Nowcasting seen from a global perspective: WMO Nowcasting Symposium 2016

Jeanette Onvlee
(based on input from many presenters at the Symposium)
EWGLAM meeting, Rome, 03/10/2016

Contents

WMO/WWRP Nowcasting Symposium, 25-29 July, Hong Kong:

https://wsn16.hk/schedule/symposium

- ✓ **Nowcasting of high impact weather**
- ✓ **Nowcasting for aviation: the AvRDP**
- ✓ **New observations for nowcasting**
- ✓ **Very high resolution modelling and urban forecasting**
- ✓ **Nowcasting capacity building**

Nowcasting of high impact weather

Brian Golding:

“Many advances have been made in the past few years:

In observations: many new types of (ground-based and satellite) observations/products, better (dual-pol) radar precipitation accuracy

In nowcasting methods and modelling: convection-permitting models enabled dramatic improvement in local forecast skill; higher resolution improves forecasts in areas of significant topography, advances in model physics and surface modelling

In forecast content: seamless merging of extrapolation nowcasts with convection-permitting (V)SR NWP (ensembles), from weather thresholds to impact predictions and risk forecasting

In communicating: mobile phones, smart phones with much more image processing capability, social media reinforcing warnings and crowd sourcing/big data techniques.”

Nowcasting of high impact weather

Looking forward

- New technologies
- Better forecasts
- A more vulnerable society
- More hazardous weather
- The Sendai Framework for Disaster Reduction

Future trends…

… and the most important one to remember!!!

Communication: the last mile!

- Future social media?
- Sensors on smartphones?
- Wearables?
- Intelligent materials?
- Internet of Things?
- Full integration of online and phone ?
- Continuous streaming while mobile?
- How to communicate risk?
- Maintaining communication in a disaster

The changing needs of aviation

Industry needs and expectations

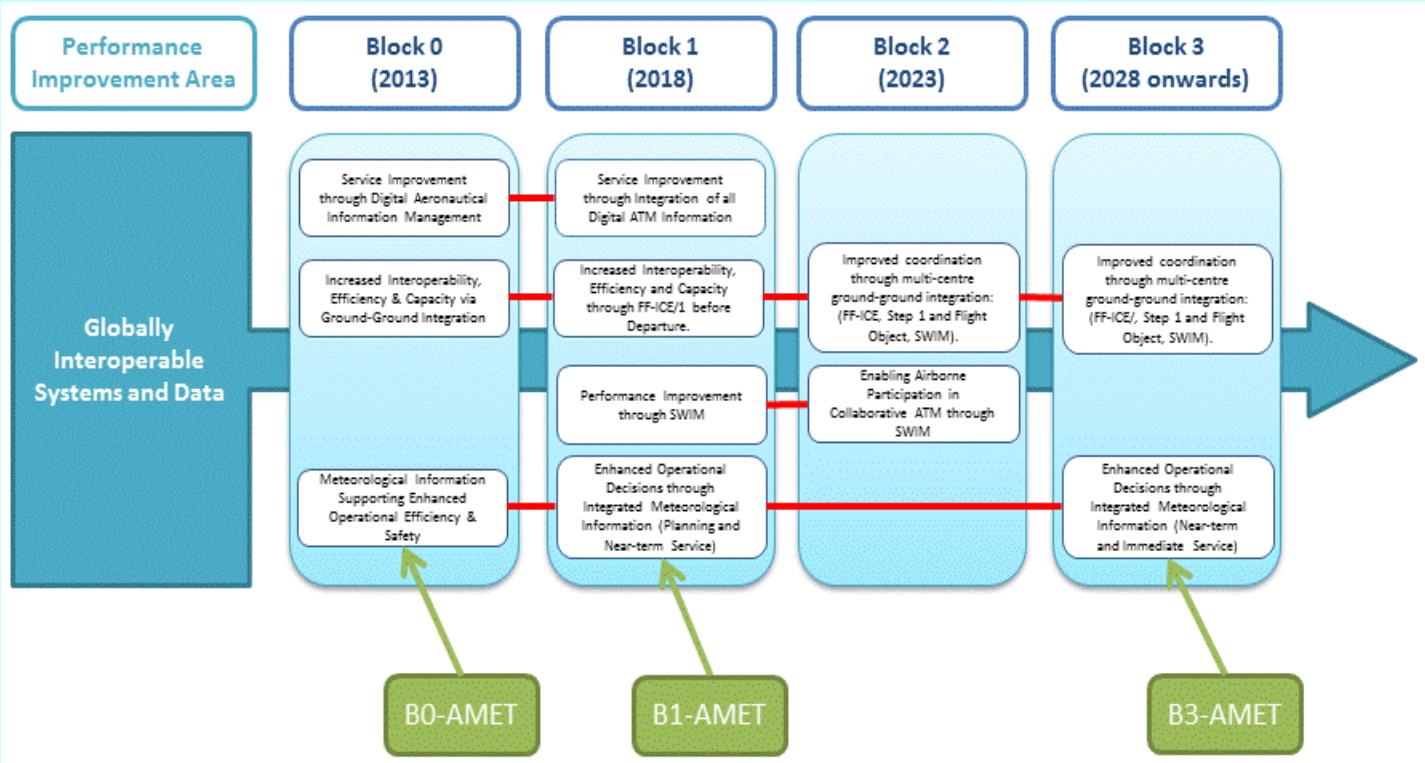
- **Need to provide information fit to support user's decisions**
- **Seamless services, global harmonization**
- **Efficiency**

Changes planned for met info for aviation: Aviation System Block Upgrades

- **ASBUs – a systems engineering modernization strategy – a series of modules across 4 performance improvement areas and 4 time blocks**

National Projects:

- *SESAR – Europe*
- *NextGen – USA*
- *CARATS – Japan*
- *SIRIUS – Brazil*
- *China*
- *Canada*
- *Etc.*



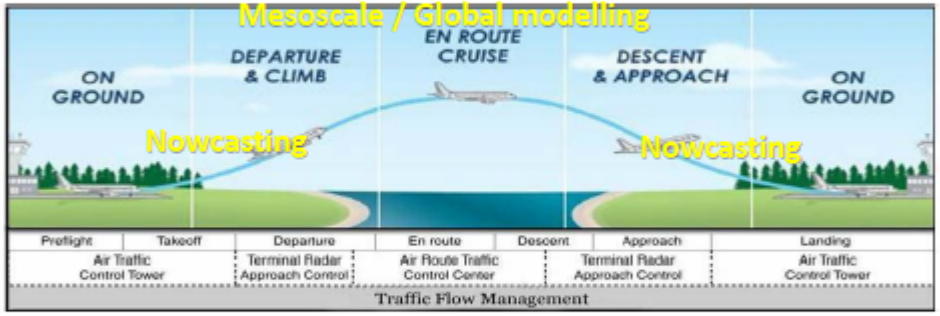
Near-term services

Immediate services (< 20 min)

Nowcasting for aviation: Key concepts from the ASBU

Trajectory-Based Operation (TBO)

Transition from nowcasting scale -> mesoscale -> global scale -> mesoscale -> nowcasting scale



Terminal Control Area: Location specific

En Route Phase: Mainly supported by global/regional Multi-model Aviation Weather Forecast Centre (AWFC)

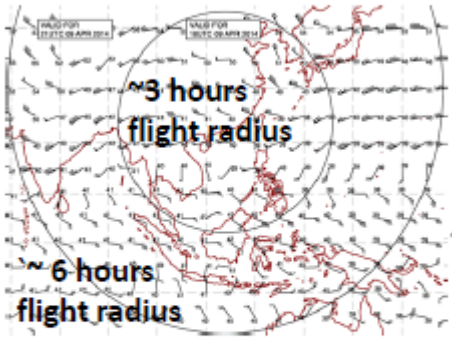
Terminal Control Area: Location specific

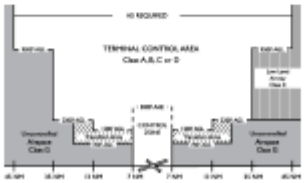
MET-ATM integration

- System-Wide Information Management (SWIM)
- "Product" centric → "Data" centric (Big Data concept)
- Collaborative, knowledge-based, decision making
- Impact-based and probabilistic
- Regional/global service delivery

This really is about nowcasting and uncertainties…

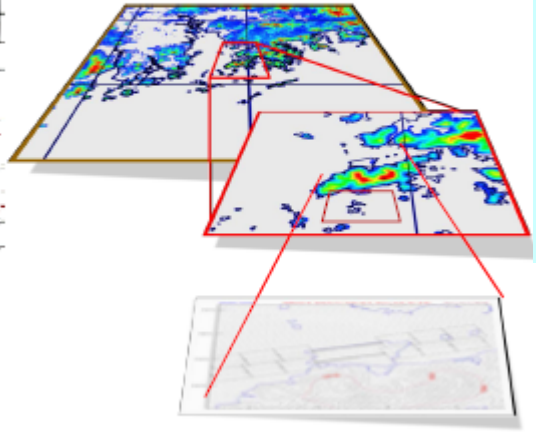
The closer to the Terminal Control Area / Aerodrome, the finer weather information required





