Atmospheric Modelling of Tritium forms transport: review of capabilities and R&D needs for the assessment of fusion facilities environmental impact

P.Castro[1], M.Velarde[2], J.Ardao[3,4], J.M. Perlado[2] y L.Sedano[1,5]

[1]EURATOM-CIEMAT Association, LNF Fusion National Laboratory, BBTU 28040-Madrid, Spain, paloma.castro@ciemat.es; l
[2]ETSII Nuclear Fusion Institute: DENIM, Madrid, Spain;
[3]AEMET, Environmental Development Service, 28040 Madrid, Spain;
[4]ECMWF European Centre for Medium Range Weather Forecast, Reading, United Kingdom;
[5]UNIOVI, Universidad de Oviedo, Spain

INDEX

1. **Introduction**
2. **Source Term selected for Tritium Forms**
3. **Influence of the atmospheric conditions in the *diffusion of the emission & transport* into the air (on and off-site)**
4. **Tritium patterns and short range trajectory of liberated emission associated to real time wind speed and direction, stability or convection.**
5. **Validation of HT-FLEXTRA source term and patterns with NORMTRI**
6. **Evolution of HTO/HT ratio in short range**
7. **New R&D requirements**
8. **Conclusions**

ABSTRACT

•One of the key scrutiny issues of new coming energy era would be the environmental impact of fusion facilities managing one kg of tritium. The potential change of committed dose regulatory limits together with the implementation of nuclear design principles (As Low as Reasonably achievable - ALARA -, Defense in Depth -D-i-D-) for fusion facilities could strongly impact on the cost of deployment of coming fusion technology. **Accurate** modeling of environmental tritium transport forms (HT, HTO) for the assessment of fusion facility dosimetric impact in Accidental case appears as of major interest. This paper considers different short-term releases of tritium forms (HT and HTO) to the atmosphere from a potential fusion reactor located in the Mediterranean Basin.

•This work models in detail the dispersion of tritium forms and dosimetric impact of selected environmental patterns both inland and in-sea using real topography and forecast meteorological data-fields (ECMWF/FLEXPART). We explore specific values of this ratio in different levels and we examine the influence of meteorological conditions in the HTO behavior for 24 hours. For this purpose we have used a tool which consists on a coupled Lagrangian ECMWF/FLEXPART model useful to follow real time releases of tritium at 10, 30 and 60 meters together with hourly observations of wind (and in some cases precipitations) to provide a short-range approximation of tritium cloud behavior. We have assessed inhalation doses. And also HTO/HT ratios in a representative set of cases during winter 2010 and spring 2011 for the 3 air levels.

•This practical exercise serves to discuss in detail review of capabilities and R&D needs for the assessment of fusion facilities environmental impact.

1. Introduction (1/3)

RECOMMENDATION:

The limit of exposure of the public to nuclear fuel is less than 1 mSv/ year (ICRP-60)

- Tritium mobilisation and transport as effluent released by ITER in *normal operation*

TABLE II: ESTIMATES OF EFFLUENTS AT EXPECTED END OF LIFE CONDITIONS

Species	Estimate	Project Guideline	% of Guideline
Tritium – as HTO in air	0.05 g tritium /a	0.1 g tritium /a	50
Tritium in water	0.0004 g tritium /a		
Tritium – as HT in air	0.18 g tritium /a	1 g tritium /a	18
Activated dust	0.25 g metal/a	1 g metal/a	25
Activated corrosion products	0.85 g metal/a	5 g metal/a	17
Species with no specified project guideline			
Species	**Estimate**	**Notes**	
Activated gases ^{41}Ar ^{14}C	 <1 TBq/a 10 MBq/a	Release limits not specifically established for these isotopes but not significant at these levels	
Direct radiation at 250 m	4 µSv/a	< 0.2% of background	

[21] ITER Generic Site Safety Report (GSSR), Volume X, Sequence Analysis, July 2001

1. Introduction (2/3)

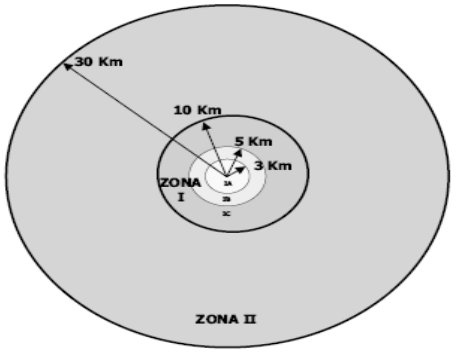
Spanish Basic Regulations: PENTA

EMERGENCY IN THE EXTERIOR OF NUCLEAR FACILITIES:

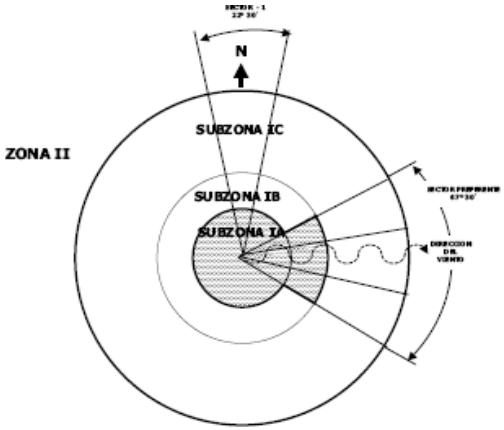
- Nowcasting/Reseach Zone: Zonas de vigilancia
- Control Zones; Zonas de control
- Evacuation/Permanence

BASIC CONCEPTS :

- Air Contamination-> Activity Concentration/CA(Bq/m^3)
- External radiation -> Dose Rates/Tasa de Dosis(µSv/h)
- Dosimetry: EDE(Sv)
- Surface contamination Bq/cm^2

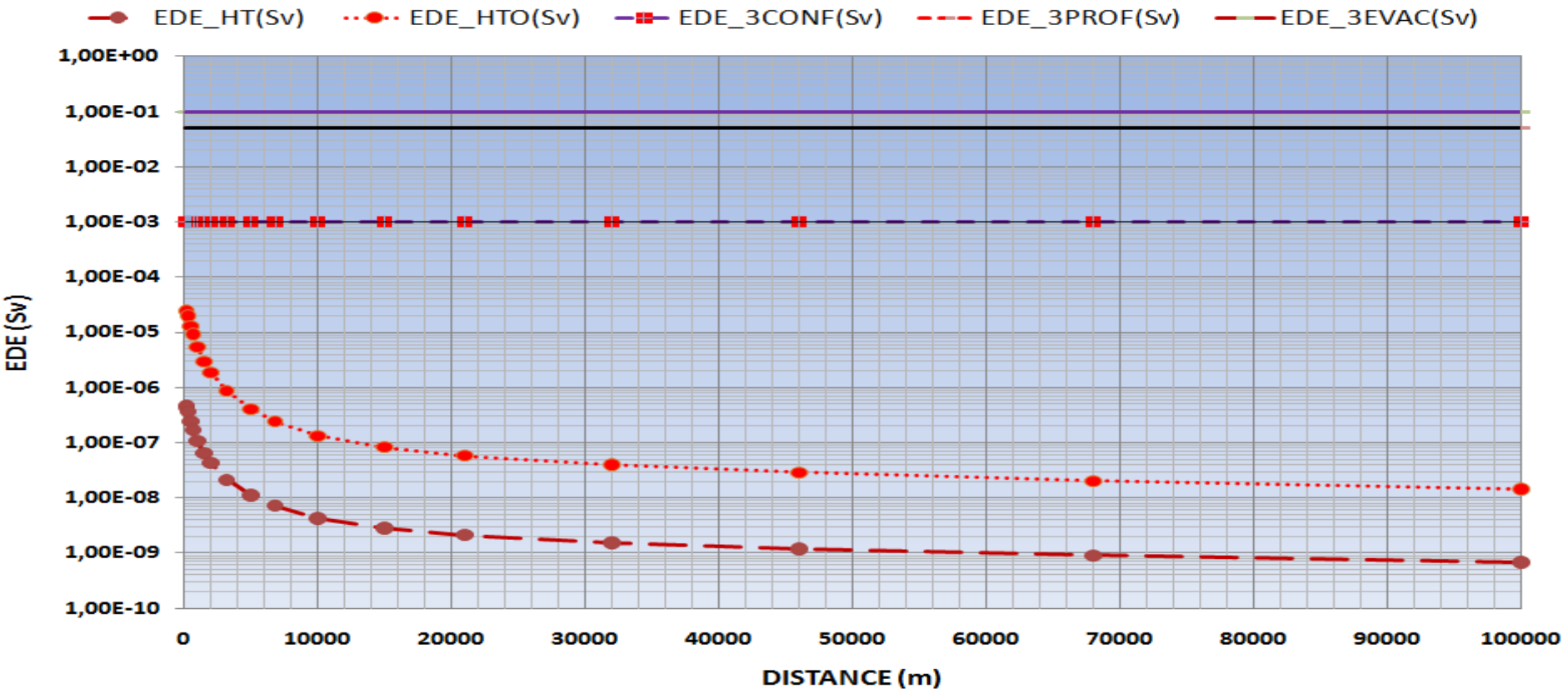


EXTERIOR ZONES.
Plan de Emergencia nuclear Exterior para Ascó y Vandellós (Tarragona), BOE no. 171, 21 July 2006, Sec.1. [6]



1. Introduction (3/3)

– Test (100% HT y 100% HTO) for ITER-V NFPP at level of 30 m. NORMTRI represents EDE contributions of all exposure paths.[Ref. Castro, Velarde et al.]

