Servicio Meteorológico Nacional
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Probabilistic volcanic ash dispersion modeling of the 2019 Ubinas volcano eruption

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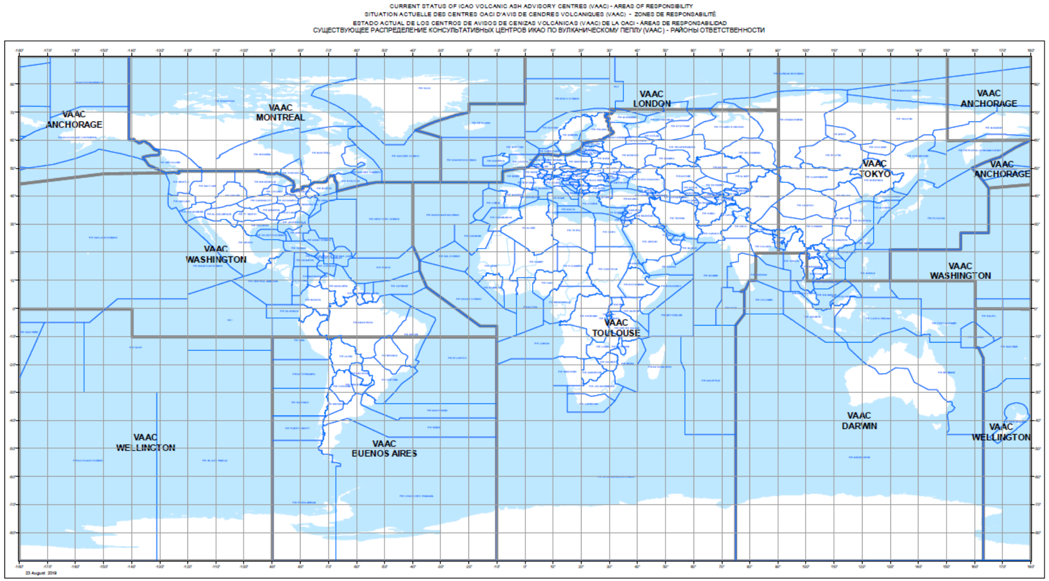
Introduction

- Volcanic ash is **threat to aviation safety**.
- Many incidents occured when airplanes encouter VA during the last 30 years (Guffanti et al., 2010, Casadeval 1993).



- Next Generation volcanic ash cloud forecasts **Quantitative Volcanic Ash Information (QVA)** produced by VAACs in the following years (ICAO Roadmap, 2019).

Introduction

- **QVA** information (ICAO Roadmap, 2019) will provide:
  - Deterministic
  - Probabilistic

  } forecasts for contamination levels → decision makers to use

Probabilistic forecasts → ensemble-based modelling to characterize uncertainties in model inputs, model physics and its parameterizations, the underlying model driving meteorological data (Folch et. al, 2020)

Ensamble dispersion forecasting of VA: HYSPLIT (Dare et al., 2016; Zidikheri et al., 2018; Crawford et al., 2022), NAME (Dacre and Harvey, 2018; Beckett et al., 2020), FALL3D (Osores et al., 2020, Folch et al., 2021), and others.

Objetive

Test FALL3D ensamble model version 8.1 (Folch et al., 2022) applied to the July 2019 Ubinas volcano eruption and compare the results with satellite data to produce the Next Generation Volcanic Ash forecasts for VAAC Buenos Aires

Methodology - Case of study

Ubinas volcano (16.34°S; 70.89°W; 5672 m.s.n.m.) is an andesitic stratovolcano that is part of the Central Andes Volcanic Zone and is the most active volcanoes in Perú (Del Carpio and Hernando Tavera, 2019).

On 19 July 2019 the first eruption was detected at 07:30 Z GOES-16 satellite imagery.

During the following hours the VOLCAT system (https://volcano.ssec.wisc.edu/) estimated plume heights reaching upto 18- 20 km.