This is the area needs 0-6 hr nowcast

Meteorological Service for the Terminal Area (MSTA)

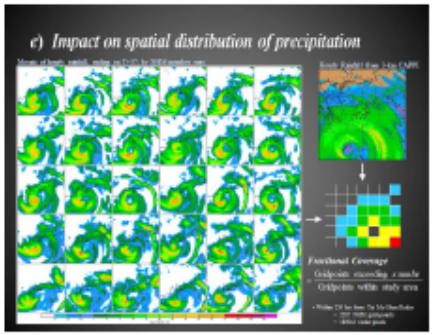


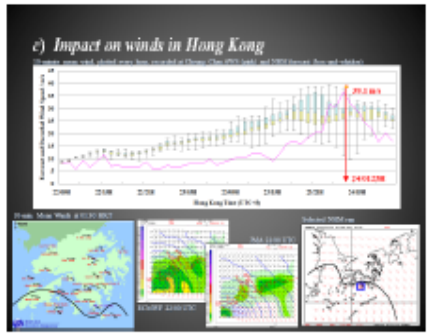
Spatial resolution Δx from 10's km to sub-km
Temporal resolution Δt from hours to minutes
Update frequency from hours to minutes

Uncertainty (confidence) of MET information

Under ASBU, not only the meteorological information's spatial and temporal resolution and accuracy performance need to be enhanced, but also the uncertainties information would need to be provided for ATM risk assessment.

Or, Hon and Wong (2013)





Ensemble NWP and Nowcast

Key: translation to impact and decision making

Translate MET information into ATM Impact. What Impact?

- Airport Capacity in network operation
- Airspace Capacity
- Arrival/Departure Delay
- Fuel consumption
- Aircraft de-icing, runway clearance, engine icing in freezing fog
- Lightning strike affecting ground ops..

Weather impact analysis

austro CONTROL

KPAs / KPIs

- Key Performance Areas considered
  - Capacity
  - Environmental Impact / Flight efficiency
  - Cost-effectiveness
  - Traffic complexity

    As proxy for Safety (safety can not be measured with perfect simulations)
- Each KPA is represented by one or more Key Performance Indicators, which should meet following criteria:
  - Specific
  - Measurable
  - Drive the desired behaviour
  - Accountable/manageable
  - Compatible with ICAO guidelines
  - **Proper with regard to weather forecasts**

According to EUROCONTROL 2011 technical note: Measuring Operational ANS performance at Airports

But… many stakeholders with different interests, and difference space/time scales!

Space/time Domain	Network Manager	Flow Management	ACC	APCH	TWR	Ground
0-30 min 100 -150 Miles	-	*	*	**	***	**
30-90 min 300 miles	*	**	***	***	**	*
1,5 -4 hrs 500-1500miles	***	***	**	*	*	-
4 – 9hrs 2000M	***	**	**	*	*	-
9-30hrs	**	*	*	*	*	-
1-7days	**	*	*	-	-	-

The need for better nowcasting for aviation

Weather impact analysis
Challenges

- KPIs contradictory, e.g.:
  - trade-off between maximizing capacity and optimizing workload
  - trade-off between optimizing workload and minimizing flight delays
  - etc…
- Different stakeholders (ANSP, airlines, airports,…) associate different priorities to KPAs/KPIs
  - e.g. ATM workload is not airlines' first priority
- In order to quantify the impact on the overall air traffic management system:
  - The various KPAs/KPIs need to be combined
  - That requires appropriate normalization and weighting considering all stakeholders' requirements
- A detailed analysis on this topic was done in an Eurocontrol commissioned research study

(Bert De Reyck, B., Degraeve, Z. and Grushka-Cokayne, Y., 2006: Decision Support Using Performance Driven Trade-Off Analysis. *EEC Note: EEC/SEE/2006/001*)

Developing useful KPI's and forecast value analyses obviously requires very close cooperation between MET and ATM!

Weather impact analysis
Forecast value

- Following a similar approach to using contingency table and cost matrix

		Observed: Yes	Observed: No
Forecasted	Yes	*hit*	*false alarm*
	No	*missed*	*Correct negative*
		o = h + m	1 - o

		Observed: Yes	Observed: No
Take action	Yes	$C + L - L_r$	C
	No	L	0

(e.g.: Richardson, D. S., 2000: Skill and relative economic value of the ECMWF ensemble prediction system. *Q.J.R. Meteorol. Soc.*, **126**, pp. 649-667.)

- A contingency table and a KPI matrix can be used to assess the forecast value

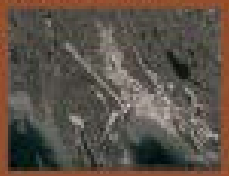
		Observed: Yes	Observed: No
Forecasted	Yes	*hit*	*false alarm*
	No	*missed*	*Correct negative*
		o = h + m	1 - o

		Observed: Yes	Observed: No
Take action	Yes	KPI_h	KPI_f
	No	KPI_m	KPI_n

The AvRDP project: a testing ground where MET and ATM can meet

AvRDP:

- Develop better nowcasting info/tools
- Translate to, and assess, impact of this improved information on KPI's
- All of this in close cooperation with ATM
- For a selected number of airports covering different conditions
- First development phase, then demonstration phase

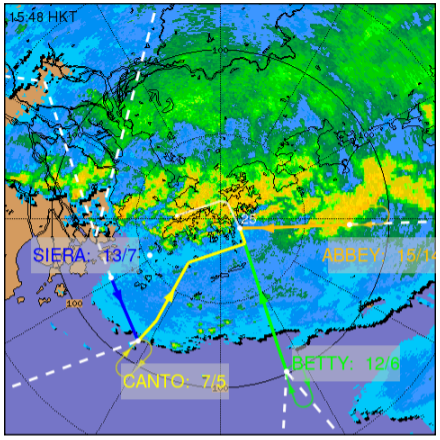
AvRDP Airport	Climatological regime	Weather elements to be studied in AvRDP
Charles de Gaulle Airport (CDG) 	Mid-latitude in Northern Hemisphere Location: Inland	Winter weather - snowfall, Icing, low temperature Fog
Hong Kong International Airport (HKG) 	Subtropical in Northern Hemisphere Location: Surrounded by water Next to high mountain	Convection and Thunderstorm Low visibility and ceiling
O.R. Tambo International Airport (Johannesburg Airport) (JNB) 	Subtropical in Southern Hemisphere Location: Inland	Convection Fog
Shanghai Hongqiao Airport (SHA) 	Subtropical/mid-latitude in Northern Hemisphere Location: Inland not far away from River Estuary and East China Sea	Convective weather
Toronto Pearson International Airport (YYZ) and Iqaluit Airport (YFB)  	Mid-latitude in Northern Hemisphere Location: Inland but not far away from Lake High-latitude in Northern Hemisphere Location: On Frobisher Bay	Winter weather – snowfall, Icing, precipitation type and amount, visibility, wind speed, direction shear, and gust, turbulence, and low ceilings Convective Weather Artic weather – Winds, blowing snow, fog, visibility, ceiling

Example product for HKO airport: Real-time airport air traffic data

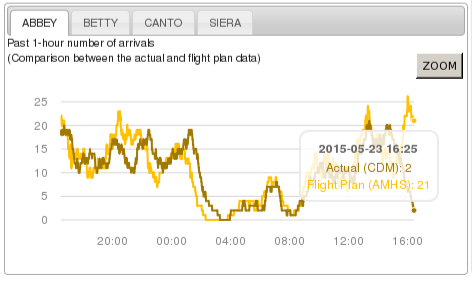
香港天文台 Hong Kong Observatory

MET-ATM Integrated Monitoring [Trial]

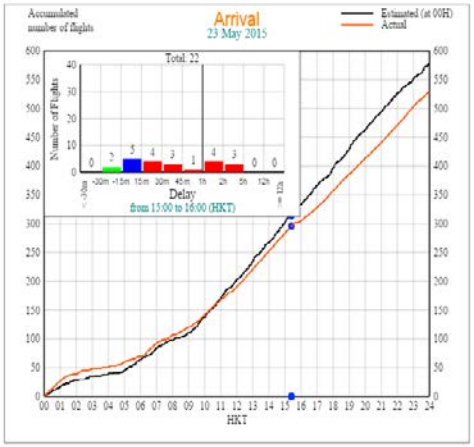
Distribution of flights arriving in the next hour (approx.)

