**RC2**: 'Comment on acp-2021-966', Anonymous Referee #2, 10 Feb 2022:

The manuscript “The Mount Everest plume in Winter” by E. E. Hindman and S. Lindstrom analyses the formation and composition of the Mount Everest plume. To do so, the authors examined two wintertime plumes in detail by using GMS images and atmospheric sounding data, which were used for an atmospheric model simulation. The results of this work conclude that the identified plumes are either composed of cloud droplets or ice particles, but were not composed of resuspended snow.

The authors describe their analysis method very clearly and summarize the history of plume studies at Mount Everest in a very nice way. Their analysis method is simple, but was never done before for the Mount Everest plume. For this reason, I recommend to publish this work in ACP after a major revision.

*We thank this reviewer for their careful and thorough reading of our manuscript. We respond to their comments in italics:*

**Major comments**:

This study is mainly based on satellite images with a very low resolution. For me as a reader, it was very hard to see the described observations on the images and especially the videos. I don’t doubt their method, but I think it is worth it to put some more effort in the presentation of the images and videos to make the authors’ statements clearer. I would recommend to add labels with time, km scale bars and markers for the location of the summits.

*In response to this comment, the following paragraph will be inserted between lines 77 and 79:*

> *To locate the features and know distances in the H-8 images and movies, a map is given in Figure 1a. The map provides a distance scale and identifies the locations of the major mountain peaks, the HEV, Phortse and the Arun Valley. The times and dates for all the H-8 images are displayed on the images and the movies themselves.*

*Figure 1 will be expanded to illustrate the important features of the Mt. Everest region presented in the manuscript:*

