Journal de Projet - Déploiement IA

Date : 25 Novembre 2025
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Contexte

Aider les villes a predire la qualité de l'air en se basant sur les anciennes données

Objectif

Préparer et containeriser l'API de prédiction pour un déploiement public et vérifier le fonctionnement local.

Choix Techniques

- Modèle : Random Forest (choisi pour son F1-score de 0.8284165091158822).
- API : FastAPI choisi pour sa rapidité et sa documentation automatique.
- Conteneurisation : Docker utilisé pour garantir la portabilité.

Étapes réalisées

1. Export du modèle depuis le notebook.
2. Création de l'API FastAPI (`app.py`) exposant `/health` et `/predict`.
3. Ajout des dépendances dans `requirements.txt`.
4. Ajout du modèle `model/best_model.pkl`.
5. Rédaction du Dockerfile et .dockerignore.
6. Tests locaux via `uvicorn` et `curl`.
7. Construction et exécution de l'image Docker, tests via `docker ps` et `curl`.
8. Réalisation des captures d'écran et génération du PDF.

Choix techniques

- FastAPI / Uvicorn pour performance et docs automatiques
- Pickle / joblib pour sérialisation; ONNX possible pour portabilité
- Image basée sur `python:3.11-slim`

Problèmes rencontrés

- Erreur lors du décodage des variables encodées par fréquence
- Erreur de désérialisation XGBoost -> solution: re-sérialiser avec joblib ou exporter en ONNX.
- Durée d'optimisation très longue à cause des variétés des hyperparamètres

Tests effectués

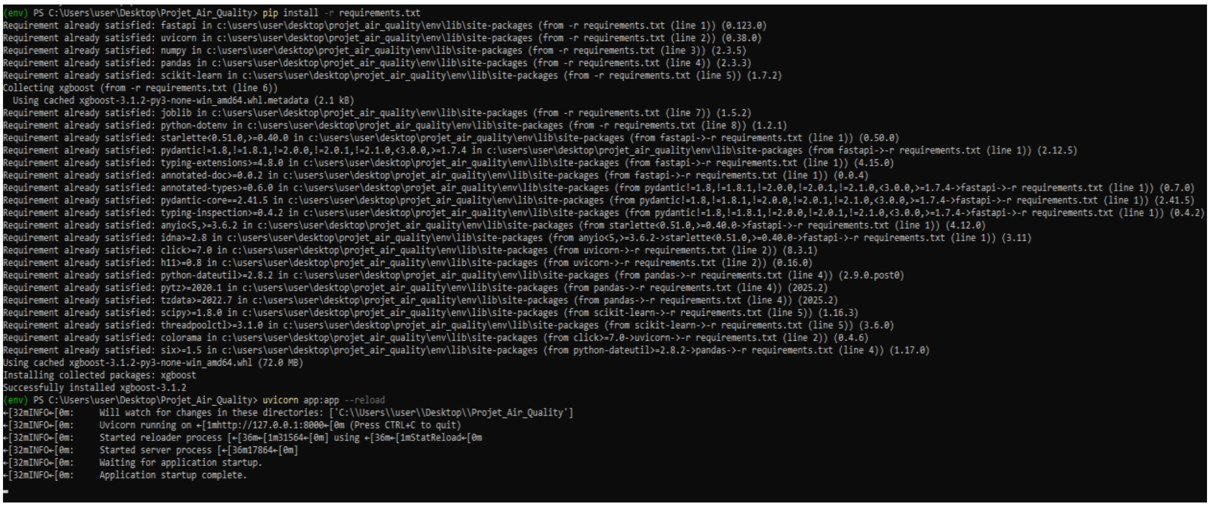
- GET /health -> ok
- POST /predict -> pas ok

Conclusion & recommandations

Convertir en ONNX pour portabilité
Ajouter tests unitaires, CI/CD)

