Effect of cloud processes on hurricane tracks

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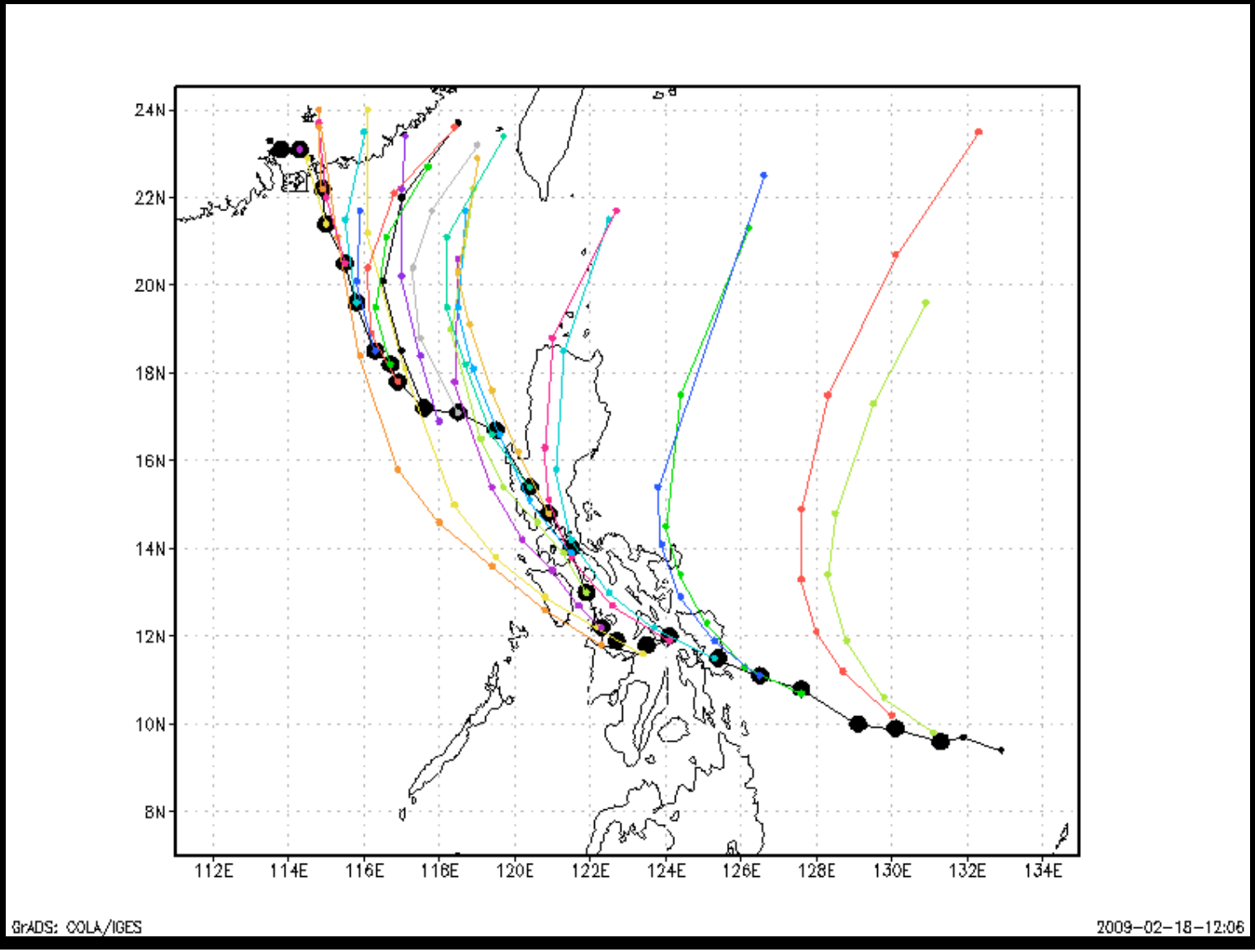
Outline

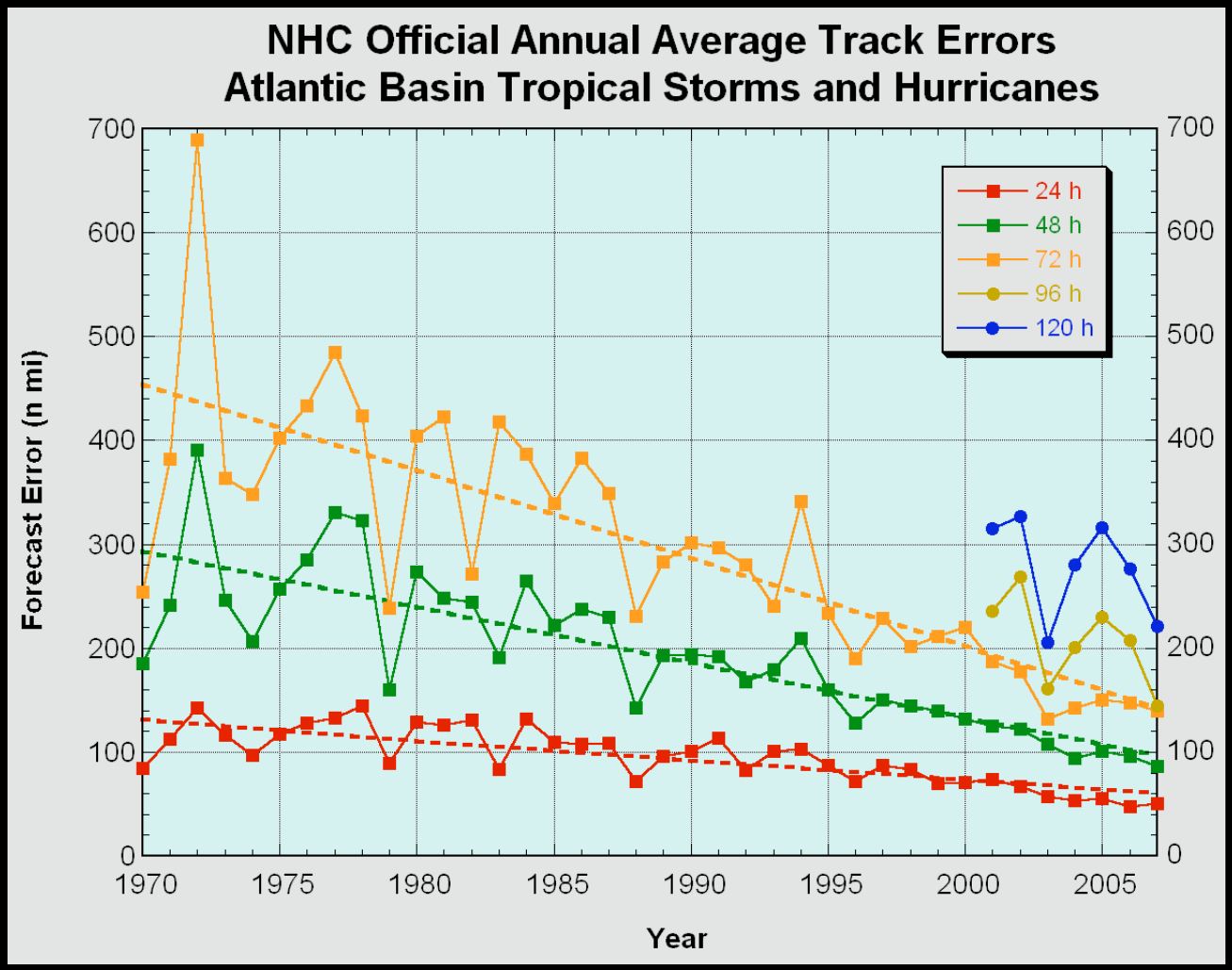
- Motivation/background
- 2008 Atlantic hurricane ensemble
- More

MP = microphysics parameterization
CP = cumulus parameterization

Typhoon Fengshen (2008)



Atlantic track forecast improvement



48h position error:

95 nm

109 mi

176 km

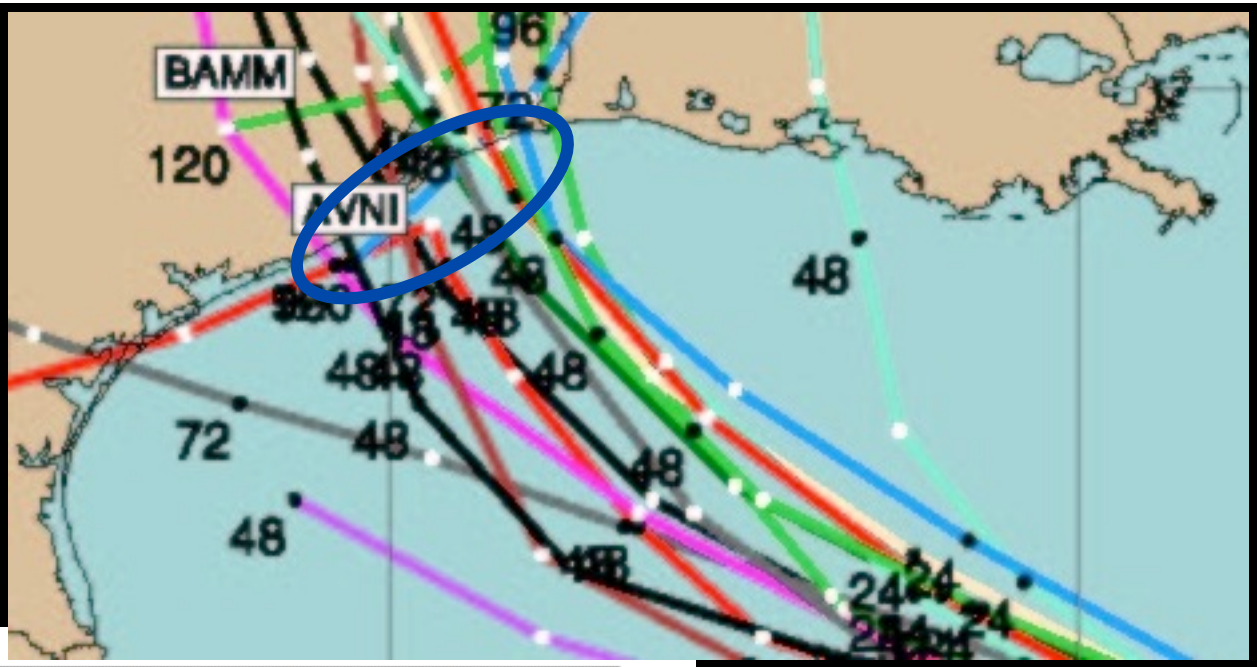
What ~100 nm position error looks like…

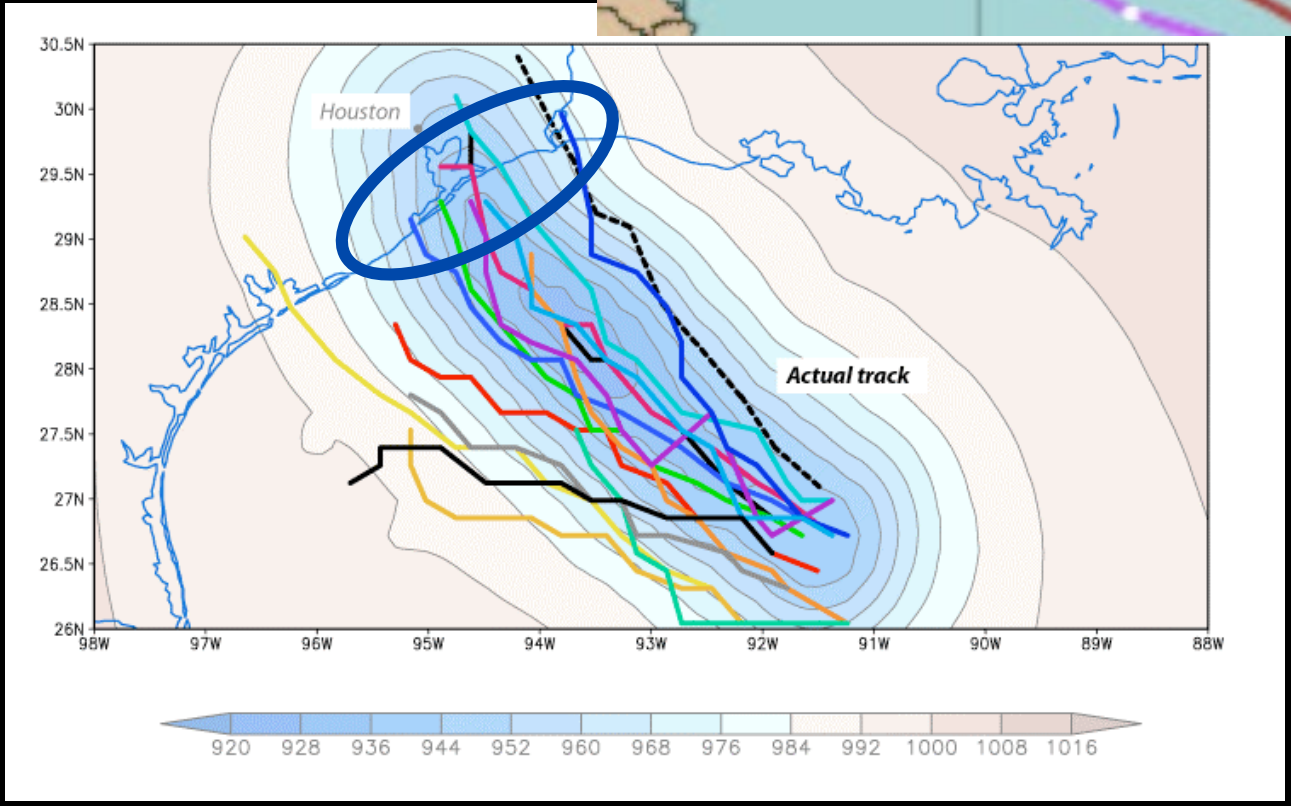
NHC Multi-model Ensemble

06 UTC 22 Sept

[longer forecast period shown]

From J. Vigh, CSU





WRF-ARW MP/CP Physics Ensemble

30 km resolution

15 ensemble Members

[only part of domain and forecast period shown]

Fovell and Su (2007)

2008 ensemble design

- WRF-ARW v.3.0
- 10000x5000 km domain @ 36 km, 33 levels, 100 mb top
- 12 members
  - 6 MP (Kessler, Lin, WSM3/5/6, Thompson)
  - 2 CP (Kain-Fritsch, Betts-Miller-Janjic)
- 96h, up to 4x/day (later in season)
- GFS-initialized cold starts
- Sole focus: track forecasts

2008 ensemble cases (65 “contests” total)

- US landfalling storms
  - Dolly
  - Fay
  - Gustav
  - Hanna
  - Ike
- Comparables:
  - Official NHC (OFCL)
  - GFS ensemble mean (AEMN)
  - Hurricane WRF (HWRF)
  - GFDL
  - Navy NOGAPS (NGPS)
  - NAM

Forecasts and best track from NHC archives.

2008 Atlantic Hurricane Ensemble

- Philosophy: many “cheap” runs instead of a few expensive simulations
- No high resolution initialization
- No nesting used
- No moving grids
- No coupled ocean or special SST handling
- No surface flux tuning
- No data assimilation or cycling
- No tropical cyclone bogusing

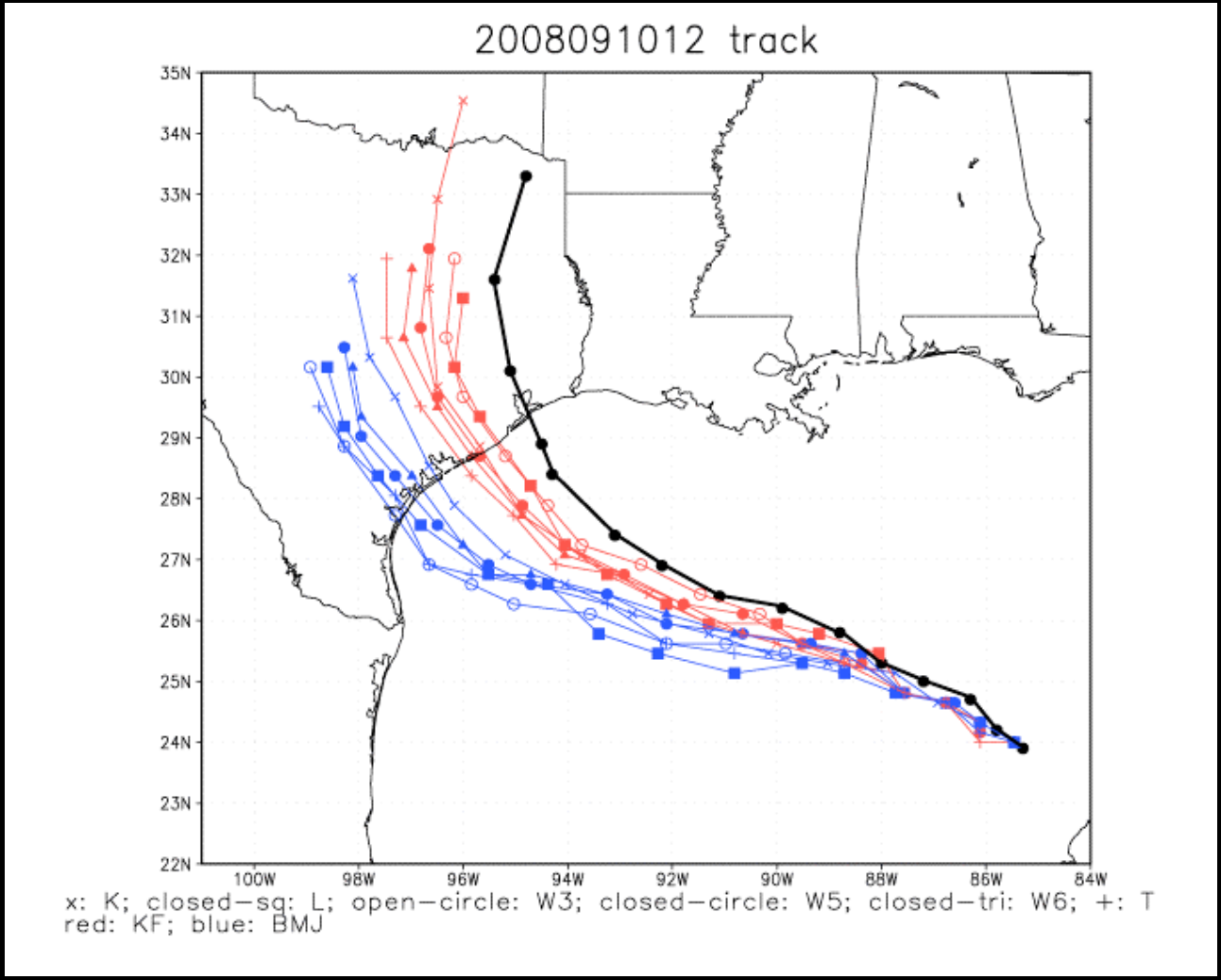
Initial hypotheses and expectations

- No single member would prove very skillful
  - Deficiencies in GFS initial condition
- About 5 or 6 would prove equally skillful
  - Initialization, physics deficiencies might "constructively interfere"
- These would have quantitatively similar *spread* to the NHC consensus
- The sub-ensemble mean would have useful skill relative to more sophisticated models
  - Track: high quality >> high resolution
- Reconfigure, culling less skillful members

