COLLABORATIVE OBSERVATIONS OF WEATHER
A Weather Information Sharers' Community of Practice

Katarina Elevant
Department of Media Technology and Graphic Arts
Royal Institute of Technology KTH, Lindstedtsv. 3, Stockholm, Sweden

Keywords: Weather, Forecast, Co-creation, Observation, Climate change, Community, Collective intelligence.

Abstract: Beside occasional disastrous impacts of weather, weather also affects daily life. Societal and environmental challenges of the future include both providing customized weather information in-time due to users' needs, and detecting climate change and its impacts on land and ecosystems. The accuracy of weather and climatic information is, however, limited by spatial and temporal borders that need to be overriden. Also, weather information services cannot be fully customized, a problem arising from the spatial inaccuracy of weather forecasts and observations. Here, the role of social media, collective and civic intelligence and crowd sourcing should be investigated. This paper envisions a community of weather-interested users that provide usable observations of weather and environmental change, and presents a web-based interface for this community as a new method to collect weather and climatic information. User-generated weather observations can be processed based on principles of collective intelligence and co-creation, in order to improve, customize and personolize weather information.

1 INTRODUCTION

In the 17th century, two centuries before the invention of the telegraph, Robert Plot, Secretary to the Royal Society in England, collected weather observations and noted 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 (such as heats, colds, dearth's, plagues, and other epidemical distempers)" (Konvicka, 1999).

Imagine Plot's expectations on the 21st century's social media. Weather can be observed by anybody, representing visible and perceivable expressions of complex processes in the atmosphere. Ancient cultures learned to understand signs of incoming weather and its impacts on the environment (Theophrastus). Fishermen and farmers, that possess *experience* of the law of physics as eye-witnessing governed movements of the air, are able to make good observations of weather (Ångström, 1926).

For centuries, the development of meteorology relied on human observers, still contributing to the international exchange of observations from meteorological *synoptic* stations (from Greek synoptikos "to see together"), organized by the World Meteorological Organization (WMO). One basic problem for weather and environmental forecasting is, however, related to the limited spatial resolution of weather observation networks.

Introducing social networks, this paper is based on the assumption that, whether an individual or an organization of individuals, everybody may perceive weather. Everybody can *see,* or *observe,* the weather in their closest environment. As a parallel to Jenkins (2006) "No one knows everything, everybody knows something", it can be stated that: *No one* can observe weather *everywhere*, but *everybody* can observe *somewhere*, or *some* of the weather. Thereby, a large number of users could *see* the weather *together*, and the essence of *synoptikos* ("to see together") suddenly reaches new proportions, as tools for collective intelligence of web 2.0 are accessible.

1.1 Reasons 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. Some early attempts to organize weather observation networks were

Elevant K.
COLLABORATIVE OBSERVATIONS OF WEATHER - A Weather Information SharersâĂŹ Community of Practice.
DOI: 10.5220/0002810203920399
In *Proceedings of the 6th International Conference on Web Information Systems and Technology (WEBIST 2010)*, page
ISBN: 978-989-674-025-2

initiated after documented losses caused by severe weather (Burton and Fitzroy, 1986; Craft, 1998; Craft, 1999; Davis, 1984; Moran and Hopkins, 2002). The usability of weather observations was, however dependent on long-distance communication overriding spatial distances larger than the size of weather systems ranging over 100 km, as the character of atmospheric motions is highly dependent on horizontal movements (Holton, 1992).

Climate change as well as the fact that societal changes and urbanisation increases the vulnerability arising from weather (Changnon et al., 2000), put weather information on the agenda. In 2005, the hurricane Katrina, the most expensive disaster in U.S. history, stated an example of the disastrous effects of weather with $130 billion damage/costs (NOAA, 2009). Through human history, climatic disasters have affected communities and populations around the world, such as the mysterious demise of Viking settlements in Greenland in the 14th and 15th, believed to have occurred due to a temperature decrease (Konvicka, 1999). The future society will also have to tackle the increased frequency of severe weather events (Parry, 2007).

New media technologies of the 21st century offer possibilities to override spatial distances between two people anywhere in the world. New ways of communicating thus open windows toward both distributing, and collecting, new weather information. The objective of this paper is to look into the opportunities offered by the “invention” of web 2.0.

