A Predictability Study of Two Intense Arctic Cyclones in Early June 2018

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Motivation

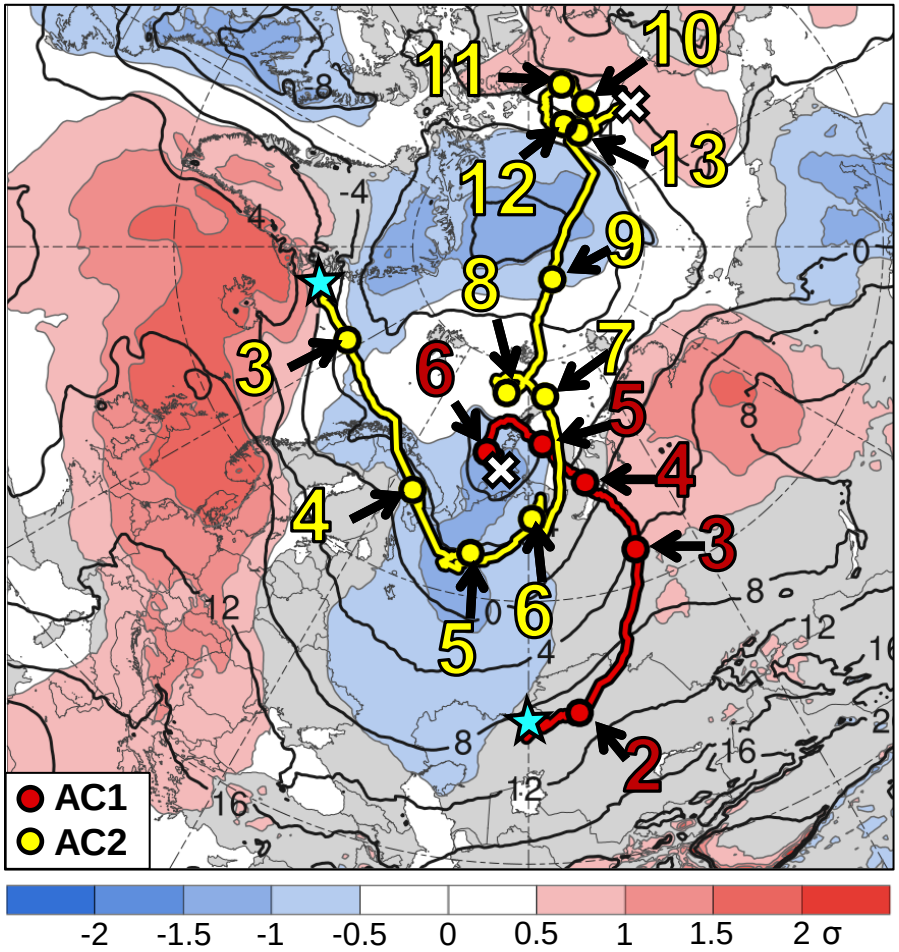
- Two unusually intense Arctic cyclones, AC1 and AC2, occurred in early June 2018

- Both AC1 and AC2 strengthen in a region of strong baroclinicity over western Eurasia ahead of respective high-amplitude upper-level troughs

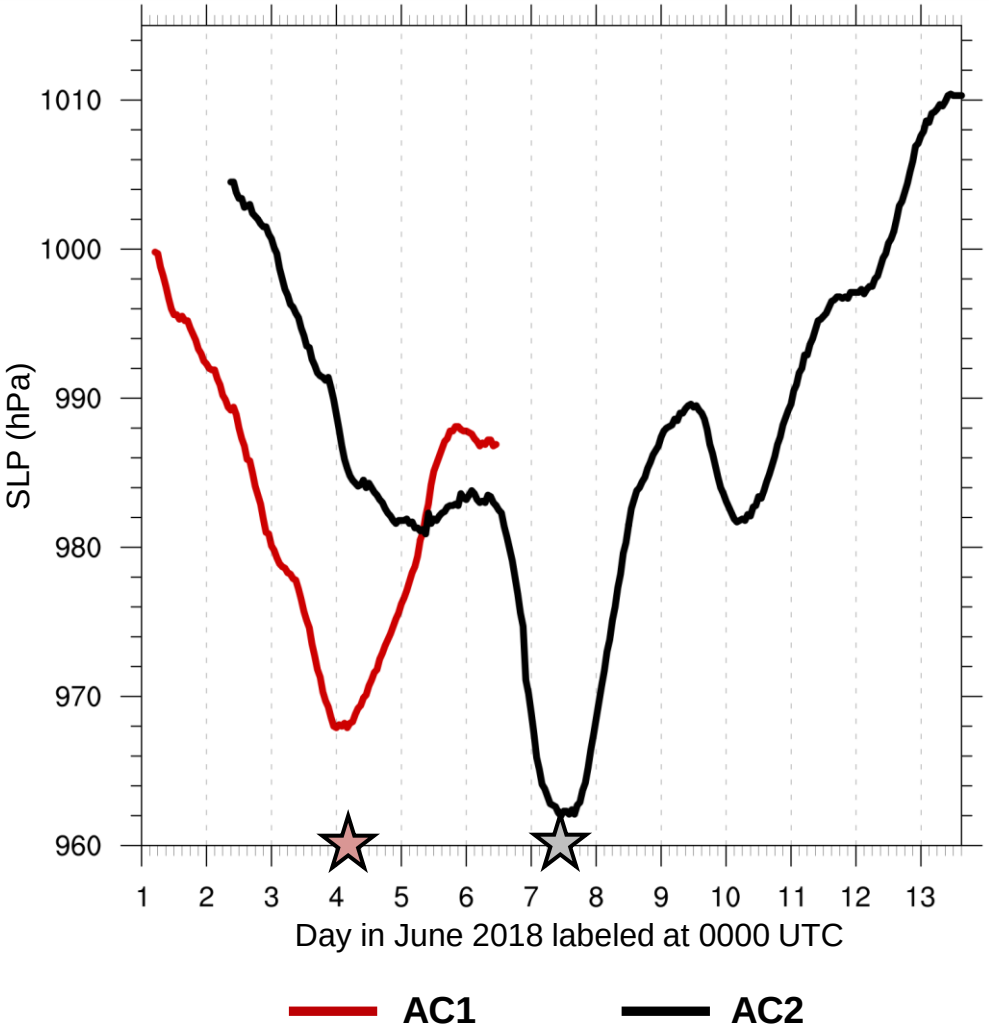
- AC1 and AC2 undergo a cyclonic rotation over the Arctic Ocean, during which AC1 is absorbed by AC2

Motivation

Data source: ERA5



1–7 June 2018 time-mean 850-hPa temperature (°C, black) and standardized temperature anomalies (σ, shaded)



Peak intensity of AC1 at 0400 UTC 4 June 2018 (968 hPa)

Peak intensity of AC2 at 1100 UTC 7 June 2018 (962 hPa)

Motivation

- Yamagami et al. (2018a,b) show that forecast skill for strong Arctic cyclones in summer can be low
  - Accurate forecasts of the Great Arctic Cyclone of August 2012 (AC12) extend only to 2–3 day lead time prior to peak intensity

Purpose

- Evaluate the forecast skill of AC1 and AC2

- Diagnose factors that may influence the forecast skill of AC1

  - **Why focus on AC1?** AC1 is absorbed by AC2, so that understanding the forecast skill of AC2 would require diagnosing factors that may influence the forecast skill of AC1

Data and Methods

- Utilize 51-member ECMWF Ensemble Prediction System (EPS; Buizza et al. 2007) from TIGGE (Bougeault et al. 2010) initialized 0–168 h prior to times of peak intensity of AC1 and AC2 in ERA5 (Hersbach and Dee 2016)

- Utilize ERA5 as verification

- Download ensemble and verification data at 0.5° horizontal resolution and 6-h temporal resolution

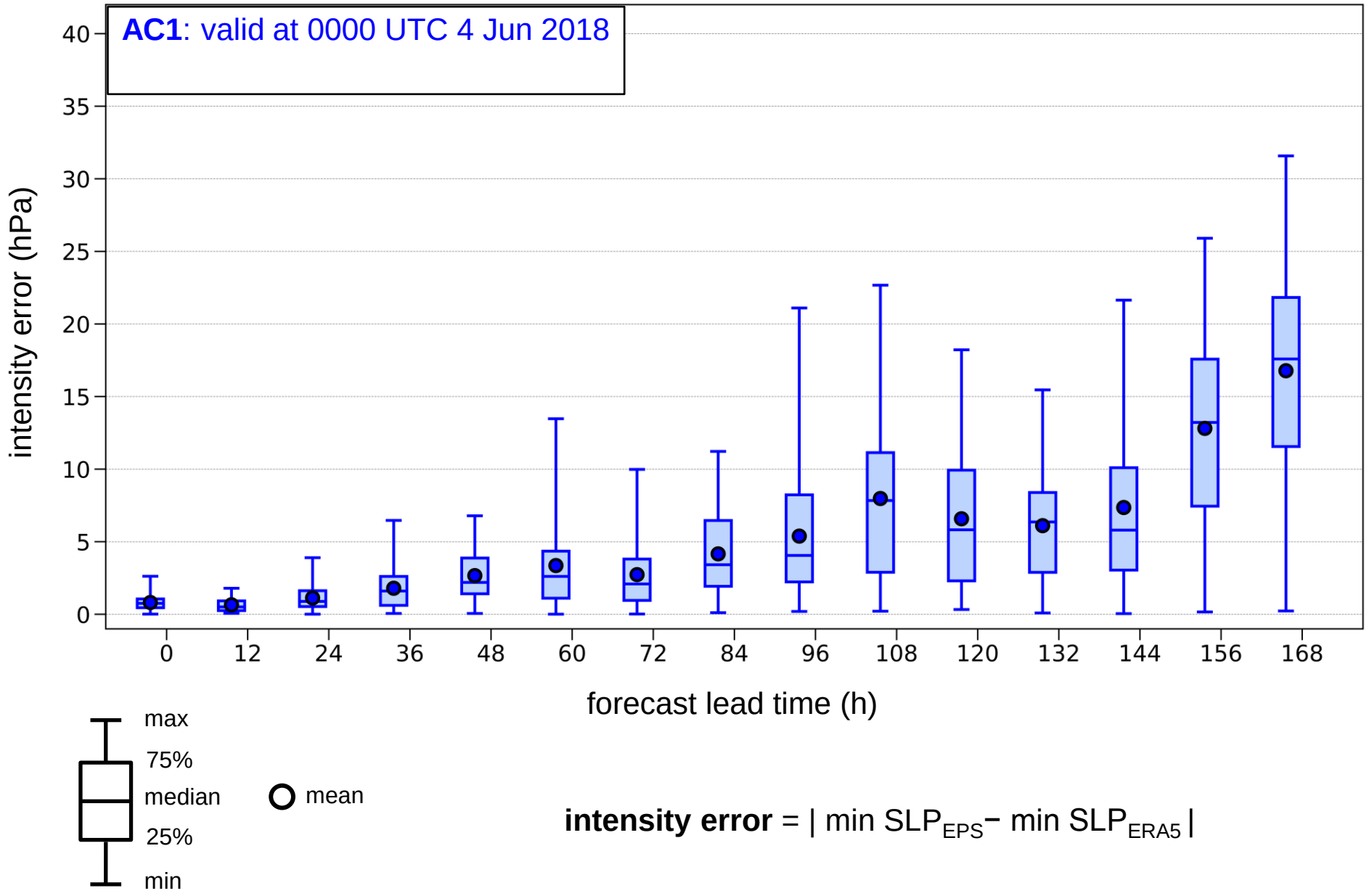
Data and Methods

- Track AC1 and AC2 in ECMWF EPS and ERA5 utilizing an objective cyclone tracking algorithm based on sea level pressure (SLP) from Crawford and Serreze (2016)

