PREDICTABILITY OF WESTERN NORTH PACIFIC TROPICAL CYCLONE EVENTS ON INTRASEASONAL TIMESCALES WITH THE ECMWF MONTHLY FORECAST MODEL*

Russell L. Elsberry and Mary S. Jordan
Naval Postgraduate School
Monterey, California
and
Fredric Vitart
ECMWF, Shinfield Park, UK

Synopsis: One of the opportunities for extension of tropical cyclone forecasting is into the intraseasonal timescales using dynamical model ensembles.

*[Manuscript in press, *ASIA-PACIFIC JOURNAL OF ATMOSPHERIC SCIENCES*]

EMC/MMM/DTC Joint Hurricane Workshop, Boulder, Colorado 22-23 February 2010

OBJECTIVE

Evaluate predictability of western North Pacific tropical cyclone formations and tracks during June 2008 to December 2008 from experimental ECMWF 32-day ensemble

Hypothesis: If tropical cyclone formation location is primarily determined by large-scale environmental fields that are predictable at intraseasonal (10-30 day) timescales, those large-scale environmental fields will also allow predictions of the subsequent tracks of the tropical cyclones

Verifying formation locations and tracks are from the Joint Typhoon Warning Center (and thus may be different from the RSMC-Tokyo Typhoon Center)

Definition of formation: Tropical warm-core cyclonic circulation over the ocean with strong convection and winds of at least 25 kt near the center (i.e., a Tropical Depression)

DATA SOURCE

Experimental ECMWF 32-day ensemble forecasts made once a week on Thursdays

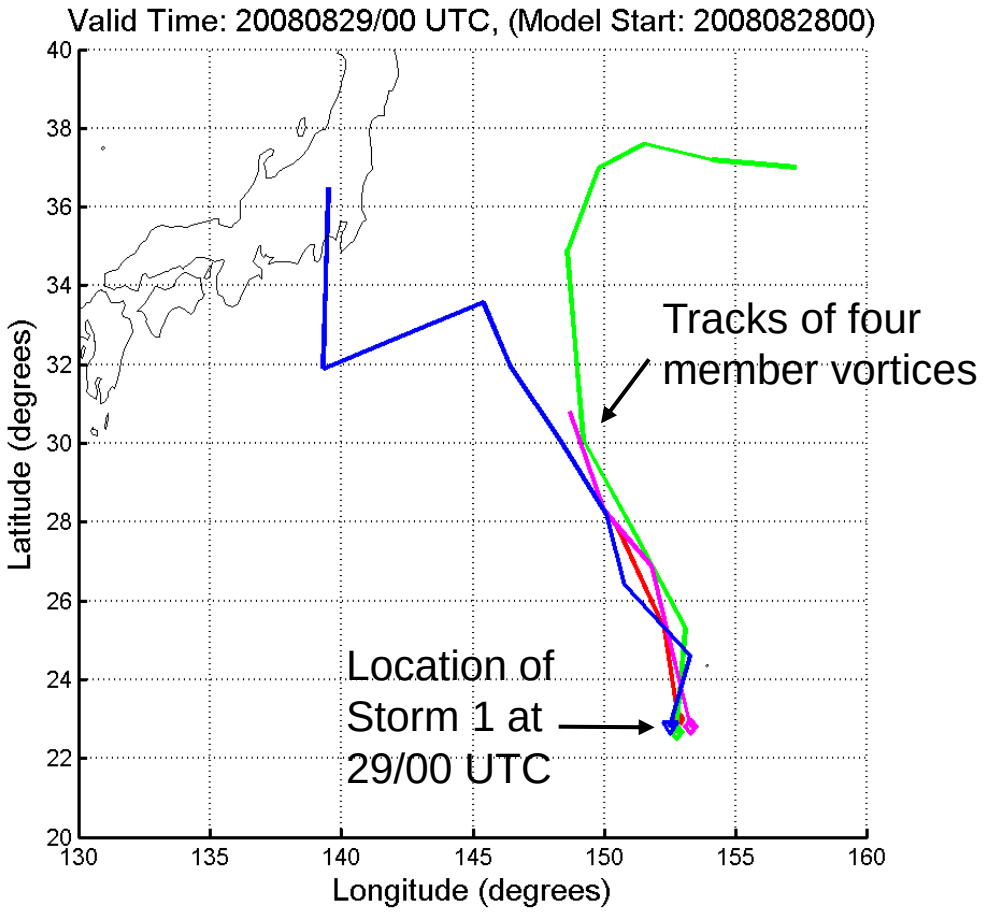
- **Extension of operational ensemble integration from 10 days**
- **50 members plus control**
- **Horizontal resolution ~ 60 km to Day 10 and then ~ 80 km**
- **62 levels**
- **Stochastic physics in tropics**
- **Coupling with ocean begins at 10 days**

Tropical cyclone-like vortex track positions each 12 h predicted by each of the members in the western North Pacific with same tracker as for seasonal forecasts

- **Relative vorticity > 3.5 x 10^{-5} s^{-1}**
- **Warm temperature anomaly in upper troposphere**
- **Thickness maximum must exceed threshold**
- **Track must be longer than one day**