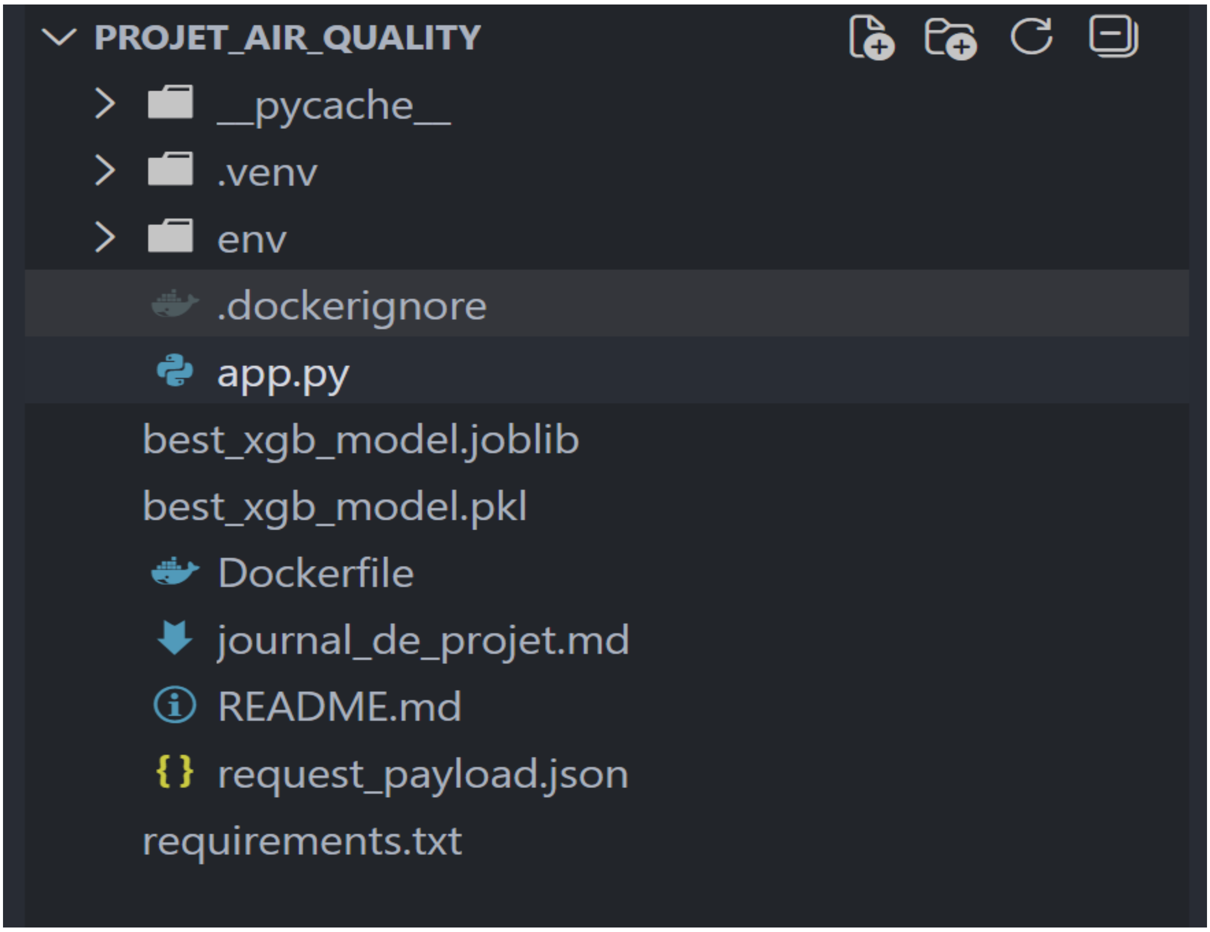
Illustrations

Script Bash pour la création de l’environnement et autres commandes



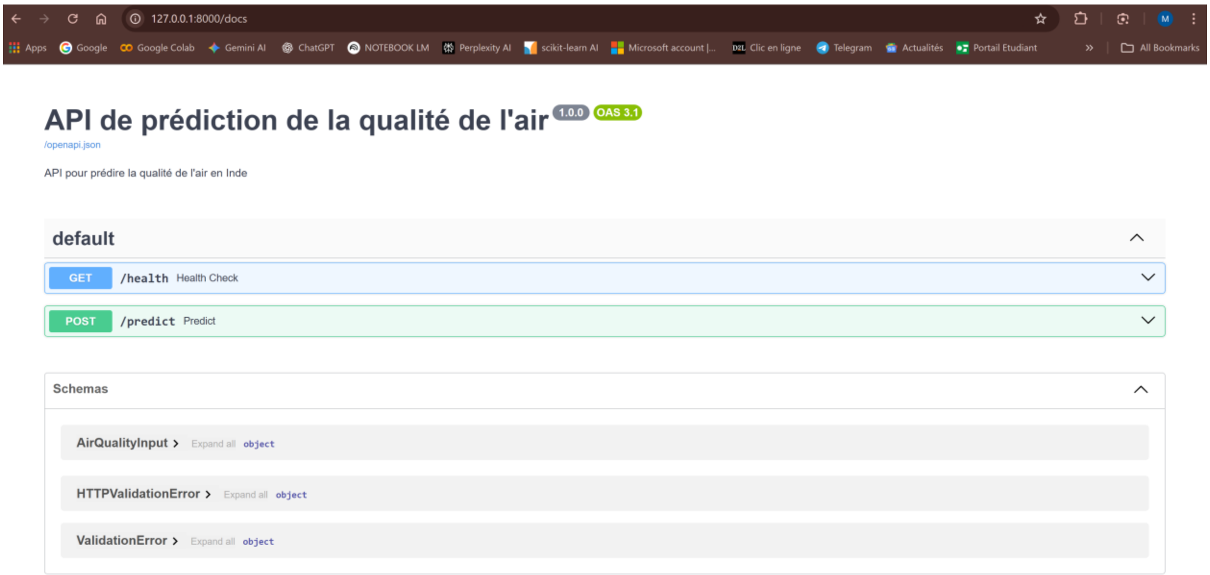
```
(env) PS C:\Users\user\Desktop\Projet_Air_Quality> pip install -r requirements.txt
Requirement already satisfied: fastapi in c:\users\user\desktop\projet_air_quality\env\lib\site-packages (from -r requirements.txt (line 1)) (0.123.0)
Requirement already satisfied: uvicorn in c:\users\user\desktop\projet_air_quality\env\lib\site-packages (from -r requirements.txt (line 2)) (0.38.0)
Requirement already satisfied: numpy in c:\users\user\desktop\projet_air_quality\env\lib\site-packages (from -r requirements.txt (line 3)) (2.3.5)
Requirement already satisfied: pandas in c:\users\user\desktop\projet_air_quality\env\lib\site-packages (from -r requirements.txt (line 4)) (2.3.3)
Requirement already satisfied: scikit-learn in c:\users\user\desktop\projet_air_quality\env\lib\site-packages (from -r requirements.txt (line 5)) (1.7.2)
Collecting xgboost (from -r requirements.txt (line 6))
  Using cached xgboost-3.1.2-py3-none-win_amd64.whl.metadata (2.1 kB)
Requirement already satisfied: joblib in c:\users\user\desktop\projet_air_quality\env\lib\site-packages (from -r requirements.txt (line 7)) (1.5.2)
Requirement already satisfied: python-dotenv in c:\users\user\desktop\projet_air_quality\env\lib\site-packages (from -r requirements.txt (line 8)) (1.2.1)
Requirement already satisfied: starlette<0.51.0,>=0.40.0 in c:\users\user\desktop\projet_air_quality\env\lib\site-packages (from fastapi->-r requirements.txt (line 1)) (0.50.0)
Requirement already satisfied: pydantic!=1.8,!=1.8.1,!=2.0.0,!=2.0.1,!=2.1.0,<3.0.0,>=1.7.4 in c:\users\user\desktop\projet_air_quality\env\lib\site-packages (from fastapi->-r requirements.txt (line 1)) (2.12.5)
Requirement already satisfied: typing-extensions>=4.8.0 in c:\users\user\desktop\projet_air_quality\env\lib\site-packages (from fastapi->-r requirements.txt (line 1)) (4.15.0)
Requirement already satisfied: annotated-doc>=0.0.2 in c:\users\user\desktop\projet_air_quality\env\lib\site-packages (from fastapi->-r requirements.txt (line 1)) (0.0.4)
Requirement already satisfied: annotated-types>=0.6.0 in c:\users\user\desktop\projet_air_quality\env\lib\site-packages (from pydantic!=1.8,!=1.8.1,!=2.0.0,!=2.0.1,!=2.1.0,<3.0.0,>=1.7.4->fastapi->-r requirements.txt (line 1)) (0.7.0)
Requirement already satisfied: pydantic-core==2.41.5 in c:\users\user\desktop\projet_air_quality\env\lib\site-packages (from pydantic!=1.8,!=1.8.1,!=2.0.0,!=2.0.1,!=2.1.0,<3.0.0,>=1.7.4->fastapi->-r requirements.txt (line 1)) (2.41.5)