Data and Methods

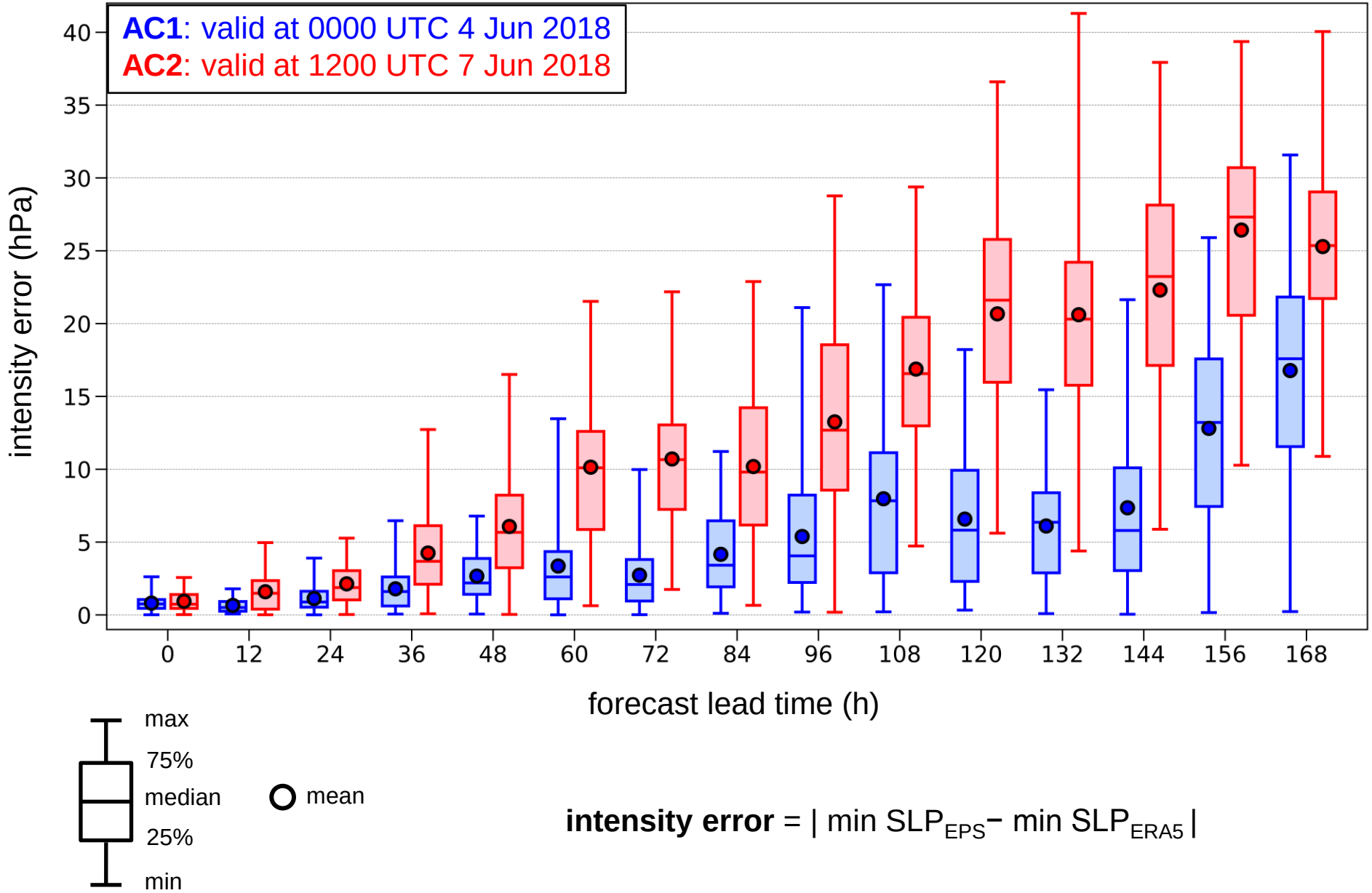
- Determine cyclone intensity and position error based on value and position, respectively, of SLP minimum for forecasts valid at time of peak intensity in ERA5
  - **AC1**: forecasts valid at 0000 UTC 4 June
  - **AC2**: forecasts valid at 1200 UTC 7 June
- Calculate corresponding spread and root mean square error (RMSE) of cyclone intensity and position for aforementioned forecasts

Intensity Error



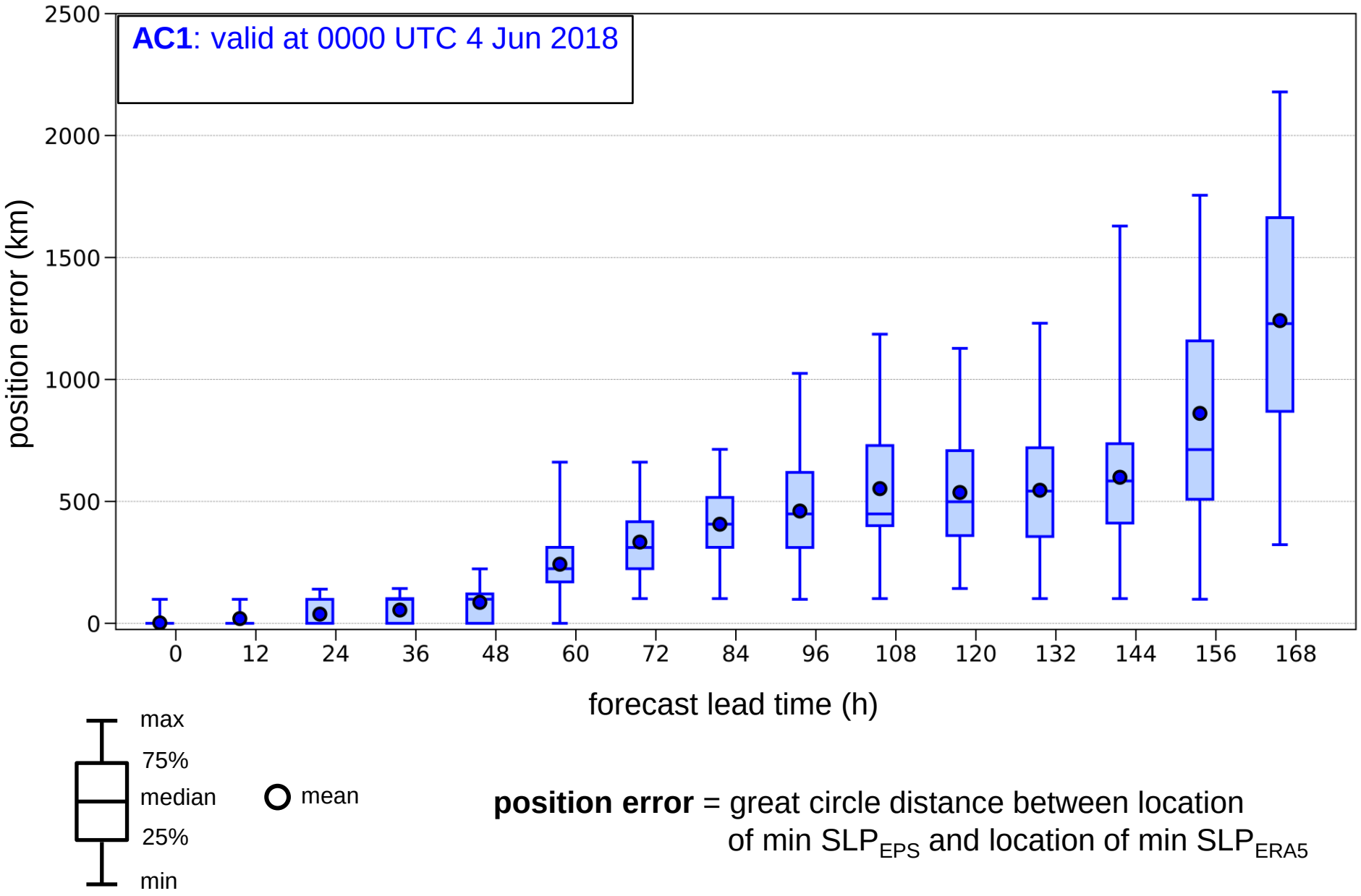
intensity error = | min SLP_{EPS} − min SLP_{ERA5} |

Intensity Error



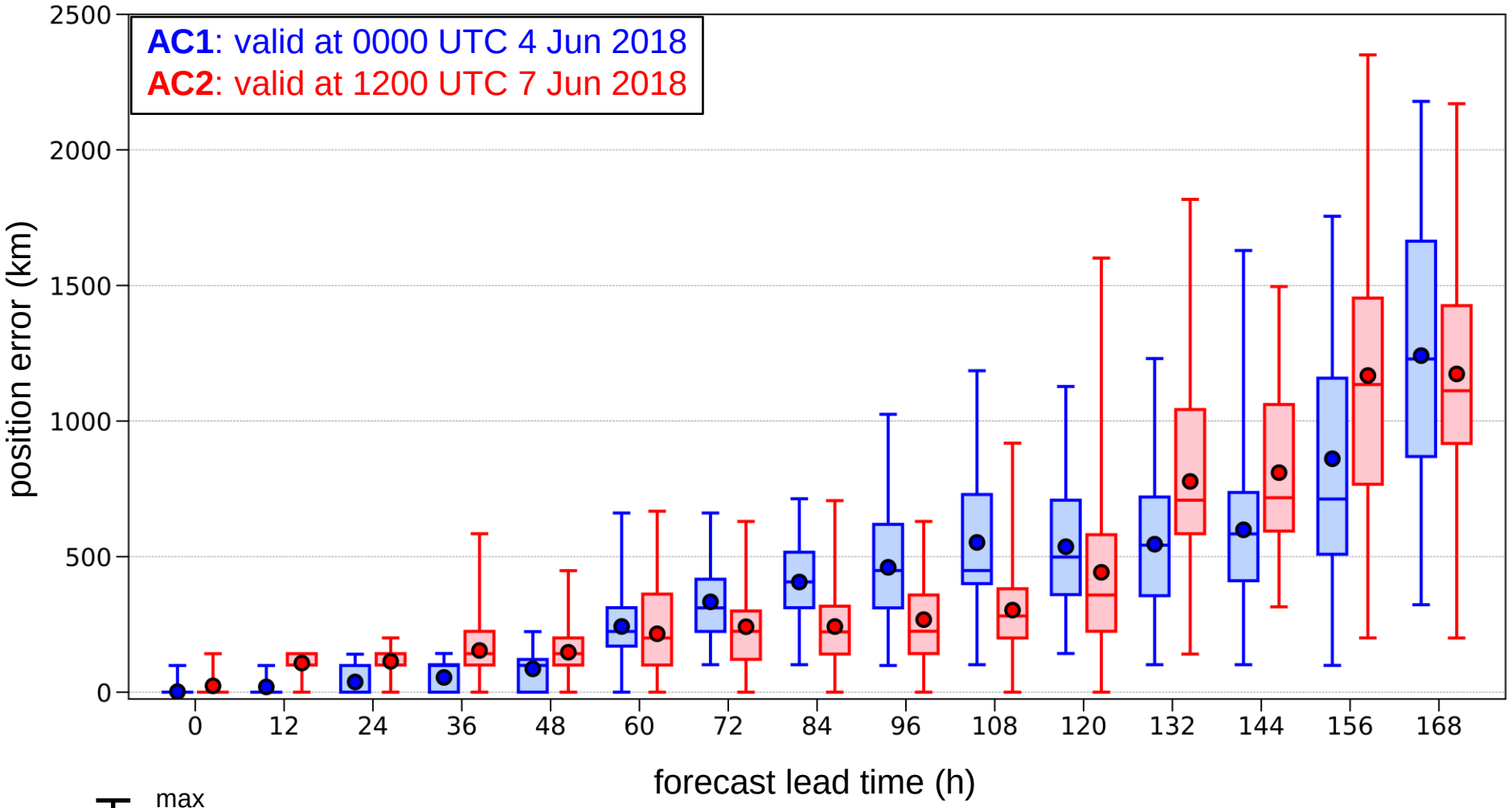
intensity error = | min SLP_{EPS} − min SLP_{ERA5} |

