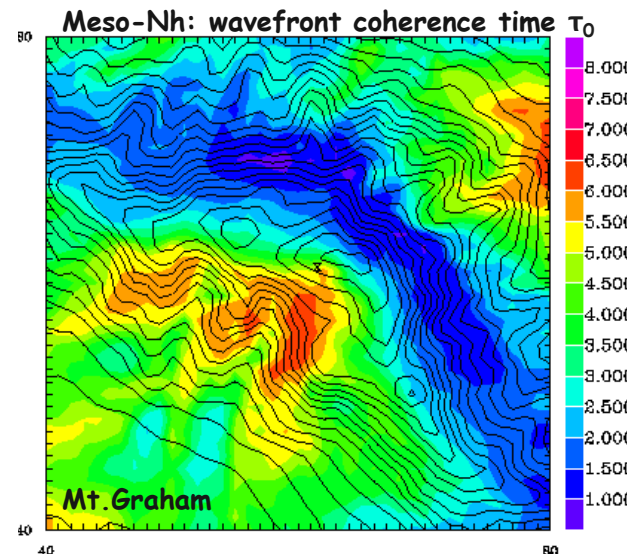
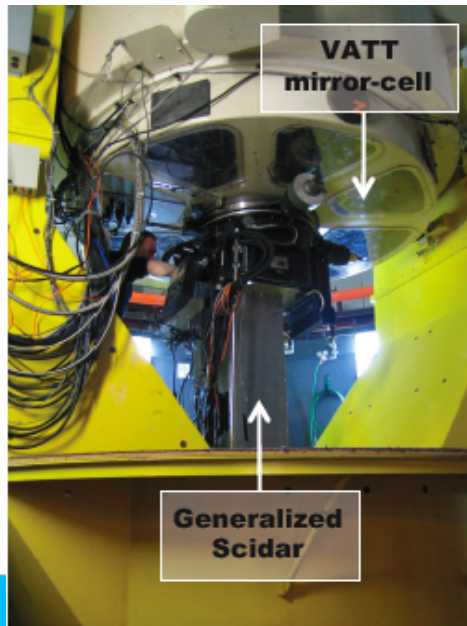
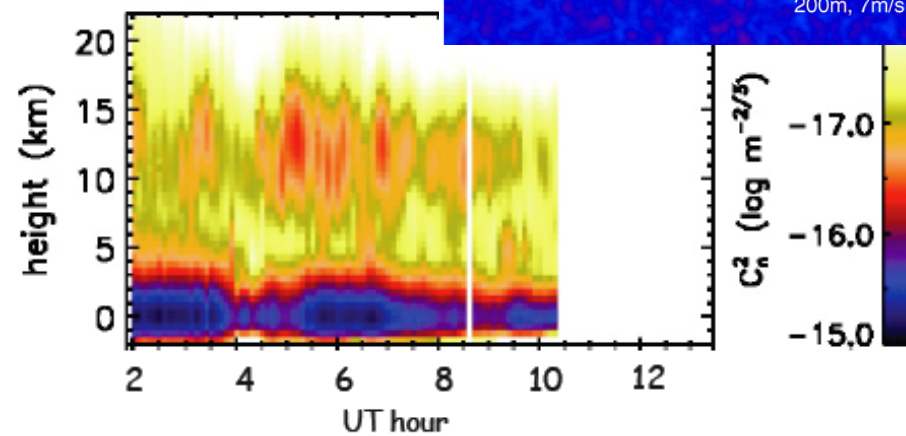
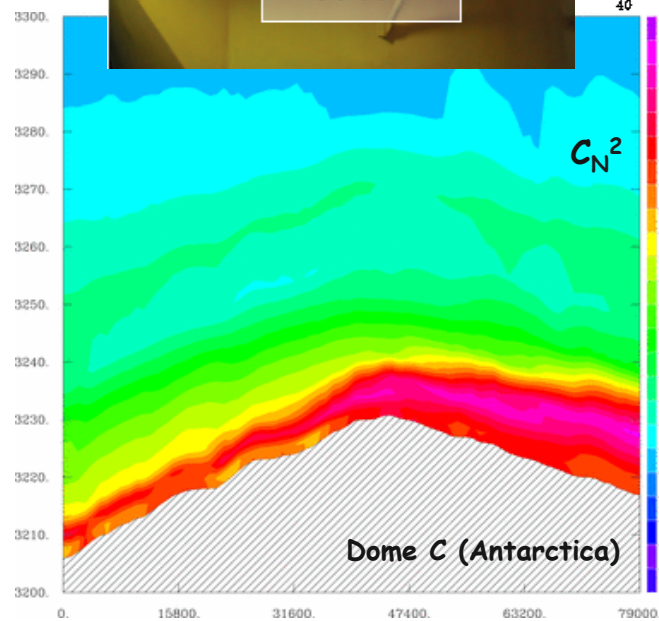
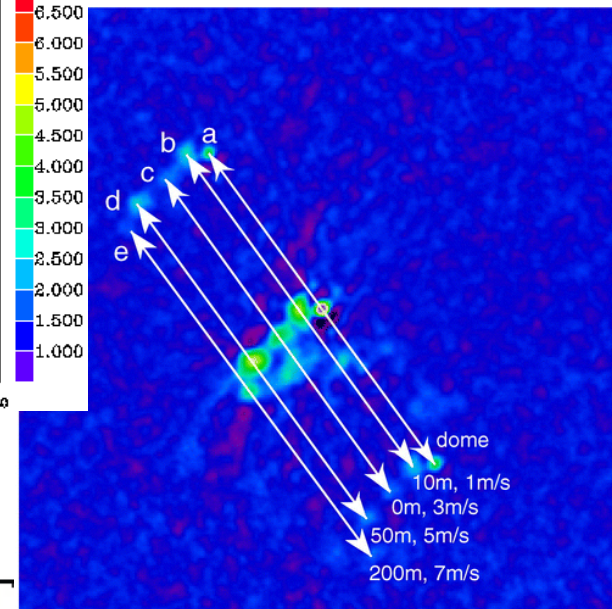


Optical Turbulence for High Angular Resolution Group



HVR-Generalized Scidar



OT HAR

Optical Turbulence for High Angular Resolution

In Arcetri since 2006....



ForOT: Forecasting Optical Turbulence

4/2006-4/2010:

1.2 M€



MOSE: Modelling Sites ESO

Phase A: 3/2011-3/2013:

120 K€

Phase B: 3/2013-3/2014:

60 K€



LTC: LBT Turbulence Centre

...contributo premiale INAF.... ??

??

