Current Status & Priorities for Tropical Cyclone Research and Operations

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IWTC-9 Summary

- IWTC-9 was held in Honolulu, Hawaii, from 3-7 December 2018
- Approximately 150 participants from numerous countries
  - Approximately 100 from the research community
  - Approximately 50 from the operational community

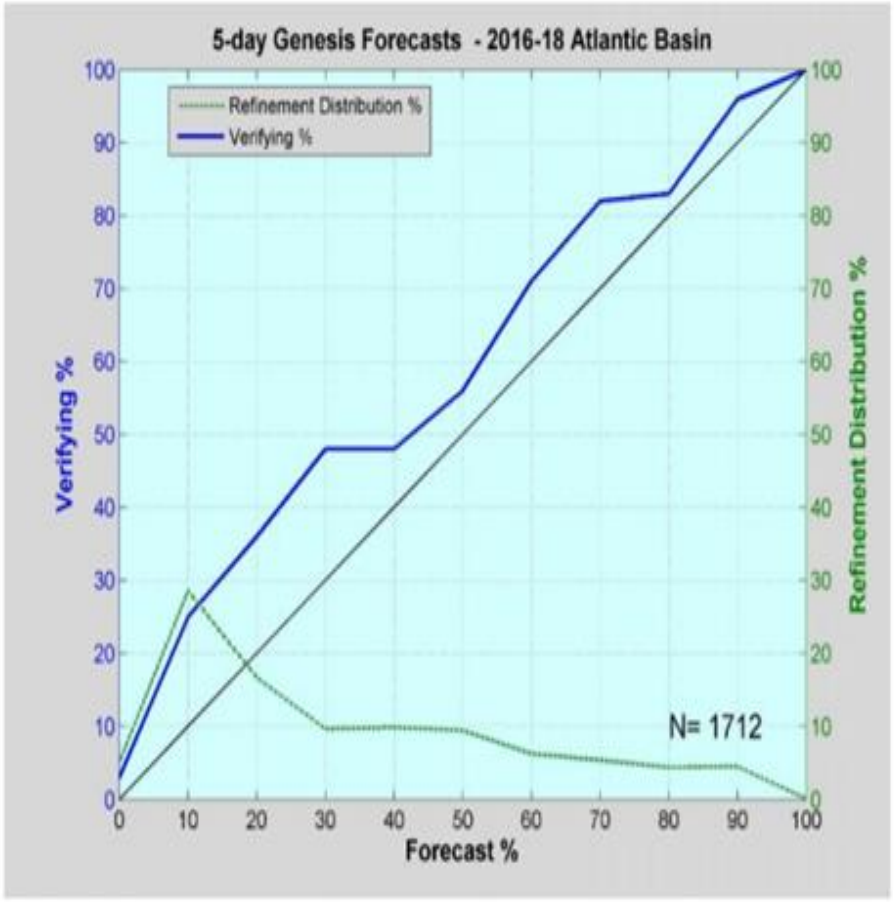
IWTC-9 Summary

- Keynote presentations provided by Prof. Russ Elsberry and Dr. Sarah Jones
- 7 Main Topics
  1. Cyclogenesis
  2. Tropical cyclone track
  3. Tropical cyclone intensity change
  4. Tropical cyclone structure analysis and change
  5. Tropical cyclone analysis and remote sensing
  6. Communication of forecast uncertainty and warnings
  7. Tropical cyclone variability beyond the synoptic scale
- Special Topic Session on NWP