Analyses

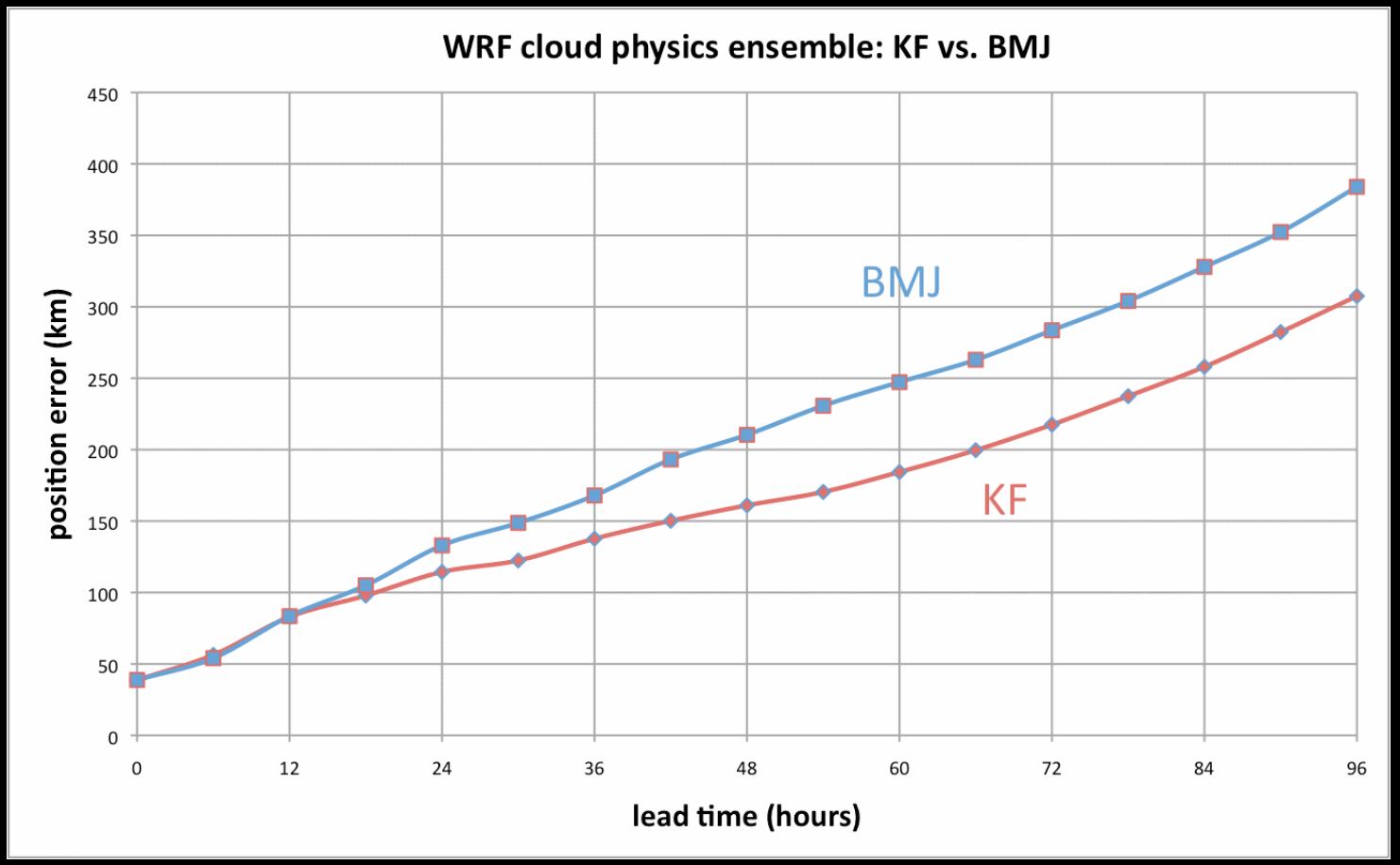
- Full analysis vs. pre-landfall subset (see preprint)
- Ike subset vs. non-Ike
  - Ike was long-lived
  - Ensemble frequency increased through season
  - 42% of contests involved Ike

9/10/2008 @ 12Z (Ike) - 84 h tracks



Red (KF) vs. blue (BMJ) separation common.
All storms to left of actual track.

KF vs. BMJ (all 65 runs)



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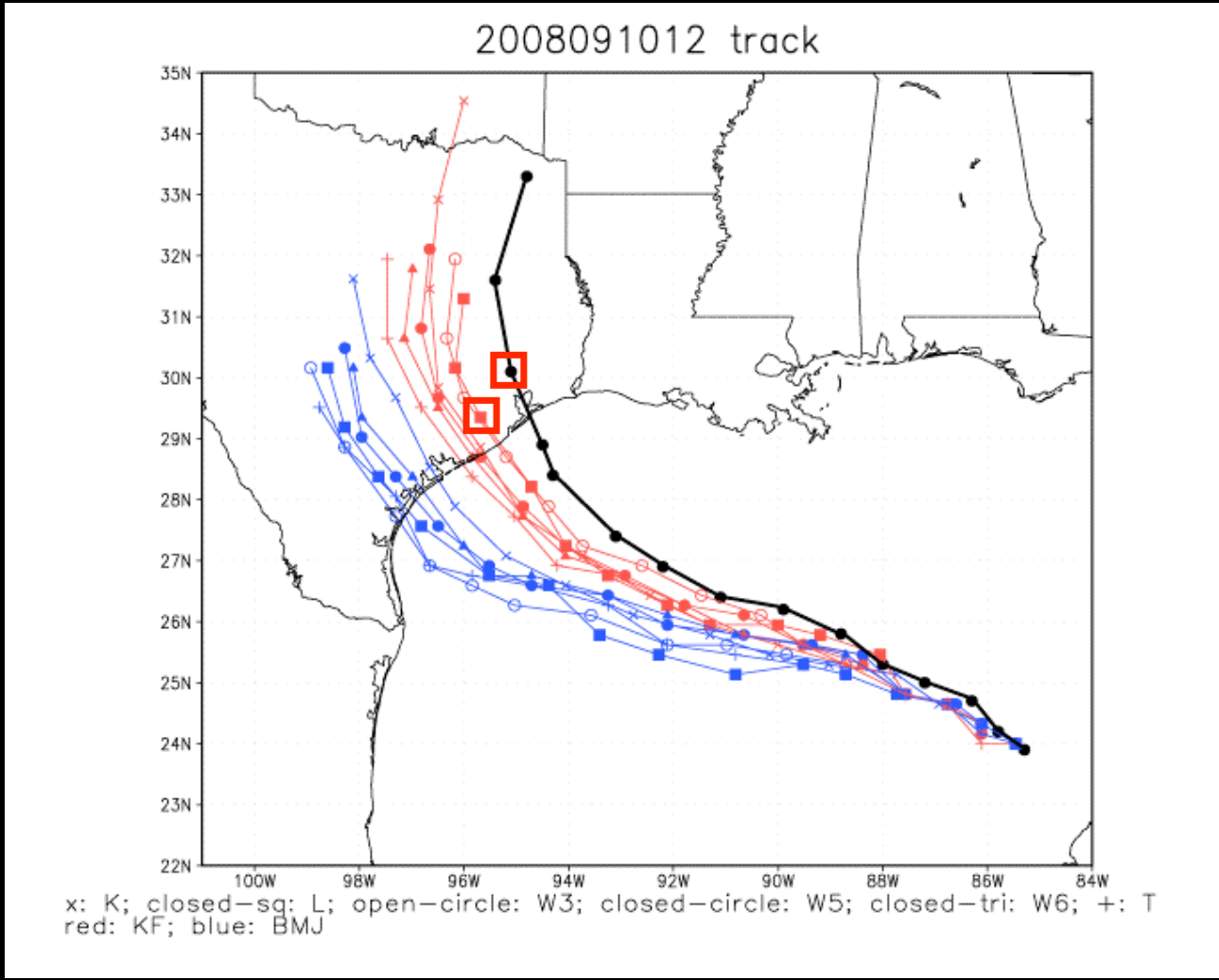


