A new tropical cyclone dynamic initialization technique using high temporal and spatial density atmospheric motion vectors and airborne field campaign data

Eric A. Hendricks[1], Michael M. Bell[2], Russ L. Elsberry[3], Chris Velden[4], and Dan Cecil[5]

[1]Dept. of Meteorology, Naval Postgraduate School, Monterey, CA

[2]University of Hawaii, Honolulu, HI

[3]Univ. of Colorado Colorado Springs, Colorado Springs, CO

[4]CIMSS, Univ. of Wisconsin, Madison, WI

[5]Univ. of Alabama, Huntsville, AL

Acknowledgements: James D. Doyle, Ron Ferek and Office of Naval Research (ONR) Marine Meteorology, Naval Research Laboratory, and ONR TCI Team

AMS 32nd Conference on Hurricanes and Tropical Meteorology, San Juan, Puerto Rico, April 18-22, 2016

Background

- Initialization of tropical cyclones in numerical weather prediction (NWP) systems is a great challenge
  - Mass-wind field balance
  - Secondary circulation and heating
  - Asymmetries
- There can be large adjustments in structure and intensity in the first 24 hours if the initial vortex is not in balance
  - Spurious gravity waves
  - Spin-up (model and physics)
- Existing mesoscale NWP model TC initialization strategies
  - Bogus vortex, cold start from global analyses
  - 3DVAR or 4DVAR, possibly with synthetic observations
  - EnKF
  - Dynamic initialization
- Dynamic initialization allows vortex to have improved balance and physics spin-up at the initial time (e.g., Hendricks et al. 2013, 2011; Nguyen and Chen 2011; Fiorino and Warner 1981; Hoke and Anthes 1976)

Background

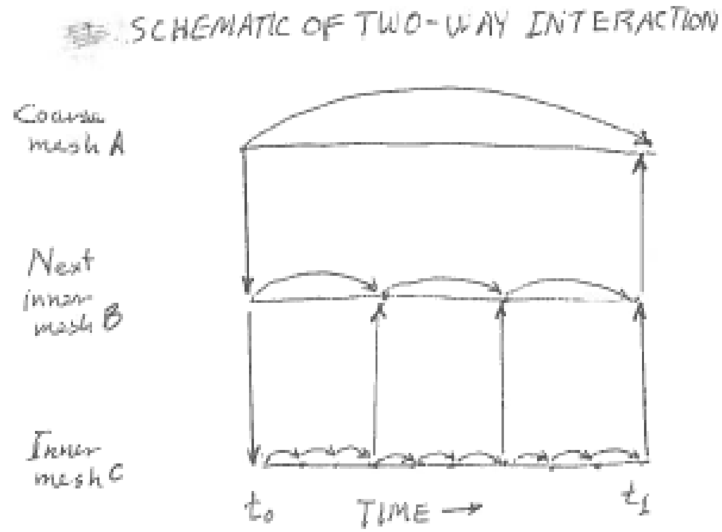
- Himawari-8 geostationary satellite has capability of continuous imagery (10-minutes) over the full disk
  - New GOES-R satellites will have same capability
- This will allow for unprecedented observations of tropical cyclones
- However, current data assimilation systems are not capable of ingesting such high temporal observations (AMVs)
  - Hourly AMVs are produced, and thinned to 100 km spacing in the horizontal
- An entirely new data assimilation concept is required to utilize these observations

Objective

- A new dynamic initialization technique, suitable for mesoscale NWP models with multiple nested grids, is developed
- This technique can utilize high temporal (10-minute) and spatial resolution atmospheric motion vectors (AMVs) and airborne observational data (e.g., dropsondes, airborne radar)
- **Hypothesis:** Obtaining improved representation of the outflow and divergence aloft (as well as lower levels) will allow model to generate proper heating and asymmetries, and allow for improved initial structure and intensity. This will lead to improved forecasts.

Dynamic Initialization Technique

- SAMURAI 3DVAR analysis (Bell et al. 2012) is prepared using COAMPS-TC background and AMVs
- Dynamic initialization is performed utilizing the SAMURAI increments for period of time
- Real forecast is launched
- This quasi-continuous data assimilation allows for th vortex to adjust to the 10-minute forcing