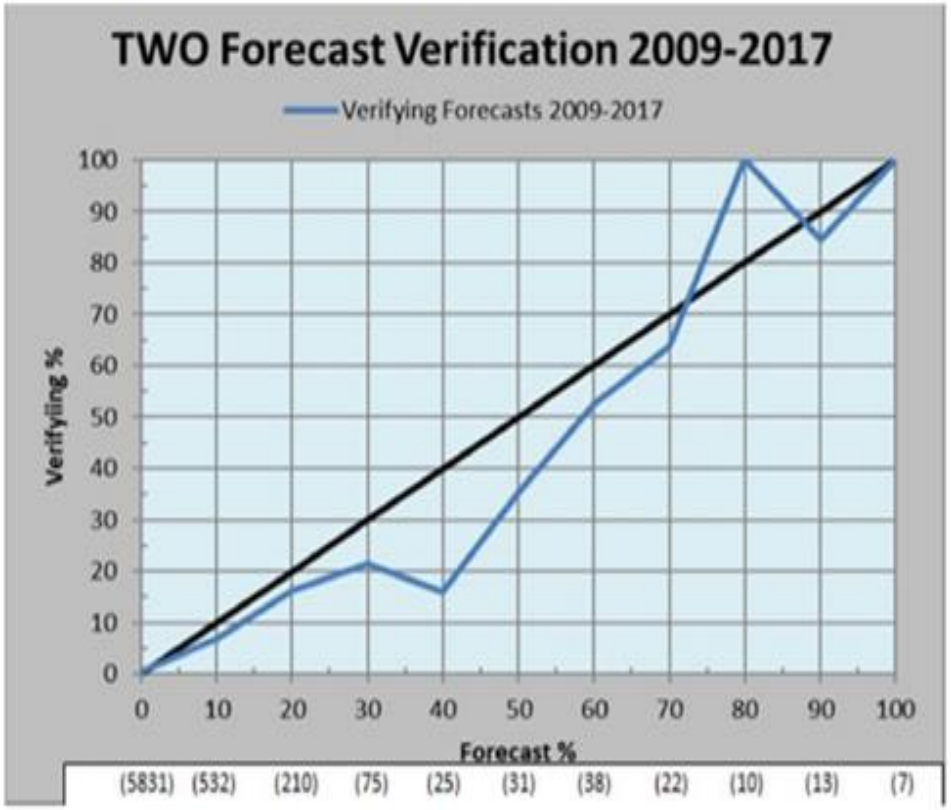
Tropical Cyclogenesis

Operational TC genesis forecasting has continued to improve

- mostly due to global model improvements



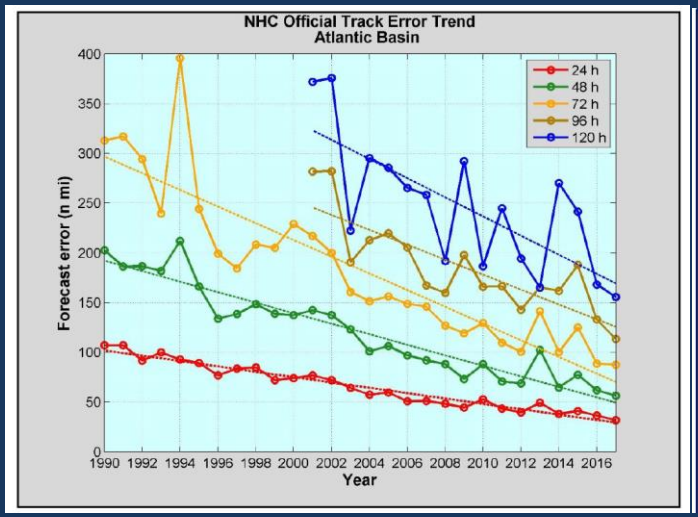
RSMC Miami

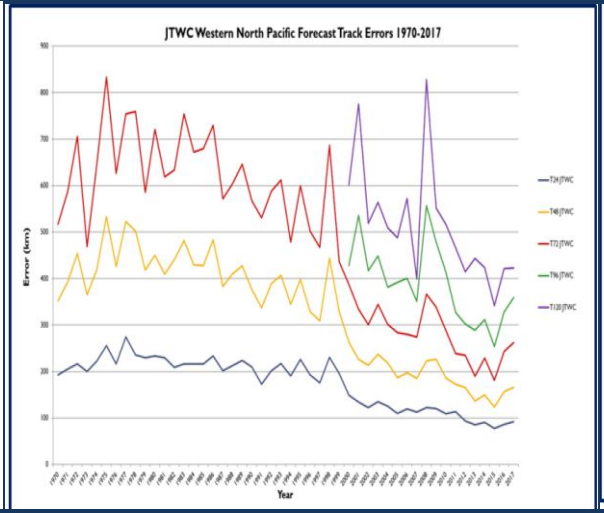


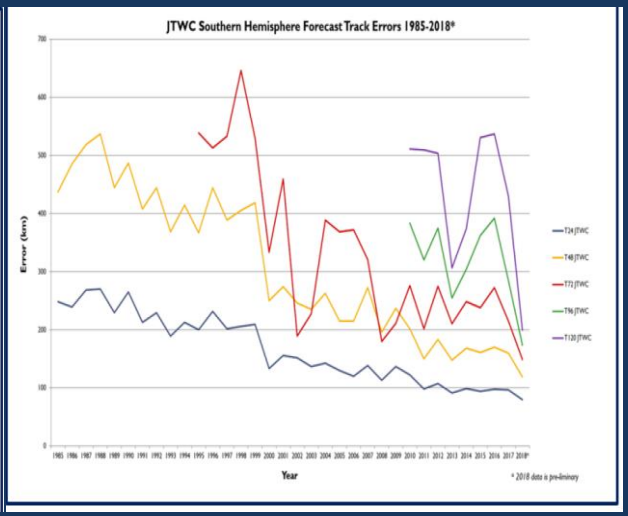
RSMC Honolulu

Tropical Cyclone Tracks

- Global models and ensembles continue to improve track forecasts
- All major operational centers showed nice progress in the past couple of decades with 5-day errors today as low as 2-day errors 10-15 years ago
- High-resolution regional models started adding value to multi-model ensemble based consensus approaches
- Small TCs still pose significant challenge for track forecasts
- Focus on difficult cases to understand better the complexities involved with TC and large-scale interactions

