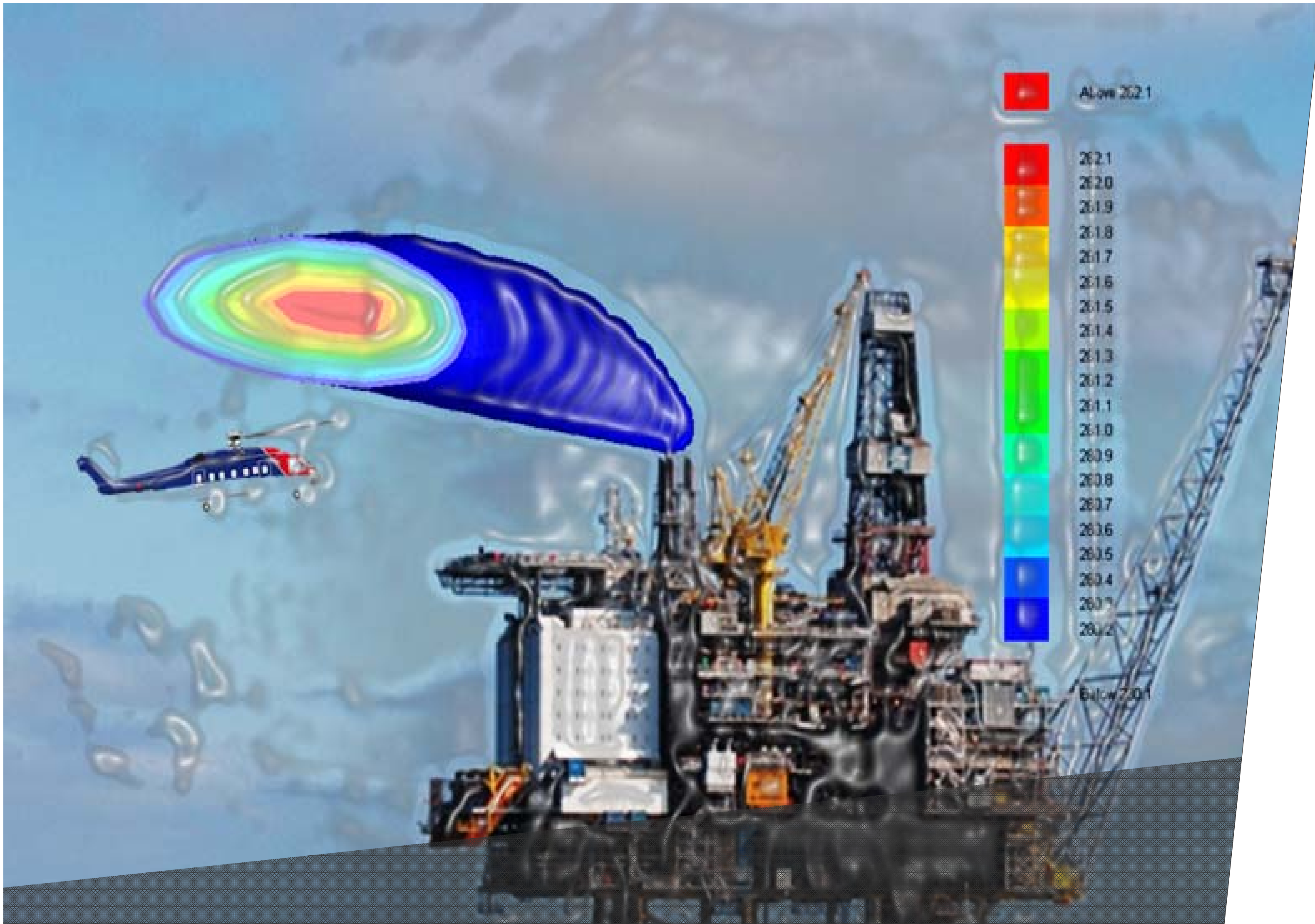

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Bristow

Pro-active approach to control the risk of exposure to hot gas emission during helicopter operations

Olav Sæter and Erik Hamremoen, Statoil

Sigmund Lockert, CHC Helikopter Service

Arne Martin Gilberg, Bristow Norway AS

69th HELICOPTER SAFETY RESEARCH MANAGEMENT COMMITTEE, Gatwick London, UK, November 18, 2014

Triggering events

- On 7/9/2009 Bristow Norway –S-92.
  During Take off from the rig, the crew heard a loud bang from behind the cockpit, right after CDP. Crew observed engine surges and NR surges, as the AC accelerated through 40 Kias. The HLO reported seeing smoke briefly exit exhaust. The pilots confirmed that the wind direction may have carried some hot gases from the rig turbine exhaust stack.

- On 26/10/2011 CHC Norway –S-92.
  Pilots reported engine stall noises during T/O from rig. Suspect hot air gas ingestion from rig turbine exhaust.

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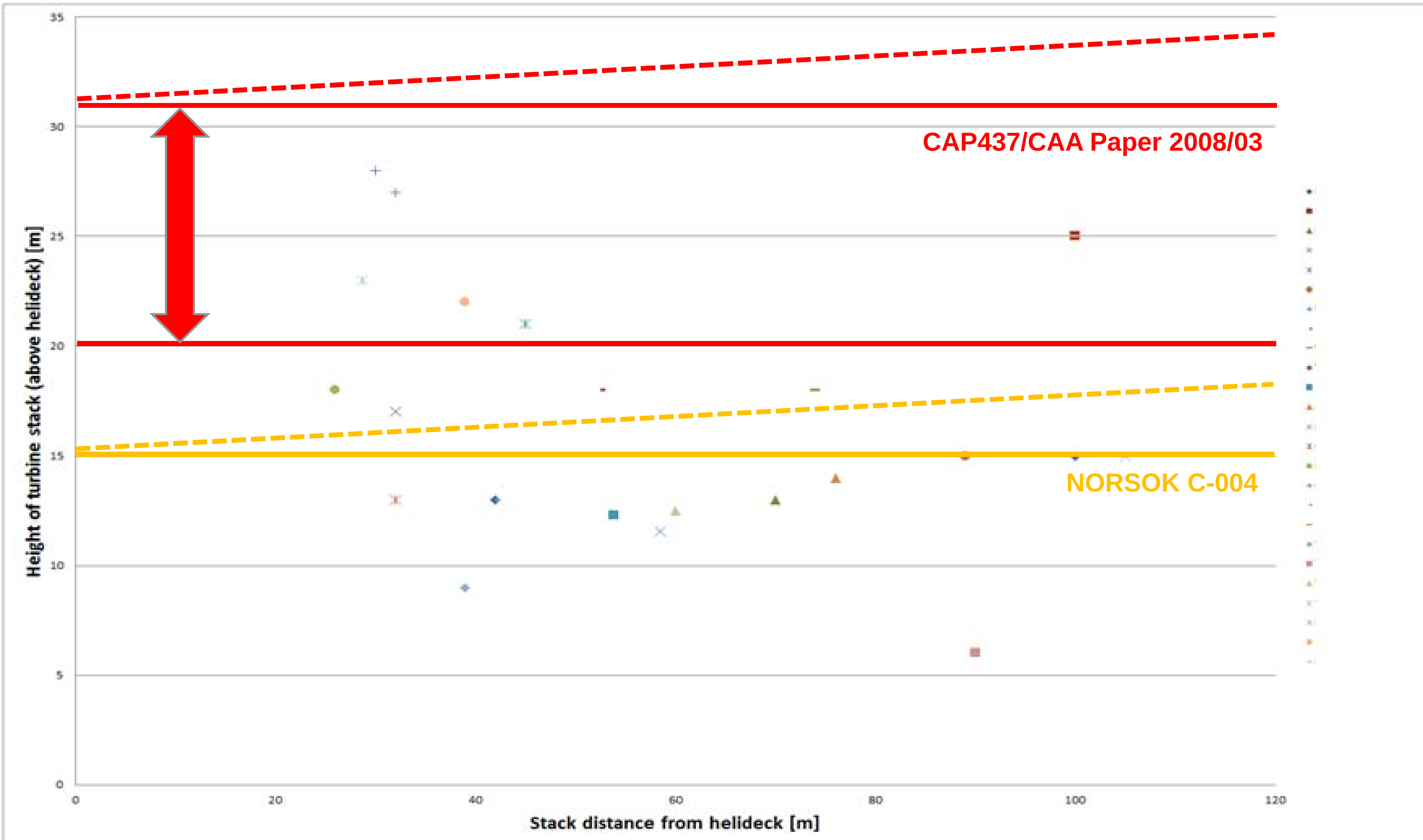
Existing installations (design criterias)



Outline

- Background
- **Guidelines**
- Assessment
- Methodology
- Practical application
- Implementation
- Summary
- Questions



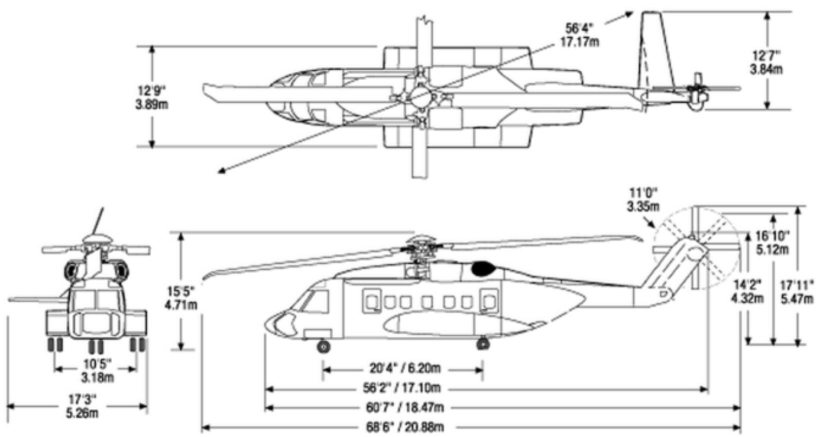
Guidelines hot air exposure

- CAP437 «Standards for Offshore Helicopter Landing Areas»
  - CAA Paper 2008/03 “Helideck Design Considerations - Environmental Effects”

- NORSOK C-004 «Helicopter deck on offshore installations”

CAP437 – Design criteria

- Volume of airspace:
  - «When considering the volume of airspace to which the following criteria apply, installation designers should consider the airspace up to a height above helideck level which takes into consideration the requirement to accommodate helicopter landing and take-off decision points or committal points. This is deemed to be up to a height above the helideck corresponding to 30 ft plus wheels-to-rotor height plus one rotor diameter.»
    - S-92 = 30 ft + 15.5 ft + 56.4 ft = 101.9 ft ~ 102 ft
    - S-92 = 9.14 m + 4.72 m + 17.17 m = 31.03 m ~ 31 m



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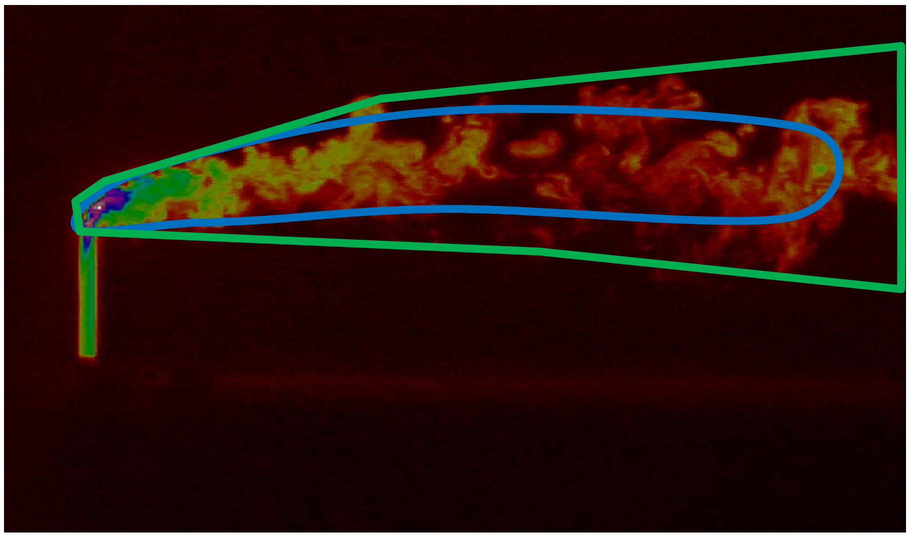
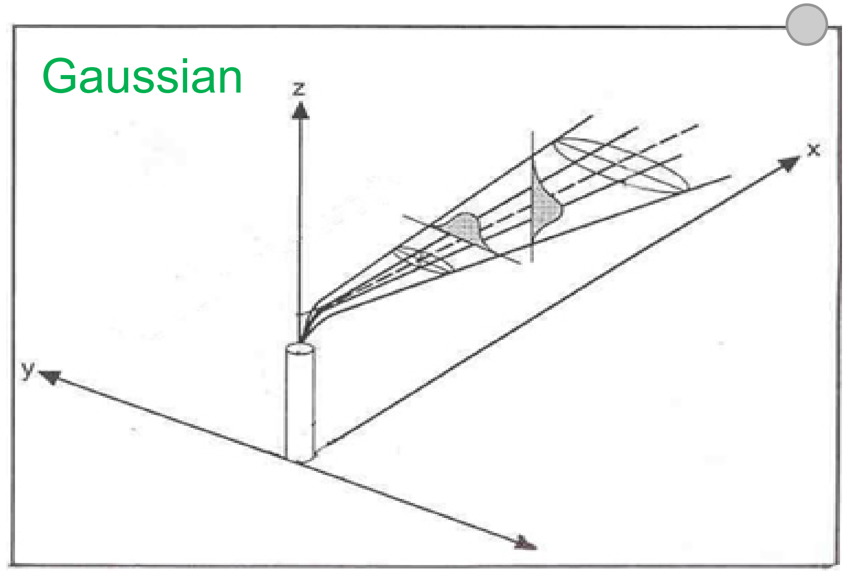
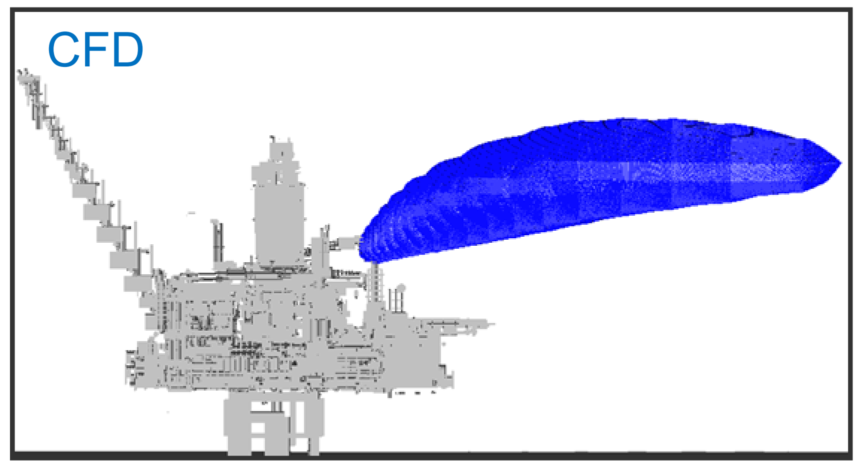
Models