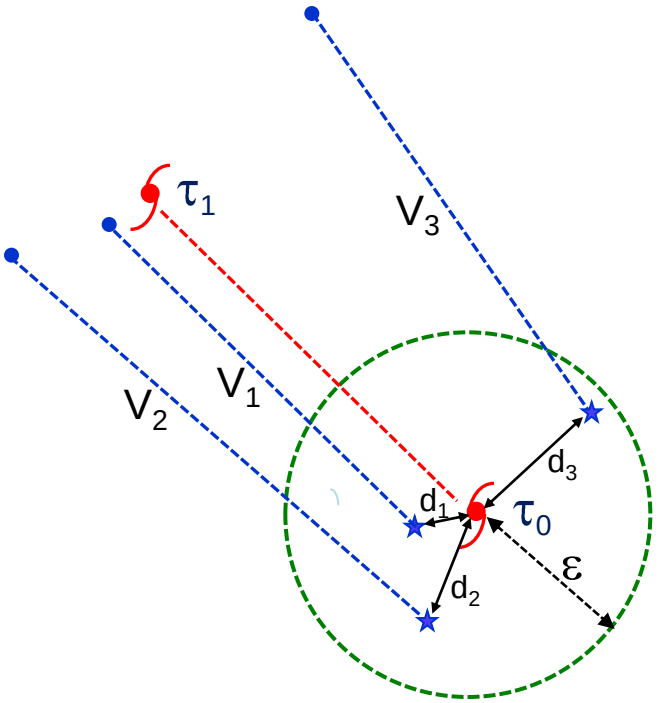
FORMING AN ENSEMBLE STORM

- Beginning at time τ = 12 h, ensemble vortices within time-dependent separation distance $\varepsilon(t)$ are grouped into an "Ensemble Storm" and a number is assigned
- Once assigned to an ensemble storm, the vortex stays as a storm member for its entire lifetime
- Example:
  - At 29/00 UTC, four vortices are within 180 n mi and form Storm 1



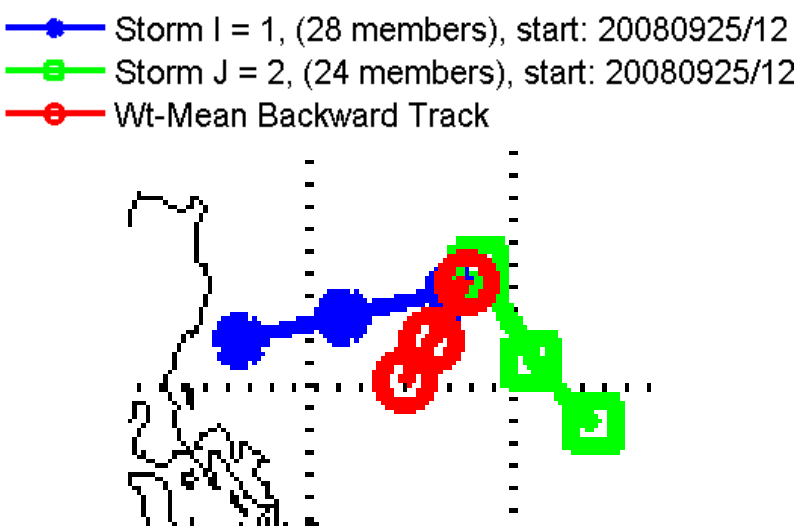
WEIGHTED-MEAN VECTOR MOTION AND VORTEX ADDITIONS

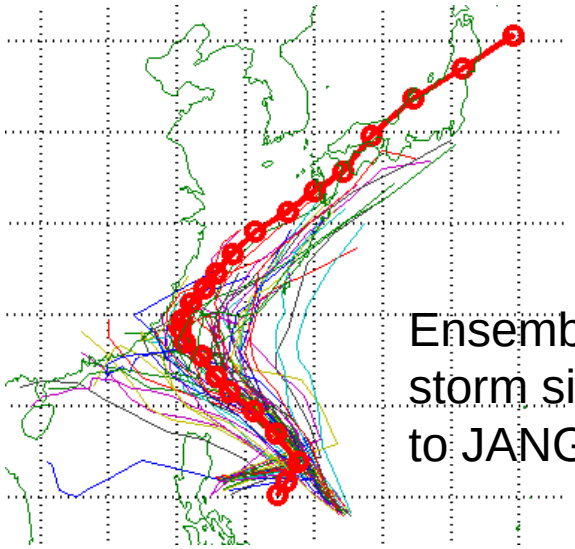
- When an ensemble storm initially forms (time τ_0), the mean latitude and longitude of all contributing vortices is defined as the ensemble storm center.
- Location12 hours later (τ_1) is the Weighted-Mean Vector Motion of the ensemble, with weighting highest for the smallest distance to the mean position.
- New vortices may join at the next time step
  - If the new vortex is within a distance (ε) of the ensemble storm location, the vortex is added to the ensemble storm.
  - The new and existing members are used to compute the next 12 h storm position using Weighted-Mean Vector Motion.
- If a new vortex is not close to any existing ensemble storms, the vortex is designated as an new ensemble storm.
- Allowable separation distance, ε (t), linearly increases with time from 180 n mi during forecast Day 1 to 420 n mi at Day 14 and is constant for Days 15-32 (420 n mi).