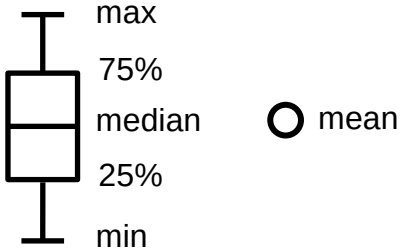
Position Error



position error = great circle distance between location of min SLP_{EPS} and location of min SLP_{ERA5}

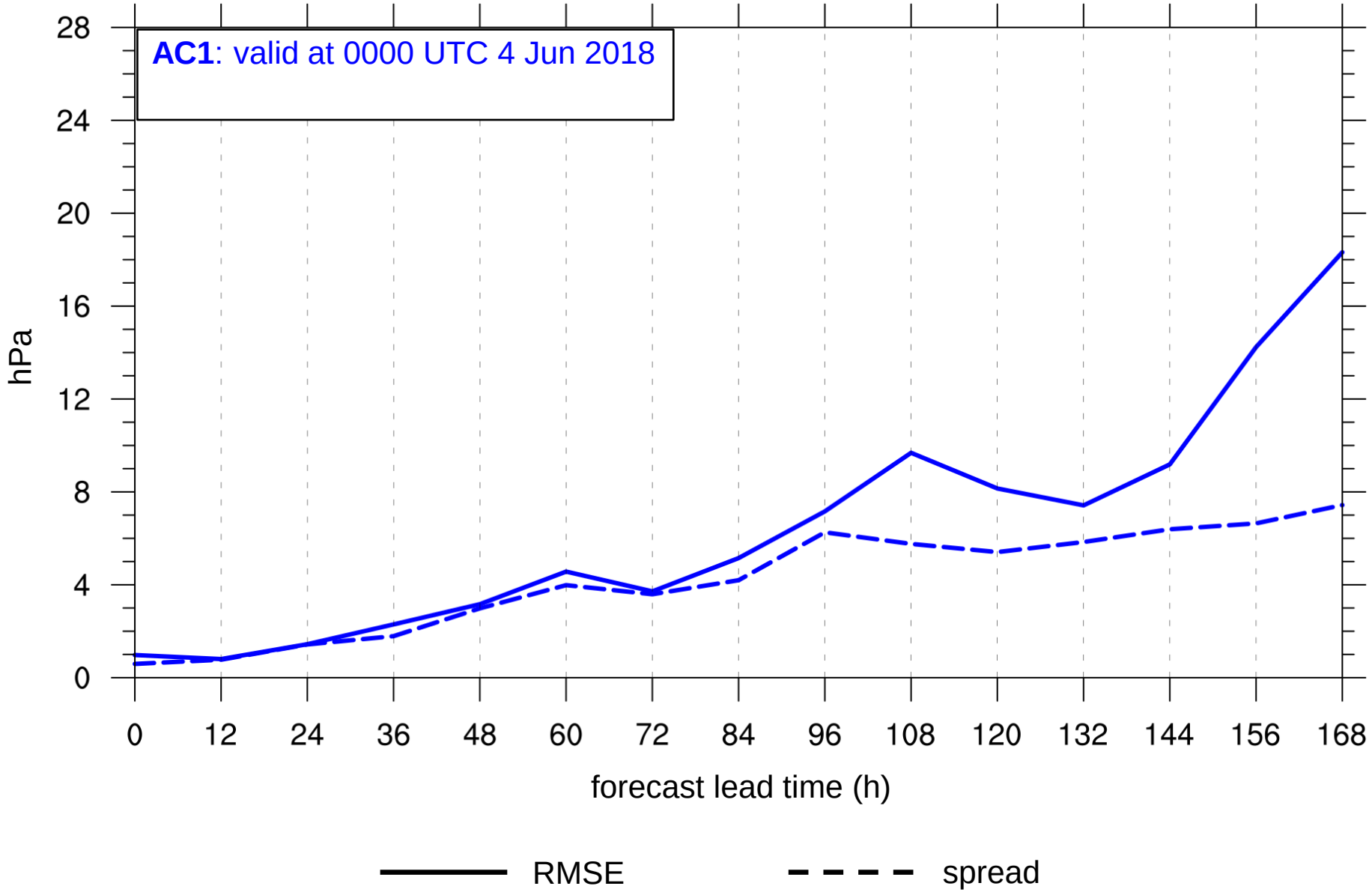
Position Error



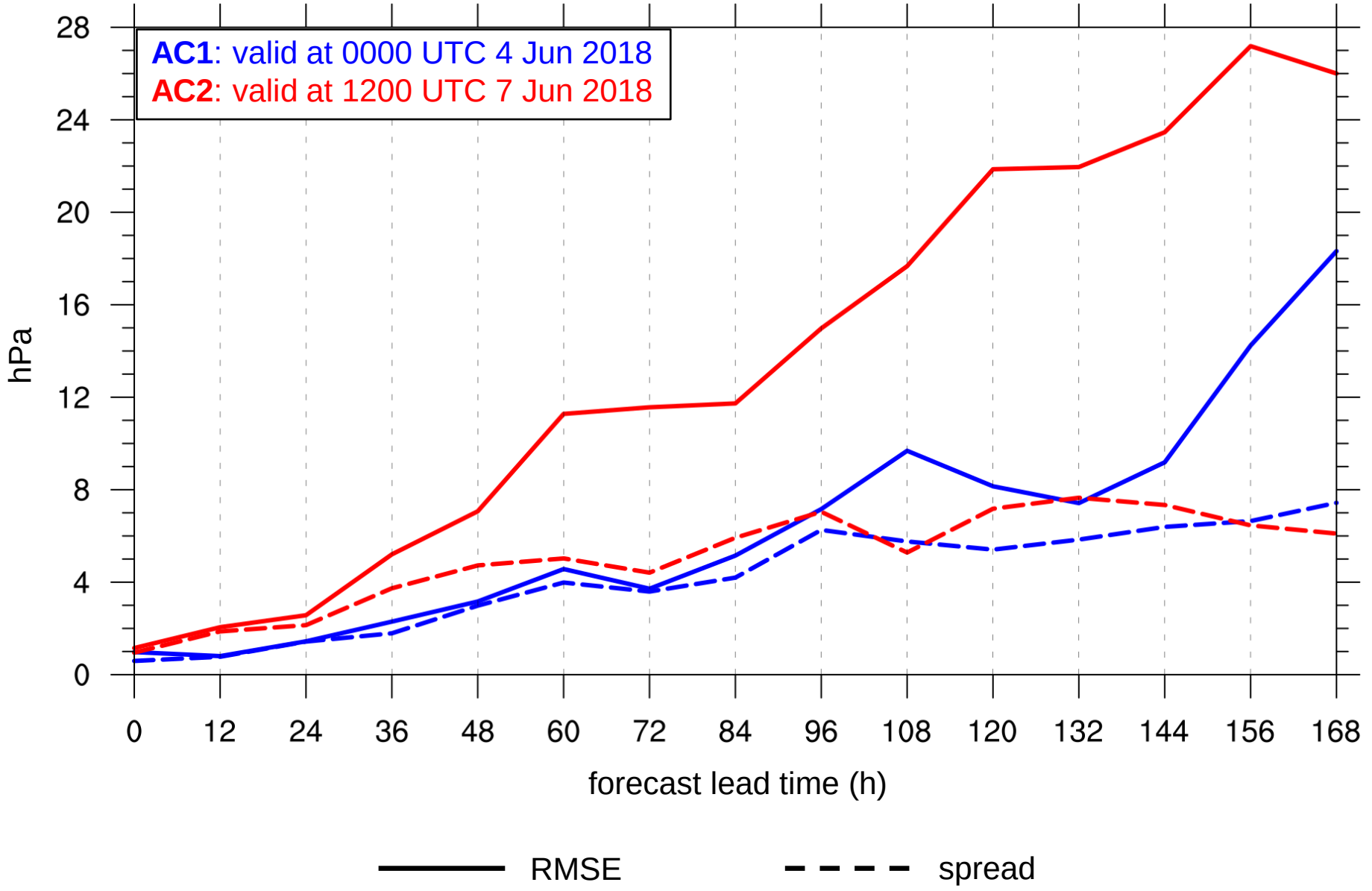


position error = great circle distance between location of min SLP_{EPS} and location of min SLP_{ERA5}