- Gaussian and CFD models gives time-averaged solutions







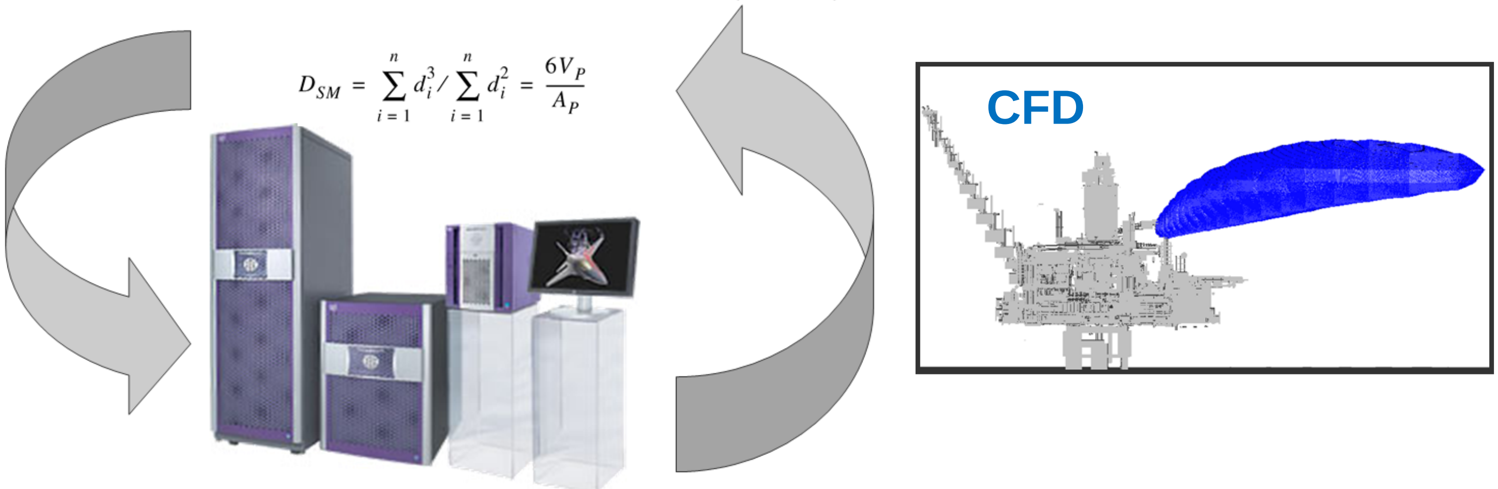
Computational Fluid Dynamics (CFD)

- Numerical methods and algorithms to solve and analyze problems that involve fluid flows. Computers are used to perform the calculations required to simulate the interaction of liquids and gases with surfaces defined by boundary conditions.

$$We = \rho_g U_{rel}^2 d_p / \sigma_{pg}$$

$$\frac{\partial}{\partial t}(\beta_v \phi_p) + \frac{\partial}{\partial x_j}(\beta_j u_{pj} \phi_p) = \frac{\partial}{\partial x_j}\left(\beta_j \mu_p \frac{\partial \phi_p}{\partial x_j}\right) + S_\phi$$

$$D_{SM} = \sum_{i=1}^{n} d_i^3 / \sum_{i=1}^{n} d_i^2 = \frac{6V_P}{A_P}$$



- The fundamental basis of CFD problems are the Navier–Stokes equations, which define any single-phase fluid flow.
- In this study the CFD-code FLACS is used (GexCon, Norway)

CAP437 – Design criteria

- Tools:
  - «Gaussian dispersion model and supported by wind tunnel tests or CFD studies for new-build helidecks, for significant modifications to existing topside arrangements, or for helidecks where operational experience has highlighted potential thermal problems»
- Temperature criteria:
  - «When the results of such modelling and/or testing indicate that there may be a rise of air temperature of more than 2°C (averaged over a three-second time interval), the helicopter operator should be consulted at the earliest opportunity so that appropriate operational restrictions may be applied»

- CAA Paper 2008/03 (ref):
  - *"To achieve this, it is recommended that the exhaust outlets are no less than 20-30 m above the helideck, depending on the gas turbine flow rates and temperatures."*

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NORSOK C-004

- «The risk of compressor stalling varies with helicopter type. In most cases it increases significantly with a momentary temperature increase of 3°C, or more. The 3°C isotherm shall therefore be at least 15 m above the helideck. Correct sizing and location of exhaust stacks relative to the location of the helideck is imperative. The position of the 3°C isotherm shall be verified through the CFD analysis»

CAP437/NORSOK C-004

S-92	CAP437*	NORSOK C-004**
Height of free airspace	31 m	15 m
Temp. criteria	2°C	3°C
Tools	CFD/Wind Tunnel	CFD

*) Operational and/or design guideline
**) Design guideline

Experienced “best practice“ adapting CAP437

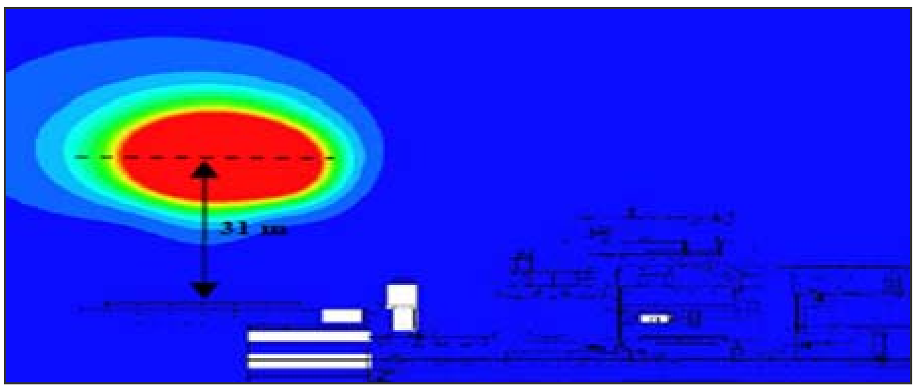
- Lack of applicable temperature criteria with respect to restrictions of type «No fly» has resulted in the industry (operators, contractors and the consultants) to adopt the 2°C temperature criteria for the “No fly” requirement

the results to be able to compare it with the CAP 437.

2.2 Temperature Criterion

The CAP 437 states that the air temperature in the flight paths or landing area of a helicopter should not increase by more than 2°C from the ambient temperature. This criterion applies to the same area as the turbulence criterion above, i.e. from the helideck and 31 meters up.

CFD →



Conclusion →

horizontally before rising above the helideck region. With wind direction from the angles between -37.5° to 55° this will cause unacceptable temperature levels above helideck. The wind speed at which too high temperature levels are obtained is above 10 knots, as previously illustrated in Figure 4.19. Hence, the sector in Figure 5.2 for which

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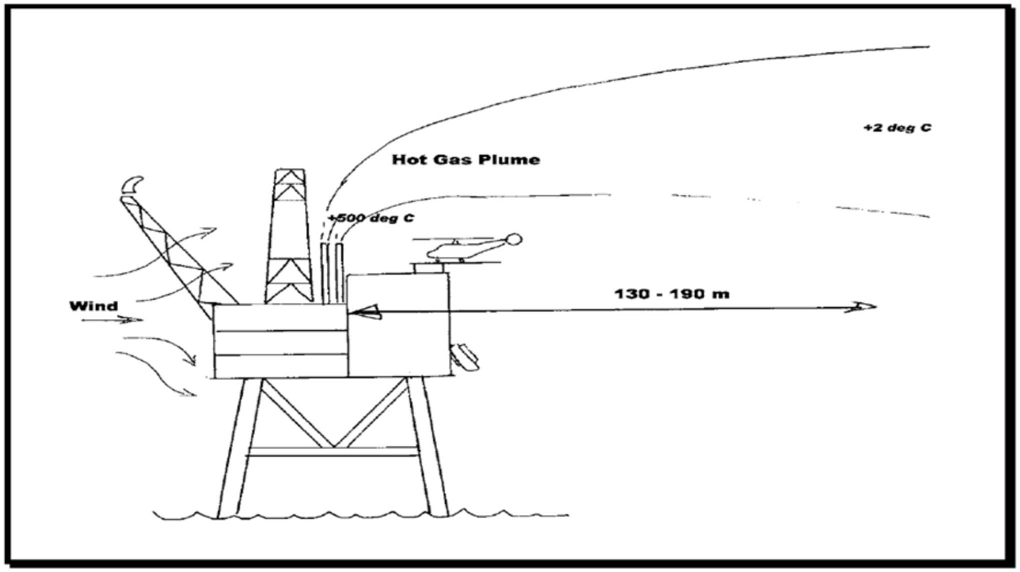
Challenging …….



- Long distance placed turbines (process areas) specially sensitive
  - Longer distance = Higher stacks?

CAP437/NORSOK C-004

S-92	CAP437*	NORSOK C-004**
Height of free airspace	31 m	15 m
Temp. criteria	2°C	3°C
Tools	CFD/Wind Tunnel	CFD

```
*)  Operational and/or design guideline
**) Design guideline
```

- CAP437 (operational):
  - It is up to the helicopter operators to enforce restrictions based on the studies
  - Suggested possible measures:
    - Adjustment of payload in order to have sufficient performance at the helideck approach.
- CAP437 (design ref. CAA Paper 2008/03):
  - *"To achieve this, it is recommended that the exhaust outlets are no less than 20-30 m above the helideck, depending on the gas turbine flow rates and temperatures."*

Outline

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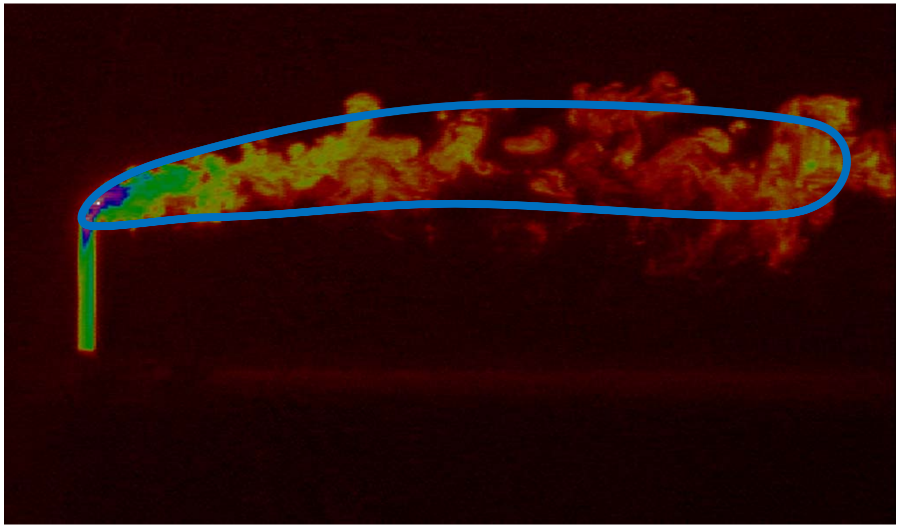
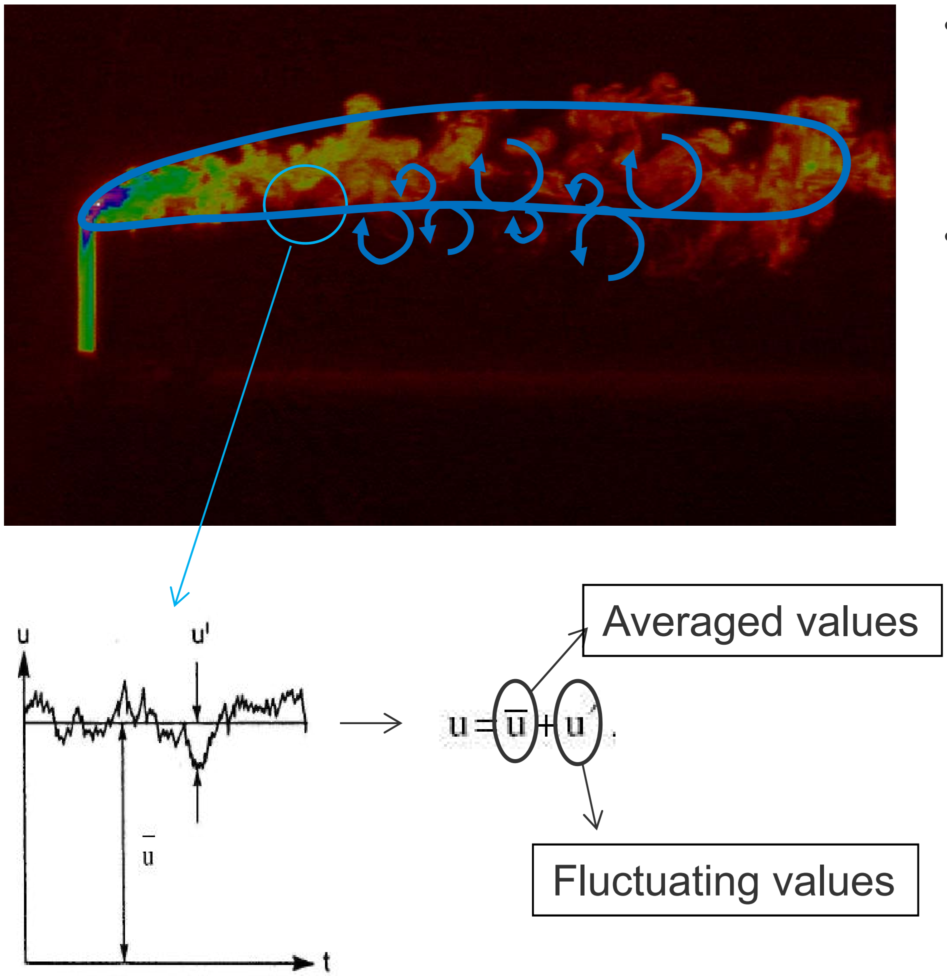
Turbulent phenonema and averaged solutions



Turbulent phenonema and averaged solutions



- CFD with turbulence equation gives by definition “time- and space-averaged” solutions

- However:
  - CFD is considered to be the best available industrial tool.
  - CFD gives a fairly good macro description of the main fluid flow across a platform, and it handles the energy/turbulence equations.
  - CFD solutions should be used to examine the vertical/(and horizontal) temperature gradient in the airspace volume in order to take into account exchange of mass and energy transported by the turbulent eddies.