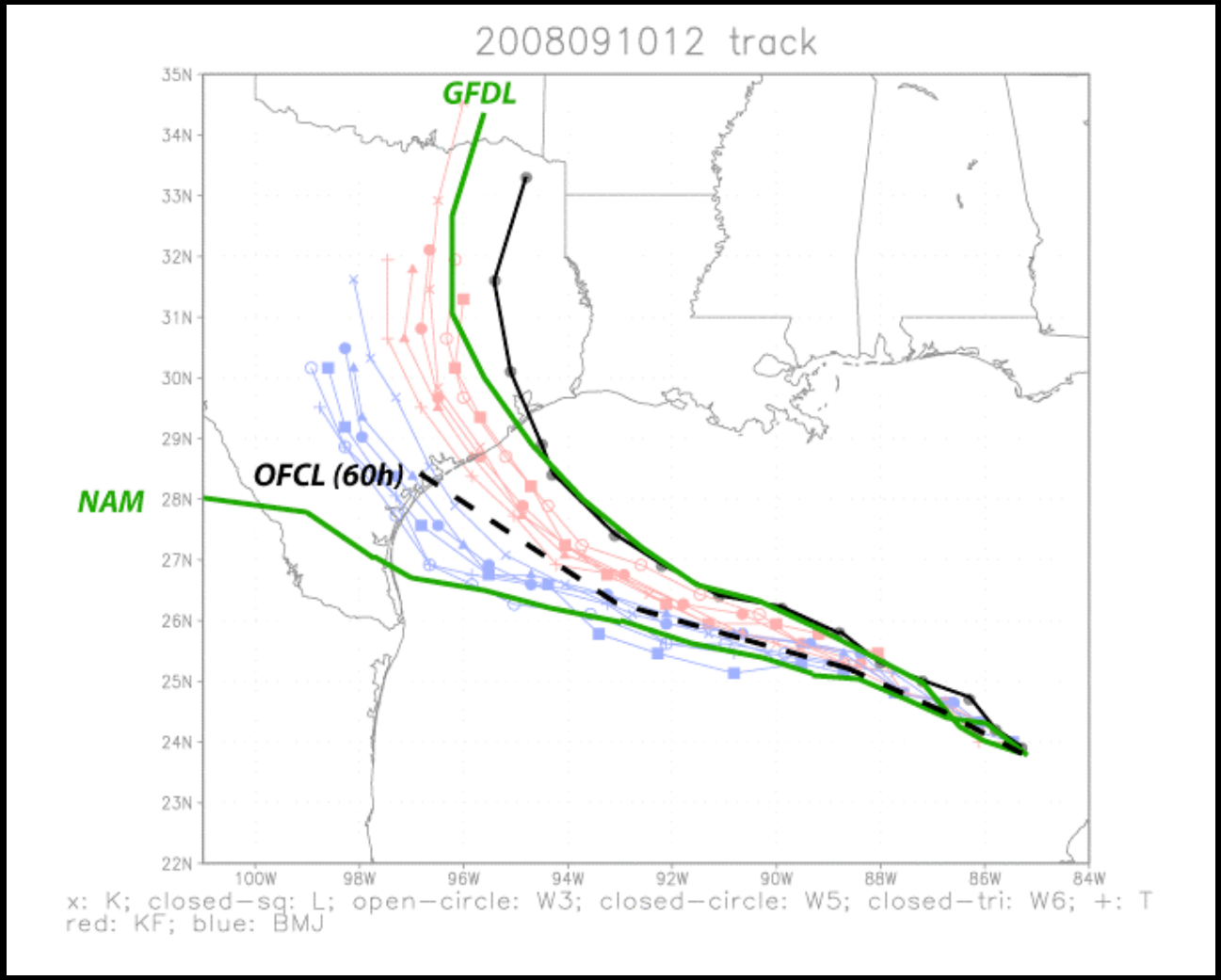
Ensemble member winner at 72 h: **L/KF**
(112 km position error)

% of 1st place finishes for ensemble members

member	24h	48h	72h	96h
K/KF	3	2	5	4
K/BMJ	6	6	8	14
L/KF	**54**	**51**	**50**	**29**
L/BMJ	8	2	8	15
W3/KF	3	11	0	14
W3/BMJ	8	6	0	11
W5/KF	6	11	5	4
W5/BMJ	9	4	0	4
W6/KF	5	15	5	4
W6/BMJ	5	4	0	4
T/KF	8	8	5	0
T/BMJ	11	2	15	4

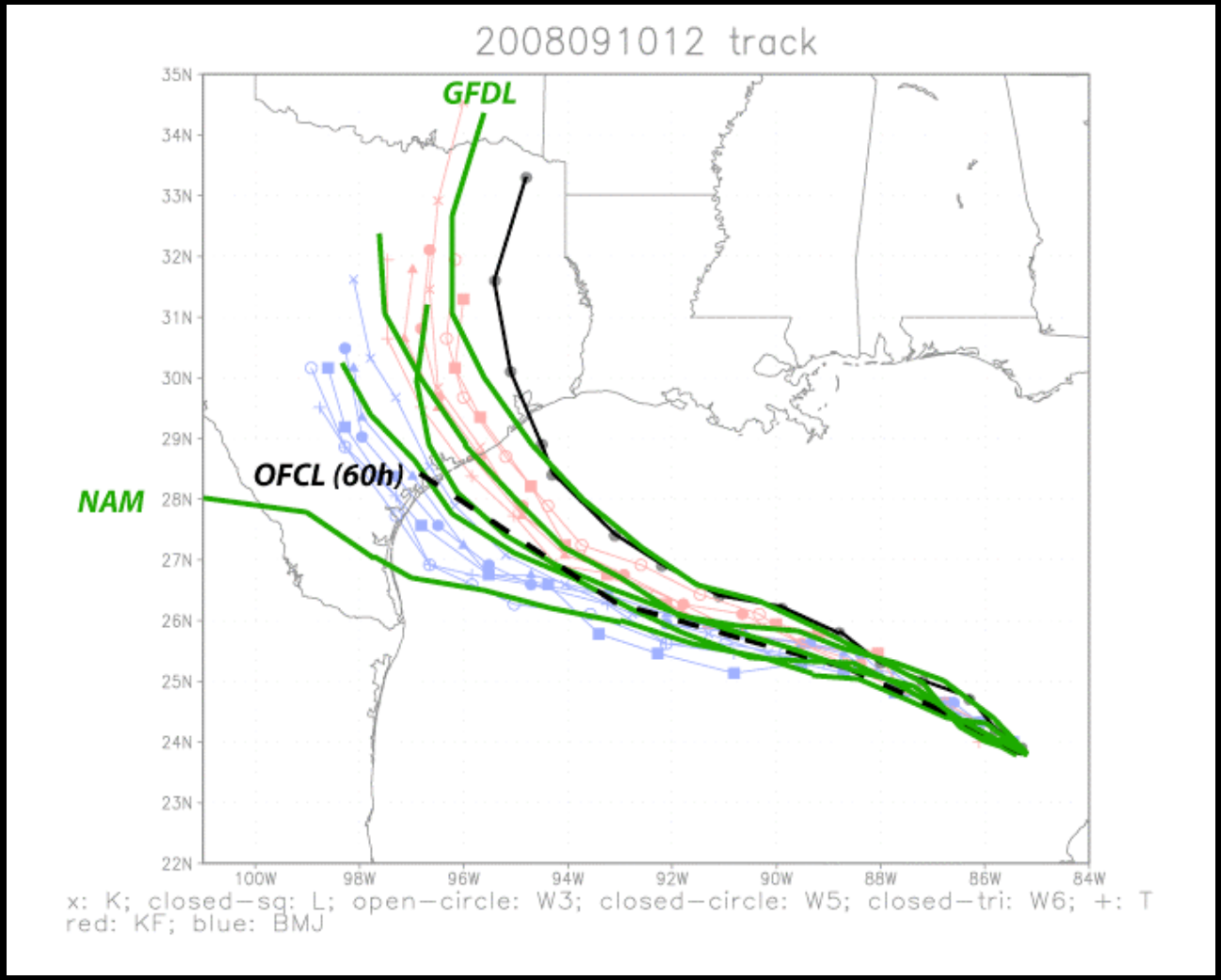
includes ties

9/10/2008 @ 12Z (Ike) - 84 h tracks



OFCL and best & worst of the models.

9/10/2008 @ 12Z (Ike) - 84 h tracks



Added:
HWRF
AEMN
NGPS

All models shown.

Overall winner at 72 h: **member L/KF**

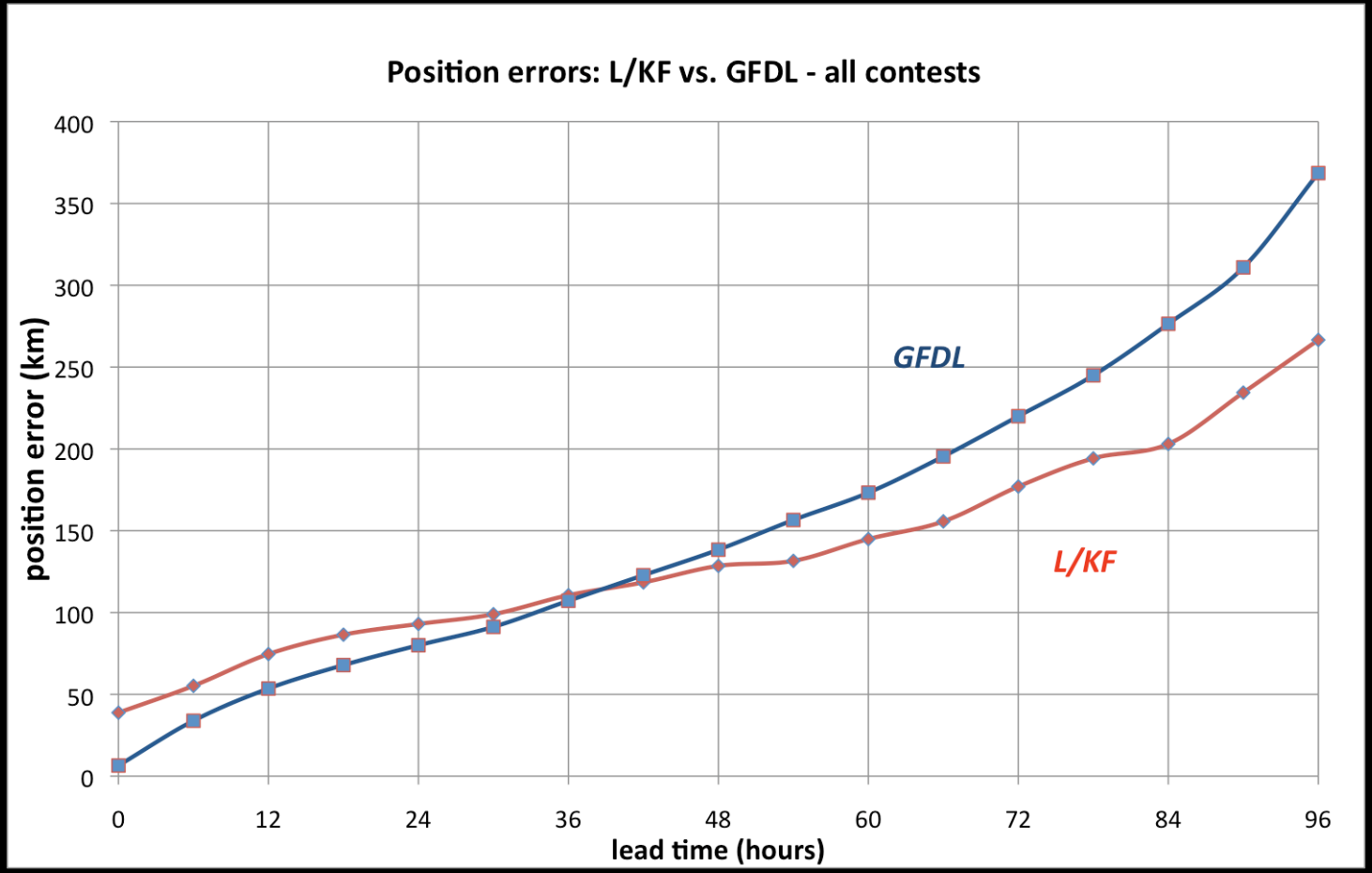
L/KF vs. OFCL & models average position error (km) for all cases

