CFD ANALYSIS

Progress Report May 2014

CFD model validation

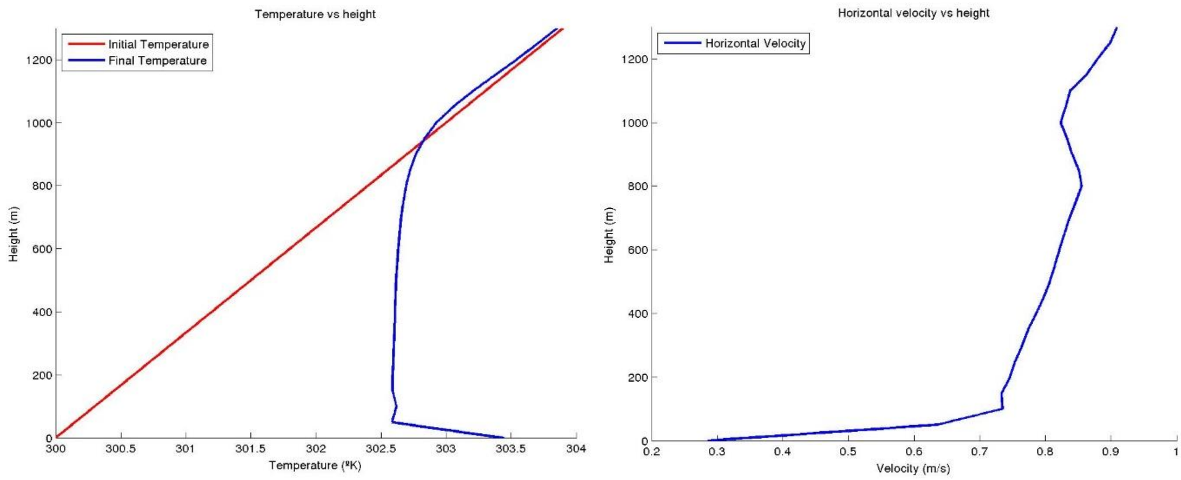
Objective

CFD simulations consist in computing pressures, temperatures and velocities at all points of the computational domain and at all-time instants. From these, average mechanical and thermal rates of dissipation depending on the turbulence model used are calculated. Then Cn^2 distribution is determined and the degradation of local seeing. The calculations are applied to the environment of EST.

The first objective is to compare the results of two different turbulence models: the classical LES Smagorinsky's model and an implicit LES (ILES) model based on the Variational Multi-Scale (VMS) framework to approximate the incompressible Navier-Stokes equations. For SOLARNET/EST, one approach for ILES model is to use directly the dissipation associated to the numerical model in order to stabilize the incompressible flow equations, without any additional turbulence model.

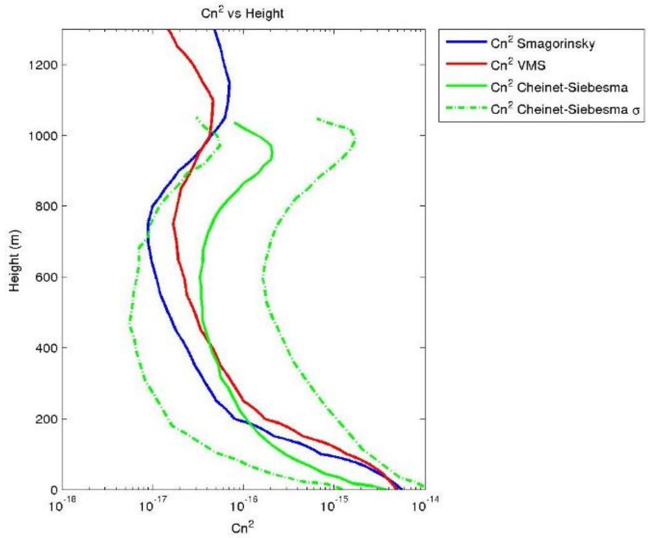
Validation test

The first numerical example consists of the analysis of the development of convective boundary layer, with a starting constant temperature gradient and a heat source located at the ground (simulating the heating of the ground produced by the solar radiation). This example is used to compare the Cn^2 stratification calculated by the VMS-based dissipation model and by the Smagorinsky´s model.



Temperature (left) and horizontal velocity (right) averaged profiles

As a result of the evolution, the temperature increases near the ground because of heat flux in the lower boundary. At greater heights, the temperature values get closer to the initial condition temperature profile. The horizontal velocity profile is characterized by a large velocity gradient close to the ground. Then, the average velocity decreases slightly at 1000m height where the temperature gets the initially constant vertical gradient. A similar evolution is obtained with both models, which makes it