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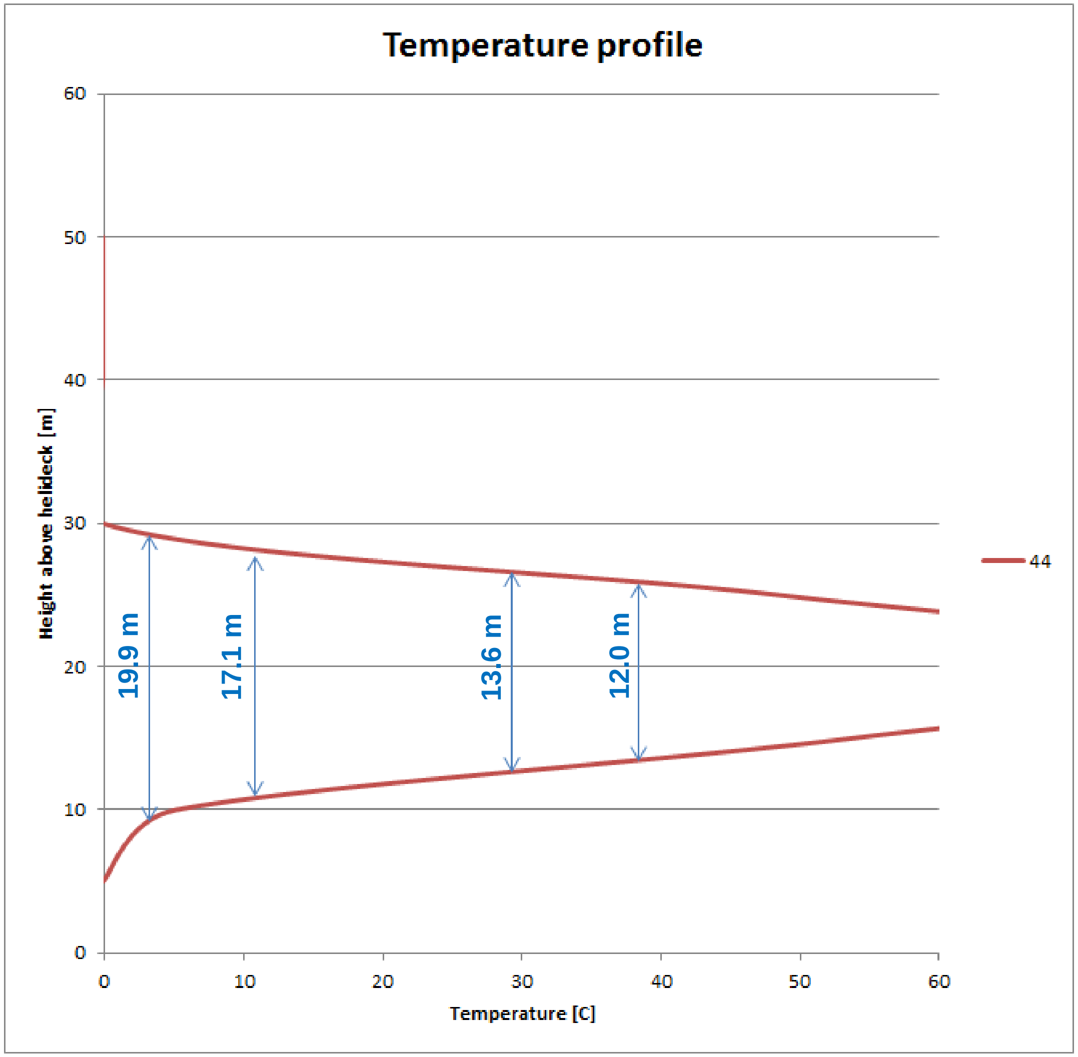
Meeting with Peutz June 2013

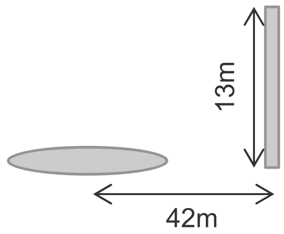
- One day meeting in Stavanger with Peutz (5th of June 2013):
  - Ferry Koopmans (Peutz)
  - Niels Moonen (Peutz)

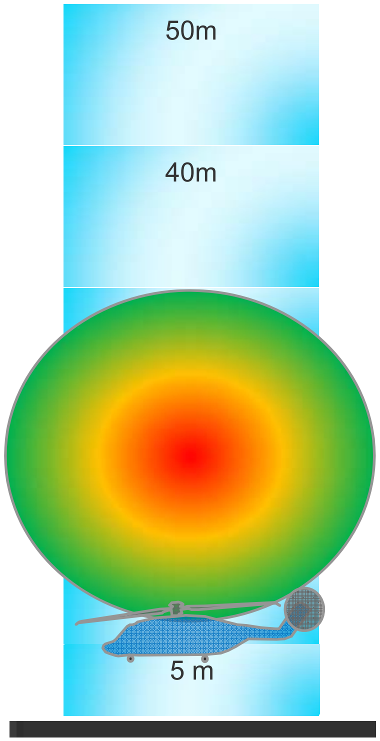
- Main outcome (MoM):
  - Unified and common understanding of the risk picture

    «..the proposed CFD approach ..(Norsok C-004).. is indirectly reflecting the risk of concern as stated in the CAP437 based on a time averaged temperature vertical gradient analysis.»

Plume properties (44kt, 57MW)







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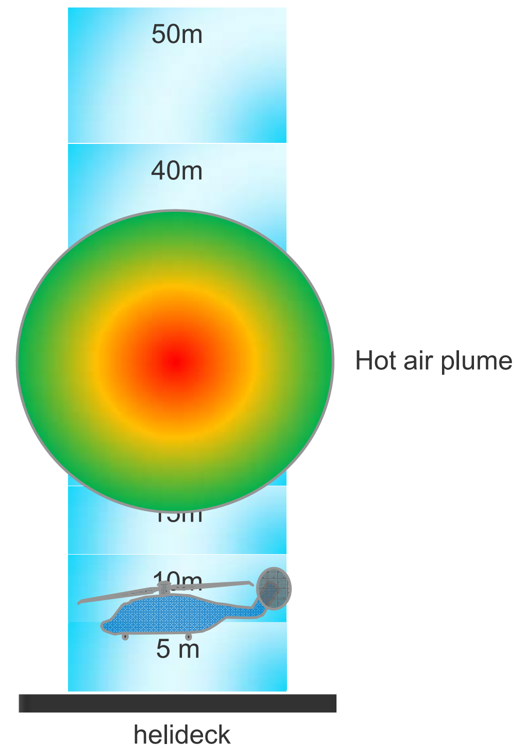
Temperature gradient matrix

TGM

Height above helideck ; m (ft)						
	> 50 (164)					
	< 40 (131)		X			
	< 30 (98)		X	X	X	X
	< 25 (82)		X	X	X	X
	< 20 (65)		X	X		
	< 15 (49)		X			
	< 10 (33)					
	< 5 (16)					
Temperature rise above ambient (^{o}C) *		0 <= 2	> 2	> 10	> 30	> 40

*) Max temperature @ Volume> 10m3 monitored in a virtual cylindrical volume centrally on helideck with a diameter of 20 mete

**) Wind at 100 meters level above seasurface



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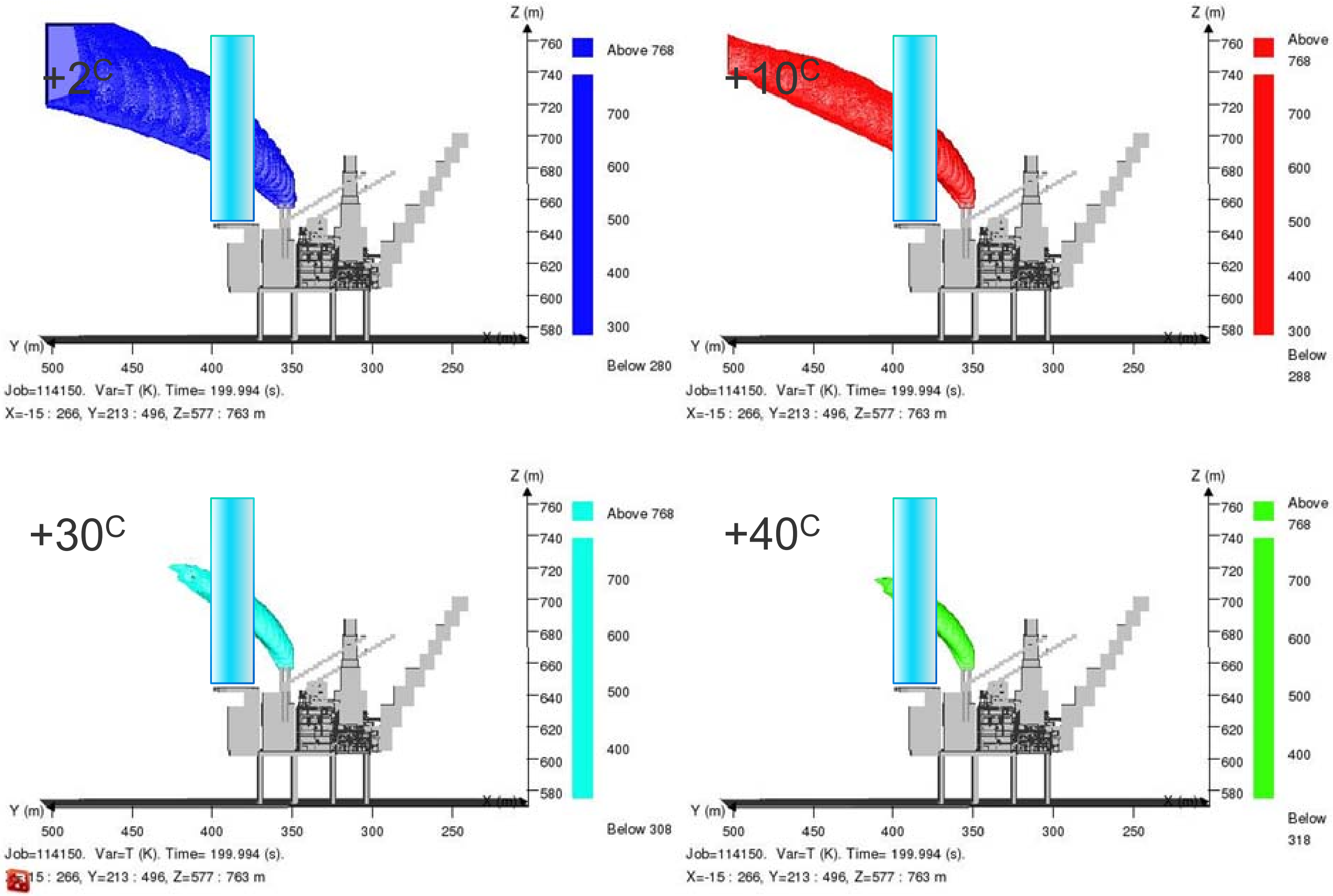
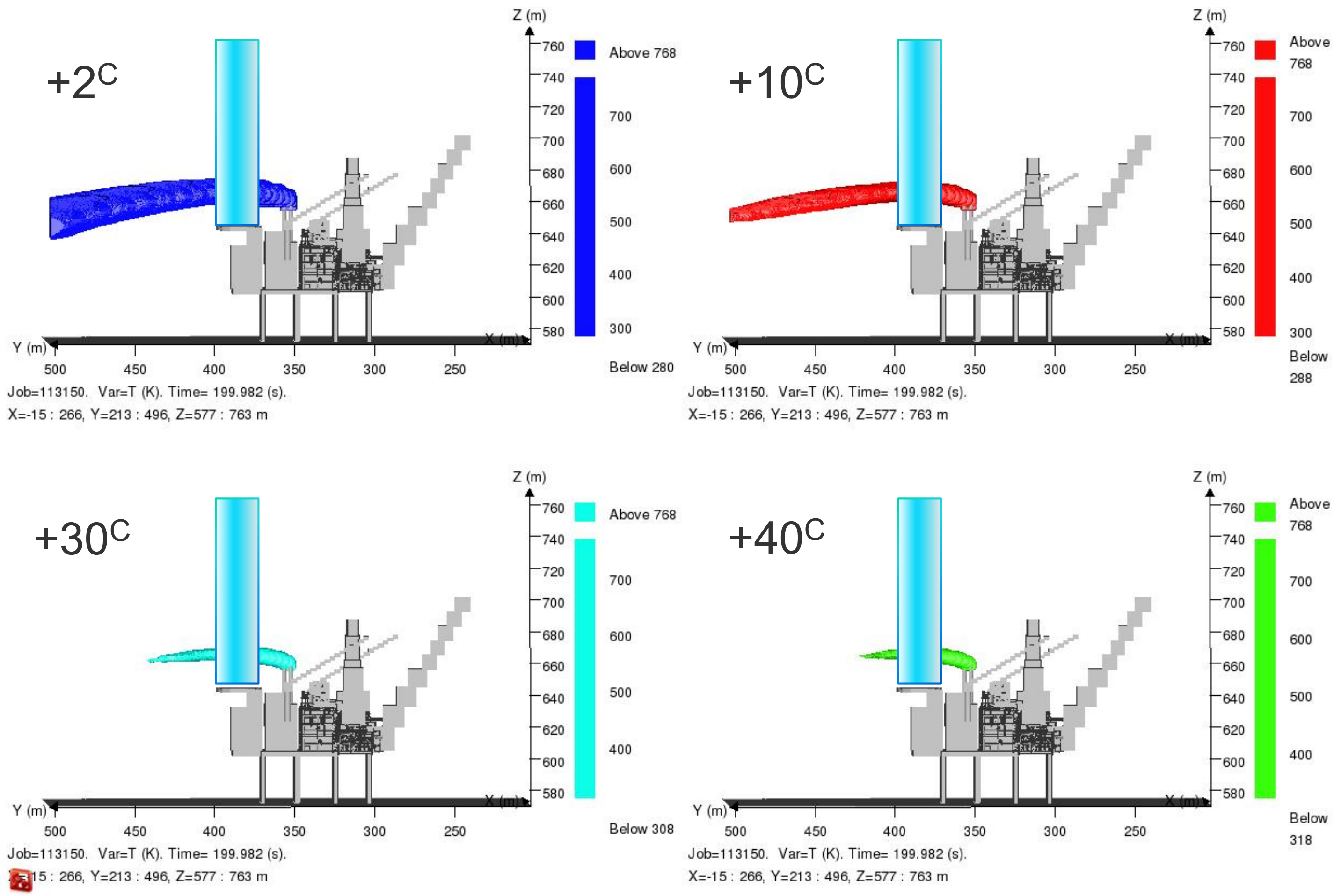
Effect of wind
CFD-calculations

WIND = 10 kt



+2C
Z (m)
760
740
720
700
680
660
640
620
600
580
Above 768
700
600
500
400
300
Below 280
Y (m)
X (m)
500
450
400
350
300
250
Job=114150. Var=T (K). Time= 199.994 (s).
X=-15 : 266, Y=213 : 496, Z=577 : 763 m
+10C
Above 768
700
600
500
400
300
Below 288
Job=114150. Var=T (K). Time= 199.994 (s).
X=-15 : 266, Y=213 : 496, Z=577 : 763 m
+30C
Above 768
700
600
500
400
Below 308
Job=114150. Var=T (K). Time= 199.994 (s).
15 : 266, Y=213 : 496, Z=577 : 763 m
+40C
Above 768
700
600
500
400
Below 318
Job=114150. Var=T (K). Time= 199.994 (s).
X=-15 : 266, Y=213 : 496, Z=577 : 763 m