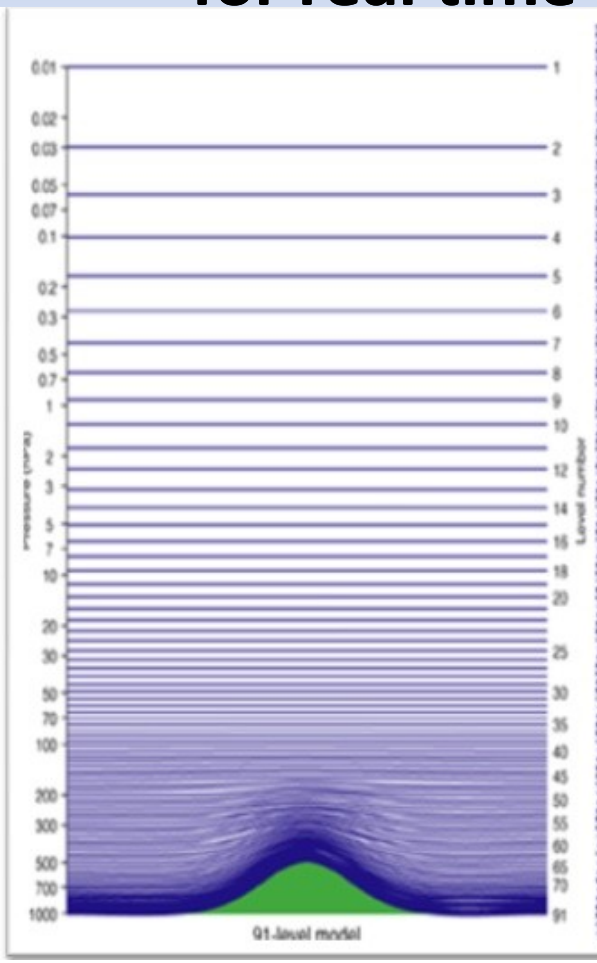


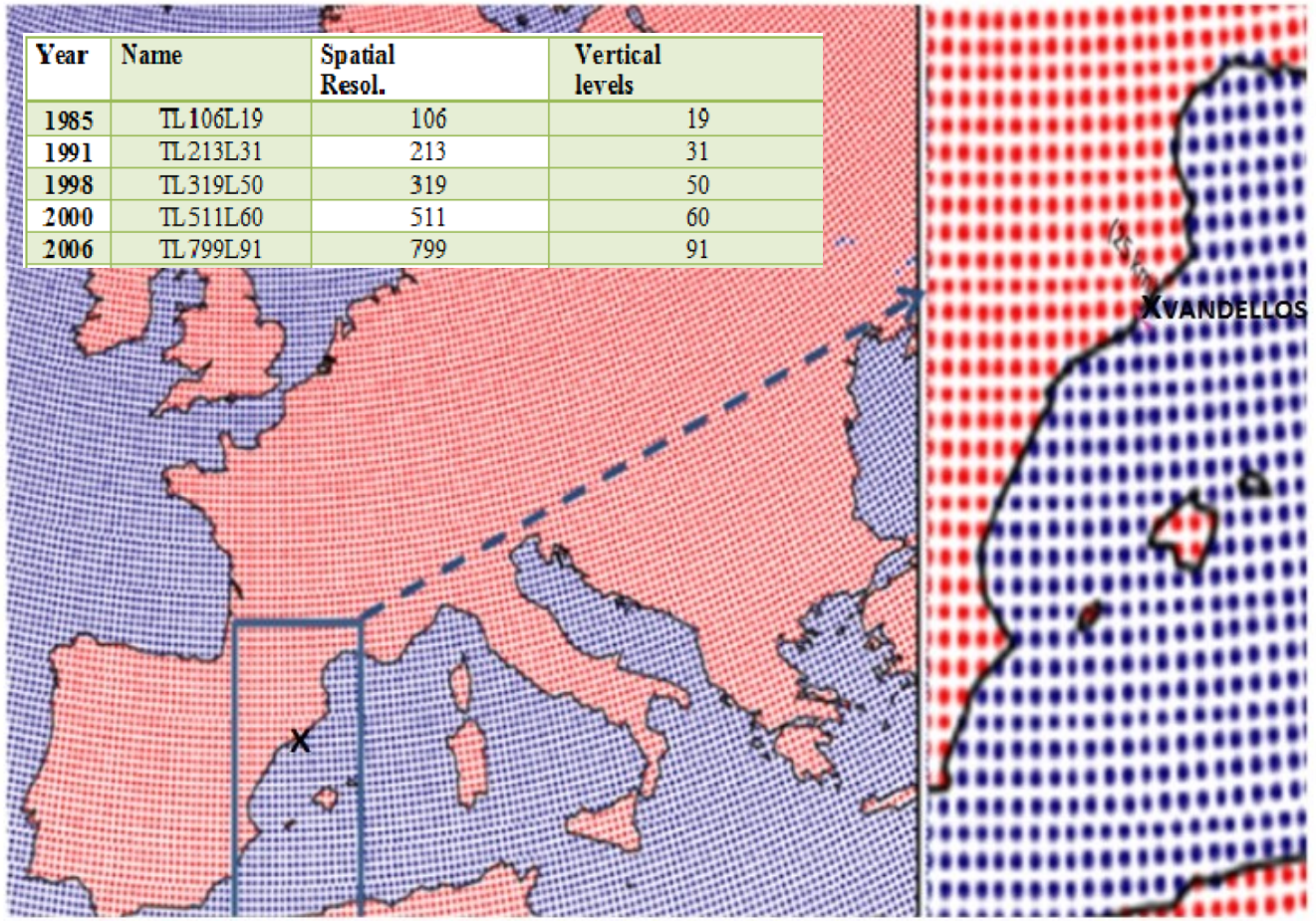
With NORMTRI EDES are under precautionary measures of PENTA NIVEL 3.

– **Can we made real time ECMWF/FLEXPART forecast *approximations to stochastic dose rates of uncontrolled HT releases in order to design an approximation to Nowcasting/Search Zone for Fusion Facilities*?**

Weather numerical prediction Model for real time forecast: synoptic *continental- scale*

Year	Name	Spatial Resol.	Vertical levels
1985	TL106L19	106	19
1991	TL213L31	213	31
1998	TL319L50	319	50
2000	TL511L60	511	60
2006	TL799L91	799	91





[4] A. Persson, User Guide to ECMWF Forecast Products ECMWF, 2011 .

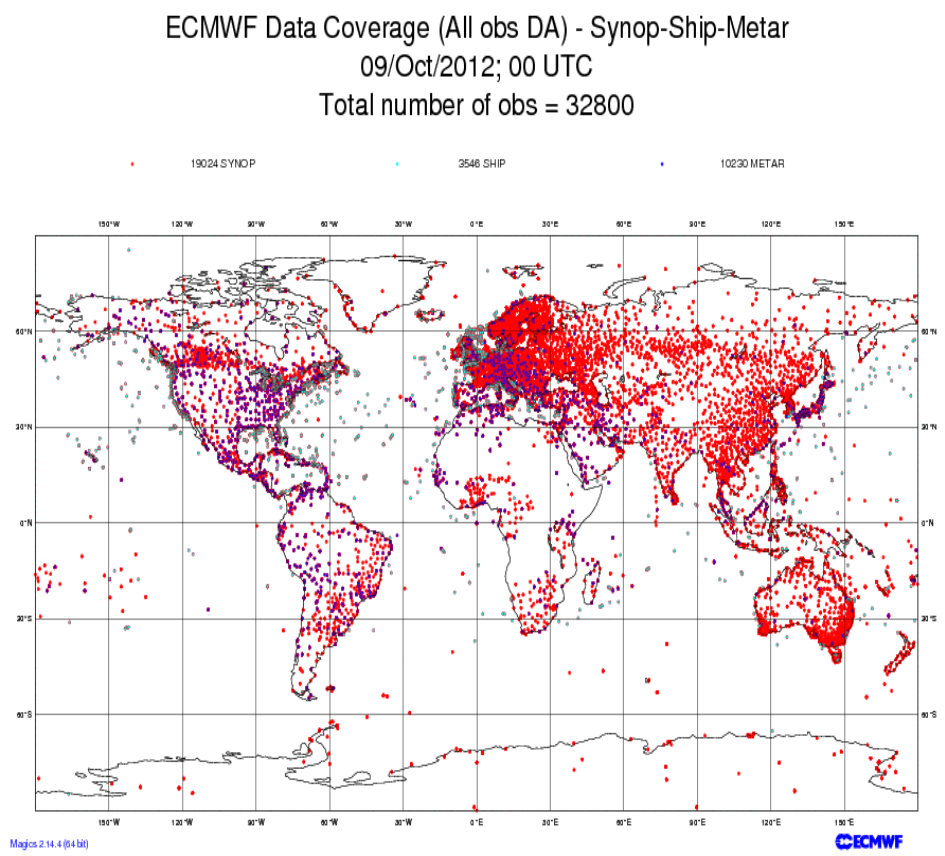
ECMWF has a vertical resolution of 91 levels; horizontal res: 799 planetary waves

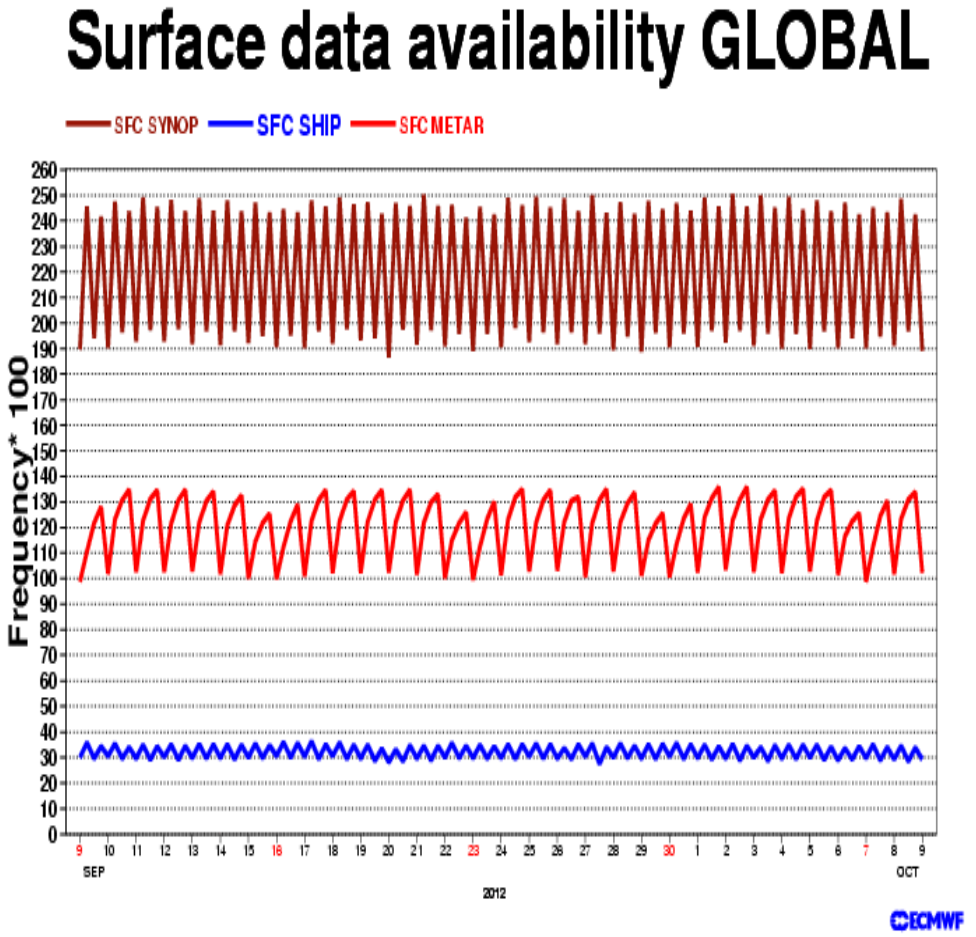
AEMET has used TL511L60, 4 hours of pre-process for the ingestion of analysis (diagnostic) and forecast fields .

FLEXPART efective resoluction will be determined by the number of released particles

Land by the resoluction of the used fields : analysis or forecast.

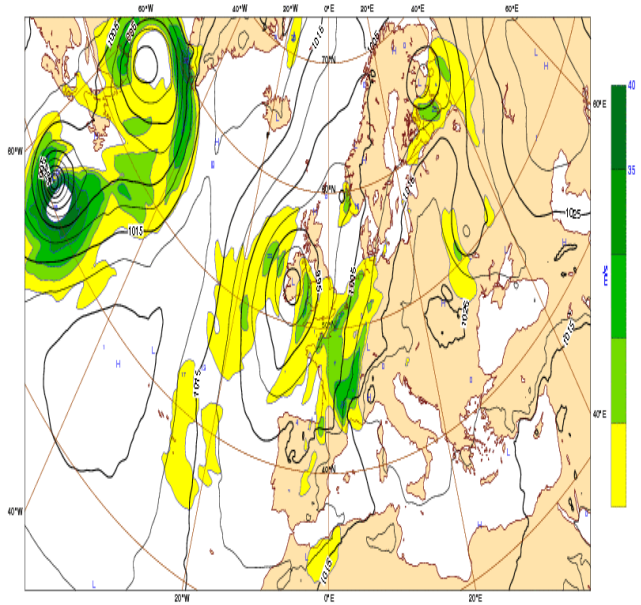
ECMWF


ECMWF Data Coverage (All obs DA) - Synop-Ship-Metar
09/Oct/2012; 00 UTC
Total number of obs = 32800
19024 SYNOP
3546 SHIP
10230 METAR
Magics 2.14.4 (64 bit)
©ECMWF

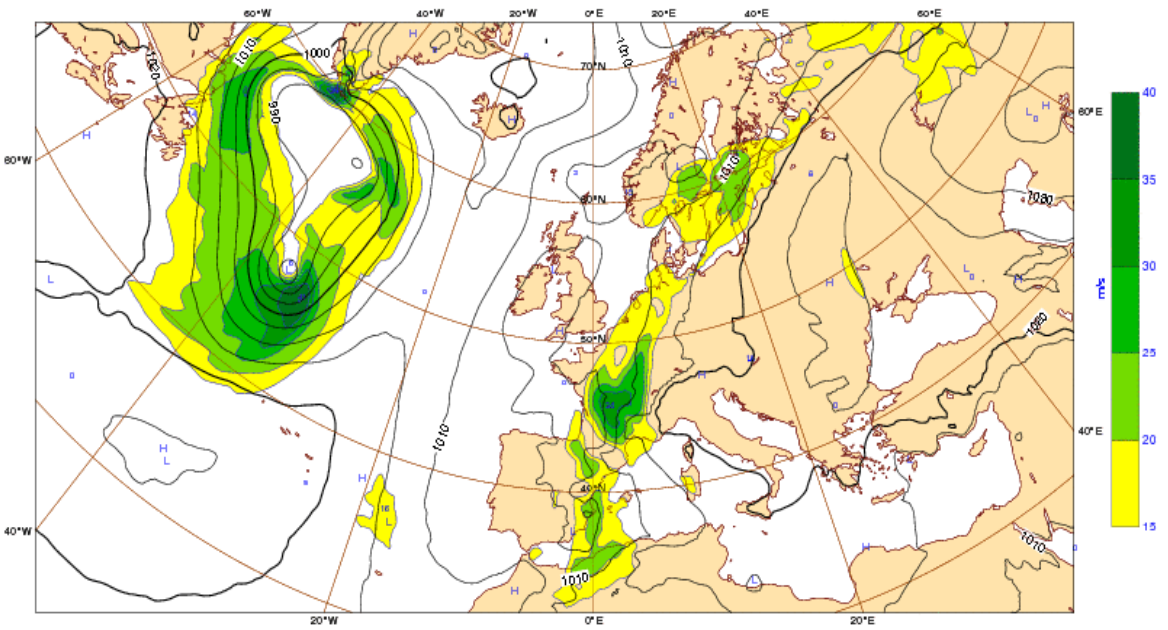

Surface data availability GLOBAL
SFC SYNOP
SFC SHIP
SFC METAR
Frequency* 100
SEP
OCT
2012
©ECMWF

ANALYSIS FIELDS

Thursday 18 October 2012 00UTC ©ECMWF Analysis t+000 VT: Thursday 18 October 2012 00UTC
Surface: Mean sea level pressure / 850-hPa wind speed

