Proposal for National Snowfall Analysis, Version 2

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Project Background

During CY 2014, in collaboration with subject matter experts from National Weather Service (NWS) field offices, NOHRSC (now part of the National Water Center, or NWC) developed a national gridded snowfall analysis, which was released in early 2015. The NWS had not previously produced a single, authoritative, national snowfall analysis.

Product Requirements

- A national, accurate, consistent, seamless snowfall analysis to enable forecast verification.
- The ability to create summary snowfall event maps, both during an unfolding event and following, to facilitate decision support for core partners and assist with public outreach and media requests.

Previous Work

- Previously, three national snowfall maps were produced by the NWS—the first at NOHRSC, the second at Central Region Headquarters, and the third at the Weather Prediction Center. These were disparate, stopgap measures that were non-operational, had little institutional support, and were not developed with enough scientific rigor to possess a suitable degree of credibility, either with the public or for use as forecast verification.
- Field offices often generate their own snowfall maps, which—in addition to being fundamentally inconsistent from a nationwide perspective—typically suffer from the same shortcomings as their national counterparts.

Initial (Phase I) Development

Given limited time and resources, collaborators agreed that the first phase of the effort would be to develop a prototype “version 1”, or “v1,” analysis at NOHRSC, taking advantage of the operational data streams, computational resources, and development capability existing in that office. The prototype analysis would fulfill a basic set of practical requirements, including:

- Periods: 24 h ending at 12 UTC and 00 UTC
- Spatial resolution: 2.5 km
- Domain: CONUS and Alaska-Pacific RFC domains

- Data sources: Observed snowfall data from as many networks as possible including NWS/FAA, SNOTEL, COOP, and CoCoRaHS.
- Temporal resolution: Initial issuance within 2 hours of analysis time, to be updated hourly.
- Format: Grids (GRIB, NetCDF) and images (for the web). Other formats may be explored as resources allow.

Early in the development it was agreed that the prototype would, like the three existing approaches, use a spatial interpolation of 24-hour snowfall observations using one of a few candidate weighting functions, and using a fixed set of interpolation parameters established through analysis of snowfall data archived at NOHRSC during the 2013-14 snow season.

The v1 analysis was successfully implemented and released to collaborators on 1 January 2015, and products were released to the public in March 2015. In addition to producing daily snowfall accumulations, the new analysis includes seasonal totals, an example of which appears in Figure 1 (below).

