ATMOSPHERIC OBSERVING TECHNOLOGY

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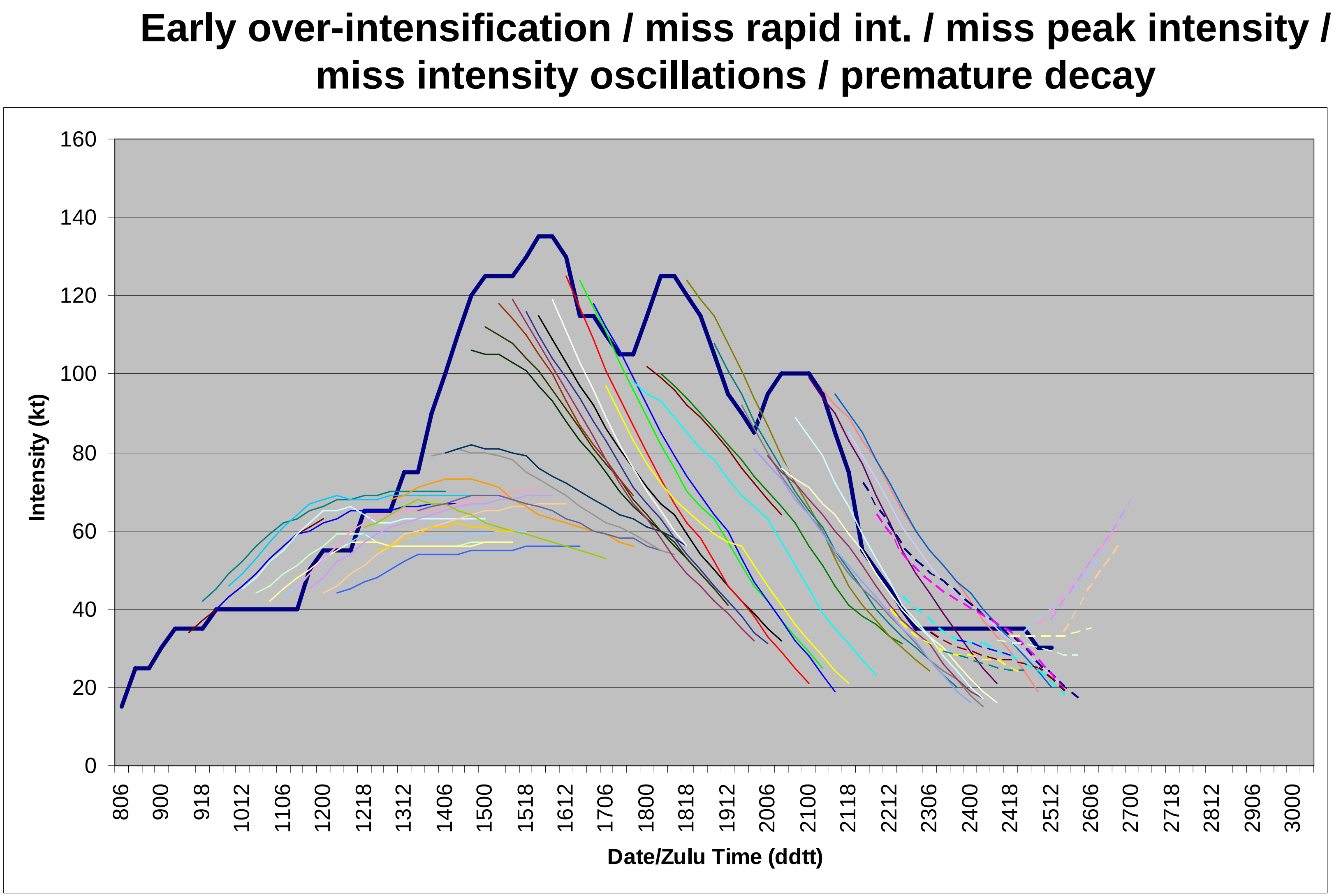
Science Strategy Workshop for Hurricane Intensity Forecast Improvements and Impacts
11-13 October 2006, Houston, Texas

Example of STIP Intensity Errors



DEFICIENCIES IN TROPICAL CYCLONE INTENSITY FORECASTING
(Elsberry et al. 2006)

Inaccuracy of time of formation (34 kt)

Rapid intensification (> 30 kt in 24 h)

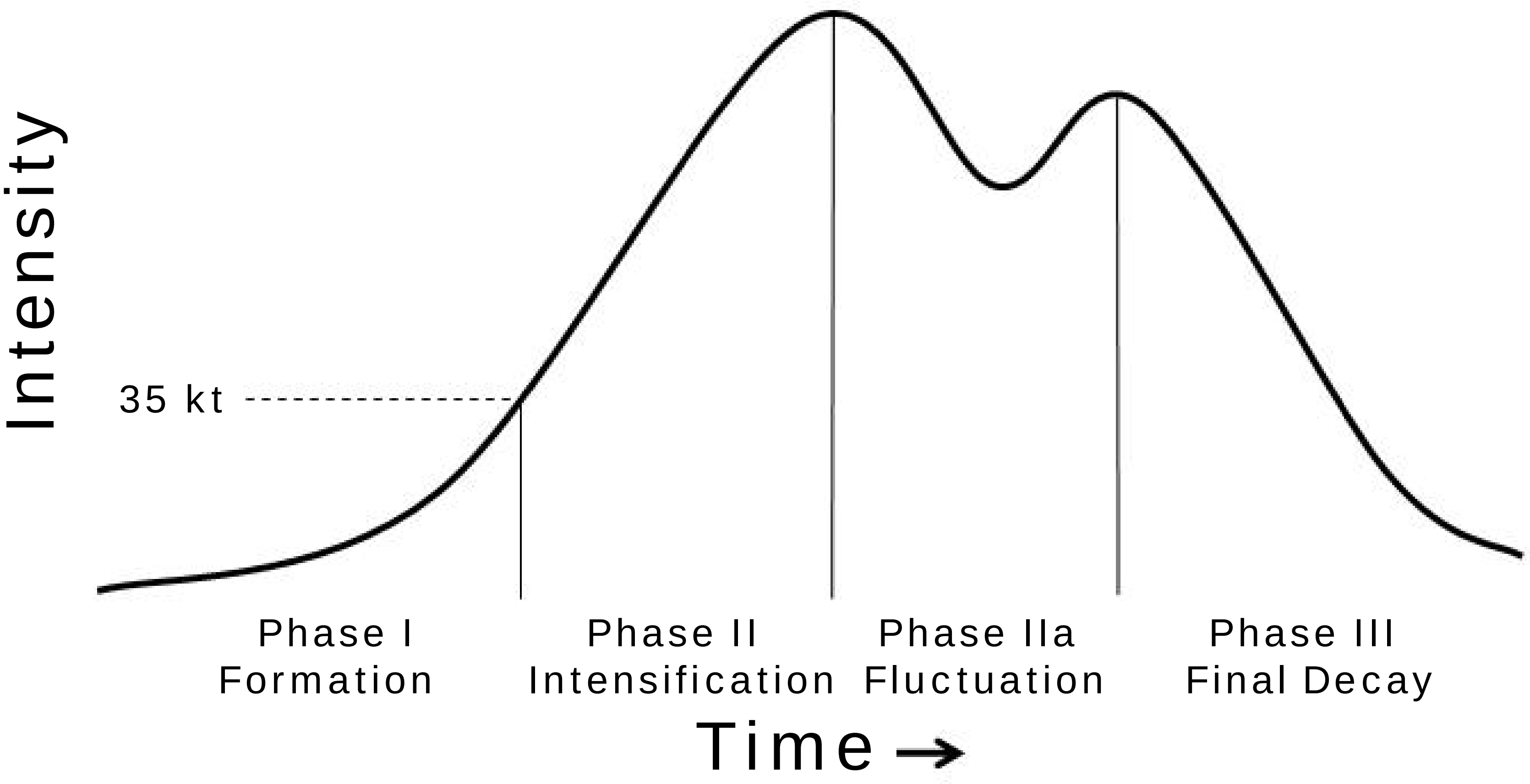
Peak intensity (time of first maximum)

Decay and intensification cycle (especially when > 50 m s^{-1})