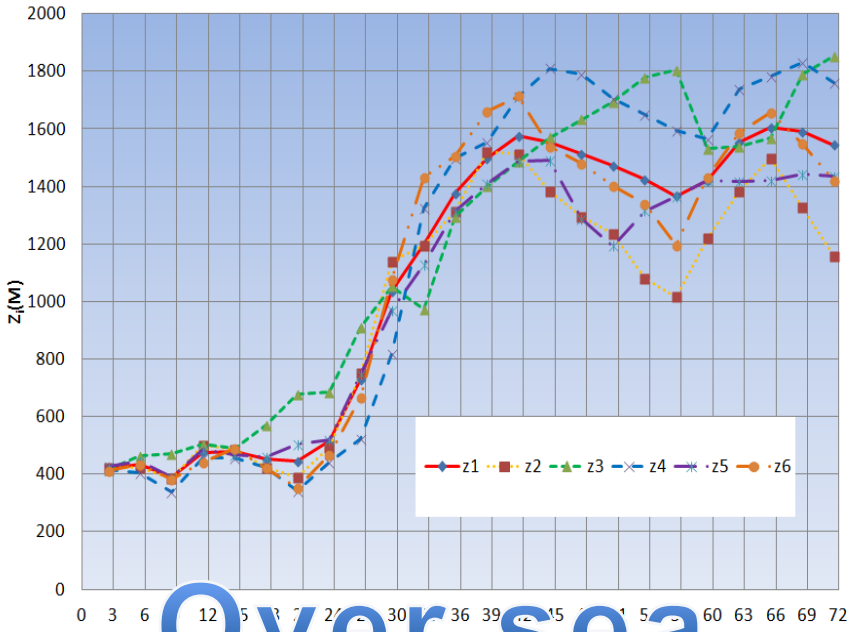


Thursday 18 October 2012 00UTC ©ECMWF Forecast t+024 VT: Friday 19 October 2012 00UTC
Surface: Mean sea level pressure / 850-hPa wind speed

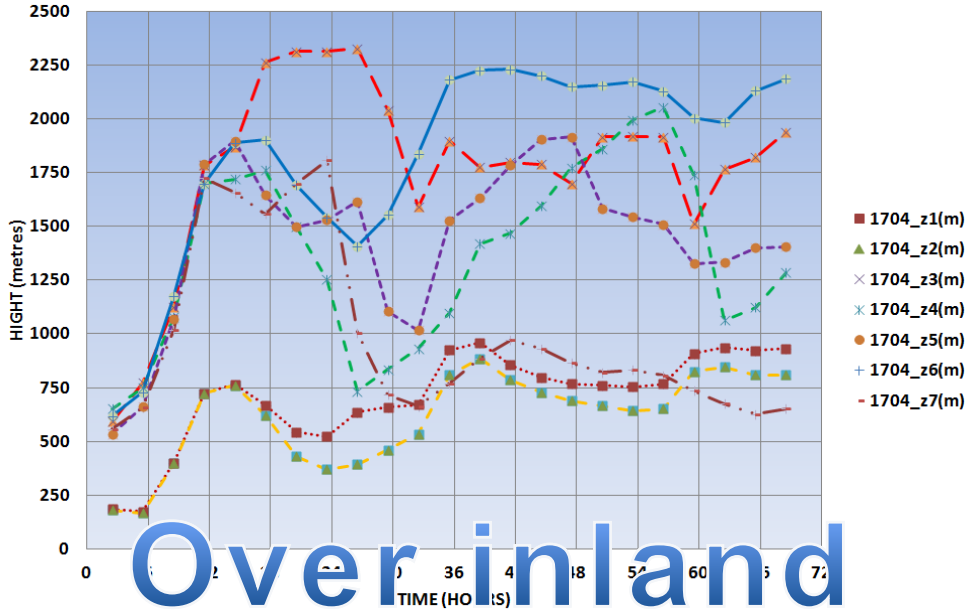


FORECAST FIELDS

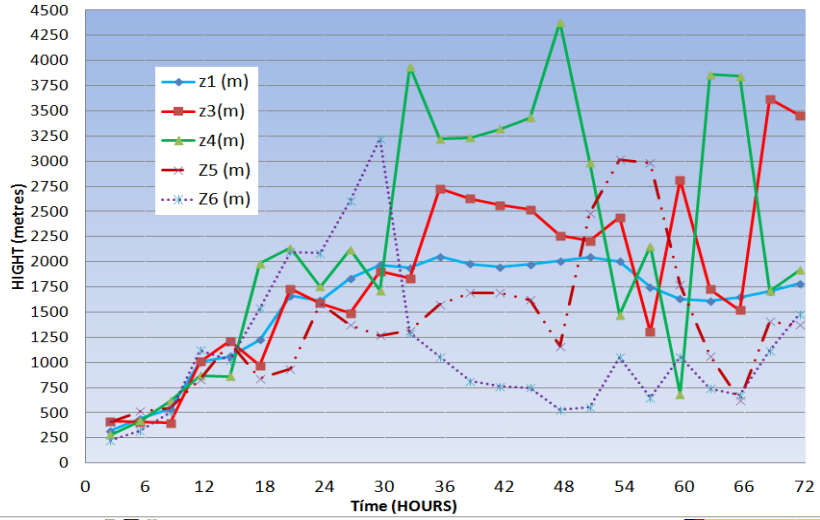
FLEXPART & FLEXTRA

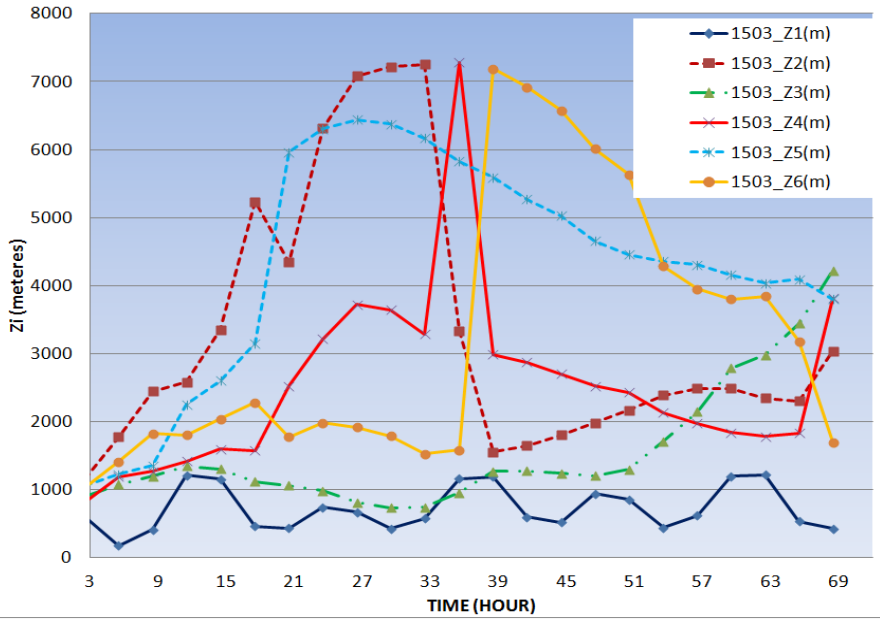


Over sea



Over inland





2. Source Term selected for Tritium Forms

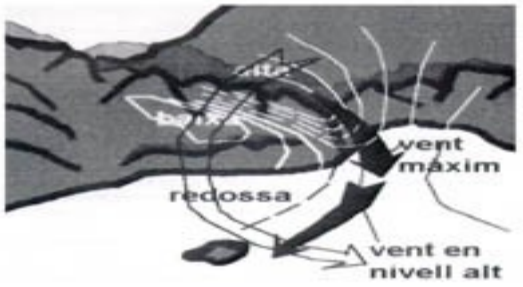
A) *Uncontroled release of 1 g of Tritium form HT/year*. 100% of HT gas

B) *Uncontroled release of 0,1 g of Tritium form HTO/year.* 100% of HTO

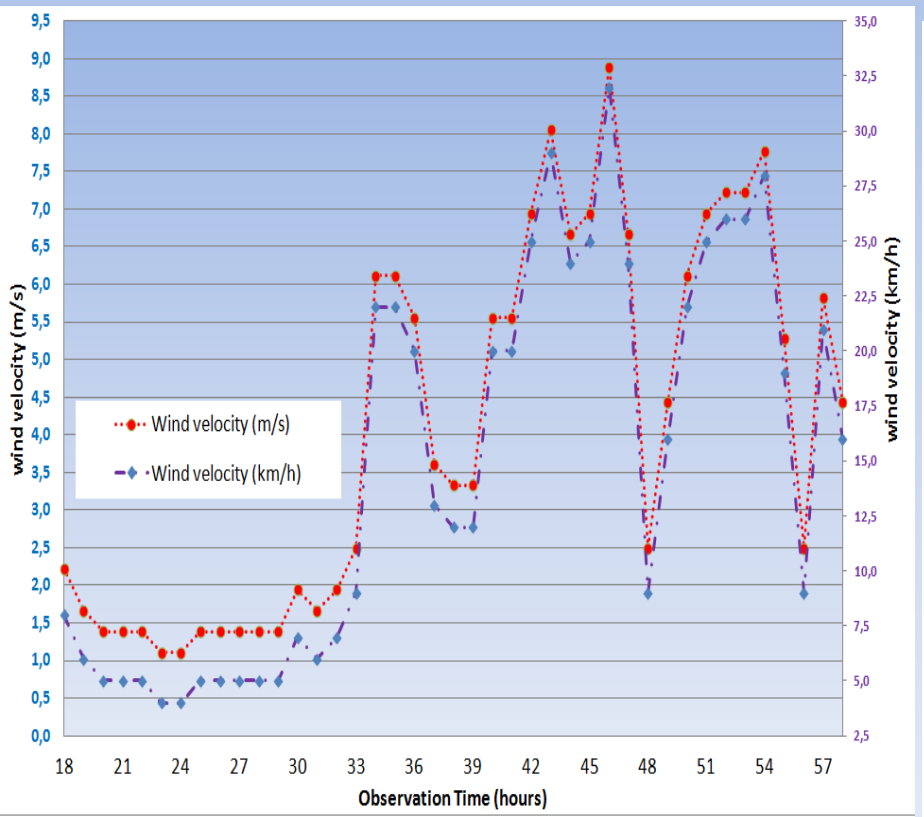
(Ref. Generic site safety report, GSSR, 19)

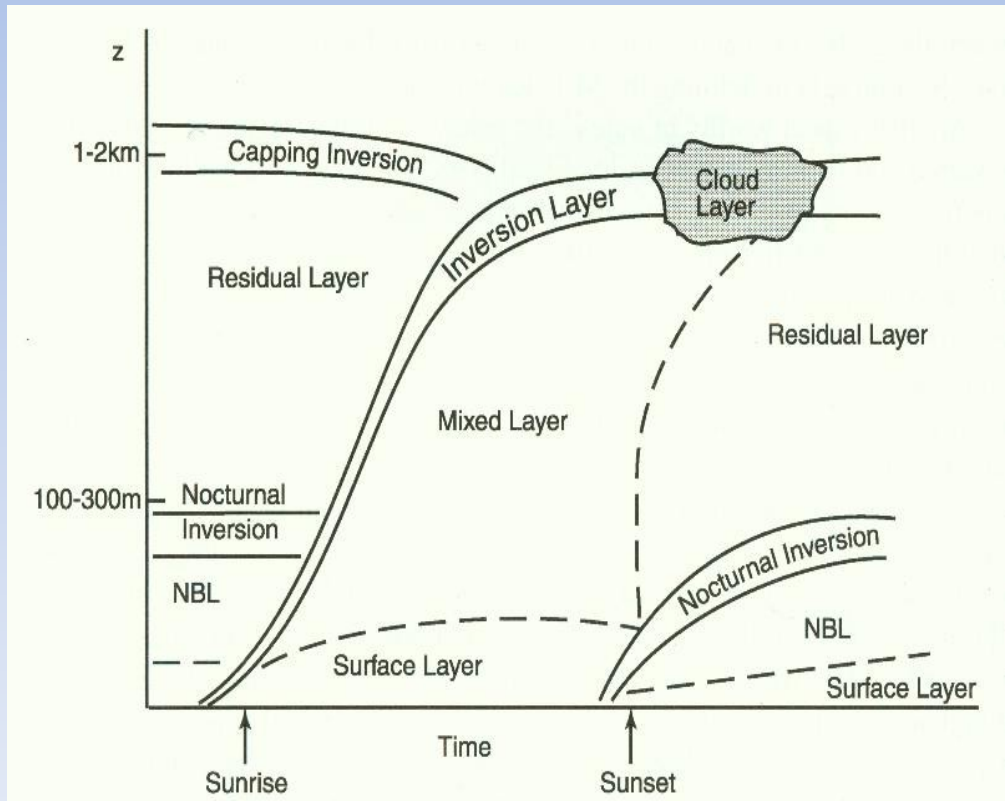
In a daily bases:

- **Tritium sources of:**
  - **2.7 mg of tritium by event-day in HT form (e.g. emitted 2.7 mg of HT)**
  - **or 0.27 mg HTO by event-day in HTO form (e.g. emitted 0.27 mg of HTO).**
  - **Or:**
    - ~25 Ci/event-d in HT form
    - ~2.5 Ci/event-day in HTO form.