WIND = 40 kt



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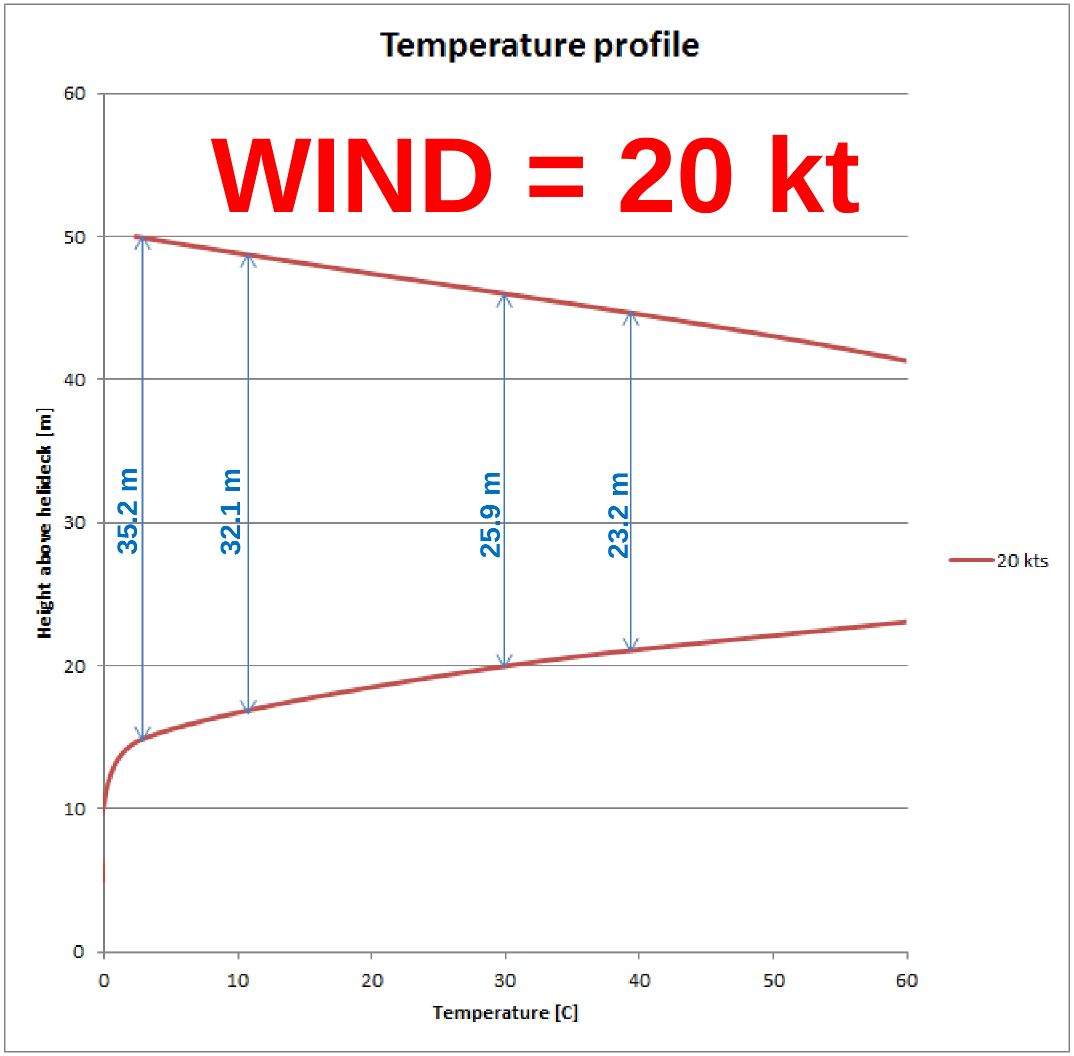
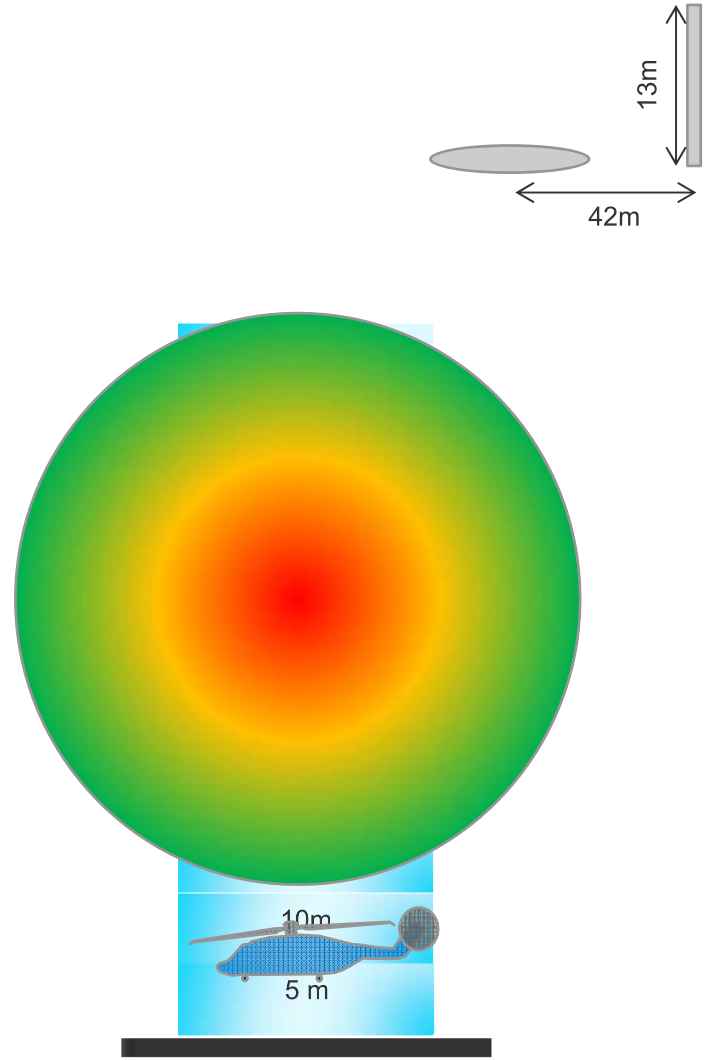
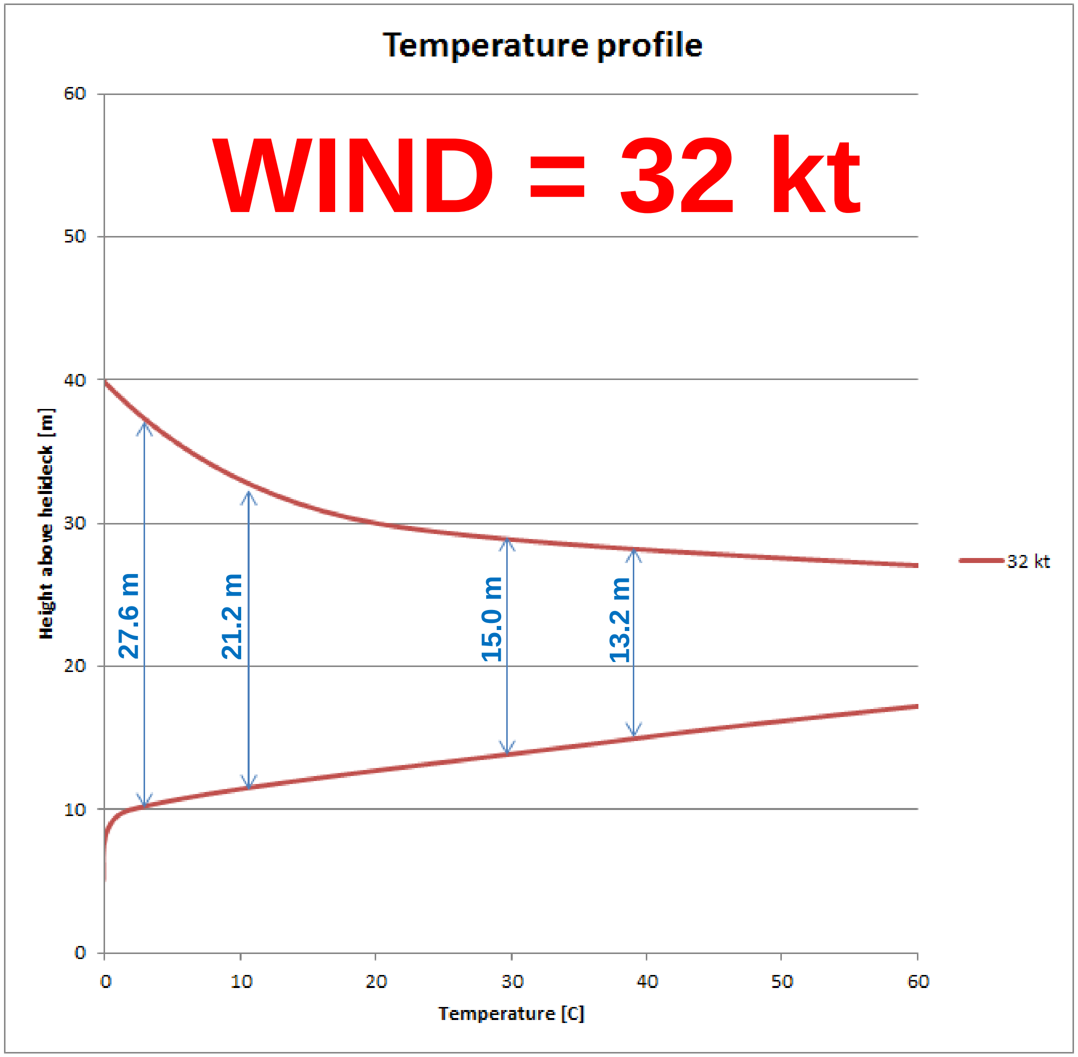
Effect of wind
Temperature profile from CFD-calculations

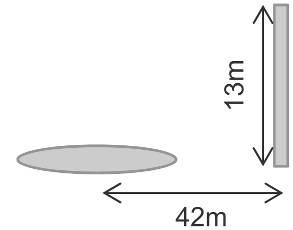
Plume properties (57MW)

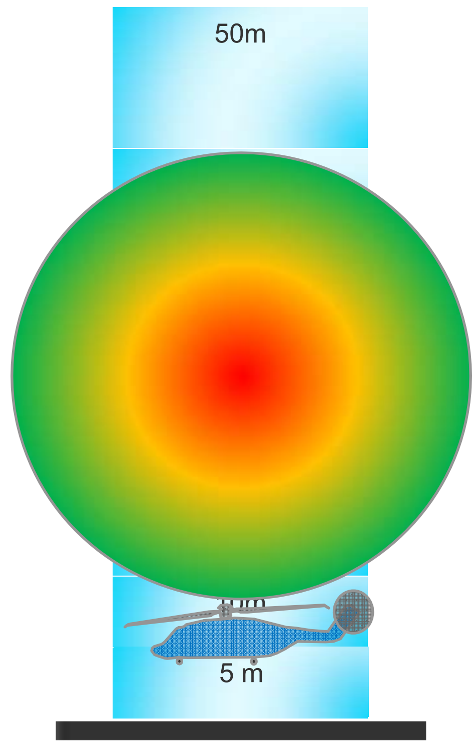




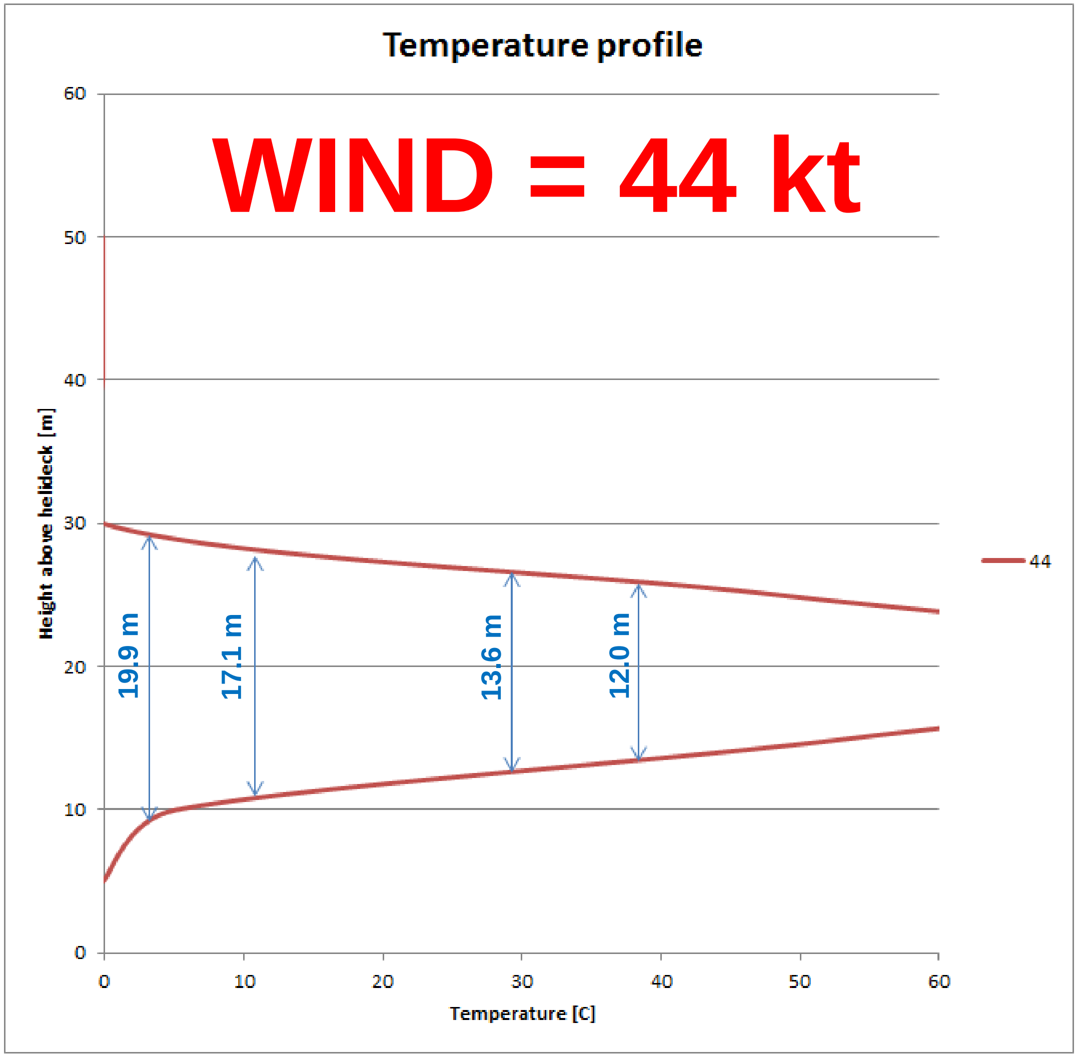
Plume properties (57MW)

