Nowcasting Overview

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Environment and Climate Change Canada (retired)
Nowcasting and Mesoscale Research (WMO/WWRP)

CPAM Sao Paolo 20 Aug 2024

Outline

- Background
- Warning Value Chain
- Science of Summer Nowcasting
- Science of Winter Nowcasting complex terrain
- Systems
- Challenges

T-NOTE workshop
Celeste Saulo, S-G of WMO

My Perspective

- Research Scientist with Environment and Climate Change Canada
  - Cloud Physics -> Weather Radar -> Applications
- Research and Operations
  - Weather Radar Network (Science Support)
  - Radar Data Processing (Forecaster Workstation, Algorithms)
- Summer and Winter Nowcasting
- International perspective
  - Nowcasting Mesoscale Research Working Group
  - Forecast Demonstration and Research Development Projects

Nowcasting is ….

Nowcasting is defined as the detailed description of the current state of the atmosphere and the prediction of changes on a timescale of a few hours (0-2 hours) by any method (Browning 1982, Conway, COST-78). Mesoscale forecasts are high resolution predictions for up to 48 hours. The very short-range forecasting (VSRF) is less than 6 hours (Schmid et al. 2019, AMS 2023a).

Operational Nowcasts

- 0 to 2 (6?) hours
- high accuracy, precision, specific critical
- Operationally = convective severe weather
- Watches/Advisories/Special Statements
  - Potential of Severe Weather
  - Environment
- Warnings
  - Severe weather is imminent
  - Spotter reports, Observations

Broad Area (200-500's km)
6+ hours
Synoptic to Mesoscale

Small Area / ~50 km
Very Short Lead Times (minutes)
< Thunderstorm scale (40km to 100 m for tornadoes)

Watches are based on the synoptic environment.

Ingredients: temperature, moisture, wind profiles

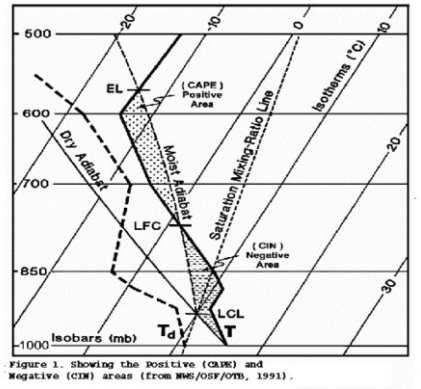
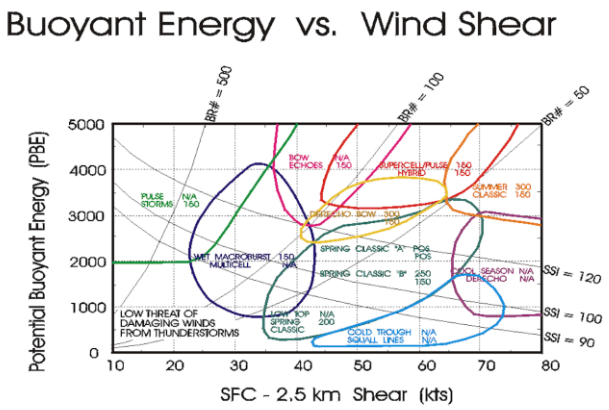
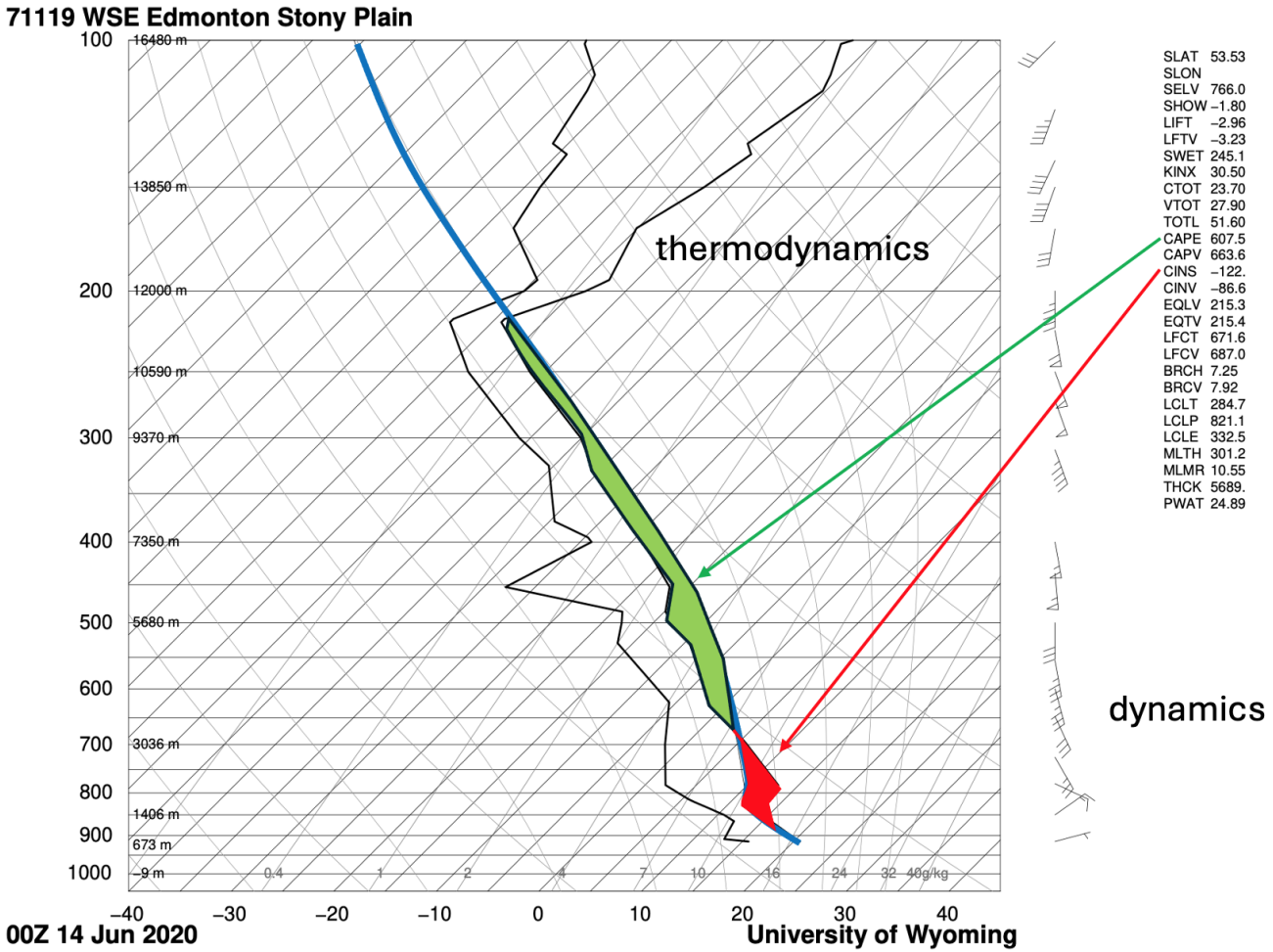


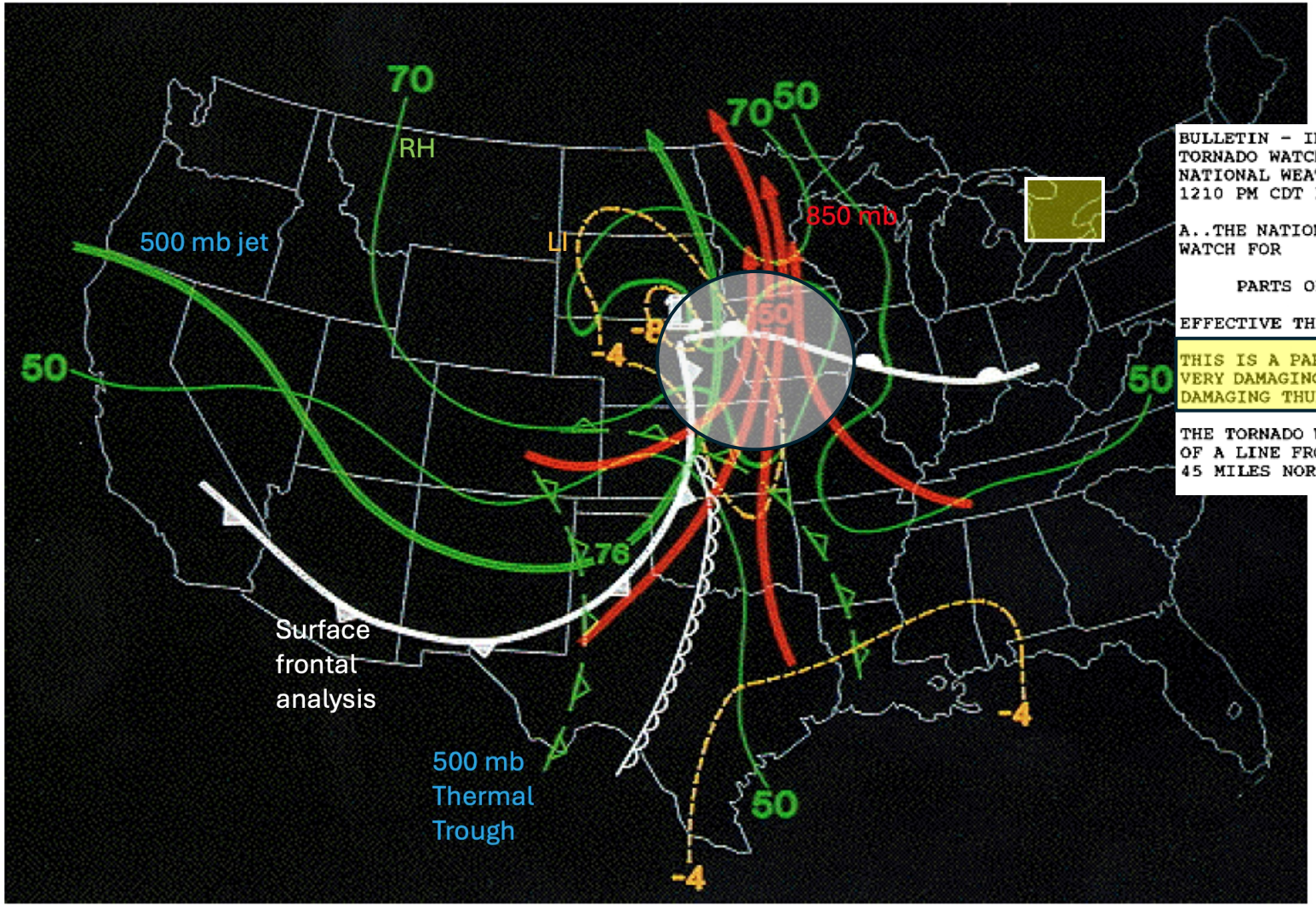
Figure 1. Showing the Positive (CAPE) and Negative (CIN) areas (from NWS/OSF/OTB, 1991).





Composite Analysis

Narrow the area, look for 4th ingredient, synoptic lift



Possibility of ....

BULLETIN - IMMEDIATE BROADCAST REQUESTED
TORNADO WATCH NUMBER 183
NATIONAL WEATHER SERVICE KANSAS CITY MO
1210 PM CDT FRI APR 26 1991

A..THE NATIONAL SEVERE STORMS FORECAST CENTER HAS ISSUED A TORNADO WATCH FOR

PARTS OF CENTRAL AND EASTERN KANSAS

EFFECTIVE THIS FRIDAY AFTERNOON AND EVENING UNTIL 800 PM CDT.

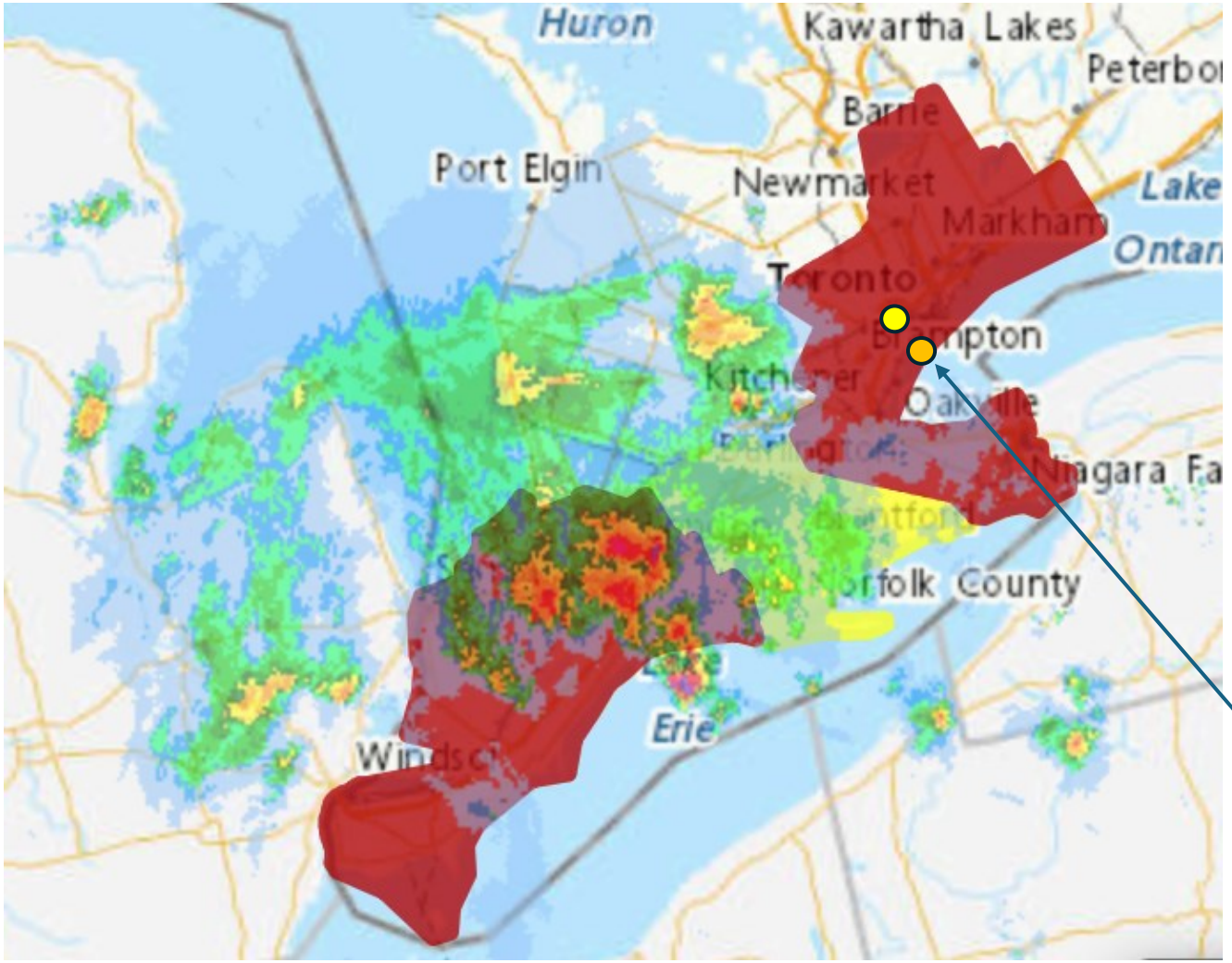
THIS IS A PARTICULARLY DANGEROUS SITUATION WITH THE POSSIBILITY OF VERY DAMAGING TORNADOES. ALSO..LARGE HAIL...DANGEROUS LIGHTNING AND DAMAGING THUNDERSTORM WINDS CAN BE EXPECTED.

THE TORNADO WATCH AREA IS ALONG AND 65 STATUTE MILES EAST AND WEST OF A LINE FROM 45 MILES EAST SOUTHEAST OF MEDICINE LODGE KANSAS TO 45 MILES NORTHEAST OF CONCORDIA KANSAS.

Note:

1. Circle – watch area
2. White box – next slide
3. Tornado is less than a "dot" on the map

Warnings indicate imminent damage and to take immediate action (minutes)



Thunderstorm Watch

Issued at: 3:20 pm EDT Saturday 17 August...

Conditions are favourable for the development of severe thunderstorms that may be capable of producing strong wind gusts, large hail and heavy rain.

Rainfall Warning

Issued at: 5:19 pm EDT Saturday 17 August...

Rain, at times heavy, is expected. The ground, already near saturation, has little ability to absorb further rainfall.

Note: Warnings is used in different ways – climate, synoptic, hurricane, tornado

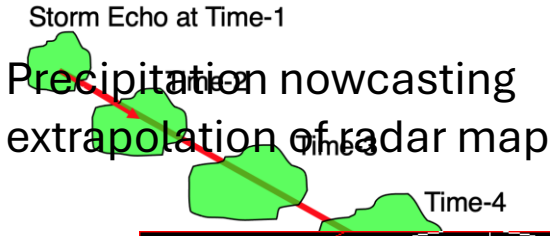
Traditionally based on observation of severe weather, radar, spotter reports (volunteer)

Point warnings!

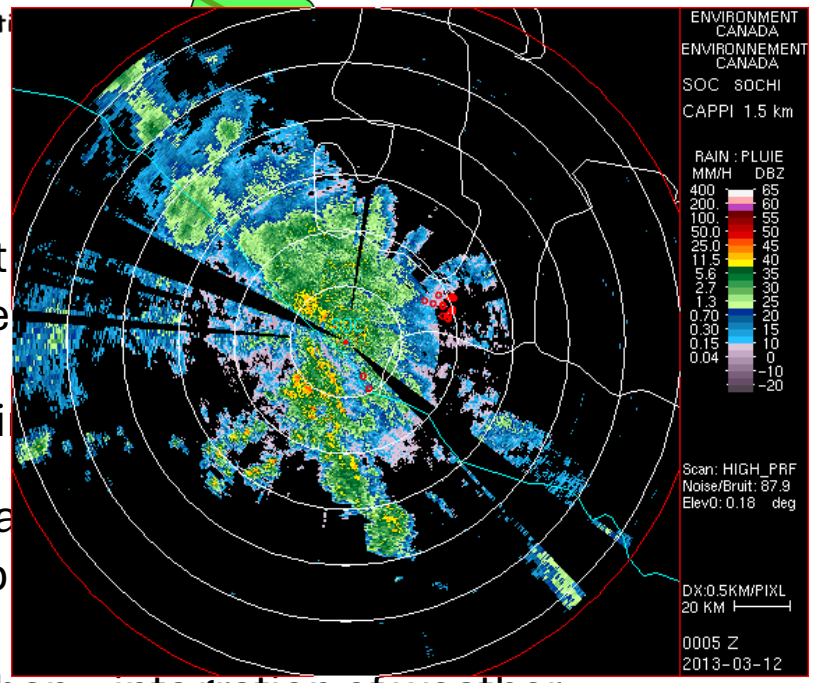
Nowcasting has evolved…

- 1948 Fawbush-Miller (tornado watch)
- 1953 Echo Tracking- Ligda
- 1978 SHARP – Bellon-Austin
- 1970-80's – formalize warning preparation rules
- 1982-8's Purdom/Wilson – fine lines
- 1988 Browning/Conway (COST) – nowcasting definition
- 1985…1993… TITAN / WDSS
- 2000 S2K – Algorithm Demonstration
- 2008 B08 – Blending, NWP +++
- 2010 SNOW-V10 – Winter Complex Terrain /2014 FROST / 2018 ICEPOP
- 2012-2015 INCA-CE – trans-national
- 2015 ECPASS / TOMACS / 2024 Paris

Forecast by tracking cells



Precipitation nowcasting extrapolation of radar maps



Algorit
severe

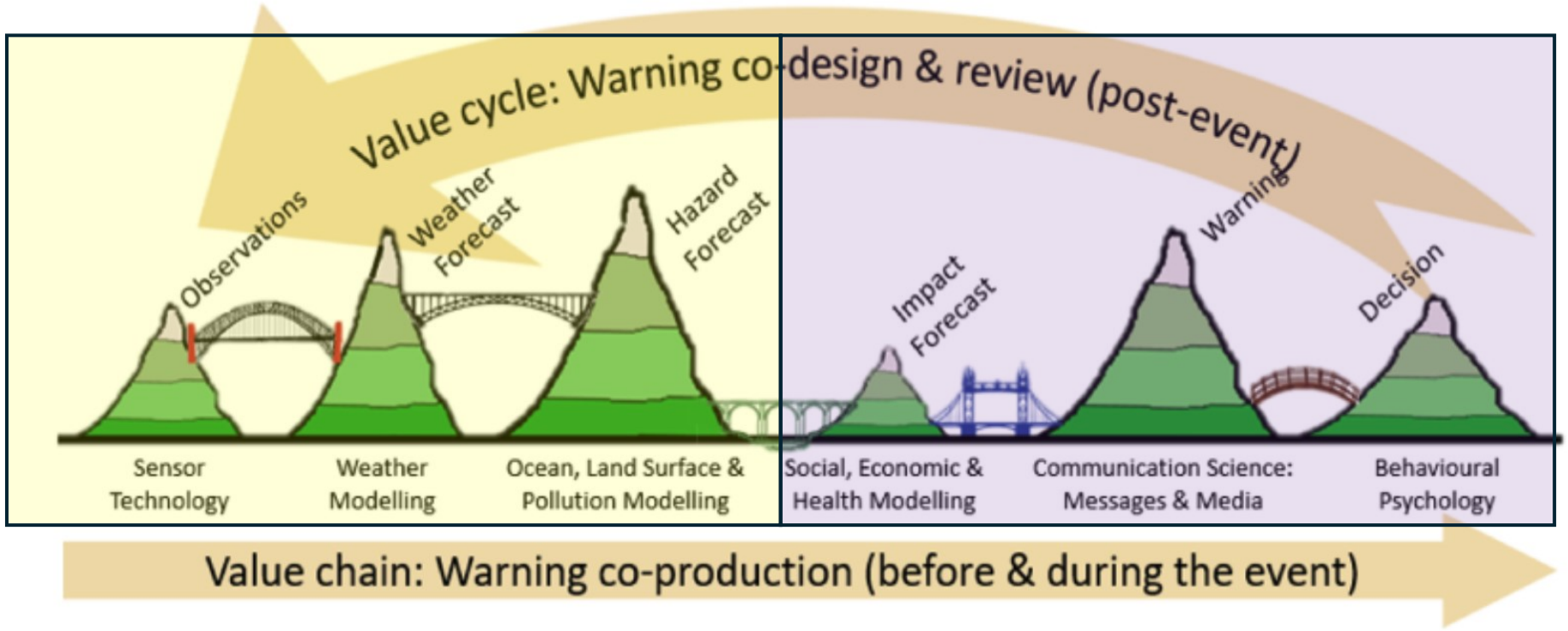
Blendi

Non-ra
multip

- Urban – integration of weather, air quality, hydrology and health
- Aviation

Communication of the warning is critical!

Warning Area, Precision and Accuracy!



Schematic value chain for high impact weather warning showing the capabilities and outputs (green "mountains") and information exchanges (bridges) linking the capabilities and their associated communities (from Golding et al. GAR2019).

1. There will be a tornado in the U.S.

5. Know your client

6. Balance!

Science and Challenge of Convective Nowcasting

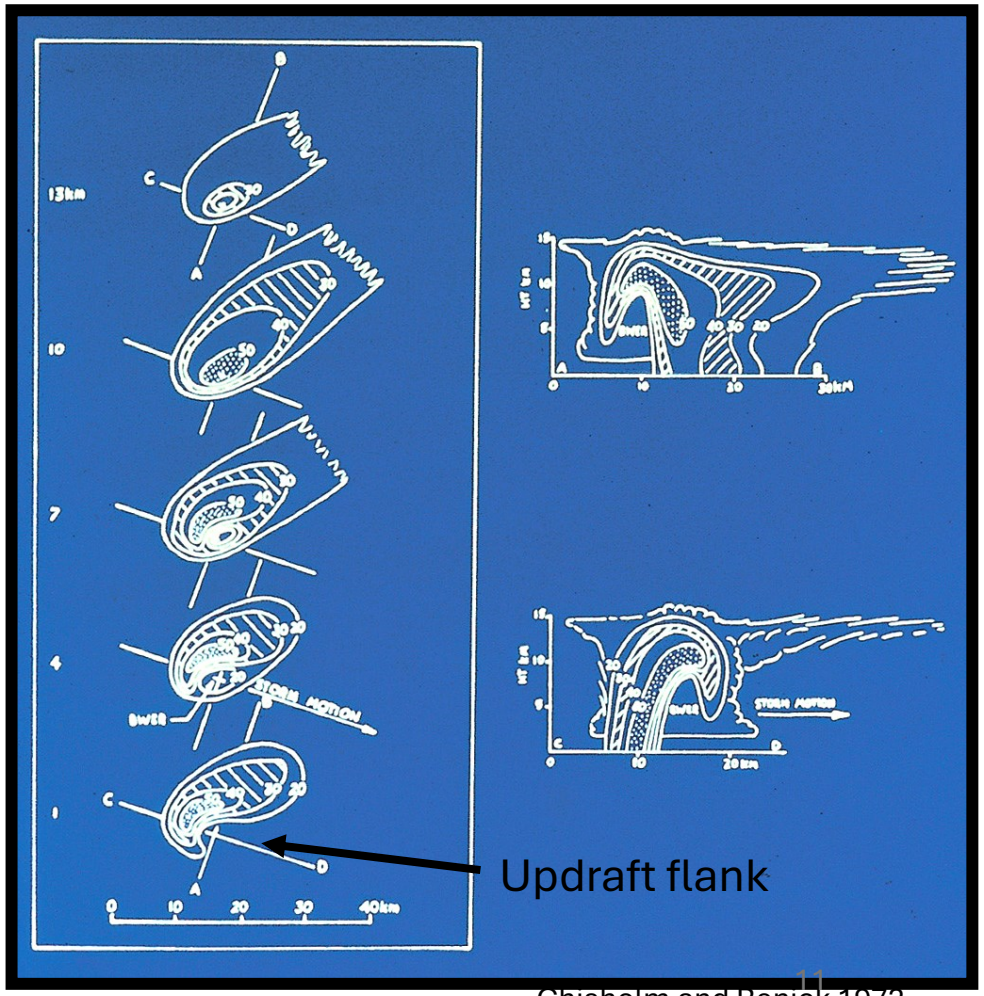
Lemon/Purdom/Wilson

Warnings are based on observations or identifying severe storm features or morphology

3D Radar

1. Strong low-level reflectivity gradients.
2. Displaced low-level Echo Core.
3. Occasionally concaved echo open to inflow.
4. Mid-level sloping echo overhang: WER/BWER.
5. Strong upper mid-level echo core over low-level reflectivity gradient/concavity.
6. Echo top above mid-level echo core.
7. *Deep Convergence Zone (Mid-Altitude Convergence, Upper level divergence, anvil)*
8. *Rotation (mesocyclone, tornado vortex signature)*
9. *Downburst*
10. *Hail Signature (Three body scatter, hydrometeor type)*
11. *Tornado Debris, Hydrometeor Type (polarization)*

Doppler Era, Polarization Era Les Lemon 1980

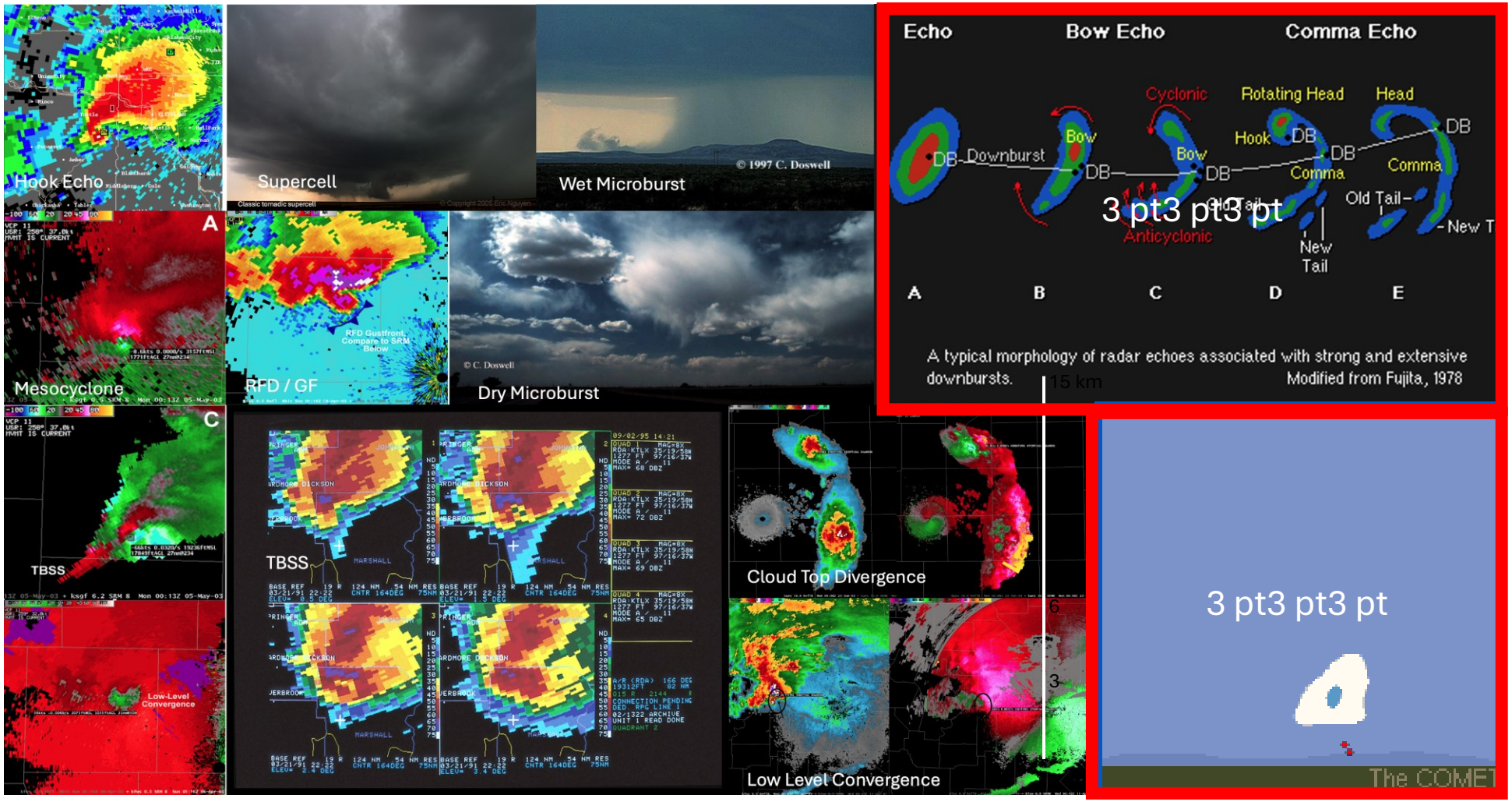


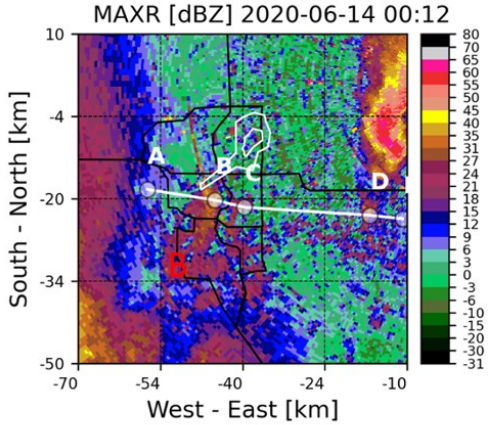
Chisholm and Renick 1972

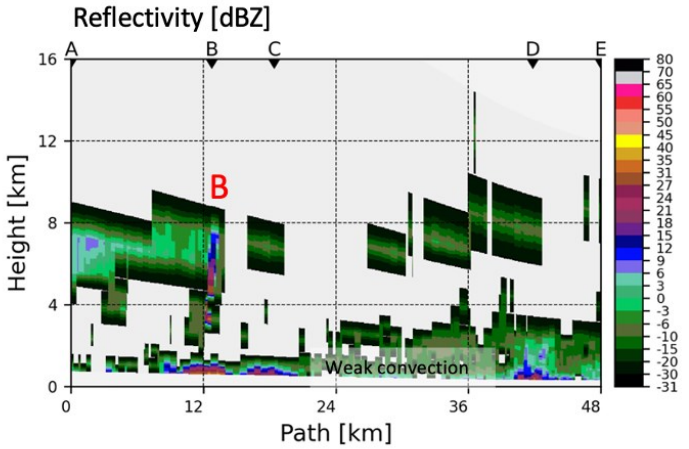
Need to identify that the storm is severe before it is severe

