HURRICANE SCIENCE ADVANCES IN THE 30 YEARS SINCE HURRICANE ANDREW

PRESENTED AT

CYBRARIUM

HOMESTEAD, FL

AUGUST 27, 2022

IN 1992

- There was no Forecast Cone.
- Hurricane predictions only out to 72 hours.
- Aviation global model had a resolution of 45 km and was run twice a day
- 72-hour average track forecast error was ~280 nautical miles.
- 72-hour average intensity forecast error was ~22 knots.
- Miami NWS radar (WSR57) was installed in 1959.
- Geosynchronous Satellites provide full-disk scan every 30 minutes. Visible resolution 1.5 km and IR resolution 14 km.
- Surface wind speeds from aircraft were estimated by looking at sea surface or applying a reductions factor to flight-level winds.
- Dropwindsondes use older Omega location system and wouldn't work when dropped in clouds or rain.

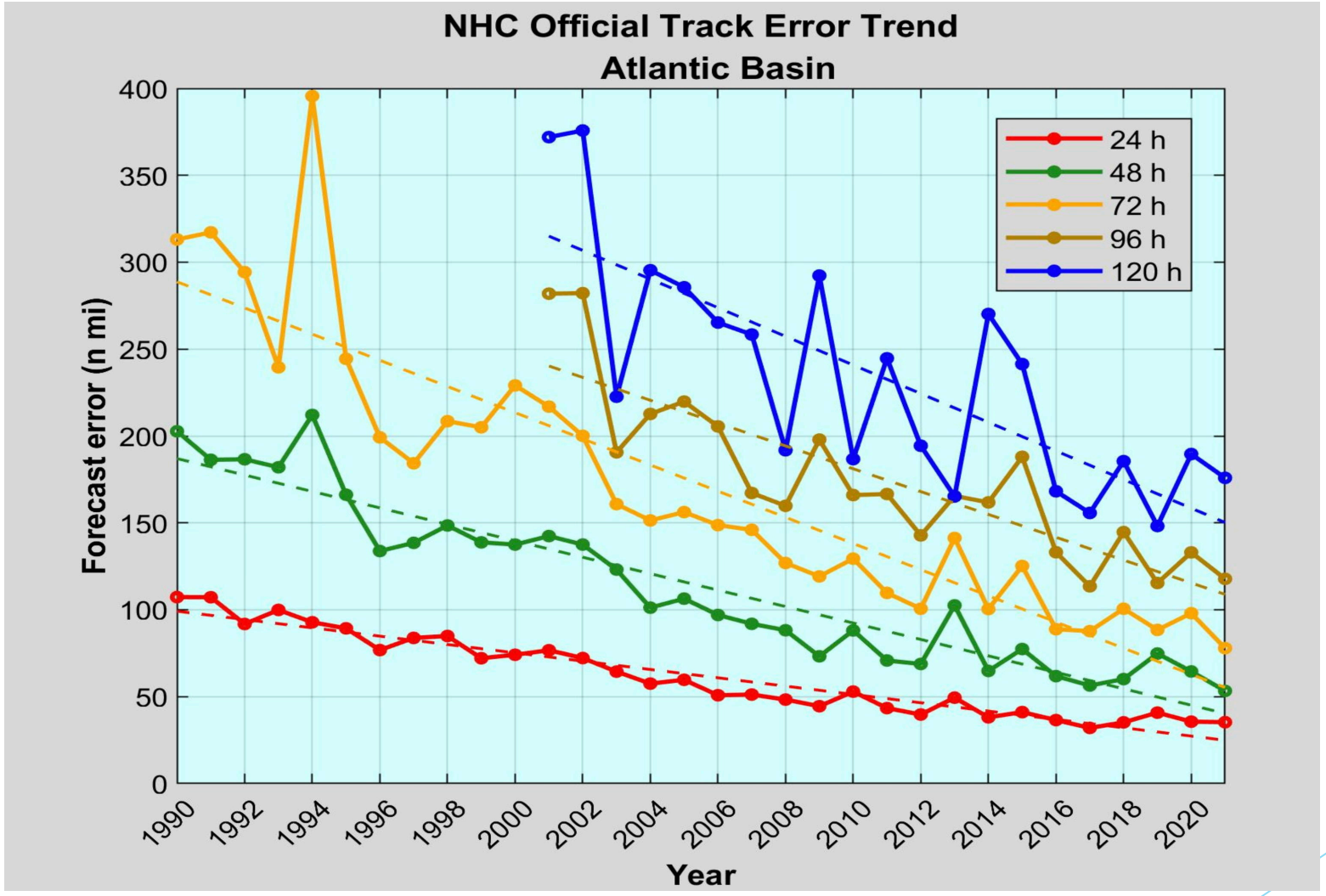
Changes in operations

- **1995** – GFDL (Geophysical Fluid Dynamical Laboratory) model becomes operational.
- **1996** – NOGAPS (Navy) and UKMET (British) track forecasts available to NHC.
- **1997** – Statistical Hurricane Intensity Prediction Scheme (SHIPS) becomes operational.
- **2000** – First real-time ensemble hurricane forecast available.
- **2000** – Hurricanes depicted in the Global Forecast System (GFS) for the first time. GFS resolution down to 13 km and ran 4 times a day.
- **2001** – Rapid Intensification Index added to SHIPS.
- **2002** – NHC begins to display Forecast Cone.
- **2002** – Hurricane Andrew reclassified as a Category 5.
- **2003** – NHC extends hurricane forecasts out to 120 hours.

