

Growing  
**ideas**  
through  
**networks**

inDust  
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## **Dust Icing - AirFrance accident**

***S. Nickovic, B. Cvetkovic, RHMSS Serbia***

***Contributions: RHMSS and NOA (Athens) teams***



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of the European Union



**User Workshop on Dust Products for Aviation, 20th May 2021, remote meeting**


# Results of recently published article (supported by inDust)

nature

SCIENTIFIC  
REPORTS

Article | [Open Access](#) | Published: 19 March 2021

## Cloud icing by mineral dust and impacts to aviation safety

Slobodan Nickovic, Bojan Cvetkovic, Slavko Petković, Vassilis Amiridis, Goran Pejanović, Stavros Solomos, Eleni Marinou & Jugoslav Nikolic 

*Scientific Reports* **11**, Article number: 6411 (2021) | [Cite this article](#)

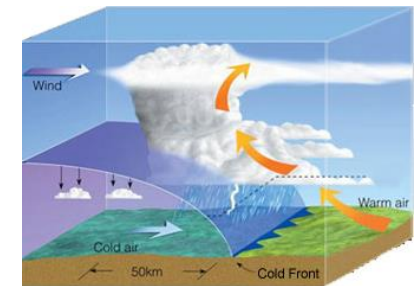
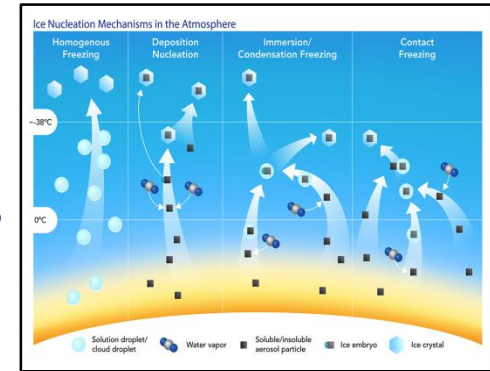
### Motivation for study

- ☐ Exploring if/how much icing caused by dust affects the aviation en-route operations
- ☐ DREAM dust model used to reconstruct environmental conditions
- ☐ Introducing new dust-dependent prognostic Icing Index
- ☐ Testing the method for two catastrophic aviation accidents

# Cloud icing – major threat for aviation

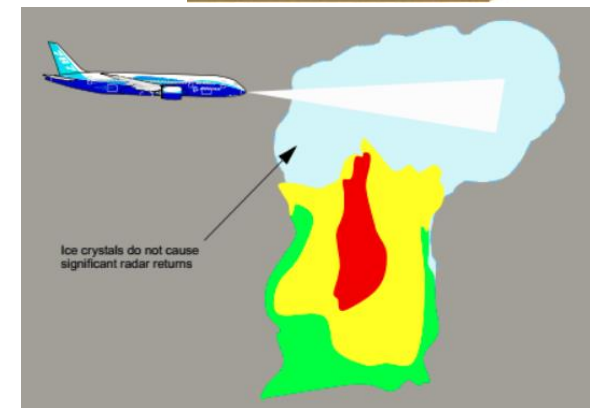
## Mineral dust – the most efficient ice nuclei agent

- ☐ Does dust enhance cloud ice crystals production?
- ☐ If yes, how much?
- ☐ Does it affect aircraft safety?



## Cumulonimbus anvil - most dangerous icing zone

- ☐ Cockpit radars cannot detect small ice particles
- ➔ Ice can freeze aircraft instruments (Pitot tube, air pressure sensors)



# Icing Indices examples (no dust inside)

## No single icing index considering dust in the community

**SMHI**

*Meteorol. Appl.* 10, 111–114 (2003)

DOI:10.1017/S1350482703002020

A new algorithm to estimate aircraft icing in the HIRLAM model

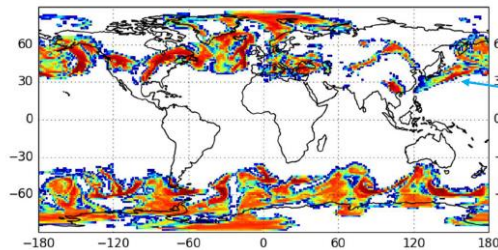
### The current operational Inflight Icing Index

- If  $-20^{\circ}\text{C} < \text{Temp} < 0^{\circ}\text{C}$  and cloud is present:

Icing index = relative humidity

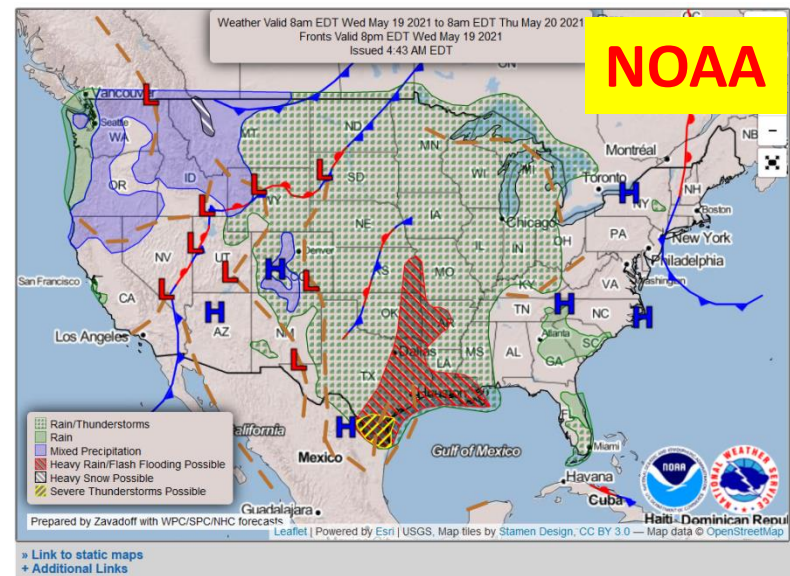
**UKMO**

WAFC London UnBlended, regridded, mean inflight icing forecast at 700hPa  
11/01/2018 00Z model run, T+24



Almost  
binary output

© Crown Copyright 2016, Met Office



# Accident reports

## June 2009 Air France flight (AF477)

❑ BEA Rreport: ...following the obstruction of the Pitot probes by ice crystals, the speed indications were incorrect and some automatic systems disconnected...probably caused by ice crystals... '.

❑ 228 deaths



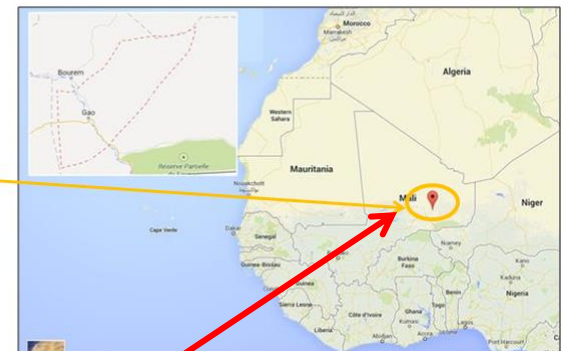
## July 2014 Air Algérie flight (AH5017)

❑ BEA Rreport: ...high dust content was combined with convection over the northern area of the Sahel...'

'... the concentration of dust may affect the quantity and concentration of condensation nuclei in cumulonimbus.'  
...'the presence of ice crystals within the anvil cloud was very likely'

❑ 116 deaths

Estimated location of  
Accident ~2am UTC





# DREAM dust model + ice nucleation

## Dust Regional Atmospheric Model (DREAM)

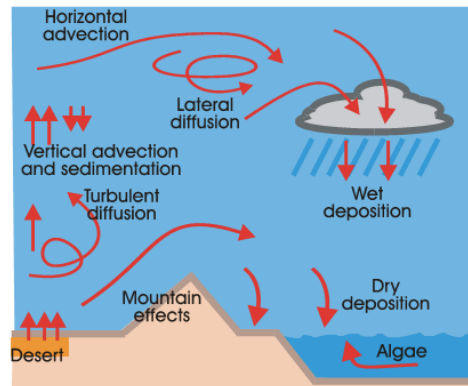
[Nickovic et al., 2001, Perez et al, 2006; Vukovic et al, 2014]

$$\frac{\partial C_k}{\partial t} = -u \frac{\partial C_k}{\partial x} - v \frac{\partial C_k}{\partial y} - (w - v_{gk}) \frac{\partial C_k}{\partial z} - \nabla \cdot (K_H \nabla C_k) - \frac{\partial}{\partial z} \left( K_z \frac{\partial C_k}{\partial z} \right) + \left( \frac{\partial C_k}{\partial t} \right)_{\text{SOURCE}} - \left( \frac{\partial C_k}{\partial t} \right)_{\text{SINK}}$$

