WWOSC White Paper

## 5. Weather Related Hazards and Impacts

# Development of applications for the weather forecasting process to detect and forecast weather related hazards and their impacts

## 5.1 Introduction

- Envisioned system
  - "Seamless, Multi-hazard, Multi-scale Environmental Prediction"
  - Services convey uncertainty and impact
- Goal of white paper:
  - Identify key issues and status of advances
  - Identify Underpinning research and development
- Definition of "applications" and "weather forecasting process"
- 4 themes:
  - Service and Requirements
  - New Technologies (Monitoring, Modeling, External)
  - Applications, Processing and Techniques
  - Semi-automated Forecast System
- Role of forecaster will evolve with new applications and new services in both developed and developing countries
  - The semi-automated forecast system
  - What is fully automated (seasonal?, some nowcasts)
  - What is not automated but technology assisted?
  - Interpretation Services/Consultancy of automated products (Private-Public Sector???; contracting and relationship limitations)
- Drivers : Technology, Scientific Advances, Efficiency, Broader Reach (new services, requirements)

### 5.1.1. Requirements/Services

#### Requirements

- Key customers of NMHS (Public, Emergency managers, Aviation…); sophisticated vs non-sophisticated users (public, ???)
- Prediction system vision: multi-hazard (element=winds, rain, lightning, hail PLUS AQ, health, drought, waves, landslides, avalanche, ??? ), multi-scale (time=nowcasting to seasonal?, space=point,area); Environmental Prediction
- Services: Forecasts and Warnings, Other = temperature, humidity, etc
- Seamless – from WHI theme, what is the systems perspective, how to deliver to user, automated, semi-automated and manual services to external users
- NMHS are poised to deliver services and do dissemination; other hazards use NHMS to get message out
- Skill vs time scale
    - Skill vs Types of Decision Making
    - Spatial/temporal time scales of decision making
    - Decision Making Types/Paradigms/Scales – Prepare vs Take Action Now (function of ability to react – evacuate, go to basement)
    - e.g. Hurricanes (t=days/10's of hours) vs Tornadoes (t=10's of minutes) vs Downburst/Wind Shear(t=minutes/seconds))
- Nowcasting
    - time, space, wx element
    - focus on call to action (vs public nowcasting)
    - current nowcasting service is all about convective summer severe weather
    - future – non-severe weather elements (see Olympics, B08 – not good enough at 6 hours; see V10 – competition decisions)
    - probabilistic/ensemble -> how to develop application or use for decision-making
    - have we outgrown traditional definitions of nowcasting?
    - The hasty generalization: $$ = linear function of f(t of warning)???
- If you were the CEO, where are the growth areas
    - Everywhere, specific nowcasts for specific application for specific clients
    - Long range forecasts
    - NHMS vs Private Sector???; who collects the data, who produces the information, who produces the services
- Does this vision apply to all WMO Members: Services in Developing Countries
- Urban, Climate Change

#### Services

- What are the New Services?
- Impact statements, convey uncertainty
- What are the Delivery Mechanisms: push vs pull for what users.

- Rapidly Changing: now it is Twitter, Internet, Cell phones but what is next…
- Push – how to target non-severe nowcasts, subscribe, private sector doing this now; weather bug
- Push what? Data, Products, CAP etc
- Pull – pull what, data, raw NWP, products
- What about a "No requirements, no service model" – build it and they will come? Apple paradigm?

### Underpinning Issues and R & D

- Demonstration / R&D into mass dissemination efficacy from nhms/private sector
- Data availability/access policies, IP models (eg nwp, nowcast systems)
- Perhaps data is the only thing for nhms supplemented with partner/private data; what becomes of standards; network of networks focus
- Decision making and warnings research
- Cross-discipline R&D (traditional)
- Focus on applications, services and decision-making R&D

## 5.1.2. Observations/Technology

Modeling

- NWP progression, Ensembles
- Coupled models
- Data Assimilation / Grey Zone
- Issues of Parameterizations at various scales