3.Influence of the atmospheric conditions in the *diffusion of the emission & transport* into the air (on and off-site).



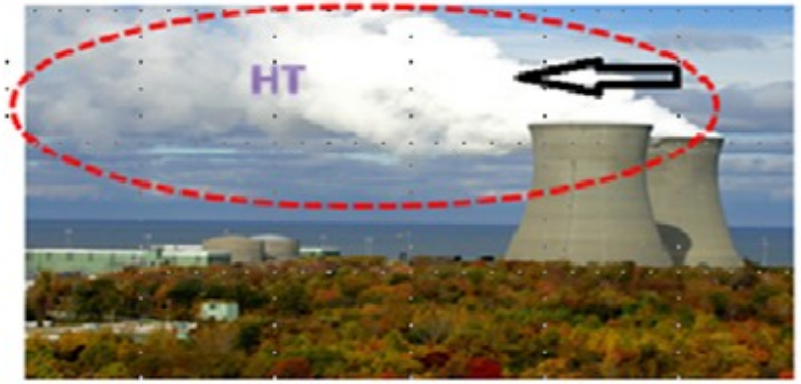


Weather conditions:

* STABILITY /CONVECTION
* WIND (CALMS, DIR:E, W; VEL: Moderate, strong; effects of shear, turbulence…)

Boheme over photo Courtesy: © Exelon Nuclear Byron Station Units 1 and 2

Moderate Winds before a warm front.
Pattern C (INLAND)



Boheme over photo Courtesy: © First Energy-Perry Nuclear Power Plant, Unit 1

Strong Winds before a cold front.
Pattern D (OVER SEA)

Our source term:
1 hour of HT release at midnight (no radiation)

NO

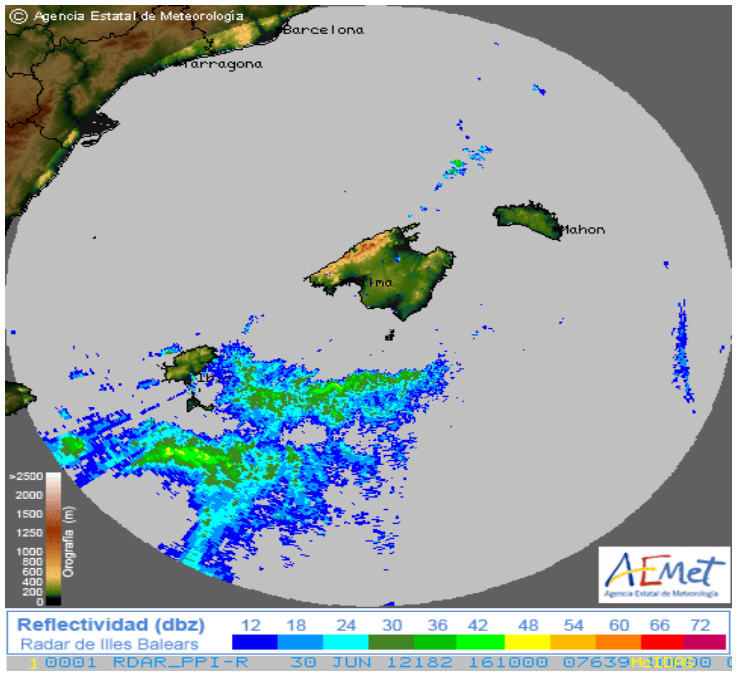
Posible stability or convection scenarios (in which HT & HTO source term arrives)

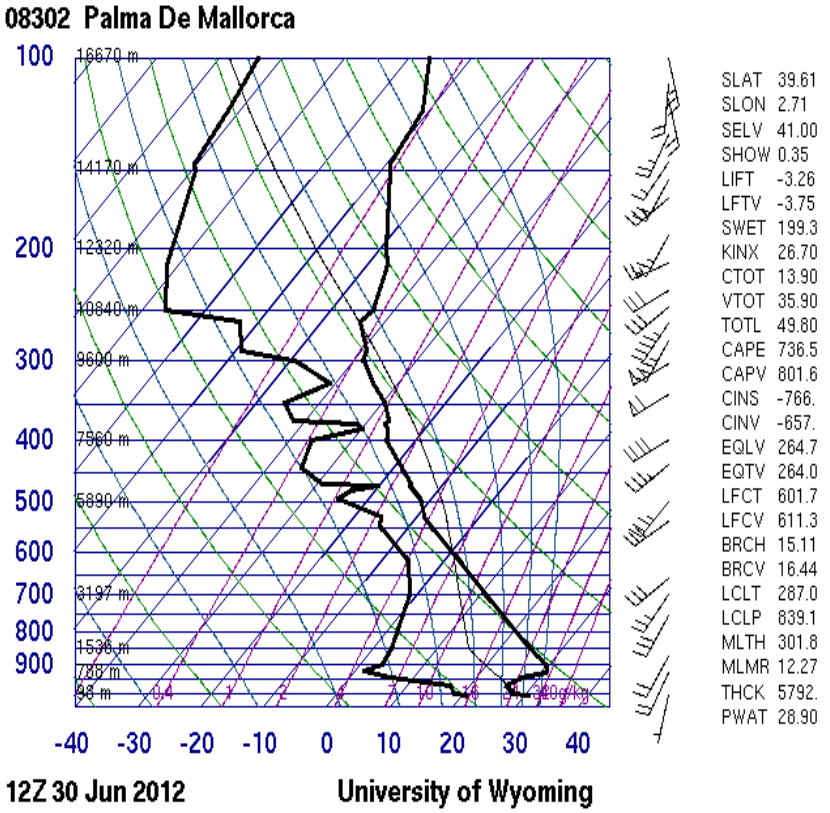
- A: **High pressure system without thermal inversion**. Migration from the source point to high levels of the atmosphere (e.g to the stratosphere)
- B: **High pressure system with thermal inversion**. Trapping+arrival to earth level? It use to remain until noon (e.g. 12 UTC)
- C: **Cold front/Warm front (W wind component, *moderate-strong*)**: Transport to east (from Vandellós the Mediterranean Sea).
- D: **Mediterranean Ciclogenesis (E wind component)**: If Vandellós transport off-site should be inland.
  - The release is supossed to be **at 0 UTC during 1 hour**.

(e.g. with earth radiation & without sun radiation effects of evapotranspiration)

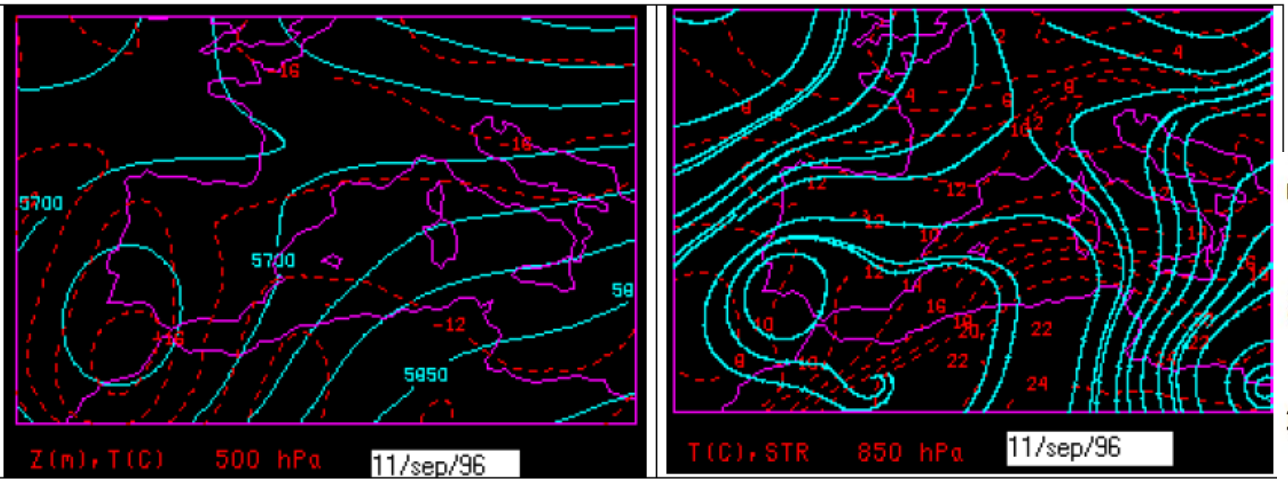
  - In each scenary what is HT & HTO transported *on and off-site*?

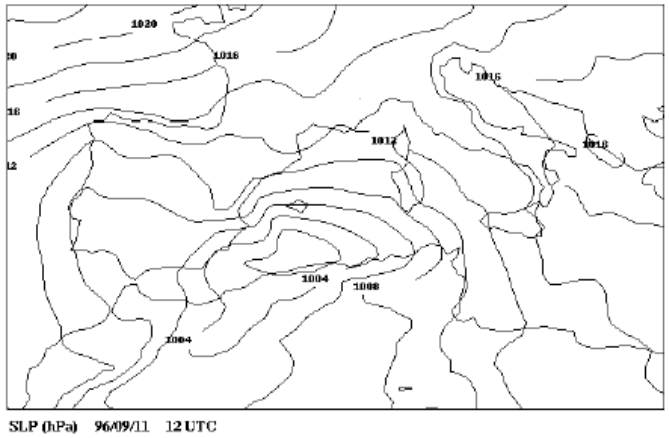
Example of input of African air in the Mediterráneum (applicable to A pattern)

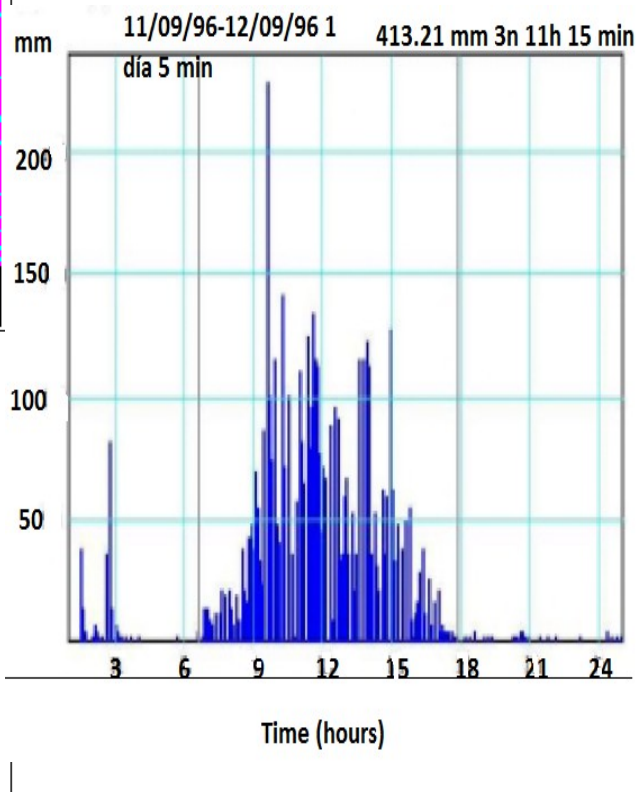




Example of Intense rainfall in the Mediterraneum aplicable to D pattern (Precipitation case)







Example of Analysis 11 Sep 1996 [20] with HIRLAM (R. Díaz Pavón) model for Spain, presenting a Mediterranenan Ciclogenesis. Cold pool in 500 hPa of -20 ºC, Warm advection in 850 hPa and a surface low 1004 hPa close to Balearic Islands. Precipitation observations at Pina

Posible stability or convection scenarios

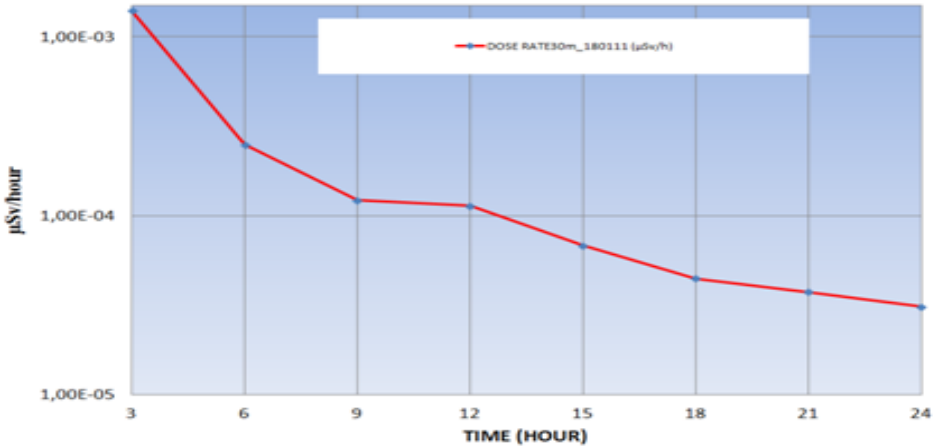
RELEASE	A	B	C	D
On site	Yes	On site	no	no
Off site	Upward	Trapped	Yes	Yes
Offsite-inland	no	no	no	Yes, if E wind
Off-site-Sea	no	no	Yes, if W wind	no
Wind	Calms	Calms-Light	Moderate/strong	Moderate/strong
Radiation at 0 UTC	no	no	no	no
Humidity/temp	variable	inversion	variable	variable
FROM 0 TO 24 HOURS	daily thermal ocilation	may desapear at 12UTC	daily thermal ocilation	daily thermal ocilation