OTHAR

Group

2006

Masciadri Elena **staff**
 Lascaux Franck **post-doc**
 Stoesz Jeffrey **post-doc**
 Hagelin Susanna **PhD**

2012

Masciadri Elena **staff**
 Lascaux Franck **post-doc senior**
 (7 years)

Fini Luca **staff**
 Salinari Piero **associato**

Perspective:

Miglietta Luciano **staff**

time
 ↓



Fini



Hagelin



Lascaux



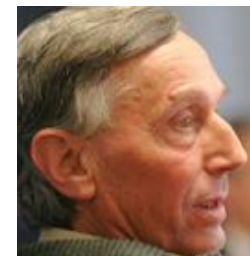
Masciadri



Miglietta



Stoesz



Salinari

October 2007

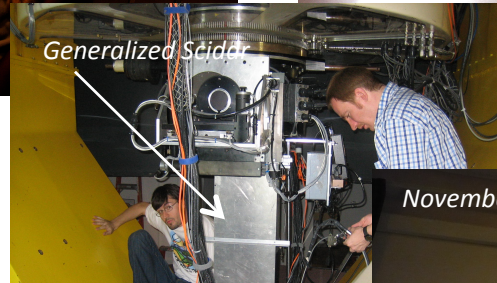


VATT control room: Hagelin

February 2008



VATT control room: Lascaux



Generalized Scidar



VATT roof: Masciadri Egnor

May 2007

November 2008



VATT control room: Stoesz

Mt. Graham Arizona, (US)
 ForOT Site testing Campaigns
 2006-2010 - 45 nights

Running activities and researches

Optical turbulence and environmental conditions

- How does the atmospheric parameter affect the OT ?
- Inferring OT characteristics from atmospheric parameters

Hagelin et al. 2008, MNRAS

Modelling with atmospherical non-hydrostatic meso-scale models

- Meso-scale model validation, model calibration methods
- Astronomical sites discrimination
- Characterization of atmospheric parameters not accessible from GCMs
- Optical turbulence forecast

Hagelin et al. 2010, MNRAS; Hagelin 2011, MNRAS

Lascaux, et al. 2009, MNRAS

Lascaux et al. 2010, MNRAS

Lascaux et al. 2011, MNRAS

Optical turbulence measurements - Site testing

- Characterization of astronomical site. Ex: Mt.Graham
- Inputs for AO simulations

Masciadri et al. 2010, MNRAS

Masciadri et al. 2010, MNRAS; ARGOS Design Review

Development of techniques for optical turbulence measurements

- HRV-GS: High Vertical Resolution Generalized Scidar
- Microthermal sensor for C_N^2 - ForOT@DC: (INAF-Arcetri (PI:Masciadri); UNSW, Sydney; ENEA, Roma; Italian Air Force, Vigna del Valle, (RM))

Masciadri & Egner, 2007, PASP, Masciadri et al., 2010, MNRAS

Applications to adaptive optics

- Estimation of the 'Gray Zone' for applications to ARGOS
- GLAO performances: Dome C versus Mt.Graham

Masciadri et al., 2010, MNRAS

Stoesz, et al. 2008, SPIE

Theory: Optical turbulence in stable regimes

- Parameterization of turbulence in stable regimes for mesoscale applications

Masciadri et al. in preparation

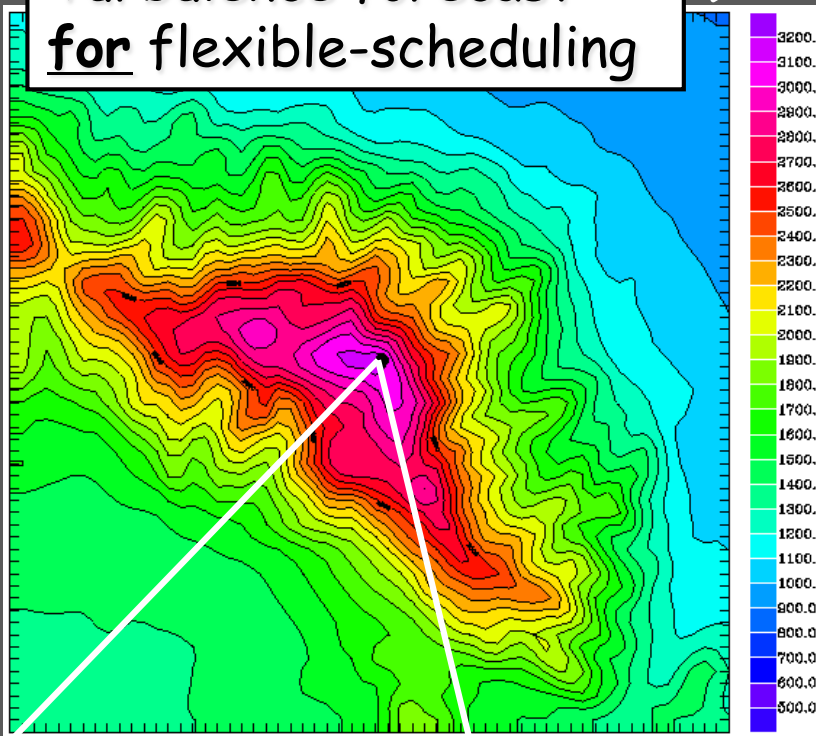
ForOT site <http://forot.arcetri.astro.it>

OT HAR

ForOT: CORE PROJECT

Main goal:

Turbulence forecast
for flexible-scheduling

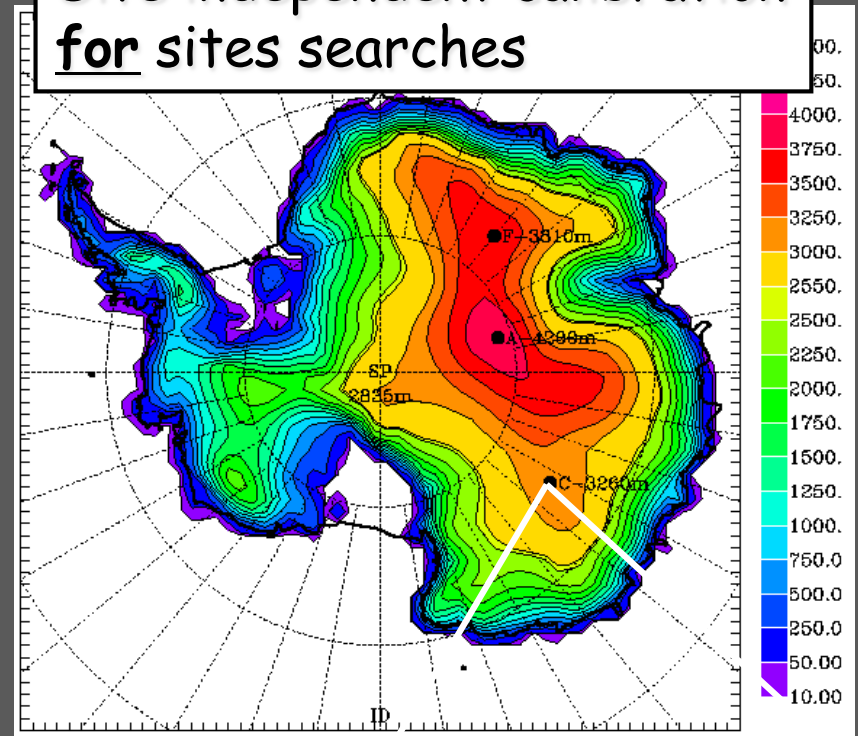


$\Delta x = 500 \text{ m}$



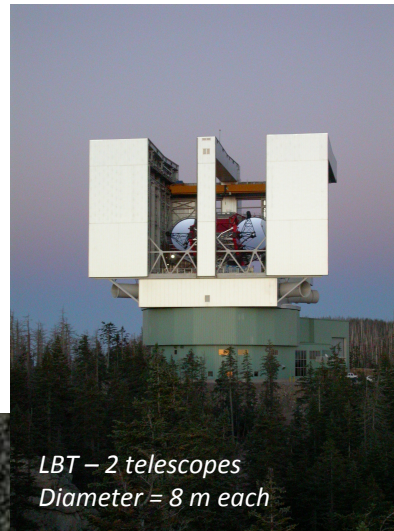
Main goal:

Site independent calibration
for sites searches



$\Delta x = 100 \text{ km}$





LBT – 2 telescopes
Diameter = 8 m each

Site testing campaign 2007-2010 / 45 nights

1. GS run: [28/5/2007 – 4/6/2007] - 8 nights
2. GS run: [15/10/2007 – 28/10/2007] - 15 nights
3. GS run: [21/2/2008 – 3/3/2008] - 11 nights
4. GS run: [9/11/2008 – 20/11/2008] - 11 nights



LBT seen from the VATT

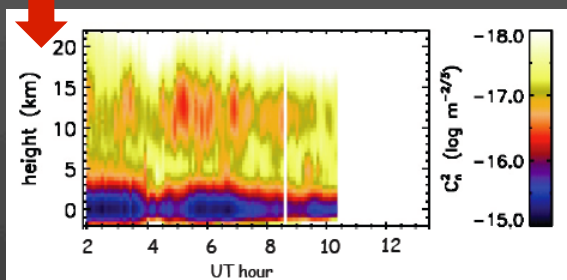
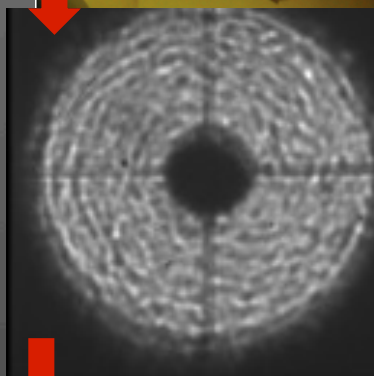
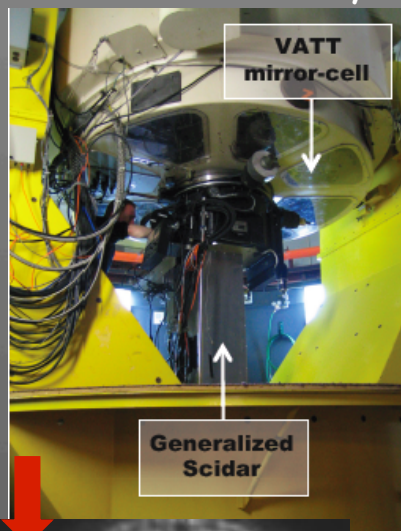


VATT seen from the LBT

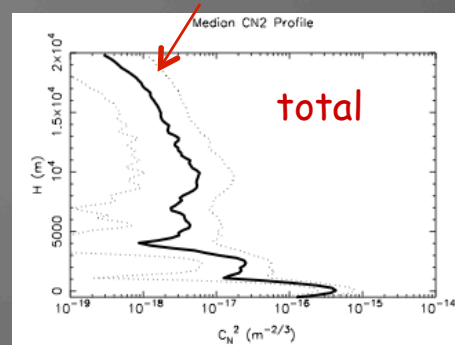
Site characterization

Masciadri et al. 2010, MNRAS

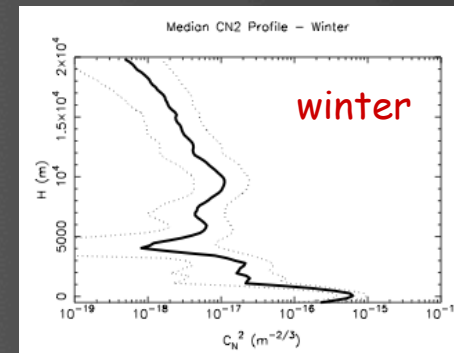
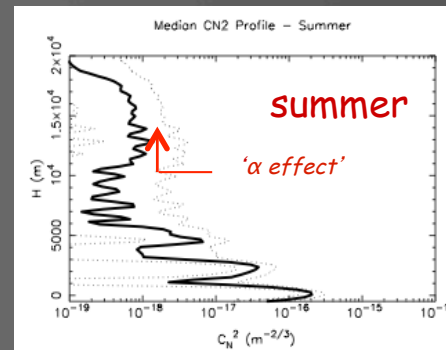
43 nights uniformly distributed in the year



1st and 3rd quartiles



Vertical distribution: C_N^2



α effect: Masciadri & Egner, 2006

Integrated parameters

	Total			Summer			Winter		
Parameter	25th	50th	75th	25th	50th	75th	25th	50th	75th
ε (arcsec)	0.65	0.95	1.34	0.53	0.61	0.72	0.89	1.19	1.50
θ_0 (arcsec)	1.6	2.5	3.6	3.1	3.8	4.5	1.4	2.0	2.7
τ_0 (ms)	2.7	4.8	8.7	6.4	10.1	14.6	2.5	3.8	6.2
V_0 (ms ⁻¹)	5.1	7.2	9.3	3.7	5.1	7.8	5.9	7.7	9.6

→ dome included

Parameters	ε	θ_0	τ_0
Units	(")	(")	(msec)
Mt. Graham(*)	0.72	2.50	4.8
Mauna Kea(**)	0.79	2.69	5.1

(*) Generalized Scidar

(**) DIMM at h=6.5 m

Mt. Graham *definitely* comparable to the best sites in the world for OT!

