

Institute of Logistics and Aviation

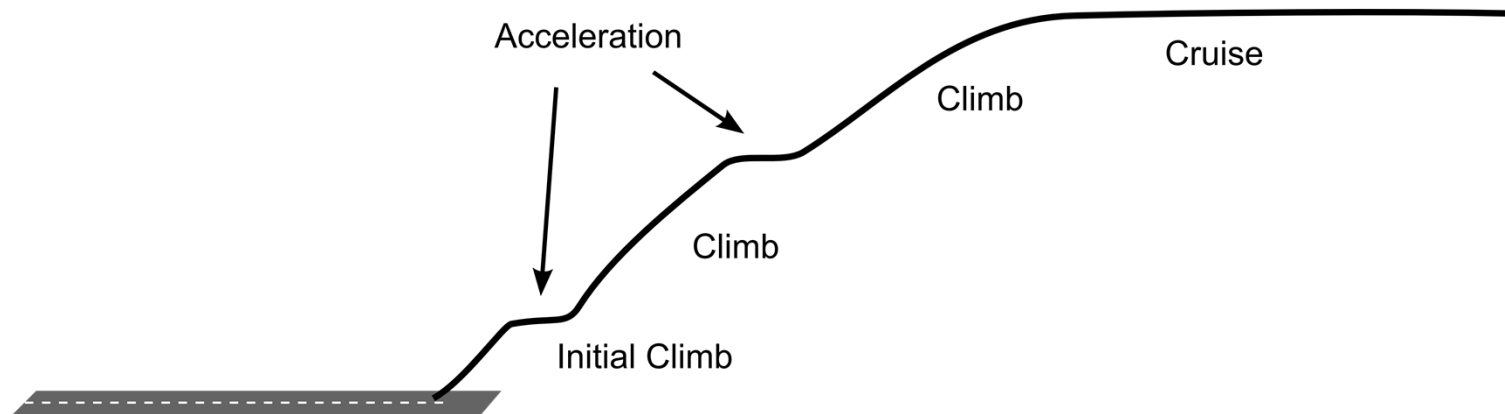
Chair of Air Transport Technology and Logistics

CONTINUOUS CLIMB OPERATIONS WITH MINIMUM FUEL BURN

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Delft, 2016-11-2016

Continuous Climb Operations

Conventional climb profile

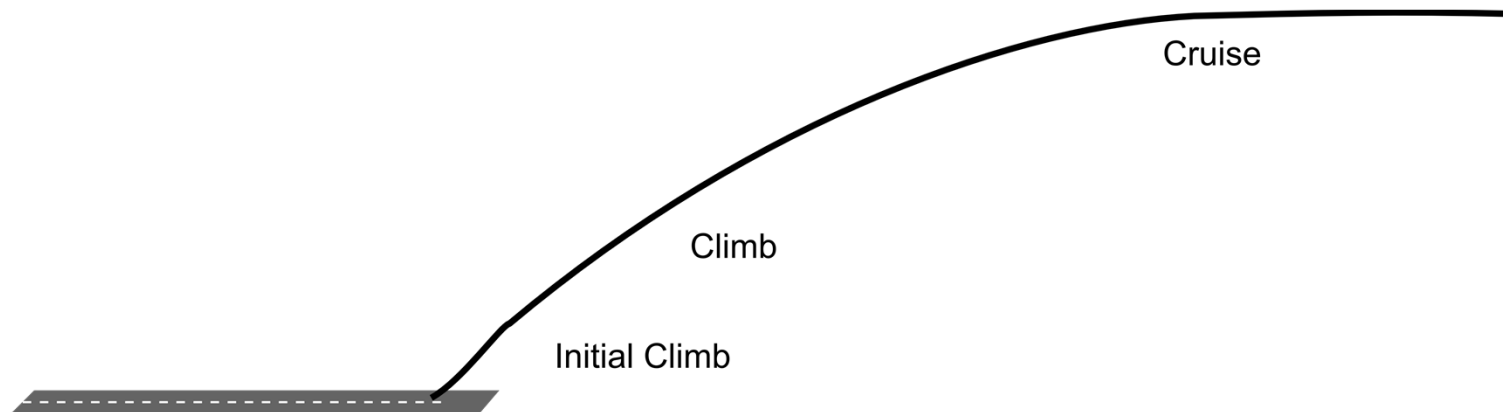


Continuous Climb Operations

Continuous climb profile:

min. level-offs

min. thrust changes



Continuous Climb Operations

Continuous climb profile:

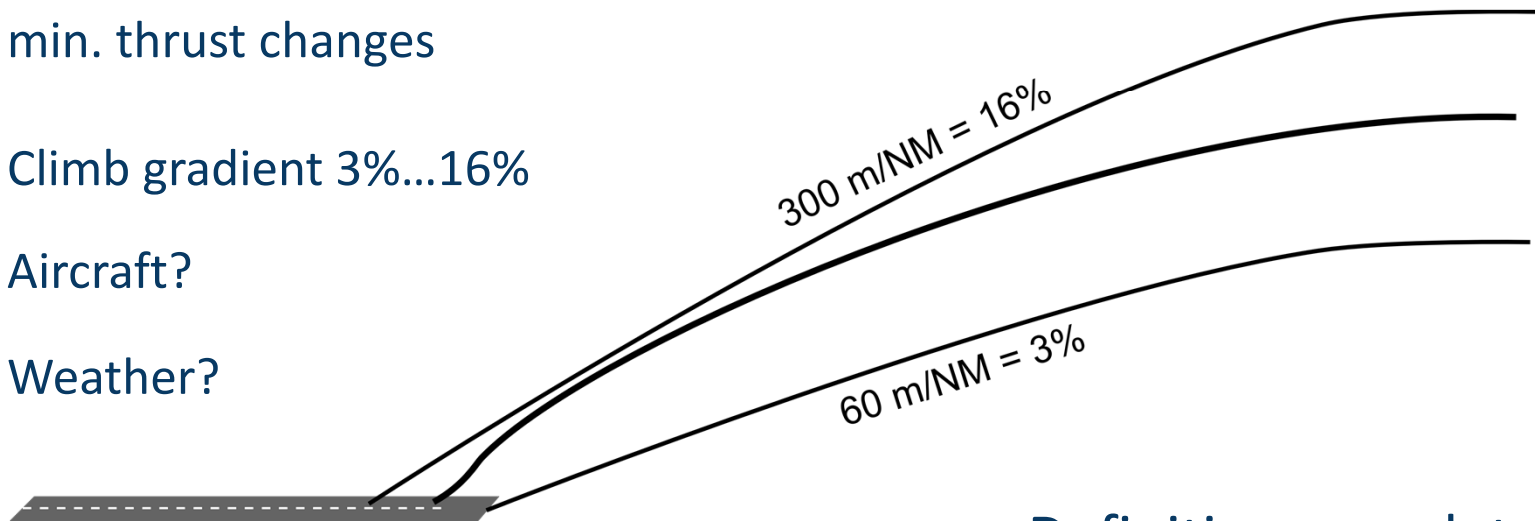
min. level-offs

min. thrust changes

Climb gradient 3%...16%

Aircraft?

Weather?



Definition complete?



Continuous Climb Operations

Conjectures:

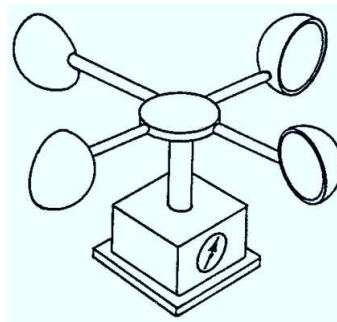
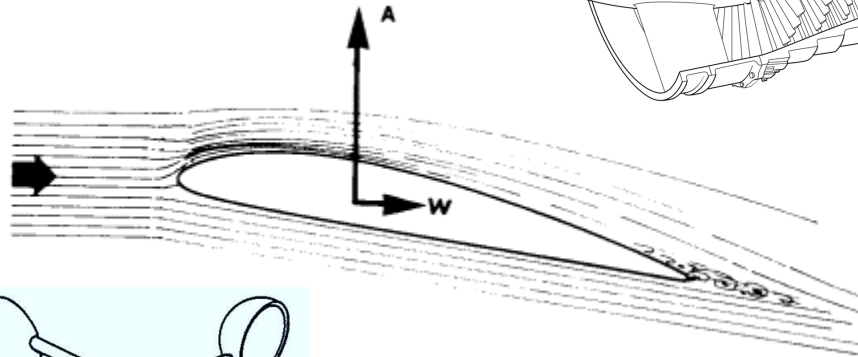
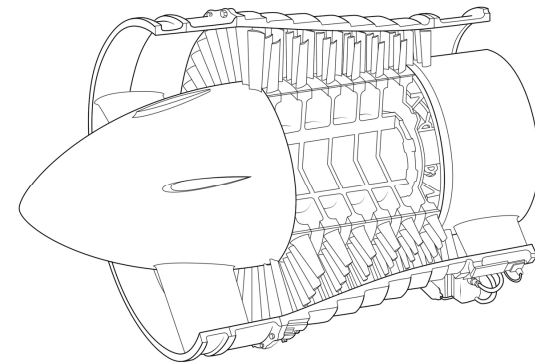
Min. fuel CCO depend on

Aircraft weight

Engine power

Aircraft aerodynamics

Atmosphere

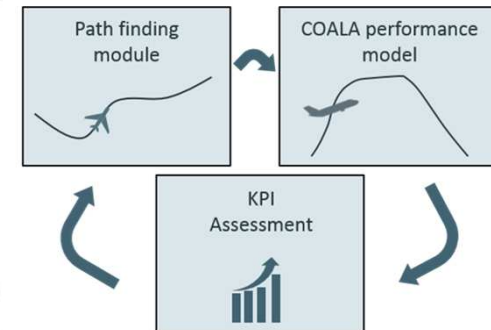
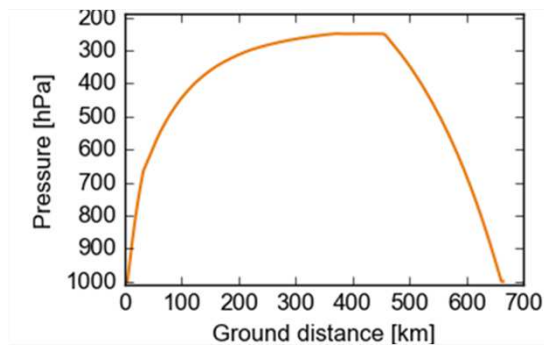
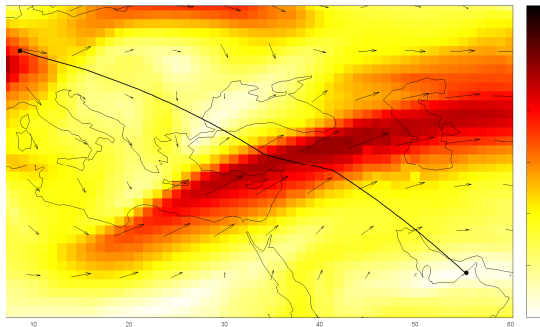