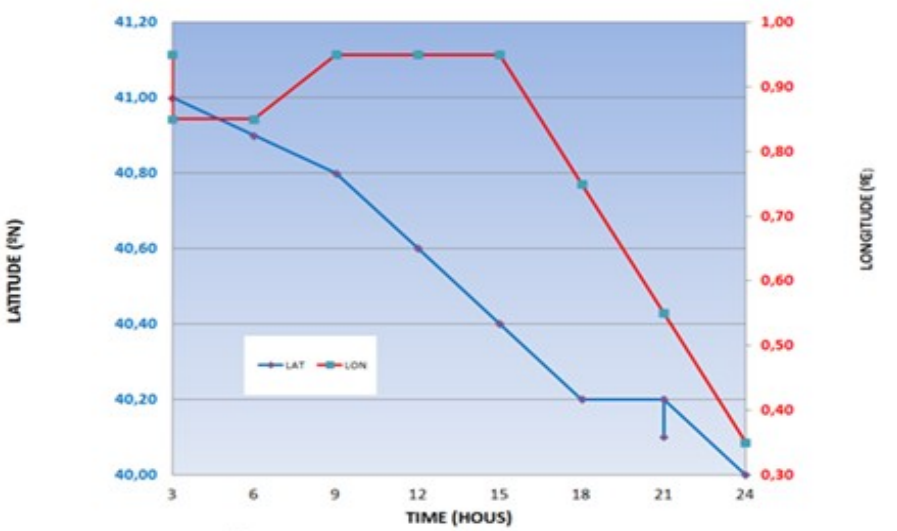
4. Tritium patterns and short range trajectory of liberated emission associated to real time wind speed and direction, stability or convection.

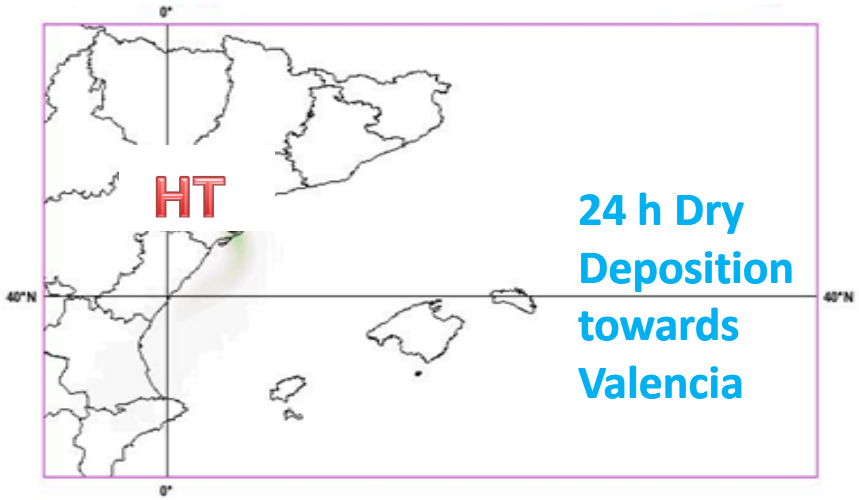
Patterm	Transport plume distance (Km)	Magnitud order range HT (Bq/m^3)	Tendency HT reduction	Observed 10m wind (km/h)
A-Stationary Plume to North	0 < R < 100 km Local to mesoscale	6-3	Caotic fashion ruduction	CALM OR VERY LIGHT 0 < v < 5 km/h
B-Stationary plume to the South	0 < R <100 Km Mesocale transport	3-6	No Reduction (& orographic effects Ijust in coast)	LIGHT 0 < v < 20 km/h
C-Fast displacement plume+ Vortex by orography	100 < R < 200 Km Large transport distance (in mesoescale)	6-2	Quasi lineal reduction	MODERATE 20 < v < 50 Km/h
D-Very fast displacement Plume	R > 240 Km Very Large transport distance (to synoptic)	6-2	Continuos reduction	STRONG 50 < v < 100 Km/h

[2] Validation of real time dispersion of tritium in ITER reactor over the Western Mediterranean Basin in different assessments P. Castro, M. Velarde, J. Ardao, J.M. Perlado, L. Sedano. ICENES 2011 Proceedings, San Francisco (USA), May (2011)

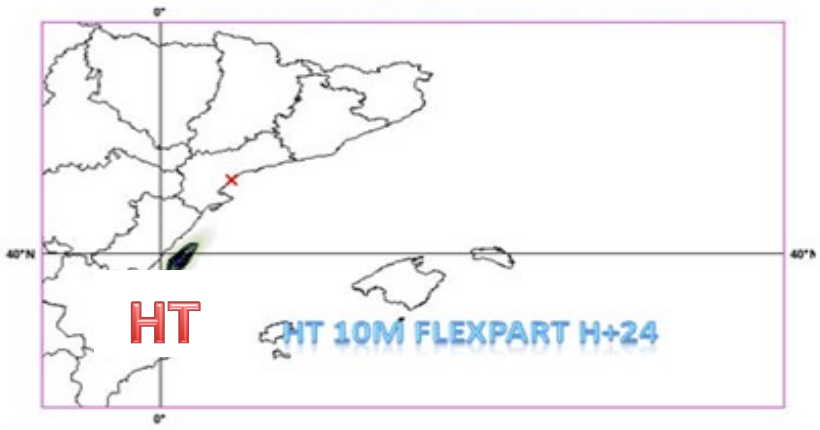
Short Trajectory to SE for 24 h (Pattern-A)



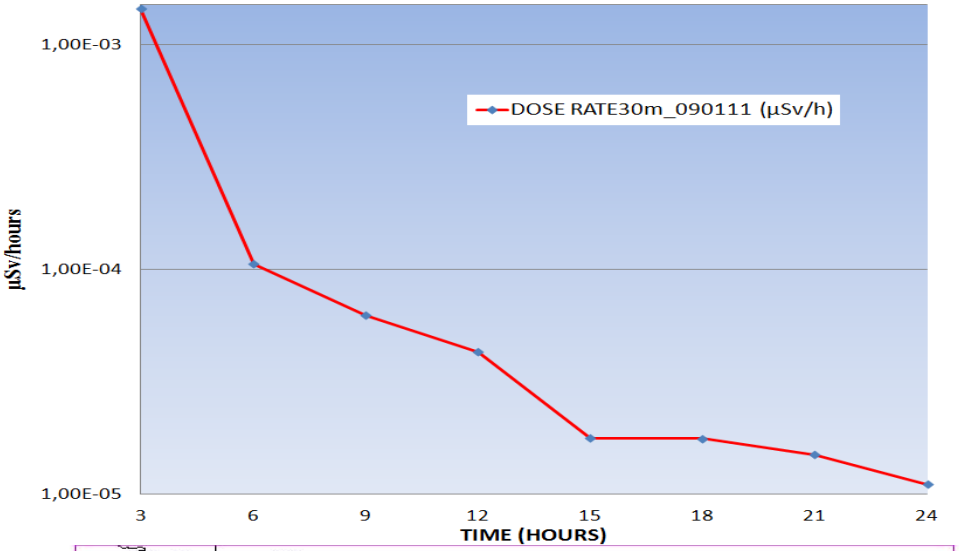


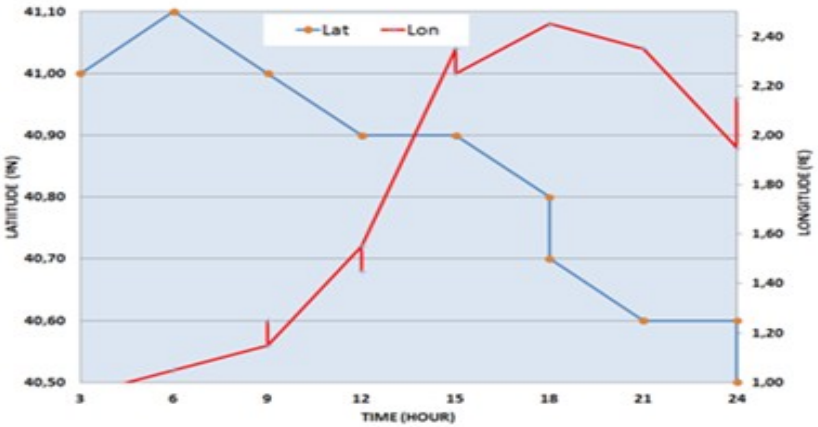


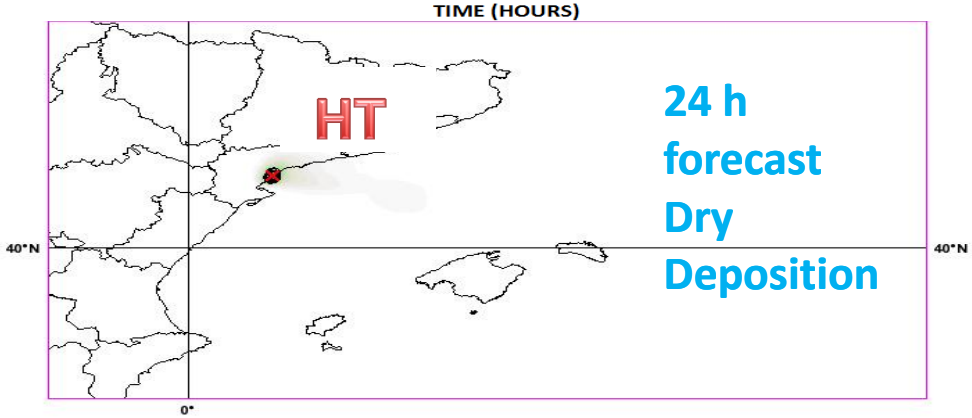
24 h Dry Deposition towards Valencia



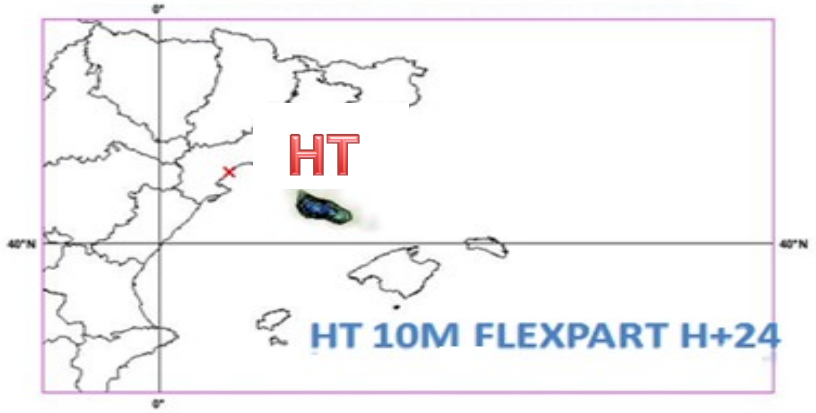
Short Trajectory to SE for 24 h (Pattern-B)



