**SOCIAL MEDIA AND WEATHER SURFACE OBSERVING TECHNOLOGIES AND SYSTEMS: EXPANDING THE SYNOPTIC NETWORK THROUGH WEB 2.0**

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**ABSTRACT**

Currently, the quantity of unofficial, and non-standardized, weather observations is growing due to new observational technologies available at low cost, as well as new communication technologies enabling sharing of meteorological data and applications. This paper presents the idea of improving the quality and spatial resolution of NWP outputs, by making use of social media as a new source of weather information. The idea emerges from recent developments within communication technologies, enabling collection of new weather observational data on the current state of the atmosphere. The role of social media, co-creation and networked production should be investigated in order to explore the potential utilities of these data on modern meteorology and environmental sciences. Inspired by the important role of space technology introduced in the 70’s, and the immense impact of implementation of satellite technology, this paper envisions an introduction of web 2.0 type technologies as tools to collect weather observations on spatial scales not covered by the presently established weather observation network, while introducing a platform for such weather information exchange, shareweather.com. Experiments based on web interfaces and mobile technology were performed in Sweden at the Royal Institute of Technology (KTH), centered on building a community of weather-interested users, aiming at testing the usability of ”user-generated weather observations”, including their possible future implementation into NWP-s and parameterizations for climate modeling. Weather observations created by non-experts can be processed based on principles of collective intelligence and co-creation, in order to improve and personalize weather information. The shareweather.com method for collection of usable weather information is described, and motivation of individuals to contribute with user-generated observations of weather regarded in particular. Previous findings within social media technology research were confirmed, of which the most important are that weather information can be exposed to similar filtering processes, and that weather information sharing by individuals is driven by similar incitements. Beside occasional disastrous impacts of weather, weather also affects daily life, and climate change representing a challenge of the future, may increase motivation to share weather data accross cyberspace. Due to these results, the paper suggests further implications of “share weather” community platforms on nowcasting, NWP, modelling of environmental processes, and public involvement in environmental change issues.

**Introduction**

Weather has been observed and recorded by individuals since ancient times. The pre-industrial weather pioneers could only speculate on future implications of collecting weather data, suggesting that, if the same observations were made “in many foreign and remote parts at the same time” we would “probably in time thereby learn to be forewarn certainly” of diverse emergencies, including severe weather (Robert Plot, Secretary to the Royal Society in England cited by Konvicka, 1999).

Imagine Plot’s expectations on the 21st century’s web 2.0. Here, we will apply an ancient idea on currently available communication technologies, assuming that the ability of a large group of connected individuals to unrestrictedly communicate with each other, will add a new dimension to the Greek word synoptikos - “*to see together*” (Konvicka, 1999).

Weather can be observed by anybody, as representing expressions of complex processes in the atmosphere visible and perceivable to human senses. During recent years, weather has received increased attention due to the enlightenment of the problem of climate change. Moreover, Internet and mobile technologies offer new opportunities to distribute weather information to individuals with increased quantity and quality of weather services, making weather a more common commodity beside a popular subject of conversation.

Currently, from the societal and scientific point of view, the following needs for improvements are identified by WMO (2009):

* Climatic information with higher spatial and temporal resolutions, such as the catchment scale and monthly or weekly time scales;
* Substantial improvements of forecasting skills for seasonal, interannual to decadal variability for better flood and drought emergency preparedness;
* Increased investments in National Meteorological and Hydrological Services (NMHSs) for strengthening observing networks, and data maintenance systems;
* Mainstream climate information, with urgent need to assist developing countries in mainstreaming local and regional climate change and variability information into planning/policy development;
* Data quality, availability and data sharing;
* Active participation by civil society.

**1.1 The real reason to talk about weather**

The development of weather services through history has been connected to: (1) inventions of new communication technologies, and (2) incitements to save lives and property (Elevant, 2010a).

Some earliest attempts to organize weather observation networks were initiated after documented losses caused by severe weather (Moran, 2002; Craft, 1998; Craft, 1999; Burton and Fitzroy, 1986; Davis, 1984; Burstyn et al., 1973). Secondly, the breakthrough of weather services was encouraged by the invention of the telegraph, the first available long-distance communication technology overriding spatial distances larger than the size of weather systems. Given that the character of atmospheric motions is highly dependent on horizontal movements (Holton, 1992), communication technologies represent a cornerstone of modern meteorology.