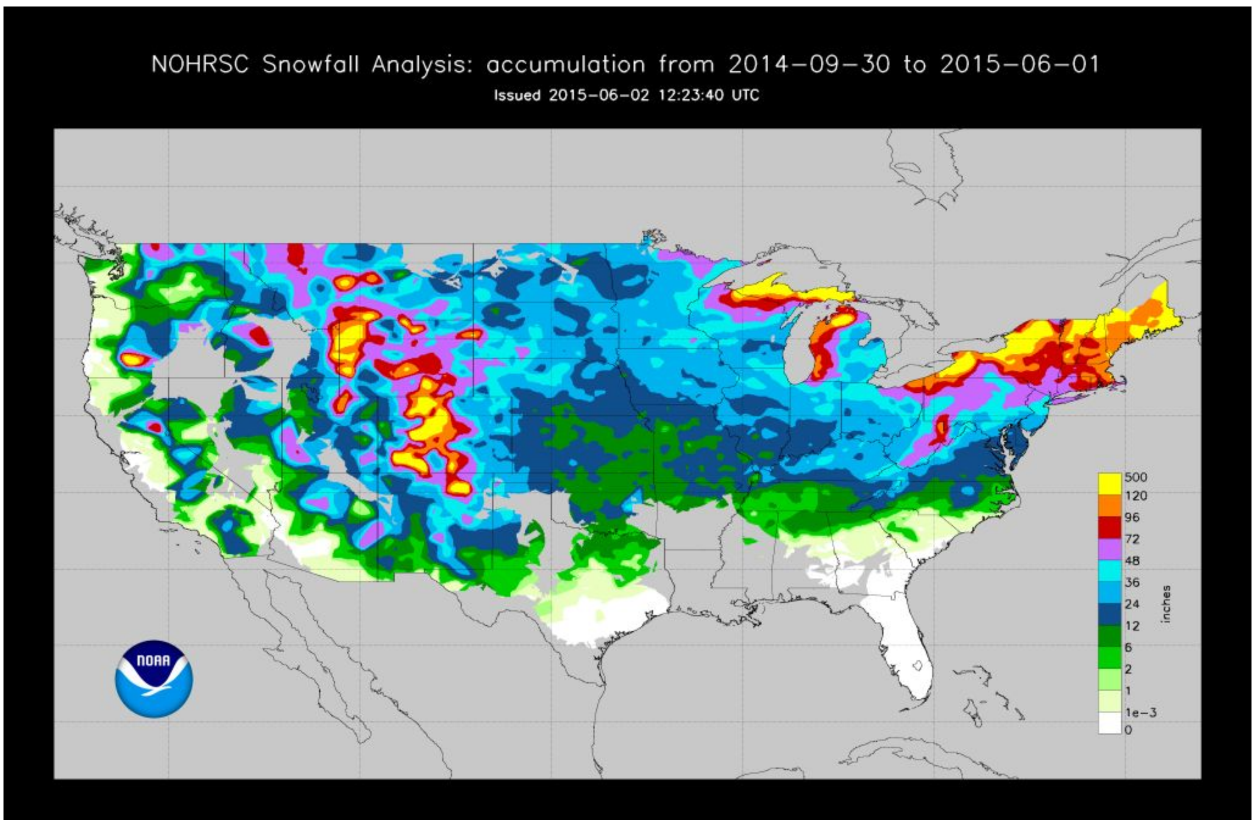

Figure 1. Seasonal snowfall total for the 2014-15 season over the CONUS using version 1 of the snowfall analysis.

Since its public release the v1 analysis has received largely positive feedback. It was used to address numerous media inquiries related to heavy snowfall in the Northeastern U.S. during January and

February 2015, and many journalists found the seasonal totals produced each day (such as the example in Figure 1) to be particularly compelling.

Proposed Phase II Development

Motivation

The initial work was conducted with the understanding that while the resulting v1 analysis would only represent a small improvement over existing efforts, it would establish a single national analysis, and its limitations would be addressed in future development cycles. The practical limits imposed on the development of the prototype meant that it would have four key shortcomings:

1. The interpolation method distributes snowfall using an arbitrarily-weighted interpolation function, and makes no use of weather inputs other than observed snowfall at discrete sites.

2. The analysis has poor quality in areas of high spatial variability in snowfall (such as complex terrain) and in data-sparse areas.

3. Snowfall data contained in Local Storm Reports (LSR) and Public Notification Statements (PNS) was mostly (with the exception of the Eastern Region's Hydromet Database) unavailable to the prototype because of inconsistent reporting procedures and formatting irregularities.

Collaborators agreed that the above issues severely limit the utility of the v1 analysis, particularly in Alaska and the Western United States. Thus, **the key requirement to provide a seamless and gap-free national map for quantitative snowfall forecast verification and decision support services has not been met by the prototype.** All collaborators agreed that a second development cycle to address these shortcomings is necessary.

Proposed Work

To address the shortcomings of the prototype, and to more fully meet product requirements, we propose to develop a "version 2," or "v2," analysis. The "v2" analysis addresses key shortcomings #1 and #2 by completing the following work:

- A "first guess" precipitation estimate based on a combination of numerical weather prediction (NWP) analysis cycles, short term NWP quantitative precipitation forecasts (QPF—possibly necessary for early issuances of the analysis), radar-derived quantitative precipitation estimates (QPE) such as Multi-Radar, Multi-Sensor (MRMS—see Zhang, 2011), and Stage IV precipitation analysis. This estimate will provide snowfall information in areas where observations are sparse, as well as an unbiased background to which an observation-driven adjustment can be applied.

- An assessment of the phase and density of frozen precipitation in the first guess estimate, based on climatological information, atmospheric profile data, and snow/rain/ice/graupel mixing ratios provided by direct observations or NWP analyses.

- An adjustment to the first guess analysis based on an improved interpolation method.
- Improved quality control to limit the impact of doubtful or spurious reports.

While the development of an effective first guess/adjustment approach to the analysis may be challenging, this approach is consistent with most of the variational and sequential data assimilation methods currently employed for real-time and retrospective analysis of geospatial data (Daley 1991). Therefore, the proposed work is largely an implementation of methods already used in operational data assimilation (Barker 2004), and is not a high-risk research-to-operations exercise.