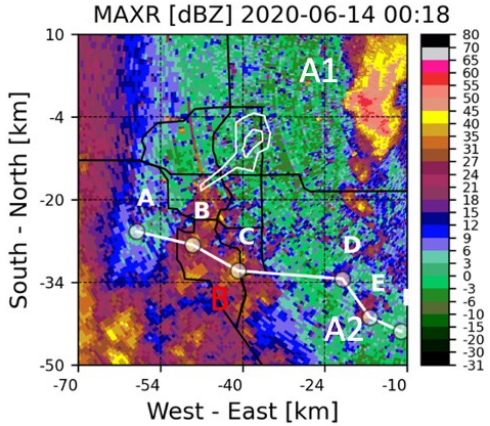
Severe storm features

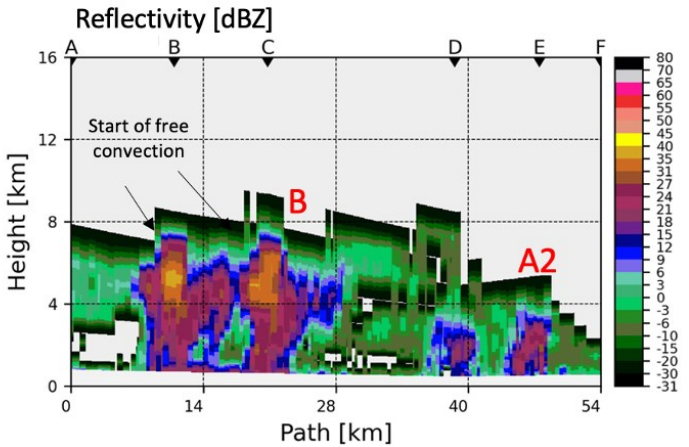
but a storm evolves in

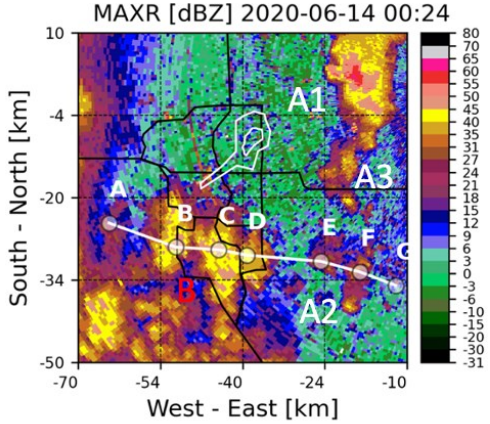


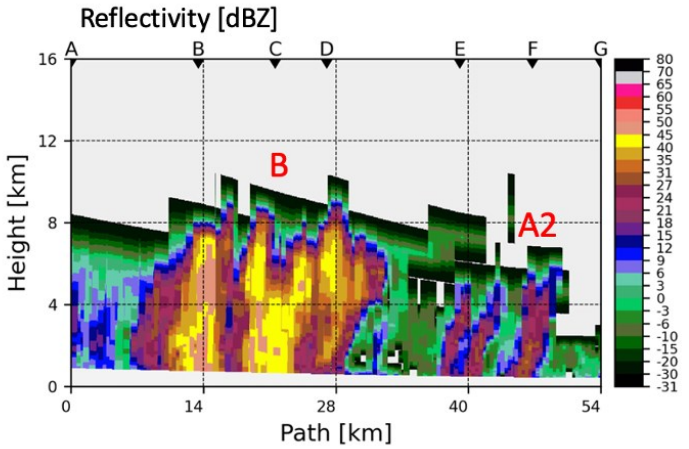












In 12 minutes, storm develops hail.

Must predict severe before it becomes severe!

How well is nowcasting working?

Accuracy, Precision, Lead Time

In Canada,

- tornadoes have warnings 35% of the time (probability of detection or POD)
- were issued preceding tornado development 24% of the time
- warnings with lead times of at least 10 minutes were issued 20% of the time

In U.S.,

- the average number of tornadoes per year is about 1200 for approximately a 60% POD
- the average lead time for the warnings was 8 to 10 minutes for all tornado intensities

30 minutes needed – longer lead time
Greater accuracy and precision needed

How to improve?

Convective Initiation

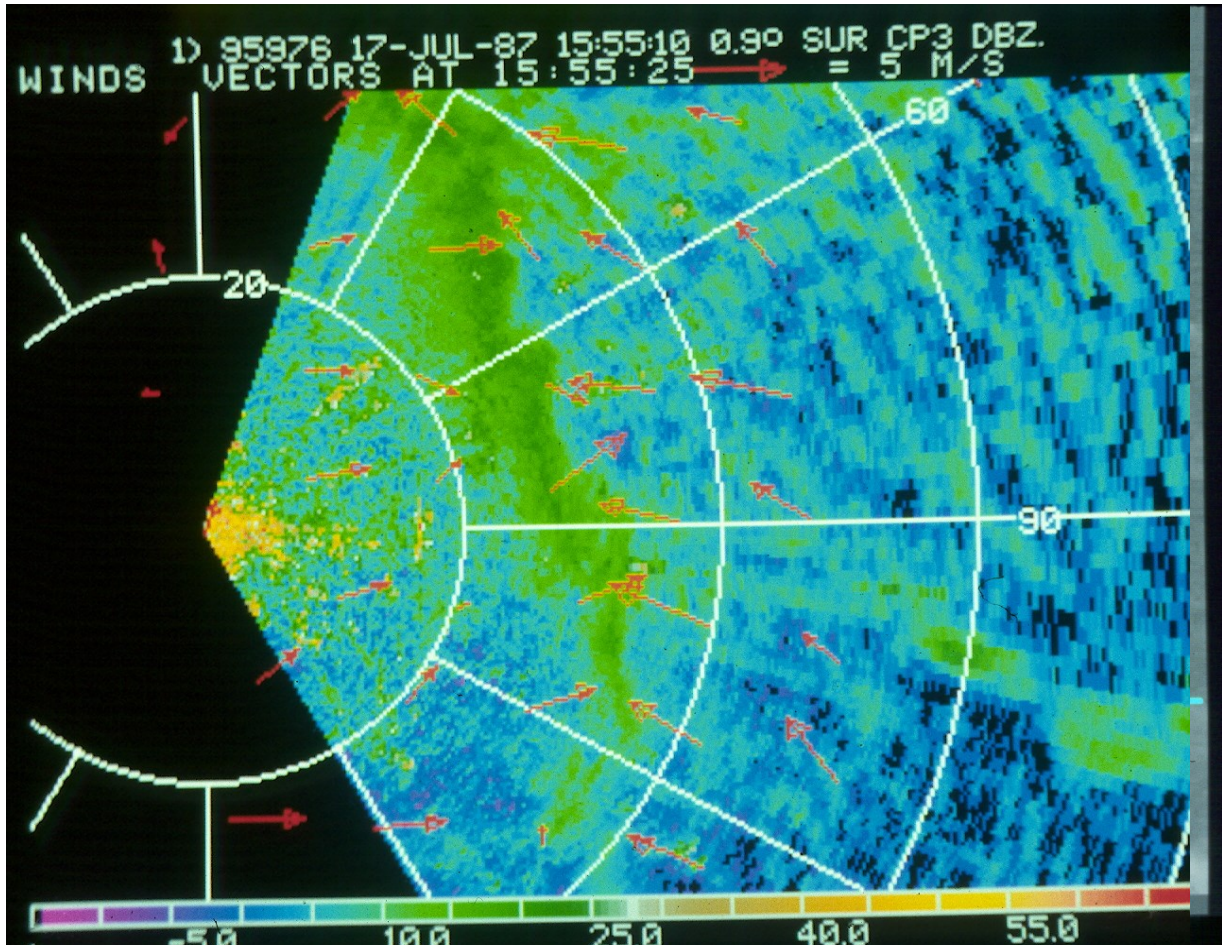
James Purdom, Jim Wilson

Satellite and Radar Provide Breakthrough

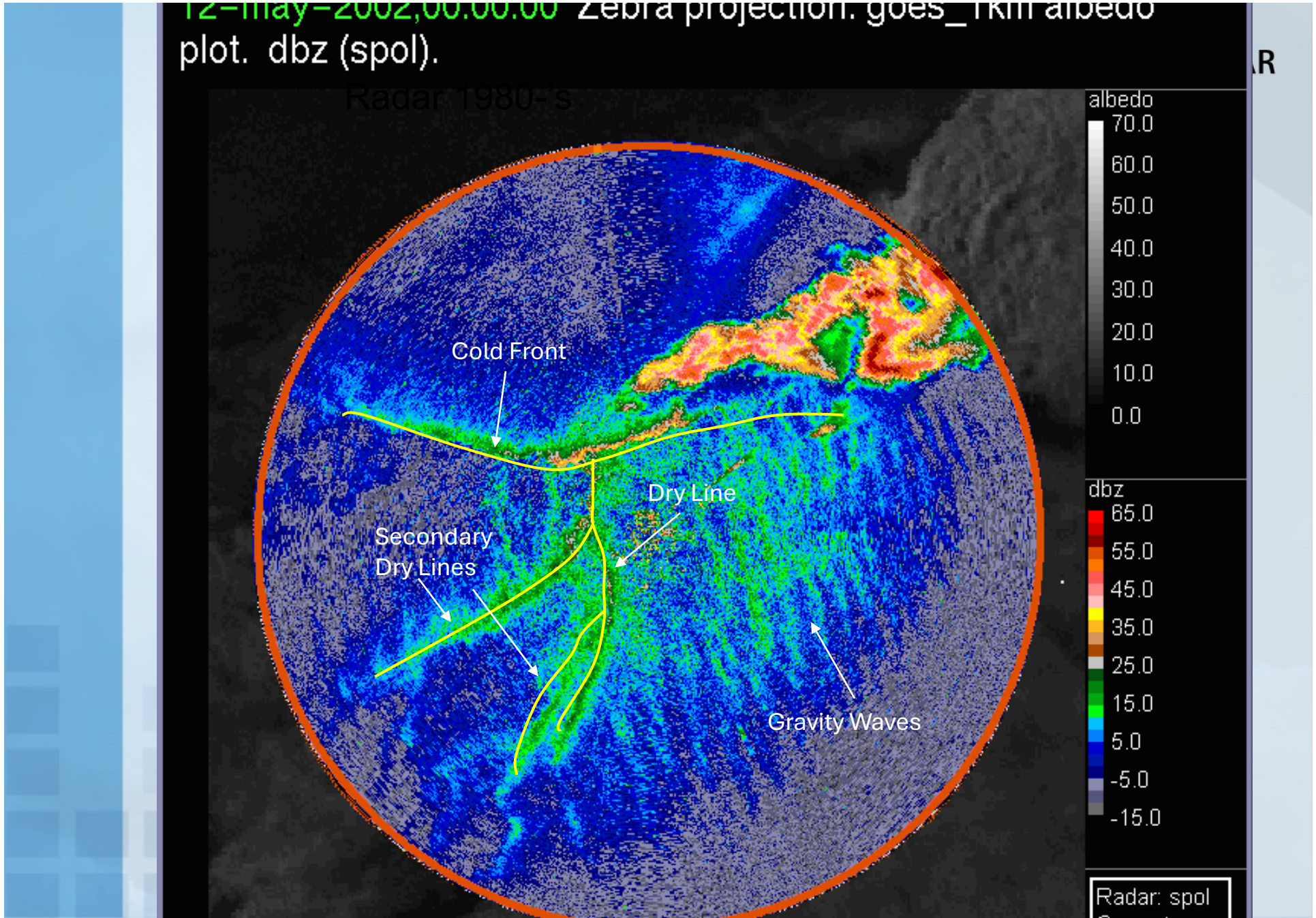
Boundary layer convergence lines (boundaries) frequently influence the evolution of thunderstorms. These boundaries can often be observed in:

1. Satellite cloud imagery. Note the N-S line of cumulus associated with a sea breeze along the Florida east coast.

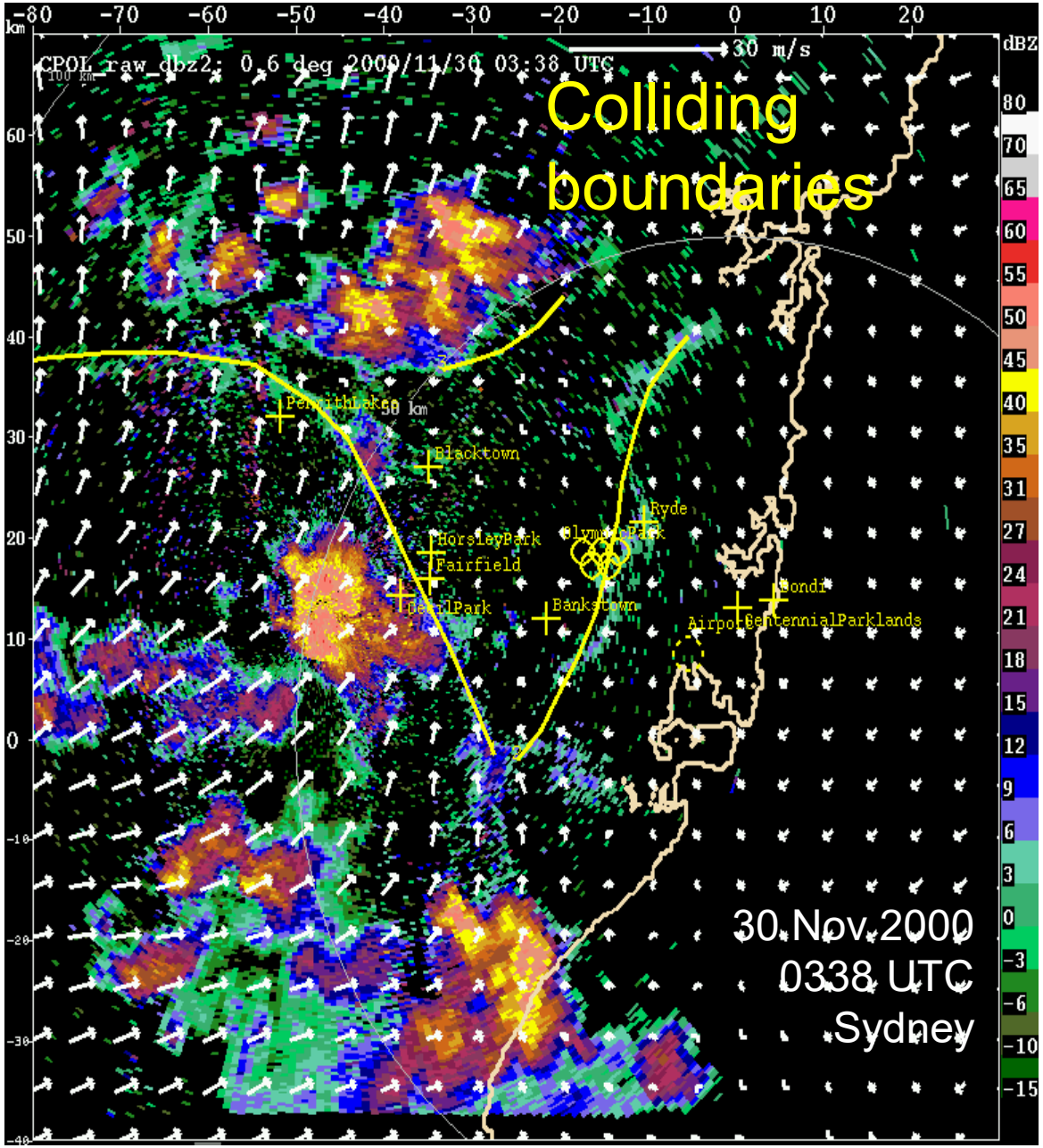
2. Clear-air radar features. Note enhanced N-S line of reflectivity associated with a boundary. Red arrows are wind direction from surface stations.

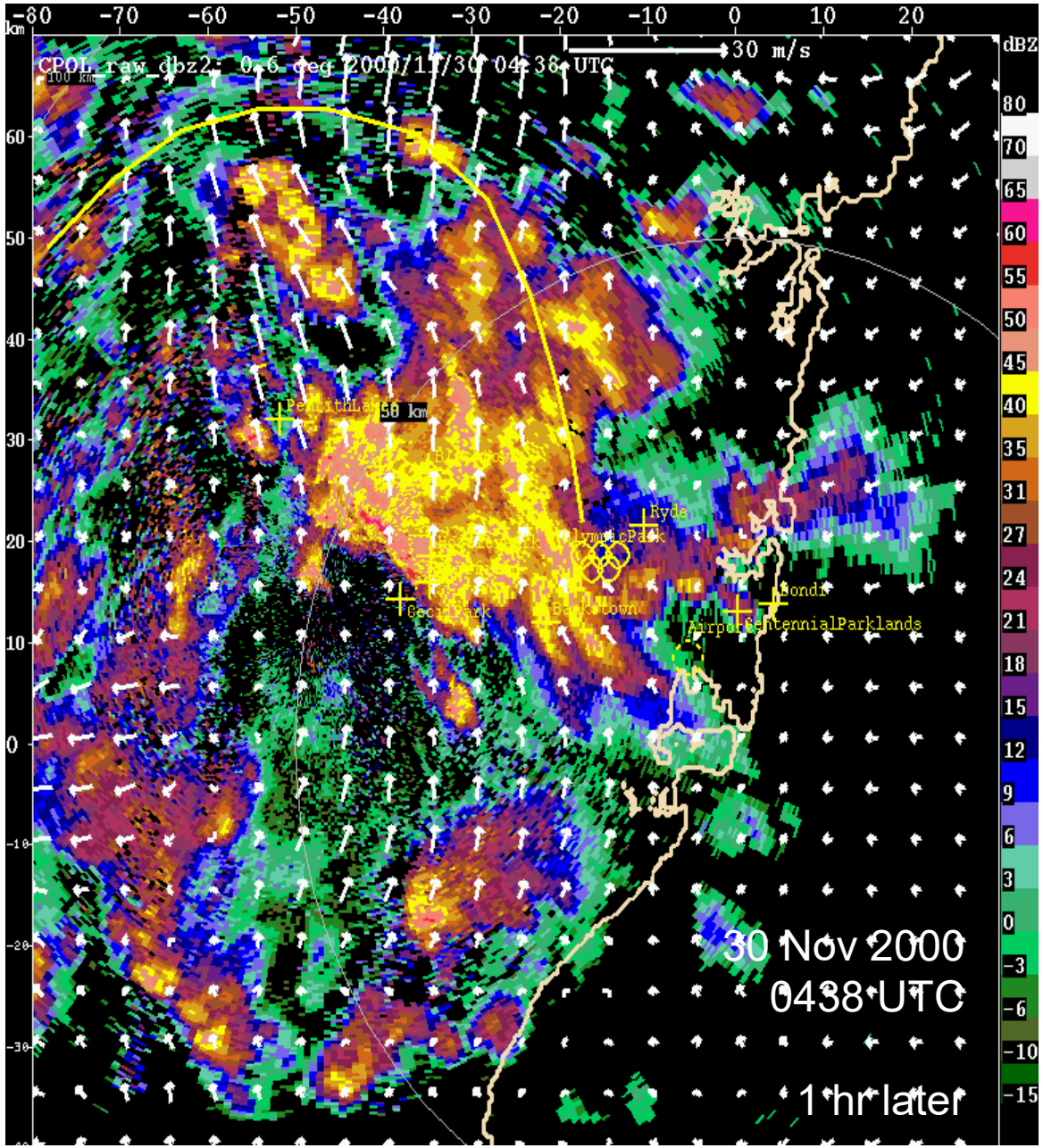


Radar observes convergence lines even in absence of clouds!



When boundaries collide, convergence occurs leading to…. Initiation and growth





This study convinced me!

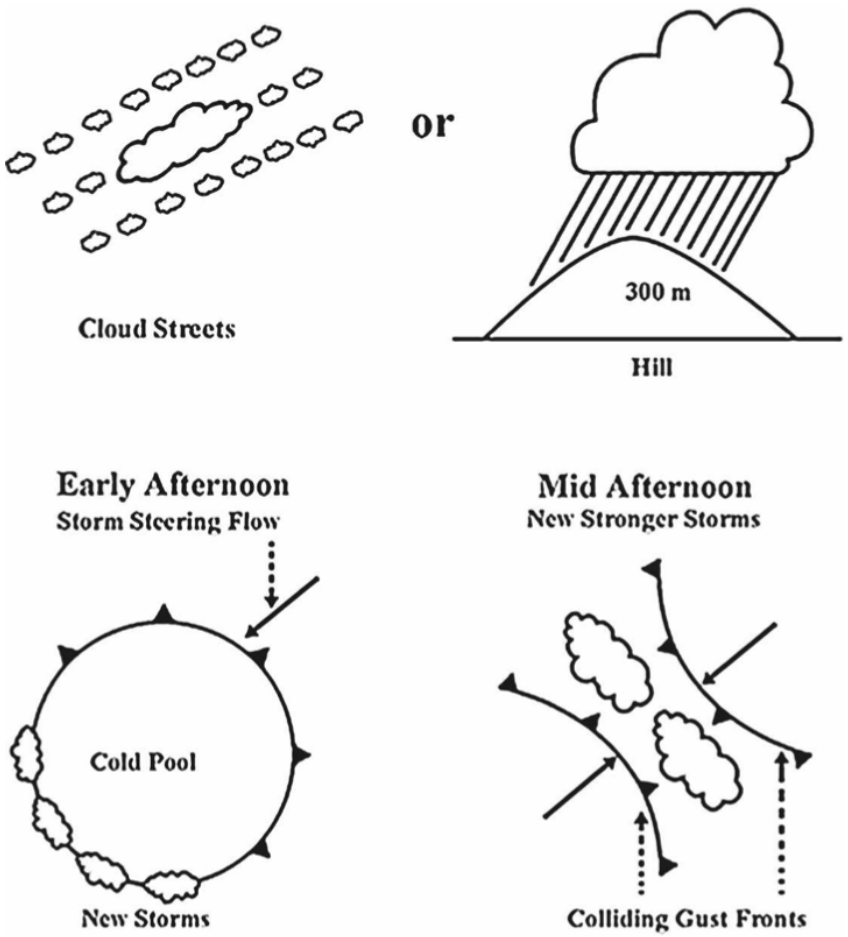


FIG. 17. Conceptual model of storm initiation and evolution over the Amazon for weak synoptic forcing situations. Two separate mechanisms for first storm initiation are provided.

TABLE 1. Triggering mechanisms of the first storm initiation and the resulting storm evolution for the 44 days of TRMM–LBA.

How storms first initiated	Resulting storm's pattern

75% of storms associated with boundary layer features

Convective Storm Initiation in a Moist Tropical Environment

MARIA ANDREA LIMA

Instituto de Pesquisas Meteorológicas/UNESP, Bauru, São Paulo, Brazil

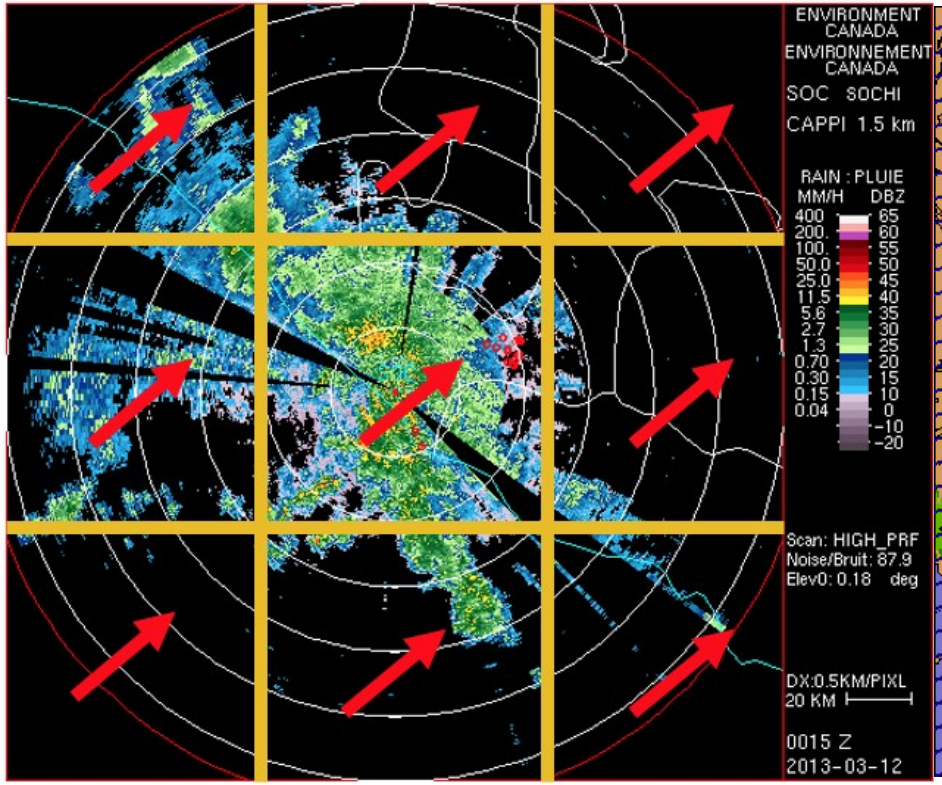
JAMES W. WILSON

National Center for Atmospheric Research, Boulder, Colorado*

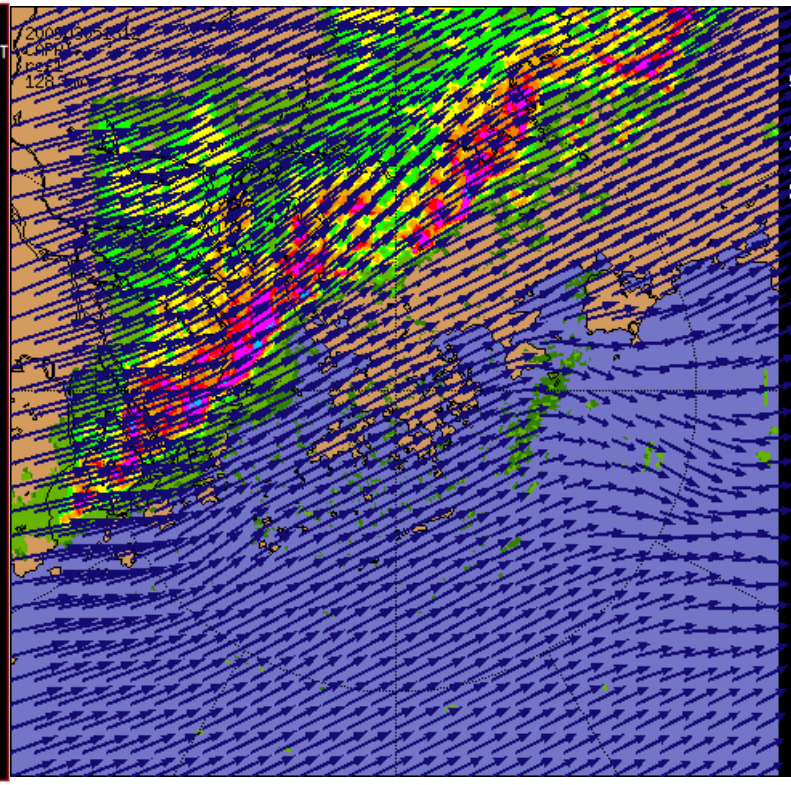
Precipitation Nowcasting

Estimation of precipitation motion affects nowcasting!