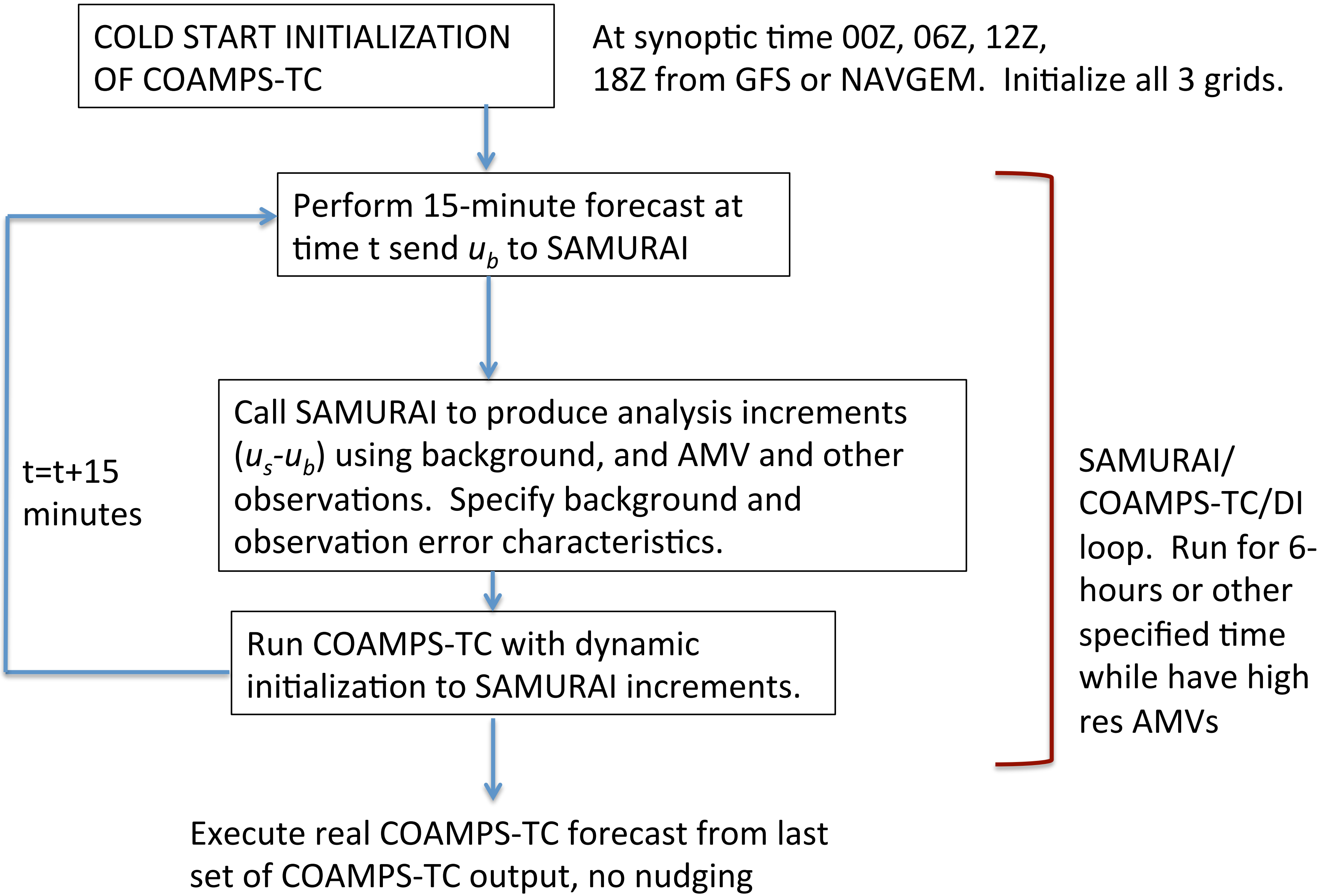


$$\frac{\partial u}{\partial t} = F(u) + \propto (u_s - u_b)$$

$$\frac{\partial v}{\partial t} = F(v) + \propto (u_s - u_b)$$

(u_s-u_b) are the SAMURAI increments

Flow chart of Initialization



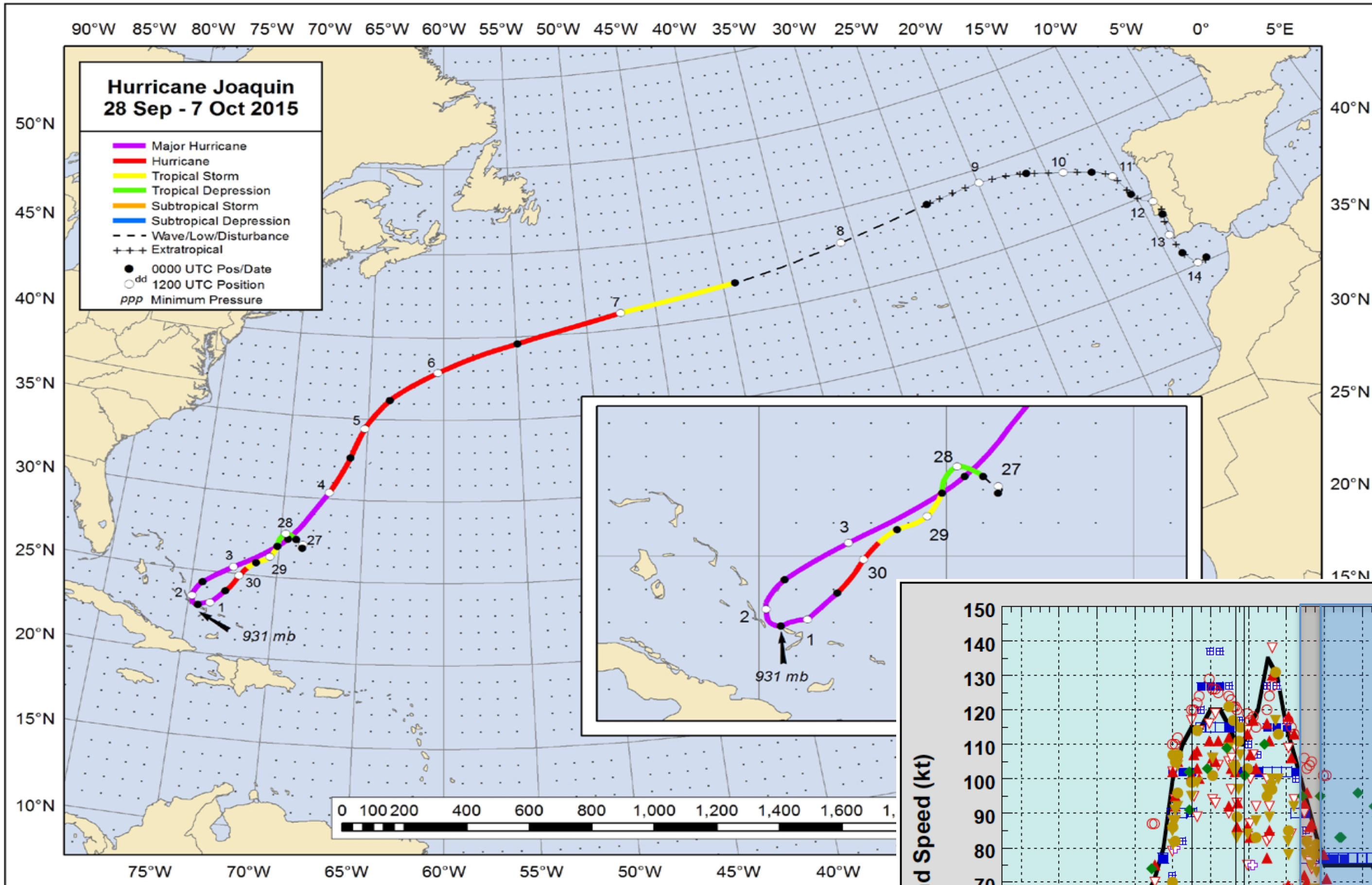
Proof-of-Concept

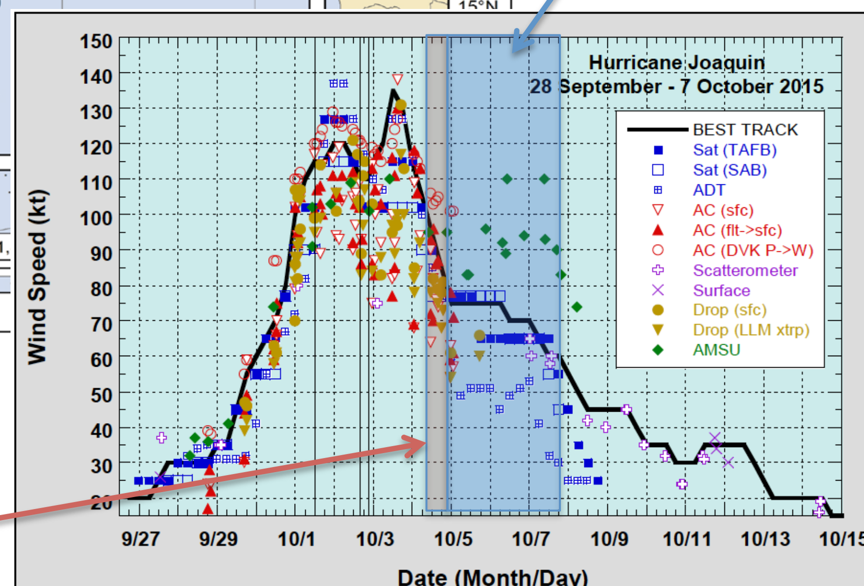
- A proof-of-concept of the technique is performed for Hurricane Joaquin (2015)
- Dynamic initialization using SAMURAI increments with 15-minute AMVs
  - 2015100412-2015100418
- Real forecast (SCDI)
  - 2015100418- 72 hour forecast
  - Compare SAMURAI/COAMPS-TC/DI (SCDI) method to CNTL method in terms of track, intensity and structure
- **<u>Three forecast to compare on 2015100418:</u>**
  - CNTL: standard COAMPS-TC initialization, bogus vortex, cold start with GFS data on
  - SCDI0: SCDI scheme with zero SAMURAI increments
  - SCDI: SCDI scheme with actual SAMURAI increments