Decay

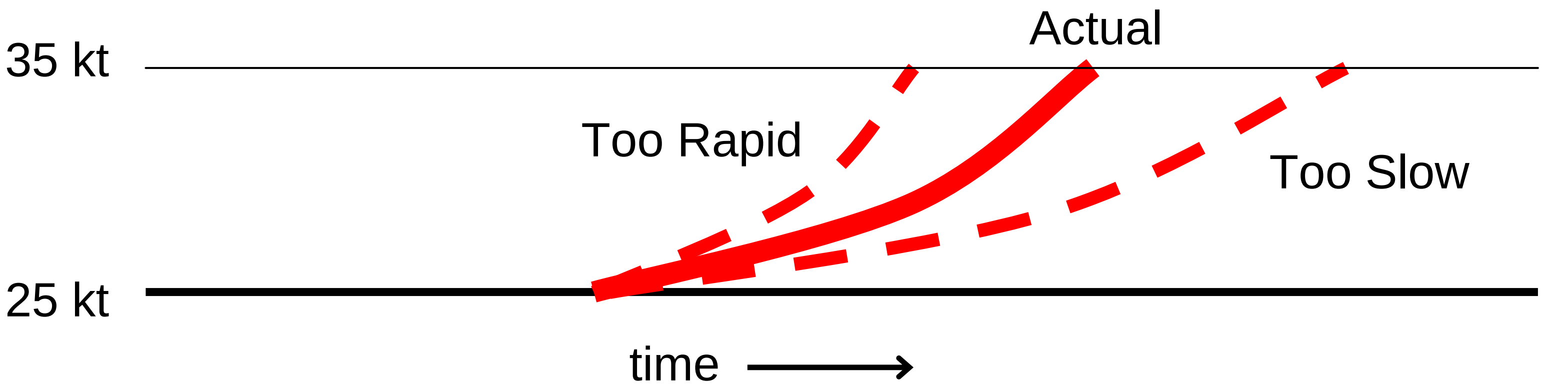
- Landfall (large forecast errors due to timing of landfall)
- Open ocean
  - Track over SST gradient
  - Interaction with midlatitude circulations and associated vertical wind shear