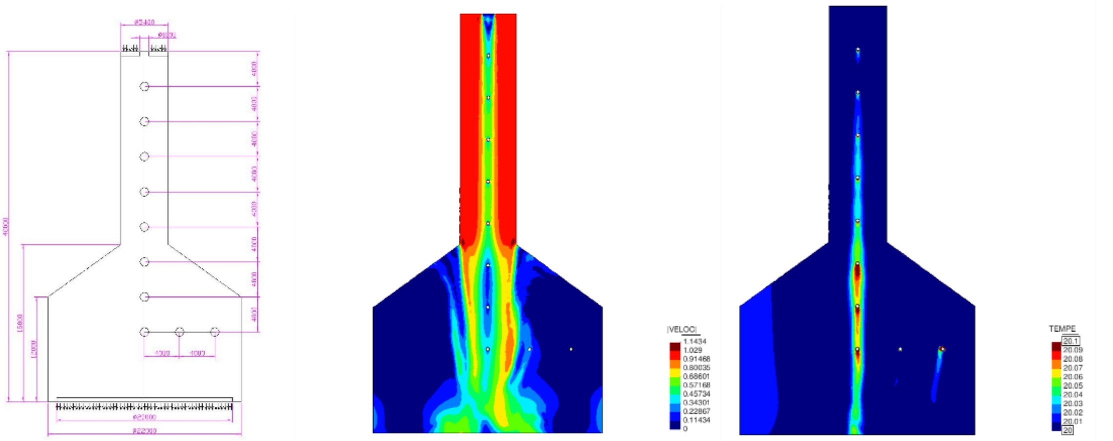


possible the comparison in terms of turbulence (Cn^2) and seeing stratification (r_0), as well as with previous estimates (Cheinet-Siebesma, 2009) [1].

With the exception that Cn^2 values estimated by Cheinet-Siebesma [1] increase at a lower height, the Cn^2 distribution with height has a similar shape in each case.
Viscous and thermal turbulent dissipations obtained in the VMS method are qualitatively the same as the ones in the Smagorinsky model.

Transfer optics and Coudé room

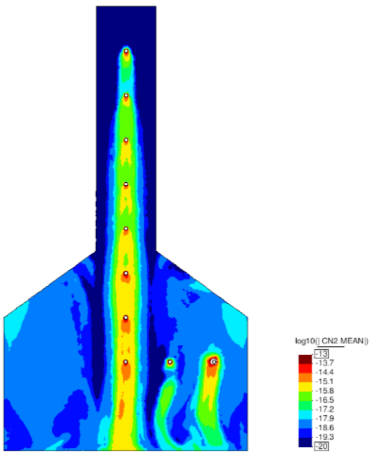
The objective of the study is to analyze the seeing degradation in the transfer optics and Coudé room of EST with both models. The transfer optics is a vertical structure with thermal control based on a number of sources of cool air, as well as heating sources in the locations of optical elements (assumed heated by the solar radiation transmitted by the telescope).



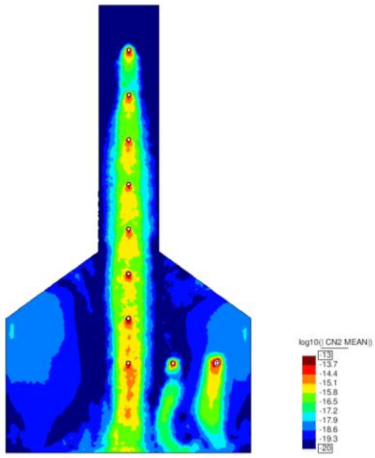
Geometry Velocity snapshot Temperature snapshot

As a result of the calculations, the velocity is larger in the central region, where most of the injected air is circulating. The heating point reduce the flow, which generate boundary turbulent layers, which has a negative effect in the resulting seeing conditions. The surface of the heating sources have the largest temperatures and temperature gradients, and give to hot air jets that follow the path of the vertical air inflow.

Ref.[1]: Cheinet Sylvain, A. Pier Siebesma, 2009, Variability of Local Structure Parameters in the Convective Boundary Layer. *Journal of the Atmospheric Sciences*, Volume **66**, p. 1002–1017.



Cn^2 snapshot by Smagorinsky

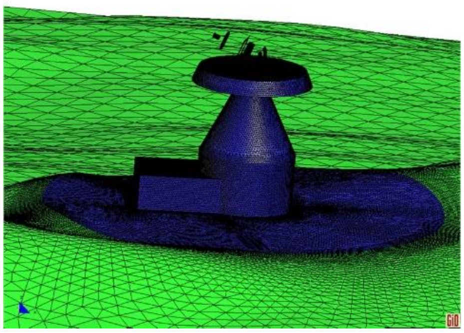


Cn^2 snapshot by VMS

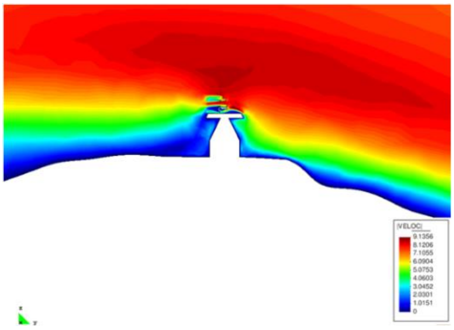
Both models provide very similar results in the transfer optics and Coudé room, the Cn^2 field is smoother for the Smagorinsky case (left case).

CFD analysis

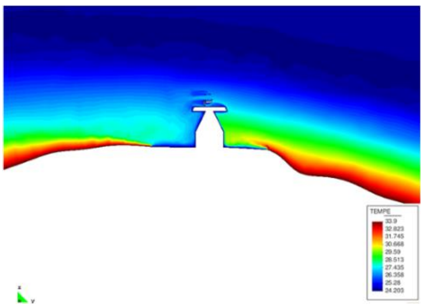
CFD simulations are performed for different configurations of the EST environment. Below, the results obtained for one case.



Meshed model (6 million tetrahedral elements)



Velocities map



Temperatures map

For this particular case, The Fried parameter is 17, 2 cm for λ= 500 nm and the Greenwood frequency is 19.67 Hz.

Conclusion

The CFD model proposed has been validated. ILES models are preferred as they are less dissipative than classical models.

CFD analysis for different EST configurations have been done during the phase A of EST project. For SOLARNET, temperatures maps have been estimated for more EST configurations and from these data, CFD analysis are to be performed.