Oct 2019 Aug 2020 – May 2021
	JB-B-1	20	2	Fluke 87/89 CR 3000	Monthly, MANU 2h, AUTO	Mar 2014 – Sep 2017 Oct 2017 – Aug 2021
	JB-B-2	15	2	CR 3000	2h, AUTO	Jun 2015 – Aug 2021
	JB-B-3	15	2		2h, AUTO	Jun 2015 – May 2018
	JB-B-4	15	2		2h, AUTO	Jun 2015 – May 2019
	JB-B-5	10	3		2h, AUTO	Jun 2015 – Aug 2021
	JB-B-6	14	3		2h, AUTO	Jun 2015 – May 2018
	JB-B-7	15	3		2h, AUTO	Jun 2015 – May 2020
	JB-B-8	15	4		2h, AUTO	Jun 2015 – Aug 2021
	JB-B-9	15	4		2h, AUTO	Jun 2015 – May 2018
	JB-B-10	15	4		2h, AUTO	Jun 2015 – May 2020
Soil volumetric liquid water content on pipeline ROW	JB-W1 JB-W2 JB-W3	2.5	1	CR 3000	2h, AUTO	Jun 2015–Aug 2021
Electrical resistivity	P-JS	24		SuperSting R8 system	Site visit	Apr 11, 2018
	P-SL	24			Site visit	Apr 12, 2018
	P-JB-1	24			Site visit	Apr 06 – Apr 10, 2018
	P-JB-2	24				
	P-JB-3	24				
	P-JB-4	18				

* Boreholes were drilled on the ROW of CRCOP II. The ROW width along the pipeline is about 20 m.

Section 3 doesn't really provide a clear description of the data in the dataset but rather provides some information on instrumentation as well as presentation of some of the data in graphic form and interpretation of the results. It would be useful to have a brief and clear description of the data. For example, are hourly, daily, annual mean values provided; if annual values provided, what is the time period (calendar or hydrologic year) and how do you deal with missing values; describe any processing done to ensure data quality and any derived parameters that might be included in the dataset. The presentation of the data and interpretation of results could be in a separate section.

Response:
Section 3 has been revised to improve the description of the data according to your comments. For example, we have added the description of quality control of data in the revised manuscript. Obvious erroneous recordings are manually removed and all the missing or abnormal data are replaced with null values before daily average values are calculated. All meteorological data from the small automated AWS, GT data at different depths in boreholes, and VWC data, at the daily resolution, have been complied in this dataset.

A number of specific comments are provided below. Some of these are editorial while others are related to clarity of the content. I hope the authors find the comments helpful in preparing an improved manuscript that should be acceptable for publication.

Specific Comments

L19-20 – suggested revision: "In 2011 we initiated a…."

Response:
It was revised according to your suggestion.

L21-24 – Not clear. Do you mean you compiled an integrated dataset on the ground thermal state utilizing the various types of data that are mentioned in the first part of the sentence. You should revise to be clear.

Response:
The sentence has been revised as "We compiled an integrated dataset of the ground thermal state along the CRCOPs route, consisting of meteorological data near the southern limit of latitudinal permafrost (SLLP), ground temperature data in 20 boreholes with depths of 10–60.6 m, soil volumetric liquid water contents and 2-D electrical resistivity tomography (ERT) data at different sites.".

L24–26 – Are you referring to the undisturbed sites off the ROW? Revise to be clear. A revision is also suggested: "Results demonstrate that permafrost has warmed between 2011-2020 in the vicinity of SLLP, manifested as an increase in ground temperature at depth likely in response to climate change."

Response:

Thanks. The sentence has been revised according to your suggestion.

L28 – Insert “an: between “as” and “insulation”

Response:
Added.

L37-38 – I suggest you remove the older references (ones between 1999 and 2008) and add more recent ones such as Etzelmuller et al. (2020); Zhao et al. (2020) and Liu et al. (2021). You could also cite the most recent BAMS State of the Climate sections on permafrost (i.e. Smith et al. 2021 and Noetzli et al. 2021).
L39 – You could delete the older Zhang et al. ref and add newer ones such as Burke et al. (2020) and other recent papers (you could also cite most recent IPCC reports of 6th Assessment).
L41 – I think you can delete the older references here (before 2010) as you have several recent ones.

