# Single Conjugate AO with the E-ELT: Impact of Sky-Subcooling (Low Wind Effect)

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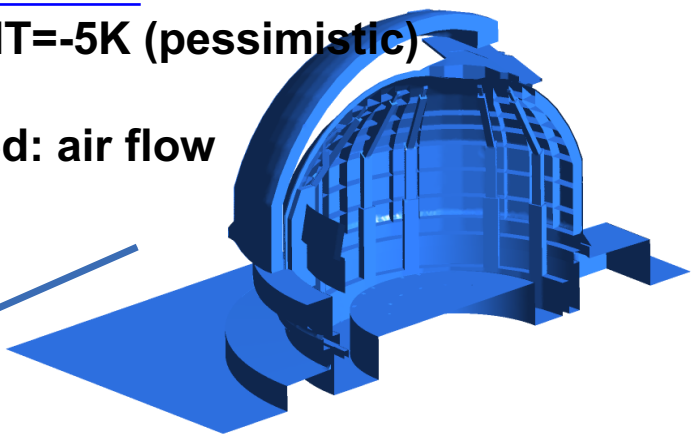
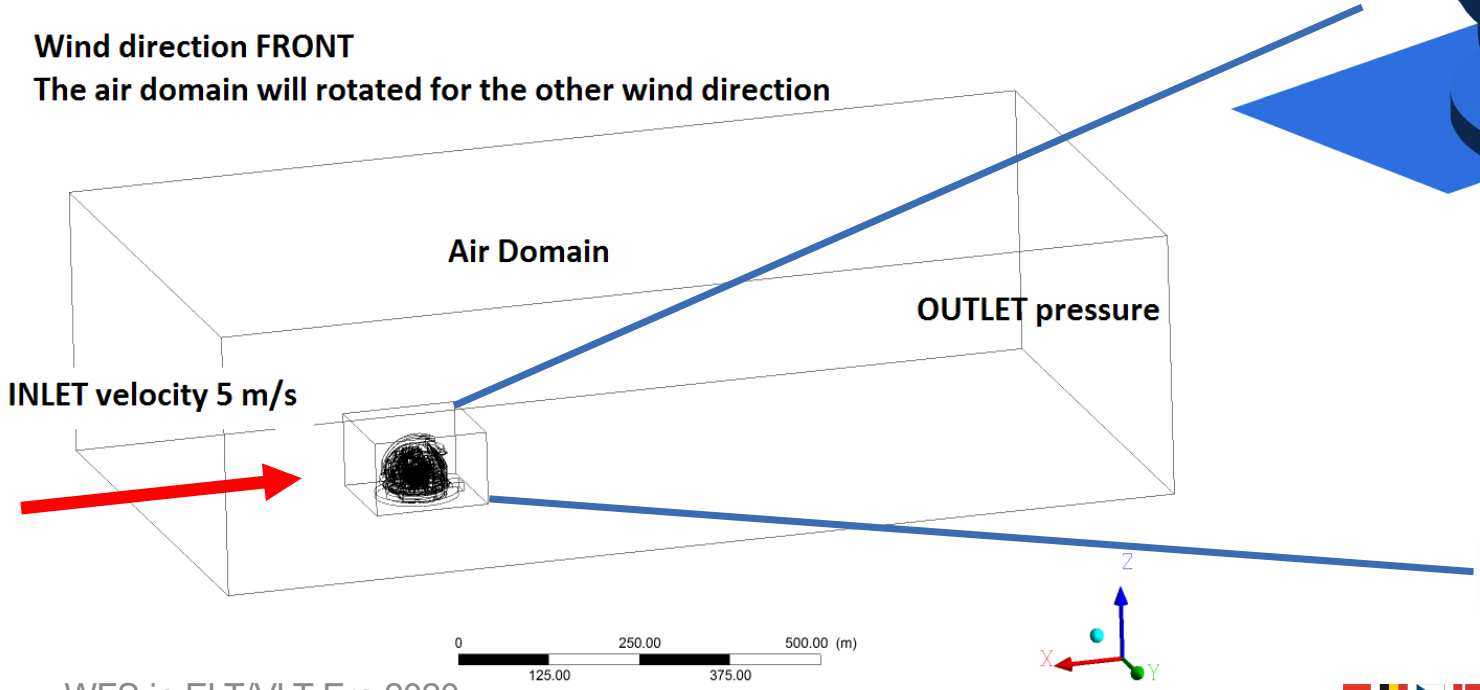
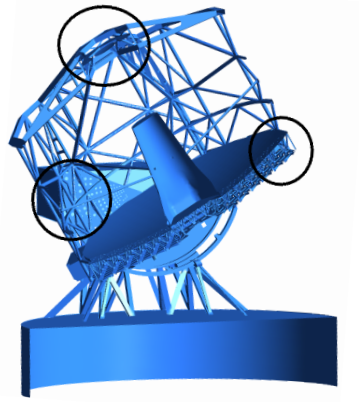
# Computational Fluid Dynamics (CFD)