Management and Resource Requirements

1. **Development Resources**
   The proposed phase II development requires a 6 month full-time development effort (target Associate Scientist Level II, or GS-13 federal level). This is equivalent to $80K contract support or 0.5 FTE.

   Note that key shortcomings #3 and #4 will remain. If the scope is increased to address all four key shortcomings, then the development requirement is a 12 month full-time development effort (target Associate Scientist Level II, or GS-13 federal level). This is equivalent to $160K contract support or 1 FTE.

2. **O&M Resources**
   The integration of the snowfall analysis into NOHRSC operations, both for version 1 and the proposed second version, is a low-cost, high-value arrangement:

   a. **Phase I**
      The processing, storage, and bandwidth requirements of the prototype system currently running at NOHRSC are modest:

      i. One year of data uses ~100 GB of storage.

      ii. The analysis runs every 30 minutes, taking about 15 minutes to generate all data and imagery using one of four available operations servers.

      iii. No significant added burden on the NOHRSC web server has been detected since the system was released publicly in March 2015.

      iv. The management of the current system also currently includes a measure of manual quality control and stakeholder engagement, which we estimate at about 2% FTE time (one week per year).

   b. **Phase II**
      The second version of the analysis will include some information (hourly MRMS grids, for example) not fully implemented in NOHRSC operations. However, given the familiarity we have with these data sources, as well as the presence of most of them on

our development systems, we expect the burden placed on existing systems to be minor, and we estimate the associated risk to be negligible.

c. **Consideration of Alternate Processing Site**
The operational data streams, databases, and computational resources provided by NOHRSC operations are a valuable existing infrastructure we have leveraged to conduct the snowfall analysis. Implementing version 1 on a different, independent system would involve establishing new data flows of observations, organizing and managing observations from multiple sources, and managing gridded datasets. The relocation of the version 1 analysis from NOHRSC operations is estimated to require ~9 months development time ($120k), with operational resources similar to those described above in the "O&M Resources/Phase I" section above. Phase II development would incur additional costs. Thus, relocation of the snowfall analysis processing environment to another site is not recommended at this time.

d. **Project Management**
The Phase II development effort will be planned, and its progress tracked, using the project management framework currently being established for all NWC projects and functions. The four bullets in the "Proposed Work" section above will represent key milestones in the development cycle.

Benefits to the NWS Hydrology and Winter Weather Programs

It is critical to understand that the proposed development will benefit multiple NWS programs. The data and methods produced by this enhanced effort will include some or all of the following:

- De-biasing of NWP-based QPF to produce a zero-latency first guess analysis.
- Combining national QPE products (e.g., MRMS accumulations) with QPF where radar coverage is poor, for a low-to-medium-latency first guess analysis.
- Identification of the type (phase) and density of accumulating precipitation, which are handled very crudely in existing land surface model implementations such as SNODAS and WRF-Hydro.
- Methods developed to perform observation-driven adjustment to first guess analysis.

Development of these capabilities would directly contribute to and benefit from work that has begun at the NWC. For example, the methodology to combine MRMS QPE with bias-corrected HRRR QPF is already under development at the NWC. Similarly, current SNODAS development includes an effort to estimate the density of accumulating snow, perhaps based upon the work of Baxter (2005) and Koren (1999). Clearly there exists tremendous potential for coordination and shared benefits between national gridded snowfall product development, SNODAS development, WRF-Hydro implementation, and the water resources forcing data service at the NWC.

The production of an enhanced snowfall analysis will also greatly benefit the NWS Winter Weather Program by providing critical real-time feedback for verification purposes and longer term verification of human and NWP snowfall forecasts to support product development. The analysis will also facilitate decision support activities for core partners, assist with public outreach and media requests, and improve NWS winter products and services consistency.

Future Development

If development of the snowfall analysis continues beyond version 2 to address all 4 key shortcomings, then additional work includes:

- Adding an Alaska domain;
- bias correction of QPF and QPE to improve the first guess;
- an expanded observation database including LSR and PNS reports;
- the incorporation of other station observation types, such as present weather and precipitation.

Conclusion

In conclusion, without a second development cycle, the continued use of the existing snowfall analysis will fail to meet the requirement for a national, accurate, consistent, seamless snowfall analysis to enable snowfall forecast verification, and will not adequately facilitate real-time decision support for core partners. Consequently, we propose the phase II development to meet these critical requirements.

References

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