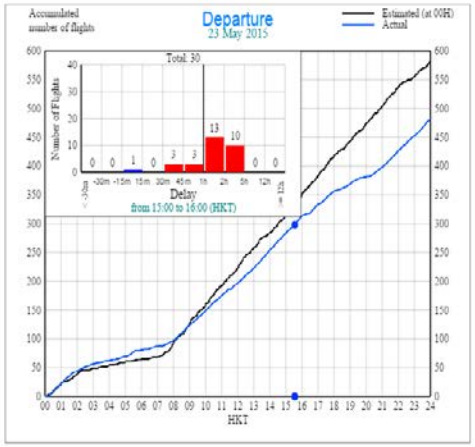


NW Route (SIERA)			SW Route (CANTO)			S Route (BETTY)			E Route (ABBEY)		
ELDT	RWY	STAR	ELDT	RWY	STAR	ELDT	RWY	STAR	ELDT	RWY	STAR
0841	25	6B	0827	25	2B	0839	25	2B	0829	25	2B
0847	25	6B	0837	25	2B	0847	25	2B	0833	25	2B
0849	25	6B	0839	25	2B	0848	25	2B	0832	25	2B
0841	25	6B	0841	25	2B	0849	25	2B	0833	25	2B
0846	25	6B	0853		2B	0853		2B	0843	25	2B
0848	25	6B	0903		2B	0854		2B	0842	25	2B
0848	25	6B	0910		2B	0857		2B	0833	25	2B

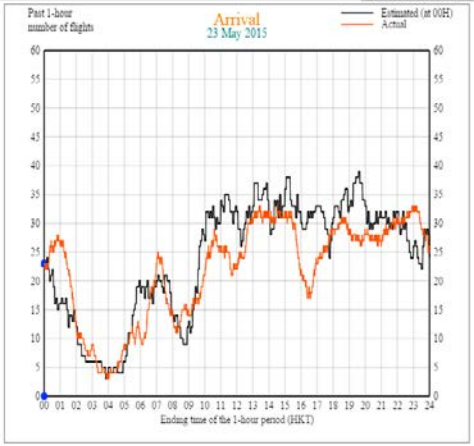


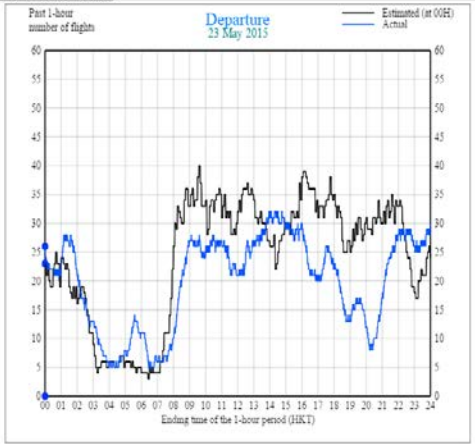
4-in-1 | One-year Statistics





Switch to Number of Flights in Past 30 Minutes





Capacity Forecast (for Arrivals)

Last update:	2015-05-23 05:16
VALID:	230800 to 231600 UTC
CAPACITY LEVEL:	1
AIRPORT ACCEPTANCE RATE:	29 flights per hour
EXPECTED DELAY:	Up to 15 mins
REASON:	-
REMARK:	Trough of low pressure continues to affect the northern boundary of Hong Kong FIR and holding fixes ABBEY and FISHA. Holding may be in excess of 30 minutes due to traffic backlog.

Traffic Interruption Related Messages from ATIS

Last Update: 08:07 UTC

HONG KONG ARRIVAL INFORMATION

A-TIME	0805
A-RUNWAY	25R
A-INFO-D2	RWY SFC WET
A-SUPPL1	
A-SUPPL2	
D-WXCHG	SFC WIND AND VIS CHANGING RAPIDLY DUE TS

HONG KONG DEPARTURE INFORMATION

D-TIME	0806
D-RUNWAY	25L
D-SUPPL1	RWY SFC WET EXP 1 HR DELAY
D-SUPPL2	
D-WXCHG	SFC WIND AND VIS CHANGING RAPIDLY DUE TS

Traffic Interruption Related Messages from NOTAM

Last Update: 16:30 HKT

VALID FROM: 2015-05-23 07:30 UTC
VALID TO: 2015-05-23 16:00 UTC
(ISSUED AT: 23 07:10 UTC)

A0407/15 NOTAMN
Q)VHHK/QXXXX/IV/NBO/E/000/999/2010N11430E268
A)VHHK B)1505230730 C)1505231600
E)10 MIN FLOW CONTROL OVER DOSUT, IKELA AND SIKOU FOR TRAFFIC LANDING
HKIA DUE TO TRAFFIC CONGESTION AND WEATHER WITHIN

Flow Restriction (from ATC Watch Manager)

Last Update: 2015-05-20 19:34

[Re: Traffic via BEKOL expect delay]

To whom it may concern,

Please cancel my message sent below at 13:25 on

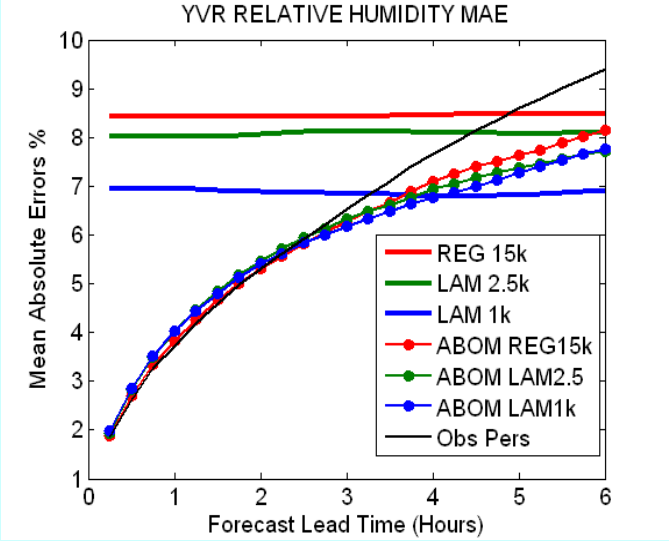
Nowcasting and VSR NWP

How well do VSR NWP models operate in the nowcasting range? Opinions and expectations differ:

Brian Golding: Models will soon dominate >1hr. For <1hr, focus on process-based nowcasts

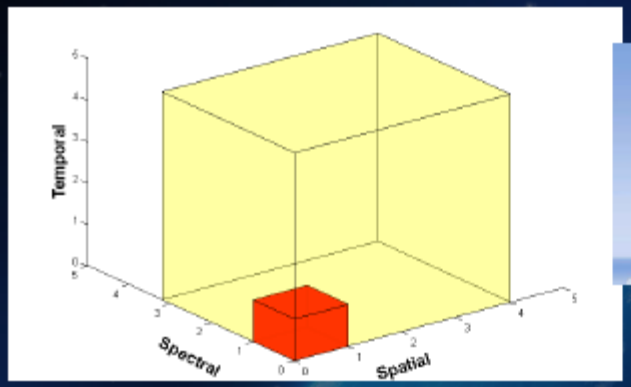
Rita Roberts: Nowcasting methods (observations-based and/or blending) are still consistently better than NWP in 0-2h range

George Isaac: still big errors in important NWP parameters, like RH. Modelling community should concentrate more on this. Persistence is really hard to beat by NWP!



New observations: satellite

GOES-R Advanced Baseline Imager (ABI)



5X Faster coverage (5-minute full disk vs. 25-minute)

4X Improved spatial resolution (2 km IR vs. 4 km) (0.5 km for a VIS vs. 1 km)

3X More spectral bands (16 on ABI vs. 5 on the current imager)

4

"The greatest advantage to the 1-minute imagery is in detecting deep, moist convective initiation, with 15-30 minutes of lead-time advantage compared to current GOES."

Challenges and Opportunities for Nowcasting with the New Generation Geo Satellities

Decision Aids

- Cloud and Moisture Imagery (cloud top features, overshooting tops, synthetic imagery, RGBs, environment)
- Super Rapid Scan Imaging
- Fused Products (satellite, radar, lightning, in-situ, NWP)
- Probabilistic High Impact Hazards (tornado, hail, wind, flood, lightning, fire, volash, fog, aircraft turbulence and icing)

Data Assimilation

- Radiances, T,q profiles
- High density AMVs
- Total Lightning
- Storm Scale NWP- WoF

Courtesy: Steve Goodman, NOAA

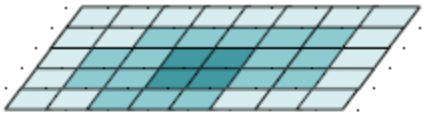
New satellite products

NWC SAF GEO package v2016:

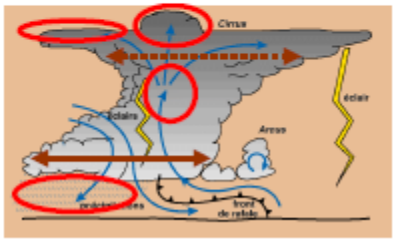
- New products:
  - ✓ CMIC: cloud phase, cloud water path, effective radius, optical depth
  - ✓ ASII-NG: automatic satellite interpretation new generation
  - ✓ EXIM: extrapolation of SEVIRI imagery or NWCSAF products up to a lead time of 1 hour
  - ✓ CI: convection initiation
- Adaptation of HRW to GOES-N satellites (included validation)
- New output format: NetCDF

