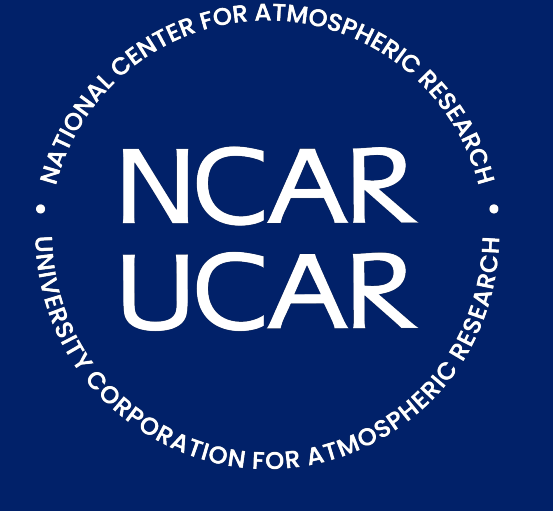


Impact of GNSS RO Data on the Prediction of Atmospheric River Events: A ROMEX Experiment



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Abstract

- The ROMEX dataset provides 40,000 daily RO profiles, compared to the 12,000 operationally available.
- The study focuses on an AR event from November 3–5, 2022, using the WRFDA system.
- GNSS RO data assimilation enhances AR predictions, particularly in moisture transport and timing of AR landfall.
- Caution is needed when assimilating RO data from different missions due to varying error characteristics.
- Insights from this study will inform future RO observing system designs for improved numerical weather prediction.

OBJECTIVES

- Evaluating the effectiveness of the default RO observation error in WRFDA for ROMEX data, and
- Examining the impact of increased RO data on AR forecasting.

