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Cold spell prediction beyond a week: extreme snowfall events in February 2012 in Italy

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Cold spell prediction beyond a week: extreme snowfall events in February 2012 in Italy

Federico Grazzini

Recent winters will be remembered in Italy for the return of substantial snowfall episodes after there being very few in the 1990s. The winters of 2004, 2005, 2010, 2012 and 2013 are characterized by abundant snowfalls, not only in the mountains but also at low levels (e.g. reaching the Po valley and other lowland areas of northern and central Italy). These events are often associated with blocking patterns. A growing number of studies show that the frequency of blocking patterns is increasing over land in the northern hemisphere in response to diminishing Artic sea ice. More blocking patterns and larger waves lead to an increased probability of cold surges over large parts of northern continents (*Liu et al.*, 2012).

In Italy, and in particular in Emilia-Romagna, February 2012 can be considered a good example of what has occurred in recent winters, especially in terms of extreme variability. Therefore it is worthwhile studying in detail the weather of that month. The beginning of the 2011/12 winter was very dry and warm until the end of January when a large retrogressive wave (Figure 1) brought very cold air from Eurasia into the Mediterranean. This situation, which persisted for about 15 days, transformed the winter weather; it marked an abrupt swing from warm towards very cold conditions. We recorded up to 1 m of snow in some lowland areas (see the photos in Figure 2) and up to 3 m in the mountains of Romagna, falling mainly in two very heavy precipitation events. Towards the end of February the cold weather rapidly turned first towards normal conditions, and then became even warmer and drier. March was one of the warmest and driest months ever recorded in spring with +4°C temperature anomaly in Emilia-Romagna with respect to the 1991−2010 climate.

This brief introduction highlights the importance of having an early prediction of sudden changes in weather in an emerging scenario of enhanced variability and an increase in extreme events. In this article we will give a brief overview of the ECMWF forecasts of the onset, evolution and demise of the February 2012 cold spell used by ARPA-SIMC (Agenzia Regionale per la Protezione dell'Ambiente – Servizio Idro-Meteo-Clima), the Regional Weather Service of Emilia-Romagna. Particular emphasis will be given to the value of the forecasts for the planning and handling of an unprecedented weather situation (*Nanni,* 2012).

Long-range indications

In mid-January we observed a rapid transition of the hemispheric circulation, from zonal toward a more meridional flow characterized by larger Rossby waves with low wavenumbers (3–4). It is interesting to examine to what extent the ECMWF monthly forecasts captured this transition.

Figure 3 shows the observed 500 hPa geopotential anomaly for the calendar week 30 January to 5 February along with the ECMWF ensemble-mean forecasts for the same period from 5 January (days 26–32), 12 January (days 19–25), 19 January (days 12–18) and 26 January (days 5–11). The transition to more meridional flow was apparent in the monthly forecast a few weeks in advance (i.e. from 19 January) with a correct positioning of a strong ridge over the Norwegian Sea and Scandinavia. The forecast from 19 January was also somewhat successful in maintaining the negative geopotential anomaly for the following week (6–12 February, week 3 of forecast) as shown in Figure 4.

Now consider the impact of the prediction of a transition from zonal to meridional flow on the surface temperature. Figure 5 compares the observed 2-metre temperature anomaly for 6 to 12 February with the forecasts for that period from 12 January (days 26–32), 19 January (days 19–25), 26 January (days 12–18) and 2 February (days 5–11). It shows that there was some weak evidence for the cold temperature anomaly three weeks ahead (i.e. from 19 January) but displaced over northern Europe. A significant shift towards very cold conditions and correct positioning of the cold anomaly could be traced back to the forecast issued on 23 January: this further enhanced the signal for a significant cold anomaly in week 2 (30 January to 5 February) and indicated its persistence into week 3 (6 to 12 February).

AFFILATION
Federico Grazzini, ARPA-SIMC Regional Weather Service of Emilia-Romagna, Bologna, Italy

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Based on the ECMWF monthly forecast from 19 January and the more recent 15-day ensemble forecast (ENS) from 23 January, ARPA-SIMC issued the following long-range outlook valid for the week from 30 January to 5 February 2012.

"In the period under consideration the large-scale atmospheric flow will push toward Italy very cold air masses of continental origin. This type of meteorological situation could bring typically wintry conditions over our region with freezing temperatures and snowfalls even at lower grounds….".

