This project is supported by the European Commission´s FP7 Capacities Programme for the period April 2013 – March 2017 under the Grant Agreement number 312495.

Micro-meteorological contribution to the SHABAR seeing retrieval

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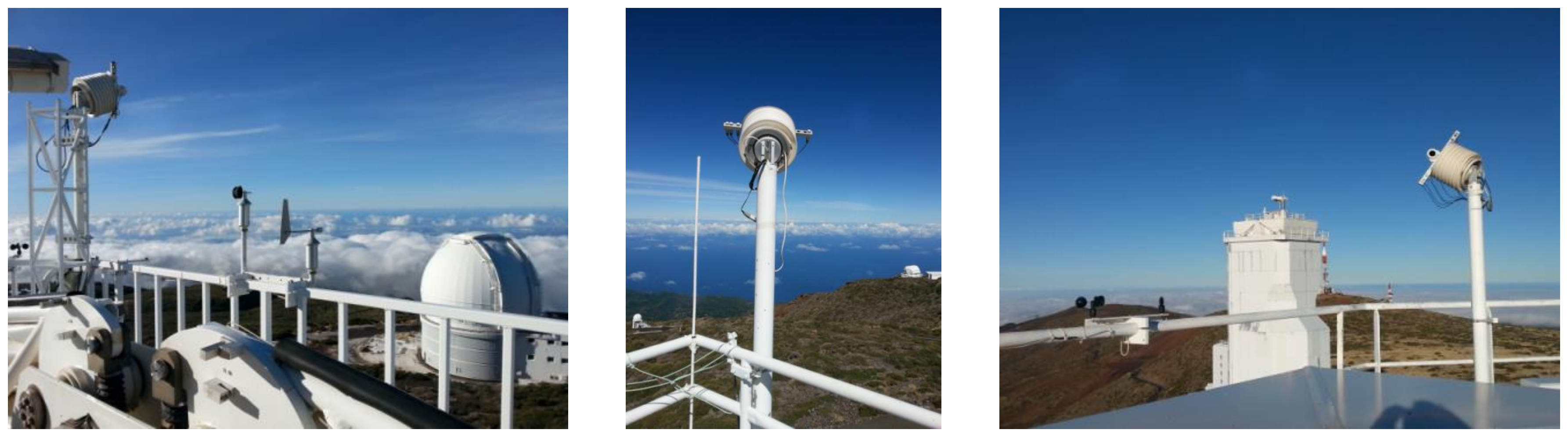
Goals

General: Refine seeing retrievals for the short-line SHABARs installed at the DOT, SST and GREGOR telescopes by constraining the algorithm based on micro-meteorological concepts

Specific:

1. Outline the proposed adjustments to the C_n^2-profile algorithm described by e.g. Hill et al. (2003)
2. Describe micro-meteorological methods to determine C_n^2 at telescope level using a sonic anemometer or a line-of-sight laser scintillometer.



Short-line SHABARs installed at the DOT (left), SST (middle) and GREGOR telescope (right).

Hill, F., Radick, R. and Collados, M.: 2003, 'Deriving $C_n^2(h)$ from a Scintillometer Array', ATST Site Survey Working GroupFinal Report. ATST Proj. Doc., 14

C_n^2 profiles from SHABARs

Proposed refinements include (analysis ongoing, nearing completion):

- Constrain C_n^2-profile retrieval with local C_n^2 measurements at telescope level (sonic anemometer or scintillometer) and atmospheric boundary layer scaling of C_n^2
- Optimize the retrieval height-levels:
  - Minimum height: depends on receiver aperture averaging and inner-scale, l_0, sensitivity
  - Maximum height:
    - Bound by validity of prescribed Kolmogorov turbulence to the boundary layer height (~1km)
    - Bound by reduced scintillation sensitivity beyond ~1km
    - Bound by scintillation saturation at large zenith angles
- Optimize high-pass-filter of scintillation measurements based on cross-wind profile and scintillation spectra

Conclusions

- **Existing infra-structure (turbulence measurements with sonic-anemometer and laser-scintillometer) utilised to constrain SHABAR retrieval algorithm**
- **Further refinements of retrieval algorithm implemented based on micro-meteorological concepts**

