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Advanced multimodal fusion method for very short-term solar irradiance forecasting using sky images and meteorological data: from single weather array to multi array

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Sky Images on Solar Irradiance Forecasting

Ground-based sky imagery: High-frequency data with high spatial resolution.

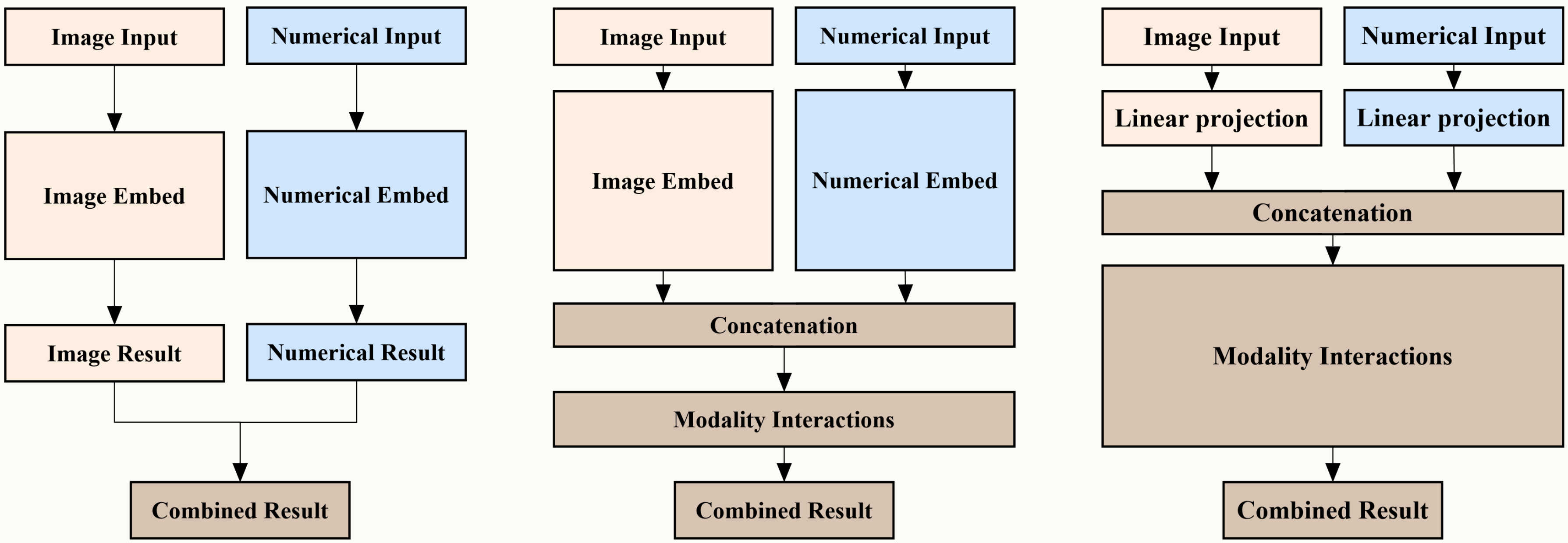
Advances in deep learning solutions:

- Demonstrated success in sub-hourly forecasting.
- Rapid prediction capabilities, essential for real-time applications.

Challenges:

- Deep learning methods with poor interpretability
- Site-specific models due to unique climate and micro-climate conditions.
- Significant investment in time and resources for local data collection

Current Deep Learning Prediction Methods and Challenges



Traditional Approach
(Result level fusion)

- Image and numerical data processed separately
- Combined output generation

Weak Modular Interaction Model
(Late feature-level fusion)

- Image and numerical data processed separately
- Joint feeding into a weak interaction model
- Combined output generation

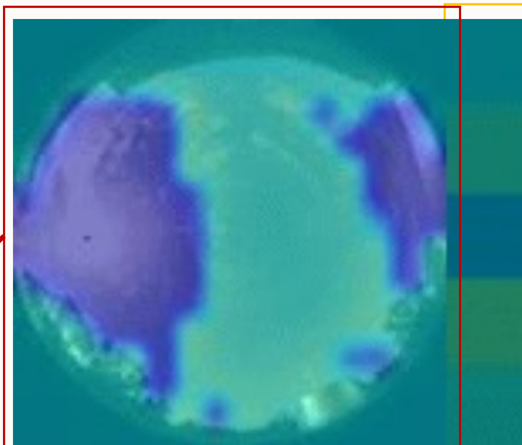
Proposed Strong Modular Interaction Model
(Early feature-level fusion)

- Linear projection of pictures and values
- Parallel element feeding into a strong interaction model
- Results deduced from inter-element relationships