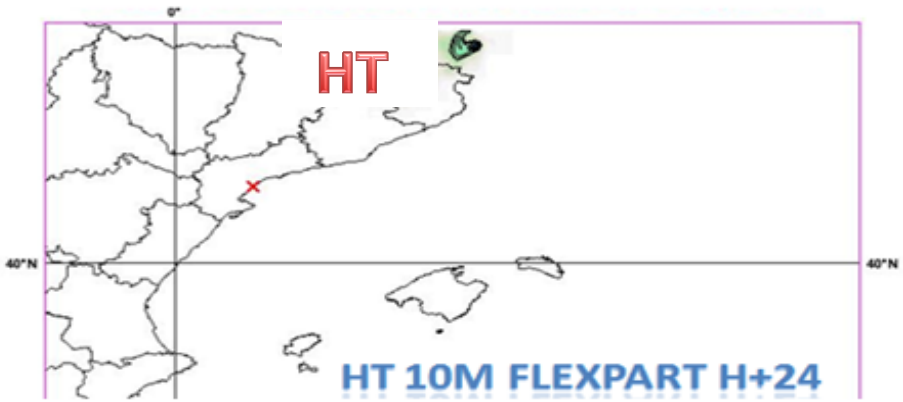


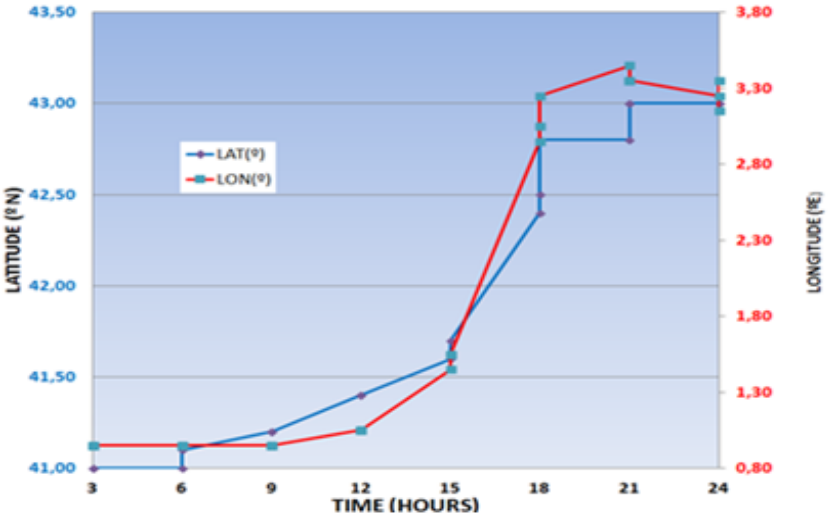


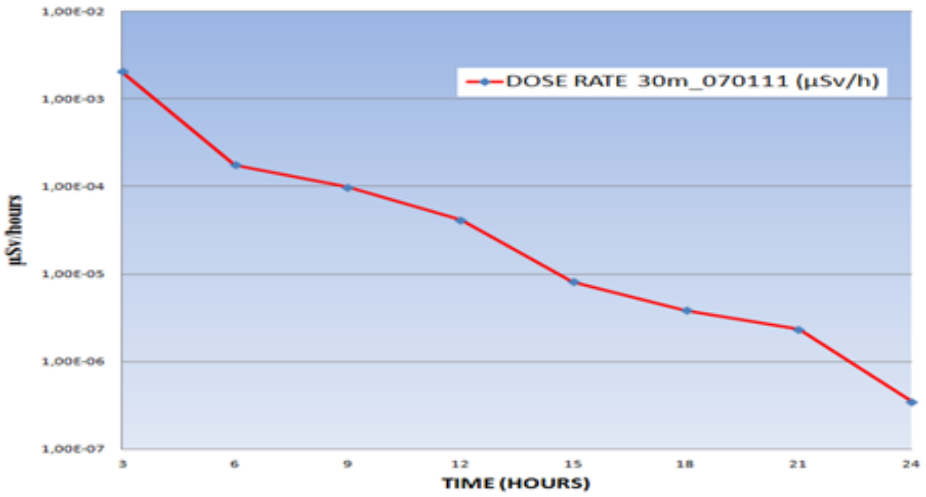
24 h forecast Dry Deposition

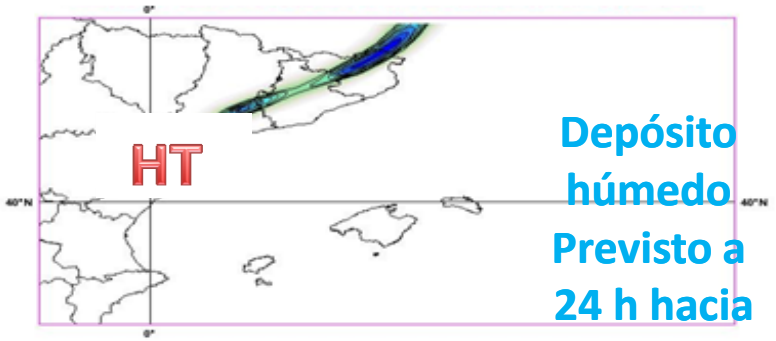


Long Trajectory to NE for 24 h (Pattern-C)



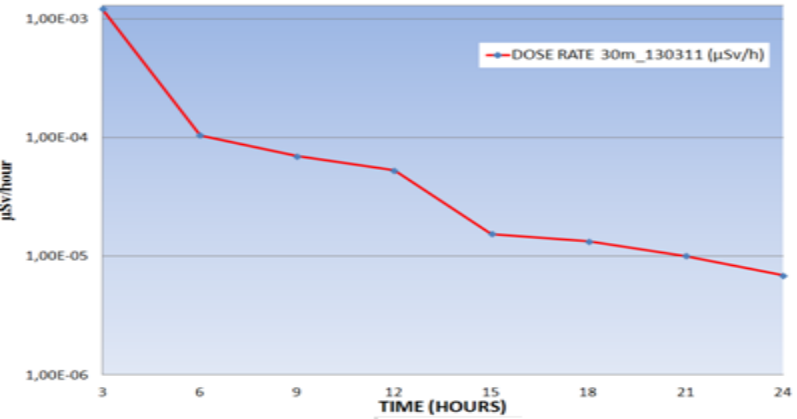


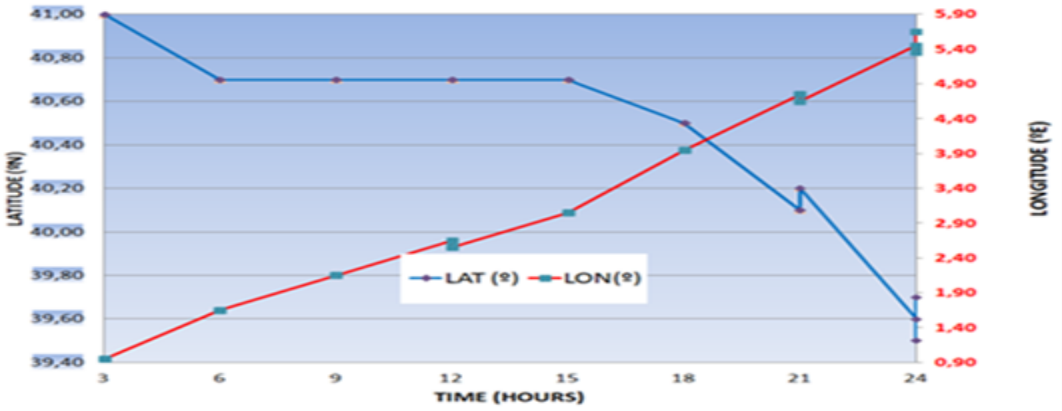


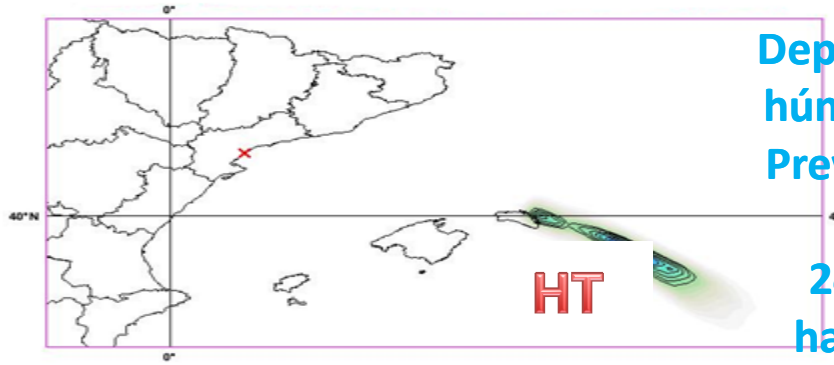


Depósito húmedo Previsto a 24 h hacia Francia

Long trajectory towards SE for 24 h (in Pattern-D)