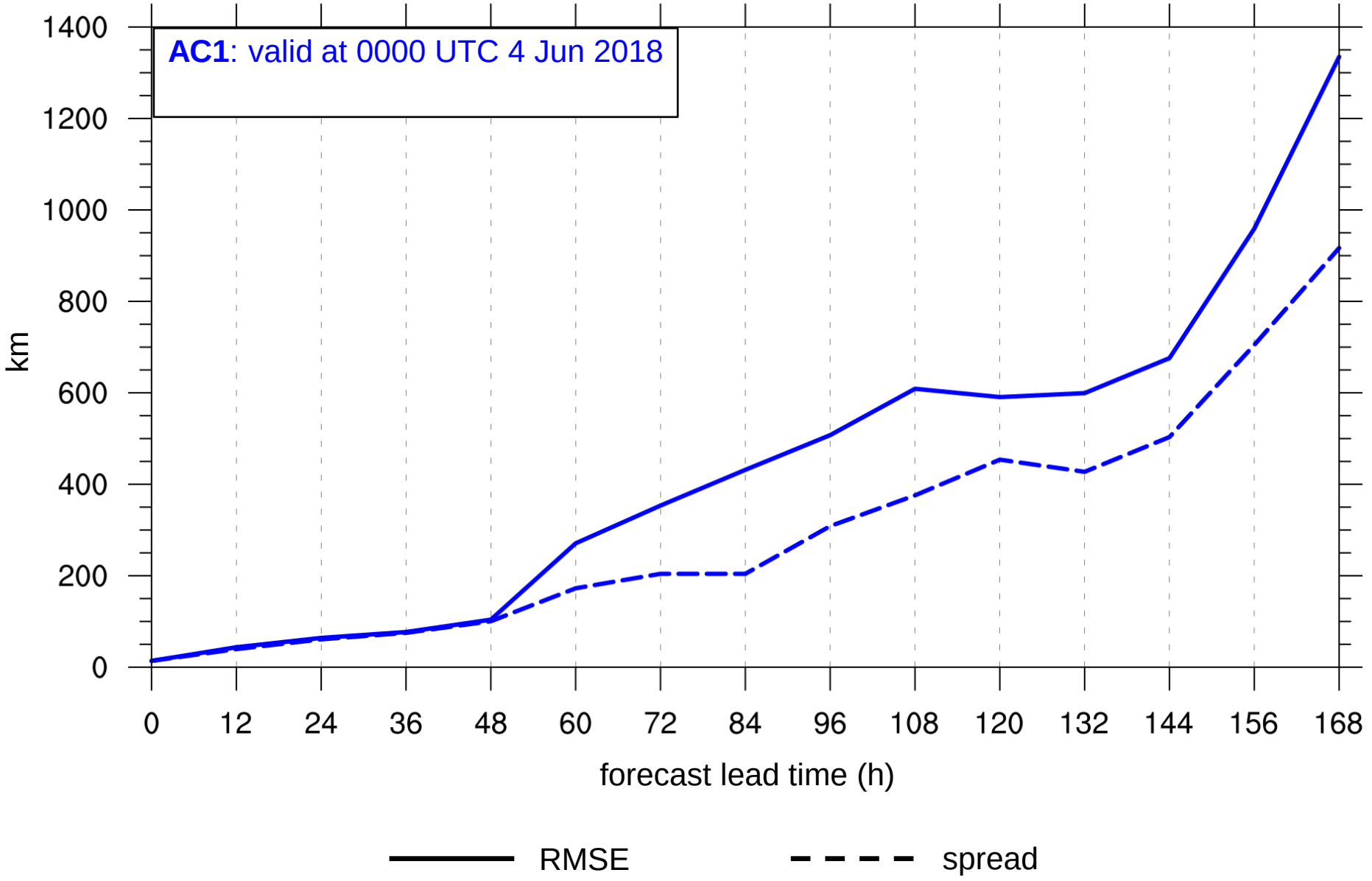
Intensity RMSE and Spread



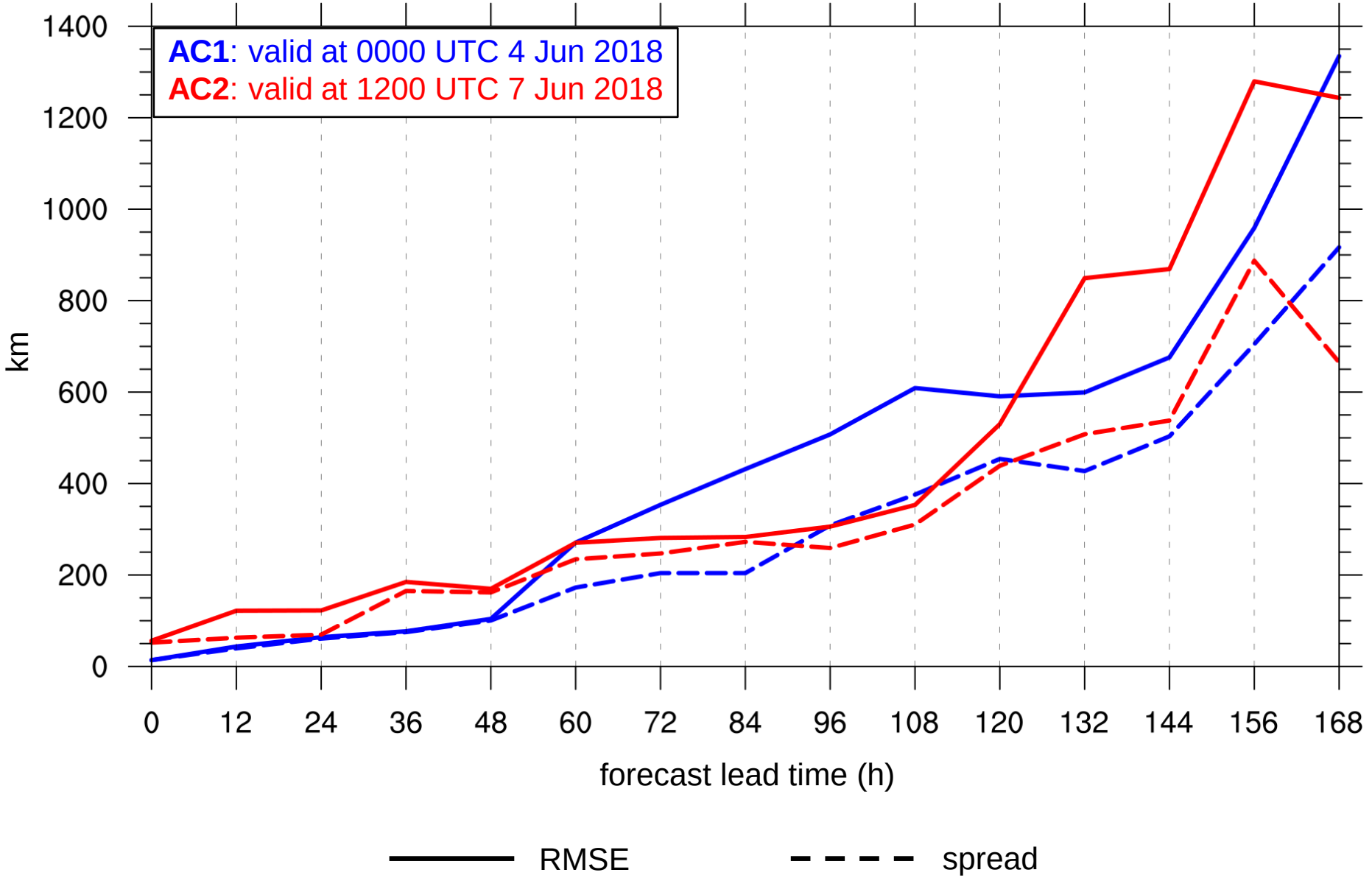
Intensity RMSE and Spread



Position RMSE and Spread



Position RMSE and Spread

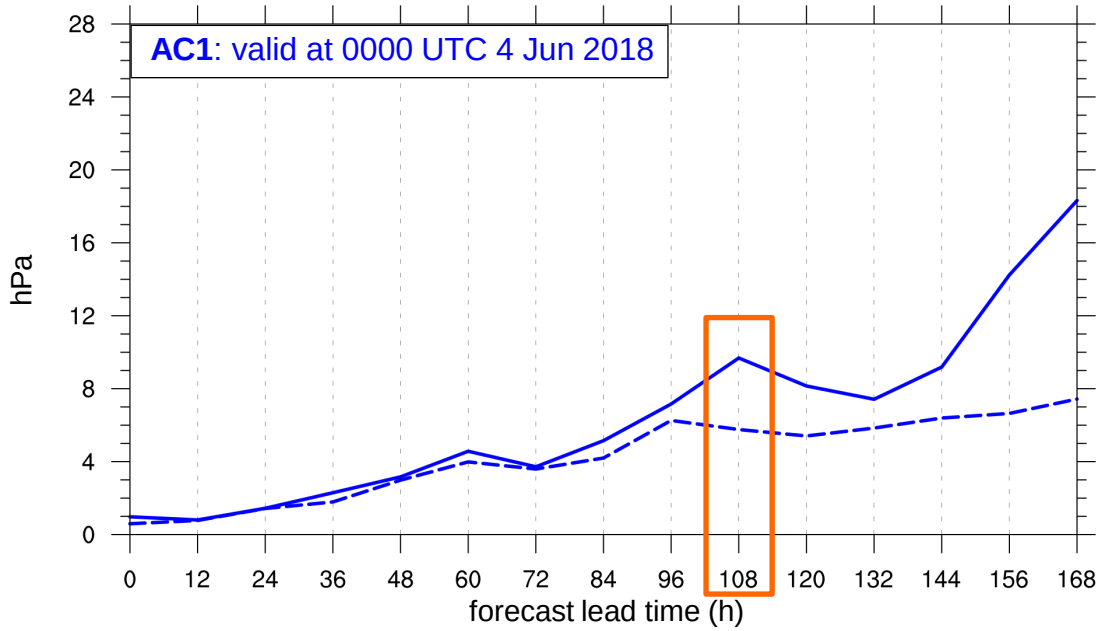


Diagnose Factors Influencing Forecast Skill of AC1

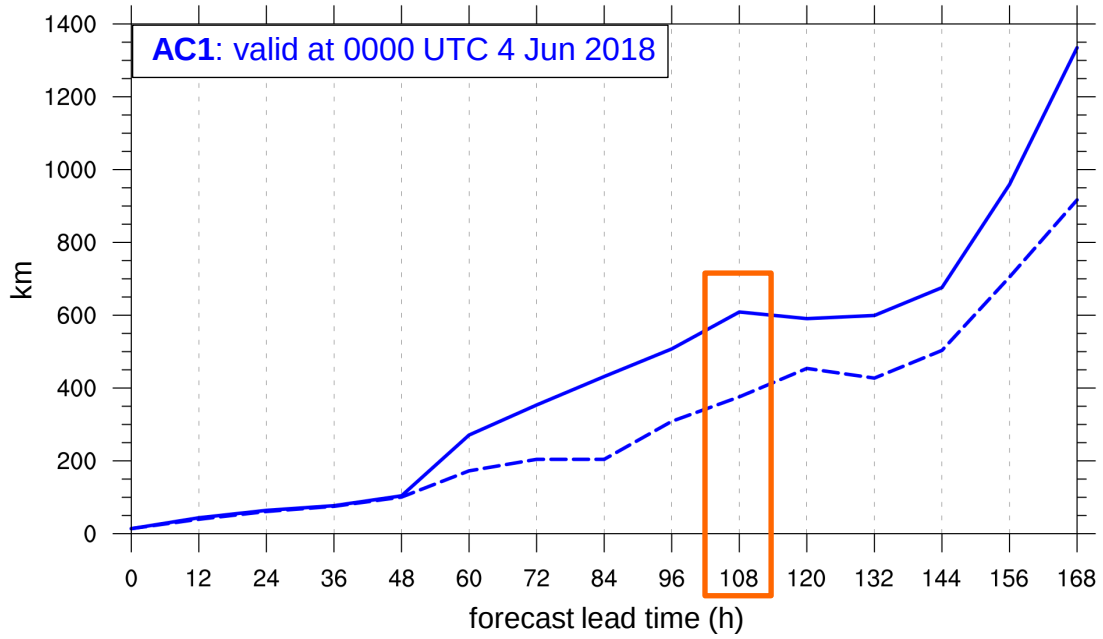
- Utilize ensemble forecasts initialized at 1200 UTC 30 May, which is 108 h prior to time of peak intensity of AC1 in ERA5 (0000 UTC 4 Jun)