Requirement already satisfied: typing-inspection>=0.4.2 in c:\users\user\desktop\projet_air_quality\env\lib\site-packages (from pydantic!=1.8,!=1.8.1,!=2.0.0,!=2.0.1,!=2.1.0,<3.0.0,>=1.7.4->fastapi->-r requirements.txt (line 1)) (0.4.2)
Requirement already satisfied: anyio<5,>=3.6.2 in c:\users\user\desktop\projet_air_quality\env\lib\site-packages (from starlette<0.51.0,>=0.40.0->fastapi->-r requirements.txt (line 1)) (4.12.0)
Requirement already satisfied: idna>=2.8 in c:\users\user\desktop\projet_air_quality\env\lib\site-packages (from anyio<5,>=3.6.2->starlette<0.51.0,>=0.40.0->fastapi->-r requirements.txt (line 1)) (3.11)
Requirement already satisfied: click>=7.0 in c:\users\user\desktop\projet_air_quality\env\lib\site-packages (from uvicorn->-r requirements.txt (line 2)) (8.3.1)
Requirement already satisfied: h11>=0.8 in c:\users\user\desktop\projet_air_quality\env\lib\site-packages (from uvicorn->-r requirements.txt (line 2)) (0.16.0)
Requirement already satisfied: python-dateutil>=2.8.2 in c:\users\user\desktop\projet_air_quality\env\lib\site-packages (from pandas->-r requirements.txt (line 4)) (2.9.0.post0)
Requirement already satisfied: pytz>=2020.1 in c:\users\user\desktop\projet_air_quality\env\lib\site-packages (from pandas->-r requirements.txt (line 4)) (2025.2)
Requirement already satisfied: tzdata>=2022.7 in c:\users\user\desktop\projet_air_quality\env\lib\site-packages (from pandas->-r requirements.txt (line 4)) (2025.2)
Requirement already satisfied: scipy>=1.8.0 in c:\users\user\desktop\projet_air_quality\env\lib\site-packages (from scikit-learn->-r requirements.txt (line 5)) (1.16.3)
Requirement already satisfied: threadpoolctl>=3.1.0 in c:\users\user\desktop\projet_air_quality\env\lib\site-packages (from scikit-learn->-r requirements.txt (line 5)) (3.6.0)
Requirement already satisfied: colorama in c:\users\user\desktop\projet_air_quality\env\lib\site-packages (from click>=7.0->uvicorn->-r requirements.txt (line 2)) (0.4.6)
Requirement already satisfied: six>=1.5 in c:\users\user\desktop\projet_air_quality\env\lib\site-packages (from python-dateutil>=2.8.2->pandas->-r requirements.txt (line 4)) (1.17.0)
Using cached xgboost-3.1.2-py3-none-win_amd64.whl (72.0 MB)
Installing collected packages: xgboost
Successfully installed xgboost-3.1.2
(env) PS C:\Users\user\Desktop\Projet_Air_Quality> uvicorn app:app --reload
←[32mINFO←[0m:     Will watch for changes in these directories: ['C:\\Users\\user\\Desktop\\Projet_Air_Quality']
←[32mINFO←[0m:     Uvicorn running on ←[1mhttp://127.0.0.1:8000←[0m (Press CTRL+C to quit)
←[32mINFO←[0m:     Started reloader process [←[36m←[1m31564←[0m] using ←[36m←[1mStatReload←[0m
←[32mINFO←[0m:     Started server process [←[36m17864←[0m]
←[32mINFO←[0m:     Waiting for application startup.
←[32mINFO←[0m:     Application startup complete.
```