At that time we were formulating our long-range bulletin only once a week, every Monday, based on the previous Thursday run. In this particular case we were not able to use the forecast from 23 January, though subsequently it was found that this gave an even better indication of the severity of the cold spell. Also, based on this experience, in 2013 we revised the scheduling of our long-range outlook by going from one issue per week (on Monday) to twice per week (on Friday and Tuesday).

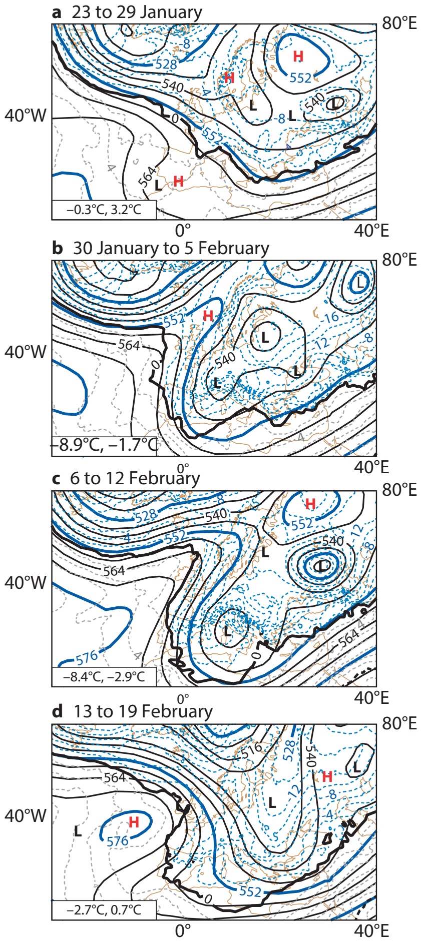

Figure 1 Observed weekly mean 500 hPa geopotential height (solid black lines) and 850 hPa temperature (blue dashed contours every 4°C) for (a) 23 to 29 January, (b) 30 January to 5 February, (c) 6 to 12 February and (d) 13 to 19 February 2012. The boxes in the bottom-left corner indicate the weekly mean 850 hPa and 2-metre temperatures computed for the Emilia-Romagna region. Note the strong temperature drop that occurred at the beginning of February due to the retrogressive extension toward Europe of a large trough.

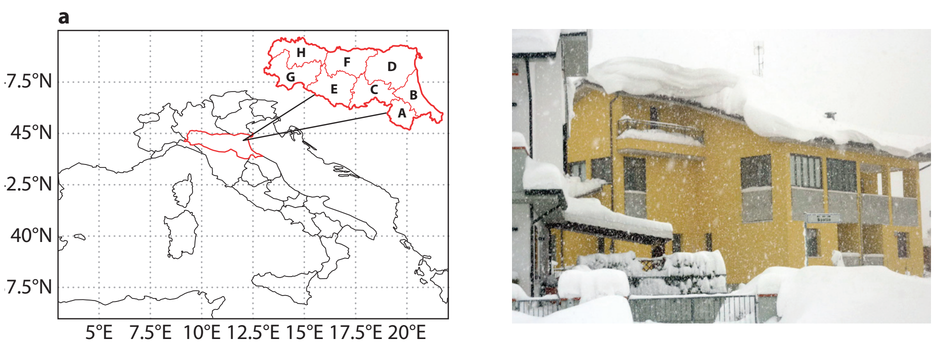

Figure 2 (a) The Emilia-Romagna region and its subdivision into eight warning regions. (b) Picture taken in S. Carlo (about 100 m above sea level) near Cesena (warning area A) during the second big snowfall event in February 2012. The snow depth is about 1 metre.