Monitoring

- Integrated Observing System Concept
- Space vs Ground Base benefits – scale, coverage, bias and precision, resolution
- Traditional (T,Td,P, W) vs Surrogate data (quasi-traditional) Radiance, Tv, Radiometric Profiles, dBZ within the context of Data Assimilation
- Golden Age of Satellite??? Really? Hyper-spectral = redundant data for one product and what is that???
- Why have wind profilers not broadly adapted in many NMHS's
- Demonstration to Operations – Technology Transfer Process; standards; role of WMO
- Network of networks – focus on DQ and QC
- QC is a function of the application, scale
- The mantra: Low maintenance, low infrastructure and low cost (e.g. radar)
- Role of DA vs Interpretation

External Technologies

- Telecommunications
- Computing
- Open Data Access
- Can we predict this? How to adapt? Always catching up? How to build a nimble system?
- Do we enable only and don't worry about the delivery?

## Underpinning Issues and R & D

- NWP for nowcasting – what scale, how to cycle, reducing spin up
- Need for microphysics, parameterizations, PBL development, basic understanding for high resolution NWP
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- Development of innovative weather observation technology
    - Microwave link
    - QC = f(application)
- Reducing the cost of observations
- Applications in Data sparse regions (how to use understanding to overcome sparcity; accuracy and expectations)
- Networks and delivery of data
- Data IP issues
- Network Design
- Support models (regional, see Cuba)
- Technology Transfer/Adoption
- Coordination with DA/Research vs Operational data sets

## 5.1.3. Applications, Techniques and Tools

- What time scales are considered in the forecast system – nowcasting to ??? – seasonal???
- Application development along the whole forecasting process
    - Observation, Detection and Nowcasting of high impact weather of all scales
    - Post processing and combining of several Nowcasting- and ensemble based NWP
    - Forecasts and Probability estimation of hazards and impacts instead of model variables
    - Product development to meet customer requirements

- Nowcasting and Techniques at the transition from Nowcasting to NWP
        - Why Nowcasting needed?
        - Key customer requirement: accurate forecasts for T+0..T+60 min
        - Expensive response actions with appropriate response times between 15-45 min require accurate forecast of rapidly changing high impact weather

        - NWP is not able to provide high quality forecasts for rapidly changing weather phenomena with lead times between T+15.. 45min for many reasons
        - Remote sensing observations have been developed to detect severe weather with high temporal and spatial resolution to meet user requirements
        - Nowcasting techniques have been developed using observational data
        - Increasing application of NWP in Nowcasting nowadays due to higher temporal and spatial resolution and higher quality of NWP
    - Why transition from Nowcasting to NWP?
        - Key customer requirement: seamless prediction of HIW for T+0…72h
        - weather information as part of business processes of key customers need to be consistent and not differ between nowcasting and short range forecasting for both - meteorological content and data integration in business processes
    - Merge Nowcasting and NWP to ensure seamless prediction for time ranges T+0..72
        - Simple Blending techniques with defined weights as function of forecast time
        - MOS/ CellMOS using the "verifying information" of existing observations to define the limit until Nowcasting stand alone techniques have better skills than blending with NWP and to define the weights of the existing several models compared to Nowcasting – for locations where observations are available – valuable information is there
            - transition between observation – nowcasting – NWP using MOS
            - predictive information, from all sources is used as predictors and weighted according to its predictive quality calculated based on the training sample
            - statistical methods are a common and flexible methodology for correcting and combining forecasts from different sources (smart post processing)

        - Use of data assimilation techniques of ensemble prediction systems to identify those ensemble members closest to observation – using the verifying information of observations as well

- Techniques at the combining of different independent forecast sources
    - Increasing operational availability of different (ensemble) models (TIGGE)
    - Combining of forecasts from different sources to give a "best pdf" ensures that a consistency is applied to all downstream products
        - Bayesian Model Averaging (BMA) where the spread and relative weight is determined according to the quality of forecasts from each system based on a training sample – which can be short (update mode
        - Other techniques
        - continuously updated single database of optimal combined forecast data will remove the requirement of impact models handling multiple model sources on

different grids, ensemble sizes, diagnostics and data formats as well as the confusion as to which output should be chosen over all those available