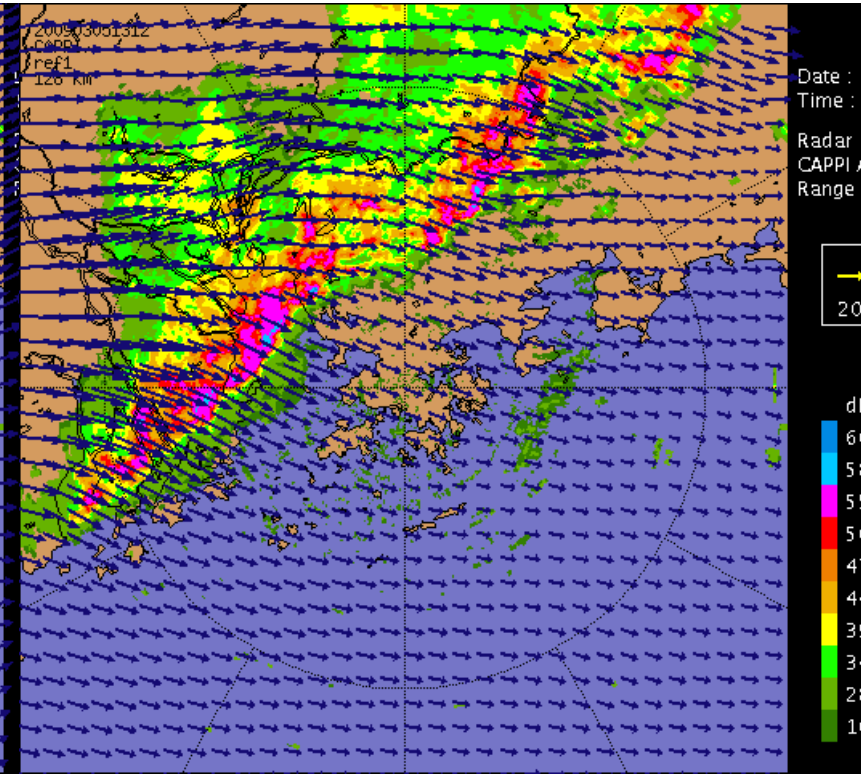
SHARP (McGill ~1978)



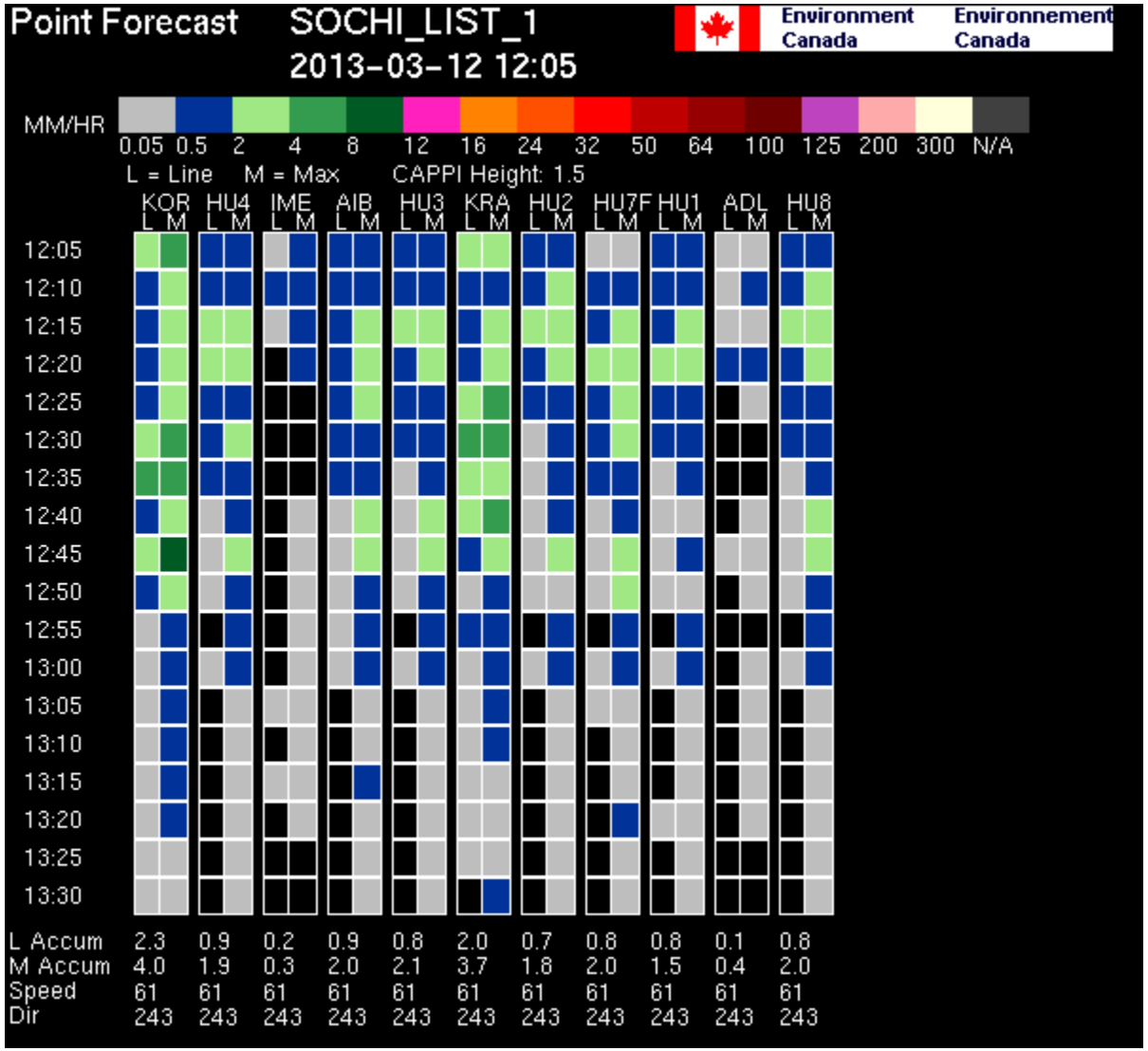
TREC (NCAR ‘80s)



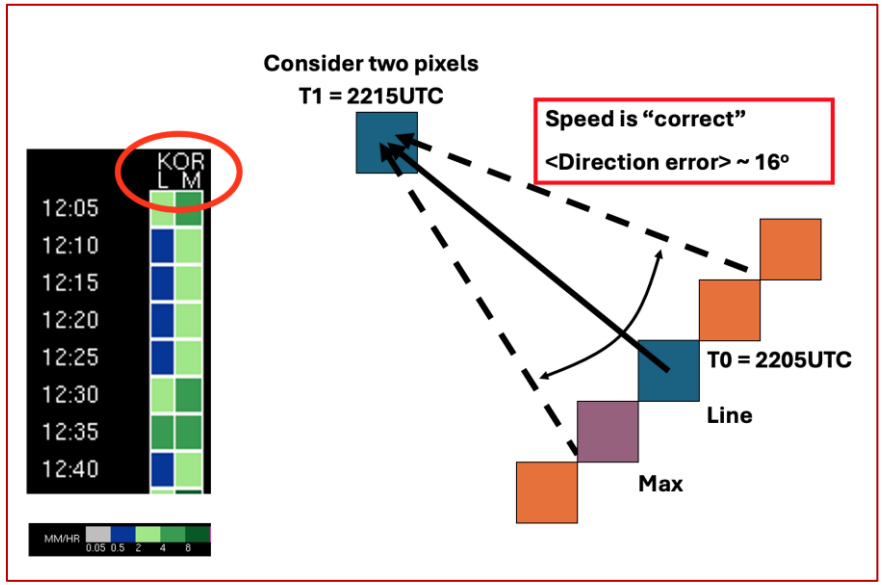
Optical Flow (HKO 2008)

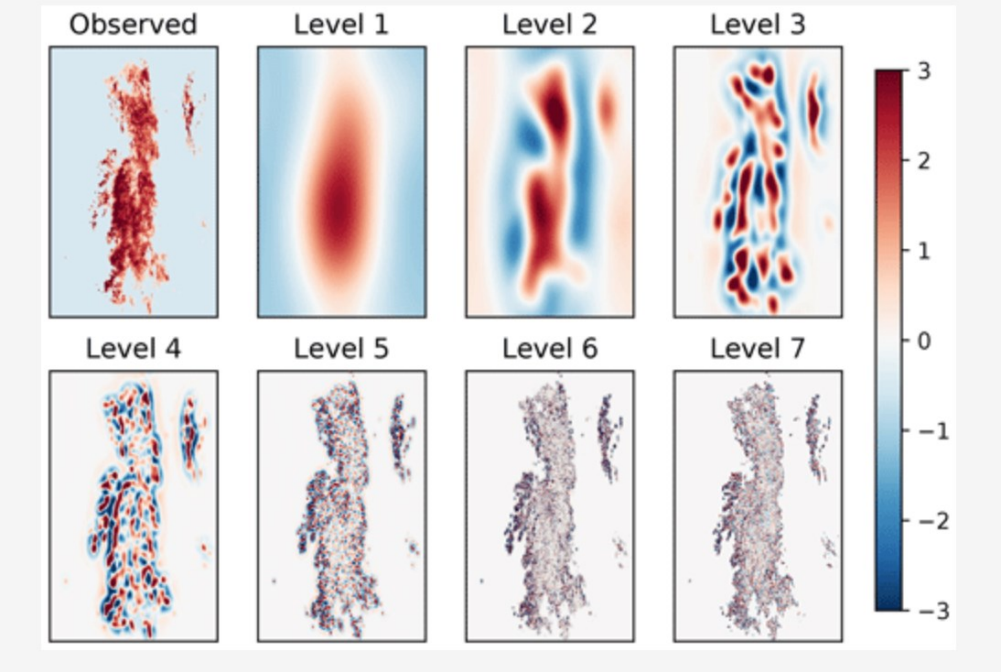


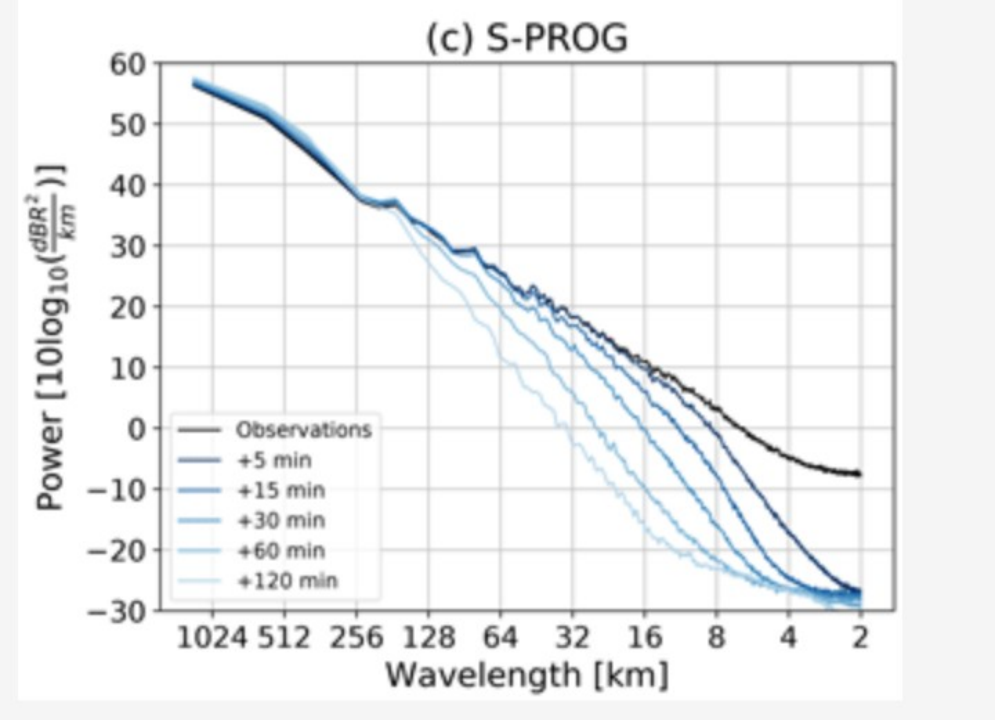
Example of the Point Forecast Product



Direction Error







STEPS filters the small scales

- Great uncertainty in forecasting rainfall using extrapolation
- Predictability is scale dependent
- Use probabilities to portray this uncertainty

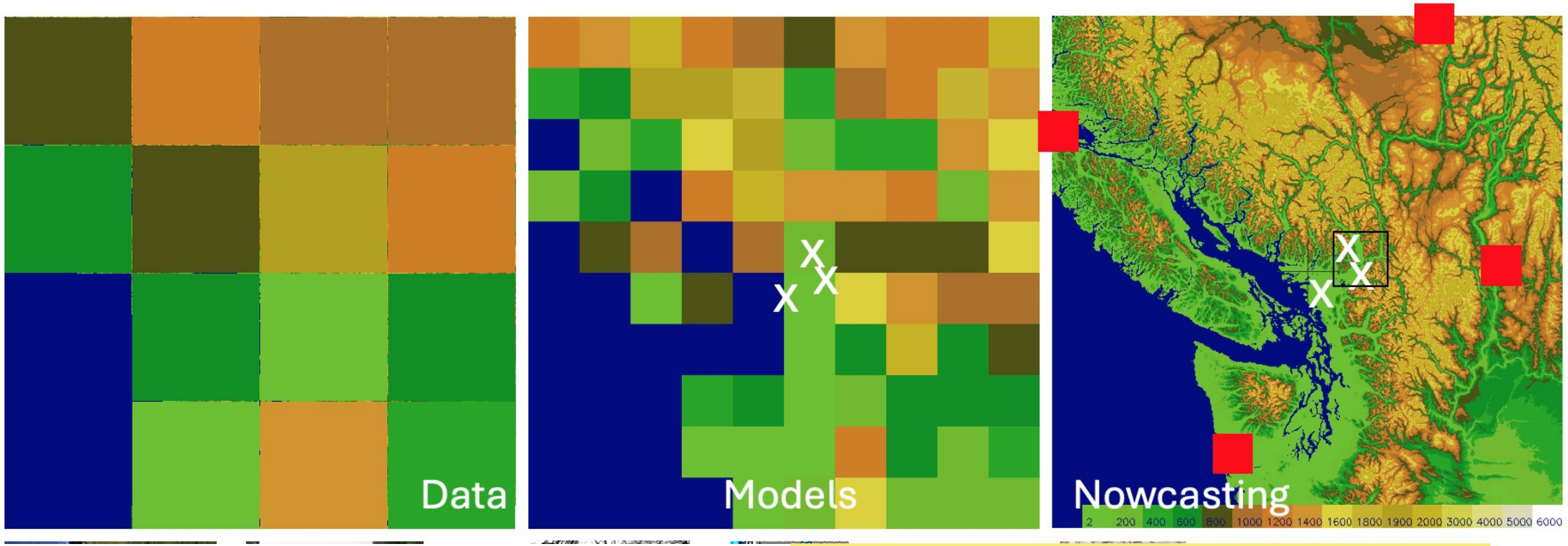
1. Fourier decomposition and filter small scales with time.

2. Replace small scales

Alan Seed, Australia

Science and Challenge of Winter Nowcasting

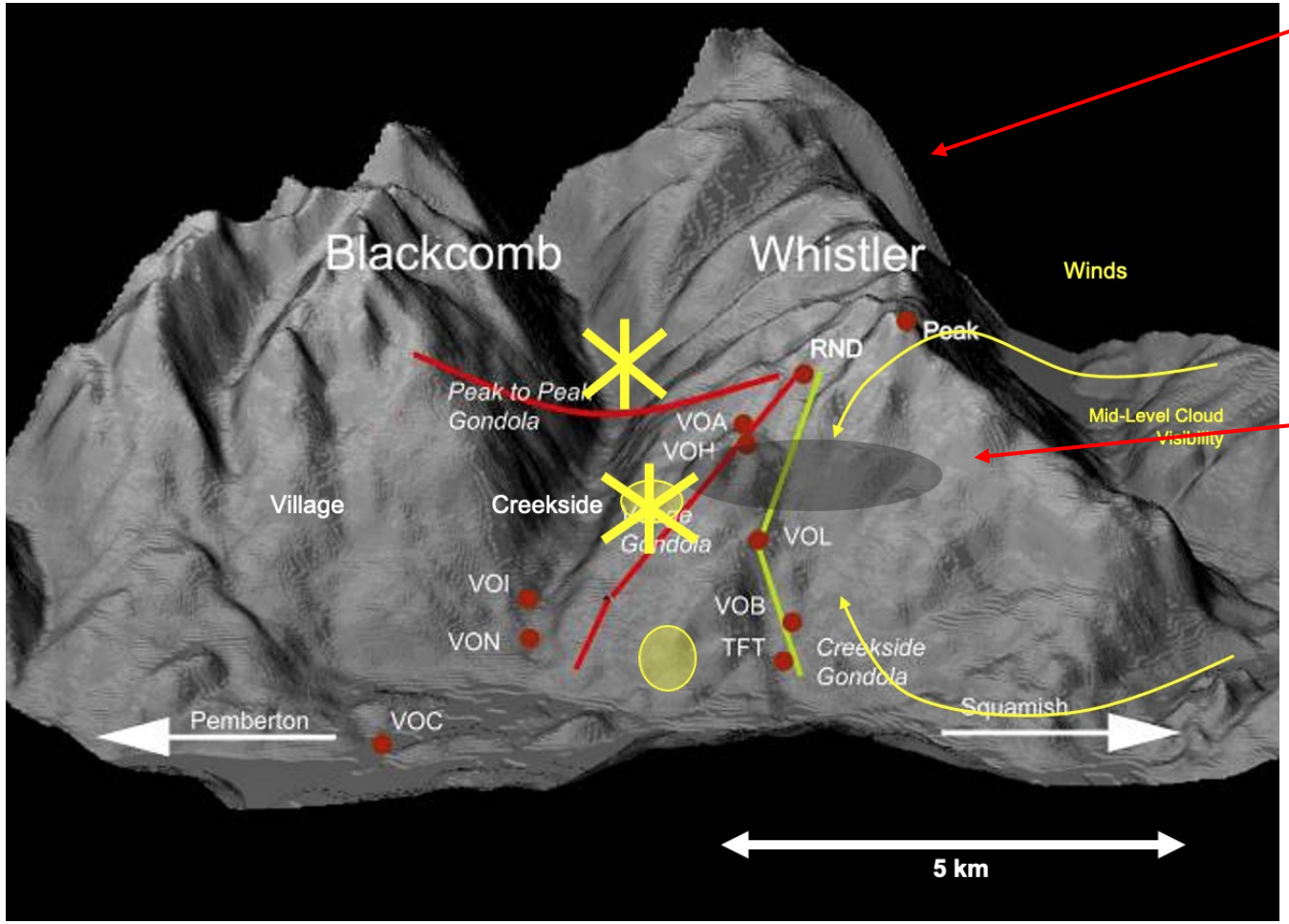
Operational monitoring/models do not resolve complex terrain very well!



NMHS do not forecast for complex terrain!

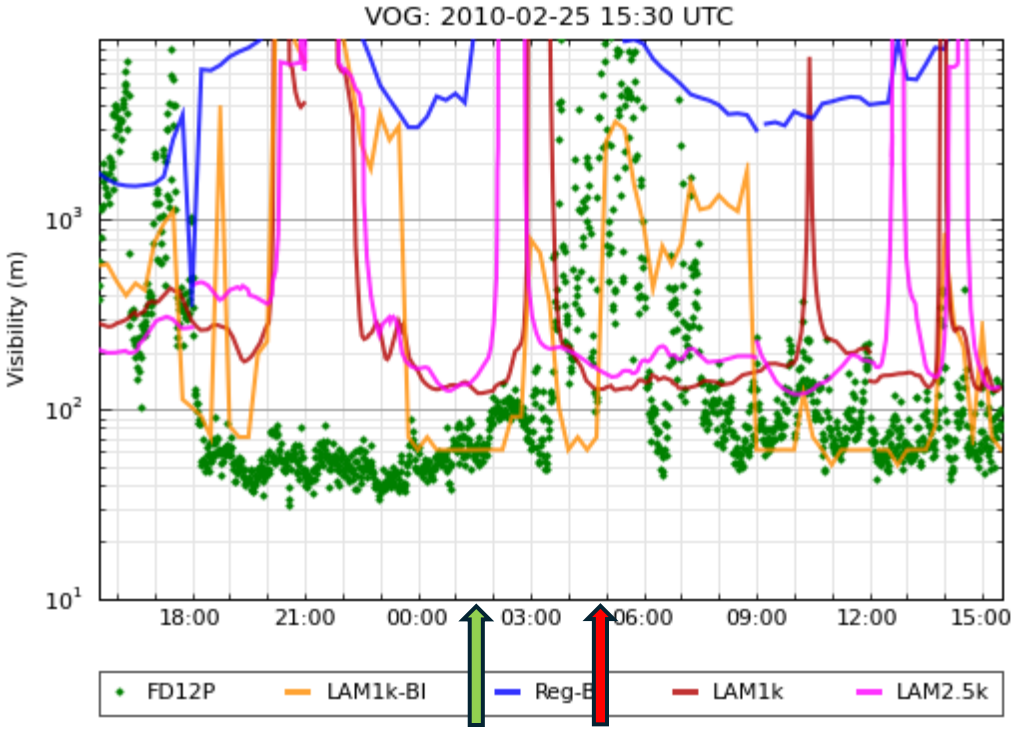
Winter weather in complex terrain is a BIG challenge!

Expert skiers change slopes with the conditions



1. High winds at the top
2. Snow in the middle
3. Poor visibility in the mid-mountain cloud
4. Rain at the bottom

Ladies Aerial Example



Freestyle Skiing Ladies Aerials Final
February 24, 2010

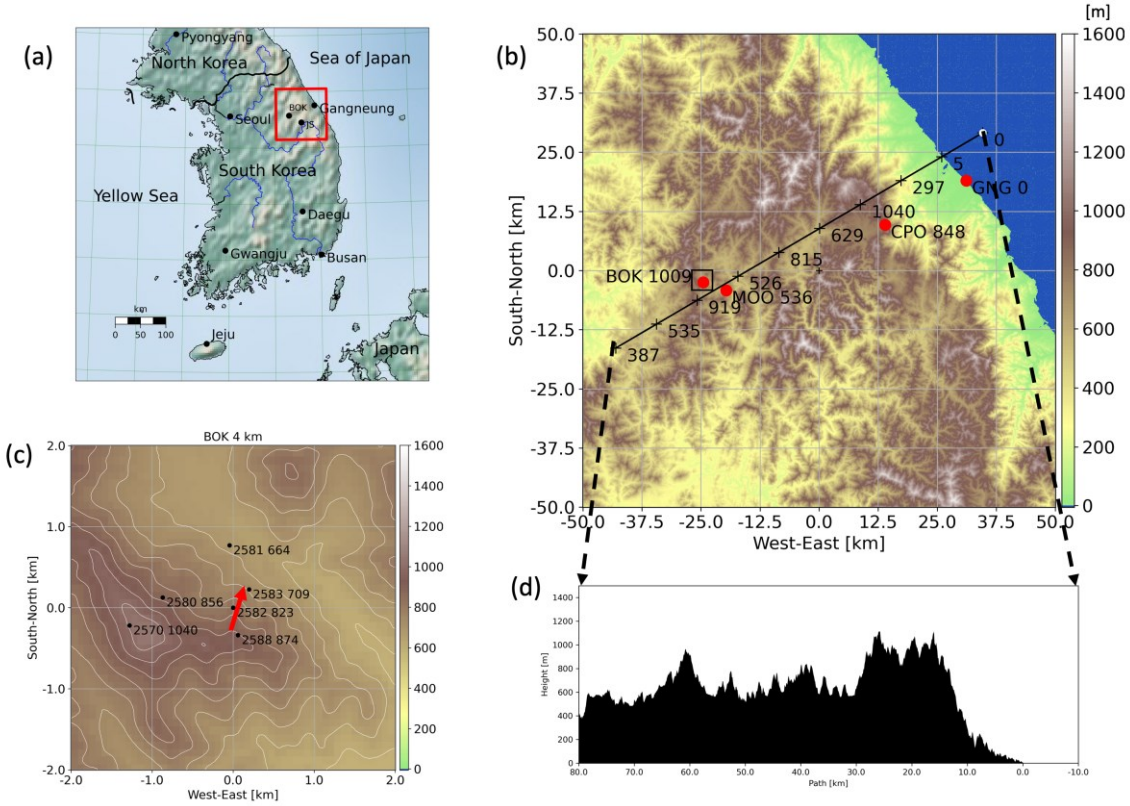
Notes by **Mindy Brugman** as posted on SNOW-V10 Blog

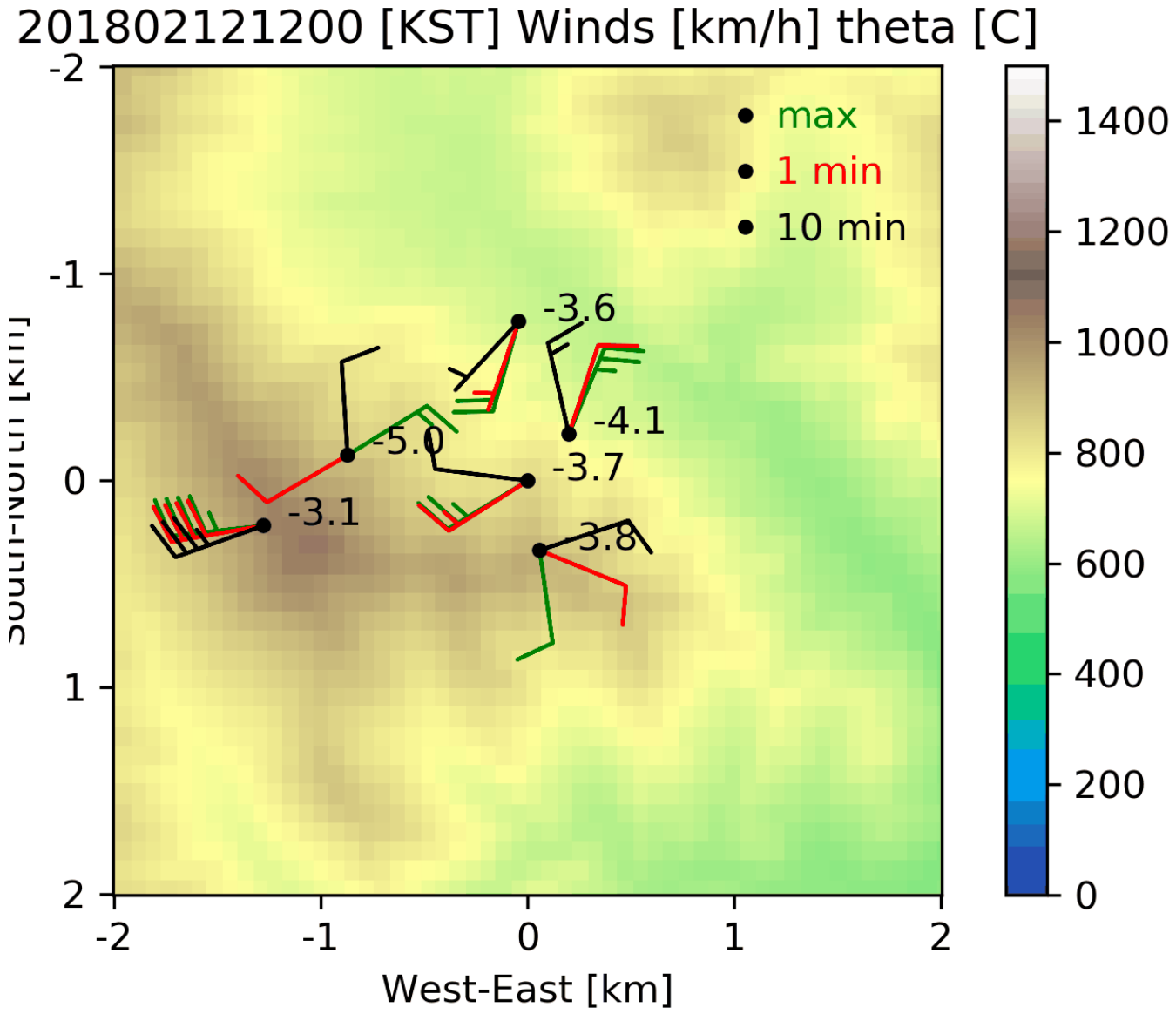
The event….Last night at the Cypress aerial site it began with drizzle and was quite foggy… We walked to the bright lights of the venue. There was no precipitation at the venue the entire competition. The competition started at 1930 PST. The first pictures (not shown here) are taken at the start of the competition and you can see that the fog was much worse at the start. I stopped taking pictures since I could not see anything. Then it began to clear just near the end of the competiton – and I clicked a few pictures. You can detect a flying bug above the lights. Thats really the gold medal winner, Lydia Lassila, of Australia! Based on the event last night – I suspect ladies aerials may qualify as a new paralympic sport for the visually impaired.

Wind Gust/Pattern Example

ICEPOP

Winds are in opposite directions on adjacent slopes and gusty!