Methodology

- CCO simulation
- A320, B738, MD11F, B777F
- Real weather

Flight performance
model COALA

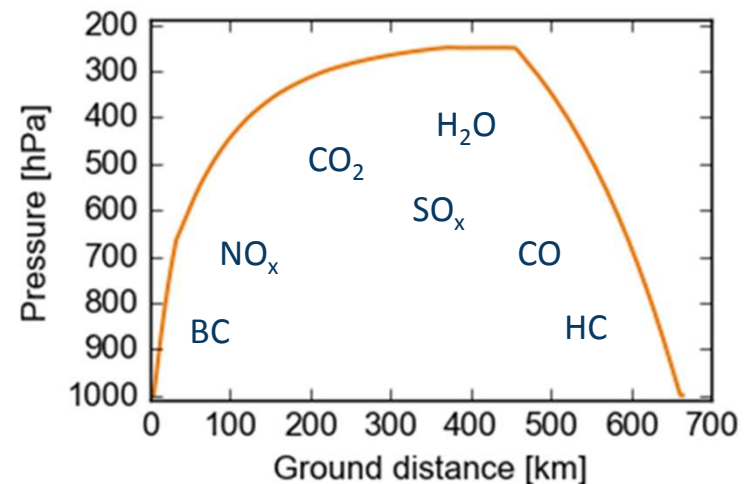
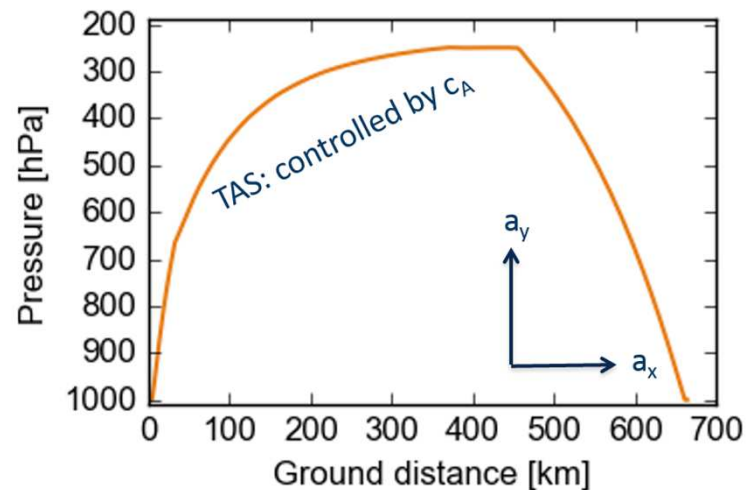
Air traffic simulation
tool TOMATO



Methodology

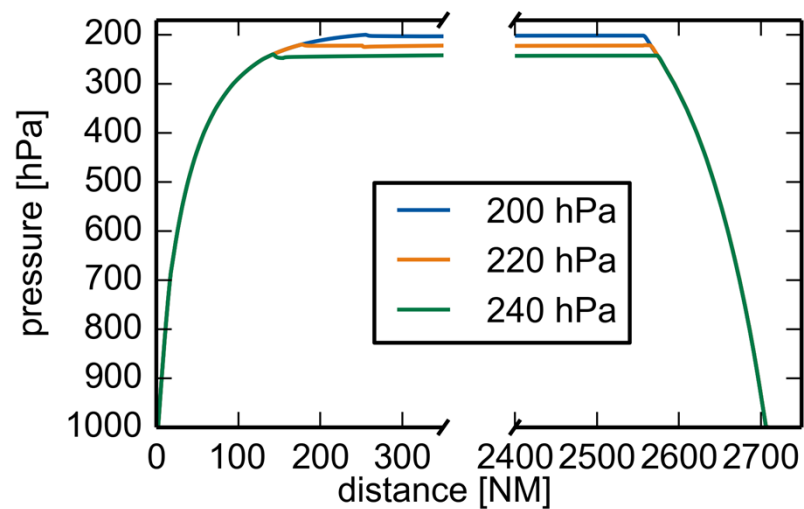
COALA: COMpromized Aircraft performance model with Limited Accuracy:

- Unsteady flows
- (not) empirical
- BADA: c_W (c_A), MMO, MCL, m_f
 $\sin \gamma \text{ TAS} \rightarrow \max$



