CORRESPONDENCE

Comments on “A CloudSat–CALIPSO View of Cloud and Precipitation Properties across Cold Fronts over the Global Oceans”

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ABSTRACT

Naud et al. constructed satellite-based composite analyses of clouds and precipitation across cold fronts. However, their approach does not exclude occluded fronts, does not separate anafronts from katafronts, does not separate frontlike phenomena primarily identified by thermal gradients from those primarily identified by wind changes, and smooths over alongfront variability. By lumping these disparate frontal structures together, the front-centered composite cross sections reveal forward-sloping structures and weak gradients across them, raising questions about how to interpret their composite cross sections.

1. Introduction

Naud et al. (2015) describe the cloud and precipitation structure of cold fronts over the global oceans from satellites using CloudSat radar data, CALIPSO lidar data, and MERRA reanalyses for temperature and wind. Using a set of automated approaches, more than 30 000 fronts over the global oceans within 30°–60°N and 30°–60°S over a 4-yr period were composited to produce cross sections of various properties across the fronts. In this comment, concerns are raised about the approaches used to produce these mean cross sections and how to interpret the resulting cross sections.

2. Concerns

Four concerns are raised that pertain to the frontal structures going into the composites.

1) Naud et al. (2015) state that their study is about cold fronts, but an unspecified number of occluded fronts are included in their composite. “Because we could not differentiate cold and occluded fronts objectively, occluded fronts may be included in our database” (p. 6745). No effort is made to quantify to what extent their results are contaminated by occluded fronts. The classic warm-type occluded front is characterized by a forward-sloping frontal structure, cloud pattern, and ascent, which differs from the classic rearward-sloping cold front. Because the majority of occluded fronts are of the warm type (Schultz and Mass 1993; Schultz and Vaughan 2011; Schultz et al. 2014), any occluded fronts in the sample would easily contaminate any composite cold-frontal structure.

2) Although commonly depicted as rearward-sloping in textbooks, some cold fronts have the structure of a katafront or split cold front, a forward-sloping cloud structure formed as the dry airstream from behind the cyclone flows over the surface cold front (e.g., Bergeron 1937; Sansom 1951; Browning and Monk 1982; Browning 1986; Young et al. 1987; Mass and Schultz 1993). Katafronts tend to be observed some distance equatorward from the center of the cyclone, which is the region targeted by Naud et al. (2015). Moreover, cold fronts can possess a variety of additional different structures such as the following:
   • narrow cold-frontal rainbands (e.g., Browning and Harrold 1970; Knight and Hobbs 1988),
• wide cold-frontal rainbands (e.g., Houze and Hobbs 1982).
• cold fronts with deep convection (e.g., Koch 1984),
• cold fronts with rope clouds (e.g., Seitter and Muench 1985),
• gravity current–like structures (e.g., Schoenberger 1984; Koch and Clark 1999; Geerts et al. 2006),
• shallow cold fronts (e.g., Sanders 1955; Shapiro 1984; Bond and Fleagle 1985),
• tropospheric-deep cold fronts (e.g., Schwerdtfeger and Strommen 1964; Bond and Shapiro 1991),
• cold fronts with prefrontal wind-shift lines (e.g., Hutchinson and Bluestein 1998; Schultz 2004, 2005),
• multiple frontal structures (e.g., Miles 1962; Mulqueen and Schultz 2015), and
• shallow fronts with core-and-gap structures (James and Browning 1979; Hobbs and Biswas 1979; Hobbs and Persson 1982; Jorgensen et al. 2003).

The possibility of these various types of frontal structures in the same composite is also of concern to the quality of the composite.

3) Naud et al. (2015, p. 6745) produce an automated scheme using MERRA reanalyses to identify fronts. This scheme is a result of two different diagnostic approaches to identifying fronts: the thermal front parameter using potential temperature at 1 km AGL (Hewson 1998) and the 6-h change in meridional wind (Simmonds et al. 2012). Fronts identified by either approach are apparently merged into a single dataset. However, previous studies that compared the two approaches showed that they sometimes did not identify the same feature (e.g., Table 4 in Hope et al. 2014; Fig. 1 in Schemm et al. 2015). Specifically, the wind shift and temperature gradient associated with cold fronts are sometimes not coincident, as reviewed by Schultz (2005). Using two different approaches to identify fronts and compositing them risks lowering the quality of the composite.

4) Cold fronts can show a substantial alongfront variability (e.g., Jorgensen et al. 2003; Norris et al. 2017), but the approaches employed by Naud et al. (2015) average satellite data along the cold front (pp. 6745–6746) and average MERRA output along 1000 km of the front (p. 6751). "This compositing technique does not assume a general direction of the cold fronts and averages together information anywhere along and across the cold front." (p. 6746). Thus, any of this alongfront variability is likely eliminated when the composite is constructed.

3. Results from the compositing procedure

These concerns about how the composite is constructed affect the quality of the composite. Indeed, the composites show a number of unusual properties.