Deep Learning Innovations in Solar Forecasting

- Utilisation of advanced ViT-E model for deep learning forecasting.
- Patches(Pixel)-meteorological data relationship.
- Noticeably demonstrates the focus on different elements depending on the real-time climate

Original dataset from CA, Folsom



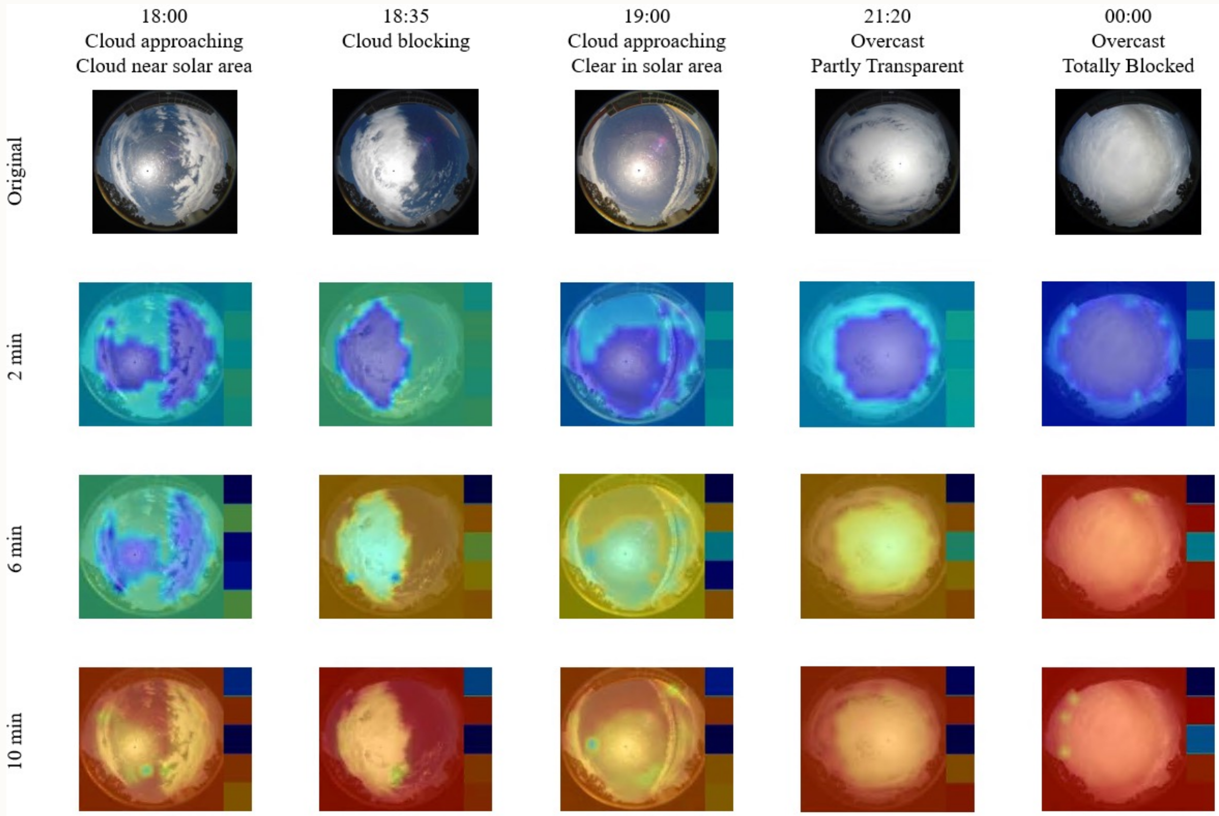
Attention on Images patches

Attention on numerical,
Top to bottom:
- **Irradiance**
- Environmental variables (temperature, humidity, pressure)
- Clear sky irradiance
- Wind (speed, direction)
- Solar angles

Relative attention weight heatmap between Image & Meteorological data In 2-min ahead forecast