Response:
According to your suggestions, the older references have been deleted and more recent references have been added. The sentence has been revised as “Over the last few decades, the warming and thawing of permafrost have been observed in most permafrost regions (e.g., Ran et al., 2018; Biskaborn et al., 2019; O’Neill et al., 2019; Etzelmüller et al., 2020; Liu et al., 2021; Noetzli et al., 2021; Smith et al., 2022), and permafrost degradation will continue in response to a warming climate (Koven et al., 2013; Burke et al., 2020). Permafrost change affects the geomorphological characteristics, carbon release, hydrological process, ecosystem, climate system, and integrity of infrastructure (Cheng and Jin, 2013; Beck et al., 2015; Hjort et al., 2018, 2022; Turetsky et al., 2020; Jin and Ma, 2021; Jin et al., 2021, 2022; Luo et al., 2021; Jones et al., 2022; Liu et al., 2022; Miner et al., 2022).”.

L70-71 – Permafrost presence/absence is inferred or interpreted from the ERT results rather than “detected”. A revision is suggested: “… electrical resistivity tomography (ERT) surveys were used to determine the distribution of frozen and unfrozen ground in the vicinity of the CCOPs……ERT surveys to characterize freeze-thaw dynamics in….”

Response:
We are sorry for this unreasonable description. The sentence has been revised according to the suggestion.

L68-74 – I don’t think you need this much detail here as it should be covered in the methods section (section 2). You could just say that boreholes were instrumented to measure ground temperatures and ERT surveys were used to delineate frozen and unfrozen ground.

Response:
According to your suggestion, the sentence has been revised as “Boreholes were instrumented to measure GTs in the active layer and near-surface permafrost on and off the right-of-way (ROW) of

the CRCOPs and electrical resistivity tomography (ERT) surveys were used to delineate frozen and unfrozen ground in the vicinity of the CRCOPs (Kneisel et al., 2008; Farzamian et al., 2020).".

L82 – replace "are" with "were"

Response:
It was revised.

L88-90 – Revision suggested "Between 1972 and 2017, MAAT increased at a …" You can also delete "climate wetting".

Response:
According to the suggestion, the sentence has been revised as "Between 1972 and 2017, MAAT increased at a rate of 0.32 °C per decade while annual precipitation increased at a rate of 14.6 mm per decade.".

L91 – You can delete the last part of the sentence from "retrieved" onward. The additional information can be provided in the Table (or its caption) if you need to provide references to previous studies.

Response:
It was deleted according to your comment .

L92-93 – Suggested revision – "Permafrost is warm with mean annual ground temperature…….ranging from -1.8 to -0.4°C. The reference may not be necessary as it seems to be a textbook, rather than a reference that specifically reports on MAGT in the region – perhaps one of the other papers in the list would be more suitable.

Response:
The sentence has been revised according to the suggestion and the less related reference was deleted.

L95-97 – Suggested revision – "The XA site, located in a permafrost wetland, is the most northern site and has the lowest air temperature, while……China has the highest air temperature and permafrost occurs in isolated patches.

Response:
The sentence has been revised according to the suggestion.

L99-100 – Can't you just say it is ice-rich permafrost?

Response:
It was revised as "ice-rich permafrost".

L108 – replace “built” with “installed”

Response:
It was revised.

L111 – You could just say when the hole was drilled and instrumentation installed. It isn’t clear why it is important to say that it was finished 6 months before installation of AWS. If it was a long drilling time and likely caused significant disturbance to the thermal regime just give the number of days of drilling and the implication of this.

Response:
We are sorry for this vague statement. The sentence has been revised as “Besides, a new borehole (JB-B-I) was drilled in March 2017 down to 60.6 m near the above-mentioned AWS.”.

L119 – How far off the ROW were these sites – this information should be provided.

Response:
The distances of off-ROW boreholes at each site from the centerline of CRCOP I were added in Table 3 in the revised manuscript.

L118-139 – Some of the detail could be reduced by putting some of the information in a table (or figure) such as the distance from the pipe, or depth of borehole. The table could also summarize all the instrumentation or surveys at a site, i.e. add this information to Table 3 for example. In this section you could just mention the instrumentation used to acquire information on the various parameters such as GT, soil moisture etc. You should also indicate how wide the ROW is at each site as this will give the reader an indication of the amount of the disturbance.