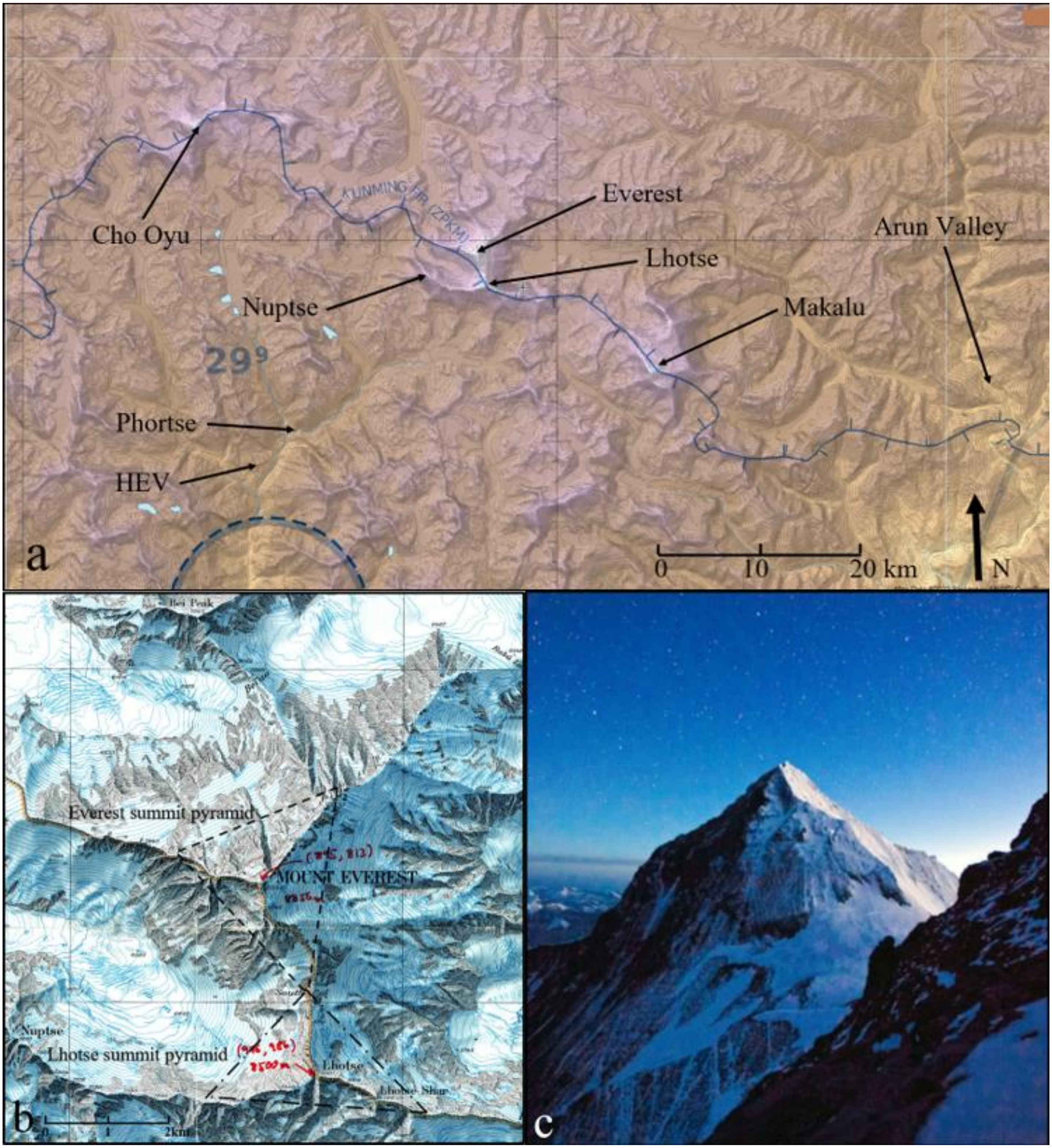


*Figure 1. **a**. The Mount Everest region with the major summits and locations identified; the HEV is the Hotel Everest View. **b**. The Mount Everest and Lhotse summit pyramids are identified, respectively, by the black-dashed and black dash- dot lines. The bases of the pyramids are at an elevation of approximately 7900m. The summits are, respectively, 8848m and 8501m in elevation. The map segment is from the November 1988 issue of the National Geographic Magazine. **c**. The Everest summit pyramid at sunrise in May 2010 as viewed from near the summit of Lhotse (from CoryRichards.com and Anker, et. al. (2013)).*

*The Anker, et. al. reference will be added to the list: Conrad, A., et. al., The call of Everest. National Geographic Society, 303 pp. ISBN 978-1-4262-1016-7, 2013.*

The authors are focusing on the development process of the plumes and describe that the observed plumes and the Moore plume are not composed of resuspended snow. It gives the impression that plumes from resuspended snow are not possible at all, which I don't think the authors intend. I think the Authors should make clear that this is just a case study over a few days (see Table 1) and plumes of resuspended snow might be still possible.

*In response to this insightful comment, the following text will be inserted between line 111 and 113:*

> *All our daily observations were analyzed. Recorded were the days the Everest massif was observed to produce a plume, the formation time of the plume, the plume duration and how many plume events were predicted by the LCL model. Cases where a plume was observed but not predicted are investigated because they might be plumes of resuspended snow.*

I would also be interested in some more statistics. For example, how often do these plumes occur per month and how long do they usually persist?

*To answer this important suggestion, a new section will be inserted before Section 3.4:*

***3.4 Plume statistics***

*Table 2 displays the results from our 151 daily observations of H-8 imagery and the corresponding 400 mb LCL values calculated from the atmospheric profiles. It can be seen from the table, Everest was almost always visible (95%), especially*

Table 2

Results from the observations of H-8 imagery and Lifted Condensation Level (LCL) calculations from the corresponding atmospheric profiles

| Month 2020-21 | Number of days observed | Everest visible | Plume observed | Average plume formation time (hour LST) | Average plume duration (hours) | Average LCL temperature ($^0$C) | Average 300 mb (degrees) | winds (m/s) | Plume predicted | Plume not predicted |
|---|---|---|---|---|---|---|---|---|---|---|
| November | 30 | 26 | 7 | 10 | 8 | -32 | 271 | 38 | 7 | 0 |
| December | 31 | 31 | 15 | 7 | 14 | -31 | 268 | 47 | 14 | 1 |
| January | 31 | 31 | 7 | 9 | 14 | -31 | 266 | 45 | 6 | 1 |
| February | 28 | 28 | 17 | 9 | 11 | -35 | 247 | 28 | 15 | 2 |
| March | 31 | 27 | 17 | 9 | 11 | -34 | 269 | 32 | 17 | 0 |
| Sum | 151 | 143 | 63 | 9 | 12 | -33 | 264 | 38 | 59 | 4 |
| | | 95% | 44% | | | | | | 94% | 6% |