- **1. CFD Model :** Turb. /Transport equations → Steady state **3D Temperature distribution**
- **2. Ray Tracing through 3D dT:** From Top of ELT through reflexions by M1,M2,… → **Pupil OPD**
- **Subcooling** : Structures cool down by radiation against cold sky
  - See paper by Ron Holzloehner: http://arxiv.org/abs/2010.01978
  - 2 scenarios **dT=-2K**(models LO/MIT silver paint) **and dT=-5K (pessimistic)**
- **Very Detailed model of the Dome and Telescope included: air flow**
  - 3 Wind orientations: Front, Back, Side

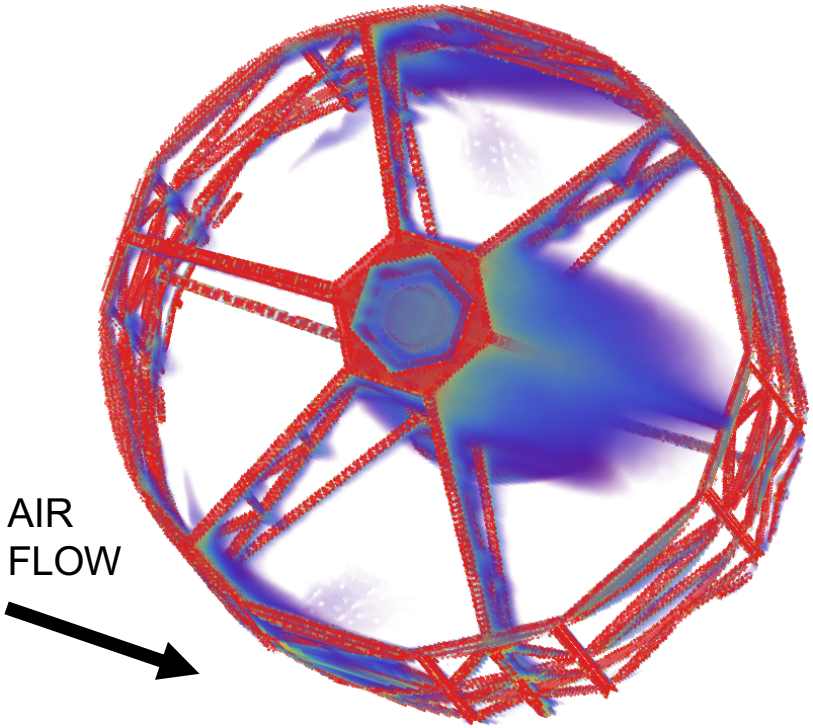


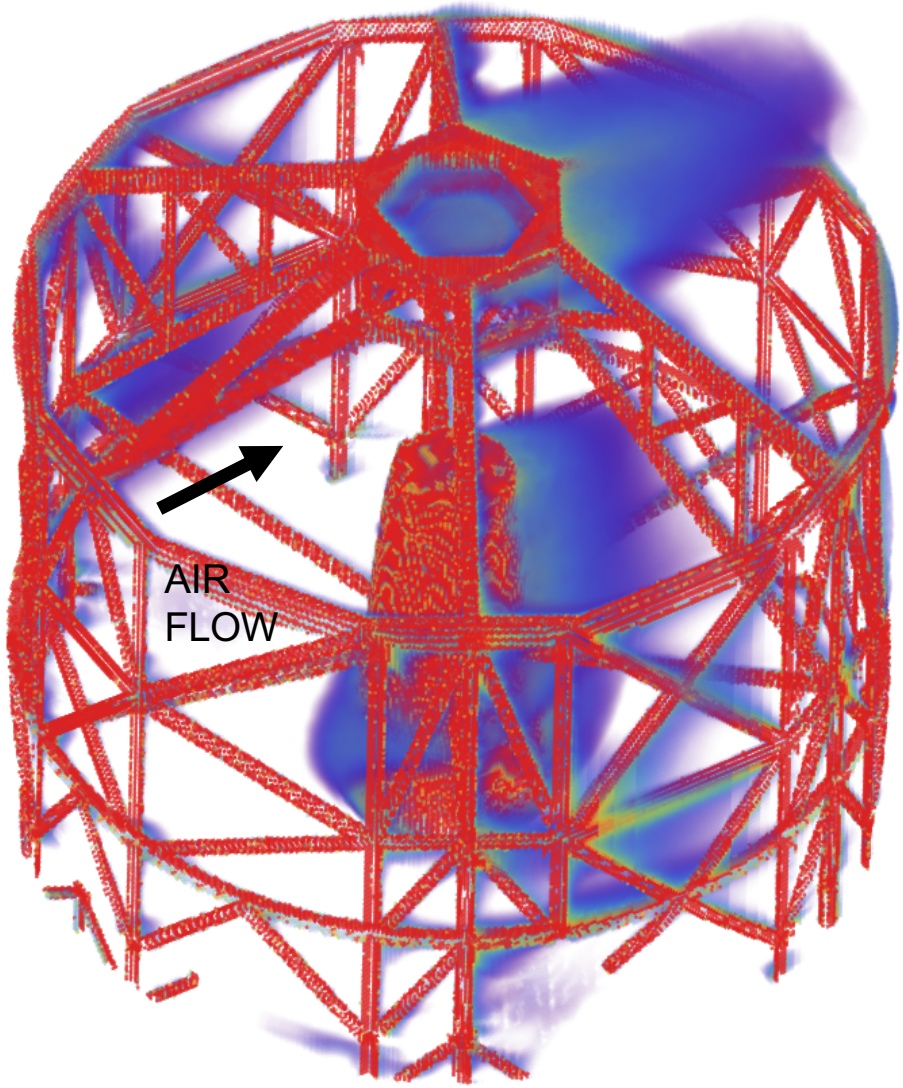


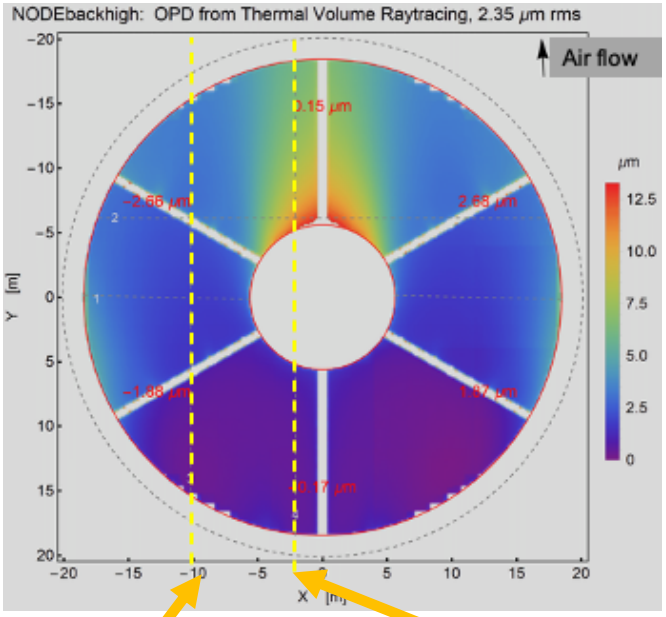
# Sub-Cooling and Air Flow

- Telescope structures exposed to cold sky cool down by radiation faster than the air
- Air flow cools down by convection and creates local air temperature gradients in the direction of the air flow
- Most serious contributors are : M2 crown, M4 Tower, vertical tube trusses, spider arms