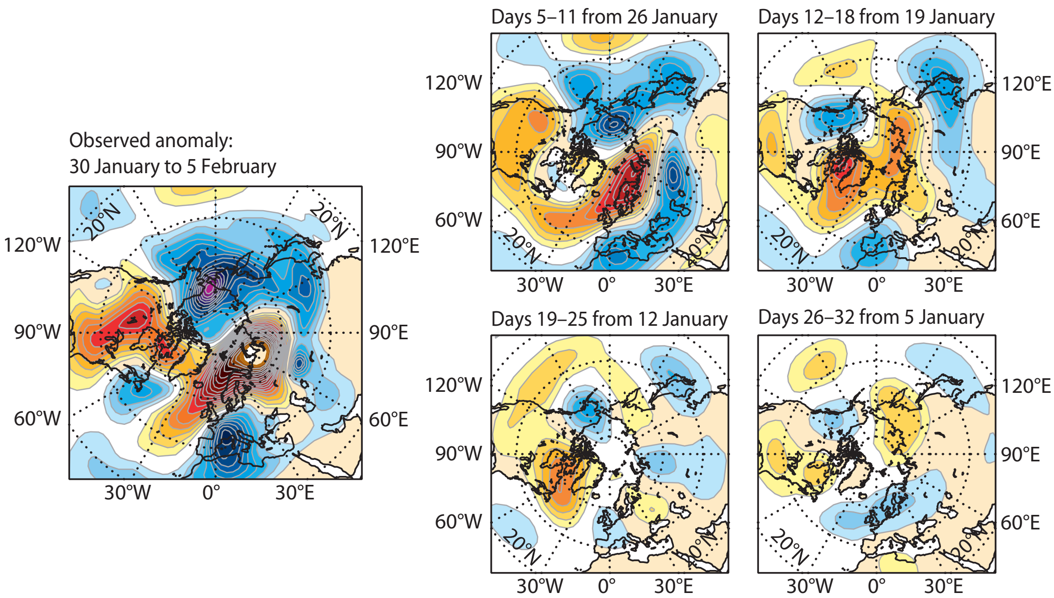

Figure 3 Comparison of the observed 500 hPa geopotential anomaly for 30 January to 5 February with the forecasts valid for the same period from 5 January (days 26–32), 12 January (days 19–25), 19 January (days 12–18) and 26 January (days 5–11).

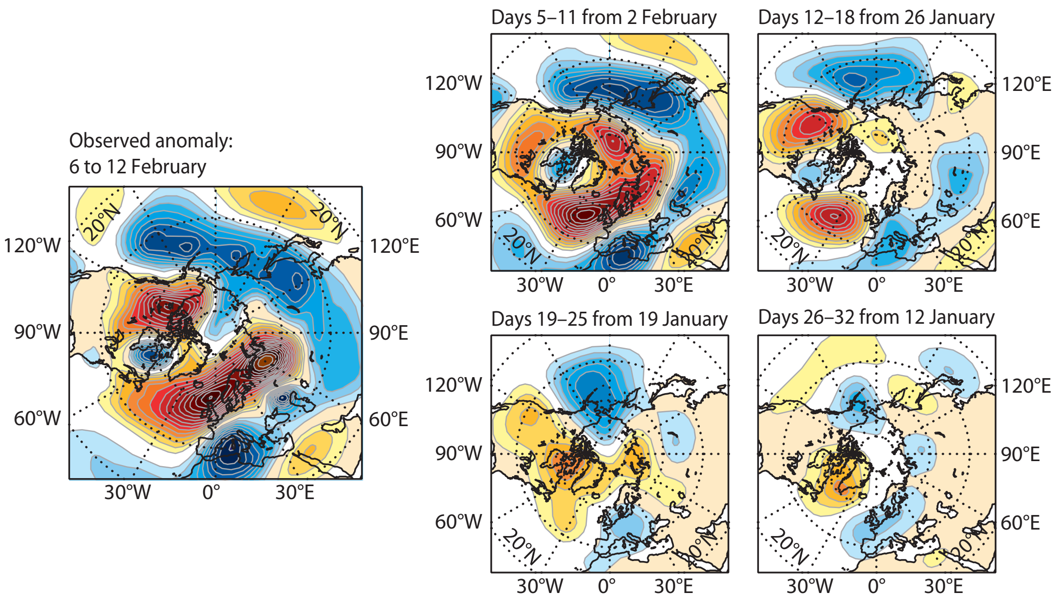

Figure 4 As Figure 3 but for the period 6 to 12 February with forecasts from 12 January (days 26–32), 19 January (days 19–25), 26 January (says 12–18) and 2 February (days 5–11).