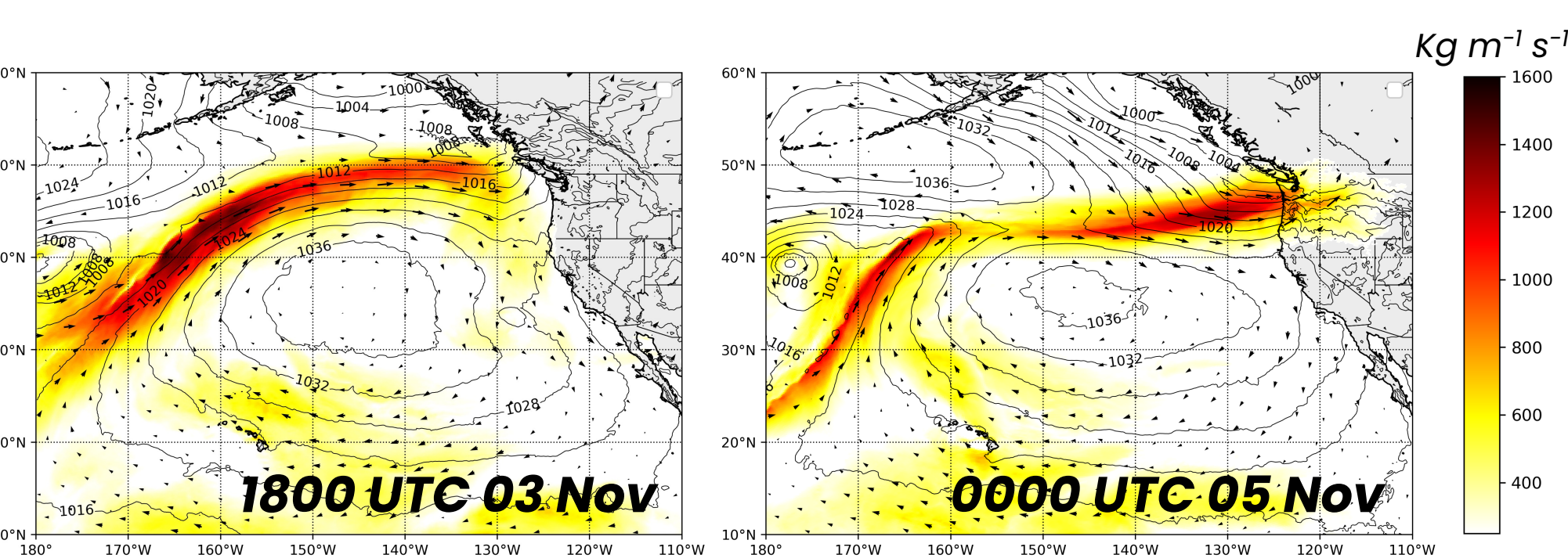


Figure 1. IFS analysis of IVT (shaded), SLP (contours), 850-hPa wind at 1800 UTC on 03 November and 0000 UTC on 05 November 2022.

EXPERIMENT DESIGN

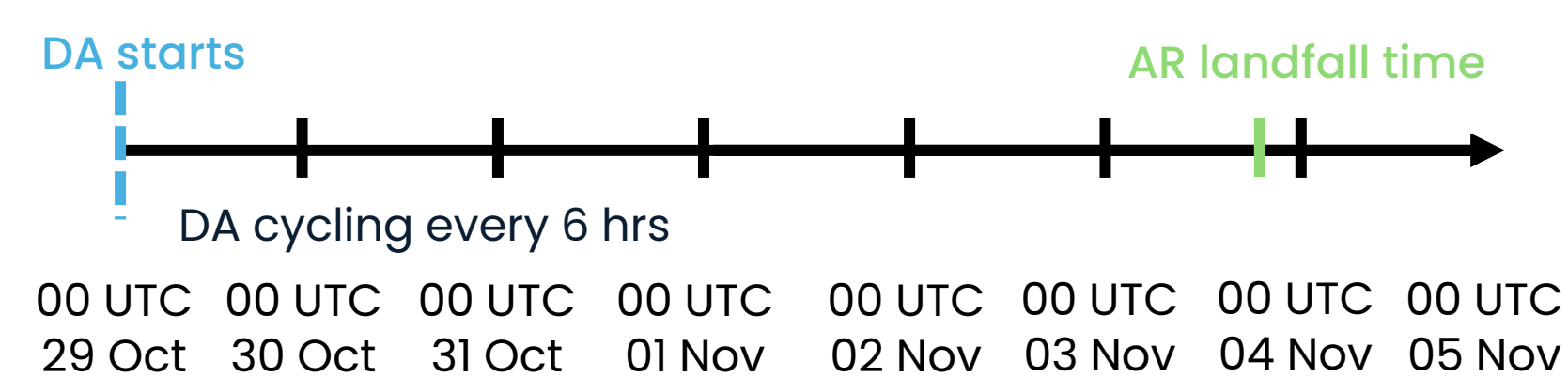


Figure 2. Diagram of 6-hourly DA cycles for each experiment from 0000 UTC 29 October to 0000 UTC 05 November 2022.

Table 1. Experiments and assimilated observations: Conventional data includes surface, radiosonde, aircraft, and satellite winds; ROMEX_{obserr1} uses a different RO error profile.

Experiment	Assimilated Observations	RO OBS Error
Conv	Conventional observations	default
Baseline	Conventional + RO _{Baseline}	default
ROMEX	Conventional + RO _{ROMEX}	default
ROMEX _{obserr1}	Conventional + RO _{ROMEX}	See figure 5a