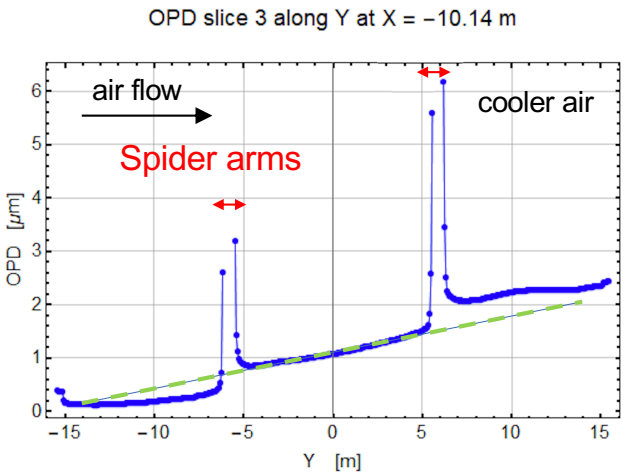
# Zoom on the Back wind case

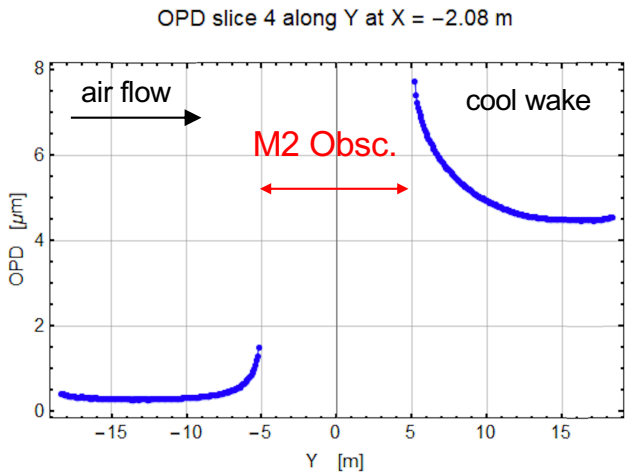



- **Thin boundary layer of cool air creates very steep OPD near spider arms**
- Higher resolution needed in the future to estimate more precisely the thickness and the impact on OPD disconnection