Diagnose Factors Influencing Forecast Skill of AC1

intensity



position



RMSE

spread

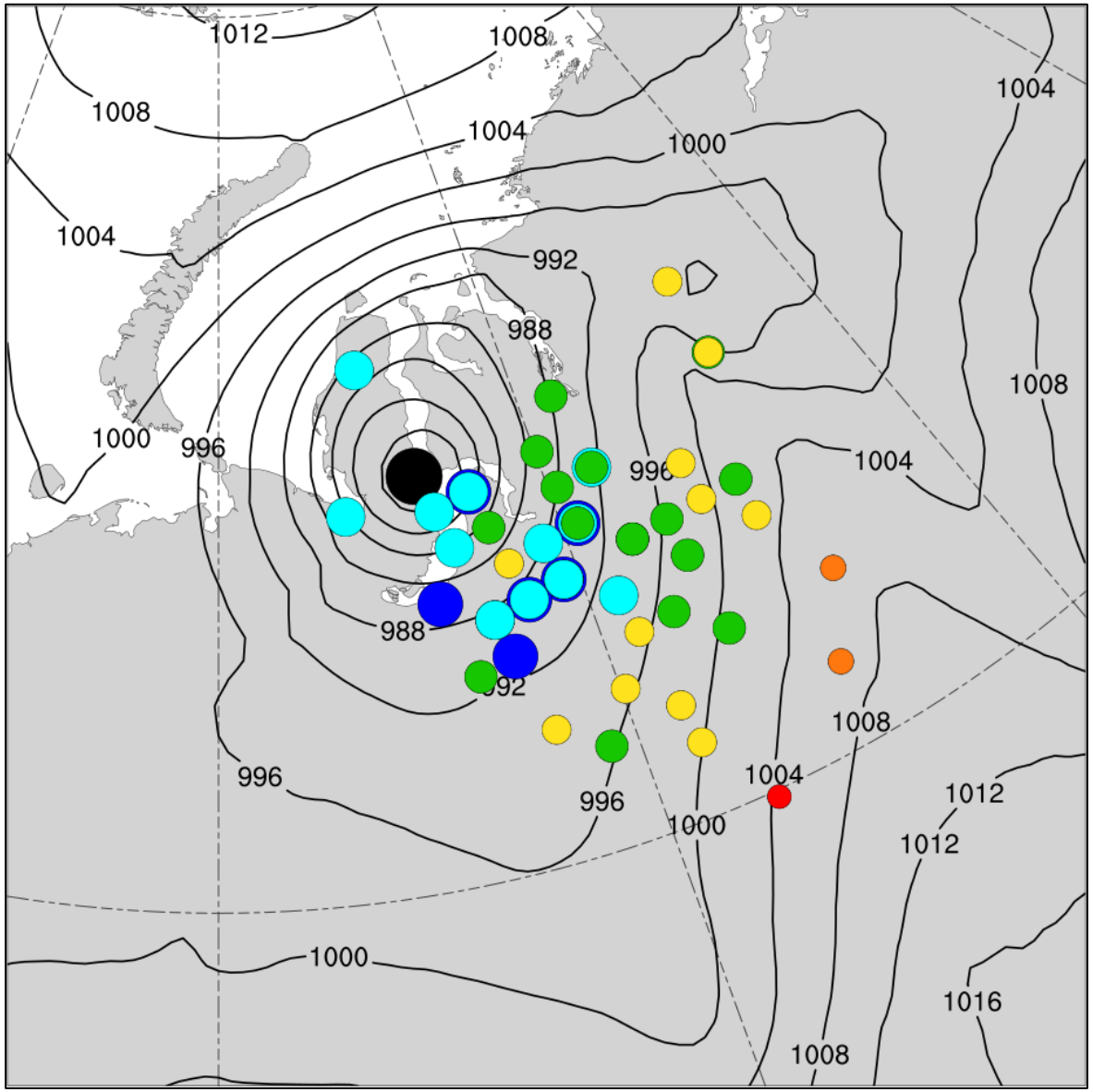
Diagnose Factors Influencing Forecast Skill of AC1

- Separate ensemble members in terms of a metric adapted from Lamberson et al. (2016) that combines intensity and position error of AC1

- Subdivide members into two groups in terms of metric: one containing the 10 most accurate members and one containing the 10 least accurate members

108-h Forecast Position and Intensity of AC1

108-h forecast valid 0000 UTC 4 Jun 2018



SLP from ERA5 (hPa, contours); position of minimum SLP of AC1 [dots, colored by intensity (hPa) for ensembles]

ERA5 (969)

965–970

970–975

975–980

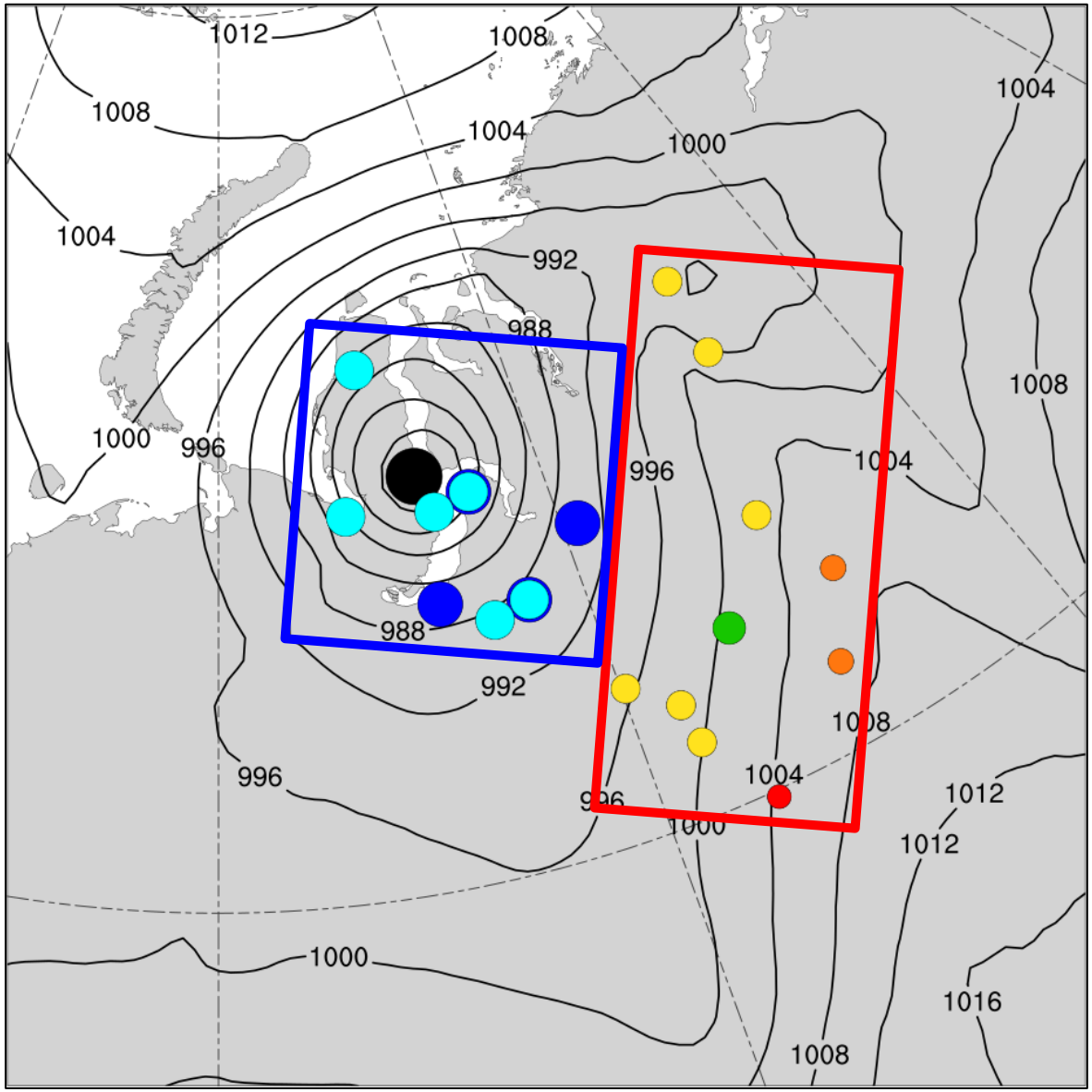
980–985

985–990

990–995

108-h Forecast Position and Intensity of AC1

108-h forecast valid 0000 UTC 4 Jun 2018



SLP from ERA5 (hPa, contours); position of minimum SLP of AC1 [dots, colored by intensity (hPa) for ensembles]

ERA5 (969)