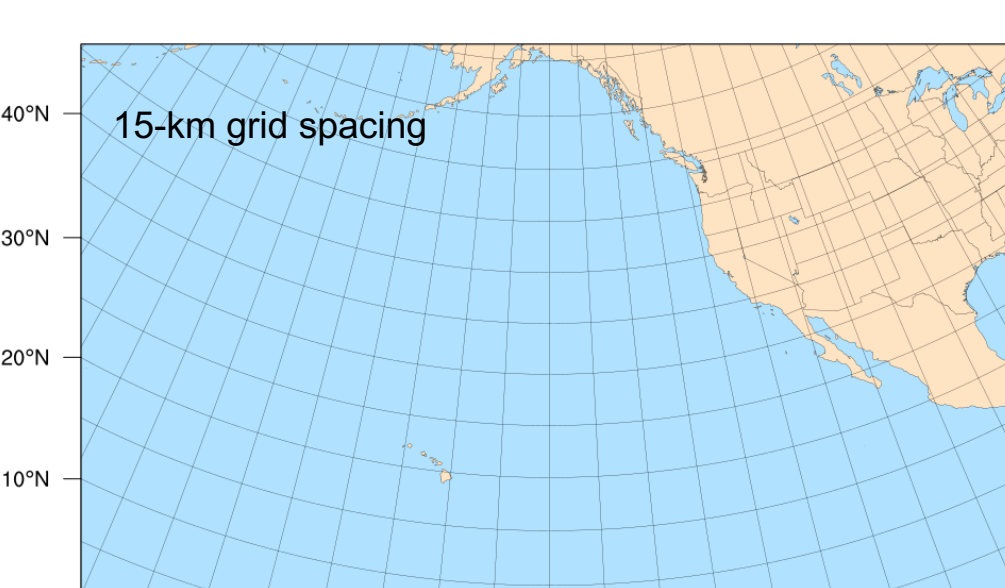


Table 2. Satellite missions included in the RO_{Baseline} and RO_{ROMEX} datasets.

RO	Satellite Missions
RO _{Baseline}	COSMIC-2, KOMPSAT-5, MetOp-B, MetOp-C, PAZ, Sentinel-6A, TanDEM-X, TerraSAR-X
RO _{ROMEX}	RO _{Baseline} + FY3, PlanetIQ, Spire, Tianmu, Yunyao

Figure 3. WRF model domain with 15-km grid spacing.

RESULTS

(1) Analysis at the First DA Cycle

- ROMEX data offers many samples in high IVT (AR) regions.
- The WRF forecast shows under/overestimation of IVT compared to ECMWF IFS analysis.
- Assimilating RO_{Baseline} and RO_{ROMEX} adjusts IVT but overcorrects, likely due to ineffective RO observation error.