Methodology - Model

FALL3D (Folch et al., 2020, 2022)

Model Setup

Start: 19 July 7:30 Z **End**: 21 July 06Z

Meteorological driver: Global Forecasting System (analysis and short term forecast from cycles 00, 06, 12, 18 Z)

Horizontal resolution: 0.25°

Vertical resolution: 1km – top: 30 km

Control Run:

Source term: Suzuki (Pfeiffer et al., 2005)

Top Column height (H) : correlation of brightness temperatures, plume horizontal speed and atmospheric temperature and wind profile.

TGSD: Gaussian Distribution based on Mastin et al., (2012) and Costa et al., (2016)

Ensemble members:

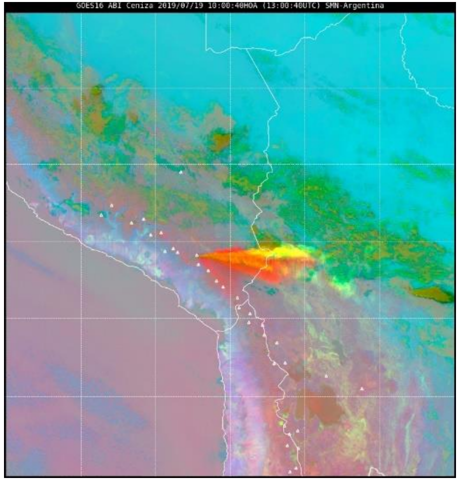
Random samples from a uniform distribution of H, Suzuki-A and Mean grain size from Control Run parameters and wind perturbations.

Parameters	S1	S2	S3
H (rel)	**30%**	**30%**	**30%**
Suzuki-A (abs)	**2**	**2**	**2**
Mean grain size (abs)	-	-	**2**
Wind (rel)	-	**20%**	-
Ensemble members	20	30	30