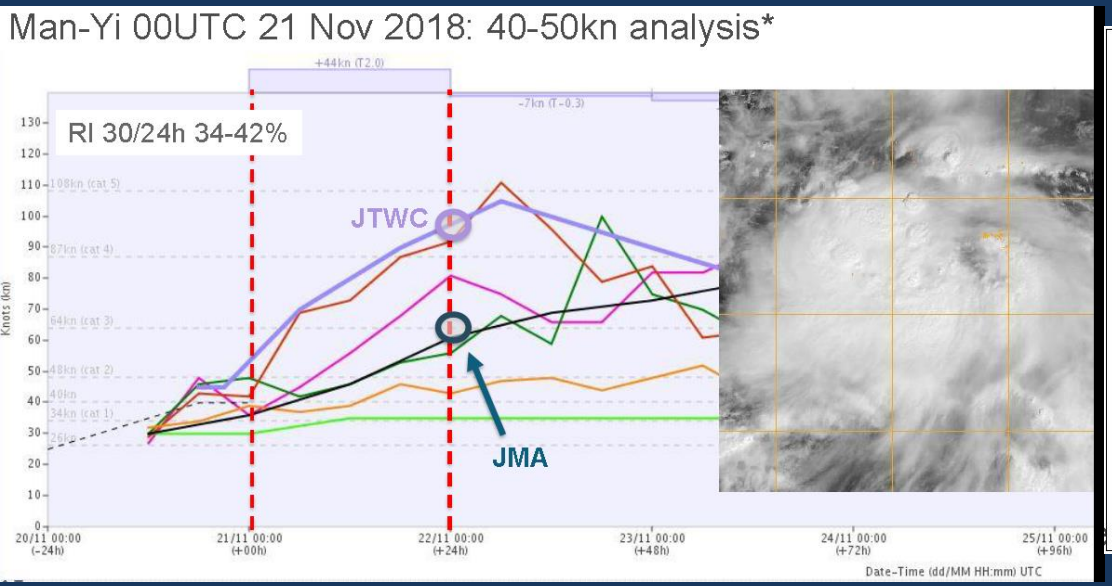


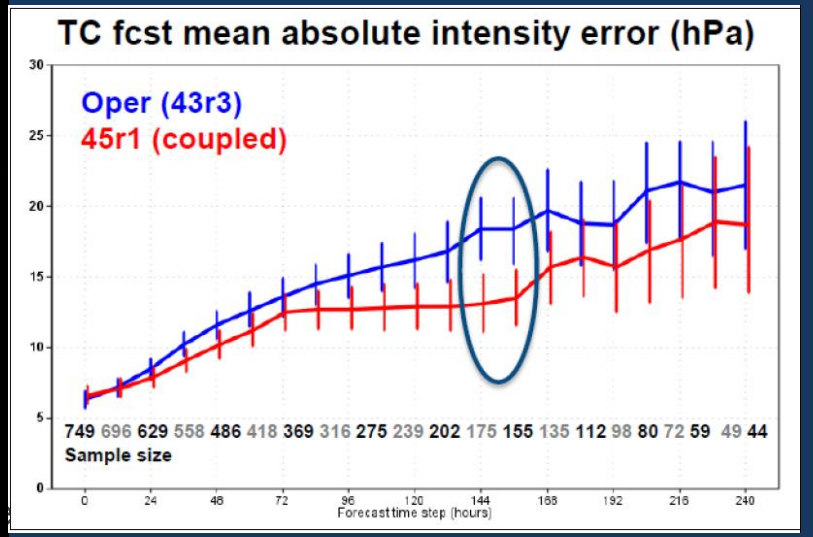


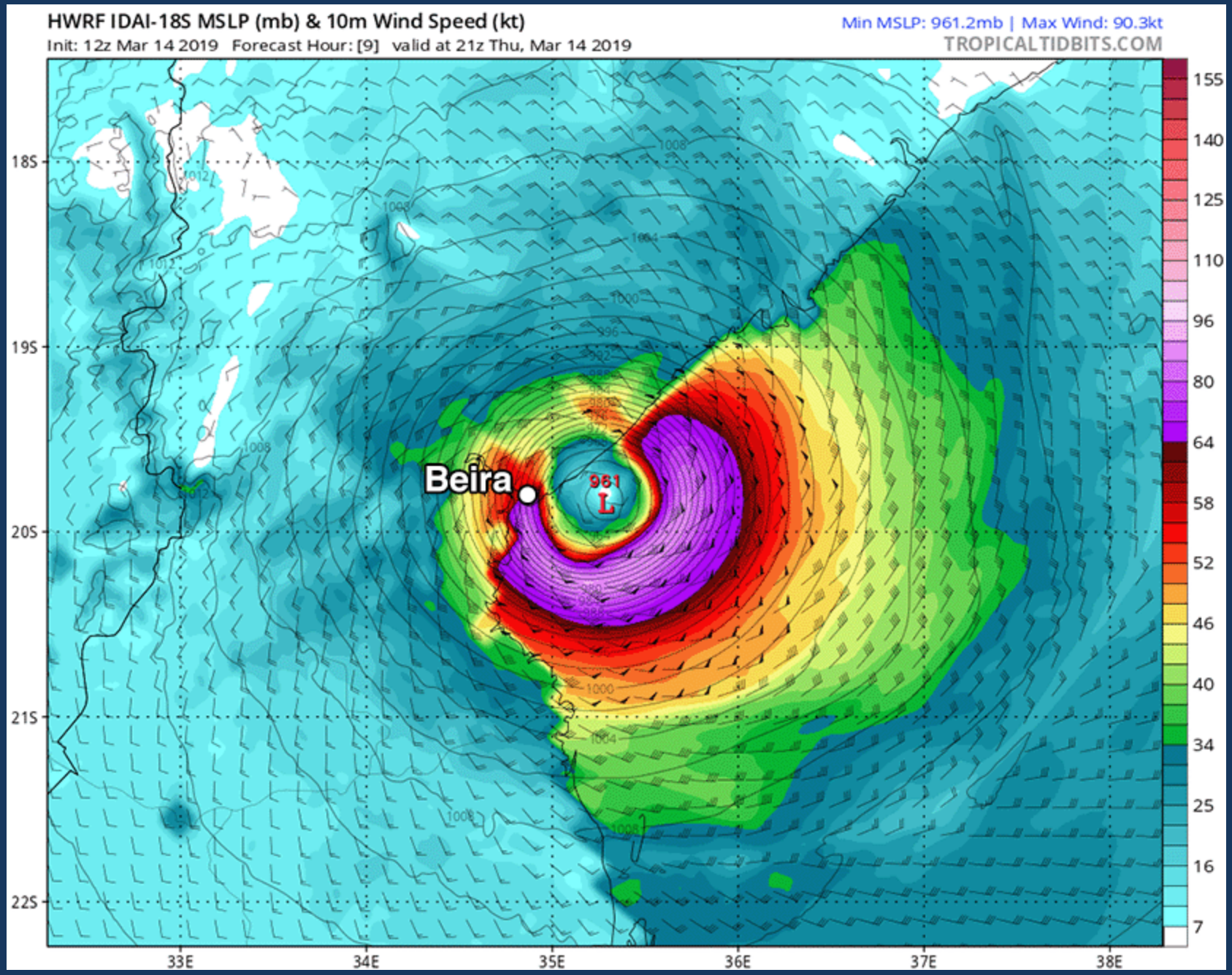


Tropical Cyclone Intensity and Intensity Change

- The operational challenge: making sense of different guidance on intensity
- Significant improvements from global models and hi-resolution regional models for TC intensity predictions, competing with statistical models
- Multi-model ensemble based consensus approaches leading the pack (HCCA, IVCN etc..)
- RI remains a major challenge, with recent improvements noted in models and operational forecasts
- Regionally varying skills for intensity forecast improvements