MERGING ENSEMBLE STORMS

- At the end of each 12-h time interval, the storm positions are compared to determine if two storms should merge.
- Storm centers within 180 n mi are merged.
  - All members of the two storms are combined and the mean location becomes the new storm center.
  - The prior merged storm track is computed using weighted-mean “backward” vector motion – starting at the merger time and stepping backwards to the origin time.





Ensemble storm similar to JANGMI

CHARACTERISTICS OF ECMWF 32-DAY ENSEMBLE STORMS

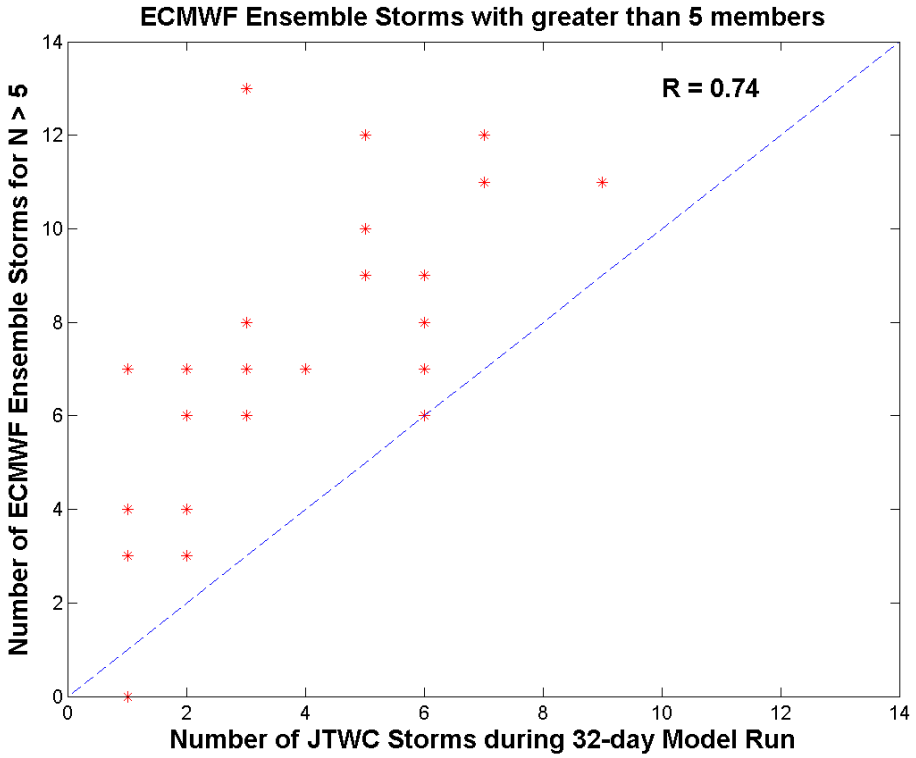
- This methodology was applied to match ensemble vortices and merge adjacent prototype storms during 30 weekly forecasts of 32-day length from 5 June 2008 to 25 December 2008

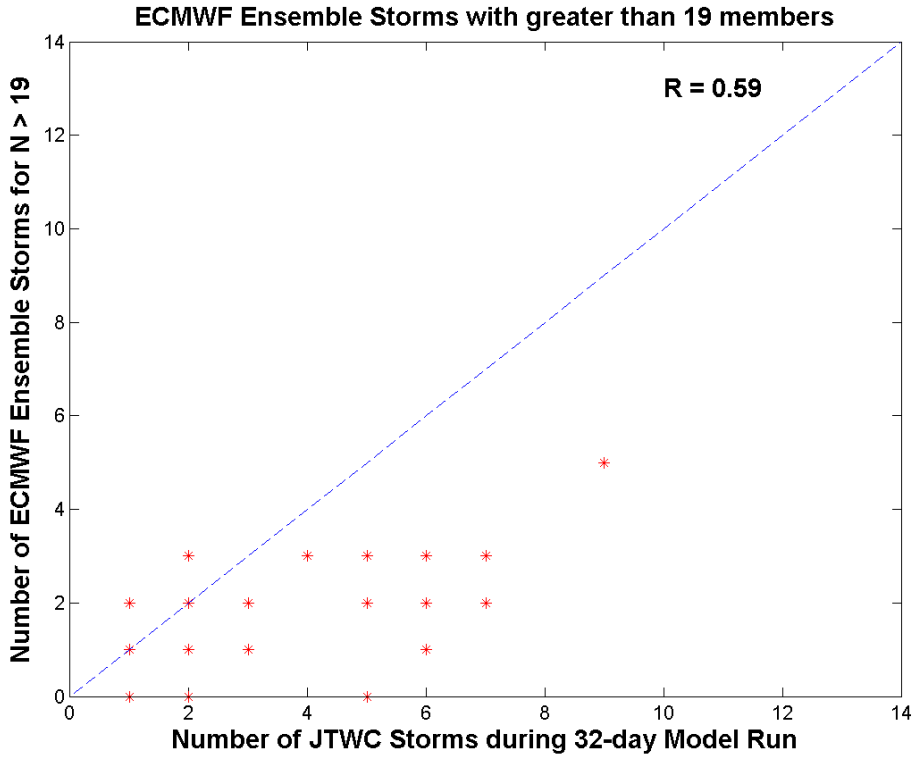
- All Joint Typhoon Warning Center tropical depressions and stronger tropical cyclones were counted in each corresponding 32-day period