Arborescence du projet avec environnement



```
PROJET_AIR_QUALITY
  > __pycache__
  > .venv
  > env
    .dockerignore
    app.py
    best_xgb_model.joblib
    best_xgb_model.pkl
    Dockerfile
    journal_de_projet.md
    README.md
    request_payload.json
    requirements.txt
```

Interface de l’API sur un navigateur web



API de prédiction de la qualité de l'air 1.0.0 OAS 3.1

/openapi.json

API pour prédire la qualité de l'air en Inde

default

GET /health Health Check

POST /predict Predict

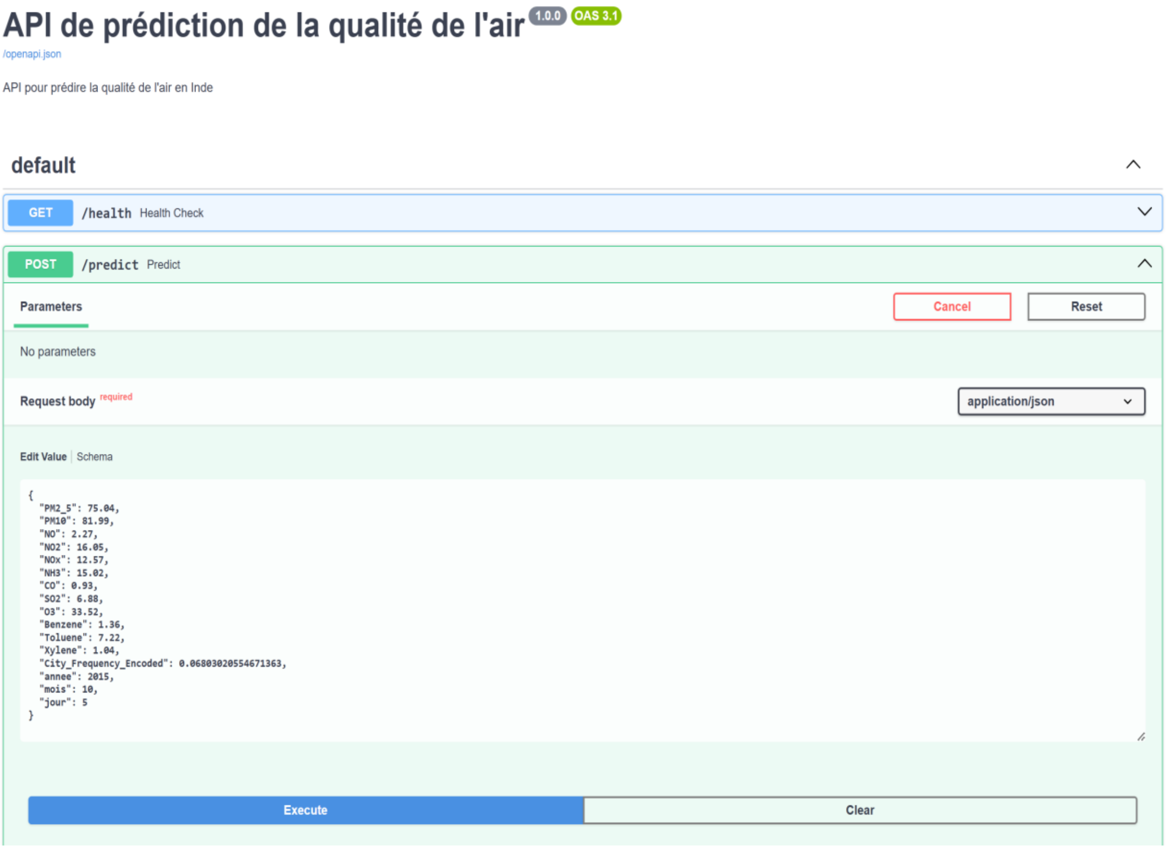
Schemas

AirQualityInput › Expand all object

HTTPValidationError › Expand all object

ValidationError › Expand all object

Lancement d’un script json sur try out



API de prédiction de la qualité de l'air 1.0.0 OAS 3.1

/openapi.json

API pour prédire la qualité de l'air en Inde

default

GET /health Health Check

POST /predict Predict

Parameters

No parameters

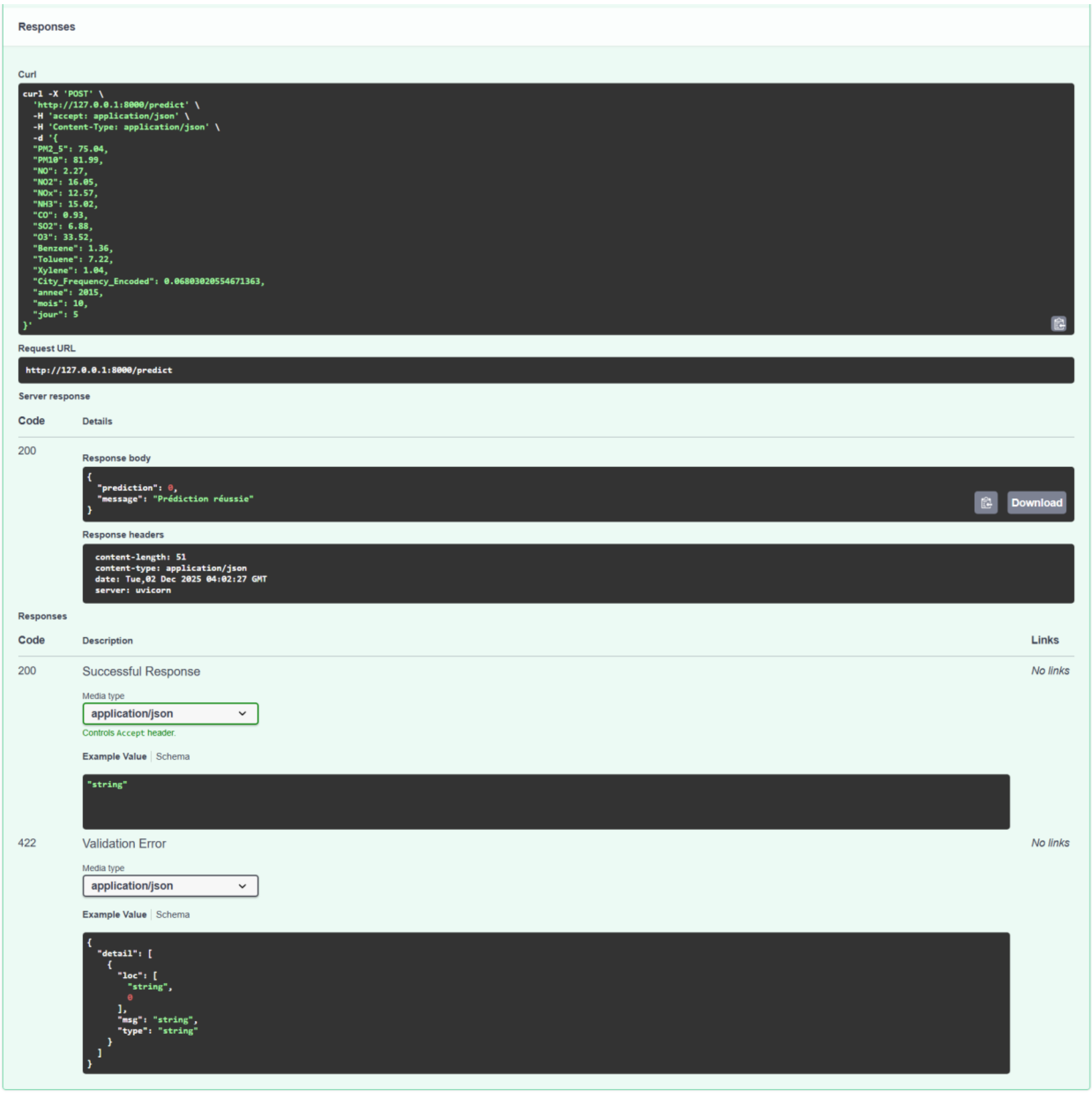
Request body required

application/json

Edit Value | Schema

```
{
  "PM2_5": 75.04,
  "PM10": 81.99,
  "NO": 2.27,
  "NO2": 16.05,
  "NOx": 12.57,
  "NH3": 15.02,
  "CO": 0.93,
  "SO2": 6.88,
  "O3": 33.52,
  "Benzene": 1.36,
  "Toluene": 7.22,
  "Xylene": 1.04,
  "City_Frequency_Encoded": 0.06803020554671363,
  "annee": 2015,
  "mois": 10,
  "jour": 5
}
```

Réponse du try out



Curl

```
curl -X 'POST' \
  'http://127.0.0.1:8000/predict' \
  -H 'accept: application/json' \
  -H 'Content-Type: application/json' \
  -d '{
  "PM2_5": 75.04,
  "PM10": 81.99,
  "NO": 2.27,
  "NO2": 16.05,
  "NOx": 12.57,
  "NH3": 15.02,
  "CO": 0.93,
  "SO2": 6.88,
  "O3": 33.52,
  "Benzene": 1.36,
  "Toluene": 7.22,
  "Xylene": 1.04,
  "City_Frequency_Encoded": 0.06803020554671363,
  "annee": 2015,
  "mois": 10,
  "jour": 5
}'
```

Request URL

```
http://127.0.0.1:8000/predict
```

Server response

Code | Details

200

Response body

```
{
  "prediction": 0,
  "message": "Prédiction réussie"
}
```

Response headers

```
 content-length: 51
 content-type: application/json
 date: Tue,02 Dec 2025 04:02:27 GMT
 server: uvicorn
```

Responses

Code | Description | Links

200 Successful Response — No links

Media type: application/json

Controls Accept header.