Methodology - Verification

Qualitative comparison

Ash RGB GOES

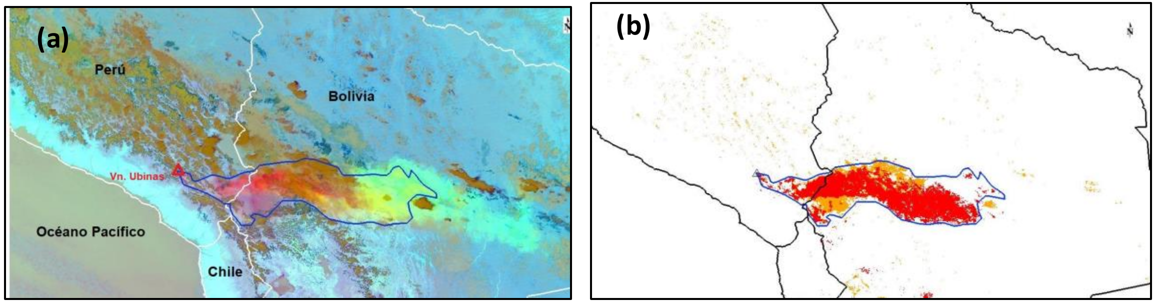


Color	Band/ Band diff (µm)
Red	12.3 – 10.3
Green	11.2 – 8.4
Blue	10.3

Categorical verification

NPP-VIIRS Classification

Ash (red and orange) – No Ash

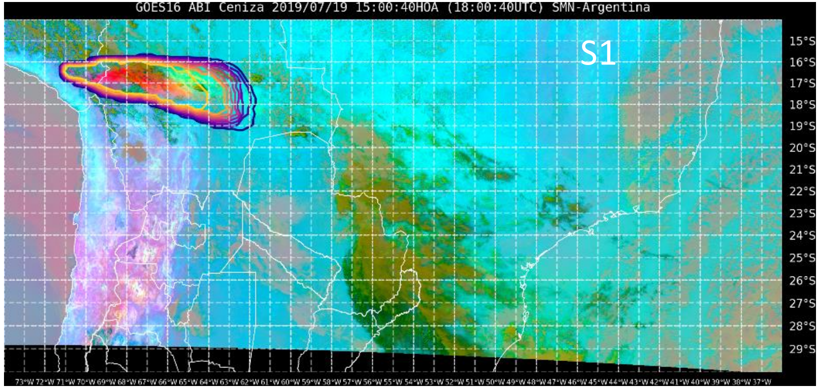


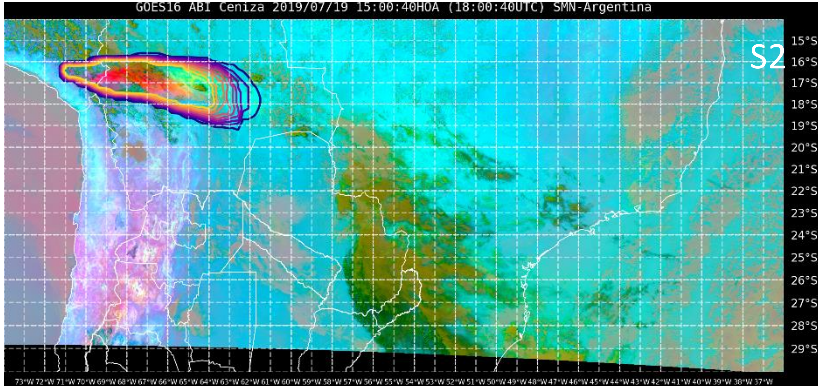
RGB ASH for 19/07/2019 at 17:56 UTC

Classification of ash and no ash pixels based on a 3 IR band differences (using 8.55, 10.763, 12.013 µm) method proposed by Guehenneux et al. (2015) that was adapted for VIIRS Sensor by Rodriguez et al.(2022).

Results - Qualitative comparison

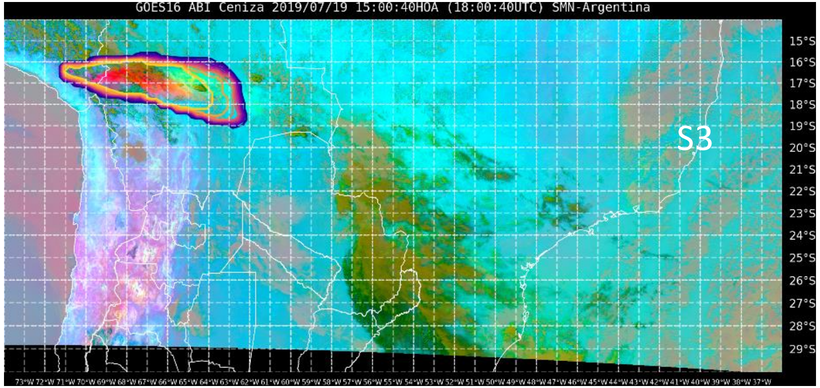
19jul2019 18:00 UTC





Ash RGB using GOES-16 ABI data (shaded)