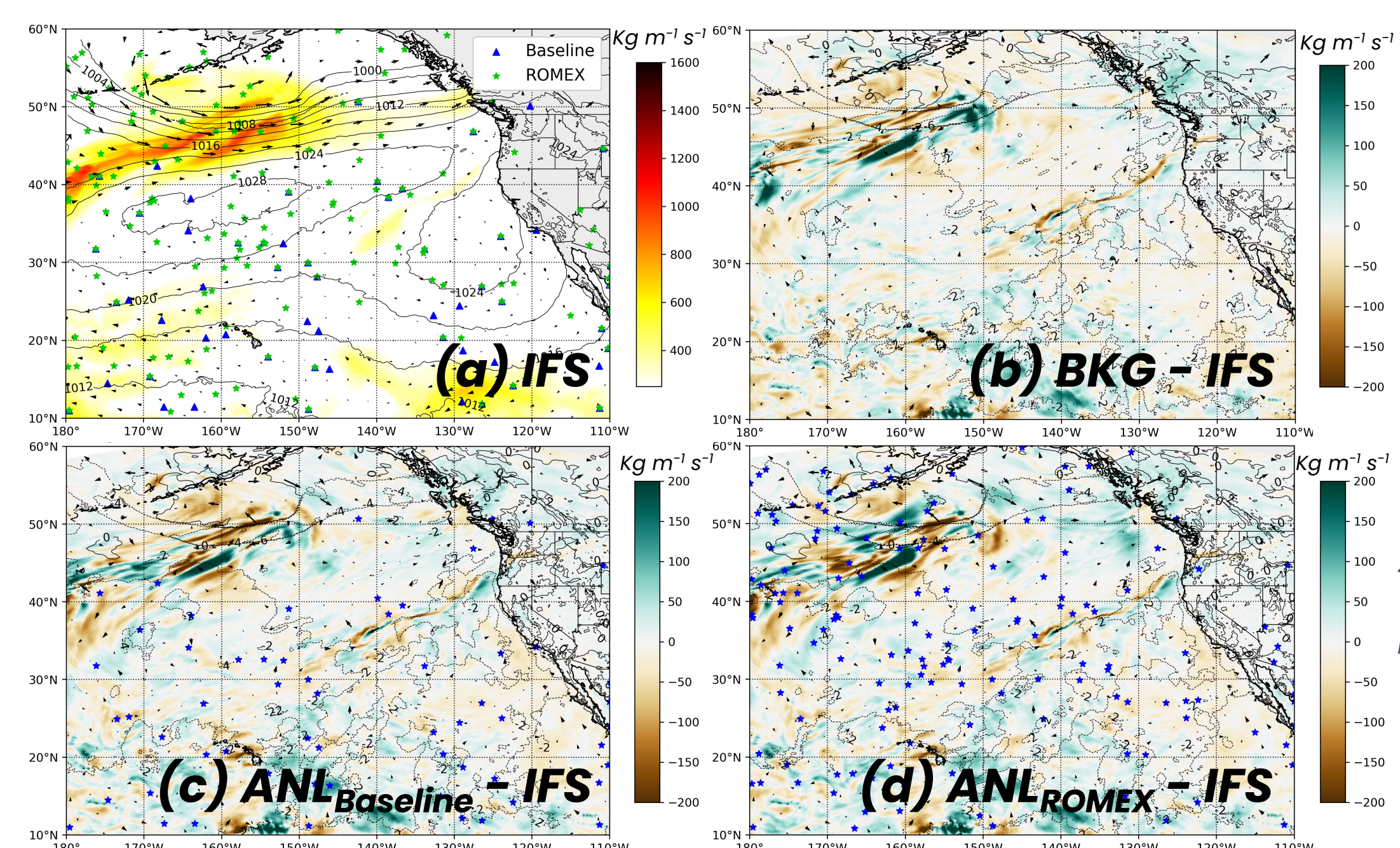


Figure 4. (a) IVT (shaded), SLP (contour), and 850-hPa wind vectors from IFS at 0000 UTC 29 October 2022. Differences shown in (b-d).