New media technologies of the 21st century offer possibilities to override spatial distances between two people anywhere in the world. We can thus add a new dimension to established communication channels and look into including new methods of communicating weather data, including distribution and collection of useful weather information contributing to the society and sustainable development. As illustrated in Table 1, the potential number of observations points has drastically increased through history, due to development of new communication technologies. If adding web 2.0 as the latest technology, e.g. defined by O’Reilly as *the network as platform, spanning all connected devices, with applications and services that consume and remix data from multiple sources and are updated and improving the more people are using them*, it represents the first technology based on participation and may thus potentially address hundred millions observation spots.

The objective of this paper is to look into the opportunities offered by web 2.0, and in particular present a “share weather” platform with functionalities that can filter such data. The findings of the paper are based on a research project conducted at the Royal Institute of Technology KTH in Stockholm, supported by: Vinnova (The Swedish Governmental Agency for Innovation Systems), Swedish Transport Administration, the city of Stockholm, Stockholm Public Transport, and Swedish public service radio SR. Additionally, the project has gained volunteer contributions from a primary school in Hammarby sjöstad, Stockholm, and over 400 volunteer test persons. The platform used for further research is available at www.shareweather.com.

**1.2 Motivation to purchase weather information: Societal needs and individuals**

The consensus and public debate on climate change, documented high-cost disasters (e.g. NOAA, 2009), increased frequency of severe weather events (Parry, 2007) and more property being subject to damage and “lifestyle and demographic changes subjecting lives and property to greater exposure” (Changnon, 2000), are all facts contributing to increased motivation to purchase weather information and develop methods to both forecast and understand atmospheric processes. Concerning property as an economic incitement, for weather-dependent business segments (e.g. transportation, agriculture, energy), there are strong incitements to search for methods that can provide more accurate weather information. Media corporations consider weather information important, as weather forecasts are a basic element of the news flow. However, when regarding end-consumers targeted here, individual needs and motives to purchase weather information may differ largely (Elevant, 2009). Due to research within psychology and cognition, passive consumption of broadcasted information is filtered due to personal relevance (e.g. Schneider and Laurion, 1993). The motivation of the fisherman to observe weather is due to the impact of weather on most “events” in the fishermen’s daily life (Ångström, 1926), and concern about own property and life.

Individual motivation to actively purchase weather services must thus be searched for within the personal life, and concern about property and life. It may be argued that a logical step for “the commons” of the 21st century is - as following the Maslow steps from basic needs such as safety, to esteem and self-actualisation in the modern society – to value quality of life such as travel, hobbies, leisure and sports, which create a demand on personalized weather information services. Studying customization of weather services, (Elevant, 2009) concluded that some are more interested in weather, and that their interest had four different origins: leisure and spare-time activities (e.g. outdoor hobbies), transportation, interest in technology, and genuine interest in weather. Obviously, the modern society also evolves motivation to purchase weather information in order to increase quality of life.

Concerning individuals’ involvement in climate change and environmental issues, research shows that motivation to participate does exist, and that lack of information or available platforms is provided as a reason of lack of participation. It can also be suggested that the definition of the problem should be conducted and expressed in such a way that it appears manageable, and not beyond reach of the individual’s personal influence. For example, results from a study on how the film “A day after tomorrow” was embraced by the audience (Lowe et al., 2006) showed that the viewer’s first reactions were a serious concern about climate change, although reduced as the film progressed. Additionally, many viewers expressed “strong motivation to act onclimate change”, but they did not “have information on what action theycan take to mitigate climate change”. Here, a need for useful and accessible tools enabling individual contributions, is expressed. In general, policy-makers propose that “tragedy of the commons” (e.g. Connelly and Smith, 2003) is manageable with increased public involvement, beside good decision and policy-making.

The challenges arising when aiming at not only creating attractive weather services, but attracting attention of the public to extreme weather and climate change issues (e.g. disaster management, transport administrators, public involvement in climate change issues and changed practices) are: (1) easily accessible information services, and (2) services personalized due to users’ exact needs (e.g. Basher, 2006; Elevant, 2009).