- **Red** ⇨ Ash
- **Yellow** ⇨ Ash+SO2
- **Green** ⇨ SO2

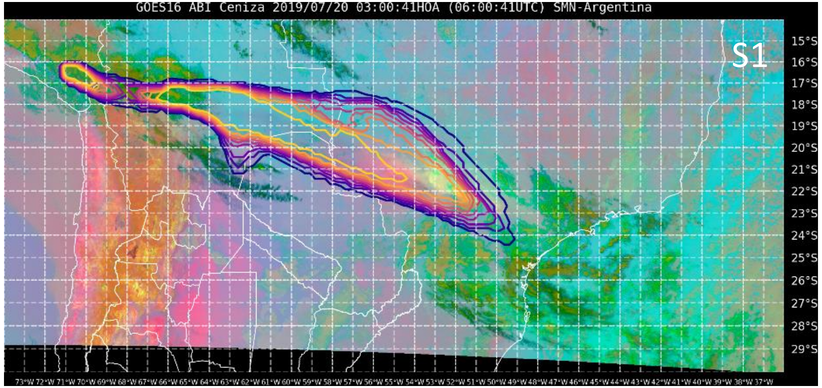


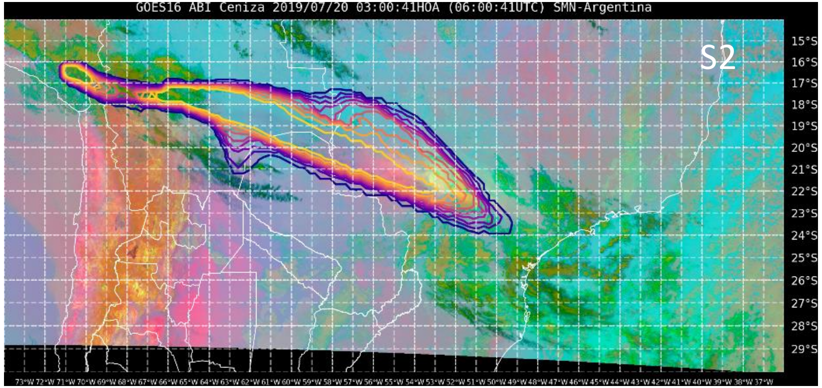
Ash mass load Relative Frequency of exceeding 0.2 g m^{-2} from 0.1 to 1 (contours)

- 0.1
- 1

Results - Qualitative comparison

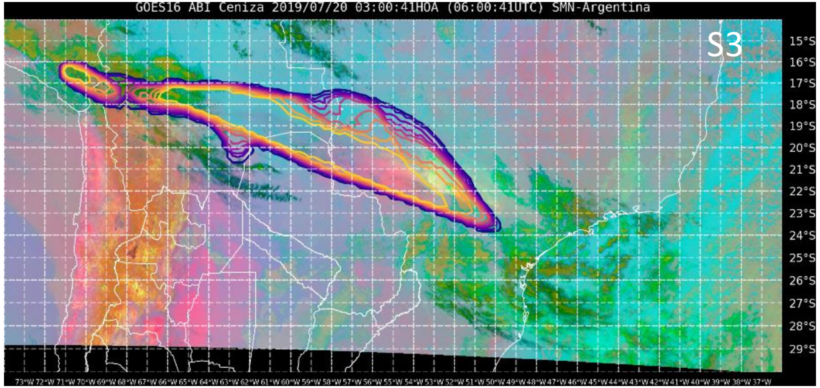
20jul2019 06:00 UTC





Ash RGB using GOES-16 ABI data (shaded)

Red → Ash
Yellow → Ash+SO2
Green → SO2



Ash mass load Relative Frequency of exceeding 0.2 g m^{-2} from 0.1 to 1 (contours)

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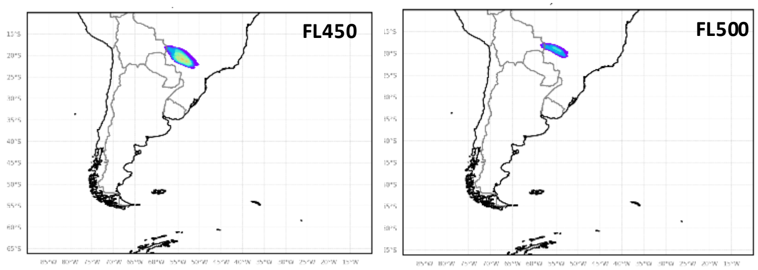
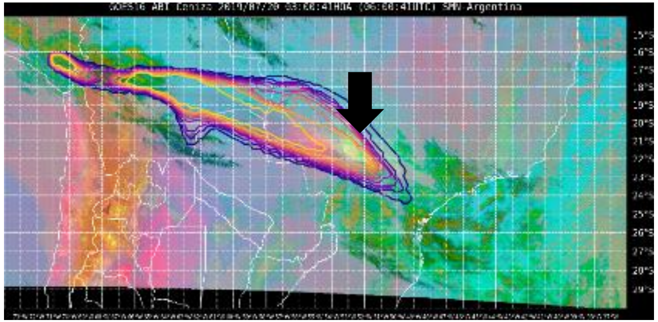
1