	Minimum #	**Maximum #**
ECMWF Storms	**14 (5 June)**	**44 (31 July)**
JTWC Storms	**0 (25 December)**	**9 (18 September)**

- A total of 826 ECMWF storms were analyzed during the 30 weekly forecasts, and 626 (76%) had less than 5 member vortices in the storm

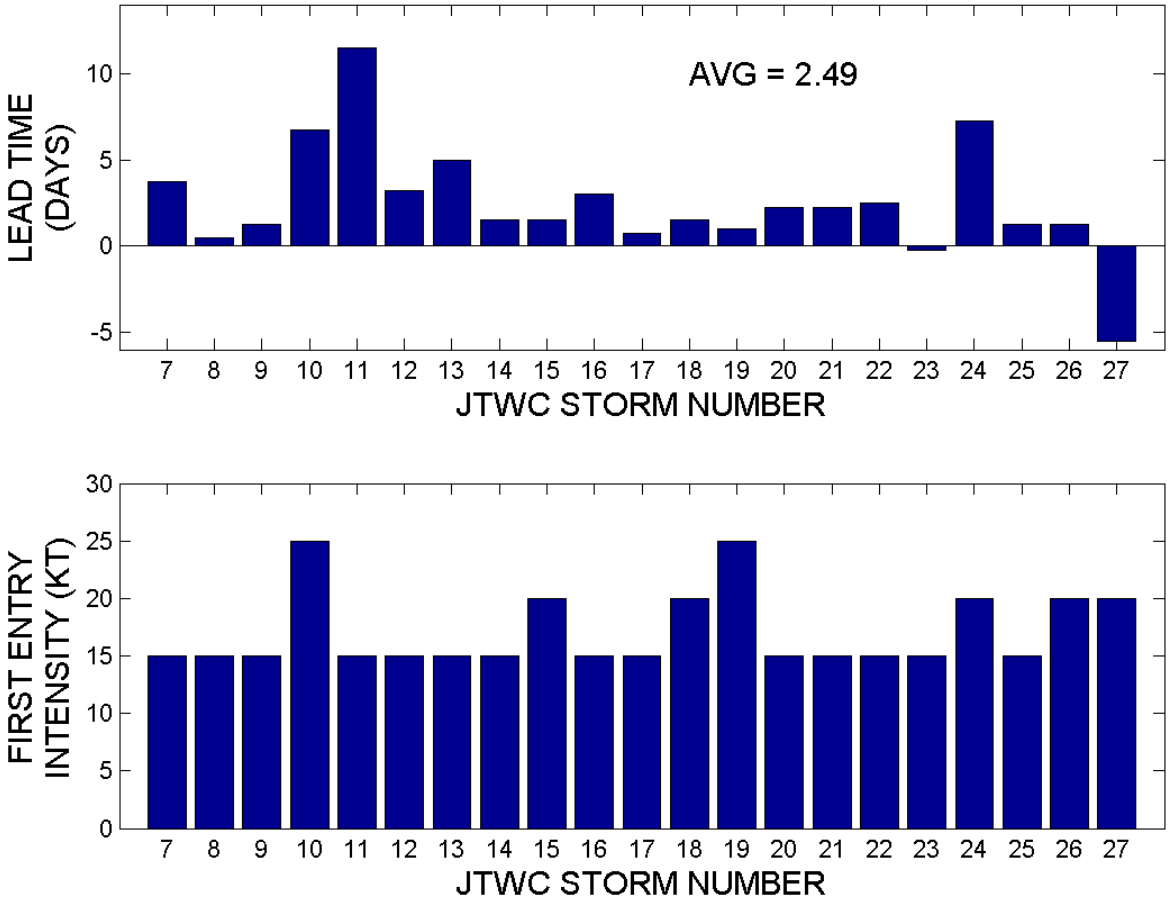
CORRELATION OF ECMWF STORM NUMBERS IN 32-DAY FORECASTS VERSUS JOINT TYPHOON WARNING CENTER (JTWC) STORM NUMBERS FOR 30 WEEKLY FORECASTS 5 JUNE - 25 DECEMBER 2008





CHARACTERISTICS OF ECMWF 32-DAY ENSEMBLE STORMS

The ECMWF storms in most cases start before the first entry in the corresponding JTWC best track.



MATCHING ROUTINE FOR VALIDATING ECMWF STORMS

ECMWF storm tracks are matched with the JTWC storm tracks with same separation threshold ε (t) where t is forecast interval in each 32-day integration.

No time deviation is allowed, so the ECMWF position must be within ε (t) of the JTWC position at the corresponding time.