- Applications to quantify the uncertainty as well as the probability of high impact weather (HIW)
    - Ensemble based NWP is essential to the forecasting process, because of their ability to quantify the uncertainty in the meteorological situation as well as the probability of HIW. On the other hand the availability of forecast scenarios enable the uncertainty in the forecast to be propagated through to downstream modelling of the impacts.
- Semi-automated guidance in the forecast process
    - Why semi-automated guidance needed to improve forecast quality?
        - Huge amount of high density remote sensing observations allow further progress in nowcasting and numerical weather prediction and enable NMHS to provide products and to monitor the weather in high detail.
        - Nowcasting and NWP provide an huge and further increasing amount of data (observations, nowcasting, different deterministic models, different ensemble prediction systems). This all can't be handled by human subjectively without semi-automated guidance
        - forecaster or costumer are not able to combine all information in the best verifying way for the increasing requirements of users – semi-autoamted guidances can help  but have to be monitored by forecasters as experts

    - … foecasters still needed in the loop: Even with forecast skill continually improving accurate prediction of high impact weather will pose substantial challenges for the foreseeable future.
        - Automated system designs are always created with respect to a context of design assumptions, task goals, and boundary conditions. Forecasters/ Experts are needed in the process at the boundaries of the operating context for which the machine was designed, maintaining adequate performance may become a challenge.
        - Operational nowcasting information cannot represent the development of HIW
        - operational model resolution cannot represent the hazard (e.g. hailstorms, topographic funnelling),
        - intrinsic uncertainty can be substantial, *particularly* for high impact weather (e.g. due to elevated dynamic/convective instabilities),
        - Extraneous factors influence net impact (e.g. elevated rush hour vulnerability). So although we can move towards semi-automation, human judgement will still be needed, and the forecaster will thus retain an essential role
        - customers need explanations and help for interpretation

    - How to develop semi-automated guidance
        - Combine high quality observations and NWP using model output statistics (MOS)  and he advantage of the verifying information of observational data for long training periods

        - other semi-automated guidance
    - Human centered user interfaces to enable forecasters to use semi-automated guidance properly - analysis of cognitive tasks and workflows of the forecaster rather than "designer centered design" or "developer centered development"

    - Further Challenges for the development of semi-automated guidance
        - Need not fewer but more humans with expertise in new kinds of jobs
        - Need new contents for trainings on the job
        - Bring together developer and forecaster during the development

- Applications to forecasts hazards and impacts
    - Customers need information about the impacts to their business processes

### Underpinning Issues and R & D

- Improvements of Detection and Nowcasting algorithms using leading edge observational data
- Techniques at the transition from Nowcasting to NWP
- Combination of different ensemble based NWP systems to a single optimal forecast database
- Development of probability based forecast products
- Combining different NWP models in a way which maintains the consistency and co-variances between gridded meteorological diagnostics.
- Post-processing of different ensemble based NWP systems which improve model skill where calibrating observations are sparse.
- Forecasts of hazards and impacts
- Future of statistical interpretation methods
- Probability thresholds and cost lost estimations for decision making processes
- Handling of complex data in the weather warning process for decision making

## 5.1.4. Envisioned Semi-Automated Forecast System – Foundation, Design

- What is the forecast process for semi-automated predictions?
    - For impact type services, does the forecast system run impact prediction models as guidance for the semi-automated system or does it rely on a collaborative relationship with sophisticated users to issue them?

- What are the system requirements and system design to match the process?
- What are the core human-centred design issues? Are there things that can be automated but should not be automated because it would be “stupid” to do so because it would prevent good decision making to be done.
- Are there things that can be automated but should not be automated because it would be “stupid” to do so because it would prevent good decision making to be done
- Established semi-automated guidance with probabilistic information for all forecasts and warnings covering all ranges
- Deterministic warnings only until the deterministic limit (Hewson 2006)
- Improved development of applications based on remote sensing and nowcasting data as well as combinations of several ensemble based NWP systems
- Different systems at the globe depending on the observational networks and NWP available

## Underpinning Issues and R & D

- How do we better define model climate tails? More model realisations *and* statistics?
- Underpinning work to develop higher resolution re-analyses
- Expansion of feature-based products (to include new features) and of their uptake
- Amalgamation of numerical model output with societal application models
- Definition of map-based “deterministic limit” products for different weather types