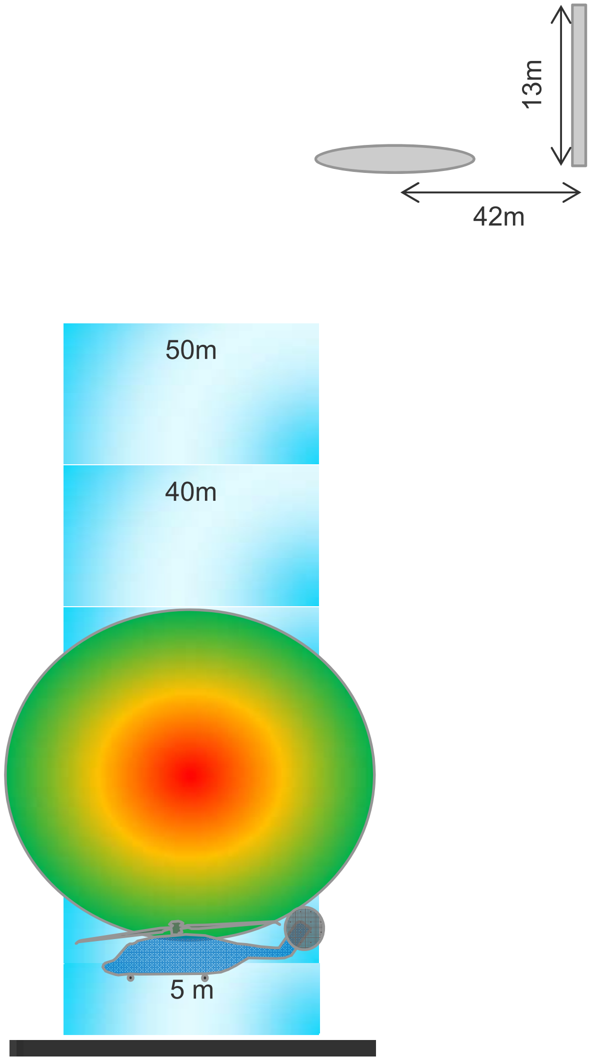






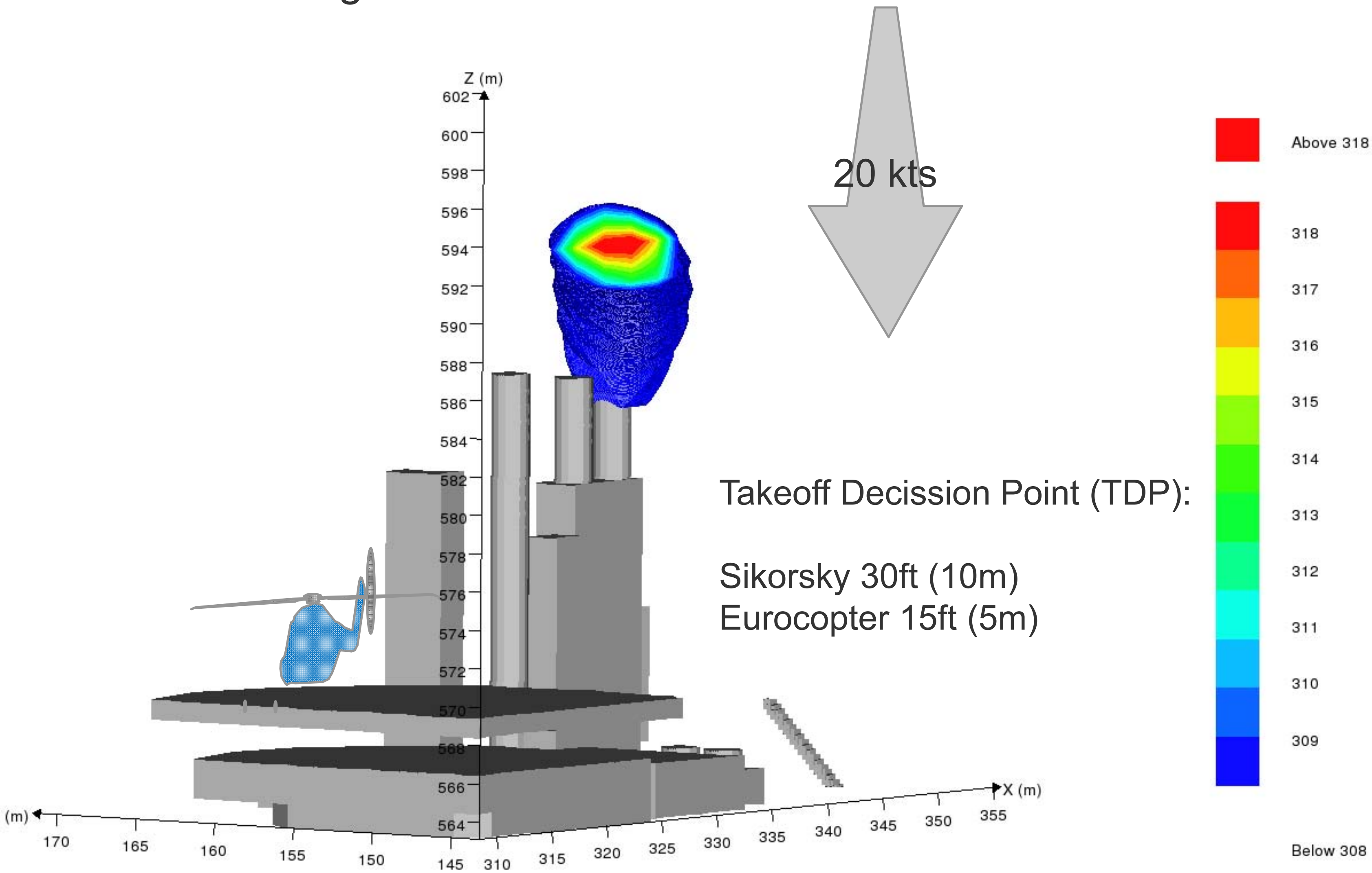
Plume properties (57MW)





Operational assessment

Takeoff from rig



Takeoff Decission Point (TDP):

Sikorsky 30ft (10m)
Eurocopter 15ft (5m)

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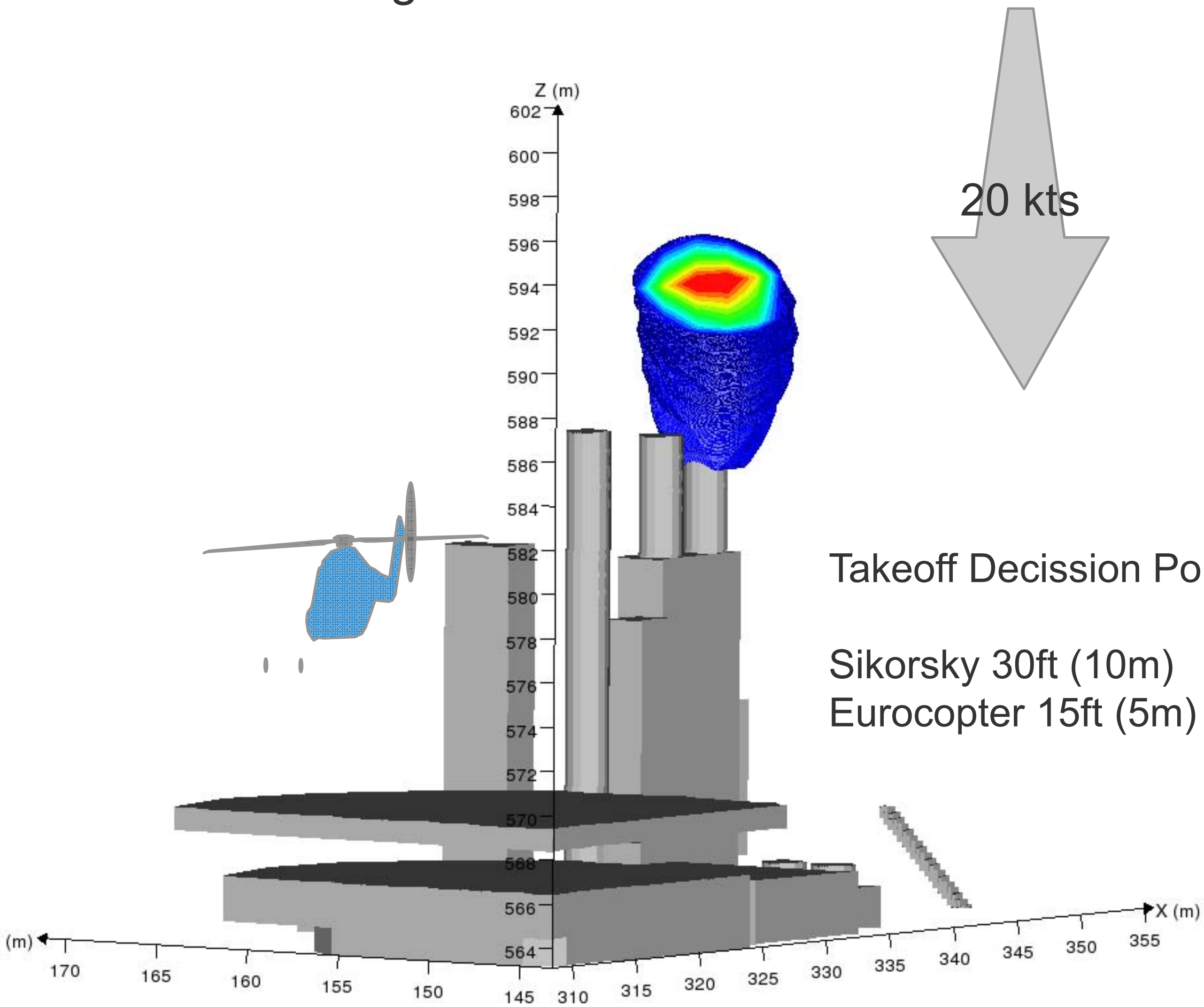
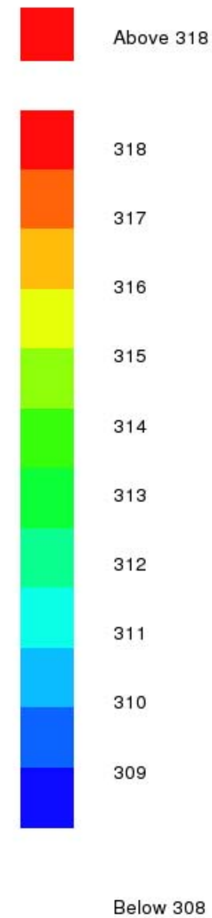
Takeoff from rig

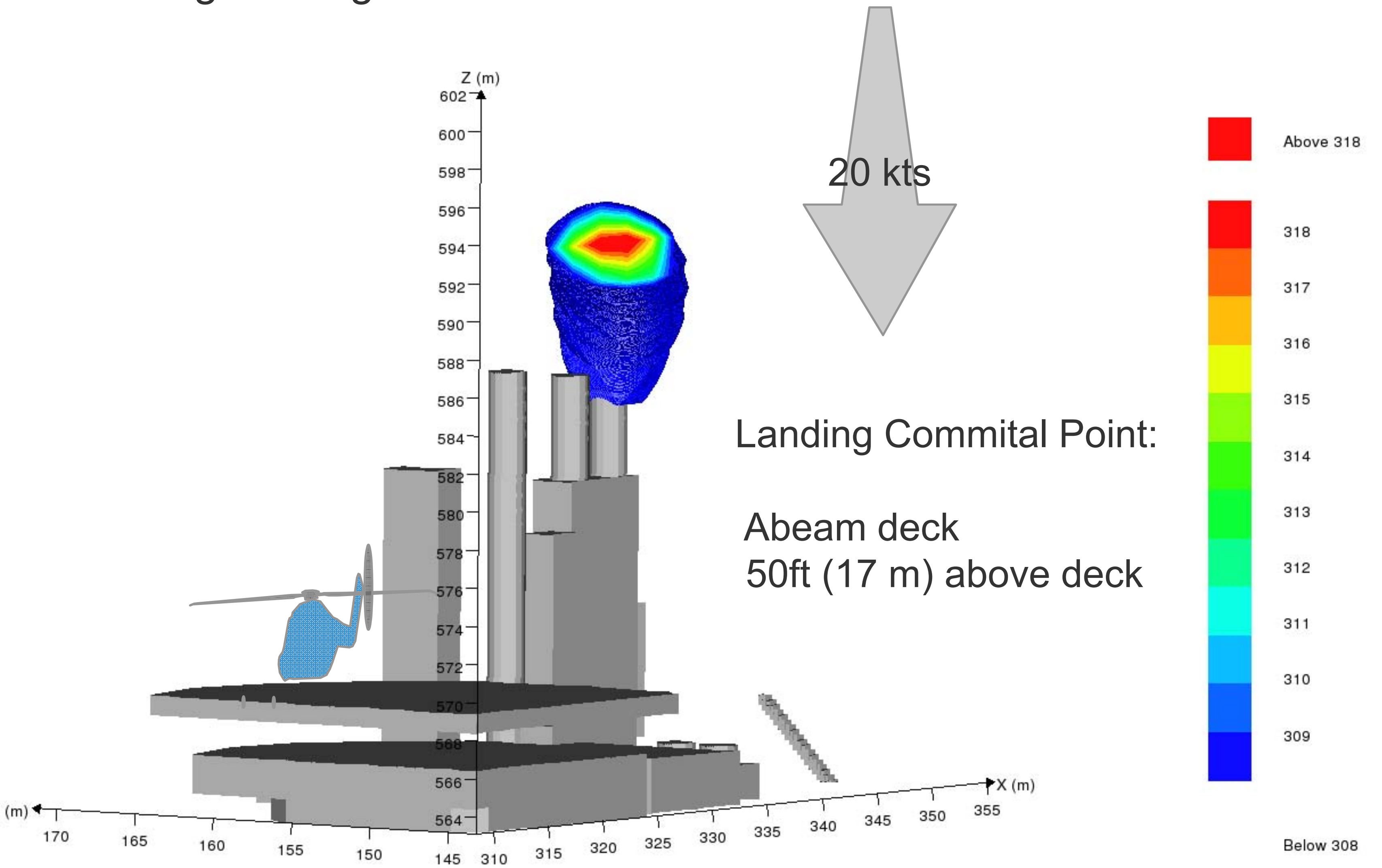


Takeoff Decission Point (TDP):

Sikorsky 30ft (10m)
Eurocopter 15ft (5m)