1) The inclusion of occluded fronts in an ostensible composite of cold fronts would result in forward-sloping properties of the composite, as is shown in Naud et al.'s (2015) Figs. 1 and 8c. That 20%–30% of their fronts have a forward-sloping cloud structure is indicative of this potential contamination.
2) That the convection lies about 300 km ahead of the cold front suggests that this might be due to some of the fronts having an elevated frontal zone (as might be the case in a warm-type occluded front or katafront), prefrontal trough or wind-shift line.
3) Because of the different shapes and structures to the fronts that comprise the composite (i.e., occluded fronts, anafronts, katafronts), the composite will necessarily result from quite a bit of variability of cold- and occluded-frontal structures. By lumping these disparate frontal structures together, the front-centered composite cross sections smooth out any signal and reveal relatively weak gradients across them, as seen in their Figs. 3, 4, 5, 6, and 7.

For this reason, the approach by Naud et al. (2015) raises questions about how the compositing is done and whether the resulting composite is meaningful.

4. Conclusions

The remarkable variety of cold-frontal structures observed in nature, plus those from occluded fronts, are lumped together through the Naud et al. (2015) compositing approach. Thus, one cannot generalize about cold fronts in the real world through a compositing process that includes an unspecified number of occluded fronts, katafronts, and anafronts, smoothing out such an observed diversity of frontal structures and alongfront structures. As such, these issues raise questions about the best way to interpret their composite cross sections.

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REFERENCES
Bergeron, T., 1937: On the physics of fronts. Bull. Amer. Meteor. Soc., 18, 265–275.
Bond, N. A., and R. G. Fleagle, 1985: Structure of a cold front over the ocean. Quart. J. Roy. Meteor. Soc., 111, 739–759. https://doi.org/10.1002/qj.49711146905.
——, and M. A. Shapiro, 1991: Research aircraft observations of the mesoscale and microscale structure of a cold front over the eastern Pacific Ocean. Mon. Wea. Rev., 119, 3080–3094. https://doi.org/10.1175/1520-0493(1991)119<3080:RAOOTTM>2.0.CO;2.
Hutchinson, T. A., and H. B. Bluestein, 1998: Prefrontal wind-shifts.

Houze, R. A., Jr., and P. V. Hobbs, 1982: Organization and structure of precipitating cloud systems. *Advances in Geophysics*, Vol. 24, Academic Press, 225–315, https://doi.org/10.1016/S0065-2687(08)60521-X.

Hewson, T. D., 1998: Objective fronts. *Meteor. Appl.*, 5, 37–65, https://doi.org/10.1017/S1350482798000553.

Hobbs, P. V., and K. R. Biswas, 1979: The cellular structure of narrow cold-frontal rainbands. *Quart. J. Roy. Meteor. Soc.*, 105, 723–727, https://doi.org/10.1002/qj.49710544516.

Hobbs, P. V., and O. G. Persson, 1982: The mesoscale and microscale structure and organization of clouds and precipitation in midlatitude cyclones. Part V: The substructure of narrow cold-frontal rainbands. *J. Atmos. Sci.*, 39, 280–295, https://doi.org/10.1175/1520-0469(1982)039<0280:TMASMA>2.0.CO;2.

Hope, P., and Coauthors, 2014: A comparison of automated methods of front recognition for climate studies: A case study in southwest Western Australia. *Mon. Wea. Rev.*, 142, 343–363, https://doi.org/10.1175/MWR-D-12-00252.1.

Houze, R. A., Jr., and P. V. Hobbs, 1982: Organization and structure of precipitating cloud systems. *Advances in Geophysics*, Vol. 24, Academic Press, 225–315, https://doi.org/10.1016/S0065-2687(08)60521-X.

Hutchinson, T. A., and H. B. Bluestein, 1998: Prefrontal wind-shift lines in the plains of the United States. *Mon. Wea. Rev.*, 126, 141–166, https://doi.org/10.1175/1520-0493(1998)126<0141:PWSLIT>2.0.CO;2.

James, P. K., and K. A. Browning, 1979: Mesoscale structure of line convection at surface cold fronts. *Quart. J. Roy. Meteor. Soc.*, 105, 371–382, https://doi.org/10.1002/qj.49710544404.

Jorgensen, D. P., Z. Pu, P. O. G. Persson, and W.-K. Tao, 2003: Variations associated with cores and gaps of a Pacific narrow cold frontal rainbow. *Mon. Wea. Rev.*, 131, 2705–2729, https://doi.org/10.1175/1520-0493(2003)131<2705:VAVCWAG>2.0.CO;2.

Knight, D. J., and P. V. Hobbs, 1988: The mesoscale and microscale structure and organization of clouds and precipitation in midlatitude cyclones. Part XV: A numerical modeling study of frontogenesis and cold-frontal rainbands. *J. Atmos. Sci.*, 45, 915–931, https://doi.org/10.1175/1520-0469(1988)045<0915:TMASMA>2.0.CO;2.

Koch, S. E., 1984: The role of an apparent mesoscale frontogenesis circulation in squall line initiation. *Mon. Wea. Rev.*, 112, 2090–2111, https://doi.org/10.1175/1520-0493(1984)112<2090:TROAAM>2.0.CO;2.