Response:
This paragraph has been rewritten and some necessary information has been added in Table 3. Details can be found in the above replies to the comment.

L122-123 – Don’t you mean the boreholes were drilled vertically? (rearrange sentence)

Response:
Sorry for the unclear statement. Yes, all boreholes were drilled vertically. This sentence has been revised as “At the SL site, two on-ROW boreholes (SL-B-1 and SL-B-2, 3 and 5.9 m from the centerline of CRCOP II, respectively) and one off-ROW borehole (SL-B-I, 2.6 m from the edge of the CRCOP I ROW) were drilled in March 2017 and instrumented in September 2017.”.

L129 – Weren’t thermistor cables used in other BHs?

Response:
The GT measurement was carried out by installing a thermistor cable protected by a steel tube into

the borehole. When a borehole was completed, a steel tube was installed in it. Then, the borehole outside the steel tube was densely backfilled with fine-grained sand and a thermistor cable was placed in the steel tube. Thermistor cables containing thermistors at designed intervals were used to monitor ground temperatures.

L134 – Do you mean precision (resolution) rather accuracy here? Wouldn't accuracy be more related to the temperature sensor?

Response:
Agree. In the revised version, we changed this sentence to "…generally has a lower resolution than the CR3000 data logger (±0.05℃).".

L148 Table 2 – The resolution/precision of instrumentation, including the dataloggers used should also be provided.

Response:
The accuracy of the manual readings is estimated to be ±0.1 ℃, which is lower than the CR3000 data logger (±0.05℃) (Juliussen et al., 2010). The GT data collected by the RTB37a36V3 data logger is not as steady as that collected by the CR3000 data logger, i.e., the RTB37a36V3 data logger has a lower resolution than the CR3000 data logger. This content has been added in the revised manuscript.

L151 – Table 3 – You could just give the maximum measurement depth in the table as the various measurement depths would be included in the database. Alternatively, you could include this additional information as a supplementary information table. You could then include the additional information in the table suggested in an earlier comment (distance from pipe, ROW width at each site, and whether BH is on or off ROW).

Response:
Table 3 has been improved and revised according to your comments.

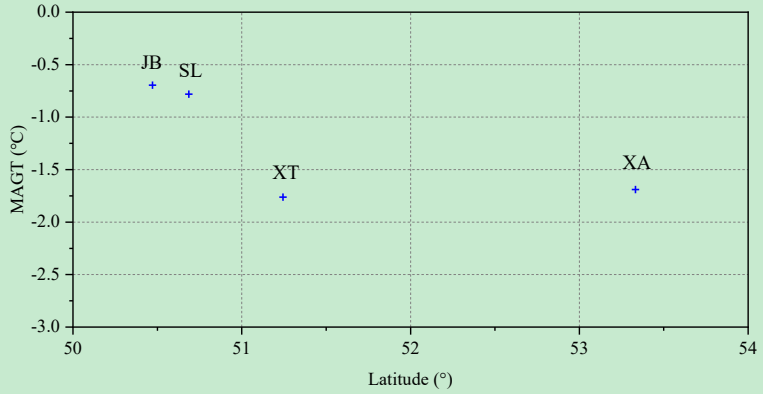
L153 – Section 3 - Data description – You seem to be confusing methodology with dataset description. Much of this information including type of instrumentation used should be included in Section 2 which describes methods including instrumentation. In some cases such as Section 3.2 there is a repeat of the instrumentation description that was given in Section 2. Section 3 also presents results, analysis and discussion so some consideration should be given to revising the organization of sections.

Response:
According to your suggestions, the paper was re-organized and section 3 has been revised to improve the description of the data. Details can be found in the above responses.

L190 – Fig. 3b doesn't clearly show the relationship between GT and latitude and whether it is linear or not. MAGT at DZAA for each undisturbed site could be plotted vs latitude to better show

this.

Response:
As shown in Figure 3b, the annual changes of ground temperatures at the depth of 15m at all monitoring sites are negligible except for the JS site. This depth is considered as the depth of zero annual amplitude (DZZA). The MAGTs at DZAA at the sites of JB, SL, XT, and XA are −0.7, −0.8, −1.8, and −1.7°C respectively, indicating that the MAGT at DZAA is greatly affected by the latitude, but the relationship between MAGT and latitude is not linearly dependent.