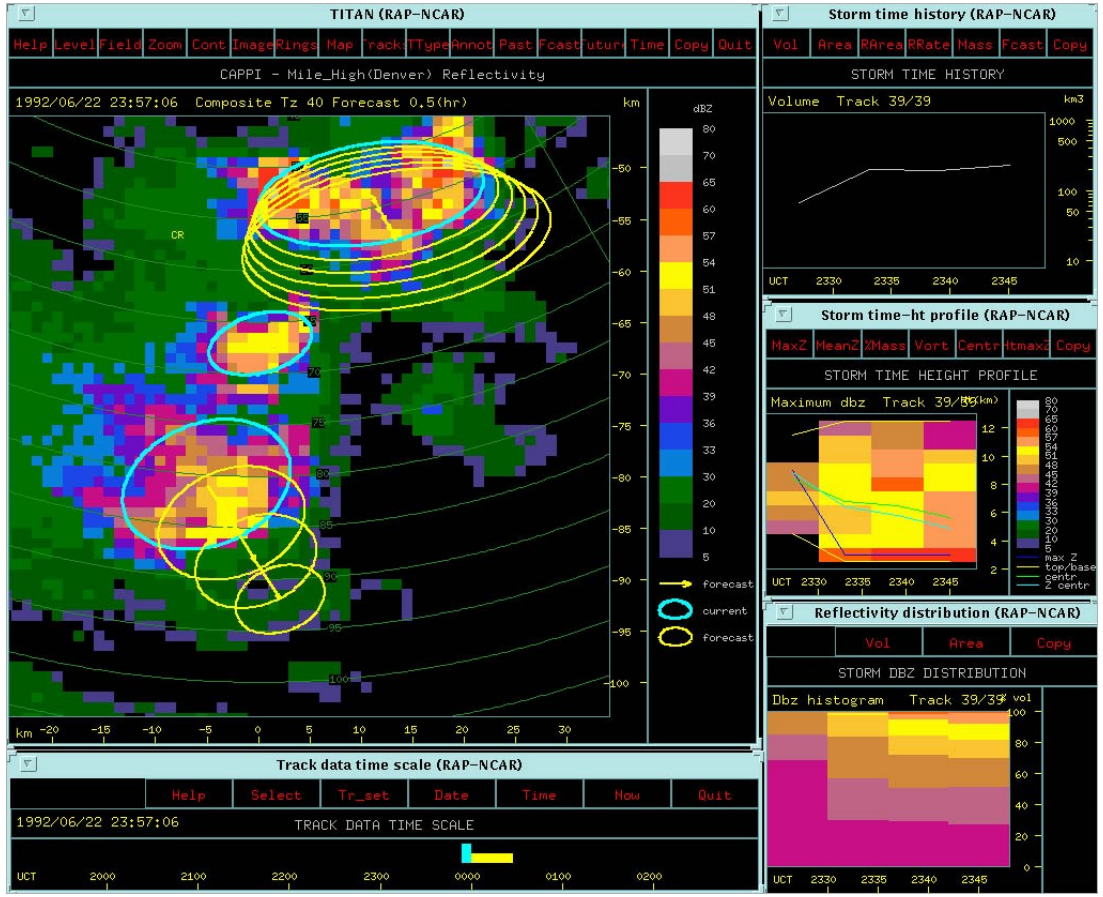


Systems

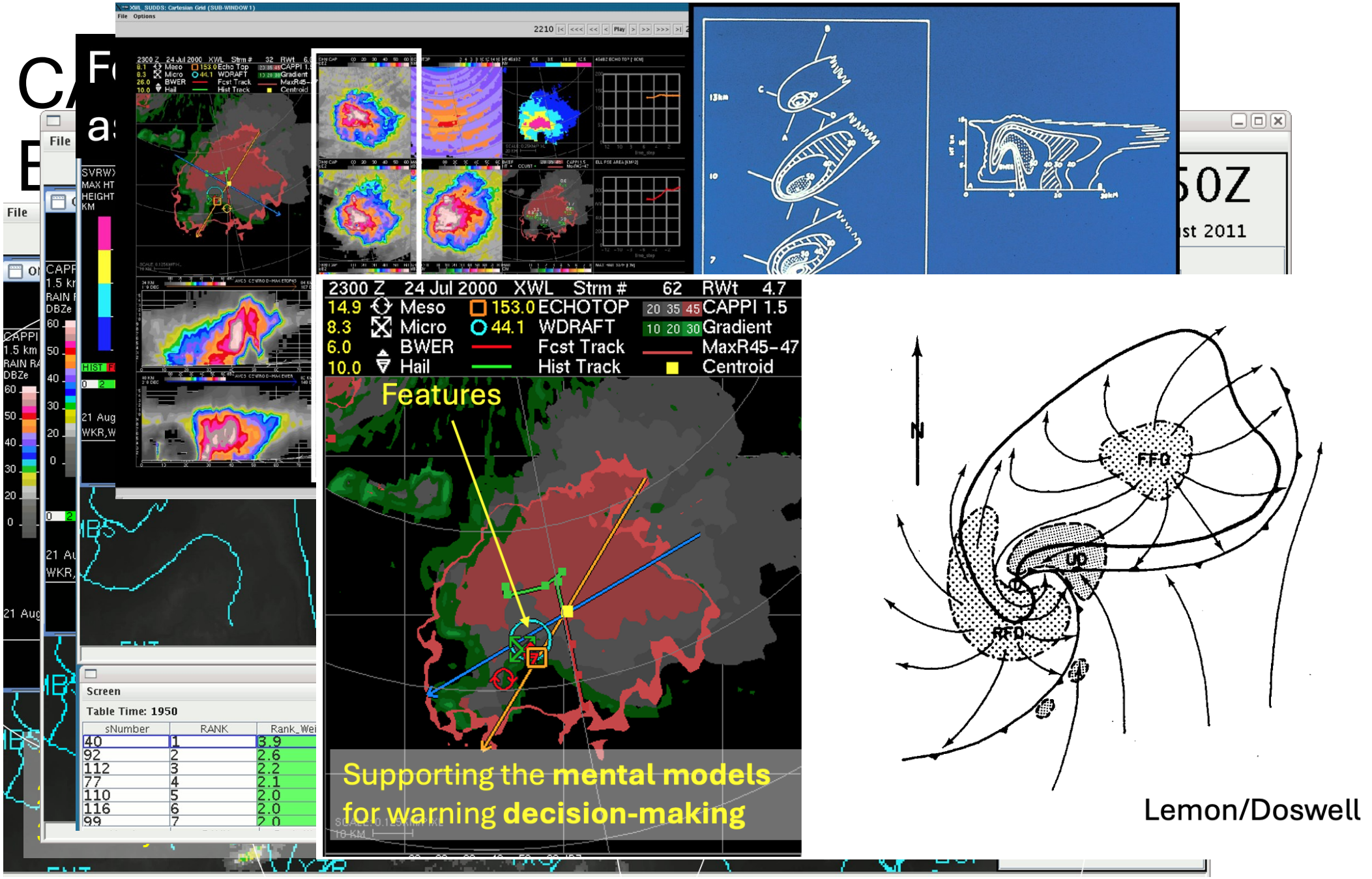
Nowcast systems
Automating the Lemon/Wilson/… Rules for severe thunderstorm identification

TITAN

The most popular (free) system

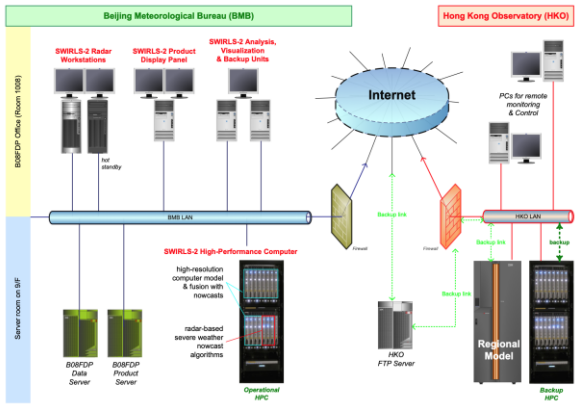


TITAN
Dixon and Weiner 1993
See Zrnic 1985, Lakshamanan 1997, Joe et al 2004

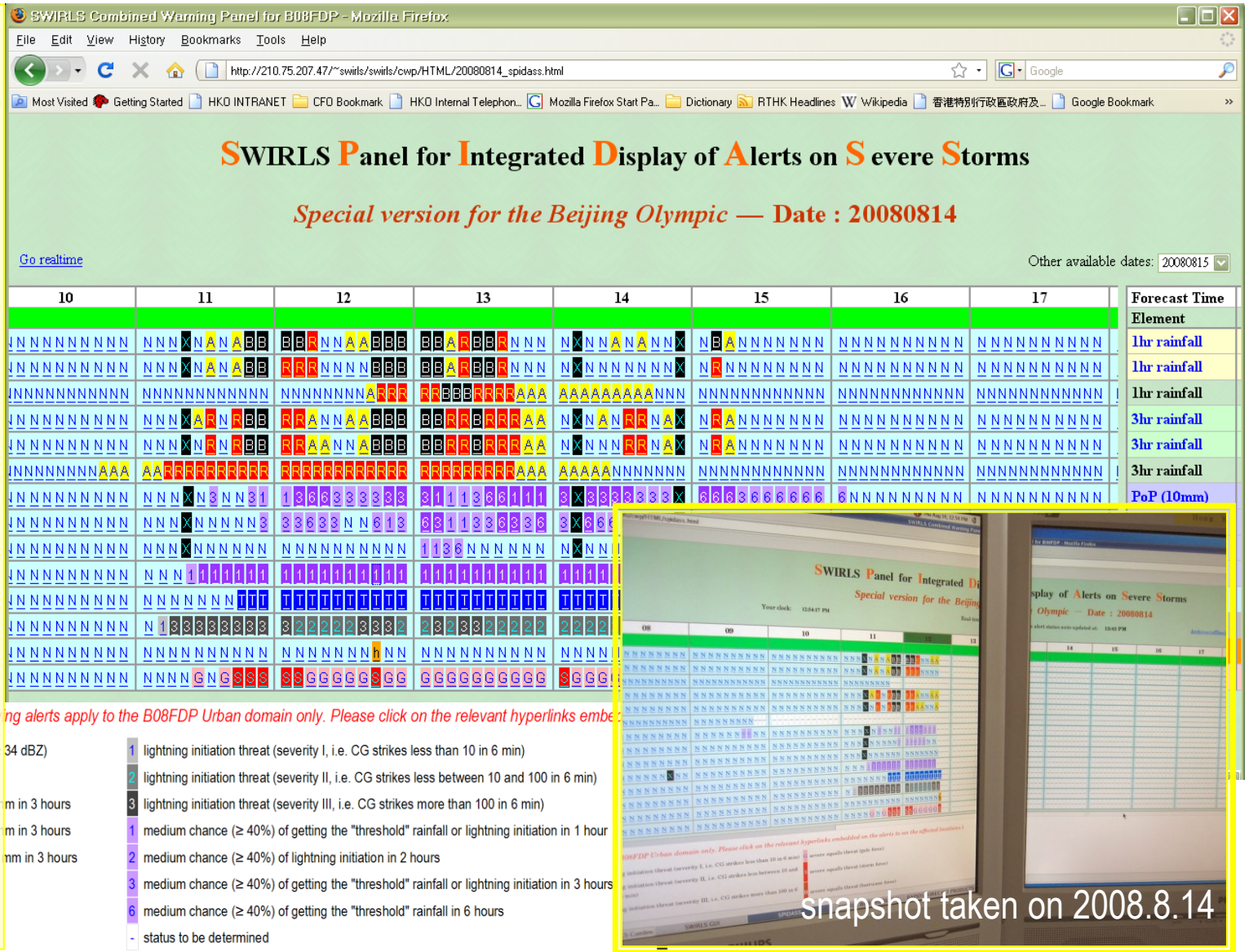

2300 Z 24 Jul 2000 XWL Strm # 62 RWt 4.7
14.9 Meso 153.0 ECHOTOP 20 35 45 CAPPI 1.5
8.3 Micro 44.1 WDRAFT 10 20 30 Gradient
6.0 BWER Fcst Track MaxR45-47
10.0 Hail Hist Track Centroid
Features
Supporting the mental models for warning decision-making
Screen
Table Time: 1950
sNumber RANK Rank_Wei
40 1 3.9
92 2 2.6
112 3 2.2
77 4 2.1
110 5 2.0
116 6 2.0
99 7 2.0
FFG
UD
RFD
Lemon/Doswell

SWIRLS an operational fully integrated nowcasting system

HKO: SPIDASS *in action*



- **S**WIRLS **P**anel for **I**ntegrated **D**isplay of **A**lerts on **S**evere **S**torms
- all likely weather threats at a glance!
- detailed weather map popping up on click!!

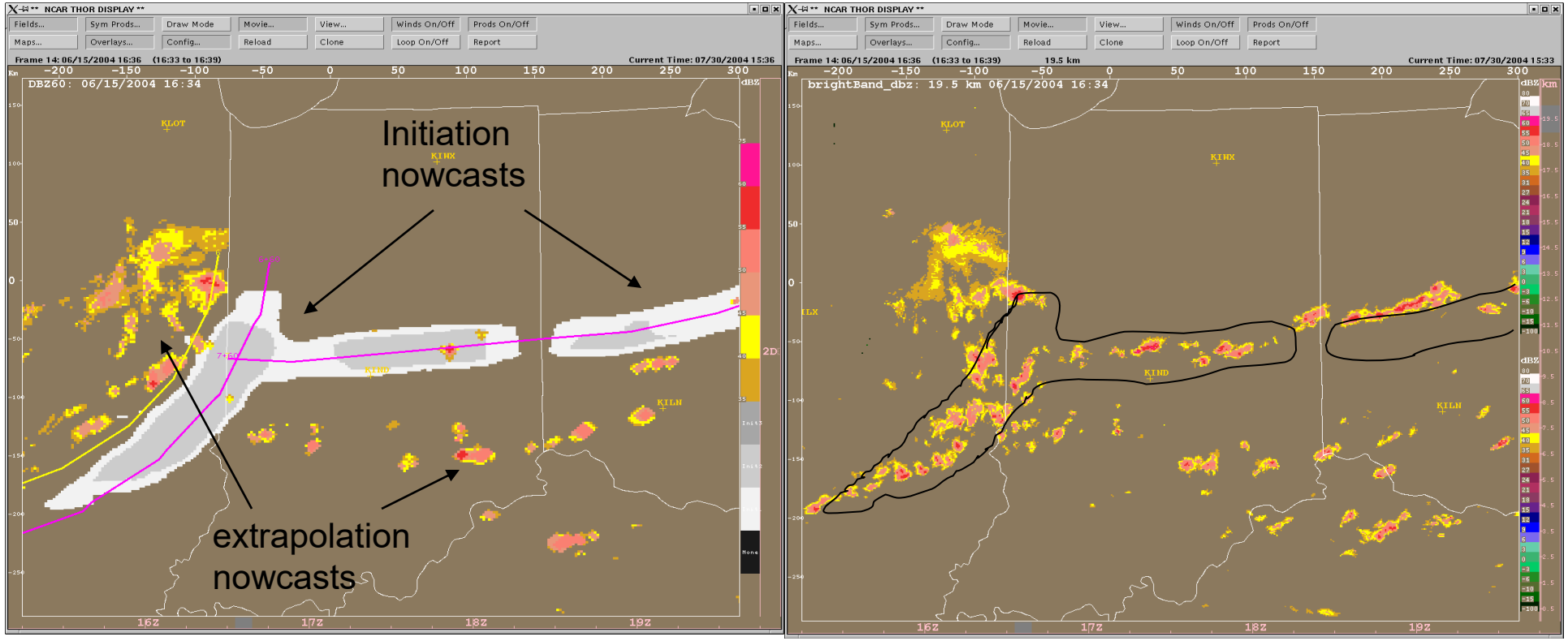


Autonowcaster

A system for convective initiation

1 hour forecast

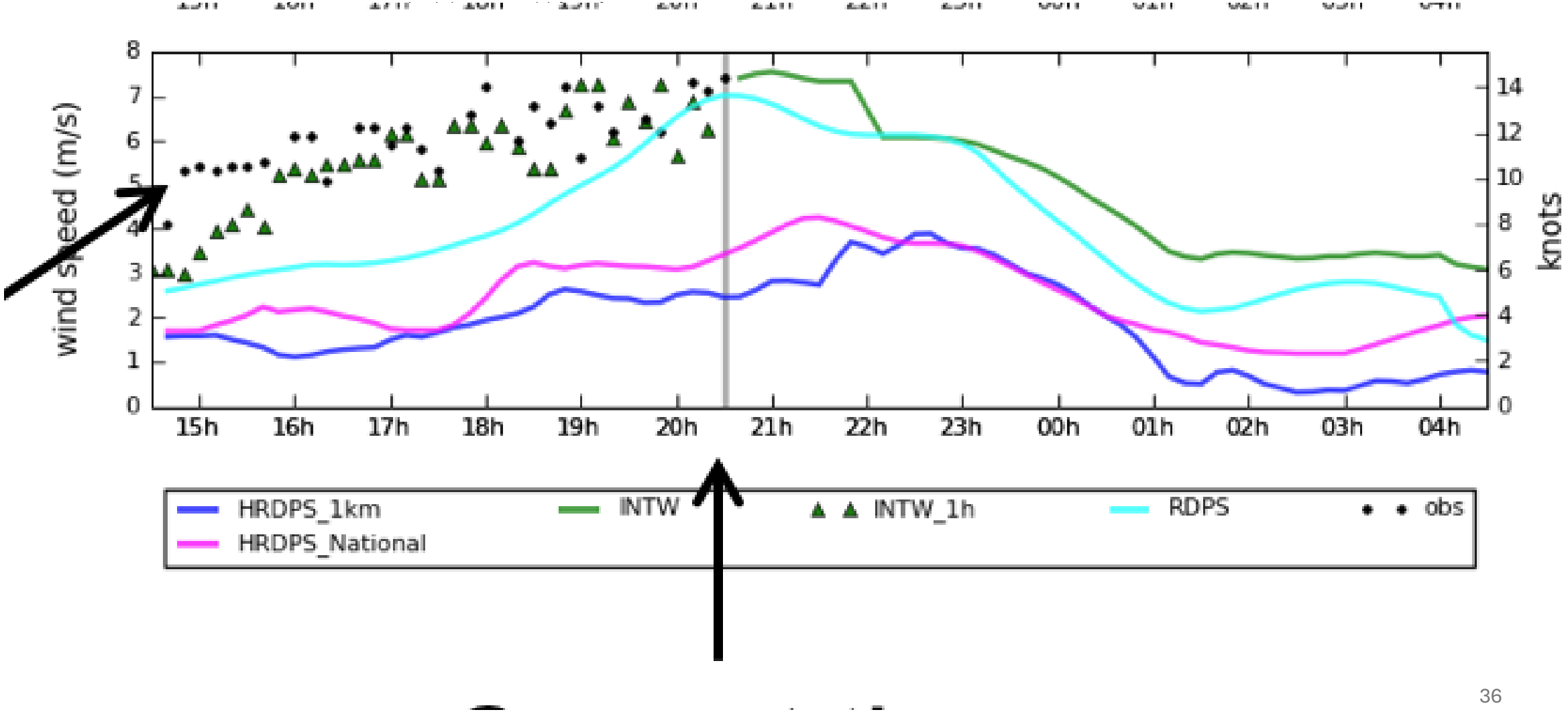
Verification



INTW

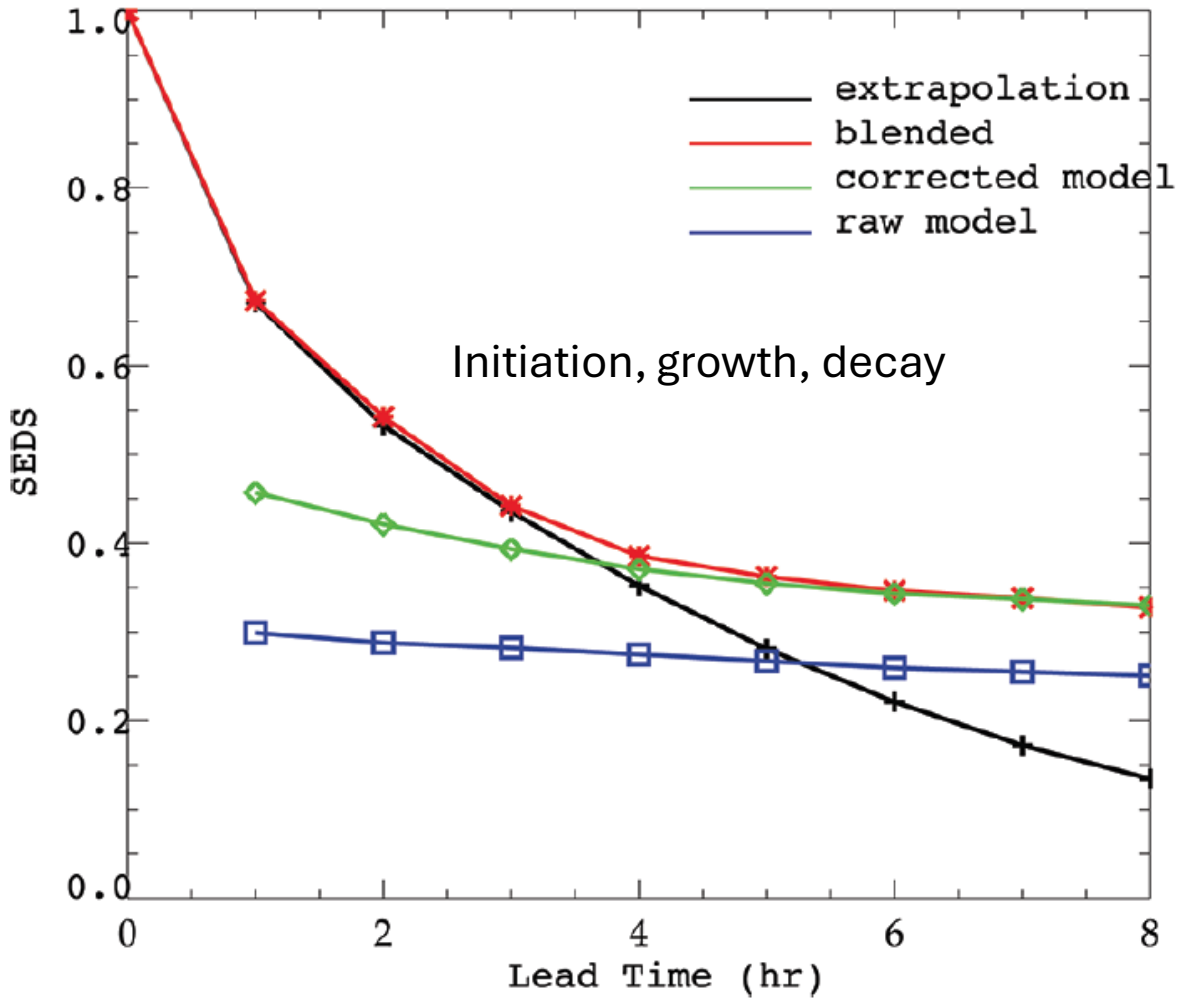
A super-ensemble with rapid update and adjustment to the latest observations was implemented.

A winter multi-variable non-radar point forecast system



What is the skill of persistence, trending using models and blending

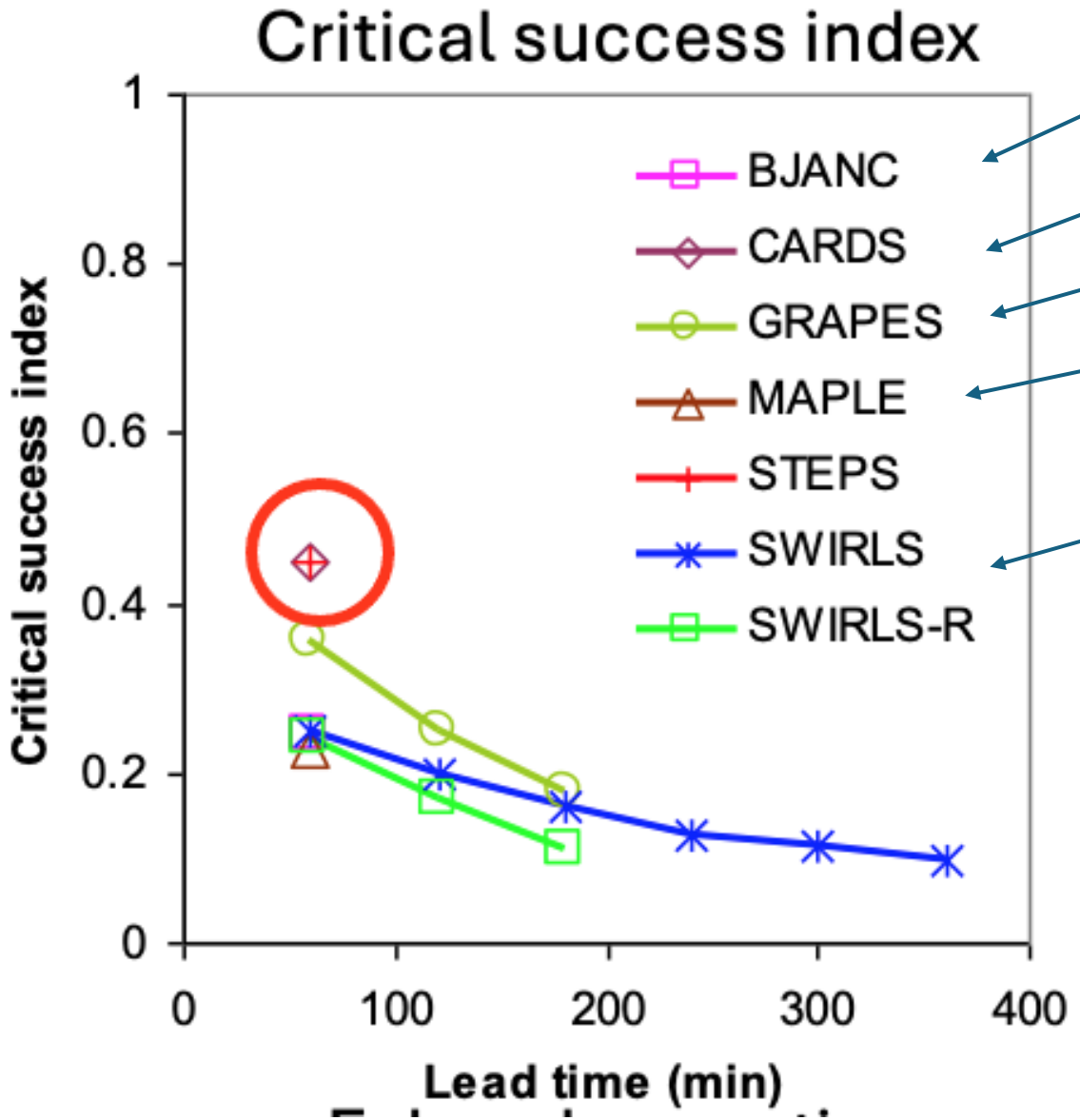
- Persistence
- Trending
- Blending



USE OF NWP FOR NOWCASTING CONVECTIVE PRECIPITATION
Recent Progress and Challenges
by Juanzhen Sun, Ming Xue, James W. Wilson, Isztar Zawadzki, Sue P. Ballard, Jeanette Onvlee-Hooimeyer, Paul Joe, Dale M. Barker, Ping-Wah Li, Brian Golding, Mei Xu, and James Pinto

Beijing 2008: Precipitation accumulation

Categorical scores for rain ≥ 1 mm h^{-1}



Beijing Autonowcaster

Original

China Model

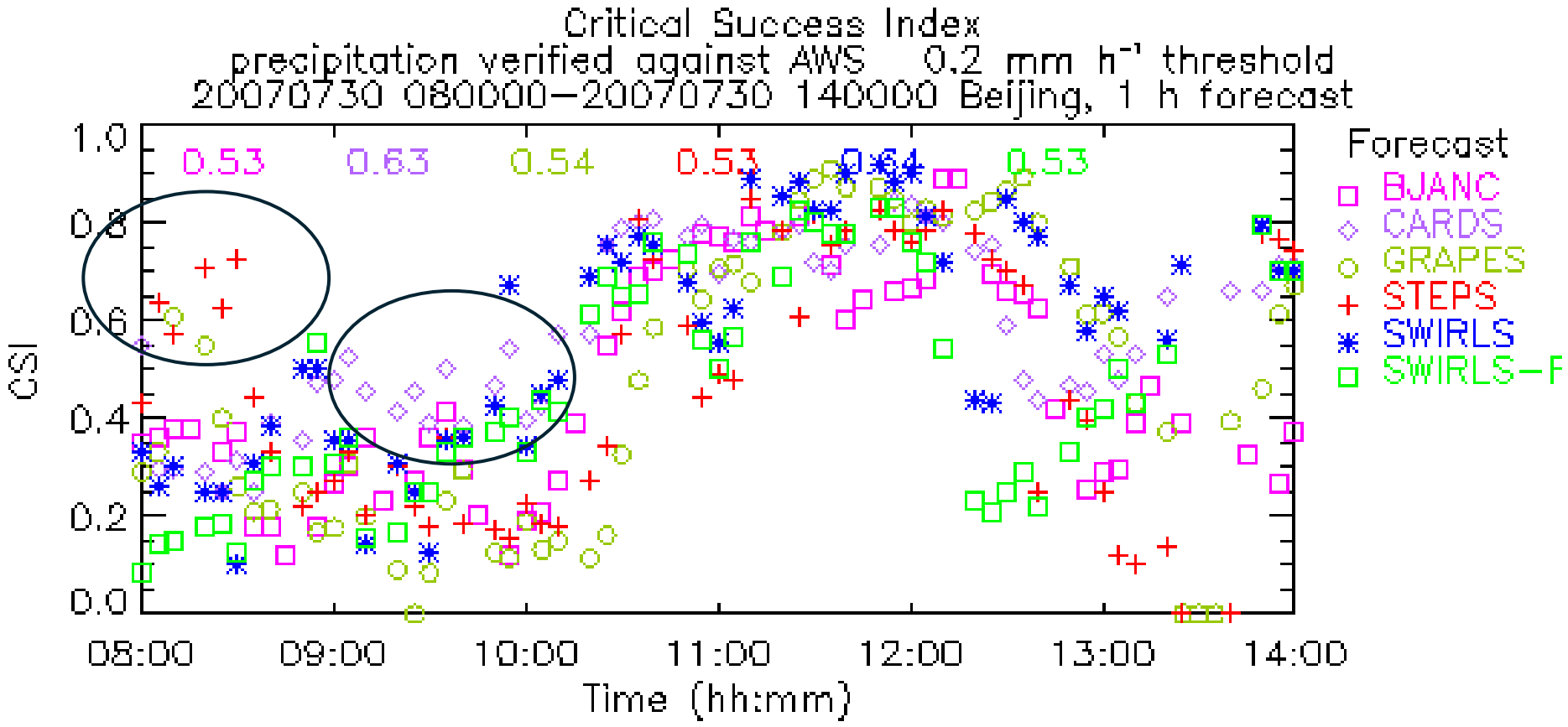
McGill

Hong Kong

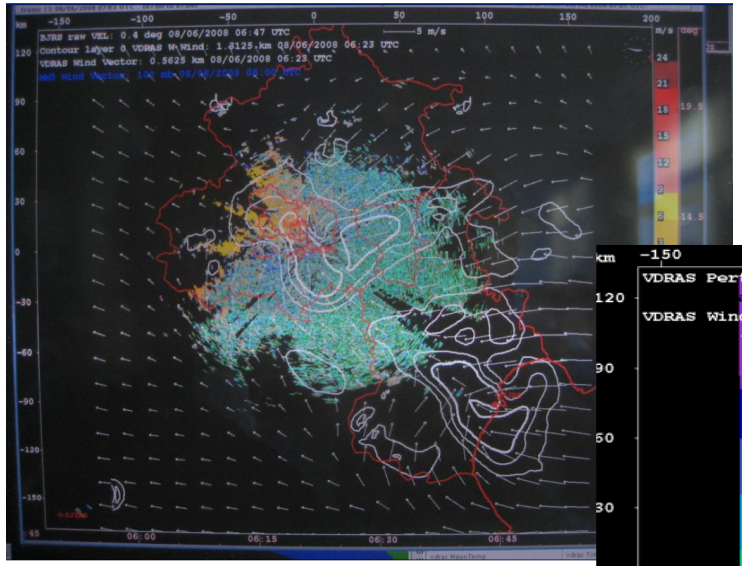
Ebert et al 2014

B08

Real-Time Verification shows which system to trust?

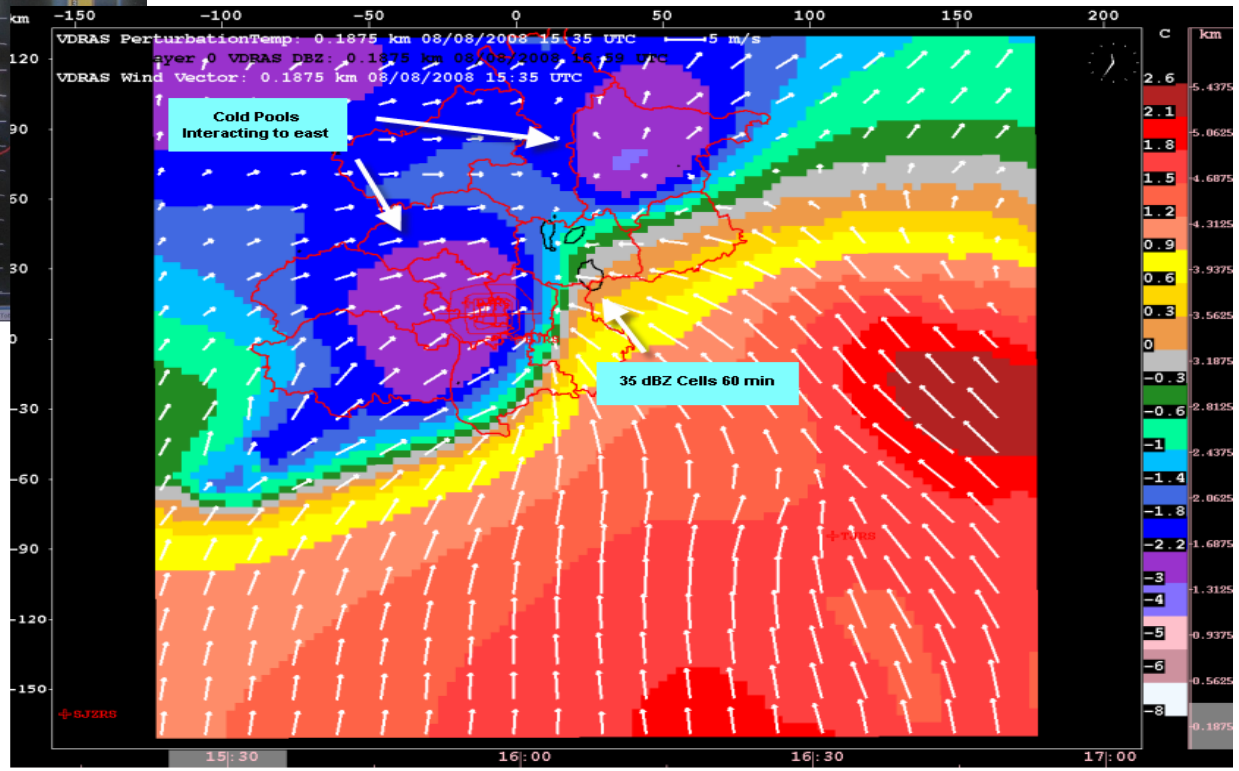


Variational Doppler Radar Assimilation System (VDRAS) Diagnostics for Growth/Decay



Doppler radial velocity image with wind vectors and contours of convergence

All data sources assimilated into a model, various model parameter fields are displayed for **diagnostic** purposes for support of identifying convergence in different fields!