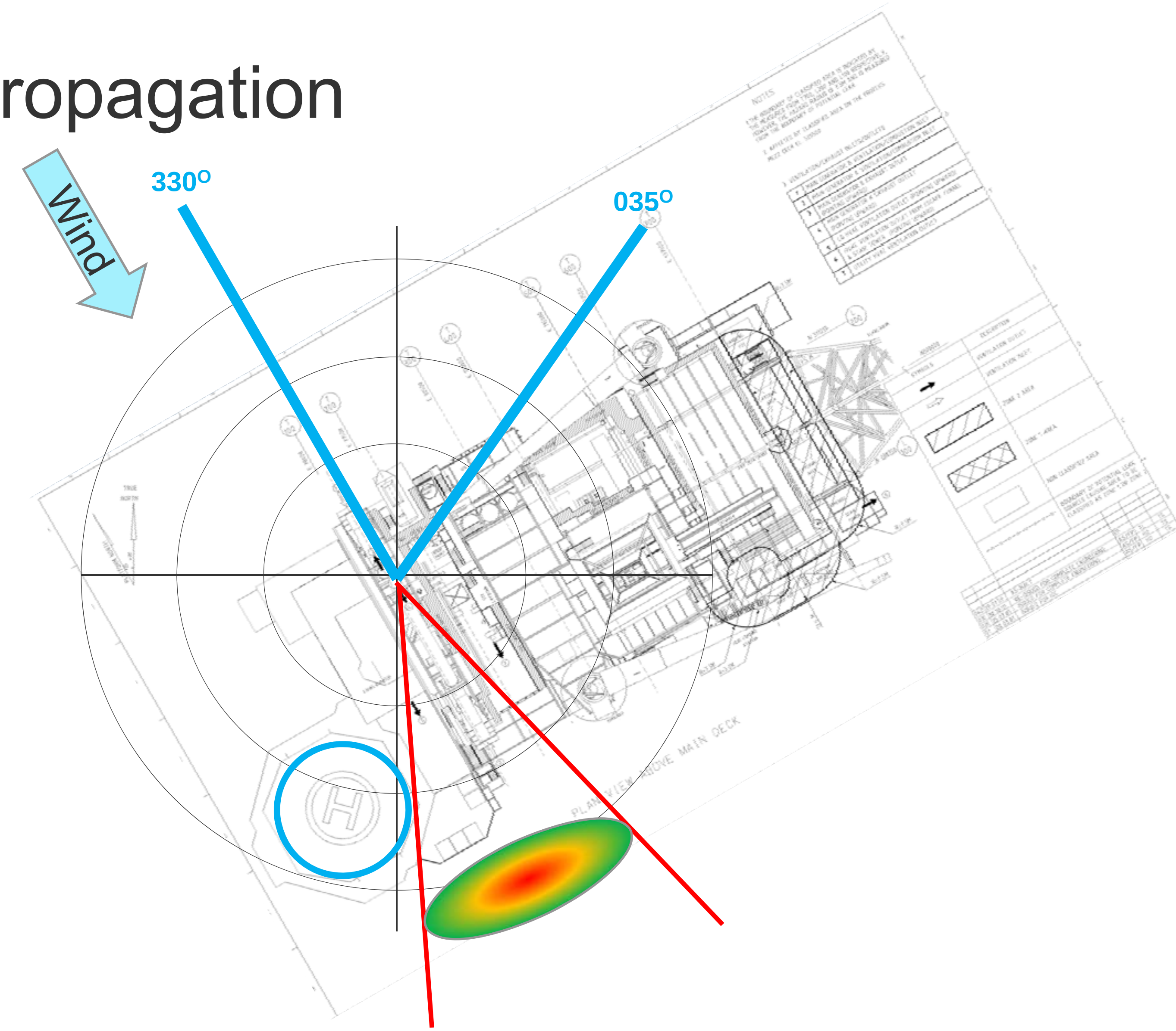
Landing on a rig



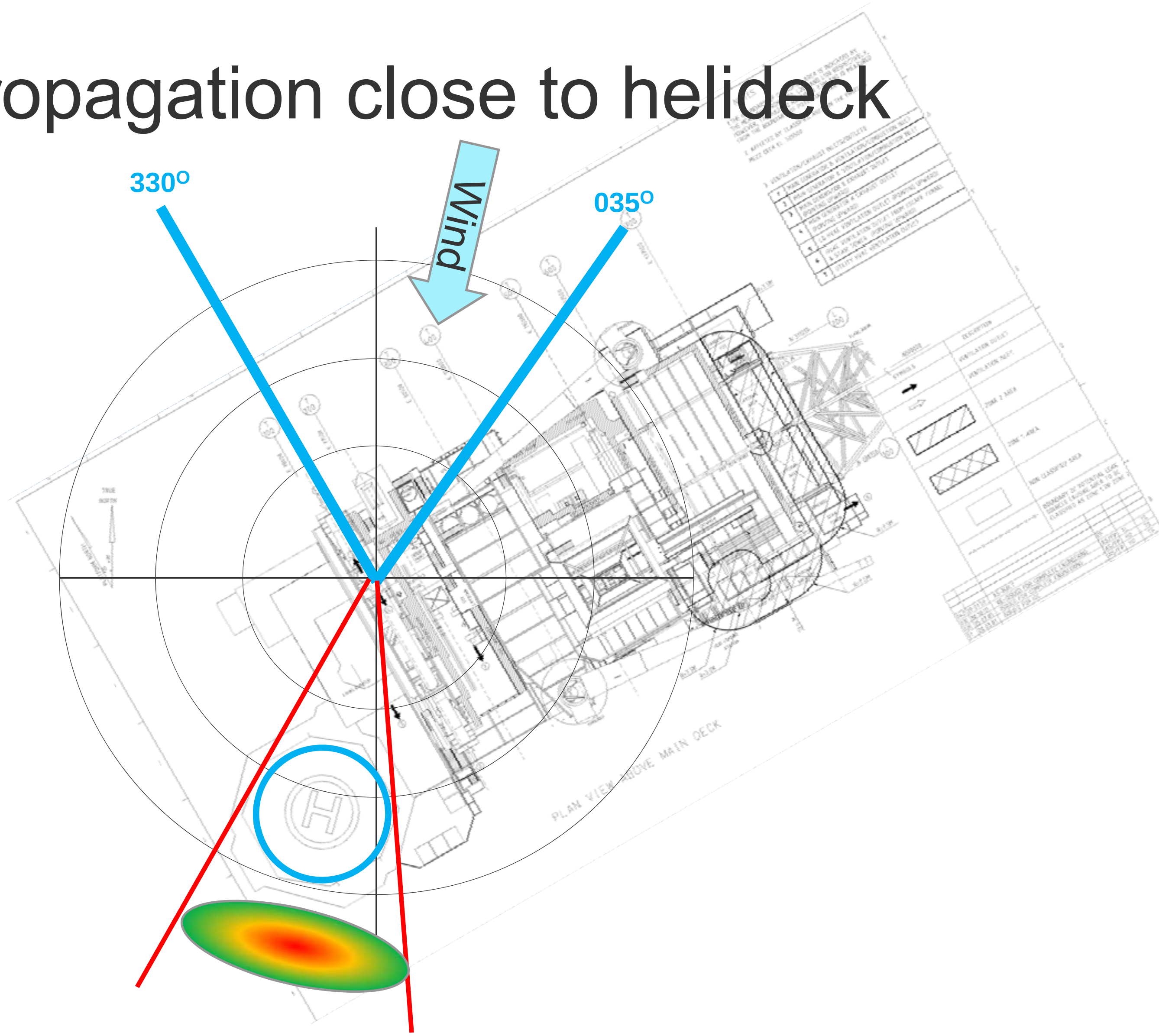
Landing Commital Point:

Abeam deck
50ft (17 m) above deck

Plume propagation



Plume propagation close to helideck



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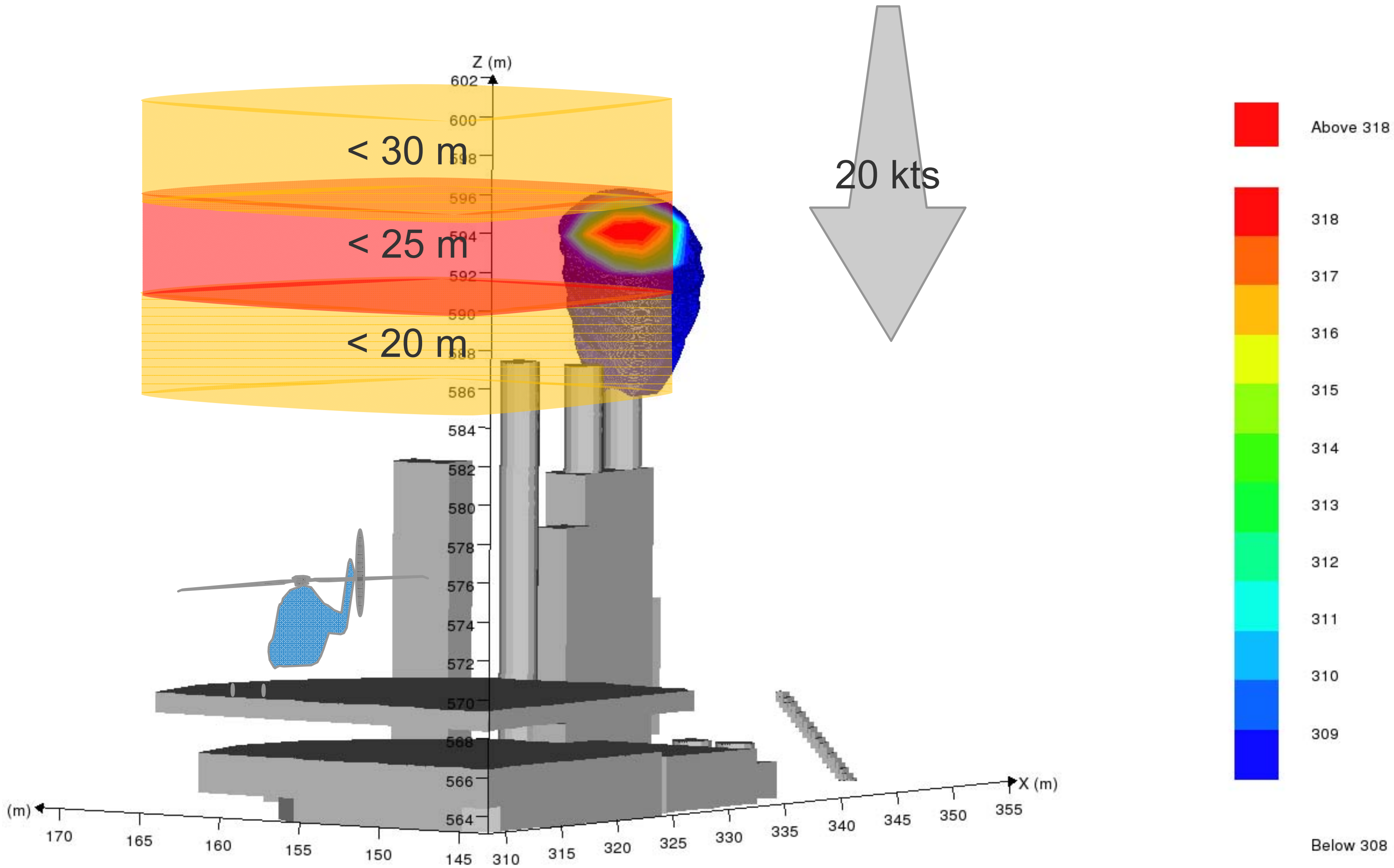
The challenge: How do we quantify and mitigate the risk?



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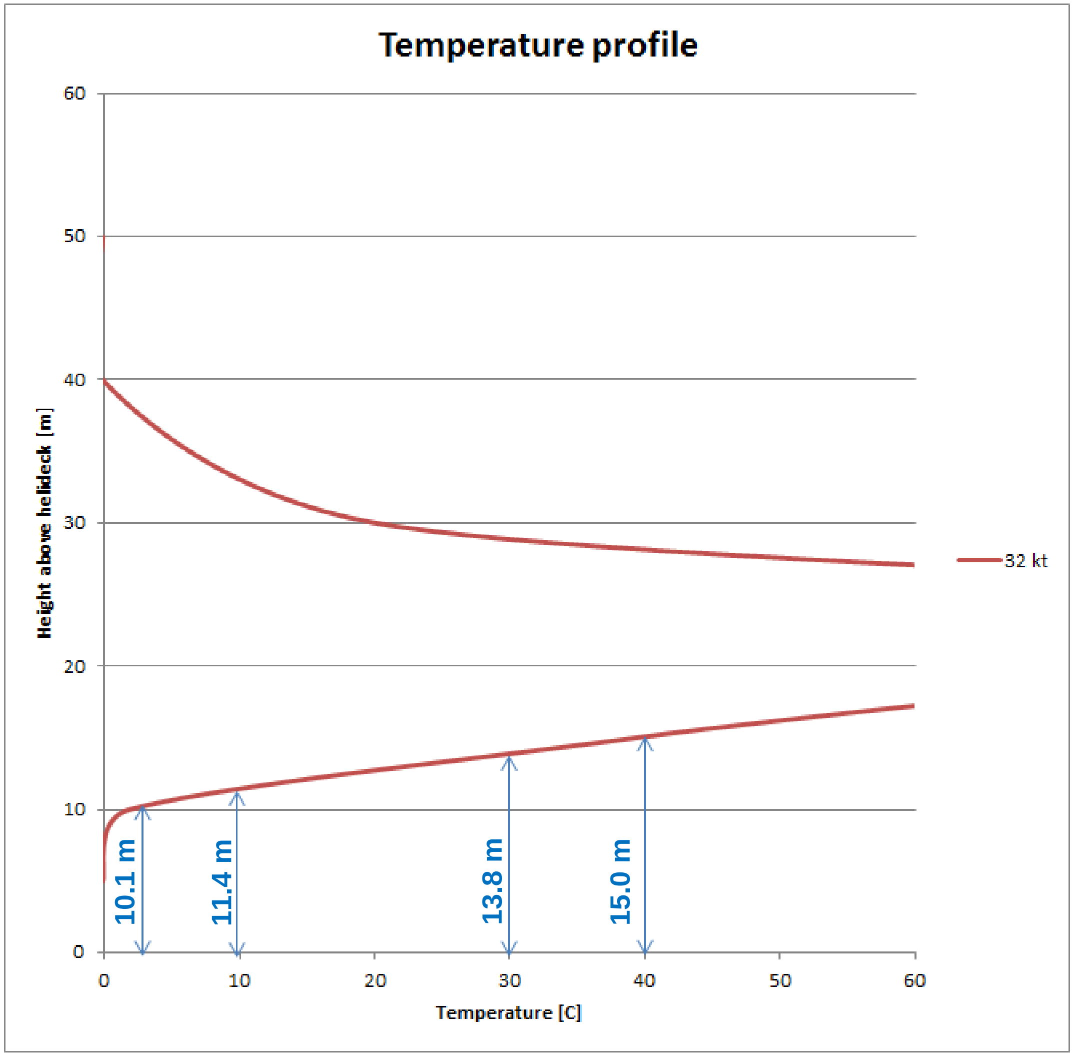
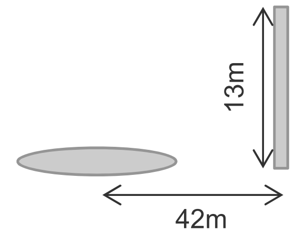
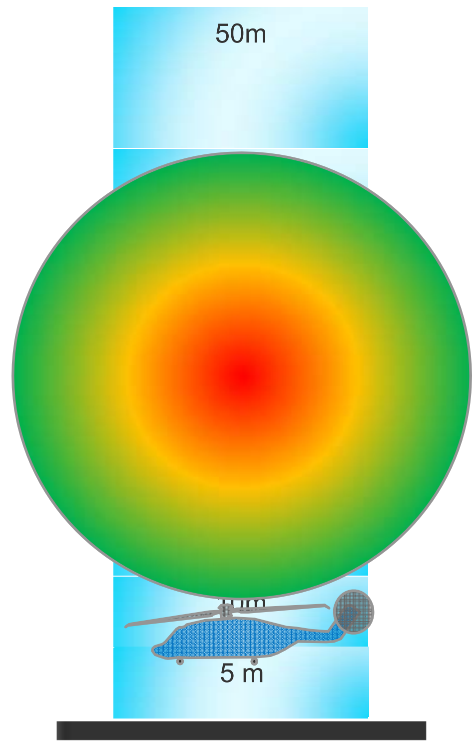
Plume properties (32kt, 57MW)







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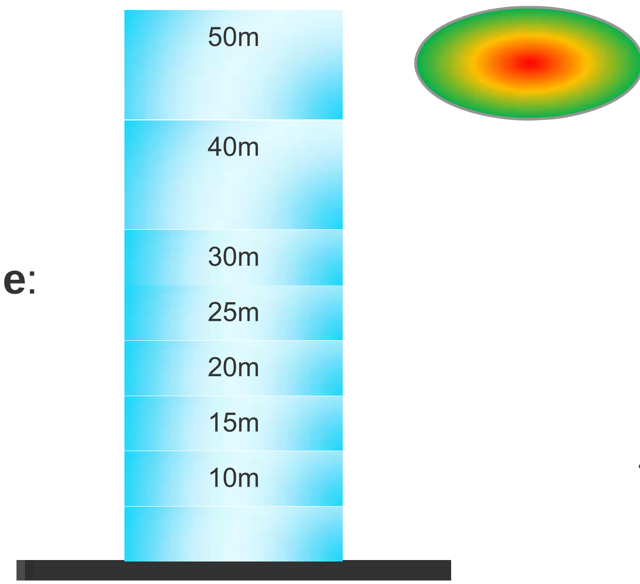
Tolerance Criteria

Elevation of the plume:
•Exhaust stack elevation
•Distance from helideck
•Windspeed.