Courtesy: Pilar Ripodas, Xavier Calbet, Jean-Marc Moisselin

- **CI**=Convection Initiation
  - Pixel-based product
  - First delivery NWCSAF v2016

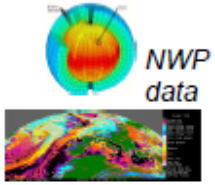


- **RDT**=Rapidly Developing Thunderstorm
  - Object-mode product
  - Actual delivery: v2013
  - Next delivery: v2016



RDT: data fusion for description of convection

Input Data: Multisource



NWP data

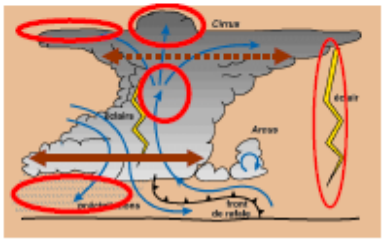
Other NWCSAF products

GEO data (5 IR channels + VIS)

RDT

Lightning Data

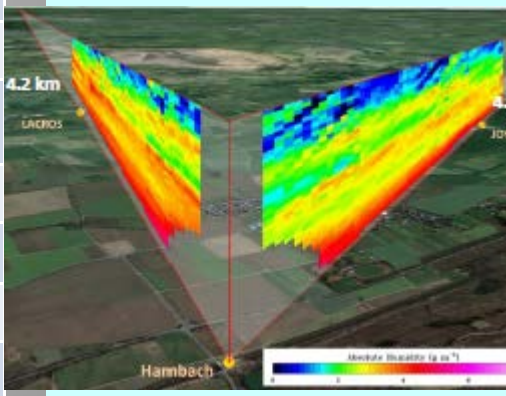
Output: Multilevel Description Of Convection



- *Main description of cell: Yes/No convection diagnosis, cell-development phase, position, surface, T, gap to tropopause, cloud type and phase, cloud top pressure. Severity Index high IWC hazard. Displacement Relevant trends are calculated*
- *Overshooting Tops, Lightning Activity, Convective Index, Rainfall Activity*

Requirements for Earth System Research and Predictions in Comparison to Ground-based Lidar Performance

Parameter	Monitoring	Verification	Data assimilation	Process studies	Lidar
Vert. res. in ABL, m					
Surface layer	10 – 30	10 – 30	10 – 30	10	2
Mixed layer	100 – 300	100 – 300	100 – 300	10 – 100	50
Interfacial layer	10 - 100	100	100	10 – 100	50
Lower free trop.	300 - 500	300 - 500	300 – 500	100	100
Time resolution, min	< 60	< 15	5 – 15	1/60 - 1	< 1/6 in ABL
WV noise error , %	< 10	< 5	< 10 + error covariance matrix	< 10	< 5 + error covariance
WV bias, %	2 – 5	2 – 5	< 5	< 10	2 – 5
T noise error , K	1	1	1	0.5	1 + err. cov.
T bias , K	0.2 – 0.5	0.2 – 0.5	0.2 – 0.5	0.2 – 0.5	0.2 – 0.5
Latency , min	---	---	1 for nowcasting, 1 to 60 for short-range	---	Immediately including errors
Hor. res. of network	Down to meso-γ-scale	Meso-γ-scale	Meso-γ-scale	Turbulent to meso-γ-scale	Tbd
Coverage	All climate regions				Yes



Only active thermodynamic profiling provides the vertical resolution and accuracy to explore „Terra Incognita“.

These profiles are fundamental for advanced predictions of convection initiation and convective systems.

Advanced network design and sensor synergies should contain WV and T lidar systems, which will significantly improve NWP from nowcasting up to the short range.

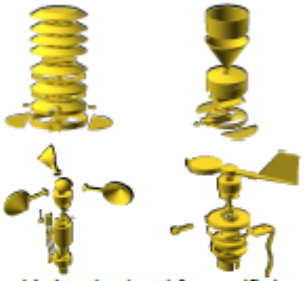
Courtesy: Volker Wulfmeyer

Overcoming the lack of observations…

Overcoming the lack of surface network observations

Using 3-D Printed Automatic Weather Stations (3D-PAWS)

- Inexpensive
- Built with local materials
- Easily replaceable (if stolen or broken)
- Compares well with reference sensors

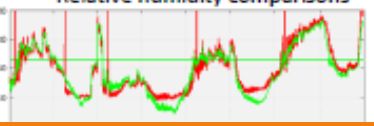


Computer Aided Design (CAD) for specific instruments

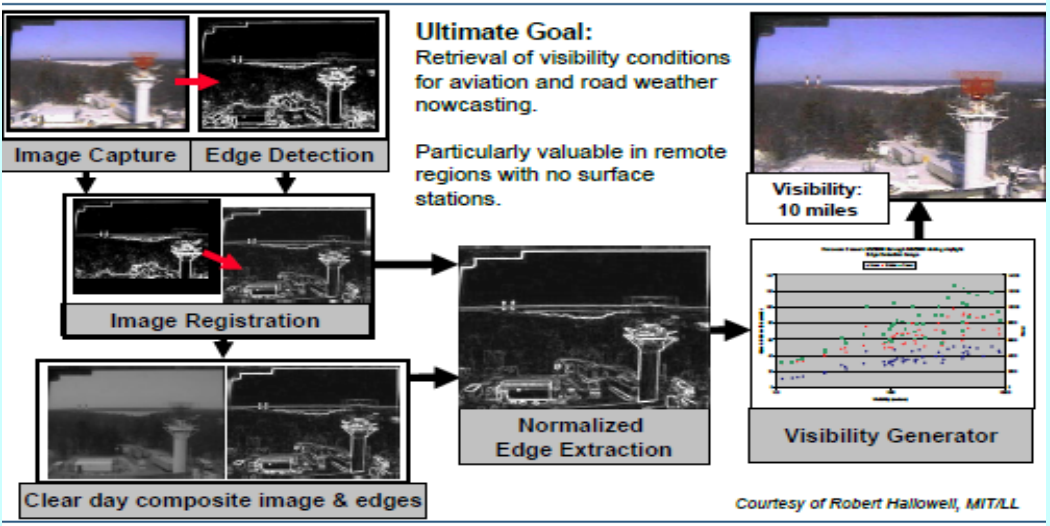
Ultimate Goal:

-obs for forecasters
-obs for initializing regional forecast models
- obs for verification of forecasts

Relative humidity comparisons



Using Web-Based Camera Imagery



Ultimate Goal:
Retrieval of visibility conditions for aviation and road weather nowcasting.

Particularly valuable in remote regions with no surface stations.

Courtesy of Robert Hallowell, MIT/LL

Courtesy: Rita Roberts

Many locations in the world have limited or no soundings collected daily

- UAVs can be used to obtain thermodynamic profiles in the CBL.
- Are inexpensive compared to radiometers
- Basic atmospheric sensors are available or can be built

Ultimate Goal:

-hourly collections of data in remote regions
-use for initializing regional forecast models
- collect data over complex terrain
- for fire weather prediction
- obs in pre-storm environments

Question

Can Real-Time Pressure Observations from Hundreds of Millions or Billions of Smartphones Improve Nowcasting and Short-term Prediction?

Courtesy: Chris Mass

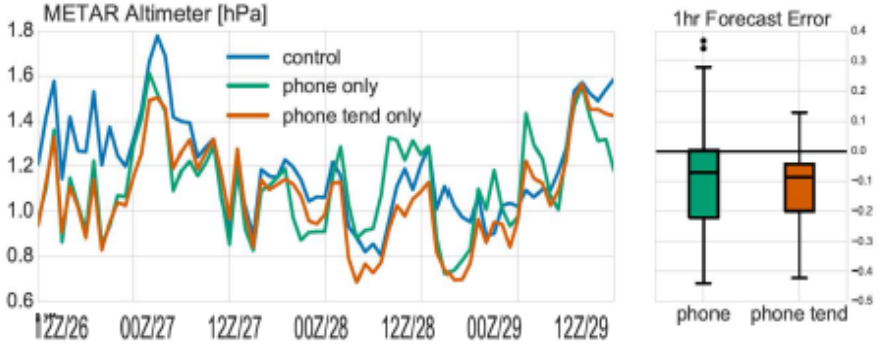
Where would smartphone pressures have the biggest impact?