965–970

970–975

975–980

980–985

985–990

990–995

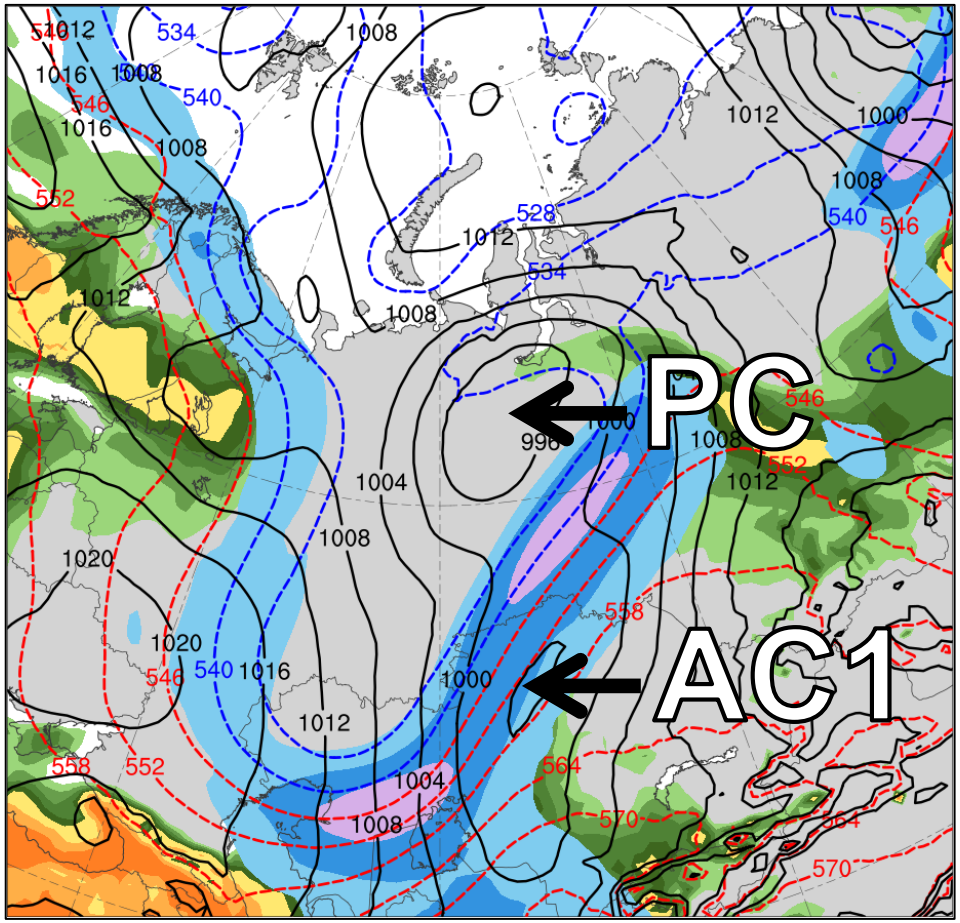
most accurate group

least accurate group

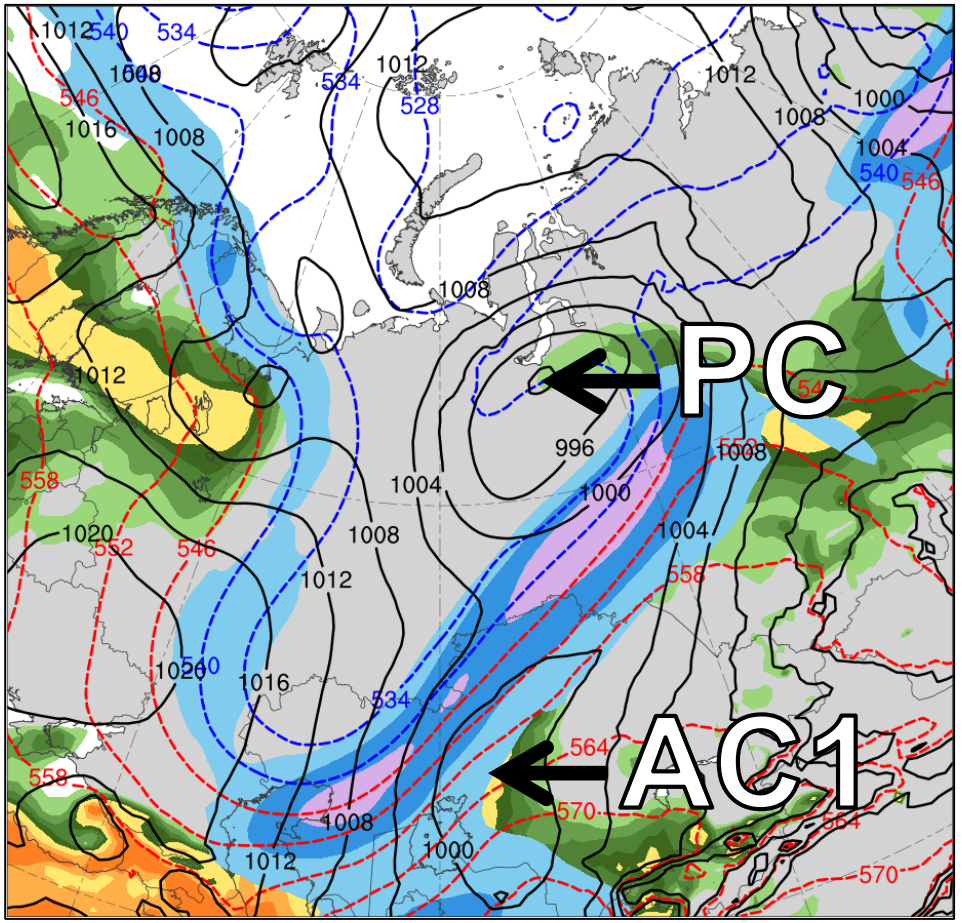
Synoptic Comparison

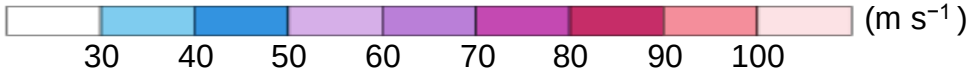
0000 UTC 2 June (60-h forecast)

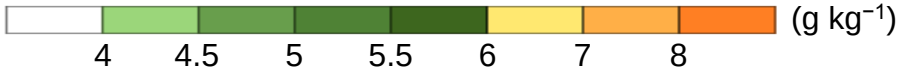
Most Accurate Group



Least Accurate Group







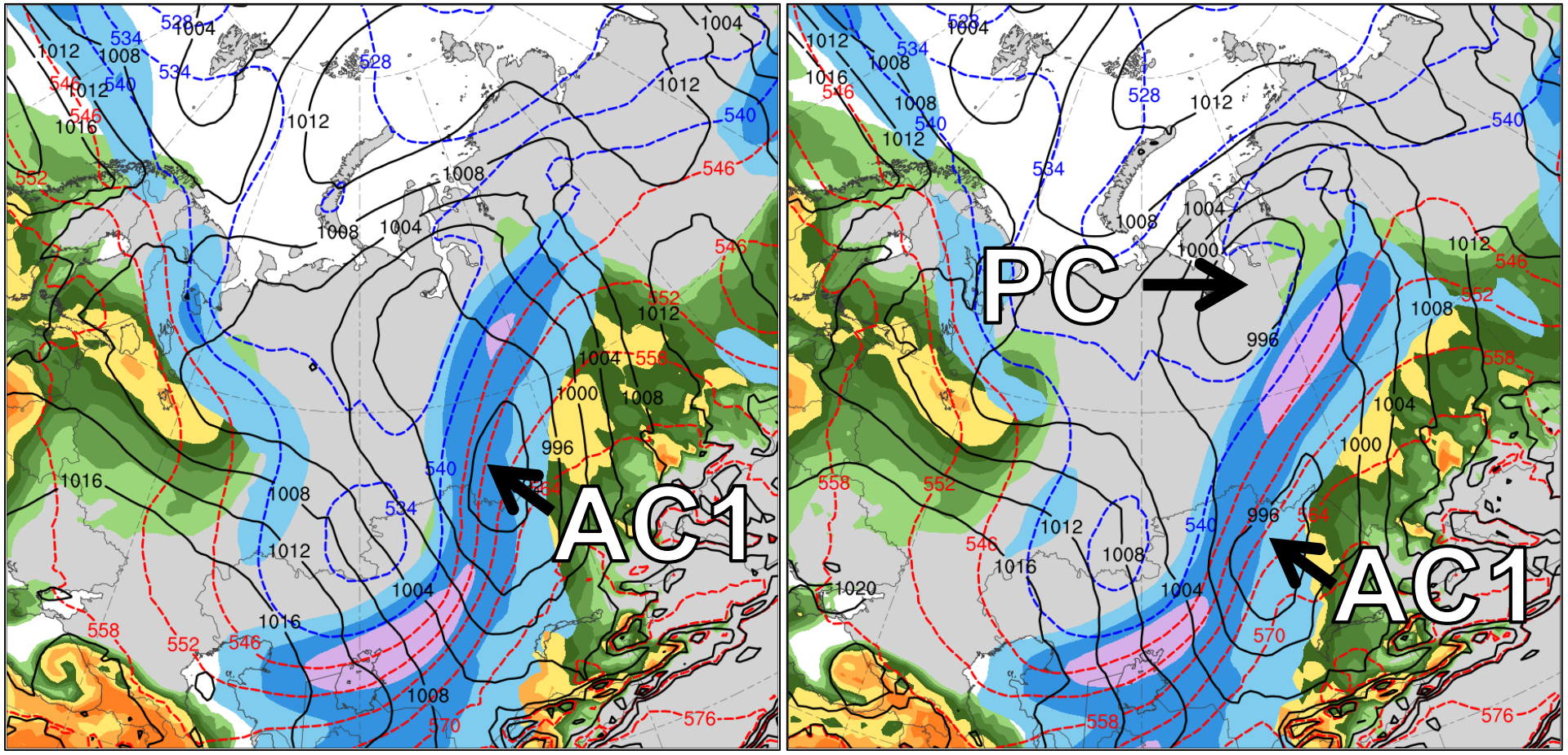
Ensemble mean 300-hPa wind speed (m s^{-1}, shaded), 1000–500-hPa thickness (dam, blue/red), SLP (hPa, black), and 925-hPa mixing ratio (g kg^{-1}, shaded) for most and least accurate groups

Synoptic Comparison

1200 UTC 2 June (72-h forecast)

Most Accurate Group

Least Accurate Group



30 40 50 60 70 80 90 100 (m s^{-1})

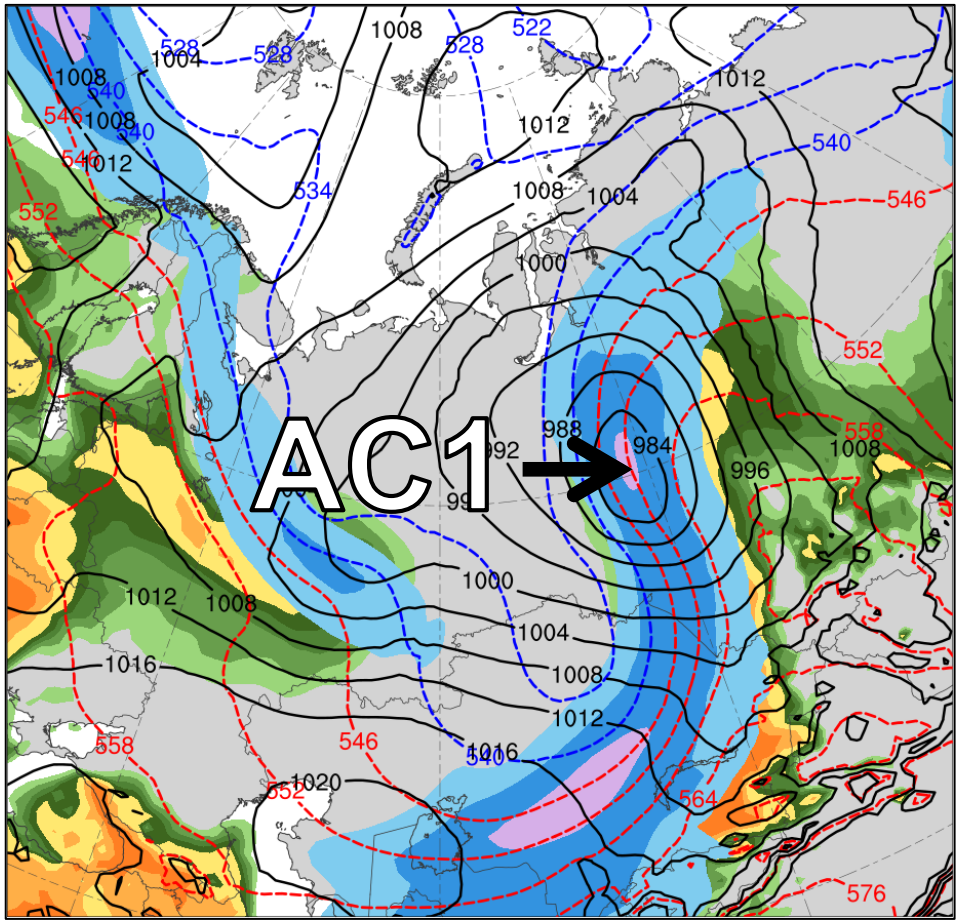
4 4.5 5 5.5 6 7 8 (g kg^{-1})

Ensemble mean 300-hPa wind speed (m s^{-1}, shaded), 1000–500-hPa thickness (dam, blue/red), SLP (hPa, black), and 925-hPa mixing ratio (g kg^{-1}, shaded) for most and least accurate groups