HWRF IDAI-18S MSLP (mb) & 10m Wind Speed (kt)
Init: 12z Mar 14 2019 Forecast Hour: [9] valid at 21z Thu, Mar 14 2019
Min MSLP: 961.2mb | Max Wind: 90.3kt
TROPICALTIDBITS.COM
Beira
961
L
18S
19S
20S
21S
22S
33E
34E
35E
36E
37E
38E
155
140
125
110
96
80
64
58
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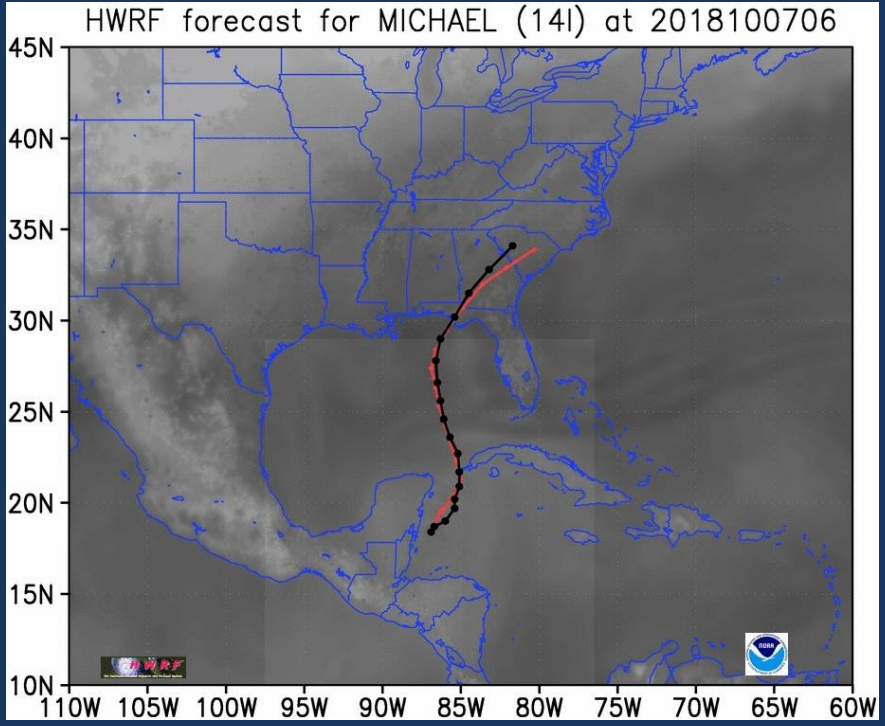
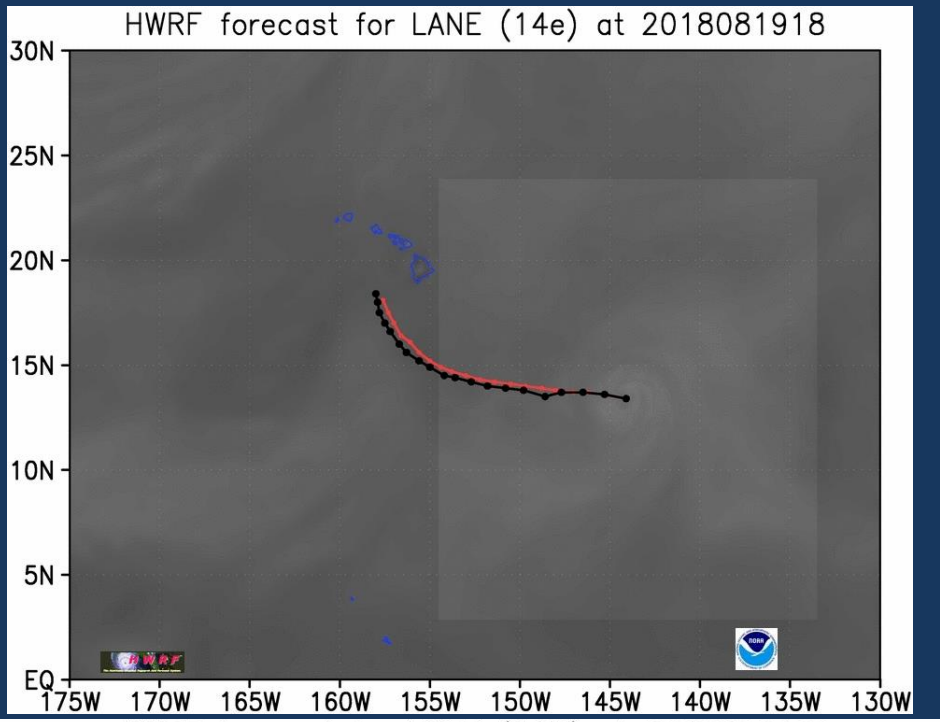
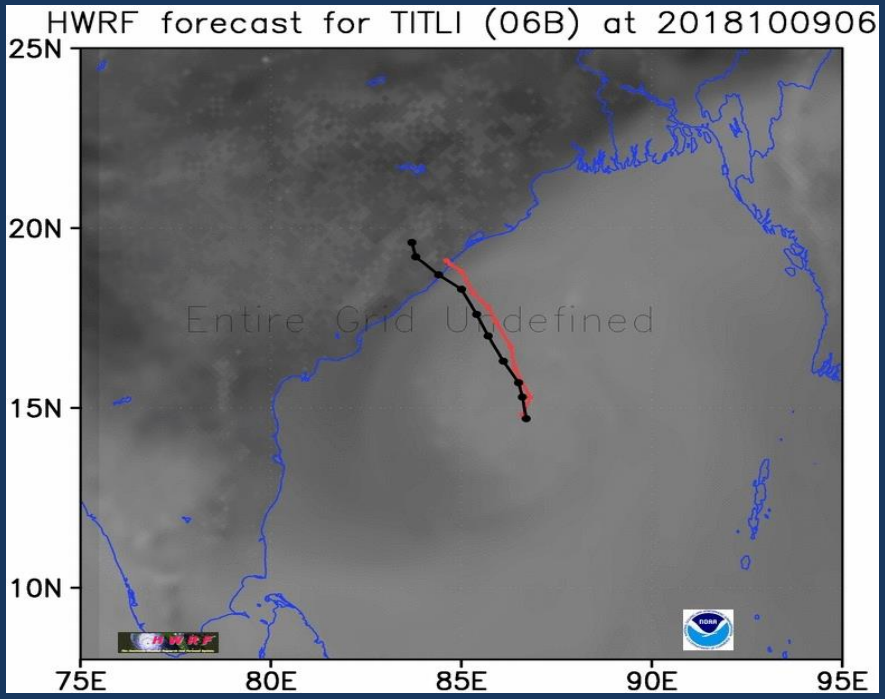
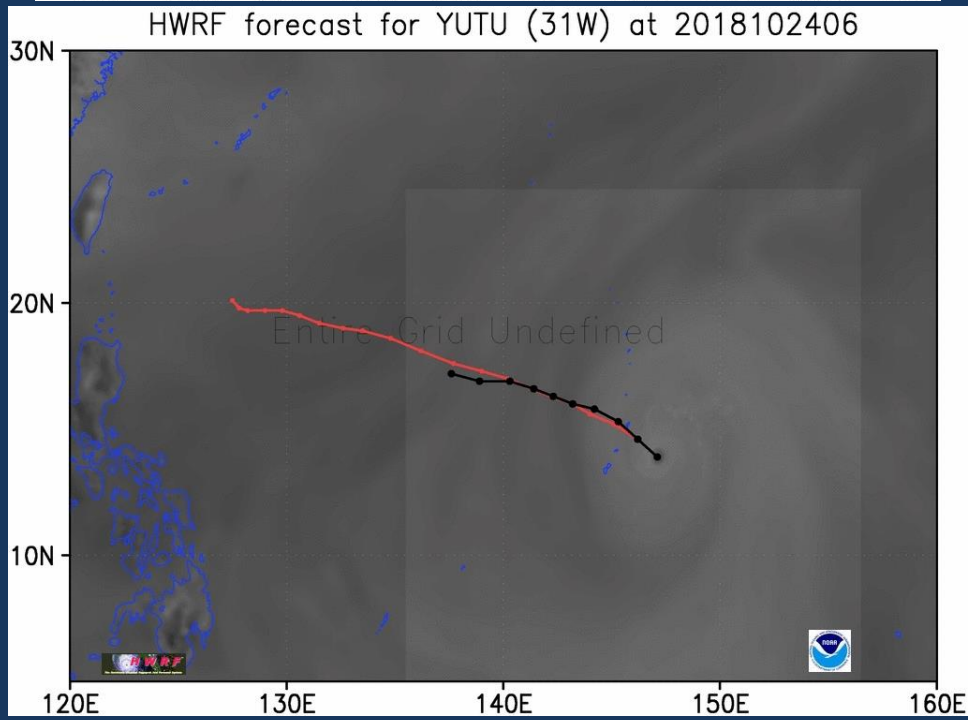
34
25
16
7