Temperature Perturbation Field

Courtesy: Jenny Sun - NCAR

Many Other Systems

- WDSS – commercial (WDT-NSSL)
- INCA – integrated comprehensive analysis (ZAMG)
- SWANS – China
- AWIPS – U.S.A.
- NinJo – Germany, Switzerland, Denmark, Canada, …
- …

Challenges ahead…

General Aviation Navigation Plan

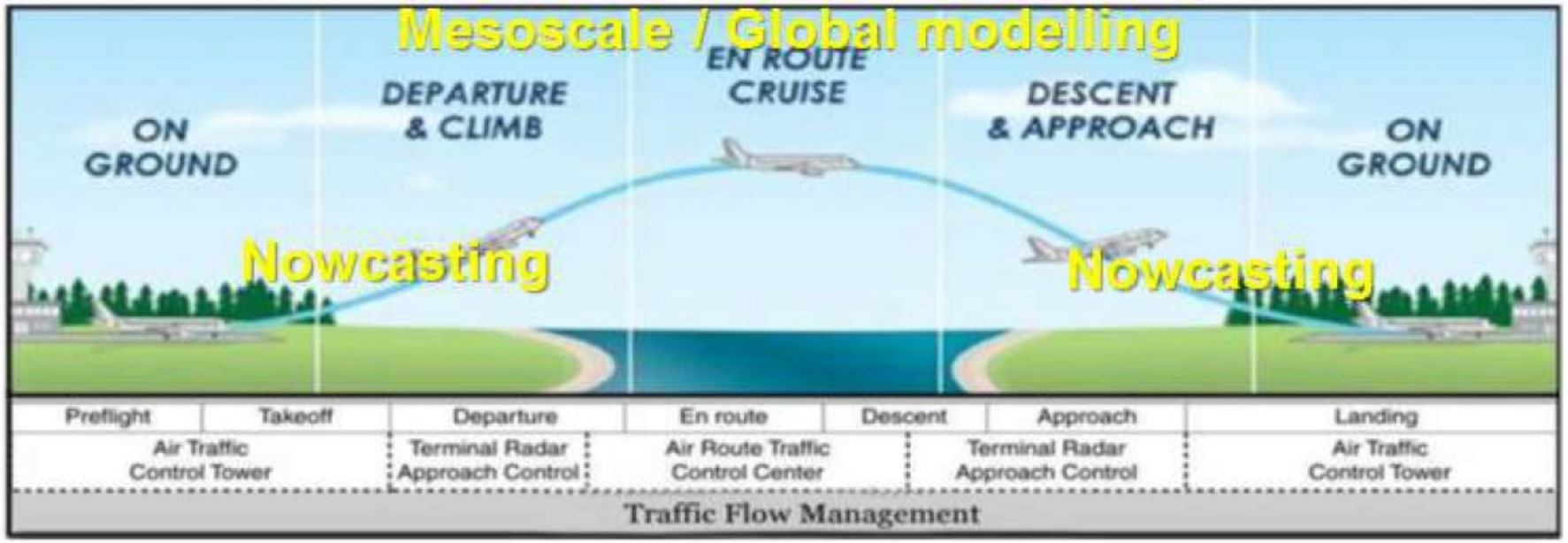
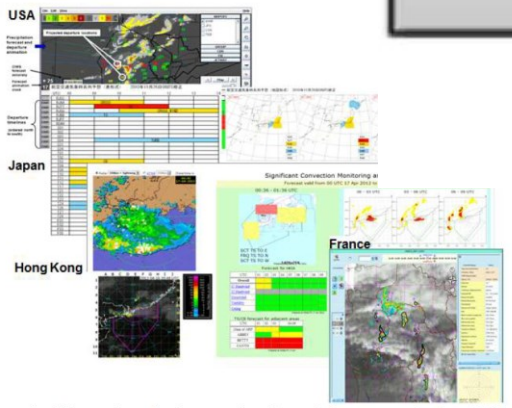
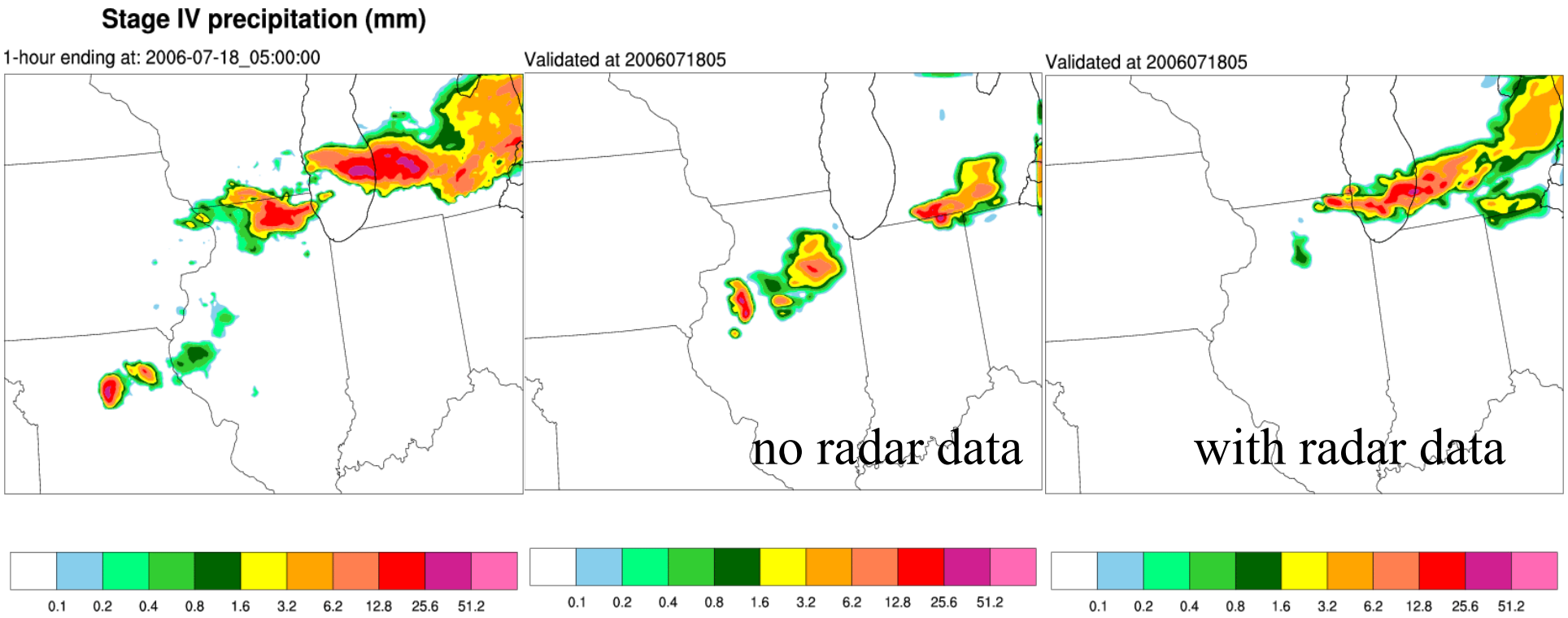


Fig.1 Seamless meteorological information required under the Trajectory Based Operation (TBO) concept



Impact of assimilating reflectivity via nudging

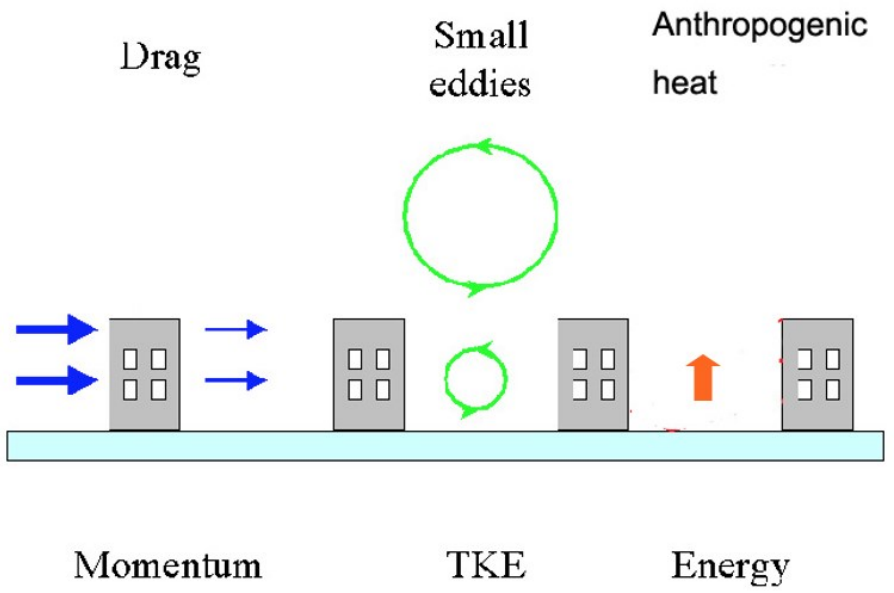
convective storm July 17, 2006

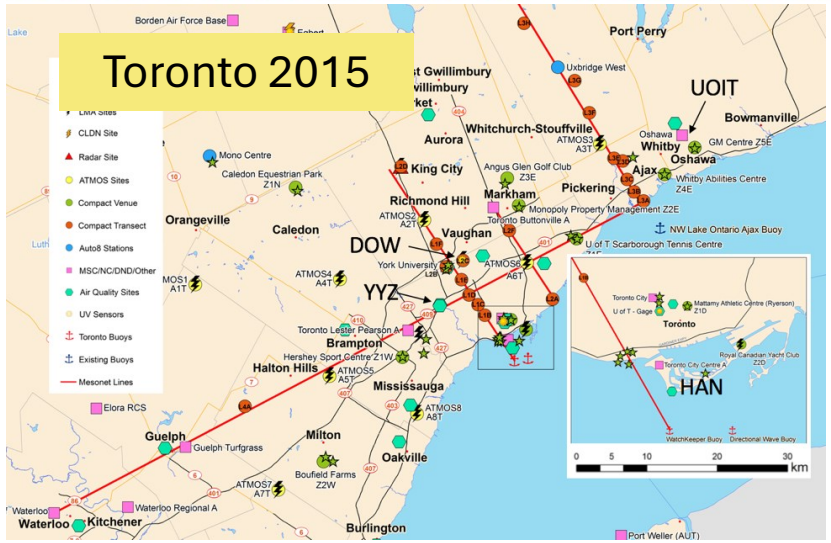


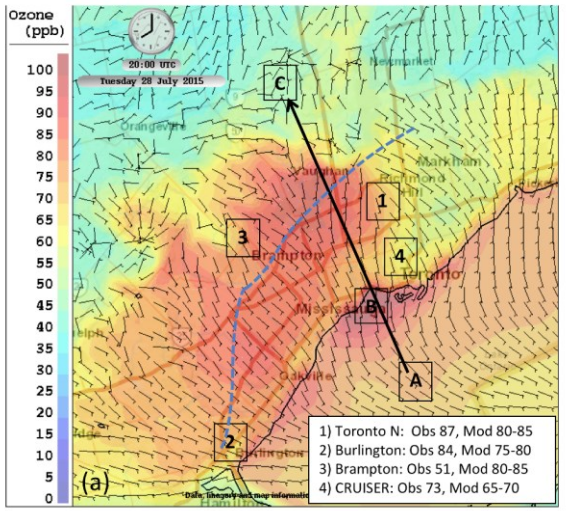
20060718 05 Z: 6 h forecasts

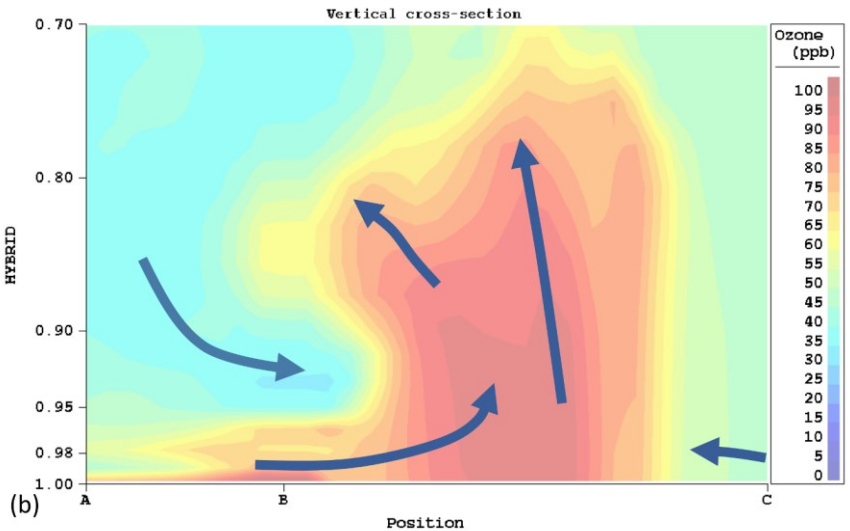
Helsinki NWG Meeting,
Courtesy J. Sun, NCAR

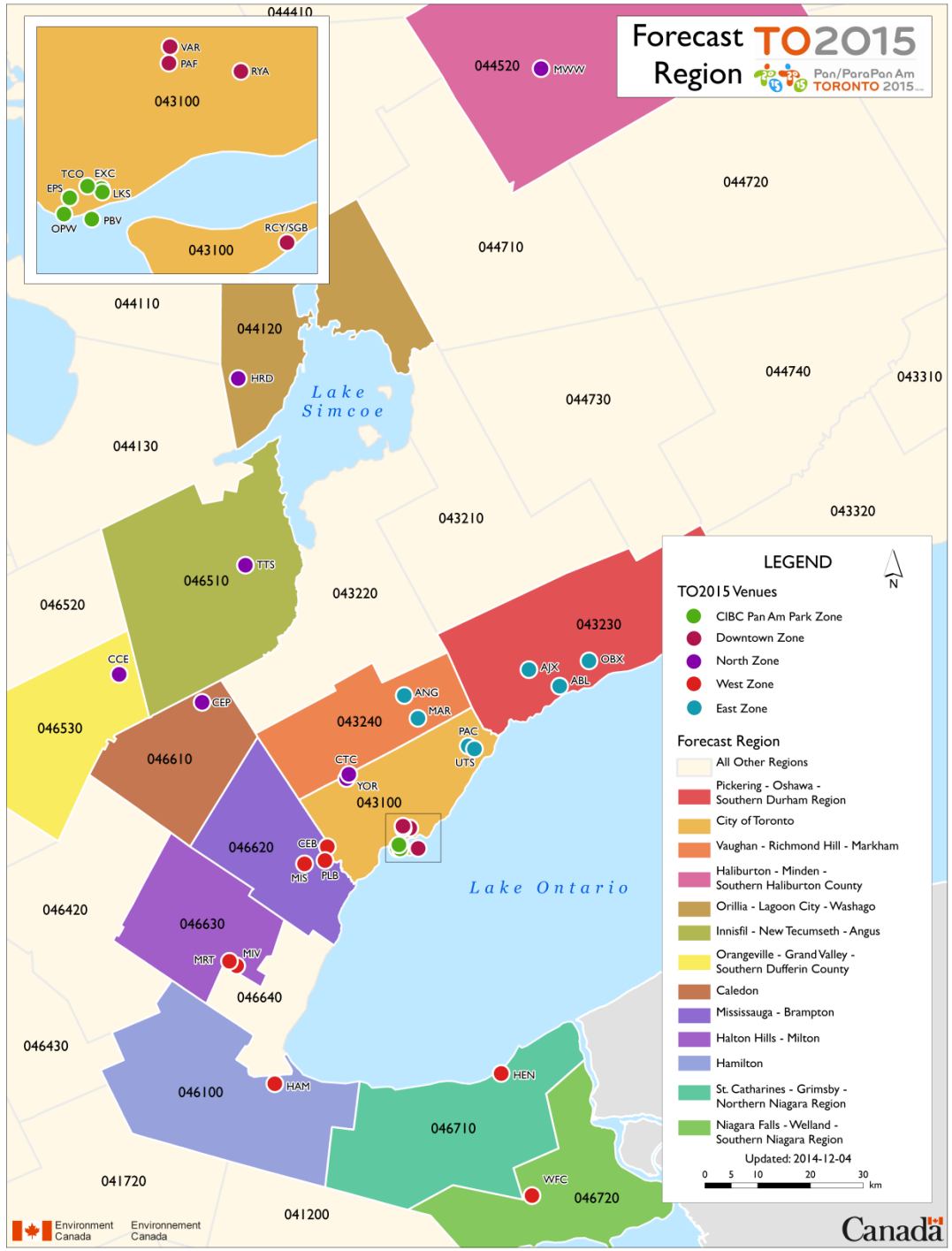

RDP on the Paris 2024 Olympic Games
Valéry Masson


Drag
Small eddies
Anthropogenic heat
Momentum
TKE
Energy


Toronto 2015
Port Perry
UOIT
Bowmanville
Whitchurch-Stouffville
Aurora
King City
Markham
Pickering
Ajax
Whitby
Oshawa
Richmond Hill
Vaughan
Orangeville
Caledon
DOW
YYZ
Brampton
Halton Hills
Mississauga
Milton
Oakville
Guelph
Burlington
Waterloo
Kitchener
HAN
Toronto
CLDN Site
Radar Site
ATMOS Sites
Compact Venue
Compact Transect
Auto8 Stations
MSC/NC/DND/Other
Air Quality Sites
UV Sensors
Toronto Buoys
Existing Buoys
Mesonet Lines
km

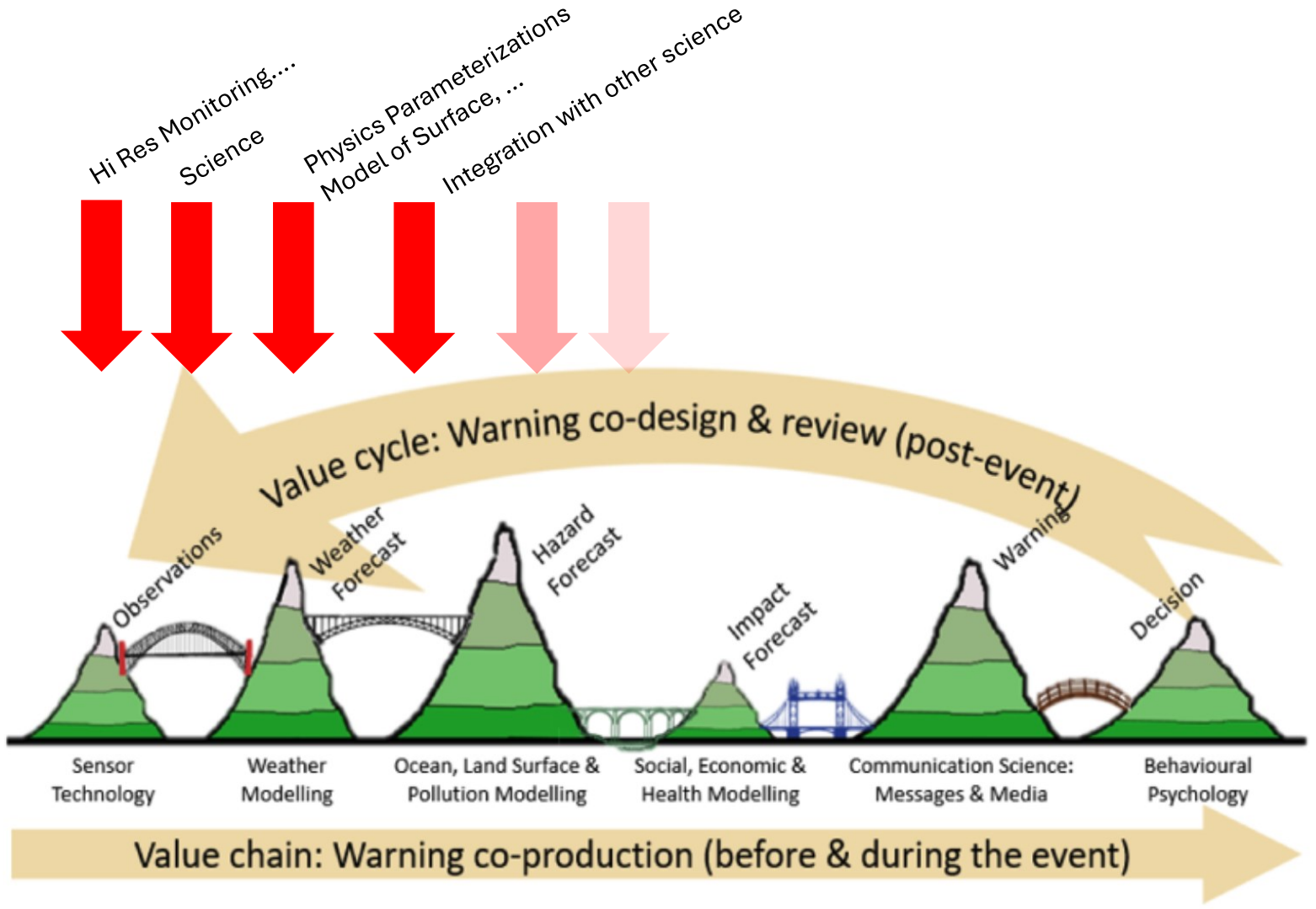

Ozone (ppb)
20:00 UTC
Tuesday 28 July 2015
1) Toronto N: Obs 87, Mod 80-85
2) Burlington: Obs 84, Mod 75-80
3) Brampton: Obs 51, Mod 80-85
4) CRUISER: Obs 73, Mod 65-70
(a)


Vertical cross-section
Ozone (ppb)
HYBRID
Position
(b)


Forecast Region TO2015
Pan/ParaPan Am TORONTO 2015
044410
044520
MWW
044720
044710
044110
044120
HRD
Lake Simcoe
044740
044730
043310
044130
043210
043320
046510
TTS
046520
043220
043230
AJX
OBX
ABL
CCE
CEP
046530
ANG
MAR
043240
PAC
UTS
046610
CTC
YOR
043100
046620
CEB
MIS
PLB
Lake Ontario
046420
046630
MRT
MIV
046640
046430
HAM
046100
HEN
046710
WFC
046720
041720
041200
VAR
PAF
RYA
043100
TCO
EXC
EPS
LKS
OPW
PBV
RCY/SGB
043100
LEGEND
N
TO2015 Venues
CIBC Pan Am Park Zone
Downtown Zone
North Zone
West Zone
East Zone
Forecast Region
All Other Regions
Pickering - Oshawa - Southern Durham Region
City of Toronto
Vaughan - Richmond Hill - Markham
Haliburton - Minden - Southern Haliburton County
Orillia - Lagoon City - Washago
Innisfil - New Tecumseth - Angus
Orangeville - Grand Valley - Southern Dufferin County
Caledon
Mississauga - Brampton
Halton Hills - Milton
Hamilton
St. Catharines - Grimsby - Northern Niagara Region
Niagara Falls - Welland - Southern Niagara Region
Updated: 2014-12-04
0 5 10 20 30
km
Environment Canada
Environnement Canada
Canada

Direction

- Data
- Science gaps
- Integration with other disciplines
  - hydrology
  - AQ
  - Heat
  - Urban
- Post-processing including ensembles
- Hazards, impacts
- Communication gaps
- Service gaps
- Behaviour / psychology issues

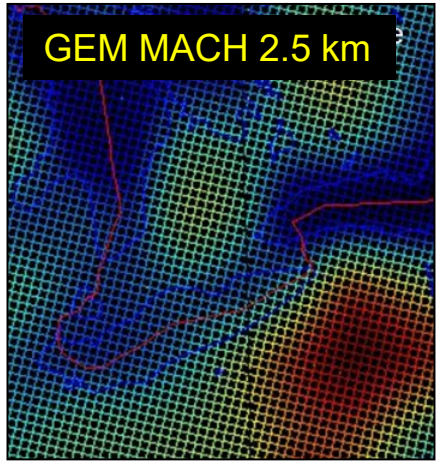


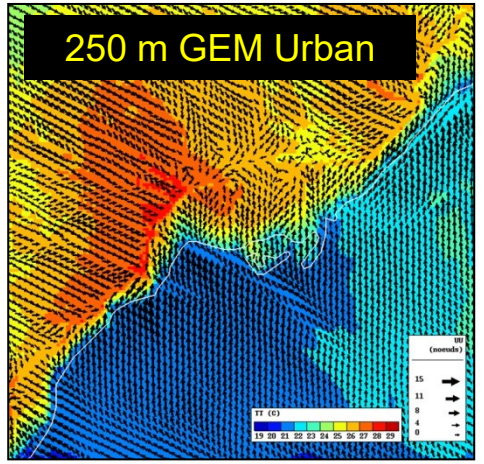
Schematic value chain for high impact weather warning showing the capabilities and outputs (green "mountains") and information exchanges (bridges) linking the capabilities and their associated communities (from Golding et al. GAR2019).

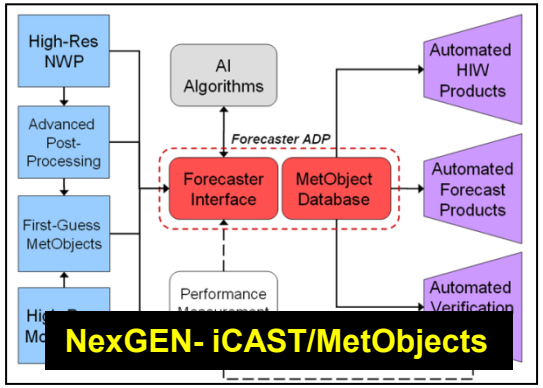
Obrigado!