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Medium-range indications

Given the very good indications in the long-range forecasts of a cold spell, in the following days much attention was dedicated to using the medium-range predictions to better quantify the impact of the predicted cold advection. Since 27/28 January, it was clear from the medium-range forecasts that there was an increasing possibility of major snowfall over the Emilia-Romagna region associated with very low temperatures. In the following days the signal intensified leading to the issue of an alert for heavy snowfall on 30 January covering the period 31 January to 2 February. The timing of the event occurred as indicated by the forecast, although the intensity was somewhat underestimated. About 45 cm of dry powdery snow fell in two days (1 and 2 February) in Bologna city and up to 1 m on the Apennines.

This was the first snowfall event. Despite the actions taken in response to the alert issued on 30 January, there were several problems (e.g. school and road closures due to the unusual amount of snow), especially for the southern part of our region.

In places weak to moderate snow kept falling in the next few days making it difficult for clearance operations. Just few days later, on 5 February, the ENS indicated a second, deep and cold cyclonic system approaching from the north-east, bringing more heavy snow between 10 and 12 February. At this stage, with civil protection authorities still in the process of restoring normality, local governments were faced with another major problem – there was a moderate likelihood of having to deal with another extreme event, just 10 days after the previous one, that would have even greater impact in terms of snow accumulation.

In this unusual situation it became a high priority to issue a warning as early as possible to provide the time required (a few days) to move extra rescue workers and specialized snow clearing equipment, such as snow turbines, from neighboring alpine regions. In this context the medium-range forecast acquired great importance for planning the deployment of rescue teams. It is also worth mentioning that the issuing of an early warning was needed due to the high risk of collapse of many snowpacked roofs, especially in rural buildings; with a new fresh snowfall event in the forecast, removing the existing snow from the roofs became a priority (Figure 6). A correct medium-range forecast became, therefore, a key factor for the optimization of the resources and activities.

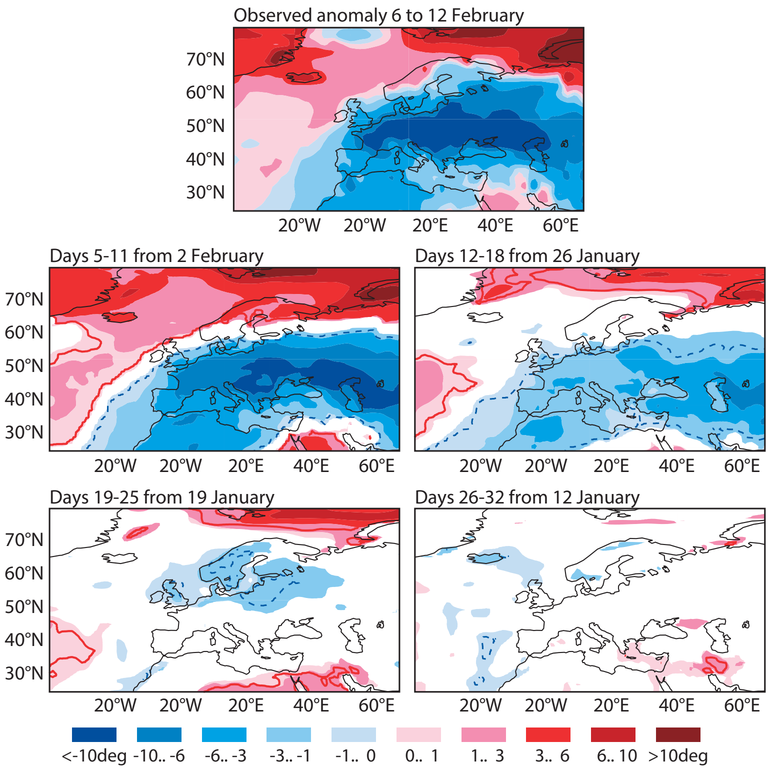

Figure 5 Comparison of the observed 2-metre temperature anomaly for 6 to 12 February with the forecasts for that period from 12 January (days 26–32), 19 January (days19–25), 26 January (days 12–18) and 2 February (days 5–11).

Figure 6 A colleague rushing to clear packed snow because of fear the roof would collapse under the weight of incoming new snow (taken on the 7 February before the second big snowfall).