*in the morning because the plumes most often formed later in the morning. On almost half of the days Everest was visible (143 days), plumes were observed to form on 63 days (44%). Of these plumes, 59 (94%) were predicted to form and 4 (6%) not predicted. Were the four plumes composed of resuspended snow?*

*Here are the steps we used to determine if a plume was a banner cloud or resuspended snow. Scrolling frame-by frame through the Movie 4 (Event 3) shows the plume was not visible as the sun rose and was clearly visible as the sun set. This behavior was consistent with the LCL results: the LCL was above the Everest summit in the morning and below the summit in the afternoon; this plume was a banner cloud. If this plume had been visible at sunrise and the corresponding LCL value was above the Everest summit, then the plume was composed of resuspended snow. These steps are applied to the four plumes suspected to be blowing snow.*

*The four plumes were observed on 2020-12-05, 2021-01-29 and 2021-02-03 and 11. The 400 mb LCL values ranged between 295 to 249 mb, all above the 300 mb level of the Everest summit. The plumes formed between 1200 and 1400 LST and dissipated around 1900 LST. The plumes were not visible at sunrise and visible at sunset. Therefore, these plumes were not composed of resuspended snow. Thus, none of the 63 plumes we observed we conclude were composed of resuspended snow. Though, plumes of resuspended snow may have occurred smaller than our detection limit of a couple of kilometers.*

*We observed, though, plumes we think were composed primarily snow formed insitu. For example, on 2020-12-20, plumes were observed in the H-8 infrared images to form downwind of the Everest massif at 1100 LST and dissipate four days later on 2020-12-24 at 1900LST. For those days, the 400 mb LCL values were between 393 and 356 mb, extremely moist conditions, though no precipitation was measured at Phortse. The plumes were observed to stream well into Tibet. The plumes probably appeared as those in Figure 9; initially liquid then forming snow particles downwind. This plume outbreak caused the average plume formation time in December 2020 (Table 2) to be 0700 LST.*

*The following paragraph will be added to the Conclusions:*

> *The Everest massif was visible on 143 of the 151 observation days (95%), especially in the morning because the plumes most often formed later in the morning. On the days the massif was visible, plumes were observed to form on 63 days (44%). The plumes lasted an average of 12 hours. Of these plumes, 59 (94%) were predicted to form and 4 (6%) were not predicted. These four plumes were not composed of resuspended snow because they were not visible at sunrise. Though, plumes of resuspended snow may have occurred smaller than our detection limit of a couple of kilometers. Snowfall from the plumes, formed insitu, was estimated and may be significant.*

*The following sentence will be inserted in the abstract on line 12 between 'wake.' and 'We':*

> *The massif was visible on 143 days (95%), plumes formed on 63 days (44%) and lasted an average of 12 hours.*

Also, the authors mention in the conclusions that the Everest plumes may be a source of snowfall. They didn't mention that before in the manuscript. A rough estimation of how much the plumes contribute to the snow fall would benefit the manuscript.