LBT-Newsletter, February 2010

Composite profiles for estimate of ARGOS and FLAO performances



"composite profiles"

$$J = \int_0^{\infty} C_N^2(h) dh$$

r_0

20%-30%

45%-55%

70%-80%

Bins (m)	'Good' J ($m^{1/3}$)	'Typical' J ($m^{1/3}$)	'Bad' J ($m^{1/3}$)
14000-20000	7.61e-15	1.02e-14	1.91e-14
12000-14000	5.10e-15	9.65e-15	1.57e-14
10000-12000	7.24e-15	1.27e-14	2.89e-14
8000-10000	8.52e-15	1.72e-14	3.22e-14
6000-8000	6.45e-15	1.05e-14	1.77e-14
4000-6000	9.50e-15	1.23e-14	2.10e-14
3000-4000	9.18e-15	1.14e-14	1.45e-14
2000-3000	1.97e-14	3.39e-14	4.02e-14
1500-2000	6.98e-15	1.52e-14	2.86e-14
1000-1500	5.28e-15	1.50e-14	2.86e-14

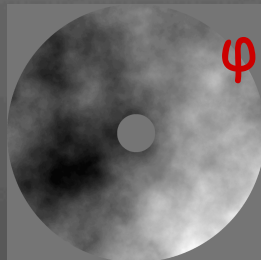
Bins (m)	'Good' J ($m^{1/3}$)	'Typical' J ($m^{1/3}$)	'Bad' J ($m^{1/3}$)
900-1000	4.35e-15	7.06e-15	1.33e-14
800-900	2.48e-15	3.53e-15	6.29e-15
700-800	3.30e-15	6.04e-15	1.04e-14
600-700	5.72e-15	1.09e-14	2.05e-14
500-600	4.30e-15	7.70e-15	1.38e-14
400-500	4.21e-15	9.60e-15	1.86e-14
300-400	2.05e-14	4.26e-14	8.26e-14
200-300	6.15e-15	1.14e-14	2.53e-14
100-200	2.03e-14	4.14e-14	8.11e-14
0-100	1.79e-13	3.27e-13	6.17e-13
0-100	3.4e-14	8.5e-14	2.20e-13

$h > 1km$

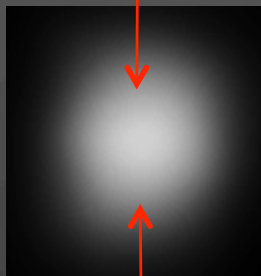
$h < 1km$

dome seeing excluded

pupil

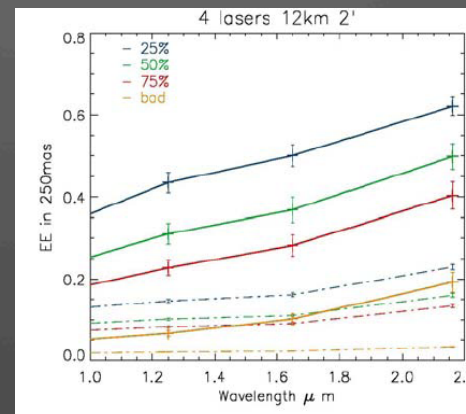


CCD

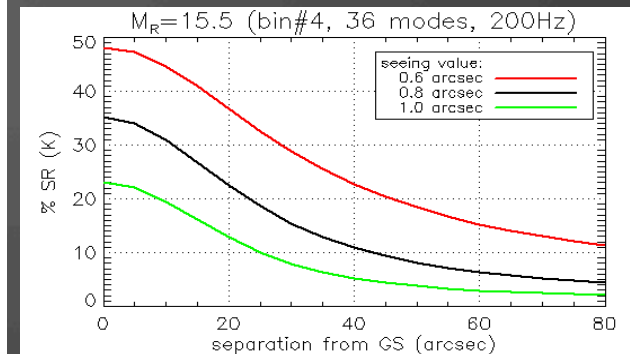


PSF long exposure

$\frac{\lambda}{r_0}$



ARGOS- Phase A report

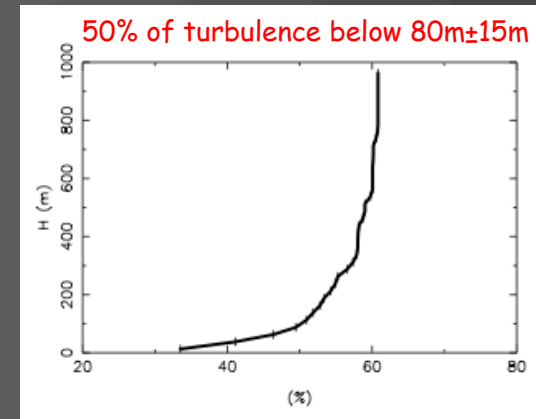
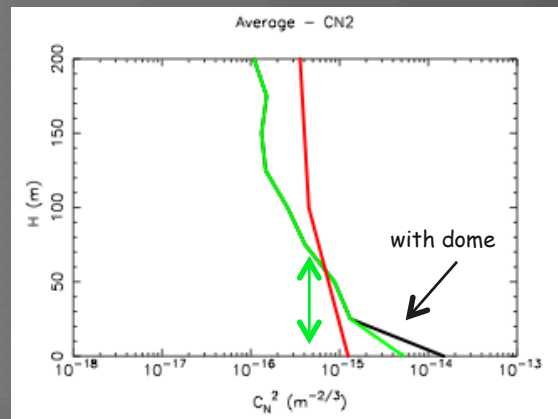
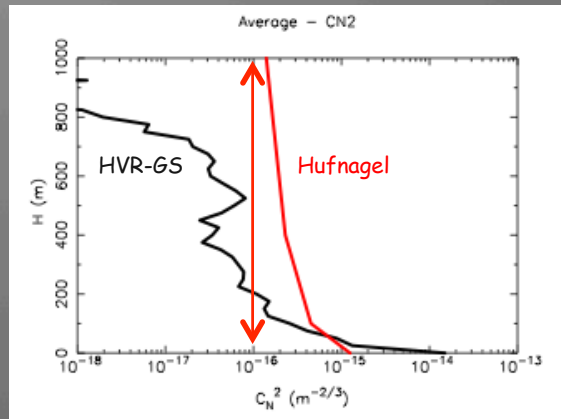