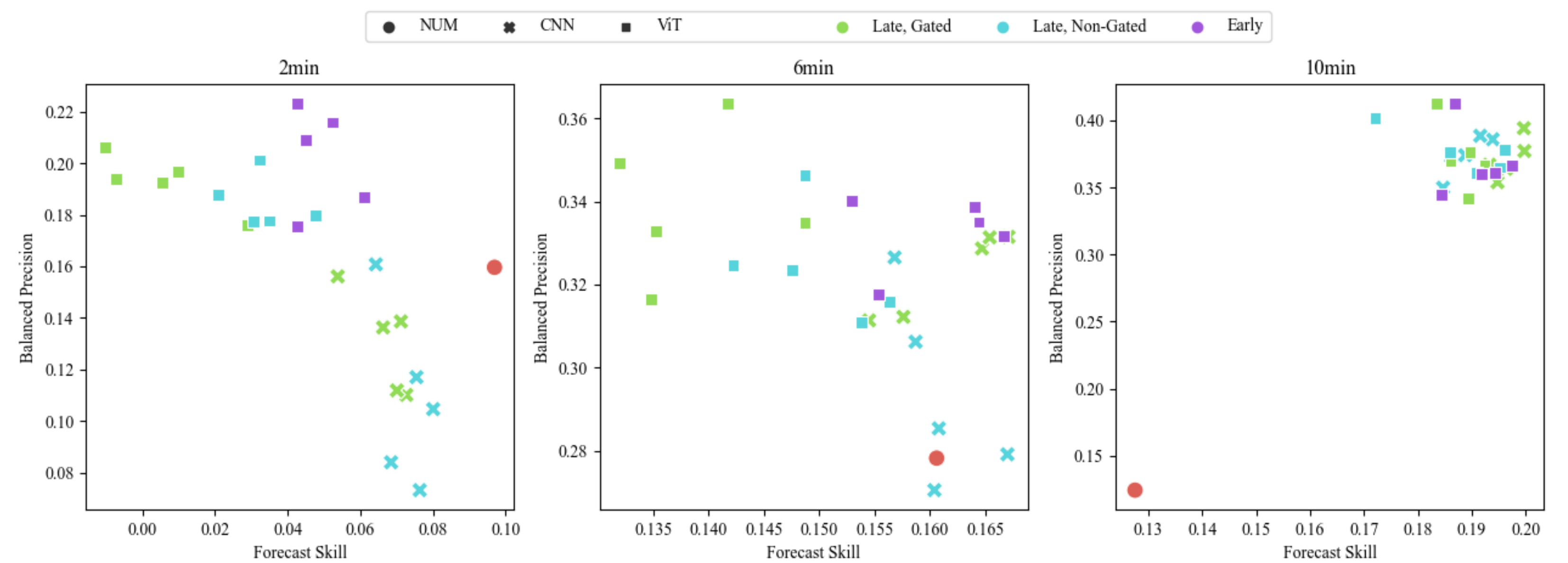
Decline in relevance

- The correlation between image data and meteorological data is weakening as the prediction scale is extended.
- The model gradually degenerates into a numerical model focusing on meteorological data.



Comparative Model Performance Over Forecast Horizons

Capability to capture ramp events

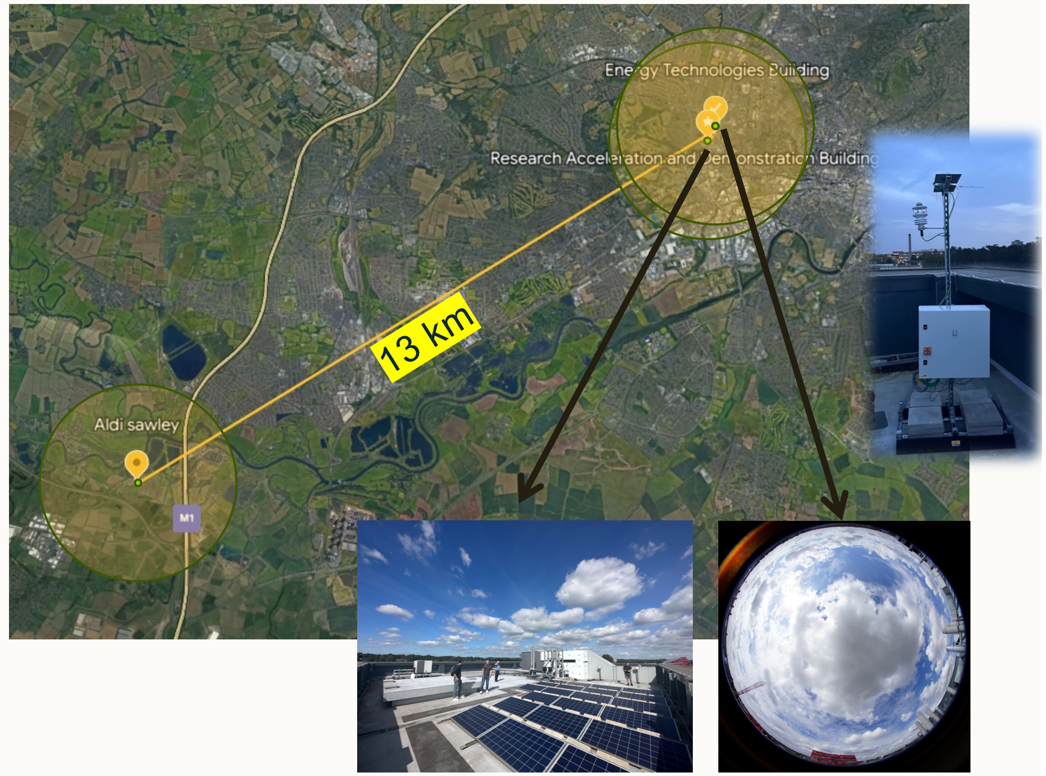


Forecast skill for irradiance.