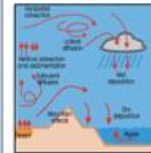
-25km resolution;  
- Sahara/Mediterranean domain  
- Particle bin r: 0.15, 0.25, 0.45, 0.78, 1.3, 2.2, 3.8, 7.8 μm

### DREAM:

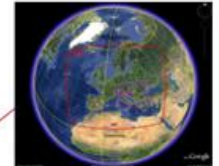
- simulates all major processes of the **atmospheric dust cycle**
- Driven by the non-hydrostatic NCEP NMME model
- includes different dust **mineral fractions**
- simulates **ice nuclei concentration**



## Cold cloud formation: 'cooking' recipe



DREAM model



NMM model

Dust C

T, RH

DeMott (2015) [-35°C < T < -5°C]

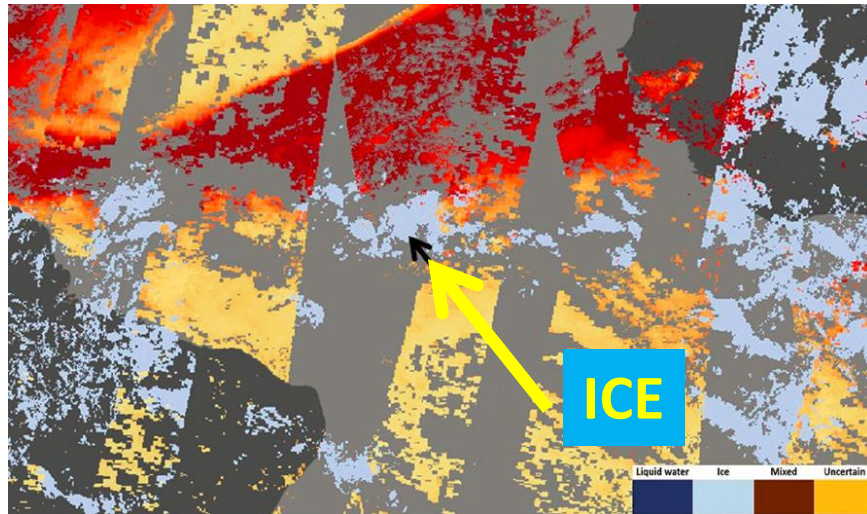
$$n_{IN} = C(n_{dust})^{\alpha(27316-T)+\beta} \exp(\gamma(27316-T)+\delta)$$

Steinke et al (2015) [-55°C < T < -35°C]

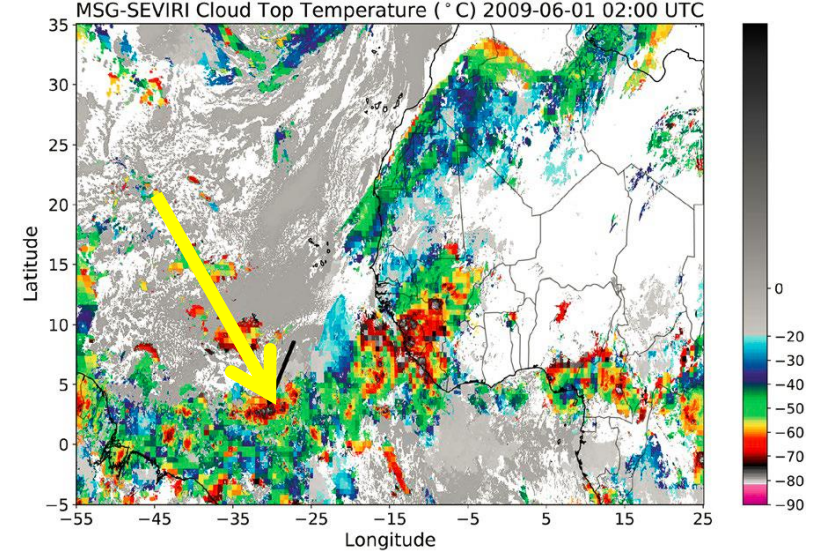
$$n_{IN} = S_{dust} 1.88 \cdot 10^5 e^{-pT+q(RH_{eq}-100\%)}$$