1.2 Motivation to Purchase Weather Information

A fisherman’s motivation to observe weather is due to the impact of weather on most “events” in the fisherman’s daily life (Ångström, 1926) and comes with concern about own property and life. Individual motivation must thus be searched for within the personal life, such as economic incitements, improved quality of life, individual freedom, planning and mobility. Studying customization of weather services, Elevant (2009) concluded that interest in weather had four different origins: leisure time activities (such as outdoor hobbies), travel to work, interest in technology, and genuine interest in weather. Easy access to weather information through different traditional and linear media channels mostly offer passive consumption of weather information. The information is thereafter filtered due to personal relevance (Schneider and Laurion, 1993). Thus a challenge arises for not only private enterprises aiming at creating attractive weather services, but decision-makers that want to inform the broad public about coming weather events.

1.3 Limitations in Current Services

Compared to traditional linear media weather services, created to suit the majority of a target group, web 1.0 do offer some level of customization (e.g. city, region, hobby). Tools like GPS and digital maps can zoom applications down to geographical distances of meters. The service content is, however, based on weather observations and forecasts operating on spatial scales of kilometers (WMO, 2006).

Climatic information is based on an even coarser spatial resolution of hundreds of kilometers. Detection, as well as understanding of complex processes related to climate change, point at the need to increase both data volumes and quality. Incomplete data sets restrict understanding of changes in extremes and attribution of changes to causes (Solomon et al., 2007). Most fingerprint work has focused on global-scale changes in “primary” climate variables, which underlines the importance of developing methods to detect *the effects* of greenhouse gases on climate and the environment. Similar relations exist between the resolution of the weather forecast and variables describing *consequences* of weather such as: road conditions, power plant efficiency, soil moist, crop growth.

This 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 customizing the content of a weather service to a particular user’s geographical position, and activity. As a result, consumers acquire weather forecasts not entirely relevant in regard to their needs.

Studying customized traffic weather alerts, Elevant (2009) suggested that personalized weather information can be based on user profiles and information on perception, position, habits and recent weather experiences, indirectly or directly provided by the user while observing weather (e.g. by ranking received weather forecasts). The level of personalization will depend on the amount of information provided by the user.

1.4 Objective: The “Share Weather” Community

We can conclude that current weather services struggle with problems regarding spatial inaccuracy. Secondly, users should be more actively engaged, if we ought to increase active acquisition of weather information, which may be of particular interest before severe weather events. The objective of the paper is to demonstrate a web service based on co-creation, discuss motivations to use the service as well as some wider implications.

Web 2.0 has not only opened windows toward customization of weather services, but offers the opportunity to co-create weather information. Almost everybody owns a cellular phone. Sensor networks, such as road observation networks measuring road conditions, are on progress and they are used to improve the quality of local weather information. However, the possibilities to collect weather information from a large number of individuals, now offered by web 2.0, are still unexplored.

The paper suggests a community of interest, which offers important practice as creating information valuable not only to the individual and the community of interest, but to the whole society.

2 SHARED WEATHER DATA

Organized observation networks provided the first systematic records by 1860. Climatologists additionally use proxy palaeoclimatological sources of information, derived from tree rings, ice cores, coral growth, or features like ship logbook data.

Table 1 illustrates the development of weather information networks, from reports provided through the first telegraphic networks in the 19th century, to currently 10^5 observations: 15 satellites, 700 buoys, 3 000 aircraft, 7 300 ships and some 10 000 land-based stations (WMO, 2006).

Table 1: Weather information paradigms.

	TECHNOLOGY	OBSERVATION POINTS
	Human speech	10^0
1850	Telegraph	10^1 - 10^2
1940	Aviation	10^3
1950	Computer	10^3 - 10^4
1970	Satellites	10^4 - 10^5
1990	Web 1.0	10^5 - 10^6
2010	Web 2.0	10^6 – 10^8

Connecting hundred millions of people in different places through web 2.0, offers a potential solution for synoptic meteorology and the idea of synoptikos “*to see together*”, as a large number of citizens may share their weather observations with each other, and *see together*. Hereby, we introduce the idea of a web weather 2.0 paradigm.

2.1 Predictions and Observations

Weather forecasting is an initial-state problem represented by a set of non-linear differential equations (Holton, 2992). The initial state is achieved from synoptic stations, which are boundary condition input to numerical weather forecast models (NWP). Due to complexity of the system, simplifications are necessary. Here arise the two major problems within weather forecasting. The first is the simplification of the basic equations used to calculate future states of the atmosphere. The second is due to lack of observations of the current state.