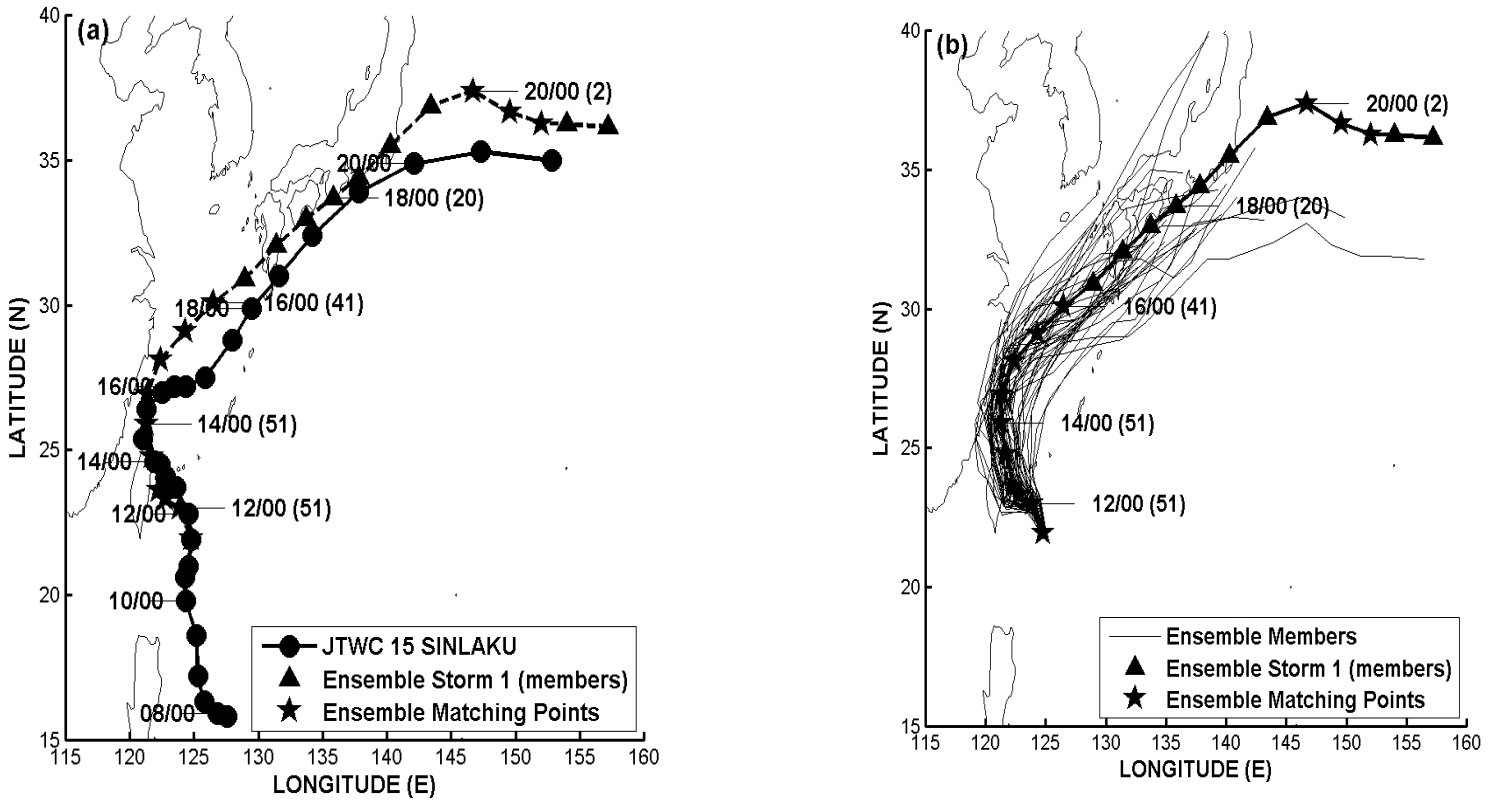
For each ECMWF storm in which at least one 12-h position matched a JTWC storm position, a quality indicator (excellent, above average, good below average, poor) is subjectively assigned based on similarity of paths and agreement in time over significant fractions of the tracks.

EVIDENCE OF INTRASEASONAL PREDICTABILITY FROM MATCHES OF ECMWF STORMS WITH JTWC STORM TRACK

Key: (Storm number in that week) Quality of match – number of member vortices
Red indicates secondary matches