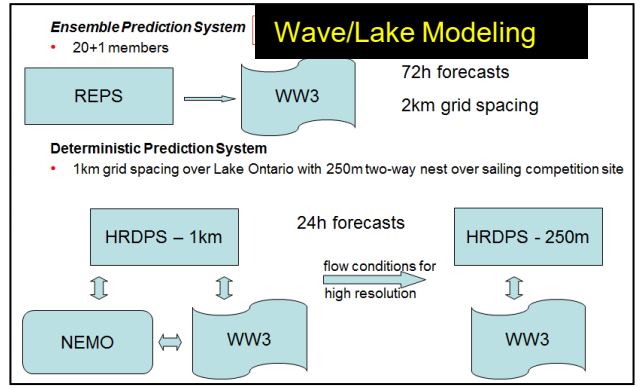
Forecast/Nowcast System

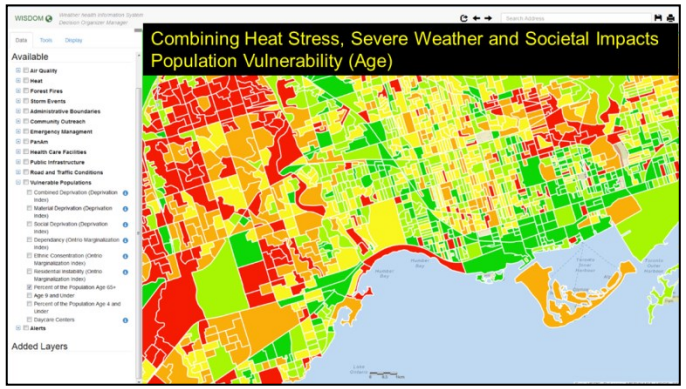
- 2.5 km GEM MACH AQ (HPC)
- 250 m GEM Urban Model (HPC)
- Wave/Lake Model (MetAreas)
- NexGEN (MetObjects)
- Point Nowcasting
- Health Services
- Societal User Impacts

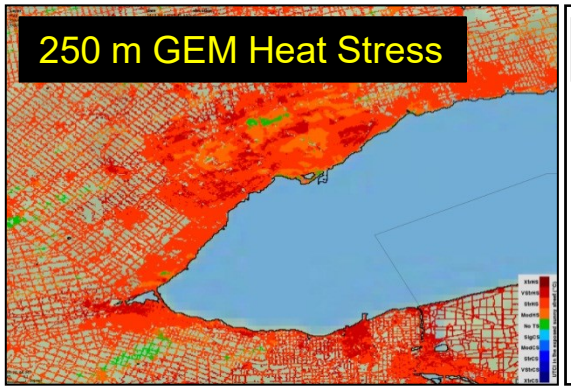


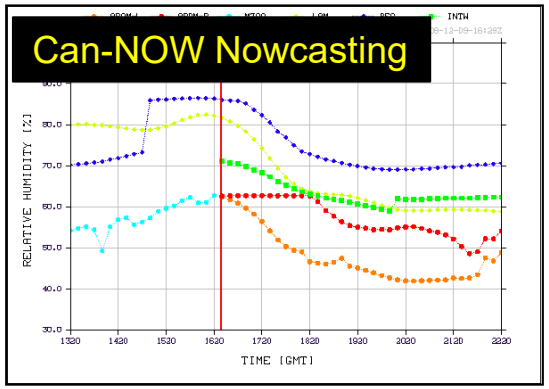






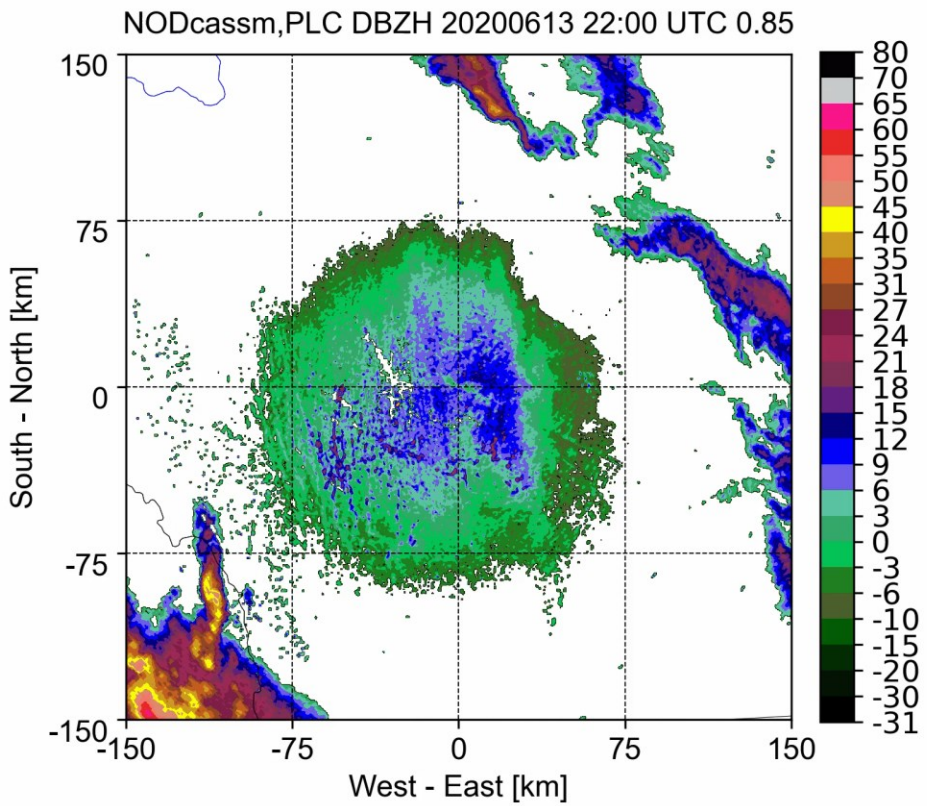


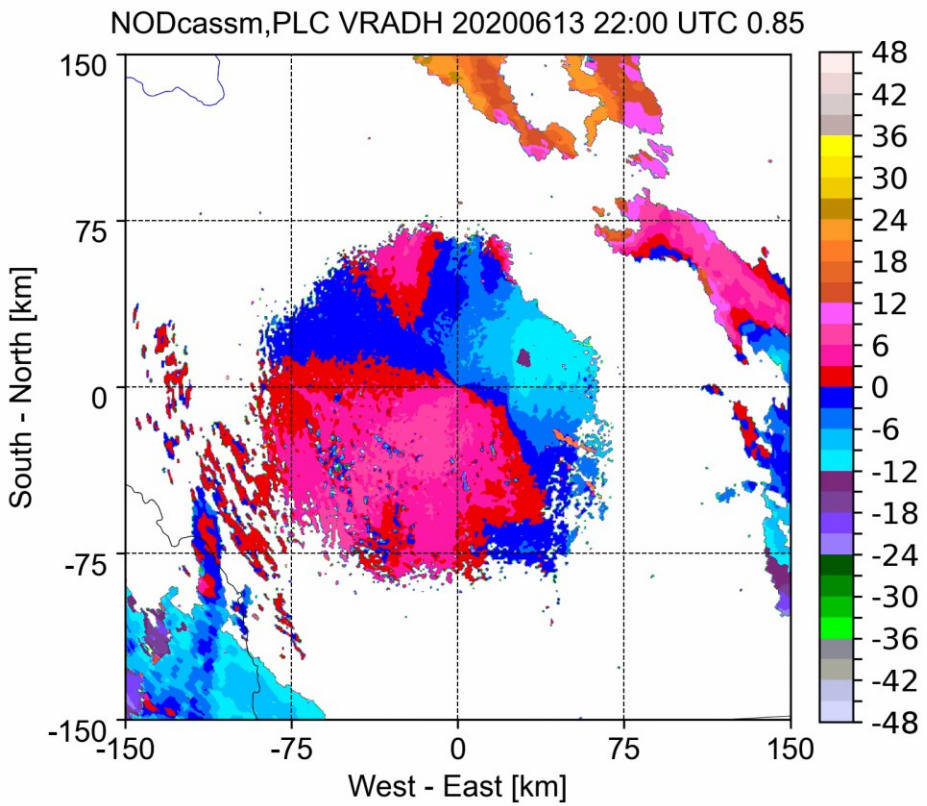




	RDP	FDP*	National	Focus
Atlanta 1996			X	NWS+
MAP (Map Alpine Project) 1999	X			First RDP, EU, hydrology focus, mountains and high impact
Sydney 2000				torms, algorithms
Salt Lake City 2002 (w) / Torino 2006 (w) /Athens 2006			X	ector; Regional Wx Office; None
Beijing 2008	X	X		Nowcasting, Blending, User interface
Vancouver 2010 (w)	X	X		First Winter nowcasting visibility, precipitation, mixed weather, hybrid
London 2012			X	MO Technology transfer
Sochi 2014 (w)	X	X		Winter, technology introduction (high resolution, automation, integrated nowcasting), hybrid
Toronto PA 2015	(X)		X+	Data open under GURME (post-project) Global Atmospheric Watch Urban Meteorology
TOMACS 2010-2015 Tokyo Metropolitan Area Convection Study	X		X+	International RDP 2013-2015, urban convection, high resolution (non sport)
Rio 2016 / HIGHWAY			(X)	Local or regional nowcasting introduction / (non sport)
Pyeongchang 2018 (w)	X	X		Microphysical parameterization
Tokyo 2020			X	Follow on to TOMACS
Beijing 2022 (w)			X	Wind, (snow ~5 cm), technology transfer, service focus
Paris 2024	X	X		Urban air quality, modelling

Research Development Project
Forecast Demonstration Project
* real-time, verification, societal impacts


NODcassm,PLC DBZH 20200613 22:00 UTC 0.85
South - North [km]
West - East [km]
150
75
0
-75
-150
80
70
65
60
55
50
45
40
35
31
27
24
21
18
15
12
9
6
3
0
-3
-6
-10
-15
-20
-30
-31


NODcassm,PLC VRADH 20200613 22:00 UTC 0.85
South - North [km]
West - East [km]
150
75
0
-75
-150
48
42
36
30
24
18
12
6
0
-6
-12
-18
-24
-30
-36
-42
-48

The Storm Changes ….

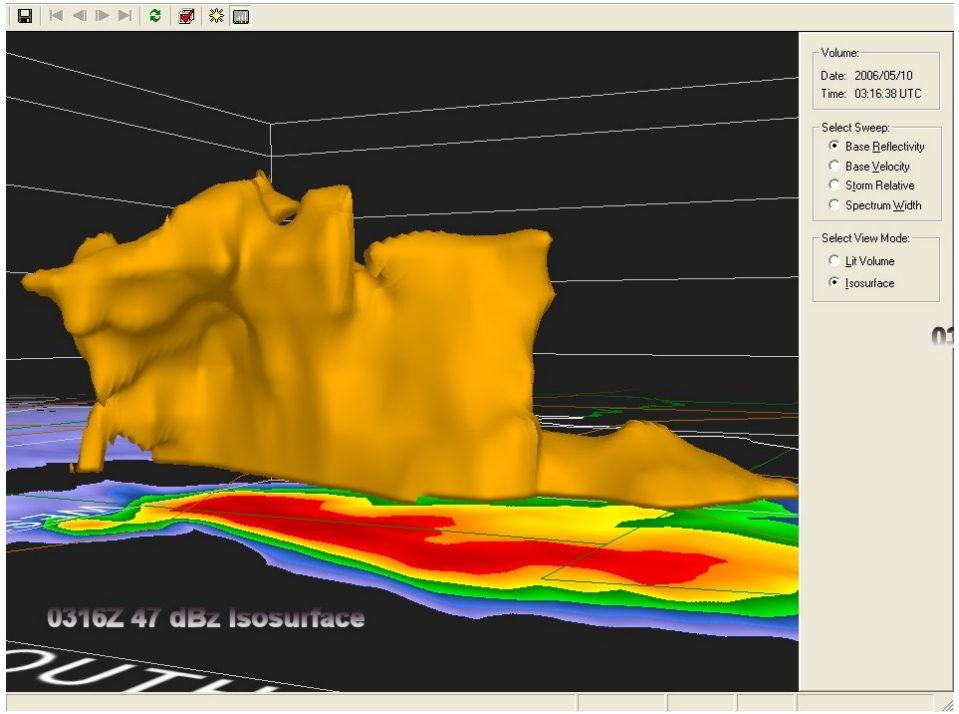
1. WER forms & severe weather commences.

2. BWER, mid-level mesocyclone develops, & hook echo forms, largest hail falls, strong winds can occur.

3. Mesocyclone matures, BWER fills, WER lessens, echo top descends, hook echo wraps up, (echo collapse phase) hail decreases, microbursts occur, tornado develops & intensifies.

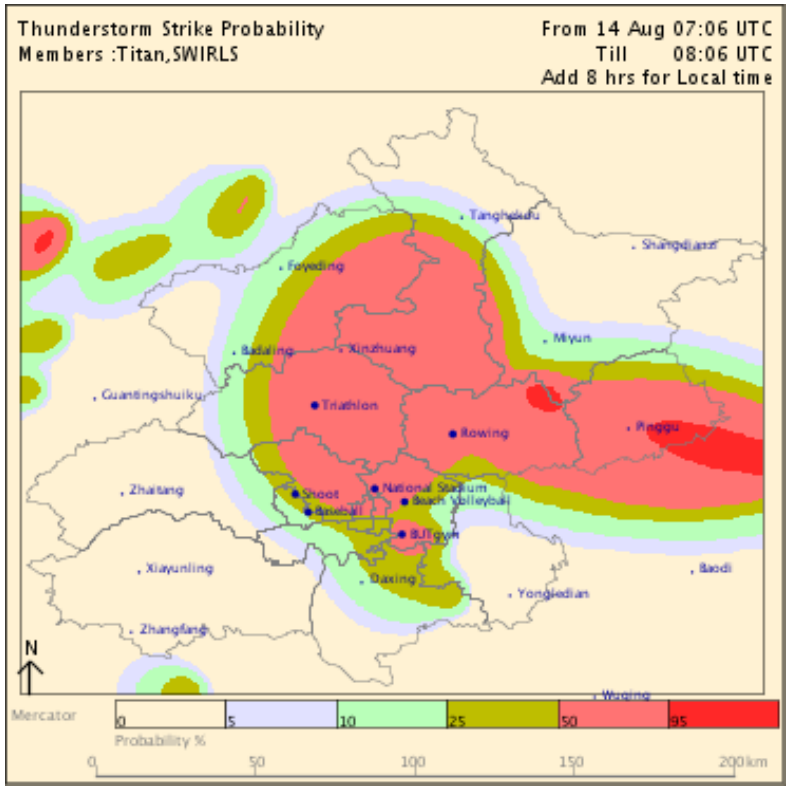
4. *Most significant tornadoes often occur AFTER BWER/storm top collapse (descent of RFD precip), and even after storm loses “classic” reflectivity features.

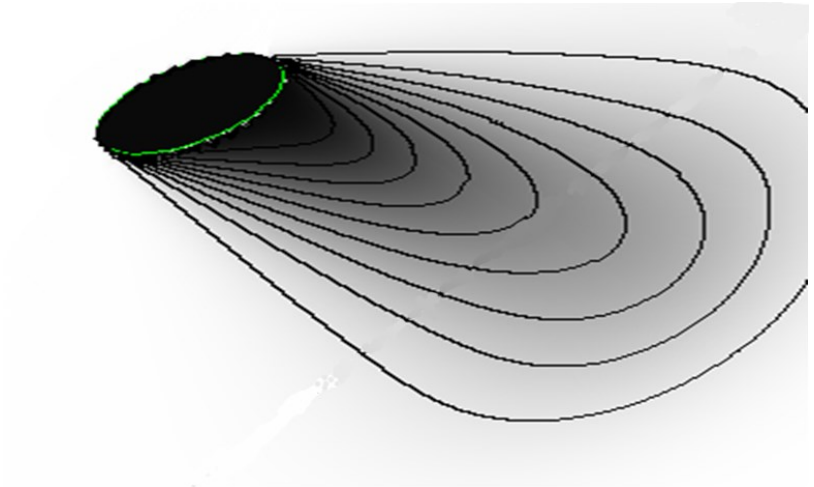
- Can recycle.



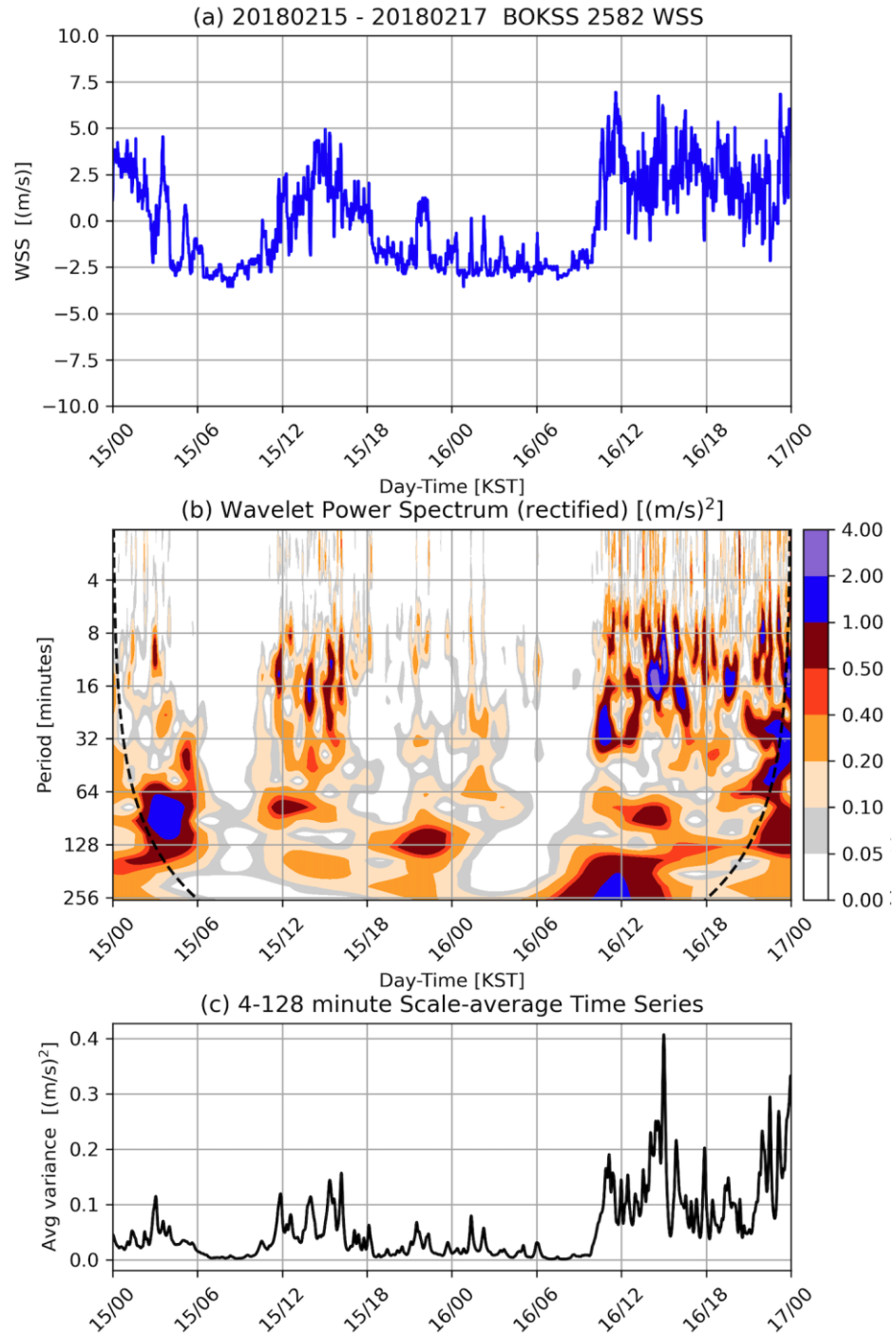
Strike Probability

Track based warnings, probabilistic
narrow the area – convey uncertainty

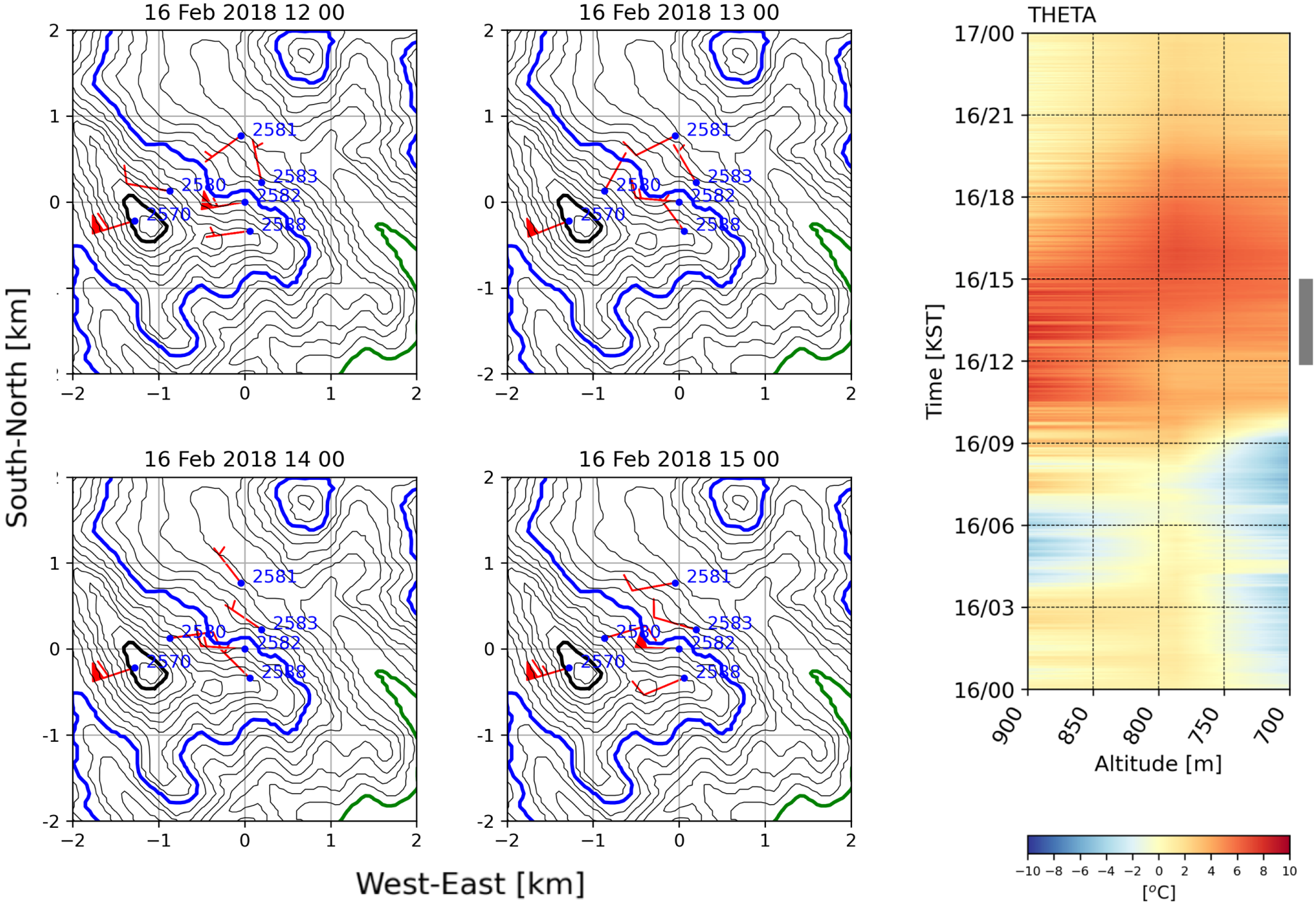




Bally 2009


(a) 20180215 - 20180217 BOKSS 2582 WSS
WSS [(m/s)]
10.0
7.5
5.0
2.5
0.0
−2.5
−5.0
−7.5
−10.0
15/00
15/06
15/12
15/18
16/00
16/06
16/12
16/18
17/00
Day-Time [KST]
(b) Wavelet Power Spectrum (rectified) [(m/s)^2]
Period [minutes]
4
8
16
32
64
128
256
4.00
2.00
1.00
0.50
0.40
0.20
0.10
0.05
0.00
Day-Time [KST]
(c) 4-128 minute Scale-average Time Series
Avg variance [(m/s)^2]
0.4
0.3
0.2
0.1
0.0

final


16 Feb 2018 12 00
16 Feb 2018 13 00
16 Feb 2018 14 00
16 Feb 2018 15 00
2581
2583
2580
2582
2570
2588
South-North [km]
West-East [km]
THETA
Time [KST]
17/00
16/21
16/18
16/15
16/12
16/09
16/06
16/03
16/00
900
850
800
750
700
Altitude [m]
−10 −8 −6 −4 −2 0 2 4 6 8 10
[°C]

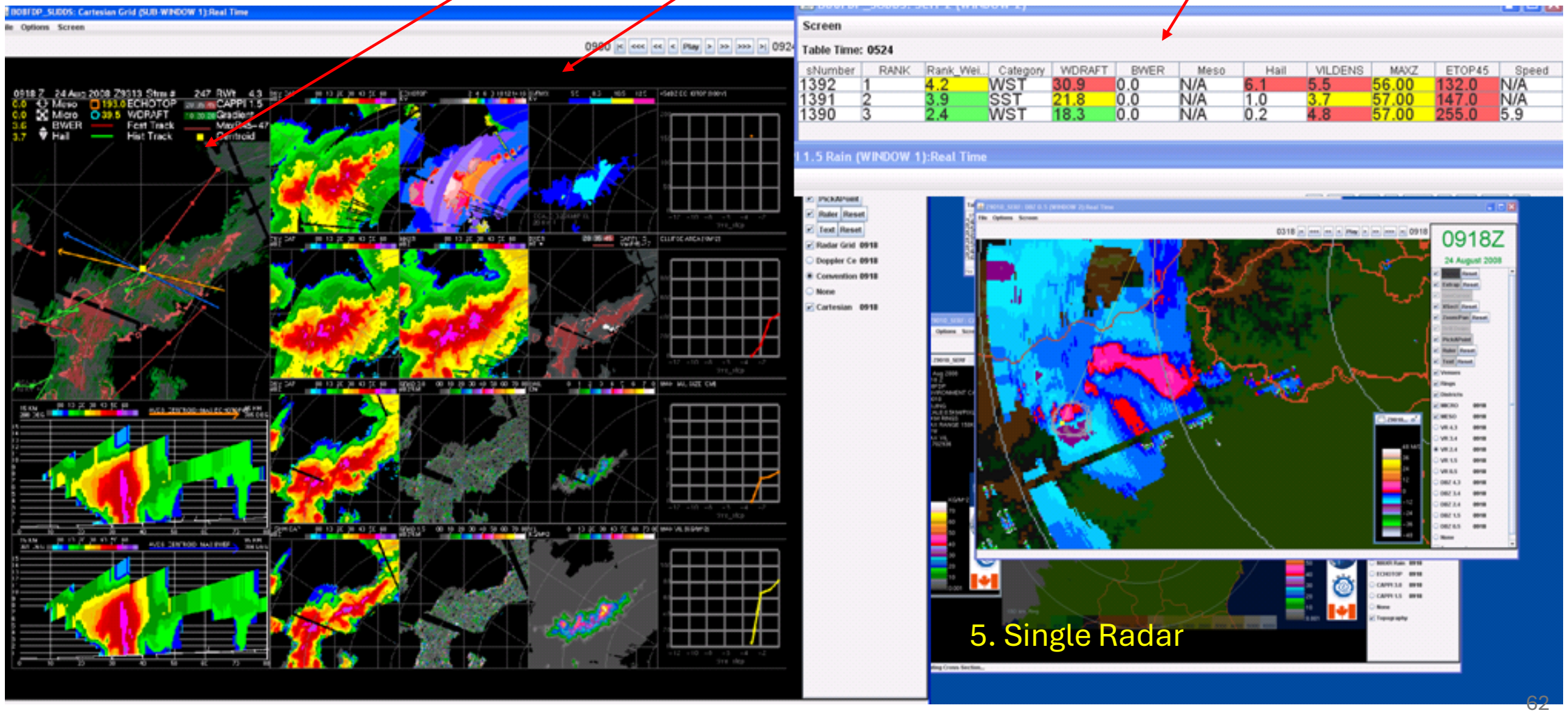
CARDS designed based on a task analysis…

2. Automatic Feature Identification of Lemon Technique

4. Fuzzy logic classification of storms

3. Diagnostic Support

1. Cell view



Forecasters must be able to diagnose the salient features to make a warning decision

Severe Storm Features

-Large cell with strong reflectivity (MAXR>45 dBZ)

-Tall (high echo top)

-Hail

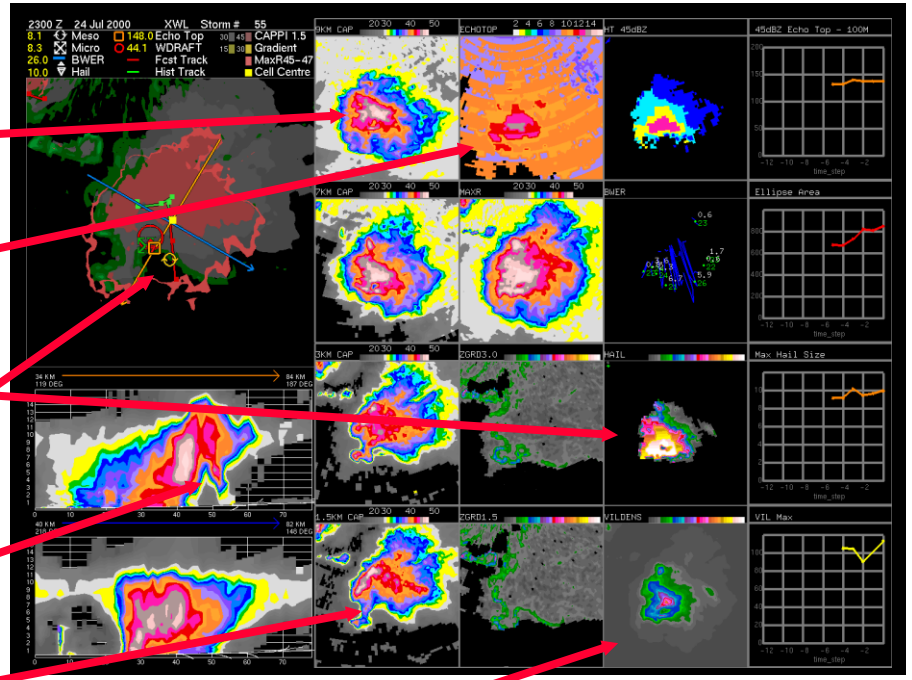
-Low level Reflectivity gradients under highest echo tops