6-h DI with SAMURAI increments
2015100418

Real forecast
2015100418

Summary of Joaquin (2015)





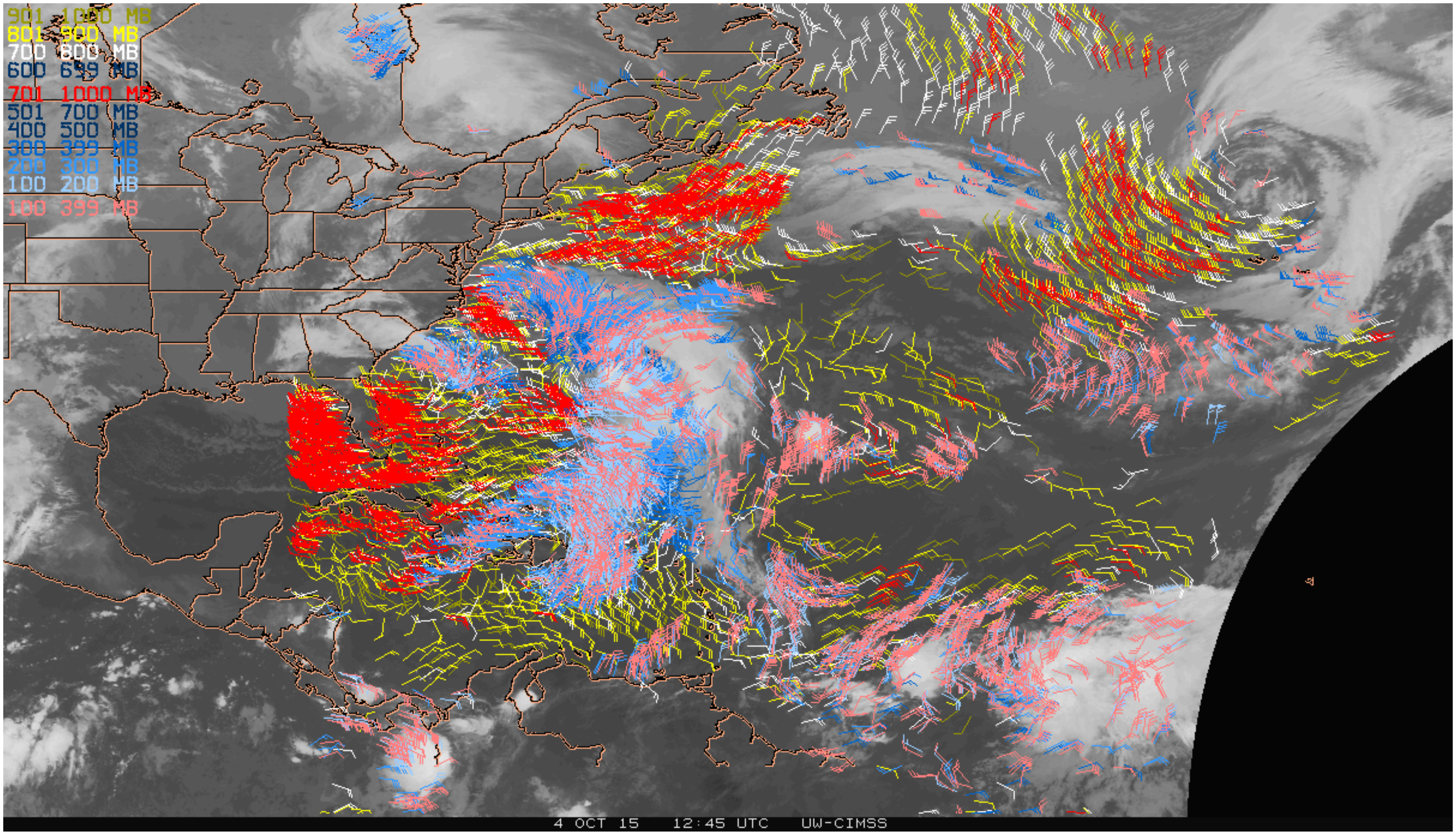
Real forecast

6-h dynamic initialization

Figs. Courtesy National Hurricane Center

Atmospheric Motion Vectors (AMVs)