FLAO-performances

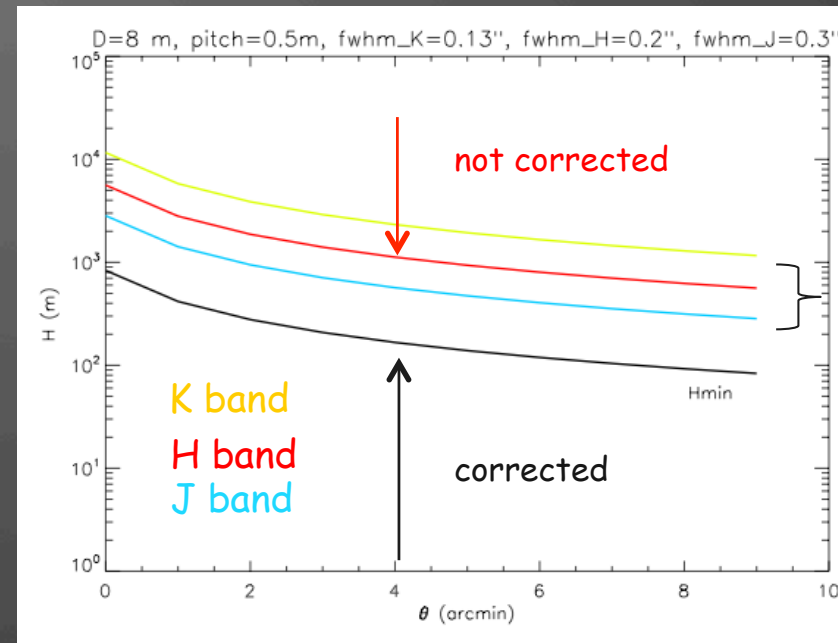
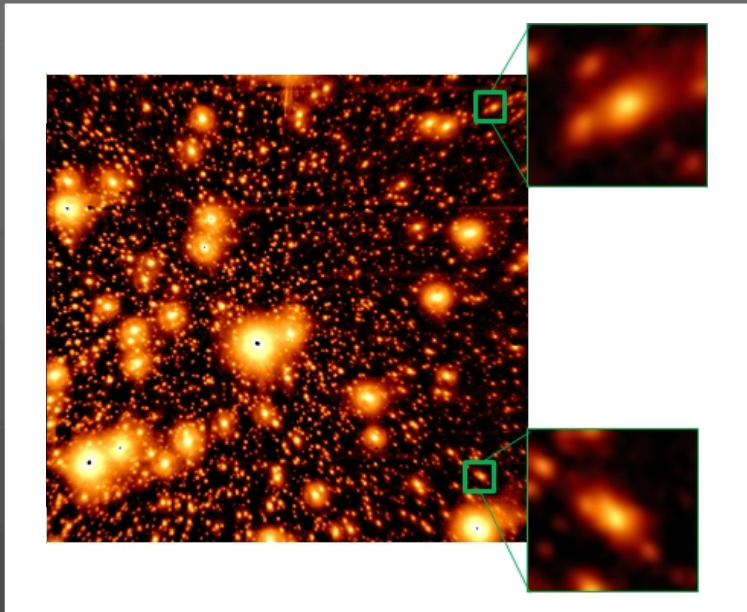
Courtesy: Quiros-Pacheco

Masciadri et al. 2010, MNRAS

★ Optical turbulence vertical distribution at high resolution in [0-1km]: $\Delta h \sim 25\text{-}30\text{ m}$



★ Estimate of the GRAY ZONE in application to GLAO systems (ARGOS)

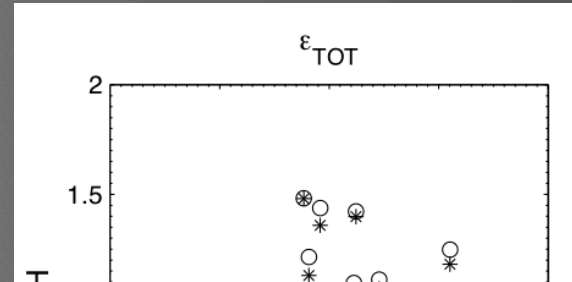
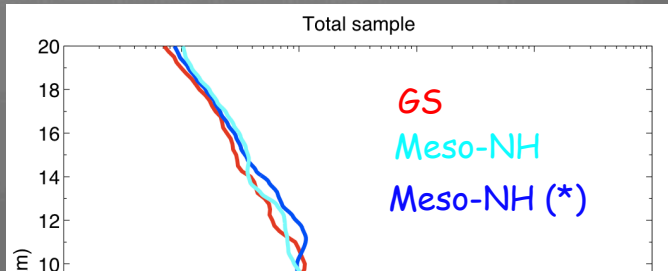


$$H_{\text{max}} = r/\theta$$

Mt. GRAHAM: Meso-NH model validation

Hagelin et al., 2011, MNRAS

Generalized Scidar 41 nights - uniformly distributed in the year



* Meso-NH
○ Meso-NH (*)

Masciadri & Jabouille, 2001

TOTAL SAMPLE

	Relative error (%)		
	$\Delta\epsilon_{TOT}$	$\Delta\epsilon_{BL}$	$\Delta\epsilon_{FA}$
Total	3.6	9.2	0.4
Summer	13.5	11.6	13.0
Winter	10.1	14.9	6.3

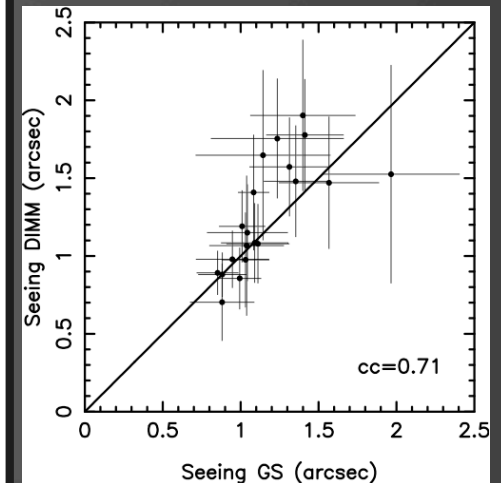
41 nights

15 nights

26 nights

GS: dome seeing subtracted from the boundary layer

MNH: first 20 m subtracted from the boundary layer
(20m = height of the telescope)

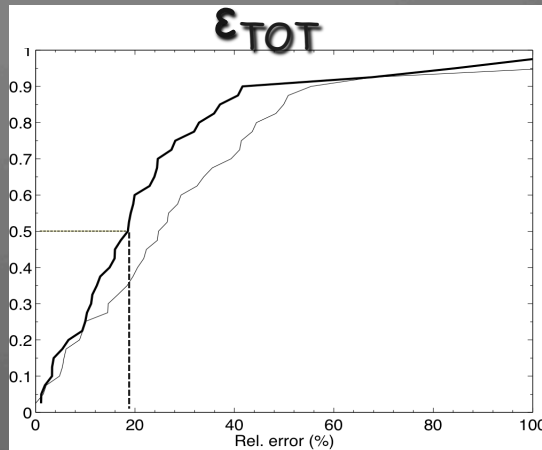


PARANAL - 20 nights
GS vs. DIMM

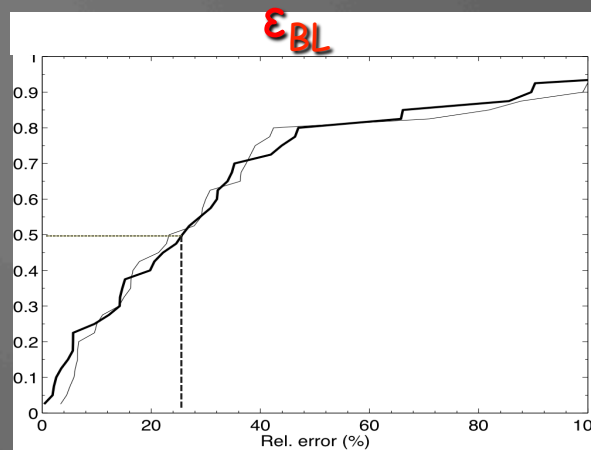
Mt.GRAHAM: RELATIVE ERROR - SINGLE NIGHTS