Lateral position of the plume:
•Exhaust stack position
•Plume touching the helideck edge
•Wind direction



Remember:
Landing and takeoffs are normally carried out away from the plume

Temperature gradients used at the evaluation stage

0-2 degrees No risk
> 2 degrees «No risk», but information required
> 10 degrees Higher risk, but depending on position
> 30 degrees High risk depending on position
> 40 degrees High risk depending on situation

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TGM with Tolerance Criteria

TGM

Height above helideck ; m (ft)						
	> 50 (164)					
	< 40 (131)					
	< 30 (98)					
	< 25 (82)					
	< 20 (65)					
	< 15 (49)					
	< 10 (33)					
	< 5 (16)					
Temperature rise above ambient (^{o}C) *		0 <= 2	> 2	> 10	> 30	> 40

*) Max temperature @ Volume> 10m3 monitored in a virtual cylindrical volume centrally on helideck with a diameter of 20 meters

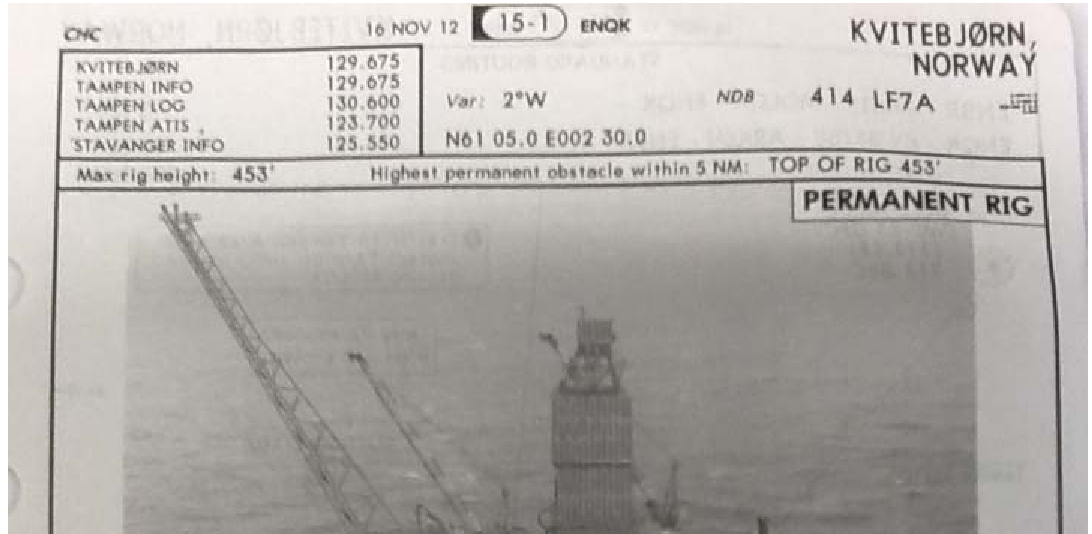
**) Wind at 100 meters level above seasurface

Measures

Zone	Type
3	*No operations :*
2	*Caution :*
1	*Normal operations*

Information to crew

Differentiate limitations:



Limitation/Comment:

Limitations due to hot gas from turbine exhaust outlets:

- sector 325°-040°, - use caution,
- sector 330°-035°, - winds above 35 kts, - no operations (2 turbines normal operations),
  - no restrictions during "revisjonsstans" (turbines with max. 1x12MV output).

Limitations due to turbulence from structures:

- sector 000°-060°, - winds 15-35 kts, - HLL Table 2 (L&T), all types,
  - winds above 35 kts, - no operations.

Type of Rig: FIXED PLATFORM
Operator: Statoil

Outline

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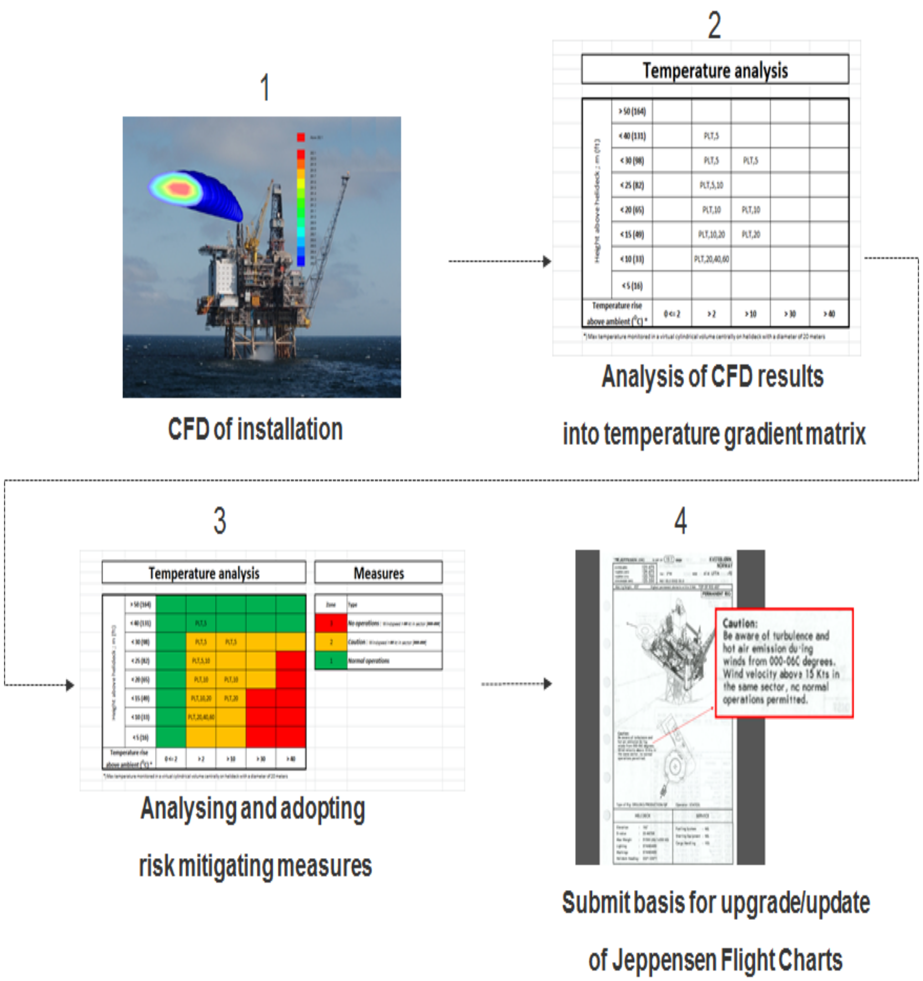
Methodology



1. Perform CFD hot exhaust plume dispersion for different wind speeds and wind directions for a given turbine configuration
2. Examine temperature profiles in the airspace volume and extract maximum temperature at different heights above helideck for all wind speeds → Temperature Gradient Matrix (TGM)
3. Apply the fixed Tolerance Criteria (TC) and determine restriction levels.
4. Operationalize information for crew (or change design/layout)

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Method applied on two events

- **On 7/9/2009 Bristow Norway –S-92**.
  Platform A

- **On 26/10/2011 CHC Norway –S-92.**
  Platform B

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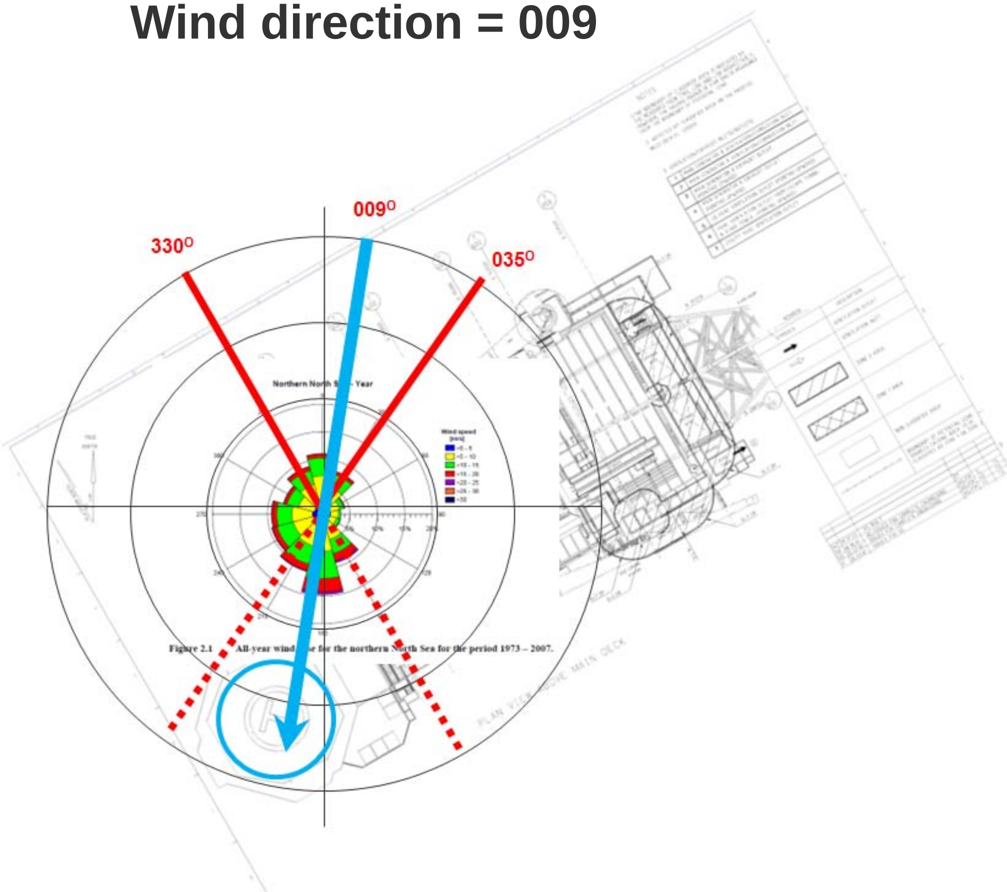
Platform A

Wind direction = 009



Wind speed = 37-40 kt

TGM Platform A

Height above helideck ; m (ft)						
	> 50 (164)			24	20	12,16
	< 40 (131)				40,44	16,20,24,28,32,36
	< 30 (98)		12			24,28,32,36,40,44
	< 25 (82)		12,14	20,24,28	32	36,40,44
	< 20 (65)					
	< 15 (49)					
	< 10 (33)					
	< 5 (16)					
Temperature rise above ambient (°C) *		0 <= 2	> 2	> 10	> 30	> 40

No operations: Windspeed > 35 kts in sector 330-035

Caution: Sector 325-040

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Method applied on two events

- On 7/9/2009 Bristow Norway –S-92.
  Conditions = 009/37-40

TGM Platform A						
Height above helideck ; m (ft)	> 50 (164)			24	20	12,16
	< 40 (131)				40,44	16,20,24,28,32,36
	< 30 (98)		12			24,28,32,36,40,44
	< 25 (82)		12,14	20,24,28	32	36,40,44
	< 20 (65)					
	< 15 (49)					
	< 10 (33)					
	< 5 (16)					
Temperature rise above ambient (^{o}C) *		0 <= 2	> 2	> 10	> 30	> 40

- On 26/10/2011 CHC Norway –S-92.
  Conditions = 130/37

TGM Platform B						
Height above helideck ; m (ft)	> 50 (164)		20,22,24,26,28	20,22,24,26,28	20,22,24,26,28	20,22,24,26,28
	< 40 (131)		20,22,24,26,28	20,22,24,26,8	20,22,24,26,28	20,22,24,26,28
	< 30 (98)		20,22,24,26,28	20,22,24,26,28	20,22,24,26,28	20,22,24,26,28
	< 25 (82)		20,22,24,26,28	20,22,24,26,28	24,26,28	26,28
	< 20 (65)		26,28,30,32	34,36,38	40,42	44,46
	< 15 (49)					
	< 10 (33)					
	< 5 (16)					
Temperature rise above ambient (^{o}C) *		0 <= 2	> 2	> 10	> 30	> 40

No operations: Windspeed > 35 kts in sector 330-035

Caution: Sector 325-040

No operations: Windspeed > 25 kts in sector 080-140

Caution: Sector 075-145

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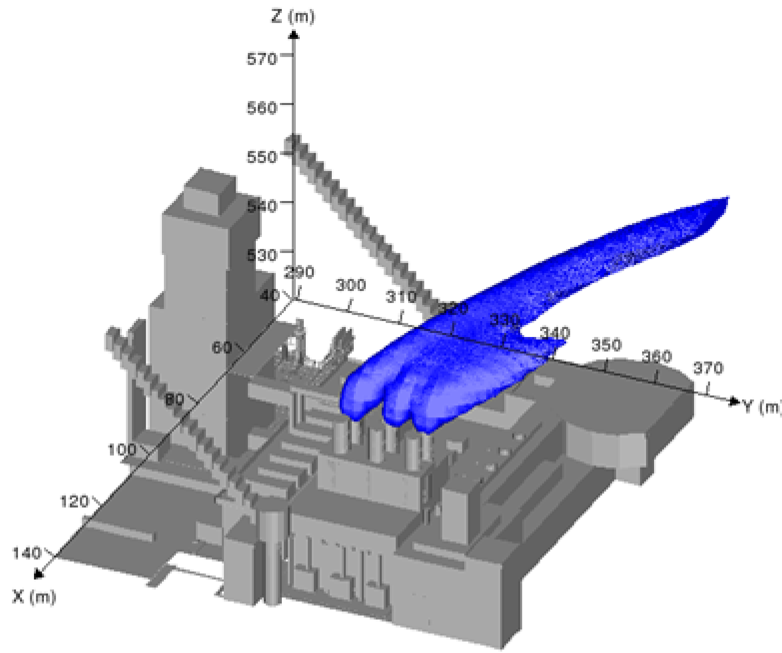
Case A