HWRF forecast for MICHAEL (14l) at 2018100706
45N
40N
35N
30N
25N
20N
15N
10N
110W 105W 100W 95W 90W 85W 80W 75W 70W 65W 60W


HWRF forecast for LANE (14e) at 2018081918
30N
25N
20N
15N
10N
5N
EQ
175W 170W 165W 160W 155W 150W 145W 140W 135W 130W


HWRF forecast for TITLI (06B) at 2018100906
25N
20N
15N
10N
75E 80E 85E 90E 95E
Entire Grid Undefined


HWRF forecast for YUTU (31W) at 2018102406
30N
20N
10N
120E 130E 140E 150E 160E
Entire Grid Undefined

Tropical Cyclone Structure Analysis and prediction

- Satellite data vital for TC structure analysis at various stages of the life cycle
- Aircraft/in-situ measurements are crucial to get more accurate structure and intensity information
- Secondary eye-wall formation, eye-wall replacement cycles, structural asymmetries, shear interactions, land interactions, ocean conditions, and internal variability of TC structure are major determining factors for TC intensity evolution
- NWP model guidance is showing improvements in these areas, still long way to go to accurately predict the size and structure of TCs

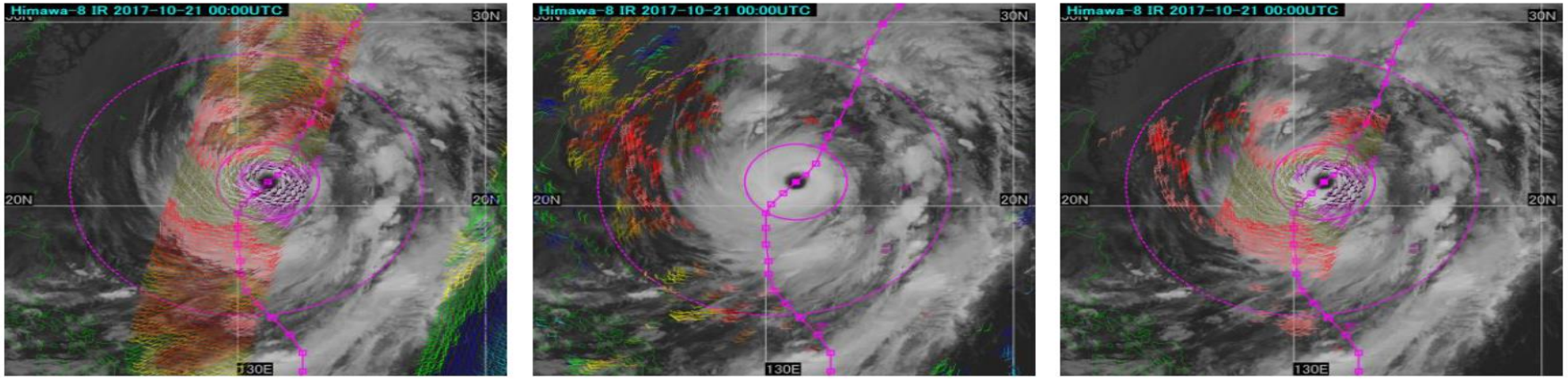


Figure 7. Sea surface AMVs and ASCAT wind composite for Typhoon Lan October 21, 2017 (left: sea surface winds from ASCAT, middle: sea-surface AMVs, right: overlapped for both winds ≥30 kts).

IWTC-9 Summary

- 8 Special Focus Sessions
  1. Significant tropical cyclones of 2017 and 2018
  2. New observation strategies
  3. Next generation meteorological satellite systems
  4. Verification metrics for tropical cyclone forecasts
  5. Improving skill of tropical cyclone forecasts and the seasonal to sub-seasonal database
  6. New uses of UAVs in tropical cyclone research
  7. Global multi-hazard alert system
  8. Storm surge forecasts and warnings

IWTC-9 Recommendations

- 34 overall recommendations
  - 14 for the research community
  - 1 for the research community and WMO
  - 5 for the operational community
  - 1 for operations and WMO
  - 6 for integrated research and operations
  - 7 for WMO

For RESEARCH:

1. How multiscale nonlinear interactions of environmental factors affect genesis, including multiple genesis events and baroclinically-influenced genesis?
2. Improve the understanding of the conditions, precursors, and processes leading to TC intensification, with special focus on rapid intensification, onset, duration, and potential intensification rate.
3. Research on interactions and processes that impact TC track, including structural changes
4. Research on secondary eyewall formation/ eyewall replacement cycles (SEF/ERC) and associated structure and intensity changes, to guide on the likelihood of SEF/ERC, what wind field changes may occur, and whether the ERC will complete

For RESEARCH:

5. Develop a definition of extratropical transition (ET) that builds on cyclone phase space, but that takes into account different pathways to ET
6. Continue efforts to develop, improve, document, and maintain climate-quality datasets including periodic reanalysis of tropical cyclones and impact-relevant TC metrics across all ocean basins, reanalysis of large-scale atmosphere/ocean fields and error characteristics.
7. Encourage peer-reviewed attribution studies (or at least real-time attribution studies based on established peer-reviewed methods), as opposed to “real-time” attribution studies using un-reviewed methods. Event attribution studies should include an expression of uncertainties and provide open access to data used.

For RESEARCH:

8. Improve our understanding of the relationship between climate and TCs by, e.g., improving climate models by including ocean coupling as a TC-relevant environmental condition.
9. More research on the MJO and other modes and timescales of variability is recommended owing to its importance for subseasonal TC forecasting.
10. Additional efforts should be spent to improve region-specific forecasts and actionable information on tropical cyclones and associated landfall and user-relevant parameters. This can include timescales ranging from sub-seasonal to climate change, and be based on various methods (e.g., machine learning, statistical methods, dynamical methods, etc.).

For RESEARCH:

11. Expand the evaluation of the skill of climate models in representing TC activity from monthly to climate change timescales, using standardized verification techniques to allow comparison of different methodologies. Involve WMO verification groups in TC sub-seasonal verification. Encourage the sharing of verification codes through public repositories.
12. Develop new aircraft, unmanned, tethered and ground-based observations of ocean and atmospheric fields and, when possible, provide real-time or near real-time, high quality, high-resolution observations in both space and time.

For RESEARCH:

13. Make better use of ensemble uncertainty information for targeting observations including airborne and space-borne observations, such as those from new high-resolution satellite AMVs. Emphasis should be placed on weak systems, regions commonly with large forecast errors, and regions typically without airborne measurements
14. Develop an international community-based platform to support expanded R&D efforts on new intensity prediction methods to facilitate the real-time exchange of forecast model data, observational data, and the data inputs that are needed to drive intensity prediction techniques, and to facilitate consistent verification according to identified community standards

For RESEARCH and WMO:

15. Consider new strategies to observe the TC inner-core and environment with high spatial and temporal resolution from the upper ocean (including pre-and post-storm) to the lower stratosphere. The observations should be used to diagnose physical processes, improve initialization through data assimilation, and evaluate and improve NWP models. In particular, WMO request that the European Union's Earth Observation Programme (the space component of Copernicus) prioritizes access to C-Band SAR data collection from Sentinel -1A and 1B satellites in Interferometric Wide swath mode over global tropical cyclones for the purpose of wind speed estimates (including RMW) for operational (and other) uses, provided that there is no additional cost. This would include the set up of an internationally coordinated framework for targeting SAR acquisitions on TCs.