**1.3 Limitations in current data sets: Spatial resolution and customization**

Compared to linear media (e.g. TV) weather services, created to suit the majority of its consumers, web services offer some level of customization. Tools such as GPS and digital maps can zoom the area down to geographical distances of meters. The service content (e.g. Benkler, 2006) is, however, based on weather observations and forecasts operating on spatial scales of kilometres.

Climatic information is based on an even coarser spatial resolution by a scale of 100 kilometers. Incomplete data sets restrict understanding of changes in extremes and attribution of changes to causes (Solomon et al., 2007). Detection, as well as understanding of complex processes related to climate change, point at the need to increase both data volumes and quality. Most fingerprint work has focused on global-scale changes in individual, “primary” climate variables which underlines the importance of developing methods to detect *the effects* of greenhouse gases on climate.

A similar problem may be identified for meteorological applications. Current resolution of weather forecasts does not correspond to the local variation of variables describing societal *consequences* of weather (e.g. road conditions, power plant efficiency, soil moist, crop growth).

**1.4 The web 2.0 synop observation network: The “Share weather” community**

The gap between the spatial scales requested by meteorological applications, and the spatial resolution of available weather information upon which we base the content of weather information services, illustrates the problem of personalizing the weather service content to a particular user’s geographical position, and activity. Personalization can, however, be based on information indirectly or directly provided by the user: perception, position, habits and recent weather experiences (Elevant, 2009), where the level of customization will depend on the amount of information provided by the user.

Web 2.0 now opens windows toward personalization of services and innovation (e.g. Chesbrough, 2003). Additionally, it offers new opportunities to co-create weather information. Almost everybody owns a cellular phone. Sensor networks (e.g. road weather information systems) are on progress and they are used to improve the quality of local weather information. Here, collection of weather information from a large number of individuals, now offered by web 2.0, is unexplored. Recent research within human communication, media technology and open innovation states examples of value-creation generated through crowd-sourcing and collective intelligence (e.g. Jenkins, 2006; Levy, 1999) and communication between individuals, instead of organizations. Here, we may refer to Benkler (2006) and the definition of different societies due to its communication practices, censorship and ownership of the information. Benkler (2006) defined three types of societies: (a) society of the pre-industrial era where story-telling was inefficient due to lack of resources to process large information volumes, (b) a society where selected experts are given the privilege of decision-making and role of story-telling (due to Elevant, 2010a illustrated by mass-media and different organizations providing weather information to the public), and (c) a society where everybody can participate and generate weather observations, co-creating large volumes of information that may be filtered, for example by the process of peering. This paper takes the approach of assuming a transition between a society of type (b), where weather data are created by a limited number of organizations and standardized networks (e.g. the current synop network), to type (c), where individuals are enabled to communicate weather observations through cyberspace (forming a denser observation network than the synop network), as described by Elevant (2010a), and based on the “expert paradigm” (e.g. Walsh, 1999).

Instant communication of real-time weather data was first enabled by the telegraph, followed by a rapid development of synoptic meteorology. Climatologists, however, need data for periods prior to the recording of instrumental data, and reconstruct such data from proxy palaeoclimatological sources of information, derived from tree rings, ice cores, coral growth. Other proxy data can be derived from features such as early ship logbook data. In this paper, a method to create new proxy data for climatic data purposes and analysis of the impacts of climate change, by using reports of changes of environmental variables, is introduced.

Research within media technology introduces collective intelligence and crowd-sourcing as an important factor as today’s society transits from “industrial information economy” to “networked information economy”. By introduction of the expert paradigm (e.g. Walsh, 1999), Jenkins (2006) stated that “No one knows everything, everybody knows something”, which can be applied on weather data as suggesting that: *No one* can observe weather *everywhere*, but *everybody* can observe *somewhere*, or *some* of the weather (Elevant, 2010).

Table 1 illustrates the historical connection between available technology and the development of weather information exchange, starting with the emergence of first weather observation networks of the 19th century, to currently 105 observations (WMO). Connecting hundred millions of people in different places through web 2.0, offers a full realization of the idea of synoptikos “*to see together*”.