Framework for Intensity

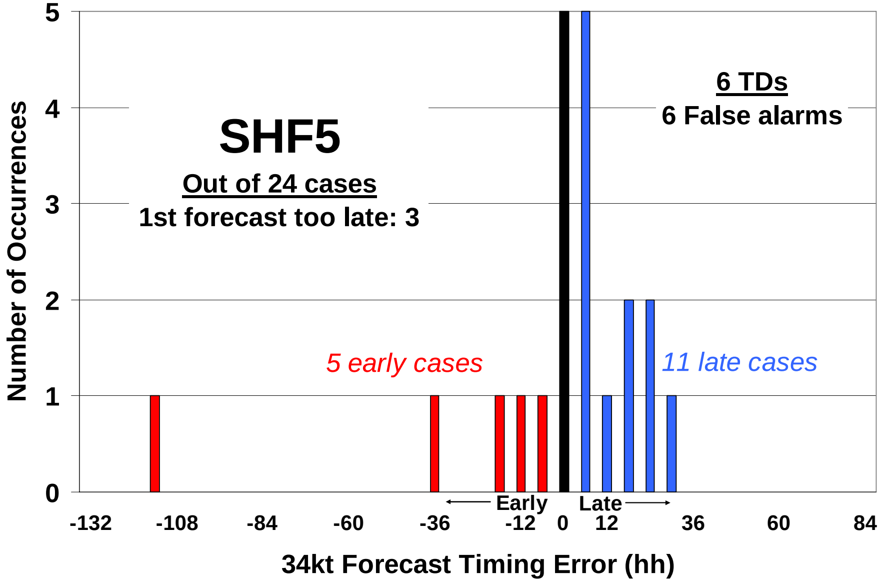


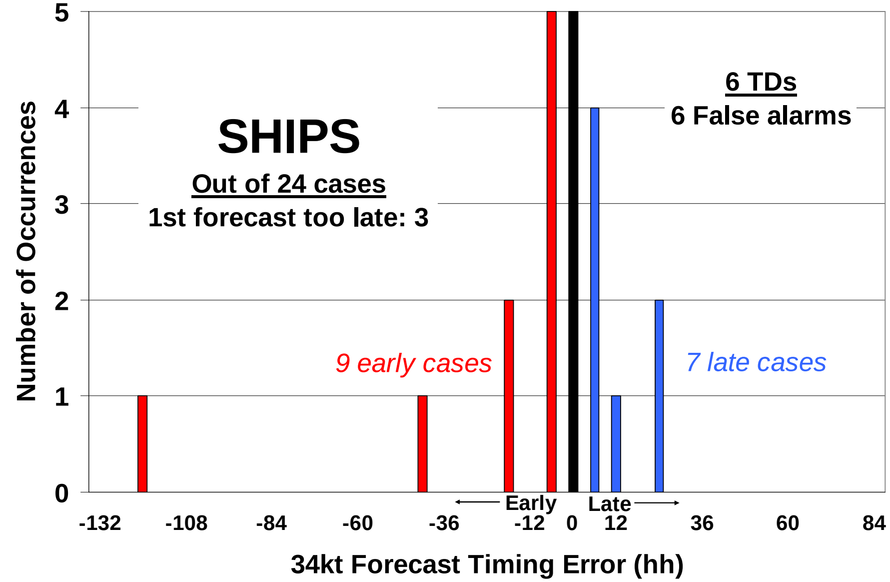
Timing and Rate of Formation

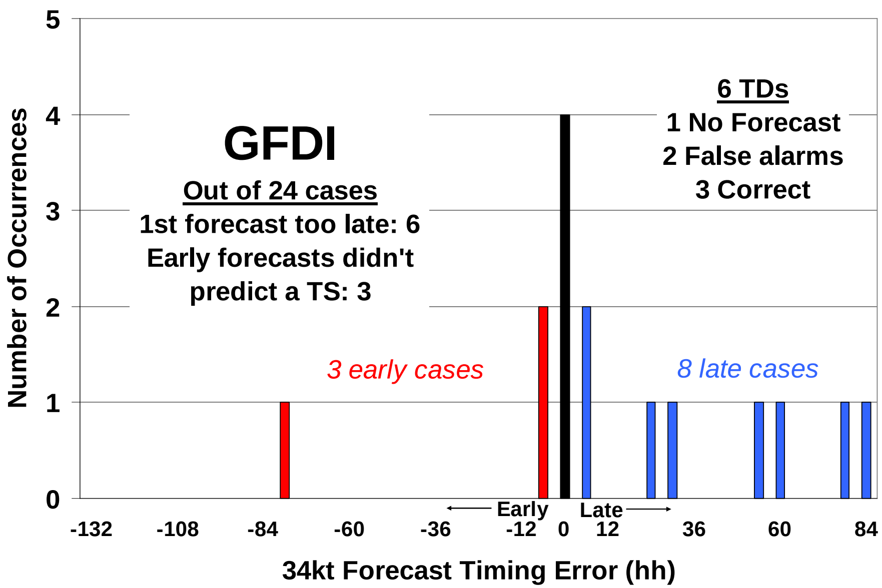
Phase I: Rate of Early Intensification

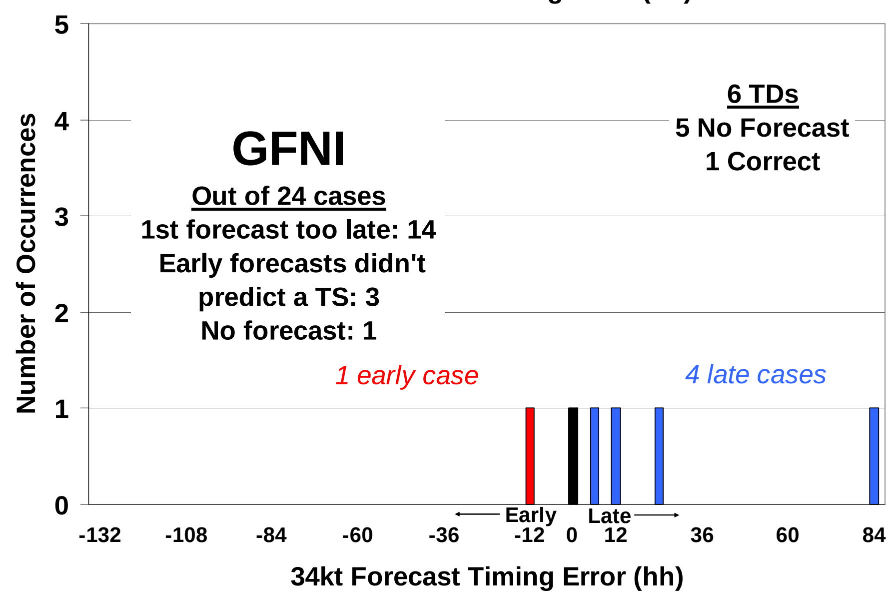


Formation Timing Errors









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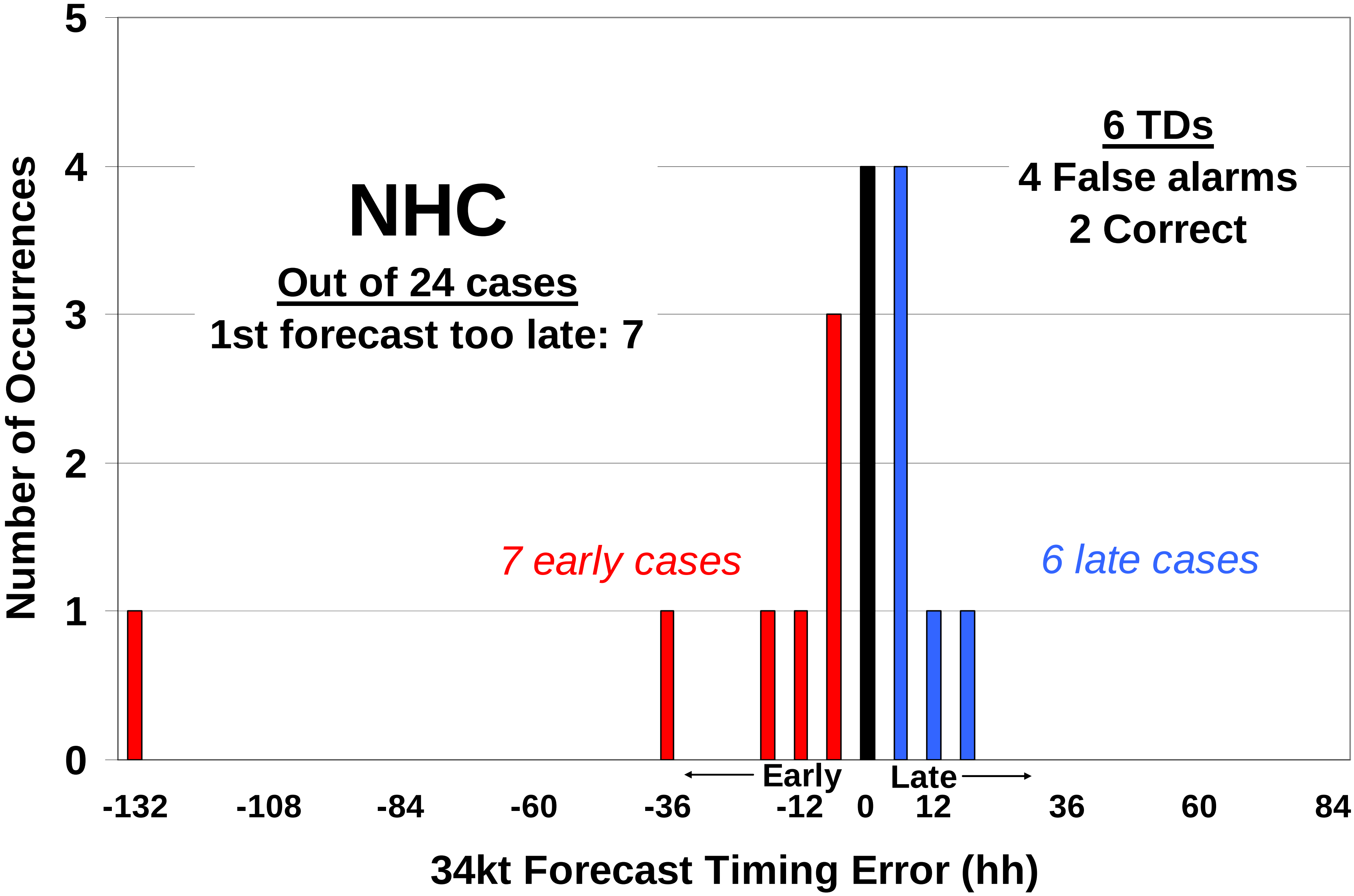
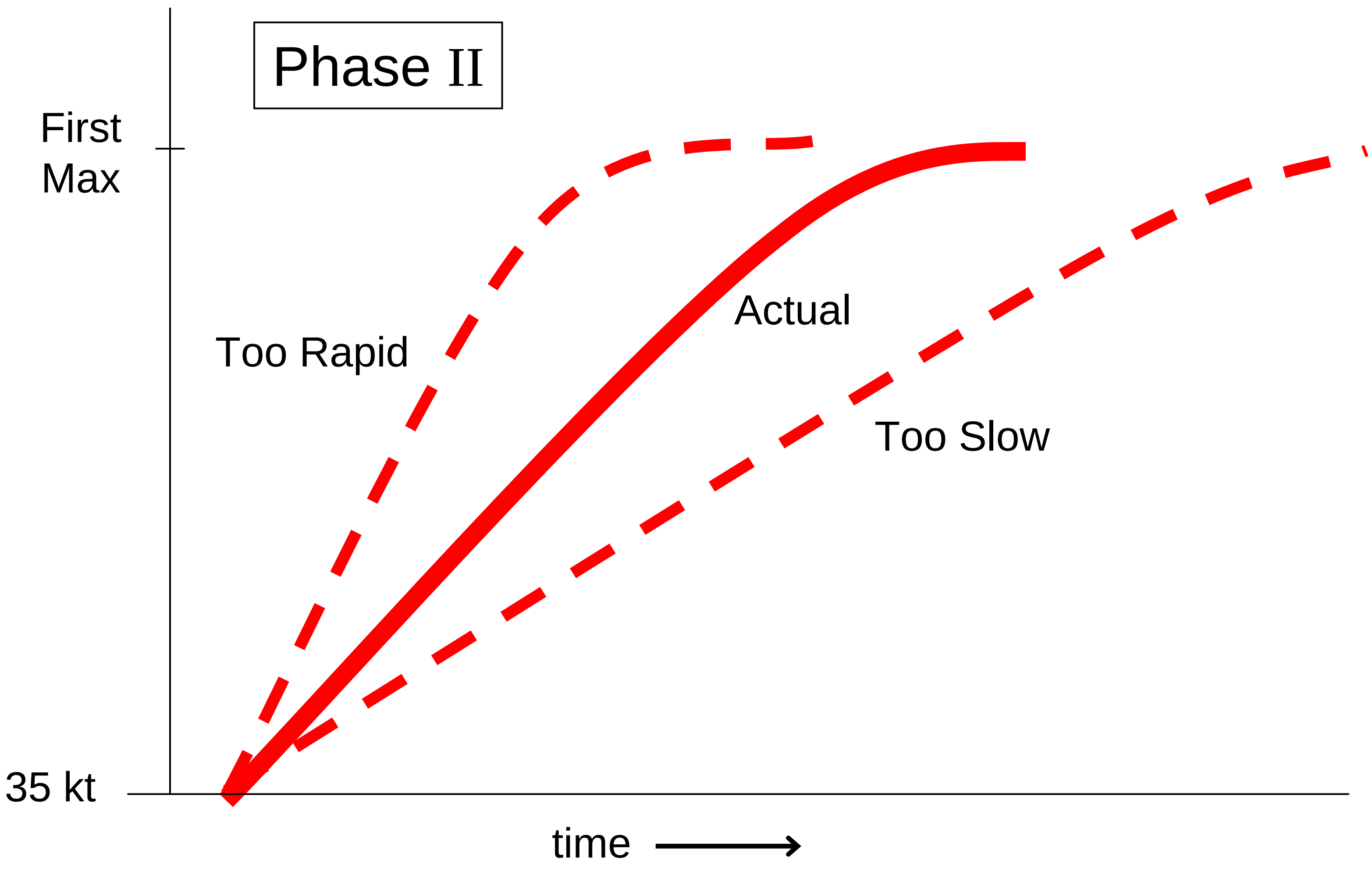
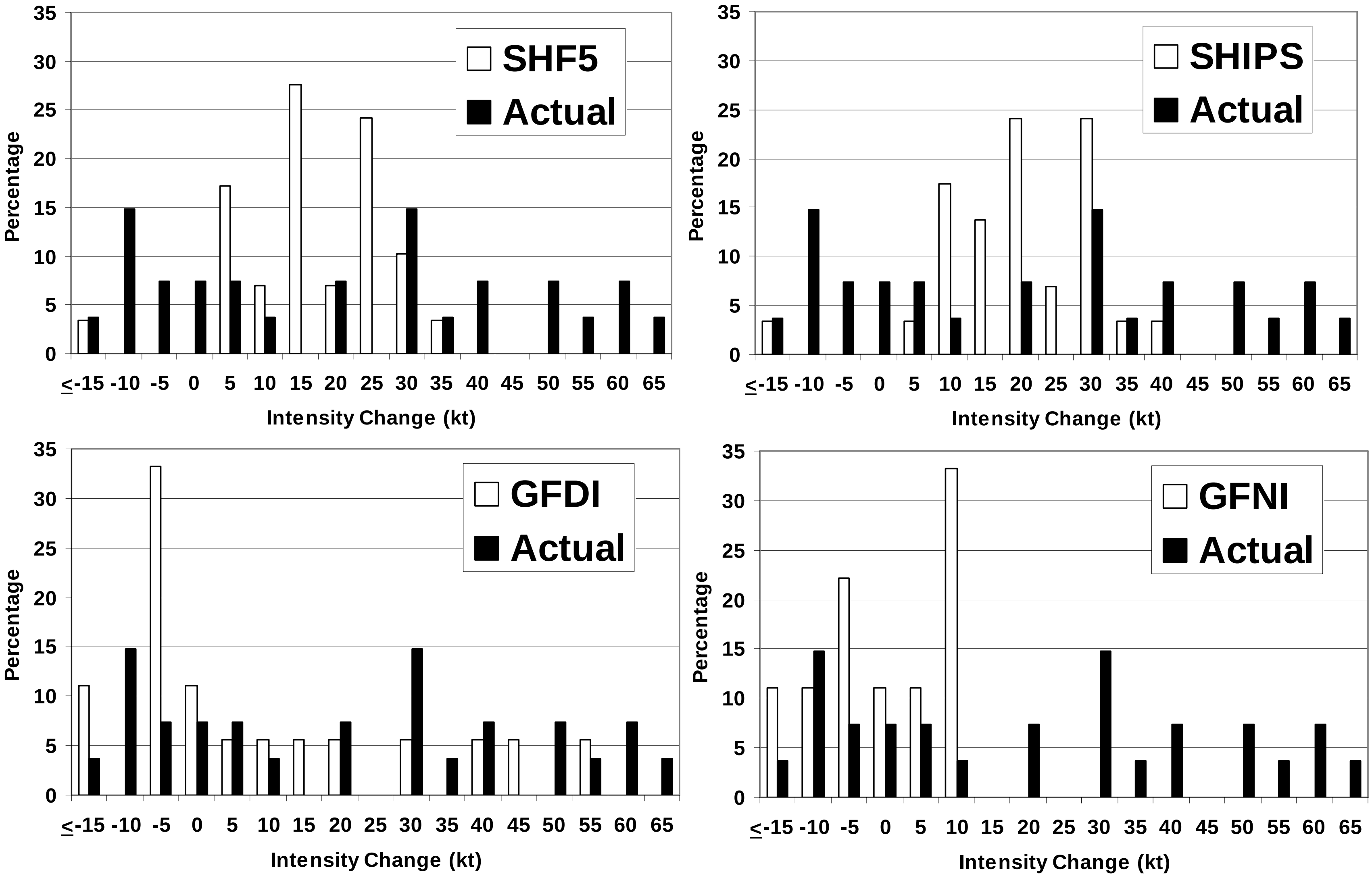


