Optimizing atmospheric turbulence predictions for optical links and astronomical observations by an instrumented drone

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Why prediction ?

Anticipating atmospheric conditions in advance helps in both the astronomy and optical telecommunication communities:

Astronomical observation

Flexible scheduling:

→Prioritize observations according to optical conditions.

→Maximize scientific output quality.

→Efficient resource management.

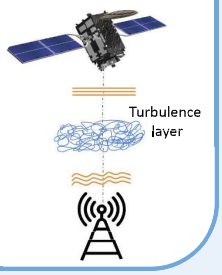
ELT: >200k €/night

Optical telecommunication

Smart scheduling:

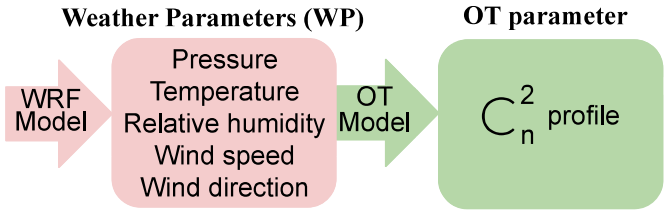
→Identify optimal time windows for optical laser links operation.

→Facilitates optimal selection of optical ground stations to receive information, enabling site switching in adverse conditions.



How to predict ?

We use the Weather Research and Forecasting (WRF) model, developed at NCAR (Boulder, USA), combined with an optical turbulence (OT) model.



Two different turbulence models are used:

- Empirical model (radio sounding balloons)
- Tatarskii model

Prediction optimization

❖ Models alone are not enough. Optimization methods have been developed, showing improvements in free atmosphere but limited impact in the ground layer (GL):

- Statistical learning *(Ref1)*
- New Outer Scale method for Tatarskii's model *(Ref2)*
- Optimizing WRF physico-dynamics configuration *(Ref2)*

❖ GL prediction optimization by an ***instrumented drone***:

Equipement: weather probes

Scans the GL (450m), up and down above a fixed point

The collected data are injected into WRF to improve the WP predictions and then OT forecasting

Results

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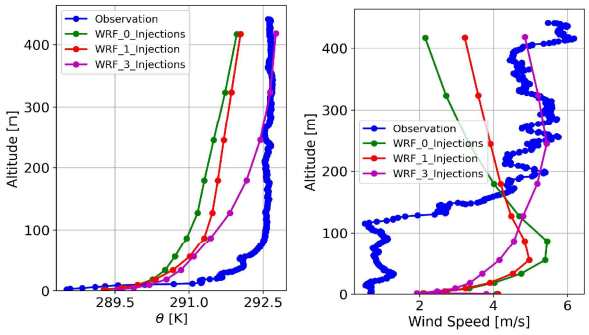

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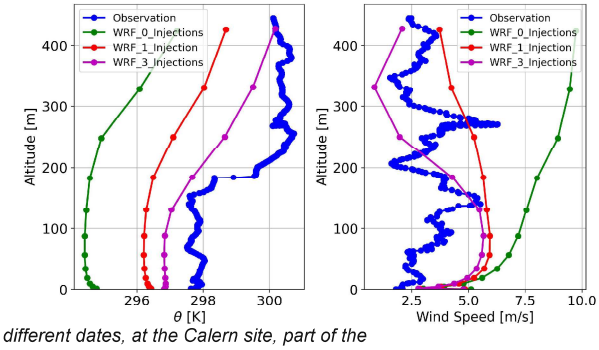

Profiles of potential temperature and wind speed for two different dates, at the Calern site, part of the observatoire de la Côte d'Azur. WRF_0_injection, WRF_1_injections, and WRF_3_injections present the predicted profiles with 0, 1, and 3 injections, respectively.

Conclusion:

→ With drone data injections, the prediction accuracy improves.

→ As the number of injections increases, the prediction becomes significantly more accurate.

Perspective:

Future improvements will focus on increasing drone injections by:

→ Implementing an automated drone station for higher daily injection frequency.

→ Incorporating better vertically resolved data in WRF for injections at more pressure levels.

References: (1) *Giordano et al. 2021, MNRAS, 10.1093/mnras/staa3709*
(2) *Rafalimanana et al. 2022, PASP, 10.1088/1538-3873/ac6536*
(3) Ziad et al. 2018, SPIE, 10.1117/12.2313386
(4) Medlej et al. 2024, SPIE, 10.1117/12.3018254