(2) Effectiveness of RO OBS Error in WRFDA

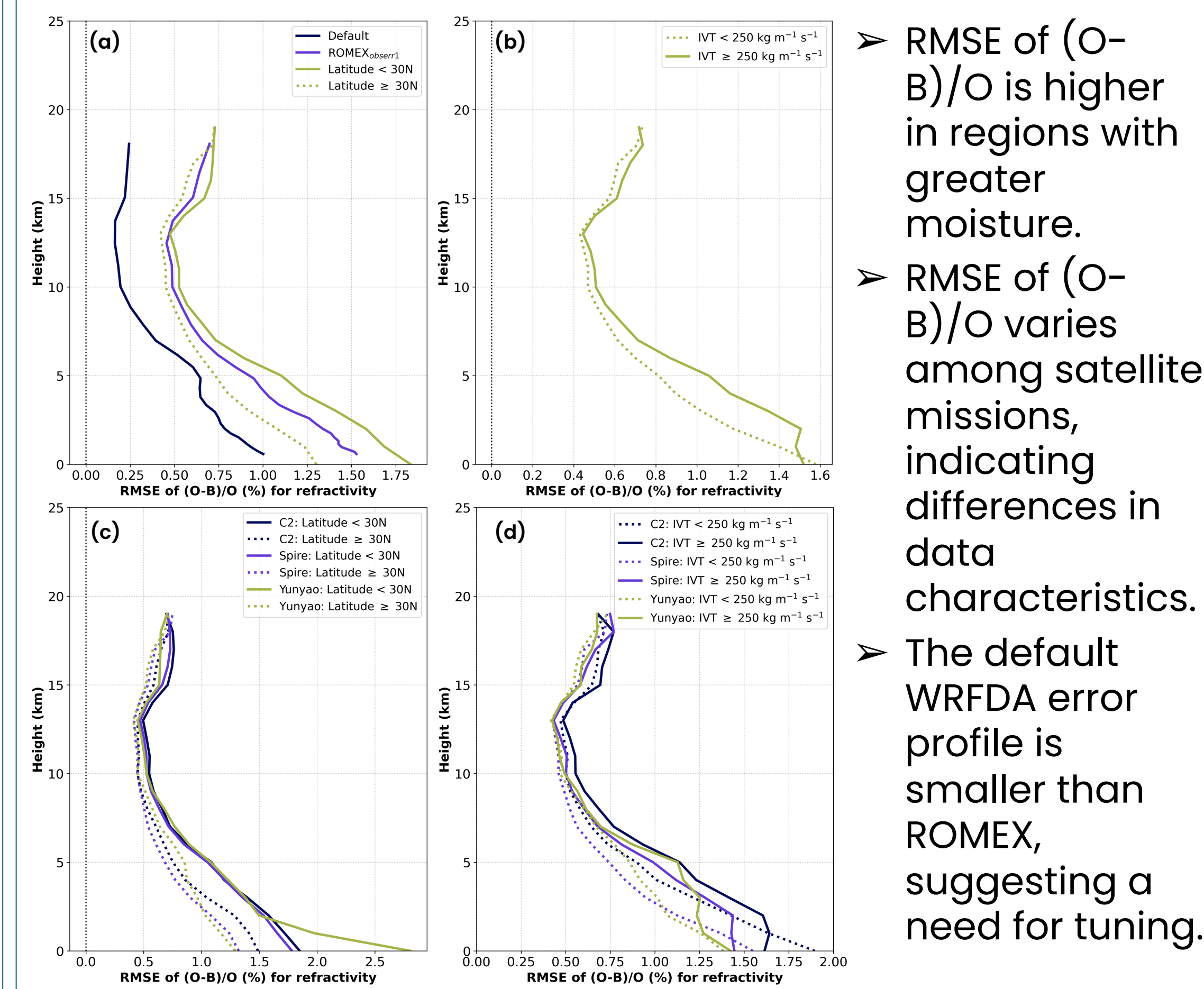


Figure 5. RMSE of (O-B)/O (%) for refractivity. (a) error profiles in WRFDA and by latitude, (b) by IVT threshold, (c-d) by satellite missions.

(3) AR Landfall Forecast

- The ECMWF IFS 9-km analysis serves as the observation reference.
- AR improvements noted in Baseline, ROMEX, and ROMEX_{obserr1} experiments.
- Incorporating more RO data and increasing the sample size could improve AR predictions.
- Tuning the observation error profile with ROMEX statistics improves AR predictions.