Table 1: Weather information paradigms. (Source: Elevant, 2010a)

|  |  |  |
| --- | --- | --- |
|  | TECHNOLOGY | OBSERVATION POINTS |
|  | Human speech | 100 |
| 1850 | Telegraph | 101 - 102 |
| 1940 | Aviation | 103 |
| 1950 | Computer | 103 - 104 |
| 1970 | Satellites | 104 - 105 |
| 1990 | Web 1.0 | 105 - 106 |
| 2010 | Web 2.0 | 106 – 108 |

Volunteer observations of weather is not novel to the scientific and meteorological community. For example, organized collection of weather data from over 10.000 volunteer weather observers in the US (www.coop.nws.noaa.gov). Additionally, volunteer observations from ships (VOS) are considered an important source in areas with poor synop spatial coverage.

Based on a research project at KTH Royal Institute of Technology, Elevant (2010b) suggested a “share weather” system based on social media and a “community on interest” (Lave and Wenger, 1991) that may transform into a “community of practice”, creating information valuable not only to the individual and the community of interest, but to the whole society.

**Weather Observation Techniques and Implications**

**2.1 Current methods**

Weather observations are used both for understanding fundamental environemntal processes, and as input to NWP’s, where most weather forecasting centres use a combination of deterministic models and nowcasting methods, i.e. statistical methods integrating observational data on the current state.

**2.1.1 Spatial resolution and forecasting techniques.** Weather forecasting is an initial-state problem. Deterministic model approaches like numerical weather forecast models (NWP), require boundary conditions administrated by WMO, e.g. synop observations, in order to calculate future states. Due to the complexity of the set of non-linear differential equations describing the motions of the atmosphere, simplifications are necessary (e.g. replacing them with algebraic equations that can be numerically solved by time differencing), contributing to two major problems within numerical weather system modelling, beside computational stability: 1. simplification of the basic equations and unsatisfactory representation of physical processes involving radiation, clouds, precipitation, and boundary layer fluxes, and 2. there is an unavoidable level of error in determination of the initial state, due to poor spatial coverage both on horizontal and vertical levels, collected prior to model data assimilation (e.g. Holton, 1992). Benefits of increasing the spatial coverage are larger for short-range forecasts compared to long-range forecasts that contain larger error growth (e.g. Lorenz).

Climate modeling meets even greater challenges, while aiming at modeling three different sets of processes: radiative, dynamic and surface process, requiring coupling general circulation models of the atmosphere and oceans to land surface and cryospheric models (Peng, 2002). There are continuing problems with sustaining adequate spatial sampling of climate conditions (Martinson, 1998) and necessary parameterizations are derived from large-scale observations or extensive field investigations.

Summarizing, weather and climate models use a smaller grid size than what is available with current observations, requiring interpolations due to missing data points and incomplete formulation of physical processes. The number of observations is thus inadequate to achieve the high-resolution local information for both personalization of weather information, climate projections and detection of environmental change. Here, a common interest, shared by the individual and the society, is created.

**2.1.2 Observation Biases.** Human observers have served synoptic weather stations of the WMO global observation network for decades, although eventually replaced by automatic stations. Consequently, (1) observer biases related to human perception are integrated with its records. Aircraft observations and volunteer ship observations (VOS) have provided knowledge on systematical errors and illustrate problems with non-standardized observations. Kent and Berry (2004) argue that errors due to randomness and systematic errors due to different standards should be handled by weighting observations and by calculating the main bias from different ships.

However, even standardized weather measurements contain (2) biases due to instrumentation and measurement methods. This is of particular interest when regarding methods for measuring variables such as cloudiness, precipitation, wind profiles and visibility, based on “surrogate” variables like spectral radiance, radar reflectivity, turbulence, rather than fundamental model variables (pressure, temperature, wind and moisture), measured by satellites, radars, wind profilers (Park and Xu, 1999). For example, the problem of accurate measurements of rain gauges is known (Robinson et al., 2004). Furthermore, the location of weather stations is determined by required standards and (3) physical environmental preconditions. WMO standard measurements are performed at 2 m above surface level. Spots characterized by for example rich precipitation may thus be eliminated as observation points. The generally poor spatial coverage raises (4) the problem of measuring extremes and meso-scale phenomena such as thunderstorm frequency.