*To address this insightful comment, we will insert the following section:*

> ***4.3 Estimate of snowfall from the observed plumes***
>
> *Assume a saturated parcel of air ascends moist adiabatically from the elevation of the South Col of Everest (~7900 m, ~400 mb) to the summit (~8900 m, 300 mb). The parcel is initially -33 $^0$C (the average plume temperature, Table 2) and cools to -40 $^0$C at the summit. The initial parcel saturated mixing ratio is 0.59 g/kg and the final is 0.39 g/kg for an average of 0,49 g/kg. Employing the precipitable water calculator at [http://www.shodor.org/os411/courses/_master/tools/calculators/precipwater/](http://www.shodor.org/os411/courses/_master/tools/calculators/precipwater/), ~1 mm of water is expected to precipitate from the parcel.*
>
> *Assume the parcel ascends in the turbulent wake the 1000 m from the South Col to the summit at 0.1 m/s, the ascent takes $10^4$ s. So, every $10^4$ seconds 1 mm of liquid precipitates from the parcel. The average duration of the observed plumes was 12 hours (Table 2) or 4.32 x $10^4$ seconds. The amount of precipitation from the average plume was 1 mm/$10^4$ s x 4.32 x $10^4$ s or about 4 mm.*
>
> *Sixty-three (63) Everest plumes occurred during our four-month observation period (Table 2). So, 63 plumes x 4 mm/plume equals about 252 mm (~25 cm) of liquid-equivalent may have precipitated. The amount of liquid-equivalent precipitation measured at Phortse during our observation period was 284.5 mm (~28 cm). Thus, Everest plumes may be a significant source of precipitation.*

The authors mentioned the visible differences between resuspended snow and banner clouds (line 51), which were shown in Schween et al. (2007). I was wondering if this might be another indicator to support the analysis, if pictures from Mount Everest would be available. But according to line 65, continuous imaging is not available. I was wondering about that and found a video live stream

(https://www.skylinewebcams.com/de/webcam/nepal/khumbu-pasanglhamu/khumjung/mount-everest.html ),

which shows a view of Mount Everest from a similar position as in Figure 3. I think it would be possible to develop a simple program which takes snapshots of this stream and identify the plumes in addition to satellite images. Maybe that would help for a follow up study.

*Thank you for identifying this live-stream feed from the HEV, the same location as our 1995-11-28 time-lapse movie associated with Figure 3. We contacted the HEV and learned this feed began in January 2022 and is not archived. So, unfortunately, the feed cannot help our study.*

The title is "The Mount Everest plume in winter". If you would change it to "The formation and composition of the Mount Everest plume in Winter" the reader would already have an idea what you are going to analyze.

*Good suggestion, we will change the title as you suggest.*

**Minor comments**:

Line 8: „plume often forms"…. How often?

*"'often forms' will be replaced by 'can form'.*

Line 10: „collect the corresponding meteorological data"… What kind of data?

*Lines 9 through 11 will be revised to read:*

> *Accordingly, daily, we observed real-time images from a geosynchronous meteorological satellite from 1 November 2020 through 31 March 2021 (151 days) to identify the days plumes formed. Daily, surface and upper-air meteorological data were collected.*

Line 18: „is the highest elevation" …. How high?

*In line 18, the following value will be inserted after 'elevation': (8856 m)*

Fig. 2 to Fig. 8: All Figures need panel labels like „a) , b), c)". That would make it much easier for the reader to find the panel.

*Will do.*

Line 88: „400mb" and later in line 90 „300 mb". A space between number and unit is correct. Try to be consistent through the manuscript.

*This comment will be followed.*

Line 99: „-35C" … it is -35 °C. This needs to be changed in the whole manuscript.

*Will do.*

Figure 4 and 5: The profiles are too small and the resolution is too bad. It is not possible to identify the numbers.