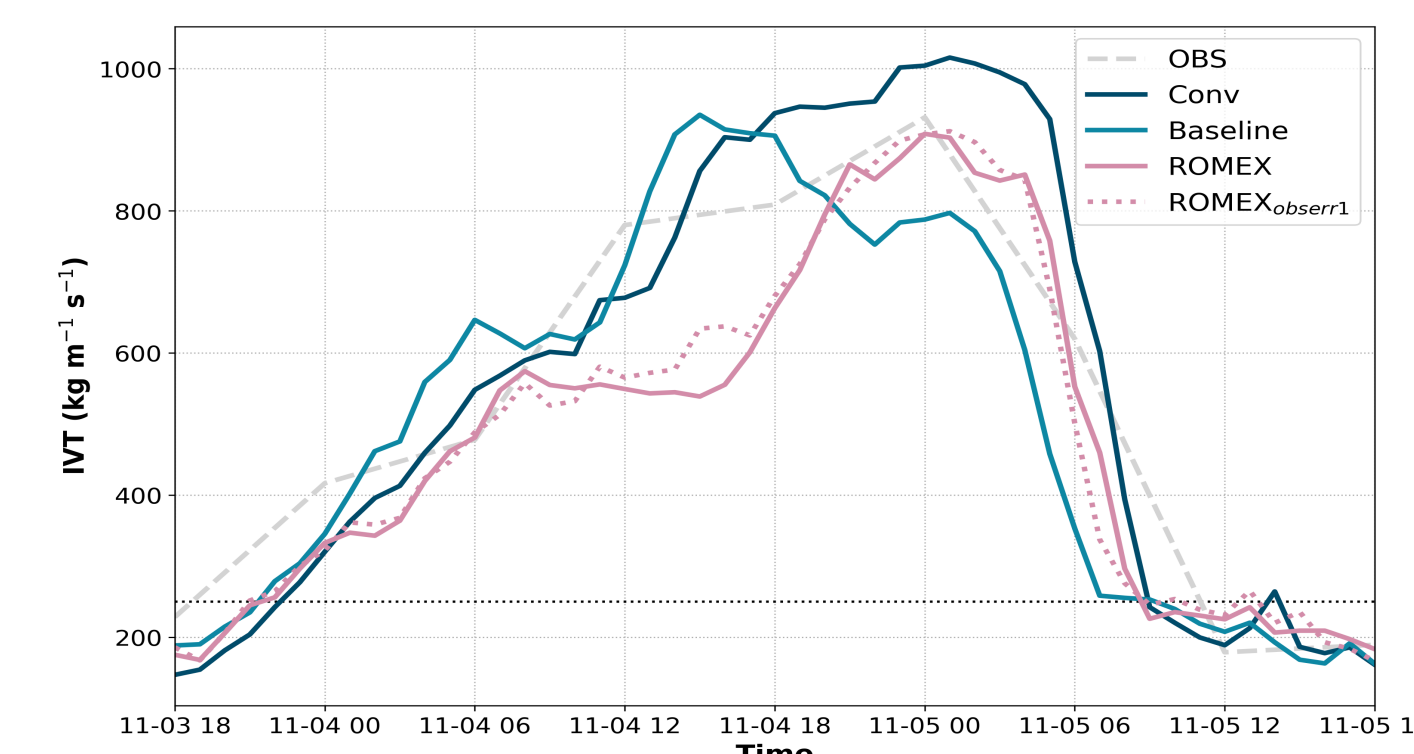


Figure 6. Temporal variation of IVT at (46°N, 124°W) from IFS analysis (OBS), Conv, Baseline, ROMEX, and ROMEX_{obserr1}.

Table 3. Forecast of AR landfall time, AR scale, AR duration, maximum IVT during the AR, time of maximum IVT, and time-integrated IVT during the AR event at (46°N, 124°W). OBS is from IFS analysis.

	OBS ⁺	Conv	Baseline	ROMEX	ROMEX _{obserr1}
AR landfall time	20Z 03 Nov	00Z 04 Nov	23Z 03 Nov	23Z 03 Nov	22Z 03 Nov
AR scale	3	4	3	3	3
AR duration (hrs)	41	34	36	35	36
Maximum IVT (kg m ⁻¹ s ⁻¹)	931.5	1015.6	935.1	908.3	912.0
Time of Max IVT	00Z 05 Nov	01Z 05 Nov	15Z 04 Nov	00Z 05 Nov	01Z 05 Nov
Time integrated IVT (10 ⁷ kg m ⁻¹)	9.1	8.8	8.1	7.4	7.5