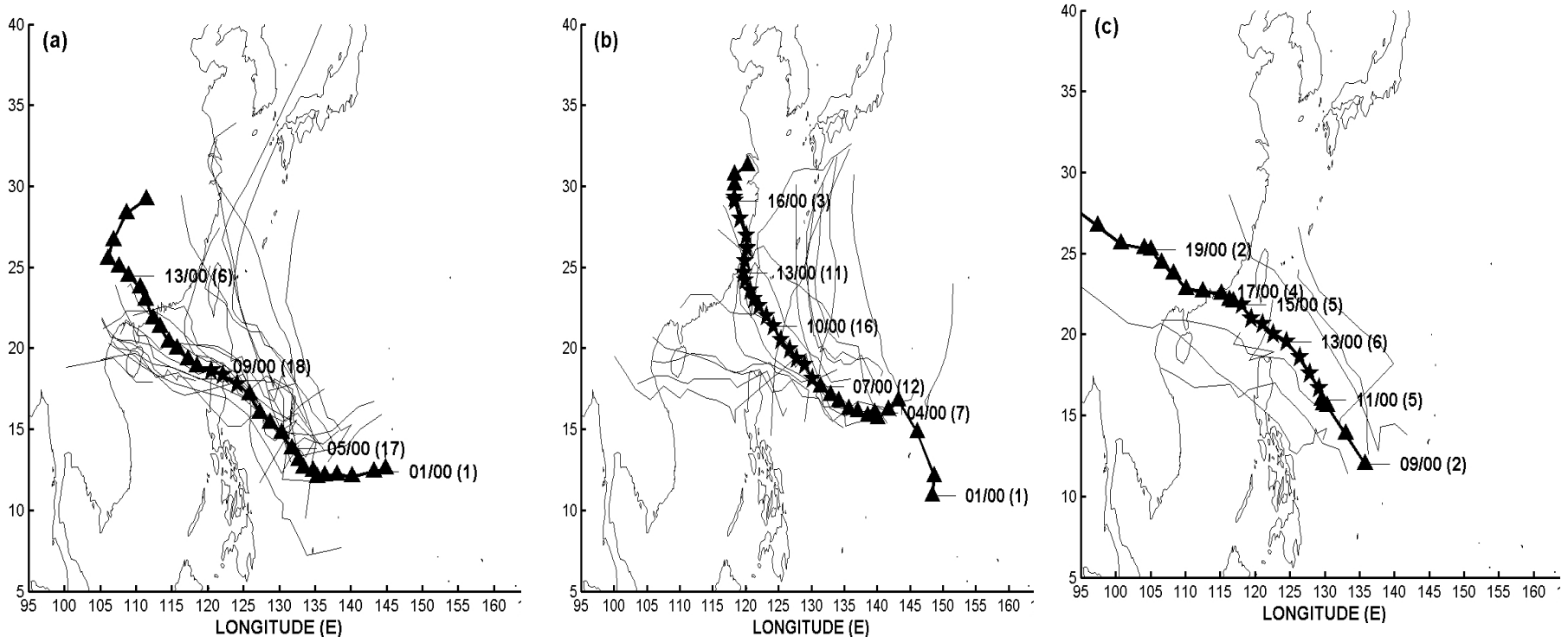
STORM	INITIAL	WEEK 1	WEEK 2	WEEK 3	WEEK 4-5
15 W					
Sinlaku	(1) Excellent [51]	(4) Good^{o} [23] (8) Above [4] (11) Poor$^{\#}$ [6]	(2) *Good [20]* (4) *Above [18]* (13) *Above [7]*	(16) *Above [5]* (20) *Above [5]* (23) Good [6] (26) Good^{e} [5] (31) Poor $^{\#}$ [1]	(21) *Above [10]* (29) Good [3] (30) *Above^{e}[6]*

$^{\#}$ Indicates an coincidental match, usually at normal incidence as tracks cross;
^{e} –shifted to east; ^{o} – only good early