Timing and Rate of Intensification



Intensification Errors



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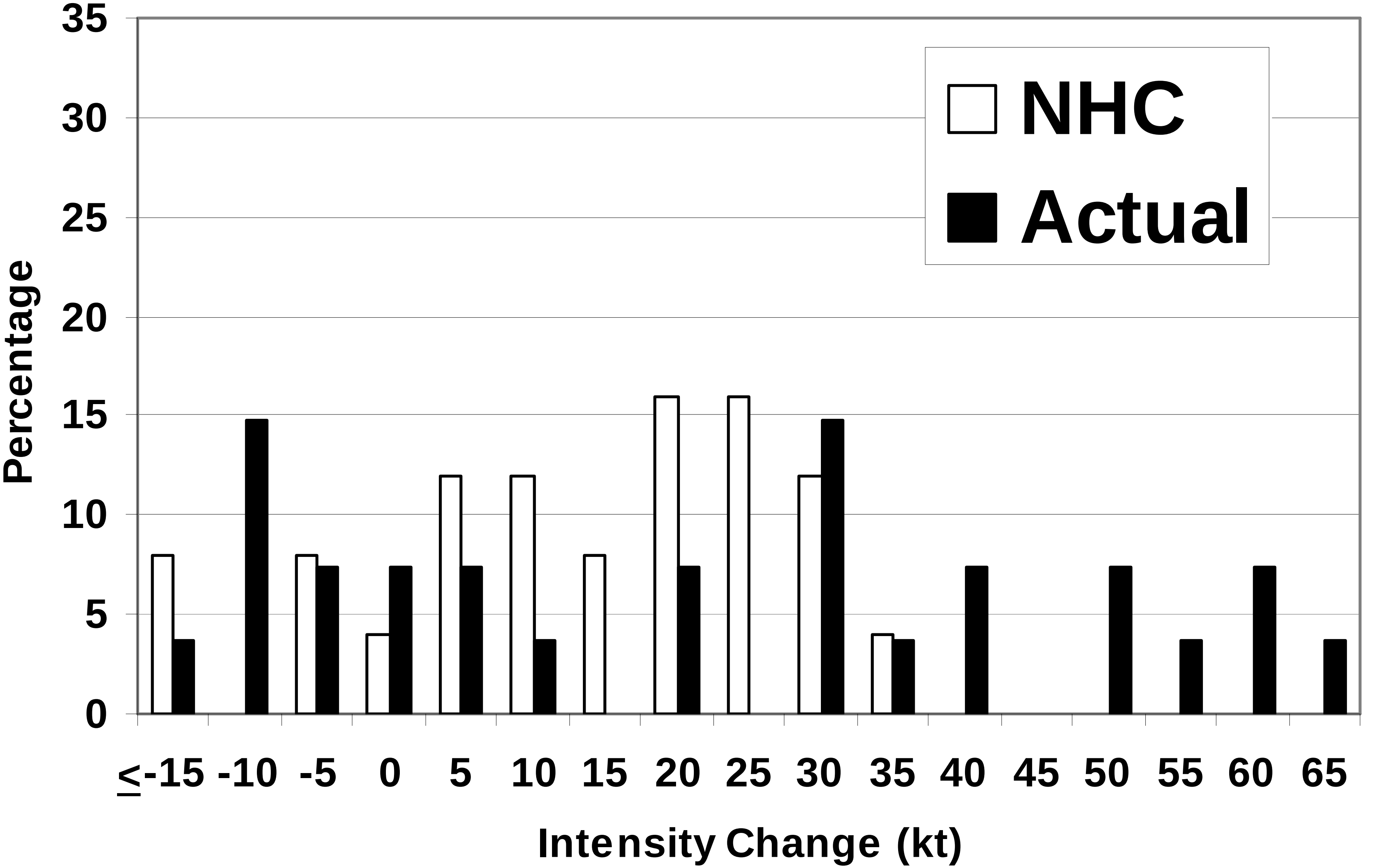
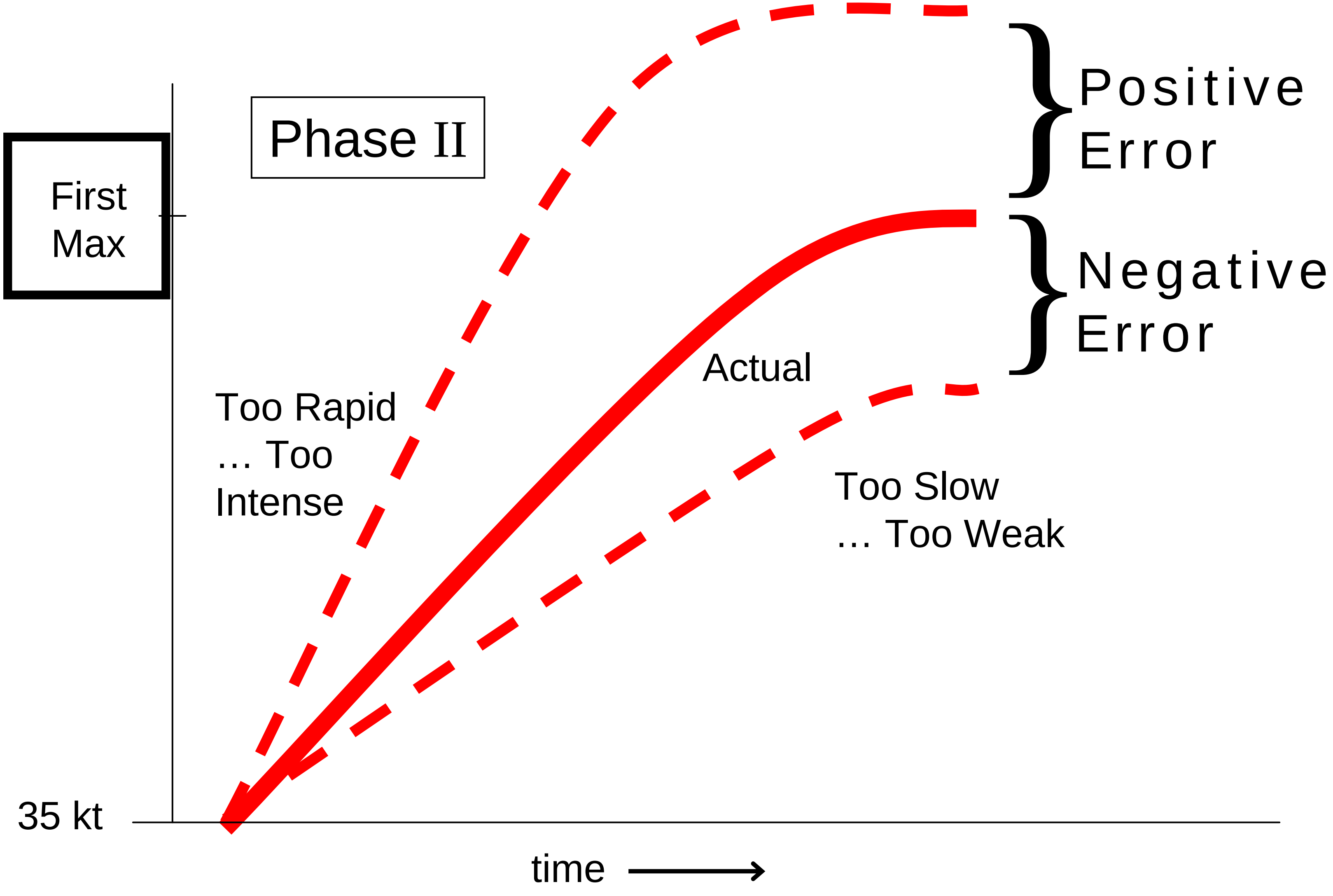