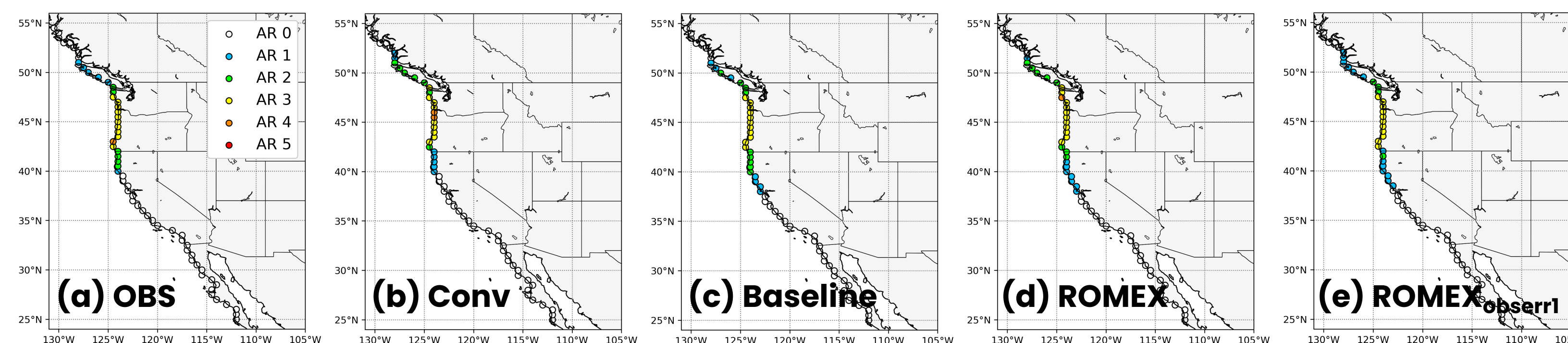


Figure 7. AR scale at coastal stations during the AR event. OBS is the ECMWF IFS analysis.

(4) Prediction of Maximum IVT

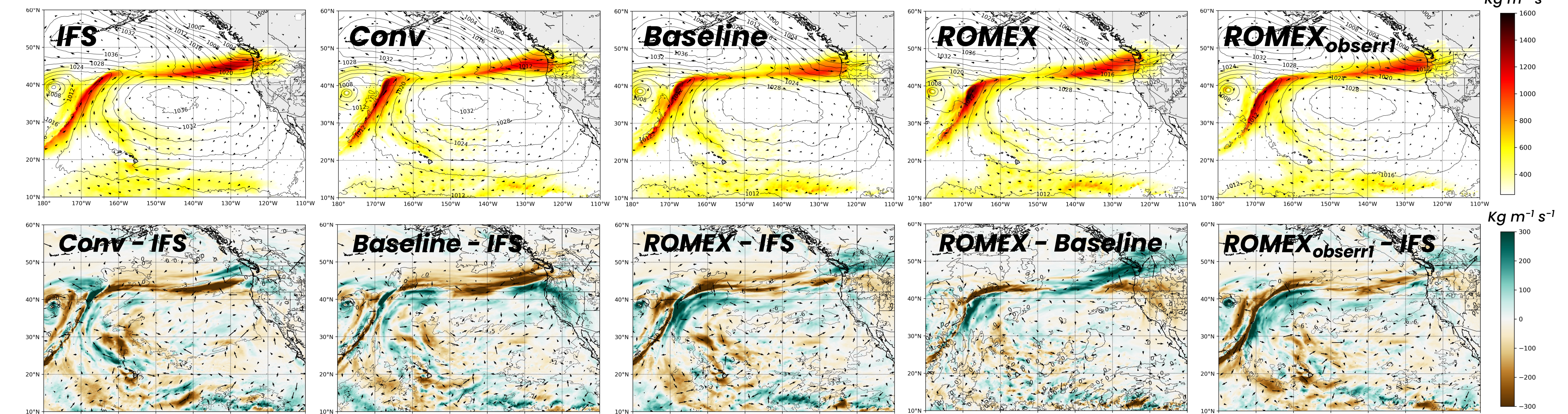


Figure 8. IVT (shaded), SLP (contour), and 850-hPa wind vectors from IFS, Conv, Baseline, ROMEX, and ROMEX_{obserr1} and their differences at 0000 UTC on 05 November 2022.

Quantitative Precipitation Forecast

- The 15-km model analysis is downscaled to 3-km for precipitation forecasts.
- The predicted 48-hr accumulated precipitation amount is underestimated.