-Weak Echo Region

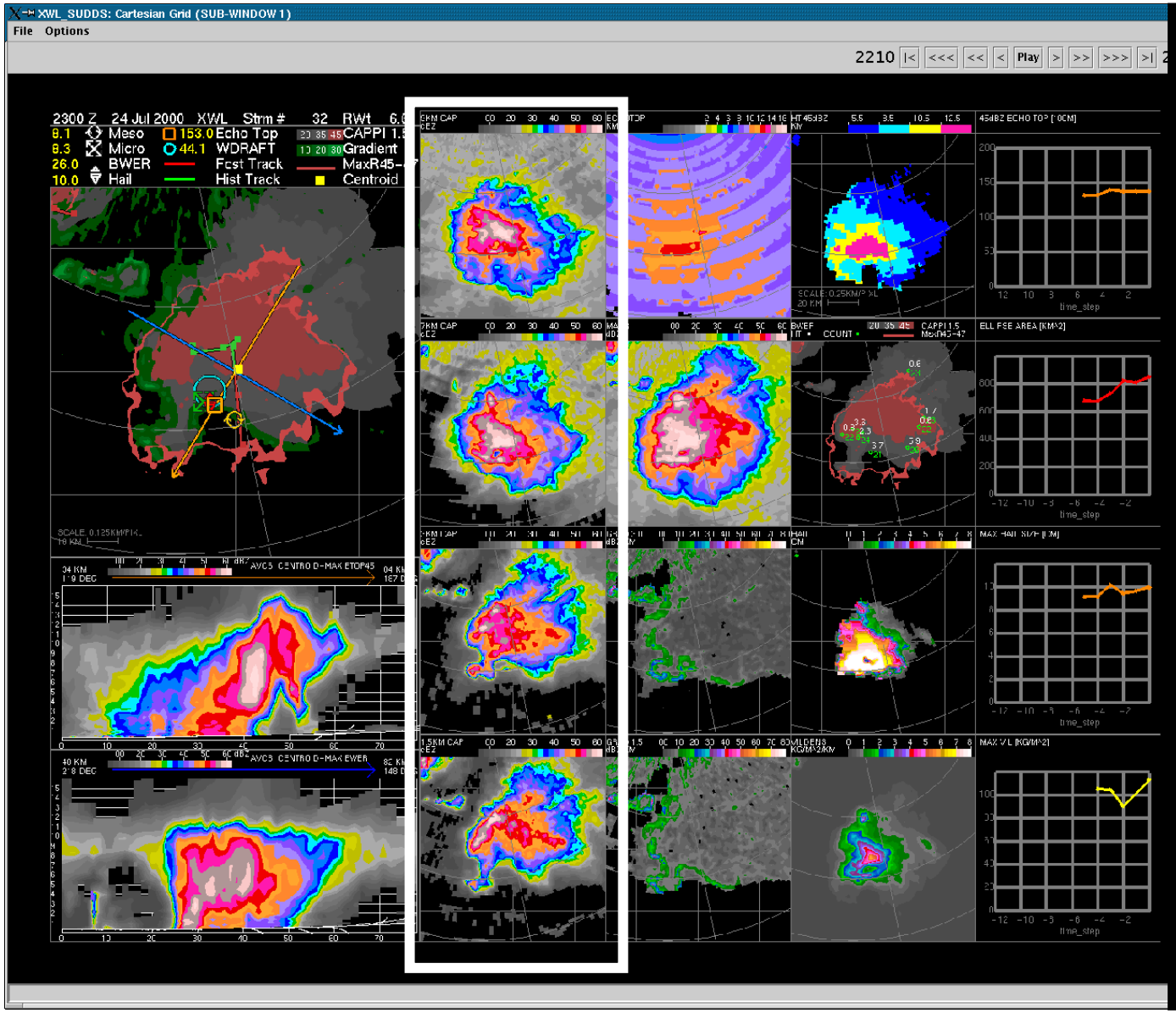
-Hook/Kidney beam shape

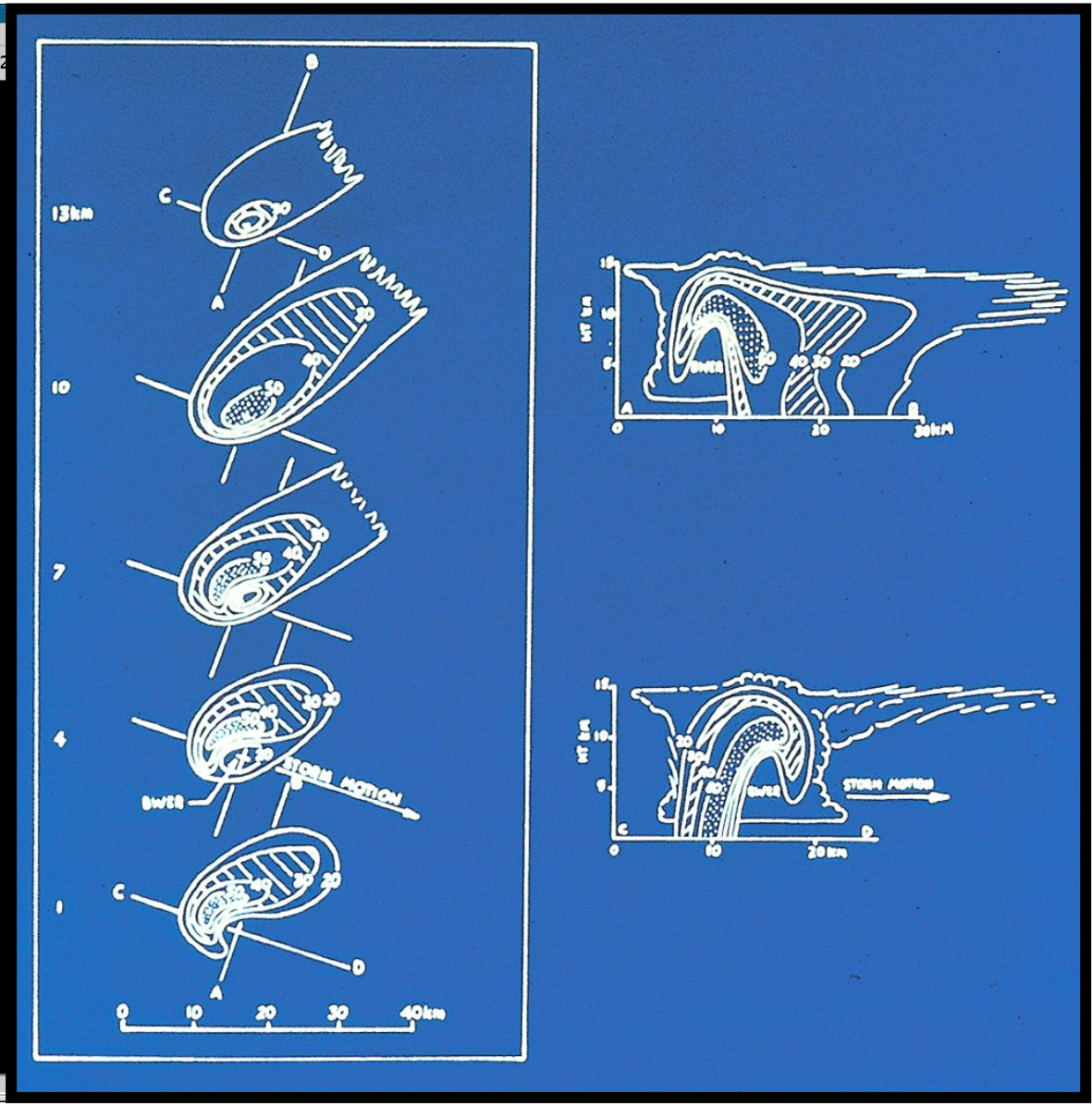
-Mesocyclones

-Downdrafts

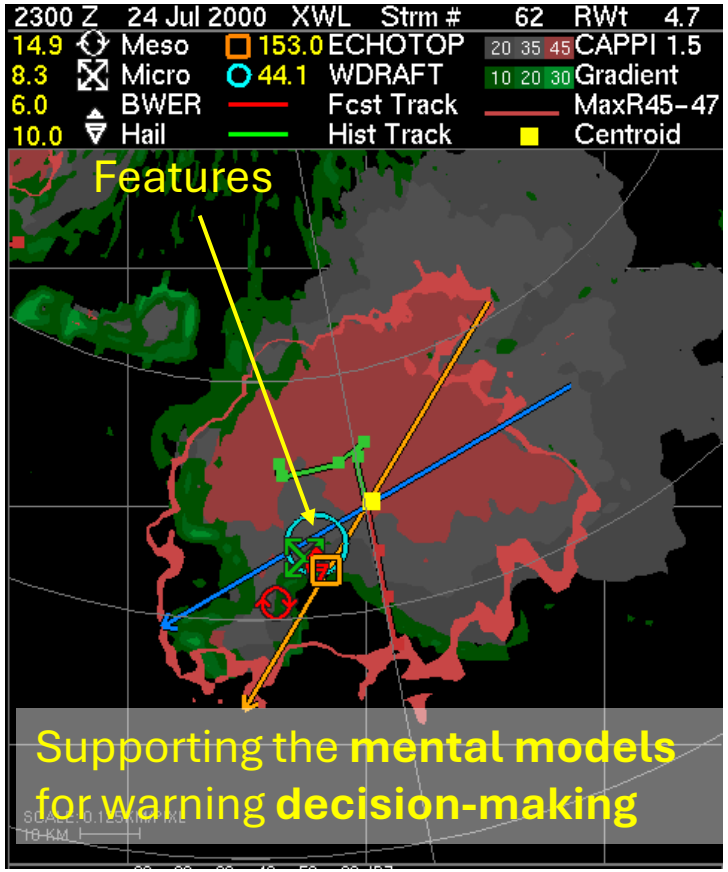


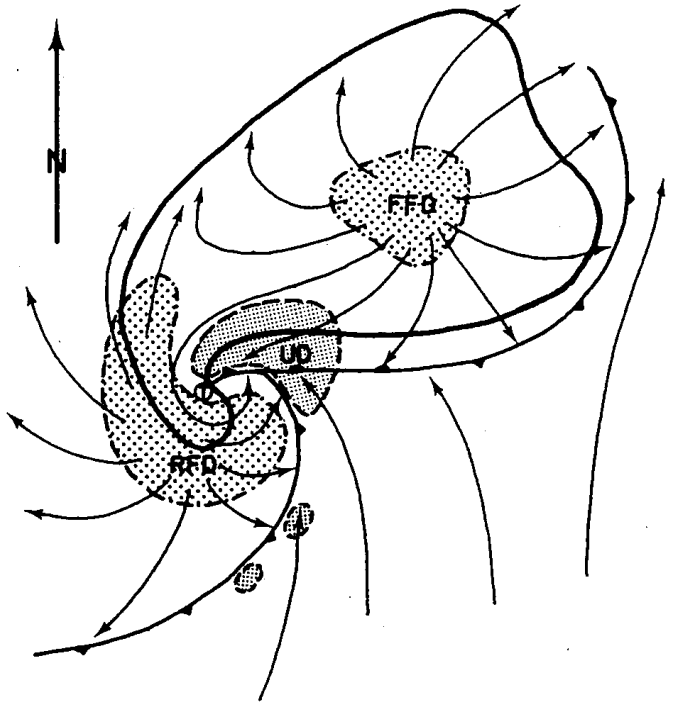
Cell View


XWL_SUDDS: Cartesian Grid (SUB-WINDOW 1)
File Options
2210
Play
2300 Z 24 Jul 2000 XWL Strm # 32 RWt
Meso
Micro
BWER
Hail
Echo Top
WDRAFT
Fcst Track
Hist Track
Gradient
Centroid
time_step


13km
10
7
4
1
A
B
C
D
BWER
STORM MOTION
0
10
20
30
40km

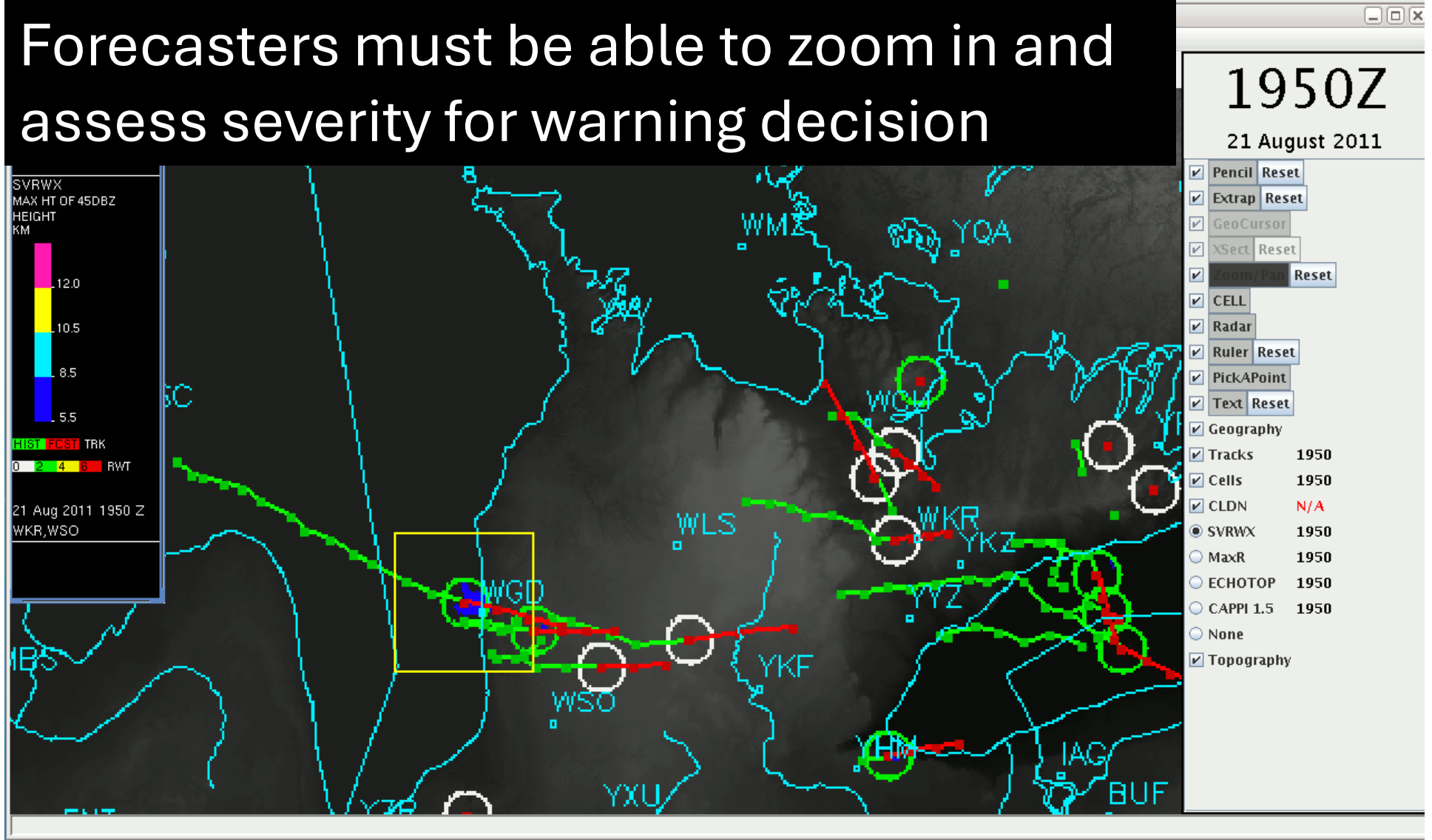
Ensemble of Algorithm View support the **mental models** for **decision-making**





Lemon/Doswell

Forecasters must be able to zoom in and assess severity for warning decision



ONT_SUDDS: SCIT 2 (WINDOW 2)

Screen

Table Time: 1950

sNumber	RANK	Rank_Weight	Category	WDRAFT	BWER	Meso	Hail	VILDENS	MAXZ	ETOP45	Speed
40	1	3.9	SST	22.1	3.1	17.3	3.6	2.3	60.00	78.0	21.8
92	2	2.6	SST	13.7	0.5	22.1	0.0	1.3	60.50	53.0	17.5
112	3	2.2	WST	11.5	0.0	10.0	0.0	1.3	53.50	43.0	17.5
77	4	2.1	WST	5.8	0.0	10.0	0.0	0.8	50.50	44.0	10.9
110	5	2.0	SST	24.3	0.0	0.0	2.4	3.1	65.00	49.0	16.2
116	6	2.0	WST	4.6	0.0	7.0	0.0	0.4	48.50	28.0	N/A
99	7	2.0	WST	5.7	0.0	10.0	0.0	0.8	53.50	42.0	14.5

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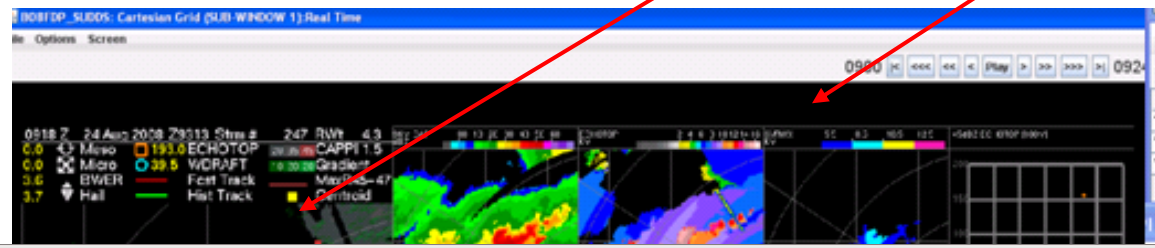
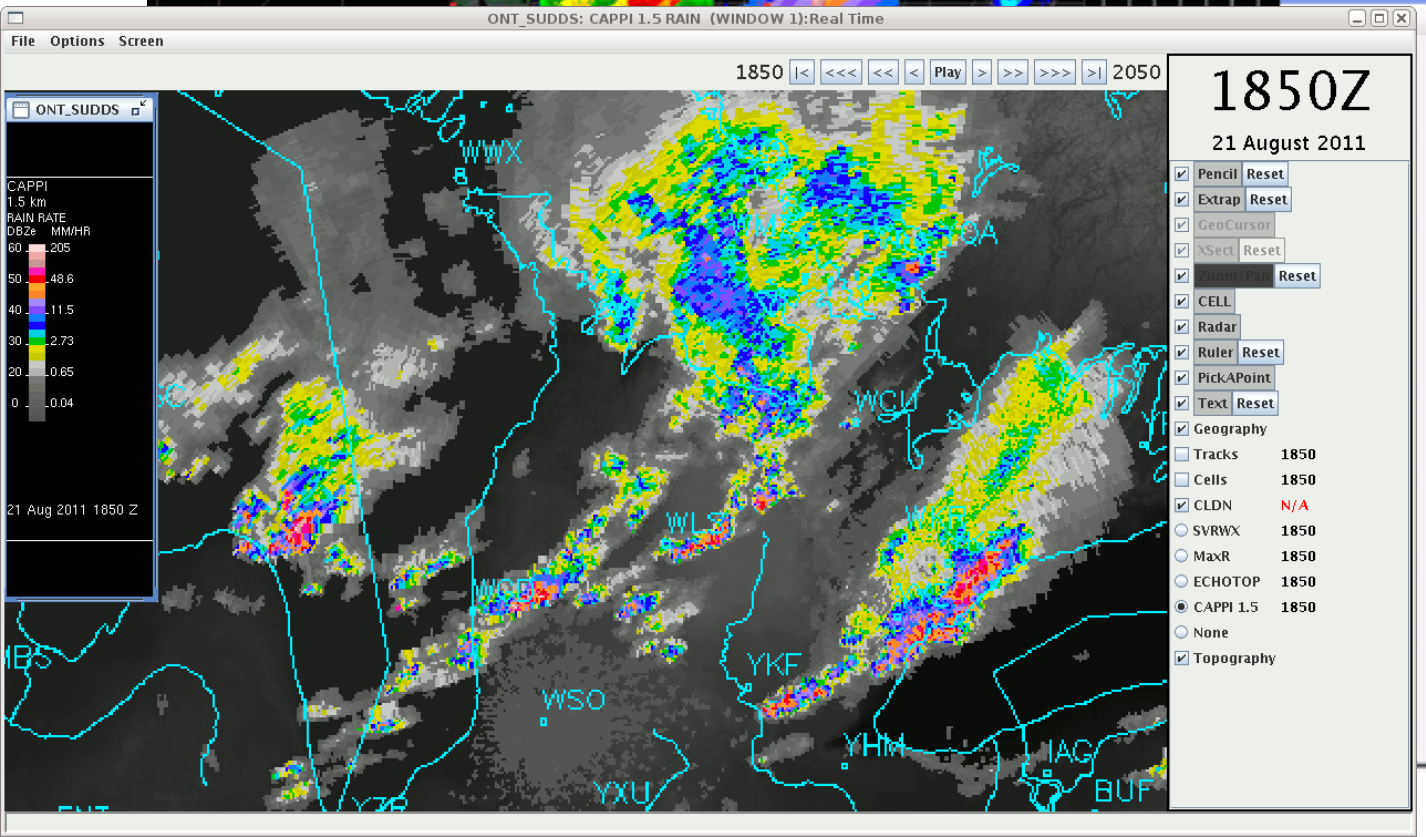
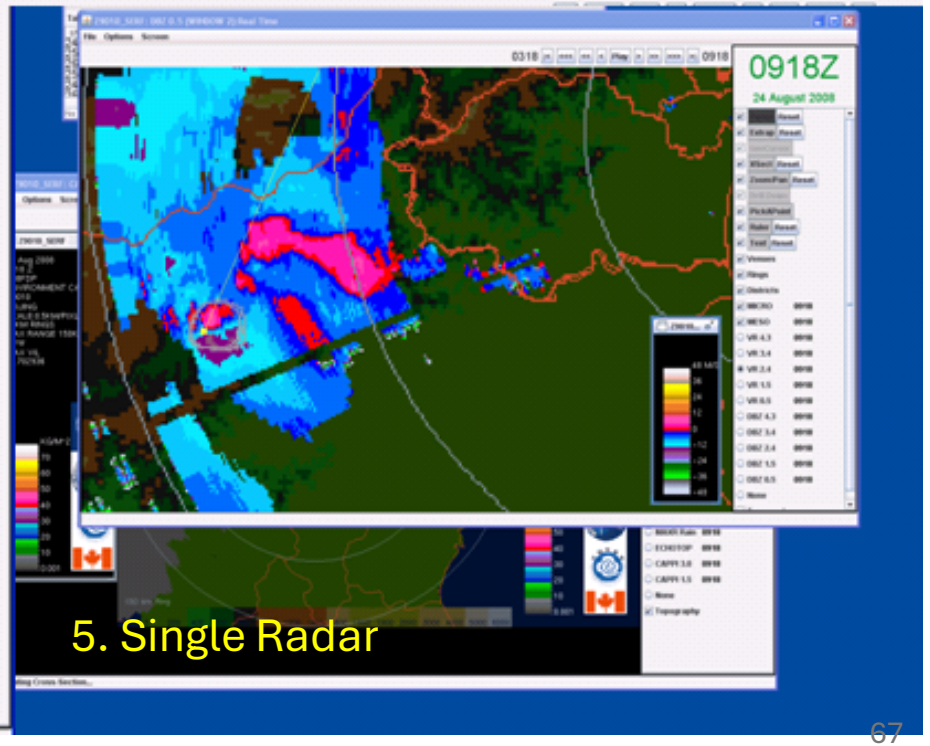
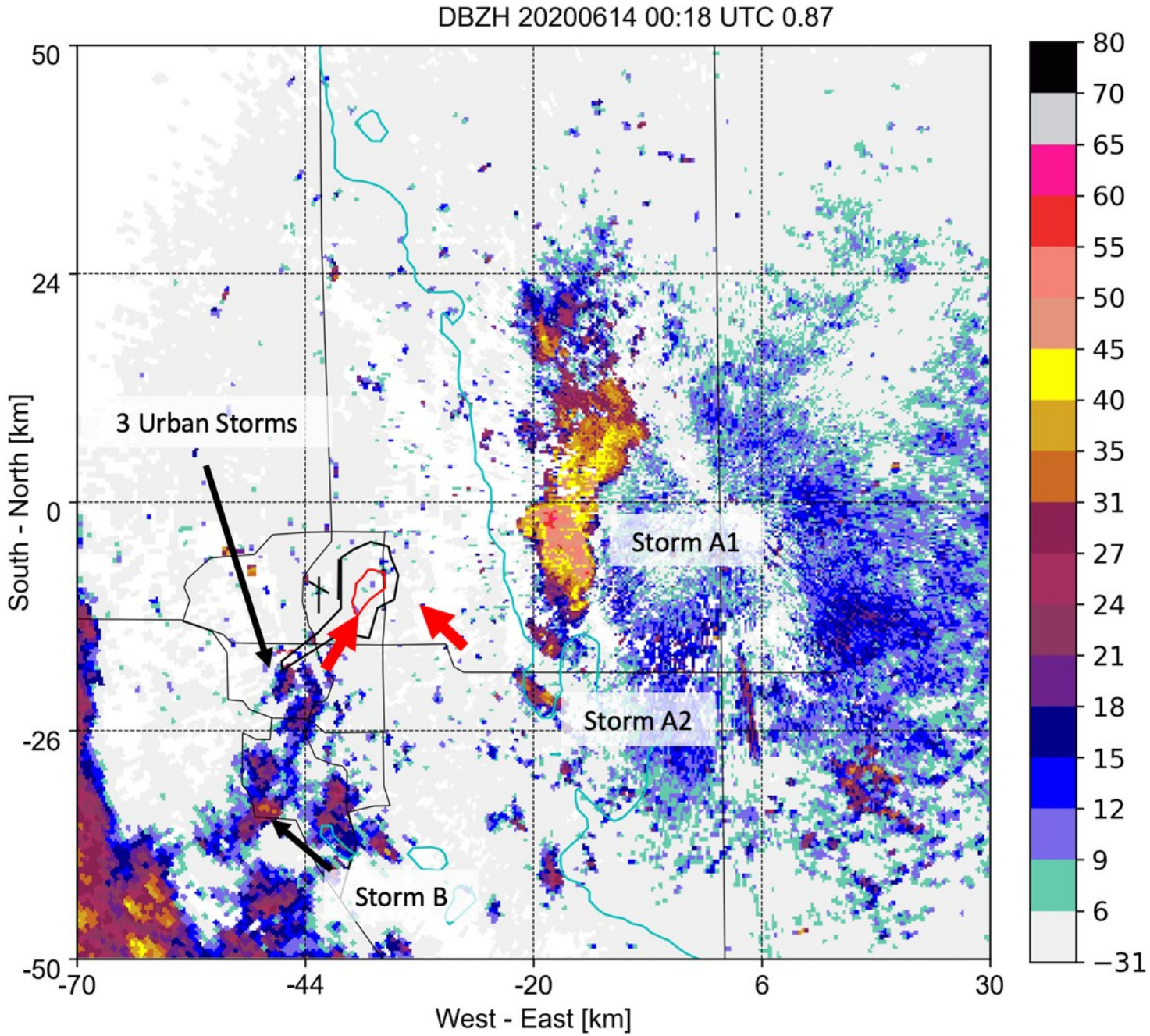
1. Cell view

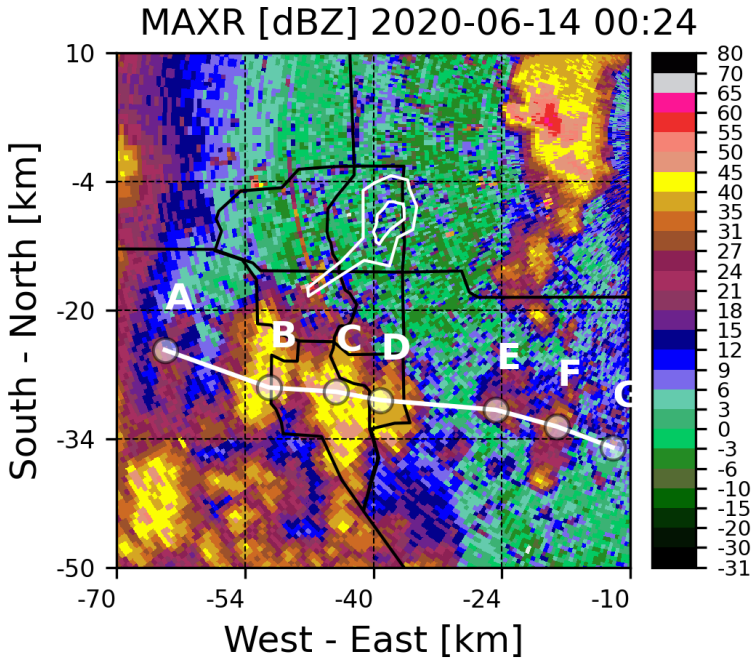


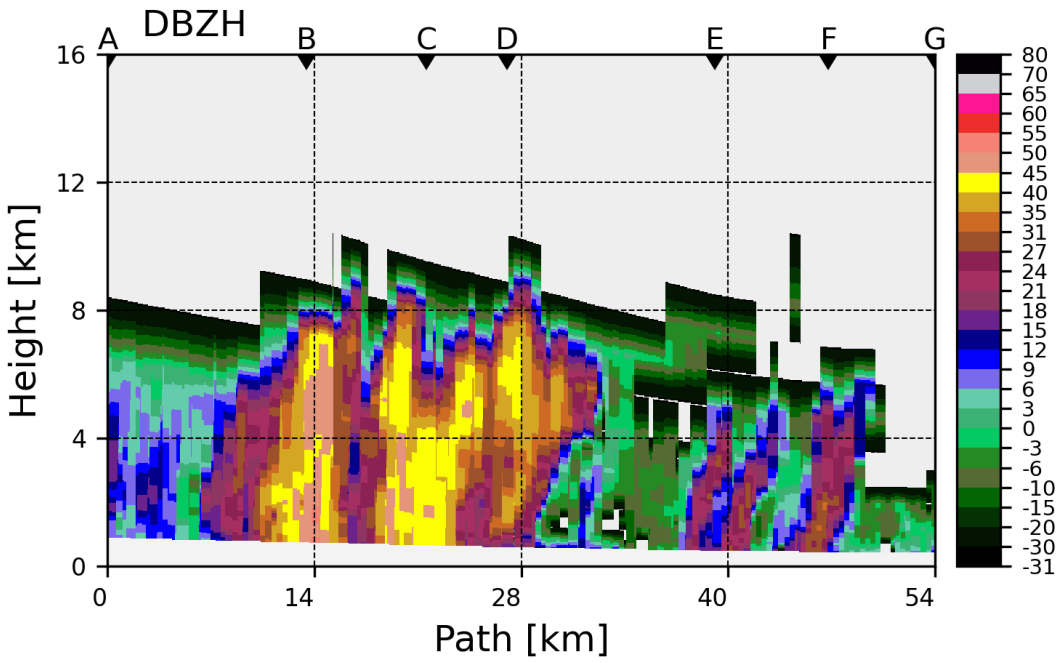




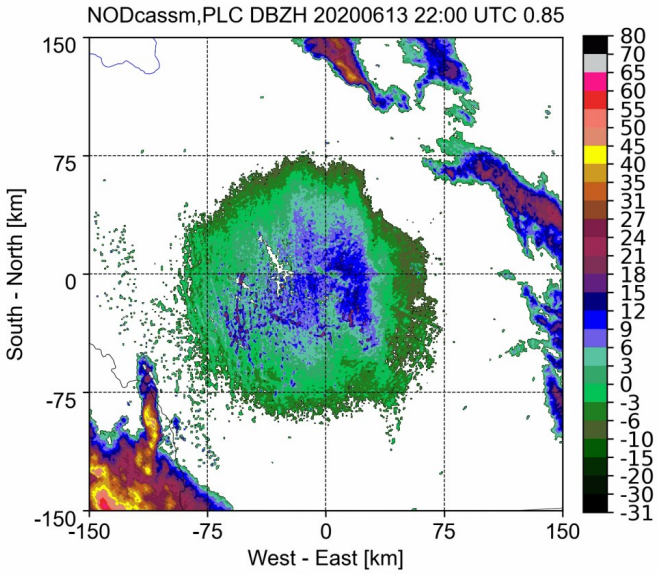

DBZH 20200614 00:18 UTC 0.87
3 Urban Storms
Storm A1
Storm A2
Storm B
South - North [km]
West - East [km]
50
24
0
-26
-50
-70
-44
-20
6
30
80
70
65
60
55
50
45
40
35
31
27
24
21
18
15
12
9
6
−31

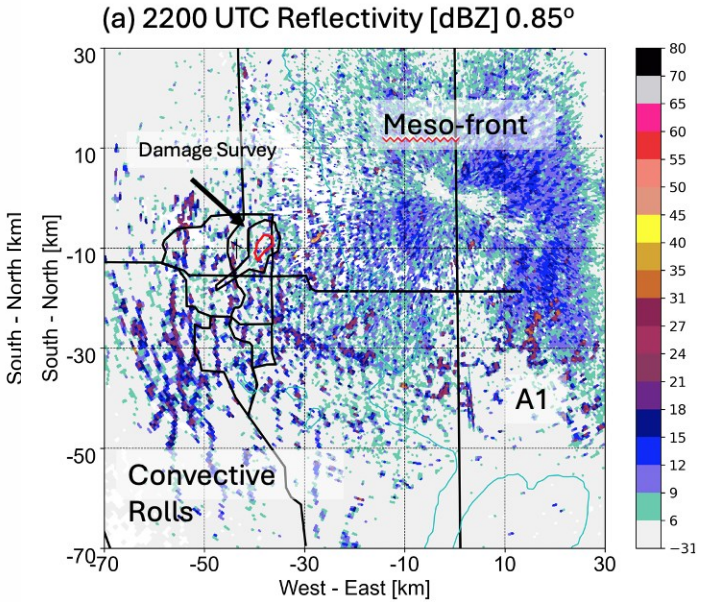
A Fast Developing Storm

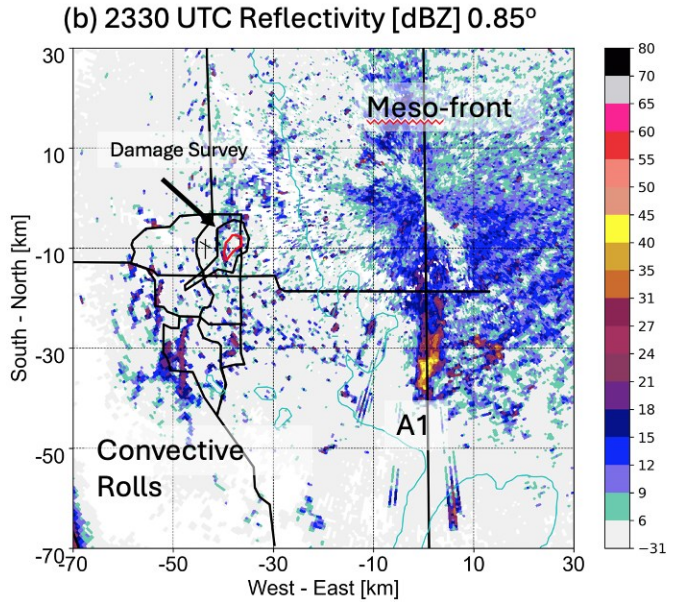


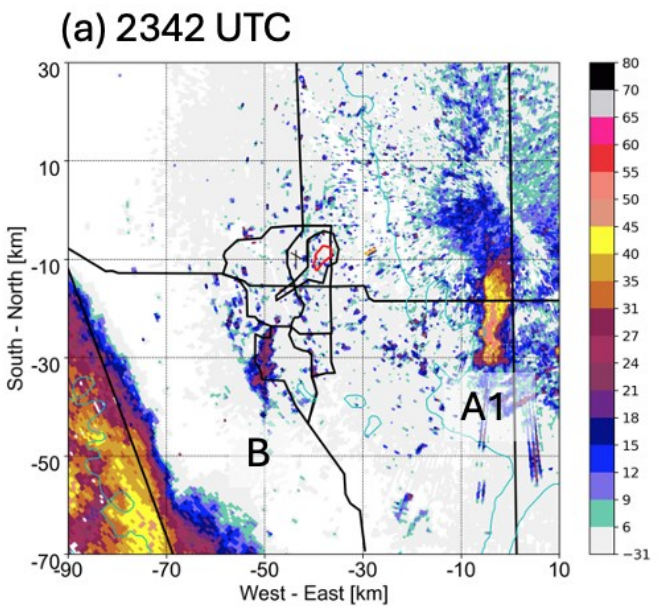


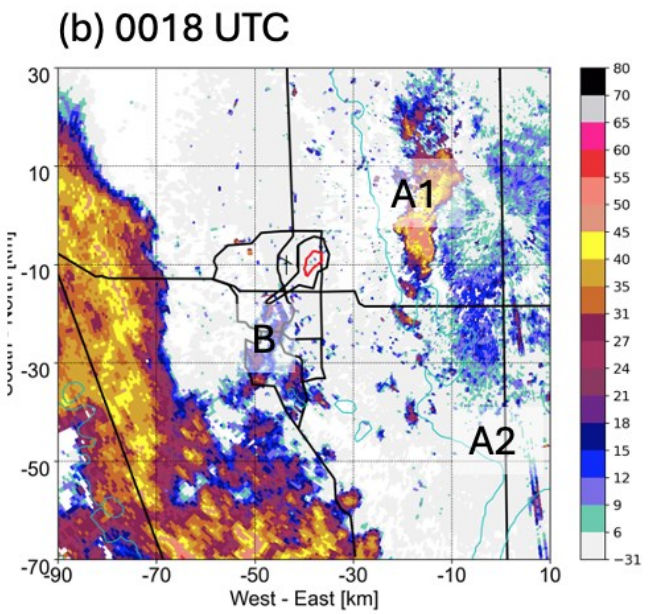
Can we warn earlier?