Regarding meteorological applications for industry and consumers, there may exist (5) an inconsistency between WMO standards and different applications, for example the problem of measuring road surface temperatures by RWIS (Wallman el al., 2005) arising from locally specific microclimatic conditions. Accurate electricity production forecasts for the wind power industry require accurate wind forecasts at 100 m above the standard level, and road surface temperature forecasts are necessary for road maintenance.

Introduction of satellites has increased data volumes for studying climate change and enabled monitoring of for example aridity (Svoboda et el., 2002), and represents an important contribution to WMO data set and NWP boundary conditions. Despite advanced space technology, the results from modeling impacts of climate change on ecosystems and land use are uncertain due to lack of local data (e.g. Stroosnijder, 2007). On the other hand, issue (3) above illustrates the need to study extremes in order to document serious effects of climate change. Again, the inconsistency between available weather observations and applications (5) on climate change - the urgent need to detect how the weather is changing on long-term - is clearly expressed.

**2.2 Volunteer weather observations using web 2.0: Co-creation as a method**

Statistical approaches have to be introduced if looking beyond the limitations set up by the complexity of the reality. Nowcasting, or statistically “correcting” outputs of NWP’s, as well as model output statistics (MOS) is a part of daily operations in many weather service centers, providers and businesses (e.g. road transportation, wind power). Additionally, post-processing of NWP outputs applies statistical corrections of known biases, created due to incomplete parameterizations of physical processes. The weather forecasting of the future may attribute a large number of real-time weather data, that can be integrated into data-assimilation and post-processing. Basic requirements are to: motivate sharing, define filtering and processing methods, and establish data standards. Here, we suggest the method of co-creation of weather data, or user-generated “shared weather” information, created by individuals. The key questions connected to this method are: 1. filtering, and 2. motivation of citizens to contribute with local information.

**2.2.1 Co-creation as a method.** Collective intelligence (Jenkins, 2006; Levy, 1997), is redefining our traditional assumptions about expertise, encouraging changes in the knowledge hegemony of a number of fields (Walsh, 1999). An example from geosciences is available. Tapscott and Williams (2006) described how a gold-mining firm managed geological information based on contributions from non-experts such as ordinary citizens, while adopting an open data policy approach. This example demonstrated that useful information about the environment can be achieved from a variety of information sources, even within an area traditionally held by specialists and experts. NASA performed an experiment known as “clickworkers”, confirming that a large number of non-experts can do the work of an expert (Benkler, 2006). Studies on open innovation (e.g. Chesbrough, 2003) provide other examples of “expert paradigms” (Walsh, 1999).

The new claim here is that observations of variables in the environment (e.g. wind, temperature, cloudiness) can be regarded as pieces of information systematically collected and stored by different bodies of knowledge – such as WMO, institutes and enterprises - possessing the necessary expertise within the field. However, observations of the environment can in fact be performed by anybody.

In order to make that information useful to the society, the information must be processed in order to reduce biases caused by human perception and randomness. In the early beginning of human communication, with human speech serving as the only communication technology, weather documentation started with the “story-telling” as described by Benkler (2006). With establishment of long-distance communication technology, synoptic meteorology evolved as observations were collected from some few experts in their role as weather observers. Thus an information “censoring” process commenced, where selected individuals provided information from selected sports. Consequently, weather observations were “censored” due to sparse spatial coverage, even when the work of the pioneers became largely organized, once economic incitements to save life and property were great enough for funding large-scale activities (Elevant, 2010a).

**2.2.2 Benefits of co-creation.** Based on a denser observation network on regional level, weather information sharers can perform spatial sampling of climate conditions, flora and fauna. Such voluntary observations may serve as “field investigations”, extending the empirical data set necessary to create environmental model parameterizations. The shared weather data may also be processed together with other climatic data, in order to be used as boundary conditions to environmental models. For example, shifts in storm tracks and intensification in the evaporation and precipitation cycles due to climate change altering the frequency and intensity of floods and droughts (Milly et al., 2002), can be recorded if by human weather observers in cyberspace providing more frequent local observations of wet (or dry) soil and flooding (or droughts), and actual long-term effects on flora and fauna caused by increased or decreased precipitation. These high-resolution records on environmental data collected from non-experts may be seen as high-resolution proxy data containing biases.