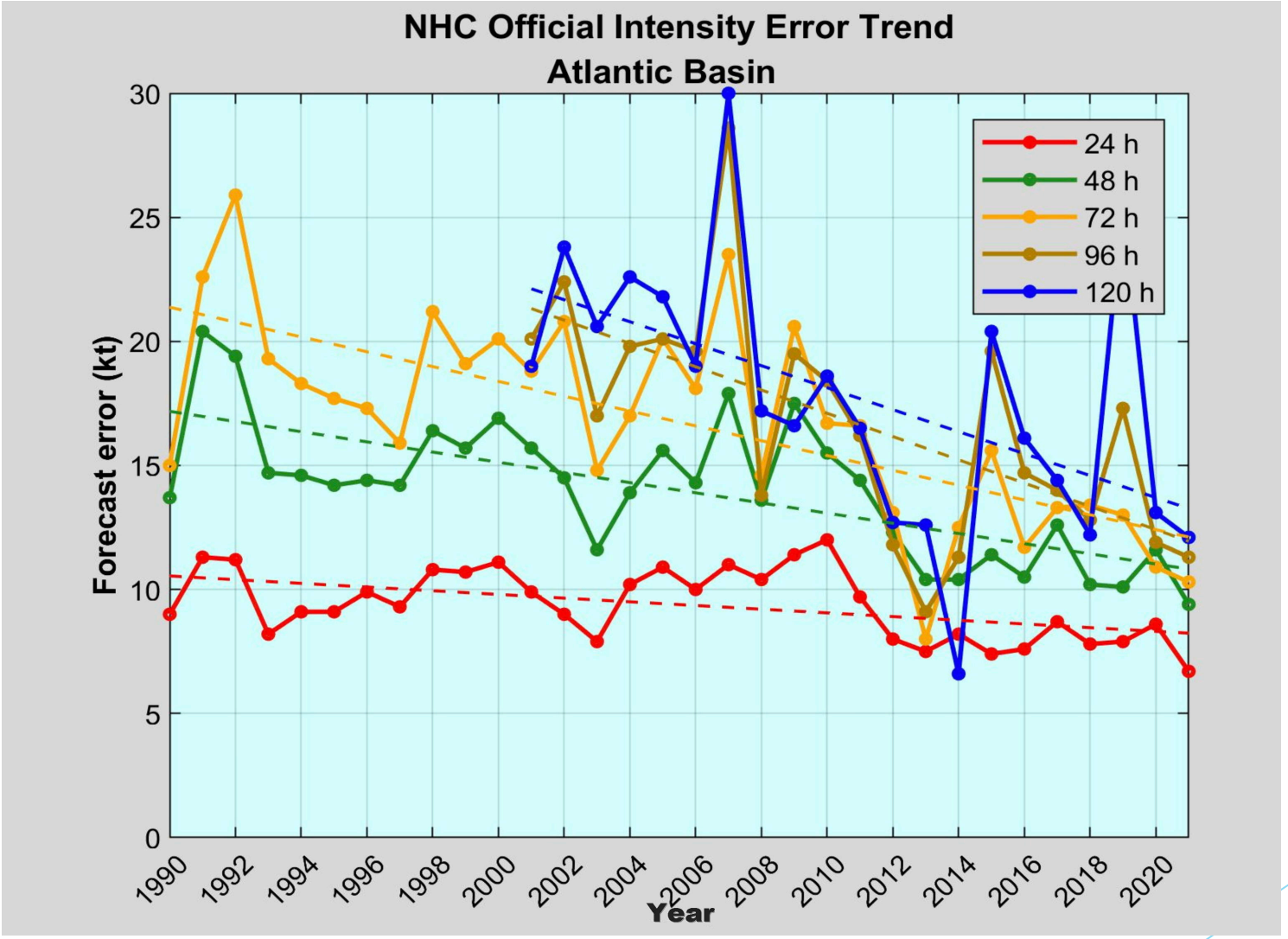
Changes in operations

- **2005** – First real-time Doppler wind data transmitted from NOAA Aircraft to NHC.
- **2006** – NHC issues probabilistic surface wind speed graphics.
- **2007** – HWRF (Hurricane Weather Research and Forecasting) model becomes operational.
- **2008** – Real-time aircraft Doppler wind data ingested into computer models .
- **2011** – NHC joins Facebook and Twitter.
- **2013** – NAVGEM (Navy Global Environmental Model) replaces NOGAPS model.
- **2014** – Tropical cyclone formation forecast program makes predictions out 5-days.
- **2017** – NHC begins issuing graphical storm surge warnings.
- **2018** – HMON (Hurricanes Multi-scale Ocean-coupled Non-hydrostatic) model becomes operational. Resolution of inner grid down to 2 km.