L192-193 – Are you sure this isn't an issue with the sensors?

Response:
We think it is not the failure of sensors. Firstly, the thermistor cable used to measure GT has a high accuracy of ± 0.05 °C and the measuring range of the thermistor ranges from −30 to 30 °C. The collected data thus are reliable. Secondly, this abnormal phenomenon has occurred at depths of 10, 15, and 20 m for two consecutive years, which would seem to indicate that the failure of the thermistors is not possible. In addition, the strata of this site (obtained from the JS-B-I borehole) are composed of peaty soil (0-0.8 m), grey silty clay (0.8-2 m), yellowish-brown gravel (2-5.5 m), and strong weathered granite (5.5-20 m). The presence of the rock layers with high permeability provides a channel for the movement of intra-permafrost water.

L197-199 – A bit confusing as Fig. 4 shows seasonal variation.

Response:
It was changed in the revised manuscript.

L199-200 – Are you referring to the thermal offset here?

Response:
We describe the characteristics of the ground temperature curve. As for the thermal offset, it is not discussed. At depths from 1 to 2 m, the monthly average GTs in 2018 was fluctuating in proximity to 0 °C.

L201-204 – A couple of other things to consider: ALT also responds more to shorter-term

variations in air temperature compared to the deeper ground temperatures for which the higher frequency variations are filtered out. ALT will therefore show more interannual variability as shown in Fig. 5. The ground at JB is ice-rich, and melting of ground ice as thaw progresses deeper into the ground can lead to surface subsidence and consolidation of the unfrozen material. Changes in ALT over time can be relatively small as ice-rich material thaws compared to sites where excess ice is negligible. See for example Nyland et al. (2021), O'Neill et al. (2019).

L217-218 – The key thing is that insulation doesn't prevent heat transfer but reduces it.

Response:
Thanks for your comments. The above questions have been considered carefully and interpreted in revising the manuscript. Meanwhile, the relevant references are added.

L219-221 – As well as the effect of the pipe, any ROW disturbance such as changes to the surface, clearing of vegetation will also have an effect on the ground thermal regime. These changes could also effect the ground thermal regime off ROW (lateral heat transfer). See for example some of the publications on the Norman Wells pipeline mentioned earlier and also Burgess and Smith (2003), Smith and Riseborough (2010).

Response:
What you said is right. Our results also show that many factors lead to permafrost thawing and thaw settlement along the pipeline route including ROW vegetation clearing, trenching, warm oil temperature, surface water infiltration, groundwater flowing, and climate warming. Besides, the thermal effects of ROW disturbance can extend to the adjacent undisturbed terrain.

L225 – It isn't clear why this is an artificial permafrost table – is this the site with thermosyphons? If so, it should be mentioned first.

Response:
We are sorry for this mistake. It was changed to permafrost table.

L228-230 – Are you referring to surface settlement (subsidence) here?

Response:
Here it refers to the total settlement of pipeline foundation soil.

L245 – Figure 8 – Consider reversing the colour scale and using blue for higher resistivity (colder ground –permafrost) and red for lower resistivity (warmer ground – unfrozen). This is more intuitive and has been done in other papers presenting ERT results. If some of the transect is off ROW, indicate the ROW edge. Was there a topographic survey done? – no change in ground elevation is shown.

Response:
Thank you for your comments. We re-draw the figure and appendix D based on your suggestion.

The ERT surveys have been conducted at JB, SL, and JS sites. These three sites are selected on relatively flat terrain and there are no obvious changes in ground elevation, which is also described in the revised manuscript.

L246 – There acronym TPCT isn't really needed – just say thermosyphons in the rest of the paragraph.

Response:
It has been changed.

L246-262 – The papers mentioned earlier on the Alaska Alyeska oil pipeline might be relevant here as the effect of thermosyphons are described.

Response:
Yes, the relevant references have been added.

L269 – Volumetric moisture content doesn't really have units. (dimensionless) You could give as %.

Response:
Yes, we added the unit in Figure 9 in the revised version.

References

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