Results - Qualitative comparison

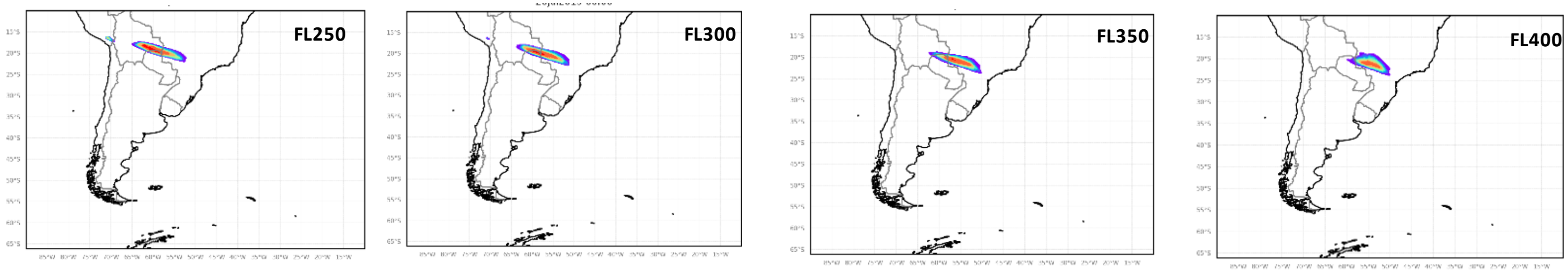
20jul2019 06:00 UTC

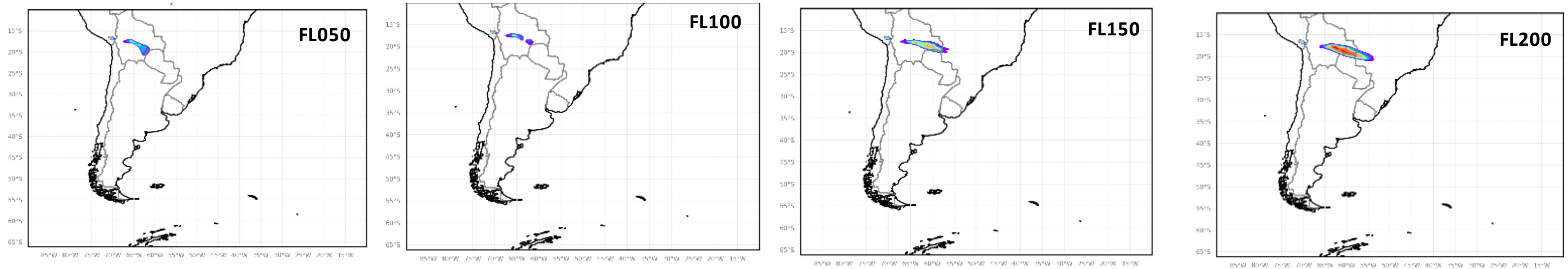


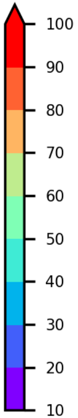


S1

Concentration Relative Frequency of exceeding 0.2 mg m^{-3} at each vertical level







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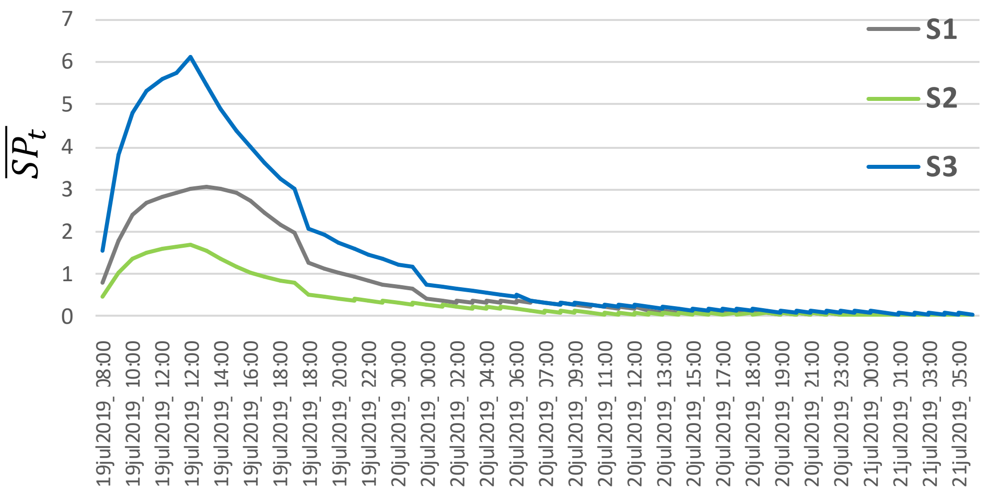
Results – Ensemble variabillity