- Height of exhaust stack above helideck:
  - 13 meters (closest)
- Distance from centre of helideck to grouping of exhaust stacks:
  - 42 meters (closest)
- Power:
  - 2 turbines + 1 (stdby) = 34 MW
  - Exhaust temperature at stack outlet = 436C
  - Exhaust rate = 2 x 75 kg/s



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Results Case A

Temperature analysis — No WHRU

Height above helideck ; m (ft)						
	> 50 (164)		HDN,5	HDN,5	HDN,5	HDN,5
	< 40 (131)		HDN,10	HDN,10	HDN,10	HDN,10
	< 30 (98)		HDN,10,20,40	HDN,20	HDN,20	HDN,20
	< 25 (82)		HDN,20,40,60	HDN,20,40,60	HDN,40,60	HDN,40
	< 20 (65)		HDN,20,40,60	HDN,40,60	HDN,40,60	HDN,40
	< 15 (49)		HDN,60			
	< 10 (33)					
	< 5 (16)					
Temperature rise above ambient (°C) *		0 <= 2	> 2	> 10	> 30	> 40

Measures

Zone	Type
3	***No operations :*** *Windspeed > 31 kts** in sector [080-125]*
2	***Caution :*** *Ssector [080-125]*
1	***Normal operations***

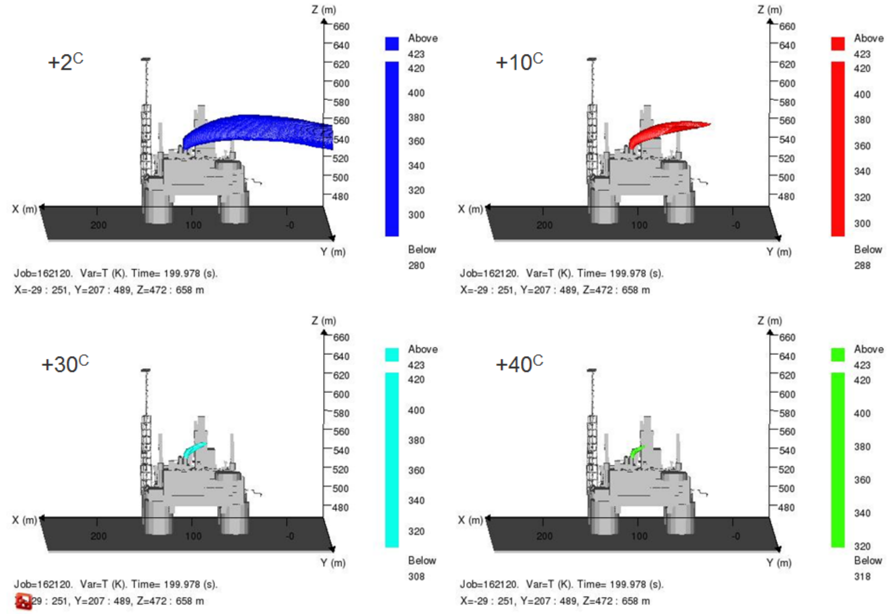
No operations: Windspeed > 31 kts in sector 080-125

Caution: Sector 080-125

Case B

- Same as case A but with a Waste Heat Recovery Unit (WHRU) in operation

- Power:
  - 2 turbines + 1 (stdby) = 34 MW
  - Exhaust temperature = 436C
  - Exhaust temperature outlet **WHRU = 150C**
  - Exhaust rate = 2 x 75 kg/s



Results Case B

Temperature analysis

Height above helideck ; m (ft)						
	> 50 (164)		HD,5	HD,5		
	< 40 (131)		HD,5,10	HD,10		
	< 30 (98)		HD,10,20	HD,10		
	< 25 (82)		HD,20,40,60	HD,20,40		
	< 20 (65)		HD,20,40,60	HD,40		
	< 15 (49)					
	< 10 (33)					
	< 5 (16)					
Temperature rise above ambient (°C) *		0 <= 2	> 2	> 10	> 30	> 40

Measures

Zone	Type
3	***No operations :***
2	***Caution :*** *Ssector [080-125]*
1	***Normal operations***

No operations:

Caution: Sector 080-125

NORSOK C-004 Edition 2, May 2013

These risks can be controlled by either proper design, which should be the main priority, or by operational measures that may involve certain helicopter flight limitations. The risk varies with helicopter type, and the risk level increases with large temperature gradients in the flight path. In view of this the following 3 methods should be assessed, where method 1 represents a deterministic approach, while methods 2 and 3 are risk based approaches:

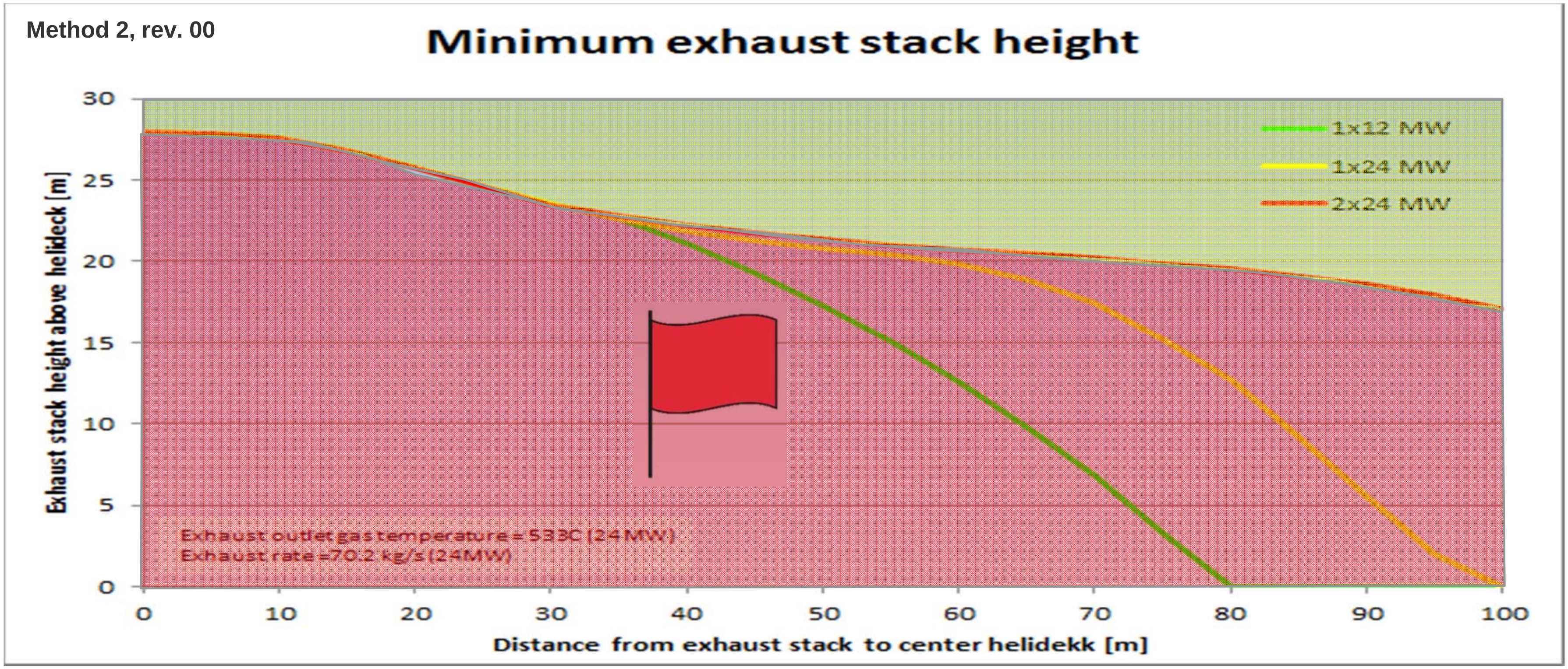
Method 1 is a conservative approach that should be used when designing a new installation. The method is based on CFD analysis and implies that the free airspace above the helideck should not be exposed to temperature increase of more than 2 °C (iso-contour from CFD). The free airspace is defined as a height above the helideck corresponding to approximately 10 m plus wheels-to-rotor height plus one rotor diameter. This method will normally require a minimum exhaust stack height of 30-32 m based on experience data, but should be verified in each case. When several stacks are required the design shall allow for optimal location and alignment to minimize gas plume exposure over the helideck. In difficult cases cooling of the exhaust gas may be considered by use of a reliable waste heat recovery system, or similar, based on a total assessment. In situations where this method is deemed impossible, unpractical or noncompliant, methods 2 and 3 should be considered. These methods utilize a risk based approach.

NORSOK C-004 (Cont.)

Method 3 is a CFD risk based approach and methodology that has been developed in close corporation with the offshore helicopter operators. The method identifies the temperature gradient levels in the airspace above the helideck with predefined measures reflecting different risk levels. Details of the method are described in the document: "A method utilizing Computational Fluid Dynamics (CFD) codes for determination of acceptable risk level for offshore helicopter flight operation with respect to hot gas emission from turbine exhaust outlets", (the document is available on C-004 home page).

Method 2 is an approach based on method 3 and is pre-processed for conservative gas turbine configurations. The outcome of this process indicates minimum exhaust stacks heights for different gas turbine configurations as shown in figure 1. The stack height is dependent on both distance to the helideck and gas turbine power. In case of noncompliance, method 3 is recommended. This method is capable of taking into account specific geometrical considerations as well as specific gas turbine configuration.

Proposed guidelines for design (cont)



Method 2 is a compressed assessment of Method 3 based on conservative gas turbine configurations. In case of non-compliance, it is recommended to follow Method 3. The method is capable of taking into account specific geometrical considerations as well as specific gas turbine configuration and weather conditions.

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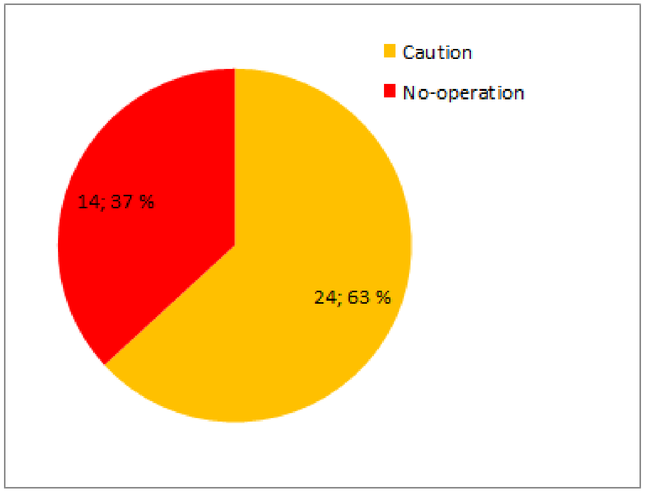
Implementation

- Norsok C-004 (Edition 2, May 2013)
- All other operators informed by Statoil through:
  - Norwegian oil and gas association (LFE)
  - IOGP (Aviation sub-committee)
  - CHC Summit March 2013
  - FLUG (risk analysis community) May 2013
  - 69th HSRMC November 2014
- Professional meeting with Peutz (June 2013)
- Screening of all Statoil installation/configurations →
  - Snorre A (+12 meter) exhaust stack
- Greenfields designed according to TGM
- Initiative and work recognized and awarded in Statoil



NORSOK C-004 (LINK)

• Start • Sectors • Energi og petroleum • Petroleum • C-Architect • C-004

C-004 Helicopter deck on offshore installations (Edition 2, May 2013)

Supporting document to NORSOK Standard C-004, Edition 2, May 2013, Section 5.4 Hot air flow

Additional requirements: ConocoPhillips

NORSOK C-004:2013 **Standard**

Helicopter deck on offshore installations. Edition 2, May 2013

Language: Edition: **2** (2013-06-04)

Product information Monitor standard

Free download

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Summary

- An method for assessing the risk from hot gas emission is presented. The method is based on state of the art industrial computational fluid dynamics codes (CFD). Exposure of helicopters with rapid change temperature is accounted for by assessing the temperature gradients in the air volume at different heights above the helideck.
- Temperature tolerance criteria's are established at different elevations in the air space volume above the helideck, leading to an operational restriction mode "Caution" or "No Operation" for a given turbine configurations at various weather conditions.
- The two triggering events (2009 and 2011) are compiled with the method indicating that the method is capable of addressing the risk of hot gas exposure. Tolerance criteria's are subject to adjustment based on knowledge/future incidents.
- NORSOK C-004 revised Edition 2, May 2013 (+ guideline)
- Roll-out completed in Statoil

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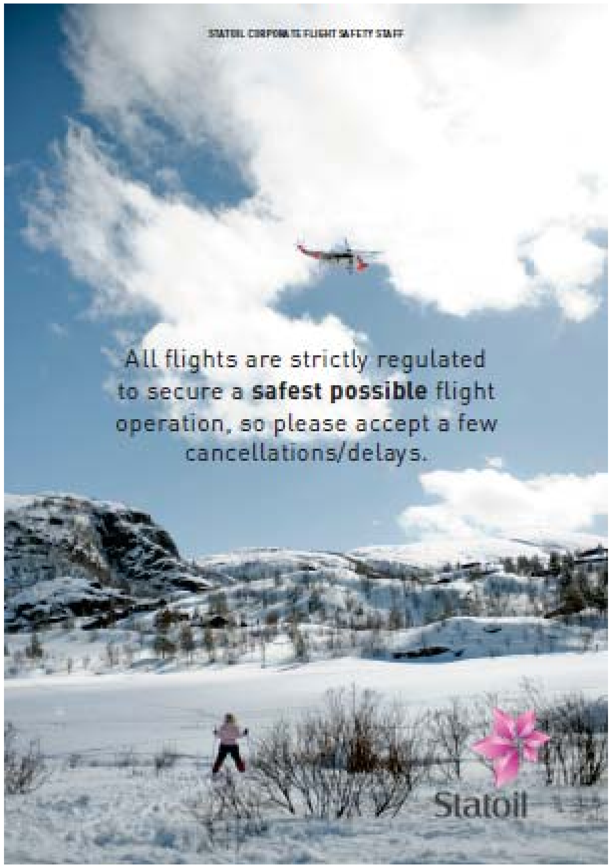
Thank you.   Questions?



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