Climate models, used to simulate global environmental processes and trends meet even greater challenges, while aiming at modeling three different sets of processes: radiative, dynamic and surface process (Peng et al., 2002; Oliver, 2005), and are assembled by coupling general circulation models of the atmosphere and oceans to land surface and cryospheric models. Climate models use parameterizations derived from large-scale observations or extensive field investigations. However, there are continuing problems with sustaining adequate spatial sampling of climate conditions (Martinson et al., 1998).

Summarizing, the number of observations from around the world is inadequate to achieve the high-resolution local information in order to provide customized and personalized weather information, as well as reliable detection of climate change and climate projections. The models use a smaller grid size than what is available with observations, requiring interpolations due to missing data points.

2.2 Observation Biases and Limitations

Current weather observations are exposed to biases due to: (1) human perception (e.g. Kent and Berry, 2004), (2) methods for measuring based on “surrogate” variables (e.g., spectral radiance, radar reflectivity, turbulence used to measure cloudiness, precipitation, wind profiles and visibility, as described by Park and Xu (1999), and the problem with rain gauges studied by Robinson et al. (2004)),

(3) physical environmental preconditions characterizing the spot (e.g. topography, vegetation).

In meteorological applications additional biases are created while: (4) performing necessary spatial extrapolations non-representative of extreme values and meso-scale phenomena (such as thunderstorms or road surface microclimate conditions (Wallman el al., 2005)), and (5) introducing different standards (e.g. measuring wind speed at different heights).

For some applications, technological progress like the introduction of satellites significantly improved the data, such as increased data volumes for monitoring of aridity and environmental change (e.g. Svoboda et el., 2002), addressing issue (4). In order to supply different applications for industry and consumers with adequate input, additional weather observations are operated by companies and organizations conducting weather-sensitive operations (e.g. wind power enterprises, road administrators, sports), however creating observation sets of different standards (issue (5)).

Despite advanced space technology, applications like modeling impacts of climate change on ecosystems and land provides uncertainties due to extrapolations and parameterizations (issue (4)), and methods (issues (2) and (3)). For example, when assessing land degradation, experts tend to underestimate "the abilities of local farmers, many of whom have been able to modify their land management." (Stroosnijder, 2007). Again, the need to study local extremes in order to improve NWP's, as well as document serious effects of climate change - the urgent need to detect how the weather is changing on long-term - is clearly expressed by issues (2), (3) and (4).

2.3 Creating Additional Weather Data

Statistical approaches have to be introduced if looking beyond the limitations set up by the complexity of the reality. Statistically "correcting" outputs of NWP's, so called "nowcasing", is a part of daily operations in many weather service centers, providers and businesses (e.g. road transportation, wind power). The weather forecasting of the future may attribute a large number of data, if we can find ways to motivate sharing, and establish methods of processing, and standards. The objective is to focus on user-generated "shared weather" information, and motivation of citizens to contribute with local information forming human observation networks in cyberspace.

2.3.1 Co-creation of Weather Information

We are aiming at answering the question whether the weather-men may be replaced by the weather community. 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). A delicate example from geosciences was illustrated by a story of a gold-mining firm that shared knowledge on geological information with the world (Tapscott and Williams, 2006), demonstrating how useful information about the environment can be achieved from a variety of information sources, even within an area traditionally held by specialists and experts. In the early beginning of weather forecasting, all observations were collected from individuals that served as experts in their role as weather observers (Table 1). The "share weather" system presented here will collect information from non-experts, at low cost, with the purpose of "nowcasting" the web service the users can directly benefit from.

2.3.2 Co-creation of Climatic Information

Based on a denser observation network on regional level, world-wide, weather information sharers can perform adequate 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. Shifts in storm tracks and intensification in the evaporation and precipitation cycles due to climate change would alter the frequency and intensity of floods and droughts (Milly et al., 2002), which can be recorded by human weather observers in cyberspace providing more frequent local observations of wet (or dry) soil and flooding (or droughts). These high-resolution records of the environment can be collected by "weather information sharers". Observations made by individuals can be useful, even necessary, in order to address climate change issues.

2.4 The "Shared Weather" Bias

Because different people perceive weather differently, each user will provide an observation error, a combination of randomness and a systematic error. From the example of Wikipedia (e.g. Jenkins), it is, however, evident that documentation on objective information can be created from a large number of individual contributions by the process of peer-viewing. Additionally, we can learn, even quantify, human biases by keeping records of users' own observations and habits (Elevant, 2009). Furthermore, individual biases may be measured by comparing human observations to the closest source of more reliable data (e.g. WMO). Mobile weather spotters guarantee some observation overlapping, enabling comparison between different observations. The key argument is though, that within the "shared weather community", enough data quantities can be collected to erase individual biases, and quantify user biases in order to make systematic corrections of incoming observations. Additionally, human senses and simple instruments can be combined, using low-cost instruments.