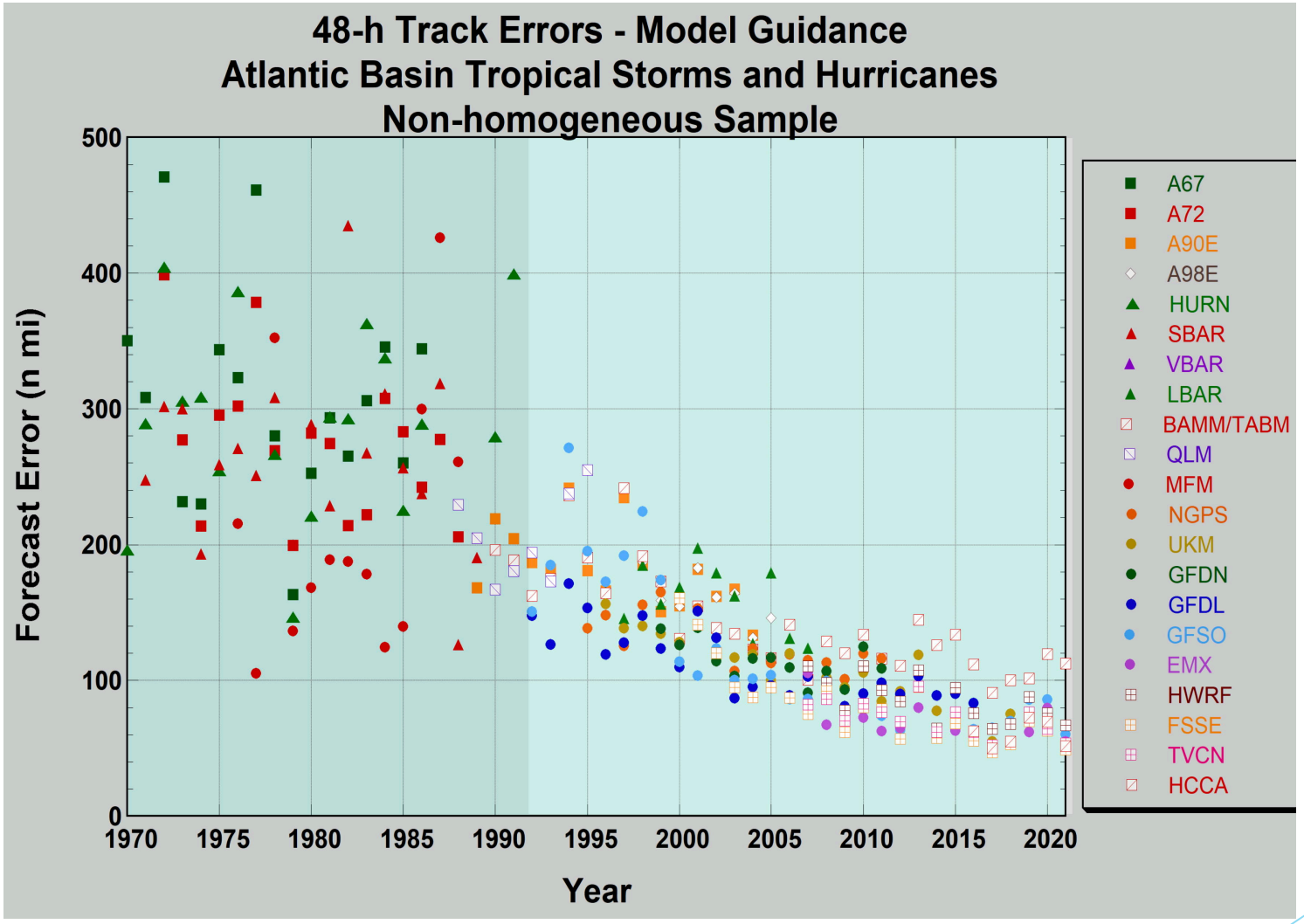
Changes in operations



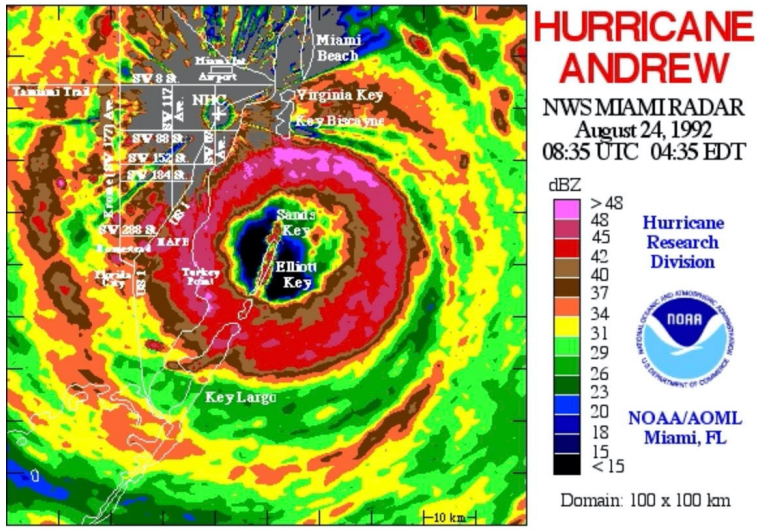
Changes in operations



Changes in operations

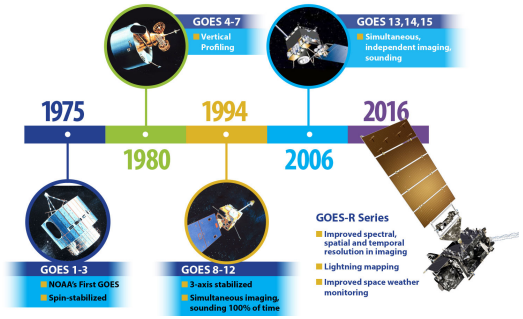


Changes in observations (radar)



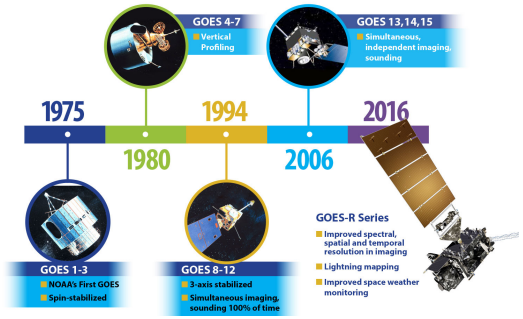
- **1993** – WSR-88D radar installed in Miami ahead of schedule to replace the WSR-57 destroyed in Hurricane Andrew. New system has Doppler capability.
- **2012** – Dual polarization capability added to WSR-88D radars, which allows identification of different target types, such as hail, raindrops, snow, or insects.

Changes in observations (satellite)



- **1994** - GOES-8 new generation of geosynchronous satellite improves resolution to 4 km in IR and reduce noise in visible. It can take soundings independent of imaging camera. Rapid scan high-resolution loops of Hurricane Luis reveal complex motions in the eye.
- **1997** - Tropical Rainfall Research Mission (TRMM) launched. The microwave imager for the first time allowed scientists to see the cloud structure underneath the upper-level clouds.
- **1999** - QuickSCAT launched. It provides surface wind measurements from space. Allows observation of tropical cyclone circulation formation.

Changes in observations (satellite)



- **2000** – NOAA-16 new generation of orbiting satellite offers higher resolution scans at 1.1 km and a microwave sounding instrument.
- **2001** – JASON satellite offers ocean surface observations near hurricanes.
- **2007** – ASCAT launched to replace aging QuickSCAT in providing surface winds in tropical cyclones.
- **2014** - Global Precipitation Measurement satellite launched to replace TRMM.
- **2016** – GOES-16 next generation of geosynchronous satellite with visible resolution down to .5 km visible and 2 km IR. Section scans every 30 seconds. Can map lightning.