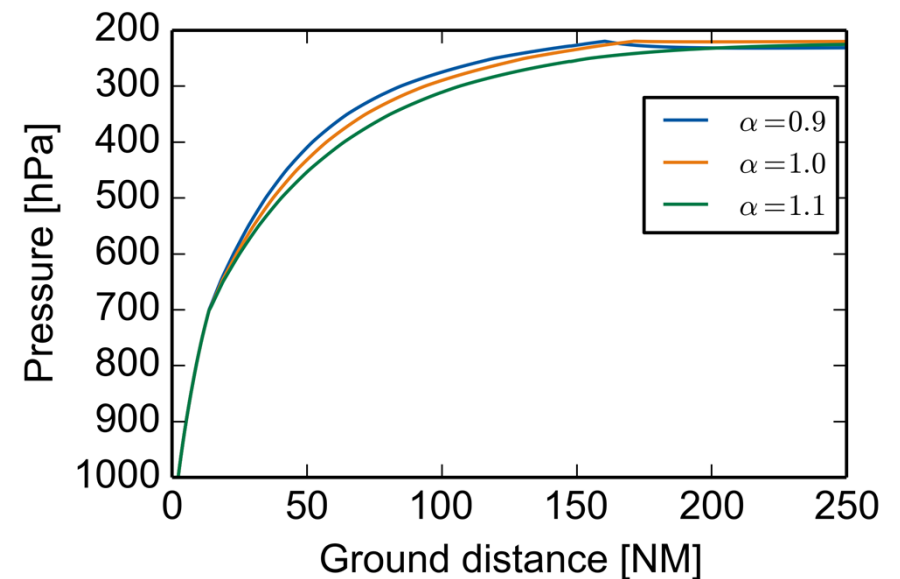
Methodology

Min. fuel CCO depend on:
Cruising pressure and cruising TAS



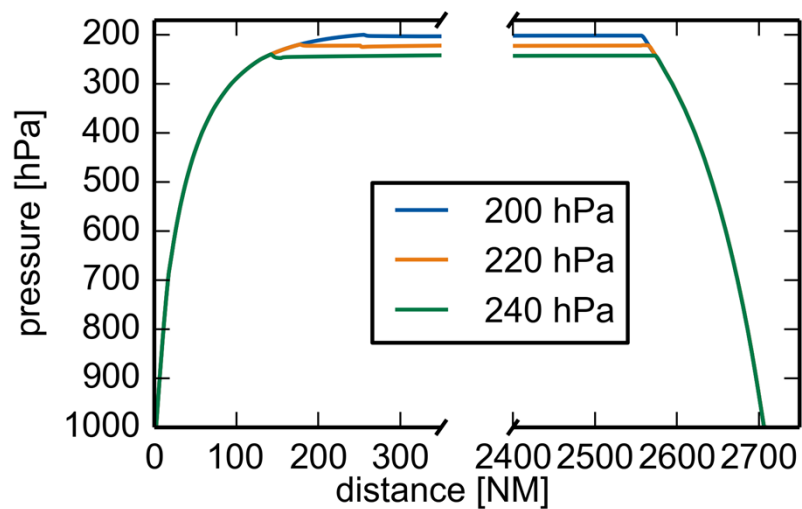
Climb angle and TAS

$$TAS_{\text{new}} = \alpha \cdot TAS$$



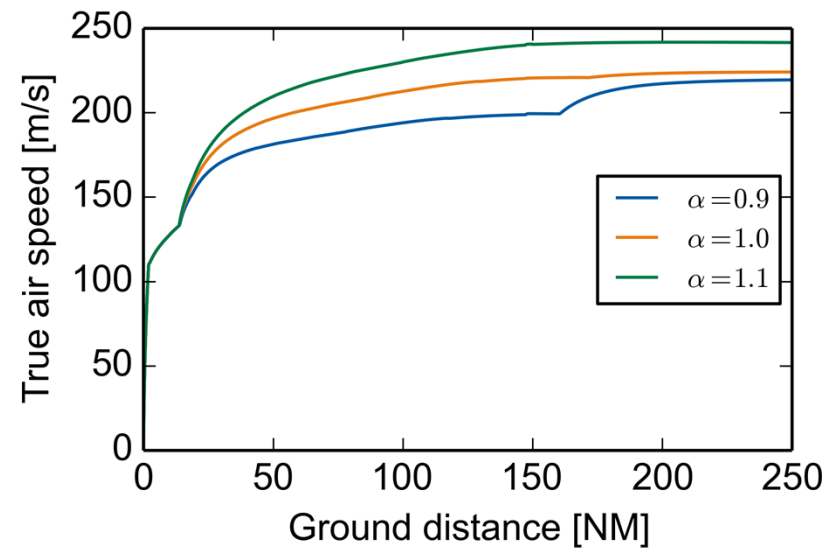
Methodology

Min. fuel CCO depend on:
Cruising pressure and cruising TAS



Climb angle and TAS

$$TAS_{new} = \alpha \cdot TAS$$



Are these parameters constant for each aircraft type?