C_n^2 from local turbulence measurements

1. C_n^2 from a sonic anemometer (DOT)

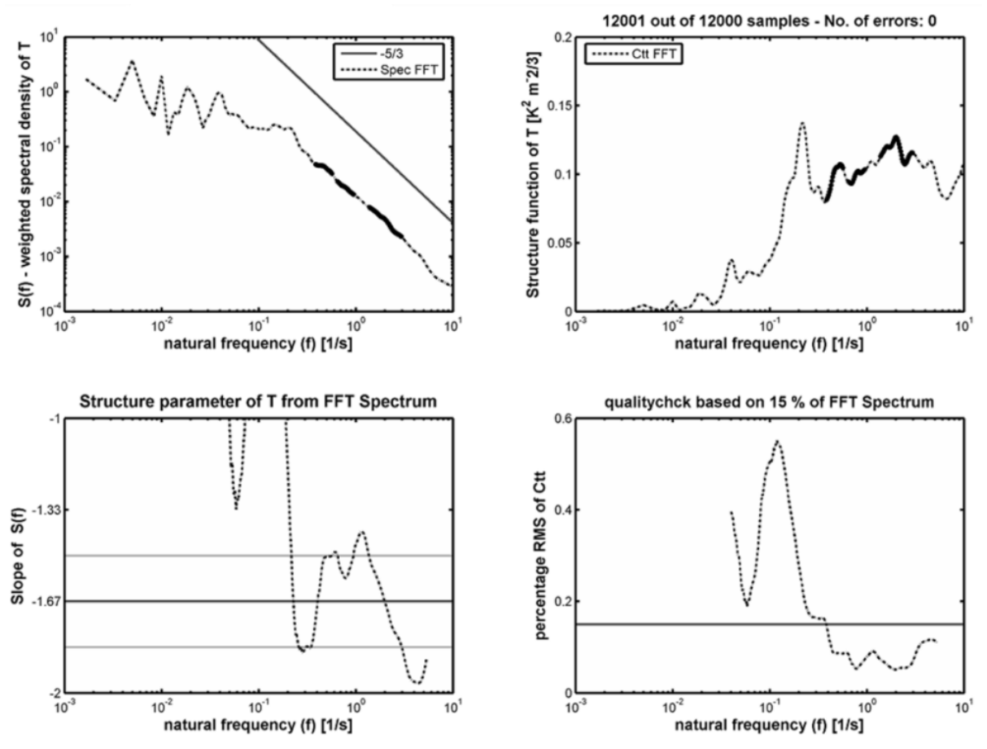
- Sonic anemometer provides local 20Hz temperature, T, data
- C_T^2, the structure parameter of T can be determined from a Fourier Spectrum of the measured T, S_T:

$$C_T^2 = 4\left(2\pi/U\right)^{2/3} f^{5/3} S_T(f)$$

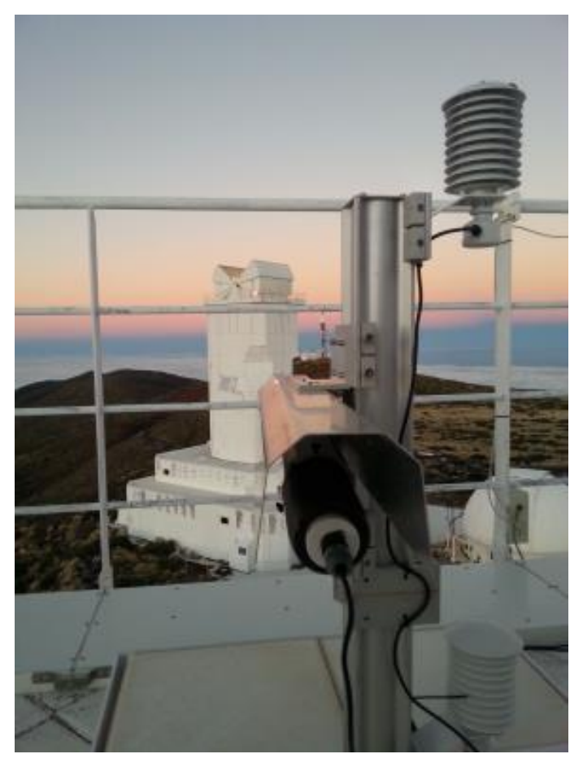
where *U* is wind-speed [m/s] and *f* the spectral frequency [Hz]

