NOWCASTING – NOW AND THEN

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OUTLINE / SUMMARY

• **Current status**
  – Traditional nowcasting methods empirically / statistically based, subjective
  – NWP not ready yet - Last frontier

• **Satellite-derived products** fill gap in support of nowcasting
  – Products of opportunity derived directly from selected set of observations
  – Fragmented approach
    • Disconnected observations, methods, production streams, teams

• **NWP-based nowcasting**
  – Synthesize all obs. & NWP data into common reference state (5D analysis)
  – Derive all user products from common reference state
  – Comprehensive, potentially high quality & consistent guidance

• **Examples**
  – Simulated Weather IMagery (SWIM)
  – Probabilistic tornado indicators

• **Challenges / opportunities**
  – Quality and timeliness of 5D analysis
NOWCASTING

• Definition
  – Fine scale analysis and ~ 0-3 hour forecast

• Context
  – Larger spatial / longer timescales covered by dynamical (NWP) approach

• Traditional approach to nowcasting
  – “A human given the latest radar, satellite and observational data will be able to make a better analysis of the small scale features present and so will be able to make a more accurate forecast for the following few hours”

Wikipedia on Nowcasting, 2017

• Dynamical nowcasting
  – What’s the holdup? Model or its initialization?
NWP PARADOX

• **NWP basics**
  – Initial value problem – most accurate info about system at initial time
    • Due to chaos, forecast skill should gradually drop with lead time
  – Most weather forecasts beyond ~6 hrs based on NWP

• **Reality**
  – Paradoxically, fine scale measures of forecast skill increase w lead time

• **Explanation**
  – Large scales
    • Analyzed well in initial condition
    • Skill drops with lead time
  – Fine scales
    • Not or poorly analyzed / initialized
    • Model forecast creates fine scale motions consistent w large scales
      – Not a “forecast” per se but a “simulation”
    • => Skill initially increases with lead time
TRADITIONAL NOWCASTING TECHNIQUES

• Observations
  – In-situ, radar, satellite

• Analysis
  – Manual (or computer aided) analysis of selected observations
  – Spatial mosaic of observations (eg, radar)
  – Derived products (eg, satellite)

• Forecast
  – Subjective extrapolation
  – Advection of existing systems
    • Trend in recent past can be considered
  – Statistical enhancements to advection & trends

• Short of a theoretically founded NWP solution to Nowcasting
  – Traditionally generated nowcast products fill void
Lacking theoretically sound NWP solution, traditional nowcast product generation proliferates.
TRADITIONAL PRODUCT GENERATION

- **Knowledge base** - Invaluable
  - Direct relationships (physical and/or statistical) between
    - Selected set of observations (& possibly NWP background)
    - Specific user products (variables or phenomena of interest) – Products of opportunity
      - Cloud drift winds, cloud top pressure, overshooting cloud tops, cloud optical depth, etc

- **Input data** - Only selected / individual observations used
  - Multiple versions of same product
  - Suboptimal products
  - Inconsistency across & in quality of products

- **Methods** - Large set of disconnected algorithms w partially overlapping functionalities
  - Inefficiencies in development, operations, maintenance

- **Workflow** – S³
  - Stand-alone / segmented / stove piped

*Resources scattered across stovepipes, benefitting indiv. products*
PRODUCT GENERATION - REALITY

Is there an alternative?
Numerical Weather Prediction (NWP)

USER PRODUCTS

APPLICATIONS

NATURE

OBSERVATIONS

Water
Hazards
Forestry
Food
Health
Cities
NWP-BASED PRODUCT GENERATION

OBSERVATION OPERATORS

NWP DA + MODEL

PRODUCT GENERATORS

SIMULATED NATURE
Incl. atm. chemistry, land, ocean, ice, etc

Object Oriented Repositories for Obs Opers, DA schemes, Numer. Models, Product Generators