- 15-minute resolution AMVs from 2015100412-2015100418 (courtesy CIMSS)

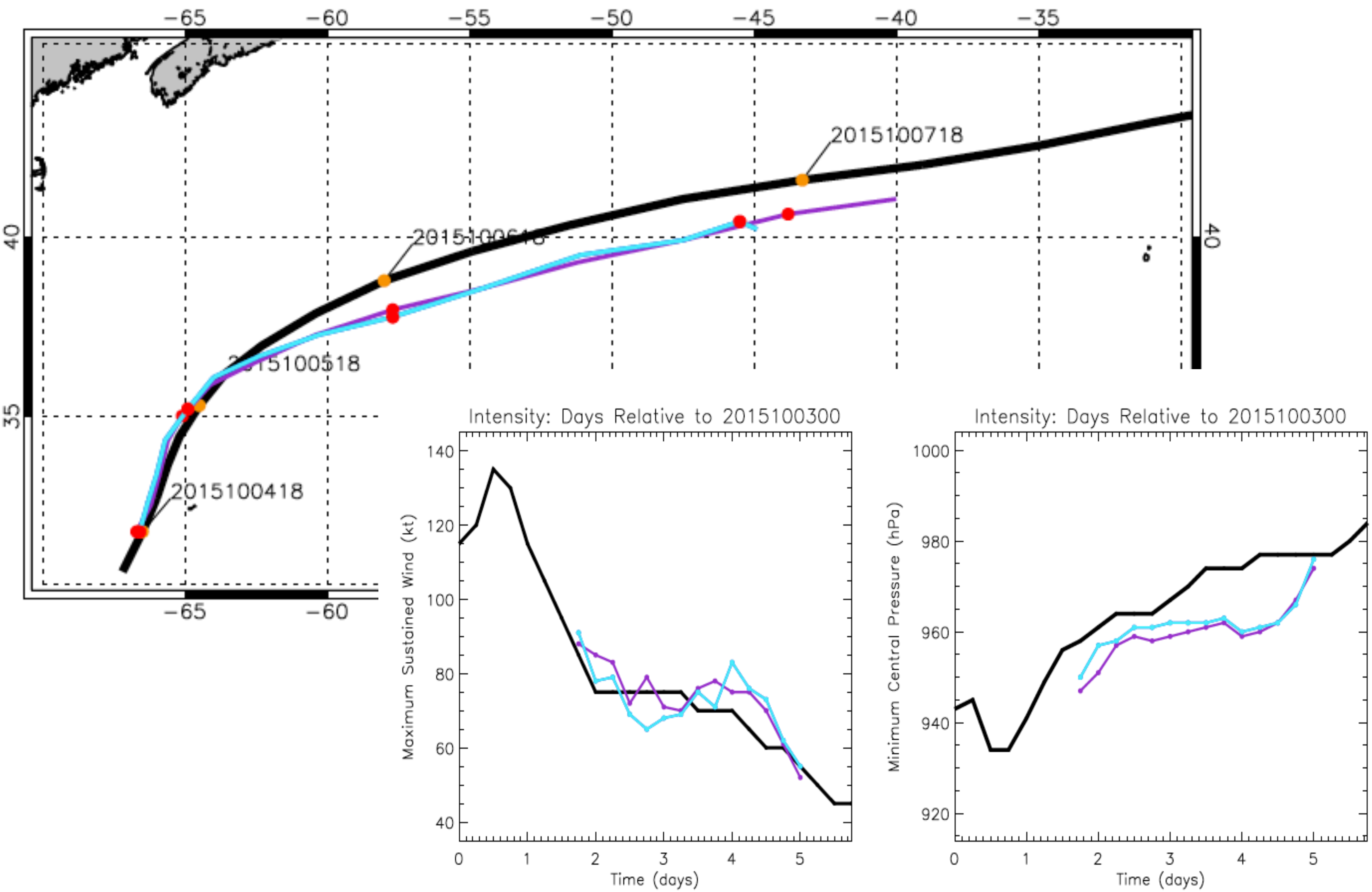


Examples of SAMURAI increments on 3 COAMPS-TC grids

- Show increments on all 3 grids

Comparison of SCDI and CNTL Track and Intensity

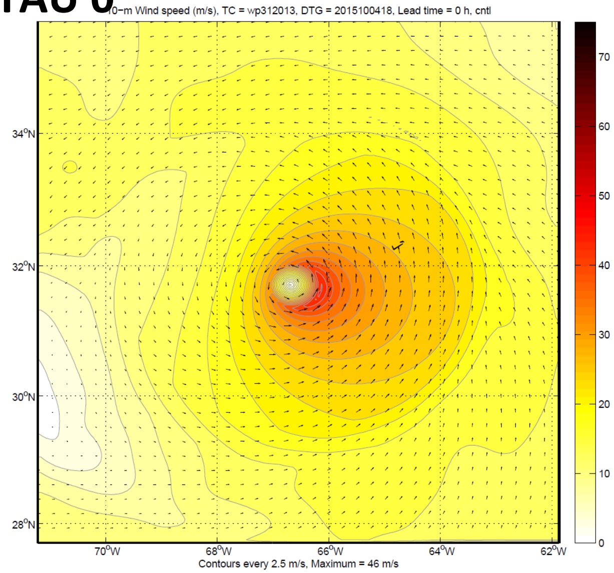
CNTL
SCDIO
SCDI

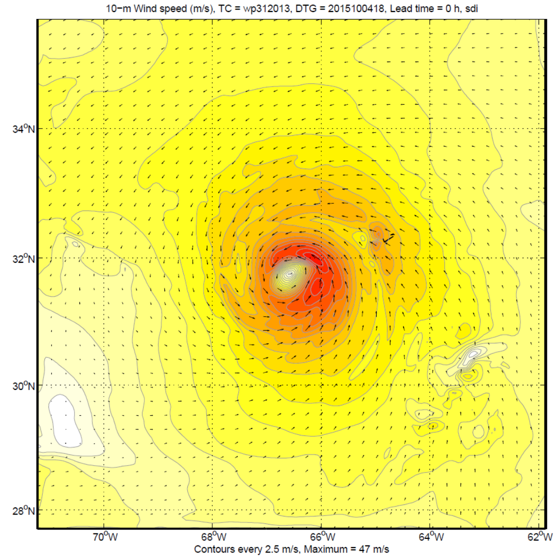