Member	24 h 65 cases	48 h 64 cases	72 h 52 cases	96 h 41 cases
L/KF	93	**129**	**177**	266
OFCL	83	144	204	262
AEMN	113	189	234	**253***
HWRF	97	169	247	296
GFDL	**80**	138	220	369

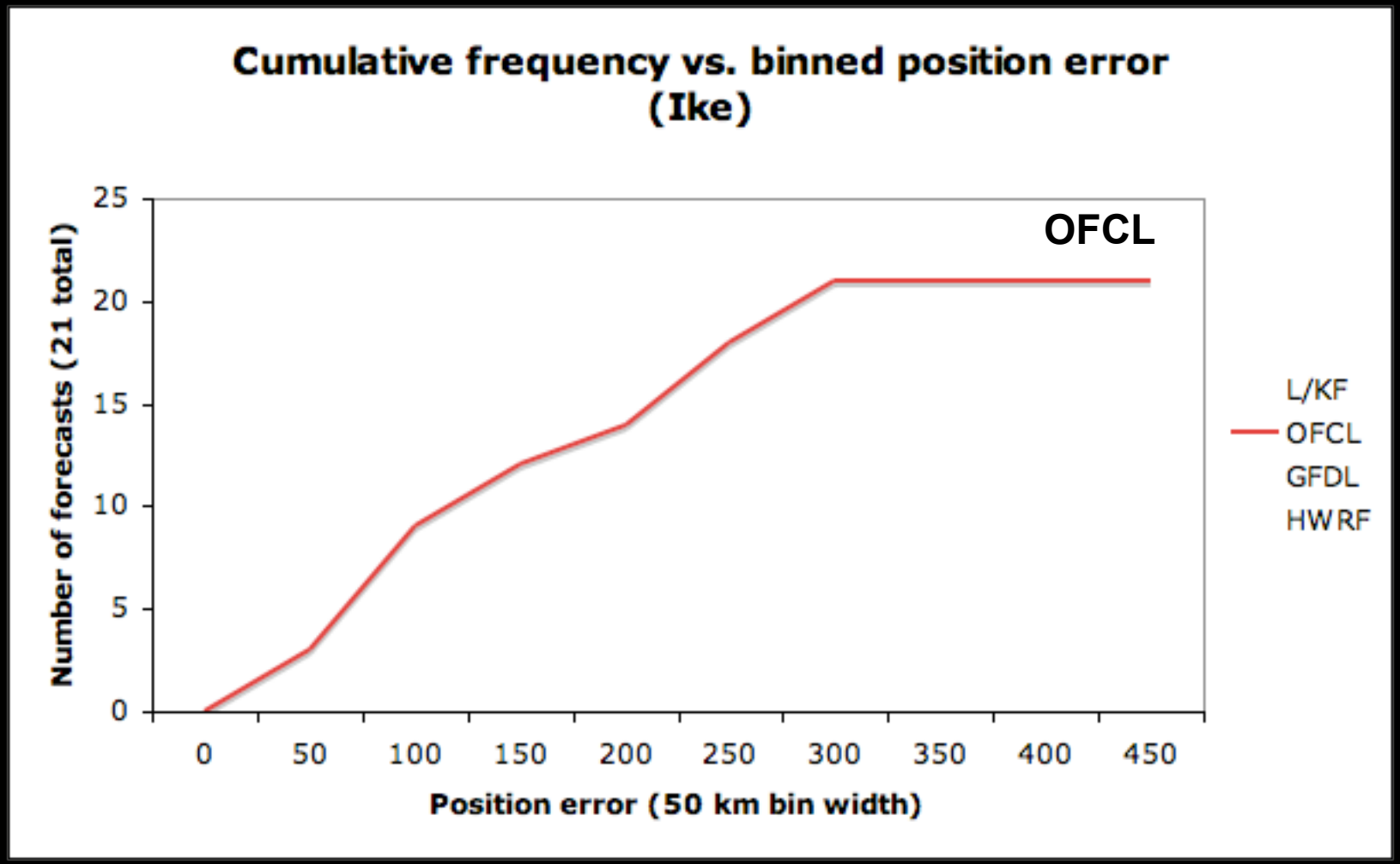
Standard deviations are large

*fewer cases

L/KF vs. GFDL: all 65 contests



72 h forecasts for Ike



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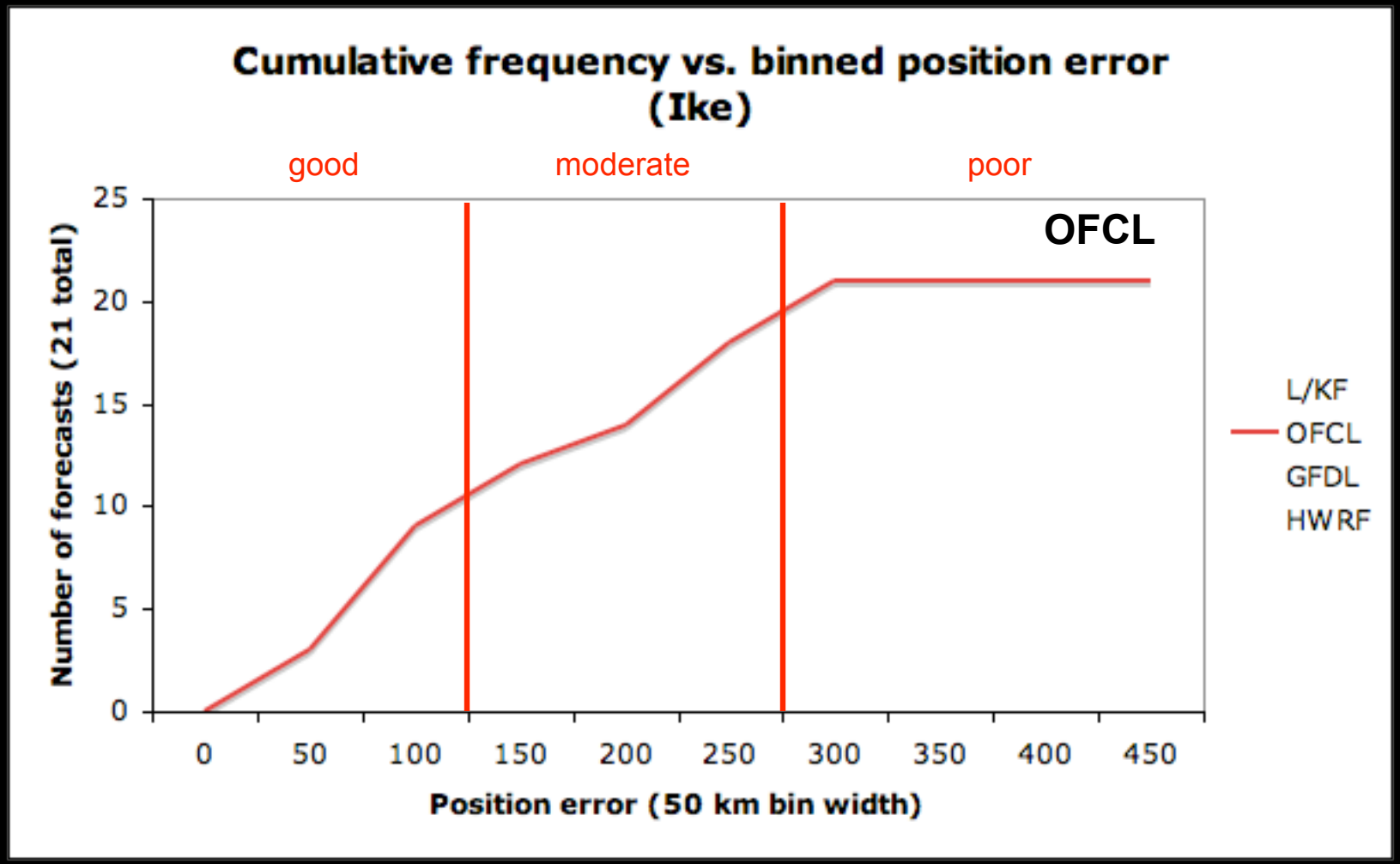