Hagelin et al., 2011, MNRAS

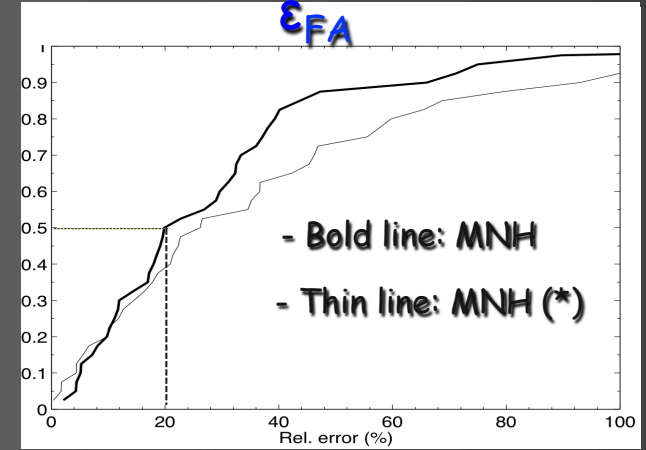
Cumulative distribution of the relative error for single nights



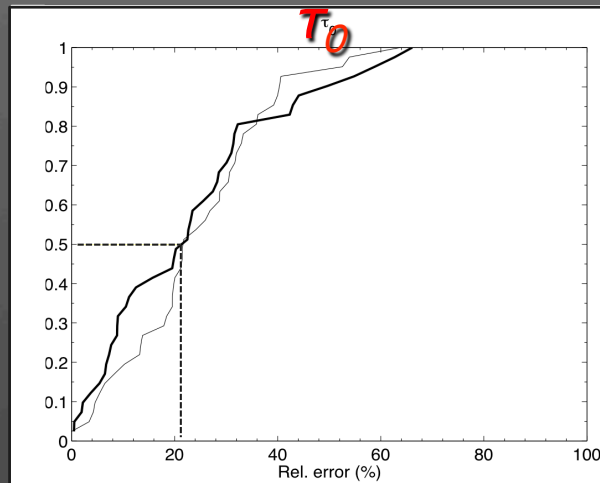
18.7%



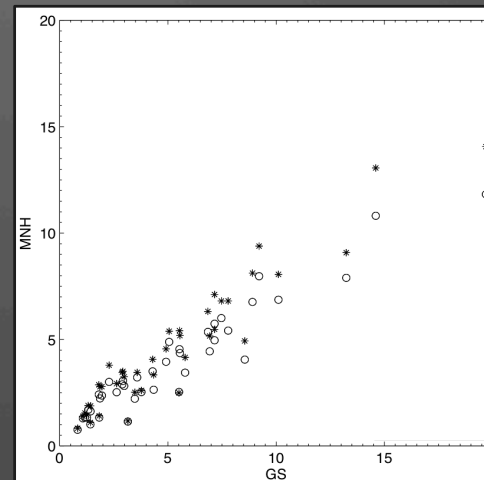
26.3%



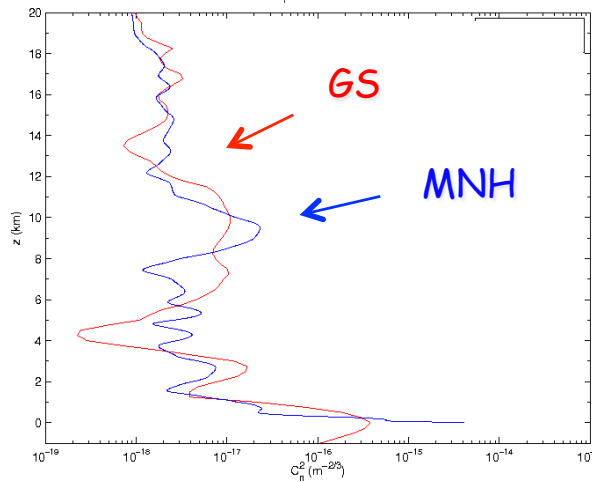
20%



22.5%



Mt. Graham - Night of 2/2008

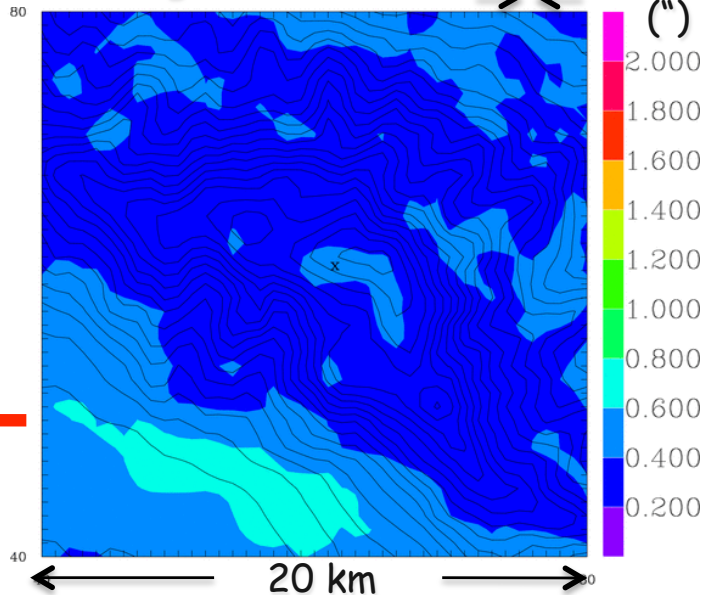


average

$$\epsilon_{\text{MNH}} = 0.57''$$

seeing

$\Delta x = 500\text{m}$



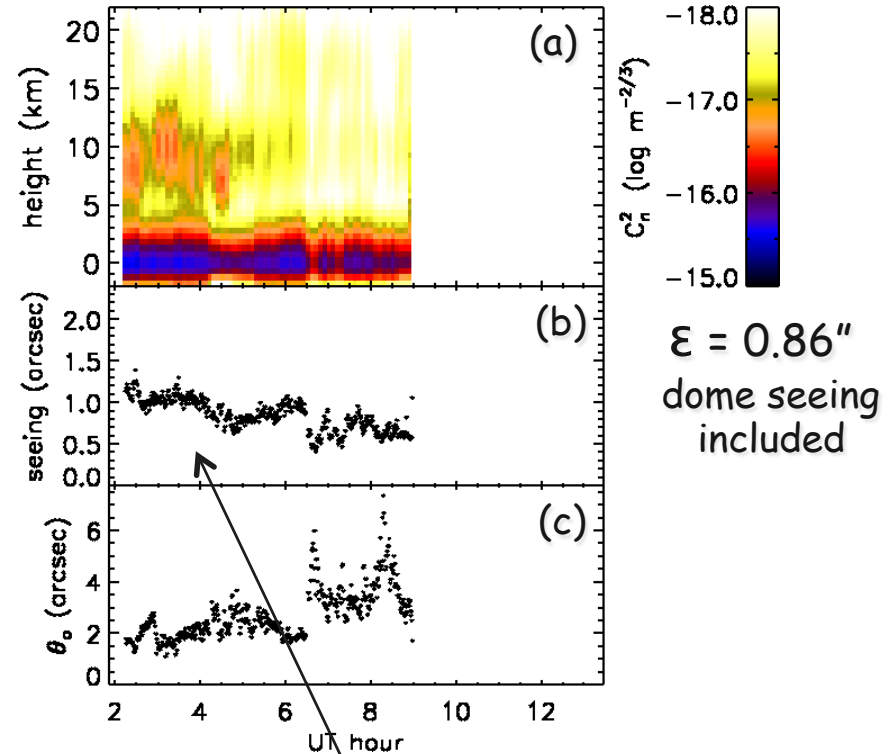
VATT

DATE MOD. 2008/ 2/29 0H 0M 0S DATE CUR. 2008/ 2/29 0H10M 0S

SIMULATIONS with the non-hydrostatic atmospherical meso-scale model (Meso-Nh)

$\Delta T = 12$ hours: (00:00 - 12:00) UT; sampling=10 min

Generalized Scidar MEASUREMENTS



- (a) Temporal evolution of the optical turbulence vertical distribution (C_n^2 profiles).
- (b) Temporal evolution of the seeing ϵ
- (c) Temporal evolution of the isoplanatic angle θ_0

average

$$\epsilon_{\text{GS}} = 0.53''$$

dome-seeing excluded



MODEL VALIDATION ON DOME C: ($h_{sl}, \epsilon_{TOT}, \epsilon_{FA}$)

C_N^2 in winter time associated to 15 nights - (balloons)

Trinquet et al. 2006

Surface thickness: h_{sl}

$$\frac{\int_{8m}^{h_{sl}} C_N^2(h) dh}{\int_{8m}^{1km} C_N^h(h) dh} < 0.90$$

STAT	OBS (m)	MODEL (m)	