•At the 2-minute forecast interval, distinct performance variations are evident among different models: early fusion exhibits a more pronounced balance.
•As the forecast horizon extends, the differences between models diminish, indicating a convergence (homogenization) in performance.

Future work

- Future Explorations:
  - Transferability under different climate types
  - Transferability under similar microclimate types
  - Climate type transferability in urban/non-urban settings
  - Interconnectivity between multiple sites

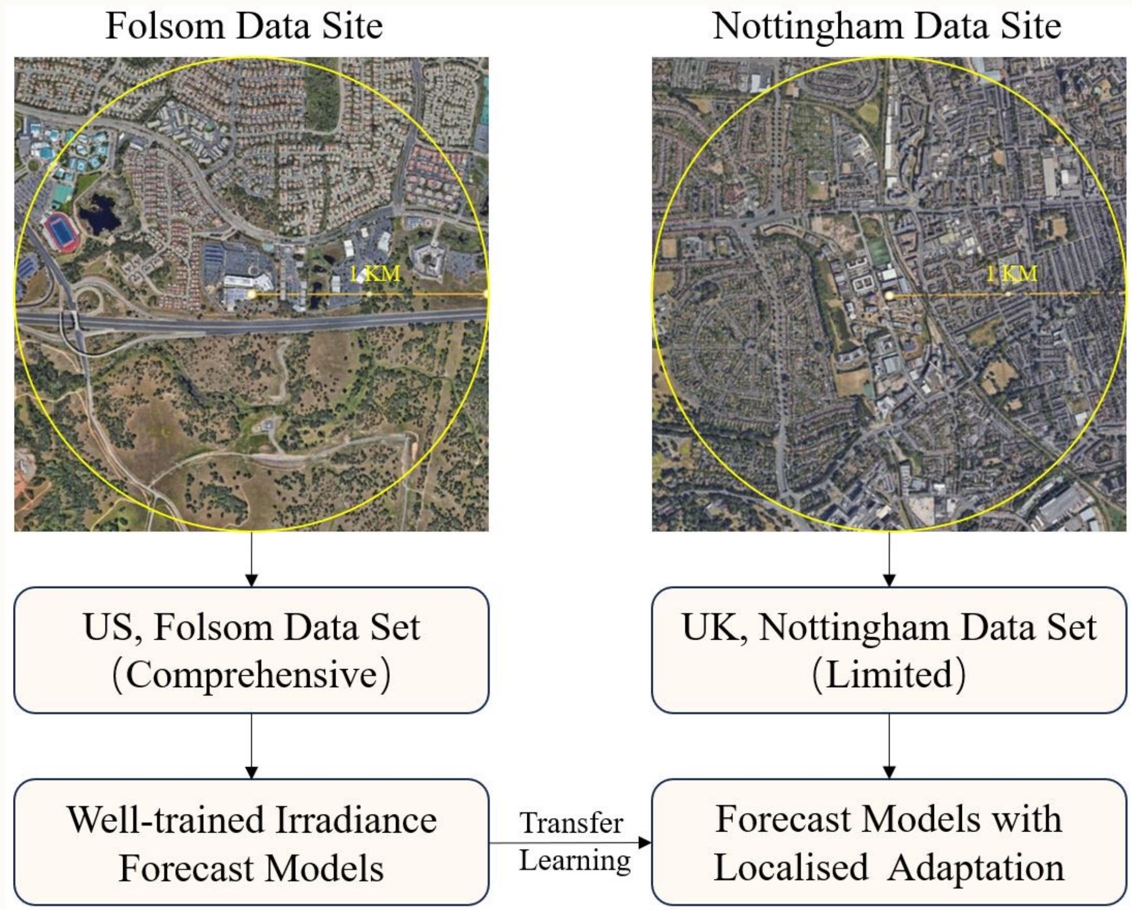


Transportability of priori knowledge

- A priori model knowledge is transferable, despite differences in meteorological and geographic data.

- Initial result:
    - Model training time reduced by 90% using migration methods.

    - Migrated model achieves fit with only 2 weeks of data, compared to 12-18 weeks for non-migrated models.



Acknowledgement

- This work was supported by the Engineering and Physical Sciences Research Council, UK [grant number EP/W028581/1].
- This work was supported by the Department for Energy Security and Net Zero, UK [grant number 208857380].