$n_{IN}$

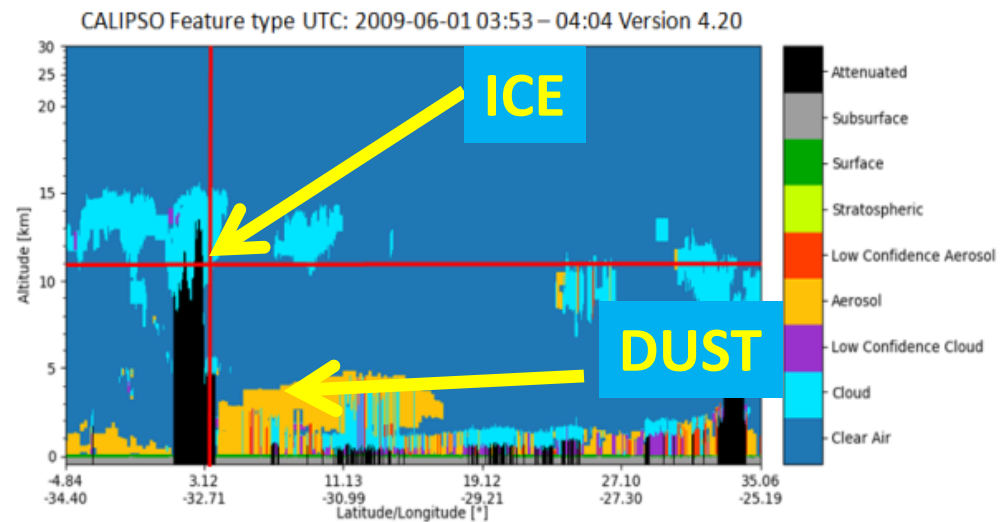
# AF477 flight conditions: Satellite obs



Dust optical depth and ice (MODIS)

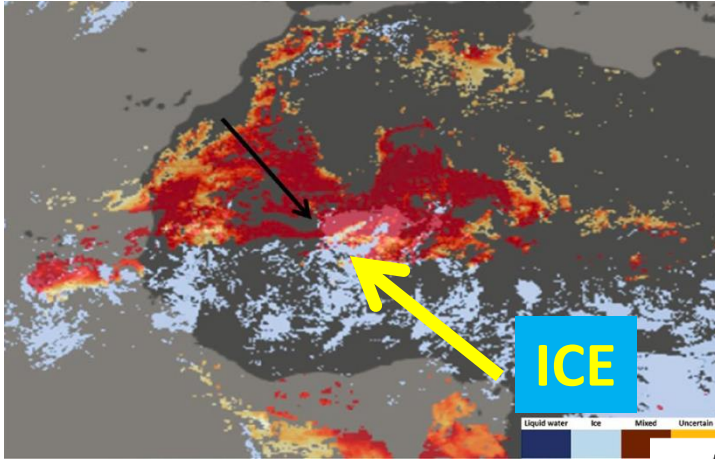


Cloud top temperature (MSG SEVIRI)

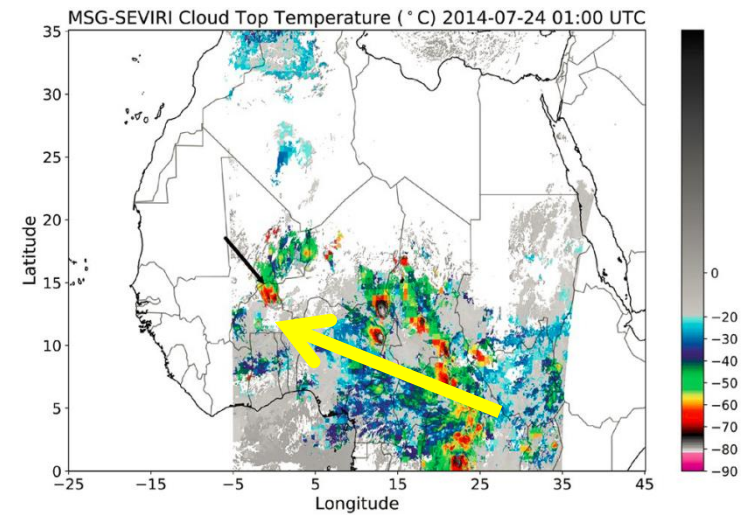


Ice and dust (CALIPSO)