*Here is revised Fig. 4; Fig. 5 will be revised similarly:*

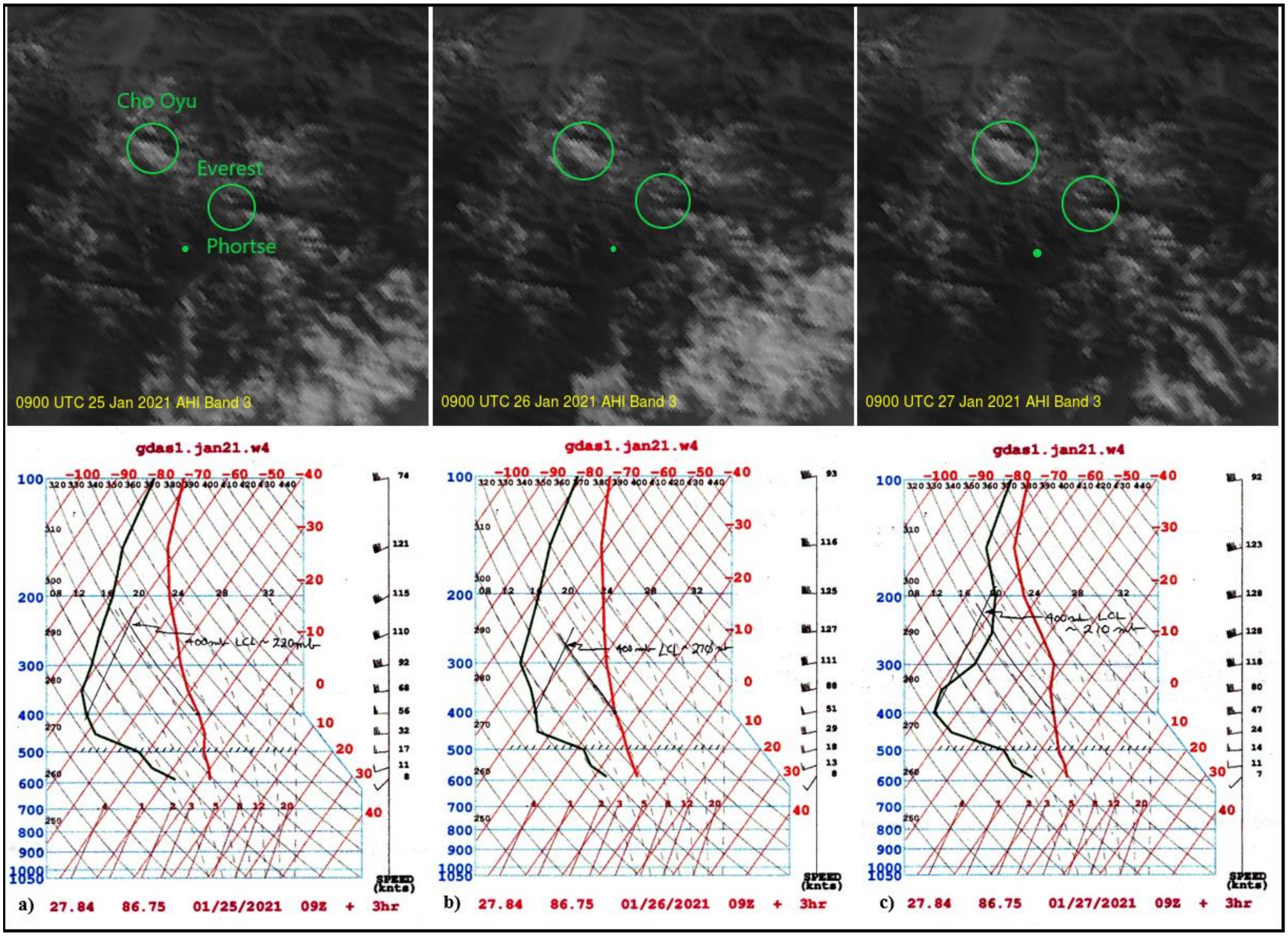


*Figure 4: The images and profiles, a) to c), are for 2021-01-25, -26 and -27 at 15LST (Local Solar Time) or 09Z. The locations of the major peaks are circled. The lifting-condensation-level (LCL) values are determined graphically on the corresponding atmospheric profiles from Phortse and are listed in Table 1. The graphical procedures are described in the text. The approximate pressures at the base and summit of the Everest pyramid, respectively, are approximately 400 and 300mb.*

All Satellite images: It would be nice to have a km scale bar on the pictures to see the dimension. Same for the Videos.

*In response to this comment, the following paragraph will be inserted between lines 77 and 79:*

> *To locate the features and know distances in the H-8 images and movies, a map is given in Figure 1a. The map provides a distance scale and identifies the locations of the major mountain peaks, the HEV, Phortse and the Arun Valley. The times and dates for all the H-8 images are displayed on the movies and the images themselves.*

Citation: https://doi.org/10.5194/acp-2021-966-RC2