Example Value | Schema

```
"string"
```

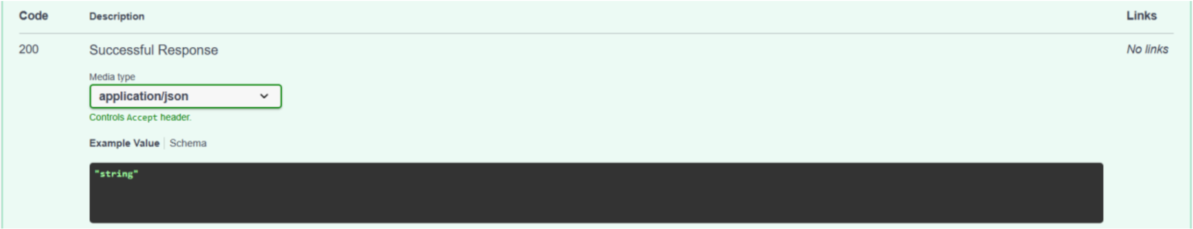
422 Validation Error — No links

Media type: application/json

Example Value | Schema

```
{
  "detail": [
    {
      "loc": [
        "string",
        0
      ],
      "msg": "string",
      "type": "string"
    }
  ]
}
```

Reponse de l'API



Code | Description | Links

200 Successful Response — No links

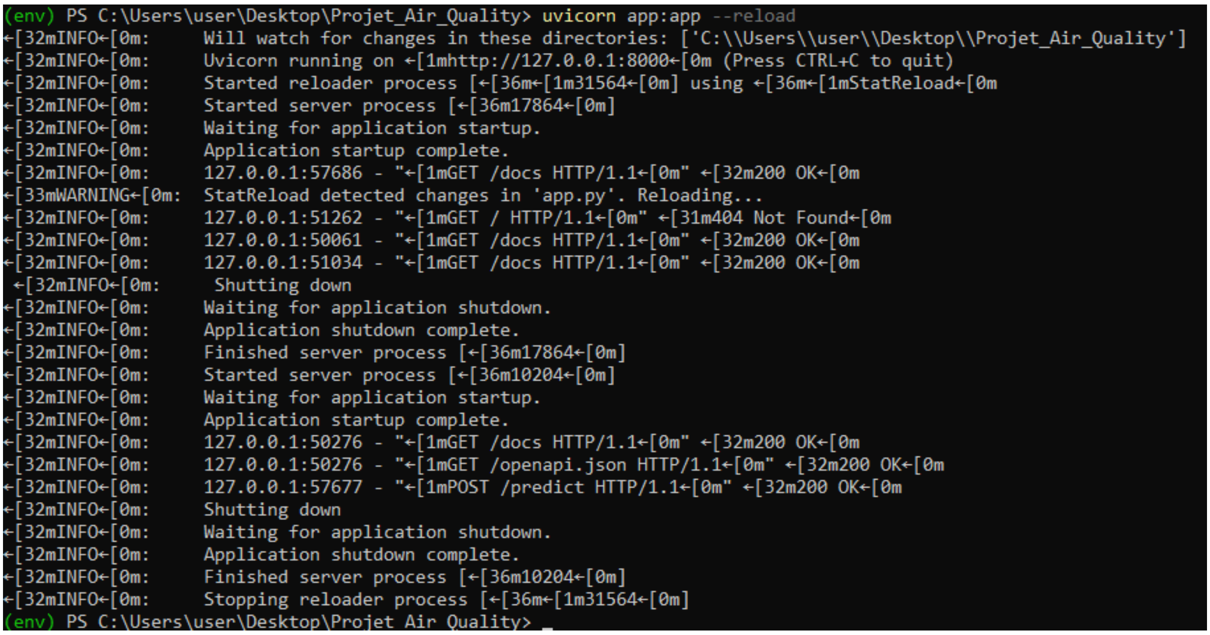
Media type: application/json

Controls Accept header.

Example Value | Schema

```
"string"
```

Arrêt du serveur avec la commande << Ctrl + C >> après avoir testé l'API



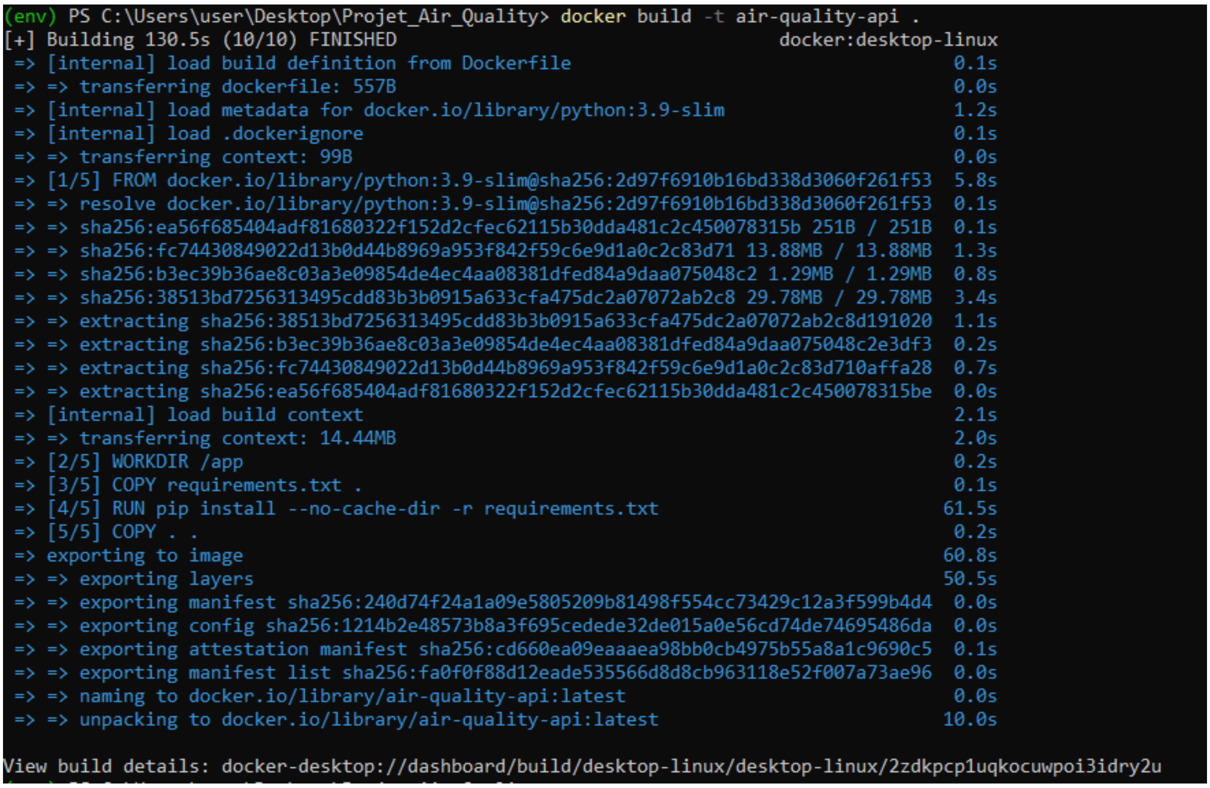
```
(env) PS C:\Users\user\Desktop\Projet_Air_Quality> uvicorn app:app --reload
←[32mINFO←[0m:     Will watch for changes in these directories: ['C:\\Users\\user\\Desktop\\Projet_Air_Quality']
←[32mINFO←[0m:     Uvicorn running on ←[1mhttp://127.0.0.1:8000←[0m (Press CTRL+C to quit)
←[32mINFO←[0m:     Started reloader process [←[36m←[1m31564←[0m] using ←[36m←[1mStatReload←[0m
←[32mINFO←[0m:     Started server process [←[36m17864←[0m]
←[32mINFO←[0m:     Waiting for application startup.
←[32mINFO←[0m:     Application startup complete.
←[32mINFO←[0m:     127.0.0.1:57686 - "←[1mGET /docs HTTP/1.1←[0m" ←[32m200 OK←[0m
←[33mWARNING←[0m:  StatReload detected changes in 'app.py'. Reloading...
←[32mINFO←[0m:     127.0.0.1:51262 - "←[1mGET / HTTP/1.1←[0m" ←[31m404 Not Found←[0m
←[32mINFO←[0m:     127.0.0.1:50061 - "←[1mGET /docs HTTP/1.1←[0m" ←[32m200 OK←[0m
←[32mINFO←[0m:     127.0.0.1:51034 - "←[1mGET /docs HTTP/1.1←[0m" ←[32m200 OK←[0m
 ←[32mINFO←[0m:     Shutting down
←[32mINFO←[0m:     Waiting for application shutdown.
←[32mINFO←[0m:     Application shutdown complete.
←[32mINFO←[0m:     Finished server process [←[36m17864←[0m]
←[32mINFO←[0m:     Started server process [←[36m10204←[0m]
←[32mINFO←[0m:     Waiting for application startup.
←[32mINFO←[0m:     Application startup complete.
←[32mINFO←[0m:     127.0.0.1:50276 - "←[1mGET /docs HTTP/1.1←[0m" ←[32m200 OK←[0m
←[32mINFO←[0m:     127.0.0.1:50276 - "←[1mGET /openapi.json HTTP/1.1←[0m" ←[32m200 OK←[0m
←[32mINFO←[0m:     127.0.0.1:57677 - "←[1mPOST /predict HTTP/1.1←[0m" ←[32m200 OK←[0m
←[32mINFO←[0m:     Shutting down
←[32mINFO←[0m:     Waiting for application shutdown.
←[32mINFO←[0m:     Application shutdown complete.
←[32mINFO←[0m:     Finished server process [←[36m10204←[0m]
←[32mINFO←[0m:     Stopping reloader process [←[36m←[1m31564←[0m]
(env) PS C:\Users\user\Desktop\Projet_Air_Quality> _
```