**2.2.3 Biases of the co-creation process.** Communication technologies and practices of the 21st century enable information sharing within social media networks like communities. Because different people perceive weather differently, each user will provide an observation error, a combination of randomness and a systematic error typical for that user. However, in contrast to traditional single weather observations spread out in space, collaborative weather observations may be *compared to each other*. The lack of instantaneous observations, but in particular the spatial distance between ships, creates difficulties when handling errors in voluntary observations from ships (Kent and Berry, 2004). From the example of Wikipedia, it is evident that documentation on objective information can be created from a large number of individual contributions by the process of *peer-viewing*. (e.g. Jenkins, Benkler, 2006). Additionally, we can learn, even quantify, human biases if asking the user to report his or her own observations and habits (Elevant, 2009a). The bias of observed weather is dependent on the activities performed and the perception of weather. Furthermore, individual biases may be measured by comparing human observations to the closest source of more reliable data such as WMO. The continuous displacement of the observer also guarantees some observation overlapping, enabling comparison with other man-made observations. Additionally, human senses and simple instruments can be combined, like taking pictures of the sky with a cellular phone, or using simple low-cost rain gauges.

**2.2.4 Man versus weather instruments: Peering.** Peer-viewing as a filtering method may be efficient enough even with a small number of human observers of for example cloud cover. Cloud cover can be observed not only from the observation spot, it may be visible within a range of kilometers. Asking other users to confirm or reject cloud pictures, peer-viewing will result in a “true” picture of the sky. The example of cloud pictures addresses present limitations due to instruments (2). Regarding other limitations of instruments such as the physical environmental preconditions for synoptic stations (3), and the inconsistency between standards for meteorological purposes versus applications and user needs (5), they can be eliminated if using human mobile observers. In the case of human observers, both the location and the application are defined by the individual, thus personalized to the user. Other advantages with mobile observers are detection of meso-scale phenomena (4), such as mesoscale winds and storms, perceivable by ordinary citizens (non-experts).

**The “Share Weather” Community of Practice**

The research (Elevant and Turpeinen, 2010) has provided evidence that co-creation of weather information can be performed within a “community of interest” gathering people with interest in weather. The idea is to further expand the community to other groups in the society, offering a platform for public involvement in co-creation of weather observations, climate change and environmental issues, transforming the “share weather” platform into a community of practice.

**3.1 The “Shareweather” interface**

We present an example of a community of interest - [www.shareweather.com](http://www.shareweather.com) - as a method to collect weather information. Additionally, motivation to participate is touched upon, and further discussed in the next section. Some examples are available in Picture 1.

Weather variables can be measured either *subjectively*, or using instruments, which, although not objective in the sense that they are not standardized, we call *objective*. As illustrated in Picture 2, subjective measurements are for example picking a suitable descriptive phrase from a drop-down menu, describing cloud cover, cloud type, change of cloud cover, the part of the sky to which the clouds are concentrated, wind direction and estimated speed using the Beaufort scale, temperature change compared to yesterday’s, visibility, precipitation, precipitation intensity, slipperiness on road (ice, hoarfrost, black ice). Cloud categories are chosen by clicking on a suitable picture resembling the clouds observed. Additional variables related to different applications, are possible. For example, traffic-related subjectively measured variables are traffic congestion and traffic flow, and objectively measured variables are: wind, humidity, temperature, precipitation amount, travel time, snow depth.

Observations of the environment represent a central application. They consist of subjective reports on the status of the soil and ground, water levels, rivers and run-off. Additionally, observations of the environment such as seasonal changes in the surrounding habitat and nature are reported: spring blooming, peak blooming ranges and calendars, amount of particular flowers and other plants, as well as cultivated vegetables and fruits in the garden. The shareweather community may also receive reports on observed species such as animals and insects.