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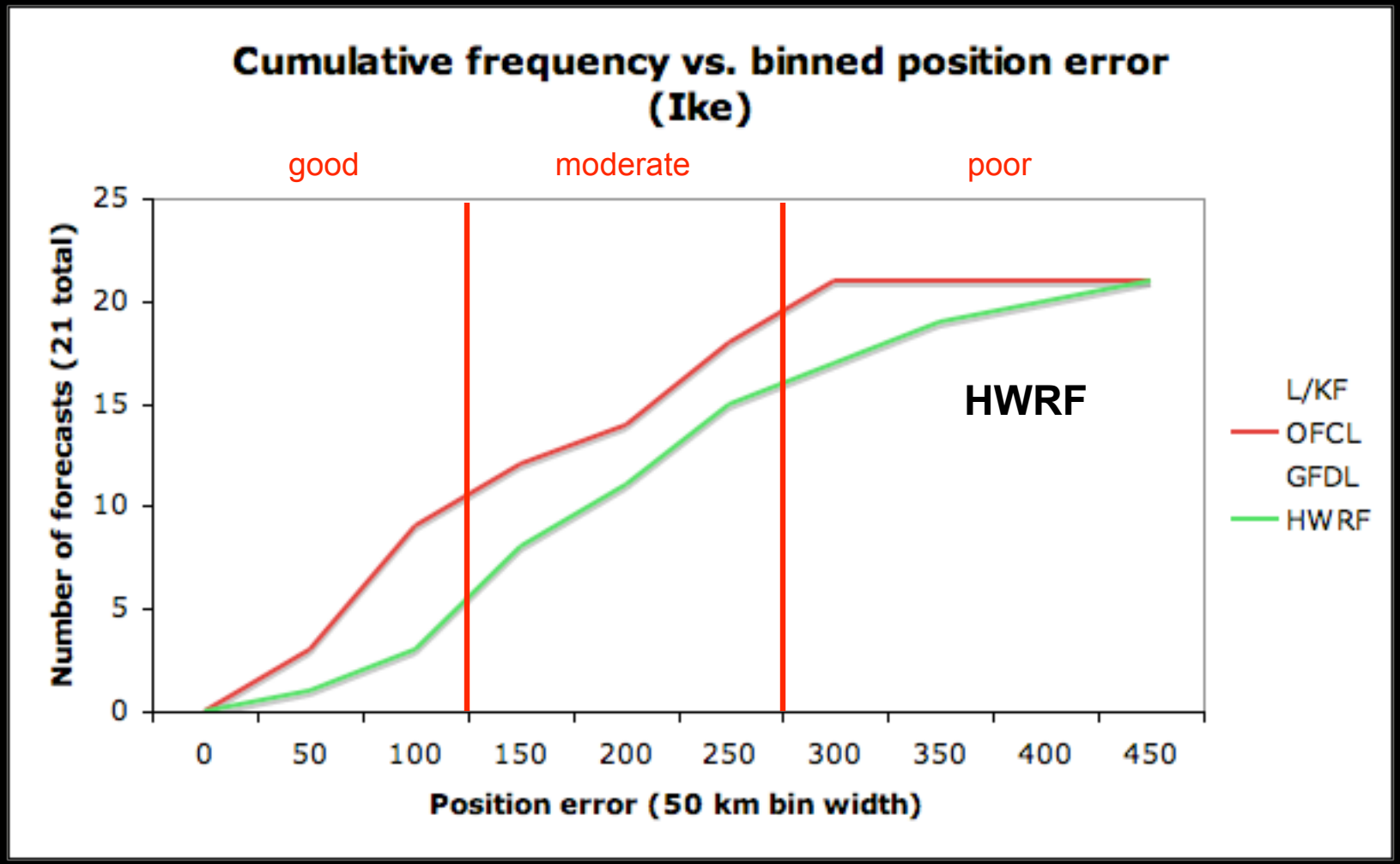

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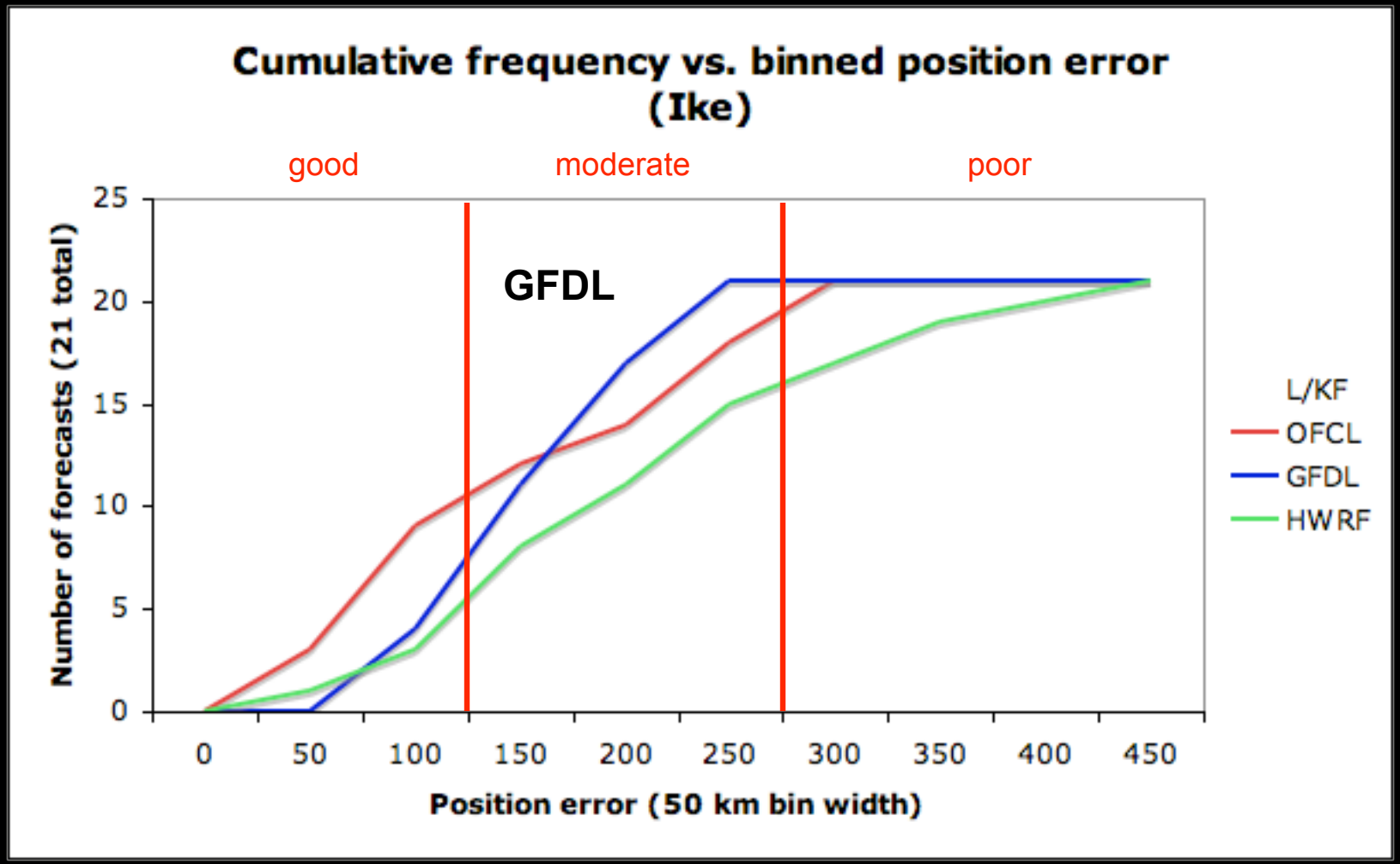
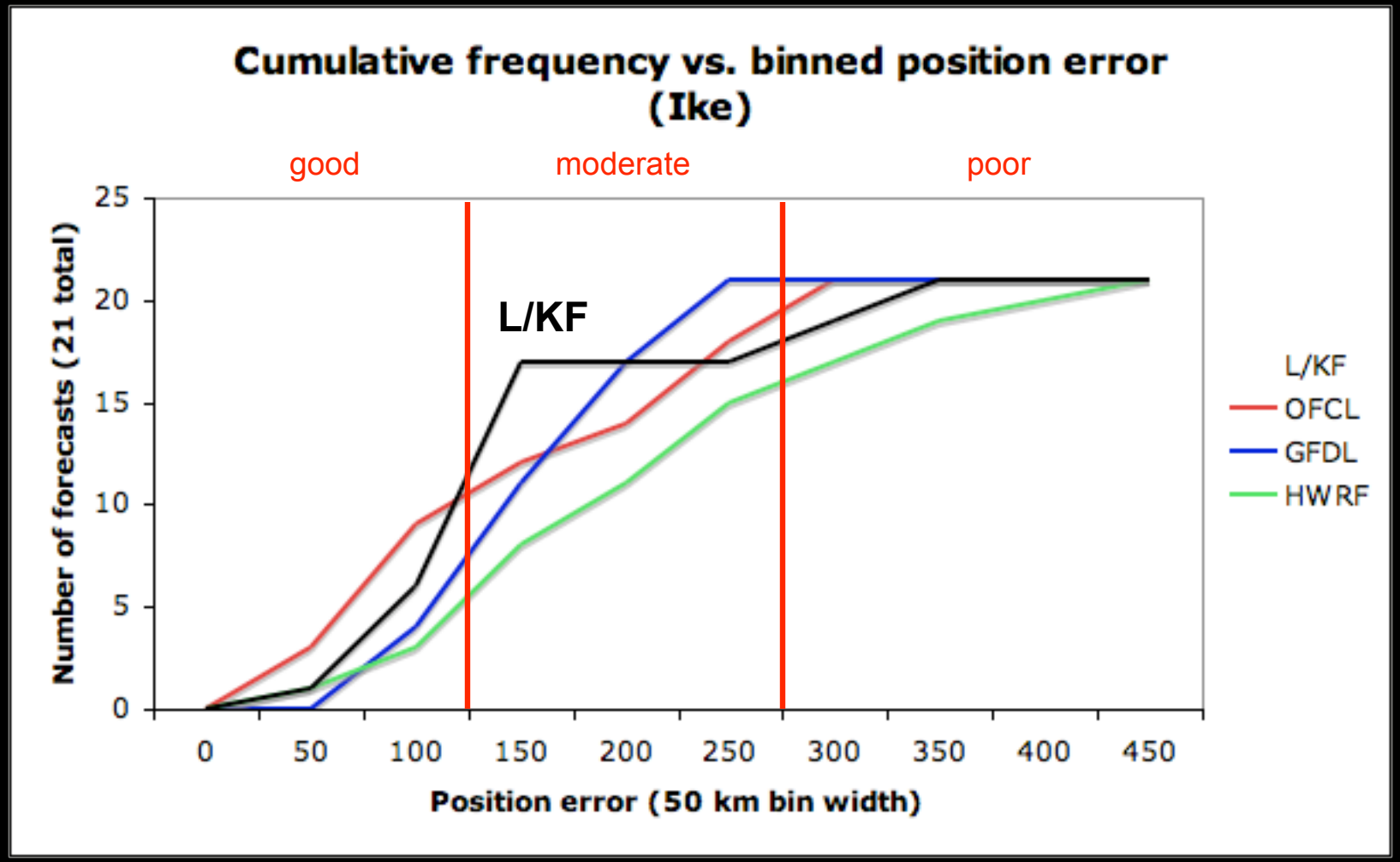
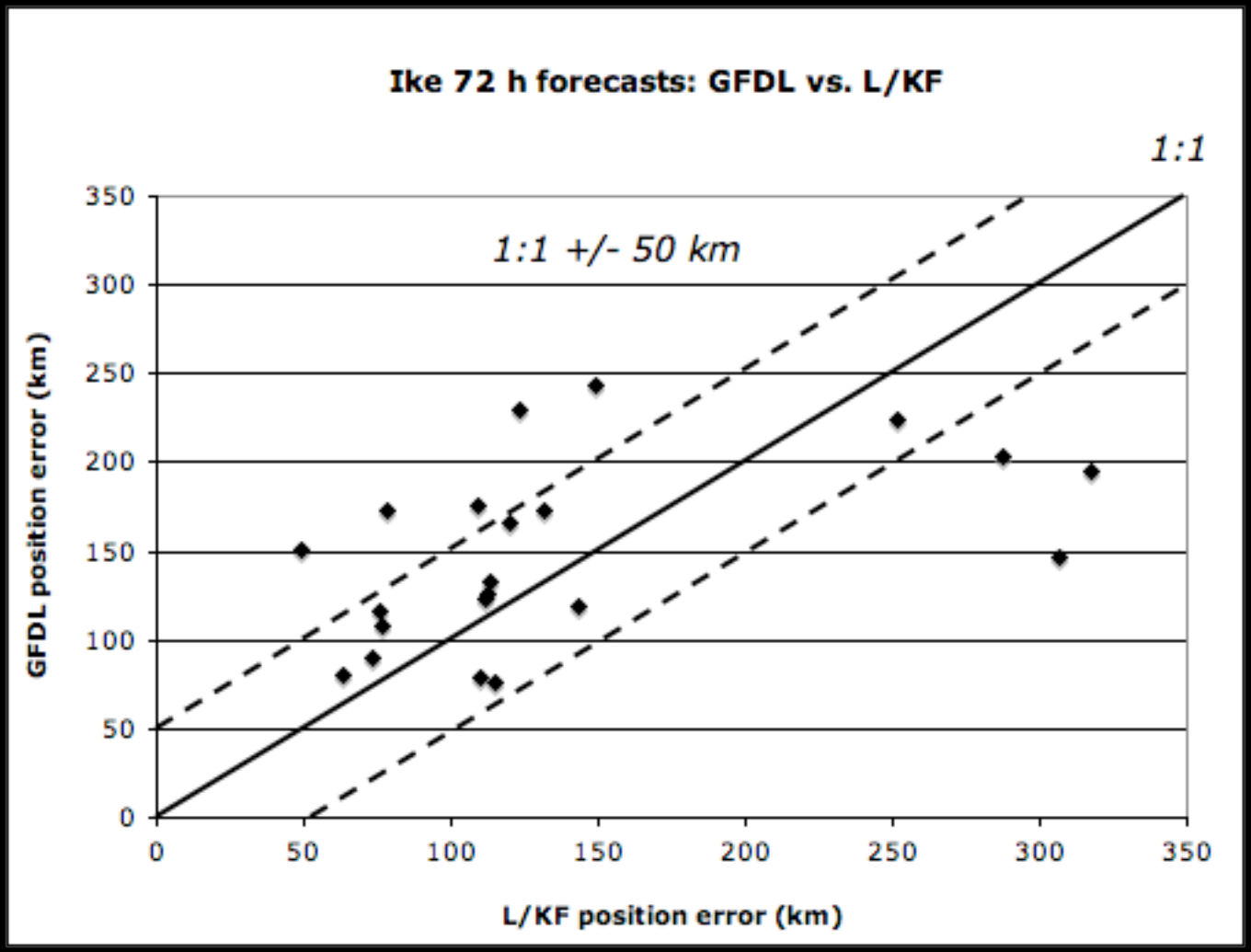