Changes in observations (aircraft)

- **1993** – NOAA aircraft send radar composite images to NHC in real-time.
- **1996** – NOAA acquires high-altitude jet G-IV “Gonzo”. It allows dropsondes to profile a greater depth of the atmosphere (40,000 feet).
- **1997** – New generation of moisture-tolerant GPS-location dropsondes released in eyewall of Hurricane Guillermo.
- **1998** – Ocean surface waves measured from NOAA aircraft in hurricane using a scanning radar altimeter (SRA).
- **2005** – Operational Stepped Frequency Microwave Radiometer (SFMR) installed on NOAA P-3s allowing surface wind measurements from aircraft.
- **2005** – Unmanned Aerosonde launched into Tropical Storm Ophelia, gathering low-level data.

Changes in observations (aircraft)

- **2007** - Unmanned Aerosonde flown into Hurricane Noel, first time measuring boundary-layer in hurricane-force winds.
- **2008** - Operational SFMR installed on Air Force Hurricane Hunter C-130s measuring surface winds on all reconnaissance flights.
- **2012** - NASA/NOAA Global Hawk launches high-altitude dropsondes around Hurricane Leslie (65,000 feet).
- **2014** - Unmanned COYOTE launched from NOAA P-3 into Hurricane Edouard. Gathers data in boundary layer in hurricane eyewall.
- **2017** - Doppler Winds Light Detection and Ranging (LIDAR) measurements gathered in Hurricane Maria. This allowed wind measurements in clear air.
- **2018** - High resolution dropsonde data transmitted from NOAA aircraft.

Changes in observations (oceans)

- **1994** - Launched from commercial ships, Expendable Bathythermographs (XBT) profile ocean temperatures.
- **1998** - Argo program deploys a global fleet of buoys which take temperature soundings of the ocean as they drift with the currents.
- **2003** - Ocean Heat Content measured from satellite. Helps map warm eddies that can fuel hurricanes.
- **2009** - Ocean gliders deployed. By 2014, they measure the ocean under a hurricane.
- **2014** - Air-Launched Autonomous Micro-Observer (ALAMO) ocean floats launched from aircraft.
- **2021** - Saildrone makes observations of ocean surface in hurricane conditions.

Scientific advances

- **1993** – Mini-swirls detected in damage from Andrew. Small scale features in eyewall shown to have significant impact.
- **1993 - H**urricane surface wind fields analyzed from multiple observation platforms.
- **1997** – Wind field of hurricane with concentric eyewalls mapped by NOAA aircraft Doppler radar. Better understanding of eyewall replacement cycles (ERC).
- **1997** – GPS dropwindsonde data ingested into computer models.
- **1998** – Areas most critical to computer models targeted for dropwindsonde deployment.
- **1998** – Hurricane intensification related to passage over eddies of deep warm water documented.
- **1999** – Lightning in the inner core of a hurricane linked to changes in intensification.
- **2001** – *Science* article published showing Atlantic hurricane activity related to ENSO and ocean decadal oscillations.
- **2003** – Dropsondes in Hurricane Guillermo (1997) show boundary winds do not diminish as quickly as thought. The flight-level wind reductions were wrong. This also had implications for concept of “vertical evacuation”.

Scientific advances

- **2004** - Effects of Saharan Air Layer on limiting tropical cyclone formation shown.
- **2005** - IFEX (Intensity Forecasting Experiment) begins. Proposes to improve intensity forecasts by sending Doppler wind fields from the aircraft to hurricane models in real-time.
- **2007** - The Hurricane Forecast Improvement Project (HFIP) is inaugurated to use hurricane research to improve forecast models.
- **2008** - Doppler wind radials from hurricane sent in real-time for ingestion into computer models.
- **2013** - Location of strongest convection inside of the maximum winds shown to have connection to rapid intensification.
- **2014** - Better representation of cloud drops in small-scale computer models leads to more realistic physics.
- **2017** - Hurricanes can intensify even in moderate shear provided sufficient moisture in the right area.
- **2020** - Eyewall replacement cycles begin at mid-levels in hurricanes. Detection of anomalies there could lead to forecasting start of ERC.
- **2020** - Tropical cyclone formation dependent on vertical alignment of center of circulation.

Acknowledgments

The following scientists contributed to this presentation:

- Sim Aberson, Bob Black, Peter Black, Sandra Bringas, Peter Dodge, Neal Dorst, John Gamache, John Kaplan, Frank Marks, Rob Molleda, Shirley Murillo, Rob Rogers, and Paul Reasor.