In order to motivate participation, members of the “share weather community” are able to make weather reports in different formats (web, sms, mms) using different devises (computers, mobile phones), depending on present needs and abilities. Weather reports can be created for chosen places (e.g. chosen on a map or using positioning).



Picture 1: The “share weather” interface (Source: Elevant, 2010b)

One innovation integrated into the system are objective cloud cover and cloud type observations, documented by pictures. Pictures of the sky are taken with a cellular phone representing an easy way of creating and sending reports. The system returns a weather forecast for the same spot, a functionality aiming at motivating continued reporting. A local weather forecast is provided to the user whenever pushing the “send report” button. The system is based on the principle that the more information the user will send, the more – and more accurate – weather information will he or she receive. Other functionalities motivating participation in the “share weather” community are logbooks, calendars, and personalized books, discussion forums and possibility to share and see reports performed by others, or applications created from those data.

**3.2 Quantity and quality of co-created weather information**

In order to transform shareweather into a community of practice, quality of created information, as well as expected quantities, should be investigated.

**3.2.1 Community of interest: Weather-dependency and available time.** The previously provided examples of individuals whose life and property are confirmed to be exposed to nature and its elements (e.g. fishermen and farmers) are examples of small weather-dependent enterprises with motives to share weather and environmental observations, in order to receive a product they can use and benefit from. Additionally, groups that are weather-dependent due to their time-consumption and distribution of weather-dependent activities (Elevant and Turpeinen, 2010), such as time spent in transportation, are of interest.

Other groups of particular interest are those with large amounts of available time to invest in performing activities during their spare-time. Elevant and Turpeinen (2010) concluded that groups like pensioners and school children may represent an important societal resource considering co-creation of environmental information.

Experiments on about 60 school children, providing reports on regular basis, showed that school children were able to provide useful information, further supporting the assumption that the human bias is manageable if applying common web 2.0 filtering processes like peering, and, most important, if offering methods adjusted to the individual (e.g. children) performing the observation. Additionally, the results of tests performed on 350 traffic weather interested adults, applying a method of “ranking” weather forecasts (Elevant and Turpeinen, 2010), showed that the respondents partly valued the forecast due to their time of exposure to the community of interest, and manifested higher response rate, the longer the time when joining the experiment, indicating that trustworthiness and participation are closely connected.

Studying acquisition of traffic weather information, Elevant (2009) provided evidence supporting that the best weather observers are those who need weather information the most (e.g. long-distance travellers) and that an initial need for accurate weather forecasts in daily life also encouraged sharing weather information (Elevant, 2009). Not only the motivation, but also *the ability,* of the fisherman to observe weather is due to training and awareness of weather and wind as it happens to have great impact on most “events” in the fishermen’s daily life (Ångström, 1926). The tests with school children also confirmed that the children did develop their skills as weather observers over time (Elevant and Turpeinen, 2010), most probable as their attention and knowledge increased during the five months of the duration of the experiment.

It can be suggested that individuals can be “trained” in the same way as the farmer and the fisherman, if their attention was directed toward weather phenomena. A parallel can be drawn between recruited volunteer observers of the “shareweather” system, and professional synop observers.

**3.2.2 Motivation of the Commons.** Although the motivation of an ordinary citizen may be questionable, from findings on research on shareweather.com presented above, (e.g. increased attention and improved skills demonstrated by school children), it can cautiously be argued that raised attention due to environmental concern and the issue of climate change, may increase attention to weather phenomena, and as such stimulate participation in co-creation of weather information.

The stronger argument is, however, that, if adopting a web 2.0 solution, motivation can be searched for in self-actualisation (due to Maslow steps) and willingness to contribute to a good cause, increased knowledge, common wealth and the society. Studies of so called “trust networks” – networks of those people one views as trustworthy - and social dilemmas arising from not knowing the service provider through anonymous exchange of goods and services (e.g. Cheshire, and Cook, 2004), show that the social context and community responsibility norms (social approval and a sense of group solidarity) can play an important role in trust-building, even with lack of any specific reputational information. Even more interesting, surprising results were found on motives to make volunteer contributions, where experience of fun is found to represent the strongest incitement (Nov, 2010; Pink, 2009), further underlining the importance of creating user-centred interfaces with innovative functionalities.