- Countries with poor observational density but where they are a lot of smartphones
- Locations where there is insufficient mesoscale data for initialization
- For mesoscale phenomena sensitive to mesoscale initial conditions
- Mesoscale features that have persistent structures (e.g., dry lines)

Smartphone Pressure Sensors

- Absolute accuracy ~+- 2 hPa
- Relative accuracy ~+- .1 hPa
- **Thus, quite good for pressure change.**
- Smartphones also have GPS and cell tower location services (good to within 10s of meters)
- Also accelerometers, light sensors, and internal temperature sensors

Improved Pressure Forecasts Verified with Unassimilated Observations



Smartphone pressures assimilated in a 1-h cycled EnKF system using WRF

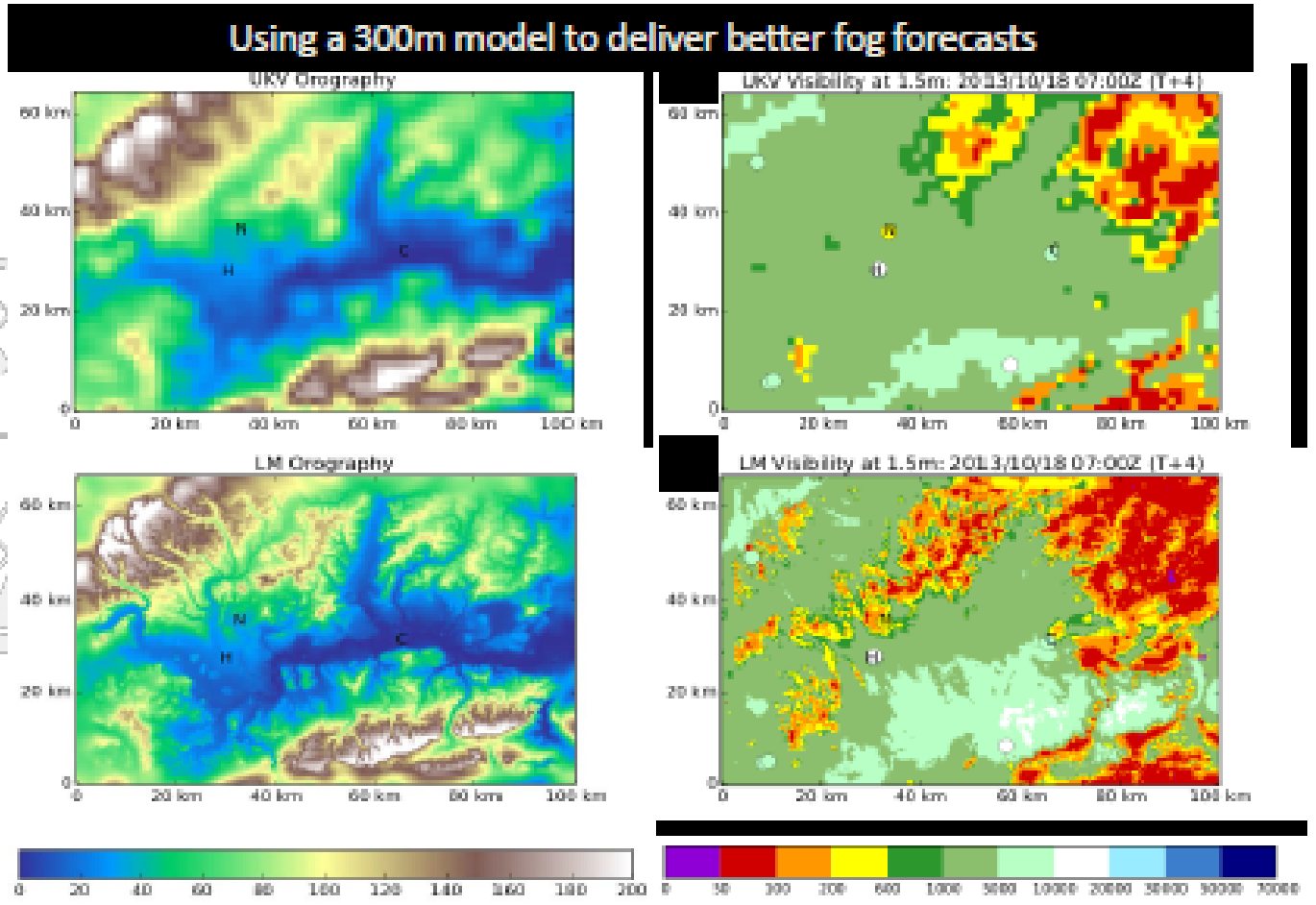
Very high resolution modelling (urban, aviation): Some examples

HIWeather

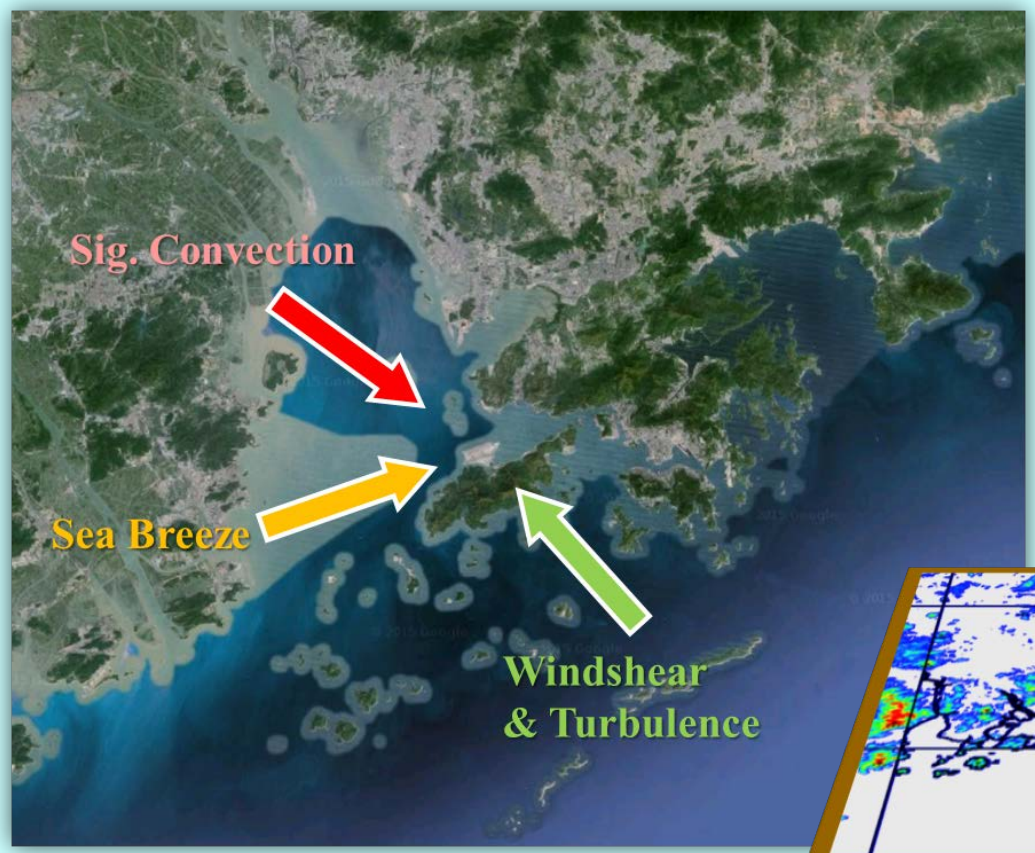
WWRP

WMO
OMM

Local impacts and the benefits of very high resolution modelling



Fine-scale Aviation Model (AVM) for HKIA



Aviation-impact Weather around HKIA

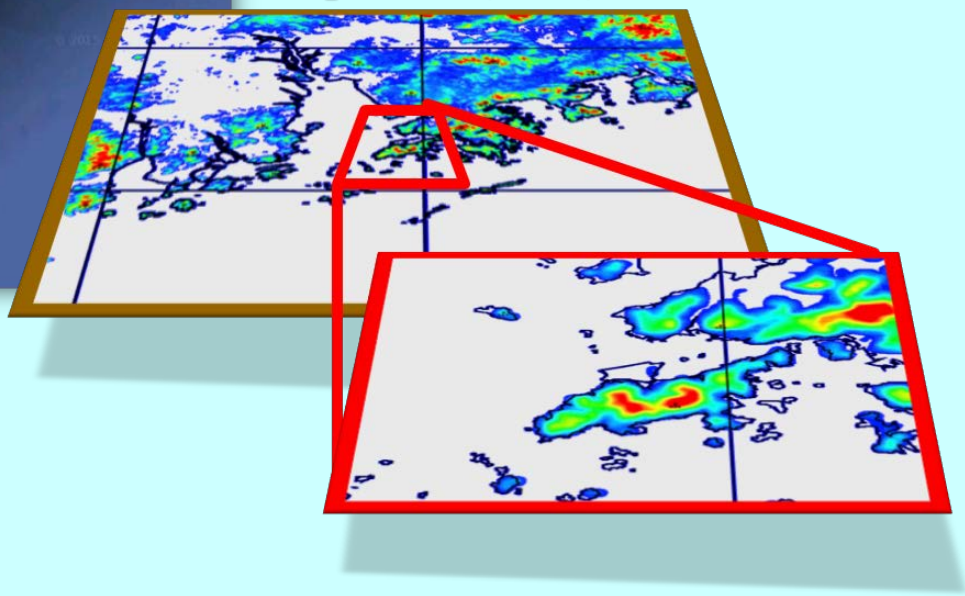
Sub-*km* implementation of WRF-ARW v3.4.1