10-m wind speed

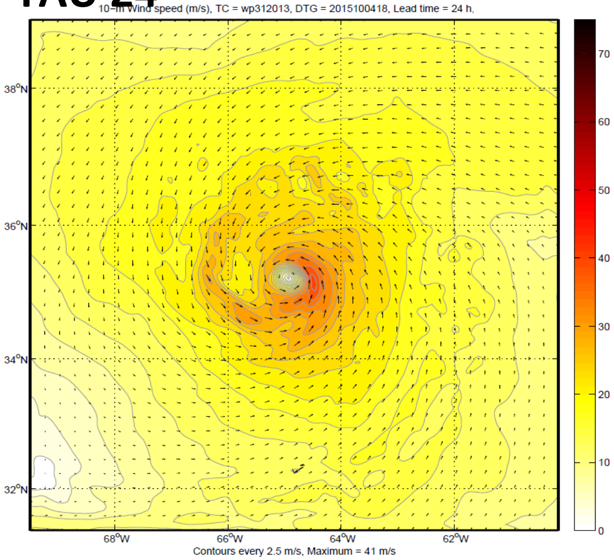
CNTL | SCDI0 | SCDI

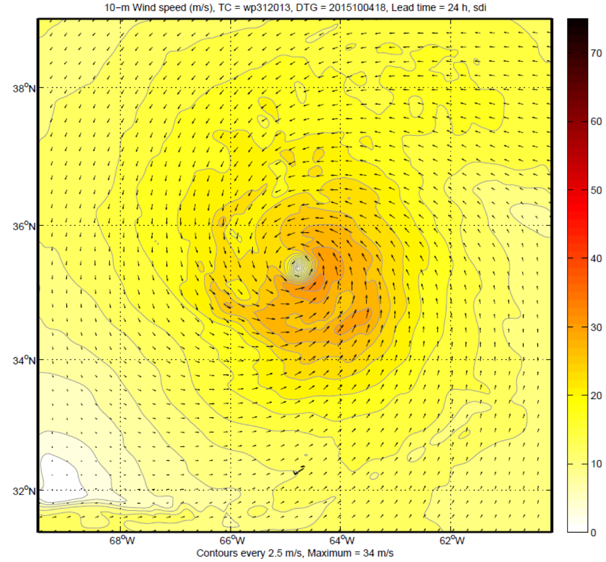
TAU 0





TAU 24

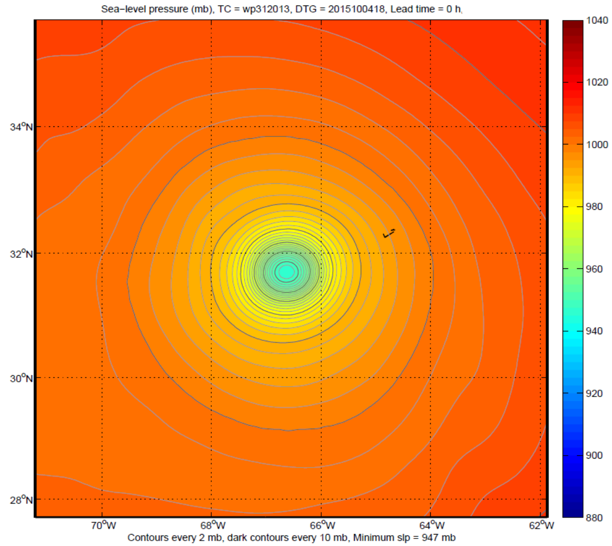


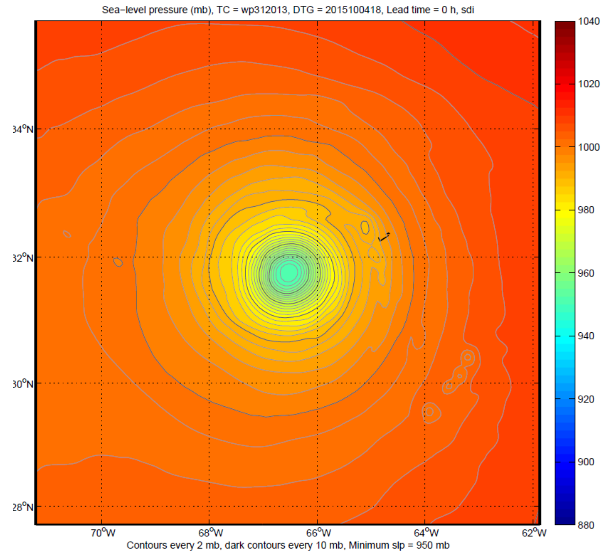


MSLP

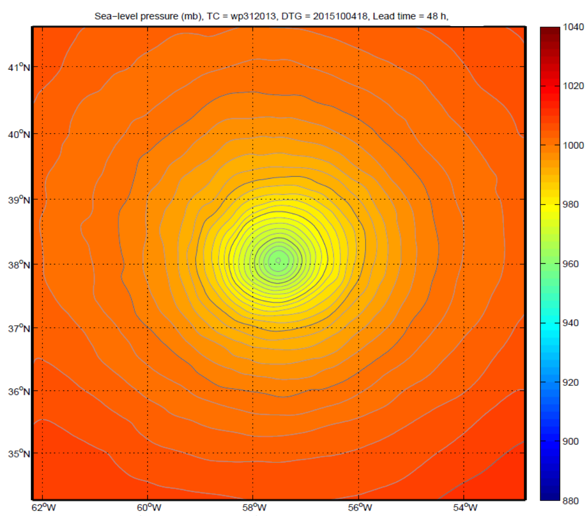
CNTL | SCDI0 | SCDI

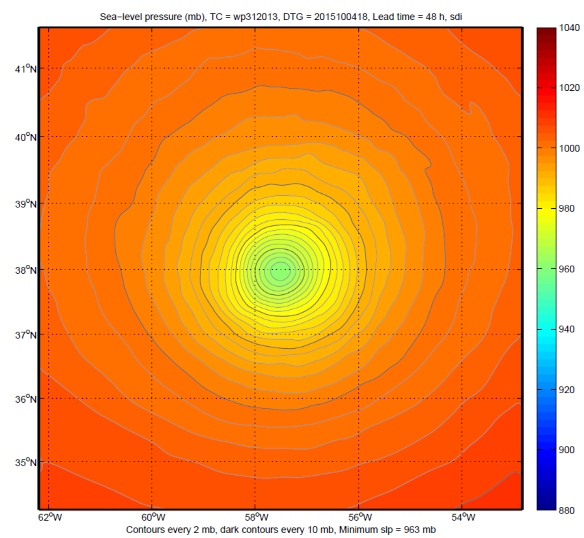
TAU 0