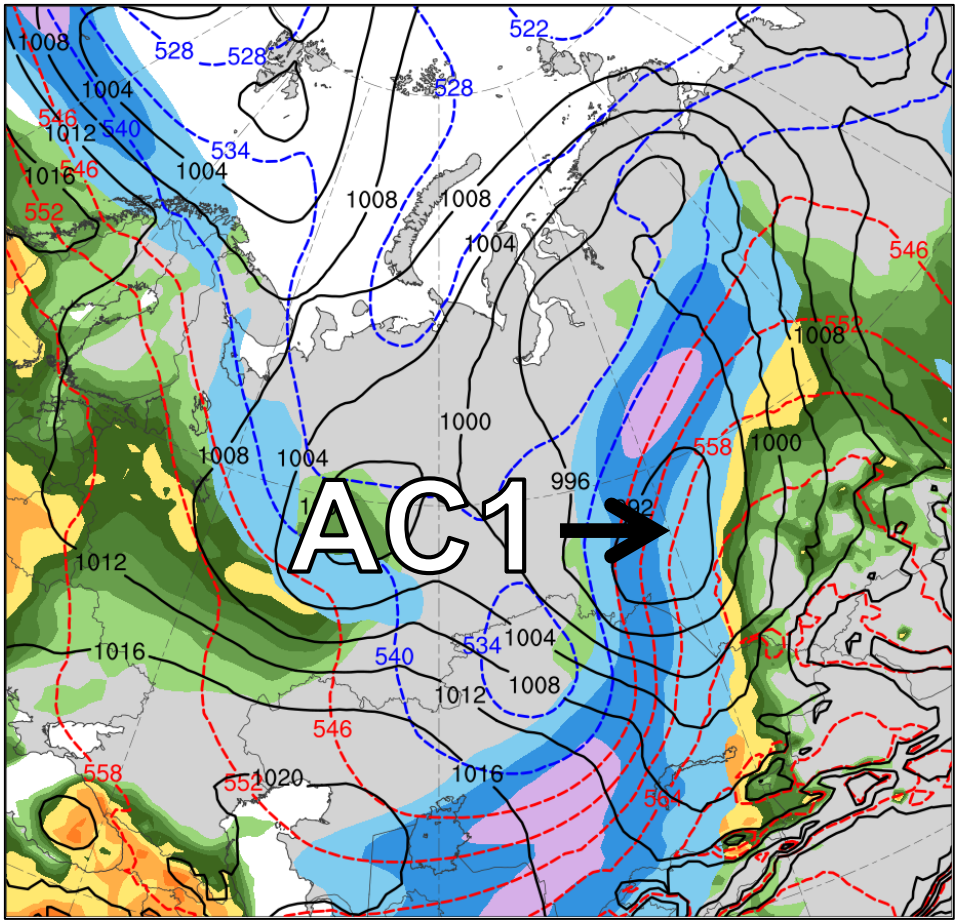
Synoptic Comparison

0000 UTC 3 June (84-h forecast)

Most Accurate Group



Least Accurate Group



(m s^{-1})

30 40 50 60 70 80 90 100

(g kg^{-1})

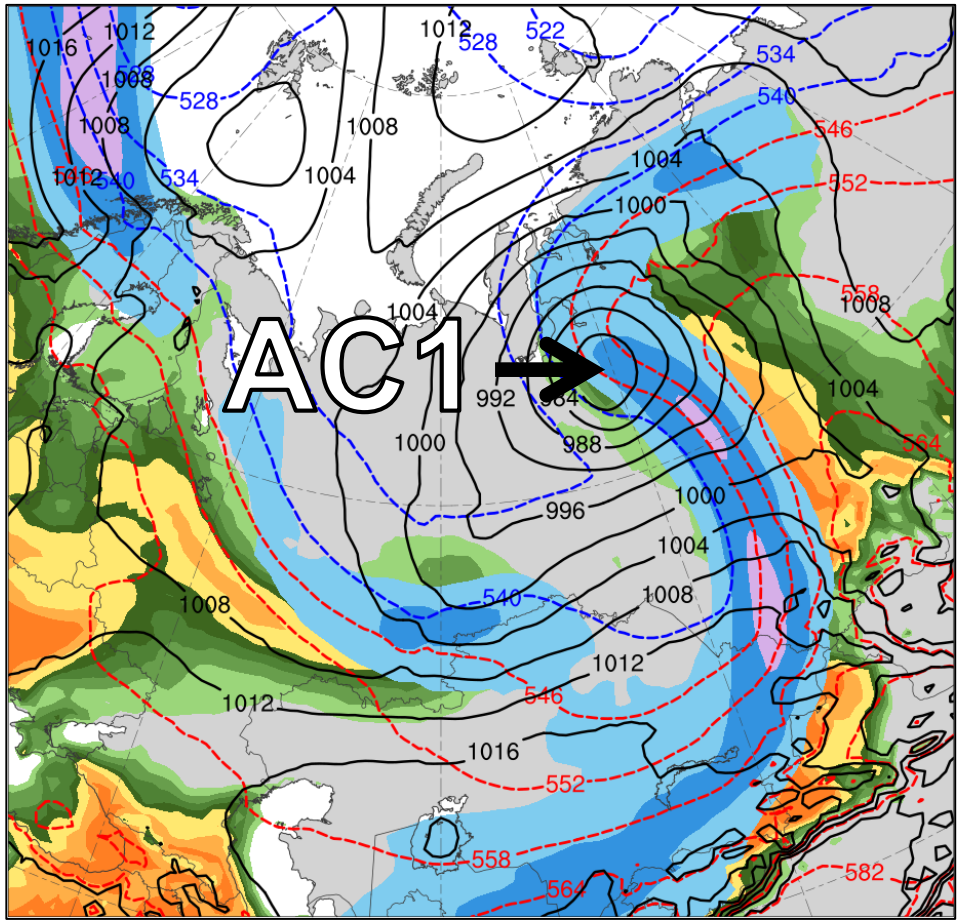
4 4.5 5 5.5 6 7 8

Ensemble mean 300-hPa wind speed (m s^{-1}, shaded), 1000–500-hPa thickness (dam, blue/red), SLP (hPa, black), and 925-hPa mixing ratio (g kg^{-1}, shaded) for most and least accurate groups

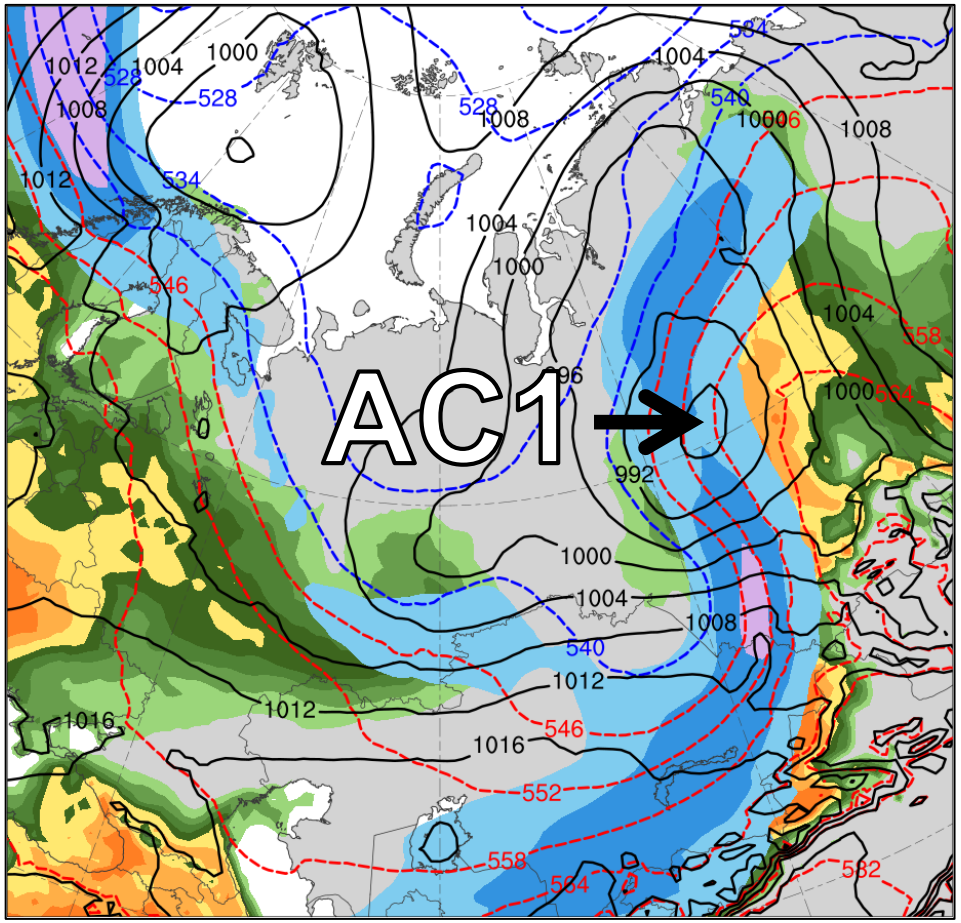
Synoptic Comparison

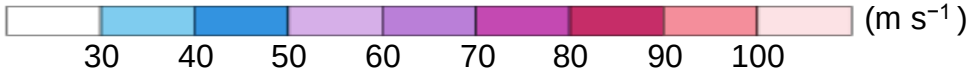
1200 UTC 3 June (96-h forecast)

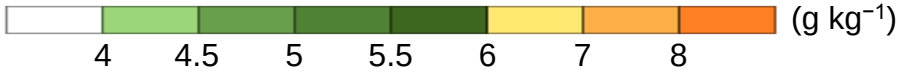
Most Accurate Group



Least Accurate Group





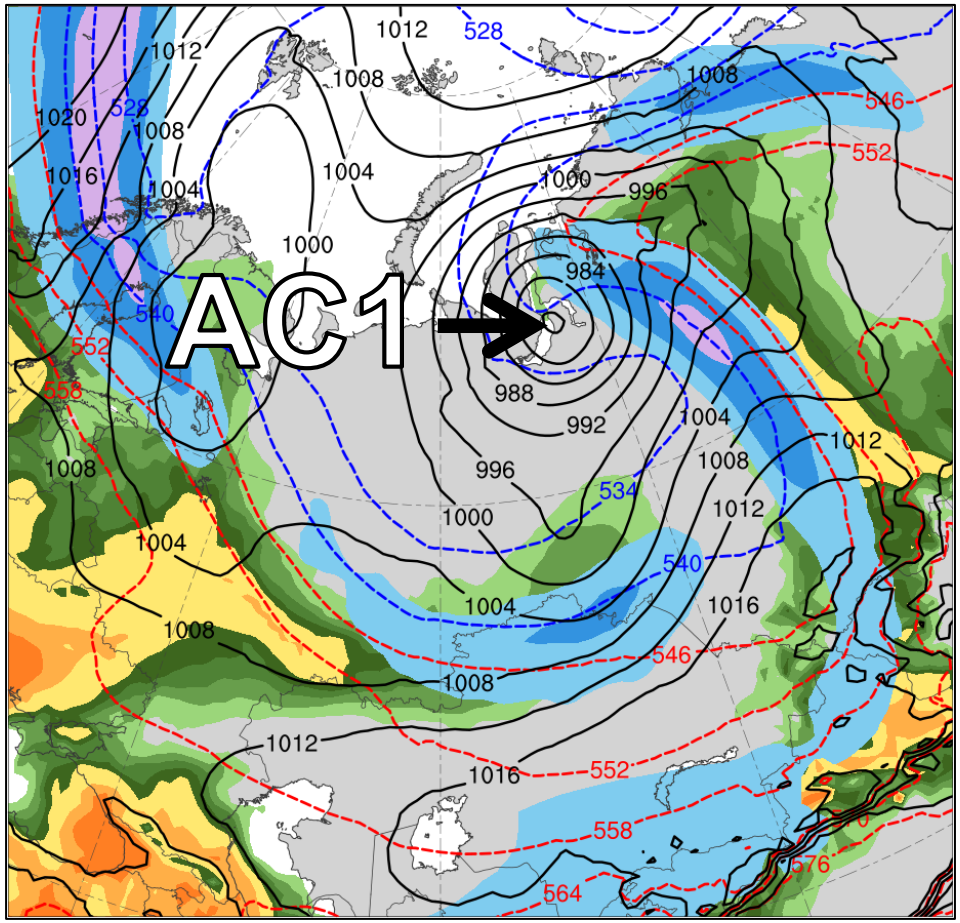


Ensemble mean 300-hPa wind speed (m s^{-1}, shaded), 1000–500-hPa thickness (dam, blue/red), SLP (hPa, black), and 925-hPa mixing ratio (g kg^{-1}, shaded) for most and least accurate groups