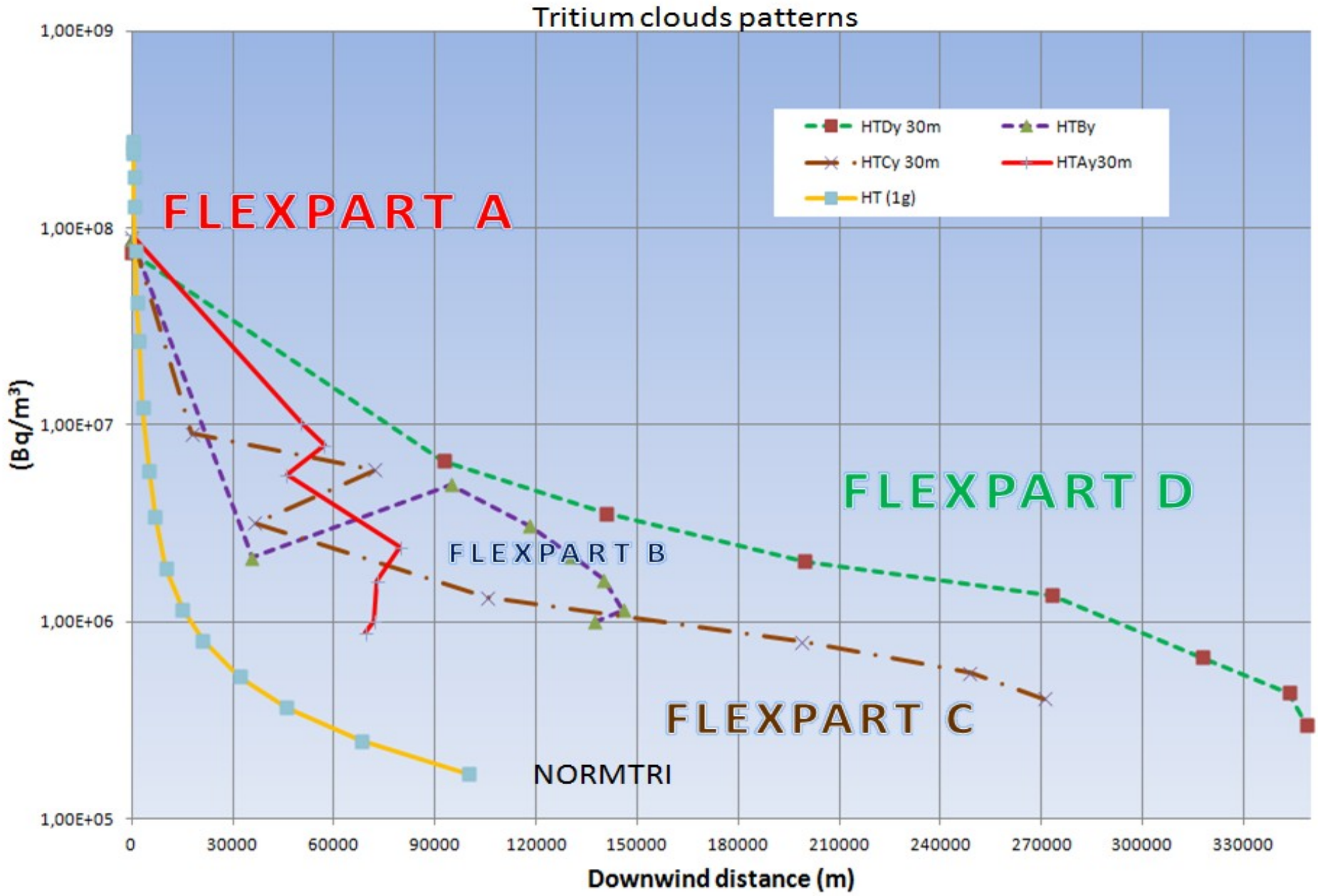




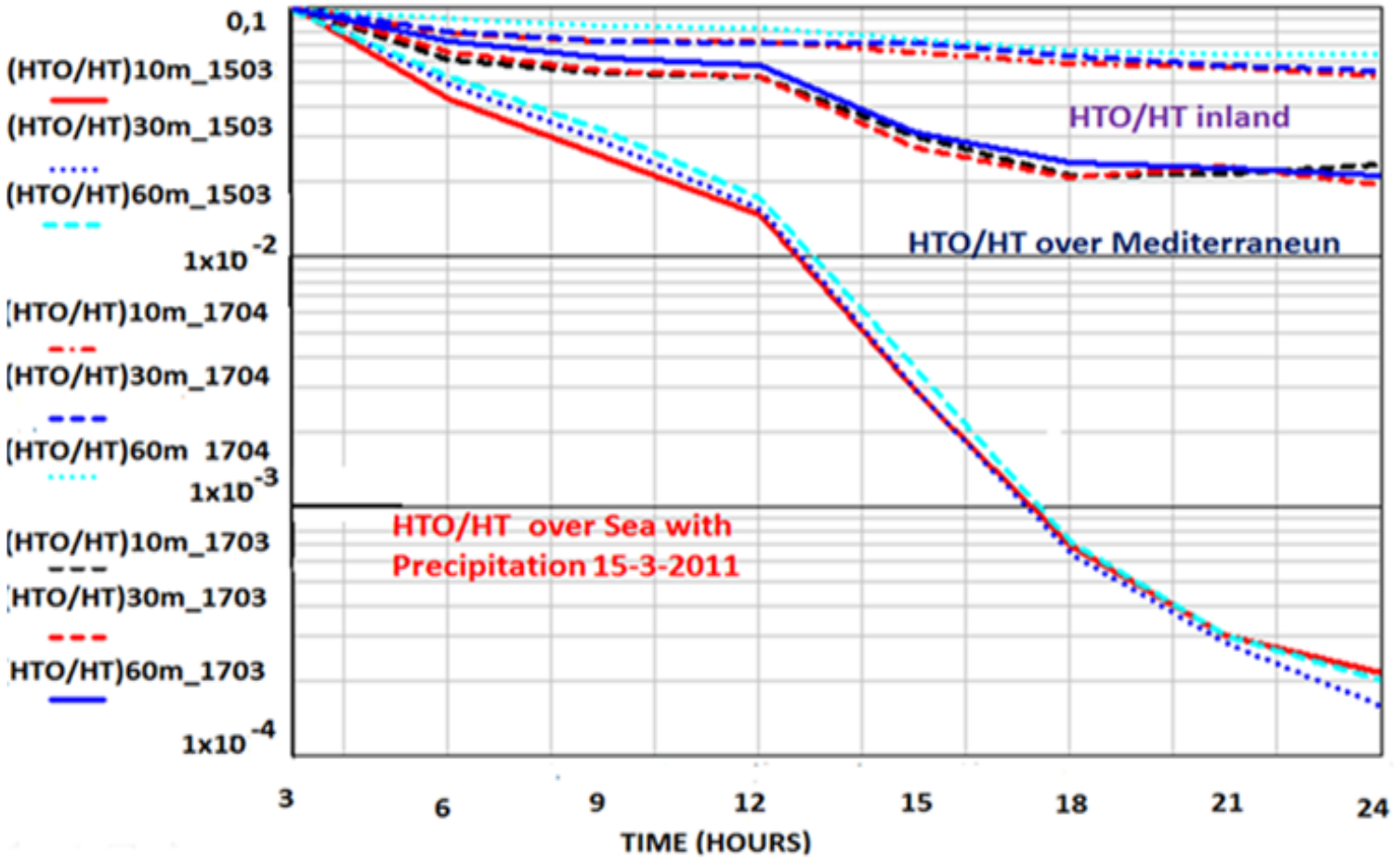


Depósito húmedo Previsto a 24 h hacia Menorca

5. Validation of HT-FLEXTRA source term and patterns with NORMTRI.

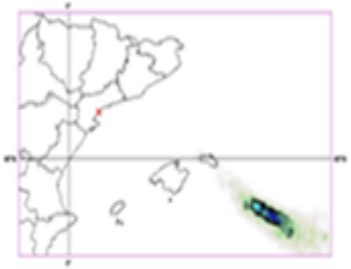

Tritium clouds patterns
HTDy 30m
HTBy
HTCy 30m
HTAy30m
HT (1g)
FLEXPART A
FLEXPART B
FLEXPART C
FLEXPART D
NORMTRI
1,00E+09
1,00E+08
1,00E+07
1,00E+06
1,00E+05
(Bq/m³)
0
30000
60000
90000
120000
150000
180000
210000
240000
270000
300000
330000
Downwind distance (m)

6. Evolution of HTO/HT ratio in short range



forecast H+24

17-4-2011



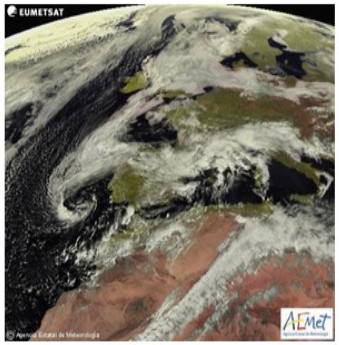
17-3-2011

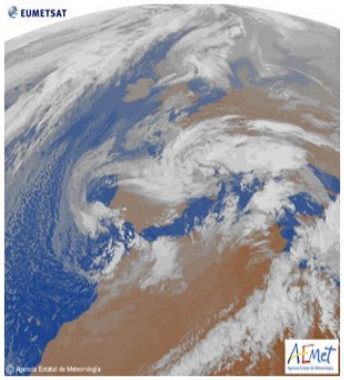
15-3-2011

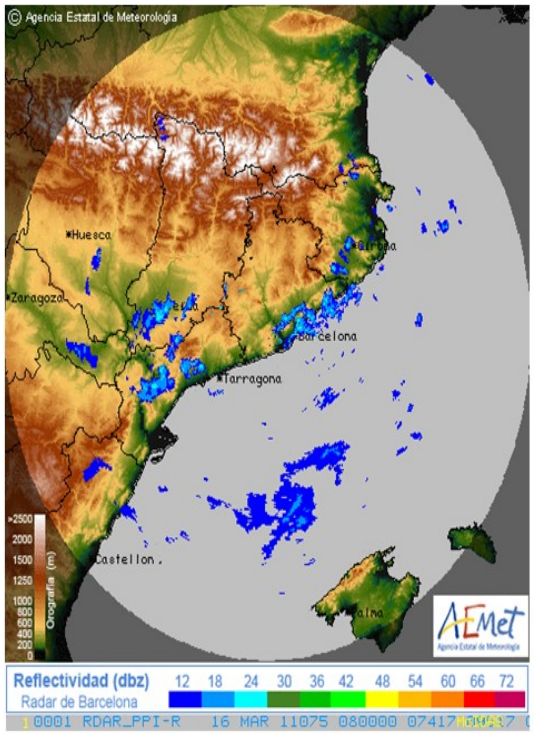
Maximum dose reduction in air by PCP

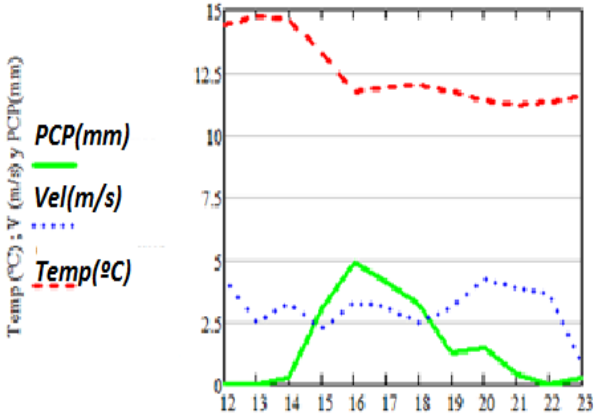
(important deposition)

VIS & IR MSG 15-March 2011 &
PCP in Regional BCN Radar

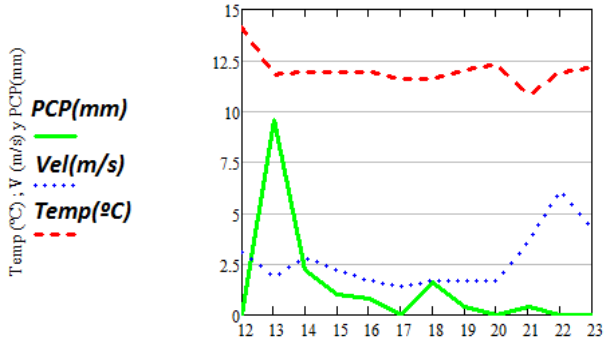








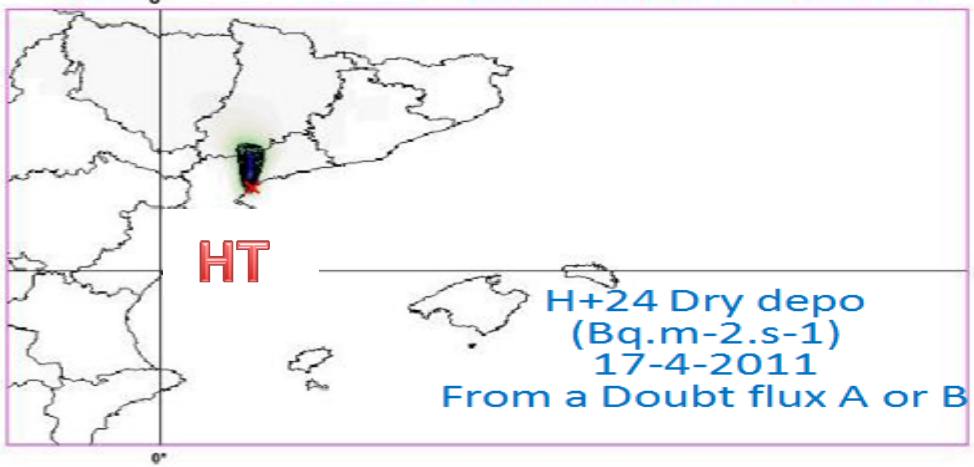
Reus 15-3-2011



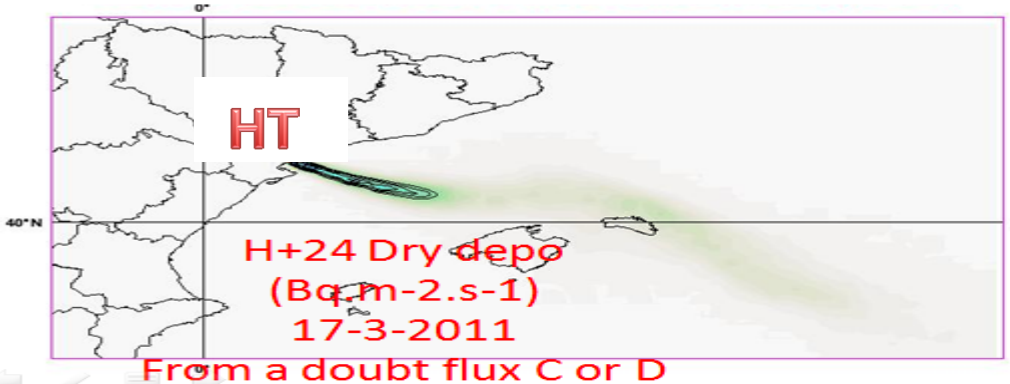
Tortosa 15-3-2011

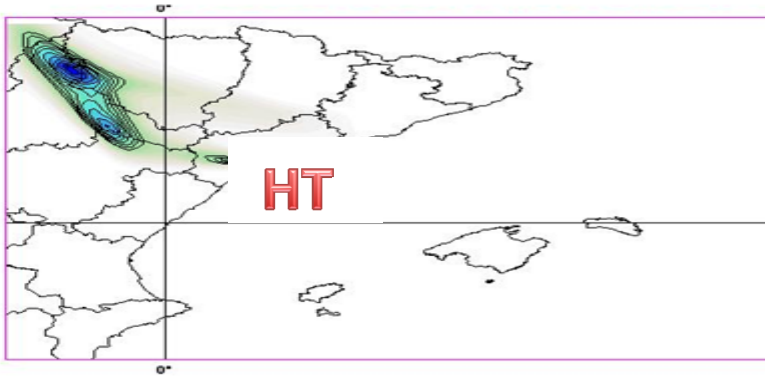
7.New R&D Requirements

Dry or Wet depositions (without accumulation)
A patern & C – D doubtful patterns

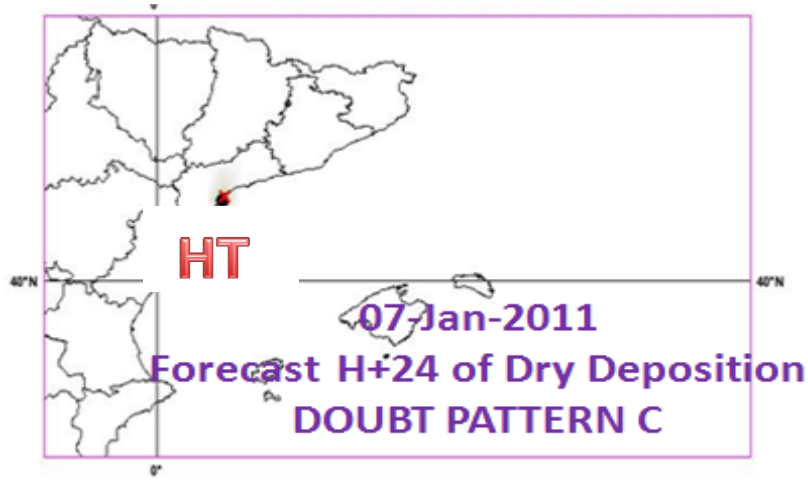


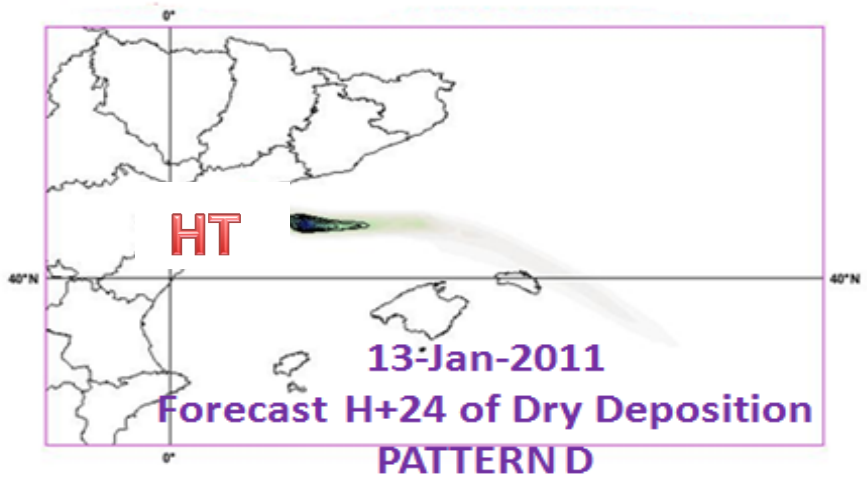
H+24 Wet deposition
(Bq.m-2.s-1)
15-3-2011
Precipitation