Test 2 : Construction et Exécution avec Docker

On commence par lancer l'application docker

1. **Compiler (Build) :**

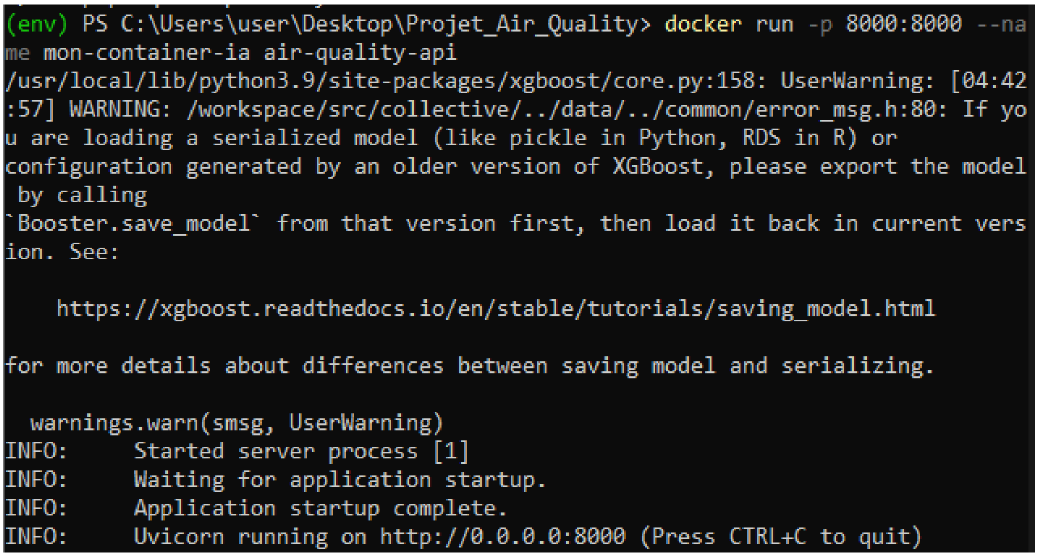
   docker build -t air-quality-api .



```
(env) PS C:\Users\user\Desktop\Projet_Air_Quality> docker build -t air-quality-api .
[+] Building 130.5s (10/10) FINISHED                                           docker:desktop-linux
 => [internal] load build definition from Dockerfile                                               0.1s
 => => transferring dockerfile: 557B                                                               0.0s
 => [internal] load metadata for docker.io/library/python:3.9-slim                                 1.2s
 => [internal] load .dockerignore                                                                  0.1s
 => => transferring context: 99B                                                                   0.0s
 => [1/5] FROM docker.io/library/python:3.9-slim@sha256:2d97f6910b16bd338d3060f261f53              5.8s
 => => resolve docker.io/library/python:3.9-slim@sha256:2d97f6910b16bd338d3060f261f53              0.1s
 => => sha256:ea56f685404adf81680322f152d2cfec62115b30dda481c2c450078315b 251B / 251B              0.1s
 => => sha256:fc74430849022d13b0d44b8969a953f842f59c6e9d1a0c2c83d71 13.88MB / 13.88MB              1.3s
 => => sha256:b3ec39b36ae8c03a3e09854de4ec4aa08381dfed84a9daa075048c2 1.29MB / 1.29MB              0.8s
 => => sha256:38513bd7256313495cdd83b3b0915a633cfa475dc2a07072ab2c8 29.78MB / 29.78MB              3.4s
 => => extracting sha256:38513bd7256313495cdd83b3b0915a633cfa475dc2a07072ab2c8d191020              1.1s
 => => extracting sha256:b3ec39b36ae8c03a3e09854de4ec4aa08381dfed84a9daa075048c2e3df3              0.2s
 => => extracting sha256:fc74430849022d13b0d44b8969a953f842f59c6e9d1a0c2c83d710affa28              0.7s
 => => extracting sha256:ea56f685404adf81680322f152d2cfec62115b30dda481c2c450078315be              0.0s
 => [internal] load build context                                                                  2.1s
 => => transferring context: 14.44MB                                                               2.0s
 => [2/5] WORKDIR /app                                                                             0.2s
 => [3/5] COPY requirements.txt .                                                                  0.1s
 => [4/5] RUN pip install --no-cache-dir -r requirements.txt                                      61.5s
 => [5/5] COPY . .                                                                                 0.2s
 => exporting to image                                                                            60.8s
 => => exporting layers                                                                           50.5s
 => => exporting manifest sha256:240d74f24a1a09e5805209b81498f554cc73429c12a3f599b4d4              0.0s
 => => exporting config sha256:1214b2e48573b8a3f695cedede32de015a0e56cd74de74695486da              0.0s
 => => exporting attestation manifest sha256:cd660ea09eaaaea98bb0cb4975b55a8a1c9690c5              0.1s
 => => exporting manifest list sha256:fa0f0f88d12eade535566d8d8cb963118e52f007a73ae96              0.0s
 => => naming to docker.io/library/air-quality-api:latest                                          0.0s
 => => unpacking to docker.io/library/air-quality-api:latest                                      10.0s

View build details: docker-desktop://dashboard/build/desktop-linux/desktop-linux/2zdkpcp1uqkocuwpoi3idry2u
```