CCO Results

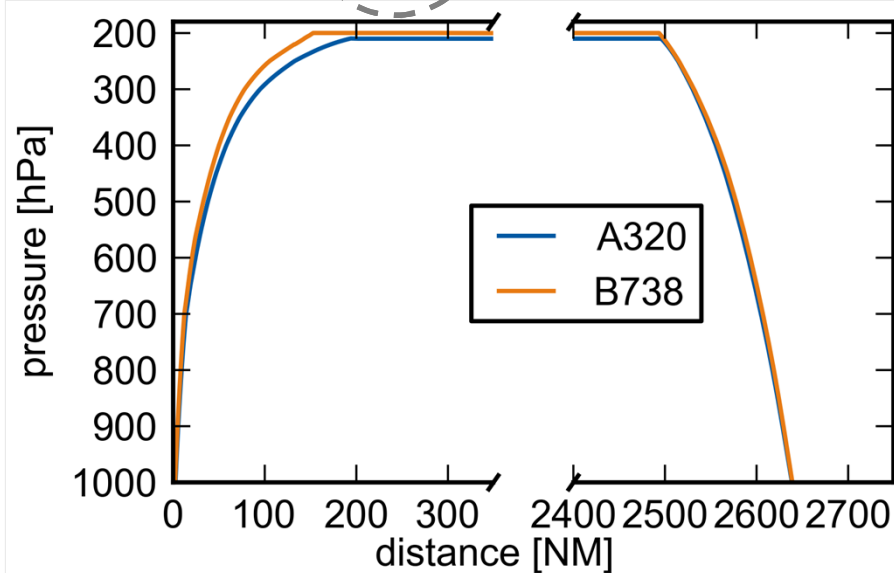
Optimized CCO:

A320: $\alpha = 1.01$

B738: $\alpha = 1.01$

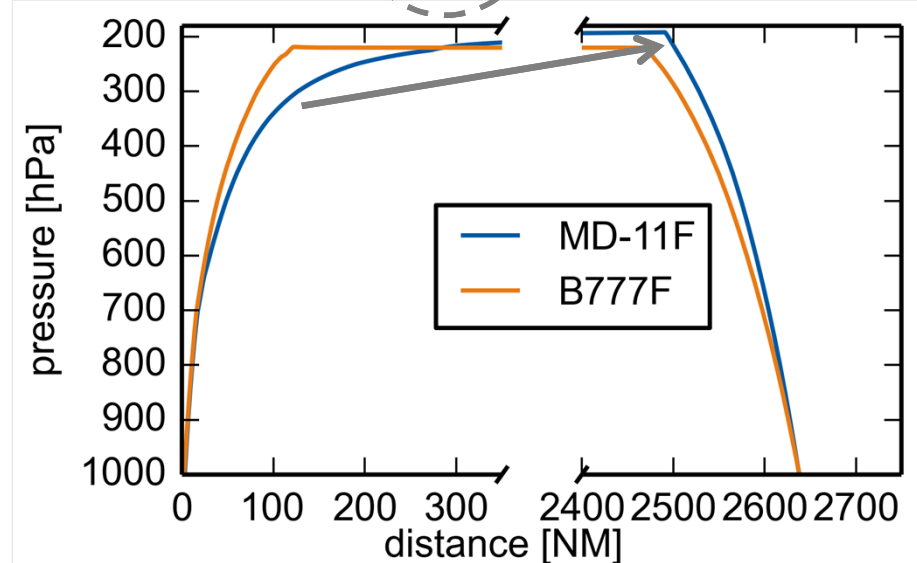
p=210 hPa

p=200 hPa



MD11F: $\alpha = 0.98$ p=190 hPa

B777F: $\alpha = 1.00$ p=220 hPa



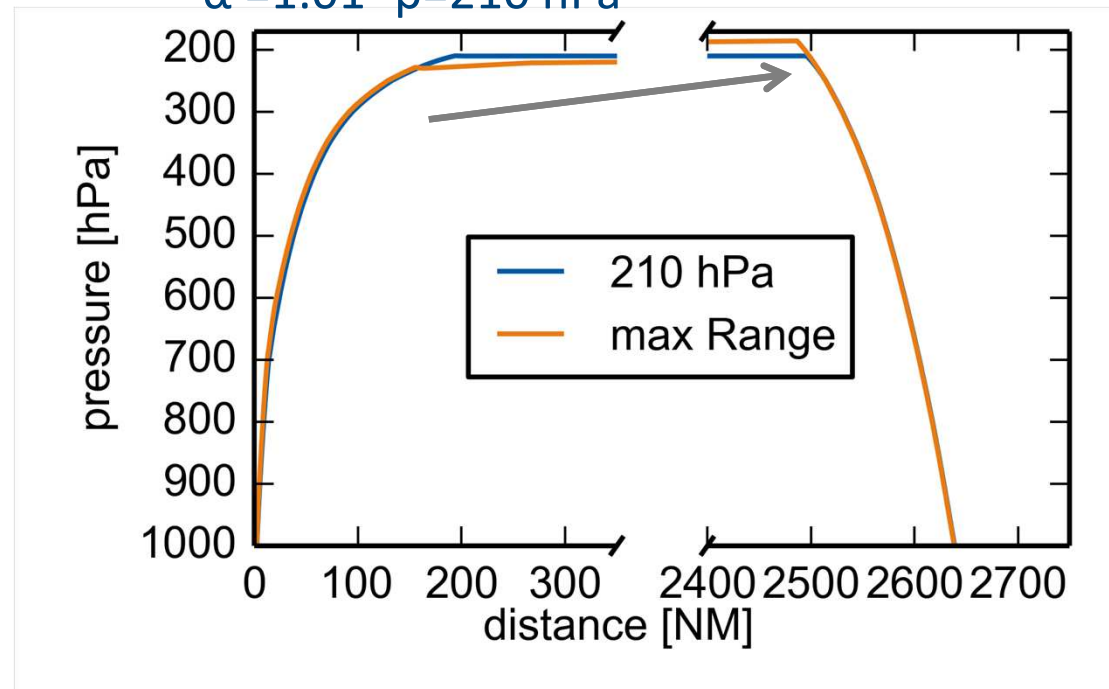
Outlook

Continuous climb cruise A320

$\alpha = 1.01$ $p = 220 \dots 180$ hPa

$$\frac{TAS}{m_f} \rightarrow \max$$

$\alpha = 1.01$ $p = 210$ hPa



Outlook

Application

Today:

1. Wind optimal lateral path at preferred flight level
2. Climb: TAS for max. climb rate

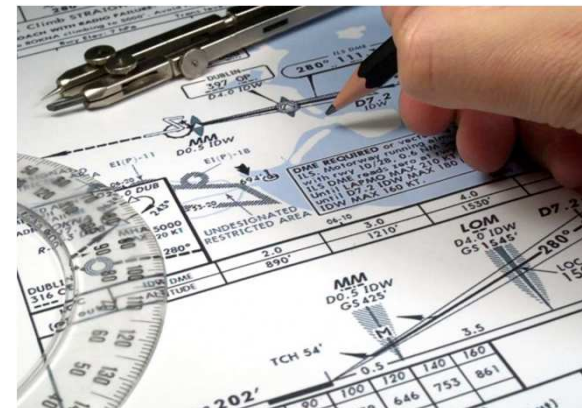
$$\sin \gamma TAS$$

1. Cruise: TAS for max. spec. Range

$$\frac{TAS}{m_f}$$

Tomorrow:

4. Cruise: Altitude adjustment to max. spec. Range and wind optimal lateral path



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Thank you for your attention

Continuous Climb Operations with Minimum Fuel Burn

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