		$\Delta X=1km$	$\Delta X=100km$
median	35.3	44.2	68.4
σ	19.9	24.6	26.5

grid-nesting

monomodel

Good correlation
measurements/simulations
with the grid-nesting configuration

Lascaux, et al., 2009, MNRAS
Lascaux et al., 2010, MNRAS

$$\epsilon_{TOT} \sim \left(\int_{8m}^{h_{top}} C_N^2(h) dh \right)^{-3/5}$$

$$\epsilon_{FA} \sim \left(\int_{h_{sl}}^{h_{top}} C_N^2(h) dh \right)^{-3/5}$$

High resolution - $\Delta X=1km$

STAT	OBS (°)		SIM (°)	
	ϵ_{TOT}	ϵ_{FA}	ϵ_{TOT}	ϵ_{FA}
median	1.60	0.30	1.70	0.30
σ	0.70	0.70	0.77	0.67

very good correlation !!!

ANTARCTICA: RESULTS

Lascaux et al., 2011, MNRAS

	h_{sl} (m)	σ	$\sigma/\sqrt{N}$	ϵ_{FA} (arcsec)	σ	$\sigma/\sqrt{N}$	ϵ_{TOT} (arcsec)	σ	$\sigma/\sqrt{N}$
Observations – Dome C	35.3	19.9	5.1	0.30	0.70	0.20	1.60	0.70	0.20
Meso-NH – Dome C	44.2	24.6	6.6	0.30	0.67	0.17	1.70	0.77	0.21
Meso-NH – Dome A	37.9	30.2	8.1	0.23	1.08	0.28	2.37	1.03	0.27
Meso-NH – South Pole	165.0	67.3	17.4	0.36	0.43	0.11	1.82	0.90	0.23

15 nights

$\Delta X = 1\text{km}$

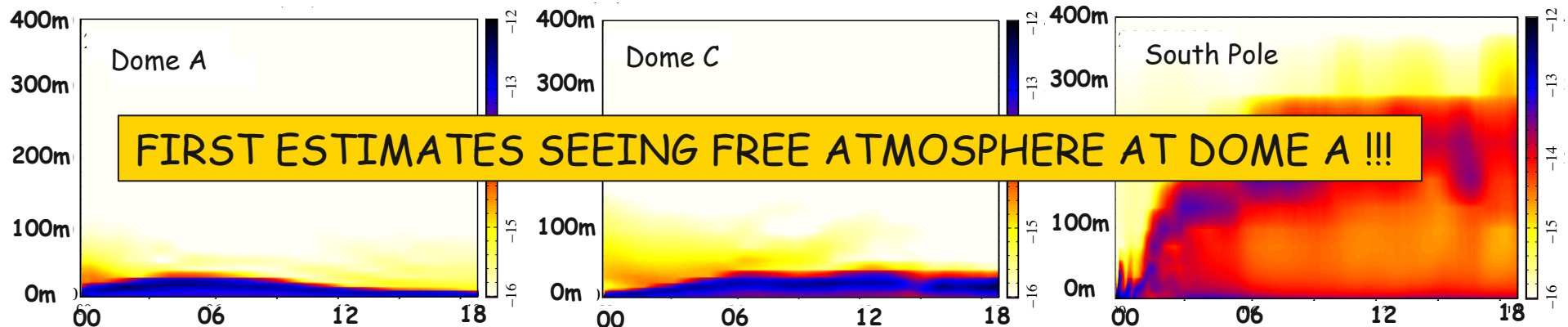
MEASUREMENTS

- South Pole: $h_{sl} = 220\text{m}$
 $\epsilon_{TOT} = 1.86\text{arcsec}$
 $\epsilon_{FA} = 0.37\text{arcsec}$

Marks et al. 1999 - balloons C_N^2

- Dome A: still NO seeing measurements (expected best site in the world...)