72 h forecasts for Ike

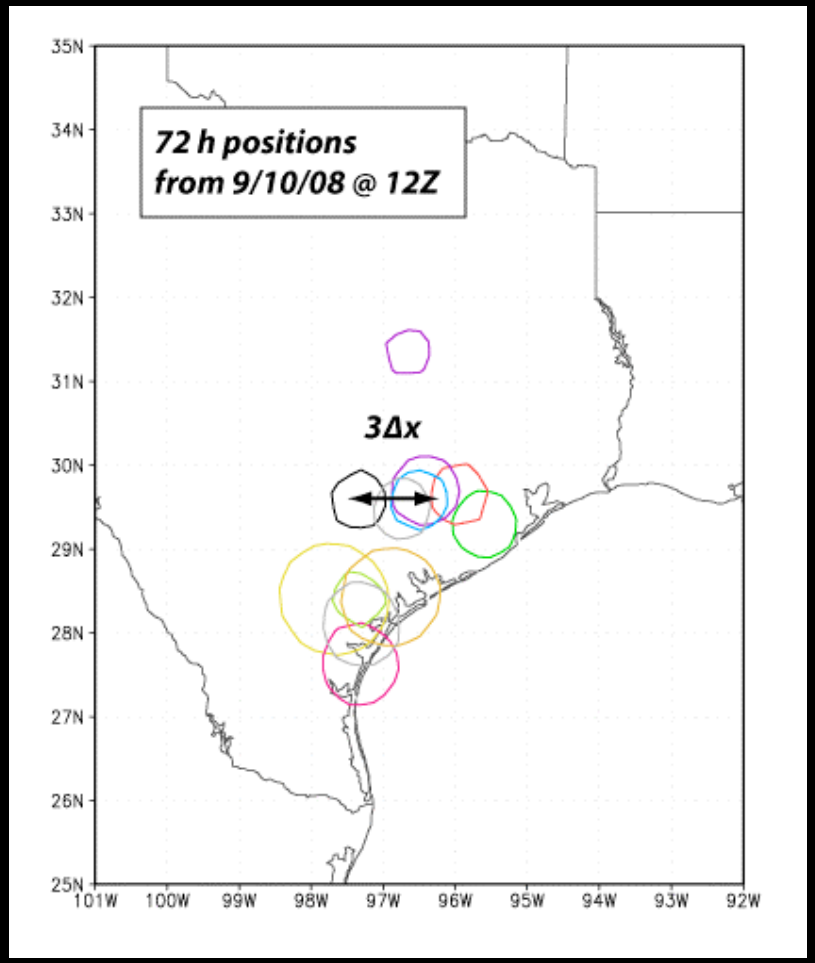


GFDL vs. L/KF



+/- 50 km range (a grid diagonal) excessive
since SLP interpolated to 13 km grid before fixing cyclone location

9/10/2008 @ 12Z (Ike) - 72 h positions



Recap

- One ensemble member (L/KF) far superior to others
  - Does not imply L “best”; works “best” with KF
- L/KF member competitive with more sophisticated models at medium range
- BMJ members generally uncompetitive
- WSM 3/5/6 highly correlated
- Ensemble spread seems reasonable
  - Including lack of spread when NHC consensus tightly clustered
- Better results with better initialization???

Why do cloud processes influence track?

- Fovell, Corbosiero and Kuo (2009, this month's JAS)
  - Real data WRF-ARW used for idealized experiments
    - No land, uniform SST, no initial wind
    - 3 nests down to 3 km Δx
  - MP schemes determine or modulate:
    - Radial wind structure beyond core -- f advection (beta effect)
    - Convective asymmetries
    - Depth of storm -- steering flow -- in more realistic cases
  - One path: MP => Anvil structure => latent heating & cloud/radiative processes => T gradients => p gradients => winds => track
  - Thermodynamics => dynamics