Even with a small number of observers, peer-viewing reduces the human bias, addressing issue (1) in section 2.2. The web 2.0 solution is of particular interest when regarding variables difficult to measure by instruments (e.g. cloudiness). Asking users to confirm or reject cloud pictures, peer-viewing may address present limitations due to measurement instruments (2). The mobility of weather spotters addresses limitations caused by physical environmental conditions for spatially fixed synoptic stations (3). The information possess a strong user perspective overriding the problem of different standards (5), and while defined by different individual's position, activities and perception, it is more easily customized to users with similar profiles. Most importantly, meso-scale phenomena (e.g. thunderstorms) (4), not easily detected by WMO stations and predicted by NWP, are detectable by human mobile observers.

3 THE "SHARE WEATHER" COMMUNITY

Inspired by the example from the contest on geological data (Tapscott and Williams, 2006), it can be argued that the users of "share weather" should be offered compensation for their efforts. Here suggested is that, for every volunteer contribution, a new weather forecast is generated. Earlier was concluded that motivation is related to personal life and interests. Thus it can be suggested that co-creation of weather information can be performed within a community of interest gathering people with interest in weather. It is evident from section 1.2 that the best observers are those already interested in weather, further supporting the argument that a community of interest can be established on these grounds.

3.1 The "Shareweather" Interface

In order to motivate participation, members of the "share weather community" should be able to make weather reports in different formats using different devises, depending on present needs and abilities. Weather reports can be created for chosen places (e.g. chosen on a map or using positioning systems), either instantly or several hours or days after observing.

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 1, subjective measurements are for example picking a suitable text from a drop-down menu, describing the type of clouds, change of cloudiness during the latest hours, the part of the sky to which the clouds are concentrated, wind direction and estimated speed, 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 traffic-related subjectively measured variables are for example traffic congestion and traffic flow. Variables that can be measured objectively are: wind, humidity, temperature, precipitation amount, travel time, snow depth.

Observations of the environment are represented by 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 "share weather" portal may also receive reports on observed species such as animals and insects.

One innovation integrated into the system, are pictures taken with a cellular phone (objective reports), representing an easy way of reporting and probably added value in terms of entertainment. An important rewarding mechanism is a local weather forecast provided to the user whenever pushing the "send report" button. The system is based on the

Figure 1: The "share weather" interface.

principle that the more information the user will send, the more – and more accurate – weather information will the user receive. Other functionalities motivating membership 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 Community of Interest

Earlier, illustrations of empirically accumulated knowledge on weather and environmental processes between the air, land and water, conserved by local habitants that are personally affected by weather, were provided (Stroosnijder, 2007 and Ångström, 1926). Other evidence support that the best weather observers (among travellers) are those who need weather information the most and that an initial need for accurate weather forecasts in daily life also encouraged sharing weather information (Elevant, 2009).

Fishermen, farmers and long-distance drivers – whose life and property are exposed to nature and its elements - are examples of motivated weather observers that could join and benefit from the "share weather" community of interest. As not only the motivation, but also *the ability,* to observe weather is due to training and awareness of weather, it can be suggested that other individuals can be "trained" in the same way as the farmer and the fisherman, if their attention was directed toward weather phenomena, possibly encouraged by participation in the "share weather" community.

However, beside the high-quality spatial information and personalized services, the "share weather" system may also provide motives such as contributing to the environment.

3.3 Environmental Practice of the "Shareweather" Community

Environmental politics and practice meet challenges like conflicts between environmental interests and interest of individuals, often regarded the roots of unsustainable development (Connelly and Smith, 2003). Despite motivation to act on climate change, many consider that they do not have information on what action they can take to mitigate climate change (e.g. Lowe et al., 2006).

Studies of so called "trust networks" (e.g. Cheshire and Cook, 2004), show that the social context and community responsibility norms can play an important role in trust-building. Studying what motivates wikipedians, (Nov, 2007) reached similar conclusions on ideological incitements, and not the least the importance of experience of fun. Most important, ideological incitements and willingness to participate for "the common good" were discovered.