Pearl River Delta (PRD): Δx = 600 *m*

Hong Kong Int'l Airport (HKA): Δx = 200 *m*

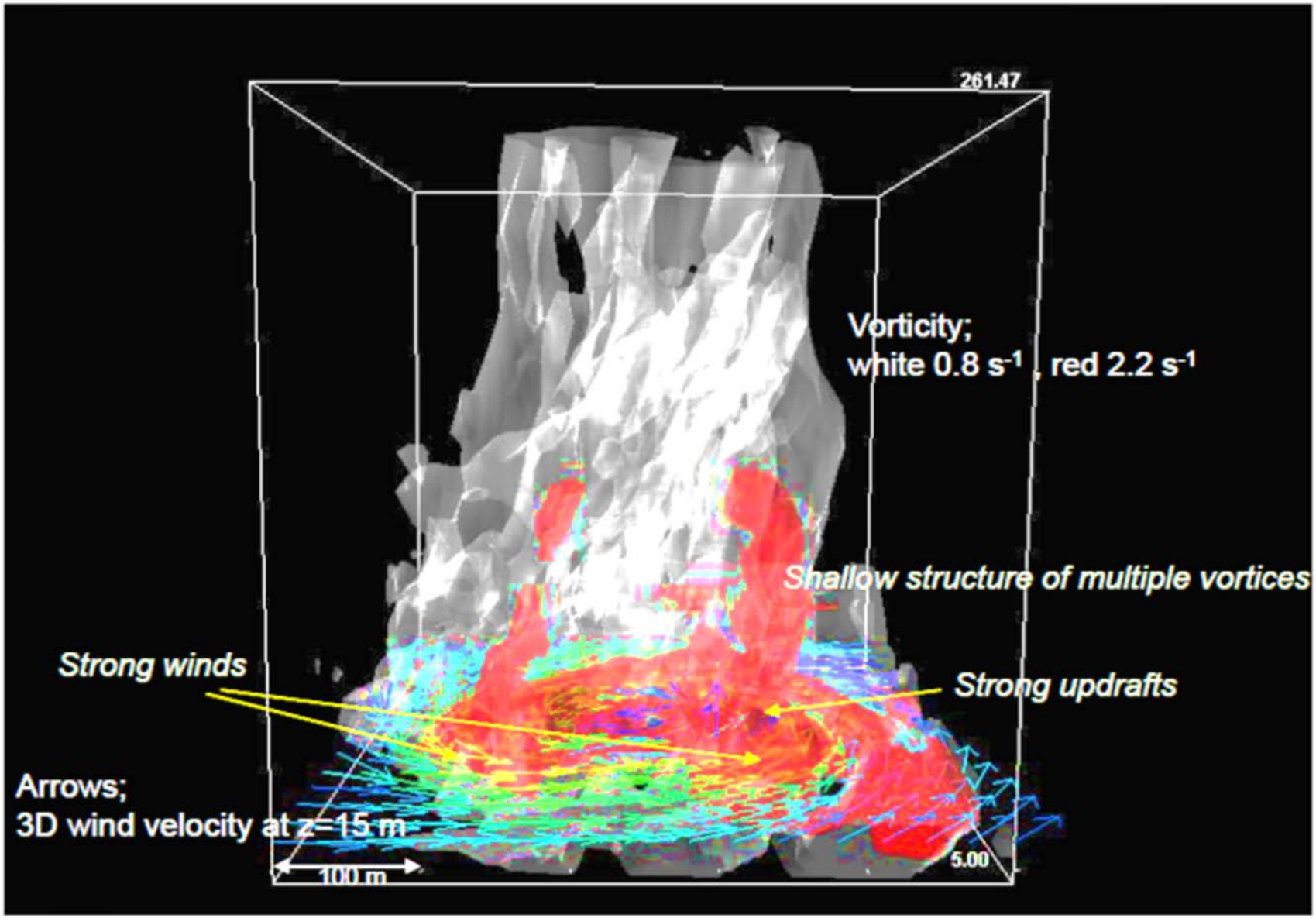
Hourly-updated forecasts

Up to T+(7 – 9)



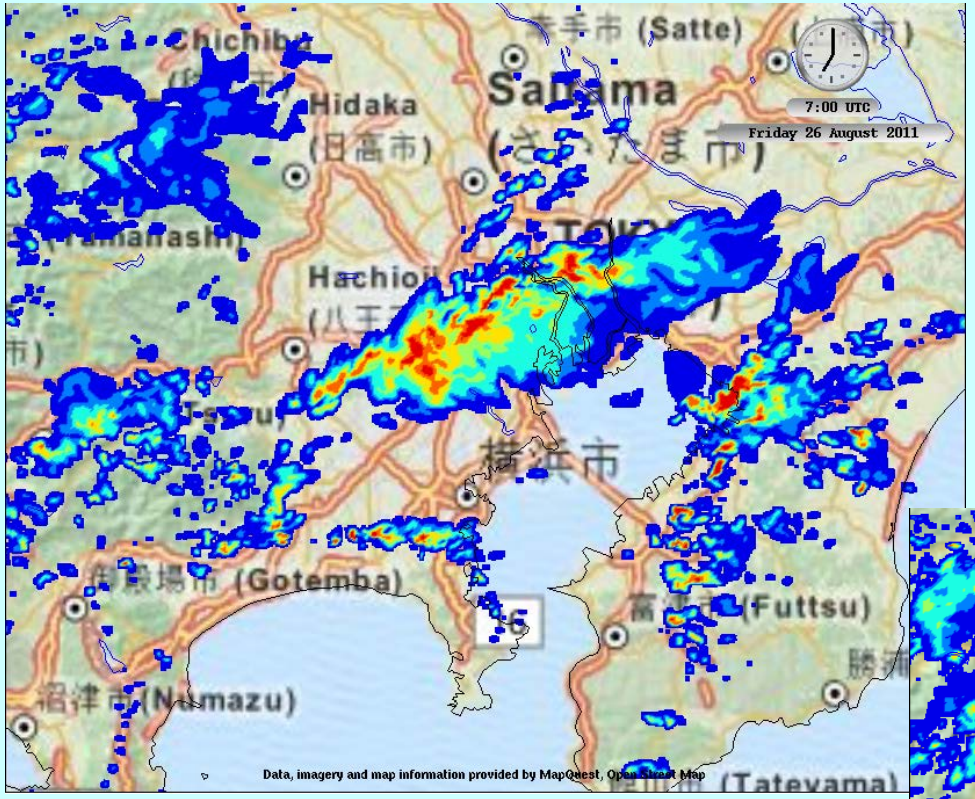
Outer domain: 350kmx350km
Inner domain: 60kmx60km
Courtesy: Peter Li (HKO)

Downscale Experiments with Δx=10m



Courtesy: Kazuo Saito

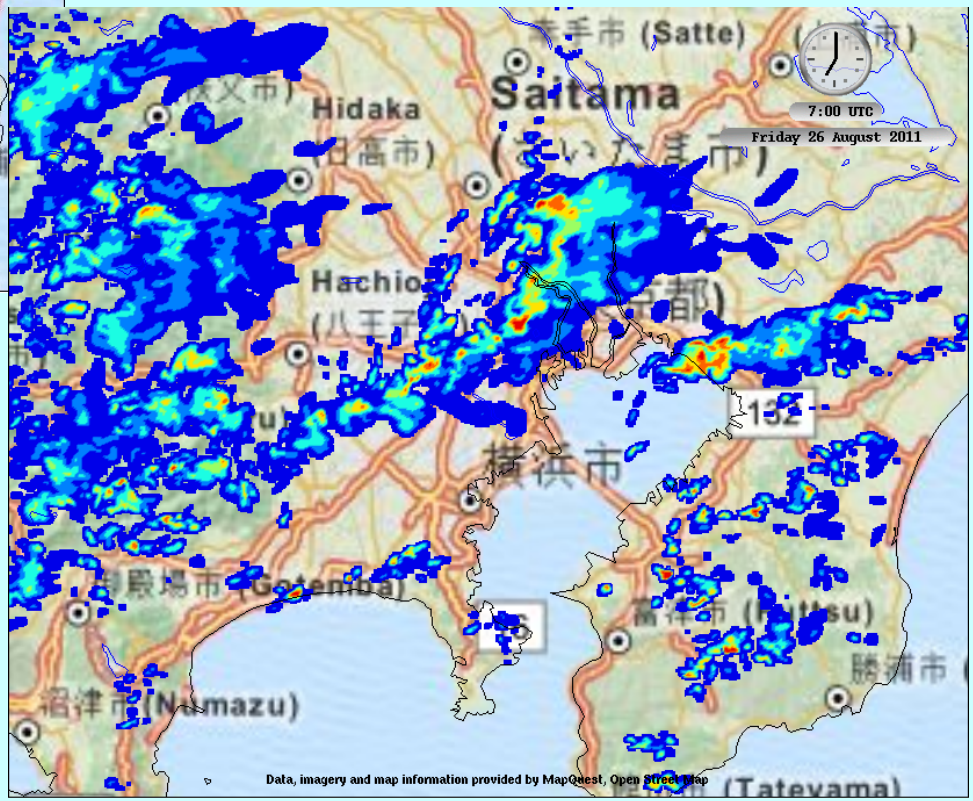
Impact of Urbanization (Tokyo metropolitan area)



