Best SARIMAX order (v4): (2, 1, 0) (1, 0, 1, 7) CV MAPE: 15.971854292042869

deep28 -> val_loss=0.120265, window=28, bidir=False

deep21 -> val_loss=0.118881, window=21, bidir=False

bidir28 -> val_loss=0.118535, window=28, bidir=True

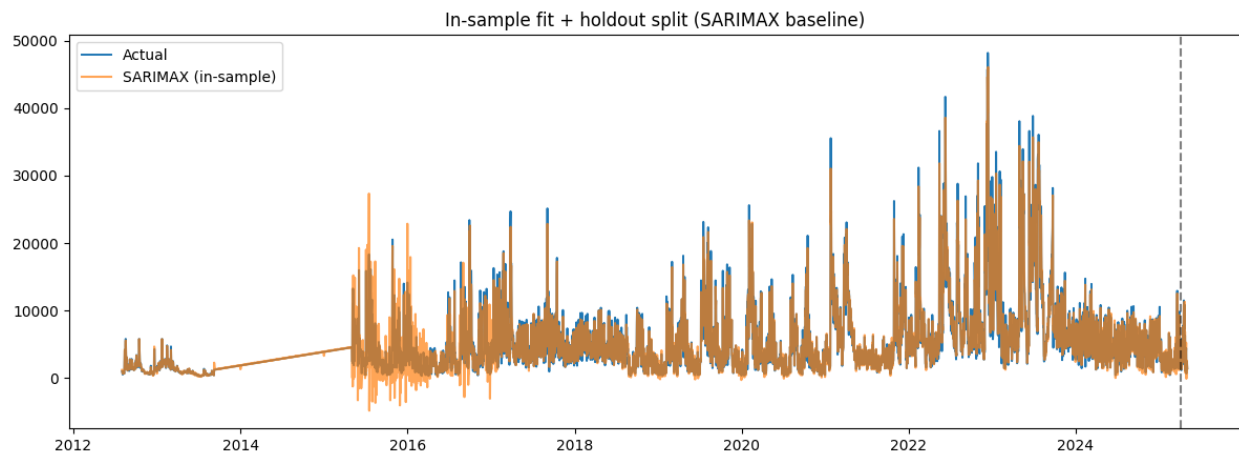=== HOLDOUT (28d) RESULTS — v4 ensemble+ridge ===
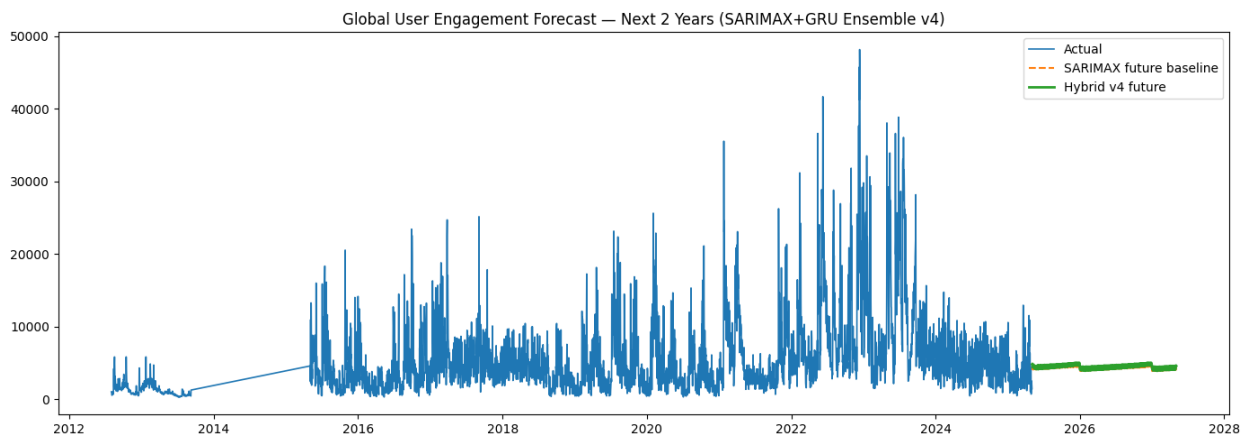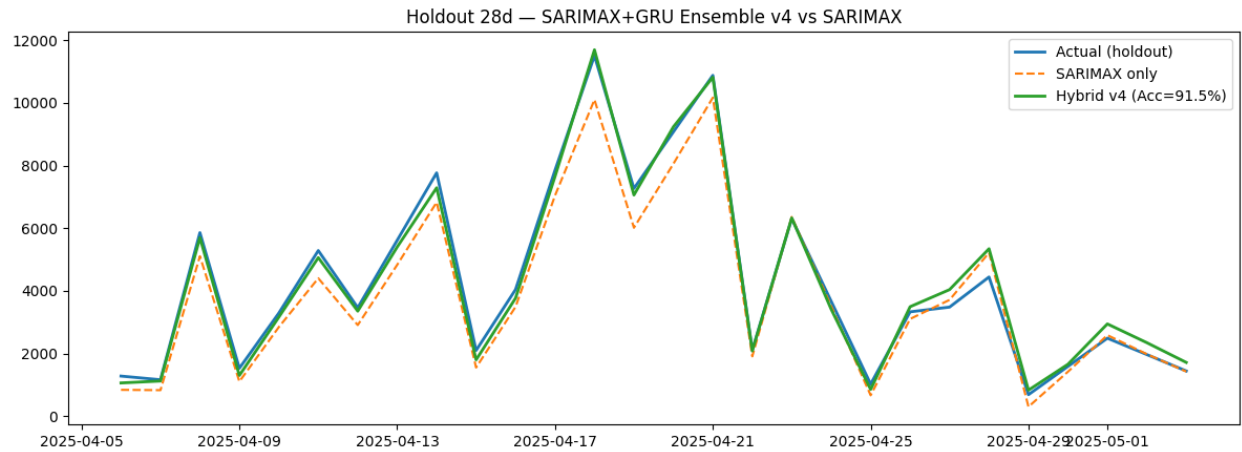
MAE: 236.68

RMSE: 298.63

MAPE: 8.53%

Accuracy (1-MAPE): 91.47%

SARIMAX-only MAPE: 15.23% → ΔMAPE vs Hybrid: +6.70 pts

Calibration coefficients (ridge):

{'z1': np.float32(1.0262967), 'z2': np.float32(-1.6629965), 'z3': np.float32(-0.9205698), 'z1^2': np.float32(3.914474e-06), 'z2^2': np.float32(0.01502316), 'z3^2': np.float32(-0.015977373), 'z1*z2': np.float32(0.00018898422), 'z1*z3': np.float32(-0.0010111154), 'z2*z3': np.float32(-0.007918403), 'bias': np.float32(163.42982)}

In-sample fit + holdout split (SARIMAX baseline)

Holdout 28d — SARIMAX+GRU Ensemble v4 vs SARIMAX

Global User Engagement Forecast — Next 2 Years (SARIMAX+GRU Ensemble v4)

Artifacts: /content/hybrid_arima_gru_v4_artifacts

 - 2year_forecast_sarimax_gru_v4.csv

 - gru_v4_bidir28_win28.keras

 - gru_v4_deep21_win21.keras

 - gru_v4_deep28_win28.keras

 - metrics_sarimax_gru_v4.json

 - sarimax_order_v4.json

 - sarimax_v4_model.pkl

 - x_scaler_v4.npy

 - y_scaler_v4.npy

Checkpoints: /content/arima_gru_v4_ckpts

 - gru_v4_bidir28_win28.keras

 - gru_v4_deep21_win21.keras

 - gru_v4_deep28_win28.keras