Cut through Spider arms

Cut through M2 Obscuration



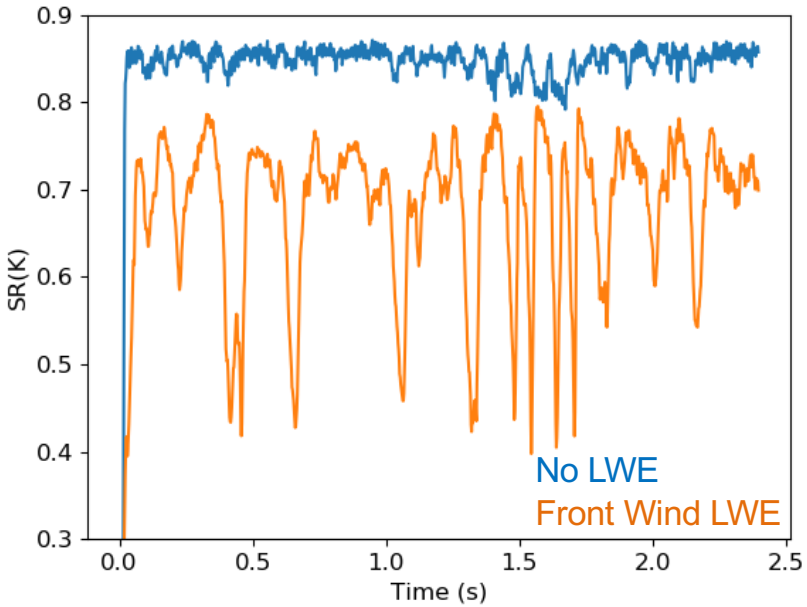




| | |
|---|---|
| RMS | ~2.5 $\mu$m |
| **PTV** | **~10 $\mu$m** |

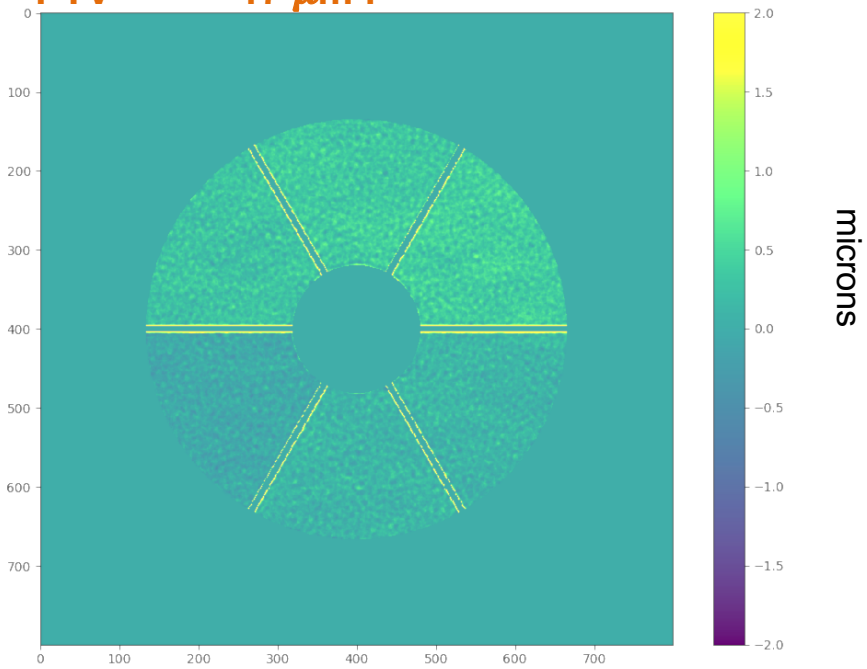
# Very Preliminary SCAO (92x92) WFS in K band for PDS Phasing and Diagnostic Station

- **Loop Stays stable for 4000 correction modes, SR=85% is same as without LWE.**
  - This is an optimistic case: 4000 modes is 93% of the Degrees Of Freedom
- **Loop Highly unstable for 3000 correction modes** (PDS nominal case): **no firm conclusion yet**
  - Note: modal basis does not include (yet) explicitely the fragmentation modes
- **Further analysis needed to understand Stability VS Number of modes, and role of spider arms**

**Seeing = 0.67 arcsec (median), 3000 modes**
**Assumption for subcooling: dT=-2 K**
Short exposure Strehl curves




**Residual screen (at time 0.8 s)**
**PTV 17 $\mu$m !**



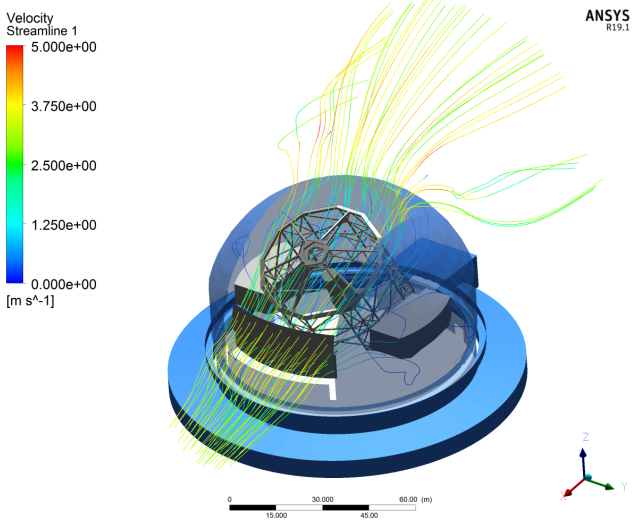

(colormap range is [-2,2] microns)

# Conclusion

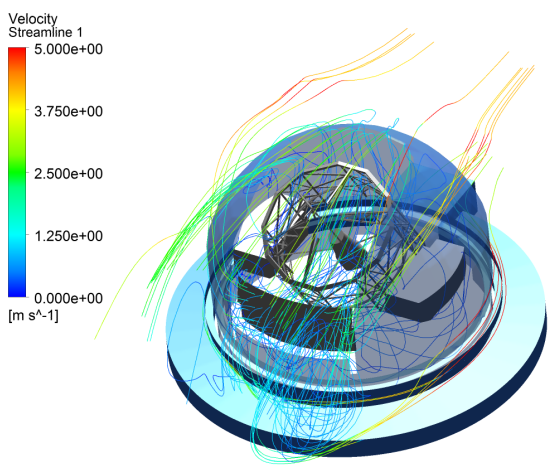
- A Detailed CFD model of Sky Subcooling has been developed
- Optical Maps of LWE have been produced and highlight the presence of the steep OPD  near spider arms
- Preliminary SCAO simulations show that impact is non-negligible
  - Reconstruction needs to be optimized regarding fragmentation
  - Analysis of M4 in terms Forces saturation management remains to be done
- CFD simulations to be extended:
  - Analyze precisely the boundary layers near spider arms  with higher resolution
  - Open louvers in dome model → increases slightly air flow speed
  - Develop a parametric model and Explore Temporal variations
- This work = Inputs for studying passive/active counter-measures