USER PRODUCTS

APPLICATIONS

NATURE

OBSERVATIONS

Winds

Precip-1

Clouds

Aerosol

Fire

Ozone

Radiation

Soundings

Water

Hazards

Forestry

Food

Health

Cities
NWP-BASED PRODUCT GENERATION

• **Modularize by methodology** - Not by individual obs. or products
  – Transparent design, systematic & simplified approach, efficiency
    • Potential for faster progress, clearer focus, integration, enhanced collaboration

  *All resources come to bear on common problems, benefitting all*

• **Simulate nature** - Digital representation (common reference state)
  – Synthesize all observations using NWP first guess & DA methods
    • Comprehensive 5D dataset - 3D in space, 1D in time & across variables
  – Elements of product generation algorithms to be used in obs. operators
  – Some pre-generated products can be “assimilated” for expediency
    • Products result of translucent filter of obs – Variational use of obs preferred

• **Derive all products** from simulated nature (common reference state)
  – Potentially improved quality due to use of all obs. & model constraints
  – Consistency across products
  – Elements from “product generation” algorithms can be reformulated & used
WILL IT WORK?

- **Challenges**
  - High fidelity
    - Use of spatially/spectrally detailed obs. (multiscale approach), balance
  - Short latency
    - Efficient DA (multiscale approach); adequate computational resources
  - Streamlined workflow
    - Realign satellite community, reconfigure traditional algorithms into repositories

- **Examples**
  - All-weather imagery from 5D cloud analysis
  - Tornado warning – NSSL
  - Radar reflectivity nowcasting – OU, LAPS
  - Visibility around topography

- **Practical approach**
  - Gradually shift resources from traditional to NWP “product generation”
    - Focus developmental resources on NWP-based approach
  - Establish repositories, adopt Object Oriented design
    - Obs operators, DA – JCSDA; Model – NGGPS; Product generation - ?
  - Maintain traditional schemes until NWP approach supercedes them
3D 500 m CLOUD ANALYSIS

Courtesy Steve Albers

NOWCASTING WITH LOCAL ANALYSIS AND PREDICTION SYSTEM – LAPS

Clouds as seen from top of DSRC building in Boulder by LAPS ANALYSIS

LAPS Simulated

All-Sky Camera

Camera images as independent validation

16:45 UTC Jul 6, 2014
3D 500 m CLOUD ANALYSIS - LOOP

Unique feature of LAPS, critical for WOF, Nextgen, etc

16:30-18:45 UTC June 27, 2014, 15-min frequency
GSI hybrid DA for May 8th 2003 OKC Tornadic Supercell

Xuguang Wang et al., 2015, MWR, to be submitted

Radar reflectivity 22:00 UTC  1-hr Prob. fcst. Initialized 2200 UTC

http://www.srh.noaa.gov

Isolated supercell 2210 – 2400 UTC with F-4 tornadoes in Moore & Oklahoma City (OKC) between 2210—2240 UTC
SW OK TORNADO, 16 MAY 2015

Real-time 90-min Prob. Updraft Helicity Forecast (>25m²/s²)
OPPORTUNITIES / PROMISING AREAS

• **Observational operators**
  – Harvest possible schemes from satellite product generation algorithms (CRTM, etc)

• **Data assimilation**
  – Thermodynamically balanced microphysical / aerosol parameters
  – Adjoint-based 4DVar w ensemble-based covar. – Success at ECMWF
  – Multiscale technique

• **Numerical models – R³**
  – Resolution (space), resolution (physics), resolution (probabilities)

• **Product generation**
  – Reuse elements of traditional product generation algorithms
  – Expand UPP
OBSERVATIONS LEAD THE WAY

• **Which way?**
  – Disjoint suboptimal products based on subsets of observations
    • “React to individual snippets of nerve impulses”
  – Integrated, holistic, digital depiction of reality
    • ”Process totality of sensory input & form view before reacting”

• **Invest in advanced use of observations**
  – Modular NWP-based approach to nowcasting
  – Rational study of observational needs in that context
BACKGROUND