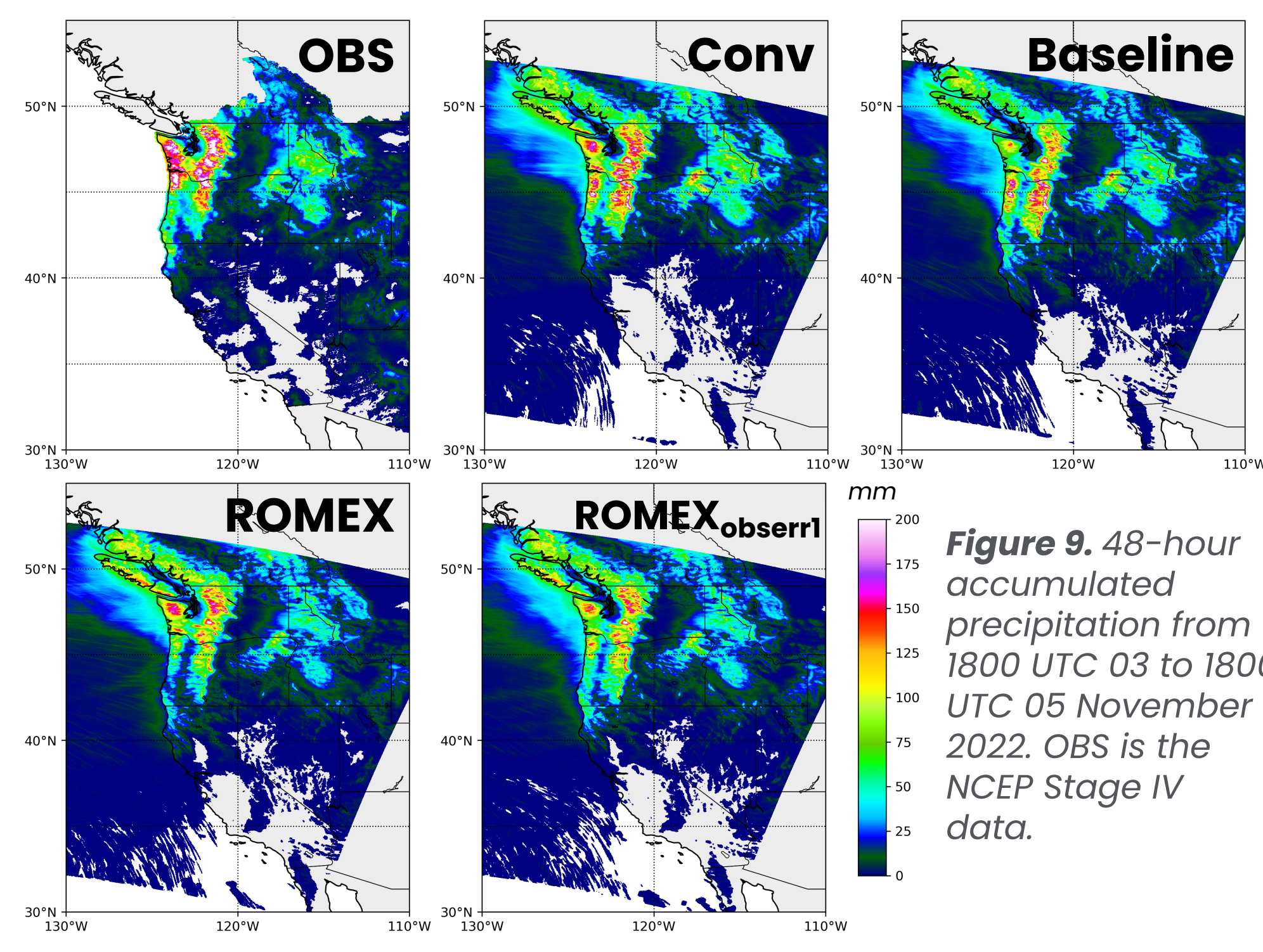


Figure 9. 48-hour accumulated precipitation from 1800 UTC 03 to 1800 UTC 05 November 2022. OBS is the NCEP Stage IV data.

CONCLUSIONS

- ROMEX data provides a large number of samples over AR regions.
- ROMEX data significantly impacts IVT over the AR region, though there seems to be an over-adjustment in the model state, potentially linked to observation error.
- RMSE of (O-B)/O is higher in regions with greater moisture.
- RMSE of (O-B)/O profiles varies among COSMIC-2, Spire, and Yunyao satellite missions.
- Improvements in AR landfall, scale, duration, and IVT are noted in Baseline, ROMEX, and ROMEX_{obserr1} experiments with additional RO data.
- However, the predicted 48-hr precipitation amount is underestimated in 3-km model run due to weaker IVT.

ACKNOWLEDGMENTS

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