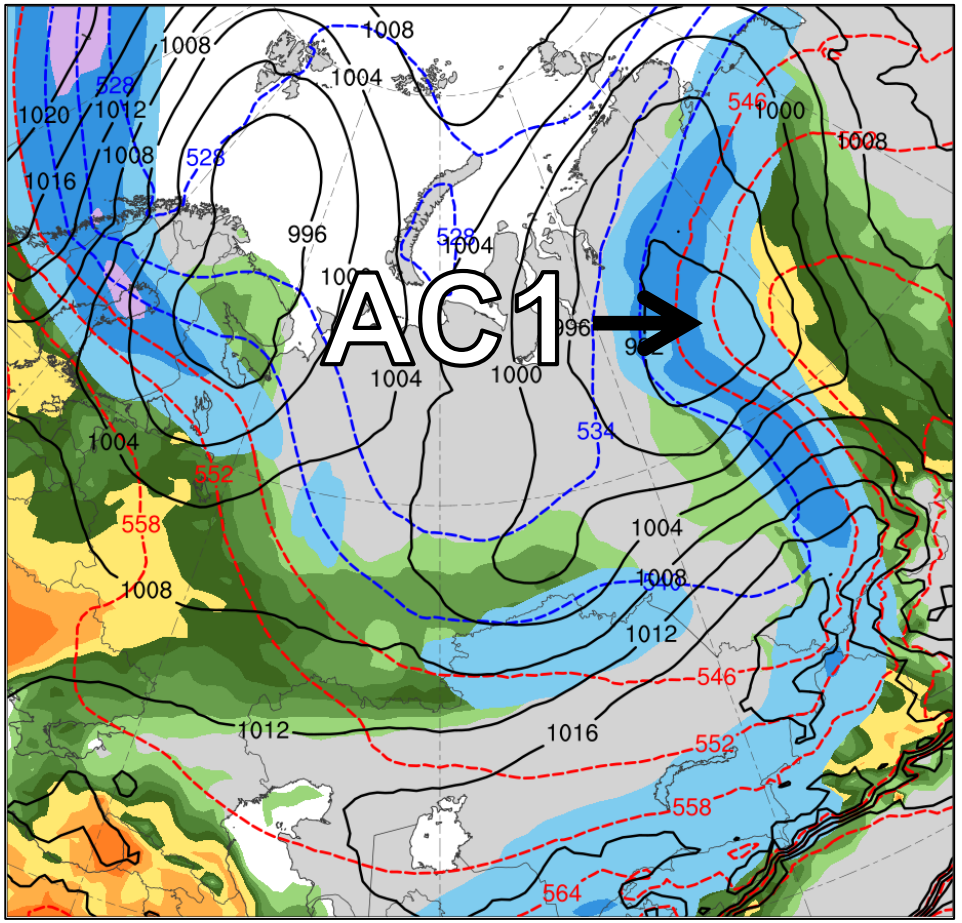
Synoptic Comparison

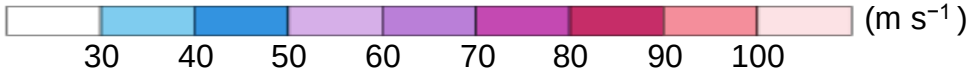
0000 UTC 4 June (108-h forecast)

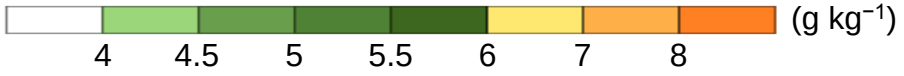
Most Accurate Group



Least Accurate Group







Ensemble mean 300-hPa wind speed (m s^{-1}, shaded), 1000–500-hPa thickness (dam, blue/red), SLP (hPa, black), and 925-hPa mixing ratio (g kg^{-1}, shaded) for most and least accurate groups

Summary

- Forecast skill of intensity in terms of RMSE for AC2 is much lower than that for AC1
- Intensity forecasts are strongly underdispersive for AC2 and slightly underdispersive for AC1
- Forecast skill of position in terms of RMSE for AC2 is higher than that for AC1 at 72–120-h lead time and lower than that for AC1 at other lead times
- Position forecasts are somewhat underdispersive for AC2 and moderately underdispersive for AC1

Summary

- Intensity forecasts for AC1 are less underdispersive than position forecasts for AC1

- Intensity forecasts for AC2 are more underdispersive than position forecasts for AC2

Summary

- Comparison between most and least accurate groups for AC1 show a thermal trough is more amplified and a predecessor cyclone is weaker and positioned farther westward in most accurate group
  - Enables AC1 to intensify more and move farther northwestward in most accurate group

References

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Appendix

Diagnose Factors Influencing Forecast Skill of AC1

- Separate ensemble members in terms of a metric adapted from Lamberson et al. (2016) that combines intensity error and position error of AC1

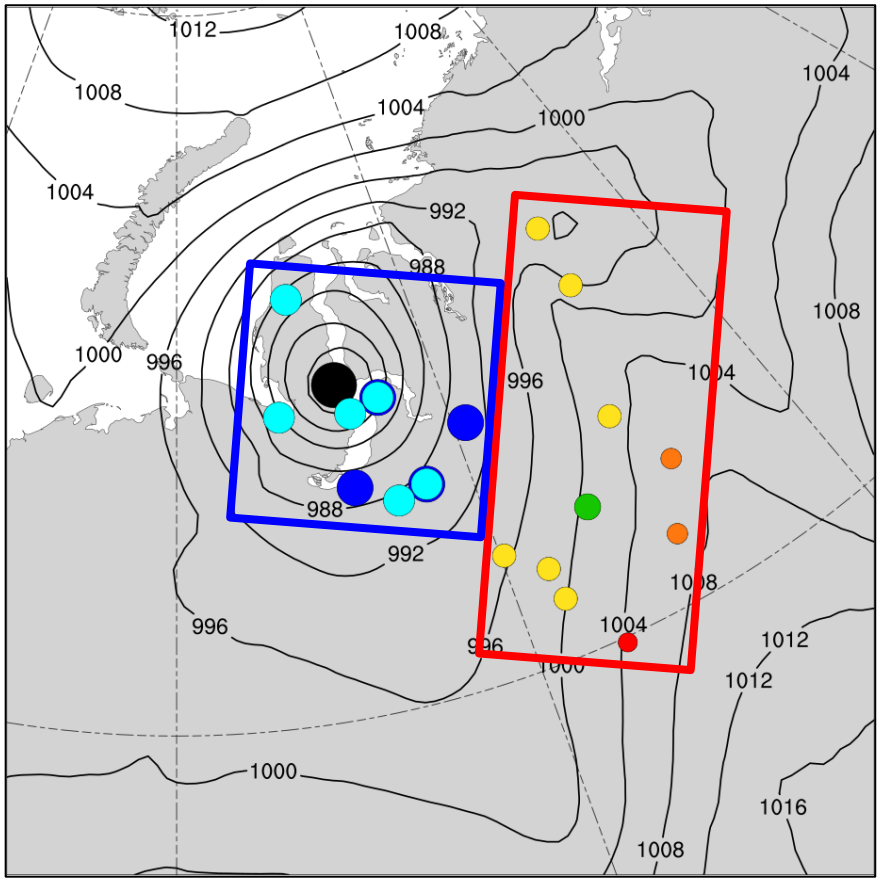
- Rank members 1–51 for both intensity error and position error at time of peak intensity of AC1, with 1 corresponding to member with lowest error

- Add intensity error rank to position error rank to determine a combined error rank

- Subdivide members into two groups: one containing the 10 most accurate members and one containing the 10 least accurate members in terms of combined error rank

108-h Forecast Position and Intensity of AC1

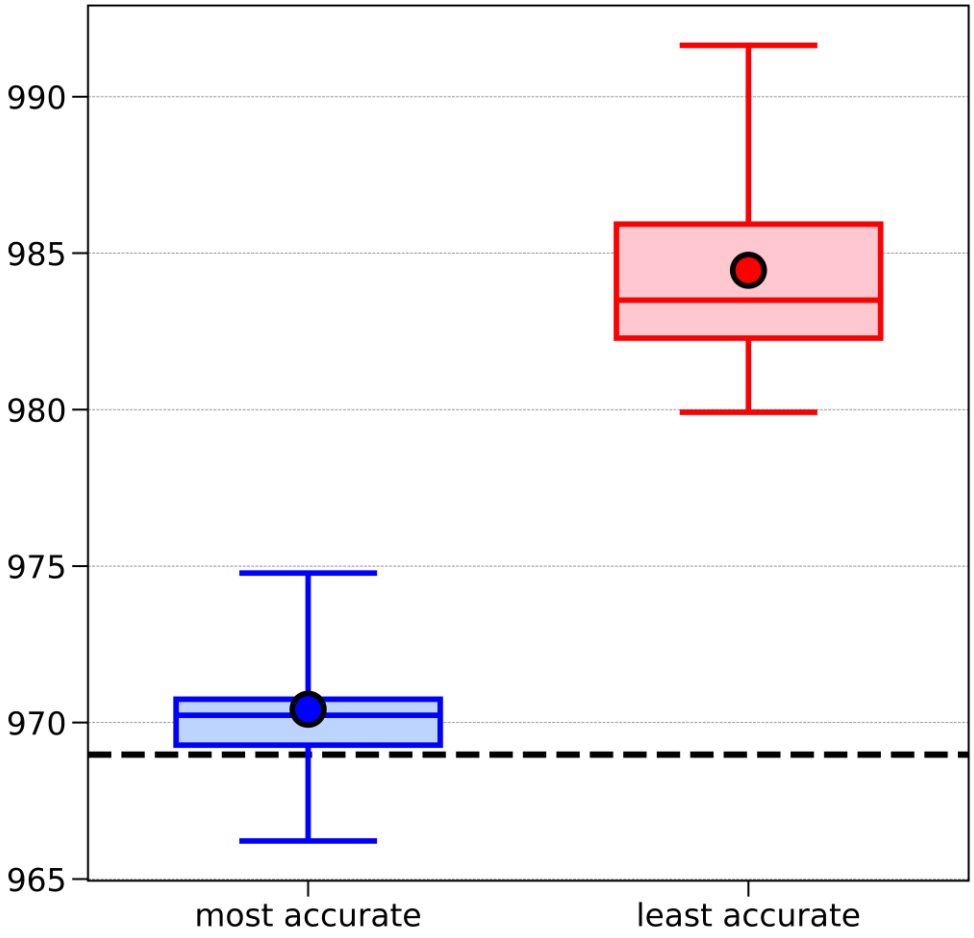
108-h forecast valid 0000 UTC 4 Jun 2018



ERA5 (969) 965–970 970–975

975–980 980–985 985–990 990–995

SLP from ERA5 (hPa, contours);
position of minimum SLP of AC1 [dots,
colored by intensity (hPa) for ensembles]



Distribution of minimum SLP of AC1 (hPa) for
most accurate group and least accurate group

ERA5

ensemble
group mean