# OPD maps

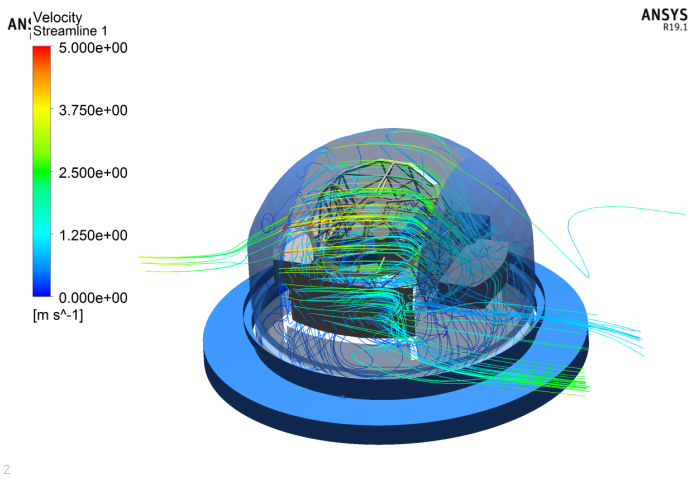
## Front Wind

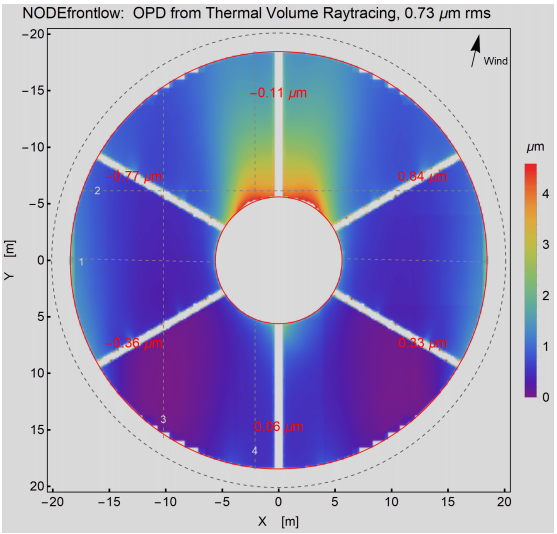


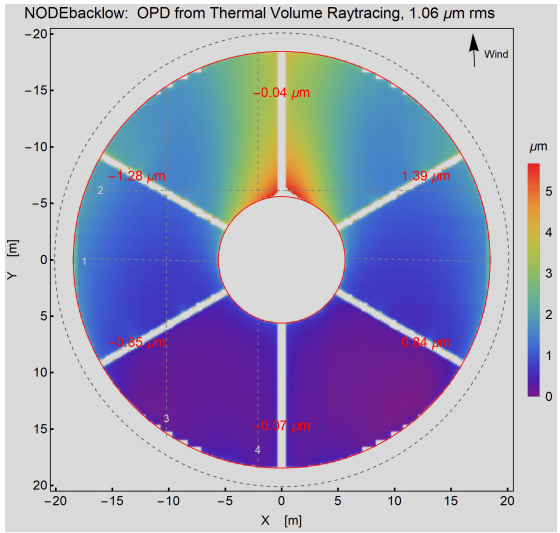

## Back Wind

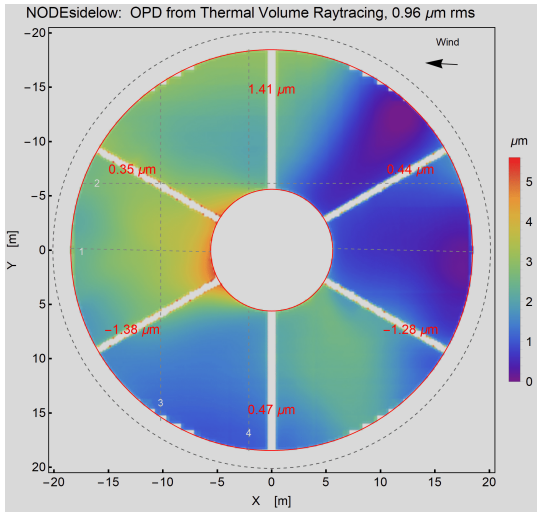



## Side Wind



- Ray Tracing is performed from the Top of the Telescope down to M1, to M2 and to M3
- $OPD = \frac{dn}{dT} \int \Delta T(\vec{x}(l))\, dl$
- Valid OPD points: air only → definition of pupil