Rapid Intensification

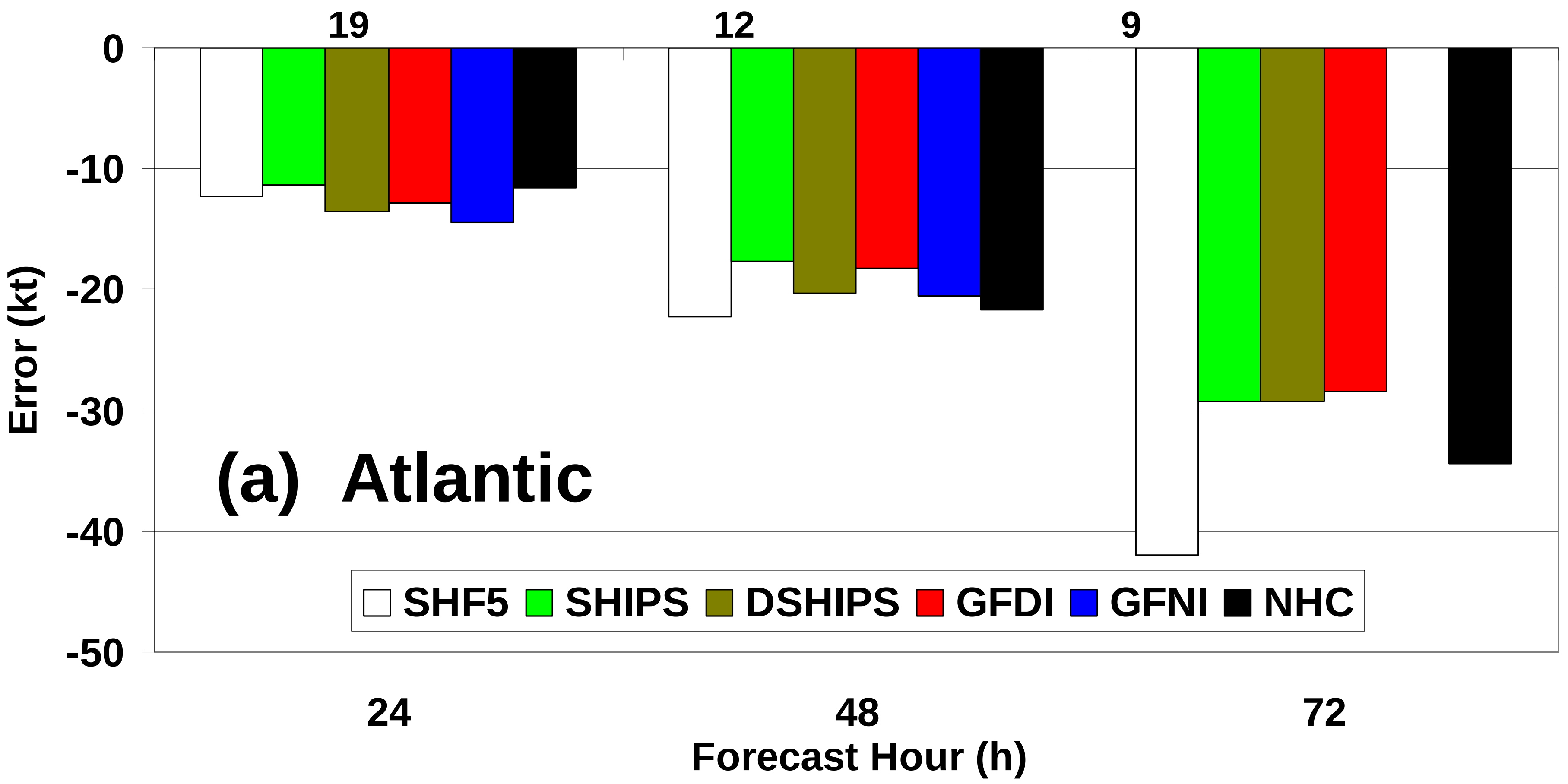
- **An increase of 30 kt or more in 24 hours**
- **12 cases in the Atlantic (2003-2004)**

	SHF5	SHIPS	DSHIPS	GFDI	GFNI	NHC
Hits	0	1	1	1	2	0
Early	0	0	0	1	0	0
Late	0	0	0	2	1	0
Misses	12	11	11	8	9	12
False alarms	8	1	0	12	11	0