EC's GEM 500 m simulation by Bélair et al. (2015)

CONTROL RUN – with URBAN

Without URBAN (no TEB)



19-h Forecast
Valid at 1600 JST
26 Aug. 2011

Toronto integrated urban weather / environmental system

Environment Canada

Operations

Research

Venue Warnings

Air Quality

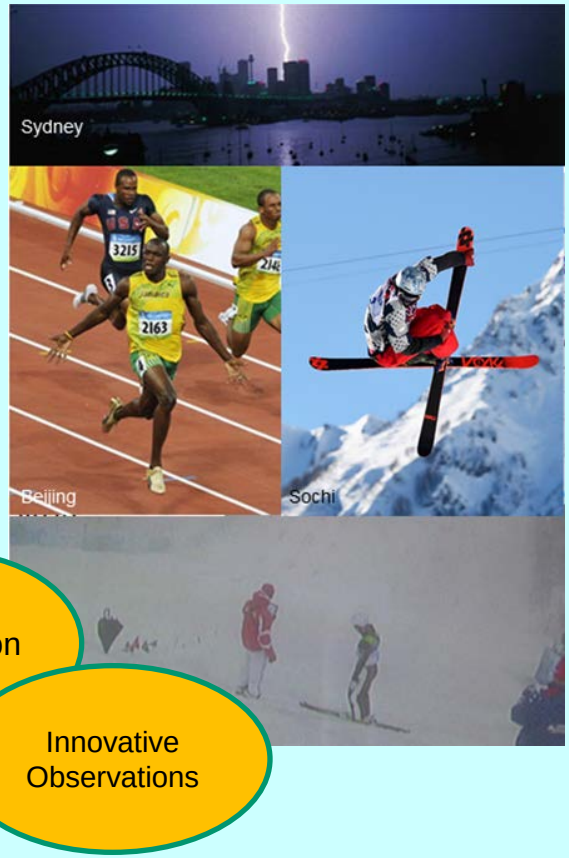
Enhanced Weather Monitoring

Treasury Board Sub

Multi-Faceted Showcase

Hi-Resolution Model

Innovative Observations



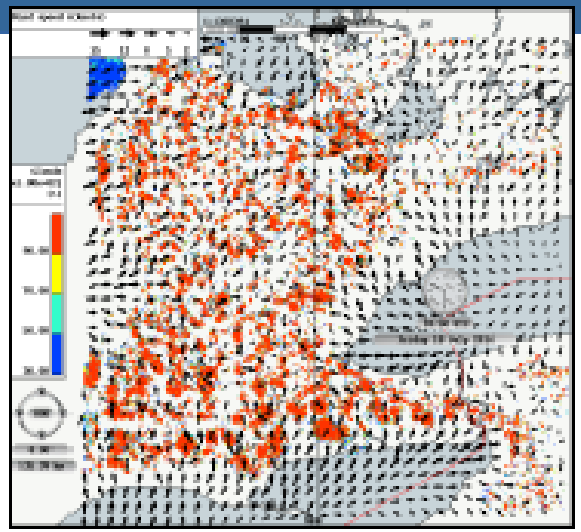
Operations + Science Synergies

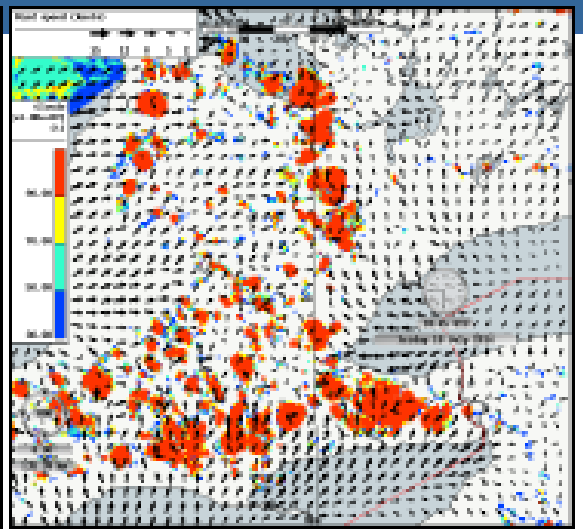
Courtesy: Paul Joe/Stephane Belair

Urban modelling: Toronto area

CLOUD COVER STRUCTURE

250 m





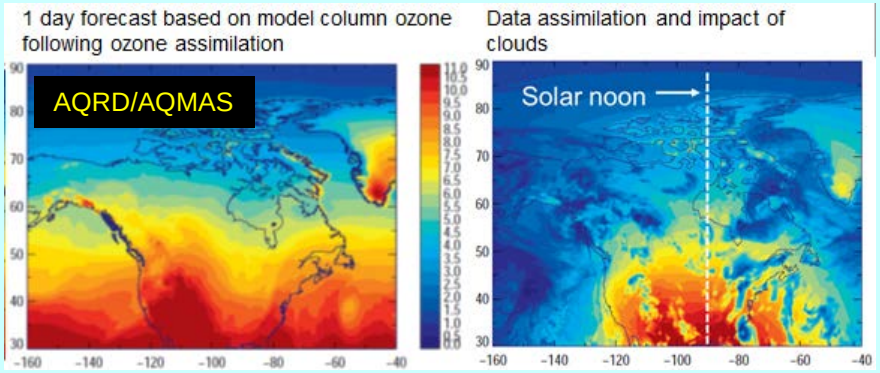
1 km

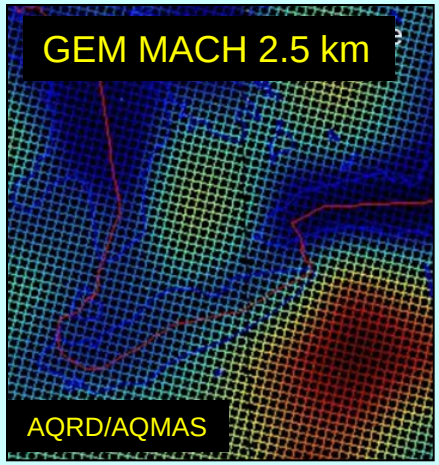
MODIS
Aqua
250 m

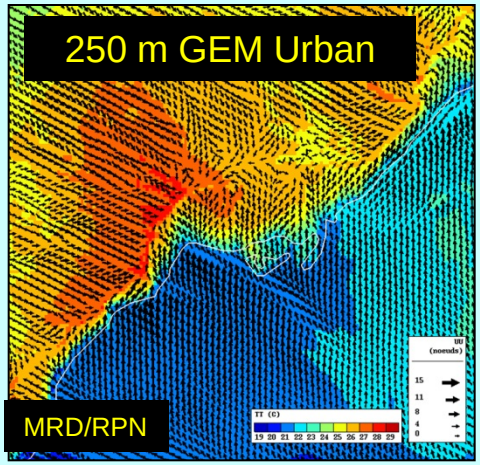
Lake Breeze Fronts From MET-Objects analyses (19:00 UTC)

AURORA
Sills et al 2011

Environmental Prediction Applications







Validate:

2.5 km Air Quality Model

UV Index Model

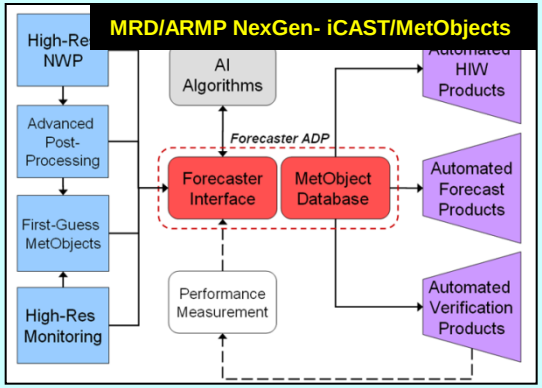
250 m Urban Model

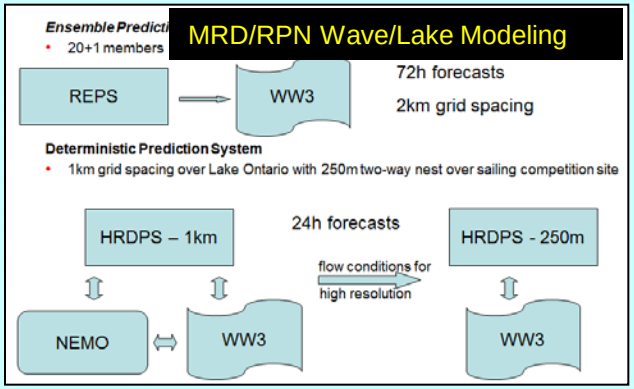
Wave/Lake Model

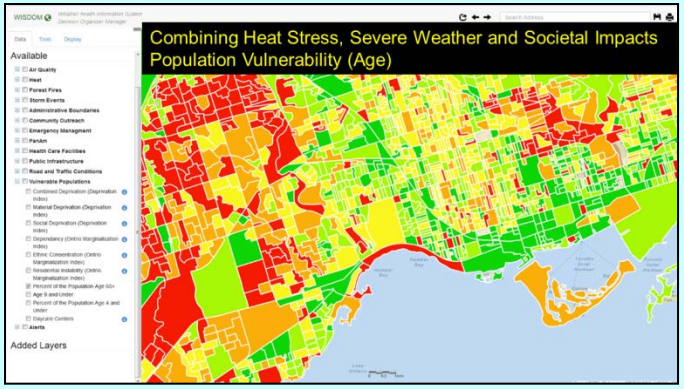
Other

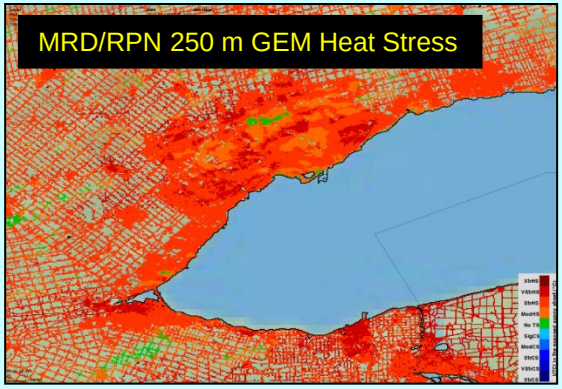
Weather and Health Services

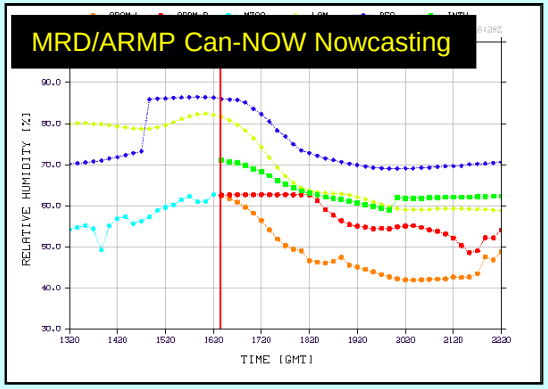
Aviation Nowcasting





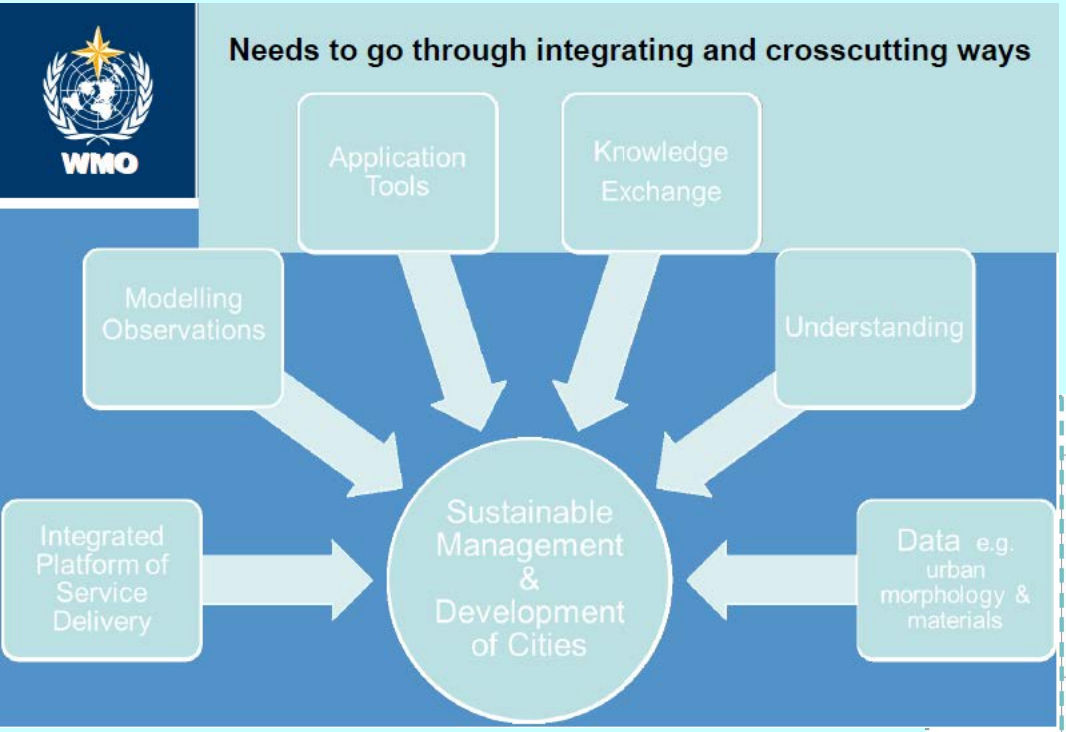


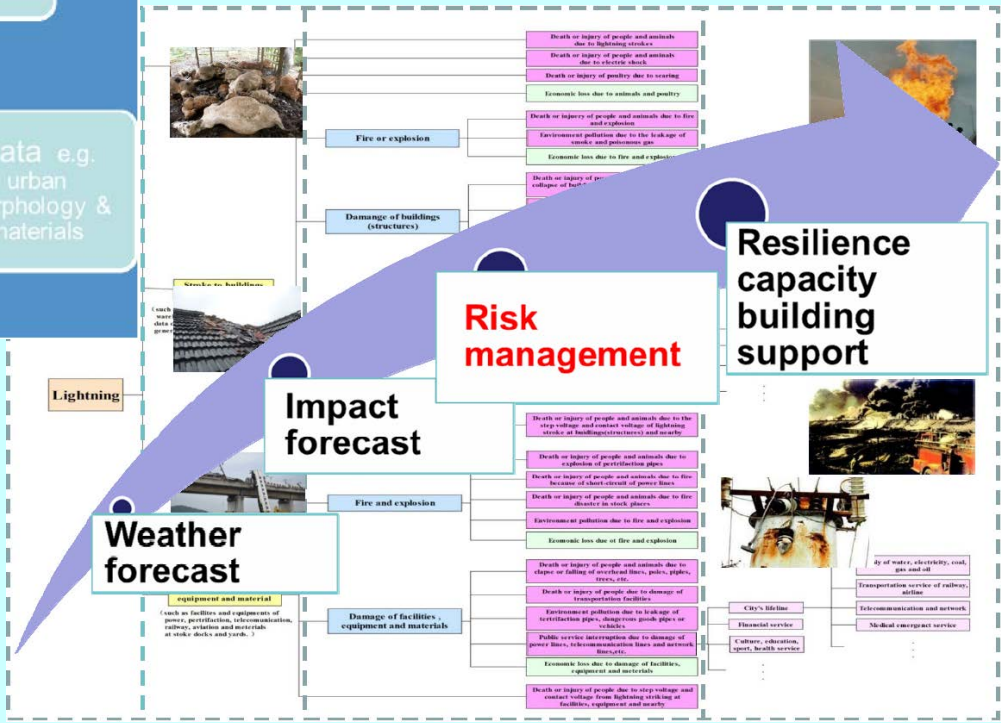




Courtesy: Paul Joe/Stephane Belair

Integrated Service Delivery on Weather and Climate including Supporting Research for Megacity and in Urban Areas, WMO Priority Area (2016-2019) as a response action to UN New Urban Agenda





- **Cg-17 Resolution 9.8: Establishing WMO Cross-cutting Urban Focus**
- **WMO GAW APP, GURME SAGs, IGIS**
- **Guide for Urban Integrated Services**
- **Input to HABITAT-III conference**

Courtesy: Alexander Baklanov

Capacity building for nowcasting

Kofi Annan
former UN Secretary-General (21 July 2016)

- "We need to *support weather and climate services in developing countries* so that rather just collecting and providing data, they can become *trusted suppliers of information and knowledge to the public.*
- We need to place greater emphasis on providing people with the timely information they need to protect themselves from extreme weather.
- Early warnings of hazards can not only help communities respond and adapt.. but also raise awareness of the causes and effects of climate change — and hence *build public support for policies that strengthen resilience and mitigate against the impact of climate change.*
- I am confident that the growing awareness of the links between health and climate change will encourage health professionals, UN and government agencies, policy makers and the scientific community to come together to tackle these problems."

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Capacity Building Workshop

20 Jul (Wed)	21 Jul (Thu)	22 Jul (Fri)
Aviation Research Demonstration Project	Probabilistic Nowcast Meososcale modelling	Satellite-based nowcast
Radar-based nowcasting techniques	Seamless Nowcast & SESAR	Breakout discussions
Aviation Mesoscale Numerical Weather Predication	Low Visibility Nowcast	Nowcasting System: Community-SWIRLS (hands-on training)
Aviation Nowcasting System CAN-NOW	Winter Weather Nowcast	

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Training Workshop on
NOWCASTING TECHNIQUES

Training Workshop on NOwcasting TEchniques: T-NOTE