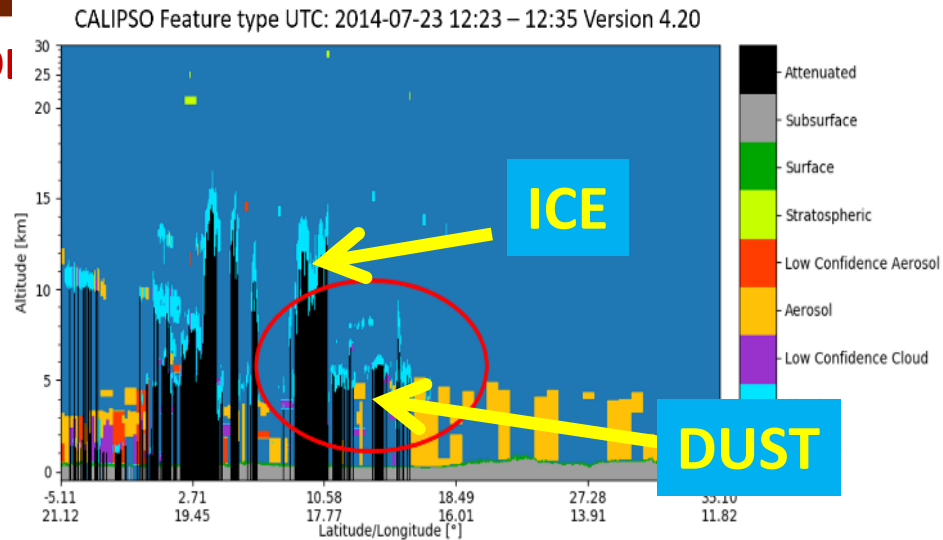
# AH5017 flight conditions: Satellite obs



Dust optical depth and ice (MOI)



Cloud top temperature (MSG SEVIRI)



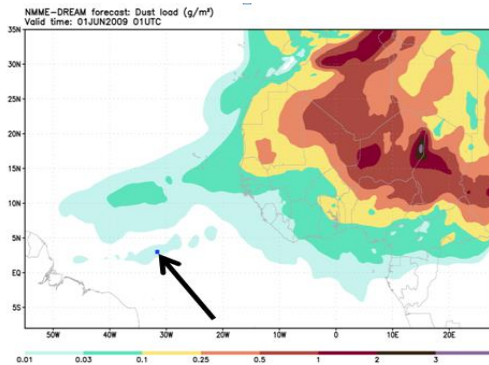
Ice and dust (CALIPSO)