2. Exécuter (Run) :

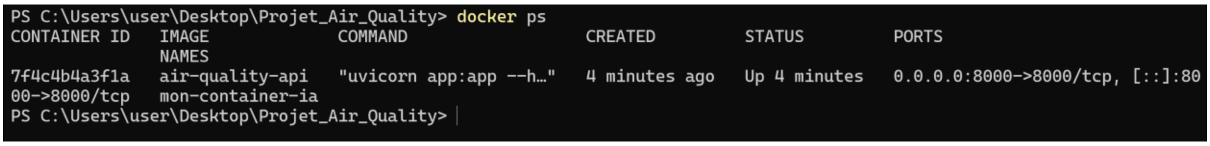
   docker run -p 8000:8000 –name mon-container-ia air-quality-api



```
(env) PS C:\Users\user\Desktop\Projet_Air_Quality> docker run -p 8000:8000 --na
me mon-container-ia air-quality-api
/usr/local/lib/python3.9/site-packages/xgboost/core.py:158: UserWarning: [04:42
:57] WARNING: /workspace/src/collective/../data/../common/error_msg.h:80: If yo
u are loading a serialized model (like pickle in Python, RDS in R) or
configuration generated by an older version of XGBoost, please export the model
 by calling
`Booster.save_model` from that version first, then load it back in current vers
ion. See:

    https://xgboost.readthedocs.io/en/stable/tutorials/saving_model.html

for more details about differences between saving model and serializing.

  warnings.warn(smsg, UserWarning)
INFO:     Started server process [1]
INFO:     Waiting for application startup.
INFO:     Application startup complete.
INFO:     Uvicorn running on http://0.0.0.0:8000 (Press CTRL+C to quit)
```

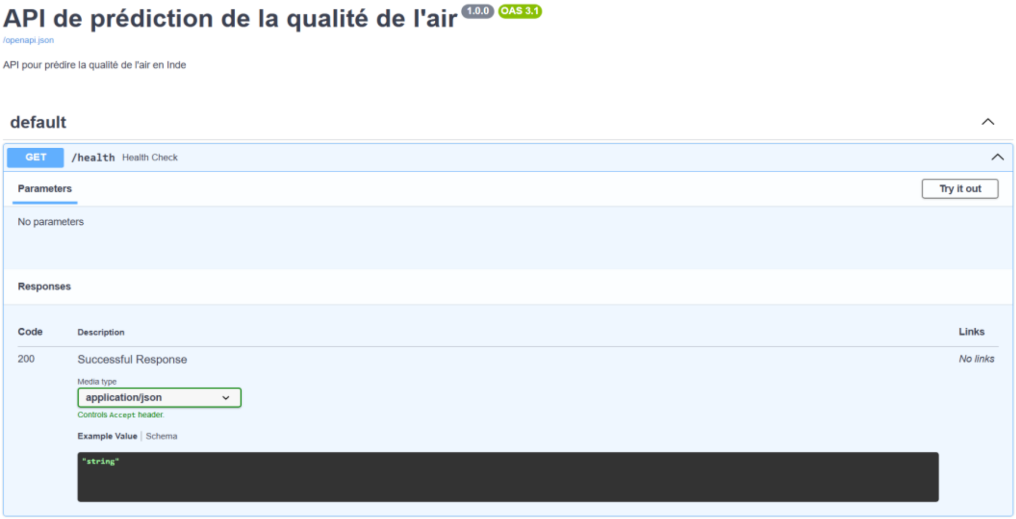
3. Vérifier que le moteur docker tourne en exécutant la commande suivante dans un deuxième terminale

   docker ps



```
PS C:\Users\user\Desktop\Projet_Air_Quality> docker ps
CONTAINER ID   IMAGE             COMMAND                  CREATED         STATUS         PORTS
               NAMES
7f4c4b4a3f1a   air-quality-api   "uvicorn app:app --h…"   4 minutes ago   Up 4 minutes   0.0.0.0:8000->8000/tcp, [::]:80
00->8000/tcp   mon-container-ia
PS C:\Users\user\Desktop\Projet_Air_Quality>
```

Affichage dans le terminal lorsque le lien http://127.0.0.1:8000/docs est lancé avec docker