Our forecasting operations department was requested to provide civil protection warnings at longer lead time than the usual 48 or 24 hours. Being forced to push further ahead with the alerting procedures, we decided to rely more on probabilistic products, both from ECMWF's ENS and COSMO-LEPS (see *Montani et al*., 2011 for a description of the COSMO- LEPS system). Having noticed the good consistency amongst subsequent probabilistic forecasts and relying mostly on ENS and COSMO- LEPS outputs available on 7 February (see Figure 7), we issued a first alert to the civil protection authorities; this provided a warning, 3 days before the beginning of the event, that in the next 4–5 days exceptional snowfalls were likely to affect the same area already hit a few days earlier. Box A has a translation of the full text sent to the Regional Civil Protection.

The severity and rarity of these two consecutive events made it very challenging to decide whether to issue a second warning for more than 1 m of fresh snow in 48 hours. Should we announce, with an unusual 3-day warning period, something that we have never seen in output from an NWP model for our region? At the end, based on the available forecasts, we decided to issue the warning.

The day after we issued the alert, the meteorological briefing was extraordinarily well attended, not only by civil protection operators but also by high-level decision makers, such as the regional governor and some members of the regional council. They were stunned at hearing of the possibility of a second massive snowfall, possibly bigger than the one that happened only ten days earlier.

The forecasts turned out to be very good both in terms of quantity and timing. From a weather-risk management perspective, the issuing of the warning 3 days before the event was extremely valuable. It gave enough time for the regional and national civil protection authorities to deploy rescue teams in advance in the part of the region that we thought would be the hardest hit. This planning was done on the basis of the very successful combination of low- and high-resolution probabilistic forecasts (ENS and COSMO-LEPS) and ECMWF's high-resolution forecasts (HRES). In particular the combined use of these different kind of systems allowed us to:

- Estimate at longer lead time (6 to 7 days) the probability of occurrence of significant snowfall over our region (mainly from ENS).
- Estimate the probability of snowfall exceeding a specific threshold for sub-areas allowing a better definition of which areas to be warned (mainly from COSMO-LEPS for 4 to 5 days before the event).
- Further specify the expected amount of snowfall over various sub-areas 1 to 2 days in advance from deterministic forecasts (mainly from HRES and COSMO-I7/COSMO-I2 which have horizontal resolutions of 7 and 2.8 km).

Note that, if we had only deterministic forecasts, it would have been impossible to estimate forecast uncertainty, while if we had only ensemble forecasts we would have underestimated the amount of snow. Combining information from probabilistic and deterministic forecasts was very successful and helped the population deal with extreme weather conditions.

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The message sent to Regional Civil Protection on 7 February 2012 **A**

"A descent of a cold trough from continental Europe toward central Europe and northern Italy, will bring a new deterioration of weather conditions especially between Friday 10/02 and Saturday 11/02. On these two days, the probability of having heavy and widespread snowfall is high for all parts of the region with larger amounts more probable in the south-eastern part of the region. For this area (warning area A) there exists a ***moderate probability*** *that the 48 h total of fresh snowfall could reach up to 1 m adding to the snow that is already on the ground. Temperatures will stay well below zero with a further decrease during the passage of the trough. Winds will be sustained from the north-east."*