Thus, assuming that attractive interface and functionality are present, and based upon the expert paradigm and the fact that weather can be observed by anybody anywhere, it is justifiable to assume that the "share weather" community of co-creating weather-enthusiasts, can grow and become a community of practice collecting important information on weather, environment and climate change.

4 CONCLUSIONS

From small weather observation networks enabled by the invention of the telegraph, we are now about to face a 21st century web weather 2.0 paradigm. A "share weather" system based on co-creation, collective intelligence and peer-viewing of users' own weather observations can be a community of practice offering high-resolution short-term weather forecasts, and contributing to detecting climate change.

The 20th century development of meteorological services led to sophisticated tools and methods for more accurate weather predictions (e.g. NWP). By contrast, the accuracy of measuring instruments has not changed and the number of weather observation stations is sparse compared to the resolution of available models. Future NWP's may integrate data from a number of sources, including the "share weather" system. Historical steps like introduction of satellite data as input to NWP's illustrate the immense potential of sensor networks. This paper suggests that meteorological data also may include human networks in cyberspace based on social media.

Local weather phenomena, in particular special requirements by different applications and customization and personalization of weather services for media consumers, are beyond reach of current weather observations and sensor networks. The ability of individuals to observe, understand, adapt to, even modify, their environment and habitat, is an unexplored societal resource and source of knowledge that can be shared. If systematically collected, user-generated weather information can be processed and integrated into a share weather system as presented here, offering a high-quality web service and attractive services to the members of the "shareweather" community – a community of interest in weather information. Most important, the shared weather information can contribute to significant progress within weather "nowcasting" raising the quality of weather information services and applications. Additionally, the share weather web service would generate values in its users' daily life, and practices valuable to the community as collecting information on climate and environmental change.

Local observations of the "shareweather" community can detect local phenomena and extremes, addressing the current problems with lack of spatial data coverage necessary to detect, understand and model the effects of climate change.

Time-demanding processes of collecting and verifying weather and climate data (e.g. IPCC synthesis reports), may be shortened by using web 2.0 tools to collect a large number of local observations, further analysed by experts. On the other hand, early weather warning services may be improved, as for such traditional public sector services "information typically travels serially and sequentially, from one processing unit to the next" (Horan and Schooley, 2007), while social media networks possess the flexibility to collect and distribute information fast, and additionally are trustworthy improving the odds that citizens will adopt to severe weather.

The rise of social networks provides not only an option for storage of expert opinions and distribution of knowledge, but enables co-creation of weather information by everybody, as: nobody can observe everything, but everybody can observe some(thing) of the weather.

REFERENCES

Ångström, A. 1926. *Praktisk Meteorologi En Inledning till Väderleksförutsägelsernas Teori och Praktik*, Natur och Kultur. Stockholm.

Burton, J., Fitzroy, R, 1986. The Early History of the Meteorological Office, *British Journal for the History of Science*, vol. 19, 147-76.

Changnon, S.A., Pielke, R.A., Changnon, D., Sylves, R., Pulwurty, R., 2000. Human Factors Explain the Increased Losses from Weather and Climate Extremes. *Bulletin of the American Meteorological Society,* vol. 81 (2000) 437-442.

Cheshire, C., Cook, K.S., 2004. The Emergence of Trust Networks under Uncertainty – Implications for Internet Interactions. *Analyse & Kritik*, Lucius & Lucius. Stuttgart.

Connelly, J., Smith, G., 2003. *Politics and the Environment from Theory to Practice*, Routledge, an imprint of Taylor & Francis Group. London 2nd edition.

Craft, E., 1998. The Value of Weather Information Services for Nineteenth-Century Great Lakes Shipping. *American Economic Review*, vol. 88, no. 5, 1059-1076.

Craft E., 1999. Private Weather Organizations and the Founding of the United States Weather Bureau. *Journal of Economic History*, vol. 59, no. 4, 1063-1071.

Davis, J.L., 1984. Weather Forecasting and the Development of Meteorological Theory at the Paris Observatory. *Annals of Science,* vol. 4, 359-82.

Elevant, K., 2009. Customization by Sharing Weather Information: A Study on Winter Road Weather Warnings. In proceedings of the *5th World Congress on Mass Customization and Personalization*. Aalto University. Helsinki.

Holton, J.R., 1992. *An Introduction to Dynamic Meteorology*, The International Geophysics Series vol. 48, Academic Press inc, San Diego California, United Kingdom edition published by Academic Press Limited. London, 3rd edition.