API de prédiction de la qualité de l'air 1.0.0 OAS 3.1

/openapi.json

API pour prédire la qualité de l'air en Inde

default

GET /health Health Check

Parameters

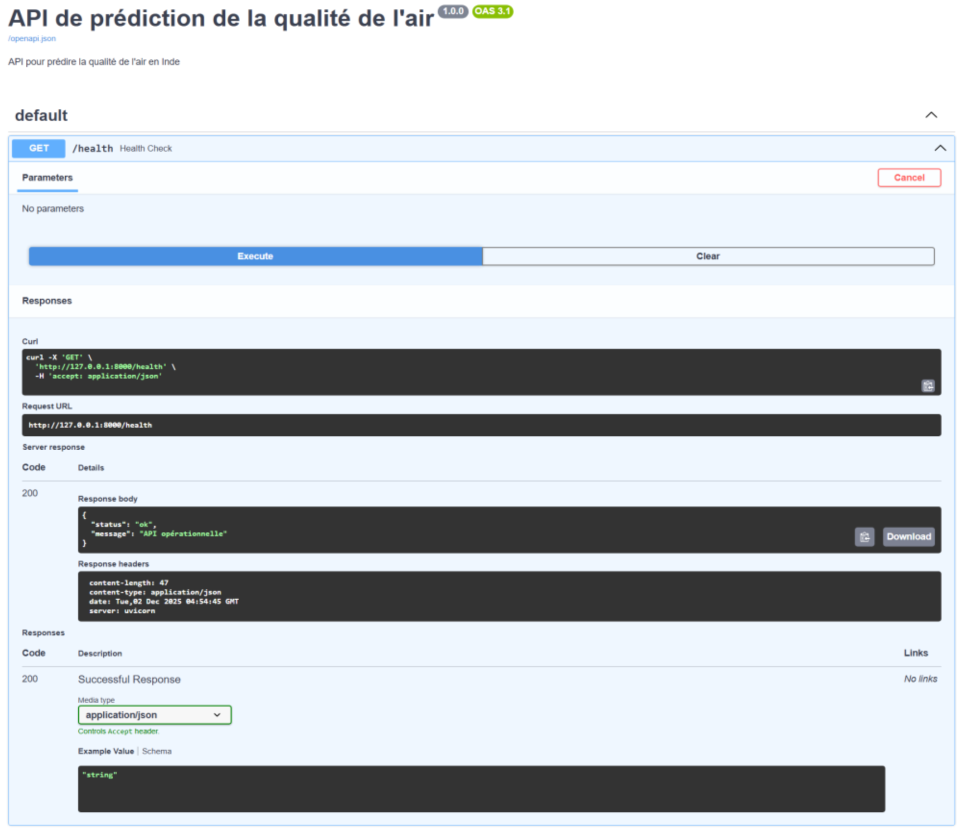
Try it out

No parameters

Responses

Code	Description	Links
200	Successful Response Media type application/json Controls Accept header. Example Value | Schema "string"	*No links*

Try out de GET /health



API de prédiction de la qualité de l'air

/openapi.json

API pour prédire la qualité de l'air en Inde

default

/health Health Check

Parameters

No parameters

Responses

Curl

```
curl -X 'GET' \
  'http://127.0.0.1:8000/health' \
  -H 'accept: application/json'
```

Request URL

```
http://127.0.0.1:8000/health
```

Server response

Code Details

200

Response body

```
{
  "status": "ok",
  "message": "API opérationnelle"
}
```

Response headers

```
 content-length: 47
 content-type: application/json
 date: Tue,02 Dec 2025 04:54:45 GMT
 server: uvicorn
```

Responses

Code	Description	Links
200	Successful Response	*No links*

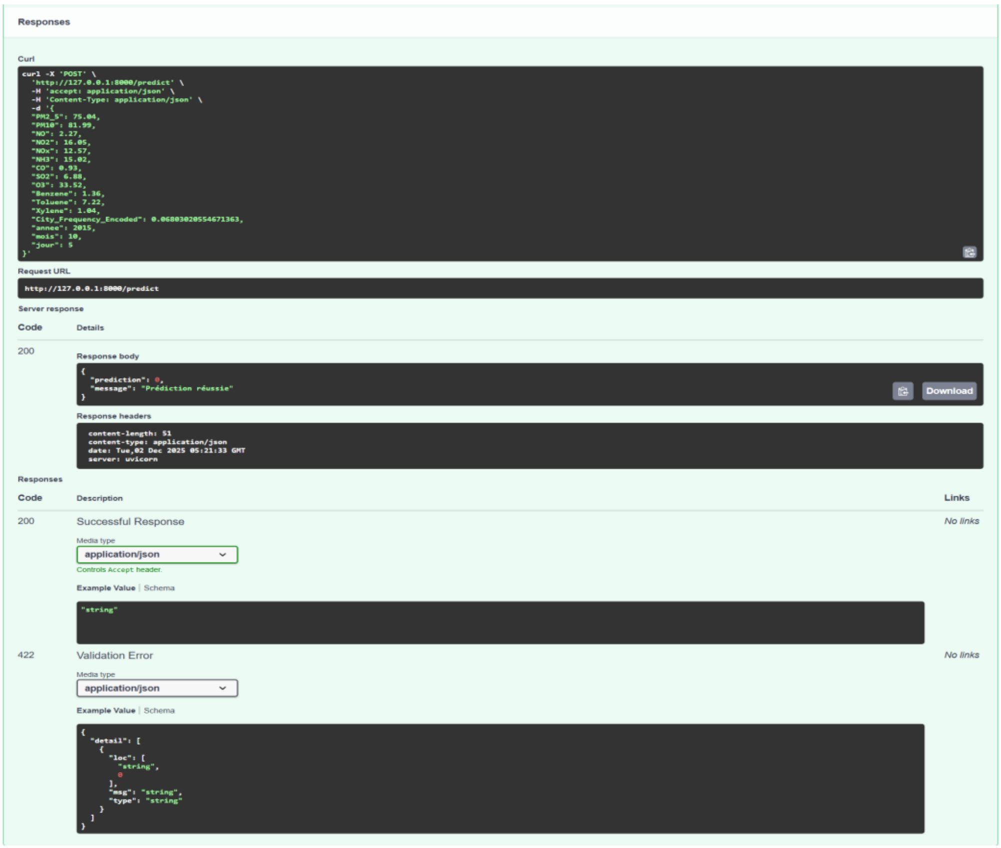
Media type: application/json

Controls Accept header.

Example Value | Schema

```
"string"
```

Try out de POST Predict



Responses

Curl

```
curl -X 'POST' \
  'http://127.0.0.1:8000/predict' \
  -H 'accept: application/json' \
  -H 'Content-Type: application/json' \
  -d '{
  "PM2_5": 75.04,
  "PM10": 81.99,
  "NO": 2.27,
  "NO2": 16.05,
  "NOx": 12.57,
  "NH3": 15.02,
  "CO": 0.93,
  "SO2": 6.88,
  "O3": 33.52,
  "Benzene": 1.36,
  "Toluene": 7.22,
  "Xylene": 1.04,
  "City_Frequency_Encoded": 0.06803020554671363,
  "annee": 2015,
  "mois": 10,
  "jour": 5
}'
```

Request URL

```
http://127.0.0.1:8000/predict
```

Server response

Code Details

200

Response body

```
{
  "prediction": 0,
  "message": "Prédiction réussie"
}
```

Response headers

```
 content-length: 51
 content-type: application/json
 date: Tue,02 Dec 2025 05:21:33 GMT
 server: uvicorn
```

Responses

Code	Description	Links
200	Successful Response	*No links*
422	Validation Error	*No links*

200 — Media type: application/json

Controls Accept header.

Example Value | Schema

```
"string"
```

422 — Media type: application/json

Example Value | Schema

```
{
  "detail": [
    {
      "loc": [
        "string",
        0
      ],
      "msg": "string",
      "type": "string"
    }
  ]
}
```