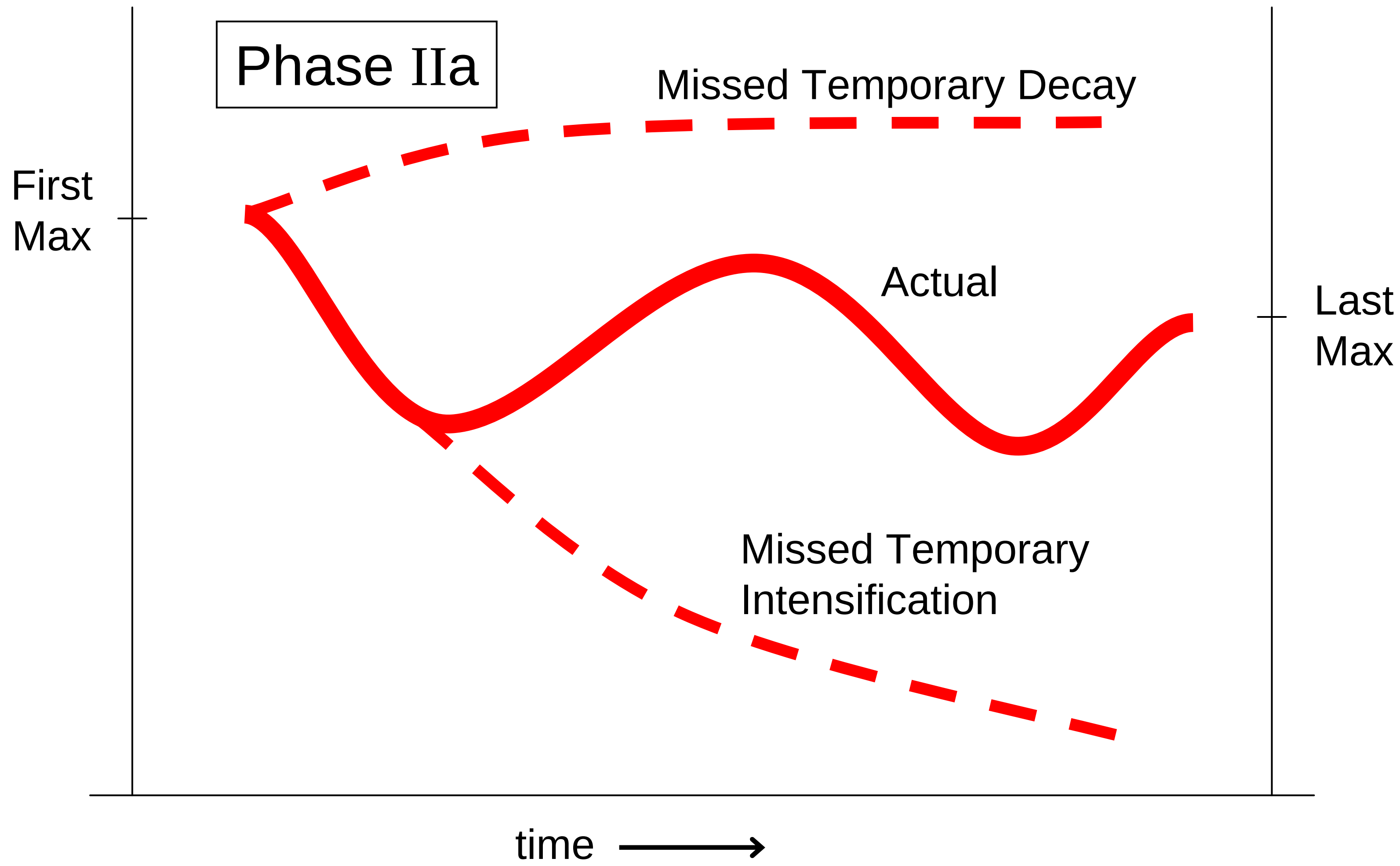
Timing and Rate of Intensification



Peak Intensity Errors



Decay-Reintensification (Fluctuation) Cycles

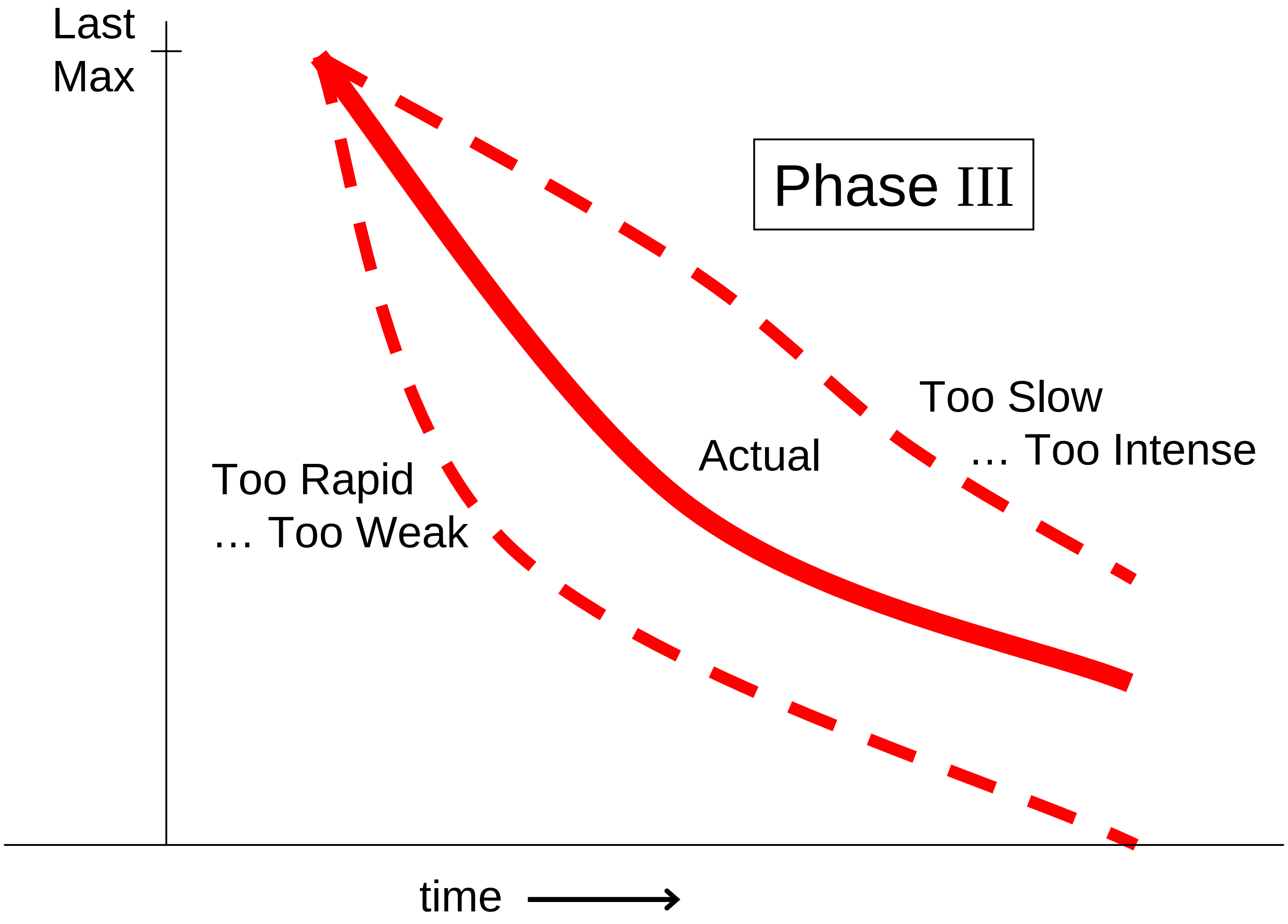


Decay-Reintensification (Fluctuation) Cycles

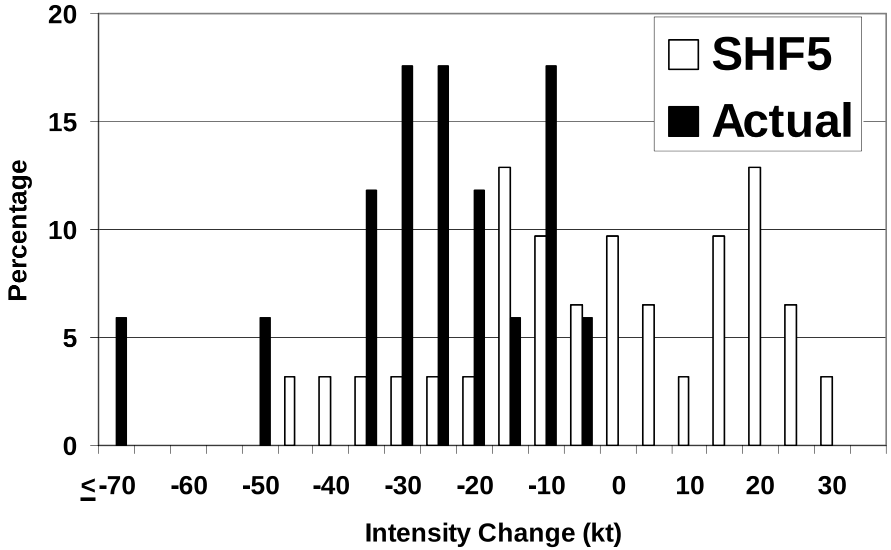
- **A decrease and increase of at least 10 kt**
- **21 cases in the Atlantic (2003-2004)**

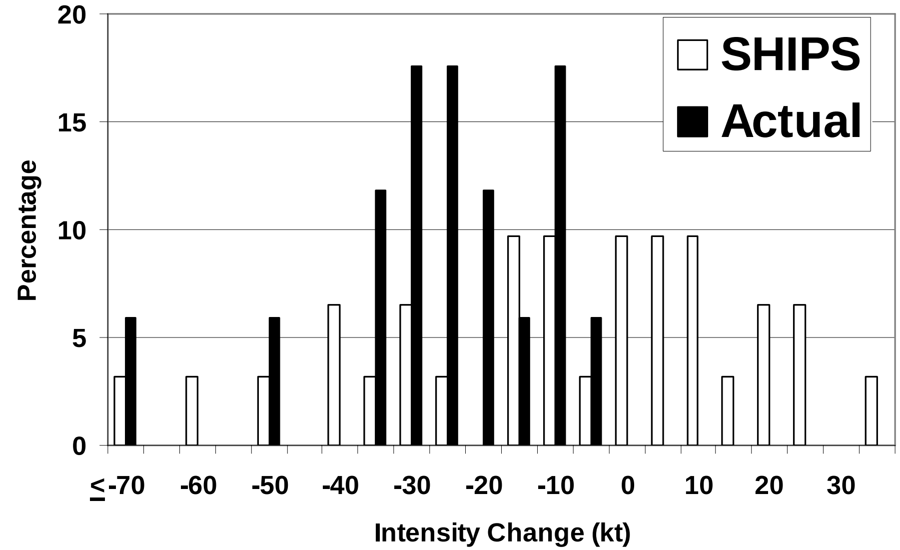
	SHF5	SHIPS	DSHIPS	GFDI	GFNI	NHC
Decays > 10 kt	4	0	4	3	4	1
Intensifies > 10 kt	4	0	2	7	4	2
Both	0	0	2	1	3	1