Horan, A., Schooley, B.L., 2007. Emergency Response Information Systems: Emerging Trends and Technologies. *Communications of the ACM*, Vol. 50, no. 3, 73-78.

Jenkins, H., 2006. *Convergence Culture: Where Old and New Media Collide,* New York University Press. New York.

Konvicka, T., 1999. *Teacher's Weather Sourcebook*, Teacher Ideas Press.

Levy, P., 1999. *Collective Intelligence: Mankind's Emerging World in Cyberspace*, Translated from French by R. Bononno, Plenum Trade. New York.

Lowe, T., Brown, K., Dessai, S., de França Doria, M., Haynes, K., Vincent, K., 2006. Does Tomorrow Ever Come? Disaster Narrative and Public Perceptions of Climate Change. *Public Understanding of Science*, Vol. 15, no. 4, 435-457.

Martinson, D.G., Battisti, D.S., Bradley, R., Cole, J., Fine, R., Ghil, M., Kushnir, Y., Manabe, S., McCartney, M., McCormick, P., Prather, M., Sarachik, E., Tans, P., Thompson, L., and Winton, M., 1998. Decade-to-Century-Scale Climate Variability and Climate Change: A science strategy, *National Research Council*. Washington D.C..

Milly, P. C. D., Wetherald, R. T., Dunne, K. A., Delworth, T. L., 2002. Increasing risk of great floods in a changing climate. *Nature,* vol. 415, p. 514-517 .

Moran, J.M., Hopkins, E.J., 2002. Disease, Shipwreks and Crops: Weather Observation Before the Technological Age. In *Wisconsin's Weather and Climate*, University of Wisconsin Press. Madison Wisconsin.

NOAA NCDC, 2009. *Billion Dollar U.S. Weather Disasters, 1980-2008*, National Climatic Data Centre Asheville, NC.

Nov, O., 2007. What motivates Wikipedians? *Communications of the ACM*, vol. 50, no. 11, 60-64.

Oliver, J.E., 2005. *Encyclopedia of World Climatology*, Springer.

Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J., and Hanson, C.E., 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the *Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press. Cambridge.

Peng, G., Leslie, L.M., Shao, Y., 2002. *Environmental Modelling and Prediction*, Springer Verlag Berlin Heidelberg. Germany.

Kent, E.C, and Berry, D.I., 2004. Quantifying random measurement errors in voluntary observing ships' meteorological observations. *Int. J. Climatol.* 25: 843 – 856.

Park, S.K., Xu, L., 1999. *Data Assimilation for Atmospheric, Oceanic and Hydrologic Applications*, Springer.

Robinson, M., Grant, S.J., Hudson, J.A., 2004. Measuring Rainfall to a Forest Canopy: an Assessment of the Performance of Canopy Level Rain Gauges. *Hydrology and Earth System Sciences*, vol. 8 no. 3 (2004) 327-333.

Schneider, S.L., and Laurion, S.K. (1993). Do we know what we've learned from listening to the news?. *Memory and Cognition*, 21, 198-209.

Stroosnijder, L., 2007. Chapter 9 Rainfall and Land Degradation, In: M.V.K. Sivakumar, N. Ndiang'ui (Eds.) *Climate and Land Degradation*, Springer Berlin Heidelberg. pp.167-195.

Svoboda, M.D., Hayes, M.J., Wilhite, D.A., Tadesse, T., 2002. *Recent Advances in Drought Monitoring*, National Drought Mitigation Center, University of Nebraska-Lincoln, Lincoln, Nebraska.

Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor, M., Miller, H.L., 2007. Climate Change 2007: The Physical Science Basis, Contribution of Working Group I to the *Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press. Cambridge.

Tapscott, D., and Williams, A.D., 2006. *Wikinomics*, Atlantic Books, An Imprint of Grove Atlantic Ltd. London.

Theophrastus (ca. 373-286 B.C.). *Book of Signs*.

Wallman, C-G., Möller, S., Blomqvist, G., Bergström, A., 2005. The Winter Model: Stage 1. *Swedish National Road and Transport Research Institute (VTI), 958*. Linköping.

Walsh, P., 1999. *That Withered Paradigm: The Web, the Expert, and the Information Hegemony*, available online: http://web.mit.edu/comm-forum/papers/walsh.html 2009 July 2009

World Meteorological Organization, 2006. *WMO at a glance*, WMO-No. 990, 2006. World Meteorological Organization.