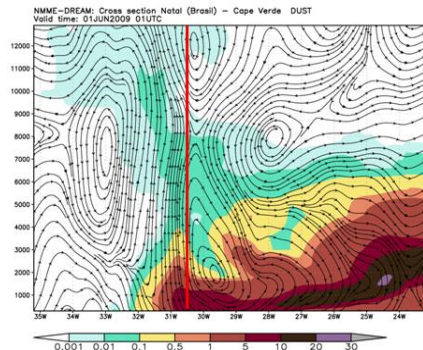
# Model predictions

AF477

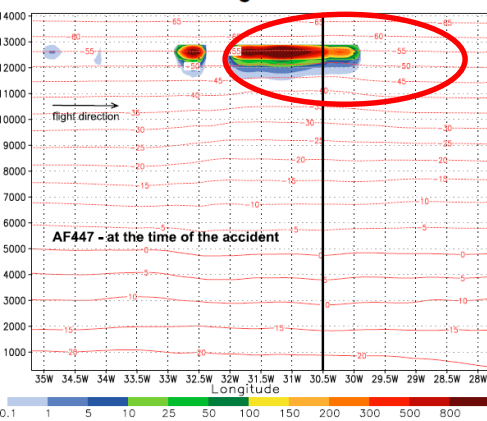
AH5017



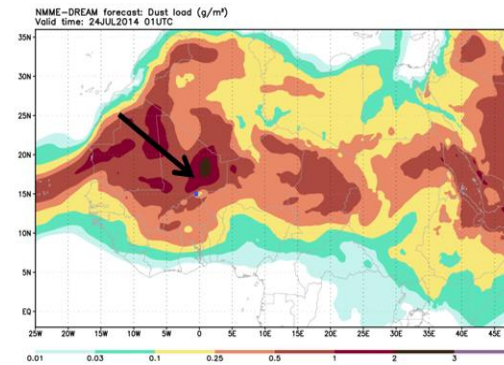
Dust load



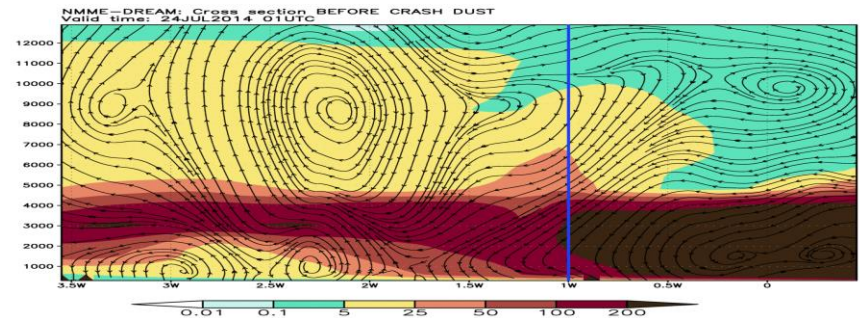
Dust C – cross section



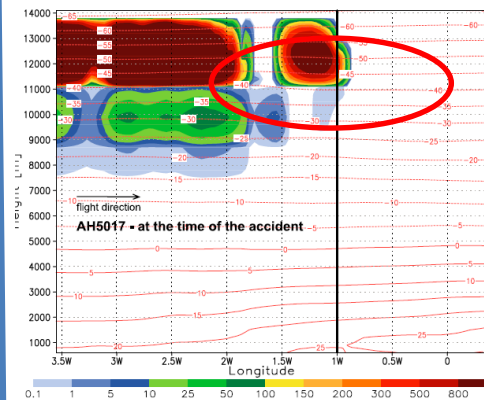
Log10(IN) cross sect



Dust load



Dust C – cross section



Log10(IN) cross sect

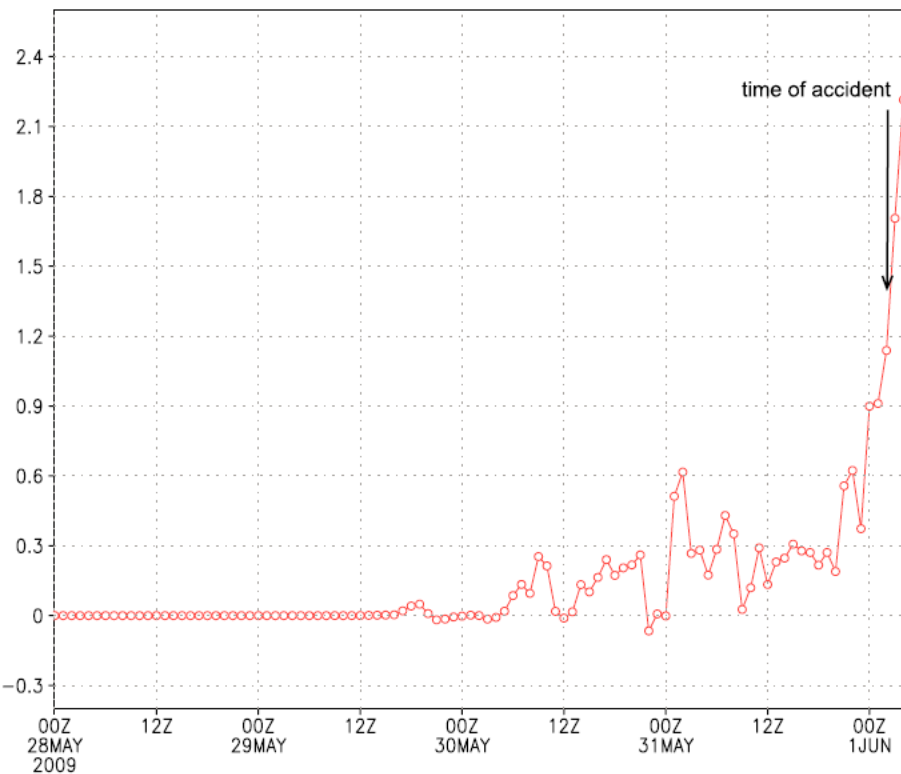
# ICING INDEX

$$DII = n_{IN} w$$

ice nuclei number:  
includes T, RH, dust C

vertical velocity:  
reflects convective  
dynamics

## AF477



## AH5017



$$DII = n_{IN} w$$