C_N^2 temporal evolution



On-going project:



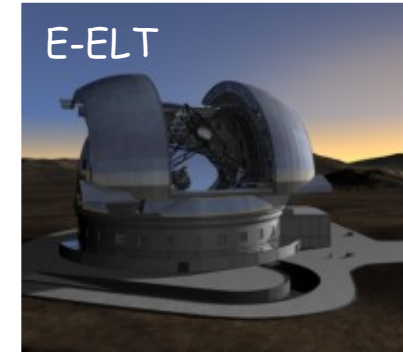
Modeling ESO Sites



Cerro Paranal

GOAL

Feasibility study to set-up a system for the forecast of the Optical Turbulence (C_N^2) and all the main integrated astroclimatic parameters (ϵ , θ_0 , τ_0)



Cerro Armazones

OVERCOME MAJOR LIMITATIONS

- 1) Difficulty in having independent samples of measurements for the model calibration and model validation to estimate if and how the correlation between calculations/measurements decreases with increasing the number of nights
- 2) Difficulty in having a large number of simultaneous measurements done with different and independent instruments for the OT estimate (vertical profilers) to quantify the model score of success

Special Project at the European Centre for Medium Weather Forecasts (ECMWF)

2 IBM POWER 6 Clusters

- 264 standard nodes with 32 CPUs and 64 Gb memory
- 8 high memory compute nodes with 32 CPUs and 256 Gb memory
- around 8500 physical processors in total
- Operating System: AIX 5.3

For each processor

- Clock frequency: 4.7 GHz
- Peak performance: 18.8 Gflops

SPITFOT Project: 2011-2013

PI: E. Masciadri: 400000 SBU x 3

Title: Optical Turbulence modeling for
astronomical applications: towards the ELTs



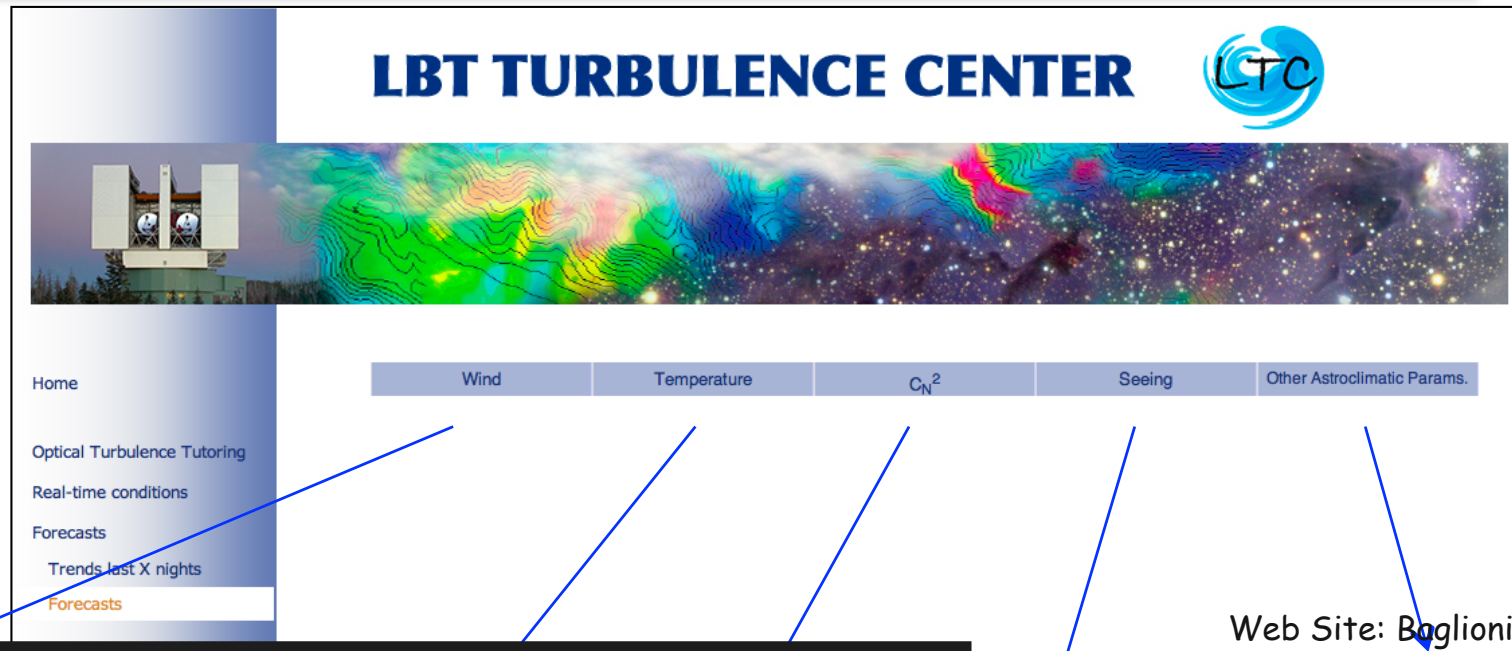
- faster calibration
- richer statistic
- higher resolution

Simulations with 64 proc. at ECMWF





LTC: LBT Turbulence Center



Ve
Te
Ho
Ho

TECNO 2011 (submitted)
extension of LTC at a national level

- Osservatorio Astrofisico di Arcetri (Coordinator)
- Osservatorio Astronomico Bologna
- Dipartimento Astronomico Universita' di Padova
- TNG

Web Site: Baglioni

Temporal evolution
Horizontal map average
Horizontal map median
Horizontal map animation

Temporal evolution
Horizontal map average
Horizontal map median
Horizontal map animation

== OTHAR ==

Conclusions

- ForOT successfully concluded: all objective achieved
- Setting-up of an independent research group (intense activity of training)
- Astro-Meso-Nh code has been parallelized by our group and it is run locally
- Extended site testing campaign at Mt. Graham (2006-2010)
- Contribution to ARGOS (Phase A)
- Very positive feedback after ForOT: contract with ESO (MOSE)

PROJECTS (since 2006)

ForOT (EU-PI: Masciadri)

MOSE (ESO: PI: Masciadri)

ForOT@DC (PNRA: (INAF-Arcetri, UNSW, Enea - mark: excellent) (PI: Masciadri)

STABLEDC (PNRA: CNR-ISAC Roma, INAF-Arcetri, ISAC, Lecce) (PI: Argentini)

SPITFOT (2011-2013, Special Project - ECMWF): 400.000 SBU x 3 (PI: Masciadri)

LTC: (PI: Masciadri - stand-by for lacking of funds)

TECNO 2011 (submitted) (PI: Masciadri)

most of projects with PI from INAF-Arcetri

man power critical mass

Suitable 2 positions: 1 modeling, 1 instrumental

the most urgent thing at present: 1 stable position (modeling)

OT HAR