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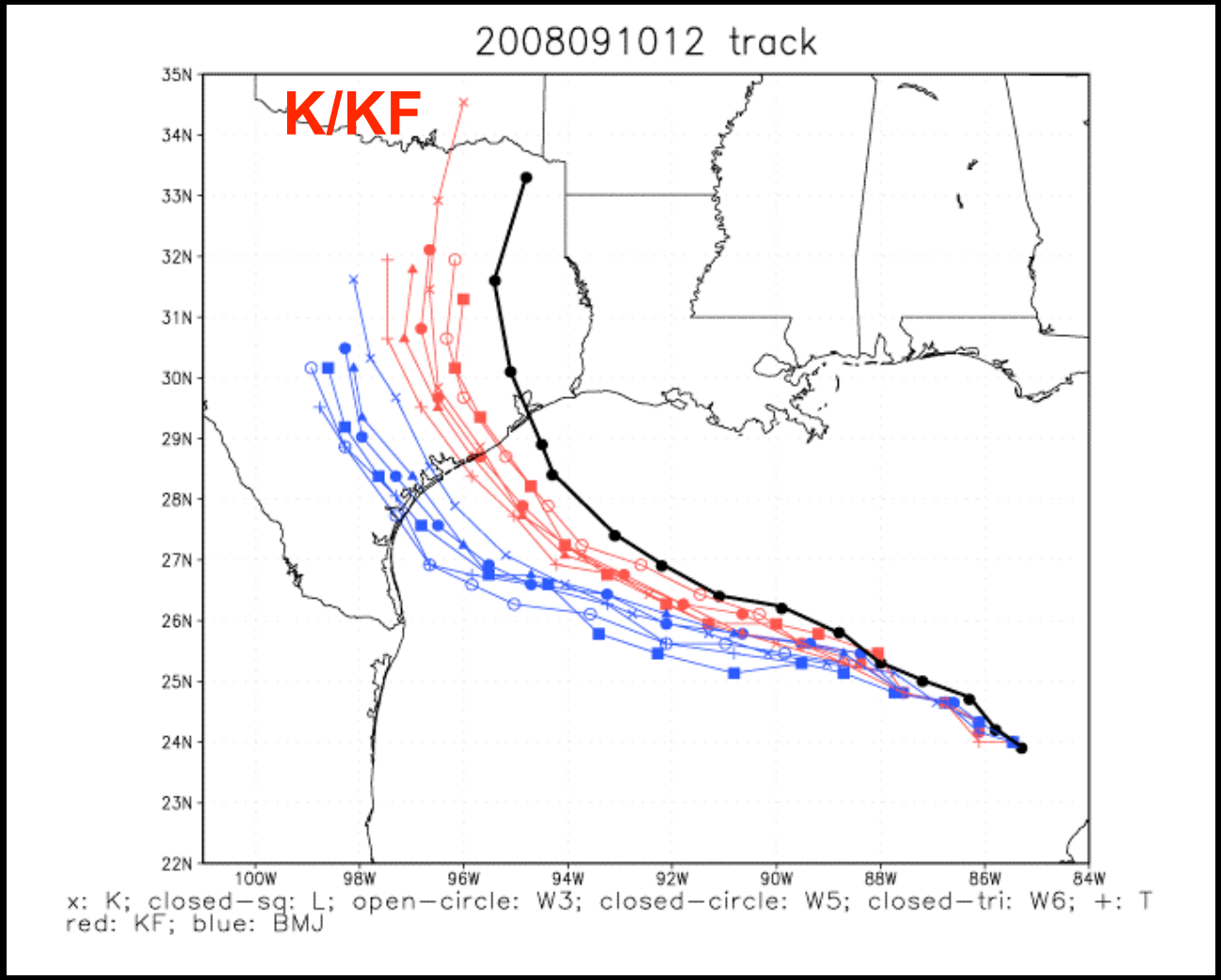
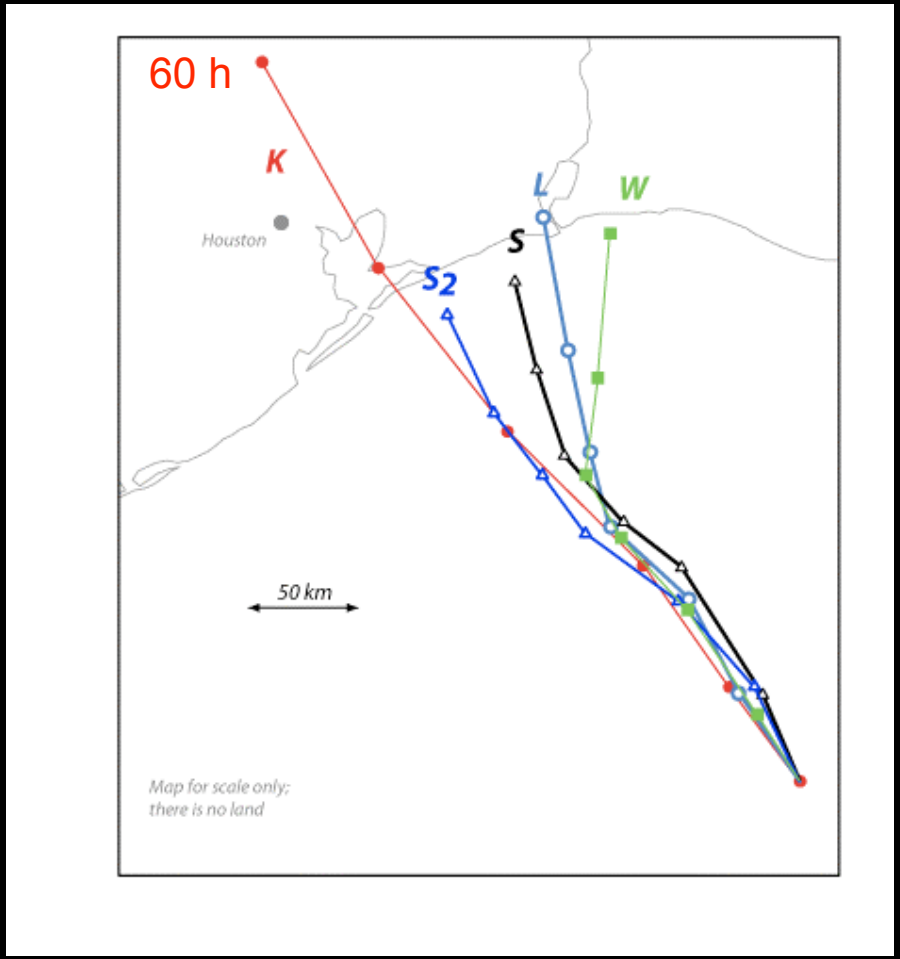


Note K/KF



72 h tracks

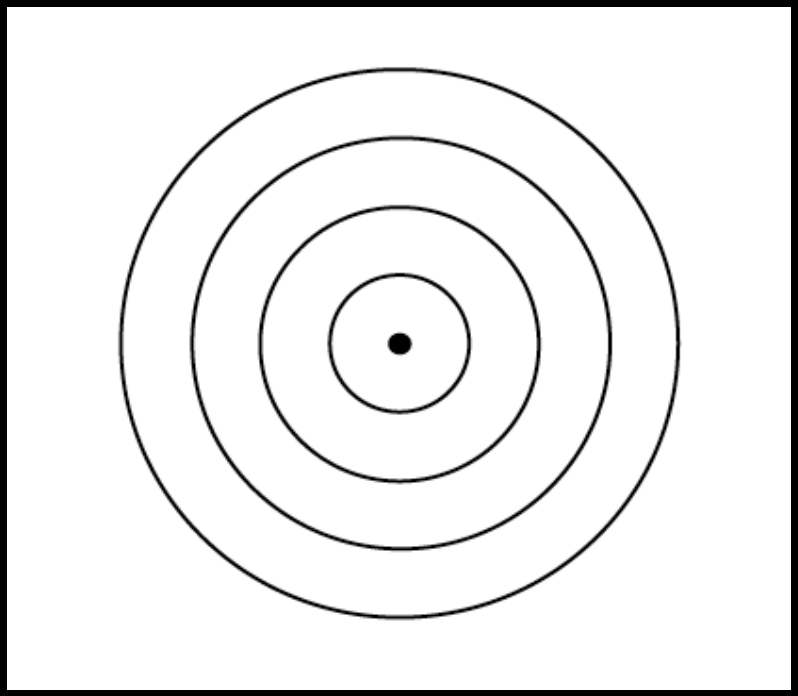
Map for scale only;
NO LAND

Updated experiment:
Uniform 4 km resolution, two versions of Seifert's double moment MP scheme

Summary/conclusions

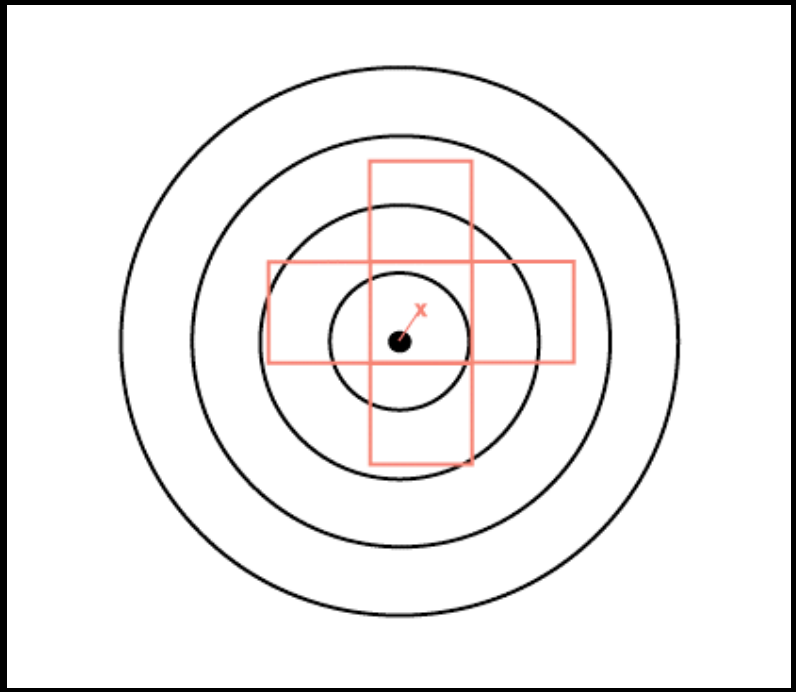
- 2008 Atlantic hurricane ensemble
  - Unsophisticated strategy with surprisingly positive results
  - One prominent member: L/KF
- Idealized modeling reveals routes for MP influence on track
- 2009 season: less physics, more initialization variations

Interpolation error



A symmetric TC

Interpolation error



If grid-quantized, max position assignment error
on 36 km grid is 50 km.
However, fields are interpolated to 13 km grid first
and not grid-quantized.