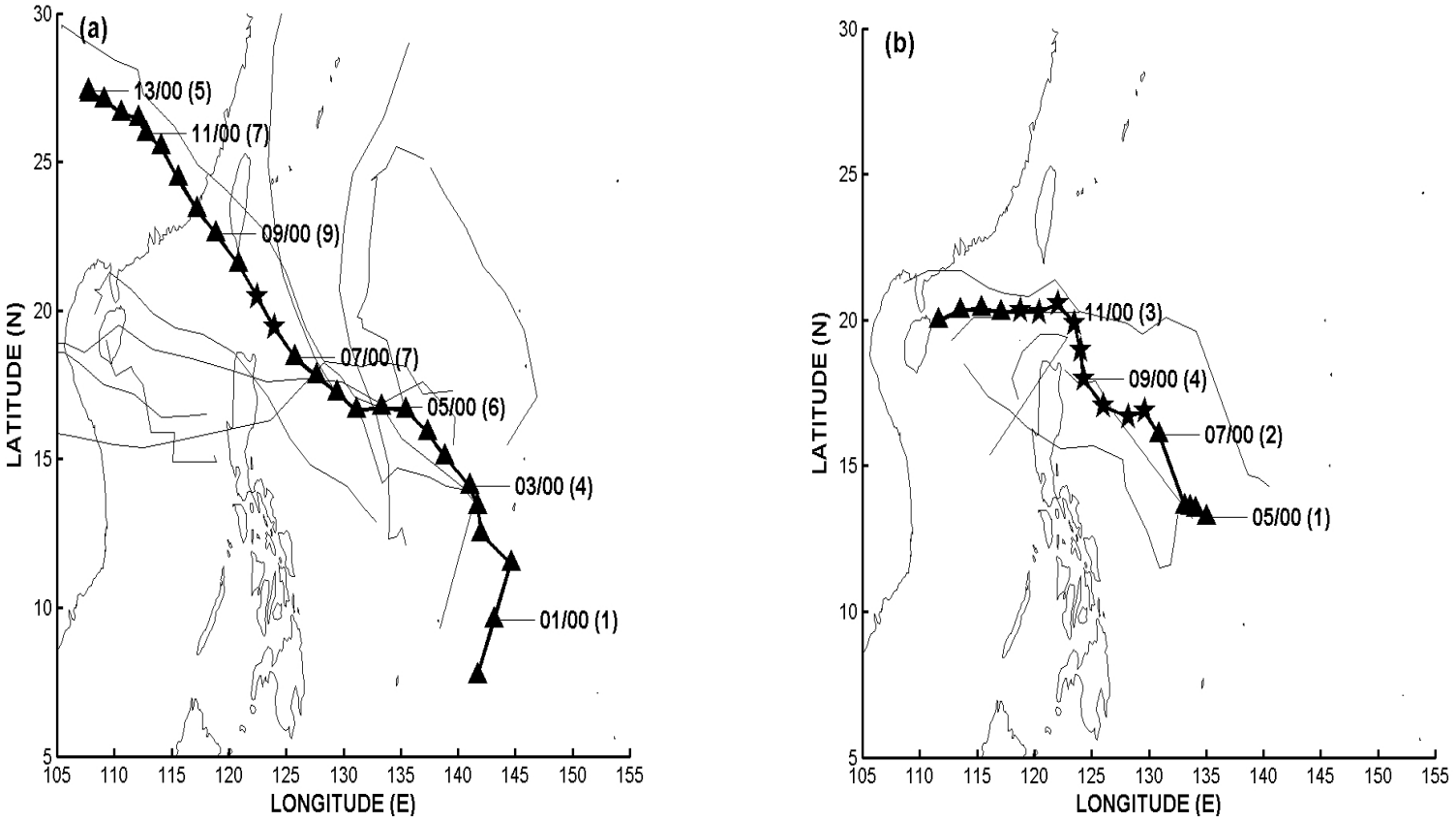


(a) Best-track positions (circles, selected dates/times on left) each 12 h from JTWC for 15 W (Sinlaku) and ECMWF ensemble storm 1 in the 11 September 32-day forecast with numbers of members in parentheses and matched points within ε (t) distance indicated by star symbols. (b) Ensemble storm 1 track as in panel (a) with individual ensemble vortex tracks indicated by thin lines.

x



(a) ensemble storm 2 with 20 members, (b) ensemble storm 4 with 18 members, and (c) ensemble storm 13 with 7 members in the 28 August 2008 forecast (Week-2) of Sinlaku.



(a) ensemble storm 21 with 10 members and (b) ensemble storm 30 with 6 members in the 14 August 2008 forecast (Week-4) of Sinlaku.

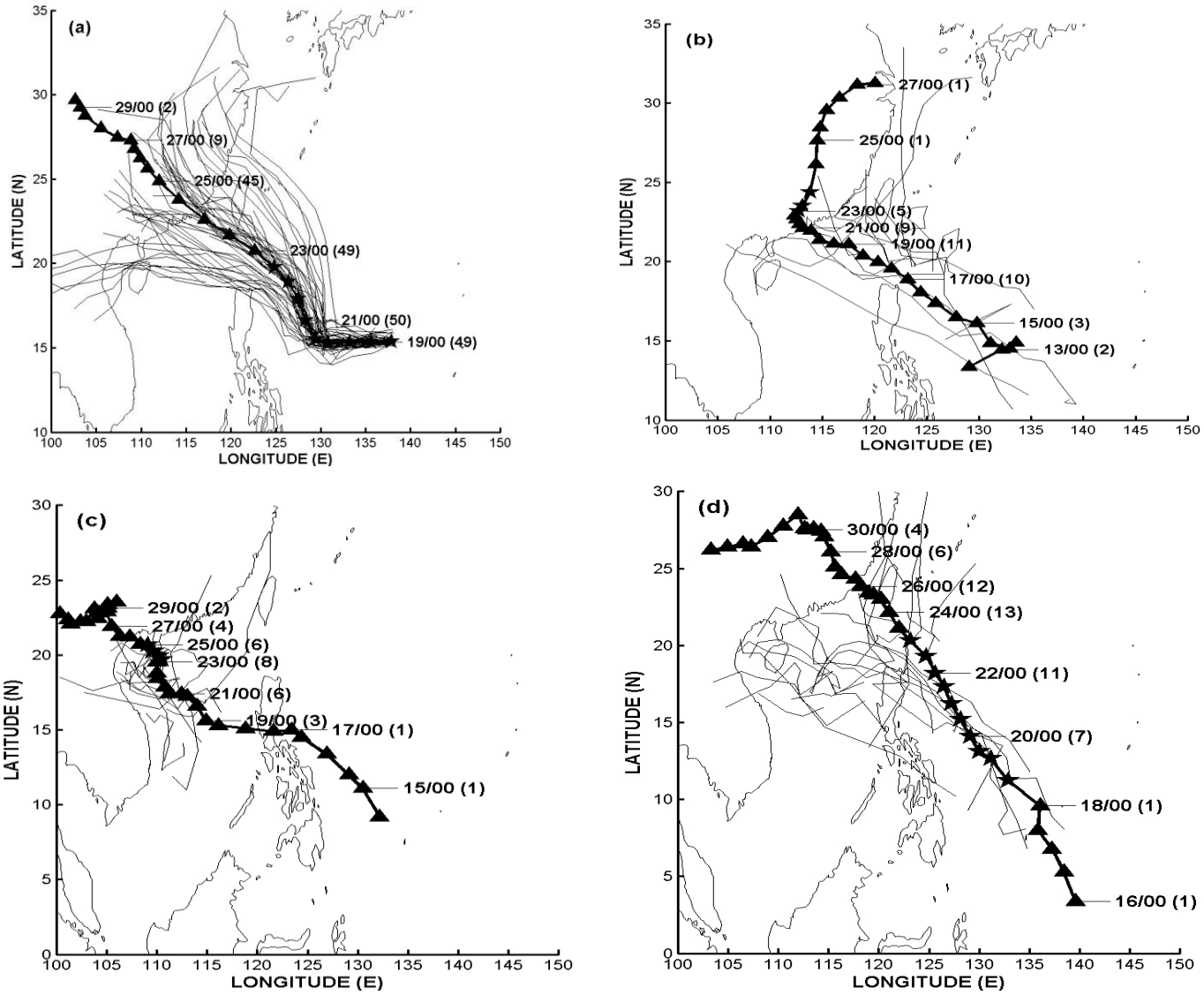
EVIDENCE OF INTRASEASONAL PREDICTABILITY FROM MATCHES OF ECMWF STORMS WITH JTWC STORM TRACK