- The challenge of applying the above equation in practice is to automatically detect where the spectrum exhibits inertial range behaviour, i.e. a $f^{-5/3}$-slope
- Relation C_n^2 to C_T^2 for optical-wavelengths in a dry atmosphere:

$$C_T^2 = C_{n_{vis}}^2 \left(\frac{T}{A_{T,vis}}\right)^2$$



2. C_n^2 from a laser scintillometer (GREGOR)

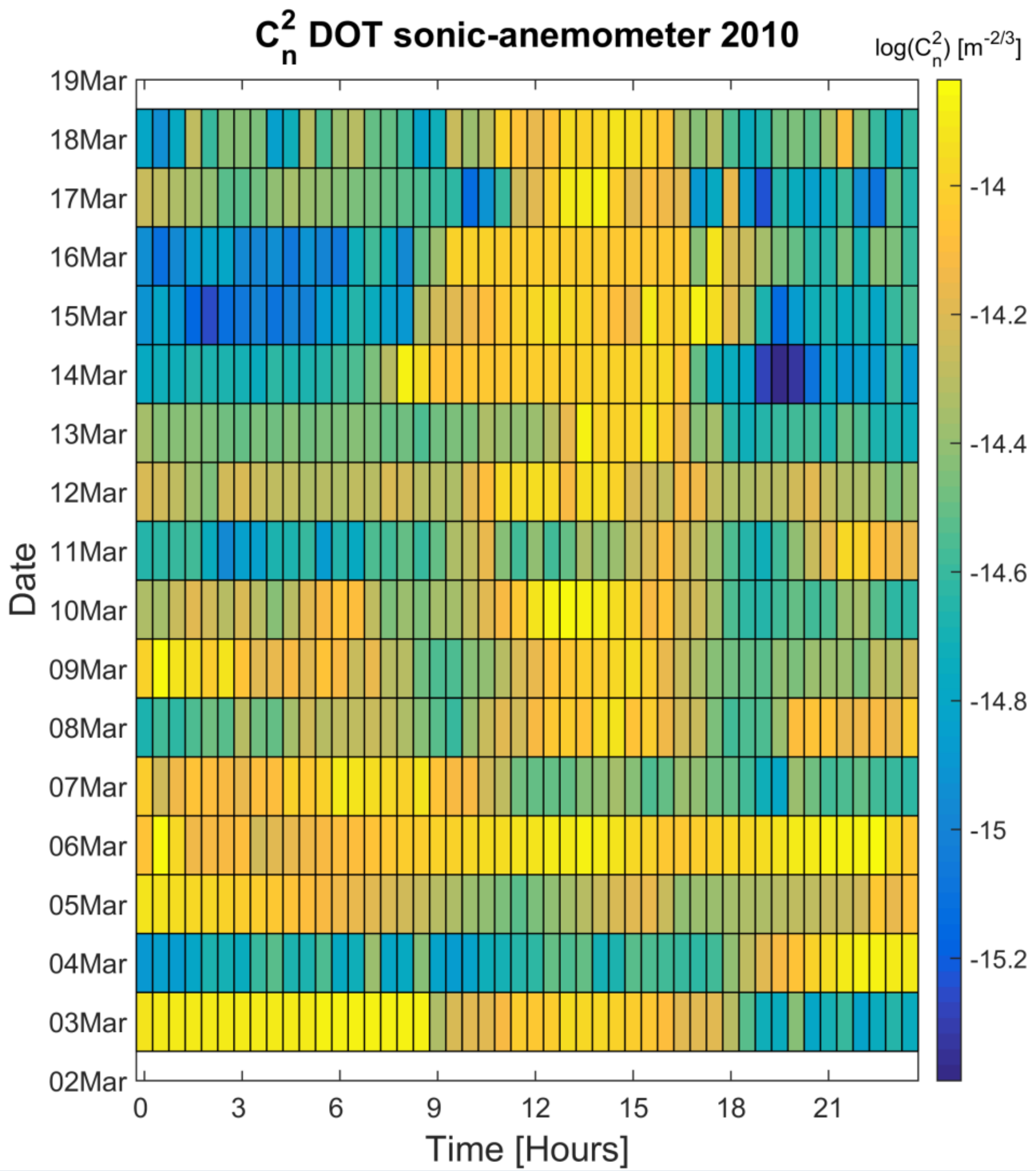


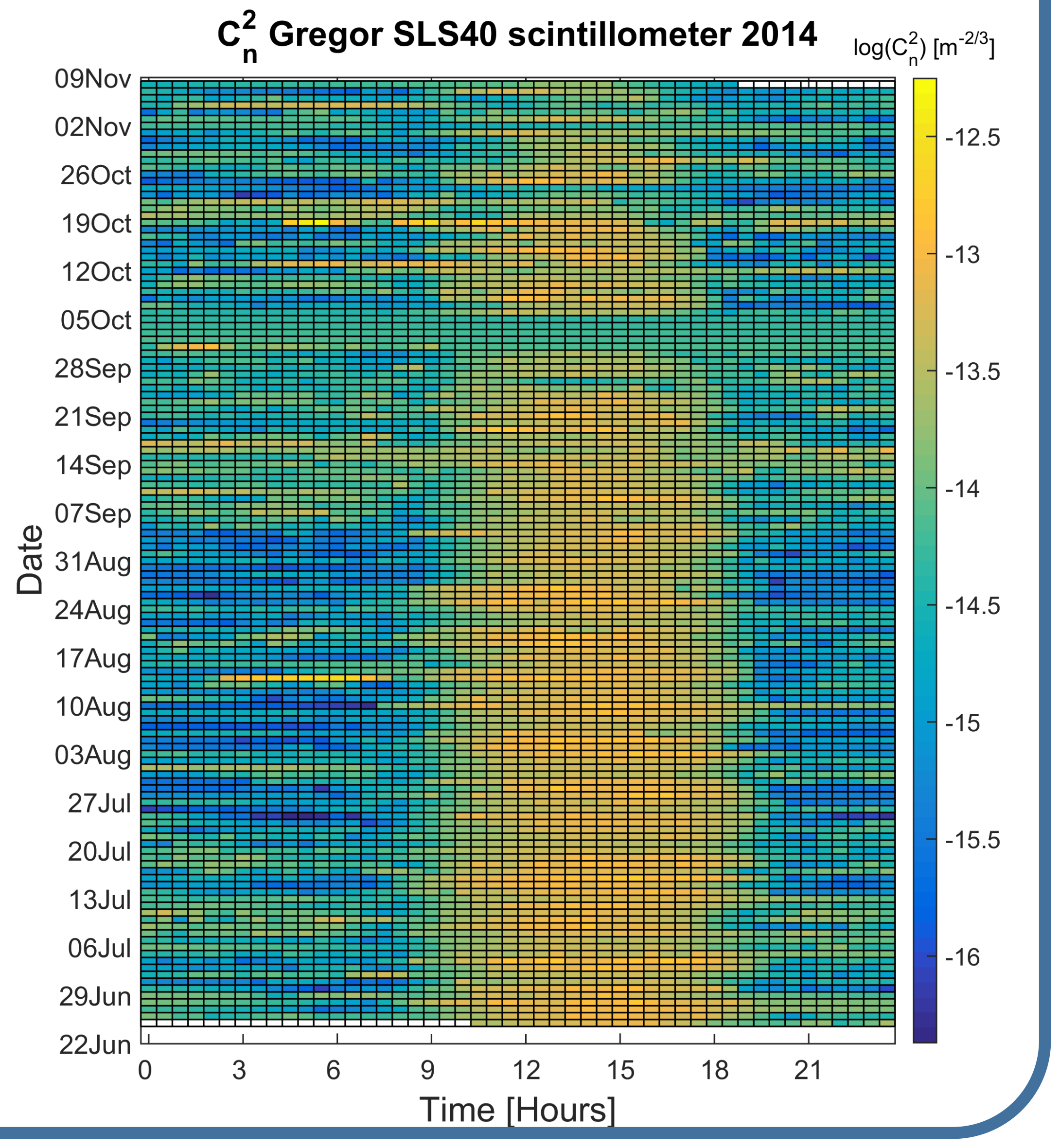
- The double-beam laser scintillometer is a line-of sight instrument consisting of a transmitter (VVT) and receiver (GREGOR)
- Relation of the scintillation covariance, B_{12}, and C_n^2 is based on weak-scattering theory, similar to that used for the SHABAR:

$$B_{12} = 4\pi^2 K^2 \int_0^L \int_0^\infty k\phi_n(k, l_0, C_n^2) J_0(kd) \sin^2\left(\frac{k^2 x(L-x)}{2KL}\right)\left[\frac{4J_1^2(kDx/2L)}{(kDx/2L)^2}\right] dk\,dx$$

where *x* is the co-ordinate along path length *L*, $K = 2\pi/\lambda$ is the optical wave-number, *k* the turbulent spatial wave-number, *d* the distance between the two beams, *D* is the detector diameter, ϕ_n is the 3D Kolmogorov spectrum of the refractive index, which is a function of *k*, l_0 and C_n^2 and J_0 and J_1 are Bessel functions of the first kind.

- Both C_n^2 and the inner scale of turbulence, l_0 are solved





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IV SOLARNET Meeting
Lanzarote, January 16-20, 2017