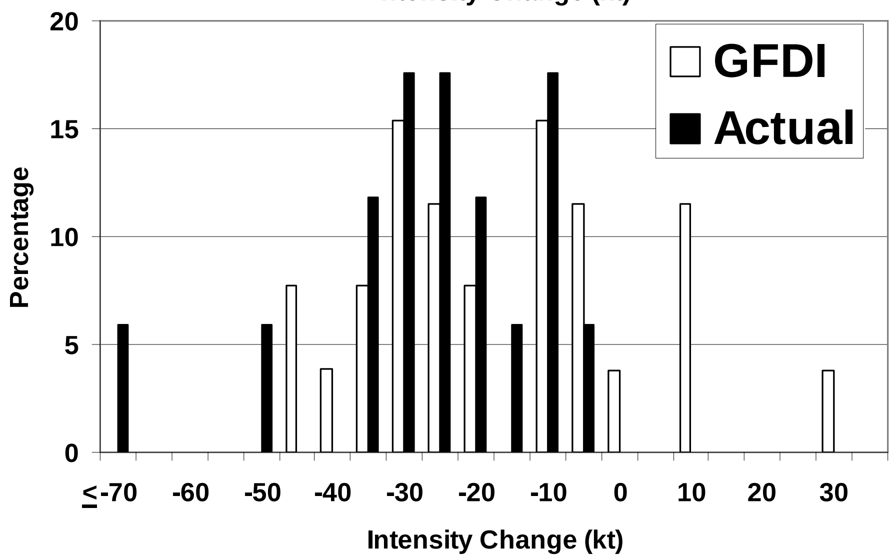
Timing and Rate of Decay

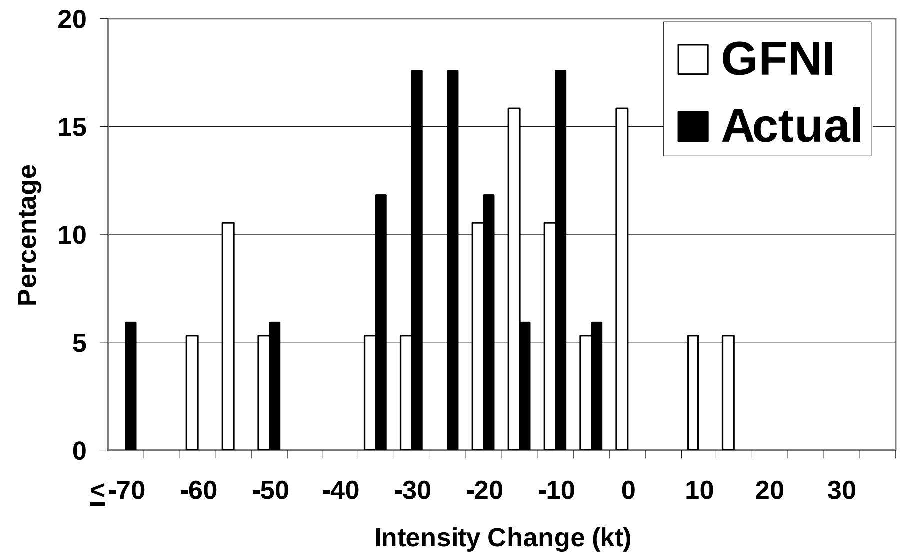


Decay Errors









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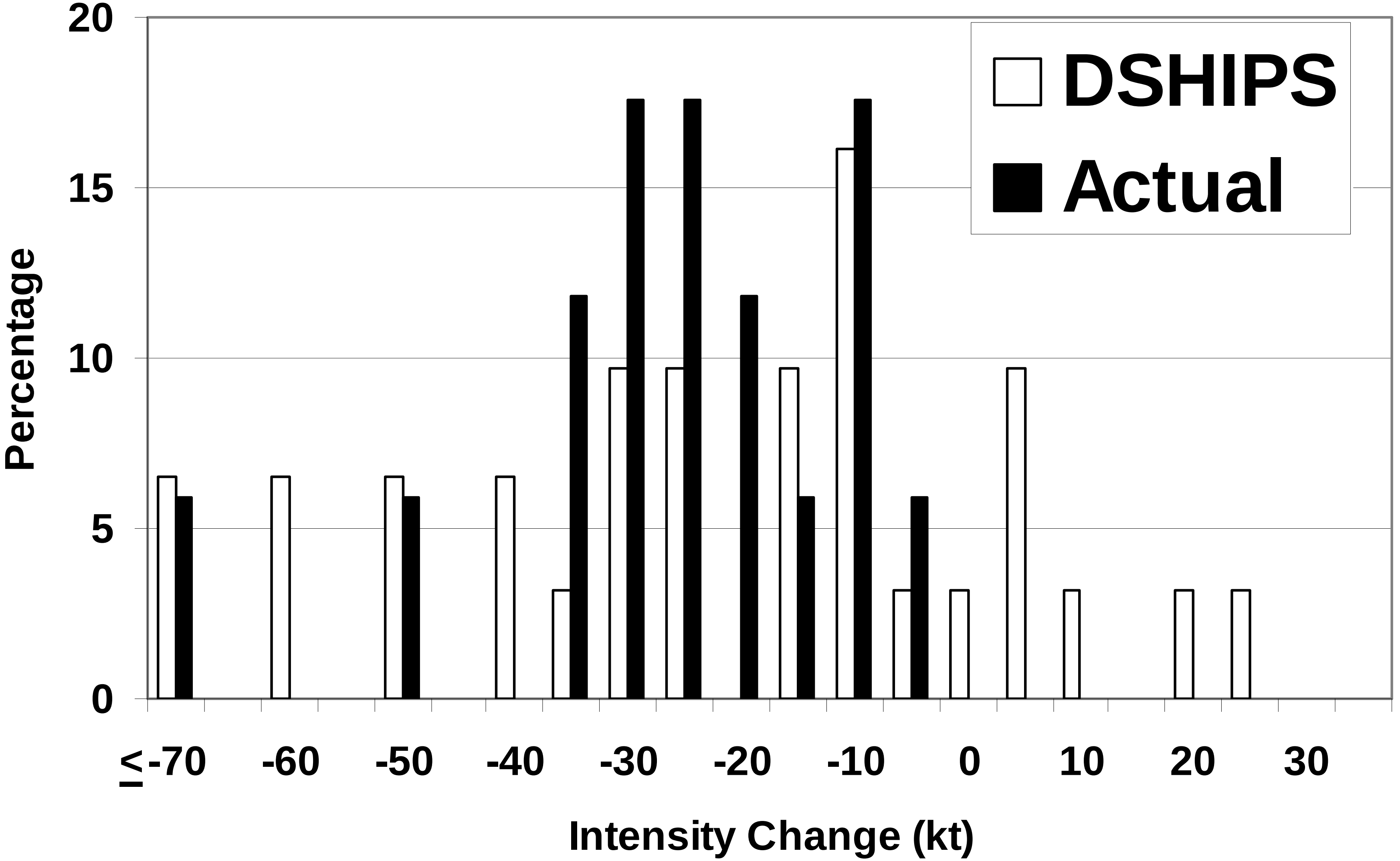

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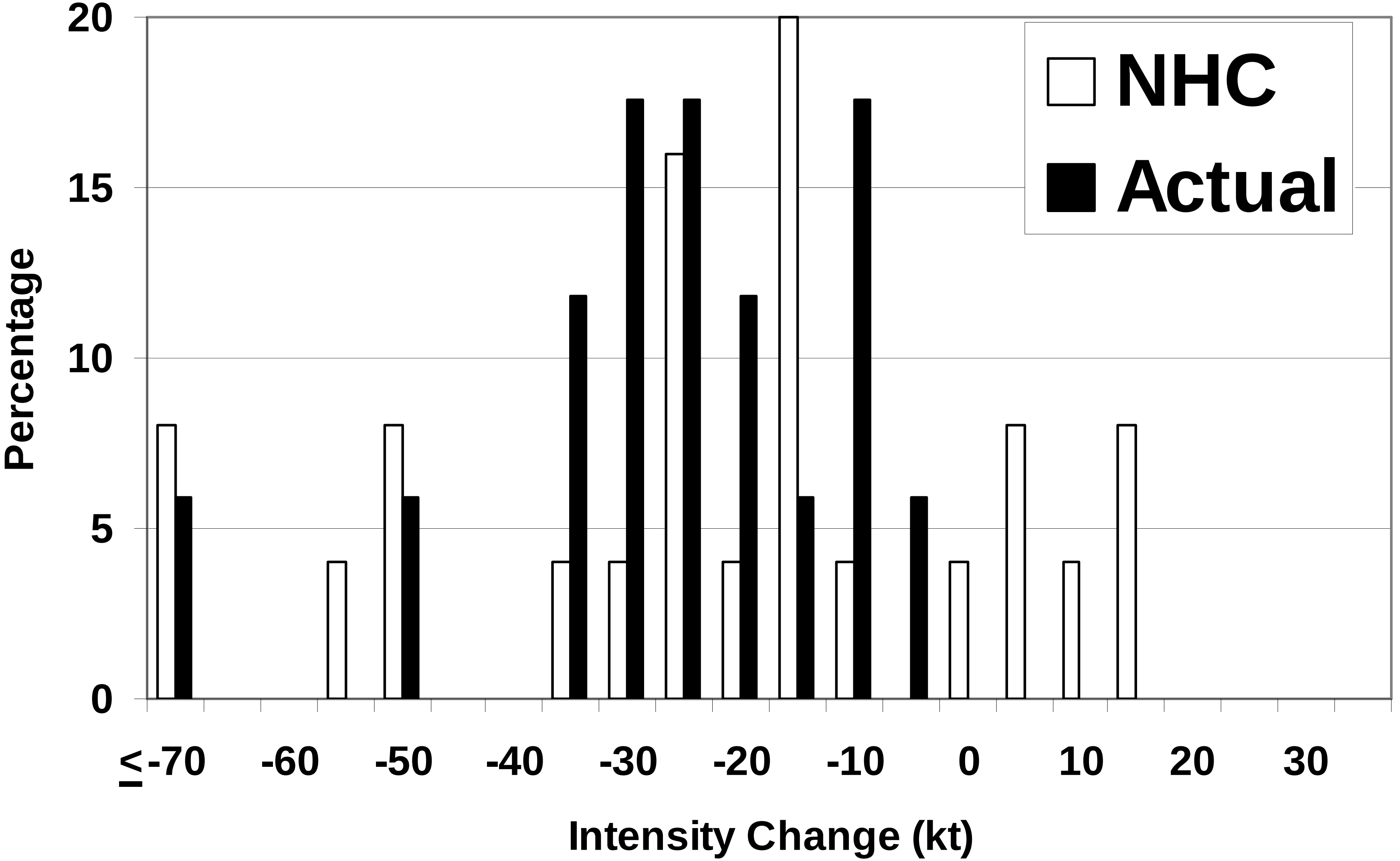