When stimulating participation and increasing the skills of weather observers, socializing within the share weather network is obviously an important ingredient. One goal of the share weather system is to stimulate diffusion of innovation, knowledge and information within the share weather community, which can be initiated by connecting the “best observers” with each other. The advantages of the system for volunteer weather observations presented here, are, beside offering (1) the high-quality spatial information improved by applying peering and user-generated observations, a solution based on a community platform also offers: (2) personalized content substance and form including, and (3) experience of fun and contributing to the environment.

**Conclusions**

The modern society creates new motivates to purchase weather information, in order to increase quality of life. Additionally, we are faced with the challenge of environmental change. In this paper, some important issues of modern weather services and meteorology, and needs defined by WMO (2009), were addressed: higher spatial and temporal resolutions (monthly or weekly time scales), quantification of uncertainties and biases in future projections, better representation of physical processes and higher spatial resolution, and understanding of the mechanisms that lead to the variability on the different timescales, impacts on water quantity, water quality and effects on aquatic ecosystems and biodiversity**.**

It is here suggested that collection of weather observations from individuals, through a web community based platform, e.g. shareweather.com, represents an alternative weather observation technique and potentially an important future step to be taken within nowcasting, parameterizations and modeling of environmental systems, quantifying and understanding the impacts of climate change. Including the public in collection of important weather information, through the Internet and mobile phones, may additionally be a useful tool of realizing public involvement in environmental issues. It can even be suggested that the method of organized crowd-sourcing of weather information may have implications within NWP, if carefully implemented into established systems of data assimilation and post processing, further suggesting that definition of standards are required. A comparison can be made to the introduction of other technology through history, like satellite remote sensing. Collecting pictures of the sky taken by a large number of individuals’ mobile phones, may be compared to a satellite picture from beneath.

The “expert paradigm” and recent developments on communication practices suggest that, as previously through history, nobody can observe everything, but, with web 2.0 technology, now everybody can observe and record some(thing) of the weather, e.g. a part of the sky. Individuals as non-expert observers, may address the problems of some current observation techniques (e.g. biases created by surrogate variables like spectral radiance and radar reflectivity). Secondly, volunteer observers may be particularly useful for collection on mesoscale phenomena where NWP’s do tend to fail. Provided that the number of observers is great enough, the process of peering would be very efficient, with implications such as: detecting extremes such as intensification in the evaporation and precipitation cycles, by altered frequency of local observations of wet (or dry) soil, long-term effects on flora and fauna caused by changed precipitation, melting of mountain glaciers, sea level rise, sudden thresholds and non-linearities in the climatic system, detailed mapping of environmental change, biodiversity informatics, ecological niche modelling.

The method is based on findings from media technology research, here applied on weather information. Concluding, results from several studies conducted in Sweden, suggest that weather information may be filtered due to established peering methods and collective intelligence programming methods applied in web-based communities. The method can be compared to volunteer observations from ships, weighting observations and calculating the main bias from different ships (Kent and Berry, 2004), here replaced by individuals*.* Additionally, the findings imply that “share weather” communities of interest may follow the same patterns as other communities (e.g. Wikipedia), regarding incitements to make contributions, such as: experience of fun, the sense of contributing to the common wealth and the society, norms like responsibility toward the community of interest. This would further suggest that “share weather” systems like shareweather.com are suitable tools for public involvement in environmental issues. In general, multiple individuals are assumed to act independently in their own self-interest, known as “tragedy of the commons”, often regarded the roots of unsustainable development (e.g. Connelly and Smith, 2003). Web 2.0 based communities’ norms may, however, add incitements to make volunteer contributions to the common wealth.

A “share weather” community of interest, used for improving nowcasting and weather forecasting methods, may therefore have additional implications like organized collection of high-resolution climate proxy data consisting of volunteer reports on environmental state and variables recorded by individuals, forming a community of practice that may collect important information on the environment and climate change. Work of individuals may support other scientific projects as described by Guralnick and Hill (2009).

Methods based on social media have the advantage that they do not require large-scale initial investments. On the contrary, social media represents an alternative to increased investments in NMHSs for strengthening existing observation networks.

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