Ash Mass Load ensemble spread spatial mean



$$\overline{SP_t} = \sqrt{\overline{m^{-1}\sum_{i=1}^{m}(y_t^{(i)} - \overline{y_t})^2}^{lat,lon}}$$

$\boldsymbol{t}$: $time$

$\boldsymbol{m}$: $number\ of\ members$

$\boldsymbol{y_t^{(i)}}$: *ash mass load ensemble member i*

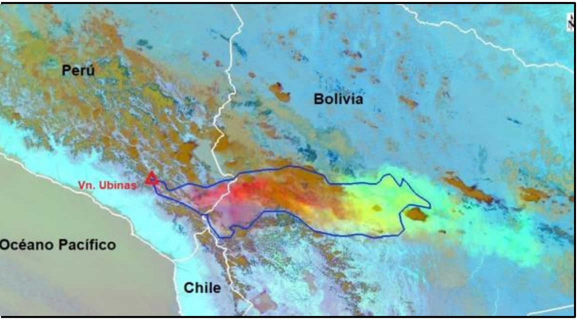
$\boldsymbol{\overline{y}_t}$: *mean ash mass load*

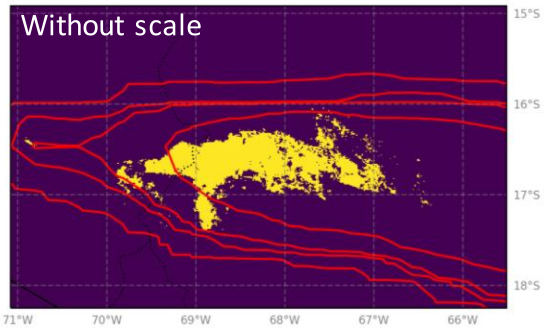
lat,lon: *latitude and longitud grid points*

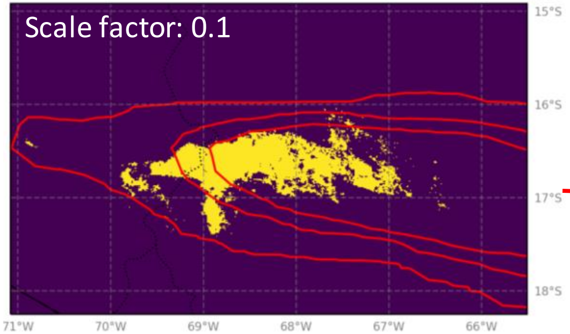
- S3 shows more $\overline{SP_t}$
- S2 shows the lowest $\overline{SP_t}$ -> wind perturbation seems to produce lower variability in the ensemble
- S1 improves S2 $\overline{SP_t}$

Results – Categorical verification

19jul2019 17:56 UTC (NPP-VIIRS) - 18:00 UTC (model)







Ash

No Ash

Mean ash mass load [g m-2]

	Mean Ash Mass Load ≥ 0.2 g m^{-2}				Ash Mass Load relative Frequency of exceed. 0.2 g m-2
Scale	**Accuracy**	**Bias**	**POD**	**FAR**	**Brier Score**
1	0.52	8.69	1	0.88	0.37
0.1	0.69	5.91	0.98	0.83	0.13

ACC perfect=1
POD perfect=1
FAR perfect=0
BIAS perfect=1
Brier Score perfect =0

All the indexes, particularly FAR and BIAS, are skewed due to the lack of a filter for uncertain pixels due to the presence of a meteorological cloud.

Conclusions

- The volcanic ash dispersion of the 2019 Ubinas eruption was modelled using an ensemble approch using FALL3D model. Each ensemble member was a random combination of different eruptive source parameters and wind fiels.
- Qualitative comparison with Ash RGB.
- Ensemble variability analysis using the mean SP of the ensemble
- Categorical comparisons

Future work

- More experiments will be done including the use of meteorological ensembles and the increase in the horizontal resolution.
- Satellite classification inlcuding meteological cloud layers to filter uncertain pixels.
- Include observations in an objective way.
- Compare the results with ash mass loading retrievals.

Thanks for your attention

Questions?

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