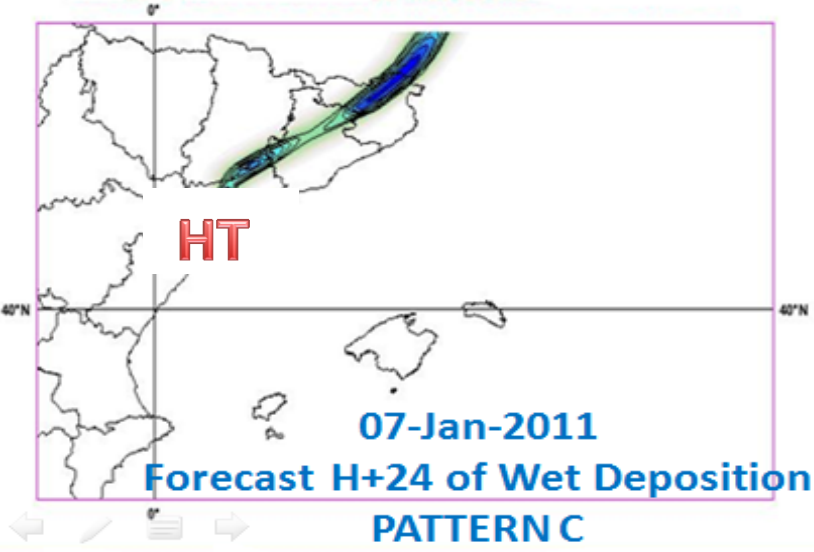


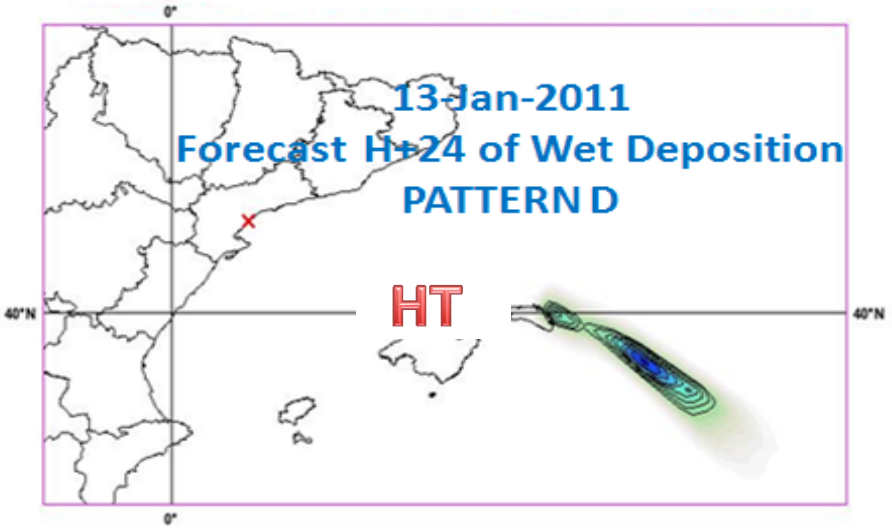


Dry or Wet deposition
H+ 24 hours C and D

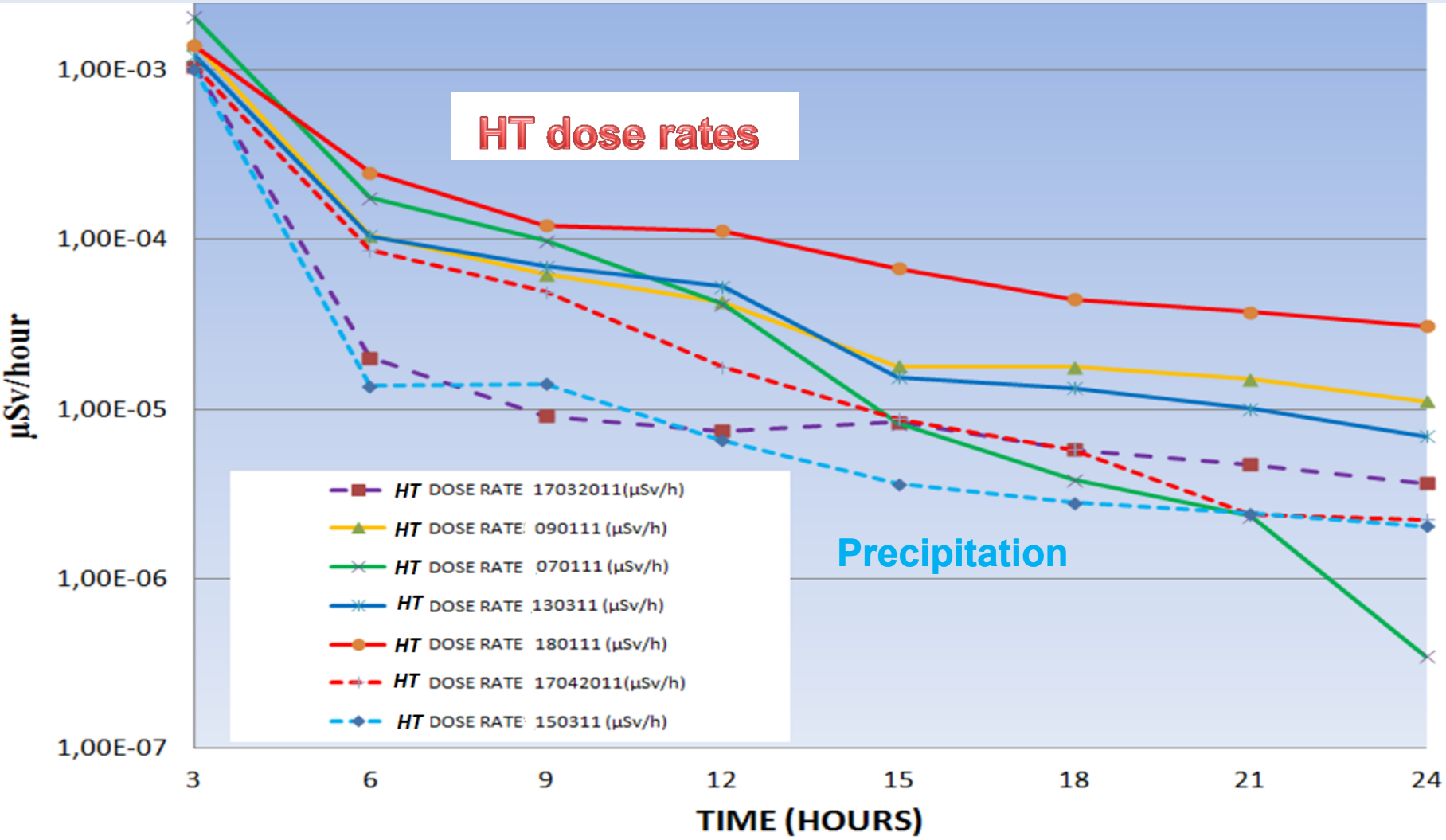




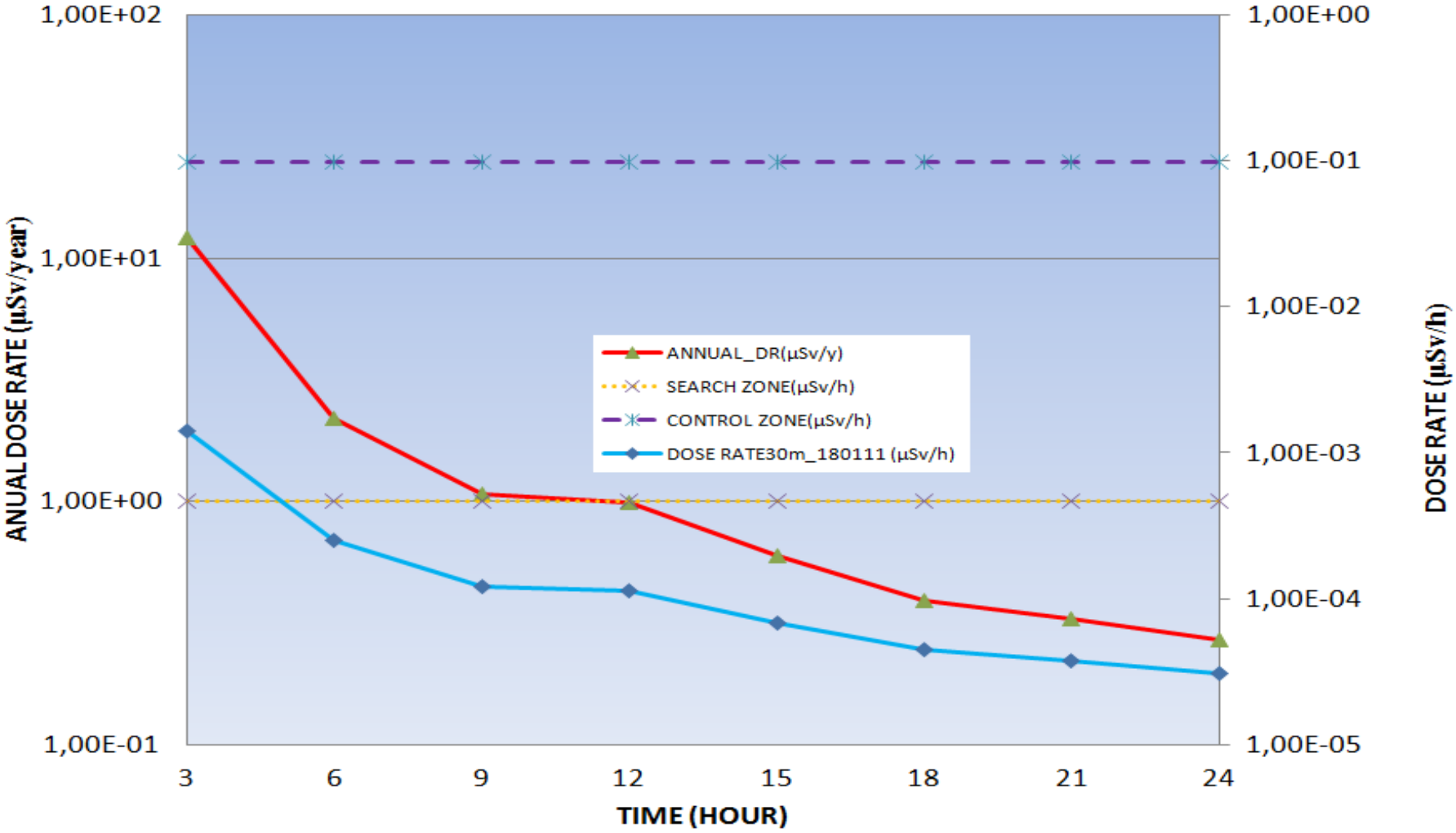




Decreasing of inhalation HT *dose rates* in *all cases*.



An approximation to probable *annual & daily HT dose rate* by inhalation



8.Conclusions (1/3)

- **The activities output in *real time with* ECMWF/FLEXPART – in the cases of short term releases – has been validated with NORMTRI from a determined tritium source term: annually 1 g of HT (or 0,1 g of HTO).**
- **It has been determined *4 patterns of tritium clouds in* the primary phase with transport over the western Mediterranean basin and over continental Europe (Spain and France…). A and B patterns corresponds to stability (due a High pressure system with or without thermal inversion). The tritium clouds incidentally formed have a vertical development trapped under thermal inversion (in that case). The trajectories are almost quasi stationary for HT and HTO trajectories, they are on site or downwind very close the liberation point.**

8.Conclusiones (2/3)

- **C & D patterns corresponds to *convection sceneries*. The tritium clouds by incidental releases have a bidirectional development with off-site trajectories as forecast in short range.**

- **In addition to the patterns other trajectories are possible as demonstrated by means of the ratio HTO/HT :**

  i) IN LAND TRAJECTORY: Forecast ratio HTO/HT can be in the range from 0.1 to 0.06 in 24 hours (may be Pattern A or B);

  ii) OVER SEA TRAJECTORY: Forecast ratio HTO/HT can be in the range of 0.1 to 0.01 in 24 hours (may be Pattern C or D):

  iii) PRECIPITATION: Forecast ratio HTO/HT in the range from

  0.1 to 1.E-4 in 24 hours.

8.Conclusions (3/3)

- **For HT, the approximated dose rate (ICRP-60,ICRP-71,ICRP-72) - at level of 30 m – should presents a value *around 2,05E-3 µSv/h in the 3 first hours.* This stochastic dose rate should be insignificant. Therefore they will not became NOWCASTING OR CONTROL ZONES (e.g. as proposed in draft CSN_IS-10 regulation ~3 *µSv/h*).**
- **Following extrapolation annual efective dose rate should be for a person living in Vandellós Area, around 0.012 mSv/año. Again insignificant level in comparison with the standar value. The exposure to nuclear fuel limit, for public, recommended by ICRP-60 should be 1 mSv/ year.**
- **A new review of requirement and capabilities of R+D for environmental impact of *fusion facilities should be made with contributions to dose rates* (by inhalation and ingestion in base of new DCF for FUSION).**

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