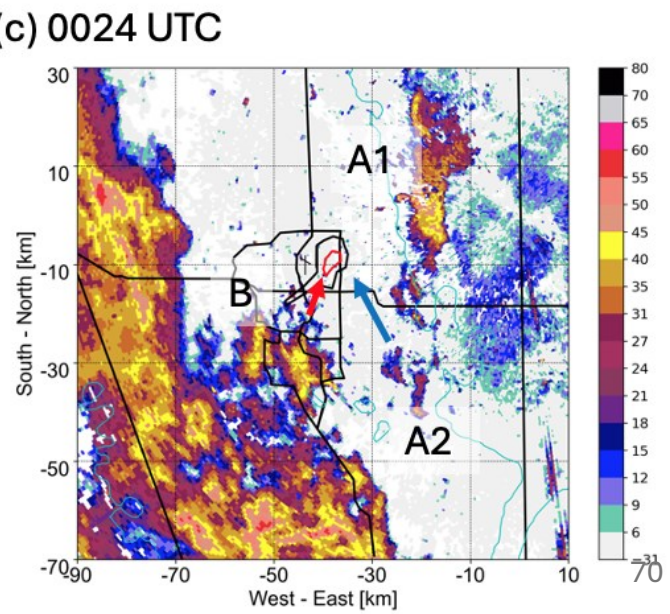


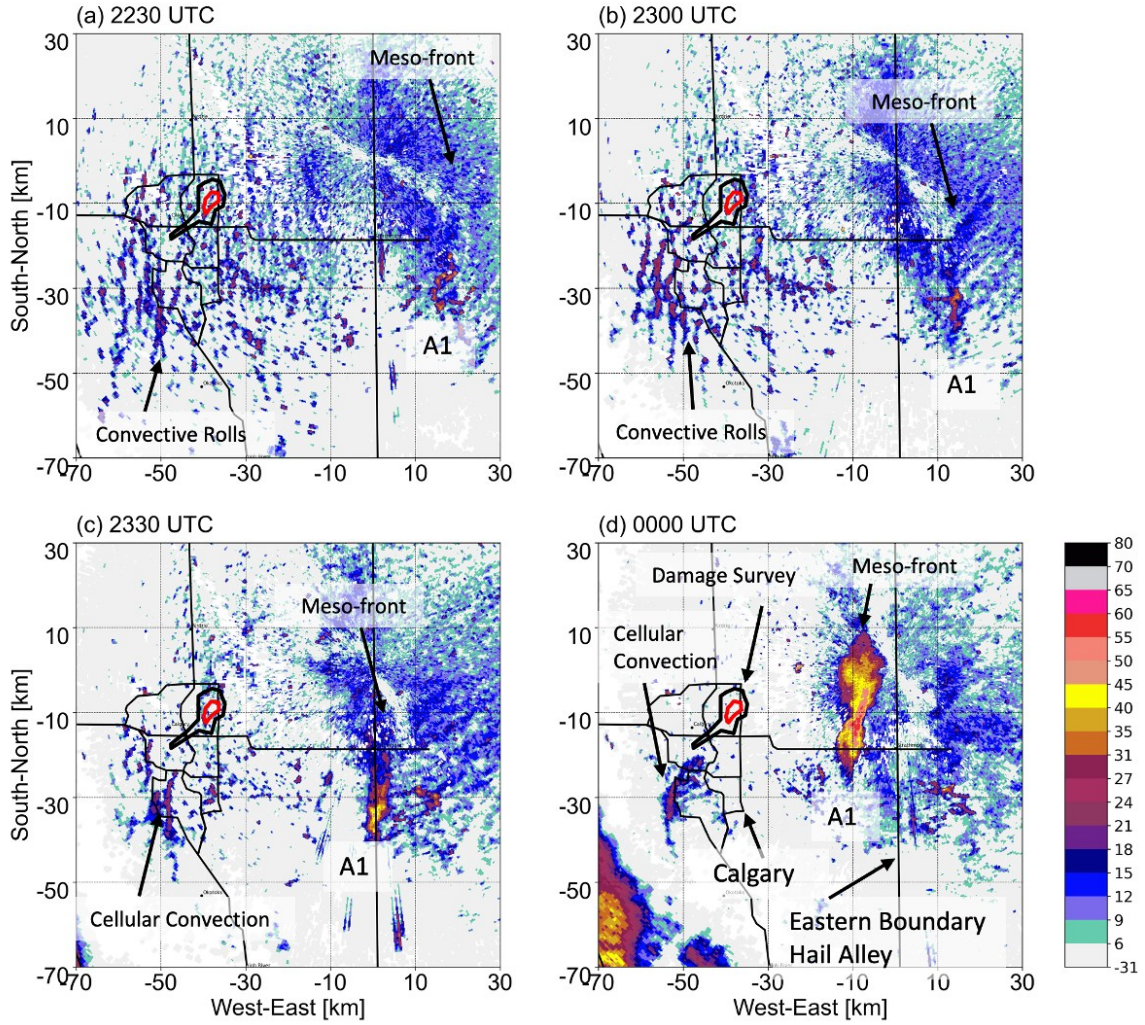


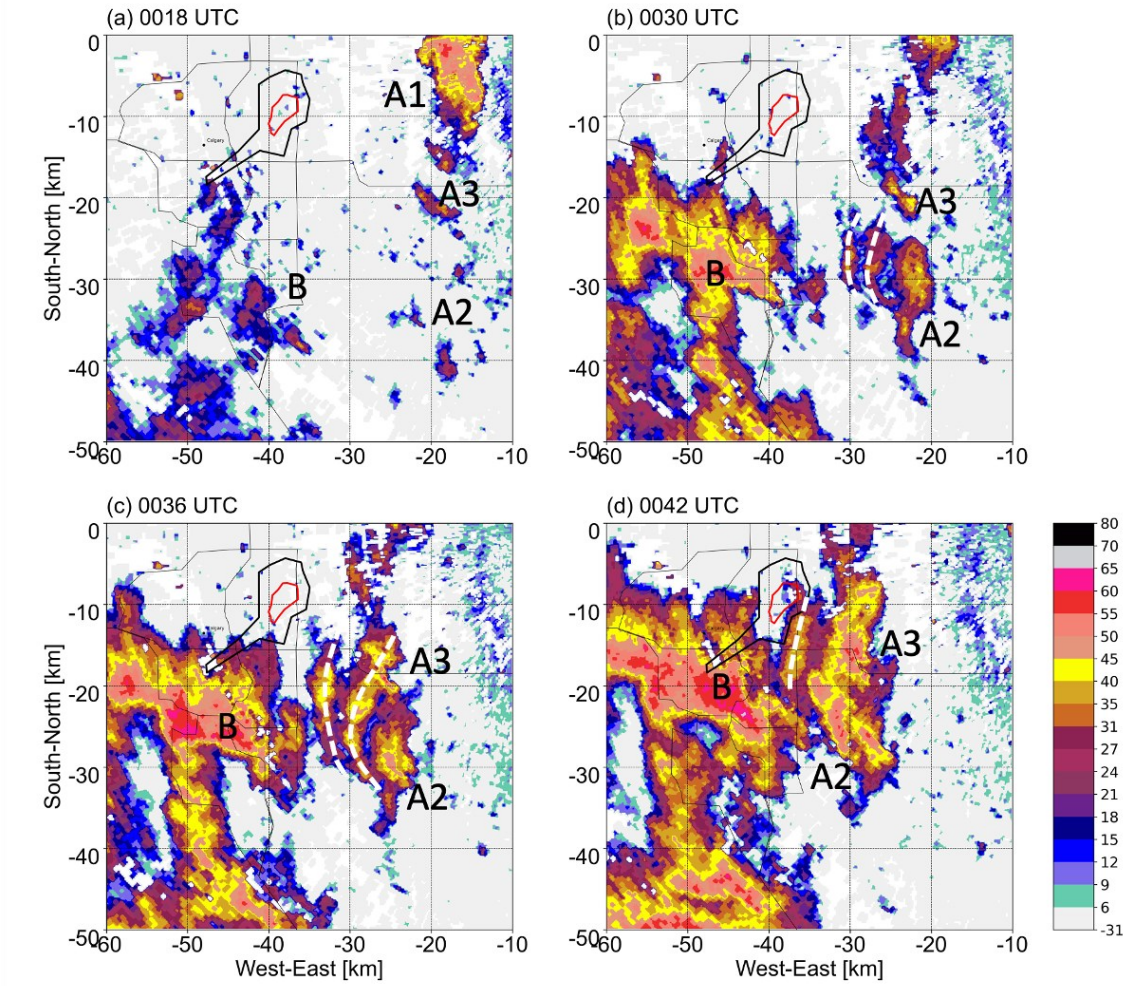









(a) 2230 UTC
(b) 2300 UTC
(c) 2330 UTC
(d) 0000 UTC
Meso-front
A1
Convective Rolls
Cellular Convection
Damage Survey
Calgary
Eastern Boundary
Hail Alley
South-North [km]
West-East [km]
30
10
-10
-30
-50
-70
-70
-50
-30
-10
10
30
80
70
65
60
55
50
45
40
35
31
27
24
21
18
15
12
9
6
-31

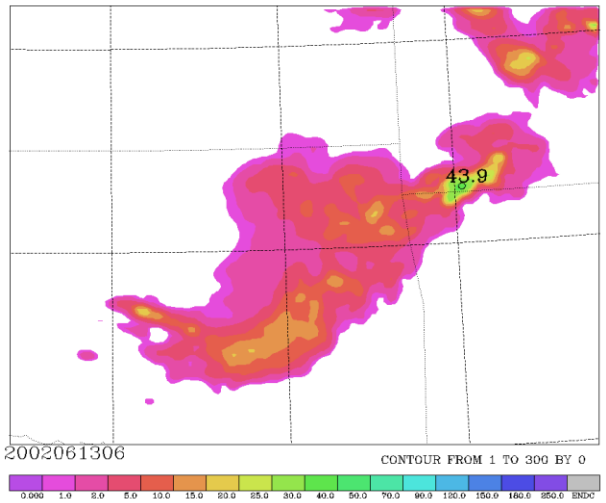

(a) 0018 UTC
(b) 0030 UTC
(c) 0036 UTC
(d) 0042 UTC
A1
A2
A3
B
South-North [km]
West-East [km]
0
-10
-20
-30
-40
-50
-60
80
70
65
60
55
50
45
40
35
31
27
24
21
18
15
12
9
6
-31

Acronym	Location and Date	Description
S2K	Sydney 2000	FDP: Demonstration of summer severe weather nowcasting and radar algorithms, verification, societal benefits
B08	Beijing 2008	FDP/RDP: Summer convective weather – 3D mosaic of multi-radar raw data, precipitation blending, forecaster interaction, wind analysis, real-time verification, high-resolution NWP
SNOW-V10	Vancouver 2010	RDP/Hybrid: Winter, complex terrain, 1 km NWP
FROST-2014	Sochi 2014	FDP/RDP: Winter, complex terrain, deterministic (down to 250 m) and ensemble (down to 2.2 km) NWP
ECPASS	Toronto 2015 Integrated Urban Services	National/RDP, urban, integrated (weather, hydrology, air quality, health, integrated urban services), Global Atmosphere Watch RDP (post-project RDP)
INCA-CE	Central Europe (2011-2014)	Regional demonstration, transnational products, end-user engagement
AvRDP	Various Airports Phase 1 (2014-9); Phase 2 (2020-)	Aviation Research Development Project, meteorological demonstration in support of the Global Air Navigation Plan
TOMACS	Tokyo (2012-2016)	National (post-project RDP), urban, high-resolution, new technology, data assimilation, societal impacts
ICEPOP	PyeongChang 2015-2018	RDP/FDP, improve winter microphysics, advanced instrumentation, Forecaster's request FDP after initial trials
PARIS 2024	Paris 2024	Summer, urban RDP, weather, air quality and heat warnings

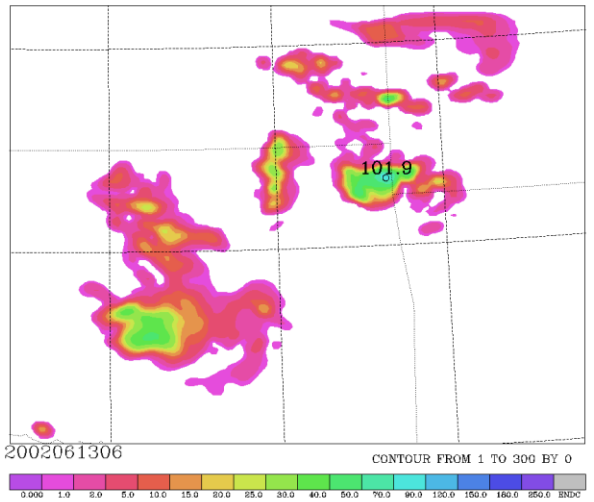

Aerials' jump
Spectator grandstand
Preparation of field-of-play 2 hours before training…

Hourly precipitation at 0600 UTC 13 June

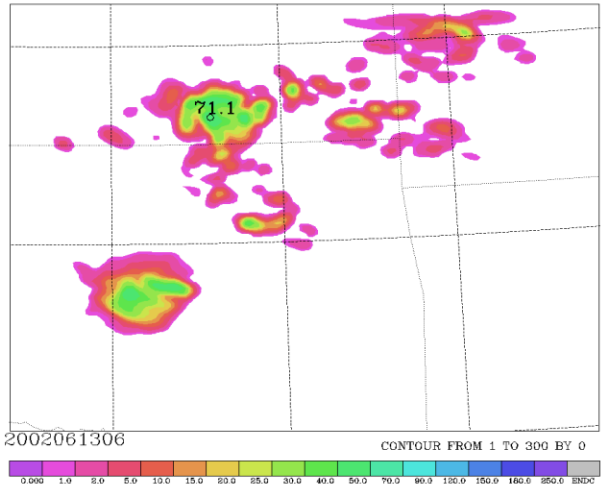
OBS



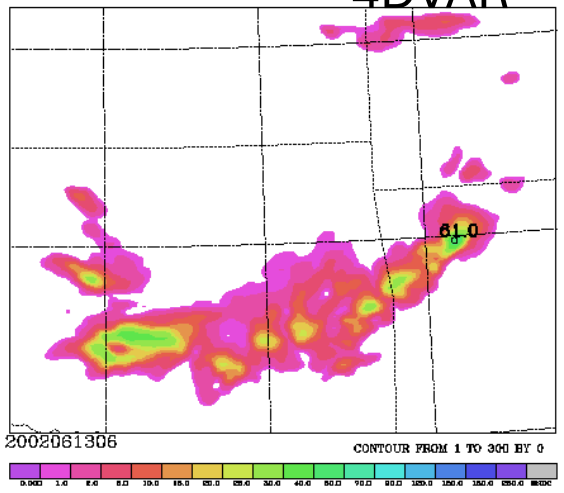
GFS



3DVAR

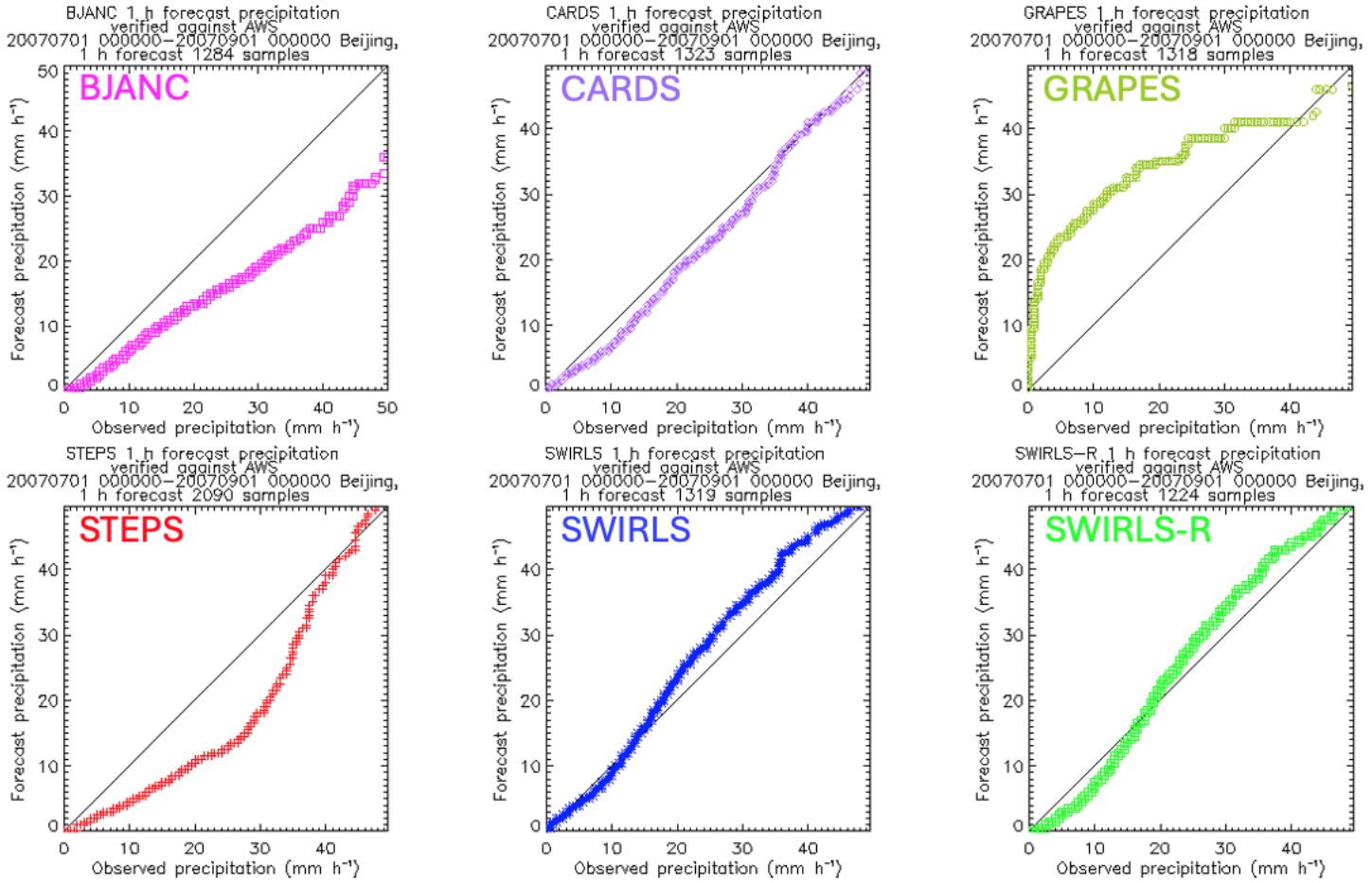


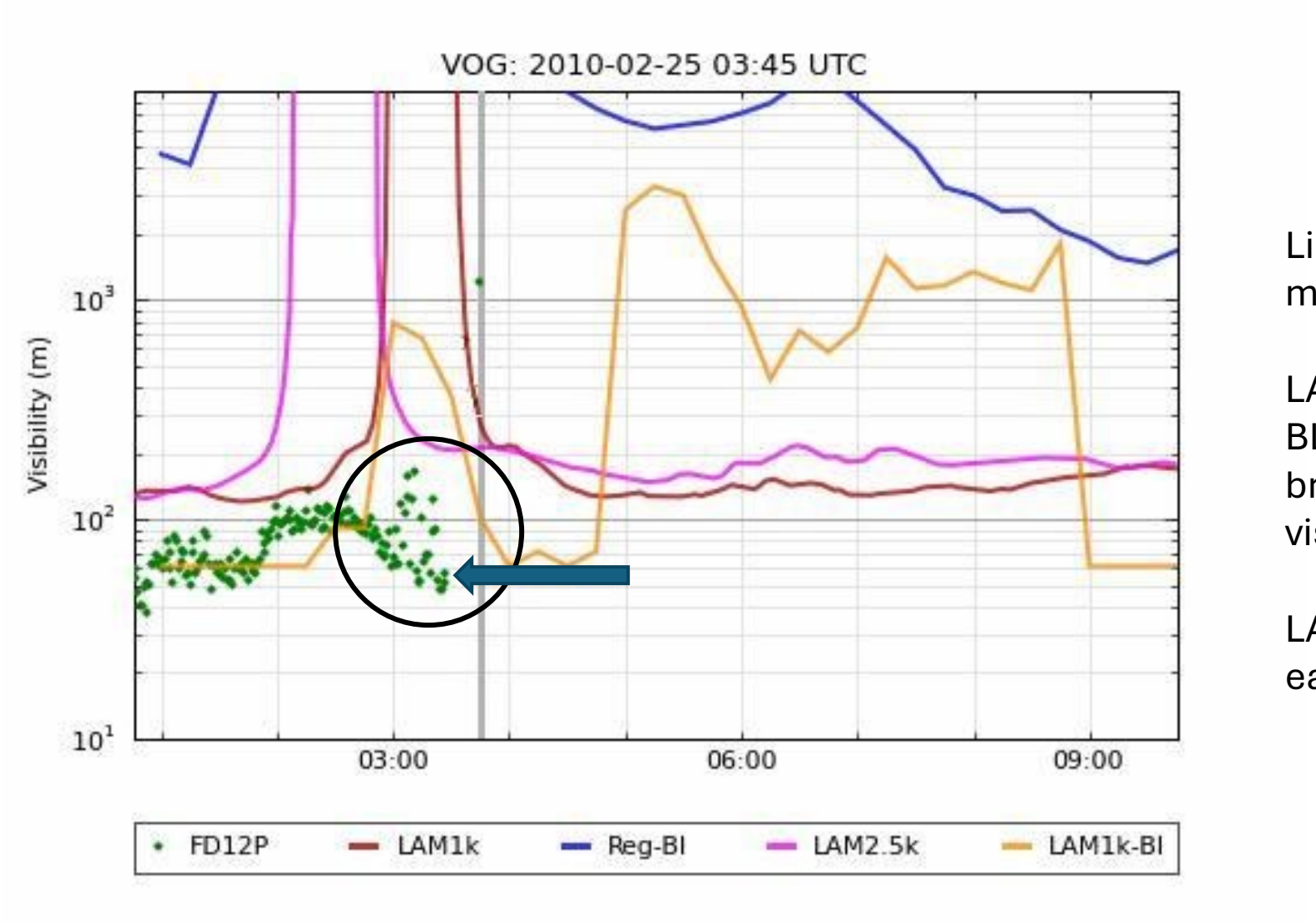
4DVAR



Helsinki NWG Meeting, Courtesy J. Sun, NCAR

Quartile-Quartile plots show accuracy of rain distribution

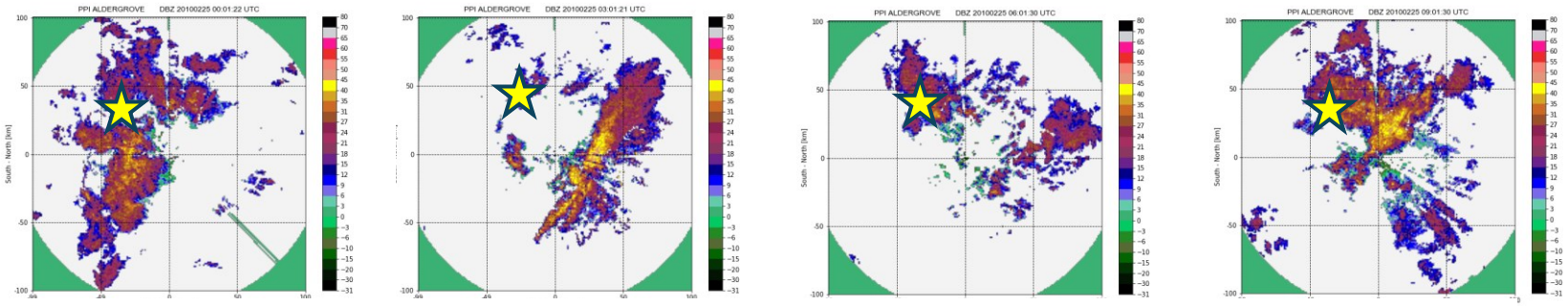


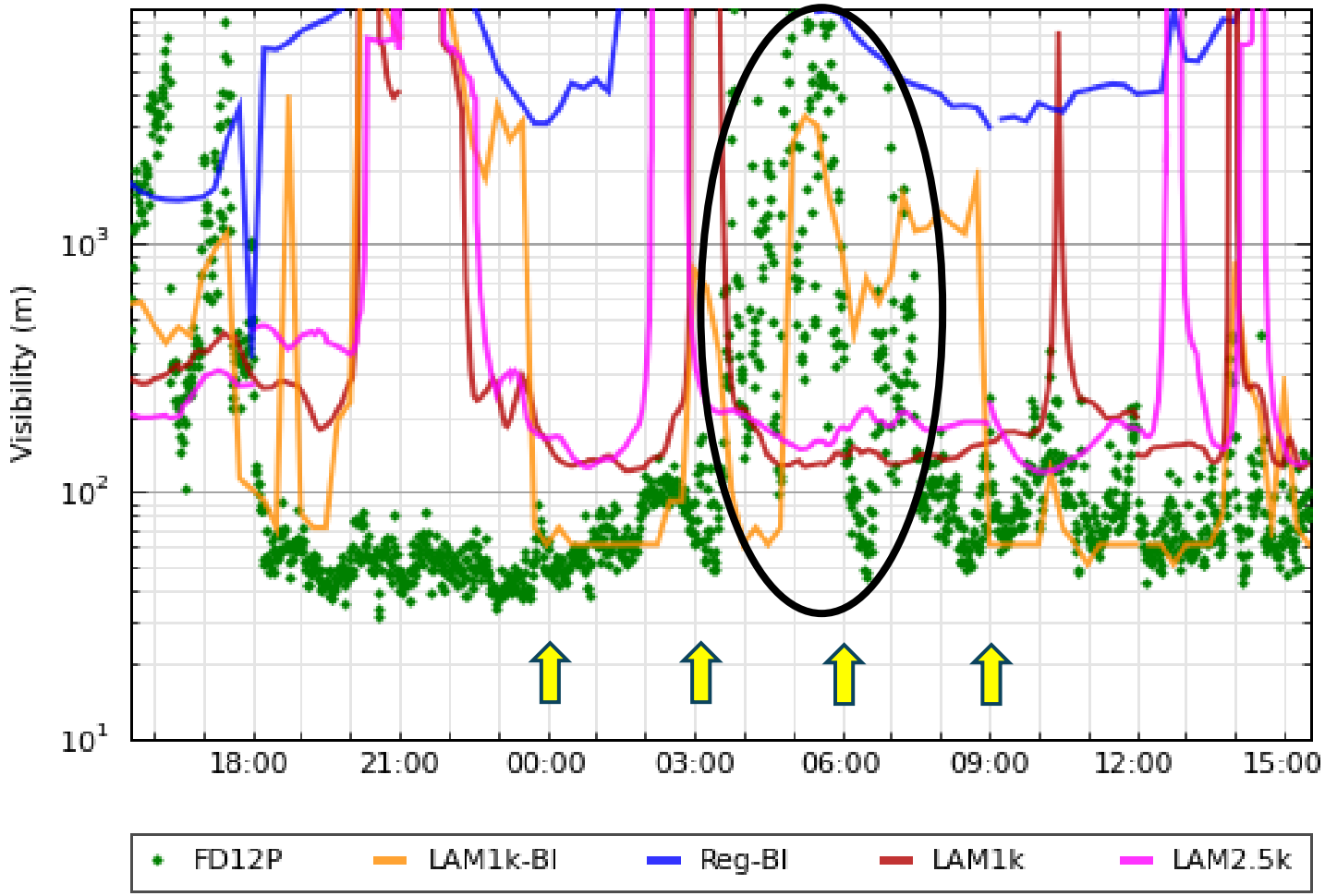


Lines are models

LAM 1k and BL show the break in visibility.

LAM2,5K is early





Forecaster also used radar to confirm time of the clearing.