—and W. L. Clark, 1999: A nonclassical cold front observed during COPS-91: Frontal structure and the process of severe storm initiation. *J. Atmos. Sci.*, 56, 2862–2890, https://doi.org/10.1175/1520-0469(1999)056<2862:ANCFOD>2.0.CO;2.

Mass, C. F., and D. M. Schultz, 1993: The structure and evolution of a simulated midlatitude cyclone over land. *Mon. Wea. Rev.*, 121, 888–917, https://doi.org/10.1175/1520-0493(1993)121<0888:TSAEOA>2.0.CO;2.

Miles, M. K., 1962: Wind, temperature and humidity distribution at some cold fronts over SE England. *Quart. J. Roy. Meteor. Soc.*, 88, 286–300, https://doi.org/10.1002/qj.49708837708.

Mulqueen, K. C., and D. M. Schultz, 2015: Non-classic extratropical cyclones on Met Office sea-level pressure charts: Double cold and warm fronts. *Weather*, 70, 100–105, https://doi.org/10.1002/wea.2463.

Naud, C. M., D. J. Posselt, and S. C. van den Heever, 2015: A CloudSat–CALIPSO view of cloud and precipitation properties across cold fronts over the global oceans. *J. Climate*, 28, 6743–6762, https://doi.org/10.1175/JCLI-D-15-0052.1.

Norris, J., G. Vaughan, and D. M. Schultz, 2017: Precipitation cores along a narrow cold-frontal rainband in idealized baroclinic waves. *Mon. Wea. Rev.*, 145, 2971–2992, https://doi.org/10.1175/MWR-D-16-0409.1.

Sanders, F., 1955: An investigation of the structure and dynamics of an intense surface frontal zone. *J. Meteor.*, 12, 542–552, https://doi.org/10.1175/1520-0469(1955)012<0542:AIOTSA>2.0.CO;2.

Sansom, H. W., 1951: A study of cold fronts over the British Isles. *Quart. J. Roy. Meteor. Soc.*, 77, 96–120, https://doi.org/10.1002/qj.4970733311.

Schemm, S. I., R. Rudeva, and I. Simmonds, 2015: Extratropical fronts in the lower troposphere—Global perspectives obtained from two automated methods. *Quart. J. Roy. Meteor. Soc.*, 141, 1686–1698, https://doi.org/10.1002/qj.2471.

Schoenberger, L. M., 1984: Doppler radar observation of a land-breeze cold front. *Mon. Wea. Rev.*, 112, 2455–2464, https://doi.org/10.1175/1520-0493(1984)112<2455:DROOAL>2.0.CO;2.

Schultz, D. M., 2004: Cold fronts with and without prefrontal wind shifts in the central United States. *Mon. Wea. Rev.*, 132, 2040–2053, https://doi.org/10.1175/1520-0493(2004)132<2040:CFWAWP>2.0.CO;2.

—and C. F. Mass, 1993: The occlusion process in a midlatitude cyclone over land. *Mon. Wea. Rev.*, 121, 918–940, https://doi.org/10.1175/1520-0493(1993)121<0918:TOPMIA>2.0.CO;2.

—and G. Vaughan, 2011: Occluded fronts and the occlusion process: A fresh look at conventional wisdom. *Bull. Amer. Meteor. Soc.*, 92, 443–466, https://doi.org/10.1175/2010BAMS3057.1.

—and B. Antenescu, and A. Chiariello, 2014: Searching for the elusive cold-type occluded front. *Mon. Wea. Rev.*, 142, 2565–2570, https://doi.org/10.1175/MWR-D-14-00003.1.

Schwerdtfeger, W., and N. D. Stommern, 1964: Structure of a cold front near the center of an extratropical depression. *Mon. Wea. Rev.*, 92, 523–531, https://doi.org/10.1175/1520-0493(1964)092<0523:SOACFN>2.0.CO;2.

Seitter, K. L., and H. S. Muench, 1985: Observation of a cold front with rope cloud. *Mon. Wea. Rev.*, 113, 840–848, https://doi.org/10.1175/1520-0493(1985)113<0840:OOACFW>2.0.CO;2.

Shapiro, M. A., 1984: Meteorological tower measurements of a surface cold front. *Mon. Wea. Rev.*, 112, 1634–1639, https://doi.org/10.1175/1520-0493(1984)112<1634:MTMAOAS>2.0.CO;2.

Simmonds, I., K. Keay, and J. A. T. Bye, 2012: Identification and climatology of Southern Hemisphere mobile fronts in a modern reanalysis. *J. Climate*, 25, 1945–1962, https://doi.org/10.1175/JCLI-D-11-00100.1.

Young, M. V., G. A. Monk, and K. A. Browning, 1987: Interpretation of satellite imagery of a rapidly deepening cyclone. *Quart. J. Roy. Meteor. Soc.*, 113, 1089–1115, https://doi.org/10.1002/qj.49711347803.