For OPERATIONS:

16. Routinely analyze radius of maximum winds (RMW) and include this as a best-tracked parameter in post-season best track databases for all basins
17. Expand verification beyond current WMO guidelines to identify difficult cases of track, intensity, structure, and impacts, and for such cases to be collated and stored on a community-based database for subsequent research
18. Explore the capability of issuing pre-genesis track, intensity, and size forecasts with watches and warnings as required for disturbances with a high probability of genesis, in particular near land

For OPERATIONS:

19. Consider working toward replacing static cones of uncertainty with dynamic types (ensemble-based or hybrid statistical and dynamical techniques).
20. Include social science aspects and knowledge of ensemble and uncertainty as (mandatory/desirable) components of basic meteorological training under WMO, taking into account latest scientific advances and the forecasters' continually evolving role
21. Encourage access to forecast data particularly TIGGE, to facilitate research and operational use of ensemble forecasts. WMO should promote such sharing of data and code more widely across all topics covered in IWTC-9, by providing links to data sets from different sources

For INTEGRATED RESEARCH and OPERATIONS:

22. Explore the possibility of standardizing the definition of TC genesis and how genesis is tracked, independent of basin and model configuration, to be used for forecast and verification purposes.
23. Develop a consistent definition of SEF/ERC onset, including confidence levels, that is useful for both the research and operational community, and use it to develop a database for use by the research community
24. Advance intensity forecast guidance, visualization and integration into operational centers, including diagnostics (especially vertical wind shear), dynamic models, statistical-dynamical techniques, machine learning approaches, and ensembles to promote probabilistic intensity output

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For INTEGRATED RESEARCH and OPERATIONS:

25. Establish a database of developing and non-developing disturbances. Include storm characteristics such as center location, Dvorak CI number, & Invest designation, when applicable.
26. Support efforts to make current and future research and developmental satellite data and products available in real-time or near real-time and aggregate the products on a web site. Upon successful demonstration of capability from research missions, efforts should be made to transition these capabilities to operations and provide appropriate training
27. Researchers, operational forecasters and social scientists to jointly work together to design early warning systems using impact-based parameters with users in mind considering the decision-making processes, cascading TC impacts, forecast uncertainties, and varying capacity to respond. Special emphasis should be placed on maximizing the use of social media in a responsible manner, as a platform to engage communities

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For WMO:

28. Coordinate the transfer of probabilistic tools and forecast guidance to all TC forecast agencies.
29. Coordinate intercomparison project on different diagnostic techniques, such as ensemble sensitivities, to better understand large errors associated with forecast busts from existing databases such as the TIGGE and WGNE collection of model forecasts on ensemble sensitivity experiments
30. Assist with multi-country coordination of TC reconnaissance efforts and promote the real-time sharing and exchange of aircraft/UAV –based observational data in a standardized format to encourage easy use
31. Encourage the growing number of research and operational programs that are providing validation data for radar-derived, aircraft-derived and satellite-derived surface wind speeds/vectors outside the Atlantic basin. These efforts would include support for validation and development needed for assimilation into NWP

For WMO:

32. Encourage and support another International Workshop on Satellite Analysis of Tropical Cyclones (IWSATC) in the near future, expanding the role to better reach underdeveloped TC-prone countries to provide information on the satellite sensors, data availability, data accessibility, and platforms and to develop training for how to use the products/applications.
33. Encourage sharing and facilitate training of the research community advances in observing and modeling subseasonal TC basin-wide activity and for skillful regional forecasts

For WMO:

34. Encourage the opportunity for major interdisciplinary research activity in the Asian Region aimed at improving the information available to typhoon forecasters and providing the research needed to enhance the communication and utility of typhoon warnings. **This should be a pilot project for the future seamless Global Data Processing and Forecasting System co-designed between WWRP and the Typhoon Committee to ensure a strong linkage between research and operational forecasting**. The WWRP focal point of the activity would be its HIWeather project with significant contributions from all WWRP Working Groups and from WGNE. Key aspects of the activity could include increasing knowledge of the impacts of typhoons and heavy rain, assessing the value and utility of probabilistic NWP products for Typhoon forecasting, enhancing the use of observations (aircraft, radar, satellite); developing tools to enable provision of tropical cyclone information to the TC-RSMCs from the WMCs, contribute to the advancement of regional coupled ocean-atmosphere models for typhoon prediction. IWTC-9 recommends that interested parties meet early 2019 to discuss the development of such an activity.