TROPICAL CYCLONE INTENSITY FORECASTING

Present ability	Statistical Technique	Numerical models
Formation timing	**No (early; false alarm)**	**No (late)**
Rapid intensification	**No (mean rate)**	**Sometimes; false alarms**
Peak intensity	**Not consistently**	**Sometimes**
Decay/reintensification	**No**	**Sometimes; timing problems**
Decay		
If track accurate	**Yes**	**Yes**
If track inaccurate	**No**	**No**

SCIENCE ISSUES IN TROPICAL CYCLONE INTENSITY - I

Formation stage (especially transformation of cold core to a warm core)

Mechanism that organizes convection
Role of mesoscale convective system
Role of Vortex Hot Towers (VHT)
Inhibiting effect of vertical wind shear

Rapid intensification (RI)

Combination of factors contributing to triggering of RI event
Spatial correlation between the convection and the high potential vorticity

Eyewall mixing and re-sharpening inner eyewall potential vorticity gradient
Post decay-reintensification-cycle recovery at RI rate

Peak intensity

Maximum potential velocity modifications due to TC-induced circulations
Inhibiting effects (vertical wind shear, dry air ingestion, asymmetric effects) versus intensification effects (air-sea fluxes, convective organization); also including vortex resiliency.

Existence and timing of a decay and intensification cycle associated with concentric eyewalls or other effects that prevent maximum potential intensity from being achieved

SCIENCE ISSUES IN TROPICAL CYCLONE INTENSITY - II

Decay and re-intensification cycles

Mechanisms for formation and contraction (if does contract – annular tropical cyclones) of partial or concentric outer eyewall

Decay

Whereas the onset of rapid decay over land is primarily a track prediction problem, the asymmetric effects (convection, wind distribution, dry air intrusions) introduced during landfall also affect the intensity changes.

ATMOSPHERIC TECHNOLOGY NEEDS FOR INTENSITY FORECASTING

General Comment 1: Without advances in scientific research to improve our understanding of the physical processes and mechanisms for structure/intensity change, we will not be able to fully state the locations, variables, and accuracies of the required observations.

General Comment 2: Following the deliberations of the NOAA Science Advisory Board Hurricane Intensity Research Working Group, it is assumed that the fundamental approach is to develop an advanced, very high-resolution numerical modeling system; These atmospheric technology (non-satellite based) needs are those required to support such a system.

ATMOSPHERIC TECHNOLOGY PLATFORMS/INSTRUMENTS

- Aircraft (manned)
  - Air Force Reserve C-130J
    - Dropwindsonde
    - SFMR (2007)
  - NOAA P-3D research
    - Horizontal and vertical radar
    - Dropwindsonde
    - Microphysics
    - SFMR
  - NOAA Gulfstream – 4
    - Dropwindsonde
    - Doppler radar (2008)

ATMOSPHERIC TECHNOLOGY PLATFORMS/INSTRUMENTS (continued)

Aircraft (manned)

- NCAR HIAPER
  - Dropwindsondes
  - Lidar wind profiler
- NASA DC-8
  - Dropwindsondes
  - Microphysics
  - Prototype radiometers, profilers (T,q)
- NASA ER-2
  - Dropwindsonde
  - Prototype radiometers, profilers (T,q)
- NRL P-3
  - ELDORA

ATMOSPHERIC TECHNOLOGY PLATFORMS/INSTRUMENTS (continued)

Aircraft (unmanned)

- Low/Slow (e.g., Aerosonde)
  - Flight-level winds, T, q
  - Fluxes ?
- Middle-level/Medium Speed (e.g., Predator)
  - Flight-level winds, T, q
- High/Long endurance (e.g., Global Hawk)
  - Unknown capability

ATMOSPHERIC TECHNOLOGY PLATFORMS/INSTRUMENTS (continued)

- Land-based (fixed)
  - Rawindsondes
  - Doppler radar reflectivity and radial winds
  - Radar wind profilers/acoustic sounders
- Land-based (mobile)
  - Doppler on Wheels type (several universities)
  - Phased array radar (CIRPAS)
  - Meteorological towers (several universities)
- Drifting systems
  - Driftsonde

APPLICATIONS OF ATMOSPHERIC TECHNOLOGY FOR PROCESS STUDIES

TROPICAL CYCLONE FORMATION

Strategy: Global model predictions indicate likelihood of formation, which triggers integration of regional, mesoscale models that indicate likely locations of key mesoscale convective systems (MCS), which then provides targets for mobile platforms (and intensive satellite observations).

Multiple-scale observations

Large-scale: Rawinsonde network and Driftsondes

Synoptic-scale: Rawinsondes, Driftsondes, Manned Aircraft

Mesoscale: Manned and unmanned aircraft targeted on location, structure and evolution of MCS, and interaction with larger scale

Convective (VHT): Manned and unmanned aircraft targeted on location, structure, and evolution of VHT, and interaction with mesoscale. Land-based radar if properly located.

APPLICATIONS OF ATMOSPHERIC TECHNOLOGY FOR PROCESS STUDIES

RAPID INTENSIFICATION*

Strategy: Regional models of the tropical storm indicate favorable scenario for a rapid intensification event, which triggers the launch of special synoptic-scale mobile (and satellite) observations. The manned and unmanned aircraft focus on the inner-core processes from the air-sea interface through the troposphere around times of predicted rapid intensification.

Triggering by synoptic-scale: Rawinsondes, Driftsondes, Manned and unmanned aircraft

Physical mechanisms on mesoscale: Manned and unmanned aircraft targeted on inner-core structure evolution.

*Consistent under-forecasting of peak intensity is believed to be a consequence of inability to predict formation timing and periods of rapid intensification.

APPLICATIONS OF ATMOSPHERIC TECHNOLOGY FOR PROCESS STUDIES

DECAY AND RE-INTENSIFICATION CYCLES

Strategy: (1) Assuming externally forced triggering of outer convective band; or (2) Assuming internally forced triggering of band; and (3) Test hypotheses on contraction mechanisms and rates, and subsequent re-intensification

Externally-forced: Rawinsondes, Driftsondes, Manned and unmanned aircraft targeted on potential land-triggering regions or interaction zone between tropical cyclone and midlatitude system

Internally forced: manned and unmanned aircraft observations focused on the location, structure, and evolution of Vortex Rossby Waves triggered in the region of the eyewall convection

Hypothesis testing: Manned and unmanned aircraft focused on observing processes in the near-environment of outer convective band as it contracts and replaces the inner eyewall convection

APPLICATIONS OF ATMOSPHERIC TECHNOLOGY FOR PROCESS STUDIES

(continued)

DECAY OVER LAND

Strategy: Depending on an accurate forecasting of landfall, deploy mobile land-based platforms and augment radar coverage for land observations, and provide aircraft observations offshore

Land-induced flow modifications: Observe 3-D cyclone structure changes from combined aircraft and land-based platforms

Physical process studies: Over-land (and over and under coastal ocean) observations of boundary layer fluxes and convective structures

APPLICATIONS OF ATMOSPHERIC TECHNOLOGY FOR INTENSITY PREDICTION

Initial state specification must include actual wind, T, q, and precipitation distribution (versus bogus vortex).

Air Force C-130 with dropwindsondes limited in spatial coverage, elevation limitation; equipping with SFMR in 2007 will add surface wind distribution and rain rate.

NOAA P-3 adds Doppler radar winds and reflectivity but is a research aircraft versus a reconnaissance platform; Acquisition of a third P-3 will presumably increase availability.

Present G-4 usage as a surveillance aircraft provides only dropwindsondes in the environment. Although double-crewed, this presently is limited to observations at 12-h frequency. In 2008, the G-4 will have a Doppler radar capability.

Aerosonde is in test-evaluation phase.

Conclude: For real-time prediction models for intensity change over the ocean, the atmospheric technology is presently very limited. The hopeful aspects are the forthcoming G-4 Doppler radar and the SFMRs on the C-130s.