TAU 24

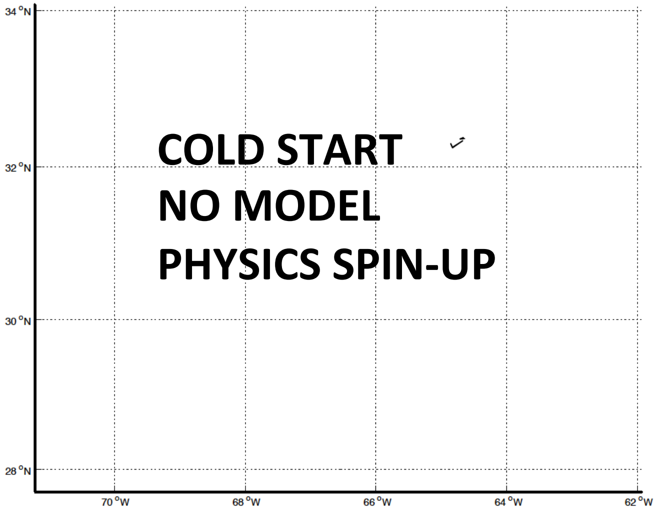


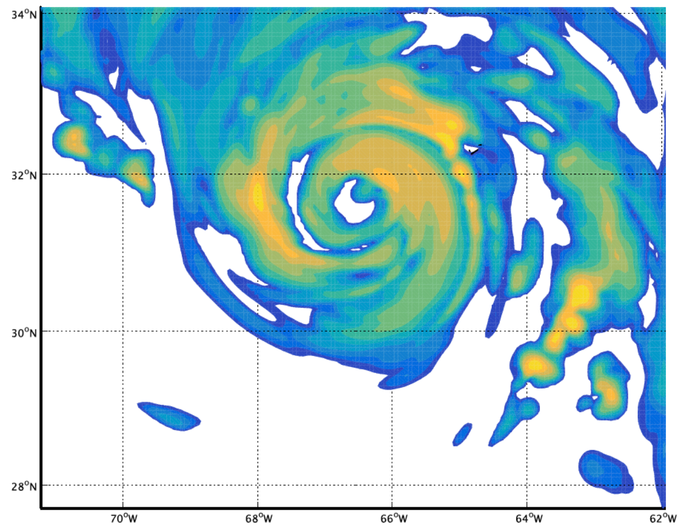


Simulated Radar Reflectivity

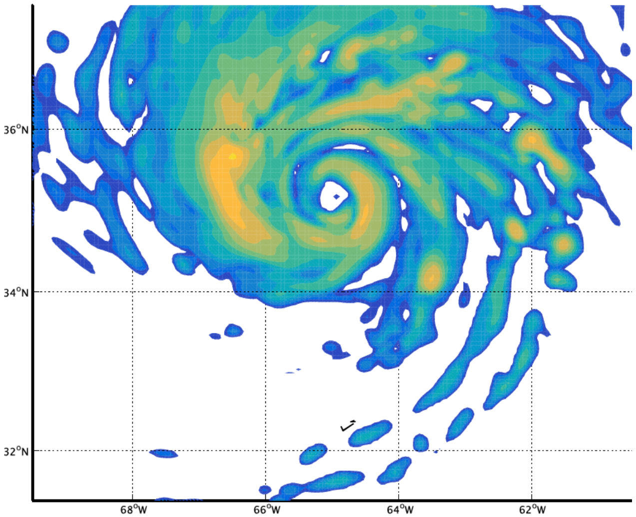
CNTL **SCDI0** **SCDI**

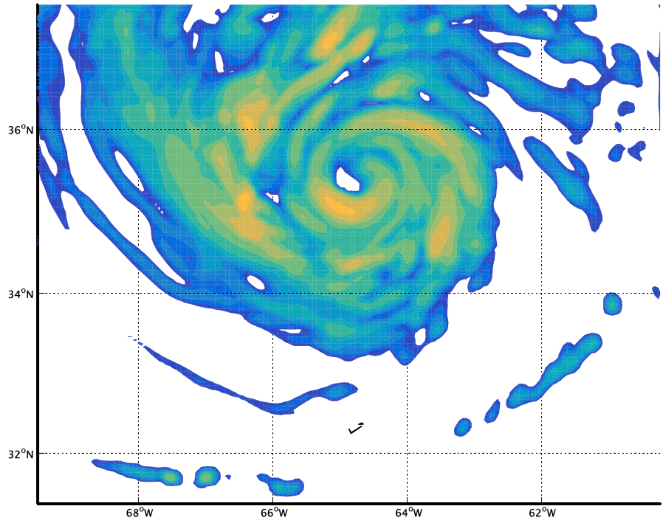
TAU 0





TAU 24





Conclusions

- We have demonstrated a new dynamic initialization technique for mesoscale NWP models that can fully utilize high temporal AMVs (10 or 15 minutes)
- A proof-of-concept of this technique was performed on Hurricane Joaquin (2015)
- Improved initial structure was evident and intensity and track forecast was similar
- Future work: add HIRAD and HDSS data from ONR TCI experiment to the SAMURAI analysis for improved analysis and forecasts