Key: (Storm number in that week) Quality of match – number of member vortices
Red indicates secondary matches

STORM	WEEK 0	WEEK-1	WEEK-2	WEEK-3	WEEK-4
18 W Hagupit	(1) Excellent [51]	(5) Above [20]	(13) *Above $^{\ell}$ [12]* (17) *Above [12]* (18) *Above^{o} [18]*	(15) Good^{l} [24] (19) *Good ^{s} [10]* (24) Above [4] *(26) Above* [8]*	(32) Excellent^{e} *[3]*

^{o} Only good early; * several days late; $^{\ell}$ - only good late; ^{s} – shifted to south

Note: Forecasts of Hagupit have many good tracks, but with shifts in timing.



(a) ensemble storm 1 with 51 members in the 18 September 2008 forecast (Week 0), (b) ensemble storm 13 with 12 members, (c) ensemble storm 17 with 12 members, and (d) ensemble storm 18 with 18 members in the 4 September 2008 forecast (Week-2).

EVIDENCE OF INTRASEASONAL PREDICTABILITY FROM MATCHES OF ECMWF STORMS WITH JTWC STORM TRACK

Key: (Storm number in that week) Quality of match – number of member vortices
Red indicates secondary matches

STORM	WEEK 0	WEEK-1	WEEK-2	WEEK-3	WEEK-4
13 W					
Nuri	(1) Excellent [51]	None	(9) *Above^{s}[14]* (12) *Excellent [6]*	(23) *Excellent [12]* (25) *Excellent [4]*	(30) Good^{s} [4] (34) Good^{e} [1]

^{e} Indicates shifted to east; ^{s} indicates shifted to south

Note: ECMWF Week-1 forecasts followed northern wave and thus were at greater distance than ε (t) from actual track to verify

LACK OF INTRASEASONAL PREDICTABILITY FOR CERTAIN CIRCULATIONS

Elsberry et al. (2009) demonstrated four global models had little skill in predicting formations from baroclinic systems even on 120 h time scales.

Similar tendencies are indicated for the ECMWF ensemble model forecasts.

Key: (Storm number in that week) Quality of match – number of member vortices

STORM	WEEK 0	WEEK-1	WEEK-2	WEEK -3	WEEK -4
16 Tropical Depression (Baroclinic)	**(5) Good [20]**	**(10) Above [2]** **(12) Below [1]**	**(17) Excellent [5]**	**(27) Above[l] [3]** **(38) Above [1]**	**None**
25W Haishen (Baroclinic)	**(20) Excellent [5]**	**None**	**None**	**None**	**None**

[l] Indicates only good late

CONCLUSIONS

A viable technique has been developed to match ECMWF 32-day ensemble member tropical cyclone-like vortices to form storm tracks

The ECMWF ensemble generates too many vortices that either can not be matched (orphan storms) or with less than five member vortices in the matched storms

In most cases, the ECMWF ensemble storm tracks begin earlier than the corresponding cyclone start time (First item in JTWC best track, when intensity is only 15-25 kt)

Evidence of some predictability of tropical cyclone formation and tracks on time scales up to four weeks is indicated by matches with typhoon tracks, but not with cyclones that originate from baroclinic systems

Testing as a forecast tool will require a combination at weeks 2-4 of similar tracks that are formed from a minimum number of ensemble vortices as part of a calibration technique, which will likely require a larger sample than this seven-month data base during June 2008-December 2008

FUTURE EXTENSIONS

- ECMWF is providing the weekly 32-day forecast tracks during the 2009 season
- A calibration of the ensemble storm tracks from the 2008 and 2009 seasons will be first step in developing a probablistic forecast technique
- ECMWF is increasing horizontal resolution of the monthly forecast, and may go to two forecasts each week
- ECMWF will provide the 32-day forecast tracks during the 2010 season for use during the combined Tropical Cyclone Structure (TCS-10)/Interacting Typhoon-Ocean Program (ITOP) field experiment