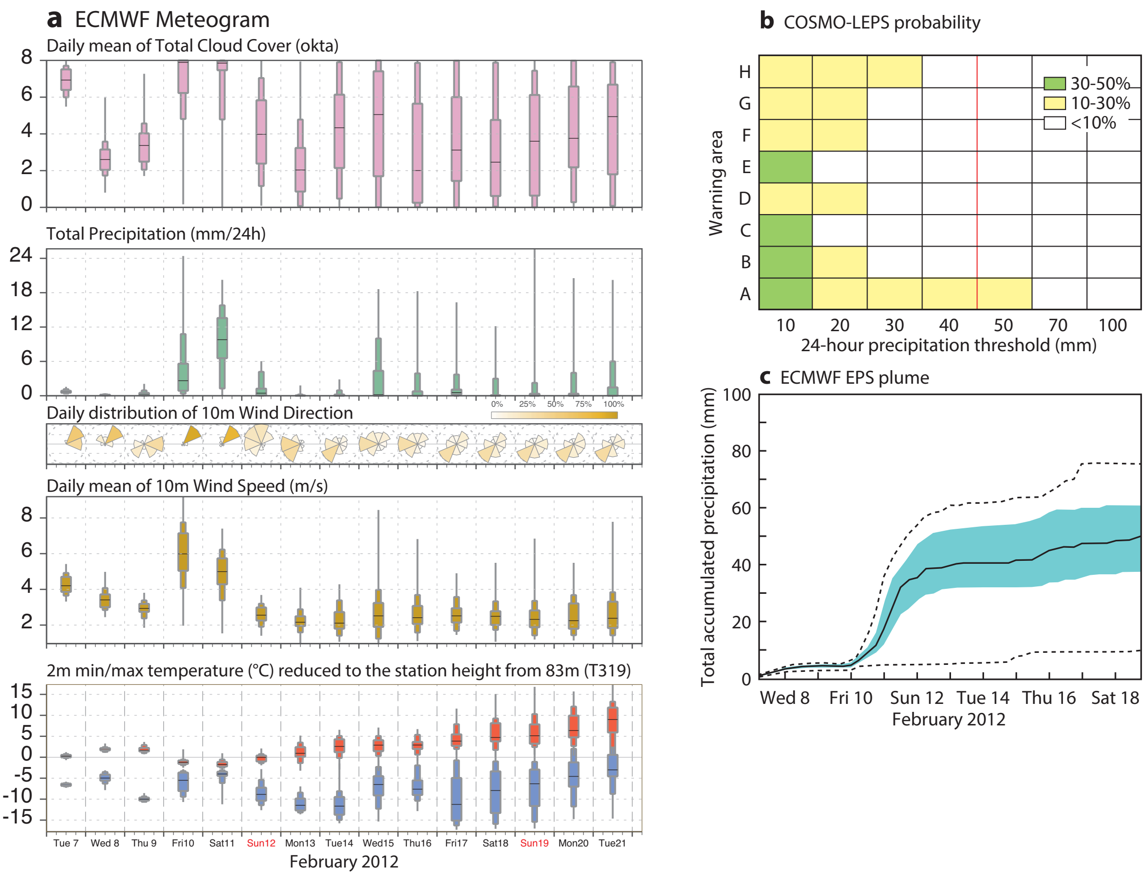

Figure 7 Some probabilistic products from ECMWF-ENS and COSMO-LEPS used as a basis for issuing a warning on 7 February of heavy snowfall in the coming days. (a) ENS 15-days meteogram valid for a location in the southern part of the region. (b) COSMOS-LEPS 5-day forecast, valid for 11 February, showing the probability of exceedence of the 24-hour precipitation thresholds (x-axis) and the warning areas (y-axis). A low probability of a very high threshold of 24-hour precipitation (all falling as snow) were evident for areas A and C (the area mainly affected) in the five-day forecast from COSMO-LEPS. (c) ECMWF EPSplume showing the total accumulated precipitation during the forecast period. Upper dashed line indicates the 90th percentile of the forecast distribution, the blue line corresponds to value greater than 25th percentile and less than 75th percentile and the dashed low line indicates the 10th percentile. The middle black line is the median.

Improving forecasts through collaboration

ARPA-SIMC is committed in improving the forecasting of high impact events as well as being able to predict abrupt transitions between weather regimes. This will allow regional resources to be managed more effectively. Regarding this aspect, we are interested in developing methods to exploit the 'residual' predictability beyond one week lead time by fostering collaboration with ECMWF and other Italian research institutions such as the Institute of Atmospheric Sciences and Climate (ISAC-CNR) in Bologna.

In this context it is worth mentioning two projects in which the author and other colleagues of ARPA-SIMC are involved.

- Collaboration with the ECMWF Predictability Division to develop an objective method for tracking Rossby wave trains to be applied at the ECMWF monthly forecasts.
- Involvement in an ECMWF Special Project SPIT-SPIA, in partnership with ISAC-CNR Italy, to investigate a multi-model ensemble approach for producing a monthly forecast.

Further reading

Liu, J., J.A. Curry, H. Wang, M. Song & **R.M. Horton,** 2012: Impact of declining Artic sea ice on winter snowfall. *Proc. Natl. Acad. Sci*., **109,** 4074–4079. doi:10.1073/pnas.1114910109

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Nanni, S., 2012: Febbraio 2012, ma quanta neve è caduta?, *Ecoscienza n.1*, http://www.arpa.emr.it/cms3/documenti/_cerca_doc/ecoscienza/ecoscienza2012_1/nanni_es1_12.pdf

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